Korean VLBI Network

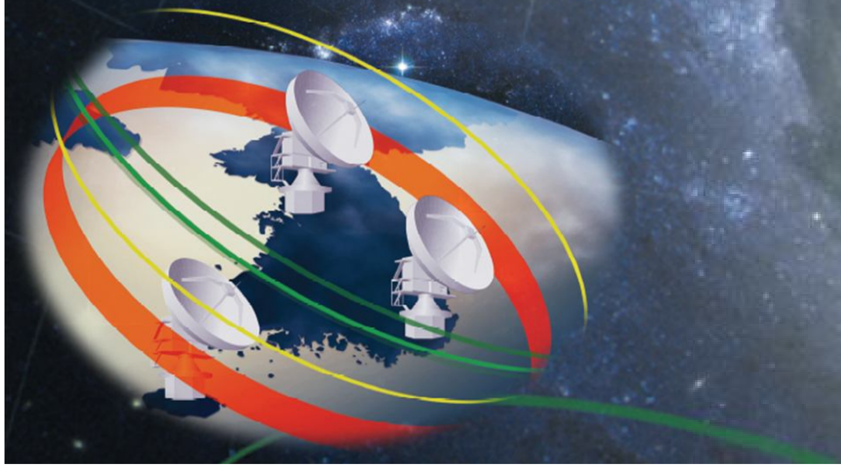
- Recent Activities -

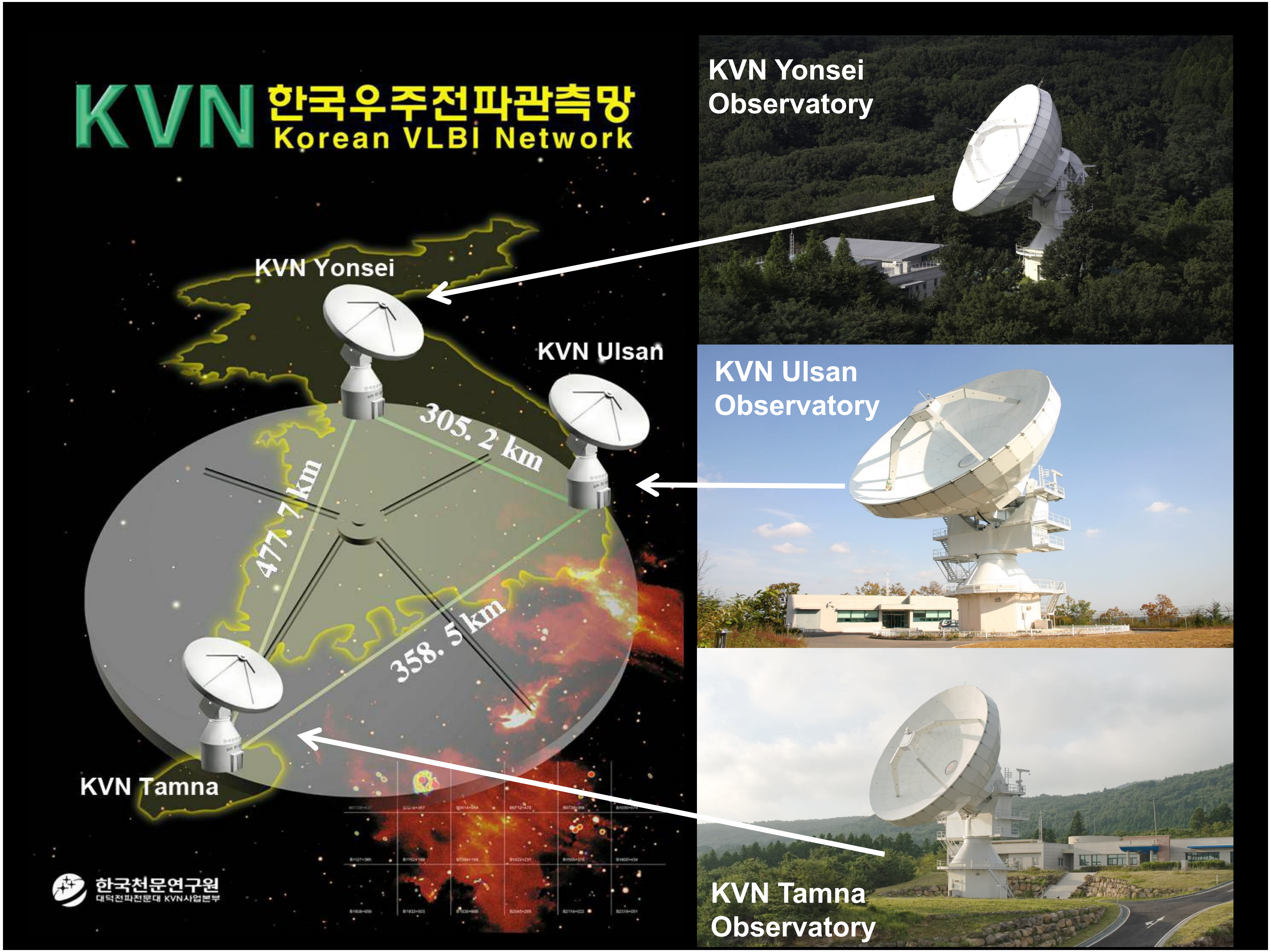
Multifreuqency AGN Survey with the KVN

- Discover high frequeActivities -

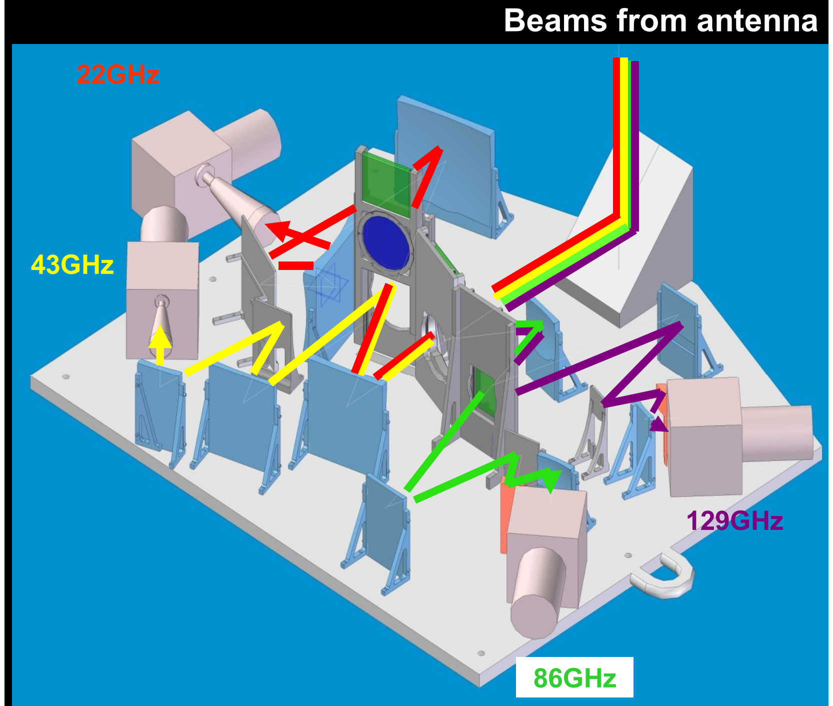
Taehyun Jung (KASI)

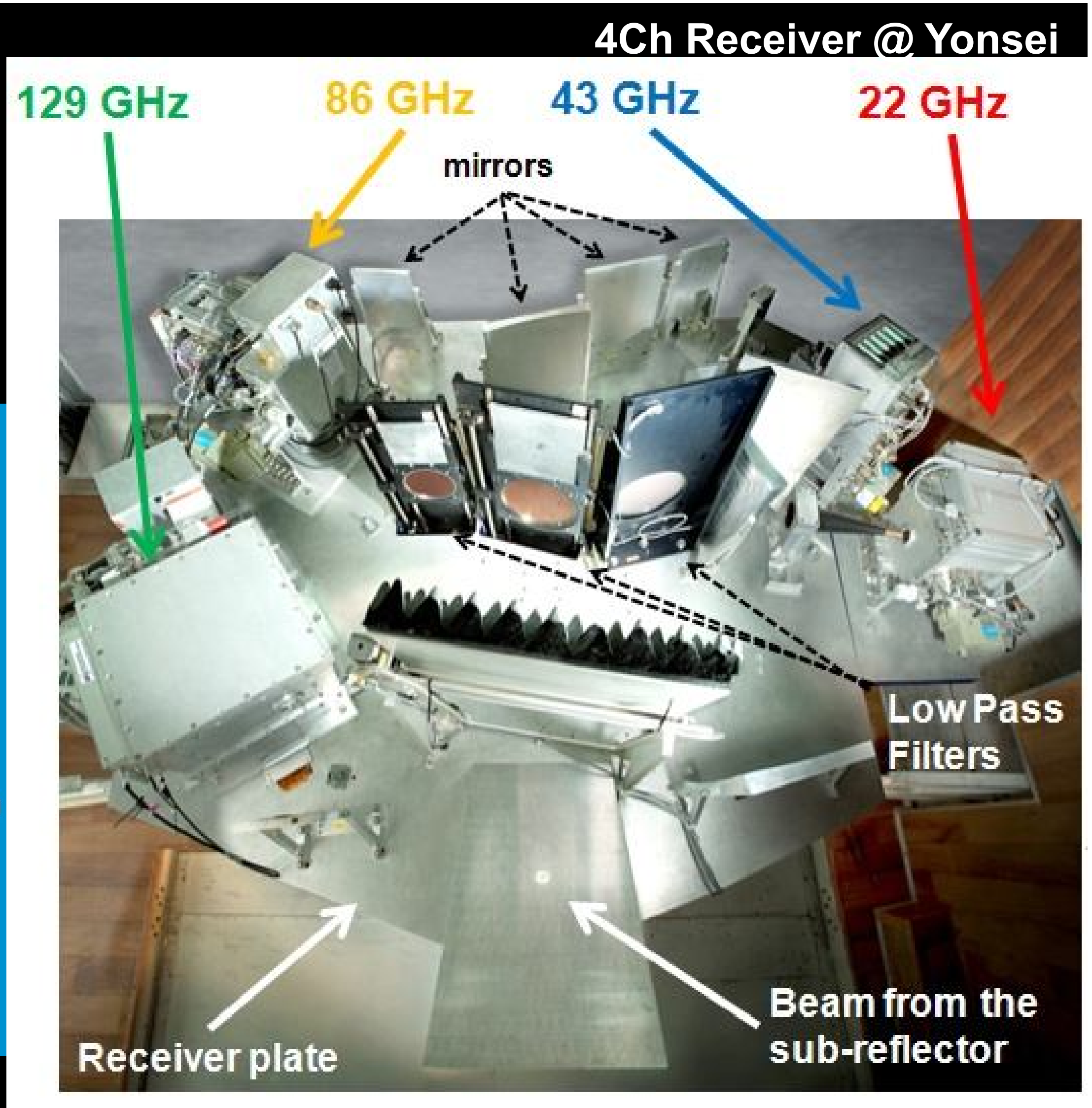
on be half of KVN team




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

Multi-Frequency Receiving System

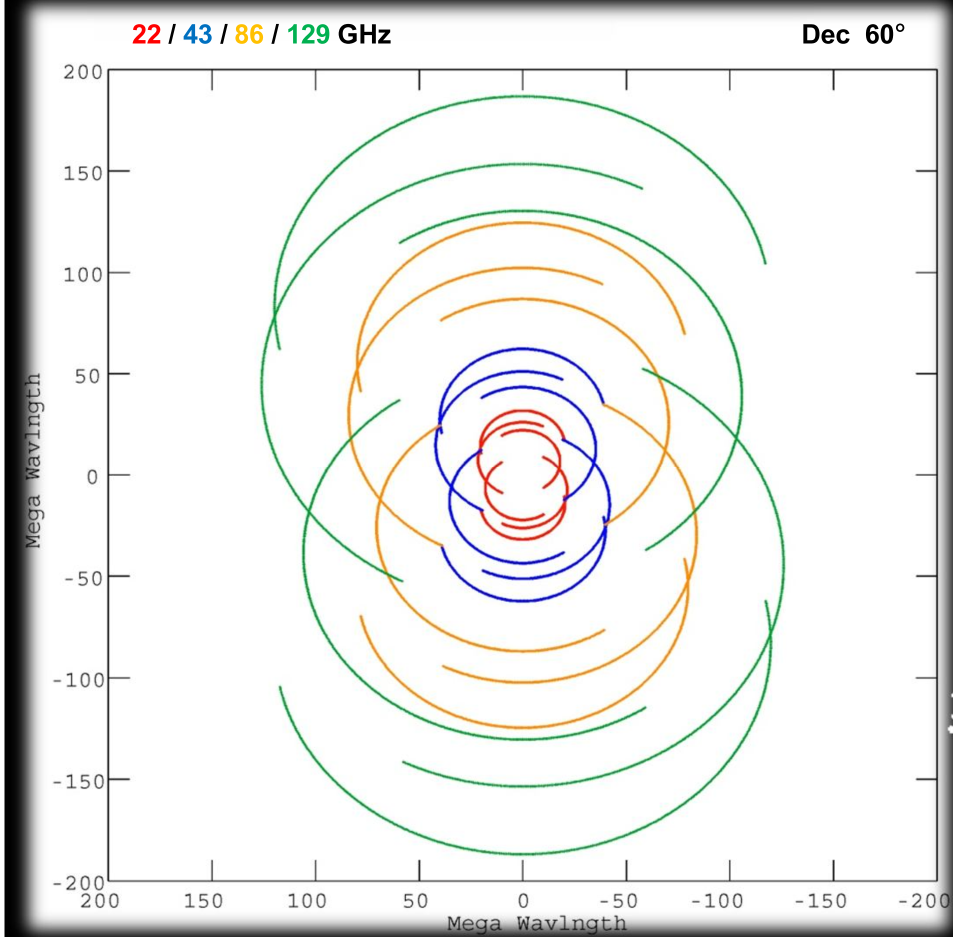




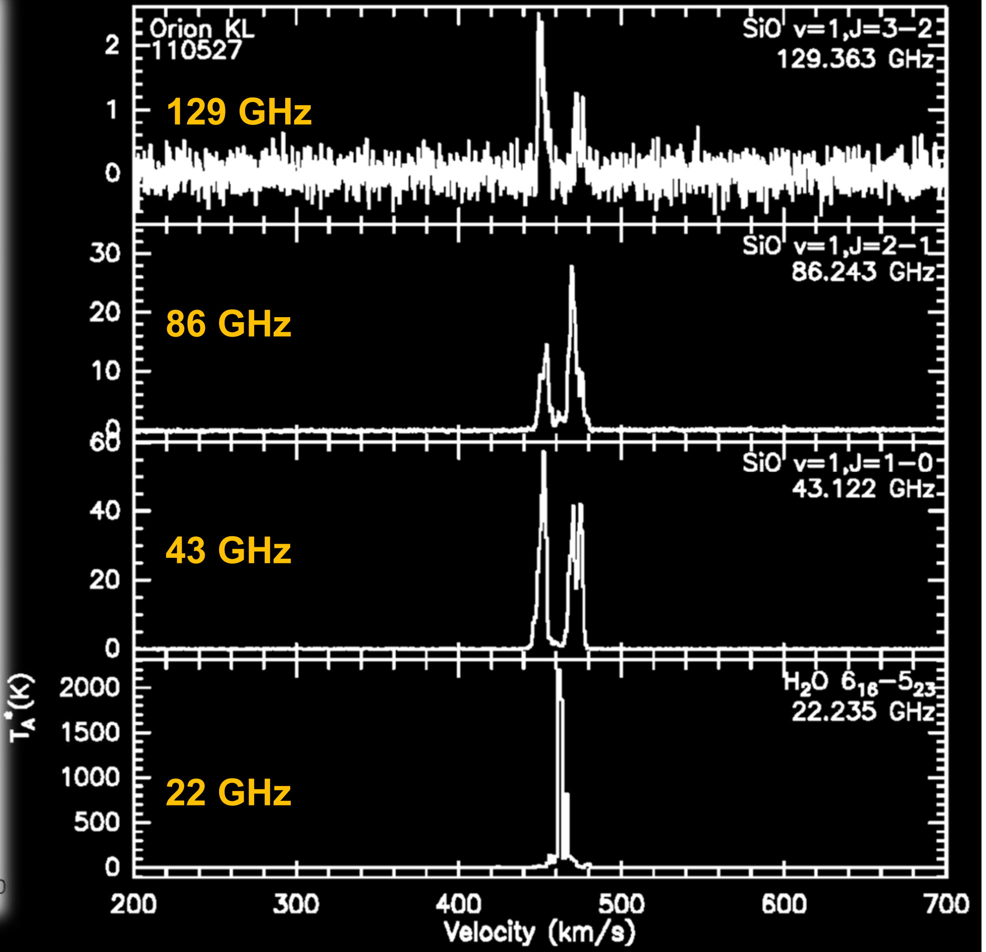
Band	K	Q	W	D
Freq. Range	21.25-23.25	42.11-44.11	85-95	125-142
Trx (K)	30-40	70-80 (40-50 KUS)	80-100	50-80

Han et al. (2008)

First Light from 22/43/86/129 GHz Simultaneous Single Dish Observation

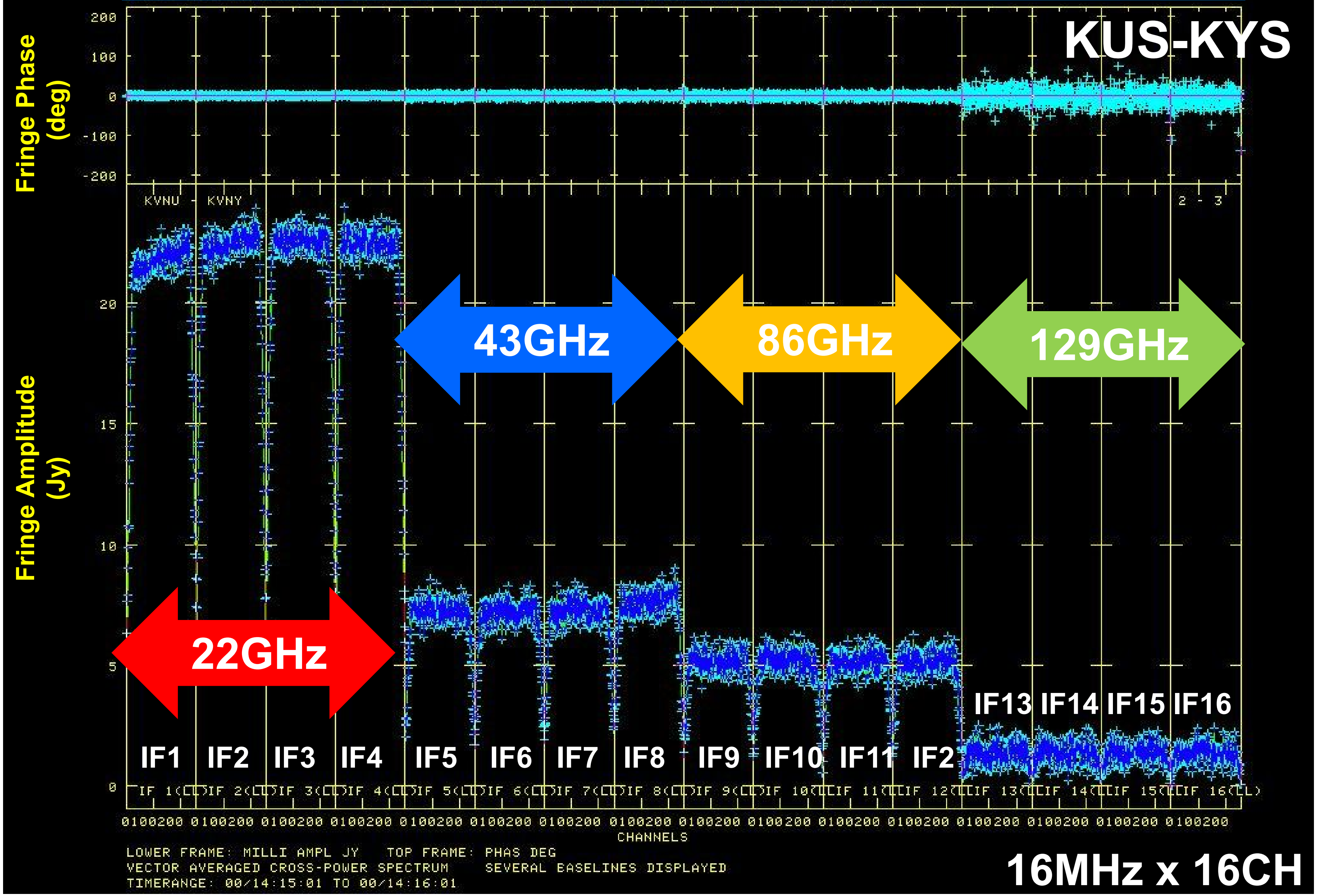


4CH UV Coverage

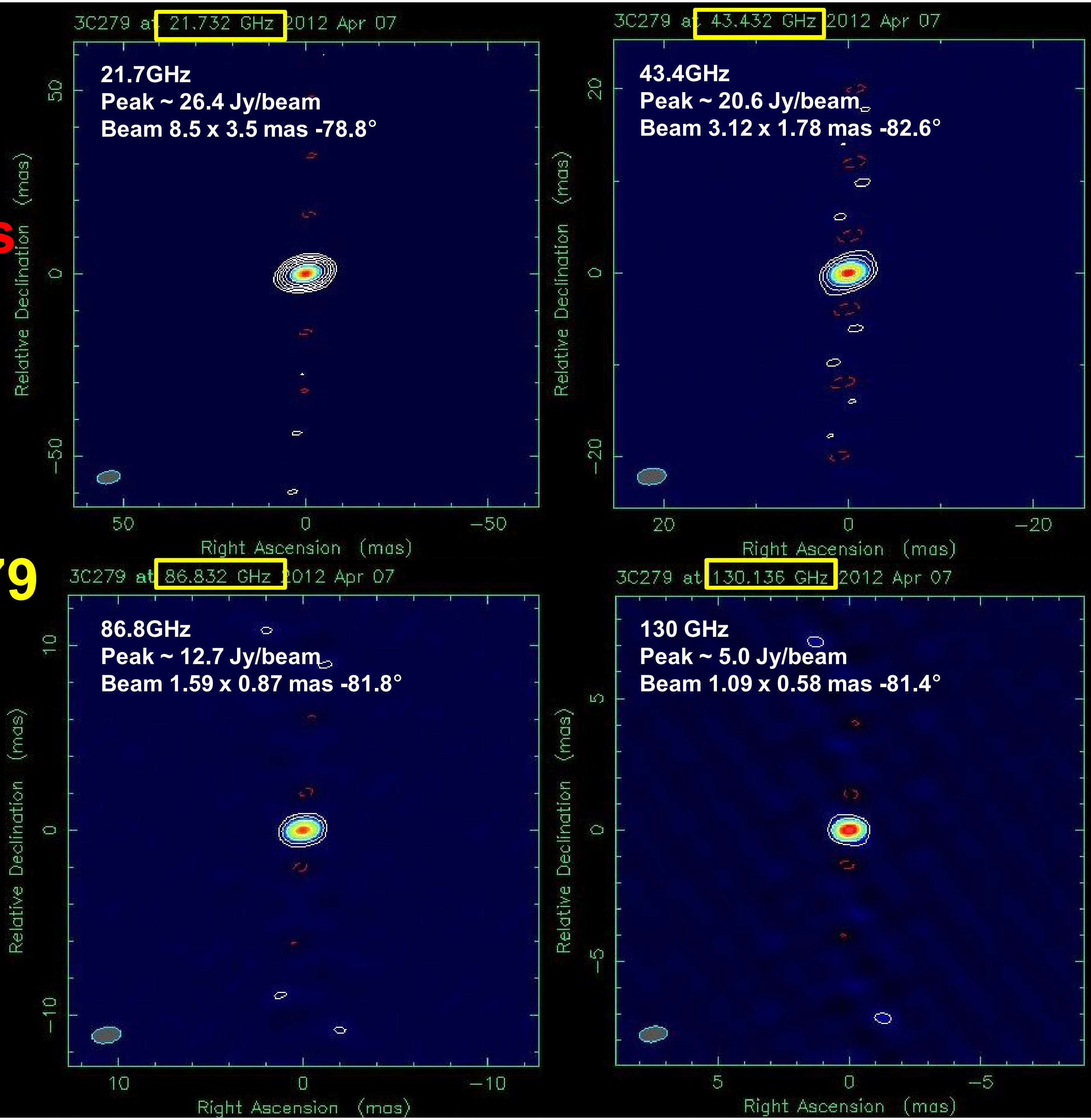


H20/SiO Masers in Orion KL

1st KVN VLBI 4-band Fringes (2012 April)



First KVN's 4-channel Simultaneous Observation VLBI Images



Source: 3C279

43/86/130GHz visibility phases are calibrated by 22Ghz

KVN Activities

High Precision Astrometry

GPS Installation - close collaboration with KASI GPS group

1. KVN antenna position

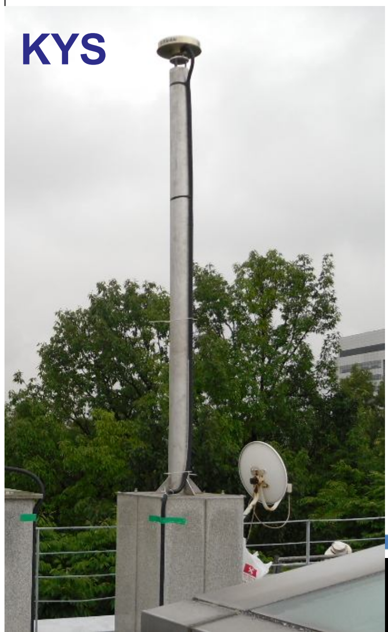
- displacement of KVN antenna position
- In-Variant Point (IVP) measurement

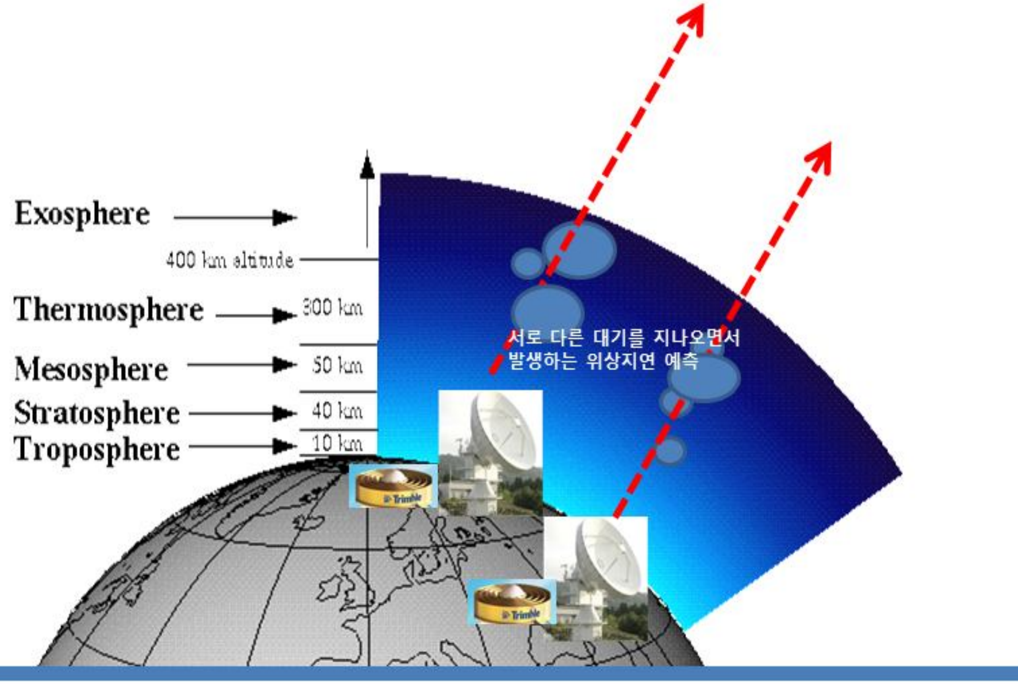
➔ To monitor accurate KVN antenna positions

2. Atmospheric model calculation

- Wet delay & TEC estimation

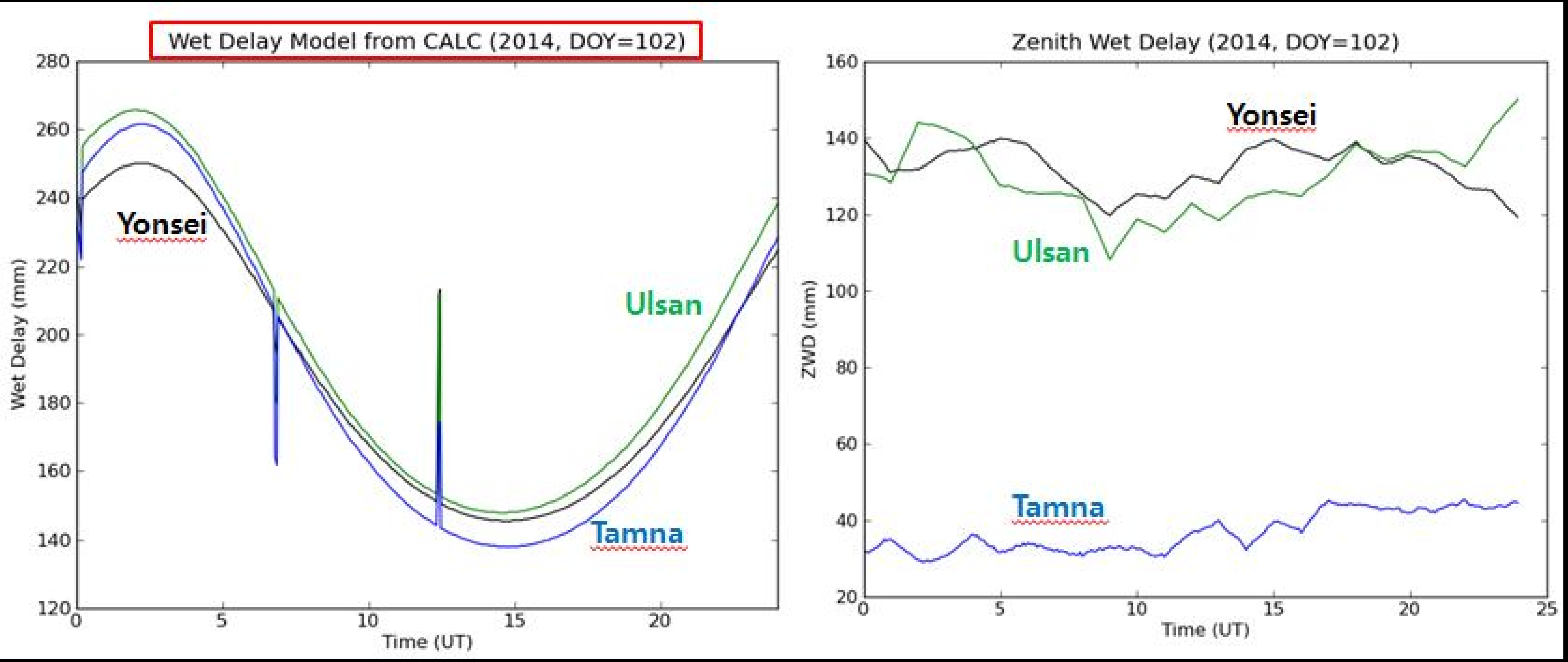
➔ To improve a phase referencing capability & astrometric accuracy





GPS applications towards better modeling of atmosphere

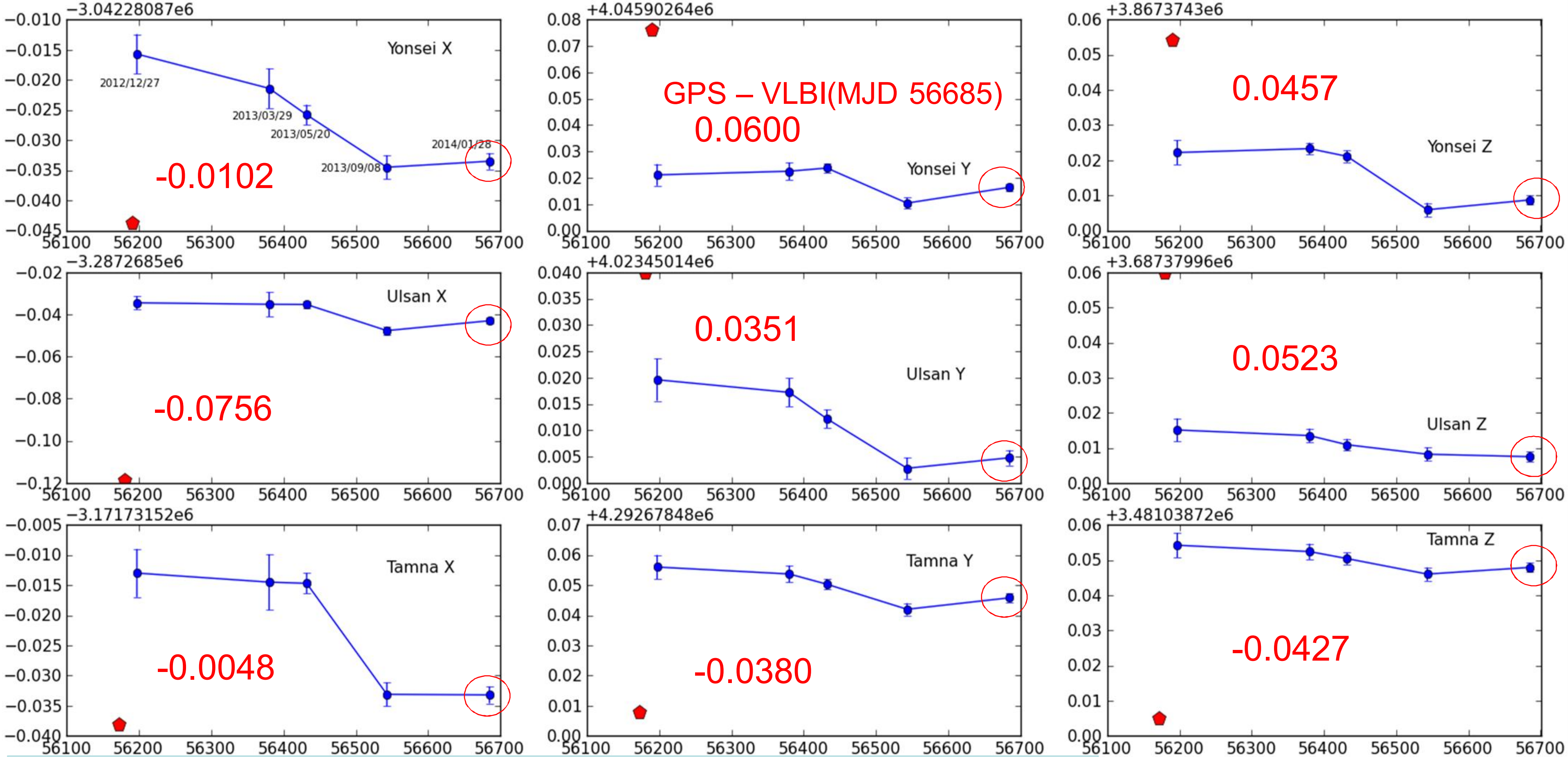
- ZTD were obtained from GPS at each KVN site
- GPS sampling period ~ 5 min
- Example: one PolarCap (1803+784), 24hr
- Correlation model of wet delay (line of sight)
  - model path = [ZWD(correlator model) + ΔZWD] / sin(elevation)
  - comparison: "true path (from GPS) – model path (from CALC)"



IVP measurements from K-band Geodesy

Observational Status

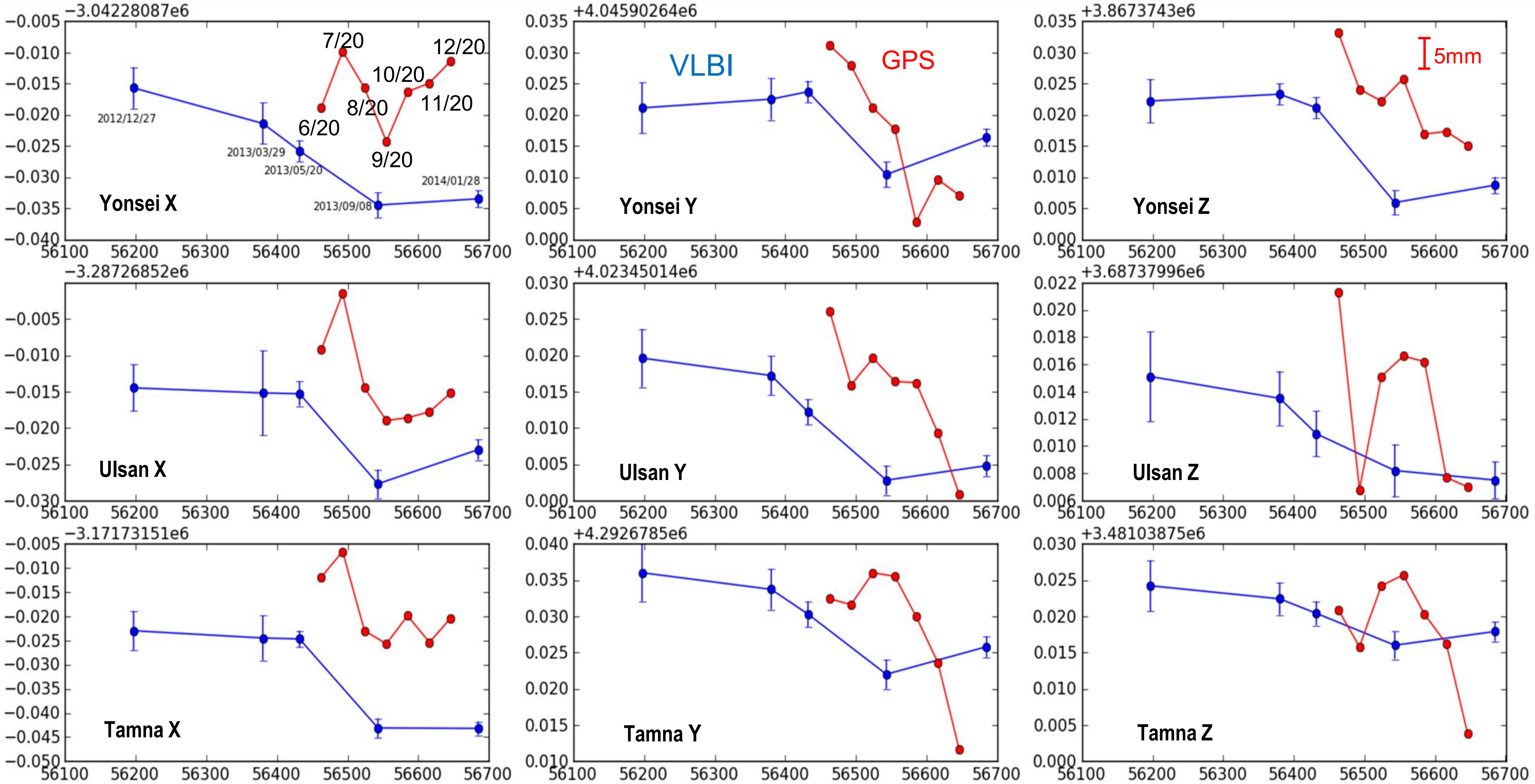
- 2011 : r11361k (2011/12/27) ** only KYS solution was obtained*
- 2012 : r12271k (2012/09/27) ** all solutions were obtained * waiting correlation & analysis*
- 2013 : r13088k (2013/03/29), r13140k (2013/05/20), r13251k (2013/09/08), r13313k (2013/11/09)
- 2014 : r14028k (2014/01/28), r14095k (2014/04/05), r14159k (2014/06/08), r14246k (2014/09/03)



Offsets: X: 0.5~7.5 cm, Y: 3.5~6.0 cm, Z: 4.3~5.2 cm

X-axis: MJD Y-axis: Position (m)

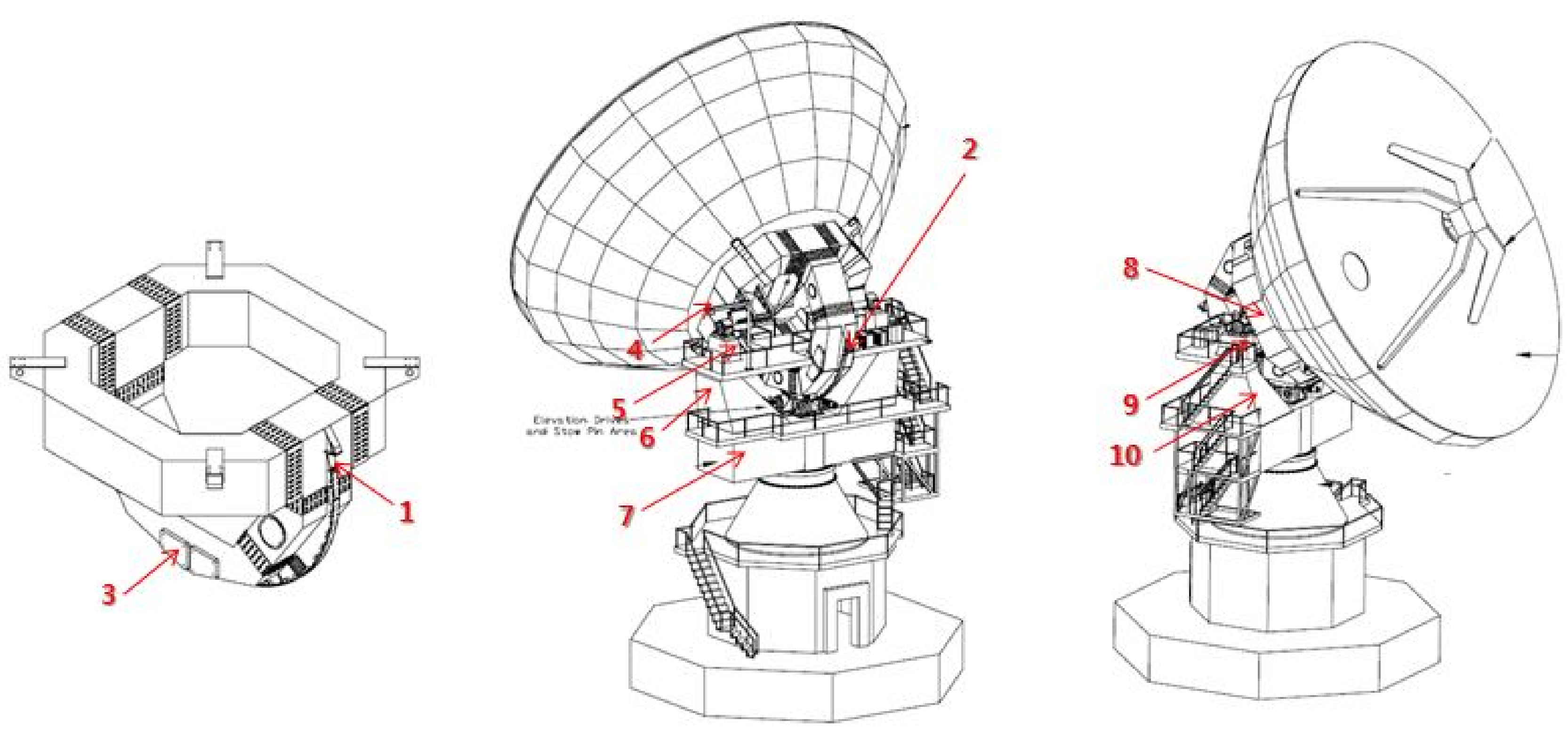
Monitoring of Time Variation of GPS & VLBI positions of KVN antennas



- There seems to have similar trend between GPS & VLBI positional variations, but not so tight! → more data is essential
  - Daily GPS measurements with error bars are necessary
  - Rough estimation of GPS measurement errors: ~3mm in X & Y, ~5mm in Z axis

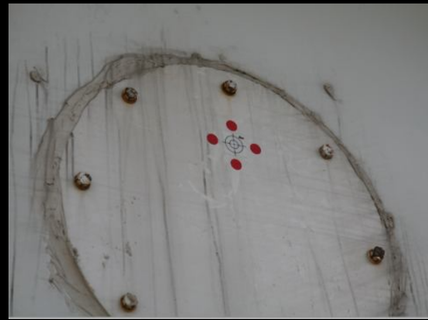
Feasibility Test of KVN Antenna Reference Position (IVP) Target & Optical Survey Matrix

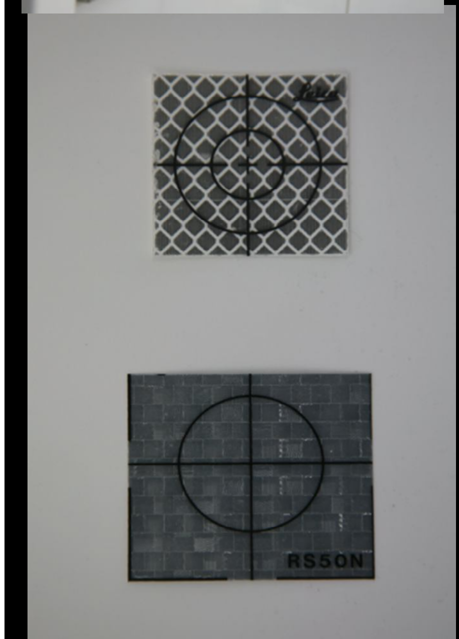
1. Define Pillar Position
2. Target Installation
3. Optical Survey
4. Analysis (GPS & Optical Tie)



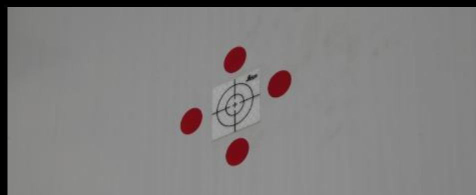
Antenna Position ID	1	2	3	4	5	6
AZ (deg)	0	60	120	180	240	300
EL (deg)	0	35	47	60	75	85

IVP measurements of KVN Tamna (2014 Sep 29-30)





Targets for optical survey



IVP measurements of KVN Tamna (2014 Sep 29-30)

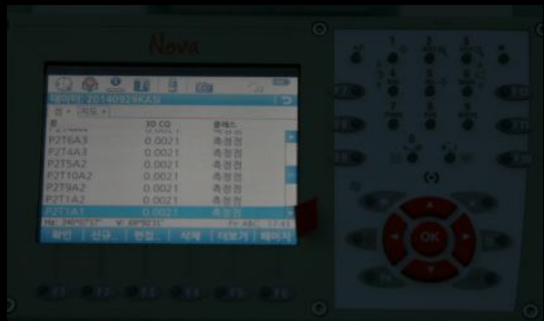






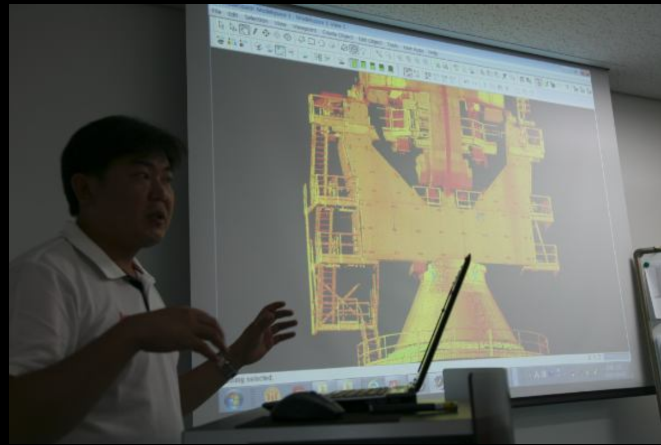


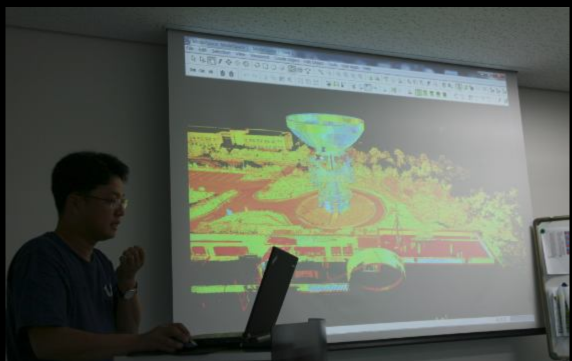




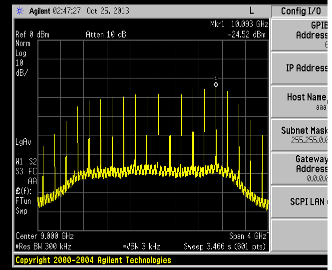

IVP Measurements Discussions

Leica Instruments

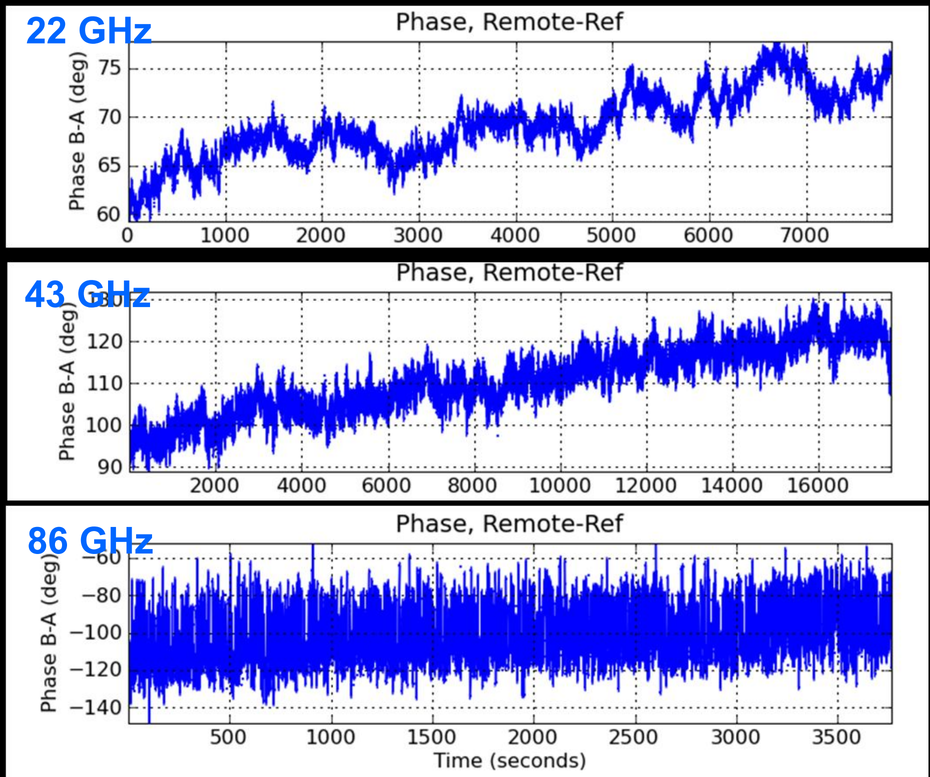


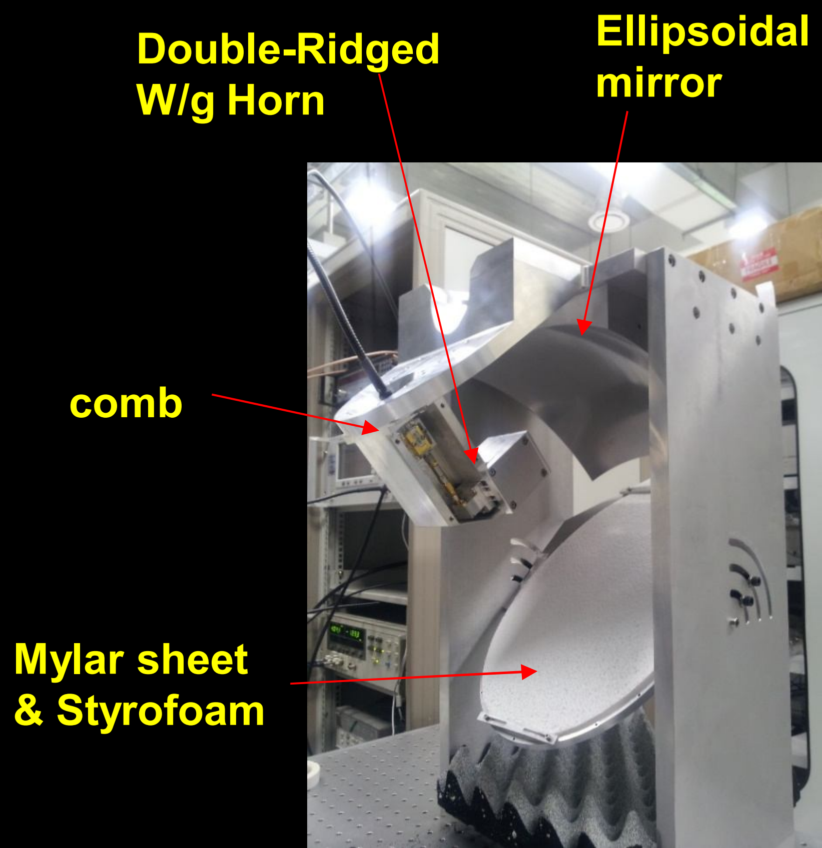


Developments of Phase Tone Calibration System



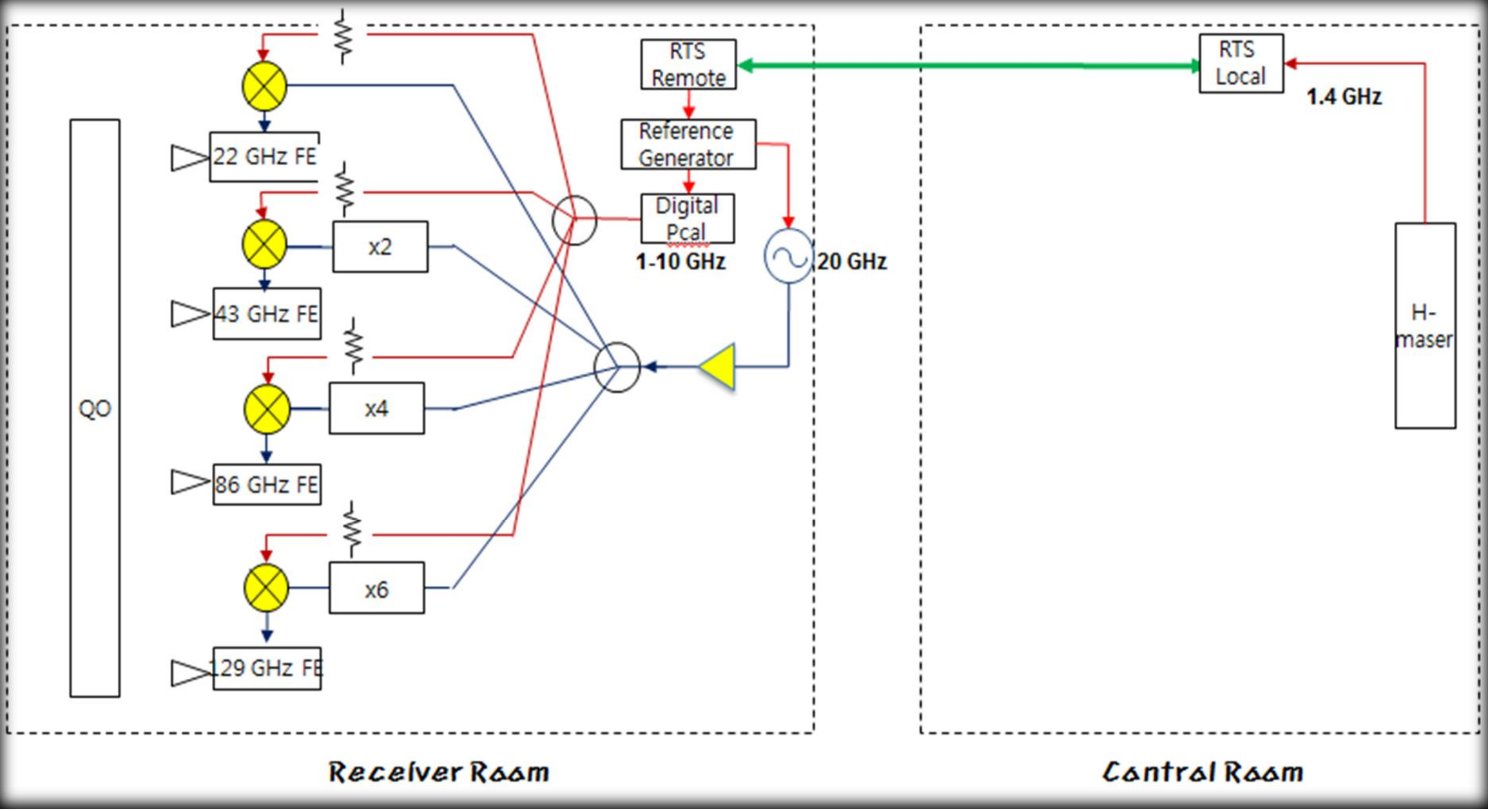
- **1st approach: Quasi-optics Injection Method**
  - Reference signal frequency : 200 MHz
  - Comb generator : commercial NLTL(2.4mm connector, spec: <50 GHz)
  - Quasi-optics injection using DRWH, ellipsoidal mirror & Mylar sheet
  - Custom designed comb needed for 129 GHz-band power generation
  - Equalization problem have to be solved





Developments of Phase Tone Calibration System

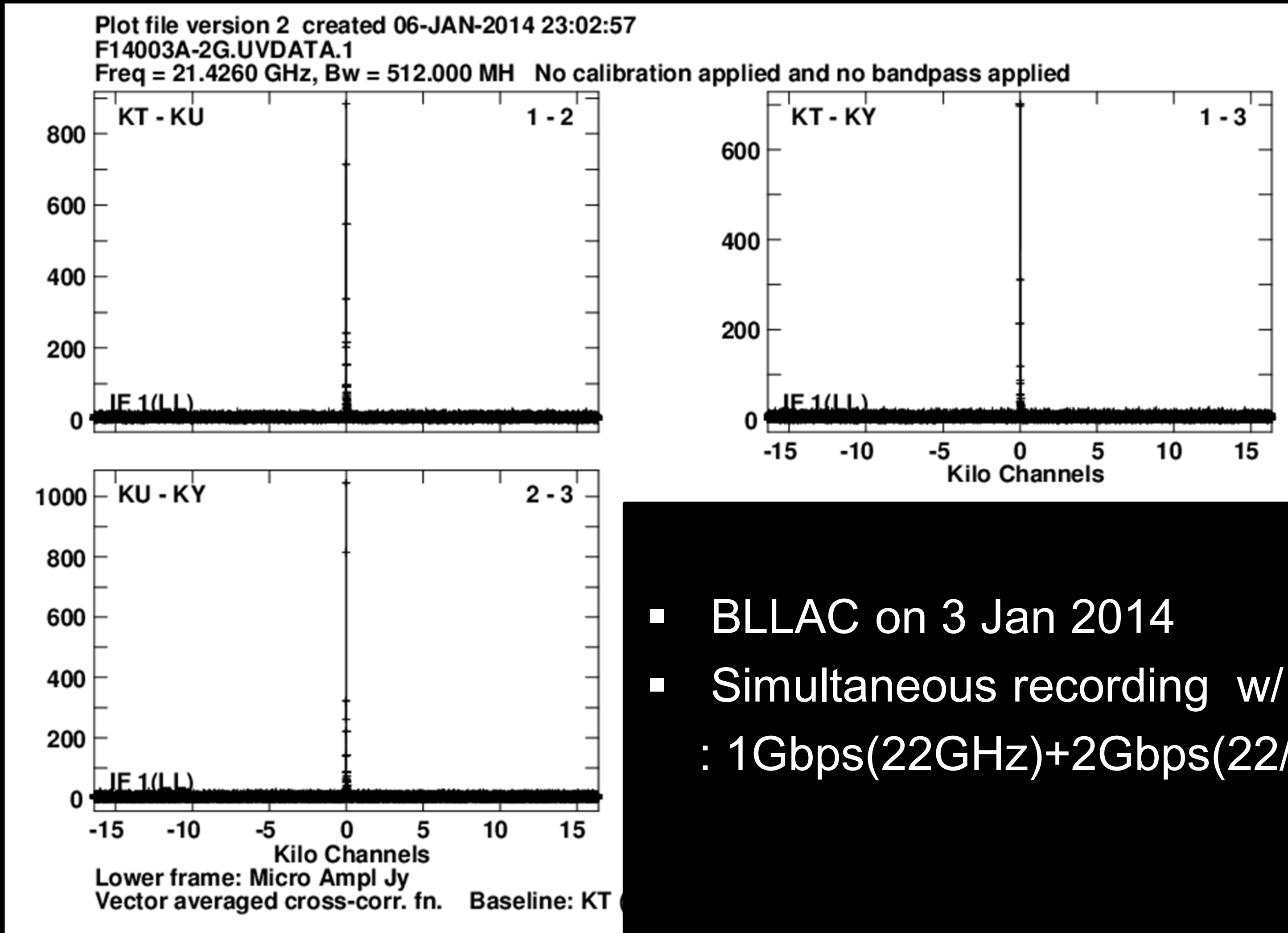
- 2nd approach: Digital P-cal Method
  - Transmission Line injection thru coupling ports using Low-frequency Phase calibrator, PDRO, and multipliers
  - Expected to be no big problem comparing to quasi-optics injection method
  - No component development needed
  - Quasi-optics components are not calibrated.



KVN Activities

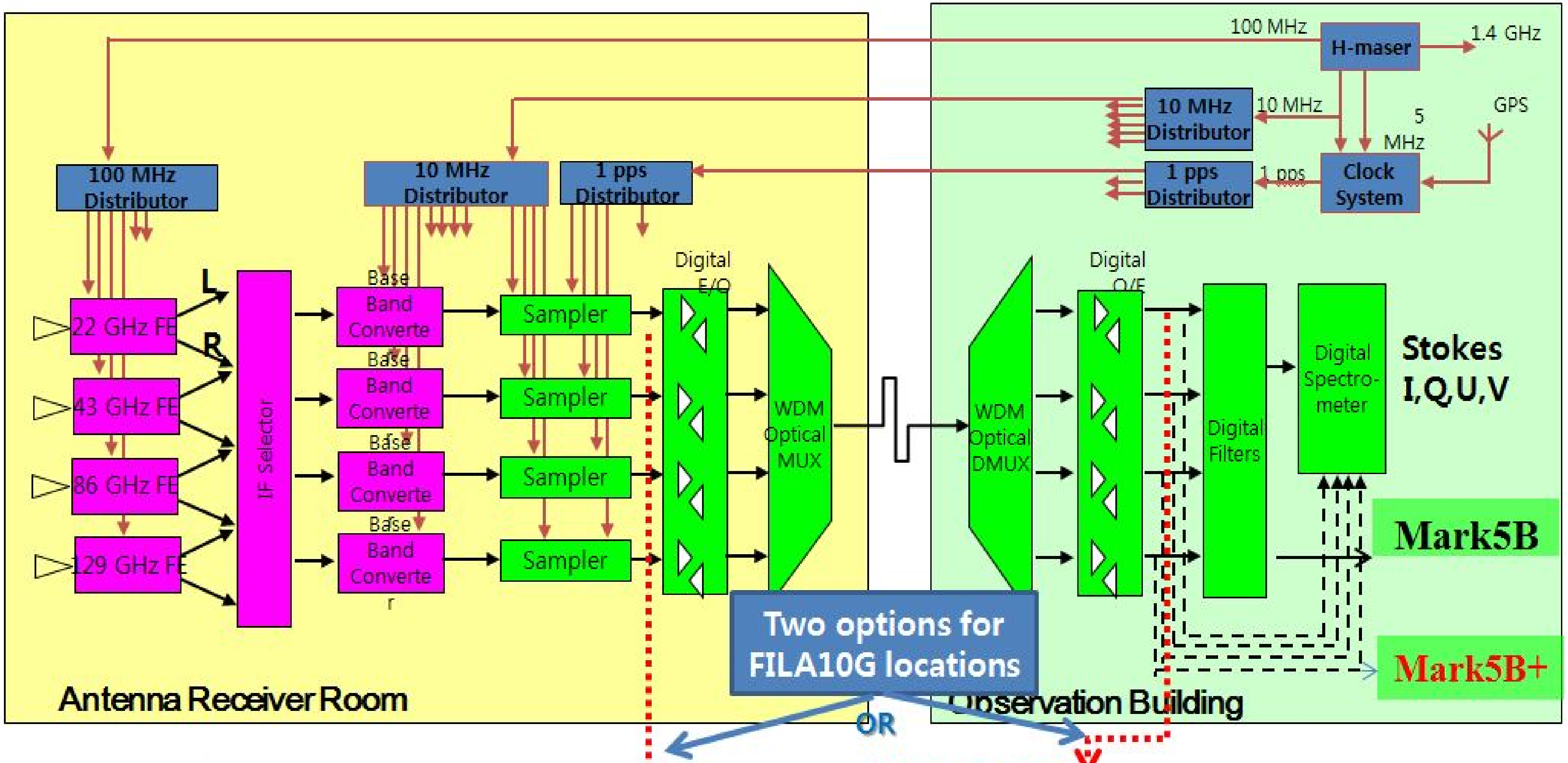
High Sensitivity

2Gbps (512MHz BW) using Mark5B+



- BLLAC on 3 Jan 2014
- Simultaneous recording w/ Mark5B+ & 5B
  : 1Gbps(22GHz)+2Gbps(22/43/86/129GHz)

KVN 8Gbps Operations with FILA10G & Mark6



- current

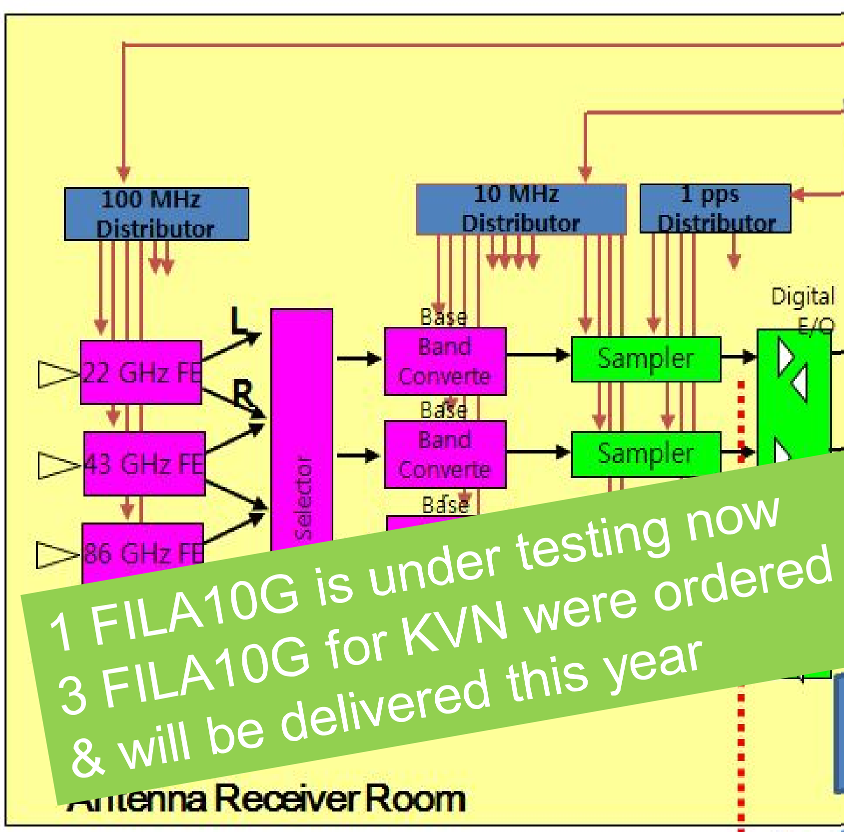
Mark5B : 1Gbps (BW = 256MHz)

Mark5B+ : 2Gbps (BW = 512MHz)

- with FILA 10G + Mark6

Mark6 : 8Gbps (BW = 4 x 512MHz) : 2Gbps per each 22/43/86/129 GHz

KVN 8Gbps Operations with FILA10G & Mark6



1 FILA10G is under testing now
3 FILA10G for KVN were ordered
& will be delivered this year

- current

Mark5B : 1Gbps (BW = 256MHz)

Mark5B+ : 2Gbps (BW = 512MHz)

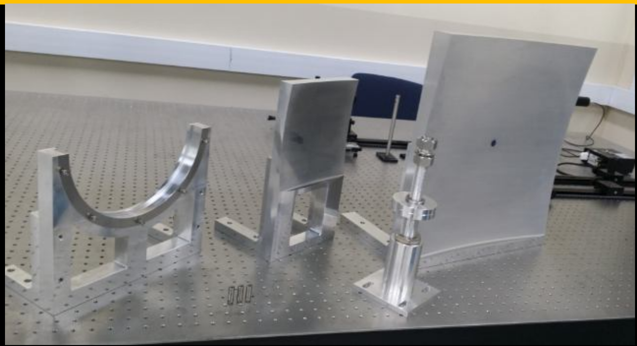
- with FILA 10G + Mark6

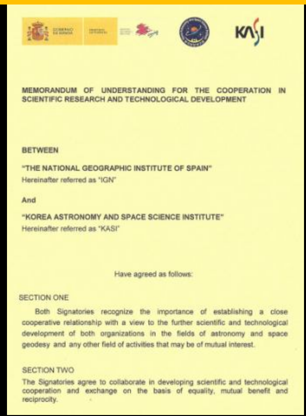
Mark6 : 8Gbps (BW = 4 x 512MHz) : 2C ... per each 22/43/86/129 GHz

KVN Activities

International Collaborations

Quasi-Optics as a Powerful Tool of mm-VLBI
Collaboration with Yebes 40m & VERA Mizusawa





MEMORANDUM OF UNDERSTANDING FOR THE COOPERATION IN SCIENTIFIC RESEARCH AND TECHNOLOGICAL DEVELOPMENT

BETWEEN

"THE NATIONAL GEOGRAPHIC INSTITUTE OF SPAIN"
Hereinafter referred as "IGN"

And

"KOREA ASTRONOMY AND SPACE SCIENCE INSTITUTE"
Hereinafter referred as "KASI"

Have agreed as follows:

SECTION ONE

Both Signatories recognize the importance of establishing a close cooperative relationship with a view to the further scientific and technological development of both organizations in the fields of astronomy and space geodesy and any other field of activities that may be of mutual interest.

SECTION TWO

The Signatories agree to collaborate in developing scientific and technological cooperation and exchange on the basis of equality, mutual benefit and reciprocity.

History & Plans

- 2011 Nov. : K/Q/W QO discussion
- 2014 Jan-Aug : QO design
- 2014 Jun : KASI-IGN MOU
- 2014 Sep : Manufacture
- 2014 Oct : Shipping to Yebes
- 2014 Nov : Installation & Initial Test
- 2015 Jan : K/Q band fringe test

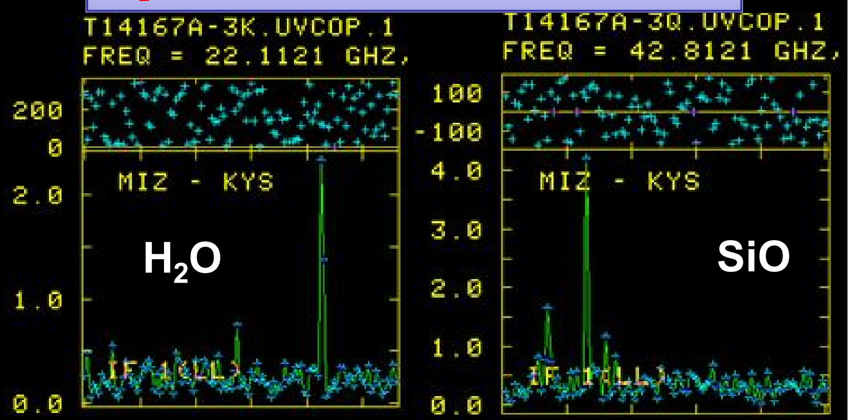
History & Plans

- 2013 Nov : Manufacture
- 2013 Dec. : Shipping & Installation
- 2014 Jun : K/Q VLBI fringe test
- 2014 Sep : Fringe Detection
- 2014 Dec : Science verification test

Success on QO test outside of KVN

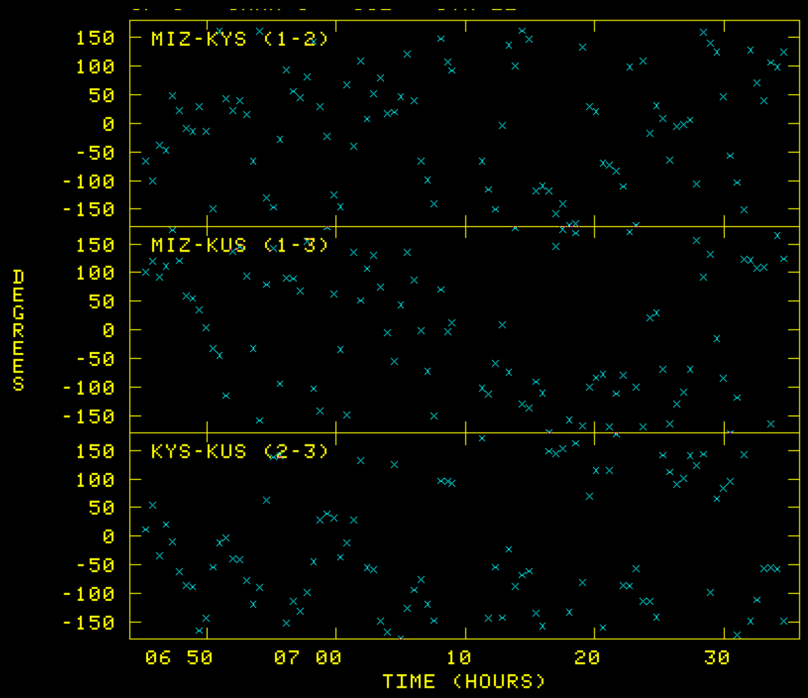
K/Q simultaneous fringes of OJ287

H_20/SiO Simultaneous fringes of ORION-KL

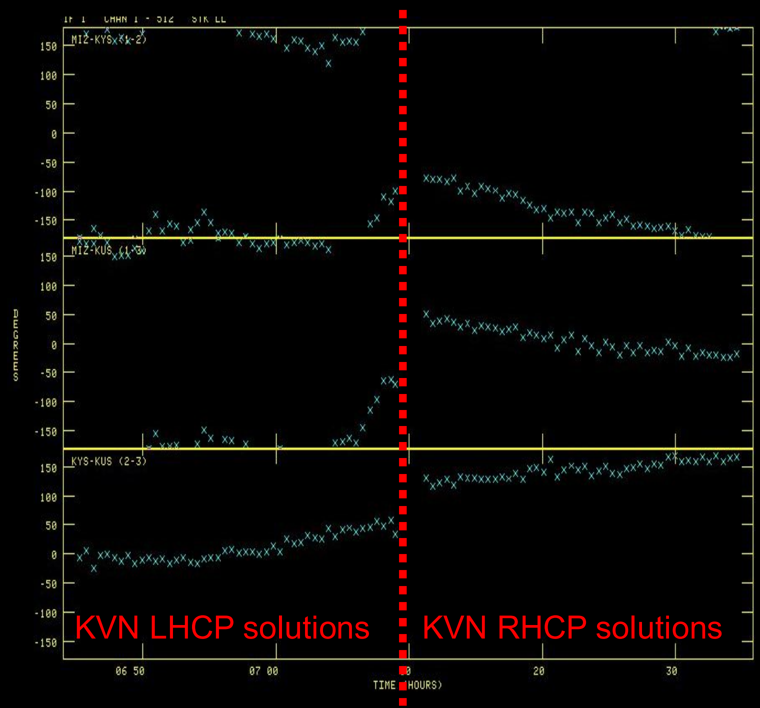


Phase Correction with QO systems (K→Q, OJ287)

Q-band Visibility Phase
No calibration applied



Q-band Visibility Phase
Calibrated by K-band Phase Solutions



- K-band fringe phase solutions of OJ287 were applied to calibrate Q-band data
- Visibility phase of Q-band calibrated by K-band shows more stable phase than raw data although there are high phase rates at MIZ related baselines
  ➔ The feasibility of K/Q simultaneous observing system has been demonstrated !!

- Science demonstration will be made on be half of KaVA science sub-working group

Multi-Frequency VLBI Applications

The BEST way to overcome atmospheric barriers

- Weak source detection
- Astrometry (AGN core-shift)

Multi-Frequency Phase Referencing (MFPR)

$$\Phi^h = \Phi^h{}_{str} + 2\pi\nu^h(\tau_g + \tau_C + \tau_{inst} + \tau_{trop} + \tau_{ion}) + \Phi^h{}_{LO}$$

$$\Phi^l = \Phi^l{}_{str} + 2\pi\nu^l(\tau_g + \tau_C + \tau_{inst} + \tau_{trop} + \tau_{ion}) + \Phi^l{}_{LO}$$

Self-calibration at lower frequency

$$\Phi^l{}_{str} \qquad 2\pi\nu^l(\tau_g + \tau_C + \tau_{inst} + \tau_{trop} + \tau_{ion}) + \Phi^l{}_{LO}$$

$$\Delta\Phi = \Phi^h - r\Phi^l \qquad r = \nu_h / \nu_l$$

slow varying term

$$\Delta\Phi = \Phi_h - \frac{\nu_h}{\nu_l}\Phi_l = \Phi_h{}^{str} + 2\pi\nu_h(\tau_h{}^g - \tau^g{}_l) - 2\pi\left(1 - \frac{\nu_h^2}{\nu_l^2}\right)\frac{\nu_0^2}{\nu_h^2}\tau^{ion} + (\Phi_h{}^{LO} - \frac{\nu_h}{\nu_l}\Phi_l{}^{LO})$$

Source Structure

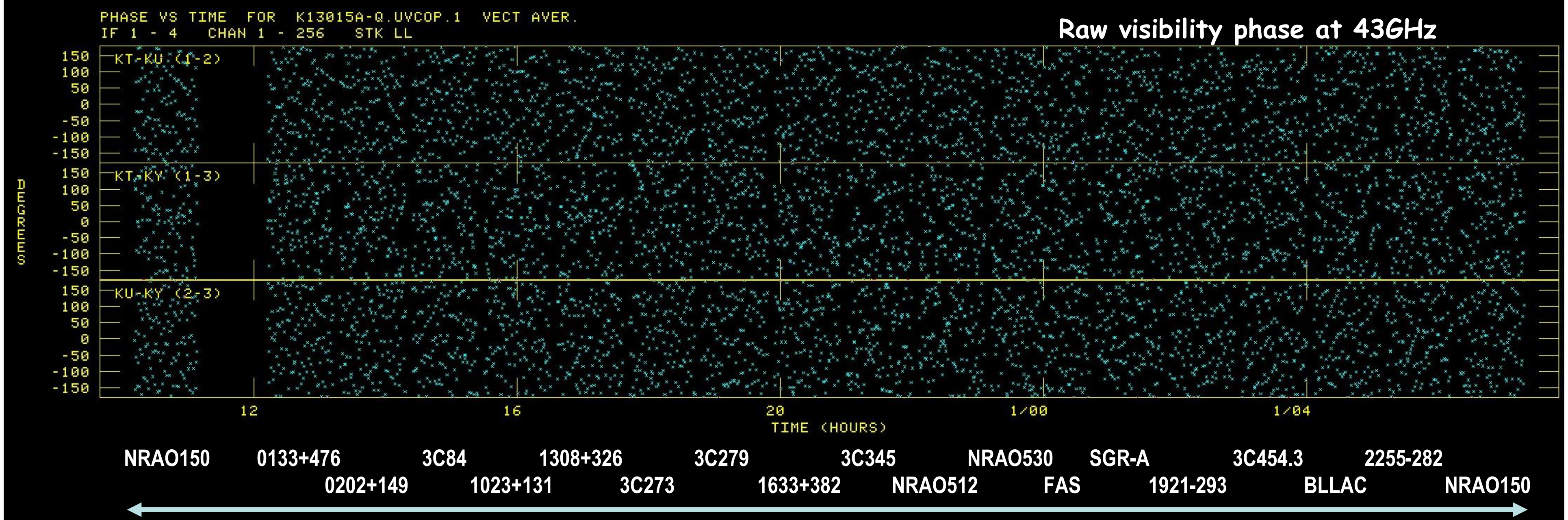
Core-shift diff in maser lines

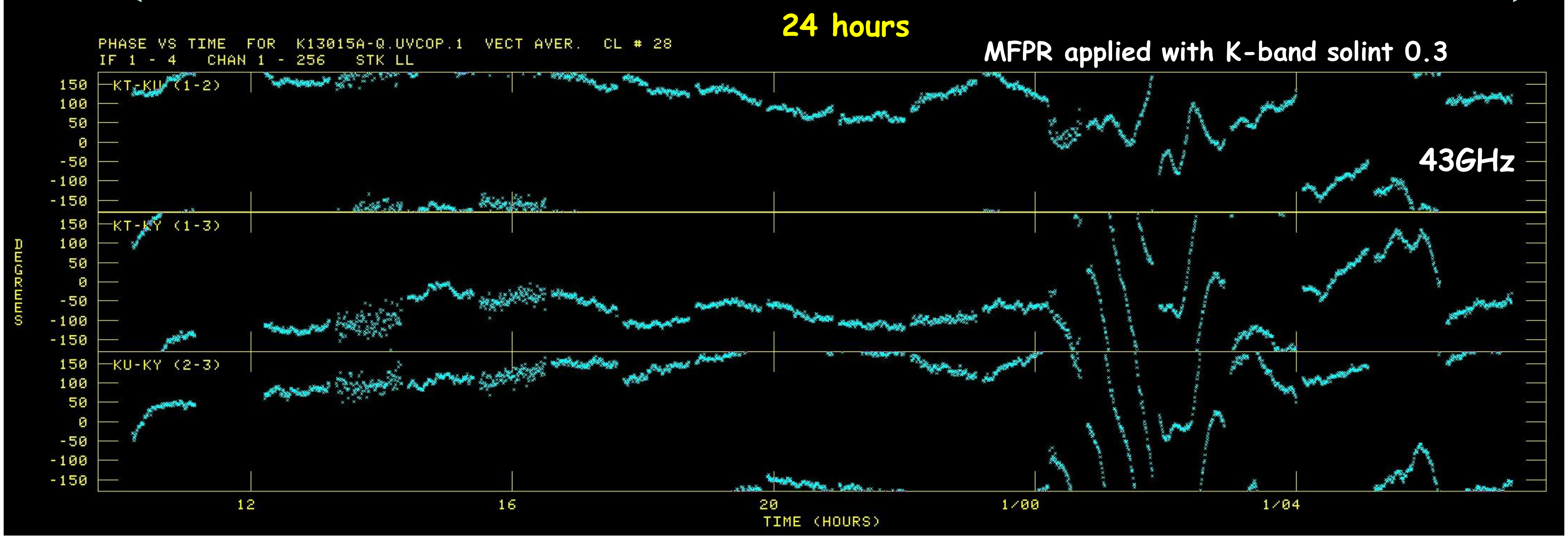
ionosphere

instrument

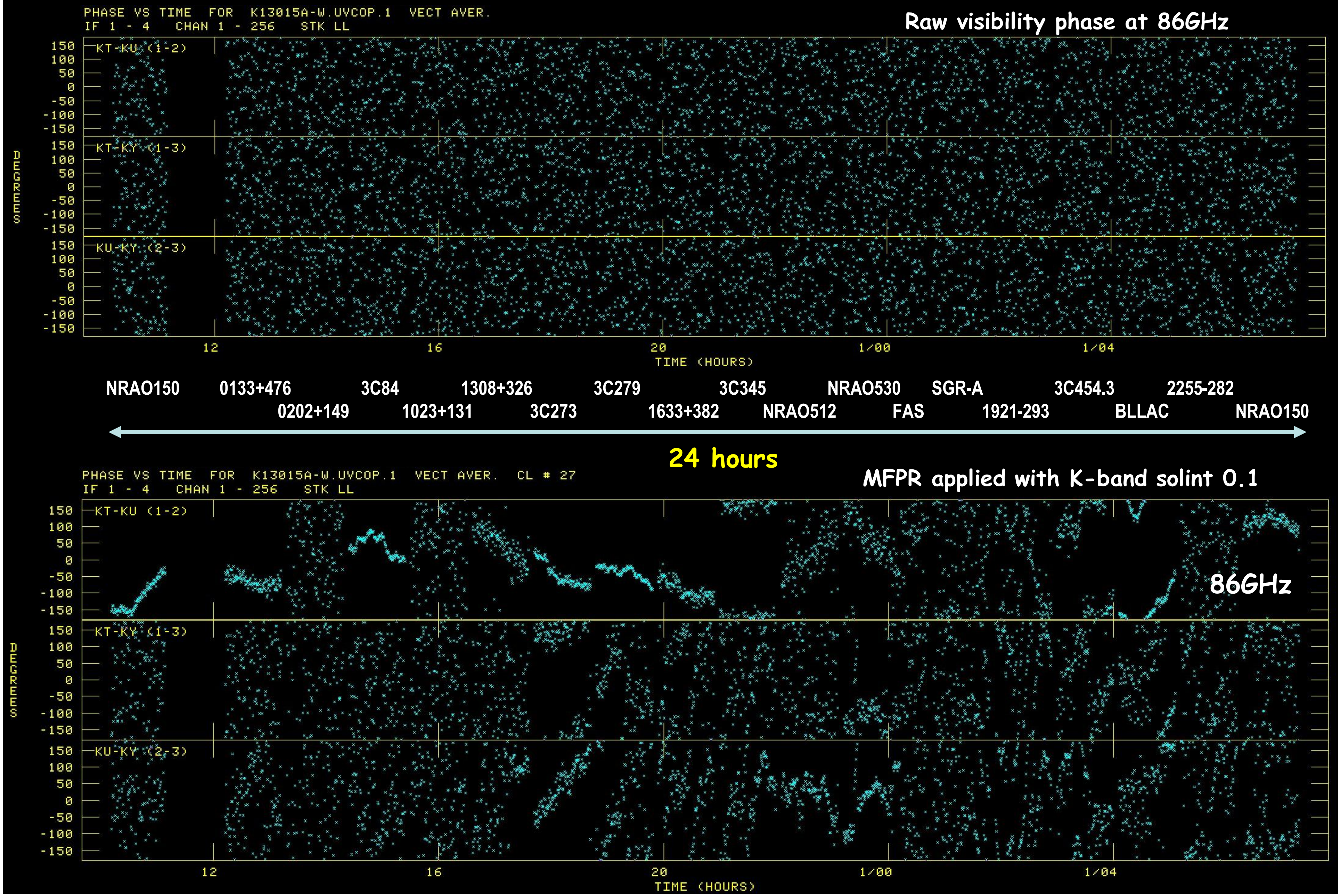
By doing Self-calibration again for longer solution interval, we can get an image at higher frequency

43GHz Visibility Phase referenced by 22GHz

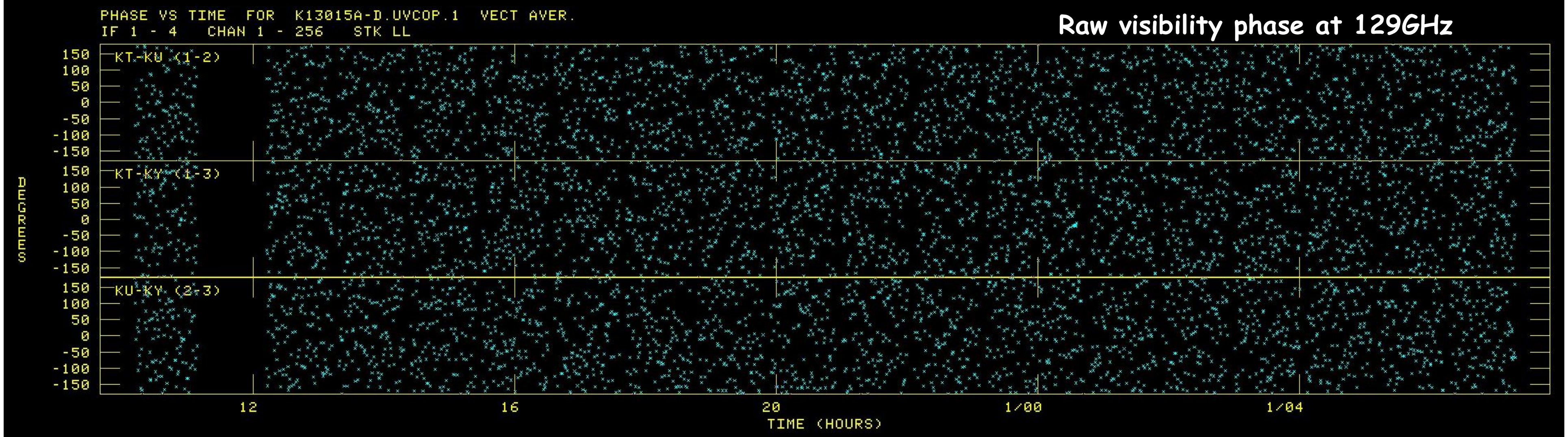




86GHz Visibility Phase referenced by 22GHz

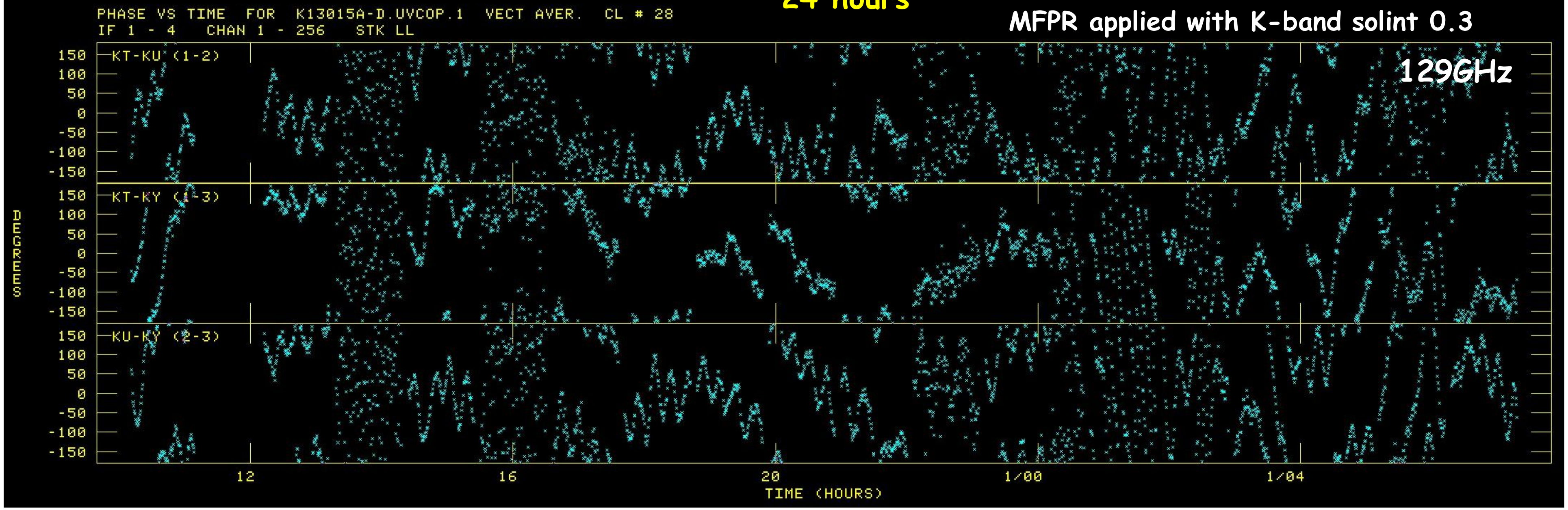


129GHz Visibility Phase referenced by 22GHz

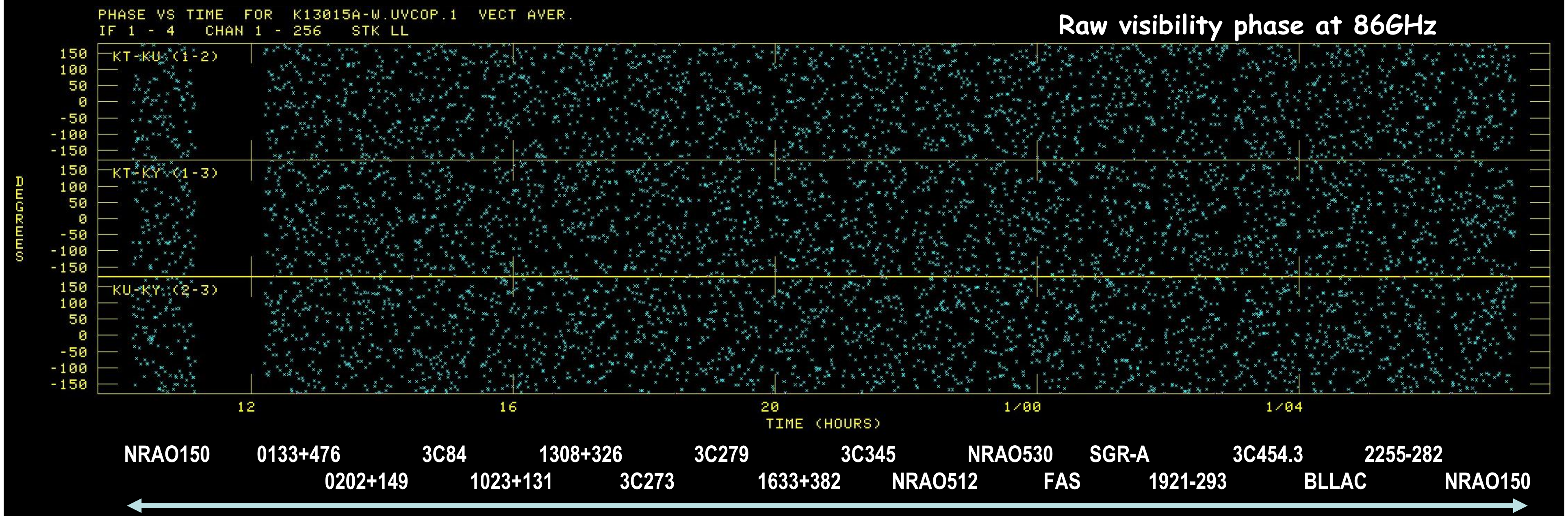


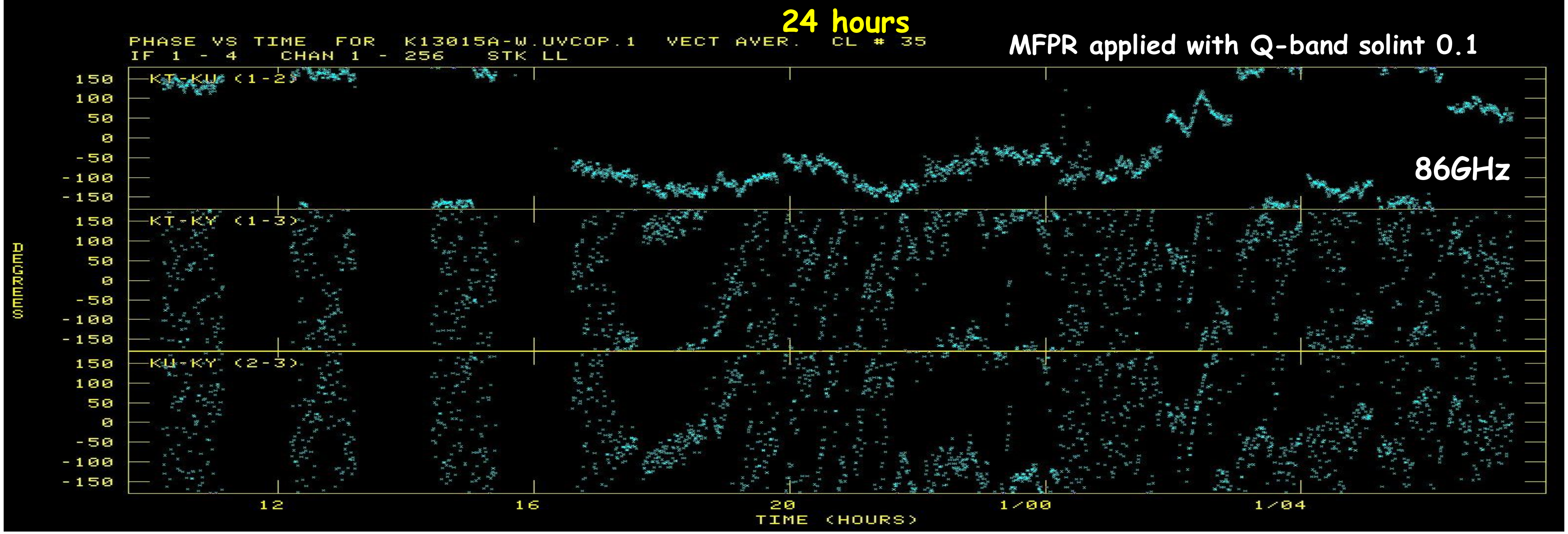
NRAO150 0133+476 0202+149 3C84 1023+131 1308+326 3C273 3C279 1633+382 3C345 NRAO512 NRAO530 FAS SGR-A 1921-293 3C454.3 BLLAC 2255-282 NRAO150

24 hours

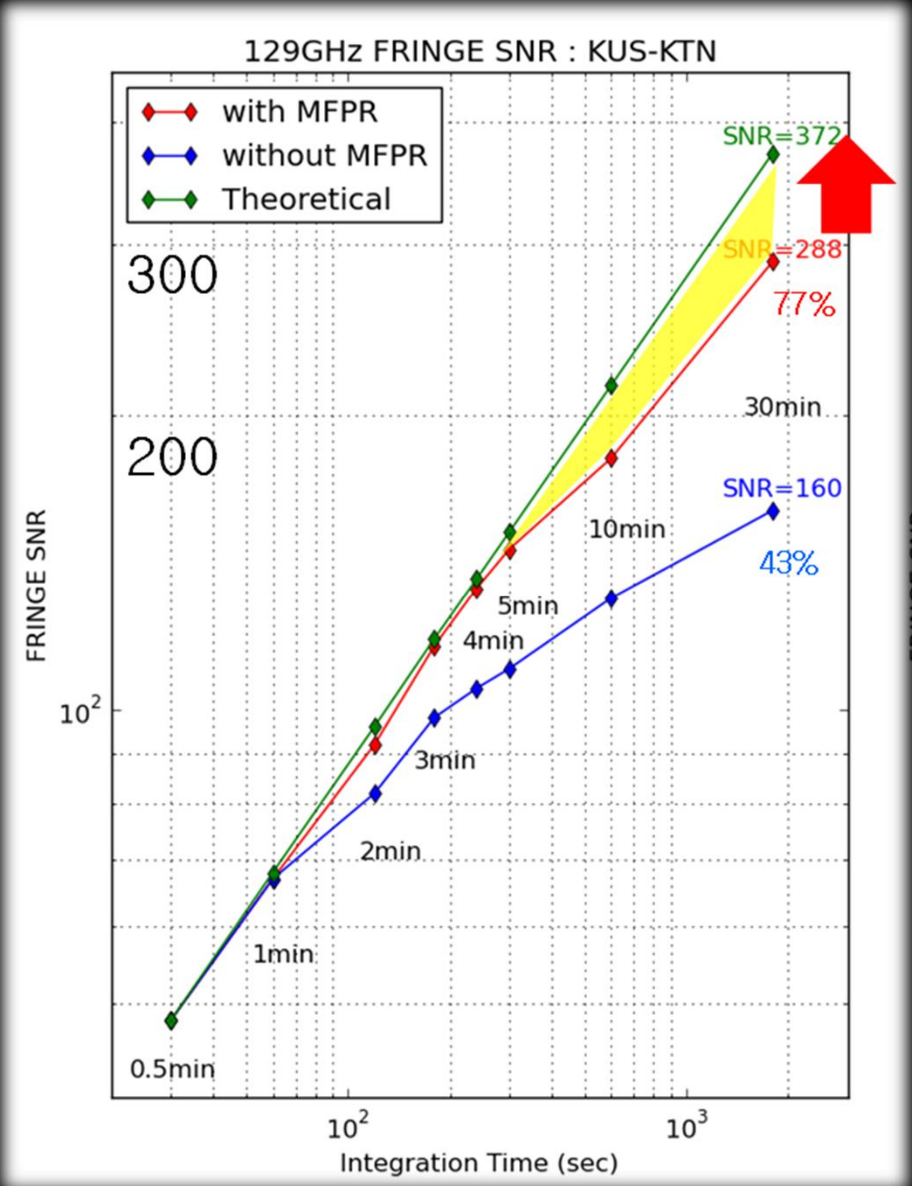


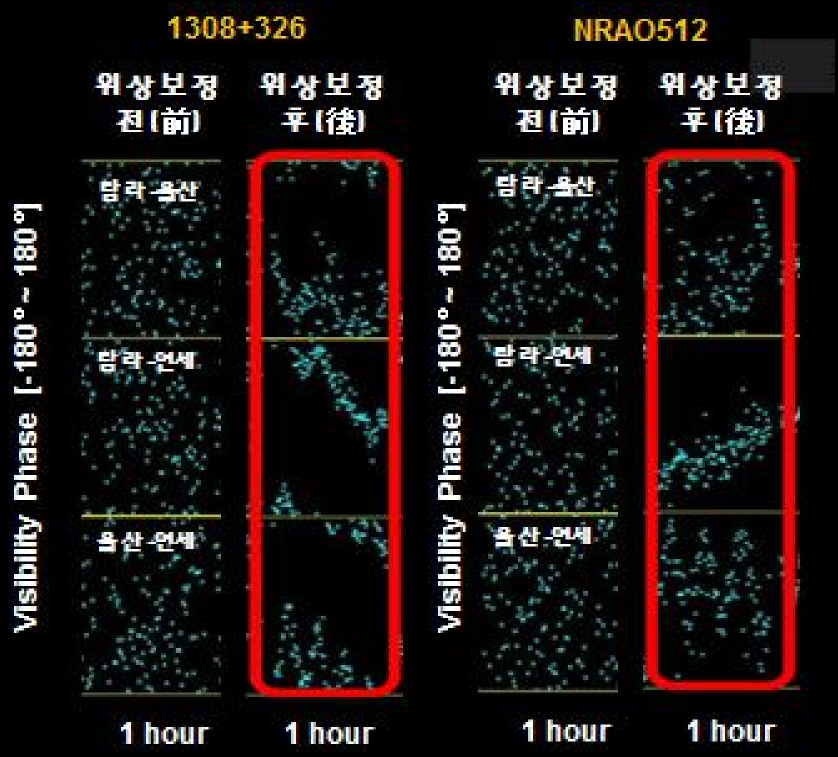
86GHz Visibility Phase referenced by 43GHz





Superiority of FPT





The First Detection of 1308+326 & NRAO512 at 129 GHz

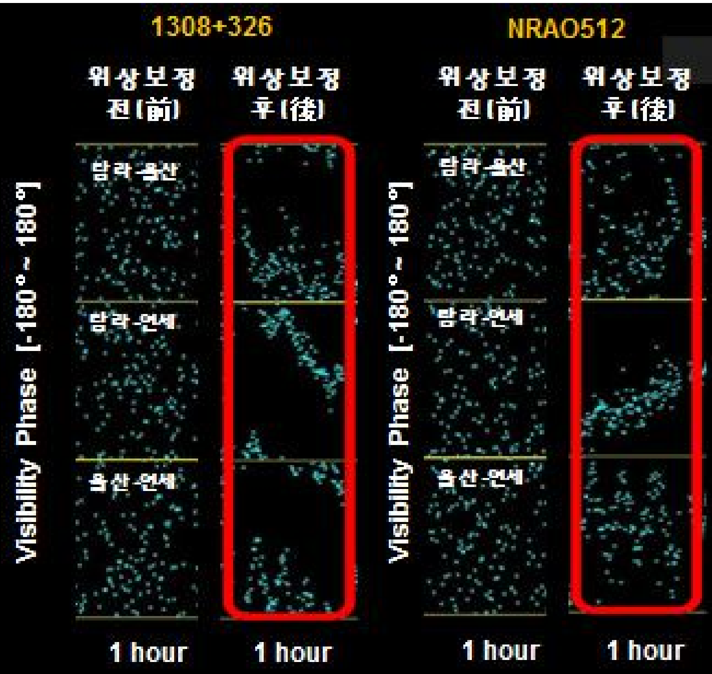
Source	1308+326	NRAO512
SNR	130	100
Flux (mJy/beam)	300~420	160~250

Other results will be followed soon!

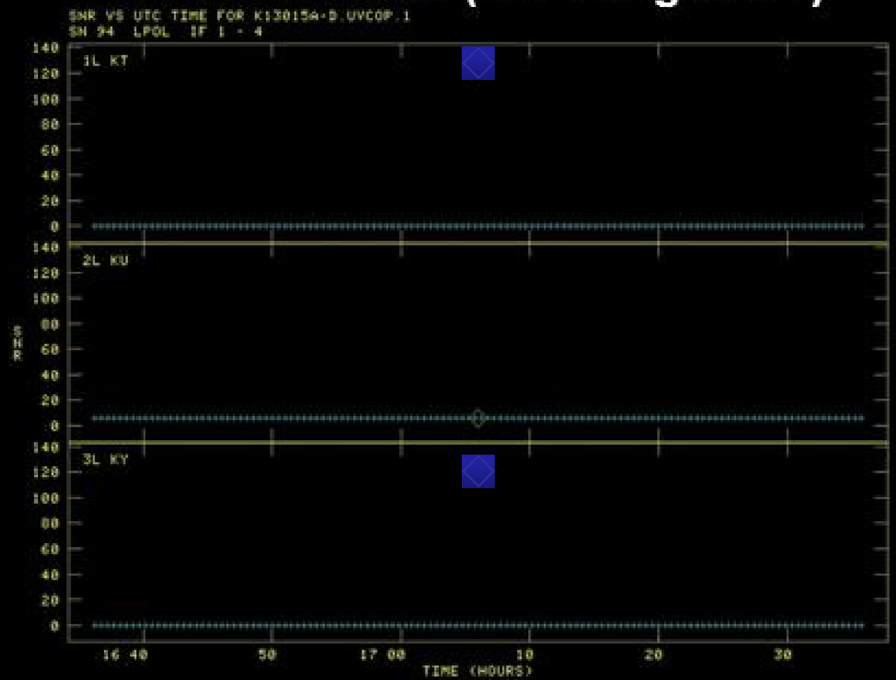
Source Detection at High Frequency by MFPR

- 1308+326 & NRAO512 were not detected at D-band
- After applying MFPR with1 hour integration, these sources are detected with high SNRs (~130, ~80)
  ➔ The FIRST detection of 1308+326 & NRAO512 at 129GHz

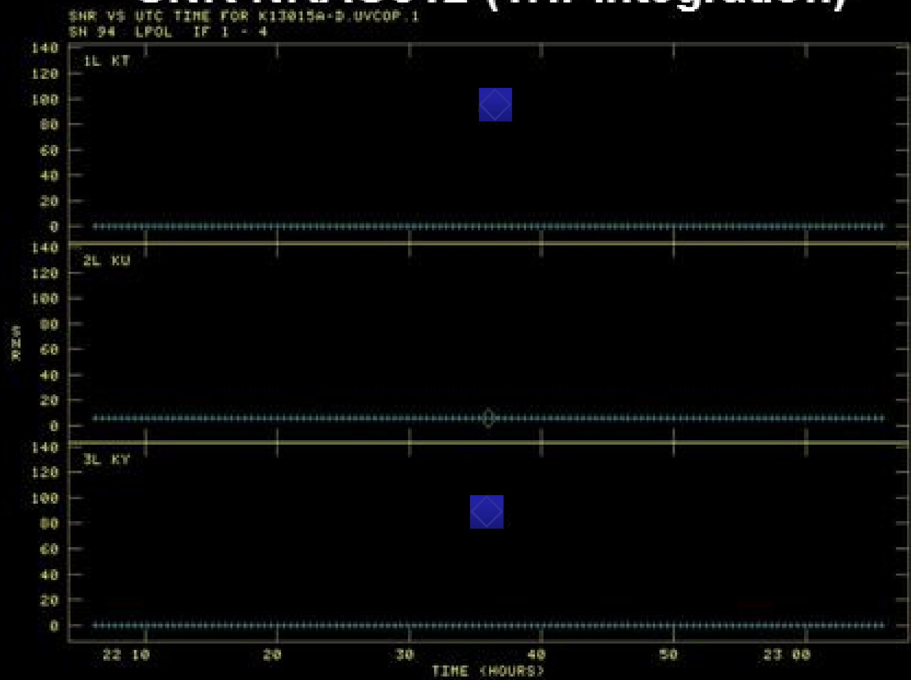
- SNR : 1308+326 ~ 130, NRAO512 ~ 100
- Flux : 1308+326 : 300~420 mJy
  NRAO512 : 160~250 mJy



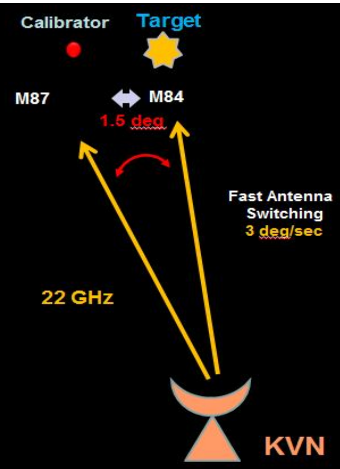
SNR 1308+326 (1Hr integration)

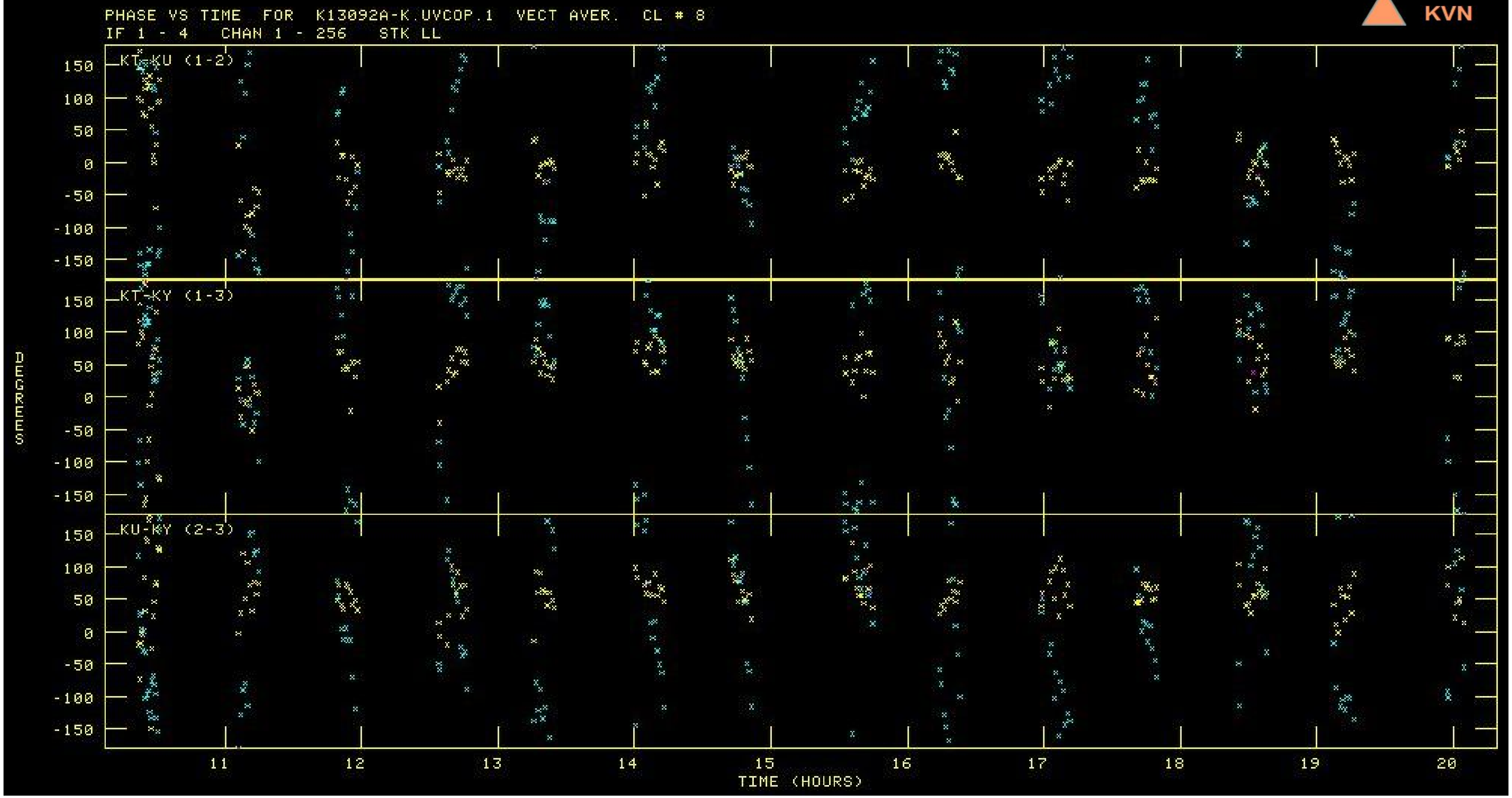


SNR NRAO512 (1Hr integration)

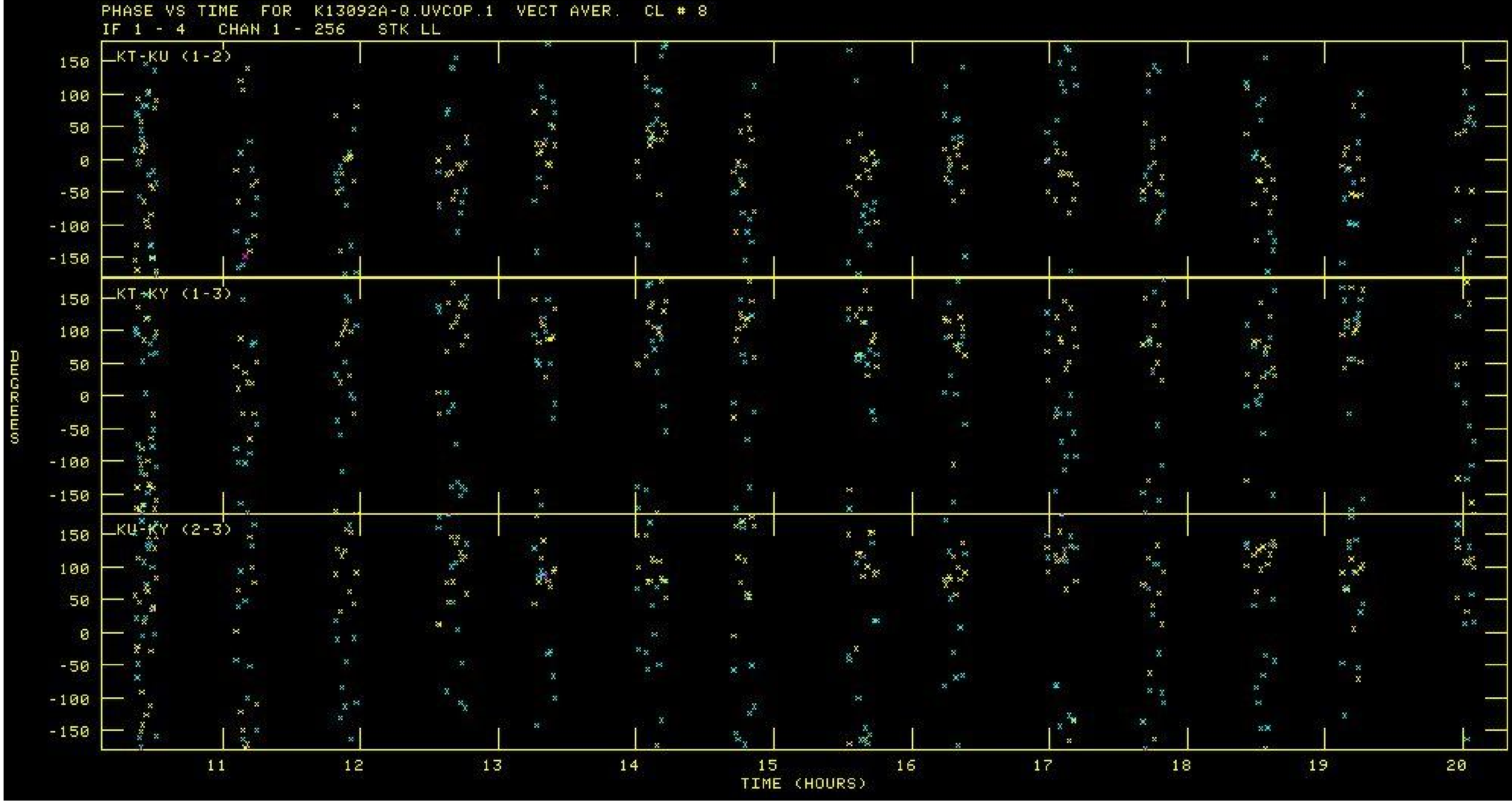


Fast Antenna Switching Phase Referencing
M87-M84 Test at 22Ghz



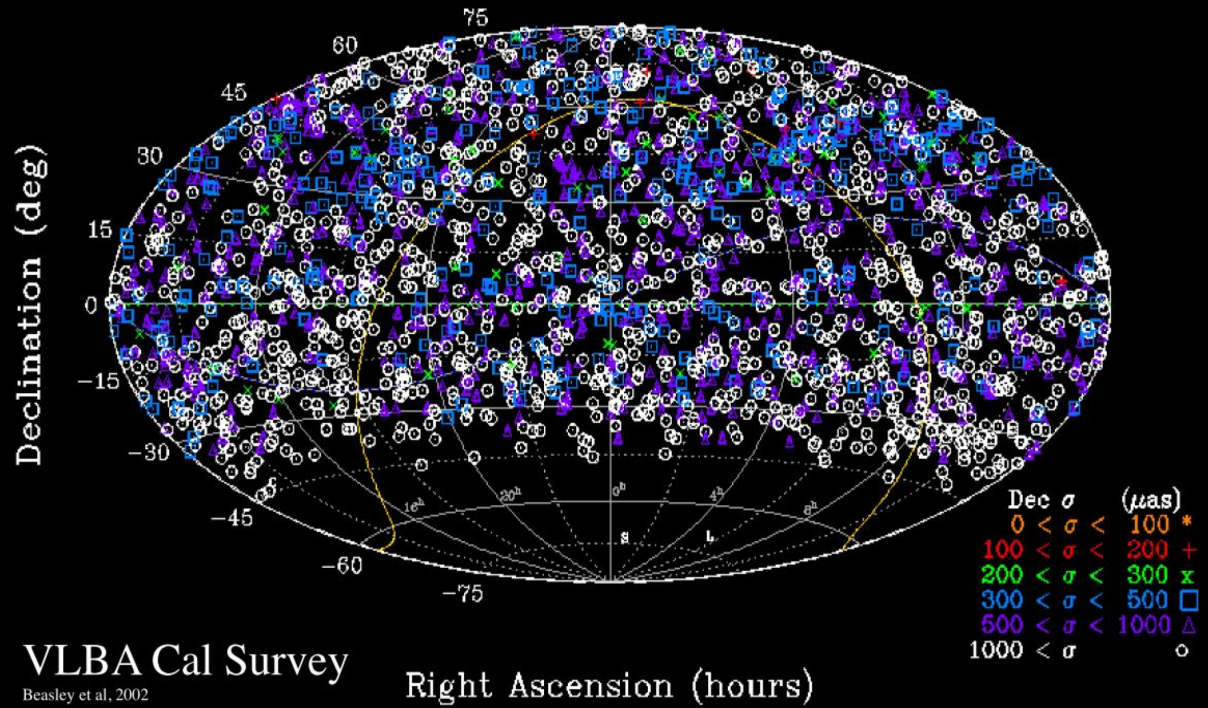


Fast Antenna Switching Phase Referencing
M87-M84 Test at 43Ghz



Multifrequency AGN Survey with the KVN

Discovering high-frequency sources & Maximizing the KVN uniqueness



Taehyun Jung
on be half of KVN Group

mm-VLBI study of AGN

- High-frequency VLBI (mm-VLBI) observations are required to understand of the physical processes at the innermost region in AGN and in the vicinity of supermassive black holes
  - much less affected by the source intrinsic opacity effects

- Determination of the physical parameters of the innermost & most compact component (e.g. the jet base)
  - constraints for current jet and shock models
    (Blandford & Königl 1979, Königl 1981, Marscher & Gear 1985 etc)
  - multi-band spectra & VLBI structures

VLBI Surveys

Name	Wavelength	# of Sources	Reference
CJF survey	18 & 6 cm	293	Pollack et al. 2003
ICRF/RDV	13 & 3.6 cm	~ 500	Ojha et al. 2004
VLBA Calibrator Survey	13 & 3.6 cm	> 3400	Kovalev et al. 2007
VSOP VLBApls	6 cm	374	Fomalont et al. 2000
VSOP Survey	6 cm	~ 300	Dodson et al. 2008
VIPS	6 cm	1127	Helmboldt et al. 2007
2cm Survey	2 cm	250	Kovalev et al. 2005
MOJAVE	2 cm	> 133	Lister & Homan 2005
VERA FSS / GaPS	1.35 cm	500	Petrov et al. 2007
ICRF 22 & 43 GHz	1.37 & 0.7 cm	~100	Lanyi et al. 2010
GMVA 3mm	3 mm	123	Lee et al. 2008
TANAMI	3.5 & 1.3 cm	80	Ojha et al. 2010

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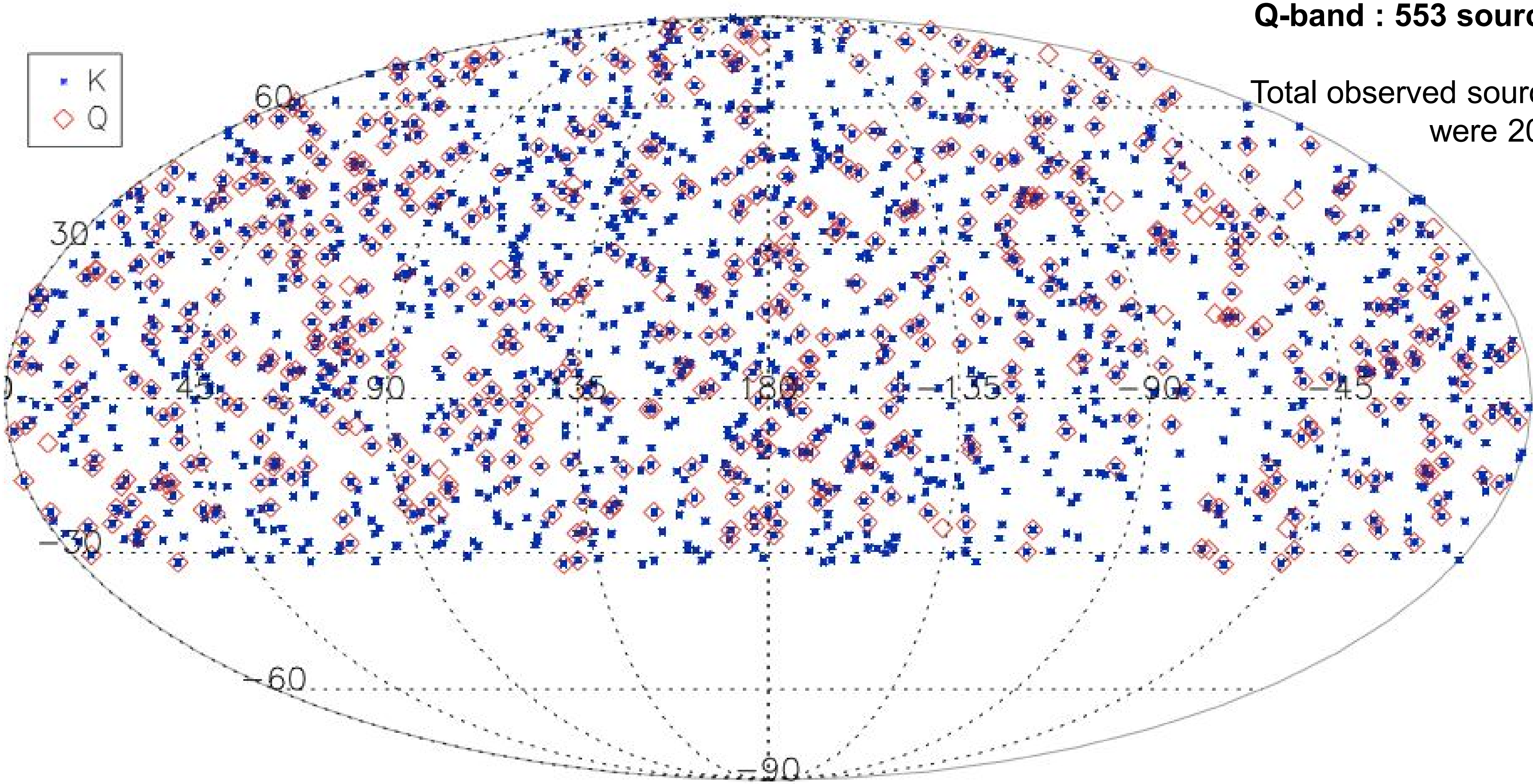
GMVA 3mm			
TANAMI			
KVN Q-CAL survey	7 mm	638	Petrov et al. 2012
KVN W/D-CAL survey	3.5 & 2.3 mm	> 500 (W)	Lee S.S et al. (In prep.)
KVN K-CAL survey	1.3 cm	> 400 (K)	Lee J.A et al. (in prep.)

High-frequency VLBI observations with the KVN

KVNCS1 (single dish)

K-band : 1533 soruces
Q-band : 553 sources

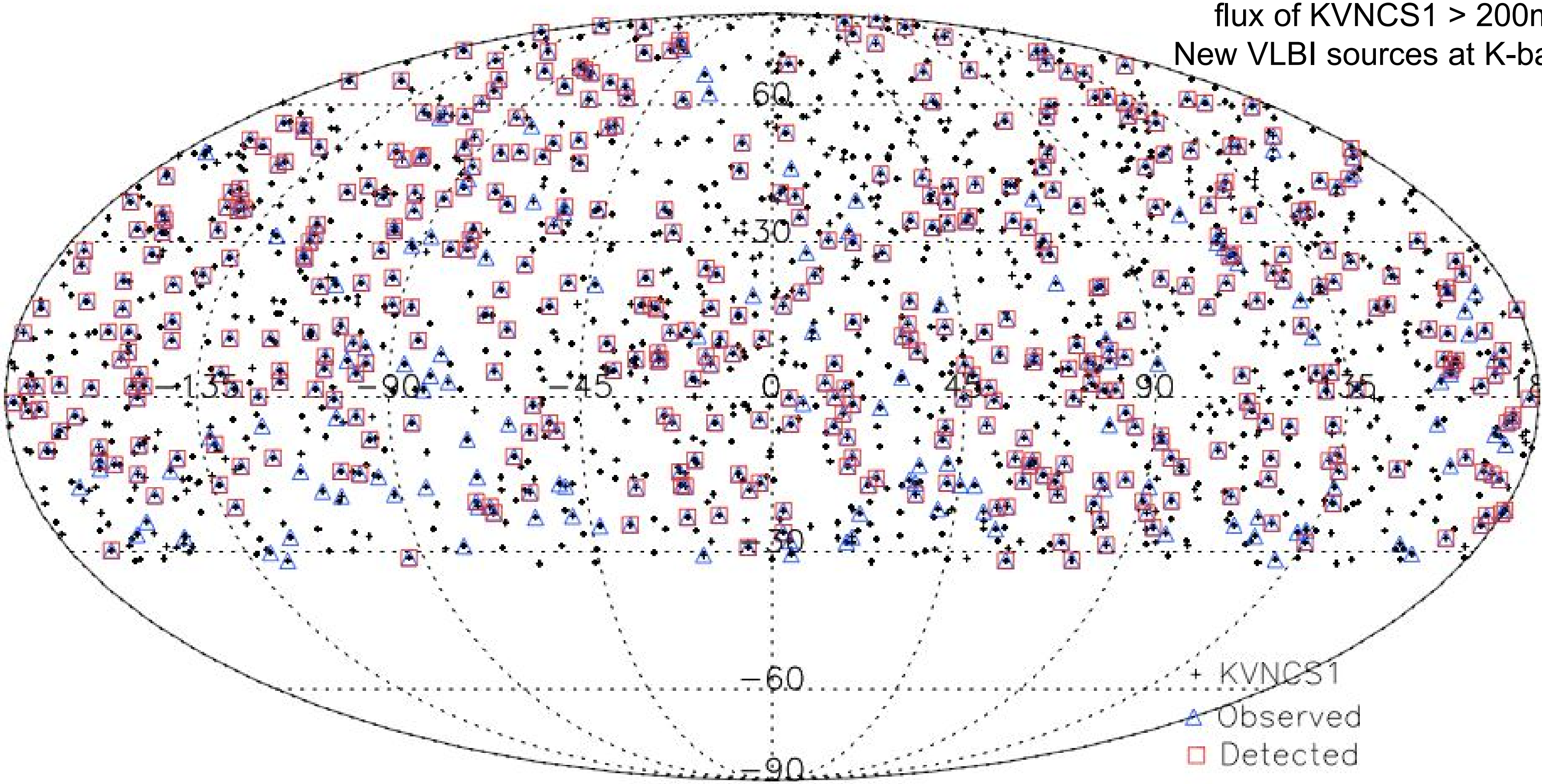
Total observed sources were 2043



Lee in prep.

KVNCS2 (KVN VLBI)

Target : 556 sources
flux of KVNCS1 > 200mJy
New VLBI sources at K-band

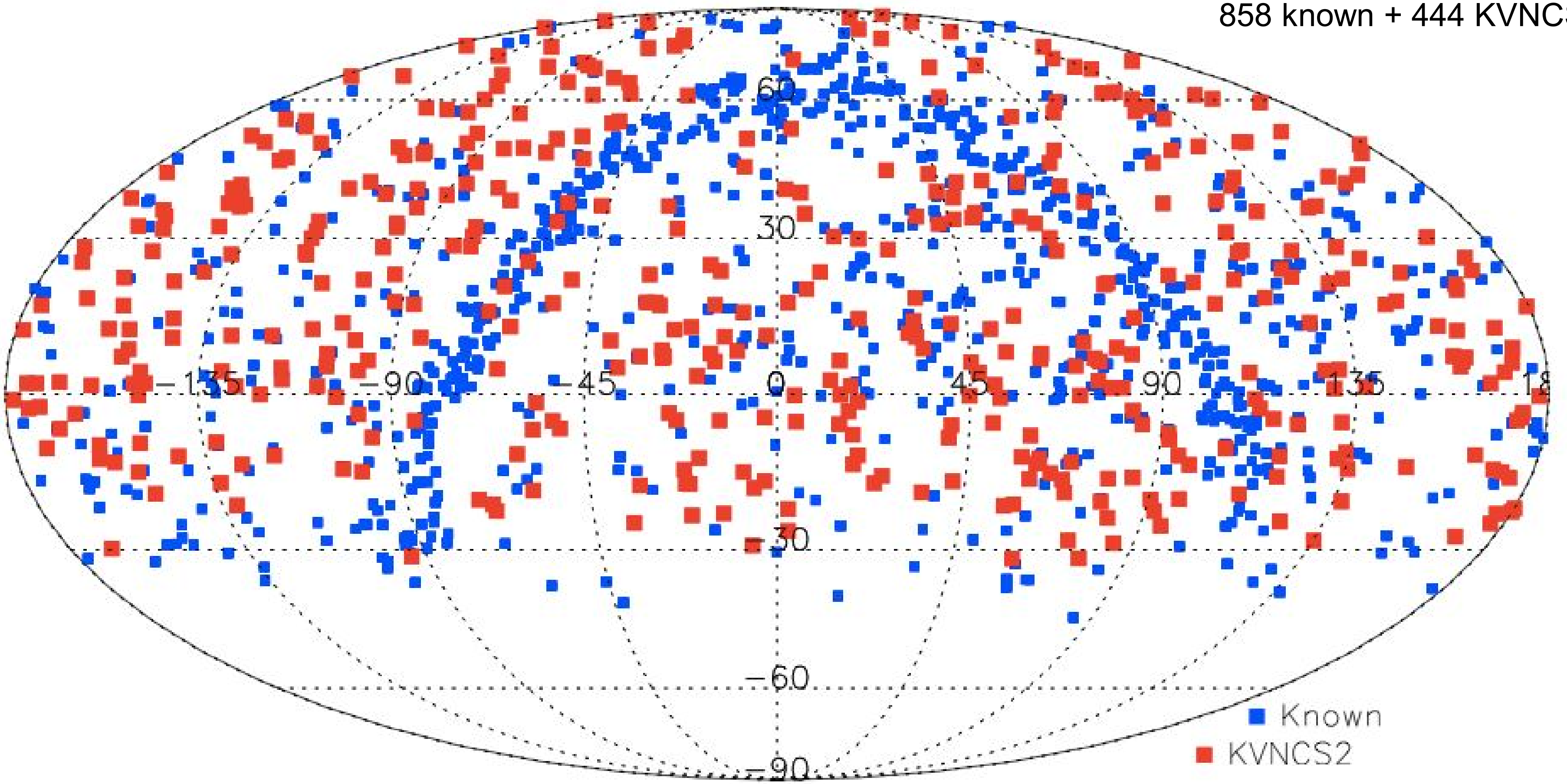


preliminary detection rate ~ 80% (444/556)

Lee in prep.

VLBI sources at K-band

Total: 1302 sources
858 known + 444 KVNCS



credit: J. A. Lee

444 KVNCS2 sources + 858 known calibrators at K band

Full MASK Program

- More than 1300 sources (> dec -30°) are available at K-band VLBI
  - radio spectra from 20GHz ~ 130 GHz (incl. previous catalogs)
  - 22/43/86/130 GHz source positions with their simultaneous spectra

- Total observing time estimated ~ 650 hours
  - 30 min / source, several years
  - 10 / 15 / 35 / 50 mJy sensitivity limit at 22/43/86/129GHz

- KVN Legacy Program or KVN Institute Program in near future

Sensitivity

KVN 1 Gbps 4CH operation

Frequency Band	22 GHz	43 GHz	86 GHz	129 GHz
Bandwidth (MHz)	64			
System temperature (K)	80	90	180	200
SEFD (Jy)	981	1196	2870	3986
Integration time (sec)	1800 (30 min)			
Sensitivity (mJy)	2.3	2.8	6.8	9.4
5σ Sensitivity (mJy)	11.6	14.1	34.0	47.2

KVN 3 Gbps 2CH operation: 1Gbps(K) + 2Gbps(Q,W,D)

Frequency Band	22 GHz	43 GHz	86 GHz	129 GHz
Bandwidth (MHz)	256	512		
System temperature (K)	80	90	180	200
SEFD (Jy)	981	1196	2870	3986
Integration time (sec)	1800 (30 min)			
Sensitivity (mJy)	1.2	1.0	2.4	3.3
5σ Sensitivity (mJy)	5.8	5.0	12.0	16.7

KVN 8 Gbps will be perfect ! (test this year!)

Pilot MASK program

- Statistical demonstration of the feasibility of KVN MFPR for weak radio source detections
  - flux & fringe SNR limits
  - practical coherence time
  - weather condition

- Multi-frequency catalogs of selected samples
  - Physical properties at four radio frequencies
    - flux densities, spectral index, compactness, populations etc.
  - High frequency radio positions (absolute astrometry)
  - Provides high frequency VLBI calibrators

- 1st Test: 175 compact radio sources
  - 158 sources of them were non-detected during 86 GHz fringe test (W-CAL1 by S. Lee) + 17 bright sources
  - Four pilot observations have been made (122 sources)

- 2nd Test : K/W band astrometry
  - Test K/W band VLBI geodesy observations (ICRF sources + W-band sources)
  - Testing the registration of source positions (relative telescope positions)

Future Plan & Prospects

- Data Reduction in Progress

- Classifying samples according to the scientific merits

- Registering high frequency VLBI source positions (astrometry)

- Accurate amplitude calibration is still very difficult with KVN three stations
  - roughly ~ 30% errors
  - flux calibrators (monitoring), accurate gain measurements

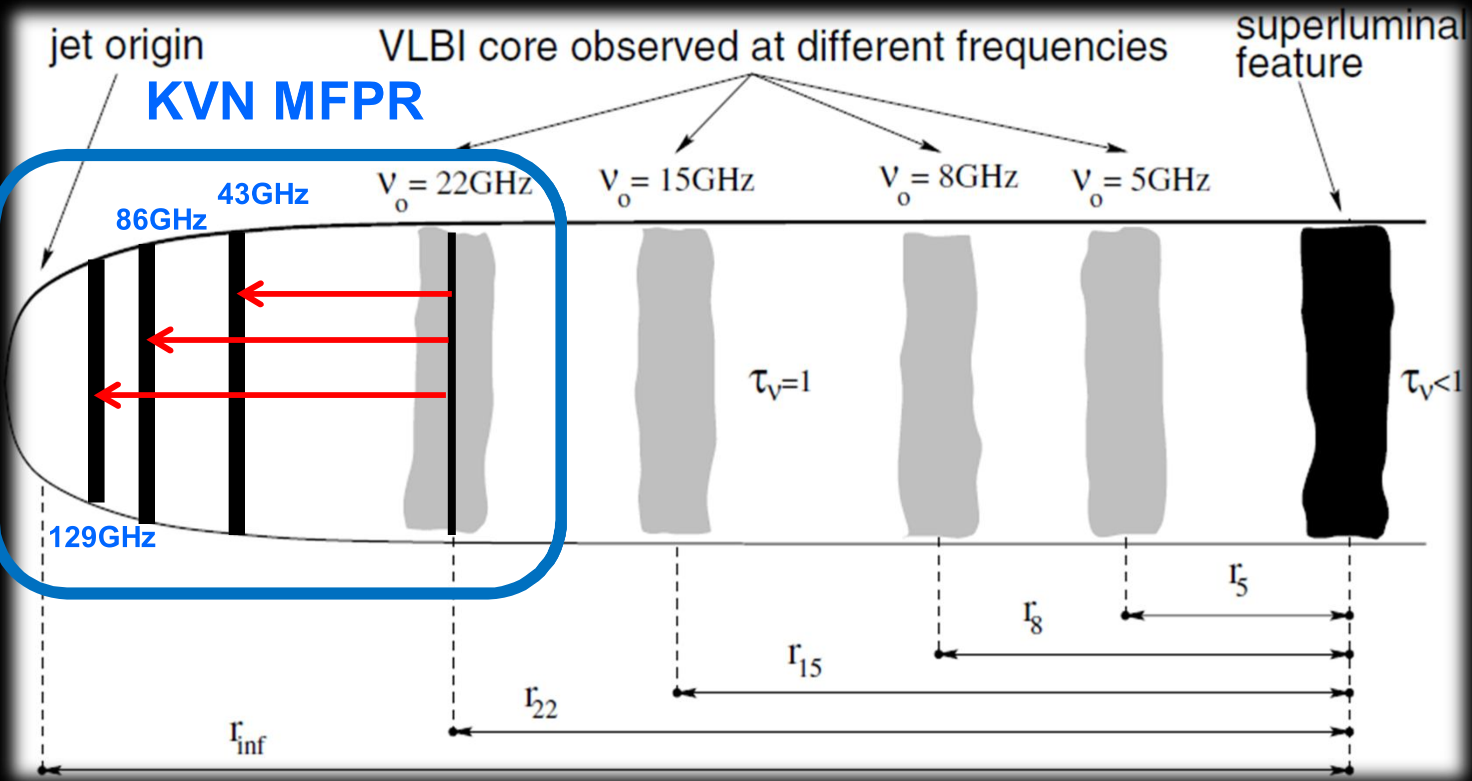
- Collaboration!!
  - together with KVN (internal) users
  - MFPR data reduction tutorial & feedback
    - 13 Aug 2014, then monthly (KVN Calibration WG)

- Plan & discussion for more ideas & coming fruits

- E-KVN : 2 and more KVN antennas

  e.g. more than 3 times of sensitivity improvement

New Method in mm-VLBI Astrometry



Simultaneous multi-frequency observation

Perfect calibration to the troposphere

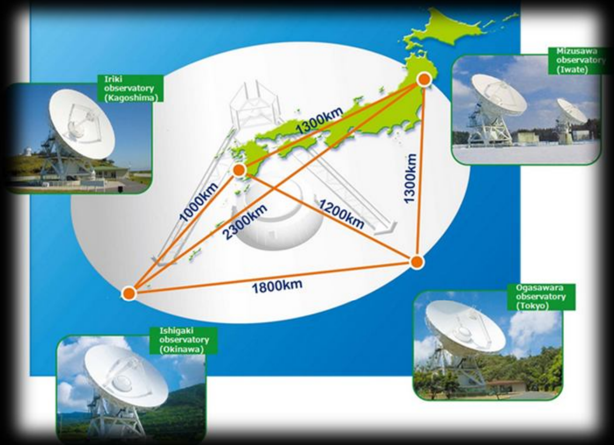
No assumptions such as optically thin components, jet direction

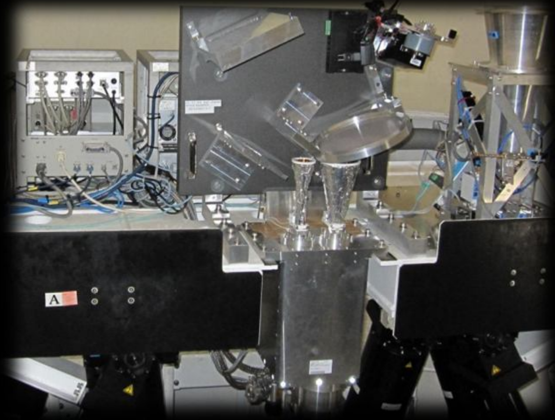
Ideal methods, especially mm/submm- VLBI

Unique access to the inner most region of the Jet
→ High precision VLBI astrometry can be done at high frequencies!!

International Collaborations!!

VERA 20m. 22/43 Fringe Test 2014 June



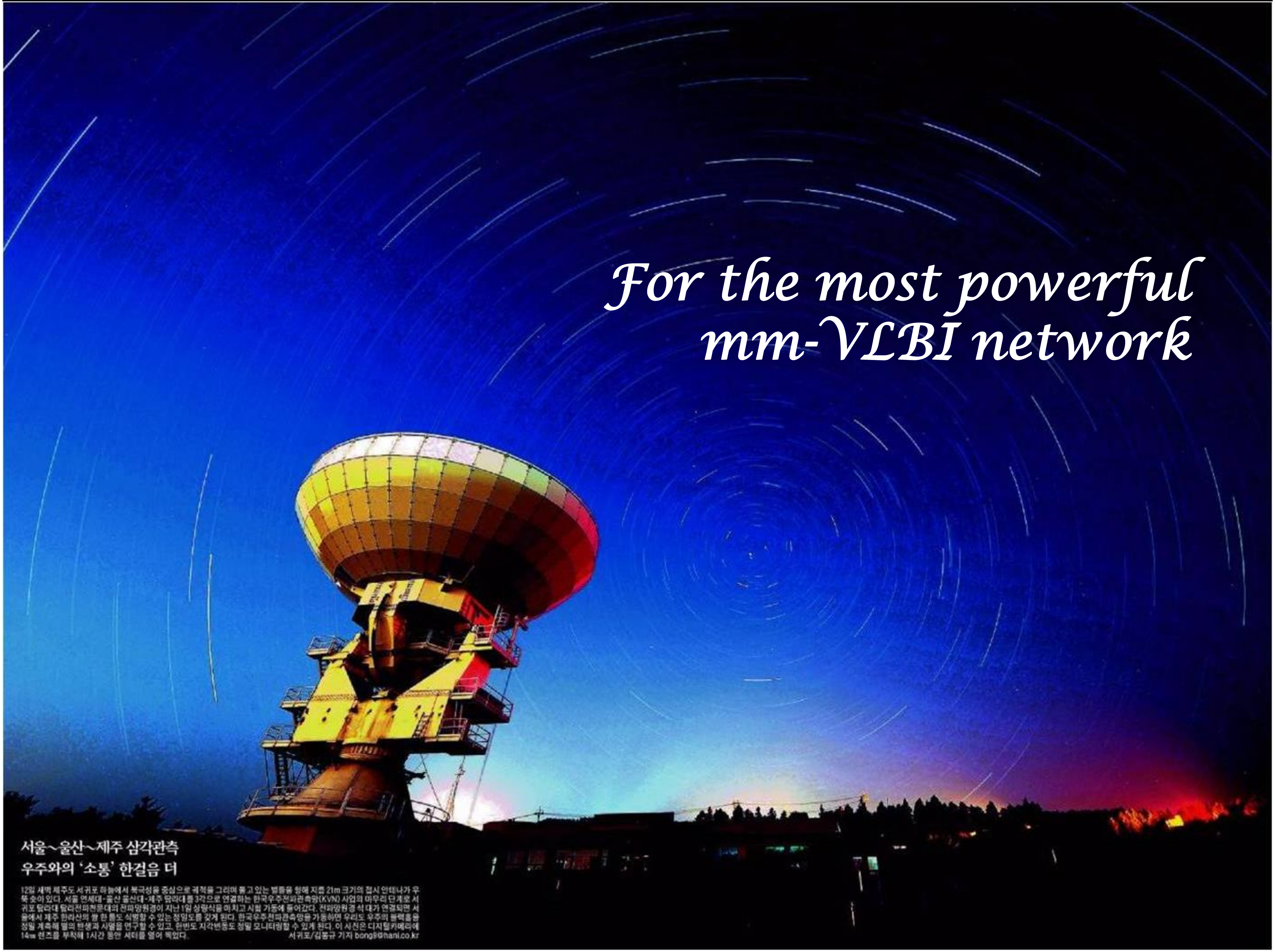


Yebes 40m
22/43/(86/129)
22/43 Installation
in 2014 Nov

VLBA (MK) 25m
discussion on QO
22/43/86 (2014 May)

ATCA 22m x 6
43/86 Test in 2014 Sep

Noto or Sardinia in near future??


For the most powerful
mm-VLBI network
서울~울산~제주 삼각관측
우주와의 '소통' 한걸음 더
12일 새벽 제주도 서귀포 하늘에서 북극성을 중심으로 궤적을 그리며 돌고 있는 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 상량식을 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/김봉규 기자 bong9@hani.co.kr