e-VLBI

Franco Mantovani

Istituto di Radioastronomia

- Consortia and Networks
- EC funded projects: RadioNet, EXPReS

ESTRELA workshops

- First workshop: Dwingeloo, Netherlands, January 2007

- Second workshop: Manchester, UK, October 2007
  - Principles of Interferometry *(Neal Jackson)*
  - VLBI and e-VLBI *(Ralph Spencer)*

- Third workshop: Bonn, Germany, 7-11 April 2008
  - Millimetre VLBI *(Thomas Krichbaum)*
  - The Art and Science of VLBI *(Alan Roy)*

- Fourth workshop: Bologna, 19-22 January 2009

Consortia and Networks

- European VLBI Network (Europe)
- International VLBI Service for Geodesy and Astrometry
- Global Millimetre VLBI Array (Europe + USA)
- Very Long Baseline Array (USA)
- High Sensitivity Array (USA + Effelsberg)
- Long Baseline Array (Australia)
- VERA (Japan)

The European VLBI Network (EVN) was formed in 1980

The founding radio astronomy institutes were:

MPIfR	Bonn	Germany
IRA	Bologna	Italy
ASTRON	Dwingeloo	The Netherlands
OSO	Onsala	Sweden
JBO	Manchester	UK

and the Geodetic Department of the University of Bonn

The EVN is an interferometric array of radio telescopes spread throughout Europe and beyond

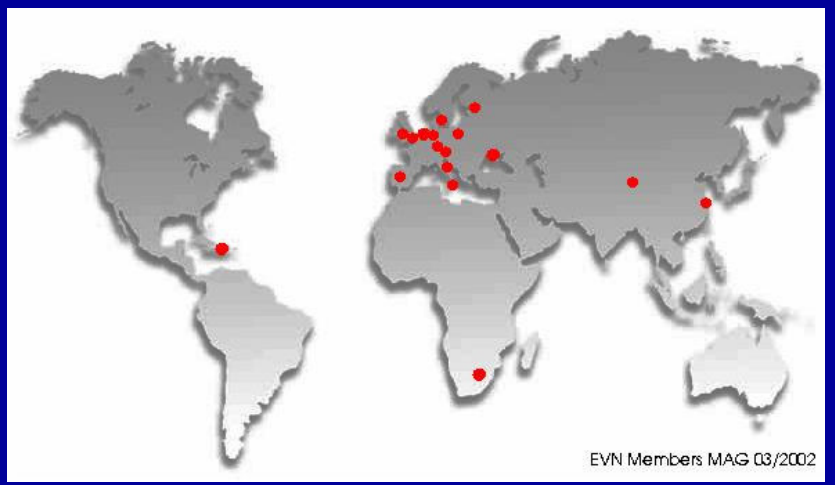
The EVN now includes a total of 14 major institutes, including the Joint Institute for VLBI in Europe (JIVE).

EVN institutes and stations:

Effelsberg	(Germany)	Jodrell Bank & Cambridge	(UK)
Medicina	(Italy)	Metsähovi	(Finland)
Noto	(Italy)	Onsala	(Sweden)
Robledo	(Spain)	Shanghai	(China)
Torun	(Poland)	Urumqi	(China)
Westerbork	(Netherlands)	Wettzell	(Germany)
OAN-Yebes	(Spain)	Hartebeesthoek	(SA)
Arecibo	(Puerto Rico)		

Correlator centres for EVN observations:

JIVE	Dwingeloo (Netherlands)
MPIfR	Bonn (Germany)
VLBA	Socorro (USA)



Yellow/Red:
current operational EVN stations

Cyan/Red:
existing tel. soon to be EVN stations

Cyan/Blue:
new EVN stations under construction

Pink/Purple:
non-EVN stations that can participate in EVN observations

Green/Brown:
non-EVN stations with whom initial EVN tests have been carried out

EVN Structure and Management

Overall policy:	EVN Consortium Board of Directors
Technical aspects and operations:	Technical and Operations Group
Observing proposals:	EVN Programme Committee
Observing Sessions:	EVN Scheduler
EVN correlator at JIVE	

European VLBI Network Call for Proposals

Deadlines:	1 February, 1 June, 1 October 2009
Call text	http://www.ira.inaf.it/evn_doc/call.txt
Arrays:	EVN, GLOBAL and e-VLBI
Proposals submission	ONLINE (tool Northstar, http://proposal.jive.nl)
The observations	disk recording (standard EVN) in real-time (e-VLBI).

The EVN facility is open to all astronomers

Use of the Network by astronomers not specialised in the VLBI technique is encouraged.

The Joint Institute for VLBI in Europe (JIVE) can provide support and advice
on project preparation, scheduling, correlation and analysis
EVN User Support at http://www.jive.nl.

Standard EVN Observing Sessions in 2009 (disk recording)

Session 1	Feb 26 - Mar 19	18/21cm, 6cm, 5cm, 7mm
Session 2	May 28 - Jun 18	18/21cm, 6cm, ... (7mm)

e-VLBI Observing Sessions in 2009 (real-time)

Jan 22 - Jan 23	18/21cm, 6cm, 5cm, 1.3cm
Feb 10 - Feb 11	18/21cm, 6cm, 5cm, 1.3cm
Mar 24 - Mar 25	18/21cm, 6cm, 5cm, 1.3cm
Apr 21 - Apr 22	18/21cm, 6cm, 5cm, 1.3cm
May 19 - May 20	18/21cm, 6cm, 5cm, 1.3cm

e-VLBI observation classes:

- General e-VLBI proposals
- Triggered e-VLBI proposals
- Short observations

General and triggered e-VLBI proposals must be submitted by the October 1 deadline
to be considered for scheduling in the next year e-VLBI sessions

Requests for short observations may be submitted up to three weeks prior to any e-VLBI session

Continuum and spectral line observations can be carried out
http://www.ira.inaf.it/evn_doc/guidelines.html for details

current e-VLBI array: http://www.evlbi.org/evlbi/e-vlbi_status.html
availability of different e-VLBI stations per observing band
dates of the e-VLBI observing sessions in 2009

e-VLBI

General information and current features

The current antenna capabilities: e-VLBI status table

The full array now includes: Ef, Wb, Tr, On, Mh, Mc, Jb2, Cm, Ar and Sh

The wavebands covered are: 18/21 cm, 6 cm, 5 cm and 1.3 cm

Transmitted data rate: 512 Mbps

Proposals for any science goal, not just rapid response science can be made

In addition, a special class of "triggered" proposal for the pre-set eVLBI dates is supported.

e-VLBI can be combined with EVN session disk observations for denser time monitoring of variable sources.

EVN Target-of-Opportunity (ToO) observations set-up at short notice on any date for high priority unanticipated events (See the EVN ToO policy)

e-VLBI

Technical details

> Continuum observations

Continuum observations will be run at the highest possible reliable bit rate: 512 Mbps

Continuum observations can be proposed for only one of the available frequency bands in any given 24 hour session.

> Spectral line observations

Spectral line observations recording rates: 32 - 512 Mbps

Observations may be proposed for the 18/21cm, 5cm and 1cm bands

Only standard and short observation proposal types are allowed

Triggered spectral line proposals will not be accepted

IRA support to the EVN activities - 1

Network Observations

Two 32-m dishes

Very reliable stations

100 obs. days + e-VLBI 24 hours every 6 weeks

Frequency range 300 MHz – 43 GHz

Flexible in changing the observing frequency

Medicina

Noto

SRT

IRA support to the EVN activities - 2

Data server and archiving

> VLBEER data server: the EVN's Central Ancillary Data Server

> European VLBI Network Archive: managed with “Dira2 database”

Software for the Global VLBI Array

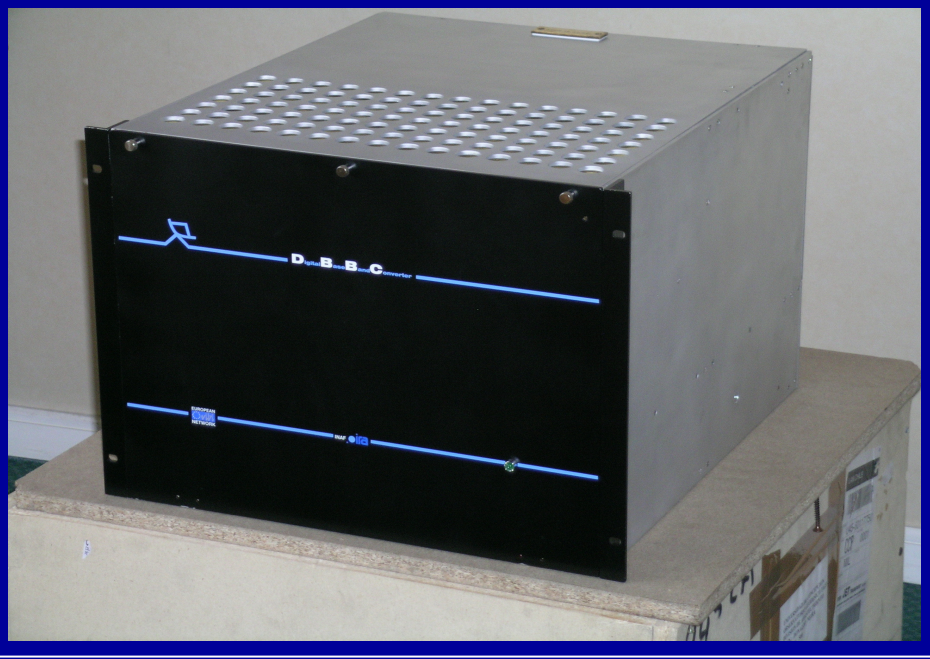
> SCHED graphic interface

> Field System – Control software for radio stations maintained by geodesists

IRA support to the EVN activities - 3

Hardware for the Global Array

> Digital Base Band Converter
> a project endorsed by the EVN CBD
> (Dwingeloo, May 2007)



EC funded project

"RadioNet" – Advanced Radio Astronomy in Europe

RadioNet is an Integrated Infrastructure Initiative (I3),

RadioNet has 24 partners.

RadioNet in FP7

> Trans National Access 45%

Improving the access of European astronomers to the major radio astronomical infrastructures (EVN, MERLIN, WSRT, JCMT, IRAM, MPIfR, OSO, SRT)

> Network Activities 15%

Science Workshop

Engineering Forum

Training

Spectrum Management

RadioNet in FP7

> Joint Research Activities 40%

ALBiUS - Software tools for new and upgraded telescopes

AMSTAR+ - For mm and sub-mm telescopes

APRICOT - All-Purpose Radio Imaging Camera for cm and mm telescopes

UniBoard - A Multi-purpose Scalable generic digital board enhancing the signal processing capability

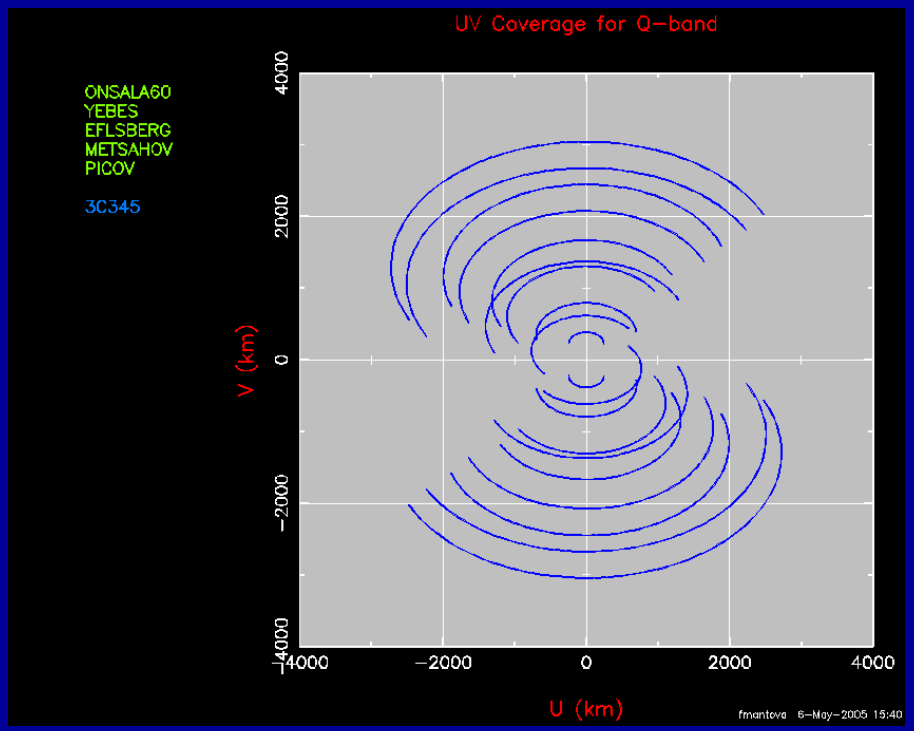
(spectroscopy, pulsar searches, high resolution interferometry)

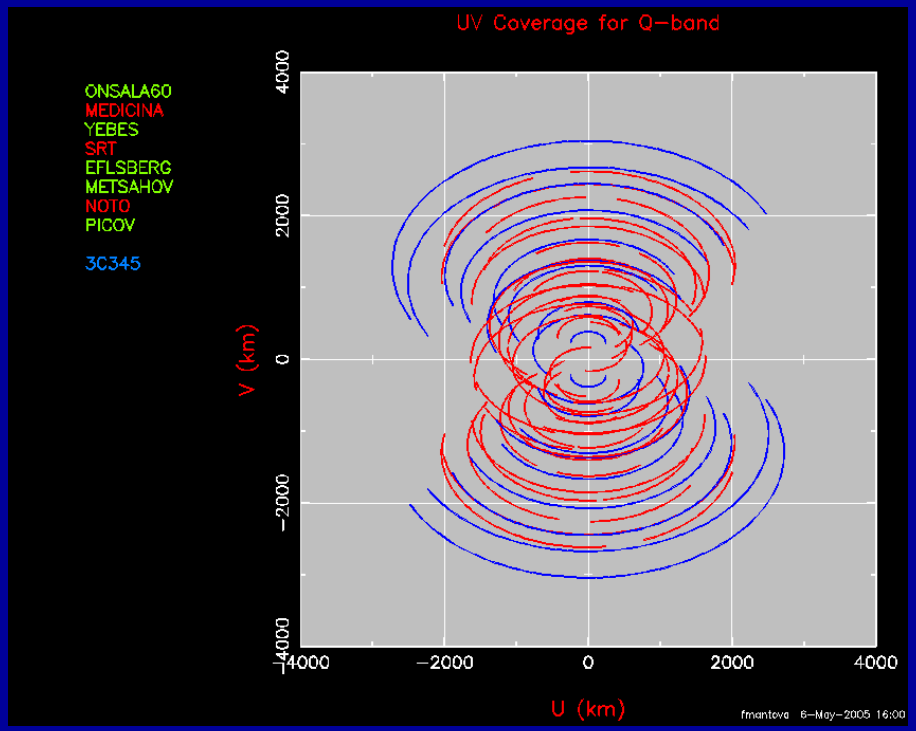
EUROPEAN Array a 43 GHz

D ≈ 2500 km

Angular Resolution ≈ 0.2 mas

Linear Resolution ≈ 2 pc (at $z = 1$; $q_0 = 0$, $H_0 = 100$ km s^{-1}/Mpc)





International VLBI Service for Geodesy and Astrometry

http://ivscc.gsfc.nasa.gov

IVS is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components

Established in 1999

IVS provides data and products for the scientific community:

- terrestrial reference frame (TRF)
- the international celestial reference frame (ICRF)
- Earth orientation parameters (EOP)

IVS Components

38 Member Organizations

IVS Management (1)

1 Coordinating Center
26 Network Stations
3 Operation Centers
6 Correlators
6 Data Centers
22 Analysis Centers
7 Techn. Develop. Centers

Global Millimetre VLBI Array

Set up by a group of radio observatories interested in performing astronomical VLBI observations at millimetre wavelengths.

Motivation and Scientific Aims:

> it is possible to study emission regions which appear self-absorbed at longer wavelengths

> mm-VLBI is now able to provide good quality images in the 3mm band (86.2 GHz)

> angular resolution of typically 50-70 micro-arcseconds

> typical single baseline detection thresholds: 0.1- 0.4 Jy

Global mm VLBI Array Participating Stations:

in Europe	Effelsberg	100 m
	Onsala	20 m
	Pico Veleta	30 m
	Plateau de Bure	6x15 m, phased
	Metsähovi	14 m
in USA:	VLBA	8 x 25 m

potential candidates:

Yebes	40 m
Noto	32 m
GBT	100 m
Sardinia Radio Tel.	64 m
Medicina	32 m

Very Long Baseline Array

The VLBA is a system of 10 radio telescopes controlled remotely from the Array Operations Center in Socorro, New Mexico,
The construction began in February, 1986, and was completed in May, 1993.

VLBA Angular Resolution

$$\theta_{\rm HPBW} \sim 2063 \times \frac{\lambda^{\rm cm}}{B^{\rm km}_{\rm max}} \quad {\rm mas},$$

λ^{cm} is the receiver wavelength in cm

At the center frequencies and for the longest VLBA baseline (~8600 km):

Receivers	90	50	21	18	13	6	4	2	1	cm
θ_{HPBW}	22	12	5.0	4.3	3.2	1.4	0.85	0.47	0.32	mas

plus 0.17 mas at 7 mm

The longest VLBA-only baseline at 3 mm is currently the one between MK and NL, which is about 30% shorter than the longest baseline at other wavelengths.

Frequency Ranges and Typical Performance Parameters

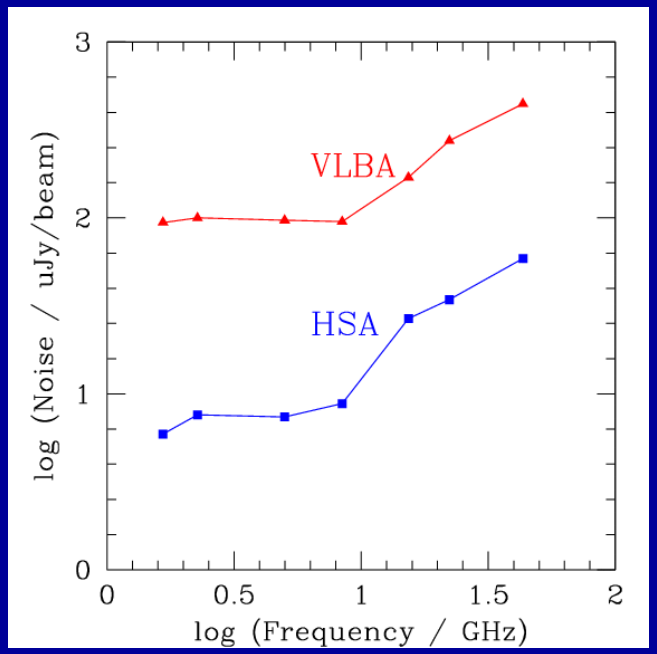
Receivers and Feeds	Nominal Frequency Range [GHz]	Typical Zenith SEFD [Jy]	Center Frequency for SEFD [GHz]	Typical Zenith Gain [K / Jy]	Baseline Sensitivity $\Delta S^{256,2m}$ [mJy]	Image Sensitivity $\Delta I_m^{256,8h}$ [µJy / beam]
90 cm	0.312 - 0.342	2227	0.326	0.097	51.1 (a)	350
50 cm	0.596 - 0.626	2216	0.611	0.088	101.1 (b)	700 (b)
21 cm (c)	1.35 - 1.75	296	1.438	0.096	3.3	32
18 cm (c)	1.35 - 1.75	303	1.658	0.100	3.7	36
13 cm (d)	2.15 - 2.35	322	2.275	0.093	3.6	35
13 cm (d,e)	2.15 - 2.35	337	2.275	0.090	3.8	37
6 cm	4.6 - 5.1	312	4.999	0.130	3.5	34
4 cm	8.0 - 8.8	307	8.425	0.113	3.6	35
4 cm (e)	8.0 - 8.8	407	8.425	0.106	4.7	46
2 cm	12.0 - 15.4	550	15.369	0.104	6.2	60
1 cm (f)	21.7 - 24.1	502	22.236	0.107	5.9	57
1 cm (f)	21.7 - 24.1	441	23.799	0.107	5.1	50
7 mm	41.0 - 45.0	1436	43.174	0.078	22.2 (a,g)	151
3 mm (h)	80.0 - 90.0	4000	86.2	0.025	57. (i)	850 (j)

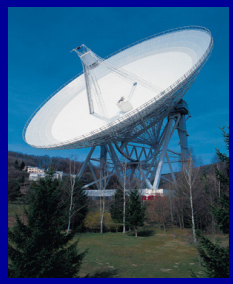
High Sensitivity Array

GBT, phased VLA, Arecibo, Effelsberg, and VLBA

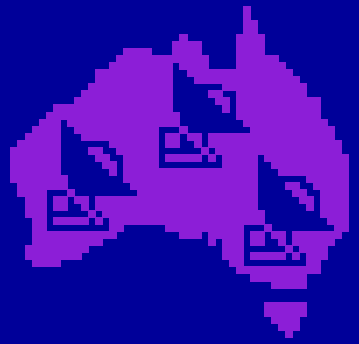
- The sensitivity can be increased by an order of magnitude

- Studies of low-power AGN, extragalactic masers, gravitational lenses.





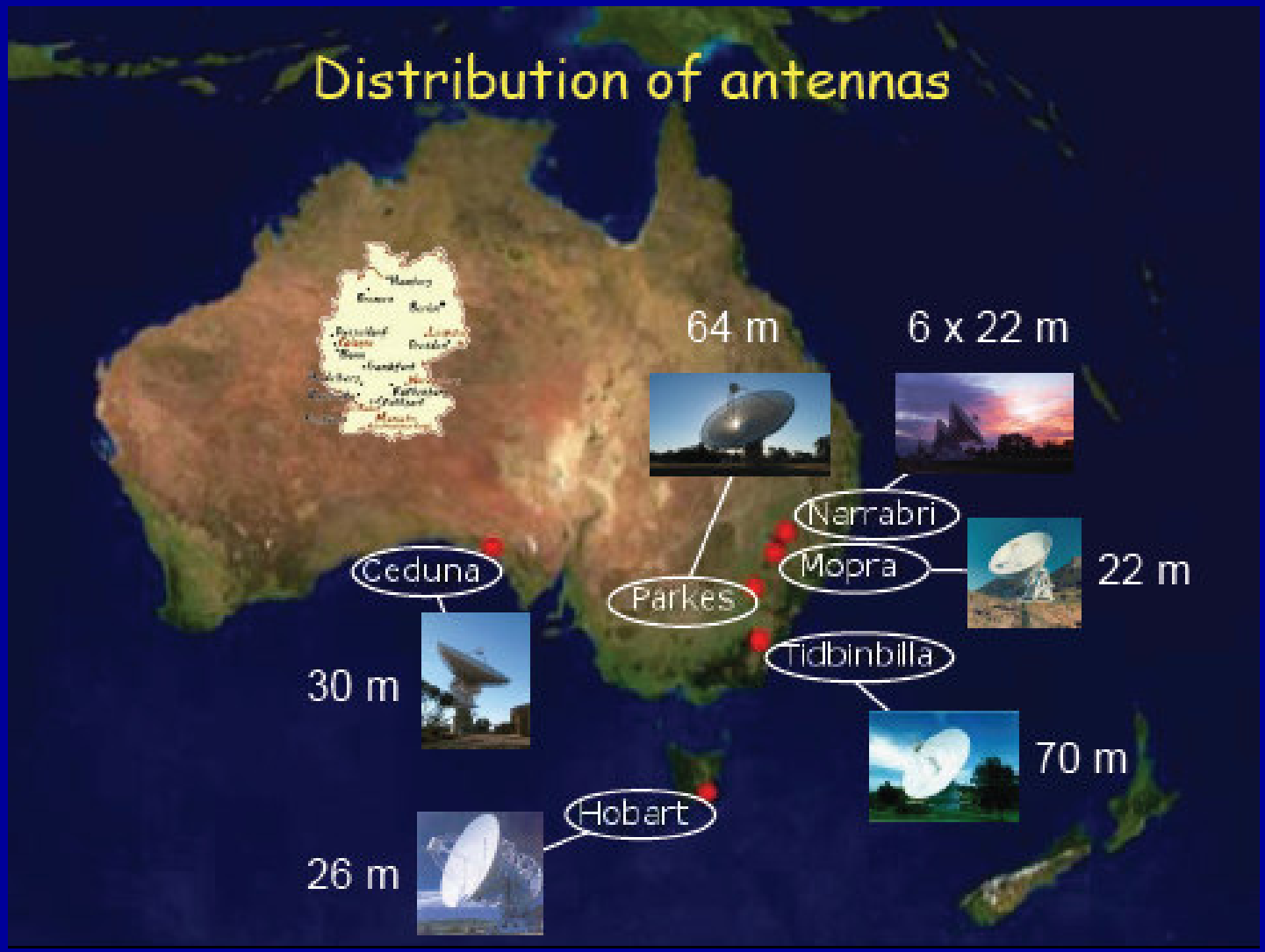
sensitivities for a 1 hour integration recording at 256 Mbps



Long Baseline Array

Australian Long Baseline Array (LBA)

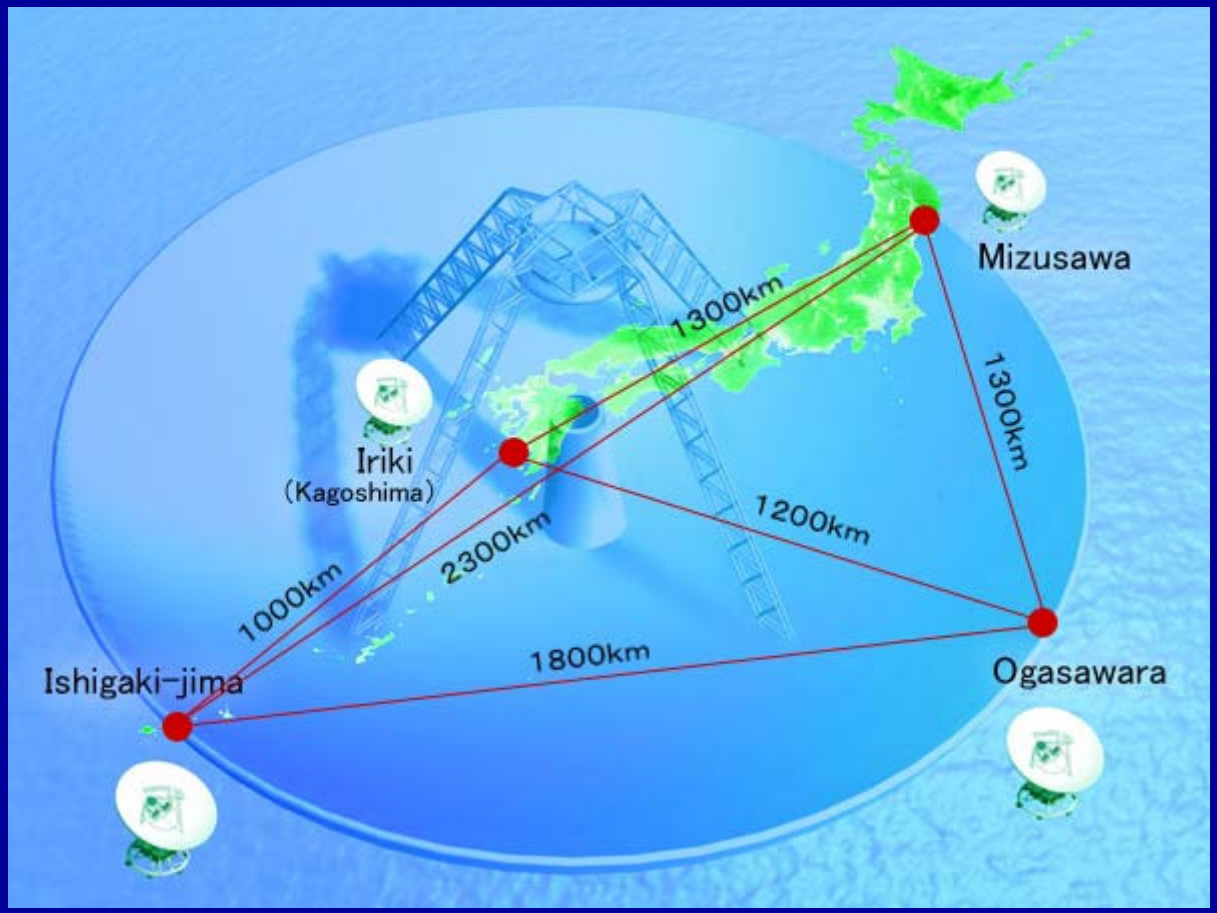
- Consists of 6 antennas;
- Baseline lengths: 100 km - 1700 km;
- Frequencies: 1.4, 1.6, 2.3, 4.8, 6.7, 8.4, 22 GHz;
- Data rates up to 1024 Mbps;
- Data processed using software correlator;
- e-VLBI capabilities;
- International partners;
- Extensions to the array in the medium term


Distribution of antennas
64 m
6 x 22 m
Narrabri
Mopra
22 m
Ceduna
Parkes
Tidbinbilla
30 m
70 m
Hobart
26 m

Long Baseline Array

L B A

VLBI Exploration of Radio Astrometry (VERA)



VERA

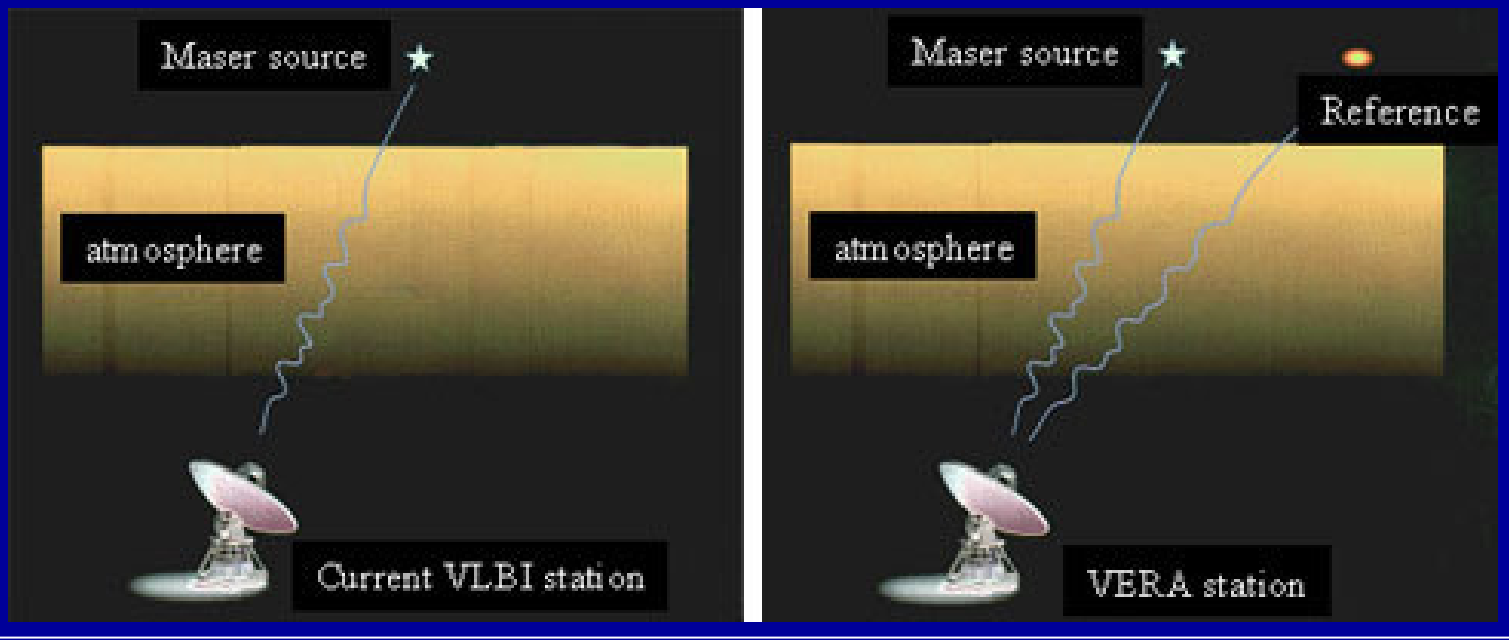
Japanese VLBI array aimed for obtaining 3-dimensional map of the Milky Way galaxy.

VERA will measure distances and motions of radio sources in the Galaxy
with high accuracy, unveiling the true structure of the Galaxy.

Dual-Beam VLBI : free from the atmosphere

Most unique aspect of VERA is `dual-beam' telescope, which can observe two nearby sources at the same time. While single-beam VLBI significantly suffers from fluctuation of atmosphere, VERA's dual-beam observations effectively cancel out the atmospheric fluctuations, and then VERA can measure relative positions of target sources with respect reference sources with highest accuracy ever achieved. Such VLBI observation technique is referred to as 'phase-referencing' observation.

VERA is the only VLBI array dedicated to phase-referencing astrometry.



EXPReS is an Integrated Infrastructure Initiative

European Commission's Sixth Framework Programme

Contract number: 026642

From: March 2006 through February 2009

EC funded project "EXPReS"

Express Production Real-time e-VLBI Service

http://www.expres-eu.org/

EXPReS is a three-year project for real-time "electronic VLBI"

Objectives: connect up to 16 of the world's most sensitive radio telescopes to the central data processor of the EVN at the Joint Institute for VLBI in Europe

e-VLBI: fibre optic networks to connect radio telescopes to a central data processor

- Targets of Opportunity of transient events
- High precision tracking of space probes

EXPReS Specific activities:

- securing "last-mile connections"
- upgrading existing connections to the telescopes,
- updating the correlator (16 data streams at 1 Gbps each in real time)
- research possibilities for distributed computing

Network Activities:

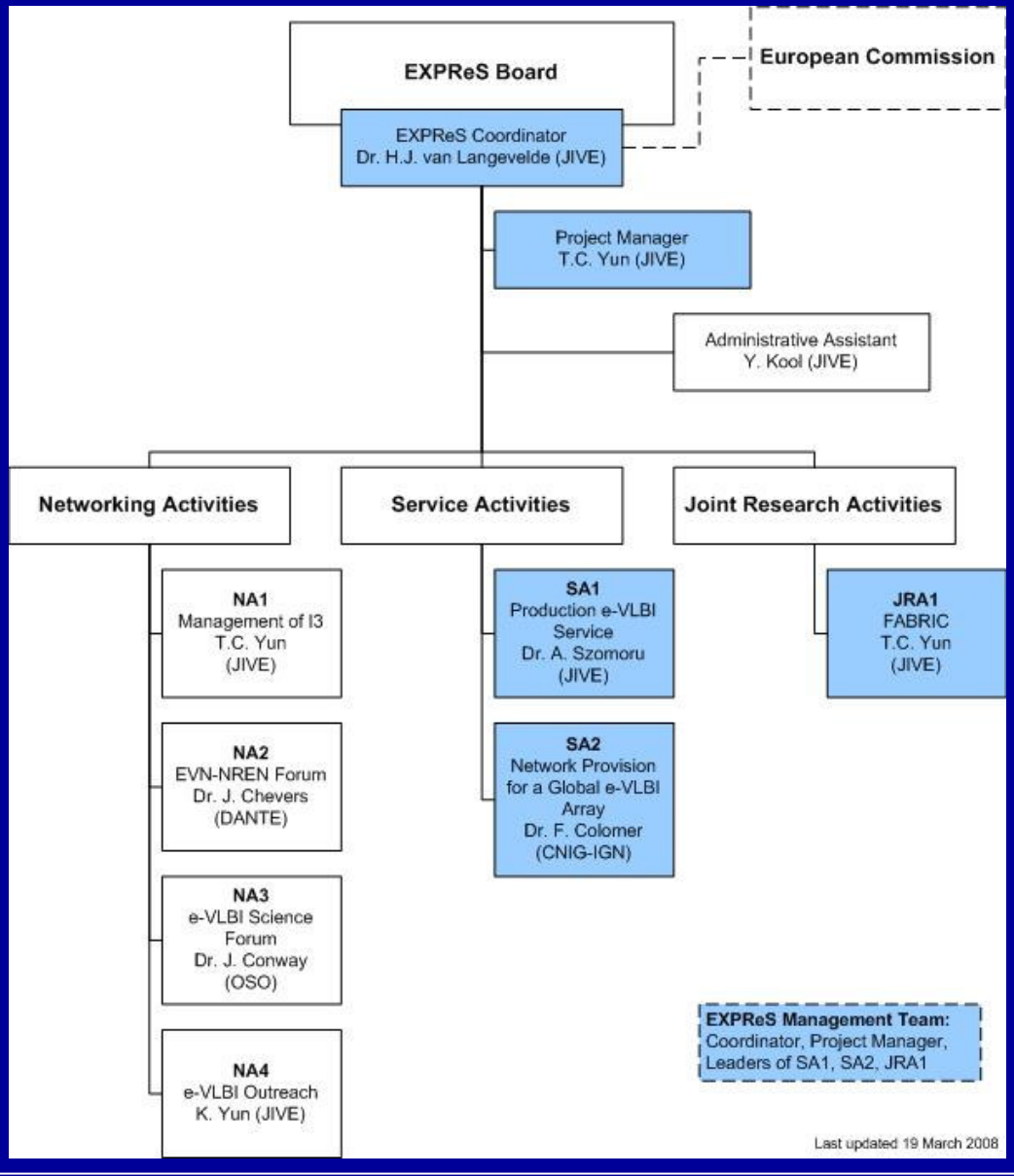
NA1 Management of I3
NA2 EVN-NREN Forum
NA3 e-VLBI Science Forum
NA4 e-VLBI Outreach, Dissemination & Communications

Specific Service activities

SA1 Production e-VLBI Service
SA2 Network Provision for a Global e-VLBI Array

Research activities

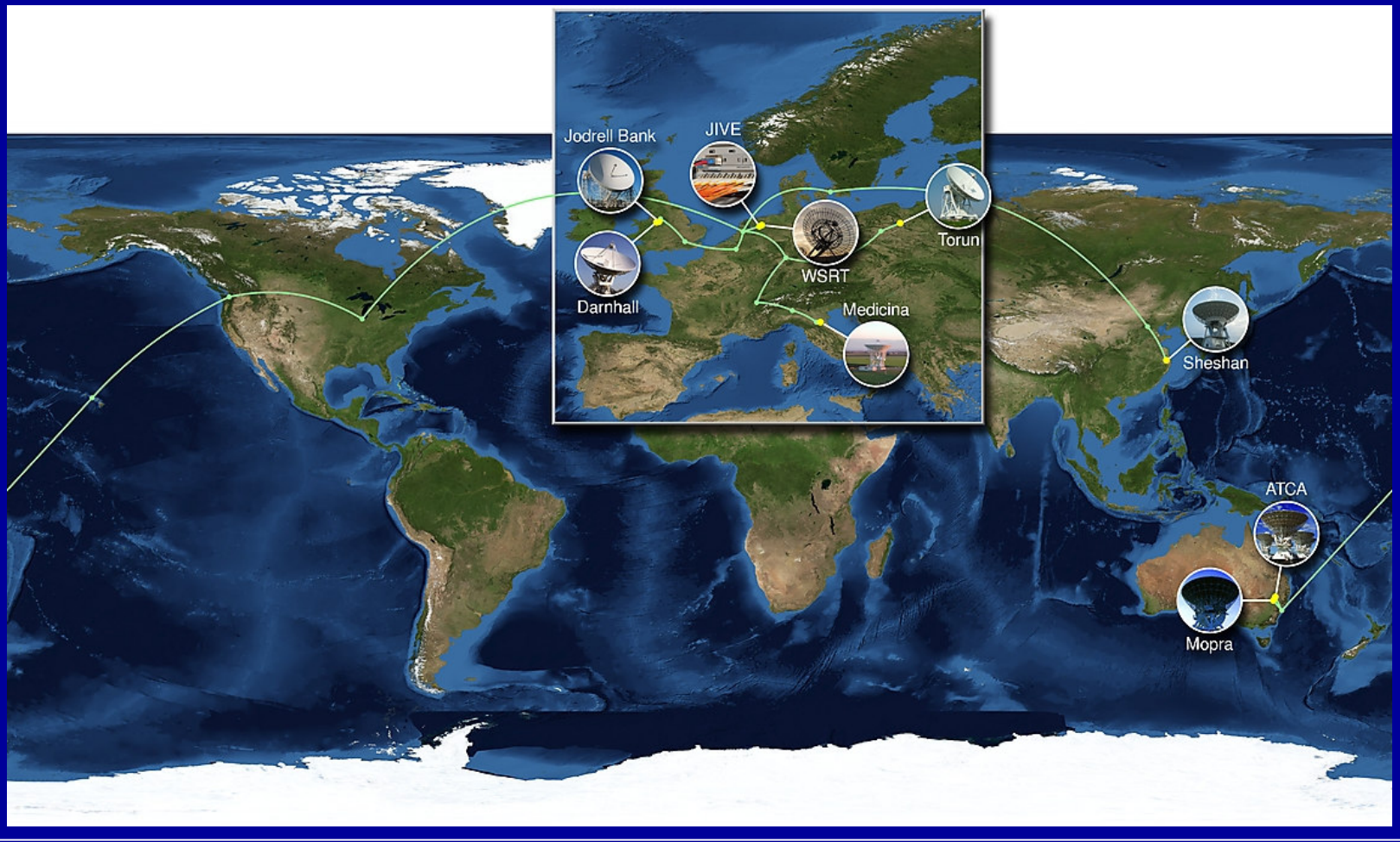
JRA1: Future Arrays of Broadband RTs on Internet Computing


EXPReS Board
European Commission
EXPReS Coordinator
Dr. H.J. van Langevelde (JIVE)
Project Manager
T.C. Yun (JIVE)
Administrative Assistant
Y. Kool (JIVE)
Networking Activities
Service Activities
Joint Research Activities
NA1
Management of I3
T.C. Yun
(JIVE)
NA2
EVN-NREN Forum
Dr. J. Chevers
(DANTE)
NA3
e-VLBI Science
Forum
Dr. J. Conway
(OSO)
NA4
e-VLBI Outreach
K. Yun (JIVE)
SA1
Production e-VLBI
Service
Dr. A. Szomoru
(JIVE)
SA2
Network Provision
for a Global e-VLBI
Array
Dr. F. Colomer
(CNIG-IGN)
JRA1
FABRIC
T.C. Yun
(JIVE)
EXPReS Management Team:
Coordinator, Project Manager,
Leaders of SA1, SA2, JRA1
Last updated 19 March 2008

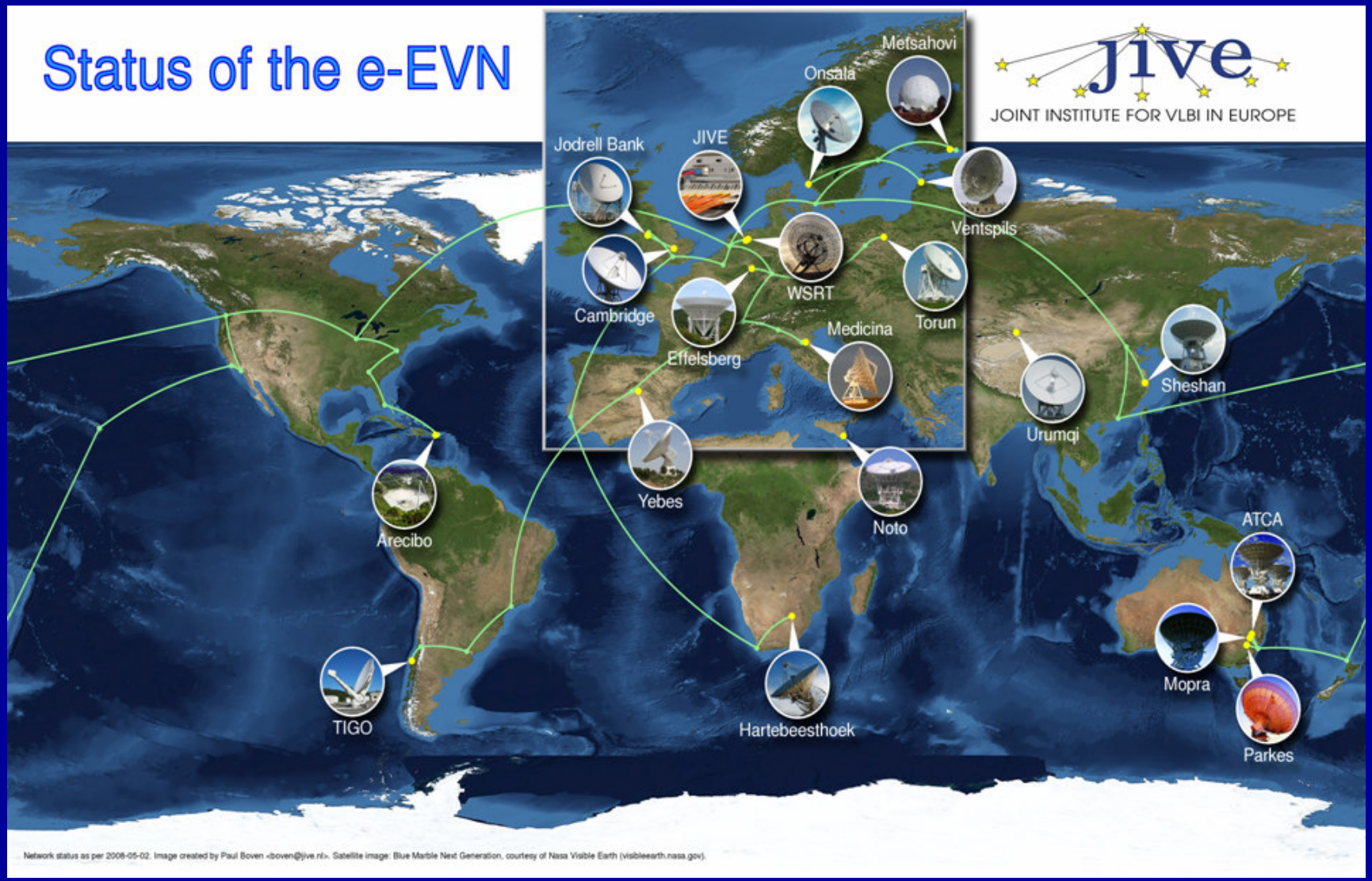
Telescopes Participating in EXPReS

First e-VLBI data from China-Australia, China-Europe and Australia Europe baselines (28 August 2007)

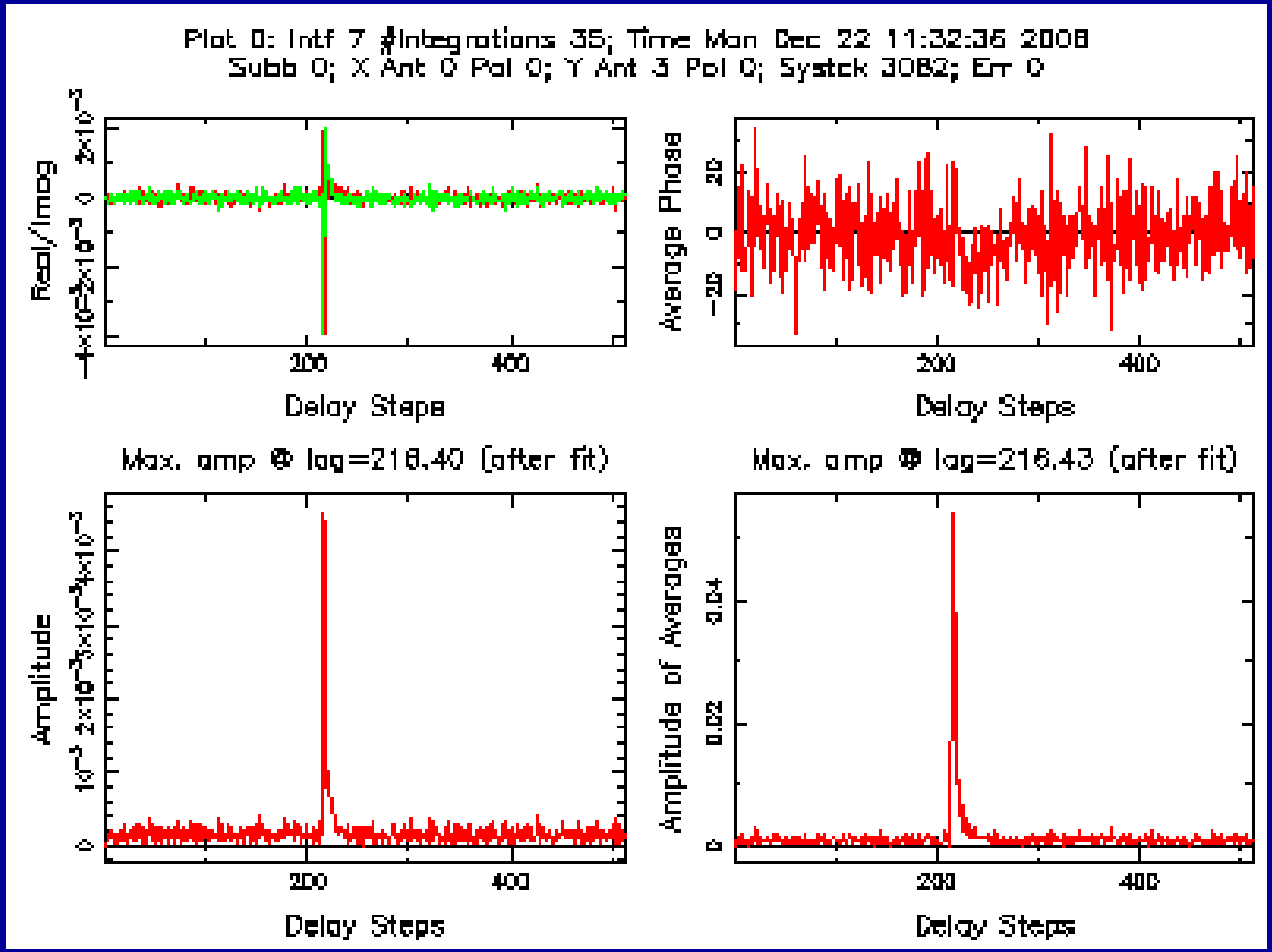
Data transferred to JIVE Correlator at a rate of 256 Mbps per telescope.



Status of the e-EVN



Urumqi - 22 December 2008



First e-VLBI publications

Mon. Not. R. Astron. Soc. 374, L47–L50 (2007) doi:10.1111/j.1745-3933.2006.00262.x

First e-VLBI observations of GRS 1915+105

A. Rushton,[1*] R. E. Spencer,[1] M. Strong,[1] R. M. Campbell,[2] S. Casey,[1] R. P. Fender,[3,4] M. A. Garrett,[2] J. C. A. Miller-Jones,[4] G. G. Pooley,[5] C. Reynolds,[2] A. Szomoru,[2] V. Tudose[4,6] and Z. Paragi[2]

[1]*The University of Manchester, Jodrell Bank Observatory, Cheshire SK11 9DL*
[2]*Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, the Netherlands*
[3]*School of Physics and Astronomy, University of Southampton, Highfield, SO17 1BJ Southampton*
[4]*"Anton Pannekoek" Astronomical Institute, University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, the Netherlands*
[5]*University of Cambridge, Mullar Radio Astronomy Observatory, J. J. Thomson Avenue, CB3 0HE Cambridge*
[6]*Astronomical Institute of the Romanian Academy, Cutitul de Argint 5 RO-040557 Bucharest, Romania*

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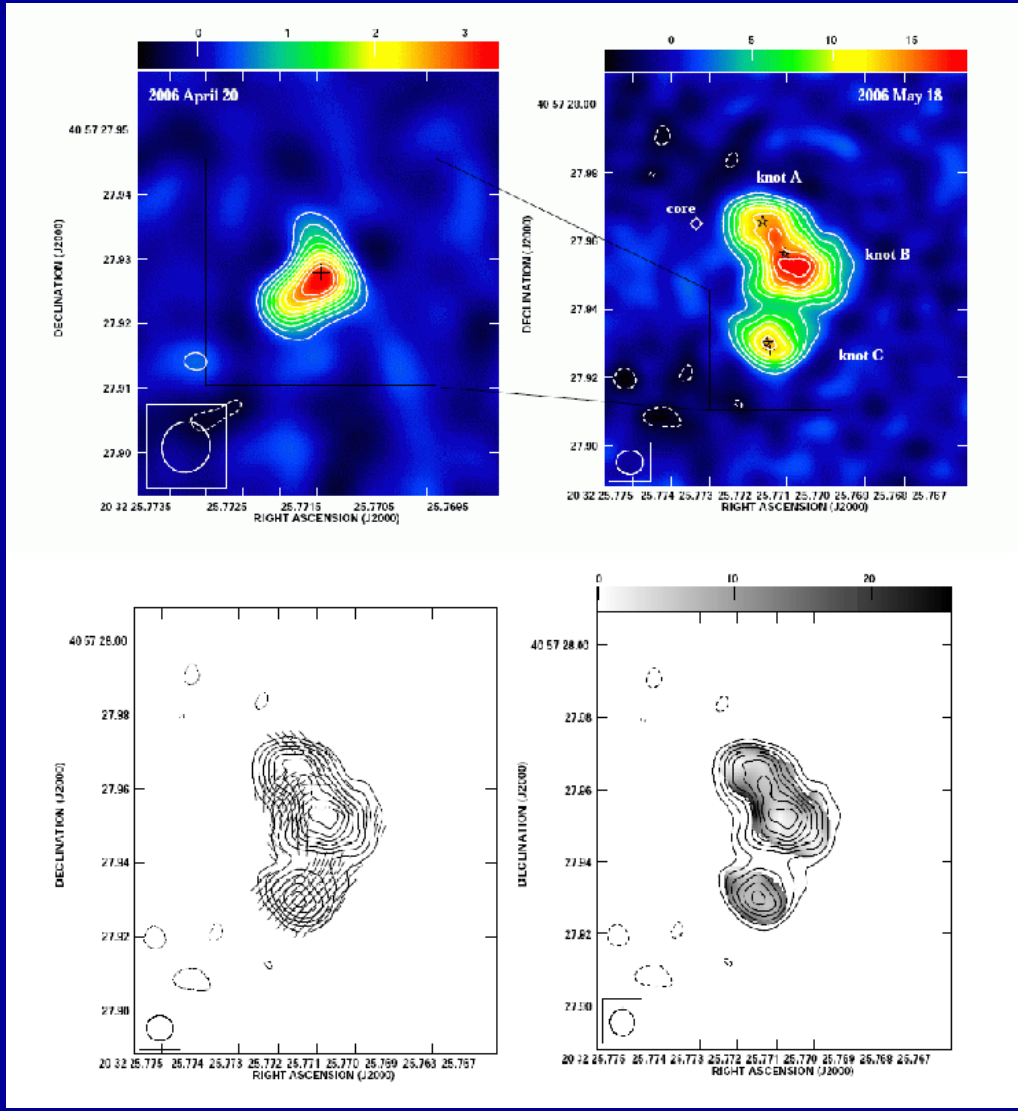
Mon. Not. R. Astron. Soc. 375, L11–L15 (2007) doi:10.1111/j.1745-3933.2006.00264.x

First e-VLBI observations of Cygnus X-3

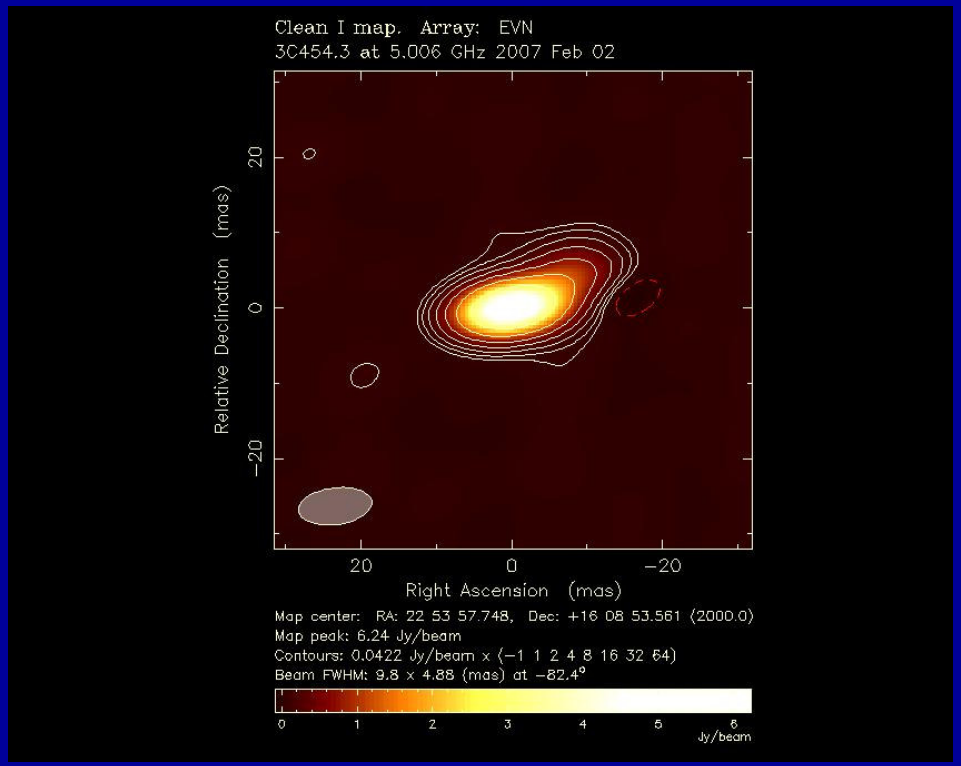
V. Tudose,[1,2★] R. P. Fender,[1,3] M. A. Garrett,[4] J. C. A. Miller-Jones,[1] Z. Paragi,[4] R. E. Spencer,[5] G. G. Pooley,[6] M. van der Klis[1] and A. Szomoru[4]

[1]*Astronomical Institute 'Anton Pannekoek', University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, the Netherlands*
[2]*Astronomical Institute of the Romanian Academy, Cutitul de Argint 5, RO-040557 Bucharest, Romania*
[3]*School of Physics and Astronomy, University of Southampton, Highfield, Southampton SO17 1BJ*
[4]*Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, the Netherlands*
[5]*University of Manchester, Jodrell Bank Observatory, Macclesfield, Cheshire SK11 9DL*
[6]*University of Cambridge, Mullard Radio Astronomy Observatory, J. J. Thomson Avenue, Cambridge CB3 0HE*

Accepted 2006 November 2. Received 2006 November 2; in original form 2006 October 26



Microquasar Cygnus X-3 (10 kpc) on 20 April (a) and 18 May 2006 (b). The source as in a semi-quiescent state in (a) and in a flaring state in (b), The core of the source is probably ~20 mas to the N of knot A. (Tudose et al.)



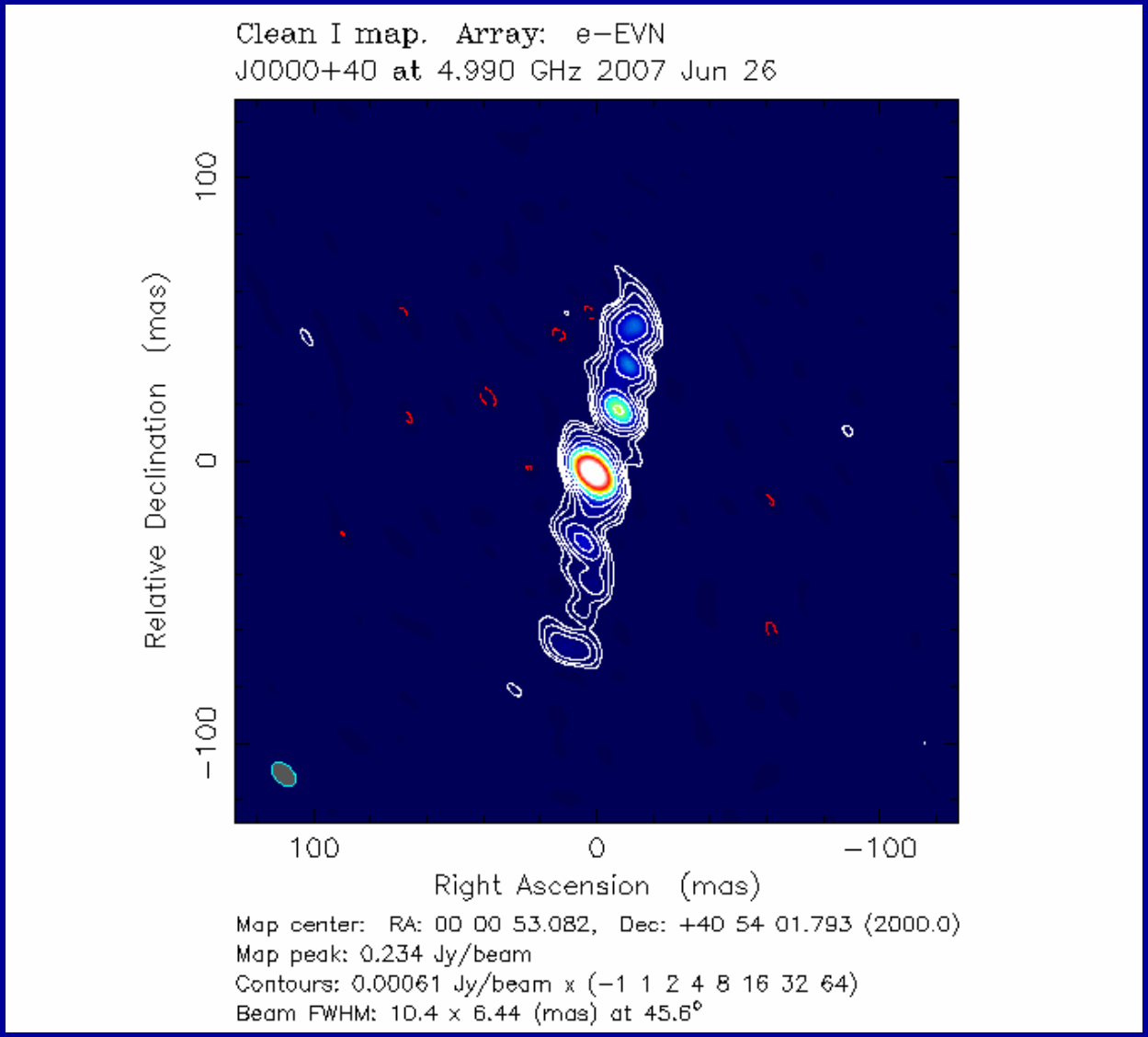
First 512 Mbps e-VLBI map

(2 February 2007)

The EVN carried out the first successful five European station e-VLBI run at 512 Mbps data rate, using:

- Cambridge
- Jodrell Bank (MkII)
- Medicina
- Onsala
- Westerbork (single dish)

Experiment	
Source	3C454.3
Duration	about one hour
Data rate	512 Mbps
UV-coverage	poor
Dynamic range	400:1



CSO J0000+4054

First successful six European station e-VLBI observations at 512 Mbps data rate.

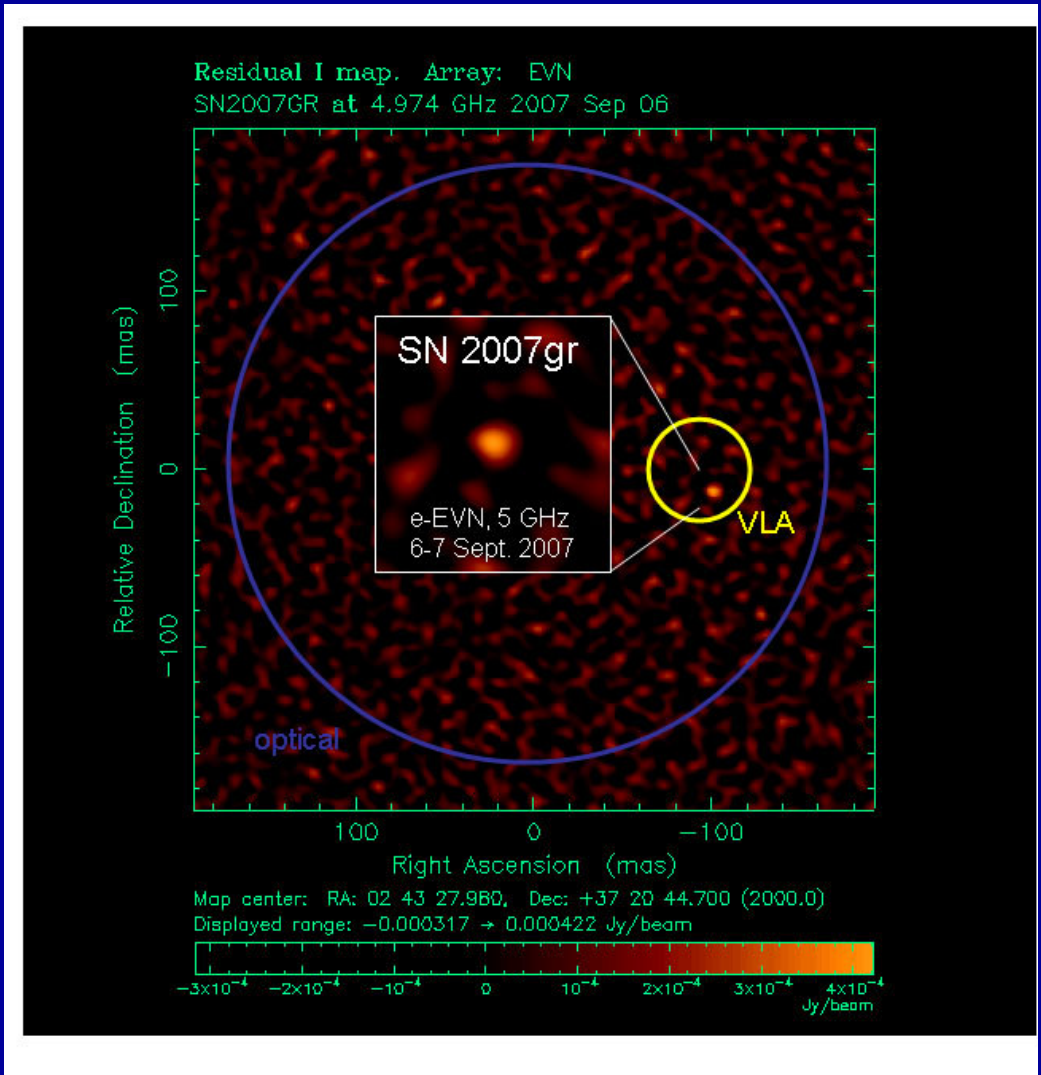
Radio telescopes:
Cambridge, Jodrell Bank (MkII), Medicina, Onsala, Torun and Westerbork (phased array).

Observing time: 3 hours

Obs. Mode: phase-referencing

Dynamic range: ~1000:1

Noise level: 200 microJy/beam.



Type Ibc SN2007gr

Identified an unresolved source

Considered an e-VLBI detection of a supernova

Observing date: 6-7 Sept 2007

Duration: 12 hours

Frequency: 4.97 GHz

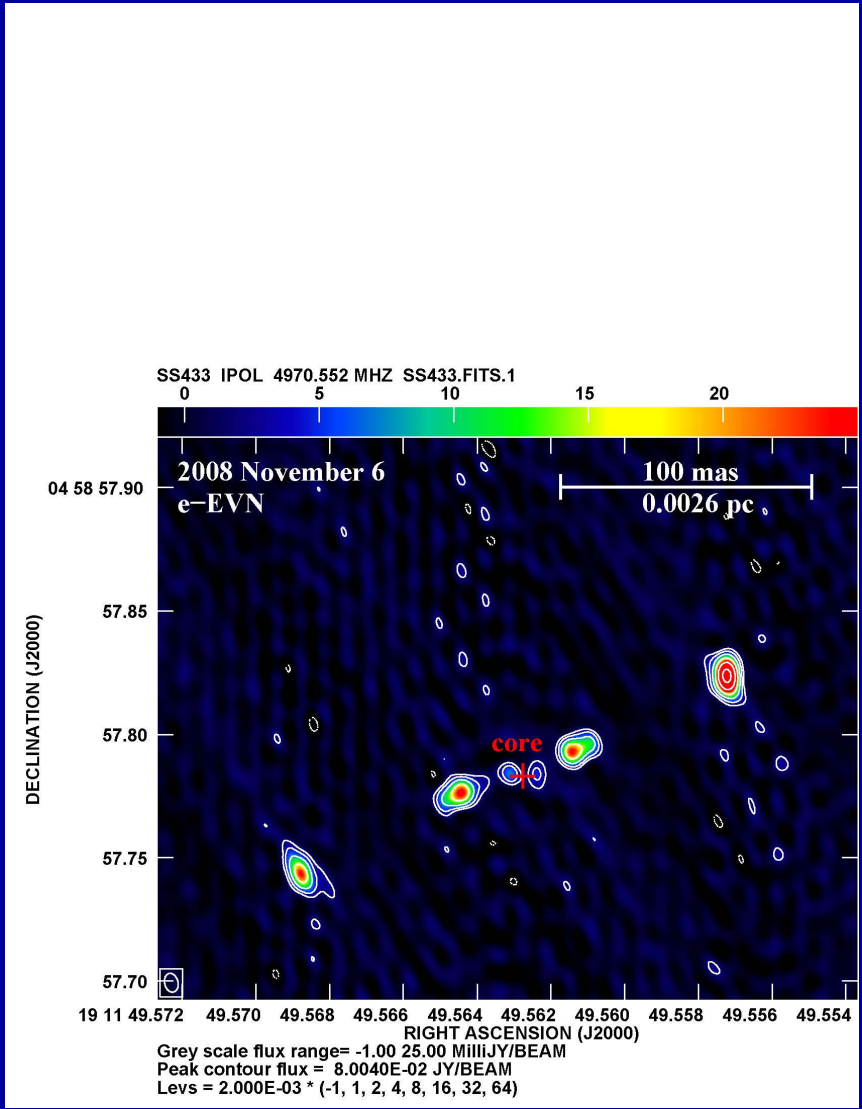
Aggregate bitrate: 256 Mbps

Participating telescopes:
Darnhall, Jodrell Bank (MkII), Medicina, Onsala, Torun and Westerbork (phased array)

Beamsize: 7 milliarcsecond
Flux density: 422+-21 microJy

The microquasar SS 433 in outburst

(V. Tudose et al. 2008)



X-ray binary observed on November 6, 2008

Precessing jet blobs moving at 8 mas / day (0.26c at 5.5 kpc)

The furthest blobs ejected about October 24

Radio burst observed by RATAN-600 on October 28

UNESCO, Paris
January 15-16 2009

Friday January 16
Global e-VLBI demo
33 hours of e-VLBI

Target:	J0204+1514, 0234+285 and 3C395
Radio telescopes:	17 in Asia, Australia, Europe, North America and South America
Data transfer:	streaming data in real-time to the correlator in the Netherlands via high-bandwidth fibre networks

e-VLBI : the future

> 16 x 1 Gbps production e-EVN network

> Lightpaths across GEANT point -to-point connections between JIVE and telescopes

> Guaranteed bandwidth, no need to worry about congestion

Towards a true connected-element interferometer

Towards a true connected-element interferometer

Dead of VLBI

The end