A Simultaneous Multi-Frequency Receiving System as a Powerful Tool for mm-VLBI Study

Taehyun Jung
鄭 太 現

Korean VLBI Network (KVN)
Korea Astronomy & Space Science Institute (KASI)

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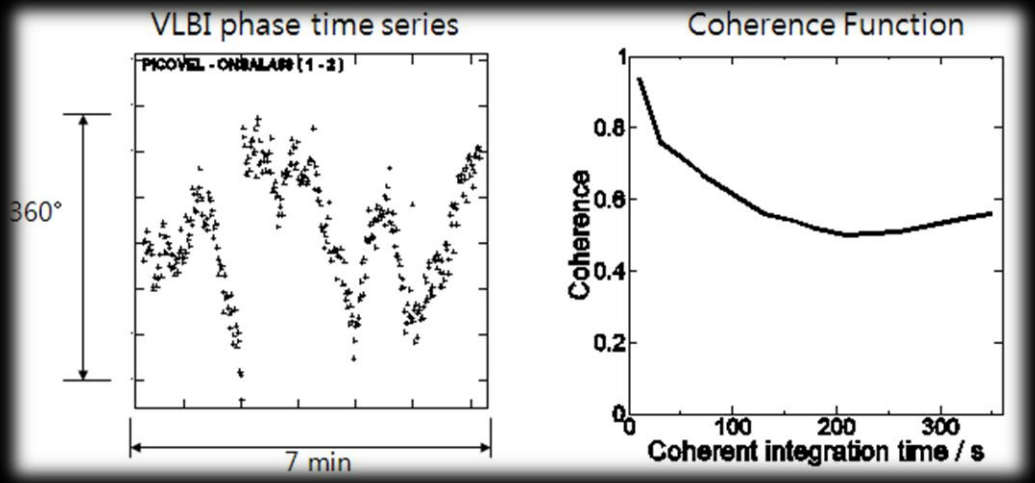
Coherence

Errors coming from the **ATMOSPHERE** are still remain the most serious difficulty which significantly degrade the sensitivity and imaging capability of mm and sub-mm VLBI observation



Coherence Function

$$C(T) = \left| \frac{1}{T} \int_0^T e^{i\phi t} dt \right|$$

VLBI Sensitivity

$$S_v = (SNR) \frac{8k}{\pi \eta_c} \frac{\sqrt{T_{s_1} T_{s_2}}}{\sqrt{\eta_{A_1} \eta_{A_1}} D_1 D_2 \sqrt{2B\tau_\alpha}}$$

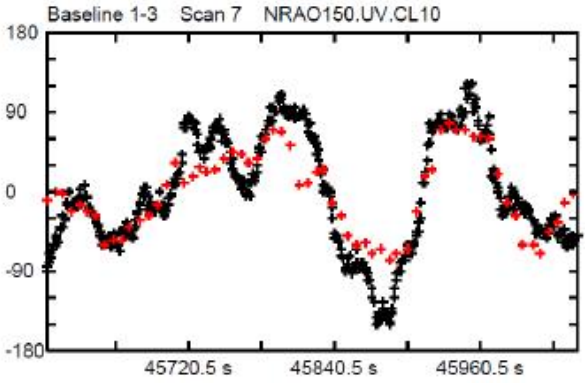
Pico Veleta – Onsala baseline (A. Roy)
Source : BL Lac
Frequency : 86 GHz

Coherence Time

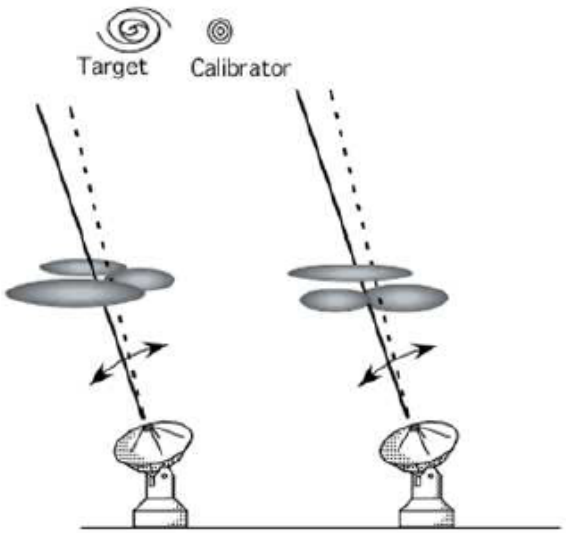
Frequency (GHz)	2	8	15	22	43	86	129
Coherence Time (sec)*	800	200	100	73	37	19	12

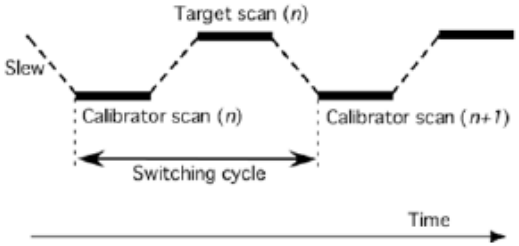
*Typical value of atmospheric phase stability ~ 10^{-13}

Phase Referencing Techniques

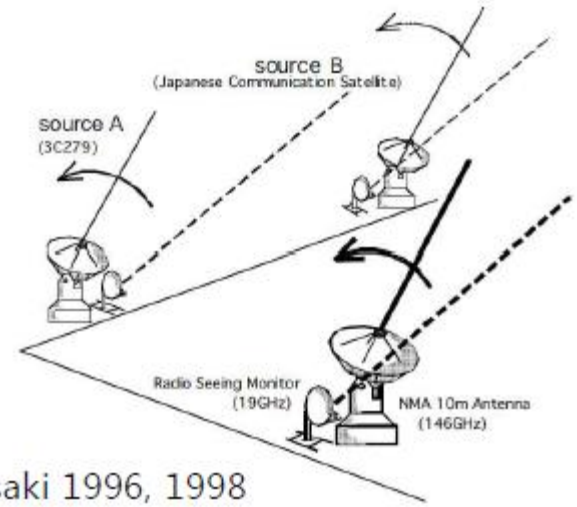


VLBI phase time series (black) and WVR-derived phase correction (red) (Roy et al. 2006)

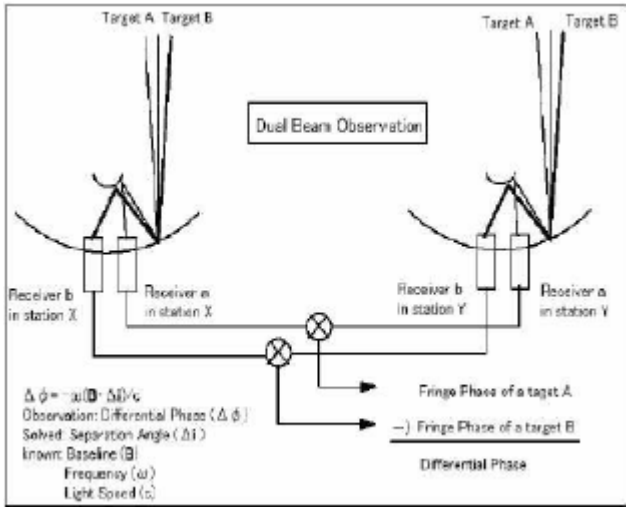




(source : Asaki)



Asaki 1996, 1998

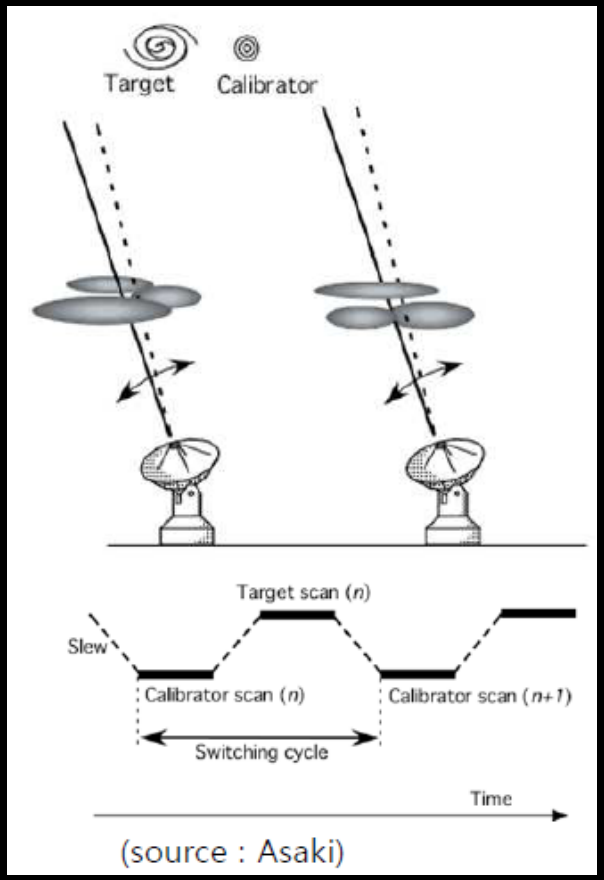


VERA & KVN System for VLBI Phase Referencing

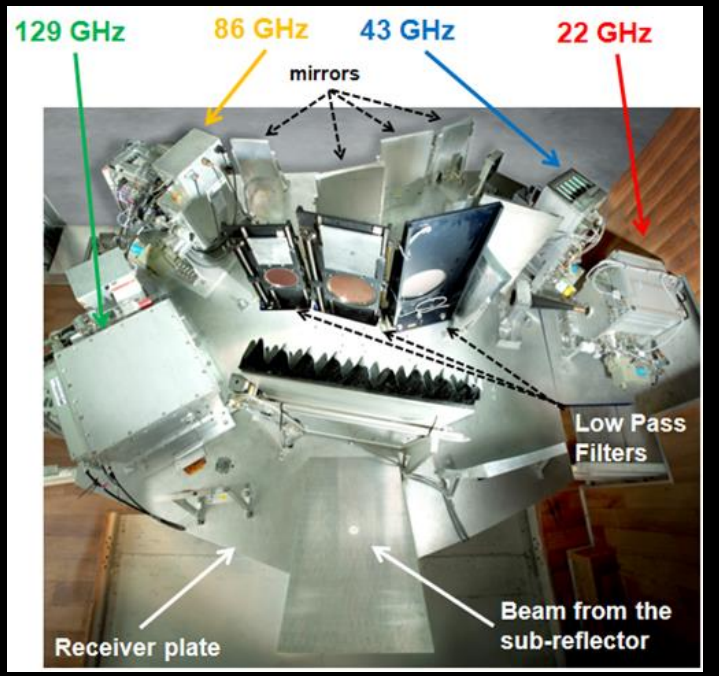
- **Increase coherence time** by removing atmospheric fluctuations
  → **weak source detection** with high SNR
- **Precise Astrometry**

Atmospheric phase errors are calibrated by

near by calibrators **lower frequency phase solutions**

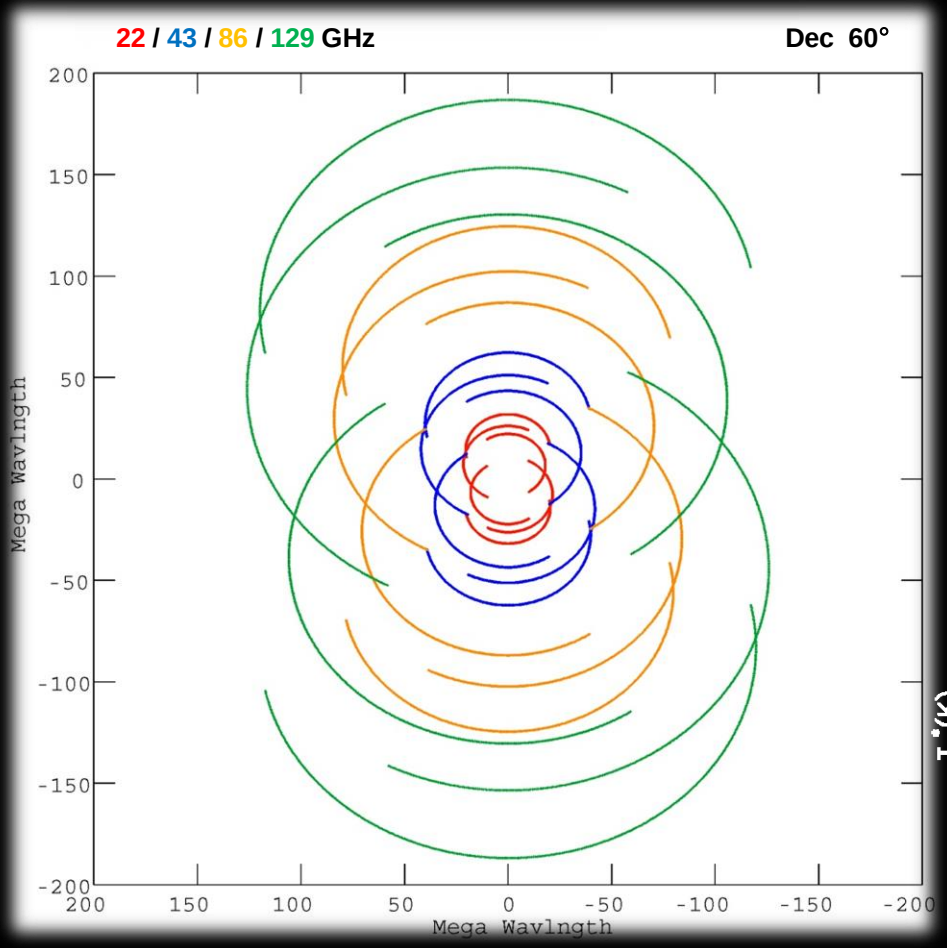


VERA dual-beam

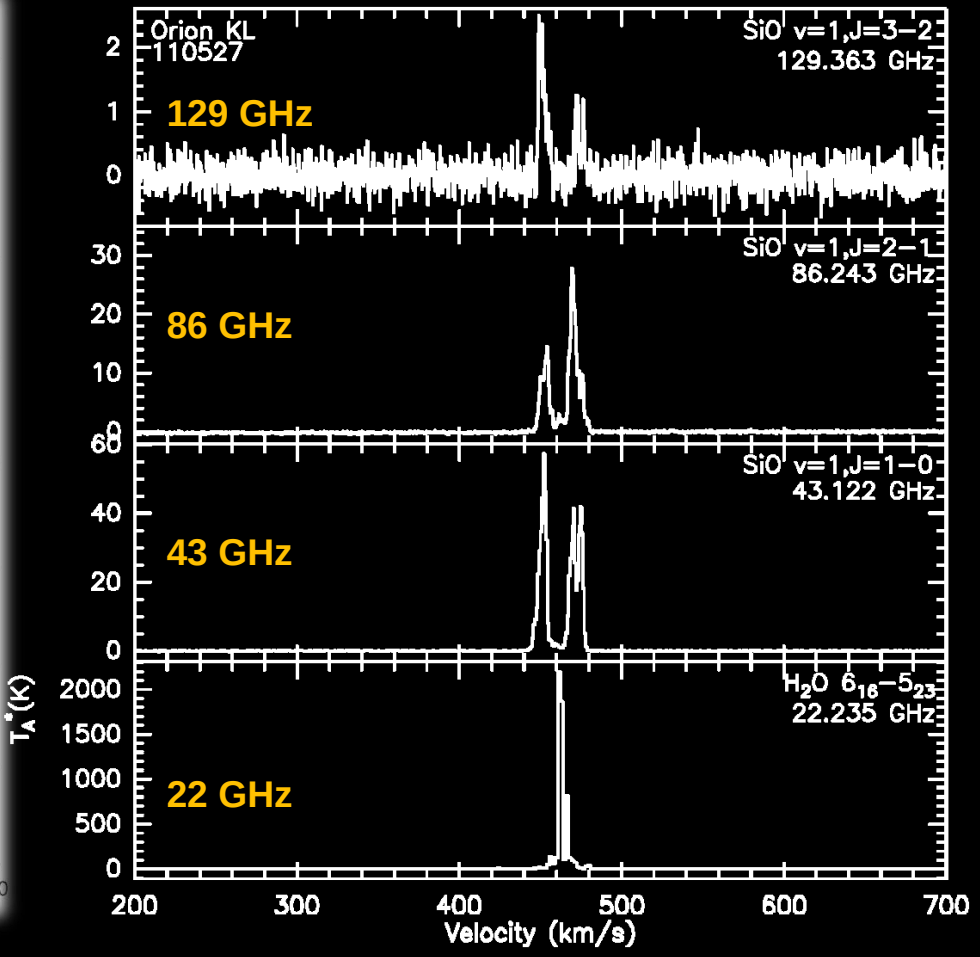


KVN multi-freq. receiving system

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

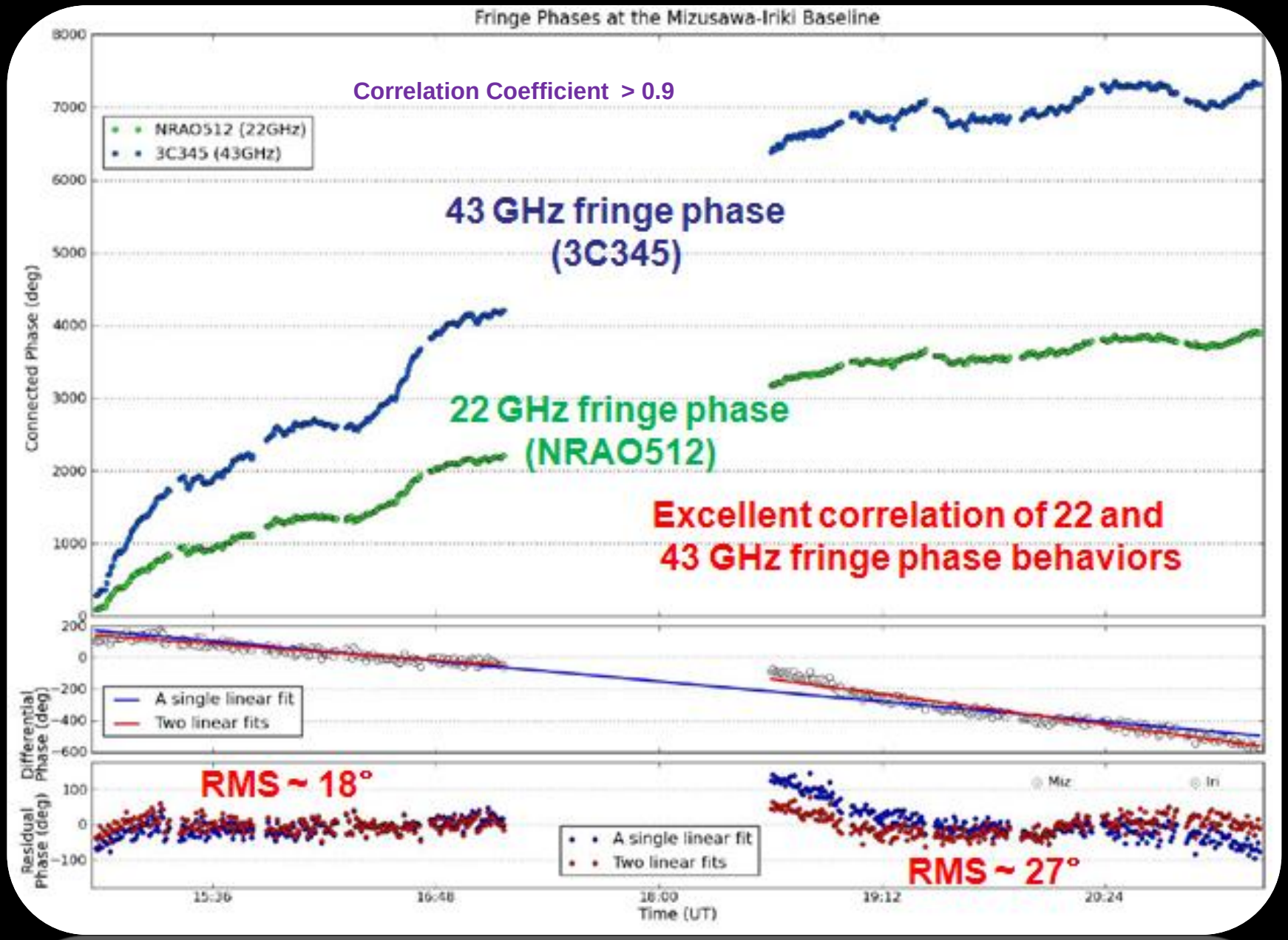


4CH UV Coverage



H20/SiO Masers in Orion KL

VERA Dual-Beam Experiment



Jung et al. 2011

An Ideal System for mm-VLBI

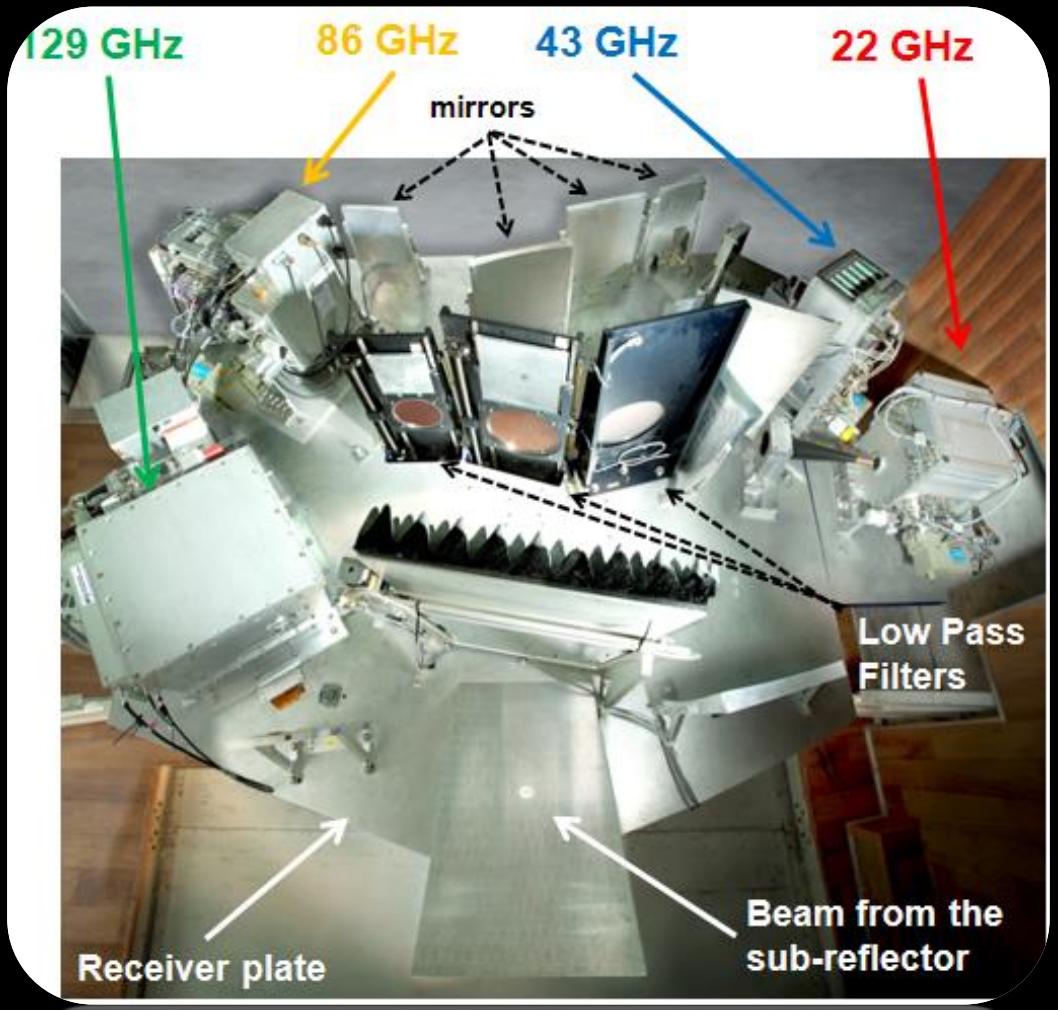
KVN Multi-Frequency Feeds

Target itself is the reference
→ resolving the reference source problem

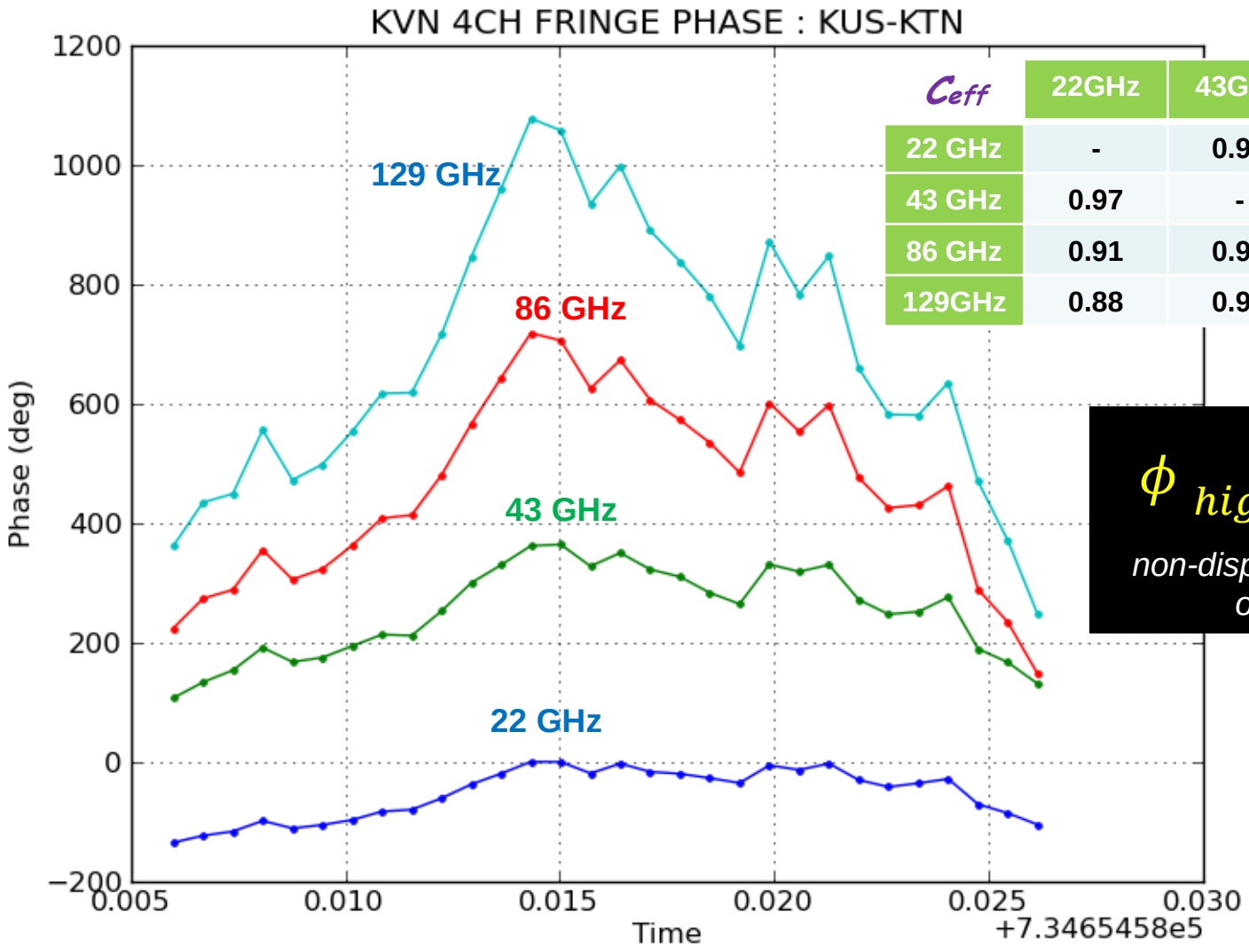
No coherence loss
→ due to the same sky position

Integrate mm VLBI fringes as long as a single dish telescope does
→ weak source detection at mm

New possibilities of science such as AGN core shift & H_2O/SiO masers by overlapping the VLBI images of radio sources at different frequencies



KVN Multi-Freq. Simultaneous Observation



Ceff	22GHz	43GHz	86GHz	129GHz
22 GHz	-	0.97	0.91	0.88
43 GHz	0.97	-	0.97	0.96
86 GHz	0.91	0.97	-	0.99
129GHz	0.88	0.96	0.99	-

$$\phi_{high} \propto \frac{\nu_h}{\nu_l}\phi_{low}$$

non-dispersive characteristic of troposphere

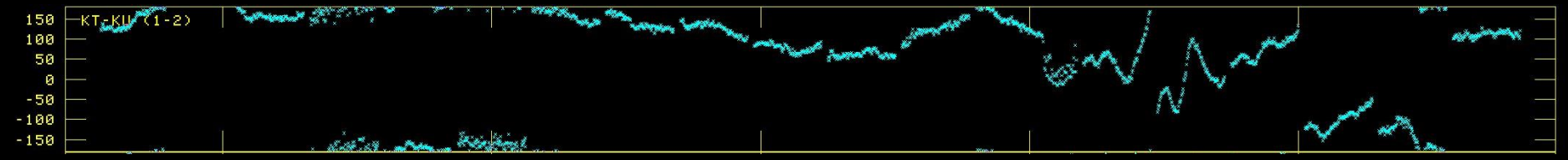
30min

High frequency VLBI Phase Calibration by Lower Frequency Phase Solutions

24 hours

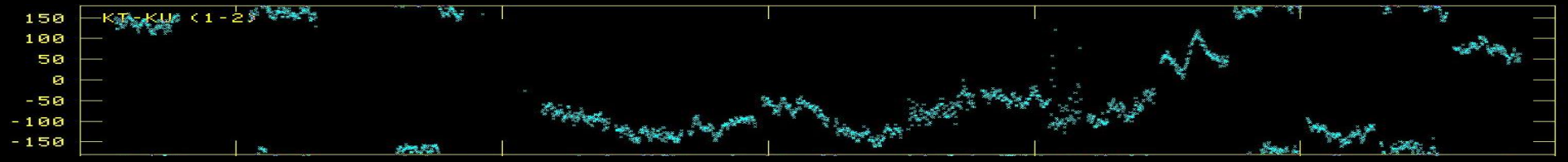
MFPR applied with K-band solint 0.3

43GHz



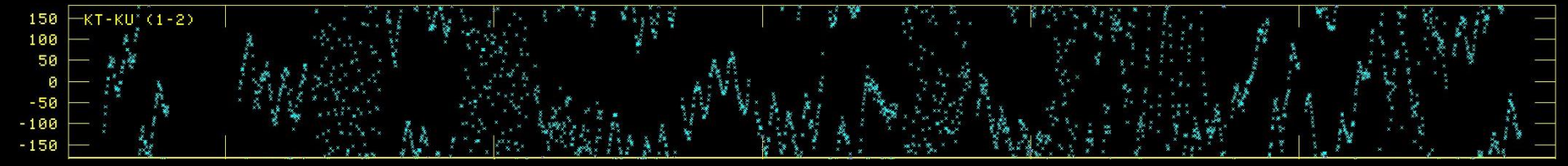
MFPR applied with Q-band solint 0.1

86GHz



MFPR applied with K-band solint 0.3

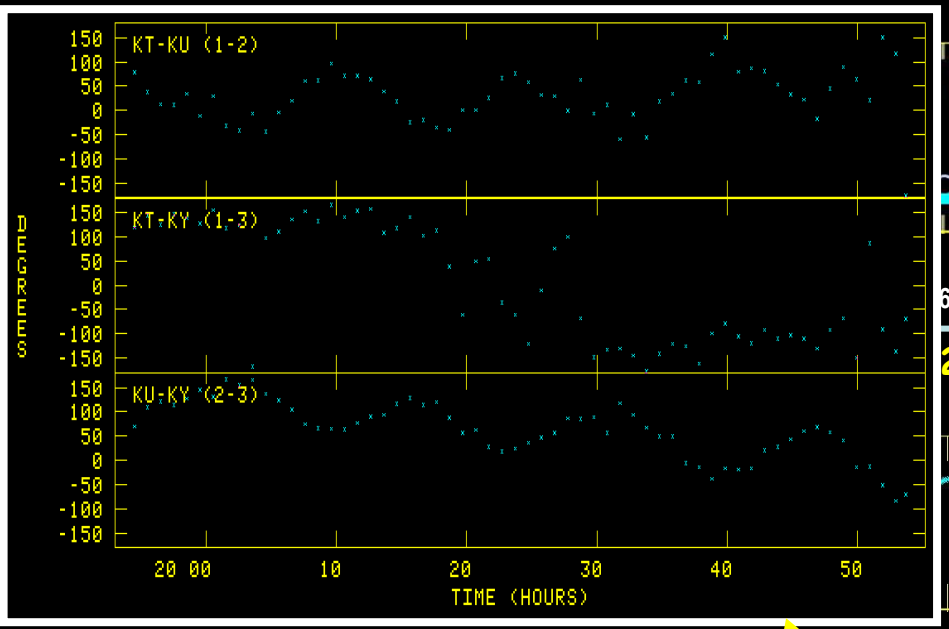
129GHz

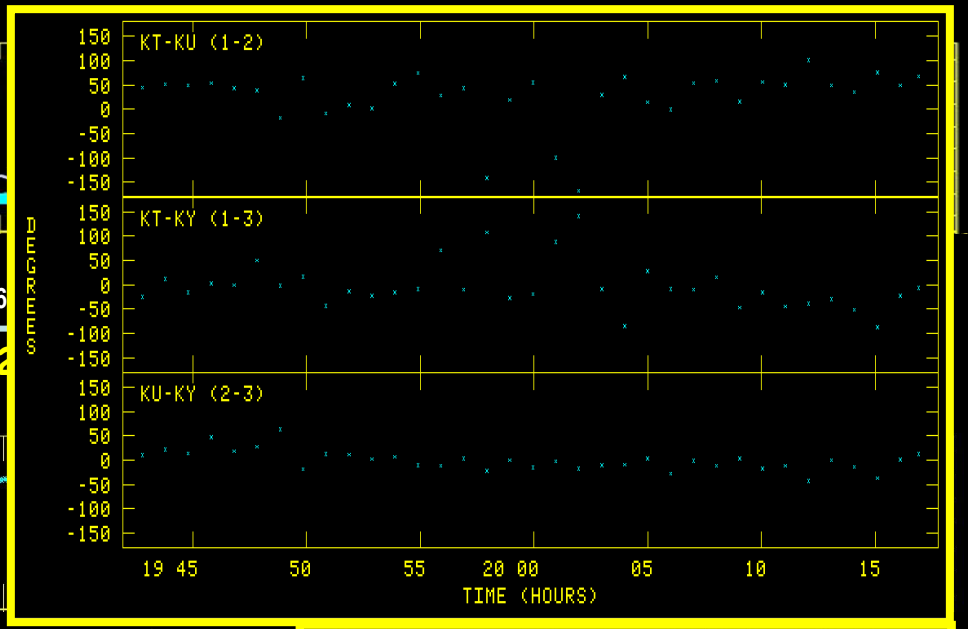


NRAO150 0133+476 3C84 1308+326 3C279 3C345 NRAO530 SGR-A 3C454.3 2255-282
0202+149 1023+131 3C273 1633+382 NRAO512 FAS 1921-293 BLLAC NRAO150

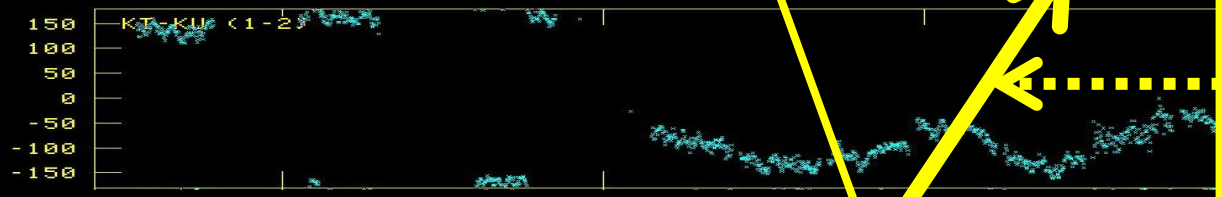
24 hours

129GHz Visibility Phase Calibrated by 22GHz

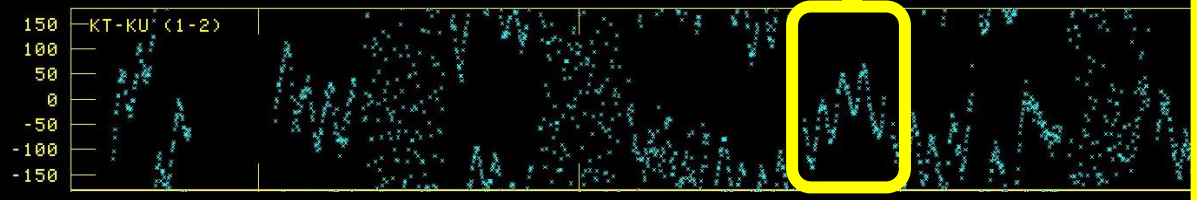




MFPR applied with Q-band solint 0.1



MFPR applied with K-band solint 0.3



New thermal control system at KVN Yonsei Rx Room

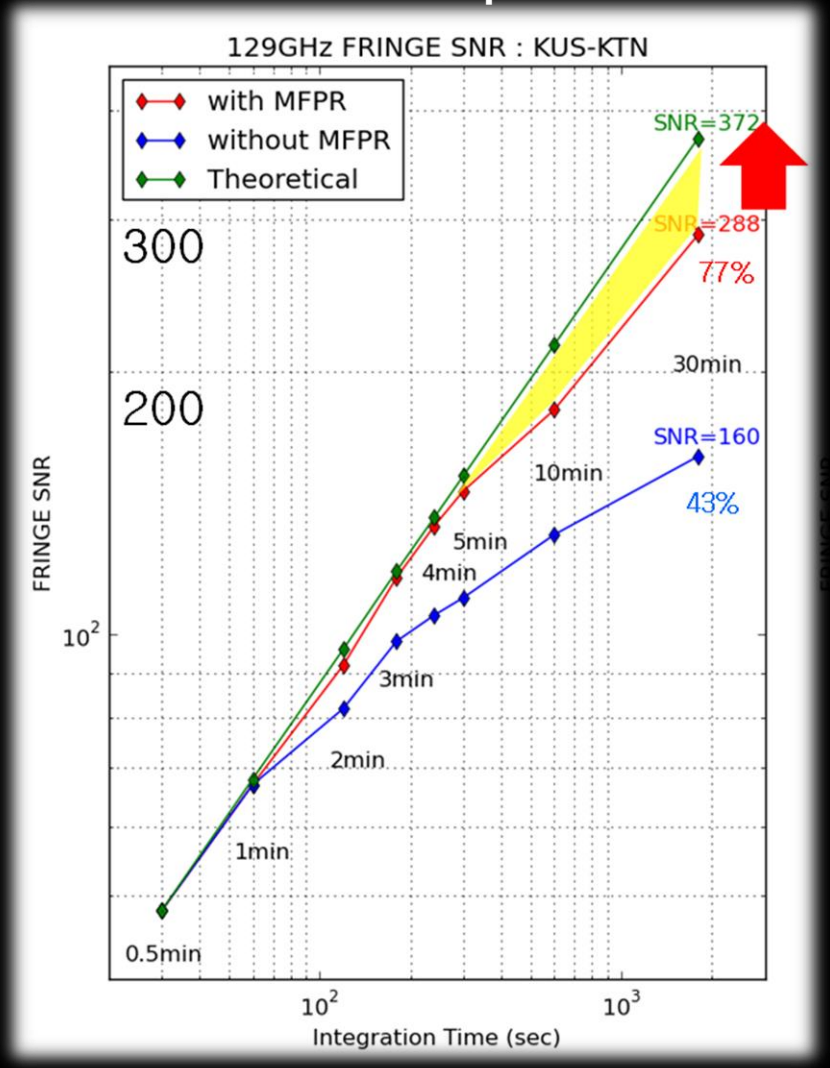
NRAO150 0133+476 3C84 1308+326 3C279 3C345 NRAO

0202+149 1023+131 3C273 1633+382 NRAO512

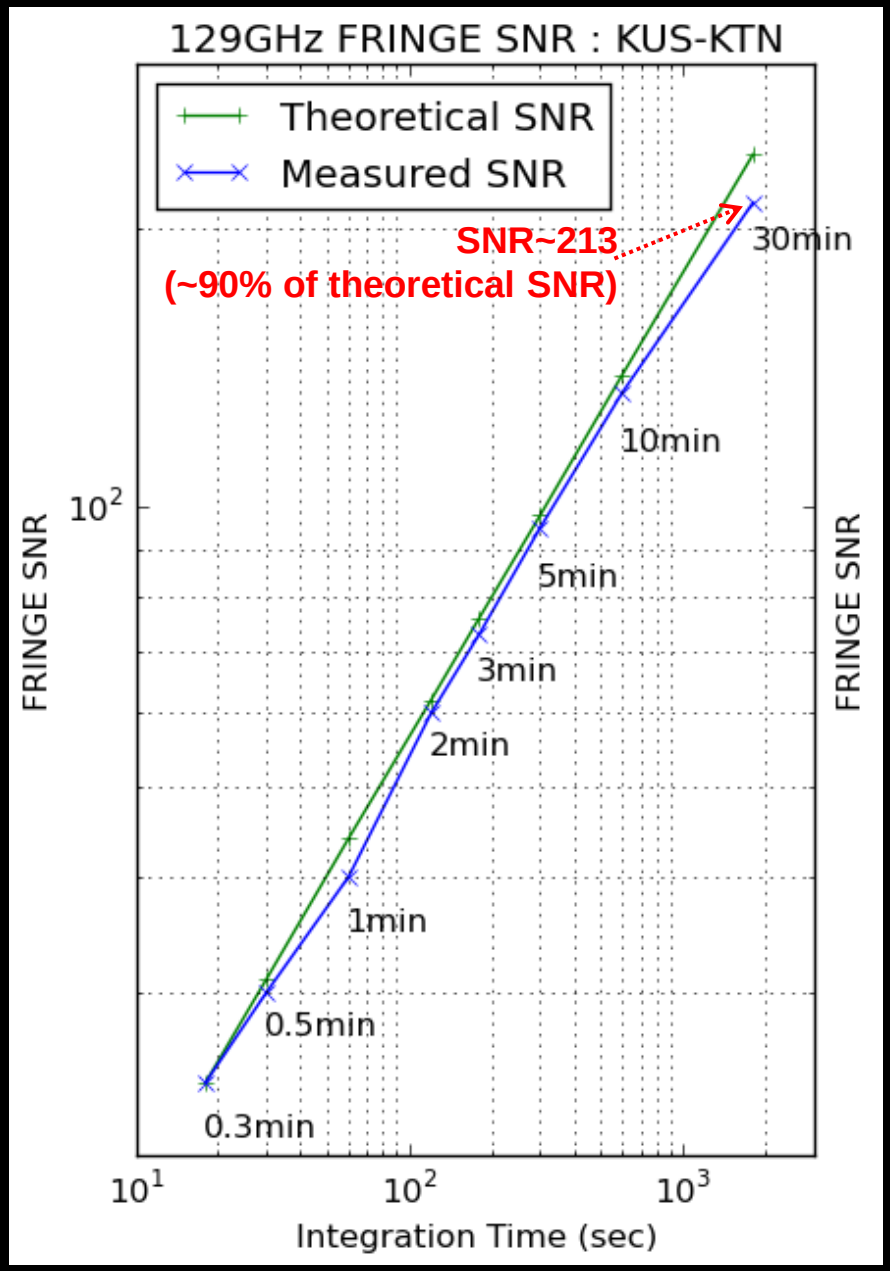
24 hours

Increase coherence time → weak source detection with high SNR

Before Rx Room Temp. Stabilization



After Rx Room Temp. Stabilization →

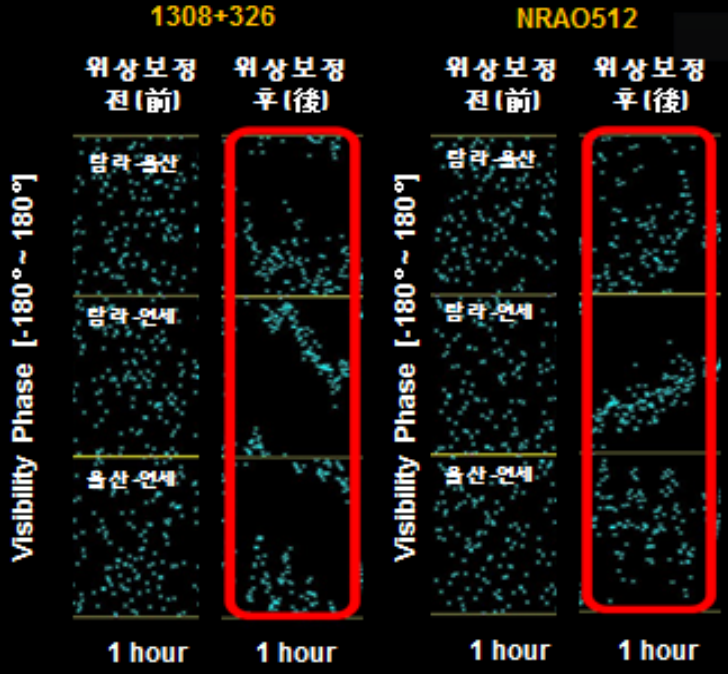


Source Detection at High Frequency

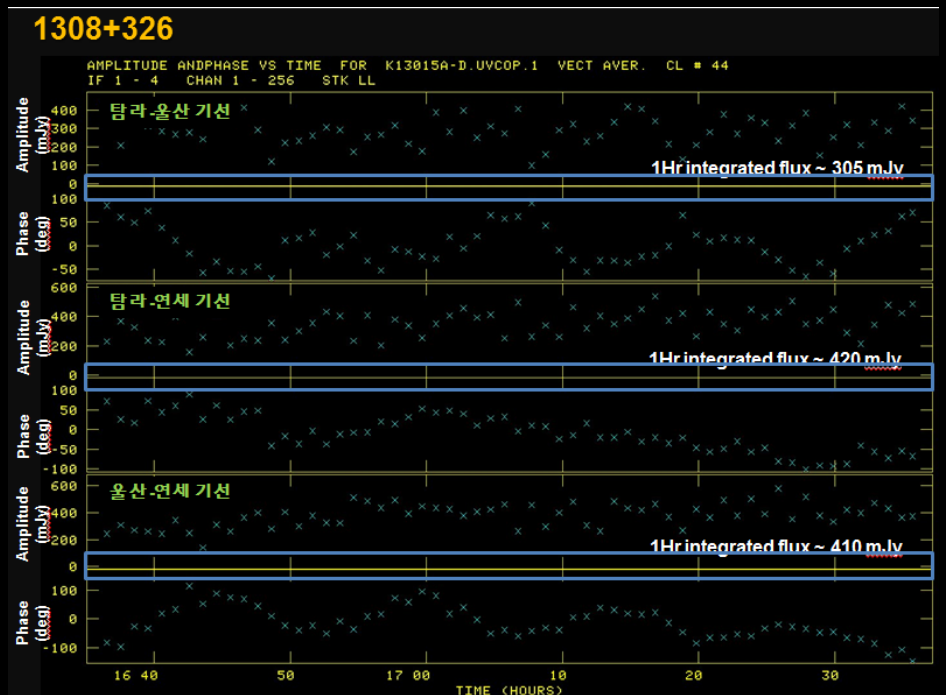
- 1308+326 & NRAO512 were not detected at D-band
- After applying MFPR with1 hour integration, these sources are detected with high SNRs (~130, ~80)

➔ The FIRST detection of 1308+326 & NRAO512 at 129GHz

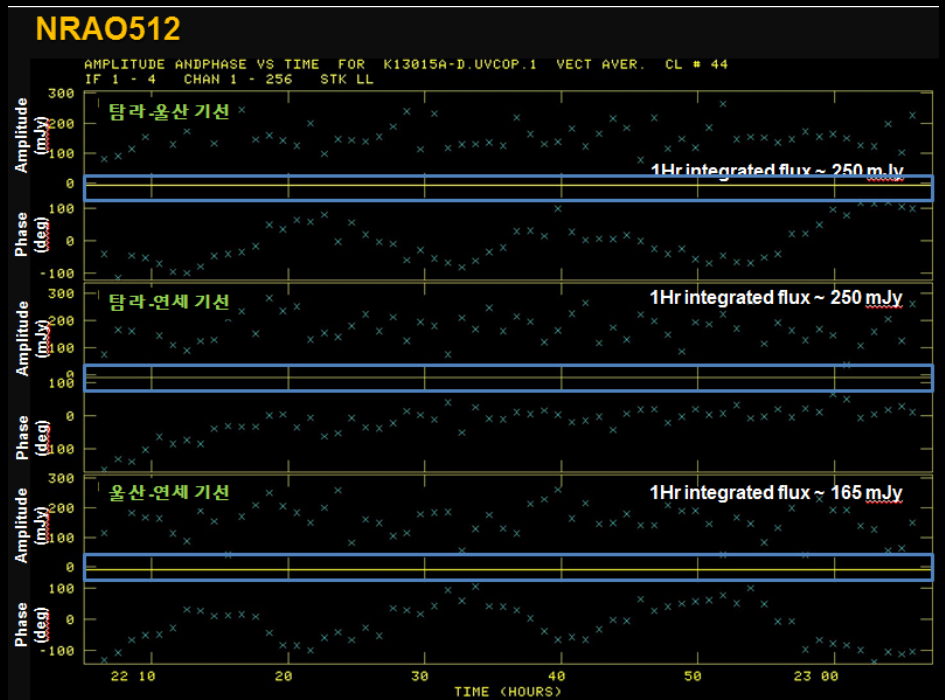
- SNR : 1308+326 ~ 130, NRAO512 ~ 100
- Flux : 1308+326 : 300~420 mJy
  NRAO512 : 160~250 mJy



SNR 1308+326 (1Hr integration)

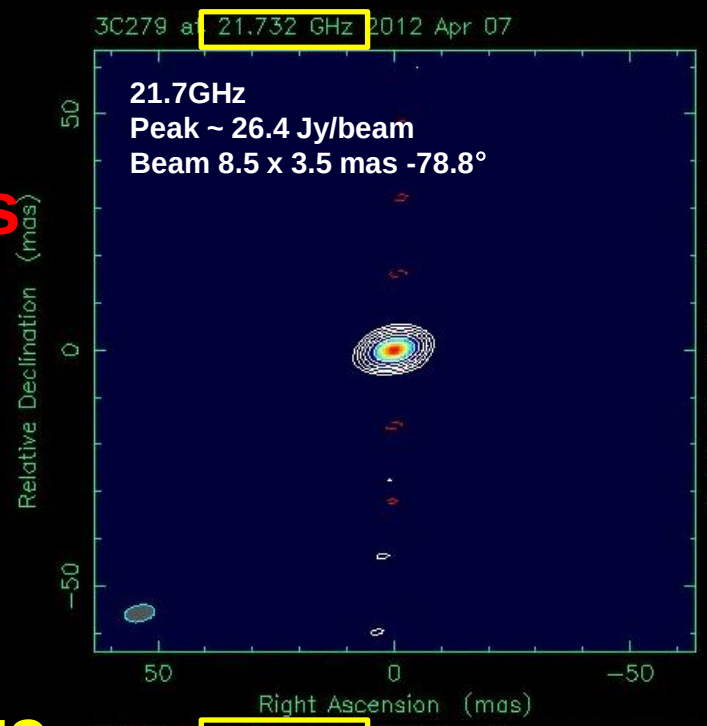


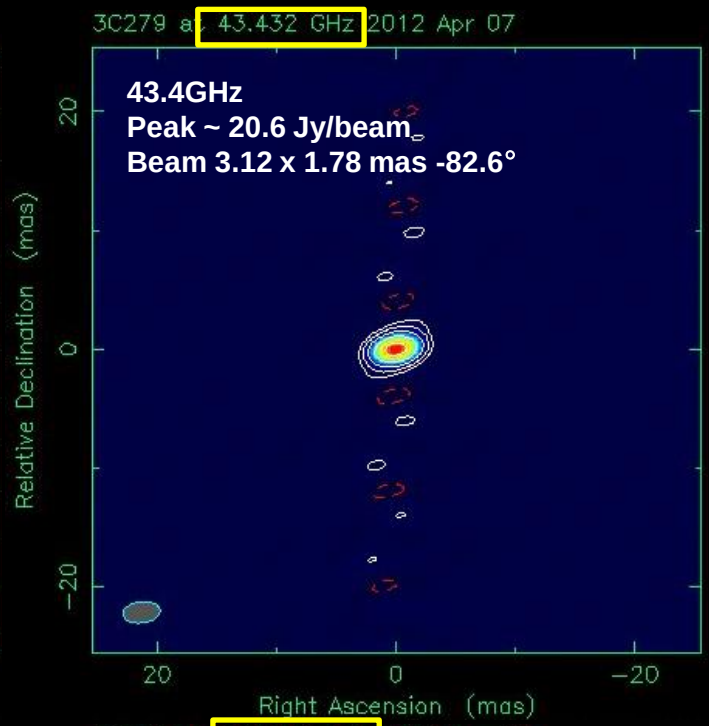
SNR NRAO512 (1Hr integration)

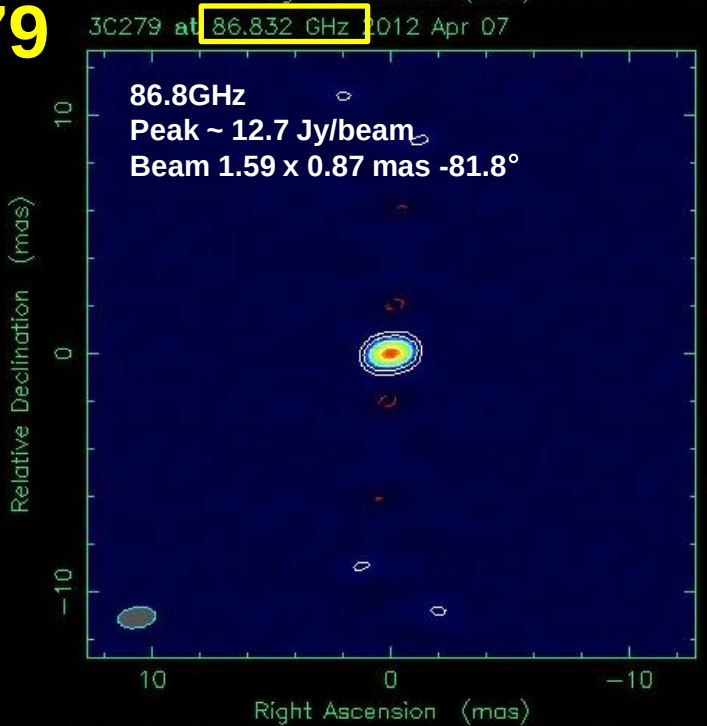


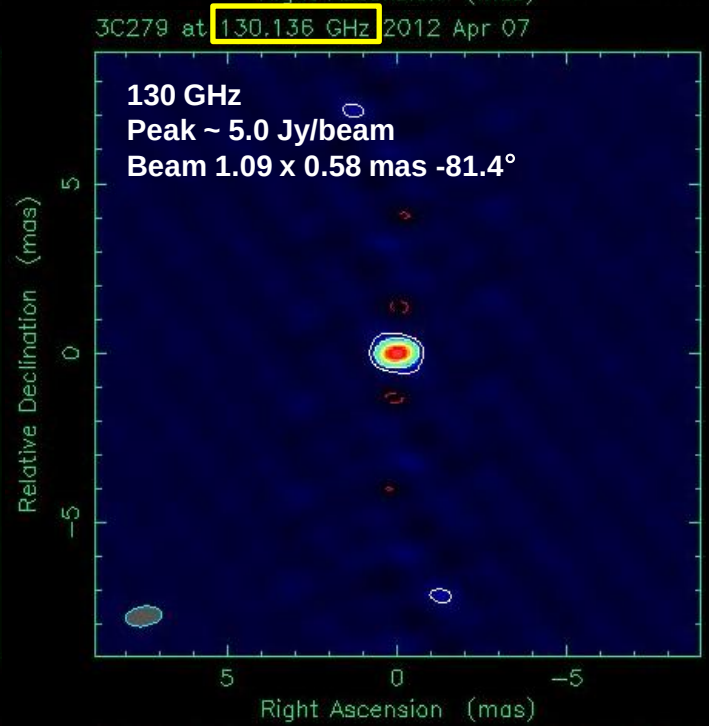
First Simultaneous 4-channel Observation VLBI Images

Source: 3C279





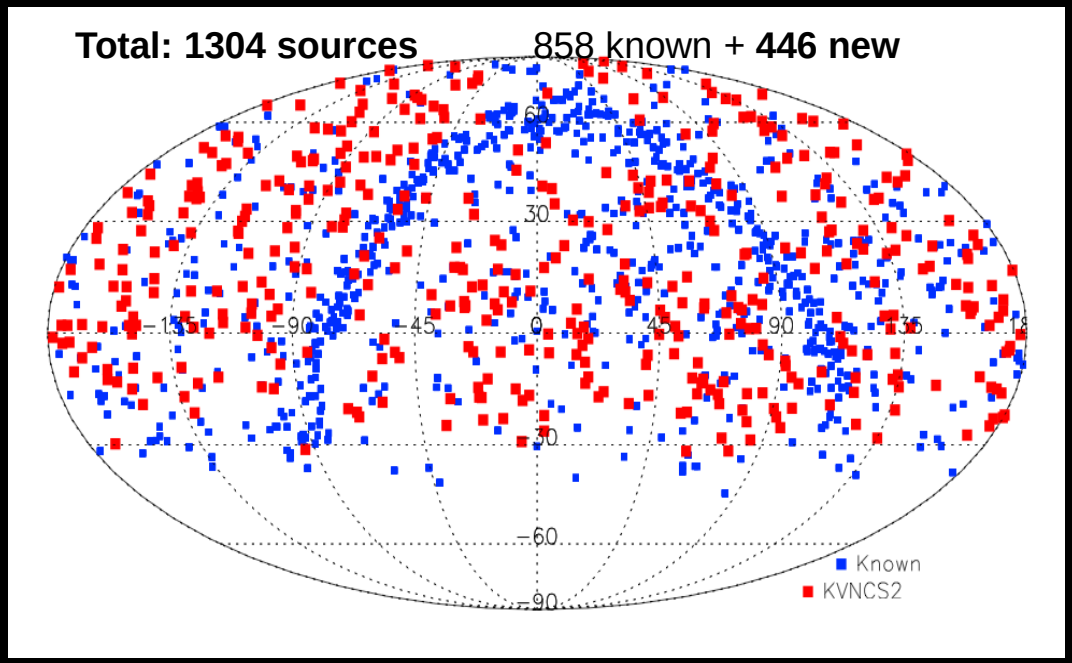




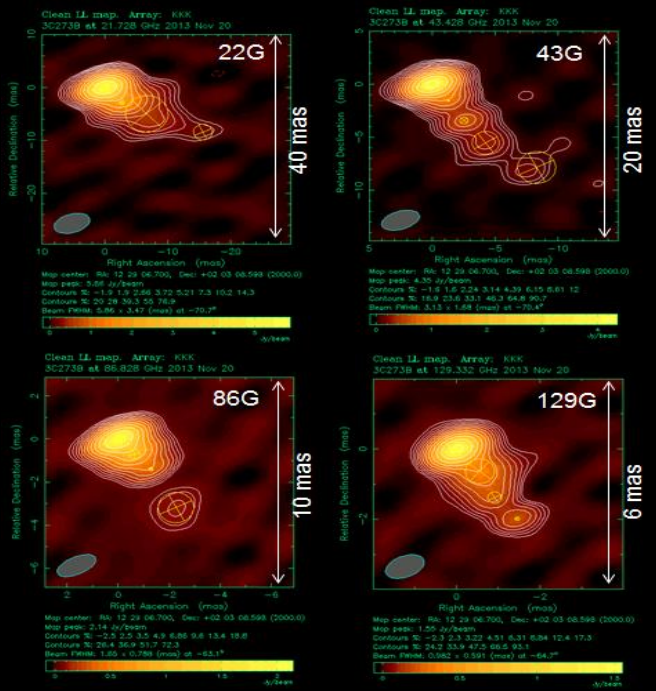
43/86/130GHz visibility phases are calibrated by 22Ghz

Multifrequency AGN Survey with the KVN

Discovering high-frequency sources & Maximizing the KVN uniqueness



KVN Calibrator Survey (22/43GHz) by J.A. Lee



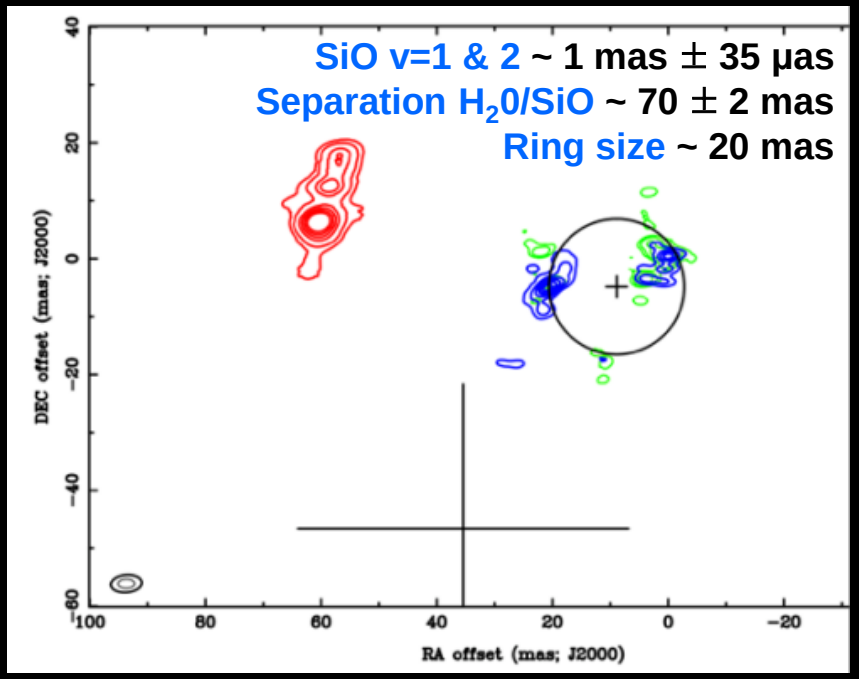
iMOGABA by S.S. Lee

Multi-frequency source catalogue of selected samples

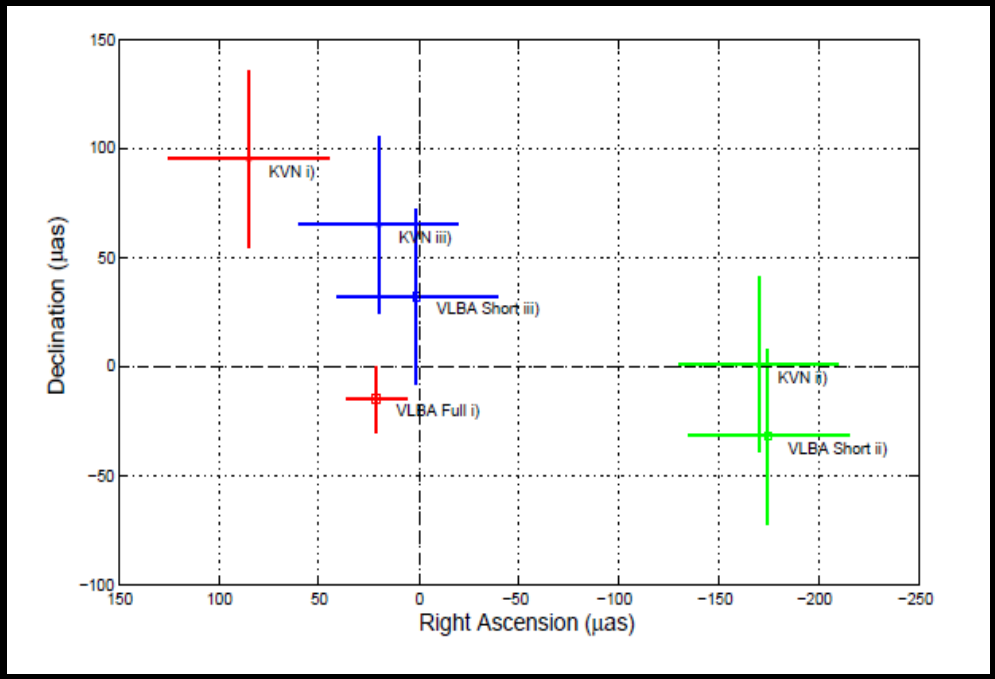
- Physical properties at 2-13mm wavelengths
  - flux density, spectral index, compactness, populations etc.
- Provides high frequency VLBI catalogue

Two Main Reasons in VLBI Phase Referencing

2. Astrometry → high-precision astrometry at mm wavelengths

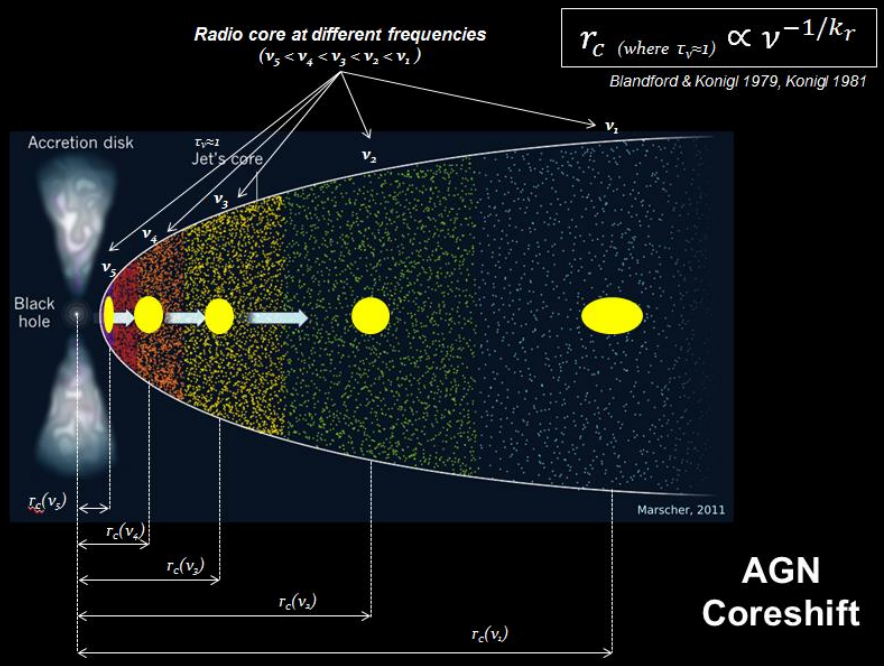


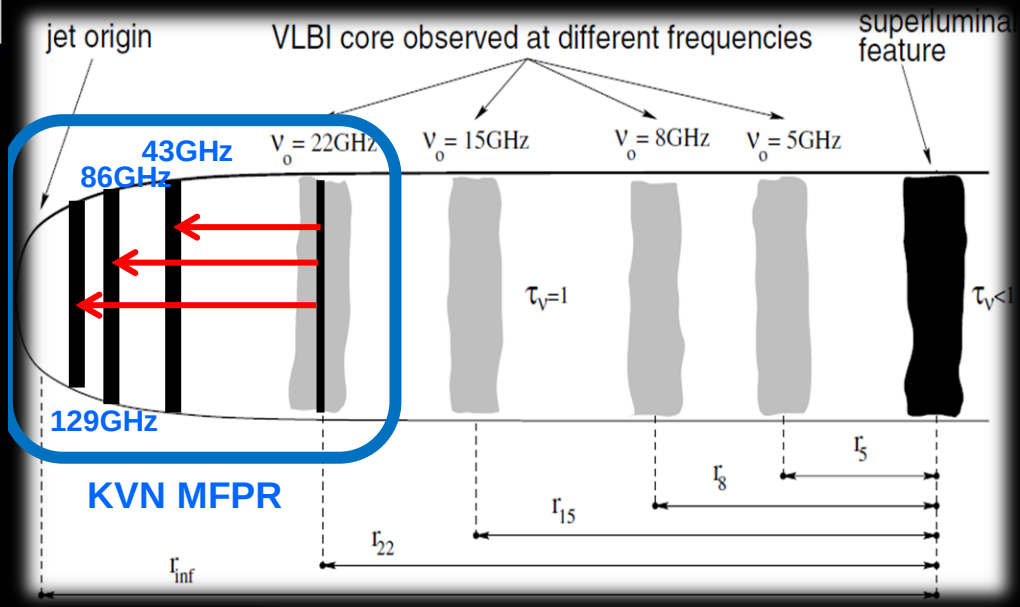
- Dodson et al. 2014
- Simultaneous observation of H_2O & SiO (v=1 & 2) maser lines for R Leo Minoris
- SiO maser phase referenced to H_2O maser



- Rioja et al. 2014
- Simultaneous 22/43GHz
  - 0854+213 w/ reference OJ287
  - 1.2deg away
- Core shift accuracy ~ 40 μas
- Consistent with VLBA within 1σ-error
- Structure blending effect should be considered
- Flux recovery ~ 94% using KVN SFPR

New Method in mm-VLBI Astrometry

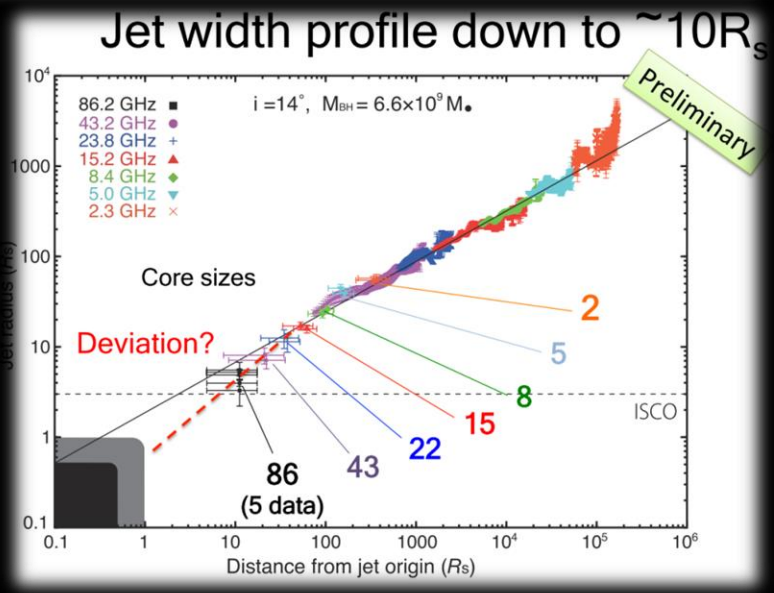




Simultaneous multi-frequency observation

Perfect calibration to the troposphere

Ideal methods, especially mm/sub-mm VLBI



Unique access to the inner most region of the Jets

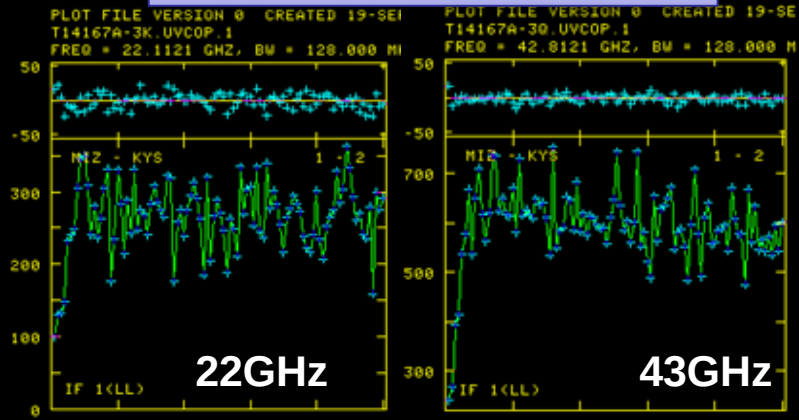
➔ High precision VLBI astrometry can be achieved at mm/sub-mm wavelengths with unprecedented sensitivity

Quasi-Optics as a Powerful Tool of mm-VLBI in Collaboration with VERA 20m

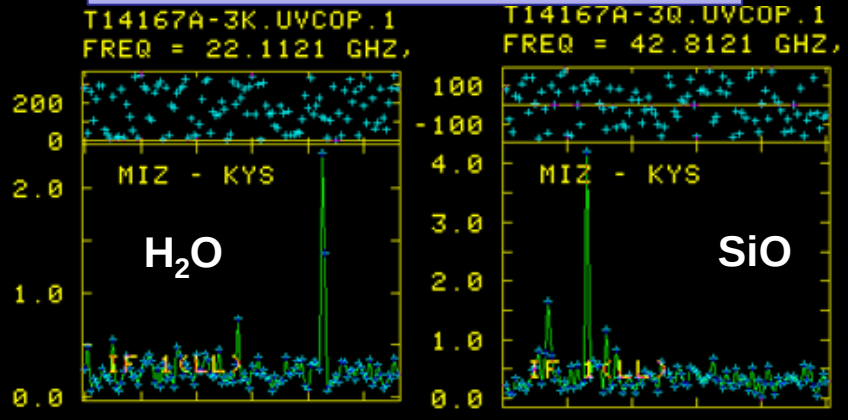
History & Plans

- 2013 Nov : Manufacture
- 2013 Dec. : Shipping & Installation
- 2014 Jun : K/Q VLBI fringe test
- 2014 Sep : Fringe Detection
- 2014 Dec : Science verification test
- 2015 VERA QO for Miz & Iri stations

K/Q simultaneous fringes of OJ287

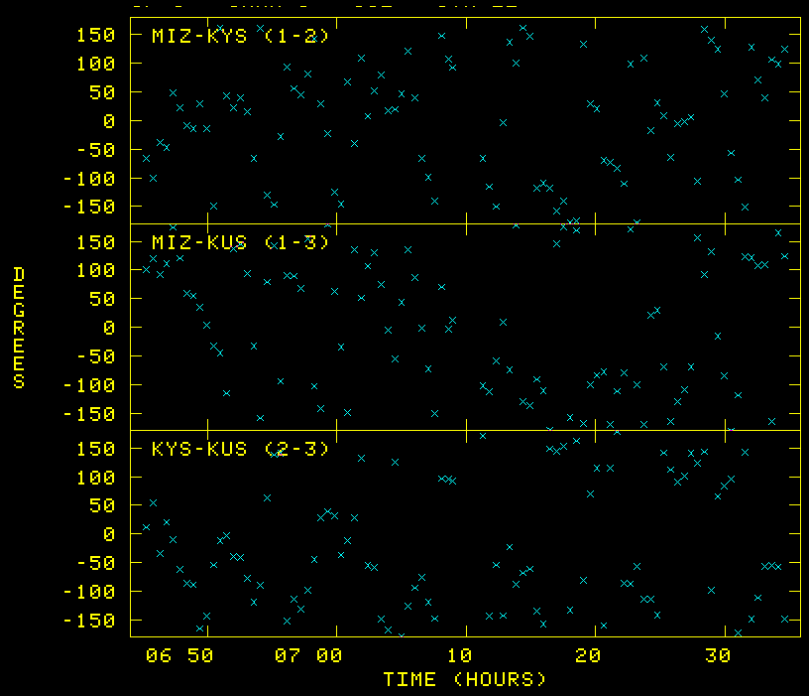


H_20/SiO Simultaneous fringes of ORION-KL

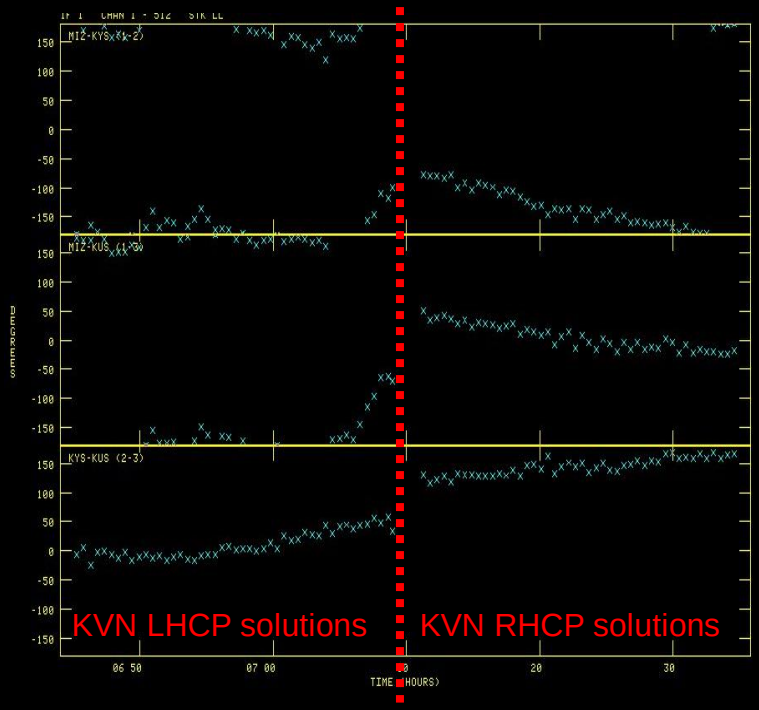


Phase Correction with QO systems (K→Q, OJ287)

Q-band Visibility Phase
No calibration applied



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

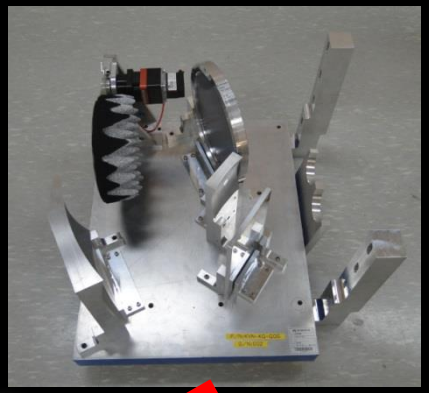


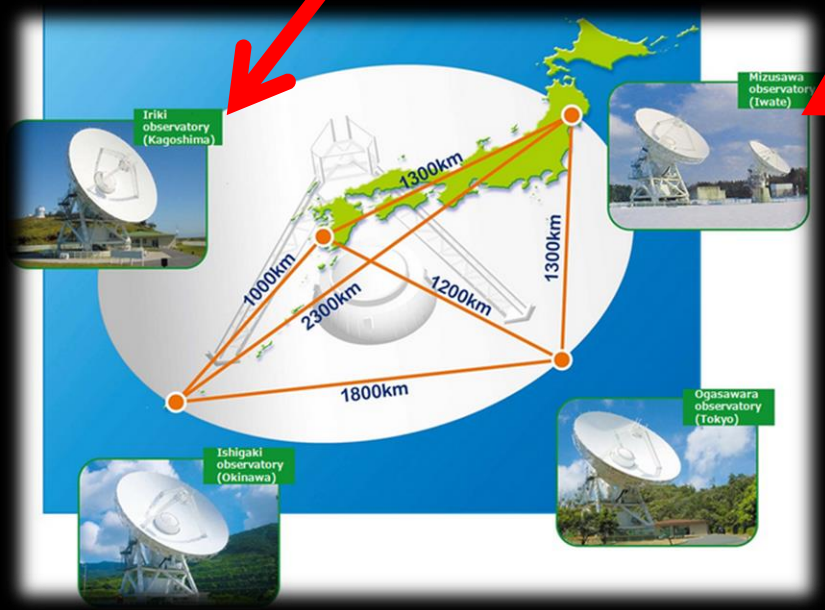
- K-band fringe phase solutions of OJ287 were applied to calibrate Q-band data
- Visibility phase of Q-band calibrated by K-band shows more stable phase than raw data although there are high phase rates at MIZ related baselines
  ➔ The feasibility of K/Q simultaneous observing system has been demonstrated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

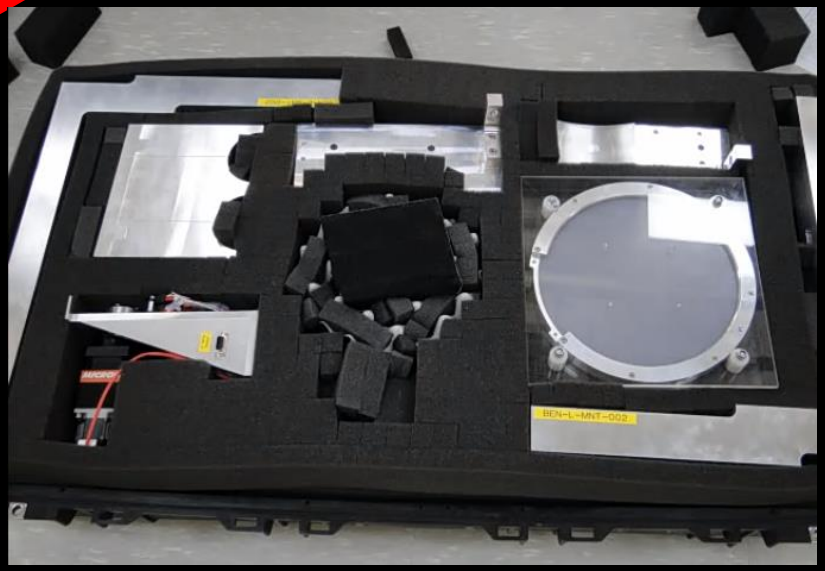
- Science demonstrations has been conducted on be half of KaVA science sub-working group in Feb 2014.

Upgraded Quasi-Optics for VERA Mizusawa & Iriki Radio Telescopes

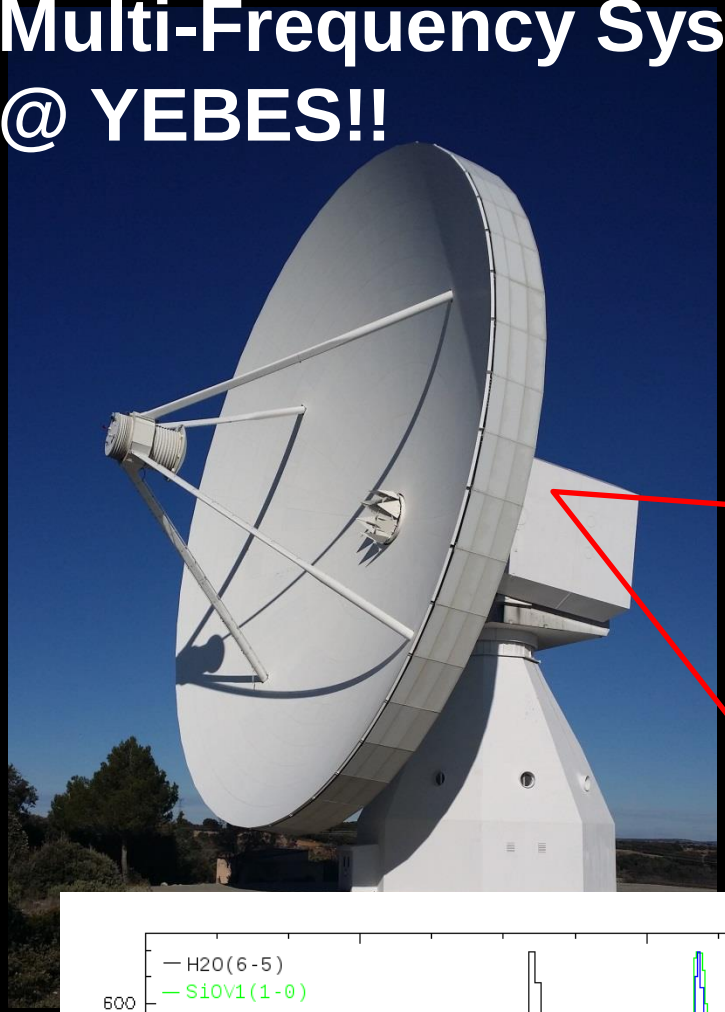
Delivery : Next week

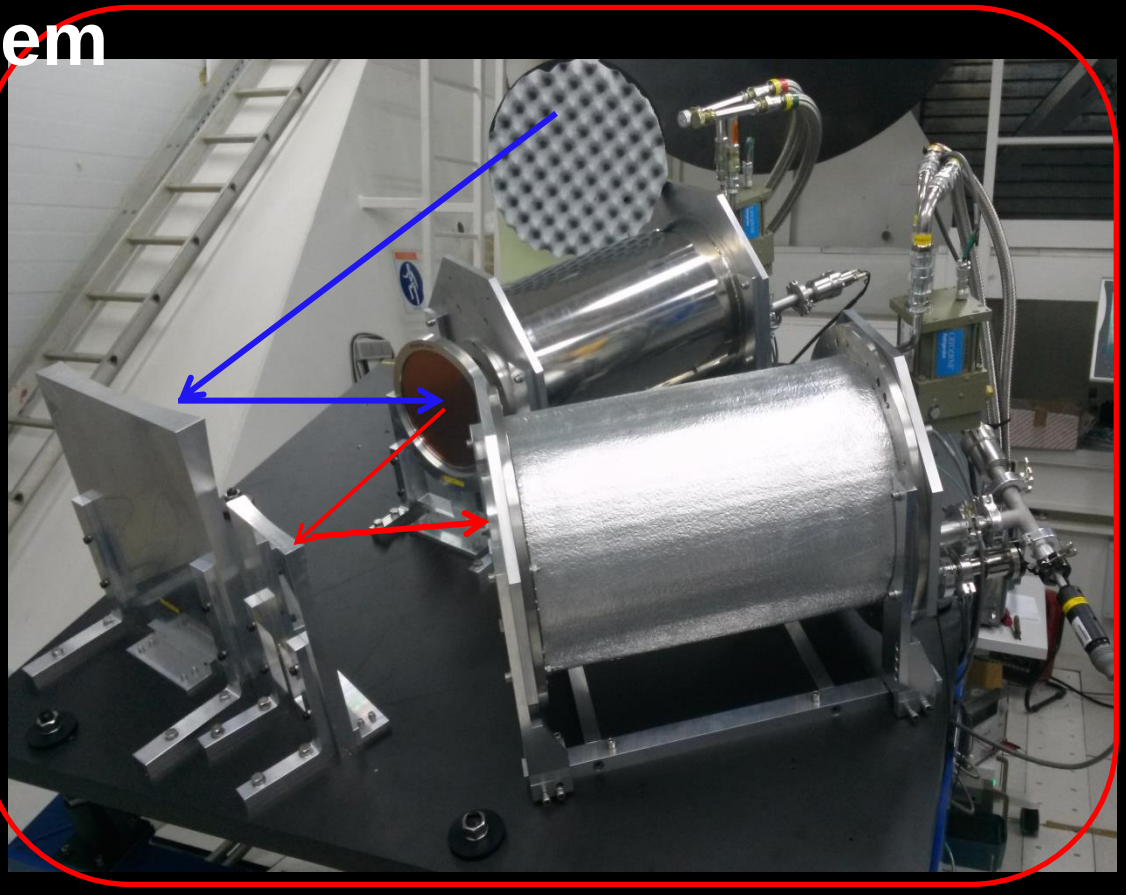


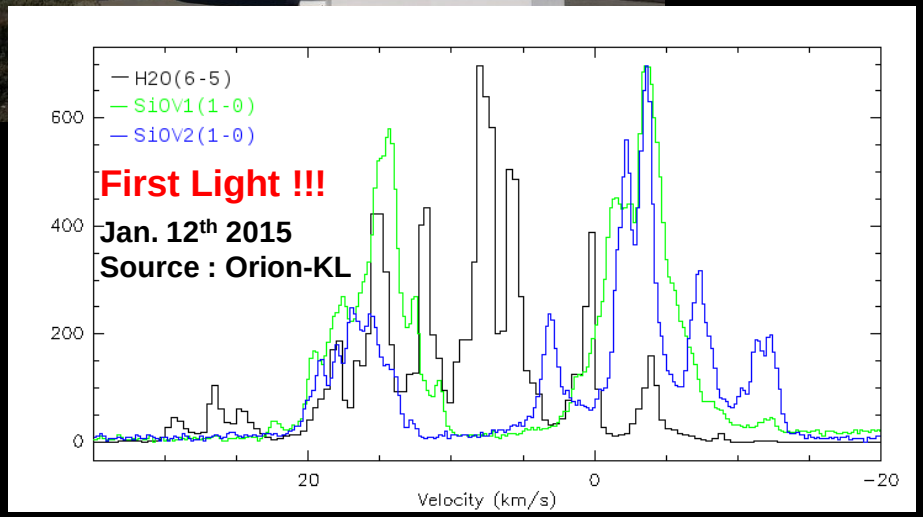


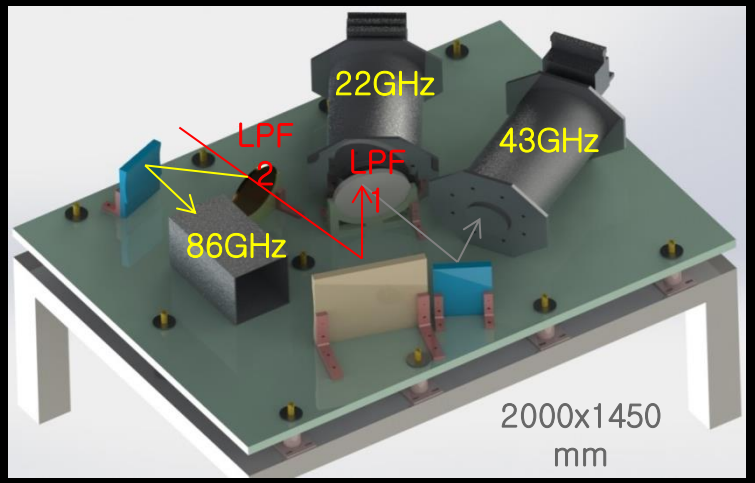


Multi-Frequency System @ YEBES!!





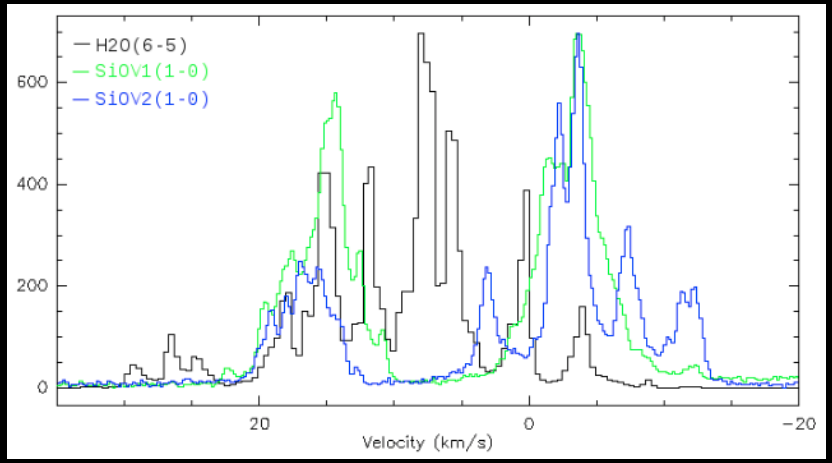


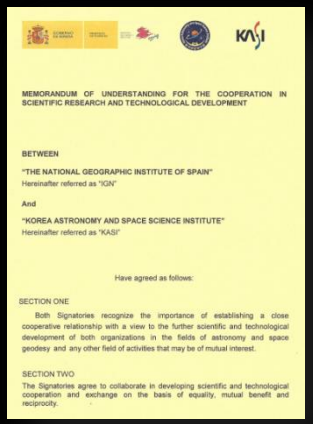


Quasi-Optics as a Powerful Tool of mm-VLBI in Collaboration with Yebes 40m

History & Plans

- 2013 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 Apr : First K/Q band fringe test
- 2015 Jun : Scientific demonstration test





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"

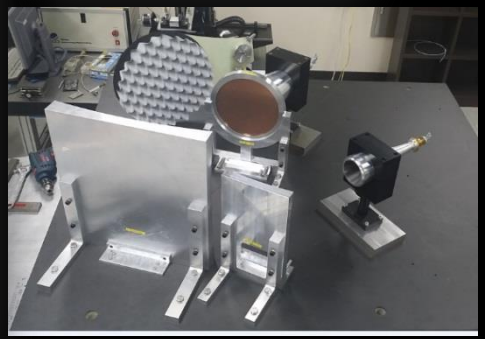
Have agreed as follows:

SECTION ONE

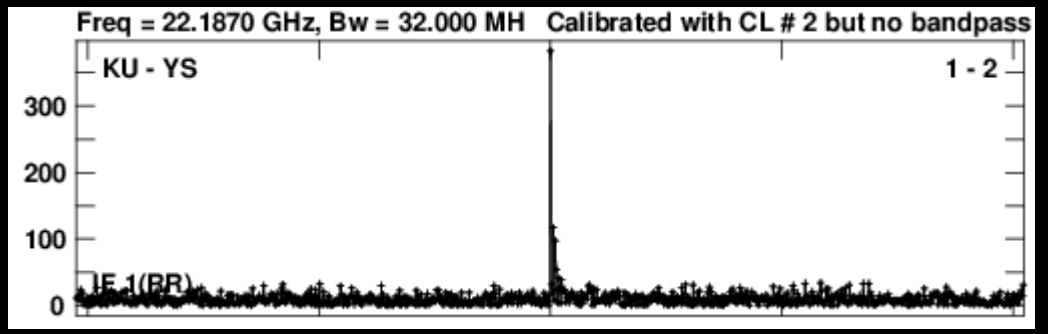
Both Signatories recognize the importance of establishing a close cooperative relationship with a view to the further scientific and technological development of both organizations in the fields of astronomy and space geodesy and any other field of activities that may be of mutual interest.

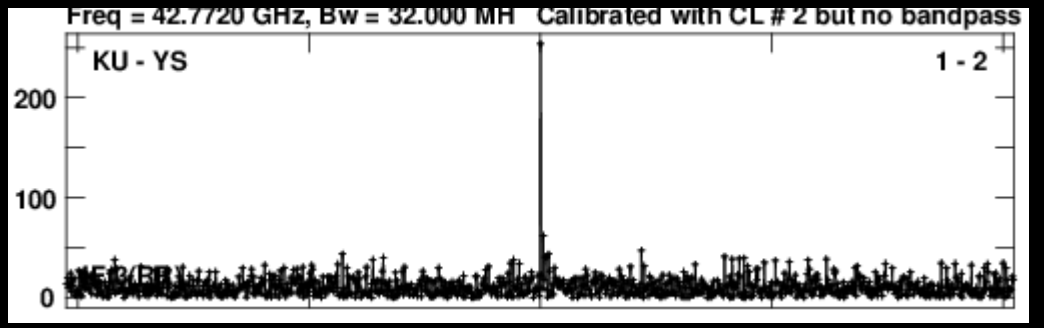
SECTION TWO

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



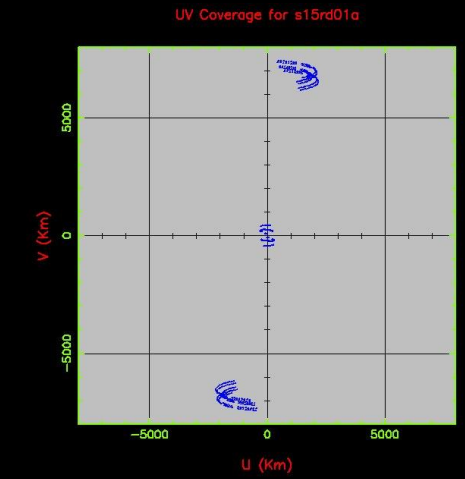
First K/Q simultaneous fringes between KVN Ulsan and Yebes

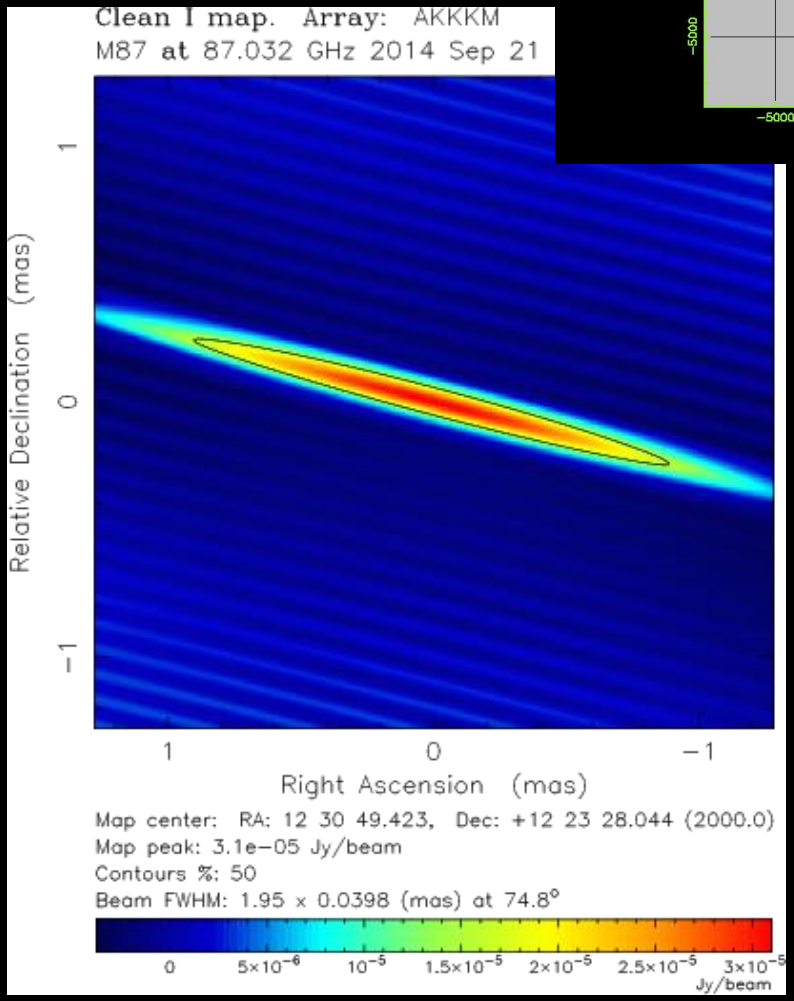




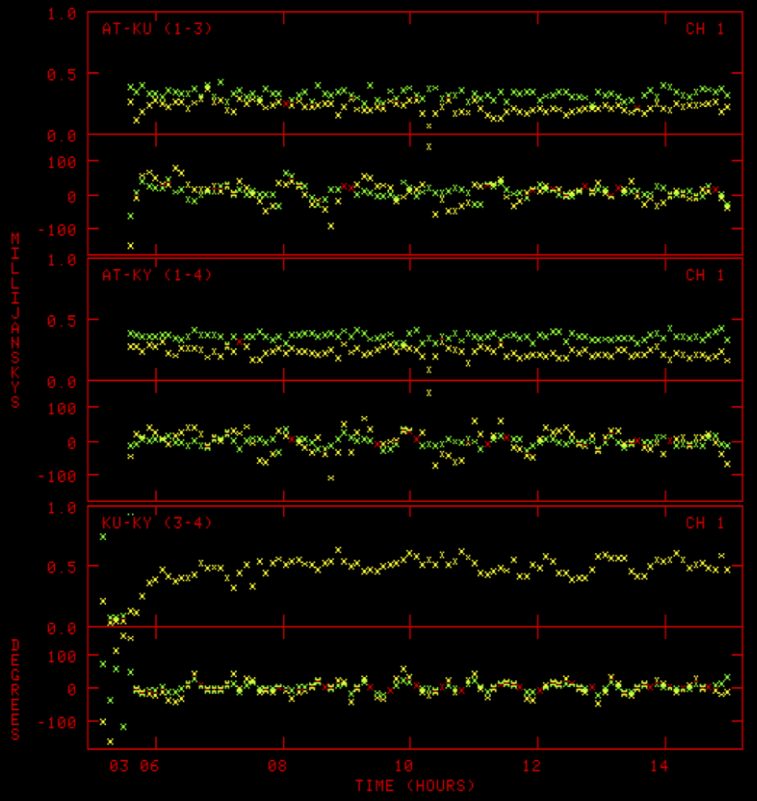
44/86GHz VLBI Observation with ATCA

- **80 micro-arcsecond** fringes between northern and southern hemisphere baselines !!





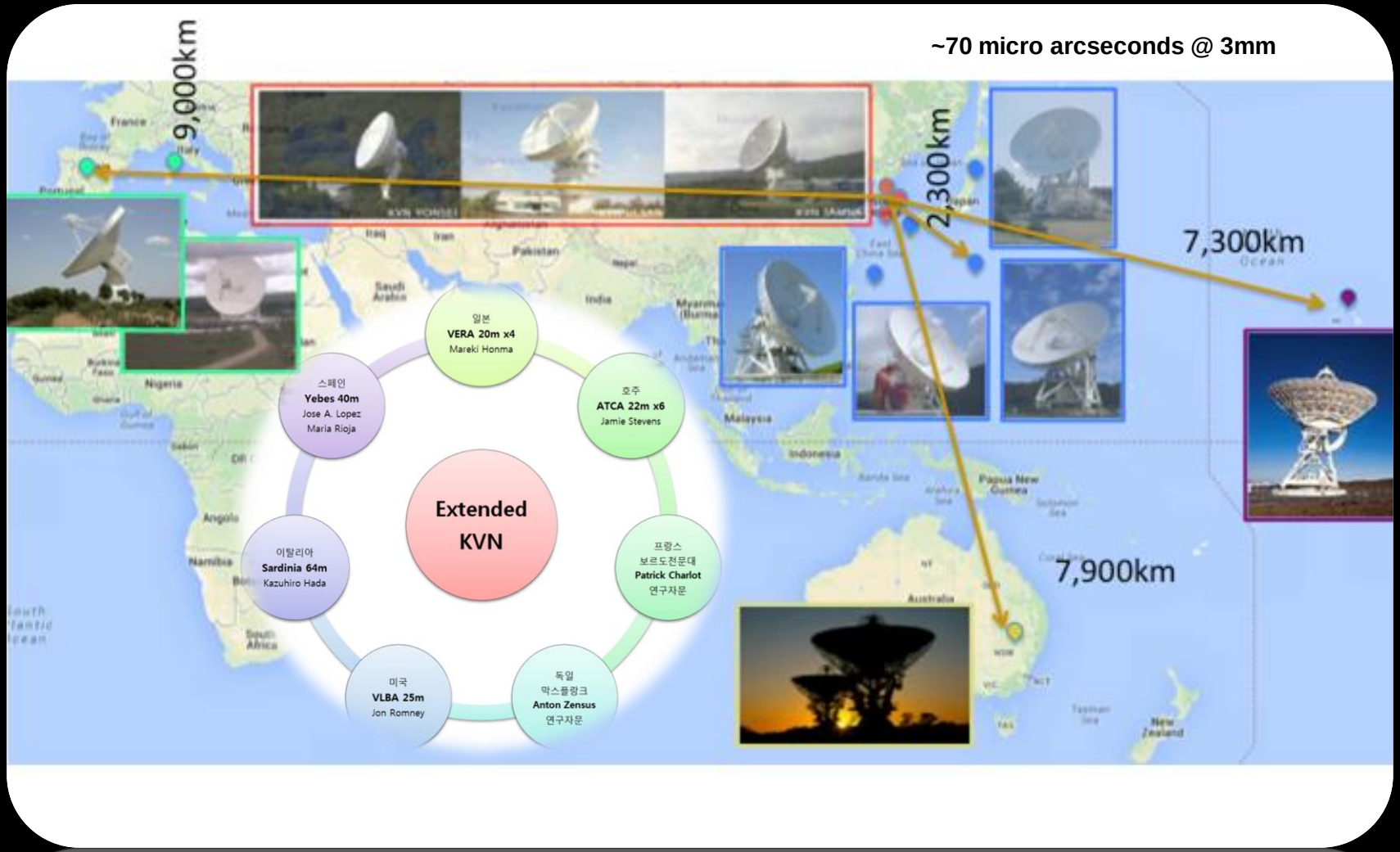
3C273 44/88 GHz
(North-South Baseline)



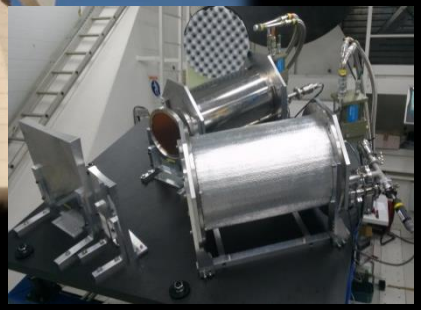
Better Resolution & More Sensitivity
with Global Multi-Frequency System

because it's Simple & Powerful

more observing time, multi-frequency data, tropospheric calibration

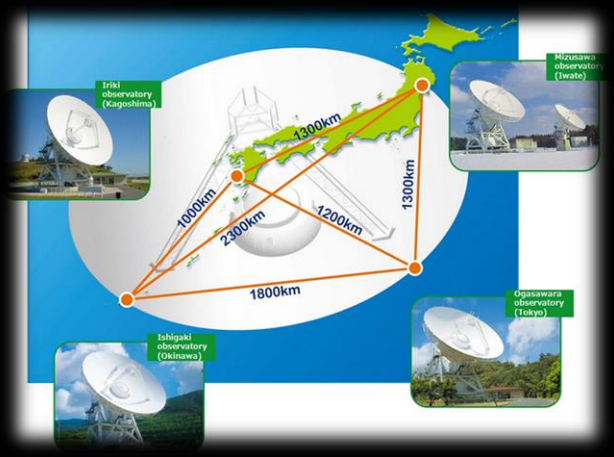


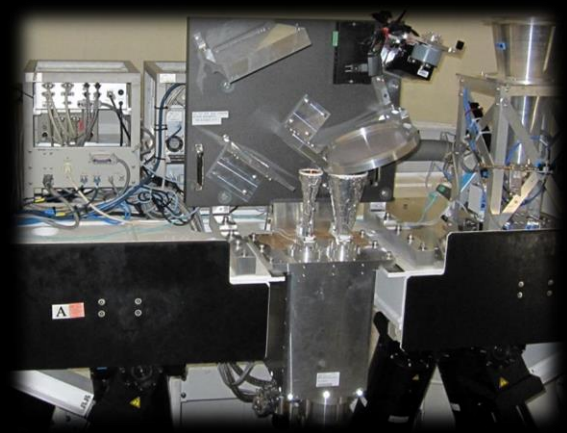
International Collaborations!!



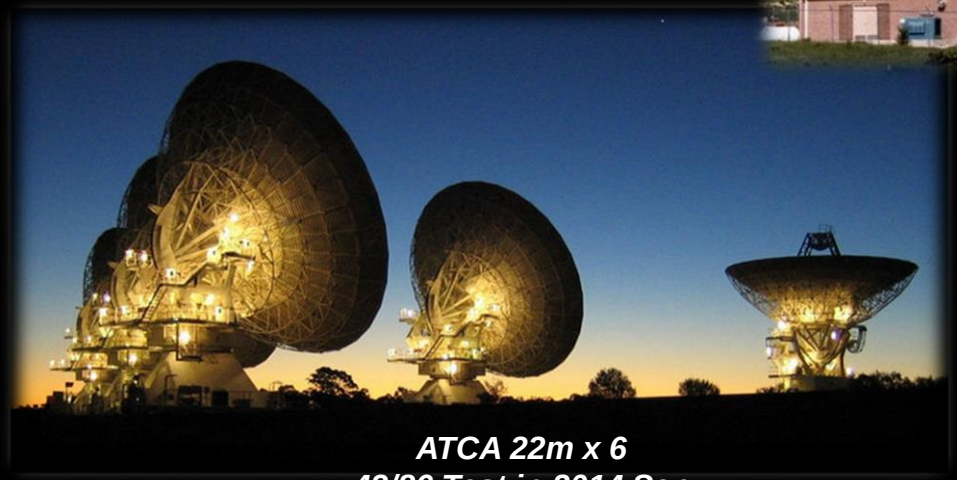
Yebes 40m
22/43/(86/129)
22/43 Installation
in 2014 Nov

VERA 20m. 22/43 Fringe Test 2014 June





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



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

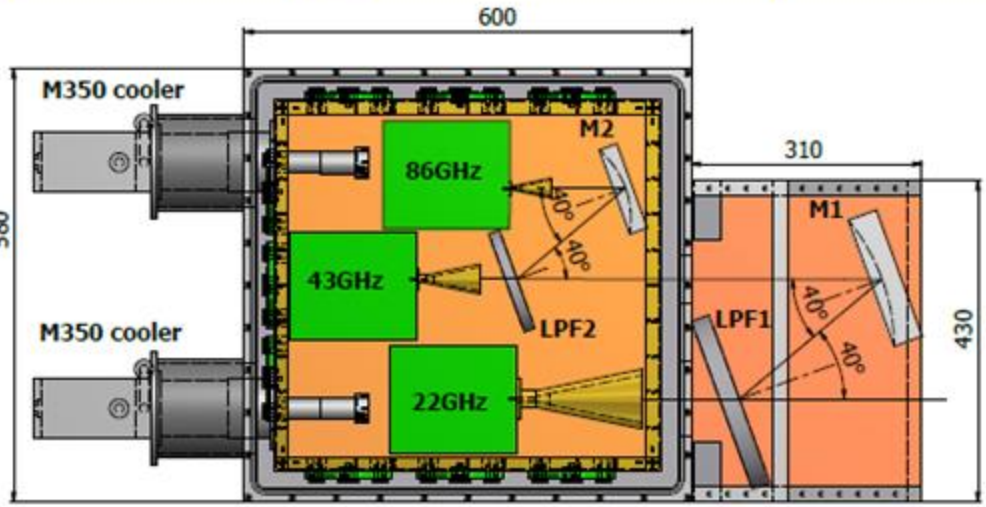
Noto or Sardinia in near future??

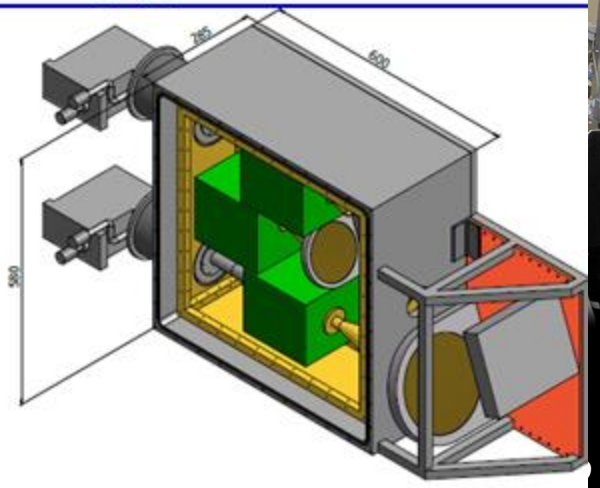
International

Co

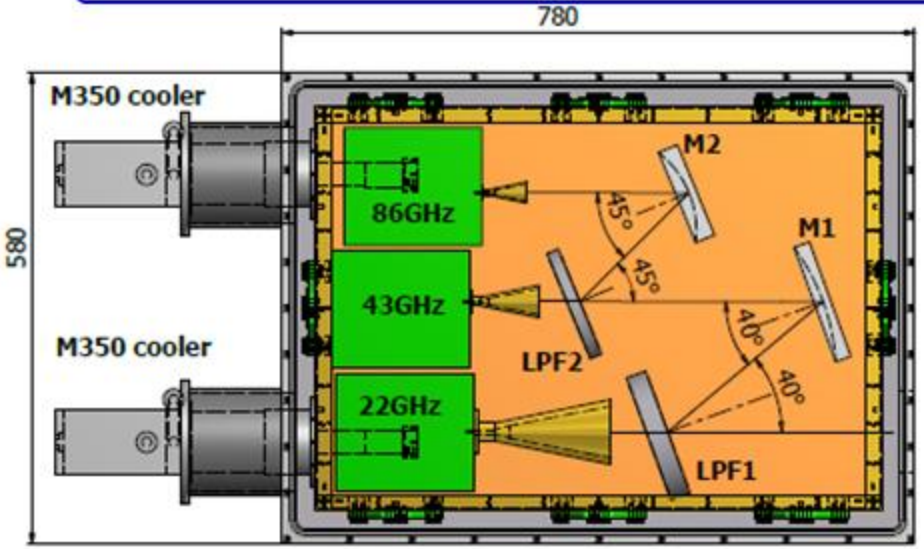
VERA 20m. 22/43 Fringe Test 2014 June

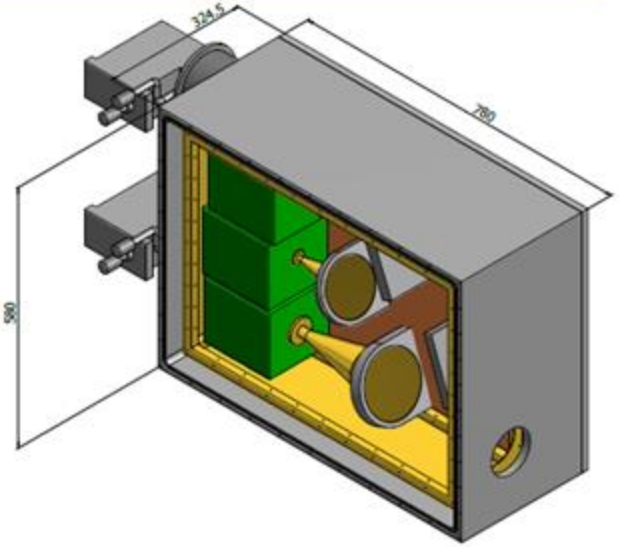
Cryogenic chamber and optical circuit for K/Q /W bands





Optical circuit for K/Q/W bands installed in cryogenic chamber





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

Noto or Sardinia in near future??

http://www.ira.inaf.it/eratec/florence

RadioNet ERATec

HOMEPAGE CONTACT US

RadioNet3 is made possible by the EU Seventh Framework Programme (FP7), Contract No. 283393.

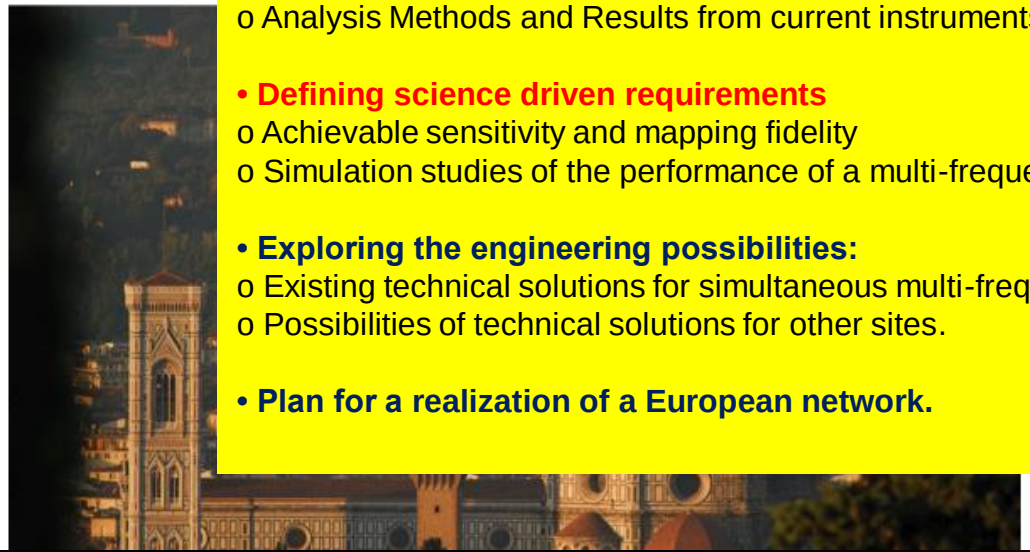
MULTI-FREQUENCY MM-WAVE RADIO TELESCOPES & OTHE

OCTOBER 5 – 7
ARCETRI ASTRO
FLORENCE, ITAL

INFO & TO-DO

Workshop program

Registration



Topics to address are the following:

FOR THE IMPLEMENTATION OF (NEAR) SIMULTANEOUS OBSERVATIONS AT MM-WAVE BANDS:

- **mm-VLBI Studies and Key Science Case(s):**
  - o Astronomical Studies using continuum and spectral line observations
  - o Analysis Methods and Results from current instruments using multi- frequency observations
- **Defining science driven requirements**
  - o Achievable sensitivity and mapping fidelity
  - o Simulation studies of the performance of a multi-frequency mm-VLBI network of European telescopes
- **Exploring the engineering possibilities:**
  - o Existing technical solutions for simultaneous multi-frequency observations;
  - o Possibilities of technical solutions for other sites.
- **Plan for a realization of a European network.**


Tamna 21 m
Miyun 50 m
KASI/KJVC
Sejong 22 m
Yonsei 21 m
Ulsan 21 m
Gifu 11 m
Usuda 64 m
Tomakomai 11 m
Nanshan 26 m
Mizusawa 20 m
Tianma 65 m
Takahagi 32 m
Sheshan 25 m
SHAO/DiFX
Kunming 40 m
Yamaguchi 32 m
Ishigakijima 20 m
Hitachi 32 m
Iriki 20 m
Tsukuba 32 m
Ogasawara 20 m
Kashima 34 m
Thank you for your attention!
For the best mm-VLBI network
with Multi-frequency System
The East-Asian VLBI Network
(Image Credit: Reto Stöckli, NASA Earth Observatory)
6.7 GHz
8 GHz
22 GHz
43 GHz