



VLBI in Europe

Huib van Langevelde
JIVE & Leiden

EVN: 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

- Can include MERLIN

- 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 μ 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

Effelsberg

Wettzell

Torun

Evpatoria

Zelenchuk

Svetloe

Erzene

Westerbork

Onsala



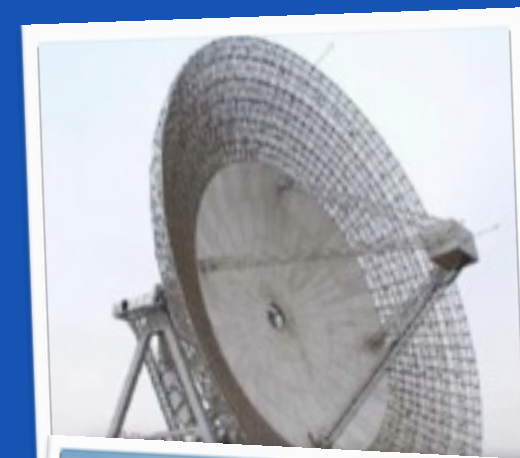
Irbene LV



3 telescopes in Russia



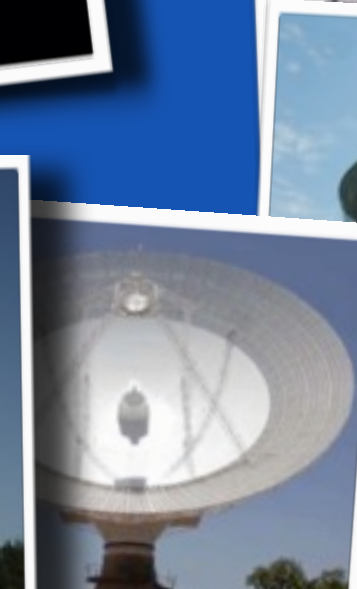
Sardinia 64m



Arecibo, Puerto Rico



Harte



4 telescopes in China

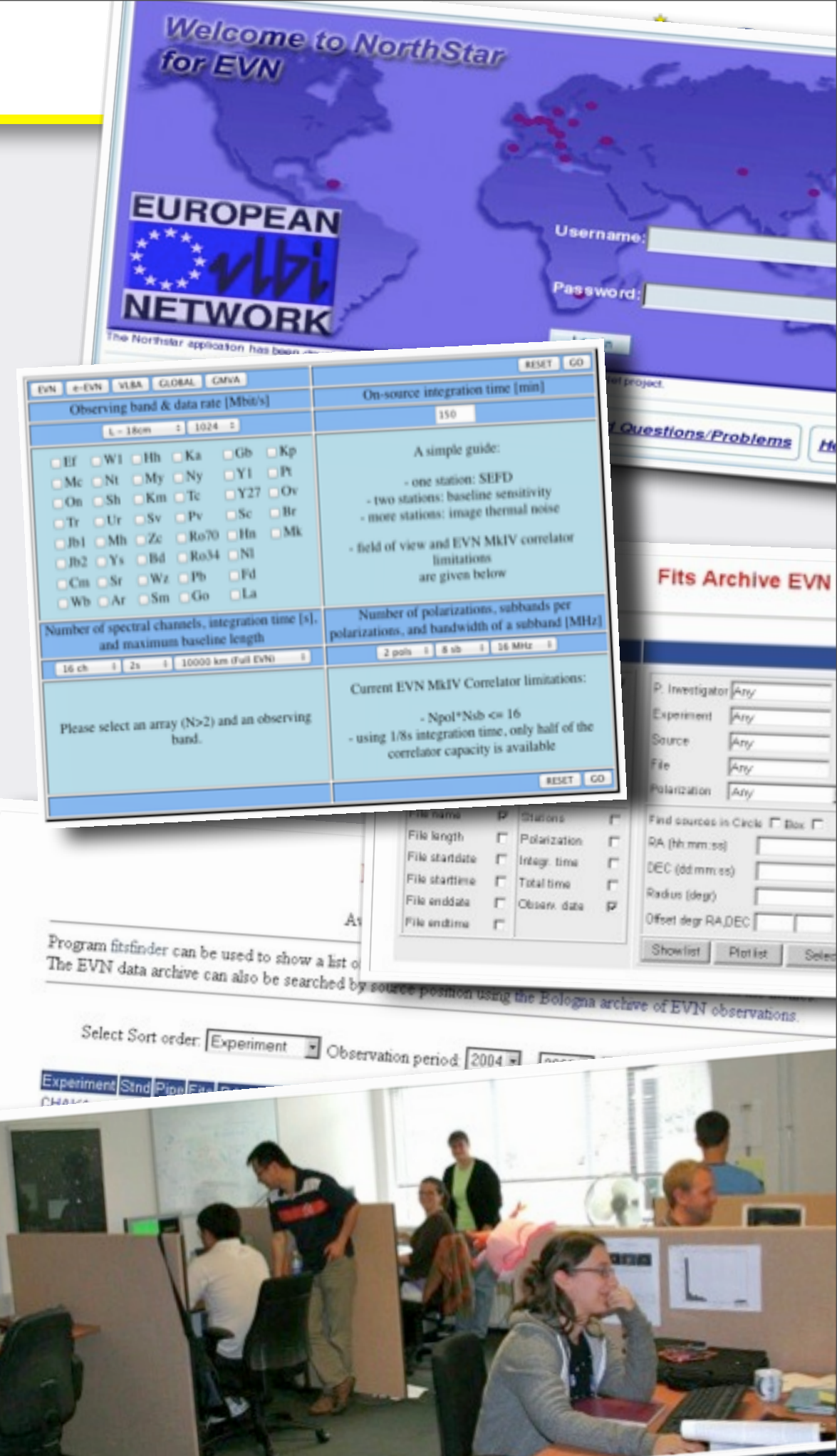


- **Promote the use and advance of VLBI for astronomy**
 - Central correlation; User services; Network support; Innovation; EC liaison/representation
- **Founded in 1993**
- **South Africa joined in 2012**
 - Base budget from partners in 8 countries:
 - China, France, Germany, Italy, Spain, Sweden, South Africa, United Kingdom, Netherlands
 - Large number of external projects
 - Hosted by ASTRON
- **Just been reviewed**
 - Next 5-year funding cycle
 - In a newly build wing
- **Want to become an ERIC**
 - European legal entity

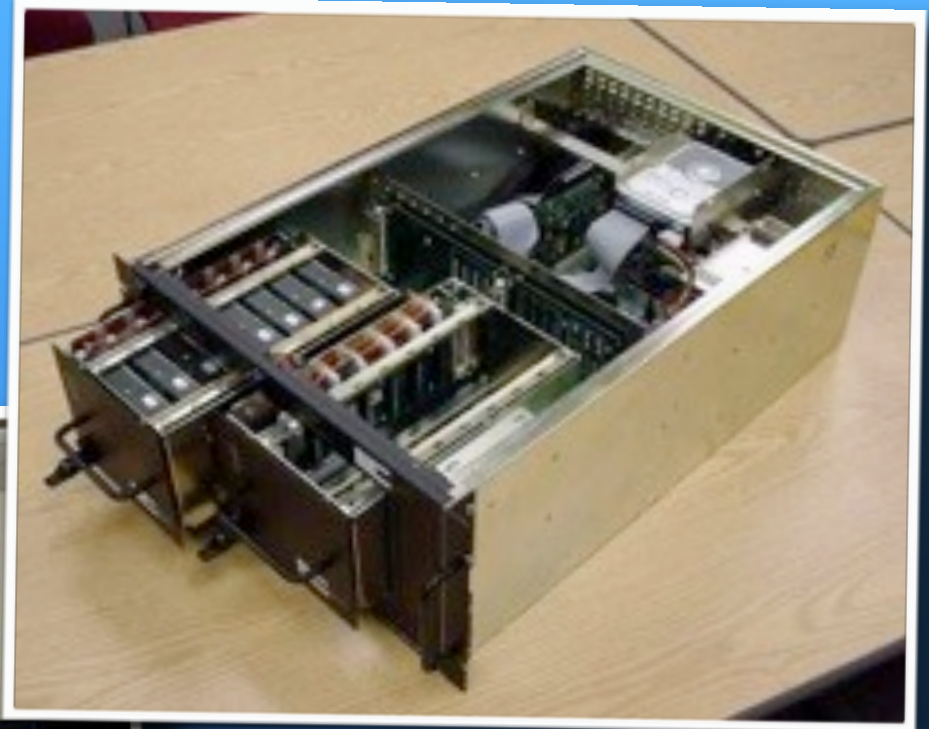


JIVE: User hub of EVN

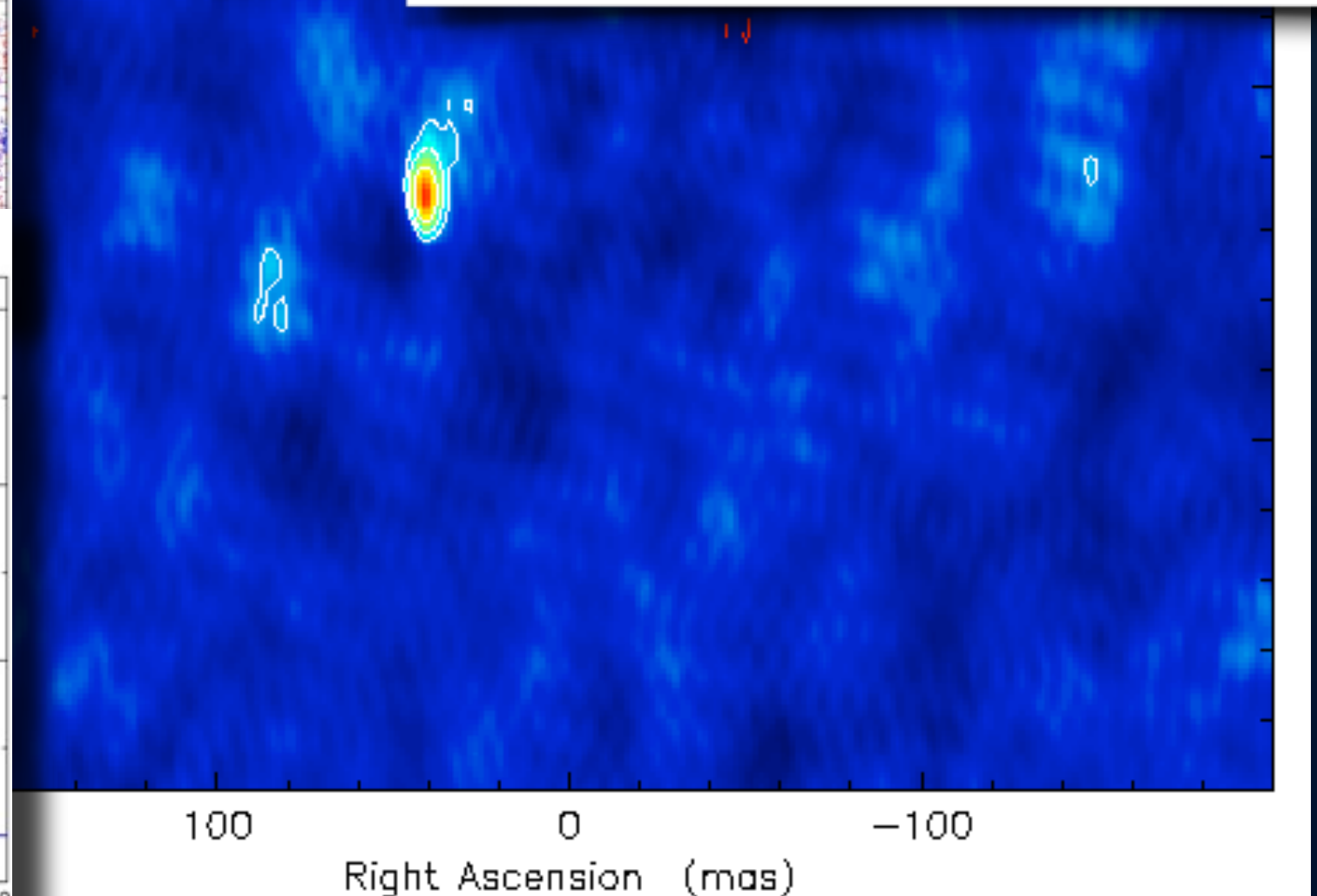
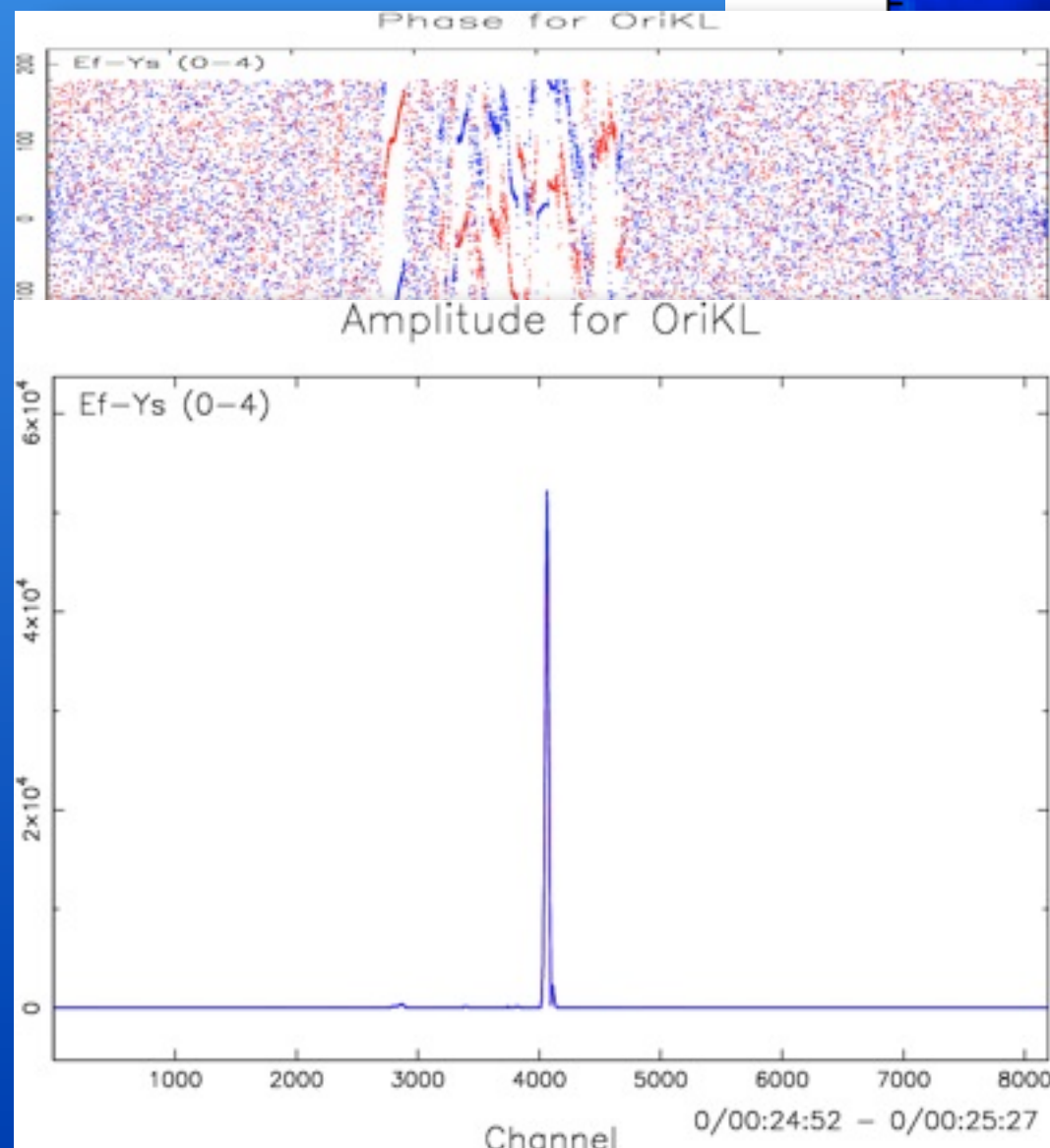
- User interfaces
 - Proposal tool
 - Sensitivity calculator
 - EVN observation scheduling
 - Data product
 - And related software interfaces
 - Archive
 - proprietary for one year after observation
 - Pipeline: calibration info & preliminary images
- User support
 - Offer help in all stages
 - Check the correlation of all user data
 - Pipeline calibration and imaging
 - Visitor facilities
 - EVN TransNational Access program
 - Open for user visits
 - Point of contact various RadioNet fur
- Telescope support



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



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

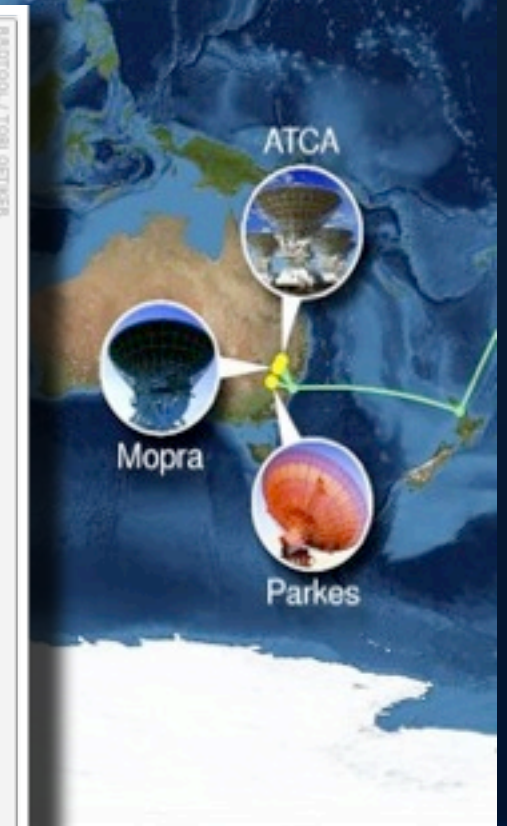


R+D: Introduced e-VLBI as operational facility:

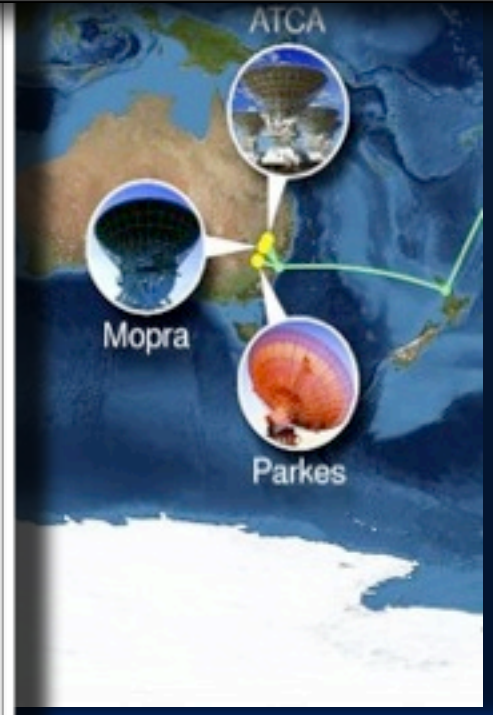
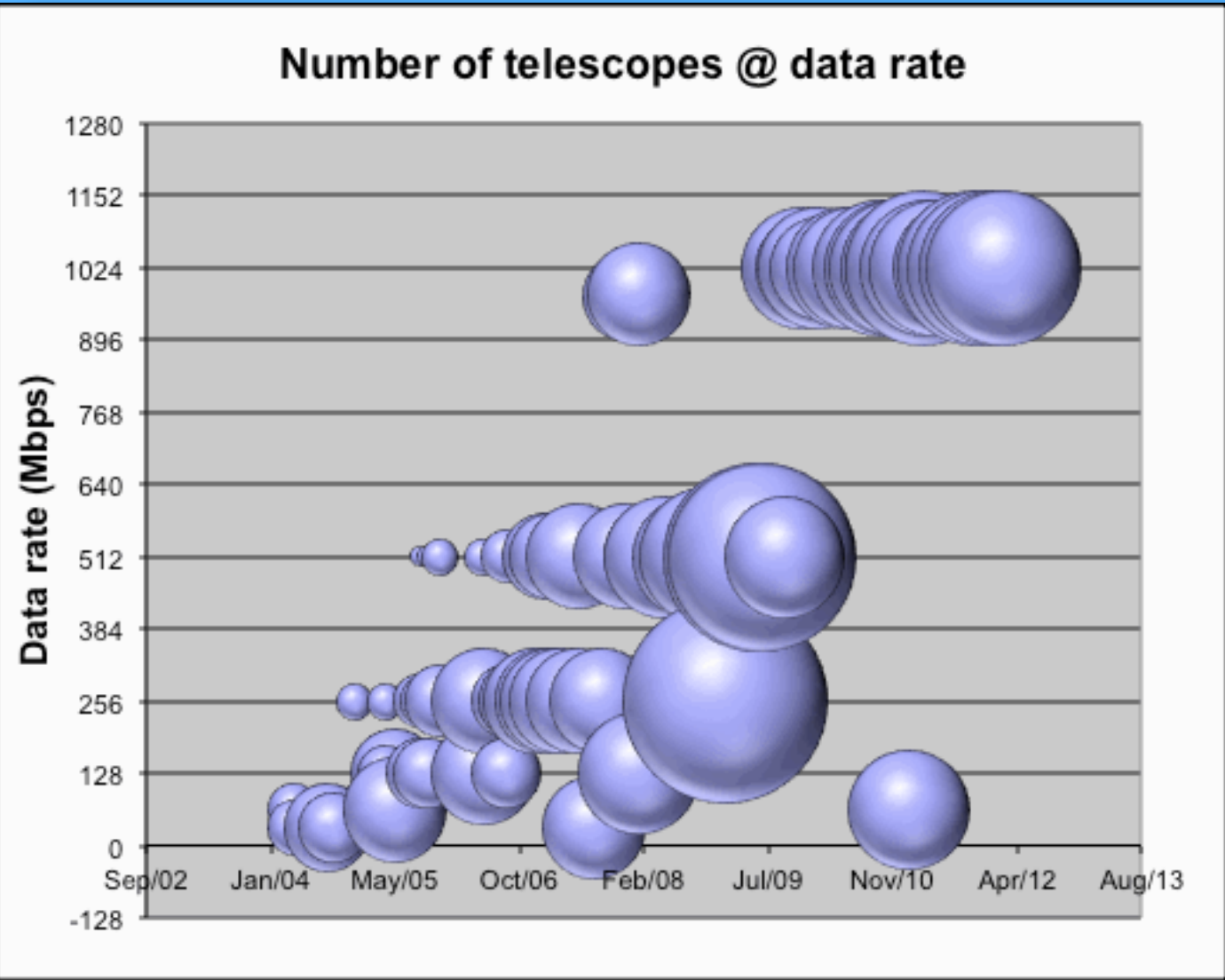
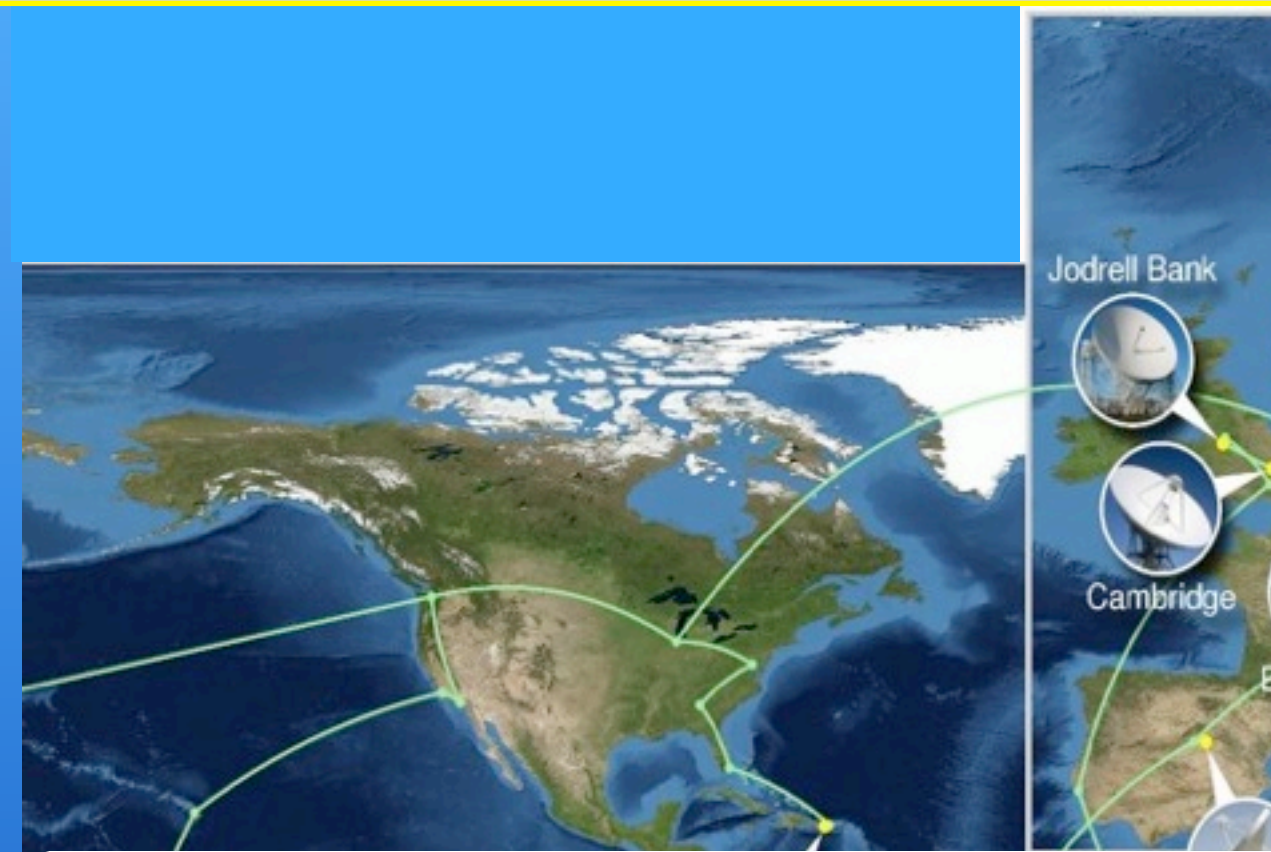


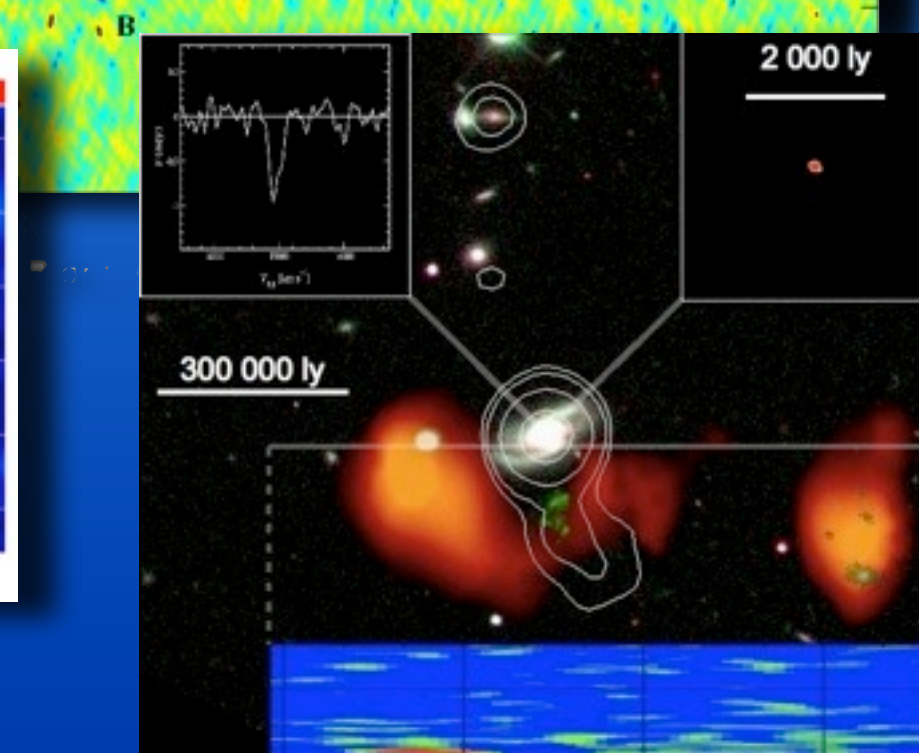
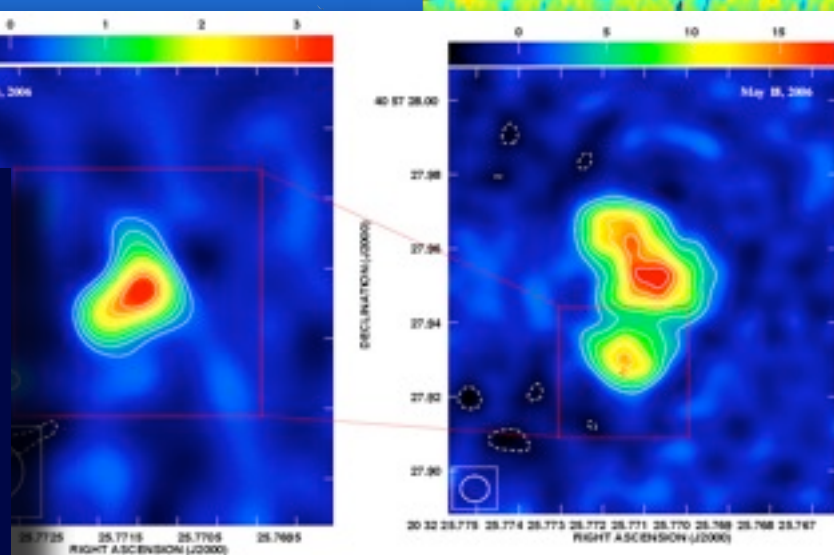
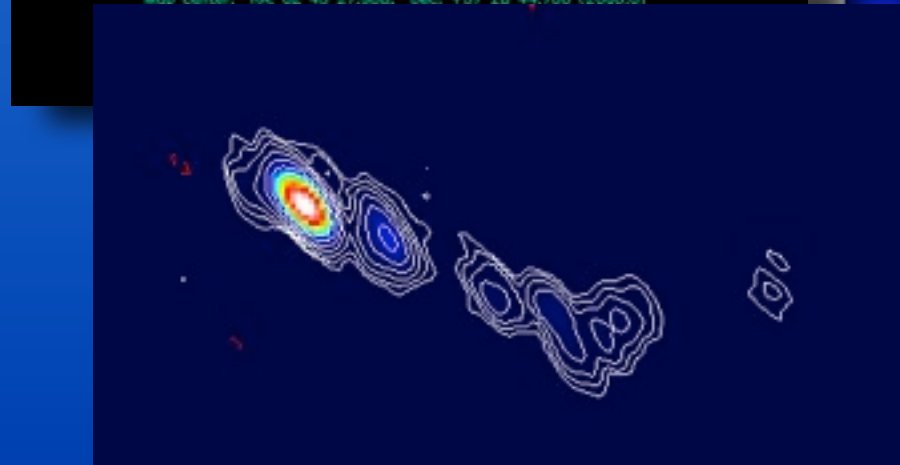
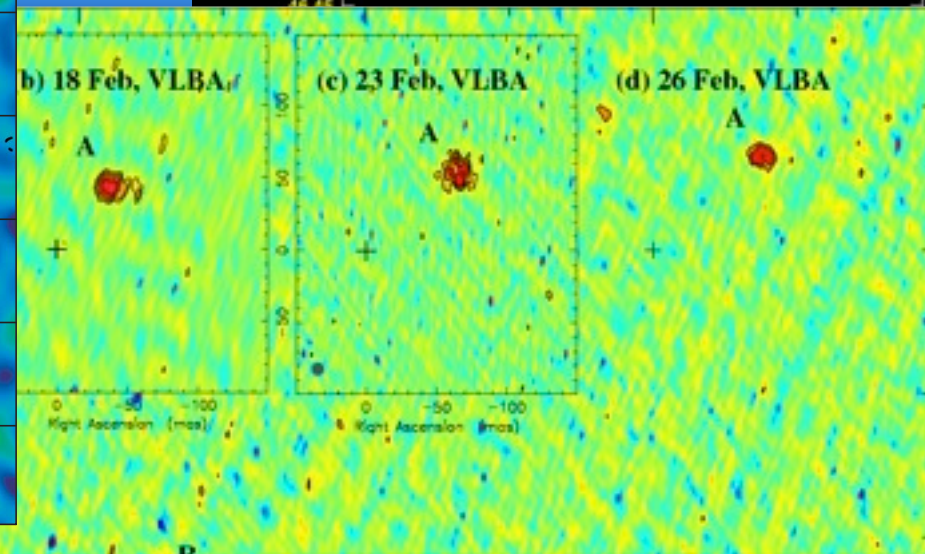
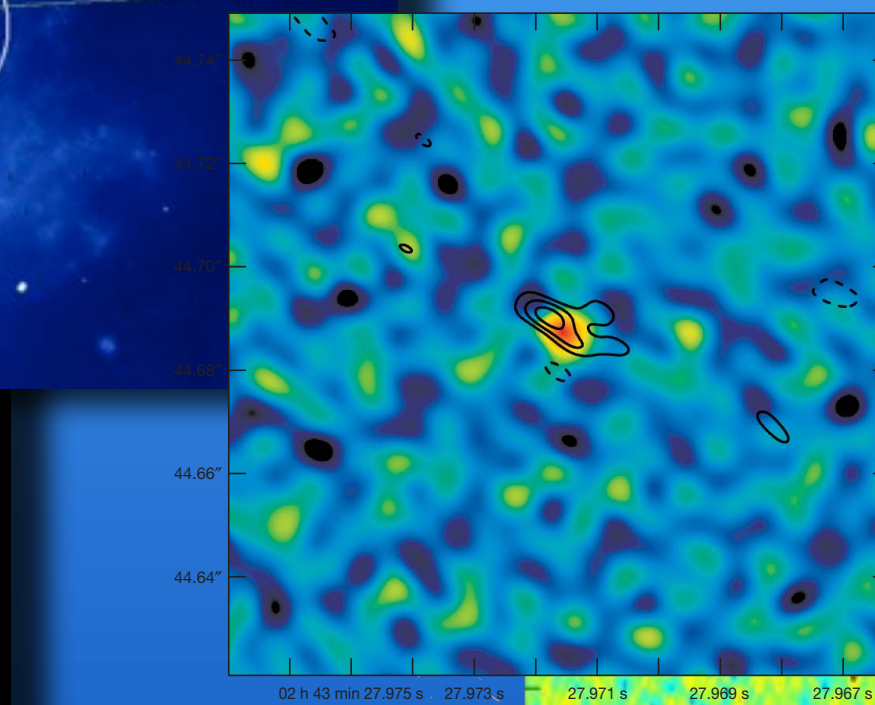
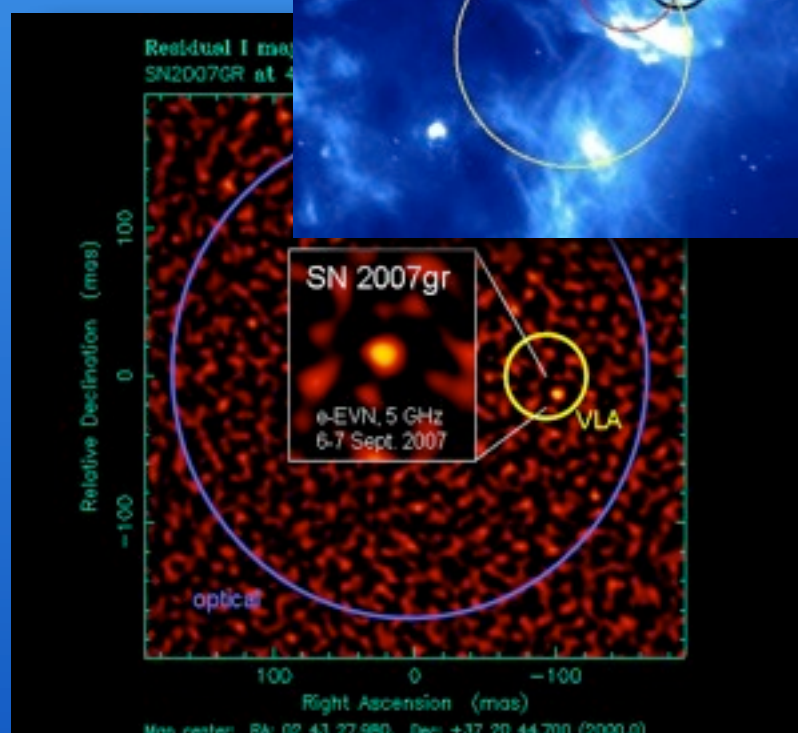
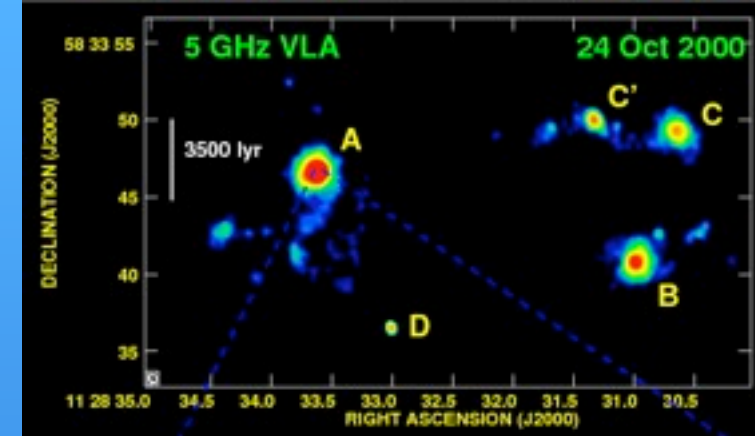
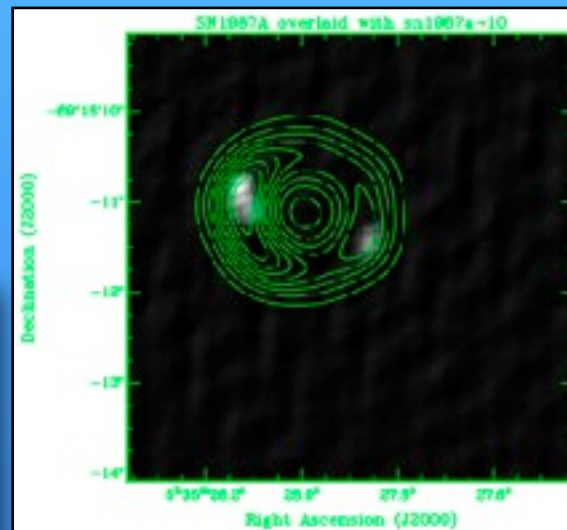
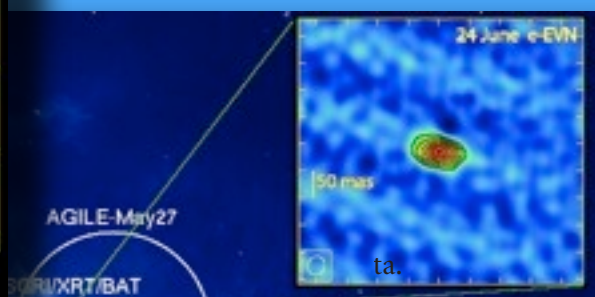
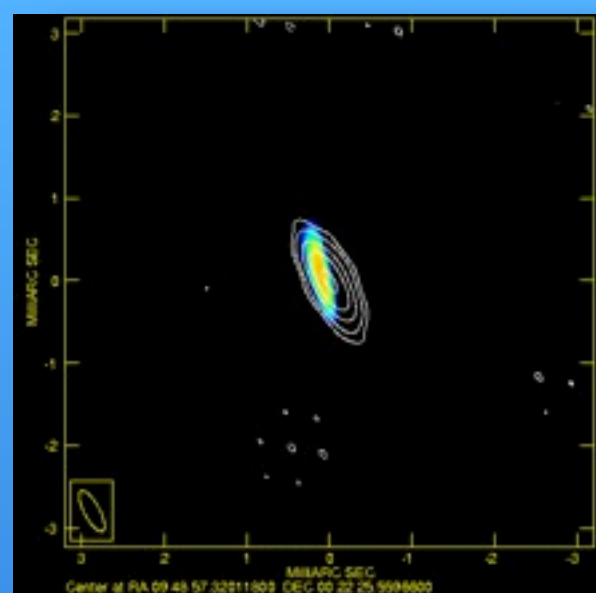
- **Connections work great!**
 - often dedicated light paths
 - Use optimized protocols
- **Closed feedback loop makes e-VLBI more robust**

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



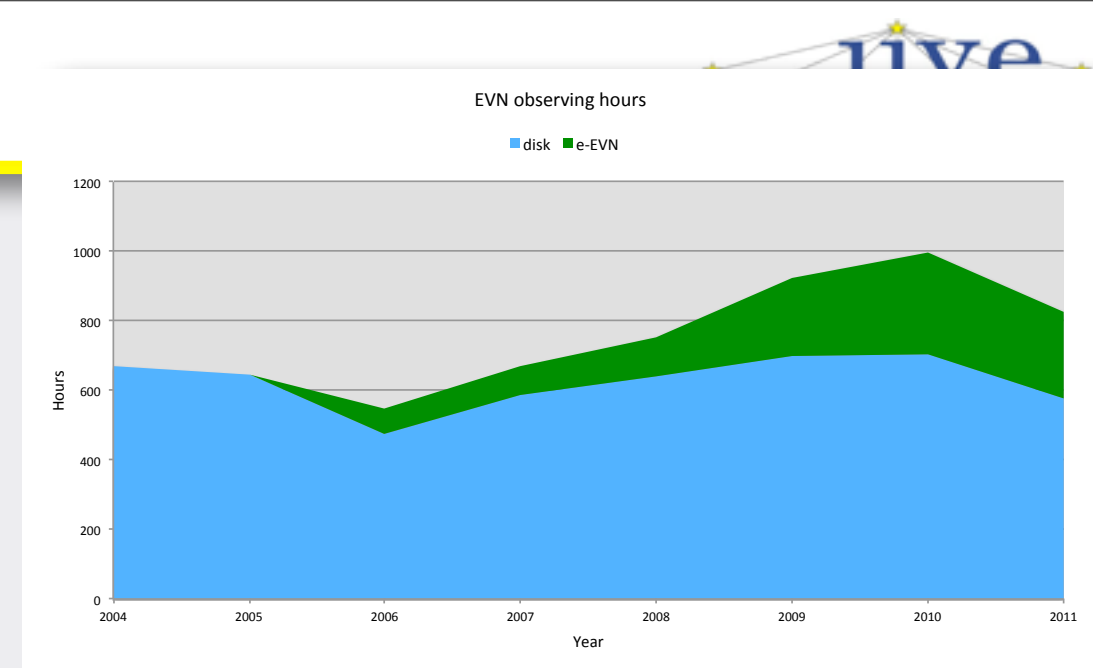
R+D: Introduced e-VLBI as opera





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



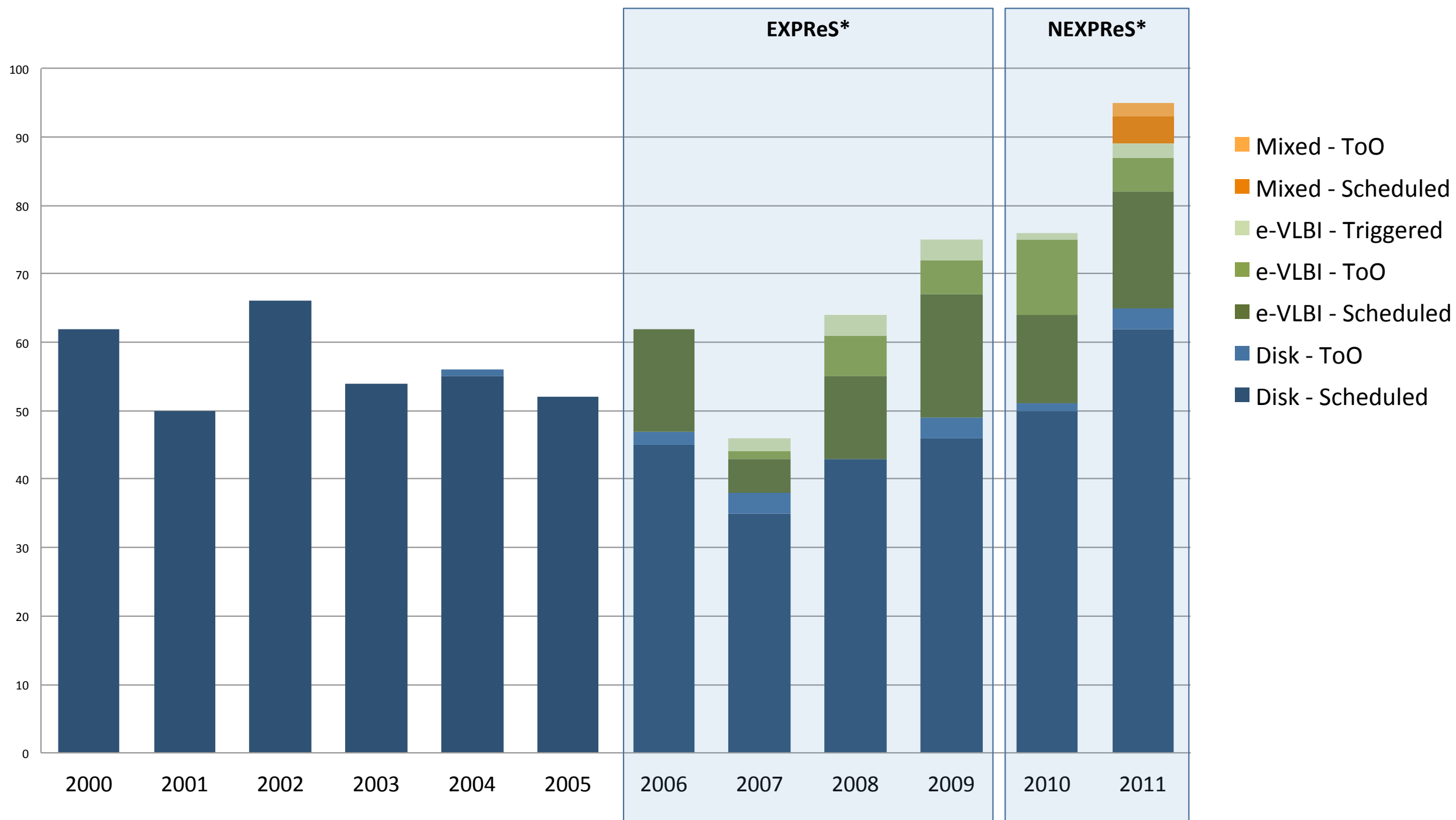
Observations



EVN observing hours

disk e-EVN

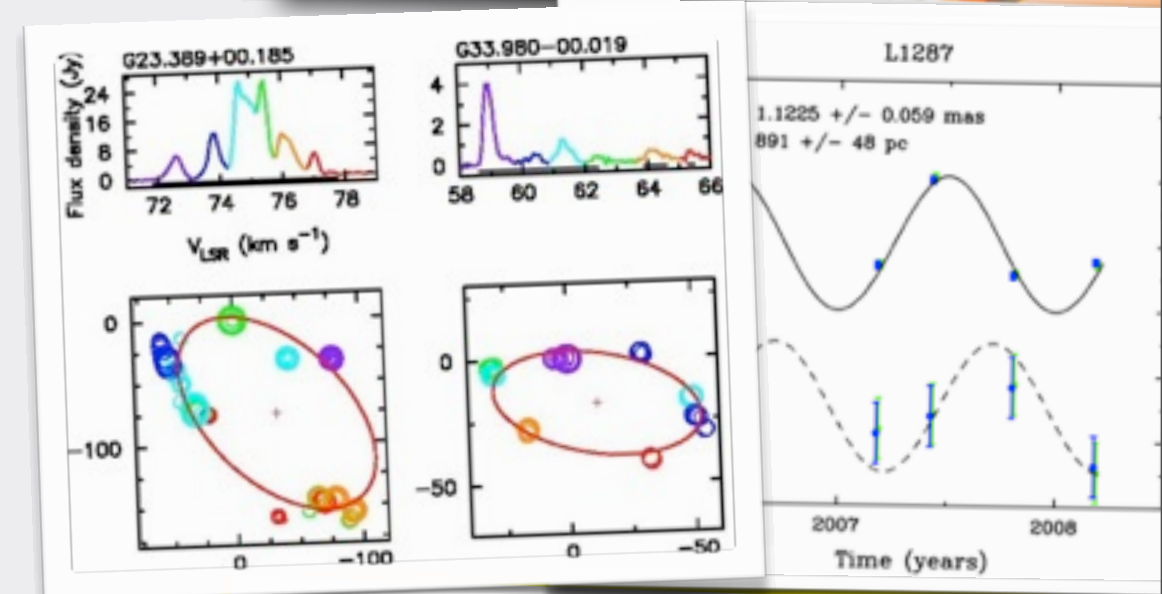
EVN Observation Proposals



• Because of logistics or (disk) resources

New project: NEXPReS

- 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
 - NEXPReS maintains expertise
 - Collaborations with NRENs
 - 3.8 M€ for 3 years, 15 partners



NEXPReS
Novel EXplorations Pushing
Robust e-VLBI Services

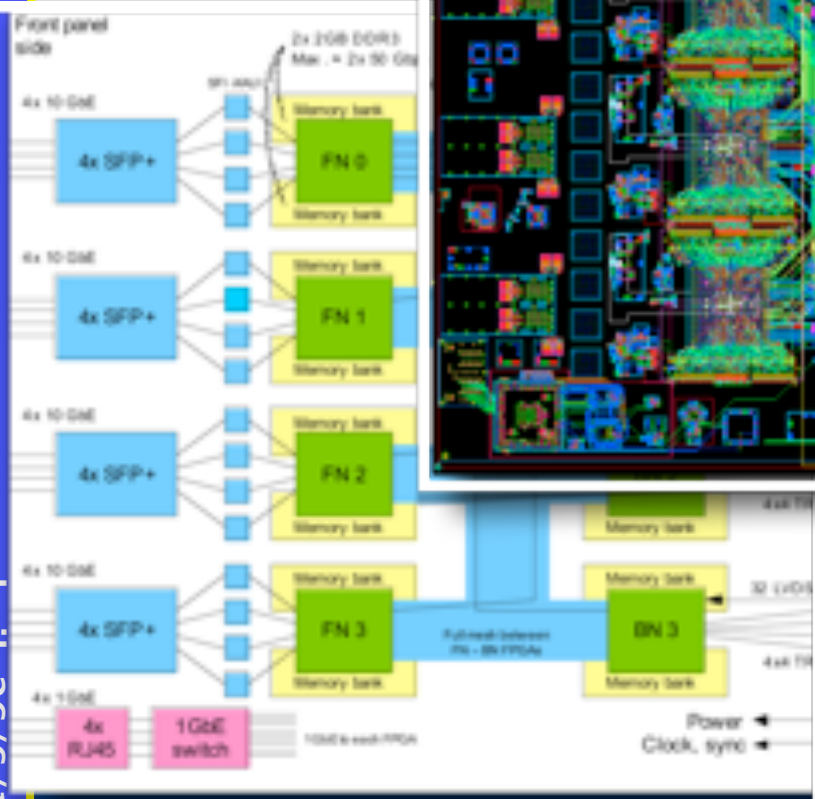
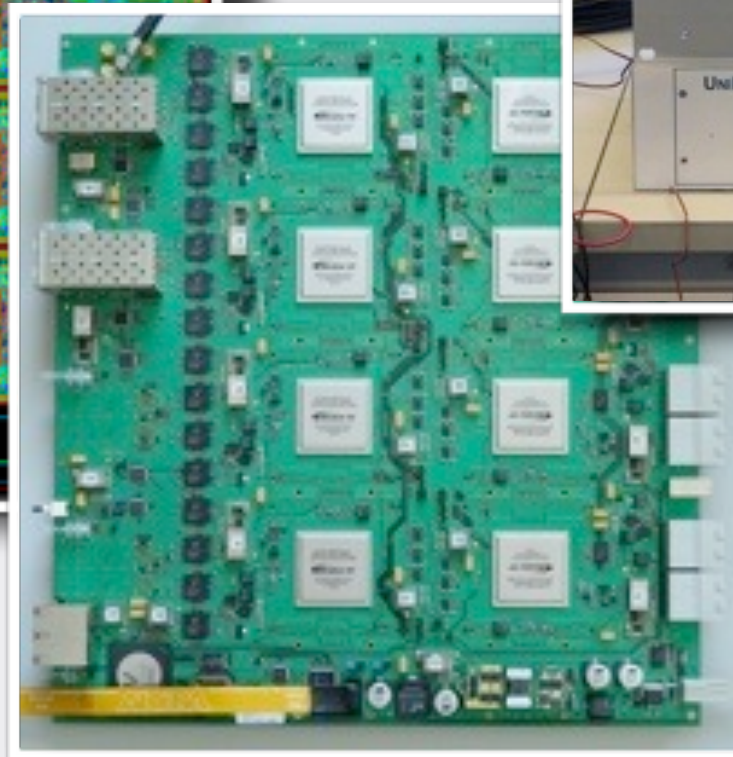
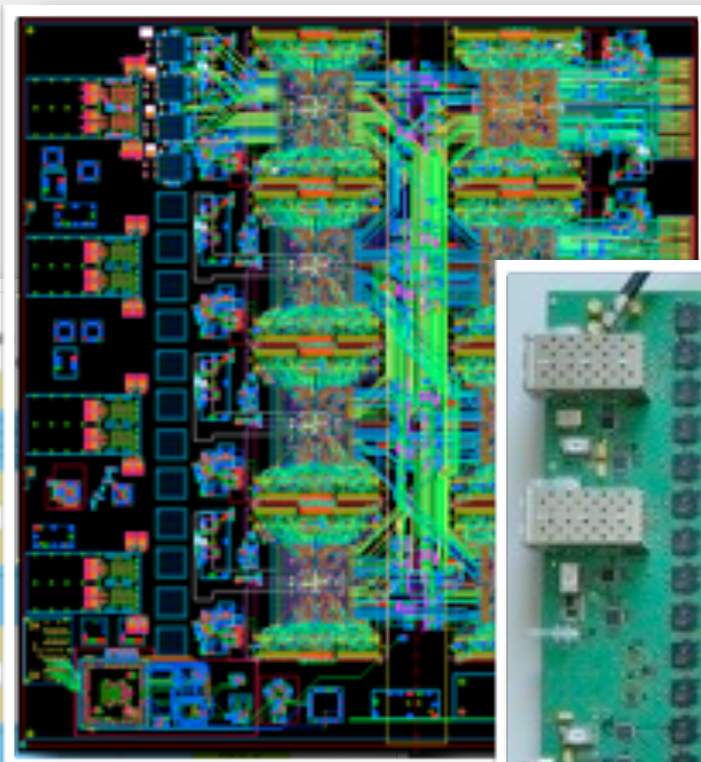
Options for VLBI

- **Improve imaging: more telescopes**
 - New telescopes: Latvia, Sardinia, China, Ukraine
 - New locations: Africa, Goonhilly, Madeira, Brasil....
 - Joint observations with e-MERLIN
- **Need for better sensitivity, more digital bandwidth**
 - with more bit sampling against interference
 - Accommodating number of space applications
- **Especially for higher frequencies**
 - As dictated by science case
- **Science synergy with new (survey) instruments**
 - Apertif, LOFAR, MeerKAT, ASKAP
 - eMERLIN, EVLA, ALMA



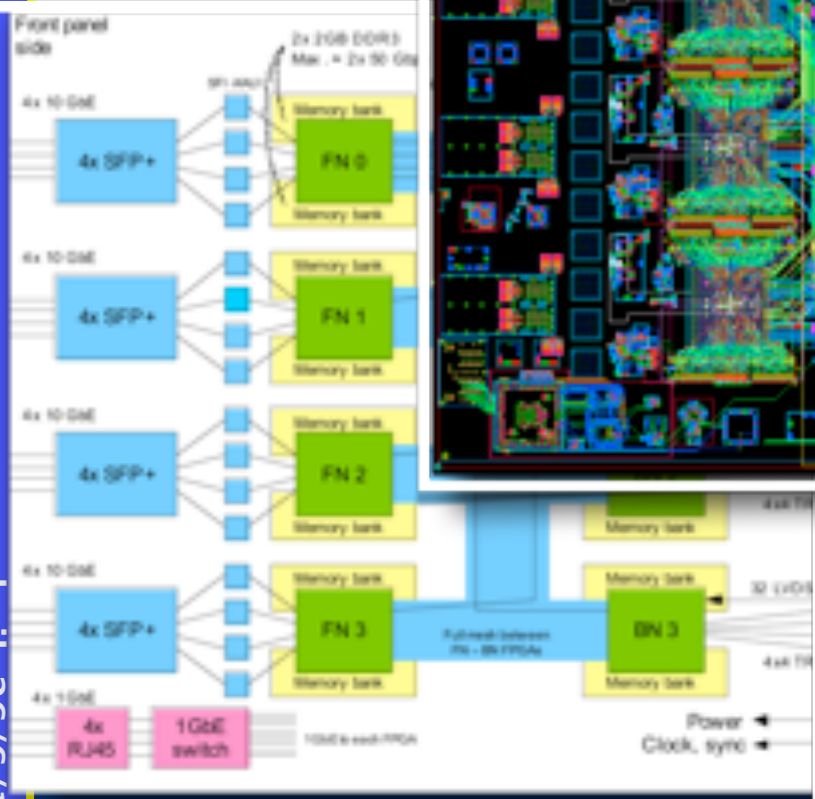
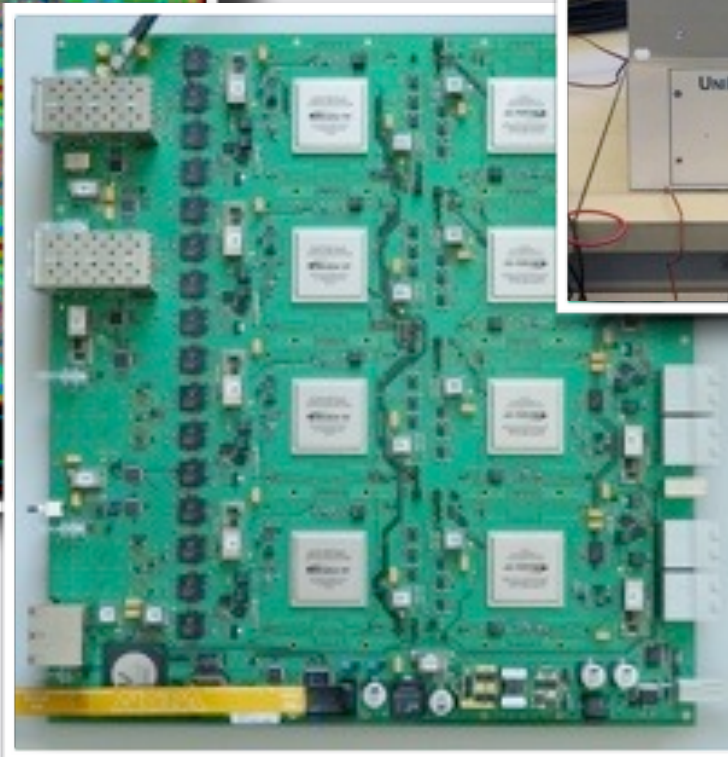
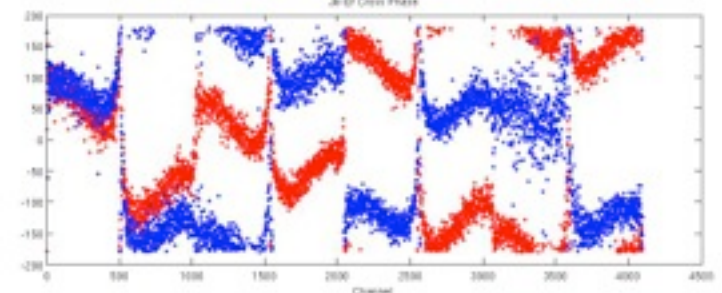
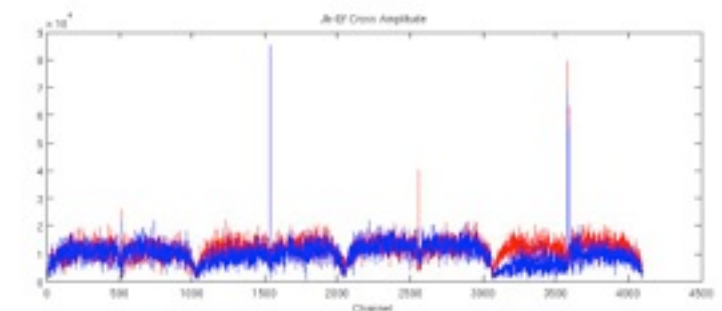
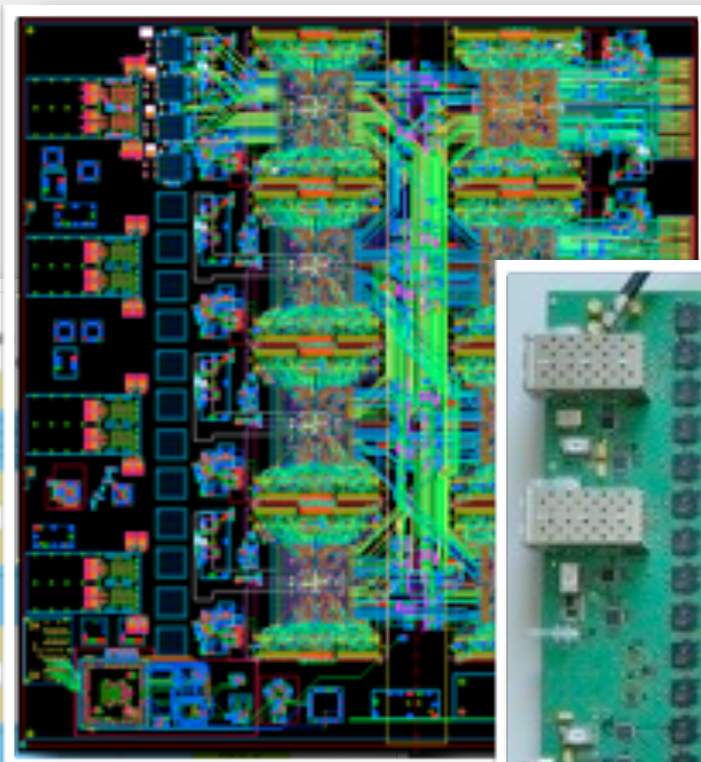
Needed: next generation correlator

- Aiming for 32 station 10+ Gbps FPGA correlator
 - Flexibility of software correlator
 - Power consumption should be much better
 - Started in RadioNet::UniBoard, next step in RadioNet3
- Feeding into the SKA programme
 - As well as being used for EVN, LOFAR, WSRT, Effelsberg



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VLBI for Space applications...

JUICE-Laplace ?

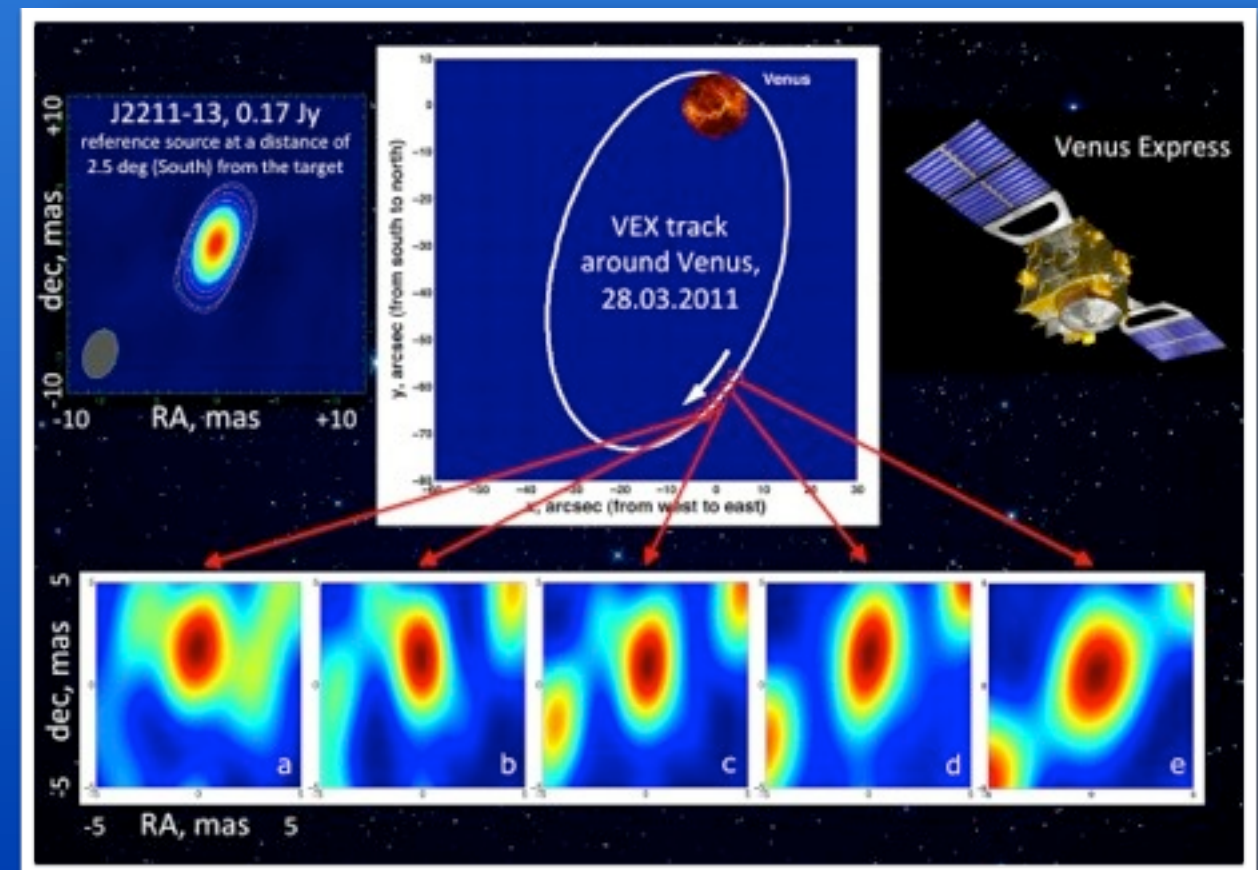
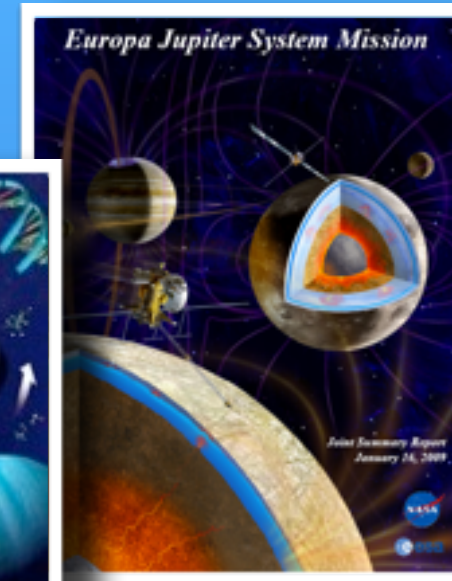
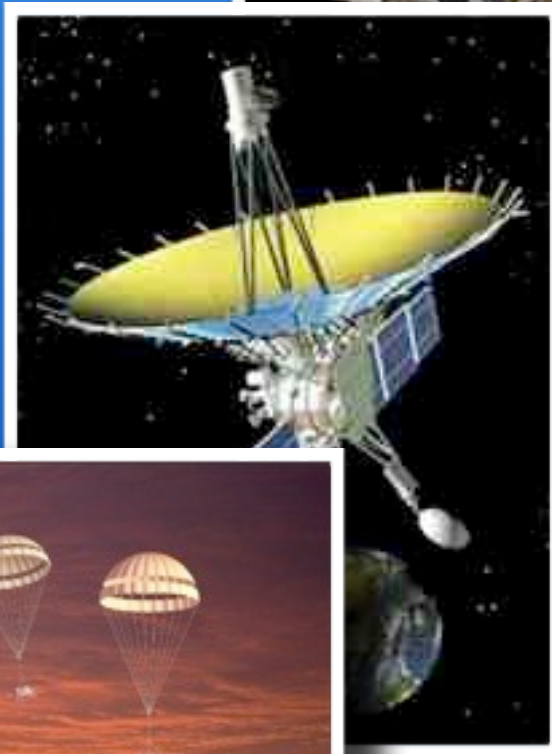
MarcoPolo-R?

ExoMars

BepiColombo

RadioAstron

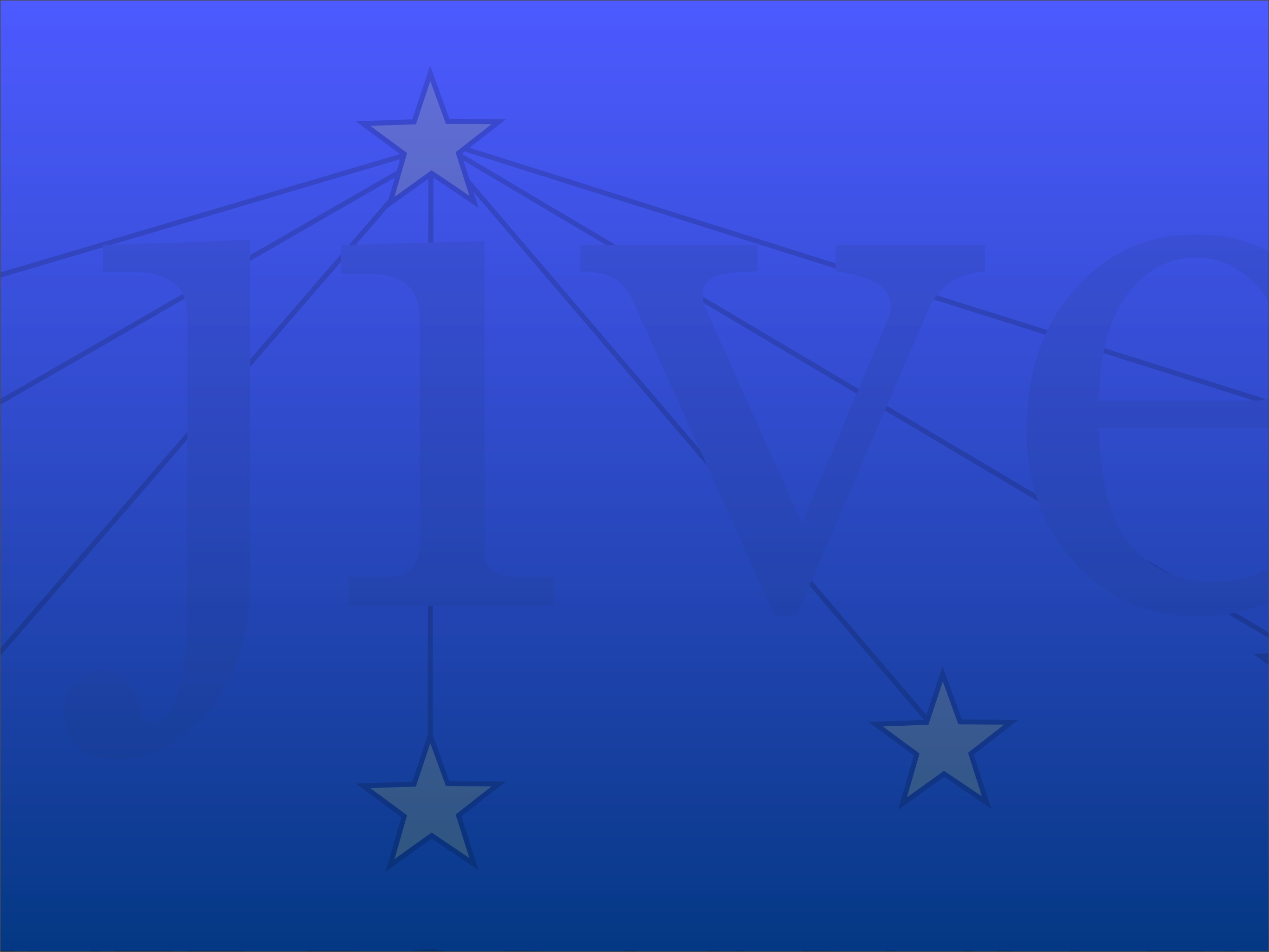
Huygens



- **User interfaces EVN include processing software**
 - VLBI still largely dependent on AIPS
- **JIVE managed RadioNet ALBUS, ALBiUS**
 - **Advanced Long Baseline interoperable User Software**
 - Adopt new algorithms for RadioNet facilities
 - And make existing algorithms available for new facilities
 - **Resulted in development of ParselTongue**
 - “AIPS talking Python”: few hundred users
 - **Work on interoperability and casa fringe fitting**
- **Continues in RadioNet3: HILADO**
 - **User models; casa VLBI pipeline**
 - Warning: not the same as mm-VLBI processing
- **Interest shared with other SKA pathfinders**
 - Dutch collaboration with ALMA regional centre ALLEGRO
 - HPC processing of radio data



- **Scientific interest among JIVE staff**
- **Expertise in real-time connectivity**
 - Including to South America
 - Maybe not directly relevant at this time
- **Familiar with (VLBI) correlators**
 - Have expertise working with NRAO on correlator GUI
- **User interfaces, scheduling, acquisition control**
 - User software, casa for VLBI
 - Admittedly mm-VLBI can be different
- **In addition to expertise around the EVN**
- **Serving European (cm) community**
 - Large scale correlator operations
 - User support in all stages of process
 - Data curation, archive, access methods



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

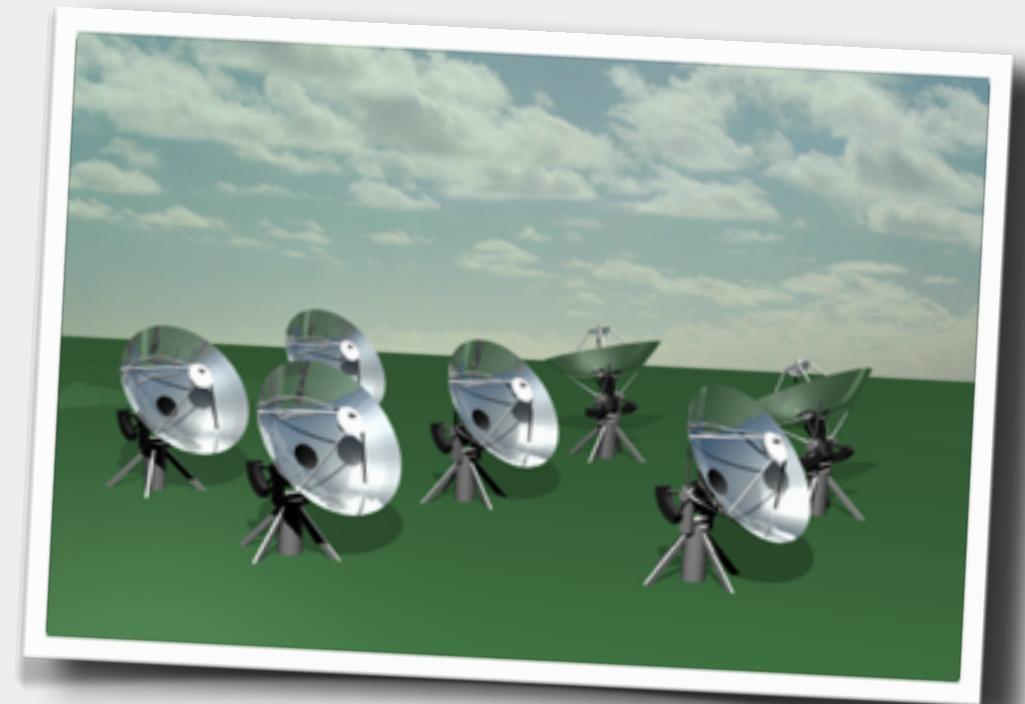


- **Lots of overlap with SKA technology**

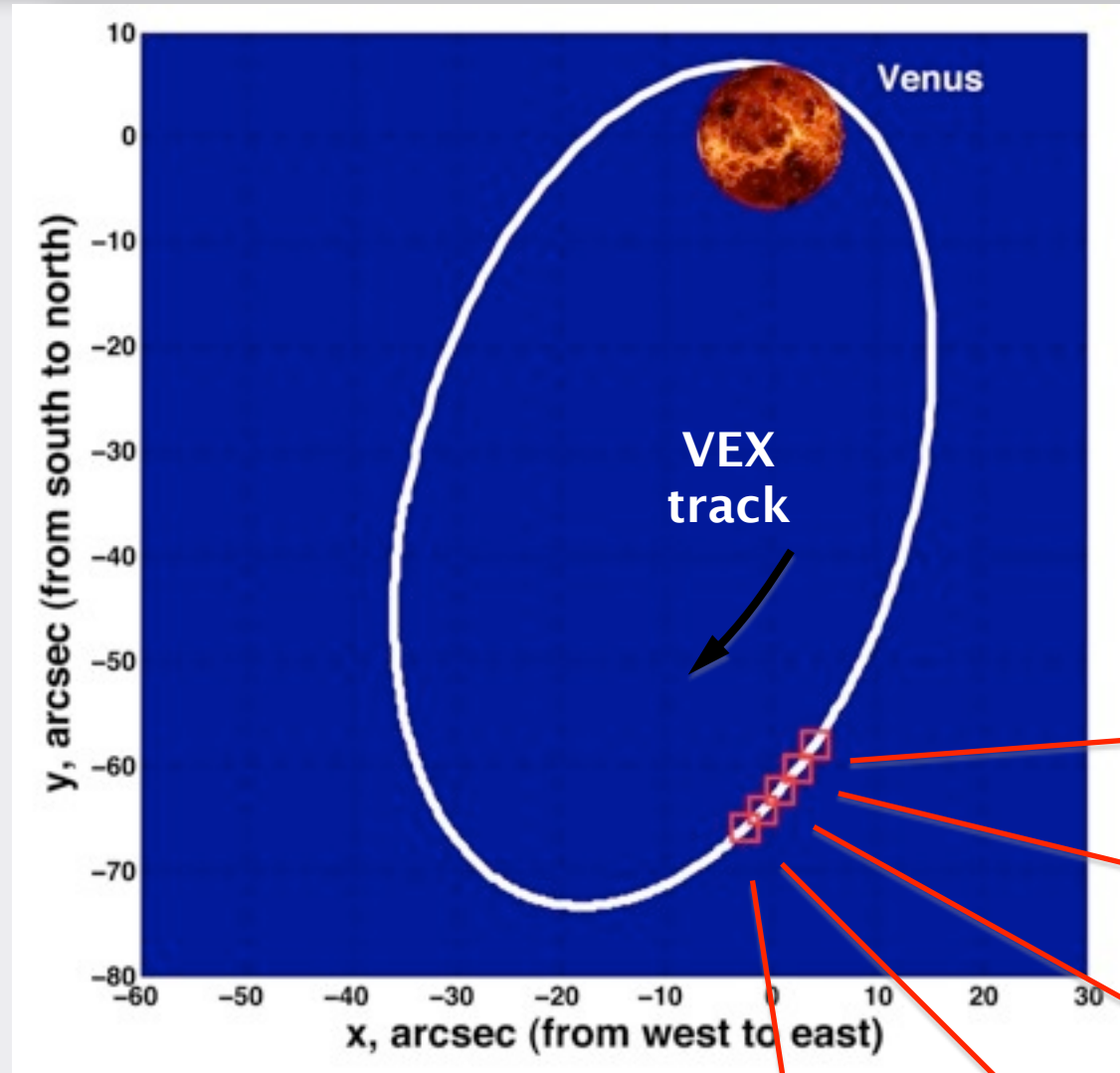
- Benefit from digital components
- Connectivity
 - Data en timing
- Processing software
- Maybe even antennas

- **Important for SKA**

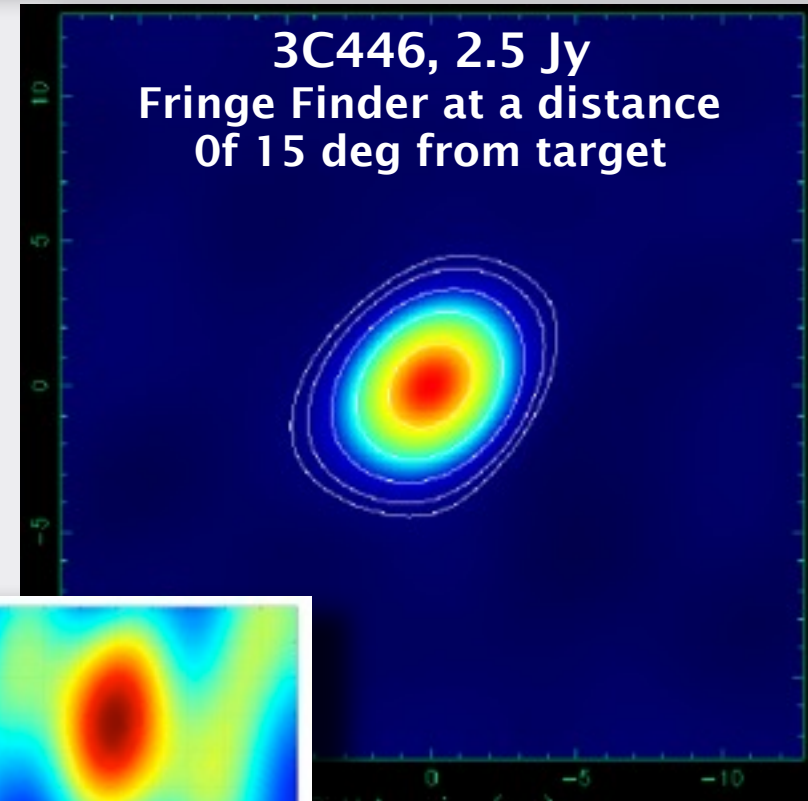
- Community building
- Training aspects
- Home telescope
- Outreach



EM081c: On, Wz, Mc, Ma, Ys, Mh, Sv, Zc



8.4 GHz
2011.03.28



09^h05^m TDB
OnWzMaMcMhSvZ
+Ys
c

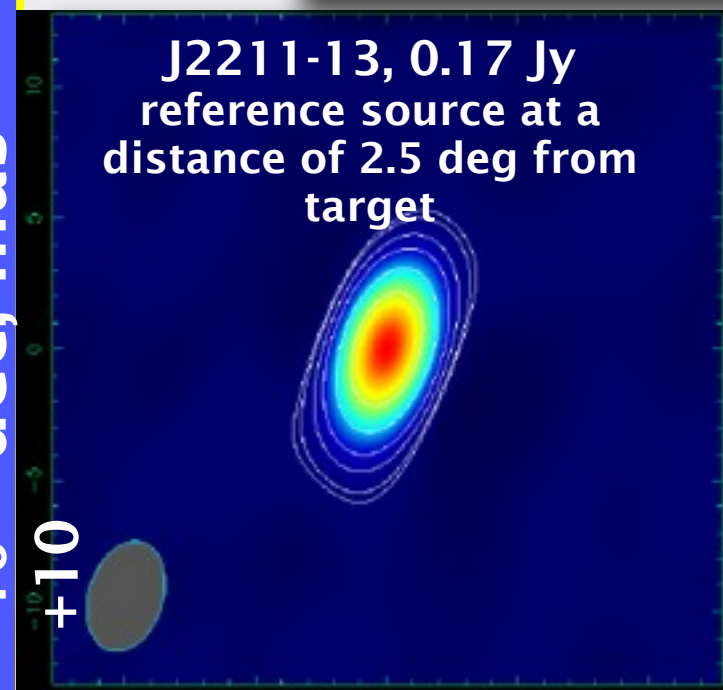
09^h30^m TDB
OnWzMaMcYsMhSvZc

09^h55^m TDB
OnWzMaMcYsMhZc

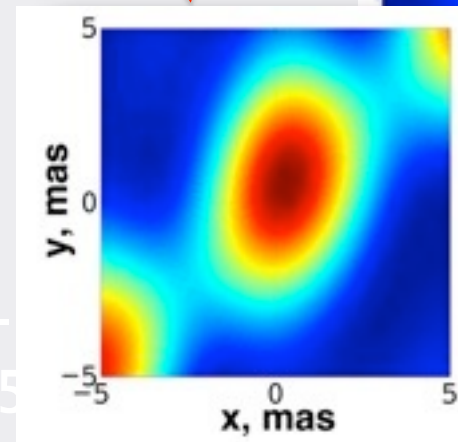
10^h20^m TDB
OnWzMaMcYsZc

10^h45^m TDB
OnWzMaMcYs

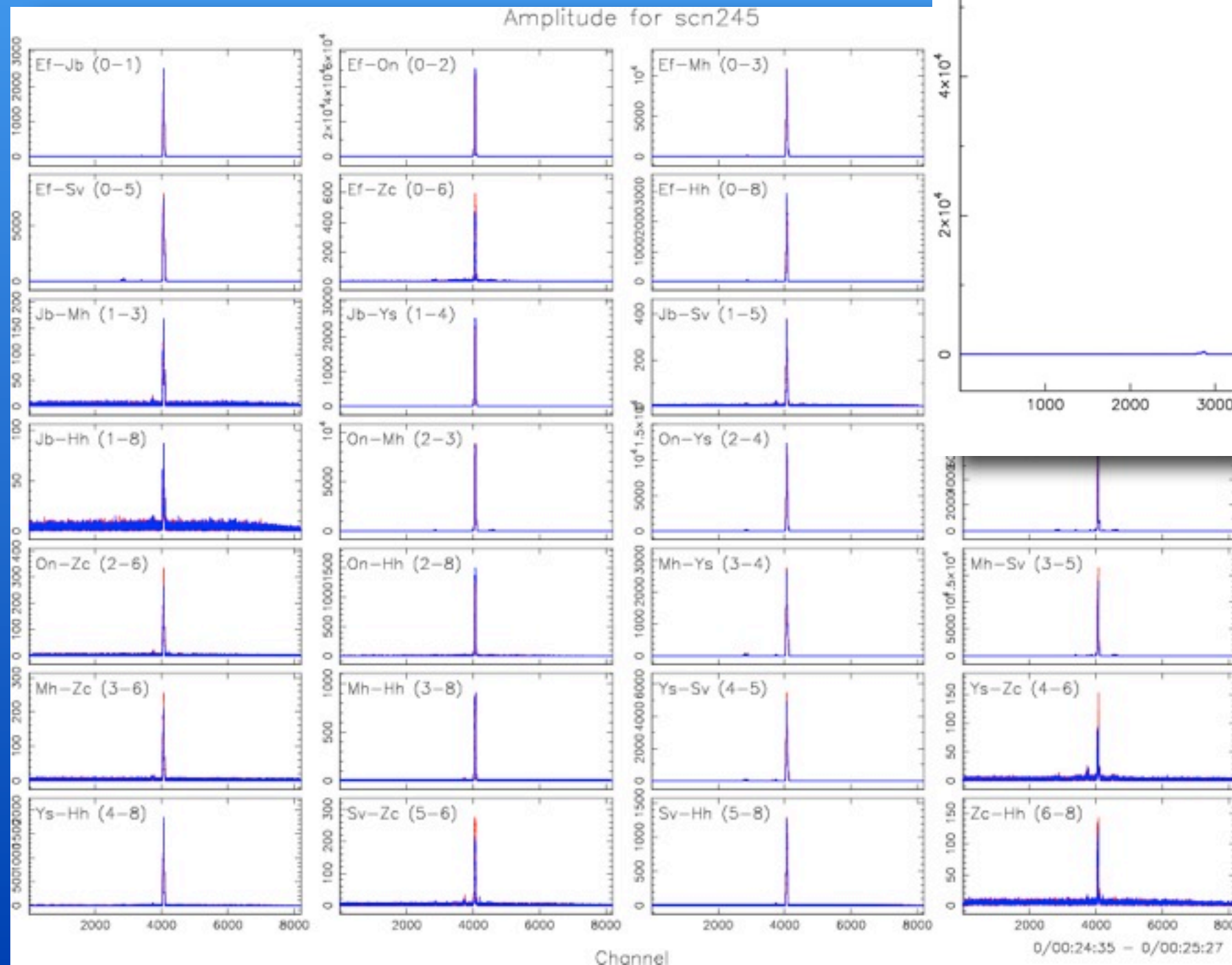
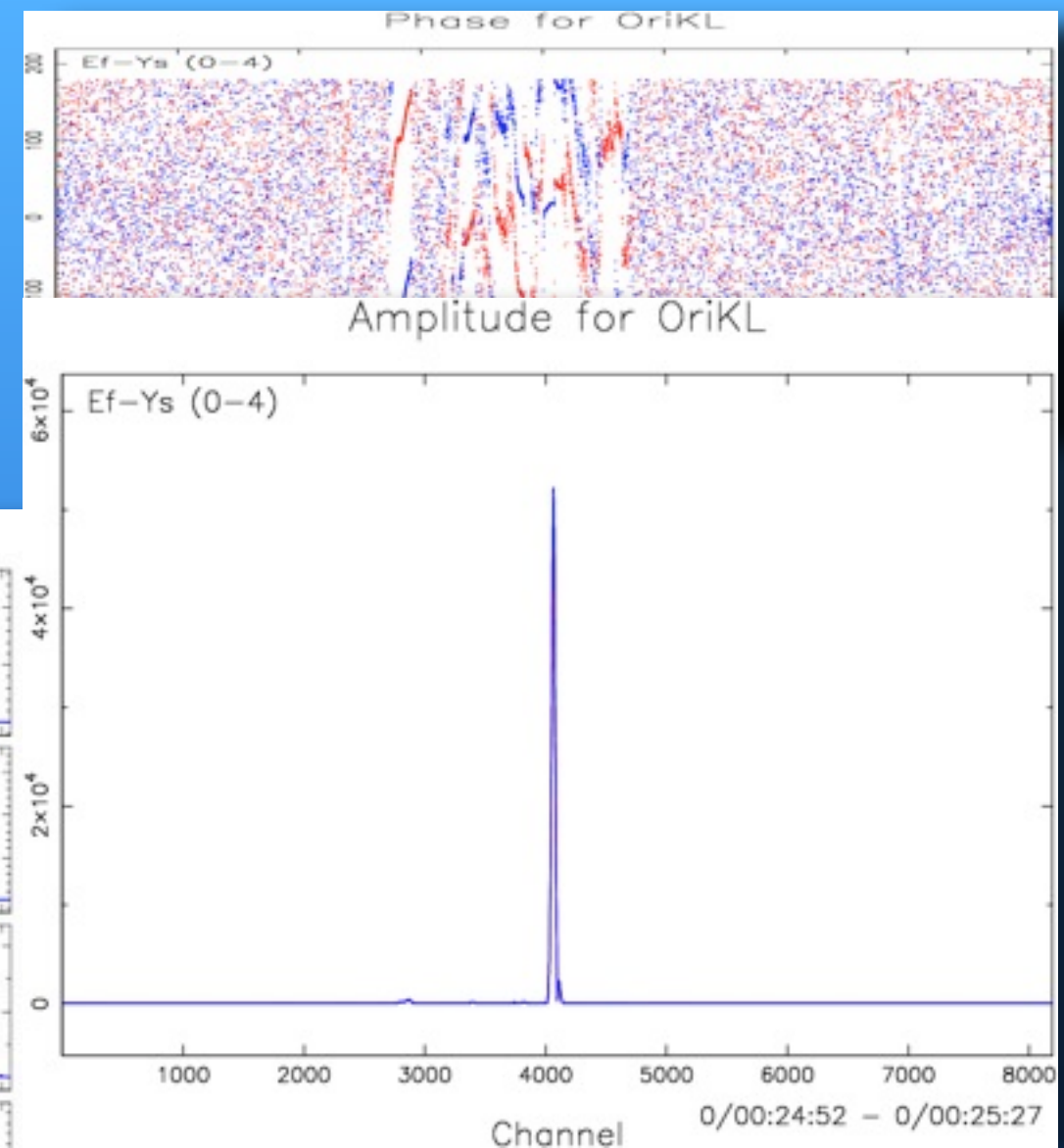
Cimo, Duev, Molera et al.
2011, in preparation



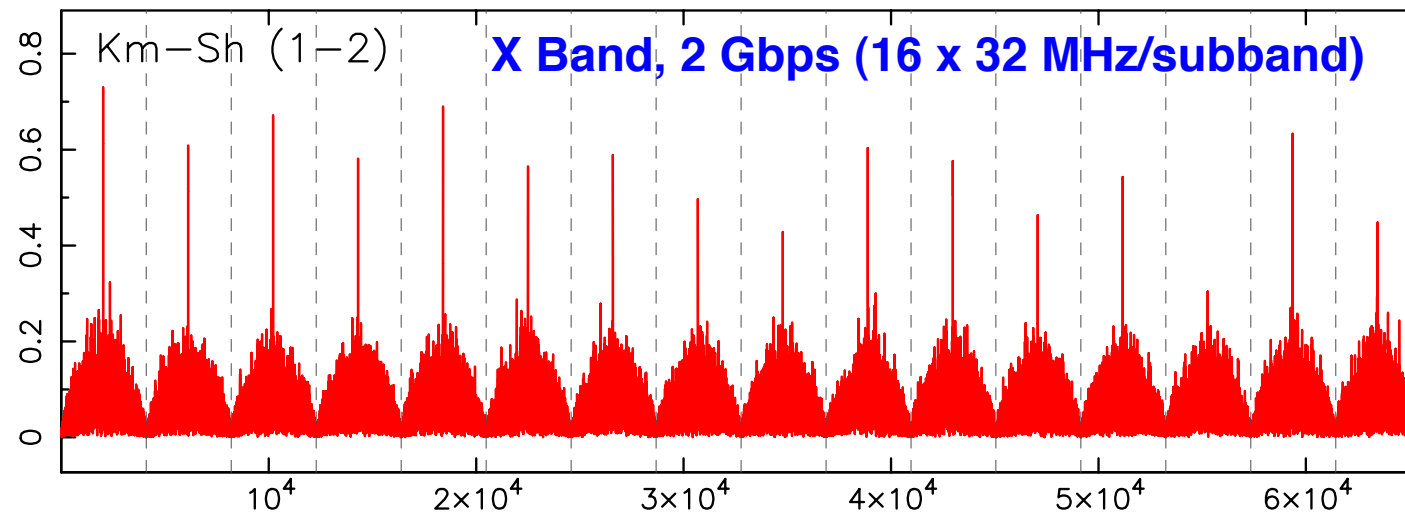
y, mas



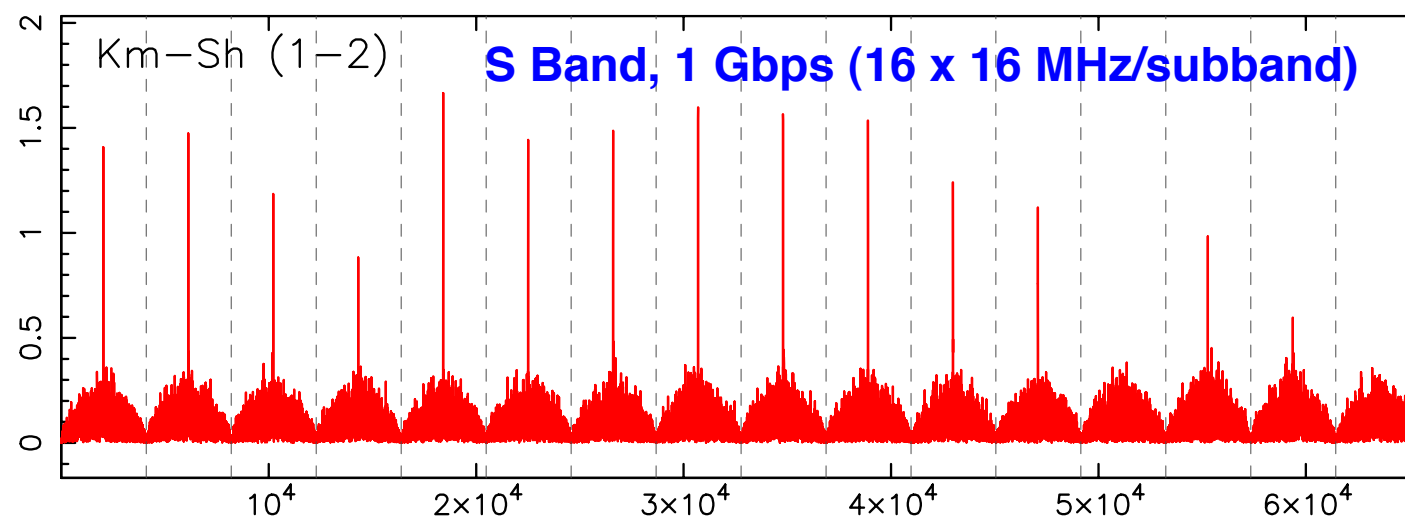
New capabilities include 8192 spectral points on Orion KL water masers flare



Amplitude for chin06a.ms

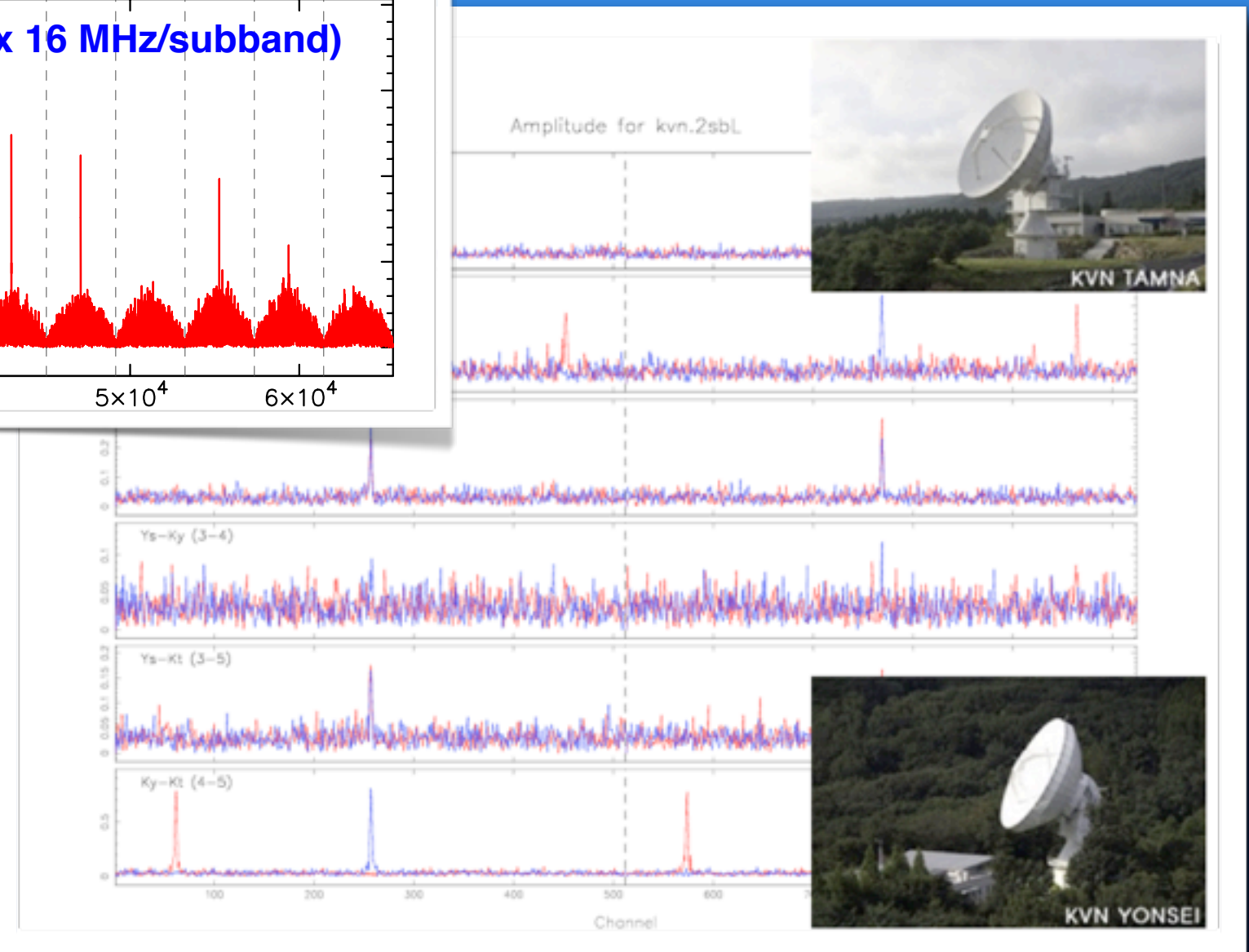


Amplitude for chin06b.ms



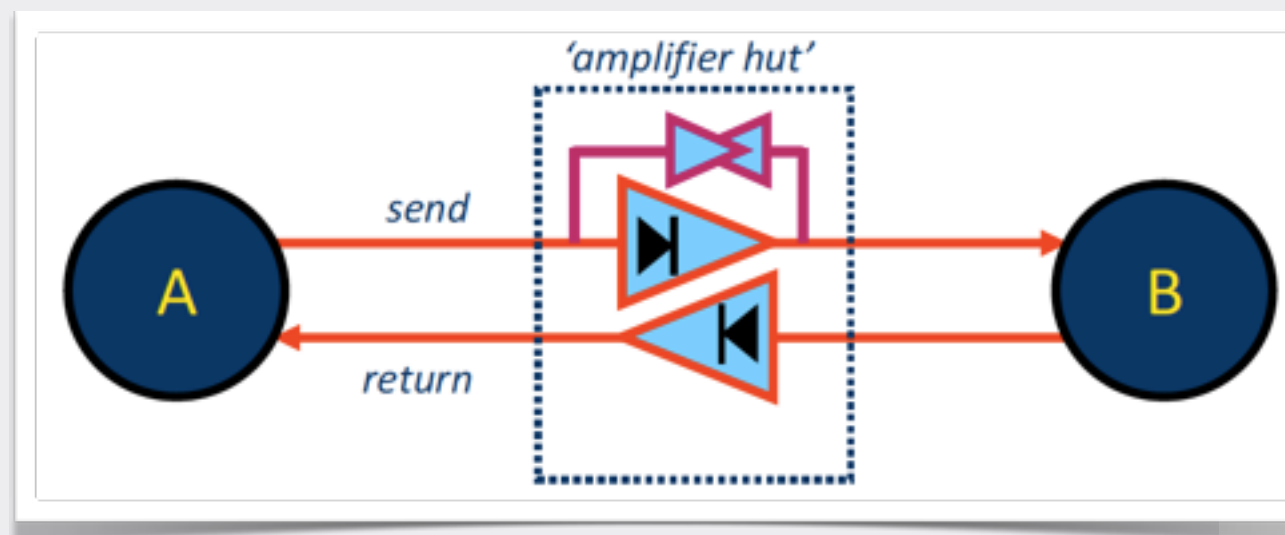
**First 3Gbps fringes
with Chinese tels.
Combining CDAS and
Mk5**

**First correlation of
European - Korean
baselines at K-band**



Future 2: clock distribution

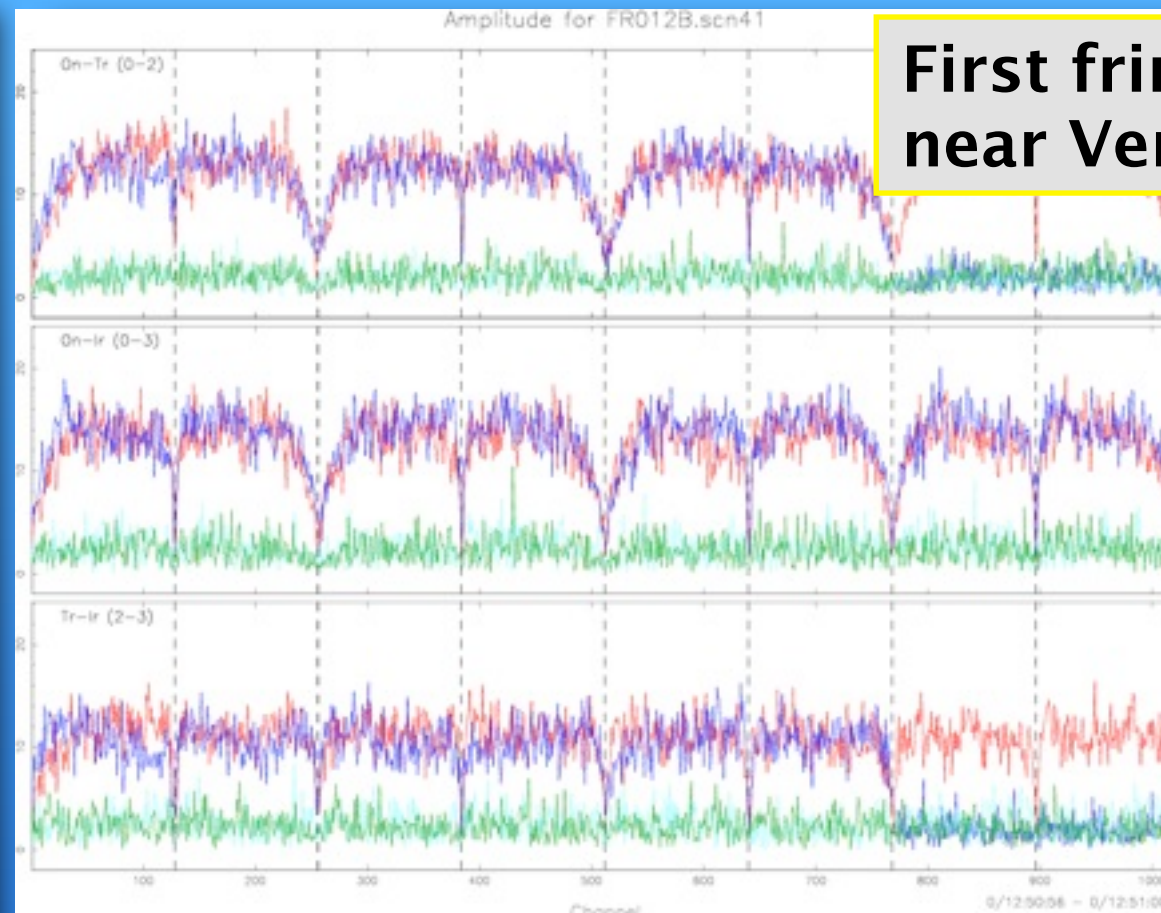
- VLBI depends on availability of extremely accurate clock and frequency standard (10^{-15})
 - All telescopes must have 100k€ maser clock
 - In principle can be distributed over dedicated fibre
- Investigate clock distribution on public network
 - Requires dedicated wavelength and stable amplification
 - To measure return loop



- Will improve stability, operations
- And many more VLBI sites!



- **User community is the most precious asset**
 - Make sure the interfaces are uniform and robust
 - User software, User support, Training, Proposal handling, Scheduling
 - Do not increase number of interfaces to different networks
 - but reduce and simplify
 - We do not have a user community to run 6 different networks
 - e-VLBI is helping us to foster user involvement
 - Gets the excitement of astronomical observation into VLBI
- **Should build on these e-VLBI meetings**
 - Could have a wider topic, they already have
 - BTW, next EVN symposium is in Bordeaux, October 2012
- **Pushing technology is part of the mission**
 - e-VLBI has helped keeping us visible
- **Long-term common goal?**
 - Global VLBI array which react flexible on user demands
 - Needed to satisfy scientists used to SKA/ALMA



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

