EXPReS- Real-Time VLBI

- The Current Status and Next Steps

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Project Manager
JIVE, Coordinating Institution

Overview

- Project Description, context, background
- Current Operational Status
- Possibilities and future research

- And a mention that the 7th International e-VLBI Workshop just concluded, hosted by Shanghai Astronomical Observatory at their Institute in Shanghai

EXPReS- the Project

- EXPReS = Express Production Real-time e-VLBI Service

- 3 year project, start March 2006,
  - funded by FP6 DG-INFSO
  - Contract #026642.

- Objective: to create a distributed, large-scale astronomical instrument of continental and inter-continental dimensions.

- Means: high-speed communication networks operating in real-time and connecting some of the largest and most sensitive radio telescopes on the planet.

EXPReS' Goal

The overall objective of EXPReS is to create a **production**-level, **real-time**, "electronic" VLBI (e-VLBI) **service**, in which the radio telescopes are reliably **connected** to the central **supercomputer** at JIVE in the Netherlands, via a high-speed optical-fibre communication **network**...

- or -

Make e-VLBI *routine, reliable* and *realistic* for astronomers today and through the future

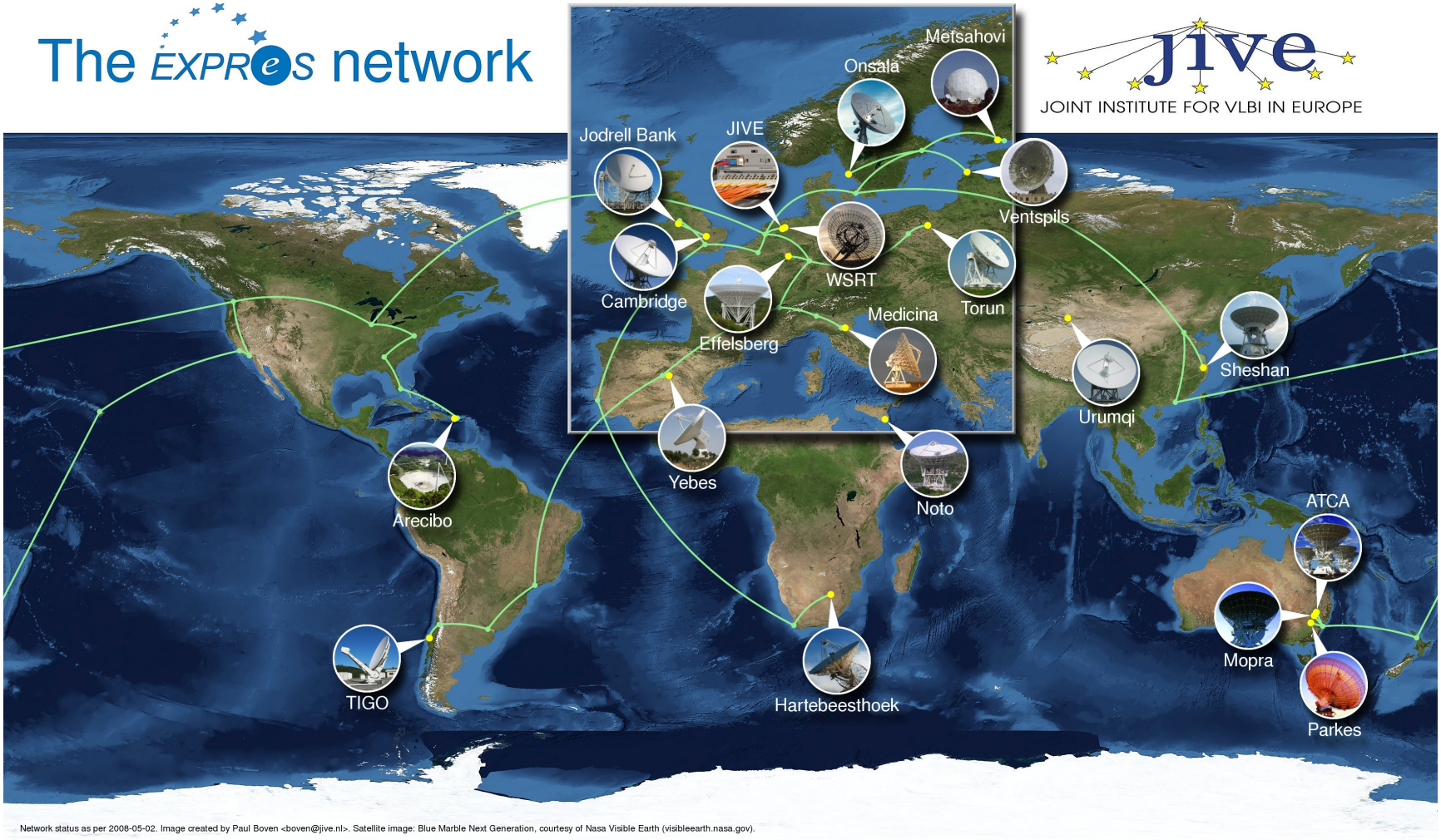
EXPReS Partners

- Joint Institute for VLBI in Europe (coordinator)
- AARNET Pty Ltd., Australia
- ASTRON, the Netherlands
- Centro Nacional de Informacion Geografica, Spain
- Chalmers Tekniska Hoegskola Aktiebolag, Sweden
- Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
- Cornell University, USA
- Delivery of Advanced Network Technology to Europe Ltd. (DANTE), UK
- Instituto Nazionale di Astrofisica, Italy
- Instytut Chemii Bioorganicznej PAN, Poland
- Max Planck Gesellschaft zur Foerderung der Wissenschaften e.V., Germany
- National Research Foundation, South Africa
- Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
- SURFNet b.v., The Netherlands
- Teknillinen Korkeakoulu, Finland
- The University of Manchester, UK
- Universidad de Concepcion, Chile
- Uniwersytet Mikolaja Kopernika, Poland
- Ventspils Augstskola, Latvia

EXPReS Telescope Locations

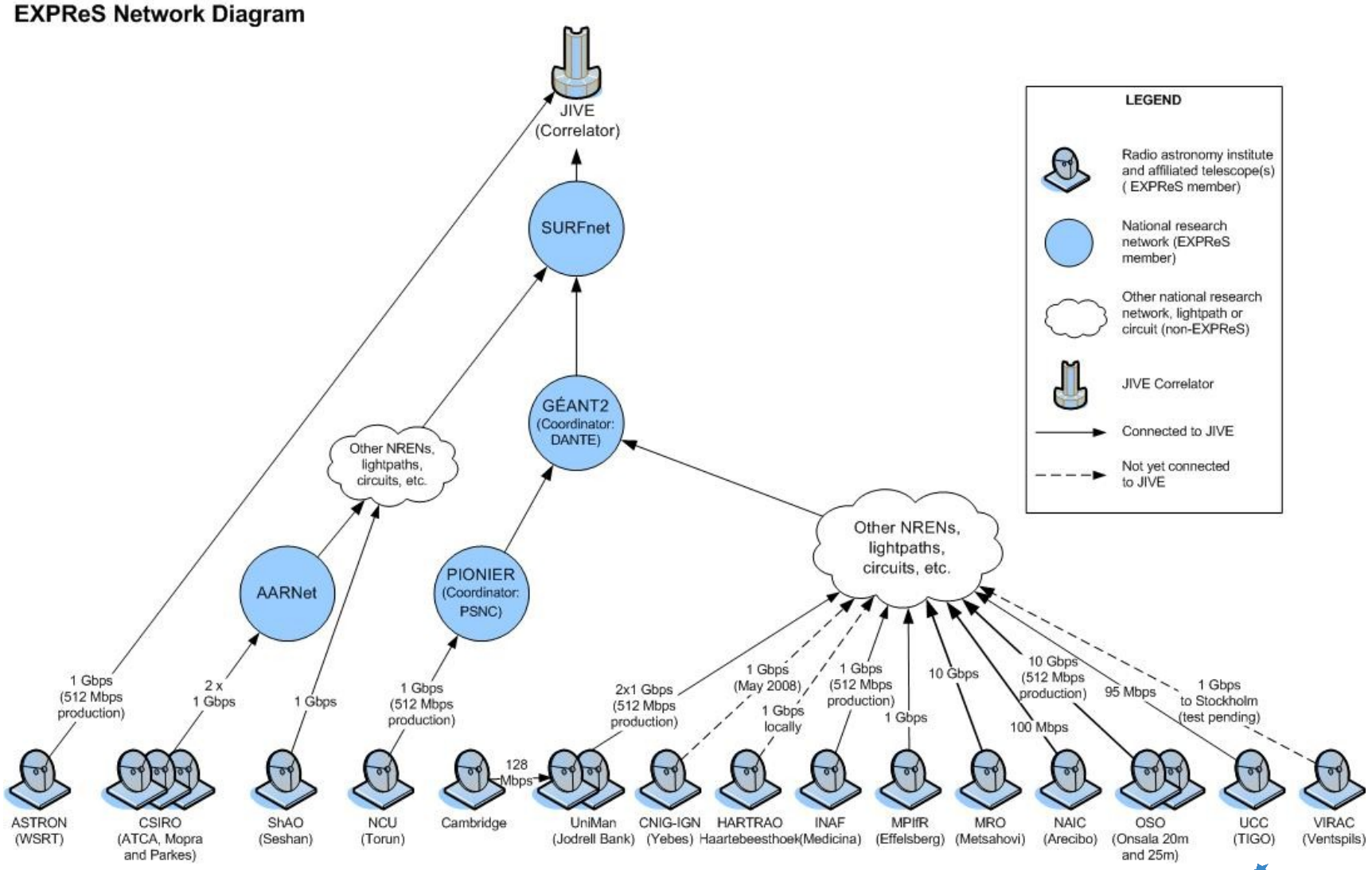
The EXPReS network

JIVE
JOINT INSTITUTE FOR VLBI IN EUROPE



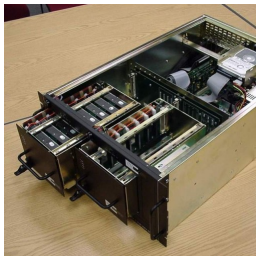
Network status as per 2008-05-02. Image created by Paul Boven <boven@jive.nl>. Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Network Connections to JIVE



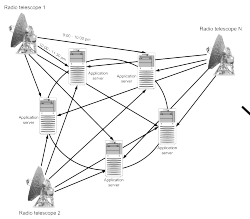
Basic Overview

Today



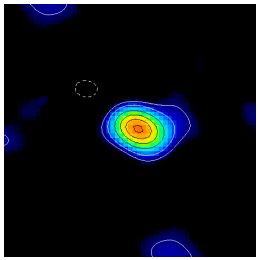
Today

Past



Soon

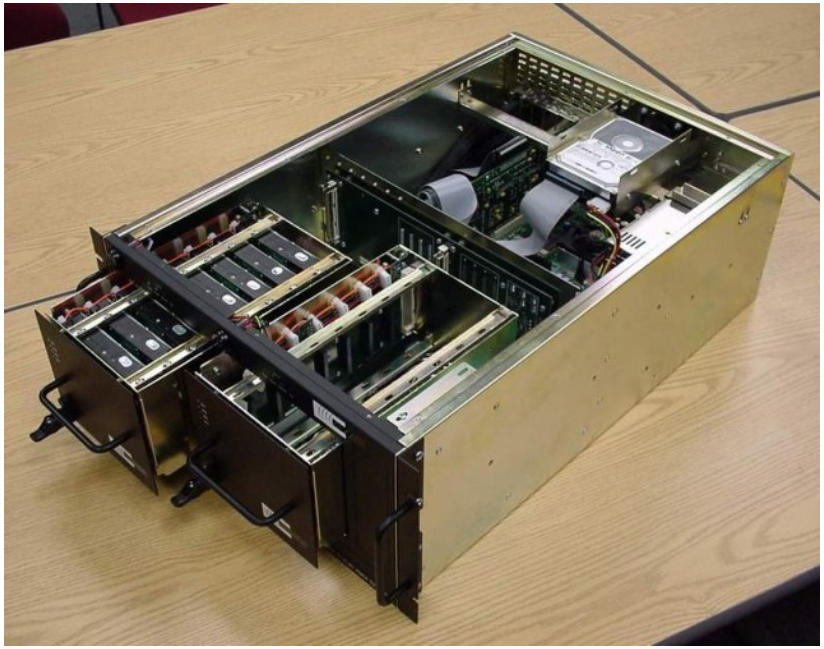
Today



Results

VLBI, historically

- Telescopes collected data on tapes… heavy and bulky… postal mail… once all the tapes arrived… tapes were lost/damaged… hard drive arrays slightly improved the situation...
- e-VLBI solved shipping problem... introduced regular and flexible upgrades to data transport process



- We can now send data faster than the correlator can process

Why e-VLBI?

- e-VLBI:
  - shortens the delay between observations and images
    - From months to hour(s)
  - Can offer more frequent and reliable observations
    - Potentially more bandwidth × observation time
    - Ensures data quality already during observations
    - Relaxes storage logistics for raw noise data
  - Enables a new class of fast response observations
- Intellectual collaboration across disciplines
  - Pushing the technology, protocols etc
  - International cooperation, infrastructure investments

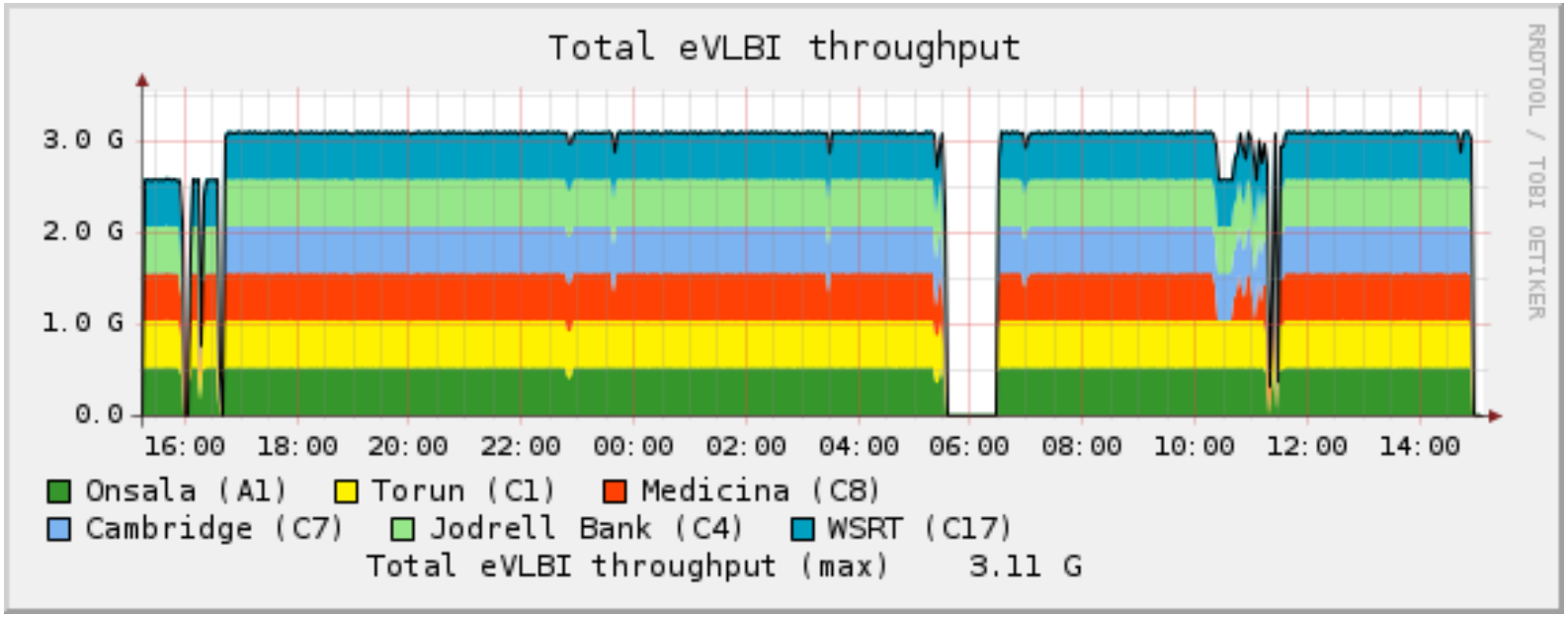
We run a PRODUCTION Service

- Monthly observations
- Published science from our observations
- e-VLBI is competitive with disk based VLBI
  - network bandwidth is on par with and will soon overtake (current) disk recording speeds
  - Stability of e-VLBI correlation is greater than that of disk based correlation
    - Longest uninterrupted correlation is more than 12 hours
    - Stopped only to look at new source
  - Large dishes now online- sensitvity

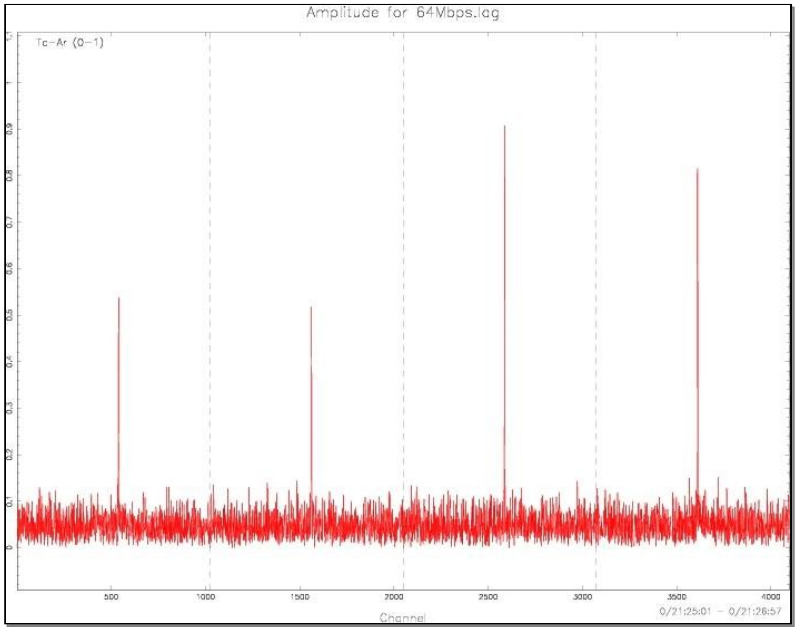
- All the benefits of traditional VLBI, but now with immediate monitoring and feedback

512Mbps Production

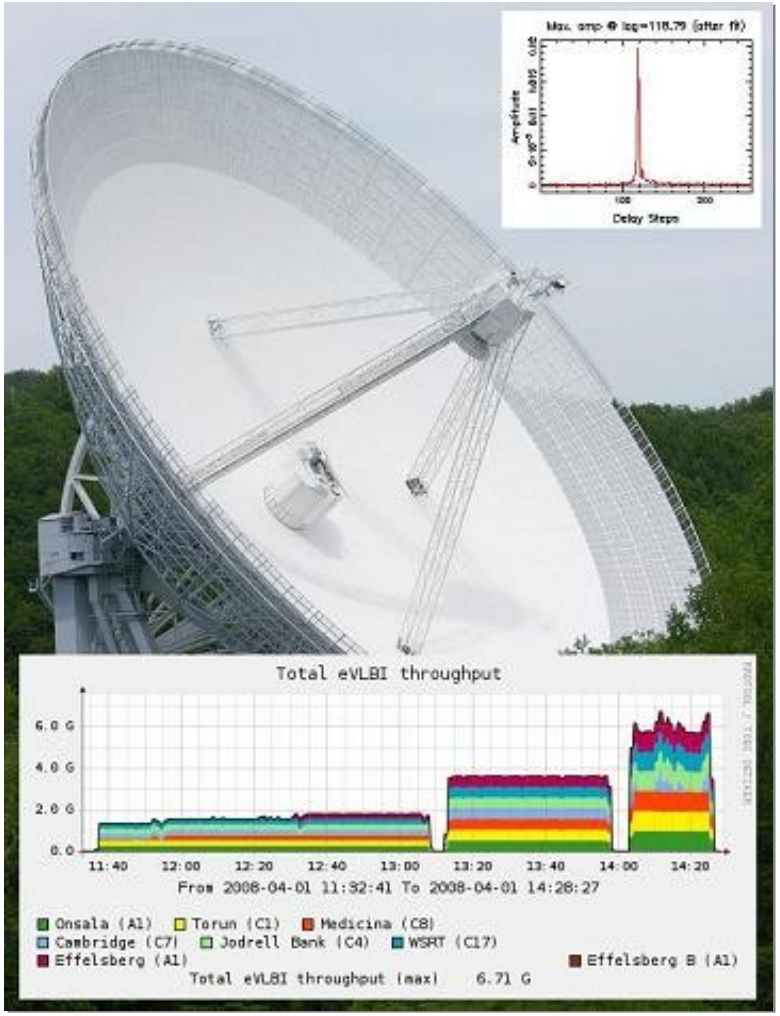
- On 8-9 April the first production 512 Mbps e-EVN observations took place
- Two science projects were observed
  - The first was a normal non-triggered project on Arp229 (RP009)
  - The second (RT006A) was triggered on Cyg X-3
- The correlation of RP009 started at 14:37 UT and ended at 3:30 UT
  - Longest ever uninterrupted correlation job (**including disk operation**)



Recent results



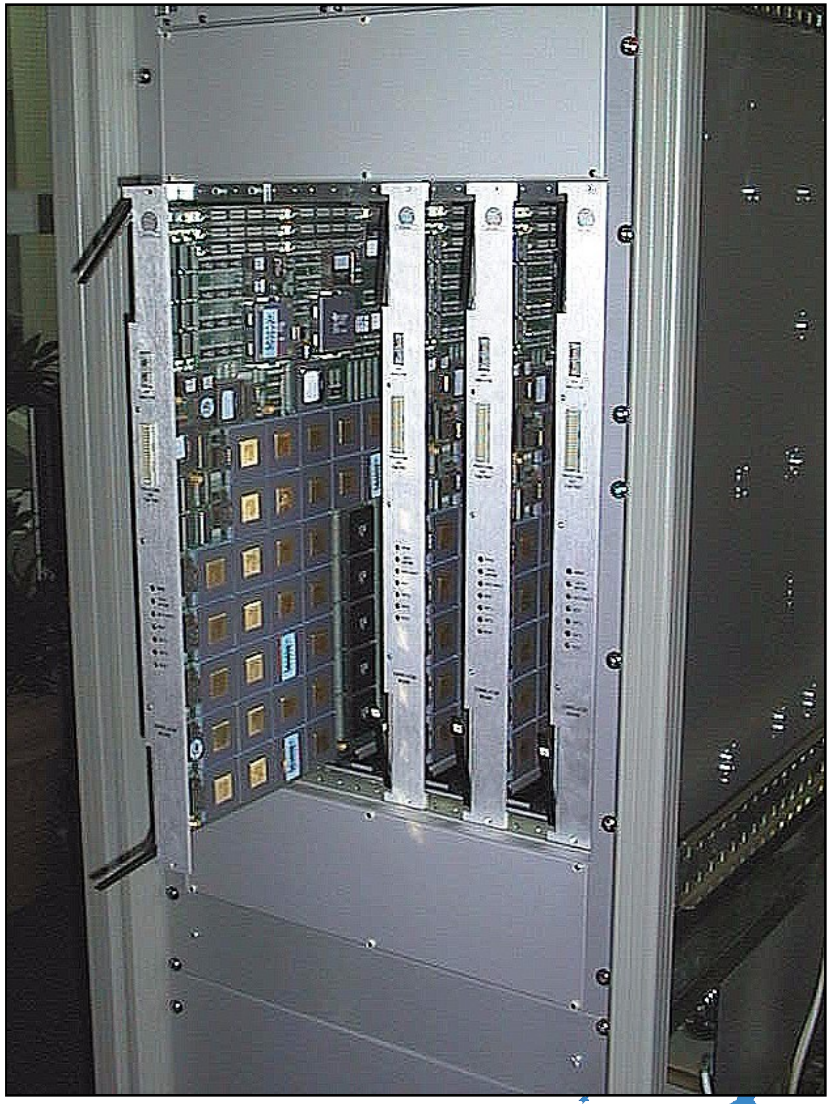
- First connections to TIGO, Chile
- Much improved connection to Arecibo, Puerto Rico



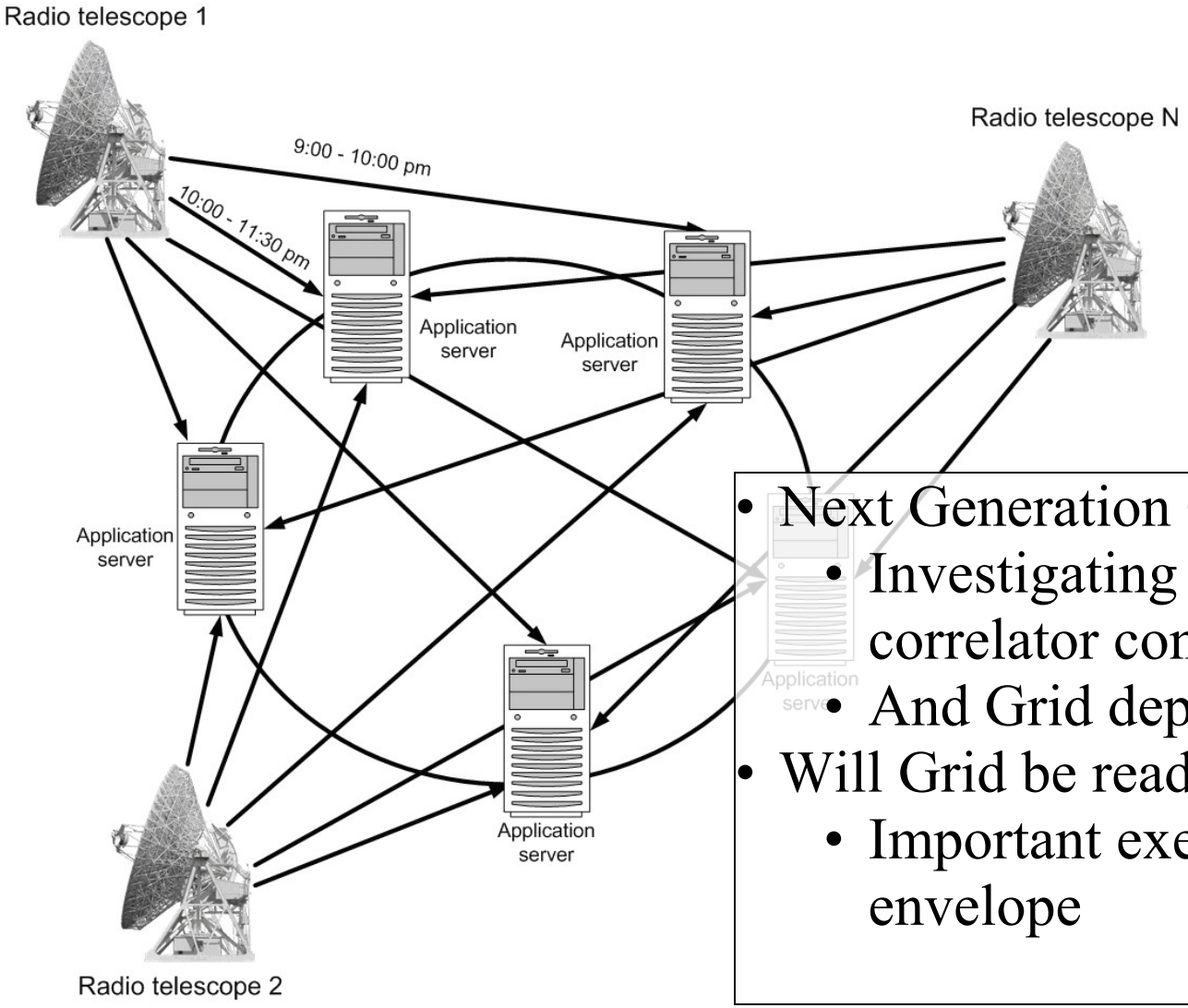
Effelsberg on line (at 1 Gbps!)

Why Distributed/Software Correlation?

- Cost to build correlator… limited flexibility (majority of computation in custom hardware)… preset data input rates… scheduling of scarce resource (correlator)… upgrade cost forces longer life-cycle than desired



Distributed Correlation



- Next Generation Correlator
  - Investigating distributed correlator concept
  - And Grid deployment
- Will Grid be ready for this?
  - Important exercise to push the envelope

Next Steps

- Harness evolutionary/regular improvements in network and computational speed
- Looking for partners and cooperation
  - Collaboration will span multiple disciplines: astronomy, computer science, international networking, hardware design

- Planned/desired demonstrations
  - Increased bandwidth to remote sites
  - 25 hour, continuous, all continent observation

- Hoping that you are interested and will contribute/participate in the efforts

aarnet

DANTE

POZNAN SUPERCOMPUTING AND NETWORKING

SURF NET

ASTRON

MINISTERIO DE FOMENTO
DIRECCIÓN GENERAL DEL INSTITUTO GEOGRÁFICO NACIONAL
CENTRO NACIONAL DE INFORMACIÓN GEOGRÁFICA

CSIRO

HartRAO

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Max-Planck-Institut
für Radioastronomie

HELSINKI UNIVERSITY OF TECHNOLOGY
Metsähovi Radio Observatory

ARECIBO OBSERVATORY

UNIVERSITAS NICOLAI COPERNICI
TORUN

ONSALA RYMDOBSERVATORIUM
CHALMERS TEKNISKA HÖGSKOLA

The University of Manchester
Jodrell Bank
Observatory

VENTSPILS AUGSTSKOLA

jive
JOINT INSTITUTE FOR VLBI IN EUROPE

EXPReS

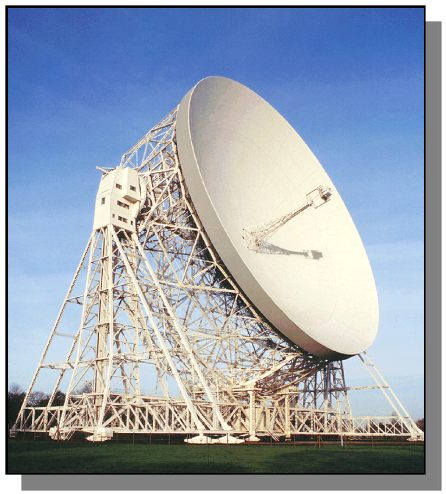
Yebes, new 40m telescope

- First fringes last month
- first ever VLBI participation
- In so-called ftp tests
- Using software correlator
- First ever telescope to have first fringes without recording?

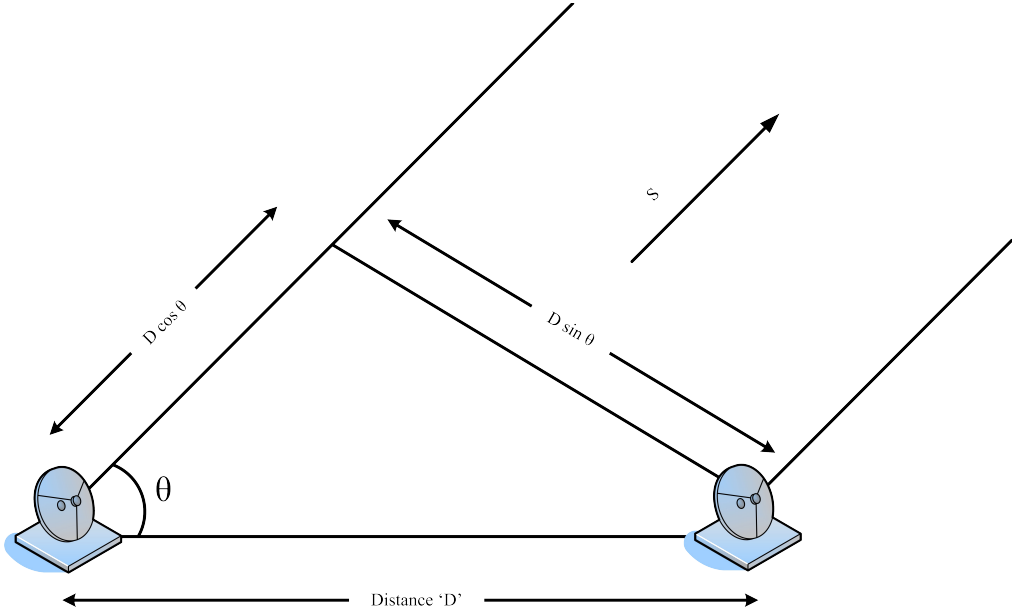

EUROPEAN
vlbi
NETWORK
Jodrell Bank Lovell (UK)
Onsala 20m (SE)
Onsala 25m (SE)
Dwingeloo (NL)
JIVE
JOINT INSTITUTE FOR VLBI IN EUROPE
Jodrell Bank Mk2 (UK)
Metsähovi (FI)
Arecibo (PR)
Cambridge (UK)
Torun (PL)
Urumqi (CN)
Hartebeesthoek (ZA)
Westerbork (NL)
Wettzell (DE)
Seshan (CN)
Effelsberg (DE)
Medicina (IT)
Robledo (ES)
Yebes (ES)
Noto (IT)

Radio Astronomy, VLBI

- Single radio-telescopes severely limited in resolution ($\propto \lambda/D$)
- Can be overcome by interferometry, creating a virtual telescope
- In VLBI the telescopes can be distributed on continent scales
- Sensitivity depends on bandwidth sampled and number of bits transported
  - And the telescope diameter



Correlation



- Data between all telescope pairs needs to be correlated
  - Requires accurate timing to line up the data signals
  - Dedicated supercomputer aligns signals, evaluate correlation function, accumulate data
- Central correlator for EVN is at JIVE, Dwingeloo
  Based on 90's VSI technology, deals with 1 Gbps data