Wide bandwidth data transport in radio astronomy: creating an on-line telescope as large as Europe

Richard Schilizzi

Joint institute for VLBI in Europe

(schilizzi@jive.nl)

Outline

1) A few words about radio astronomy, present and future
2) Focus on the European Very Long Baseline Interferometry Network
3) Plans for wide bandwidth data transport through the NRENs
4) Last mile connections

In astronomy, four types of use of wide bandwidth links are envisaged

- Transport of raw data from telescope(s) to data processing facility
- Distribution of data from processing facility to users
- "Mining" of databases
- Real-time remote control of telescopes

Transport of raw data in radio astronomy arrays

Examples:

- national scale — e-MERLIN (UK)
- regional scale — LOFAR (NL, DE, SE)
- European scale — e-EVN
- global scale — Global VLBI

VLBI = Very Long Baseline Interferometry

EVN = European VLBI Network

Radio telescope arrays

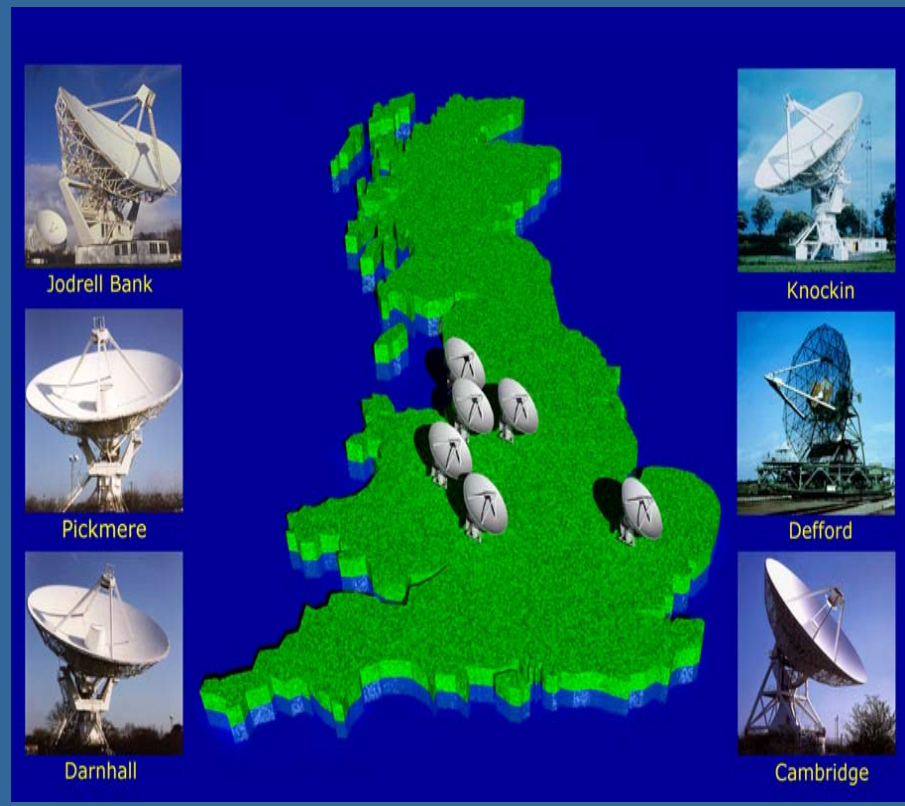
create images by interferometry

- the more telescopes in the array, the better the image quality
- the greater the bandwidth detected, the higher the sensitivity
- data transported is incompressible “white” noise
- 24x7x365 operation

networks of radio telescopes spread over 100’s to 1000’s of km provide zoom lenses for astronomers

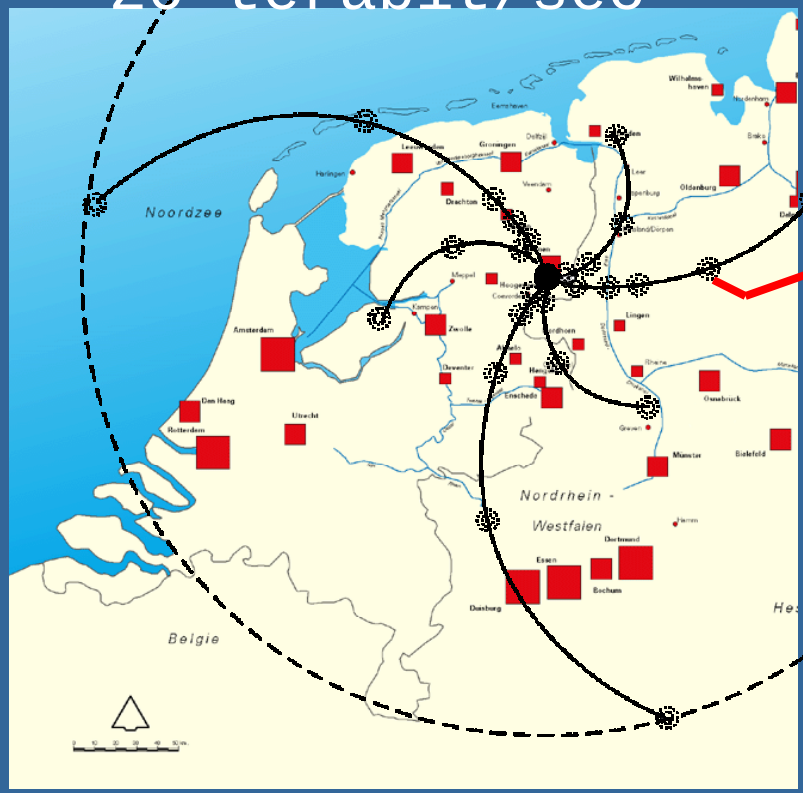
Transport of raw data on a national scale: e-MERLIN (UK)

- Dark fibres to connect telescopes to Jodrell Bank Observatory near Manchester
- Sustained data rates of 30 Gbps/telescope to data processor
- Funded, operational in 2006

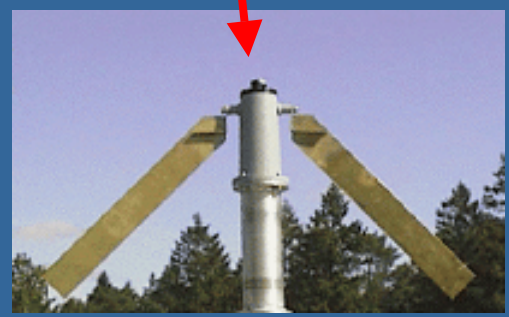


Transport of raw data on a regional scale: LOFAR (NL, DE, SE (LOIS))

total data rate to centre up to 20 terabit/sec

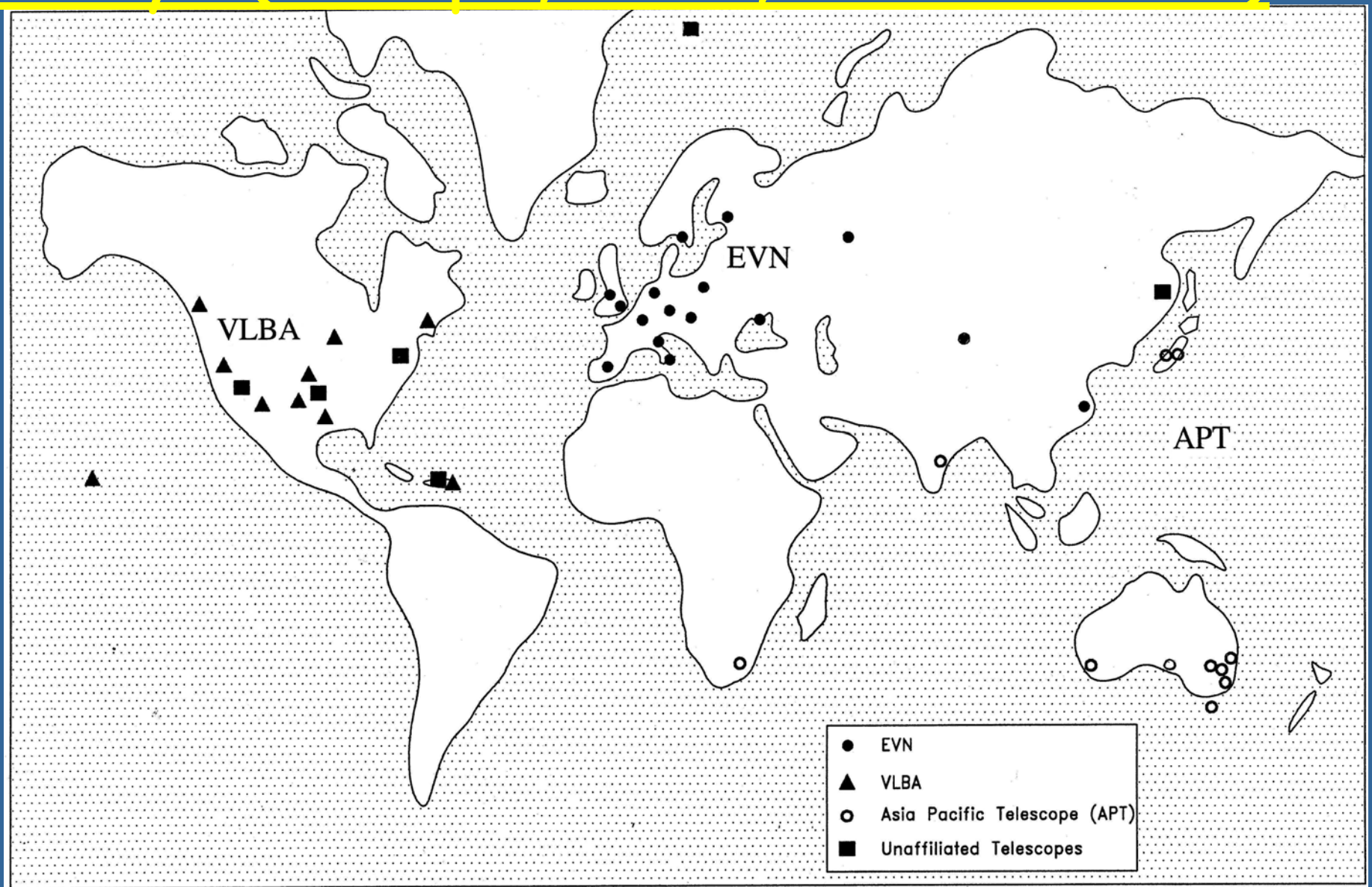


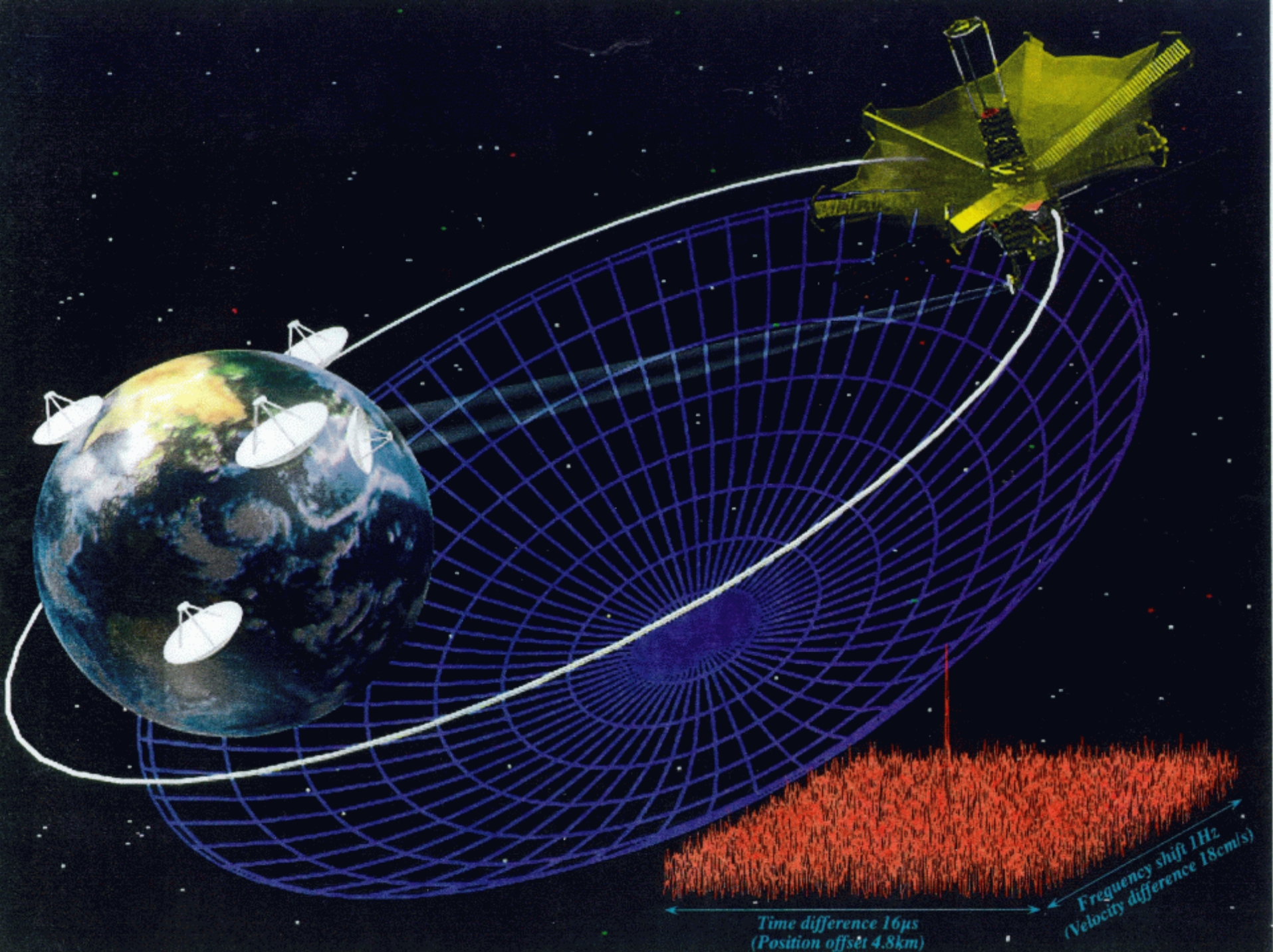
Log-spiral distribution, 300 km



Not yet funded; target for operation 2007

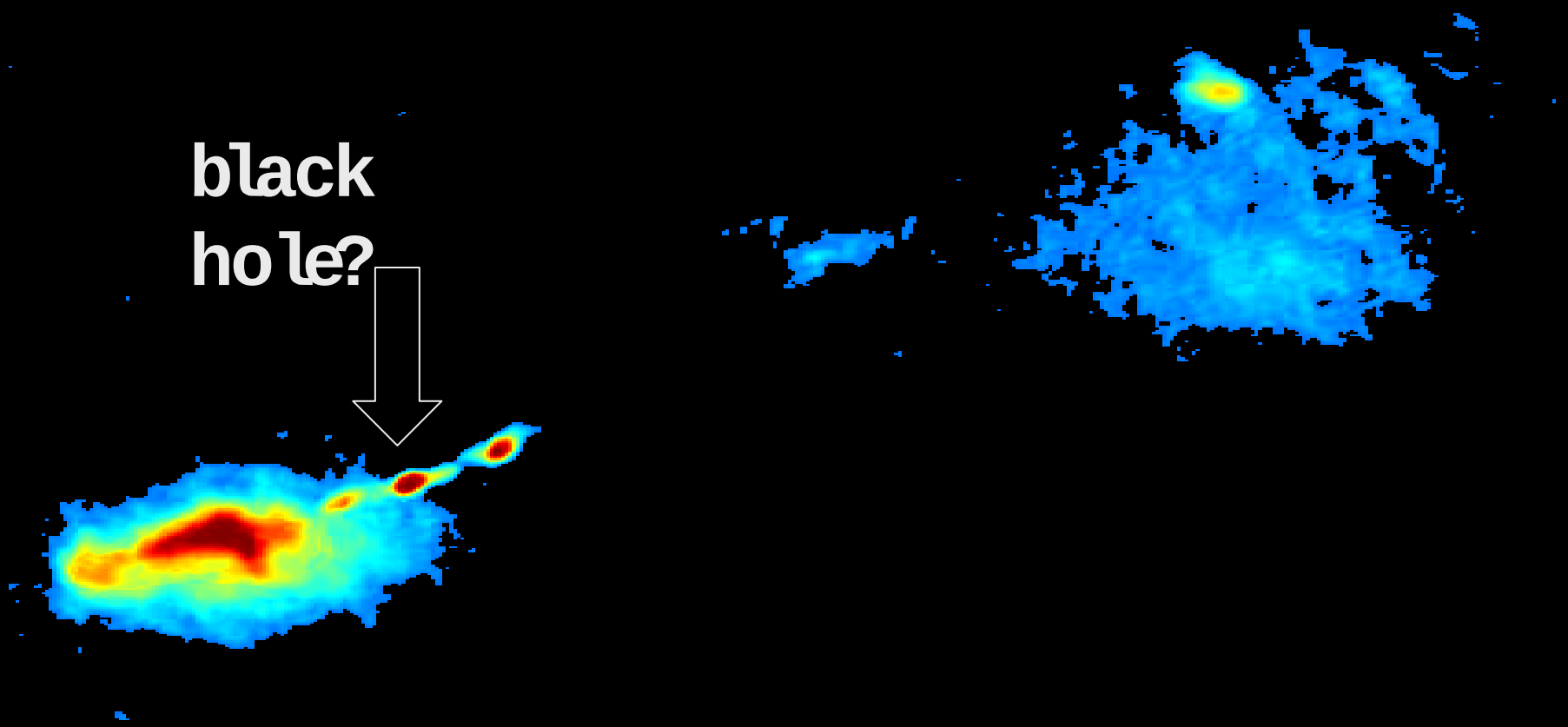
Transport of raw data on a global scale: VLBI arrays (Europe, USA, Asia-Pacific)




Time difference 16μs
(Position offset 4.8km)
Freguency shift 1Hz
(Velocity difference 18cm/s)

And now, an example of radio zoom lens imaging

deep in the heart of the galaxy (zoom factor=1000)

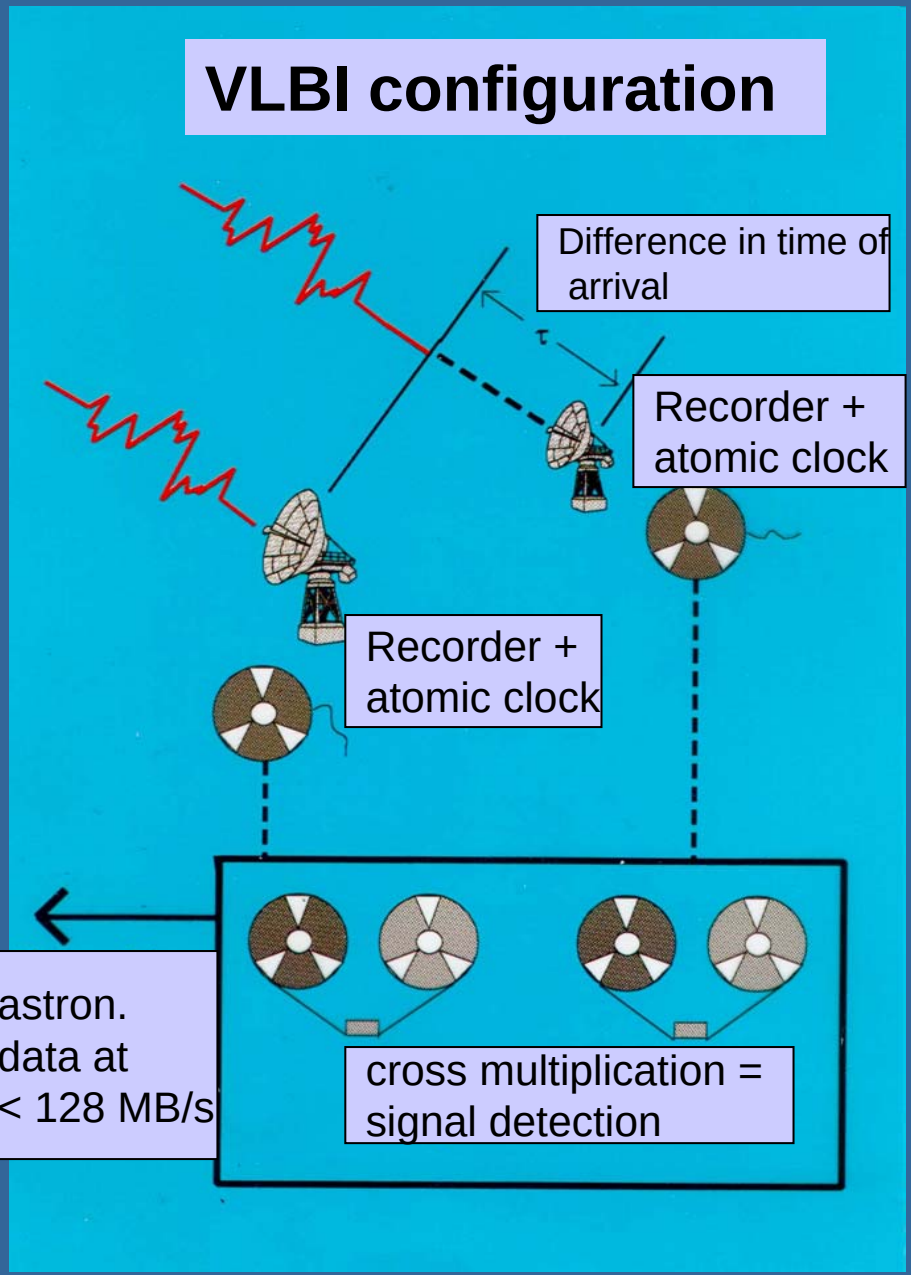


Back to the European VLBI Network

16 telescope data processor at JIVE

Onsala 25m + 20m, Sweden

Effelsberg 100m Germany



how do we currently do this?

⇐ telescopes in different countries

⇐ data recorded on tape/PC disk at 1 Gbps and transported to a central location (300 tera-bytes/day)

⇐ data processor multiplies and adds at a rate of 10^{14} ops/sec

e-EVN: a real-time connected radio telescope as large as Europe

use the Grid infrastructure for

-- transporting raw data-streams of 1-10 Gbps from each radio telescope to the central data processor at JIVE

-- quality of service not a big issue

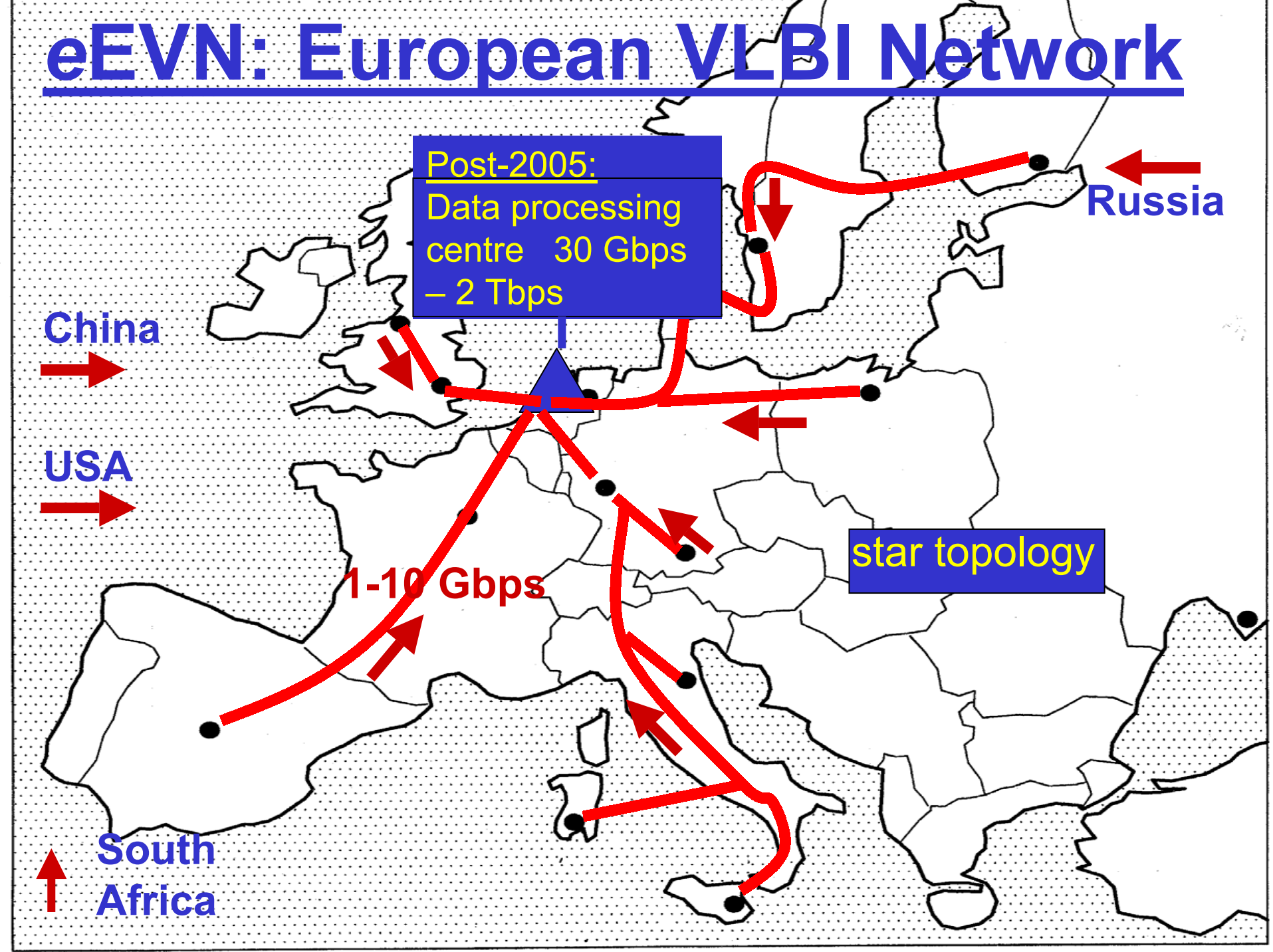
to provide

- new astronomical capabilities
- operational robustness and flexibility

timescale

first tests: 2002, full-scale deployment: post-2005

eEVN: European VLBI Network



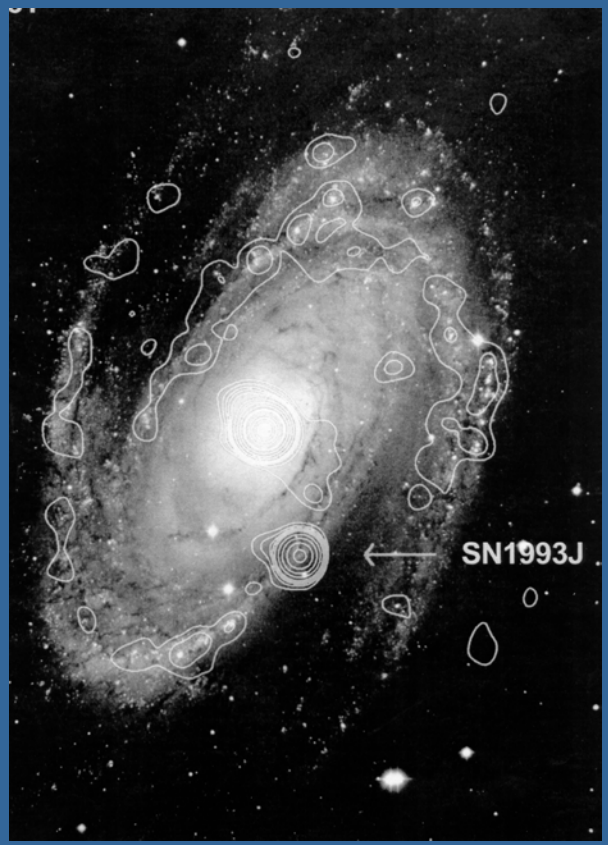
Science impact

- real-time operation allows flexible dynamic scheduling to respond to "targets of opportunity" like exploding stars

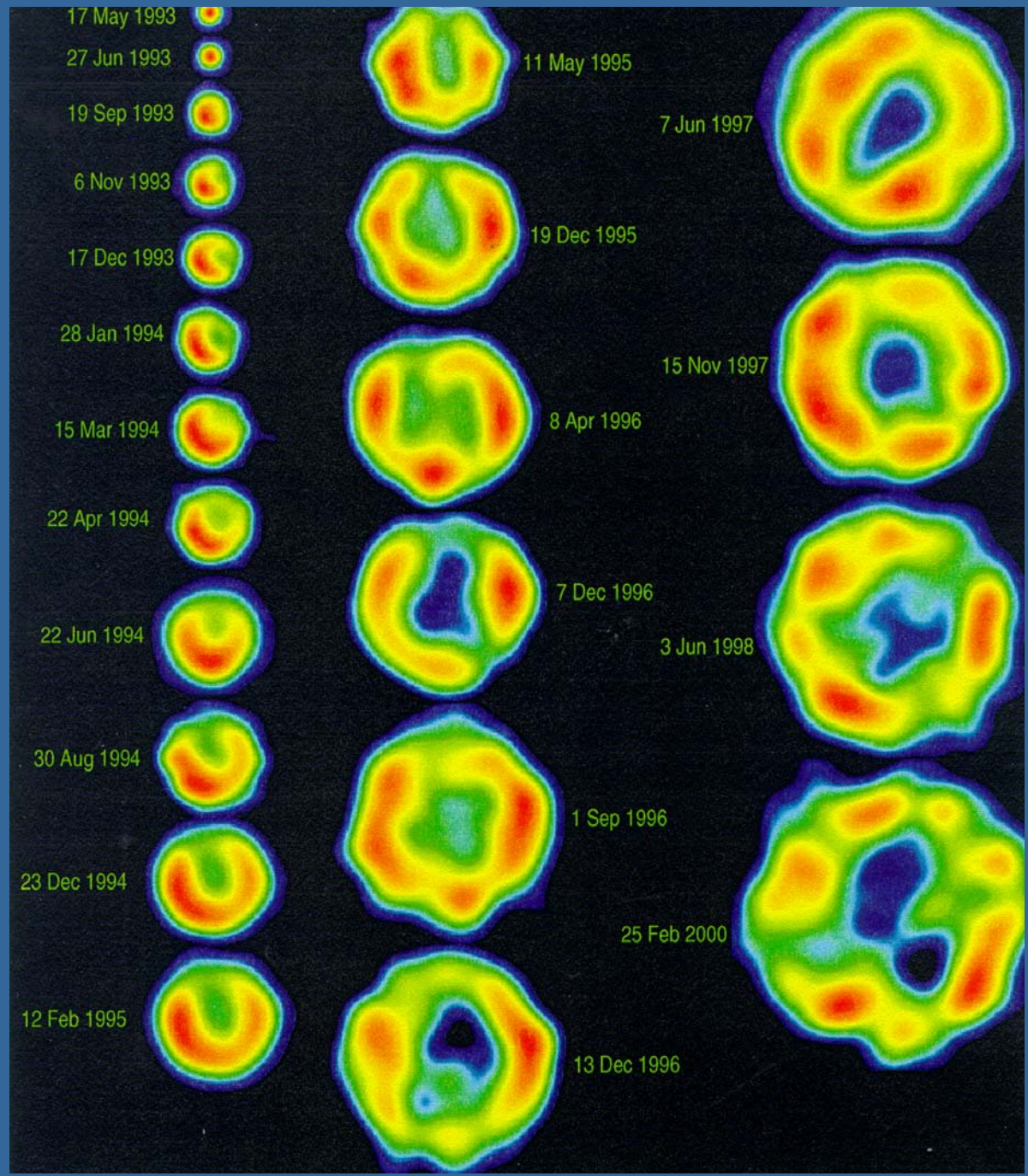
- wide bandwidth that is always available ⇒ major increase in sensitivity for radio sources at the edge of the universe

- wide bandwidth ⇒ very high quality imaging

supernova in M81in 1993



(Bietenholz et al)



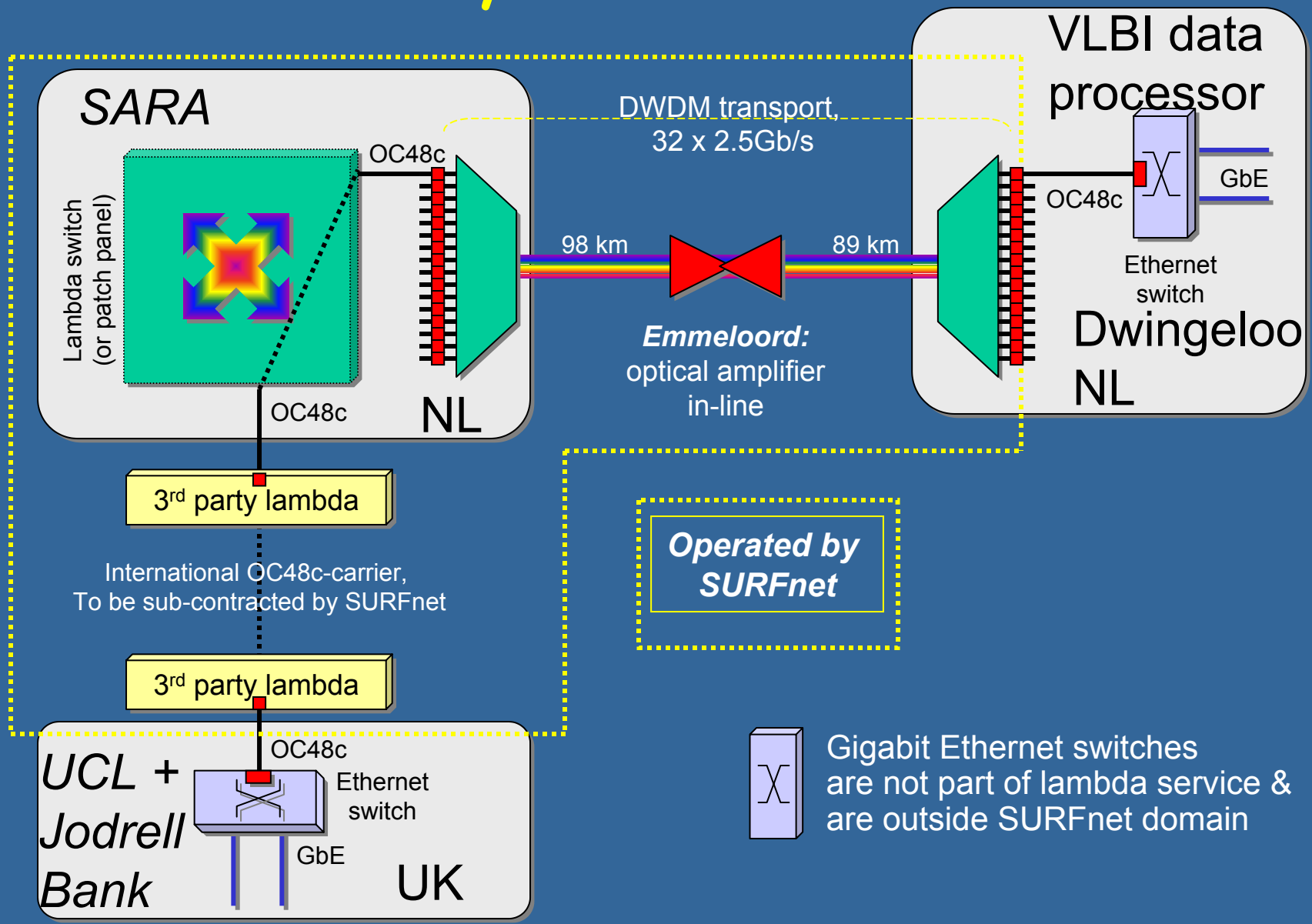
Operational impact

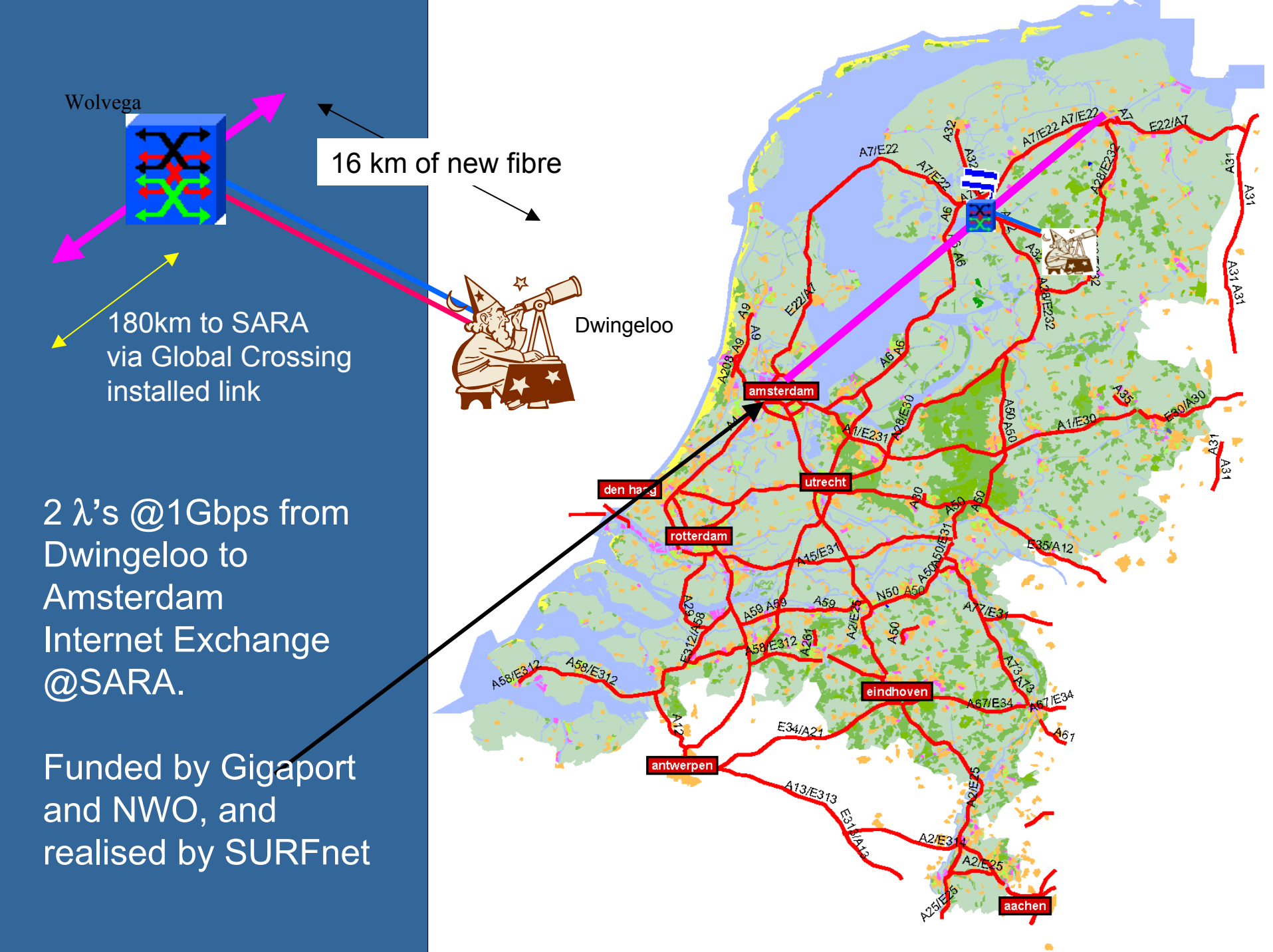
- more robust operation
- easier data transfer logistics
- flexible scheduling
- lower operating costs
- more effective network monitoring

Lambda Networks: Perfect for VLBI?

- End-to-end connections (layer 1)
- Virtual, dark fibre networks
- dedicated chain of wavelengths between telescope and data processor
- Lambda always-on!

Network layout for VLBI λ-test





2 λ's @1Gbps from Dwingeloo to Amsterdam Internet Exchange @SARA.

Funded by Gigaport and NWO, and realised by SURFnet

iGrid 2002

The International Virtual Laboratory

www.startap.net/igrid2002
www.igrid2002.org

24-26 September 2002
Amsterdam Science and Technology Centre (WTCW)
The Netherlands

Call for Applications with Insatiable Bandwidth Appetites!

"We hereby challenge the international research community to demonstrate applications that benefit from huge amounts of bandwidth!"

Beyond iGRID

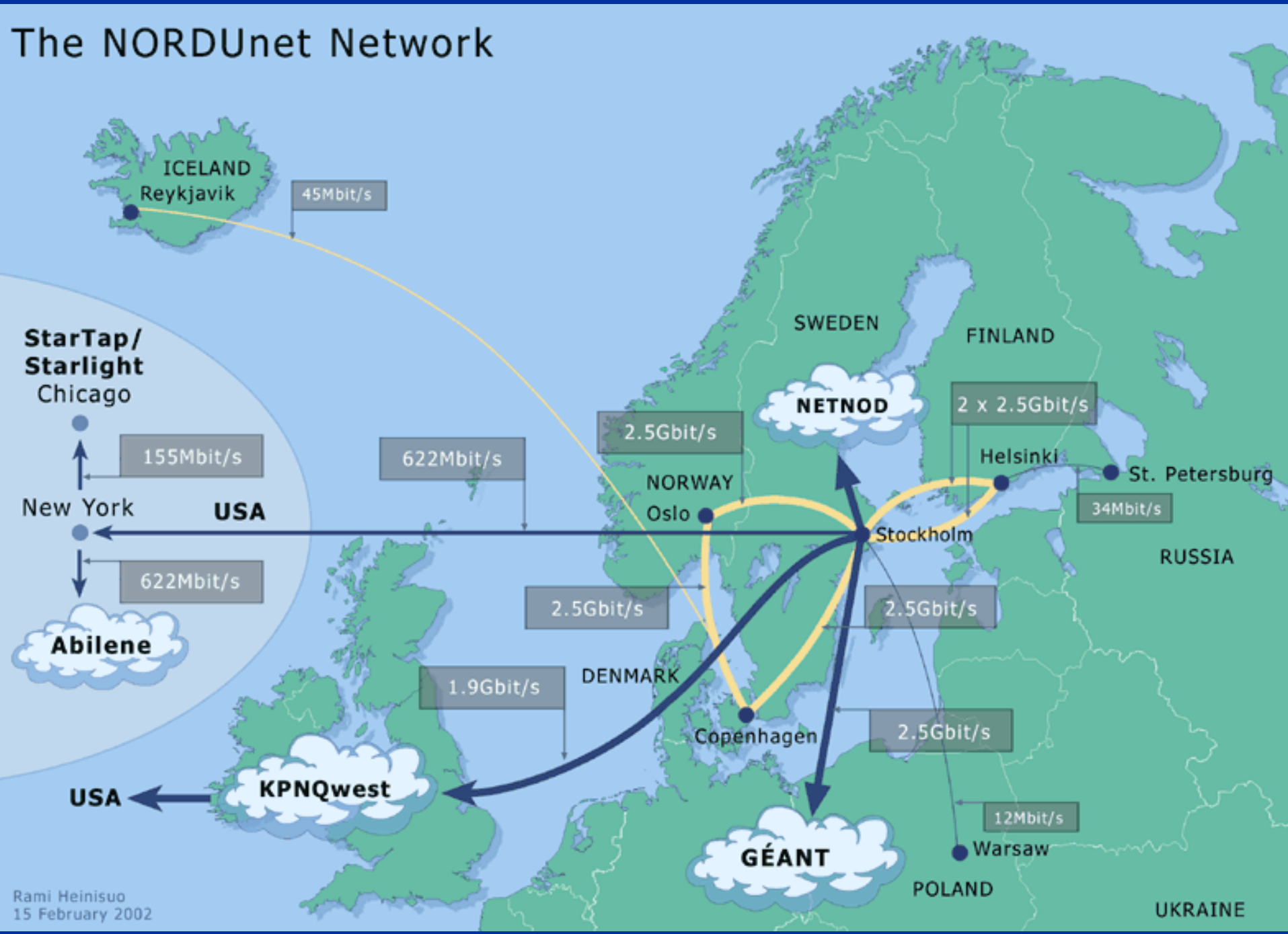
- links from Nordic radio telescopes in Sweden and Finland
- links from remaining EVN telescopes (e-EVN)
- link from USA via Chicago/New York
- link from Japan via TransPac/Chicago

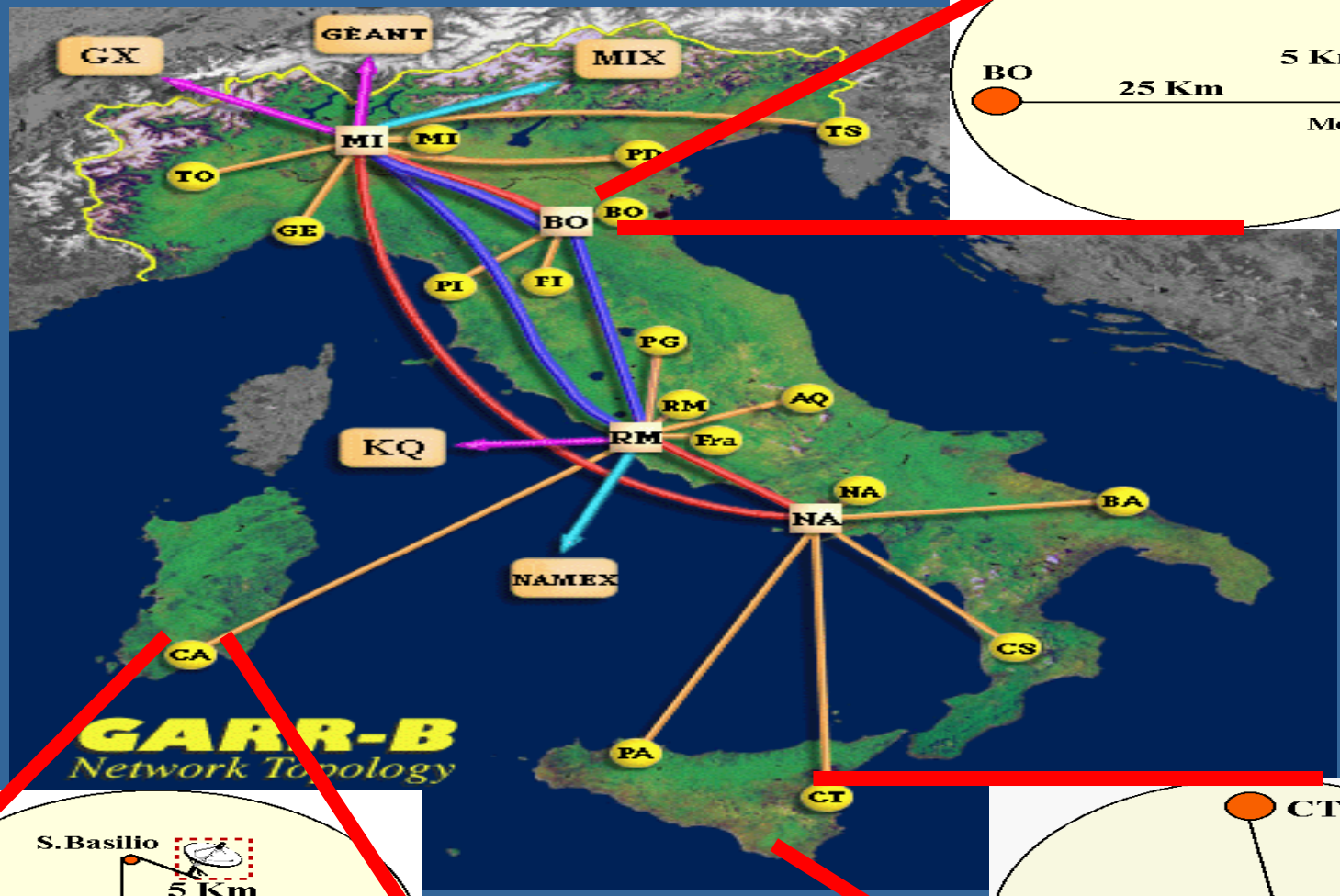
- Dwingeloo connection can be upgraded to multiple λs with multi-gigabit/s capacity

Challenge for the research community (NRENs, Research Councils, Institutes)

How to deal with the “first km problem” for the radio telescopes in Europe

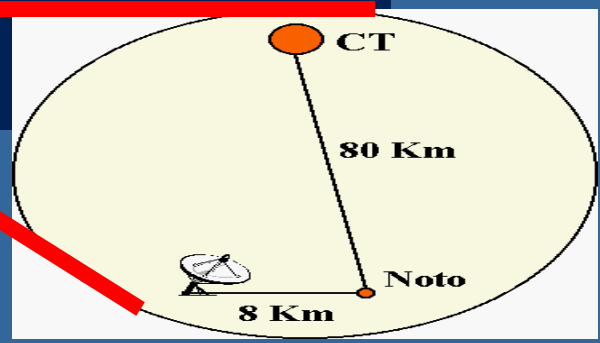
location	distance	NREN	status	timescale	bandwidth
JIVE (NL)	16 km	SURFnet	approved	Aug 02	2x1 Gbps (mdf)
e-MERLIN (UK)	10 km	under investig.	approved		
Westerbork (NL)	30 km	SURFnet	not yet appr.		
Metsähovi (FI)	6 km	FUNET	to be ordered	3 months	1, 2.5 Gbps (mdf)
Medicina (IT)	30 km	GARR	under study		2 Gbps
Noto (IT)	88 km	GARR			
SRT (IT)	42 km	GARR			
Matera (IT)	100 km	GARR			
Effelsberg (DE)	5 km	DFN	under study		
Onsala (SE)	10 km	SUNET			
Yebes (ES)	70 km	Rediris	under study		
Torun (PL)	0 km	Posnan	in place		155->622 Mbps
Shanghai (Ch)					
Urumqi (China)					


The NORDUnet Network
ICELAND
Reykjavik
45Mbit/s
StarTap/
Starlight
Chicago
155Mbit/s
New York
USA
622Mbit/s
Abilene
622Mbit/s
SWEDEN
FINLAND
NETNOD
2.5Gbit/s
2 x 2.5Gbit/s
Helsinki
St. Petersburg
NORWAY
Oslo
34Mbit/s
Stockholm
RUSSIA
2.5Gbit/s
2.5Gbit/s
DENMARK
1.9Gbit/s
Copenhagen
2.5Gbit/s
USA
KPNQwest
12Mbit/s
Warsaw
GÉANT
POLAND
UKRAINE
Rami Heinisuo
15 February 2002


GX
GÈANT
MIX
MI
MI
TS
TO
PD
GE
BO
BO
PI
FI
PG
RM
AQ
KQ
RM
Fra
NA
BA
NA
NAMEX
CA
CS
PA
CT
GARR-B
Network Topology

BO
25 Km
5 Km
Medicina


S.Basilio
5 Km
37 Km
CA


CT
80 Km
Noto
8 Km

e-VLBI international working group

- established 9 April 2002 during the first international workshop at MIT Haystack Observatory
- will meet as a “BOF” group at other meetings
- second international workshop in Europe at Joint Institute for VLBI in April 2003
- charter and “white paper” to be written
- website supported by Internet 2
- Japan well advanced in e-VLBI;
US “last km” problem may be less severe than in Europe

Summary

- radio astronomy will be a heavy user of research network infrastructure

- it pushes the envelope of sustained data transfer at very high bit rates through the research networks

- creating an on-line radio telescope as large as Europe is a novel application, with potentially high public visibility for both astronomy and the research networks