



the Future of VLBI

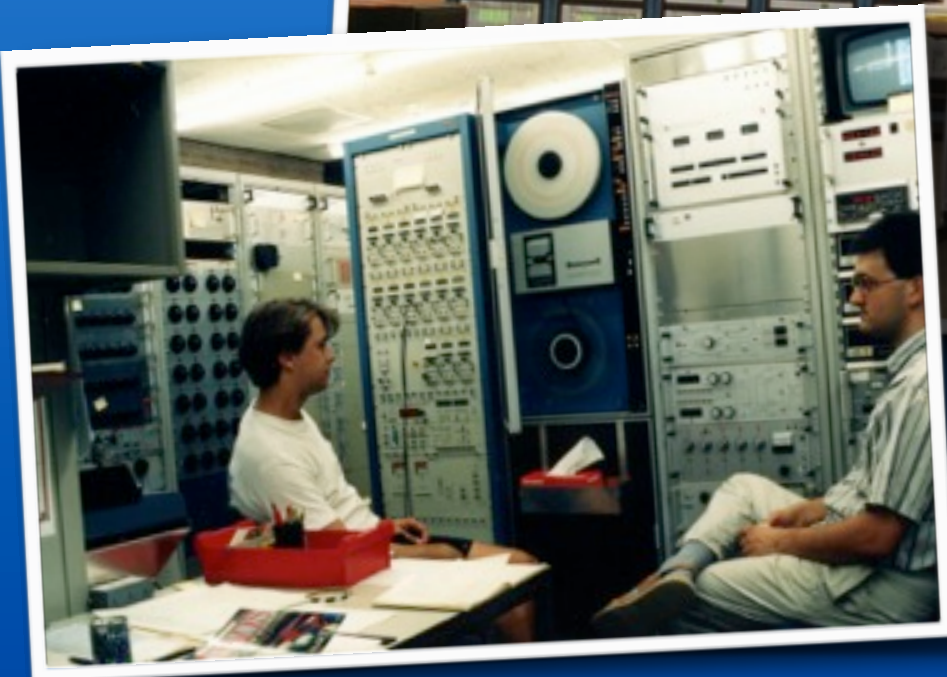
Huib van Langevelde
JIVE



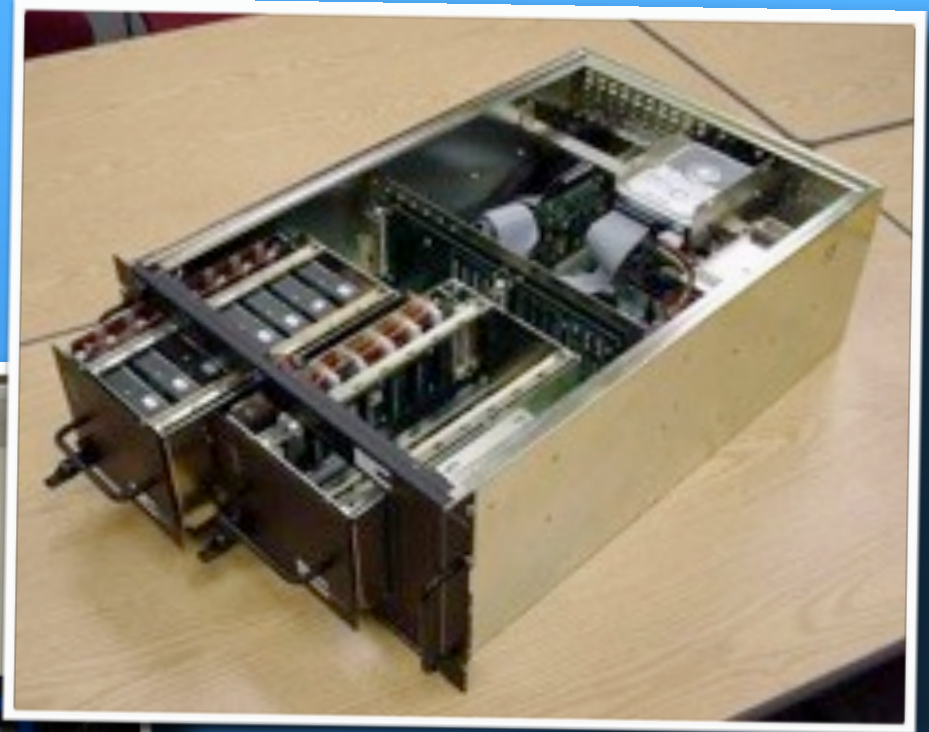
the Future of VLBI

Today, entirely from the EVN/JIVE perspective

Huib van Langevelde
JIVE



- **Went to disk in 21st century**
 - Enormous boost in robustness
 - Correlator efficiency



- **Promote the use and advance of VLBI for astronomy**
 - Central correlation; User services; Network support; Innovation; EC liaison/representation
- **Founded in 1993**
 - Base budget from partners in 7 countries:
 - China, France, Germany, Italy, Spain, Sweden, United Kingdom, Netherlands
 - Large number of external projects
 - Hosted by ASTRON
- **Just been reviewed**
 - Next 5-year funding cycle
 - In a newly build wing



The European VLBI Network

- Big telescopes in number of European countries
- 20+ possible antennas
 - Ef, Mc, On, Jb, Nt, Tr, Wb, Sh, Ur, Hh, Ar, Mh, Ys, Sv, Ro, Ku, My, Wz, Sm, Ny, Ka
 - Ran by up to 14 different organizations
 - And 12 more antennas for “Globals” with NRAO
- Covering range of frequencies
 - Workhorse frequencies 18cm, 6cm,
 - Also available: SX, 5cm, 1.2cm
 - And at limited stations 90cm, 21cm, UHF, 50cm, 2cm, 0.7mm
- Reaching mas resolutions
 - From 15mas for 1.4 GHz EVN (can add MERLIN for brightness sensitivity)
 - To 1 mas at 5GHz with Asian, African or American baselines
- Sensitivity of $5\mu\text{Jy}$ in 8hr at 1.4 GHz
 - Combination of Big Antennas and 1 Gbps bandwidth
 - Big antennas also vital for spectroscopy (mJy sensitivity)
- Operational approximately 60 days/year
 - 3 sessions augmented with e-VLBI once a month





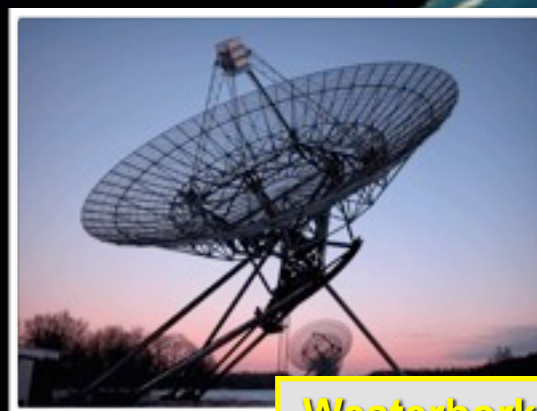
Jodrell Bank UK



Onsala SE



Metsahovi FI



Westerbork NL



Effelsberg DE



Torun PL



Medicina IT



Yebes ES



Noto IT

Arecibo

Engel

ala

bork

rbane

Svetloe

Torun

Wettzell

Evpatoria

Zelenchuk



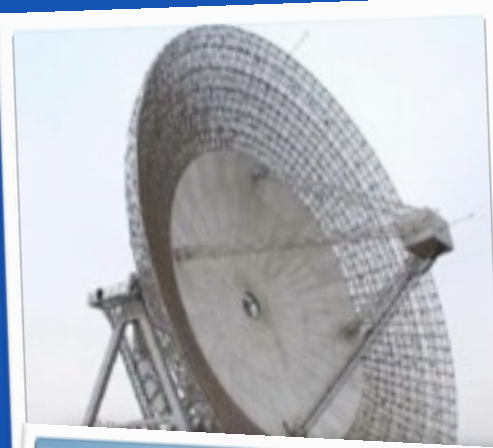
Irbene LV



3 telescopes in Russia



Sardinia 64m



Arecibo, Puerto Rico



Harte

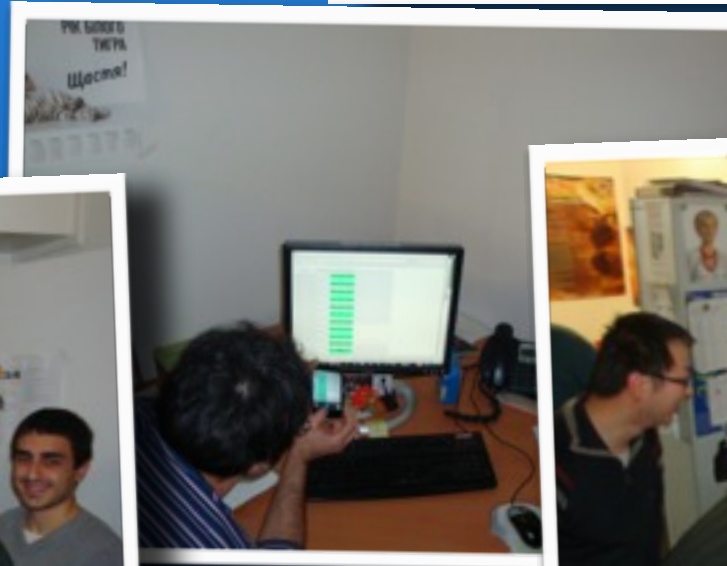
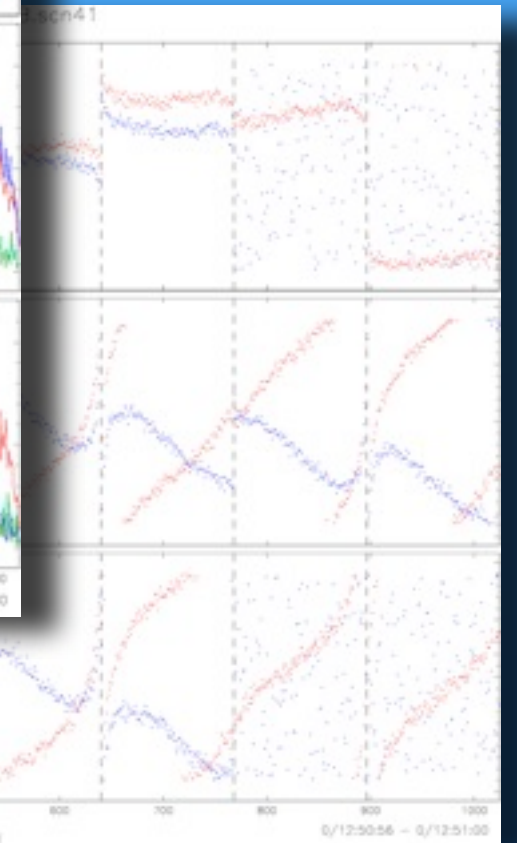
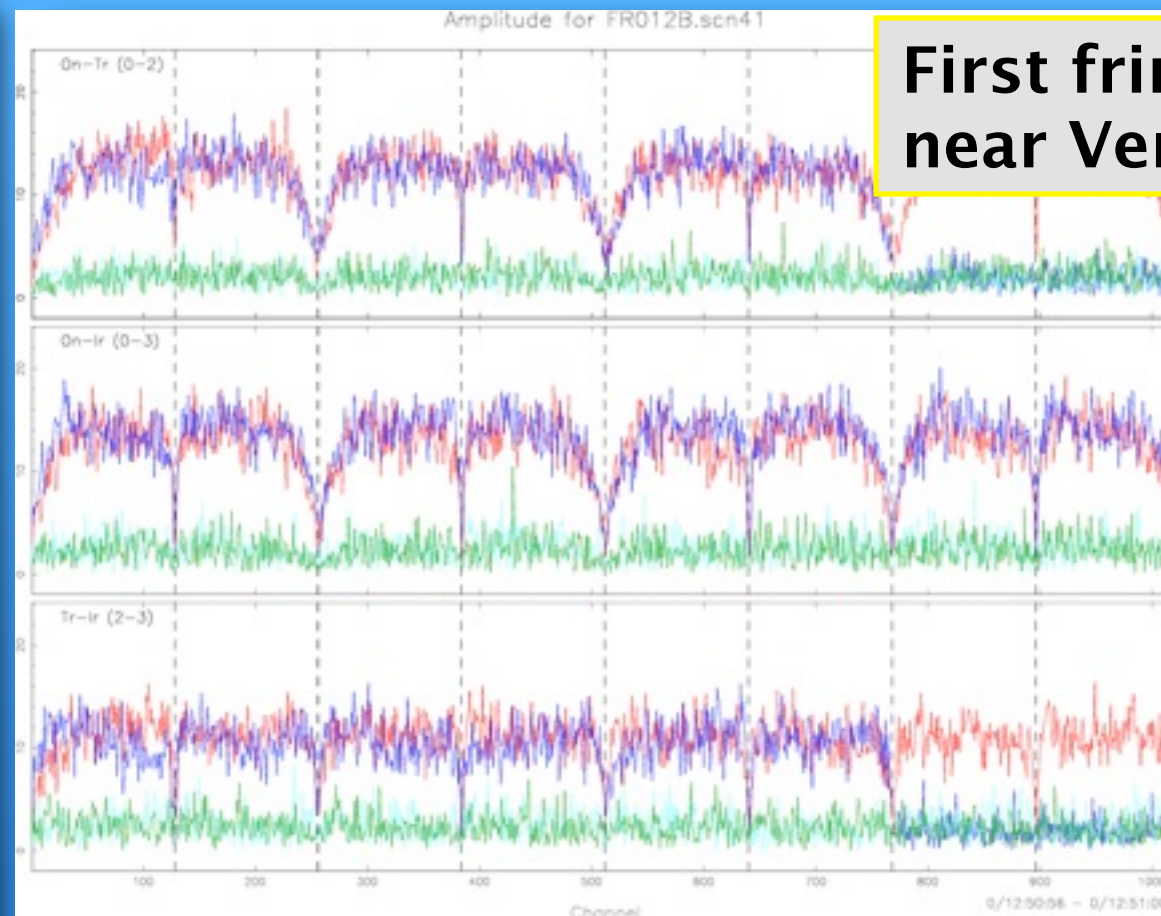


4 telescopes in China

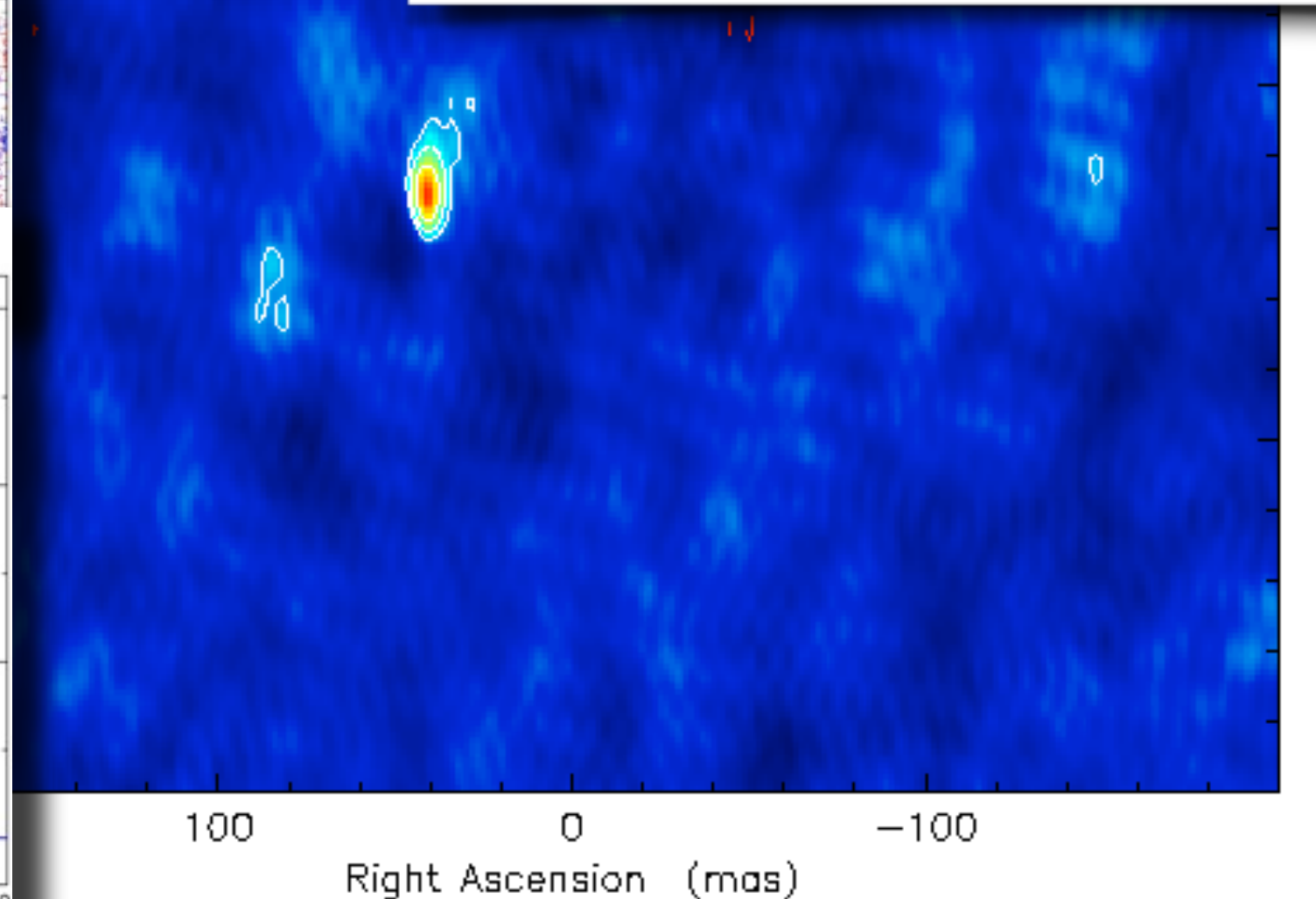
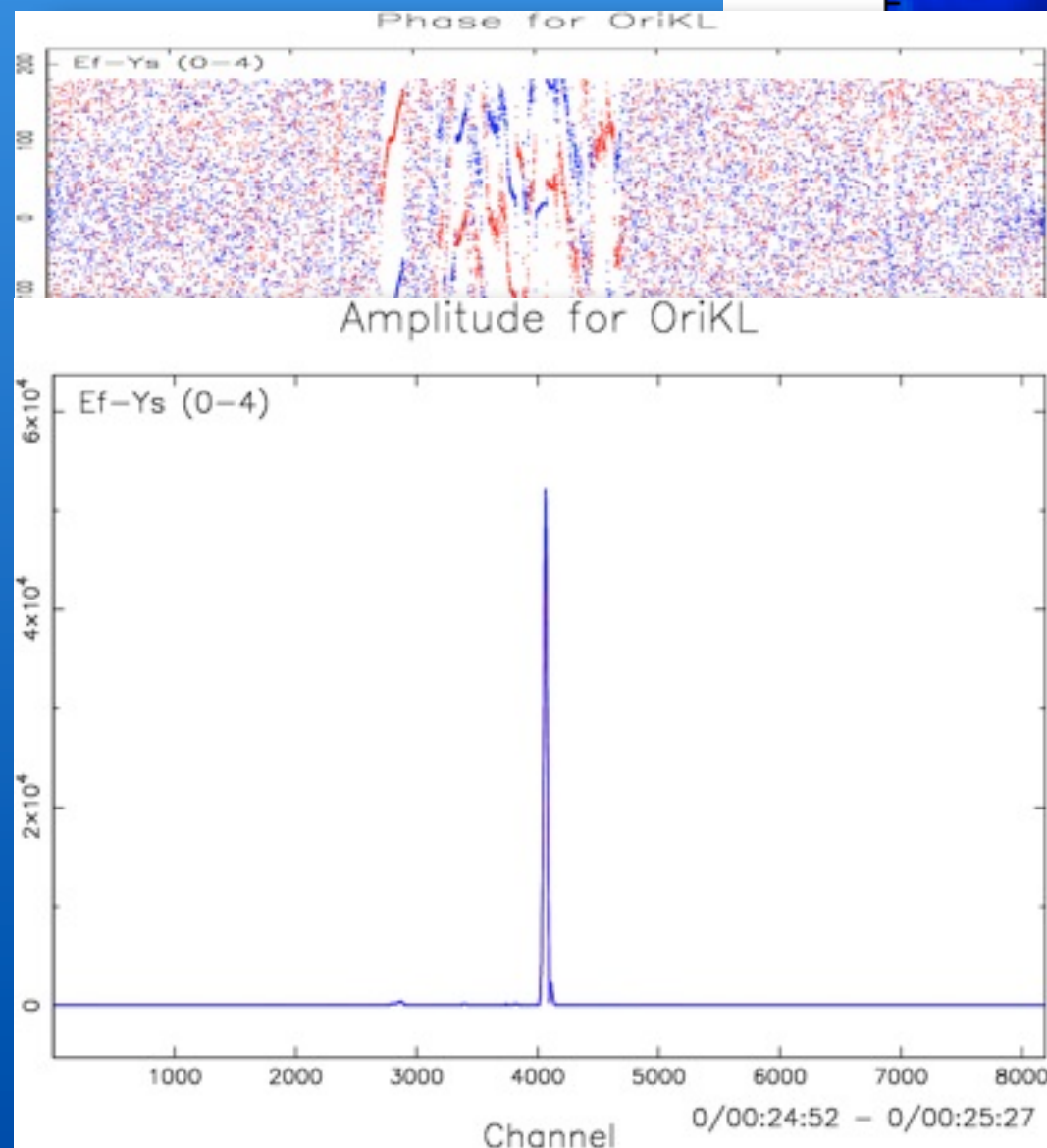




**First fringes to Irbene,
near Ventspils, Latvia**



- The EVN software correlator at JIVE (SFXC)
- 9 stations 1Gbps real-time
 - Pulsar gating
 - Space craft applications
 - Spectral polarimetry
 - Many field of views



R+D: Introduced e-VLBI as operational facility:

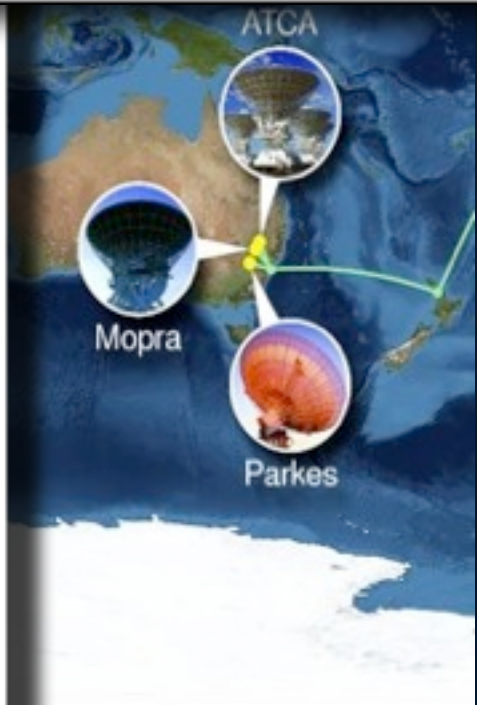
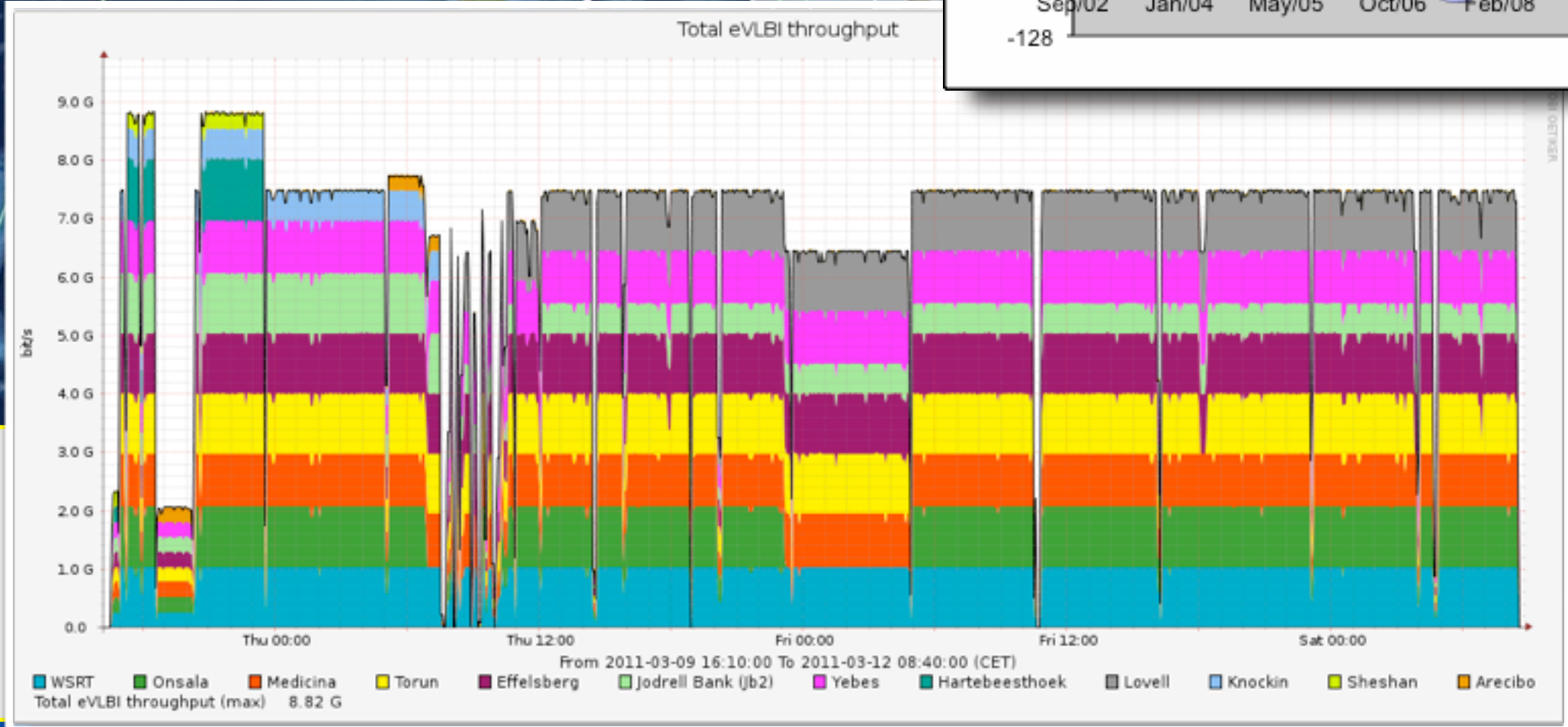
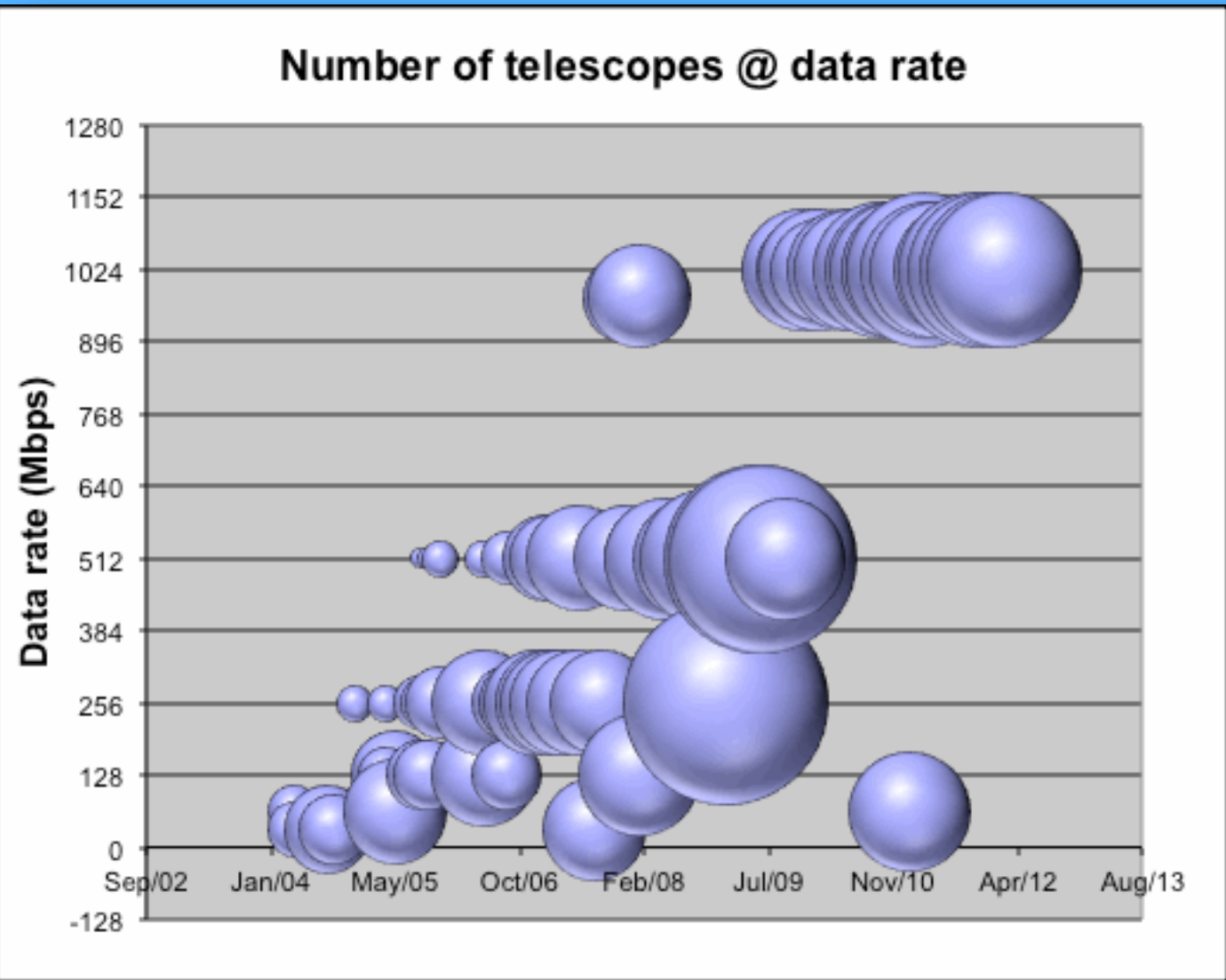
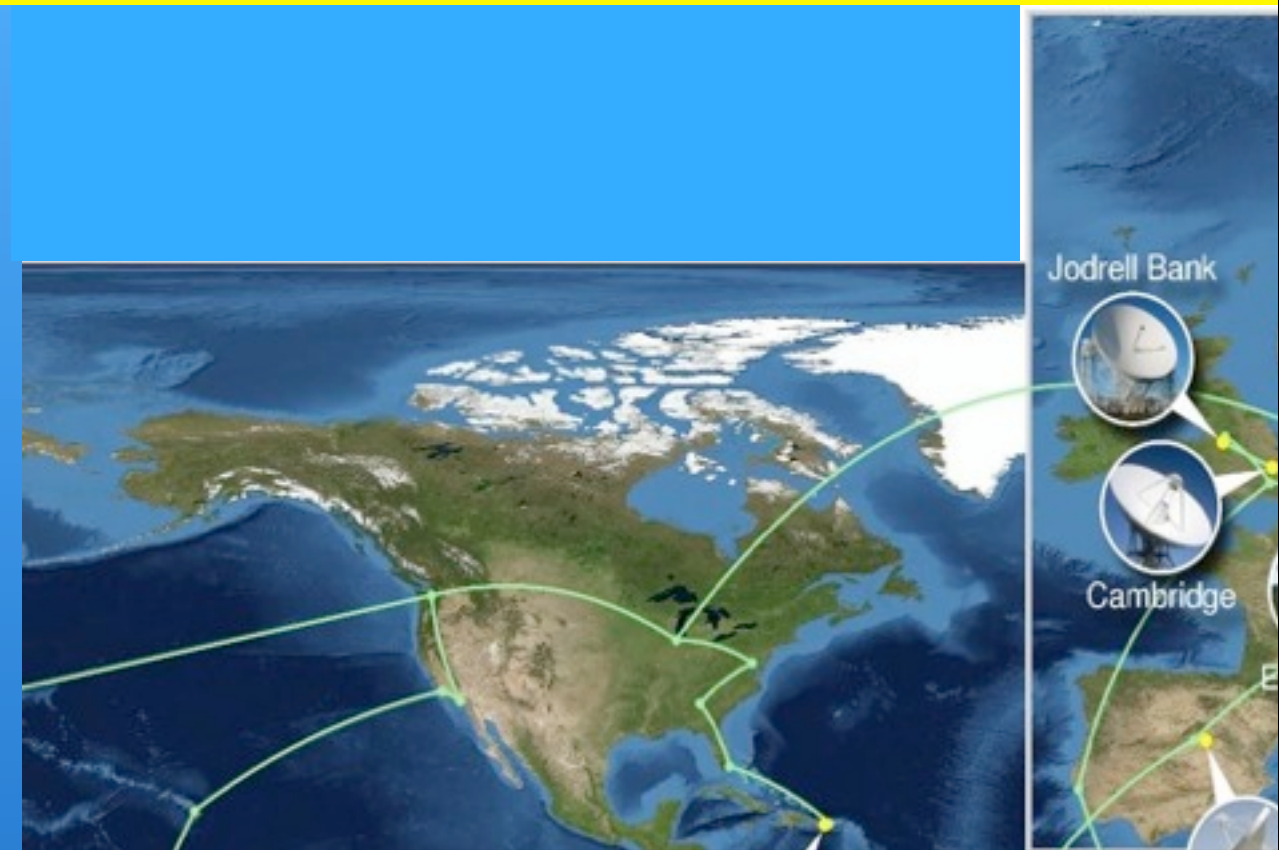


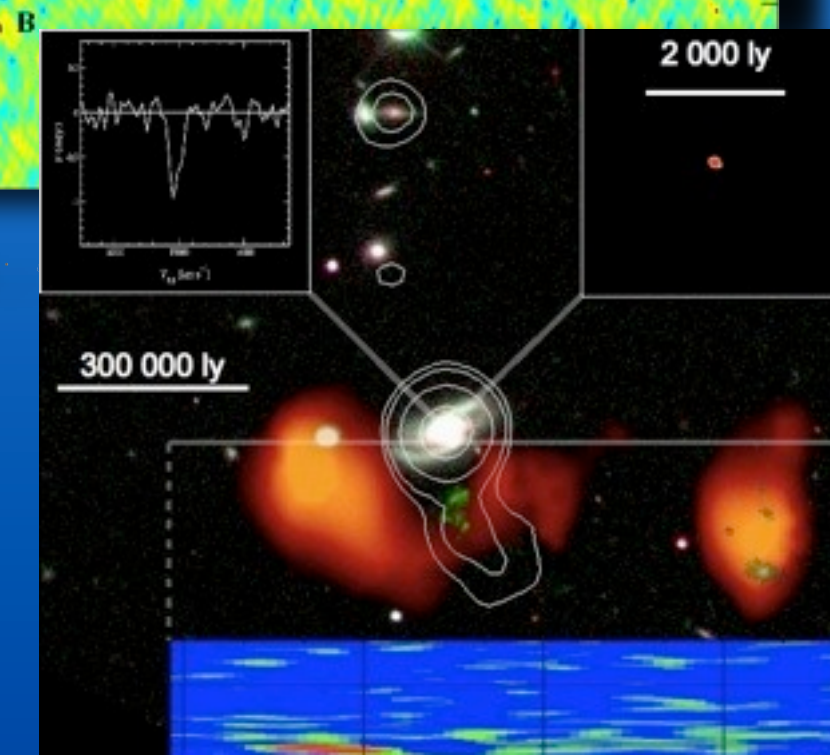
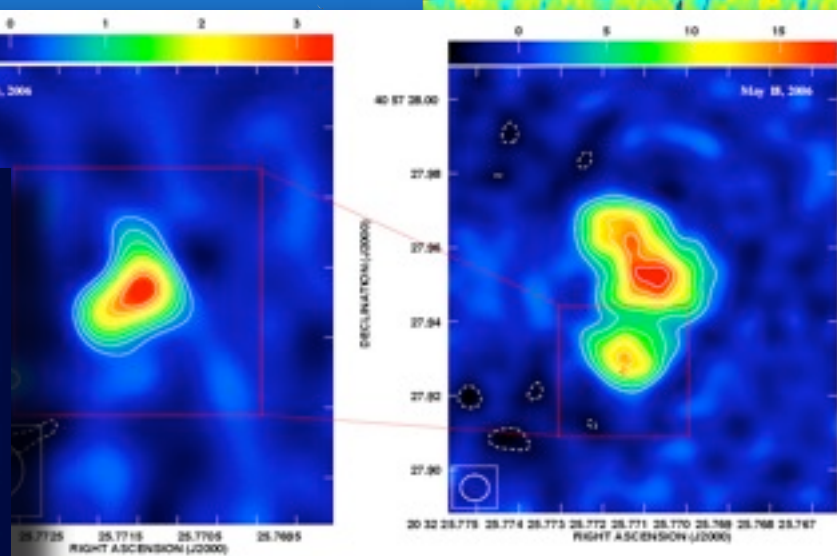
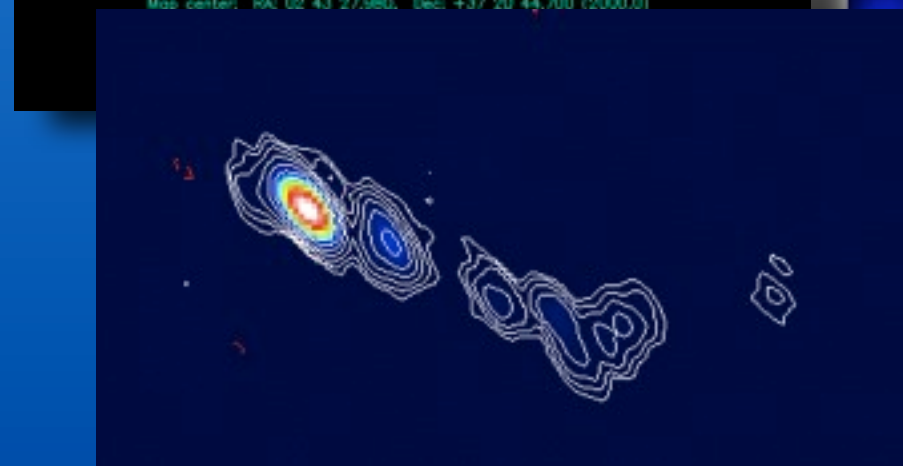
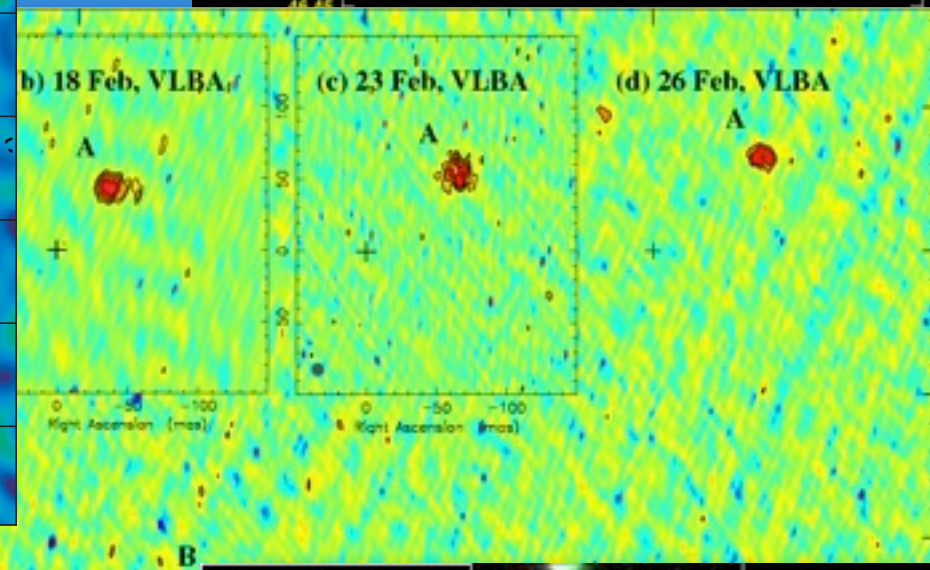
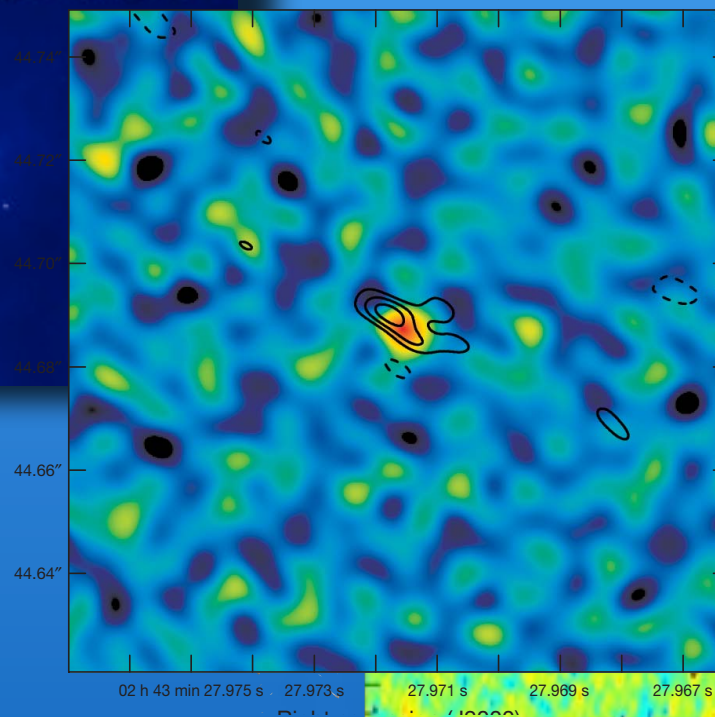
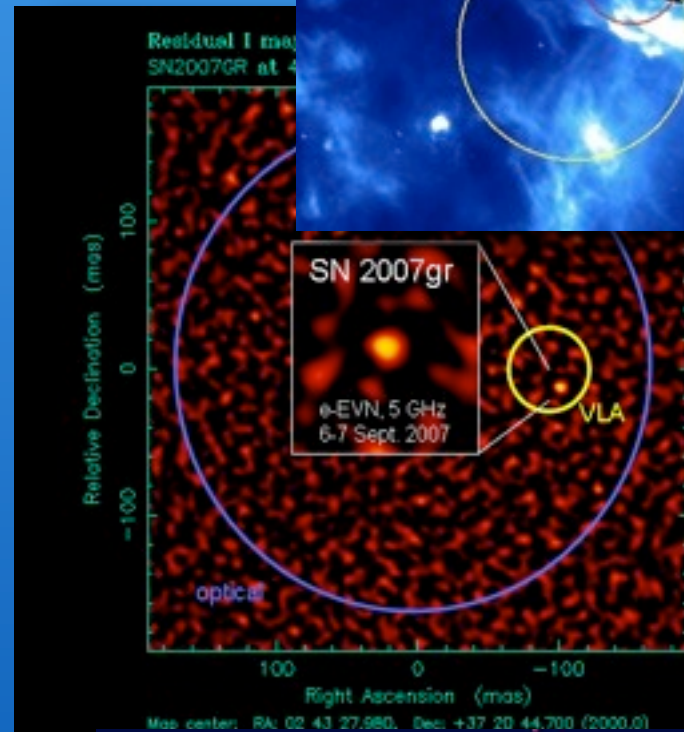
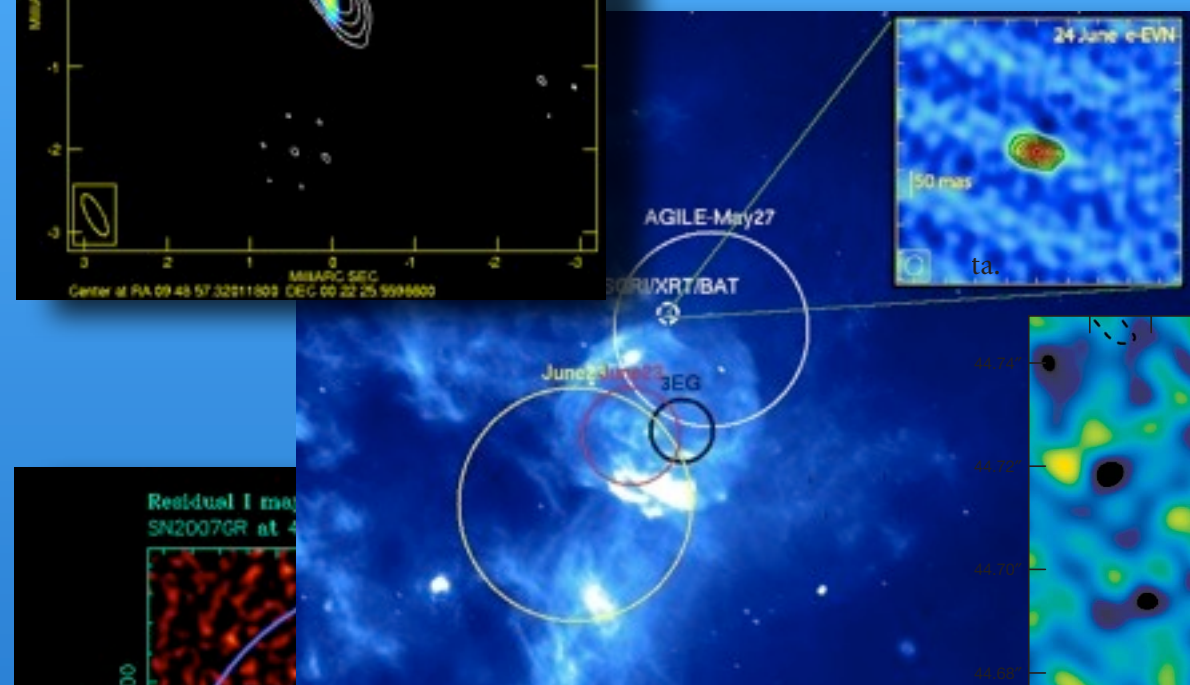
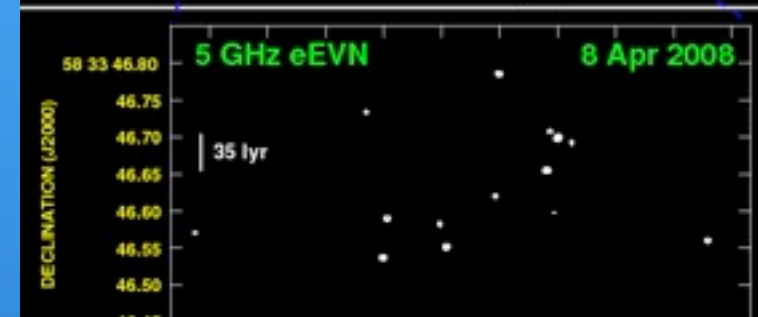
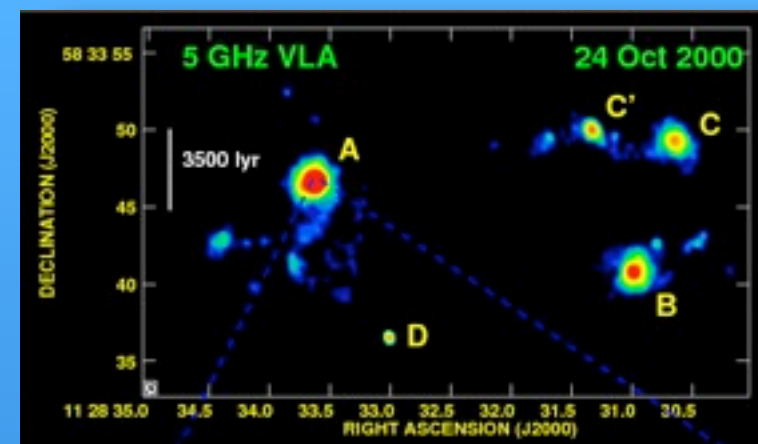
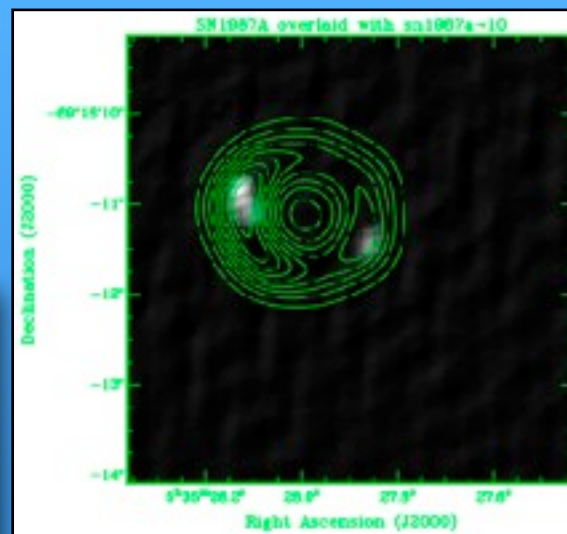
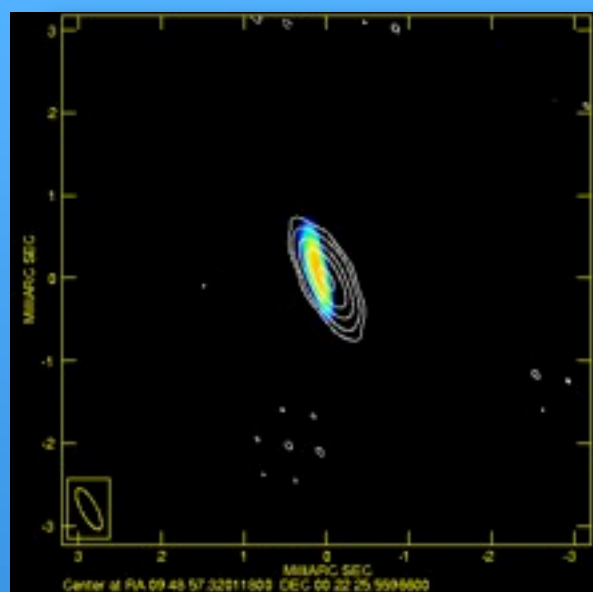
- **Connections work great!**
 - often dedicated light paths
 - Use optimized protocols
- **Closed feedback loop makes e-VLBI more robust**

R+D: Introduced e-VLBI as operational facility:



R+D: Introduced e-VLBI as opera

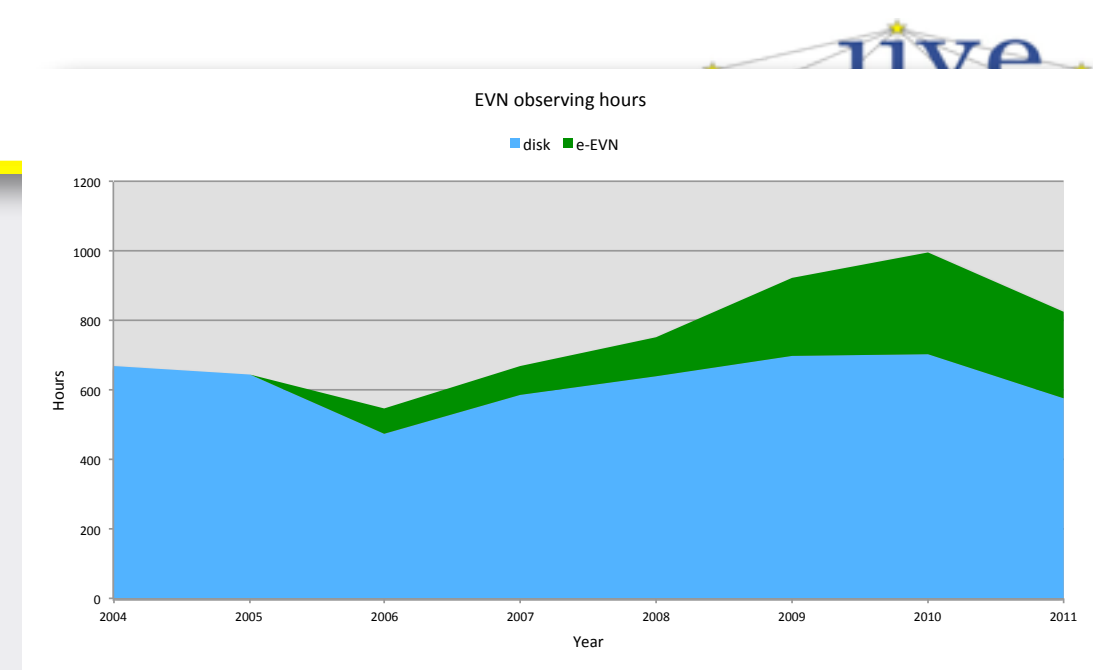




Observations

- **Now an operational facility**

- **Guaranteed 10 x 24h per year**
 - And quite bit more in practice (>30%)

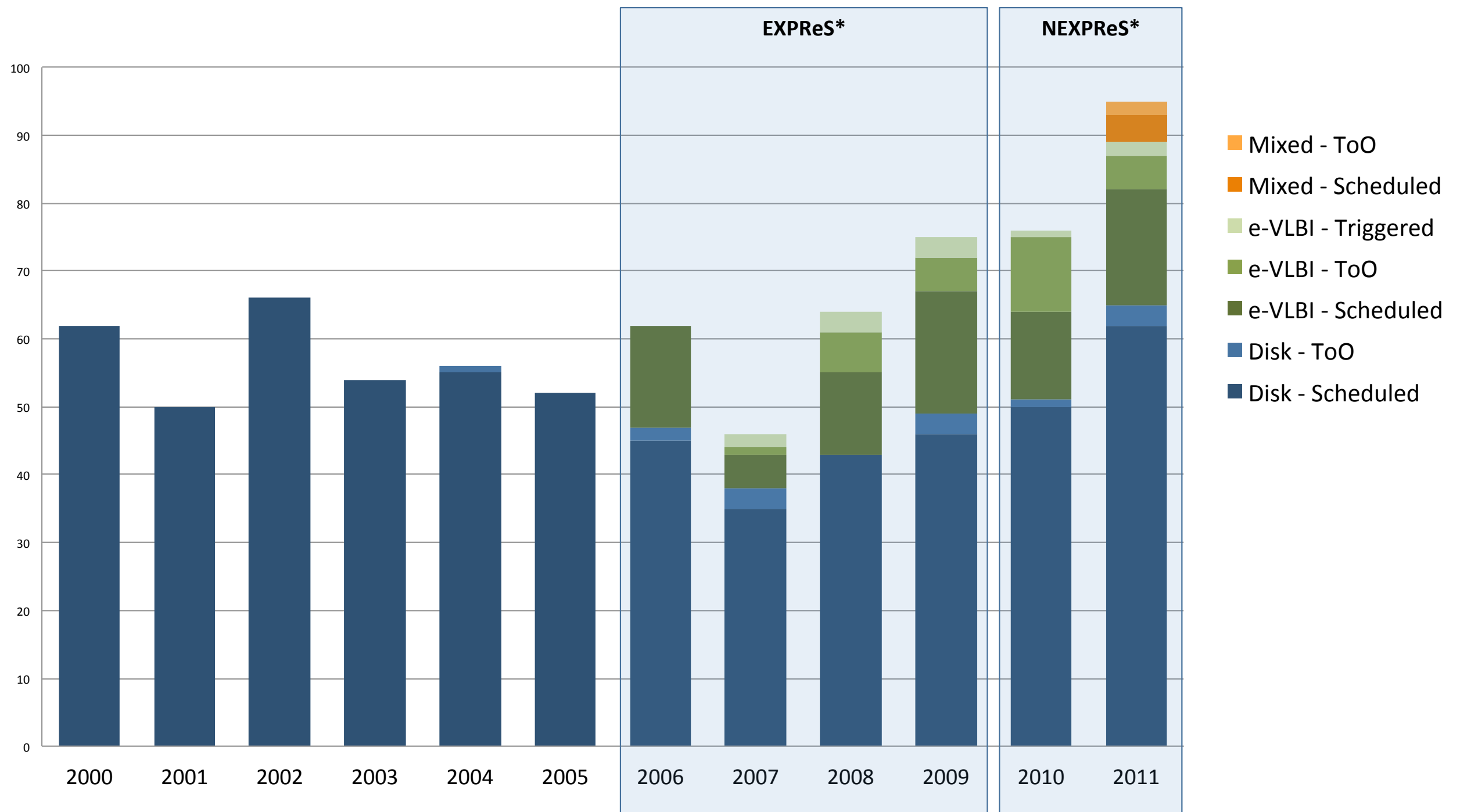


- **Flexible ways to get into e-VLBI**

- **Request e-VLBI for fast response**
 - Can be approved by PC for existing sessions
- **Or for triggered proposals**
 - To be submitted at regular proposal dates
 - Requires specific trigger criteria
- **Short requests <2hr**
 - e.g. calibrator checks
- **Target of Opportunities**
 - EVN agreed to have substantially more of these
- **Or just because you prefer to e-VLBI**
- **Or just because the EVN prefers to do e-VLBI**
 - Because of logistics or (disk) resources

Observations

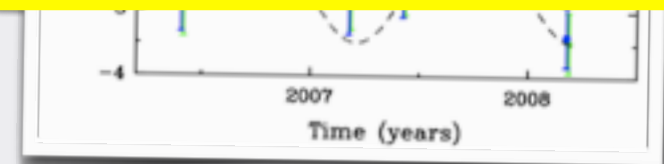
EVN Observation Proposals



- Because of logistics or (disk) resources

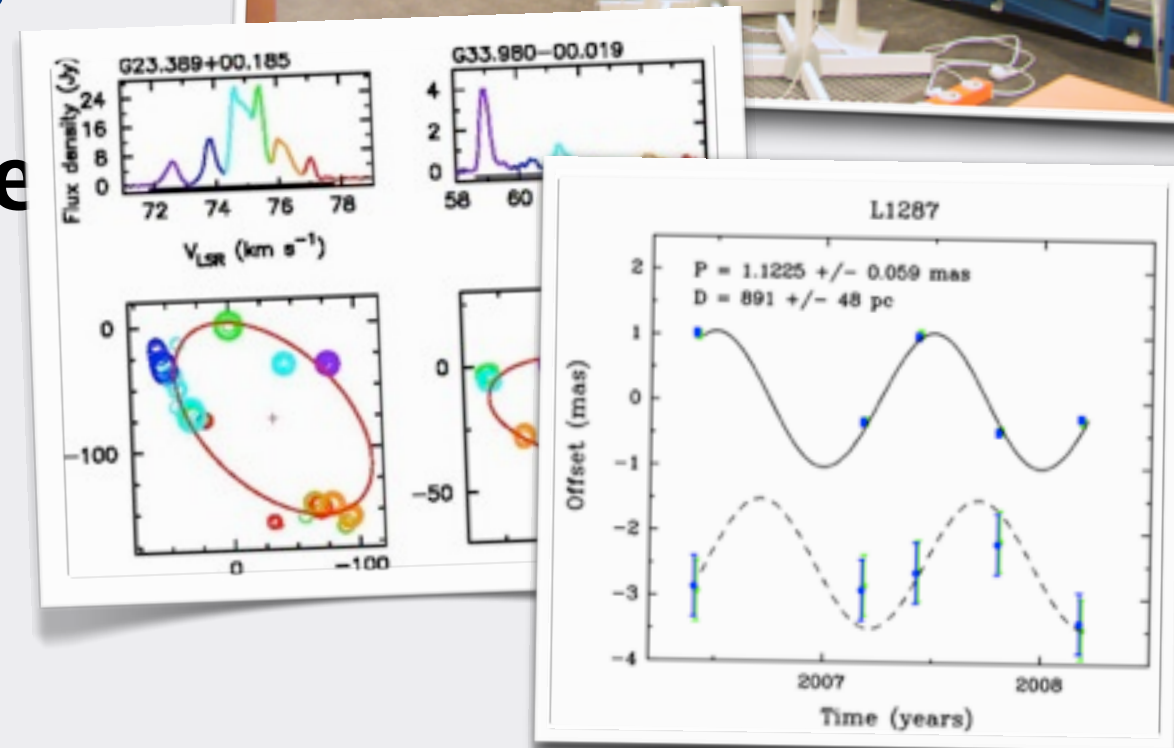
NEXPReS

*Novel EXplorations Pushing
Robust e-VLBI Services*



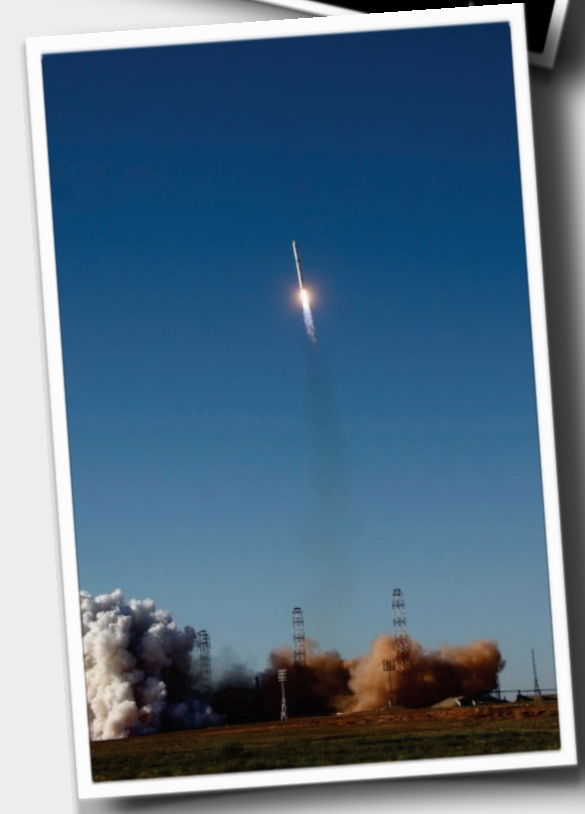
New project: NEXPRoS

- Correlate in real time what you can,
 - Correlate later what you need
-
- Allow multiple correlator passes
 - Continue to connect more telescopes
 - Reliable operations
 - addressed by simultaneous recording
 - and get the best of both worlds
 - NEXPRoS maintains expertise
 - Collaborations with NRENs
 - 3.8 M€ for 3 years, 15 partners



New opportunities

- **New requests for (new) observing types**
 - Impact on policy discussions
 - RadioAstron
 - Observations of spacecraft (planetary/fundamental)
 - Monitor programmes/astrometry/joint observations
 - Triggers set by other observatories (link with LOFAR)
- **Must try to keep procedures simple**
 - Complex for telescope & correlator operators
 - Even more complex for users!
 - Data ownership for triggers, concurrent observations
- **Must offer new services**
 - Offer tailored arrays?
 - More e-VLBI days, “VLBI every Friday”?
 - Central scheduling?
 - Large programmes
 - Contribute to resources?



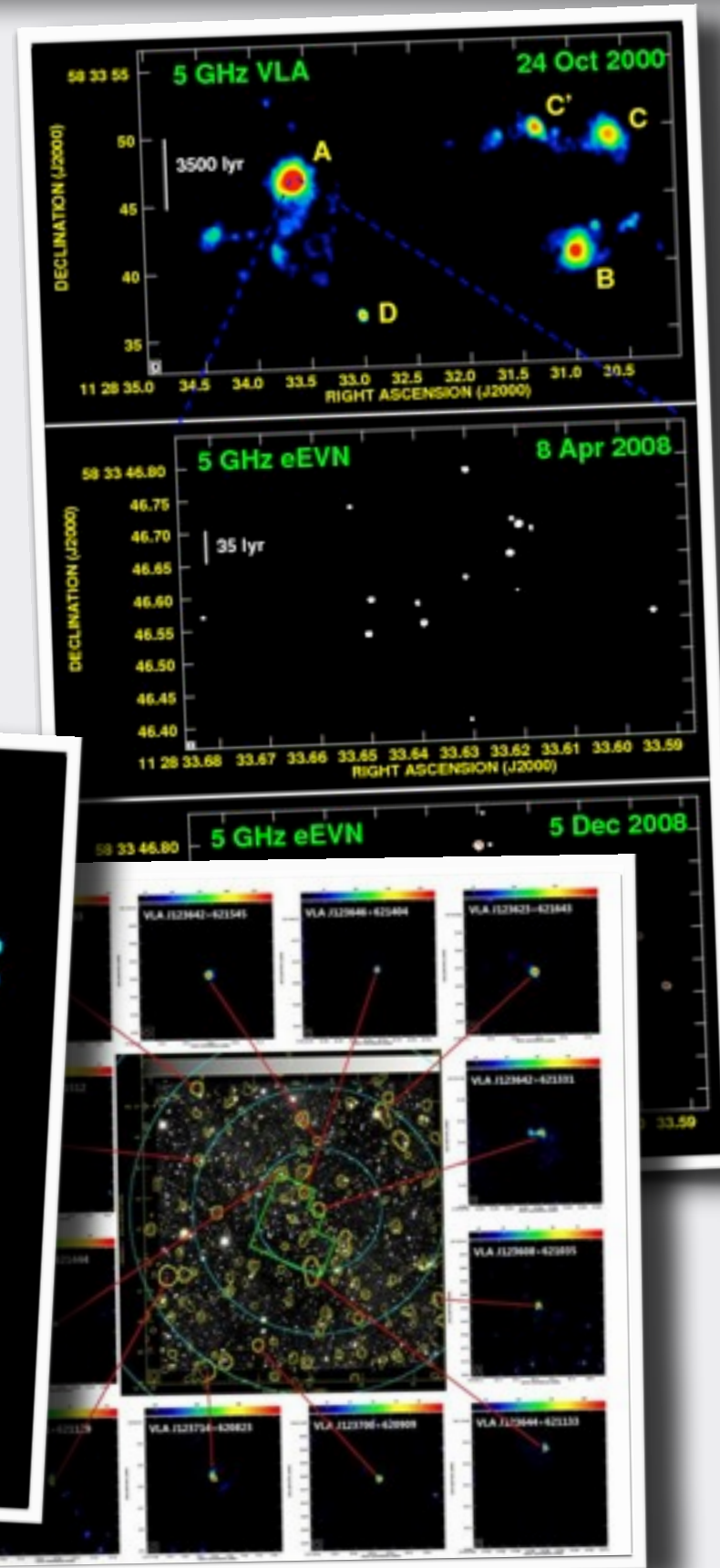
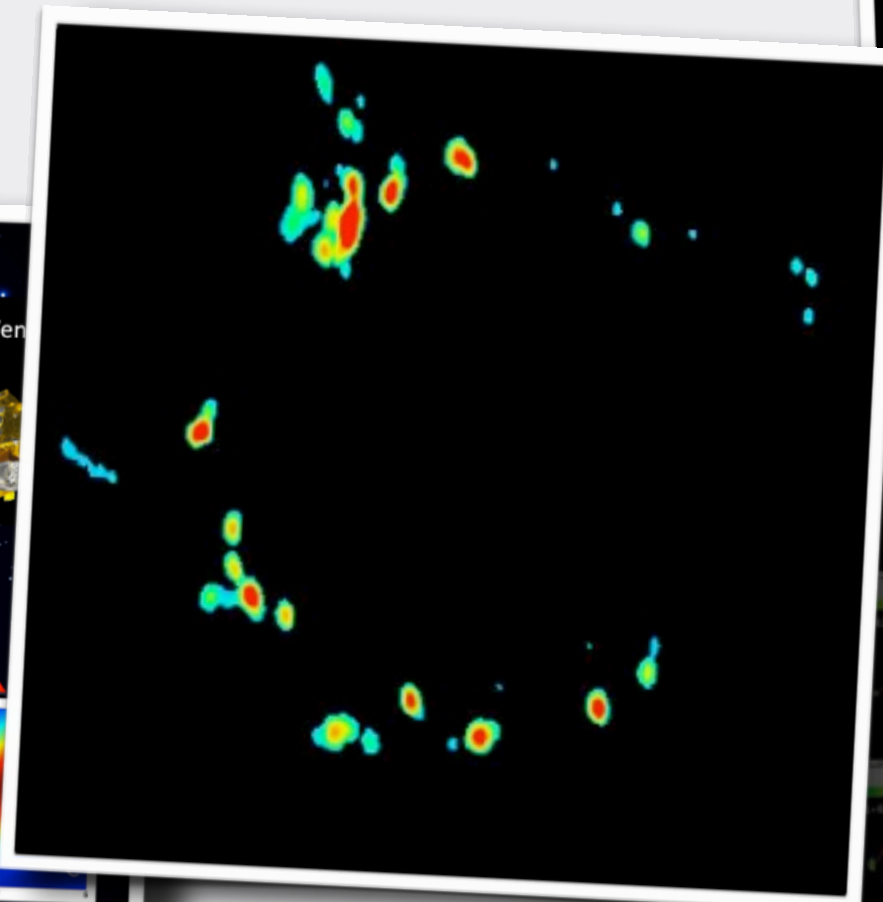
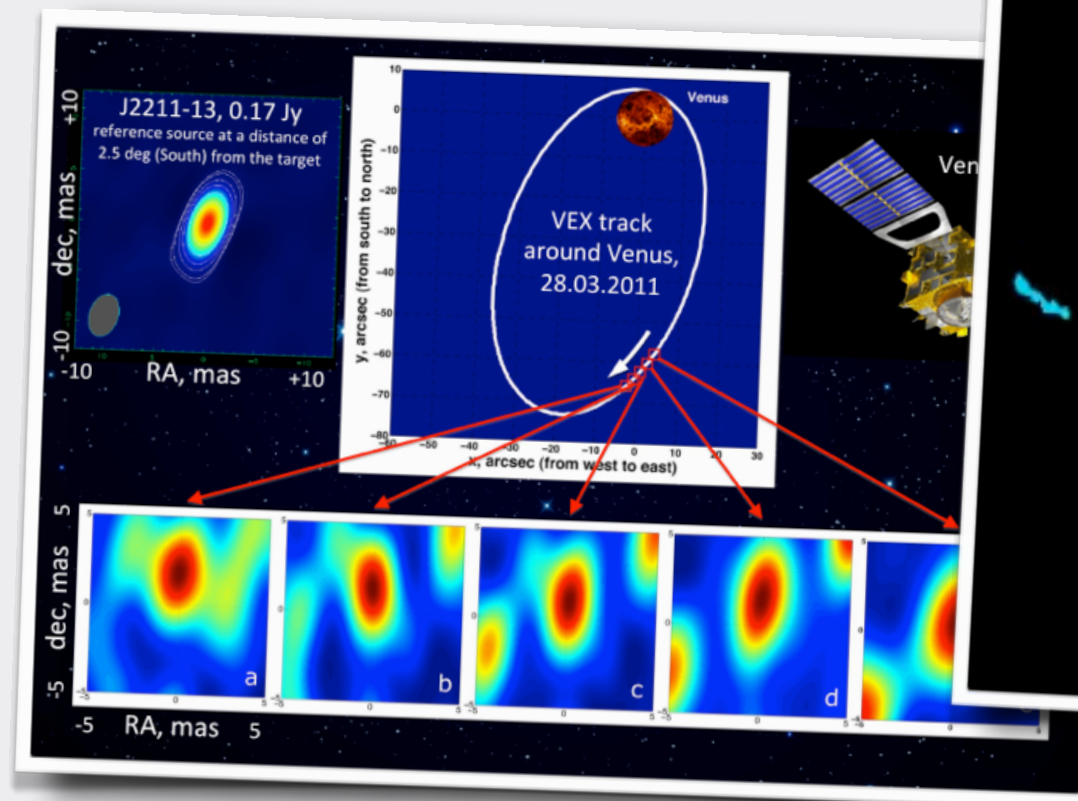
Options for VLBI

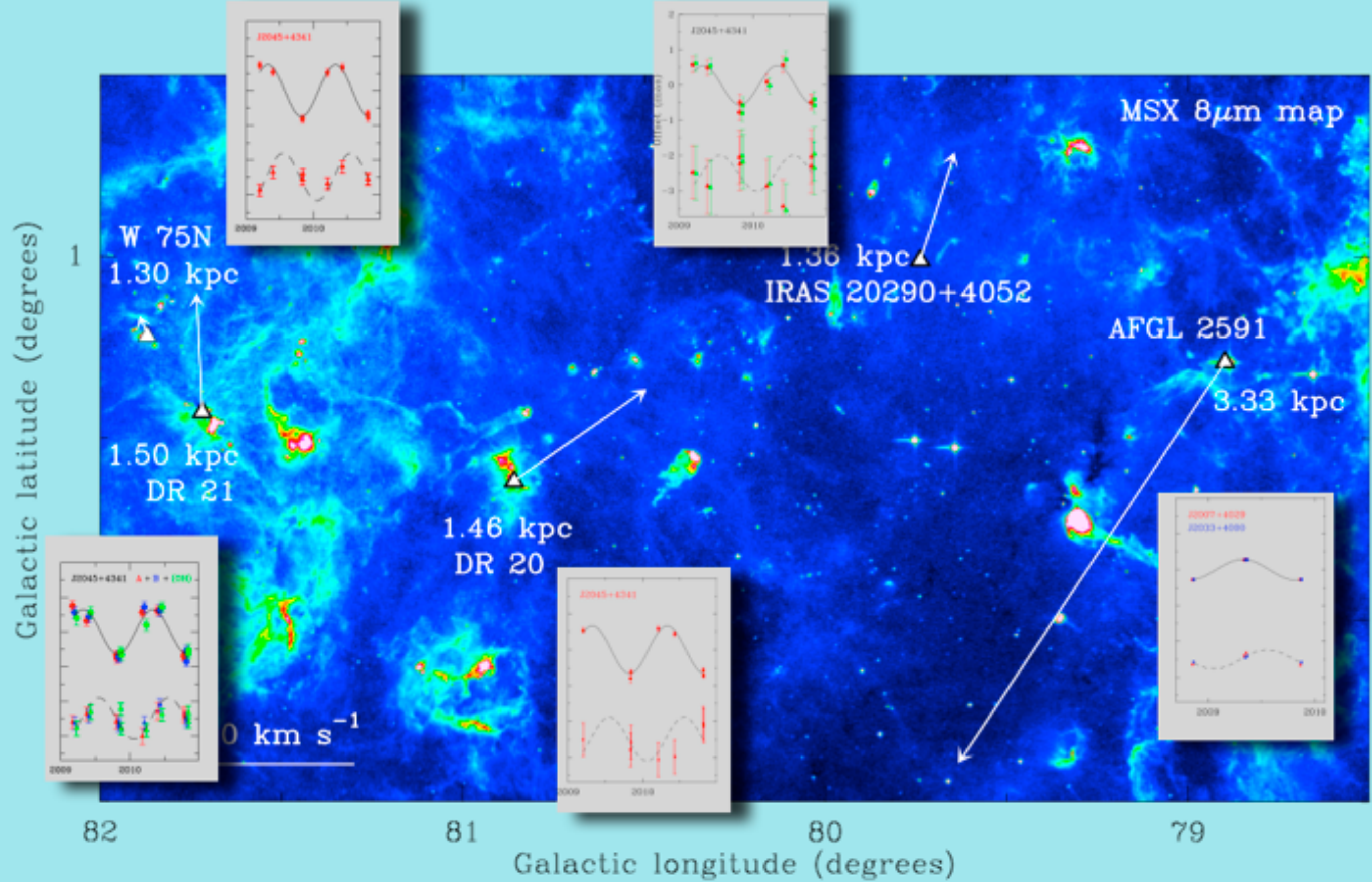
- **Increasing data rate will not stop any time soon:**
 - New stations: Africa, Goonhilly, Madeira, Brasil....
 - Joint observations with e-MERLIN
 - Joint observations with ALMA
- **Need for better sensitivity, more digital bandwidth**
 - with more bit sampling against interference
 - Accommodating number of space applications
- **Science synergy with new survey instruments**
 - Apertif, LOFAR, MeerKAT, ASKAP
 - eMERLIN, EVLA



VLBI future science case

- Science case has been developed
 - <http://www.evlbi.org/publications/publications.html>
- Fit well with scientific priorities
 - A. Extremes of the universe
 - B. Evolution of Galaxies
 - C. Birth of stars and planets
 - D. How do we fit in

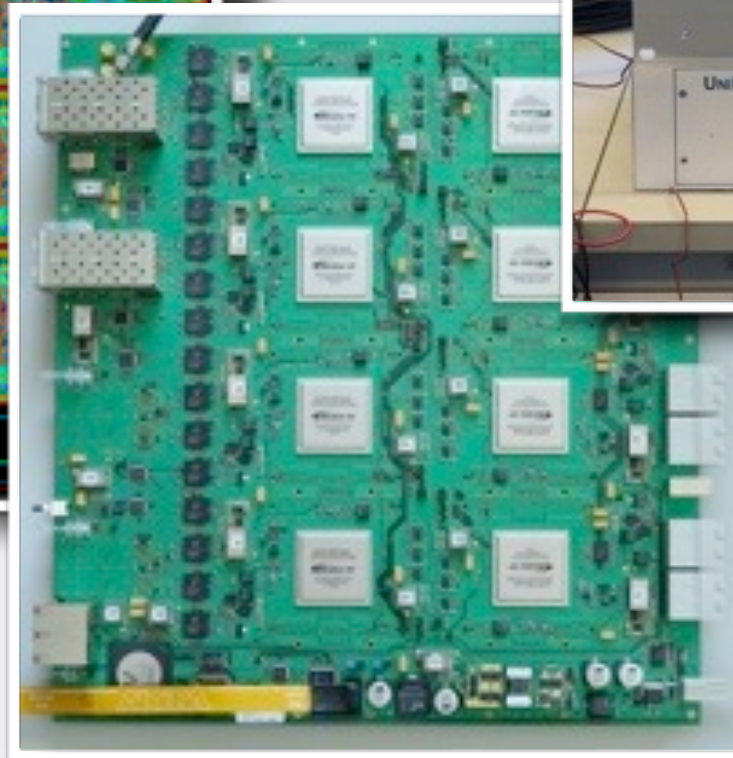
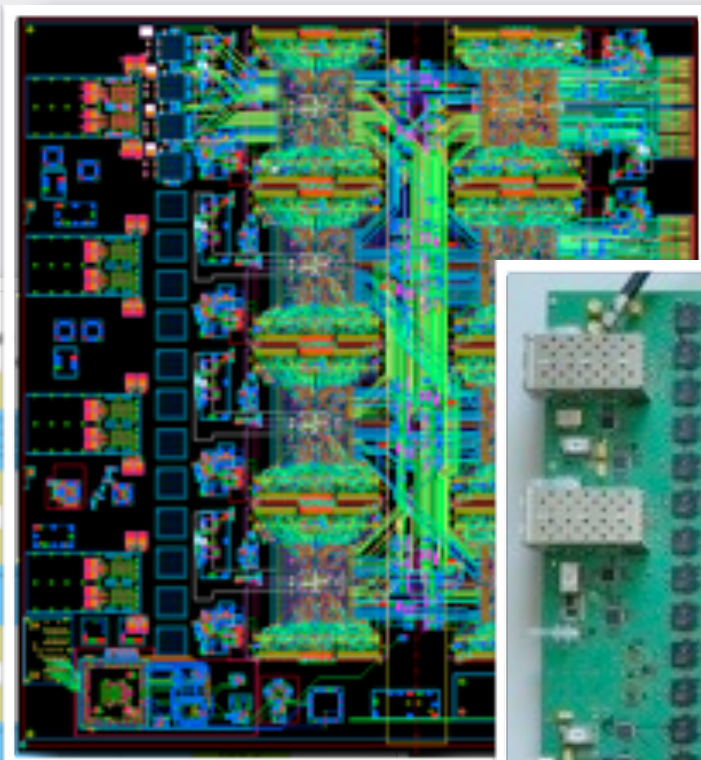




Rygl et al. 2012

- **Unique science: long baselines and high frequencies**
 - Keep up with EVLA/MERLIN sensitivity
 - Going for 4Gbps in 2012
 - Follow up LOFAR, MeerKAT, ASKAP
- **Even in the SKA era**
 - At least for phase I
 - Most certainly phase II
 - Spacecraft applications (and geodesy) need Northern Hemisphere coverage
- **Global baselines for better images**
 - And better time coverage
 - Data quality and image fidelity for SKA users
- **Only single (or two) user communities for all of us**
 - Critical mass reached on continental scale or larger

- # huib 18/4/12

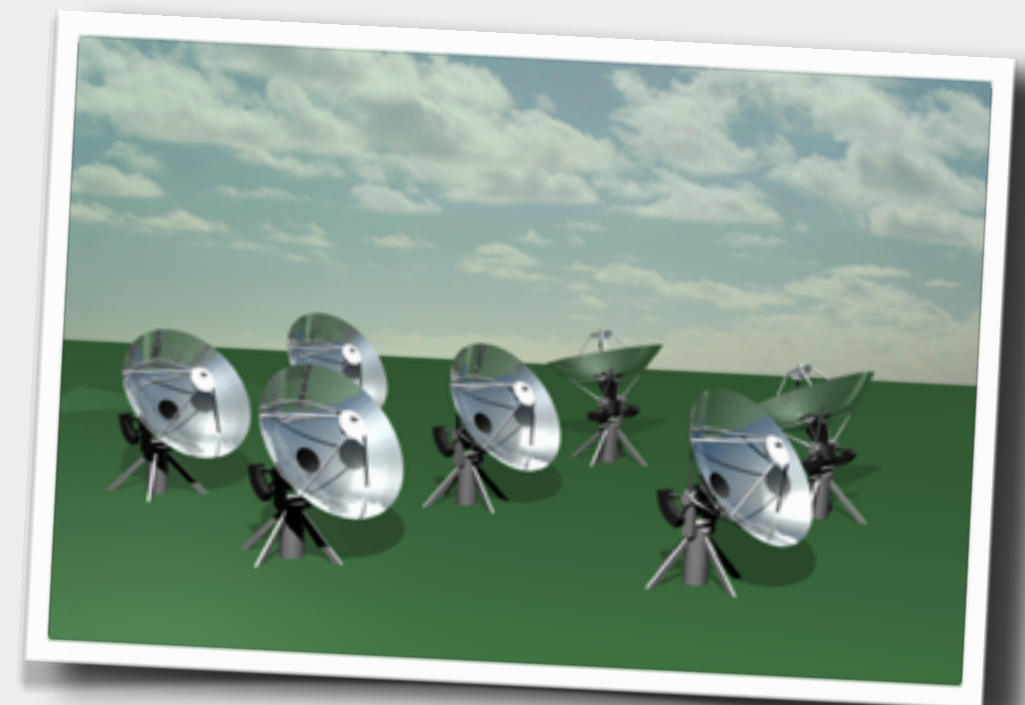


- **Lots of overlap with SKA technology**

- Benefit from digital components
- Connectivity
 - Data en timing
- Processing software
- Maybe even antennas

- **Important for SKA**

- Community building
- Training aspects
- Home telescope
- Outreach



JIVE Review

- public at <http://www.jive.nl/>
- **Excellent marks in all areas**
 - Only imperfection on spreading the VLBI gospel
- **Endorsing JIVE strategy**
 - Current SFXC processing
 - FPGA correlator
 - Space programme
- **Good recommendations**
 - VLBI can be more widely visible
 - Keep score on publications
 - Proceed careful with governance



ERIC option

- **European Research Infrastructure Consortium**

- Legal entity in Europe established 25 June 2009
 - Addresses establishment of European scale facilities
- Members are countries
 - Needs to be approved by EC
 - May have VAT exemption
 - Status of international, public body

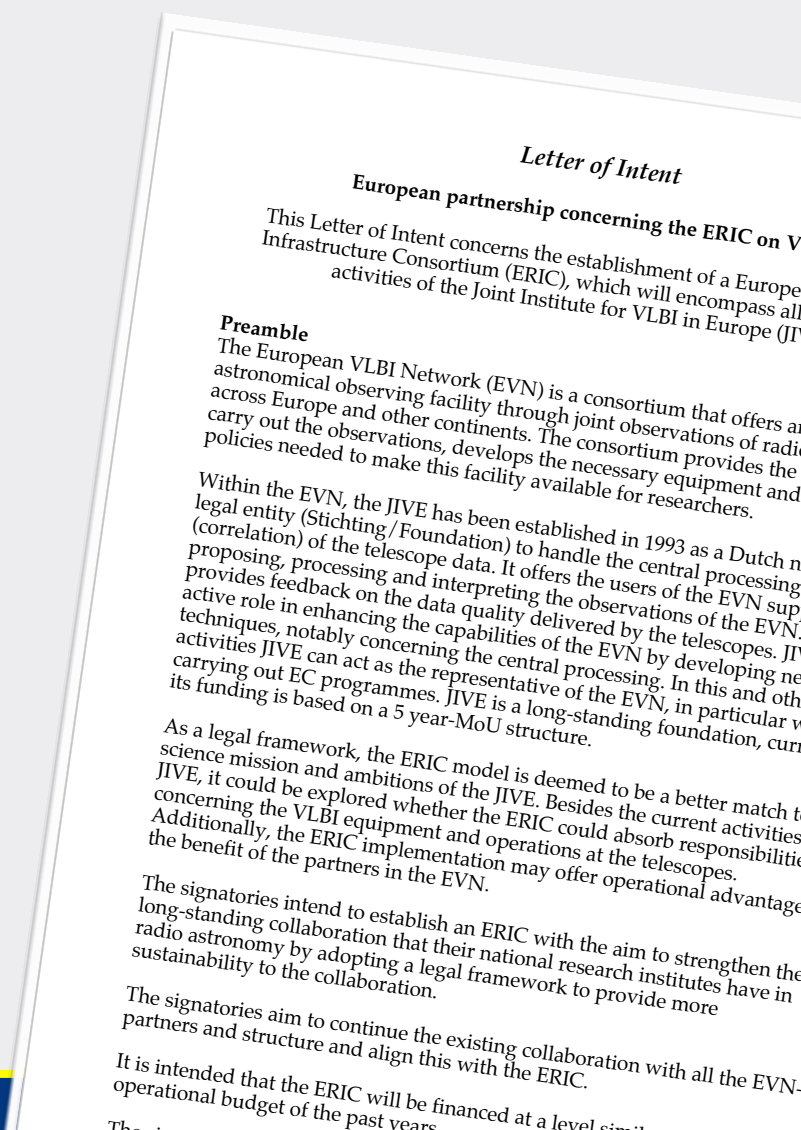


- **Some obvious advantages for JIVE/EVN**

- Personal responsibility of board members is lifted
- No VAT on personnel, large investments
 - could include EVN equipment
- Directly eligible for (future) EC funding schemes
- Attractive for new prospective members

- **JIVE partners looking into this**

- Not equally attractive to all, but best for JIVE



- **Mission clear on all different timescales**
 - Deliver the best possible science
 - Push e-VLBI and reach 4Gbps
 - Accommodate space programmes
 - Global baselines and high frequency
 - Needs a big correlator
 - Implement large-scale VLBI programmes
 - Participate in European SKA operations
 - As recognized European entity
- **JIVE on the right course**
 - The Schilizzi course!
 - be consistent, transparent, positive
 - have a drink (afterwards)



Thank





Thank you!