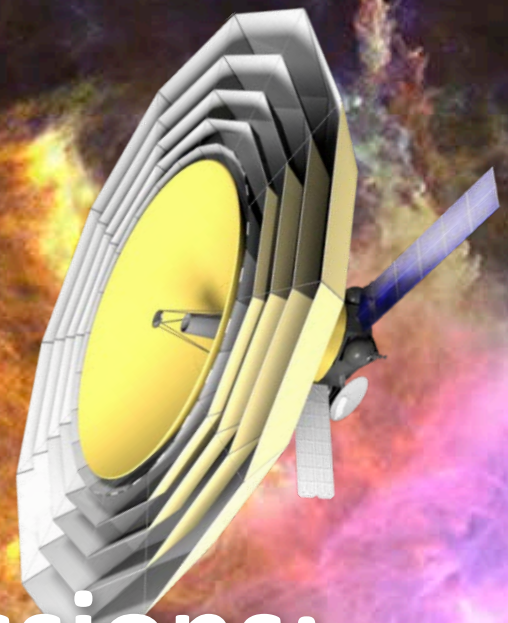


Russian Space-VLBI missions: results and prospects

Sergey Likhachev (On behalf of Astro Space Center, Lebedev Physical Institute Russian Academy of Sciences), and Alexangr Alferov (Scientific Secretary of RAS Space Council)

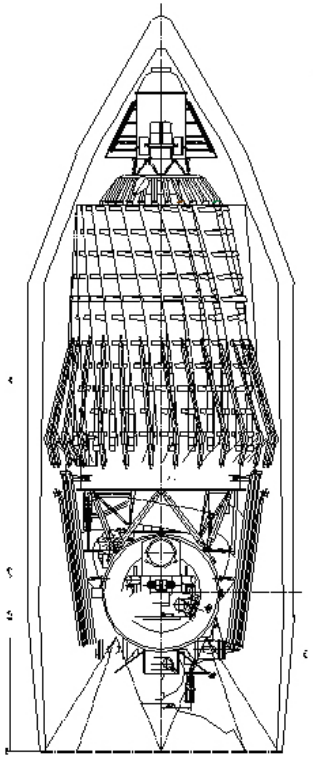
*Horsehead image captured by Herschel telescope

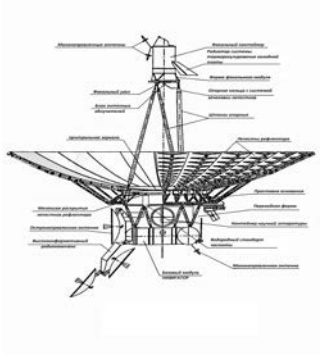
Radioastron Mission

“Radioastron” is the largest space radio telescope in the world, forming the largest ever space-ground interferometer.

The aim of the mission is to use the space telescope to investigate the Universe with the extraordinary high angular resolution up to 8 micro arc seconds at the shortest wavelength 1.35 cm.

Tests in Lavockin Assotiation, Summer, 2011





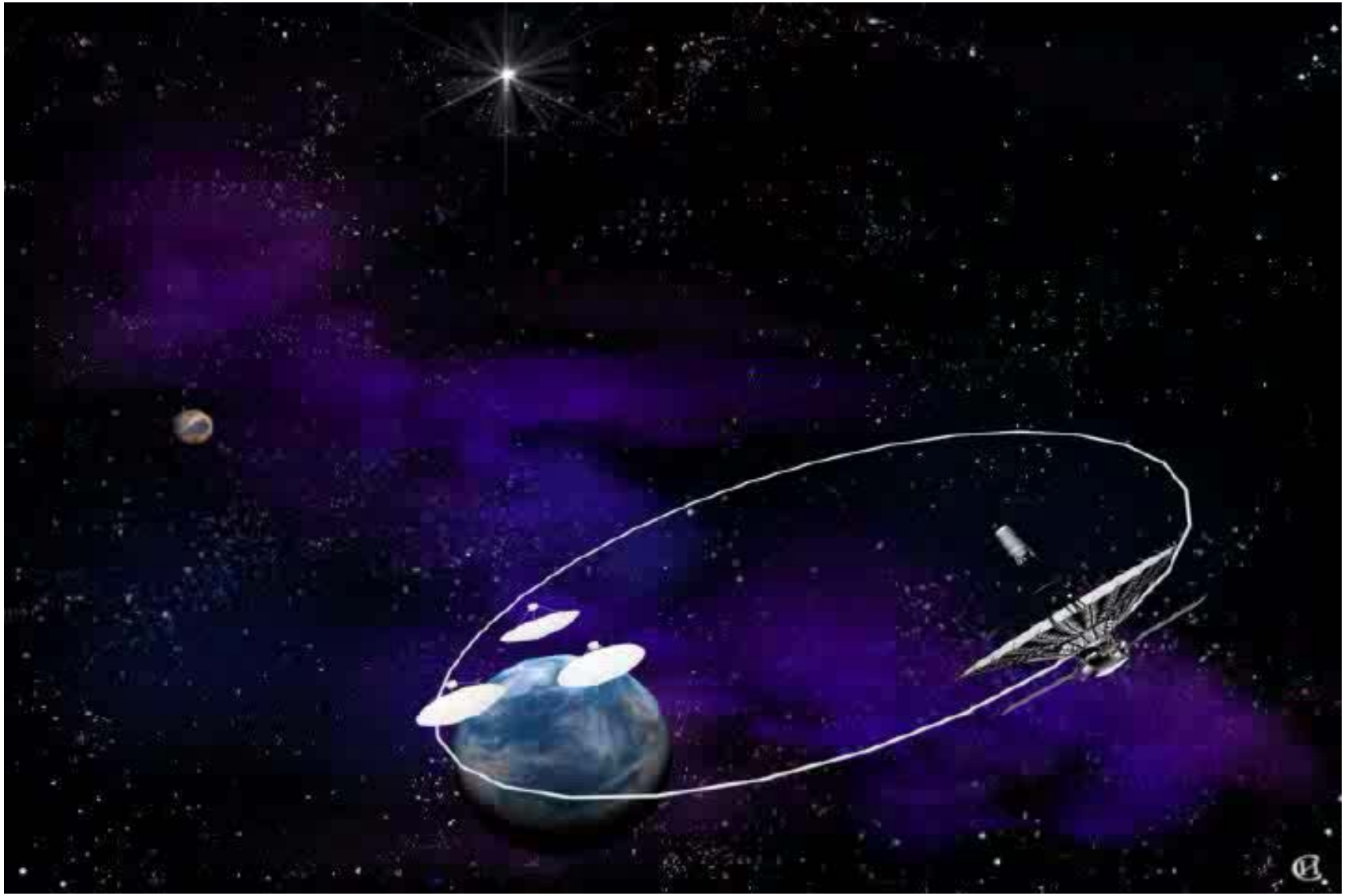
July 18, 2011

6:31 Moscow time, Baykanoor.

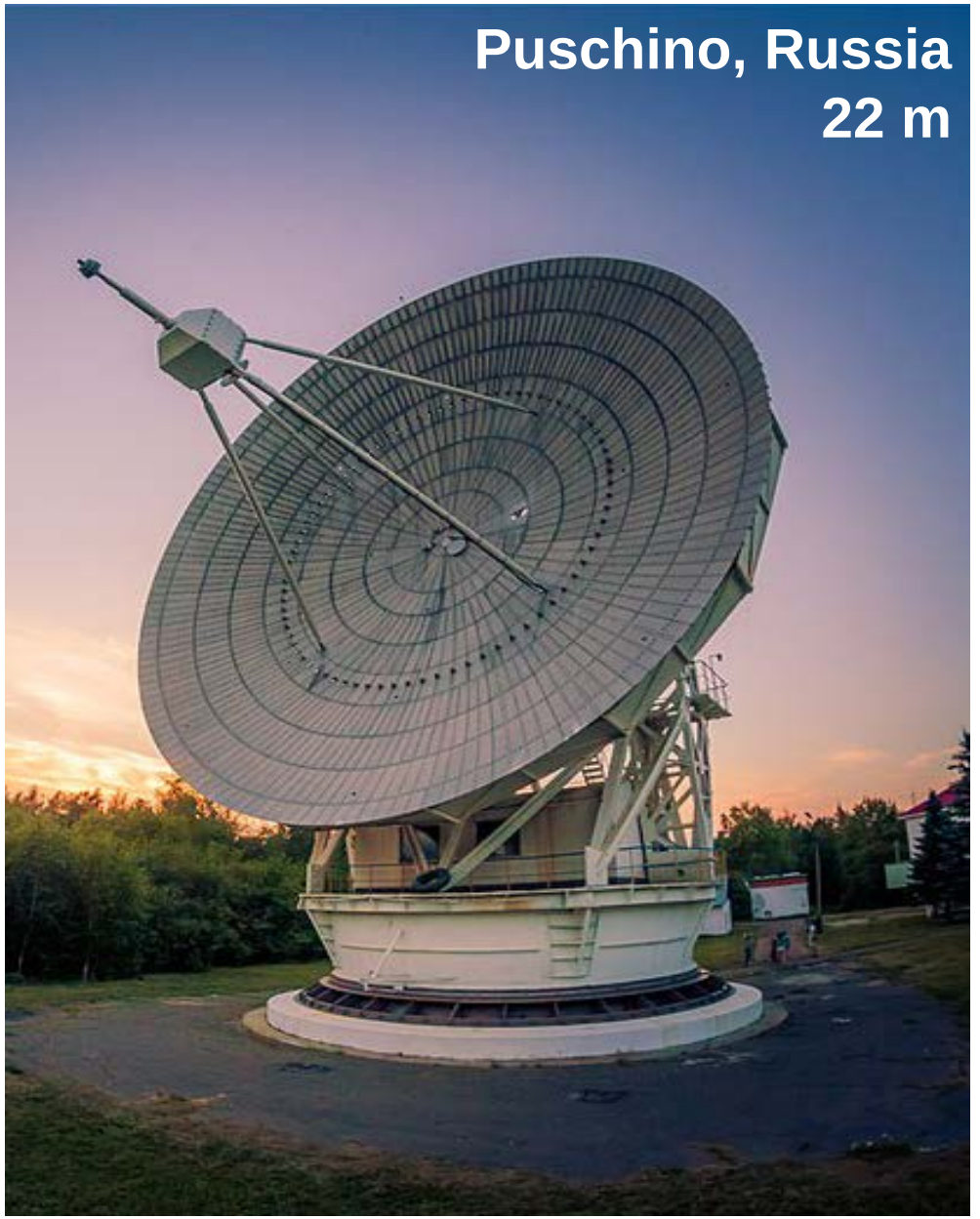
Launch of the observatory.

Radioastron Orbit

Antenna diameter [m]	10
Apogee height [km]	350,000
Orbital period	9.5 days
Polarization	LC/RC
Data downlink	128 Mbit/s
Observing frequencies [Ghz]	0.2 -- 22
Highest resolution [microarcsec]	8



Ground tracking stations



Scientific Data Transferring from Ground Telescopes


Parks Australia


Tidbinbilla Australia


ATCA Australia


Urumqi China


Shanghai China


Noto Italy


Badary Russia

Robledo Spain


Onsala Sweden


Jodrell Bank UK


Hart Africa


Torun Poland


Arecibo Puerto Rico


Zelenchuk Russia


GBT USA


Usuda Japan


Westerbork Netherlands

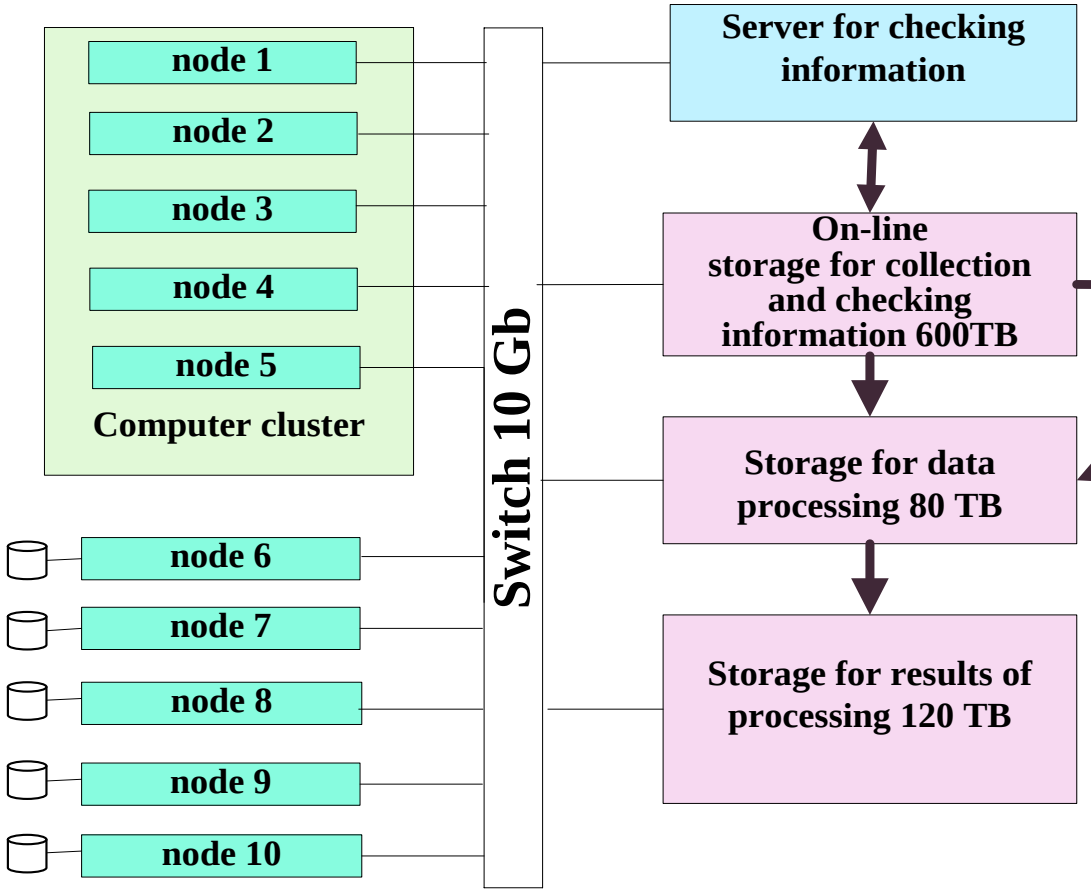

Yebes Spain


Effelsberg Germany

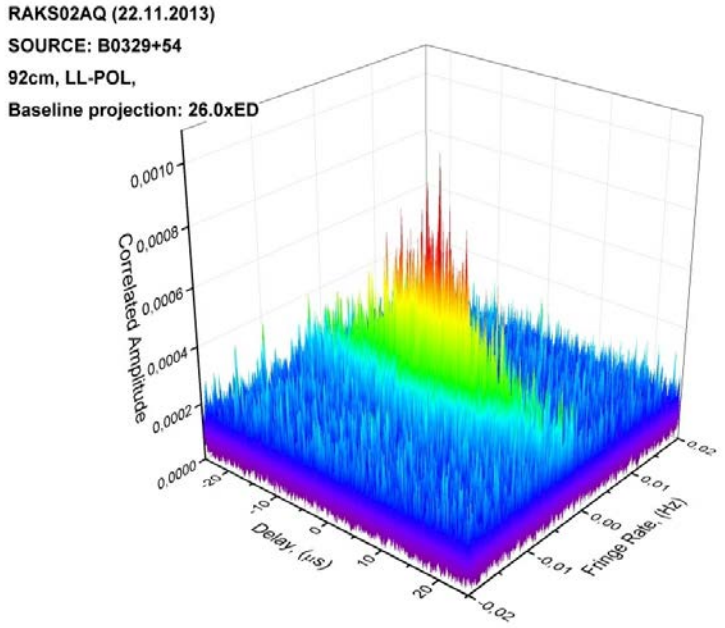

Medicina Italy


Svetloe Russia

Structure of Data Processing Center

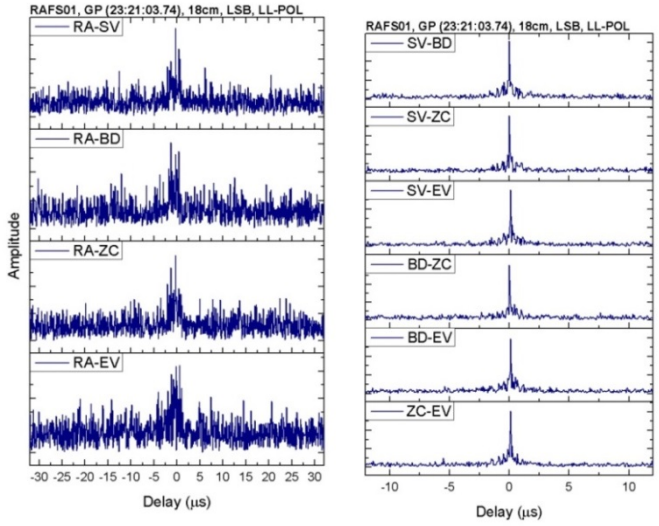


Main Pulsar Results in Radioastron Mission



With "Radioastron" was obtained the spatial distribution of the interstellar medium inhomogeneities in the direction of the pulsars: B1919 + 21, B0950 + 08, B0329 + 54, B0531 + 21.
For the first time with ultra-high resolution, was discovered a sub-structure in scattering disk of these pulsars.
Published статья Astrophysical Journal, 2014

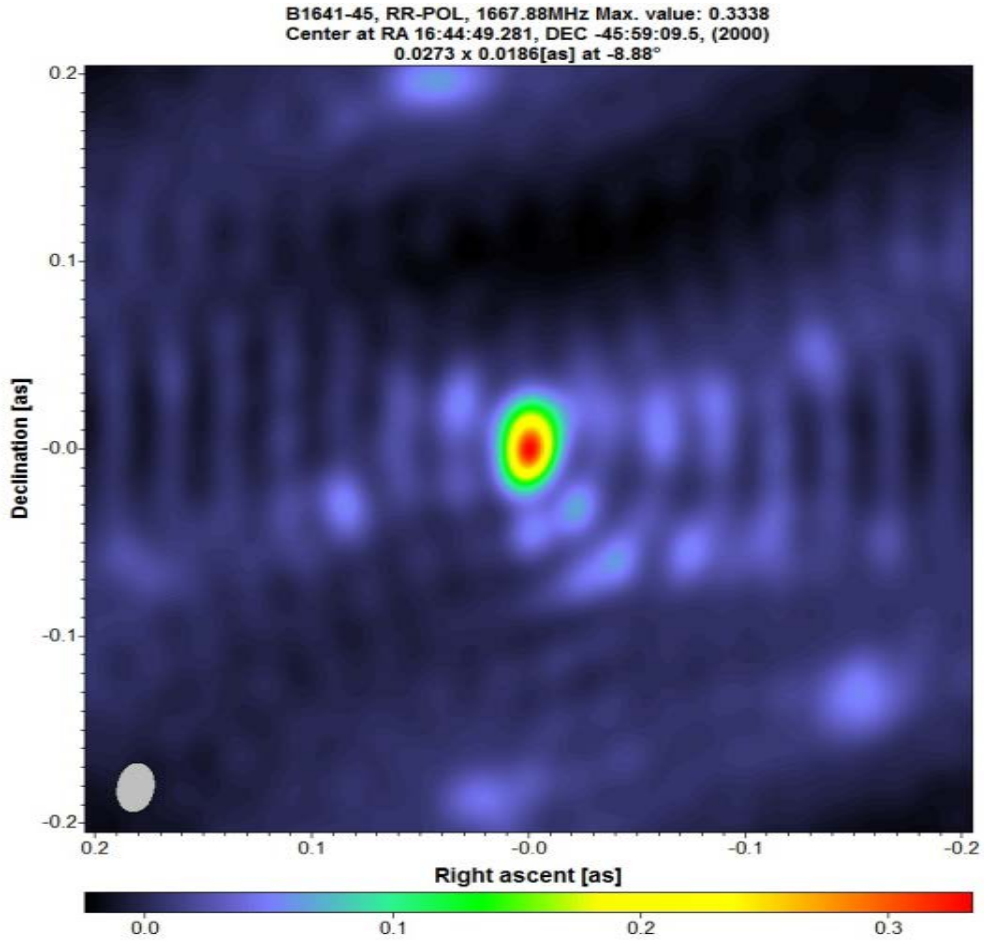
Scattering disk for PSR 0329+54 was resolved by direct observations at long baselines with angular diameter of 5 mas
Published Astrophysical Journal, 2016



Giant pulses from Crab pulsar

First time Space-VLBI observations of giant pulses from B0531+21 pulsar.
Observed significant change in CCF shape for space-ground baselines.
At 92 cm scattering disk is being resolved on ground-ground baselines.
Rudnitskiy A.G., Popov M.V., Soglasnov V.A., "Preliminary results of giant pulse investigations from Crab pulsar with Radioastron.", Proceedings of Science, EVN 2014 (065)
Rudnitskiy A.G., Popov M.V., Soglasnov V.A., Karuppusamy R., Astronomy Reports, 2016, 93

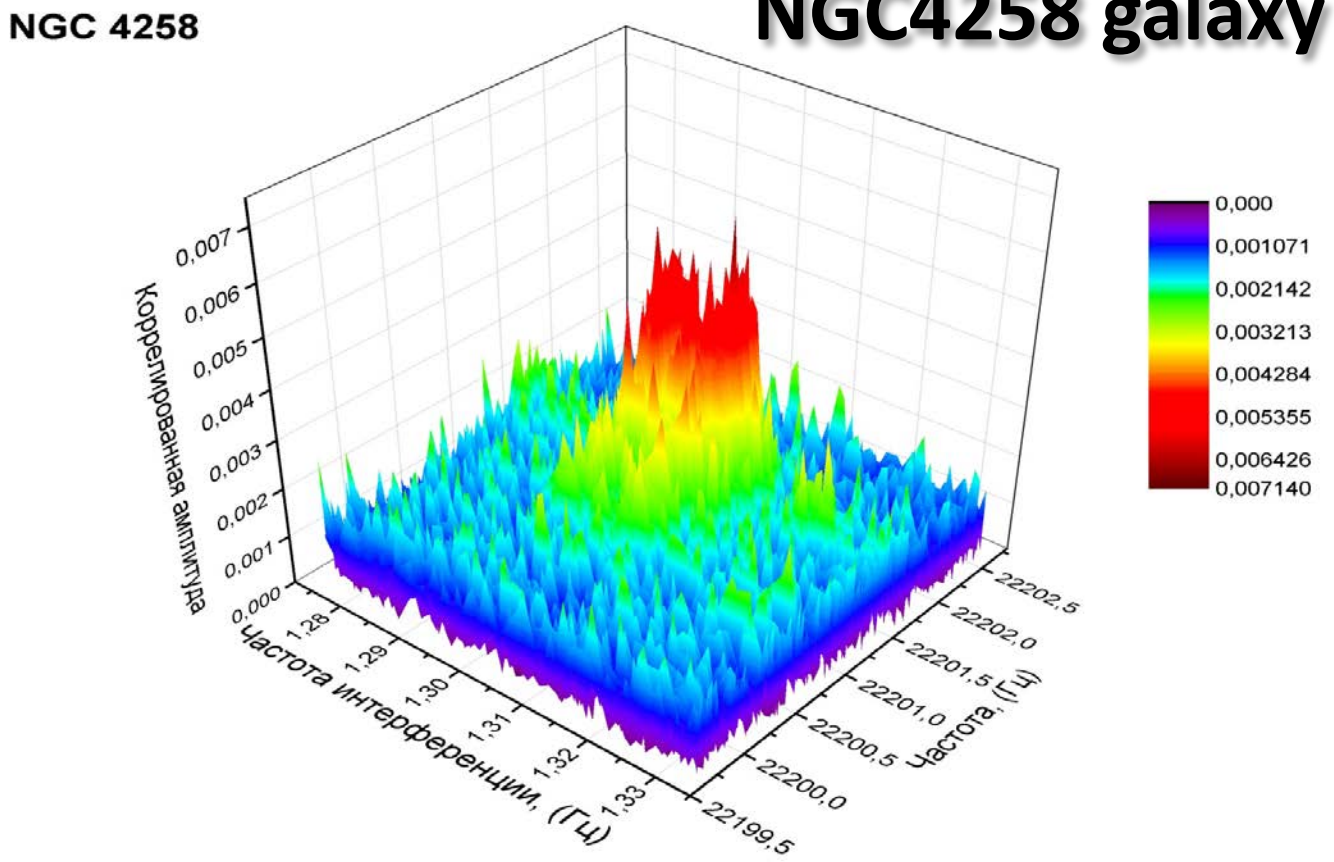
Radioastron mission main results.
Pulsar 1641-45



An image of pulsar B1641-46 scattered by interstellar medium.

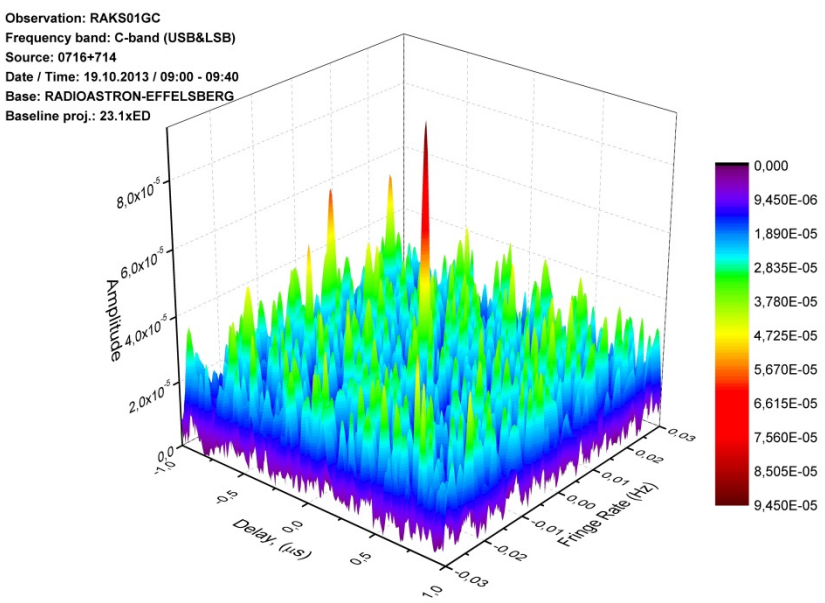
Radioastron mission main results.

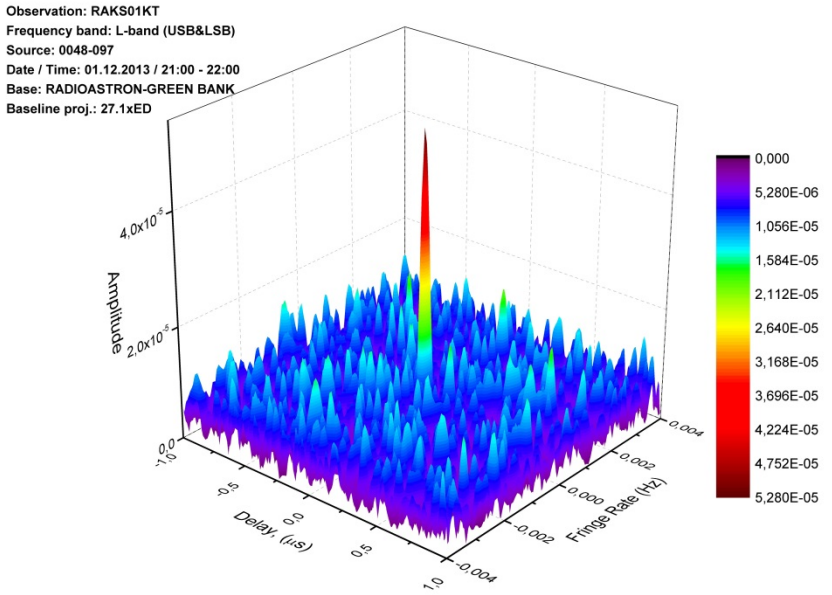
NGC4258 galaxy

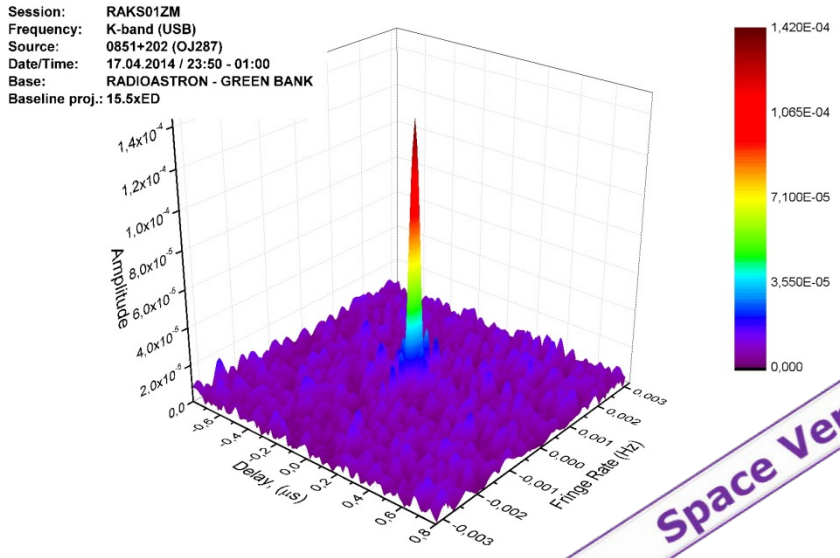


- For the first time in the history of radio astronomy space-ground interferometer detected water in extragalactic mega maser (18.12.2014.).
- Baseline projection Radioastron – Green Bank (USA) - 2 Earth diameters.
- Galaxy NGC4258, z = 0.00149, distance 24 millions of light years.
  Mega maser is located in the accretion disk gas around the black hole.

Radioastron Angular Super-Resolution







Space Very-LBI WORKS!!!

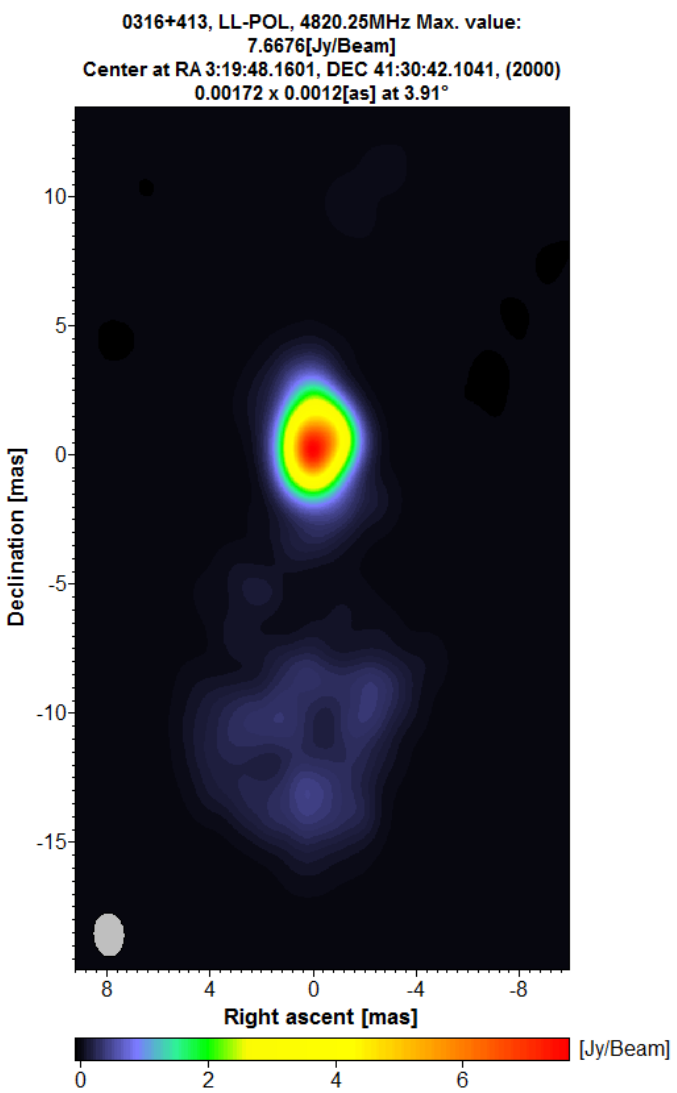
Baseline projections:

L-band: **27.1xED**, (345 000 km), Source: 0048-097

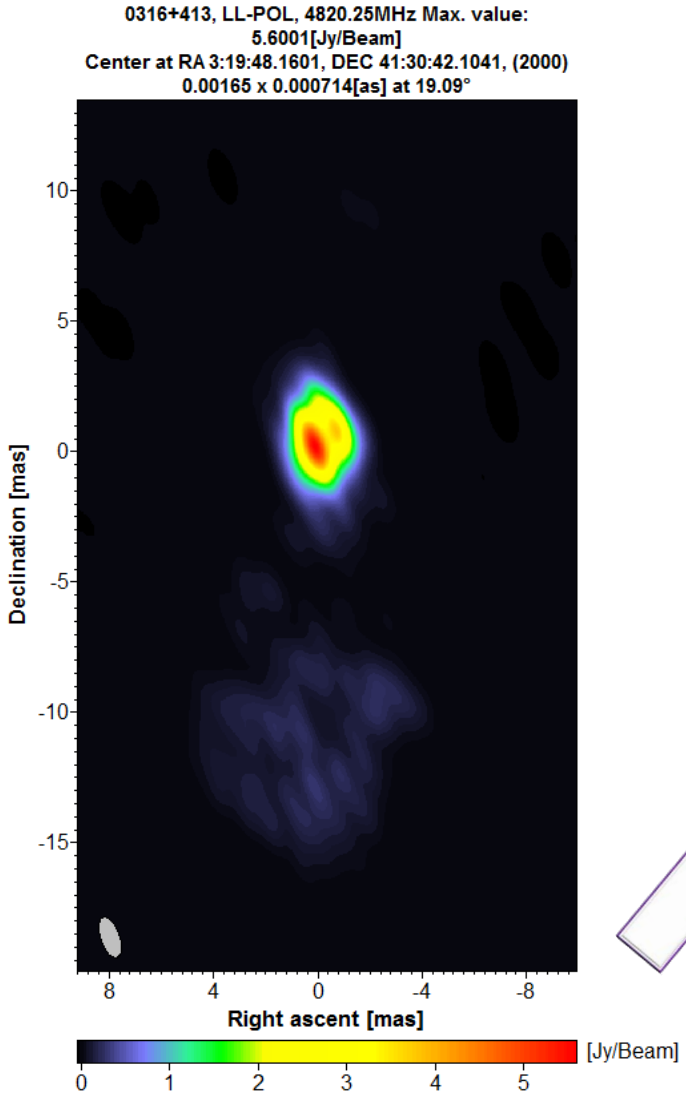
C-band: **23.1xED,** (295 000 km), Source: 0716+714

K-band: **15.5xED**, (190 000 km), Source: 0851+202

Comparison with Ground VLBI (3C84, 5 GHz)



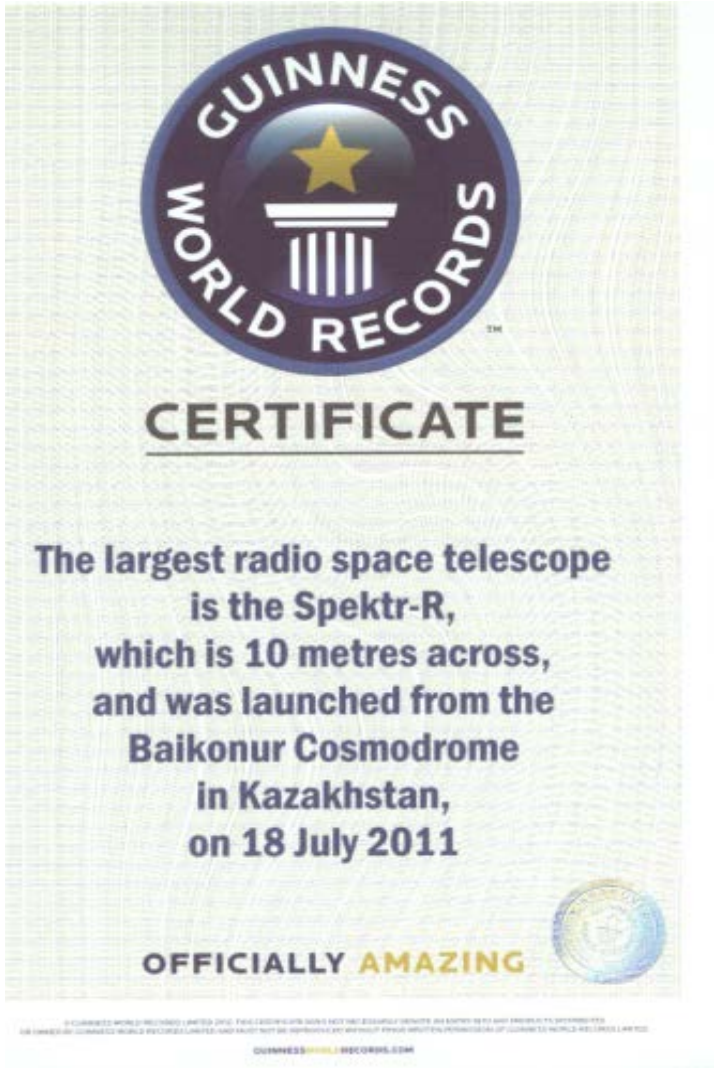
without “Radioastron”



with “Radioastron”

Space VLBI WORKS!!!

Current Radioastron Correlation Results



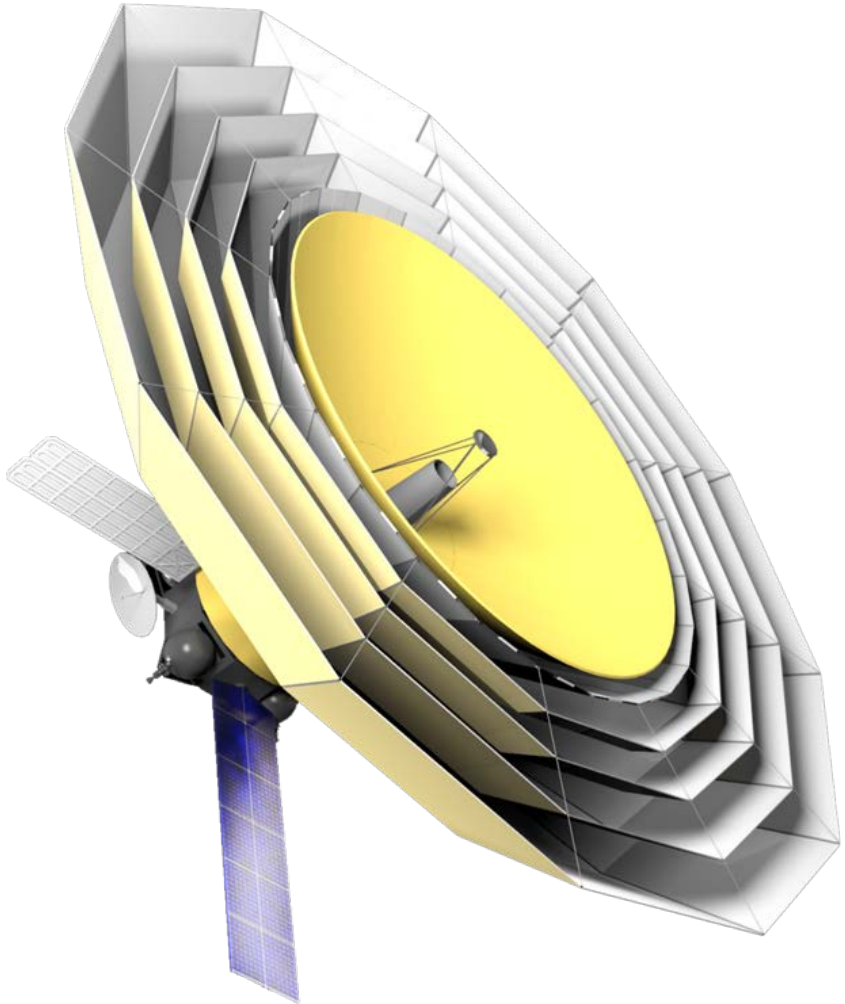
- Data from **2130 sessions** have been **successfully correlated**. Fringes on Space-Ground baselines were found in **703 observations**.

- For now, data processing rate in "Radioastron" mission is about **160 sessions per month**, observation rate is **80-120 experiments per month**. Thus, ASC correlator performance is enough to correlate all the data in "Radioastron" project.

Millimetron Mission

The first 10-m space telescope

- ✓ for the FIR, submm and mm range (diffraction limited 80μm)
- ✓ for cosmology and astrophysics
- ✓ deployable and adjustable on orbit
- ✓ mechanically cooled **(<10K)** with post-cryo life
- ✓ orbit around L2 Lagrange point
- ✓ lifetime: 10 years; at cryo >3 years
- ✓ dual operation modes:
  - S-VLBI for 0.3 – 17 mm
  - Single dish for 0.02 – 3 mm



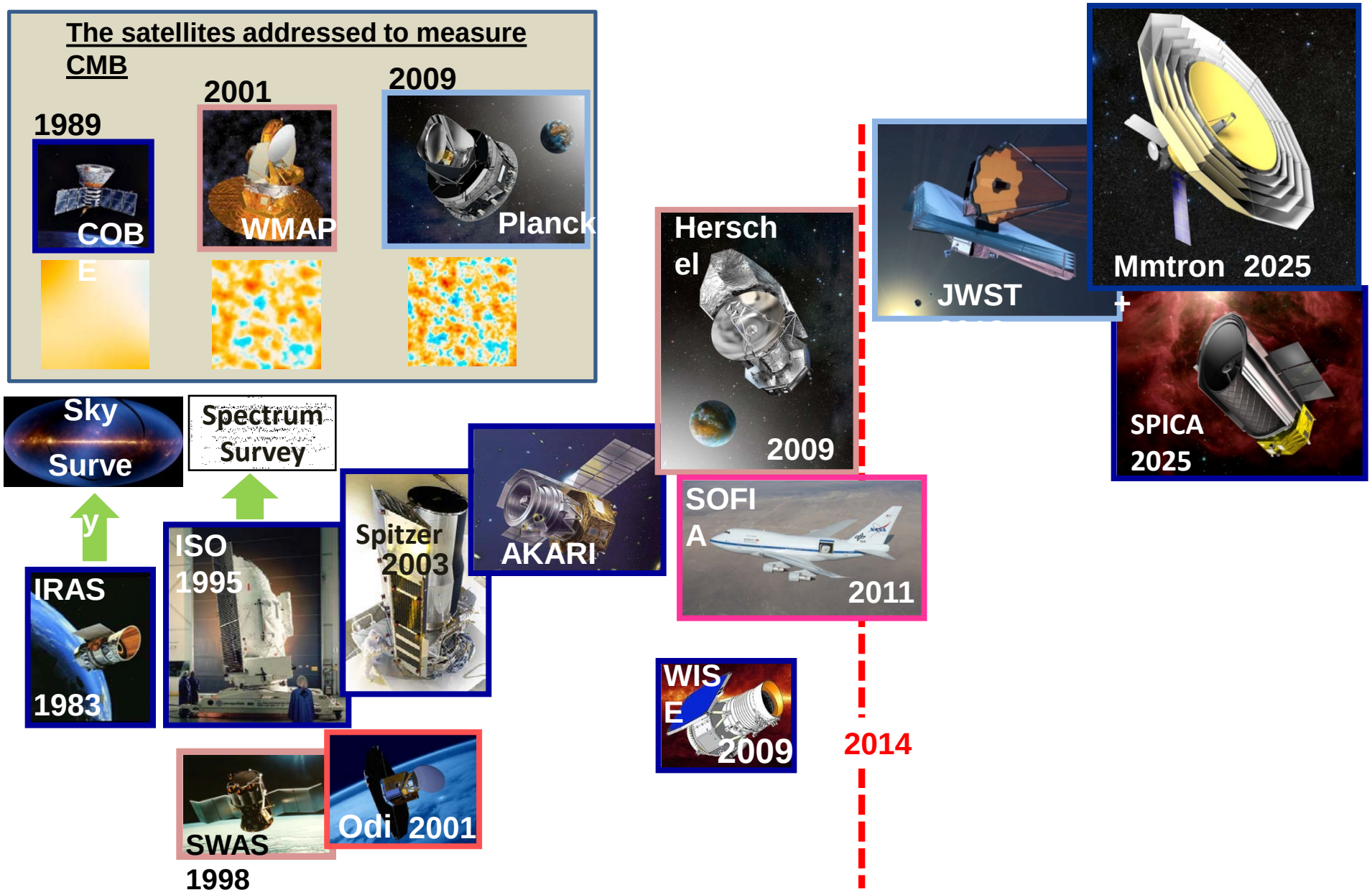
Mission has been approved and supported by RSA

Spacecraft in Phase-B

Science payload in Phase-A

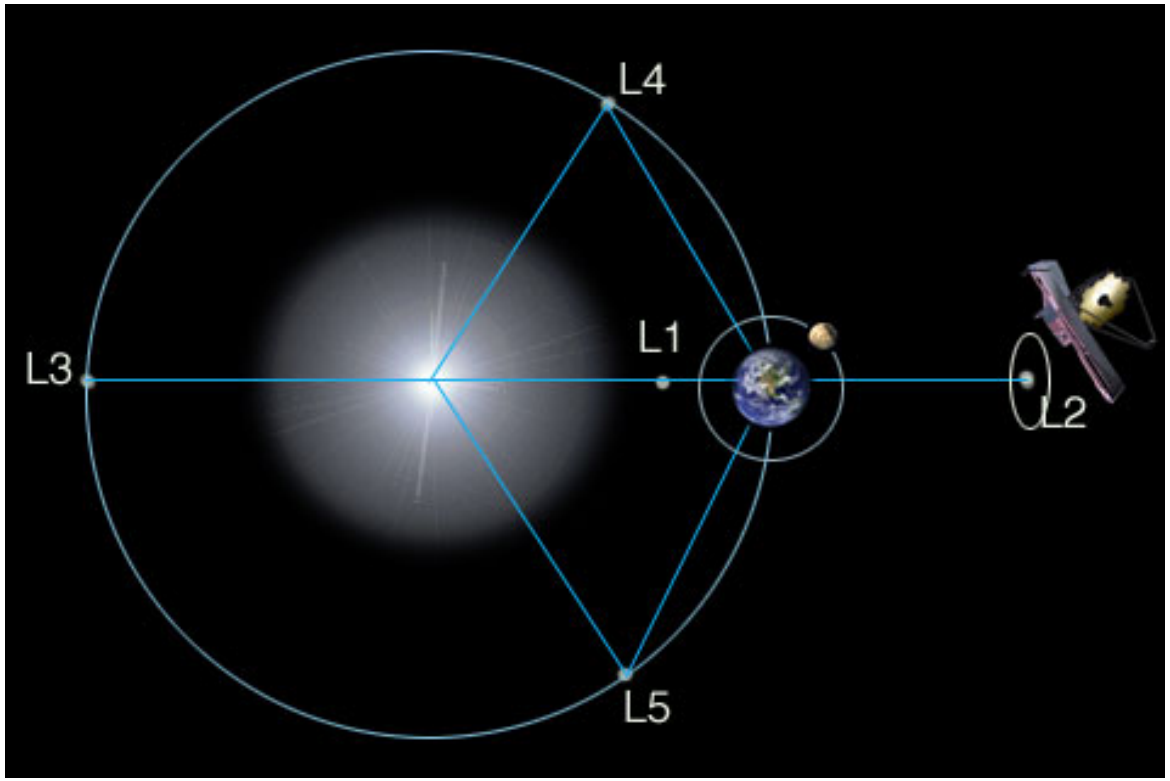
Launch date : 2025

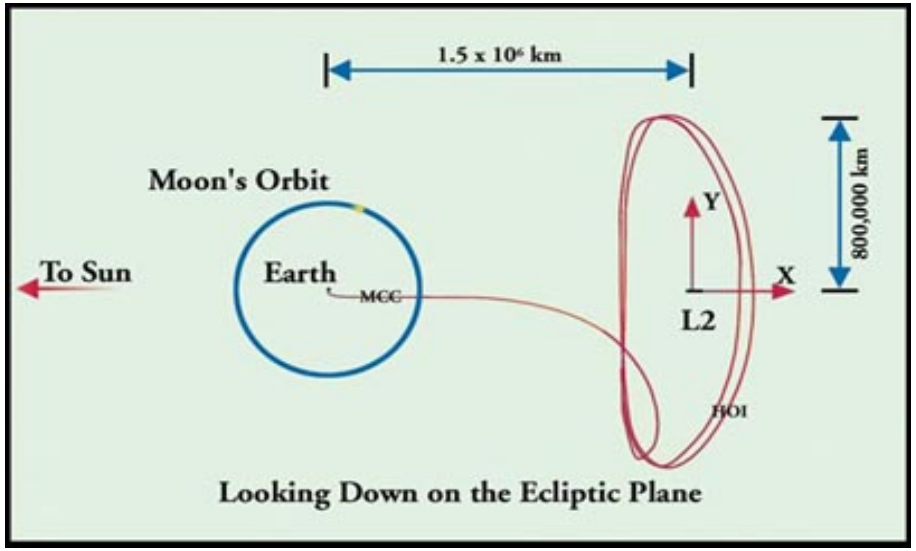
Evolution of the FIR/Submm/Mm Instruments for Space Science



Millimetron Orbit

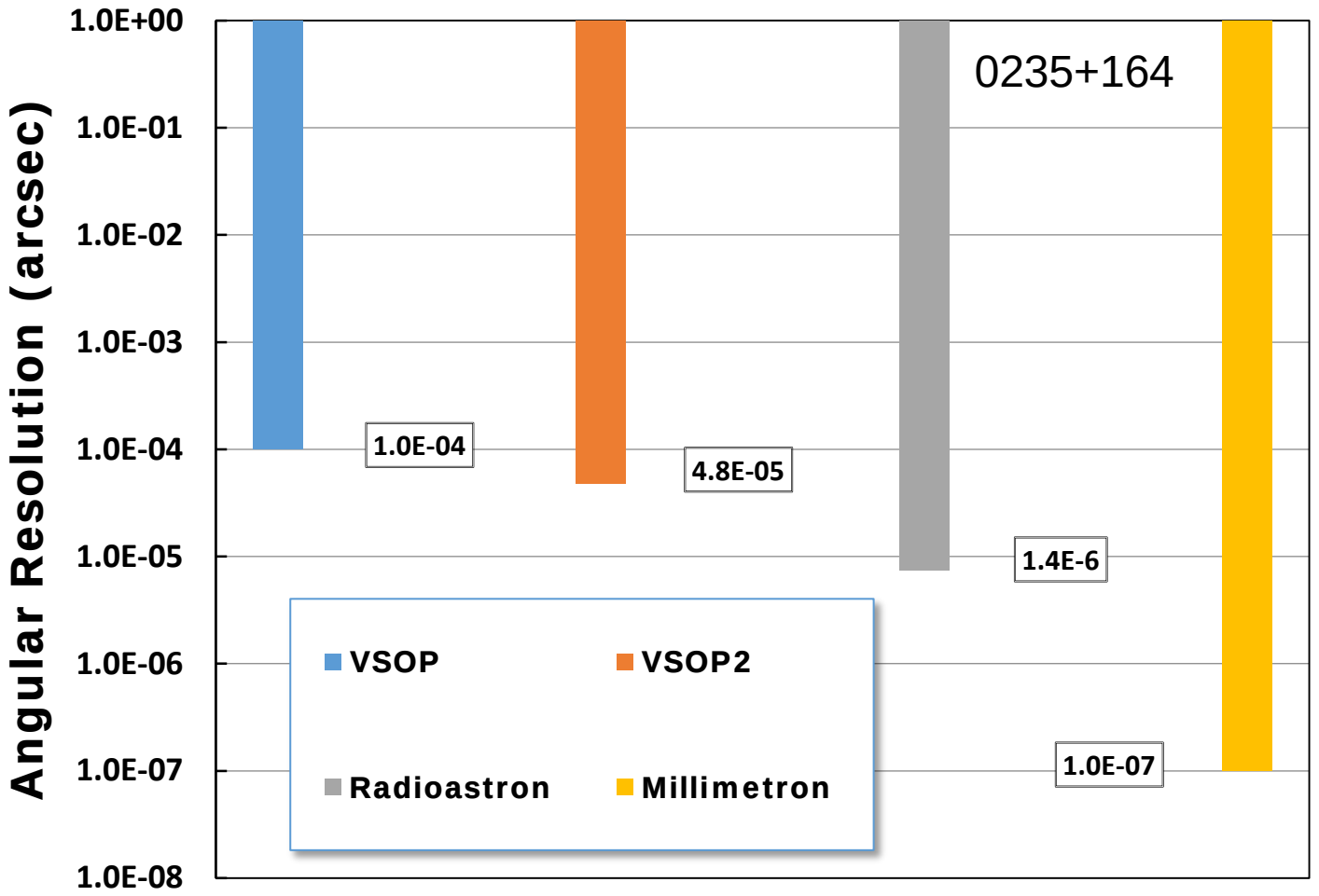
- Orbit period – 365 days (L2).
- Baseline – 1 500 000 km, max.
- Time of oscillation around L2 is about half of a year.
- MM antenna view angle opening is+/- 75 deg in ecliptic latitude and longitude.

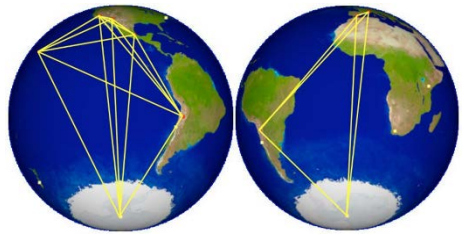




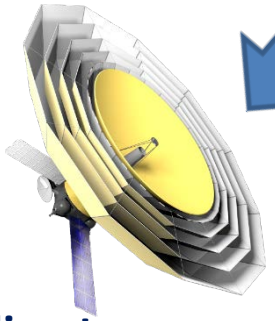
Capabilities of the Millimetron

✓ unprecedented high angular resolution in observing mode as S-VLBI element





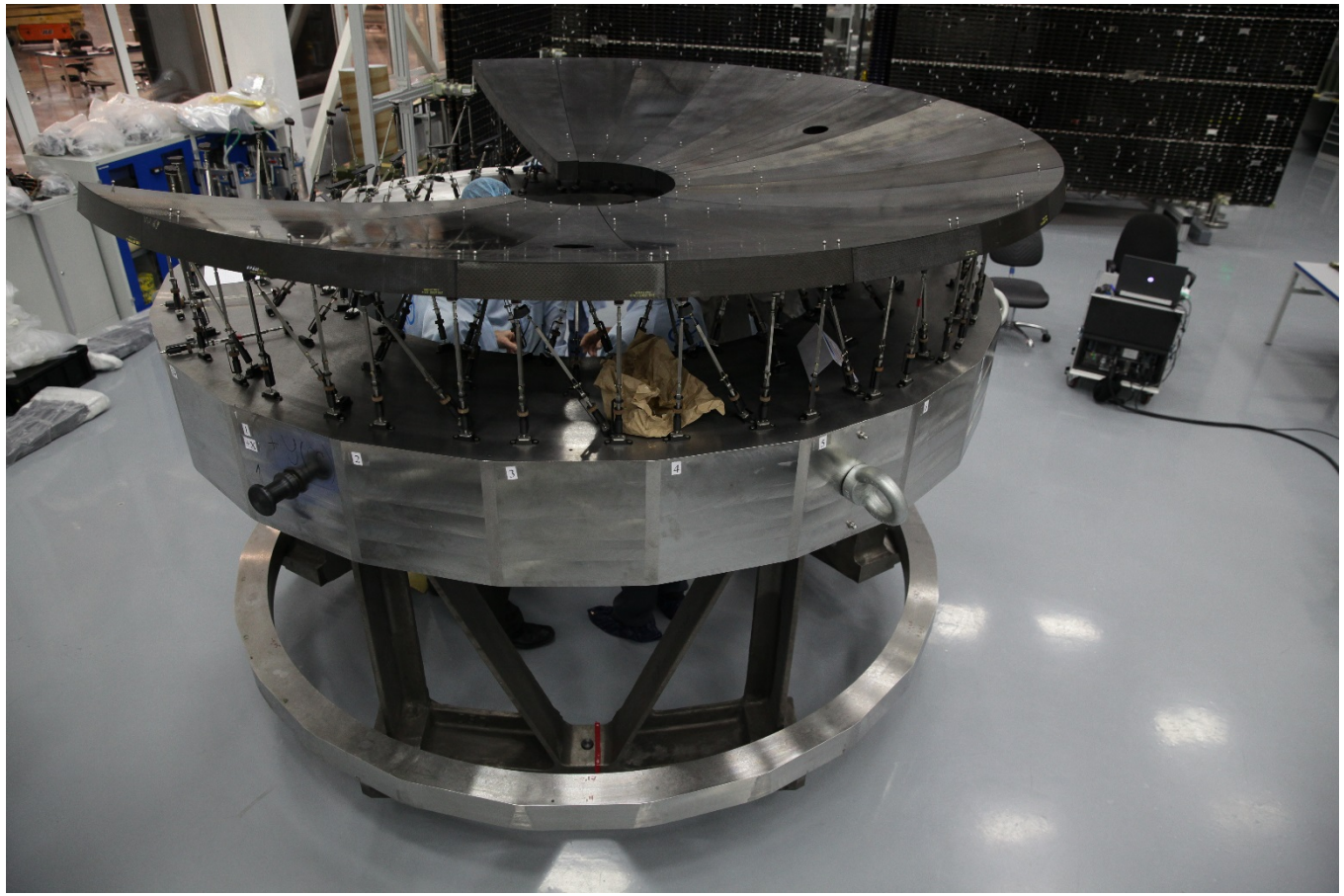
EHT



Millimetron

ALMA

Antenna Mock-Up (ISS-Reshetnev, Russia, 2014)

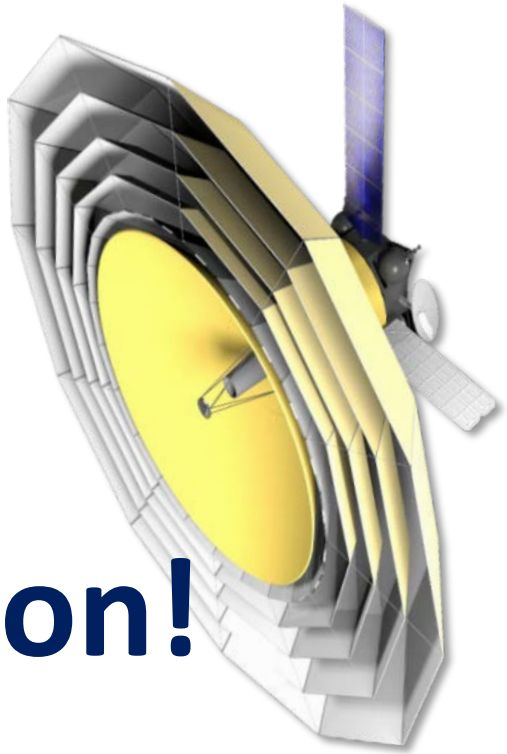


Conclusions

- The Russian Federation has the technology create unfolding space antennas of large diameter ("Radioastron" and "Millimetron“ missions).

- The Russian Federation has the technology of space-ground interferometer scientific data processing and analysis.

- Mission "Radioastron" yielded scientific results that are unique in modern radio astronomy.



Thank you for your attention!