History of VLBI in China

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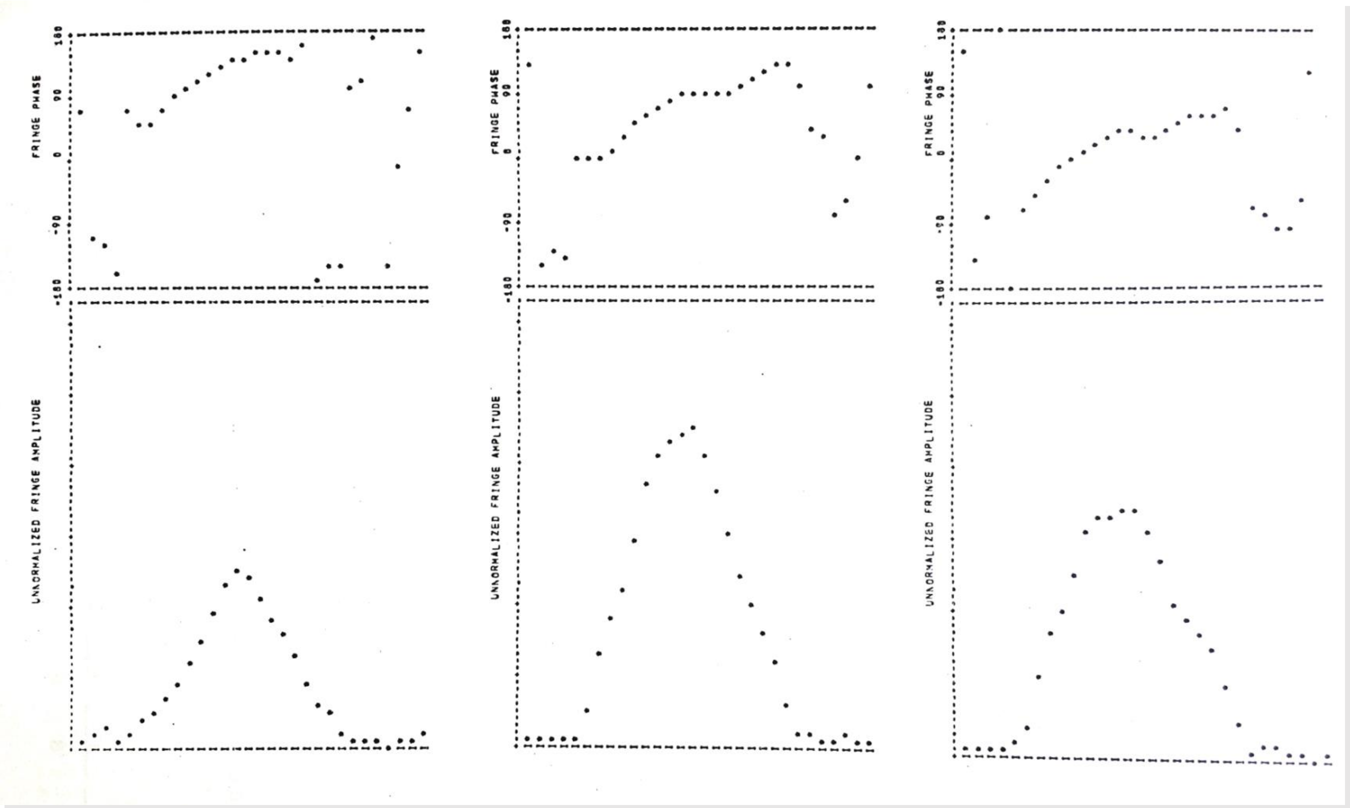
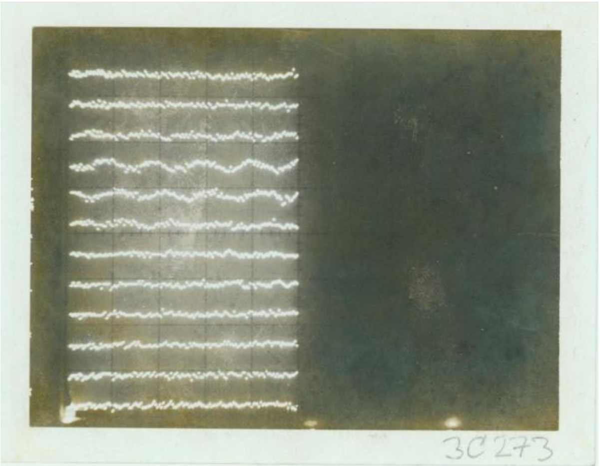
1967: First VLBI Experiments in USA and Canada

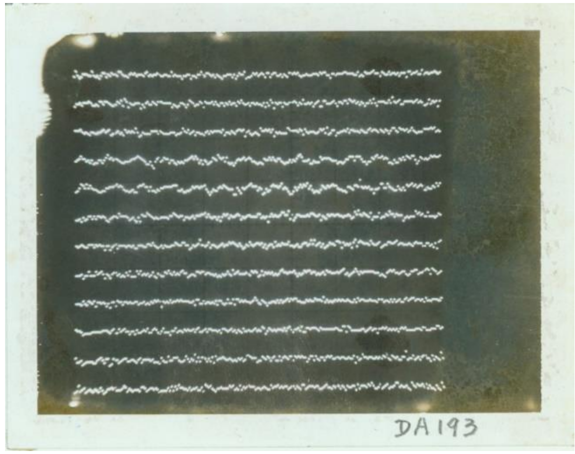
Three groups -- one Canadian, another a collaboration between NRAO and Cornell University, and a third at MIT and Haystack Observatory -- were each working to achieve the first VLBI observation.



Plots from the first VLBI measurements between Haystack and NRAO Greenbank from measurements recorded on **June 8, 1967**. (Image credit: Moran, J.M 1968, "Interferometric Observations of Galactic OH Emission," PhD thesis, MIT, p. 160.,.)

- **1975 A research group in ShAO led by Prof. Ye Shuhua submitted a proposal on the feasibility study of VLBI development in China.**
- **1981 Nov: First fringe detected between Shanghai and Effelsberg.**
- **First trans-Eurasian continent VLBI experiment in the word!**





VLBI Development in China

- 1970s VLBI Network Concept
- 1987 Shanghai 25m

- 1993 Urumqi 25m

ChangE National Project (2004-2021)

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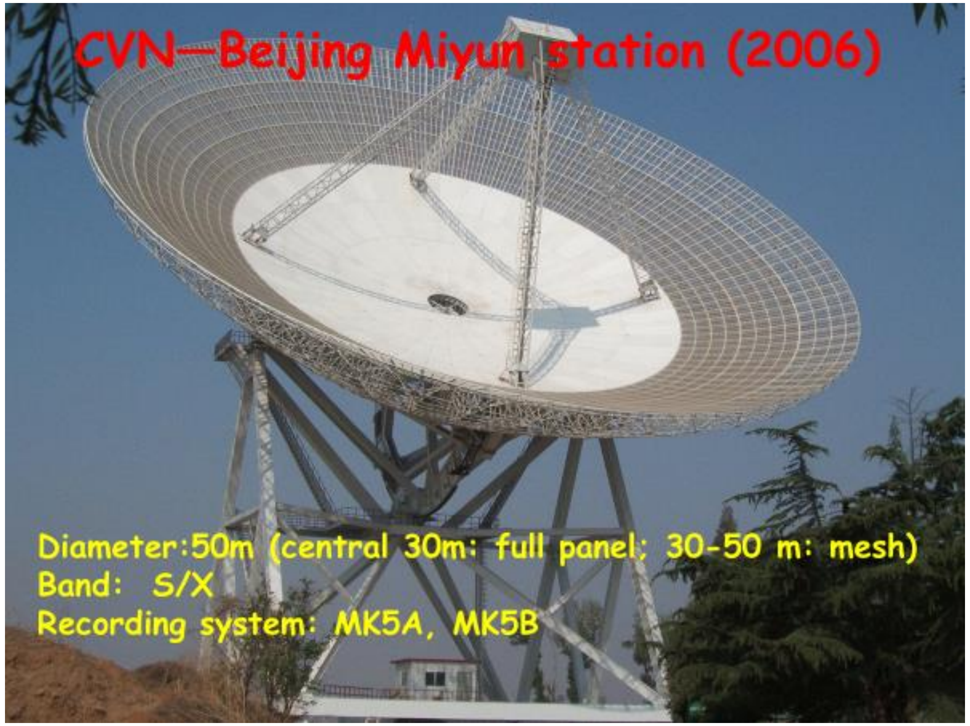
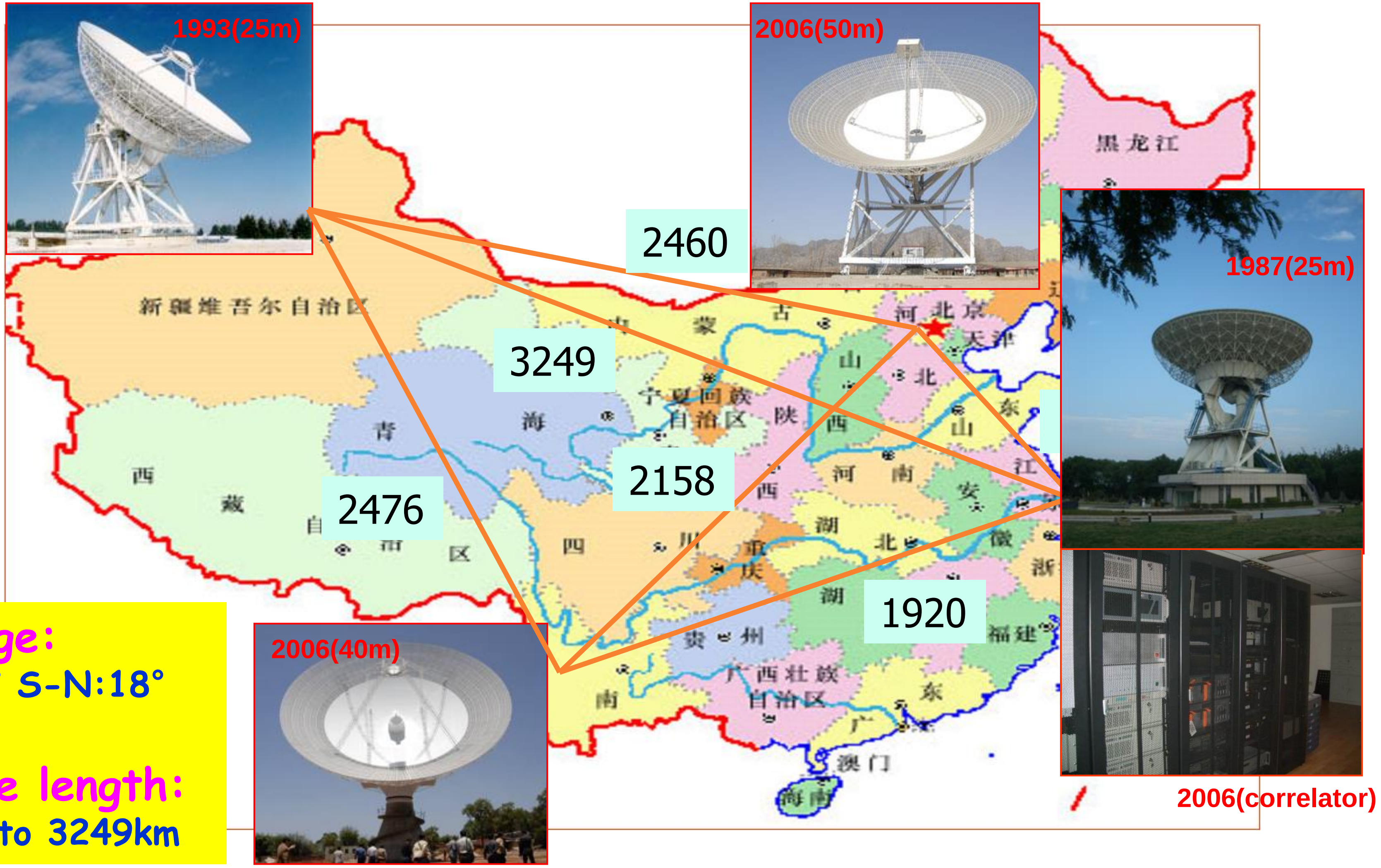
- 2006 Beijing 50m & Kunming 40m + Correlator Center



CVN—Kunming station (2006)

Chinese VLBI Network (CVN):
4 stations+ soft/hard-ware correlators



Coverage:
E-W:34° S-N:18°

Baseline length:
1115km to 3249km

Technical specs of CVN antennas

	Shanghai	Urumqi	Beijing	Kunming
Operation start (yr)	1987	1993	2006	2006
Structure	BWG, Cassegrain	BWG, Cassegrain	Prime focus	BWG, Cassegrain
Size in Diameter (m)	25	25	50 (30 +20)	40 (25+15)
Pointing (arc-sec)	20	15	19	30
Az/El Slewing rate (degree/sec)	1.0/0.6	1.0/0.5	1.0/0.5	1.0/0.5
Receiver bands	L, C, S/X, K	P, L, C, S/X, K	S/X	S/X, C
Efficiency (at S/X band)	38%/40%	54%/52%	60%/68%	64%/47%
Recording terminal	Mark5B, 5A, VLBA, S2, K4	Mark5B, K4	Mark5B	Mark5B

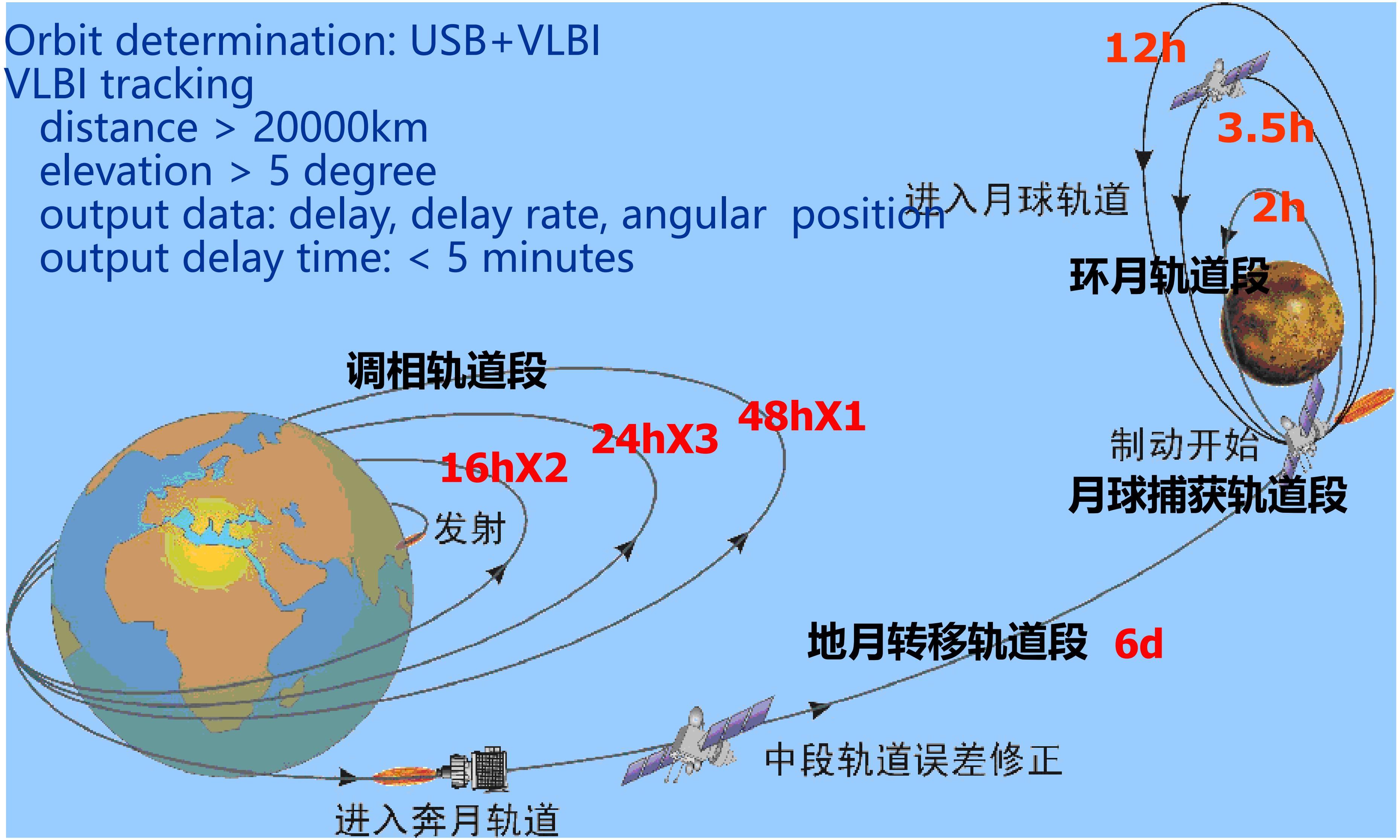
Output data: CE format (for satellite tracking)
FITS format (for astronomy)

CVN - Application to CE-1

Orbit determination: USB+VLBI

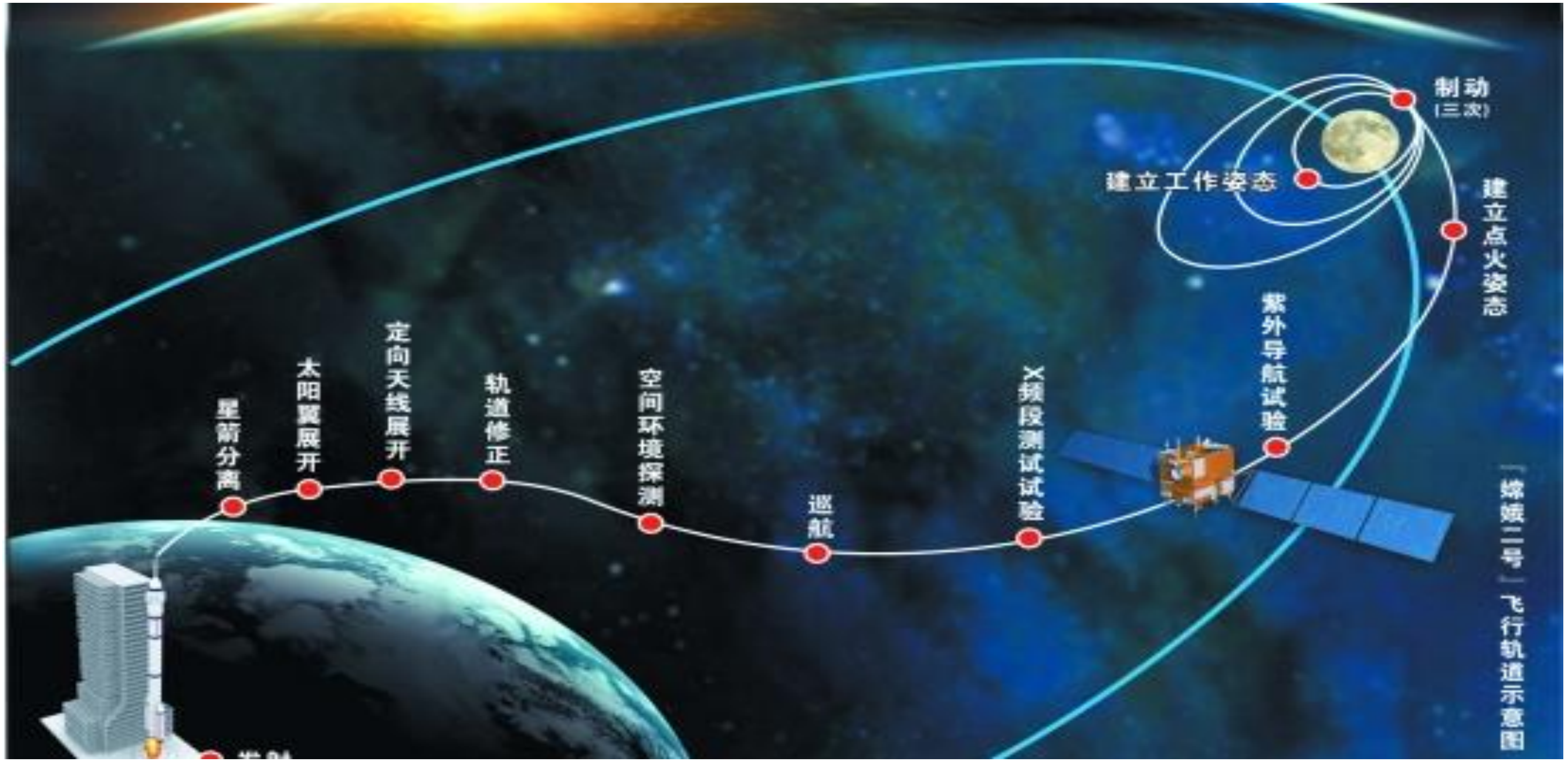
VLBI tracking

- distance > 20000km
- elevation > 5 degree
- output data: delay, delay rate, angular position
- output delay time: < 5 minutes



CVN - Application to CE-2

It took about 112 hours (< 5 days) for CE-2 to arrive at its lunar orbit (c.f. 12 days for CE-1).



Near-real CVN observations at S/X band: 32Mbps/station; 10 hr/day accuracy: delay (~1ns) , delay rate (~0.5ps/s)

ShanghaiTianma (65-m) Radio telescope

~40% increase of the sensitivity of CVN with the 65-m

In 2021; Full cm wavebands (1.4–50 GHz) w/ 8 sets of Rxs; **active surface**

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- 1970s VLBI Network Concept
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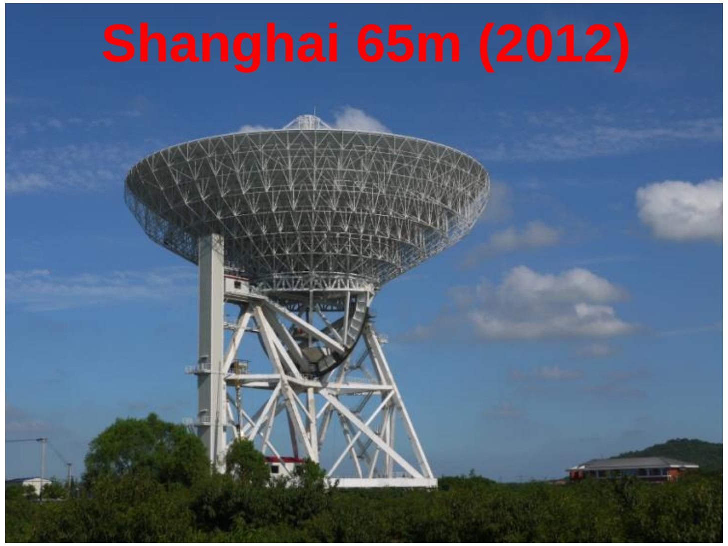
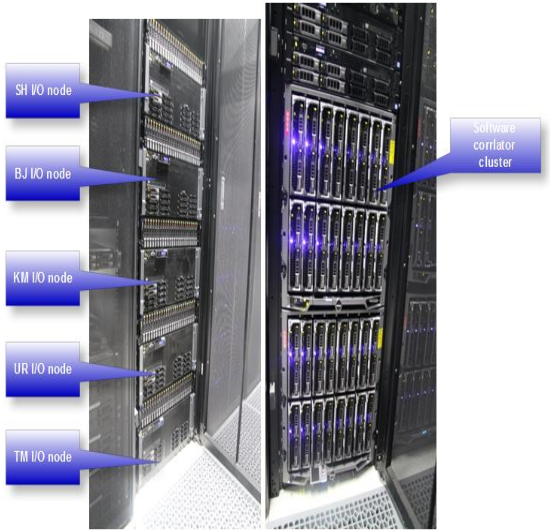
- 2006 Beijing 50m & Kunming 40m + Correlator Center

  pre-study of Space VLBI

- 2010s Shanghai 65m, FAST (500m)



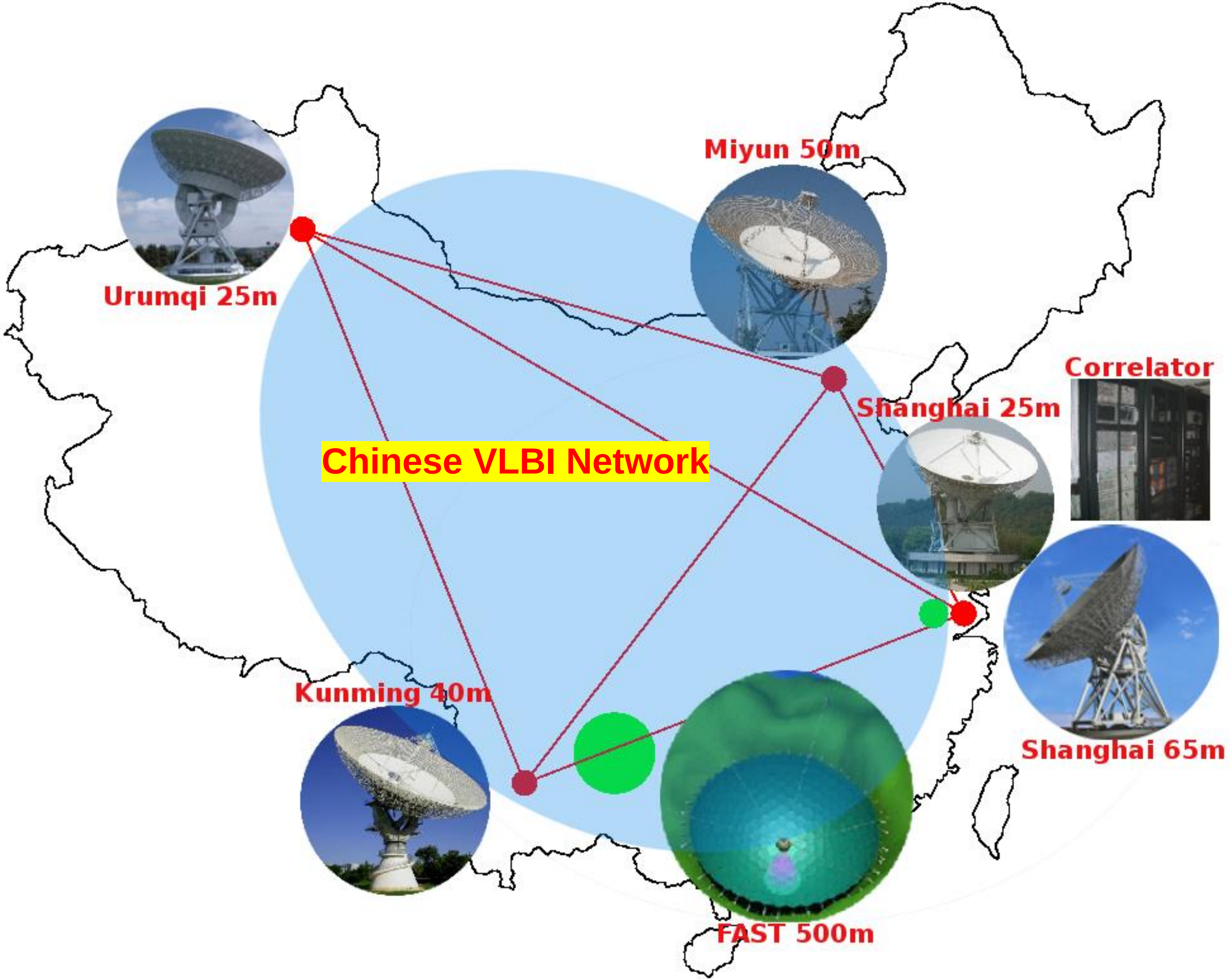
CVN-VLBI Center



Hardware correlator

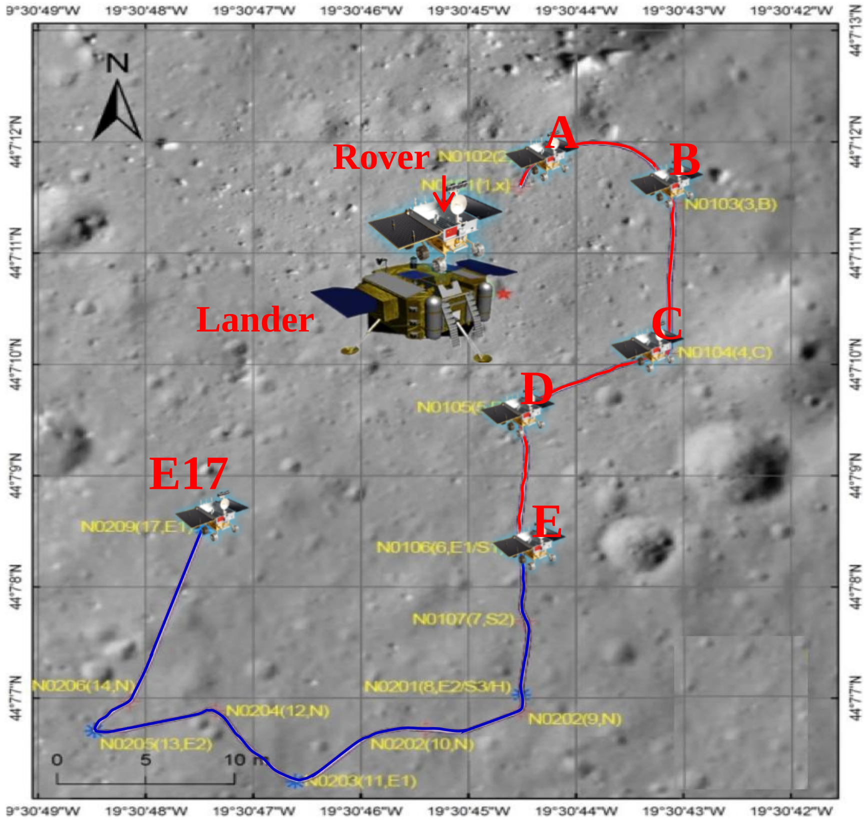
CVN software correlator

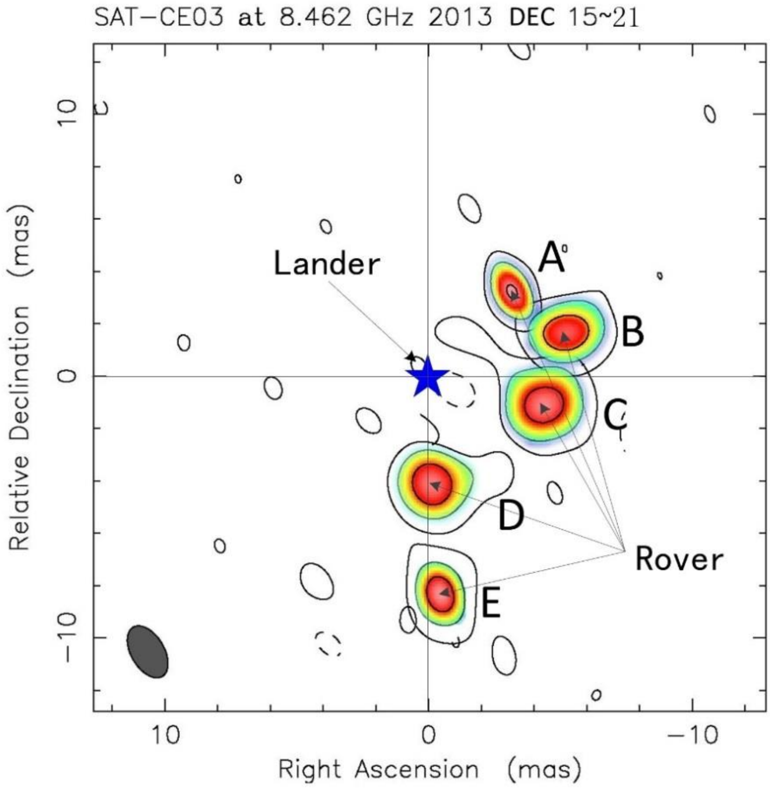
DiFX correlator


Miyun 50m
Urumqi 25m
Correlator
Shanghai 25m
Chinese VLBI Network
Kunming 40m
Shanghai 65m
FAST 500m

Phase-reference results of CE-3 Rover

- ➢Target: Rover using the Lander as the Calibrator.
- ➢The accuracy of the relative position between Lander and Rover is ~1m (0.5mas).

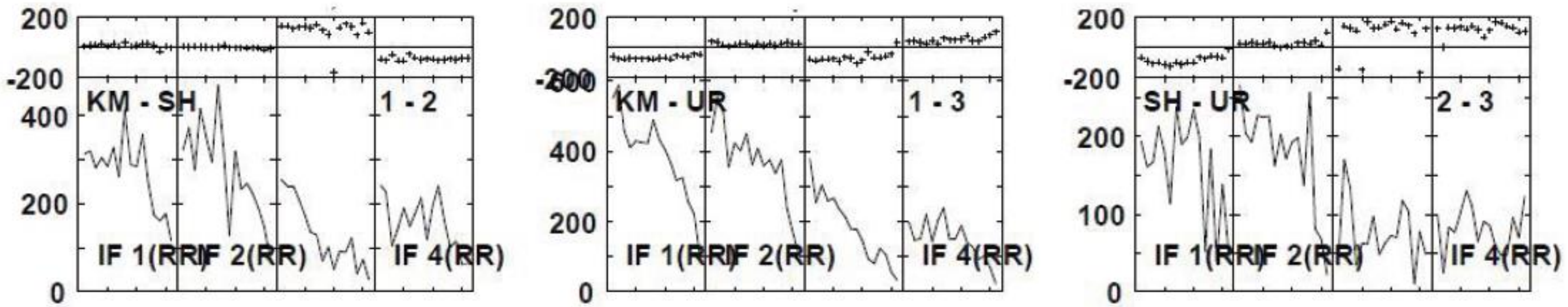




Pulsar Astrometry with CVN

CVN (Km+Sh+Ur); PSR B0329+54 (200 mJy @ 1.4 GHz); phase-ref

~3 hr (2008 Oct 16) @ S-band; software correlator (DiFX)



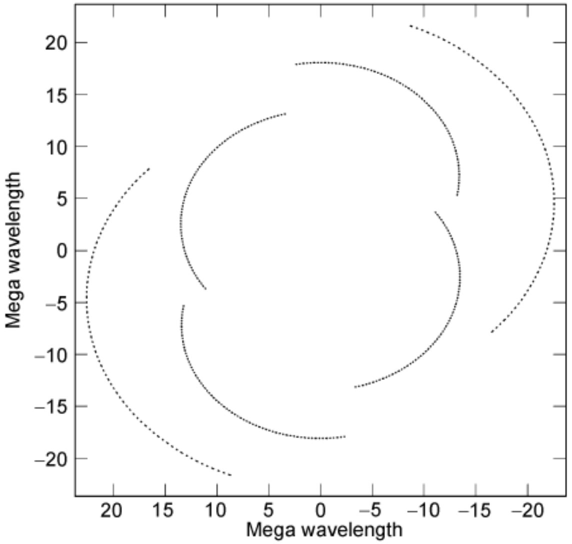


Figure 1 The (u, v) coverage obtained for PSR B0329+54 at 2.2 GHz from 3 baselines formed from the CVN antennas Shanghai Kunming and Urumqi.

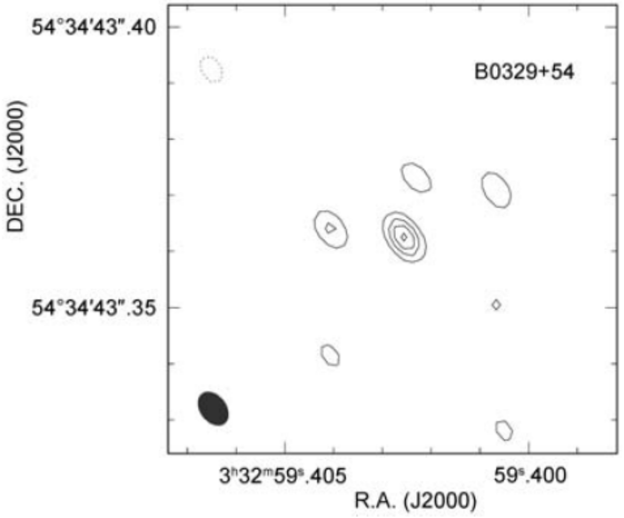


Figure 4 Image of PSR B0329+54 observed with CVN at 2.2 GHz. Contour levels are spaced linearly at 8.0 mJY beam^{-1} (2σ). The peak flux density is 23 mJy beam^{-1}.

(Guo et al. 2010)

VLBI astrometry/geodesy

- With the current CVN geometry and specifications, several dozens of **ICRF defining sources** could be monitored on a regular base.

- Capable of determining distance of several 1000 km at cm and even mm accuracy.

  Simultaneous observations of CVN and international VLBI antennas could also be used to study **crustal motion and deformation**.

- Regular determination of **EOP** (VGOS).

New 13-m VGOS antenna at Sheshan

Sheshan 25m

Sheshan 13-m VGOS

e-VLBI

2007 August 28: Shanghai –Australia & Europe (256Mbps)
2008 June 17: Shanghai –Australia & Japan (512Mbps)
2009 January 6: Shanghai-Urumqi (256Mbps)
2009 January 15-16: IYA marathon obs. (Asia, Australia, Europe, America)
2009 February - : Shanghai 25-m participates in the routine eEVN sessions

Broadband Observations

Mon. Not. R. Astron. Soc. **426,** L66–L70 (2012) doi:10.1111/j.1745-3933.2012.01327.x

Very long baseline interferometry detection of the Galactic black hole binary candidate MAXI J1836−194

Jun Yang,[1★] Yonghua Xu,[2,3] Zhixuan Li,[2,3] Zsolt Paragi,[1] Robert M. Campbell,[1] Leonid I. Gurvits,[1,4] Zhiqiang Shen,[5,6] Xiaoyu Hong,[5,6] Bo Xia[5,6] and Fengchun Shu[5,6]

ABSTRACT

The X-ray transient MAXI J1836−194 is a newly identified Galactic black hole binary candidate. As most X-ray transients, it was discovered at the beginning of an X-ray outburst. After the initial canonical X-ray hard state, the outburst evolved into a hard intermediate state and then went back to the hard state. The existing RATAN-600 radio monitoring observations revealed that it was variable on a time-scale of days and had a flat or inverted spectrum, consistent with optically thick synchrotron emission, possibly from a self-absorbed jet in the vicinity of the central compact object. We observed the transient in the hard state near the end of the X-ray outburst with the European very long baseline interferometry (VLBI) Network (EVN) at 5 GHz and the Chinese VLBI Network (CVN) at 2.3 and 8.3 GHz. The 8.3-GHz observations were carried out at a recording rate of 2048 Mbps using the newly developed Chinese VLBI data acquisition system, twice higher than the recording rate used in the other observations. We successfully detected the low-declination source with a high confidence level in both observations. The source was unresolved ($\lesssim$0.5 mas), which is in agreement with an au-scale compact jet.

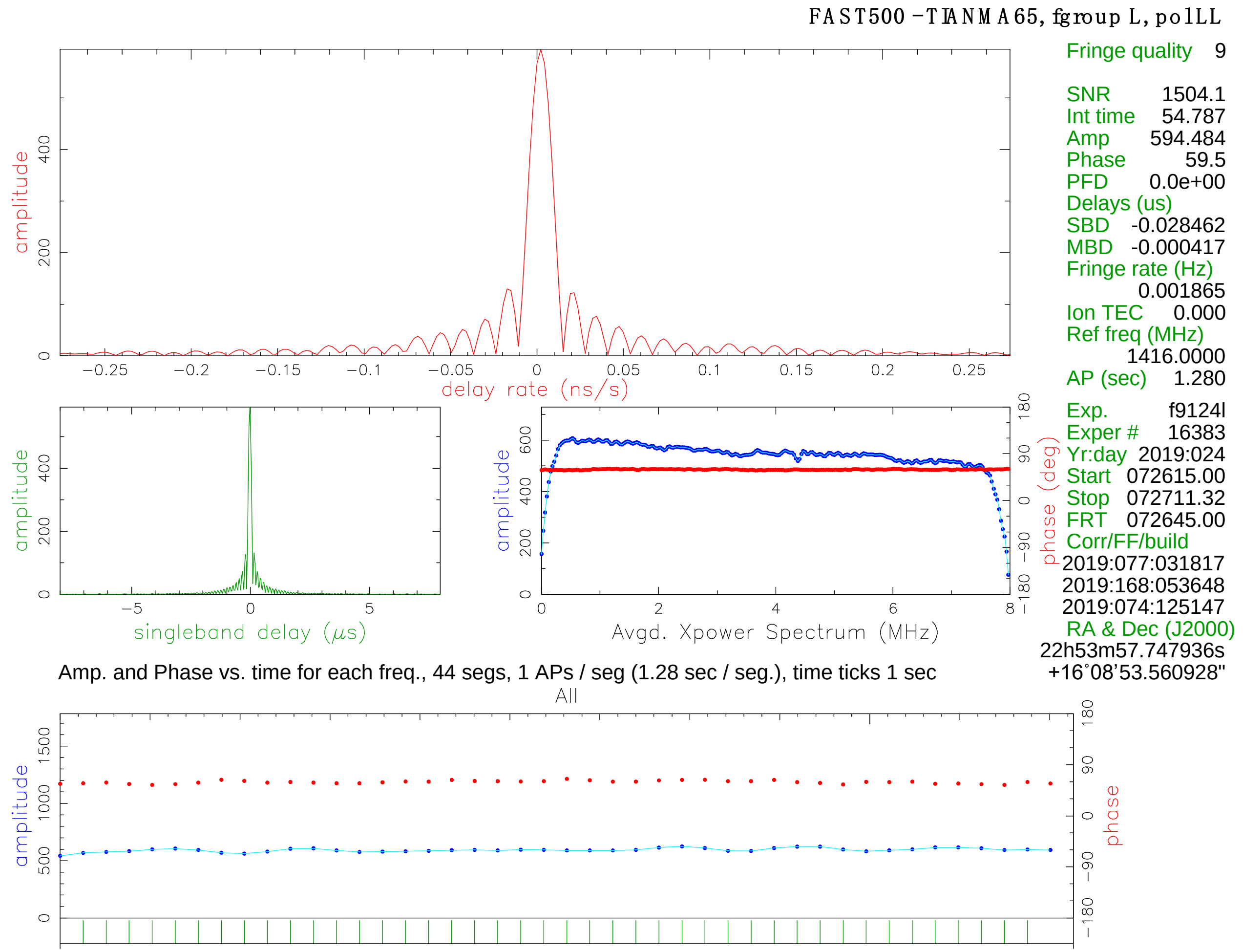
VLBI observations at L-band with FAST

FAST- Five-hundred-meter Aperture Spherical Telescope

- Unique Karst depression as the site
- Active main reflector
- Cable - parallel robot feed support

Approved in Nov 2005;
Start full construction in 2010;
9 bands from 70MHz to 3 GHz
Commissioning in 2016 Sept
VLBI fringe with TMRT in 2019 Jan!

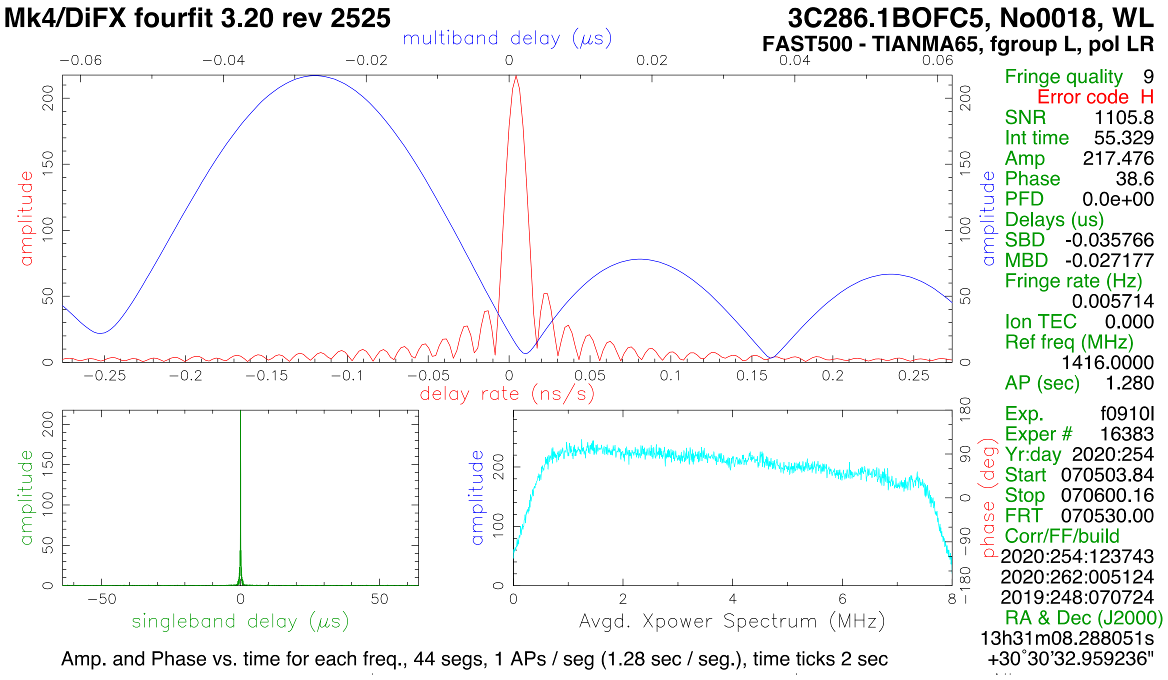
The 1st FAST VLBI fringe (FAST- Tianma 65m) on 2019 Jan 24!



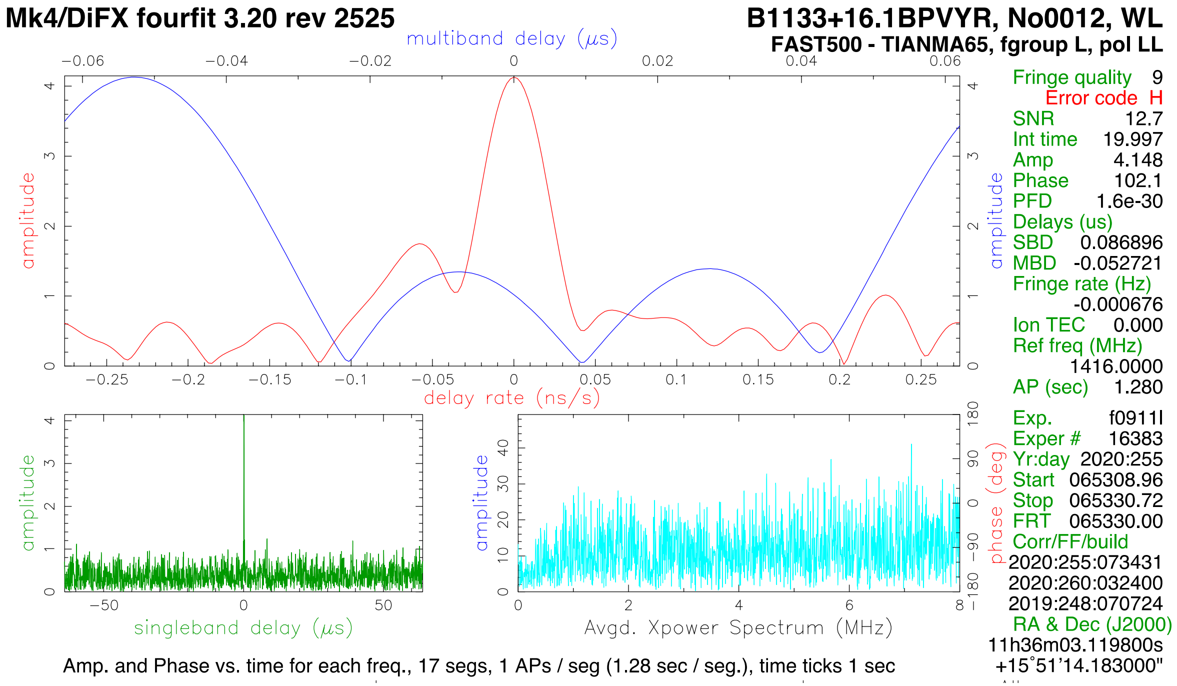
The first fringe between FAST and Tianma 65-m telescope. The signal-to-noise ratio (SNR) is 1504 with an integration period of 55 seconds, and the amplitude and phase are extremely stable during the 55-second scan. The bottom panel shows the fringe amplitude (blue) and phase (red), which are steady at ～600 and 60º, respectively. (Chen et al. 2020)

Both TM65 and UR26 have fringes with FAST on 2020 Sept. 10-11！

AGN:3C286



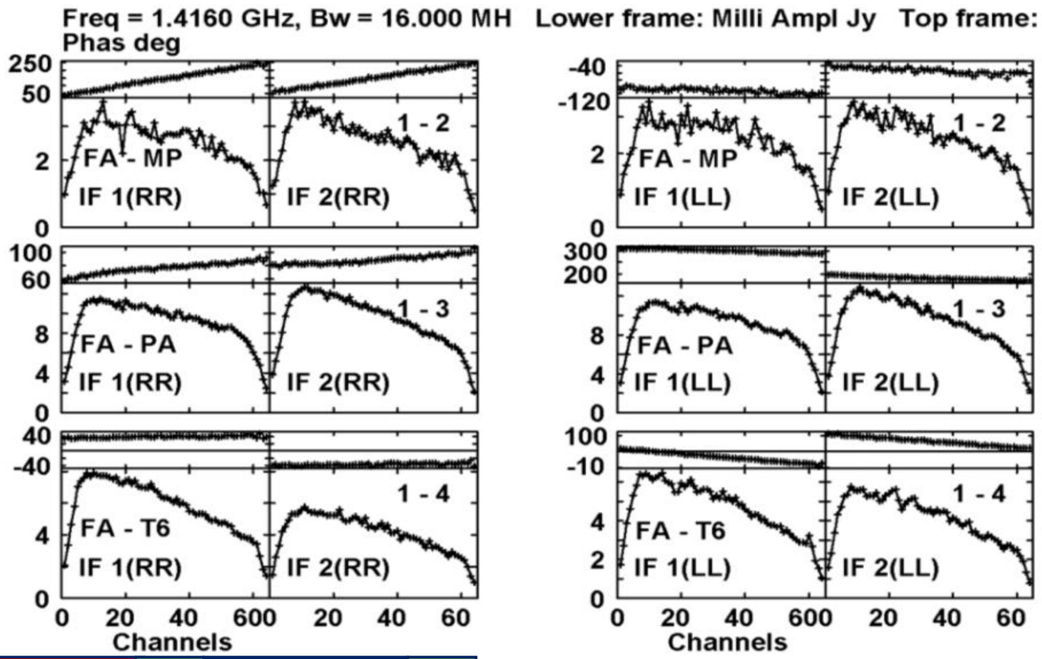
Pulsar:B1133+16

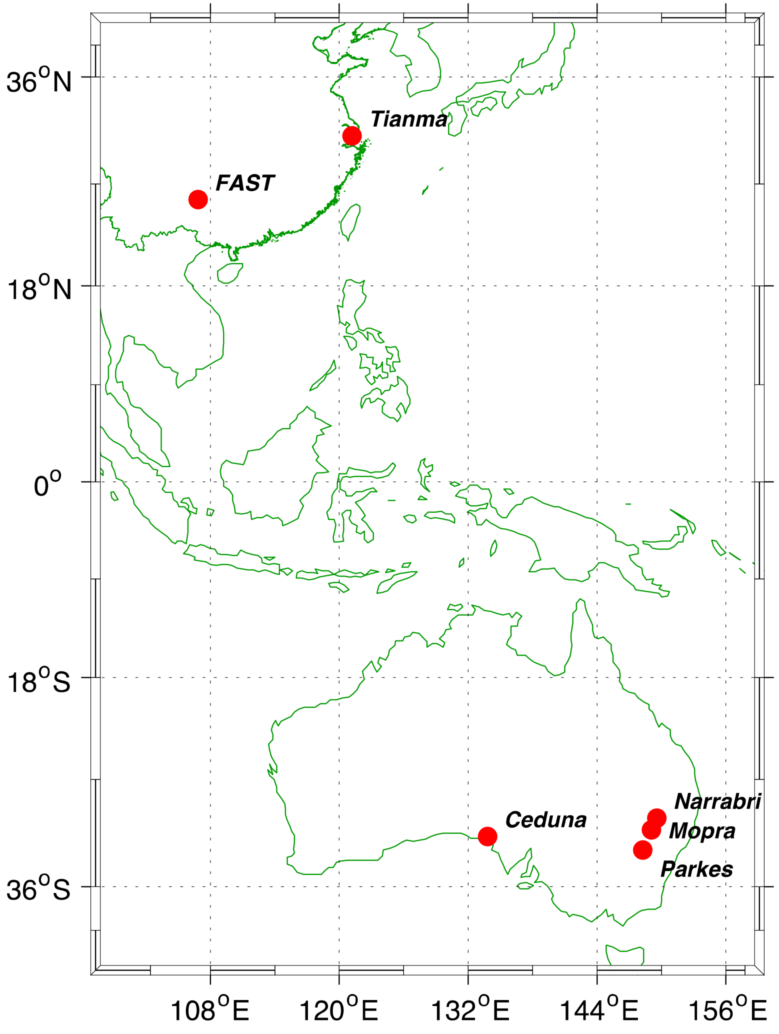


FAST VLBI experiments with LBA (1st nodding obs) in 2021 Oct!

- **Frequency setup:**
  - *FAST: 1.05 - 1.45 GHz*
  - *TM65: 1.35 – 1.70 GHz*
  - *Parkes: UWL 0.7 – 4.0 GHz*
  - *Mopra: 1.3 – 1.8 GHz*
- **Obs. Frequency:** *1416 MHz – 1448 MHz*
- **Recording:** *16MHz * 2IF * 2 Pol*

Spectra of calibrator J1605-1139





Target: 3 min *Slew: 1 min* *Calibrator: 3 min*

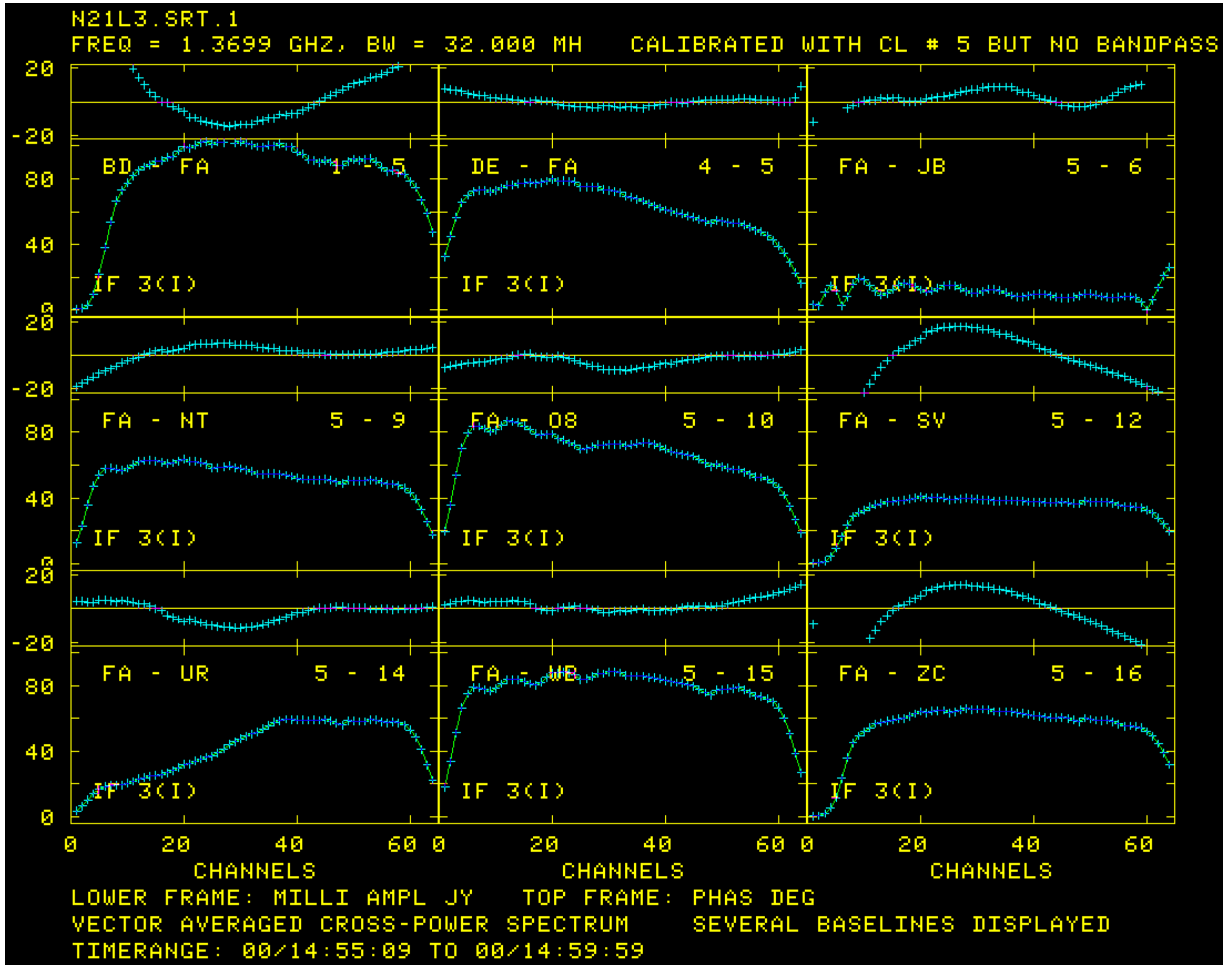
European VLBI Network + FAST in 2021 Oct!

First trial experiment with EVN was carried out on 2021 Oct. 26 with 15 stations of EVN

all the fringes were detected!

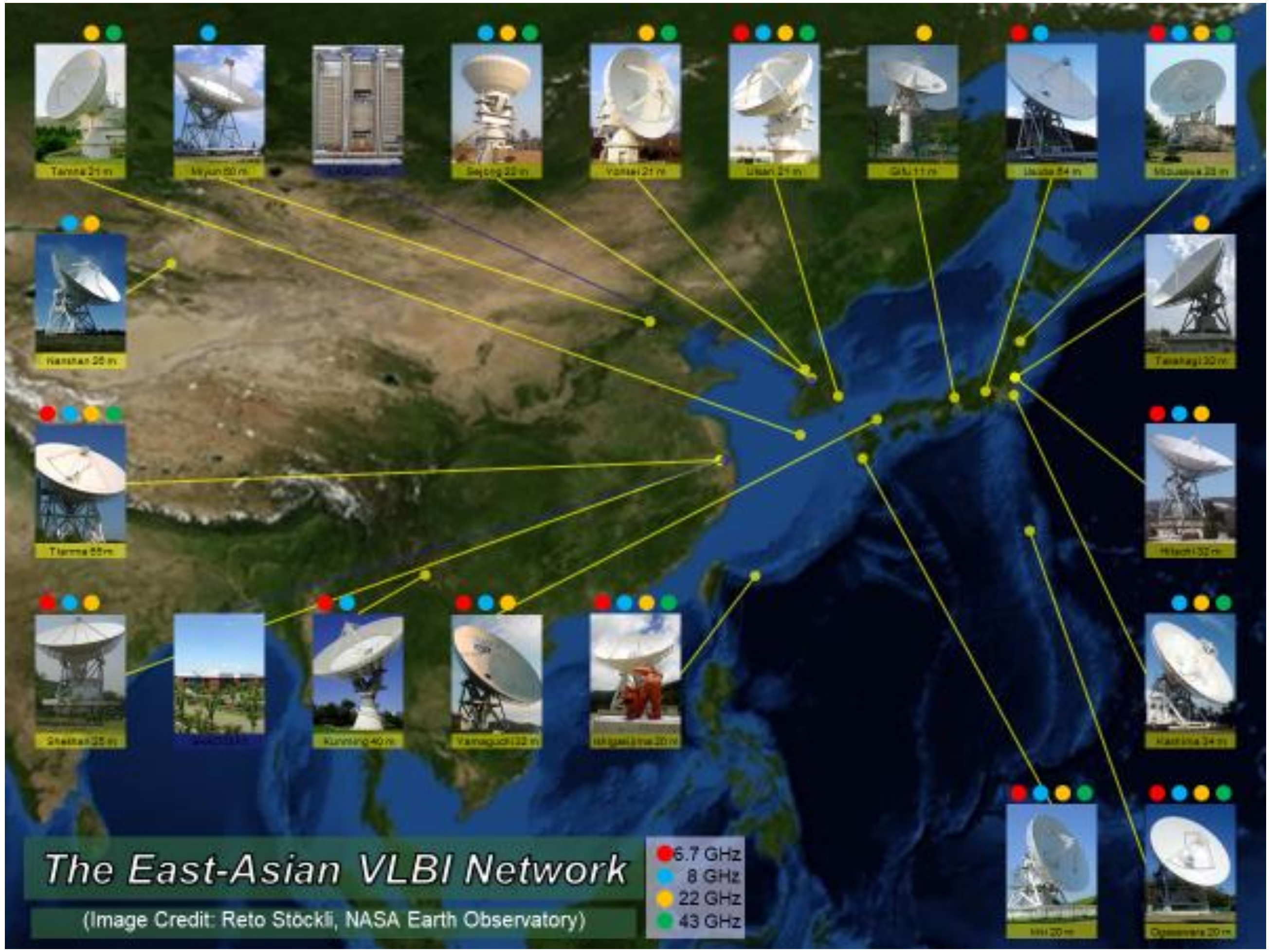
- **Stations:**
  - *FAST: 1.05 - 1.45 GHz*
  - *EVN >15 stations*
- **Obs. Frequency:** *1305MHz – 1433MHz*
- **Recording:** *32MHz * 4IF * 2 Pol*
- **Source:** *3C454.3*

Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).



East-Asian VLBI Network (EAVN) since 2003

- Largest number of VLBI stations
  - 8GHz 13 stations
  - 22GHz 19 stations
  - 43GHz 8 stations
- Phase referencing
  - VERA 2 beam system
  - KVN multi-frequency + fast nodding
- Good UV coverage
  - Minimum baseline length ; 50 km
  - Maximum baseline length ; 5500 km



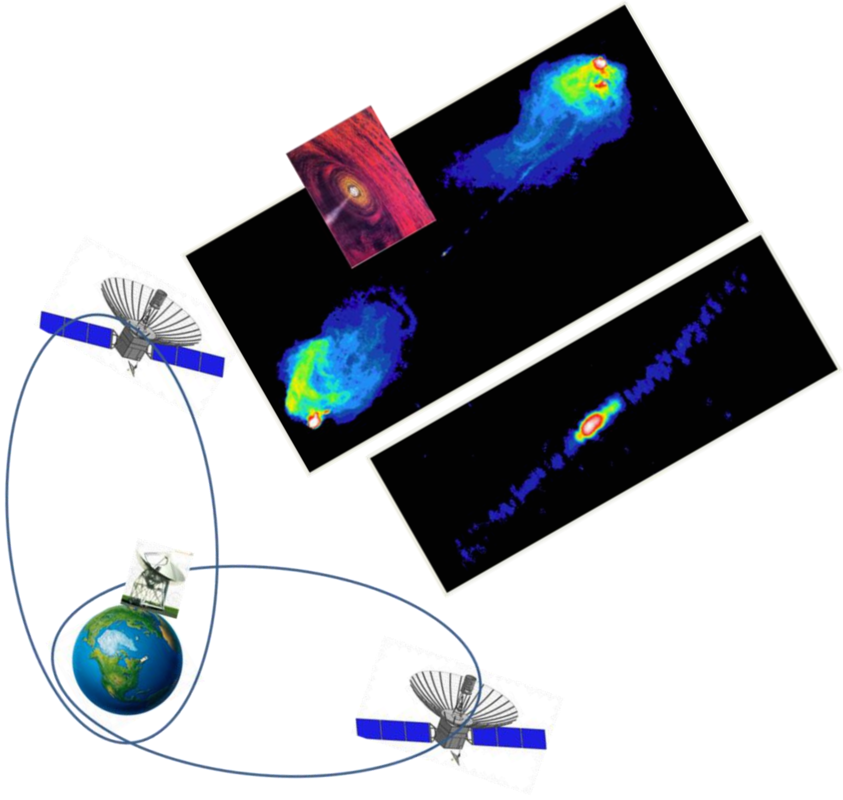
Space Millimeter VLBI Array

Main Scientific Objectives:

- High-resolution imaging of emission structure surrounding super-massive black hole (SMBH)
    - SMBH Shadow (e.g. M87)
    - Disk structure & dynamics, SMBH mass (water mega-masers)
    - Astrophysical Jet in Active Galactic Nuclei (AGN)

Specifications:

- Two 10-m (in diameter) space antennas
- Three frequency bands (8, 22 & 43 GHz)
- Dual polarization (LCP/RCP)
- Date rate (1.2 Gbps , or 2.4 Gbps)
- Angular resolution: 20 micro-arc-second
- Optimized orbits for a better (u,v) coverage
    - Apogee: 60,000 km
    - Perigee: 1,200 km
    - Inclination: 28.5 deg
- Life time: 3 year



High precision reflector: 10m diameter with a surface accuracy better than 0.4mm (RMS)

Summary

It takes 30+ years (1975-2006) for the establishment of the Chinese VLBI network (CVN)!

Nowadays, the CVN of five VLBI stations plus a correlation center has gradually started performing astrophysical and geodetic observations as well as the VLBI tracking of space probes.

More activities are expected with the newly proposed some big telescopes (**QTT110m, JingDong120m, 2x40m** ...) including **FAST** at L-band, and the ever-increasing international collaborations, such as **EAVN collaborations**!