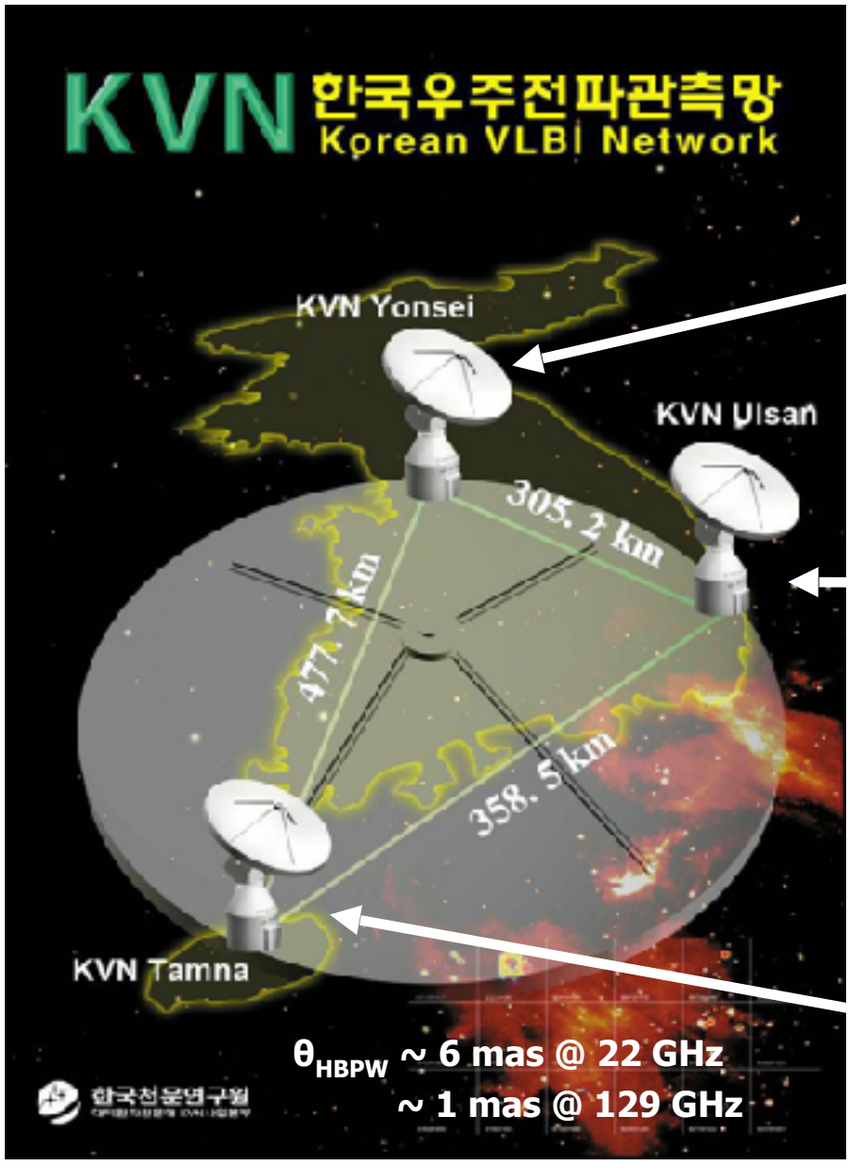
Korean VLBI Network
Current Status and Plan

Taehyun Jung (KASI)

On behalf of KVN TEAM

2019 전파망원경 사용자 회의 @ 서울대 평창캠퍼스 (August 29)

Korean VLBI Network (KVN)



- 3 Telescopes (D = 21m)
- 22/43/86/129GHz
- 300 - 500 km
- **Θ** = 1 - 6 mas

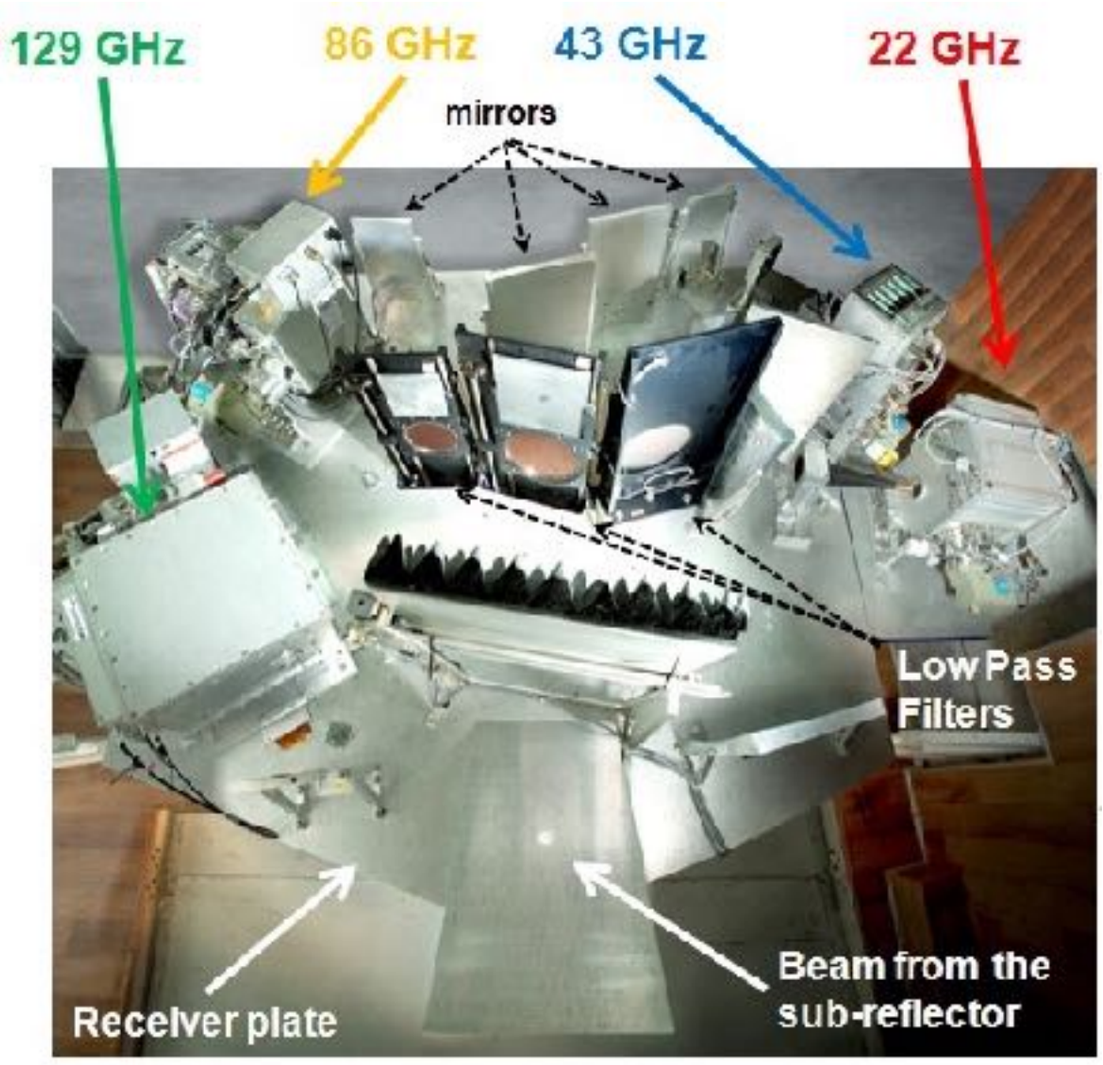
- Science Targets
  AGN/SF/Evolved Star
  + microquasar

Multi-Frequency Receiving System

- Simultaneous Multi-frequency Observation
  - @ 22/43/86/129GHz
  - Dual Pol : LCP & RCP

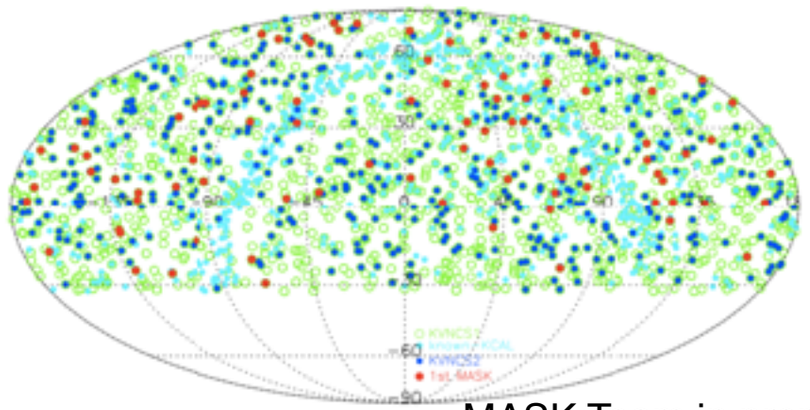
- (Source) Frequency Phase Transfer
  - Weak Source Detection
  - Chromatic Astrometry

- Multi-Frequency Observation
  - SED
  - Rotation Measure



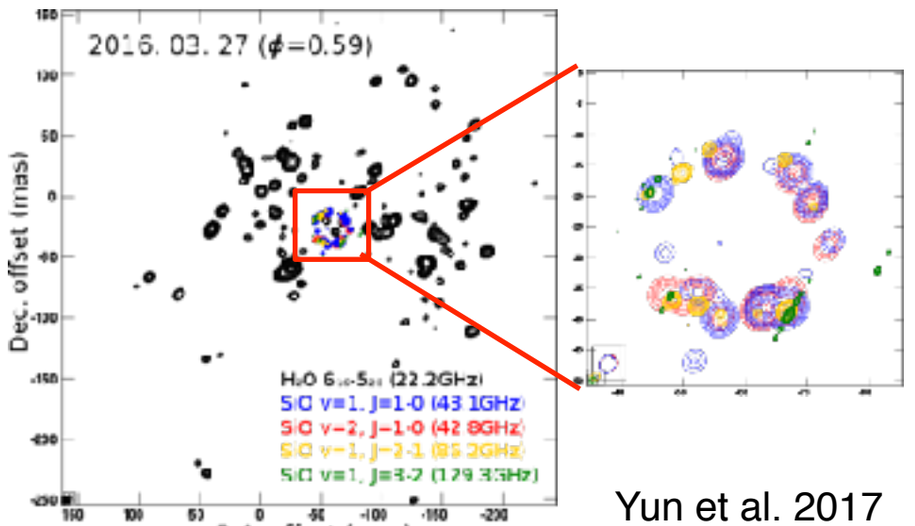
KVN Multi-Frequency Observations

MASK: Multi-Frequency AGN Survey with KVN



MASK Team in prep

- Largest number of New detections Ever! (on-going)
  - ~574 AGNs(>80%) @ 43GHz
    ~428 AGNs(>60%) @ 86GHz
    ~281 AGNs(>50%) @ 130GHz
  - ~80 high-z AGNs (z = 2.5-6.5)



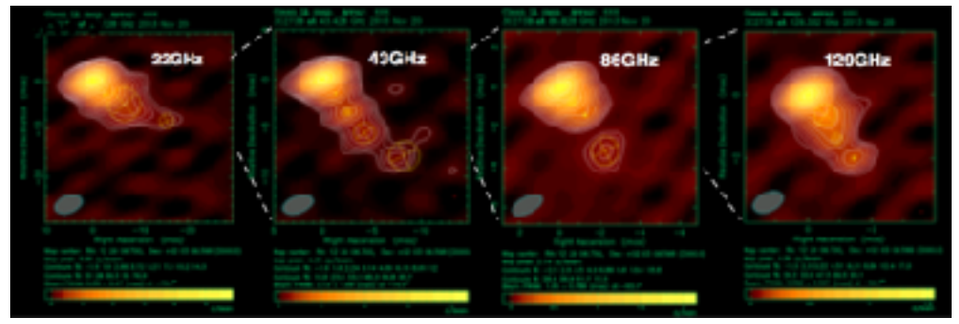
Yun et al. 2017

M/F maser maps of Vx Sgr

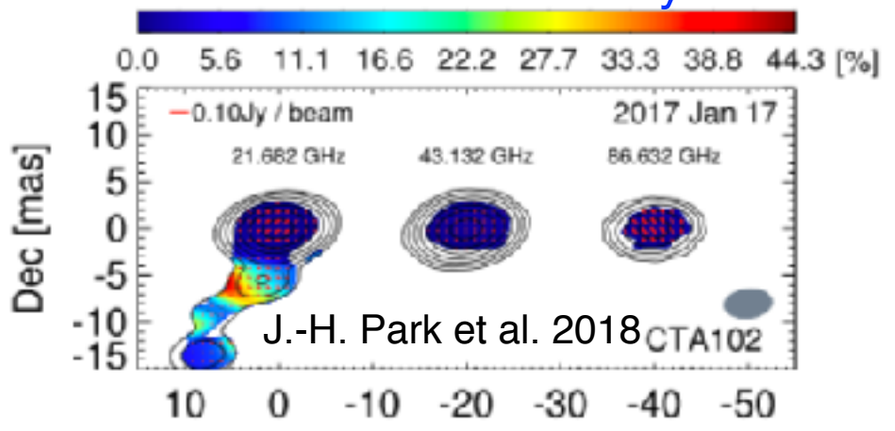
- Multi-Frequency Polarimetry
  - AGN jet structure and magnetic fields from M/F Rotation Measure

- Demonstration on the performance of simultaneous M/F
  - Tropospheric / Ionospheric phase calibration
  - Ideal system for mm-VLBI observation

iMOGABA



M/F VLBI Polarimetry



J.-H. Park et al. 2018

KVN Operation Status

- VLBI > 3500h/yr (+ SD 500-1000 h/yr/site)
  - KVN Only : 2500h
  - KaVA (KVN and VERA Array) : 1000h
  - EAVN/EVN/GMVA/Sejong > 300h

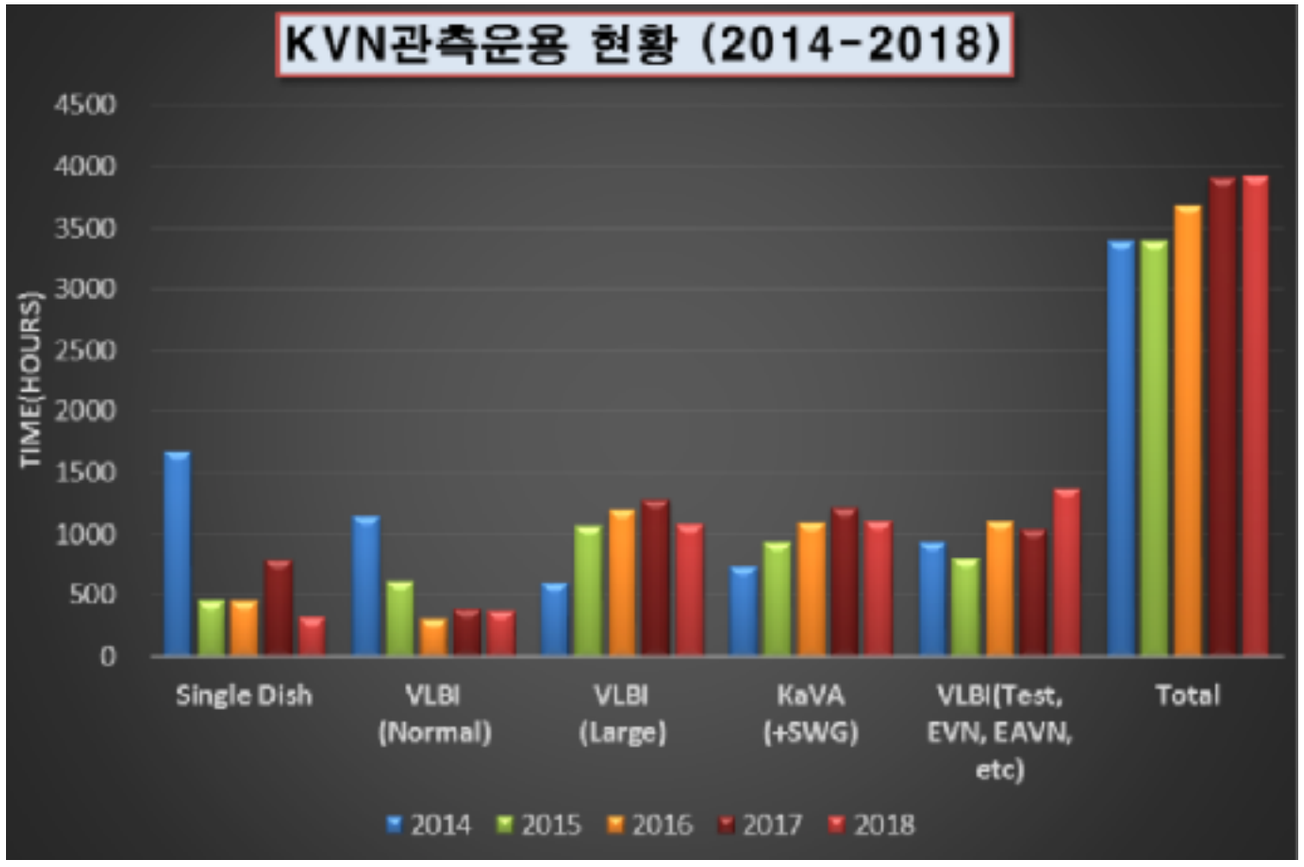
- KVN Key Science Projects : 1000h/yr
  - Evolved Star(1) & AGN (2)

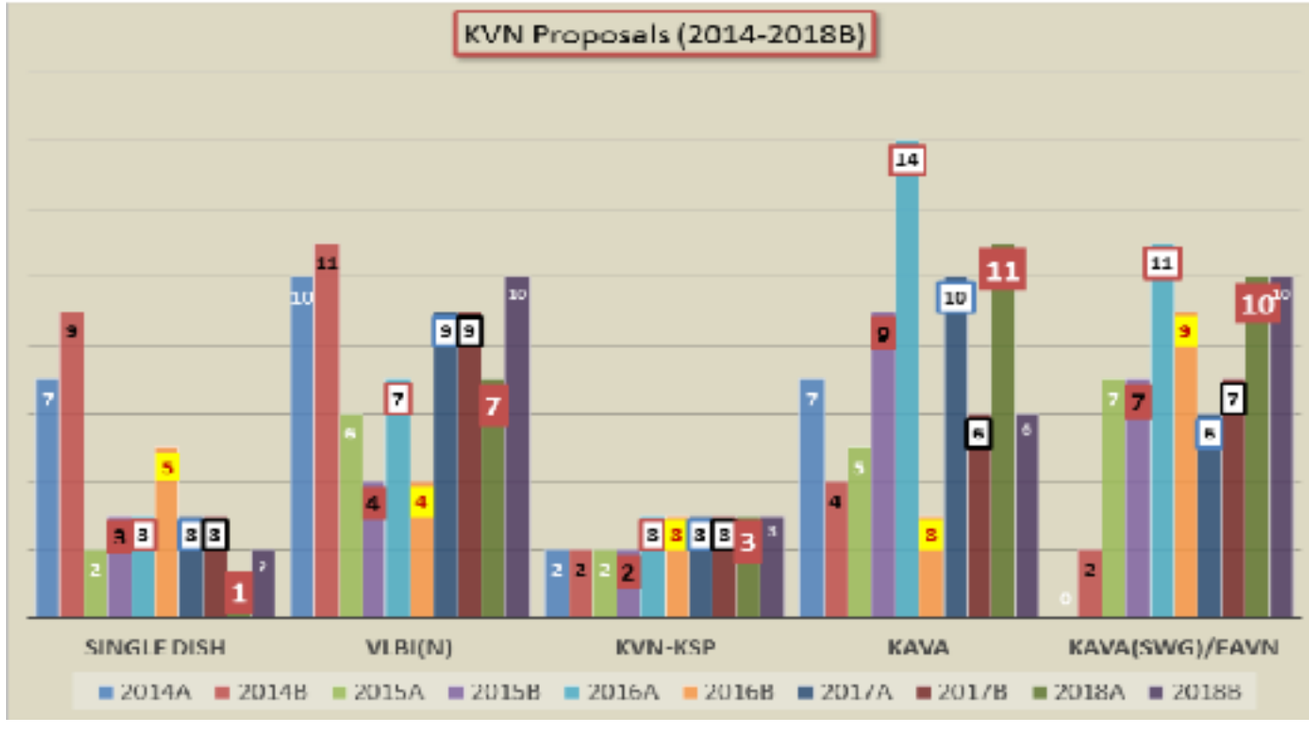
- KaVA Large Programs : 500h/yr
  - AGN, Star formation, Evolved stars, Galactic astrometry

- Global Common Use : 1000h/yr
  - KVN(500h/yr) + KaVA/EAVN (500h/yr)

- Proposals status
  - 2018B: KVN(16), EAVN (14)
  - 2019A: KVN (12), EAVN (19)
  - 2019B: KVN (8), EAVN (24)

- Total 122 refereed papers using KVN (from 2013)
  - Toal 95 SCI papers (14 SCI papers/yr)

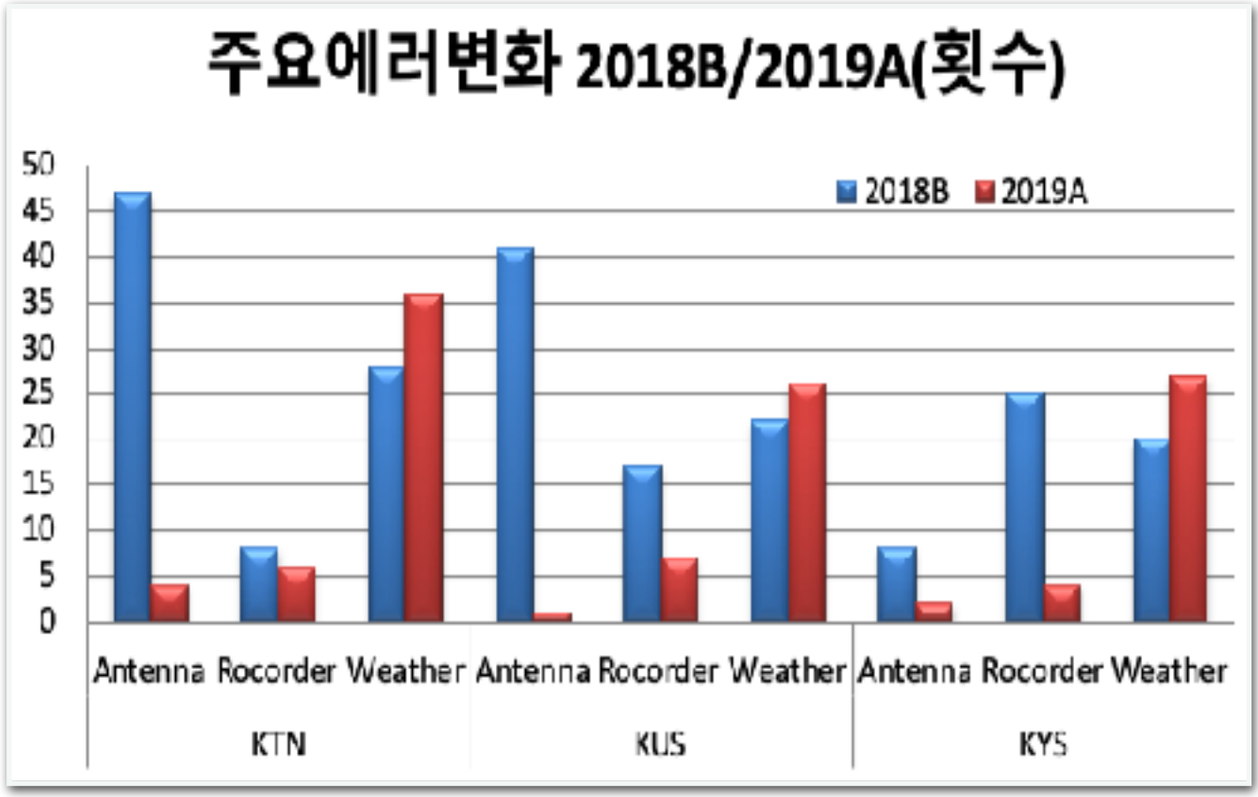




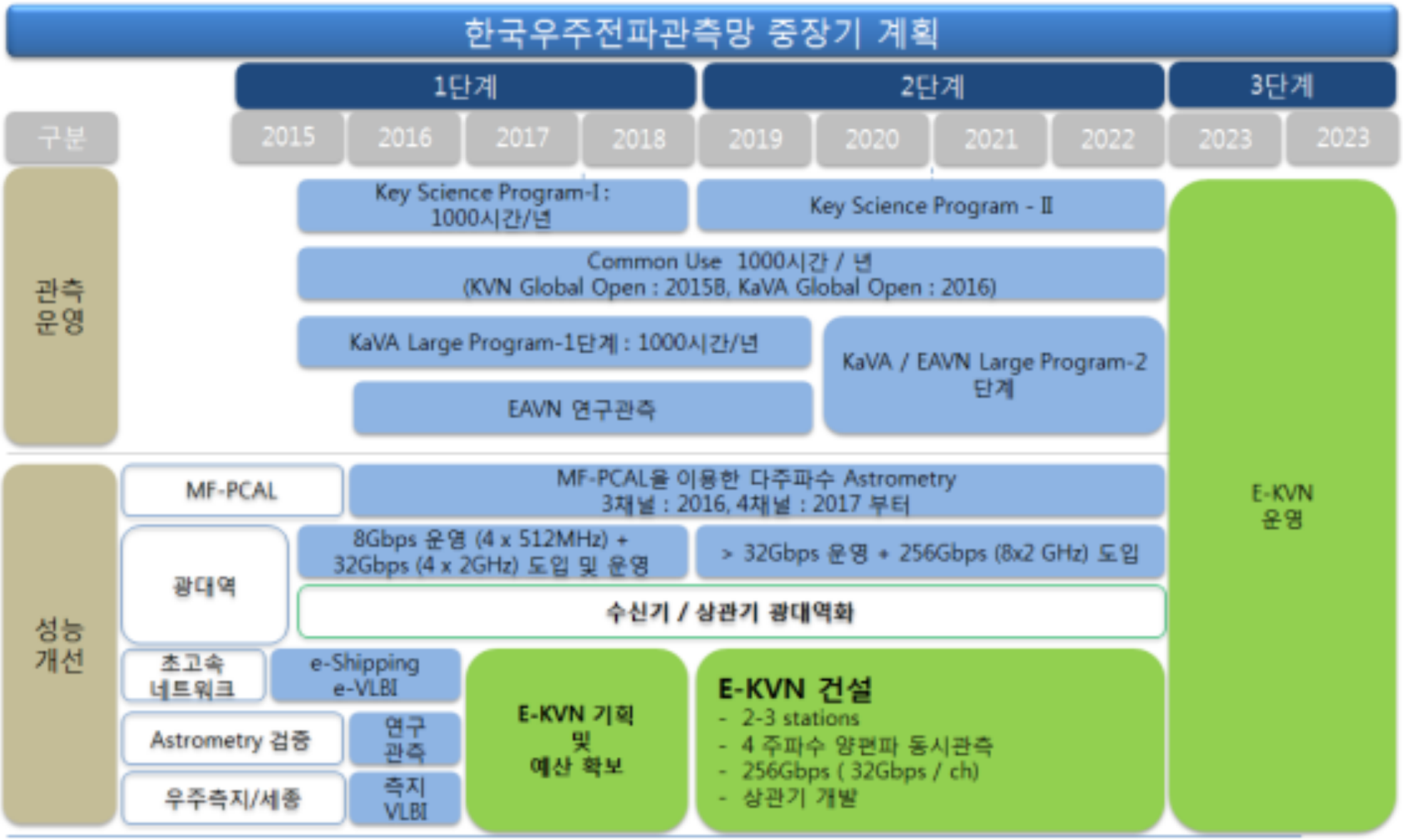
KVN Operation Statistics 2018B/2019A

관측시즌	총 관측수	총관측시간	실관측시간	Success w/ minor err	Cancel	Fail
2019A	246	2010	1866	232	8	6
2018B	231	2030	1924	218	11	2

2018B Error counts	KTN	KUS	KYS	Sum
Antenna control failures	47	41	8	96
Problems with recorder	8	17	25	50
Severe weather condition	28	22	20	70
Other problems	55	54	37	146
Sum	138	134	90	362
2019A Error counts	KTN	KUS	KYS	Sum
Antenna control failures	4	1	2	7
Problems with recorder	6	7	4	17
Severe weather condition	36	26	27	89
Other Problems	25	22	37	84
Sum	71	56	70	197



KVN System Upgrade Plan

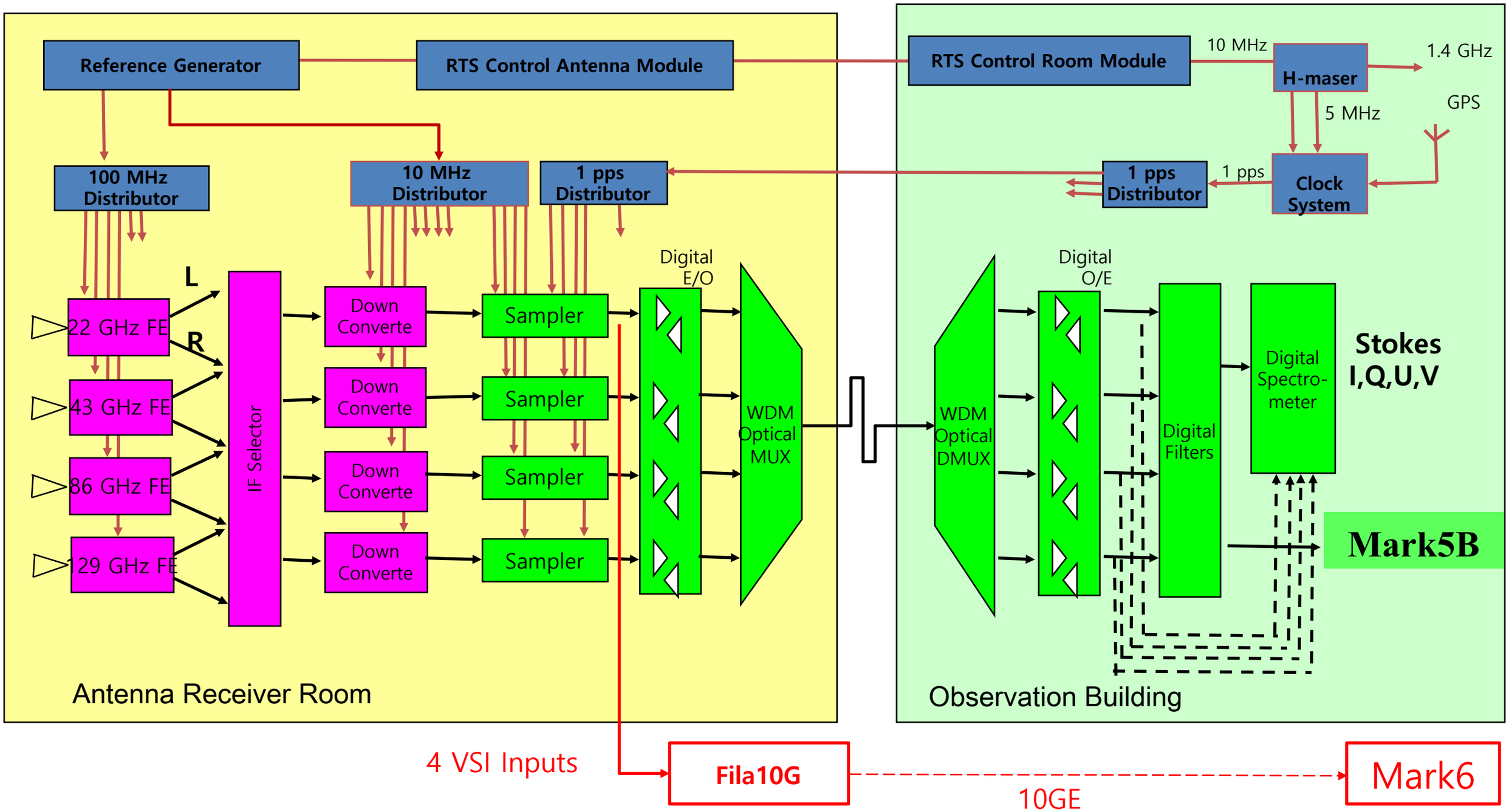


KVN System Upgrade: Receiver

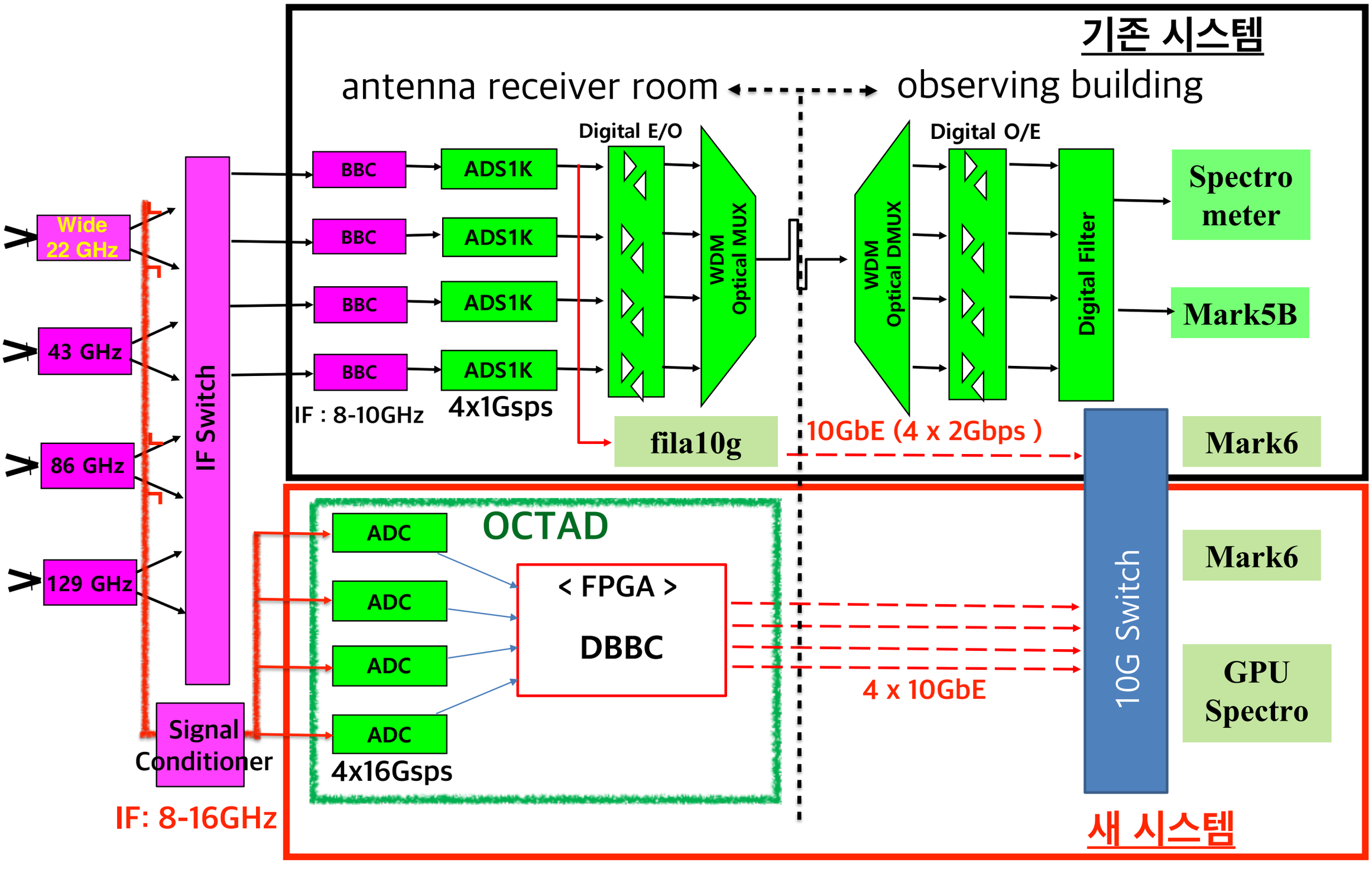
- Upgrade current Rx by replacing narrow band components
  ~ LNA, Feed Horn, Polarizer, tunable LO etc
- Instantaneous Bandwidth = 8GHz

KVN Receiver	Freq. (old)	Freq. (new)	Trx (new)	Installation
K-band	21.24 – 23.25	18 – 26	< 40	Completed in '18 (all KVN stations)
Q-band	42.10 – 44.10	35 – 50	< 50	KYS ('19 Sep) KUS ('20) KTN ('20 or '21)
W-band	85 – 95	85 – 116	< 80	KYS ('19 Sep) KUS (done, '18) KTN ('20)
D-band	125 – 142	125 – 172	< 60	'23 ~

KVN System Upgrade: (old) DAS



KVN System Upgrade: (new!) DAS



OCTAD

- 4 ADC (4 x 16Gsps)
- Input Freq. 8 - 16GHz
- Digital Down Conversion
- Digital Filtering
- 4 x 10GbE output
- VDIF format

KYS

KUS

KTN

Bandwidth (MHz)	Max Num of Channels	Max Data Rate (Gbps)
8192	1	32
4096	2	32
2048	4	32
1024	8	32
512	16	32
256	16	16
128	16	8
64	16	4
32	16	2
16	16	1

KVN 4-Frequency Full Polarization

K-DAS (4 CH)+ OCTAD (4 CH) or OCTAD (8 CH) with Mark6

22 R/L, 43 R/L, 86 R/L, 129 R/L
Data rate: 1, 2, 4, 8, 16, 32 Gbps

Mark 6

- Max 16Gbps recording
- 4 disk modules with 8 HDDs each
- 4 10GbE input

16Gbps Fringes with 32Gbps mode

KYS-KUS with 22/86GHz Dual-Pol (f18324 & f18362)

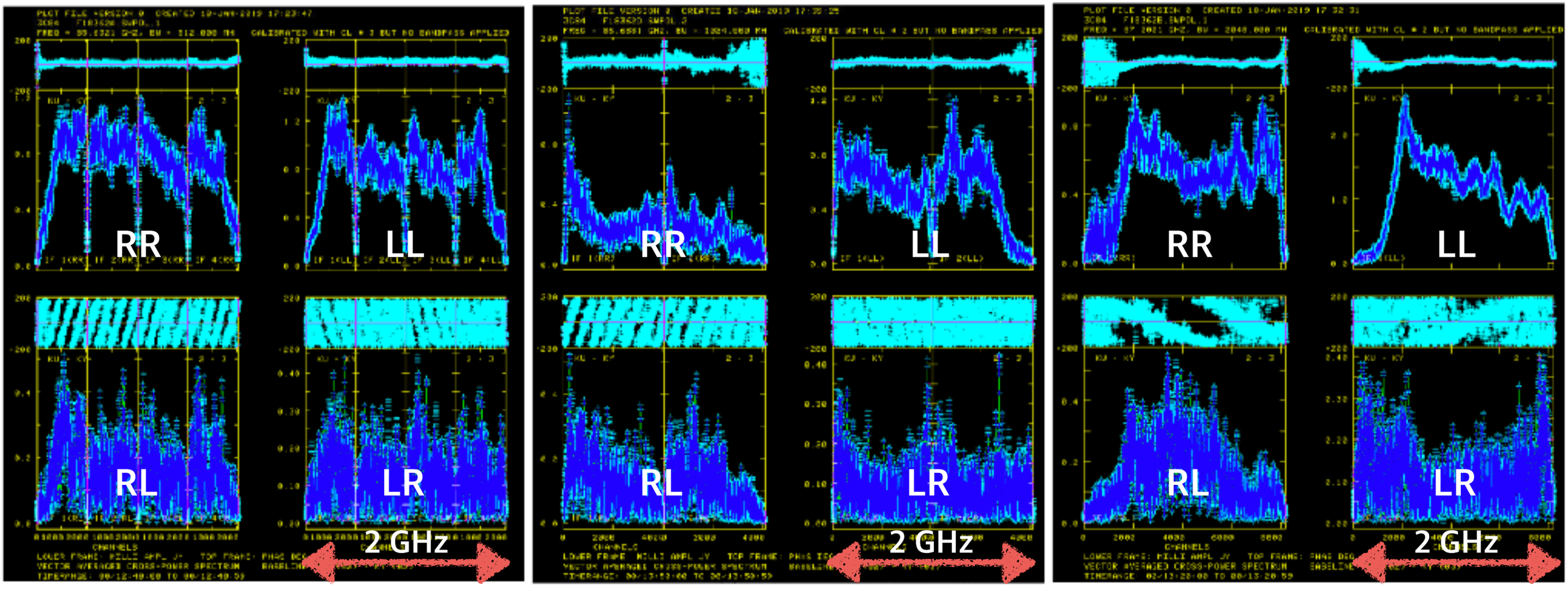
f18362 fringe test

32Gbps setup in simultaneous K/W observation —> W-band fringes (16Gbps) detected!

512 MHz x 8 Channels x 2 Pols

1024 MHz x 4 Channels x 2 Pols

2048 MHz x 2 Channels x 2 Pols



- Signal Chain: K/W-band Rx (2 Pol) —> OCTAD —> 10G switch —> Mark6 (2EA)

- 2048 channels / IF
- Partial fringe detection at K-band Pol data (f18324)

KVN Baseline/Image Sensitivity

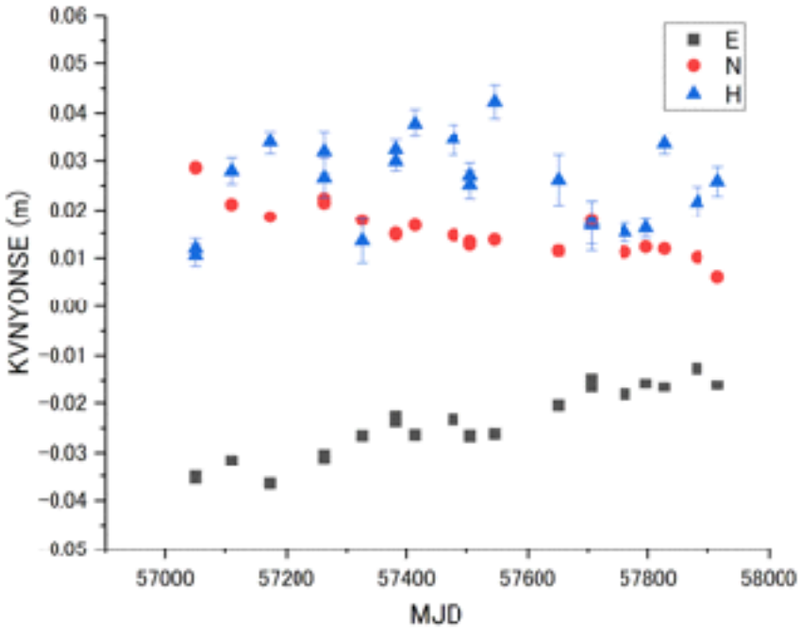
Frequency	22 GHz	43 GHz	86 GHz	129 GHz
SEFD (Jy)	1500	1800	3400	5000
Sensitivity (mJy, 1-sigma)	T_{int}=100s / T_{int}=1hr	T_{int}=60s / T_{int}=1hr	T_{int}=30s / T_{int}=1hr	T_{int}=30s / T_{int}=1hr
1 Gbps (Max 256 MHz)	9.6 / 1.28	14.9 / 1.53	39.8 / 2.89	58.5 / 4.25
2 Gbps (Max 512 MHz)	6.8 / 0.90	10.5 / 1.08	28.1 / 2.05	41.3 / 3.01
4 Gbps (Max 1024 MHz)	4.8 / 0.64	7.4 / 0.77	19.9 / 1.45	29.2 / 2.13
8 Gbps (Max 2048 MHz)	3.4 / 0.45	5.3 / 0.54	14.1 / 1.02	20.7 / 1.50
16 Gbps (Max 4096 MHz)	2.4 / 0.32	3.7 / 0.38	9.9 / 0.72	14.6 / 1.06
32 Gbps (Max 8192 MHz)	1.7 / 0.23	2.6 / 0.27	7.0 / 0.51	10.3 / 0.75

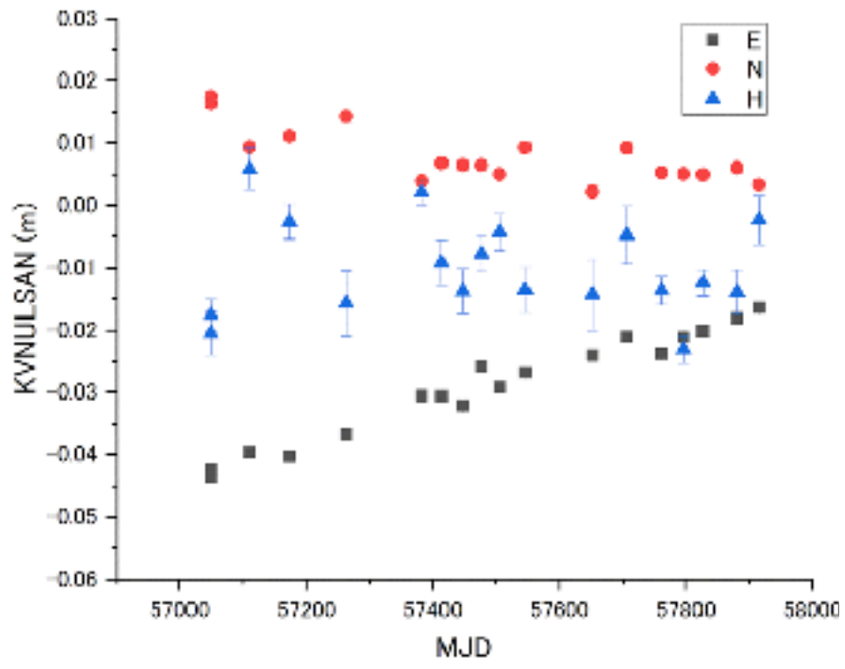
- Note: (baseline) / (image) sensitivity in the unit of mJy
- When FTP is applied (maximum integration time of 30min & referrenced from K), the expected improvement of baseline sensitivity is more than 2 times better!

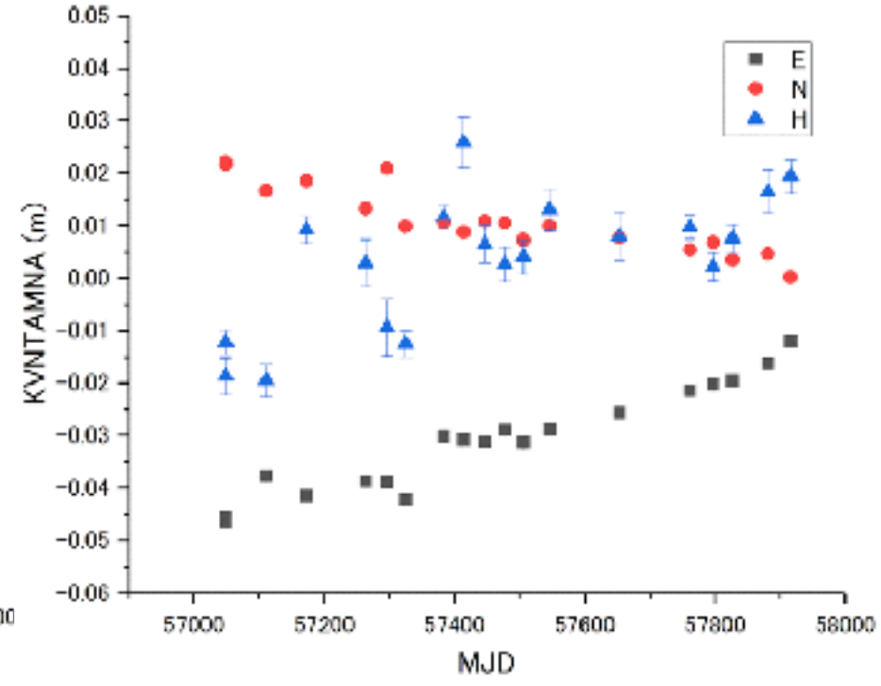
KVN Antenna Position Updates

- The accuracy of KVN antenna positions are much improved (~ a few mm level) based on KaVA K-band geodesy
- Daily antenna positions of KVN is available
- Great advantage for VLBI astrometry/geodesy

ENH coordinates of KVN
Analyzed by Dr. Jike (NAOJ)







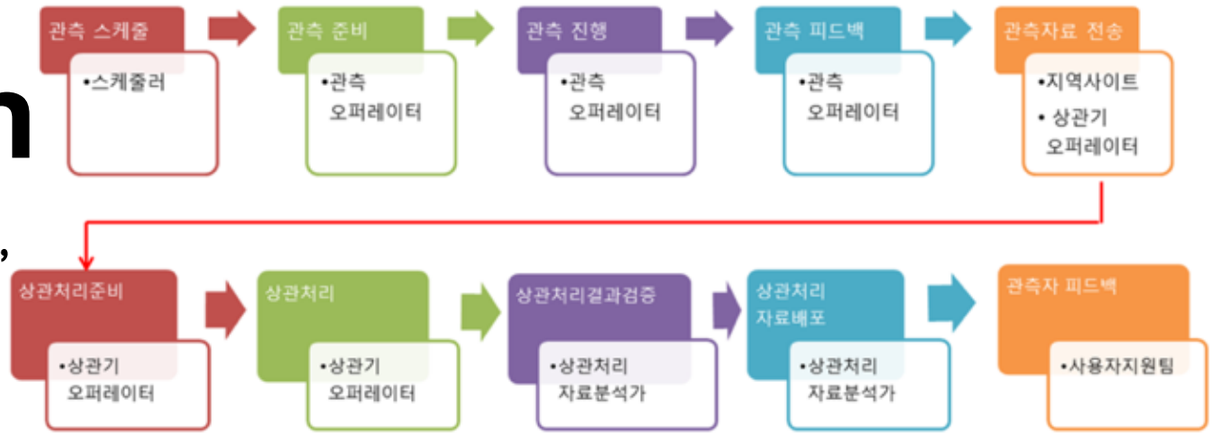
Example: Daily IVP of KVN Yonsei radio telescope (2015. 1. 1 ~ 2020.12.31)

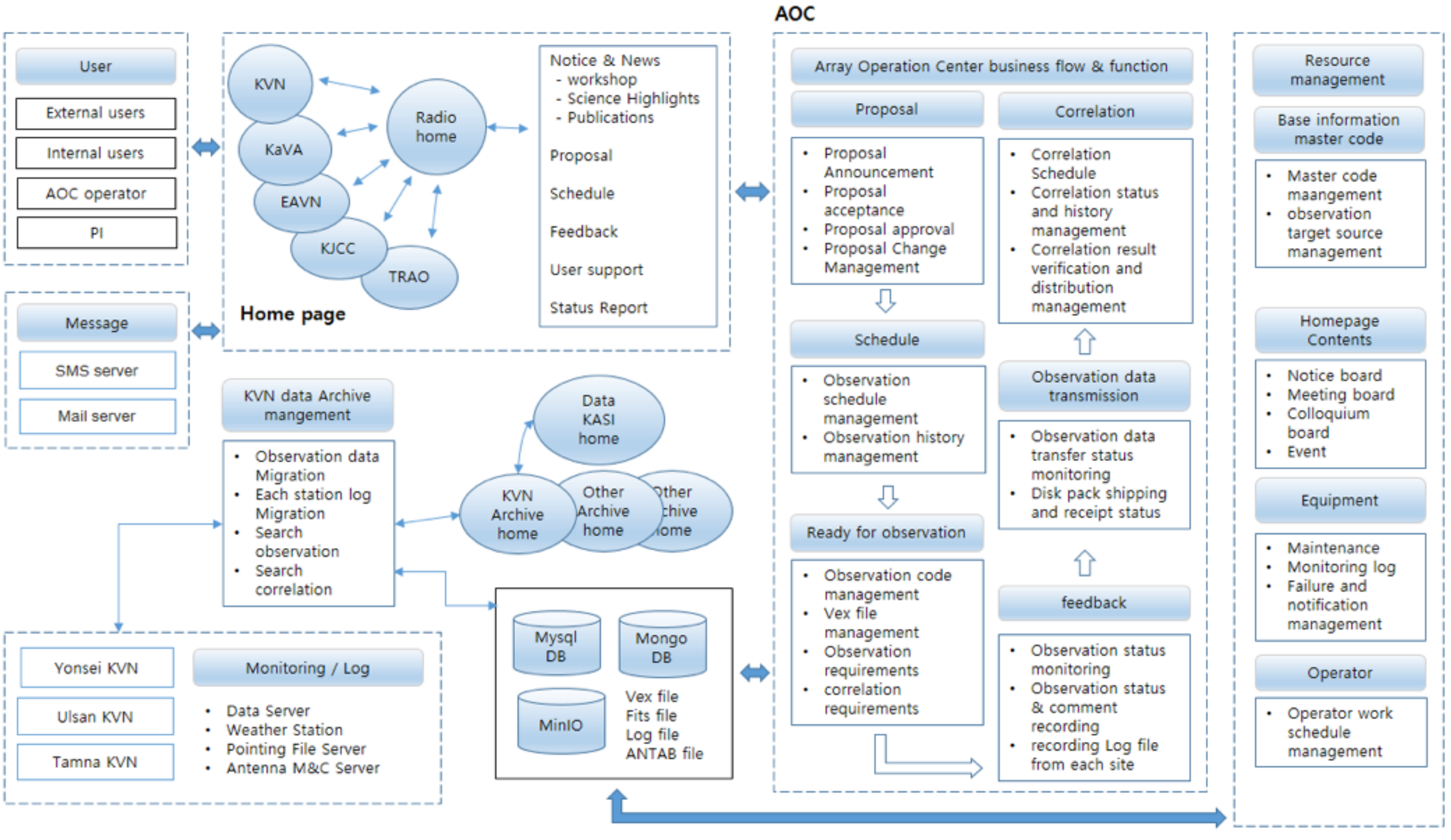
kvnyonse.xyz14

2015/01/01	1	57023	-3042280.9740	4045902.6891	3867374.3521
2015/01/02	2	57024	-3042280.9740	4045902.6891	3867374.3521
2015/01/03	3	57025	-3042280.9740	4045902.6891	3867374.3521
2015/01/04	4	57026	-3042280.9741	4045902.6890	3867374.3521
2015/01/05	5	57027	-3042280.9741	4045902.6890	3867374.3520
2015/01/06	6	57028	-3042280.9741	4045902.6890	3867374.3520
2015/01/07	7	57029	-3042280.9741	4045902.6890	3867374.3520
2015/01/08	8	57030	-3042280.9742	4045902.6890	3867374.3520
2015/01/09	9	57031	-3042280.9742	4045902.6890	3867374.3520
2015/01/10	10	57032	-3042280.9742	4045902.6890	3867374.3520
2015/01/11	11	57033	-3042280.9742	4045902.6890	3867374.3519
2015/01/12	12	57034	-3042280.9743	4045902.6890	3867374.3519
2015/01/13	13	57035	-3042280.9743	4045902.6890	3867374.3519
2015/01/14	14	57036	-3042280.9743	4045902.6889	3867374.3519
2015/01/15	15	57037	-3042280.9743	4045902.6889	3867374.3519
...					
2020/12/16	351	59199	-3042281.0314	4045902.6671	3867374.3145
2020/12/17	352	59200	-3042281.0314	4045902.6671	3867374.3145
2020/12/18	353	59201	-3042281.0315	4045902.6671	3867374.3144
2020/12/19	354	59202	-3042281.0315	4045902.6671	3867374.3144
2020/12/20	355	59203	-3042281.0315	4045902.6671	3867374.3144
2020/12/21	356	59204	-3042281.0315	4045902.6671	3867374.3144
2020/12/22	357	59205	-3042281.0316	4045902.6671	3867374.3144
2020/12/23	358	59206	-3042281.0316	4045902.6671	3867374.3144
2020/12/24	359	59207	-3042281.0316	4045902.6670	3867374.3143
2020/12/25	360	59208	-3042281.0317	4045902.6670	3867374.3143
2020/12/26	361	59209	-3042281.0317	4045902.6670	3867374.3143
2020/12/27	362	59210	-3042281.0317	4045902.6670	3867374.3143
2020/12/28	363	59211	-3042281.0317	4045902.6670	3867374.3143
2020/12/29	364	59212	-3042281.0318	4045902.6670	3867374.3143
2020/12/30	365	59213	-3042281.0318	4045902.6670	3867374.3142
2020/12/31	366	59214	-3042281.0318	4045902.6670	3867374.3142

“Web-based” Operation

포스터 ’KVN Data Archiving을 위한 AOC 응용프로그램 개발’ (신재식) 참조





Important Dates

- **January 15 ~ June 15: 1st season**
- **June 15 ~ August 15: summer maintenance**
- **August 15 ~ January 15 : 2nd season**

- **Call for Proposals** (announcement / deadline)
  - 1st season: mid-September / early-November
  - 2nd season: mid-April / early-June

- **Schedule announcement**
  - ~ 20th of the month (for the next month schedule)

- User Surveys (summer)
- User's Meeting (summer)

KVN Data Reduction Tutorial
KVN AOC Workshop

Notice to Users (1)

KASI-INAF MoA (signed on Apr 9, 2019)

MEMORANDUM of AGREEMENT
BETWEEN
THE ISTITUTO NAZIONALE DI ASTROFISICA
AND
THE KOREA ASTRONOMY AND SPACE SCIENCE INSTITUTE
ON JOINT VLBI OBSERVATIONS

The Istituto Nazionale di Astrofisica (hereafter referred to as INAF) headquartered at Viale del Parco Mellini n.84, 00136 Roma, Italy and represented by its President, Prof. Nicolo' D'Amico, and the Korea Astronomy and Space Science Institute (hereafter referred to as KASI), headquartered at 776 Daedeoke-daero, Yuseong-gu, Daejeon 34055, the Republic of Korea and represented by its President, Dr. Hyung Mok Lee,

hereafter referred to as Parties of this Memorandum,

- Taking into account their mutual interest in conducting Very Long Baseline Interferometry (VLBI) experiments,
- Considering the long-standing collaboration between INAF and KASI,
- Considering the international joint research project between KASI and INAF since December, 2016: "Supermassive Black holes: turning on the most powerful engines in the Universe", funded by the National Research Council of Science and Technology (of the Republic of Korea), KASI, and INAF

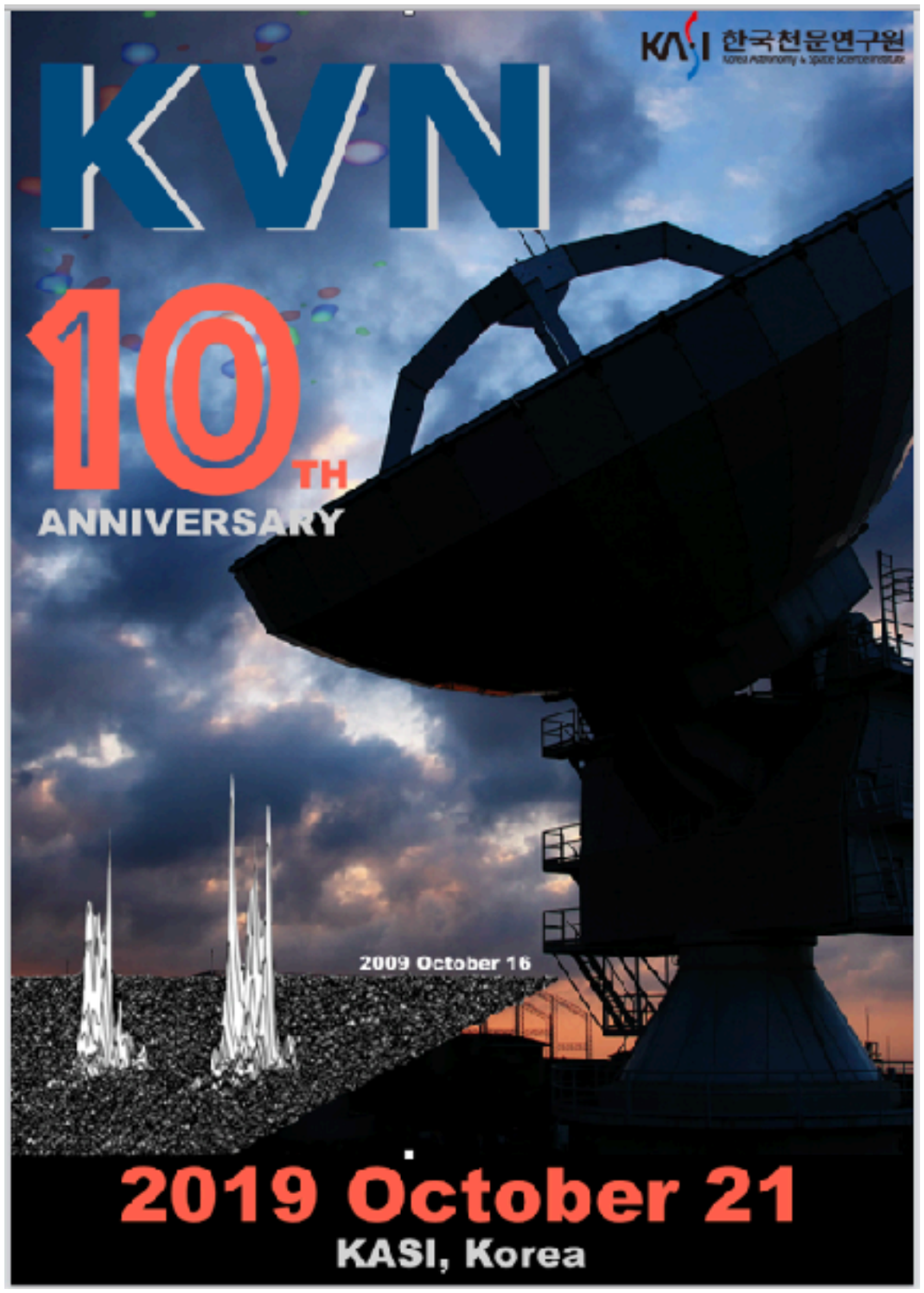
- **Korea-Italy collaborations in conducting VLBI observations**

- KVN + IVN (Medicia, Noto, Sardinia)

- 30 hours per season
  (Guaranteed for common VLBI observations)
  - PI associated with INAF and KASI
  - No restrictions for Co-I
  - Submit two proposals to each network
  - Publication “acknowledgement”

- Start from 2020A season and details under discussion (CfP, UST etc)

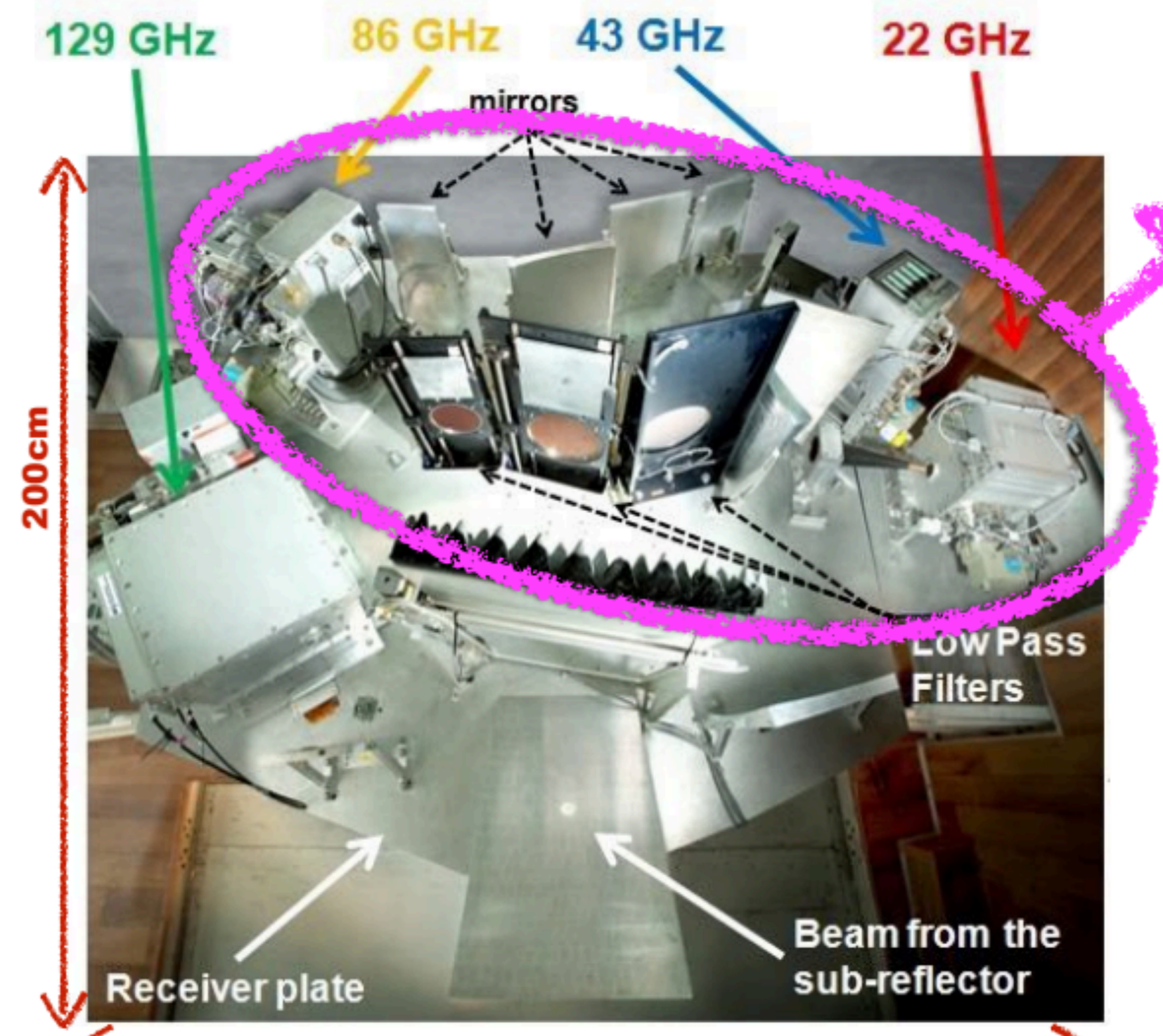
Notice to Users (2)



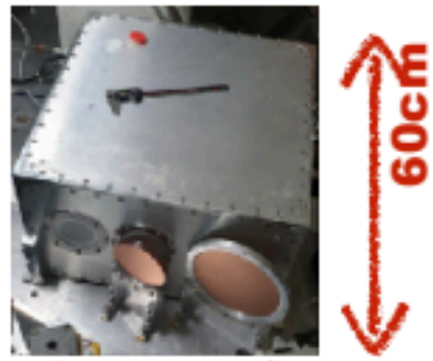
Notice to Users (3)

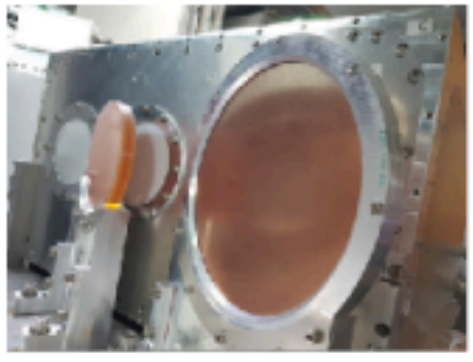
(S. T. Han)

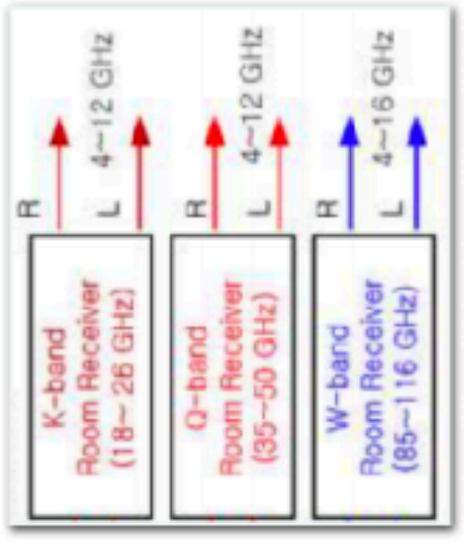
Compact Triple-band Receiver (CTR)



Installed on Sep. 2~3 at KYS



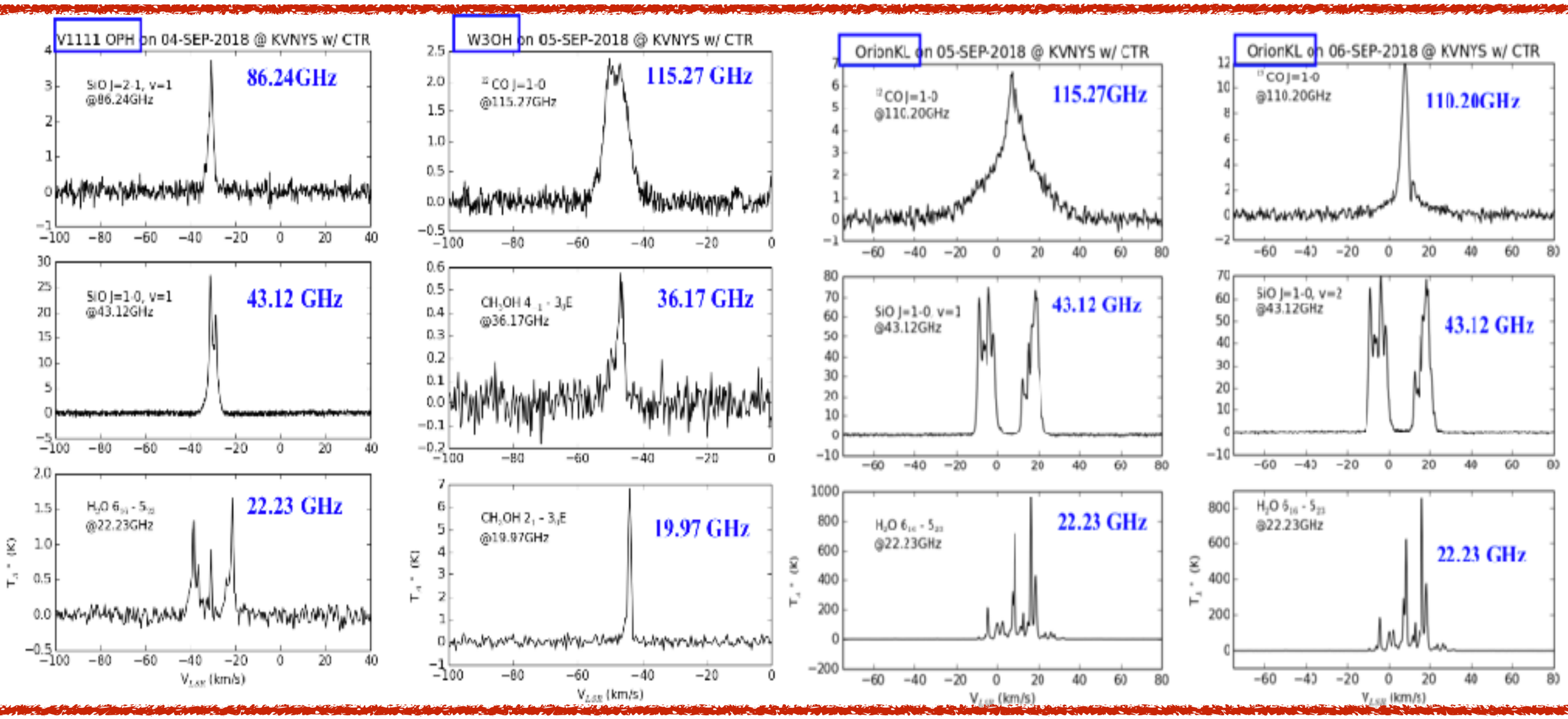




RF: 18-116GHz

Compact Triple-band Receiver (CTR)

(S. T. Han & D. Y. Byun)



- **Pointing offset among 3 channels : less than 3 arcsec to conduct simultaneous observations**
- **Aperture efficiencies : Obtained as much as we could (K- : 68 %, Q-: 66 %, W-band : 50%)**
- **Receiver noise temperatures : Not bad, but have to be improved (OMT, Polarizer and LNA)**

❖ **CTR is tailorable for use in telescopes with a small receiver cabin.**

❖ **Ultimately this concept may lead to development of much more compact multi-frequency receiver systems for mm-wave and sub-mm radio telescopes**

Simultaneous Multi-Freq. VLBI System in Globe

KVN (K/Q/W/D)
VERA (K/Q)
Sejong (K/Q/W)

Yebes 40m (Spain, K/Q/W)

Nobeyama 45m (Japan, K/Q/W)

Metsahovi 14m
(Finland, K/Q/W)

Tianma 65m
(China, K/Q)

E-KVN
(K/Q/W/D+230GHz)

"Standard System" in mm-VLBI

VLBA MK 25m
(USA, K/Q/W)

Sardenia 64m, Noto 32m, Medicina 32m (Italia, K/Q/W)

Mopra 22m (Australia, K/Q/W)

ATCA 22m x5
(Australia, Q/W)

The Most Powerful Eyes in the Universe

서울~울산~제주 삼각관측
우주와의 '소통' 한걸음 더

12일 새벽 제주도 서귀포 하늘에서 북극성을 중심으로 궤적을 그리며 움직이는 별들을 향해 지름 21m 크기의 접시 안테나가 우뚝 솟아 있다. 서울 연세대·울산 울산대·제주 탐라대를 3각으로 연결하는 한국우주전파관측망(KVN) 사업의 마무리 단계로 서귀포 탐라대 탐라전파천문대의 전파망원경이 지난 1일 성령식을 마치고 시험 가동에 들어갔다. 전파망원경 석 대가 연결되면 서울에서 제주 한라산의 쌀 한 톨도 식별할 수 있는 정밀도를 갖게 된다. 한국우주전파관측망을 가동하면 우리도 우주의 블랙홀을 정밀 계측해 별의 탄생과 사멸을 연구할 수 있고, 태반도 지각변동도 정밀 모니터링할 수 있게 된다. 이 사진은 디지털카메라에 14㎜ 렌즈를 부착해 1시간 동안 셔터를 열어 찍었다.

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Thank you !