

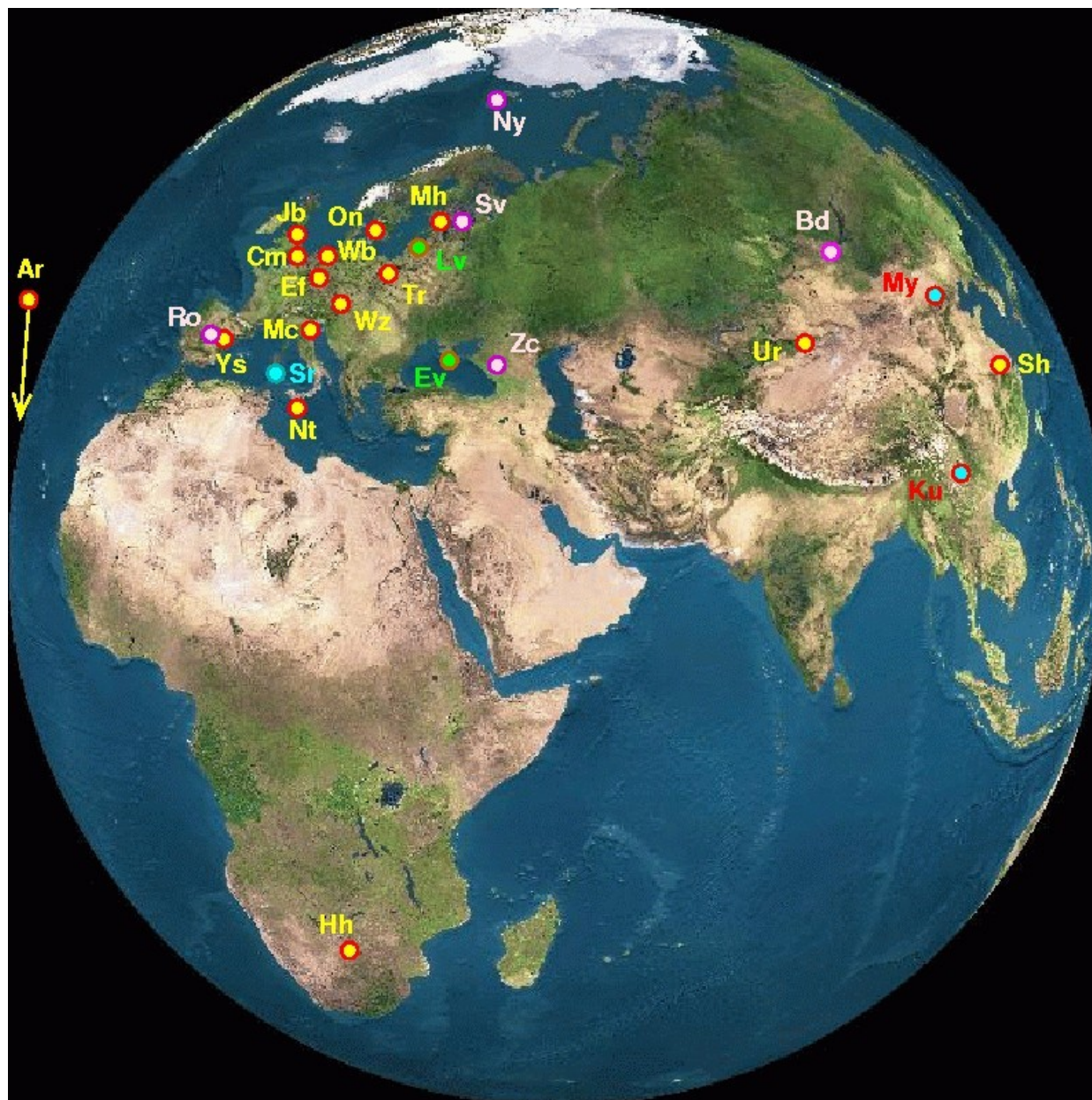
e-VLBI & Other Developments at the EVN MkIV Data Processor at JIVE

Bob Campbell & Arpad Szomoru, JIVE

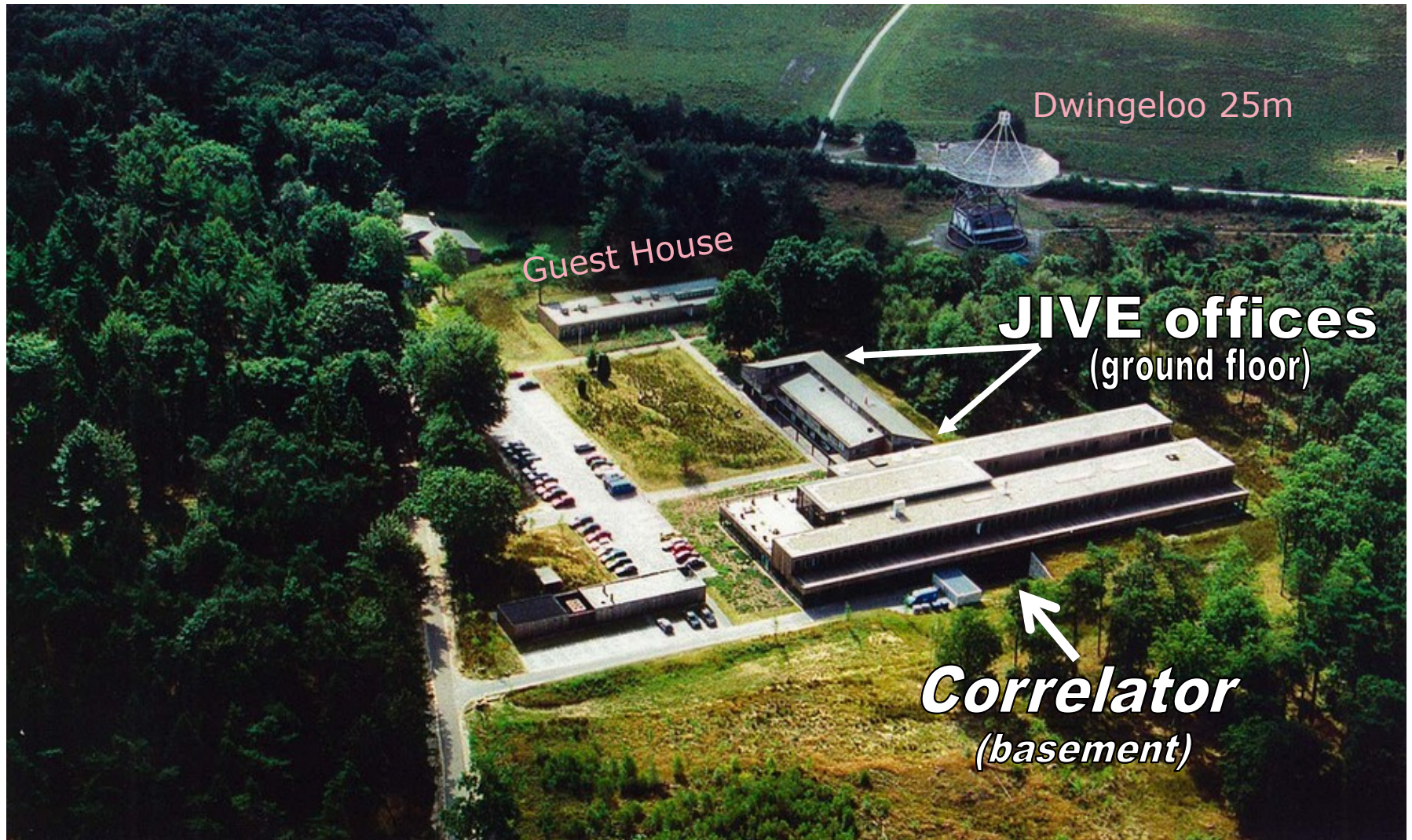
- EVN (astronomical) Correlation
 - Astronomical Capabilities
 - Input/Output Capacities
 - New Stations
- Real-time e-VLBI
 - Chronology & Connectivity
 - **EXPR**eS & Operational (astronomical) e-VLBI
- Software Correlation at JIVE

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JIVE in Dwingeloo



Specific Correlator Capabilities

- ❑ 16 station, 32 GHz clock rate
- ❑ Full Stokes polarization output
- ❑ 1-, 2-bit sampling (include VLBA's @ 512Mbps in Gbps obs)
- ❑ Up to 2048 frequency points per SB/pol
- ❑ Full-correlator $t_{\text{int}} \geq \frac{1}{4}$ sec (half-corr $t_{\text{int}} \geq 1/8$ sec)
- ❑ Total observed rates up to 1Gbps
- ❑ Oversampling (2, 4x Nyquist \rightarrow 500kHz filters)
- ❑ 5A, 5B playback (currently through 5A+ firmware)
- ❑ Real-time e-VLBI operation
- ❑ Recirculation (time-sharing correlator in low-BW obs)

Correlator Capacity (Spectral Resolution)

$$N_{sta}^2 \cdot N_{sb} \cdot N_{pol} \cdot N_{frq} \leq 131072 \cdot R$$

$$N_{sta} = (4, 8, 12, 16); \quad N_{pol} = (1, 2, 4); \quad N_{chan} \leq 16; \quad N_{frqmax} = 2048$$

Recirculation: $R \leq 16 \text{ MHz/BW}_{sb}$; N_{frqmax} still 2048

Exmpls:

5—8 Sta	1 SB	1 Pol	2048 Frq
9—16 Sta	1 SB	1 Pol	512 Frq
9—16 Sta	1 SB	2 Pol	2048 Frq
9—16 Sta	8 SB	4 Pol	16 Frq

$R=8$ ($\text{BW}_{sb}=2\text{MHz}$)

Maximal Spectral Resolution ($N_{frq}=2048$)

BW_{sb} [MHz]	Δv [Hz]	Δv_{1420}	Δv_{1665}	Δv_{6668}	Δv_{22235}
16	7813	1651	1408	351	105
2	977	206	176	44	13
0.5	244	52	44	11	3.3

Correlator Output Capacity

Raw output (local validity):

- lag-space correlation functions (32 kB/brd) + headers (16 kB/brd)
- Full-correlator min. $t_{\text{int}} = 1/4$ sec (half-corr. min. $t_{\text{int}} = 1/8$ sec)
 - Max. operational output rate = 6 MB/s

Approximate FITS file growth rate:

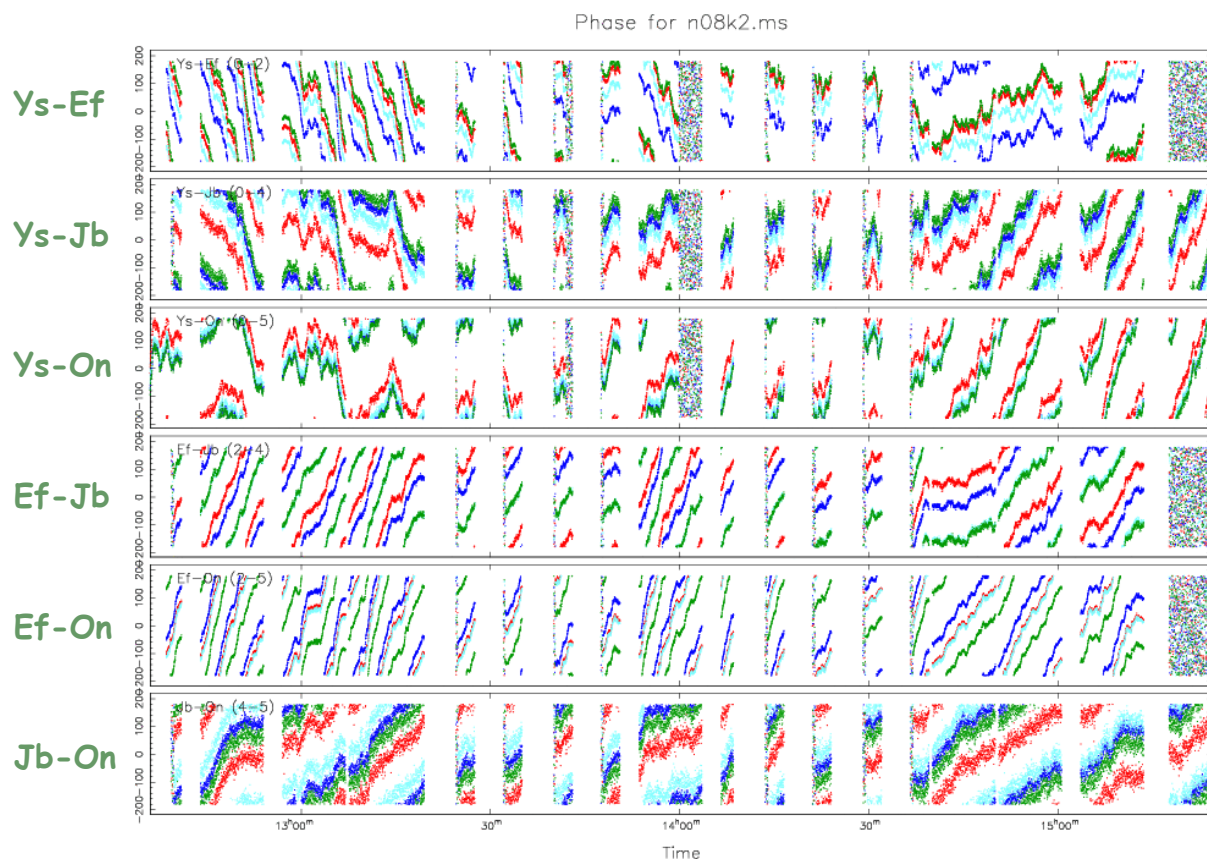
- $1.75 \kappa f / t_{\text{int}}$ GB per hour of observation
 - $\kappa \approx 1\text{--}1.7$ (fudge-factor for "efficiency" of FITS storage)
 - f = fraction of correlator used
- Record for a single experiment: 1028.7 GB

Recirculation: min. $t_{\text{int}} \longrightarrow (\text{min. } t_{\text{int}}) \cdot R$

New Stations: Yebees 40m



Phs(t) for 4C39.25 in Jun'08
K-band NME {Ys,Ef,Jb,On}



Oct'08: X-band; Mar'09: 5cm

New Stations (to EVN): KVASAR



Phs(t) for phs.ref sources in L-band
EK028C (Oct'08) {Sv, Zc, Bd, Ef}

Phase for ek028c.ms

Sv-Zc

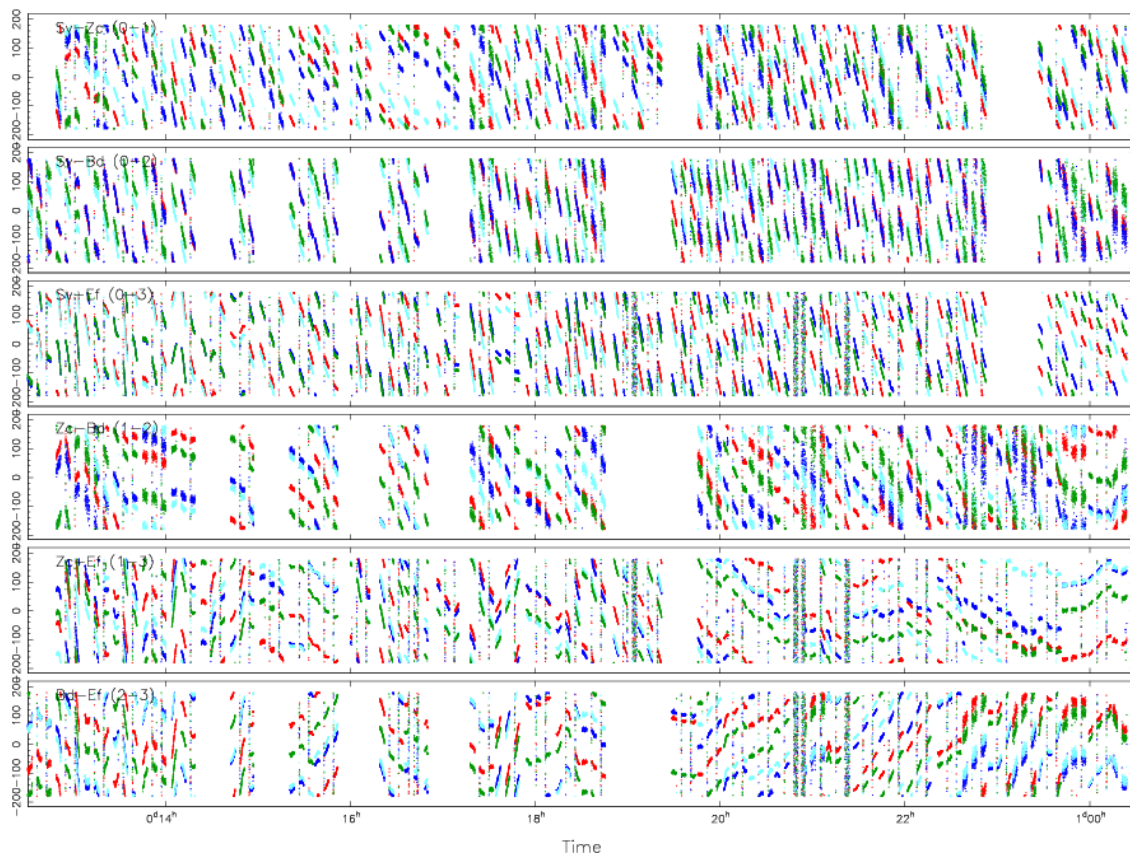
Sv-Bd

Sv-Ef

Zc-Bd

Zc-Ef

Bd-Ef



Further Oct'08 EVN obs at S/X, C bands

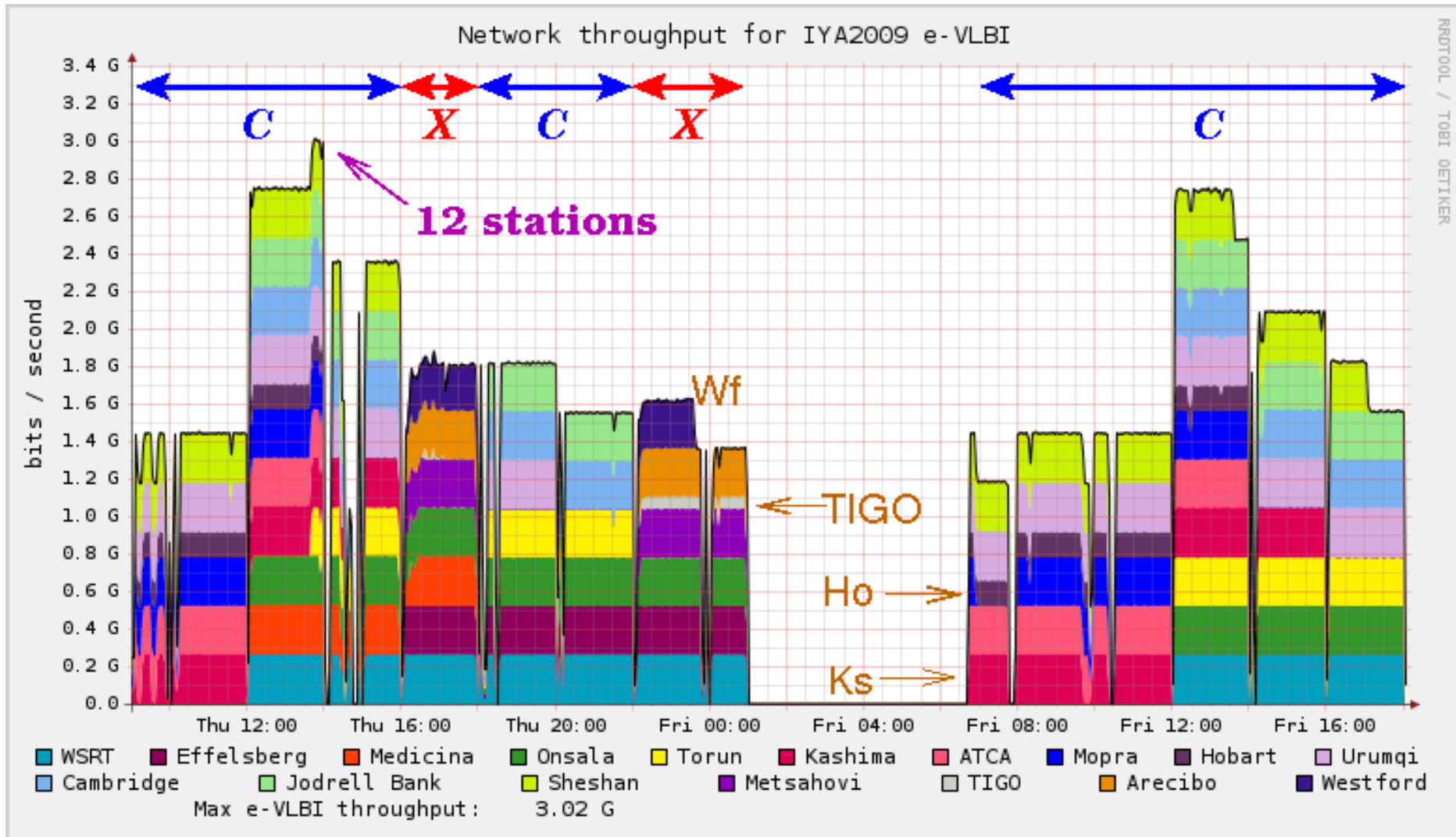
Real-time e-VLBI Chronology (I)

- 20apr06: 1st successful scheduled e-science run
16hr at 128 Mbps to 6 stations
-
- 25jun07: 4hr of 512Mbps from 6 stations
- 28aug07: Demo at 24th APAN conference (Xi'an)
 - 256Mbps on Sh-Mp, Sh—{Jb,Da,Mc,Tr,Wb}
 - ~10 minutes of Mp-Da fringes (longest RTe-|B|(?) 12304km)
- 8oct07: Pa-Mp-At at 512Mbps sustained for >12hr
- 24jan08: 978Mbps for >3hr from {Mc,On,Tr}
 - Packet dropping (4.5%) while headers remain intact
- 5feb08: Ar at 128 Mbps (155 Mbps to mainland)
- 8apr08: e-science runs at 512 Mbps from here on

Real-time e-VLBI Chronology (II)

- 5-9may08: Hh at 64 Mbps (128 Mbps briefly); Hh-Ar fringes
Tc-Ar fringes at 32 & 64 Mbps
- 21may08: 1st Ef participation in e-science observations
- 22may08: Demo at TERENA Networking conference (Bruges)
 - Mc, On, Wb, Ef, Ar (256Mbps), Hh, TIGO (On-Tc ~ 10840 km)
- 22jul08: Multiple MERLIN out-station multi-casting
- 9sep08: Ar at 512 Mbps (early AM local time)
- 13nov08: Ef, Wb, Mc, On, Tr, Jb, Cm, Kn, Sh @512; Ar @ 128
- 19nov08: Gbps without dropping packets {Wb, On, Ef}
- 4dec08: IYoA prep: At, Mp, Ks, Sh, Ur, Wf @256; Ho @ 128
- Very, very soon: Yebes 40m in tonight's e-science observations

Throughput Graphs



Int'l Year of Astronomy Opening Ceremony: 15jan09

(Tested) Network Overview

Station	Connection
Westerbork	1 Gbps dark fibre
Jodrell Bank	2x 1 Gbps LP
Medicina	1 Gbps LP
Onsala	10 Gbps VLAN
Torun	1 Gbps LP
Effelsberg	10 Gbps VLAN
Sheshan	622 Mbps LP (<i>via</i> HK)
Arecibo	128 Mbps (512 early AM)
Metsahovi	10 Gbps
Urumqi	256 Mbps (<i>via</i> Sh/HK)
Yebes	1 Gbps

Station	Connection
ATNF	2x 1Gbps LP (At,Mp,Pa)
Hobart	128 Mbps (Tas->Aus)
TIGO	64 Mbps
Kashima	256 Mbps (1Gbps)
Westford	256 Mbps (1Gbps)
Hart	64—128 Mbps

Yet to come: Sardinia,
Miyun, Kunming, Noto,
Irbene,...

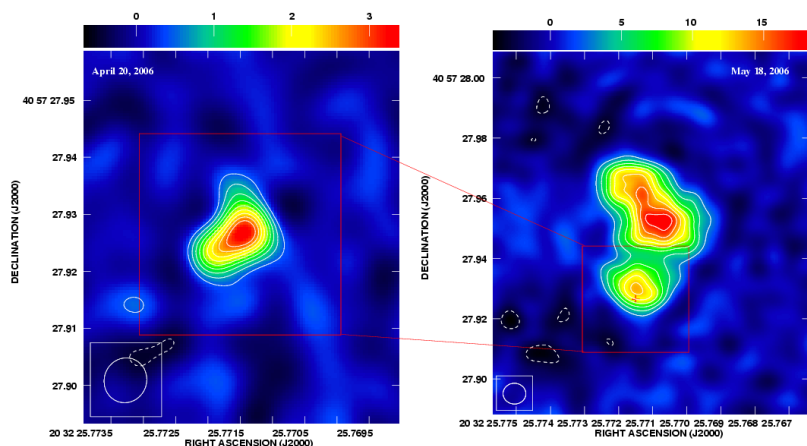
Real-time e-VLBI Science (I)

- Proposal-driven e-VLBI science observations
 - 1st observation = 20 Apr 2006 (6 stations at 128 Mbps)
 - 38 observations to date; 27 since the 18th WMEVGA (Vienna)
 - 18 different PIs
- Topics (rapid turn-around; urgency; denser time-sampling):
 - X-ray binaries in flaring states
 - GRBs or other transients detected in γ -ray/X-ray observations
 - Binary stars at specific orbital phases
 - Just-exploded supernovae
 - Monitoring SNe population/birth in starburst galaxies
 - OH/IR star astrometry
 - Gravitational lenses // AGN in a sub-mm galaxy?
 - Seeking IMBH in ULX source via compact radio emission
 - Check candidate reference sources prior to phs-ref obs.

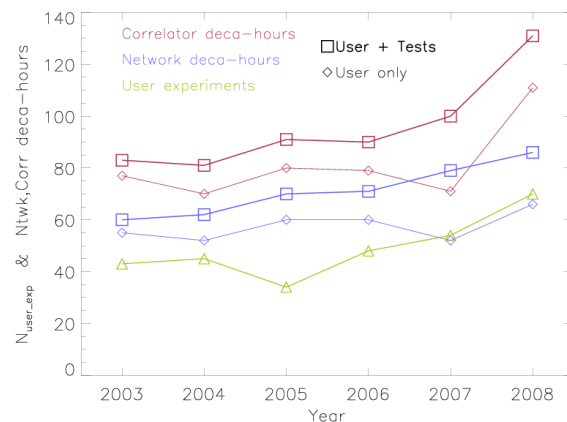
Real-time e-VLBI Science (II)

□ Evolution of e-VLBI procedures

- Currently run on fixed dates (fit other station commitments)
 - Working towards more flexible scheduling
- Proposals originally due 2-weeks prior to each e-date
 - Now within standard proposal submission cycles
 - Proposal Class for “triggered” observations
- Target of Opportunity Proposals
 - in 2008: 4 e-EVN, 3 disk-EVN ToO observations
- Working towards dynamic control of schedules being observed



**e-EVN
maps of
Cyg X-3:
before
& after
outburst**

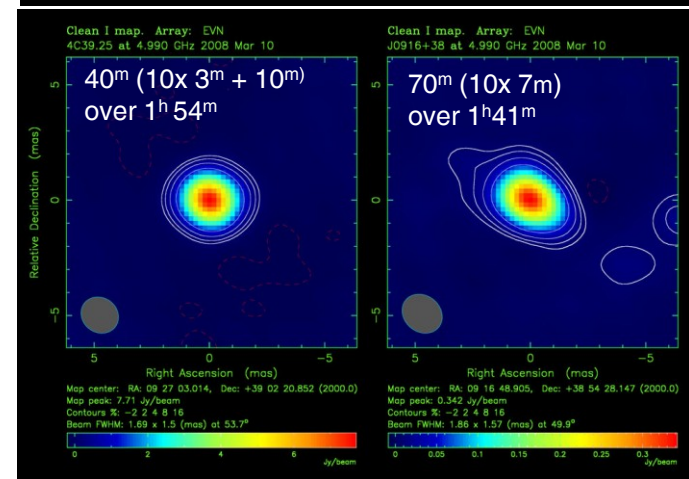
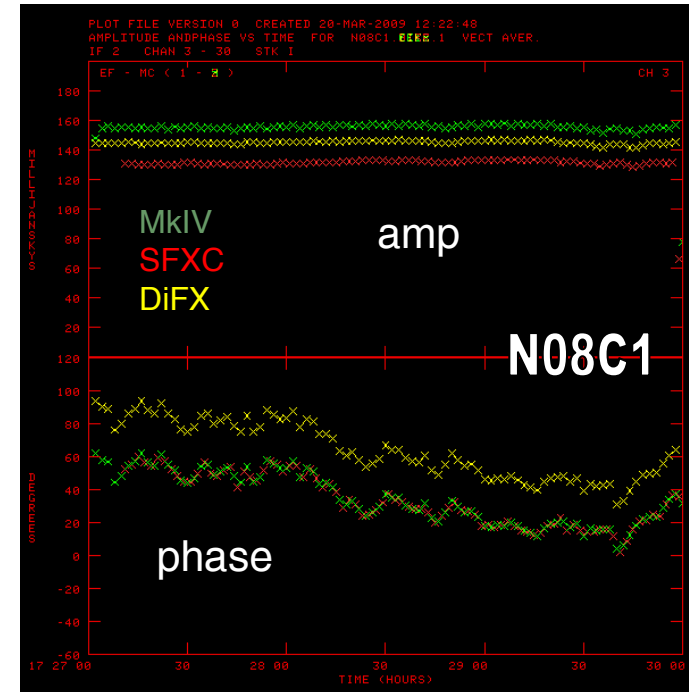
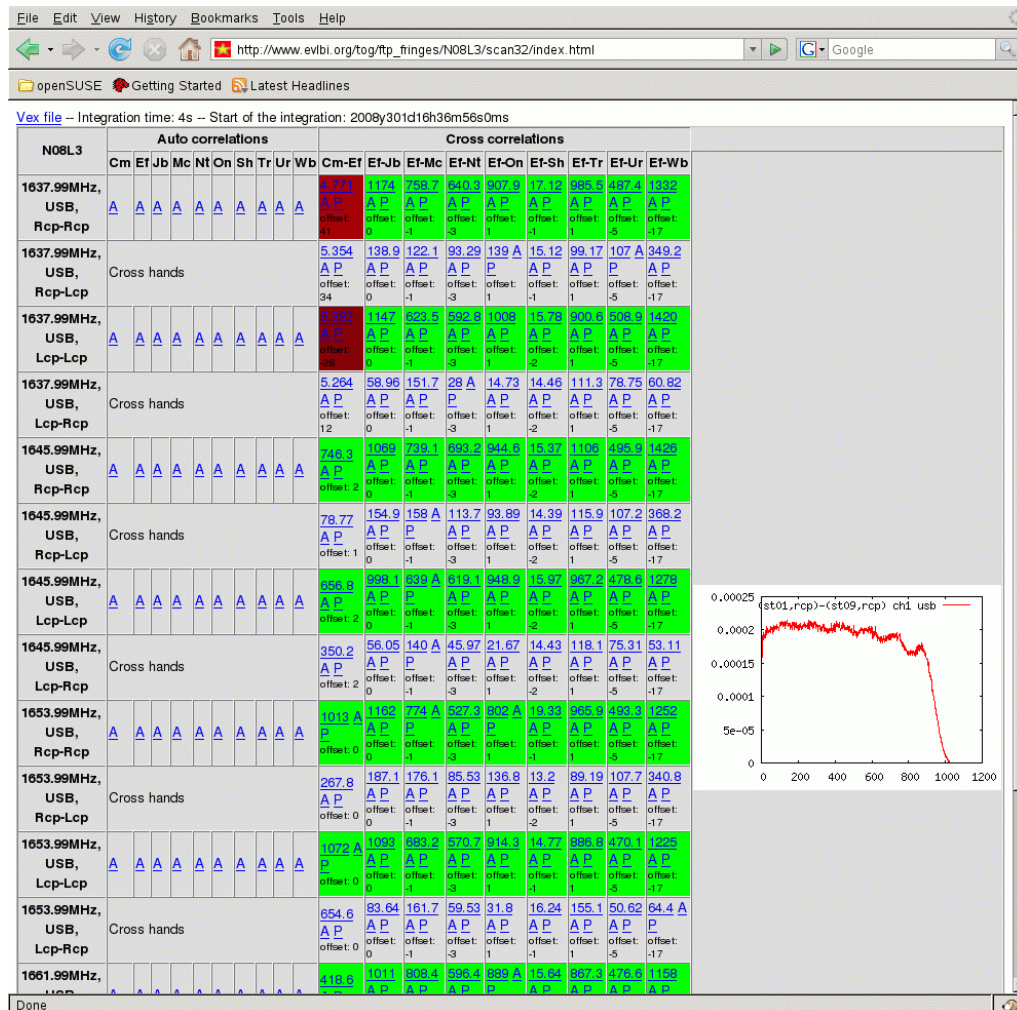


Software Correlation at JIVE

- SFXC (based on correlator for tracking Huygens descent*)
 - VEX-driven + simple config. file with correlation parameters
 - Conversion into IDI-FITS in place
 - Phases match EVN MkIV correlator (better SNR than 5A)
 - Speed comparable with DiFX
 - **ftp fringe-tests in NMEs since 2007**
- FABRIC: "gridification" in progress (w/ Poznań)
- SCARIE (with UvA [Amsterdam], SARA)
 - Integration into GÉANT AutoBAHN BW-on-demand (e-delivery)
 - Integration with Internet2, on 60-node cluster at UvA

* www.jive.nl/docs/resnotes/resnotes.html (all 3 listed)

Software Correlation at JIVE (pix)



ftp fringe-test results web interface

Network for IYA Opening Ceremony



Networks and telescopes used for IYA2009 24hr e-VLBI. Image by Paul Boven <boven@jive.nl>. Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

www.evlbi.org

www.jive.nl

www.expres-eu.org