International Lightpath Experiences

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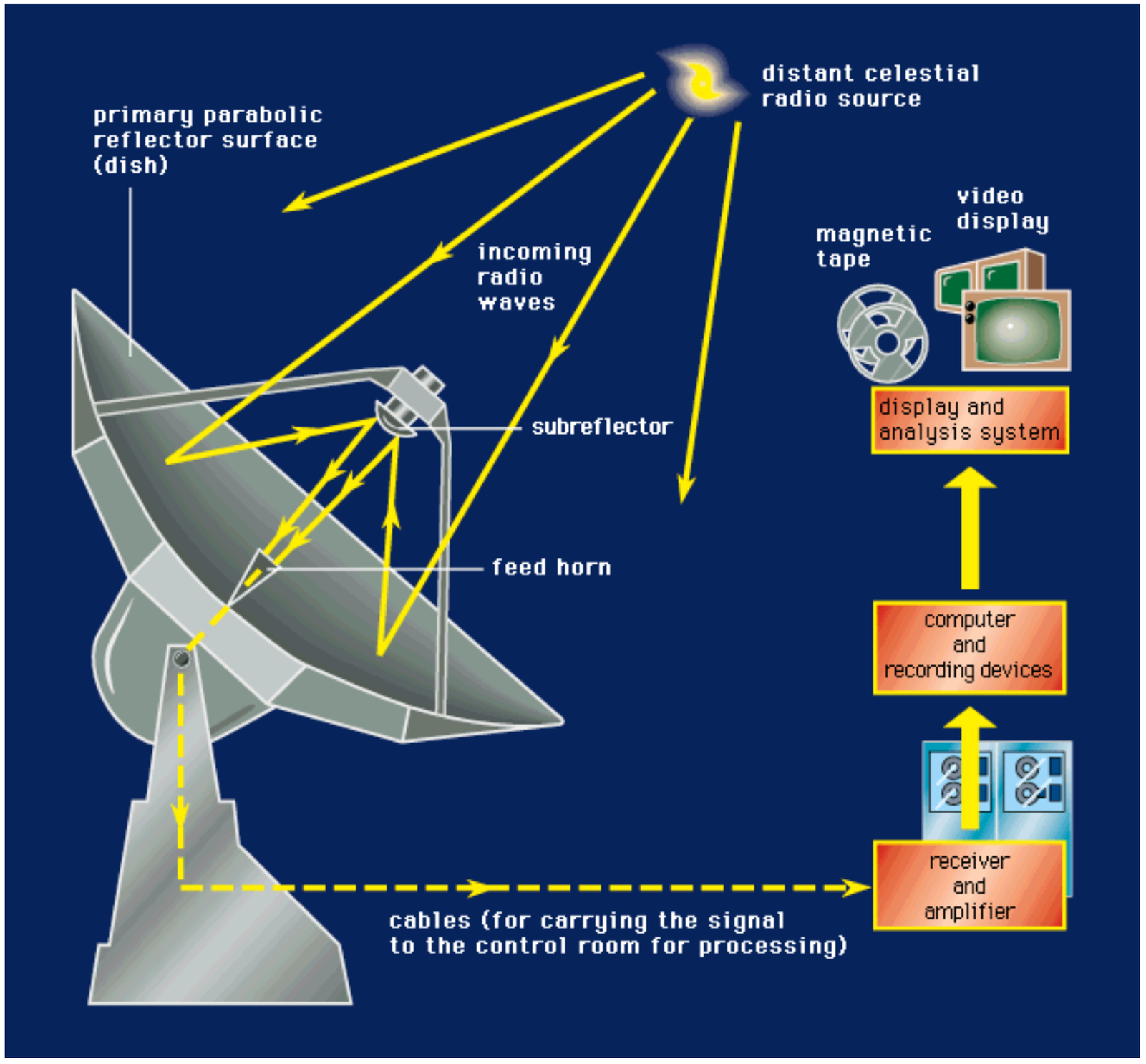
Network status as per 2008-05-02. Image created by Paul Boven <boven@jive.nl>. Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

Radio Astronomy



Courtesy of NRAO

Radio vs. Optical astronomy

The imaging accuracy (resolution) of a telescope related to its wavelength and diameter: $\theta \approx \lambda/D$

Hubble Space Telescope:

$\lambda \approx 600nm$ (visible light)

$D = 2.4m$

$\theta = 0.1$ arcsecond

Onsola Space Observatory:

$\lambda = 6cm$ (5GHz)

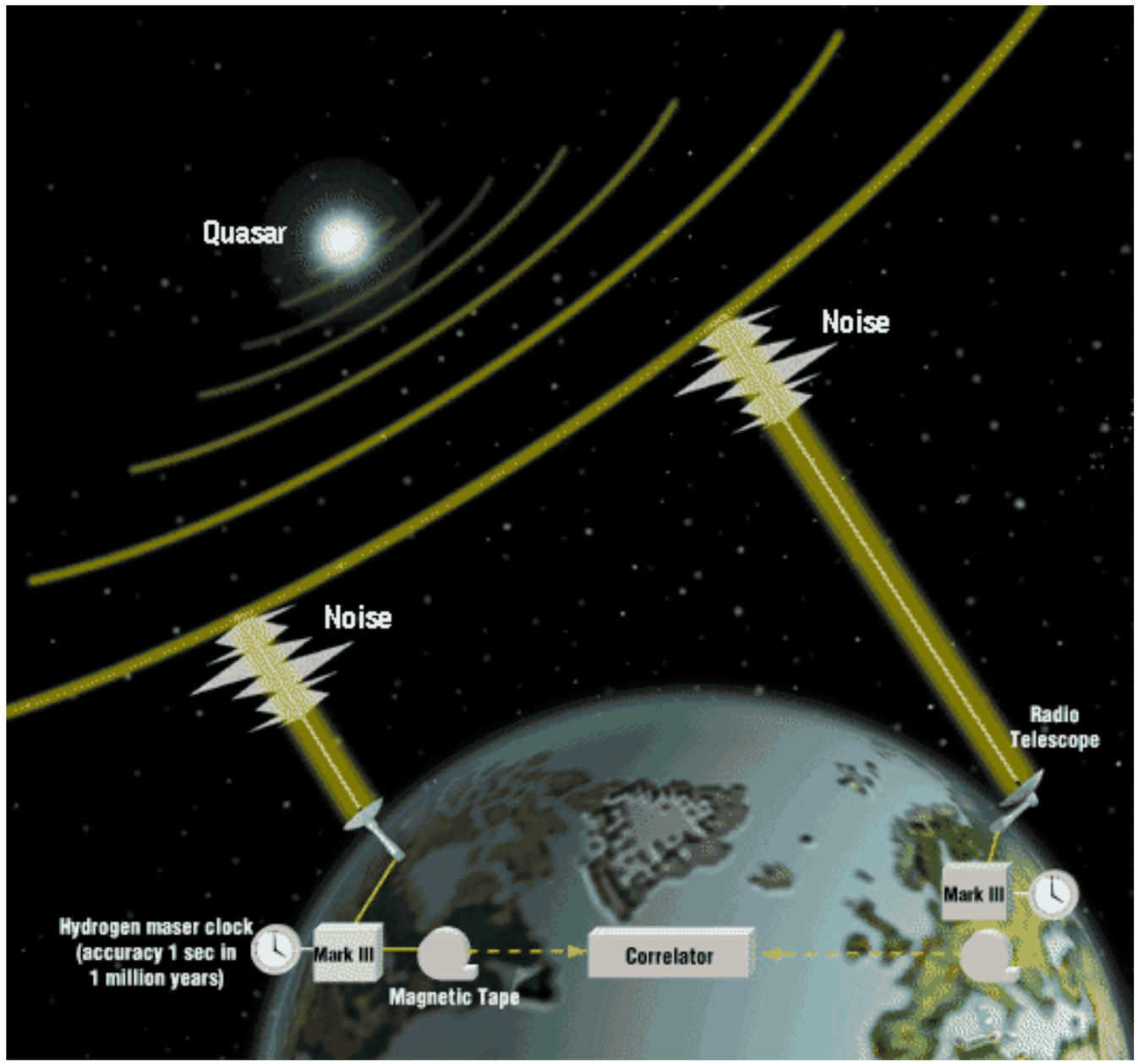
$D = 25m$

$\theta = 600$ arcseconds

Moon: 3x3 pixels

Very Long Baseline Interferometry

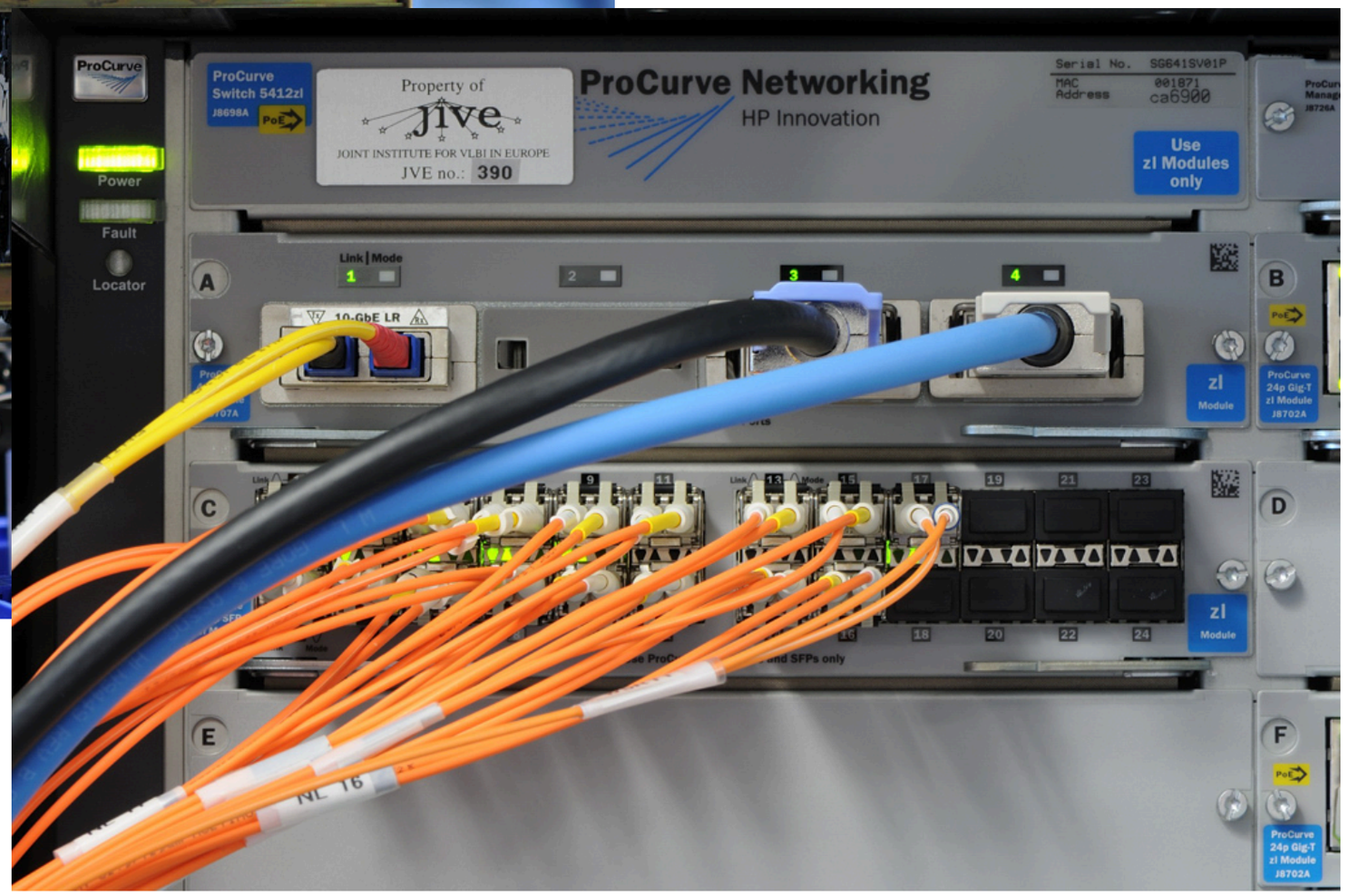
- Create a huge radio telescope by using telescopes in different locations around the world at the same time
- Resolution depends on distance between dishes, milli-arc second level
- Sensitivity on dish area, time and bandwidth
- Requires atomic clock stability for timing
- Processed in a special purpose super-computer: Correlator, 16x 1024Mb/s



Very Long Baseline Interferometry

- Initially (1990) we used large single-reel tapes

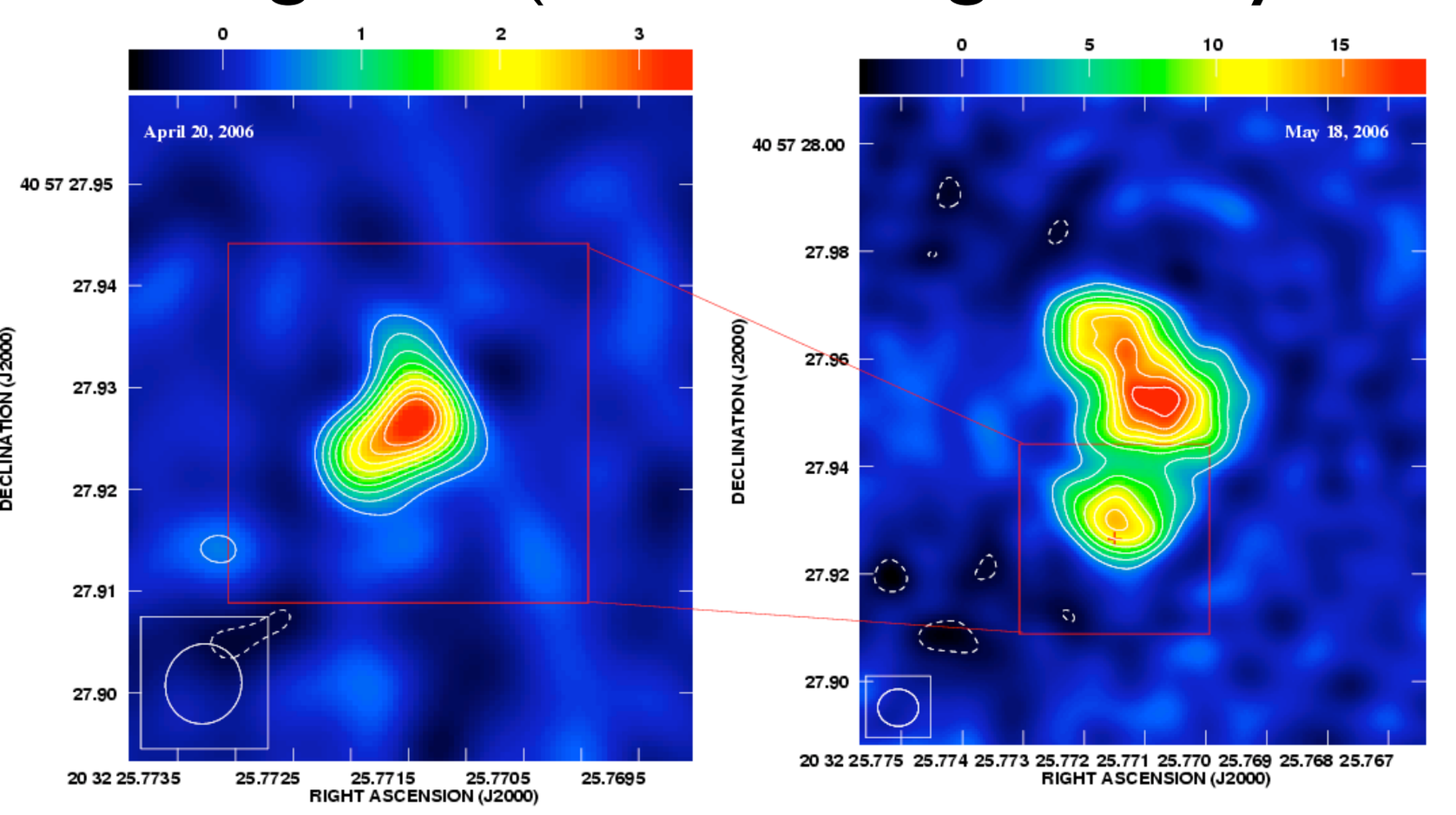
- Then came harddisk-packs



- And now: e-VLBI

Why e-VLBI

- Quick turn-around
- Rapid response
- Check data as it comes in, not weeks later
  (You can't redo just 1 telescope)
- More bandwidth
- Logistics (disks damaged/delayed/deleted...)

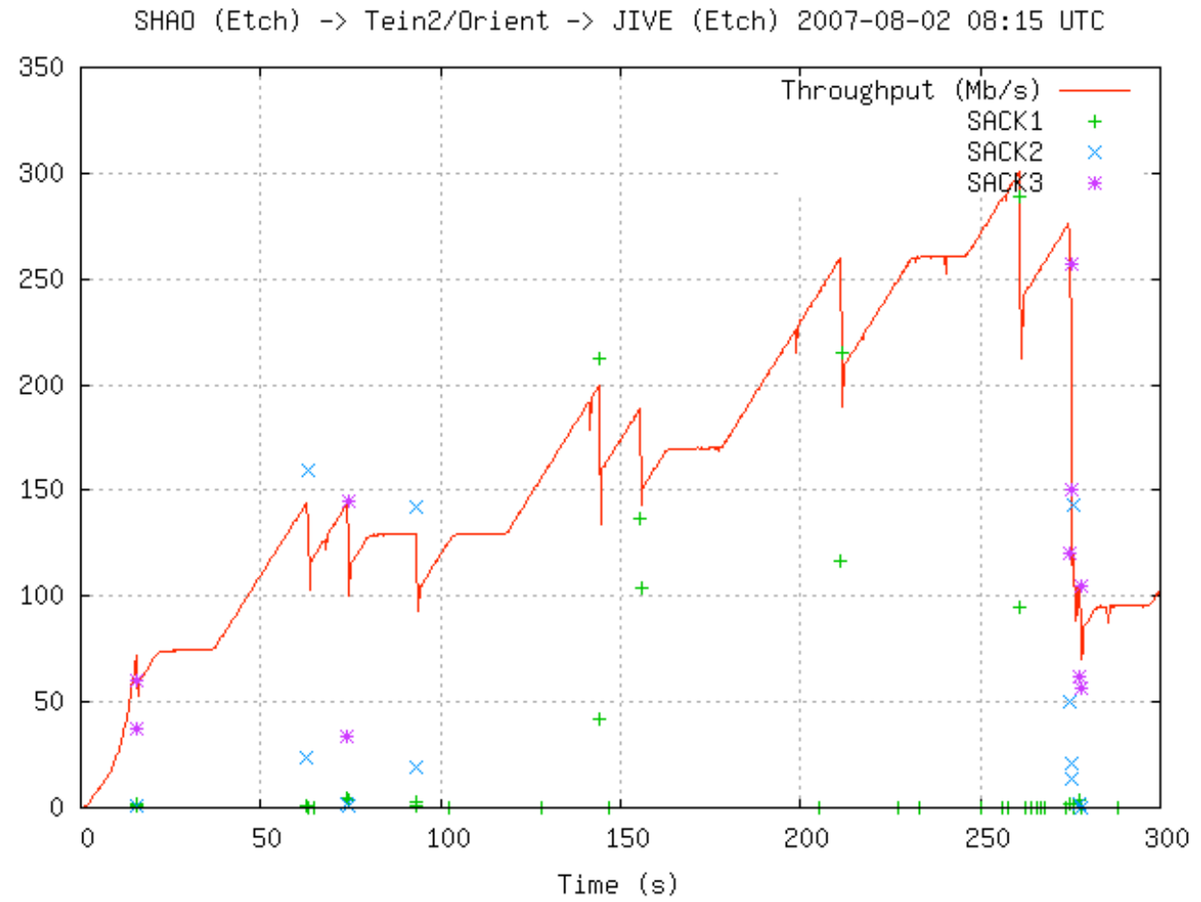


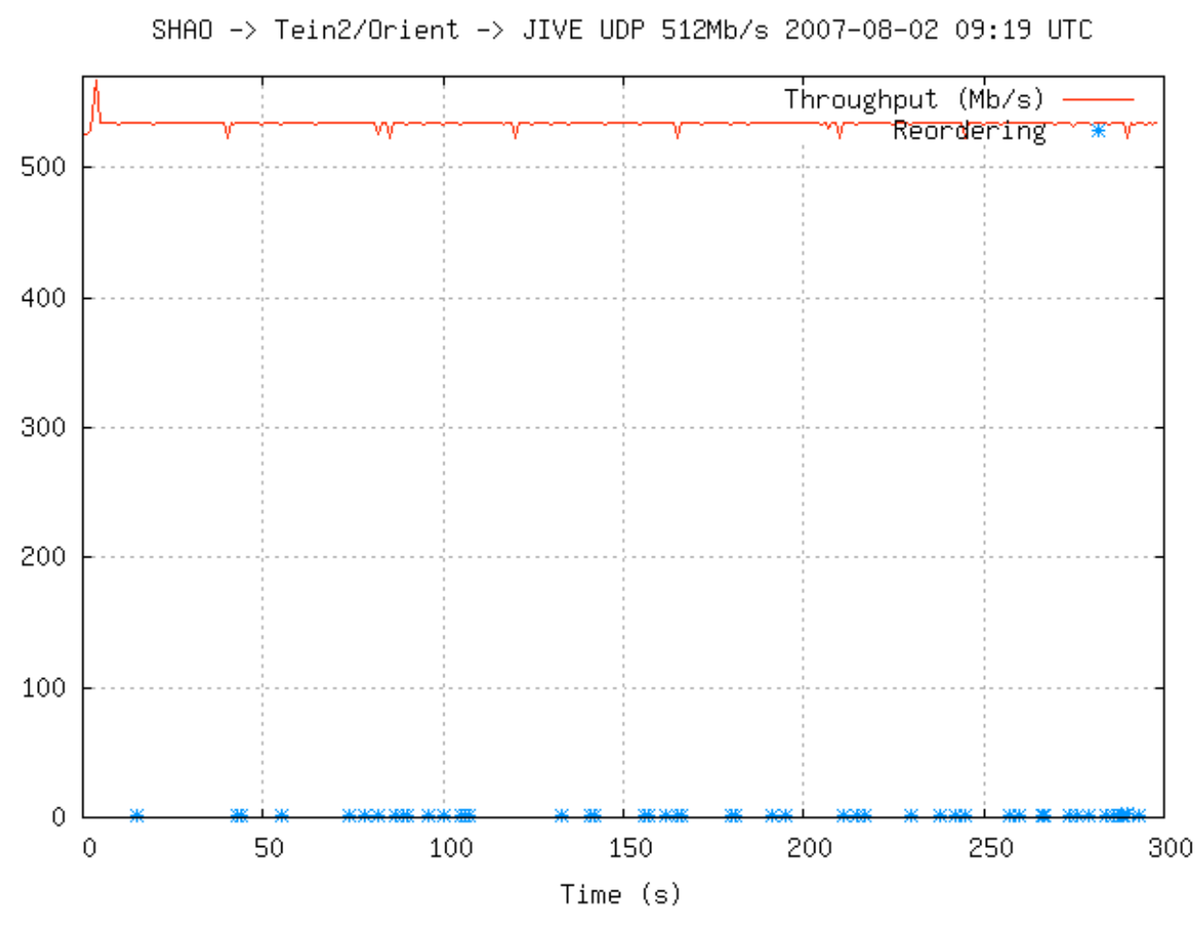
Example: CygX-3

- Star + black hole
- Flares irregularly
- Timescale: days
- Left: 2 weeks late
- May: Observed flare with e-VLBI

TCP Research

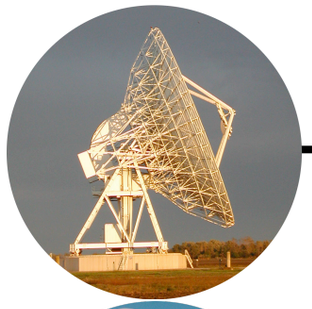
- Mirror port (span)
- eVLBI: RTT up to 354ms
- Window Size (kernel vers.)
- SACK-bugs
- Tuning defeats fairness
- Conclusion:
  - UDP
  - Lightpath connections





Network Overview





Telescope	Bandwidth	RTT
Sheshan	512 + 622 LP	180ms / 354ms
ATNF (2x)	2x 1Gb/s LP	343ms
Arecibo	512Mb/s VLAN*	154ms
TIGO	95Mb/s*	150ms
Medicina	1Gb/s LP	29.7ms
Onsala	1.5Gb/s VLAN	34.2ms
Torun	1Gb/s LP	34.9ms
Jodrell Bank	2x 1Gb/s LP	18.6ms
WSRT	2x1Gb/s CWDM	0.57ms
Effelsberg	10 Gb/s VLAN	13.5ms





The current e-VLBI network

Connected stations and other EVN members

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Network status as per 2008-03-31. Image created by Paul Boven <boven@jive.nl>. Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

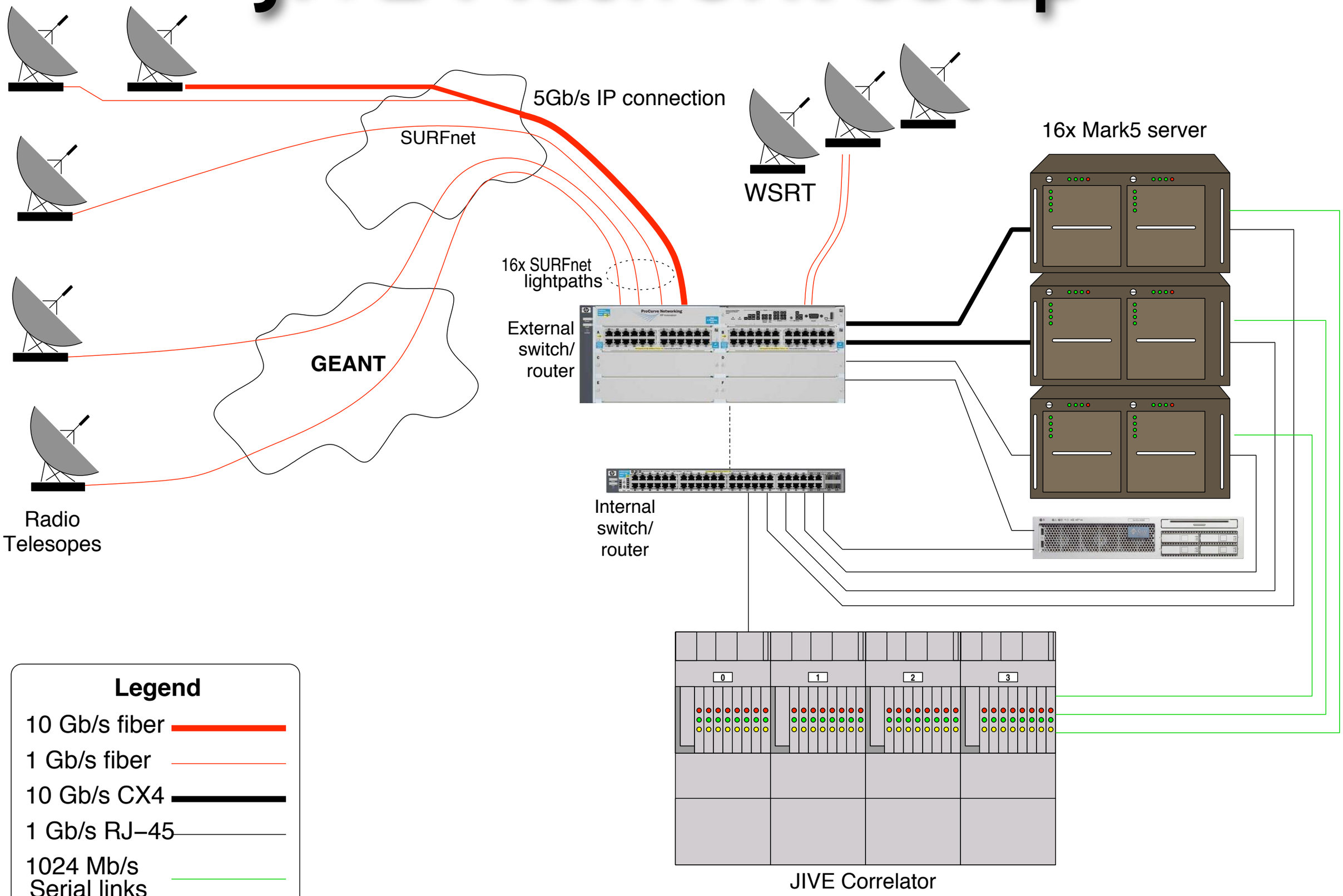
Our ‘last mile problem’...

... is usually more like 25 miles.

Radio telescopes are located in ‘uninhabited’ places.

A number of European telescopes do not have a connection yet.

JIVE Network Setup

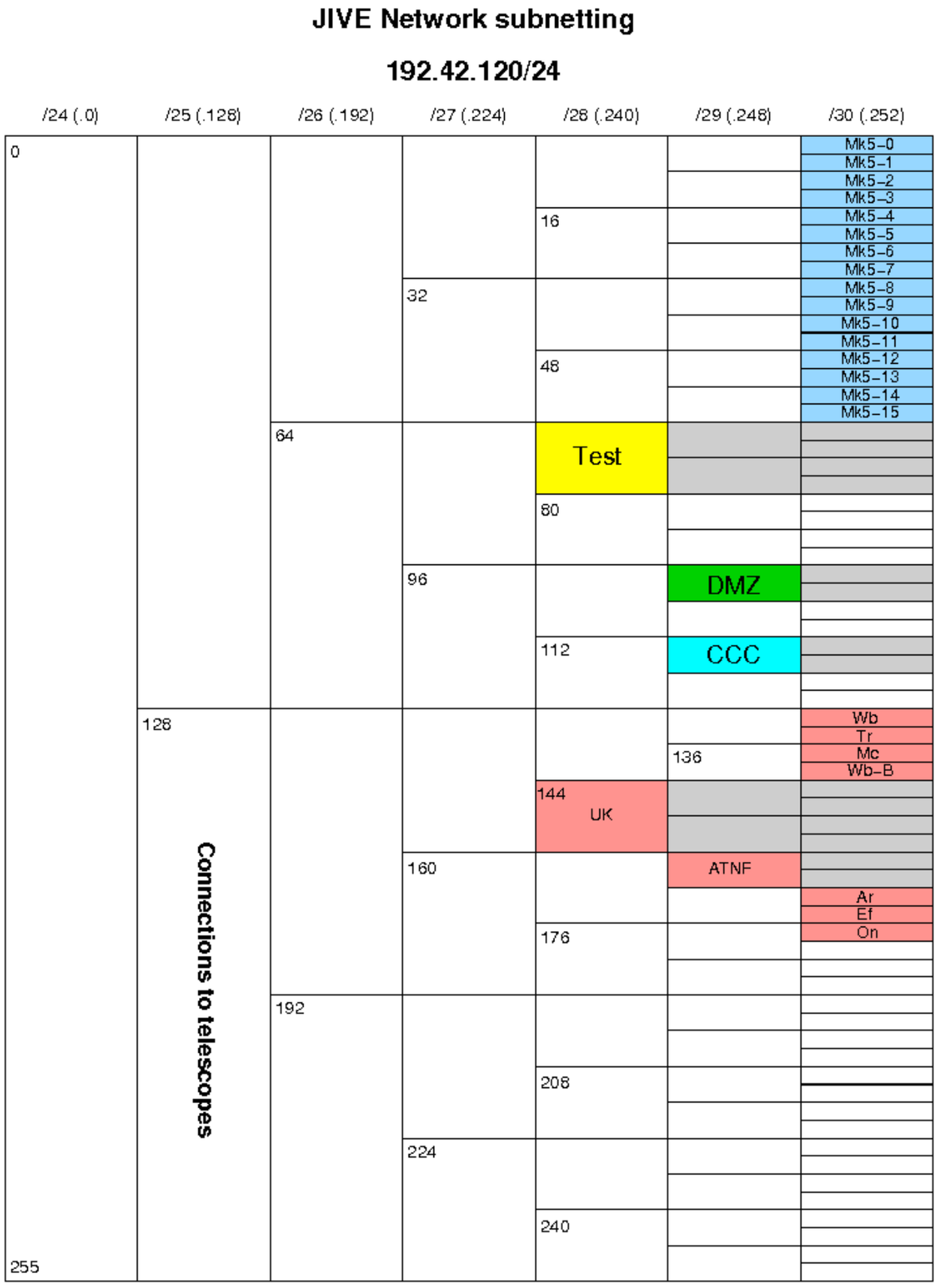


Legend

- 10 Gb/s fiber
- 1 Gb/s fiber
- 10 Gb/s CX4
- 1 Gb/s RJ–45
- 1024 Mb/s Serial links

JIVE Network Setup

- A single class C (192.42.120.0/24)
- Top /25: our servers
- Bottom /25: connections for telescopes
- No RFC-1918
- 16 e-VLBI servers each in its own /30

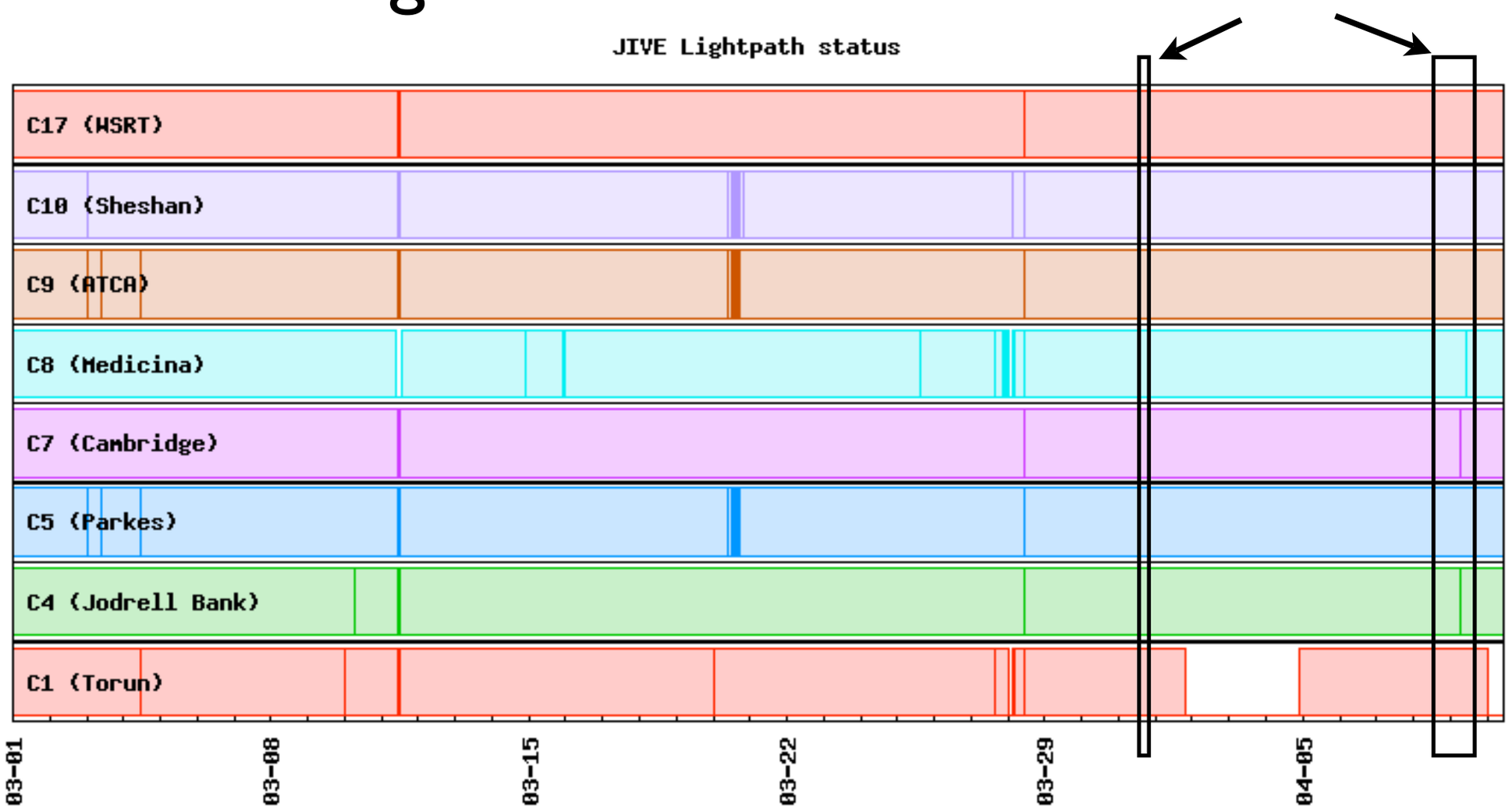


Security

- Lightpaths often bypass firewalls
  - Performance, different administrative domains
- We do not want to be the world's largest 'back-door network'
- Very simple access lists on L3-switch:
  - Telescopes can talk to JIVE servers
  - Can not connect to one another
  - Can not connect to outside world
  - Can not be contacted from outside network.

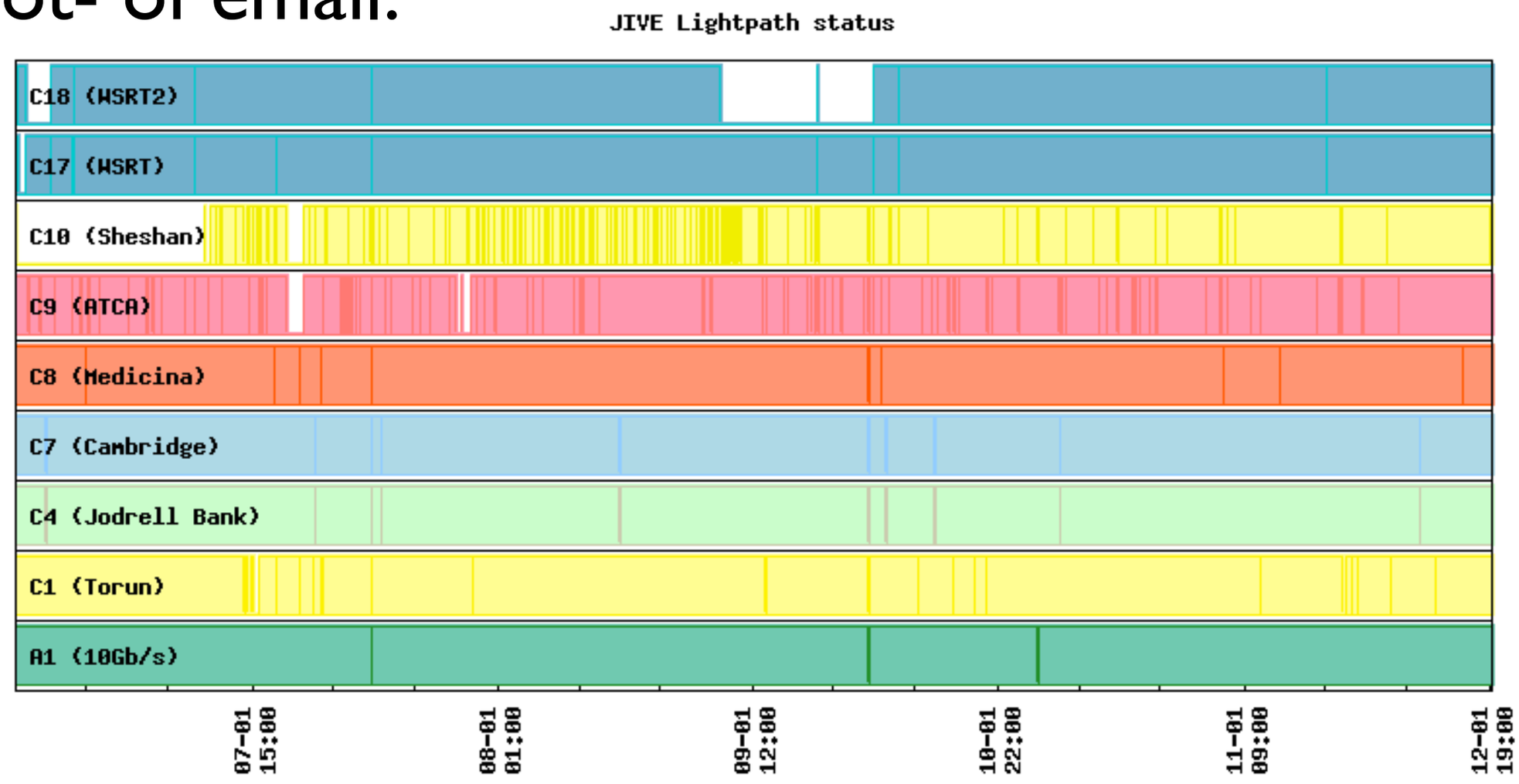
Lightpaths

- Dedicated point-to-point circuit
- Based on SDH/Sonet timeslots (NOT a lambda)
- Stitched together at cross-connects
- Guaranteed bandwidth
- But also: a string of SPFs



Lightpaths

- Especially the longer lightpaths have many outages
- NRENs usually very good about announcing maint.
- A -lot- of email.



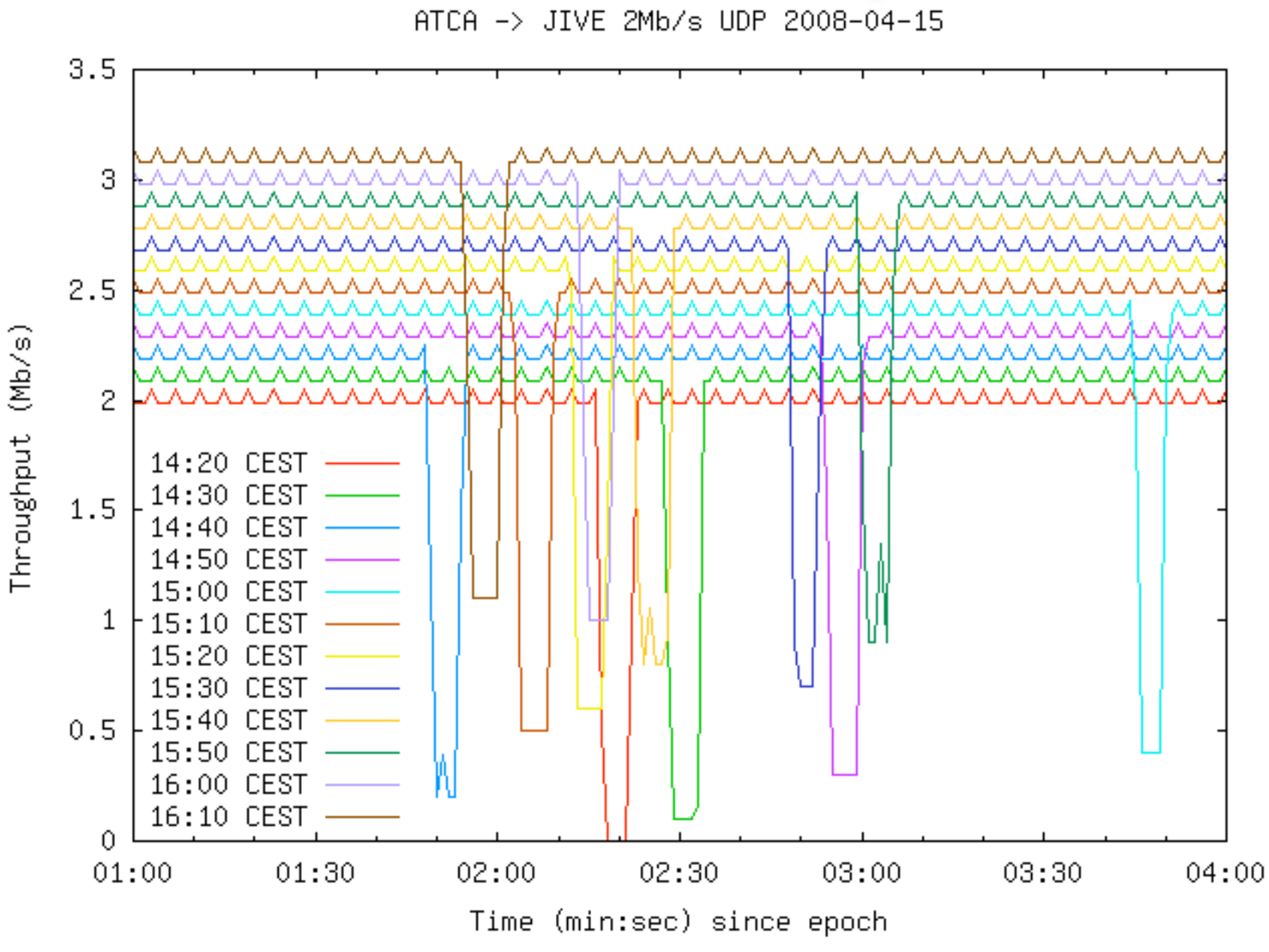
- e-VLBI is becoming a ‘target of opportunity’ instrument, planned and unplanned observations

One-way lightpaths

- Two 1Gb/s lightpaths, but only worked UK → JIVE
- Ethernet level debugging, mirror/span ports
- PTEs from different vendors
- Great support from NRENS
- Set up a ‘detour’/break-out:
  - LP - ethernet - LP
- Used UDP (set our Mac-addr at their switch)
- Observed SN2007gr supernova
- Turned out to be a CRC config mismatch, fixed

The 10 minute LOS

- Initially three LP from ATNF (Australia) to JIVE
- The long way round (via Hawai, Canada) - 343ms
- Every 10 min.: LOS for 4 seconds, 2 minutes past
- OZ: Far-End alarm
- JIVE: path stays up (but 4s no data)
- Every sub-part of the ligthpath works
- Ethernet break-out at Canarie: lightpath works



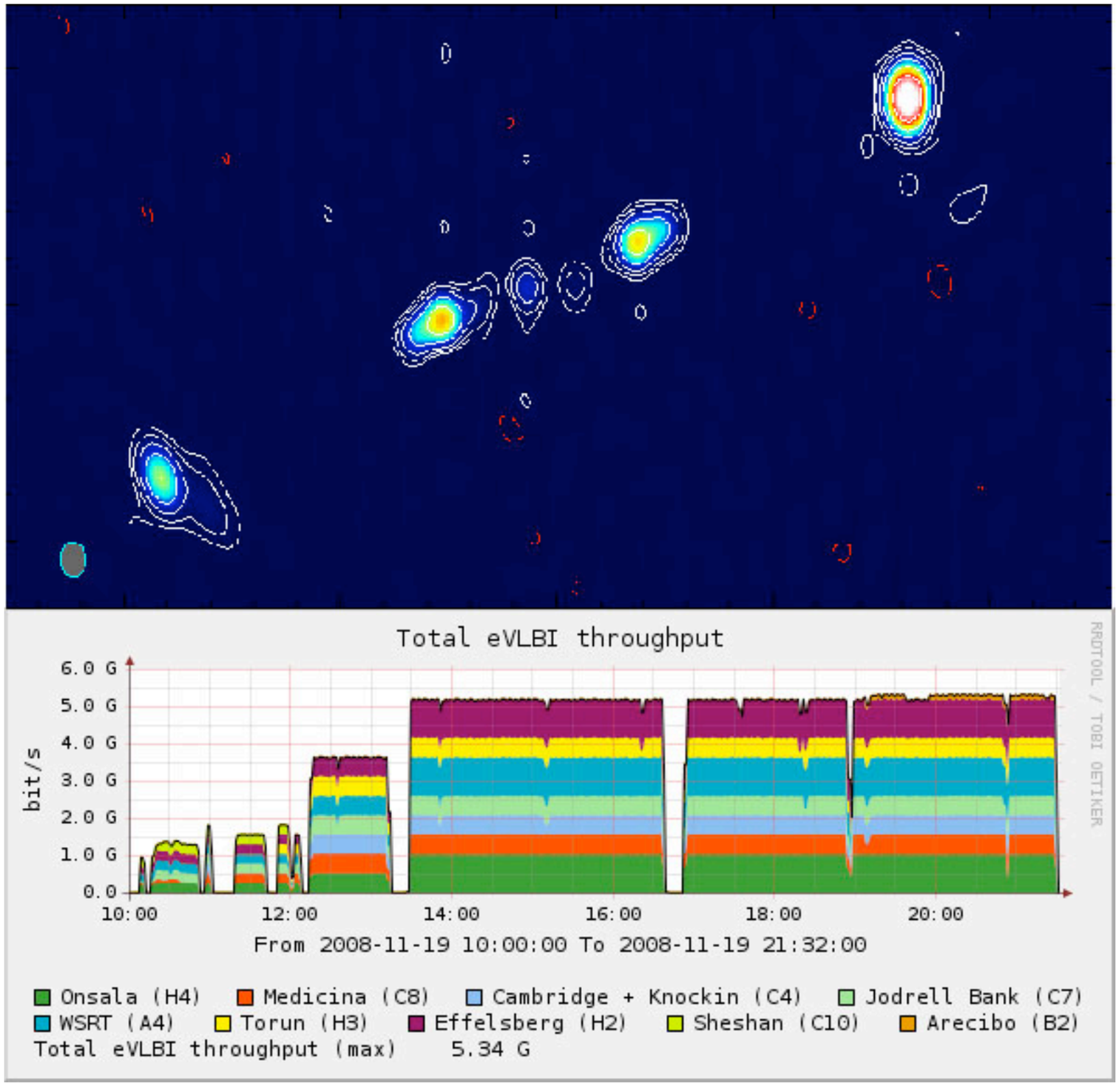
Debugging VLANs/Lightpaths

- Step one: figure out exact topology
- Traceroute is of very little use
- Check ARP tables at endpoints
- Mirror / Span ports, tcpdump, CDP broadcasts
- VLAN: pick some RFC-1918 space,
  assign IP to every switch, see who you can ping
- Check MTU at every hop (we need Jumbos!)
- Lightpaths: create a lot of traffic (e.g. CBR UDP)
  - Check interface counters/graphs (5 min RRD ☹)
  - Make ‘breakouts’ or ‘loopbacks’

Finally

- e-VLBI:
  - Research subject
  - Astronomical instrument
- Requires a broad mix of networking technologies:

Lightpaths, VLANs, routing, CWDM, bonding, multicast, 1GE and 10GE, ...



2008-11-19: First use of 1024Mb/s in science observation

Even more finally

- This week, 4/5 december: full 24 hour observation, 3 science projects, European telescopes + Sheshan

- Opening International Year of Astronomy 15/16 january 2009
- Many outreach/educational activities
- Global e-VLBI observation