

**NEXPR***e***S**

# NEXPR*e*S

## Lunch Talk

Huib Jan van Langevelde  
T. Charles Yun  
2012 January



# Overview

- Background: e-VLBI status
  - Achievements of EXPReS

Huib

- NEXPReS project
  - WP1-4: Network activities
  - WP6 SA on Bandwidth on demand
  - WP8 JRA on wide-band storage

Charles

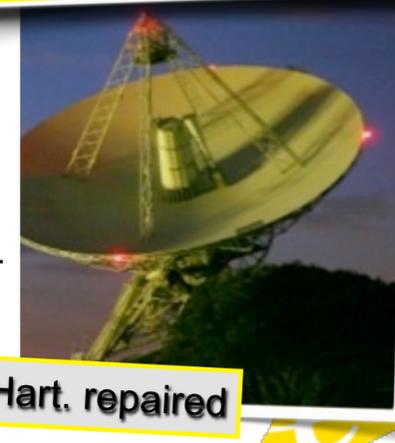
- WP5 SA on Cloud correlation
- WP7 JRA on Distributed correlation
- Conclusions and forward look

Huib



# the European VLBI Network

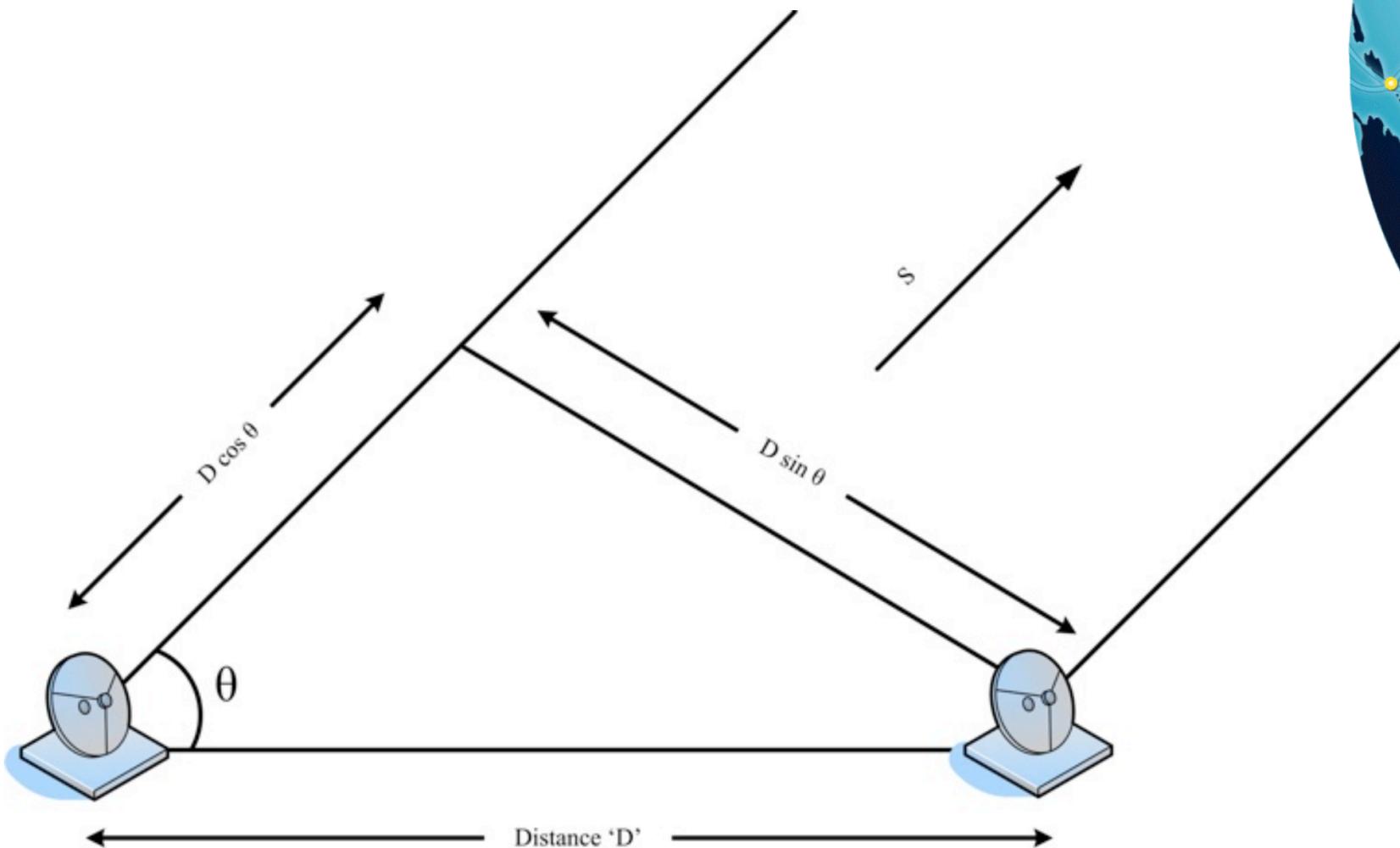
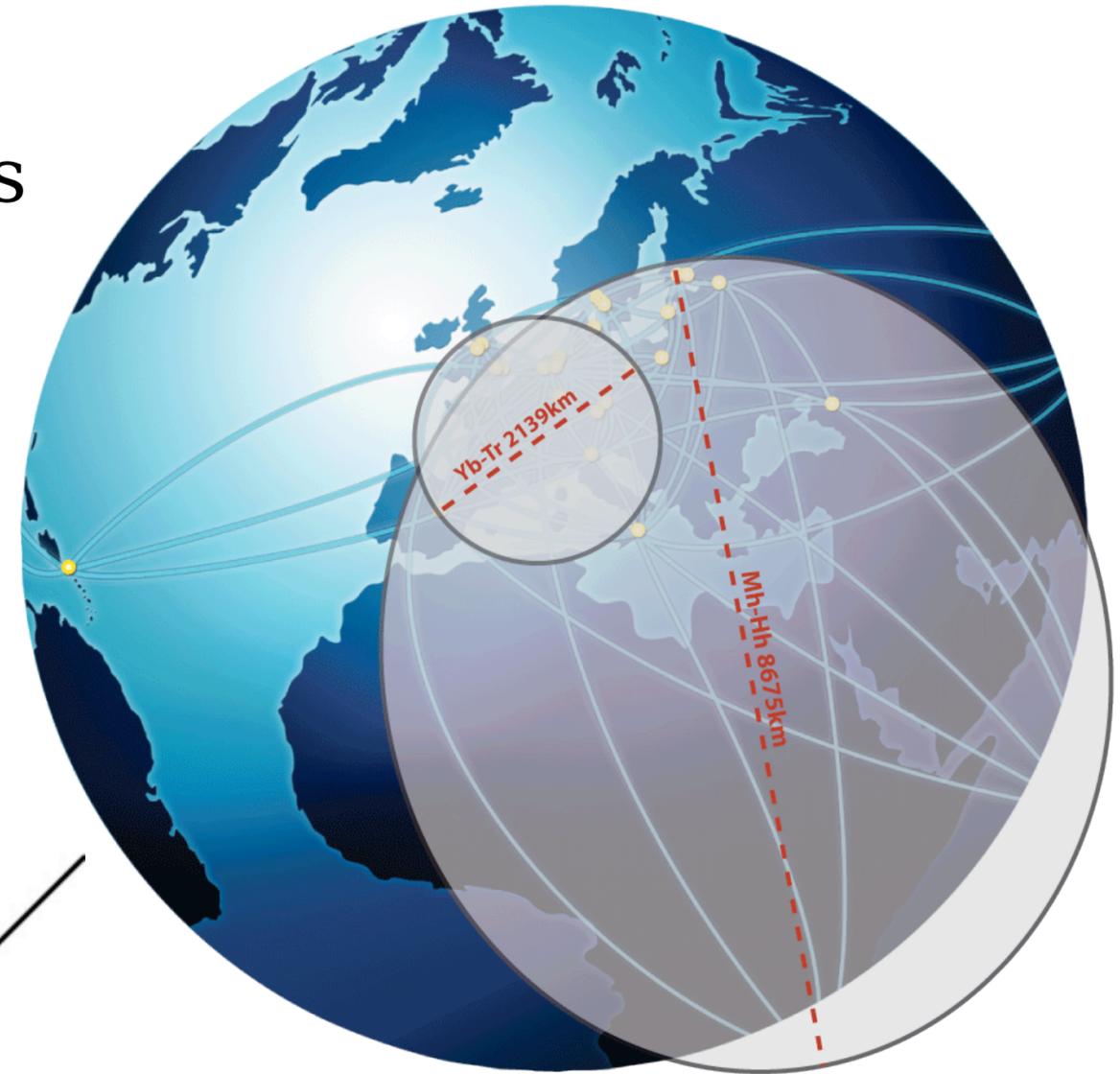
- Consortium with 20+ possible antennas
  - Ran by up to 14 different organizations
  - And 12 more antennas for “Globals”
- Covering range of frequencies
  - Workhorse frequencies 18cm, 6cm,
  - Also available: SX, 5cm, 1.2cm
  - And 90cm, 21cm, UHF, 50cm, 2cm, 0.7mm
- Reaching mas resolutions
  - From 15mas for 1.4 GHz EVN
  - To 1 mas at 5GHz with intercontinental
  - Low brightness with MERLIN
- Sensitivity of  $5\mu\text{Jy}$  in 8hr at 1.4 GHz
  - Combination of Big Antennas and 1 Gbps
    - And 2 Gbps coming with new DBBC
  - Big antennas for spectroscopy (mJy sensitivity)
- Operational approximately 60 d/yr
  - 3 sessions augmented with e-VLBI each month



VLBI- Very Long Baseline Interferometry

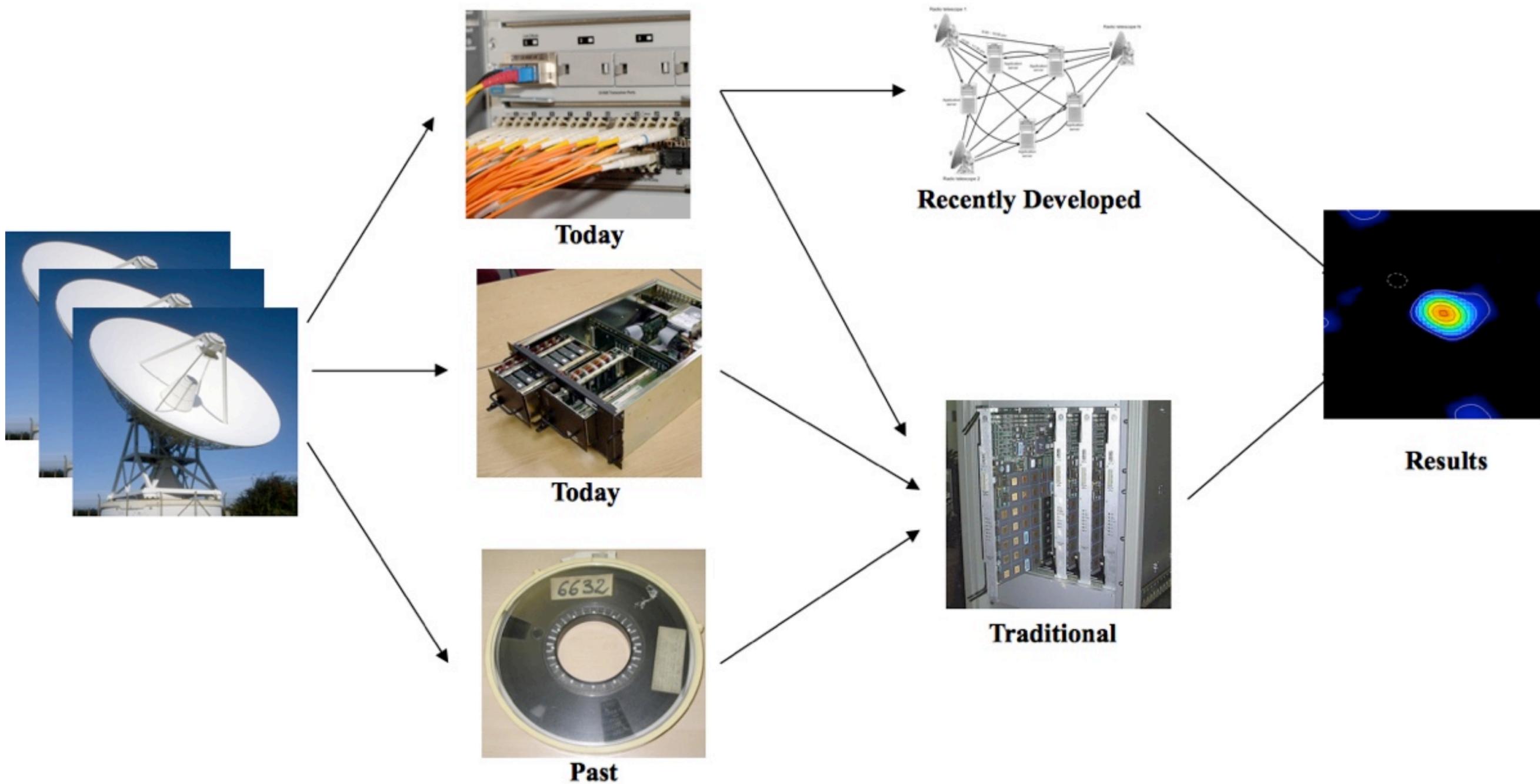
# Multiple Telescope Observation

- Resolution increases with baseline
- Sensitivity increases with **bandwidth**
  - Data storage and transmission
- Precise locations & accurate clocks



VLBI- Very Long Baseline Interferometry

# Moving Data from Dish to Result



# Turned into e-VLBI

- Started many times in many places
  - Fringe verification, modem lines
  - For EVN started with a pilot in 2004



3.9M€ project, with additional resources from partners and additional NRENs. Started Q3 2006 ended Q2 2010

- Really took off 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



# Introduced e-VLBI as operational facility

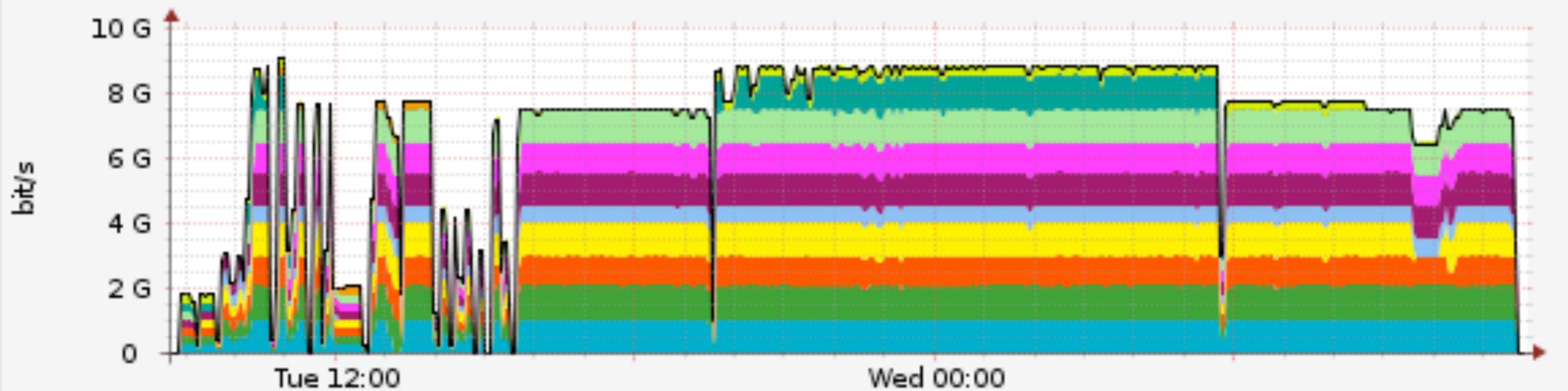


- **Connections work great!**
  - often dedicated light paths
  - Use optimized protocols
- **Closed feedback loop makes e-VLBI more robust**

# Introduced e-VLBI as operational facility



Total eVLBI throughput



From 2010-11-23 08:40:00 To 2010-11-24 11:50:00 (CET)

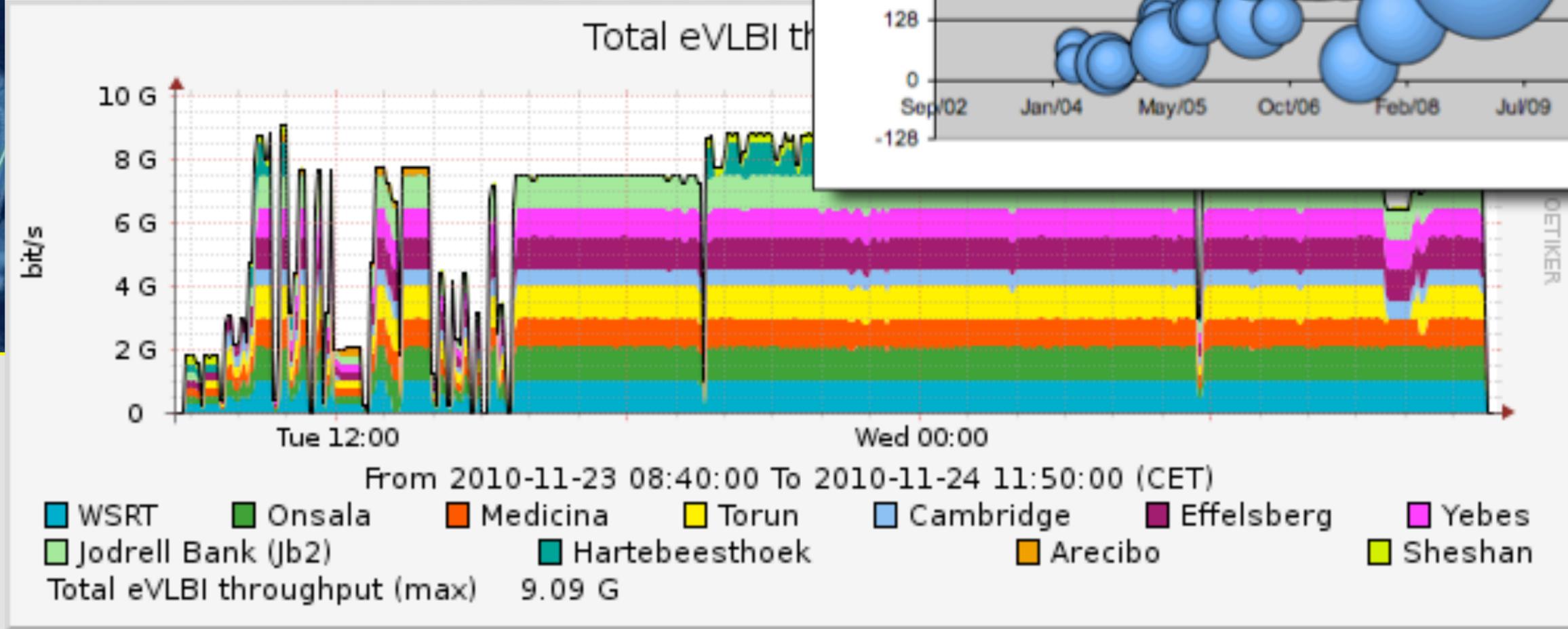
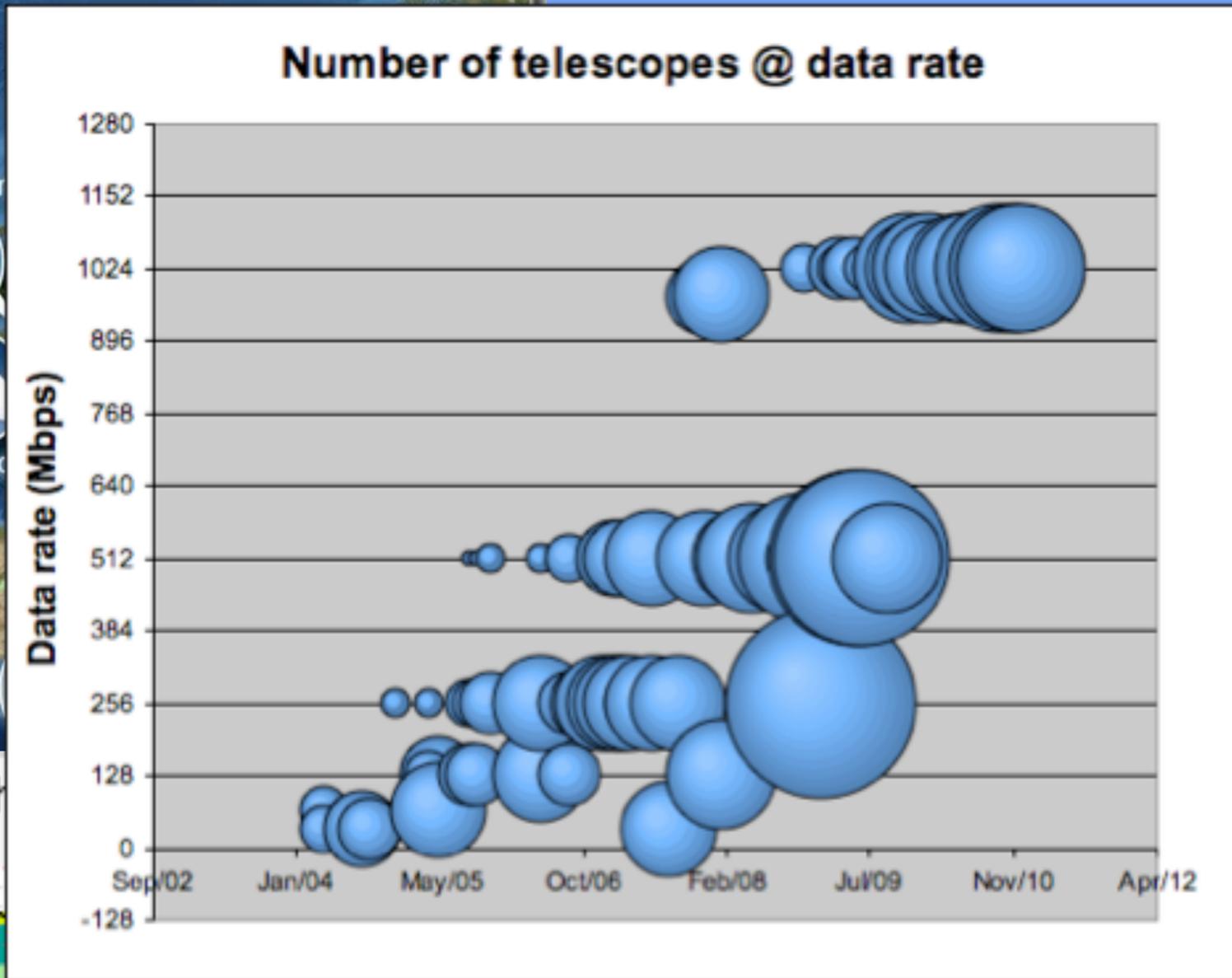
- WSRT
- Onsala
- Medicina
- Torun
- Cambridge
- Effelsberg
- Yebes
- Jodrell Bank (Jb2)
- Hartebeesthoek
- Arecibo
- Sheshan

Total eVLBI throughput (max) 9.09 G

RRD2TOOL / TOBI OETIKER

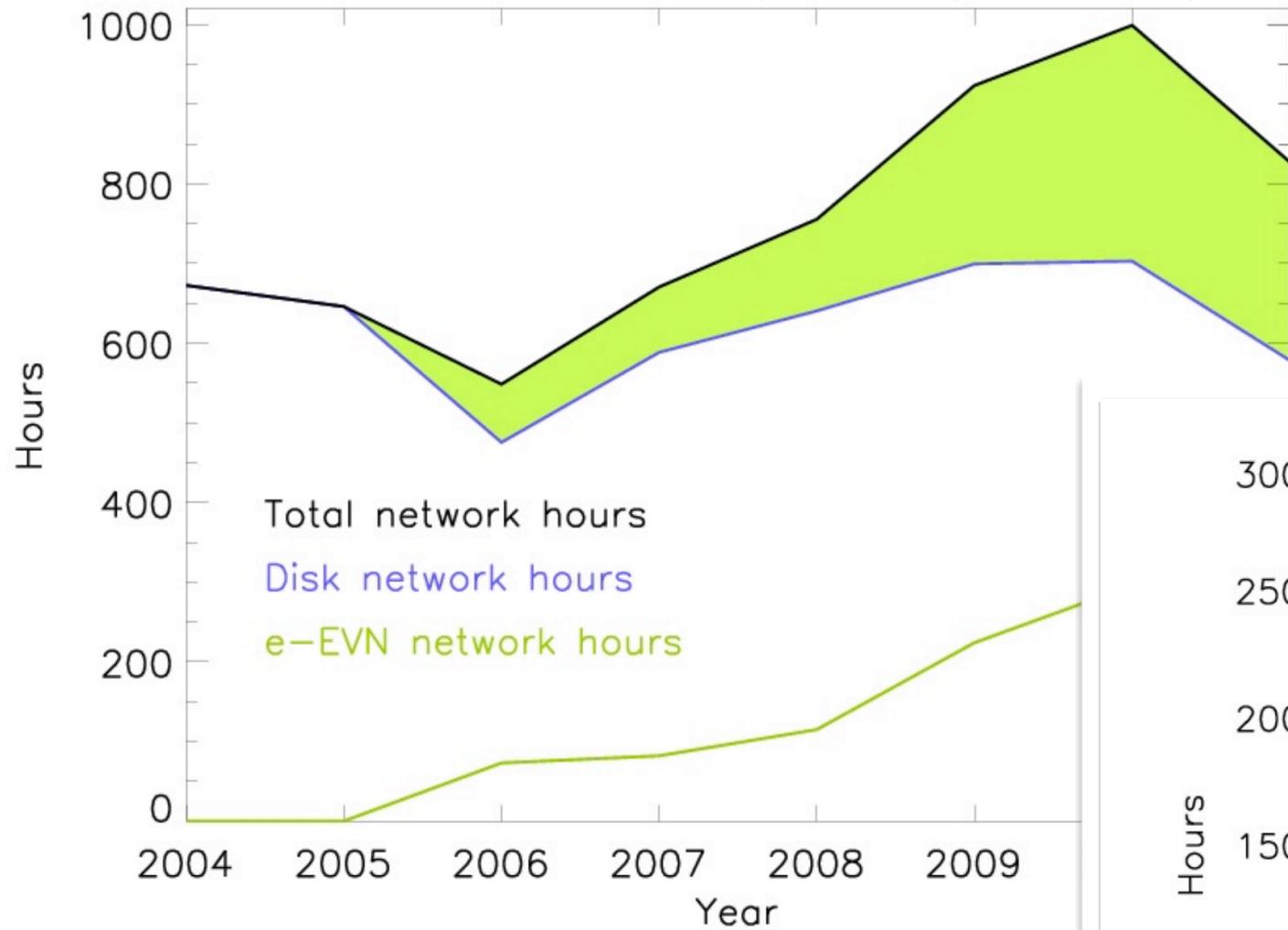


# Introduced e-VLBI as operational facility



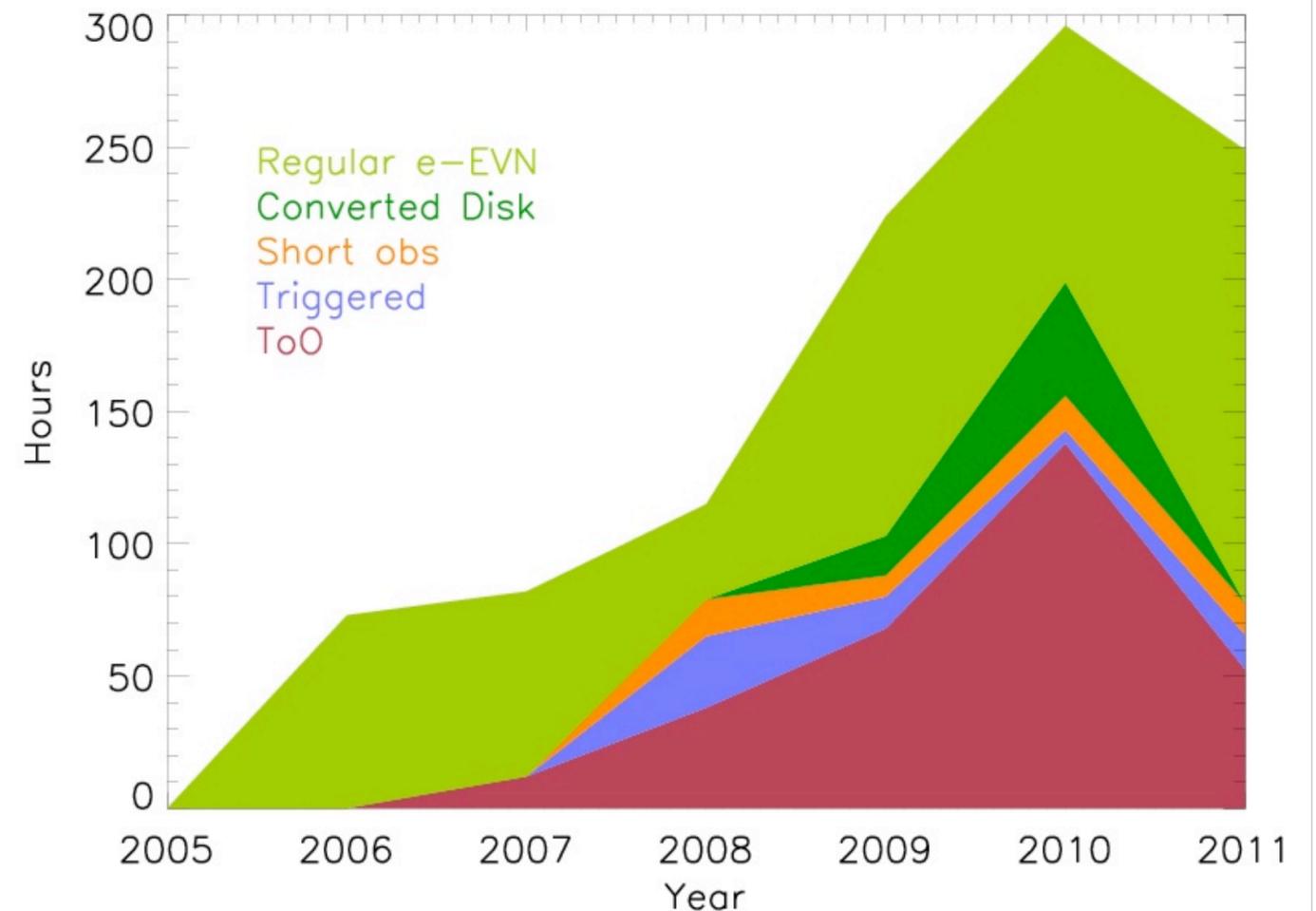
# e-EVN operations plots

EVN network hours (user experiments)



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

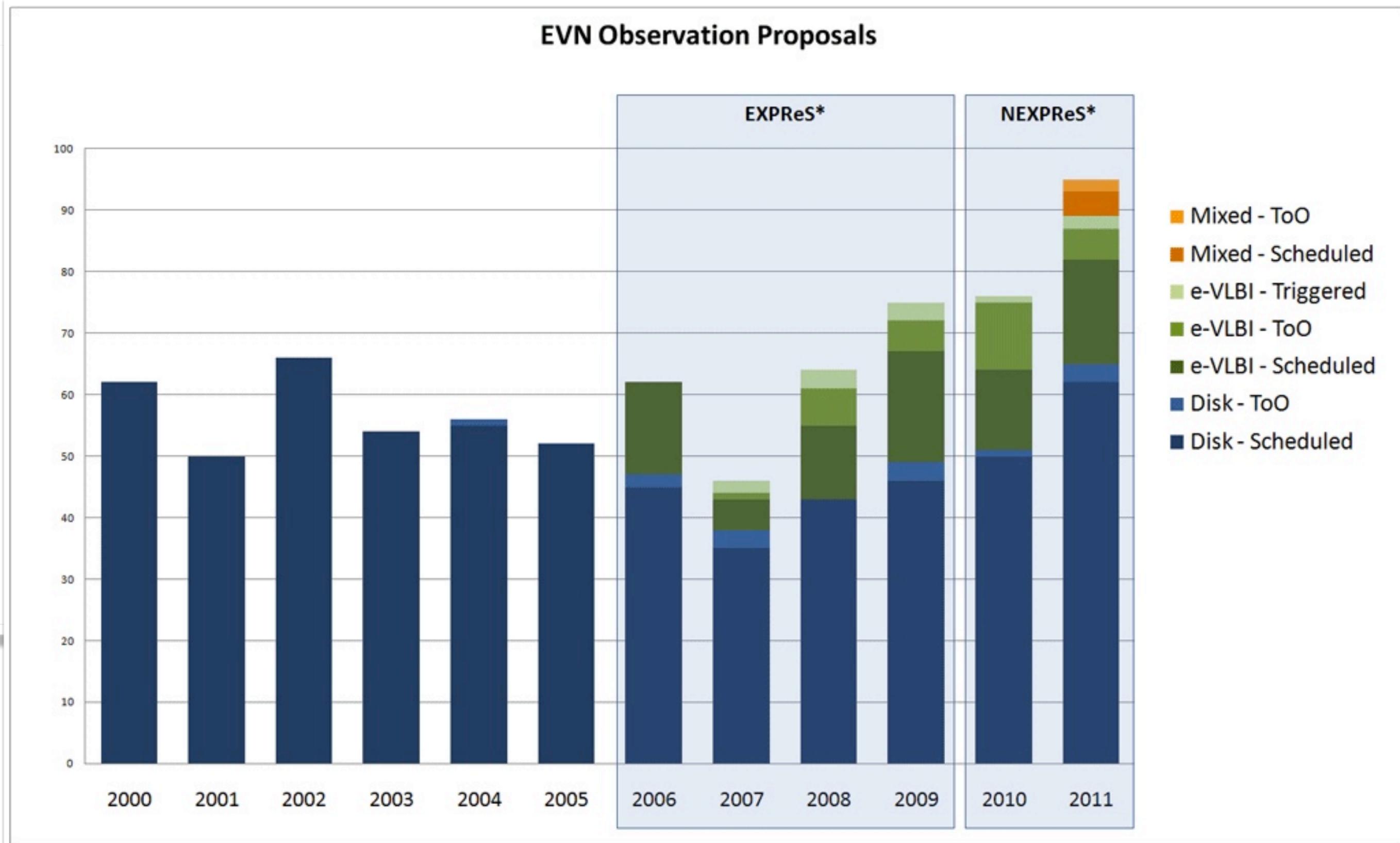
e-EVN network hours



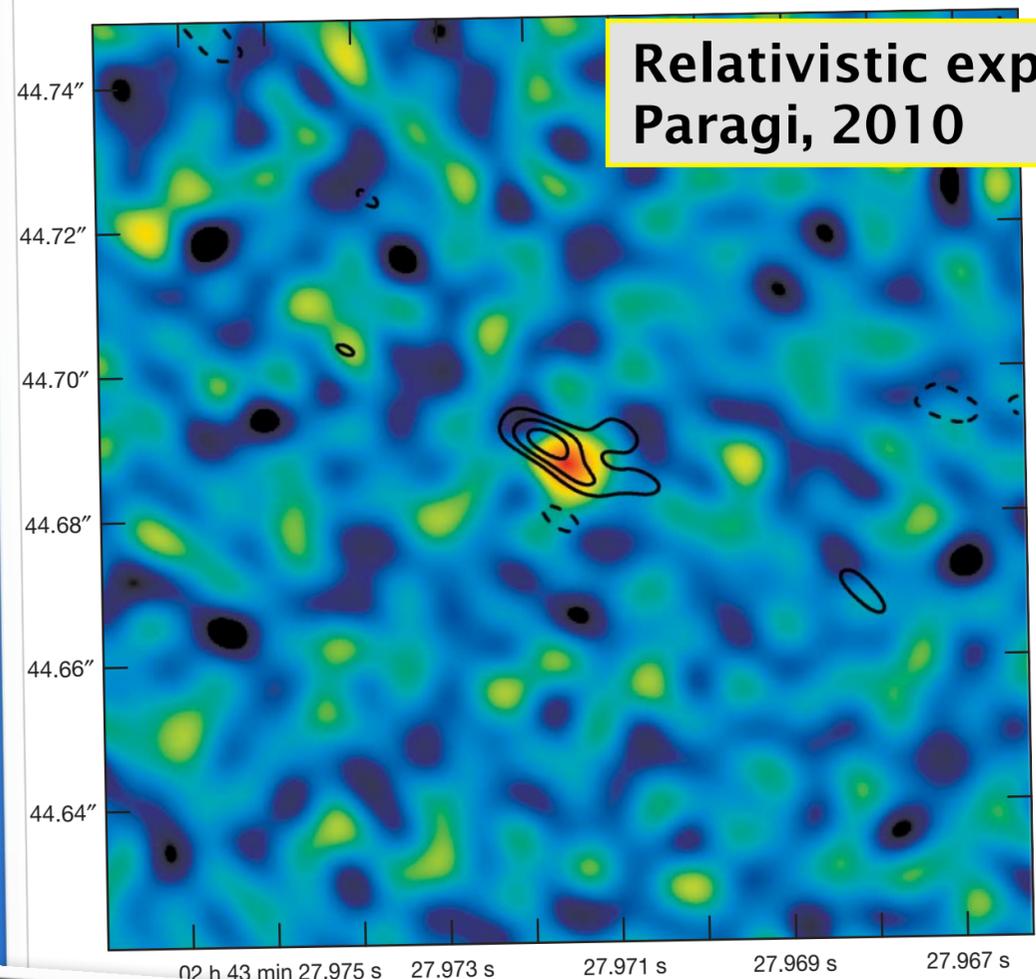
ToOs: half (49.5%) of the total e-EVN observing time in 2010



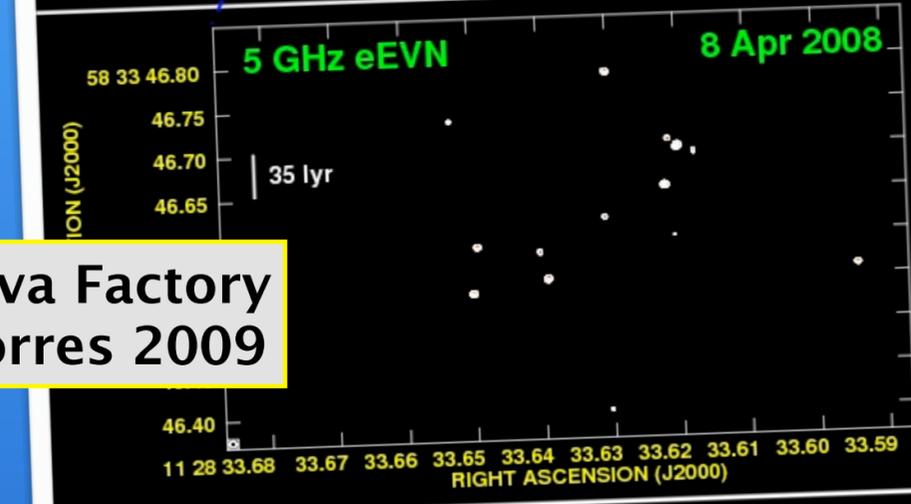
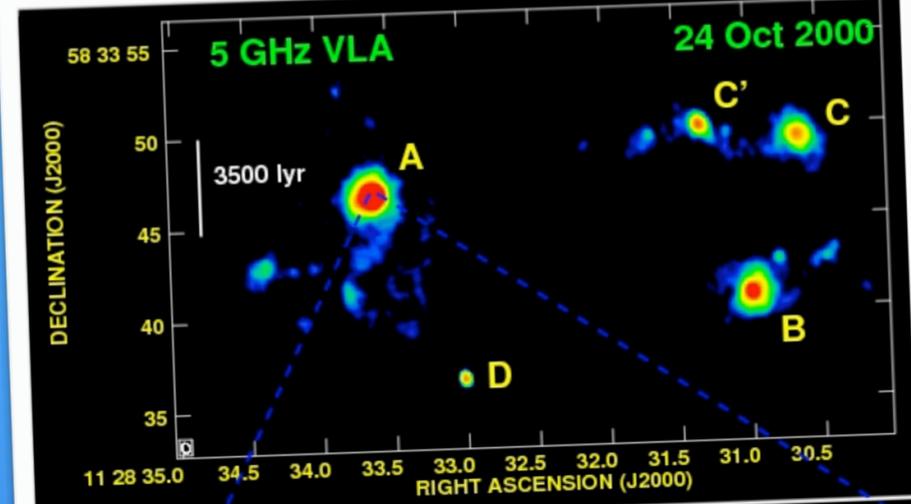
# e-EVN operations plots



ta.



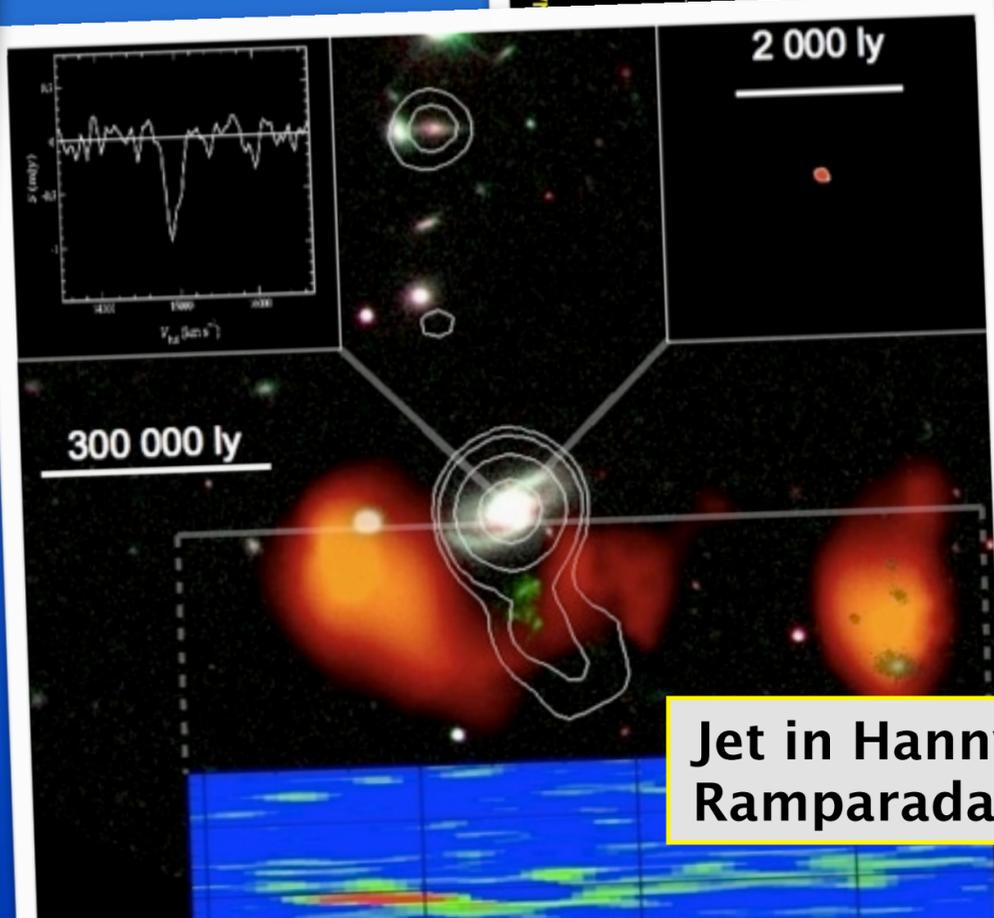
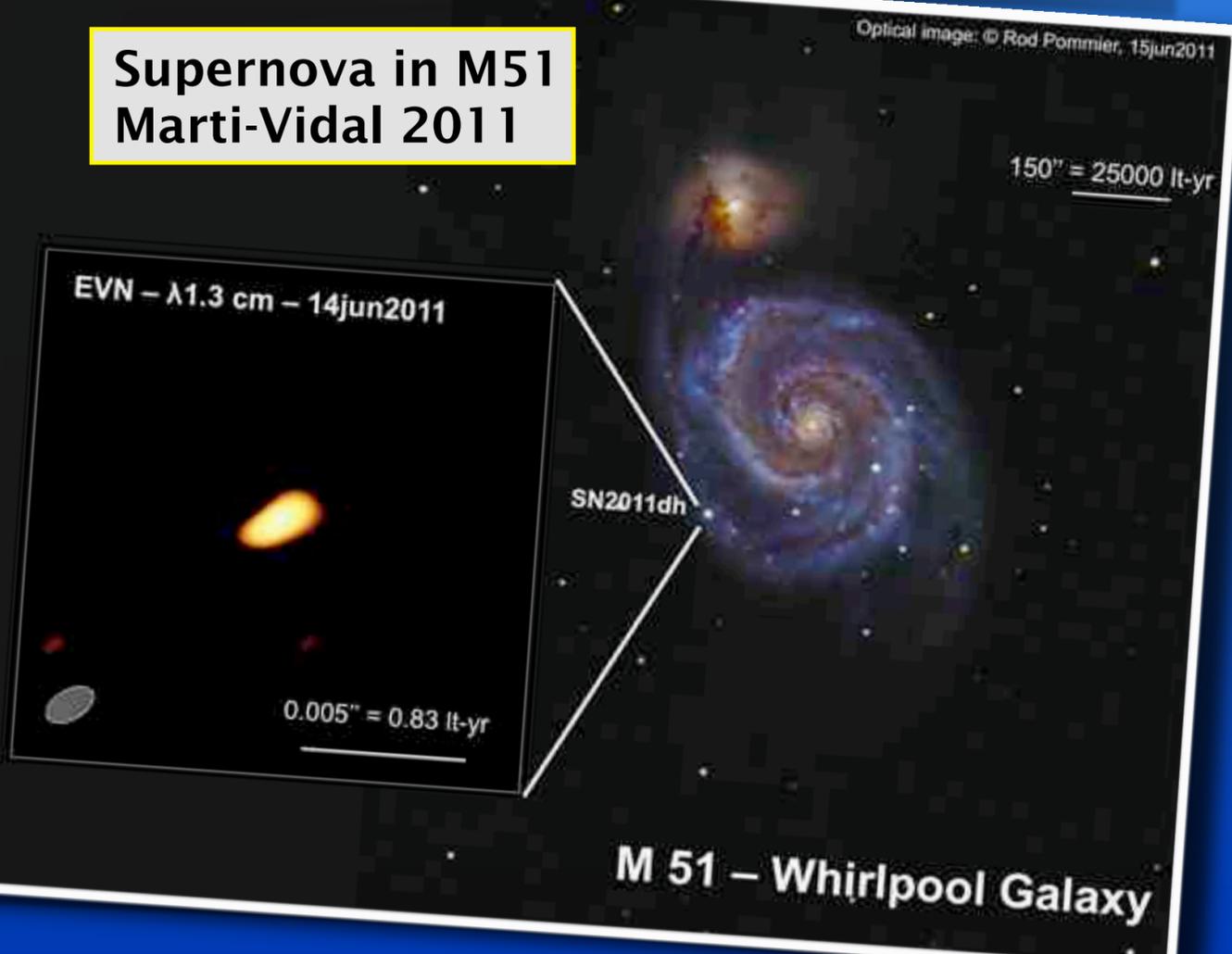
Relativistic expansion in GRB?  
Paragi, 2010



Supernova Factory  
Perez-Torres 2009



Supernova in M51  
Marti-Vidal 2011



Jet in Hanny's voorwerp  
Ramparadath et al 2011

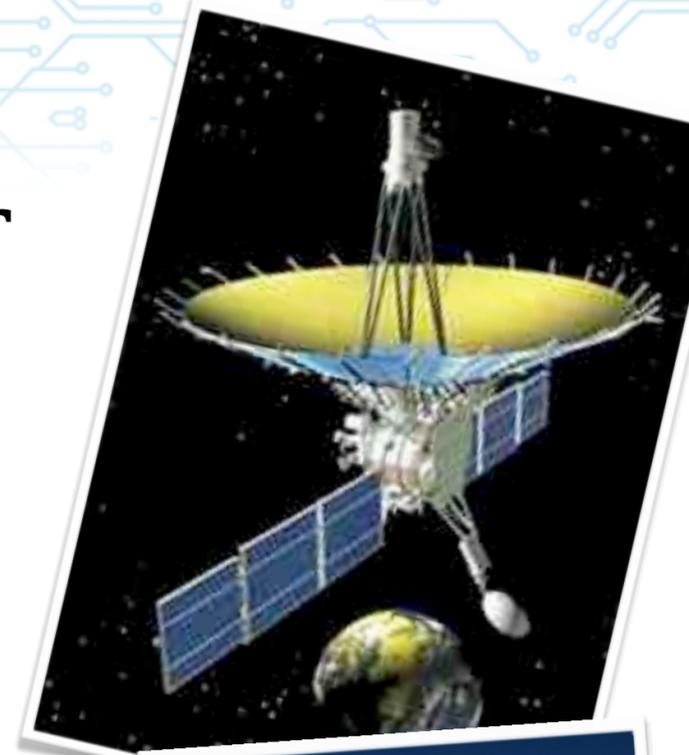
# Open for Observations

- 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
  - 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



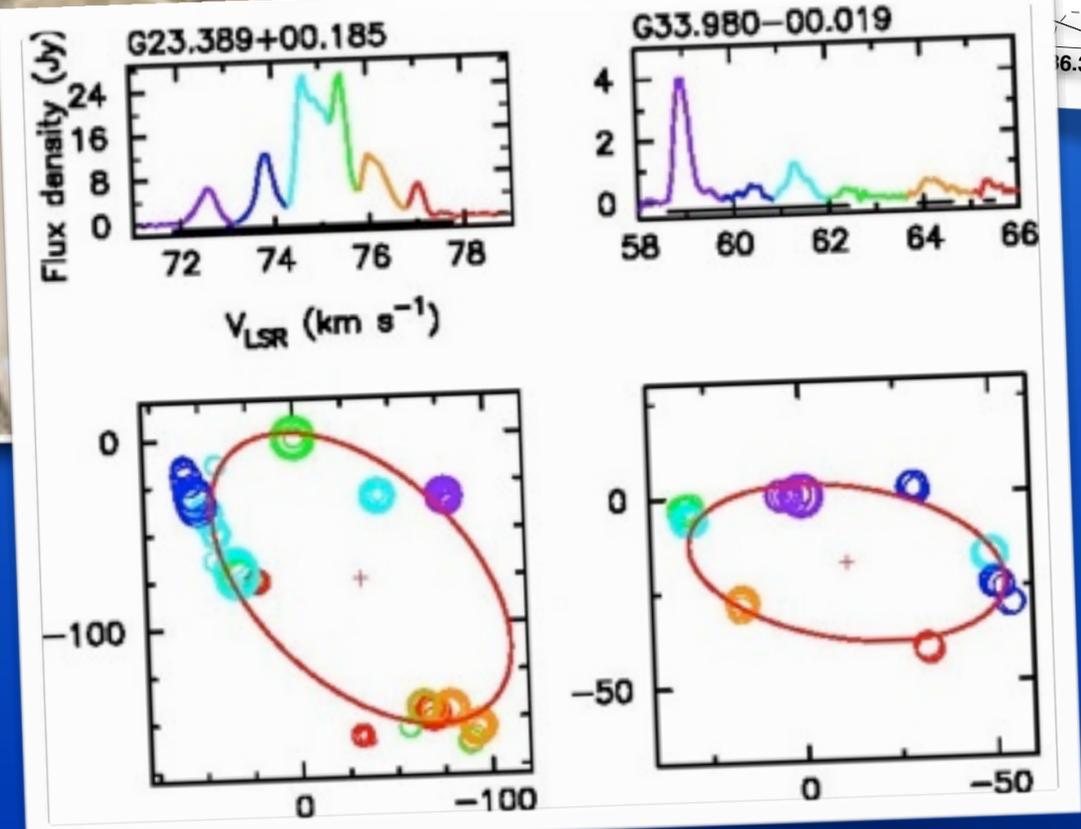
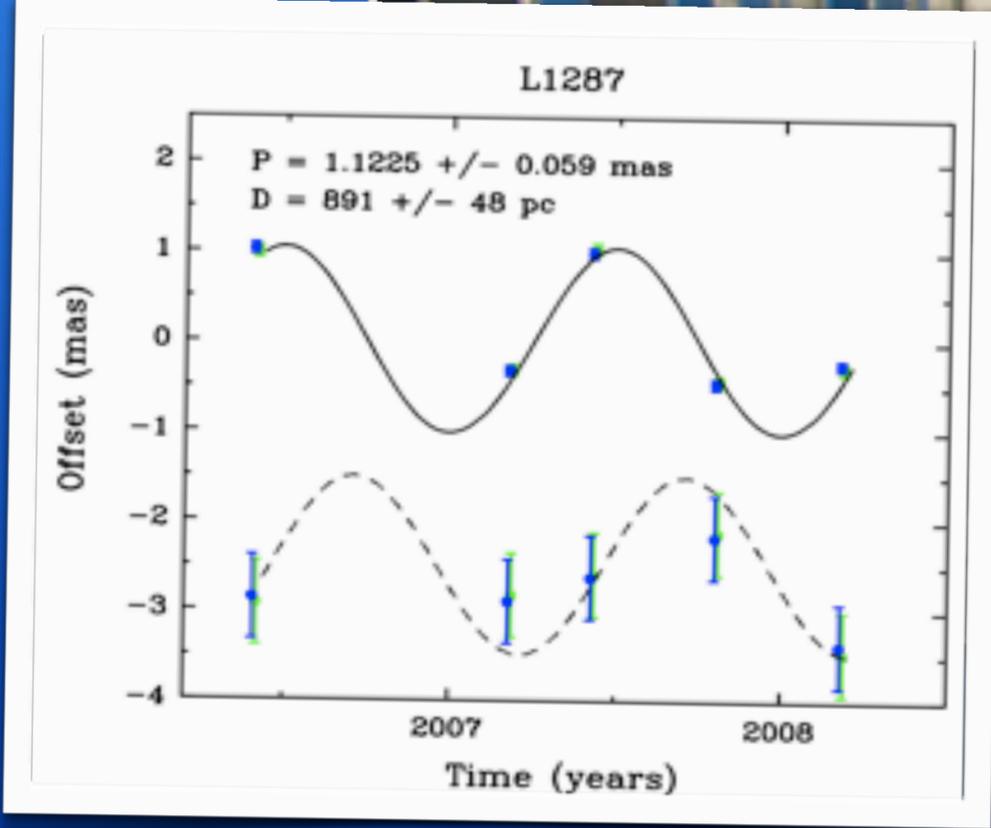
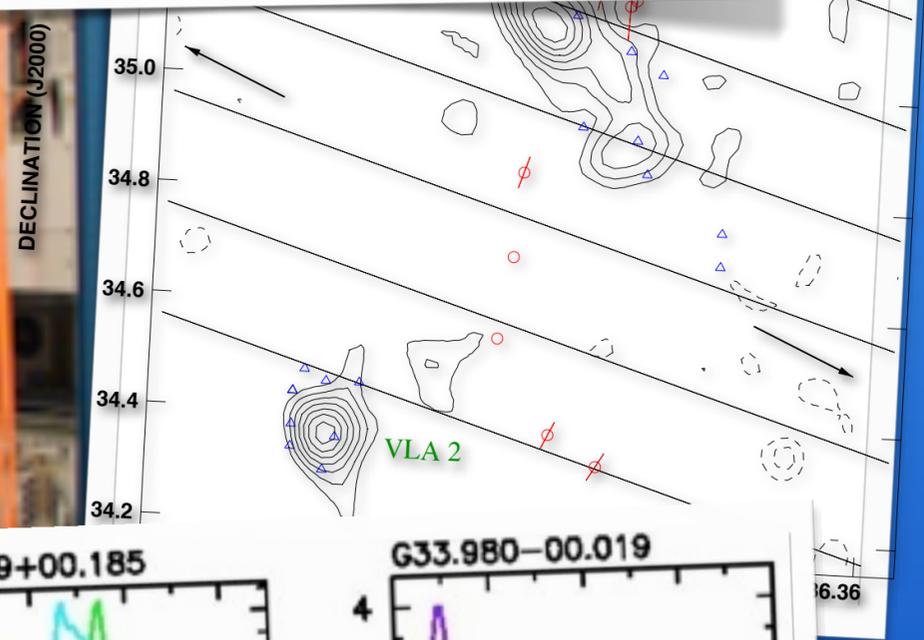
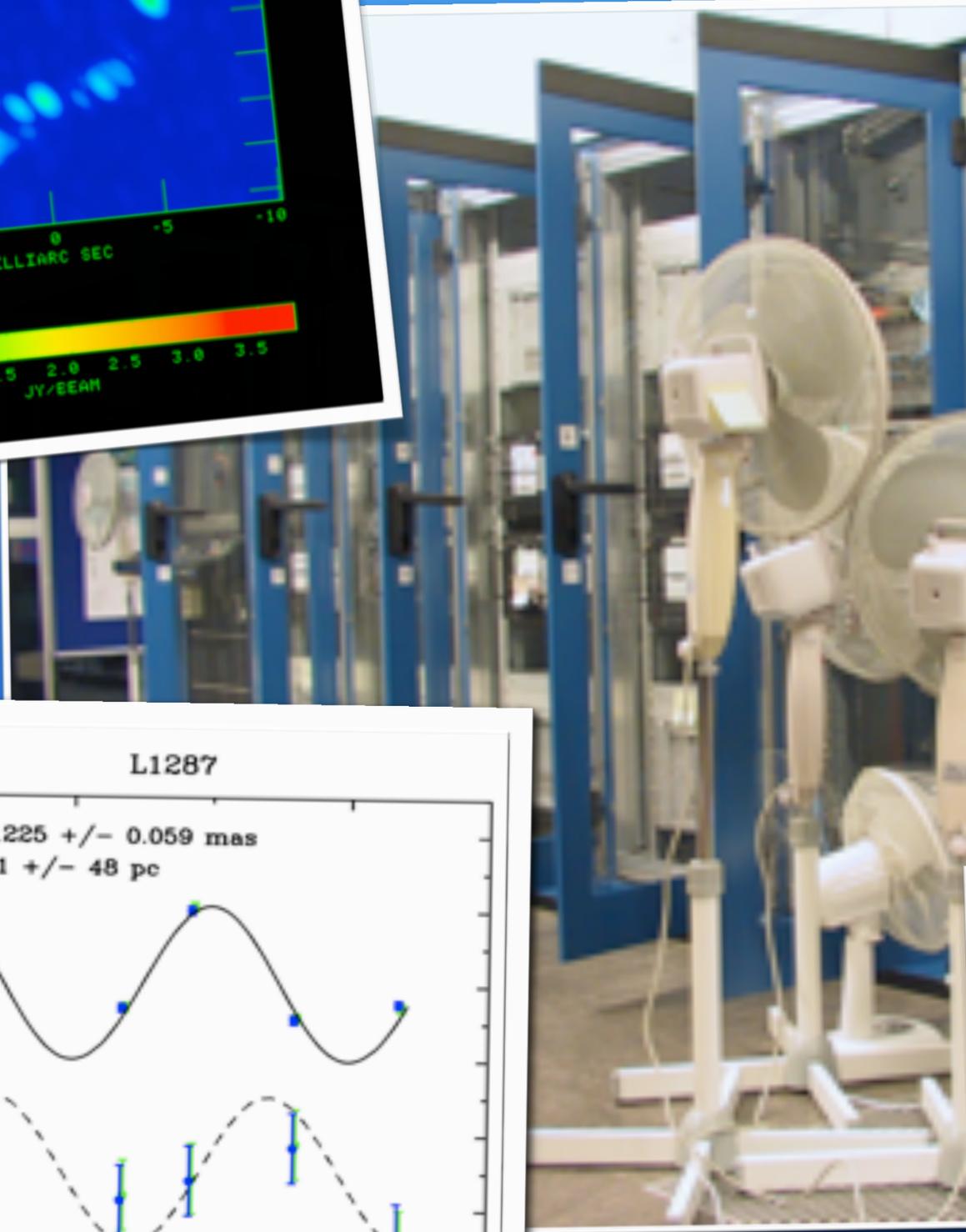
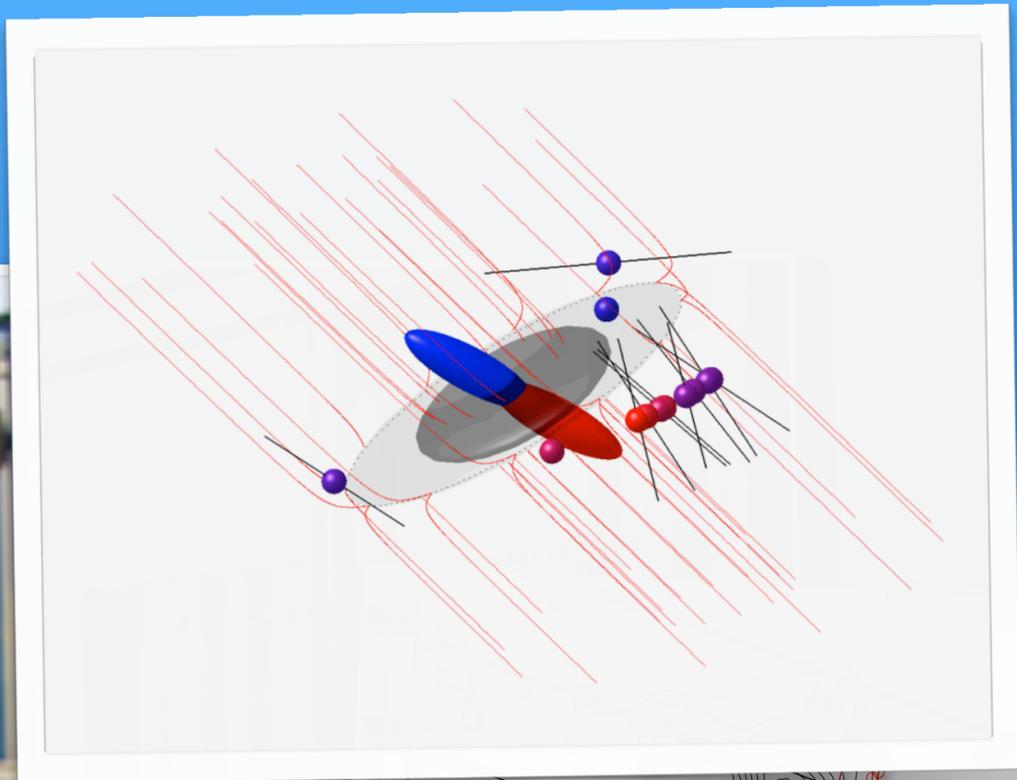
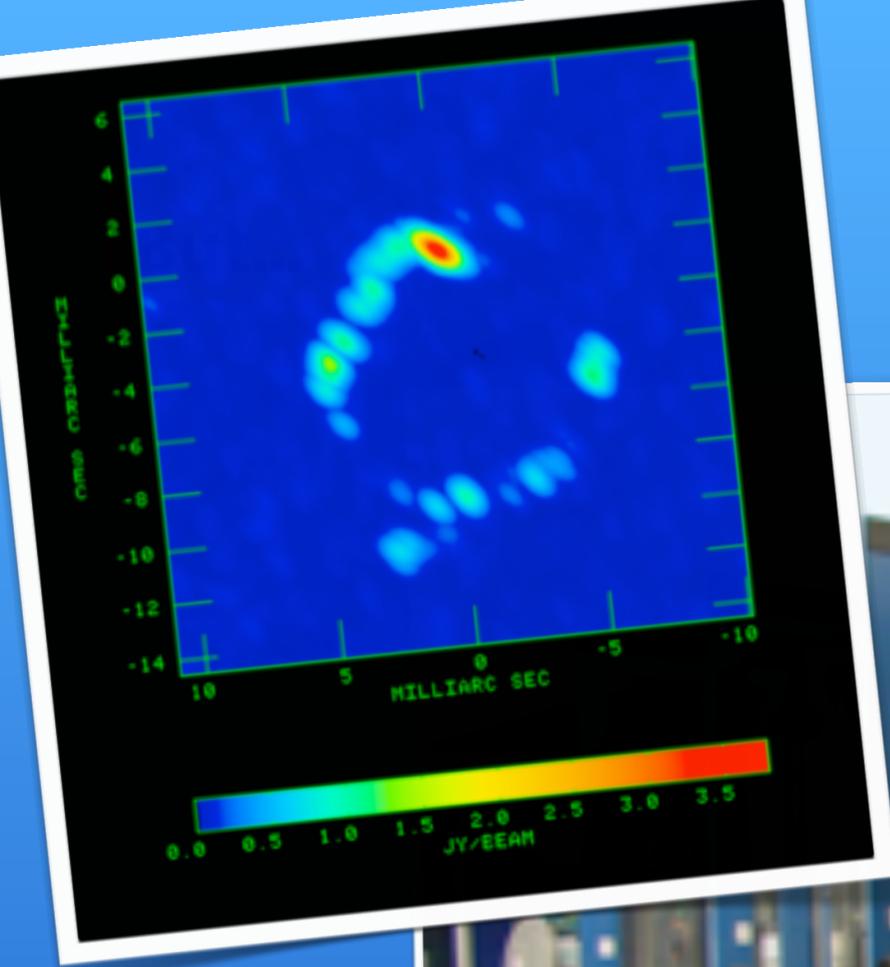
# New policy discussions

- In addition, new requests from (new) user communities
  - Could impact on policy discussions
    - RadioAstron, space applications
    - Monitor programmes/astrometry/joint observations
    - Triggers set by other observatories (link with LOFAR)
- Worried about exploding the procedures
  - Already complex for telescope & correlator operators
  - Also complex for users!
  - Data ownership for triggers, concurrent observations
- Can we address this by (yet) new services?
  - Offer smaller sub-arrays?
  - More e-VLBI days, leading to “VLBI every Friday”
    - And some telescopes on Thursday as well?
  - Central scheduling?



**But...**





# 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
    - Retrofit Mk5AB code
    - Implement Bandwidth on demand
    - Distributed correlation workflow
    - High bandwidth storage solutions
  - and get the best of both worlds
- NEXPReS maintains expertise
  - Collaborations with NRENs



# NEXPReS (1 of 2)

- **N**ovel **EX**plorations **P**ushing **R**obust **e**-VLBI **S**ervices
  - FP7 project involving radio astronomy, computing, storage and networking
  - Acronym came first, inter-capitalization, incorrect representation of existing caps... but it does build nicely of EXPReS
- Radio astronomy project
  - Operational improvements to the complex array of tools supporting radio astronomy observations
  - Software Correlation (distributed, real-time computation)
  - High-speed data buffering between telescopes and correlator
  - Network technology development (Bandwidth on Demand)



# NEXPreS (2 of 2)

- FP7, DG-INFISO
  - Grant Agreement RI-261525
  - 3.5M Euro EC Contribution
  - 36 month Project (2010 July to 2013 June)
- NEXPreS is a successor to EXPreS (EXpress PRoduction e-VLBI Service)
  - Radio Astronomy, Computing, Networking
  - e-VLBI is a SKA pathfinder technology
  - Continue the evolution, development and operationalization of e-VLBI



# 15 Partners

- **JIVE** (NL)
- **ASTRON** (NL)
- **INAF** (IT)
- **MPG** (DE)
- **UMan** (UK)
- **OSO** (SE)
- **VENT** (LV)
- **FG-IGN** (ES)
- **NorduNet** (DK)
- **SURFnet** (NL)
- **PSNC** (PL)
- **DANTE** (UK)
- **AALTO** (FI)
- **TUM** (DE)
- **CSIRO** (AU)

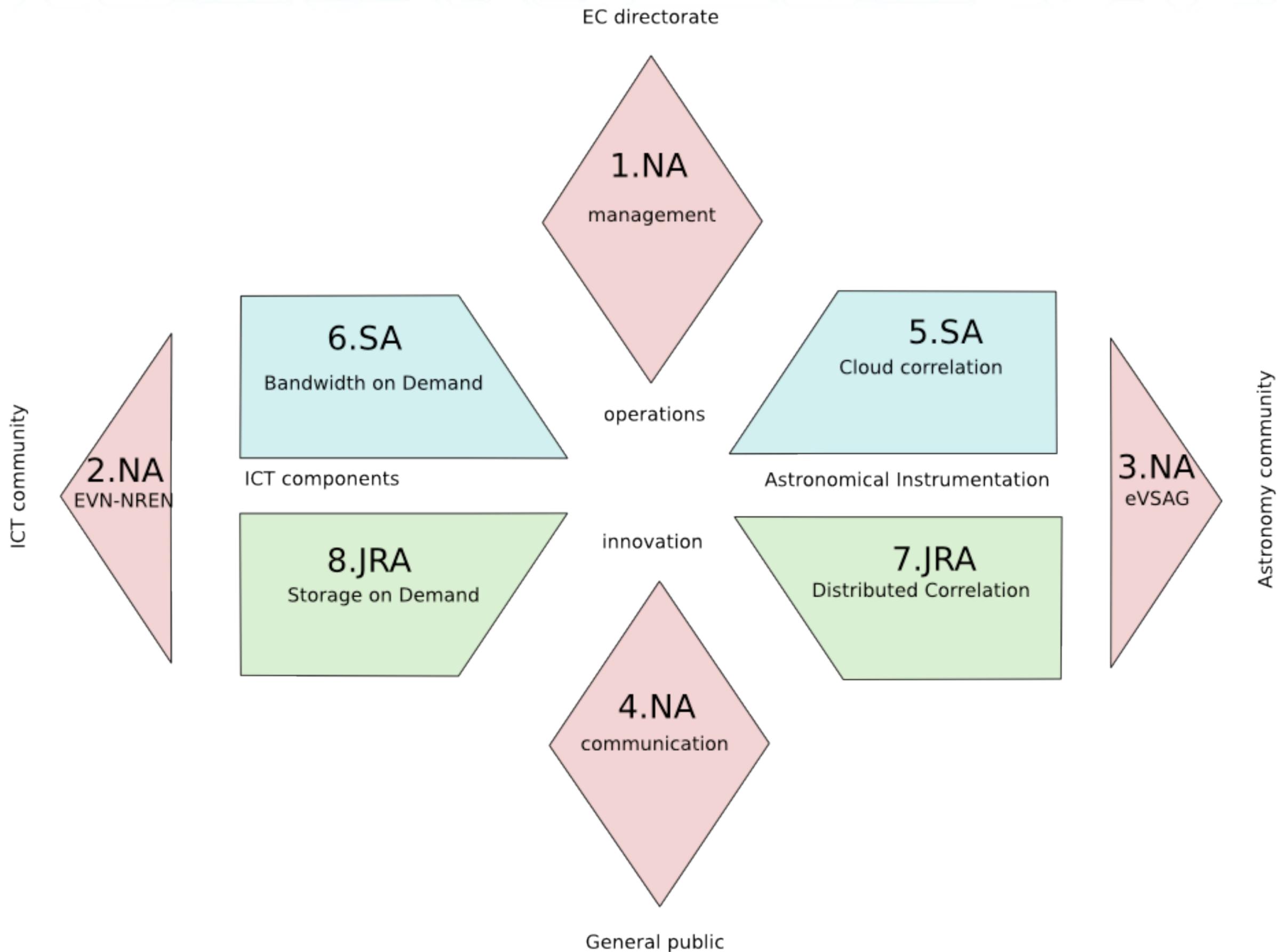


# Per partner financial breakdown

#	Partner	Management	Coordination	Other	RTD	Total	Requested EC contrib.
		NA 1	NA 2,3,4	SA 5,6	JRA 7,8		
1	JIVE	€326,700	€426,000	€1,356,400	€554,200	€2,663,300	€1,581,240
2	ASTRON	€2,500	€0	€222,877	€339,044	€564,421	€334,390
3	INAF	€0	€0	€0	€259,000	€259,000	€158,250
4	MPG	€0	€0	€135,375	€0	€135,375	€135,375
5	UMAN	€0	€0	€204,540	€126,524	€331,064	€219,113
6	OSO	€0	€0	€63,360	€386,648	€450,008	€287,088
7	VENT	€0	€0	€0	€86,025	€86,025	€52,144
8	FG-IGN	€12,250	€0	€0	€0	€12,250	€0
9	NORDUnet	€0	€0	€214,825	€0	€214,825	€129,145
10	SURFnet	€0	€0	€80,000	€0	€80,000	€0
11	PSNC	€0	€0	€0	€354,400	€354,400	€184,800
12	DANTE	€29,600	€0	€29,600	€0	€59,200	€0
13	AALTO	€0	€0	€54,000	€312,760	€366,760	€229,605
14	TUM	€0	€0	€136,520	€0	€136,520	€109,425
15	CSIRO	€0	€0	€79,425	€0	€79,425	€79,425
<b>Total</b>		<b>€371,050</b>	<b>€426,000</b>	<b>€2,576,922</b>	<b>€2,418,601</b>	<b>€5,792,573</b>	<b>€3,500,000</b>



# Workpackages, visually



# Workpackages, textually

- WP1 Management (JIVE)
- WP2 EVN-NREN (DANTE)
- WP3 eVSAG (FG-IGN)
- WP4 Communication (JIVE)
- WP5 Cloud Correlation (JIVE)
- WP6 High Bandwidth on Demand (JIVE)
- WP7 Computing in a Shared Infrastructure (JIVE)
- WP8 Provisioning High-Bandwidth, High-Capacity Networked Storage on Demand (Aalto)
  
- Today:
  - Charles: WP1,2,3,4,5,6
  - Huib: WP5,7



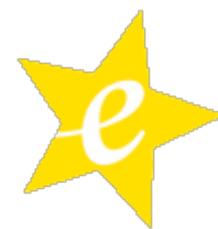
# WP1 Management

- WP Lead: JIVE, T. Charles Yun
- Main Tasks
  - Project centered (not JIVE, EVN, e-VLBI, etc.)
  - Point of contact with the EC
  - Coordinate the annual, in person, project review
  - Run support, provide shelter and create interference as necessary
  - Lunch Talks

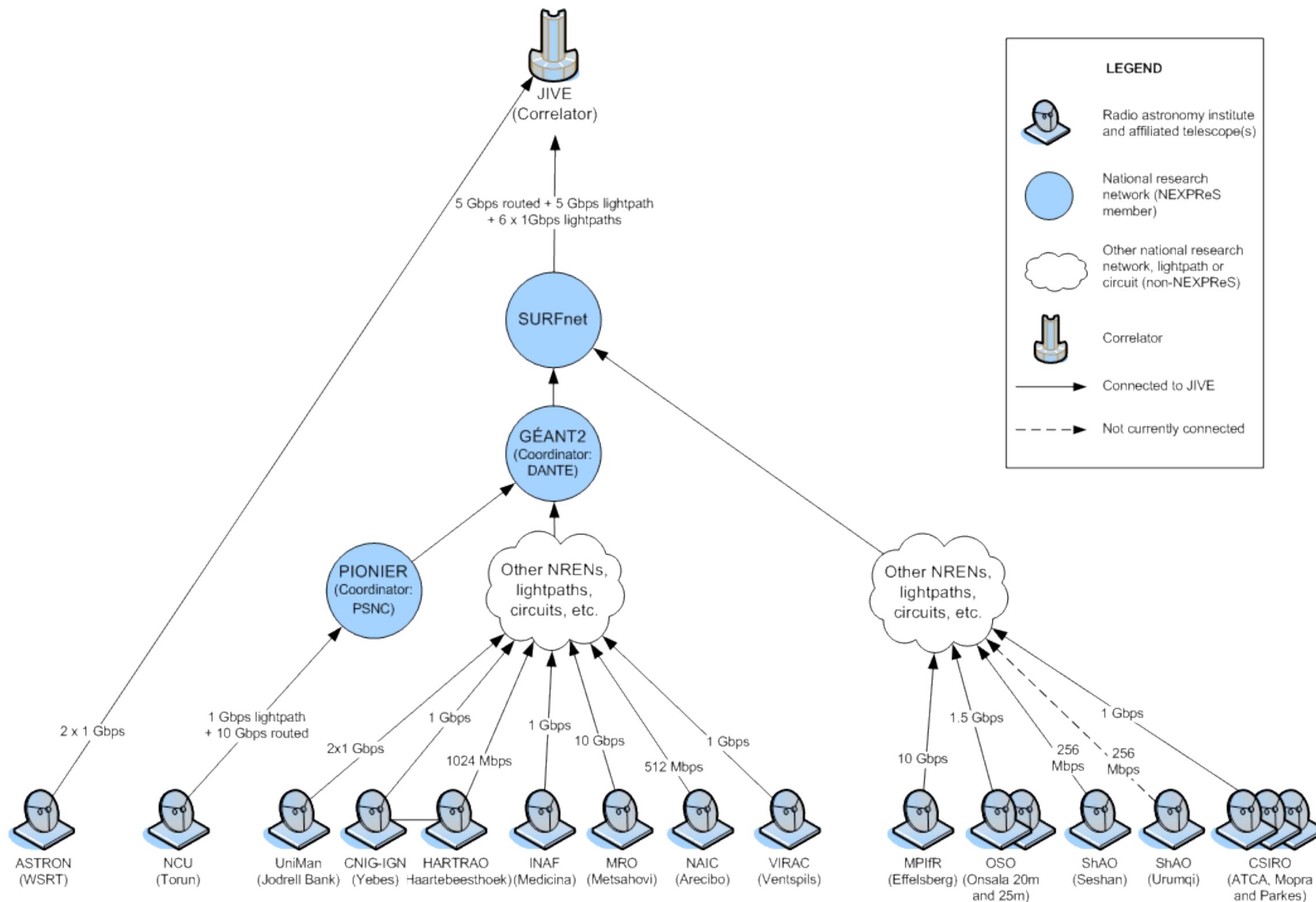


# WP2 EVN-NREN

- WP Lead: DANTE, Richard Hughes-Jones
  - European VLBI Network, National Research and Education Networks
- Main Tasks:
  - Maintain communication between the wider networking community and astronomers
    - Signal networking improvements into the astronomy community in advance of their proliferation
    - Carry upcoming astronomy needs (desires) to those who are carrying out infrastructure upgrades (minor and major) in advance of deployment



# Schematic- Network Routes



# EVN-NREN Mtg 1

- 24-25 May 2011, Aveiro, Portugal
  - Hosted by Instituto de Telecomunicações
  - In conjunction with “The growing Demands on Connectivity and Information Processing in Radio Astronomy from VLBI to the SKA”
  - [http://www.av.it.pt/workshops/ict\\_vlbi2ska.html](http://www.av.it.pt/workshops/ict_vlbi2ska.html)
  - EC participation at the meeting
- We somehow missed taking an official workshop photograph...



Workpackages

# EVN-NREN Meeting Photo



# WP3 eVSAG

- WP Lead: CNIG-IGN, Paco Colomer
  - e-VLBI Science advisory Group
- Main Tasks
  - Coordinates the discussions linking the science and technology of e-VLBI with possible operational and policy impacts
  - Continuation of a format that was quite effective during EXPReS



# eVSAG Mtg 1

- 4 November 2011, Madrid, Spain
  - Simultaneously via EVO vidconf
  - In conjunction with the EVN PC
  - Half of the project participants used EVO
- The technology has worked well for about 7 years and is free to use
- Most problems come from old computers and old (fashioned) users
  - flight + hotel + dinner + 30 mins **training** =  
new MacBook + **many** useful vidconf + time



Workpackages

# eVSAG Meeting Photo



Available

- My EVO Buddies
  - Paul Boven
  - NEXPreS eVSAG
  - Mark Kettenis
  - James M. Anderson
  - ICT ASTRON
  - Speaker Anton
  - Lars Buchten
  - Laura Barbas Cahu
  - Simon Casey
  - Paco Calomer
  - Marc Luchies
  - Meijin Martins
  - Tom Muxlow
  - Wes Smelds
  - Dominik Stokhosa
  - Klaas Stuurwold
  - Hub van Langvelde
  - SHAO VLB
  - Wouter Vlemmings
  - ic yun
- My EVO Communities
  - Connected to Panda RAP\_FR
  - eVLBI scheduled sessions: [http://www.zwtb.org/evlbi/e-vlb\\_status.html](http://www.zwtb.org/evlbi/e-vlb_status.html)
  - Notes on NEXPreS WP7 demo (see wiki)

Chat messages:

- hey, maybe Mark and I can assume that the non-mod
- Arpad Szomoru joined
- Zsolt Parag joined
- John, is your mic muted?
- Paul Boven joined
- Arpad Szomoru sound completely disap
- audio is cutting out
- John Conway same for me, can only hea
- now we do
- Arpad Szomoru barely audible
- Mark Kettenis Hub is too far away from
- Mark Kettenis sound is more important th
- Arpad Szomoru we hardly hear anything
- NEXPreS eVSAG Better now??
- Arpad Szomoru yep
- Paul Boven Should there be video too?
- Arpad Szomoru I can see the meeting ar
- Paul Boven Got it, me too now.
- Paul, do not stream video o
- Paul Boven I like the fish
- Arpad Szomoru Don't worry, no camera here
- Arpad Szomoru nice to see Zsolt un't it?
- I could stream the back of f
- NEXPreS eVSAG Please tell me if you all

EXPRES was concluded in Mar 2010

## NEXPreS

Novel EXplorations Pushing Robust e-VLBI Services

Successful NEXPreS proposal kicked off in July 2010

# WP4 Communications, Outreach

- WP Lead: JIVE, Kristine Yun
- Main Tasks:
  - Coherency to make make the project:
    - Look smart
      - Commissioned graphic elements, consistent look and feel, new display/posters...
    - Sound good
      - Press releases, announcements and proof reading for other human beings (not radio astronomers)...
  - Get out there
    - Send display to each partner, posters/pamphlets to various events...



# Major Activities/Presentations

- Logo and visual elements designed for use in all outreach materials, digital and print
- Display made and sent to e-VLBI Workshop and e-VLBI/SKA Workshop
- Brochure designed and distributed to partners, distributed at events
- Presentation: "Outreach Activities for JIVE and NEXPreS" at the RadioNet Outreach Workshop (Bologna, November 2010)
- Press release: "Astronomers simulate real-time telescope as big as the world to study peculiar active galaxy" (3 February 2011)



Workpackages

**Website, Pamphlets, Display, etc.**

# Website, Pamphlets, Display, etc.



In recent years, e-VLBI has evolved from an experimental technique, connecting a small number of telescopes in real-time at modest bandwidths, into an operational astronomical service with competitive sensitivity and imaging capabilities. In spite of its obvious advantages, this enhanced mode is not yet offered to all astronomers, due to connectivity, bandwidth and processing capacity limitations.

**NEXPRoS is combining "the best of both worlds" - data archiving and reprocessing afforded by traditional disk-based VLBI with the speed and flexibility of**

**Activities**

**SERVICE ACTIVITIES**

 **Cloud Correlation** is transforming the complete VLBI observational chain and removing the current strict distinction between disk-based and electronic VLBI. The focus is the development of a system capable of simultaneous buffering, transmission and correlation of data to create a system in which all observations benefit from having a real-time component, while retaining the option to re-correlate the data at a later time.

 **High Bandwidth on Demand** is upgrading operational connectivity from static to dynamically allocated connections, freeing up resources when there is no ongoing e-VLBI observation. Additionally new on-demand paths should initially support at least

**Benefits**

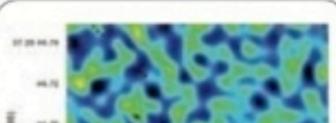
**IMPROVED ASTRONOMICAL CAPABILITIES**

NEXPRoS will benefit the entire VLBI user community, providing:

- error-free data from more telescopes for a larger fraction of the time
- more efficient use of the telescope infrastructure, resulting in more hours for science observations
- greater sensitivity for the study of transient events and fainter objects
- data re-correlation, making spectral line e-VLBI observations possible

In addition, NEXPRoS will:

- take full advantage of Europe's large telescopes to complement new radio telescopes with high sensitivity and high resolution capabilities



**What is e-VLBI?**

**Very Long Baseline Interferometry (VLBI)** is an astronomical method by which multiple radio telescopes located hundreds or thousands of kilometres apart observe the same region of sky simultaneously. Data from each telescope is recorded and shipped to a central "correlator", a purpose-built supercomputer which processes the data. This simulates a single telescope with a diameter as wide as the most distantly located telescopes and produces images with higher resolution than the most powerful optical telescopes.

**Electronic VLBI (e-VLBI)** improves upon the traditional disk-based method by streaming data directly from the telescopes and correlating it in real-time, currently at a rate of one Gigabit per second (Gbps) from each telescope, and eventually tens of Gbps. The speed of e-VLBI allows immediate identification and correction of problems during an observation, and astronomers receive data in a matter of hours rather than weeks. If so-called transient activity is detected, such as a supernova or gamma-ray burst, the astronomer can quickly schedule additional observations, an advantage not possible with traditional VLBI.



**Partners**

**Coordinator**

- Joint Institute for VLBI in Europe (JIVE), EU (The Netherlands)

**National Astronomy Institutes**

- Aalto University Metsähovi Radio Observatory (AALTO), Finland
- Chalmers Tekniska Högskola AB (OSO), Sweden
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Fundación General de la Universidad de Alcalá, together with Instituto Geográfico Nacional (FG-IGN), Spain
- Istituto Nazionale di Astrofisica (INAF), Italy
- Max-Planck-Institut für Radioastronomie (MPIFR), Germany
- The Netherlands Institute for Radio Astronomy (ASTRON), The Netherlands
- The University of Manchester (UMAN), UK
- Ventspils International Radio Astronomy Center of Ventspils Augstskola (VENT), Latvia



**NREN and Advanced Computing Facility Providers**

- Delivery of Advanced Network Technology to Europe Limited (DANTE), EU (UK)
- NORDUnet A/S (NORDUnet), Denmark
- Poznan Supercomputing and Networking Center (PSNC), Poland
- SURFnet bv (SURFnet), The Netherlands
- Technische Universität München (TUM), Germany



**Novel EXplorations Pushing Robust e-VLBI Services**



**Forging a path to the future of Radio Astronomy**

[www.nexpres.eu](http://www.nexpres.eu)



**NEXPRoS Project Office**

<p><a href="http://www.nexpres.eu">www.nexpres.eu</a>  <a href="mailto:nexpres@jive.nl">nexpres@jive.nl</a>                  Tel: +31 (0)521 596 500                  Fax: +31 (0)521 596 539</p>	<p>Mailing Address:                  Postbus 2                  7990 AA Dwingeloo                  The Netherlands</p>	<p>Visiting Address:                  Oude Hoogeveensedijk 4                  7991 PD Dwingeloo                  The Netherlands</p>
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 NEXPRoS is an e-Infrastructure project funded by the European Union's Seventh Framework Programme under Grant Agreement RI-261525.

# WP6 High Bandwidth on Demand

- WP Lead: JIVE, Paul Boven
- Main Tasks
  - Integrate, test and demonstrate that on demand networking works in the e-VLBI context (real-time observations and archives)
- Terms of importance
  - Lightpath (exclusive)
  - Dynamic (changeable via non-heroic effort)
  - Reservations (something in the future)
  - Network Services Interface, NSI (protocol)
- ASTRON has a part in this WP (xref Hanno)





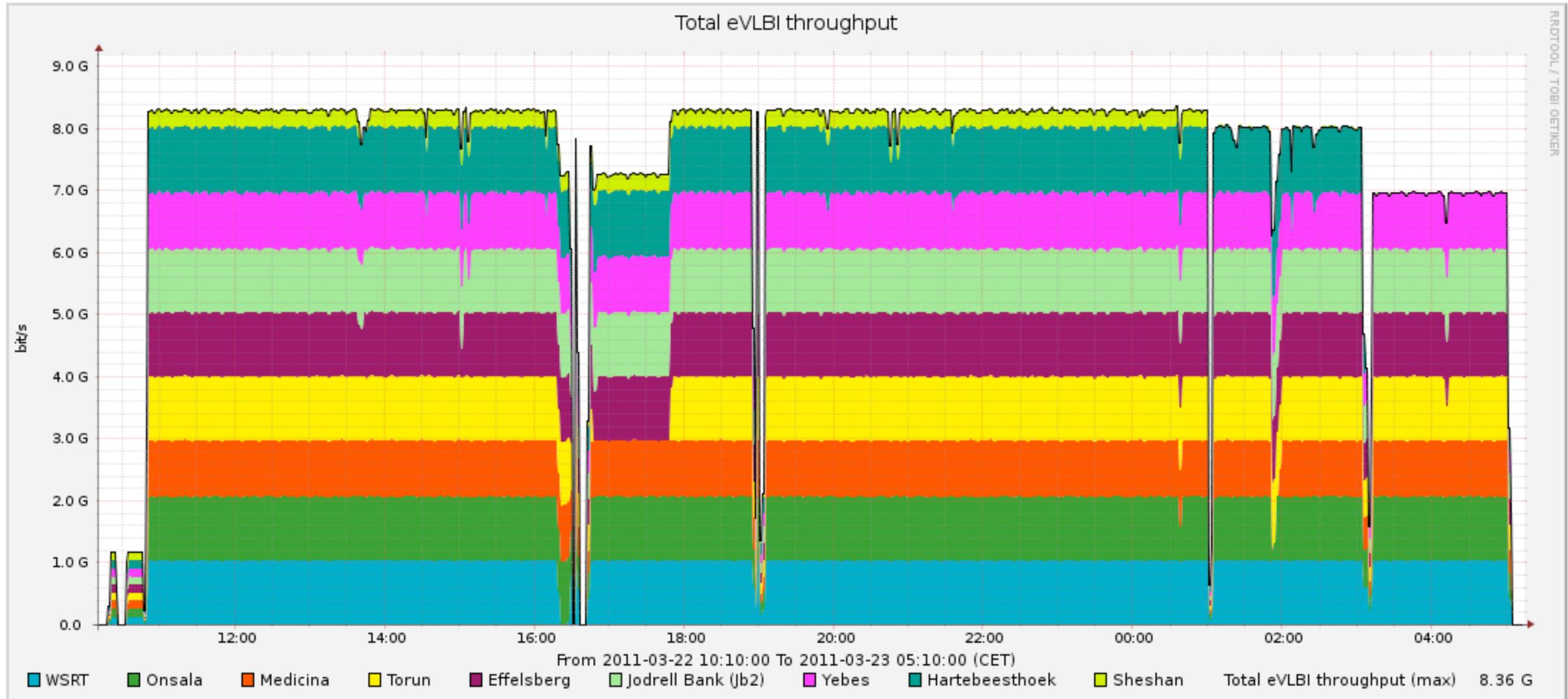
# Items of note

- NSI is a protocol being developed (note verb tense) by network infrastructure operators
  - NEXPreS is a user of networks and network services
  - For a variety of reasons it is useful for NEXPreS/e-VLBI community at large to write an NSI client
- Currently there are many pieces of software that are working to NSI compliance... They are all at different stages of completeness
- The complexity of the effort is organizing multiple independent entities to coalesce around a common protocol in a short period of time.
  - The highway metaphor is appropriate



VLBI- Very Long Baseline Interferometry

# But do we really use the network?



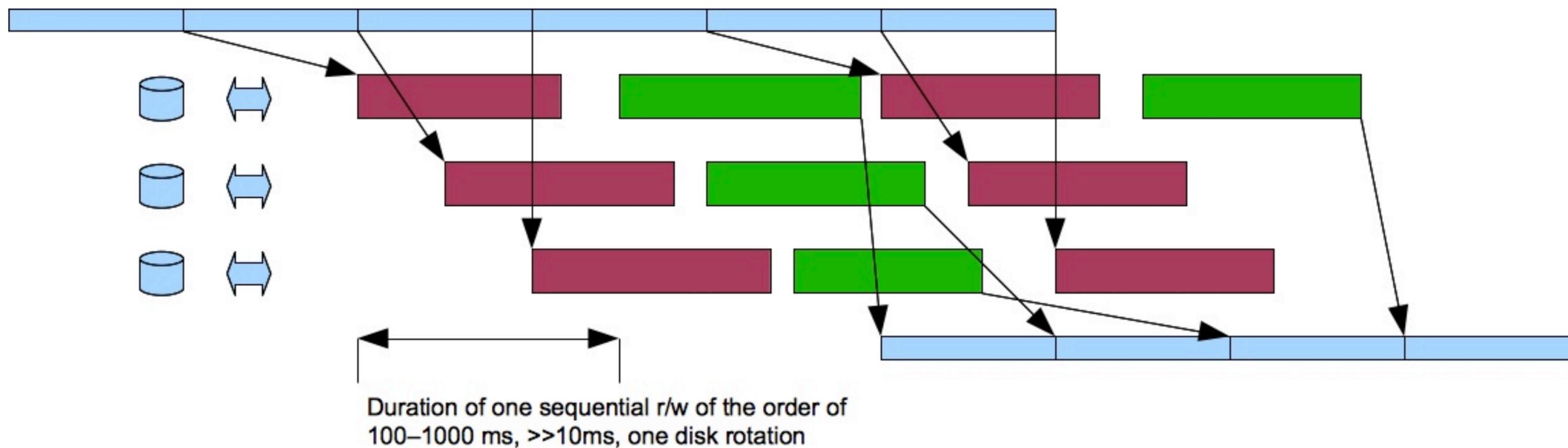
# WP8 Storage on Demand

- WP Lead: Aalto (Metsahovi), Ari Mujunen
  - really, the formal task title is “Provisioning High-Bandwidth, High-Capacity Networked Storage on Demand” but that is too long
- Main Tasks
  - Identify the mix of technology that will serve to build a next generation storage device: spindle, solid state/memory buffers
  - Centralized (power consumption), distributed storage (networking, APIs, Auth(n|z), etc.
  - Allocation, deallocation, access...
  - Price, performance, distance from the cutting edge
- ASTRON also participates in WP8



# It's not just a bucket of bits

- Simultaneous read-write is intensive



- It's not just a big RAID bucket
- It's probably not "just" a bucket of ZFS/XFS



# Keeping in mind...

- Large capacity storage systems online is power intensive
- Fundamental improvements in technology
  - SSD improvements, large scale memory buffers, networked memory buffers
- What others are doing
  - MIT- Mark6 (very similar to the prototype built by Aalto)
  - Industry- Violin/TMS (interesting, but expensive)
- Assuming a prototype, what is the deployment process across the EVN?



Workpackages

**Cheapest, +30% cost, to \$\$\$**

Workpackages

Cheapest, +30% cost, to \$\$\$



# WP5 Cloud Correlation

- WP Lead: JIVE, Arpad Szomoru
  - With efforts from Eldering, Verkouter, Schoenmaker, Kettenis, Boven
- Core of the NEXPreS objective
  - Flexibility in storage vs streaming vs shipping
    - May require addressing scheduling as well
  - Requires simultaneous recording and streaming
    - At 4 Gbps!
  - And simultaneous storage and correlation
    - With more than 1 correlator
- Lots of work, mostly behind the schemes
  - Working for long-term objectives...



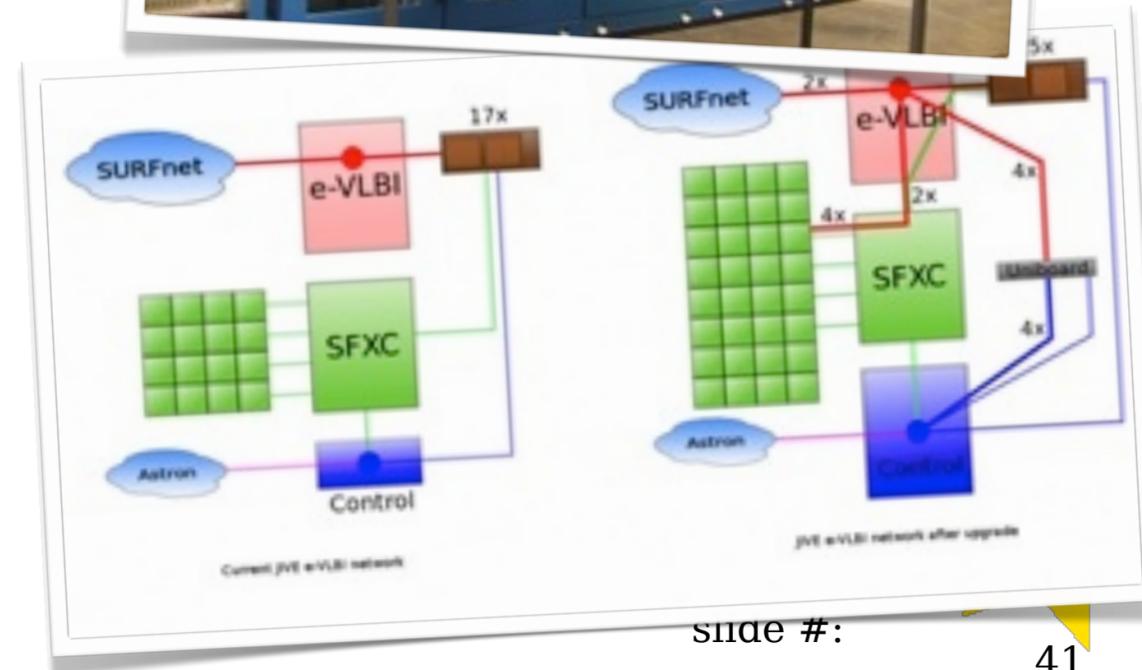
# Activities

- Flexible Buffering
  - Together with Metsahovi, WP8
- Introducing VDIF standard
  - Allows flexible connection various systems
  - 4Gbps, UniBoard correlator, distributed correlation
- Continuous quality monitoring & station control
  - Driven by TUM (Wetzell geodetic station), MPG Bonn
- Automated network-dependent correlation
  - JIVE working on the correlator control



# JIVE progress

- Cloud correlation
  - Overhaul of local network
  - Flexibly connecting playback
  - Fibres & correlators
- Control code
  - Allowing mixed rate operations
  - Making various playback units usable
    - Including Mk5C
  - Uniting correlator interfaces
- Transparent buffering
  - Working on JIVE Mk5 control code
  - For use in the field
  - And at the correlator
  - With input from WP8



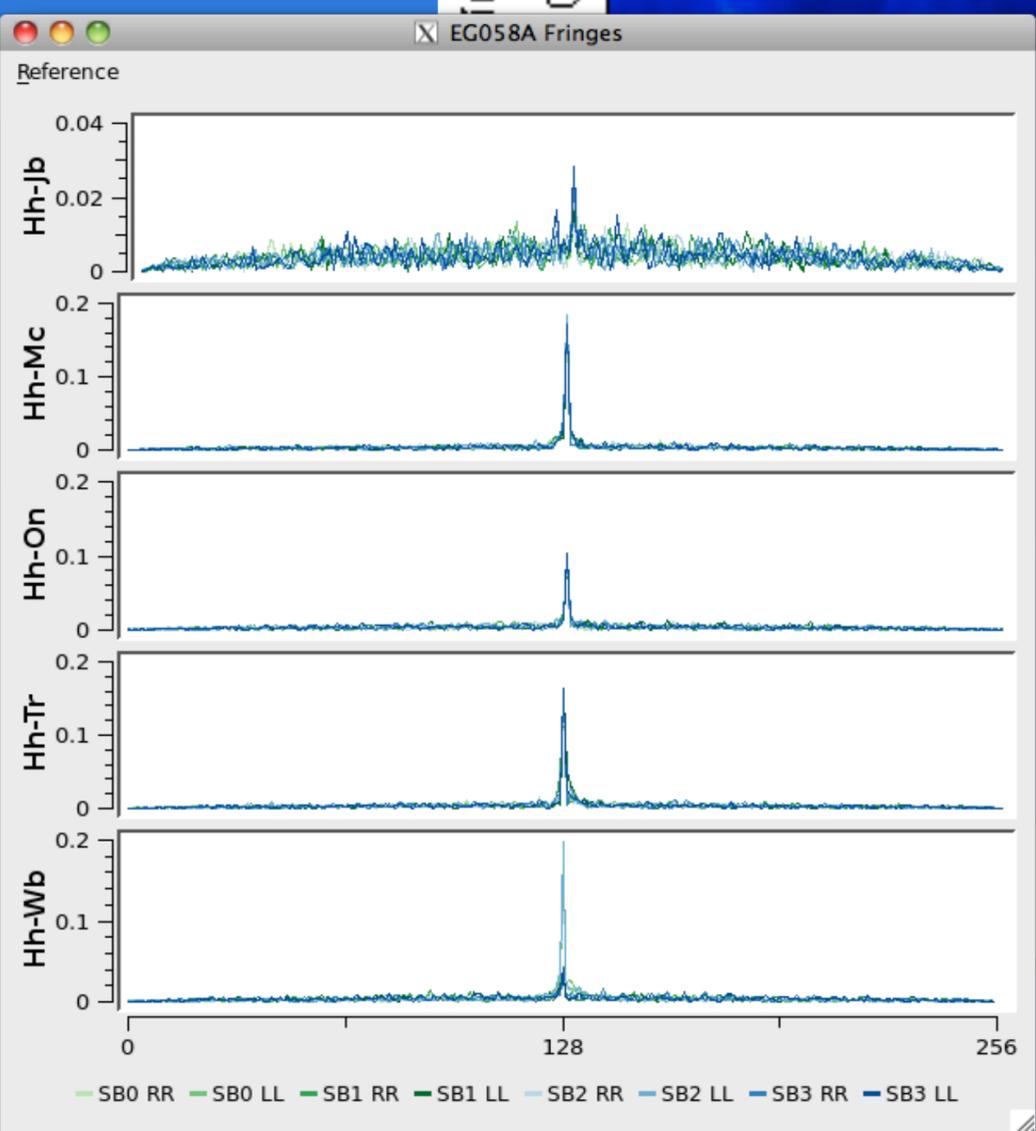
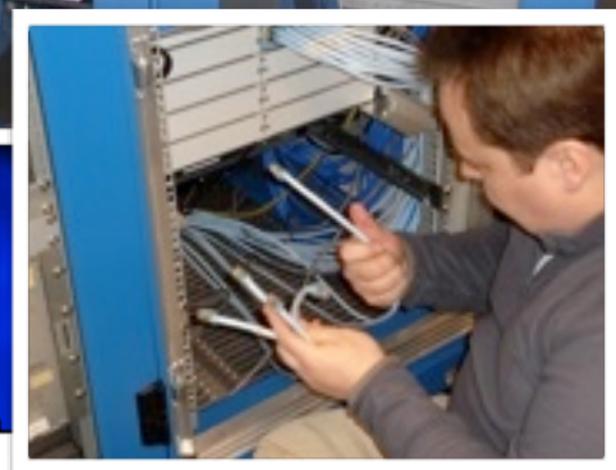
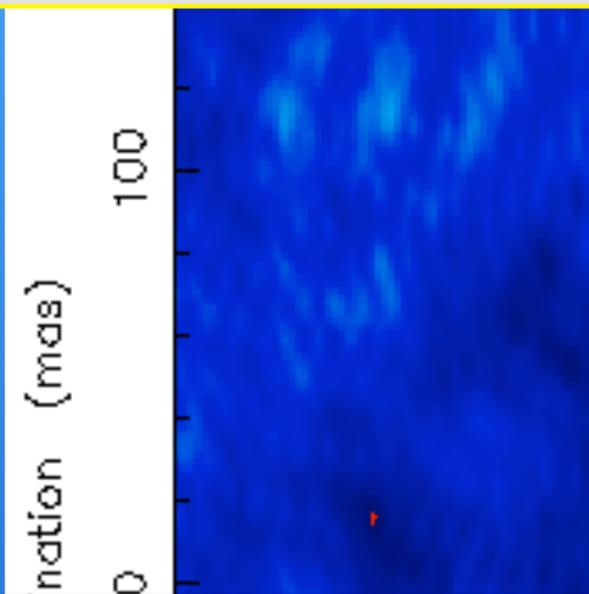
# WP7 Compute in Shared Infrastruc.

- WP Lead: JIVE, Mark Kettenis
  - Together with Poznan, Ventspils, Onsala
  - Aard Keimpema at JIVE
- Based around the software correlator
  - The EVN software correlator at JIVE (SFXC)
  - Operational for dedicated EVN projects
    - Determination of Spacecraft position
    - Pulsar processing
    - High spectral resolution
    - Multiple field centres



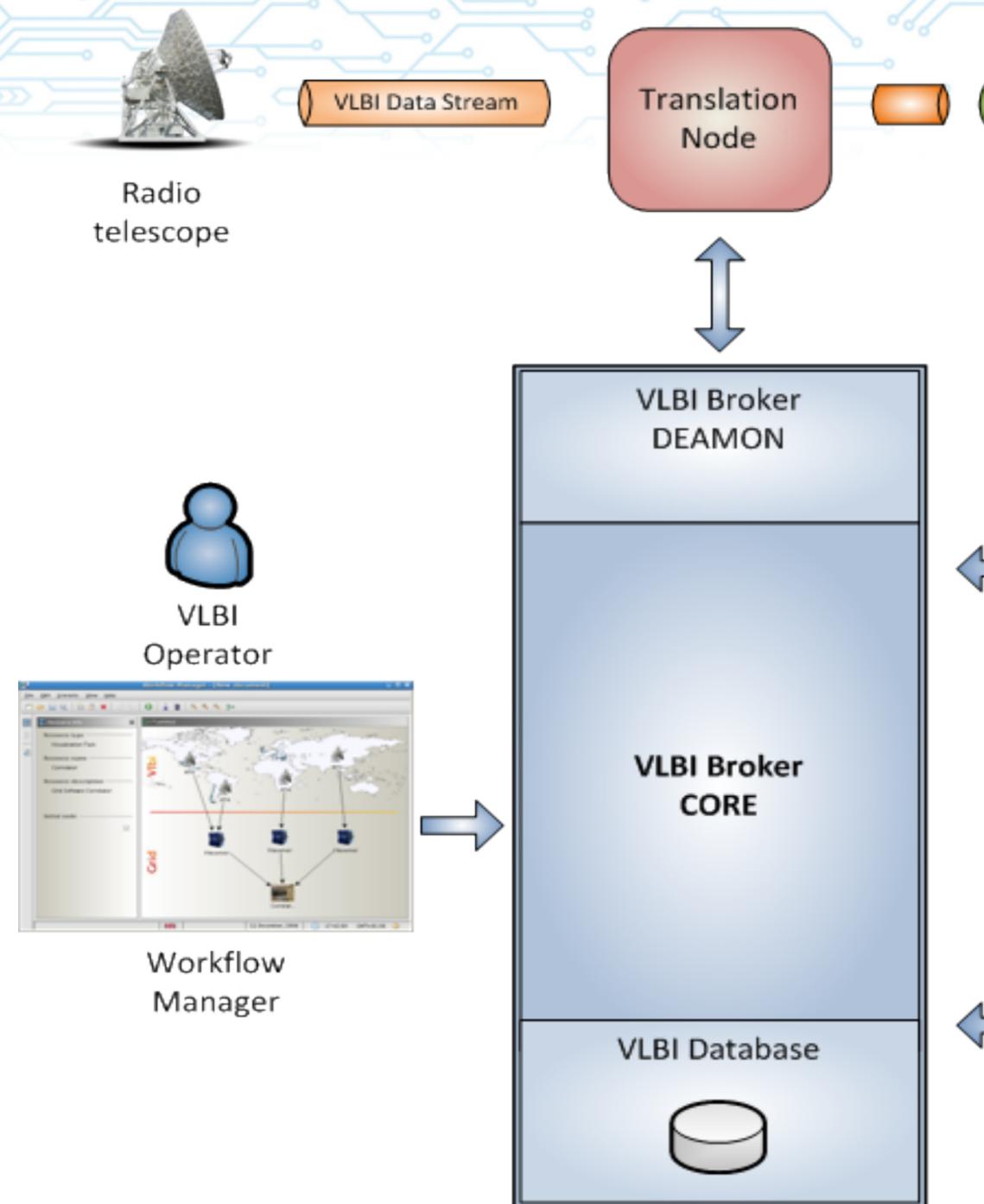
- The EVN software correlator at JIVE (SFXC)

- 9 stations 1Gbps real-time
- Tested for e-VLBI



# Distributed correlator

- Run SFXC on multiple site
  - Moved away from Grid
  - Focus on radio astronomy domain
- Applicable for special projects
  - Long-term monitoring/astrometry



Demo at "Supercomputing '10" New Orleans. Pulsar detection "life"

processing JIVE data on DAS-3 cluster



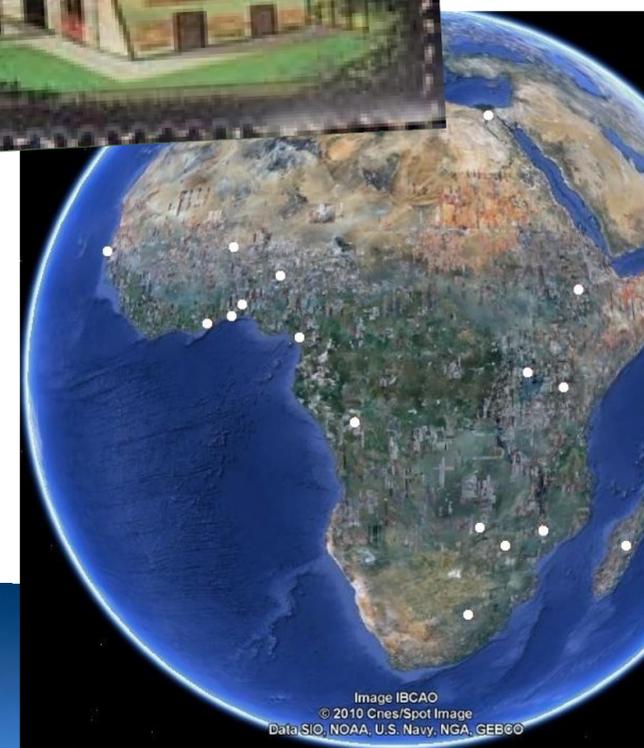
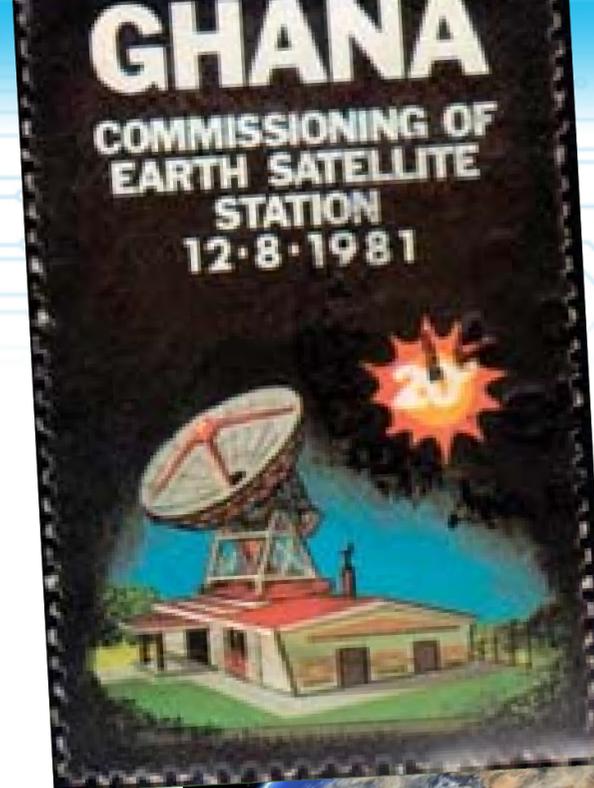
# NEXPreS impact on EVN/JIVE

- Development of e-VLBI continues through NEXPreS
  - Essential in keeping local expertise
  - Vital for keeping in touch with NRENs
  - Continued effort in outreach/dissemination
- NEXPreS continues to support e-VLBI operations
  - Reports on e-VLBI science
- Gets some upgrades going
  - Notably Mk5Cs at JIVE
- Step towards all EVN in e-VLBI
  - Must increase interoperability with other VLBI networks
- Makes a recognized SKA-pathfinder
  - Essential in keeping up with developments



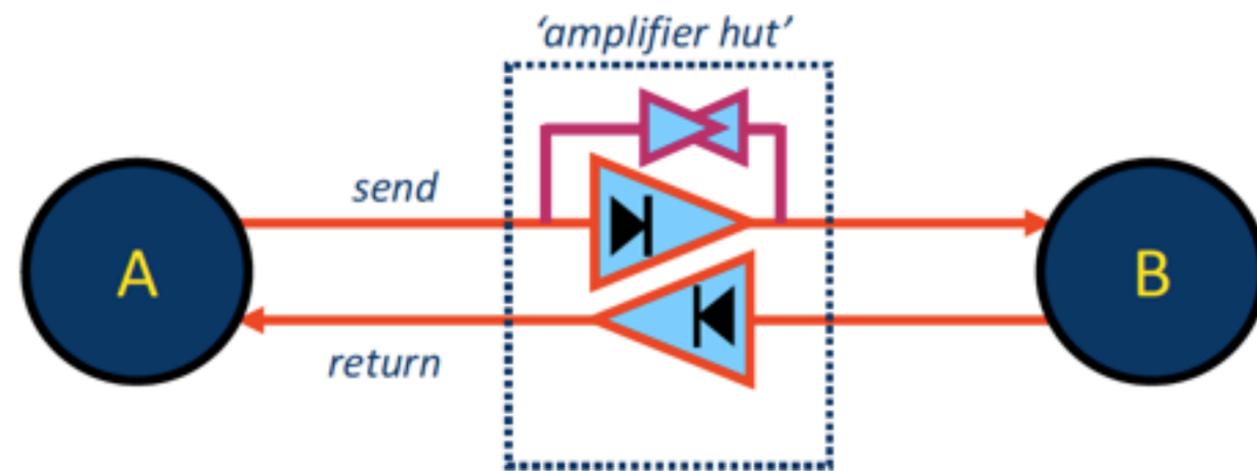
# Next? More VLBI!

- 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
- And increasing number of space applications
- Science synergy with new survey instruments (SKA pathfinders)



# Future project?: 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!

# Long term perspective

- Perspective for SKA era
  - Global, high frequency VLBI has complementary science case
  - Large (N=30+) networks, e-VLBI based
- Exploring synergy with SKA (pathfinders)
  - VLBI is helping us to foster user involvement
    - Gets the excitement of astronomical observation into VLBI
  - Pushing technology is part of the mission
    - e-VLBI has helped keeping us visible in Europe
    - And in our partner countries
- Crucial part of JIVE strategy



Closing

# Questions & Contact Information

- Huib

langevelde@jive.nl

Charles

tcyun@jive.nl

<http://www.nexpres.eu/> or <http://www.jive.nl/>

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