e-VLBI applications & requirements

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Joint EGEE SA2 - TERENA NRENS and Grids Workshop, 22 Sept 2009, Barcelona

What is JIVE?

JOINT INSTITUTE FOR VLBI IN EUROPE

Operate the EVN correlator and support astronomers doing VLBI.

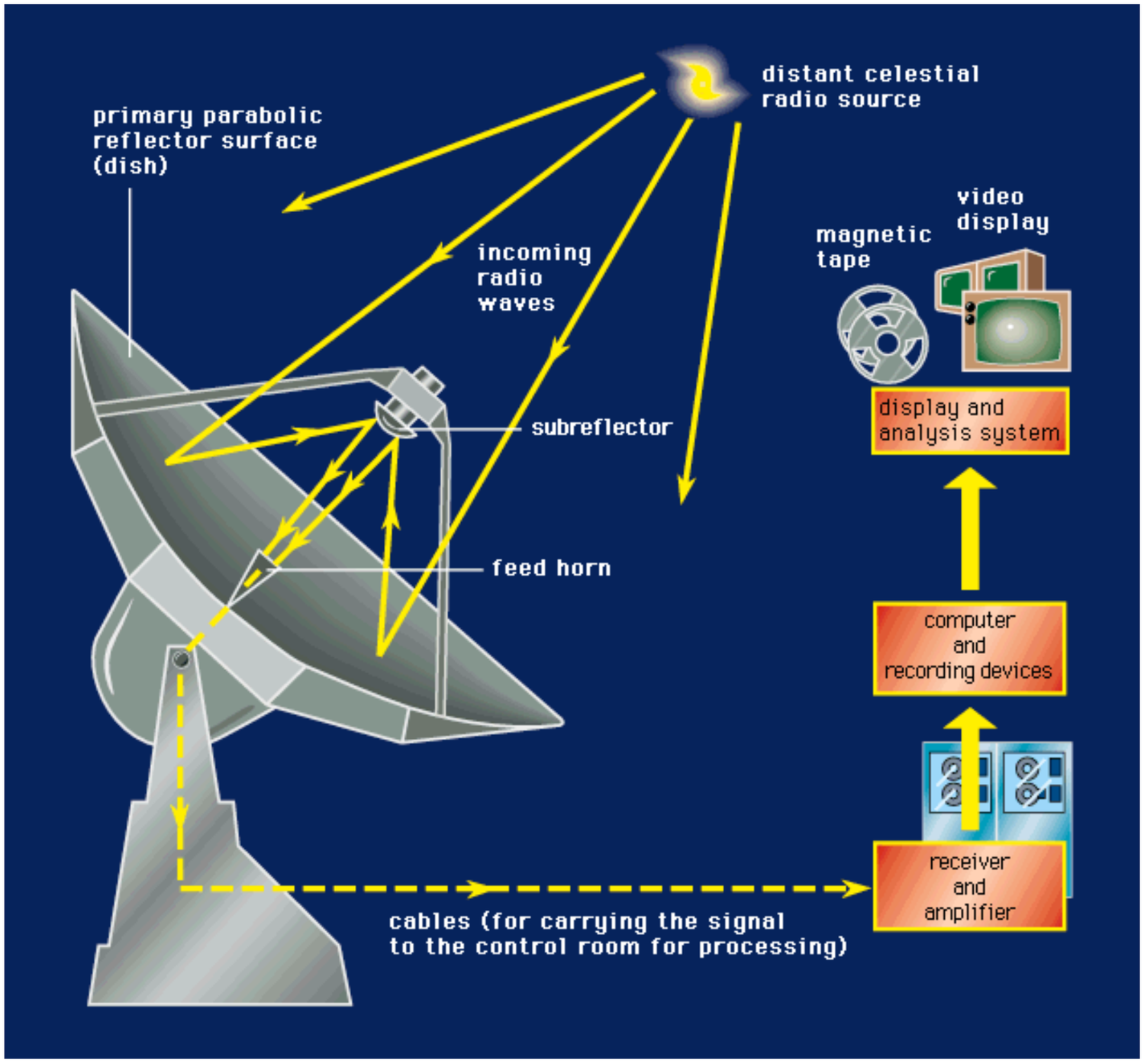
A collaboration of the major radio-astronomical research facilities in Europe, China and South Africa

EUROPEAN VLBI NETWORK

EXPReS

A 3 year program to create a distributed astronomical instrument of inter-continental dimensions using e-VLBI, connecting up to 16 radio telescopes

Radio Astronomy



Courtesy of NRAO

Radio vs. Optical astronomy

The imaging accuracy (resolution) of a telescope:

$\theta \approx 1.2\ \lambda/D$ (λ = wavelength, D = diameter)

Hubble Space Telescope:

$\lambda \approx 600$nm (visible light)

D = 2.4m

$\theta = 0.06$ arcsecond

Onsola Space Observatory:

λ = 6cm (5GHz)

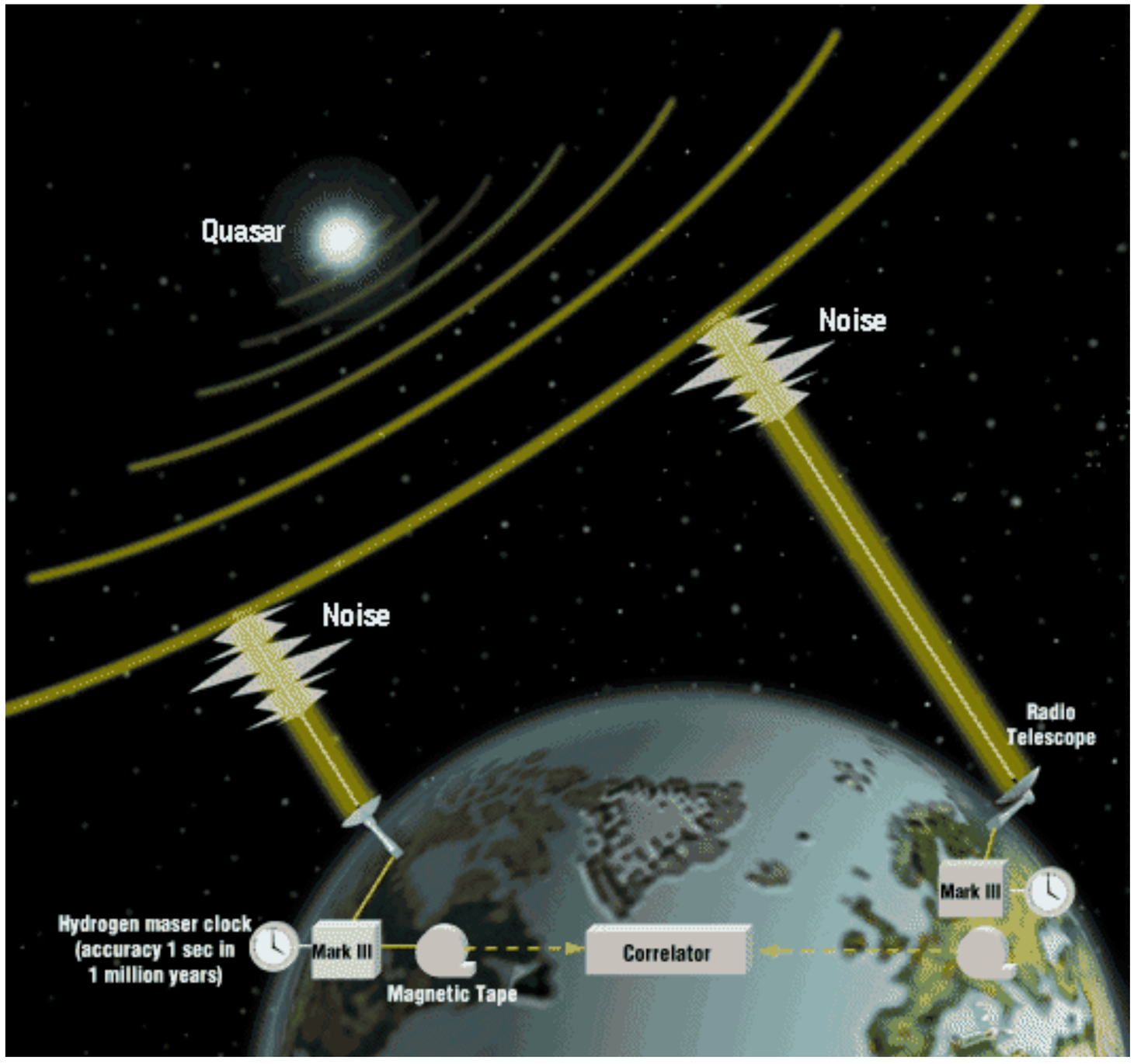
D = 25m

$\theta = 600$ arcseconds

Wanted: 240km dish

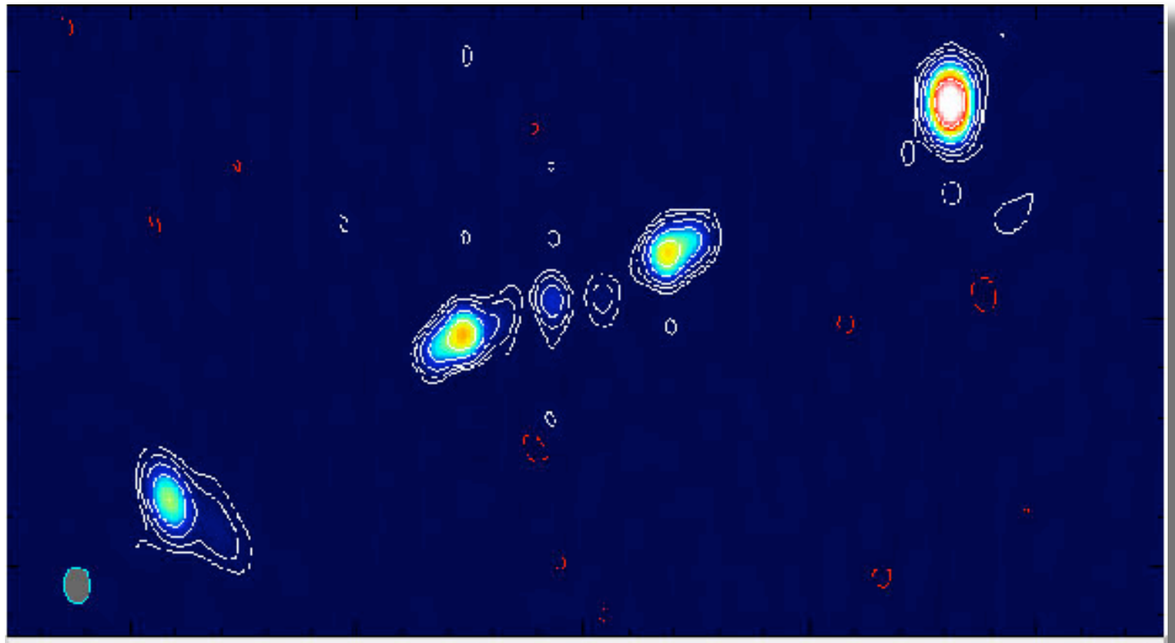
Very Long Baseline Interferometry

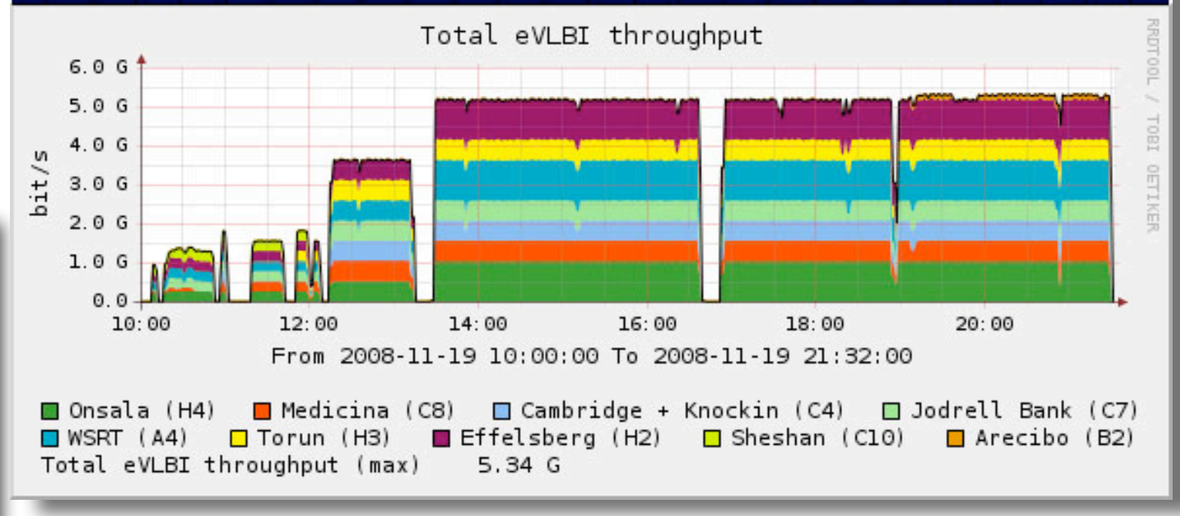
- Create a huge radio telescope by using telescopes in different locations around the world at the same time

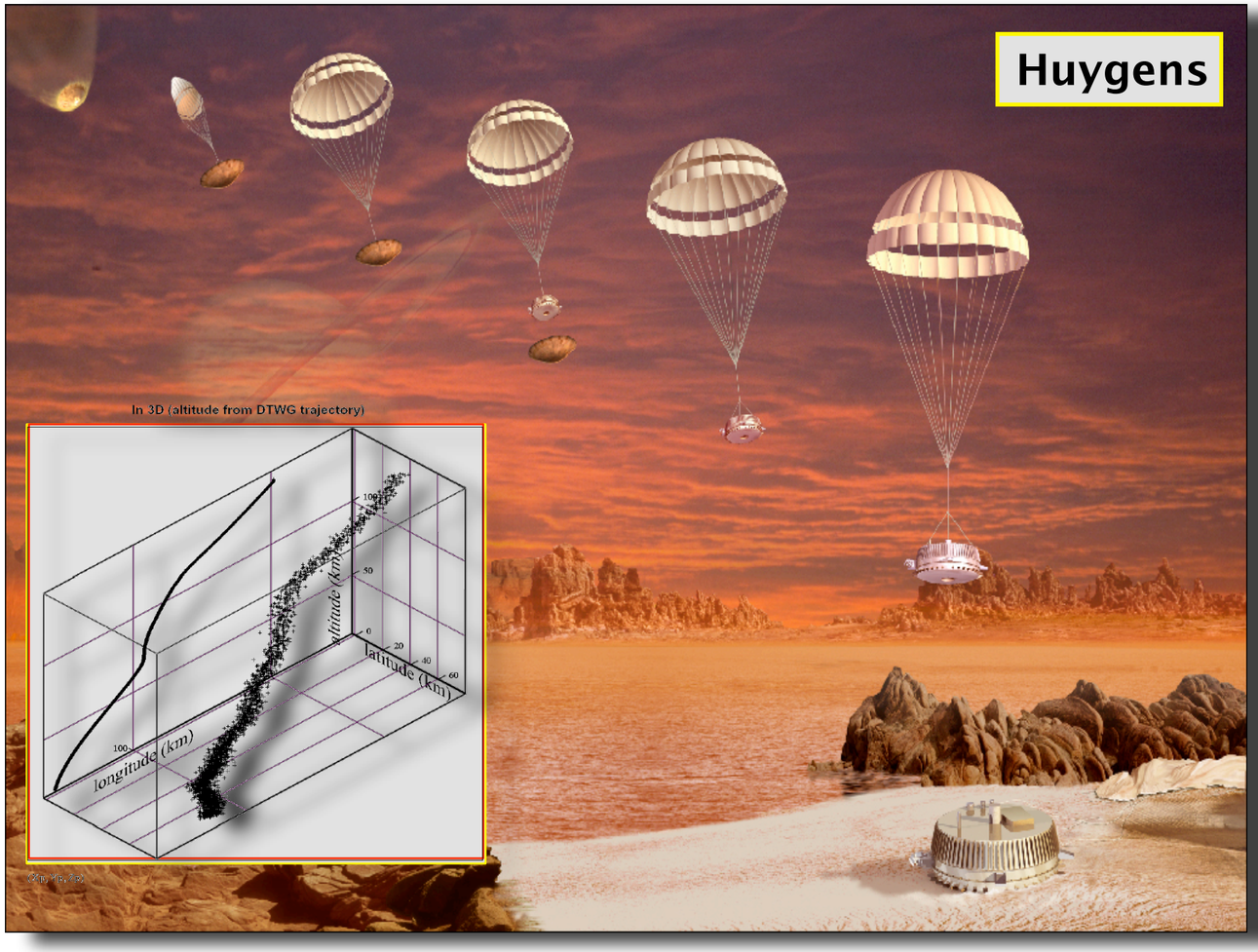


Very Long Baseline Interferometry

- Highest angular resolution
- High sensitivity
- Observations typ. 12 hours
- Large data volume





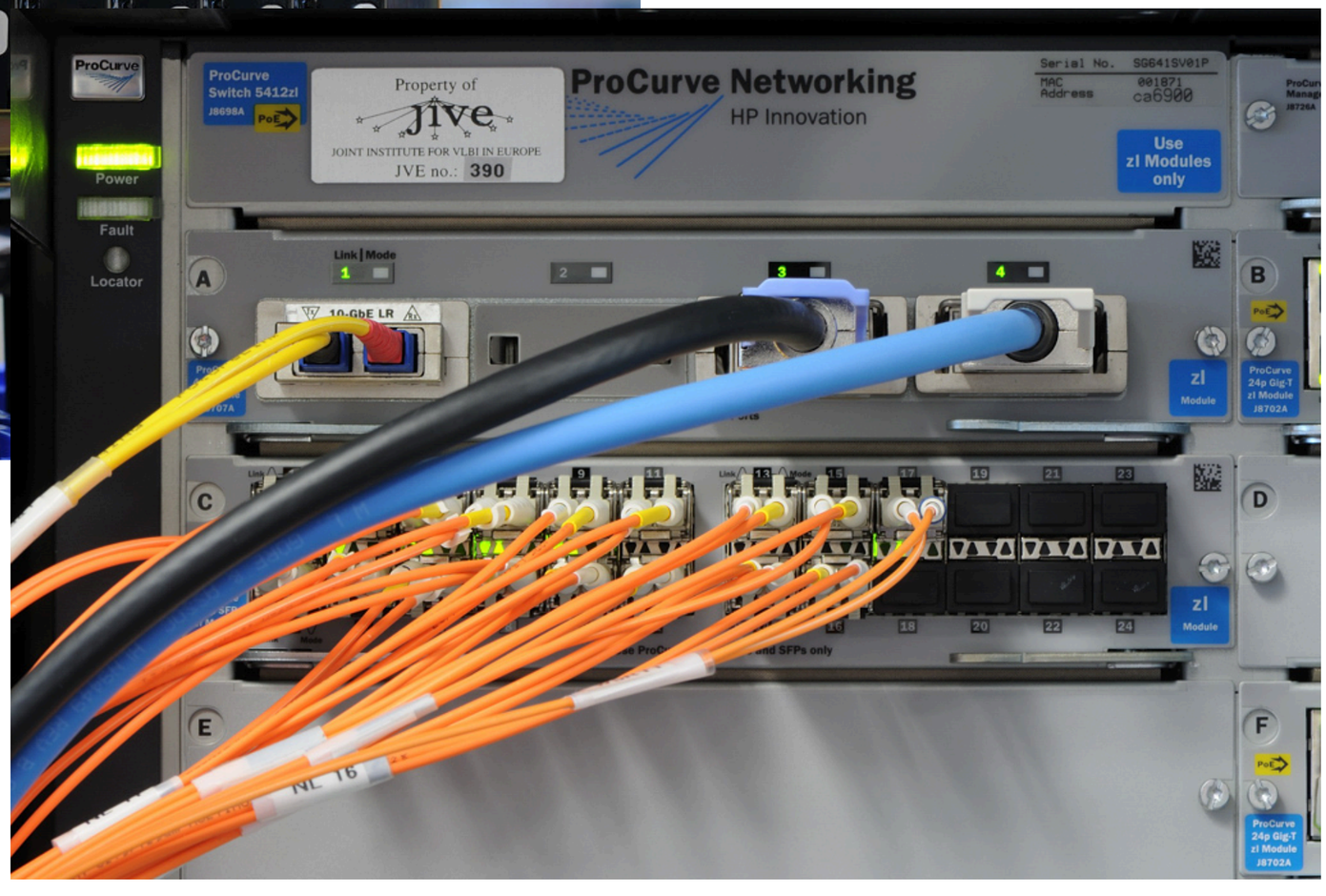


- Active Galactic Nucleae
- Supernovae, remnants, pulsars
- Spacecraft
- And much more

Very Long Baseline Interferometry

- Initially (1990) we used large single-reel tapes

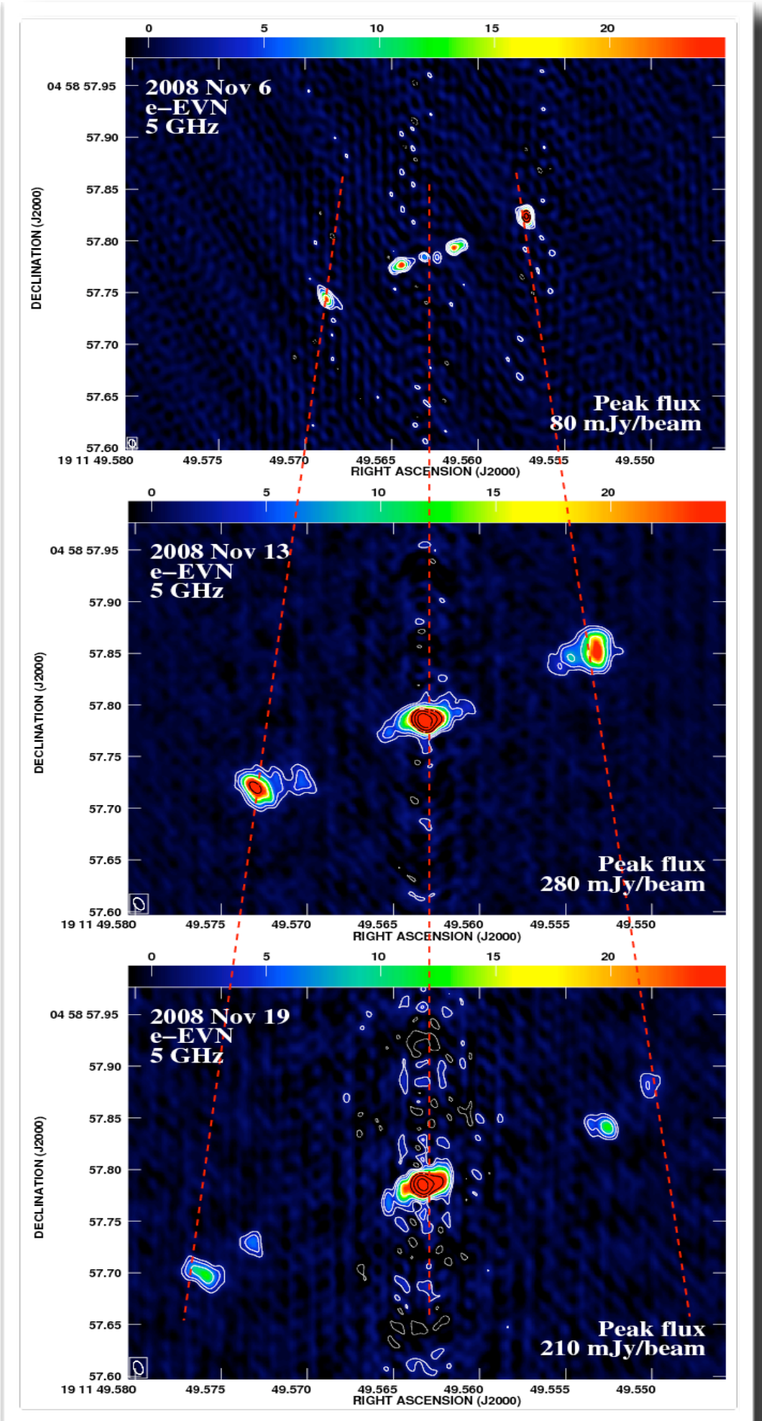
- Then (2004) came harddisk-packs



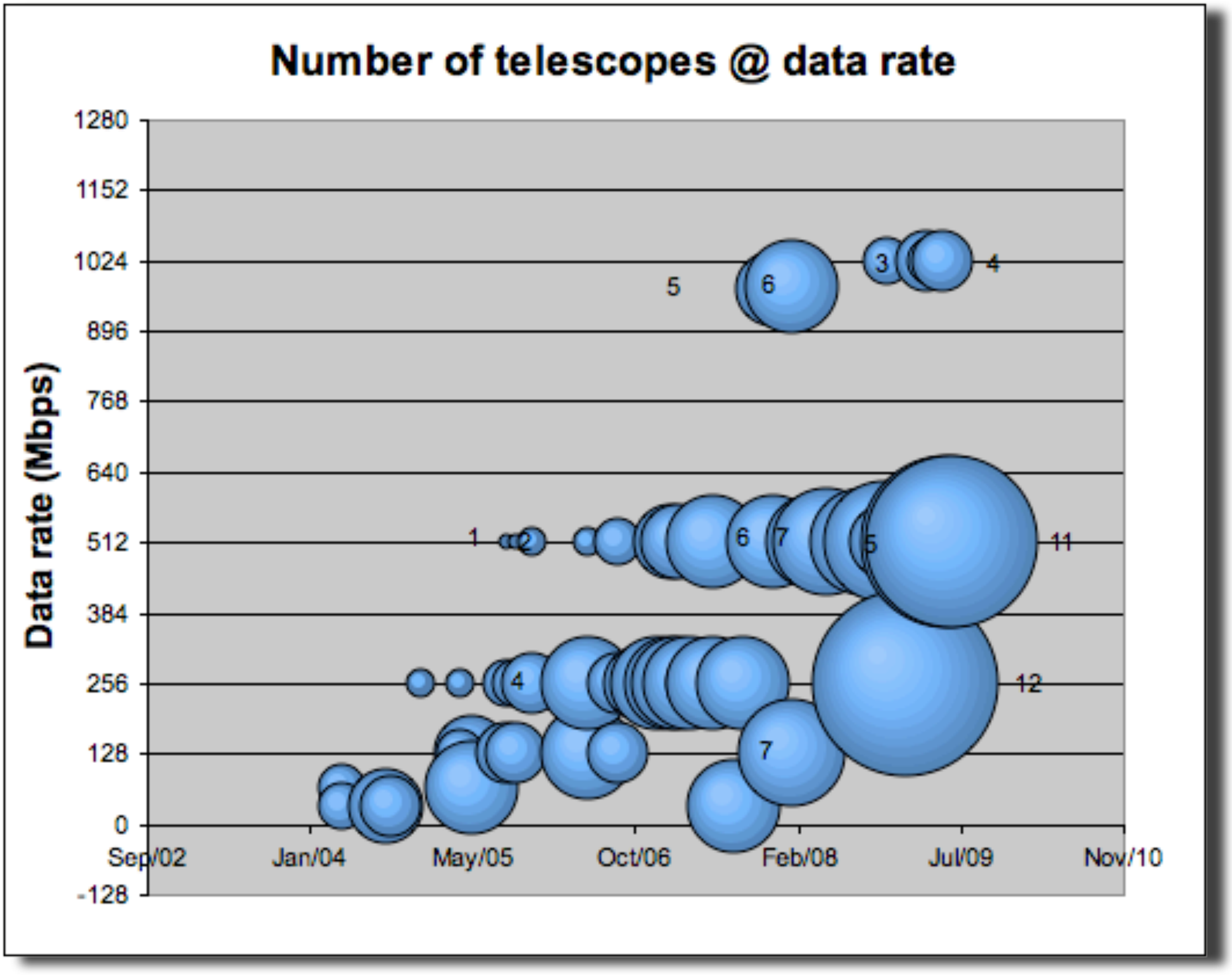
- And now: e-VLBI

The EXPReS project

- EXPReS ran from March 2006 to September 2009
- Fundec by the EC
- Established competitive, real-time VLBI
- Regularly connecting > 10 telescopes
- Global collaboration and reach
- Target-of-Opportunity observations
- Robust
- Producing new science



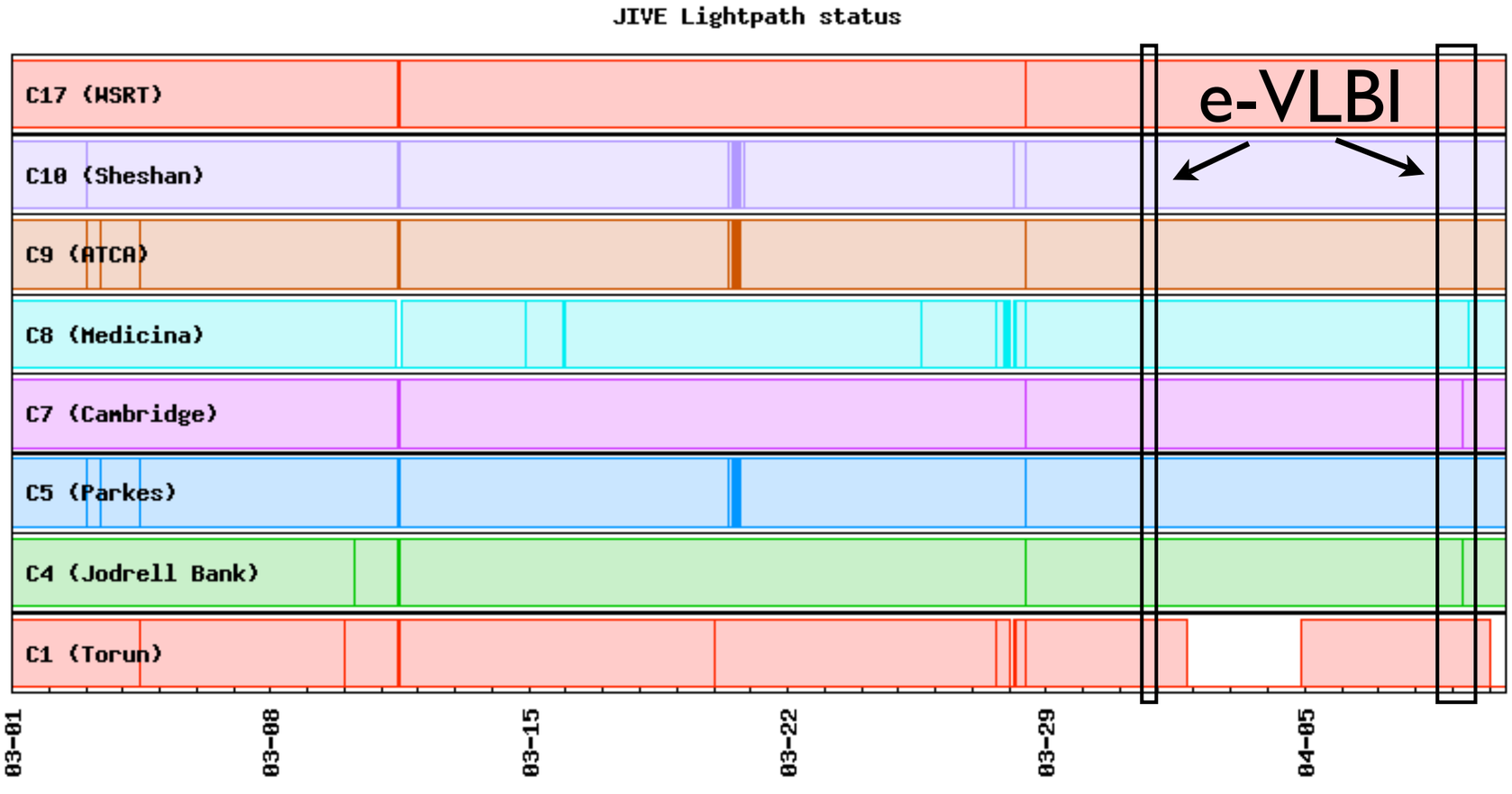
The EXPReS project



Size of bubble set by number of telescopes participating, height by station sustained bit-rate

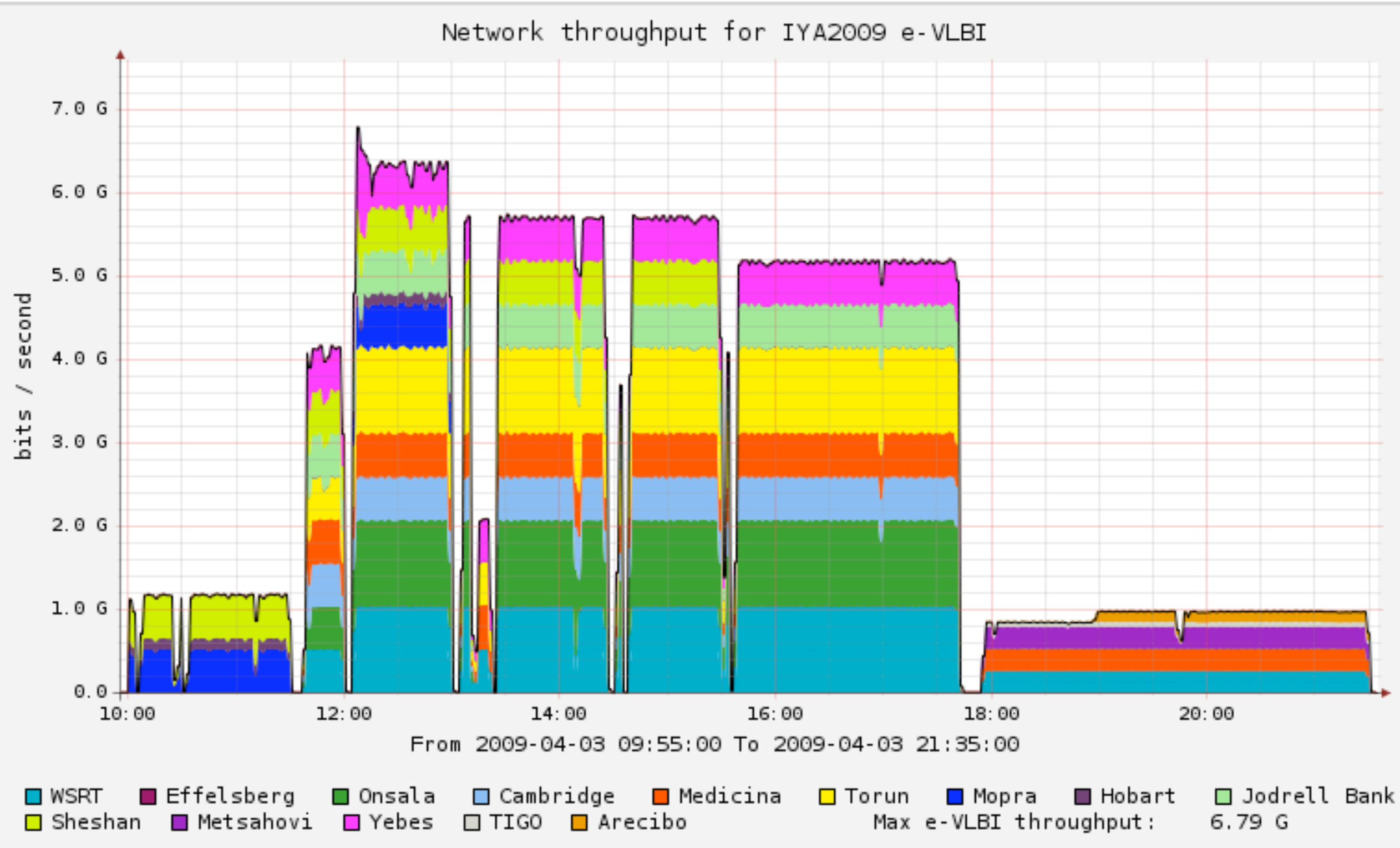
Lessons from EXPReS

- TCP does not perform well on long paths at high speed
- UDP requires overprovisioned or dedicated networks
  - Routed (research) networks, VLANs, Lightpaths
- Paths without redundancy have unscheduled outages

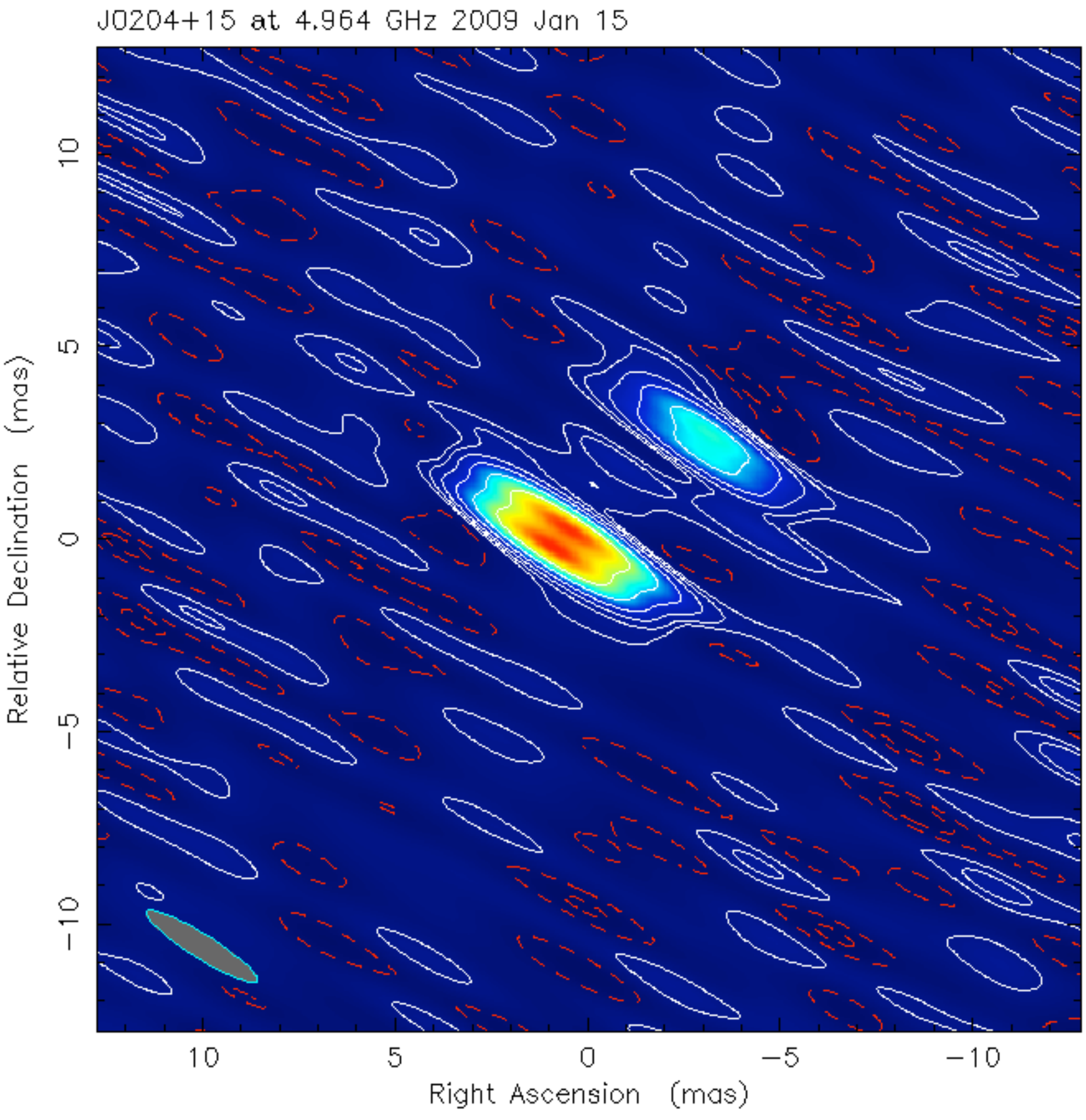


- Especially the long-haul paths
- e-VLBI is robust and efficient

International Year of Astronomy



Observation of J0204+15 (IYA)



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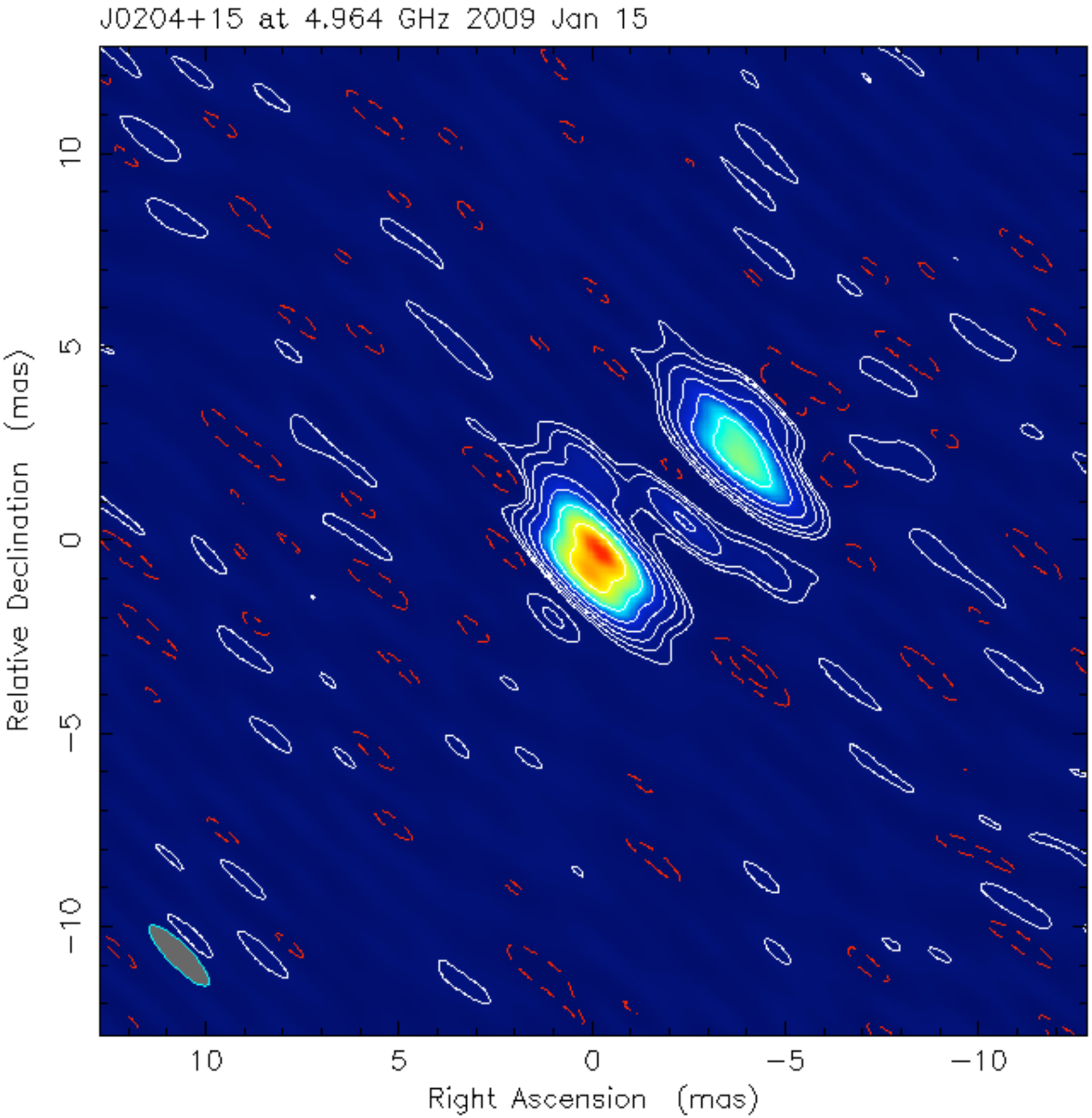

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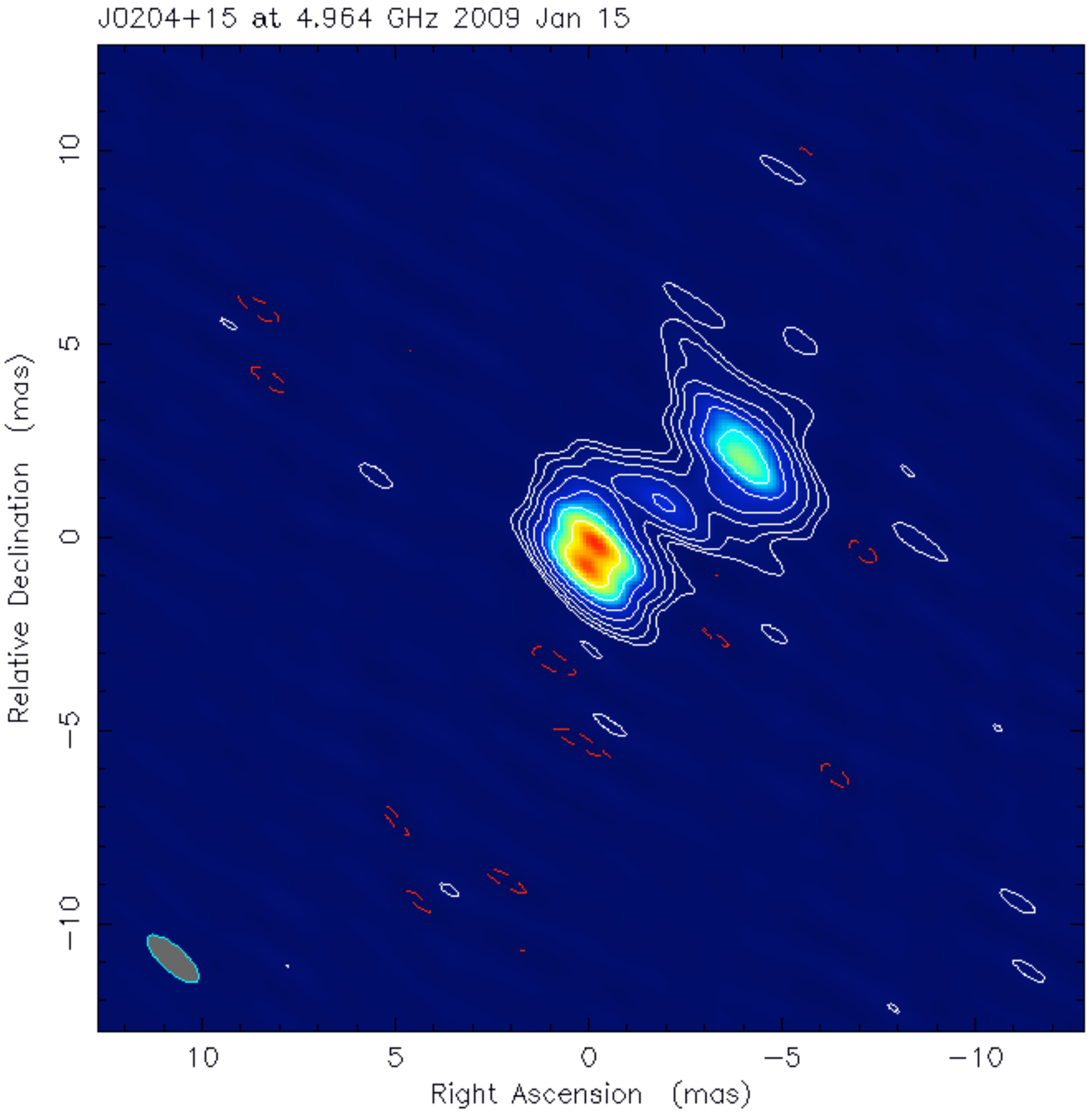
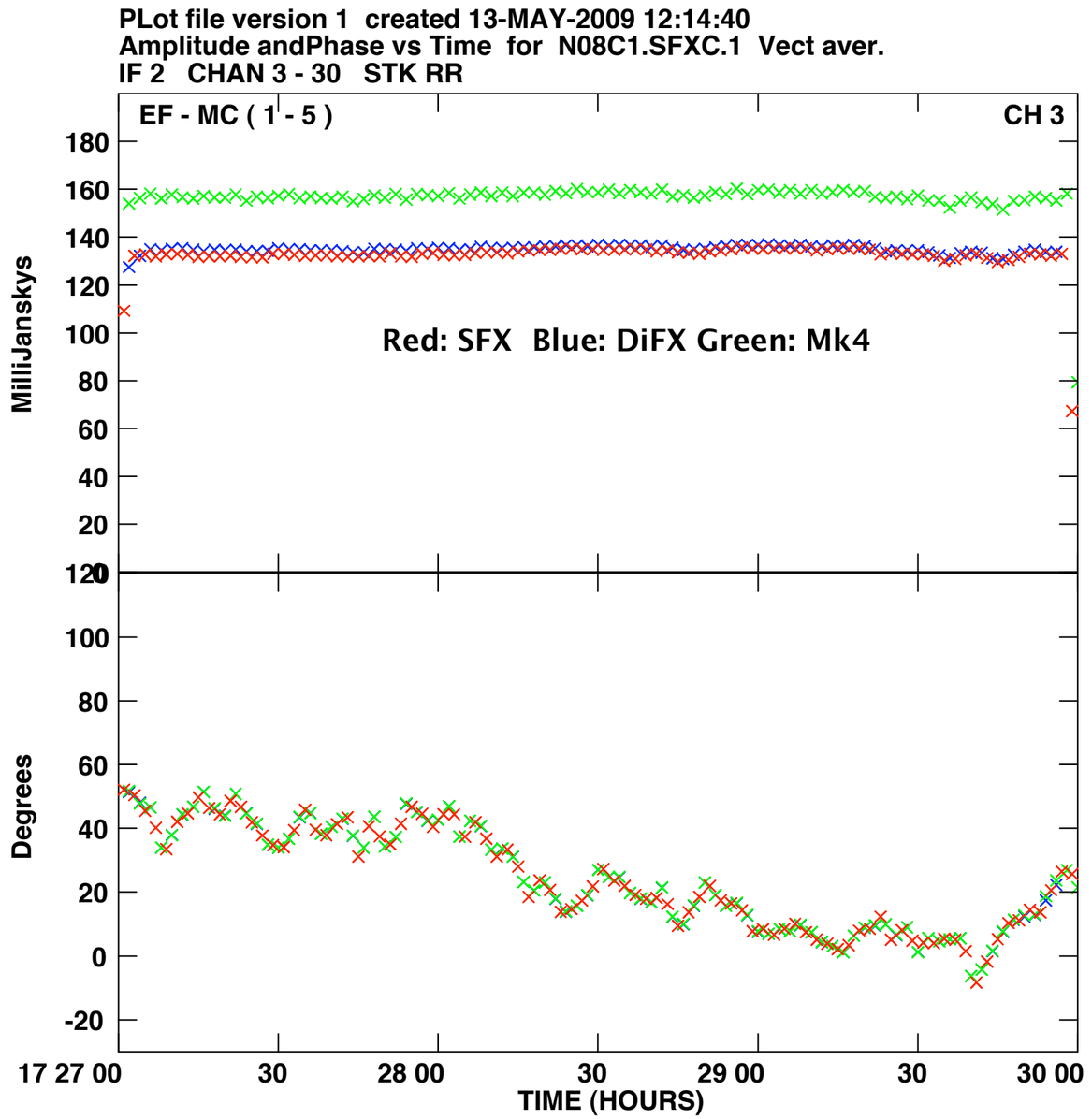
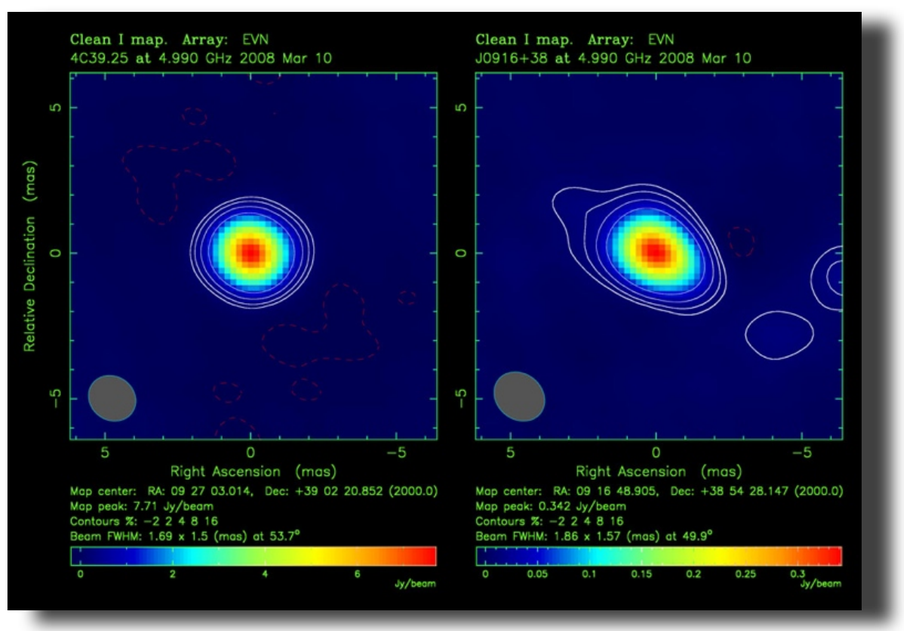


VLBI and Grids

- EVN correlator is hardware based
- We have also developed a software correlator:
  - Higher flexibility, frequency resolution
  - Huge computational demand
- Correlation is fairly easy to parallelise
- Low number of operations per byte, but high input data rate
- Regular ‘batch’-like Grid processing (GridFTP etc.) not a good match
- Need clusters with high input connectivity
- Researching distributed correlation





VLBI paramater space

- Resolution: depends on longest baseline, and observing frequency
- Sensitivity: depends on $\sqrt{\text{Bandwidth}}$, number and size of radio telescopes
- Current EVN correlator limitations: 16 stations @ 1024Mb/s each

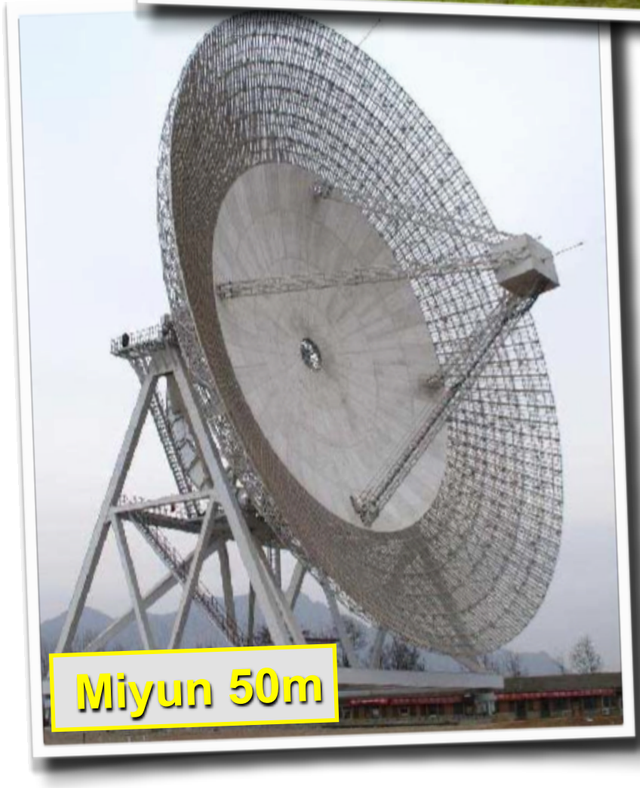
Technological advances in e.g. A/D converters, RF technology, digital signal processing, networking and HPC can now enable much increased sensitivity

The Uniboard project

- Collaboration of European & Korean Astronomical Institutes
- Reconfigurable FPGA-based platform for astronomical signal processing
- Digital back-end, pulsar timing, RFI mitigation, beam-forming, correlation
- Standardized on Ethernet 10Gb/s connections
- First hardware in December

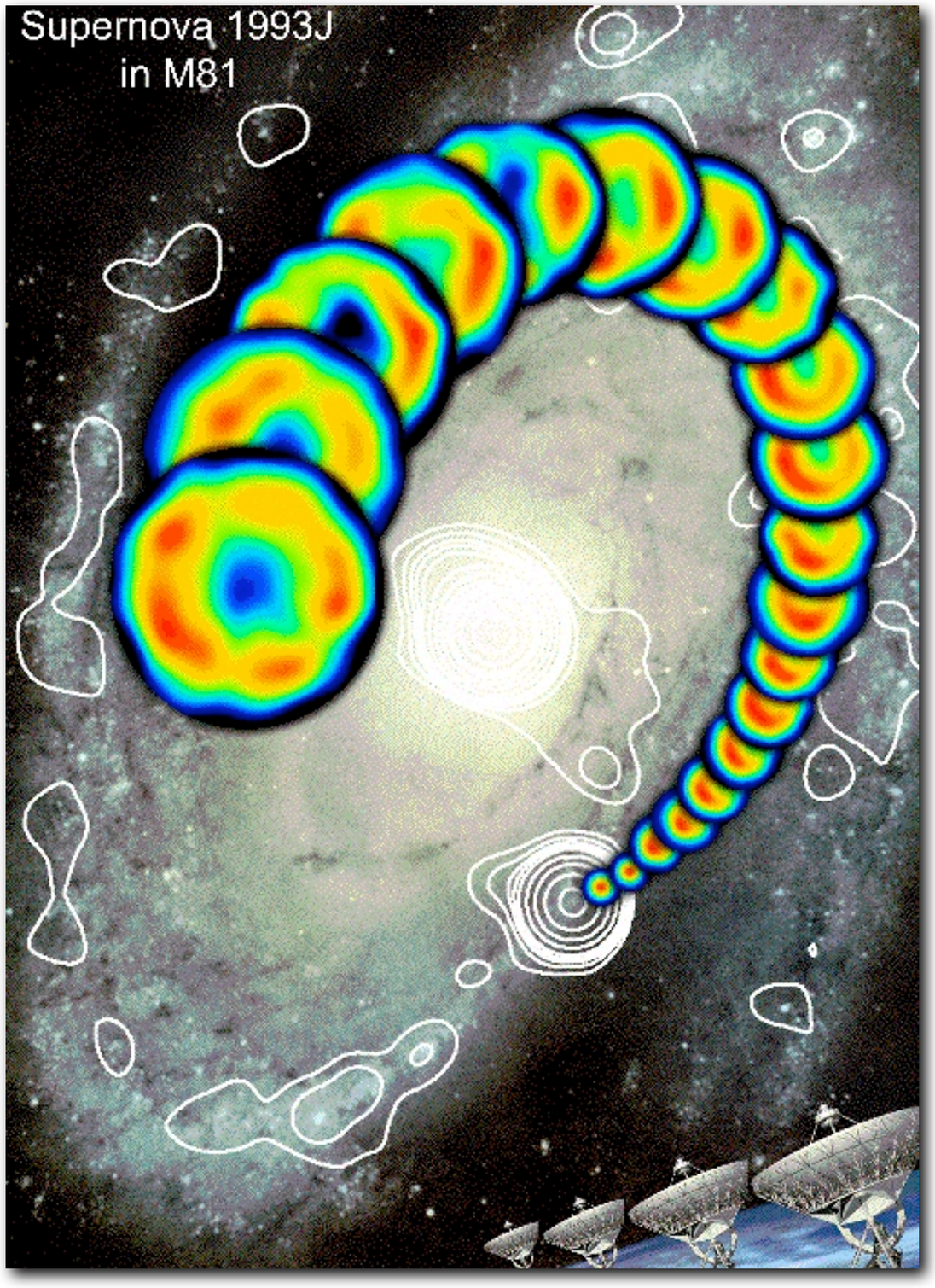
UNIBOARD
Size: 9HE (366,7)x 280 x 2.4mm

New telescopes



The future of VLBI

- All VLBI can be e-VLBI !
- Caching when neccesary (outages, lack of bandwidth)
- Real-time correlation is a great diagnostic tool
- Much higher bandwidths per telescope
    - 4 Gb/s soon, 10 Gb/s, how about 64Gb/s ?
- More telescopes, global array
- New correlators (hardware, software)



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Questions?