Aletha de Witt
AVN/Newton-fund 2017
Ekudeni, South Africa

NRF
National Research Foundation

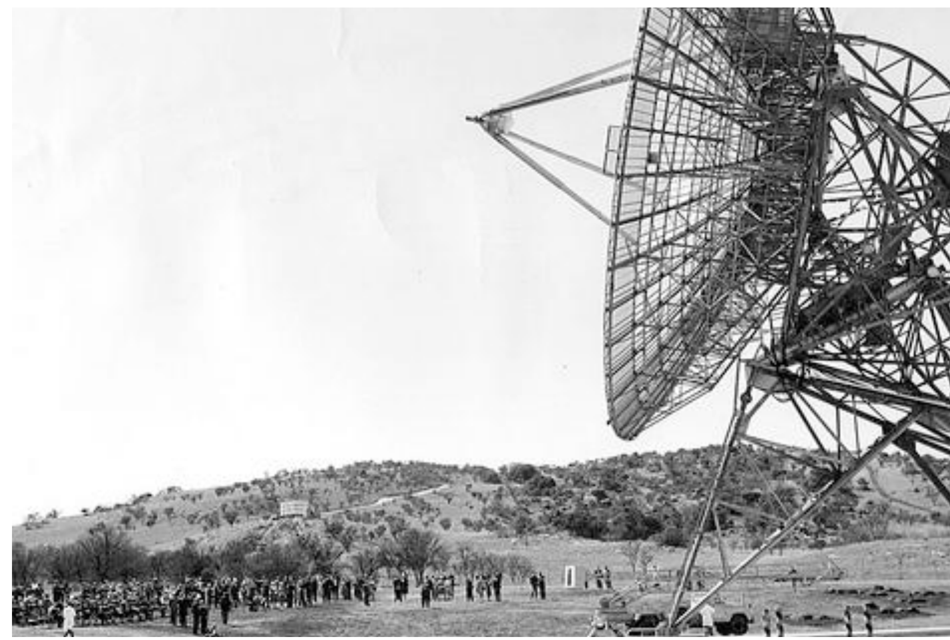
HartRAO
Hartebeesthoek Radio Astronomy Observatory

HartRAO location in South Africa

Latitude 25° 53' 27.1" South
Longitude 27° 41' 12.7" East.

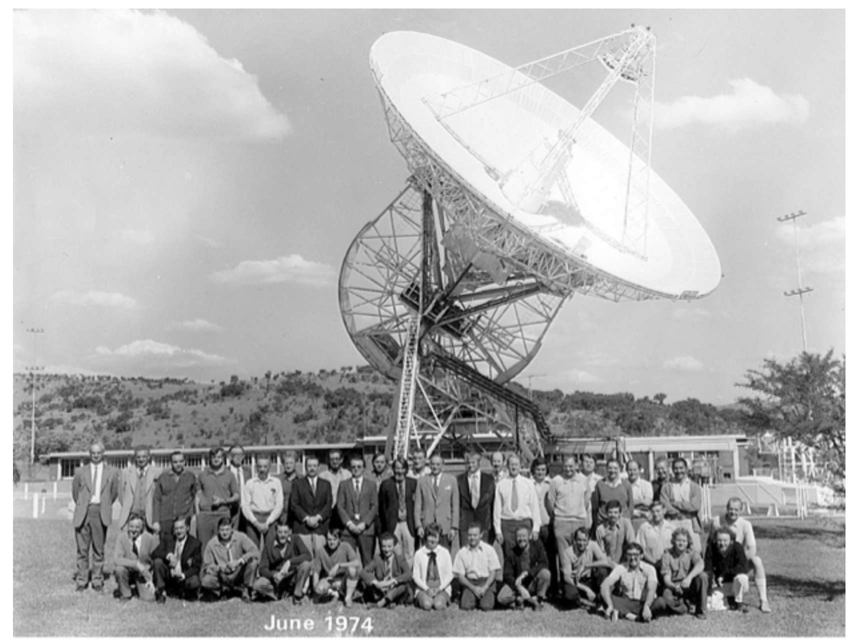
National Research Foundation
HartRAO
Hartebeesthoek Radio Astronomy Observatory

1961 - 1974 NASA Deep Space Station 51 operated by CSIR for NASA



Origins of HartRAO - tracking station

National Facility for Radio Astronomy and Space Geodesy



HartRAO since 1974

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HartRAO today

NRF National Research Foundation | HartRAO Hartebeesthoek Radio Astronomy Observatory

What HartRAO does

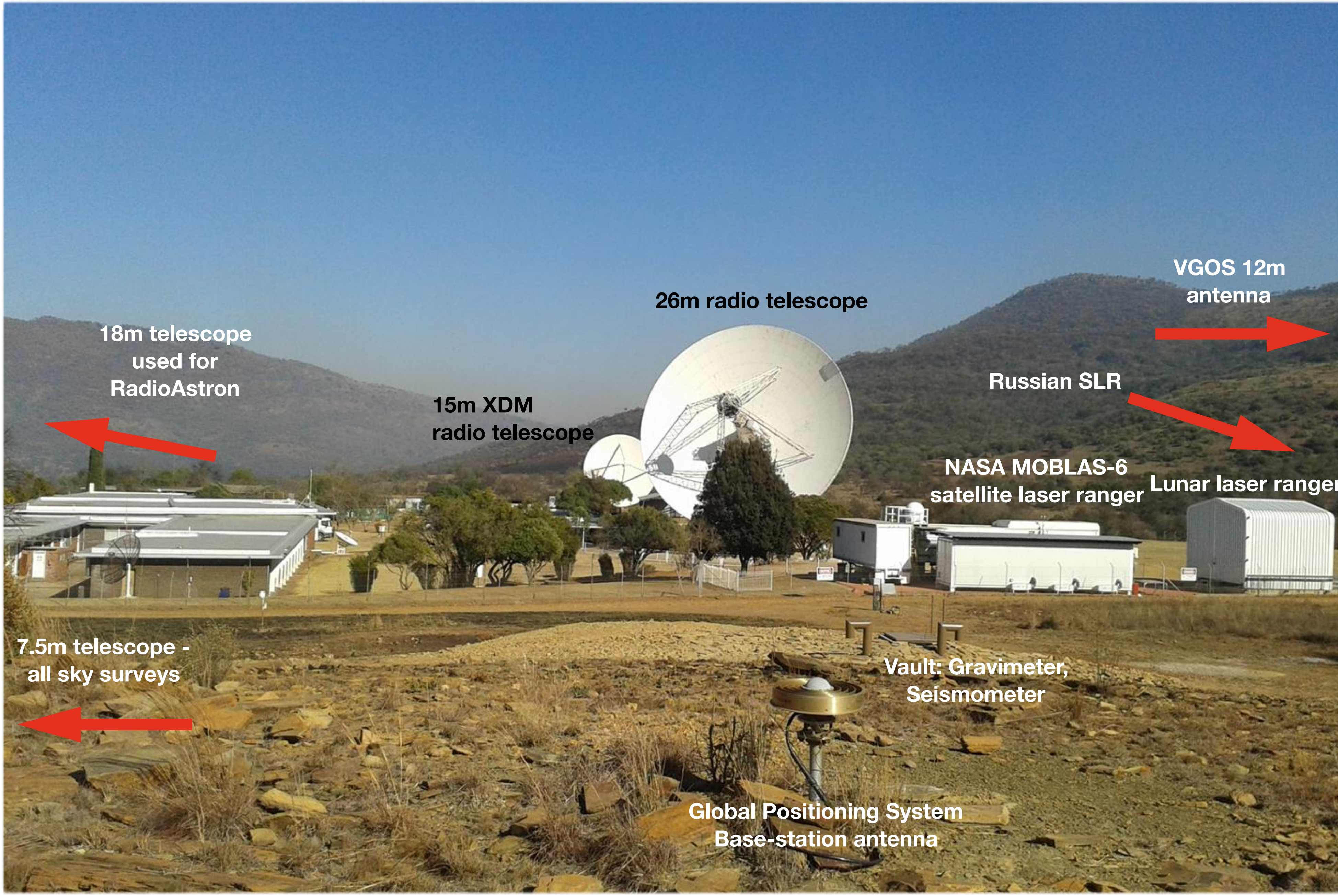
- Radio Astronomy Research -
  Studying objects in the Universe that produce radio waves (VLBI)

- Space Geodesy Research -
  Using radio astronomy and space techniques to study the Earth (VLBI)

- Engineering and Technical -
  Maintenance, upgrading, testing and development

- Radio Astronomy & Geodesy Development -
  e.g. SKA, AVN, VGOS, ICRF-3 ….

- Tertiary Education and Training & Science Awareness and Outreach
  In association with Universities e.g. NASSP, WITS, AVN-Newton Fund
  public and school visits and workshops for educators



HartRAO Facilities

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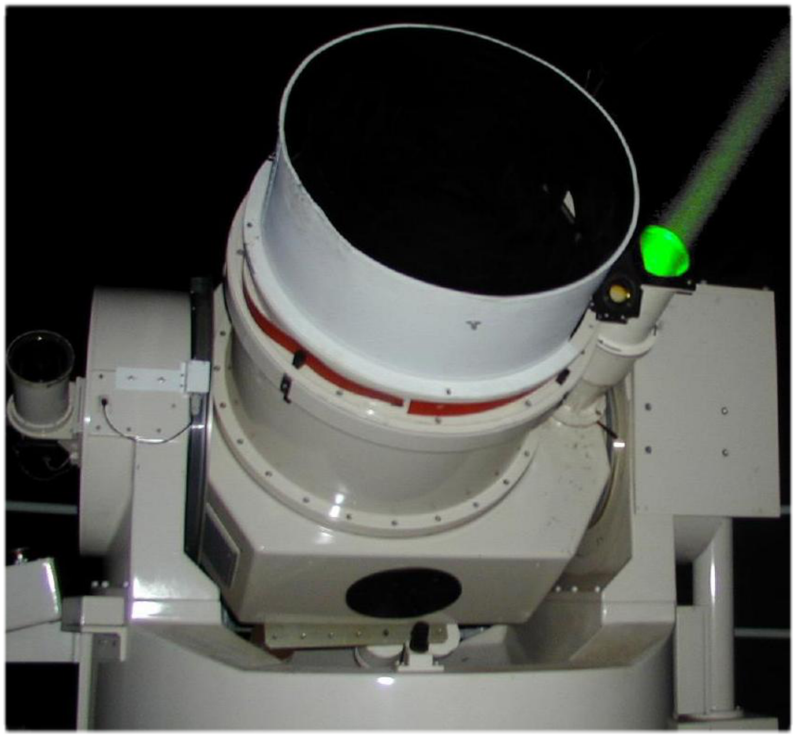
HartRAO Facilities



HartRAO/NASA **Satellite Laser Ranger**

HartRAO **Lunar Laser Ranger**

Gravimeter, Seismometer
Seismic network across SA, Gough and Marion island: 10 additional seismic stations.

Global Navigation Satellite System (GNSS) receivers for GPS, GLONASS and Galileo, at HartRAO and at other locations, for geodesy

Gough Island **Tide Gauge** installed.

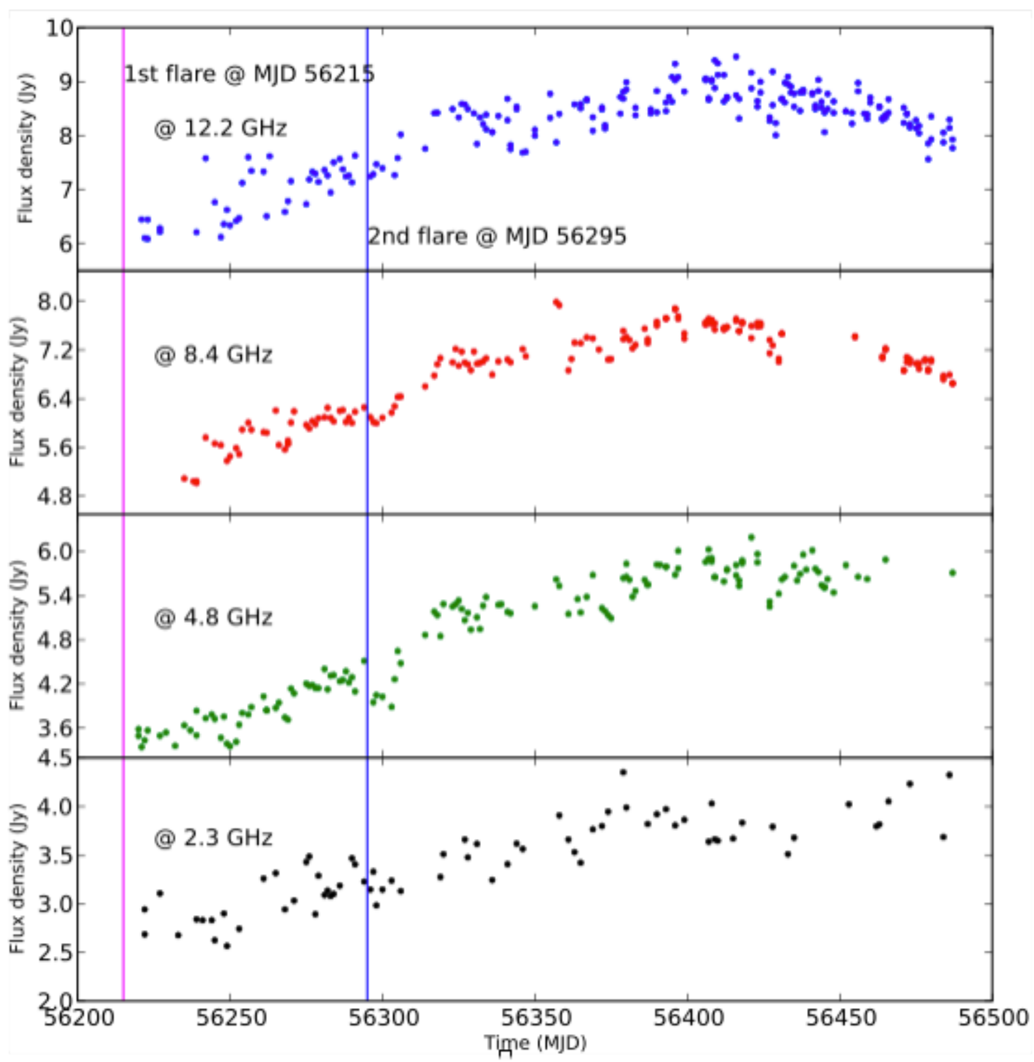
HartRAO Facilities

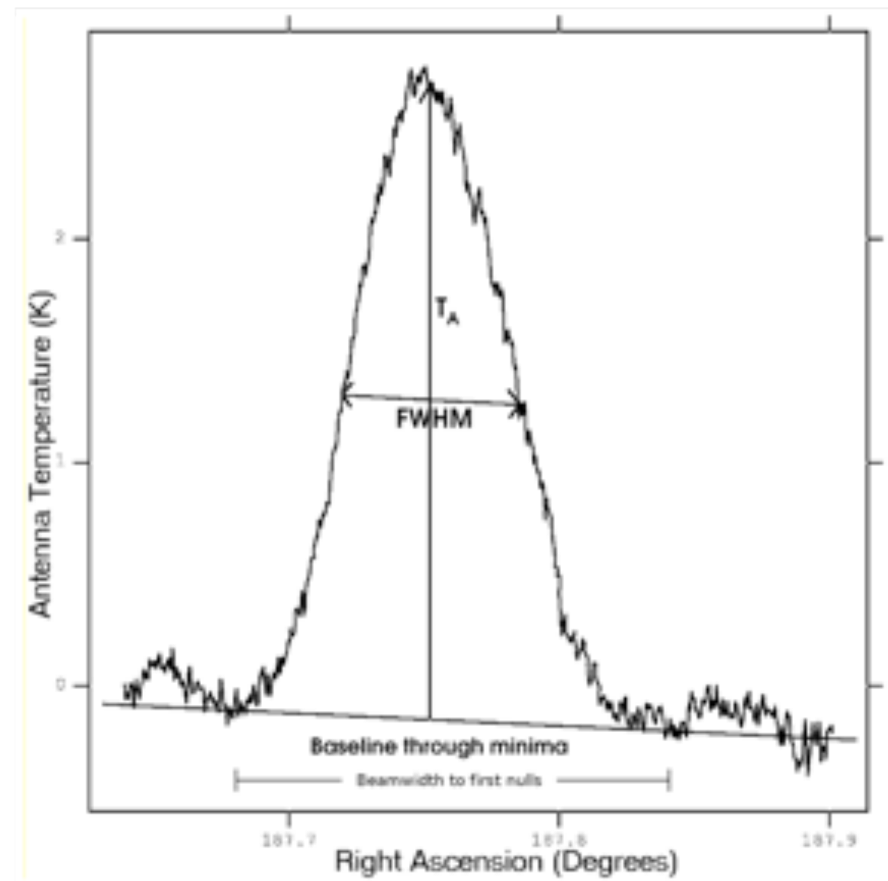
New Russian SLR: Opening 27 February 2017

Single Telescopes

- **Radiometry –** measuring the strength of radio emission from objects in space in a specific frequency band
- **Spectroscopy –** measuring the strength of emission lines at specific frequencies emitted by atoms and molecules
- **Pulsar timing –** measuring the arrival time of radio pulses from the collapsed remnants of stars that have exploded

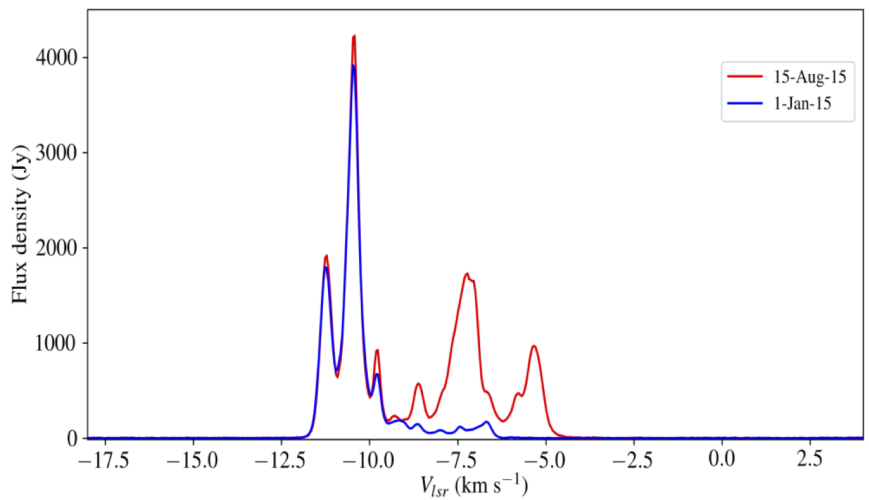
Single Telescopes



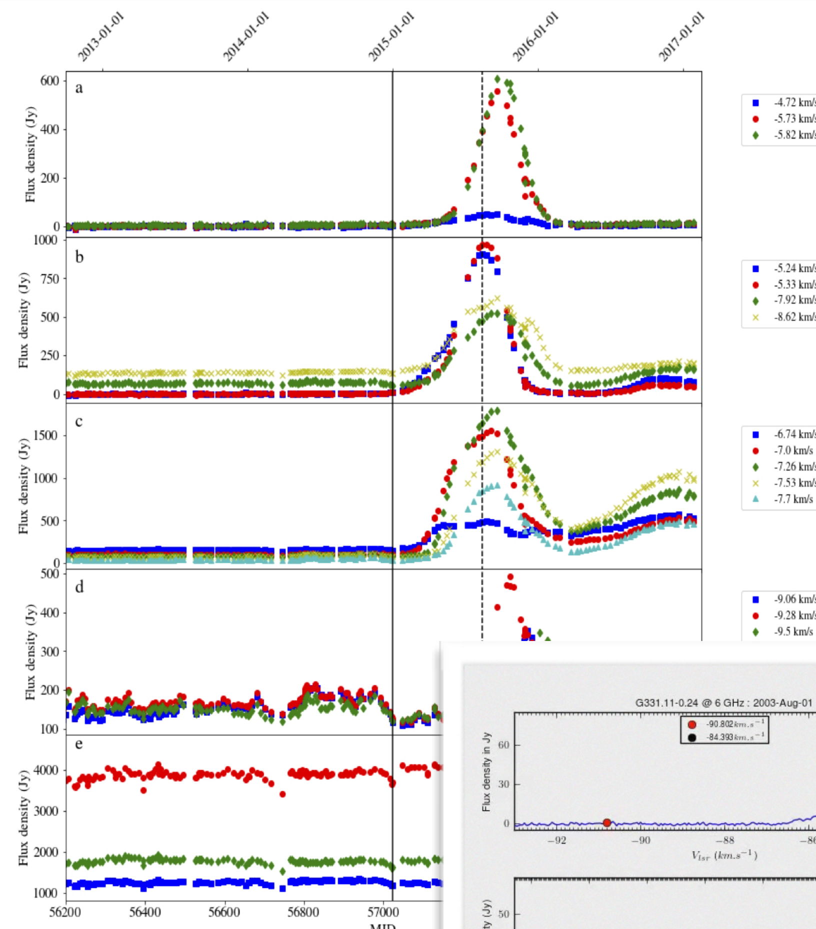


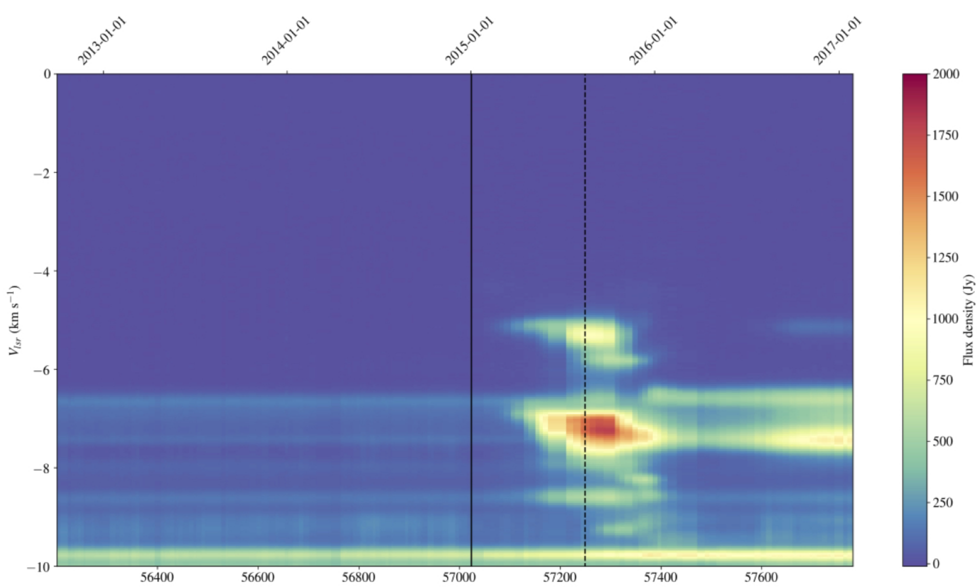
PKS 1424-41 / J1427-4206
Image Credit: Pfesesani Nemanashi, Mike Gaylard

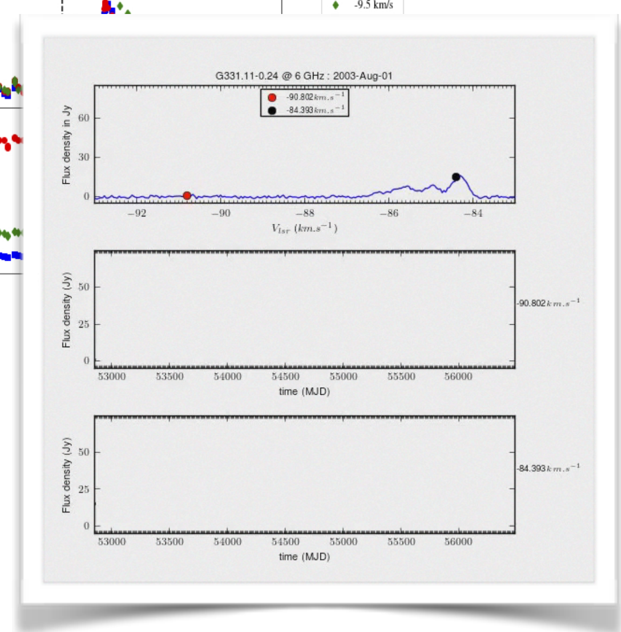
Single Telescopes



NGC6334F, 6.7 GHz (methanol) masers
Image Credit: Dr Gordon MacLeod

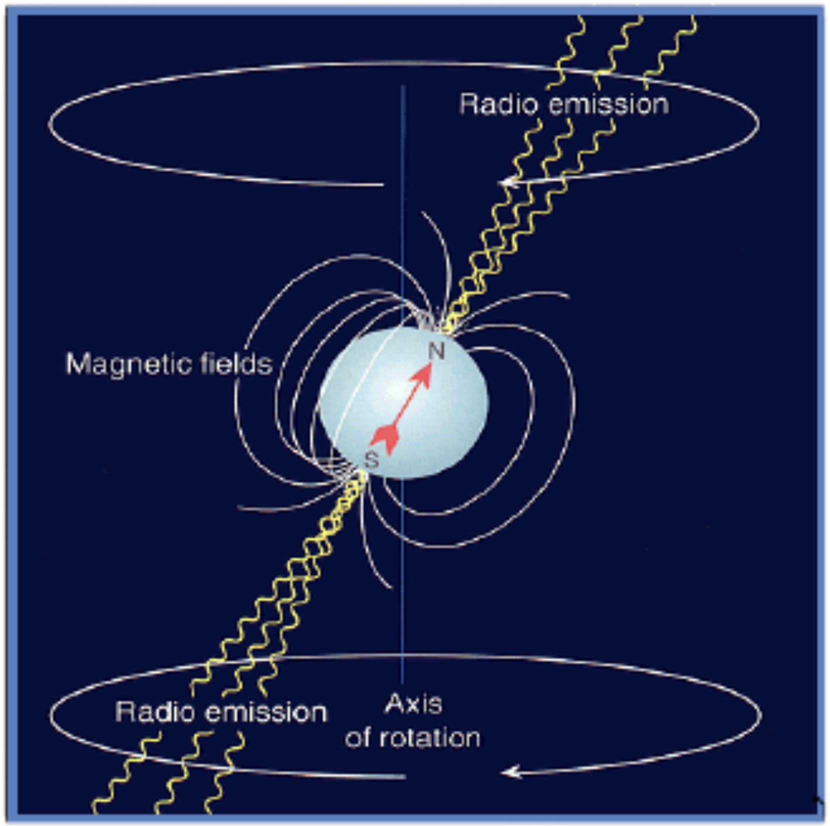


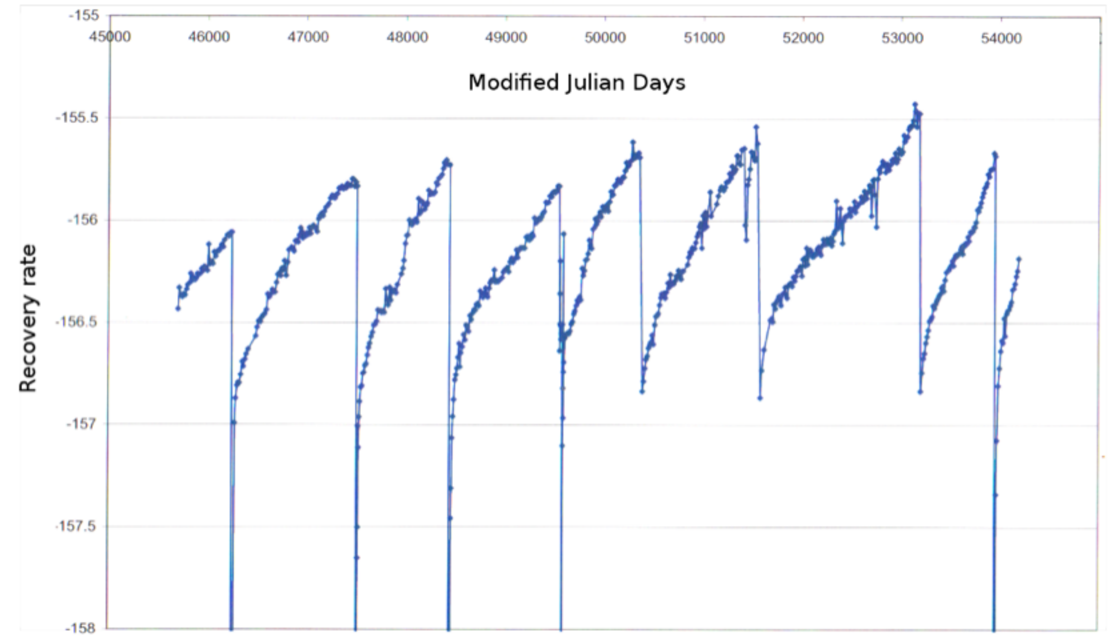




6.7 GHz (methanol) masers from massive star forming regions.
Image Credit: Jabulani Maswanganye

Single Telescopes

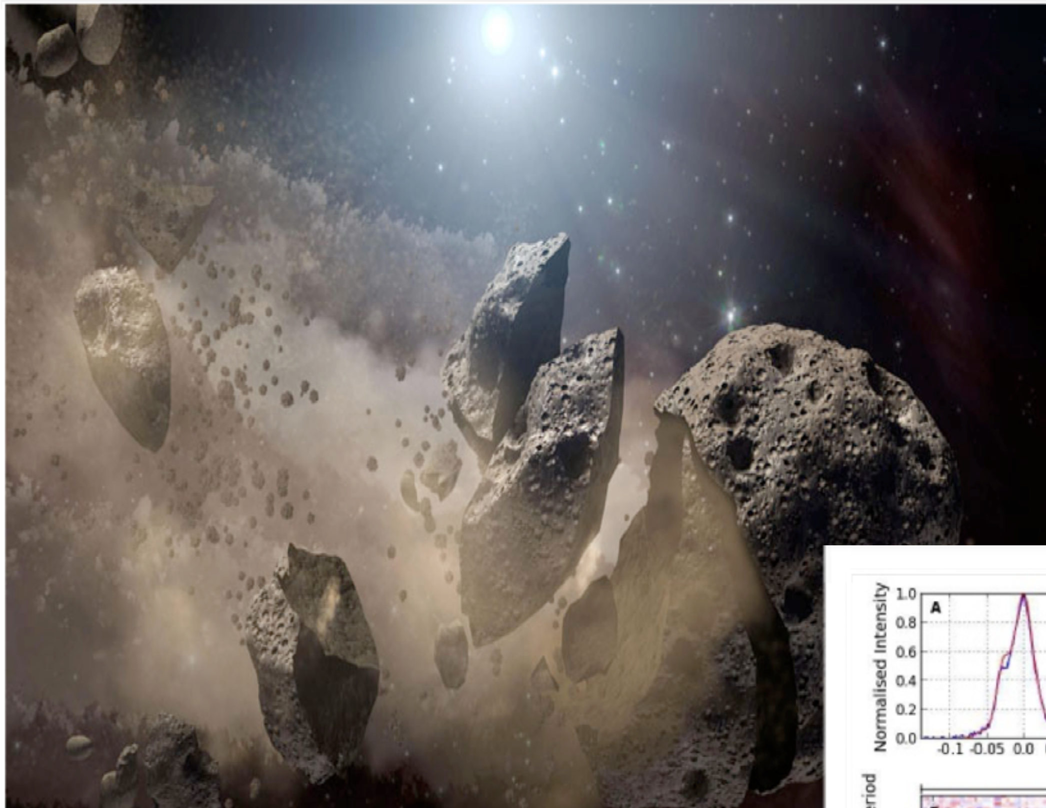




Pulsars are usually very stable clocks. But occasionally they suddenly speed up in an event known as a glitch.
By monitoring how the pulsar spin rate recovers from a glitch we can find out about the inside of the neutron star.
Image Credit: Sarah Buchner

A massive star ends its life in a supernova explosion. Left behind is a small dense, rapidly rotating neutron star. This emits radiation at its magnetic poles. These beams sweep across the sky like a lighthouse. Each time the beam passes the Earth we see a pulse.

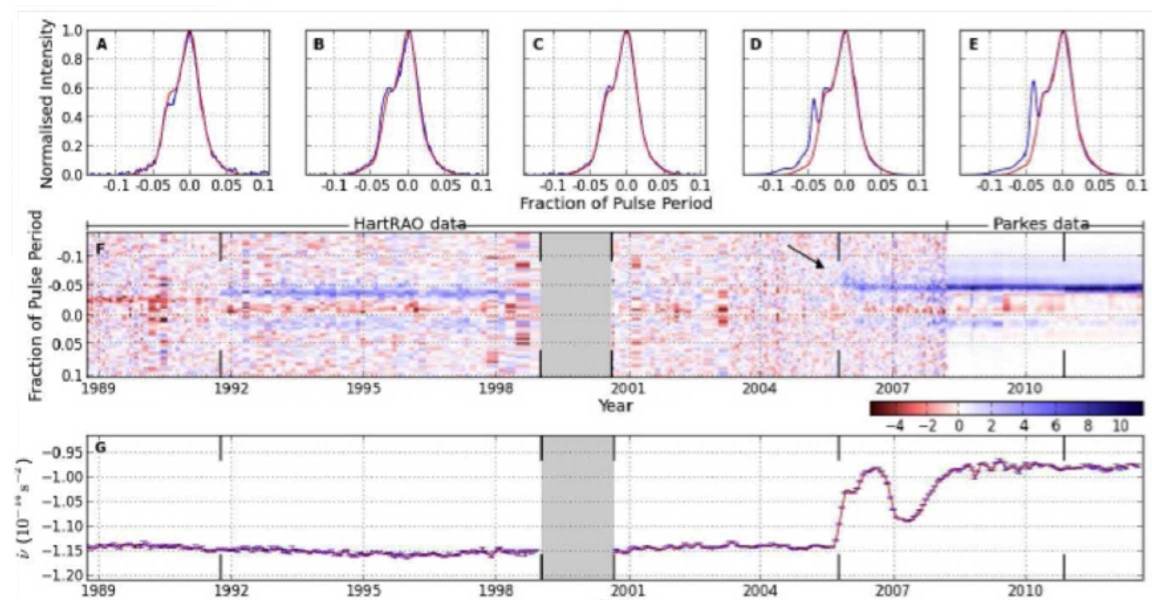
Single Telescopes



Artist's impression of an asteroid being vaporised (JPL-Caltech/ NASA)

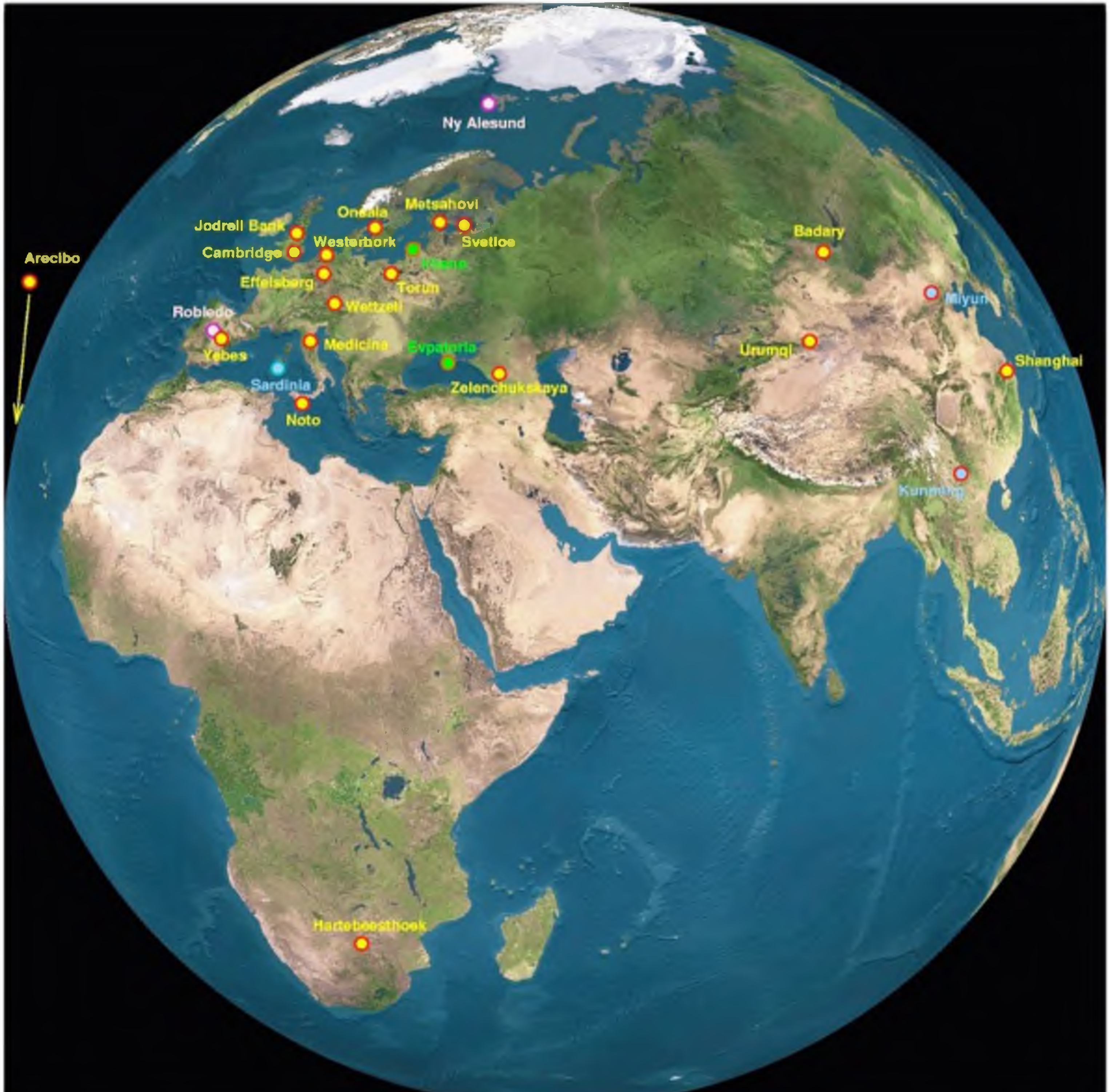
PSR J0738-4042 in the constellation Puppis are regularly monitored by radio astronomer Sarah Buchner using the HartRAO 26 m antenna.

Analysis of the data show pulse profile changes occurring coincided with an abrupt, significant change in the rotation rate.



We expect that material ejected in a supernova explosion will form debris disks and asteroid belts around the newly formed pulsar. An infalling asteroid would interact with the pulsar magnetosphere to produce changes in the pulse shape and rotation rate.

VLBI



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Very Long Baseline Interferometry (VLBI)

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- **Astronomy** -
  Very fine detail of the radio emission from compact objects with high brightness temp e.g. active galactic nuclei (AGN's), interstellar masers (star-forming regions), Megamasers (extragalactic), radio stars, core collapse supernovae, pulsars

- **Astrometry** -
  Very precise positions for radio sources in space:
  - Sources absolute and differential positions, proper motions, parallaxes
  - definition and densification of the celestial reference frame (ICRF)
  - spacecraft tracking

- **Geodesy** -
  Very precise positions for the radio telescopes in the network:
  - Terrestrial reference frame
  - Earth orientation and rotation (the length of day)
  - Tectonic plate motion

VLBI Networks

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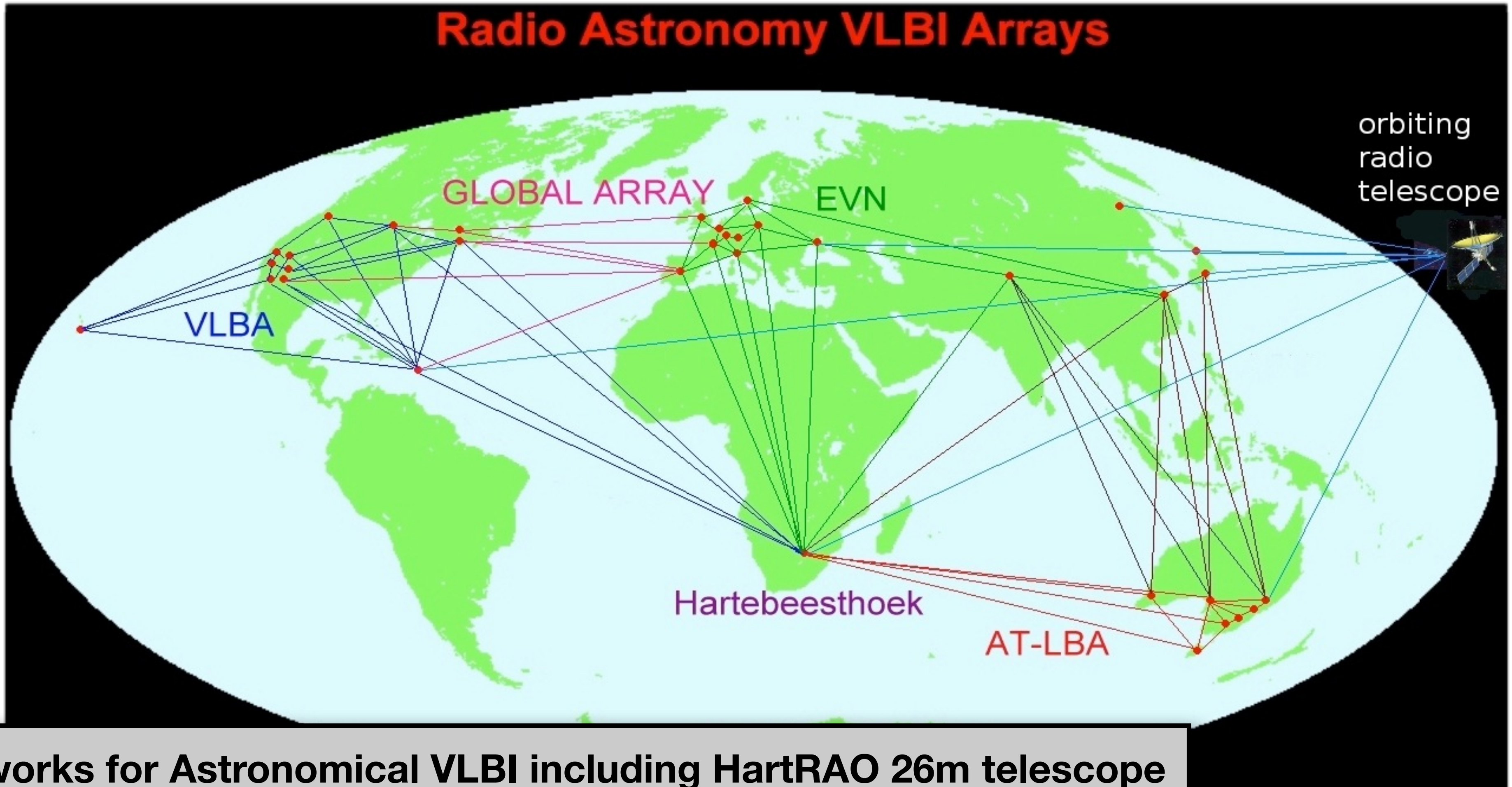
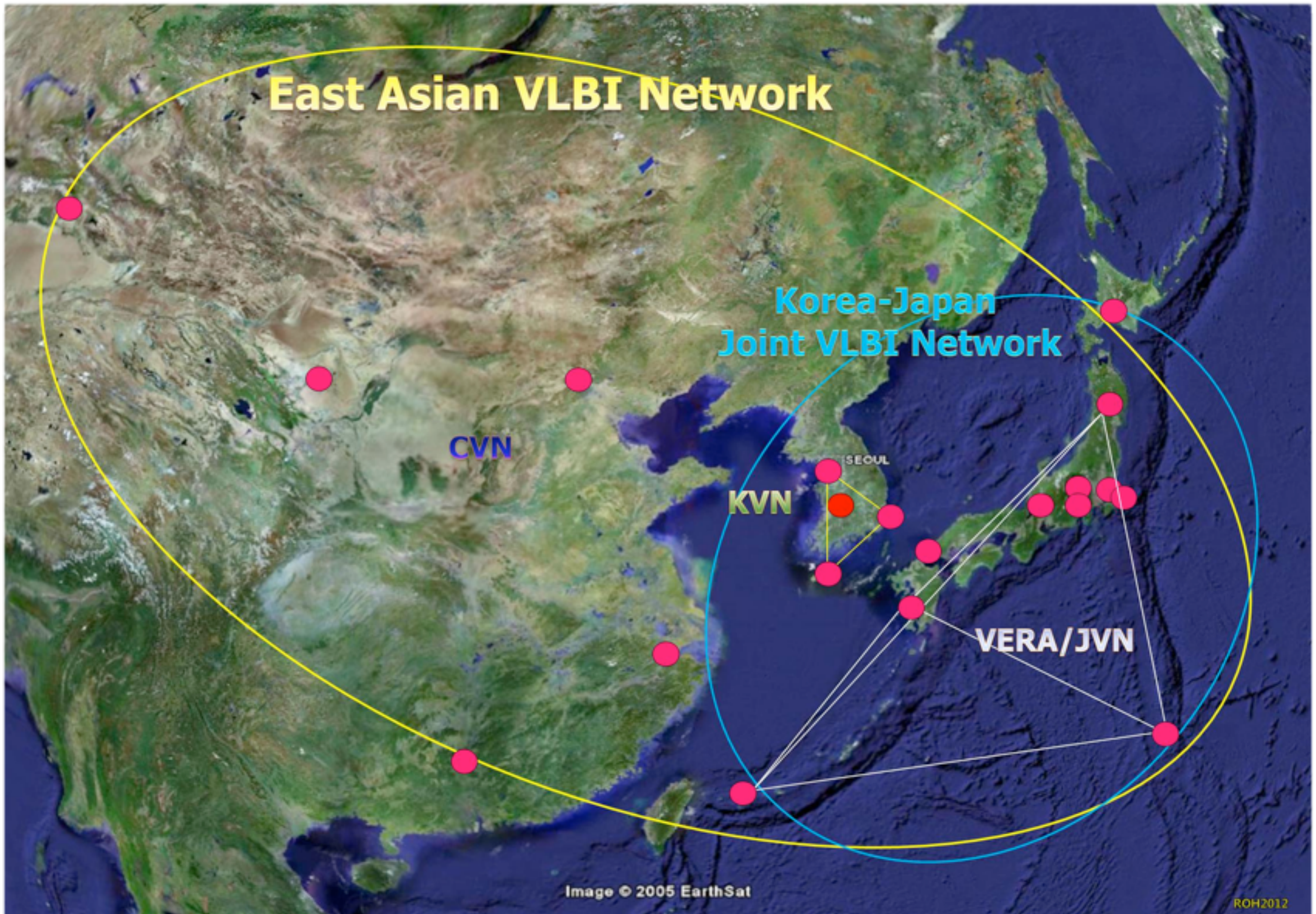


Networks for Astronomical VLBI including HartRAO 26m telescope
- EVN: European VLBI Network (eEVN)
- AT-LBA: The Australian Telescope Long Baseline Array
- Global Array: EVN + US VLBA + others
- Space VLBI: RadioAstron

VLBI Networks



EAVN: East Asia VLBI Network (CVN, JVN, KVN)

VLBI Networks

- AVN - African VLBI Network (HartRAO and SA SKA project)

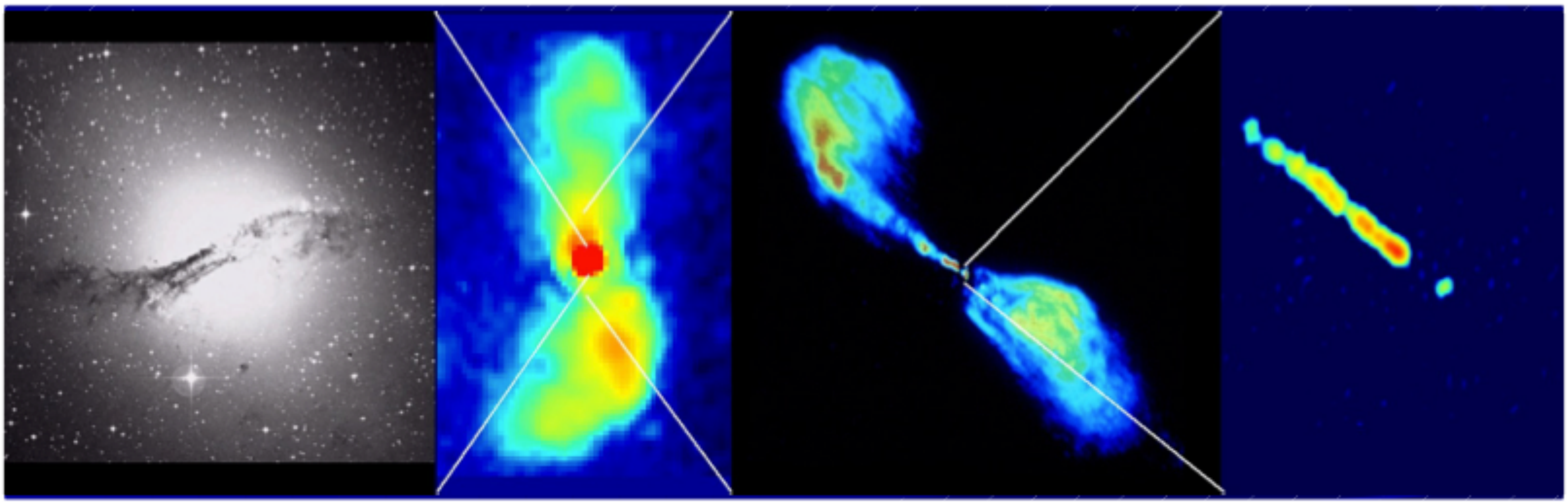
1. Start with HartRAO/SA
2. Add countries with available large satellite antennas
3. Add countries with new antennas

The 32m dish in Ghana shown on the right.

VLBI: Astronomy

Optical image: angular extent on the sky of about **one quarter of a degree.**

VLBI (LBA + HartRAO) image: fine details of upper jet as it leaves the area around the black hole (centre). This part of the jet is about **one hundred thousandth of a degree** long, and we see details smaller than **a millionth of a degree.**

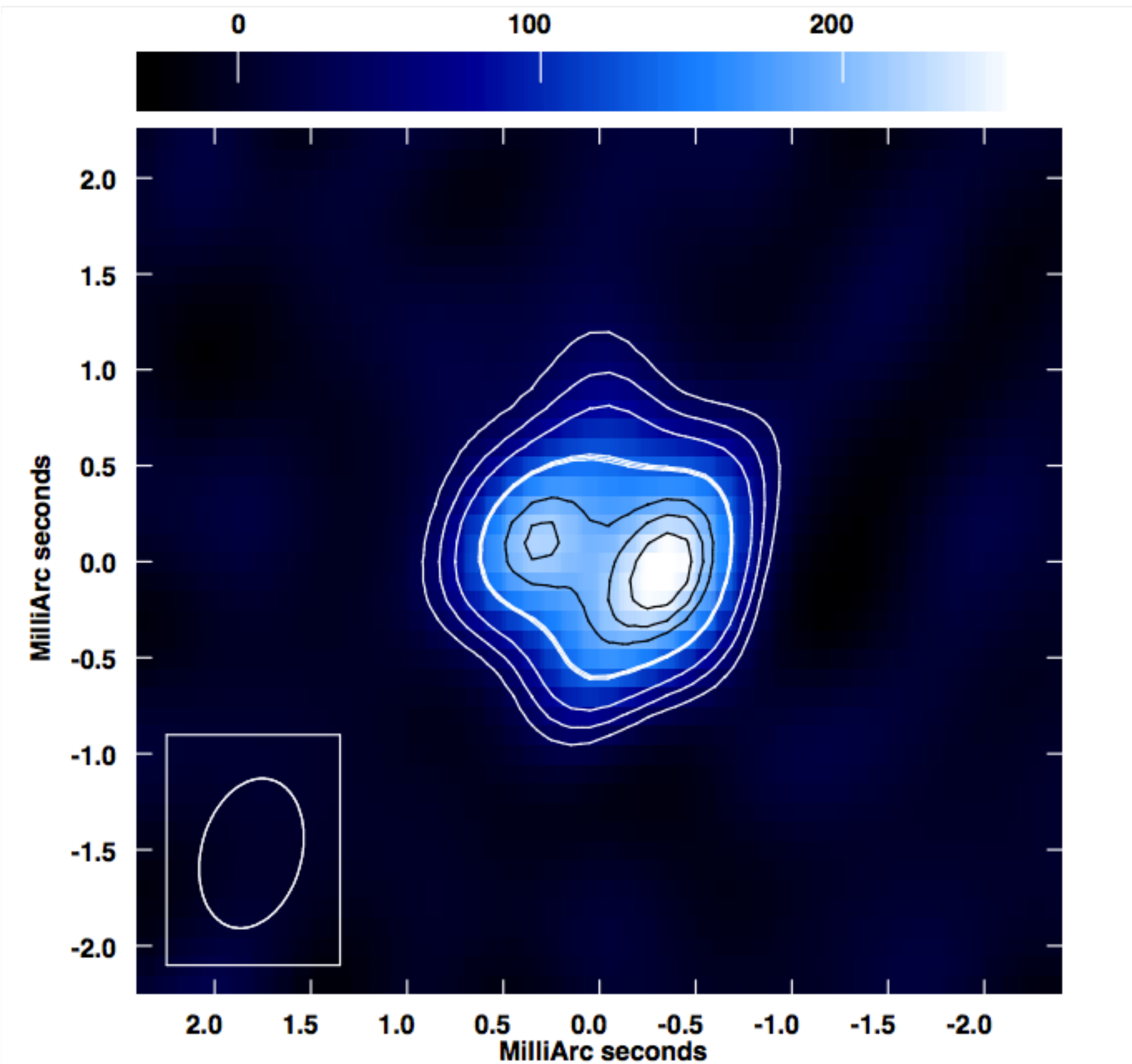


The full radio emission: HartRAO 26m at 13cm, **resolution of 1/3 of a degree.** Cover nearly **ten degrees on the sky.**

VLA radio continuum observations of the inner lobes at 20cm. **Field of view 11x11 arcmin** at a **resolution 30x10 arcsec.**

NGC5128 / Centaurus A

VLBI: Astronomy

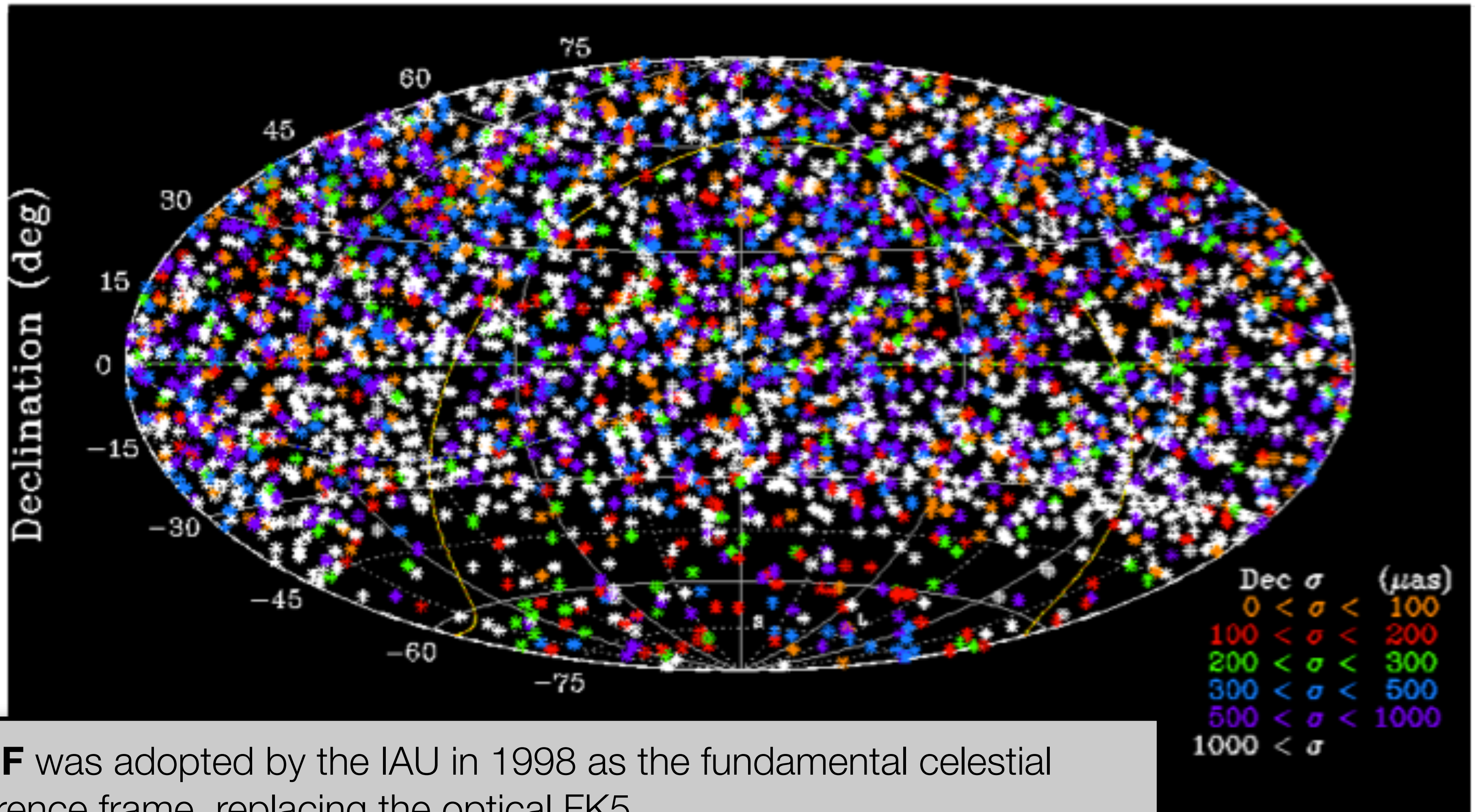


Only very few supernovae are close enough and radio bright enough that the expanding shell of ejecta can be clearly resolved by VLBI observations.

SN 2011dh is one of only a few supernovae for which the shell has been resolved.

SUPERNOVA 2011dh.
VLBA observations at 8.4 GHz.
A circular shell structure is visible, but there is a hot-spot to the west

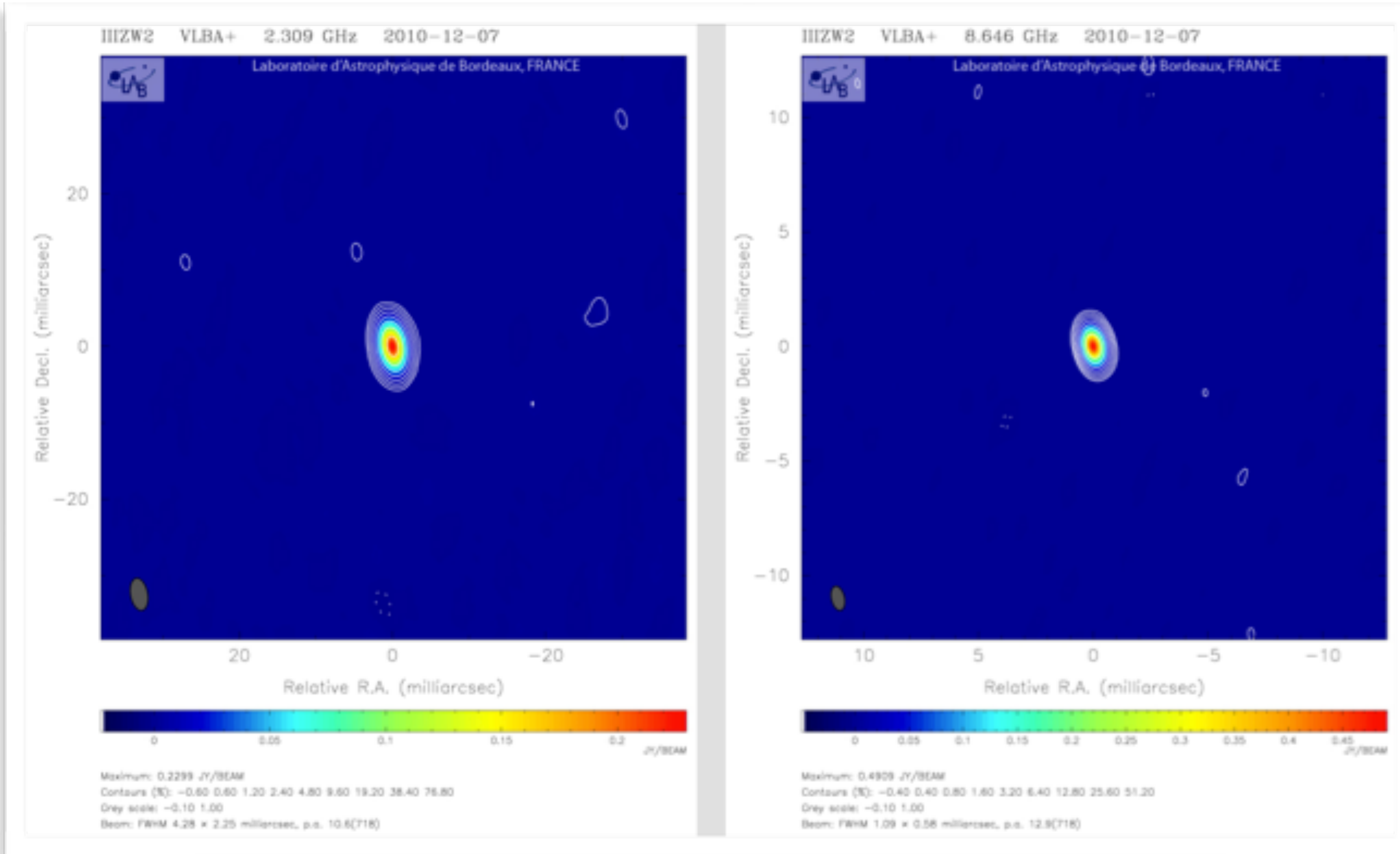
VLBI: Astrometry



- **ICRF** was adopted by the IAU in 1998 as the fundamental celestial reference frame, replacing the optical FK5.
- Since 1 January 2010 the IAU adopted the ICRF-2 including coordinates of 3414 extragalactic sources (AGN's), comprising 295 defining sources.
- ICRF-3 currently being built by a working group of the IAU.

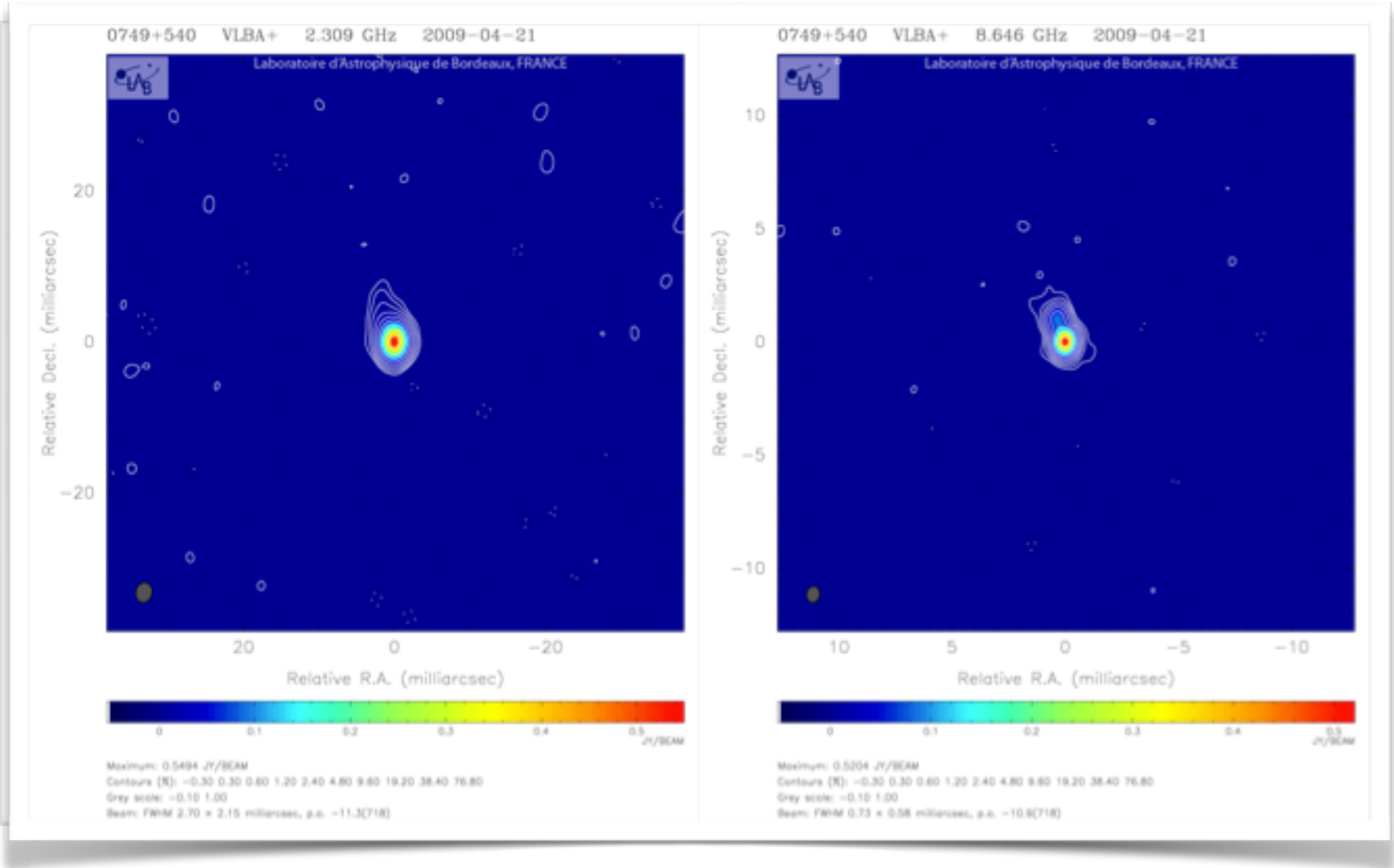
VLBI: Astrometry

- good source



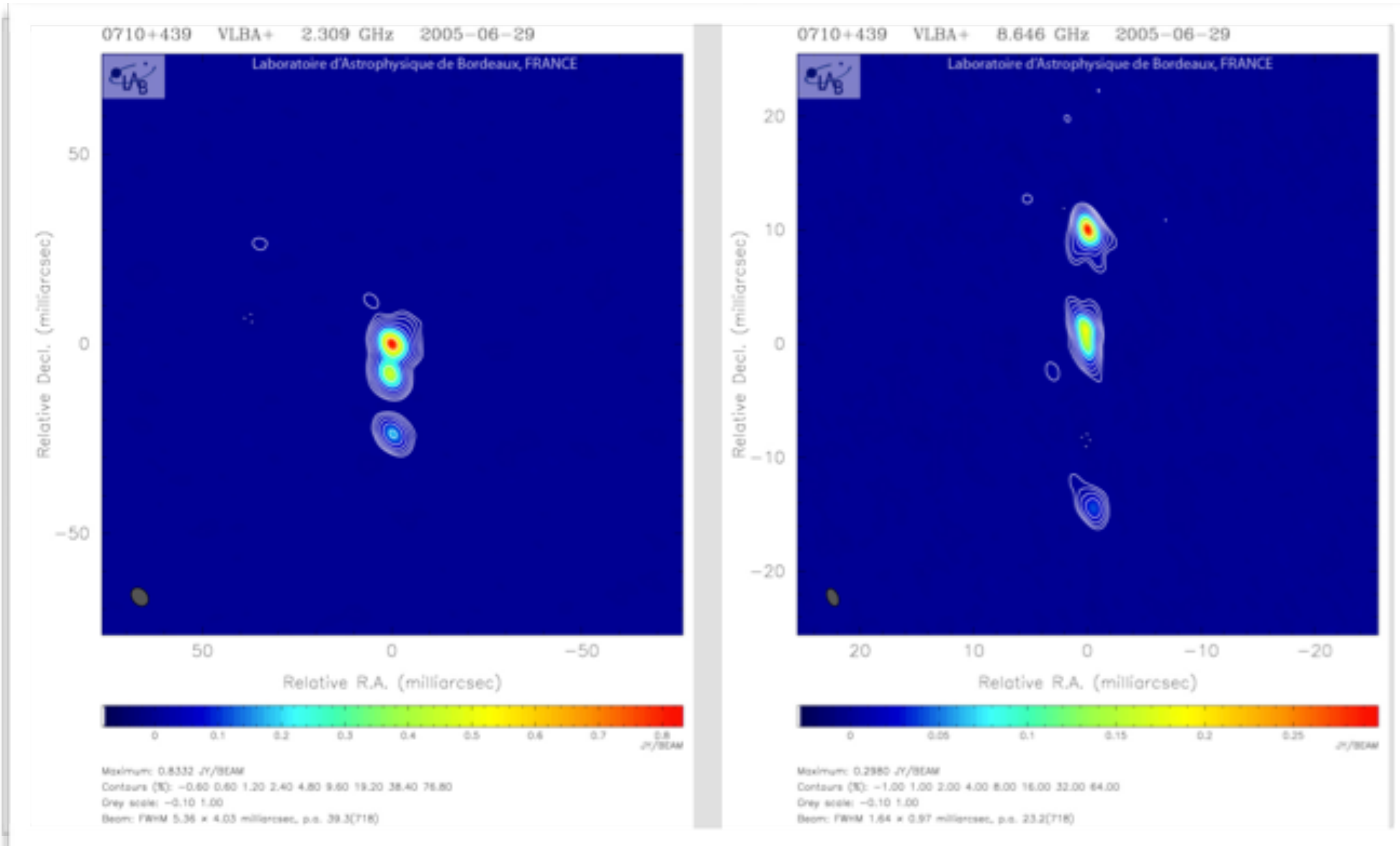
VLBI: Astrometry

- ok source

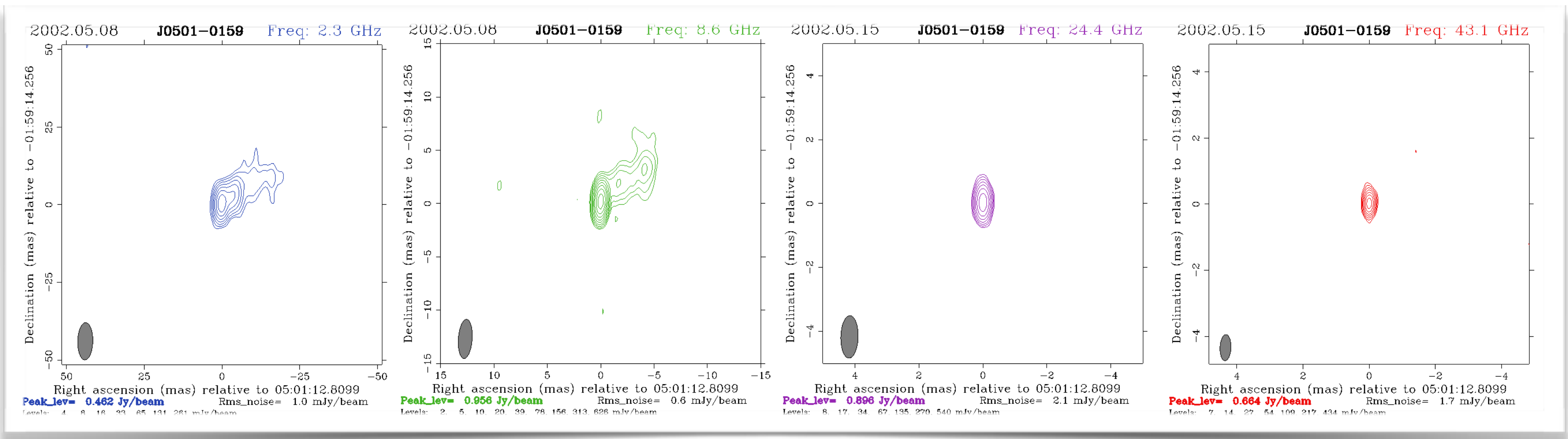


VLBI: Astrometry

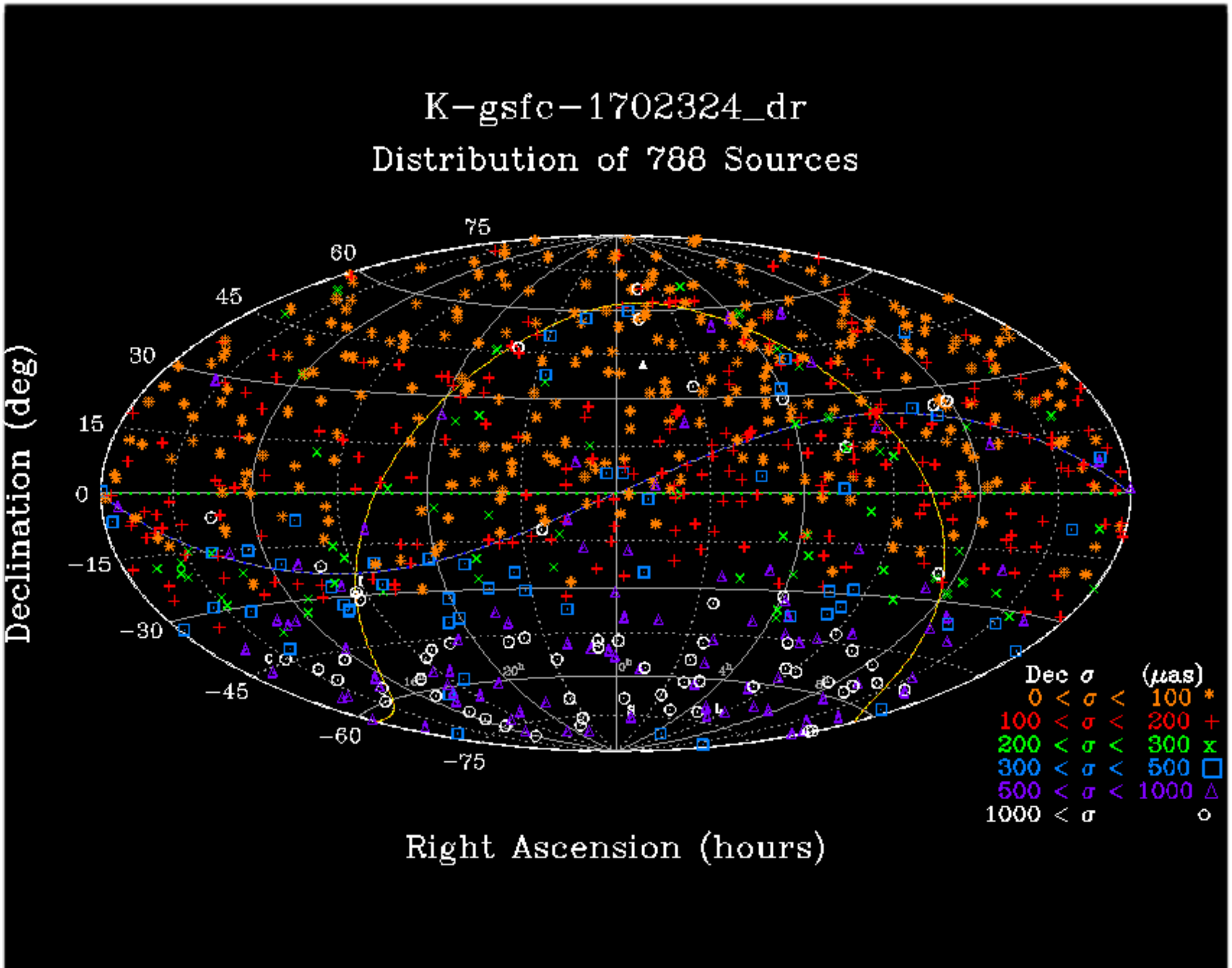
- bad source



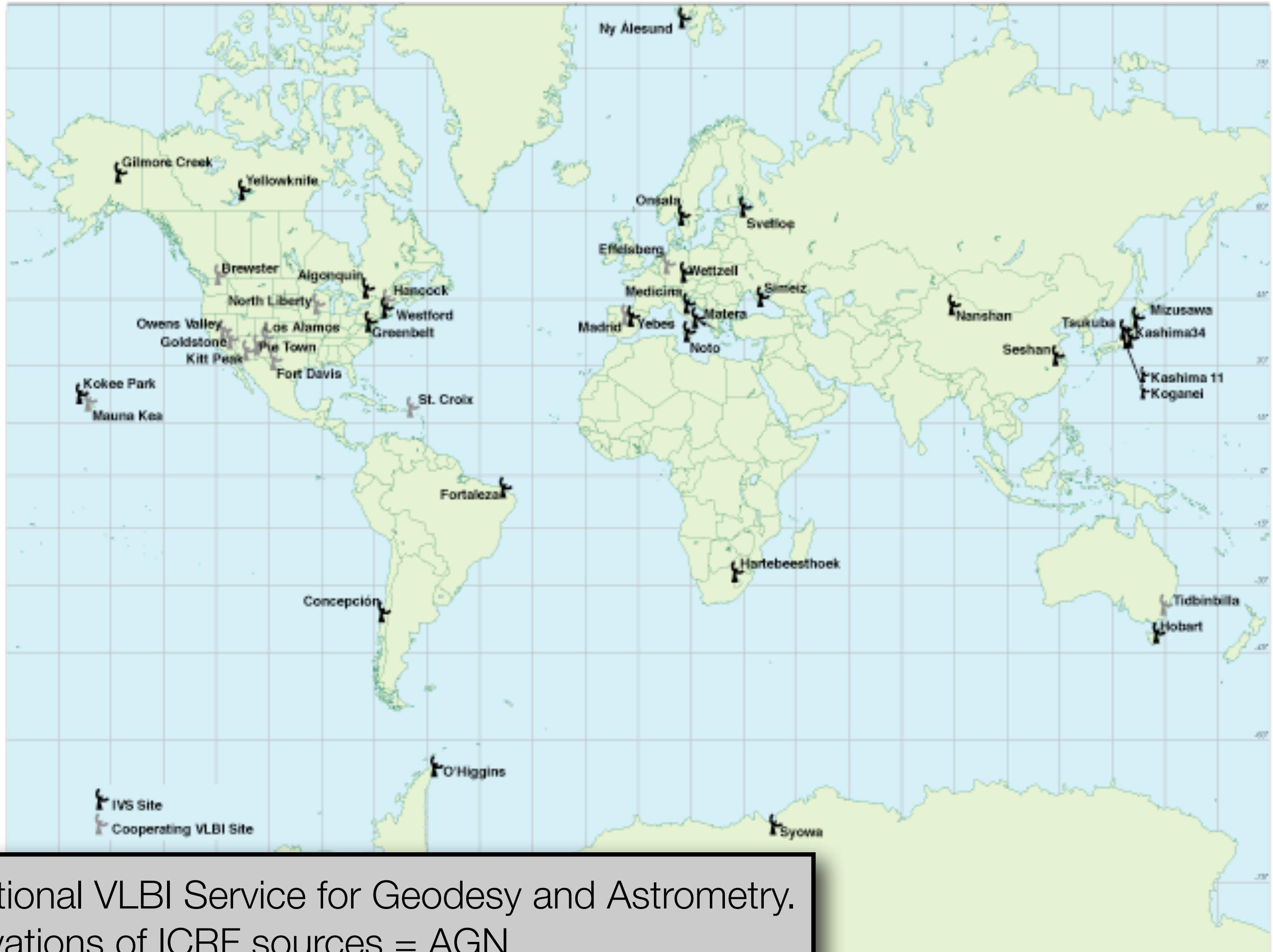
VLBI: Astrometry



VLBI: Astrometry

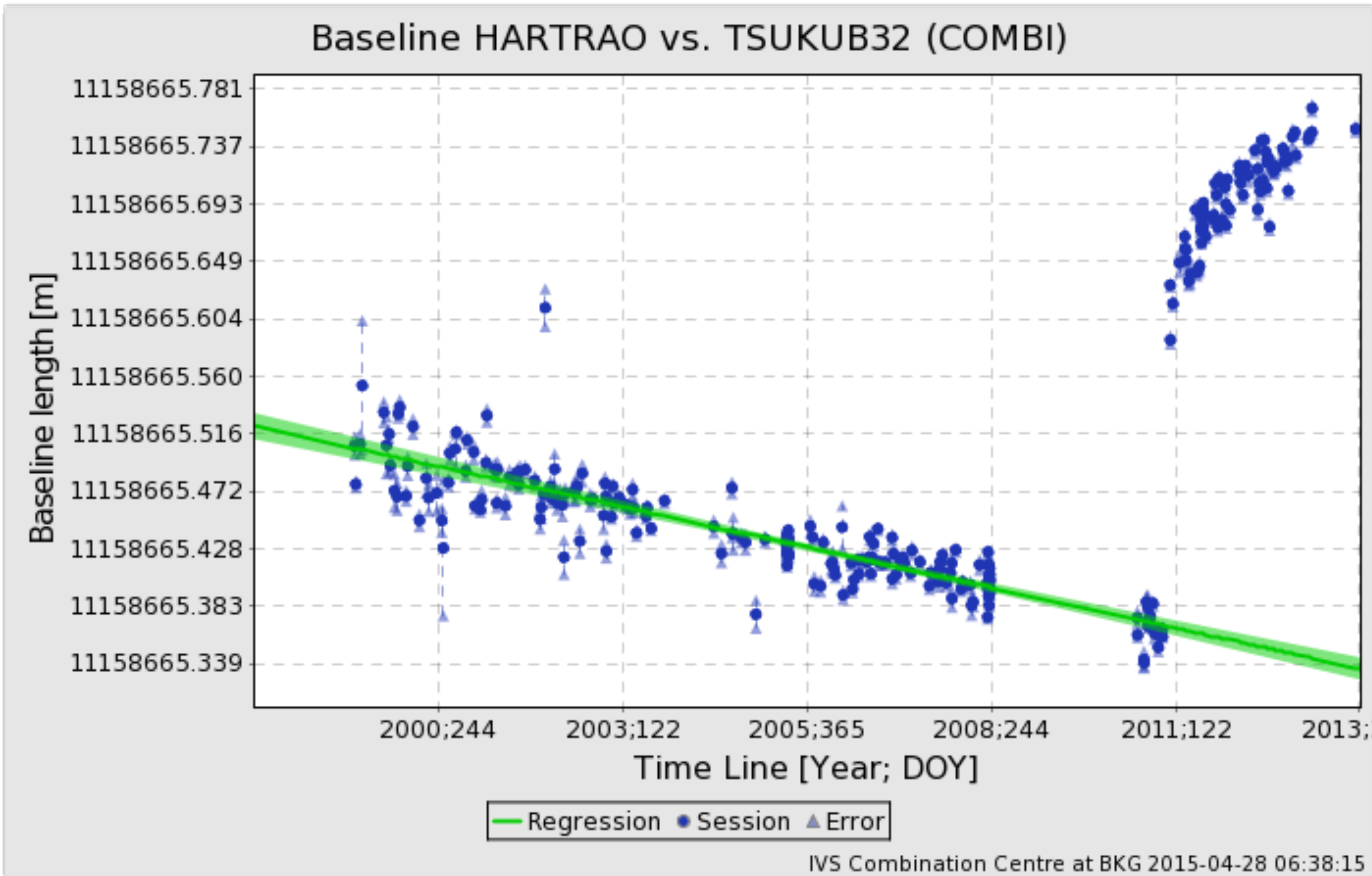


VLBI Networks



IVS: International VLBI Service for Geodesy and Astrometry.
VLBI observations of ICRF sources = AGN

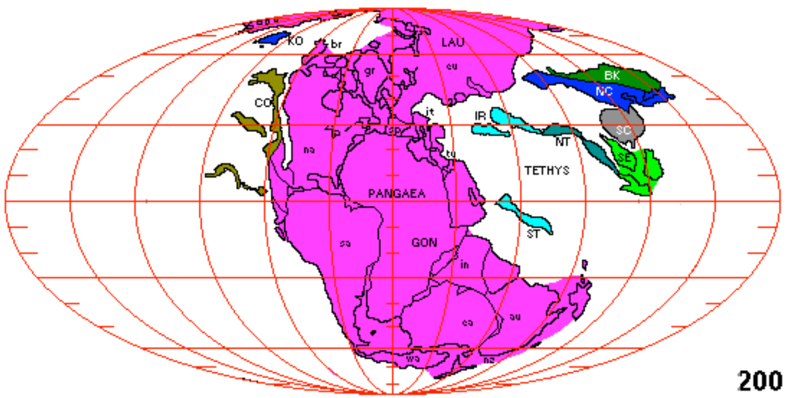
VLBI: Geodesy



VLBI Measuring Radio Telescope Separations => South Africa – Japan (post-Earthquake)

VLBI: Geodesy

Geodetic VLBI measures continental and regional **plate tectonic motion**



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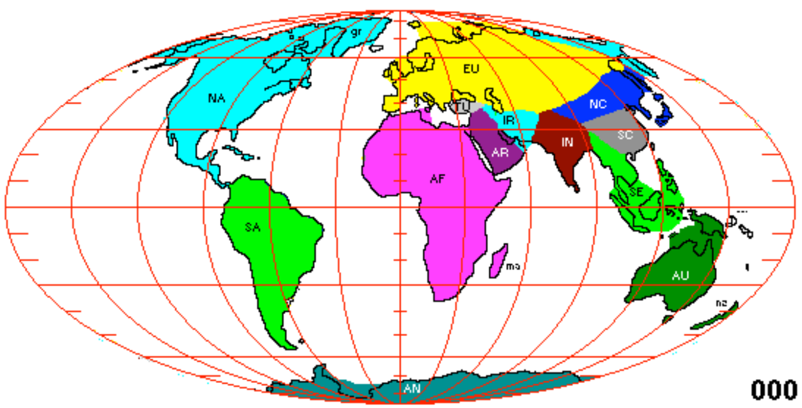

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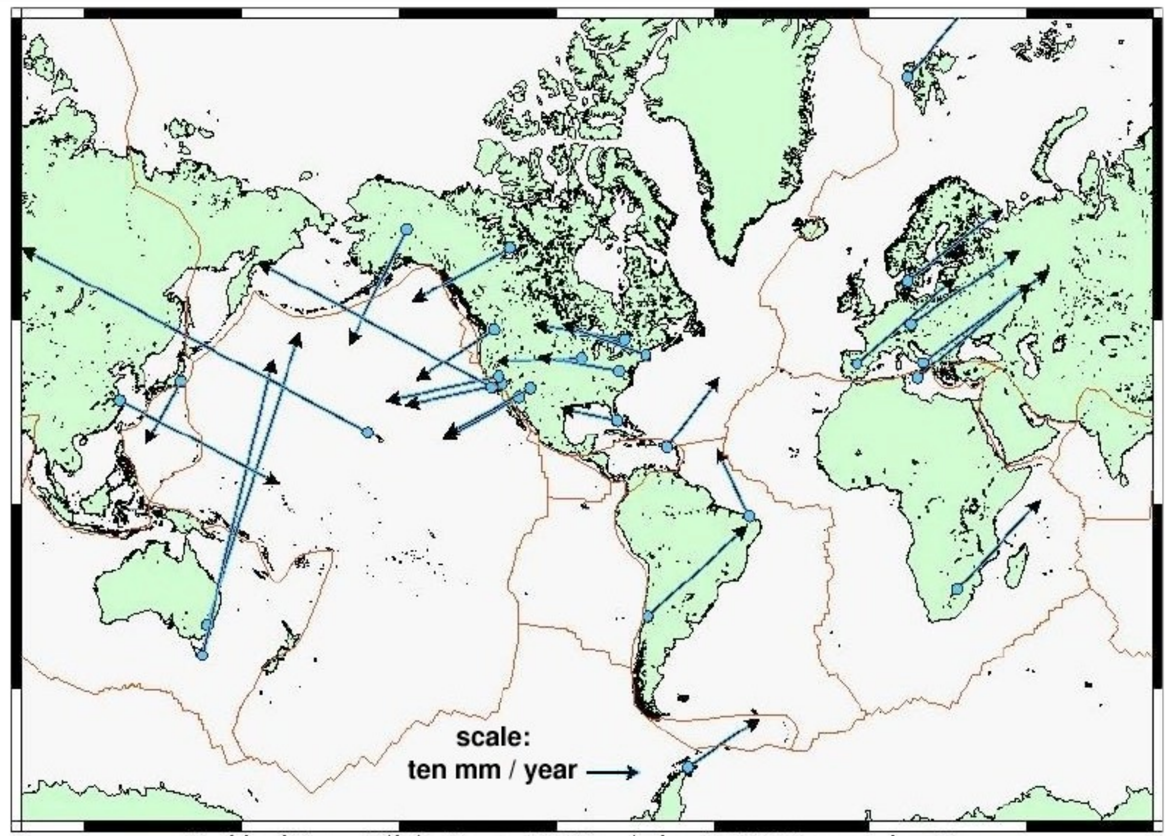
Animation of motion over last 200 Million years, reconstructed by geologists

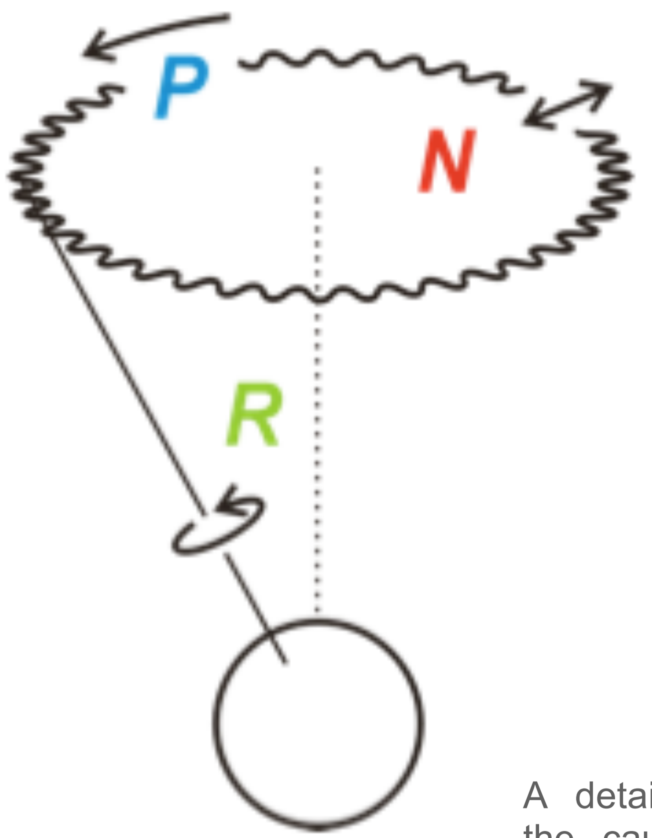


Goddard Space Flight Center VLBI solution KB 2002cn version 01
NUVEL1A-NNR reference frame.

Present day motion measured by radio telescopes in VLBI global networks. HartRAO is moving North-East at 25mm/ year

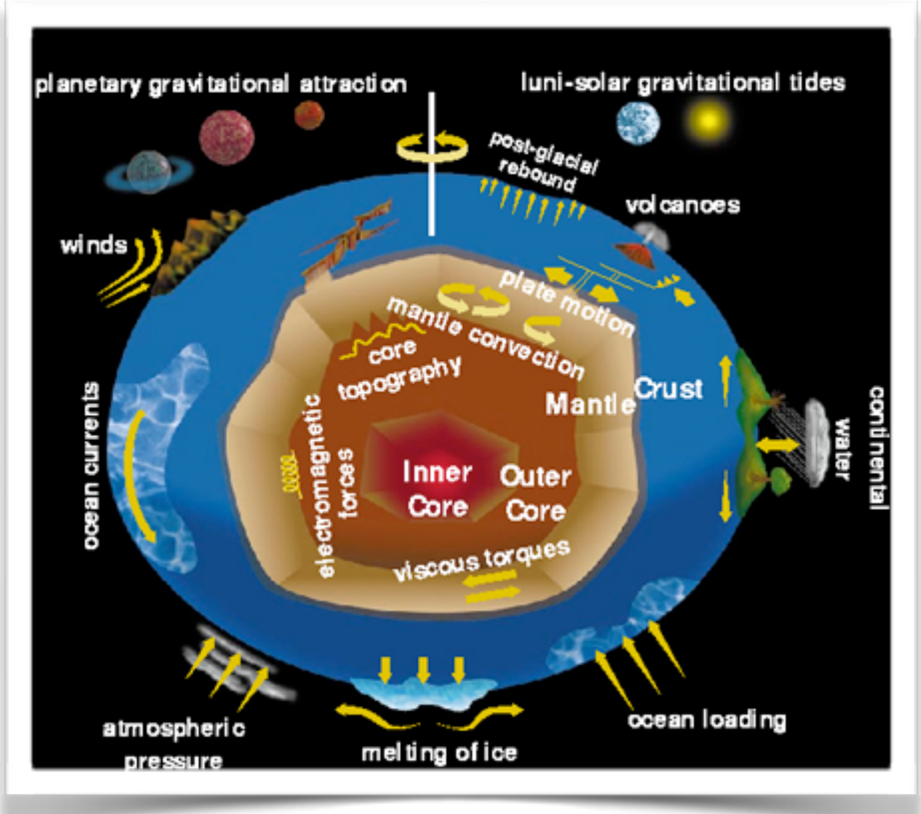
VLBI: Geodesy

Precise VLBI measurements also permit the **orientation of the Earth (EOP's)** to be determined.

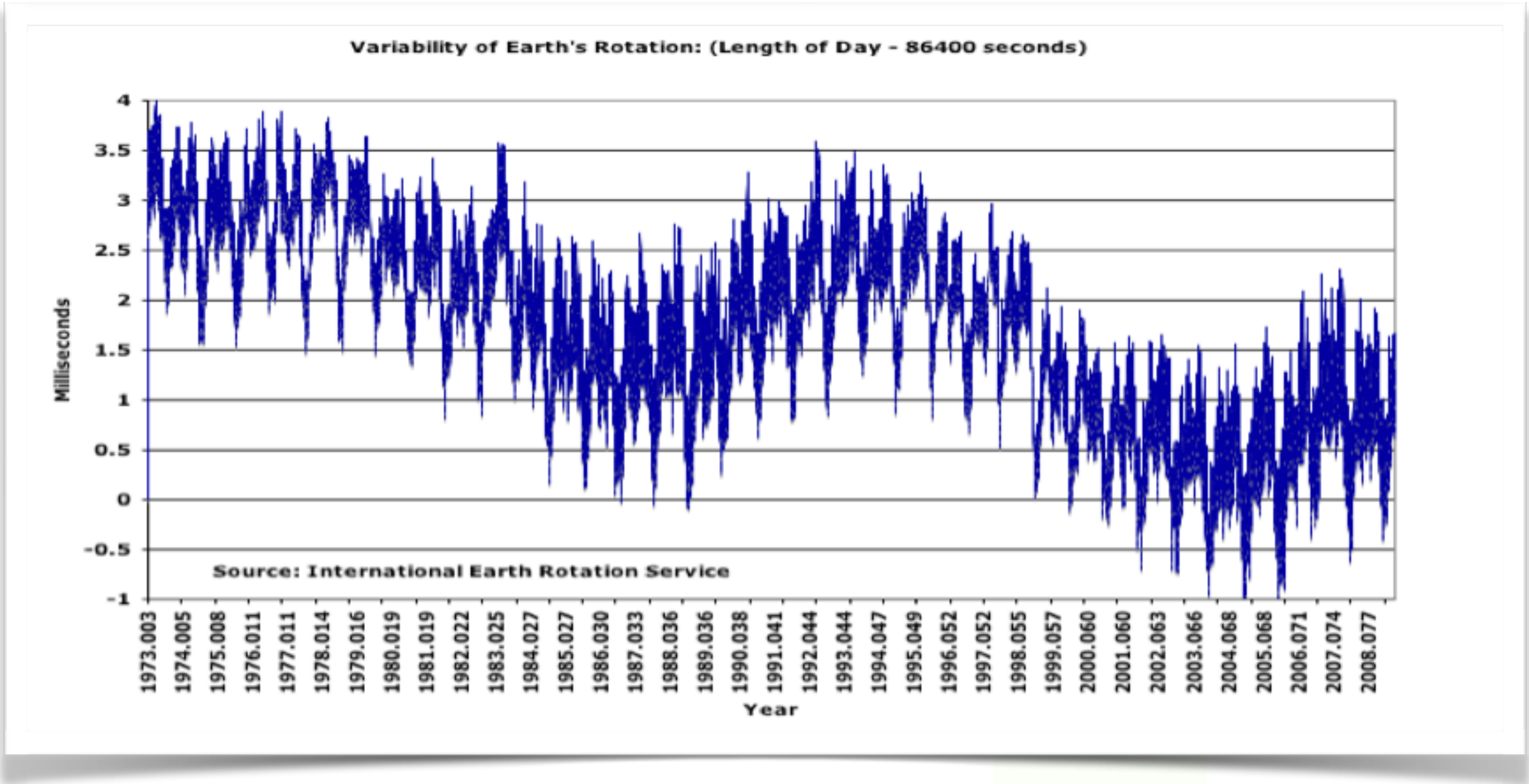


Nutation (N) and Precession (P) can be measured by VLBI as well as changes in the Earth's rotation rate (R) (length of the day also referred to as "UT1")

A detailed description of the causes for variations on the Earth's Orientation and rotation rate include:



VLBI: Geodesy



VLBI measurements show that the Earth's rotation rate is slowing => the length of the day is increasing

The length of an Earth day has distinct small-scale variations, changing by about one thousandth of a second over the course of a year. Roughly every 100 years, the day gets about 1.4 milliseconds longer.

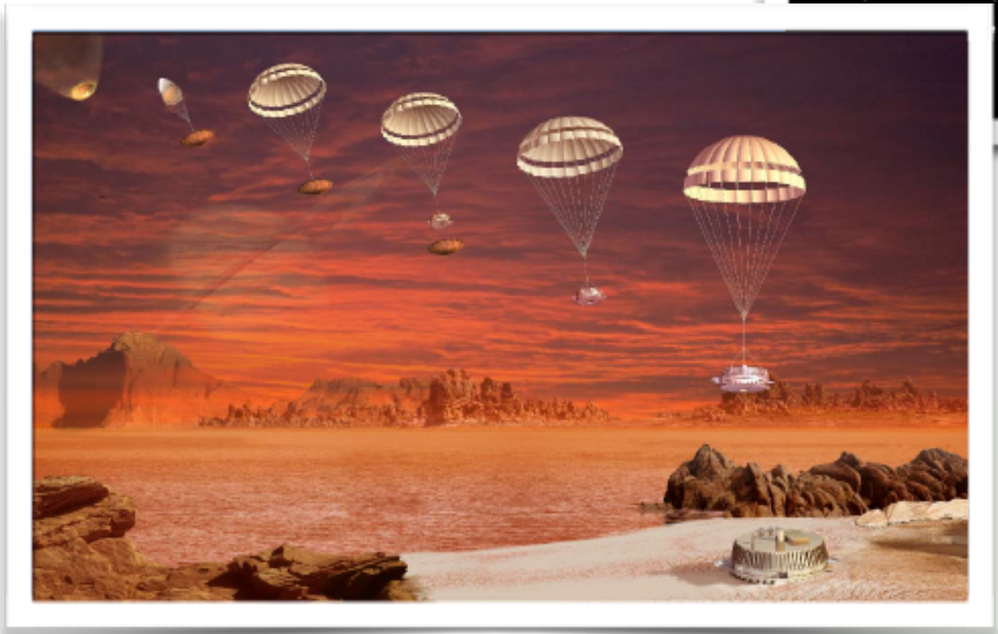
Differential VLBI for Deep Space Tracking

Track spacecraft in 2-dimensions on the sky by measuring difference position to nearby quasar

Abandoned by NASA in 1980's; reinstated after losing two spacecraft on Mars

Also saved the day for the Huygen's probe to Saturn's moon Titan

Cassini-Huygens probe to Saturn (14 January 2005)



Huygens probe parachuting to Titan

Geodesy

- **Satellite Laser Ranger (SLR)** for precise orbit determination (cm accuracy) as part of the International Laser Ranging Service **(ILRS).** The SLR measures the time it takes for a pulse of laser light to travel to a satellite and back again.

- **Lunar Laser Ranger (LLR)** measures the distance between the Earth and the Moon. Lasers on Earth are aimed at special mirrors placed on the moon during the Apollo and other programmes.

- **Seismometer** for measuring seismic events

- **Gravimeter** for measuring Earth's changing gravity field, ties in with precise position measuring systems

- **Global Navigation Satellite Systems (GNSS),** GNNS satellites like GPS transmit radio signals that let us measure the **positions of receivers** on the ground to within a few millimetres, and their change with time. Measure **atmospheric water vapour content** – provides corrections for radio astronomy data & data for weather predictions. Measure the **total electron content** of the ionosphere – ionospheric science, space weather, HF radio communication prediction.

Engineering …

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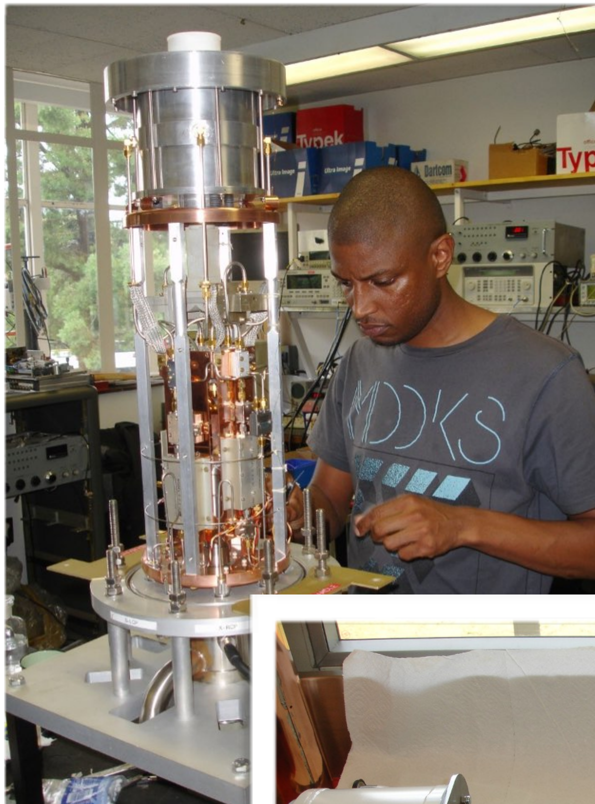
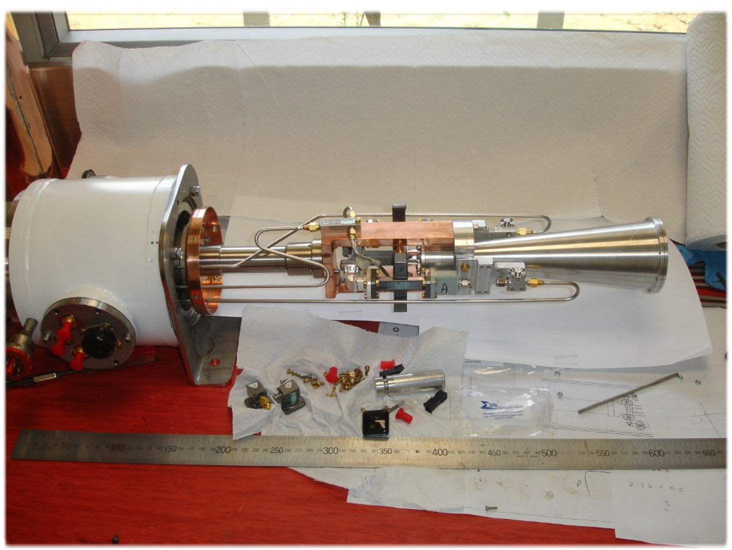
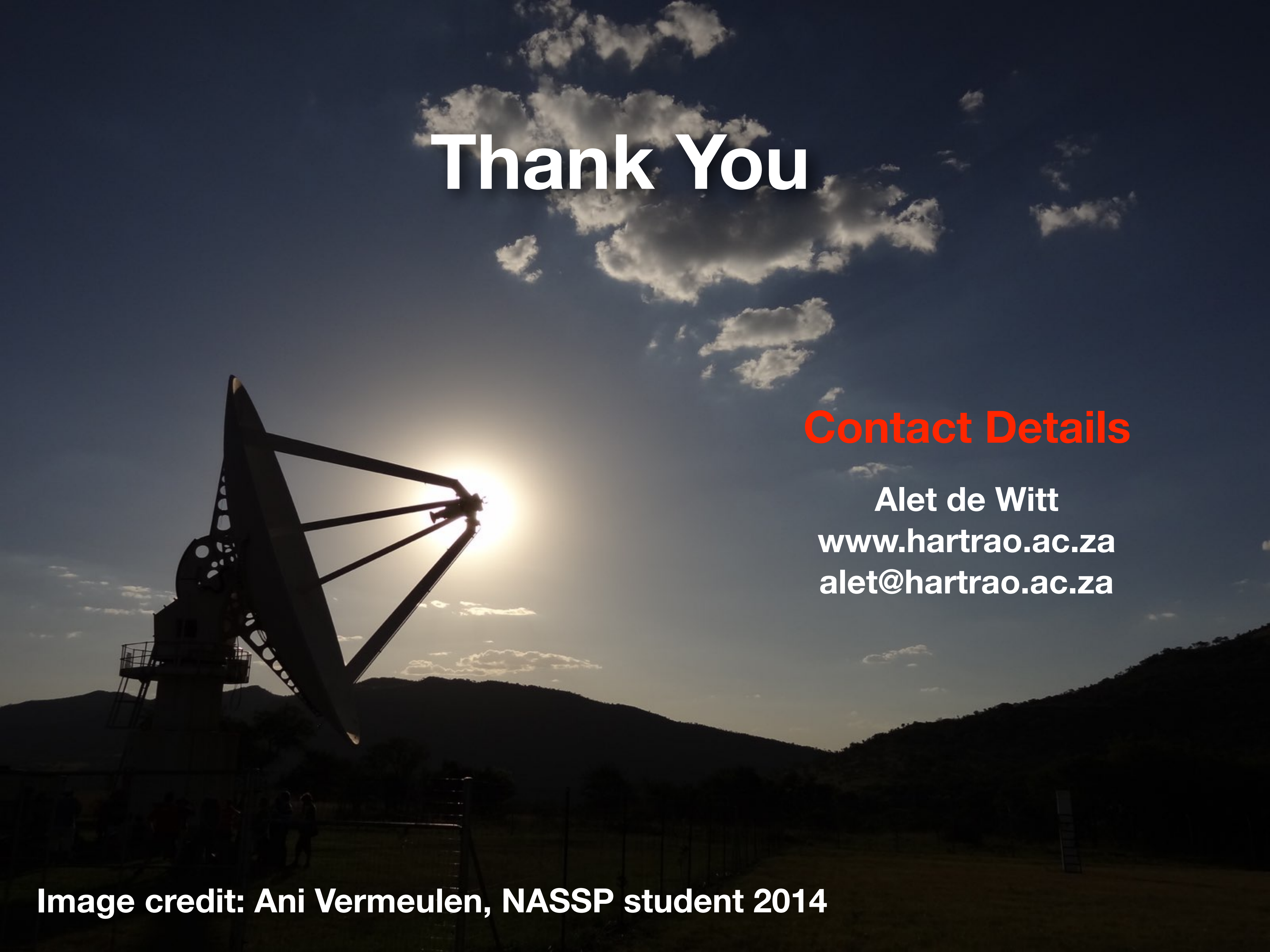


Maintenance, upgrading, development





Thank You

Contact Details

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Image credit: Ani Vermeulen, NASSP student 2014