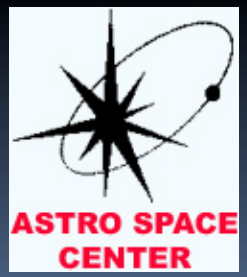
Space VLBI at Ger's wavelengths *and brightness*

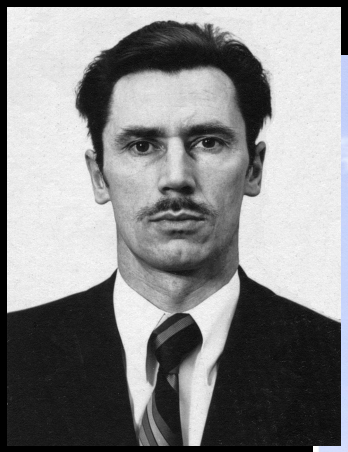
Leonid Gurvits *and* *Yuri Y. Kovalev*

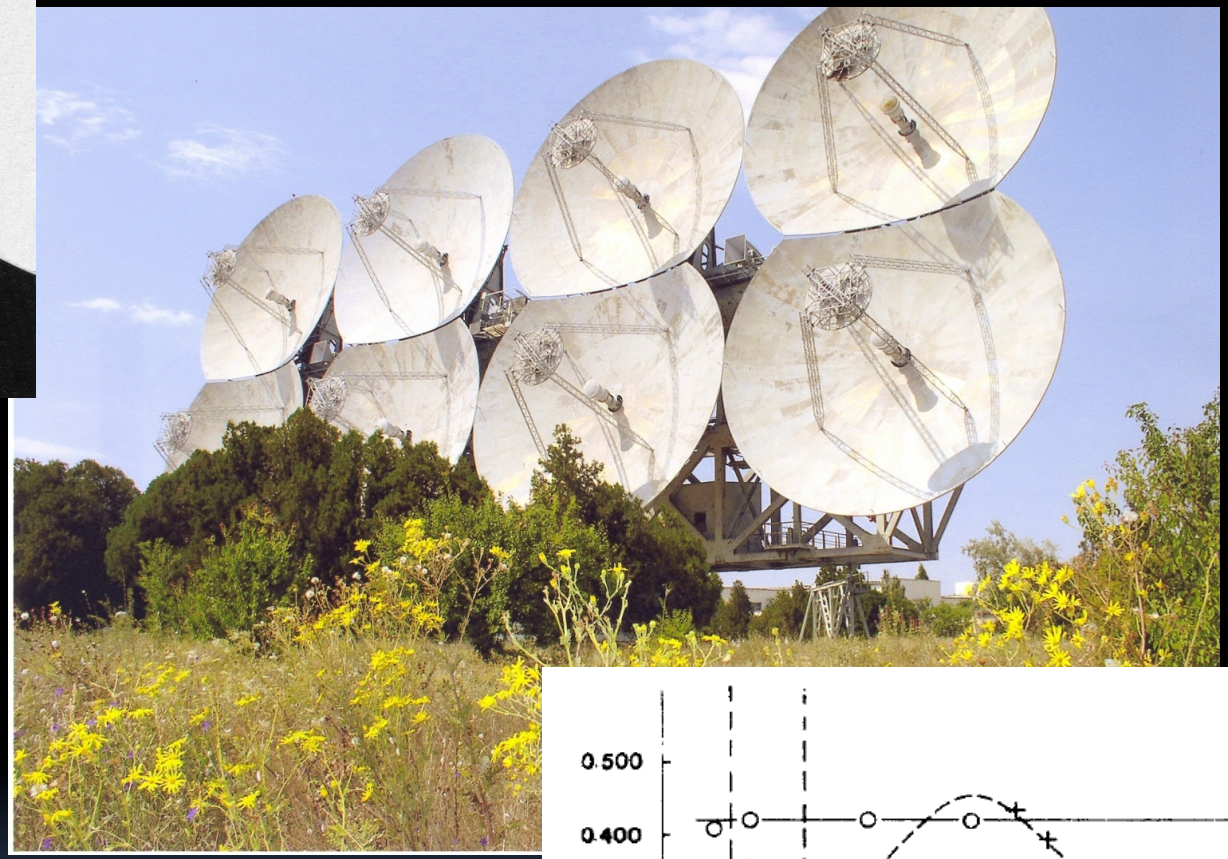


1963: a special year for radio astronomy

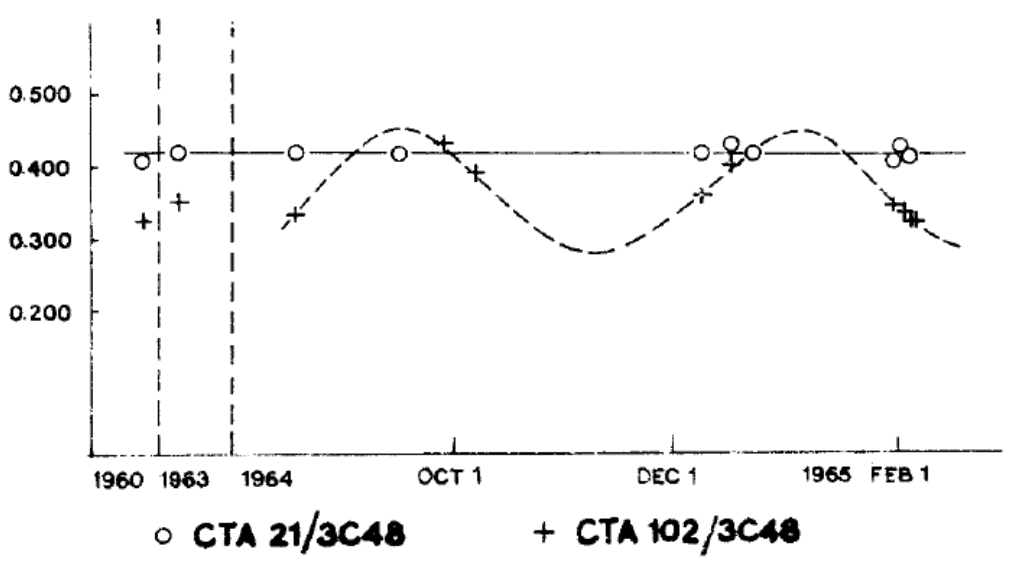
- **50 years ago:**
  - Discovery of quasars
  - First observations of variability of extragalactic radio sources
  - Inauguration of the Arecibo Observatory
  - Early discussions on VLBI
    - *Matveenko, Kardashev, Sholomitskii 1965, Radiophysics 8, 651*
  - *The speaker went to a primary school…*

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





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



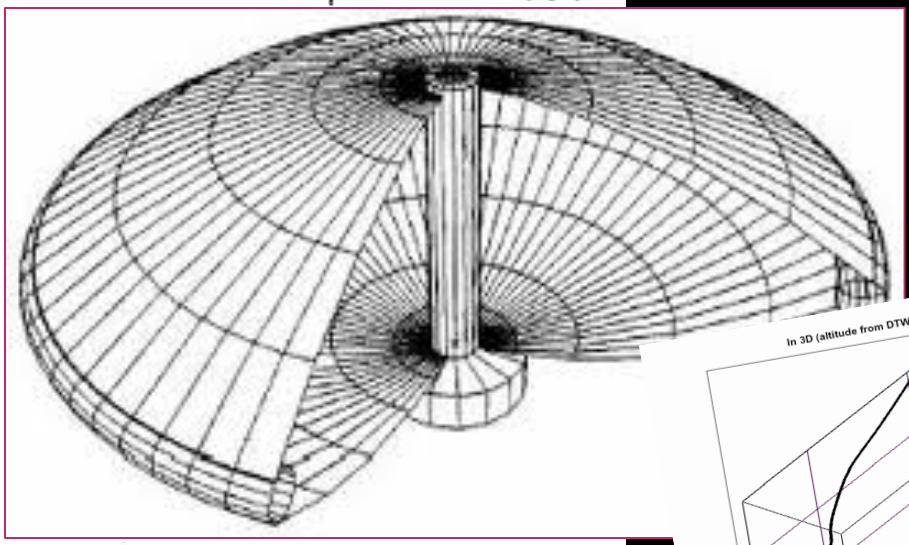
Space VLBI over Drenthe:

truly VERY long baselines

QUASAT – the first international SVLBI project

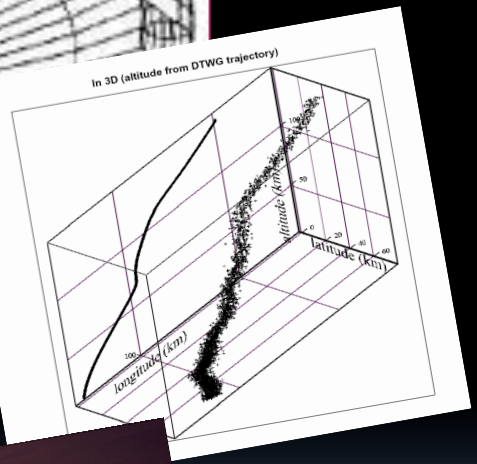
SP-213

September 1984



Quasat –

a VLBI observatory in space

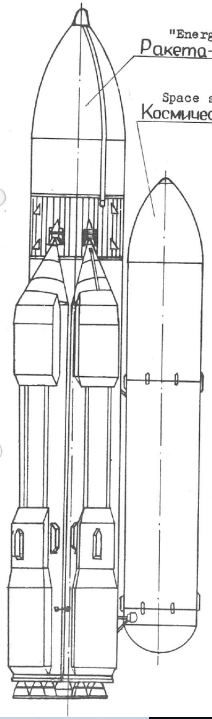


Proceedings of a workshop held at Gross Enzersdorf, Austria, on 18-22 June 1984 – jointly sponsored by the European Science Foundation & the USA National Academy of Sciences, with the collaboration of the European Space Agency & the USA National Aeronautics and Space Administration – local organisation by the Austrian Solar & Space Agency

IVS – the most ambitious SVLBI project

РАКЕТА-НОСИТЕЛЬ "ЭНЕРГИЯ"
С КОСМИЧЕСКОЙ ЧАСТЬЮ

"ENERGIA" BOOSTER WITH SPACE SEGMENT



1. Стартовая масса, т - 2400
2. Масса космической части, выводимая на опорную орбиту ($H_{кр}$ = 200 км, i = 63°), т до 90

1. Launching mass – 2400 t
2. Mass of space segment to be inserted into reference orbit ($H_{circular}$ = 200 km, i = 63°) – up to 90 t.

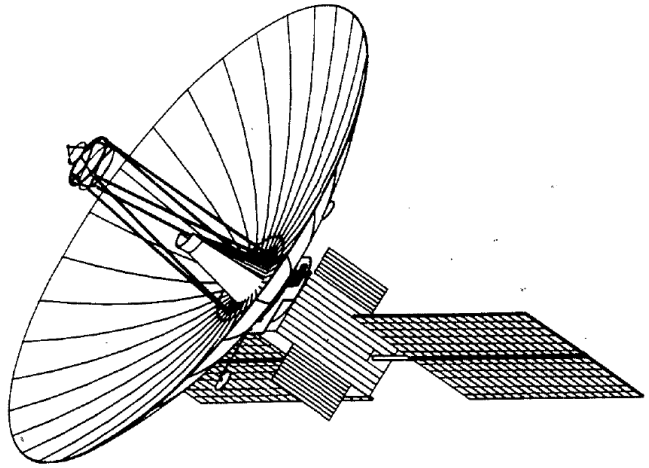
Fig.2

esa european space agency

ASC

I V S

AN ORBITING RADIO TELESCOPE



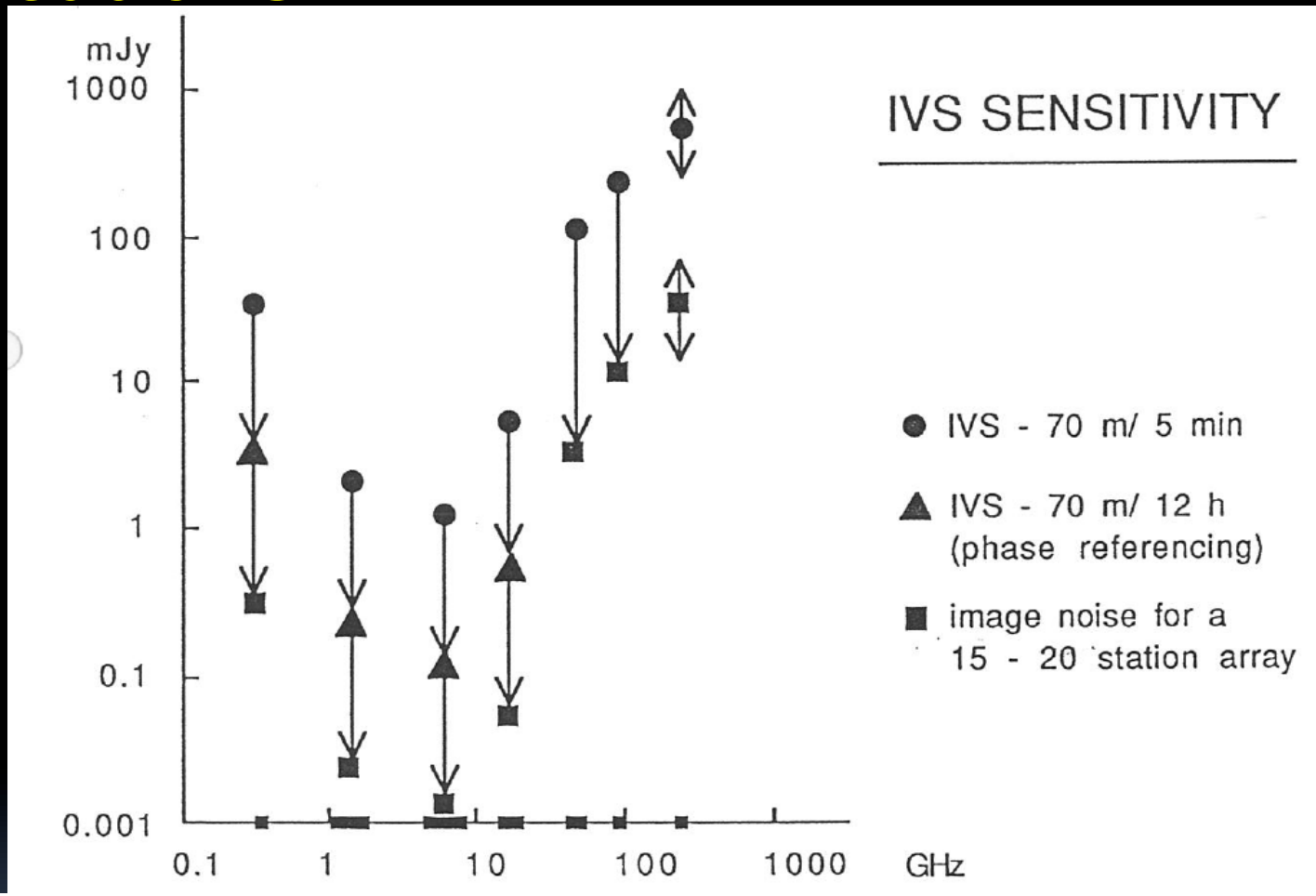
REPORT ON THE ASSESSMENT STUDY

V.Altunin, B.Anderson, J.W.M.Baars, A.Baudry, R.S.Booth, B.E.Chertock, J.Cornelisse, Yu.S.Denisov, L.I.Gurvits, N.S.Kardashev, Ya.P.Kolyako, T.Kuiper, G.Pilbratt, R.A.Preston, R.T.Schilizzi, V.I.Slysh, G.Tofani, S.Volonte, P.N.Wilkinson, T.L.Wilson

JANUARY 1991

SCI(91)2

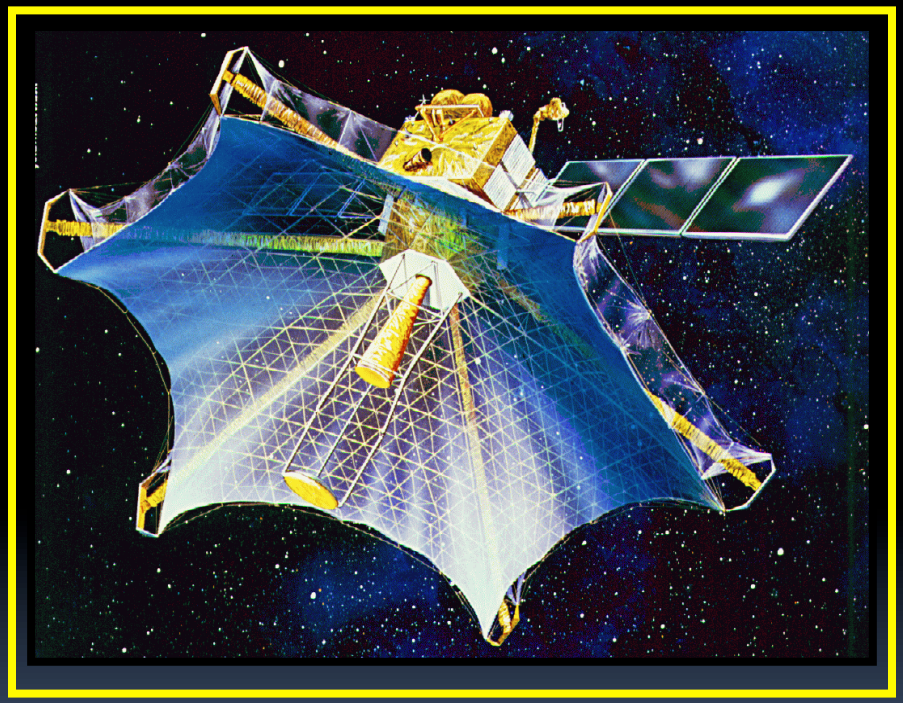
IVS specifications



- angular resolution at 43 GHz
  - orbit(1) 50 μas
  - orbit(2) 25 μas
  - orbit(3) 6 μas

Space VLBI in reality

1997-2003



VSOP-HALCA, Ø 8m

2011-2016?

RadioAstron, Ø 10m

VSOP
(VLBI Space Observatory Programme)

http://www.vsop.isas.ac.jp/

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

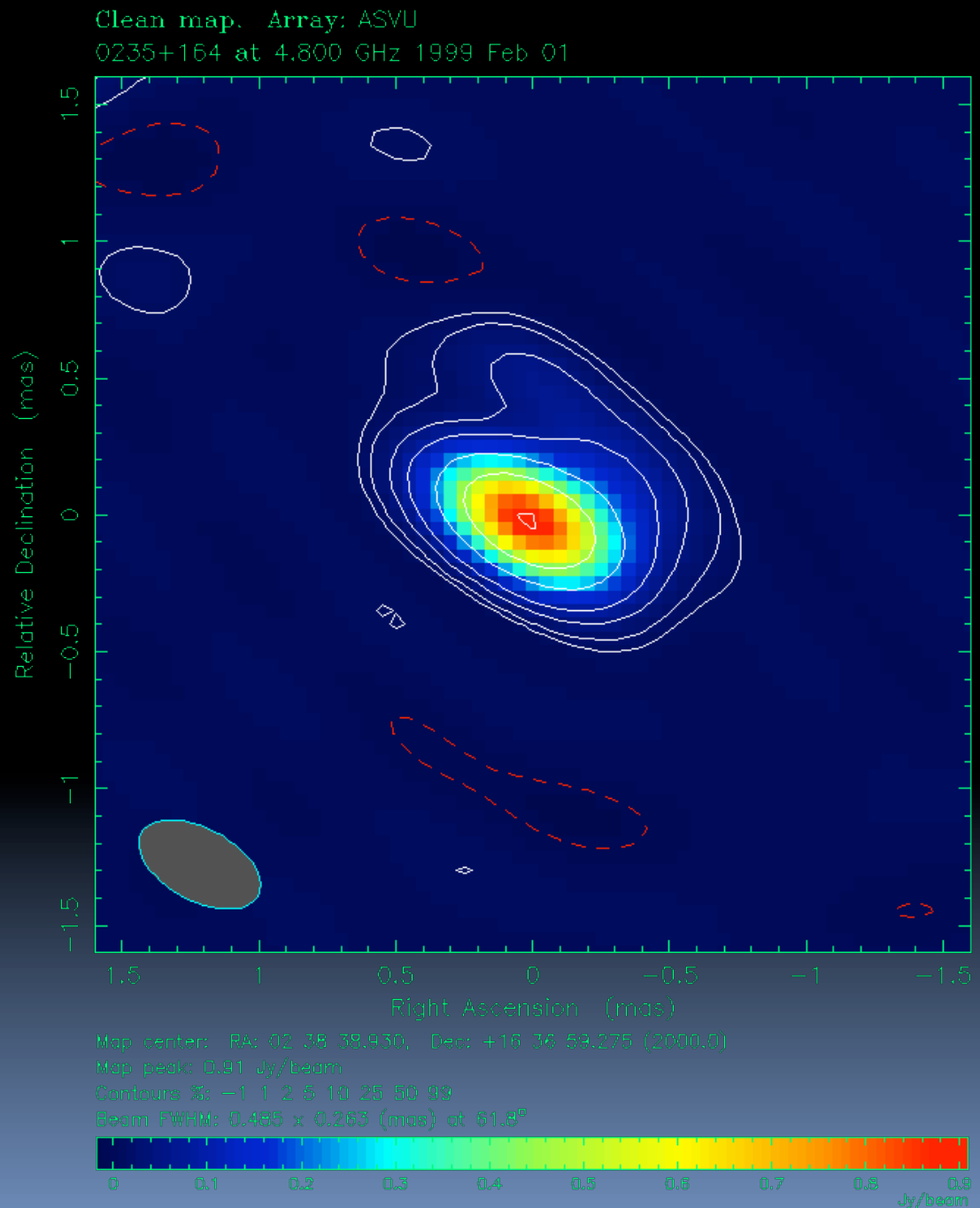
- Factor of ~4 increase in angular resolution →
- T_B exceeding the inverse Compton limit could be measured
- High brightness temperatures are indeed found in a few individual sources, e.g.
  - NRAO 530 (3×10^{12} K) - Bower & Backer (1998), *ApJ* **507**, L117
  - 1921-293 (2.6×10^{12} K) - Shen et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

AO 0235+164 – a record holder

- Optcal identification: BL Lac (1975)
- z_{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



AO 0235+164

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

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

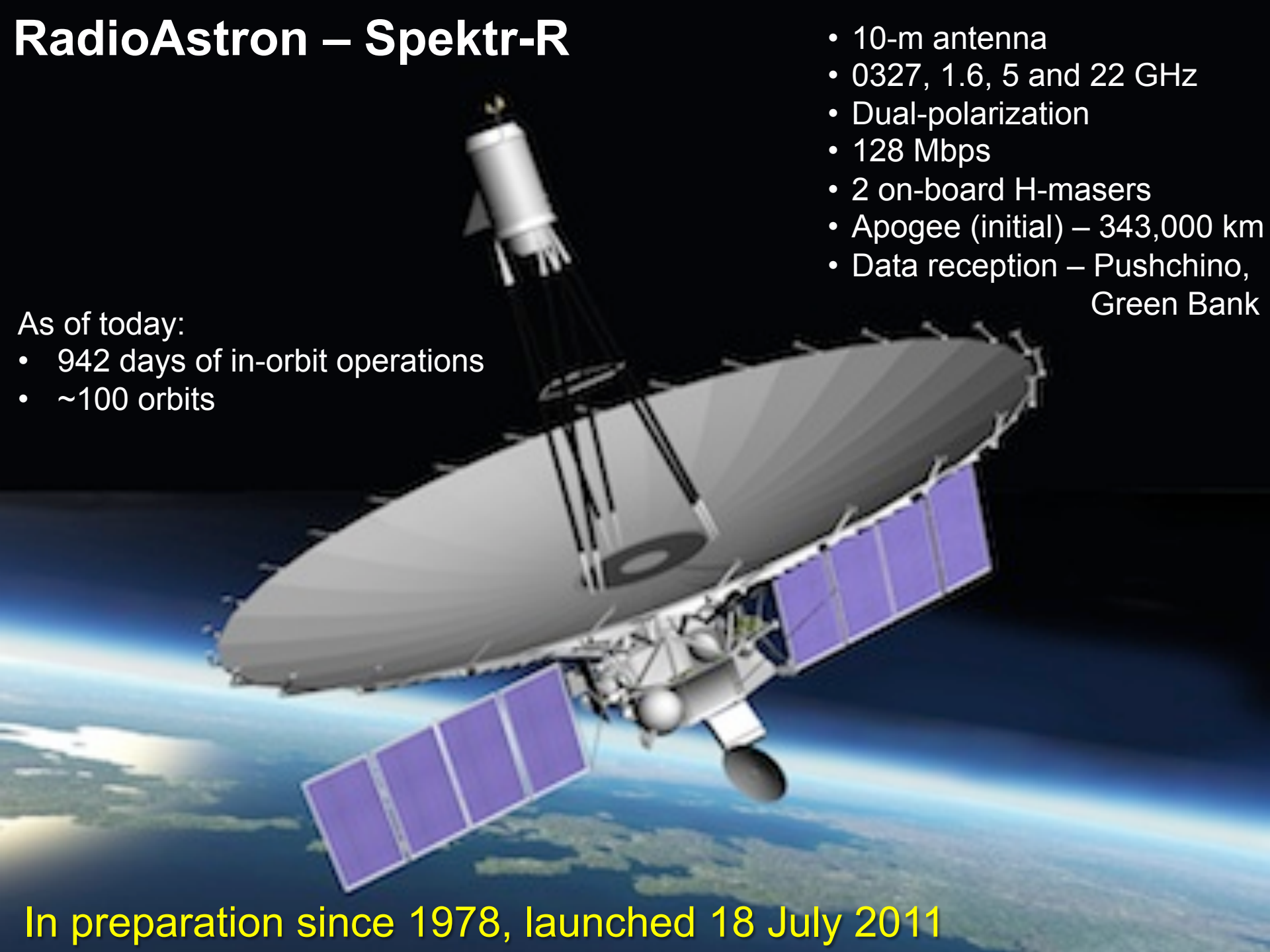
Frey et al. 2000, *PASJ* **52**, 975

RadioAstron – Spektr-R

- 10-m antenna
- 0327, 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

As of today:

- 942 days of in-orbit operations
- ~100 orbits



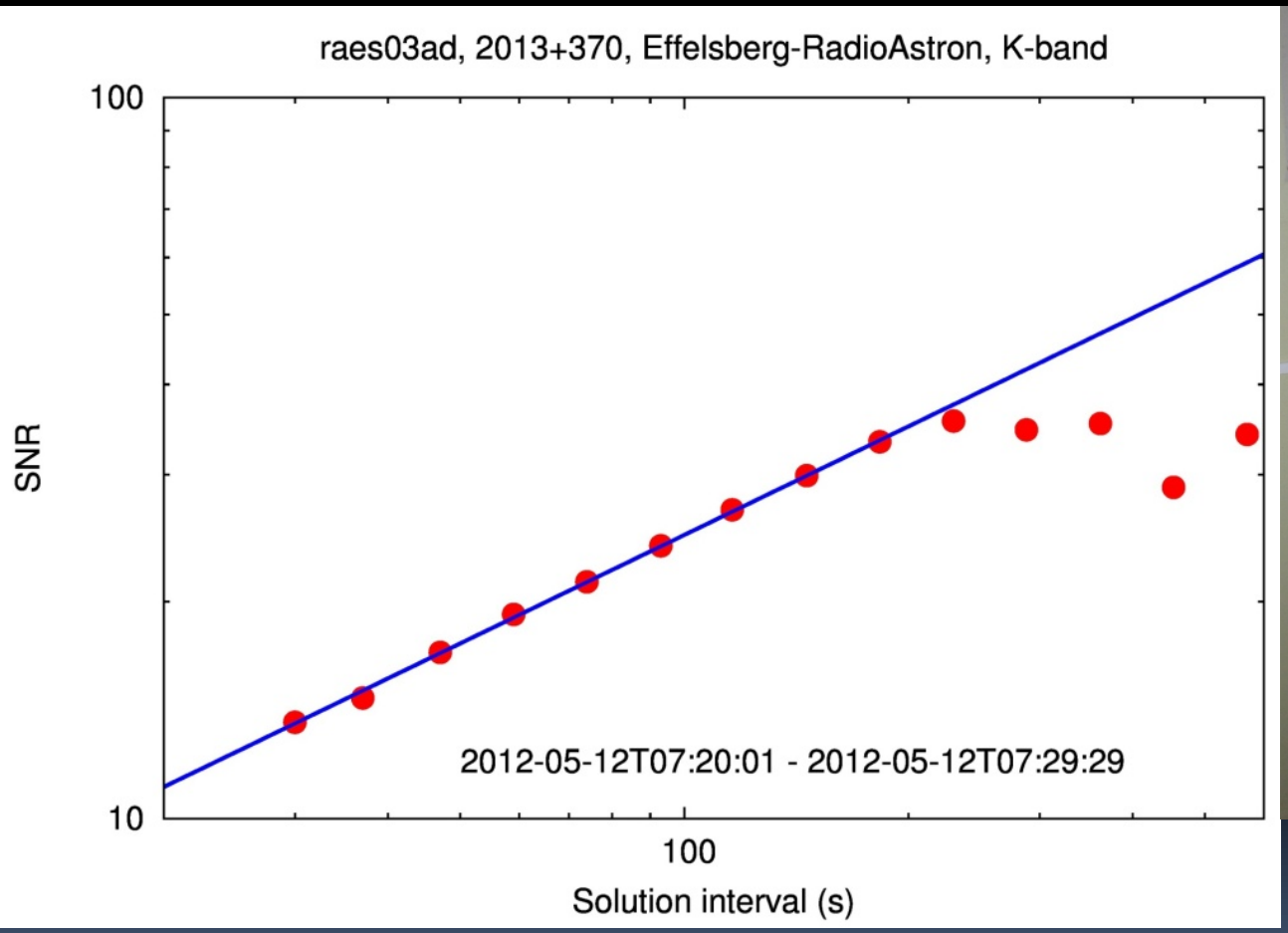
In preparation since 1978, launched 18 July 2011


2011 July 18

2011 July 18

2011 July 18

RadioAstron on-board hydrogen maser



The first operational active H-maser in orbit

RadioAstron science (so far)

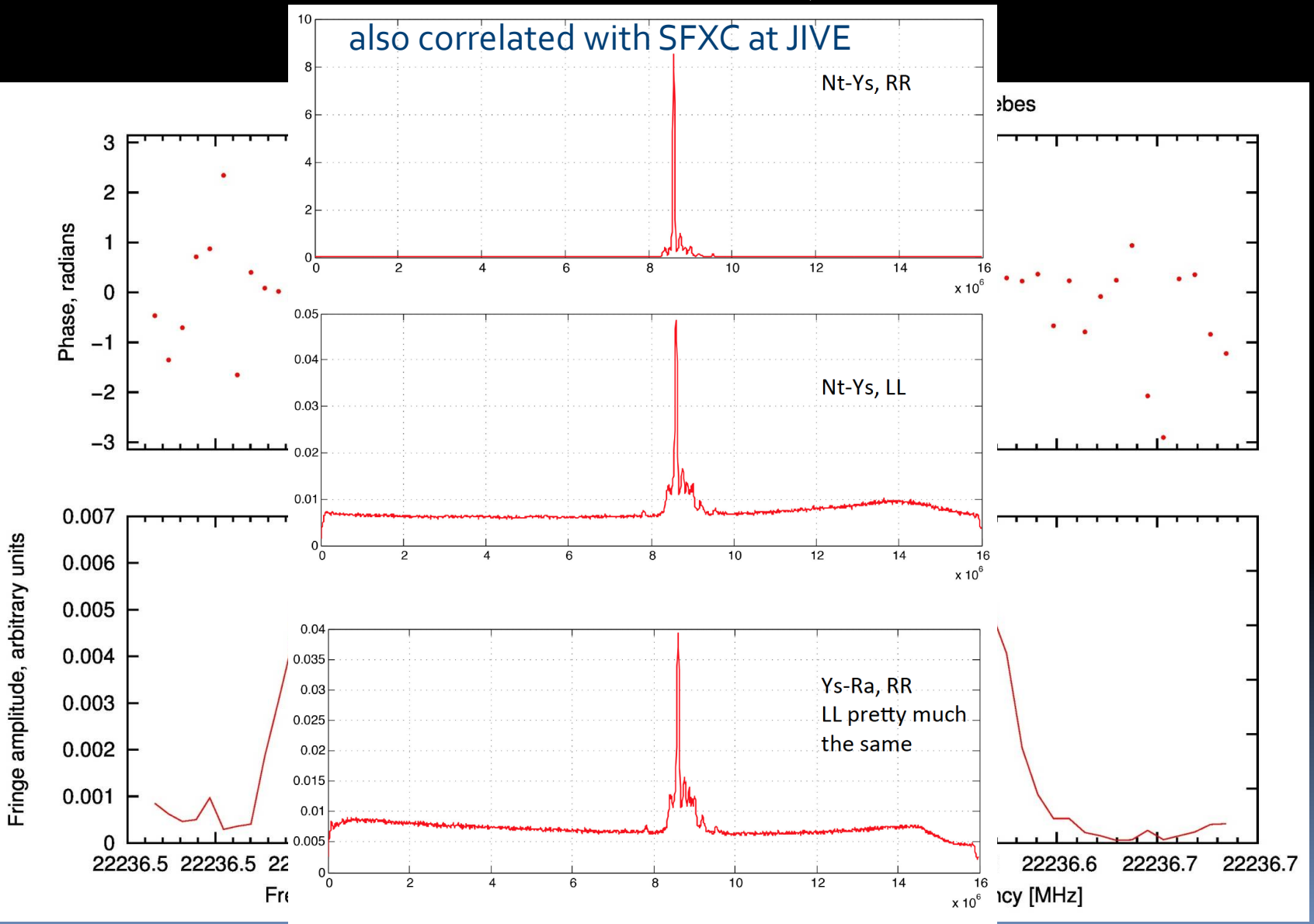
- Early science programme (mission-led) – almost completed

- 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

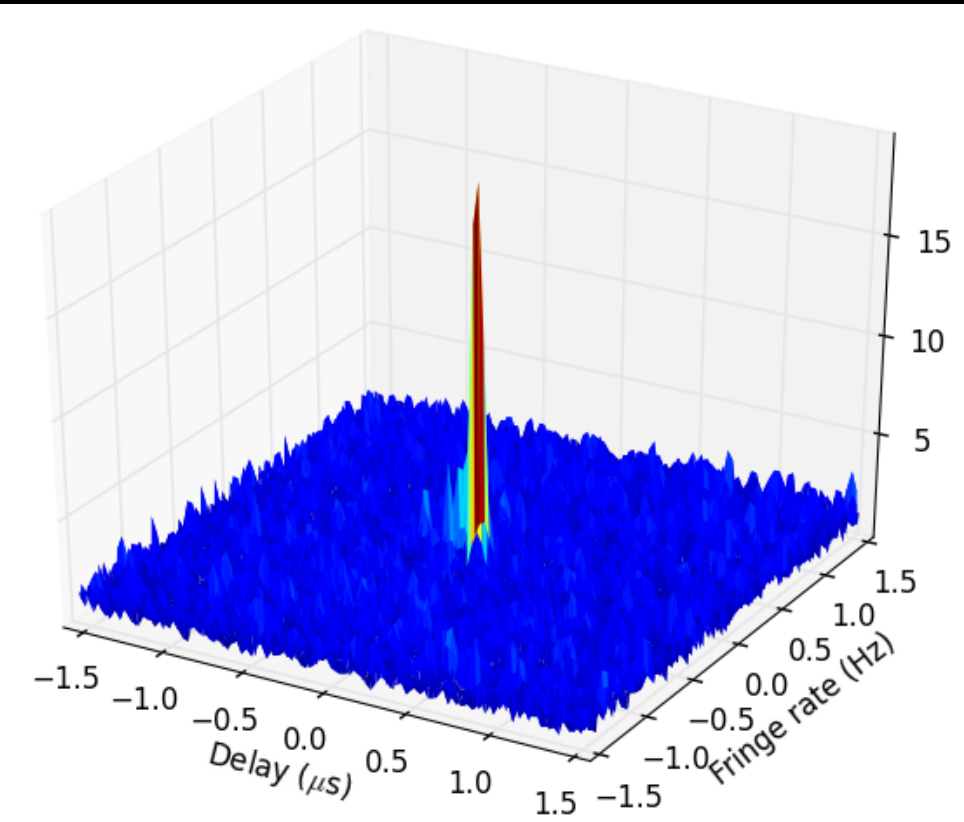
Galactic water maser W3 IRS5, 22 GHz, B = 5.4 ED,

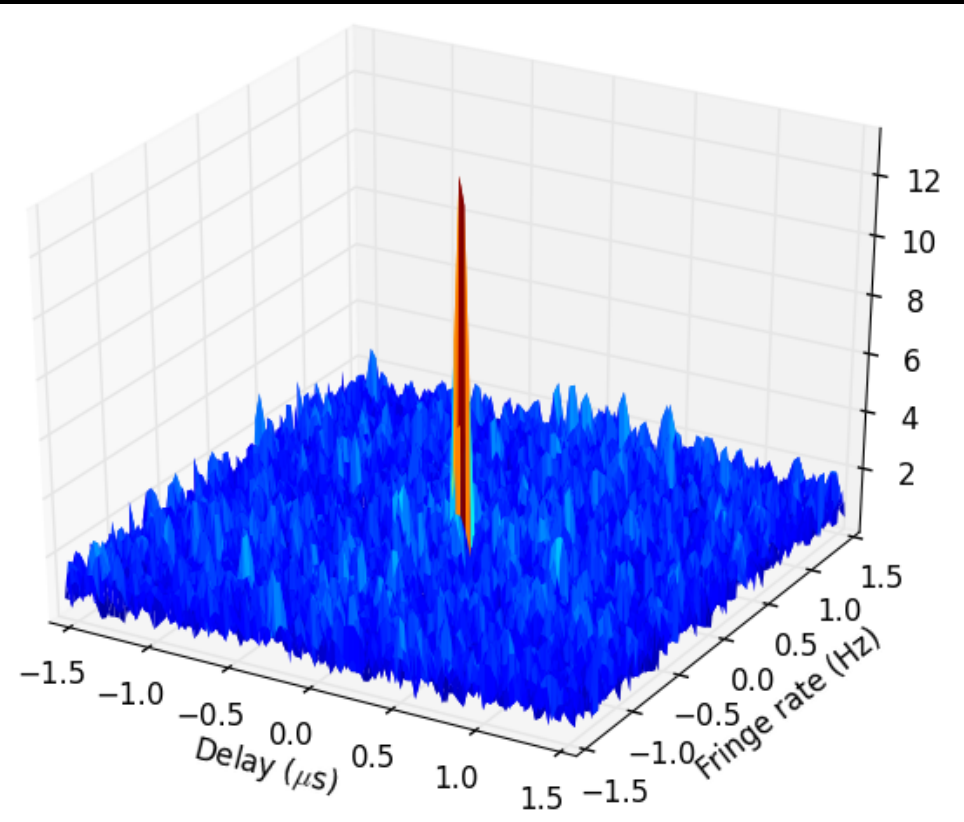


In-orbit checkout: 2013+370

5 GHz: RadioAstron-WSRT

22 GHz: RadioAstron-Eff



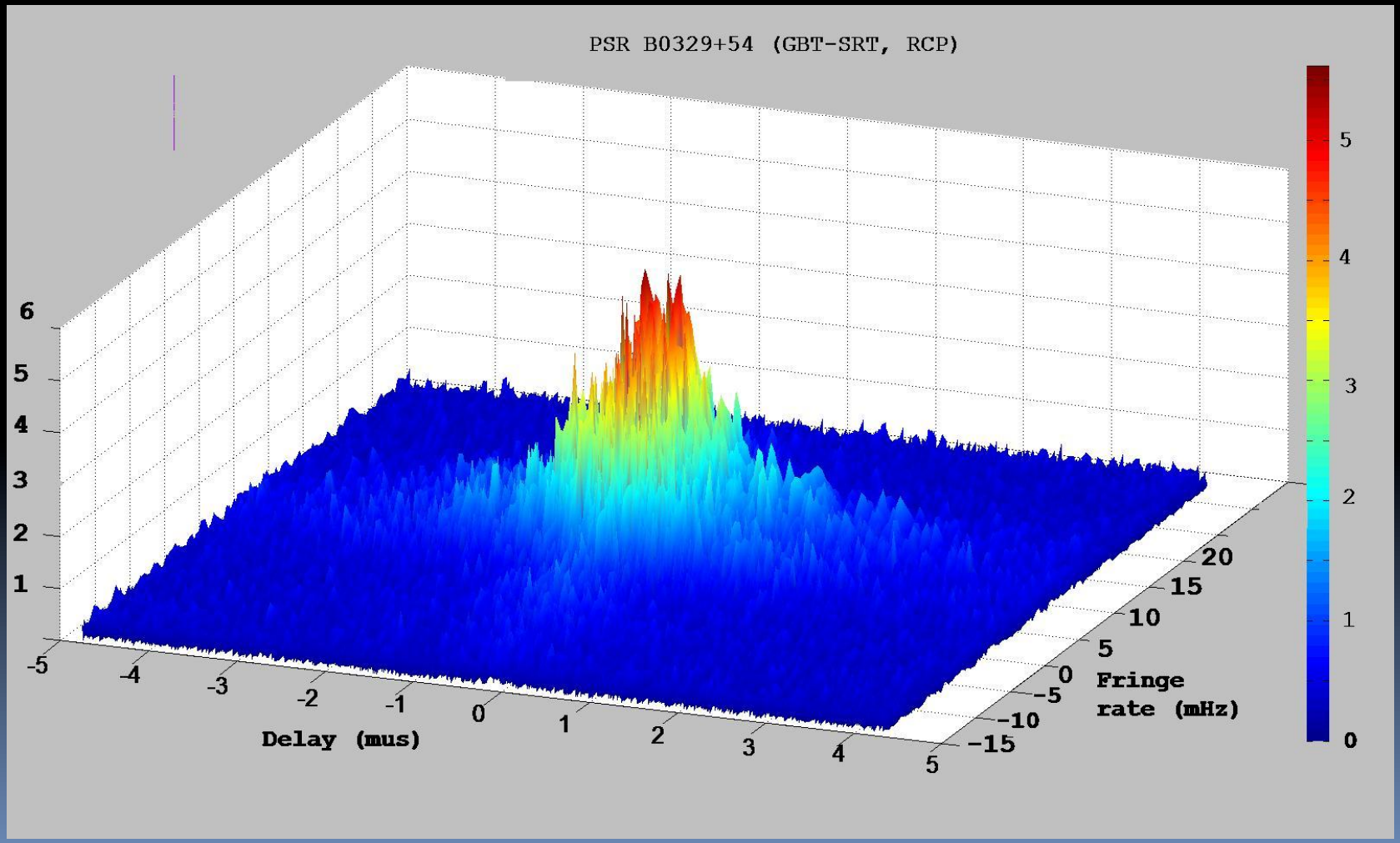


B ~ 0.25 ED, 1 min integration

RadioAstron pulsars (and ISM) results

PSR 0329+54: this must not be!

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

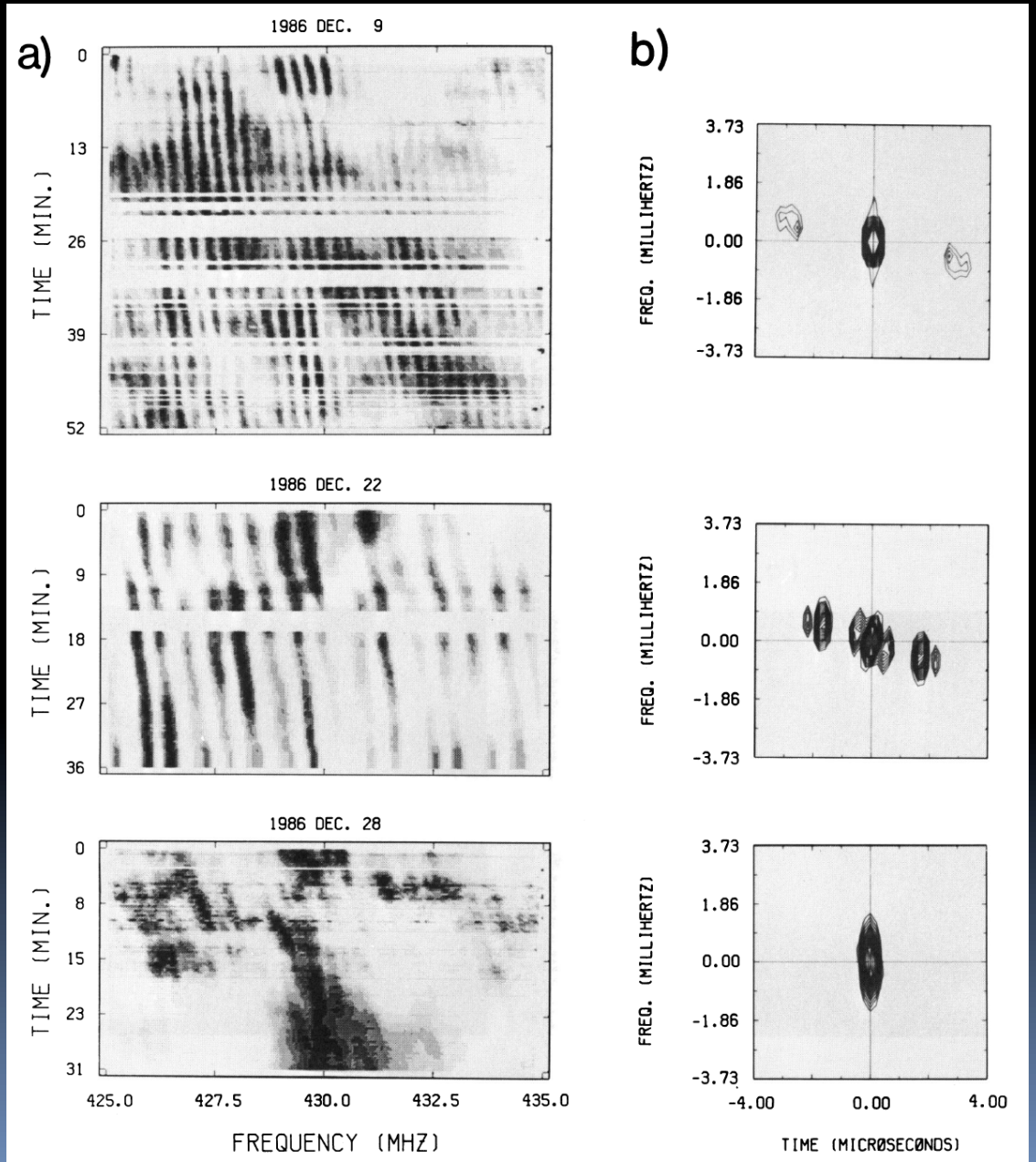


The precedent: PSR 1237+25

Wolszczan & Cordes, 1987

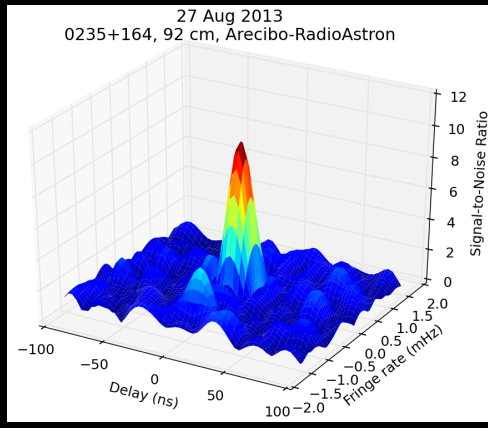
Interstellar interferometry:

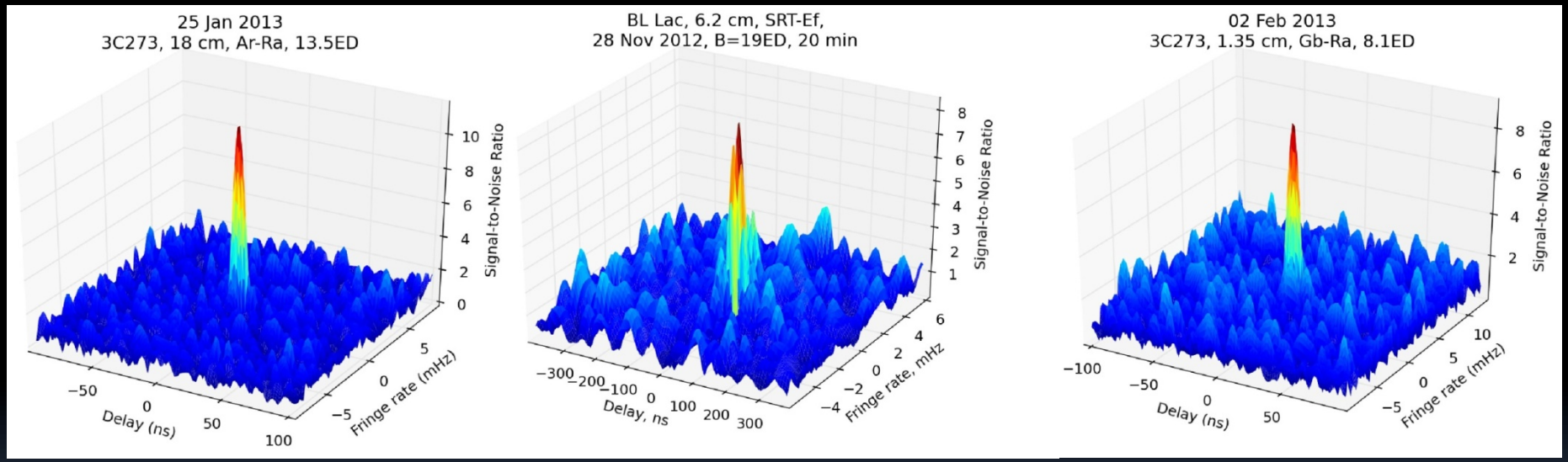
- Effective baseline ~ 1 AU
- Angular resolution ~ 1 μas
- Implications for the emission model



RadioAstron AGN survey status

92 cm:	2.3 ED AO 0235+164 (Ra-Ar)
18 cm:	16.4 ED 0529+483 (RA-GBT), 14 ED 3C273 (RA-Ar);
6 cm:	19 ED BL Lac (RA-Ef) and 19 ED 0529+483 (RA-Ef);
1.3 cm:	8.1 ED, 3C273 (RA-GBT and RA-VLA).
	Record breaking (formal) resolution: 27 μas.





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

RadioAstron + GBT

- 1.3 cm

Core size: ~24 μas;
absolute record on angular resolution