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Preliminary Results of Pulsar Astrometry with CVN

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Outline

- Introduction
- Some results with CVN
- Learn from VGOS system
- Remarks

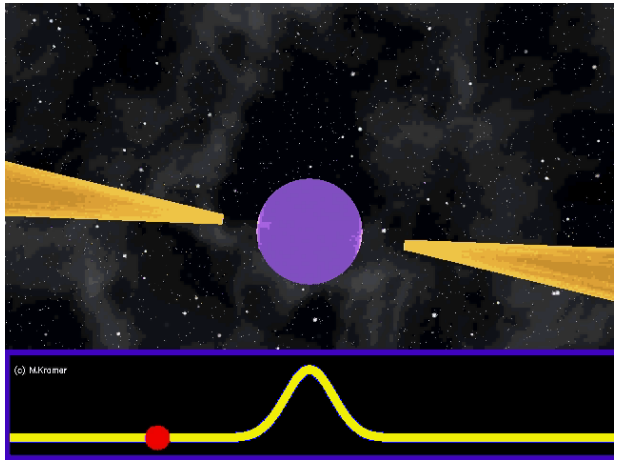
Pulsar

Rotating neutron star with pulsar emission

Highest magnetic field B, ($10^{8\text{-}14}$ G)

Highest volume density (10^{14}g/cm^3)

Steep power law spectrum, dispersion phenomena

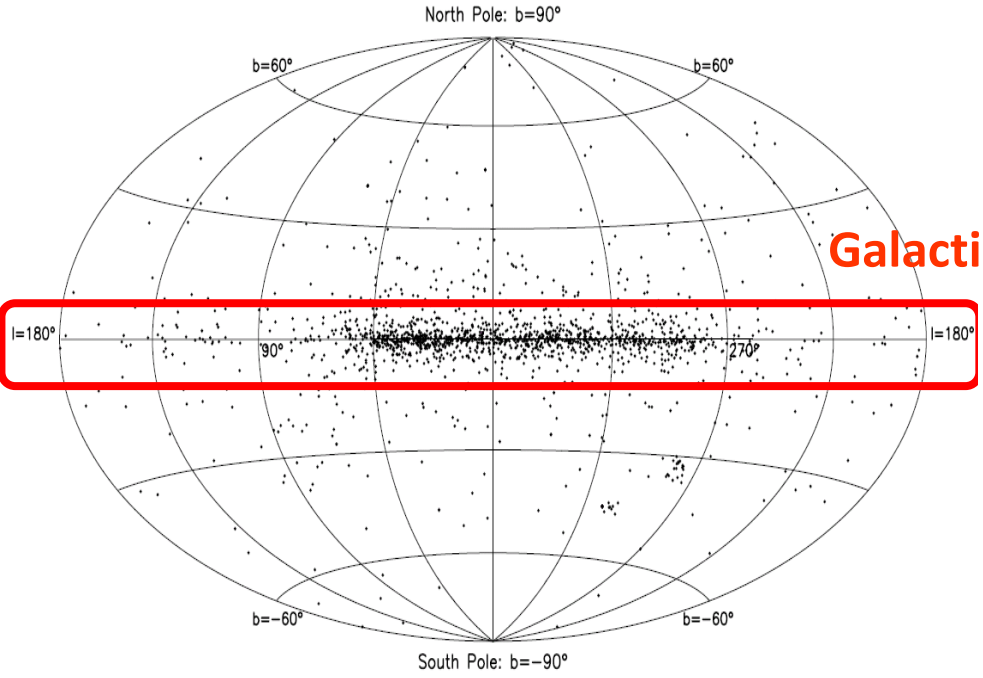


Pulsar astrometry

- Pulsar Origins:
  - SNR associations
  - NS birth sites in stellar clusters / OB associations
  - True ages
- Astrophysics:
  - NS atmospheres, cooling curves etc. need absolute distances
- Evolution:
  - NS distribution and population velocities
- Environments:
  - Galactic electron density
  - local ISM
- Reference frame ties

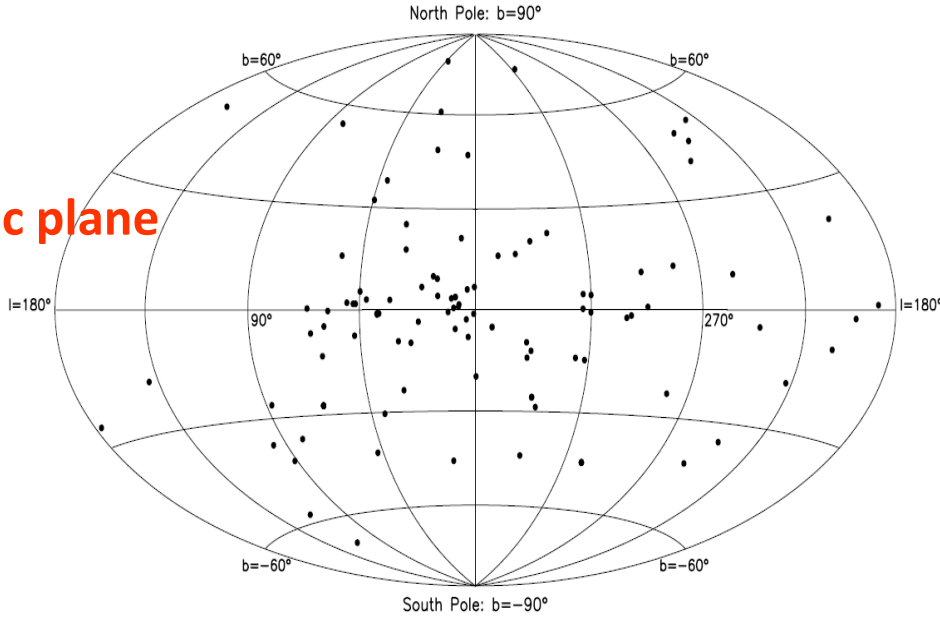
Distribution of pulsar in Milky Way

Normal pulsar (>1700)

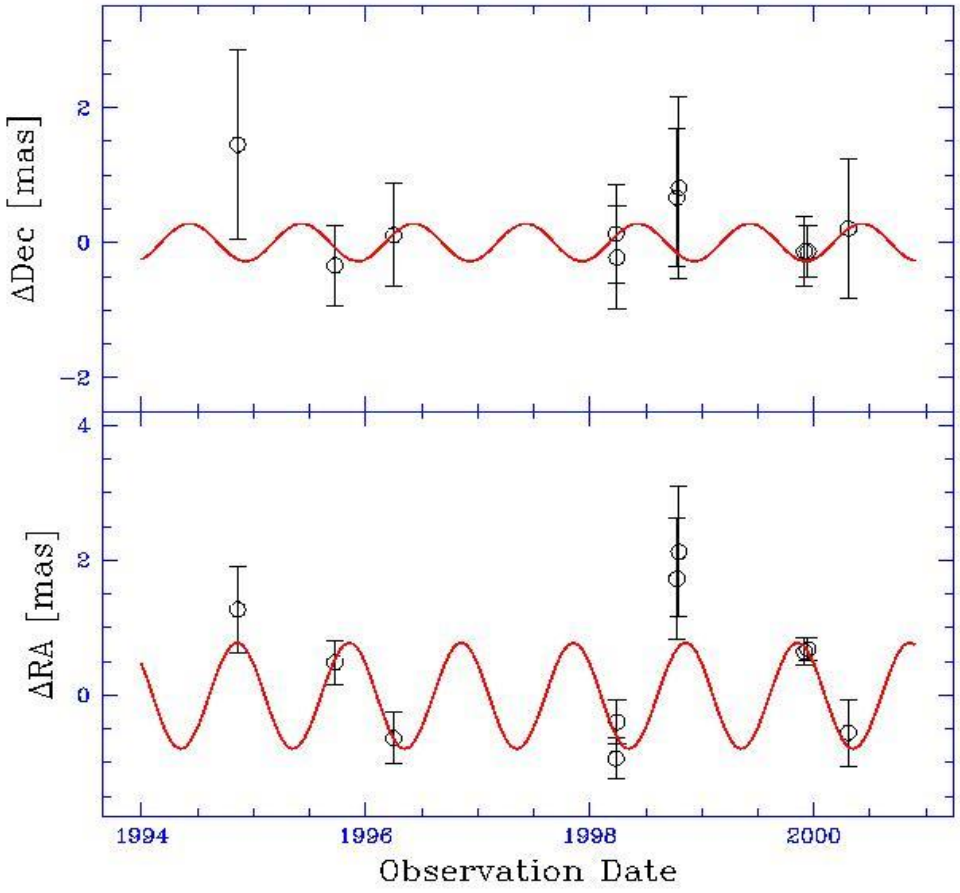


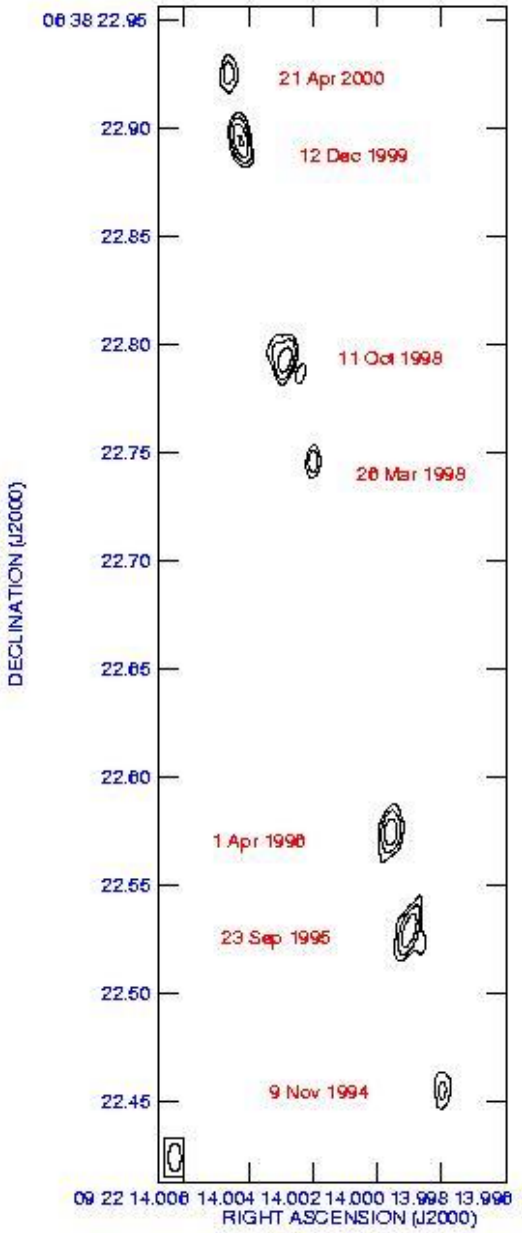
Galactic plane

Millisecond pulsar



Triangle parallax measurement through VLBI





B0919+06: 1994-2000

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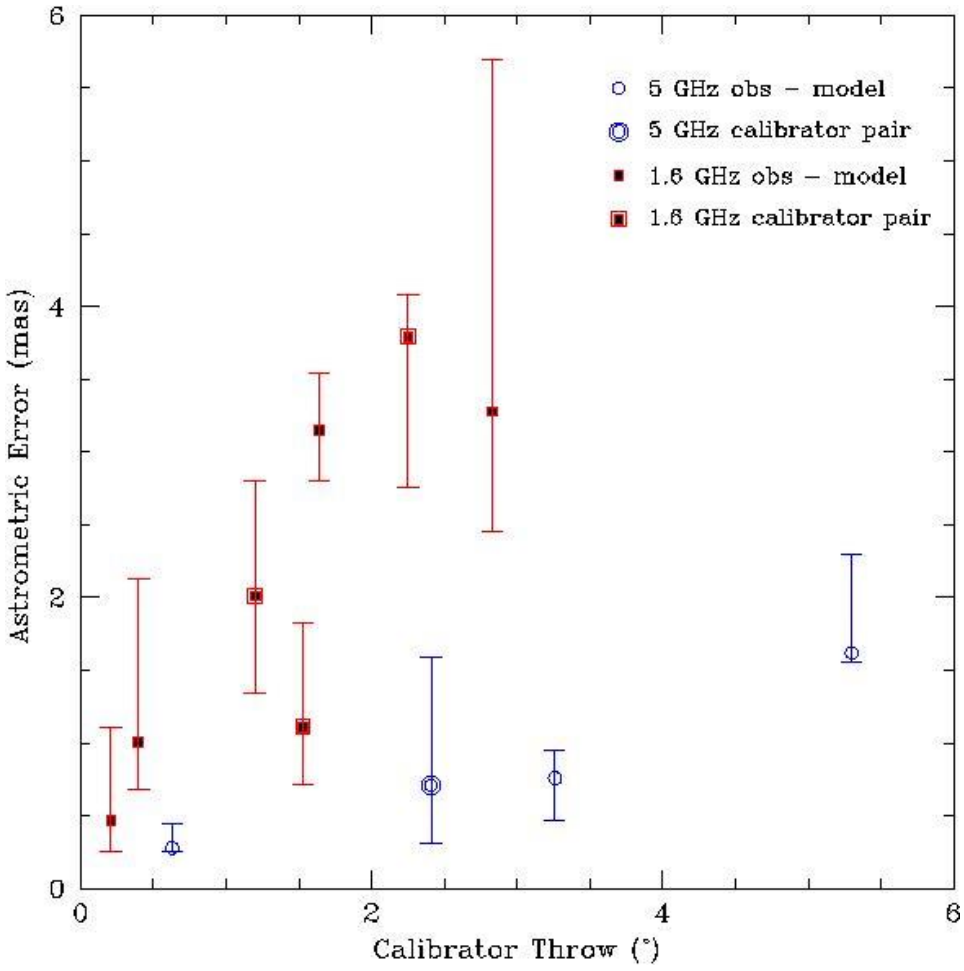
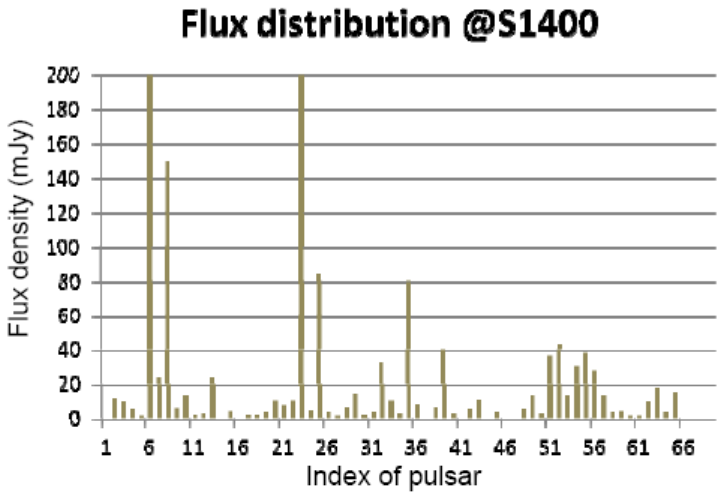
Phase referencing

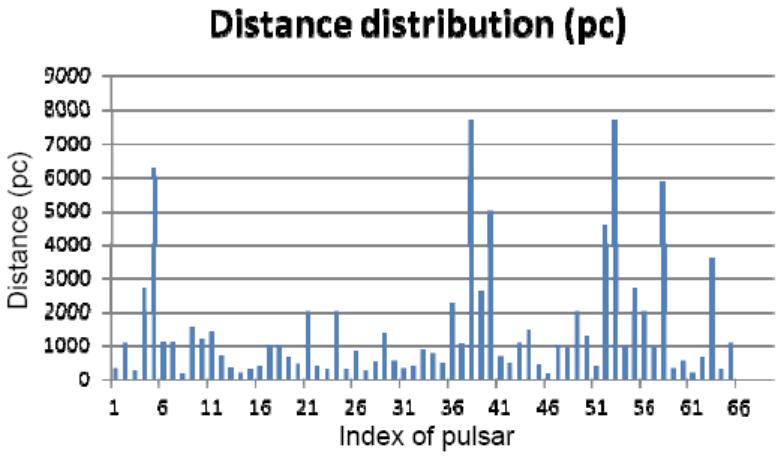
- Alternating scans on extra-galactic reference source with known position
  - solves for atmospheric effects
    - ionosphere $\propto \nu^{-1}$
    - troposphere $\propto \nu^{+1}$
- Pulsar flux $\propto \nu^{-\alpha}$, α=1.5 to 2.5
  - phase referencing at 1.4 GHz compromise
  - positional scatter at 5 GHz lower
- Making phase connections at 1.4 GHz requires:
  - 2-3 minute alternating scans over less than 4-5°
- In-Beam calibration is pretty appreciated

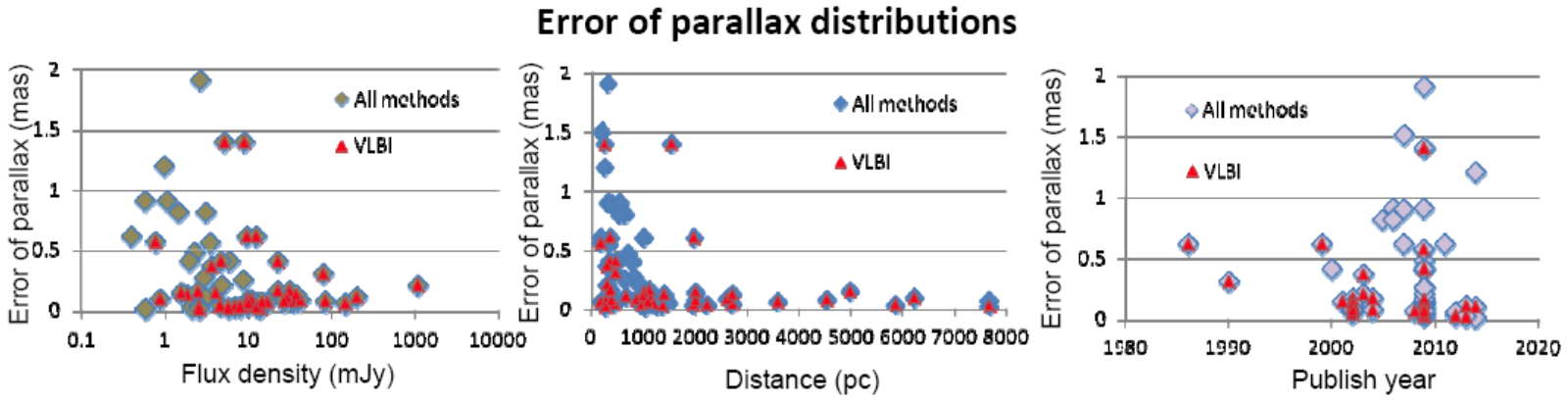


All published pulsar parallaxes as of 2014 February (64 objects).
http://www.astro.cornell.edu/research/parallax/
Nearly 40 of 64 are obtain by VLBI, others by timing, optical.

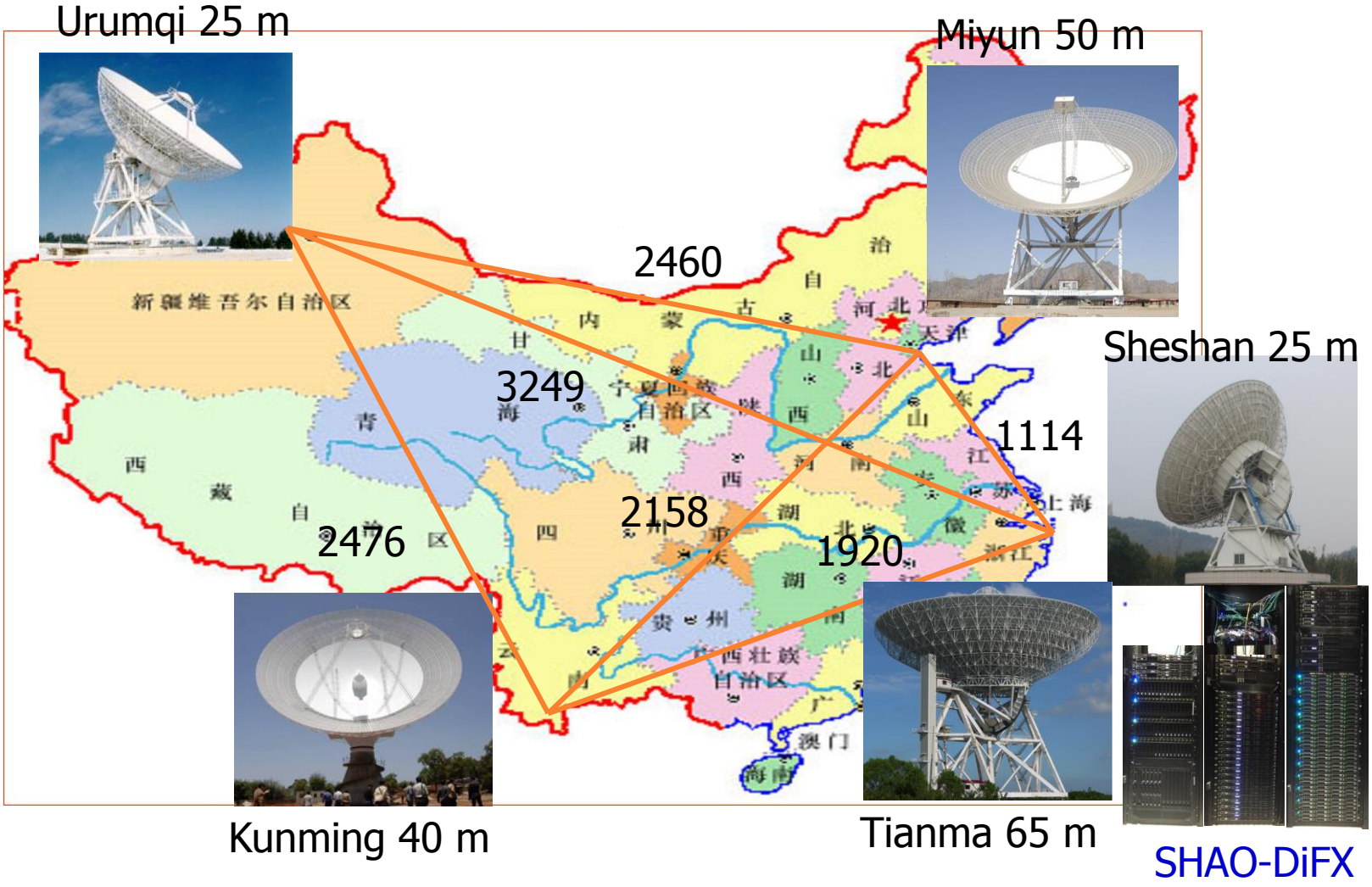
The 64 pulsar parallax distributions







Current CVN stations



SHAO-DiFX

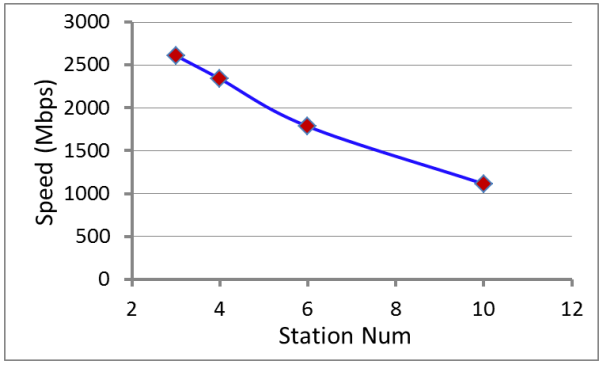
Ad hoc platform, 2012

60 CPUs, 2013

400 CPUs, 2014

Performance and operations

1. Astrophysics: domestic VLBI observations, east Asia VLBI network fringe test.
2. Geodesy: domestic geodetic observations, began to process some CRF, AOV and APSG IVS sessions in 2015.
3. Achieve speed of 10 stations, 1Gbps/station.
4. Some other test experiments.



Station positions

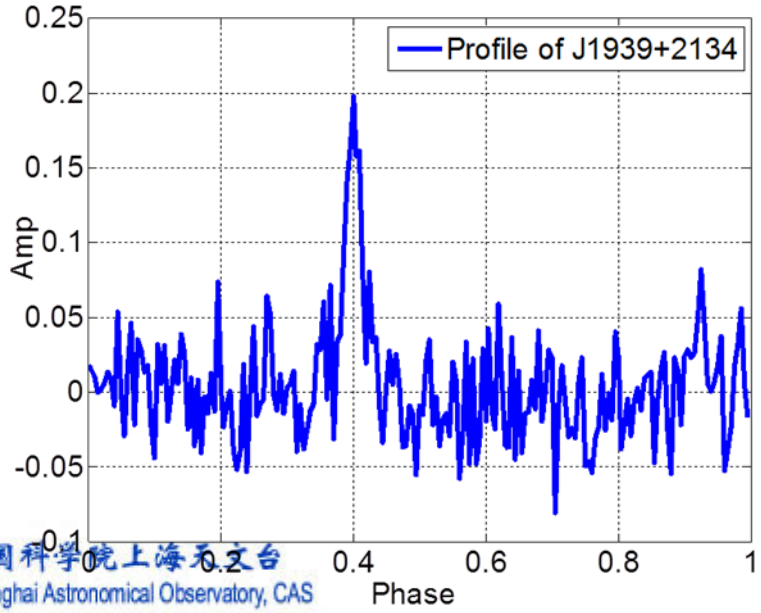
Accuracy is within several millimeter.

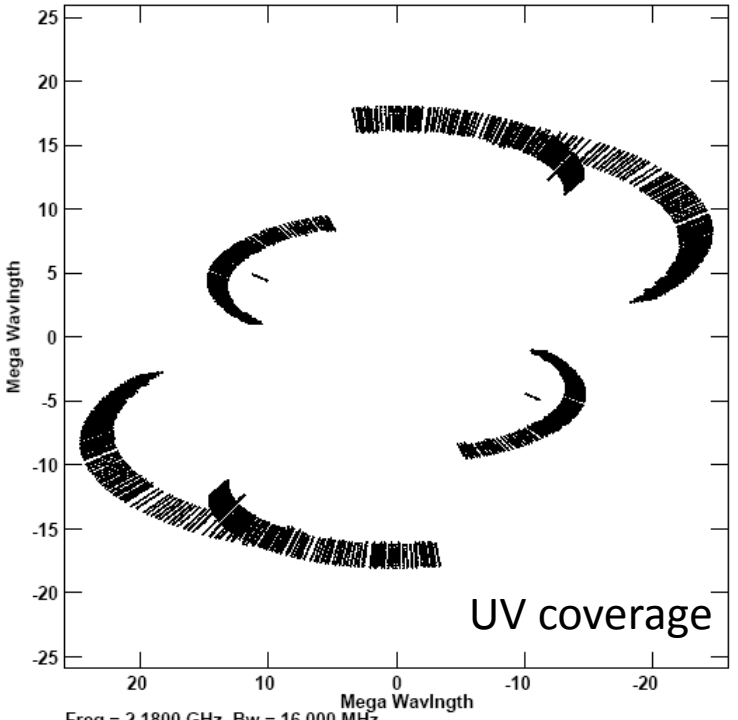
Param.	Sheshan	Kunming	Urumqi
X (m)	-2831686.99300	-1281152.42700	228310.63100
Y (m)	4675733.63900	5640864.40000	4631922.76600
Z (m)	3275327.64100	2682653.63000	4367063.97100

Reference MJD, 51544.0

Experiment of MSP J1939+2134

- MSP: 1.56 ms period, 14 mJy @ 1400 MHz
- Stations: Sheshan 25 m, Kunming 40 m and Urumqi 25 m, 8 h.
- Frequency band: S band (2180-2436 MHz)
- Phase reference source: J1935+2031 (1.48 degree separation, 0.04 mas in RA, 0.06 mas in DEC)
- Recording rate: 1 Gbps, 16 channel x 16 MHz
- Correlation: Pulsar gating in DiFX
- Epochs: 4, from 2012.4.8-2015.4.25





4 epoch positioning of MSP J1939+2134

Parallax could not acquire this time,

μ_α = 0.20 ± 0.14 (mas/year)

μ_δ = -0.34 ± 0.68 (mas/year)

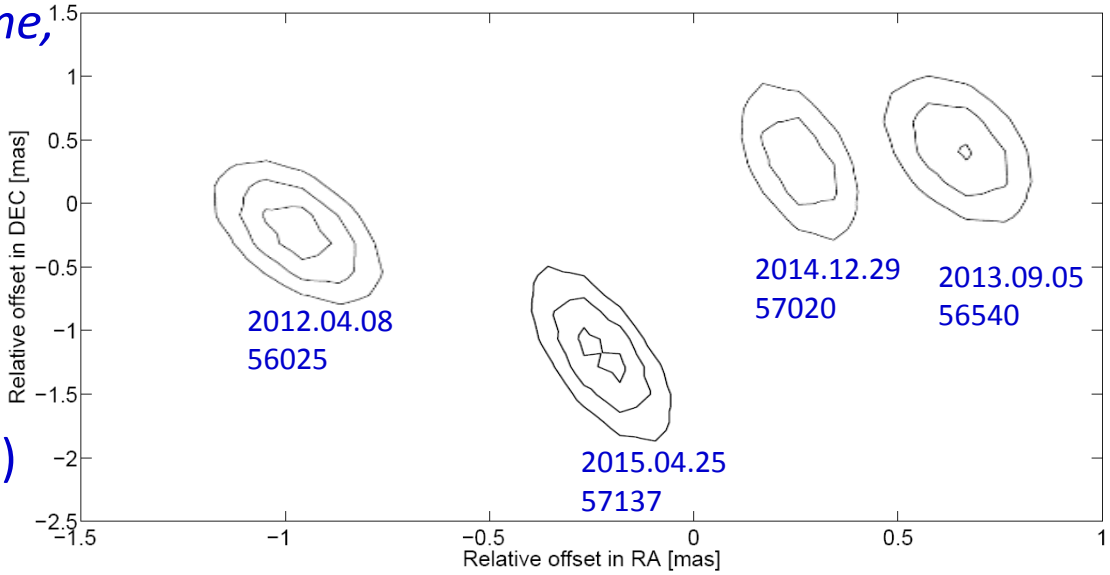
Compared to timing results

Π = 0.13 ± 0.065 mas

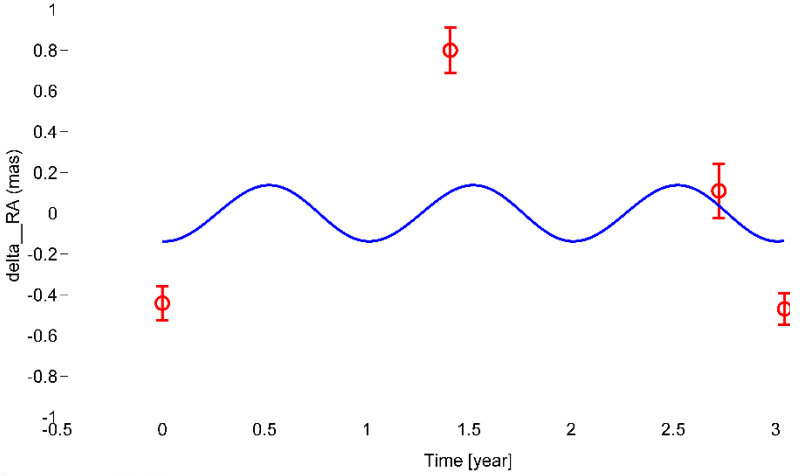
μ_α = 0.072 ± 0.001 (mas/year)

μ_δ = -0.415 ± 0.0015 (mas/year)

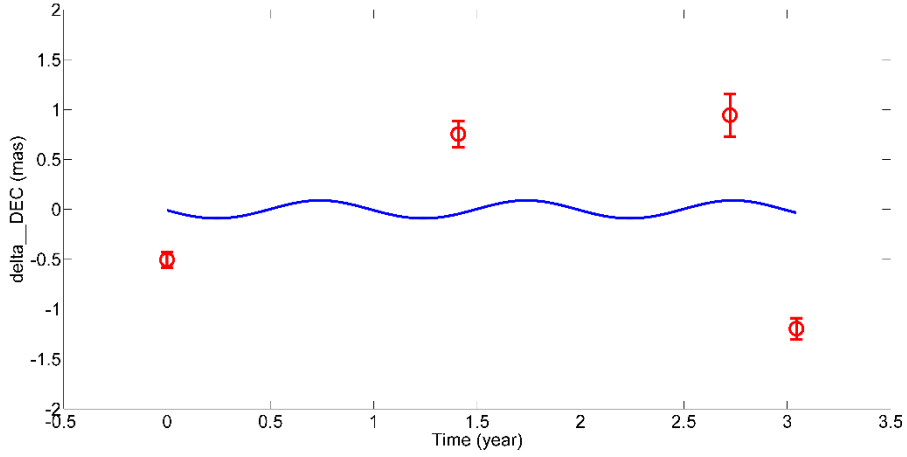
MJD 46024.8-54526.9



Beam size= 8.4x4.3 mas



RA



DEC

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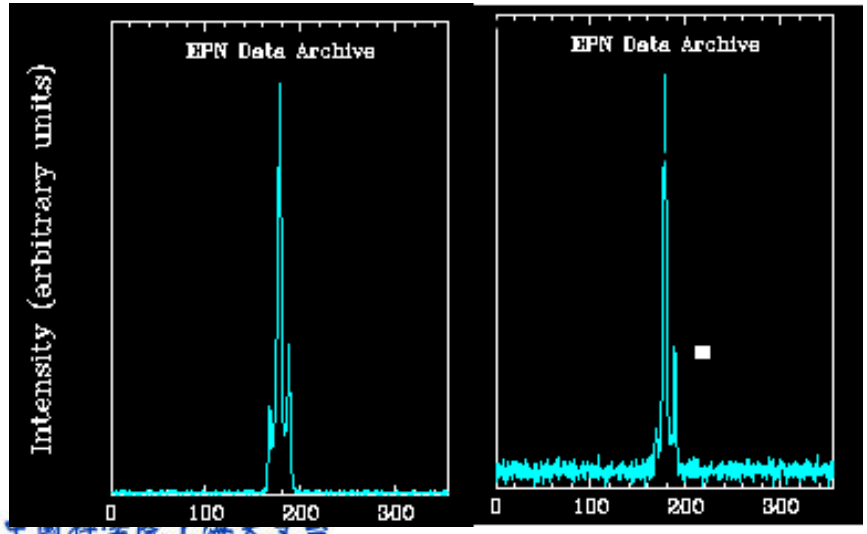
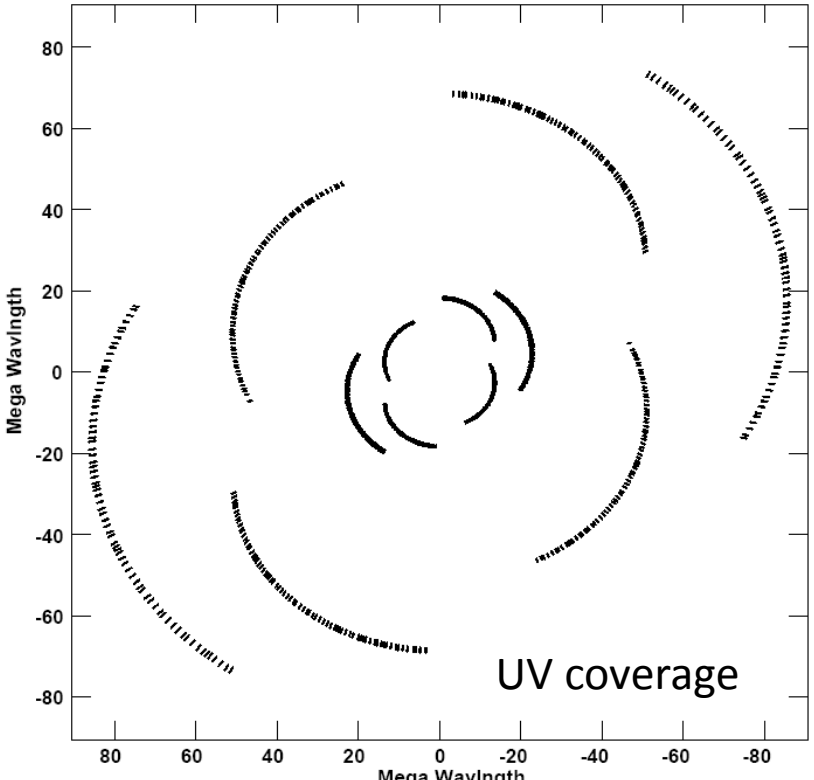
Experiment of Pulsar B0329+54

- B0329+54: 0.7145s period, 203 mJy @ 1400 MHz
- Stations: Sheshan 25 m, Kunming 40 m and Urumqi 25 m, 8h.
- Frequency band: S/X band, 2240/8400 MHz
- Phase reference source: J0337+5557 (2.53 degree separation, 0.31 mas in RA, 0.48 mas in DEC)
- Recording rate: 1 Gbps, 16 channel x 16 MHz
- Correlation: Pulsar gating in DiFX
- Epoch: 1, 2015.2.15



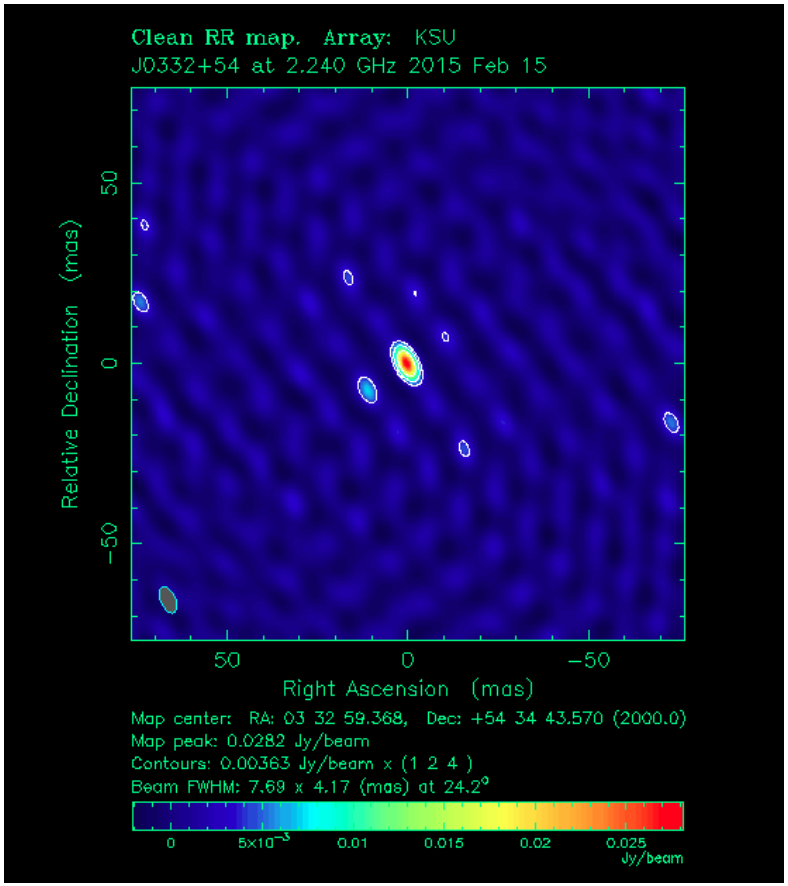
Profiles in S/X band

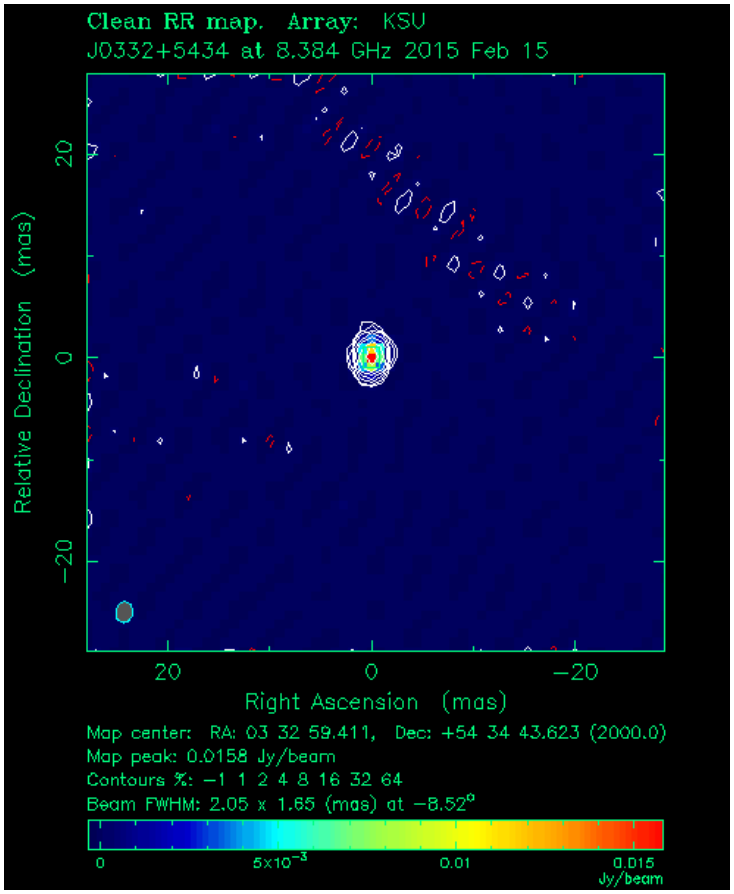


UV coverage

Preliminary results

The analysis is undergoing…

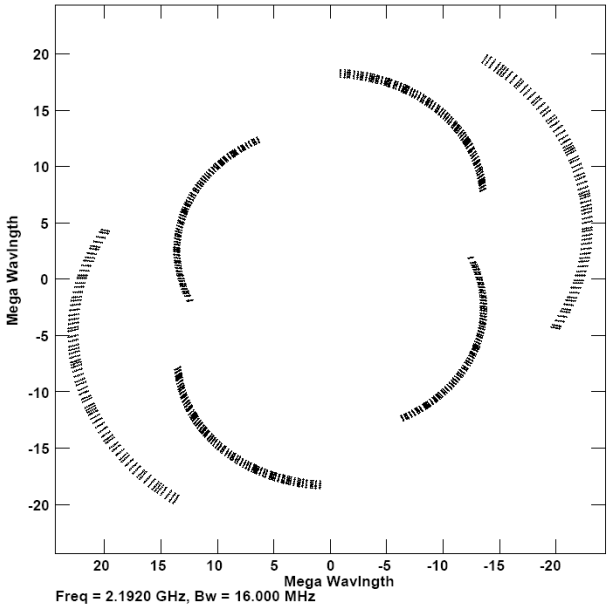


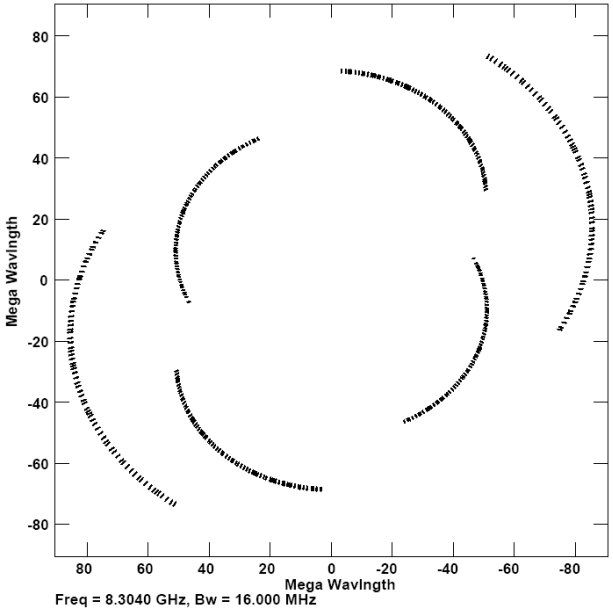


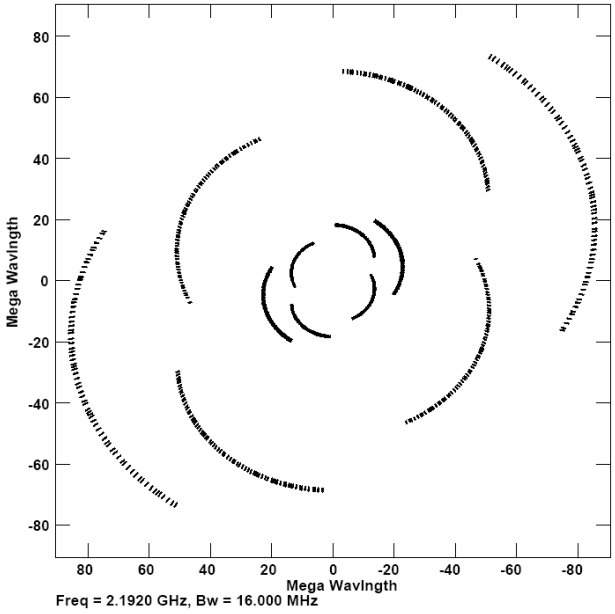
A S/X dual frequency observation on pulsar B0329+54 with CVN.

Learn from VGOS system

- Bandwidth synthesis -> multiband synthesis
- Improve UV coverage
- Involve more visibility data, improve the sensitivity







UV coverage

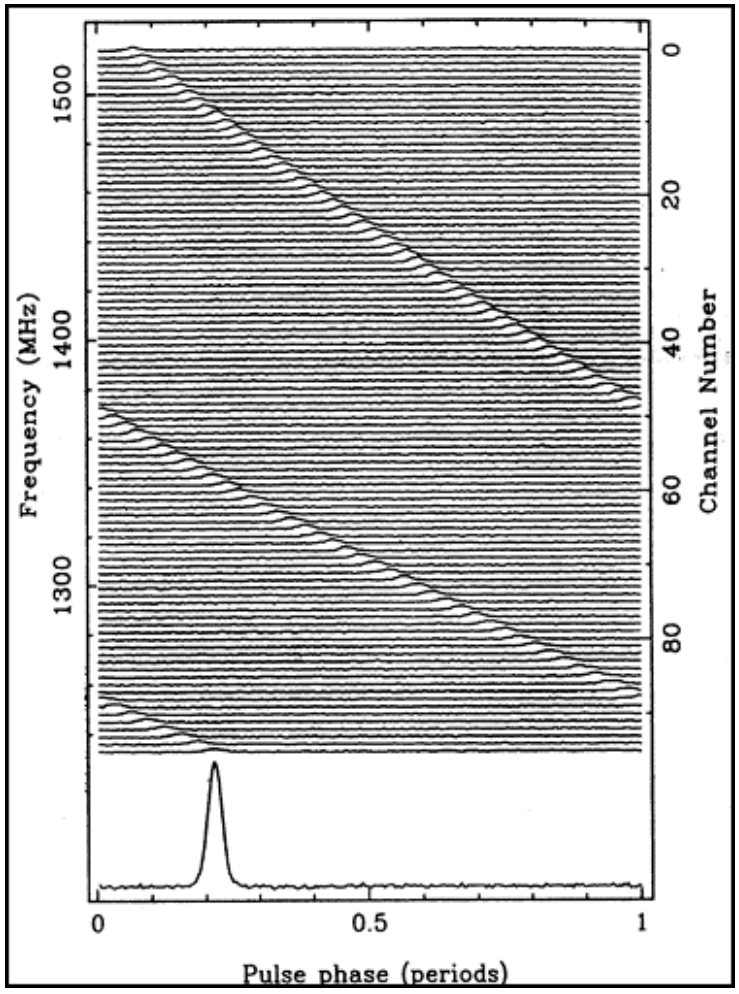
Learn from VGOS system

- Ionosphere correction
- Not only the ionosphere of the earth but also the ISM induce the phase dispersion.

DM = $\int ds\, n_e$ Dispersion Measure

Ionosphere free linear combination

$$\tau_{if} = \frac{f_{gx}^2}{f_{gx}^2 - f_{gs}^2}\tau_{gx} - \frac{f_{gs}^2}{f_{gx}^2 - f_{gs}^2}\tau_{gs}\,.$$



Learn from VGOS system

- RFI
- L, S band are problematic for geodesy, it is also a very bad news for pulsar observation!

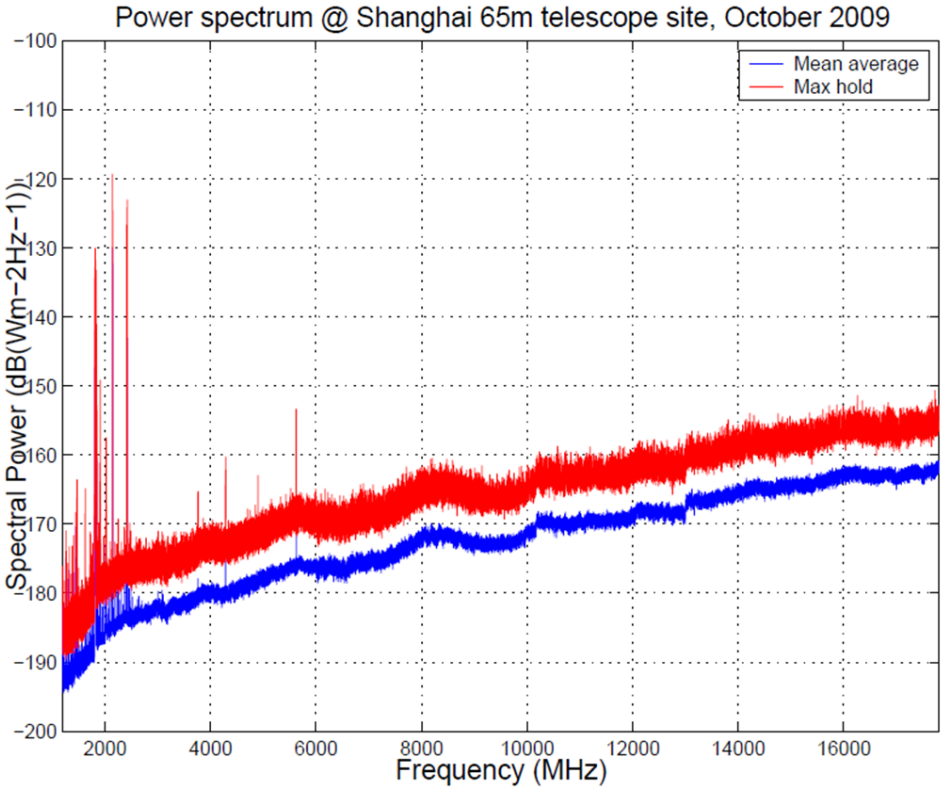


Figure 1: RFI spectrum for the Shanghai Sheshan telescope site

Remarks

- More observations are planning for the pulsar astrometry, more antenna are welcome.
- Experience in geodesy can share with pulsar astrometry.
- Higher accuracy and higher density distribution of calibrator sources are still in great demanding.
- Astrometry do astrophysics, such as in the case of pulsar astrometry.
- Wide band receiver and data recording system are beneficial to all astronomers.

Thank you!

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