

Arecibo Observatory: a long life with very long baselines

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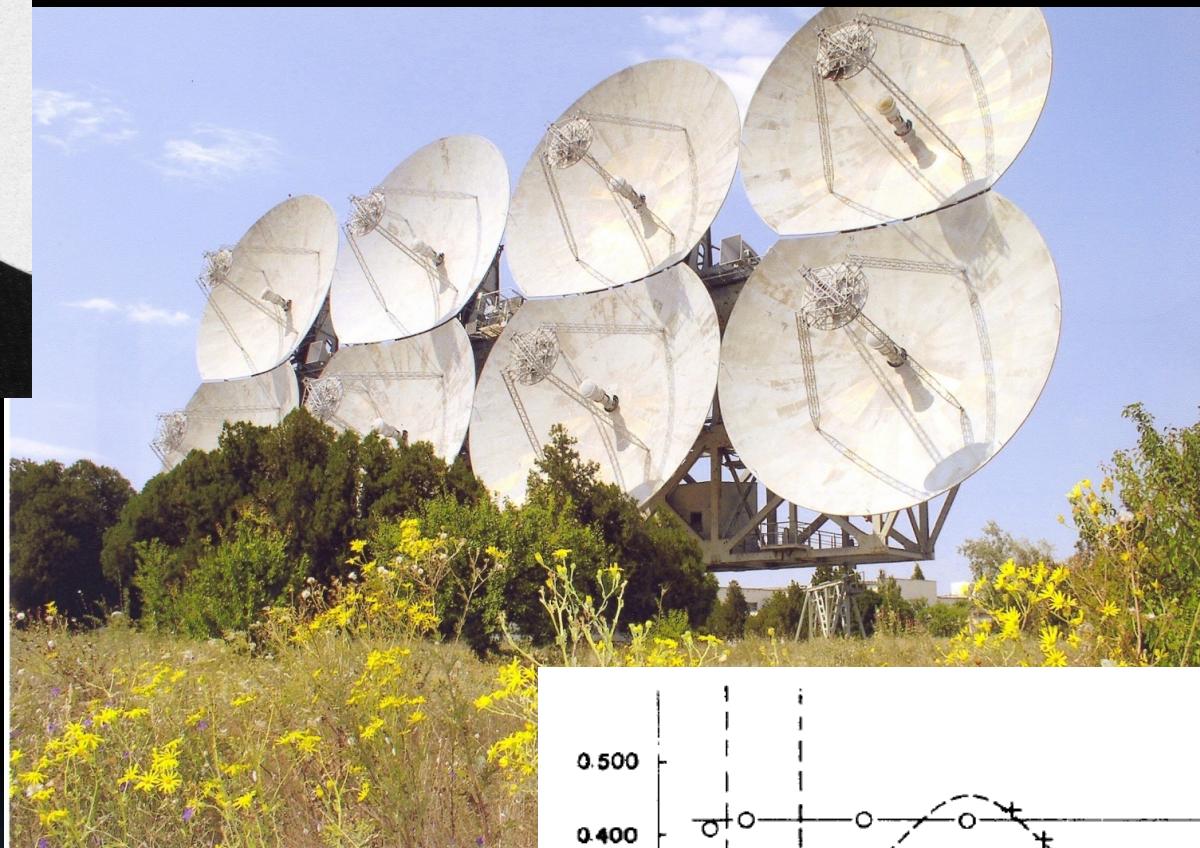
Max Planck Institute
for Radio Astronomy



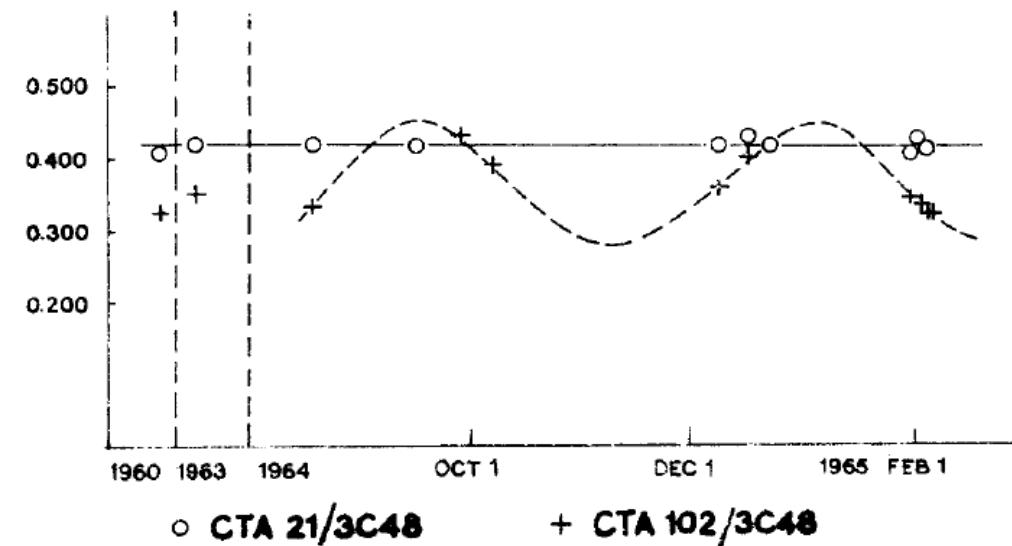
50 years ago...

- 1963:
 - Inauguration of the Arecibo Observatory
 - Discovery of quasars
 - First observations of variability of extragalactic radio sources
 - Early discussions on VLBI
 - *The speaker went to a primary school...*
- Matveenko, Kardashev, Sholomitskii 1965, Radiophysics 8, 651
- ~1967, Arecibo as a VLBI telescope?
(see Burke in Radio Astronomy from Karl Jansky to microjansky", EDP Sci 2005, 27)
- *First VLBI fringes with Arecibo – 1967?*
- *Arecibo Lunar Occultation survey – 1967-1970?*

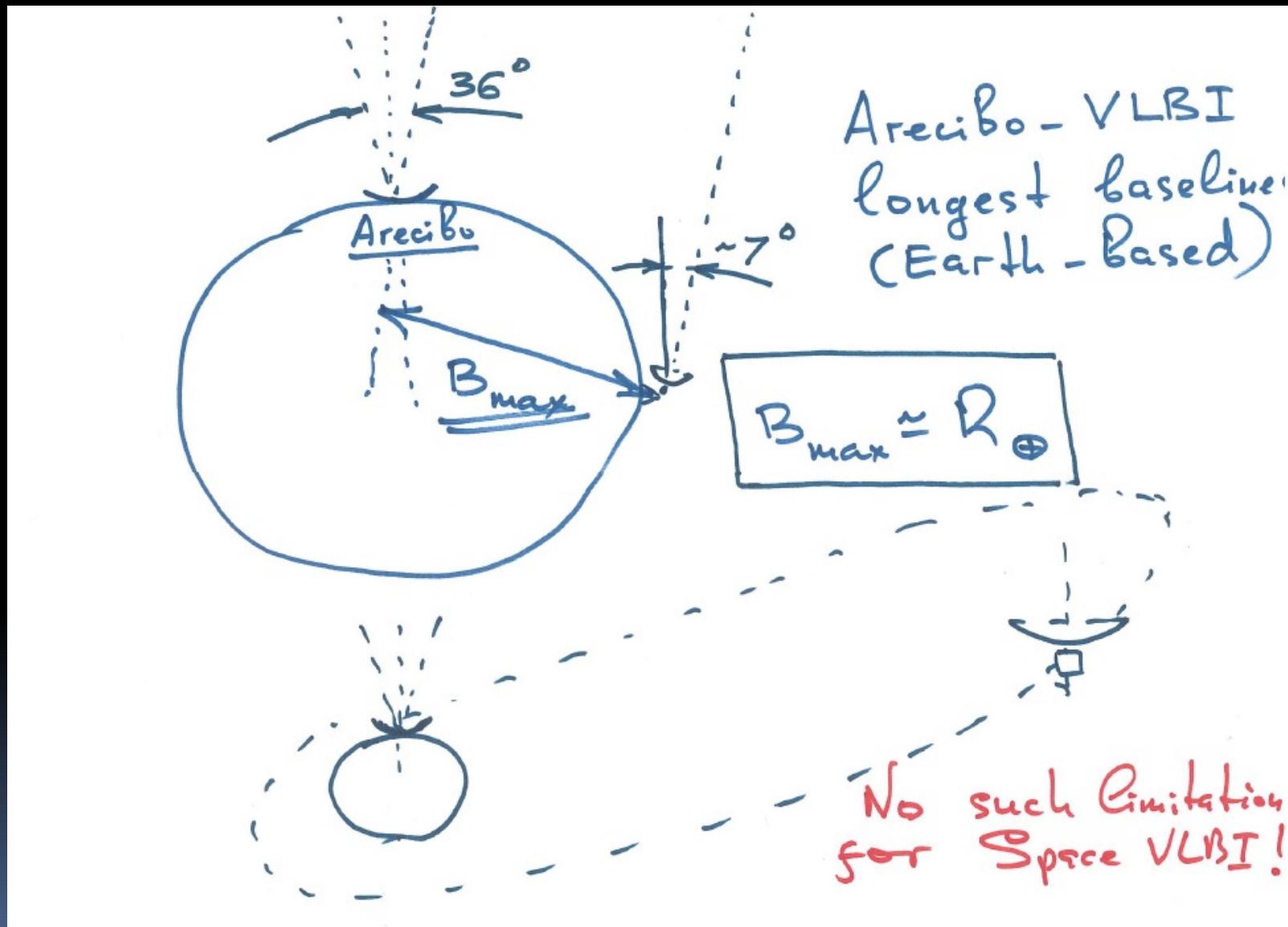
1963-65: precursors of VLBI (*with space flavour*)



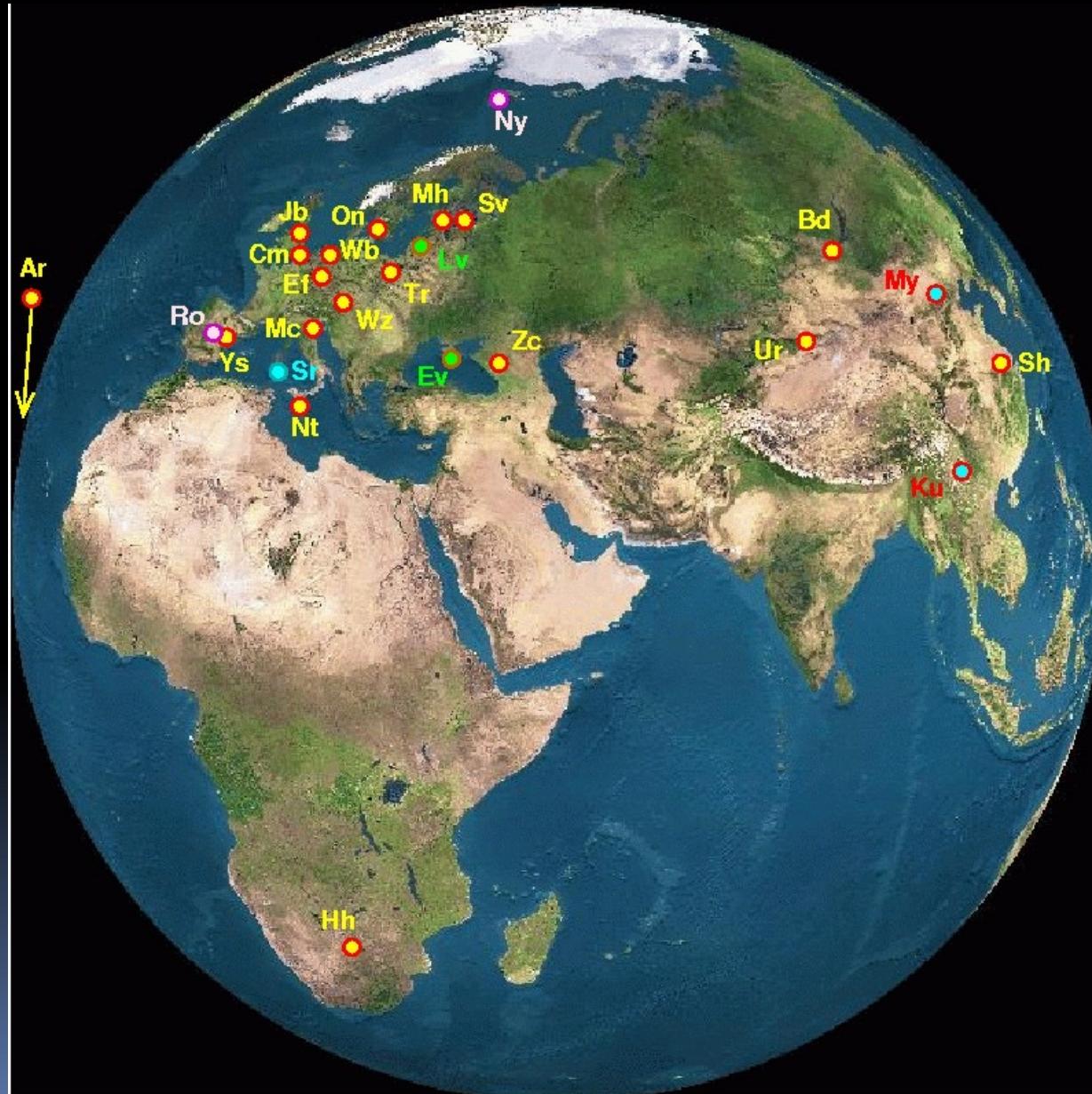
Variability of CTA 102
G. Sholomitskii, 1965, IBVS 83



Arecibo and SVLBI in “viewgraphs” time



Arecibo on the VLBI map (of “Europe”)



Space VLBI
over Arecibo:
truly VERY
long baselines

1997-2003

SVLBI over Arecibo

2011-2016?



VSOP-HALCA, Ø 8m



RadioAstron, Ø 10m



VSOP
(VLBI Space Observatory Programme)



ISAS (Japan)

HALCA start: February 12, 1997 (new M-V rocket)

8-m parabolic antenna on board
HALCA

observing frequencies:

1.6 and 5 GHz

recording data rate: 128 Mbps

bandwidth: 32 MHz

orbital period: 6.3 h

21 400km (apogee)

560 km (perigee)

baselines: up to ~30 000 km

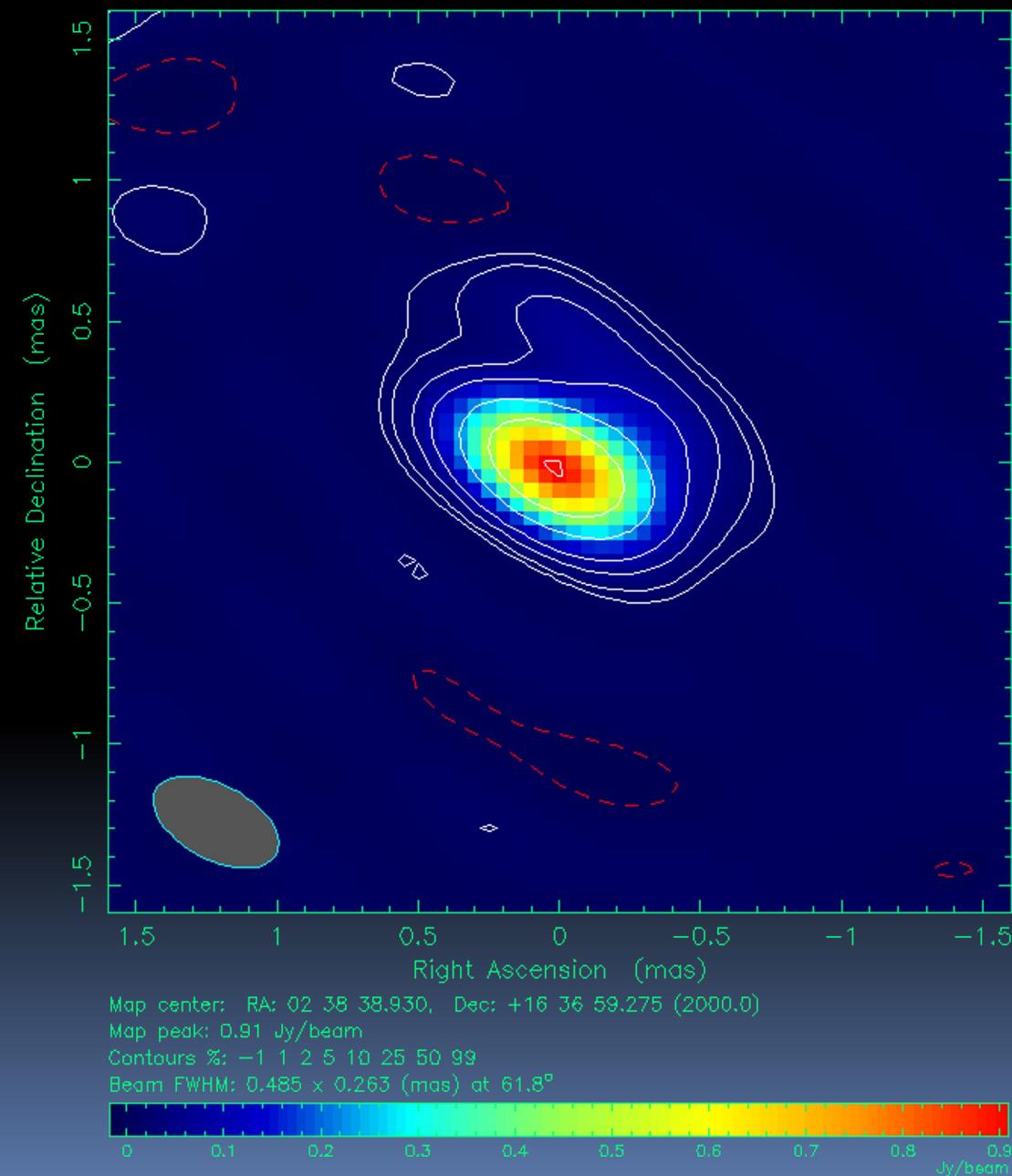
VSOP and brightness temperatures

- Factor of ~ 4 increase in angular resolution →
- T_B exceeding the inverse Compton limit could be measured
- High brightness temperatures are indeed found in a few individual sources, e.g.
 - NRAO 530 (3×10^{12} K) - Bower & Backer (1998), *ApJ* **507**, L117
 - 1921-293 (2.6×10^{12} K) - Shen et al. (1999), *PASJ* **51**, 513
- The case of AO0235+164

AO 0235+164 - a native of Arecibo

- Optical identification: BL Lac (1975)
- $z_{\text{em}} = 0.940$ (1987)
- Absorption line systems at $z=0.851$ and $z=0.524$
(the latter in emission as well)
- Group of galaxies within a few arcsec
- Object A (2" South): AGN? - Burbidge et al. 1996, AJ **112**, 2533
- Gravitational microlensing - to explain rapid variability and VLBI components - Stickel et al. 1988, A&A **198**, L13
- Variability in radio, IR, optical, X-rays, gamma-rays,
both IDV and longer-term
- 5-6 yr periodicity? - Raiteri et al. 2001, A&A **377**, 396

Clean map. Array: ASU
0235+164 at 4.800 GHz 1999 Feb 01



AO 0235+164

The highest brightness temperature (lower limit) measured with VSOP:

$$T_B > 5.8 \times 10^{13} \text{ K}$$

Frey et al. 2000, PASJ 52, 975

RadioAstron – Spektr-R



- 10-m antenna
- 0.327, 1.6, 5 and 22 GHz
- Dual-polarization
- 128 Mbps
- 2 on-board H-masers
- Apogee (initial) – 343,000 km
- Data reception – Pushchino, Green Bank

In preparation since 1978

2011 July 18



2011 July 18

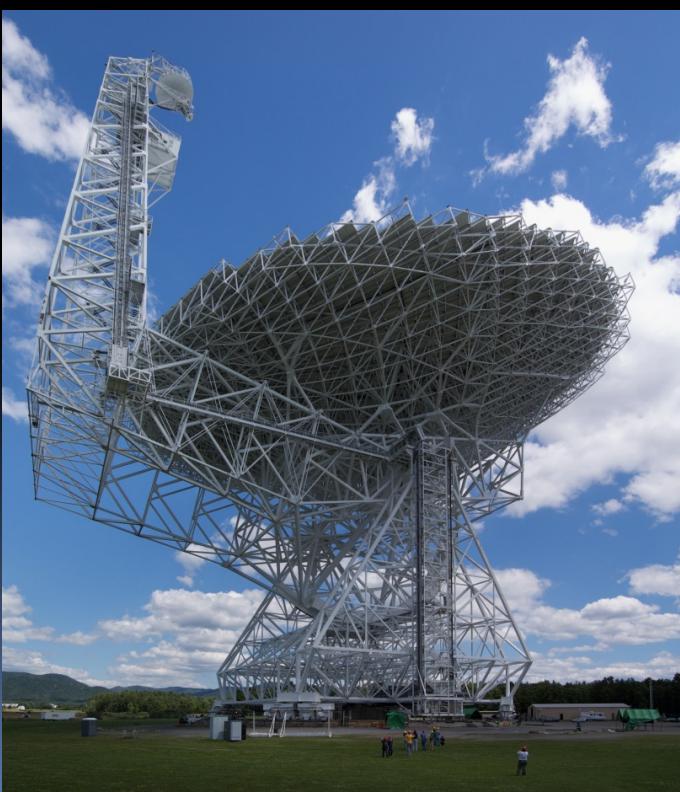
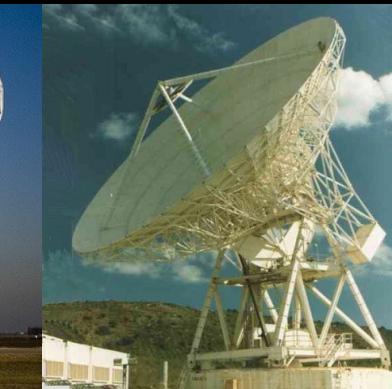


2011 July 18

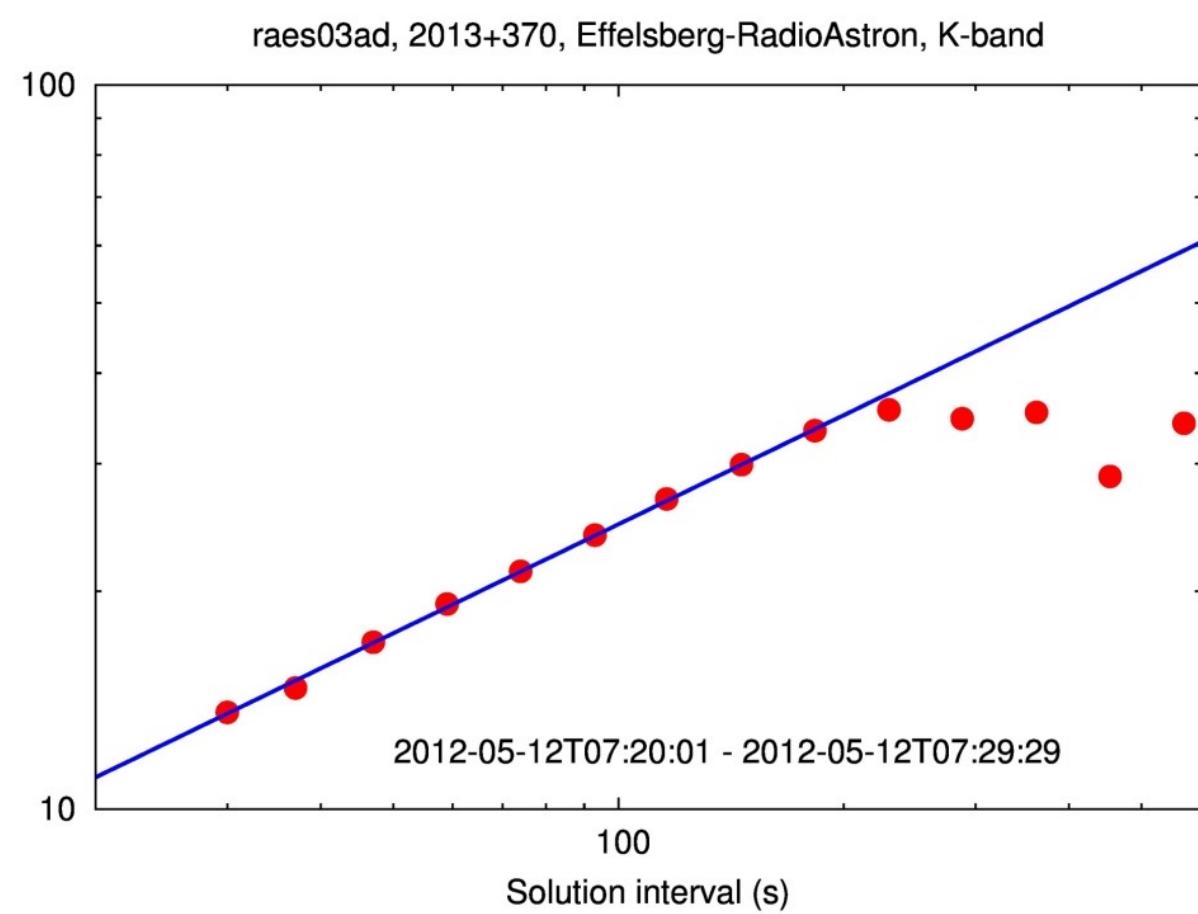


RadioAstron's Earth-based partners

KVAZAR network, Evpatoria, Effelsberg, Yebes, WSRT, GBT, Arecibo, VLA, Usuda, EVN, VLBA, LBA, et al.



RadioAstron on-board hydrogen maser



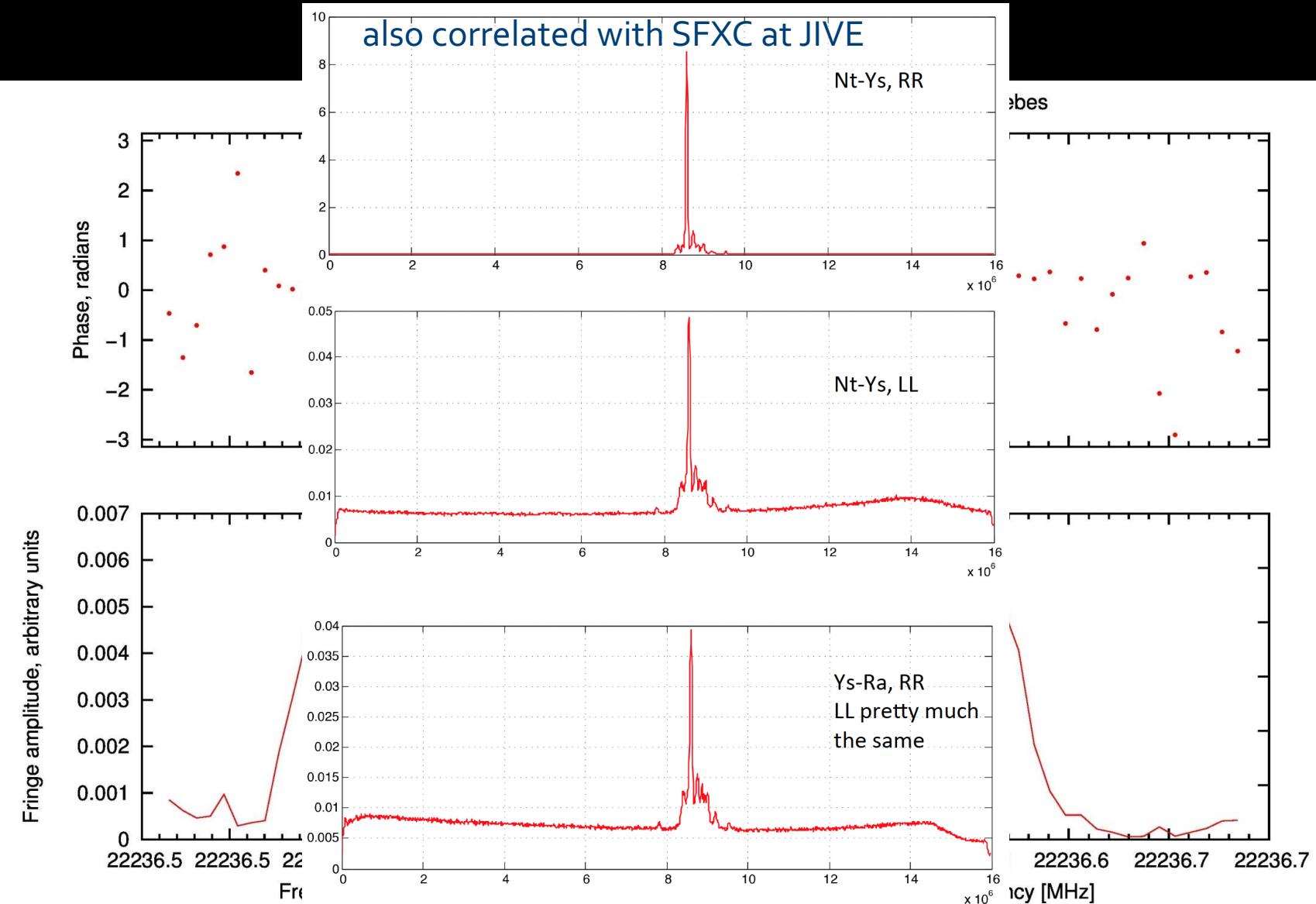
The first operational active H-maser in orbit

RadioAstron science (so far)

- Early science programme (mission-led) – almost completed
- Key Science Programmes (based on peer-reviewed proposals) – underway
 - *AGN (individual and survey);*
 - *Pulsars + ISM*
 - *Masers (H_2O and OH)*
- “Open sky” phase – call expected in ~mid 2014

RadioAstron maser results

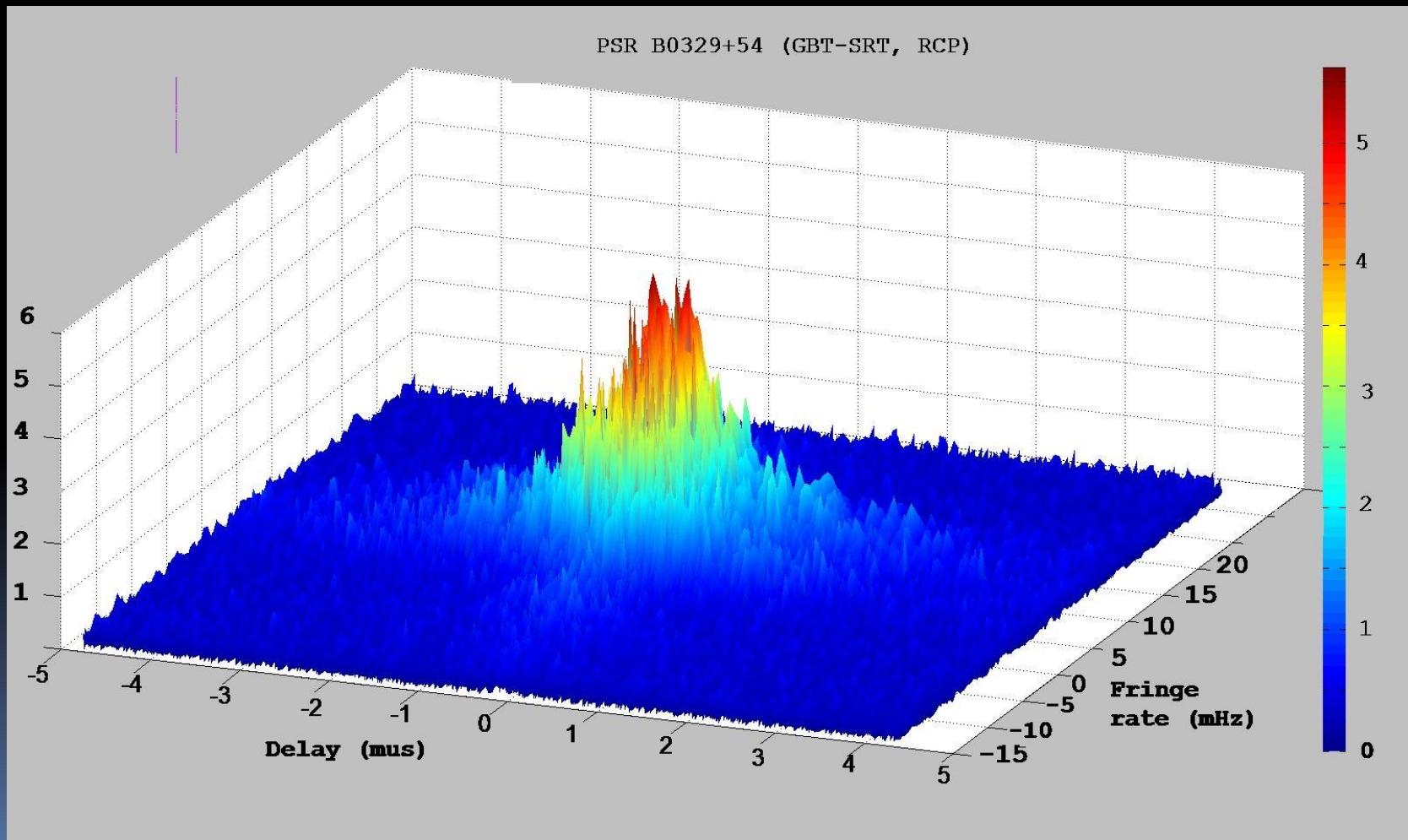
Galactic water maser W3 IRS5, 22 GHz, B = 5.4 ED,



RadioAstron pulsars (and ISM) results

PSR 0329+54: this must not be!

RA - GBT, 327 MHz, B ~ 100,000-200,000 km

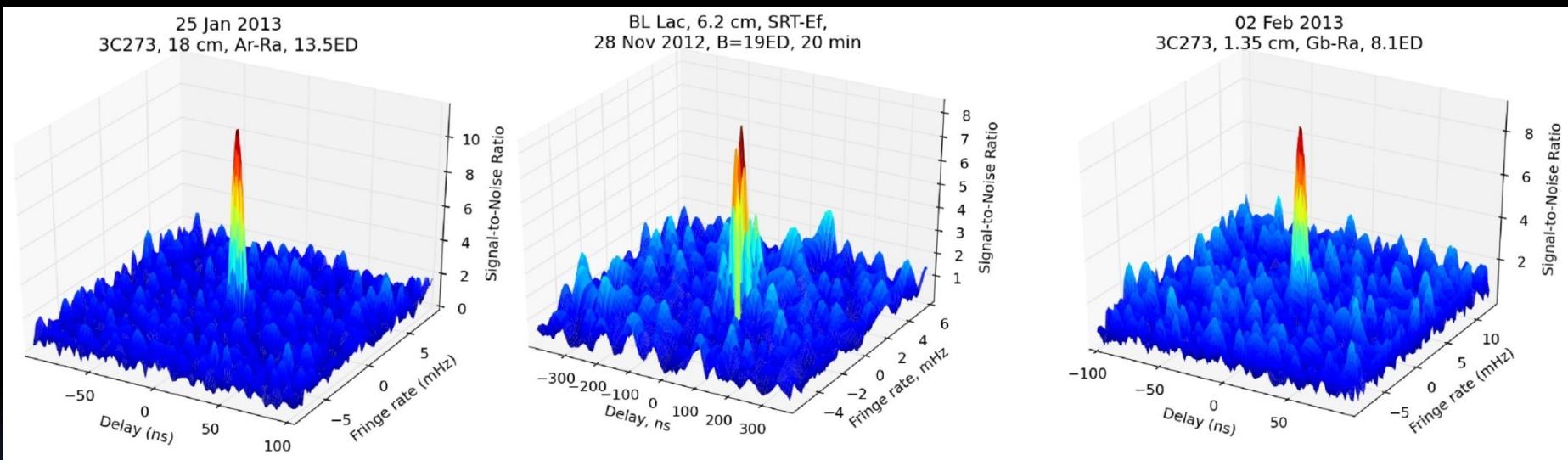
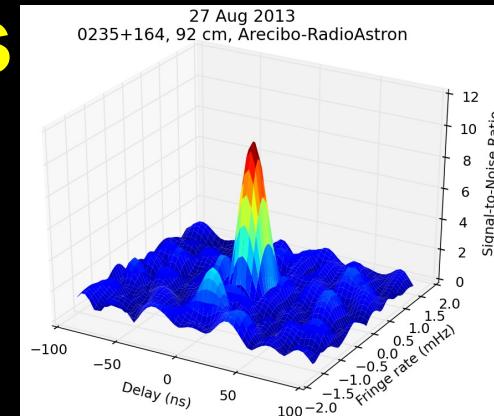


RadioAstron AGN survey status

92 cm:
18 cm:
6 cm:
1.3 cm:

2.3 ED AO 0235+164 (Ra-Ar)
16.4 ED 0529+483 (RA-GBT), 14 ED 3C273 (RA-Ar);
19 ED BL Lac (RA-Ef) and 19 ED 0529+483 (RA-Ef);
8.1 ED, 3C273 (RA-GBT and RA-VLA).

Record breaking (formal) resolution: 27 μ as.



- Several dozen AGN observed, most of them – detected at long baselines;
- Brightest AGN cores: 0529+483, 0716+714, 3C273, 3C279, 3C345, BL Lac, etc;
- Typical T_b so far in the range 10^{12} to $>10^{14}$ K;
- ISM does not “kill” compact emission at 6 and even 18 cm.

3C273: another jubilar

RadioAstron + Arecibo

➤ 18 cm

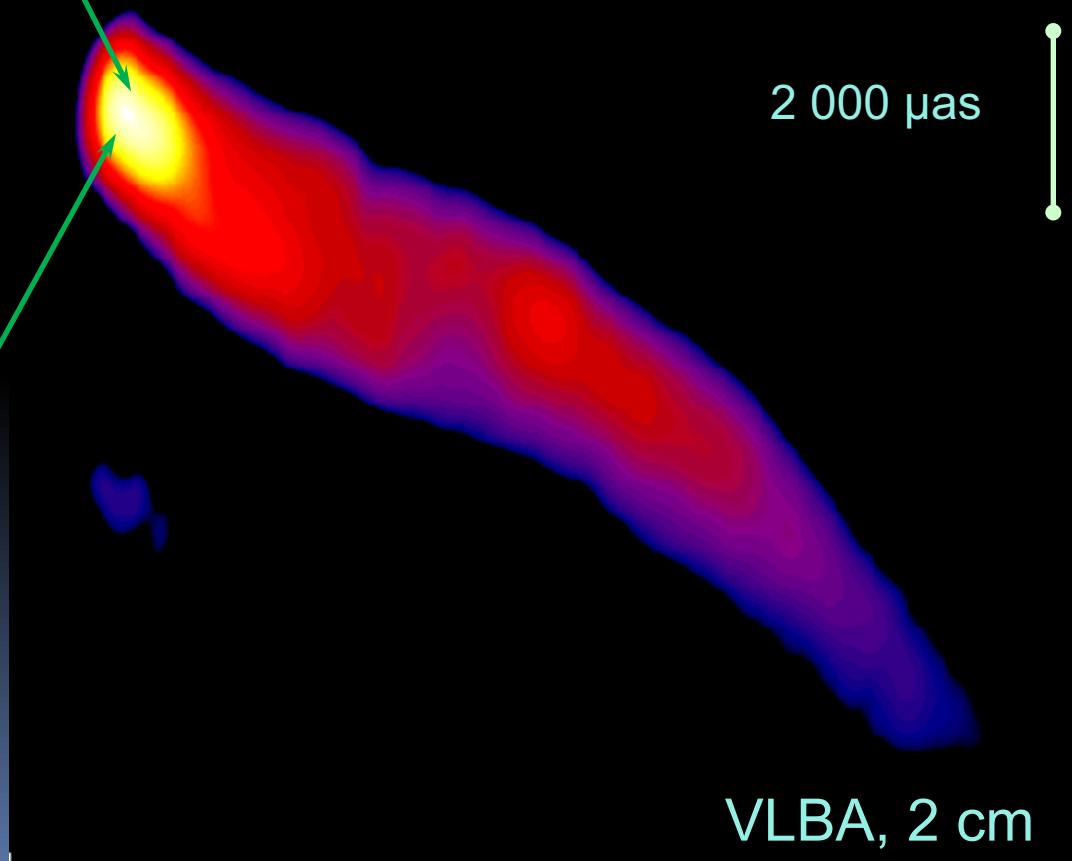
Core size: < 270 μ as;

Core brightness: $>10^{14}$ K.

RadioAstron + GBT

➤ 1.3 cm

Core size: ~24 μ as;
absolute record on
angular resolution



VLBA, 2 cm

*Congratulations
to 50-years old APR
from 100-orbits old RAO!
Best wishes!*

