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사단법인 한국우주과학회

The Korean Space Science Society

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<사단법인 한국우주과학회 입회 안내>

사단법인 한국우주과학회는 천문·우주과학 및 관련분야에 종사하는 여러분의 입회를 환영합니다. 우리 학회에 입회를 희망하시는 분은 입회원서 양식에 인적사항을 기재하시어 학회로 보내 주시거나 홈페이지에서 가입하시고 입회비와 연회비는 학회 은행계좌로 송금하시기 바랍니다.

■ 보낼곳: 한국우주과학회
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■ 은행계좌:
국민은행 012-01-0603-888
예 금 주 한국우주과학회

■ 회비납부안내

회원구분	입회비	연회비
학생회원(학부생)	10,000원	10,000원
정회원	10,000원	50,000원
회장, 부회장	-	100,000원
이사, 감사	-	100,000원

※ 회원의 구분은 정관 제6조에 의거하며, 변경된 연회비는 학회운영에 대한 규정 제2조에 의거한 사항입니다.

※ 뒷면의 입회원서를 복사하여 사용해 주십시오.

[표지사진 설명]

차세대 태양코로나그래프 개발(Development of Next Generation Solar Coronagraph)

한국천문연구원은 2023년까지 NASA와 공동으로 3-10 태양반경 코로나의 온도, 속도, 밀도를 동시에 관측할 수 있는 차세대 태양코로나그래프를 개발하여 국제우주정거장에 설치 및 운영할 예정이다. 1단계 2017년 개기일식 관측(DICE)과 2단계 2019년 고고도 지구 실험(BITSE)으로 코로나 관측 기술을 지상과 성층권에서 시험하였으며, 3단계로 국제우주정거장용 태양코로나그래프(CODEX)를 개발하고 있다.

입 회 원 서

성 명	한글		성 별	남/여	생 년 월 일	년 월 일	
	영문						
자택주소				우편번호		전 화	
직장주소				우편번호		전 화	
e-mail						이동전화	
직 장 명				직 위			
학 력	학위명	입학년도	학위취득일	학교명		전 공	
경 력							
연구 업적							

위 본인은 귀 학회의 설립 목적과 취지에 찬동하여 이에 회원 가입을 신청합니다.

이
예
로

신청인: (인)

위 사람을 귀 학회의 회원으로 추천합니다(참고: 정관 7조 1항에 따라 추천인은 우리 학회 정회원이면 누구나 가능합니다.).

추천인 : 직장 및 직위	성명	(인)
추천인 : 직장 및 직위	성명	(인)

사단법인 한국우주과학회 귀중

한국우주과학회

2020년 가을 학술대회

일 시 : 2020. 10. 28.(수) 13:00 ~ 30.(금) 17:00

장 소 : 제주 신화월드

발표논문 : 초청강연 4편, 구두발표 93편, 포스터발표 160편, 총 257편

발표시간 : 초청강연(30분), 연구발표(10분~15분) 3세션~4세션 동시 진행

포스터 발표 : 1부 2020. 10. 28.(수) 15:50~16:50

2부 2020. 10. 29.(목) 13:00~14:00

후원 : 
한국과학기술단체총연합회


Jeju Convention & Visitors Bureau
|사|제주컨벤션뷰로

사단법인 한국우주과학회

등록 및 교통 안내

1. 등록

회원의 등록비는 270,000원이며, 학생회원과 정회원 중 석·박사과정(전일제) 학생은 150,000원입니다. 사전등록을 하신 회원은 등록자 명부에 서명 후 학회보, 명찰, 등록비 영수증(계산서)을 수령하시기 바랍니다.

2. 회원 가입

회원가입을 원하시는 분은 학회 홈페이지에서 회원가입신청 후 입회원서를 인쇄하여 추천인(2인) 서명을 받아 학회 사무국으로 송부하여 주시고, 입회비와 연회비는 학회계좌로 송금하여 주시기 바랍니다.

입회비: 10,000원, 연회비: 50,000원(학부학생회원은 입회비 10,000원, 연회비 10,000원)입니다.

학회계좌: 국민은행 012-01-0603-888

예금주 한국우주과학회

3. 발표자료 준비

구두발표: 발표자료는 파워포인트 파일로 준비하시기 바랍니다.

포스터발표: 포스터 발표 1부 세션은 10월 28일(수) 13시까지 지정된 장소에 게시하고, 28일(목) 10시에 수거하여 주시고, 2부 세션은 28일(목) 11시까지 게시하고, 30일(금) 10시에 수거하여 주시기 바랍니다. 집중발표 시간에 발표자는 자신의 포스터 앞에서 회원들의 질문에 답할 수 있도록 준비해 주시기 바랍니다. 포스터를 부착하지 않거나, 학회 종료 후 수거하지 않은 회원은 추후 학회발표가 제한될 수 있습니다(2006년 3차 이사회 결정).

4. 발표장

	Room	Area
ORAL	Landing BallroomA	- Invited Talk - Space Situational Awareness & Space Application - Lunar & Space Exploration (I)(II) - Toward a Next Generation Coronagraph
	Landing BallroomB	- AI/Deep Learning - Space Technology & Space Astronomy (I)(II) - Space Radiation
	Halla Room	- Space Industry - Sun & Space Environment (I)(II)(III)
POSTER	Lobby	- Toward a Next Generation Coronagraph - Lunar & Space Exploration - Space Situational Awareness - Space Technology - Space Radiation - Space Application - Space Astronomy - AI/Deep Learning - Nano Satellite - Solar System & Space Expl. - Miscellaneous

5. 교통

가. 주소 : 제주특별자치도 서귀포시 안덕면 신화역사로
304번길 38 (Tel: 064-908-8888)

나. 찾아오시는 길

▶버스 이용 시:

제주국제공항정류장(대정, 화순 방면)에서 151, 152번에 승차하여 동광환승정류장에서 255, 820-2, 771-1, 771-2, 784-1, 784-2번 버스로 환승하신 후 신화역사공원 정류장에서 하차

2020 KSSS FALL CONFERENCE PROGRAM

Oct. 28. (Wed)

Time	Functions					
12:00~	Registration Open : Convention Lobby					
13:00~13:10	Opening Ceremony : Landing BallroomA					
13:10~13:40	Invited Talk I Room : Landing BallroomA Chair : Gi-Hyuk Choi (KARI)					
	Director, Changyune Lee (MSIT) Korea's Confronted Issues for Space Development					
13:40~13:50	Coffee Break					
Room	Landing BallroomA		Landing BallroomB		Halla Room	
Session I	Space Situational Awareness & Space Application Chair: DaeHoon Yoo (KARI)		(Special Session) AI/Deep Learning Chair: KyungSuk Cho (KASI)		(Special Session) Space Industry Chair: JungA Hwang (KASI)	
13:50~14:05	I-1-1	JaeYoung Kim	I-2-1	SooJeong Jang	I-3-1	Airbus (On-line)
14:05~14:20	I-1-2	SeokBae Seo	I-2-2	KangWoo Yi	I-3-2	Satrec Initiative (ByungJin Kim)
14:20~14:35	I-1-3	DaeHoon Yoo	I-2-3	RyunYoung Kwon	I-3-3	Soletop (HoJin Lee)
14:35~14:50	I-1-4	DaeJun Jung	I-2-4	SeungHeon Shin	I-3-4	InSpace (MyungJin Choi)
14:50~15:05	I-1-5	EunJung Choi	I-2-5	JiHyeon Son	I-3-5	AP위성 (HoSang Lee)
15:05~15:20	I-1-6	JongTae Lee	I-2-6	EunSu Park		
15:20~15:35	I-1-7	HaYeon Choi	I-2-7	HyunJin Jeong		
15:35~15:50	Coffee Break					
15:50~16:50	Poster Session (I) No.1~80					
16:50~17:50	Society Subcommittee Meeting					
17:50~19:30	Board Meeting					

Oct. 29. (Thu)

Time	Functions					
Room	Landing BallroomA		Landing BallroomB		Halla Room	
Session II	Lunar & Space Exploration (I) Chair: JooHyeon Kim (KARI)		Space Technology & Space Astronomy (I) Chair: JeongYeol Han (KASI)		Sun & Space Environment (I) Chair: SooJeong Jang (KASI)	
09:00~09:15	II-1-1	JongWon Lee	II-2-1	JongYeob Park	II-3-1	RokSoon Kim
09:15~09:30	II-1-2	HaingJa Seo	II-2-2	JiHye Baek	II-3-2	HyeonOck Na
09:30~09:45	II-1-3	EunHyeuk Kim	II-2-3	HeeSu Yang	II-3-3	JaeOk Lee
09:45~10:00	II-1-4	HyeonHu Park	II-2-4	JongHa Kim	II-3-4	DaYe Lim
10:00~10:15	II-1-5	YunHo Jang	II-2-5	YoungBum Song	II-3-5	JiHye Kang
10:15~10:30	II-1-6	SungSoo S. Kim	II-2-6	MinJi Jeong		
10:30~10:45	II-1-7	SeulMin Baek	II-2-7	KiYeong Han		
10:45~11:00	Coffee Break					
11:00~11:30	Invited Talk II Room : Landing BallroomA Chair : Gi-Hyuk Choi (KARI) Professor, KyoungWook Min (KAIST) Thirty Years of Space Science Observations in Korea					
11:30~12:00	Invited Talk III Room : Landing BallroomA Chair : RyunYoung Kwon (KASI) Dr. Angelos Vourlidas (JHU/APL) The Solar Corona from Within: Overview of WISPR Science Results & Future Outlook					
12:00~13:00	Lunch					
13:00~14:00	Poster Session (II) No.81~160					
Session III	Lunar & Space Exploration (II) Chair: YoungJoo Song (KARI)		Space Technology & Space Astronomy (II) Chair: DaeHee Lee (KASI)		Sun & Space Environment (II) Chair: HyuckJin Kwon (KOPRI)	
14:00~14:15	III-1-1	JaeIk Park	III-2-1	BongKyu Park	III-3-1	KhanHyuk Kim
14:15~14:30	III-1-2	DongHun Lee	III-2-2	SungSoo Jang	III-3-2	HyuckJin Kwon
14:30~14:45	III-1-3	YoungRok Kim	III-2-3	JeongHeum Im(1)	III-3-3	JunHyun Lee
14:45~15:00	III-1-4	BangYeop Kim	III-2-4	JeongHeum Im(2)	III-3-4	KyungGuk Min
15:00~15:15	III-1-5	HongKyu Moon	III-2-5	JinPyong Jung	III-3-5	YoungSook Lee
15:15~15:30	III-1-6	MyungJin Kim	III-2-6	JeongYeol Han	III-3-6	JongHo Seon
15:30~15:45	III-1-7	PuReum Kim	III-2-7	EunJi Lee	III-3-7	WonHyeong Yi
15:45~16:00	III-1-8	TaeHyun Jung				
16:00~16:10	Coffee Break					
16:10~16:40	Invited Talk IV Room : Landing BallroomA Chair : Gi-Hyuk Choi (KARI) Vice President, Robert Laing (Lockheed Martin)					
16:40~16:50	Photo Time					
16:50~18:00	Regular General Meeting : Landing BallroomA					
18:00~20:00	Banquet : Landing BallroomC					

Oct. 30. (Fri)

Time	Functions					
Room	Landing BallroomA		Landing BallroomB		Halla Room	
Session IV	(Special Session) Toward a Next Generation Coronagraph Chair : YongJae Moon (KHU)		(Special Session) Space Radiation Chair : JongDae Sohn (KASI)		Sun & Space Environment (Ⅲ) Chair : JeongHeon Kim (KASI)	
09:00~09:15	Ⅳ-1-1	YeonHan Kim	Ⅳ-2-1	UkWon Nam	Ⅳ-3-1	GeonHwa Jee
09:15~09:30	Ⅳ-1-2	JinYi Lee	Ⅳ-2-2	Sung-Joon Ye	Ⅳ-3-2	ByeongGwon Song
09:30~09:45	Ⅳ-1-3	KyoungSun Lee	Ⅳ-2-3	SungHwan Kim	Ⅳ-3-3	EunSol Kim
09:45~10:00	Ⅳ-1-4	IlHyun Cho	Ⅳ-2-4	HongJoo Kim	Ⅳ-3-4	YoungSook Lee
10:00~10:15	Ⅳ-1-5	JaeOk Lee	Ⅳ-2-5	SukWon Youn	Ⅳ-3-5	JunSeok Hong
10:15~10:30	Ⅳ-1-6	JunMo An	Ⅳ-2-6	JungA Hwang	Ⅳ-3-6	JeongHeon Kim
10:30~10:45	Ⅳ-1-7	KyuHyoun Cho			Ⅳ-3-7	YongHo Lee
10:45~11:00	Ⅳ-1-8	KyungSuk Cho			Ⅳ-3-8	GwangSu Kim
11:00~11:15	Ⅳ-1-9	JongChul Chae			Ⅳ-3-9	SeHeon Jeong
11:15~11:45	Closing Ceremony : Landing BallroomA					
	(Workshop) Space Microgravity Environment Utilization Workshop				Room : Halla Room Chair : JooHee Lee (KARI)	
13:05~13:30	최기혁	우주 마이크로중력 환경 과학/산업활용 전략 및 해외 현황				
13:30~13:55	이근우	한-중-일 부양연구 국제 동향				
13:55~14:20	박설현	마이크로중력 활용 연소-화재 연구동향(일본-중국 중심으로)				
14:20~14:45	김학창	국내외 유인 우주산업 동향과 참여방안				
14:45~15:10	김규성	동북아시아 마이크로중력 활용연구: 우주의학, 생리학 분야				
15:20~15:45	김택영	Effect of the Simulated Microgravity on Proliferation and Differentiation of 3D Bioprinted Stem Cell Sample				
15:45~16:10	윤태성	From Astrobiology to Space Biology: Lessons from Recent Asian Microgravity Symposium				
16:10~16:35	박준수	Recent Biomedical Research Results Using Simulated Microgravity in China & Japan				
16:35~17:00	이진일	Recent Development in Gravity Biology Using Animal Models in Studies from East Asia				

Poster Session I

2020. 10. 28.(Wed) 15:50~16:50

Area	No	Author	Area	No	Author
Toward a Next Generation Coronagraph	P-1	YounKyu Kim	Space Technology	P-41	SeoRim Lee
	P-2	JungJoon Seough		P-42	SunIk Lee
Lunar & Space Exploration	P-3	HoLak Kim		P-43	SeungHun Lee
	P-4	JooHyeon Kim		P-44	JaeYeol Lee
	P-5	YoungJoo Song		P-45	EunSook Lim
	P-6	HanWoong Ahn		P-46	JongMin Im
	P-7	JongWon Lee		P-47	JiHyeon Yim
	P-8	JoRyeong Yim		P-48	HyunSu Lim
	P-9	ByungKwan Jang		P-49	GabHo Jeun
	P-10	YoonJeong Jang		P-50	JungNam Jun
	P-11	SeungBum Hong		P-51	HyeonJin Jeon
	P-12	ChiHo Kang		P-52	OkChul Jung
Space Situational Awareness	P-13	AMi Yun		P-53	YoueYun Jung
	P-14	InHoi Koo		P-54	JinPyong Jung
Space Technology	P-15	KiHo Kwon		P-55	JeongHoon Hyun
	P-16	DongOh Kim	Space Radiation	P-56	KiLyoung Hwang
	P-17	MinA Kim		P-57	BongKon Moon
	P-18	YoungYun Kim	Space Application	P-58	GuHyeok Kim
	P-19	ChangHo Kim		P-59	YoungSun Kim
	P-20	JunHo Kim		P-60	HeeSeob Kim
	P-21	JoongPyo Kim		P-61	JongEuk Park
	P-22	JinHyuck Kim		P-62	JongEuk Park
	P-23	HyeWon Kim		P-63	SeokBae Seo
	P-24	HwanChun Myung		P-64	SungMin Lee
	P-25	GeoSeong Moon		P-65	WonBeom Lee
	P-26	SunJu Park		P-66	IlSeop Lee
	P-27	SungWoo Park	Space Astronomy	P-67	HyeJeong Jo
	P-28	EunBin Park		P-68	Bendict Lawrance
	P-29	JongBum Park	AI/Deep Learning	P-69	Sumaiy Rahman
	P-30	JongOh Park		P-70	SuJin Lee
	P-31	JooHo Park		P-71	HaRim Lee
	P-32	JinHyung Park		P-72	WooJin Kim
	P-33	HeeSung Park	Nano Satellite	P-73	JongDae Sohn
	P-34	HeeJin Bae		P-74	Chul Kang
	P-35	SaeHan Song	Miscellaneous	P-75	JuHyun Kim
	P-36	JeoungHeum Yeon		P-76	ChunWon Kim
	P-37	TaeBong Oh		P-77	NaGyun An
	P-38	SeokTeak Yun		P-78	SangSoon Yong
	P-39	HeeKwang Eun		P-79	TaeJin Lee
	P-40	BoYoung Lee		P-80	JeongWoo Han

Poster Session II

2020. 10. 29.(Thu) 13:00~14:00

Area	No	Author	Area	No	Author
Lunar & Space Exploration	P-81	DongGyu Kim	Space Technology	P-121	ChangKwon Cho
	P-82	BangYeop Kim		P-122	DongSeok Chae
	P-83	InKyu Kim		P-123	SeongHwan Choi
	P-84	JongHee Bae		P-124	JungSu Choi
	P-85	ChangKyoon Kim		P-125	ChoYoung Han
	P-86	SangMan Moon	Space Application	P-126	YunGoo Huh
	P-87	SeungHee Son		P-127	JongPil Kong
	P-88	JaeHoon Song		P-128	JooHee Lee
	P-89	HyunJin Shin		P-129	JongTae Lee
Space Situational Awareness	P-90	DongHyo Lee	Space Astronomy	P-130	DaeJun Jung
Space Technology	P-91	GmSil Kang		P-131	SooHyun Kim
	P-92	BeomSuk Kang		P-132	YoungSoo Kim
	P-93	SangWook Kang		P-133	JangHo Park
	P-94	SooYeon Kang		P-134	YoungSoo Jo
	P-95	HyunMo Gu	Nano Satellite	P-135	GoEun Choi
	P-96	MyungGil Kim		P-136	JiSeok Kim
	P-97	Myungmuk Kim	Sun & Space Environment	P-137	JinHyung Kim
	P-98	SangGoo Kim		P-138	GeukNam Kim
	P-99	JungDo Kim		P-139	SuIn Kim
	P-100	HyungWan Kim		P-140	SuJin Kim
	P-101	SeungYong Min		P-141	EuiKeun Kim
	P-102	KyunSang Park		P-142	HeeEun Kim
	P-103	BongKyu Park		P-143	SaRah Park
	P-104	SungWook Park		P-144	SunMie Park
	P-105	SuHyun Park		P-145	HaingJa Seo
	P-106	MyungJin Baek		P-146	SeokMin Song
	P-107	JaeMin Shin		P-147	SeungBum Yang
	P-108	HyunKyu Shin		P-148	SuYeon Oh
	P-109	SeungEun Yang		P-149	KyoungSun Lee
	P-110	YoungJin Won		P-150	WonSeok Lee
	P-111	YoungSu Youn		P-151	JinYi Lee
	P-112	NaYoung Lee		P-152	Changsup Lee
	P-113	SangRok Lee	Miscellaneous	P-153	JooHee Lee
	P-114	SeonHo Lee		P-154	KyungKeun Kim
	P-115	ChoonWoo Lee		P-155	DongOk Ryu
	P-116	HyeJin Yi		P-156	ByeongHee Mihn
	P-117	WonGyu Lim		P-157	SuWan Bang
	P-118	KyungDuk Jang		P-158	YoungChun Youk
	P-119	SungSoo Jang		P-159	ChangEun Lee
	P-120	SeungWon Cho		P-160	SooHwan Jun

구두발표 논문 초록

10월 28일(수) 제1발표장 Landing BallroomA

Invited Talk I

좌장: GiHyuk Choi (KARI)

13:10 [IS-I]

Korea's Confronted Issues for Space Development

Changyune Lee

MSIT

제1발표장 Landing BallroomA

I-1 Space Situational Awareness & Space Application

좌장: DaeHoon Yoo (KARI)

13:50 [I-1-1]

Analysis of Geosynchronous Transfer Orbit Space Object for Optical Tracking Possibility and Orbit Determination Method Using OWL-Net.

Jae-Young Kim¹, Sung-ki Cho², Chun-Hwey Kim¹, Yong-gi Kim¹

¹Chung-buk National University

²Korea Astronomy and Space Science Institute

The orbits of most of space object rotating around the Earth change over time due to various perturbation forces (Earth's non-spherical gravity, Earth's atmospheric drag force, solar radiation pressure etc.). Precise trackings and predictions of the orbits of the space objects are necessary to carry out various purposes, including scientific research. The Optical Wide-field patrol Network (OWL-Net) is the first Korean-type optical surveillance system for space objects currently operated by the Korea Astronomy & Space Science Institute, and consists of five observatories (Mongolia, Morocco, Israel, United States and the Korea). The observatories' latitudes are between 30N deg and 48N deg, so observations of satellites passing more than 30S deg may be limited. Therefore, if more observation stations are installed in the southern hemisphere, it is expected that the optical observation area will be expanded and the orbits of the satellites will be more accurately determined. To verify this, we actually observed the Geosynchronous Transfer Orbit (GTO) space object, CZ-3B Rocket Body (NORAD ID 43709) with the OWL-Net from February 12 to March 3, 2019. And, assuming that two virtual observatories (Exmouth, Australia and Vicuna, Chile) were installed in the southern hemisphere, the

expected observation results were simulated using Systems Tool Kit (STK). In addition, the observation conditions were classified into 7 cases in consideration of the chopper use and the characteristics of the orbit, and the preliminary orbit was determined using Orbit Determination Tool Kit (ODTK). Two-line Element (TLE) was used as an initial orbit (February 26 09:36:57.370, 20:24:44.055 and March 3 07:45:54.211) for the preliminary orbit determination. As a preliminary result, cases with orbital characteristics succeeded in orbit determination, but in cases involving the use of chopper, orbit determination failed. We discuss the many implications of the preliminary experiment results.

14:05 [I-1-2]

Results of GEMS' Initial Activation and Check

Seok-Bae Seo, Seonghoon Lee

Korea Aerospace Research Institute

This paper explains early test results of GEMS (Geostationary Environment Monitoring Spectrometer) which is developed to monitor air pollutions around the Korean peninsula in a geostationary orbit. The GEMS is on the IOT (In Orbit Test) after successful Initial Activation and Check tests. It is expected that the GEMS will work the important parts for the geostationary air quality constellation with the TEMPO (Tropospheric Emissions: Monitoring of Pollution) by NASA and with the Sentinel-4 by ESA in the early 2020s.

14:20 [I-1-3]

Acceleration of Flattening Gamma on K5 Products for Practical Application

Daehoon Yoo

Korea Aerospace Research Institute

Flattening Gamma accurately models the geometry and the radiometry of synthetic aperture radar (SAR) imagery to normalize radiometric effects of terrain variations. In spite of the benefits, applying flattening gamma is practically hard because the computational cost is even higher than the cost of conventional ellipsoid or local incident angle based approaches. This paper describes the optimized algorithm to accelerate flattening gamma on K5 products with the implementation details of C++ CPU parallelization and OpenCL GPGPU parallelization and evaluates the performance of the algorithm.

14:35 [I-1-4]

Performance Analysis of Optical Module for the LUTI (Lunar Terrain Imager) after AIT (Assembly-Integration and Test)

Daejun Jung, Haengpal Heo

Korea Aerospace Research Institute

The main module of space-born telescope is optical module with 2 optical components such as mirrors and lens module in the LUTI (Lunar Terrain Imager). The performance verification of these optical components should be conducted before the AIT (Assembly-Integration and Test) of optical module. In this paper, the performance verification of mirrors and lens module is introduced briefly and then the sequence of AIT is described with related MGSE (Mechanical Ground Support Equipment) and OGSE (Optical Ground Support Equipment). Finally, the results of OM performance such as WFE (WaveFront Error) and EFL (Equivalent Focal Length) are also analyzed.

14:50 [I-1-5]

Orbit Determination and Prediction Results from Optical and Radar Tracking Data of LEO Satellite

Eun-Jung Choi, Soo-Young Kim, Jin-Choi, Myung-Jin Kim, Dong-Goo Roh, Hong-Suh Yim, Sungki Cho

Korea Astronomy and Space Science Institute

This paper focuses on the key results of orbit determination and prediction using in-house total solution program SSTOD (Space Surveillance and Tracking Orbit Determination) for the orbit of space objects. This program was developed for optical and radar measurements and verified using the precision orbit ephemeris of the KOMPSAT-5 satellite, of which the position accuracy is 20 cm (1σ). In addition, using the optical and radar measurement data such as OWL-Net and LEOLabs, we analyzed whether it is sufficient enough for Space Situational Awareness (SSA) activity, like the orbit catalogue maintenance, space conjunction analysis and re-entry prediction.

15:05 [I-1-6]

Memory EDAC System of Flash Memory Recorder on Low Earth Orbit Satellite

JongTae Lee, Eung Shik Lee, Haeng-Pal Heo

Korea Aerospace Research Institute

It is necessary to temporarily store imagery data before sending the data to the Ground Station due to the limitation of contact area of low earth orbit satellite. Flash-based memory is increasingly used for better memory capacity, low power consumption and low mass. In order to make a memory recorder supporting a file management system, various memory devices can be used as well as flash device. This paper shows an example of flash-based memory recorder and EDAC functions suitable for each memory device on low earth orbit

satellite. It provides an opportunity to think about policies to ensure data integrity inside memory recorder.

15:20 [I-1-7]

Pre-Processing Function Module Design of C-Band SAR Image

Ha-Yeon Choi, Sang-Ho Bang, Byong-Guk Kang, Young-Bo Sagong

SOLETOP Co., Ltd

SAR radars are known to be used for easier observation of natural disasters such as floods, droughts, bushfires and typhoons since the weather influence is relatively less compared to optical sensors. In particular, the C-band SAR satellite is widely used to prevent water related disasters. This is due to its flood damage assessment calculation capability in rivers and streams. Developed countries such as the United States, Europe, and Japan operate observation satellites to conduct monitoring of their water resources to prevent water related disasters. As water related natural disasters are increasing in Korea due to climate change, it is necessary to establish an efficient water management system to minimize such damage. Therefore, "Water resources satellite" project is being developed. The K-water is in charge of "Development of Core Base Technology with Satellite Image Radar for Diagnosis of Water Resources Information" project and SOLETOP is participating in the task of "Building Modularization/Standardization system for Image Radar Algorithm". We are studying ways to develop the Water Resources Satellite Imaging (LIA) Pre-processing SW in our current project. Satellite images are distorted by topography, atmospheric effects, etc. Thus, the process of radiation correction, removal of speckles, correction of vertices, etc. is necessary to correct distortion. This requires a pre-processing to accurately derive factors that can be input to backscatter coefficients such as ground surface detection and soil moisture content. In this paper, each function was identified in the preprocessing process, and the function module was designed accordingly, and the sequence of operation was mapped. In the future, we would like to propose a SW structure with algorithm componentization that can enhance re-useability of components developed thus reducing development time. This will allow us to process images of satellites that will be developed later in line with the Water Resources Satellite Development and Utilization Roadmap. This study was funded by the Korea Ministry of Environment (MOE) under the Service Program for Demand-Responsive Water Supply (2016002650003).

제2발표장 Landing BallroomB

I-2 (Special Session) AI/Deep Learning

좌장: KyungSuk Cho (KASI)

13:50 [I-2-1]

Inversion Method of 3D Coronal Density from Rotational Coronagraphic Data Using a Deep Learning MethodSoojeong Jang¹, Ryun-Young Kwon¹, Gyungin Shin², Yeon-Han Kim¹¹*Korea Astronomy and Space Science Institute*²*Department of Engineering Science, University of Oxford*

We present an inversion method of the coronal density distribution from coronagraphic images. The observed intensity in the coronagraphic images results from Thomson scattering of photospheric lights by the coronal electrons. The inversion of the observation into the electron distribution is non-trivial and needs heavy numerical calculations with many iterations, since the intensity is the integrated emission over the line of sight. We develop a model to generate coronal density images, which can be used as the initial guesses of such heavy calculations. We use pix2pixHD based on conditional generative adversarial networks (cGAN), which is an image translation technique. The training data set consists of polarized brightness (pB) images as the model input and density distributions as the target. We have obtained the 3D coronal electron density from MHD simulations and derived the synthetic pB images from the given electron densities using the Thomson scattering theory. Due to the effects of the Thomson scattering geometry, we train the individual models using the 2D images of the pB and electron density at six spherical surfaces ($\rho = 2.0, 2.2, 2.5, 4.0, 6.0, 12.0$ solar radii). As a result, the mean percent absolute error is 6% for the test sets. The full 3D coronal density, from 2 to 12 solar radii, is reconstructed by the interpolation of the electron densities at these surfaces.

14:05 [I-2-2]

Visual Explanation of a Deep Learning Solar Flare Forecast Model

Kangwoo Yi, Yong-Jae Moon, Daye Lim, Eunsu Park, Harim Lee

School of Space Research, Kyung Hee University

In this study, we have presented visual explanation of a deep learning solar flare forecast model and its relationship with physical parameters of solar active regions (ARs). For this, we use full-disk magnetograms at 00:00 UT from Solar and

Heliospheric Observatory/Michelson Doppler Imager (1996 May–2010 December) and Solar Dynamics Observatory/Helioseismic and Magnetic Imager (2011 January–2017 June), physical parameters from Space-weather HMI Active Region Patch (SHARP), and Geostationary Operational Environmental Satellite X-ray flare data. Our deep learning flare forecast model based on the Convolutional Neural Network (CNN) predicts “Yes or No” of daily flare occurrence for C-, M-, and X-class. We interpret the model using two CNN attribution methods (guided backpropagation and Gradient-weighted Class Activation Mapping, Grad-CAM) which provide quantitative information on explaining the model. Major results of this study are as follows. First, we successfully apply our deep learning models to the forecast of daily solar flare occurrence with TSS = 0.65 and ApSS = 0.61, without any preprocessing to extract features from data. Second, thanks to the attribution methods, we find that a result of the model is mainly determined by the areas near the polarity inversion lines of ARs. Third, the ARs with high Grad-CAM values produce more flares than those with low Grad-CAM values. Fourth, 9 SHARP parameters such as total unsigned vertical current, total unsigned current helicity, total unsigned flux, and total photospheric magnetic free energy density are well correlated with Grad-CAM values.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, study on analysis and prediction technique of solar flares).

14:20 [I-2-3]

Inversion of Rotational Coronagraph Data into 3D Electron Density using a Deep Learning Method: (2) Validation for Scientific Uses

Ryun-Young Kwon, Soojeong Jang

Korea Astronomy and Space Science Institute

Jang and Kwon (2020) have presented the model translating the polarized brightness synoptic map obtained from coronagraphic images into the density synoptic map using the so-called pix2pixHD that is one of the Supervised Deep Learning methods. Here, we show how to reconstruct the full three-dimensional coronal electron density and validate the results for scientific uses. There are two main obstacles to using such deep learning models in science. First, it is not guaranteed that the output of a deep learning model is physically reasonable. Second, the data format obtained from a specific deep learning technique could differ from the scientific format. The models developed in Jang and Kwon (2020) provide the density maps at various heights in JPEG format with values ranging from 0–255. We use Thomson scattering theory to synthesize polarized brightness images from the given electron densities by the models. We repeat the comparison between the synthetic image and the observation used for the model input and correct the

3D electron density to reduce the difference between the synthetic and observed images. In this respect, the result electron density can be validated by the difference between the synthetic and observed images. This method is essentially the same as the traditional tomography for coronagraph data while it is much simpler and easier to use, and hence the results can be used for scientific purposes.

14:35 [I-2-4]

A Two-Step Kp Forecasting Model Using the Random Forest and the Sequence-to-Sequence

Seunghoon Shin¹, JiHyeon Son¹, Yong-Jae Moon^{1,2}, Kangwoo Yi¹, Gyungin Shin³

¹*School of Space Research, Kyung Hee University*

²*Department of Astronomy and Space Science, College of Applied Science, Kyung Hee University*

³*Department of Engineering Science, University of Oxford*

In this study, we develop a two-step Kp forecasting model using the random forest and the sequence-to-sequence. Our model forecasts the Kp index every 3 hour in advance. In the first step, the model uses a random forest to predict that the geomagnetic storm will occur (storm: $K_p \geq 5$) or not (non-storm: $K_p < 5$). In the second step, the model forecasts the Kp index using the random forest for storm cases or the sequence-to-sequence for non-storm cases. As input data, solar wind parameters (proton density, proton velocity, Bz and total B) observed from ACE satellite, the preliminary Kp from NOAA, the Boyle index, and the dynamic pressure are used. We divide these data into the training data (2000–2012) and the test data (2013–2014) chronologically. Major results of this work are as follows. First, our model successfully forecasts the Kp index. Second, our model shows better results than other machine learning algorithms such as CNN, simple LSTM etc. Also, our results are better than those of Tan et al. (2018) who used the LSTM and a simple regression method. Third, statistical scores for test datasets are as follows: 0.57 for root-mean-square-error, 0.43 for mean-absolute-error, and 0.87 for correlation-coefficient.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, Study on analysis and prediction technique of solar flares).

14:50 [I-2-5]

Generation of He I 1,083 nm Images from SDO/AIA 193 and 304 Å Images by Deep Learning

Jihyeon Son¹, Junghun Cha², Yong-Jae Moon¹, Harim Lee², Eunsu Park², Gyungin Shin³,

Hyunjin Jeong¹

¹*School of Space Research, Kyung Hee University*

²*Department of Astronomy and Space Science, Kyung Hee University*

³*Department of Engineering Science, University of Oxford*

In this study, we use “pix2pixHD” model, one of deep learning models, based on conditional Generative Adversarial Networks (cGAN) to generate He I 1,083 nm images from Solar Dynamic Observatory (SDO)/Atmospheric Imaging Assembly (AIA) images. National Solar Observatory (NSO)/ Synoptic Optical Long-term Investigations of the Sun (SOLIS) images are used as target data of the models. We make two models, one with only SDO/AIA 193 Å images as input and the other with SDO/AIA 193 and 304 Å as input. We use data from May 2010 to July 2015 except for June and December for training and the remaining one for test. The major results of our study are as follows. First, the models successfully generate He I 1,083 nm images. Second, the model with two input images shows better results than that with one input image in terms of metrics, correlation coefficient (CC) and root mean squared error (RMSE). CC and RMSE of the model with two input images are 0.83 and 14.98, respectively. Third, AI-generated images show well not only active regions but also coronal holes. This work is meaningful in that our model can produce He I 1,083 nm images with higher cadence without data gaps, which is useful for studying the time evolution of chromosphere and coronal holes. This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, Study on analysis and prediction technique of solar flares).

15:05 [I-2-6]

Can Ai-Generated EUV Images be used for the Determination of Differential Emission Measure of Solar Corona?

Eunsu Park¹, Jin-Yi Lee¹, Yong-Jae Moon^{1,2}, Harim Lee¹, Il-Hyun Cho¹, Daye Lim¹

¹*Department of Astronomy and Space Science, Kyung Hee University*

²*School of Space Research, Kyung Hee University*

In this study, we determinate the differential emission measure (DEM) of solar corona using three SDO/AIA EUV channel images and three AI-generated ones. To generate the AI-generated images, we apply a deep learning model based on multi-layer perceptrons by assuming that all pixels in solar EUV images are independent of one another. For the input data, we use three SDO/AIA EUV channels (171, 193, and 211). For the target data, we use other three SDO/AIA EUV channels (94, 131, and 335). We train the model using 358 pairs of SDO/AIA

EUV images at every 00:00 UT in 2011. We use SDO/AIA pixels within 1.2 solar radii to consider not only the solar disk but also above the limb. We apply our model to several brightening patches and loops in SDO/AIA images for the determination of DEMs. Our main results from this study are as follows. First, our model successfully generates three solar EUV channel images using the other three channel images. Second, the noises in the AI-generated EUV channel images are greatly reduced compared to the original target ones. Third, the estimated DEMs using three SDO/AIA images and three AI-generated ones are similar to those using three SDO/AIA images and three stacked (50 frames) ones. These results imply that our deep learning model is able to analyze temperature response functions of SDO/AIA channel images, showing a sufficient possibility that AI-generated data can be used for multi-wavelength studies of various scientific fields.

SDO, Solar Dynamics Observatory; AIA, Atmospheric Imaging Assembly; EUV, Extreme Ultra Violet; DEM, Differential Emission Measure.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (2018-0-01422, Study on analysis and prediction technique of solar flares).

15:20 [I-2-7]

Solar Coronal Magnetic Field Extrapolation from Synchronic Data with Ai-Generated Backside

Hyunjin Jeong¹, Yong-Jae Moon^{1,2}, Eunsu Park², Harim Lee²

¹*School of Space Research, Kyung Hee University*

²*Department of Astronomy and Space Science, College of Applied Science, Kyung Hee University*

Solar magnetic fields play a key role in understanding the nature of the coronal phenomena. Global coronal magnetic fields are usually extrapolated from photospheric fields for which backside data were taken about two weeks ago when it was at the frontside. For the first time we have constructed the extrapolations of global magnetic fields using frontside and AI-generated backside magnetic fields at a near-real time basis. We generate the backside magnetograms from three channel backside observations of STEREOs by our deep learning model trained with frontside SDO EUV images and magnetograms. We make global magnetic field synchronic maps in which conventional backside data are replaced by backside ones generated by our model. The synchronic maps show much better not only the appearance of solar active regions but also the disappearance of others on the solar surface than before. We use these synchronized magnetic data to extrapolate the global coronal fields using Potential Field Source Surface (PFSS) model. We show that our results are much more consistent with coronal observations than those of the conven-

tional method in view of solar active regions and coronal holes. We present several positive prospects of our new methodology for the study of solar corona, heliosphere, and space weather. This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, Study on analysis and prediction technique of solar flares).

제3발표장 Halla Room

I-3 (Special Session) Space Industry

좌장: JungA Hwang (KASI)

13:50 [I-3-1]

Airbus (On-line)

14:05 [I-3-2]

Activities of Satrec Initiative (SI) in Space System Development

Byungjin Kim

Satrec Initiative Co., Ltd.

SI was founded in 1999 by the engineers who developed the first Korean satellite and a series of advanced small satellites. It has been focusing on developing high-performance small/medium satellite systems for Earth observation, space science, and telecommunication missions. It also has contributed to the success of over 28 international and domestic space programs. With two subsidiaries, the SI group has four vertically-integrated business areas in Earth observation. The parent company, SI provides Earth observation satellite and ground systems, SI Imaging Services focuses on satellite imagery distribution services, and SI Analytics provides AI-based geospatial analytics services.

14:20 [I-3-3]

The New Space Trend in the Global Smallsat/Cubesat Industry and Its Implication to the Domestic Space Stakeholders for Global Space Business Opportunities

Ho-Jin Lee, Hong Rae Kim, Youngbo Sakong

Soletop Ltd.

Recently the New Space trend is globally heating the space industry up specifically in developing and deploying the LEO smallsats (including cubesats) for scientific, civil, government and deep space exploration missions. The term New Space is

quoted as a new industrial paradigm in the global space business where the private sectors now are seeking to business opportunities that has been played dominantly by the government/public space organizations and big companies. This movement makes happen not only the lower costs of satellite and launch service but also a sharp reduction of the satellite production time until the deployment of customer missions. Since the smallsats are moving onto LEO orbits, the constellation is required to achieve seamless revisits for missions and this again accelerates further a mass production of smaller and cost effective satellite solutions. Though big players like SpaceX and OneWeb lead the smallsat megaconstellation construction for global LEO communications, most of New Space players are startup and/or small companies funded and backed by private investment towards the innovative technologies and services. The functional/service performance provided by smallsat constellations now proves to be comparable to the traditional medium/big satellites at the cheaper costs. The application area is expanding to space science, space monitoring, space awareness, geointelligence, communication, IoT, Moon/Mars exploration, not limited to the earth observation or service concept validation. Domestic space industry in Korea, mostly relying on the governmental and military programs, is painstaking to catch up with the global trend for themselves while asking for government smallsat incubation program in place of private funding. The global smallsat market is proliferating but any chance of market share by the domestic industry will never come unless any investment or business opportunity is provided for the global competitiveness build-up. In this presentation, we will briefly present the New Space concept and global space business trend as an introduction. Then a detailed classification and definition of smallsat and cubesat will be given. The global New Space activities will be detailed with the focus on the 3U/6U cubesats. The global smallsat/cubesat market growth with the various applications will be summarized with a graphical representation to give an insight of New Space trend. The concerns and expectations about the cubesat reliability issues will be discussed as well. The domestic smallsat and cubesat development chronicles will be reviewed and some lessons learned will be discussed. The maturity level of cubesat technology and expertise of the domestic universities and SMEs will be discussed. This presentation will conclude by summarizing and suggesting a paradigm shift of the national space development policy to foster domestic SME and startups by providing with the New Space challenge programs for their own cubesat innovative technologies/services development and space qualification which will result in the space heritage essential for global space business.

14:35 [I-3-4]

Introduction to InSpace

Myungjin Choi

InSpace

I will introduce to InSpace to young and junior space scientists and engineers. InSpace is a leading company of satellite ground systems and AI-based image processing, analysis, and applications in Korea. As a combined team of over 50 aerospace engineers, geospatial analysts, weather and ocean experts, software developers, data scientists, and developers engineers, InSpace apply disruptive technologies and our unique intellectual property to both national security and commercial problems.

14:50 [I-3-5]

AP위성 (HoSang Lee)

15:50~16:50 1부 포스터 발표

10월 29일(목) 제1발표장 Landing BallroomA

II-1 Lunar & Space Exploration (I)

작장: JooHyeon Kim (KARI)

09:00 [II-1-1]

An Introduction and Application of Simulation Tool "Biosim" for Manned Space Exploration

Jong-Won Lee, Joo-Hee Lee, Youn-Kyu Kim

Korea Aerospace Research Institute

This paper describes a simulation tool of Environmental Control and Life Support System (ECLSS) under a typical mission scenario. The tool, Biosim, is one of the NASA's open source program and developed for research on long-term manned space missions. The ECLSS is one of the things for astronauts to survive in the space environment such as LEO, Moon, Mars. It interacts with multiple subsystems such as Water Processor Assembly (WPA), Oxygen Generation Assembly (OGA), Urine Processor Assembly (UPA), and Power Supply Module, which makes it difficult to control. Moreover, in recent years, as the development of advanced ECLSS combined with ISRU technology progresses, the system becomes more complex. Therefore, it is necessary to have a complex control strategy to operate ECLSS and optimize the system effectively. The biosim provides a platform for developing the advanced ECLSS. We will present the application of Biosim for

development of ECLSS and our plan for the future.

09:15 [II-1-2]

Lunar Crater Counting Using Deep Learning

Haingja Seo, Sang Min Park, Mijeong Kim,
Myungjin Choi

InSpace Co., Ltd.

There are many studies that have been approached in a variety of ways because a lot of data is released by spacecraft for planetary exploration. It is one of them that is the research on applying deep-learning to images. And an example of crater counting using images of the Moon and Mars is representative. The lunar crater counting is a powerful way to estimate lunar age, and many studies are researching. However, as most studies manually count the lunar craters, there are many errors that affect the results of estimating the lunar age. We tried counting lunar craters with applying on deep-learning using LROC/LRO images. The archive releases the shapefiles of craters with 5 to 20 km, so we did not create labeling data files. We proceeded as following: 1) Using LROC data and crater-shapefile, make patch images and training dataset, validation dataset, and test label set. 2) YOLOv3 and RetinaNet, the object detection models are trained with training dataset and validation dataset. 3) The model has carried out the evaluation with a test dataset. This model will be applied to the crater with under 5km and the images by Kaguya. The final goal of this study is to apply to the crater counting in PSR. Although the obtained image by ShadowCam is a different optical feature, we will try to apply this model to them. And we expect that this model suitable for the Moon is able to be used for the airless bodies like Mercury and Ceres.

This research was conducted by NRF (2018M1A3A3A02065832) support.

09:30 [II-1-3]

Korea Pathfinder Luner Orbiter Mission: Science and Development of Science Instruments

Eunhyeuk Kim

Korea Aerospace Research Institute

With the re-adjustment of the launch date as of mid of 2022, Korea Pathfinder Lunar Orbiter (KPLO) mission is headed to assembly and test phase. All of science instruments on-board KPLO except for NASA instrument (ShadowCam) are expected to be delivered for the final assembly and test process within this year. The participating scientist program (PSP) operated by NASA which is initiated for enhancing the scientific collaboration of KPLO science mission will be started by mid of 2021 for 3 years. Summary of science goals of KPLO mission,

development status and further detail of science instrument related activities, and scientific collaboration between Korea and US based on PSP will be presented.

09:45 [II-1-4]

Analysis of the KPLO Magnetic Cleanliness for the KMAG Instruments

Hyeonhu Park¹, Hyojeong Lee^{1,2}, Ho Jin¹,
Taeyoon Kim³, Kwan-Hyuk Kim¹,
Byungwook Jeong¹, Yunho Jang¹

¹*School of Space Research, Kyung Hee University*

²*Technology Development Division, INTORULE Inc.*

³*Korea Aerospace Research Institute*

For the magnetic field measurement in Space Exploration, a magnetic cleanliness is an important issue to separate the magnetic field generated by the spacecraft. A spacecraft has its own DC and AC magnetic fields which are generated by the flow of current of major instruments. Therefore, the analysis and test is required in the development phase. The Korea Pathfinder Lunar Orbiter (KPLO) has the KPLO Magnetometer (KMAG) instrument to observe the lunar surface magnetic field and near moon space environment. For this scientific objective, we carried out the analysis of the magnetic field which was generated by the spacecraft. In this analysis, we assumed that magnetic field sources were magnetic dipole moments, and examined magnetic dipole moments of 25 major instruments in spacecraft. The analysis method was carried out using a Python program with a Magpylib. The simulation results show that the spacecraft magnetic field has a down below 700 nT which is the KMAG performance requirements of the magnetometer in the boom. Based on the simulation, we also confirmed that the KMAG multiple sensors can observe a magnetic field in a predicted Lunar surface magnetic dipole moment. In this paper, we present the simulation method and results.

10:00 [II-1-5]

Experiment of the Temperature Characteristics of AMR and Fluxgate Magnetometer

YunHo Jang¹, Hyojeong Lee^{1,2}, Byungwook Jeong¹,
Hyeonhu Park¹, Woohyun Jo¹, Ho Jin^{1,3}

¹*School of Space Research, Kyung Hee University*

²*Intorule Inc.*

³*Department of Astronomy & Space Science, Kyung Hee University*

The instrument calibration is the most sensitive issue to determine its characteristics. In the case of a magnetometer, there are a lot of calibration processes such as linearity, offset, gain, resolution, noise etc. Among these parameters, the tempe-

temperature characteristic is not easy to derive by experiment because of the magnetic field variations and other variables of the experiment space. In this paper, we introduce two kinds of tests. One is the fluxgate sensor and the other is the AMR sensor. The temperature coefficient of the lab test model of a race-track fluxgate magnetometer, is $< 0.1\%/^{\circ}\text{C}$, which was calculated by using the feedback resistor and the number of windings per unit length of the pick-up coil. To verify the theoretical temperature characteristic, the thermal enclosure had been installed inside a three-layer magnetic shielding chamber and a heat fan and an LN₂ gas was used to control the temperature. The test results show that AMR sensor is similar to data sheet characteristics and the fluxgate sensor has a different characteristic from theoretical calculation over the test temperature range. This test will be improved to achieve the wide temperature range and more stable magnetic cleanliness environment. In this paper, we present the temperature experiment method and preliminary results for the fluxgate and AMR sensors.

10:15 [II-1-6]

Light Field Cameras for Dust Particles on and near the Lunar Surface

Sungsoo Kim¹, Young-Jun Choi^{2,3}, Minsup Jeong², Chae Kyung Sim², Dukhang Lee², Bongkon Moon², Seonghwan Choi², Dae-Hee Lee², Jakyung Nah², Minbae Kim¹, Mingyeong Lee^{2,3}, Ian Garrick-Bethell^{1,4}

¹*Kyung Hee University*

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³*University of Science and Technology*

⁴*University of California at Santa Cruz, USA*

We are currently designing and developing an instrument package, GrainCams, with consideration to be onboard one of the rovers provided by NASA's Commercial Lunar Payload Services program in the future. GrainCams will be composed of two light field cameras, SurfCam and LevCam. The SurfCam is being designed to capture 3-dimensional microscopic structures in the uppermost few mm layer of the lunar regolith, and the LevCam is being designed to detect dust particles levitating or lofting a few tens of cm above the lunar surface.

10:30 [II-1-7]

Lunar Science Expected from CLPS Magnetometers on the Surface of the Moon

Seul-Min Baek¹, Ho Jin², Khan-Hyuk Kim², Young-Jun Choi^{1,3}, Chae Kyung Sim¹, Dukhang Lee¹

¹*Korea Astronomy and Space Science Institute*

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³*University of Science and Technology*

Unlike the Earth, the Moon has dispersed crustal magnetic anomalies instead of a global magnetic field. Although there are many previous studies on the origin of lunar crustal magnetism, the formation of crustal magnetic anomalies is not completely understood. The characteristics of magnetic anomalies suggested in the literature so far show little coherence in terms of locations of the anomalies, magnetization directions, and so on. This lack of consistency is partially related to the lack of magnetic field data measured on or very near the lunar surface, which is an important key to develop better independent constraints on the model of lunar magnetic anomalies. Through NASA's Commercial Lunar Payload Services (CLPS) program, new magnetometers will be delivered to the lunar surface. In order to understand lunar magnetic anomalies, we will estimate the surface magnetic field on the CLPS landing sites using several magnetic field data measured from the lunar orbit and discuss the expected science result for each landing site. We will also briefly present the scientific objectives of Lunar Lander Magnetometer (LMAG), one of the candidate payloads of the CLPS which will be suggested through the KASI-NASA exploration working group.

제2발표장 Landing BallroomB

II-2 Space Technology & Space Astronomy (I)

좌장: JeongYeol Han (KASI)

09:00 [II-2-1]

Flight Software Development for the Next-Generation Solar Coronagraph

Jongyeob Park, Ji-Hye Baek, Be-Ho Jang, Seonghwan Choi, Jihun Kim, Heesu Yang, Jinhyun Kim, Su-Chan Bong, Yeon-Han Kim, Kyung-Suk Cho

Korea Astronomy and Space Science Institute

The next-generation solar coronagraph is built to observe the linearly polarized brightness of solar corona with a polarization camera, a filter wheel, and an aperture door. We build a flight software to handle the command, data, and hardware for a pointing subsystem, a communication subsystem, and a coronagraph telescope subsystem in a remote environment. BITSE is a project of balloon-borne experiments for the coronagraph developed by a collaboration with KASI and NASA. The project was one of the technical milestones for the flight software development of the coronagraph. It was launched in 2019 and made about 17,000 solar coronal images in 4 hours of successful operation. The flight software is developed using the core Flight System (cFS) which is a

software framework including a set of reusable software applications that take advantage of a rich heritage of the successful space mission of NASA. The flight software development is one of the crucial contributions of KASI for the next project called CODEX, which will be installed at the International Space Station in 2023. In this talk, we will introduce the BITSE data acquisition process and the current status of the flight development for CODEX.

09:15 [II-2-2]

Ground Software Using COSMOS for Space Mission

Ji-Hye Baek, Jongyeob Park, Seonghwan Choi,
Jihun Kim, Heesu Yang, Yeon-Han Kim

Korea Astronomy and Space Science Institute

COSMOS is a suite of applications for command and control of embedded systems. COSMOS architecture consists of Command & Telemetry Server, Realtime Commanding and Scripting Tools, Realtime Telemetry Visualization Tools, Offline Analysis Tools, and Utilities. Those can make development easier and less hazardous. COSMOS supports any systems such as satellites, test equipments and development boards. It can be also used as the same interface from test to operations and all of the codes is open source. These advantages allow that COSMOS can be used in projects undertaken by many organizations such as NASA, Lockheed Martin, Ball Aerospace, etc. We have developed the Ground Software (GSW) of BITSE (Balloon-borne Investigation of Temperature and Speed of Electrons in the corona) using COSMOS as well and accomplished BITSE operation. We have completed development and operation of BITSE with NASA successfully and currently cooperation between KASI and NASA is continuing through the development of CODEX (Coronal Diagnostic Experiment) in the International Space Station.

09:30 [II-2-3]

Sub-Orbital Flight Uses of a Piezo-Ceramic Module in a Filter Wheel Assembly

Heesu Yang, Sung-hwan Choi, Jihun Kim,
Jongyeob Park, Jihye Baek, Yeon-Han Kim

Korea Astronomy and Space Science Institute

Space applications of the motion have been served with DC motors for decades. But their functionality with a gearbox and lubricants, weights, and the EMIs are always an issue for its application. A piezo-motor has an advantage on the direct driving with higher accuracy, smaller size, and no-EMI. We use the piezo-motor to rotate a filter wheel directly in a balloon-borne coronagraph launched in September 2019. The piezo-

motor works well in a temperature range from -10 to 40 Celsius with high reliability and high positioning accuracy (~ 0.1 degree) with a photo-encoder. In the low-temperature regime, the motor is not working well due to the surface condition is changed. It is necessary to test the mechanism to use the motor in a harsh environment.

09:45 [II-2-4]

Study on Trajectory of Air Launch Vehicle for Micro Satellite Orbit Insertion

Jong-Ha Kim, Pureum Kim, Sang-Young Park

Department of Astronomy, Yonsei University, Seoul, Korea

Due to geopolitical constraints on the Korean Peninsula, air launch method has been proposed as quick and easy launch methods for micro satellites. This study analyzes the relation between the maximum mass of micro satellites that can be lifted into orbit and the performance of airborne launch vehicles. The airborne launch vehicles are three or two stage projectile that reflects mass, thrust, aerodynamic characteristics, external load restrictions, and fairing separation time, etc. The fuel-optimal trajectories of launch vehicles are solved by GPOPS-II, that is a general-purpose optimal control software using a direct optimization method. The graphical user interface (GUI) version of the optimal launcher trajectory generation software is developed, which also enables users to easily visualize the airborne launch process in 3D using STK.

10:00 [II-2-5]

Cross-Track Formation to Collect Spatial Science Data for SNIPE Mission

Youngbum Song, Sang-Young Park

Department of Astronomy, Yonsei University, Seoul, Korea

The SNIPE mission comprises four 6U nanosats to observe the micro-scale structure of physical phenomena in the geomagnetic field. Two types of satellite formation flying are devised to meet the scientific objectives. Along-track formation is used to observe temporal science data, and cross-track formation is used to observe spatial science data. This presentation introduces the detail on the cross-track formation flying such as orbit control scenario, constraints in orbit control, control strategies in cross-track formation. The shape of the formation is switched from the along-track formation to the cross-track formation according to the scenario. There are four constraints to be considered during orbit control. The constraints are caused by the time interval between orbital data epoch and orbit control epoch, an attitude of nanosat, power safety, and specification of thrust module. To construct and extend the cross-track formation, nanosats should change their orbital planes. The

control utilizes the effects of J2 orbital perturbation to extend the size of the cross-track formation. Software simulations with the intended environments are conducted to verify the strategies.

10:15 [II-2-6]

The Simultaneous Analysis of Light and Radial Velocity Curves of V505 Lacertae

Min-Ji Jeong¹, Chun-Hwey Kim¹, Kyeongsoo Hong², Jang-Ho Park³

¹*Department of Astronomy and Space Science, Chungbuk National University, Cheongju, Korea*

²*Institute for Astrophysics, Chungbuk National University, Cheongju, Korea*

³*Korea Astronomy and Space Science Institute, Daejeon, Korea*

We present the physical parameters of V505 Lac investigated by our multi-band *BVR* light curves and high-resolution spectra. The photometric and spectroscopic observations were performed at the Sobaeksan Optical Astronomy Observatory and the Bohyunsan Optical Astronomy Observatory, respectively, in 2019. The radial velocities of both components were measured by the broadening function method with the MgI triplet lines, and the temperatures of both components were estimated by the modeling of spectra. These were simultaneously analyzed with the light curves to obtain the photometric and spectroscopic solutions of the system. It is found that V505 Lac is a W-subtype contact binary system with a mass ratio of 2.88, a low inclination of approximately 61°, and a fill-out factor of 0.177. The deduced individual masses, radii and temperatures of the components are $M_1 = 0.462(9)M_\odot$, $M_2 = 1.292(18)M_\odot$, $R_1 = 0.731(4)R_\odot$, $R_2 = 1.151(6)R_\odot$, $T_1 = 5983(66)$, and $T_2 = 5857(66)$, respectively.

10:30 [III-2-7]

Absolute Dimensions and Orbital Period Study of the W UMa-Type Eclipsing Binary EF Bootis

Ki-Yeong Han^{1,2}, Jang-Ho Park¹, Chun-Hwey Kim², Yonggi Kim²

¹*Korea Astronomy and Space Science Institute, Daejeon 34055, Korea*

²*Department of Astronomy and Space Science, Chungbuk National University, Cheongju 28644, Korea*

New photometric and spectroscopic observations of EF Boo have been made between March and April 2019 at the Sobaeksan Optical Astronomy Observatory and the Bohyunsan Optical Astronomy Observatory, respectively. The fundamental parameters of EF Boo were determined by a simultaneous analysis of the *BV* light and radial velocity curves, using the

Wilson-Devinney binary model. The individual masses, radii, and luminosities of both components are $M_1 = 0.73 M_\odot$ and $M_2 = 1.23 M_\odot$, $R_1 = 1.03 R_\odot$ and $R_2 = 1.30 R_\odot$, and $L_1 = 1.47 L_\odot$ and $L_2 = 2.30 L_\odot$ respectively. Including our 6 timing measurements, a total of 98 times of minimum light were used for orbital period study. A detailed analysis of the *O - C* diagram disclosed that the orbital period shows an upward parabolic variation superposed on a periodic oscillation. The continuous increase rate is estimated as $+1.25 \times 10^{-7} \text{ d yr}^{-1}$, which can be interpreted as a mass transfer from the less massive primary star to the more massive secondary. The most likely explanation of the periodic oscillation having a period of 27.5 yr and a semi-amplitude of 0.0048 d is a light-travel-time effect due to a third body with an eccentric orbit of $e_3 = 0.54$. Our results indicate that EF Boo is a W-subtype contact binary star with a circumbinary object.

제3발표장 Halla Room

II-3 Sun & Space Environment (II)

좌장: SooJeong Jang (KASI)

09:00 [II-3-1]

Historic Events in Solar Activity and Geomagnetic Response Recorded in Korean Chronicles

Rok-Soon Kim^{1,2}, Hong-Jin Yang¹

¹*Korea Astronomy and Space Science Institute*

²*University of Science and Technology*

We have examined 38 sunspots and related 26 auroras found in Korean chronicles from the 10C to 18C. The records can be divided into the warm period before and AD1300 including the medieval warming period and the cool period after 1300 including several grand minima. The sunspot observation rates are similar in two periods, while more auroras are observed in the cool period. We also studied notable strong sunspots and associated auroras and found some interesting results. First, the rate of the large sunspot is more than three times higher in the warm period than in the cool period, and the large sunspot is around two times more geoeffective than the small sunspot in the cool period. Second, We confirmed the recursive sunspot in 1185 and it seemed to have similar activity to the Halloween event in 2003 in the size and geoeffectiveness. Last, the size of the sunspot recorded in Korean chronicles can be an index of solar activity such as the sunspot number. From these results, we insist that the historical sunspot records are useful not only to examine long-term solar activity but also to speculate extreme activities of the Sun and the Earth.

09:15 [II-3-2]

Halo CME Mass Using a Synthetic CME Based on a Full Ice-Cream Cone Model

Hyeonock Na, Yong-Jae Moon

School of Space Research, Kyung Hee University

In this study, we suggest a new method to estimate the mass of a halo coronal mass ejection (CME) using synthetic CMEs. For this, we generate synthetic CMEs based on two assumptions: (1) the CME structure is a full ice-cream cone, (2) the CME electron density follows a power-law distribution ($\rho_{cme} = \rho_0 r^{-n}$). The power-law exponent n is obtained by minimizing the root mean square error between the electron number density distributions of an observed CME and the corresponding synthetic CME at a position angle of the CME leading edge. By applying this methodology to 57 halo CMEs, we estimate two kinds of synthetic CME mass. One is a synthetic CME mass which considers only the observed CME region (M_{cme1}), the other is a synthetic CME mass which includes both the observed CME region and the occulted area larger than 4 solar radii (M_{cme2}). From these two cases, we derive conversion factors which are the ratio of a synthetic CME mass to an observed CME mass. The conversion factor for M_{cme1} ranges from 1.4 to 3.0 and its average is 2.0. For M_{cme2} , the factor ranges from 1.8 to 5.0 with the average of 3.0. These results imply that the observed halo CME mass can be underestimated by about 2 times when we consider the observed CME region, and about 3 times when we consider the region including the occulted area. Interestingly these conversion factors have a very strong negative correlation with angular widths of halo CMEs.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (2018-0-01422, Study on analysis and prediction technique of solar flares).

09:30 [II-3-3]

Comparisons of CoMP and Hinode/EIS LOS Doppler Velocities and Non-Thermal Line Widths

Jae-Ok Lee¹, Kyoung-Sun Lee², Jungjoon Seough¹¹*Korea Astronomy and Space Science Institute*²*Seoul National University*

In this study, we compare Line of sight (LOS) doppler velocities and non-thermal line widths obtained by Coronal Multichannel Polarimeter (CoMP) Fe XIII 10747 Å line and Hinode/EUV Imaging Spectrometer (EIS) Fe XIII 202.04 Å line to check their similarity and/or dissimilarity on a prominence cavity, equatorial loop, and polar plume. The EIS Fe XII 195.12 Å line is used for examining active region loops. For this, we use

12 data sets from four different coronal regions: 2 prominence cavities, 1 equatorial loop, 1 polar plume, and 8 active region loops. We determine two spectroscopic quantities by analyzing three data points (spectral lines at 10,745.0, 10,746.2, and 10,747.4 Å) of the CoMP Fe XIII line, and about twenty data points (spectral lines ranging from 194.9 to 195.4 Å and from 201.8 to 202.3 Å) of the EIS Fe XII and XIII lines. To easily compare them between CoMP and EIS, we make pseudo CoMP raster scan images during the EIS raster observations. We determine averages and standard deviations of CoMP and EIS LOS doppler velocities (non-thermal widths) along the specific positions in the coronal regions, and compare them. Here, the standard deviations of LOS doppler velocities indicate LOS velocity amplitudes on the coronal regions. The main results of this study can be summarized as follows. (1) By comparing the CoMP and EIS raster scan velocity maps, we find that they are spatially and temporally consistent with each other overall in the active regions and the equatorial loop, while they are partially similar to each other along the overlying loops of the prominence and at the bottom of the polar plume. (2) The CoMP LOS velocity amplitudes are $< 1.0 \pm 0.56 >$ km/s ranging from 0.32 to 2.74 km/s at the heights between 1.06 and 1.21 Rs, which is about 21% lower than EIS ones ($< 1.27 \pm 0.44 >$ km/s ranging from 0.62 to 2.28 km/s). (3) Regarding to the non-thermal widths, we find that CoMP and EIS non-thermal width distributions are fairly similar to each other in the several active regions and the polar plume with different observational tendencies: the observed widths seems to be decreased or increased with increasing heliocentric distance in the active regions, while they seems to be increased in the polar plume region. (4) The averages of CoMP non-thermal widths are $< 26.02 \pm 4.28 >$ km/s ranging from 18.32 to 32.97 km/s, which is about 20% lower than that by EIS ($< 31.88 \pm 4.09 >$ km/s ranging from 24.9 to 41.46 km/s). Our results demonstrate that CoMP observations by using only three-point data of Fe XIII lines can provide us reliable 2-D LOS doppler velocity and non-thermal width distributions within bright coronal structures such as active region and equatorial loops, and further to estimate their Alfvén wave energy fluxes.

09:45 [II-3-4]

Effect of Higher Radial Harmonics of Sausage Oscillations in the Corona

Daye Lim¹, Valery M. Nakariakov^{2,3},
Yong-Jae Moon^{1,3}, Dae Jung Yu¹, Il-Hyun Cho¹¹*Department of Astronomy and Space Science, Kyung Hee University*²*Department of Physics, University of Warwick*³*School of Space Research, Kyung Hee University Institute of Geoscience and Mineral Resources*

Impulsively excited sausage oscillations of a plasma cylinder

with a smooth radial profile of Alfvén speed are analyzed with a numerical solution of the initial-value problem for a partial differential equation of the Klein–Gordon type, describing linear magnetoacoustic oscillations with a fixed axial wavelength and an azimuthal mode number. The range of analyzed ratios of Alfvén speeds outside and inside the cylinder is from 2 to 10. Both trapped and leaky regimes of the oscillations are considered. It is shown that even in the long-wavelength limit, i.e., for axial wavenumbers much smaller than the cutoff values, damping times of higher radial sausage harmonics could be significantly greater than the oscillation periods, i.e., several oscillation cycles could be present in the signal. The quality factors decrease with decreasing ratios of Alfvén speeds outside and inside the cylinder. Oscillation periods of the second and third radial harmonics remain practically independent of the axial wavelength even when the wavelength is shorter than the radius of the cylinder. The ratios of oscillation periods of fundamental and higher radial and axial harmonics are found to be significantly different, up to a factor of two in the long-wavelength limit. It is concluded that higher radial harmonics could be responsible for the departure of observed sausage oscillation signals from a harmonic shape, especially during the first several cycles of the oscillation. Even in the absence of spatially resolved data, higher axial and radial harmonics can be distinguished from each other by the period ratios.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (2018-0-01422, Study on analysis and prediction technique of solar flares).

10:00 [II-3-5]

Triggering Process of an Eruptive M6.5 Flare Observed in Active Region 12371

Jihye Kang¹, Satoshi Inoue², Kanya Kusano²,
Sung-Hong Park², Yong-Jae Moon^{1,3}

¹*Department of Astronomy and Space Science, Kyung Hee University*

²*Institute for Space-Earth Environmental Research, Nagoya University*

³*School of Space Research, Kyung Hee University*

We investigated a flare onset process in terms of stability of a three-dimensional (3D) magnetic fields of an eruptive M6.5 flare in active region 12371. In order to examine the MHD instability, we first reconstruct the 3D coronal magnetic fields using a nonlinear force-free field (NLFFF) model before and after the onset of the flare. NLFFFs show two branches of sheared arcade loops which is a sigmoidal structure seen in the EUV images in the flaring region. In the two branches of sheared arcade loops, we investigate three representative

instabilities: kink, torus and double arc instabilities (DAI). Consequently, the sheared arcade loops are quite stable against the kink and torus instabilities, but unstable against the DAI before the onset of the flare. Based on the stability analysis, we suggest a possible scenario for the onset process of the M6.5 flare in three-step: (1) the tether-cutting reconnection cause the sheared arcade to form into double arc loops during an initial phase of the flare, (2) the DAI contributes to the expansion of destabilized double arc loops, and (3) finally, the torus instability makes the full eruption. This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (2018-0-01422, Study on analysis and prediction technique of solar flares).

제1발표장 Landing BallroomA

Invited Talk II

좌장: GiHyuk Choi (KARI)

11:00 [IS-II]

Thirty Years of Space Science Observations in Korea

Kyoung Wook Min

Korea Advanced Institute of Science and Technology

Nearly 30 years have passed since Korea's first satellite was launched in 1992. During this period, scientific observations were carried out with two sounding rockets, as well as on four satellites as their primary or secondary missions. The most notable of these is the all sky survey conducted by the Far-ultraviolet IMaging Spectroscopy (FIMS) on board the Science and Technology Satellite-1 (STSAT-1). FIMS covered ~75% of the sky during its short lifetime, producing spectral maps with 5° angular resolution in the 900–1150 Å and 1335–1750 Å wavelength bands, with 1.5 Å and 2.5 Å spectral resolution, respectively. The resulting dataset has been used extensively for the study of interstellar medium such as the interaction of hot gases with cooler environments, fluorescence emission of molecular hydrogen in photo-dissociation regions, and the scattering of stellar photons by dust grains. Further, FIMS observed the terrestrial auroras occasionally, for which spectra of precipitating electrons were measured simultaneously with the particle detectors on board the same spacecraft, thereby establishing the relationship between the two. In this paper, a brief review of these FIMS results will be presented, along with those of other missions, including the recent NEXTSat-1.

제1발표장 Landing BallroomA

Invited Talk III

좌장: RyunYoung Kwon (KASI)

11:30 [IS-III]

The Solar Corona from Within: Overview of WISPR Science Results & Future Outlook

Angelos Vourlidas

JHU/APL on behalf of the WISPR Science Team

The Parker Solar Probe's (PSP) first four perihelia have been a treasure trove of scientific insights and surprises on the structure of the solar wind and generally of the circumsolar environment. In this talk, I review that major results from imaging the solar from within by PSP's WISPR telescopes over the first four perihelia and outline the exciting science opportunities in the near future which range from coordinated observations with Solar Orbiter to planetary physics with Venus and comet observations.

13:00~14:00 2부 포스터 발표

제1발표장 Landing BallroomA

III-1 Lunar & Space Exploration (II)

좌장: YoungJoo Song (KARI)

14:00 [III-1-1]

KPLO Lunar Mission Orbit Design Using Eccentricity-Argument of Periapasis Vector

Jae-ik Park, Donghun Lee, SeungBum Hong, Young-Joo Song, Young-Rok Kim, Jonghee Bae, Dae-Kwan Kim, Sang-Ryool Lee

Korea Aerospace Research Institute

The Korea Pathfinder Lunar Orbiter (KPLO) will perform a science mission in the relatively low orbit at an altitude of 100 km. The altitude of the lunar orbit is varied rapidly due to the effects of the asymmetric lunar gravity field. This variation can be expressed as a two-dimensional graph showing the path of eccentric vectors over time. The eccentricity and argument of periapsis (AOP) can be expressed in polar coordinates for the eccentricity vector space. This evolution has a pattern that

repeats almost every 27.3 days, same as the lunar sidereal month. The eccentricity vector is evolved from left to right in eccentricity and AOP polar coordinate frame. The evolution is invariant to its initial values of eccentricity and AOP. Using this invariability, it is possible to design the lunar mission orbit so that KPLO can stay within the mission altitude for a long time without orbit maintenance. In this paper, we will present the design method and results of the KPLO mission orbit that can minimize orbit maintenance maneuvers by adjusting the eccentricity and the AOP vector evolution.

14:15 [III-1-2]

WSB/BLT Trajectories for the KPLO Mission

Donghun Lee, Jae-ik Park, Young-Joo Song, Young-Rok Kim, SeungBum Hong, Jonghee Bae, Dae-Kwan Kim and Sang-Ryool Lee

Korea Aerospace Research Institute

There are several routes for transferring a spacecraft from an Earth parking orbit to a lunar mission orbit, such as the direct transfer trajectory and the phasing loop transfer trajectory. Because the transfer strategy utilizing weak stability boundary/ballistic lunar transfer (WSB/BLT) technique, which is one of low energy transfer technologies, has an advantage in terms of the fuel consumption, the transfer strategy was implemented in the past lunar exploration missions, and have been considered as the transfer strategy for the future lunar exploration missions. This paper deals with the KPLO lunar transfer trajectories, in which the advanced WSB/BLT technologies was applied. In general, because it is difficult to construct a WSB/BLT trajectory, the N-method is proposed. The N-method is a methodology to design WSB/BLT trajectory, and developed by the BLT design team at KARI. Through the numerical examples, the efficiency of the N-method will be shown, and the several considerations in designing the realistic WSB/BLT trajectories will be discussed.

14:30 [III-1-3]

The Effective Strategies of Precise Orbit Determination for Lunar Orbiting Spacecraft Using Sequential Estimation

Young-Rok Kim¹, Eunseo Park²

¹*Korea Aerospace Research Institute*²*Korea Astronomy and Space Science Institute*

Orbit determination of lunar orbiting spacecraft is an essential procedure for mission operation and payload data processing. For the science data processing such as imaging, measuring, and surveying the lunar surface, lunar orbiting spacecraft's position and velocity information is critical. If the accuracy of

that information is improved, the quality of achieved science data products is also enhanced. Most lunar orbiter missions provide precise orbit by post-processed estimation using a large amount of tracking data for the best product generation. For the precise orbit determination (POD) of a lunar orbiter, batch estimation using the least-squares filter is generally used for the estimation results' stability and accuracy. However, the conventional batch approach has shortcomings such as computational burdens, inefficient maneuver estimation, and sufficient measurements. In this study, we try to perform POD for the lunar orbiter using sequential estimation for the convenient and quick post-processing. The extended Kalman filter and a fixed point backward smoother are applied. Various estimation strategies such as force modeling refinement, arc length selection, process noise, and initial covariance adjustments are considered. Finally, the improvement of orbit accuracy by the POD is investigated, and the effective strategies are suggested.

14:45 [III-1-4]

A Study of the South-Directed Launch Vehicle's Separation Requirement and Constraints for the Lunar and Interplanetary Exploration Missions

Bangyeop Kim

Korea Aerospace Research Institute

The constraints and requirements of space launch vehicles with a limited launch direction to the south were investigated when used in lunar and interplanetary missions. If the flight direction is restricted to the south, there are restrictions on the time tolerance and speed tolerance at the moment of spacecraft separation. The effect of these restrictions on the launch of a lunar or interplanetary spacecraft was analyzed.

15:00 [III-1-5]

Apophis Rendezvous Mission: I. Draft Overview

Hong-Kyu Moon¹, Young-Jung Choi^{1,2}, Myung-Jin Kim¹, Youngmin JeongAhn¹, Hongu Yang¹, Minsup Jeong¹, Masateru Ishiguro³, Seul-Min Baek¹, Hee-Jae Lee¹, Jin Choi¹, Sang-Young Park⁴, Pureum Kim⁴, Chae Kyung Sim¹, Dukhang Lee¹, Bongkon Moon¹, Taehyun Jung¹, Do-Young Byun¹, Do-Heung Je¹, Se-Jin Kwon⁵, Goo-Hwan Shin⁵, Kwang-Sun Ryu⁵, Son-Goo Kim⁵, Jeong-Soo Lee⁵, Joun-Ki Seo⁵, Se-Yon Kim⁵, Dong-Guk Kim⁵, Im-Hyu Shin⁵, Sung-Og Park⁵, Tae-Jin Chung⁵, Gun-Soo Shin⁵, Hyun-Tae Choi⁵, Hyosang Yoon⁶

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⁶*Department of Aerospace Engineering, KAIST*

99942 Apophis is a Sq-type Aten group Near-Earth Asteroid (NEA) with an estimated size of 340 m. It will approach the Earth to come within the geostationary orbit during the upcoming encounter on April 13, 2029 to offer a unique chance to study its 1) global properties, 2) surface arrangements, and 3) their detectable changes expected to happen, in sub-meter scale, during the approach. With a dedicated space mission to this asteroid, we aim to fill in the knowledge gaps in our scientific understanding of NEA population and in the tidal effects that could also be used for planetary defense when there is a real threat. Therefore, we propose a dedicated rendezvous mission to Apophis for both scientific investigation and technology demonstration. It is basically based on the third revision of the Basic Plan for Space Development (제3차 우주개발진흥 기본계획, 2018) of the Korean Government. In this talk, we will briefly present the objectives, the requirements and the draft system design of this proposed project.

15:15 [III-1-6]

Apophis Rendezvous Mission: II. Science Mission and Payloads

Myung-Jin Kim¹, Hong-Kyu Moon¹, Young-Jun Choi^{1,2}, Youngmin JeongAhn¹, Hongu Yang¹, Minsup Jeong¹, Masateru Ishiguro³, Seul-Min Baek¹, Hee-Jae Lee¹, Chae Kyung Sim¹, Dukhang Lee¹, Bongkon Moon¹

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The scientific purpose of the Apophis Rendezvous Mission is to investigate the physical and surface properties of the asteroid during the close approach in 2029. To achieve this science goal, we propose five science payloads as in the following: 1) Mapping Camera is for global mapping of the asteroid with a multi-band, 2) Polarimetry Camera will obtain the polarimetric information from the different phase angles, 3) Laser Altimeter will measure the distance between the probe and the asteroid surface, 4) Magnetometer will survey the magnetic field around the asteroid and during cruising phase. And 5) Dust Particle Detector is for detecting the inter-planetary dust particle on cruising phase, it could also observe the dust particles from the asteroid surface. For the Polarimetry Camera and Magnetometer, they use heritage from the KPLO payload. In addition, the Navigation Camera with wide/narrow angles that are the optical navigation cameras on cruising phase could be utilized for the

research on the lightcurve and shape modeling of the target. In this talk, we will briefly introduce the scientific objectives and payloads of this proposed project.

15:30 [III-1-7]

Apophis Rendezvous Mission: Mission and Trajectory Design

Pureum Kim, Sang-Young Park

Department of Astronomy, Yonsei University

99942 Apophis is a 350-meter near-Earth asteroid well-known for its predicted close approach to Earth in April 2029. At its closest, the asteroid will be closer to Earth than geostationary satellites. Such close approach is expected to bring about significant changes to the surface properties of the asteroid due to tidal effects. Apophis will provide us with a rare investigation opportunity where humankind can acquire scientific knowledge about potentially hazardous asteroids. In this study, preliminary design analysis of trajectories to Apophis was performed under the assumption of impulsive maneuvers. Trajectories with different swing-by sequences and those without swing-by maneuvers were examined, and a few feasible options were identified. For each feasible option, a more thorough analysis was carried out to spot a few near-optimal launch/arrival times. This preparatory analysis will aid in preliminary design of the future Apophis mission.

15:45 [III-1-8]

Apophis Rendezvous Mission: VI. Spacecraft Tracking with the VLBI Network

Taehyun Jung^{1,2}, Do-Heung Je¹, Do-Young Byun^{1,2}, Jin Choi¹, Myung-Jin Kim¹, Young-Jun Choi^{1,2}, Hong-Kyu Moon¹

¹*Korea Astronomy and Space Science Institute*

²*University of Science and Technology*

Very Long Baseline Interferometry (VLBI) is a technique to achieve ultra-high angular resolution (e.g., a few ten micro-arcseconds) by connecting multiple radio telescopes placed on hundreds to thousands of kilometers away. Based on this aspect, VLBI is widely used for studying distant objects that have an extremely small angular size and for high-precision astrometry and geodesy. In particular, it has been also used varies space applications such as spacecraft tracking and measuring the lunar gravitational field since the mid-1980s (e.g., VLBA tracking of the Cassini spacecraft, NASA's Mars Exploration, SELENE and Change'E-3 Missions etc). In this presentation, we will introduce the principles and examples of spacecraft tracking using VLBI and will discuss the feasibility of VLBI tracking for the Apophis rendezvous mission using the VLBI network including

the Korean VLBI Network (KVN).

제2발표장 Landing BallroomB

III-2 Space Technology & Space Astronomy (II)

좌장: DaeHee Lee (KASI)

14:00 [III-2-1]

On-Board Station-Keeping Algorithm for Geostationary Satellites Based on GNSS Receiver

Bong-Kyu Park

Korea Aerospace Research Institute

GEO (Geostationary Earth Orbit) satellites are in the circular orbit with a very small inclination and altitude of 35,786 km. It revolve around the Earth once a day so as to be observed at same location in the sky. But the perturbing forces such as geopotential disturbance, Sun and moon gravitational forces and Solar radiation pressure induce gradual deviation from the original orbit. This is the why station-keeping maneuvers are essential for GEO satellites mission. For GEO satellites, the station-keeping consists of two types of maneuvers: North/south maneuver and east/west maneuvers. Process of the station-keeping includes the orbit determination, maneuver planning and maneuver execution. Typically, these are performed by ground crews manually using ground tracking system, flight dynamic software and command loading system. Station-keeping maneuver process is very routine, but it was difficult to be performed automatically unlike the case of attitude control, because of none availability of on-board tracking system and complexity of maneuver planning algorithm. Autonomous station-keeping algorithm has to be simple, robust and consume only minimum computational burden. However, today, we are under new technical possibilities: the availability of GNSS receiver and EP (Electrical Propulsion) system for GEO satellites. Application GNSS receivers for LEO satellites is common today, but for GEO satellites, it is state-of-the-art technology. Accommodation of EP system with low and constant thrust makes the onboard thruster modelling simple and robust.

This paper proposes a straightforward autonomous station-keeping algorithm under assumption of using GNSS receiver and EP system. The main feature of the algorithm is the absence of on-board orbit propagator by accommodating an extrapolation based eccentricity vector and mean longitude predictor. The proposed algorithm accommodates a harmonic and 2nd order polynomial function with predetermined key parameters to predict eccentricity vector and longitude precisely. This study introduces simulation results performed to prove the feasibility

of the proposed algorithm.

14:15 [III-2-2]

Review of Electric Propulsion System Models for the Next Generation GEO Communication Satellite

Sung-Soo Jang

Korea Aerospace Research Institute

The next generation GEO Communication Satellite will be developed as a hybrid propulsion system using chemical and electric thruster on the basis of GK2. In general, the electric propulsion system using hall type is composed of a electric thruster, a power processing unit (PPU), pointing thruster orientation mechanism (PTM), filter units, and HET/XFC harness set assembly (HSA). By applying an electric thruster system on orbit, the GEO Communication Satellite is expected to be able to cut the weight of approximately 400 kg or more. The electric thruster system of the GEO Communication Satellite is designed to generate at least 50 mN thruster and meet the operating time of an average 1.4 hours per day. The main electric thruster models currently under review are Airbus' ion electric thruster system and SAFRAN's hall thruster system. This paper summarizes the major requirements of the electric propulsion system being studied for hybrid propulsion system of the GEO Communication Satellite. In addition, the results of system impact according to candidate models of major electric propulsion system are summarized.

14:30 [III-2-3]

System Jitter Test and Line of Sight Analysis for Image Performance Estimation of Low Earth Orbit Electro-Optical Satellite

Jeong-Heum Im¹, Jae Hyuk Lim²

¹*Korea Aerospace Research Institute*

²*Jeonbuk National University*

Korea aerospace research center is developing an optical satellite which will be operated on a low earth orbit. The satellite is equipped with an electro optical payload system. A system jitter test has been conducted by using a flight model satellite on which electro optical payload are installed. The electro optical payload consists of 5 mirrors and 1 focal plane. There are two micro vibration sources on the satellite, which will affect the final image performance in terms of jitter. They are 4 reaction wheel assemblies which is used for satellite maneuver and 2 X-band gimbal antennas which are used to transit image data to ground station. The main purpose of this test is to evaluate the coupling effects between the micro

vibration sources and the spacecraft structure on the jitter response for the final jitter verification. To evaluate the coupling effects, the test results were compared to the ones obtained from Structural Thermal Model jitter test, which was conducted in 2018 by using a structural thermal model of spacecraft. And finally to evaluate the image performance, fined tuned Finite Element Model of satellite was generated by modal test. Micro vibration data which was obtained during each unit's test were used as jitter input.

14:45 [III-2-4]

Spacecraft Bus Operation Test for Launch and Early Operation of Low-Earth Orbit Satellite

Jeong-Heum Im

Korea Aerospace Research Institute

A spacecraft bus operation test has been conducted by using a set of electrical test bed, electrical ground support equipments and test aids. The objective of this test is to verify overall spacecraft bus operation including specific operations of each subsystem in early operational phase. Three sub tests has been conducted. They are 1) overall spacecraft bus operation test in case of on-ground solar array deployment success, 2) in case of on-ground solar array deployment failure and 3) in case of spacecraft fail-over during operation. The test scenario was prepared to simulate the real launch day operation as much as test configuration allows. The orbit of satellite was simulated to be propagated from the initial orbital parameters which is expected to be injected by the launch vehicle. Solar environment was simulated by using solar array simulator in terms of electrical power generation. The satellite dynamics system was used to simulate the position and velocity of the satellite and attitude of the satellite at a specific time. This paper summarized the test from the test preparation, configuration and documentation to the confirmation of each operation by using the telemetry and system log obtained during the test.

15:00 [III-2-5]

Applications FSO (Free-Space Optical) Communication in Space

Jin Pyong Jung¹, Seongmin Pyo²

¹*Satellite Payload Development Division, Korea Aerospace Research Institute*

²*Department of Information and Communication Engineering, Hanbat National University*

Currently, the requirements for the resolution of the satellite electro-optical camera are expected to continue to drop below the sub-meter level.

In order to downlink this amount of image data to the ground,

it must have a transmission speed of at least several Gbps. Therefore, advanced countries in Europe and the United States are commercializing satellite data relay systems using FSO communication.

Now in Korea satellites, video data downlink uses X-band RF signals, but additional scalability is insufficient.

FSO has the advantages of data speed, low power, volume and weight reduction, and no international restrictions on frequency. So not far away, FSO is expected to be applied to Korea satellite.

15:15 [III-2-6]

Initial Prediction Model of Tool Influence Function (TIF) Depth on SiC Surfaces

Jeong-Yeol Han^{1,2}, Hyukbin Lee³, Dohoon Kim⁴,
Hyung Kwon Lee⁴, Jaeyeong Jo⁴

¹*Korea Astronomy and Space Science Institute*

²*University of Science and Technology*

³*Chungnam National University*

⁴*Green Optics Co. Ltd.*

On mirror polishing process, various machine input parameters such as loading pressure, rotation speed of wheel, and dwell time affect Tool Influence Function (TIF) depth. However, the depth, in general, is difficult to predict based on a sort of learning curve from the relationship between the input and output parameters due to their complexity. The complexity leads prediction inaccuracy and increase confusion to figure out the polishing process. In this investigation, we adopt input parameters with random function in order to eliminate biased input variable combination by human errors as well as to extend variable ranges from polishing machine. Resultant TIF depths as an output parameters according to the random input parameters set were obtained by polishing head in the polishing machine. The prediction model enables to conduct ultra-precision polishing process and to solve deterministic polishing in mirror manufacturing factory.

15:30 [III-2-7]

Precise Relative Navigation Algorithm for CANYVAL-C Cubesat Mission in Formation Flying

Eunji Lee, Jihae Son, Sang-Young Park

Department of Astronomy, Yonsei University, Seoul, Korea

CANYVAL-C is a space mission to take pictures of solar corona using two cubesats holding alignment with respect to the Sun. For satisfying strict precision and robustness requirements, it employs extended Kalman filter (EKF) with GNSS data for relative navigation. EKF, however, needs to empirically designate the dynamic and measurement noise covariances. To overcome deficiencies in EKF, this research proposes an

operation strategy employing parameter tuning with a modified adaptive Kalman filter (AKF) in a ground station, and verifies it by the hardware-in-the-loop simulation (HILS). The relative positioning error with adaptively determined parameters was about 30 cm for each axis. The adaptive process is robust to the initial guess of the tuning parameters, and determines the parameters to well describe the system property regardless of the tracking data and control scenarios. Furthermore, the proposed strategy imposes no additional computational burden on the cubesat with a restricted onboard processor.

제3발표장 Halla Room

III-3 Sun & Space Environment (II)

좌장: HyuckJin Kwon (KOPRI)

14:00 [III-3-1]

A Case Study of Transversely Heated Low-Energy Helium Ions by EMIC Waves in the Plasmasphere

Khan-Hyuk Kim¹, Hyuck-Jin Kwon², Junhyun Lee¹,
Ho Jin¹, Jungjoon Seough³

¹*Kyung Hee University*

²*Korea Polar Research Institute*

³*Korea Astronomy and Space Science Institute*

The Radiation Belt Storm Probes-A (RBSP-A) spacecraft observed strong ~ 0.5 -Hz helium (He^+) band and weak ~ 0.8 -Hz hydrogen (H^+) band EMIC waves on 17 April 2018, at $L = \sim 4.5 - 5.2$, in the dawn sector, near the magnetic equator, and close to the outer edge of the plasmasphere. We examined low-energy ion fluxes observed by the Helium Oxygen Proton and Electron (HOPE) instrument onboard RBSP-A during the wave interval and found that low-energy He^+ flux (< 10 eV) enhancements occur nearly simultaneous with He-band and H-band EMIC wave power enhancements in a direction mostly perpendicular to the background magnetic field without significant low-energy H^+ and O^+ flux variations. We suggest that cold He^+ ions (< 1 eV) are preferentially and transversely heated up to 10 eV through the interaction with EMIC waves inside the plasmasphere. The low-Earth orbit spacecraft observed an isolated spectral enhancement, which is short-lived and lasting only ~ 1 min, at ~ 0.5 Hz and localized precipitations of energetic protons in the upper ionosphere at subauroral latitudes near the magnetic field footprint of RBSP-A. Our observations provide a clear evidence that EMIC waves play an important role in the overall dynamics in the inner magnetosphere, contributing to the loss and energization of magnetospheric particles.

14:15 [III-3-2]

Simultaneous Observations of Ducted Pc1 Waves at Multi-stations in Antarctica

Hyuck-Jin Kwon¹, Geonhwa Jee^{1,2}, Changsup Lee¹, Khan-Hyuk Kim³

¹*Division of Polar Climate Sciences, Korea Polar Research Institute*

²*University of Science and Technology*

³*School of Space Research, Kyung-Hee University*

Electromagnetic ion cyclotron (EMIC) waves generated in the equatorial plane, propagate from the magnetosphere to the ionosphere along field lines and convert to compressional waves by mode-conversion. Such propagated waves are observed in the Pc1 band (0.2–5 Hz) on the ground and horizontally propagate through the maximum electron density region in the ionosphere. Korea Polar Research Institute has been operated the array of search-coil magnetometers with identical system at Jang Bogo Station, (JBS, -74.4° geographic latitude, 164.1° geographic longitude), Neumayer (VNA, -70.4° geographic latitude, -8.2° geographic longitude), and King Sejong Station (KSS, -62.1° geographic latitude, -58.5° geographic longitude). We statistically examined the spectral features of Pc1 waves simultaneously identified at JBS, VNA, and KSS. It is found that the amplitude of Pc1 waves rapidly reduced as they propagate to lower latitude than higher latitude. We also confirmed the Pc1 waves in the ionosphere when Swarm spacecraft pass over near VNA. We found that the frequency of Pc1 waves at Swarm slightly higher than those on the ground. We suggested that this difference of frequency due to Doppler effect at Swarm.

14:30 [III-3-3]

A Statistical Study of Heated Helium Ions Associated with EMIC Waves in the Plasmaspheric Region

Junhyun Lee, Ensang Lee, Khan-Hyuk Kim

School of Space Research, Kyung Hee University

It has been reported that the presence of cold heavy ions can generate EMIC waves in distinct bands and these waves interact with cold ions. In this study, we statistically analyze enhanced helium flux of energy below 1 keV for He-band EMIC wave events using the Helium, Oxygen, Proton, and Electron (HOPE) onboard the Van Allen Probe (VAP) satellites from January 2013 to December 2017. 90 wave events, clearly related to helium flux enhancement, occurred predominantly for the post-noon to dusk sector near the equatorial plane ($MLAT \sim \pm 10^\circ$). Only $\sim 7\%$ of EMIC waves interact with cold He⁺ ions. For each event, He-band EMIC waves preferentially heated unseen cold (below 1eV) helium ions up to ~ 100 eV in the

plasmaspheric region. The integrated helium flux in the energy range 1–10 eV and the maximum energy of the heated helium flux show slightly positive correlations with the transverse EMIC wave power, and the minimum wave power to heat cold He⁺ ion is about 0.001 nT^2 . Most of the events show the 90° -peaked or pancake pitch angle distribution. These results indicate that there are thresholds of the wave power to accelerate cold ions, and suggest that He-band EMIC wave contributes to the transverse acceleration of cold helium ions to the background magnetic field, in the dusk sector of the plasmaspheric region.

14:45 [III-3-4]

A Source for Oxygen Ion Cyclotron Harmonic Waves in the Inner Magnetosphere: Implication of Wave Superposition on Wave Mode Identification

Kyungguk Min¹, Kaijun Liu²

¹*Department of Astronomy and Space Science, Chungnam National University*

²*Department of Earth and Space Sciences, Southern University of Science and Technology*

During storm times, waves at or near the oxygen ion (O^+) cyclotron frequency and its harmonics—aptly named oxygen ion cyclotron harmonic waves—have been observed by the Van Allen Probes, as well as earlier missions, at locations near the plasmopause. Their true identity is still under debate: Some suggested that the apparent quasi-parallel propagation from wave normal angle (WNA) analysis is the manifestation of electromagnetic ion cyclotron (EMIC) waves, while others pointed out that the harmonic frequency pattern is suggestive of the ion Bernstein modes at quasi-perpendicular propagation. In our earlier study, we showed that based on the observed plasma parameters during one such wave event, the O^+ Bernstein instability driven by energetic O^+ ions of a ring-like velocity distribution can generate waves with the properties consistent with those from observations, but at differing WNAs. We suggested that the WNA discrepancy is the result of wave superposition. To further demonstrate this scenario, we have recently carried out multi-dimensional hybrid simulations. First, multiple one-dimensional simulations confirm the earlier linear theory prediction and the generated waves have the properties consistent with those from observations. Second, the WNA analysis on the waves generated in a three-dimensional simulation indeed yields apparent quasi-parallel wave normal directions as a result of wave superposition, similar to the result from the WNA analysis of observed waves reported earlier. The latter result has broader implication on WNA analysis in general because wave superposition occurs for any types of waves and can, therefore, potentially hide the true identity of constituting

wave modes.

15:00 [III-3-5]

Disseminating Plan of SNIPE Data for Space Science Research

Young-Sook Lee¹, Yong Ha Kim¹, Jaejin Lee²,
Young-Sil Kwak², Jaeheung Park², Tae-yong Yang²

¹Chungnam National University

²Korea Astronomy and Space Science Institute

Small Scale Magnetospheric and Ionospheric Plasma Experiment (SNIPE) mission is planned to be launched in 2021, orbiting at an altitude of 500 km with 97.7° inclination. It takes a formation flying of four nano satellites sized in 6U. The payloads of each satellite consist of a solid state telescope (SST), two 3-axis fluxgate magnetometers (MAG), and a Langmuir probe (LP). This paper presents suggested solutions of promoting the utilization of the produced data for the benefits of not only domestic but also international space scientists. The solutions include data formats acceptable to users and data engineering; how to provide web service; what kind of data to be reserved; what to be the rule of the data access. In addition, the solutions consider advertising issues of SNIPE data. Discussions will be provided by reviewing the web site for the data produced from foreign satellites, including SWARM, POES, GOES and ERG.

15:15 [III-3-6]

Observations of the Earth's Outer Radiation Belt during a Moderate-Sized Magnetic Storm in May 2019

Jongho Seon, Chan-Haeng Lee, Woo-Hyung Seol,
Khan-Hyuk Kim

School of Space Research, Kyung Hee University, Korea

A multi-satellite conjunction study of the Earth's outer radiation belt is presented for a moderate-sized magnetic storm in May 2019. The primary observation is made with a suite of space weather sensors aboard the geostationary GK2A at 128.2°E. This space weather suite of KSEM consists of a set of particle detectors, a charging monitor and a four-sensor magnetometer instrument. The Particle Detector (PD) experiment consists of three sensors viewing different angles relative to spacecraft. Each sensor separately measures electrons and ions in the energy range of 100–3,600 keV for electrons and 148–18,000 keV for ions, respectively. The Service Oriented Spacecraft Magnetometer (SOSMAG) consists of two science-grade fluxgate sensors on an about 1-m long boom and two additional magnetoresistive sensors mounted within the spacecraft body for effective correction of disturbances from the spacecraft. The

instrument has made measurements of a series of particle injection events for both the electrons and ions in the energy range of 100–300 keV with geomagnetic field lines strongly stretched tailward at the dusk side of the outer radiation belts. We discuss the results of preliminary analysis of this event in conjunction with existing missions in the Earth's magnetosphere such as Van-Allen probes, THEMIS and GOES satellites.

15:30 [III-3-7]

The Preliminary Results of Intercomparison of High-Energy Particle Flux of Geo-KOMPSAT-2A

Wonhyeong Yi

*National Meteorological Satellite Center, Korea
Meteorological Administration*

GEO-KOMPSAT-2A (GK2A) has been operated since July 2019, launched in December, 2018. One of its payload is Korea Space Weather Monitor (KSEM) for space weather monitoring on geostationary orbit. The KSEM consists of three instruments that are the particle detector (PD), magnetometer (SOSMAG), and charging monitor (CM) and it measuring near-earth space weather environment continuously. We perform inter-comparison of GK2A/KSEM high energy particles data measured by geostationary orbit satellites with Magnetospheric Electron Detector (MAGED) and Energetic Proton, Electron and Alpha Detector (EPEAD) of GOES-15, SEISS (Space Environment In-Situ Suite)/Magnetospheric Particle Sensor – High Energy Range (MPS-HI) of GOES-16, and SEDA (Space Environment Data Acquisition monitor) of Himawari-8. We use 5 minute data of GK2A from March to July in 2020 to compare with GOES-16 and Himawari-8 data from June 2019 to October 2019 are used for GOES-15. For the condition of intercomparison, Roederer's L (L^*) values of each satellite from ONERA library are used considering the same L^* of satellites as the similar space environment. In this study the data samples of which the difference of L^* lower than 0.1 and same UTC time are selected. And then we adjusted the energy range of channels of GK2A/KSEM to similar energy range of channel of other satellites because energy range among each satellites are different. The results show that the flux with energy between 200 keV and 1350 keV show relatively good relation with 0.99~1.47 for slope and -0.88~0.32 for intercept in log scale. And the fluxes of GK2A are slightly lower than those of other satellites at low flux level between 200 keV and 1350 keV. For the energy lower than 200 keV, GK2A fluxes are generally higher than those of GOES-15 in energy between 50 keV and 100 keV. Interestingly, it seems that there are two separated groups when compared with GOES-15 for the energy level larger than 200 keV.

제1발표장 Landing BallroomA

Invited Talk IV

좌장: GiHyuyk Choi (KARI)

14:10 [IS-IV]

Vice President, Robert Laing (Lockheed Martin)

10월 30일(금) 제1발표장 Landing BallroomA

IV-1 (Special Session)

Toward a Next Generation Coronagraph

좌장: YongJae Moon (KHU)

09:00 [IV-1-1]

Progress Report on the Development of a Diagnostic Coronagraph on the ISS

Yeon-Han Kim¹, Seonghwan Choi¹, Su-Chan Bong¹,
Kyungsuk Cho^{1,2}, Young-Deuk Park¹,
Jeffrey Newmark³, Nat. Gopalswamy³,
Seiji Yashiro³, Nelson Reginald³

¹Korea Astronomy and Space Science Institute²University of Science and Technology³NASA Goddard Space Flight Center, USA

The Korea Astronomy and Space Science Institute (KASI) has been collaborating with the NASA Goddard Space Flight Center (GSFC), to install a diagnostic coronagraph on the International Space Station (ISS). The coronagraph is designed to obtain simultaneous measurements of electron density, temperature, and velocity using multiple filters in the 3–10 Rs range. In 2019, we developed a new coronagraph and launched it on a stratospheric balloon (BITSE) from Fort Sumner, New Mexico in USA. As the next step, the coronagraph will be further developed, installed and operated on the ISS (CODEX) in 2023 to understand the physical conditions in the solar wind acceleration region, and enable and validate the next generation space weather models. In this presentation, we will report recent progress and introduce future plan.

09:15 [IV-1-2]

Heating and Energy Balance of Coronal Mass Ejection Plasma Observed by the Ultraviolet Coronagraph Spectrometer

Jin-Yi Lee

Kyung Hee University

In this presentation, I introduce two studies (Lee et al. 2006, Lee et al. 2009) on the three-dimensional structure and energy balance of coronal mass ejections (CMEs) observed by the Ultraviolet Coronagraph Spectrometer (UVCS) on board the Solar and Heliospheric Observatory (SOHO). One is the three-dimensional reconstruction of a CME observed on 2002 April 21. UVCS observed the O VI line profiles split into strongly red- and blue-Doppler shifted components and the more localized [Fe XVIII] bright emission. The reconstructed [Fe XVIII] emission allows two interpretations, as ejection of preexisting hot plasma or as a current sheet. The evidence favors the current sheet interpretation. The other is investigating the heating and energy balance of a CME observed on 2001 December 13. This study investigate the heating rates, which represent a significant fraction of the CME energy budget. The parameterized heating and radiative and adiabatic cooling used to evaluate the temperature evolution of the CME material with a time-dependent ionization state model. The functional form of a flux-rope model for interplanetary magnetic clouds was also used to parameterize the heating. They find that continuous heating is required to match the UVCS observations. To match the O VI bright knots, a higher heating rate is required such that the heating energy is greater than the kinetic energy. In the context of the flux-rope model, about 75% of the magnetic energy must go into heat in order to match the O VI observations.

09:30 [IV-1-3]

Recent Observational Results from the Hinode/EIS Related to the Coronal Heating and Solar Wind Acceleration: Relevant to the New Solar Coronagraph

Kyoung-Sun Lee

Seoul National University, Korea

High-sensitivity spectral and spatial resolution observations from Hinode/Extreme Ultraviolet (EUV) Imaging Spectrometer (EIS) enable us to understand the quantitative physical properties in the solar corona and their dynamics below the 1.5 solar radii from the solar surface. In this talk, I briefly review some of the recent observational studies on the coronal heating and solar wind acceleration using the Hinode/EIS: (1) quantitative estimation of the physical properties and energy flux in the corona, (2) detection of the waves and their energy dissipation, (3) origin of the solar wind and their properties. Based on these recent results, I discuss the possible studies using the new solar coronagraph which has an ability to simultaneously measure the temperature and velocity distribution from 3 to 12 solar radii.

09:45 [IV-1-4]

Properties of Solar Wind Speeds Observed in the AIA, C2, and C3 FOVs

Il-Hyun Cho¹, Yong-Jae Moon¹, Kyung-Suk Cho^{2,3}

¹*Kyung Hee University*

²*Korea Astronomy and Space Science Institute*

³*University of Science and Technology*

As a part of CODEX science mission, we had been explored a two-dimensional structure of solar wind speeds from 6 to 26 solar radii using SOHO/LASCO C3 data, and found that the solar wind speed exhibits a bi-modal distribution and their evolution resembles the Parker's solar wind. Recently, we explored the evolution of propagating intensity disturbances in plumes, and found that they are accelerating with supersonic speeds in the SDO/AIA FOV. These were interpreted as slow magnetoacoustic waves propagating in flowing backgrounds which are accelerating with subsonic speeds. In this presentation, we explore solar wind speeds along ray-like structures including plumes in the AIA and LASCO C2 and C3 FOVs. For this, we define slits at different azimuth angles in the northern and southern polar limbs. The slits are largely inclined to the normal directions to the solar surface and curved. We construct time-distance images along the slits as well as the radial directions based on the positions of foot point of the slits. From these images, lagged cross-correlation maps are constructed to obtain solar wind speeds as functions of radial and slit distances. Properties of solar wind speeds at different azimuth angles, inclinations and curvatures will be presented. As preliminary results, we find that a solar wind speed accelerates and decelerates in the AIA FOV, and then gently accelerates in the C2 FOV, and continues an acceleration in the C3 FOV. The final acceleration exhibits a power law: the speed is proportional to the distance with a power law exponent of ~ 0.7 . The positive speed of the solar wind could be calculated at around 1.05 solar radii which may be the starting distance of nascent solar wind.

This work was partly supported by the Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, study on analysis and prediction technique of solar flares).

10:00 [IV-1-5]

Investigations of Solar Corona Phenomena by Using Current and Next-Generation Space-Based Coronagraphs

Jae-Ok Lee, KASI CODEX Team

Korea Astronomy and Space Science Institute

Coronagraphs measure the total brightness (tB) and polarization of K-corona in the visible light, which is created by electron Thomson scattering of photospheric light, and they provide coronal electron densities by using the polarized brightness (pB) images with Thomson scattering theory. In the SOHO/LASCO

era, with a spatial resolution (> 11.9 arcsec/pixel) and temporal cadence (> 12 min) on tB images (> 240 min on pB images), several researchers estimate fundamental physical quantities: (1) 2-D electron density distributions and 3-D ones using tomographic analysis, (2) electron temperature distributions using the density distributions with hydrostatic assumption, (3) solar wind speeds by investigating localized brightness enhancement structures (plasma blobs), and (4) magnetic field strengths using density compression ratio, observed CME's standoff distance, and streamer kink oscillations. In addition to that, many researchers investigate 2-D CME kinematics, 3-D ones using cone model assumptions, CME geoeffectiveness, and formation heights of decahertzometric (DH) type II radio bursts. In the twin STEREO/COR era, with > 3.5 arcsec/pixel and > 3 min on intensity and pB images, many researchers mainly focus on 3-D CME morphologies and propagations using stereoscopic analysis as well as 3-D coronal structures (streamers and post-CME rays) using stereoscopic and/or tomographic analysis. Recently, Korea Astronomy and Space Science Institute (KASI) in cooperation with NASA is developing a next-generation coronagraph (CORonal Diagnostic EXperiment, CODEX) to measure the coronal electron temperature, speed, and density simultaneously using the temperature and speed sensitive filters (393.5, 405.0, 398.7, and 423.4 nm with bandpass of 10 nm) as well as the broadband filter (380–430 nm) around 400 nm, where strong Fraunhofer absorption lines from the photosphere experience thermal broadening and Doppler shift through scattering by coronal electrons. CODEX will provide tB and pB images with 12.8 arcsec/pixel and ~ 10 sec, densities with 25.6 arcsec/pixel and 1 min, temperatures with 3.4 arcmin/pixel and 90 min, and speeds with 8.5 arcmin/pixel and 90 min. By using high-time cadence observations of densities (or tB and pB), we can study the following sciences: coronal turbulence, macroscopic vortices on CME flanks and outer streamer boundaries, and kinematic oscillations on CMEs and blobs. With temperature and/or speed observations, we are able to find the direct evidences of coronal interchange magnetic reconnections. When we use the observed physical quantities together with MHD numerical simulations, we can estimate coronal magnetic fields.

10:15 [IV-1-6]

Three-Dimensional MHD Models for ICME Propagation and the Solar Corona: Model Results and Applications

Junmo An

Department of Astronomy and Space Science, Kyung Hee University

The corona mass ejection (CME) is one of the most dynamic phenomena occurring in the solar corona and is a major cause of adverse effects on space weather around the Earth. In this paper, we show a global 3-D MHD model of Interplanetary

CME (ICME) propagation using the REPPU (Reproduce Plasma Universe) code and some key results from it. We also show a 3-D MHD simulation for the solar corona that uses the REPPU code. The simulation is performed in a period including the solar eclipse of August 21, 2017. The synoptic charts of solar-surface magnetic fields provided by the Wilcox solar observatory (WSO) are used as the inner boundary condition. The simulated coronal plasma structures are compared with images of the eclipse taken at the Earth. The results show that the simulation well reproduces positions of coronal streamers on the plane of the sky (POS), although there are clear limitations. Lastly, we suggest several science topics that may be newly enabled to study using the Coronal diagnostic experiment (CODEX) data.

10:30 [IV-1-7]

Comparison of Results from the DICE Filter System and the Solar Rotational Tomography

Kyuhyoun Cho

Seoul National University

In this study, I compare the physical quantities of a polar plume obtained by two different methods. The polar plume was observed by the Diagnostic Coronal Experiment (DICE) in the 2017 solar total eclipse. The NUV filter system in the DICE made it possible to infer the approximate temperature distribution of the polar plume. Meanwhile, it is also possible to obtain the physical quantities of the polar plume by the Solar Rotational Tomography (SRT). Recently developed SRT using the filtered backprojection algorithm can easily generate 3D coronal structures from the Solar Dynamics Observatory (SDO) data. By comparing the two results, I will discuss how to improve the accuracy of physical quantities obtained by the COroanal Diagnostic EXperiment (CODEX) in the future.

10:45 [IV-1-8]

Propagations of Hot and Cold Plasmas in Coronal Hole Plumes during 2017 Total Solar Eclipse

Kyung-Suk Cho¹, Il-Hyun Cho²

¹*Korea Astronomy and Space Science Institute*

²*Kyung-Hee University*

Polar plumes are relatively bright and magnetically open linear dense structures extending from the Sun's surface to about 30 Rs. Kinematics of propagating (radiance variation) features in plumes and their relationship with the EUV brightening are poorly known, and the identity (magnetoacoustic wave or flow) is an open question. We study the plumes in the northern polar region observed during the 2017 total solar eclipse (TSE). The plumes have different activities (temperature, jets, and macro-

spicule) on their base, and we investigate properties of upward propagations in polar plumes. Temperature structures at the base of the plumes are obtained from the filter ratio data of Hinode XRT and the passband ratio around 400 nm from an eclipse instrument (diagnostic coronagraph experiment, DICE). Phase speed (v_r), frequency (ω), and wavenumber (k) of the propagations in plumes are estimated by applying the Fourier transformation to the space-time (r - t plane) plot in AIA's different wavelength channels (171 Å, 193 Å, and 211 Å). Chromospheric activities related to the plumes are inspected by using the 304 Å channel. We find the temperature dependence of the propagation (phase) speeds. The propagation in the hotter channels (193 Å and 211 Å) is faster than that of the cooler channel (171 Å). This tendency is more significant for the active plumes accompanying jets, and macrospicules that come from the high-temperature region on the base of the plumes. The observed speed ratio (~ 1.3) between the colder (171 Å) and hotter channels (193 Å) is similar to the expected value from theory (1.25) of a slow magnetoacoustic wave. It is found that the cooler has broader ranges of ω and k than those of hotter channels. The plasma in active plumes has faster speed than that of the quiet plumes. The hotter channels' speed in the active plumes is higher than the cooler channel, and the speed difference between hot and cool channels of the active plumes is bigger than quiet plumes. Our results support that propagations in the plumes represent a mixture of slow magnetoacoustic wave and outflow materials that are consisted of dense cold plasma and hot jets. Based on the results, we propose two types of plumes (active and quiet), in which the kinematics and temperatures of plasma are controlled by the activities on the bottom of plumes.

11:00 [IV-1-9]

Detection of Alfvén Waves in the Sunspot Chromosphere: An Observational Challenge with FISS

Jongchul Chae

Seoul National University

Magnetohydrodynamic Alfvén waves have been thought to be important as the process of transferring mechanical energy required for the heating of the solar corona and the acceleration of the solar wind. Even though a series of observational studies of high resolution image data reported the detection of Alfvén waves, most of them are known to be kink waves that are distinct from Alfvén waves. An unambiguous detection of Alfvén waves requires the determination of the spatio-temporal patterns of both line-of-sight velocity and nonthermal speed, which requires high-resolution imaging spectrograph observations at high time cadence. This is exactly what can be done with the Fast Imaging Solar Spectrograph (FISS) observations. In addition, we note that there have been few reports of Alfvén

waves in the sunspot chromosphere despite the importance of sunspots in solar magnetic activities. We aim to detect Alfvén waves in the sunspot chromosphere based on the FISS observations. In fact, we found a spatio-temporal pattern of line-of-sight velocity in superpenumbral fibrils, supporting the ubiquitous occurrence of incompressible transverse oscillations such as kink waves.

제2발표장 Landing BallroomB

IV-2 (Special Session) Space Radiation

좌장: JongDae Sohn (KASI)

09:00 [IV-2-1]

Development of Low Earth Orbit Space Radiation Dosimeter Onboard the NEXTSat-2

Uk-won Nam¹, Bong-Kon Moon¹, Won-Kee Park¹, Jeonghyun Pyo¹, Jongdae Shon¹, Junga Hwang¹, Jaejin Lee¹, Sunghwan Kim², Sukwon Youn³, Sung-Joon Ye³, Hongyoung Park⁴, Taeseong Jang⁴

¹Korea Astronomy and Space Science Institute, Daejeon, Korea

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⁴Satellite Technology Research Center, KAIST

The LEO-DOS (the low earth orbit space radiation dosimeter) has been developed as a scientific payload of the NEXTSat-2, which is the next generation small satellite program in Korea to be launched on 2022. During space missions, astronauts are exposed to a stream of energetic and highly ionizing radiation particles that can suppress immune system function, increase cancer risks and even induce acute radiation syndrome if the exposure is large enough. therefore the radiation protection remains one of the key technological issues that must be resolved. The major scientific objectives of the LEO-DOS are to map the dose contribution by charged particles and neutrons in LEO, to study the space radiation environment variations and to verify the relative biological effectiveness (RBE) of neutrons for radiation risk assessment. The LEO-DOS consists of a tissue equivalent proportional counter (TEPC) and a fast neutron spectrometer. The TEPC constructed from tissue-equivalent plastic and filled with low-pressure tissue equivalent propane gas is a microdosimetric instrument and will serve as radiation monitors in the near earth orbit. Especially, in LEO-DOS system, the dose contribution by charged particles and neutrons will be separated by using the anti-coincidence method in combination with a plastic detector for detecting charged particles. Also the neutron spectrometer based on CLYC-7

scintillator has been developed to analyze biological effects comes from the fast neutrons in the range of 0.5 MeV to 10 MeV. Therefore the LEO-DOS system is expected to provide accurate and comprehensive in-situ measurement of the local radiation environment in the low earth orbit. In this talk, the progress status of the development of LEO-DOS will be presented.

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIP) (NRF-2017M1A3A4A01077173).

09:15 [IV-2-2]

Scientific Application of LVRad

Sung-Joon Ye¹, Sukwon Youn¹, Mingi Eom¹, Yeseul Kim¹, Uk-won Nam², Won-Kee Park², Jongdae Sohn², Junga Hwang², Young-Jun Choi², Hongjoo Kim³, Sunghwan Kim⁴, Insoo Jun⁵

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For manned missions on the moon, it is essential to expand the knowledge of the space radiation environment and assess the radiation risk to human being on the lunar surface. Seoul National University (SNU), Korea Astronomy and Space Science Institute (KASI), Kyungpook National University (KNU), and Cheongju University (CJU) are working together to develop radiation dosimeter called LVRad (Lunar Vehicle Radiation Dosimeter) to investigate lunar surface radiation environment. In this project, the lunar radiation environment and its biological effects, and space weathering on the moon will be investigated using K-CLPS: LVRad instrument which consists of PDS (Particle Dosimeter and Spectrometer), TED (Tissue Equivalent Dosimeter), FNGRS (Fast Neutron and Gamma Ray Spectrometer).

The human biological effects from various types of radiation with a wide range of energy can be evaluated by measuring LET (Linear Energy Transfer) spectra using PDS and TED and estimating absorbed dose and dose equivalent. The effective dose to human being in mixed radiation environment of the lunar surface can be evaluated for the manned missions. In addition, fast neutrons of 1 to 10 MeV which would be a high radiation risk to human being can be detected and evaluated by FNGRS. By using FGMAG (Fluxgate Magnetometer), it is

expected to deduce a correlation between the GCR (galactic cosmic ray), SEP (solar energetic particles) space radiation environments, and space weathering above the local magnetic anomalies on the lunar surface. In summary, LVRad instrument is a cost-effective payload to expand a human knowledge on the space radiation environment as well as its radiation risk to human beings on the lunar surface. The specification of each instrument and the role of each participated institution will be reported in detail.

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by Korea government (MSIP) (NRF-2020M1A3B7108845).

09:30 [IV-2-3]

Design and Characterization of Si Dosimeter on the Lunar Applications

Sunghwan Kim¹, Hong Joo Kim², Uk-Won Nam³, Won-Kee Park³, Jongdae Shon³, Junga Hwang³, Sukwon Youn⁴, Sung-Joon Ye⁴

¹*Cheongju University*

²*Kyungpook National University*

³*Korea Astronomy and Space Science Institute*

⁴*Seoul National University*

In this work, we summarize the design and characterization of a Si dosimeter. The main purposes of the Si-based dosimeter are measurement of absorbed dose, equivalent dose and LET (linear energy transfer) spectra on the surface the moon. The dosimeter is based on a planar silicon detector (KNU) and designed to measure the energy deposition of charged particles and to convert the absorbed dose in human tissue. A pulse analysis technique is used to measure the energy deposited in the Si detector. The amplitudes of pulses are digitized and organized in the spectrum. And the absorbed dose in Si is calculated from the measured spectrum. We also present an algorithm to determine the absorbed dose of the human body from Si absorbed dose by correcting the inhomogeneity between silicon and the human body.

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIP) (NRF-2020M1A3B7108845).

09:45 [IV-2-4]

Development of Crystal Scintillators for Thermal and Fast Neutron Detection at Space

Hong Joo Kim¹, Phan Quoc Vuong¹, Sinchul Kang¹, Uk-Won Nam², Won-Kee Park², Jongdae Shon², Junga Hwang², Sukwon Youn³, Sung-Joon Ye³, Sunghwan Kim⁴

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We developed LaCl₃ crystal scintillator for the fast neutron spectroscopy and LiI:Ag crystal scintillator for thermal and epithermal neutron detection which can be used for the LvRAD mission. Both crystals have pulse shape discrimination (PSD) capability that gamma background can be efficiently removed from neutron induced signal. They have several advantage over newly developed Cs₂LiYCl₆(CLYC) crystal such as radiation hardness. We will present crystal growth, luminescence and scintillation property as well as neutron test results.

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIP) (NRF-2020M1A3B7108845).

10:00 [IV-2-5]

Spectrum Unfolding of CLYC-7 Neutron Spectrometer for LEO Neutrons

Sukwon Youn¹, Uk-won Nam², Jeonghyun Pyo², Won-Kee Park², Bongkon Moon², Mingi Eom¹, Yeseul Kim¹, Sung-Joon Ye¹

¹*Department of Applied Bio-engineering, Graduate School of Convergence Science and Technology, Seoul National University, Seoul, Korea*

²*Korea Astronomy and Space Science Institute, Daejeon, Korea*

Fast neutrons in low earth orbit (LEO) created from interactions of solar energetic protons (SEP) and galactic cosmic radiations (GCR) with the atmosphere have high biological effects to human. There has been many researches about charged particles and their biological effects in space, however, biological effects of neutrons in space are still insufficient. Therefore, it is necessary to analyze fast neutron spectrum in LEO to protect human in space missions. CLYC-7 is a promising neutron spectrometer for detecting space neutrons due to its good radiation hardness and neutron/gamma separation ability. Neutron spectrum unfolding algorithms for CLYC-7 neutron spectrometer were developed to obtain neutron energy spectra from detected pulse height spectra.

A CLYC-7 neutron spectrometer was developed in Korea Astronomy and Space Science Institute (KASI) to detect fast neutrons and obtain fast neutron spectrum in LEO. Unfolding algorithms of CLYC-7 neutron spectrometer were developed by using 1D CNN (Convolutional Neural Network) and LSTM (Long Short-Term Memory) model. These algorithms took into account several Q-values of (n,p) and (n,α) reactions which make it difficult to predict incident neutron energies. Random neutron energy spectra and its pulse height spectra by MCNP6.2 Monte Carlo simulations were used as targets and inputs for

training models. Cf-252, AmBe, and RaBe neutron pulse height spectra separated by gamma spectra using pulse shape discrimination (PSD) were used to evaluate these algorithms. Scintillation quenching was considered with a factor of 0.71 obtained by KOMAC (Korea Multi-purpose Accelerator Complex) monoenergy neutron beam experiment.

Predicted neutron energy spectra using the unfolding algorithms from pulse height spectra of neutron sources were matched well with the original neutron energy spectra. Some discrepancies were shown in high energy regions due to the differences between the ENDF/B-VII neutron cross section library used to generate response functions and experimental data.

In this study, unfolding algorithms to obtain 1–10 MeV fast neutron energy spectrum have been developed. Although predicted neutron energy spectra were matched well with neutron energy distributions of neutron sources, there were some limits due to the differences of MC-generated response functions from real experimental data, especially over 5 MeV. This unfolding algorithms will be used to obtain neutron energy spectrum in LEO in the near future.

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIP) (NRF-2017M1A3A4A01077173 and NRF-2017M1A3A4A01077220).

10:15 [IV-2-6]

Comparison between Measurements of Space Radiation and KREAM Model

Junga Hwang^{1,2}, Ukwon Nam¹, Gyeongbok Jo³, Jaeyoung Kwak^{1,2}, Hee-Bok Ahn⁴, Kyu-Wang Kim⁴

¹Korea Astronomy and Space Science Institute

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³Chungnam National University

⁴Korean Air

During 2019–2020, we performed several experiments to measure quantitative space radiation exposure on Korean commercial airplanes. We used Liulin-6K LET spectrometer and Tissue Equivalent Proportional Counter (TEPC) for measurements. And we compare those observations with radiation exposure assessment models such as KREAM, CARI-6M and NAIRAS. We found that KREAM shows most similar results with Liulin-6K observations for most experiments. Among those three model estimation results, NAIRAS shows highest estimation, KREAM is mostly in the middle and CARI-6M shows lowest results. It is possible to interpret this result by that fact, CARI-6M does not include solar proton events and just only considers galactic cosmic rays. Both NAIRAS and KREAM consider solar proton effects by including the proton flux measurements in the geosynchronous orbit.

제3발표장 Halla Room

IV-3 Sun & Space Environment (III)

좌장: JeongHeon Kim (KASI)

09:00 [IV-3-1]

Numerical Modeling Study on the Middleatmospheric Responses to Medium Energy Electron (MEE) in the Polar Region

Ji-Hee Lee¹, Geonhwa Jee^{1,2}, Young-Sil Kwak^{3,4}, Heejin Hwang¹, Annika Seppälä⁵, Esa Turunen⁶, Dae-Young Lee⁷

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⁶Sodankylä Geophysical Observatory, University of Oulu, Tähteläntie, Finland

⁷Department of Astronomy and Space Science, Chungbuk National University, Cheongju, Korea

Energetic particle precipitation (EPP) is an important source of chemical changes in the polar middle atmosphere during winter. Furthermore, recent modeling studies suggest that chemical changes by EPP can cause dynamic changes of the atmosphere. In this study, we investigate the atmospheric and climatic responses to the precipitation of medium-to-high energy electron (MEE) during 2005–2013 by using Specific Dynamics Whole Atmosphere Community Climate Model (SD-WACCM). Results show that the MEE precipitation significantly increases the amount of NO_x and HO_x, resulting in mesospheric and stratospheric ozone losses by up to 60% and 25%, respectively during polar winter. MEE-induced ozone loss leads to changes of meridional circulation, resulting in the strong downward motion in the lower mesosphere and the weak downward motion in the middle and upper mesosphere. The changes of meridional circulation induce the warming by up to monthly mean 4 K in the polar lower mesosphere. MEE precipitation results in meaningful change of temperature and winds in the polar region.

09:15 [IV-3-2]

Statistical Analysis of Neutral Winds in the MLT Using 14 Years (2007–2020) of Meteor Radar Data at King Sejong Station

Byeong-Gwon Song¹, Changsup Lee¹,
Jeong-Han Kim¹, In-Sun Song¹, Geonhwa Jee¹,
Hye-Yeong Chun²

¹*Korea Polar Research Institute*

²*Yonsei University*

As the mesosphere and lower thermosphere (MLT) region is an important layer connecting the lower atmosphere and the space, investigation of neutral winds in the MLT region is essential to understand a coupling process between them. The meteor radar at King Sejong Station, Antarctica (KSS; 62.22°S, 58.78°W) has been continuously observing neutral winds in the MLT region regardless of weather conditions since March 2007. In this study, statistical analysis of the neutral winds in the MLT is conducted using 14-year (2007–2020) meteor radar observations over KSS. In a zonal wind, an annual variation with the strongest easterlies in summer is evident below 90 km, while a semiannual variation with two peaks in both solstices can be found above 90 km. The meridional wind is smaller in magnitude than the zonal wind and its temporal variation extends from days to annual timescales. Poleward winds dominates in winter and summer, while equatorward winds appear in spring and autumn. Statistically significant decreasing trends in the observed zonal wind exist in autumn, while increasing trends are found in winter. In contrast, there are no significant linear trends in the meridional wind. Spectral analysis of the observed horizontal winds is performed to investigate the characteristics of tides and planetary waves. Strong semidiurnal tidal signals are found from autumn to spring with a maximum amplitude in May, while diurnal tidal signals are evident in summer. The activities of 2-day waves are strong in both summer and winter, whereas 4-day wave signals are mainly observed in winter. Further investigation of the possible cause of the long-term variations in the neutral winds in the polar MLT will be conducted.

09:30 [IV-3-3]

Interhemispheric Differences in the Polar Ionospheric Density Using Radar Observations and TIEGCM Simulations for Solar Minimum Period

Eunsol Kim^{1,2}, Geonhwa Jee^{1,3}, Yong Ha Kim²,
Young-Sil Kwak^{3,4}, Alan G. Burns⁵, Wenbin Wang⁵,
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⁵*National Center for Atmospheric Research*

⁶*The Catholic University of America*

Vertical incidence pulsed ionospheric radar (VIPIR) has been observed polar ionosphere over Jang Bogo station (JBS), Antarctica, since 2017 and the data are expected to help understand the southern polar ionosphere, where the observations are insufficient. Using the JBS-VIPIR data for solar minimum period of 2017–2019, we investigate the characteristics of density profiles in the southern polar cap region and compare with data from European incoherent scatter Svalbard Radar (ESR) in the northern polar cap region. The observations show larger density and larger diurnal variation at JBS than at ESR station, due to the lower geographic latitude of JBS. The ionospheric density is reduced in winter due to the limited solar production at high geographic latitudes, but Thermosphere-Ionosphere-Electrodynamics Global Circulation Model (TIEGCM) significantly overestimates the winter density that is even larger than summer density. The equinoctial asymmetry is also different in between the observations and simulations; daytime F-region density is larger in September (March) than in March (September) in the northern (southern) hemisphere, but the TIEGCM results show the opposite tendency. During geomagnetically disturbed time, the model simulates larger F-region density than for quiet time while the observed densities decrease at both stations. The disagreements might be caused by strong interhemispheric density gradient due to thermospheric winds in the model. In order to understand polar thermosphere-ionosphere system and improve the model, more observational and theoretical studies are required at high latitudes, especially in southern hemisphere.

09:45 [IV-3-4]

On Utilizing Bohyun Astronomical Observatory for Space Science

Young-Sook Lee¹, Yong Ha Kim¹, Young-Sil Kwak²,
Changsup Lee³, Jeong-Han Kim³, Jong-Kyun Chung²,
Jaeheung Park², Hee-su Yang², Kwan-Hyuk Kim⁴,
Suyeon Oh⁵

¹*Chungnam National University*

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³*Korea Polar Research Institute*

⁴*Kyung Hee University*

⁵*Chonnam National University*

This presentation introduces collected ideas on how to improve the utilization of Bohyun astronomical observatory for space science. The suggested ideas are mostly about new instrument installations in addition to the existing ones: the solar telescope, all sky camera monitoring upper atmosphere and fluxgate magnetometer. The new instruments can be listed as follows: a meteor radar to make multi dimensional observation in association with Gyeryong station in Daejeon; a lidar for upper atmosphere; a mesospheric temperature mapper using OH (3,1) airglow at ~1500 nm; a Fabry-Perot Interferometer for wind

measurement; a GNSS scintillation monitor for the ionosphere; a small UHF communication station to send or download data to/from satellites; search coil magnetometers to detect EMIC wave; seeing measuring instruments by sunlight monitoring; a muon detector and a mini-neutron monitor. The detailed information on applications and cautions in their usage at Bohyun observatory will be discussed in the presentation.

10:00 [IV-3-5]

Estimation of the Ionospheric Electron Density Irregularity Speed Using GNSS Dual-Frequency Measurements from a Single Receiver at High Latitudes

Junseok Hong¹, Jong-Kyun Chung¹, Yong Ha Kim², Young-Bae Ham^{3,4}, Young-Sil Kwak^{1,4}, Changsup Lee³, Jeong-Han Kim³, Geonhwa Jee^{3,4}

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Ionospheric scintillation means rapid fluctuations of radio signals' amplitude or phase penetrating the ionosphere. Generally, it is known that the ionospheric electron density irregularity having smaller scale than the Fresnel radius causes the amplitude scintillation at low latitudes. On the other hand, the large scale irregularity is the main source of the phase scintillation at high latitude. Recently, it has been suggested that low frequency fluctuations of radio signals by the refractive effects induced by the irregularity larger than Fresnel radius may be misinterpreted as the ionospheric scintillation, and it should be removed. Based on the concepts of the refractive effects, we find the refractive term using high time-resolution (100 Hz) measurements from a dual frequency receiver at high latitudes. Derived Fresnel frequency corresponding to the refractive term is changed to the ionospheric irregularity speed. Although only speed can be estimated excluding direction through our method, it is worthy due to the lack of ground-based measurements for ionospheric (or thermospheric) particle speed. Single receiver estimation of the ionospheric irregularity would be helpful to understand high latitudinal ionospheric dynamics.

10:15 [IV-3-6]

The Possibility of Regional Ionosphere Prediction Using the LSTM Deep-Learning Algorithm Specialized for Geomagnetic Storm Periods

JeongHeon Kim¹, Young-Sil Kwak^{1,2}, Su-In Moon³, YongHa Kim³, JongYeon Yun⁴

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⁴*Korea Space Weather Center, KSWC*

In our previous study (Kim et al., 2020), we utilized an LSTM model for geomagnetic quiet days, effectively performing long-term predictions for the regional ionosphere. However, in the case of geomagnetic storm days, our model could not predict at all. The problem pointed out in previous studies is that most of the training data sets are included in quiet periods. In this study, to overcome this problem, we re-made a deep learning model suitable for geomagnetic storms by redesigning the new training data set, input parameters, and the hyperparameters. We collected a total of 131 days of geomagnetic storm cases from 1 January 2009 to 31 December 2019, provided by the Japan Meteorological Agency's Kakioka Magnetic Observatory. Also, we obtained the Bz, Dst, Kp, and AE indices related to the geomagnetic storm corresponding to each storm date from the OMNI database. These indices and Jeju ionosonde's (33.43°N, 126.30°E) foF2 and hmF2 values were used as input parameters for the LSTM deep-learning model. To test and validate the prediction performance of the LSTM model for geomagnetic storms developed in this way, we developed and analyzed the 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours prediction LSTM models respectively. According to the results of this study, it was difficult to predict more than 12 hours previously desired, but short-term predictions such as 30 minutes, 1, 2, 3, 6 hours were sufficiently possible. In this study, we present the short-term predictability of rapidly changing ionosphere states during geomagnetic storms using deep learning techniques and discuss the limitations of long-term prediction. Also, based on this study, we propose what to pay attention to and what needs to be discussed in the future when using the results using deep learning for prediction and monitoring.

10:30 [IV-3-7]

Mesosphere Temperature from SDSS Over Apache Point Observatory during the 2011–2018 Period

YongHo Lee, Yong Ha Kim, YoungSun Lee

Chungnam National University

From OH airglow emission lines in sky spectra of Sloan Digital Sky Survey (SDSS), we derived mesospheric temperatures for a period of 2011–2018. The SDSS spectra were measured with spectrographs, APOGEE-1 and 2 which were operated at Apache Point Observatory (APO, 32°N 105°W 2788 m). Rotational temperatures of OH (3–1) band were computed from the ratios of P1(2), P1(3), P1(4), P2(1), P2(2), P2(3), and P2(4) line intensities. The lowest fluctuation of rotational temperatures was found to be the ratio of P1(2) and P1(4) lines, which may indicate the ambient atmospheric temperature at the

OH airglow layer around 87 km, thus representing mesospheric temperatures. We obtained a time series of mesospheric temperatures for total of 1429 nights. From this time series, we have confirmed that the mesospheric temperature is lower in summer and higher in winter at the mid-latitude. We will analyze the temperature variations in the time series due to solar activities and sudden stratospheric warming events.

10:45 [IV-3-8]

Characterizing Ionospheric Disturbances Caused by the North Korean Rocket (Hwasung-15) with a Four-Dimensional Variational (4D-var) Data-Assimilation Model

Gwang Su Kim¹, Yong Ha Kim¹, Byung-Kyu Choi², Junseok Hong², Nicholas Ssessanga³

¹*Department of Astronomy and Space Science, Chungnam National University*

²*Korea Astronomy and Space Science Institute*

³*Research Institute for Sustainable Humanosphere, Kyoto University*

The four-dimensional variational (4D-var) technique, originally developed in weather forecasting applications, has been used to develop a data-assimilated model for estimating Rocket emission from the observed ionospheric hole (Ssessanga et al., 2018). In this study we applied the 4D-var model to characterize ionosphere disturbances caused by the Hwasung-15(H-15) rocket exhaust chemicals. The H-15 rocket was launched southeastward from North Korea at 18:17 UT on 28 November 2017. During the first hours of the launch, Korean GNSS network measured ionospheric disturbances along the trajectory in terms of total electron contents (TEC) by Global Positioning System (GPS) and Global Orbiting Navigational Satellite System (GLONASS) receivers. By assimilating the measured TEC data into the 4D-var model, the ionospheric depletion and recovery will be characterized with respect to the standard ionospheric model, IRI-2016. The rocket exhaust emissions will also be estimated in terms of water and hydrogen amounts, which are the main exhaust chemical from liquid fuel rockets.

11:00 [IV-3-9]

A Regional Ionospheric Modeling Study with Different Data Types Using the Ionospheric Data Assimilation Four-Dimension (IDA4D) Algorithm

Se-Heon Jeong, Yong Ha Kim

Chungnam National University

Ionospheric Data Assimilation Four-Dimensional (IDA4D) is, developed by Bust et al., (2007), a continuous time and three-dimensional ionospheric algorithm that can optimally estimate the ionosphere from measured data. IDA4D is based on three-dimensional variational (3D-var) data assimilation method that uses a Gauss-Markov Kalman filter to assimilate the next time step. The assimilation model can ingest variety of data types. In this study, we use slant total electron contents (STEC) obtained from a Global Positioning System (GPS) network, NmF2 (peak electron density of the F2 layer) and STEC from Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) satellite. The IDA4D code assimilates these multiple type data into a background model, International Reference Ionosphere (IRI) 2016. The assimilation was performed on the following data combinations (cases): (1) GPS-STEC's only; (2) GPS-STEC's and COSMIC-STEC's; (3) GPS-STEC's and NmF2's from COSMIC; and (4) NmF2's from COSMIC and STEC's from GPS and COSMIC. We compare computed foF2's (F2 layer critical frequency) from IDA4D with measured values from five ionosondes in the region of Korea and vicinities during geomagnetic quiet (March 15–16th, 2015) and disturbed days (March 17–18th, 2015). The comparison shows that results from IDA4D have higher correlation with measured values and smaller root mean square (RMSE) from measured values than IRI estimated values. In case 2–4, IDA4D performance is further improved in areas where GPS measurements are not covered because COSMIC STEC and NmF2 data were added over those remote areas. Thus, our study confirms that IDA4D algorithm can provide reliable initial conditions (nowcast) of the ionosphere to a forecasting model in the region of Korea and vicinities, with an improving accuracy by utilizing multiple data types available.

포스터발표 논문 초록

1부 발표시간 : 10월 28일(수)
15:50~16:50

[P-1] Conceptual Design of Carbon Dioxide Removal System for Space Exploration

Youn-Kyu Kim, Jong-Won Lee, Joohee Lee

Korea Aerospace Research Institute

The United States recently announced an Artemis plan to resume manned lunar landings, which had been suspended since the Apollo program, and is seeking to land astronauts on lunar surface by 2024 and manned landings on Mars' surface by 2033, and the launch of the lunar lander is also planned in Korea by 2030. In addition, many private companies are offering business models about space exploration in various fields such as space tourism, space hotels, and Mars exploration. For such manned space exploration to be realized, a system (ECLSS, Environment Control & Life Support System) is essential to make a habitable environment in pressurized modules, including spaceships and lunar surface habitation module. The ARS (Air Revitalization System) that controls air in ECLSS requires a system that eliminates carbon dioxide. In other words, a carbon dioxide removal system (CDRS) is needed to adjust the concentration of carbon dioxide generated by crew breathing in enclosed room to the optimum conditions. The CDRS can be divided into regenerable systems and one-time (replacement) systems depending on the regenerable property of the material that collect carbon dioxide. In this paper, the performance of regenerative and non-regenerative CDRS was compared and analyzed, and for regenerative systems, the optimal system concept design was carried out according to the time, heating power, flow rate, pressure, etc. that affects the elimination rate and repeatability. In addition, optimization studies were conducted on CDRS according to space exploration missions (the size of mission system space, duration of mission, number of crew members) and cost (power, weight) of performance metrics.

[P-2] A Kinetic-Fluid Model of Solar Wind and Importance of Kinetic Features for the Electron Properties

Jungjoon Seough

Korea Astronomy and Space Science Institute, Korea

Many viable theories relevant to the solar wind model have been developed to account for the heating of solar corona, the solar wind acceleration, and its (thermo) dynamic evolution into

the interplanetary medium. In the present talk, we briefly review theoretical aspects of currently available models and discuss the importance of kinetic physics, especially in the context of in situ observations. Here we present a recently developed kinetic-fluid model of solar wind and discuss theoretical results relevant to the Parker Solar Probe's measurements. Based on the kinetic features, we discuss possible physical mechanisms controlling the electrons, which are located in the observational range of the Coronal Diagnostic Experiment.

[P-3] Thrust Analysis of Orbit Maneuver Thruster of Korea Pathfinder Lunar Orbiter (KPLO)

Holak Kim, Sunhoon Kim, Su-Hee Won, Sukyung Kim

Korea Aerospace and Research Institute (KARI)

For space exploration, a propulsion system is an essential component, and representatively, electric and chemical thrusters have been widely used. Korea Aerospace Research Institute (KARI) is planning to launch Korea Pathfinder Lunar Orbiter (KPLO) for lunar exploration, and a 30N class orbit maneuver thruster (OMT) is developed for orbit transfer. In this presentation, a detailed analysis of the thruster performance of OMTs will be presented.

[P-4] Science Data Sequence in KARI Planetary Data System

Joo Hyeon Kim

Korea Aerospace Research Institute

KARI Planetary Data System (KPDS) will release science data from space explorations and the supported data to the publics in order to enhance scientific achievements and share it with international science communities. Currently KPDS is being developed in support of KPLO science missions. However KPDS will be also compatible to future space explorations for other solar system objects beyond the Moon because KPDS carries out the validation of the science data for NASA PDS4 standard compliance. KPDS is not a simple web service or a database but the Korean first developed system for public release and management of science data for space explorations. For science data providers and potential users, I will present the sequence of upload, download and PDS4 standard compliance validation of science data in KPDS, and KPDS GUI for public users.

[P-5] Mission Coordinate System Definition, Precise Transformation Algorithm and Its Implementation Results for Korea Pathfinder

Lunar Orbiter Flight Dynamics

Young-Joo Song, Donghun Lee, Jonghee Bae,
Young-Rok Kim, Jae-ik Park, SeungBum Hong,
Dae-Kwan Kim and Sang-Ryool Lee

Korea Aerospace Research Institute

Not only for precise trajectory design but also for the successful operation of Korea Pathfinder Lunar Orbiter (KPLO), diverse coordinate systems are defined and will be used interchangeably dependent to each different KPLO mission phase. Current work treated detailed definition of each different coordinate system, and precise transformation algorithm between those of coordinate system is provided. Each different coordinate system includes: Earth International Celestial Reference Frame (ICRF), Moon Principal Axis (PA), Moon Inertial, Moon Mean Earth (ME), Moon Fixed and Moon True of Date (TOD). Based on the transformation algorithm, mission coordinate systems can be transformed very precisely, and transformation results are validated and confirmed with respect to flight proven Systems Tool Kit's (STK) results. Every coordinate system transformation results showed differences less than order of 10^{-5} km in position and 10^{-9} km/s in velocity. Provided details will give numerous insights into wide ranges of mission relevant communities, including science community world-wide who are interested in application of KPLO science data.

[P-6] Analysis of High Gain Antenna Disturbance for Korea Pathfinder Lunar Orbiter

Hanwoong Ahn

Korea Aerospace Research Institute

Korea Pathfinder Lunar Orbit (KPLO), Korea's first lunar exploration satellite, transmits and receives data to and from the Earth using the High Gain Antenna. High Gain Antenna is configured in a dish shape for long-distance communication, and when the High Gain Antenna operates, it acts as a disturbance to KPLO. In this paper, the disturbance torque generated by the operation of High Gain Antenna on KPLO was analyzed.

[P-7] Mass Prediction of Rover's Mobility System for Planetary Exploration

Jong-Won Lee, Youn-Kyu Kim, Joo-Hee Lee

Korea Aerospace Research Institute

The main considerations in rover's design for planetary exploration are mobility system for avoiding or overcoming obstacles and the scientific mission. Since these are considered in the early stages of the rover's design, it is very important to approximate the mass of the rover. In this study, we

developed mass prediction model of the rover's mobility system based on factors such as the number of wheels, mechanisms, wheel diameter, and overall size. We designed a simple model of the rover's mobility using the "Solidworks". The rocky-bogie and four wheel rover, which are typical mobility mechanisms, were designed in various sizes. Then, we measured the mass of the rover on a 3d models and performed a regression analysis.

As a result, we obtained a prediction equation for mobility mass according to the wheel size of the rover and the number of wheels. In addition, to verify the equation, we analyzed an various planetary exploration rover and applied it to the equation.

[P-8] Development of Radiometric Calibration and Geometric Correction for KPLO LUTI Image Level Processing System

Jo Ryeong Yim¹, Seung Bum Yang², Mijung Kim²,
GwangSoo Shin¹, Dong-Gyu Kim¹

¹*Korea Aerospace Research Institute*

²*InSapce*

Korea Pathfinder Lunar Orbiter (KPLO) is Korea's first moon exploration spacecraft being developed by Korea Aerospace Research Institute, expected to launch in 2022. LUTI (Lunar Terrain Imager) is one of the main payloads of KPLO and LUTI Image Calibration and Analysis Subsystem (ICAS) has been developed by KPLO Program Office for LUTI image level process. As introduced in previous research, the LUTI Level Processor (LP) is mainly composed of radiometric calibration and geometric correction, KARI has a lot of accumulated technical experience for processing Earth images taken from low-earth and geostationary orbit satellites. On the other hand, since KPLO is the first space exploration satellite for the Moon, it has no heritage with moon image processing obtained by LUTI. Therefore, it was decided to use ISIS3, a standard image processing tool of USGS. In this paper, we will briefly present the ground verification concept for LUTI level process in accordance with the radiometric calibration and implementation results of radiometric calibration level processor (LP). The geometric correction level process for LUTI images are performed by using main functions provided by ISIS3 with KPLO SPICE kernels generated by ADG (Ancillary Data Generator). The geometric correction LP implementation in ICAS will be described and the preliminary verification results by using SPICE toolkit will be presented in detail.

[P-9] Thermal Analysis of Korea Pathfinder Lunar Orbiter Attitude Maneuver for Lunar Orbit Insertion

Byung-Kwan Jang, Jang-Joon Lee, Moon-Jin Jeon

Korea Aerospace Research Institute

Korea Aerospace Research Institute (KARI) has been developing Korea Pathfinder Lunar Orbiter (KPLO). KARI should determine the orbital maneuvers entering the lunar mission orbit. The time required for the planned delta-V maneuvers is expected to be approximately 90 minutes. If a body-fixed orbit-attitude is maintained for about 90 minutes, it is necessary to analyze whether KPLO shows thermal issues that could influence the electronic devices. In other words, it is essential to scrutinize if there are solar incident angles that the spacecraft must avoid during the delta-V maneuver period. Therefore, KARI performed thermal analysis of KPLO throughout the Lunar Orbit Insertion (LOI) maneuver using Thermal Desktop software. This paper describes the results of the temperatures of major avionics according to different solar incident angles.

[P-10] Design of Cross-Platform Software Interface Architecture for Applying Deep Space Communication Relay Protocol to Multi-Platform

Yoon-Jeong Jang, Cheol Hea Koo

Korea Aerospace Research Institute

Currently, the space exploration research division of KARI is focusing on researches related to the advanced core technology for moon exploration. With regard to the mentioned efforts, we are actively studying cross-platform software interfaces which enable multi-platform application of deep space communication relay protocol eg., Delay/Disruption-Tolerant Networking. In this part, it is important that the cross-platform core software interface remains unaffected. This function can be realized by implementing an Abstraction Layer (AL) between applicable operating systems and computing environments. Comprehensive supports are required to fulfill the requirements that are necessary to run the protocol software on multi-platform successfully without significant code architecture changes. Network API, File, and various OS API such as thread, semaphore, signal, etc, are the minimum essential functions in the protocol software. We consider an Android platform to bring an experimental solution to the aforementioned Abstraction Layer as the Android OS is particularly different from Linux and RTEMS platform. While developing the abstraction layer on the considered multi-platform, we tested the basic interface between Linux and Android. In This paper presents set out above solution possibilities and implementation results of the general concepts among multi-platforms.

[P-11] KPLO Ground Station Tracking Time Analysis

SeungBum Hong, Jae-Ik Park, In Kyu Kim,

Young-Joo Song, Young-Rok Kim, Jonghee Bae,
Donghun Lee, Dae-Kwan Kim, Sang-Ryool Lee

Korea Aerospace Research Institute

The Korea Pathfinder Lunar Orbiter (KPLO) will perform a normal mission after few months of translunar cruise phase and lunar orbit acquisition phase. For smooth operation, contacts between KPLO and ground stations should be maintained except inevitable situations. Especially, during critical events such as trajectory correction maneuvers, lunar orbit insertion burns, and station keeping maneuvers, the contacts between KPLO and ground stations are essential for accurate burn planning and OD/OP. Therefore maneuver execution time needs to be adjusted by ground station tracking time analysis. Currently KPLO program will be supported by a Korea Deep Space Antenna (KDSA) sited in Yeosu and three Deep Space Network (DSN) stations sited in Goldstone, Madrid, and Canberra. This study analyzes ground station tracking time utilizing one KDSA and three DSN antennas for entire mission phases; the analysis will be utilized for optimal maneuver planning.

[P-12] Ocean Surface Underneath Tropical Storms Observed by KOMPSAT-5 Satellite in 2020

Chiho Kang¹, Mi-Ri Kim², Ho-Il Cho²

¹*Korea Aerospace Research Institute*

²*SI Imaging Service*

The roughness of ocean surface, which is influenced by wind and waves, can drive the backscatter of the synthetic aperture radar (SAR) signal. The active signal of SAR penetrates clouds and can image at any time of day. Based on this characteristic of SAR, the ocean surface underneath tropical storms can be detected. Also, SAR can provide information on ocean surface that cannot otherwise be obtained below the cloud with finer resolution. During 2020, there have been trials to acquire SAR images of ocean surface roughness underneath large-scale tropical storms by using KOMPSAT-5 SAR wide swath mode. In this paper, we summarize the campaign to observe ocean surface underneath tropical storms and present resultant imagery, which shows eye shape and patterns of ocean surface wind driven by tropical storms are clearly shown.

[P-13] Research on Leveling Space Weather Disaster by Industry

Ami Yun¹, Sarah Park¹, Jae-Woo Park¹,
Young-Kyu Kim², Eun-Joo Kwon²

¹*Rader & Space*

²*Korean Space Weather Center, National Radio Research*

Agency

Active solar activities have both direct and indirect influence to various industrial areas. In this research, it tried to develop Space Weather Alert Index in Satellite, Aviation, Global Positioning System, Electric Power, Wireless Telecommunication devices (LTE, 5G, WiFi, GPS). It used observation data and modelling result data to research how to display Alert Index in real time(near-real time) for each industrial areas. It used SEASE GEO model in Satellite area and NAIRAS model in Aviation. It used S4 observation data in GPS and Geomagnetic Induced Currents observation data from KSWC in Electric Power. Finally, in case of Wireless Telecommunications Devices, it used Solar Radio Flux data from SWS as an input. Five Stage of Leveling was displayed based on the each data in each area.

[P-14] Measurement of RF Cable Loss for RF Compatibility Test

In Hoi Koo, Jong Bum Park

Korea Aerospace Research Institute

Before the launch of the satellite, RF compatibility test is carried out using RF cable buried between the satellite assembly building and the ground station to ensure that the satellite and the ground station are connected.

Before performing the RF compatibility test, check the cable connection status for the RF cable and measure the cable loss to determine whether the cable is appropriate to perform the RF compatibility test.

This paper describes procedures and measurement results for measuring the connection status and cable loss of RF cable connected between the satellite assembly building and the ground station antenna building of the Korea Aerospace Research Institute (KARI).

[P-15] GNSS Receiver Visibility Analysis for GEO Satellite

Kiho Kwon

Korea Aerospace Research Institute

This paper provides a visibility performance study of GNSS receiver for GEO satellite. Historically, most GNSS Receiver users have been located at low altitude because signal source (GNSS constellation) is located at high altitude. GNSS Receiver under GEO Satellite is more challenging due to reduced signal power level and visibility. For the visibility analysis, GEO satellite mission analysis is necessary and GNSS antenna location trade-off study should be performed. In this paper shows that GNSS satellite visibility and DOP analysis and it will be used for next GEO satellite mission performance and

requirement generation of GNSS Receiver

[P-16] Test Report of Image Collection Planning System and Product Management System of CAS500-1

Dong-Oh Kim, In-Hoi Koo

Satellite Operation & Application Center, Korea Aerospace Research Institute

Korea Aerospace Research Institute (KARI, hereafter) is on a mission to operate satellites.

In order to operate the satellite, it is necessary to receive an order from users, establish a image collection plan and a reception plan, transmit a command to the satellite, receive images from the satellite, and generate products using the received image data. The Image Collection Planning System (ICPS, hereafter) performs the image collection plan and reception plan. The Product Management System (PMS, hereafter) performs the generate and manage of image product. In this paper, we summarized the test results for ICPS and PMS required to operate CAS500-1 (Compact Advanced Satellite 500-1).

[P-17] Analysis of the Operational Results of Multi-Satellite Integrated Data Processing System

Min-a Kim¹, Kyeongmi Jeon², Guhyeok Kim¹, Jaeyeol Lee¹, Jihyeon Yim¹, Dae-Won Chung¹

¹*Korea Aerospace Research Institute*

²*SI-Imaging Service*

The multi-satellite data processing system develops a common module that recycles modules of multi-purpose satellites No. 2, 3, 3A, and 5 currently in operation, establishes the concept of multi-satellite operation based on the existing operational concept, and obtains high utilization by optimizing the performance/function of the single-satellite data processing system through optimal system environment composition and design based on the understanding of the single-satellite data processing system. In addition, the system is designed/developed in accordance with the concept of multi-satellite operation to identify common property information of satellites and to ensure scalability for further operation of new satellites through designs that can reflect unique characteristics of each satellite. In addition, by laying the foundation for an integrated data processing system considering the next satellite and making the most of idle equipment through batch processing of integrated servers, the processing speed can be improved, and the environment for multi-satellite data processing can be optimized by reducing hardware costs and minimizing operating personnel by minimizing operating equipment.

[P-18] Launch Vehicle Interface Check of CAS500-1 with Electrical Ground Support Equipment

Young-Yun Kim, Dong-Chul Chae

Korea Aerospace Research Institute

KARI is developing CAS500-1 (Compact Advanced Satellite 500 kg series-1). CAS500-1 is scheduled to launch this year. LVIF (Launch Vehicle) IF (InterFace) should be checked comprehensively before launch. We have conducted the test procedure to validate LVIF of the satellite and the function of EGSE used at launch phase. LVIF is composed of several signals to check the good signs of satellite and to set launch configuration of satellite. EGSE was also validated which is used to get and show the acquired signals and to send signals setting the final configuration. We will introduce the interface check including the test configuration and the brief results.

[P-19] The Assessment of Solar Array Separation Shock for Geo-Stationary Satellite

Chang Ho Kim

Korea Aerospace Research Institute

Satellite structure should be designed to accommodate and support safely the payload and equipments necessary for its own missions and to secure satellite and payloads from severe launch environments. During launch, environmental loads such as quasi-static acceleration, sinusoidal vibration, acoustic loads and shock loads are imposed on satellite. The expected shock for satellite is due to launch events such as satellite separation from launcher and deployment of internal components. This paper deals with the assessment of shock effect due to solar array separation.

[P-20] GEO-KOMPSAT-2A AMI Image Navigation and Registration Performance in the Early Stages of Operation

Junho Kim, Jin Woo, SeongHui Kim, Jiyoung Kim, Dohyeong Kim

Satellite Operation Division, National Meteorological Satellite Center (NMSC)

The GK2A (GEO-KOMPSAT-2A) was launched on December 5, 2018. It has been in official operation with data release since July 25, 2019 after IOT (In-Orbit-Test). An observation image of GK2A received by NMSC should be coordinated because it contains the image distortion such as celestial perturbations and inaccuracy of LOS (Line of Sight). INR (Image Navigation and Registration) is the process that corrects this image distortion. Image navigation is the process that matches the location of a

pixel with Earth latitude and longitude. Image registration is the process that keeps the location of matched pixel within images. INR is, therefore, a measure of absolute pointing accuracy and stability. These are quality indicators of INR performance. In GK2A, these measurements are used as quality indicators of INR performance. In this paper, we present the INR performance statistics during operation periods. We analyses the major quality indicators of navigation for AMI FD (Full Disk) image such as Navigation Residual, SSR (Swath to Swath Registration), CCR (Channel to Channel Registration), WFR (Within Frame Registration) and FFR (Frame to Frame Registration).

[P-21] Performance Analysis of Sensor Data Channel in GEO-KOMPSAT-2B

Joong-Pyo Kim, Sun-Ik Lee, Won-Gyu Lim, Sang-Goo Kim

Korea Aerospace Research Institute

In GEO-KOMPSAT-2B satellite, there is SD (Sensor Data) channel in ODCS (Observation Data Communication Subsystem) sending the payload sensor data to the ground station in the beam coverage by using the X-band downlink frequency. After the launch of the GEO-KOMPSAT-2B satellite, the SD channel activation in GEO-KOMPSAT-2B was performed. It is found that all the telemetry status of ODCS SD channel was within the operating range and the received downlink spectrum was the expected one and the measured power level were similar to the calculated power level. Finally the received frame loss was not occurred during the sensor data activation. It is concluded that the SD channel performance on orbit was in line with the specified performance.

[P-22] A Simplified Verification Method Using Cyclical Redundancy Check for the Downlink Telemetry of Satellite

Jin Hyuck Kim, Jin Ho Lee

Korea Aerospace Research Institute

At the ground station, health of state for satellite is checked through real-time and playback downlink telemetry. But, an invalid downlink telemetry is sometimes received due to unstable communication status and abnormal operation of satellite. Then, an invalid downlink telemetry is detected by carried out a validation for Reed-Solomon (RS) check symbol and cyclical redundancy check (CRC). In this paper, we will briefly present a simplified verification method using CRC for the downlink telemetry that is currently useful in development phase of satellite and describe what the error according to RS check symbol and CRC means.

[P-23] Study on the Mission Planning after a Mission Termination of Multi-Mission Geostationary Satellite

Hye-Won Kim, Daewon Chung

Korea Aerospace Research Institute

Korea Aerospace Research Institute (KARI) is currently operating 7 satellites including four LEO (Low-Earth Orbit) satellites and three geostationary satellites, COMS (Communication, Ocean and Meteorological Satellite), GK-2A (Geo-KOMPSAT-2A), and GK-2B (Geo-KOMPSAT-2B). The latest satellite GK-2B (Geo-KOMPSAT-2B), which is the twin satellite with GK-2A, was successfully launched on February 2020 from Kourou Space Center. Since KARI has to operate three different geostationary satellites and plan their own missions simultaneously, understanding individual missions is absolutely important to operate multi-satellite in safe. From April 2020, the meteorological mission of COMS was officially terminated, the remaining mission of COMS is only two missions; ocean and communication. In order to avoid mission conflicts perfectly in this changing situation, the operator has to understand deeply the relationship between mission types and these constraints. In this study, we investigate the status of mission planning for currently operating geostationary satellites considering the mission termination of COMS. This study helps to operate other multi-mission geostationary satellites, especially GK-2B.

[P-24] Development Trend of 2D Large Format Infrared Array

Hwan-chun Myung, Jae-dong Choi

Korea Aerospace Research Institute

Since 1940s, the development of the IR FPA (focal plane array) has been continuously focused on minimization of a pixel pitch and maximization of a pixel number. Throughout the four generation leaps of technology, its application has largely expanded from a ground-based thermal measurement to a space IR observation, using diverse IR-photosensitive materials such as HgCdTe, InSb, and InGaAs. The presentation introduces the status quo of the large format IR FPA, based upon the real products of the related developers. As the main providers, 8 major companies are carefully selected, which are Teledyne Imaging Sensors, Raytheon Vision System, LYNRED (formerly Sofradir), LEONARDO (formerly SELEX-ES), Semiconductor Devices, DRS, L3Harris (formerly L3 Communication), and FLIR. Among their IR FPAs, the 2D large format arrays over 1Kx1K are mainly considered in the presentation and their features are shortly described. Finally, all the surveyed IR FPAs are graphically compared in terms of a pixel pitch and a pixel number.

[P-25] Anomaly Detection for Quality Control of GEO-KOMPSAT-2A AMI Images

Geoseong Moon, Jin Woo, Seonghui Kim,
Jiyoung Kim, Dohyeong Kim

National Meteorological Satellite Center (NMSC), Korea Meteorological Administration (KMA)

The second geostationary meteorological satellite of the Republic of Korea, GK2A (GEO-KOMPSAT-2A) has been officially operated since July 25, 2019. The AMI (Advanced Meteorological Imager) generates more than 70,000 Earth images daily. Compared to the COMS (Communication, Ocean and Meteorological Satellite), the number of produced images and data volume were dramatically increased, making difficulties to manually check the quality of individual image. Therefore, it is necessary to develop an automated system for checking data quality. In this paper, we introduce some cases of image anomalies in GK2A AMI data such as image registration error and partial loss. In addition, we suggest two methods for detecting image anomaly. The first method measures the changes in the statistical values of image. Another one applies image quality assessment method such as GMSD (Gradient Magnitude Similarity Deviation). The suggested method shows a detection rate of over 86% in the optimal environment. The proposed detection method will contribute to detect anomalies in GK2A AMI images more quickly as well as qualified data service.

[P-26] A Study on the Mission Planning for IDHU (Image Data Handling Unit) Preparation for CAS500-1

Sunju Park¹, Okchul Jung¹, Daewon Chung¹

¹*Korea Aerospace Research Institute*

The Korea Aerospace Research Institute (KARI) has developed and operated a Mission Planning System (MPS) for low orbit satellites. The MPS can simultaneously generate mission plans for multiple satellites. The CAS (Compact Advanced Satellite) 500-1 is scheduled to be launched in 2020. And, the flight operation team is preparing satellite mission operation by using integrated MPS. However, a unique feature is required for the operation of CAS500-1. The CAS500-1 image data handling Unit (IDHU) is quite different from the existing satellite system. The nominal state of IDHU for CAS500-1 is off mode. so it should be switched on before imaging or downlink for mission activity. The MPS should automatically determine when the IDHU will operate using Image Collection Plan (ICP), and also identify the File ID that should be generated at that point in advance. This paper introduces the concept for preparing IDHU for the operation of CAS500-1.

[P-27] Review on the Various Power Limitation Methods of Solar Array Regulators for LEO Satellites Applications

Sung-Woo Park¹, Hee-Sung Park¹,
Jeong-Hwan Yang¹, Kyu-Dong Kim¹,
Jeong-Eon Park¹, Jin- Baek Jang¹, Seung-Hee You²,
Se-Yong Park², Hyoung-Jun Jang²

¹Korea Aerospace Research Institute

²Korea Aerospace Industries, Ltd.

The solar array regulator converts solar array output power to the unregulated primary bus and controls the battery charging. And, the power capability of solar array regulator is typically determined with considering the peak output power of solar array at BOL (Beginning of Life) condition and the maximum charge and discharge current of battery at EOL (End of Life) phase. At LEO application, the solar array output power at the very beginning of sun period is much larger than that of at nominal sun period. But, it is not very efficient to design the regulator as to cover solar array output power at the whole mission period including the whole period of these kind of very short and high peak power. Instead of increasing the power capability, to apply power limitation on the regulator for any given period or condition is more realistic ways considering volume and mass requirements of solar array regulator. In this paper, various power limitation methods which are actually applied to several LEO applications are given and reviewed.

[P-28] Real Time Image Processing Operation of GeoKompsat-2A (GK-2A) Satellite

Eun-Bin Park, Sae-Han Song, Dae-Won Chung

Korea Aerospace Research Institute

Geo Korea multi purpose satellite-2A (GK-2A) was successfully launched on 5th December 2018, as South Korea's geostationary satellite following the Communication, Ocean and Meteorological Satellite (COMS). The GK-2A, which has performed Launch and Early Orbit Phase (LEOP) and In Orbit Test (IOT), is observing the earth for 24 hours a day and disseminating earth observation data to users around the world. Korea Aerospace Research Institute (KARI) has operating real-time image processing system of GK-2A earth observation data as a backup for National Meteorological Satellite Center (NMSC). The GK-2A observes the earth in three modes: Full-Disk (FD), Extended Local Area (ELA) and Local Area (LA). The real-time image processing system can produce the FD images every 10 minutes, and ELA and LA images every 2 minutes. The images from the real-time image processing can be used for weather forecasting, typhoon prediction and so on. This study explains both of concept and structure about the real-time image processing. Also, normal operation of the GK-2A image

processing will be presented in this paper.

[P-29] RF Compatibility Test for Verifying S-Band Interface between Satellite and Ground Station

Jong Bum Park, In Hoi Koo

Korea Aerospace Research Institute

RF compatibility test is to finally verify that there are no defects in the interface environment and communication between the satellite body and the ground station, and through the RF communication equipment, the satellite body and the ground station will be tested while sending and receiving signals similar to the actual normal operation. The signal exchanged between the satellite body and the ground station has remote command and condition data and ranging tones required for satellite control.

This paper conducts RF compatibility tests and describes the test results using RF cables connected between the satellite assembly building and the ground station antenna building of the Korea Aerospace Research Institute.

[P-30] LEOP (Launch Early Operation Plan) of CAS500-1 (Compact Advanced Satellite500-1)

Jong-Oh Park, Jeong-Heum Im

Korea Aerospace Research Institute

The CAS500-1 is a 500 kg-class satellite for national territory management, agriculture and forestry management, disaster monitoring & control, Korean peninsula observation etc. And the CAS500-1 has a standard platform to support a variety of payloads with minimal design changes. The CAS500-1 FM (Flight Model) was finally integrated and performed functional and environmental test. Now the CAS500-1 FM satellite is ready to launch on the early of 2021.

In this paper, I will introduce LEOP plan for CAS500-1 FM Satellite just after launch.

[P-31] Study of Constraints Handling Capability and Performance of Model Predictive Control for Spacecraft Attitude Control

Jooho Park, Seon-ho Lee

Korea Aerospace Research Institute

Last several decades, many satellites have been successfully developed and operated. Based on these achievements, more challenging missions will be come out for future space programs. To satisfy the high requirements, newly designed and developed actuators or sensors are adopted. However, it tends to rely on hardware capability. For optimization of the hardware, which maximizes system performance, software development is

also required in parallel. At this perspective, modern controller design, especially model predictive control, is suited for spacecraft attitude control. Compared to conventional method, it has advantages, ability of performance optimization and constraints handling. In practical system, there exists several limitations (e.g., actuator saturation). Unlike modern technology, conventional method cannot cope with the multiple constraints. This paper presents the simulation results of attitude stabilization in presence of multiple constraints to verify its performance.

[P-32] Computation on Projected Slot Position from ECEF Position for GEO-KOMPSAT-2 GOCI-II DPS

Jinhyung Park, Hyun-su Lim, Junyoung Bok
Korea Aerospace Research Institute

In this paper, we proposed algorithm to calculate projected slot position of the GEO-KOMPSAT-2B view point from ECEF slot position. The GOCI-II (Geostationary Ocean Color Imager II) is payload for ocean monitoring on the GEO-KOMPSAT-2B. GOCI-II DPS (Data Pre-processing Subsystem) decomposition, reconstruction image from GOCI-II payload packet data, radiometric calibration and shows images to UI for users. The GOCI-II observes a fulldisk image per every day. One fulldisk image consists of almost 250 image slots. The GOCI-II observes a fulldisk image from UTC 20:15 to next day of UTC 10:45. From 11 to 30 of fulldisk image slots are observed every hour. Mission Planning Subsystem in GEO-KOMPSAT-2B ground system generates 'Mission Event File' and transfers to DPS everyday which contains ECEF position information for all fulldisk image slots. Therefore, the DPS should convert ECEF position into projected 2D slot position of satellites view point to generates full disk image for UI. This paper introduces algorithm to calculate 2D projected image slot position from ECEF position with satellite longitude. This algorithm is currently implemented to DPS for KARI SOC (satellite operations center) and KIOST. It will be used in 10 years of operation of GEO-KOMPSAT-2B.

[P-33] Derating Analysis of Blocking Diodes for the Solar Array of LEO Satellites

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Blocking diodes of the solar array pass the current generated in the solar array to the regulator and block the current flowing back from the electric bus. Also, these are arranged in series in each solar cell string for prevent the current flowing back due to imbalances between solar cell strings. Since all strings must have at least one blocking diode, they are mounted on

the PCB board and installed on the rear of the solar panel. As a result, blocking diodes work on at a temperature almost similar to that of a solar array. Therefore, these are subject to large temperature variation as LEO satellites repeatedly place in eclipse and sunlight. Diodes are not a big problem at low temperature, but forward current decreases significantly at high temperature. In this paper, blocking diodes used for the solar array of LEO satellites are selected and the validity of the operation is shown through derating analysis based on ESA and NASA derating rules.

[P-34] Analysis of Commercial Receiving Service for Increase of Global Receiving in Overseas Ground Station of KARI

HeeJin Bae, OkChul Jung, Dae-Won Chung
Korea Aerospace Research Institute

The Korea Aerospace Research Institute (KARI) performs operation for several satellites like as KOREA Multi-Purpose SATellite (KOMPSAT) series (K3, K3A and K5) and prepares operation to launch K6, K7 and K7A. So, it's necessary to consider not only foreign ground station on operation of KARI but also other global ground station to operate increasing satellite. There are two types to use for commercial receiving service. One is that we build, lease or rent the overseas ground station (or antenna system). In this case, we need to manage the ground station (or antenna system) and sometimes have difficulty repairing and maintaining the system and the equipment. Another is that we use cloud service like as AWS (Amazon Web Service). In this case, we need to review security policy and the system throughly. In this paper, we will compare and analyze commercial receiving service for increase of global receiving in overseas ground station of KARI.

[P-35] The Performance Analysis of COMS MI INRSM Processing

Sae-Han Song, Eun-Bin Park, Dae-Won Chung
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COMS (Communication, Ocean, and Meteorological Satellite), which launched in 2010, is the first geostationary satellite of Korea with multi-functional applications. COMS performs three missions such as a Meteorological Imager (MI) mission, an experimental Ka-band telecommunication mission and an Geostationary Ocean Color Imager (GOCI) mission. To accomplish the imaging missions of COMS with desired geometric performance, the performance of the Image Navigation and Registration (INR) system should meet its requirement specification.

In this paper, we briefly introduce the COMS MI INR Software Module (INRSM) and the requirement specification. We extract

the image quality information from the level 1B products, which are produced by radiometric processing and geometric processing. Also we analyze the performance of the COMS MI INRSM compared to its requirement specification.

[P-36] Studies on the Full Disk Slot Position Optimization of GK2B GOCI-II Imaging

Jeoung-Heum Yeon, Gm-Sil Kang, Sung-Yong Cha, Sang-Soon Yong

Korea Aerospace Research Institute

Geostationary Ocean Color Imager II (GOCI-II) is the one of the payload of GK2B satellite. Its mission is to monitoring of ocean color in the geostationary orbit with multiple channels of narrow bands. Its observation principle is the step-and-stare with 2D detector. Basic observation unit is called slot which corresponds to the footprint of the 2D detector. GOCI-II has a pointing mechanism which rotates the pointing mechanism to move the slot position in the field of regard. The field of regard will be covered with slots in a mosaic pattern. There are some overlap between adjacent slots by considering satellite attitude and GOCI-II pointing errors and stabilities. In this study the optimization of slot position is performed to cover the full disk area of the Earth. To reducing the required number of slots with maintaining the overlap margin is the concern. The results can be applied for the Earth observation with GOCI-II.

[P-37] Collecting Dataset for Ship Classification Using SAR and AIS Data Fusion Technique

Tae-Bong Oh

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The first step to getting reliable result at deep learning is collecting dataset. This paper presents one methodology of collecting trustworthy dataset for ship classification using data fusion technique. The approach to information fusion is originally devised to detect and track vessel using SAR (Synthetic Aperture Radar) and AIS (Automatic Identification System) data. However, now, the study is focused on achieving more reliable dataset for ship classification. The simulation result of data fusion and methodology of getting dataset is shown in the poster.

[P-38] Comparison and Analysis of LEO Satellite Battery State Estimation Methods

Seok-Teak Yun, Day-Young Kim, Sang Kon Lee

Korea Astronomy and Space Science Institute

The LEO (low-earth orbiting) satellite battery state is important

to mission design and power failure propagation prevent design. The battery state are consist of SOC (state for charge), OCV (open circuit voltage) and SOH (state of health). There are several methods to estimate the battery state. Each method has the merit and demerit. For LEO satellite mission design, SOC is more critical than other states. Therefore, this paper analysis the SOC estimation methods for various model and load profile case which used for simulation. By those comparison and analysis, this paper give the guide line for battery state estimator design for in-orbit and ground station for maximum mission planing.

[P-39] Improvement of Mass Properties Measurement Method for Satellite

Hee-Kwang Eun, Nam-Jin Moon, Sung-Hyun Woo

Korea Aerospace Research Institute

For improving controllability of satellite, sensor and actuator of satellite are upgrading. Three dimensional center of gravity, moment of inertia and product of inertia of satellite are basic parameters for control. But actual measurement has a risk to install satellite for three configurations. In this paper, the measurement method without installing satellite in horizontal configuration is presented. Especially the measurement of product of inertia without high speed rotation is very useful for fragile structure like solar panel.

[P-40] Reconfigurable Microwave Filter for Satisfying Demand for Flexible Payload

Boyoung Lee, Daewon Chung

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In times past, the satellite payload is developed to operate at a specific frequency range to fulfill a specific mission which is planned before its launch. Therefore, RF components such as microwave filters, dividers, antennas and so on have been designed to operate at a fixed frequency range. However, recently, it is desired to have flexible payloads to deal with the changes of the mission objectives due to political and commercial reasons, hence, reconfigurable RF components should be developed. Few works on reconfigurable RF filters have been introduced but they require N+1 tunable coupling structures with tuning components, leading to a bulky and complex system composition. In this work, we present a method for reducing the number of tunable coupling structures for reconfigurable filters.

[P-41] Final Step in Acquiring Frequency Resources for Geostationary Satellite Programs

Seorim Lee

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Acquiring frequency resources for geostationary satellite programs is a long term process that can take up to seven years. The final step in acquiring satellite frequency resources for geostationary satellite programs is the entering and recording of the necessary frequency assignments of the satellite network in the Master Register of the ITU. This is accomplished through the notification of the satellite network to the ITU and the bringing into use of the satellite network after the launch and 90 days operations of the actual satellite in the planned orbital location. This paper takes a glance into this process which completes the acquisition stage of acquiring the necessary frequency resources for geostationary satellite programs.

[P-42] An Introduction of TC&R RF Communication System for Deep Space Application

Sun-Ik Lee, Won-Gyu Lim, Ki-Ho Kwon

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The TC&R subsystem is one of main subsystems for Earth orbit satellite or deep space satellite. For deep space application, a highly longer distance (range) to the satellite is a dominant factor we have to consider to fulfill the communication performance. In this regard, the configuration of RF front-end is one of interests. In this paper, we introduced a TC&R RF communication system of deep space application we designed, for instance, lunar orbiter mission. The main features such as operation concepts, RF front-end configuration, and required performances, are presented. In our design, one of main characteristics is that three antennas are used, so it requires a polarization plan and antenna placement. To decide those, we also presented the results of polarization combination study and antenna composite gain analysis.

[P-43] Compatibility of Result between Satellite Dynamics Simulation and Electrical-Test-Bed Test for Low Earth Orbit Satellite

Seung-Hun Lee, Hyungjoo Yoon

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The satellite dynamics simulator (SDS) has been developed for testing on satellite electrical test bench (ETB) and simulates the electrical signal inputs and outputs of all the sensors and actuators used in the attitude control subsystem of satellite. When the SDS is run independently, it does the function of performance analysis simulator which includes not only all sensors and actuators models of the satellite but also control algorithm code together. By independently operating the SDS, the desired operation mode is simulated and the satellite control

result is generated through calculation of current attitude, determination of errors between target point and current attitude, and actuator driving. It also includes a software model that simulates space environment, such as ephemeris and disturbance, in order to implement a more rigorous verification environment. Verification of the SDS was carried out through the additional SDS which also served as a backup function in case of emergency. We confirmed that there is no problem in connecting the SDS to ETB through the interface check test. In this presentation, we show that the SDS operates without significant differences by comparing the result of satellite operation mode using only the SDS and the result of satellite operation mode using the SDS and ETB.

[P-44] DIAS Implementation Case Analysis and Implications

Jaeyeol Lee, Min-A Kim, Gabho Jeun, Jihyeon Yim, Guhyeok Kim, Daewon Chung

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In recent years, the importance of satellite data is gradually increasing due to the increase in acquisition and utilization of information using satellites. In order to use satellite data in the right place at the right time, it must be possible to standardize and store and supply satellite data. The European Commission (EC) has added a new DIAS (Data and Information Access Services) platform from the existing ESA and EUMETSAT Data Access Hubs to provide businesses and citizens free and free access to satellite data. In particular, satellite data can be processed and used in various ways by granting data, authority, and copyright to a private platform called Third Party. In this study, the composition and characteristics of DIAS are analyzed, and the implications of transmitting them to the Korean satellite system are investigated.

[P-45] A Study on the Utilization of Rainfall Data for Improvement of the Image Collection Planning Subsystem

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In the Image Collection Planning Subsystem, image collection plan and downlink plan are carried out. To increase valid satellite images acquisition rate, The image collection plan is carried out in consideration of weather information such as ice cover maps and cloud prediction data provided by NOMADS. As rainfall is confirmed to affect the download of images, it is necessary to find ways to reduce the failure of reception due to rainfall by reflecting weather information not only in the

image collection plan but also downlink plan. In this paper, the possibility of improvement was confirmed by using the ultra-short-term forecast and village forecast, which are rainfall data provided by the Open Data Portal. In the future, we plan to improve the Image Collection Planning Subsystem to reflect weather information in download plans.

[P-46] Analysis on the Asymmetric Responses of Spacecraft during Sine Burst Test

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During launch, vibrations are transmitted in the spacecraft through launch vehicle mechanical interface. In order to verify the adequacy of strength in the spacecraft's primary structure during launch, quasi-static test is performed by using sine burst testing method. Sine burst testing is used for strength testing of aerospace hardware as an alternate to static pull and push test. It imposes static loads on spacecraft with a fixed frequency of 5–10 cycles on vibration shaker system. During the sine burst test for spacecraft developed in KARI, asymmetric responses are found in the structure as the testing load increases from low to target level. To investigate the abnormal phenomena, the measured acceleration signals are analyzed in time domain and frequency domain as the shaker excitation levels increase. To verify the trend of asymmetric responses according to the excitation levels, simple analytical model is introduced. In this paper, the phenomena of asymmetric responses are presented during sine burst test and analysis processes for finding root causes are described.

[P-47] Design of Cloud Coverage Assessment System Based on Semantic Segmentation for Satellite imagery

JiHyeon Yim, Min-A Kim, GuHyeok Kim, Jaeyeol Lee, Daewon Chung

Korea Aerospace Research institute

In satellite imagery, cloud analysis, which refers to detection of clouds and estimation of cloud coverage, is essential for providing cloud coverage information to the user. The Korea Multi-Purpose Satellite (KOMPSAT) provides cloud coverage information and plans are underway for upgrading its designing a system to accurately analyse numerous images in response to the increasing satellite and image demand. An important point in this system enhancement is to ensure that it accurately identifies the cloud and non-cloud regions through semantic segmentation, which allows segmentation of images based on their pixel units. In this study, we designed a cloud coverage

assessment system for satellite imagery that can detect clouds in pixel units using semantic segmentation-based algorithms.

[P-48] In-Orbit Test Result of Ultra-HRIT Broadcasting Data Generation on GEO-KOMPSAT-2A Satellite

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Image Data System Development Division, National Satellite Operation & Application Center, KARI

The latest generation of GEO-KOMOPSAT-2A (GK2A) geostationary meteorological satellite began its nominal operation in July 2019. The Advanced Meteorological Imager (AMI), a primary payload of GK2A, is capable of frequent and flexible observation, providing Earth full-disk images every 10 minutes with advanced image resolution, spectral band number, and observation times. The real-time processed AMI full-disk images are generated into Ultra-HRIT (UHRIT) data format, newly added broadcasting service. The GK2A UHRIT service data are uploaded to the spacecraft for broadcasting service for end-users. During the in-orbit test phase, UHRIT broadcasting data generation ground subsystem were validated in the aspects of functionalities and performance. This paper introduces test results of GK2A UHRIT generation subsystem during in-orbit test phases.

[P-49] A Study on the Development and Implementation of the OPEN API Based Satellite Information Service

Gab-Ho Jeun, Dae-Won Chung

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In the satellite image data service sector, API services have been mainly aimed at improving convenience and convergence by integrating user interfaces for independent satellite programs in each country. ESA (European Space Agency)'s multi-satellite service integration programs, such as HMA (Heterogeneous Mission Accessibility) and EOLi (Earth Observation Link) are typical examples of API services to enhance the accessibility of different sensors. Recently, API services have been more attention as a method of ordering and providing satellite information data in conjunction with analysis algorithms of user's applications due to technological advances in big data analysis and artificial intelligence. This paper describes the functions and parameters of the search and request API developed for KOMPSAT data service, and also describes the application software development method using verification module.

[P-50] System Design of Automatic Downlink Scheduling for Low Earth Orbit Satellite

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The development of the space field is going rapidly around the world and the market for satellite information services is also expanding and growing due to the introduction of high-tech technologies. In addition, the space field is changing from existing security objectives into a customer-centered paradigm for utilizing satellite information. The initial satellite operation was aimed at stably operating and independent large satellite with high performance capabilities, but recently it has been in the form of and operation in which private-led, low-cost small satellites are clustered to produce and serve large amounts of value-added satellite information. therefore, in order to operate up to thousands of satellites instead of one, the processing phase of satellite operations must be carried out automatically. The image data that has acquired the imaging mission must be sent to the ground, and system on the ground must be able to generate the receiving mission based on imaging mission. In this paper, I would like to introduce the concept that automatically generates reception missions without operator intervention, taking into account the environment of receiving satellite and ground reception performance.

[P-51] Electrical Interface Test between Satellite and EGSE (Electrical Ground Support Equipment) during Satellite Launch Campaign Period

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During a spacecraft launch campaign period, all electrical interface from a spacecraft to its EGSE (Electrical Ground Support Equipment) through a launch vehicle interface shall be verified. However, it is very difficult to check all electrical interface through only one test because its complete electrical interface is formed only in its final launch configuration at a launch pad. Therefore, the electrical interface test cannot help being divided into several sub-tests. That is, each sub-test verifies a partial section, and its complete electrical interface is verified through all sub-tests.

In order to schedule all electrical interface sub-tests, test subject and test availability of each partial section, etc. shall be considered. After sub-test scheduling is completed, detailed procedures for all sub-tests shall be prepared.

This paper discussed about the electrical interface test between a satellite and its EGSE during satellite launch campaign period. This paper can be a guideline for preparing an electrical interface tests during satellite launch campaign.

[P-52] Orbital Geometry Analysis for Radio Frequency Interference of Operational Satellites

Okchul Jung, Jaedong Seong, Youeyun Jung,
Daewon Chung

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Radio frequency communications are essential to satellites mission operations, which are used to interface between ground and satellite by using both uplink (ground to space) and downlink (space to ground) channel. However, due to a limited RF resources especially for downlink, interference can result from a satellite transmitting too close to another satellite on the same or similar frequency. In this paper, orbital geometry for radio frequency interference (RFI) of an operational satellite is analyzed. Firstly, given RFI time, active satellite in low earth orbit is identified. Secondly, ground to space accessibility is checked and line of sight vector between a ground and two satellite is examined. If the angle of two LOS vector is small enough, this event is considered as a candidate for interference. Final step is to confirm the registered RF band for a candidate object. This paper presents the case study by using real-flight data.

[P-53] Ground-Based Satellite Precision Attitude Determination for Satellite Imagery

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KOMPSAT Precision Attitude Determination Software (KPADS) is a software developed by Korea Aerospace Research Institute (KARI) for currently operating low-earth orbit satellite imagery. The first version of KPADS was developed for precise attitude calculation of KOMPSAT-2, and has been migrated for KOMPSAT-3 and 3A. However, more general purposes-software, which means not dedicated to a specific satellite, has been needed because of increasing trend of satellite imagery needs. Extended Kalman Filter (EKF) is used for the precise attitude determination, and recursive technique is applied to stabilize the effect of gyro drift rate changes.

[P-54] Overview of Free-Space Optical (FSO) Communication

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FSO is defined as a technology that transmits and receives data

wirelessly through free space using optical communication technology.

In general, FSO refers to a wireless optical communication method used outdoors, and includes not only an atmospheric environment but also a vacuum space environment. Traditional optical communication uses optical fiber, but FSO is wireless, so there are many advantages and differences. In particular, it is attracting attention as an innovative communication method for downloading large amounts of data from satellite payload systems.

The advantage of FSO in satellite is that it can use the ultra-wide band of THz, there is no international restriction on the use of frequency spectrum, it uses half the power of conventional RF communication, and the antenna size is very smaller than that of RF, and is independent of electromagnetic interference. It has good security for communication channels.

[P-55] Imaging Scheduling of an Earth Observation Satellite based on Stereo and Strip Imaging Properties

Jeong Hoon Hyun

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An imaging schedule of Earth observation satellites is established in consideration of operational constraints and objectives such as the location of targets, maneuvering capacity, image quality, priority of targets and imaging modes. In order to plan an efficient imaging sequence within limited capacities and resources, it is necessary to model the environment of missions and derive optimal plans through the environment. Although a lot of methods have already been studied for setting the environment of Earth observation missions and planning tasks optimally, few of them deal with scheduling imaging with the characteristics and image quality of stereo images considered. In this paper, the FOR of an optical sensor is emulated by a combination of sub-sensors corresponding to FOVs inscribed in the FOR, and the value of each imaging task is determined by the resolution of strip images captured by the sub-sensors and the position accuracies of stereo images captured by pairs of the sub-sensors. It is assumed that the maneuvering of satellite is consistent with an attitude guidance profile for rest-to-rest maneuvering. An integer programming problem is constructed with additional constraints related to imaging operations and solved to obtain optimal plans.

[P-56] Measurement of Flatness of Mounting Surface of Large Satellite Optical Payload Using Laser Tracker and Consideration of Requirements

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In order to ensure the optical performance of the satellite in space, the surface on which the optical payload is mounted generally requires a very high flatness when assembling. However, the measurement of flatness in a high position and wide-space assembly state such as a large satellite optical equipment mounting surface in a state where there is no displacement of the satellite structure is very limited. In consideration of this environment, the point on the surface on which the optical mount is mounted was measured using a laser tracker, and the flatness was calculated based on ISO1101 using the measured value. This flatness measurement method can be an alternative in the trend that satellites and cameras are becoming larger. Nevertheless, it is necessary to evaluate the appropriateness of the calculated flatness in consideration of the measurement error of the laser tracker.

[P-57] Space Environment Test of the LEO-DOS EQM Payload for the NEXTSat-2

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The Korea Astronomy and Space Science Institute (KASI) has been developing a low-Earth orbit space radiation dosimeter (LEO-DOS) for next-generation small satellite 2 (NEXTSat-2) since August 2017. The main missions of LEO-DOS payload are to make a global map of charged particle and neutron equivalent doses and to measure the human impact weight by neutron energy bands. In this talk, we present the space environment test results of the engineering qualification model in the LEO-DOS payload. Main tests consist of the random vibration test and the thermal-vacuum test. Random vibration tests were performed to a qualification level of 14.1g rms in the X, Y, and Z directions of spacecraft. Thermal-vacuum test was also performed in the qualification level. All the test was passed and verified with the detector performance.

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[P-58] Comparison of the Pansharpeing Performance of MDPS System and ENVI Software

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Jihyeon Yim, Daewon Chung

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High spatial resolution satellite images have an advantage in object extraction and change detection and multispectral images have strength in land cover and classification. multispectral images with high spatial resolution can be produced by using pansharpening, but the quality of the image's spectral resolution and spatial resolution depend on the type of sensor, the location and topography of the image, and the method pansharpening algorithm. In this study, For KOMPSAT-3 image, Color Normalized (Brovey) and Gram-Schmidt method, which are provided by ENVI software, were used to compare existing pansharpening methods with those produced by MDPS system, and SAM, ERGAS, and CC were used as the evaluation indicators.

[P-59] Cross-Talk Effects on Multi-Band CCD by Control Clocks

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Photon energy injected into CCD sensor is absorbed in the photosensitive material such as silicon and it is converted to the charge. The collected charges by electric field within the photosensitive material are transferred to the edge of the sensor where its amplifier is located by the various control clocks. The vertical and horizontal CCD control clocks are essential and provided properly for the charge movement. The clocks by different clock drivers with same timing or different timing are generated to the multi-band CCD in order to operate it simultaneously. However, these clocks result in the cross-talks between bands on the multiband sensor, which may make undesirable darker or brighter lines on the image. This paper investigates the cross-talk effects on the multi-band CCD resulting from the vertical and horizontal clocking and gives the ways to remove and reduce these effects.

[P-60] DN to Radiance Conversion Considering Camera Exposure Time for Atmospheric Correction of KOMPSAT-3A Image

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In LEO satellites which provide high resolution images, TDI (Time Delay Integration) technique is used to improve signal to noise performance. In order to minimize image quality degradation due to the application of the TDI technique, precise satellite attitude control and camera exposure time control are performed. The camera exposure time is affected by satellite

orbit and satellite attitude. When atmospheric correction is applied to the radiance at top of atmosphere which is calculated by using DN to radiance coefficients which is provided with KOMPSAT-3A image, the result of the correction will have error due to the camera exposure time. In this paper, we explain the relationship between the satellite attitude and the camera exposure time and propose a method to correct the radiance at top of atmospheres using the camera exposure time. It is confirmed that the proposed method contributes to accuracy improvement in extracting surface physical value through real satellite image.

[P-61] A Study on Major Configuration of Camera Electronic Module Mounted on the Lunar Orbiter for Ground Environment Test

Jong-Euk Park, Haeng-Pal Heo

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The electro-optic camera mounted on the test lunar orbiter for the purpose of acquiring image information of the moon in orbit of the moon has been assembled with the qualification model, and the test is in progress with the flight model. Electro-optic camera is composed of the OM, the camera electronics, and other various structures. The camera electronics, a key component necessary for image information acquisition and major operation, has been verified and tested on the flight model, and assembled into the electro-optic camera qualification model and flight model. The mounted camera is subjected to various ground tests to verify the operation of the space environment, and camera electronics for the operation and performance verification of the camera are performed in each environmental test. The test configuration of the camera electronics for various verifications of the level of the mounted camera before mounting on orbiter is very important for effective camera verification according to the configuration of various environmental tests. In this paper, we analyzed and described the test configuration for various ground environmental tests of the electro-optical camera equipped on the lunar orbit.

[P-62] Multipurpose Satellite Payload Camera Controller Design Analysis

Jong-Euk Park, Eung Shik Lee, Haeng-Pal Heo

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The camera controller, which plays the role of the basic controller of the high-resolution payload camera of a multipurpose satellite, is being developed, manufactured, and tested through localization. The payload camera electronic module is largely divided into a focal plane electronic part, a camera controller and a power supply. The focal plane electronic unit

acquires high-resolution images through image sensor control, the camera controller controls the entire camera system, receives commands from the bus, and transmits various telemetry, and the power supply supplies purified primary power from the bus. It receives and generates and supplies secondary power used for the entire camera. The camera controller receives commands through the 1553B communication protocol and collects the status of all cameras and transmits them to the bus. It plays the role of focusing control to acquire the camera's precise image, transmits commands necessary for the operation of the focal plane electronic unit, and performs the role of collecting and organizing the state. It checks the status of the power supply and supplies the necessary power to the focal plane electronic part through relay control on the camera controller. The focal plane electronic unit is composed of three channels, and the camera control unit transmits the same command at the same time to synchronize the image data of the three channels.

In this paper, we analyzed and described the composition of a camera controller that is mounted on a multipurpose satellite and plays a key role in operation.

[P-63] GEMS Telemetry Processing for Its Initial Activation and Checks

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The GEMS (Geostationary Environment Monitoring Spectrometer) is on preparing its normal operations after successful IAC (Initial Activation and Check) tests. The GEMS has 8 telemetries to monitor air qualities around Korean peninsula, which are required quick analysis software of them during the short GEMS IAC tests. This paper explains a GEMS telemetry processing during the GEMS IAC test.

[P-64] Modulator Characteristics of High Frequency Acoustic Source

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During the launch process of a satellite, the satellite is affected by acoustic loading induced by vibration and jet noise of launch vehicle. The acoustic loading cause the random vibration and fatigue effects in the satellite structure. In order to withstand the acoustic load in the launch environment and perform the mission, a reliable ground test is required. For the acoustic environment test, the high intensity acoustic chamber has been used to generate the acoustic energy of 150 dB in the volume of 1,200 m³ at Korea Aerospace Research Institute (KARI).

In this study, computational analysis is performed on an acoustic source modulator that directly affects the quality of an acoustic test as one of the core element parts. An analysis for a single passage is performed as a basic study on the detailed characteristics of the modulator generating the acoustic load by changing the flow rate.

[P-65] Performance Verification of Micro-Length Measurement Sensor under Vacuum and Temperature Variation Conditions

Won-Beom Lee, Jeoung-Heum Yeon,
Jong-guk Choe, Haeng Pal Heo

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The optical camera consists of several mirrors and a focal plane assembly. In order to maintain the performance of optical camera in the space environment, the relative positions between these mirrors should be within the tolerance of several micrometers obtained from the optical design. In addition, during the process of developing optical camera, environmental test should be conducted to verify that the relative positions between mirrors are within the tolerance. In this test, a micro-length measuring sensor is used to measure fine length changes between mirrors. Therefore, calibration and functional verification of this sensor have been performed. This paper describes the performance verification of the micro-length measuring sensor in vacuum and temperature change conditions.

[P-66] Design Concepts of CMOS Image-Sensor for the CAP-W

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The CMOS Image-sensor (CIS) is an image detector of Focal Plane Assembly (FPA) for the CAP-W (Compact Advanced Payload with Wide swath-width). The CIS consist of a silicon die with the TDI (Time Delayed Integration) operating architecture and five multi-spectral (MS) filters for the multi-spectral image generation. Since the CIS is based on the CMOS technology, it can embed the read-out integrated circuits (ROICs) including analog-to-digital converters (ADCs). It means that the image data output from CIS is digitized. In this paper, we will present the design concepts of the CIS for the CAP-W payload.

[P-67] Analysis of CubeSat Magnetic Cleanliness for the Space Science Mission

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Recent Space explorations, it has been trying to observe a magnetic field by various ways using the CubeSat. In the ideal case, the magnetometer instrument should be far away from the satellite body in order to minimize the magnetic disturbances from satellites. But, the location setting of the magnetometer instrument is limited due to the volume constraint in the case of small satellites like a CubeSat. For these reasons, we have investigated the magnetic cleanliness and magnetic disturbances which were generated from CubeSat. In this analysis, we used a reaction wheel or magnetorquer which have relatively high power consumption as major noise sources. The magnetic dipole moments of these parts were used by the information provided in the data sheet of the manufacturer. The analysis was carried out using a Python with a Magpylib library. And, we assumed that the 3U CubeSat is operating on a 40 μ T environment in low Earth orbit. When the magnetorquer has a residual moment, our results show that the inside magnetic field reaches up to 980 nT at the end of the CubeSat body. For the precise magnetic field measurement less than 1 nT, the magnetometer should be at least 0.589 m away from the CubeSat body. If the magnetometer is installed inside a CubeSat, the multi sensor Technic is available. However, this method has difficulties such as volume constraints, data analysis and data capacity. Therefore we recommend the boom mounted magnetometer to observe more reliable data.

[P-68] Generation of Coronal White Light Images from Deep Learning Analysis of SDO/AIA EUV (171, 193 & 211 Passbands) Data

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We apply a deep learning method for the image-to-image translation from SDO/AIA (171,193 & 211) to MLSO K-coronagraph white light images. We train (from 1.11 to 1.25 Rs considering the FOV) the model using pairs of SDO/AIA images and their corresponding MLSO K-coronagraph images from 2014 to 2019 (January to September). We evaluate the model by comparing the pairs of MLSO K-coronagraph white light images and the corresponding ones generated from October and November of 2013 to 2019. Our main results from this study are as follows. First, the model successfully generates MLSO K-coronagraph-like white light images from SDO/AIA

images. Second, in view of metrics, the generated images show a good correlation of ~ 0.87 which confirms that the generated images are consistent with the target ones. Third, we note that dominant coronal features such as helmet streamers and polar coronal holes are successfully generated. Utilizing these generated K-coronagraph-like white light images, we are looking for a possibility to detect early signatures of CMEs, to check streamer deflections by CME flanks, and to examine the association between coronal structures and high-frequency metric type II's. Our method is expected to partially overcome the current limited observation time of MLSO observatory, and useful to study coronal features continuously.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, study on analysis and prediction technique of solar flares).

[P-69] Super-Resolution of Solar Magnetograms by Deep Learning Methods

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Super-resolution (SR) is a technique of enhancing the resolution of an image where a high-resolution (HR) image is reconstructed from a low-resolution (LR) image. In this study, we apply two novel deep learning models (residual attention model and progressive GAN model) for Solar Dynamics Observatory (SDO)/Helioseismic and Magnetic Imager (HMI) magnetograms. For this, we consider line-of-sight (LOS) magnetograms taken by SDO/HMI as output and their degraded ones with 4 by 4 binning as input. Deep learning networks try to find internal relationships between low-resolution and high-resolution images from the given input and the corresponding output image. We consider SDO/HMI magnetograms from 2014 May to 2014 August for training, from 2014 October to 2014 December for validation, and 2015 January to 2015 March for test. We find that the residual base model generates higher-quality results than the progressive GAN model and the bicubic interpolation in terms of visual aspects and metrics. The results of the residual base model for the test data set are as follows: 48.35 dB for peak signal-to-noise ratio (PSNR), 0.93 for correlation coefficient, 15.65 G for root mean square error (RMSE) and 0.98 for structural similarity (SSIM). We apply this model to a full-resolution SDO/HMI magnetogram and then compare the generated magnetogram with the corresponding Hinode/The Solar Optical Telescope Narrow Band Filtergrams (NFI) magnetogram. This comparison shows that the generated

magnetogram is consistent with the Hinode one with a high correlation (CC: 0.94) and a high similarity (SSIM: 0.93), which are better than the bicubic method.

This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, study on analysis and prediction technique of solar flares).

[P-70] Global TEC Map Forecasting Model Using Deep Learning Based on Conditional Generative Adversarial Networks

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In this study we develop a global Total Electron Content (TEC) map forecasting model using deep learning based on conditional generative adversarial networks. For training, we use the International GNSS Service (IGS) TEC maps from 2003 to 2012. The model is tested with two data sets: solar maximum (2013–2014) and solar minimum (2017–2018). Our model has two input images (IGS TEC map and one-day difference map) and one output image (one-day future map). Then we compare the results of our model with those of 1-day CODE prediction model. Our main results from this study are as follows. First, we successfully apply our deep learning model to the forecast of global TEC maps. Second, our model well predicts daily TEC maps using only previous TEC maps. The averaged RMSE, BIAS, and STD between AI-generated and real ones are 2.74 TECU, -0.32 TECU, and 2.59 TECU, respectively. Third, our model generates some peak structures in equatorial regions. Fourth, our model shows better performance than those of 1-day CODE prediction model not only during solar maximum but also solar minimum. Our study shows that our model based on an image translation method will be effective for forecasting future images using previous data. This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (2018-0-01422, Study on analysis and prediction technique of solar flares).

[P-71] Generation of Modern Satellite Data from Galileo Sunspot Drawings in 1612 by Deep Learning

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We generate solar magnetograms and EUV images from Galileo sunspot drawings using a deep learning model based on conditional generative adversarial networks. We train the model using pairs of sunspot drawing from Mount Wilson Observatory (MWO) and their corresponding magnetogram (or UV/EUV images) from 2011 to 2015 except for every June and December by the SDO (Solar Dynamic Observatory) satellite. We evaluate the model by comparing pairs of actual magnetogram (or UV/EUV images) and the corresponding AI-generated one in June and December. Our results show that bipolar structures of the AI-generated magnetograms are consistent with those of the original ones and their unsigned magnetic fluxes (or intensities) are well consistent with those of the original ones. Applying this model to the Galileo sunspot drawings in 1612, we generate HMI-like magnetograms and AIA-like EUV images of the sunspots. We hope that the EUV intensities can be used for estimating solar EUV irradiance at long-term historical times. Note: This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (2018-0-01422, Study on analysis and prediction technique of solar flares).

[P-72] Preliminary Design of the PolCube Payload for 12U CubeSat

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Since 2019, the KASI has been developing the PolCube polarimetric payload for nano-satellite in international cooperation with NASA LaRC in order to study fine dust around the Korean peninsula and global warming effect. PolCube is a polarimetric visible camera mounted on the 12U CubeSat supported by Busan City and KIOST. It is expected to be able to analyze the characteristics of fine dust and observe the distribution of super-thin clouds through polarization measurement at an altitude of 560 km Sun-synchronous orbit. PolCube consists of two sets of cameras, which camera employs an optical system with 98 km swath width, four filter-wavelengths

with 410 nm, 555 nm, 670 nm, 864 nm, four linear-polarized filters with 0°, 60°, 90°, 120° and CMOS image sensor. In this paper, we presents the optimized assembly model checked by feasibility in aspect of production capability, part assembly process, and payload operation environments through the preliminary design of the PolCube. Optical performance was also verified by using Finite Element Analysis, which simulate the stress and deformation generated under the conditions of assembly and launch.

[P-73] Progress of the Flight Model (FM) for Space Weather Instruments for Small Scale magNetospheric Ionospheric Plasma Experiments (SNIPE) Mission

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Uk-Won Nam, Won-Kee Park, SNIPE Payload Team
Korea Astronomy and Space Science Institute, Korea

In this time, we describe the development of the Flight Model (FM) of scientific instruments onboard the Korea Astronomy and Space Science Institute satellite-1 (KASISat-1) to verify the performance of the payload. The space weather instruments consist of the Solid State Telescopes (SST), the Langmuir Probe (LP), the 3 Axis Fluxgate Magnetometer (MAG). The SST measure electrons in the range of 100 keV-400 keV with the geometrical factor ($G = 0.02 \text{ cm}^2 \text{ sr}$) in parallel and perpendicular directions to the geomagnetic field. The LP measures the temperature from 103 to 104 K for ionospheric thermal electrons. The MAG measure the Magnetic field of $\pm 50,000 \text{ nT}$ with the noise amplitude ($\text{FWHM} = 1 \text{ nT}$). The scientific instruments are combined and tested as a module. And then, we have the Integration and Test (I & T) in terms of a payload. The FM for scientific instruments for Small scale magNetospheric Ionospheric Plasma Experiments (SNIPE) mission has performed the integration testing and system testing. We report the process and the result of the development and the test for the FM.

[P-74] A Study on the Management of Documents Status through Centralization Management of Satellite Technology Documents in KOMPSAT Programs

Chul Kang
Korea Aerospace Research Institute

A series of activities are needed for the creation, registration and distribution of technical documents for the development of KOMPSAT, and the configuration status management work can be performed through the version management of registered technical documents. Writing technical documents is necessary for common work in most cases, and sharing documents in

writing is necessary for this. Also, it is necessary to co-create technical documents such as version management, review management, and creation of registration documents for registration during the creation of shared documents, and to systematically manage the status of registered documents. Therefore, this study will examine the centralization management method for the management of technical documents and finally suggest a plan for the document status management.

[P-75] Container Internal Monitoring System for Shipping at Launch Site

Ju-Hyun Kim, Jung-Su Choi, Dong-Woo Lee,
Eui-Keun Kim
KARI (Korea Aerospace Research Institute)

If a domestically developed satellite is launched using an overseas launch site, it is transported in a specially built container. An internal monitoring system exists within the container to minimize the impact from the external environment and maintain a constant temperature and humidity during the satellite's transport. The container operator controls the environment of the container based on parameters identified through the monitoring system. In this paper, we will introduce the internal monitoring system of the container for transportation to the launch site in French Guiana.

[P-76] Selection the Optimal Location for Telemetry Relay Stations of NAROSPACE CENTER

Chun-Won Kim, Dong-Hyun Kim, Soon-Ho Kwon,
Jeong-Woo Han, Tae-Jin Lee, NaGyun An
Korea Aerospace Research Institute

New facilities and buildings, such as launch pads for Korea Space Launch Vehicles, umbilical tower, and propulsion test facilities have been built and caused many changes in the radio environment of the Naro Space Center. As a result, the need for a relay station for stable tracking launch vehicle and receiving telemetry signal has been raised. The optimal location for telemetry relay station was analyzed through simulation analysis and measurement of the radio blockage areas and multi-pass. Telemetry relay station is selected by comparing to radio environment of other ground stations where the existing signal routes can be dualized and the spacing loss can be reduced by more than 10 dB.

[P-77] Performance Analysis of Post-D Combiner in Multi-Path Environment of Naro Space Center

Na-Gyun An, Dong-Hyun Kim, Soon-Ho Kwon,
Jeong-Woo Han, Chun-Won Kim, Tae-Jin Lee

Korea Aerospace Research Institute

In this paper, we analyze Performance of Post-D Combiner in multi-path environment of Naro Space Center. In general, it is common to use Pre-D Combiner in Polization Diversity as 3dB gain. Nevertheless, we use Post-D Combiner to prevent degrading signal quality from effect of multi-path channel and RF signal fading. Because, we have to receive RF signal from Launch pad to initial trajectory in low Elevation angle. we verified that applying best channel in Post-D Combiner could get better result than Pre-D Combiner in prior RF communication test. And Therefore, we analyze performance of best channel in Post-D Combiner and signal quality on period of Launch pad Qualification Test in Naro Space Center. And it is need to measure Eb/N0 in advance between Launch Pad and Telemetry Station located in multi-path environment of Naro Space Center. we finally apply diversity combining technique on Launch mission through tests about analyzing performance and quality.

[P-78] Current LEOP (Launch and Early Operation) Status of GOCI-II on Geo-KOMPSAT-2B

Sang-Soon Yong, Sung-Yong Cha, Gmsil Kang

Korea Aerospace Research Institute,

The mission objective of GOCI-II (Geostationary Ocean Color Imager 2) on GK2B (Geo-KOMPSAT-2B) satellite is the ocean color observation and monitoring in the range of 2,500 km × 2,500 km around Korean peninsular with 13 band including star imaging band to continue GOCI on COMS. LEOP of GOCI-II was planned and prepared to check and validate improved performance and function, such as 10 times daytime operation, 250 m GSD (Ground Sample distance), one per day full disk imaging, lunar calibration, and so on. GK2B was successfully launched in February 19, 2020 and started early operation of spacecraft and payloads, IAC (Initial Activation & Checkout and IOT (In-Orbit Test) after few days settledown to geo-stationary mission orbit. In this paper, the early operation procedure and status of GOCI-II was analyzed and described.

[P-79] Analysis of Pointing and Tracking Error Budget of Palau Ground Station

Tae-Jin Lee, Dong-Hyun Kim, Sun-Ho Kwon, Jeong-Woo Han, Chun-Won Kim, Na-Gyun An

Korea Aerospace Research Institute

Recently, NARO Space Center built new telemetry ground station in Palau, South Pacific for acquiring telemetry data of launch vehicle during the KSLV-II (Nuri) launch mission. To ensure stable signal acquisition, various conditions must be satisfied. Especially, it is essential to consider the pointing and tracking error budget from the design phase for performance of the antenna system. Mechanical components and environmental conditions are involved in the performance. In this paper, we analyze the pointing and tracking error budget of the ground station and compare with the result of satellite passes. The analysis shows that the ground station has a good performance of pointing and tracking accuracy.

[P-80] Performance Analysis of SOQPSK for Telemetry in Multi-Path Channel

Jeong-Woo Han, Dong-Hyun Kim, Sun-Ho Kwon, Chun-won Kim, Tae-Jin Lee, Na-Gyun An

Korea Aerospace Research Institute

In conditions where the size, weight, and power supply of launch vehicles are limited, the RF power amplifier must operate in the best power-efficient state for the telemetry system to reliably transmit data signals. Because the CPM(continuous phase modulation) is the best modulation technique to operate with RF power amplifiers, the IRIG-106 defines three CPMs such as PCM/FM, SOQPSK-TG, and ARTM CPM. Even with a CPM technique, multipath propagation occurs when the elevation angle of the telemetry antenna is low. In this paper, we analyze the performance of SOQPSK-TG in multi-path channel.

2부 발표시간 : 10월 29일(목) 13:00~14:00

[P-81] Operation Concepts for KPLO Payloads Mission Planning between KPLO Mission Operation Center and Payload Science Operation Centers

Dong-Gyu Kim

Korea Aerospace Research Institute

Korea Aerospace Research Institute (KARI) has been designing and implementing the Korea Pathfinder Lunar Orbiter (KPLO) and the KPLO Deep-Space Ground System (KDGS) in order to support KPLO payloads mission operation. There are 6 payloads for the KPLO mission and Lunar Terrain Imager Camera (LUTI Camera), ShadowCam, and Wide-Angle Polarimetric Camera (PolCam) are optical payloads. KPLO Gamma Ray Spectrometer (KGRS), KPLO Magnetometer (KMAG), and Delay Tolerant Network Experimental Payload (DTNPL) are non-optical payloads. For the KPLO payload mission operation, a high level operation concept and a dedicated operation procedures should be established and fully verified before the launch. In this paper, the author will introduce the KPLO payloads mission planning concepts and operation flows between the payload Science Operation Centers (SOCs) and the KPLO Mission Operation Center (KMOC). This paper will also propose the operation procedures for payload mission planning such as mission requests processing, mission planning, and generating mission schedule for payload SOCs.

[P-82] A Study of the Required Energy Calculation for the Interplanetary Transfer by the Lambert's Problem Solution

Bangyeop Kim

Korea Aerospace Research Institute

A program was created to calculate the amount of energy required for launching a probe to Mars and Earth-approaching asteroids by year, and using this, the amount of energy input to the transfer orbit of Mars and asteroid probes by year for the period 2026-2045 was compared. JPL's DE431 file was used as the ephemeris of the planets needed for calculation, and Battin-Vaughan's Elegant Lambert algorithm was used to find the solution to Lambert's Problem. The calculated results were compared with the table for predicting the energy required to launch a Mars exploration mission for the same period of the Interplanetary Mission Design Handbook issued by NASA at 2010.

[P-83] The Introduction of Deep Space Network (DSN) RF Compatibility Test Procedure for Korea Pathfinder Lunar Orbiter (KPLO)

In-Kyu Kim, Hyung-Wan Kim, Sang-Ryool Lee

Korea Aerospace Research Institute, KARI

Korea Pathfinder Lunar Orbiter (KPLO) development program is first space exploration R&D program according to the national long-term space development plan. This is fully funded by the government and extending the our space technologies to deep space region. However, we have to need the international cooperation to be supported our less resources. That means the deep space antenna will need to be supported for KPLO mission. This paper describes the DSN RF compatibility test procedure for KPLO program. This test activities are data flow tests and compatibility tests. The data flow tests are conducted at the Deep Space Station. They include the ground data system (GDS) tests, mission operations system (MOS), and operations readiness tests (ORT). The compatibility test validates the compatibility between KPLO radion frequency and telecommunication capabilities because they have to interface with DSN and KPLO data systems.

[P-84] Maneuver Recovery Function Development and Result Analysis of Trajectory Correction Maneuver of Korea Pathfinder Lunar Orbiter

Jonghee Bae, Young-Rok Kim, Young-Joo Song,

Jae-Ik Park, SeungBum Hong, Donghun Lee,

Dae-Kwan Kim, Sang-Ryool Lee

Korea Aerospace Research Institute

KPLO (Korea Pathfinder Lunar Orbiter) will be arrived at the Moon through WSB/BLT (Weak Stability Boundary/Ballistic Lunar Transfer) trajectory. During lunar transfer phase, KPLO will execute several trajectory correction maneuvers (TCMs) to compensate the errors including state error and burn error of spacecraft. After TCM execution, the maneuver recovery process is required to calibrate the maneuver based on the orbit determination result and telemetry data. For calibrating the maneuver of KPLO, the maneuver planning module (MPM) of the flight dynamic subsystem (FDS) has been developed in Korea Aerospace Research Institute (KARI). In the maneuver recovery, there are two factors to improve the performance: control variables and propagation duration after maneuver execution. In this study, we consider two types of control variables, difference of orbit element and relative position/velocity of KPLO. In addition, three propagation durations are used, 6 hours, 12 hours, and 1 day after the maneuver execution. The definitive ephemeris is used as a reference ephemeris for the maneuver recovery, which is provided by orbit determination module (ODM) of FDS. As a result, the efficiency and

burn direction of the corresponding maneuver are calculated and updated to plan the next maneuver of KPLO. In this paper, the maneuver recovery results will be presented and analyzed with respect to the control variable and the propagate duration after maneuver execution.

[P-85] Mass Storage Operation of Payload Data Handling Unit on Korea Pathfinder Lunar Orbiter

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Hyungwan Kim¹

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²*Korea Advanced Institute of Science and Technology*

The payload data handling unit (PDHU) on the Korea pathfinder lunar orbiter (KPLO) handles data from the on-board computer (OBC) and six payloads: KGRS, KMAG, PolCam, DTNPL, LUTI and ShadowCam. After receiving data, the PDHU stores it on its own mass storage. In this paper, we briefly describes the operation of the mass storage and the result of the test.

[P-86] KPLO X-Band System Level Test Verification

Sangman Moon, Changkyoon Kim,
Hyeonn-Cheo Lee

Korea Aerospace Research Institute

KPLO X-band system transmit the data of the acquired payload data and spacecraft SOH playback data. The data rate is 8.5Mbps with R-S FEC or Concatenated code (Convolution and R/S). For the system level test set verification, the X-band system test set testes and calibrates for RF power measuring. As the system level test results, X-DLTS is used for satisfying the X-band transmitter performance that is RF output power through the RF calibration. And measured BERs in demodulator were measured during one hour with delivered transmitter input data and selected FEC. The system requirements for the X-band transmitter RF output power is over 6W (37.8 dBm) and BER is lower than 10^{-5} . The X-band system values required are all satisfying in this test. In this paper the test method and process is introduced.

[P-87] Design of Payload Receiving Module (PRM) and Its Error Handling Scenarios within KDGS

Seunghee Son

Korea Aerospace Research Institute

Payload receiving module (PRM) in KPLO Deep Space System (KDGS) is a part of subsystem to preprocess the science data

telemetries from KPLO through X-band downlink. PRM will convert the raw telemetry back to output of the each science instrument. During conversion, PRM will inspect the integrity of space packets. In the study, we present the operation concept of PRM and its error handling cases for further treatment.

[P-88] Introduction to Strategic Schedule Management for the Korea Pathfinder Lunar Orbiter (KPLO) Program

Jae-Hoon Song, Hyung-Wan Kim, Dae-Kwan Kim,
Sang-Ryool Lee

Korea Aerospace Research Institute

In this article, historical footprints of Korea Pathfinder Lunar Orbiter (KPLO) Program are demonstrated in a perspective of schedule management. The distinctive feature of the current 'KPLO IMS (Integrated Master Schedule)' is the consolidation of Gantt chart, Risk Status Indicator and the Function Code. Not only the general schedule management is being executed with the KPLO IMS and the KPLO CNS (Current and Near-term Schedule), a strategic method called 'Schedule Pools' to shorten the schedule delay is also applied to the KPLO Program.

[P-89] Mechanical I/F and Unit Accommodation Design of a Mechanical Ground Support Equipement for KPLO Flight Model Test Bed

Hyun-Jin Shin¹, Hyeon-Jeong Park²,
Beom-Suk Kang¹, Seung-Yong Min¹,
Hyung-Wan Kim¹

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²*Korea Aerospace Industries*

Since KPLO program is time sensitive program, it is need to control the schedule tightly. In the KPLO, a MGSE that was named the "DUMMY PANEL TABLE" was introduced to use time efficiently. It is a kind of electrical test bed for the flight model. It is going to be used before the mechanical integration and during the mechanical integration phase in the KPLO. For the design the dummy panel table, there are several design constraints such as FM harness routing, harness path and unit accessibility, etc. In this paper, it is introduced the dummy panel table design result that was done with considering several design constraints, especially FM harness routing and path.

[P-90] Analysis of SNR Improvement Algorithms using Signal Accumulation for Naro Tracking Radar

Dong-Hyo Lee¹, Youngseok Jin², Bong-seok Kim²,

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²DGIST

In Naro space research institute in Korea Aerospace Research Institute (KARI), the tracking radars have been installed and operated for trajectory of the Naro launch. The maximum detection distance of this radar is 300 km, but in order to increase the maximum detection distance, the signal-to-noise ratio (SNR) must be increased. However, there are restrictions on increasing the intensity of transmission power due to security concerns.

Meanwhile, in [1], the authors tried to increase the SNR by accumulating the absolute value of multiple received signals. However, there is no mention of why the absolute values of received (RX) signal are used. In this paper, we attempt to apply accumulation to the two types of the signals, i.e., 1) RX signals 2) absolute values of RX signals. Then, we compare and analyze the performance of each algorithm.

Fig. 1 shows the two types of accumulation methods to improve SNR. Let us denote the analog to digital converted RX signal at k th frame by $y_k[n]$ for $k=0, 1, \dots, K-1$ where K is the number of frames of RX signal. First, an algorithm of synchronizing the timing of the RX signals and accumulating them, that is, a method called the coherent accumulation technique, is performed as follows:

$$y_{\text{coherent}}[n] = \sum_{k=0}^{K-1} y_k[n - kT_s] \quad (1)$$

where T_s is duration of the a frame of RX signal. Here, for convenience, modeling by transmit (TX) signal is omitted, and thus refer to [1] for detailed model of TX signal.

Meanwhile, the second accumulation method, the absolute version of the first method, is performed as follows:

$$y_{\text{noncoherent}}[n] = \sum_{k=0}^{K-1} |y_k[n - kT_s]|. \quad (2)$$

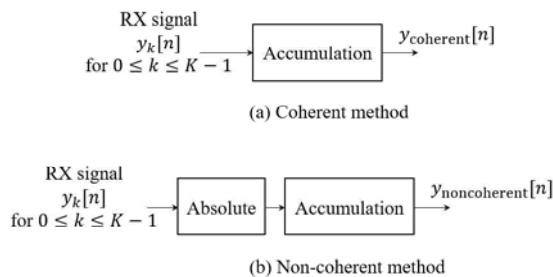


Fig. 1. Two types of accumulation methods.

Fig. 2 shows the results of two types of accumulation methods.

In Fig. 2(a), in the case of coherent method, mean of amplitude of signal is closed to zero. On the other hand, in Fig. 2(b), in the case of non-coherent method, mean of amplitude of signal is closed to 0.1. The difference between the two mean values is that in the case of the coherent method, negative and positive values are added to converge to 0, and in the case of non-coherent, constructive accumulation occurs because the absolute value is accumulated. Meanwhile, the peak values of two methods are different. In conclusion, the non-coherent method achieves better performance than the coherent method. The reason can be seen by observing the received signal in [1]. The phase of the received signal changes according to the frame, and thus, there are cases where the amplitude is negative and positive. In the case of the coherent method, the amplitude of the signal is attenuated because it is added without considering the sign of the signal.

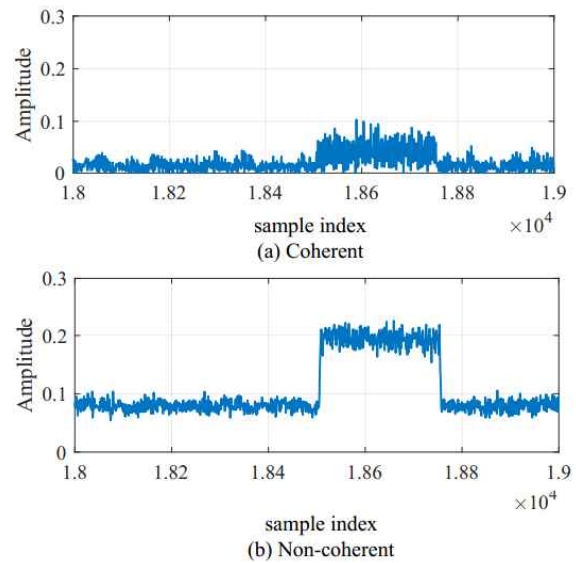


Fig. 2. Results of two types of accumulation methods.

Reference

- [1] Lee D, Chung D, Shin H, Yang H, Kim S, et al., Increment method of radar range using noise reduction, J. Korea Ind. Inf. Syst. Res. 24, 1-10 (2019). <http://dx.doi.org/10.9723/jk siis.2019.24.6.001>.

[P-91] Analysis of the Moon Radiance Images of Geostationary Ocean Color Imager-II (GOCI-II)

Gmsil Kang, Sang-Soon Yong, Seong-Yong Cha
KARI Satellite Payload Development Division

The Geostationary Ocean Color Imager-II (GOCI-II) which is one of major payload for GK2-B has been developed by KARI (Korea Aerospace Research Institute) to observe ocean around the Korean Peninsula from a geostationary platform. In-orbit

test (IOT) of GOCI-II has been performed since March of 2020. During IOT, the moon images for 13 spectral bands (380 nm – 865 nm) are acquired for the GOCI-II performance analysis. The GOCI-II takes images of stars for a navigation information of the GOCI-II image. In case of the star image, a wide spectral band is only obtained. In this paper, the moon radiance variation along spectral bands for different targets is analyzed using the two types of images obtained with long and short integration time. Using the images obtained with short integration time (around 15 ms), the moon radiance variation for different targets are examined. In spite of a large GSD (about 2.5 km) at the moon surface and relative motion between the Moon and the GOCI-II during image acquisition, the meaningful radiance profile over spectral bands (380 nm–850 nm) are acquired. However, there is a limitation to retrieve the moon radiance, especially for a specific small target. Using the star images and the moon images, background radiance level which is understood due to a stray light is examined. In case of moon images, background radiance level around the moon is observed and it is decreased far distance from the moon.

[P-92] Mechanical Ground Support Equipment (MGSE) Development Considering Propulsion System Assemble for KPLO

Beomsuk Kang¹, Hyunjin Shin¹, Seungyong Min¹, Hyeonjeong Park², Hyungwan Kim¹

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Mechanical Ground Support Equipment (MGSE) is device used to mechanical build-up and test spacecraft on the ground. MGSE of the KPLO (Korea Pathfinder Lunar Orbiter) development needs to consider propulsion system(PS) installation and structure assembly. From the PS assembly perspective, it is necessary to consider ps assembly method and space that can accommodate various tools including welding rods because PS is installed through several panels composing KPLO. And MGSEs need to have sufficient stiffness because PS is assembled with KPLO lying down. From the KPLO structure perspective, test configuration, interface of test device, convenience of handling, etc should be considered.

[P-93] Station Acquisition for the GEO-KOMPSAT- 2B

Sang-Wook Kang, Bong-Kyu Park

Korea Aerospace Research Institute,

The GEO-KOMPSAT-2B (GK2B) was launched at Guiana space center of Kourou in South America in February 19 2020 to perform the environment monitoring and ocean color

monitoring mission. After the GK2B was separated from a launch vehicle, the Launch and Early Operational Phase(LEOP) of GK2B was designed to carry the GK2B to a target orbit which is geostationary orbit with 128.25 deg of longitude. To raise the altitude at perigee and change the longitude, five maneuvers are performed and then station acquisition was carried out to move the GK2B to the final target orbit. In this study, we focused on the results of the station acquisition. The latitude of final orbit of GK2B was designed to avoid collision with GK2A. The results show that the station acquisition of GK2B was conducted successfully.

[P-94] Technical Survey on Autonomous Spacecraft Operation

Soo-Yeon Kang

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Technologies related to autonomous systems have been applied and developed in many fields such as satellites to induce high cost and high risk reduction. In particular, there is a need for an autonomous system capable of planning and executing relatively complex tasks in environments where human control is physically impossible. Above all, as the technology of sensors, actuators and information processing devices has rapidly developed and required costs have decreased over the past 30 years, research on autonomous operation methods in the aviation, land, seabed and space sectors has greatly increased. In the case of a low-orbit mission satellite system in the space field, the ground operator can stably perform satellite mission planning, control and condition management functions by maintaining a high-quality communication connection with the satellite system periodically. On the other hand, in the case of a deep space mission satellite system, in order to overcome low quality communication due to long-distance communication, there is required for an intelligent system capable of autonomously performing missions with a minimum of ground control and equipped with more functions of the satellite itself. In this paper, we introduce the recent research on autonomy technology for satellite operation.

[P-95] The Management of Satellite Electrical Configuration during Satellite System Test

Hyun-Mo Gu, Yun-Goo Huh, Seong-Won Cho, Young-Yun Kim, Dong-Chul Chae

Korea Aerospace Research Institute

In Korea Aerospace Research Institute (KARI), satellite is developed by conducting electrical system test in the shape of Electrical Test Bed (ETB) on which the Electrical Model (EM) unit of bus and payload is placed. In the satellite electrical system test process, it is important to check the electrical

configuration of the current satellite after supplying power to satellite from Electrical Ground Support Equipment (EGSE). Afterwards, the configuration of the satellite is changed to the configuration for a specific test, and the changed status should be checked. By recognizing the electrical configuration information of the satellite, it is possible to not only improve the reliability of the test process against the electrical configuration change during the satellite test, but also detect errors of the test procedure and problems with the satellite hardware. Therefore, it is essential to check the status of the satellite configuration when power is supplied to the satellite from the EGSE, which is the starting stage of the satellite test. Also, it is necessary to maintain the satellite configuration consistently by restoring the changed configuration during the test to the configuration at the start of the test before cutting off the power supply from the EGSE at the end of the satellite test. In this paper, based on the satellite electrical system test in the ETB platform, the process of checking the electrical configuration of the satellite after power is supplied at the start of the test and the process of restoring the electrical shape at the end of the satellite test are described.

[P-96] Study on the Certification of Space FM-class High Reliability Heater

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Recently, many satellites have been developed in the domestic space industry according to mid- to long-term space development plans. However, alternative efforts are required due to high foreign dependence on device components in the industrial field. In this environment, the industry is actively responding to these changes.

Since parts and materials used in space are operated in a strict environment, it consists of a system that reports and approves the results of sufficient environmental tests and certification programs. In Korea, in performing localization of the heater, which is a thermal control subsystem hardware, a systematic plan of the certification program is required at the level of space-class components. This study presented the certification standards and procedures for space-class localized heaters in the future by systematizing the stage of development test certification based on ESCC 4009/002 for heater certification. The goal was to provide a stable heat source for the thermal environment of electrical equipment applied to satellites.

[P-97] Design Method of Satellite Operation System Structure for Multi-Satellite Operations

Myungmuk Kim, Myeongshin Lee, Woomin Lee,
Daewon Chung

Korea Aerospace Research Institute

The Korea Aerospace Research Institute (KARI) is preparing to operate and operate a KOMPSAT (Korea Multi-Purpose Satellite) series and a CAS500 (Compact Advanced Satellite 500) series. The number of satellites in operation is increasing every year, and the difficulty of operation is also increasing because the structure of the operating system is different for each satellite. This raises the need for a system to efficiently operate numerous satellites in the future. Different operating systems are trying to solve the problem through automatic operation using A.I, but this is a situation that cannot solve the inconvenience of maintenance. This is paper, we present an design method of satellite operating system structure that can manage different satellites to solve these problems.

[P-98] The Performance Analysis of GPS Test Results for Low Earth Orbit Satellite

Sang-Goo Kim, Ki-Ho Kwon

Korea Aerospace Research Institute

In this paper, we provide LEO GPS test results and analyze performance. The performance parameters exist visibility, position, velocity and etc., and those are important factors in measuring GPS performance. GPS connected to the satellite through electrical interfaces and communicated with satellite BUS though MIL-STD-1553B. Using these 1553B communication data between BUS and GPS, and GPS telemetry, we compare and confirm the integrity of those data. Also, we present the performance of GPS 3D position, velocity, acceleration and power for received signal using the transmitted data to earth station based on received data from GPS satellites. This results are expected to be used for future GPS performance improvement.

[P-99] Thermal Pointing Error Analysis of the Structure of Korea Pathfinder Lunar Orbiter

Jungdo Kim, Sun-Won Kim, Byung-Kwan Jang

Korea Aerospace Research Institute

In space environments where typical temperature variation is from -100°C to 100°C , structural deflection of the satellite structure and payload units occurs due to coefficient of thermal expansion (CTE) mismatch and ununiformly distributed temperature field. This leads to make deviation of line of sight (LOS) of star tracker and affect attitude control of the satellite. For these reasons, a pointing error analysis is necessary to find that the pointing error shall be satisfied to the requirement. In this

study, thermo-elastic analysis of Korea Pathfinder Lunar Orbiter (KPLO) structure is performed to assess pointing error of LOS of star tracker. The pointing errors are calculated in consideration of various worst conditions including orbital and seasonal cases.

[P-100] Defining A Complexity Index for Spacecraft Development Schedule

Hyung-Wan Kim, Dae-Kwan Kim

Korea Aerospace Research Institute

The spacecraft development schedule is relied on technical and programmatic complexity, so it is needed to quantify how complex the system is. There were several indices to distinguish the technology maturity and system complexity, but most of them are subjective. The complexity of a spacecraft may be derived based on performance, mass, power, pointing accuracy, downlink data rate, and technology choices. In this article, I would like to investigate to chose technical parameters contributing to a spacecraft complexity. The parameters will contribute to be calculated spacecraft complexity index. A schedule as Function of Complexity will be derived by using several spacecraft missions.

[P-101] Payload Mechanical Interface of KPLO

Seung-Yong Min, Hyun-Jin Shin, Beom-Suk Kang

Korea Aerospace Research Institute

Korea Pathfinder Lunar Orbiter (KPLO) has six payloads; LUTI, PolCam, KGRS, KMAG, DTNPL, ShadowCam. Each payload is accommodated with specific mechanical and thermal interfaces to comply with its mission. Critical Design Review (CDR) of KPLO was completed last March, and currently system-level mechanical design integration is finalized. In this paper, Payload Mechanical Interface of KPLO is described including payload harness routing. KPLO has High-Gain Antenna Assembly (HGAA) to transmit payload data to the Earth. Mechanical Interface of HGAA is also summarized in the paper.

[P-102] X-band Antenna Pointing Area Calculation for Simultaneous Transmission of Image Data to Different Ground Stations

Kyun-Sang Park

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For the low earth orbit satellite, the image data is transmitted through X-band antenna that has a specific coverage property. The X-band antenna coverage is represented by the antenna beamwidth that depends on the satellite elevation angle. Thus,

X-band antenna is pointed to the ground station to transmit the image data within the antenna beamwidth. For simultaneous transmission of the image data to multiple ground stations, it is necessary to calculate the antenna pointing area. In this paper, the worst-case analysis of the antenna pointing area is conducted so that two different ground stations are located in the antenna beamwidth coverage.

[P-103] GEO-KOMPSAT-2 LEOP Orbit Maneuver Planning and Assessment

Bong-Kyu Park, Sang-Wook Kang, Jae-Dong Choi

Korea Aerospace Research Institute

COMS launched in 2010 is still continuing its mission far exceeding its 7 years of mission life. To undertake the COMS mission, GK2A and GK2B were launched in 5th of December 2018 and in 18th of March 2020 respectively. After separation from Ariane 5, through five LAE (Liquid Apogee Engine) burns, the GK2s injected into drift orbit at longitude of 119 deg. E. The target drift rates were 1.4 degree/day. Through additional five station acquisition maneuvers consisting of one north maneuver and four east maneuvers, the GK2s were inserted into the same target geostationary orbit which are 128.25 deg. E for collocation. For successful satellite injection into target orbit, the precise orbit maneuver planning, maneuver execution and orbit determination are essential. For GK2 mission analysis, the commercial software FOCUSLEOP developed by GMV, had been applied. Using FOCUSLEOP, KARI with GMV support, performed maneuver planning, orbit determination and LAE performance estimation for next maneuver calibration. This paper introduces the summary of LEOP mission analysis performed for GK2A and GK2B in comparison.

[P-104] The Manufacturing and Verification of Thermal Radiation Panel for Satellite EOS Thermal Vacuum Test

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The performance of satellite optical payload must be verified under the space orbit environment before the launch. Thermal radiation panels surrounded payload create thermal environment to payload using radiation. Because optical payloads have recently become larger for high performance, the design and manufacturing of radiation panels have technical difficulties. This paper described the manufacturing and verification results of thermal radiation panel designed considering payload shape

and test fixture.

[P-105] Telemetry Parsing Rule Updates of Minimized Integrated Verification Facility (Mini-IVF) for LEO-Satellite

Su-Hyun Park

Korea Aerospace Research Institute

Korea Aerospace Research Institute has been developed several LEO-satellites and the Flight SoftWare (FSW), which is embedded on the satellites computers. The FSW of LEO-satellites has been through verification using an Integrated Testing and Operation System (ITOS). The ITOS, however, does not provide all the testing capabilities for the FSW verification because it is aimed for the later development phase, i.e. the Assembly, Integration and Test (AIT) and even for the ground operation after launch. In this paper, we introduce the minimized Integrated Verification Facility (Mini-IVF) which is specialized in the FSW verification. The Mini-IVF is connected to the FSW Simulator (FSS) so that users can generate commands, sends them to FSS, and check the telemetries received from FSS. For the latest LEO-satellites, the telemetry parsing rule has changed to reduce the restriction of telemetry packet composition. This paper explains how the mini-IVF is updated to apply new telemetry parsing rule.

[P-106] CAP-W Payload Mission Operation Concept Study of the CAS-4 Satellite

Myung-Jin Baek, Seok-Bae Seo, Sang-Gyu Lee, Sang-Burm Ryu

Korea Aerospace Research Institute

CAP-W (Compact Advanced Payload with Wide Swath) is the 5-channel multi-spectral Electro-Optics Camera of the CAS-4 (Compact Advanced Satellite-4) satellite. The main mission objective of CAS-4 Satellite is to monitor national level of agriculture production environment, periodic growth, growth of the agricultural produce and the forest trees. The CAP-W payload has the capability of taking strip imaging, spot imaging and multi-path stereo imaging. Especially, the user requirement of CAS-4 satellite is to operate the payload by taking the same area images in nadir direction everyday and acquire national agriculture and forest images within 3 days. In this paper, CAP-W payload mission operation concept is introduced. Overall CAS-4 program architecture, major payload operational requirements and operational modes, imaging types, and domestic and foreign area imaging scenarios are described.

[P-107] Study on an Analytic Model for SAR Radiometry Considering Pointing Error

Jae-Min Shin

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On the view point of Satellite Image Applications, It is important to acquire as many images as possible at a pass. However there are constraints on satellite operation in order to good quality images. After change its attitude for the pointing to the target position, times to make the satellite attitude stable are required as operation constraints. In the case of SAR satellite, time for system stability gives an important effect to image qualities as radiometry, resolution and son on. On this study, under the condition of an unstable pointing after attitude changes, a model and a method in order to analyze degradation effects on the radiometric point of view are suggested. For the purpose of defining a condition of an unstable pointing, error components of pointing are modelled as static and dynamic errors related to mechanical and/or electrical pointing. Their effects are reflected as converted errors of the SAR antenna beam pointing. Especially, dynamic part with a transient property in error components are mainly considered on degradation of radiometry. With a suggested model and method to analyze radiometric error, satellite operation constraints can be optimized efficiently because it has possibility to reduce time required for system stability. Finally it gives the benefit of various applications to acquire as many satellite image as possible at a pass.

[P-108] Precise On-Board Time for GEO Satellite

Hyun-Kyu Shin

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Providing accurate time information is very important to accomplish satellite missions due to that position and attitude have close associations with time. KARI has developed a novel method for precise on-board time(OBT) and applied it to two geo satellites, recently launched. On-board flight software calculates precise OBT with two predefined factor: offset and drift rate. Offset represents time difference of 1 pps between UTC and OBT. Drift rate shows the quantity of time drift. These two factors are determined by ground system and transferred to the satellite. Through the analysis after launch, the drift rate trend has been identified to vary in a certain pattern with season. This paper introduces the design of precise OBT and its empirical analysis.

[P-109] Feature Selection Method of a LEO Satellite for Autonomous State Determination

Seung-Eun Yang

Korea Aerospace Research Institute

The number of contact time of LEO (Low Earth Orbit) satellite is limited because of its orbital characteristics. The satellite

store SOH (State of Health) data in its storage and down link the data (telemetry) at contact time. In convention, ground station human operator analyze the data to determine the satellite status but it is hard task because of the limited contact time and massive size of the data. Therefore, autonomous state determination method is being developed to improve the conventional method. Appropriate feature selection is the first and the most important step to develop an autonomous system. In this paper, feature selection method through PCA (Principal Component Analysis) for periodic satellite telemetry is described. The periodicity of satellite telemetry is useful clue to construct state determination rules and PCA is a very powerful tool to achieve informative feature from various attributes.

[P-110] Verification Results of the SAR Payload Interfaces for the Next Generation High Resolution SAR Satellite

Young-Jin Won

Korea Aerospace Research Institute

Spaceborne Synthetic Aperture Radar (SAR) attracts attention because the SAR payload can perform the imaging mission regardless of the weather conditions and the sunlight illumination. Major advanced countries regarding the remote-sensing satellite area have entered into the space race to develop the SAR satellite for the high resolution radar image acquisition. Korea Aerospace Research Institute (KARI) launched the first Korean SAR satellite in 2013 and is operating normally in orbit. KARI has been developing the next generation SAR satellite for the demand of the high resolution radar image.

In this study, the verification results of the second Korean SAR satellite are summarized. The verification testings were divided into two phases and performed by using the Engineering Model (EM) and the Engineering Qualification Model (EQM) for the SAR payload electronics units. The verification results show that the electrical interface requirements are satisfied and the SAR payload units are compatible with the bus units. Based on the verification results, the final verification testing campaign will be performed by using the SAR payload Flight Model (FM).

[P-111] Compatibility Tests between Spacecraft and Launch Vehicle

Young-Su Youn, Hee-Kwang Eun, Jang-Won Suh

Korea Aerospace Research Institute

The compatibility tests such as fit check, separation test, spacecraft simulator with LV mux telemetry test between spacecraft and launch vehicle are required before launch. The primary objective of fit check is to verify the mechanical and electrical compatibility of the satellite with the adaptor ring. The fit check includes the shock test and Vesta test. The

separation test is the drop test which consists in a clamp-band release at max tension. During this test, interface levels and equipment base levels are measured. The qualification is obtained by comparing the component unit qualification levels to the measured equipment base levels. The spacecraft simulator with LV mux telemetry test is to check the telemetry monitoring interface for transmission of S/C parameters such as the analog parameter, discrete channels which are allocated in the telemetry measurement system. The purpose of this test is to verify the LV mux telemetry system developed by the launch vehicle service provider.

[P-112] Checkout Methods and Reviews of the Satellite Pyrotechnic interface

Nayoung Lee, Ja-Chun Koo, Jong-Seok Park, Jae-Dong Choi

Korea Aerospace Research Institute

The pyrotechnic interfaces of Geo-KOMPSAT2B (GK2B) were designed for the battery cell bypass control, the NEAs (Non-Explosive Assemblies) for the solar panel deployment and the EEDs (Electro-Explosive Devices) for the pyro valves in the propulsion system. Since this pyrotechnic interface is to hold down the critical pyro interface and to release the interface with single shot operation, it is designed, integrated and tested with the several safety measures. For the safety operation design, it has the 3 sequential commanding structure with the ESD (Electrostatic Discharge) proven interface. During the integration phase, the safety jumper is installed between the ignition current driving system and the pyro devices to protect them from the ESD effect and commanding operation errors. For the electrical requirement checkout, the resistance of the pyro devices and the non-voltage existence in the current driving system were verified with the designated test equipment. In this paper, the several checkout methods and test results were described during the AIT (Assembly, Integration and Test) phase and the satellite launch preparation phase.

[P-113] Understanding of Time Domain Transient Conducted Emission Test of Satellite

Sangrok Lee, Tae-Youn Kim, Jae-Woong Jang, Kyung-Duk Jang, Chang-Eun Lee

Korea Astronomy and Space Science Institute

Conducted emission test of satellite includes time domain transient test. The purpose of time domain transient test is to check the influence on power bus or overstress on circuit protection device for whole actions to operate EUT. The purpose of this paper is to enhance the understanding of time domain transient test, because misunderstandings often arises on interpreting the verification items only as when at the moment

of power on. To achieve the purpose, examples of ECSS [1] and GSFC [2] test configuration are introduced. Test configuration of GSFC includes the alternate test case which utilize the series resistor instead of current probe. In the following, the test results of EUT including plug-in, power on, and preparation of operation stage are introduced. An understanding of the test configuration and purpose is essential prior to the test. This paper will help to improve the understanding of the CE time domain transient test.

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[P-114] Concept Study for Satellite Payload Misalignment Calibration Using AIS Information

Seonho Lee

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In order to calibrate the satellite payload misalignment the reference targets such as ground control points for optic payloads and radar reflectors for SAR payloads are required. Speaking of the domestic use of the radar reflectors, they all are located in Mongolian area and the number in use is limited. Moreover their update and maintenance are restricted in practice due to the human resources and regional accessibility. When it comes to the domestic ground control points, their locations are mostly concentrated in the southwest area of Korean peninsula, which means that satellite accessibility is also limited. This paper proposes a new concept for the payload misalignment calibration (Patent application no. KR 10-2018-0133725) that incorporates the AIS (Automatic Identification System) information as a replacement of the reference target. The AIS signals received periodical from the vessels provide the information about the ship identification and cruise/navigation. The advantage of using AIS information is that the vessels transmitting the AIS signals are spreaded out around the world and the their number is quite enough to be used for the measurement data of the numerical filter algorithm in statistical point of view.

[P-115] Review on Air Transportation Requirements for Satellite Shipping Container

Choon-Woo Lee

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In general, satellite is delivered to launch site by air-cargo transportation and during the whole flight, highly-sensitive

satellite is exposed to air flight environment such as vibration, shock, pressure & pressure difference, temperature and humidity which is different from ground handling condition. In order to protect sensitive satellite from the air transportation environment, satellite shipping container shall be specially designed to ensure a safe, secure and on time satellite delivery to launch site, taking into account the characteristics of the air-cargo aircraft. It is presented in this paper how to define several design requirements for air-cargo transportation and how to verify the design performance of satellite shipping container. In particular, the level of the minimum allowable pressure and pressure variation which are induced from aircraft flight climb and decent shall be carefully defined in the acceptable range, considering the internal volume or the vent hole of the SC container enough to equalize the pressure inside the containers. As a general requirement of air-cargo aircraft, the pressure in the cargo compartment will vary from 760 to 180 mm Hg in accordance with the standard atmosphere and the pressure variation rate at a vertical speed of 20 m/sec is not more than 2.0 mm Hg/sec (266.6 Pa/sec). For compliance with these pressure requirement, venting hole design of satellite container and the proper packing method shall be considered

In this paper, several design requirements and techniques which can be applied for satellite shipping container are introduced as the design baseline of satellite air transportation to launch site.

[P-116] Contamination Results of Inside Chamber during the Nanosat Bake-Out Test

Hye-Jin Yi, Hyok-jin Cho, Hee-jun Seo,
Sung-Wook Park, Sang-hoon Lee, Soo-hwan Jun

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he bake-out chamber is equipped with a TQCM (Thermoelectric Quartz Crystal Microbalance) that measures the adsorption rate of the outgassing, and a Cold Plate that is kept below -180 degrees to maintain the vacuum environment. In this paper, the measured TQCM value is checked during the nanosat bake-out. And installing the contamination samples on the Base plate and Cold plate, check the result of the contamination measurement according to the location inside the chamber.

[P-117] The Capability of the Satellite Radio Frequency TCTM Channel for the Deep Space Communication

Won-Gyu Lim, Sun-Ik Lee, Ki-Ho Kwon

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In this paper, we presented the capability of the S band communication for the deep space communication. S band communication used for the satellite TCTM is consist of uplink (or forward link) and downlink (or reverse link). For the

purpose of the analysis, we considered the general radion frequency front-end for the deep space mission which have the antenna and transponder. Antenna and Transponders are connected via radion frequency distribution unit. Omni- and directional antenna are included in the analysis. The available communication range according to the TCTM data rate, modulation methods and ranging are extracted as the results of this study. The results shown in this paper could be used for the estimation of the deep space communication performance.

[P-118] Comparison and Analysis of Conducted Emission and Susceptibility Transient Test of ESA and NASA Test Standards

Kyung-Duk Jang, Tae-Youn Kim, Jae-Woong Jang, Sangrok Lee, Chang-Eun Lee

Korea Aerospace Research Institute

The satellites continue to repeat the turn-on and off behavior of some units according to their mission during their life on orbit. When the units are turn-on and off, or when their modes are switched, the bus potential may changes because of a rapid current change. This change in bus voltage can affect other units and subsystems connected to the bus and cause malfunction. Therefore, many EMC standards require verification whether the amount of change in current or bus voltage is limited to a certain range when the unit is powered on and off, and whether a malfunction of the unit occurs when the bus voltage is changed. But the test method and limit are different for each standard. ECSS[1] and GSFC[2] standard require to measure the current, but the MSFC[3] standard require to measure the bus voltage in CE transient test. Injected voltage waveform is also different for each standard in CS transient test. In this paper, we compare and analyze the conductive emission and susceptibility transient test requirements specified by NASA and ESA EMC standards, and discuss the test method.

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[P-119] Introduction to the Electrical System Design Overview for the Next Generation GEO Communication Satellite

Sung-Soo Jang

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The next generation GEO Communication Satellite will be developed with Flexible Ka-band Instrument, Space Based Augmentation System (SBAS) Instrument, and Data Collection System (DCS) Instrument to perform the Public Safety Management for National Disasters, High Technology Development for GEO Communication, and Support Korean Space Industry. The next generation GEO Communication Satellite will be developed in the 3.2 ton class with 5.3 kW of power generation. And the next generation GEO Communication Satellite will use the same bus platform of the GK2 satellite, but additionally Global Navigation Satellite System (GNSS) and Electric Propulsion (EP) will be used to improve the performance of the satellite. In this paper, the major mission requirements for the next generation GEO Communication Satellite are summarized. Additionally major requirements of electrical system are described.

[P-120] Spacecraft Health Check at Launch Site

Seung Won Cho, Yun Goo Huh, Su Wan Bang, Min Jun Kim

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The spacecraft is moved to the launch site for the launch after AIT (Assembly, Integration, and Test). The function of the spacecraft is finally checked and launched. The test items include the function check of electrical power subsystem, flight software, telemetry, command and ranging subsystem, attitude orbit control subsystem and payload system. Recently, the geo-stationary satellite was launched successfully in KARI. In this paper, the spacecraft health check will be introduced.

[P-121] Introduction on Launch Early Orbit Phase (LEOP) and In Orbit Test (IOT) of GK2B

Chang-Kwon Cho

Korea Aerospace Research Institute

The Geostationary Earth Orbit-Korea Multi-Purpose SATellite-2B was launched on February 19 of this year. the initial operation of the spacecraft bus, the Geostationary Ocean Color Imager (GOCI-II) payload and the Geostationary Environment Monitoring Spectrometer (GEMS) payload was carried out. Currently, all functional tests of satellite including two payloads have been completed. and the GOCI-II payload Image Navigation and Registration (INR) has also been completed and the service is expected to be performed in October. However, the world's first payload to monitor air pollution from space, GEMS is currently carrying out INR and is in service within this year. The satellite launched from the Guiana Space Center was separated from the launch vehicle, and the solar array was fully deployed through the automatic sequence of the on-board computer mounted on the satellite. and to check whether the

CMOS sensor of GOCI-II was damaged or not, it was checked whether the shutter status is closed. After that, the attitude of the satellite was changed to the sun-oriented mode, and five Liquid Apogee Engine (LAE) were injected to obtain the target orbit. After obtaining the target orbit, the attitude of the satellite was changed using thrusters and a reaction wheel to face the earth. To settle the final orbit, the functional performance test of the satellite was completed by performing the east-west position maintenance using a thruster, and then the functional performance test was ended after the completion of the Initial Activation Checkout (IAC) of the GOCI-II payload and the verification of various performance parameters for image correction was completed. Currently, the functional test of the GEMS payload has been completed and the INR work is in progress. This paper briefly introduces the contents of the initial operation and in orbit tests of the satellite after the launch of GK2B.

[P-122] Selective Data Transmission of Telemetry Data

Dong-Seok Chae

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In low earth orbit satellite, all telemetry data are stored in mass memory in the order of generation, regardless of data type. And all the data stored in mass memory are downlinked to the ground in the order stored during contact time. The communication time is very limited, so the amount of the stored data may exceed the downlink capacity. Or, in case the communication environment is bad or satellite is in safe mode, it is difficult to transfer the whole data. It needs a function to selectively transfer only essential data among all the stored data. There are several ways to implement the function of selective data transmission. This paper shortly introduces the telemetry processing in low earth orbit, and suggests several methods for implementing the selective data transmission function of telemetry data.

[P-123] Imaging Electronics Platform Based on FPGA for Space Applications

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Korea Astronomy and Space Science Institute has plans for various space missions for solar physics, planetary science, and astrophysics. Most instruments require an imaging observation, and we need standard imaging electronics platform that requires a radiation hardened and reliable solution. We are developing the platform based on a Field Programmable Gate Array (FPGA) with high-performance, reconfigurable, and reliable

architecture. The electronics are composed of five separated boards: a sensor board, an imaging board, an interface board, a power board and a backplane board. High compatibility was considered to support various CCD and CMOS sensors by replacing only the sensor board. We designed the imaging electronics platform in 1U CubeSat form factor. With additional board expansion, the platform can be used not only for Space-Cube applications but also for various space missions. The imaging electronics platform is planned to be used for the next generation solar coronagraph on the International Space Station, and the light field cameras for Lunar Gateway Mission.

[P-124] Chollian-2B Satellite Final Alignment and Adjustment

JungSu Choi, JongSeok Park, Hyungwan Kim

Korea Aerospace Research Institute

Chollian-2B satellite is fitted with two sensors, the world's first Geostationary Environmental Monitoring Spectrometer (GEMS) and the Geostationary Ocean Colour Imager-II (GOCI-2) for the continuous operation of the Chollian-1 mission. Chollian-2B final preparation before launch campaign was done at the end of 2019, and moved to the French Guiana launch site and launched on February 19, 2020. Chollian-2B can continuously observe the area around the Korean peninsula, but it is about 60 times farther from the earth than low earth orbit satellite. Therefore, optical payloads, attitude control devices, antennas, thrusters and main engine, etc. must be aligned very accurately during AIT phase. In addition, the alignment stability of each device shall also be ensured after the extreme dynamic environment that occur during launch. For this purpose, this study performed alignment measurement and calibration test and the alignment stability verification test before and after the Chollian-2B launch environment tests.

[P-125] Major Considerations for Development of a Satellite Propulsion Engine

Cho Young Han

Korea Aerospace Research Institute

A powerful main engine is indispensable for the orbit transfer of a geostationary satellite as well as the orbit maneuvering of an interplanetary spacecraft. In this respect it is quite important to have our own capability on this matter. Among various candidates, the chemical and bipropellant propulsion engine would be the best choice at the moment rather than the electric propulsion engine, which is premature honestly in this country. In this study major considerations for development of a such bipropellant main engine are contemplated. Required technologies and efforts are categorized in detail, for the design and manufacturing of the main engine itself. The concept of a

ground test facility for a dedicated hot fire testing is suggested referring to useful facilities overseas as well.

[P-126] Overview of Test Battery for the Spacecraft Integration and Test on the Ground

Yungoo Huh, Suwan Bang, Minjun Kim,
Seungwon Cho

Korea Aerospace Research Institute

Until now, KARI (Korea Aerospace Research Institute) has designed and been testing many satellites on the ground. The electrical batteries commonly are used to provide electrical power for satellite. The satellite is operated and powered on by electrical battery which is charged with solar panel in satellite. That is, the electrical batteries are used on satellite as means of supplying electrical power and storing solar power. To prevent the degrading of the performance of battery and keep best condition of the battery, test battery is used Instead of real battery which is used in orbit during the spacecraft integration and test on the ground. Therefore all electrical tests for LEO satellite on the ground are performed with test battery. In this paper, the electrical test battery for the spacecraft integration and test on the ground will be introduced and we give a brief overview on the electrical test battery.

[P-127] FPU (Focal Plane Unit) Configuration Changes in a Satellite Electro-Optical Payload

Jong-Pil Kong, Sang-gyu Lee

Korea Aerospace Research Institute,

FPU (Focal Plane Unit) as a main part of electro-optical camera collects incoming light energy through optical components and converts it into electronic signal using detectors. Its structure design largely depends on EOS (Electro-Optical Subsystem) configuration which is decided based on mission requirements including swath, number of imaging bands, mass, power, etc. In this paper, we review FPU configuration changes over a few satellite programs we have built to introduce the design concepts and to have idea for future programs.

[P-128] Analysis of Spin-Off Technology Utilizing Life Support System

Joo-Hee Lee, Jong-Won Lee, Youn-Kyu Kim,
Gi-Hyuk Choi

Korea Aerospace Research Institute

The Korea Aerospace Research Institute (KARI) has been carrying out technology development related to the Environmental Control and Life Support System (ECLSS) to secure core technologies for manned space exploration. Development

models of each subsystem such as oxygen generation system, air purification system, and carbon dioxide removal system have been developed and are currently conducting functional tests of each subsystem. Through the development of these system, KARI will secure the necessary technology for future international cooperation and participate in the future manned space exploration. Based on the development of this technology, KARI also intends to expand the research areas in the field of in-situ resources utilization (ISRU) technologies such as the development of oxygen extraction or water extraction technologies. This paper will analyze the industrial utilization of these technologies before directly utilizing the manned space exploration.

[P-129] Parallel Ancillary Data Operation with Imaginary Data Operation on Low Earth Orbit Satellite

JongTae Lee, Eung Shik Lee, Haeng-Pal Heo

Korea Aerospace Research Institute

In low earth orbit earth observation satellite, ancillary data including satellite position, velocity, attitude and sensor telemetries is transmitted to the Ground Station with acquired image data for the enhancement of image quality. As the resolution of the camera increases, the time to take an image has been reduced due to limitations in resources such as memory capacity and time required for downlink. On the other hand, the transmission time of ancillary data for obtaining accurate orbit information is the same. As a result, the mission of transmitting ancillary data could not be performed with the mission of transmitting imagery data, which required the design change of the payload on-board recorder. The on-board recorder is designed to independently store and transmit missions for imagery data and ancillary data.

[P-130] Performance Verification of Optical Components for the LUTI (Lunar Terrain Imager) after Environment Test

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Space-born telescope should be maintained performance in extreme environmental conditions such as launch vibration and in-orbit environmental condition. Therefore, the performance verification is mandatory by environment test with these kinds of condition.

In the LUTI (Lunar Terrain Imager), the optical module consists of 2 optical components such as mirrors and lens module.

In this paper, the performance verification of mirrors and lens module is introduced by environment test such as vibration,

thermal cycling and thermal vacuum test. Finally, the results of verification are also analyzed.

[P-131] Rapid Spectral Variability Monitoring of the Symbiotic Stars during One Night: CH Cyg, UV Aur, Z And

Soo Hyun Kim¹, Tae Seog Yoon¹, Hyung-il Oh^{1,2}

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Continuous observation and analysis of changes in the brightness and spectral lines of symbiotic stars provide important information on the structure of symbiotic star system, the mass transfer from giant star, and the formation of accretion disk near white dwarf and their evolution. In this study, using the 1.8-m telescope and BOES spectrograph at the Bohyunsan Optical Astronomy Observatory, we have performed an overnight variation monitoring of the emission lines of UV Aur and Z And along with CH Cyg whose overnight spectral change was reported by other researchers. We present the overnight spectral change features and characteristics of these three symbiotic stars.

[P-132] Preliminary Optical Measurements of the 1 m Telescope at Chungbuk University Observatory

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The 1 m telescope of Chungbuk University Observatory needs refurbishment, especially mirrors and optical components. It hasn't been serviced since it was founded a dozen years ago. Prior to precise fine-tuning of the telescope, preliminary rough measurements were performed for both mirrors – 1 m primary and 320 mm convex secondary mirrors. The primary mirror was tested by simple Foucault zonal method and the secondary convex surface was scanned by a profilometer. In this presentation, the test details and the results are presented and discussed. The telescope shall be reworked to have better optical performances.

[P-133] New Long-Term Research and Observation Program of Sobaeksan Optical Astronomy Observatory (SOAO): Times of Minimum Light of Eclipsing Binaries

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The observed times of minima of an eclipsing binary star (EBS) are essential data for determining the period of the system as well as displaying period changes due to various causes such as apsidal motion (AM), light-traveling time effect (LTTE), mass exchange, mass loss, and so on. In this respect, it is important to continuously monitor times of minima of EBSs, which is one of long-term observational research projects of the Sobaeksan Optical Astronomy Observatory (SOAO). The SOAO has listed EBSs that showing AM and/or LTTE, and has been observing them for since the first half of 2019. Based on observation results for about one year, it is expected that 70–100 useful times of minima can be obtained per year. All data will be serviced to researchers through various on/off-line channels, and we will push ahead with the establishment of an international network between observatories with similar interests.

[P-134] Dust Scattering Simulation of Far-Ultraviolet Light in the Milky Way

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Far-ultraviolet (FUV) light is mainly produced by bright, young O-type and some B-type stars, but it is also observed in interstellar space without these stars. Called FUV diffuse Galactic light (DGL), these lights are mostly known as starlight scattered by interstellar dust. With the recent release of GAIA DR2, not only accurate distance information of stars in our Galaxy, but also accurate 3-dimensional distribution maps of interstellar dust of our Galaxy were produced. Based on this, we performed 3-dimensional Monte Carlo dust scattering radiative transfer simulations for FUV light to obtain dust scattered FUV images and compared them with the observed FUV image obtained by FIMS/SPEAR and GALEX. From this, we find the scattering properties of interstellar dust in our Galaxy and suggest the intensity of extragalactic background light (EBL) at FUV wavelength.

[P-135] Changes in the Terminology of

Astronomical Almanac around Nineteenth Century in Korea

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We investigate the changes and provenance in the terminology of astronomical almanac around nineteenth century focusing on official records such as almanacs and textbooks published by the government. We found that the 12-hour clock time was first introduced in the *Hyeonsang sinbeob secho ryuhwi* (Collection of detailed procedures for new celestial methods) published in 1710, but was applied in earnest from the late nineteenth century. We also found that with the application of the 12-hour clock time, new terms were used to denote the boundary of the time between morning and afternoon. With the implementation of Korean Standard Time in 1908, the terms for solar time, the equation of time, and differences in longitude started appearing on the academic textbooks. We think that this study will help to clarify the process of change of the astronomical terminology since the first introduction of Western astronomical almanac.

[P-136] On-Orbit Thermal Design and Validation of SNIPE Mission 6U Nano-Satellite

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With the development of computer technology and the miniaturization of electronic components, missions of satellite are diversified. It leads to the development of small satellites such as CubeSat and nanosatellite which have great advantages in development period and cost. KARI (Korea Aerospace Research Institute) and KASI (Korea Astronomy and Space Science Institute) have developed four 6U nanosatellites with scientific missions to measure physical phenomena in near-earth environment and technology demonstration mission for formation flying four nanosatellites by using cold-gas propulsion system. The project of developing four 6U nanosatellites is SNIPE (Small scale magNetosphere and Ionosphere Plasma Experiment) mission. In this study, we built a thermal model for SNIPE 6U nanosatellite and described thermal design based on the thermal model. And the validity of the thermal design was verified through the on-orbit thermal analysis. The thermal design was carried out mainly on the passive thermal control techniques in consideration of the characteristics of the nanosatellite. To improve temperature accuracy and reliability for on-orbit thermal environment, we conducted thermal balance test (TBT) with the SNIPE engineering-qualification model (EQM) for proceeding thermal model correlation study based on the existing thermal model. The thermal vacuum chamber, which

has undergone TBT, was built as a thermal model with SNIPE thermal model and the correlation study was performed step by step. At first, thermal capacity of each component and errors of thermal model were updated. In the second step, the thermal coupling parameters of the components in contact with each other were changed based on the TBT temperature data. Thirdly, applied passive thermal control techniques and duty cycle of heater were checked properly. As a result, the reliability of thermal model of the SNIPE satellite increased by conducting thermal correlation work with real temperature data from TBT.

[P-137] A Design and Implementation of CNN-Based On-Board Cloud Coverage Estimator for Earth Observation Nanosatellite

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In the past, there was a small number of large companies, such as Urthecast, Digital Globe, Airbus D&S, account for the majority percentage of the Earth observation satellite market. However, the paradigm of earthobservation satellite development is changing rapidly. In comparison with the mid-to-large-sized satellites, which are equipped with high-performance and very expensive payloads, nano-scale earth observation satellites are now open the possibility to shootwider Earth surface areas with shorter observation cycles. Moreover, the number of the startups of Earth observation nanosatellite is increasing recently. There are tradeoffs between the cost and performance for nanosatellite development. It is general that the nanosatellite developers withdraw agility in order to meet the requirement to maximize the spatial resolutionof imagery at limited form factor. Owing to the low accuracy on attitude control, the nanosatellite developers usually select 2D planar image sensor array instead of 1D line image sensor array. Moreover, nanosatellite on-board communication subsystems tendto consist with low bit rate components due to electrical power budget. Therefore, there is a necessity to take an efficient downlink strategy, such as setting priority of download by content-manner. Meanwhile, cloud detection is important for satellite-based earth exploration missions, as shown by NASA's study of the amount of clouds that constantly cover approximately 67% of the Earth's surface. Cloud has more dynamic-characteristics compare to fixed objects on earth surface, which has visual information of customers' needs. According to KARI's report, almost 75% of the downloaded images taken by KOMPSAT-1 were contaminatedby cloud. If cloud coverage estimation is directly performed within a nanosatellite and the prioritized image transmission according to the amount of clouds is operated, it is possible to prevent waste of data link and storage. Moreover, there will be improvementsthe economics

of satellite operation.

In this research, we propose a multi-phase convolutional neural network (CNN)-based cloud coverage estimation method and evaluate its performance on a nanosatellite on-board computer. The proposed network structure can be divided into three phases, a trivial saturated or cutoff image patch filter, a light-weight classifier network that pre-sorts the input image and a U-Net based light-weight deep neural network for on-board cloud detection. DNNs are trained with visible-band image from OLI (Operational Land Imager) of Landsat8. Finally, we evaluate the performance of the proposed network by porting it to a nanosatellite onboard computer. The proposed network was designed using the Pytorch framework, and the operation of the inference network was ported to the ZC702 evaluation board based on C++ using the libTorch script. We achieved to develop algorithms with relatively less computational complexity while preserving performance. And we have ported the algorithm to On-board computer of KARI's 6U nanosatellite. We are currently developing an FPGA accelerator for DNN and aims to deploy it year-round

[P-138] Design and Analysis of Electrical Power System for MIMAN CubeSat

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MIMAN mission is under development by Yonsei University since 2019. The mission is aimed to obtain aerosol images around the Korea peninsula with 3U CubeSat. An architecture of electrical power system (EPS) has been designed with commercial-off-the shelf (COTS) components for the CubeSat. The EPS is composed of deployable solar panels, body-mounted solar panels, power conditioning and distribution unit (PCDU), and Li-ion battery pack with 48.5 Wh capacity. Through numerical simulations, it is verified that the EPS can support 3U CubeSat bus and imaging payload for the mission. The electrical power budget analysis and energy balance analysis have been carried out. As a result, during the mission lifetime, the electrical power margin exceeds 30% and the depth-of-discharge (DOD) of the battery is within 20%, meeting system requirements. In this study, we will present the current status of the EPS design and analysis for the feasibility of the MIMAN CubeSat mission and system.

[P-139] A Statistical Study of Geomagnetic Field Perturbations Observed in the Upper Ionosphere Using Swarm Magnetic Field Data

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Geomagnetic field perturbations are statistically studied using magnetic field data acquired by the Swarm satellites in the upper ionosphere for 2014-2018. To identify the ionospheric magnetic field variations from the intrinsic Earth's magnetic field, the CHAOS-6 model field was removed from the observed field. The field perturbations are characterized in the North-East-Center (NEC) local Cartesian coordinates in which BN is the direction of geographic north, BE points geographic east, and BC points toward the center of the Earth. The observed ionospheric magnetic field perturbations reveal the following characteristics. (1) The BN component shows a negative perturbation on the dayside and a positive perturbation on the nightside at high latitudes. These field signatures are due to distortion of the magnetosphere. That is, the high latitude magnetic fields are compressed on the dayside and stretched on the nightside. (2) The intensities of total magnetic field and BN show a depletion near the magnetic equator in the local time sector from 12 hr to 03 hr. We suggest that this asymmetric field intensity distribution is associated with a ring current, which is intensified asymmetrically along the local time. (3) The BE component shows bipolar (negative-then-positive) perturbations in the morning sector and opposite polarity in the evening sector at high latitudes. These perturbations are induced by the field-aligned currents.

[P-140] Dynamics of Plasma Blob Observed by Nobeyama Radioheliograph and AIA/SDO

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We investigate an eruption of plasma blob observed by Nobeyama Radioheliograph (NoRH) and AIA/SDO. The plasma blob appeared above the east-limb of the sun and expelled out as a CME. For this study, we mainly use 17 GHz images of NoRH and EUV images of AIA 304 and 171 channels. The plasma blob captured at the start time of the NoRH observation, 22:30 UT (07:30 JST). It slowly rose up and started to accelerate at around 01:30 UT. It finally erupt and disappear in the field of view of the NoRH image at around 03:00 UT. According to the careful inspection of EUV images from STEREO satellite which observed the back-side of the sun, it seems that the plasma blob is a part of the quiescent filament eruption. However, prominences (filaments) have usually been displayed as broad elongated structures in NoRH imaging, whereas this plasma blob presented in this study showed isolated blob like structure which has been rarely reported. Here, we present the dynamics of the microwave plasma blob, comparing with EUV features, from its beginning and the final eruption.

[P-141] Domestic Radiation Test Facility for Space EEE Parts

Eui Keun Kim

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Cosmic radiation is a generic term for various particles and radiation with high energy in the universe. Sources are largely classified into three categories: particles trapped in the Earth's magnetic field, particles launched into space during solar flare, and particles created outside the solar system. Particles made outside the solar system are mostly composed of high-energy protons and heavy ions. And all types of cosmic radiation are ionizing radiation. Cosmic radiation can seriously affect the performance of satellite electronic components and materials. The effects of cosmic radiation appear as Displacement Damage, Total Ionizing Dose, and Single Event Effects. In this study, we would like to look at domestic test facilities and specifications for testing the effects of cosmic radiation.

[P-142] Ion Flattop Distributions at Earth's Quasi-perpendicular Bow Shock

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Electrons in the downstream region of Earth's bow shock typically have flattop distribution functions. On the other hand, ions usually have Maxwellian or Kappa distribution functions in the downstream and the ion flattop distributions have not previously been reported. In this study, we report the first observation of the ion flattop distributions in the downstream region of the Earth's quasi-perpendicular bow shock. We previously reported that the solar wind ions were not fully thermalized across the shock but consist of two different components in the downstream region of the shock: cold core and hot components. The Cluster observation on 22 December 2002 shows that the hot component exhibits flattop distributions as observed in the electrons. During the ion flattop distributions are observed, the magnetic field perturbations show ultra-low frequency (ULF) waves with the frequency ~ 0.58 Hz. Hodograms for the ULF waves show that the waves have right-handed circular polarization in the spacecraft frame. We suggest that the wave-particle interaction could be a responsible mechanism for the formation of the ion flattop distributions.

[P-143] Study on High Frequency (HF) Communication Failure Using Daytime Ionograms Recorded in Korea during Strong Radio Blackout (R3)

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Solar flare is well known for its immediate influence on the ionosphere and for causing High Frequency (HF) communication (3-30 MHz) failure. Radio Blackout, one of the space weather alert, is related to solar flare and consists of 5 scales. If there is X-class solar flare, Radio Blackout higher than scale 3 is alerted. Below Strong Radio Blackouts (R3) was alerted from 2013 to 2019, and total 15 times of R3 alert was announced during Korean daytime. We investigate HF communication failure using ionograms, when there is R3 in Korean daytime. It is expected that this research will be helpful for HF communication users to respond HF communication failure during R3.

[P-144] Ionospheric Anomalies for Mid-Latitude Large Earthquakes by US-TEC and DEMETER Data during 2009-2010

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Recent studies have provided more persuasive relation of the seismic activity to the ionospheric disturbances. In this study, to investigate whether the correlation between the seismic activity and ionospheric variation is valid, the US-TEC data around three strong earthquakes ($M \geq 6.5$) in the North America during 2009-2010 have been analyzed, and compared with the plasma data of the DEMETER ISL. The results show that the mid-latitude earthquakes contribute to the TEC anomalies and electron density changes as well. The positive or negative TEC anomalies appeared before the shock as a pre-cursors and also after the shock. The positive TEC anomalies occurred more often than negative ones. The significant affected regions did not coincide with the vertical projection of the epicenter and shifted in the north-west direction relative to the epicenter. Additionally, most of the enhancements in the ISL electron densities over the earthquake preparation zone were consistent with the TEC anomalies.

[P-145] Comparison of Various Model for Cosmic Radiation

Haingja Seo, Mijeong Kim, Seungbum Yang, Myungjin Choi

InSpace Co., Ltd

The exposure dose rate of cosmic radiation increases with higher latitude and altitude. It must be considered to dose rate for aviation workers operating the Arctic route and passengers. And it needs to be protected from cosmic radiation to regularly exposed aviation workers. Korea Space Weather Center supplies the cosmic radiation dose rate through SAFE system to the aviation workers and to the general public. In this work, in addition to CARI-6 and NAIRAS applied to the use of SAFE, we calculate the dose rate using various models such as JISCARS from Japan, EPCARD from Germany, and SIEVERT from France. We compared these results and the existing actual data on the same aviation route, and on the additional Arctic route, we only compared models. We will calculate the dose rate with the route by section using the models provided by the company that made the models. We expect that this result will help to select a suitable model.

This research was conducted by IITP (2020-0-00333) support.

[P-146] Accuracy Analysis of Tsyganenko Magnetic Field Models Using GOES Data during Quiet and Storm Times

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In conducting research on the Earth's magnetosphere, it is difficult to measure physical quantities of interest for all space. To fill in such data gaps, empirical as well as physics-based models are proven to be extremely valuable. Therefore, having models with high fidelity and high accuracy is desired. In this study, we statistically assess the accuracy of the Tsyganenko models (specifically, T96, T01, and TS04) by comparing the magnetic fields measured by GOES satellites with the magnetic fields calculated from the models. From a data-model comparison during the intervals of geomagnetically quiet times, we first set a baseline accuracy of the models. During these intervals, we find that all three models exhibit a systematic error of about 10% in magnetic field magnitude, while the error in field vector directions is on average less than 1%. We then measure the model performance during twelve geomagnetic storm events. We find that the errors in both the magnitude and the direction are maintained at the baseline level, except during the main phase of the storms, with the largest error reaching on average 20% for magnitude and 10% for direction. Interestingly, the largest error occurs not at the Dst minimum but 2–3 hour before the minimum. Finally, the T96 model has consistently underperformed in our tests, compared to the other models.

[P-147] Detection of Solar Coronal Holes and Filaments Using Deep-Learning

Seungbum Yang, Sang Min Park, Jiwon Chung,

Haingja Seo, Yunjung Yang, Myungjin Choi

InSpace Co., Ltd.

Research on space radio disasters caused by geomagnetic and ionosphere disturbances caused by solar activity have been studied for a long time. If we are able to predict and make preparations in anticipation of these solar activities, we can reduce the damage on Earth. Sunspots, solar flares, coronal holes, and filaments inform us of solar activity, among which we will focus on coronal holes and filaments. In this paper, we approach detecting such features by using deep-learning techniques. We proceeded in the following; 1) Referencing NOAA, we created one labeled dataset each for the coronal hole and filament datasets. 2) Each masked dataset was preprocessed and augmented before being put through the model. 3) Both coronal hole and filament datasets were trained under the U-Net model on segmentation. 4) The model was evaluated with a test dataset. These methods can immediately check the occurrence of coronal holes and filaments, and with this information, it is possible to minimize the damage caused by space radio disasters by predicting solar activity and their impact on Earth. This research was conducted by IITP (2018-0-01422) support.

[P-148] Effects of Solar Proton Events on the Polar Ionosphere Identified from EISCAT Radar Observations

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The polar ionosphere is characterized not only by solar EUV, but also by the coupling with interaction between solar wind and the magnetosphere, which results in characteristics of the polar ionosphere such as strong plasma convection, energetic particle precipitation, and joule/frictional heating. There have been many studies for a long time on the effect of auroral particle precipitation in the polar regions, but few studies have been conducted on the effects of solar proton events in the polar regions. European Incoherent Scatter Scientific Association (EISCAT) is an international scientific association operating incoherent radar systems located in Finland, Norway and Sweden, and all facilities located in the north of the Arctic circle. The radars are used for polar ionospheric and atmospheric measurements, for example, observation on the effects of the aurora borealis or the northern lights. Using these measurements we examine the effect of solar energetic particles on the polar ionosphere when the auroral activity is calm. We also use the profile of solar proton events from GOES data. Then we present the results in this study.

[P-149] Statistical Investigation of the Characteristics of Low Atmospheric Spectra of Flares Using Multi-Wavelength Observations by Hinode, IRIS, and SDO

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We have performed a statistical study on solar flares using ultraviolet (UV) and extreme-ultraviolet (EUV) spectroscopy along with white light (WL) continuum images to understand how the response of the lower atmosphere corresponds to the presence of WL emission. We analyzed the Mg II triplet, Si IV emission, and WL continuum from 60 M- and X-class flares that were observed by IRIS, SDO/HMI, and Hinode/SOT between 2014 and 2016. We find that the Mg II triplet primarily emits along the flare ribbons and footpoint of the flaring loop region, which indicates the presence of low atmospheric heating. The Doppler velocities derived from Si IV show red-shifted emission (~ 40 km/s) that is spatially and temporally correlated with the Mg II triplet emission. Enhanced WL continuum emission is observed in 17 of the flares ($\sim 30\%$). By comparing the time profile of the Mg II triplet emission, WL continuum, Doppler velocities, and GOES soft X-ray (SXR) light curve, we find that the SXR and Mg II triplet both have impulsive peaks when associated with WL flares. This correlation, however, does not hold for non-WL flare events. The temporal correlation between emission from the WL continuum, the Mg II triplet, and SXR suggests that the impulsiveness is an important parameter for distinguishing the energy transport mechanism unique to WL flares.

[P-150] The Observation and SD-WACCM Simulation of Planetary Wave Activities in the Upper Atmosphere during the 2019 Southern Hemispheric Sudden Stratospheric Warming

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A Sudden Stratospheric Warming (SSW) is an extremely rare

event in the southern hemisphere (SH), but occurred in early September 2019. Using the data from three meteor radars (MRs) - Davis (68.6°S, 77.9°E), King Sejong Station (62.2°S, 58.8°W), and Tirupati (13.6°N, 79.4°E), we studied the variation of horizontal winds in response to the 2019 SH SSW in the Mesosphere and Lower Thermosphere (MLT) region. The quasi 10-day oscillations are clearly observed in the zonal winds of high-latitude MRs before the central date (DOY 253). Similar oscillation appeared in O I 135.6 nm and N2 LBH band nightglow imaged by the satellite GOLD (Global-scale Observations of the Limb and Disk) near the equatorial ionization anomaly region. In the northern low-latitude MLT region, there is a strong wave activity right after the central date of the warming with a period of ~ 6 days in the zonal winds of Tirupati MR. This feature is also seen in the geopotential height measurements from MLS near the Tirupati region. To elucidate the possible source of quasi 6-day wave (Q6DW), we use a specified dynamics version of the Whole Atmosphere Community Climate Model (SD-WACCM) constrained by the reanalysis data from surface to 50 km. The simulation results show that the amplitude of westward propagating Q6DW was enhanced after the central date in the MLT region, and the divergence of Eliassen-Palm flux, which is related to the baroclinic/barotropic instability, arose in the middle latitude MLT region. Thus, we suggest that the Q6DW observed near the equatorial region through the MR is generated in middle latitude MLT region. The observation and simulation results indicate at least that the 2019 SH SSW affected not only the high-latitude MLT region but also low-latitude mesosphere and thermosphere region.

[P-151] Nonequilibrium Properties in the Plasma Sheet Observed on 2017 September 10

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We investigate the nonequilibrium properties of both a non-Maxwellian electron distribution and nonequilibrium ionization in the plasma sheet observed on 2017 September 10. We apply a Kappa (κ) electron velocity distribution (non-Maxwellian), which represents supra-thermal populations, to find the temperature and density of the plasma sheet. We also apply a nonequilibrium ionization model, which assumes that the plasma is initially in ionization equilibrium at low

temperature and heated rapidly by a shock or magnetic reconnection. We search for the best parameters, i.e. Kappa, temperature, characteristic timescale (density \times time) that explain the observations by the Atmospheric Imaging Assembly on board the Solar Dynamic Observatory and the X-ray Telescope and EUV Imaging Spectrometer on board Hinode. The plasma sheet has been widely studied in detail by many researchers with various observations under the assumption of a Maxwellian electron velocity distribution and equilibrium ionization. We discuss the nonequilibrium effects comparing the results with the previous studies assuming equilibrium ionization. We also compare the supra-thermal populations in the low corona with those in the interplanetary coronal mass ejection revealed by *in-situ* observations.

[P-152] Development of a Ground-Based Imager Network for Auroral Observations in Antarctica

Changsup Lee¹, Geonhwa Jee¹, Hyuck-Jin Kwon¹, Young-bae Ham^{1,2}, Jieun Kim¹, Jeong-Han Kim¹, Jonghyuk Yi³, Trond S. Trondsen³

¹Korea Polar Research Institute

²University of Science and Technology

³SELab

⁴Keo Scientific Ltd.

Korea Polar Research Institute (KOPRI) has been actively monitoring the polar upper atmosphere and its responses to space environments such as solar activity, magnetosphere and energetic particles since the establishment of the Korean second Antarctic Research base, Jang Bogo Station (JBS) in 2014. As the aurora is typically distributed in the aurora oval extending over about 10° in latitude, we have never fully understood the aurora itself and its effects on the polar upper atmosphere with only a single ground-based instrument. For the first time, we plan to configure the aurora imager network along the Korean route between JBS and the geomagnetic pole by collaborating with Kyung Hee Univ., KASI and NJIT. From this image network, not only the horizontal distributions of the aurora but also the vertical structure of the polar cap aurora can be investigated. In this study, the present stage in the development of the compact auroral imager and the future plan for the auroral network configuration will be presented.

[P-153] Analysis of NASA Workshop Report for the Lunar Landing Sites

Joo-Hee Lee, Dong-Young Rew

Korea Aerospace Research Institute

KARI plans to launch a pathfinder lunar orbiter in July 2022, and plans to send a lunar lander to the Moon by 2030 according to the National Space Development Master Plan. In order to

carry out the safe landing and successful mission of the lunar lander, it will be necessary to select a suitable lunar landing sites in advance through the definition of the lunar landing mission. Although the mission of the lunar lander will be determined through the related researchers and the future landing site selection committees, it would be of great help if studies were carried out to investigate the appropriate candidate areas according to the lunar landing mission in advance. Therefore, based on the NASA workshop report, the analysis of the suitability as the lunar landing site is conducted in this paper.

[P-154] A Study on the Basic Method for Localization of Space EEE Parts by Comparing the Integrated Chips Standards of ESA and JAXA

Kyung-Keun Kim

Korea Astronomy and Space Science Institute

The U.S uses standards from MIL-STD and NASA, while Europe uses ECSS standards and Japan uses JAXA standard, respectively. Currently, the U.S and European standards are mainly used because There is no systematic standard system for these quality control system at the KARI.

In this paper, We compare and analyze the quality control standards and system of EEE Parts used by ESA standards in Europe (ESCC Basic Specification 20100/ECSS Generic specification 9000) and JAXA standards in Japan (JAXA-QTS-2000/JAXA-QTS-2010). Based on this result, we suggest of basic data for localized standard system by referring to the system of advanced countries.

References

- [1] ECSS Generic Specification 9000: Integrated Circuits: Monolithic and Multichip Microcircuits, Wire-Bonded, Hermetically Sealed and Flip-Chip Monolithic Microcircuits, Solder Ball Bonded, Hermetically and Non-Hermetically Sealed and Die.
- [2] JAXA-QTS-2010: Integrated Circuits, High Reliability, Space Use, General Specification for.

[P-155] Ghost and Stray-Light from Ground Support Equipment for the Performance Test of Electro-Optical Payloads

Dongok Ryu, Youngchun Youk, Seonghui Kim, Jeeyeon Yoon, Eung-Shik Lee, Haeng-Pal Heo

Korea Aerospace Research Institute

Many electro-optical (EO) payloads of satellite missions are developed with optical and optomechanical design optimization from ghost and stray-light sources. The assembled and integrated EO payloads are tested its optical performance with confi-

gurations of ground support equipment (GSE) such as light source integrating sphere, optical target, and collimator system. In the test procedure, the ghost and stray-light contamination from the GSE has a risk of disturbance to estimate the performance of the target payload. This presentation will describe the ghost and stray-light analysis including the GSE and derivation of payload-only performance from initial optical measurement in the performance test in KARI missions.

[P-156] Basic Model of the Lantern Clock Mounted on Hong, Dae-Yong's Tongcheon-Ui

Byeong-Hee Mihn^{1,4}, Yong-Hyun Yun²,
Sang Hyuk Kim¹, Ho Chul Ki³

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²*National Science Museum*

³*Ancient Institute of Heritage*

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Hong, Dae-yong (洪大容, 1731–1783) developed Tongcheon-ui (Pan-celestial Armillary Sphere) in about 1760–1762, together with Na, Kyeong-Jeok (羅慶績, 1690–1762) and An, Cheo-in (安處仁, 1710–1781). This instrument has a celestial armillary sphere which is connected with a lantern clock driven by the force of the weight. This study design the model of the lantern clock called Hujong (候鐘), which is composed a going gear-train and a striking gear-train; the former is regulated by a foliot-and-verge and a crown gear. We find that the going tran and the striking train of Hong's clock rotate vice versa those of the artefact of the lantern clock owned by Korea University Museum respectively. We also observe that the second axis of going train from below is attaching the clock hand and transmits the rotation to the celestial armillary sphere.

[P-157] Introduction of Power EGSE for Low Orbit Satellites

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²*Chungnam National University, Department of Electronics Engineering, Professor*

Many EGSE (Electronic Ground Support Equipment) are used to develop and test low-orbit satellites. Among them, this paper will look into 'Power EGSE', an equipment that supports the test of the power meter of satellite signal.

PCDU (Power Control Distribution Unit) is power distribution unit of the low-orbit satellite. In this case, the voltage received by the SAS and battery that supplies power to the PCDU is distributed to the inside of the satellite through the regulator. At this time, it is 'Power EGSE' that simulates the power supplied to the satellite and performs the command and telemetry operation with the PCDU. This 'Power EGSE' can be

divided into PLTS (Power Load Test Set), which is the power department, and CMTS (Control & Monitoring Test Set), which is for control and monitoring, depending on the purpose of use. In general low-orbit satellites, the process of testing the actual voltage applied is called DC Integration. This 'DC Integration' is performed, and satellite units are connected by the PCPU. After 'DC Integration', 'Electronic Integration' is performed through baseband communication with the 'Base Band EGSE'. In this presentation, we are going to describe how to use RS422 serial communication for communication with PCPU and how to output voltage from Power EGSE for satellite test, not through actual solar array when power is applied to PCPU.

[P-158] 1.5 m Reference Flat System Development

Youngchun Youk, Dongok Ryu, Jeeyeon Yoon,
Seonghui Kim, Eung-Shik Lee, Haeng-Pal Heo

Korea Aerospace Research Institute

Reference flat mirror system is a key component to develop an optical module of high resolution optical telescope system. Generally to develop the large aperture optical telescope, we need a large optical reference flat system. However, the larger the flat mirror size, the more difficult it is to achieve high performance. To make high precise large reference flat system, test instruments requiring very high specification and various complicated metrology schemes are needed such as spherometer, e-level, scanning pentaprism test, stitching interferometry, and Ritchey-common test. In this paper, we will briefly present mechanical design, mechanical and thermal analysis, and the optical measurement results of the 1.5 m reference flat system.

[P-159] A Study on the Method of Radiated Emission Test for Multiple Satellite Unit

Chang-Eun Lee, Jae-Woong Jang, Kyung-Duk Jang,
Tae-Youn Kim, Sang-Rok Lee

Korea Aerospace Research Institute

Electromagnetic compatibility testing of satellite units sometimes performs several units together, not just one. In this case, the size of the composition of the EUT increases. If this configuration exceeds a certain size, the antenna should be located in several places when performing the radiated emission (RE) E-field test. When testing bands greater than 1 GHz, there is a specification that EUT and interface cable lengths of 7 cm must be within the antenna 3 dB beam width. In this paper, the RE E-field test method in large cases of EUT is discussed through the results of the satellite unit testing in bands greater than 1 GHz. The EUT size used in this paper is 158 cm, and the antenna is located in two places. The difference in levels of the same frequency component was compared and analyzed

in the test results.

[P-160] Experimental Verification of Bimetallic VCR Glands Fabricated through Explosion Welding for Thermal Vacuum Tests

Soohwan Jun¹, Keun Shik Kim², Hee-Jun Seo¹,
Hyokjin Cho¹, Sung-wook Park¹, Hyejin Yi¹

¹*Korea Aerospace Research Institute*

²*Hanyang ENG*

A bimetallic VCR gland is fabricated through explosion welding, and its applicability to a thermal vacuum chamber is

experimentally verified. The experiments are performed using the copper-stainless steel VCR glands with the diameter of 0.5 inch, which are fabricated through explosion welding and CNC machining. To verify the applicability of the fabricated VCR glands to a thermal vacuum chamber, a series of leak tests and pressurization tests is conducted at various conditions using a helium leak detector. It is experimentally found that the pressure inside the copper-stainless steel VCR gland is maintained without leakage not only at room temperature but also at approximately -196°C (the temperature of liquid nitrogen at atmospheric pressure). These results experimentally confirms the applicability of bimetallic VCR glands to thermal vacuum test of space components and system.

학회 및 관련기관 소식

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한국우주과학회

1. 학회지 발간

2019년 학술지 발간 실적은 36권 1호 4편, 2호 6편, 3호 11편, 4호 6편으로 총 27편의 논문이 발행되었다. 학회에서는 지속적인 학술지국제화를 위한 노력을 하고 있으며, 2020년도에도 SCIE등재를 목표로 하고 있다.

2. 학술대회 개최

2019년도 봄 학술대회는 4월 24일(수)~26(금) 강릉 라카이센드파인에서 개최하였다. 등록 인원은 165명이며, 논문발표는 구두발표 73편, 포스터발표 62편 총 135편을 발표하였다. 가을학술대회는 10월 23일(수)~25일(금)까지 여수 베네치아 호텔&리조트에서 개최하였다. 등록인원은 294명이며, 논문발표는 구두발표 81편, 포스터발표 148편 총 229편을 발표하였다.

3. 회의 개최

- 이사회

2019년도 이사회 1차 회의는 대전 샛별로(2019.01.22.)에서 2차 회의는 강릉 라카이센드파인(2019.04.25.)에서, 3차 회의는 여수 베네치아 호텔&리조트(2019.10.23.)에서 개최하였다.

1차 회의에서는 학술이사 임명 승인, 학술대회준비위원장 임명 승인 등이 결의되었다. 2차 회의에서는 신입회원 승인, 2020년 봄 학술대회 개최 등이 결의되었다. 3차 회의에서는 2019년 결산(안) 승인, 2020년 예산(안) 승인, 신입회원 승인, 2020년 학술대회 개최, 정관개정 준비위원회 설치 등이 결의되었다.

- 정기총회

제37차 정기총회가 2019년 10월 24일(목) 16:40에 여수 베네치아 호텔&리조트에서 개최되었다. 보고사항으로는 사업보고, 학술대회준비위원회보고, 학술보고, 포상위원회보고, 감사보고가 있었으며, 안건으로는 2019년 결산 심의, 2020년도 예산 심의, 제19대 회장 선출, 감사 선출, 부회장, 이사 선출 등이 결의되었다.

4. 2019년 수상

- 에스이랩상

2019년 봄, 오형직 회원(연세대)

2019년 가을, 홍준석 회원(충남대)

- 한국우주과학회 학술상

2019년 학술상 한원용 회원(천문연)

- 두진 우주과학자상

오수연 회원(전남대)

- 신진 우주과학자상

김정희 회원(현산중)

- 한국과학기술단체총연합회 제28회 과학기술우수논문상

최진 회원(천문연)

5. 위원회

- 편집위원회

Journal of Astronomy and Space Sciences(JASS) 편집위원회는 편집위원장으로 선종호(경희대), 위원으로는 강명석, 광영실, 구분준, 김경자, 김방엽, 김해동, 김은화, 민경욱, 박상영, 오수연, 이재진, 이지윤, 정웅섭, 조경석, 황경주, Ivan L. Andronov, Tapas Kumar Das, Paul A. Evenson, Edward F. Guinan, Lin-Ni Hau, Valery V. Hegai, Chung Yue Hui, Jeongwoo Lee, Jiuhou Lei, Xinlin Li, Charles Lin, Lee-Anne Mckinnell, Valery Nakariakov, Yuichi Otsuka, David Ruffolo, Boonrucksar Soonthornthum, Ilya Usoskin 회원으로 구성되어 있다. 편집위원회의 강화와 내실을 다지기 위해 2020년 8월 1일자로 김숙경 편집국장을 채용하였다.

- 포상위원회

포상위원회는 위원장으로 이병선(전자연), 위원으로 선종호(경희대), 오승준(에스이랩), 이주희(항우연), 최영준(천문연) 회원으로 구성되었다.

- 학술대회준비위원회

학술대회준비위원회는 위원장으로 황정아(천문연), 위원으로 김해동(항우연), 문홍규(천문연), 민병희(천문연), 박재홍(천문연), 봉수찬(천문연), 최병규(천문연), 최정림(충북대) 회원으로 구성되었다.

- JASS 발전위원회

JASS 발전위원회 위원장으로는 이유(충남대), 위원으로 박상영(연세대), 장현영(경북대), 조중현(천문연), 김해동(항우연), 이대영(충북대), 선종호(경희대), 민경욱(KAIST) 회원으로 구성되었다.

- 대외협력위원회

대외협력위원회 위원장으로는 이서구(천문연), 위원으로 김학창(인스페이스), 김주현(항우연), 심재경(경희대) 회원으로 구성되었다.

- COSPAR총회(2024년) 유치/준비위원회

COSPAR총회(2024년) 유치/준비위원회 위원장으로는 박종욱(천문연), 위원으로 이동훈(경희대), 최영준(천문연), 이주희(항우연)

연), 광영실(천문연), 선종호(경희대), 김병진(세트렉아이) 회원으로 구성되었다.

6. 회원 현황

2019년 신입회원 인준 현황은 정회원 37명, 학생회원 10명이 승인되었다. 정관 제6조에 따라 연회비 3년 미납자 67명은 준회원으로 회원등급을 조정하였다. 2019년 12월 31일 현재 회원 수는 1,549명(정회원 674명, 학생회원 12명, 3년 이상 비활동 및 해외 체류 회원 842명, 명예회원 16명이며, 기관회원 수는 5곳)이다.

7. 학회 사무국

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경북대학교 천문대기과학과

1. 인적사항

본 학과의 천문학 전공 교수는 박명구, 윤태석, 황재찬, 장현영, 김민진 회원이다. 동교 사범대학 지구과학교육과의 심현진 회원도 대학원생 논문지도를 맡고 있다.

본 학과 학부과정은 자연과학대학 지구시스템학부 천문대기과학전공이며 대학원과정은 천문대기과학과 천문학전공이다. 2020년 3월에는 91명의 신입생이 수시 및 정시모집으로 지구시스템과학부에 입학하였고, 22명의 학생들이 2학년으로 올라오면서 천문대기과학전공으로 진입하였으며, 1명이 3학년으로 일반편입으로 들어왔다. 천문대기과학전공 학생은 천문학과 대기과학 과목들을 자유롭게 선택하여 공부할 수 있다. 대학원에는 2019년 9월에 2명의 석사과정 학생, 2020년 3월에 8명의 석사과정 학생이 입학하여 현재 18명의 석사과정 학생과 2명의 박사과정 학생이 재학 중이다.

2019년 2월에는 강원기 회원(지도교수 박명구)이 '막대나선은하에서의 2차막대 찾기 및 특성 연구'로 석사학위를 취득하였다. 2019년 8월에는 이윤희 회원(지도교수 박명구)이 'Classification and Properties of Barred Galaxies'로 박사학위를, 이다희 회원(지도교수 황재찬)이 '스칼라장을 이용한 우주론적 매개변수 추정'으로 석사학위를 취득하였다. 2019년 12월에는 황현모 회원(지도교수 김민진)이 '허블 우주망원경을 이용한 활동성 은하핵과 모은하의 상관관계 연구'로, 양성현 회원(지도교수 황재찬)이 'A LT 해를 통한 허블 텐션 해결'로 석사학위를 취득하였다.

본 학과에서 수행 중인 BK21 PLUS 사업 '천체물리 및 우주론

분야 미래 창의 인재 양성팀(연구책임자 장현영)'을 통해서 2019학년도 1학기에는 석사과정 8명과 박사과정 2명, 2학기에는 석사과정 9명과 박사과정 1명, 2020학년도 1학기에는 석사과정 11명과 박사과정 1명이 연구 활동 지원을 받았다.

2. 연구 및 학술활동

박명구 회원은 박사과정 방태양 회원, 석사과정 최연호 회원 및 천문연구원의 외계행성 연구팀과 외계행성 탐색 연구를 수행하고 있으며 천문연구원의 김강민 회원, 박찬 회원 등과 외계행성투과 스펙트럼에 최적화된 분광측광기 개발 연구를 수행하고 있다. 또한 박사과정 한두환 회원 및 석사과정 오명환 회원과는 블랙홀 부착현상을, 박사과정 이윤희 회원, 박사후연구원 김태현 회원, 부산대학교 안홍배 회원과는 막대은하에 대한 연구를 수행하고 있다.

윤태석 회원은 석사과정 오형일 회원, 경희대학교 이정은 회원 연구팀, 한국천문연구원 성현일 회원과 FU Ori 형 별에 대한 가시광선-근적외선 영역에서의 분광학적 및 측광학적 관측 연구를, 박사과정 김수현 회원, 석사과정 오형일 회원, 한국천문연구원 성현일 회원과 공생별 및 Ia 형 초신성에 대한 가시광선 영역에서의 분광학적 관측 연구를 수행하고 있다. 한편, IGRINS 분광기-Gemini 남반구 망원경을 활용한 근적외선 분광 관측 연구도 함께 준비하고 있다.

황재찬 회원은 상대론적 자기유체의 중력불안정 현상을 연구하고 있다.

장현영 회원은 태양 흑점과 표면 자기장의 공간 분포를 분석하여 태양 자기장 생성에 관한 연구를 수행하고 있고, 우주환경과 장기 기후 변화의 관계를 연구하고 있다. 박사과정 김기범 회원, 조윤아 회원과 Kepler 위성 자료를 이용하여 항성 진화와 구조를 성진학적 관점에서 연구하고 있으며, 중국의 Zhibin Zhang 박사와 GRB의 모체 연구를 진행하고 있다.

김민진 회원은 천문연구원의 정웅섭 회원, 양유진 회원 및 한국의 SPHEREx과학연구 그룹과 함께 적외선 자료를 이용한 활동성 은하핵 중심부의 구조의 특성에 관한 연구를 수행하고 있다. 경북대학교의 김상현 회원, 천문연구원의 변우원 회원, 신윤경 회원 및 천문연 연구팀(김상철, 선광일, 박병권, 이준협, 정현진 회원)과 함께 KMTNet망원경을 이용하여 가까운 은하 서베이를 하는 연구를 진행 중에 있다. 석사과정 손수연 회원의 주도로 Aaron Barth (UCIrvine), Luis Ho (KIAA) 등과 고에너지엑스선으로 찾은 활동성 은하의 허블 이미지를 이용해서 블랙홀과 모은하의 공진화에 관한 연구를 진행 중이다. 석사과정 황성현 회원과 함께 젊은 활동성 은하핵에서 제트와 outflow의 상관관계에 대한 연구를 진행하고 있다. 경북대의 신재진 회원 및 서울대의 우종학 회원과 함께 2개 이상의 블랙홀을 가지고 있는 활동성 은하핵 및 활동성 은하핵 중심에서 중금속함량의 진화에 대한 연구를 공동으로 수행하고 있다. Mar Mezcuca(ISSC) 등과 중간질량블랙홀 후보의 분광학적 특성을 이해하고자 하는 연구를 수행 중이다. Luis Ho, Yulin Zhao, Jinyi Shangguan (KIAA) 등과는 허블 망원경을 이용해서 획득한 가까운 활동성 은하의 이미지를 이용해서 거대질량블랙홀과 모은

하의 특성에 대한 연구를 진행 중이다. Peter Jonker, Francesca Onori (SRON)과는 조석교란현상을 보이는 은하 중심의 블랙홀에 대해서 다양한 망원경을 이용하여 연구를 수행 중이다. 김동찬, 윤일상 (NRAO), 메타스페이스의 김지훈 회원 등과 함께 블랙홀 병합에 의해서 탈출하는 블랙홀을 찾기 위한 연구에 참여하고 있다. 서울대의 임명신, 김용정 회원, 김도형 회원 (부산대) 등이 주도하는 멀리있는 활동성 은하와 붉은 활동성 은하에 대한 연구에 참여하고 있다. 석사과정 금재혁 회원과 함께 서울대 우종학 회원팀이 주도하고 있는 블랙홀 질량측정 연구에 참여하고 있다.

본 학과는 시민과 학생들을 위해 학기마다 4차례 일반인을 위한 공개관측과 공개강연행사인 “밤하늘 이야기”를 열고 있으며, 지역의 대표적인 과학 행사로 자리 잡았다.

3. 연구시설

본 학과는 계산 및 관측자료 처리를 위해 Intel server/cluster 및 다수의 워크스테이션을 운영하고 있다. 경북대 천문대에는 천체 관측 실습을 위한 31cm 뉴턴식 반사망원경이 설치되어 있으며, 그 밖에 H alpha 및 Ca K 태양망원경을 비롯하여 다수의 소형 반사 및 굴절 망원경 그리고 Fujinon 25×150 대형쌍안망원경 등을 교육 및 연구에 활용하고 있다. 또한 이동식 천체투영시스템도 교육에 활용하고 있다.

경희대학교 우주과학과 및 우주탐사학과

1. 인적사항 및 주요동향

1985년에 창립되어 2020년에 35주년이 되는 경희대학교 우주과학과는 현재 응용과학대학에 소속되어 있고 학사과정과 함께 대학원에 석사, 박사, 석박사 통합과정을 두고 있다. 2009년 WCU (세계수준의 연구중심대학) 사업의 일환으로 대학원에 신설된 우주탐사학과는 석사, 박사, 석박사 통합과정을 두고 있다.

경희대학교 우주과학과와 우주탐사학과에는 2020년 9월 현재 총 14명의 교수(김관혁, 김성수, 문용재, 박수종, 선종호, 이동훈, 이은상, 이정은, 장민환, 전명원, 진호, 최광선, 최윤영, Tetsuya Magara)가 강의와 연구를 수행하고 있다. 2017년 정년 퇴임한 김상준 교수는 현재 고향명예교수로 재직 중이고, 2019년 정년 퇴임한 김갑성 교수는 명예교수로 재직 중이다. 아울러 독일 막스플랑크 연구소의 Sami K. Solanki, 미국 메릴랜드 대학의 Peter H. Yoon, 미국 UC Santa Cruz의 Ian Garrick-Bethell 교수 그리고 영국 Warwick 대학의 Valery M. Nakariakov 교수가 International Scholar로서 연구와 교육에 힘을 보태고 있다. 현재 우주과학과장은 이은상 회원이며, 우주탐사학과장은 Tetsuya Magara 회원이 맡고 있다.

우주과학과는 경희천문대와 함께 매년 다수의 공개 관측회를

개최하여 본교 학생들뿐만 아니라, 일반인들에게도 천문현상을 접할 수 있는 기회를 제공하고 있다. 매년 하계방학 중, 우주과학과 학생회는 학과 및 천문대의 지원으로 중고생을 위한 우주과학캠프를 개최하여 청소년들에게 천문학 및 우주과학에 대한 체험의 기회를 부여하고 있다.

우주과학과 학부는 올해 40명의 신입생을 맞이했으며, 약 170명이 재학 중이다. 대학원 우주과학과/우주탐사학과에는 총 23명의 대학원생(석사 13명, 석박통합 7명, 박사 3명)이 재학하고 있다. 양과 대학원에서 2019년 8월 이후 다음과 같이 석사 11명, 박사 13명이 학위를 받았다.

* 석사 졸업 - 11명

- 박재희 (19년 8월, 우주탐사학과, 지도교수 김관혁)
- 김기문 (20년 2월, 우주탐사학과, 지도교수 문용재)
- 김정현 (20년 2월, 우주탐사학과, 지도교수 진호)
- 김현중 (20년 2월, 우주탐사학과, 지도교수 박수종)
- 신경인 (20년 2월, 우주탐사학과, 지도교수 문용재)
- 신승혁 (20년 2월, 우주탐사학과, 지도교수 선종호)
- 이현상 (20년 2월, 우주탐사학과, 지도교수 선종호)
- 강준석 (20년 8월, 우주탐사학과, 지도교수 이은상)
- 이선우 (20년 8월, 우주탐사학과, 지도교수 박수종)
- 정병욱 (20년 8월, 우주탐사학과, 지도교수 진호)
- Sumiaya Rahman (20년 8월, 우주탐사학과, 지도교수 문용재)

* 박사 졸업 - 13명

- 백슬민 (19년 8월, 우주탐사학과, 지도교수 김관혁)
- 박은수 (20년 2월, 우주탐사학과, 지도교수 문용재)
- 신유철 (20년 2월, 우주탐사학과, 지도교수 선종호)
- 안준모 (20년 2월, 우주과학과, 지도교수 Tetsuya Magara)
- 우주 (20년 2월, 우주탐사학과, 지도교수 선종호)
- 임다예 (20년 2월, 우주탐사학과, 지도교수 문용재)
- 천경원 (20년 2월, 우주탐사학과, 지도교수 김성수)
- 김민배 (20년 8월, 우주탐사학과, 지도교수 김성수/최윤영)
- 박선경 (20년 8월, 우주탐사학과, 지도교수 이정은)
- 박소명 (20년 8월, 우주탐사학과, 지도교수 김성수)
- 박우진 (20년 8월, 우주탐사학과, 지도교수 박수종)
- 송용준 (20년 8월, 우주탐사학과, 지도교수 진호)
- 이혜인 (20년 8월, 우주탐사학과, 지도교수 박수종)

2. 연구 및 학술 활동

천체물리연구실

김성수 회원이 이끄는 천체물리연구실에서는 은하 중심부 성단과 분자구름의 역학, 월면 우주풍화(space weathering), 월면 우주탐사, 지구 대기 중 미세먼지 및 수증기 탐지 등의 연구를 수행하고 있다. 김성수 회원은 2019년 3월부터 월면 우주풍화 현상에 대한 최초의 통합모형을 도출하는 연구과제를 시작했다. 박소명

회원은 영국 Sheffield 대학의 Simon Goodwin 교수와 함께 은하 중심부 성단의 형성 및 진화를 연구하고 있으며 한국천문연구원 신지혜 회원과 함께 은하단 내 성단에 대한 연구를 수행하고 있다. 김민배 회원은 최윤영 교수의 지도 아래 SDSS 자료를 이용하여 별탄생 은하와 활동성은하핵의 특성에 대한 통계적 연구를 수행하고 있으며, 월면 표도 최상층 촬영을 위한 카메라 설계 연구도 진행 중에 있다. 연구교수인 심재경 박사는 우주 풍화가 달 표면 성숙도에 미치는 영향을, 김진규 회원은 달 크레이터를 자동으로 찾는 기법을 새롭게 개발하고 있다. 심재경 박사와 김진규 회원은 천문연구원과 함께 미국 시에라 산에 설치된 원격 망원경을 이용하여 달 표면에 대한 스펙클 편광 영상 관측 결과를 분석하는 연구도 수행 중에 있다. 천경원 회원은 2020년 2월부터, 심재경 회원은 7월부터, 박소명 회원은 9월부터 한국천문연구원으로 자리를 옮겨 연구를 지속하고 있다.

태양우주기상연구실

문용재 회원이 이끄는 태양우주기상연구실(Solar and Space Weather Laboratory)은 딥러닝을 이용한 태양 및 우주기상 연구와 태양활동 및 코로나 연구를 수행하고 있다. 2020년 2월에 박은수, 임다예 회원이 박사학위를 취득하였으며, 신경인, 김기문 회원이 석사학위를, 2020년 8월에는 수미야 회원이 석사를 취득하였다. 2020년 9월 현재 연구교수 8인(신준호, 이진이, 성숙경, 박진혜, 조일현, 지은영, 강지혜, 유대중), 박사후 4인(이하림, 박은수, 임다예, 로렌스), 박사과정 8인(박종엽, 나현욱, 이어진, 이강우, 김진현, 전성경, 정현진, 수미야) 및 석사과정 3인(이수진, 신승현, 손지현)이 연구를 함께 하고 있다. 신준호 회원은 '태양 플라즈마의 수직 구조 변화 연구', 이진이 회원은 '태양 분출 플라즈마의 질량 및 에너지 연구', 성숙경 회원은 '딥러닝을 이용한 고시간 분해능 동영상 생성 연구', 박진혜 회원은 '딥러닝을 이용한 태양풍 예보 연구', 조일현 회원은 '코로나에서의 태양풍 연구', 지은영 회원은 '딥러닝을 이용한 IRI 모델 개선 연구', 강지혜 회원은 '관측기반 시뮬레이션 모델을 통한 플레어/CME 기작 연구', 유대중 회원은 '코로나 플라즈마의 kink 파동 연구', 이하림 회원은 '딥러닝을 이용한 과거 흑점 자료 복원 연구', 박은수 회원은 '딥러닝으로 생성된 영상을 이용한 태양 대기 DEM 결정 연구', 임다예 회원은 '딥러닝을 이용한 단기 플레어 예보 연구', 로렌스 회원은 '딥러닝을 이용한 코로나그래프 영상 생성 연구', 박종엽 회원은 '우주기상 예보 평가 방법에 대한 연구', 나현욱 회원은 'CME 콘 모형을 이용한 halo CME 질량 결정 연구', 이어진 회원은 '태양 활동 영역의 시계열 인자와 플레어 관련성 연구', 이강우 회원은 '딥러닝 플레어 모델의 시각화 연구', 김진현 회원은 '태양 코로나그래프 광학 설계 및 검증 연구', 전성경 회원은 '딥러닝을 이용한 태양 자기장 영상 예보 연구', 정현진 회원은 '딥러닝 자료를 활용한 태양 3차원 자기장 외삽 연구', 수미야 회원은 '태양 고분해 영상의 Super-Resolution 연구', 이수진 회원은 '딥러닝을 이용한 TEC 예보 연구', 신승현 회원은 '2차원 영상으로부터 3차원 자료 생성 연구', 손지현 회원은 '딥러닝과 위성 자료를 이용한 He 10830 영상 생성 연구'를 수행 중에 있다.

적외선실험실

박수중 회원이 지도하는 적외선실험실은 광학/적외선천문기기의 제작과 천체관측 연구를 한다. 2020년 2월에 김현중 회원이 석사학위를 받았고, 2020년 8월에 이혜인, 박우진 회원이 박사학위를 받았고, 이선우 회원이 석사학위를 받았다. 김현중 회원은 경기과학영재고등학교 지구과학 교사로 근무 중이고, 이혜인 회원은 2020년 9월부터 천문연구원에서 박사후연구원으로 근무하고 있다. 2020년 9월 현재 적외선 실험실에는 연구박사 박우진 회원, 박사과정 지태근, 이선우 회원, 석사과정 한지민, 안호재 회원이 있다. 그리고 우주과학과 학부 4학년 김창곤, 학부 2학년 이민선, 이수민, 김도훈 회원이 학부 연구생으로 연구에 참여하고 있다.

본 적외선실험실은 고분산 적외선 분광기 IGRINS의 소프트웨어 개발 연구를 한국천문연구원의 산학연 위탁연구로 2010년부터 2014년 3월까지 수행 하였다. 그리고 미국 텍사스 A&M 대학과 공동으로 GMT의 제 1세대 관측기기인 GMACS 프로젝트에 참여하여 소프트웨어 개발을 담당하고 있다. GMACS의 CoDR (Conceptual Design Review) 연구는 2017년 3월 13일에 kickoff meeting을 하고 본격적인 연구를 시작하여 2019년 9월에 개념 설계 보고서를 제출했고, 다음 단계인 PDR (Preliminary Design Review)를 준비하고 있다.

2020년 8월부터는 5세대 SDSS(Sloan Digital Sky Survey)의 관측기기 LVM(Local Volume Mapper) 연구에 참여하여 소프트웨어 개발을 담당하고 있다. SDSS-V LVM 은 2021년 말부터 칠레 라스카파노스 천문대에서 전천 관측을 수행할 계획이다.

그리고 서울대학교 초기우주천체연구단과 20개의 필터를 장착하여 천체의 SED를 측정할 수 있는 SQUEAN(SED camera for QUasars in EARly uNiverse)을 제작을 완료하여 정기 관측을 수행 중이다. 2017년 2월에는 맥도날드 천문대 30인치 망원경에 구경 0.25 m의 Takahashi CCA250 망원경을 장착하여 반자동 관측을 위한 소프트웨어 KAOS30(KHU Automatic Observing Software for 30 inch Telescope)을 개발했다. KAOS 는 소프트웨어 엔지니어링 기술을 적용하여 지속적인 업그레이드가 가능하고, 다양한 망원경 시스템에 적용할 수 있도록 설계하였다.

2014년 7월부터 시작한 미래창조과학부의 우주핵심기술개발사업 "우주 적외선 관측을 위한 알루미늄 비축 반사망원경의 시험모델 개발" 연구는 2019년 6월에 성공적으로 마무리하고, 2020년 6월부터는 무인이동체 원천기술개발사업에 참여하여 무인이동체 임무장비 광학계 설계 및 분광영상 모델개발 연구를 시작했다. 본 연구에서는 우주핵심기술개발 사업에서 개발한 비축반사망원경 기술을 적용하여 자유곡면 알루미늄 반사경 3장으로 유효구경 40 mm 초점거리 60 mm 인 선형비점수차가 제거된 비축반사망원경(LAF-TMS, Linear Astigmatism Free - Three Mirror System)을 제작한다.

우주과학탐재체연구실

선종호 회원이 지도하고 있는 우주과학탐재체연구실(Space Science Instruments Laboratory)은 근지구 우주과학을 연구하기 위해 인공위성 탐재체를 개발하고 있다. 2018년 8월 서훈규

회원이 박사학위, 2019년 2월 이훈 회원이 석사학위, 그리고 2020년 2월 신유철, 우주 회원이 박사학위 그리고 신승혁, 이현상 회원이 석사학위를 취득하였다.

2020년 9월 현재 연구교수 2인(채규성 박사, 나고운 박사)과 박사과정 1인(설우형), 석박통합과정 1인(이찬행)이 연구를 함께 하고 있다. 우주과학탐색체 연구실은 연구실 구성원들이 함께 탐색체를 개발하고 발사하여 우주환경에서 관측된 데이터를 해석하고 물리현상을 연구함이 목적이다. 연구원들은 검출기 Analog/Digital 회로 개발, 입자물리 시뮬레이션, 기계구조 설계 및 테스트, 소프트웨어 개발, 우주관측 데이터 해석 등을 직접 수행한다.

우주과학탐색체연구실은 2018년 12월 4일에 미국 캘리포니아주 반덴버그 발사장에서 Falcon-9에 실려 고도 약 570 km 태양 동기궤도에 도착한 차세대 소형위성인 NEXTSat-1의 우주폭풍탐색체(ISSS) 중 하나인 Medium Energy Particle Detector (MEPD)와 2018년 12월 5일 발사된 정지궤도복합위성 2A의 부탐색체인 우주기상탐색체(KSEM)를 성공적으로 개발 및 발사운용을 수행하였다. MEPD는 동일한 두 개의 센서로 구성되어 있고, 이를 통해 20~400 keV 사이의 하전입자를 관측할 수 있으며 KSEM은 우주방사선 측정 및 지구 자기장 측정, 위성 대전 감시를 수행한다.

최근 우주기상탐색체연구실은 2020년 7월에 시작된 미국 NASA와 한국천문연구원과의 협력 사업인 한미 민간 달착륙선 탐색체 공동연구에 참여하여 달 표면에 입사하는 고에너지 하전입자 및 이차 입자를 관측하기 위한 Lunar Space Environment Monitor (LUSEM) 탐색체 개발을 진행하고 있다. 본 연구실의 채규성 회원은 '검출기 전장부 회로 설계', 나고운 회원은 '검출기 VHDL 개발, 탐색체 운용', 신유철 회원은 '몬테-카를로 방법을 이용한 초기 설계 요구사항 분석', 설우형 회원은 '검출기 아날로그 회로 설계', 이찬행 회원은 '검출기 검교정 및 시험'을 수행하고 있다. 이와 더불어 본 연구실은 현재 KSEM과 MEPD로부터 획득된 데이터를 중심으로 다중 위성 데이터를 활용하여 지자기권에 분포하는 하전입자의 특성에 관한 연구를 수행하고 있다.

우주공간물리연구실

이동훈 회원이 이끄는 우주공간물리 연구실은 우주 플라즈마에서 발생하는 여러 섭동 현상에 대한 이론 및 수치 모델 연구와 위성 관측 연구를 진행하고 있다. 이동훈 회원은 약 4년간 응용과학대학 학장 업무를 수행한 후 복귀하였으며, 현재 우주전파센터의 우주환경 연구과제를 수행하고 있다. 주로 우주 환경에서 발생하는 여러 종류의 지자기 섭동 및 파동 등에 대한 모델 연구를 수행하고 있다. 또한, 이동훈 회원은 지난 2년간 COSPAR 한국위원회 위원장으로서 2024년 COSPAR 총회의 국내 유치를 추진하고자 천문연 박종욱 현 위원장 및 관련 회원들과 함께 노력하고 있다.

이성환 회원은 자기권계면에서의 turbulence에 의한 자기권 섭동 과정에 대한 통계적인 연구를 수행하고 있으며, 최지원 회원은 자기권에서 오랜 동안 미제로 남아 있던 poloidal mode의 연장 수명에 대한 이론적 근거를 제시하는 연구를 마무리하였다. 또한, Danish Naeem 회원은 전리권 및 실험실에서 발생하는 전자 파

동에 대한 3-D 수치모델을 개발하였으며, 박사과정에 새로 입학한 노상일 회원은 수치모델을 활용한 자기권 자기 음파의 실시간 수치실험을 수행하고 있다. 석사과정에서는 윤우철 회원이 AI 기법을 이용한 태양풍 섭동과 자기권 도착 시간에 대한 모델을 개발하고 있다.

우주플라즈마물리연구실

이은상 회원이 이끄는 우주플라즈마물리 연구실은 위성 관측 데이터 분석과 시뮬레이션을 이용하여 우주플라즈마에서 발생하는 다양한 물리현상을 연구 중에 있다. 2020년 8월 강준석 회원이 석사학위를 취득하였고, 2020년 9월 현재 2명의 석박통합 학생과 1명의 석사과정 학생으로 구성되어 있다.

이준현 회원은 Van Allen Probes 위성 데이터를 분석하여 plasmopause 근처에서 수 십 eV에서 수 keV에 이르는 에너지를 갖는 이온의 특성을 연구하고 있다. 김희은 회원은 Cluster 위성 데이터를 분석하여 이온이 지구 bow shock을 통과할 때 발생하는 heating 과정에 대해 연구하고 있다. 고영경 회원은 hybrid 시뮬레이션을 이용하여 지구 bow shock을 통과하는 이온에서 발생하는 플라즈마 불안정성에 대해 연구하고 있다.

별탄생연구실

이정은 회원이 이끄는 별탄생 연구실은 현재 3명의 박사 후 연구원, 2명의 박사과정 학생과 5명의 석박통합 학생, 그리고 한 명의 석사학생이 별의 탄생과 관련된 다양한 연구를 진행 중이다. 본 연구실의 박사 후 연구원이었던 최윤희 회원은 한국천문연구원으로, 이석호 회원은 NAOJ로 옮겼으며, Neha Sharma 박사와 임범두 회원이 박사 후 연구원으로 새롭게 합류하였다. 이정은 회원은 Cycle 2부터 Cycle 6까지 ALMA를 이용하여 매년 관측을 수행해 왔으며, 최근에는 Cycle 5에서 얻은 관측자료를 바탕으로 폭발 중인 원시성인 V883 Ori의 원시행성계원반에서 복잡한 유기분자를 검출하였고, 이를 분석한 결과를 2019년 2월 Nature Astronomy에 출판하였다. 백기선 회원은 JCMT Large Program 중의 하나인 Transient Survey 프로젝트에서 처음으로 발견한 변광 원시성, EC 53의 quiescent phase와 burst phase의 SED를 모델링하여 폭발시 광도 증가를 정량화하고 논문을 작성하고 있다. 이와 더불어, 백기선 회원은 강력한 방출류를 보여주는 질량이 큰 원시성들에 대한 ALMA 관측자료를 분석하여, 복잡한 유기분자의 함량을 비교하고 있다. 1.5년 주기의 강착률 변화로 인해 변광하는 원시성, EC 53에 대해 Cycle 4시즌 동안 ALMA ToO 프로그램을 가동하여 메탄을 방출선과 다양한 분자선을 관측하였다. 이석호 회원이 이 자료의 분석을 주도하여, 논문을 작성하고 있다. Cycle 5시즌에 관측된 EC 53의 ACA 관측자료는 박우석 회원이 분석을 담당하고 있다. 박선경 회원은 IGRINS 레거시 프로그램으로 진행된 IGRINS spectral library를 2018년 10월 ApJS에 출판하였다. 현재 박선경 회원은 고분산 분광기인 BOES와 IGRINS를 이용하여 FUGri 천체 중 하나인 2MASS J06593158-0405277를 모니터링한 결과를 분석하여 논문을 작성하고 있다. Neha Sharma 박사는 IGRINS 레거시 프로젝트 일환으로 관측된 Class

I 원시성 중 강한 방출선을 보이는 천체의 IGRINS 스펙트럼을 분석하여, 이들 원시성에서 일어나고 있는 동역학적 조건을 연구하고 있다. 윤성용 회원은 레거시 프로젝트를 통해 관측한 원시성의 IGRINS 스펙트럼을 분석하여, Class I 원시성 중 FUOri 천체와 유사한 스펙트럼 양상을 보이는 천체를 발견하였고, Gemini 망원경을 이용하여 감도가 높은 IGRINS 스펙트럼을 얻어서 이를 분석하여 논문을 작성하고 있다. 강인 회원은 질량이 큰 원시성 중 하나인 Min 2-62의 IGRINS 스펙트럼을 분석하여 He I 방출선과, Br series, Pf series 방출선에서 disk rotation/disk wind에 의한 double-peak feature를 발견하여 연구를 진행 중이다. 김재영 회원은 AKARI/IRC로 관측된 원시성과 배경별의 공간얼음분자에 의한 흡수선 밴드를 분석하여, 별탄생 과정에서의 역학적 기작과 화학적 변이를 연구하고 있다. 이 연구는 NASA 미션인 SphereX를 위한 중요한 사전 연구가 될 것이다. 이희원 회원은 JCMT Large Program에 참여하여, Orion 영역에 있는 Planck Galactic Cold Clumps를 SCUBA-2로 관측하여, 별탄생의 negative feedback에 대한 논문을 2018년 6월 ApJS에 출판하였고, 현재는 같은 대상들에 대해 KVN으로 다양한 분자선을 관측하여, 별탄생 과정이 미치는 chemical feedback에 대한 논문을 작성하고 있다. 이용희 회원은 JCMT Transient Survey에서 관측된 천체들의 light curve의 periodogram 분석을 통해 주기적인 변광을 하고 있는 천체들을 찾고 이들의 성격을 연구하고 있다. 윤형식 회원은 TRAO Key Science Program인 TIMES 프로젝트를 수행하여, Orion A 분자운과 Ophiuchus 분자운의 6개의 분자선 맵핑을 거의 마무리했으며, Principle Component Analysis와 Spectral Correlation Function을 계산하고, 이론적 시뮬레이션 결과와 비교하여, 이들 분자운에서 난류와 별탄생 사이의 상호 관계를 연구하여 논문을 작성하고 있다. 임범두 회원은 가시광 영역대의 고분산 분광자료를 분석하여 젊은 산개성단 Messier 11의 주계열 전향점에서 나타나는 색지수 분산의 원인을 규명하여, 그 결과를 2019년 1월 Nature Astronomy에 출판하였다. 또한, 가이아 관측이 제공하는 고유운동과 Hectochelle 스펙트럼에서 얻은 시선속도를 분석하여 OB성협내 거대 항성계의 형성과정에 대한 연구를 수행 중이며, 이 중 Cyg OB2와 Car OB1의 연구결과를 MNRAS에 투고하였다.

초기우주 연구실

전명원 회원이 이끄는 초기우주 연구실은 초기 우주에서 생성된 첫 세대 별과 은하의 탄생과 진화, 특성, 그리고 초기 별들과 관련하여 근거리 우주에서의 왜소은하의 특성에 대한 연구를 수행하고 있다. 현재 초기우주 연구실에는 2019년 석박사 통합과정에 입학한 신찬희 회원, 석사과정으로 2019년에 입학한 이태용 회원이 연구를 수행 중이며, 학부 4학년인 김재은 회원이 학부 연구생으로 연구를 보조하고 있다. 전명원 회원은 2018년 3월부터 초기우주의 화학적 초기풍 왜소은하에 대한 이해를 목표로 한국연구재단 과제를 시작하였으며 앞서 언급된 참여 연구원들과 함께 현재까지 연구를 수행 중이다. 초기 별과 은하에 대한 연구 결과에 대해서는 University of Texas at Austin의 Volker Bromm 교수

와, 근거리 우주의 왜소은하의 연구에 대해서는 University of Arizona에 Gurtina Besla 교수와 긴밀한 협력을 하고 있다. 또한, 2020년 9월부터 KIST의 슈퍼컴퓨터를 이용하여 왜소은하 형성에 미치는 모은하의 중력적 영향에 대해서 거대 시뮬레이션을 수행할 예정이다. 본 연구실의 신찬희 회원은 별들의 초기질량함수(Initial mass function)에 따른 초신성 에너지가 어떻게 왜소은하의 별생성 과정을 억제시키는데에 대해 우주론적 수치계산을 수행 중에 있다. 이태용 회원은 한국천문연구원 천경원 회원의 왜소은하 시뮬레이션 결과를 분석하여 왜소은하들의 다양한 별 생성 역사에 대해 연구를 수행하고 있으며, 천경원 회원과 한국천문연구원에 신지혜 회원과 긴밀한 협력을 통해 연구를 수행하고 있다.

태양권플라즈마연구실

최광선 회원이 이끄는 태양권플라즈마연구실(Heliospheric Plasma Physics Laboratory)은 태양으로부터 태양권계면(heliopause)까지 이르는 전 태양권 공간에 존재하는 플라즈마의 전자기적, 역학적 성질을 탐구하기 위해 설립되었다. 작년부터는 태양권 밖의 천체에서 일어나는 플라즈마 물리 과정으로 연구 영역을 확대하였다. 이 연구실에서 다루는 주제들은 태양물리연구실과 공간물리연구실의 연구주제들과 밀접한 관련이 있기 때문에 이들 연구실과 연구 협력이 이루어지고 있다. 본 연구실에서는 플라즈마의 거시적 기술인 자기유체역학으로부터 미시적 기술인 입자운동론적 기술(kinetic theory)까지 다양한 방법을 사용하고 있다. 입자운동론적 연구에 있어서는 University of Maryland의 Peter H. Yoon 교수와 긴밀한 협력이 이루어지고 있으며, 자기유체역학적 연구에 있어서는 Max Planck Institute for Solar System Research의 Joerg Buechner 교수 및 Sami Solanki 교수와 협력하고 있다.

본 연구실의 이시백 회원(석박 12기)은 자기유체역학적 시뮬레이션을 통하여 total magnetic helicity에 비해 twist number가 큰 구조가 나타나는 과정에 대해 연구하고 있다. 이중기 회원(석박 수료)은 다차원(2, 3차원) 플라즈마 입자 시뮬레이션 코드를 독자적으로 개발하였으며, 이를 collisionless magnetic reconnection에 적용하여 microscopic scale에서만 나타날 수 있는 dynamo 현상을 연구 중이다. 이중기 회원은 현재 한국천문연구원의 전문연구요원으로 근무 중이다. 석사 5기인 송인혁 회원은 천체의 shear flow와 연계된 thermal instability를 해석적 방법으로 연구 중이다. 쉼트렉아이에 재직 중인 박근석 회원(박사 수료)은 달과 같은 자기장이 없는 천체와 태양풍의 상호 작용을 3차원 자기유체역학적 시뮬레이션을 통해 연구 중이다. 전홍달 회원(박사 수료)은 태양과 자기권 등에서 발생하는 ballooning instability에 대한 연구를 수행 중이다. 최창대 회원(석사 1기)은 Peter H. Yoon 교수와 협력하여 nonlinear kinetic Alfvén wave의 생성 및 전파에 대한 이론적 연구를 수행하고 있다.

Solar Dynamics Laboratory Group

We aim to clarify the dynamical nature of the Sun by studying various kinds of activity observed in the Sun,

such as solar cycles, solar flares, solar winds and coronal mass ejections. We have been investigating these phenomena by theoretical modeling based on computer simulations and ground-based and/or space observations. The members of our group are Dr. Tetsuya Magara (leader), Dr. Junmo An, Dr. Hwanhee Lee (moved to KASI in September 2020), Dr. Jihye Kang, and Mr. Yeonwoo Jang. Our current research targets are: I) dynamic recycling process of magnetic fields in the solar interior II) dynamic transportation of magnetic fields through the solar convection zone to the solar atmosphere III) fast diffusion of magnetic fields in the solar atmosphere IV) global eruption of magnetic fields toward the inter-planetary space. We are also collaborating with the space weather group at KASI to develop a state-of-the-art three-dimensional magnetohydrodynamic simulation model, which will be used to investigate the Sun-Earth system.

3. 연구시설

경희천문대

경희대학교 천문대는 1992년 10월 돔형 건물의 완공과 76cm 반사망원경의 설치를 기점으로 개관하여 1995년 9월 민영기 교수가 초대 천문대장으로 부임하였다. 1999년 1월에 김상준 교수가 제2대 천문대장으로 부임한 후, 2001년 3월에 인공위성 추적 관측을 위한 관측소를 설치하였다. 2003년 2월에 장민환 교수가 제3대 천문대장으로 부임하였고, 2010년 3월부터는 박수종 교수가 제4대 천문대장직을 수행하였다. 2012년 3월에 진호 교수가 제5대 천문대장직에 부임한 후, 2013년 10월에 공식 명칭을 '우주과학교육관'에서 '경희대학교 천문대'로 변경하였고, 새롭게 홈페이지를 개선하였다. 2015년 2월부터는 최광선 교수가 제6대 천문대장직을 수행하였고, 2017년 3월부터 김관혁 교수가 제7대 천문대장직을 수행하였다. 2019년 3월부터 현재 이정은 교수가 제8대 천문대장직을 수행하고 있다. 경희대학교 천문대는 연구 및 교육 활동 외에 천문우주과학 대중화 사업을 적극적으로 진행해 오고 있다.

본 천문대는 2009년에 리모델링 공사를 통하여 각종 연구시설을 정비하였고, 76 cm 반사망원경의 TCS를 교체하여 보다 효율적이고 정확한 관측이 가능하도록 하였다. 또한, 2010년에는 Meade사의 16인치 리치크레티앙식 망원경과 Paramount ME 마운트를 도입하여 위성 추적 및 천체 관측 실습용으로 사용 중에 있으며, 2011년과 2012년에는 FLI 4K CCD와 FLI 1K CCD를 각각 도입하여 관측에 활용하고 있다. 2013년에는 대구경 쌍안경을 도입하여 과학문화 대중화에 활용하고 있다. 2012년 4월에는 기존의 전시장 공간에 연구실을 신설하는 공사와 영상실 조성 공사가 완료되었다. 2015년 2월과 2016년 2월에는 천체관측지원을 위하여 주망원경 돔을 보수하였다.

본 천문대는 다양한 체험학습 프로그램과 과학문화 대중화를

위한, 천문 및 우주과학을 주제로 하는 교육프로그램을 상시 진행하고 있다. 이를 통해 천문·우주과학에 대한 일반의 관심을 향상시키고, 중고생들에게 전공 진로 방향을 제시하는 등, 경희대학교 천문대는 지역사회 및 일반 천문동호인들에게 중요한 교육 및 체험 현장으로서 새로운 위상을 정립하고 있다.

경희대학교 천문대에는 천문우주과학 관측기기 및 인공위성의 개발과 관련된 다수의 실험실들이 설치되어 있다. 실험 시설로는 전자장비 개발 및 시험 시설, 기계구조부 제작 및 시험 시설, 청정실 등이 있으며, 경희대학교 인공위성 지상국도 현재 천문대에 설치되어 운용되고 있다.

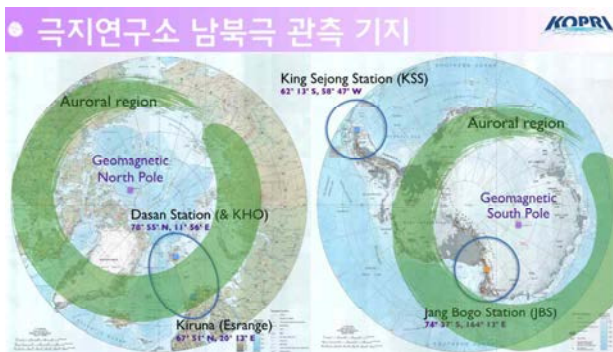
극지연구소 우주환경 연구그룹

극지연구소는 남·북 극지에서 운영 중인 과학기지에서의 연구 활동을 바탕으로 다양한 기초과학 분야를 연구하고 있는 국내 유일의 극지전문 정부출연 연구기관으로, 남북극 특수 환경에서 수행 가능한 거의 모든 자연과학 분야의 연구를 활발히 수행하고 있다. 1987년, 한국해양연구원(현 한국해양과학기술원(KIOST))의 한 연구실에서 시작된 극지연구소는 2004년 부설화 이후 질적/양적으로 비약적인 성장을 이루어 왔다. 1988년 남극 세종과학기지, 2002년 북극 다산과학기지, 2009년 쇄빙연구선 아라온, 2013년 인천 송도 독립청사 준공, 2014년 남극 장보고과학기지 준공 등 지속적인 극지 인프라 구축이 진행되어 왔고, 앞으로도 제2 쇄빙연구선 건조, 남극 내륙기지 건설과 같은 다양한 극지 연구 시설 확보를 계획하고 있다. 극지연구소 우주환경 연구그룹은 국내외 대학 및 연구기관과 공동협력을 통해, 남북극 기지에서 주로 지상 관측 장비를 이용하여 고층대기 중간권 및 열권 하부, 전리권, 열권 등의 영역을 관측하고 있으며, 특히 남극 장보고 과학기지에서는 지상 자력계를 통한 자기권 관측, 중성자 모니터에 의한 우주선/고에너지 입자 관측, 오로라 전천카메라에 의한 오로라 모니터링을 통해 오로라 관련 연구가 본격적으로 시작되었다.

극지연구소 우주환경 연구그룹의 주요 연구주제는 크게 두 가지로 요약할 수 있다. 첫번째는 남극 세종과학기지에서의 지상관측과 전 지구 수치모델을 통한 대기 중력과 관련 연구이다. 남극 세종과학기지는 대기 중력과 활동이 매우 활발한 지역에 위치하고 있어 극지연구소에서는 대기 중력과 관측을 위한 종합적인 지상관측 시스템 구축을 추진하고 있다. 두번째는 남극 장보고과학기지에서의 지상관측을 중심으로 북극 스웨덴 키루나와 노르웨이 스발바드 지역 다산기지에서의 지상관측을 통한 오로라 및 우주환경 변화 연구이다. 특히, 향후 남극내륙진출로 확보 (K-route) 사업과 연계하여 장보고기지-내륙기지 간 오로라 관측네트워크 구축을 통해 더욱 확대하여 국제적으로 경쟁력 있는 남반구 오로라 관측 연구를 수행할 예정이다. 이와 같은 연구를 위해서 국내에서는 충남대학교, 경희대학교, 전남대학교, 연세대학교, 한국천문연구원

등과 활발한 공동연구를 수행하고 있으며, 국외에서는 미국 NCAR/HAO, University of Colorado (Boulder), Utah State University, 뉴저지 공과대학(NJIT), NASA/GSFC, 일본 극지연구소(NIPR), 중국 극지연구소(PRIC), 유럽 전리권 레이더 연합(EISCAT) 등 다양한 기관과 관측기기 운영 및 자료 분석 연구를 위해 공동연구를 수행하고 있다. 또한 국내외 공동연구기관과의 협력과 함께 SCAR/GRAPE, ANGWIN 등 국제공동 관측네트워크의 적극적 참여를 통해 극지연구소 지상관측자료 공동활용을 보다 활성화하여 극지 고층대기/우주환경 연구 역량 제고에 힘쓰고 있다. (극지연구소 관련 연구사업: 오로라 발생과 극지 고층대기 교란 및 기후 변동성과의 상관관계 규명 - PE20100).

1. 연구시설



남극 세종과학기지는 1988년 준공과 함께 제1차 월동대를 시작으로 현재 제32차 월동연구대(2020년 기준)가 기지를 운영하고 있으며, 남극 해양, 생물, 대기 등 다양한 분야의 연구활동이 수행되고 있다. 세종기지에서의 우주환경 연구는 고층대기 중간권 및 열권에 대한 관측을 중심으로 수행되고 있으며, 이를 위해 전천카메라(All Sky Camera: ASC), 유성레이더(Meteor Radar: MR), GPS/Scintillation 모니터, 페브리-페로 간섭계(FPI) 등을 운영하고 있다. 2002년부터 2017년까지 운영되며 중간권계면 주변 (약 87~94 km) OH와 O₂에서 방출되는 대기광을 관측하여 야간 중성대기 온도 모니터링을 수행했던 대기광 분광계 관측에 이어 2021년에는 이 관측을 대체하기 위한 2-D 중간권 온도 관측기 (Mesospheric Temperature Mapper: MTM)를 설치하여 관측의 연속성을 확보할 계획이다. 중간권 온도에 대한 장기간의 관측 자료를 바탕으로 MLT 지역의 온도 특성 연구뿐만 아니라, 고층대기에서의 조석파, 대기 중력파 등의 연구에도 활용되고 있다. 2000년대 초·중반에 경북 영천에 있는 보현산 천문대에서 운영 중이던 전천카메라를 2008년 세종기지로 이전·설치하여 대기 중력파 연구를 위해 운영하였고, 2012년 장비노후화로 인해 기존의 전천카메라를 철거하고 새로운 전천카메라를 설치하여 운영 중에 있다. 전천카메라는 대기 중력파의 2-D 이미지를 직접 관측함으로써 대기 중력파의 다양한 물리적 특성 연구에 활용되고 있다. 광학관측기와 함께 운영되고 있는 유성레이더는 2007년 2월 충남대학교 김용하 회원 연구그룹이 세종기지에 설치한 관측기기

로서 극지연구소 우주환경연구그룹과 함께 공동으로 운영되고 있다. 야간에 맑은 날씨에서만 관측이 가능한 광학장비와는 달리 유성레이더는 하루 24시간, 기상조건에 관계없이 관측이 가능한 장비로서, 약 70~110 km 고도에서 발생하는 유성흔 관측을 통해 이 고도에서의 중성대기 바람 및 온도를 상시 모니터링 하고 있다. 또한 2015년에는 GPS Scintillation모니터를 설치하여 전리권 전자밀도 불균일성 관측이 시작되었다. 남극 세종과학기지에서는 이와 같은 관측장비를 이용하여 고층대기 중간권 및 열권 하부에서의 조석파 및 대기 중력파 관련 연구가 활발히 수행되고 있는데, 잘 알려진 바와 같이 세종기지 주변지역은 대기중력파가 가장 활발히 발생하는 지역 중 하나로서 대기중력파에 의한 저층대기와 고층대기의 상관관계 연구를 위한 최적지로 알려져 있다. 2017년 2월에는 미국 NCAR/HAO 소속의 Dr. Qian Wu와 공동으로 팔머 기지(Palmer Station)에서 운영하던 페브리 페로 간섭계를 세종기지로 이전 설치하여 중성대기 관측을 열권까지 확대했다. 따라서 기존 유성레이더 관측과 함께 중성대기 바람 및 온도를 중간권에서 열권까지 모니터링할 수 있는 관측시스템을 갖추게 된 것이다. 그리고 2019년 2월에는 경희대 우주과학과 김관혁 회원 연구팀과 공동으로 Search-Coil 자력계를 설치하여 운영을 시작했다.

2014년 2월 준공한 장보고과학기지는 세종기지 위치에서 거의 남극대륙 정 반대편에 있으며, 자남극에 인접해 있기 때문에 오로라대(Aurora oval) 및 극관(Polar cap) 지역 우주환경연구에 적합하다. 이 영역에 있는 플라스마 중성입자들은 태양풍-자기권-전리권 상호작용 에너지에 의해서 열역학적, 전자기적으로 매우 활발한 운동을 하고 있기 때문에, 우주환경 상시 모니터링 시스템 구축을 통해 지자기 폭풍이나 오로라 폭풍 등 우주환경 변화에 의해 극지 고층대기에서 발생하는 다양한 물리적 현상들의 연구가 가능하다. 이를 위한 첫 단계로, 2014년 2월에 장보고 기지의 준공과 함께 페브리 페로 간섭계(Fabry-Perot Interferometer: FPI)를 설치하여 중간권 및 열권에서의 중성대기 바람과 온도 관측을 수행하고 있으며, 2014/2015 하계 기간에는 극지 전리권의 전자밀도 분포(electron density profile) 및 이온바람(ion drift) 등의 물리량을 관측하는 전리권 레이더(Vertical Incidence Pulsed Ionosphere Radar: VIPR)를 설치하여 현재 정상 관측 중에 있다. 이 장비들의 운영 및 관측 자료를 활용한 연구는 미국 NCAR/HAO 및 콜로라도 대학교 공동으로 수행하고 있다. 또한, 한국 천문연구원, 충남대학교, 경희대학교, 전남대학교, 미국 John's Hopkins University의 Applied Physics Laboratory(JHU/APL) 등과 공동으로, 보다 다양한 극지 우주환경 관측을 위해 대기광 관측용 전천카메라, 양성자 오로라 관측용 전천 카메라, 전리권 관측용 GPS Scintillation 모니터, 자기권 관측용 자력계, 우주선/고에너지 입자 관측용 중성자 모니터 (Neutron Monitor) 등의 장비들을 추가로 설치하여 국제적인 극지 우주환경 종합 모니터링 센터로서의 역할을 수행하고 있다. 마지막으로 장보고기지는 오로라 관측을 위한 최적의 조건을 갖추고 있기 때문에 2018년 2월부터 오로라 이미지를 지속적으로 확보하기 위한 전천카메라를 설치

하여 운영하고 있다. 이 오로라 관측으로 극지연구소에서는 동시에 운영되고 있는 다양한 우주환경 관측과 함께 오로라 연구를 본격적으로 수행할 수 있는 기반을 갖추게 되었다. 또한 남극 자극점 주변에 설립될 예정인 내륙기지를 활용하여 장보기지-내륙기간 오로라 관측네트워크를 구축하여 오로라 연구를 확대해 나갈 예정이다.

북극에서는 노르웨이 스발바드 군도의 니알스네에 있는 다산과학 기지와 스웨덴 키루나에서 2002년부터 적외선 간섭계 (Michelson Interferometer)를 운영하고 있는데, 남극세종기지에서도 운영 중인 SATI와 유사한 성격의 광학 관측장비로서 중간권계면 주변 지역의 중성대기 온도 관측을 수행하고 있다. 그러나 다산과학 기지의 적외선 간섭계도 노후화로 인해 2017년 말에 관측을 종료하였다. 2015년과 2016년도에는 다산기지와 스웨덴 키루나에 각각 페브리 페로 간섭계(FPI)와 GPS Scintillation 모니터를 설치하여 극지 전리권-열권 관측 시스템을 구축하였으며, 이 관측은 한국천문연구원과 공동으로 참여하고 있는 북극지역 전리권 레이더 시스템 (European Incoherent Scatter Scientific Association: EISCAT)의 관측과 함께 북극권에서의 전리권 및 전리권-열권 상호작용 연구에 활용되고 있다.

2. 남극 과학기지 월동연구원

극지연구소 우주환경 연구그룹에서는 남극 세종과학기지와 장보고과학기지에 설치되어 있는 극지 우주환경 관측장비들의 안정적인 운영을 위하여 매년 2명의 월동연구원을 모집하고 있다. 월동연구원은 약 1년 동안 각 남극 기지에 상주하면서 고층대기/우주환경 관측기기의 운영 및 관리, 관측자료 기초 분석 등의 업무를 수행하게 된다. 매년 상반기에 극지연구소 홈페이지(<http://www.kopri.re.kr>)를 통해 모집 공고 확인이 가능하며, 우주과학관련 학사학위 소지자부터 지원이 가능하다. 월동연구원에 관심이 있는 회원들은 극지연구소 지진화 회원(ghjee@kopri.re.kr)에게 문의하면 월동연구원의 업무, 자격, 연봉 등에 대한 상세한 관련 정보를 얻을 수 있다.



서울대학교 물리·천문학부 천문학 전공

1. 인적사항

서울대학교 물리·천문학부 천문학전공에서는 구분철, 이형목, 이명균, 박용선, 채종철, 임명신, 김용태, 이정훈, 우종학, Masateru Ishiguro, 윤성철, Sascha Trippe 등 12명의 교수가 교육과 연구를 담당하고 있다. 천문전공 주임은 2019년 3월부터 이정훈 교수가 맡고 있다. 그리고 임명신 교수는 창의연구 초기우주천체연구단 단장, 윤성철 교수는 BK21 운영위원을 맡았다. 이형목 교수는 2018년 1월에 한국천문연구원 7대 원장으로 선임되어 3년간 고용휴직 중이며, 2019년 1학기에는 임명신 교수, 2학기에는 구분철 교수가 연구년을 보냈다.

조세형 교수는 2019년 3월에 객원교수로 부임하여 전파 관측 연구에 참여하고 있으며, Maria Madjarska 박사는 2019년 11월에 Brian pool 초빙과학자로 선정되어 연구를 수행 중이다.

박사 후 연구원으로는 조규현, Yashashree Jadhav 박사가 신규임용 되었으며, Rongxin Luo, 이용현, 김현정 박사가 근무를 마쳤다.

2019년도에는 석박통합과정 5명, 학부과정 12명이 입학하였고, 박사 8명, 석사 4명, 학사 6명을 배출하였다. 학위를 받은 학생은 아래와 같다.

《 2019년 2월 학위 취득 》

■ 박사

오정환 (지도교수: Sascha Trippe) High-resolution study of Active Galactic Nuclei and the development of optical intensity interferometer

조규현 (지도교수: 채종철) A Study of Oscillations and Waves in Sunspots

■ 석사

강다운 (지도교수: 우종학) Unraveling the complex structure

of AGN driven outflows using IFU observations and 3D biconical outflow models

김지훈 (지도교수: 윤성철) Evolutionary Models for Helium Giant Stars as Type Ibn Supernova Progenitors

■ 학사

권희정, 조항빈

《 2019년 8월 학위 취득 》

■ 박사

김용정 (지도교수: 임명신) Survey of Faint Quasars at High Redshifts: Contributions to the Cosmic Reionization and Growth of the First Supermassive Black Holes

박종호 (지도교수: Sacha Trippe) A Multiscale View of Active Galactic Nuclei Jets: from the Formation and Acceleration to High Energy Outbursts

신재진 (지도교수: 우종학) A multi-wavelength study of AGN feedback

윤동환 (지도교수: 박용선) Simultaneous time monitoring observations of H₂O and SiO masers toward the supergiant VX Sagittarii

윤용민 (지도교수: 임명신) Environments of Galaxies and Their Effects on Galaxy Properties

정하은 (지도교수: 박용선) Environments of Galaxies and Their Effects on Galaxy Properties

■ 석사

서강일 (지도교수: 이명균) Tracing Dark Matter Halo Mass Using Central Velocity Dispersion of Galaxies

양승원 (지도교수: 김용태) Migration of Radiative Gas Giants with GIZMO

■ 학사

강수상, 김태범, 이은채, 정만근

2. 학술 및 연구 활동

구본철 회원은 공동 연구자 및 지도학생들과 함께 초신성 및 초신성 잔해, 질량이 큰 항성의 생성 및 최종 진화, 우리 은하의 구조 등에 관한 연구를 수행하고 있다.

이명균 회원은 장인성 회원, Freedman 등의 공동연구자와 함께 TRGB/SN Ia를 이용하여 허블상수 값을 측정하는 연구를 수행했다. 이 결과는 Hubble tension이 매우 약하다는 것을 의미한다. 장인성 회원, Beaton 등의 공동연구자와 함께 TRGB를 이용하여 M101의 거리를 측정하는 연구를 수행했다. 장인성 회원, Hoyt 등의 공동연구자와 함께 TRGB를 이용하여 Leo I 은하단에 있는 M66과 M96의 거리를 측정하는 연구를 수행했다. 고유경 회

원 등의 공동연구자와 함께 병합잔해가 보이는 M85은하에 대하여 CFHT/MegaCam 광역탐사를 이용한 구상성단계 연구를 수행했다. 강지수, 장인성 회원과 함께 Ca-rich SN Ib(SN 2005cz)가 발견된 타원은하 NGC 45489에 대한 성단탐사를 수행하고 이로부터 Ca-rich SN Ib의 기원을 밝히는 연구를 수행했다. 고유경 회원, Sun 등의 공동연구자와 함께 처녀자리 은하단에 있는 구상성단을 대상으로 행성상성은 탐사 연구를 수행했다. 김지훈, 임명신, 이형목 회원, 공동연구자 등과 함께 PAH 3.3um을 이용하여 AGN 은하에 있어서 AGN 활동과 별생성 활동 사이의 상관관계를 밝히는 연구를 수행했다.

박용선 회원은 서울전파천문대 6미터 전파망원경을 이용하여 대만의 그린랜드 망원경, 하와이의 JCMT가 참여하는 230 GHz 대역 국제 공동 VLBI 관측을 수행하였다. 전파 망원경을 안정적으로 운영하기 위해서 방위각 방향 모터 감속기를 교체하는 등의 유지보수 작업을 하였다. 유형준 회원과는 중소형 광학 망원경용 적응 광학계 시스템을 개발하고 있다. 실험실에서 인공적으로 대기 요동을 만들고 이를 보정하는 알고리즘을 개발하였다. 대략 100 Hz 수준으로 위상 오차를 잘 보정하는 것을 확인하였다. 조만간 1미터 망원경에 설치하여 테스트할 예정이다. 또한, 덩어리진 분자운에서의 복사전달 문제를 3차원 공간에서 풀지 않고 1차원 공간에서 간편하게 푸는 방법을 연구하고 있다. 미시난류가 있는 경우에는 개발된 방법의 유효성을 입증하였고, 좀 더 넓은 경우에 적용할 수 있는 방법론을 개발하고 있다.

채종철 회원이 이끄는 태양천문학 그룹에는 해외석학초빙과학자인 Maria S. Madjarska 박사, 연수연구원인 조규현 박사가 있다. Madjarska 박사는 2019년 11월부터 서울대에서 근무하고 있다. 그룹에는 3인의 박사과정 회원(곽한나, 이겨레, 강주형)과 2인의 석사과정 회원(김다나, 강주형)이 있다. 이겨레 회원은 2019년 11월부터 현역으로 군복무 중이며, 강주형 회원은 2019년 9월부터 한국천문연구원에서 병역대체 전문연구요원으로 근무 중이다. 채종철 회원은 한국천문연구원과 한국연구재단의 지원을 받아 미국 빅버어 태양 천문대의 1.6미터 태양 망원경(GST)의 고속영상 태양분광기(FISS)를 이용한 관측 수행, 자료 분석 및 연관 이론 연구를 수행하고 있다. 특히 복사전달모형을 적용하여 강한 흡수선에서 광구 및 채층의 물리 인수들을 결정하는 다층 분광 되치 모형(multilayer spectral inversion model)을 개발하였고, 이를 활용해서 태양 흑점 지역의 자기유체 알펜파 검출에 도전하고 있다. 초빙과학자 Madjarska 박사는 브레인폴 프로그램의 지원을 받아 태양 코로나 명점(coronal bright point)의 코로나와 채층의 물리적 연결에 대한 관측 연구를 수행하고 있다. 조규현 박사는 연구재단의 지원을 받아, 3분 진동의 진원 위치를 활용한 흑점 구조 연구를 수행하고 있다. 이경선 박사는 극자외선 분광 우주관측 자료와 광학/근적외선 분광 지상 관측 자료를 결합하여 태양 코로나와 채층의 연결을 연구하고 있다. 곽한나 학생은 충동적 사건에 의한 진동 및 파동의 발전에 관한 관측 연구를, 김다나 학생은 시선속도 측정에 필요한 분광선 생성 높이 결정에 대한 연구를, 강수

상 학생은 FISS 자료를 이용한 코로나 및 채층 가열에 대한 기초 연구를 수행하고 있다.

임명신 회원은 한국연구재단 리더연구자사업(창의적 연구)인 초기우주천체연구단을 이끌면서 퀘이사, 원시은하단, 타원은하, 중력파천체, 감마선 폭발, 초신성 등 다양한 주제에 관한 연구를 수행하였다. 연구단에서 수행 중인 Infrared Medium-deep Survey 자료를 바탕으로 김재우, 이성국, 현민희, 백인수, 박보미 회원 등과 함께 원시은하단 및 초은하단 후보들을, 김용정, 신수현 회원과 함께 초기우주 퀘이사 후보들에 대한 선별 및 분광관측 확인 연구를 진행하여 어두운 초기우주 퀘이사를 다수 발견하는 데 성공하였다. 적색이동 5에 위치한 희미한 퀘이사 약 50개를 분광관측 및 중대역 필터관측을 통해 발견하는 데 성공하였으며, 이를 통해 초기우주 재이온화에 대한 퀘이사의 기여도가 그다지 높지 않다는 사실을 밝혀냈다. 또한, 적색이동 6에 있는 퀘이사의 모은하를 ALMA와 JCMT를 이용하여 submm 파장에서 관측하여, 이 은하의 별 형성이 100 Msun/yr 이상으로 매우 활발함을 알아냈으며, 이를 통해 초기우주 퀘이사 진화 과정이 가까운 우주 퀘이사의 진화와 다르다는 사실을 제시하였다. 그 외에도 김도형, 김민진 회원과 붉은 은하 중심부의 Gemini GMOS-IFU 관측을 수행하여 250pc 정도로 매우 근접한 쌍 AGN이 있다는 가능성을 제시하였다. 그리고 탁윤찬 회원과 함께 미래 서베이에서 발견될 퀘이사 및 은하 중력렌즈 시스템의 수에 대한 예측치를 구하여 렌즈통계로부터 은하-블랙홀 공진화 가정을 이해할 수 있음을 보였다. 윤용민 회원과는 은하의 막대구조가 은하단과 은하단 사이의 상호작용을 통해 만들어질 수 있음에 대한 최초의 관측증거를 제시하였고, 이 결과는 Nature Astronomy에 출판되었다. 김준호 회원, 황성용, 탁윤찬 회원 등과 함께 중대역 필터를 활용한 reverberation mapping 연구를 가까운 AGN에 대하여 수행하여 이러한 연구에 대한 중대역 필터의 유용성을 검증하였다. 또한 최창수 회원, 임구 회원, 김소피아 회원, 백승학 회원 등과 함께 이상각 망원경의 SNUCAM-II, 미국의 0.8 m 망원경, 레몬산 1 m 망원경, 우리나라 소백산 천문대 0.6 m 망원경, 덕흥천문대 1 m 망원경, 우즈베키스탄 1.5 m 망원경 등을 이용하여 가까운 은하의 monitoring 관측 연구를 수행하였다. Intensive Monitoring Survey of Nearby Galaxies(IMSNG)라고 명명된 이 연구는 초신성 폭발 순간의 light curve를 확보하여 초신성 원형별의 특성을 규명하기 위한 연구이며, 2019년도에도 monitoring 대상 60개 은하 중 여러 개의 은하에서 초신성 폭발이 발생하였다. 현재 이에 대한 분석 연구를 진행 중이다. 임명신 회원은 최창수, 임구, 김준호, 김소피아, 황성용, 백승학 회원 등과 함께 중력파 천체 후속 관측을 위한 관측을 LIGO O3 run 동안 수행하였다. 임명신 회원은 2019년 동안 한국천문학회 광학천문분과 위원장, 한국천문올림피아드 위원, 한국천문학회 이사, K-GMT 과학박사 준비위원, K-GMT 과학자문위원회 위원, 서울대학교 천문학과 시설위원회 위원장, Gemini Time-domain survey working group 위원으로 활동하였다.

김용태 회원은 은하 원반과 행성 원반의 역학적 진화에 대한 연

구를 계속하고 있다. 김용태 회원은 김정규 회원과 Ostriker 교수(Princeton)와 함께 수치실험으로 별탄생 영역에서 자외선의 탈출 확률을 추정할 수 있는 방법을 제시하였으며, 김창구 회원과 Ostriker 교수와 함께 나선팔과 자기장이 은하의 별형성률과 깃털 구조 형성에 미치는 영향을 연구하였다. 광성원 회원과 함께 은하단에 있는 초기형 왜소은하의 막대와 나선팔이 은하단 조석력이나 은하간 상호작용에 의해 생성될 수 있음을 보였으며, 윤한결 회원(석박사통합과정), 배재한, 한정호 회원과 함께, 행성과 원시행성 원반의 중력 상호작용에 대해 연구하였다. Hsieh 박사 등과 함께 우리은하 중심부에 있는 핵주변원반(circumnuclear disk) 안쪽의 필라멘트 구조에 대해 연구하였으며, 한정호 회원 등과 함께 미세 중력렌즈를 이용하여 행성의 물리량을 탐사하였다. 김용태 회원은 현재 문상혁 회원(석박사통합과정)과 함께 막대 은하 중심부에서 일어나는 별 형성에 대한 연구를, 윤한결 회원(석박사통합과정)과 함께 원시행성원반의 부력공명불안정(buoyancy resonance instability)에 대한 연구를, 염동력 회원(석박사통합과정)과 함께 젊은 별이 방출하는 복사압이 기체의 유착(accretion)에 미치는 영향에 대한 연구를, 이가인 회원(석사과정)과 함께 원시행성원반의 중력불안정에 대한 연구를 수행하고 있다.

이정훈 회원은 2019년 두 편의 단독저자 논문을 천체물리저널과 천체물리저널레터에 발표하였고 영국 에딘버러에서 열린 우주론 워크숍에서 초청강연을 했다. 이정훈 회원의 주요 연구 업적은 다음과 같다. 우주웹에 놓인 은하들 형태와 각운동량 방향의 정렬 현상에 대한 새로운 통합 해석적 공식을 유도 그리고 수치분석을 통해 은하단 바운드 존에 존재하는 은하들의 접선 방향 속도에 미치는 거대 조석장 효과와 조석장 주요축 방향의 서로 다른 스케일에서 상관관계가 은하단 성장에 미치는 영향력을 규명하였다.

우종학 회원은 석박사 학생 및 박사후 연구원과 함께 (1) 다수의 광학 관측시설을 사용하여 측광 분광 관측하는 SNU AGN Monitoring Project 를 5년째 진행하고 있으며 (2) AGN의 가스 분출 연구로 은하의 별생성과 AGN feedback을 연구하는 장기 연구를 수행 중이며 대형망원경을 이용한 집합필드 분광 관측과 SDSS자료를 이용한 통계적 연구를 병행하고 있다. (3) 은하의 별 생성률을 측정하기 위해 JCMT관측으로 sub-mm 플럭스를 측정하여 적외선SED 분포에서 별 생성률을 결정하는 연구를 진행 중이다.

윤성철 회원은 초신성 모체성의 성질 및 진화, 초신성의 광도 곡선 및 스펙트럼 모델, 중원소 함량비가 낮은 별의 고분산 관측 연구 등을 진행하고 있다. 그룹의 정무건 회원은 Ib/Ic형 초신성 모체성인 헬륨성 혹은 볼프레이에 별들의 non-LTE 대기 모델을 다수 건설하였다. 이를 통해 초신성 모체성의 광학적 성질(가시광선에서의 밝기, 표면 온도, 색지수)을 예측함과 동시에 관측 결과와 비교하는 연구를 수행 중이다. 정용제 회원은 항성진화 모델을 이용해 IIb형 초신성 모체성의 모델 그리드를 구성 중이며 IIb형 초신성 모체성의 다양성 및, 표면의 물리적, 화학적 성질에 따른

내부 구조의 변화를 조직적으로 분석하고 있다. 진하림 회원은 기존에 관측된 Ib형 초신성과 Ic형 초신성의 색지수가 조직적으로 차이가 난다는 사실을 발견하였고, 초신성 광도곡선 모델을 다수 계산하여 관측을 설명할 수 있는 여러 가지 시나리오들을 구성 중에 있다. 박성현 회원은 IIb형 초신성의 광도 곡선을 계산할 때 광자의 thermalisation 효과의 고려 여부에 따라 광도 곡선의 예측에 커다란 차이가 남을 발견하였다. 이는 초신성 광도곡선으로부터 IIb형 초신성 모델의 구조를 추정하는 기존의 연구에 커다란 결함이 있었음을 암시하고 있기에 기존에 합의된 연구를 재조명하는 작업을 진행 중에 있다. 이현철 회원은 무거운 별의 쌍성계 진화 연구를 진행 중이며, 그 중에서도 특히 Case A system 진화가 예측하는 초신성 모델의 다양성을 탐색하고 있다. 특히 쌍성계에서 발생하는 '진화 역전' 현상이 만들어 낼 수 있는 특이 형태 초신성의 가능성을 살펴보고 있다. 장혜은 회원은 GEMINI로 관측한 마그네슘 함량이 높은 별들의 분광 관측 결과를 이론적 모델의 예측과 비교하는 연구를 수행 중이다. 아울러 해외의 초신성 연구자들과 공동 연구를 통해, 1) 추후 관측에서 비교가 용이하도록 Ib/Ic 초신성 스펙트럼의 표준 모델을 제시하였고, 2) Ca-rich 초신성인 SN 2019ehk의 관측 분석, 3) Ic형 초신성인 SN2020oi와 SN2020bvc의 관측 분석 연구를 수행하였다.

Masateru Ishgiuro 회원의 연구팀은 태양계의 기원과 진화를 조사하기 위해 현존하는 태양계 원시 천체 연구에 힘써 왔다. 권유나 (Yuan Kwon) 회원이 중심이 되어 실시한 연구에서는 근지구 혜성 252P/LINEAR를 남아프리카 천문대 IRSF 망원경을 이용하여 근적외선 파장 영역에서 편광 촬영해, 편광도의 시간 변화로부터 방출되는 먼지 입자의 물리 특성을 조사했다. 이 연구 결과는 Astronomy & Astrophysics에 게재되었다. 박윤수(Yoonsoo P. Bach) 회원이 중심이 되어 한국천문연구원 연구자들과 공동으로 실시한 연구에서는 소행성 Toutatis를 충 부근에서 KMTNet을 이용한 측광 관측을 하고, 그 형상 모델을 고려해 절대 등급을 도출하여 반사율과 표토 입자의 사이즈를 결정했다. 또한, 본 연구그룹은 Hayabusa2 탐사 프로젝트에 참가해, 그 초기 과학 성과로서 Science에 출판된 논문에도 공저자로서 공헌하였다. 위에 소개된 출판된 연구에 덧붙여, 진선호(Sunho Jin) 회원은 삼색 동시 편광 촬영 장치 TRIPOL의 성능 평가에, 김주연(Jooyeon Kim) 회원은 고갈된 혜성의 편광 특성의 관측적 연구에, 조항빈(Hangbin Jo) 회원은 근태양 천체로부터 방출된 먼지의 궤도 진화에 관한 연구에 참여했다.

Prof. Sascha Trippe's group at Seoul National University studies the properties of the jets of active galactic nuclei, especially blazars. The group currently comprises five graduate students. They perform radio astronomical observations using data from various radio telescopes and interferometers, including KVN, KaVA, VLBA, and ALMA. The group is part of the East Asia VLBI Network and Event Horizon Telescope collaborations, and

part of the BK21+ program. Key results in 2019 were:

- The EHT Collaboration released the first image ever obtained of the photon ring around a black hole. Based on radio interferometric EHT observations obtained in 2017, it was possible to construct a map of the "black hole shadow", i.e. a photon ring with a central obscuration, of the supermassive black hole in the center of M 87. The morphology of the photon ring agrees with the predictions of general relativity. The radius of the photon ring translates into a black hole mass of about 6.5 billion solar masses, in agreement with previous measurements based on stellar dynamics, but inconsistent with previous measurements based on gas dynamics. As a member of the EHT Collaboration, Prof. Trippe received a share of the 2020 Breakthrough Prize in Fundamental Physics.

- We studied the jet kinematics of the flat spectrum radio quasar (FSRQ) 4C+21.35 using time-resolved KaVA very long baseline interferometry array radio maps obtained from 2014 September to 2016 July. During two out of three observing campaigns, observations were performed bi-weekly at 22 and 43 GHz quasi-simultaneously. At 22 GHz, we identified three jet components near the core with apparent speeds up to $(14.4 \pm 2.1)c$. The timing of the ejection of a new component detected in 2016 is consistent with a gamma-ray flare in 2014 November. At 43 GHz, we found four inner jet (< 3 mas) components with speeds from $(3.5 \pm 1.4)c$ to $(6.8 \pm 1.5)c$. Jet component speeds tend to be higher with increasing distances from the core. The flux densities of jet components decay exponentially, in agreement with a synchrotron cooling time-scale of c. 1 yr. Using known electron Lorentz factor values (around 9000), we estimate the magnetic field strength to be about 1-3 microT. When adopting a jet viewing angle of 5 degrees, the intrinsic jet speed is of order $0.99c$.

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세종대학교 천문우주학과

1. 인적 사항

세종대학교 물리천문학부에는 천문학을 전공하는 전임 교수로 성환경, 이희원, 이재우, 채규현, 김성은, M. van Putten, G. Rossi, 오세현 회원이 재직하고 있으며 2020학년도 2학기에 Jeffrey Hodgson 교수가 부임하였다. 2020년 1학기에 김학섭 박사가 연구원으로 재직하고 있다. 2019년 8월에 Papakew Rittipruk 회원이 박사 학위를 받았고, 2020년 8월에 최두현 회원이 박사 학위를 받았으며 2019년 8월에 남승현 회원이 석사 학위를 취득하였다. 박사과정에는 공인택, 이경민 회원이 석·박 통합과정에는 장석준, 이영민 회원이, 석사과정에는 최보은, 김슬기, 김미경, 박혜진, 김신나, 김신정 회원이 재학하고 있다.

2. 연구 및 학술활동

성환경 회원은 고은위에 있는 작은 별 생성영역인 MBM 110의 연구를 마치고, 그 결과를 영국 왕립천문학회지에 게재하였다. MBM 110의 연구에서는 보현산천문대의 긴슬릿분광기 등의 중분산 분광관측자료와 측광, 측성, 중적외선 관측 자료를 함께 사용한 다파장 연구를 통해, MBM 110과 같은 소규모 별생성 영역에 있는 젊은 별들의 특성을 연구하였고, 또 MBM 110과 같은 소규모 별생성 영역이 은하전체의 별 생성활동에 기여하는 바를 검토하였다. SSO 1 m 망원경 관측자료와 CTIO 4m MOSAIC II 관측자료를 바탕으로 남승현 회원과 함께 독수리 성운에 있는 젊은 산개성단 NGC 6611의 측광연구를 수행하였고, Maiadanak 천문대 1.5 m 망원경, Kuiper 61인치 망원경 및 CFHT 3.6m Megaprime 관측자료를 바탕으로 김슬기 회원과 함께 젊은 산개성단 IC 1590

(NGC 281)에 대한 연구를 진행하고 있다. 한편 김슬기 회원은 기존의 측광도구인 IRAF/DAOPHOT이 아닌 source extractor를 사용하여 모자이크 CCD 영상자료인 Megaprime 영상자료를 측광하였다.

2019년 9월부터는 6개월간의 연구년으로 터키 이스탄불대학교 천문우주학과에서 방문연구자로 체류하며 터키 천문학자들과 교류하고 또 공동연구를 시작하였다. 터키에 체류하는 동안 10월 말에는 터키 국립천문대의 1.5 m 망원경을 사용하여 관측을 수행하였고, 이스탄불대학교 및 Erciyes 대학교 천문우주학과에서 현재 진행하고 있는 장기 연구과제인 세종 산개성단 전천탐사관측에 대한 콜로퀴움을 하였다. 약 170개 젊은 산개성단의 측광자료를 분석하여 일부 젊은 산개성단에서 보이는 특이 소광법칙에 대한 연구를 수행하였고, 현재 이를 마무리하고자 박차를 가하고 있다. 연구년 동안 국외에 체류하는 관계로, 그 동안 맡고 있던 IAUGA 2020 조직위원회 재정위원장 직을 사임하였다.

석사과정의 남승현 회원은 “젊은 산개성단 NGC 6611의 측광 연구”로 2019년 8월에 석사학위를 취득하였고, 석사과정의 김슬기 회원은 석사논문 연구로 젊은 산개성단 IC 1590의 측광연구를 수행하고 있다.

이희원 회원은 공생별과 어린 행성상성운에서 질량 손실 및 질량 이동 과정과 초기 우주의 라이먼 알파 방출 천체와 활동성은하에서 복사 전달을 연구하고 있다. 이희원 회원은 2015년 6월부터 칠레 University of La Serena에 재직 중인 Rodolfo Angeloni 교수, Las Campanas Observatory에 재직 중인 Francesco Di Mille 박사, National University of Cordoba에 재직 중인 Tali Palma 교수와 함께 한국-칠레 협력 연구 사업을 추진하였으며, 2018년 1월부터 2기 한-칠레 협력 연구를 이어가고 있다. 이희원 회원은 장석준 회원, 이영민 회원, 최보은 회원과 김미경 회원을 지도하고 있다. 이영민 회원은 공생별에서 O VI 원자외선의 라만산란의 복사 전달 과정에 대한 연구 결과를 2019년 8월에 MNRAS에 출판하였다. O VI 라만산란선은 공생별의 accretion flow에 대한 풍부한 정보를 갖고 있으며, 이영민 회원은 선운곽을 설명하는 Monte Carlo 복사 전달 연구로부터 accretion flow의 비대칭성을 정량화하였다. 이영민 회원은 한국천문연구원의 김효선 회원의 지도를 받으면서 FLASH 코드를 사용하여 공생별에서 강착원반 형성 과정의 유체역학 연구를 수행하고 있다. 장석준 회원은 초기 우주의 라이먼 알파 방출 천체에서 라이먼 알파선의 복사전달을 한국천문연구원의 양유진 박사와 선평일 박사, Arizona 대학의 Zabludoff 교수와 함께 연구하고 있으며, 수소 원자의 정확한 산란단면적 계산을 적용하여 초기 우주의 재이온화 과정과 관련된 복사 전달 연구를 수행하고 있다. 장석준 회원은 grid-based Monte Carlo기법의 복사 전달을 기술하는 ‘Sejong Radiative Transfer through Raman and Rayleigh Scattering (STaRS)’ 코드를 개발하여 <http://github.com/csi607/STaRS>에 공개하였다. 석사 과정의 최보은 회원은 STaRS를 사용하여 라만 He II 산란선의 원자물리학적 성질과 후퇴하는 수소 지역에서 형성 과정을 연구하고 있으며, 팽창하는 중성 수소 지역에서 라만 He II의 선

운곽은 extended red tail structure와 secondary 혹은 tertiary peak의 형성과 같은 다양한 현상이 나타날 수 있다는 새로운 사실을 밝히고 2020년 봄에 Astrophysical Journal에 연구 결과를 출판하였다. 최보은 회원은 BOES 고분산 분광 관측으로부터 NGC 6886과 NGC 6881에 Raman-scattered He II 6545 feature를 발견하였으며 논문 발표를 준비하고 있다. 석사 과정에 재학 중인 김미경 회원은 행성상성운의 광이온화 모델을 연구하고 있으며 Raman He II 형성이 가능한 조건을 규정하여 향후 Raman He II survey에 활용할 관측 전략 수립의 토대를 이룰 것으로 기대된다. 김미경 회원은 2019년에 페임랩 코리아 본선에 진출하였으며, 과기정통부와 한국과학창의재단이 위촉하는 과학 커뮤니케이터로 임명되어 학교 방문 과학 강연, 과학 글쓰기를 포함하여 천문학 분야의 과학 확산 활동을 활발히 수행하고 있다.

이재우 회원은 지난 10년간 칠레의 세로토롤로 미국립천문대 망원경을 이용한 남반구 구상성단 확장 스트렙그렌 협대역 측광 전천 탐사 관측을 종료하였으며, 2017년 WTYN cosortium의 공식 파트너로 참가하여 북반구 구상성단에 대한 가시광 전천 탐사 관측을 새로이 시작하였다. 이재우회원은 "JWL 측광계"를 확립하였는데, 이는 이재우회원이 기존에 수행하였던 CaII H&K를 포함하는 확장 스트렙그렌 측광계와 이재우회원이 세계 최초로 고안한 JWL34, JWL39, JWL43 필터시스템을 포함한다. JWL34, JWL39, JWL43 필터는 각각 NH λ 3360Å, CN λ 3883Å, 그리고 CH λ 4300Å 분자대 흡수선의 세기를 측정한다. 이재우회원은 스펙트럼합성 방법을 이용하여 합성측광인자들을 계산하였으며, 중급속 함량 이외에 정밀한 탄소와 질소의 함량을 측광학적으로 도출할 수 있다. 이재우회원이 개발한 측광인자들은 허블우주망원경으로부터 얻은 결과들보다 우수하며, 구상성단 거성계에 대한 완전한 다중종족 샘플을 확보할 수 있다.

이재우회원은 2019년 "적외선 JWL 측광계"를 새로이 개발하였다. JWL1.1과 JWL2.5는 각각 CN λ 1.1 μ m와 CO λ 2.5 μ m 분자대 흡수선 세기를 측정하며, 가시광선 JWL측광계와 함께 사용하여 탄소, 질소 이외에 산소함량을 측광학적으로 측정할 수 있다. 세종대에 합류한 김학섭회원 및 천문연구원의 성현일, 문봉곤, 차상목 회원들과 함께 2020년 6월부터 보현산 천문대의 KASINICS 적외선 망원경을 이용한 pilot 프로그램을 시작하였으며, 새로운 관측자료를 사용하여 구상성단 다중종족의 기원 및 진화를 이해하는데 가장 중요한 CNO 함량을 측정할 것으로 기대한다.

이재우 회원은 2020년 1월부터 미국 텍사스 오스틴 대학의 천문학과를 1년간 장기 방문하여 Christopher Sneden 교수와 함께 구상성단 및 산개성단에 대한 가시광/적외선 고분산 분광학 연구를 수행하고 있다. 기획되었던 IGRINS 적외선 고분산 분광자료 이외에 McDonald천문대 2.7 m 망원경을 사용한 가시광 고분산 분광자료를 획득하여 구상성단 및 산개성단의 CNO 함량과 탄소 동위원소비 12C/13C에 대한 체계적인 연구를 수행하고 있다.

김성은 회원과 세종대학교 테라헤르츠 및 전파천문 연구실은 남극망원경으로 관측된 은하단 중 10개의 은하단들의 21 cm 연

속파 관측 및 X-선 방출과의 상관관계에 대해 하버드 스미소니언 천체물리연구소 연구원과 공동 연구를 수행해 왔으며, 이에 대한 팔로우업 관측 제안서를 준비해왔다.

채규현 회원은 은하역학을 통한 암흑물질과 중력의 문제를 연구하고 있다. 해외공동연구를 통해서 연구를 수행하고 있다. 2019년 가을에 독일에서 개최된 Bonn Gravity 워크숍과 미국 시카고 대학에서 개최된 Cosmic Controversies 컨퍼런스에 참석하여 관련 연구를 발표하였다. 또한, 타원형은하 IFU데이터에 기초한 국제공동연구를 위해 펜실베이니아대학의 M. Bernardi, R. Sheth 교수 그룹을 방문하였다

반푸텐 회원은 중력파, 우주론 및 외계 행성계 연구를 수행하고 있으며 KAGRA, THESEUS, LISA/ESA, CHEA/UNIST의 멤버로 활동하고 있다. 반푸텐 회원은 중력파 관측 자료로부터 unmodeled gravitational wave signal을 탐색하는 새로운 방법을 제시하여 post-merger emission의 성공적인 탐색을 시도하고 있다. 반푸텐 회원은 GW170817의 post-merger의 extended emission 관측을 보고하였으며 태양 질량의 약 3.5 퍼센트의 에너지 방출을 제안하였다. 이 연구 결과는 2019년에 Gerard 't Hooft 교수가 주관하는 Nico van Kampen Colloquium에서 발표되었다. 이러한 연구 결과는 0.5 Pflops/s의 성능을 자랑하는 GPU와 local area network에서 synaptic load balancing이 이루어지는 수치 계산 설비에서 이루어졌다. 반푸텐 회원은 2020년 MNRAS Letters에 출판한 우주 팽창률에 대한 새로운 연구 결과를 AAS234 Press Conference에서 발표하였다. 현재 중요한 이슈로 활발히 논의되고 있는 Lambda CDM과 Local distance ladder 사이에서 나타나는 9.4 퍼센트의 H0 tension에 대한 해법을 제시하였다. THESEUS를 포함하여 앞으로 수행될 적색이동이 큰 우주에의 Hubble parameter의 측정으로부터 이 연구 결과가 검증될 것이 기대된다. 반푸텐 회원은 박사 과정의 이경민 회원과 나선 은하의 회전 곡선 관련 연구를 수행하고 있다.

로시 회원은 2019년과 2020년에 G. Rossi 교수는 SDSS-IV, numerical 우주론 그리고 암흑영역에 주로 집중해서 은하 및 퀘이사 클러스터링을 연구해왔다. 특히, 다양한 우주론적이고 천체물리학적 변수들을 아우르는 고해상도의 유체역학 시뮬레이션인 'Sejong Suite'(Rossi 2020)를 발표했는데, 이는 주로 Lyman-Alphaforest를 모델링하기 위해 개발되었다. 이 시뮬레이션은 국가슈퍼컴퓨팅센터(KISTI)의 노드들을 9달 동안 이용해서 개발되었고, 과학 커뮤니티에서 사용 가능하도록 했다. 이것에 더해서, 2020년 7월, SDSS-IV eBOSS 연구단과함께 그는 이제껏 만들어진 것들 중 가장 큰 3차원 우주 지도에 대한 폭넓은 연구 분석 결과를 발표했고, 그것은 우리의 우주 탐사 역사상 가장 큰 공백을 채운다. - 이는 합동논문에서 두드러지게 나타난다(eBOSS Collaboration et al. 2020). 이것은 주목할만한 전례 없는 업적이었고, 상당한 언론 보도들과 함께우리의 우주 탐사에 있어서 중요한 진보를 의미했다. 최종 지도는 사실상 SloanFoundation 망원경을 사용하여 20

년 이상 우주 지도를 제작한노력이 포함된 것이다. 최종 eBOSS 결과들은 23개의 메인 발표들에 나타나있다.

G. Rossi 교수가 이끈 세종대학교 우주론 연구실은 최종 발표에 깊게 연관되어있고, mock challenge를 개발함으로써 은하 클러스터링 분석에 기여했다. 이 시기에 있었던 또 다른 흥미로운 연구들은 우주 거대 구조에서 원시 non-Gaussianity에 대한 가장 타이트한 제한을 거는 beta-skeleton(Fang et al. 2019), Lyman-Alpha forest에 대한 첫 eBOSS 단층 지도(Ravoux et al. 2020; Chabanier et al. 2019), 그리고 우주 보이드에 대한 연구들이 있었다. 2020년 6월에 그의 박사 과정 학생이었던 최두현 학생이 SDSS-IV eBOSS의 더 높은 차원에서의 클러스터링과 mock challenge에 관한 논문으로 성공적으로 졸업을 했다. G. Rossi 교수는 SDSS-IV eBOSS 시뮬레이션 연구 그룹을 이끌어왔고, 미국 국가 에너지 연구 과학 컴퓨팅 센터(NERSC)의 컴퓨팅 장비들을 관리해왔다. 2019년과 2020년에 그는 NERSC에서 꾸준한 컴퓨팅 시간을 배당받았고, 한국연구재단(KNRF)에서 새로운 지원을 받게 되었다. 또한, 그는 DESI의 speakers board의 대표로도 활동하고 있다. 2020년에 그는 eBOSS를 위한 NERSC 컴퓨팅 장비들 관리, eBOSS 시뮬레이션 연구 그룹을 이끈 것, 그리고 2018년 콜라보레이션 학회 주최에 특히 기여해 SDSS-IV Architect status를 수상했다. 2019년에 그는 Rencontres du Vietnam 2019 - Cosmology에서 과학 프로그램 위원회 회원이었다. 2019년에서 2020년 동안, 그는 그의 연구 결과들을 여러 국내외 학회들에서 발표하고, 14개의 콜로퀴움과 세미나(특히 2020년 1월 하와이 호놀룰루에서 열린 AAS eBOSS관련 세션)에 연사로 초청받았다. 그는 또한 주한 이탈리아 대사관의 기술 과학 위원회(CTS)를 위해 특히 과학 기술 분야의 젊은 연구자들을 위한 제안서 선정을 위해(이탈리아-한국 상호 협동) 수많은 리뷰들을 해왔다. 그는 많은 외부 활동들을 하였는데, 그중에서도 그는 이탈리아 Science and Technology Counsellor가 주최한 'Taste of Science' 시리즈의 첫 학회에서 'Back to the Future: Black Holes and The Arrow of Time'라는 제목의 공개 강연을 했고, 주한 이탈리아 대사관의 후원을 받았다. 그는 또한 최근에 많은 기사들에서 모습을 보이고, SBS의 일요특선 다큐멘터리 '과학 또 하나의 눈 커뮤니티'에서 갈릴레오 갈릴레이에 관한 인터뷰로 출연했다. 2020년 3월부터 G. Rossi 교수는 연구년에 있지만 코로나19로 인해 한국에 현재 머무르고 있다.

오세현 회원은 고분해능 중성수소 선 스펙트럼 관측을 통해 외부 은하들의 가스 동역학이 성간물질의 구조와 은하 내 물질분포 및 별 생성에 미치는 영향과, 궁극적으로 은하 형성과 진화 과정에서 어떤 역할을 하는지 연구하고 있다. 이를 위해, 호주와 남아프리카공화국에서 현재 운용 중인, Square Kilometre Array(SKA) Pathfinders(ASKAP-호주, MeerKAT-남아프리카 공화국)를 사용한 고분해능 외부 은하 중성수소 관측 프로젝트들(WALLABY, MHONGOOSE 등)에 참여해오고 있다. 이러한 고감도/고분해능 외부 은하 중성수소 관측들은 sub-kpc 스케일에서, 성간물질들의 형태학적/운동학적 구조, 별 생성 조건 및 은하 내 물질분포에 대

한 새로운 정보와 관점을 제공할 수 있을 것으로 기대된다. 오세현 회원은 호주의 ASKAP 전파 간섭계를 사용한 남반구 외부 은하 중성수소 전천탐사 프로젝트인 WALLABY(Local Universe에 위치하는 외부 은하들에 대한 과학 연구) 본과의 공동의장을 맡아오고 있다. 이와 함께 WALLABY로부터 얻어지는 수만여개 외부 은하들의 가스 동역학 분석을 위해 베이지안 통계분석 기법을 사용한 3차원 전파데이터 분석 알고리즘과 소프트웨어(2DBAT, BAYGAUD)를 개발하였다. 이들 소프트웨어는 ASKAP 관측으로부터 얻어지는 외부 은하들의 가스 동역학 및 성간물질 구조 분석에 사용될 예정이며 ASKAP 초기 관측 데이터를 사용하여 테스트 중이다. 오세현 회원은 현재 3명의 대학원생 연구원들과 함께 1) Local Universe에 위치하는 왜소 은하 NGC 6822의 가스 동역학 및 별 생성 연구(박혜진), 2) 3개의 은하단들(Hydra cluster, Norma cluster, NGC 4636)에 대한 ASKAP WALLABY 초기 관측 데이터 분석을 통해 은하단의 환경이 은하들의 가스 동역학과 별 생성에 미치는 영향 연구(김신정) 및, 3) 3차원 가스 속도 프로파일 분석 기법을 사용한 Large Magellanic Cloud의 회전 곡선 유도과 암흑 물질 분포 연구(김신나)를 수행 중이다.

3. 연구 및 교육시설

세종대학교가 교육과 연구 목적으로 보유하고 있는 관측시설은 곤지암에 설치된 76 cm 반사망원경과 40 cm 반사망원경이 있으며, 캠퍼스에 여러 소형 망원경을 관측실습 및 공개 행사에 사용하고 있다.

세종대학교 물리천문학과는 외국의 천문대 공동운영에도 참여하고 있다. 이재우 회원은 Wtyn Consortium의 공식 파트너로 참여하여 Wtyn 0.9 m 천문대의 공동 운영 및 관측 장비를 이용한 구상성단 다중종족에 대한 연구를 수행하고 있다. 반푸텐 회원은 중력파 관측 프로젝트인 KAGRA의 멤버로서 중력파 관측 자료를 이용한 연구를 수행하고 있다. 로시 회원은 슬론 디지털 전천탐사(SDSS)의 파트너로 참여하여 대규모 관측자료를 이용한 우주론 연구를 수행하고 있다.

학부학생들의 관측실습은 교내 영실관 옥탑의 간이관측소에 설치되어 있는 11인치 반사망원경 및 다수의 소형 굴절망원경을 이용하고 있다. 또 SRT 소형 전파망원경으로 사용하여 전파관측 실습을 하고 있다. 학생들의 컴퓨터 교육을 위해 천문계산실에 총 18대의 PC를 구비하고 있으며, Linux/Windows 운영환경을 제공하고 있다. 학부생의 취미 및 장래 진로를 위해 학과 내에 천문 관측동아리 AJA와 컴퓨터 프로그래밍 동아리 ASC가 학생들의 자발적인 활동으로 활발하게 유지·운영이 되고 있으며, 졸업생의 취업에 많은 기여를 하고 있다.

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연세대학교 천문우주학과

1. 인적사항

본 학과의 교수진은 2020년 9월 현재, 12명의 교수(이영욱, 변용익, 김용철, 김석환, 박상영, 손영중, 윤석진, 이석영, 정애리, 박찬덕, 지명국, 김태선)와 3명의 명예교수(나일성, 천문석, 최규홍)로 구성되어 있다. 학부와 대학원은 박사 후 전문 연구원 8명, 대학원 석박사 통합과정 31명, 박사과정 24명, 석사과정 18명, 그리고 학부생 130여 명으로 구성되어 있다. 학부 1학년 신입생들은 연세대학교의 정책에 따라 송도의 국제캠퍼스에서 1년간 기숙사 생활을 하면서 Residential College 교육을 받고 있다.

학과 교수진의 활동을 요약하면 다음과 같다. 이영욱 교수는 한국연구재단 선도연구센터육성사업(SRC)의 지원으로 연세대 교핵 연구소로 설립된 은하진화연구센터의 센터장직을 수행하고 있다. 변용익 교수는 천문우주학과 대학원주임으로서 갈수록 중요성이 커지는 대학원의 업무 선진화/효율화에 많은 노력을 기울이고 있다. 김용철 교수는 2020년 3월부터 2년 임기로 연세대학교 학술

정보원장직을 수행하고 있다. 박상영 교수는 한국우주과학회 이사와 한국항공우주학회 평의원으로 활동하고 있다. 손영중 교수는 연세대학교 광과학학과 주임교수와 한국우주과학회 포상위원으로 활동하고 있다. 윤석진 교수는 한국천문학회 IAU GA 2021 유치위원회 위원, 운영위원회 위원을 거쳐 현재 조직위원회 위원으로 활동하고 있다. 이석영 교수는 천문학회 이사, 천문학회지와 천문학 논총의 편집위원으로 활동하고 있으며, 2020년 9월부터 1년 6개월 임기로 연세대학교 천문대장직을 수행하고 있다. 정애리 교수는 한국천문학회 IAU GA 2021 유치활동과 함께, 학술위원회 위원으로 활동하고 있다.

본 학과는 역량있는 천문우주학 전공 박사들을 배출해내는 교육기관의 책임을 다하고 있으며, 2019년 8월에는 이범현 회원과 윤혜인 회원(지도교수 정애리)이, 2020년 2월에는 강이정 회원(지도교수 이영욱)이, 2020년 8월에는 홍진석 회원(지도교수 김석환)이 박사학위를 받았다. 또한, 본 학과에는 학과 및 천문대 소속의 박사 후 연구원(Dr. Cristiano Sabiu, 송현미, 윤미진, 홍종석)과 5명의 연구교수(Dr. Benjamin L'Huilier, Dr. Sanjaya Paudel, 박기훈, 정철, 조혜진)가 활발한 연구 활동을 펼치고 있다.

2. 연구 및 학술 활동

이영욱 교수는 초신성우주론에서 광도진화와 감속팽창의 강력한 증거를 발견하고 현재 노벨상 수상자들을 포함한 국제학계와 치열한 논쟁을 펼치고 있다. 강이정(제미니 천문대), 김영로(프랑스 CNRS), 정철 회원과 함께 초기형 호스트은하의 분광관측, Ia 초신성의 광도 표준화 분석 및 호스트은하의 항성종족 나이측정을 수행하여 광도진화의 증거를 최초로 포착하였고, 지난 1월 ApJ에 결과를 게재하였다. 최근에는 정철 회원과 함께 이 연구 결과를 반박하는 미국 연구진의 논문에서 심각한 오류를 발견하였고, 이로 부터 연구팀의 결과를 더욱 강력하게(99.99%) 지지하는 광도진화의 증거를 모든 종류의 호스트은하에서 발견하였다. 이 결과는 ApJ에 게재 예정이며, 광도진화효과를 보정할 경우 초신성우주론은 가속팽창이 아닌 감속팽창을 강력히 지지하는 결과를 보여준다. 또한, 정철, 박승현, 손준혁 회원과 함께 Ia 초신성의 광도 표준화 문제, 다양한 적색편이 구간에 있는 호스트은하의 측광학적 항성종족 나이 측정 등 여러 후속 연구를 수행하고 있다. 우리은하 별지의 구조와 형성기원에 대해서도 2015년 연구팀이 새롭게 제시한 구상성단 및 clump 기원 이론에 대해 국제학계와 논쟁을 계속 진행하고 있다. 이를 위해 임동욱(독일 하이델베르그대학), 홍승수, 박승현 회원과 함께 우리은하 별지 red clump 항성들의 마젤란 고해상도/제미니 저해상도 분광관측 및 분석을 수행 중이며 이를 통해 연구팀이 제시한 다중항성종족 모델의 타당성을 증명하는 관측적 증거를 계속 추가하고 있다. 장소희, 최정운 회원과는 우리은하 구상성단의 다중항성종족의 기원을 설명하는 새로운 기법으로 수평계열 및 RR Lyare 변광성의 항성진화모델링을 연구팀이 개발한 새로운 화학적진화 모델에 접목하는 연구를 성공적으로 수행하고 있다.

변용익 회원은 대만 및 미국의 협력연구자들과 함께, 카이퍼벨트 천체들의 분포를 알아내기 위한 성식 관측연구의 2단계 사업으로 초고속 대형카메라를 장착한 1.3미터 광시야망원경 3기를 멕시코 SPM 관측소에 건설 중이다. 높은 정밀도의 시계열 자료 분석을 통한 저 질량 항성들의 변광 특성을 연구하고 있으며, 소행성 및 혜성체의 광도변화와 소행성 종족 분포에 대한 연구, 우주물체 감시기술 개발 활동 등을 하고 있다.

김용철 회원은 생선 초기 항성의 내부구조와 활동성 연구, 항성 표면 복사유체 수치모사연구, 그리고 등연령곡선 제작 등의 3가지 연구를 진행하고 있다. 항성에서 관측되는 활동성(activity)의 관측 자료와 상세한 내부구조의 이론적 모형을 함께 연구하여 항성 구조와 항성 자기 활동성의 인과관계를 체계적으로 이해하고자 하는 것이 활동성 연구의 궁극적 목표이다. 박기훈 회원과 함께 수행하고 있는 항성표면 복사유체 수치모사연구는 복사와 유체의 상호작용을 고려한 항성표면 수치모사를 통해 항성대기와 분광 스펙트럼합성을 수행하고, 이로 부터 분광 자료 분석의 이론적 체계를 정립하는 것이 연구의 목표이다. 그리고 등연령곡선 연구는 다양한 개별 원소의 영향이 성단 색 등급도에 어떻게 나타나는지를 체계적으로 설명하는 연구를 수행하고 있으며, 외계 행성계의 모함성에 대한 표준 모형을 구축하는 연구는 박기훈 회원의 주도로 진행되고 있다.

김석환 회원이 운영하는 우주광학연구실은 아리조나 대학교(University of Arizona, USA)의 교수 및 연구진들과 국제적인 광 해석 기업인 Breault Research Organization과 함께 위성 광학시스템 및 대구경 광학 시스템의 성능 해석, 가공 제작, 조립, 정렬, 성능 측정과 3차원 지구 광학모델과 통합적 광선추적 기법을 사용한 외계행성관측 분야에서 다양한 공동연구들을 수행하고 있다. 그 밖에도 특별히 국방과학연구소, 한화탈레스, LIG 넥스원 등과 같은 대규모 방산 기업들을 포함하는 다양한 국내외 기업들과 긴밀한 공동연구를 수행하고 있다. 이와 같은 국제적 수준의 연구 활동을 통해 다수의 졸업생들이 해외 우수 대학에 유학에서 유학 중이거나 국내외 국책연구소 및 대기업 연구소로 활발히 진출하고 있다.

박상영 회원이 지도하는 우주비행제어 연구실(Astrodynamics and Control Lab)은 편대비행 위성의 궤도 결정 및 제어, 자세결정 및 제어, 위성 자세제어 하드웨어 시뮬레이터, 편대비행 설계 및 최적화, 상대우주항법에 관한 연구를 꾸준히 수행하고 있으며, 편대위성들의 우주항법을 검증하기 위한 하드웨어 시스템도 개발하고 발전시키고 있다. 특히, 자세대 분리형 우주망원경의 기술검증을 위하여 2기의 큐브위성(CANYVAL-X)을 개발하여 2018년 1월에 발사하였다. 2기의 큐브위성으로 우주에서 인공일식을 구현하여 태양의 코로나를 관측하는 우주미션(CANYVAL-C)을 개발하였으며, 2021년 상반기에 발사할 예정이다. 또한, 미세먼지를 모니터링하는 정보를 제공하는 MIMAN 우주미션에 필요한 초소형 위성을 개발하고 있으며, 2022년 우리나라 발사체인 누리호에 실

려 발사될 계획이다. 위성간 도킹과 랑데부 등의 근접운영 알고리즘도 개발하고 있으며, 우주감시에 필요한 정밀궤도 결정과 소행성 탐사에 대한 연구도 꾸준히 추진하고 있다. 이러한 연구성과를 바탕으로 2018년에 초소형위성센터를 설립하였으며, 교내 여러 연구실과 함께 초소형위성에 필요한 본체/탑재체/영상분석에 대한 연구를 선도적으로 진행하고 있다.

손영중 회원의 관측천문학연구실(YOAL)에서는 이소원 회원과 함께 항성 종족의 측광학적 특성으로부터 은하 내에서의 별들의 생성 시기와 은하의 진화에 대한 연구를 진행하고 있다. 이 연구를 위한 주 자료는 UKIRT 망원경 관측으로 항성의 분해가 가능한 근거리 은하들과 안드로메다 은하 시스템, 그리고 Leo Triplet 은하 시스템내의 항성 종족에 대한 근적외선 측광자료이다. 특히 이 은하들은 과거 병합을 겪었거나 현재 병합을 하고 있는 은하들로, 항성 및 항성 종족의 특성으로부터 은하 진화에 있어서 은하 병합의 영향을 추가적으로 연구 중이다. 또한, 최상호 회원은 소행성 표면 특성 분류에 관한 연구를 진행하고 있다. KMT-Net 소행성 관측 자료를 측광하여 한국천문연구원서 연구하고 있는 3차원 색 기반 분류 체계를 검증과 아직 분류되지 않은 소행성들의 표면 특성 분류를 수행하고 있다. 더불어, 최근 다양한 분야에서 활발히 응용되는 딥러닝과 머신러닝 기법을 천문학 연구에 적용하기 위한 연구도 수행중이다. 한편, 한국형 온라인 공개강좌(K-MOOC)에 '우주의 이해' 강좌를 개설하여 천문학의 대중화를 위해 힘쓰고 있다.

윤석진 회원은 (a) 한상일 회원, 김학섭 회원, 김수영 회원, 이상운 회원과 함께 Subaru 8 m 및 CTIO 4 m 망원경을 이용한 은하 및 성단의 측광과 분광 관측 연구를, (b) 정철 회원, 이상운 회원과 함께 항성진화 종족합성 이론을 이용한 Yonsei Evolutionary Population Synthesis (YEPS) 모델 개발 연구와 외부은하 성단계의 '색분포 양분이론'을 이용한 초기우주 은하형성 연대기 규명 연구를, (c) 문준성 회원, 지용배 회원, 유다솔 회원, 김명훈 회원과 함께 GALEX 우주망원경 관측자료 및 SDSS 관측자료를 이용한 은하의 Recent Star Formation History 연구와 이웃 은하의 영향에 대한 연구를, (d) 윤기운 회원, 안성호 회원, 문준성 회원, 서찬울 회원, 김지우 회원과 함께 N-body 및 Hydro Simulation을 이용한 은하군 및 은하단 역학 연구 및 Disk Warp 현상에 대한 연구를, (e) Sanjaya Paudel 박사, 문준성 회원과 함께 은하들 간의 중력적 상호작용이 은하의 Star Formation Rate과 Scaling Relations에 미치는 영향에 관한 연구를, (f) 나중삼 회원, 문준성 회원과 함께 우주론적 다체 및 유체 시뮬레이션을 이용하여 초기우주 은하형성 기본단위의 기원을 규명하는 연구, (g) 김정욱 회원과 함께 KVN과 VERA Array를 이용한 AGN 연구를 수행하고 있다.

이석영 회원이 이끄는 은하진화연구실(GEM)에서는 시뮬레이션 및 관측 자료를 활용하여 다양한 환경에서 은하의 형성과 진화에 관해 연구하고 있다. 은하형성 이론 연구로 GEM은 준해석적 은하형성 이론 코드 ySAM을 개발하였고, RAMSES 코드를 이용하여 여러 물리 현상이 포함된 우주론적 수치모사 실험(YZiCS: Yonsei

Zoom-in Cluster Simulation)을 수행하여 은하단 연구를 활발하게 진행하고 있다. GEM은 주로 이론적 연구에 주력하고 있지만, 은하단 규모에 대한 깊은 광학관측 또한 수행하여 이론모형을 검증하는 노력도 기울이고 있다. AGN 연구로는, Broad Line Region AGN과 환경효과와 통일이론의 검증을 중점적으로 연구하고 있다.

정애리 회원은 Interstellar Medium and Galaxy Evolution (IM&GE)의 구성원들과 함께 성간물질과 은하진화의 상관관계를 규명하기 위한 다양한 연구를 수행 중이다. ALMA 및 JVLA 자료를 이용하여 성간 가스의 비율이 매우 높은 은하의 특성으로부터 은하의 성장 과정을 연구하고 있다. 한편, 은하단 환경이 다양한 범위의 밀도와 온도를 가지는 성간 가스 및 별형성 활동에 미치는 영향을 규명하기 위하여 ram pressure를 겪은 은하의 특성과 시뮬레이션 및 이론적 계산을 비교하는 연구를 수행 중이다. 또한, JCMT, KaVA, ALMA, JVLA 관측 자료를 이용하여 활동성 은하 핵이나 은하 중심부의 집중적인 별형성 활동이 은하 진화에 미치는 영향을 연구하고 있다.

지명국 회원은 Yonsei Observable UNiverse Group(YOUNG)을 운영하고 있다. 현재 1. 암흑물질의 정체를 규명하기 위한 충돌 은하단 연구, 2. 초기은하단의 질량함수 결정을 위한 중력렌즈 연구, 3. 우주론 파라미터를 정밀하게 결정하기 위한 Cosmic Shear 연구, 4. Large Synoptic Survey Telescope(LSST)의 자료처리 알고리즘 연구를 수행하고 있다.

김태선 회원은 복사유체 수치실험을 이용하여 거대분자운과 은하의 진화, 그리고 우주의 재이온화 연구를 진행하고 있다. 무거운 별로부터 기인하는 피드백 과정을 이해하여 과거 우주에서 관측되는 은하의 동역학적 특성을 이해하는 것이 본 연구팀의 궁극적인 목표이다. 정확한 수치실험을 수행하기 위해 sink particle을 활용한 새로운 별 생성 모델 개발에 착수하였으며, 복사장에 따라 달라지는 중원소 냉각률과 자기장을 고려한 이론 은하 진화 모델을 개발 중이다. 구상성단의 형성, 환경에 따른 RAM 압력 효과, 은하 내 강한 방출선의 탐구, 초기 은하에서 라이먼 연속선과 알파선의 탈출률에 관한 다양한 연구를 수행하고 있으며, 국제협력 복사유체 재이온화 실험(SPHINX), 나선은하 형성 실험(New Horizon), 거대분자운 내 별생성 실험(AMUN) 등을 통해 재이온화 시절 중 Lyman alpha emitter의 EW 분포, HII clumping factor, Lyman alpha line profile, 초기 왜소은하 형성 등을 연구 중이다.

3. 교육 및 연구 시설

천문우주학 교육 시설로서 천문대 소속의 일산 관측소 61 cm 반사 망원경, 교내 관측소 40 cm 반사 망원경, 4대의 10인치 미드 망원경, 다수의 소형 망원경들을 확보하여 학생들의 관측 실습에 활용하고 있다. 신촌 캠퍼스 내에 설치되어 있는 KVN 전파망원경은 전문 연구자들의 관측과 함께 학부 및 대학원 학생들의 교

육에도 기여하고 있다. 또한, 정밀 연구를 위해 해외 대형 망원경을 적극적으로 활용하고 있다.

우주비행제어연구실은 차세대 분리형 우주망원경의 기술을 우주공간에서 직접 실험/검증하기 위한 2기의 큐브위성을 개발하고 있다. 우주광학연구실은 대구경 우주 광학 시스템 개발을 위한 다수의 설계 및 해석 S/W와 정렬 및 조립 성능 평가를 위한 각종 간섭계 및 광학 측정 장비를 운영하며 연구 및 프로젝트 형 교육기법에 활용하고 있다.

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충남대학교 천문우주과학과

1. 인적사항

본 학과(학과장 이영선)는 오갑수 교수가 2019년 8월에 정년 퇴임하였고, 2019년 9월에 민경국 교수가 부임하여 현재 7명의 전임교수(외국인 전임 교원 1명 포함), 및 조교 1인을 중심으로 교육과 연구에 임하고 있다. 2020년도에는 학부과정에 33명, 대학원 박사과정에 4명, 석사과정에 4명이 입학하였으며, 박사 4명, 석사 8명이 배출되었다. 또한, 외국인 2명 포함, 박사 후 연구원 9명이 관련 전공 분야 대학원생과 전임교수와 긴밀히 연구를 수행하고 있다. 2020년 현재 학부에 약 130여 명, 대학원 석박사 과정에 약 20명이 재학 중으로 지방국립대 중 최대 규모의 천문우주과학 관련 학과를 운영하여 교육과 연구에 전념하고 있다. 한편, 대학원 과정의 경우 천문우주과학과, 지질환경과학과, 대기과학과를 통합한 우주지질학과를 설립하였으며, 천문우주, 지질환경, 대기과학의 융합 교육 및 연구를 꾀하고 있다.

2. 연구 및 학술활동

김용하 교수는 과학재단 특정기초 연구과제의 일환으로 2007년 2월 남극 세종기지에 설치한 유성 레이더를 지속 운영 중에 있다. 2012년 이 레이더의 송출력을 12 kW로 증대하여 현재 일일 평균 약 30,000개 이상의 유성을 측정하고 있으며, 이를 이용해 유성 진입 고도 70~110 km 구간의 고층 대기 상태도 측정하고 있다. 또한, 극지연구소에서 남북극 지역 모두 4곳(세종, 장보고, 다산, 키루나)에 설치한 고층대기 관측기로부터 고도 90~300 km 구간의 바람 속도에 대한 측정 자료를 확보하여 이 영역의 우주과학 연구를 활발히 수행하고 있다.

이 유 교수는 전남대 오수연 교수와 함께 Neutron Monitor 관측소를 현재 표준연구원 내에 구축하여 관측을 하고 있고, 올해 2020년 남극대륙 내의 장보고 기지에 제2 관측소 설치를 완성하였다. 이와 더불어 전 세계 관측소들의 자료를 사용하여 관측되는 우주선 강도의 감소현상(Forbush Decrease) 및 급증 현상

(Ground Level Enhancement)을 연구하여 오고 있다. 이런 현상들을 태양과 지구간의 행성간 자기권을 물리적 변화로 설명하려는 연구를 지속하고 있다. 이와 관련하여 태양과 태양형 항성들의 자기 활동 변화 주기의 통계 연구를 진행하고 있다. 그리고 향후 달탐사를 위한 기초연구로서 LRO/CRaTER 관측 자료를 이용하여 달 궤도에서의 우주선 환경변화를 연구하고 있으며, 달에서 인류가 주거 가능한 전초 기지가 될 수 있는 달의 용암동굴을 찾기 위한 연구를 진행하고 있다. 또한, 최근에는 미국 NOAA 자료와 프랑스 Coriolis 프로젝트로 구축된 해양 관측 자료를 활용하여 지구 기후변화 원인에 대한 깊은 관심을 갖고 연구 중이다.

조정연 교수는 MHD 난류의 성질 및 천문학적인 응용에 대해 연구하고 있으며, 성간 먼지의 정렬현상 및 이에 의해 야기되는 적외선 편광에 대해 연구하고 있다. 또한, 외부은하의 내부소광과 CMB foregrounds의 효과적 제거 방법에 대해 연구하고 있다. 현재 관측을 통한 난류의 물리량을 구하는 방법을 연구하고 있으며 블랙홀이나 중성자성의 자기권에서 발생하는 난류에 관한 연구를 하고 있다.

이수창 교수는 광학, 자외선, 그리고 전파 등 다파장 관측자료를 이용하여 은하단, 은하그룹, 필라멘트, 필드(field) 등 다양한 환경에 있는 은하들의 특성 및 환경에 따른 은하의 진화를 연구하고 있다. 특히, 처녀자리 은하단 주위에 존재하는 필라멘트 구조에 있는 은하들의 다파장 자료를 이용하여 필라멘트 내 위치에 따른 은하의 특성 차이와 이에 대한 기작 연구를 수행하였다. 또한, 적색편이 0.05 이내에 있는 밀집타원은하(compact elliptical galaxy)의 목록을 구축하고 환경에 따른 밀집타원은하의 종족 특성 차이가 나타나도록 밝히고 서로 다른 두 가지 형성 기작이 있음을 연구하였다.

Prof. Hui conveys extensive studies of a wide range of high energy phenomena of compact objects and their environment. These astrophysical systems enable us to probe the laws of physics in the most extreme physical conditions which cannot be attained in any terrestrial laboratories. For multi-wavelength investigations, the state-of-art space and ground-based telescopes around the world, including XMM-Newton, Chandra, Suzaku, Swift, Gemini, Hubble Space Telescope, Australian Telescope Compact Array, VLA, Fermi Gamma-ray Space telescope, are utilized. Prof. Hui is also one of the founders of Fermi Asian Network (FAN) which leads a series of long-term internationally collaborative projects. Very recently, Prof. Hui has joined the project, which is led by the International Space Science Institute, for conceiving new approaches to investigate the active processes in the central regions of galaxies.

이영선 교수는 Sloan Digital Sky Survey(SDSS), SEGUE

(Sloan Extension for Galactic Understanding and Exploration), BOSS(Baryon Oscillation Spectroscopy Survey), 그리고 현재 중국에서 진행 중인 LAMOST(Large Sky Area Multi-Object Fiber Spectroscopic Telescope) 등에서 관측한 별의 스펙트럼을 처리하여 별들의 온도, 중력, 금속 함량비, 알파 원소 함량비와 탄소 함량비를 결정하는 일괄처리 프로그램들을 개발하는 연구를 수행하고 있다. 일괄처리 프로그램을 통하여 결정된 별의 물리량과 화학원소 함량비와 가이아 위성이 제공하는 별의 연주시차, 고유운동 정보를 이용하여 우리은하의 원반(disk)과 헤일로(halo)에 있는 별들의 운동학적, 화학적 특성과 분포를 조사하여 원반과 헤일로의 형성과정과 화학적 진화에 대한 연구도 수행하고 있다.

민정국 교수는 지구 자기권 내 플라스마 파동과 이 파동이 환류와 방사선 대를 구성하는 고에너지 전자와 이온들에 미치는 영향을 위성 관측 데이터 분석과 이론과 모델링을 통해 연구해오고 있다. 현재 쌍극자 자기장 내에서 particle-in-cell simulation을 통해 적도 소음(equatorial noise)이라 불리는 파동의 생성과 전파 연구에 주력하고 있으며, 대학원 학생 지도를 통해 자기권뿐만 아니라 태양권 내에서 일어나는 전반적인 플라스마 물리현상 연구로 연구영역을 넓혀 나가고 있다.

3. 연구시설

연구 시설로는 다수의 워크스테이션 서버와 고성능 PC가 갖추어진 천문전산실, 광학실험장치, Photodensitometer, 인공위성 추적시스템이 갖추어져 있는 광학실험실이 있다. 그리고 천문대, 시뮬레이션실, 천문도서실 등이 학부 학생들의 교육을 위한 실험실습실로 이용되고 있다. 천문대에는 16인치 슈미트-카세그레인 반사망원경이 4 m 돔에 설치되어 있고, 14, 12, 10인치 슈미트-카세그레인 망원경, 7인치 반사망원경, 6, 5인치 초저분산 굴절망원경, 6인치 쌍안경, 분광기, 그리고 다수의 냉각 CCD 카메라가 있다. 그리고 대전 시민천문대의 10인치 굴절망원경의 원격제어 시스템을 완성해 시민천문대가 운영을 마친 11시 이후에 이를 활용하여 관측수업을 진행 중이다. 또한, 천체투영관과 지구과학현상 3차원 투영시스템을 구축하여 학부 관측수업 및 지구와 태양계 내의 여러 물리현상 교육을 위한 보조 장비로 활용하고 있다. 이들 장비는 충남대학교 별 축제에서 일반 대중을 위한 천문교육에도 이용되고 있다.

충북대학교 천문우주학과

1. 인적사항

충북대학교 천문우주학과에는 서경원, 김용기, 이대영, 하야사

키키미타케, 안홍준 회원 등 5명의 전임 교수가 184명의 학부생과 35명의 대학원생의 교육과 연구를 맡고 있다. 국내 대학 중 유일한 대학본부 부속기관인 충북대학교 천문대는 2018년 10월부터 김용기 교수가 천문대장직을 수행하고 있으며, 윤요라 회원이 업무를 담당하고 있다. 학과 행정업무는 2017년부터 이민희 회원이 조교로 근무하고 있다.

2. 연구 및 학습활동

서경원 교수는 진화된 항성 주변 먼지층의 특성과 진화에 대한 연구를 수행하고 있다. 이를 위하여 진화된 항성의 목록을 개선하고 체계화하며 관련된 적외선 및 전파 관측 자료들을 수집하여 분석하고 있다. 또한, 진화된 항성의 구조와 진화에 따른 주변 먼지 입자의 특성에 대한 이론적 모형의 개발과 적용을 위한 연구도 함께 진행 중이다.

김용기 교수는 대학원 대중천문학과정을 담당하고 있다. 자기 격변변광성의 관측 및 관측자료 처리에 대한 연구를 하고 있으며 우크라이나 ONMU 대학의 Andronov교수와 자기격변변광성에 대한 공동연구를 하고 있다. 또한, 충북대학교 망원경 자동관측시스템을 이용한 자기격변변광성 모니터링관측, 그리고 망원경 자동 관측시스템을 이용한 과학대중화사업에의 연계연구에도 관심을 갖고 부산과학관, 경기과학고의 망원경 및 관측시스템 개발에 참여한 바 있다. 김용기 교수는 다수의 천문학 서적의 번역에 참여하고 있으며, 한국창의재단의 지원으로 STEAM교육프로그램을 개발하고 있다. 현재 김동훈, 김태우, 한기영, 박은미 회원이 박사과정, 김상걸, 김하정, 이승윤, 이현석, 임종진, 하태용, 허민 회원이 석사과정을 이수하고 있으며, 설아침 회원이 통합과정에서 김용기 교수의 지도를 받고 있다.

이대영 교수는 현재 6명의 full-time 석·박사 과정 대학원생들과 2인의 연구교수로 구성된 우주물리/우주환경 연구 그룹을 이끌고 있다. 주로 space plasma instabilities, radiation belt electron dynamics, wave-particle interaction, interplanetary magnetic field, solar wind structure, 행성 자기권 MHD simulation 관련 기초 연구와 우주 자기장 측정기 개발에 집중하고 있다. 특히, 최근 한국연구재단 지원 사업을 통해 극단적 우주환경 조건에서 고성능으로 운영이 가능한 자기장 측정기(fluxgate magnetometer)를 자체적으로 개발하였으며, 이를 통해 관련 기반 기술의 국산화에 주력하고 있다. 또 다른 한국연구재단 지원 사업을 통해서도 우주환경 교란의 가장 주요한 현상인 radiation belt의 발생 근원에 대한 매우 새로운 이론을 시험하기 위한 중장기 연구를 최근 시작하였다.

하야사키 키미타케 교수는 black hole 천문학 및 천체물리학에 대한 연구를 수행하고 있다. 현재 merging process of binary supermassive black holes in the context of disk-binary interaction에 관하여 연구하고 있다. 쌍성 블랙홀 병합 중 중력

파 검출(GW 150914)의 최근 발견은 그 어느 때보다도 이 분야에 많은 동기를 부여하고 있다. 또한, the tidal disruption of stars by supermassive black holes에 대해 연구하고 있으며, 최근 tidal disruption events가 급격하게 관측되면서 관측과 이론적 관심이 증가하고 있는 주제이다. 현재 대학원생과 함께 연구 그룹을 이끌고 있으며, black hole 천문학 및 천체물리학에 새로운 통찰력을 제공하고자 교육하고 있다.

안홍준 교수는 현재 국제 협력 연구단인 Fermi 연구단에 참여하고 있으며, X선 및 감마선 관측을 통하여 고에너지 천체현상을 연구하고 있다. 고에너지 방사는 우리 은하뿐만 아니라, 외계은하에 존재하는 밀집성에서 나타나는데, 주로 중성자 별 및 그 성운, 초신성 잔해, 거대 블랙홀 등이 연구대상이다. 이런 물체에서 발생하는 고에너지 현상을 통하여 그 물체들의 특성을 추정하는데, 중성자별 연구는 최종적으로 그 질량을 추정하여 현재의 물리학적 지식을 기반으로 유도한 상태방정식을 검증함으로써 초 고밀도하에 존재하는 물질의 상태를 추정하는 것을 목표로 한다. 중성자별 성운이나 거대 블랙홀 주변에서 입자들이 초고에너지로 가속되는 현상이 발생하여 X선 및 감마선이 방출되는 것으로 추정하는데, 관측 및 이론적 모형을 통하여 플라스마 물질의 가속현상들이 해하는 것을 목표로 하여 연구하고 있다. 현재 다섯 명의 대학원생과 함께 연구를 진행하고 있다.

3. 연구시설

각 교수의 연구실 및 실험실에는 최신 PC 및 관련 주변 기기, 그리고 워크스테이션이 구비되어 있으며, 또한 교내 35 cm 반자동 천체망원경, 40 cm 자동 천체망원경 및 3 m 태양 망원경, 5 m 위성 전파수신기, 그리고 최근 자체 제작한 2.8 Ghz 전파 수신기 등 천문우주 교육에 필요한 다수의 장비를 갖추고 있다. 이와 더불어 대학 본부 부속기관인 충북대학교 천문대(충북 진천군 소재)가 2008년 4월 개관 이후 시험 관측을 거쳐 현재 활발히 천문 관측을 수행하고 있다. 충북대학교 천문대는 국내 대학 규모로는 최대인 1 m 반사 망원경을 보유하고 있고 60 cm 광시야 망원경을 이용하여 천문 교육과 연구에 활용될 뿐만 아니라 지역사회에 개방되어 천문지식 보급에도 크게 기여하고 있다.

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의 천문우주과학 정부출연연구기관으로서 광학, 전파, 이론, 관측 천문학 및 우주과학 연구를 통해 21세기 천문우주 핵심과제를 규명하고, 천문우주 관측시스템 구축 및 핵심 기술 개발을 통해 우주시대를 선도하는 일류 선진연구기관으로 도약하고 있다.

가. 주요 보직자 현황

제7대 원장 이형목
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우주위험감시센터장 조중현
천문우주기술센터장 한정열
이론천문센터장 조정연
고천문연구센터장 김상혁
천문전산융합센터장 이창희

나. 주요 연구본부 소개

1) 광학천문본부

광학천문본부는 은하진화그룹, 변광천체그룹, 보현산천문대, 소백산천문대의 4개 그룹으로 구성되어 별과 우주의 시작과 변화를 과학적으로 분석하고 있다. 은하진화그룹은 광학/적외선을 비롯한 다양한 파장의 자료를 이용하여 우리은하와 외부은하의 형성과 진화를 연구하고 있으며, 관련 수치실험과 빅데이터 연구를 병행하고 있다. 변광천체그룹은 고정밀 측광 및 고분산 분광 관측자료를 활용하여 변광성과 외계행성의 물리적 특성을 연구하고 있다.

이러한 연구를 위하여 광학천문본부는 보현산천문대, 소백산천문대, 레몬산천문대, 외계행성 탐색시스템(KMTNet) 등의 관측시설을 운영하고 있다. 외계행성 탐색시스템은 2015년 10월에 칠레, 호주, 남아프리카공화국의 남반구 3개 관측소를 완공하고, 광시야 망원경과 모자이크 CCD 카메라를 사용하여 외계행성, 변광성, 초신성, 소행성, 외부은하 등 본격적인 연구관측을 시작해 성과를 창출하고 있다.

2) 전파천문본부

전파천문본부는 전파천문연구그룹, 대덕전파천문대, 전파기



한국천문연구원

1. 기관 현황

한국천문연구원은 우리나라 천문 연구의 정통성을 계승한 대한민국의 대표 천문연구기관으로서 1974년 국립천문대로 출범하여 현재에 이르기까지 중·대형 관측 장비의 구축과 운영을 통해 국가 천문 연구를 수행하며 과학 발전의 토대를 마련하고 있다. 국내 유일



술개발그룹, ALMA(Atacama Large Millimeter/submillimeter Array)그룹 및 KVN(Korean VLBI Network, 한국우주전파관측망)의 5개 그룹을 운영하고 있다. KVN 등의 대형 관측장비를 활용하여 별 탄생 영역과 활동성 은하 영역에 대한 선진연구를 수행하고, ALMA, KaVA(KVN and VERA Array) 등을 통해 국제 공동 관측 프로그램을 진행하고 있다. 또 핵심 관측장비의 성능 향상을 위한 시스템 개발을 하며 우수 연구결과를 창출하고 있다.



3) 우주과학본부

우주과학본부는 태양 및 근지구 우주환경 연구, 달 및 행성 과학, 그리고 레이저 기술을 이용한 고정밀 우주물체 추적연구를 통해 우주에 대한 인류의 지식 확대에 기여하고 있다. 또한 우주측지 기술을 활용한 지구 변화 정밀 분석과 태양활동에 의한 지구영향 예측, 위성 및 로켓 탑재체 개발 등 우주에서의 관측천문 연구에 주력하고 있으며, 대한민국 공식 역서를 발간하고 있다.

4) 우주위험감시센터

한국천문연구원은 2014년 개정된 우주개발진흥법 및 동법 시행령, 국가우주위험대비기본계획에 근거하여 우주위험대응 전문기관인 우주환경감시기관으로 지정되었고, 우주위험감시센터는 우주환경감시기관 역할 수행을 위한 전담부서로 우주위험에 대한 체계적 감시 및 대응을 위한 연구개발을 수행하고 있다.

국가과학기술연구회 국가현안해결형사업인 우주물체 전자광학 감시 시스템(Optical Wide-field patrol; OWL-Net) 개발 사업을 통해 지난해 국내외 5개 곳에 직경 0.5 m급 우주물체 추적 광학망원경을 설치 완료했으며, 우리나라 국적위성, 한반도 정치권도 영역을 독자적으로 감시하고 있다. 이 네트워크는 광시야 광학망원경, 고속 마운트, 효과적인 스케줄링을 채용하여 빠르게 움직이는 인공위성이나 소행성의 추적감시가 가능하며, 세계 최초로 관측 계획부터 데이터 분석까지 전 과정을 천문연구원에서 무인원격으로 관리할 수 있다.



5) 대형망원경사업단

대형망원경사업단은 대형광학망원경의 국제공동건설 및 공동활용, 대형망원경용 관측기기 개발 등의 업무를 수행하고 있다.

주요사업으로는 거대마젤란망원경(GMT) 국제공동 건설 지분 10% 확보를 골자로 하는 대형망원경개발사업과 8 m급 중대형망원경 국제공동 활용, 광학 및 적외선 관측기기 개발, GMT용 관측기기 및 부경 국제공동개발 등을 들 수 있다.

특히 GMT 시대를 대비한 연구역량의 개발과 인력 양성을 위하여 천문학계를 위한 중대형망원경 관측시간 지원, 대학원생 및 박사후연수원을 대상으로 하는 계절학교 운영, 해외 GMT 참여기관과 공동연구 및 펠로우십 프로그램 운영, 천문학 분야 국제공동연구 참여 등 다양한 업무를 수행하고 있다. GMT는 4개의 반사경만 먼저 장착해 2023년께 첫 관측을 시작할 예정이며, 2026년부터는 정상 가동을 목표로 하고 있다.



6) 이론천문센터

이론천문센터에는 우주론, 천체물리 분야의 연구자들이 참여하고 있다. 우주론 및 천체물리 분야는 우주거대구조 이론과 관측 연구를 통해 우주초기조건, 암흑물질 및 암흑에너지에 관한 연구를 수행하고 있으며, DESI 등 주요 국제관측사업에 참여하고 있다. 천체물리 연구자들은 시뮬레이션을 통한 천체물리 연구 및 시뮬레이션코드 개발 등을 수행하며, 한국과학기술정보연구원, 국가수리과학연구소와 공동으로 중력파 융합연구도 활발하게 진행 중이다.

7) 천문우주기술센터

2020년 2월, 천문우주과학 연구를 위한 경쟁력 있는 기술개발 전략을 수립하고, 국가 위상을 높일 수 있는 첨단 기술개발을 선도하며, 엔지니어링의 체계적 지원을 위하여 천문우주기술센터(Technology Center for Astronomy and Space Science)를 발족했다. 천문우주기술센터는 설립 목적 및 역할로써 기술개발 중장기 계획 수립 및 추진 등 7개로 정하고, 기술로드맵 작성, 기기개발 지원, 연구장비 공동활용 극대화를 위한 스마트랩(Smart Lab.), 포괄적 산학연 협력, 천문우주기술관련 워크숍·연구모임 주관, 기술주도형 연구개발 과제 수행 등 실질적인 활동을 진행하고 있다.

8) 고천문연구센터

우리나라는 삼국시대 이래 조선시대에 이르기까지 2천 년에 이르는 시간동안 체계적인 관측 시스템과 관측기록을 보유하고 있다. 우리의 고천문학(역사천문학)은 국가 최고 학문으로 중시되어 하늘을 체계적으로 관측한 우수한 천문학적 유산이며, 현대천문학 연구의 뿌리이기도 하다. 고천문연구센터는 옛 천문기기를 복원하

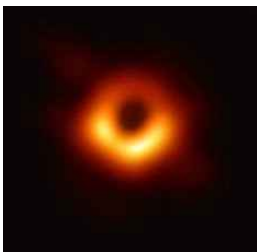
고, 역사적 관측 기록을 분석하며, 현대적인 도구로 얻은 데이터를 통해 과거의 천문현상을 조사하는 등 다양한 측면에서 연구를 수행하고 있다.

9) 천문전산융합센터

천문전산융합센터는 빅데이터 연구 국민 참여와 세계적 성과 창출을 목표로 2018년 4월 새로 구축됐다. 기하급수적으로 증가하는 천문우주 빅데이터의 저장·분석·공유와 시스템을 구축하는 역할을 한다. 기존의 광학·전파·적외선 파장별 관측 데이터를 비롯해 대규모 수치 모의실험을 통한 데이터, 우리나라의 특징적인 과거 조선시대 천문 관측기록부터 현재와 미래에 구축할 최신 인프라의 데이터들까지 망라할 계획이다. 또, 국민들이 직접 연구에 참여하고 그 성과를 체감할 수 있는 플랫폼을 구축해나가고자 한다.

2. 한국천문연구원 주요 연구 및 개발 성과

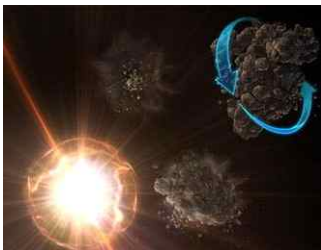
가. 사상 최초로 실제 블랙홀 영상 얻는 데 성공



한국천문연구원 연구진이 포함된 EHT 국제연구팀은 전 세계 협력에 기반한 8개의 전파망원경을 연결한 사건 지평선망원경(이하 EHT, Event Horizon Telescope)으로 초대질량 블랙홀 관측에 성공했다. 해당 관측은 2017년 4월 5일부터 14일까지 6개 대륙에서 8

개 망원경이 참여해 진행됐다. 같은 시각, 서로 다른 망원경을 통해 들어온 블랙홀의 전파신호를 컴퓨터로 통합 분석해 이를 역추적하는 방식으로 블랙홀의 모습을 담은 영상을 얻었다. 한국은 한국천문연구원 소속 연구자 등 8명이 동아시아관측소(EAO) 산하 제임스 클러크 맥스웰 망원경(JCMT)과 아타카마 밀리미터/서브밀리미터 전파간섭계(ALMA)의 협력 구성원으로서 EHT 프로젝트에 참여했으며, 한국이 운영하고 있는 한국우주전파관측망(KVN)과 동아시아우주전파 관측망(EAVN)의 관측결과도 본 연구에 활용됐다.

나. 초신성의 강력한 빛에 의해 우주 먼지가 쪼개지는 원리 발견



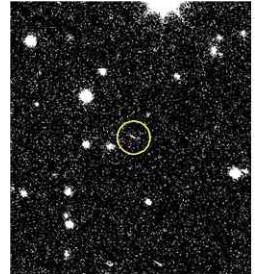
한국천문연구원은 초신성이 폭발할 때나 무겁고 젊은 별에서 나오는 강한 빛에 의해 우주 먼지가 쪼개질 수 있다는 새로운 원리를 발견했다. 연구진은 먼지가 부서지는 영역이 킬로노바나 초신성 주변 반경 수 광년 정

도의 범위에서 생기는 것을 밝혔다. 반면, 밝고 무거운 별이 천여개 모여 있는 별 탄생 영역에서는 먼지가 부서지는 영역이 반경

수십 광년 범위로 형성되는 것을 밝혔다.

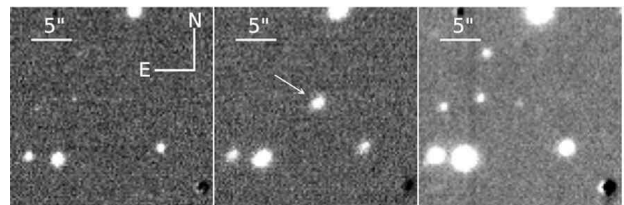
다. 국내 최초로 지구위협소행성(2018 PP29) 발견

한국천문연구원은 지난 2018년 8월 칠레, 호주, 남아공 관측소에서 운영하는 지름 1.6 m급 외계행성 탐색시스템(이하 KMTNet, Korea Microlensing Telescope Network) 망원경 3기로 새로운 천체를 발견했고, 국제천문연맹 소행성 센터(이하 MPC, Minor Planet Center)는 2019년 6월 5일 해당 천체가 지구위협소행성(PHA, Potentially Hazardous Asteroid)이라 밝혔다. 이 천체에는 '2018 PP29'(이공일팔 피피 이구)라는 임시번호(provisional designation)가 부여됐다.



라. 외계행성탐색시스템(KMTNet) 통해 가장 먼 왜소신성 발견

한국천문연구원은 외계행성탐색시스템(이하 KMTNet, Korea Microlensing Telescope Network)을 이용한 초신성 탐사관측을 통해 이제까지 발견된 왜소신성 중 거리가 가장 멀고, 우리은하의 헤일로(halo)에 존재하는 왜소신성을 발견했다. 이번에 초신성 탐사 관측 연구진이 발견한 왜소신성 'KSP-OT-201611a'는 거리가 우리은하 중심으로부터는 약 45,000광년(지구에서 약 24,000광년)이고 우리은하 평면에서 5,500광년이나 떨어져 있어 우리은하 헤일로에 존재하는 것으로 밝혀졌다.



마. 천문연-NASA 공동개발 태양 코로나그래프 관측 성공

한국천문연구원은 2019년 9월 18일 22시경부터 미국 뉴멕시코주 포트 섬너(Fort Sumner)에서 8시간 동안 진행된 미국 NASA와 공동개발한 태양 코로나그래프(coronagraph) 핵심기술 검증을 성공적으로 마무리했다. 천문연-NASA 공동연구진은 NASA 콜롬비아 과학 기구 발사장(CSBF, Columbia Scientific Balloon Facility)에서 가로 약 140 m의 대형 과학용 풍선기구에 태양 코로나그래프를 탑재해 약 40 km 상공 성층권으로 띄웠고, 세계 최초로 외부 코로나 지역의 온도 및 속도를 동시에 관측했다. 이번 관측을 위해 천문연은 코로나그래프의 핵심 기

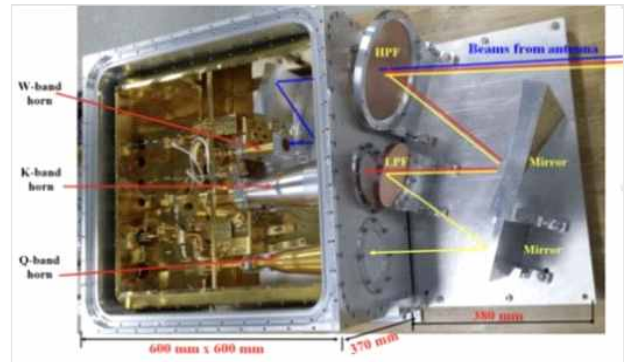


술인 영상카메라, 제어시스템 및 핵심 소프트웨어를 개발했으며, NASA는 코로나그래프의 광학계, 태양 추적 장치를 개발하고 성층권 기구를 제공했다

바. 초소형 3채널 수신기 이탈리아 국립 전파망원경 3기에 공급 계약 체결

한국천문연구원은 2020년 3월 우리나라가 독자적으로 개발한 3채널 동시 관측 우주전파 수신시스템인 '초소형 3채널 수신기(CTR, Compact Triple-band Receiver)'를 이탈리아 국립천체물리연구소(INAF, Istituto Nazionale Di Astrofisica)와 계약을 체결하여 전파망원경 3기에 공급(총 280만 유로, 약 37억 원)하기로 했다. 초소형 3채널 수신기는 우리나라가 세계 최초로 독자 개발한 '4채널(22, 43, 86, 129GHz) 동시 관측 수신시스템(이하 '4채널 수신시스템')을 1/10 크기(면적 기준)로 줄여 개발한 것으로, 천문원은 해당 수신시스템을 사양에 맞게 제작 후 계약 시점으

로부터 최대 22개월 이내 이탈리아 국립천체물리연구소에 공급할 계획이며, 공급된 수신시스템은 각 전파망원경에 설치·운용될 예정이다.



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사단법인 한국우주과학회 정관

1995년 5월 3일 제정

1996년 5월 4일 개정

2014년 10월 30일 개정

제1장 총칙

제1조 (목적) 이 법인은 사회일반의 이익에 공여하기 위하여 공익법인의 설립운영에 관한 법률의 규정에 따라 우주과학의 발전과 그 응용 및 보급에 기여하고 나아가 과학의 발전에 이바지함을 목적으로 한다.

제2조 (명칭) 이 법인은 사단법인 한국우주과학회(이하 학회)라 칭하고, 영어명칭은 The Korean Space Science Society로 한다.

제3조 (사무소의 소재지) 학회의 사무소는 대전광역시 유성구 대덕대로 776 한국천문연구원 내에 둔다.

제4조 (사업) 학회는 제1조의 목적을 달성하기 위하여 다음 각 호의 목적사업을 행한다.

1. 학술적 회합의 개최
2. 학술간행물의 발행 및 배포
3. 학술자료의 조사, 수집, 교환
4. 학술의 국제교류
5. 과학기술진흥에 관한 지원 및 건의
6. 기타 본 학회 목적에 적합한 사업

제5조 (법인 공여이익의 수혜자)

1. 학회가 목적사업을 수행함에 있어서 그 수혜자에게 제공하는 이익은 이를 무상으로 한다. 다만, 부득이한 경우에는 미리 감독청의 승인을 받아 그 대가의 일부를 수혜자에게 부담시킬 수 있다.
2. 학회의 목적 사업의 수행으로 인하여 제공되는 이익은 수혜자의 출생지, 출신학교, 근무처, 직업 또는 기타 사회적 지위 등에 의하여 차별을 두지 않는다.

제2장 회원

제6조 (회원의 종류 및 자격) 학회 회원의 종류와 자격은 다음과 같다.

1. 정회원: 정회원은 우주과학에 관심을 갖는 개인으로서 대학에서 우주과학 또는 그에 관련된 과정을 수학한 자 또는 이사회에서 동등한 자격을 가진 자라고 인정된 자
2. 학생회원: 학생회원은 대학 학부 과정에서 우주과학 또는 그에 관련된 과정을 수학하고 있는 자 또는 이사회에서 동등한 자격을 가진 자라고 인정된 자

3. 준회원: 준회원은 정회원 중 과거 3년간 회원의 의무를 이행하지 아니한 자
4. 명예회원: 명예회원은 우주과학 발전에 공적이 현저하거나 학회의 목적달성에 큰 공적이 있는 자
5. 특별회원: 특별회원은 학회에 찬조 및 기부행위 또는 동등한 기여를 한 개인 또는 단체
6. 기관회원: 기관회원은 학회의 목적에 뜻을 같이하고 사업에 기여하는 학술 및 연구단체

제7조 (입회) 학회의 회원은 다음 각 호에 따라 그 자격을 얻을 수 있다.

1. 본 학회의 정회원 혹은 학생회원이 되고자 하는 자는 정회원 2인의 추천을 얻어 입회를 신청하고 이사회의 승인 후 입회금과 회비를 납부함으로써 회원이 된다.
2. 명예회원은 회장의 제청에 의하여 이사회에서 의결하여 총회에서 추대한다.
3. 특별회원 및 기관회원은 이사 2인의 추천에 의하여 이사회의 승인을 받아야 한다.

제8조 (의무와 권리) 학회 회원은 다음 각 호의 의무와 권리를 갖는다.

1. 정관 및 의결사항의 준수와 회비납부의 의무
2. 회원은 연구발표, 논문 기고 및 학술 활동에 참여할 수 있다.
3. 회원은 학회 운영에 참여 할 수 있으며, 별도 규정이 정한 바에 따라 선거권과 피선거권을 갖는다.

제9조 (회원의 탈퇴 및 권리의 정지)

1. 회원은 임의로 탈퇴할 수 있다.
2. 회원으로서 의무를 다하지 아니한 경우나 학회의 목적에 배치되는 행위 또는 명예나 위신에 손상을 가져오는 행위를 하였을 때에는 이사회의 의결로서 권리를 정지하거나 제명할 수 있다.

제3장 임원

제10조 (임원) 학회에 다음 임원을 둔다.

1. 회 장 1인
2. 부회장 1인 이상 3인 이내
3. 감사 2인
4. 이사 15인 이상 25인 이내 (회장, 부회장 포함)

제11조 (임원의 임기)

1. 임원의 임기는 2년으로 하며 연임할 수 있다. 다만, 회장은 연임할 수 없다.
2. 임원의 임기 중 결원이 생긴 때에는 2개월 이내에 이사회에서 보선하고, 보선에 의해 취임한 임원의 임기는 전임자의 잔여기간으로 한다.
3. 임원은 임기가 끝난 후일지라도 후임자가 선출 확정될 때까지

는 그 직무를 담당한다.

제12조 (임원의 선임방법)

1. 회장과 감사는 총회에서 직접선거로 선출하며, 부회장은 회장이 지명하고 이사의 절반은 투표로 선출하고 나머지 절반은 회장이 지명한다.
2. 상기 임원 선출을 위하여 임원선출방법을 별도로 정하여야 하며, 선출된 임원은 감독관청의 취임 승인을 받아야 한다.
3. 임기전의 임원의 해임은 총회의 의결을 거쳐 감독관청의 승인을 받아야 한다.

제13조 (회장 및 부회장의 직무)

1. 회장은 학회를 대표하고 학회 업무를 총괄하며, 총회 및 이사회 의 의장이 된다.
2. 부회장은 회장의 직무를 보좌하며 회장 유고시 부회장 중 연장자가 회장의 직무를 대행한다.

제14조 (이사의 직무)

1. 이사는 이사회에 출석하여 학회의 업무에 관한 사항을 의결하며, 회장으로부터 위임받은 사항을 처리한다.
2. 필요에 따라 이사 중에서 총무, 재무, 학술 이사 등을 둘 수 있다.

제15조 (감사의 직무) 감사는 다음 각 호의 직무를 행한다.

1. 학회의 재산상황을 감사하는 일
2. 이사회의 운영과 그 업무에 관한 사항을 감사하는 일
3. 제1호 및 제2호의 감사결과 부정 또는 불법한 점이 있음을 발견할 때에는 이를 이사회, 총회에 그 시정을 요구하고 그래도 시정치 않을 때에는 감독관청에 보고하는 일
4. 제3호의 보고를 하기 위하여 필요한 때에는 총회 또는 이사회의 소집을 요구하는 일
5. 학회의 재산상황, 또는 총회, 이사회의 운영과 업무에 관한 사항에 대하여 회장 또는 총회, 이사회에서 의견을 진술하는 일
6. 총회 및 이사회의 회의록에 기명 날인하는 일

제4장 총회

제16조 (총회의 구성 및 기능) 총회는 정회원으로 구성하고 다음 각 호의 사항을 의결한다.

1. 임원 선출에 관한 사항
2. 정관 변경에 관한 사항
3. 예산 및 결산의 승인
4. 사업계획의 승인
5. 기타 중요한 사항

제17조 (총회 소집)

1. 총회는 정기총회와 임시총회로 나누며, 회장이 소집한다. 정기총회는 년 1회, 임시총회는 필요에 따라 소집할 수 있다.

2. 회장은 회의안건을 명기하여 회의 7일전에 각 회원에게 통보하여야 한다.
3. 총회는 제2항의 통지사항에 한하여서만 의결할 수 있다.

제18조 (총회의결과 정족수)

1. 총회는 국내에 있는 정회원 10분의 1 이상의 출석으로 개회한다.
2. 총회의 의사는 출석한 정회원의 과반수의 찬성으로 의결한다. 다만, 가부동수인 경우에는 의장이 결정한다.

제19조 (총회소집의 특례)

1. 회장은 다음 각 호의 하나에 해당하는 소집요구가 있을 때에는 그 소집 요구일로부터 20일 이내에 총회를 소집하여야 한다.
 - ① 재적이사 과반수가 회의의 목적을 제시하고 소집을 요구한 때
 - ② 제15조 제4호 규정에 따라 감사가 소집을 요구한 때
 - ③ 국내에 있는 정회원의 10분의 1 이상이 회의의 목적을 제시하여 소집을 요구한 때
2. 총회 소집권자가 결위되거나 또는 이를 기피함으로써 총회소집이 불가능할 때에는 재적이사 과반수 또는 국내에 있는 정회원 10분의 1 이상의 찬성으로 감독관청의 승인을 받아 총회를 소집할 수 있다.
3. 제2항에 의한 총회는 출석 이사 중 연장자의 사회아래 그 의장을 지명한다.

제20조 (총회의결 제적사유) 의장 또는 정회원이 다음 각 호의 하나에 해당하는 때에는 그 의결에 참여하지 못한다.

1. 임원 취임 및 해임에 있어 자신에 관한 사항
2. 금리 또는 재산의 접수를 수반하는 사항으로서 의장 또는 정회원 자신과 학회의 이해가 상반되는 사항

제5장 평의원회(삭제)

제21조 (평의원의 자격 취득과 상실) 삭제

제22조 (평의원회의 직무) 삭제

제6장 이사회

제23조 (이사회의 구성 및 기능) 이사회는 회장, 부회장 및 이사들로 구성되며 다음 각 호의 사항을 심의 의결한다.

1. 업무집행에 관한 사항
2. 사업계획 운영에 관한 사항
3. 예산 결산서 작성에 관한 사항
4. 총회에서 위임받은 사항

5. 정관에 의하여 그 권한에 속하는 사항
6. 기타 중요한 사항

제24조 (의결 정족수)

1. 이사회는 이사 정원수의 과반수가 출석하지 아니하면 개회하지 못한다.
2. 이사회 의사는 출석이사 과반수의 찬성으로 의결한다. 다만 가부동수인 경우에는 의장이 결정한다.
3. 감사는 이사회에 출석하여 의견을 진술할 수 있다.

제25조 (이사회 소집)

1. 이사회는 회장이 소집한다.
2. 이사회를 소집하고자 할 때에는 적어도 회의 7일전에 목적을 제시하여 각 이사에 통지하여야 한다.
3. 이사회는 제2항의 통지사항에 한하여서만 의결할 수 있다. 다만 재적이사 전원이 출석하고 출석이사 전원의 찬성이 있을 때에는 통지하지 아니한 사항이라도 이를 안건으로 채택하여 의결할 수 있다.

제26조 (이사회 소집의 특례)

1. 회장은 다음 각 호의 하나에 해당하는 소집요구가 있을 때에는 그 소집요구일로부터 20일 이내에 이사회를 소집하여야 한다.
 - ① 재적이사 과반수로부터 회의의 목적을 제시하여 소집을 요구한 때
 - ② 제15조 제4호에 의하여 소집을 요구한 때
2. 이사회 소집권자가 결위되거나 또는 이를 기피함으로써 7일 이상 이사회 소집이 불가능할 때에는 재적이사 과반수의 찬성으로 감독관청의 승인을 받아 소집할 수 있다.
3. 제2항에 의한 이사회는 출석이사 중 연장자의 사회 아래 그 의장을 지명한다.

제27조 (서면의결 금지) 이사회 의사는 서면의결에 의할 수 없다.

제7장 재산 및 회계

제28조 (재정) 학회의 재정은 다음의 수입금으로 충당한다.

1. 회원의 회비
2. 재산의 과실
3. 사업 수익금
4. 기부금 및 기타 수익금

제29조 (회계연도) 학회의 회계연도는 정부 회계연도에 따른다.

제30조 (세입, 세출, 예산) 학회의 세입, 세출, 예산은 매 회계년도 개시 1개월 전까지 사업계획서와 함께 이사회 의결과 총회의 승인을 얻어 감독관청에 제출한다.

제31조 (예산외의 채무부담 등) 학회의 예산외의 채무의 부담이나 채권의 포기는 총회의 의결을 거쳐 감독관청의 승인을 받아야 한다.

제8장 보칙

제32조 (해산) 학회를 해산하고자 할 때에는 총회에서 국내에 있는 재적 정회원 3분의 2 이상의 찬동으로 의결하여 감독관청의 허가를 받아야 한다.

제33조 (해산법인의 재산 귀속) 학회가 해산할 때의 잔여 재산은 감독관청의 허가를 받아 국가 또는 지방자치단체에 귀속된다.

제34조 (정관 개정) 학회의 정관을 개정하고자 할 때에는 재적이사 3분의 2 이상의 찬성과 총회의 승인을 얻어야 한다.

제35조 (시행 세칙) 정관의 시행에 필요한 세부적인 사항은 이사회에서 정하여 총회의 승인을 얻어야 한다.

제36조 (공고사항 및 방법) 법령의 규정에 의한 사항과 다음 각 호의 사항은 이를 일간신문에 공고함을 원칙으로 한다.

1. 법인의 명칭
2. 학회의 해산
3. 학회 운영과 관련하여 이사회에서 공고하기로 의결한 사항

제37조 (설립당초의 임원 및 임기) 학회의 설립당초의 임원 및 임기는 다음과 같다.

	성 명	현 직	전화번호	임 기
회장	오규동	전남대학교 교수	062-520-6965	94.5-96.5
부회장	정장해	충북대학교 교수	0431-61-2313	94.5-96.5
이사	강영운	세종대학교 교수	02-460-0234	94.5-96.5
이사	김천휘	충북대학교 교수	0431-61-3139	94.5-96.5
이사	김철희	전북대학교 교수	0652-70-2807	94.5-96.5
이사	김호일	천문대 연구원	042-865-3217	94.5-96.5
이사	민경옥	한국과학기술원 교수	042-869-2525	94.5-96.5
이사	박경윤	시스템공학센터연구원	042-869-1571	94.5-96.5
이사	서경원	충북대학교 교수	0431-61-2315	94.5-96.5
이사	이명옥	연세대학교 교수	02-361-2689	94.5-96.5
이사	이용복	서울교육대학교 교수	02-580-5456	94.5-96.5
이사	이우백	표준연구원천문대장	042-865-3215	94.5-96.5
이사	조경철	한국우주환경연구소장	02-761-0031	94.5-96.5
이사	천문석	연세대학교 교수	02-361-2685	94.5-96.5
이사	최규홍	연세대학교 교수	02-361-2686	94.5-96.5
이사	한원용	천문대연구원	042-865-3217	94.5-96.5
감사	나일성	연세대학교 교수	02-361-2681	94.5-96.5
감사	이용삼	충북대학교 교수	0431-61-2314	94.5-96.5

부 칙

제1조 (시행일) 이 정관은 감독관청의 허가를 받은 날부터 시행한다.

1. 1995년 12월 26일 과학기술처장관 허가

2. 1996년 7월 24일 과학기술처장관 허가
3. 2014년 12월 03일 미래창조과학부장관 허가

학회운영에 대한 규정

2014년 10월 30일 제정

2016년 2월 18일 개정

제1조(목적) 한국우주과학회(이하 “학회”) 정관 제35조에 근거하여 학회 운영에 필요한 사항을 규정함을 목적으로 한다.

제1장 회비

제2조(회비) 학회 정관 제7조, 제8조 및 제28조의 각 1호에 근거하여 회원이 납부해야 할 연회비는 다음과 같다.

1. 임원: 10만원
2. 정회원: 5만원
3. 학생회원: 1만원
4. 명예회원: 면제
5. 특별회원: 면제
6. 기관회원 : 이사회에서 결정

제3조(회비의 면제) 2년 이상 해외 체류하는 자에 한하여 연회비를 면제할 수 있다.

제2장 위원회 및 분과 활동

제4조(구분)

1. 학회 정관 제4조의 학회 활동에 관련하여 아래 각호와 같이 위원회, 분과회, 그리고 연구회를 둘 수 있다.
 - ① (위원회) 위원회는 학회원의 학술활동에 대한 지원을 목적으로 한다.
 - ② (분과회) 분과회는 학회원의 전문분야별 자율적 학술활동을 목적으로 한다.
 - ③ (연구회) 연구회는 학회원의 특정 목적 학술 활동을 목적으로 한다.
2. 상설위원회로는 편집위원회, 포상위원회, 학술대회준비위원회를 둔다.
3. 특별 위원회는 학회의 필요에 따라 수시로 구성 및 해산할 수 있다.
4. 분과회의 전문 분야는 학회원들의 자율적 논의와 참여를 통하여 정하고 회칙을 정하여 이사회의 승인을 얻어야 한다.
5. 연구회의 특정 학술 활동 분야는 대내외적 요구에 따라 수시로 정할 수 있다.

제5조(편집위원회)

1. 편집위원회는 학회에서 발간하는 정기 학술지에 게재되는 논문의 심사, 편집 및 출판을 관장한다.
2. 학술이사가 위원장을 맡고, 국내위원은 15인 내외로 하며 정회원 중에서 이사회의 동의를 얻어 회장이 임명한다. 국외위원은 20인 내외로 하며 이사회의 동의를 얻어 회장이 임명한다. 임기는 모두 2년으로 한다.
3. 학술지 논문 투고규정 및 세부사항은 편집위원회에서 논의한 후 이사회의 의결을 거쳐 시행한다.

제6조(포상위원회)

1. 포상위원회는 학회를 통한 대내외 수상 관련 수상자 추천 및 선발을 관장한다.
2. 포상위원회의 구성은 위원장을 포함하여 5인 이내로 하되 위원은 정회원 중에서 이사회의 동의를 얻어 회장이 임명하며, 임기는 2년으로 한다.
3. 포상자의 추천 및 수상 관련 세부 규정을 둘 수 있으며, 이사회의 의결을 거쳐 시행한다.

제7조(학술대회준비위원회)

1. 학술대회준비위원회는 학회가 개최하는 정기 및 비정기 학술대회와 관련된 모든 것을 관장한다.
2. 위원회는 위원장을 포함한 8인 이내로 하며 위원은 정회원 중에서 이사회의 동의를 얻어 회장이 임명하며, 임기는 2년으로 한다.

제8조 (활동)

1. 세부 사업계획은 자체적으로 결정하여 수립한다.
2. 세부 규정 및 세부 사업계획은 이사회에 보고하여야 한다.
3. 필요시 학회에서 예산 및 행정 지원을 할 수 있다.

제3장 간행물

제9조(간행물) 학회의 간행물에 대해서는 다음과 같이 정한다.

1. 정기 학술대회의 발표순서가 담긴 회보는 총무이사가 담당한다.
2. 논문집 우주과학회지는 편집위원회에서 담당한다.
3. 기타 우주과학전반에 걸친 간행물에 관한 토의 및 규정은 필요에 따라 위원회를 두어 담당한다.

제4장 이사회 운영

제10조(이사회 운영)

1. 이사회 직무를 수행하기 어려운 이사는 휴직할 수 있다.
2. 휴직한 이사는 본 학회의 정관 24조 1항의 정원수에서 제외한다.

제5장 규정의 개폐 및 시행세칙

제11조 (세칙) 이 규정의 시행을 위해 필요한 세부사항은 이사회의

승인을 받아 별도로 정할 수 있다.

제12조 (규정 개폐) 이 규정을 개정하거나 폐지할 때는 이사회 재적 이사 과반수의 찬성과 총회의 승인을 받아야 한다.

부칙

제1조(시행일) 이 규정은 총회의 승인을 받은 2014년 10월 30일부터 시행한다.

이 규정은 이사회의 승인을 받은 2016년 2월 18일부터 시행한다.

제2조(경과조치) 이 규정이 제정되기 이전에 시행된 모든 사항은 이 규정을 따른 것으로 본다.

연구윤리위원회의 설치 · 운영에 관한 규정

제정 2008년 1월 2일

제1장 총칙

제1조 (목적)

이 규정은 사단법인 한국우주과학회(이하 “학회”라 한다) 회원으로서 연구를 수행하는 자의 연구윤리를 확립하고 연구부정행위를 사전에 예방하며, 연구부정행위 발생시 공정하고 체계적인 진실성 검증과 처리를 위한 비상설 연구윤리위원회(이하 “위원회”라 한다)의 설치 및 운영 등에 관한 사항을 규정함을 목적으로 한다.

제2조 (정의)

1. 연구부정행위(이하 “부정행위”라 한다)라 함은 다음 각 호가 정의하는 바와 같이 연구의 제안, 연구의 수행, 연구결과의 보고 및 발표 등에서 행하여진 위조·변조·표절·부당한 논문저자 표시·자료의 중복사용 등을 말한다. 다만, 경미한 과실에 의한 것이거나 데이터 또는 연구결과에 대한 해석 또는 판단에 대한 차이의 경우는 제외한다.

① “위조”는 존재하지 않는 데이터 또는 연구결과 등을 허위로 만들어 내는 행위를 말한다.

② “변조”는 연구 재료·장비·과정 등을 인위적으로 조작하거나 데이터를 임의로 변형·삭제함으로써 연구 내용 또는 결과를 왜곡하는 행위를 말한다.

③ “표절”이라 함은 타인의 아이디어, 연구내용·결과 등을 정당한 승인 또는 인용 없이 도용하는 행위를 말한다.

④ “부당한 논문저자 표시”는 연구내용 또는 결과에 대하여 과학적·기술적 공헌 또는 기여를 한 사람에게 정당한 이유 없이 논문저자 자격을 부여하지 않거나, 과학적·기술적 공헌 또는 기여를 하지 않은 자에게 감사의 표시 또는 예우 등을 이

유로 논문저자 자격을 부여하는 행위를 말한다.

⑤ “자료의 중복사용”은 본인이 이미 출판한 자료를 정당한 승인 또는 인용없이 다시 출판하거나 게재하는 행위를 말한다.

⑥ 타인에게 위 제1호 내지 제4호의 행위를 제안·강요하거나 협박하는 행위

⑦ 기타 학계 또는 과학기술계에서 통상적으로 용인되는 범위를 현저하게 벗어난 행위

2. “제보자”라 함은 부정행위를 인지한 사실 또는 관련 증거를 해당 연구기관 또는 연구지원기관에 알린 자를 말한다.

3. “피조사자”라 함은 제보 또는 연구기관의 인지에 의하여 부정행위의 조사 대상이 된 자 또는 조사 수행 과정에서 부정행위에 가담한 것으로 추정되어 조사의 대상이 된 자를 말하며, 조사 과정에서의 참고인이나 증인은 이에 포함되지 아니한다.

4. “예비조사”라 함은 부정행위의 혐의에 대하여 공식적으로 조사할 필요가 있는지 여부를 결정하기 위하여 필요한 절차를 말한다.

5. “본조사”라 함은 부정행위의 혐의에 대한 사실 여부를 검증하기 위한 절차를 말한다.

6. “판정”이라 함은 조사결과를 확정하고, 이를 제보자와 피조사자에게 문서로써 통보하는 절차를 말한다.

제3조 (적용범위) 이 규정은 학회 회원의 연구활동과 직·간접적으로 관련 있는 자에 대하여 적용한다.

제4조 (다른 규정과의 관계) 연구윤리 확립 및 연구진실성 검증과 관련하여 다른 특별한 규정이 있는 경우를 제외하고는 이 규정에 의한다.

제2장 연구윤리위원회의 설치 및 운영

제5조 (소속등) 위원회는 학회내에 비상설위원회로 둔다.

제6조 (구성)

1. 위원회는 위원장 1인을 포함한 3인의 당연직위원과 3인의 추천직위원으로 구성한다.

2. 당연직위원은 학회 부회장 2인과 학술이사로 하며, 추천직위원은 학회장이 임명한다.

3. 위원장은 학술이사로 한다.

4. 위원회는 특정한 안건의 심사를 위하여, 특별위원회를 둘 수 있다.

제7조 (위원장)

1. 위원장은 위원회를 대표하고, 회의를 주재한다.

2. 위원장이 부득이한 사유로 직무를 수행할 수 없는 때에는 위원장이 미리 지명한 위원이 그 직무를 대행한다.

제8조 (위원의 임기) 위원회의 임기는 위원회의 활동기한으로 제한한다.

제9조 (간사등)

1. 위원회의 원활한 업무수행을 위하여 간사 1인을 둘 수 있다.
2. 위원회의 각종 업무를 지원하기 위하여 전문위원을 둘 수 있다.

제10조 (업무) 위원회는 다음 각 호의 사항을 심의·의결한다.

1. 연구윤리 관련 제도의 수립 및 운영에 관한 사항
2. 부정행위 제보 접수 및 처리에 관한 사항
3. 예비조사와 본조사의 착수 및 조사결과의 승인에 관한 사항
4. 제보자 보호 및 피조사자 명예회복 조치에 관한 사항
5. 연구윤리 검증결과의 처리 및 후속조치에 관한 사항
6. 기타 위원장이 부의하는 사항

제11조 (회의)

1. 위원장은 위원회의 회의를 소집하고, 그 의장이 된다.
2. 회의는 재적위원 과반수이상의 출석과 출석위원 3분의 2 이상의 찬성으로 의결한다.
3. 위원장은 심의안건이 경미하다고 인정할 때에는 서면심의로 대체할 수 있다.
4. 위원회에서 필요하다고 인정될 때에는 위원이 아닌 자를 출석케 하여 의견을 청취할 수 있다.

제12조 (경비) 위원회의 운영에 필요한 경비를 학회예산의 범위 내에서 지급할 수 있다.

제3장 연구진실성 검증

제13조 (부정행위 제보 및 접수)

1. 제보자는 학회에 구술·서면·전화·전자우편 등 가능한 모든 방법으로 제보할 수 있으며 실명으로 제보함을 원칙으로 한다. 다만, 익명으로 제보하고자 할 경우 서면 또는 전자우편으로 연구과제명 또는 논문명 및 구체적인 부정행위의 내용과 증거를 제출하여야 한다.
2. 제보 내용이 허위인 줄 알았거나 알 수 있었음에도 불구하고 이를 신고한 제보자는 보호 대상에 포함되지 않는다.

제14조 (예비조사의 기간 및 방법)

1. 예비조사는 신고접수일로부터 15일 이내에 착수하고, 조사시작일로부터 30일 이내에 완료하여 학회장의 승인을 받도록 한다.
2. 예비조사에서는 다음 각 호의 사항에 대한 검토를 실시한다.
 - ① 제보내용이 제2조 제1항의 부정행위에 해당하는지 여부
 - ② 제보내용이 구체성과 명확성을 갖추어 본조사를 실시할 필요성과 실익이 있는지 여부
 - ③ 제보일이 시효기간일로부터 5년을 경과하였는지 여부

제15조 (예비조사 결과의 보고)

1. 예비조사 결과는 위원회의 의결을 거친 후 10일 이내에 학회장과 제보자에게 문서로써 통보하도록 한다. 다만 제보자가 익명인 경우에는 그렇지 아니하다.

2. 예비조사 결과보고서에는 다음 각 호의 내용이 포함되어야 한다.

- ① 제보의 구체적인 내용 및 제보자 신원정보
- ② 조사의 대상이 된 부정행위 혐의 및 관련 연구과제
- ③ 본조사 실시 여부 및 판단의 근거
- ④ 기타 관련 증거 자료

제16조 (본조사 착수 및 기간)

1. 본조사는 위원회의 예비조사결과에 대한 학회장의 승인 후 30일 이내에 착수되어야 한다.
2. 본조사는 판정을 포함하여 조사시작일로부터 90일 이내에 완료하도록 한다.
3. 위원회가 제2항의 기간 내에 조사를 완료할 수 없다고 판단될 경우 학회장에게 그 사유를 설명하고 조사기간의 연장을 요청할 수 있다.
4. 본조사 착수 이전에 제보자에게 위원회 명단을 알려야 하며, 제보자가 위원 기피에 관한 정당한 이의를 제기할 경우 이를 수용하여야 한다.

제17조 (출석 및 자료제출 요구)

1. 위원회는 제보자·피조사자·증인 및 참고인에 대하여 진술을 위한 출석을 요구할 수 있다.
2. 위원회는 피조사자에게 자료의 제출을 요구할 수 있으며, 증거자료의 보전을 위하여 소속 기관장의 승인을 얻어 부정행위 관련자에 대한 실험실 출입제한, 해당 연구자료의 압수·보관 등의 조치를 취할 수 있다.
3. 제1항 및 제2항의 출석요구와 자료제출요구를 받은 피조사자는 반드시 이에 응하여야 한다.

제18조 (제보자와 피조사자의 권리 보호 및 비밀엄수)

1. 어떠한 경우에도 제보자의 신원을 직·간접적으로 노출시켜서는 아니되며, 제보자의 성명은 반드시 필요한 경우가 아니면 제보자 보호 차원에서 조사결과 보고서에 포함하지 아니한다.
2. 제보자가 부정행위 제보를 이유로 징계 등 신분상 불이익, 근무조건상의 차별, 부당한 압력 또는 위해 등을 받은 경우 피해를 원상회복하거나 제보자가 필요로 하는 조치 등을 취하여야 한다.
3. 부정행위 여부에 대한 검증이 완료될 때까지 피조사자의 명예나 권리가 침해되지 않도록 주의하여야 하며, 무혐의로 판명된 피조사자의 명예회복을 위해 노력하여야 한다.
4. 제보·조사·심의·의결 및 건의조치 등 조사와 관련된 일체의 사항은 비밀로 하며, 조사에 직·간접적으로 참여한 자는 조사 및 직무수행 과정에서 취득한 모든 정보에 대하여 누설하여서는 아니 된다. 다만, 정당한 사유에 따른 공개의 필요성이 있는 경우에는 위원회의 의결을 거쳐 공개할 수 있다.

제19조 (제척·기피 및 회피)

1. 위원이 해당 사건과 직접적인 이해관계가 있는 경우에는 그 직무집행에서 제척된다.

2. 위원회는 직권 또는 당사자의 신청에 의하여 제척의 결정을 한다.
3. 위원에게 직무수행의 공정을 기대하기 어려운 사정이 있는 경우에는 제보자나 피조사자는 기피신청을 할 수 있다.
4. 위원은 제1항 또는 제3항의 사유가 있는 때에는 위원장의 허가를 얻어 회피할 수 있다.

제20조 (이의제기 및 변론의 권리 보장) 위원회는 제보자나 피조사자에게 의견진술, 이의제기 및 변론의 권리와 기회를 동등하게 보장하여야 한다.

제21조 (본조사결과보고서의 제출)

1. 위원회는 의견진술, 이의제기 및 변론내용 등을 토대로 본조사결과보고서(이하 “최종보고서”라 한다)를 작성하여 학회장에게 제출한다.
2. 최종 보고서에는 다음 각 호의 사항이 포함되어야 한다.
 - ① 제보 내용
 - ② 조사의 대상이 된 부정행위 혐의 및 관련 연구과제
 - ③ 해당 연구과제에서의 피조사자의 역할과 혐의의 사실 여부
 - ④ 관련 증거 및 증인
 - ⑤ 조사결과에 대한 제보자와 피조사자의 이의제기 또는 변론내용과 그에 대한 처리결과
 - ⑥ 위원 명단

제22조 (판정) 위원회는 학회장의 승인을 받은 후 최종 보고서의 조사내용 및 결과를 확정하고 이를 제보자와 피조사자에게 통보한다.

제4장 검증 이후의 조치

제23조 (결과에 대한 조치)

1. 위원회는 학회장에게 다음 각 호에 해당하는 행위를 한 자에 대하여 징계조치를 권고할 수 있다.
 - ① 부정행위
 - ② 본인 또는 타인의 부정행위 혐의에 대한 조사를 고의로 방해하거나 제보자에게 위해를 가하는 행위
2. 징계조치에 관한 사항은 별도로 정할 수 있다.

제24조 (기록의 보관 및 공개)

1. 예비조사 및 본조사와 관련된 기록은 학회에서 보관하며, 조사 종료 이후 5년간 보관하여야 한다.
2. 최종보고서는 판정이 끝난 이후에 공개할 수 있으나, 제보자 위원·증인·참고인·자문에 참여한 자의 명단 등 신원과 관련된 정보에 대해서는 당사자에게 불이익을 줄 가능성이 있을 경우 공개대상에서 제외할 수 있다.

제5장 기타

제25조 (시행세칙) 위원회는 이 규정의 시행을 위하여 필요한 세부

사항을 별도로 정할 수 있다.

부 칙 1. (시행일) 이 규정은 2008년 1월 2일부터 시행한다.

포상위원회 운영에 관한 규정

2011년 10월 27일 제정

2011년 12월 7일 개정

2015년 1월 16일 개정

2017년 4월 27일 개정

2018년 10월 24일 개정

제1조 (목적) 본 학회 운영규정 제2장 위원회 및 분과활동, 제6조 포상위원회 규정에 따라 포상에 관련된 추천 및 수상관련 세부규정을 정함을 목적으로 한다.

제2조 (포상위원장의 역할) 포상위원장은 위원들을 회장에게 추천하고 위원회 소집, 회의 주제, 수상자 추천 등 제반 업무를 총괄하며 정기총회에서 위원회 활동 사항을 보고 한다. (신설, 2015.1.16)

제3조 (포상의 종류) 본 학회와 관련된 학술활동 및 대외활동에 있어서 뚜렷한 업적이 있는 경우 이에 대한 포상을 하며 그 종류는 다음과 같다. 세부적인 기준은 별도 포상위원회 내부기준으로 정한다.

1. 학술상: 학문적 업적이 뚜렷한 회원에게 매년 정기총회에 수여한다.
2. 두진 우주과학자상: 학문적인 업적이 뛰어난 박사학위 후 15년 이내의 회원에게 매년 정기총회에서 수여한다.
3. 신진 우주과학자상: 우주과학회 회원으로 학문적 업적이 뛰어나며 국내에서 박사학위를 취득 후 5년 이내의 회원에게 매년 정기총회에서 수여한다.
4. 에스이랩 상: 학회 발전에 기여한 학위과정 회원들에게 수여한다.
5. 공로상: 학회의 발전에 커다란 공헌을 한 회원에게 수여한다.
6. 특별상: 학회가 주관하는 활동에 대하여 그 업적이 뛰어난 자 또는 단체에게 수여한다.

제4조 (대외 추천요령) 대외에서 요청받는 포상에 대한 후보자 선정의 경우는, 적절한 기간을 설정하여 전체 회원에게 이 내용을 공지하며, 적절한 형태의 추천형식에 따라 추천을 받는다. 포상위원회에서 별도의 추천을 할 수 있다. 포상위원회에서는 이들 후보자 중에서 해당자를 선정하며, 회장이 결정한다.

제5조 (기타 사항) 선정 기준이 정해지지 않은 포상의 경우는 그 특성에 따라 수상자 혹은 후보자 선정기준을 별도로 적용할 수

있으며, 회장이 포상위원회와 협의하여 선정한다.

제6조 (내부기준) 포상위원회 세부규정 시행을 위해 필요한 세부사항을 내부기준 또는 지침으로 정할 수 있다 (신설, 2015.1.16)

제7조 (운영규정 개폐) 이 규정을 개정하거나 폐지할 때는 이사회의 승인을 받아야 하며 총회에 보고하여야 한다 (신설, 2015. 1. 16)

부칙 (시행일)

1. 이 규정은 2011년 10월 27일부터 시행한다.
2. 이 규정은 2012년 1월 1일부터 시행한다.
3. 이 규정은 2015년 1월 16일부터 시행한다.
4. 이 규정은 2017년 4월 27일부터 시행한다.
5. 이 규정은 2018년 10월 24일부터 시행한다.

편집위원회 운영에 관한 규정

2014년 4월 24일 제정

제1장 총 칙

제1조 (목적) 본 한국우주과학회 (이하 본 학회) 정관 제4조 (사업) 2항 학술간행물의 발행 및 배포와 학회 운영에 대한 규정 제5조 (편집위원회) 임무와 위원 구성 조항과 관련된 제반 사항을 규정함을 목적으로 한다.

제 2조 (임무)

1. 본 위원회의 주임무는 학술간행물의 발간과 배포와 관련하여 논문의 기획, 접수, 심사, 편집, 관리 등을 주관한다.
2. 기획 논문집, 자료의 발굴 및 수집 등 본 학회에서 발간하는 모든 도서의 기획 및 편집 등을 주관한다.
3. 학회지 발간과 관련된 제반 규정을 정한다.

제2장 편집위원회의 구성

제3조 (위원회의 구성) 위원회의 위원은 학회 운영에 대한 규정 제5조에 의거하여 내국인 15인, 내외 외국인 20인 내외로 한다.

제4조 (위원의 선임)

1. 위원은 학회 운영에 대한 규정 제5조에 따라 지역과 전공 등을 고려하여 편집위원장이 추천하고 본 학회 이사회의 동의를 받아 회장이 임명한다.
2. 위원이 개인사정으로 인하여 사임하는 경우, 그 후임자를 즉시 새로 위촉한다.

제5조 (위원의 임기)

1. 위원의 임기는 학회 운영에 대한 규정 제5조에 의거하여 2년으로 한다.
2. 위원의 사임으로 인하여 새로 보임된 자의 임기는 전임자의 잔여임기로 한다.
3. 위원은 필요한 경우 연임할 수 있다.

제6조 (위원의 자격) 편집위원의 자격은 다음과 같다.

1. 학회 활동에 적극적이고 학술 활동을 활발히 하는 자.
2. 연구 업적이 국내외의 학계에서 현저한 자.

제7조 (위원의 의무)편집위원은 다음의 의무를 가진다.

1. 위원은 위원회 개최시에 특별한 사유가 없는 한 출석하여야 한다.
2. 위원은 공정해야 하고, 항상 학회와 학문 발전을 위하여 부단히 노력하여야 한다.

제8조 (위원장 및 부위원장의 선임)

1. 위원회의 위원장은 학회 운영에 대한 규정 제5조에 의거하여 학술이사가 당연직으로 맡는다.
2. 위원장은 위원회를 소집하고, 그 의장이 된다.
3. 위원장의 업무를 보조하기 위해 부위원장을 둘 수 있으며 부위원장은 위원장이 임명한다.
4. 위원장과 부위원장의 임기는 2년으로 하고 연임할 수 있다.

제9조 (회의 소집)

1. 회의 소집은 개최일 1주일 이전에 연락하여 위원장이 행한다.
2. 위원장이 임무를 수행하기 곤란할 때는 부위원장이 소집한다.

제10조 (의결)

1. 위원회는 재적위원 과반수 출석으로 성립하고, 출석위원 과반수의 찬성으로 결정한다.
2. 출석하지 못한 위원이 위임장을 제출한 경우, 출석인원에는 포함하되, 의결시에는 포함하지 않는다.
3. 시간이 촉박한 중대한 사항에 대하여는 위원장이 직접 전화나 전자우편 등으로 위원의 의견을 들어 결정할 수 있다.
4. 특정 사안에 대하여 위원장이 위원회의 위임을 받은 경우 위원장이 처리할 수 있다.

제11조 (문서 관리)

1. 위원회의 회의록은 반드시 작성하고, 작성일로부터 3년간 보관한다.
2. 위원회의 원고 접수, 관리, 심사위원 위촉, 심사결과 보고서 취합, 심사결과통보 등은 모두 문서로 하며, 그 문서는 3년간 보관한다.

제3장 학회지 Journal of Astronomy and Space Sciences(이하 JASS)의 발간

제12조 (분야) JASS는 천문학 및 우주과학 전반에 관한 주제의 영문논문을 출판한다.

제13조 (발행 횟수) JASS는 년 4회 발행하는 것을 원칙으로 한다.

제14조 (발행일) 발행일은 매년 3, 6, 9, 12월의 15일로 한다.

제15조 (발행 부수) 현재 회원수와 보관용 등을 감안하여 위원회에서 정한다.

제16조 (편집 체제) 한국우주과학회 학술지 투고 규정에 따른다.

제17조 (학회지 배포)

1. 회비를 납부한 회원에게 발행일로부터 15일 이내에 학회지를 우송하는 것을 원칙으로한다.
2. 발행일 이후에 회비를 납부한 회원에게는 당해연도 발행부를 일괄 우송한다.
3. 학술대회 등 다수 회원이 참석하는 회의 일정이 30일 이내에 계획되어 있는 경우, 우송을 연기할 수 있다.
4. 외국에 거주하는 회원의 우송료는 별도로 징수할 수도 있다.

제18조 (논문 접수 및 투고 논문의 관리) 논문은 연중 수시로 접수하며 투고논문은 반드시 접수 대장을 작성하여 관리한다.

제19조 (심사 의무)

1. 학회지에 게재할 논문은 반드시 심사를 거쳐야 한다.
2. 기획 논문 및 특별히 청탁한 원고나 외국인의 원고와 학술대회 발표논문 등은 위원장의 결정으로 심사를 면제할 수 있다.

제20조 (심사위원 위촉)

1. 심사위원의 위촉은 위원회의 결의로 편집위원장이 행한다.
2. 심사위원은 논문 1편 당 2인을 위촉한다. 단 위원회는 만일의 경우를 대비하여 후보위원 1인을 추가로 선정하여 둔다.
3. 심사위원의 위촉은 가급적 전공, 연령, 지역 등이 편중되지 않도록 위촉한다.
4. 논문 투고자와 근무지가 같거나 학연 등 특별한 관계가 있는 자를 심사위원으로 선정하지 않는 것을 원칙으로 한다.
5. 심사위원에게는 소정의 심사료를 지불한다.
6. 심사위원의 위촉에 관한 사항은 공개하지 않는다.

제21조 (심사위원 수칙)

1. 공정한 기준을 정하여 공정하게 평가하여야 한다.
2. 논문 심사결과 등을 타인에게 발설하여서는 안 된다.

제22조 (심사기준)

1. 심사위원은 심사대상 논문이 JASS가 추구하는 주제를 다루고 있고 기존에 발표되지 않은 새로운 결과임을 확인하여야 한다.
2. 심사위원은 심사대상 논문이 국제적 수준의 결과를 포함하고 있는지 판단하여야 한다.

3. 심사위원은 심사대상 논문이 JASS의 편집체제에 맞추어 작성되었는지 확인하여야 한다.

4. 심사위원은 심사대상 논문의 영문 교열을 확인하여야 한다.

제23조 (심사결과 보고) 심사위원은 심사 대상 논문을 접수한 날로부터 10일 이내에 소정의 심사결과 보고서를 위원회에 제출하여야 한다.

제24조 (심사결과 통보) 심사위원이 심사결과 보고서를 제출하면, 위원장은 심사위원의 성명이나 소속 등을 삭제하고, 즉시 그 결과를 투고자에게 전자우편으로 통보한다.

제25조 (수정보완)

1. 심사결과 통보를 받은 투고자는 심사위원의 수정의견을 최대한 반영하여 논문의 질적 향상을 도모하여야 한다.
2. 심사의 종합결과 '게재 가' 혹은 '수정 후 게재' 등급을 받은 투고자는 학회에서 정한 기일내에 수정논문을 학회에 제출해야 한다.
3. 심사의 종합결과, '수정 후 재심' 등급을 받은 논문 투고자는 충분히 연구보완 수정 후에 다음 호에 게재될 수 있도록 완벽하게 수정한 논문을 학회에 제출해야 한다.

제26조 (논문 투고자의 자격) 논문의 교신저자는 한국우주과학회 회원으로 한정한다.

제27조 (논문 게재료 납부)

1. 심사완료 게재된 논문의 투고자는 학회에서 지정한 기일까지 소정의 게재료를 납부하여야 한다.
2. 국제 학술회의, Symposium, Workshop 등의 Proceeding 논문을 JASS에서 출판하는 경우, 편집위원장의 청원으로 이사회 동의를 받아 논문 게재료를 면제할 수 있다.
3. 위원회에서 요청한 논문이나 기타 본 학회의 국제성을 위한 특별한 원고에 대해서는 게재료를 징수하지 않는다.

제28조 (원고료) 위원회에서 요청한 논문이나 기타 본 학회의 국제성을 위한 특별한 원고에 대해서는 원고료를 지급할 수 있다.

제4장 규정의 개정

제29조 (개정절차) 이 규정의 개정은 이사회 승인을 요한다.

제30조 (개정발표) 개정된 편집규정은 다음 호의 학회지에 게재하여 발표한다.

1. (효력발생) 이 규정은 2014년 1월 1일부터 시행한다.
2. (시행규칙) 이 규정의 시행에 필요한 세부사항은 편집위원회에서 별도로 정하여 이사회 승인을 받는다.

임원 선출에 관한 규정

2011년 8월 26일 제정
2011년 12월 7일 개정
2014년 10월 30일 개정
2018년 10월 24일 개정

제1조 (목적) 한국우주과학회 정관 제12조 1항에 따라 임원선출에 관한 사항을 규정함을 목적으로 한다.

제2조 (선거권) 정회원 자격을 취득한지 만 1년이 경과된 회원은 선거권을 갖는다.

제3조 (임원 자격)

1. 회장은 최근 10년간 학회의 정회원으로 활동하고 있으며, 이사로 봉사한 경험이 있는 회원이어야 한다.
2. 이사는 최근 5년간 본 학회의 정회원으로 활동하고 있는 회원이어야 한다.
3. 감사는 10년간 본 학회의 정회원으로 활동한 회원이어야 한다.

제4조 (회장후보 선출)

1. 회장 후보는 선거권자 온라인 추천 투표에서 최소 10명 이상의 추천을 받은 자로 한다.
2. 제1항을 충족하는 복수의 후보자가 없을 경우, 이사회에서 최대 2명의 후보를 지명할 수 있다.
3. 회장은 회장 후보를 총회 개최 최소 1주일 전에 회원에게 알려야 한다.
4. 회장 후보 선출 온라인 추천 투표에서 선거권자 1인은 1명의 후보를 추천할 수 있다.
5. 회장 후보 선출 온라인 추천 투표는 임원선출 정기 총회 개최 30일 전에 실시하고 그 기간은 2주로 한다.

제5조 (회장 선출)

1. 회장은 총회에서 회장 후보를 대상으로 하여 선거권자의 무기명 비밀선거로 선출한다.
2. 무기명 투표에서 과반수의 득표를 한 후보자가 없을 경우 상위 득표자 2인을 대상으로 재투표하여 다수 득표자를 차기회장으로 한다.

제6조 (부회장 선출) 부회장은 회장이 지명한다.

제7조 (이사선출)

1. 전체 이사 수의 1/2을 선거권자 온라인 투표로 선출하며, 나머지 1/2은 차기 회장이 지명한다.
2. 이사 선출 온라인 투표는 선거권자 1인이 3명을 추천한다.
3. 투표 결과 상위 다득점자로 수락 여부를 거쳐 이사의 1/2을 확정한다.
4. 선출된 이사 중에서 총회 당일 회장 또는 감사로 선출되어 결원

이 생긴 경우 차득점 순으로 수락 여부를 거쳐 이사로 확정한다.

5. 부회장, 총무, 재무, 학술이사는 회장이 지명하며, 당연직 이사가 된다.

제8조 (감사선출) 감사는 총회에서 직접선거로 선출한다.

제9조 (세칙) 이 규정의 시행을 위해 필요한 세부사항은 이사회 승인을 받아 별도의 세칙으로 정할 수 있다.

제10조 (규정 개폐) 이 규정을 개정하거나 폐지할 때는 이사회 재적 이사 과반수의 찬성과 총회의 승인을 받아야 한다.

부칙 1. 이 규정은 2014년 10월 30일부터 시행한다.

2. 이 규정은 2018년 10월 24일부터 시행한다.

사단법인 한국우주과학회 용역사업 규정

2011년 12월 7일 제정
2020년 1월 21일 개정

제1조 (목적) 이 규정은 용역사업의 시행에 대하여 필요한 사항을 규정함을 그 목적으로 한다.

제2조 (적용범위) 이 규정은 외부로부터 수탁하거나 학회 예산으로 직접 수행하는 용역사업에 적용한다.

제3조 (사업구분) 학회에서 수행하는 용역사업은 정관 제4조의 사업 중 다음 각 호의 사업에 한한다.

1. 우주과학 및 그와 관련된 분야의 기초 및 응용 연구, 연구지원, 기술교육
2. 우주과학 및 그와 관련된 분야의 자료의 발행과 보급
3. 국내외 관련 학회와의 기술 교류
4. 우주과학 및 그와 관련된 분야의 기준 및 규정의 제언
5. 정부, 공공단체, 기타 기관에 대한 자문 및 건의
6. 기타 학회의 목적을 달성하기 위한 사업

제4조 (연구진의 구성과 자격)

1. 연구진은 연구책임자, 연구원, 보조연구원으로 구성하며, 사업의 규모, 기간 및 사업비 등을 고려하여 필요한 경우에는 총괄 연구책임자를 둘 수 있다.
2. 연구진은 학회 회원으로 구성함을 원칙으로 한다. 다만, 학회에 해당분야 전공자가 없거나 보조연구원인 경우에는 예외로 할 수 있다.

제5조 (연구책임자의 자격과 선임)

1. 총괄 연구책임자 또는 연구책임자(이하 “연구책임자”라고 칭함)는 학계의 지식과 경험이 풍부한 전문가로서, 특히 연구분야별로 연구진을 통솔하고 연구기획, 조정능력을 갖춘 자이어야 한다.
2. 연구책임자는 학회 분과위원회, 전문성, 지역성을 최대한으로 고려하여 회장이 선임한다. 단, 의뢰자가 연구책임자를 지명할 경우 의뢰자의 뜻에 따라 선임함을 원칙으로 하되, 지명된 회원이 연구책임자로 부적합하다고 판단되는 경우에 회장은 의뢰자와 협의하여 연구책임자를 변경할 수 있다.

제6조 (연구책임자의 역할과 책임)

1. 연구책임자는 연구진의 구성과 변경에 관하여 책임을 져야 한다.
2. 연구책임자는 연구사업의 진행, 성과의 신뢰성, 연구기간의 엄수 등 계약서의 모든 사항을 책임져야 한다.
3. 연구책임자는 수탁용역사업 종료 후 1년 이내에 사업수행성과에 대한 개요를 학회지 혹은 학회논문집에 게재하여야 한다.

제7조 (비용징수와 비용의 산정) 개인 또는 단체가 3조의 용역사업을 학회에 위탁하는 경우에는 필요한 비용을 징수한다. 용역비용 산정은 다음 각 호에 따른다.

1. 용역비용은 교육과학부 장관이 고시하는 연구개발사업 처리규정의 제20조의 연구개발비 사용(이하 정부기준)의 범위 내에서 학회와 의뢰자가 협의하여 정한다.
2. 전항에 규정되지 아니한 용역사업은 당해 사업 수행에 필요한 직접경비의 범위 내에서 학회와 의뢰자가 협의하여 정한다.

제8조 (정부기준 적용원칙) 정부기준의 적용은 다음에 따른다.

1. 직접인건비: 당해 사업에 참여하는 회원 및 외부전문가의 인건비로서 정부기준을 적용한다.
2. 직접경비: 당해 사업 수행에 직접 필요한 여비, 재료비, 인쇄비, 복사비, 시험비, 외부전문가 자문비 등을 포함한 실비를 계산 산출한다.
3. 간접경비: 간접경비의 계상은 의뢰자가 학회에 직접 의뢰한 경우는 전체 용역 금액의 20%로 하고, 의뢰자가 학회의 회원에게 직접 의뢰하였으나 그 회원이 학회를 통하여 수주하는 경우는 전체 용역 금액의 5% 이상으로 한다.

제9조 (용역비용의 수령 및 지출) 용역의뢰자가 용역기간 중에 용역비용의 일부만을 학회에 지급하고, 용역계약 만료 시 그 나머지 비용을 지급하는 경우, 학회는 원활한 연구 진행을 위해 필요한 비용을 연구책임자에게 선지급할 수 있다.

제10조 (용역비용의 관리) 학회는 용역사업의 용역비용의 지출을 연구책임자와 협의 하에 관리할 수 있다.

제11조 자세한 운영내용은 운영세칙에 정한다.

부 칙 (시행일)

1. 본 규정은 2012년 1월 1일부터 시행한다.

2. 이 규정은 2020년 1월 21일부터 시행한다.

한국우주과학회 학술지 투고 규정

1. PUBLICATION TYPES, QUALIFICATION FOR AUTHORSHIP

Five types of manuscripts are published in this journal: Editorials, Review Papers, Research Papers, Technical Papers, and Letters to the Editor.

Editorials:

Editorials are submitted by invitation only and will be on topics considered to be essential by the Editorial Board of the journal.

Review Papers:

Review papers will be published by direct submission as well as from invited experts. In both cases, the work will be subject to editorial review. Review papers should critically review topics not only to inform the reader of the background, but also to communicate the state of the art and outstanding research problems.

Research Papers:

Following a peer review, original findings within the scope of the journal will be published. Critical and new results of experiments or theories should be described in full-length research papers.

Technical Papers:

Articles in this category introduce scientific work on novel skills dealing with new methods and techniques.

Letters to the Editor:

Any issues of interests to the journal readership may be contained in letters to the editor. Letters concerning articles published earlier will generally be sent to the author of the previous research for possible response before publication.

2. RESEARCH AND PUBLICATION ETHICS

Research published in JASS must follow institutional, national, and international guidelines. For the policies on the research and publication ethics that are not stated in this

instructions, International standards for editors and authors (<http://publicationethics.org/node/11184>) can be applied.

Authorship

An author is defined as one who has made a significant contribution to the overall design and execution of the experiment; the Korean Space Science Society thus deems all authors responsible for the entire paper.

Originality and Duplicate Publication

All submitted manuscripts should be original and should not be submitted to other scientific journals for consideration while under JASS review. No part of an accepted manuscript should be duplicated in other scientific journals without the permission of the Editorial Board. If duplicate publication related to papers in this journal is detected, the names of the authors will be announced in this journal, the authors' institutes will be informed, and the authors will be subject to restrictions on future publications in JASS.

CrossCheck is a multi-publisher initiative to screen published and submitted content for originality. JASS uses iThenticate software to detect instances of overlapping and reproduced text in submitted manuscripts. Detailed information about CrossCheck can be found at <https://www.crossref.org>.

Conflict of Interest Statement

Authors should disclose any conflicts of interest in their manuscripts.

3. PEER REVIEW PROCESS

Once manuscripts are submitted, they will be reviewed by two or more experts in the corresponding field. The Editorial Board may request that authors revise the manuscripts in light of the reviewers' suggestions. The authors should upload the revised files with a reply to each item in the reviewers' comments after revision of the manuscript. The authors should complete the revisions within 60 days of request. If the authors want to extend the revision period to more than 60 days, they should contact the Editorial Board. The manuscript review process should be completed after the second review. If the authors wish to engage in further revision, the Editorial Board may consider it. The Editorial Board will make a final decision on the approval for publication of submitted manuscripts and can request further corrections of the

article text if necessary. Review and publication processes that are not described in the Instructions for Authors will be incorporated from the Editorial Policy Statements, approved by the Council of Science Editors Board of Directors (<https://www.councilscienceeditors.org/resource-library/editorial-policies/white-paper-on-publication-ethics/2-3-reviewer-roles-and-responsibilities/>).

4. COPYRIGHTS

The Korean Space Science Society requires a corresponding author to sign a copyright transfer agreement on behalf of all the authors in order to maintain and protect the ownership and the rights of the Society, as well as to protect the original authors from misappropriation of their work. If this agreement is not assented to, the Korean Space Science Society will not publish the manuscript. This agreement is sent with the proofs to the corresponding author.

5. PAGE CHARGES

Basic publication fee = ₩400,000 (US \$400) + ₩20,000 (US \$20) per page. Additional charges are applicable for color illustration(s), not to exceed ₩300,000 (US \$300), priced as follows: 1st colored page at ₩200,000 (US \$200) + 2nd and 3rd colored pages at ₩50,000 (US \$50) each. English correction services are provided on request for JASS authors at 50% of the cost.

6. SUBMISSION OF MANUSCRIPT

Authors must submit manuscript files to the Editorial Office of the Korean Space Science Society using the online submission system of the Journal at <http://janss.kr>. We do not accept direct email submission to the Editor-in-Chief or Editors. Incomplete manuscripts will be returned to the author without review. Manuscripts submitted to the journal must represent reports of original research and must be written in English. Manuscripts are accepted for review under the condition that important parts of the study have not been published and are not being considered for publication. Also, no submission can be published without approval of the institution and all the authors. The usual prerequisites for publication will be originality, clarity, and significance as relevant to a better understanding of space science and technology.

7. MANUSCRIPT PREPARATION

Word Processors and Format of Manuscript:

Manuscripts should be submitted in the file format of Microsoft Word 2007 or a later version. Manuscripts should be doublespaced, using a font size of 11. Pages should be numbered consecutively, beginning with the title page. Page numbers should be placed at the middle of the bottom of each page. There is no fixed maximum length for full-length papers, but they rarely exceed 30 double-spaced, typewritten pages on 210 × 297 mm (A4 size) paper, including figures and tables.

Research and Technical Papers

The manuscript for a research or technical paper should be organized in the following sequence: title page, abstract and keywords, introduction, methods, results, conclusion, acknowledgments, references, tables, and figure captions.

Title page:

The title page should include the full title of the article, authors' names, affiliations, footnotes, and a short title. The title should emphasize the principal objectives covered by the paper. Authors' names should be consistent and preferably be written in a standard form for all publications to facilitate indexing and to avoid ambiguity. If some of the authors have different affiliations, use superscript numbers (1, 2, 3...) after the surnames of authors and before the names of their affiliations. Use a dagger (†) after the name of one designated corresponding author. The contact information for correspondence should include the mailing address, e-mail address, telephone number, and the ORCID iD.

Abstract & Keywords:

The abstract should state the objectives and present salient conclusions in no more than 200 words. This should be a clear, concise summary describing the scope and purpose, methods or procedures, significant new results, and conclusions. The abstract should be written as one paragraph. At the end of the abstract, the keywords should be given in 3 to 6 words or phrases.

Introduction:

The paper should begin with an introduction that is written for the general reader of the journal as well as

for the specialist. This section should include the background and objectives, together with significant prior works.

Methods:

The methods section should include sufficient information to allow the results to be repeated. Refer to published procedures

by citing both the original description and pertinent published modifications. Do not include extensive details unless they present a substantial modification. For commonly used methods, a simple reference is sufficient. If several alternative methodologies are employed, it is useful to identify the methods briefly as well as to cite the references.

Results:

The results should be described in logical order using text, tables, and illustrations, to make clear the protocol of the study. Where appropriate, tests should be described and supported by a reference to the original citation of the test.

Conclusions:

The conclusions section should highlight key findings and compare the results of the work to appropriate findings of other studies. The conclusions should be based on the evidence presented in the paper.

Acknowledgments:

The acknowledgments section is placed at the end of body. It can cite financial and any other support.

References:

References must be obviously related to the manuscript. In the text, references should be cited with the author's surname and year of publication. When reference is made to a work by two authors, both names should be given using "&" (e.g., Kim & Lee 1996); for three or more author names, give the first author followed by "et al." and the year (e.g., Park et al. 2010). Multiple references must be arranged in chronological order (e.g., Sohn 1982; Choi & Kang 1991; Ahn et al. 2003). If more than two papers with the same authors and publication years are cited, list a, b, c... after the year to clarify (e.g., Jung & Han 2011a, b). Only cite articles or books already published or in press, not unpublished work "in preparation." In the

references section, the references should be listed in alphabetical order by letter of the first author's surname. List the first five authors followed by "et al." if there are more than five authors. If more than two papers with the same authors and publication years are cited, list a, b, c... after the year in publication order. Abstracts of conferences should not be included in the references. Lines after the first line of a reference are indented by one tab space ("hanging indent" in MS Word). The style for citing papers in periodicals is surname and initials of authors, title, journal name, volume, first and last page numbers, year, and digital object identifier (DOI) if available. The styles to be used for references are as follows:

Journal articles:

1. Takahashi K, McPherron RL, Hughes WJ, Multispacecraft observations of the harmonic structure of Pc3-4 magnetic pulsations, *J. Geophys. Res.* 89, 6758-6774 (1984). <https://doi.org/10.1029/JA089iA08p06758>
2. Hwang KJ, Kuznetsova MM, Sahraoui F, Goldstein ML, Lee E, et al., Kelvin-Helmholtz waves under southward interplanetary magnetic field, *J. Geophys. Res.* 116, A08210 (2011). <https://doi.org/10.1029/2011JA016596>

Book, Book in series:

3. Kelley MC, *The Earth's Ionosphere* (Academic Press, San Diego, 1989).

Articles from book, conference or symposium proceedings:

4. Holmberg E, Magnitudes, colors, surface brightness, intensity distributions, absolute luminosities, and diameters of galaxies, in stars and stellar systems, vol. 9, *Galaxies and the Universe*, eds. Sandage A, Sandage M, Kristian J (Univ. Chicago Press, Chicago, 1975), 123-157.
5. Capitaine N, Gambis D, McCarthy DD, Petit G, Pay J, et al., Proceedings of the IERS Workshop on the Implementation of the New IAU Resolutions, Observatoire de Paris, Paris, France, 18-19 April 2002.
6. Kim K, Hwang J, Sung S, Geosynchronous magnetic field variations associated with the passage of interplanetary shocks or solar wind discontinuities, in 2007 AGU Fall Meeting, San Francisco, CA, 10-14 Dec 2007.

Technical report:

7. Mazanek DD, Roithmayr CM, Antol J, Park SY, Koons RH, et al., Comet/asteroid protection system (CAPS): preliminary space-based system concept and study results, NASA Langley Research Center Technical Report, NASA/TM-2005-213758 (2005).

Dissertation:

8. Park SY, Optimization and guidance of ascent trajectories with inequality constraints, PhD Dissertation, Texas A&M University (1996).

Website:

9. National Radio Astronomy Observatory, Very long baseline array [Internet], cited 2011 Feb 20, available from: <https://www.vlba.nrao.edu>

Tables:

Each table should be prepared on a separate page and numbered with an Arabic numeral in the order of its appearance in the text. When it is difficult to present data that cannot be synthesized conveniently in the text, tables should be used. Authors should avoid extensively repeating in the text data that appear in tables. Abbreviated names should be defined when they are used for the first time in each table. Tables should have a concise and informative title with the table content between horizontal lines. Vertical lines should not be used. The structure should be clear, with simple column headings giving all units. A table should not exceed one page when printed. Use lower case letters in superscripts (a, b, c...) for special remarks. Unaltered computer output and notation are generally unacceptable.

Figures:

Each figure or figure plate must have a caption written in one paragraph. For figure plates, a summary statement should precede the specific explanation of each figure. Abbreviated names are not allowed when they are used for the first time in each figure. The explanatory caption of each illustration should be understandable without reference to the text. Number figures in order of citation. Authors should place the figure number in the lower-left corner of each figure, and the numbering order must be from left to right, and from top to bottom. Citations of figures in the text or parentheses are abbreviated, e.g., Fig. 1, Figs. 1 and

2, Figs. 1–3, (Fig. 1), (Figs. 1 and 2), (Figs. 1–3). When the text refers to both figures and tables, they may be mentioned in parentheses, e.g., (Table 1; Fig. 2) and (Tables 1–3; Figs. 4–6). Line drawings should be prepared in high quality using India ink on tracing paper. Computer-generated graphics must be produced with high tones JOURNAL OF ASTRONOMY AND SPACE SCIENCES and resolution. Photographs must be of sufficient contrast to withstand the inevitable loss of contrast and detail during the printing process. Authors should double check whether the text withstands reduction and remains legible if a figure or a figure plate is reduced. Electron and light microscopic figures must be original or scanned copies from the original.

Review Papers

Review papers may be solicited or submitted. A comprehensive presentation of a topic should discuss previously published material. Topics of scientific consensus as well as topics that remain controversial may be dealt with in reviews. A review is organized as follows: title page including abstract and keywords, introduction, body text, conclusions or summary, acknowledgments, and references. Text that exceeds 5,000 words, excluding references, will not be accepted.

Letters to the Editor

Brief constructive comments about previously published articles and interesting new ideas should be submitted as Letters to the Editor. The body text should not exceed 1,000 words and should include references. The Editorial Board may edit the Letters. In the case of comments on previously published articles, Letters to the Editor should be submitted no more than three months after the original paper has been published. The Editorial Board may contact the authors for a response to the Letters.

General points on text style

Verb tense:

Generally, authors should use the past tense or present perfect tense to delineate specific events in the past, including the procedures, observations, and data of the study that authors are reporting. Use the present tense for the authors' own general conclusions, firm conclusions of previous researchers, and generally accepted facts and phenomena. The Abstract, Methods, and Results should generally be in the past tense or present perfect tense, whereas most of the Introduction and some of the Conclusions can be in the present tense. However, the tense may be different in a single sentence.

Units:

If authors describe length, height, weight, and volume, they should use standard metric units. Temperature should be given in degrees Celsius. All other units should follow the International System of Units (SI). All units must be preceded by a space.

Numbers:

Except when beginning a sentence in the text, numbers should be Arabic numerals. Authors should use commas if numbers are greater than 999, e.g., 1,984,826. The 24-hour system is used to indicate time, e.g., 20:00 hr.

Abbreviations:

Abbreviations must be used as an aid to the reader, rather than as a convenience of the author, and therefore their use should be limited. Generally, avoid abbreviations that are used less than three times in the text, including tables and figure legends. Standard SI abbreviations and units in astronomy are recommended. Other common abbreviations are as follows (the same abbreviations are used for plural forms): hr (hour), sec (second), min (minute), day (not abbreviated), year (yr), and g (gravity).

한국우주과학회 제38차 정기총회

일 시 : 2020년 10월 29일(목) 16:50

장 소 : 제주 신화월드

1. 정족수 확인 총무이사 이주희
2. 개회선언 회장 최기혁
3. 전회의록 낭독 총무이사 이주희
4. 사업보고 총무이사 이주희
5. 학술대회준비위원회 보고 위원장 황정아
6. 학술보고 학술이사 선종호
7. 포상위원회 보고 위원장 이병선
8. 감사보고 감사 김용하
9. 안건 1. 2020년 결산(안) 심의 재무이사 곽영실
10. 안건 2. 2021년도 예산(안) 심의 재무이사 곽영실
11. 안건 3. 한국우주과학회 정관 개정 건 회장 최기혁
12. 안건 4. 학회운영에 대한 규정 개정 건 회장 최기혁
13. 안건 5. 임원선출에 대한 규정 개정 건 회장 최기혁
14. 기타 토의 회장 최기혁
15. 폐회 다같이

한국우주과학회 제37차 정기총회 회의록

- 소집연월일 : 2019년 10월 24일 16:40
- 개 최 장 소 : 여수베네치아 호텔&리조트
- 개 최 일 시 : 2019년 10월 24일(목) 16:40~18:00
- 참 석 회 원 : 국내 거주 정회원 675명 중 119명 참석

국내 거주 정회원 675명 중 정회원 119명 참석으로 정관 제18조 1항에 의거 총 정회원의 1/10 이상(성원 68명) 출석하였으므로 김용하 의장이 제37차 정기총회 개회를 선언함.

■ 전회의록 낭독

이의 없이 유인물대로 채택되었음.

1. 사업보고(곽영실 총무이사)

곽영실 총무이사가 2019년도 정기 학술대회, 학술지 및 학회보 발행, 이사회 회의에 대하여 보고하였으며 이의 없이 통과됨.

2. 학술대회준비위원회 보고(이주희 학술대회준비위원장)

이주희 학술대회준비위원장이 학술대회준비위원회 구성과 학술대회 개최실적에 대하여 보고하였으며 이의 없이 통과됨.

3. 학술보고(곽영실대 총무이사)

장현영 학술이사 대신 곽영실 총무이사가 편집위원회 구성, 학술지 발간 현황에 대하여 보고하였으며 이의 없이 통과됨.

4. 포상위원회 보고(곽영실대 총무이사)

손영종 포상위원장 대신 곽영실 총무이사가 포상위원회 구성, 2019년 한국우주과학회 학술상, 두진 우주과학자상, 신진 우주과학자상 및 에스이랩상 수상자, 제29회 과학기술우수논문상 수상자에 대하여 보고하였으며 이의 없이 통과됨.

5. 감사 보고(한원웅)

김갑성, 한원웅 감사가 2019년 1월 1일부터 9월 30일까지의 업무 및 회계감사를 실시(2019년 10월 10일), 한원웅 감사가 그 결과를 보고하였으며 이의 없이 통과됨.

■ 의결 안건

안건 1. 2019년도 결산(안) 승인 건

김관혁 재무이사가 2019년 결산(안)을 보고하였으며 동의와 재정으로 원안대로 통과됨.

안건 2. 2020년도 예산(안) 승인 건

김관혁 재무이사가 2020년도 예산(안)에 대하여 보고하였으며 동의와 재정으로 원안대로 통과됨.

안건 3. 제19대 회장 선출 건

학회 정관 제12조에 의하여 당 법인의 대표권이 있는 이사 김용하의 2019년 12월 31일 임기만료로 인하여 차기 회장을 선출하여 줄 것을 제안하고 임원 선출 규정에 따라 차기 회장을 선출함.

차기 회장 선출을 위하여 정회원 자격을 취득한지 만1년이 경과된 회원들로부터 온라인으로 후보를 추천받은 결과 10명 이상의 추천을 받은 이동훈 회원, 이유 회원, 최기혁 회원이 후보로 결정되어 총회에서 무기명 비밀선거를 실시함. 투표에 정회원 109명이 참여했으며, 최기혁 회원이 과반수의 득표를 얻어 차기 회장으로 선출되어 의장이 이를 공표하고 최기혁 회원은 즉석에서 취임을 승낙함.

- 임기 : 2020. 1. 1.~2021. 12. 31.

안건 4. 감사 선출 건

의장은 법인 감사 김갑성 회원, 한원웅 회원이 2019년 12월 31일 임기만료로 인하여 후임 감사를 선출하여 줄 것을 제안하고 후보자로 김용하 회원, 김천희 회원이 추천됨. 추천된 2인의 후보자를 감사로 선임하는 것에 동의와 재청이 있어 2인의 후보를 감사에 선임하기로 의장이 공표하고 김용하 회원, 김천희 회원은 즉석에서 취임을 승낙함.

- 임기 : 2020. 1. 1.~2021. 12. 31.

안건 5. 부회장, 이사 선출 건

의장은 법인 부회장 손영종, 오승준, 최기혁 회원이 2019년 12월 31일 임기만료로 인하여 후임 부회장 선임을 임원선출규정 제6조에 의하여 차기 회장에게 위임하기로 동의와 재청으로 가결함.

- 임기 : 2020. 1. 1.~2021. 12. 31.

의장은 제18대 이사가 2019년 12월 31일 임기만료로 인하여 임원 선출규정 제7조에 따라 전체 이사의 1/2을 온라인투표로 선출하고 나머지 1/2은 차기 회장이 지명하도록 함에 따라 2019년 9월 24일(화) ~ 10월 7일(월)까지 학회 홈페이지(<http://ksss.or.kr>)를 통하여 온라인투표로 선출된 이사를 공표하고 나머지 이사는 차기 회장이 지명 하는데 동의와 재청으로 가결함. 온라인투표로 선출된 이사는 즉석에서 취임을 승낙함.

- 온라인 선출이사(12명) : 곽영실, 김관혁, 김해동, 박장현, 오수연, 이병선, 이유, 이주희, 지건화, 진호, 최영준, 황정아

- 임기 : 2020. 1. 1.~2021. 12. 31.

이상으로, 금일의 회의 목적인 안건이 전부 심의 종료되었으므로 의장이 폐회를 선언함.

위 결의를 명확히 하기 위하여 본 의사록을 작성하고 의장과 출석한 이사와 감사가 다음에 기명날인함.

019년 10월 24일
사단법인 한국우주과학회 제37차 정기총회

의 장 김 용 하 ㉠	부 의 장 최 기 혁 ㉠
총무이사 곽 영 실 ㉠	재무이사 김 관 혁 ㉠
이 사 박 장 현 ㉠	이 사 박 종 욱 ㉠
이 사 유 광 선 ㉠	이 사 이 대 영 ㉠
이 사 이 동 훈 ㉠	이 사 이 주 희 ㉠
이 사 임 조 령 ㉠	이 사 정 종 균 ㉠
이 사 진 호 ㉠	

위원 6명

- 편집위원회 규정 개정 TFT 구성 승인 : 위원장 선종호, 위원 7명
- 편집국장 채용 추진 승인
- 편집국장 채용을 위한 2020년 예산 항목 변경(안) 승인
- 신입회원 인준 : 정회원 7명
- 2021년 학술대회 개최 : 회장단에 위임

사업보고

1. 정기 학술대회 개최

- (1) 봄 학술발표회
 - 코로나19로 취소
- (2) 가을 학술발표회
 - 장 소 : 제주 신화월드
 - 일 시 : 2020년 10월 28일(수)~30일(금)
 - 논문발표 : 248편

2. 학술지 및 학회보 발행

- (1) 영문학술지발간 : JASS Vol 37, NO. 1, 2, 3호 발간
- (2) 한국우주과학회보 Vol 29 NO 1호 발간

3. 이사회

- 회의 개최 및 주요안건
- 가. 2019년도 3차 회의(2019. 10. 23.) 베네치아호텔
 - 2019년 결산(안) 승인
 - 2020년 예산(안) 승인
 - 신입회원 인준: 정회원 32명, 학생회원 9명
 - 2020년 가을학술대회 개최 : 회장단에 위임
 - 정관개정 준비위원회 설치 승인
- 나. 2020년 1차 회의(2020. 01. 21.) 대전 일정한정식
 - (비상설 위원회) 정관 개정 검토 TFT 구성/운영 승인
 - 편집국 편집전담 직원 채용 승인
 - 편집위원회 운영 규정 개정 검토 승인
 - 초소형위성 분과회 승인
 - 포상위원회 구성 승인 : 위원장 이병선, 위원 4명
 - 학술대회준비위원회 구성 승인 : 위원장 황정아, 위원 7명
 - 편집위원회 구성 승인 : 위원장 선종호, 위원 35명
 - 대외협력위원회 설치 승인 : 위원장 이서구, 위원 3명
 - JASS 발전위원회 설치 승인 : 위원장 이유, 위원 7명
 - COSPAR총회(2024년) 유치/준비위원회 설치 승인 : 위원장 박종욱, 위원 6명
 - 용역사업 규정 개정 승인
- 다. 2020년도 2차 회의(2020.07.17.) 대전 경복궁
 - 정관 개정 TFT 구성 승인 : 공동위원장 박장현, 이동훈, 이유,

학술대회준비위원회 보고

1. 학술대회준비위원회 구성

- 임기 : 2020년 1월~2021년 12월
- 학술대회준비위원장 : 황정아
- 학술대회준비위원 : 김해동, 문홍규, 민병희, 박재흥, 봉수찬, 최병규, 최정림

2. 학술대회 개최 실적 보고

- (1) 2019년 가을학술대회 및 제37차 정기총회
 - 장소: 여수 베네치아 호텔&리조트
 - 일시 : 2019년 10월 23일(수)~25일(금)
 - 발표논문 : 총 229편
(초청강연 4편, 구두발표 77편, 포스터발표 148편)
 - 등록인원 : 294명
- (2) 2020년 봄 학술대회
 - 코로나19로 취소
- (3) 2020년 가을학술대회 (10월 12일 현재)
 - 장소 : 제주 신화월드
 - 일시 : 2020년 10월 28일(수)~30일(금)
 - 논문발표 : 총 248편
(초청강연 4편, 구두발표 84편, 포스터발표 160편)
 - 등록인원 : 약 290명

학술보고

1. 편집위원회 구성

- 임기 : 2020년 1월~2021년 12월
- 편집위원장: 선종호
- 편집국장:김숙경
- 편집위원: 강명석, 곽영실, 구본준, 김경자, 김방엽, 김해동, 민경욱, 박상영, 오수연, 이재진, 이지윤, 정웅섭, 조경석, Eun-Hwa Kim, Kyeong Ju Hwang, Boonrucksar Soonthornthum, Chao Xiong, Charles Lin, Chung Yue Hui, David Ruffolo, Edward F. Guinan, Huixin Liu, Ilya, Usoskin, Ivan L.

Andronov, Jeongwoo Lee, Jiuhou Lei, Lee-Anne Mckinnell, Lin-Ni Hau, Paul A. Evenson, Sungpil Yoon, Tapas Kumar Das, Valery Nakariakov, Valery V. Hegai, Xinlin Li, Yuichi Otsuka

2. Journal of Astronomy and Space Sciences 발간

(가) 출판현황

- 2019년 12월호 (Vol. 36, No. 4) 6편 출판
- 2020년 3월호 (Vol. 37, No. 1) 9편 출판
- 2020년 6월호 (Vol. 37, No. 2) 7편 출판
- 2020년 9월호 (Vol. 37, No. 3) 6편 출판

(나) 인쇄본 출판 : 학회 정회원 중 반길 희망하는 회원과 기관회원 배부, 학회 보관 20부

(다) On-line 출판 :

- JASS 홈페이지(<http://janss.kr>)
- KISTI에서 제공하는 과학기술학회마을
- 한국연구재단(KCI)
- ADS 등에서 무료로 원문 검색 가능

포상위원회 보고

1. 포상위원회 구성

- 임기 : 2020년 1월~2021년 12월
- 위원장 : 이병선
- 위원 : 선종호, 오승준, 이주희, 최영준

2. 2020년 수상자 선정

(가) 2020년 한국우주과학회 학술상 - 김용해(충남대)

(나) 2020년 한국우주과학회 두진 우주과학자상 수상자

- 김정환(극지연)

(다) 2020년 한국우주과학회 신진 우주과학자상 수상자

- 양태용(천문연)

(라) 에스이랩상 수상자(2명) -(주)에스이랩 지원

- 김지우(충남대), 김희은(경희대)

(리) 제30회 과학기술우수논문상 수상

(시행처: 한국과학기술단체총연합회)

- 수상자 : 최 진(천문연)

- 수여일 : 2020년 7월 3일

- 논문제목 : Integrity Assessment and Verification Procedure of Angle-only Data for Low Earth Orbit Space Objects with Optical Wide-field Patrol-Network (OWL-Net)

- 게재지명 : JASS.2019.36.1.35

감사 보고

(사)한국우주과학회 2020년 감사보고서

회계년도 : 2020. 1. 1.~ 2020. 9. 30.

사단법인 한국우주과학회장 귀하

본 감사는 2020년 10월 8일 2020년 1월 1일부터 2020년 9월 30일까지 한국우주과학회에 대한 회계감사 및 업무 감사를 실시하였다.

회계부문에서는 회계기간에 해당하는 결산서, 손익계산서, 대차대조표를 검토한 결과 재무제표의 모든 항목이 제반 규정대로 정확하게 표시되었으며, 차년도 사업예산도 규정에 따라 적법하게 계획되었다. 재무제표를 뒷받침하는 회계장부와 지출결의서, 통장 등 증빙서류도 제대로 정리되었으며, 통장잔액과 장부잔액이 일치한다는 사실을 확인하였다.

학술행사 사업으로 2020년 봄 학술대회는 코로나19로 개최가 취소되었다.

2020년 9월 30일 현재 학회 유동자산은 426,772,444원이며 보통예금으로 159,772,444원, 정기예금으로 250,000,000원, 두진 우주과학자상 예금으로 5,000,000원, 신진 우주과학자상으로 12,000,000원을 운영하고 있다. 2020년 9월 30일 현재 2019년 말 대비 총자산이 51,120,899원만큼 증가하였다. 12월 결산시에는 가을학술대회 행사비 지출을 하고 나면 손익이 현재보다 현저히 줄어들 것으로 예상된다.

사업부문에서는 2020년 발행된 JASS Vol.37, No.1 ~ No.3에 대한 학술지 발행사업비로 총 21,418,576원 사용되었다. 발행된 논문은 JASS 3월호 9편, JASS 6월호 7편, JASS 9월호 6편 총 22편의 논문이 발간되었다. 편집국의 효율적인 업무 수행을 통해 학술지의 SCIE 조기 등재를 추진함으로써 학회와 회원들의 발전과 우주과학 분야 연구역량을 강화하고자 편집 전담 직원을 8월부터 채용하였다. 이로 인해 금년도 인건비는 1,100만원 정도 부족이 예상되었으나 기부금으로 충당될 수 있음이 확인되었다. 그러나 내년도 약2,880만원 추가되는 인건비 예산은 연회비 증액과 편집비 감액 외에도 약1,000만원 정도 부족이 예상이 되므로 이에 대한 대책이 필요하다.

이상과 같이 2020년 9월 30일 기준으로 한국우주과학회 사업부문과 결산 회계처리 내역을 감사한 결과 결산서와 다르지 않다는 사실을 확인하고 이에 서명 날인한다.

2020년 10월 8일

사단법인 한국우주과학회

감사 김 용 하 (인)

감사 김 천 휘 (인)

안건 1. 2020년도 결산(안) 승인 건

1. 2020년도 결산서

2020년도 결산서

기간: 2020.1.1~2020.9.30.

(사)한국우주과학회 (단위:원)

수입			지출		
과목	금액		과목	금액	
1. 회비수입	24,520,000		1. 발행사업비	21,418,576	
1-1 연회비		24,520,000	1-1 인쇄비		4,479,200
1-2 특별회비		-	1-2 편집비		14,344,900
2. 기부금	1,000,000		1-3 영문교열		1,492,416
2-1 지정기부금		1,000,000	1-4 발송비 외		1,102,060
3. 학술발표회	63,190,000		2. 학술행사비	-	
3-1 봄 학술대회		-	2-1 봄 학술대회		-
3-2 가을 학술대회		63,190,000	2-2 가을 학술대회		-
3-3 비정기 학술대회		-	2-3 비정기 학술대회		-
4. 게재료	20,898,900	20,898,900	3. 비정기 활동사업비	-	
5. 광고수입	1,000,000		3-1 대중화 사업 등		-
5-1 연구홍보		-	4. 위원회 사업비	500,000	500,000
5-2 기업광고		1,000,000	5. 회의비	3,661,400	3,661,400
6. 지원금	-		6. 용역비	-	
6-1 과총		-	6-1 용역직접비		-
6-2 기타지원금		-	6-2 용역간접비		-
7. 용역비	-		7. 내부인건비(퇴직금)	29,545,370	29,545,370
7-1 용역비		-	8. 4대보험료	1,636,800	1,636,800
8. 사업수익	3,210,000		9. 운영비	1,854,200	1,854,200
8-1 용역간접비		3,210,000	10. 세금과공과/연회비	6,005,856	6,005,856
9. 사업외수익	2,835,601	2,835,601	11. 출장비	911,400	911,400
수입계 ①	116,654,501		지출계 ④	65,533,602	
전년도 이월금 ②	375,651,545	(2019.12.31)	차기 이월금 (⑤=③-④)	426,772,444	*회계장부 잔액
합계 (③=①+②)	492,306,046		합계	492,306,046	

전년도이월금	375,651,545
당기손익(+)	51,120,899
차기이월금	426,772,444

2. 전년도(2019 회계년도) 결산서

2019년도 결산서

기간: 2019.1.1~2019.12.31.

(사)한국우주과학회 (단위:원)

수입			지출		
과목	금액		과목	금액	
1.회비수입	28,280,000		1. 발행사업비	38,297,094	
1-1 연회비		28,280,000	1-1 인쇄비		6,772,700
1-2 특별회비		-	1-2 편집비		19,982,500
2.기부금	10,000,000		1-3 영문교열		4,965,524
2-1 지정기부금		10,000,000	1-4 발송비 외		6,576,370
3.학술발표회	116,225,000		2. 학술행사비	98,837,180	
3-1 봄 학술대회		39,320,000	2-1 봄 학술대회		37,455,920
3-2 가을 학술대회		76,905,000	2-2 가을 학술대회		61,381,260
3-3 비정기 학술대회		-	2-3 비정기 학술대회		-
4.게재료	19,937,000	19,937,000	3. 비정기활동사업비	-	
5.광고수입	17,900,000		3-1 대중화 사업 등		-
5-1 연구홍보		12,200,000	4. 위원회 사업비	300,000	300,000
5-2 기업광고		5,700,000	5. 회의비	2,245,700	2,245,700
6.지원금	26,057,500		6. 용역비	-	
6-1 과총		17,090,000	6-1 용역직접비		-
6-2 기타지원금		8,967,500	6-2 용역간접비		-
7.용역비	-		7. 내부인건비(퇴직금)	34,023,460	34,023,460
7-1 용역비		-	8. 4대보험료	2,199,140	2,199,140
8.사업수익	-		9. 운영비	10,100,150	10,100,150
8-1 용역간접비		-	10. 세금과공과/연회비	6,635,626	6,635,626
9.사업외수익	4,641,898	4,641,898	11. 출장비	4,079,300	4,079,300
수입계 ①	223,041,398		지출계 ④	196,717,650	
전년도 이월금 ②	349,327,797	(2018.12.31)	자기 이월금 (⑤=③-④)	375,651,545	*회계장부 잔액
합계 (③=①+②)	572,369,195		합계	572,369,195	

전년도이월금	349,327,797
당기손익(+)	26,323,748
자기이월금	375,651,545

안건 2. 2021년도 예산(안) 승인 건

1. 일반회계

단위 : 원

기간 2021. 1. 1 ~ 2021. 12. 31.

2021년도 예산 수입(안)			2021년도 예산 지출(안)		
과목	대분류	소분류	과목	대분류	소분류
1. 회비수입	35,000,000		1. 발행사업비	25,000,000	
1-1 연회비		35,000,000	1-1 인쇄비		8,000,000
1-2 특별회비		0	1-2 편집비		10,000,000
2. 기부금	0		1-3 영문교열		2,000,000
2-1 지정기부금		0	1-4 발송비 외		5,000,000
3. 학술발표회	95,000,000		2. 학술행사비	87,000,000	
3-1 봄학술대회		45,000,000	2-1 봄학술대회		41,000,000
3-2 가을학술대회		50,000,000	2-2 가을학술대회		46,000,000
4. 게재료	32,000,000		3. 비정기활동사업비	0	
5. 광고수입	15,000,000		3-1 대중화사업 등		0
5-1 연구홍보		6,000,000	4. 위원회사업비	2,500,000	
5-2 기업광고		9,000,000	5. 회의비	2,000,000	
6. 지원금	15,000,000		6. 용역비	0	
6-1 과총		15,000,000	6-1 용역직접비		0
6-2 기타지원금		0	6-2 용역간접비		0
7. 용역비	0		7. 내부인건비(퇴직금)	60,000,000	
7-1 용역비		0	8. 보험료	4,800,000	
8. 사업수익	0		9. 운영비	4,700,000	
8-1 용역간접비			10. 세금과공과/연회비	9,000,000	
9. 사업외수익	5,000,000		11. 출장비	2,000,000	
수 입 계	197,000,000		지 출 계	197,000,000	
			차기이월(당기손익)	0	
			수 입 계	197,000,000	

2. 특별회계(정기예금)

항목	2021년(A)
특별회계	250,000,000
두진상	4,000,000
신진상	11,000,000
합계	265,000,000

안건 3. 한국우주과학회 정관 개정 건

한국우주과학회 정관 개정(안)

현 행	개정(안)
제13조 (회장 및 부회장의 직무) 2. 부회장은 회장의 직무를 보좌하며 회장 유고시 <u>부회장 중 연장자가</u> 회장의 직무를 대행한다.	제13조 (회장 및 부회장의 직무) 2. 부회장은 회장의 직무를 보좌하며 회장 유고시 <u>부회장 중 연장자가</u> 회장의 직무를 대행한다.
제18조 (총회의결과 정족수) 1. 총회는 국내에 있는 정회원 10분의 1 이상의 출석으로 개최한다. 2. 총회의 의사는 출석한 정회원의 과반수의 찬성으로 의결한다. 다만, 가부동수인 경우에는 의장이 결정한다.	제18조 (총회의결과 정족수) 1. 총회는 국내에 있는 정회원 10분의 1 이상의 출석으로 개최한다. <u>다만, 위임장도 출석으로 간주한다</u> 2. 총회의 의사는 출석한 정회원의 과반수의 찬성으로 의결한다. 가부동수인 경우에는 의장이 결정한다. <u>다만, 위임장은 표결권을 가질 수 없다</u>
제28조 (재정) 학회의 재정은 다음의 수입금으로 충당한다. 1. 회원의 회비 2. 재산의 과실 3. 사업 수익금 4. 기부금 및 기타 수익금	제28조 (재정) 학회의 재정은 다음의 수입금으로 충당한다. <u>이 중 기부금은 모금액 및 활용 실적을 홈페이지에 공개한다.</u> 1. 회원의 회비 2. 재산의 과실 3. 사업 수익금 4. 기부금 및 기타 수익금
제35조 (시행 세칙) 정관의 시행에 필요한 세부적인 사항은 이사회에서 정하여 총회의 승인을 얻어야 한다.	제35조 (시행 규정) 정관의 시행에 필요한 세부적인 규정은 이사회에서 정하여 총회의 승인을 얻어야 한다. 단, 일부 규정은 <u>이사회</u> 의 승인만으로 시행 할 수 있다

안건 4. 학회 운영에 대한 규정 건

학회 운영에 대한 규정 개정(안)

현 행	개정(안)
제2조(회비) 학회 정관 제7조, 제8조 및 제28조의 각 1호에 근거하여 회원이 납부해야 할 연회비는 다음과 같다. ① 임원: 10만원 ② 정회원: 5만원 ③ 학생회원: 1만원 ④ 명예회원: 면제 ⑤ 특별회원: 면제 ⑥ 기관회원 : 이사회에서 결정	제2조(회비) 학회 정관 제7조, 제8조 및 제28조의 각 1호에 근거하여 회원이 납부해야 할 연회비는 다음과 같다. ① <u>임원: 15만원</u> ② <u>정회원: 7만원</u> ③ 학생회원: 1만원 ④ 명예회원: 면제 ⑤ 특별회원: 면제 ⑥ 기관회원 : 이사회에서 결정 ⑦ <u>입회비 : 1만원</u>
제5조(편집위원회) ① 편집위원회는 학회에서 발간하는 정기 학술지에 게재되는 논문의 심사, 편집 및 출판을 관장한다. ② 학술이사가 위원장을 맡고, 국내위원은 15인 내외로 하며 정회원 중에서 이사회의 동의를 얻어 회장이 임명한다. 국외위원은 20인 내외로 하며 이사회의 동의를 얻어 회장이 임명한다. 임기는 모두 2년으로 한다. ③ 학술지 논문 투고규정 및 세부사항은 편집위원회에서 논의한 후 이사회의 의결을 거쳐 시행한다.	제5조(편집위원회) ① 편집위원회는 학회에서 발간하는 정기 학술지에 게재되는 논문의 심사, 편집 및 출판을 관장한다. ② <u>편집위원장은 이사회의 동의를 얻어 회장이 지명하고 위원장 유고시 부위원장이 직무를 대행한다. 임기는 (2년 or 4년)으로 하고 연임 할 수 있다.</u> ③ <u>편집위원은 20인 내외로 하며 위원장의 추천을 받아 회장이 임명한다. 임기는 2년으로 하고 연임할 수 있다.</u> ④ 학술지 논문 투고규정 및 세부사항은 편집위원회에서 논의한 후 이사회의 의결을 거쳐 시행한다.
제9조(간행물) 학회의 간행물에 대해서는 다음과 같이 정한다. ① 정기 학술대회 발표순서가 담긴 회보는 총무이사가 담당한다. ② 논문집 우주과학회지는 편집위원회에서 담당한다, ③ 기타 우주과학전반에 걸친 간행물에 관한 토의 및 규정은 필요에 따라 위원회를 두어 담당한다.	제9조(간행물) 학회의 간행물에 대해서는 다음과 같이 정한다. ① 정기 학술대회 발표순서가 담긴 회보는 총무이사가 담당한다. ② 논문집 <u>Journal of Astronomy and Space Sciences</u> 는 편집위원회에서 담당한다, ③ 기타 우주과학전반에 걸친 간행물에 관한 토의 및 규정은 필요에 따라 위원회를 두어 담당한다.
제1조(시행일) 이 규정은 총회의 승인을 받은 2014년 10월 30일부터 시행한다. 이 규정은 이사회의 승인을 받은 2016년 2월 18일부터 시행한다.	제1조(시행일) 이 규정은 총회의 승인을 받은 2014년 10월 30일부터 시행한다. <u>이 규정은 총회의 승인을 받은 2016년 10월 27일부터 시행한다.</u>

안건 5. 임원선출에 대한 규정 건

임원선출에 대한 규정 개정(안)

현 행	개정(안)
<p>제7조 (이사선출)</p> <p>① 전체 이사 수의 1/2을 선거권자 온라인 투표로 선출하며, 나머지 1/2은 차기 회장이 지명한다.</p> <p>② 이사 선출 온라인 투표는 선거권자 1인이 3명을 추천한다.</p> <p>③ 투표 결과 상위 다득점자로 수락 여부를 거쳐 이사의 1/2을 확정한다.</p> <p>④ 선출된 이사 중에서 총회 당일 회장 또는 감사로 선출되어 결원이 생긴 경우 차득점 순으로 수락 여부를 거쳐 이사로 확정한다.</p> <p>⑤ 부회장, 총무, 재무, 학술이사는 회장이 지명하며, 당연직 이사가 된다.</p>	<p>제7조 (이사선출)</p> <p>① 전체 이사 수의 1/2을 선거권자 온라인 투표로 선출하며, 나머지 1/2은 차기 회장이 지명한다. <u>단, 비등기 이사로 협동이사 및 실무이사를 둘 수 있고 이사회의 동의를 얻어 회장이 지명한다.</u></p> <p>② 이사 선출 온라인 투표는 선거권자 1인이 3명을 추천한다.</p> <p>③ 투표 결과 상위 다득점자로 수락 여부를 거쳐 이사의 1/2을 확정한다.</p> <p>④ 선출된 이사 중에서 총회 당일 회장 또는 감사로 선출되어 결원이 생긴 경우 차득점 순으로 수락 여부를 거쳐 이사로 확정한다.</p> <p>⑤ 부회장, 총무, 재무, 학술이사, <u>편집위원장은</u> 회장이 지명하며, 당연직 이사가 된다.</p>

한국우주과학회보

제29권 1호 2020년 10월

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