From truck to optical fibre:

the coming-of-age of eVLBI

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Outline

- Introduction
- Protocols, tuning issues
- Tests and results
- eVLBI: towards eEVN?
- Conclusions

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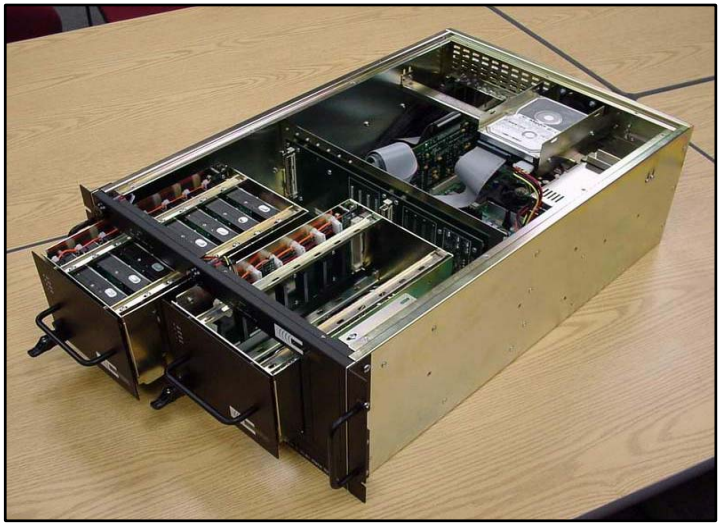
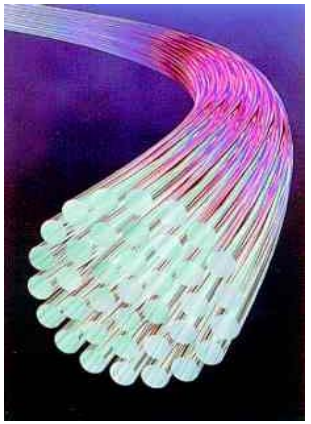
Introduction

- Moving to disk recording
  - More reliable, data quality
  - Cheaper to maintain
    - High bandwidth sustainable
  - More efficient to use
    - Direct access compared to tape
    - Unattended operations
- eVLBI will be the future
  - No consumables
  - Higher bandwidth
  - Fast turn-around

Disk based recording



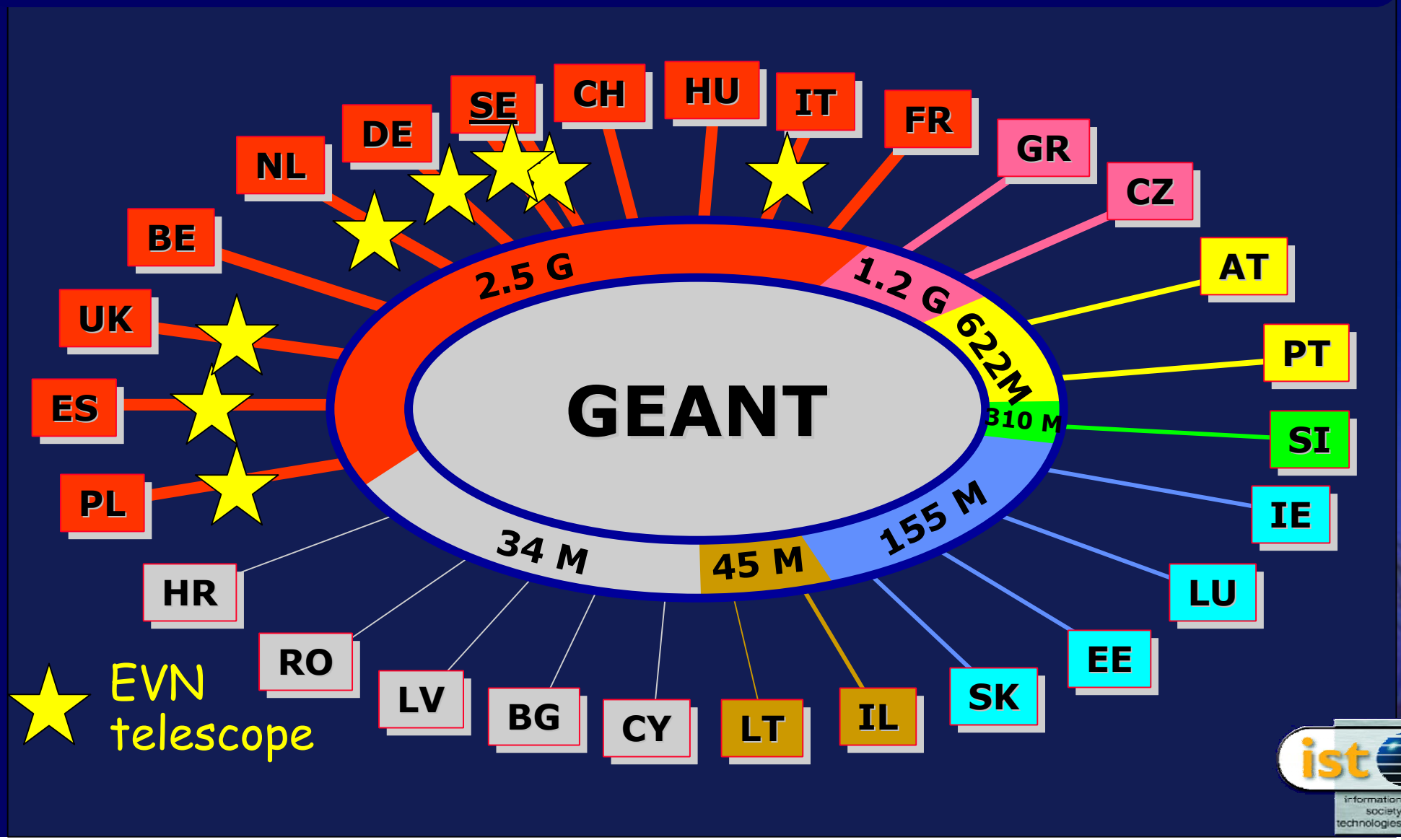


eVLBI using fiber

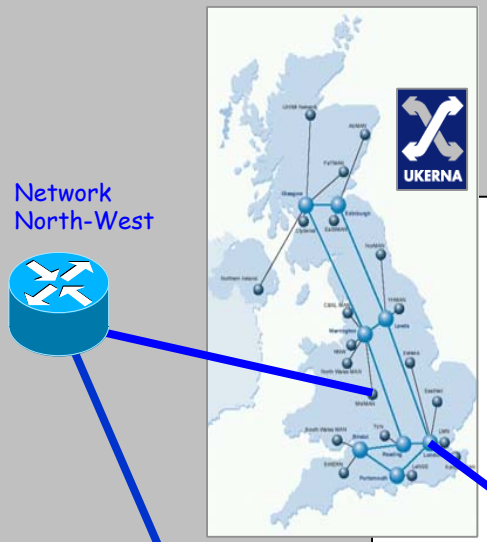
eVLBI Proof-of-Concept Project

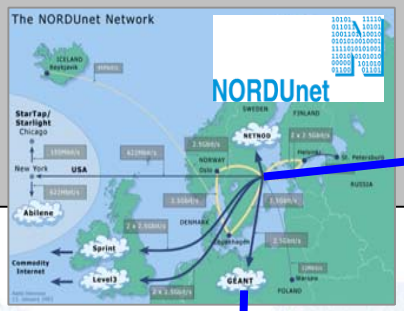
• DANTE/GÉANT	Pan-European Network
• SURFnet	Dutch NREN
• GARR	Italian NREN
• UKERNA	UK NREN
• PSNC	Polish NREN
• DFN	German NREN
• KTHNOC/NORDUnet	Nordic NREN
• Manchester University	Network application software
• JIVE	EVN Correlator
• Westerbork telescope	Netherlands
• Onsala Space Observatory	Sweden
• MRO	Finland
• MPIfR	Germany
• Jodrell Bank	UK
• TCfA	Poland
• CNR IRA	Italy

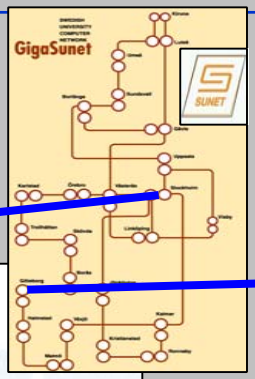
GÉANT:
Access of NRENs to GÉANT



Network Topology for eVLBI

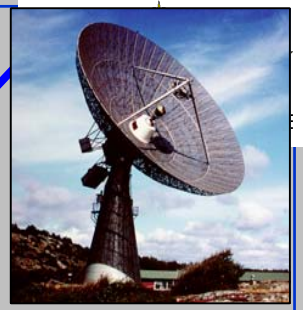






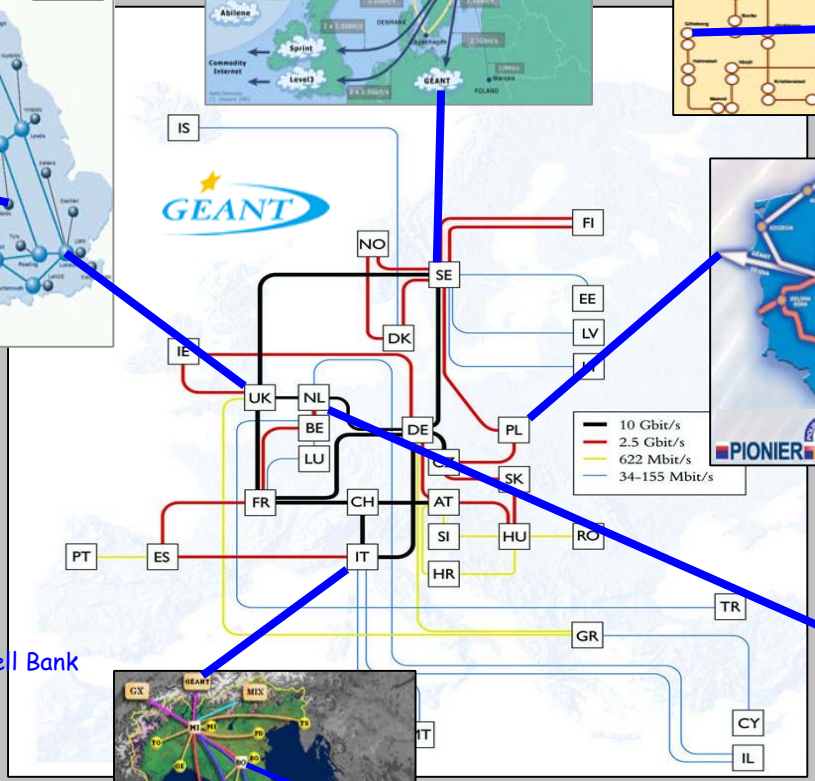
Gbit link

Chalmers University of Technology, Gothenburg



Onsala Sweden

Network North-West



Gbit link

Torun Poland

150Mbit link

Jodrell Bank UK

Westerbork Netherlands

Dedicated Gbit link

MERLIN Microwave link

Cambridge UK

Medicina Italy

Dwingeloo DWDM link

POC targets:

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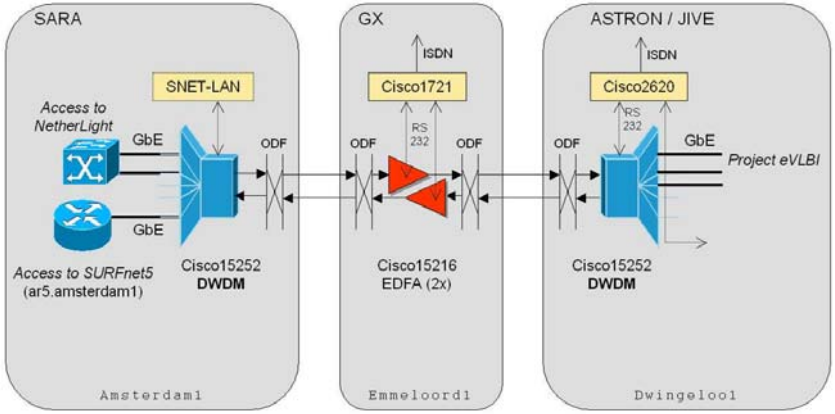
- for the EVN and JIVE
  - Feasibility of eVLBI:- Costs, timescales, logistics.
  - Standards:- Protocols, parameter tuning, procedures at telescope and correlator.
  - New Capabilities:- Higher data rates, improved reliability, quicker response.
- for GÉANT and the NRENs
  - To see significant network usage with multiple Gbit streams converging on JIVE.
  - Minimum is three telescopes (not including Westerbork)
  - Must be seen to enable new science and not just solve an existing data-transport problem
  - Real-time operation is seen as the ultimate aim, buffered operation accepted as a development stage.



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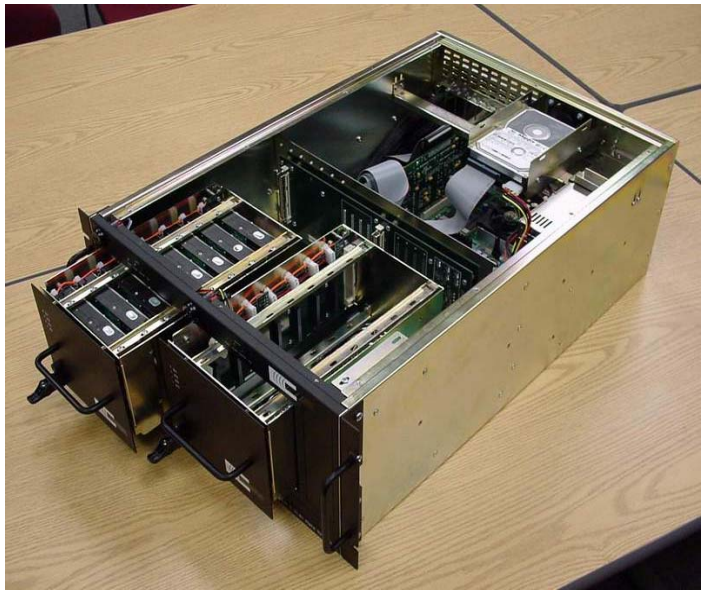
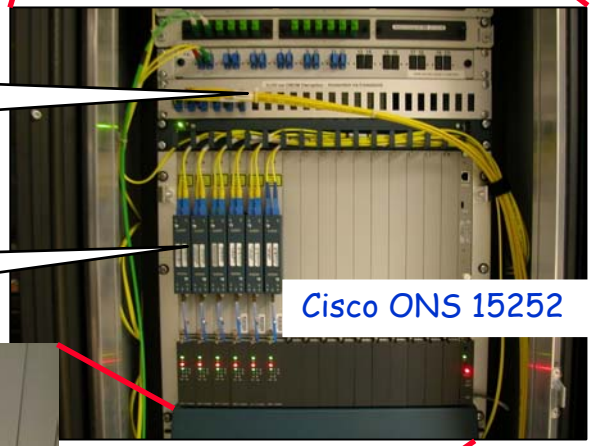


Correlator Interface

GE lines to correlator

LX Optics converters



Cisco ONS 15252

Optical Splitters

Fibre pair from Amsterdam

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Current status:

- JIVE: 6 lambdas via Netherlight, each capable of 1 Gbps
- 1 Gbps connections to Westerbork, Torun, Onsala
- 155 Mbps to Jodrell, Arecibo
- Upgrade of Jodrell to 2.5 Gbps and connection of Medicina at 1 Gbps planned later this year

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Protocols

- Use of existing protocols, available hardware
- TCP: maximal reliability, very sensitive to congestion
- UDP: connectionless, packets are sent without further accounting, fast(er) but not reliable
- Different protocols will become available shortly (VSI-E?) combining speed and reliability

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Tuning issues

- Dramatic improvement of TCP performance possible by adjusting default settings:
  - congestion window: product of roundtrip time and bandwidth
  - size of queues between kernel and NIC
  - SACK (Selective Acknowledgment) implementation
  - MTU size (jumbo frames)
  - Interrupt moderation: cpu may be bottleneck

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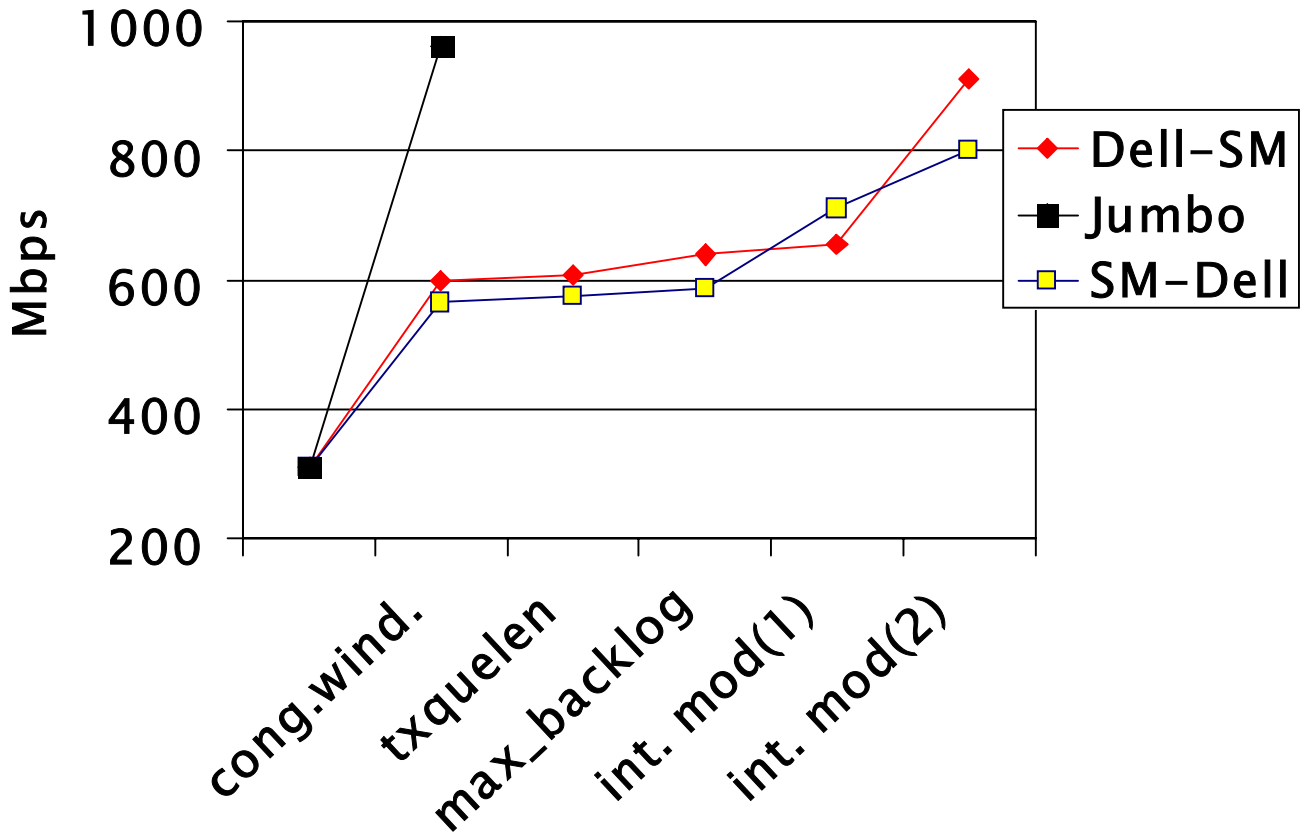
Mem-mem transfer via patch



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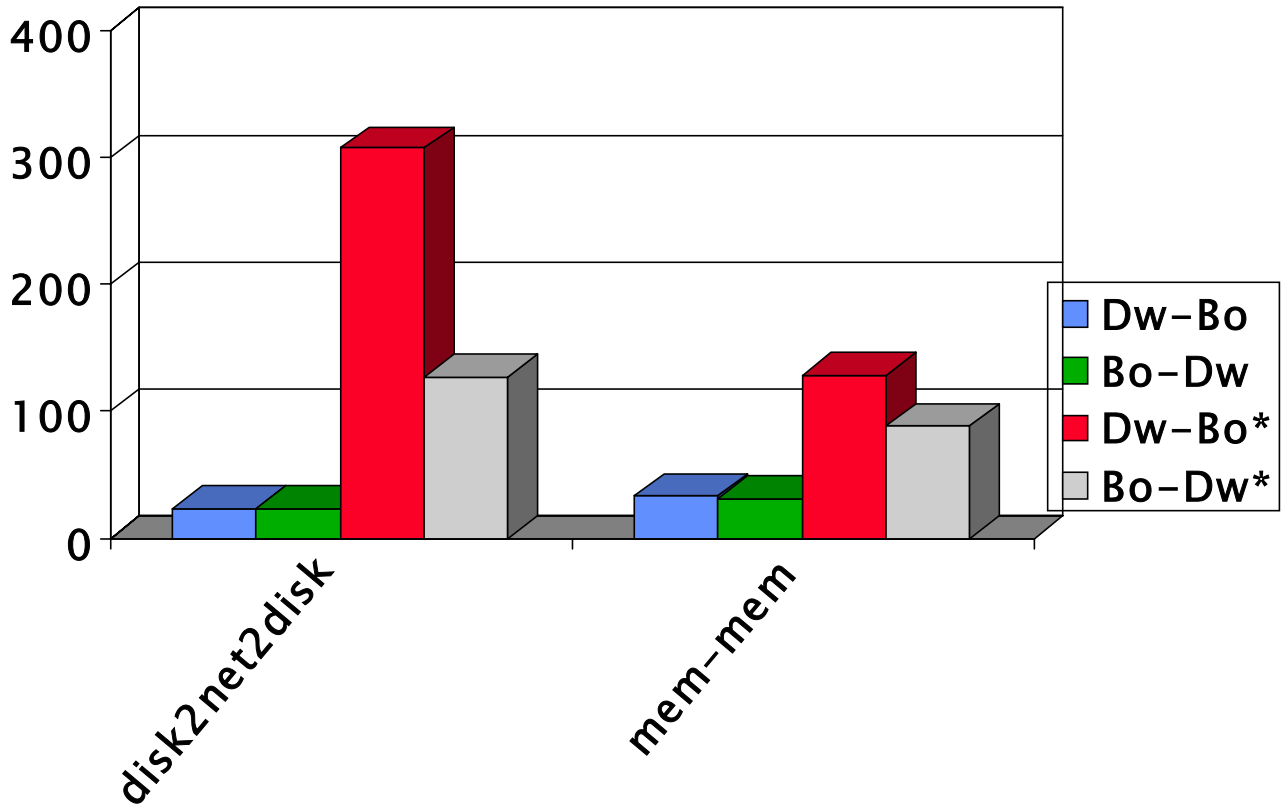
Disk2net-net2disk Dwingeloo-Bologna



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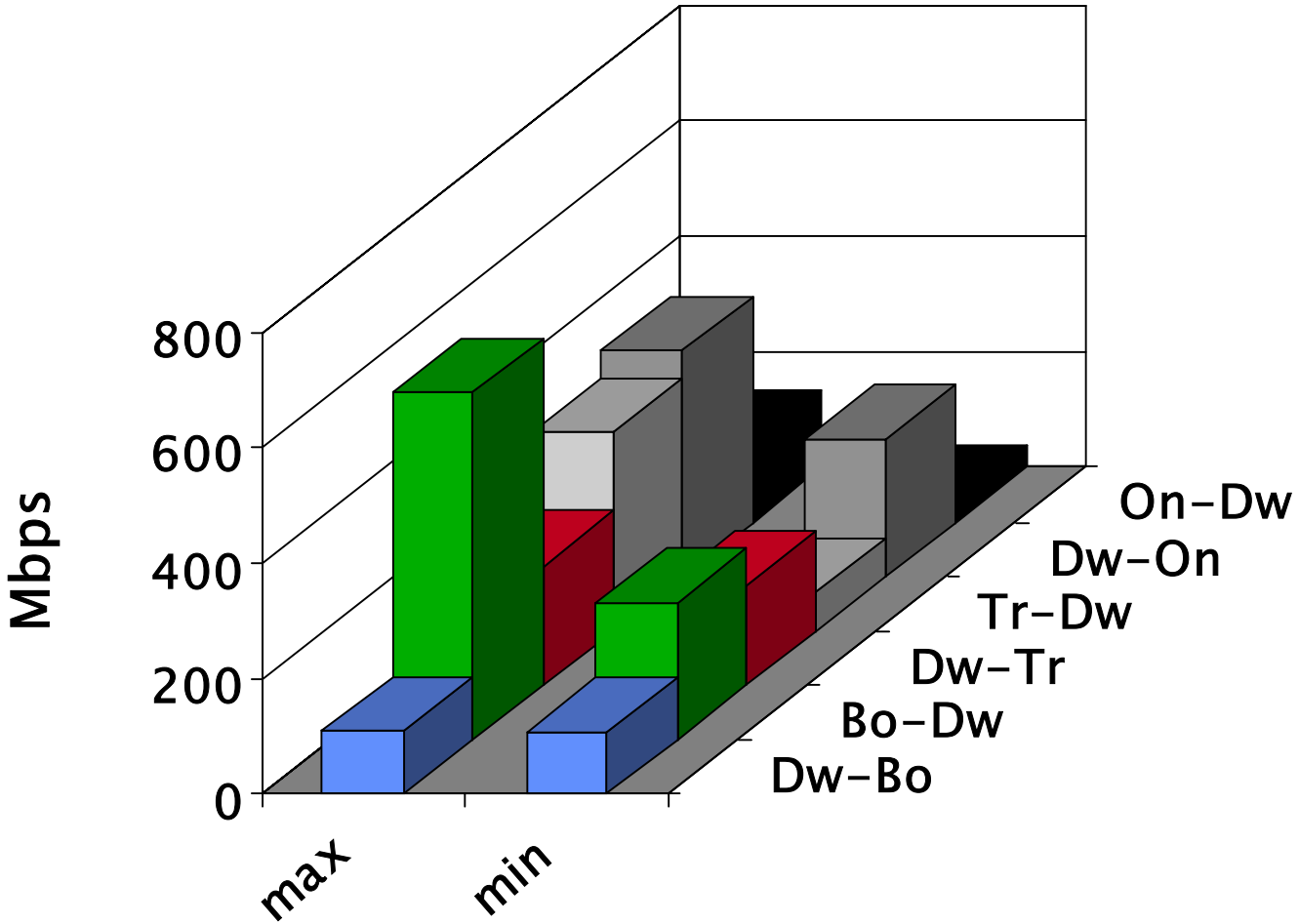
Network stress test (iperf)



Test results

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	Memory-memory		Disk2net-net2disk		In2net-net2disk	In2net-net2out
	UDP	TCP	UDP	TCP	TCP	TCP
Bench via patch		930	250			256
Idem, jumbo frames		960		544		512
Bench via Amsterdam	500	360				256
Idem, jumbo frames			341	456		
Westerbork-JIVE	867	680			256	64
Idem, jumbo frames			249	378		
Bologna-JIVE	670	128		307		
Jodrell-JIVE	50	70			64	32
Arecibo-JIVE		88				32
Torun-JIVE	800	260				32
Onsala-JIVE				177	256	64
JIVE-Haystack	612			71		

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eVLBI Transfer modes

- ftp-based: bandwidth not critical, has greatly improved response to technical problems at telescopes
- Dual buffered: recorded on Mk5 diskpack, transferred through disk2net and net2disk, played back at correlator
- Single buffered: streamed directly from formatters to diskpacks at JIVE
- Real-time: directly from formatters to correlator without disk buffering

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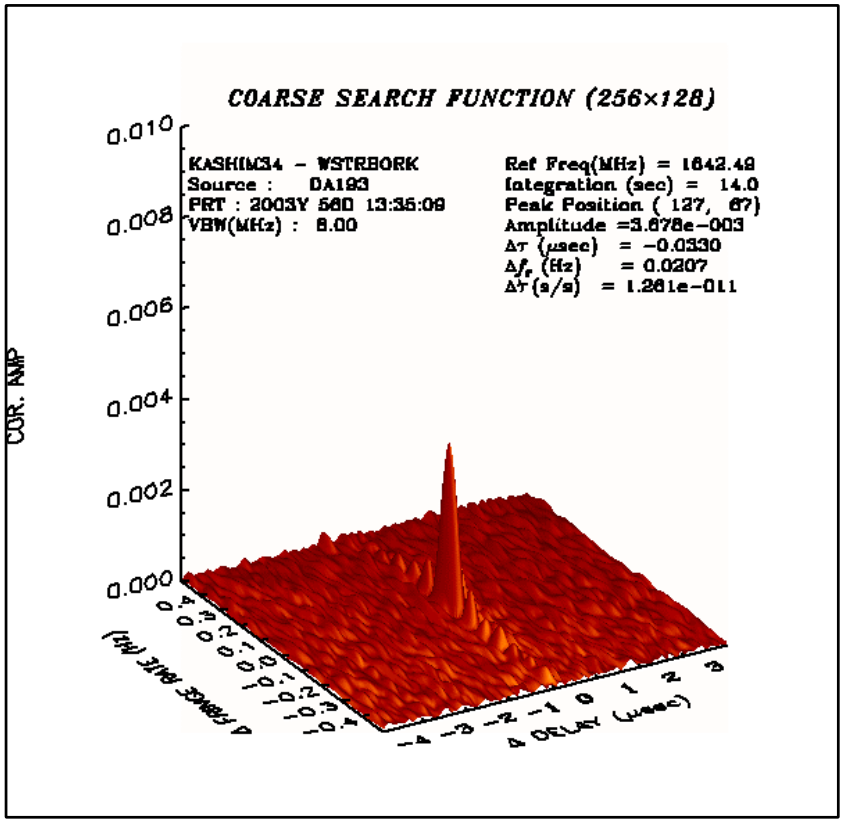
eVLBI Transfer modes



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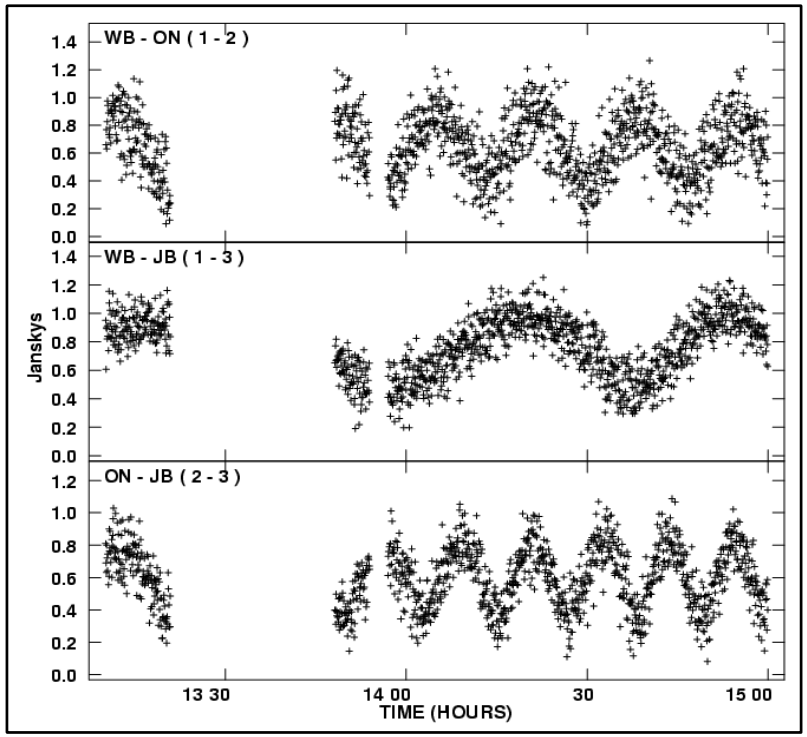
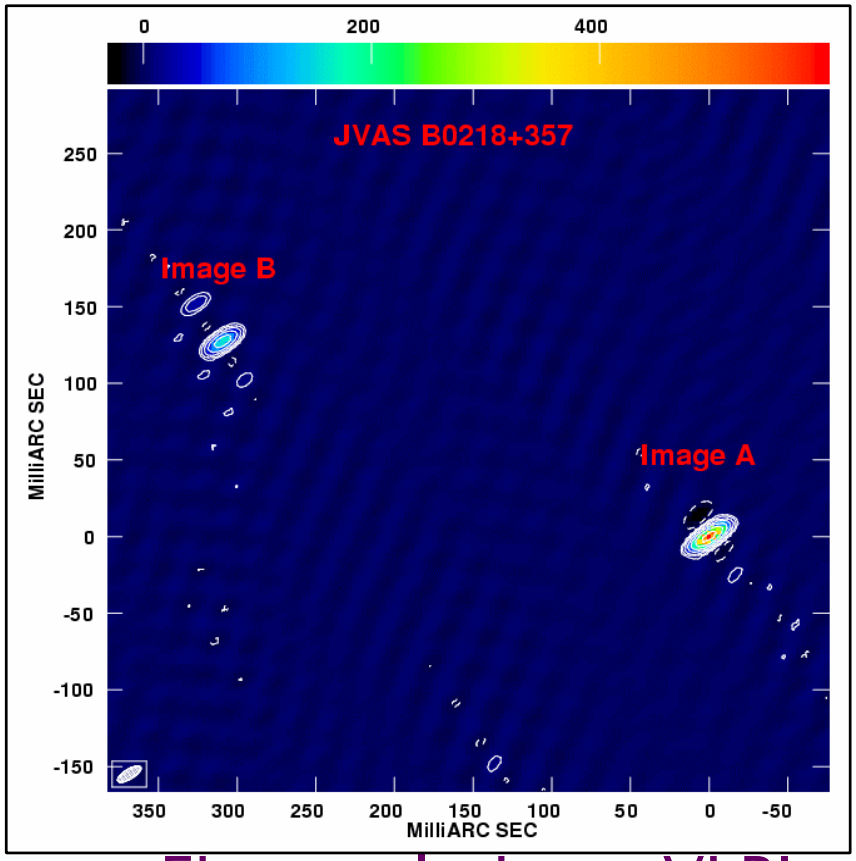
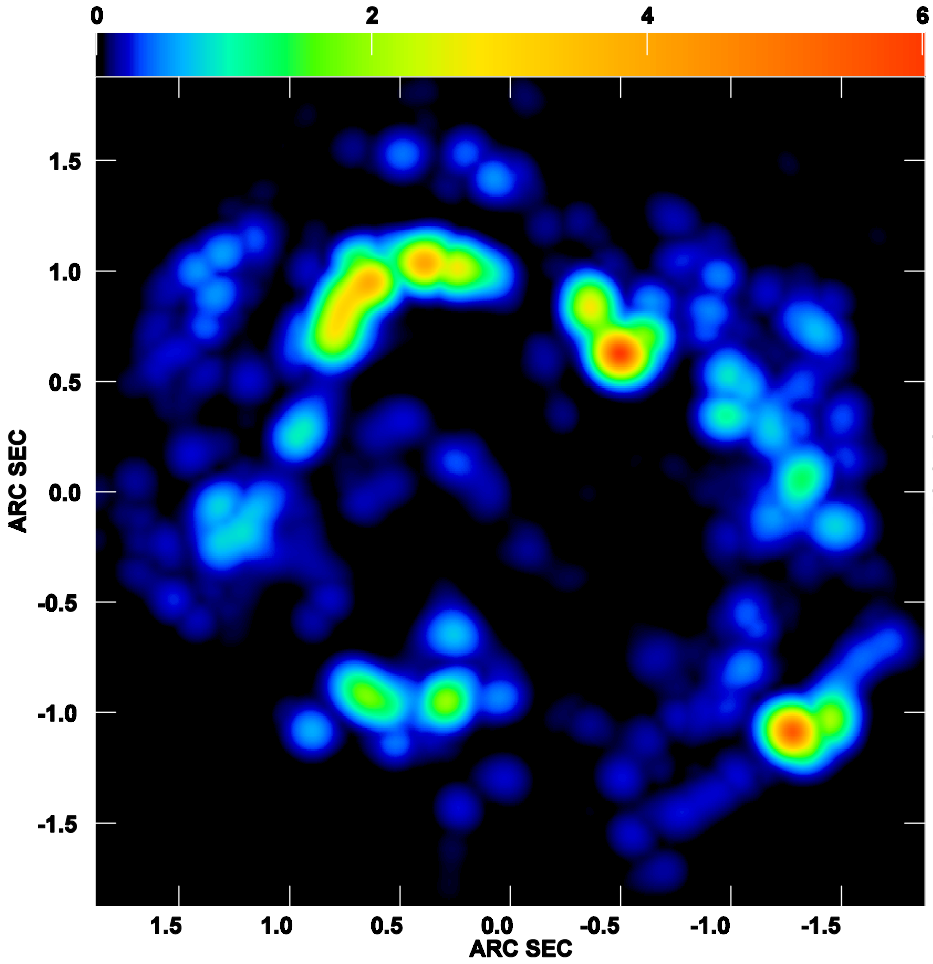


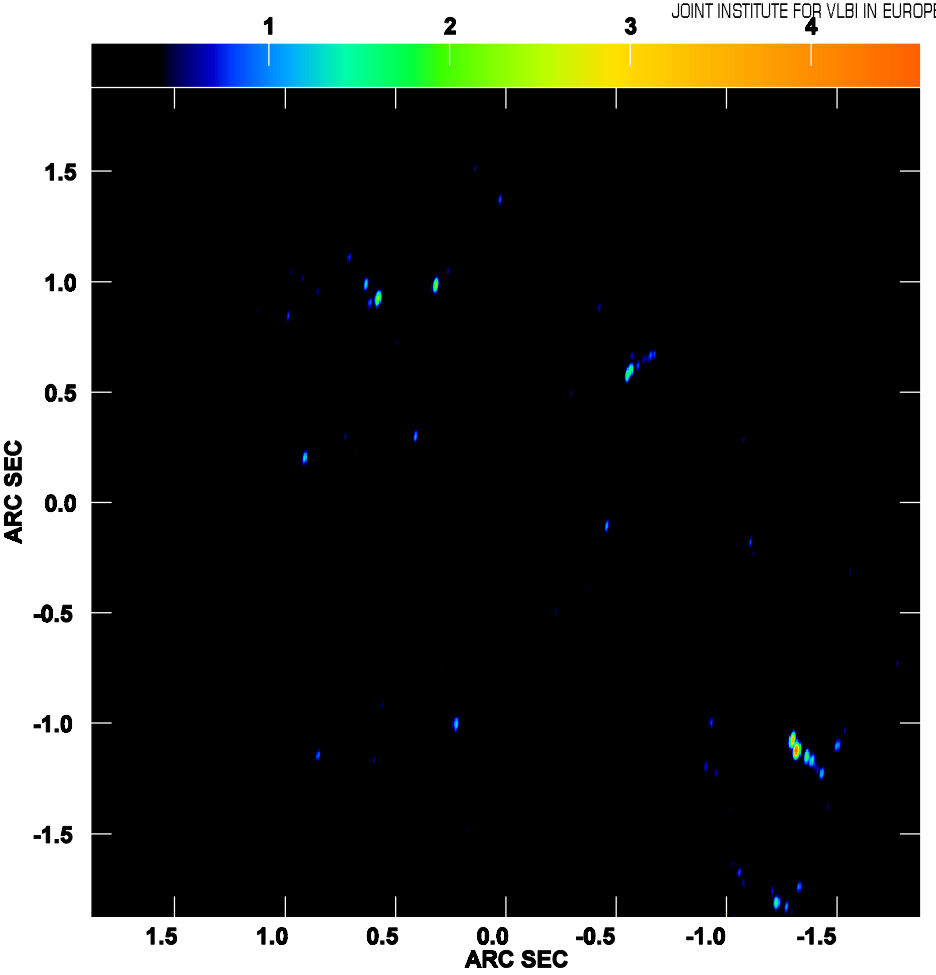


First real-time eVLBI Image

IRC+10420



MERLIN, March 2002



eVLBI, September 2004

A. Richards, 2004

eVLBI: towards eEVN?

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- Advantages:
  - No consumables
  - Fast turn-around
  - Reliability, instant feedback to stations, targets of opportunity (GRB afterglow)
  - Future bandwidth needs: eVLBI will take full advantage of commercially driven improvements
- Change of operating model of EVN: correlator as integral part of network
- One instrument, highly increased coherence
- Possibility to combine eEVN with eMerlin. In the future, ALMA, SKA?

Conclusions

- Real-time eVLBI is about to come of age and to become an EVN mode of operation
- Additional effort and investments will lead to higher data rates involving more telescopes
- Future technological developments are bound to result in an explosive growth of bandwidth, making 1Gbps real-time correlation a realistic goal, and we should look forward to multi-Gbps correlation
- eEVN, possibly through a lambda-switched network, is a logical next step

A matter of spelling?

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eVLBI e-VLBI *e*-VLBI ***EVILb***