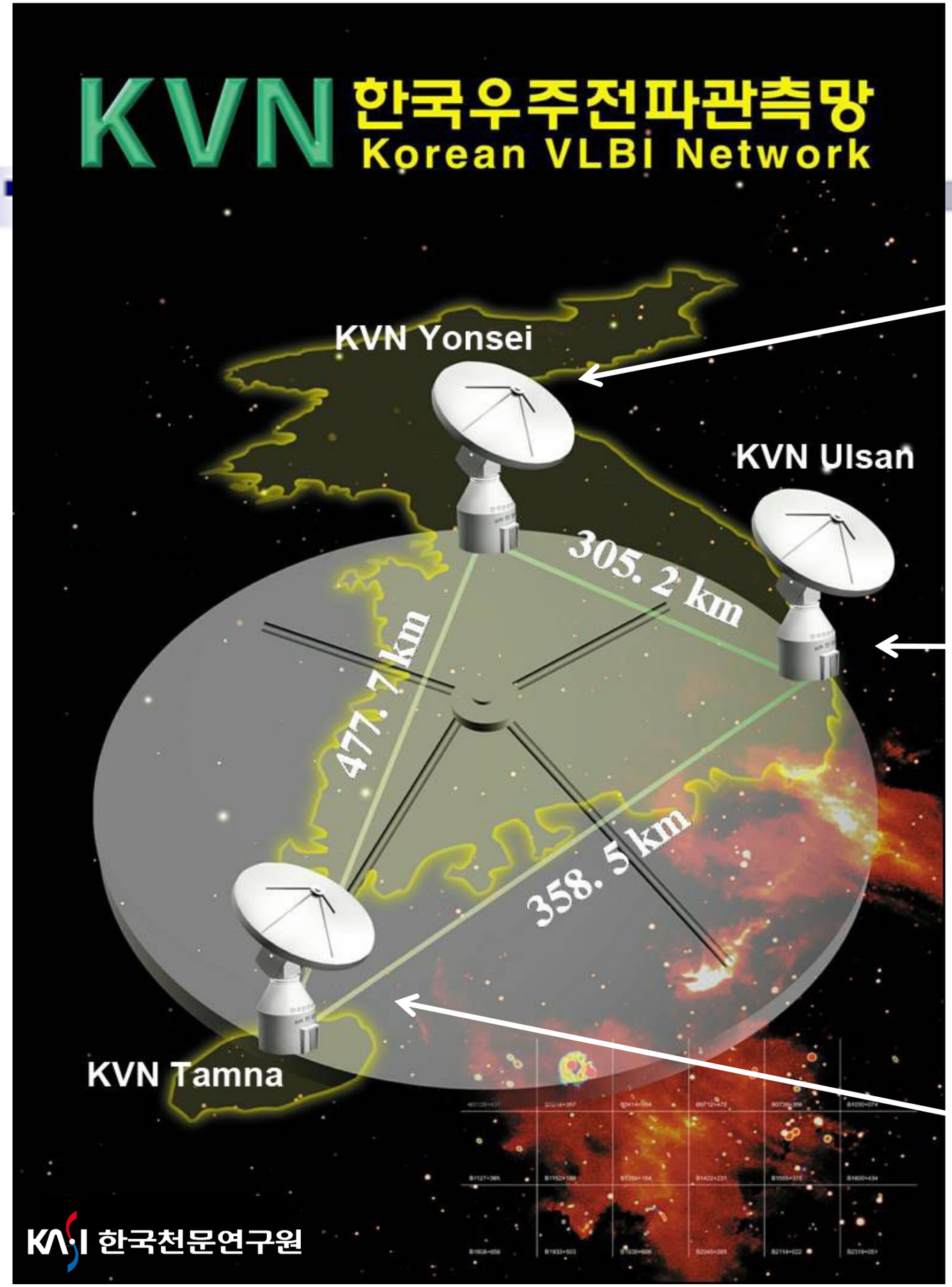
Simultaneous Multi-frequency Receiving System @ KVN

Taehyun Jung
Korea Astronomy & Space Science Institute (KASI)

On behalf of KVN TEAM

Meeting on the Triple-band Receivers in the EVN
6 September 2022

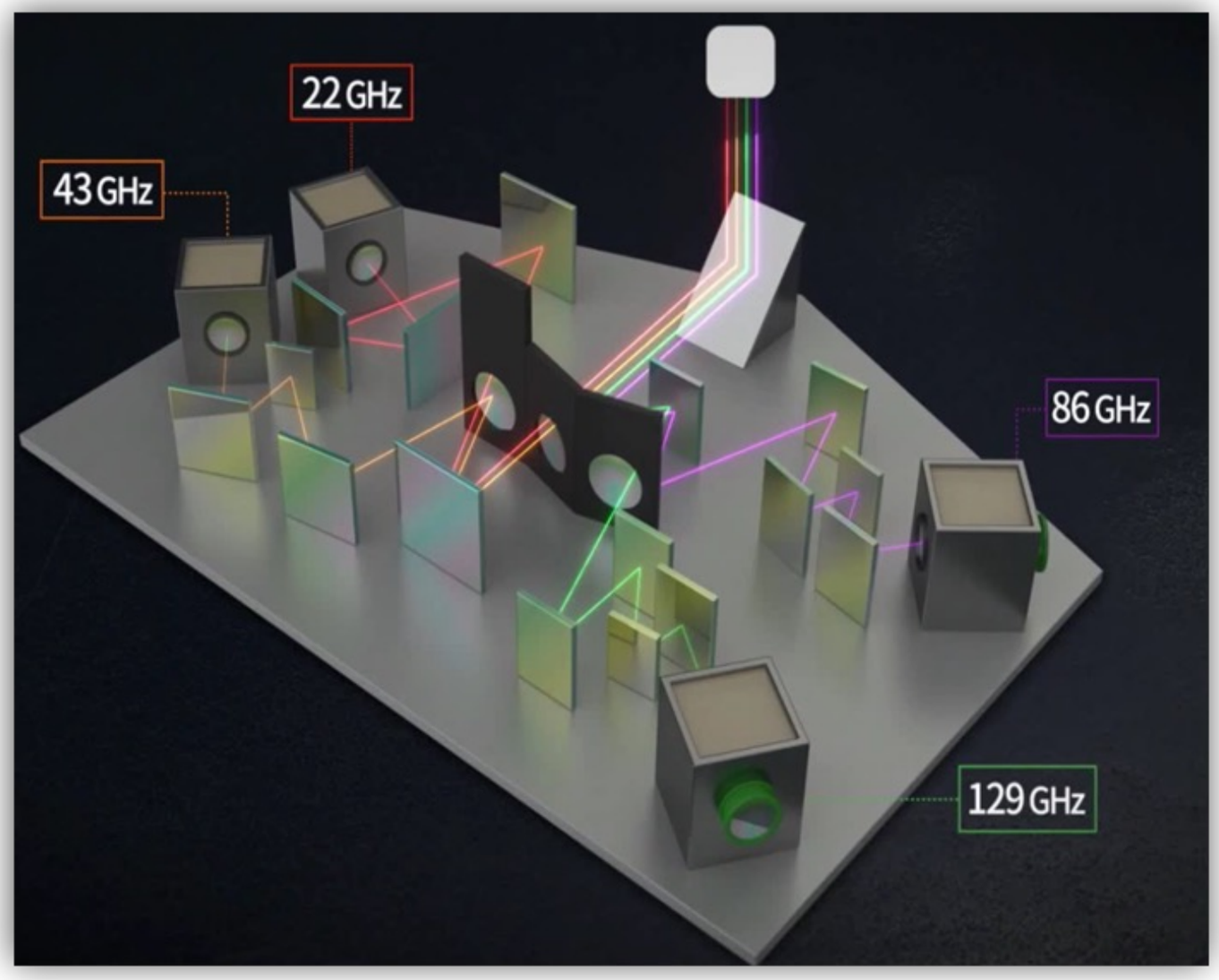

KVN 한국우주전파관측망
Korean VLBI Network
KVN Yonsei
KVN Ulsan
305. 2 km
477. 7 km
358. 5 km
KVN Tamna
KASI 한국천문연구원

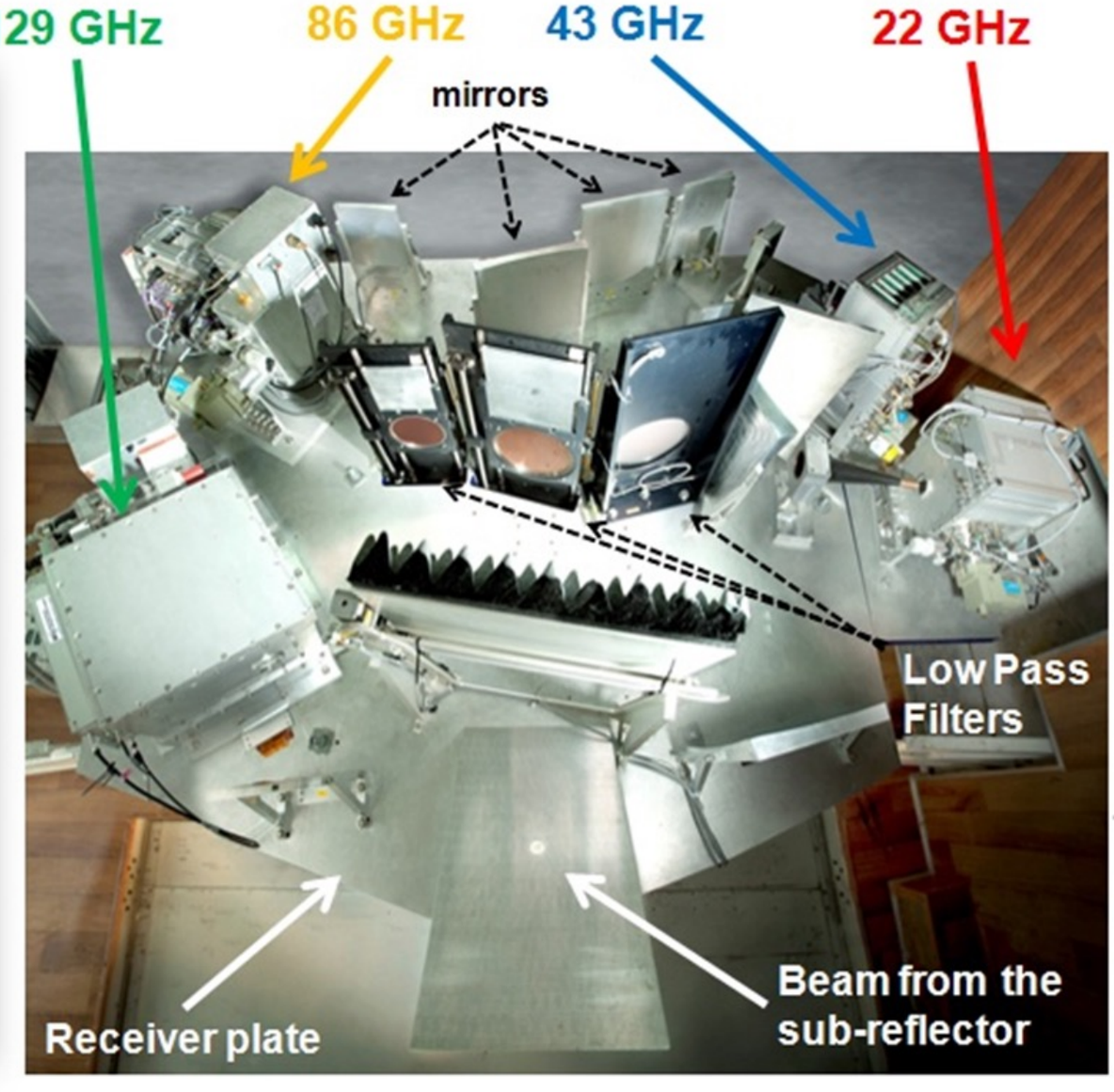

KVN Yonsei
Observatory


KVN Ulsan
Observatory


KVN Tamna
Observatory

Simultaneous Multi-Frequency Receiving System



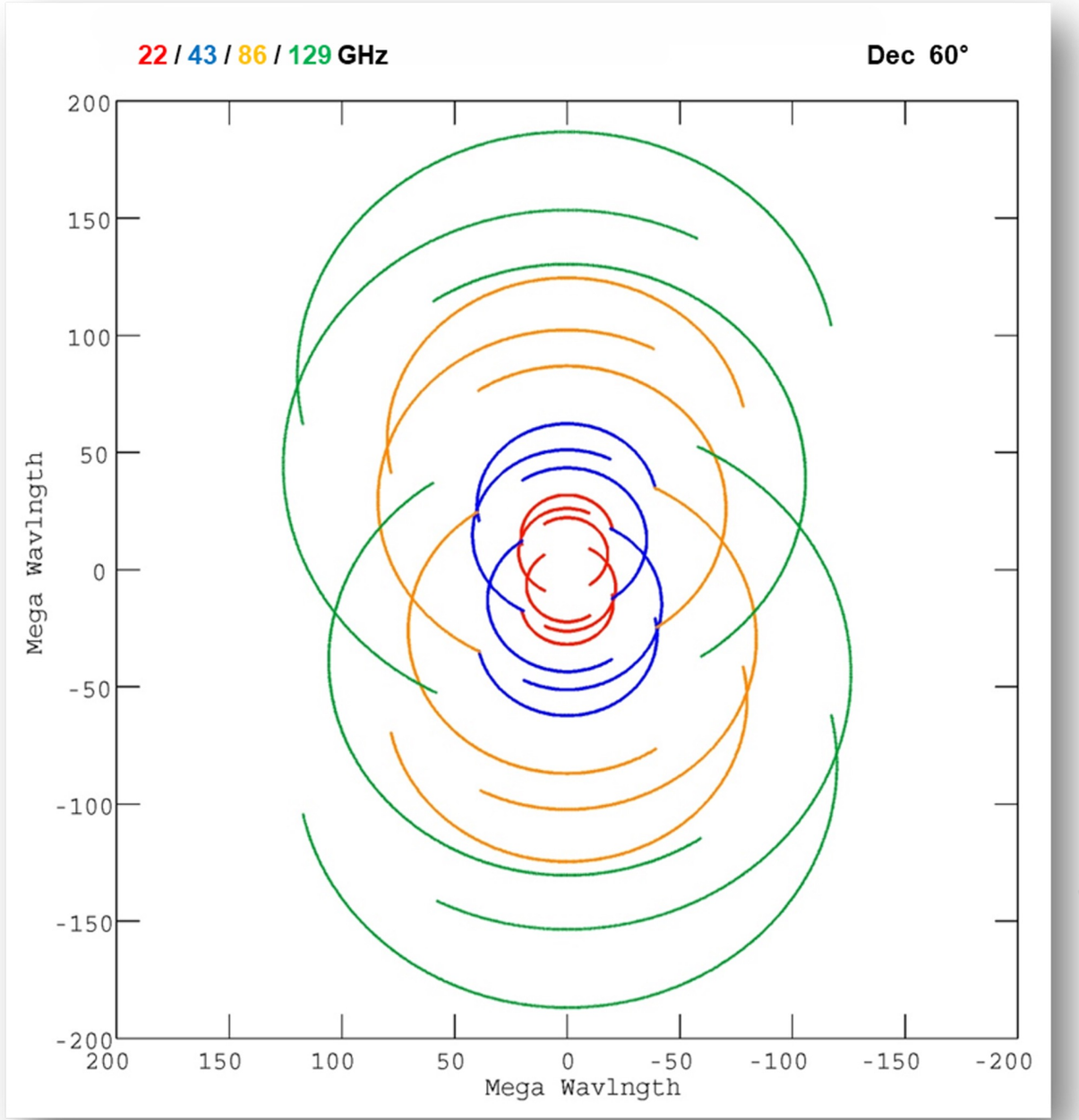


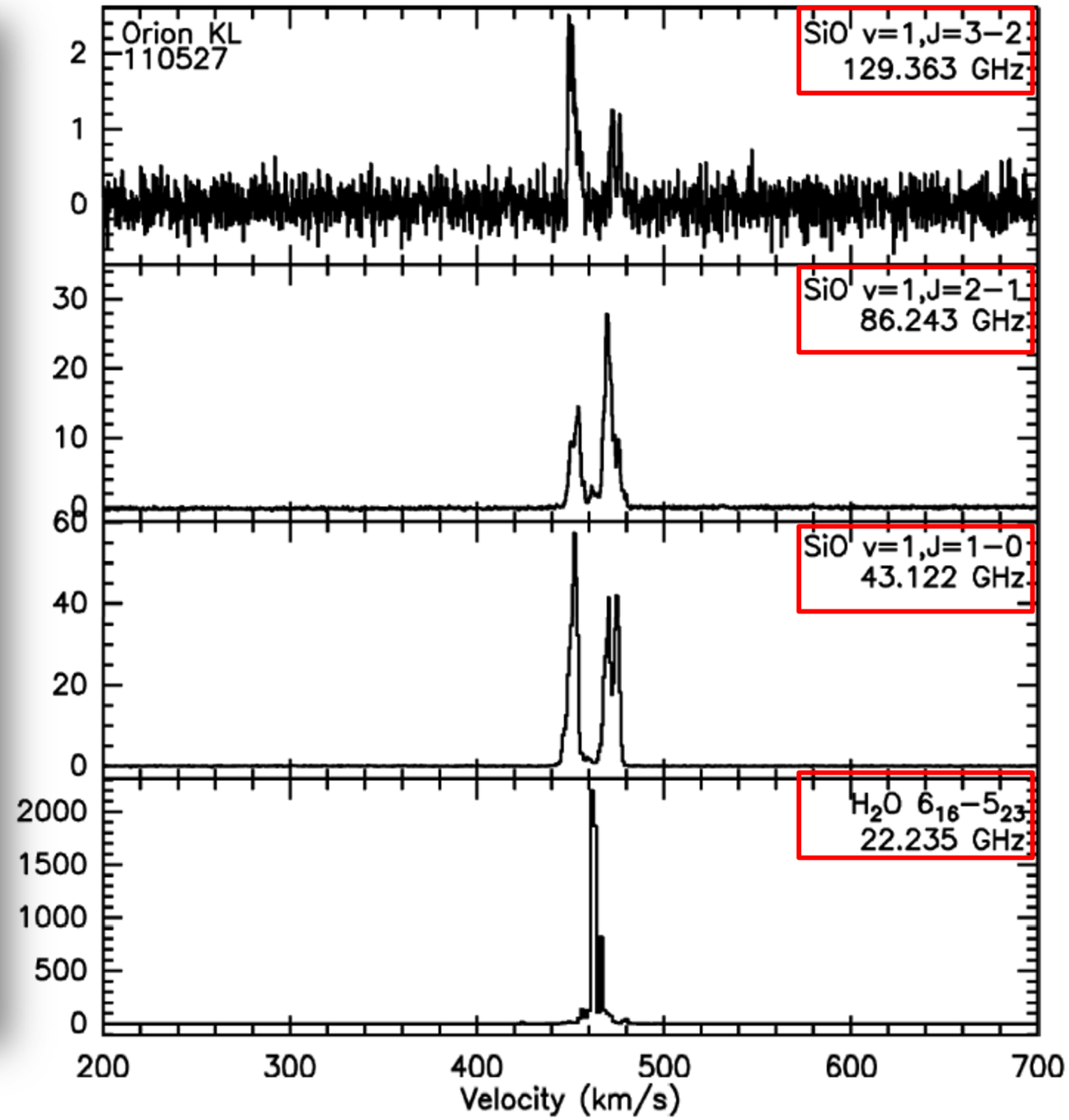
Band	K	Q	W	D
Freq. Range	18 - 26	35 - 50	85 - 116	125-142
Trx (K)	20-30	20-30	50-80	60-80

KVN 4CH Receiver
(Han et al. 2008, 2013)

All LHCP & RHCP

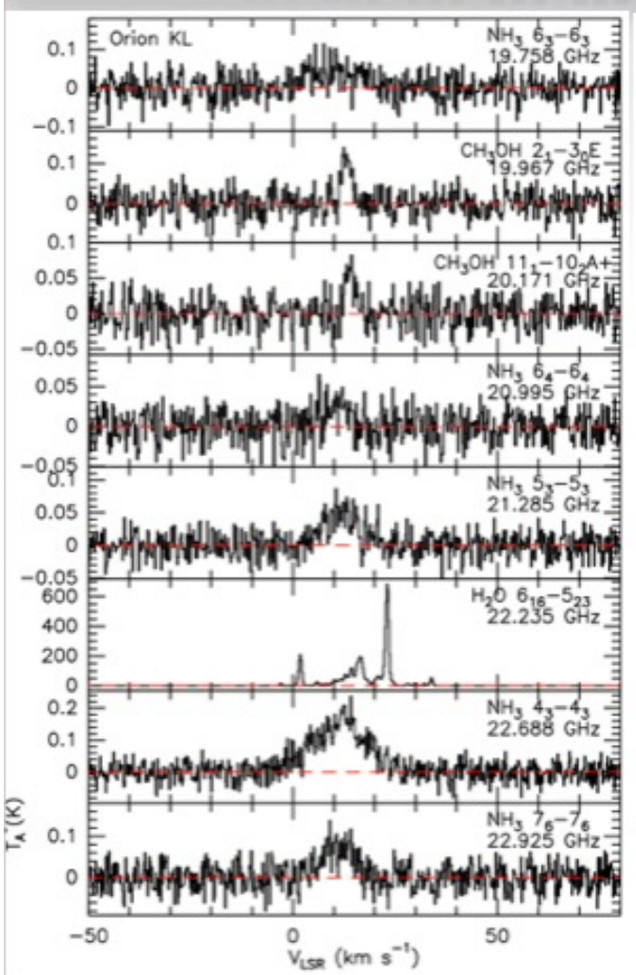
Multi-Frequency UV coverage & First Light

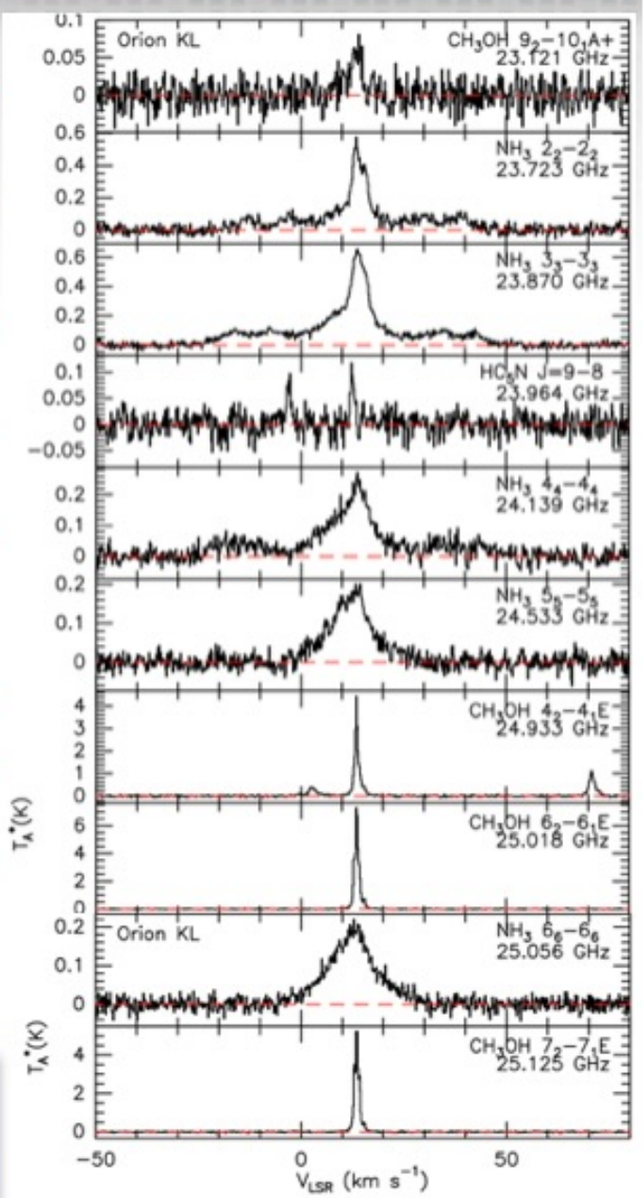


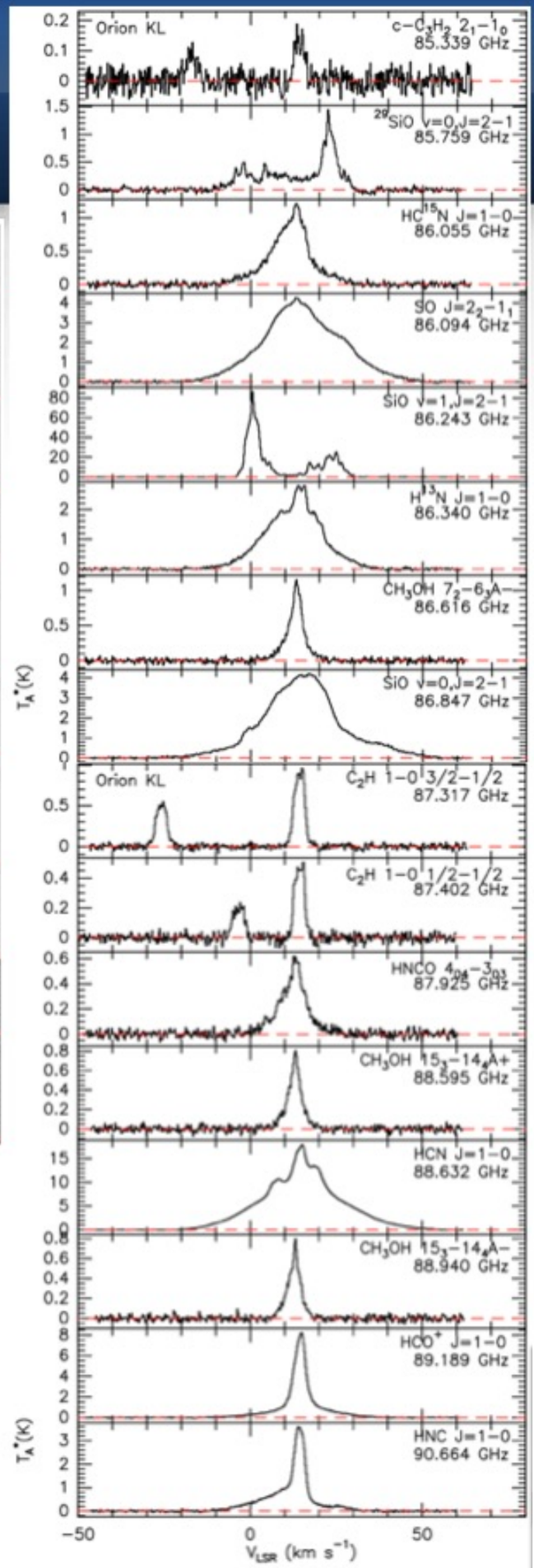


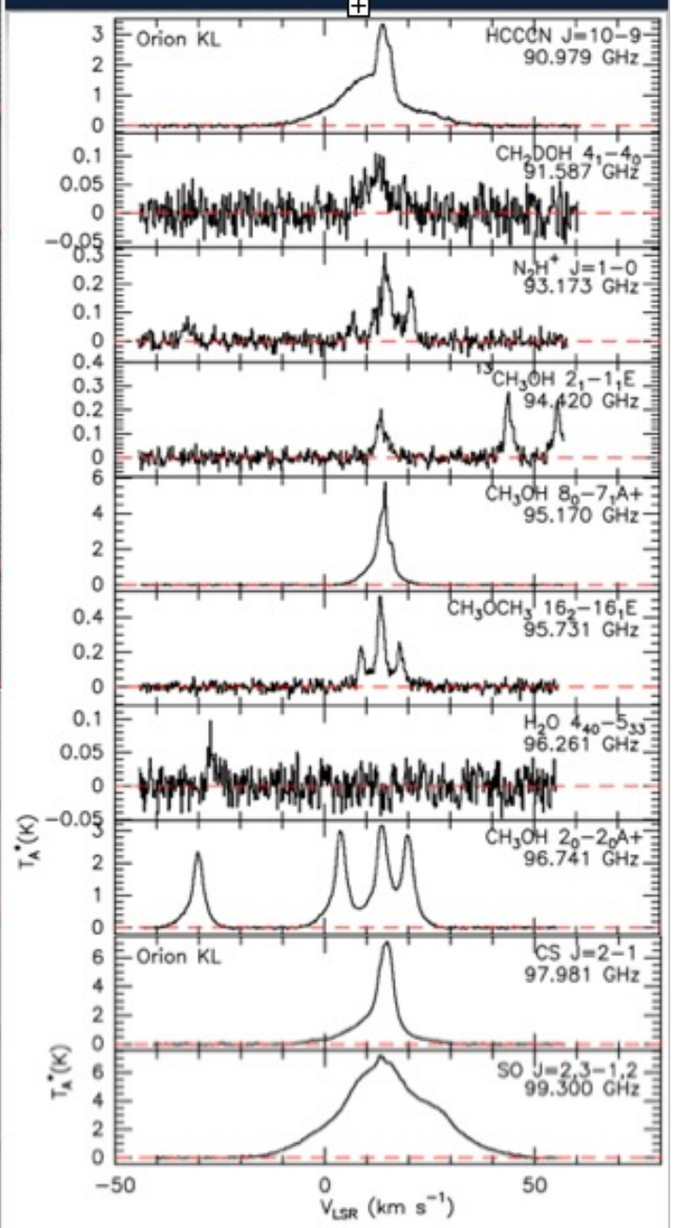
Observed Molecular Lines with Wideband Rx @ K/W band

Target Source ORION KL









Total integration time = 30 min.
(ON = 30 sec., OFF = 30 sec, Repeat = 30)
Observed molecular lines = 93 lines

Target source: Orion KL
K-band [18 -26 GHz]: 23 lines
W-band [85-100 GHz]: 26 lines

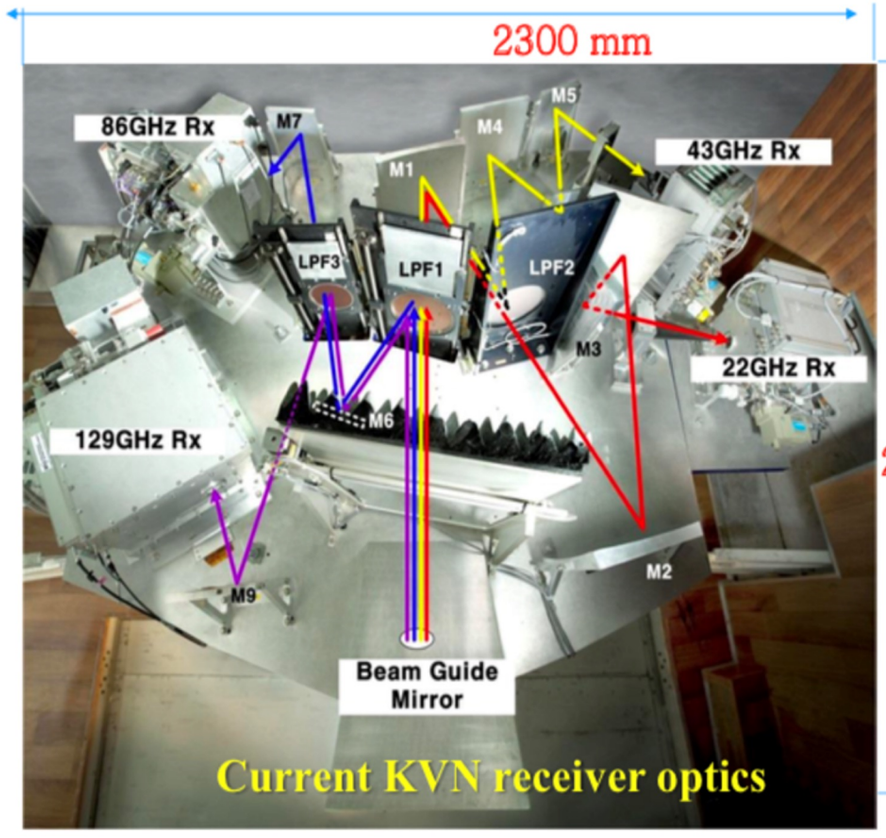
Target source: IRC+10216
K-band [18-26 GHz]: 12 lines
W-band [85-100 GHz]: 32 lines

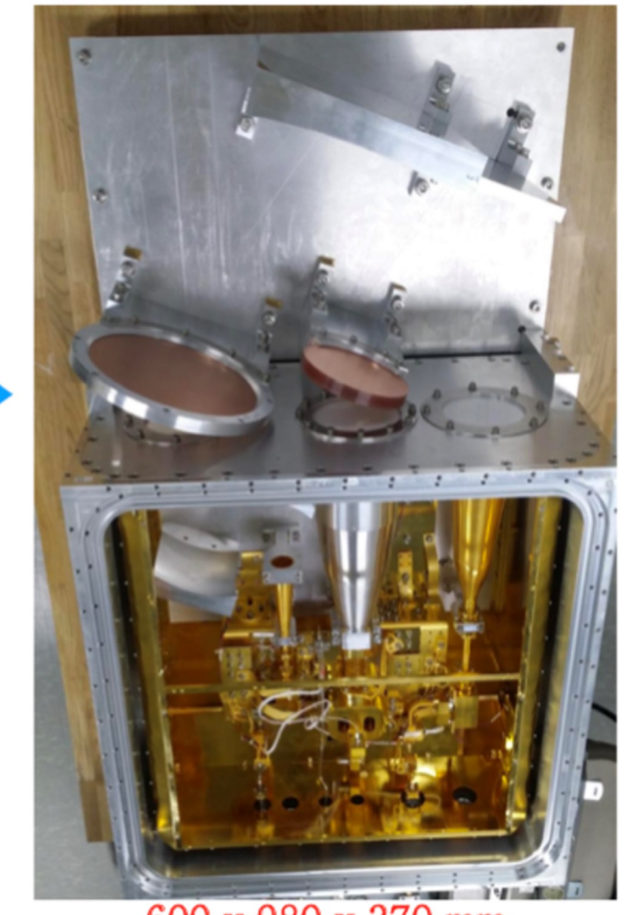
OCTAD
+ GPU Spectrometer

(J. Kim & D. Y. Byun)

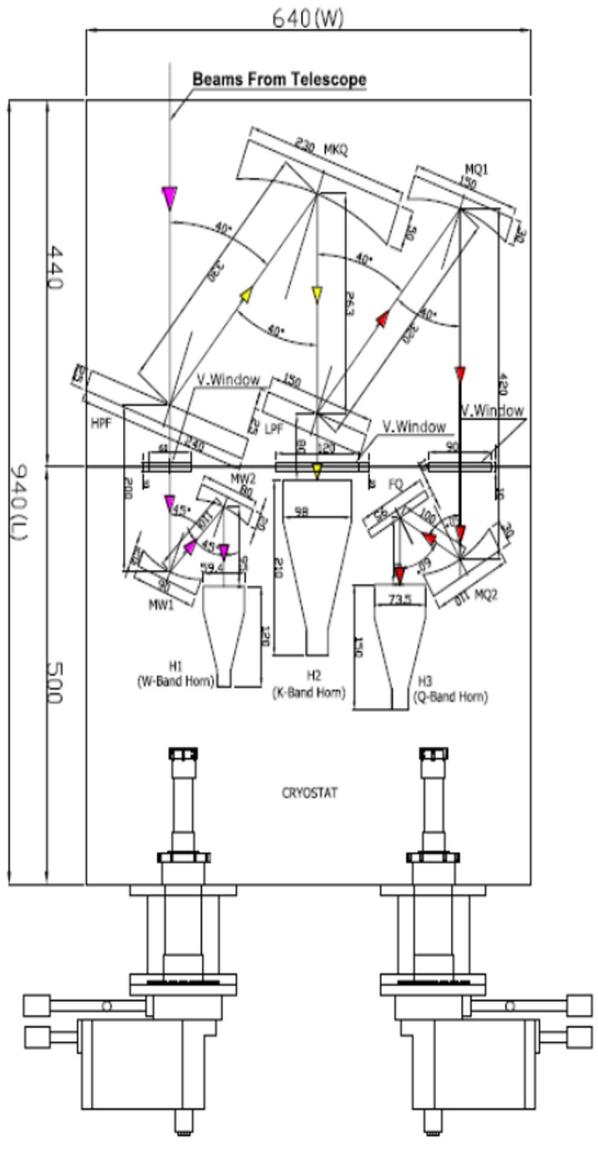
Compact Triple-band Receiver (CTR)

Compact Triple-band Receiver (CTR)





(S. T. Han)

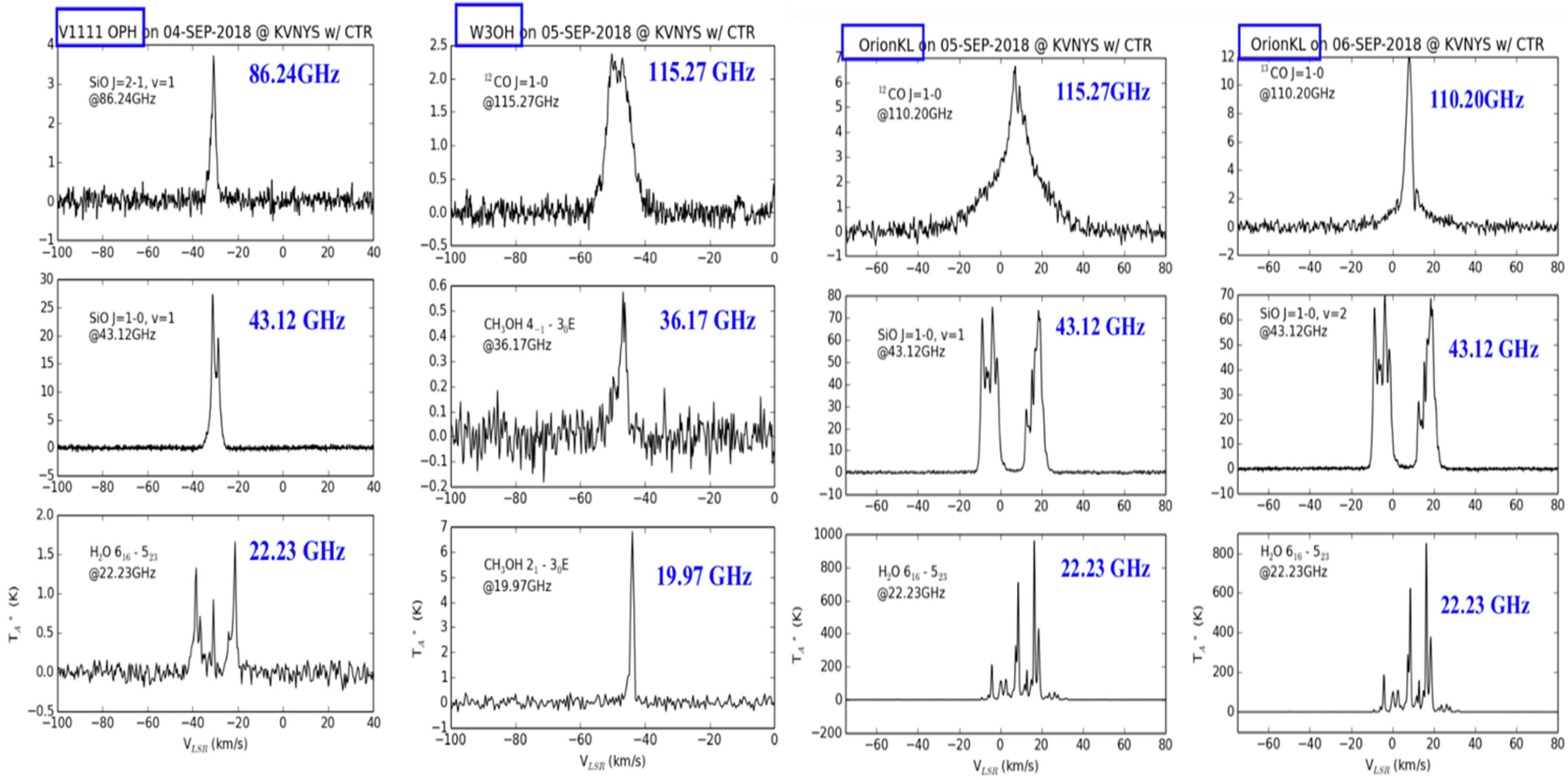


- **Pointing offset among 3 channels : less than 3 arcsec to conduct simultaneous observations**
- **Aperture efficiencies : Obtained as much as we could (K- : 68 %, Q-: 66 %, W-band : 50%)**
- **Receiver noise temperatures : Not bad, but have to be improved (OMT, Polarizer and LNA)**

- **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**

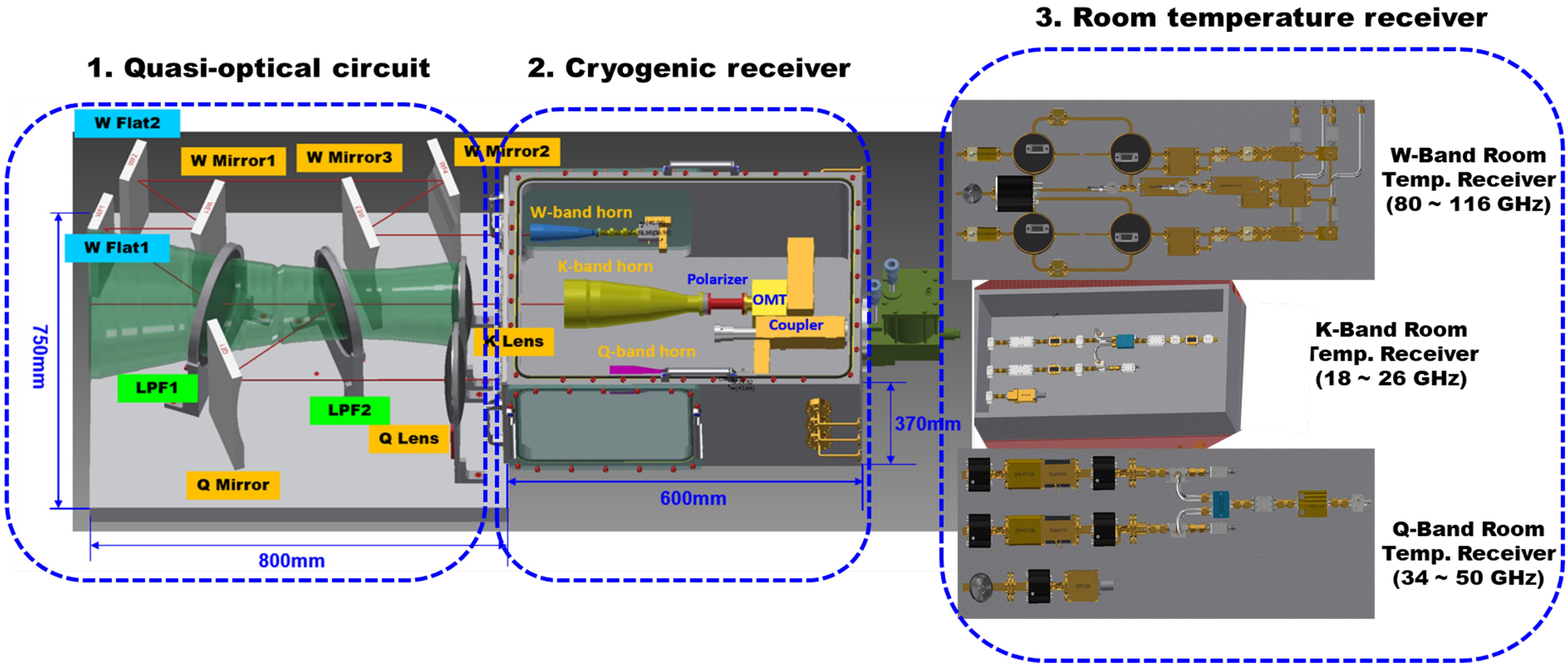
Compact Triple-band Receiver (CTR)

First Multi-Frequqncy (18 - 116 GHz) Light with CTR in 2018

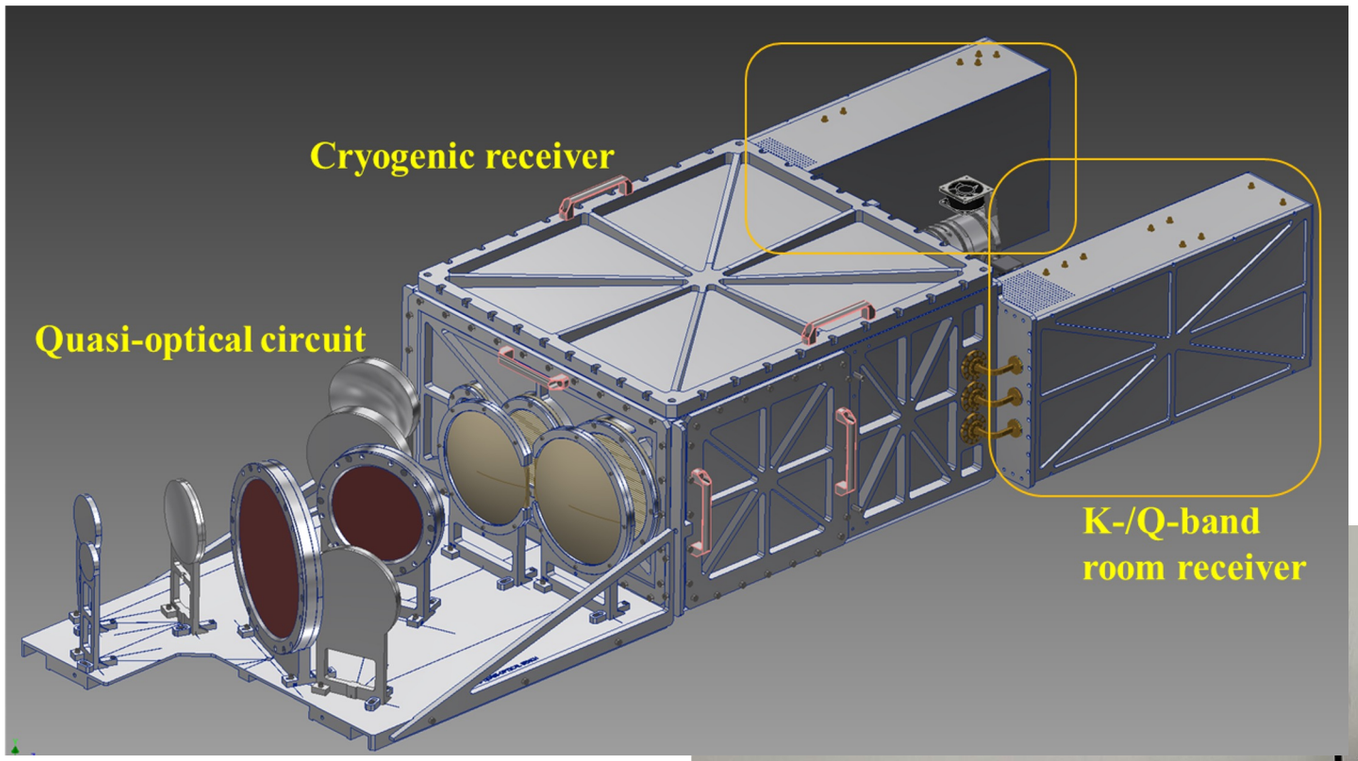


CTR for Italian Telescope

- Three CTRs for Sardinia, Medicina, Noto
- Production completed and shipped to Italy (2022. 8)



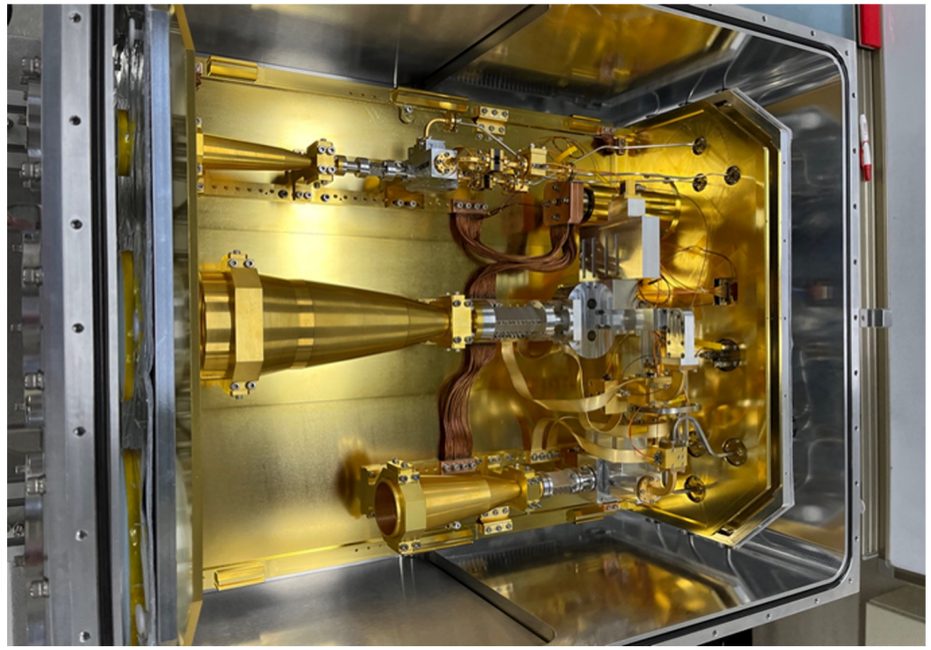
CTR for Italian Telescope

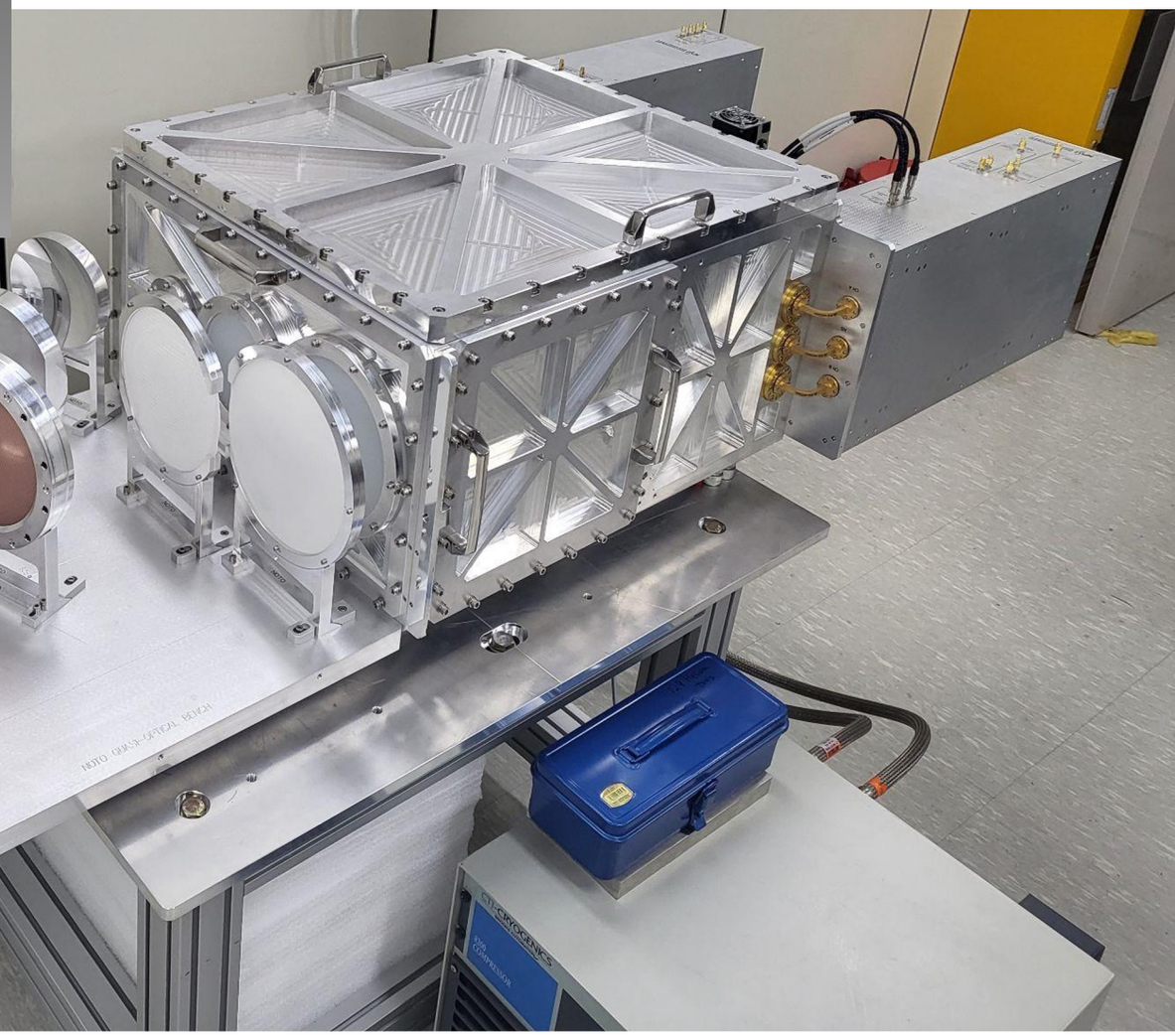


W-band

K-band

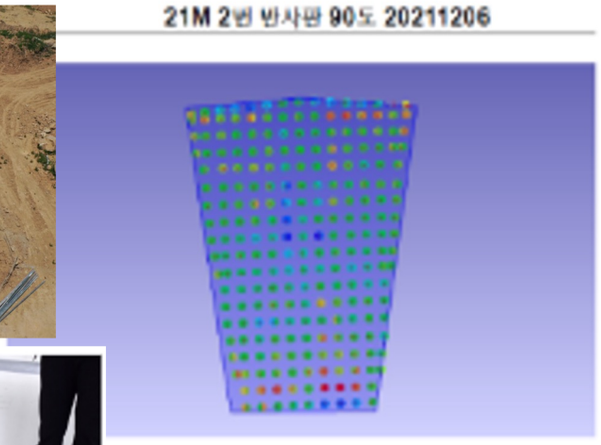
Q-band

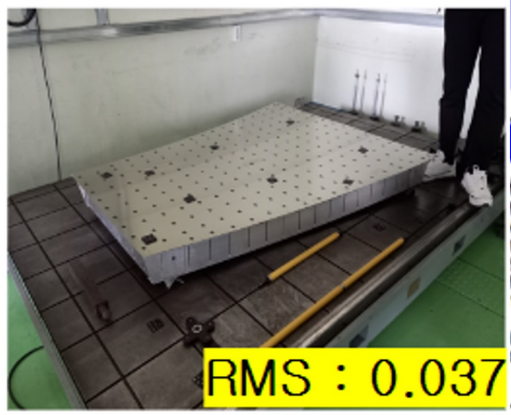


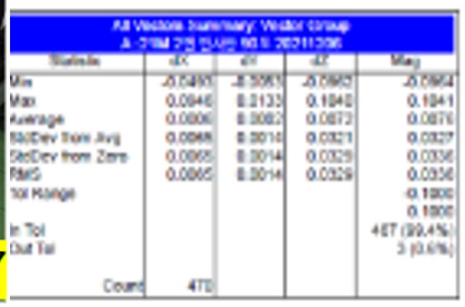


Extended-KVN Project (2020 - 2023)

- Construction of a new telescope
  - 100-200 km baselines
  - 18-230GHz
- Construction Period & Budget
  - 4 years : 2020 ~ 2023
  - 15M USD
- Developments of multi-frequency receivers
  - CTR (K/Q/W-bands)
  - 150/230GHz SIS mixer receiver
- New GUP Correlator

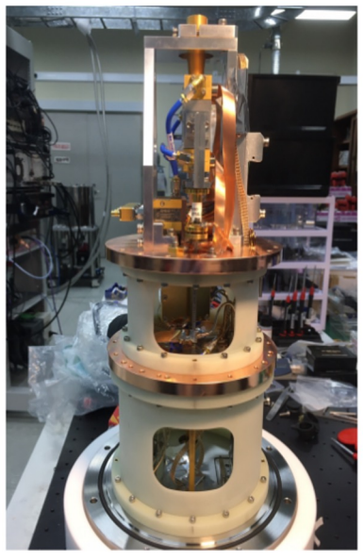


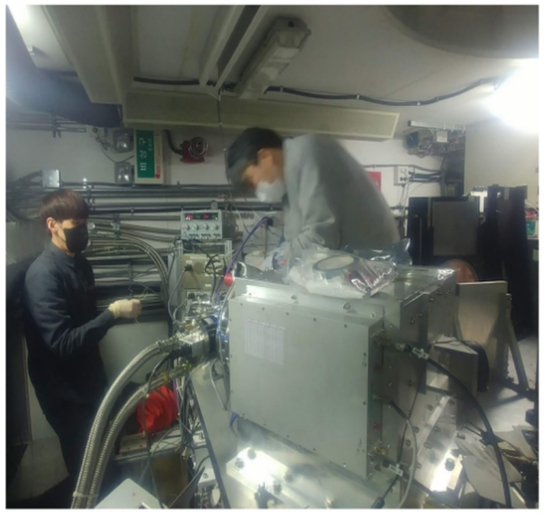


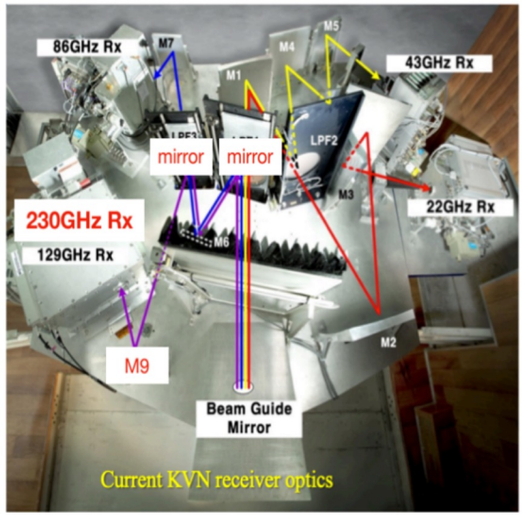


First 230GHz Test at KVN Yonsei Telescope (2022.2)

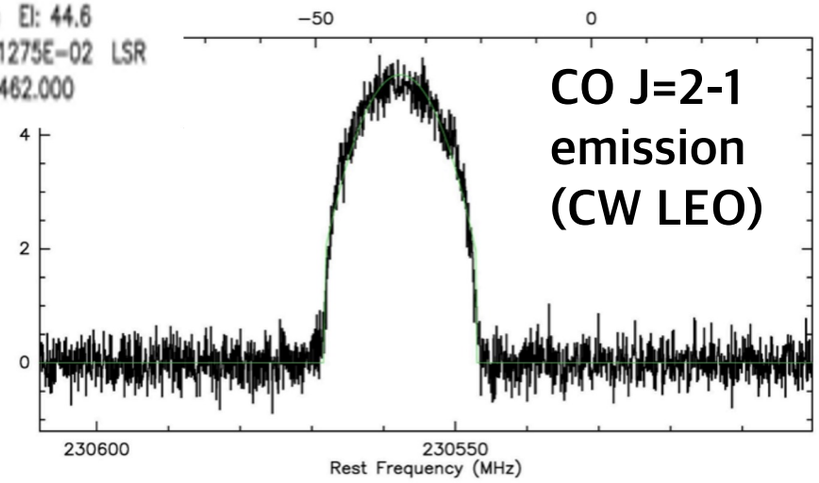
- KVN 230GHz test experiment: 2022 Feb.
- Test receiver: ~ 70K @ 230 GHz
- Backend: OCTAD + GPU spectrometer (128MHz x 16 IF)
- HPBW: 12.1 / 14.3 arcsec @ AZ / EL
- Measured aperture efficiency:
  → 14% @ 230 GHz (EL~50 deg, Uranus)
  - total surface accuracy ~ 0.13 mm
  - Tsys ~ 200K, tau ~ 0.3,
    transmission ~ 74%, PWV ~ 3 mm

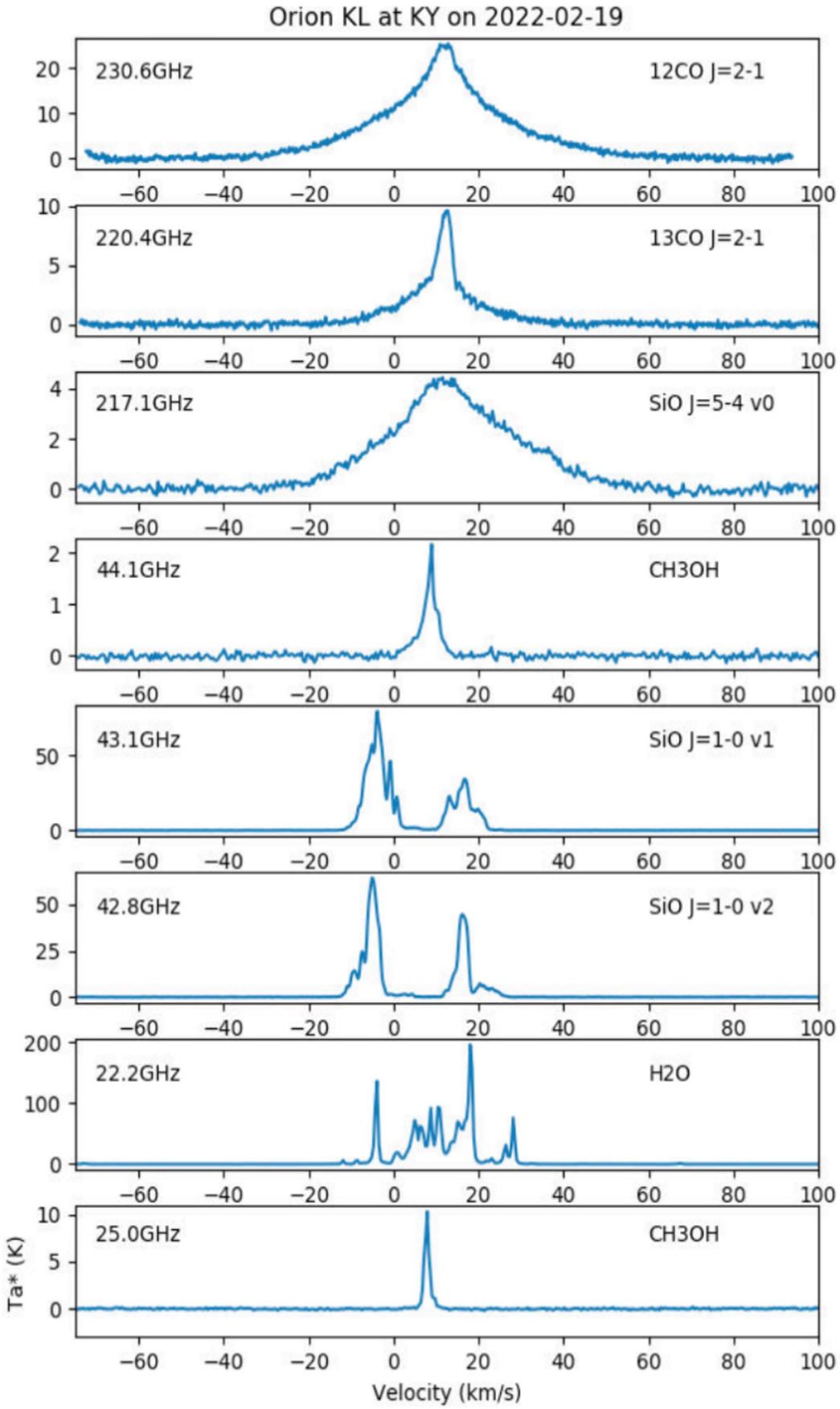




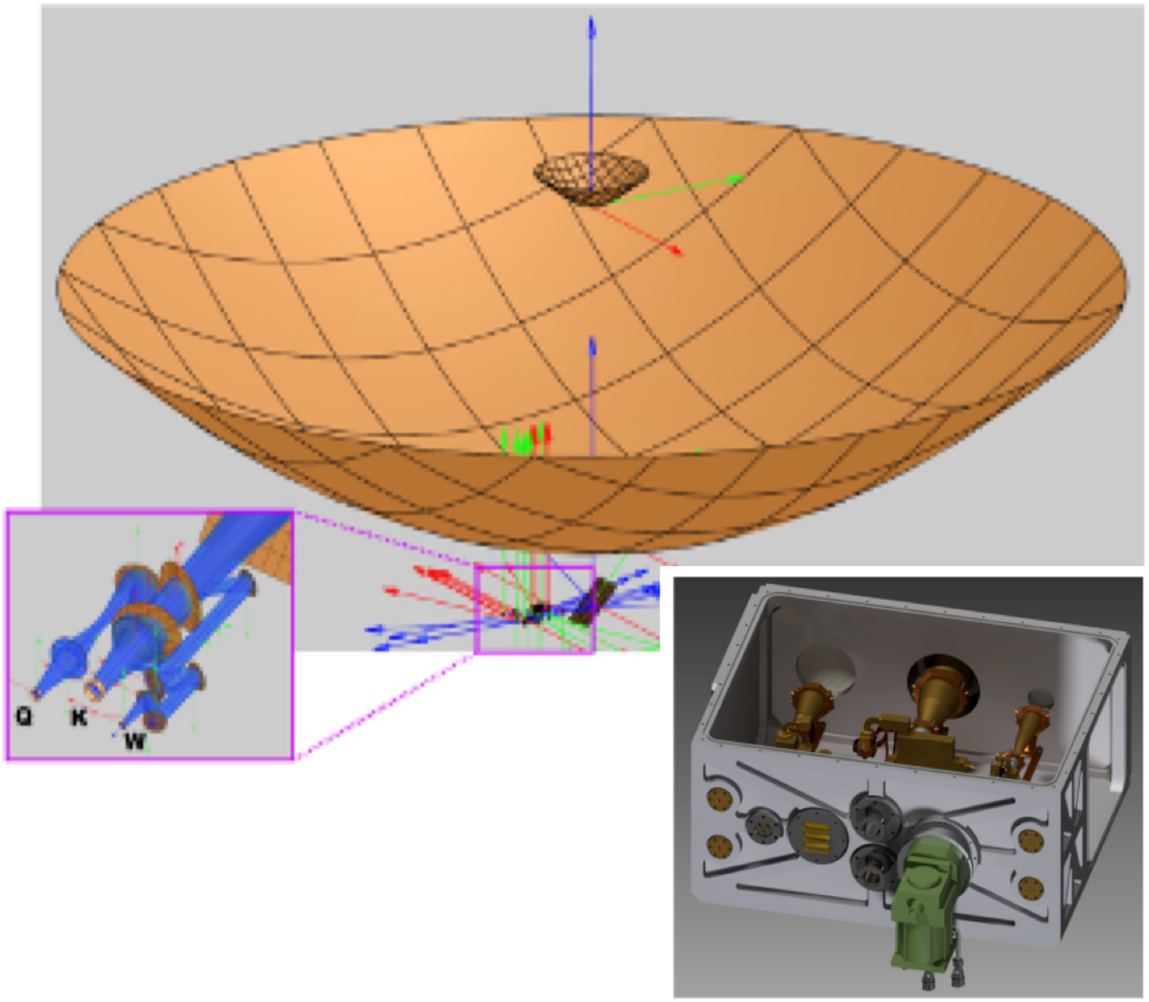


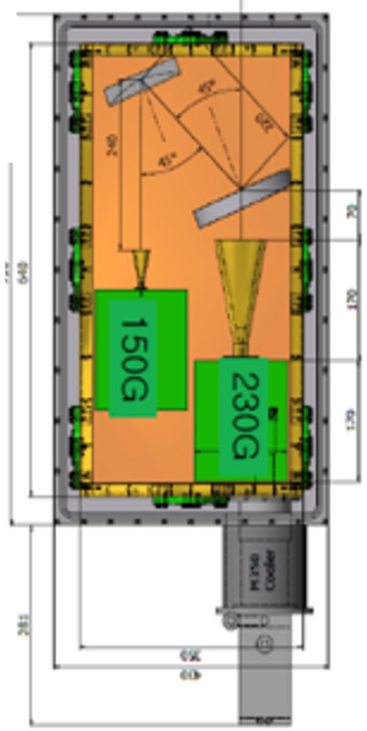
4;3 CW LEO 230538 KYS21M230L O:18-FEB-2022 R:04-MAR-2022
l: 146.989 b: 13.279 Un None 0.0° Offs: -3.5 +0.0
Unknown tau: 0.339 Tsys: 319. Time: 30.0sec El: 44.6
N: 2047 IO: 913.015 VO: -9.061 Dv: -8.1275E-02 LSR
FO: 230538.000 Df: 6.2500E-02 Fi: 219462.000





Simultaneous 5-Channel (22/43/86/150/230 GHz) Receiver

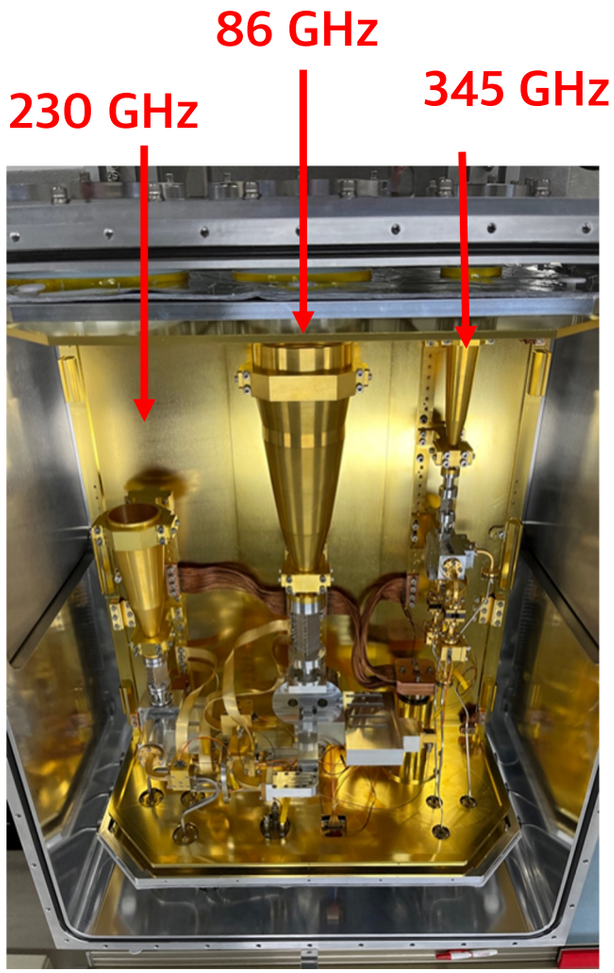




- Compact Tripple-band Receiver
  - K: 18-26 GHz
  - Q: 34-50 GHz
  - W: 84-116 GHz
- 150/230GHz SIS Mixer Receiver
  - 125-174 GHz
  - 210-270 GHz
- C/X/Ka-band Receiver (6/8/32 GHz)
- 45deg rotating mirror

Simultaneous MF receiver (18 - 230 GHz)

A new proposal for s-CTR development @ KASI

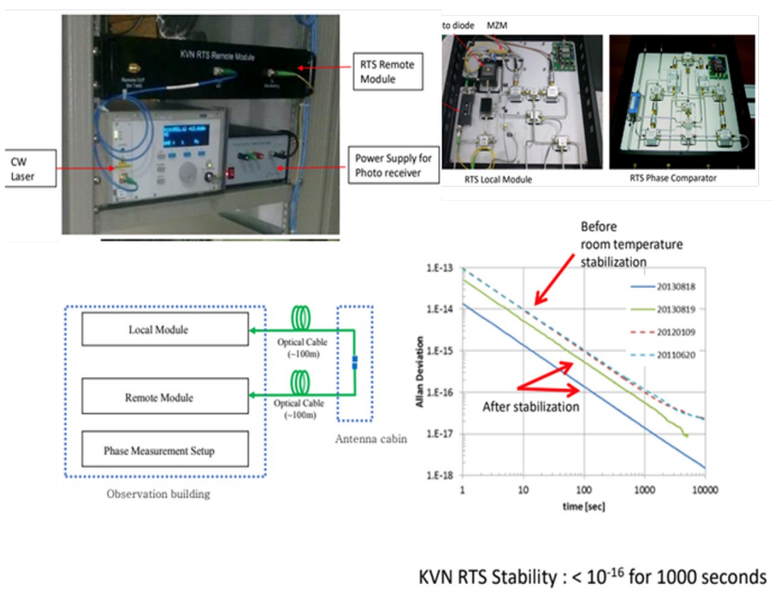


[Objective & Deliverables]

- to demonstrate VLBI phase correction (FPT) and astrometry in mm/submm frequency range
- to develop and deploy two receivers to two candidate telescopes
  - 86 GHz LNA-based (COTS device available)
  - 230/345 GHz : SIS mixer-based (in-house design)
  - LO generation and phase stabilization systems (in-house development)
  - Low crosspol quasioptical dichroic filters (in-house design, outsourced fab)

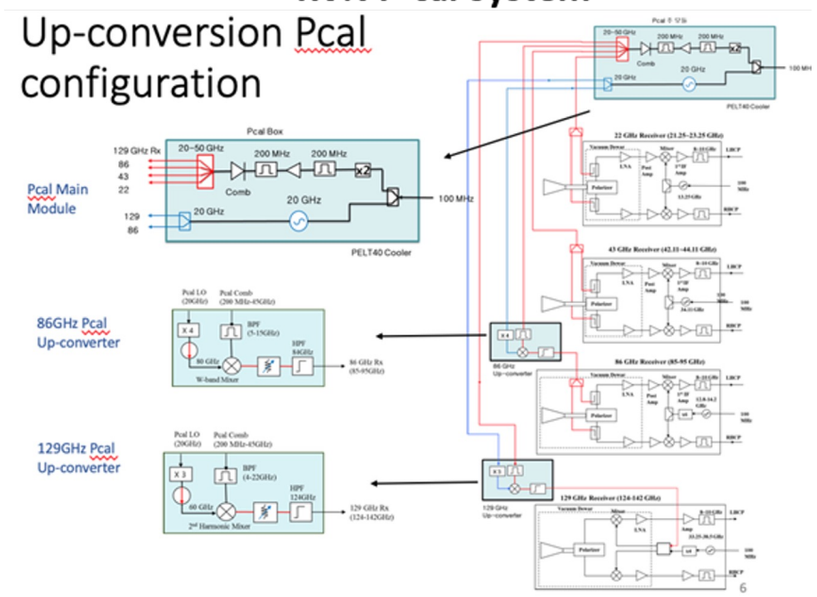
- **Testing:** photonic-based LO & P-cal tone generation for ultra-wideband (85-350GHz) instrumental phase calibration
- Applied for a new project of KASI (2024~) & under review [PI: Jung-Won Lee]

KVN Round Trip System



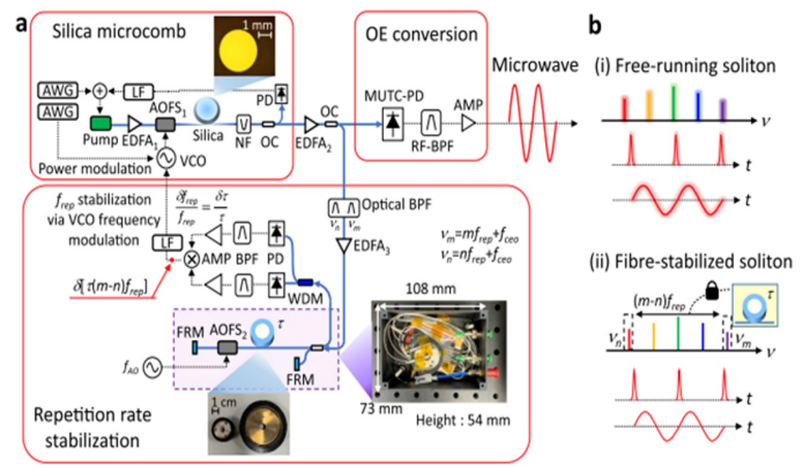
KVN RTS Stability : < 10^{-16} for 1000 seconds

KVN P-cal system



Fiber-photonic-stabilized Microcombs

(85-350 GHz wideband tone signal generation)

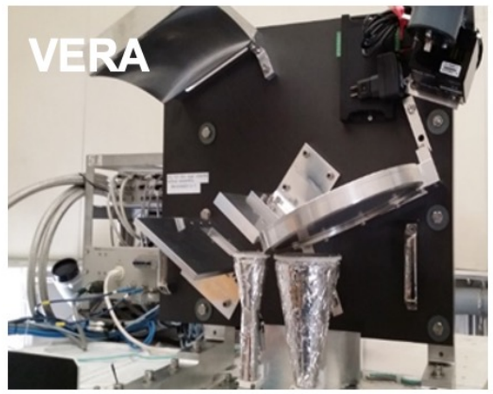


(Kim et al. 2022 Nat. comm)

Simultaneous Multi-Freq. VLBI System in Globe

- **Red**: implemented
- **Orange**: on-going
- **Green**: future?

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

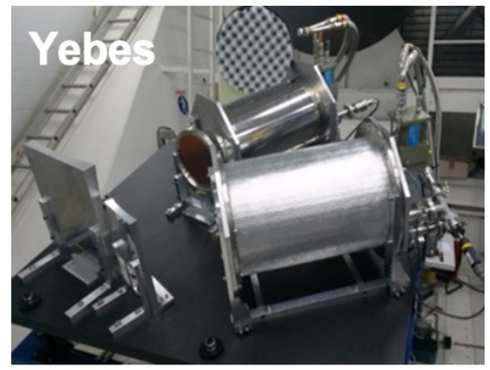


Yebes 40m (Spain, K/Q/W)

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

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

Tianma 65m
(China, K/Q)



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

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

Common MF System for mm-VLBI in Globe

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

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

ATCA 22m x5
(Australia, Q/W)

Multi-Frequency Mm-Wave Radio Telescopes
EU, ERATec workshop, Florence, Italy (Oct. 5-7)

Effelsberg

MIllimetron

Backend System

[Telescope]

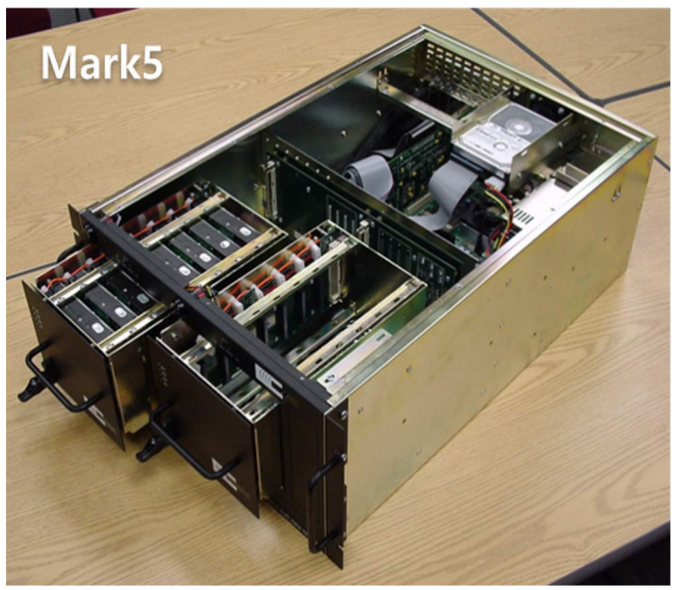
- RTS (RoundTip System)
- Samplers [ADS-1000 & OCTAD]
- Clock system, Optical transmitter etc

[Performance]

- 4 channel (22/43/86/129 GHz) & full polarizaiton
- Max 32 Gbps data rate

[Observatory]

- KDAS (digital fitler, digital spectrometer)
- GUP spectrometer
- Recorders [Mark5B, Mark6, OCTADISK]
- H-maser, GPS, RTS, Clock system, Optical receiver



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 (4 CH) + FILA10G (4 CH)

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

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, 한반도 지각변동도 정밀 모니터링할 수 있게 된다. 이 사진은 디지털카메라에 14㎜ 렌즈를 부착해 1시간 동안 셔터를 열어 찍었다.

서귀포/김동균 기자 bong8@hani.co.kr

Thank you !