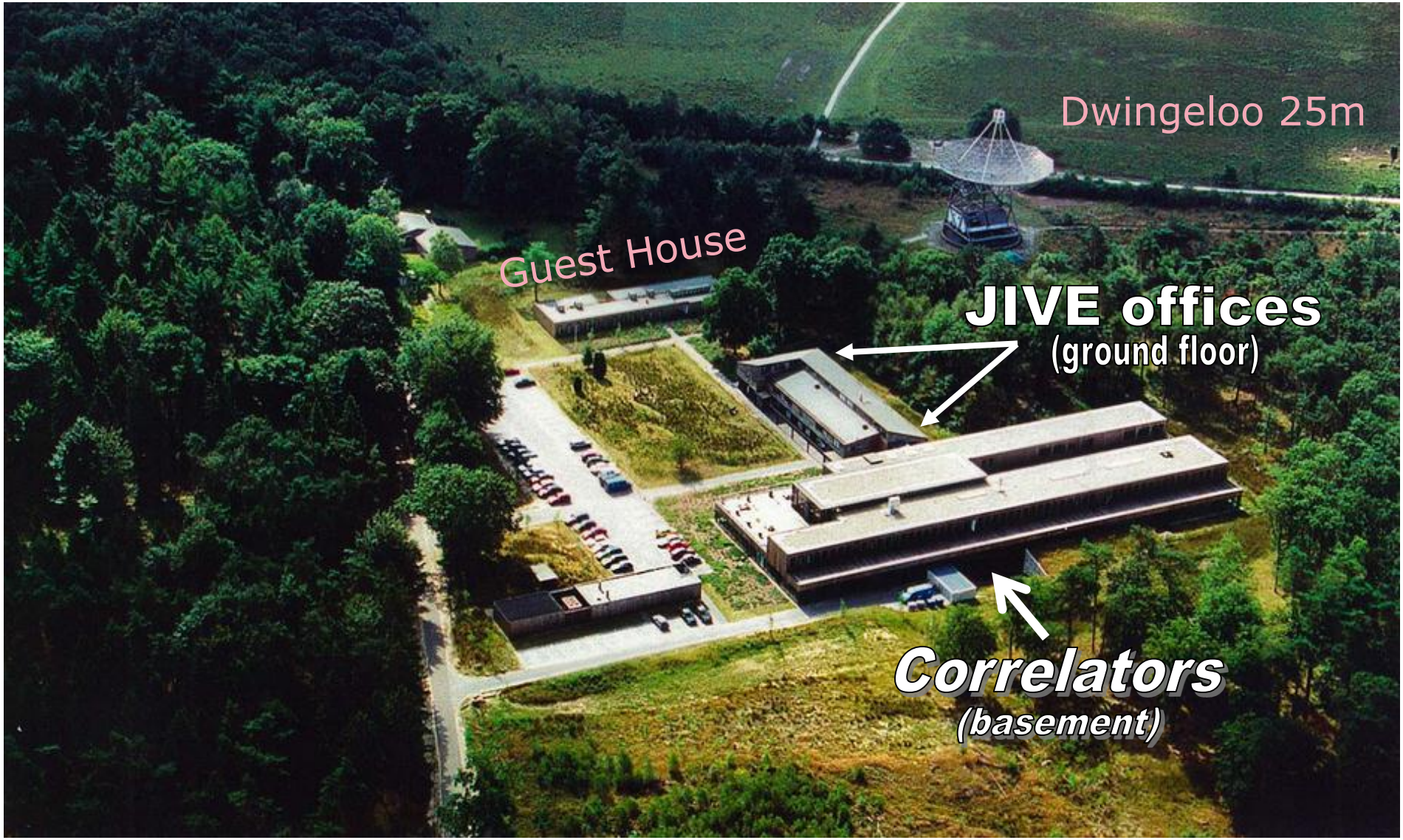
Real-time e-VLBI in the EVN & Software Correlation at JIVE

Bob Campbell & Arpad Szomoru, JIVE

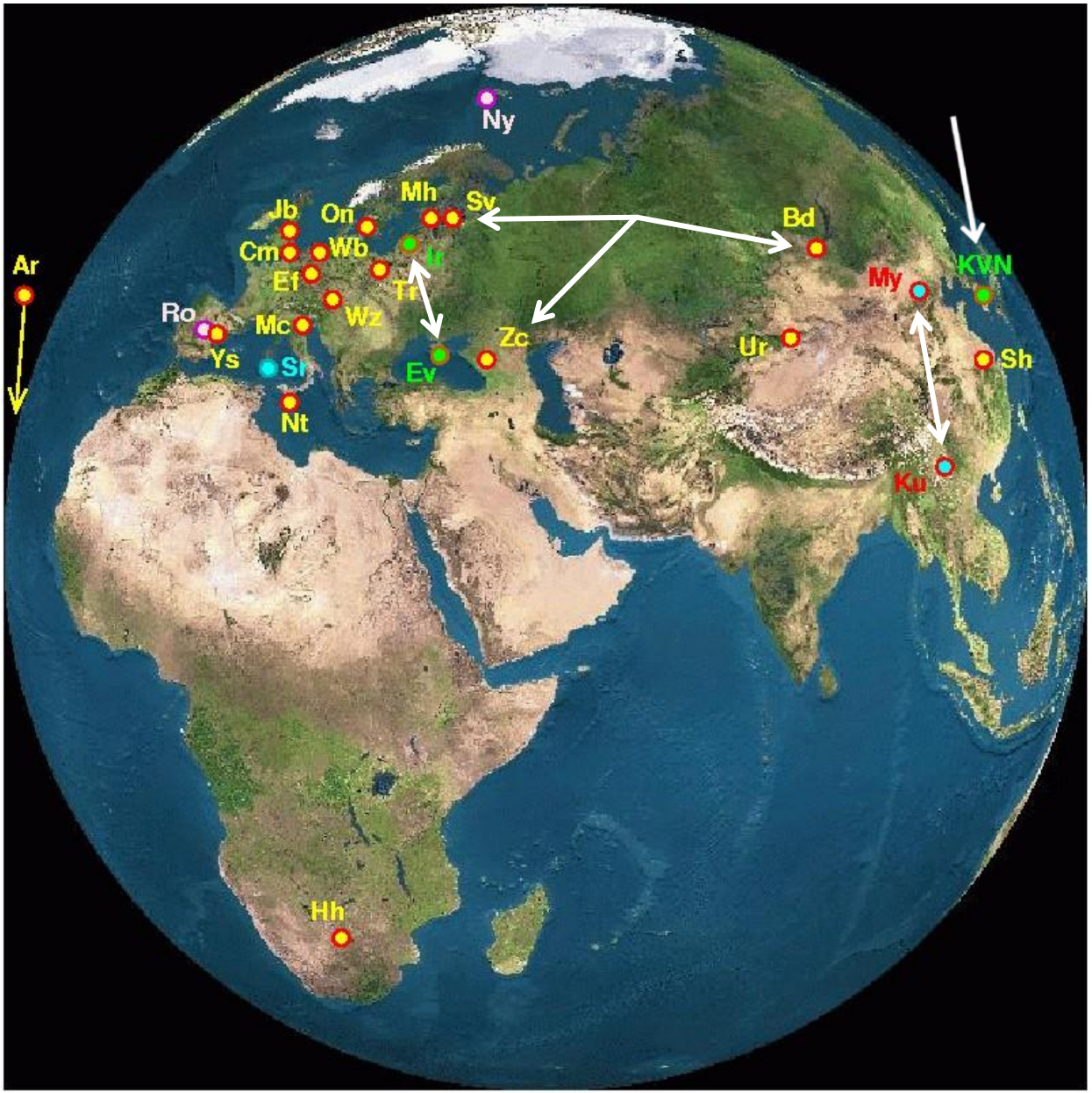
- Physical developments in Dwingeloo
- New EVN stations
- Real-time e-EVN Astronomy
- Software Correlation at JIVE

JIVE in Dwingeloo



JIVE in Dwingeloo

The EVN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Real-time e-EVN Science

- Proposal-driven e-VLBI science observations
  - 1st observation = 16 Mar 2006 (6 stations at 128 Mb/s)
  - Nowadays, network of 8-9 stations at Gbps is routine
  - 140 observations from 96 proposals (1066 hours)
  - 45 different PI's
- Evolution of e-EVN procedures
  - ~monthly 24-hour runs (+4hr prelim. test) on fixed dates
  - Proposals now within standard proposal-submission cycles
    - Proposal Class for "**triggered**" observations (8 since Apr'08)
    - Proposal Class for "**short**" observations (19 since May'08)
  - Target of Opportunity Observations (33 since Sep'07)
  - e-EVN in regular disk sessions also now common (longer runs)

e-EVN Network Overview

Station	Connection
Westerbork	2x 1 Gbps dark fibre
Jodrell Bank	2x 1 Gbps LP
Medicina	1 Gbps LP
Onsala	1.5 Gbps VLAN
Torun	1 Gbps LP
Effelsberg	10 Gbps shared VLAN
Sheshan	256-512 Mbps LP
Metsahovi	10 Gbps
Yebes	900 Mbps ← Channel-dropping

Station	Connection
Arecibo	256 Mbps (512 early AM)
Hart	1 Gbps
ATNF	1 Gbps LP (At,Mp,Pa)
TIGO	95 Mbps (on demand)

Nt, SRT expected soon

Irbene connection ready

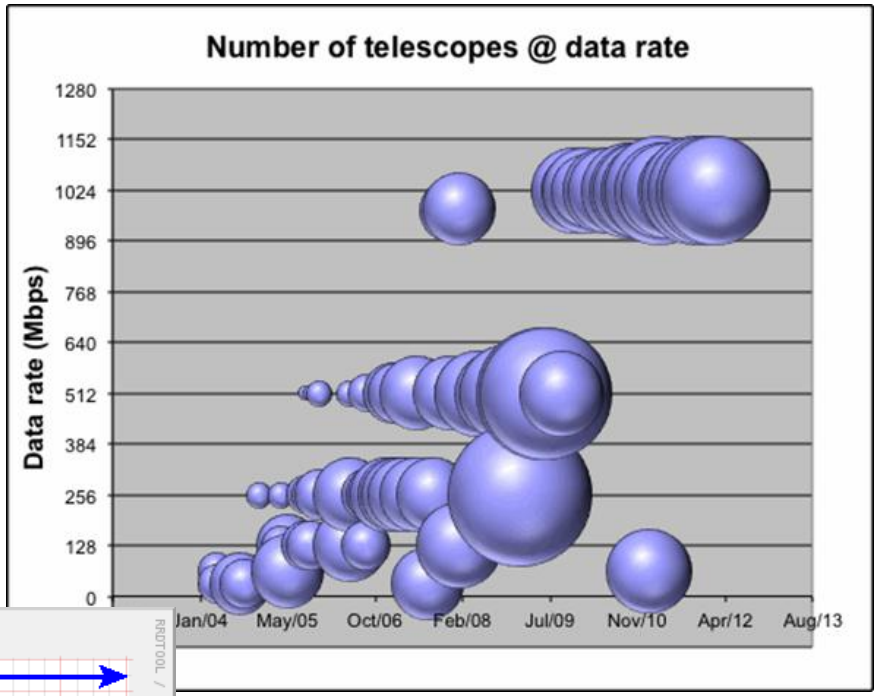
www.jive.nl/e-vlbi-station-recommendation

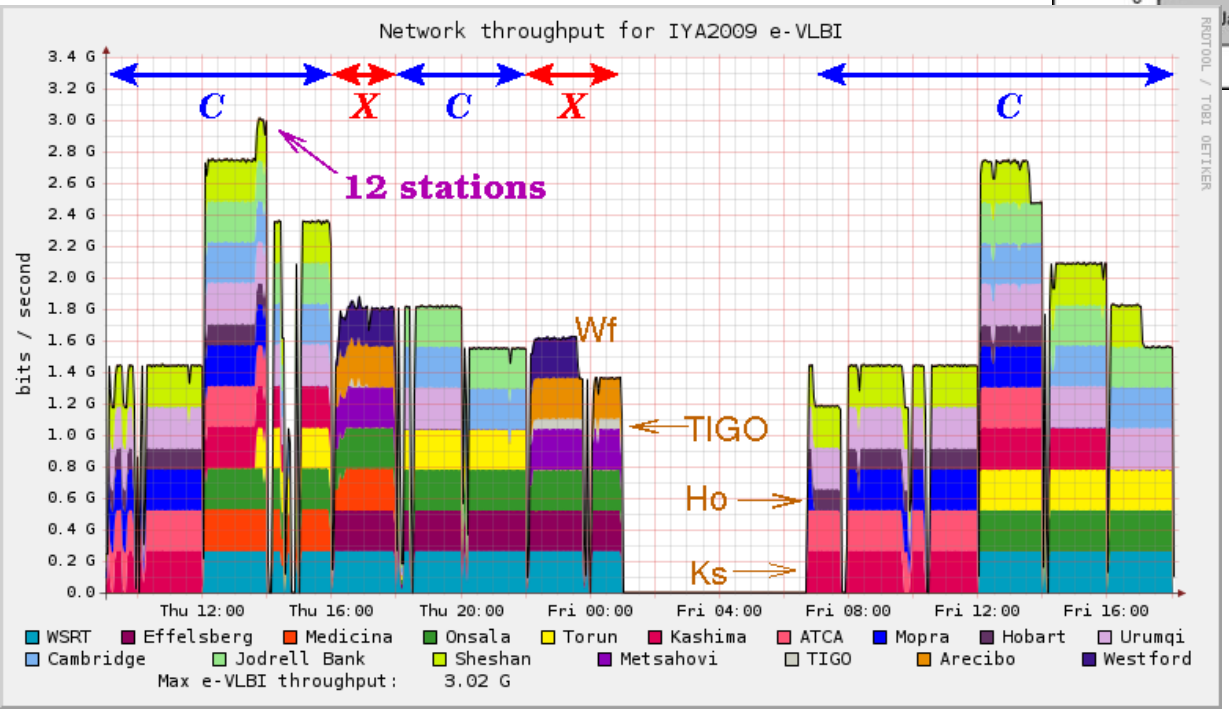
e-EVN Throughput

#1: most stations

#2: longest continuous run

#3: highest total bit-rate



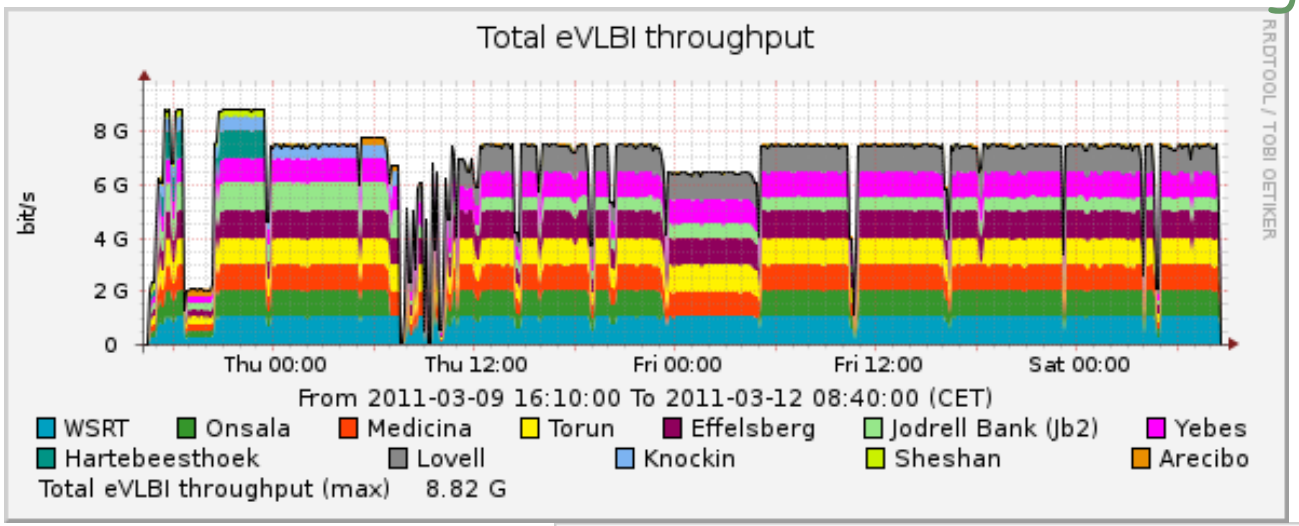


Final frame in an animated viewgraph (plots #2 & #3)

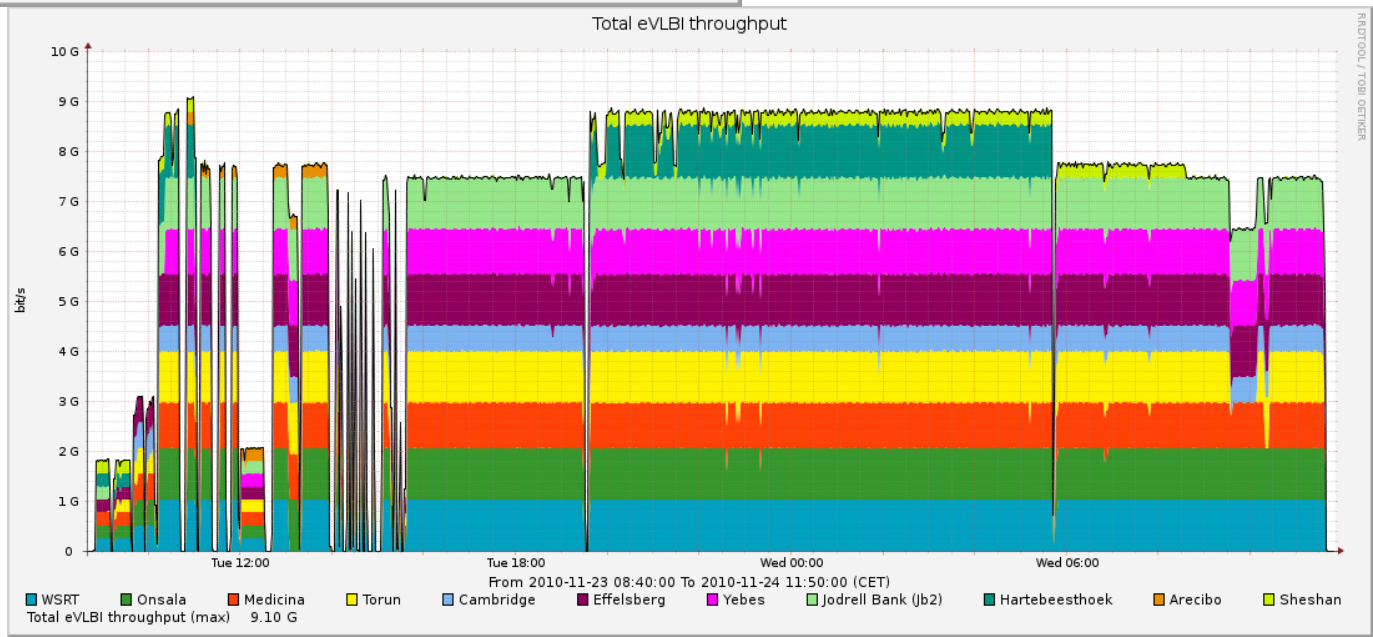
e-EVN Throughput

#1: most stations

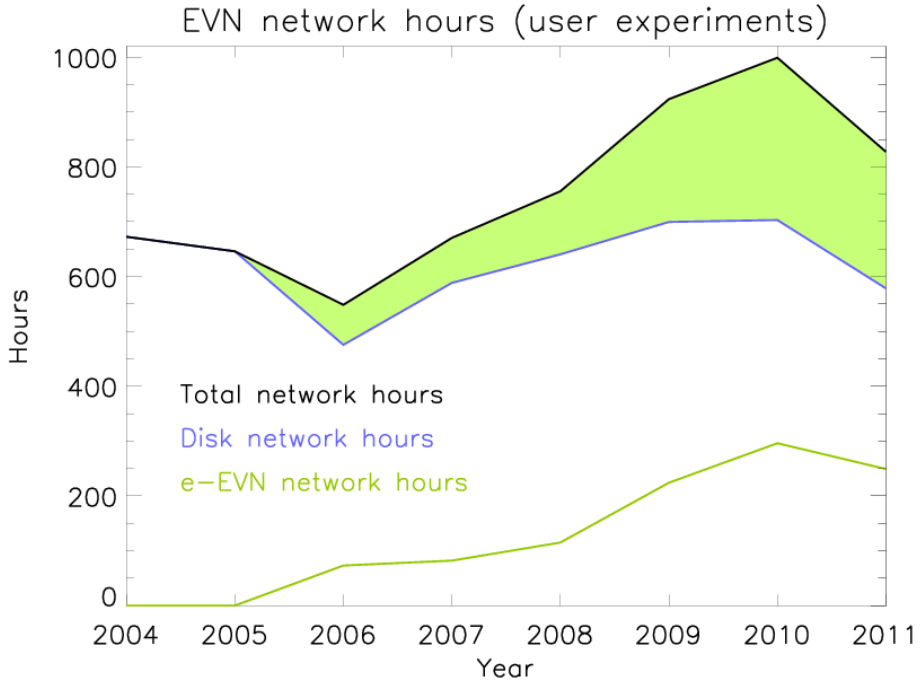
#2: longest continuous run



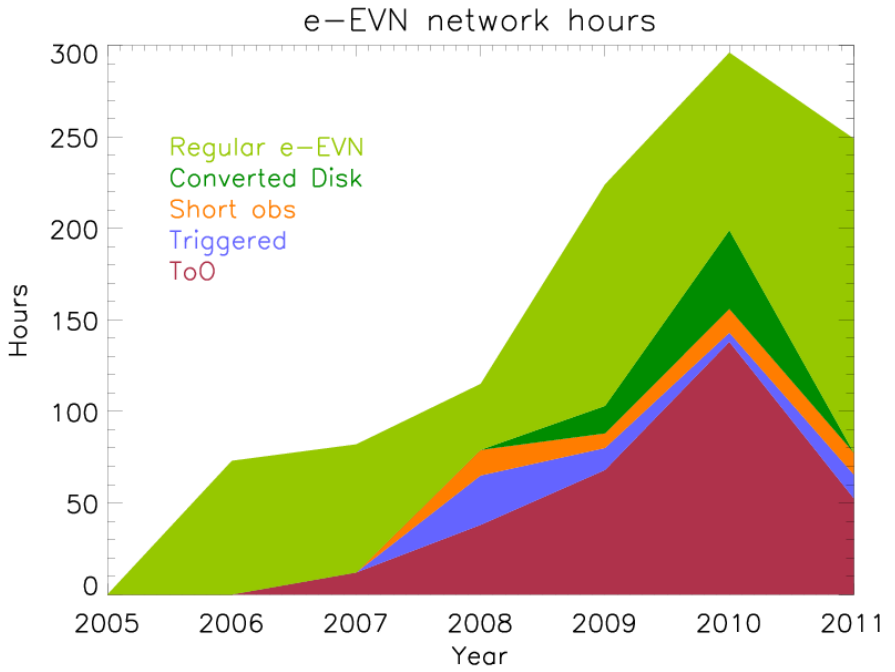
#3: highest total bit-rate



e-EVN: Growth / Composition



- Disk-based network hours roughly constant
- e-EVN now over 30% of total network hours



ToOs: almost half (47%) the total of e-EVN observing time in 2010

Software Correlation at JIVE

- SFXC (based on correlator for tracking Huygens descent*)
  - VEX-driven + configuration file with correlation parameters
  - Mark 5A, 5B, VLBA, and VDIF support
  - Post-correlation processing → IDI-FITS (as for MkIV)
- Now running on a dedicated 256-core cluster (9.5 kW)
  - "Real-time" processing currently = 9 stations at 1 Gbps
  - Replacement of MkIV ~ 4x this; EVN2015 concept ~ 64x
- NEXPReS: integration of SFXC with e-EVN(+)
  - Globally distributed correlation (dynamic resource demand)
  - Bandwidth on demand
  - Data buffering (to blur e-/disk-VLBI distinction)

•www.jive.nl/jive-research-notes (R.N #4, 5, 11)

•www.mrc.uidaho.edu/entryws/full/programme_detailed.html (C-4.6)

SFXC for Network Support

- ftp fringe-tests: find/fix problems before user exps.
  - At beginning of new frequency blocks per session
  - A few seconds of data; full e-VLBI connection not required
  - Feedback on time-scales of 10-20min (skype, web-page)
  - 3-4 such events per 3-hr network monitoring experiment
- Network Monitoring Experiments
  - At least one per frequency block per session
  - Monitor station performance, calibration, etc.
  - Allows opportunity of more-targeted testing as needs arise
- New systems at stations
  - On-going transition to digital back-ends
    - TADUmax (Wb), DBBC (Ef,On,Hh), CDAS (Sh,Ur,Km), R1002 (KVZR)

Final frame in an animated viewgraph (figure assoc. with ¶1.1)

SFXC

- ftp fringe-test
  - At beginning c
  - A few seconds
  - Feedback on t
  - 3-4 such even

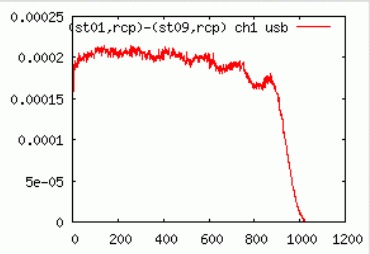
File Edit View History Bookmarks Tools Help

http://www.evlbi.org/tog/ftp_fringes/N08L3/scan32/index.html

openSUSE Getting Started Latest Headlines

Vex file -- Integration time: 4s -- Start of the integration: 2008y301d16h36m56s0ms

N08L3	Auto correlations										Cross correlations								
	Cm	Ef	Jb	Mc	Nt	On	Sh	Tr	Ur	Wb	Cm-Ef	Ef-Jb	Ef-Mc	Ef-Nt	Ef-On	Ef-Sh	Ef-Tr	Ef-Ur	Ef-Wb
1637.99MHz, USB, Rcp-Rcp	A	A	A	A	A	A	A	A	A	A	4.771 A P offset: 41	1174 A P offset: 0	758.7 A P offset: -1	640.3 A P offset: -3	907.9 A P offset: 1	17.12 A P offset: -1	985.5 A P offset: 1	487.4 A P offset: -5	1332 A P offset: -17
1637.99MHz, USB, Rcp-Lcp	Cross hands										5.354 A P offset: 34	138.9 A P offset: 0	122.1 A P offset: -1	93.29 A P offset: -3	139 A P offset: 1	15.12 A P offset: -1	99.17 A P offset: 1	107 A P offset: -5	349.2 A P offset: -17
1637.99MHz, USB, Lcp-Lcp	A	A	A	A	A	A	A	A	A	A	5.368 A P offset: -26	1147 A P offset: 0	623.5 A P offset: -1	592.8 A P offset: -3	1008 A P offset: 1	15.76 A P offset: -2	900.6 A P offset: 1	508.9 A P offset: -5	1420 A P offset: -17
1637.99MHz, USB, Lcp-Rcp	Cross hands										5.264 A P offset: 12	58.96 A P offset: 0	151.7 A P offset: -1	28 A P offset: -3	14.73 A P offset: 1	14.46 A P offset: -2	111.3 A P offset: 1	78.75 A P offset: -5	60.82 A P offset: -17
1645.99MHz, USB, Rcp-Rcp	A	A	A	A	A	A	A	A	A	A	746.3 A P offset: 2	1069 A P offset: 0	739.1 A P offset: -1	693.2 A P offset: -3	944.6 A P offset: 1	15.37 A P offset: -2	1106 A P offset: 1	495.9 A P offset: -5	1426 A P offset: -17
1645.99MHz, USB, Rcp-Lcp	Cross hands										78.77 A P offset: 1	154.9 A P offset: 0	158 A P offset: -1	113.7 A P offset: -3	93.89 A P offset: 1	14.39 A P offset: -2	115.9 A P offset: 1	107.2 A P offset: -5	368.2 A P offset: -17
1645.99MHz, USB, Lcp-Lcp	A	A	A	A	A	A	A	A	A	A	656.8 A P offset: 2	998.1 A P offset: 0	639 A P offset: -1	619.1 A P offset: -3	948.9 A P offset: 1	15.97 A P offset: -2	967.2 A P offset: 1	478.6 A P offset: -5	1278 A P offset: -17
1645.99MHz, USB, Lcp-Rcp	Cross hands										350.2 A P offset: 2	56.05 A P offset: 0	140 A P offset: -1	45.97 A P offset: -3	21.67 A P offset: 1	14.43 A P offset: -2	118.1 A P offset: 1	75.31 A P offset: -5	53.11 A P offset: -17
1653.99MHz, USB, Rcp-Rcp	A	A	A	A	A	A	A	A	A	A	1013 A P offset: 0	1162 A P offset: 0	774 A P offset: -1	527.3 A P offset: -3	802 A P offset: 1	19.33 A P offset: -1	965.9 A P offset: 1	493.3 A P offset: -5	1252 A P offset: -17
1653.99MHz, USB, Rcp-Lcp	Cross hands										267.8 A P offset: 0	187.1 A P offset: 0	176.1 A P offset: -1	85.53 A P offset: -3	136.8 A P offset: 1	13.2 A P offset: -2	89.19 A P offset: 1	107.7 A P offset: -5	340.8 A P offset: -17
1653.99MHz, USB, Lcp-Lcp	A	A	A	A	A	A	A	A	A	A	1072 A P offset: 0	1093 A P offset: 0	683.2 A P offset: -1	570.7 A P offset: -3	914.3 A P offset: 1	14.77 A P offset: -1	886.8 A P offset: 1	470.1 A P offset: -5	1225 A P offset: -17
1653.99MHz, USB, Lcp-Rcp	Cross hands										654.6 A P offset: 0	83.64 A P offset: 0	161.7 A P offset: -1	59.53 A P offset: -3	31.8 A P offset: 1	16.24 A P offset: -1	155.1 A P offset: 1	50.62 A P offset: -5	64.4 A P offset: -17
1661.99MHz,											418.6	1011 A P	808.4 A P	596.4 A P	889 A P	15.64 A P	867.3 A P	476.6 A P	1158 A P



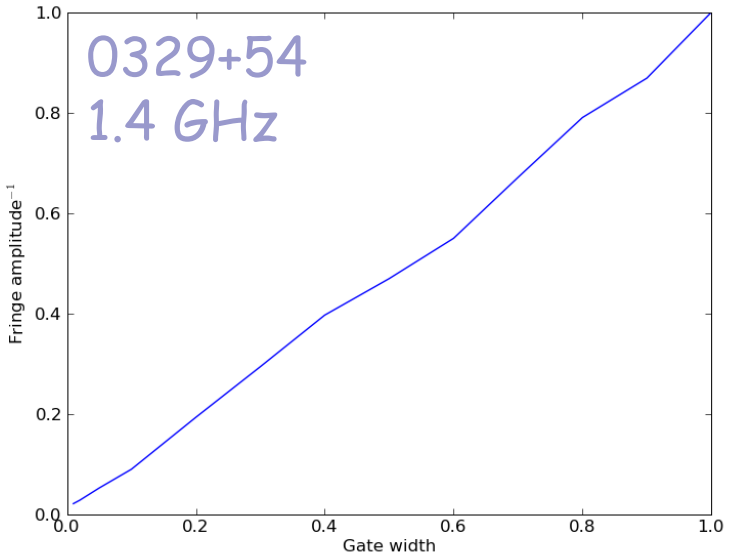
Done

MkIV → SFXC: Astronomy Gains

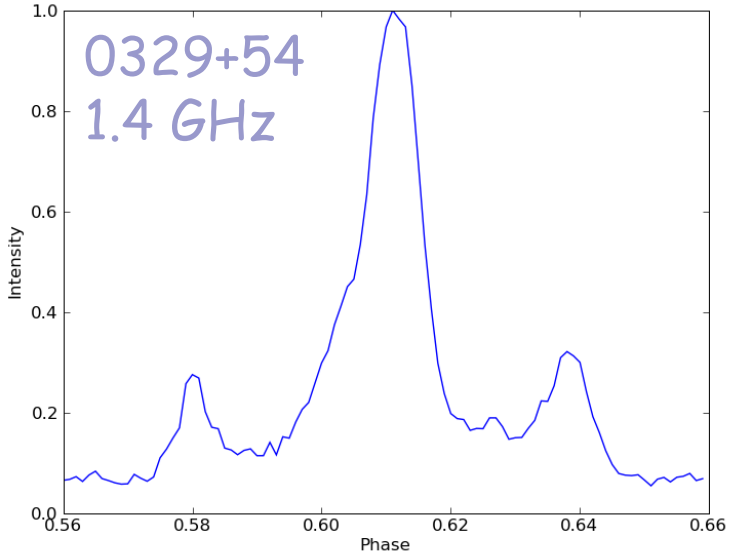
- N_{sta} limited only by available input devices (was 16)
- Arbitrary total bit-rate & BW_{SB} (was 1 Gbps & 16 MHz)
- ~arbitrarily large number of frequency points (was 2048)
  - Velocity resolution improvements w/o sensitivity penalty
- ~arbitrarily small integration times (was $\frac{1}{4}$s)
- Large N_{frq} & small t_{int} together → wider-field mapping
  - Multiple output phase centers within a wider field
- Pulsar Gating/Binning (never completed operationally)
- Improvements in correlated data
  - Pure station-based fringe rotation to center of earth
  - Decoupled correlation/delay-tracking fft sizes
  - Consistent cross-polarization handling
  - Control over spectral windowing

SFXC: Pulsar Gating/Binning

- Gating = arbitrary interval within a PSR period
- Binning = arbitrary number of bins within the gate
  - Each bin → separate correlation / output IDI-FITS file



Expected inverse relation between amp & gate-width (y-axis = 1/amp)



Pulse profile (1 gate, 100 bins)

SFXC: Pulsar Gating/Binning

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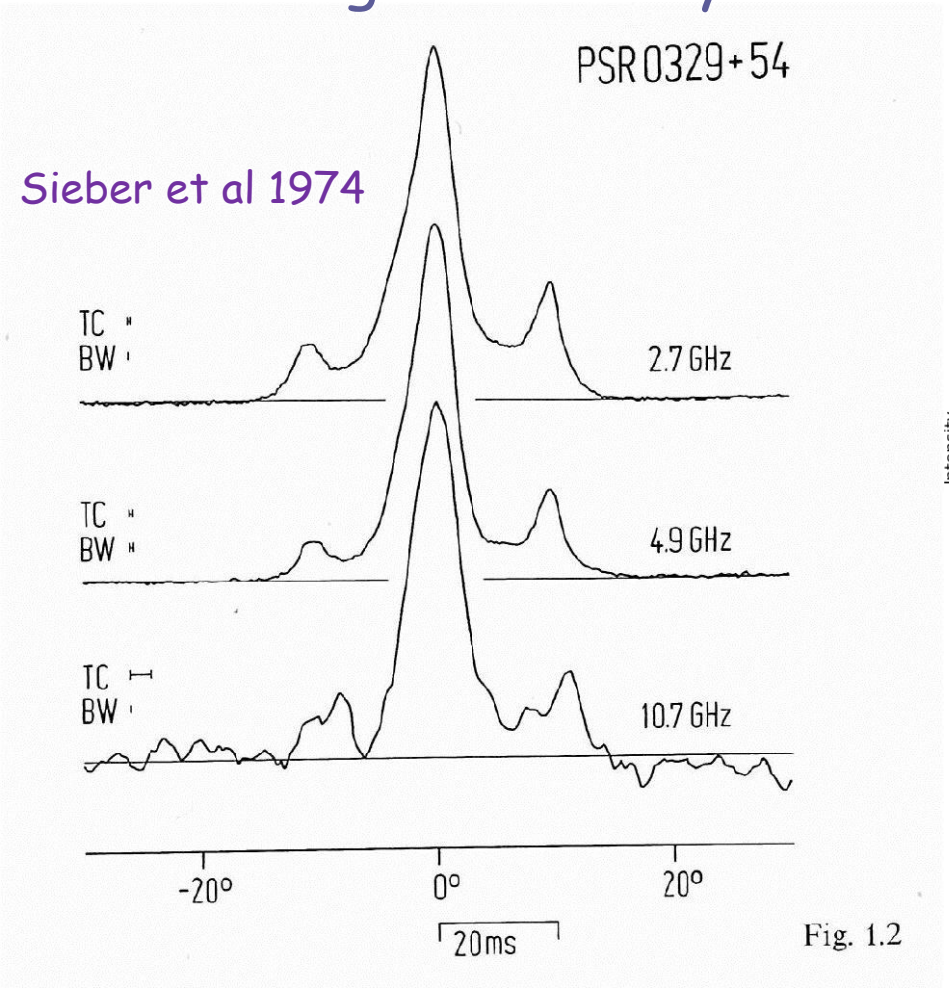
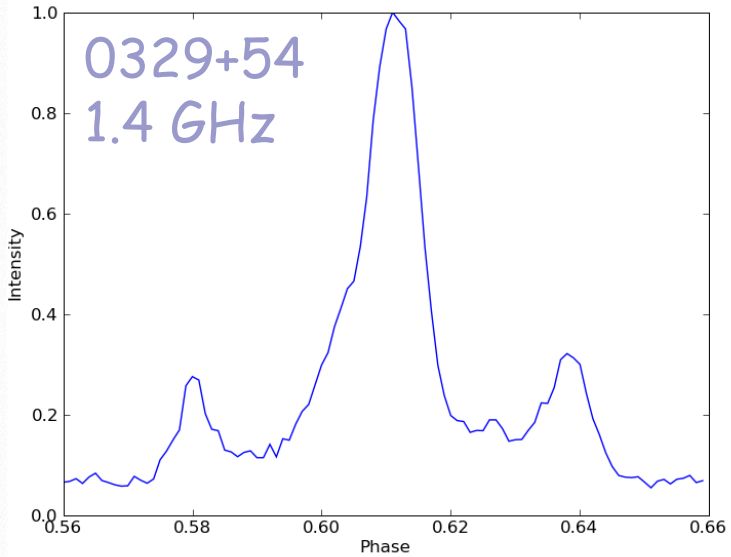
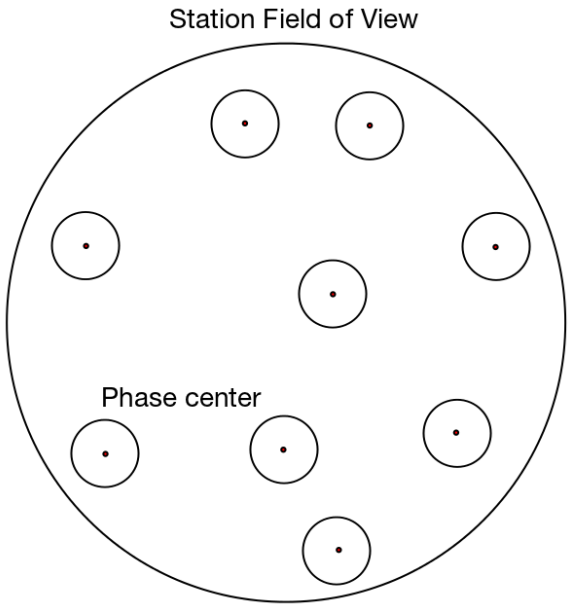




Pulse profile (1 gate, 100 bins)

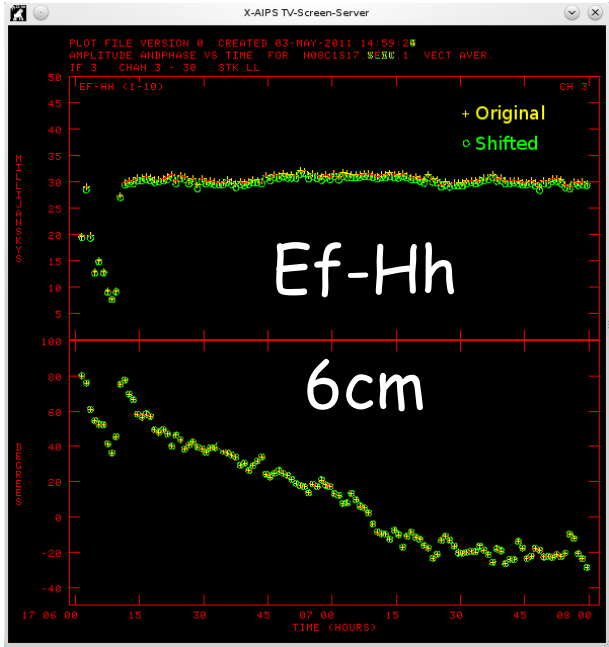
SFXC: Wide-Field Mapping

- Essentially unlimited max-N_{frq}, min-t_{int}: can map area on the sky ~single-dish beam w/ minimal smearing
  - Price = huge output data sets
- Multiple phase-center correlation: outputs only subsets of the full area (user exps. so far ~30 phs. centers)



Typical 1st-correlation
N_{frq} ~16k; t_{int} ~10 ms
Further processing-factor "penalty" small

Example validation run: same source correlated at two positions 1.4′ apart; $|\Delta\varphi|_{Ef\text{-}Hh}$ = 0.3° pk-to-pk.

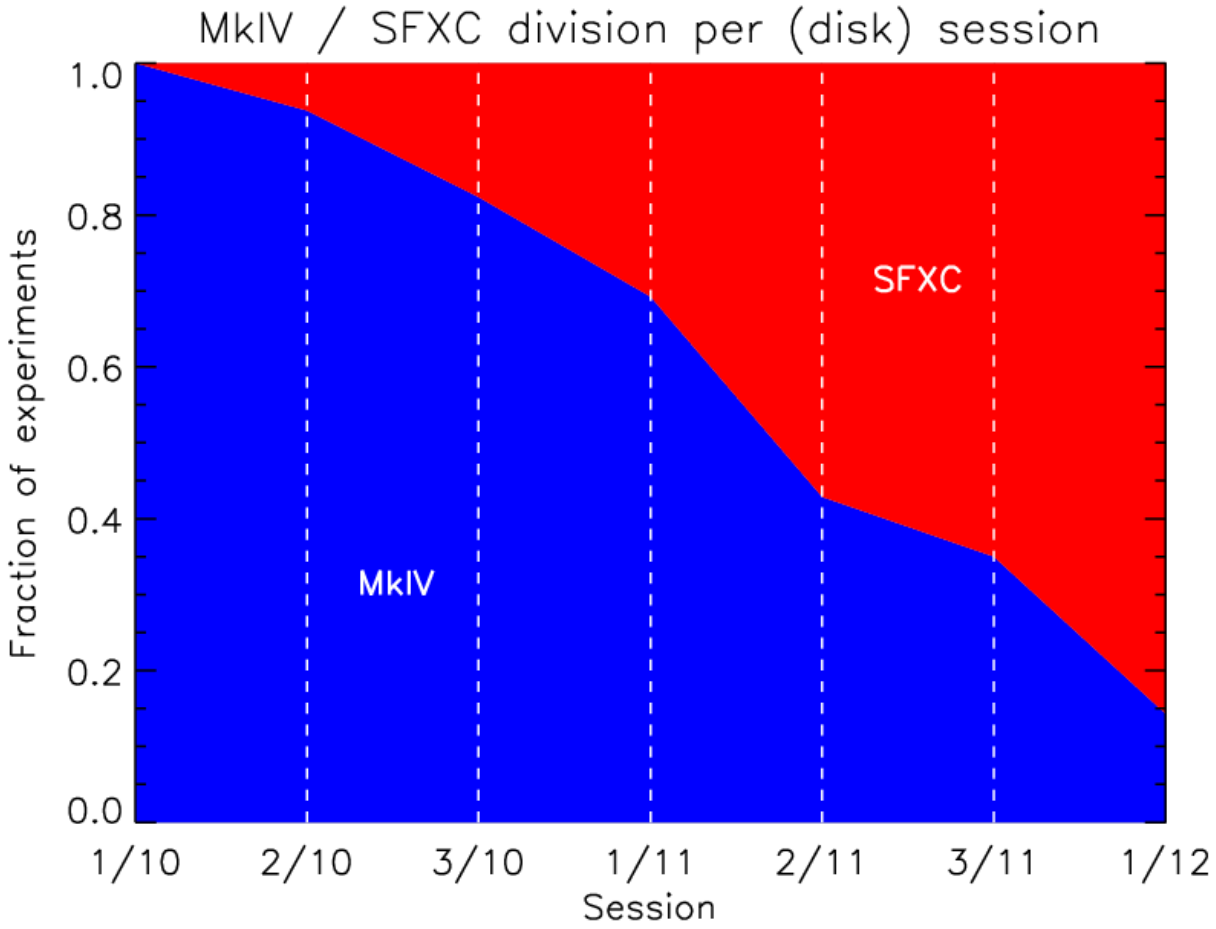


Transition: MkIV→SFXC

SFXC-correlated observations impossible on MkIV:

Pulsar gating: 7
Wide-field mapping: 3
(of which were multiple phase centers: 2)
Spectral capacity: 7
>16 stations: 1

Xpol spectral line: 6



Summary

- e-VLBI now standard/indispensable facet of EVN
  - More than 30% of network observing hours
  - New kinds of astronomy enabled
  - e-EVN = SKA pathfinder
- EVN Software Correator at JIVE (SFXC)
  - Astronomical applications beyond the MkIV
  - More straightforward capacity limitations
  - Some implications for proposal tool, AIPS
- Equipment changes at stations / new stations
  - Some implications for testing, sched