

EXPReS & NEXPReS

an evolution pathway for VLBI into the SKA era

Huib van Langevelde

JIVE

- **EXPRReS; introducing e-VLBI**
 - Technological progress
 - Operational service
 - Scientific achievements
- **Introducing NEXPRReS**
 - Objectives of the new program
- **e-VLBI and the future**
 - economic aspects
 - SKA pathfinder
 - evolving VLBI

20 min talk, time for discussion

- **EVN consortium with 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



Irbene 32m



Svetloe



Zelenchukskaya



Sardinia 64m

© INAF - Osservatorio Astronomico di Cagliari



Yebes 40m



Kunming 40m



Miyun 50m



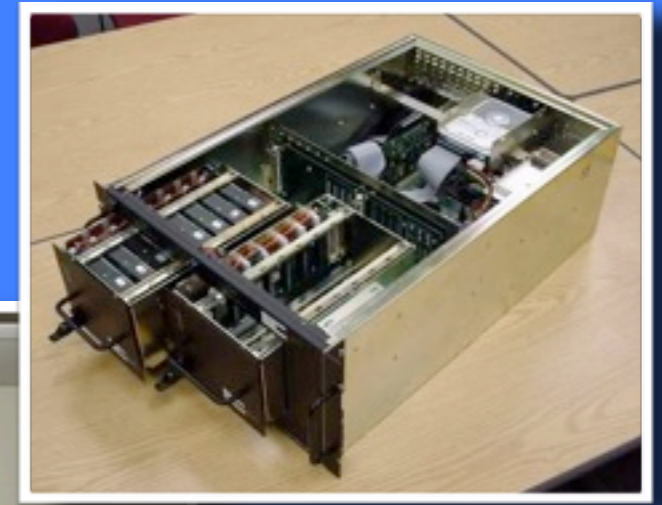
Badary

- **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, the Netherlands
 - Some funding agencies, some institute contributions
 - hosted by ASTRON
- **Large number of external projects**
 - Many people with temp positions in R&D/Science
- **32 people, 12 nationalities**
 - 3.6M€ annual budget, 2.1 in local operations



• Current correlator

- 1024 custom chips
- 16x16 baselines, 0.25s



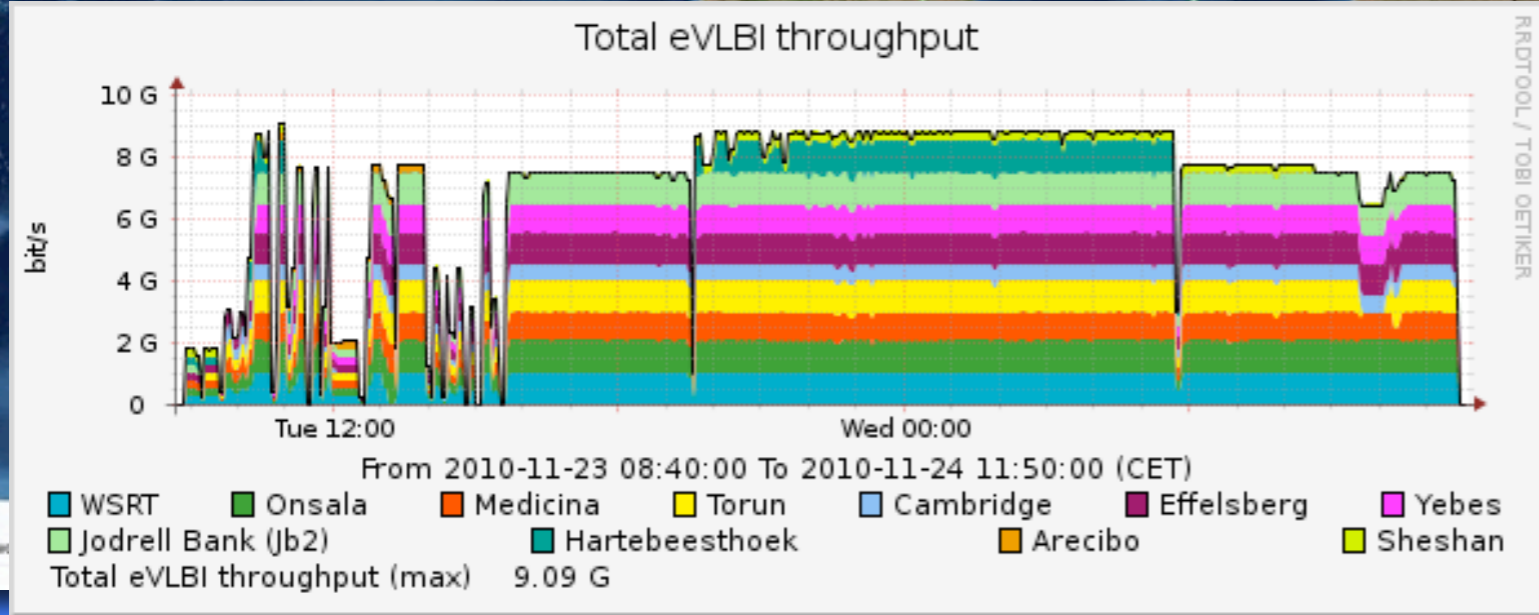
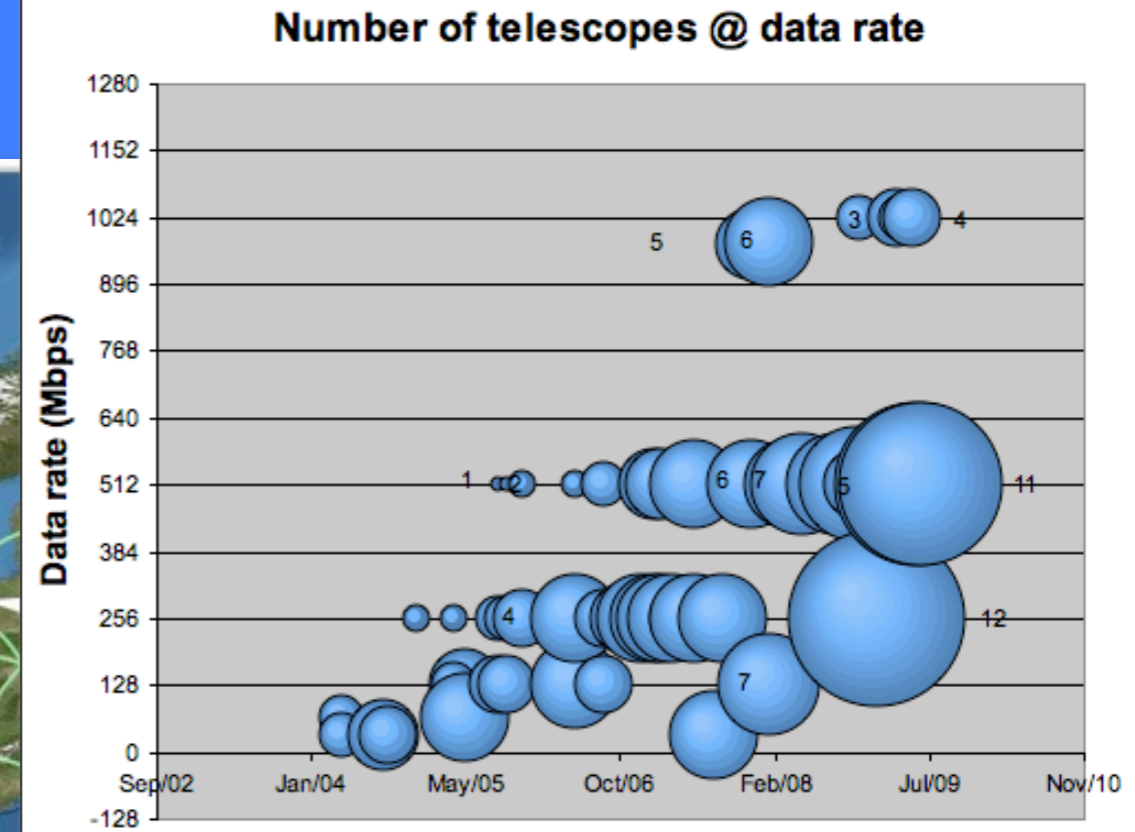
Turned into e-VLBI

- **PC based recording**
 - Also allows Internet transmission
 - Started with a pilot in 2004
- **And was boosted with EXPReS**
 - Retrofit correlator to work real-time
 - Help solve last mile problem at telescopes
 - Work with NRENs on robust connectivity
 - Push to 1024 Mb/s limit
 - Change of VLBI culture in EVN
- **Now an operational facility**
 - Guaranteed 10 x 24h per year
 - Flexible ways to get into e-VLBI
 - Request e-VLBI for fast response
 - Or for triggered proposals
 - Short requests <2hr
 - Target of Opportunities
 - Or just because you prefer to e!



Express Production Real-time e-VLBI Service

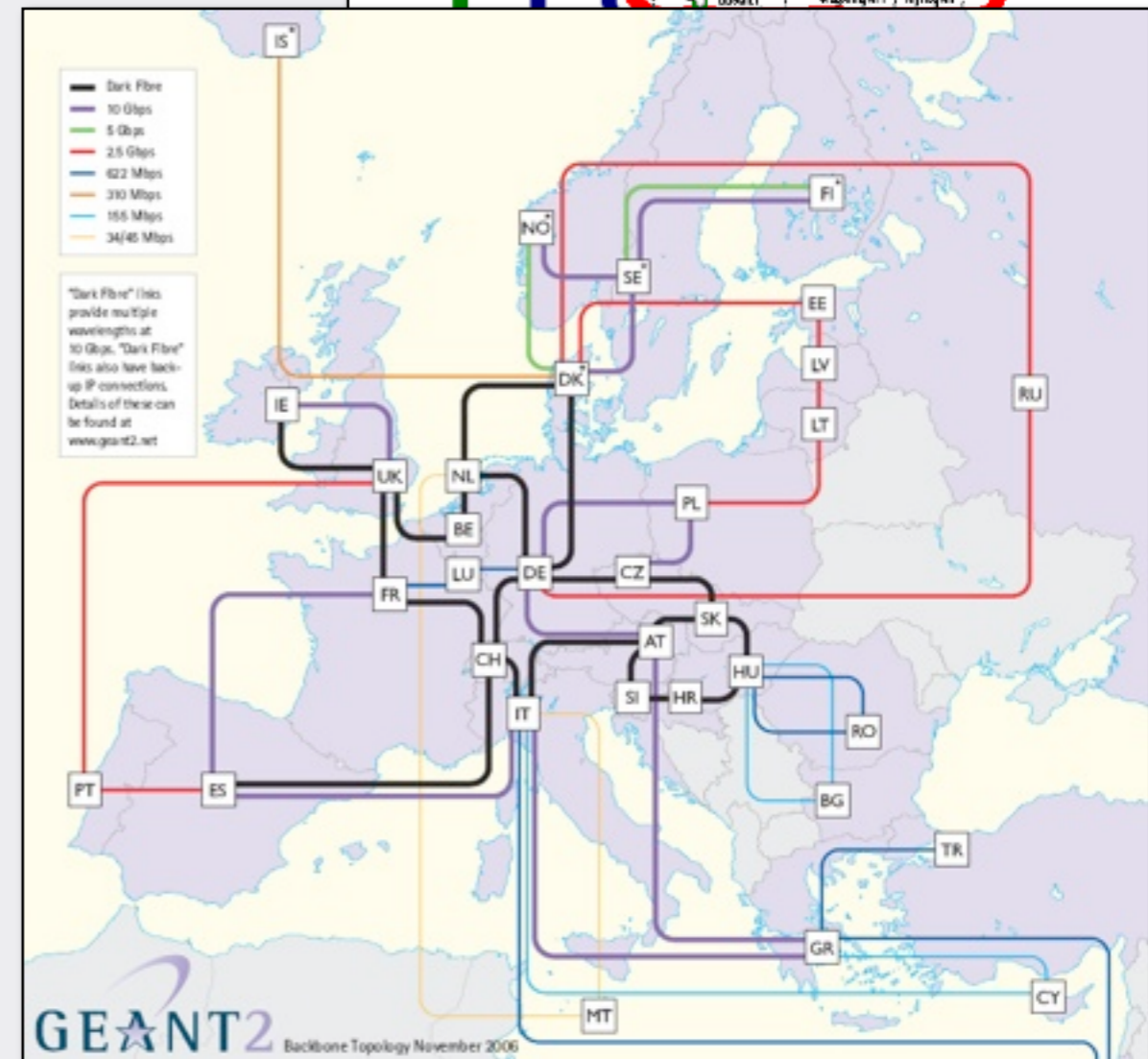
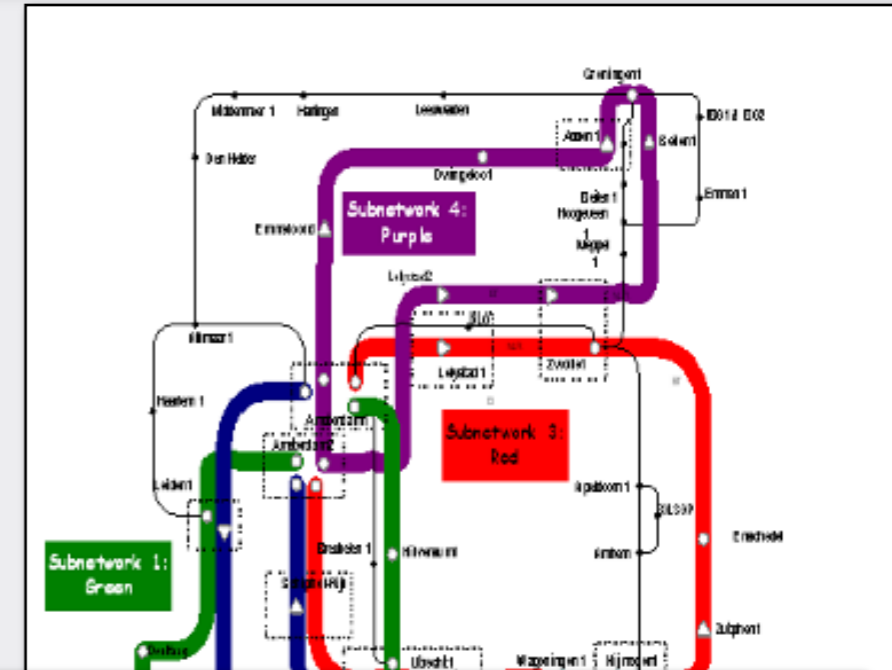
- **Connections work great!**
 - often dedicated light paths
 - Use optimized protocols
- **Closed feedback loop makes e-VLBI more robust**

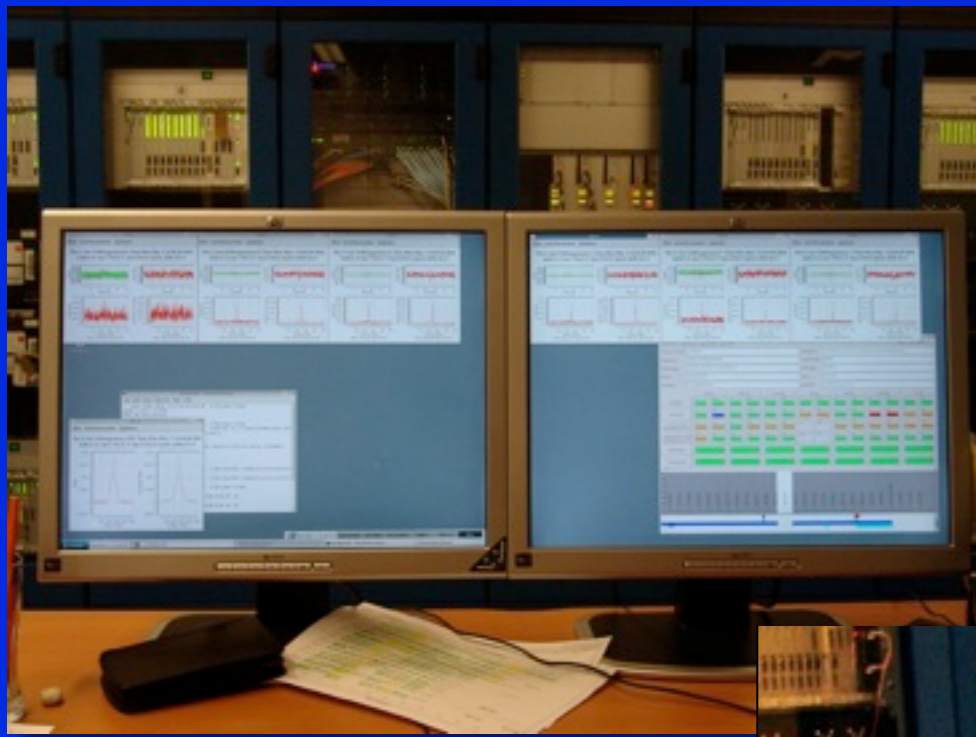


- **When we started e-VLBI and the EXPReS project**
 - First pilots in 2004
 - EXPReS funded in 2006 by the EC, finishes in September
- **Amongst our original concerns:**
 - Can we connect all telescopes on competitive time-scale?
 - Will we be able to deliver interesting bandwidth?
 - Will e-VLBI be just as reliable?
 - Will it be applicable to Global VLBI?
 - Will it produce new science?
 - Will it be cost effective?
 - Can we accommodate all types of projects?
- **Looking at the progress with e-VLBI:**
 - yes
 - yes
 - yes, even more robust
 - yes

Cost effective?

- Shipping much cheaper than bandwidth at commercial rates
 - Lucky with blessing at European level
 - Made local providers supportive
 - Commitment of partners (also LOFAR)
- Strategic issue for NRENs
 - Lightpath technology
 - will be economic and green



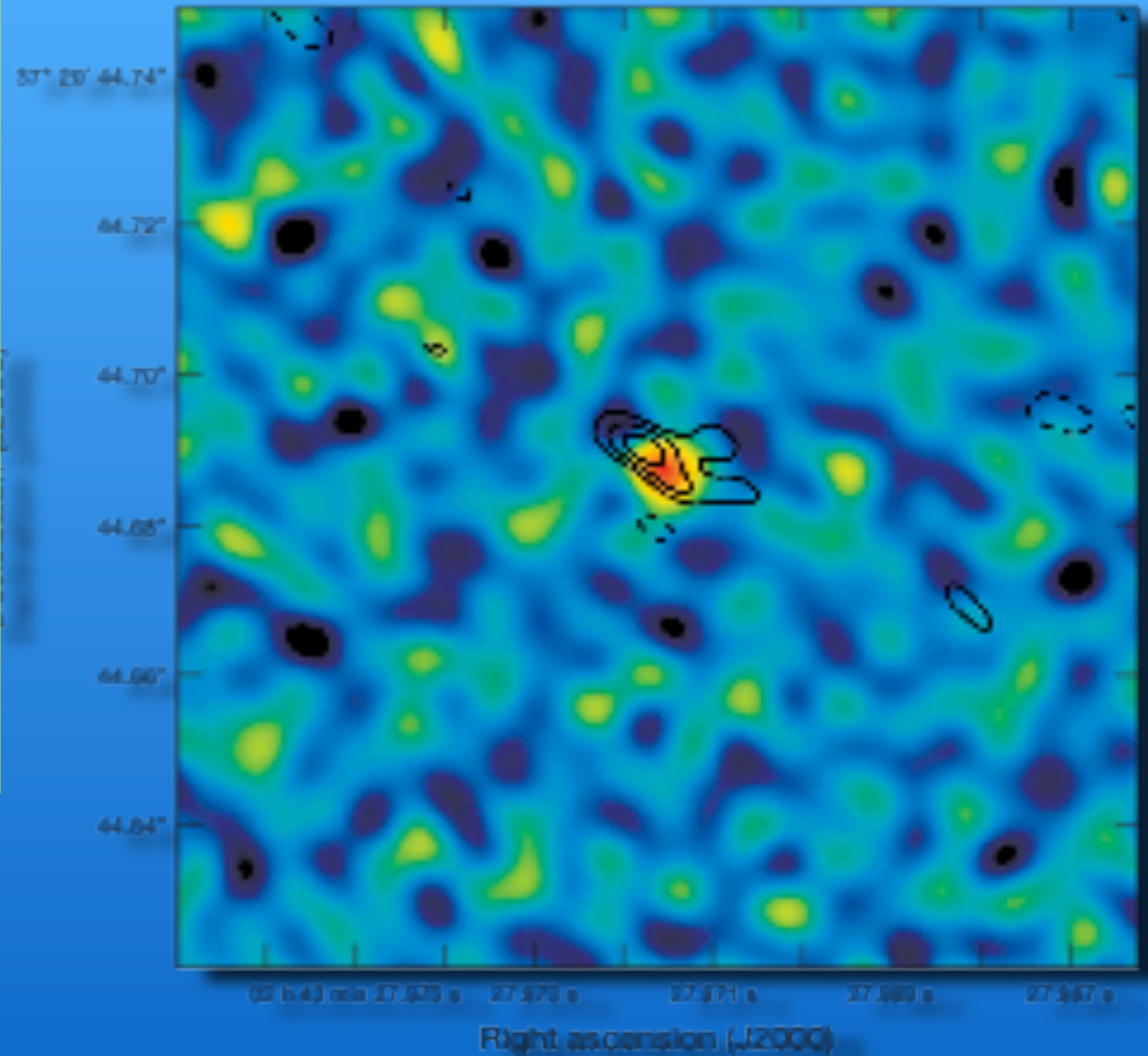


- Now sustained 24hr observing runs now possible
- Can be run by a single person
- Can be rewarding experience!



SN2007gr

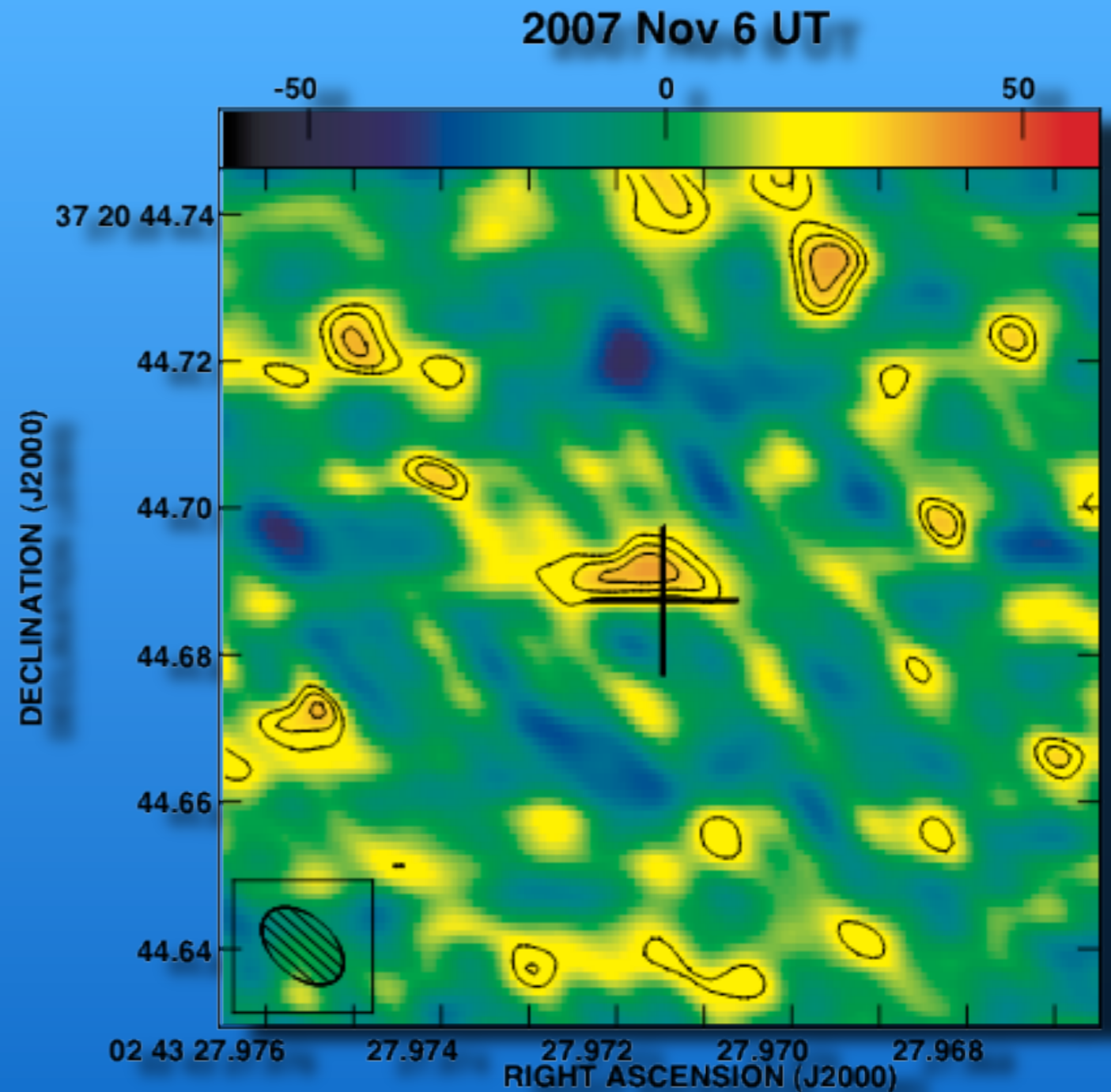
- Nearby type Ic supernova
- e-VLBI within 20 days
 - detection at $400 \mu\text{Jy}/\text{beam}$ level
- Two months later EVN+GBT:
 - Weaker detection
 - VLBI vs. WSRT total flux
 - mildly relativistic ($>0.6c$) expansion!
- First direct detection of relativistic expansion in a supernova
- Link with Gamma Ray burst



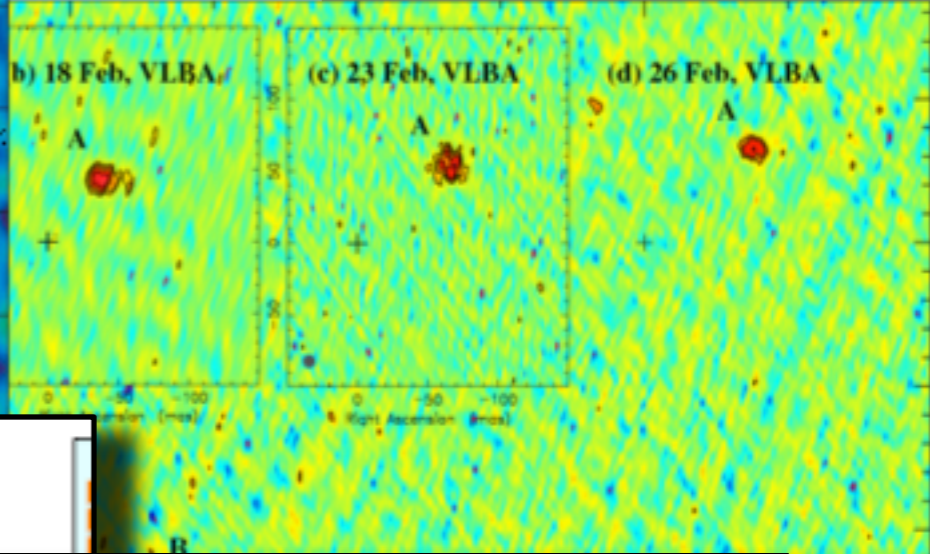
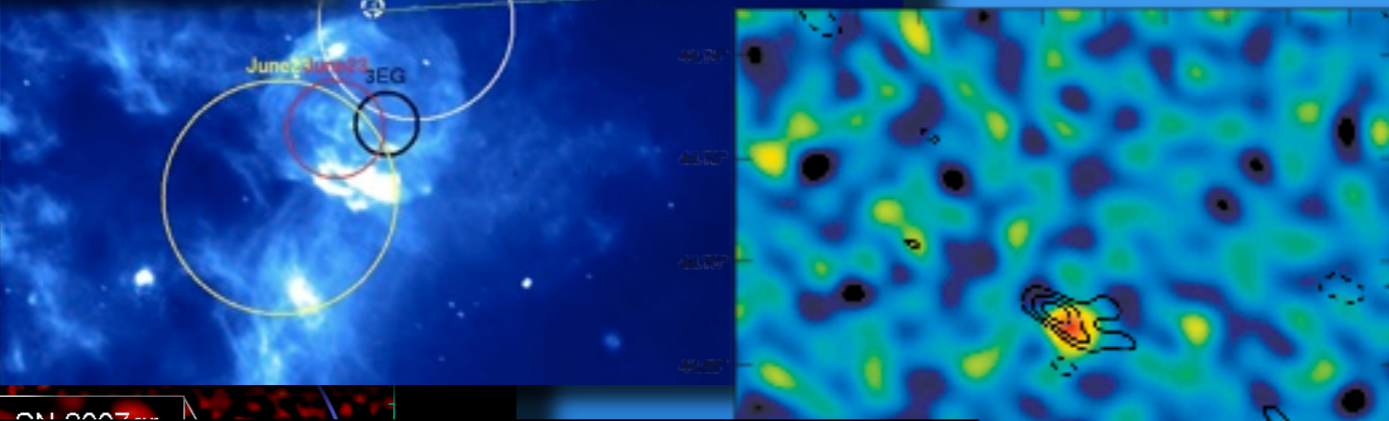
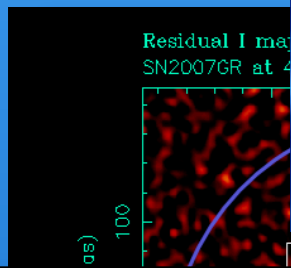
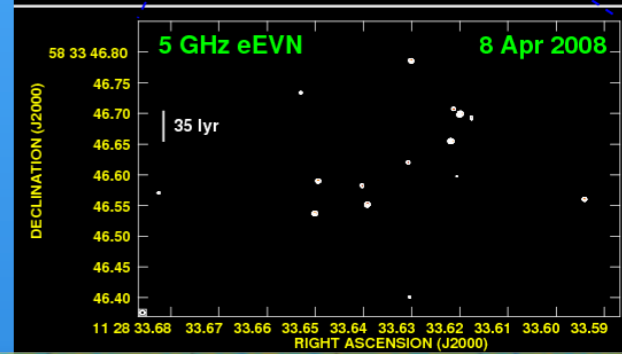
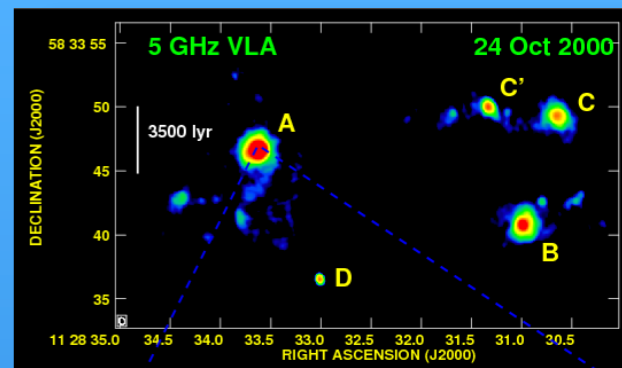
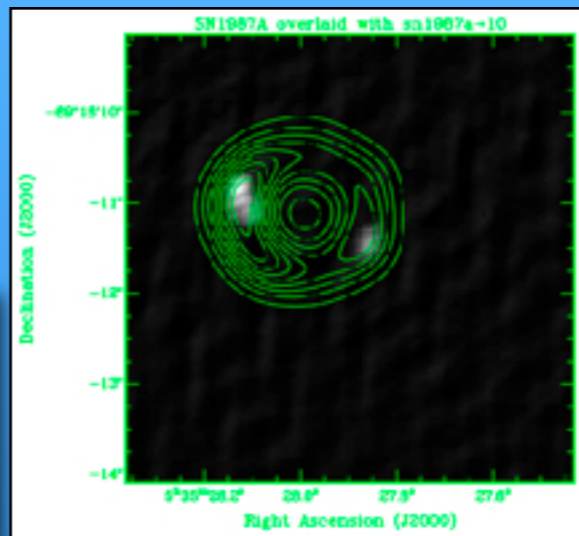
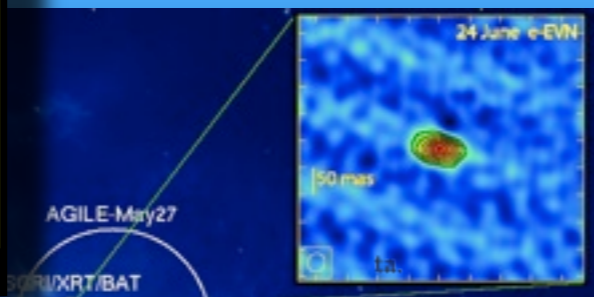
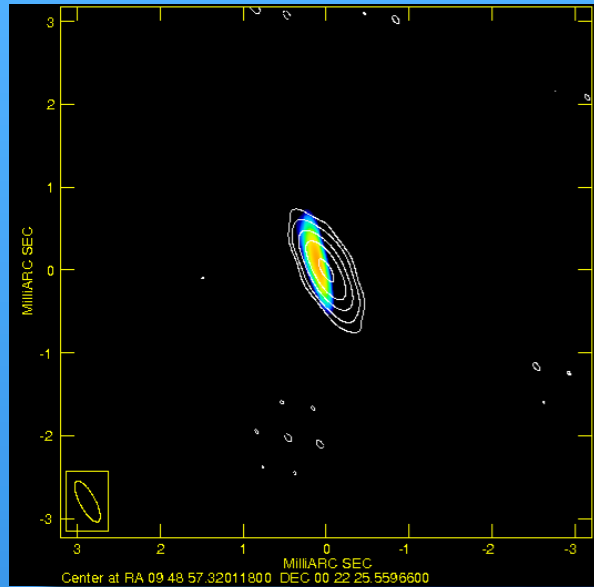
Paragi et al., Nature 2010, 463 516

SN2007gr

- Nearby type Ic supernova
- Detailed modelling
 - And use of VLA light-curve
- Argue for ordinary SNe Ibc
- Confirm e-VLBI detection
 - But question the overall calibration
- Two months later EVN+GBT:
 - Also weak detection
 - But question resolved nature
 - No need for relativistic expansion



Soderberg et al, 2010 ApJ 725 922



Outside
GCN
IAUCs

Other
MacOS: [Dashboard Widget](#)
Follow ATel on [Twitter](#)

The Astronomer's Telegram
For reporting and commenting on new astronomical observations
[Post a New Telegram](#) | [Search](#) | [Information](#) | [Mirror Software](#)

Outside
GCN
IAUCs

Other
MacOS: [Dashboard Widget](#)
Follow ATel on [Twitter](#)

[Register To Post](#) | [Email us](#)

The Astronomer's Telegram
For reporting and commenting on new astronomical observations
[Post a New Telegram](#) | [Search](#) | [Information](#) | [Mirror Software](#)

Outside
GCN
IAUCs

Other
MacOS: [Dashboard Widget](#)
Follow ATel on [Twitter](#)

[Retraction of ATel #2538](#)

The Astronomer's Telegram
For reporting and commenting on new astronomical observations
[Post a New Telegram](#) | [Search](#) | [Information](#) | [Mirror Software](#)
[Telegram Index](#)

[Register To Post](#) | [Email and RSS Subscriptions](#) | [Forgot your password?](#)

Present Time: 8 Jun 2010; 12:43 UT

RSS

- [XML](#) Top
- [XML](#) Supernovae
- [XML](#) Transients
- [XML](#) SGRs
- [XML](#) Gamma Ray Bursts
- [XML](#) Comets

EVN observations of the

ATel #2437; [M. Giroletti \(INAF/IRAF\)](#), [E. Koerding \(Univ. Paris Diderot & CEA Saclay\)](#), [S. Corbel \(Univ. Paris Diderot & CEA Saclay\)](#), [K. Sokolovsky \(MPIJR/ASC Lebedev\)](#), [L. Fuhrmann \(MPIJR\)](#), [E. Schinzel \(MPIJR\)](#), [C.C. Cheung \(NRC/NRL\)](#) on behalf of the Fermi-LAT collaboration
on 13 Feb 2010; 21:43 UT
Password Certification: Catherine Brocksopp

Subjects: Radio, >GeV, AGN, Black Holes, Transients, Variables, Stars

We report on EVN observations of the symbiotic star V407 Cyg, following its classical nova outburst (CBET #2199, CBET #2204) and its surprise detection in gamma-rays (ATel #2487) and radio cm and mm bands (ATel #2506, ATel #2511, ATel #2514). The radio continuum observations were carried out at 5 GHz by 9 telescopes for about 9 hours between 23h March 30 and 13h March 31, 2010.

Detection of Probable Jet Component in the e-EVN

ATel #2438; [Catherine Brocksopp \(MSSL\)](#), [Jun Yang \(Univ. Paris Diderot\)](#), [Tasso Trioumis \(ATNF\)](#), [Roberto Corbelli \(INAF/IRAF\)](#), [E. Koerding \(Univ. Paris Diderot & CEA Saclay\)](#), [S. Corbel \(Univ. Paris Diderot & CEA Saclay\)](#), [K. Sokolovsky \(MPIJR/ASC Lebedev\)](#), [L. Fuhrmann \(MPIJR\)](#), [E. Schinzel \(MPIJR\)](#), [C.C. Cheung \(NRC/NRL\)](#) on behalf of the Fermi-LAT collaboration
on 13 Feb 2010; 21:43 UT
Password Certification: Catherine Brocksopp

Subjects: Radio, Binaries, Black Holes, Transients

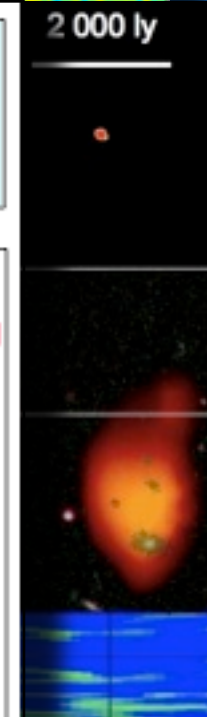
Following the reported increased radio emission of XTE J1402.0-6130 (ATel. 2387, 2391, 2396), we have made real-time e-VLBI observations with the European VLBI Network (EVN) in real-time e-VLBI mode.

VLBI detection of V407 Cyg

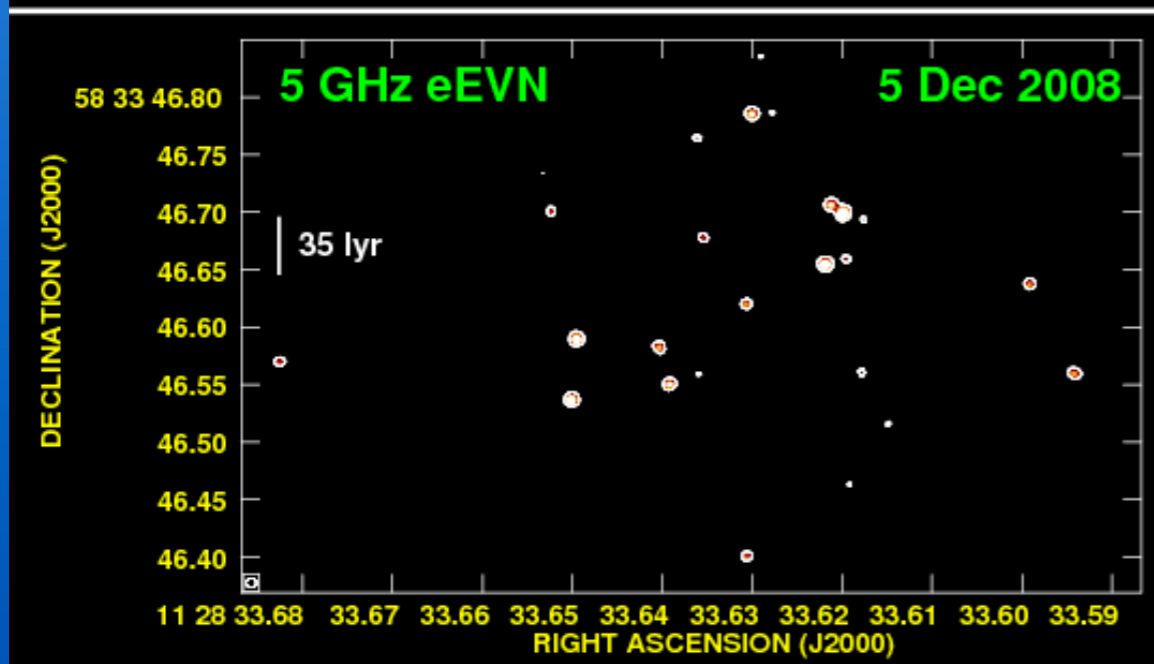
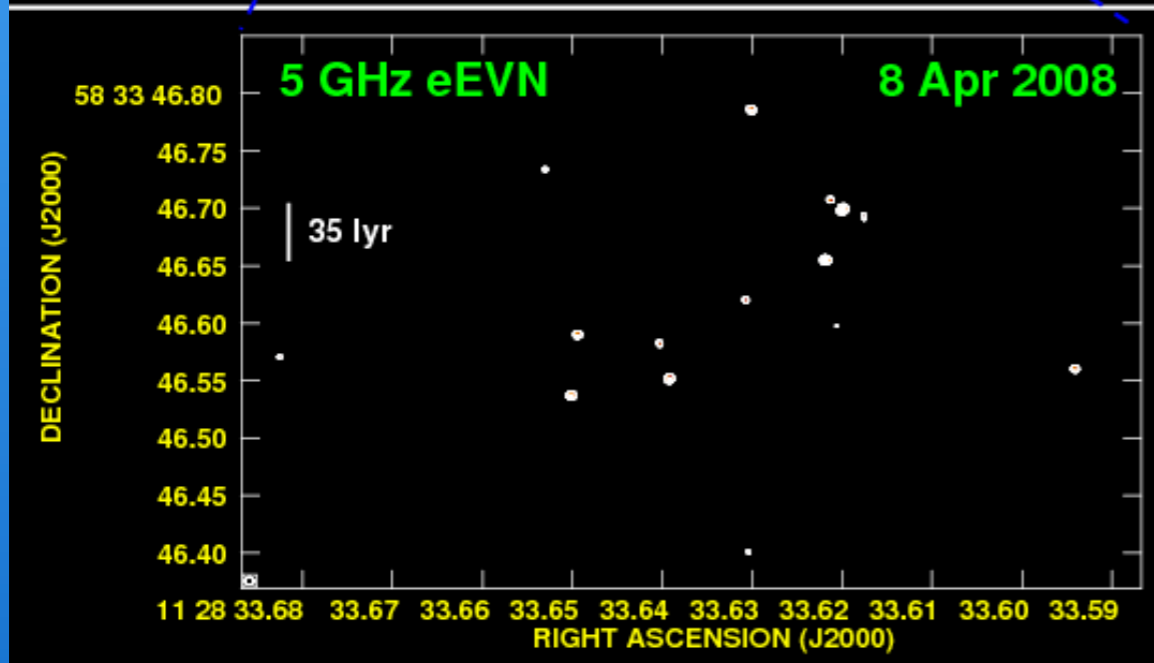
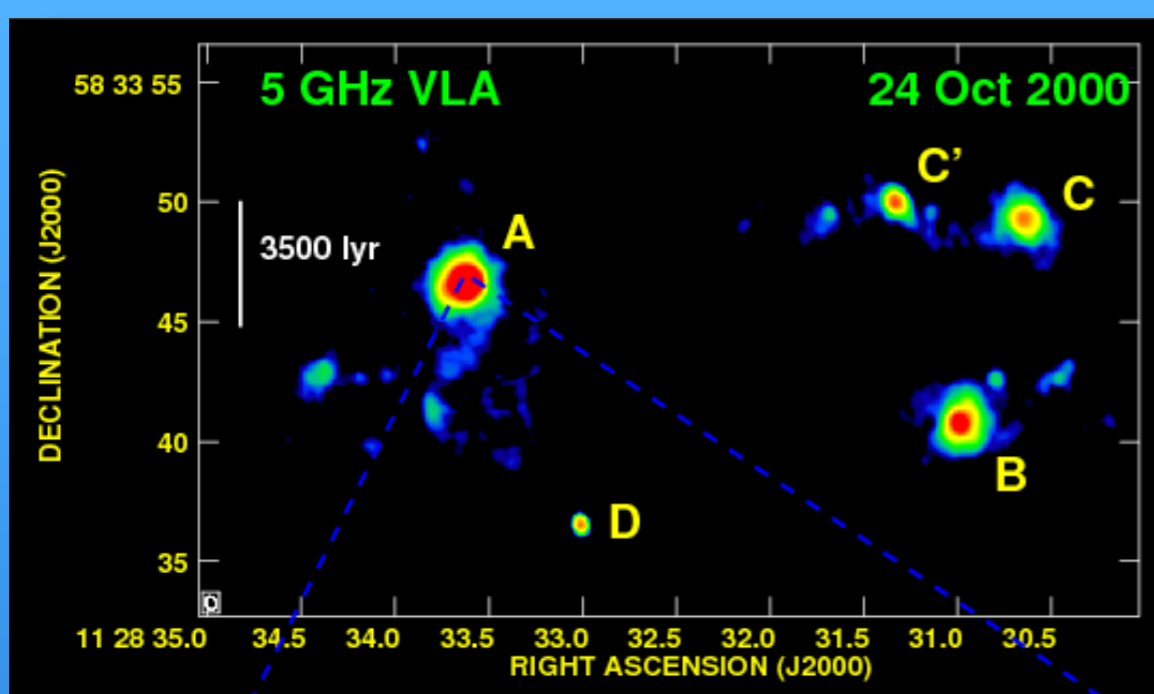
ATel #2536; [Giroletti \(INAF/IRA\)](#), [E. Koerding \(Univ. Paris Diderot & CEA Saclay\)](#), [S. Corbel \(Univ. Paris Diderot & CEA Saclay\)](#), [K. Sokolovsky \(MPIJR/ASC Lebedev\)](#), [L. Fuhrmann \(MPIJR\)](#), [E. Schinzel \(MPIJR\)](#), [C.C. Cheung \(NRC/NRL\)](#) on behalf of the Fermi-LAT collaboration
on 6 Apr 2010; 18:23 UT
Password Certification: Marcello Giroletti (giroletti@ira.inaf.it)

Subjects: Radio, Gamma Ray, Novae, Transients, Variables, Stars
Referred to by ATel #: [2546](#)

We report on EVN observations of the symbiotic star V407 Cyg, following its classical nova outburst (CBET #2199, CBET #2204) and its surprise detection in gamma-rays (ATel #2487) and radio cm and mm bands (ATel #2506, ATel #2511, ATel #2514). The radio continuum observations were carried out at 5 GHz by 9 telescopes for about 9 hours between 23h March 30 and 13h March 31, 2010.



- Related**
- 2546 [Discovery of coronal emission lines in V407 Cyg](#)
 - 2536 [VLBI detection of V407 Cyg](#)
 - 2529 [V407 Cyg: Allen Telescope Array Observations](#)
 - 2514 [15-GHz flux density of V407 Cyg](#)
 - 2511 [Radio detection of V407 Cyg at 30 GHz with OACA-2 on the Torii telescope](#)
 - 2506 [Radio detection of V407 Cyg: the possible counterpart of the new Fermi-LAT Gamma-ray transient J2102+4542 with the Effelsberg 100-m, OVRO 40-m and IRAM 30-m telescopes](#)
 - 2498 [INTERCAL view of the sky field containing Fermi J2102+4542](#)
 - 2487 [Fermi-LAT Detection of a New Galactic Plane Gamma-ray Transient in the Cygnus Region: Fermi J2102+4542 and its Possible Association with V407 Cyg](#)



Supernova factory in Arp229A

Burst of star-formation leading to numerous

- SNe hidden by dust

Closely spaced EVN e-VLBI observations

- new radio sources appear, SNe or remnants

- 26 radio sources in the central 150pc

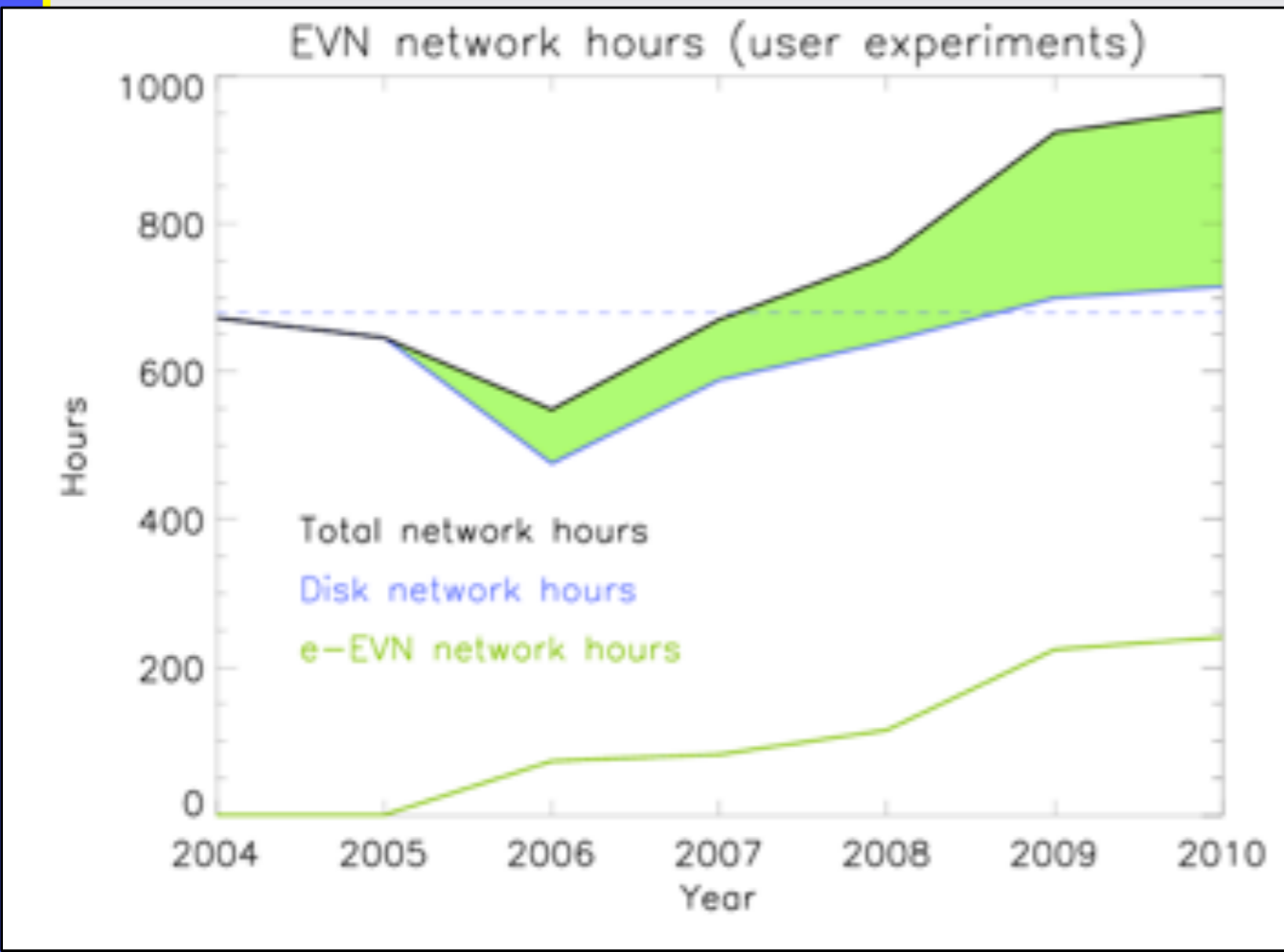
Further monitoring constrains

- the star-formation rate

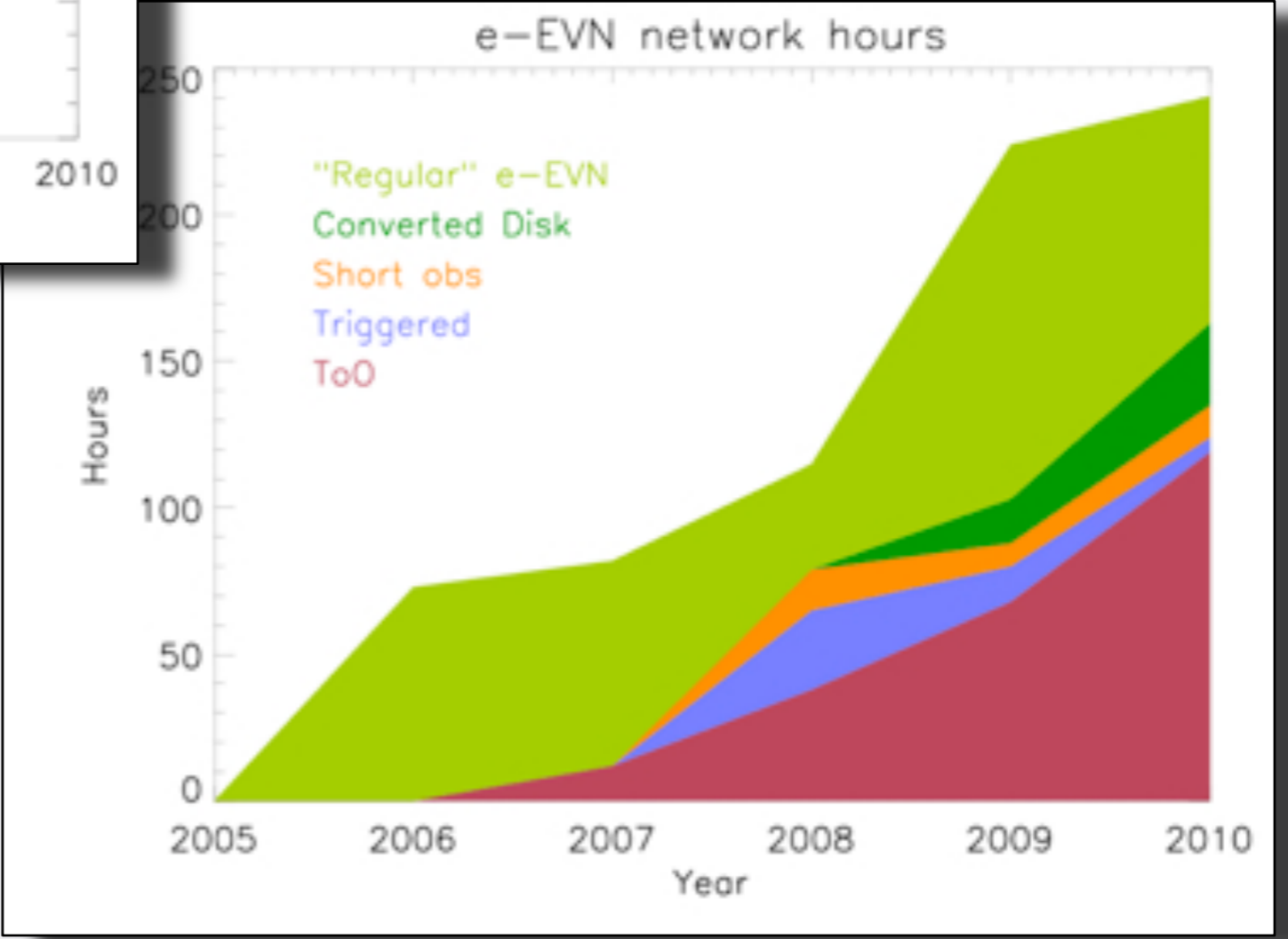
- initial mass-function

Perez-Torres et al. (2009). A&A 507 L17

e-EVN operations plots



- Disk-based network hours roughly constant
- 2010 e-EVN network hours now at 240.5
- Total network hours 2010 at 999



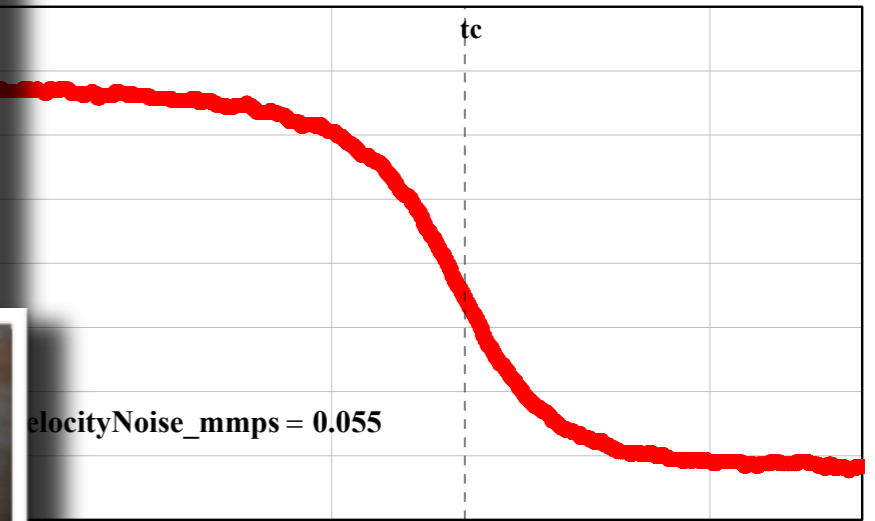
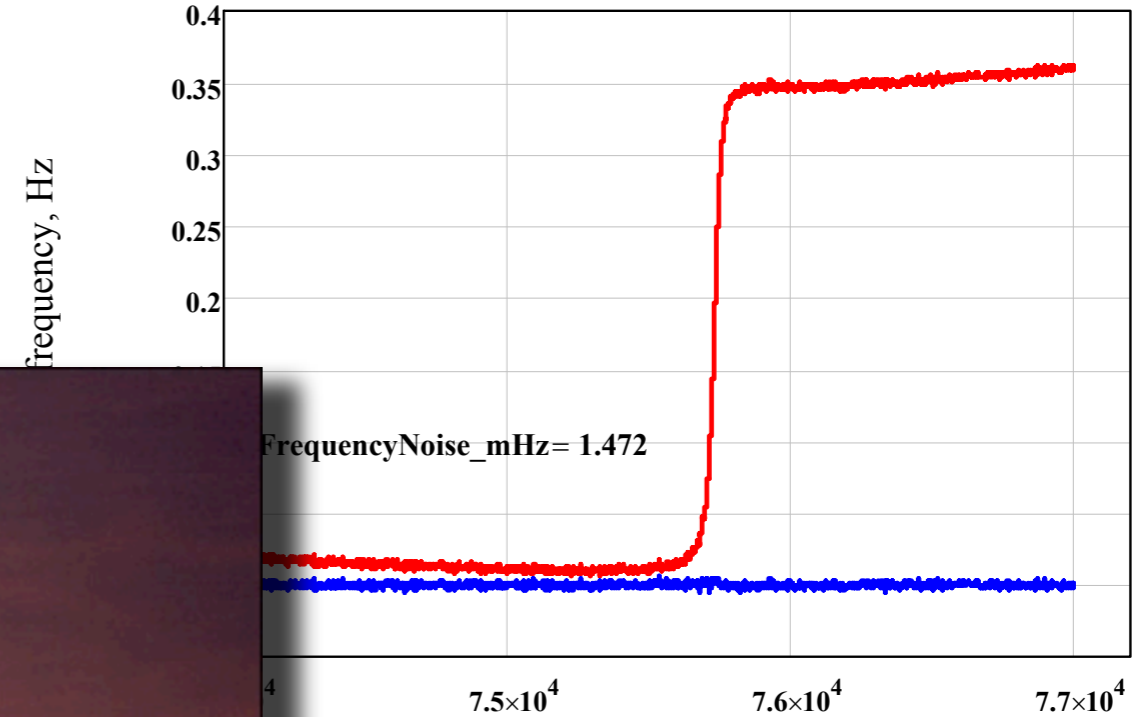
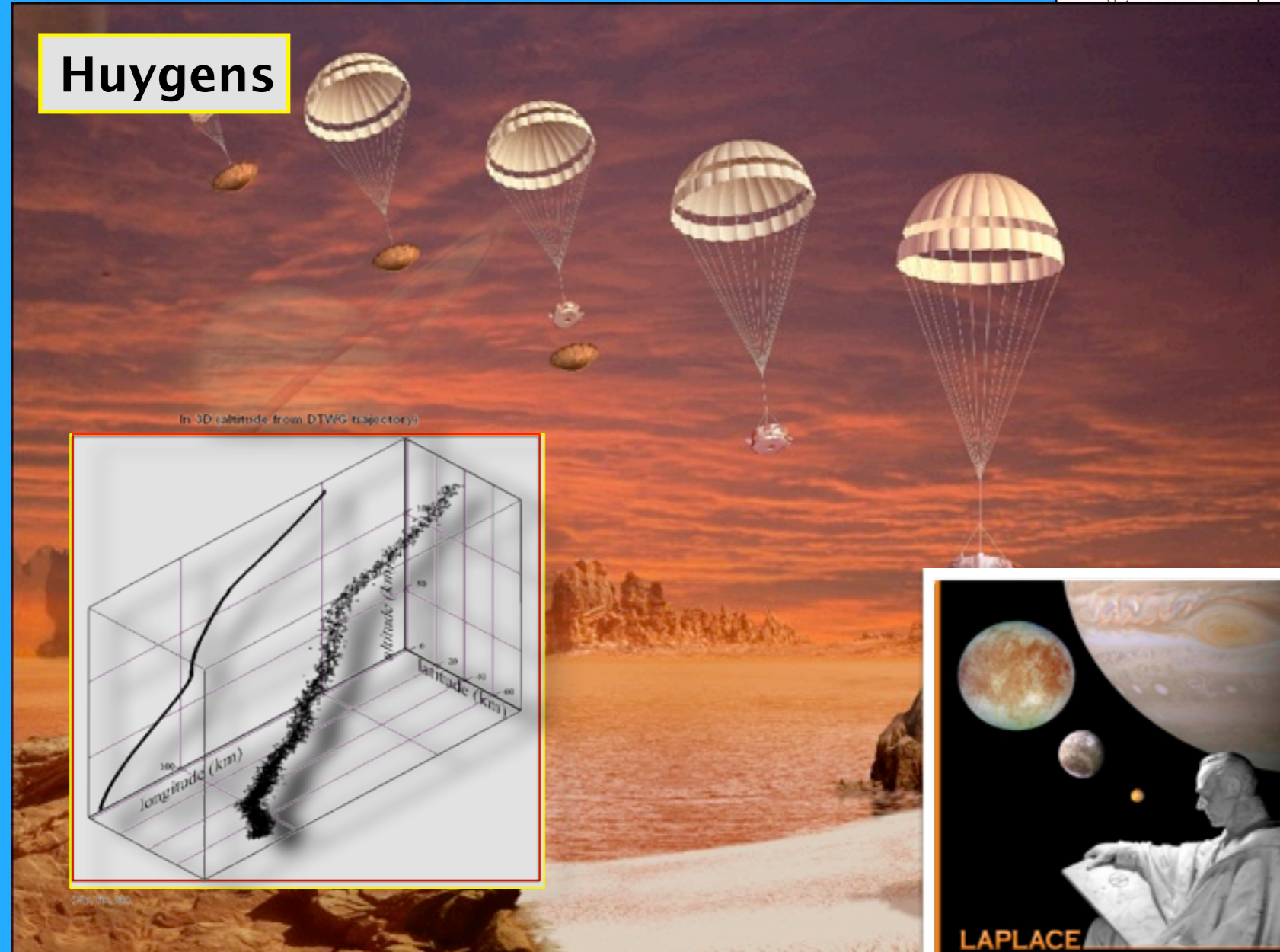
ToOs: half (49.5%) of the total e-EVN observing time in 2010 so far.

Important links to Space applications

Phobos fly by

on Metsähovi

Huygens



Time, seconds of the day 2010.03.03



EXPRoS was concluded in Mar 2010



NEXPRoS

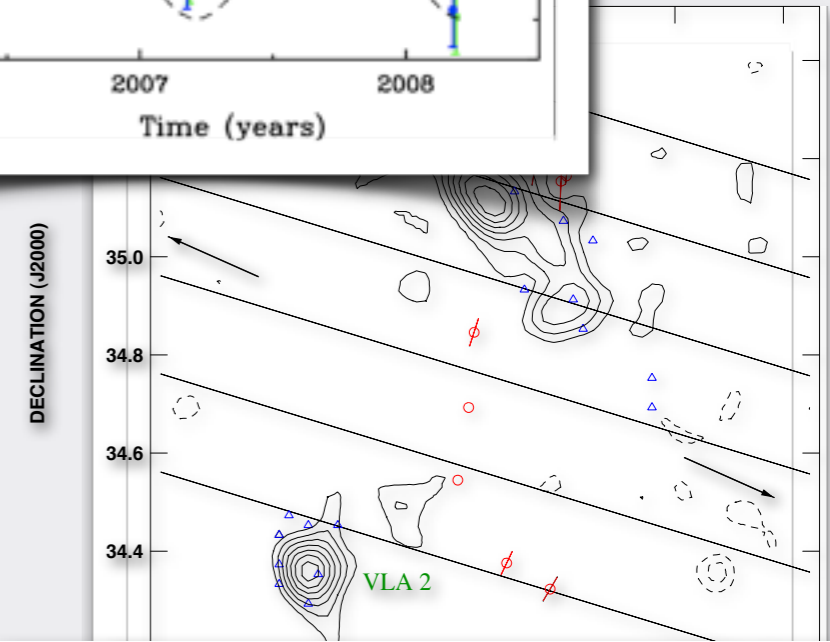
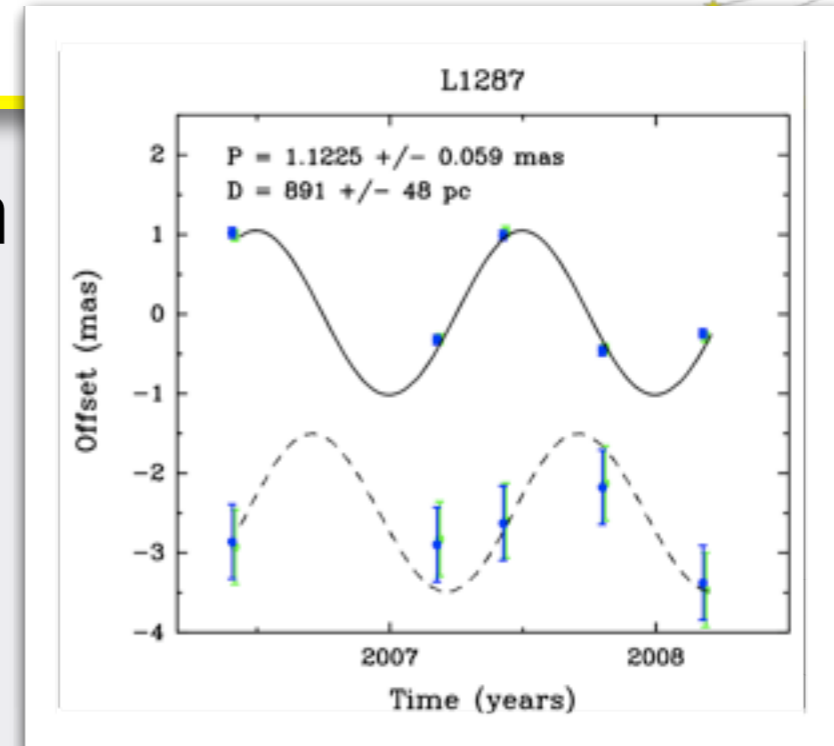
*Novel EXplorations Pushing
Robust e-VLBI Services*

Successful NEXPRoS proposal kicked off in July 2010



Addressing issues:

- **Correlator passes are a problem**
 - Not a perfect correlator
 - Partly remedied by software correlator
- **Not all telescopes connected**
 - Noto/Sardinia
 - Newly added Russian telescopes
 - Global baselines with VLBA
- **Reliable operations**
 - Of all components in the chain
- **Could be addressed by simultaneous recording!**
 - And get the best of both worlds!
- **Correlate in real time what you can,**
- **Correlate later what you need**



- **Main objective to introduce transparent caching**
 - Lift distinction between VLBI and e-VLBI operations
 - Continue collaborations with NRENs
 - Bandwidth on demand allocation
 - Common technology questions with LOFAR and SKA
 - Broadband storage
- **15 partners (cf. 19 in EXPRoS)**
 - Of which 3 choose not receive funds from EC
 - Good mix from astronomy-networking-HPC communities
 - High level of partner-contributed effort
- **Kicked off in September at EVN symposium**
 - Had to fit project within 3.5 M€ envelope
 - Relatively painless, good progress
- **Continuity for e-VLBI operations**
 - Keep key expertise, discussion on shaping eVLBI in eVSAG
 - And assures continued connectivity in collaboration with NRENs

- **Step towards exclusive use of real-time high-bandwidth e-VLBI for EVN**
 - Must increase interoperability with other VLBI networks
- **Raise level of availability**
 - Continuous data quality monitoring
 - Continuous network monitoring
 - More remote control, immediate feedback
- **Should consider more frequent, more evenly spaced observing sessions**
 - Move to VLBI every Friday... eventually
- **Introduction of observations with sub-sets of EVN telescopes**
 - semi-automatically generated schedules and control
 - transient response, multi-epoch campaigns

NEXPREs consequences for JIVE

- Allows
 - And as
- Possibilities
 - Get so
 - 7 Mk
 - Move t
 - Impl
 - High d
 - Sche
 - Netv
 - Increas
 - Para
 - Mixe
 - Eventu
 - eg r



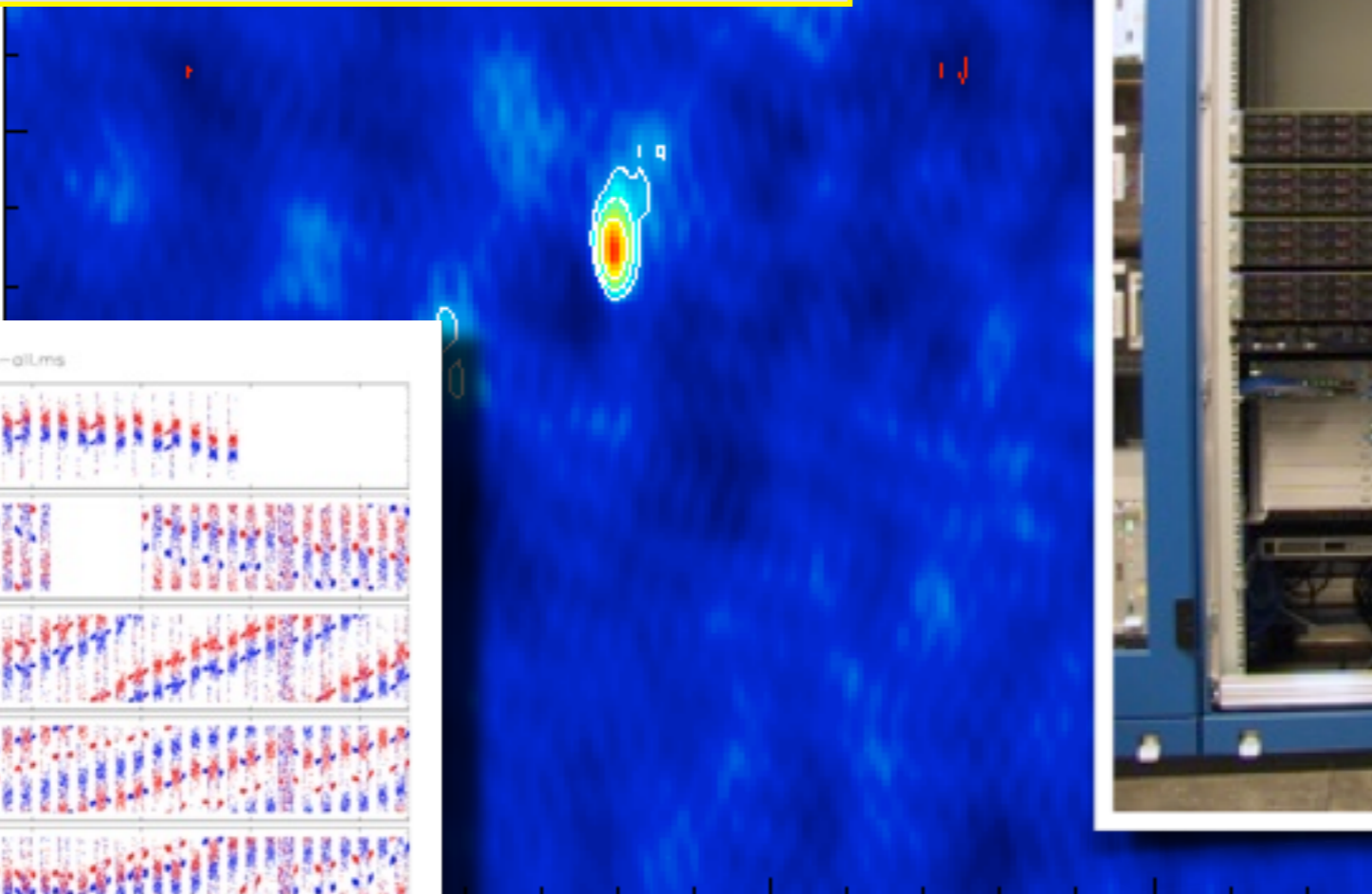
- **Good to be on the forefront of technology & science**
 - Consistent with recognition of e-EVN as an SKA Pathfinder

• SFX Correlator

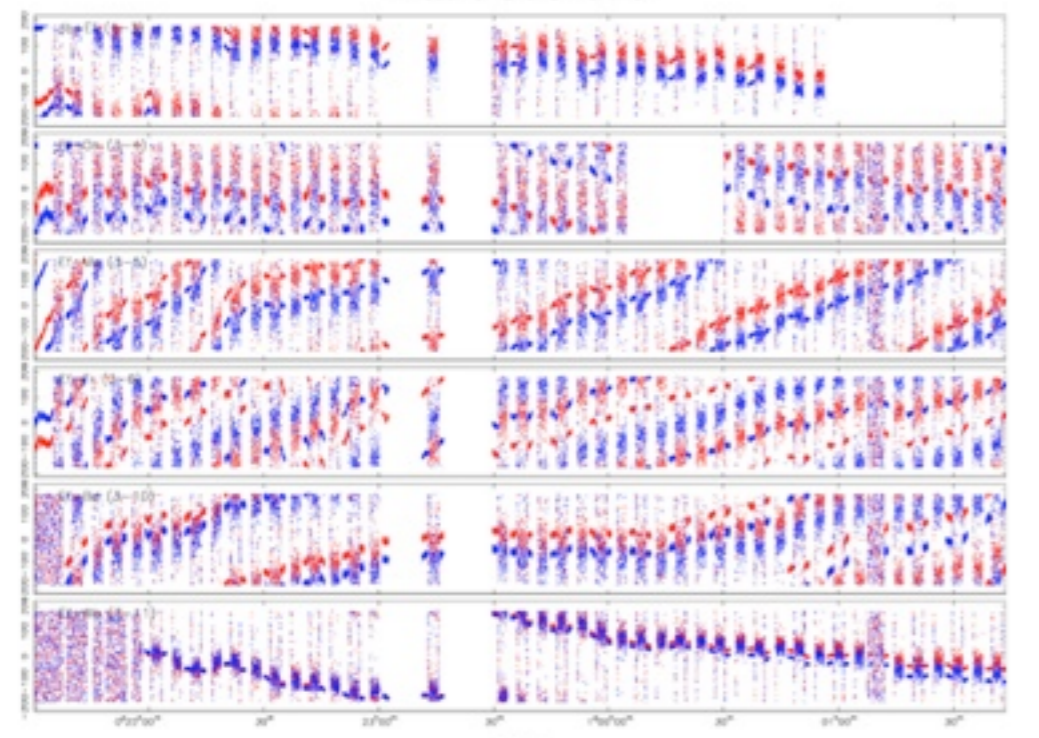
- Homegrown, based on Huygens
- **16 cluster nodes** Each 2 quad core CPUs: 128 cores Direct 1GE/2GE to M
- Pulsar gating/binning operational Preliminary VDIF support implemented



ive Declination
0



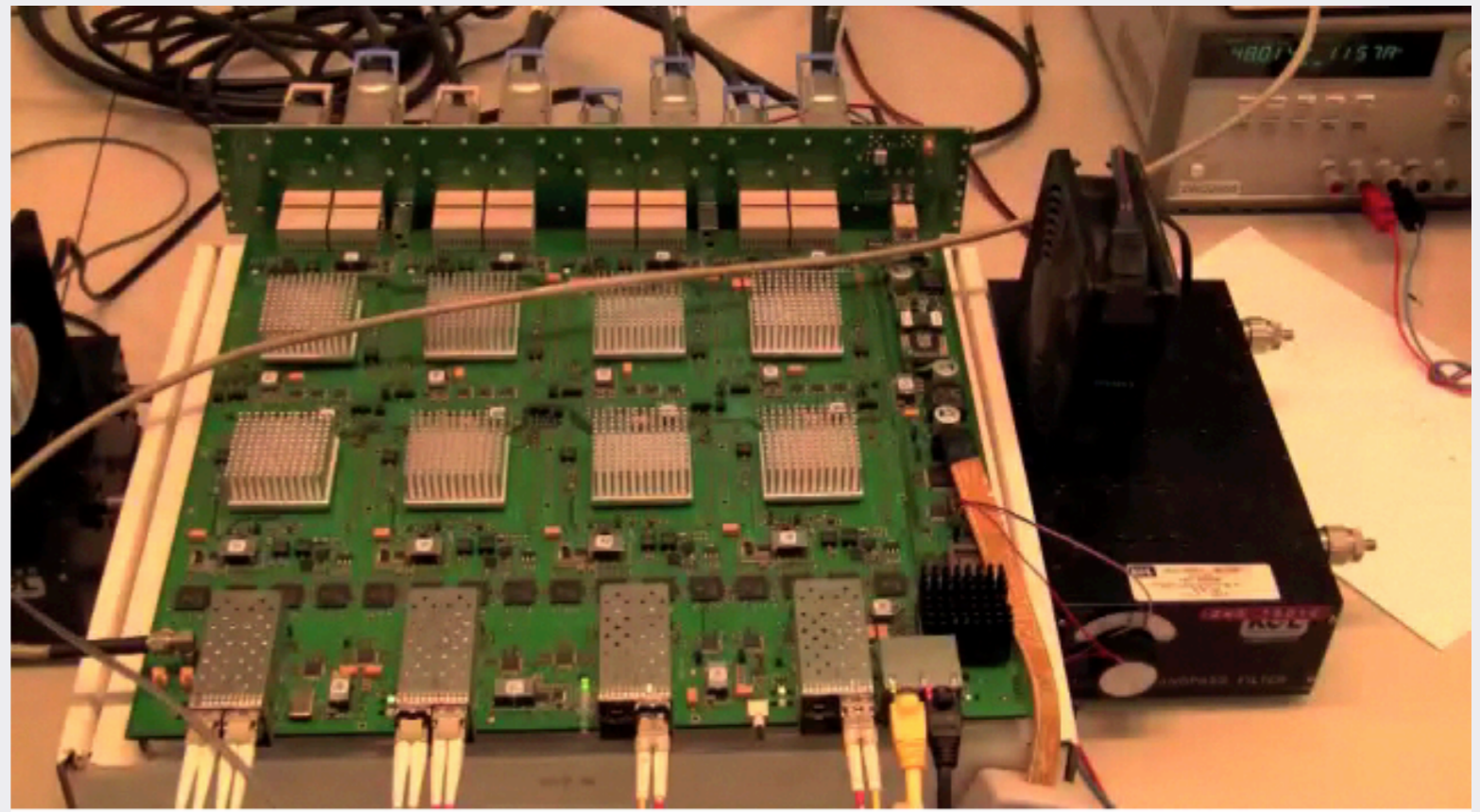
Phase for EVD18A-all.ms



0 -100
Right Ascension (mas)

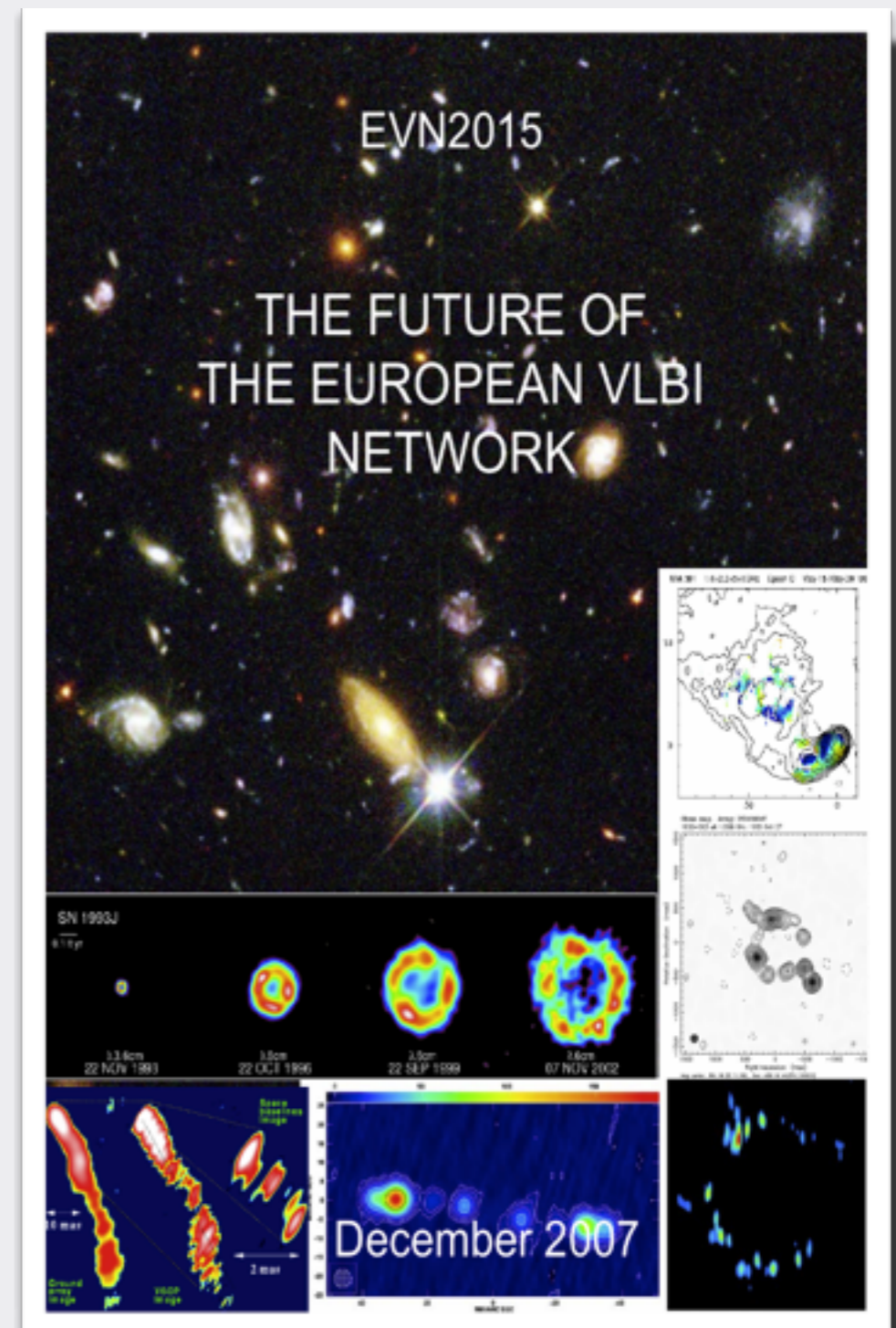
Next: FPGA based correlator

- Raised about 765k€ for NGC
 - From RadioNet UniBoard
 - In the Netherlands, link with Apertif @ WSRT
 - In collaboration with ShAO
- Will deliver prototype for EVN correlator
 - 2 boards deliver Mk4 capacity
 - Scale up to modest rack
- Will have the advantages of software correlator
 - But should be more economic



- **Unique science: long baselines and high frequencies**

- Keep up with EVLA/MERLIN sensitivity
 - Going for 4Gbps in 2011
- Follow up LOFAR, MeerKAT results
- Even in the SKA era
- Science case has been developed
 - <http://www.evlbi.org/publications/publications.html>
- Better images? More telescopes!
 - MeerKAT, African array, Azores, eMERLIN
 - 100-fold bigger correlator



- **Unique science case for VLBI**

- Definitely during SKA phase I and II

- Global baselines northern hemisphere

- **Based on eVLBI advances**

- Sensitivity, Robustness, Flexibility

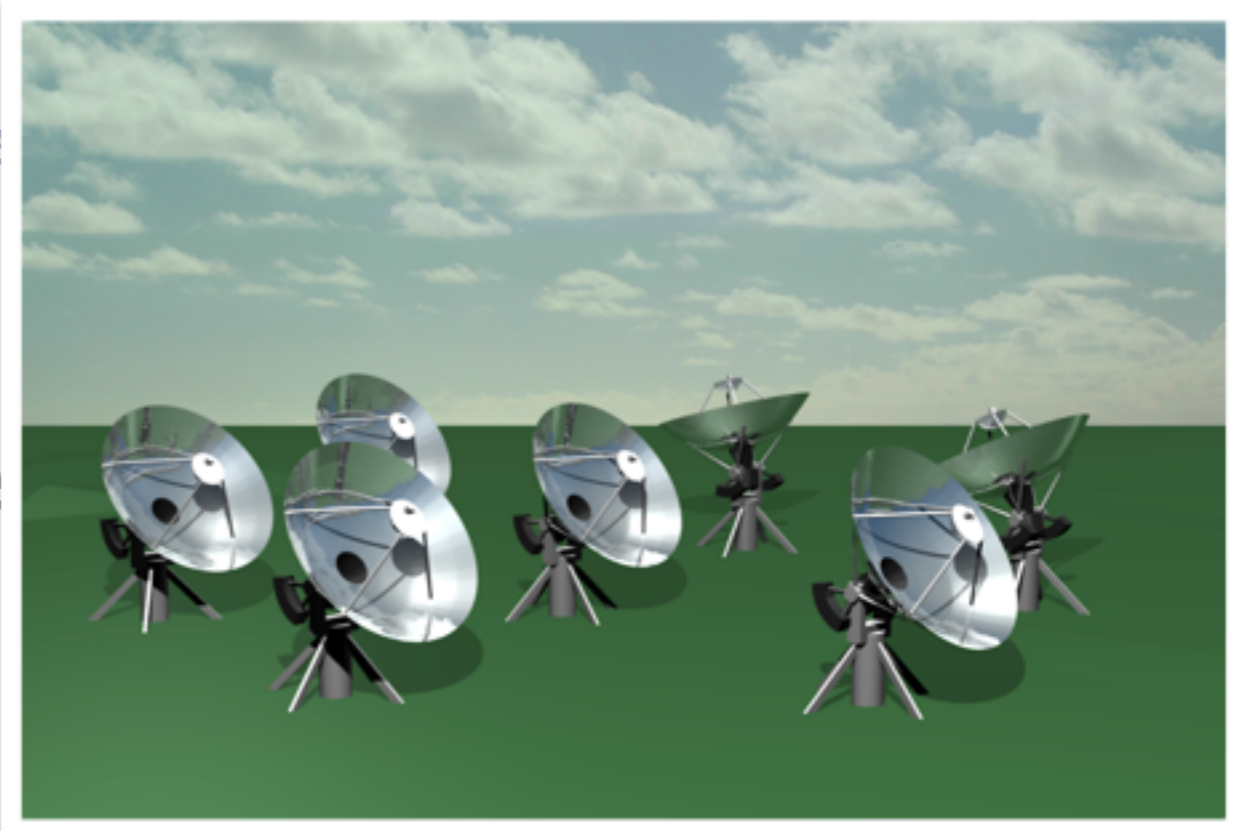
- **Lots of overlap with SKA technologies**

- Benefit from digital components

- And even antennas

- And processing software

- Synergy with other SKA pathfinders



- **Requires a Global approach**

- With a common technology roadmap

- e-VLBI could be the vehicle for doing that

- **Need SKA story to maintain funding...**

- Training aspects, home telescope, outreach

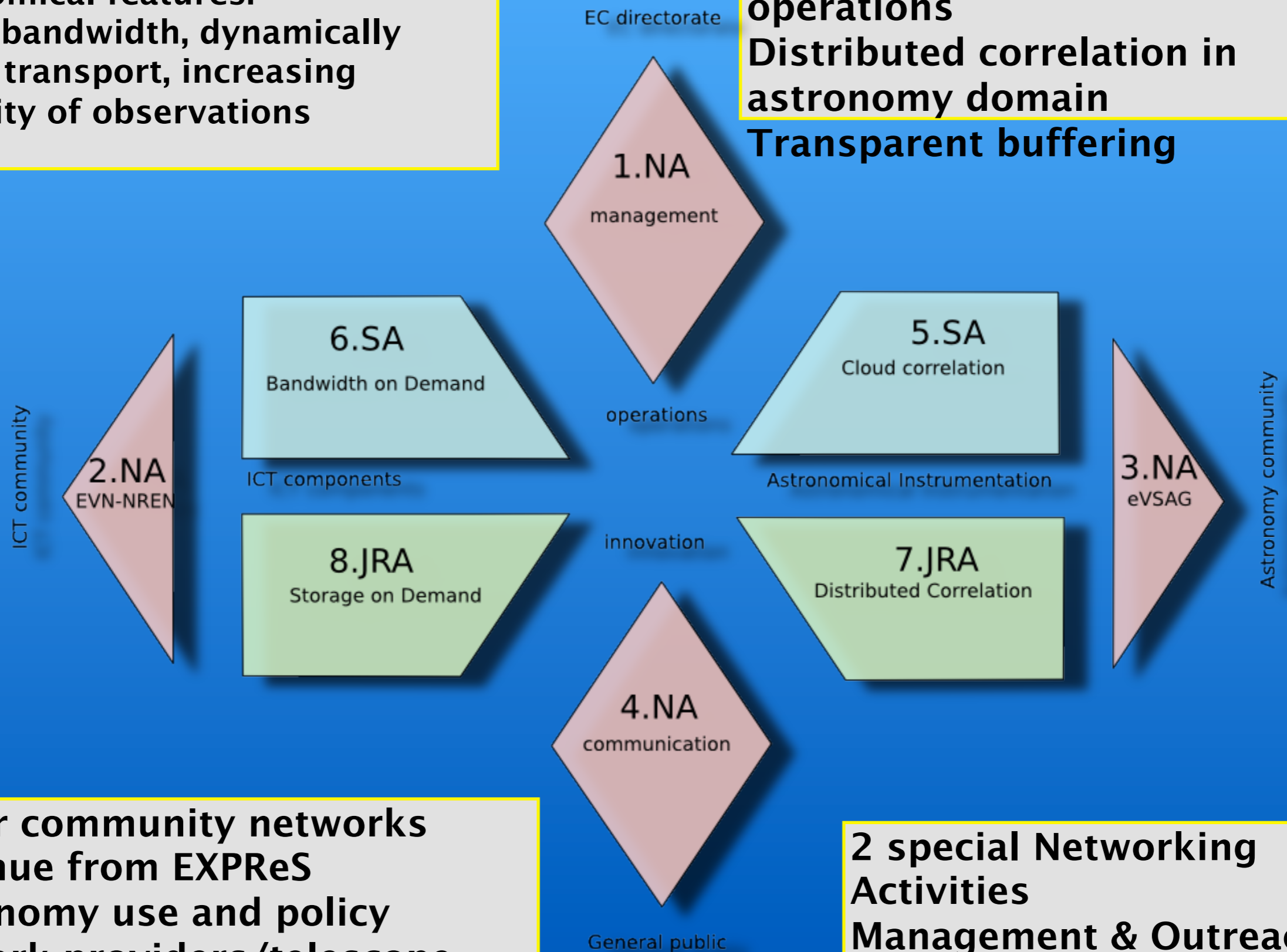
- **Too few interaction with US/Eu user communities**
 - Surely the VLBI science meetings should be joint
- **User community is the most precious asset**
 - Make sure the interfaces are uniform and robust
 - More important to get it accountable than to make it easy
 - User software, User support, Training, Proposal handling, Scheduling
 - Do not increase number of interfaces, 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
 - Dropping antennas does not help, reducing observing time may
- **Pushing technology is part of the mission**
 - e-VLBI has helped keeping us visible
 - Internet2 opportunities?
- **Long-term common goal?**
 - Global VLBI array which react flexible on user demands
 - Needed to satisfy scientists used to SKA/ALMA

BTW: the Dutch Network provider is very interested in distributing clocks over public fiber

The End

2 Service Activities
focus on new operational
astronomical features:
Higher bandwidth, dynamically
cached transport, increasing
flexibility of observations

2 Joint Research Activities
aiming at innovating future
operations
Distributed correlation in
astronomy domain
Transparent buffering



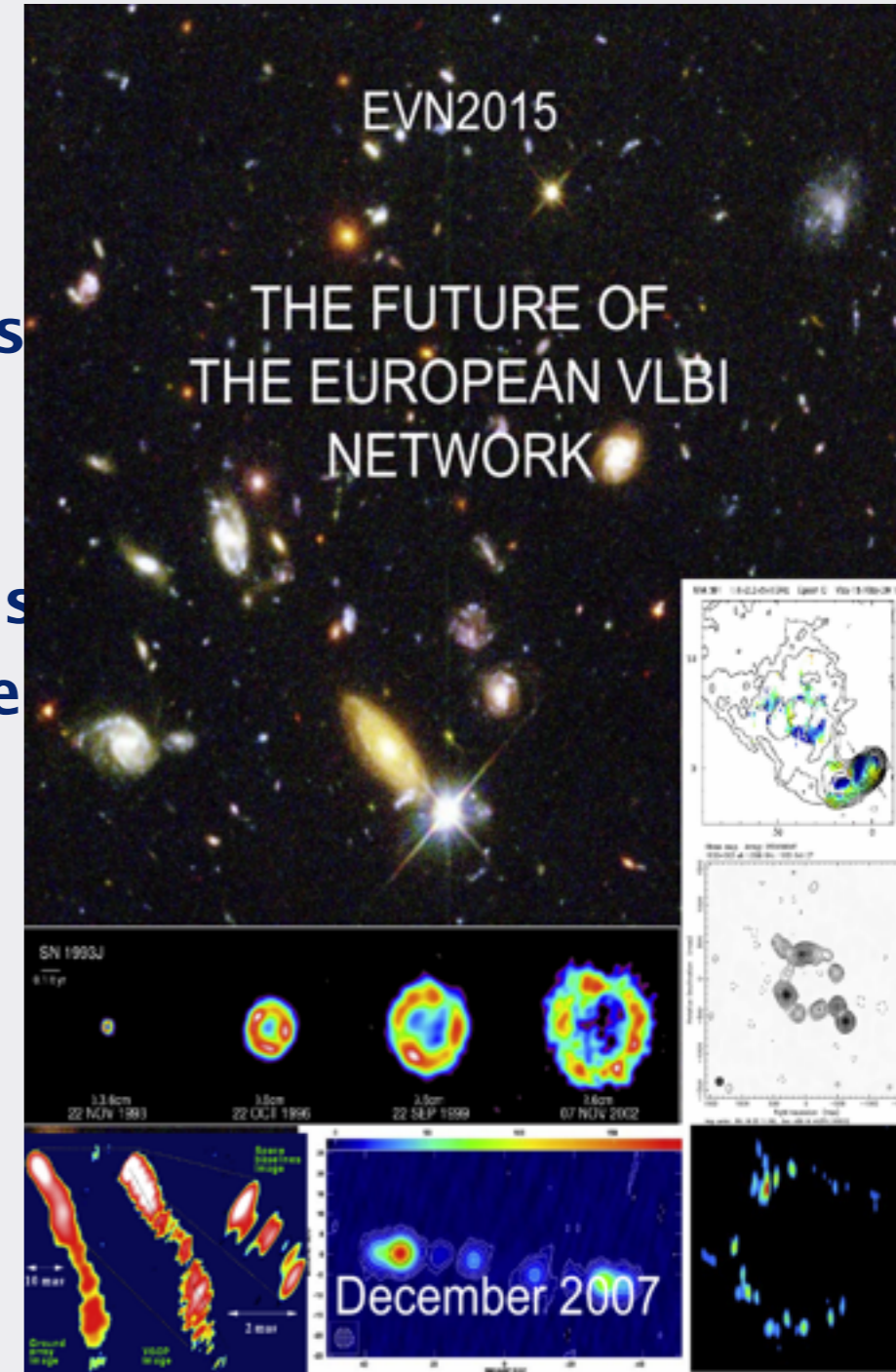
2 user community networks
continue from EXPRoS
Astronomy use and policy
Network providers/telescope
operators

**2 special Networking
Activities**
Management & Outreach
Essential for success

- Science case has been developed
 - <http://www.evlbi.org/publications/publications.html>

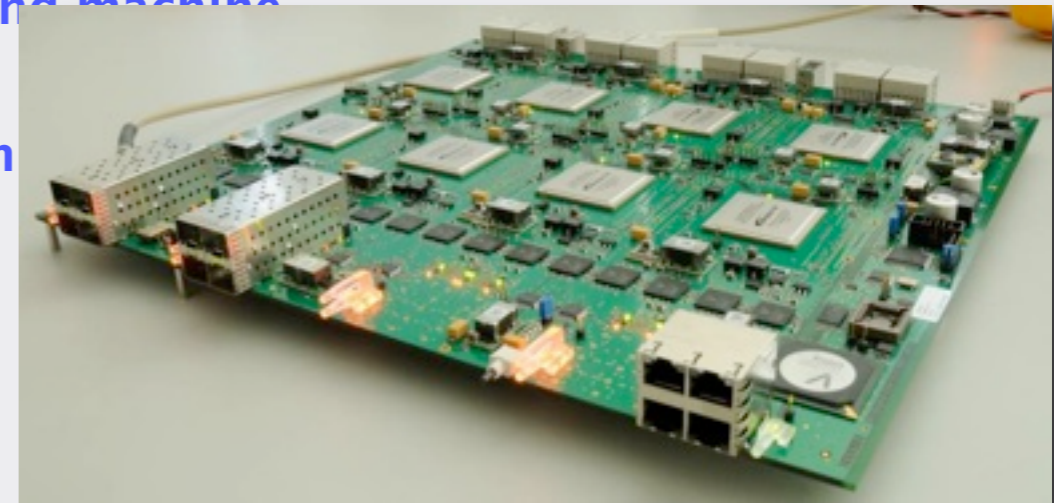
- **Some highlights include:**

- Nature of starburst/AGN in cosmological fields
- The fate of black holes/radio quiet AGN
- Jet physics close to the event horizon (VSOP2)
- Determining star burst activity, resolving SNR's
- The accretion physics in transient radio source
- The detailed 3D kinematics of star formation
- The nature of the ISM in active galaxies
- Fundamental distances from astrometry
- Pulsar astrometry
- Monitoring spacecraft in the solar system



Next Generation Correlator

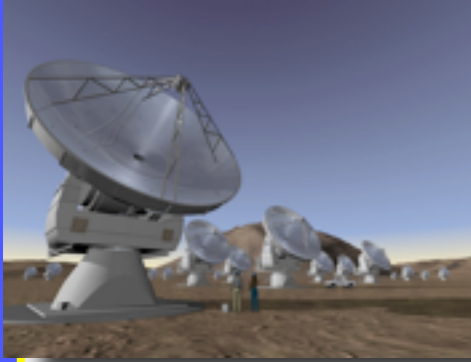
- **Raised considerable budget for prototype**
 - RadioNet: UniBoard, NWO: ExBoX, NWO-ShAO collaboration
 - Link to APERTIF correlator project
- **Scalable, generic, high-performance FPGA-based computing platform for radio astronomy**
 - **Several personalities:**
 - correlator, beamformer, digital receiver, pulsar binning machine
 - **Layout finished**
 - Various control software systems under construction
 - **Hardware purchase: Altera StratixIV**
 - First hardware has arrived and being tested
 - **Aims to deliver single crate prototype**
 - Same power as current correlator
- **Aims at 100fold more powerful machine**
 - 32 station, 10 - 64 Gbps
- **Much interest from different groups**
 - obviously maps well onto current problems (NG EVN, Apertif)
 - possible use as building block of all-station LOFAR correlator



Common issue: software



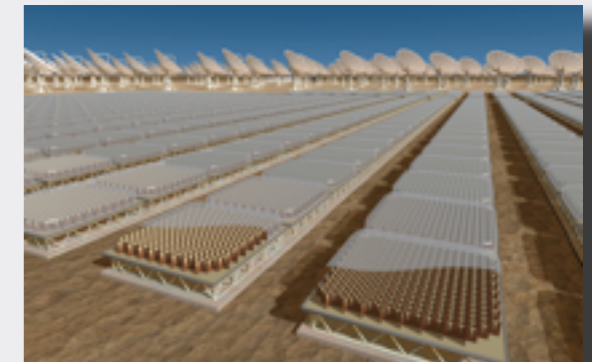
- **Trying to address with small steps**
 - EC sponsored contribution
 - Across quite different range of facilities
 - Channel collaboration & meetings
 - A platform for exchanging experiences
 - A place to train new specialists



- **A set of related work-packages**
 - A way to structure progress
 - And enforce communication



- **Addressing hot topics**
 - Interoperability
 - Includes support for ParselTongue
 - Calibration algorithms
 - Large fields, directional dependence
 - Automated processing
 - Data quality, automated flagging





LOFAR and SKA have simpler antennas

But many more, more connectivity, more correlation

e-VLBI is pioneering the development of signal transport for the SKA

Can also be important in developing correlator solutions

