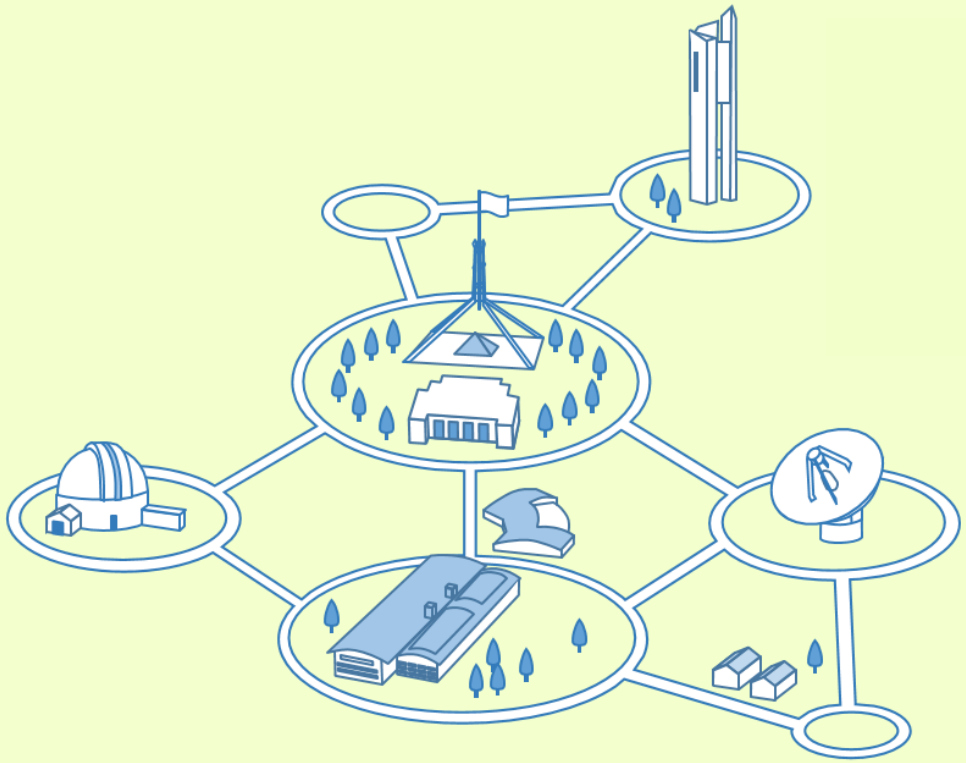
The next-generation VLBI observations and Source Structure effects



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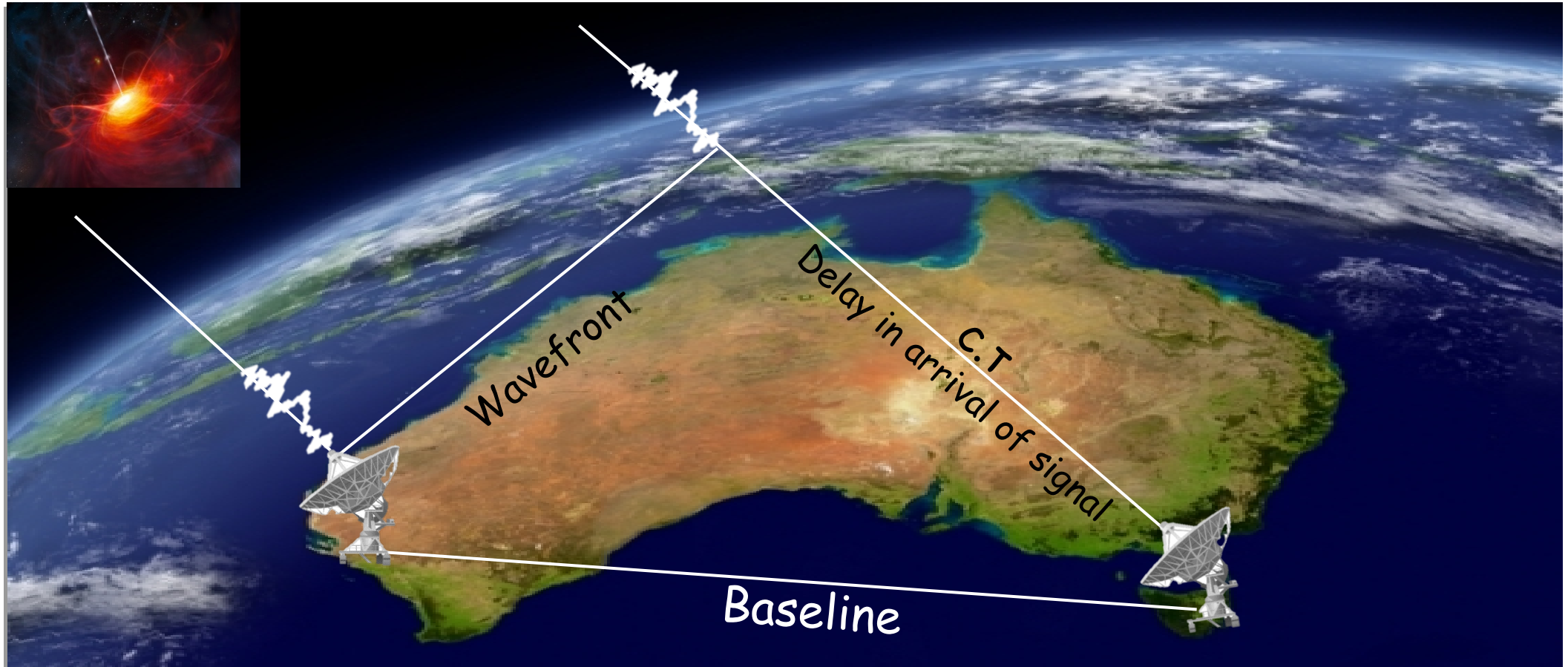
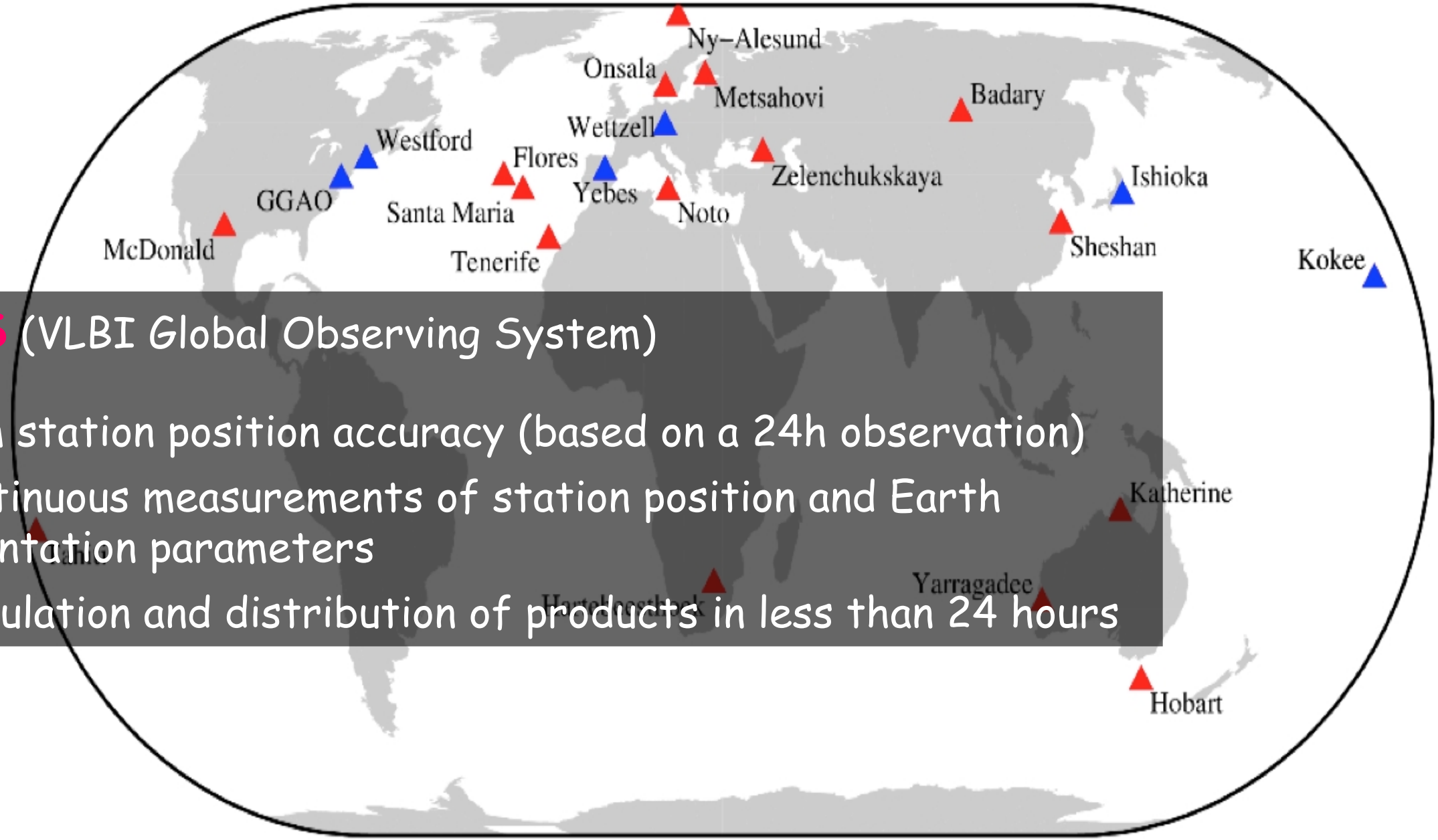
VLBI

- Radio astronomical interferometry
- A signal from an astronomical radio source (e.g. quasar) is collected at multiple radio telescopes on Earth
- Calculate the distance between the radio telescopes by using the measured time difference between the arrivals of the radio signal at different telescopes



Quasar

- Extremely luminous active galactic nucleus (AGN)
- Observable radiation across the electromagnetic spectrum at radio, infrared, visible, ultraviolet, X-ray, and gamma wavelengths
- Reference points in establishing a measurement grid on the sky
- Their positions can be measured with the utmost accuracy (0.001 arcsecond) by VLBI



VGOS (VLBI Global Observing System)

- 1mm station position accuracy (based on a 24h observation)
- Continuous measurements of station position and Earth orientation parameters
- Calculation and distribution of products in less than 24 hours

Theoretical Delay

$$\tau = \tau_g + \tau_r + \tau_a + \tau_c + \tau_t + \tau_i + \tau_e + \tau_s + \varepsilon$$

Measured

Modelled or Estimated

Error

Geometry

Relativity

Aberration

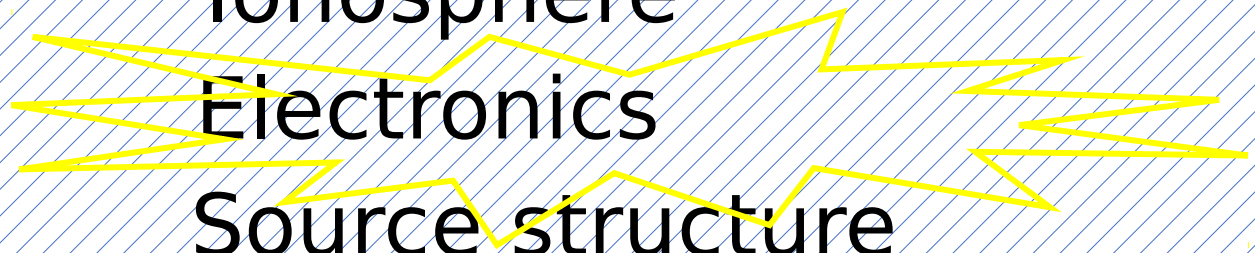
Clock

Troposphere

Ionosphere

Electronics

Source structure



Source Structure

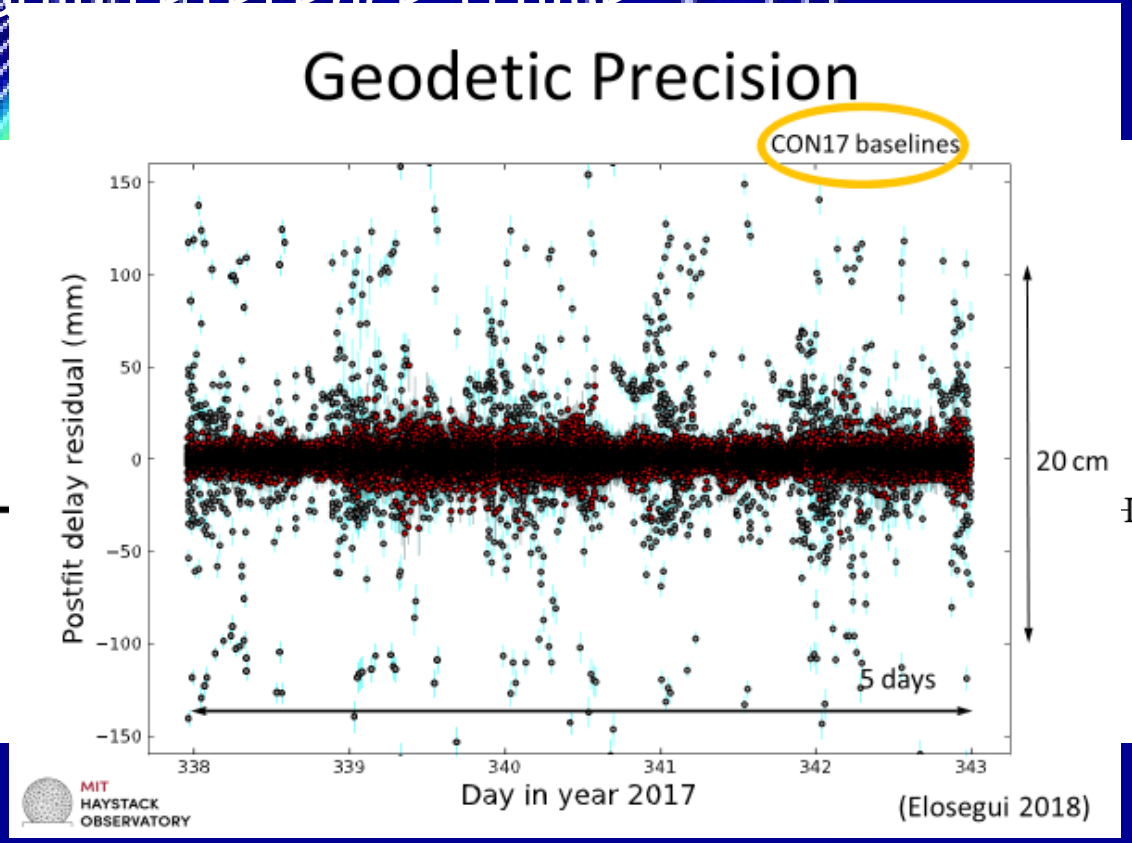
A major problem is that most of the observed radio sources tend to show structure at the level of a few milliarcseconds which varies with time and frequency. These effects, in particular the changes in the source structure, pose a limit on the accuracy of the radio reference frame

Legacy VLBI

- S band (2.2–2.4 GHz)
- X band (8.0–8.8 GHz)

VGOS

Broad bandwidth (2-14 GHz)



My PhD Project

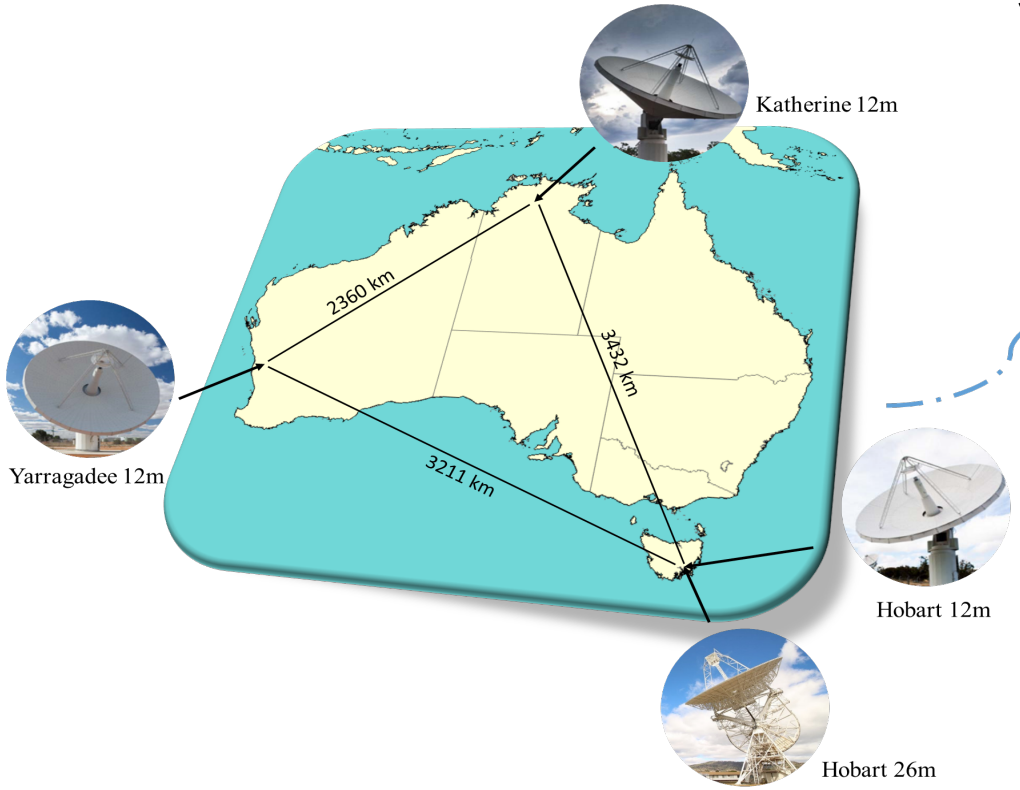
VGOS experts

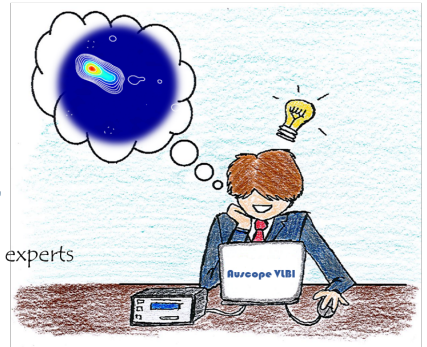
UTAS

- Operate four Australian geodetic VLBI radio telescopes (Lovell et al., 2013).
- First simulation of quasar structure effects on geodetic VLBI observations (Shabala et al., 2015, Plank et al., 2016).

UTAS is unique in bringing together expertise in:

✓Geodetic and Astrometry Simulations
✓Geodetic VLBI Observations
✓Source Structure investigations
✓VGOS technology development

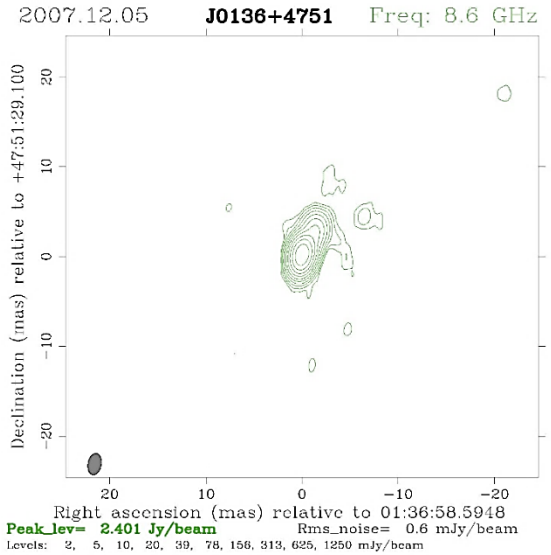




Source Structure experts

Source Selection

- Source 0133+476 (J0136+4751)
- ICRF2 - defining, well observed IVS source
- Images in S, X & U bands (2.3, 8.6 & 15.4 GHz).
- Variable structure over time



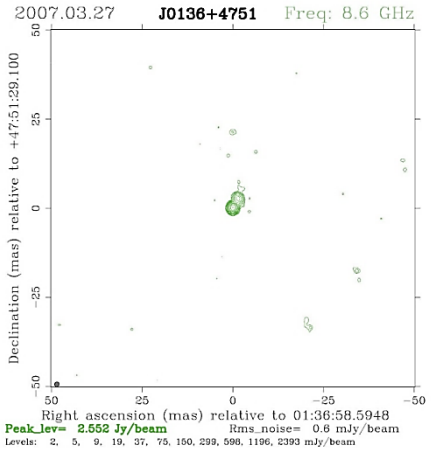


Image Processing

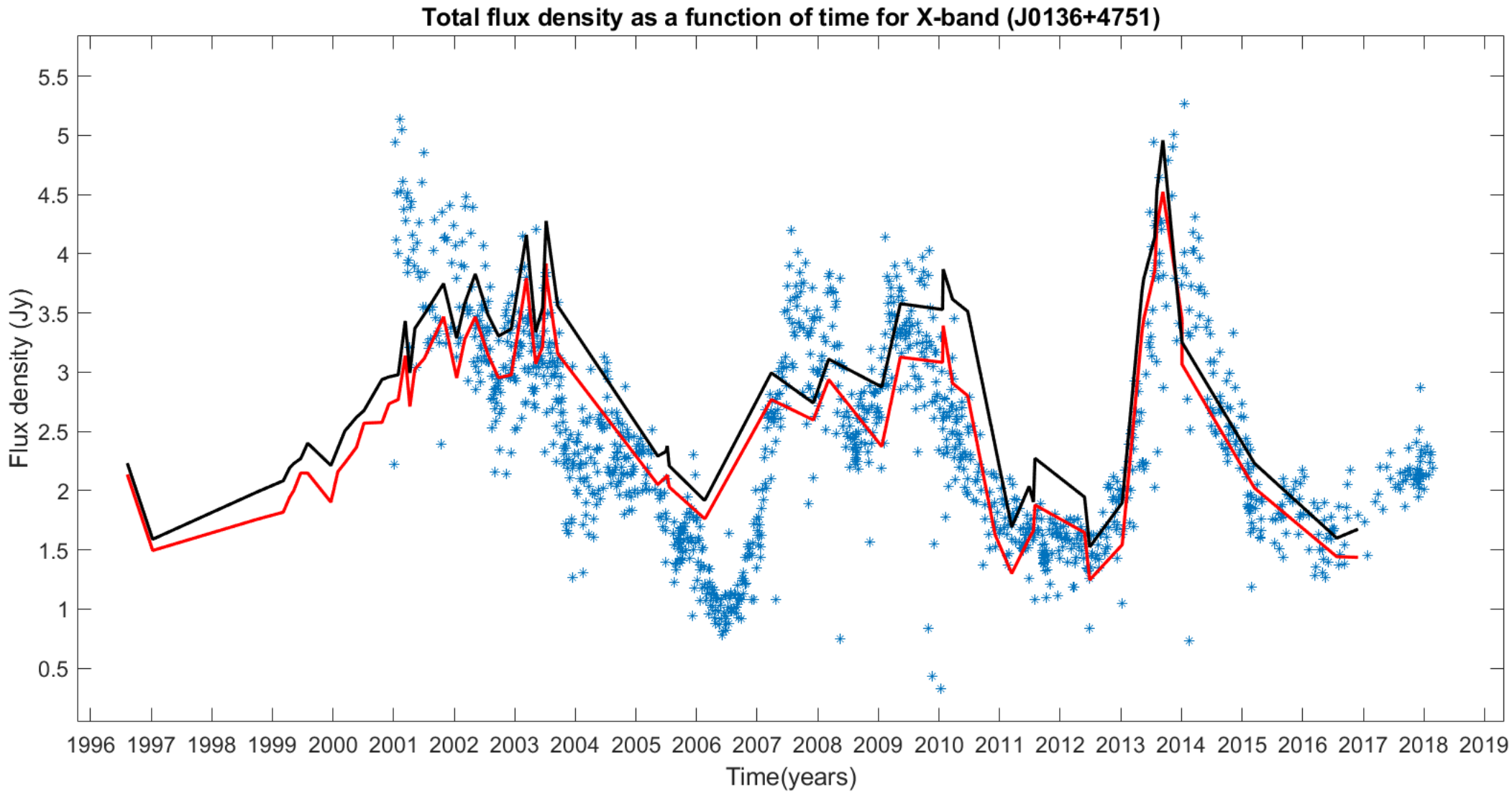
Astrogeo Center
(VLBI image database)

165 images of 0133+476 in S, X and U bands

Automated script, fits Clean Components

Components position parameters

Total and unresolved flux densities from image header



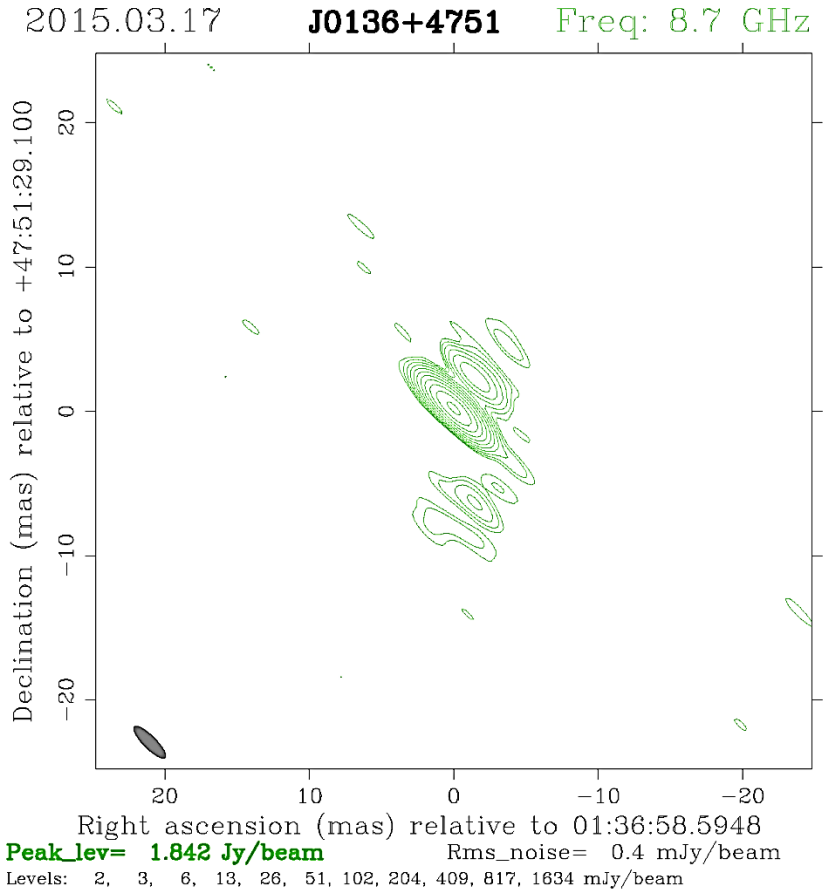
Black line: total flux density from the image header

Red line: total flux density from fitted clean components

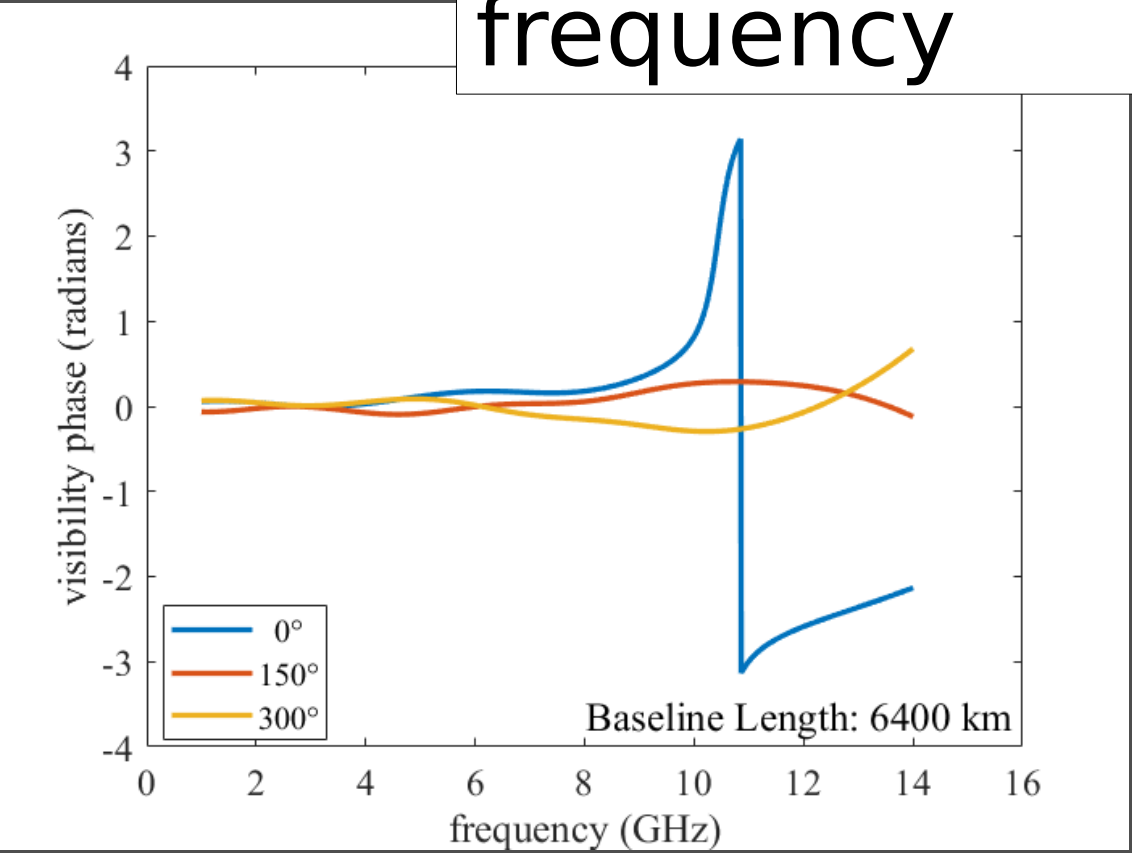
Blue dots: total flux density from IVS observations

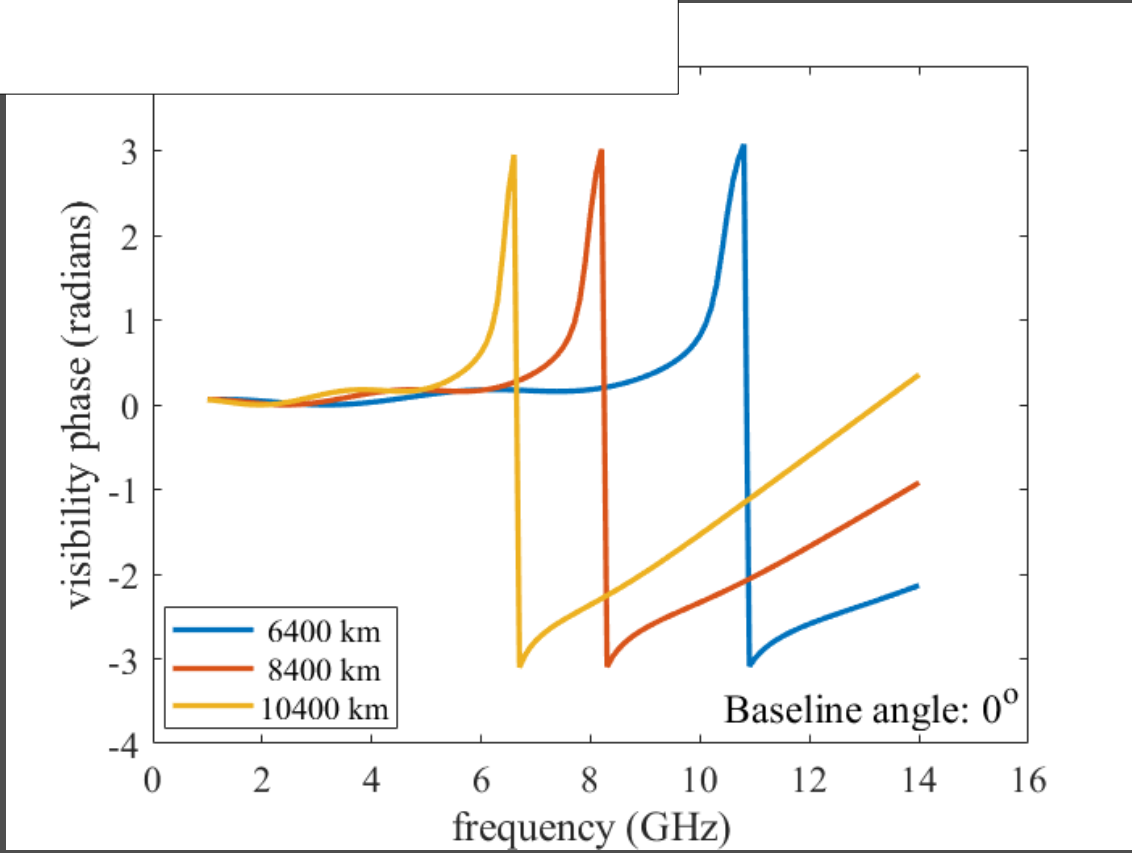
Table 1: Extracted parameters from source image. **Source Name**: J0136+4751, **Observation Date**: 2015 March 17, **Image Frequency**: 8.7 GHz, **RA**: 24.2441 degree, **DEC**: 47.8581 degree, **FITS file generator**: Alexandr Pushkarev, **Instrument used**: VLBA, **Database**: Astrogeo Center.

S_0 (Jy)	r (mas)	θ (degree)	a (mas)	b/a	ϕ (degree)
1.84	0.0	0.0	3.01	0.31	45.19
0.09	2.63	-35.2	2.91	0.37	44.53
0.08	0.79	-55.4	2.79	0.23	44.42



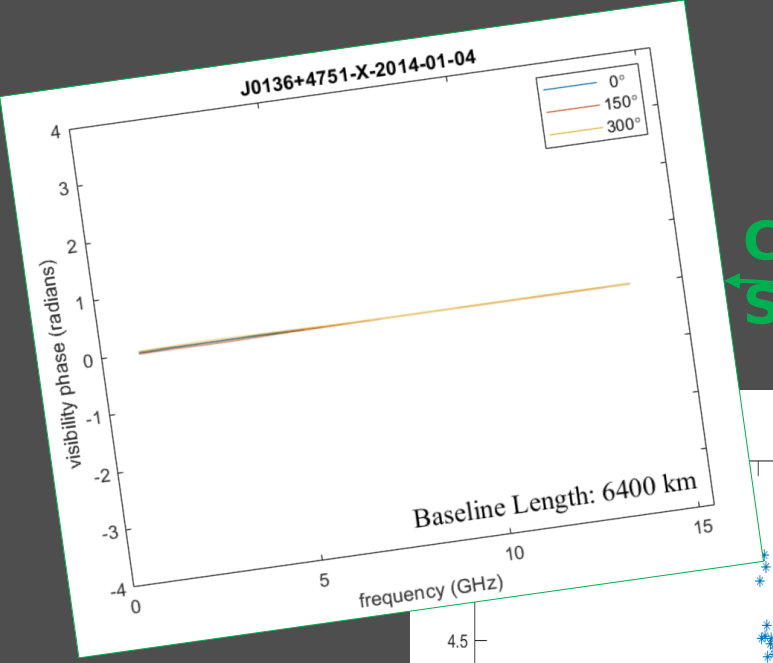
Phase as a function of frequency



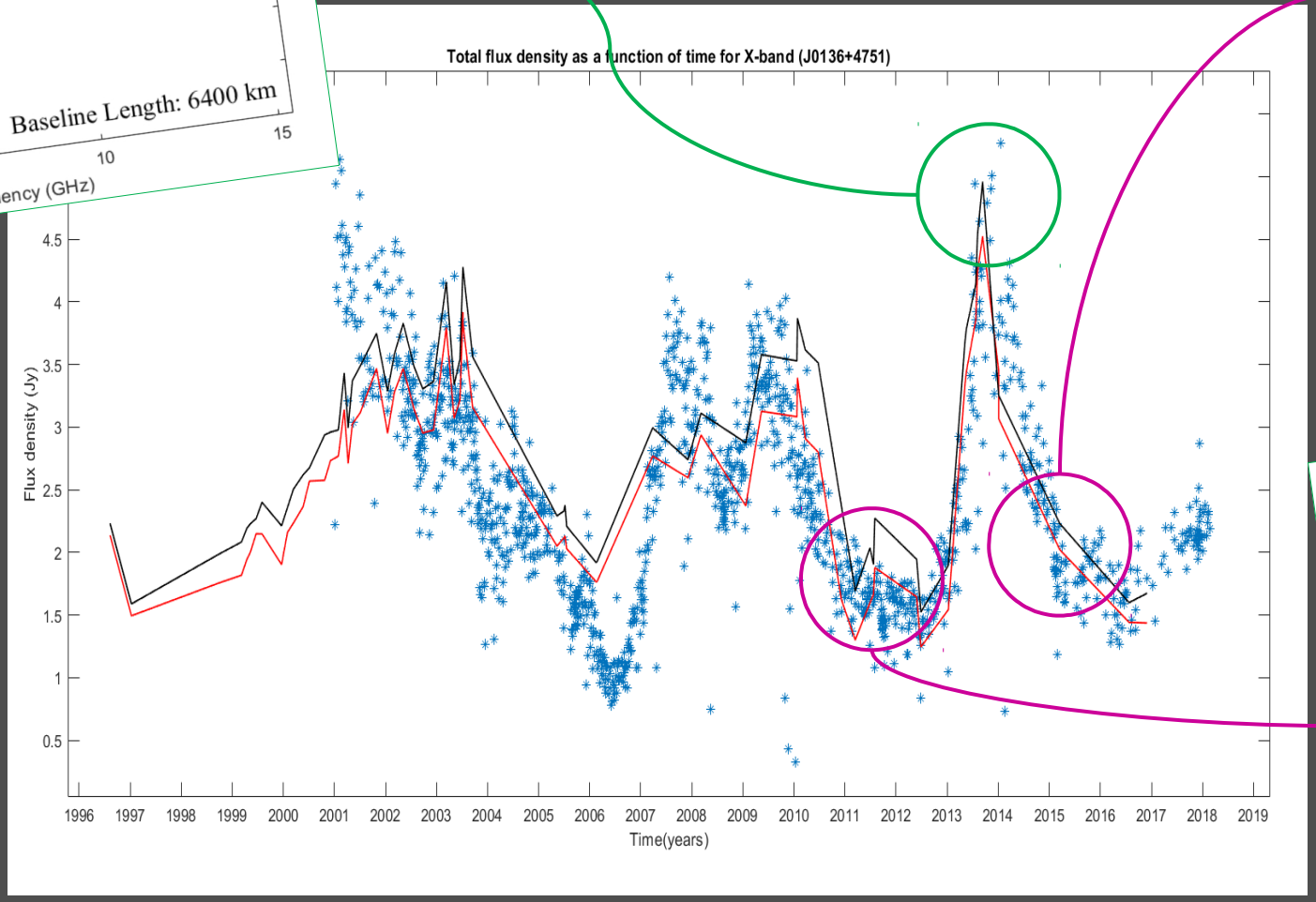


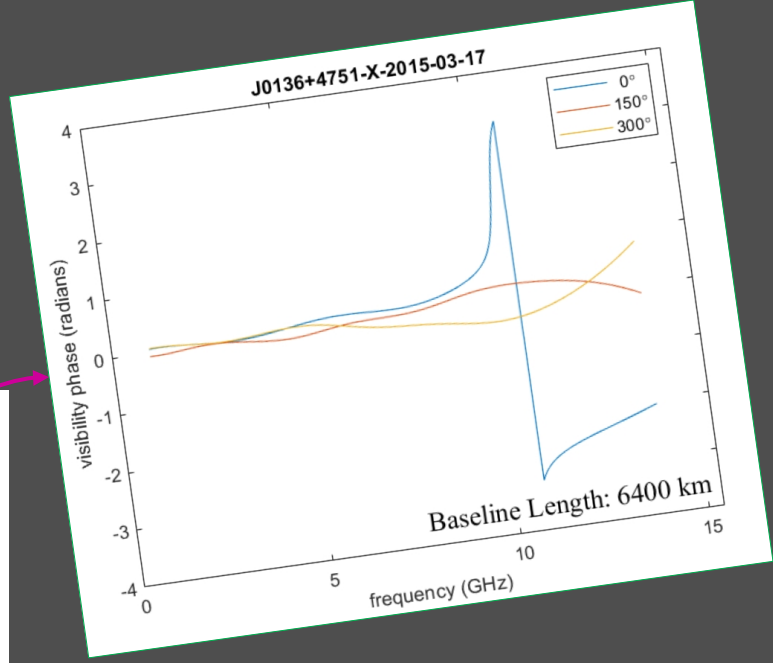
Visibility phase as a function of frequency for different baseline angles. Varying baseline angle with a fixed baseline length makes big changes in phases.

Visibility phase as a function of frequency for different baseline length. Varying the baseline length with a fixed angle causes a shift in frequency.

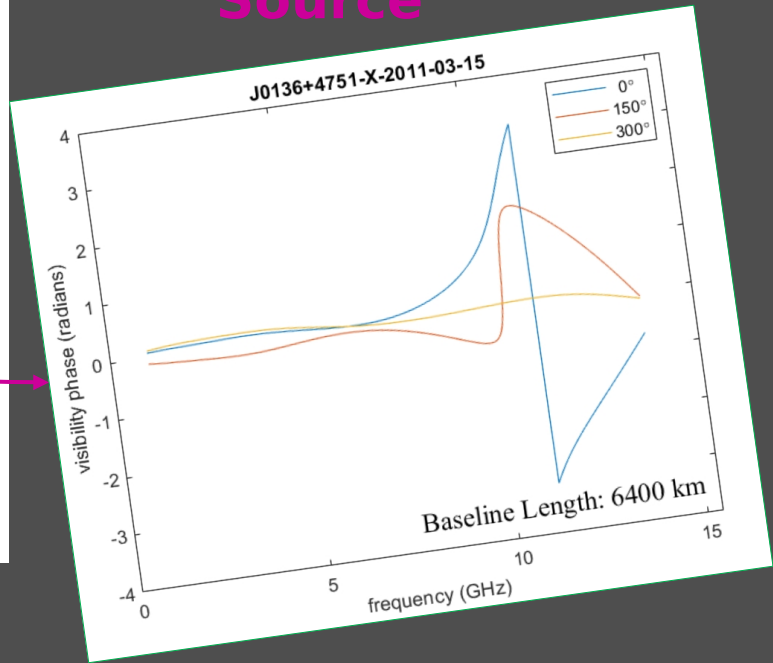


Compact Source



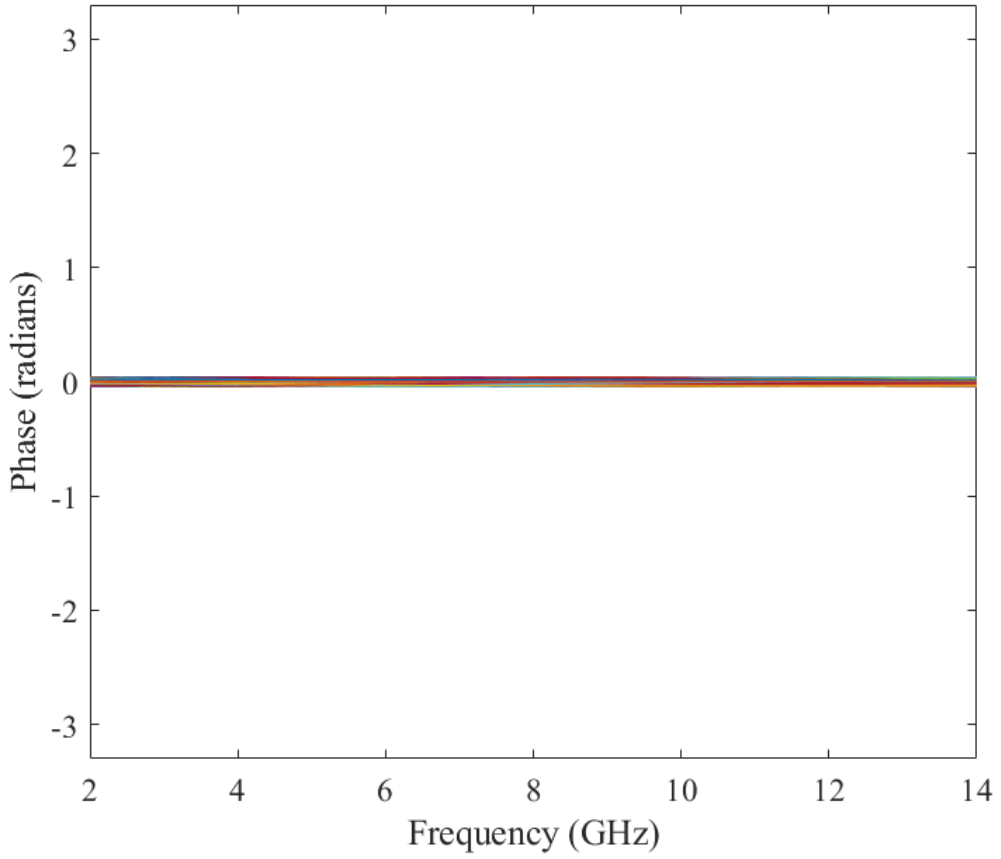


Extended Source

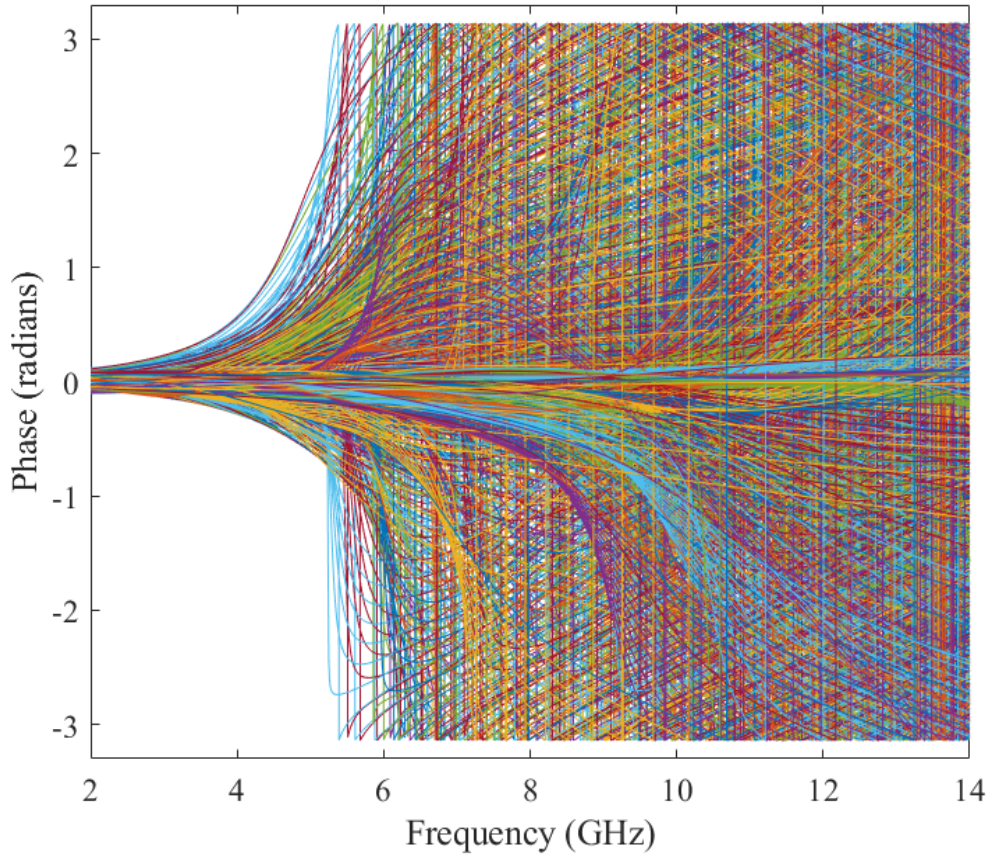


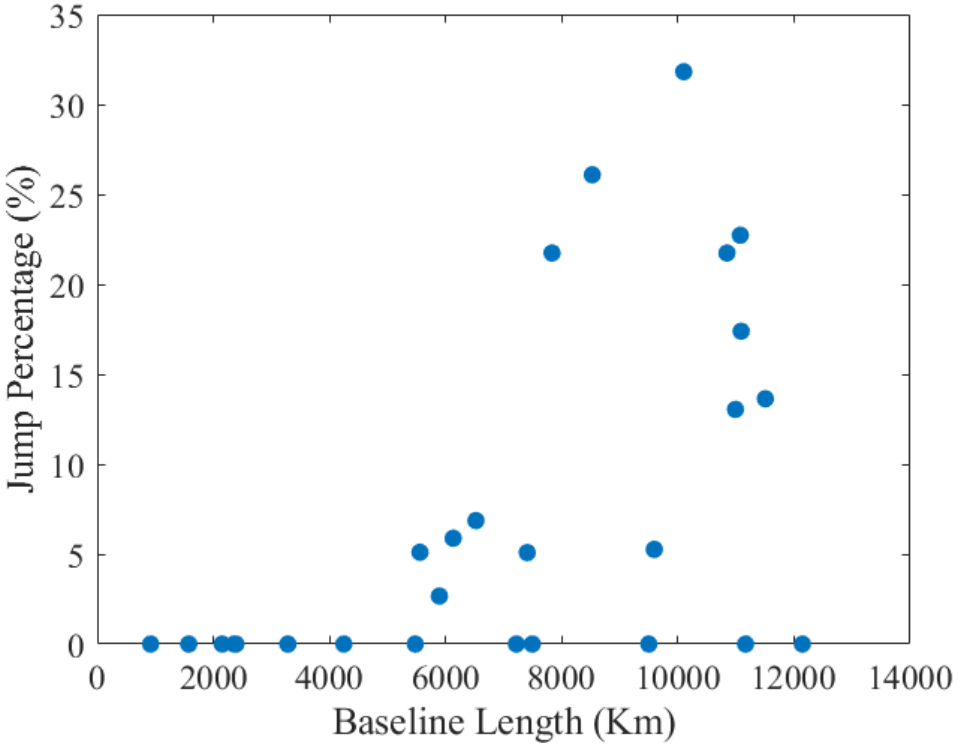
24hr observations with VGOS Baselines selection

Compact Source (2014)



Extended Source (2015)





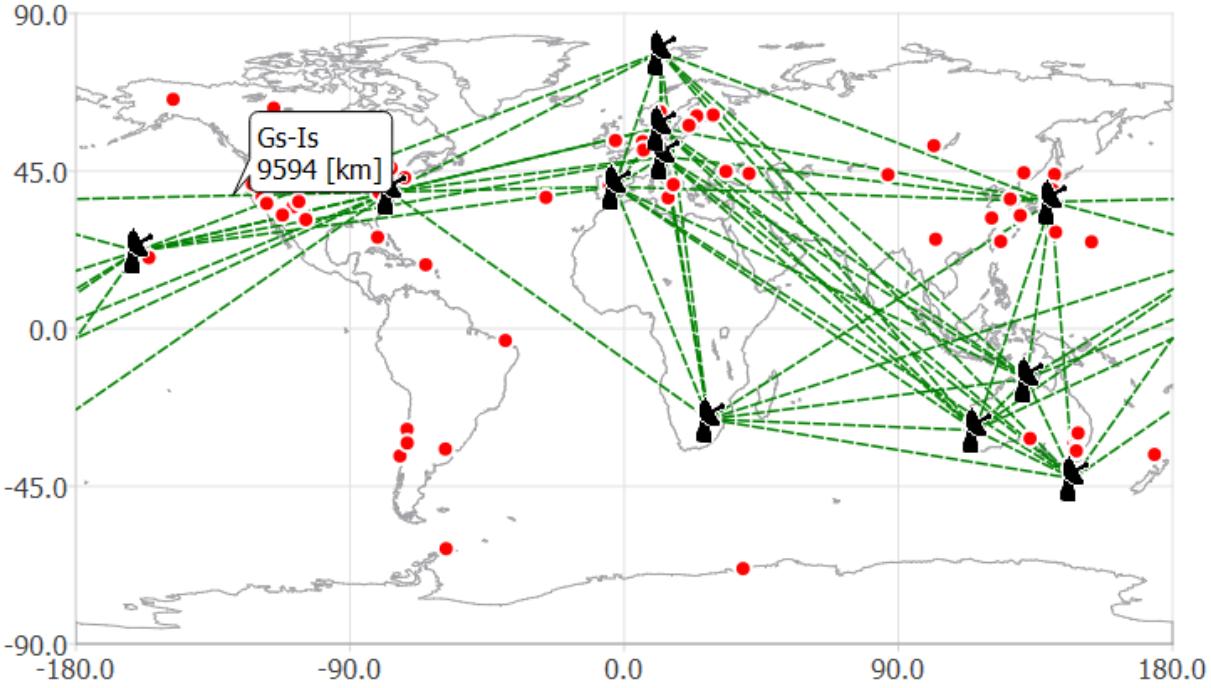
Phase jump percentage as a function of baseline length (more structure epoch)

VGOS Observations

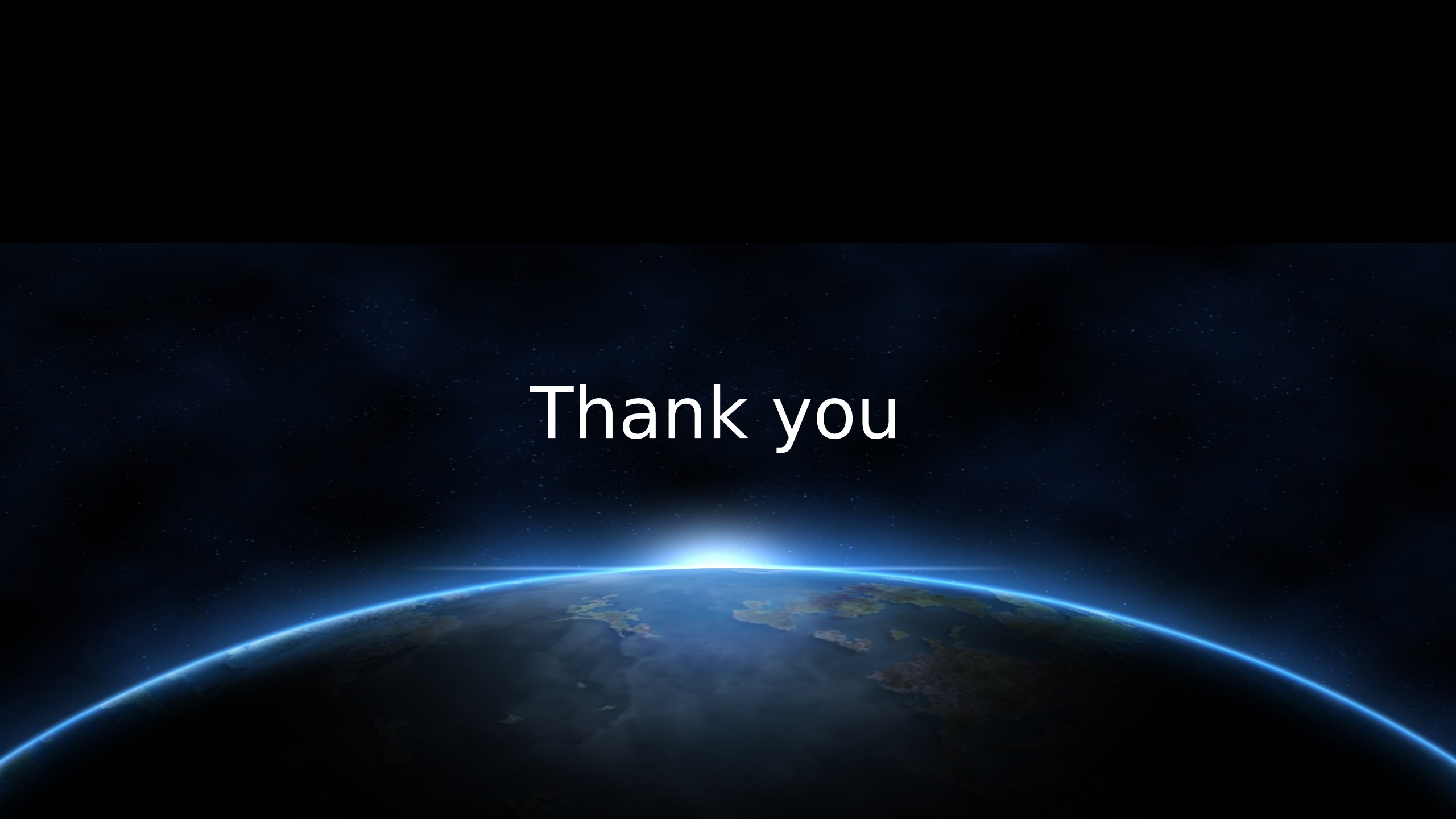
Baseline Length ↑ → Phase Jump (%) ↑

Next Steps

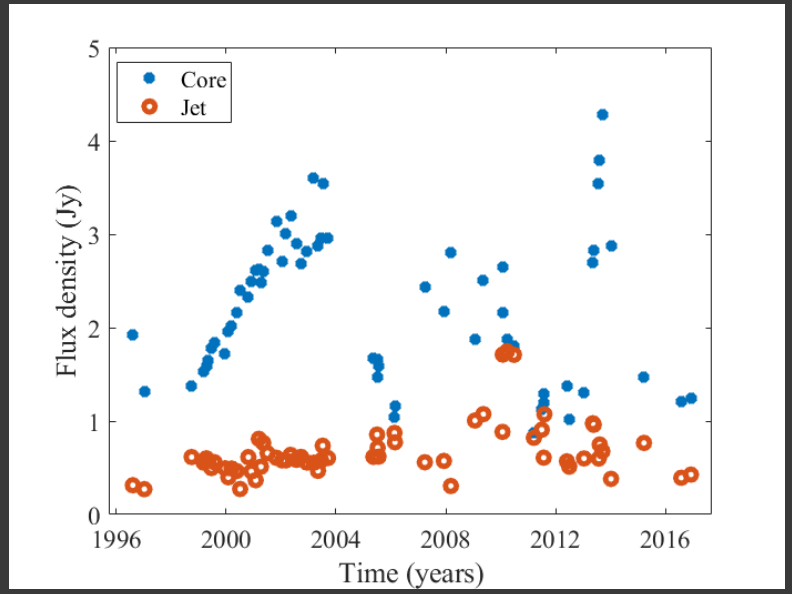
- Study more well observed sources
- Improving the routines for automatically deriving the source models
- Connect these theoretical investigations with real observations



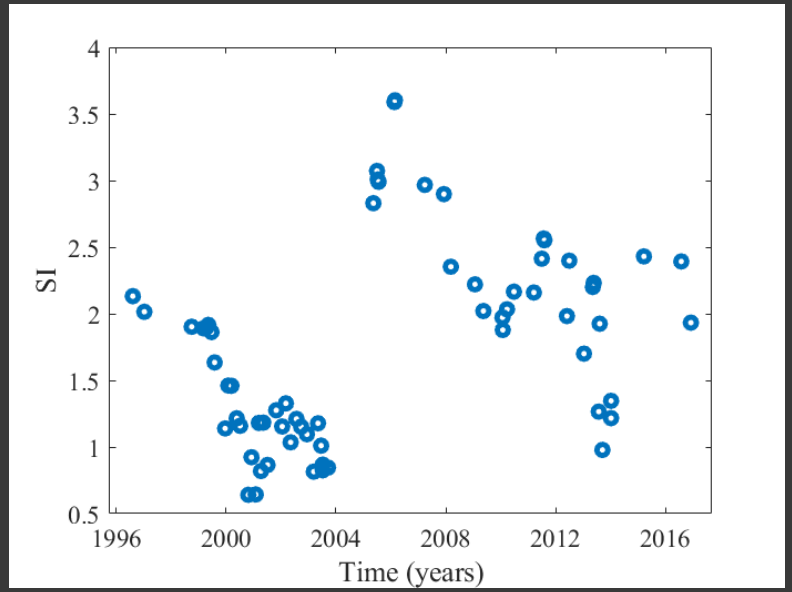
Using new, automated procedures for deriving source models allows us to investigate source structure in VGOS. The overall aim of these investigations is to identify the critical parameters which we need to know about, how they are expected to change with time; and ultimately how to observe sources with VGOS, so that they do not adversely influence geodetic and astrometric results.


Thank you

Changes in flux density of core and jet as a function of time show that we cannot consider this source as a point-like source.



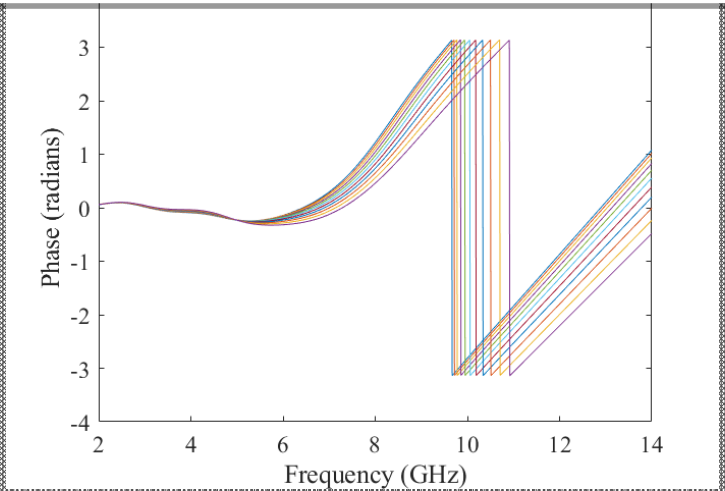
Source structure index as a function of time for X-band images. X-band structure index varies from 0.5 to 3.5 during the time. This source is a good candidate to study source structure effects.

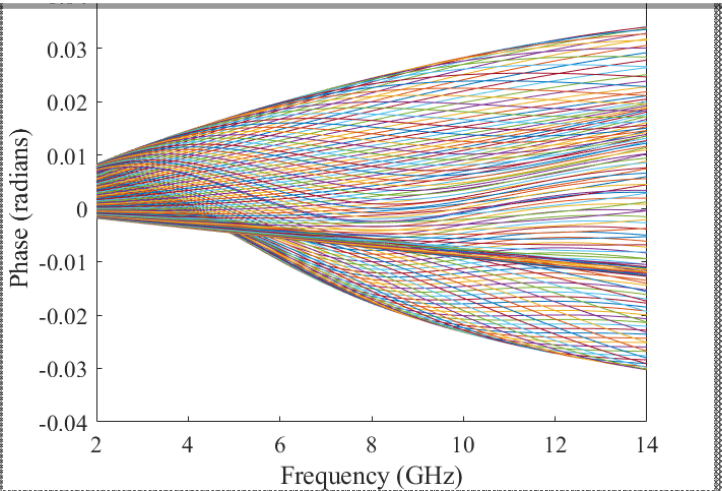


GGAO12M-KATH12M (longest baseline)

ONSA13SW-WETTZ13N (shortest baseline)

Extended Source





Compact Source