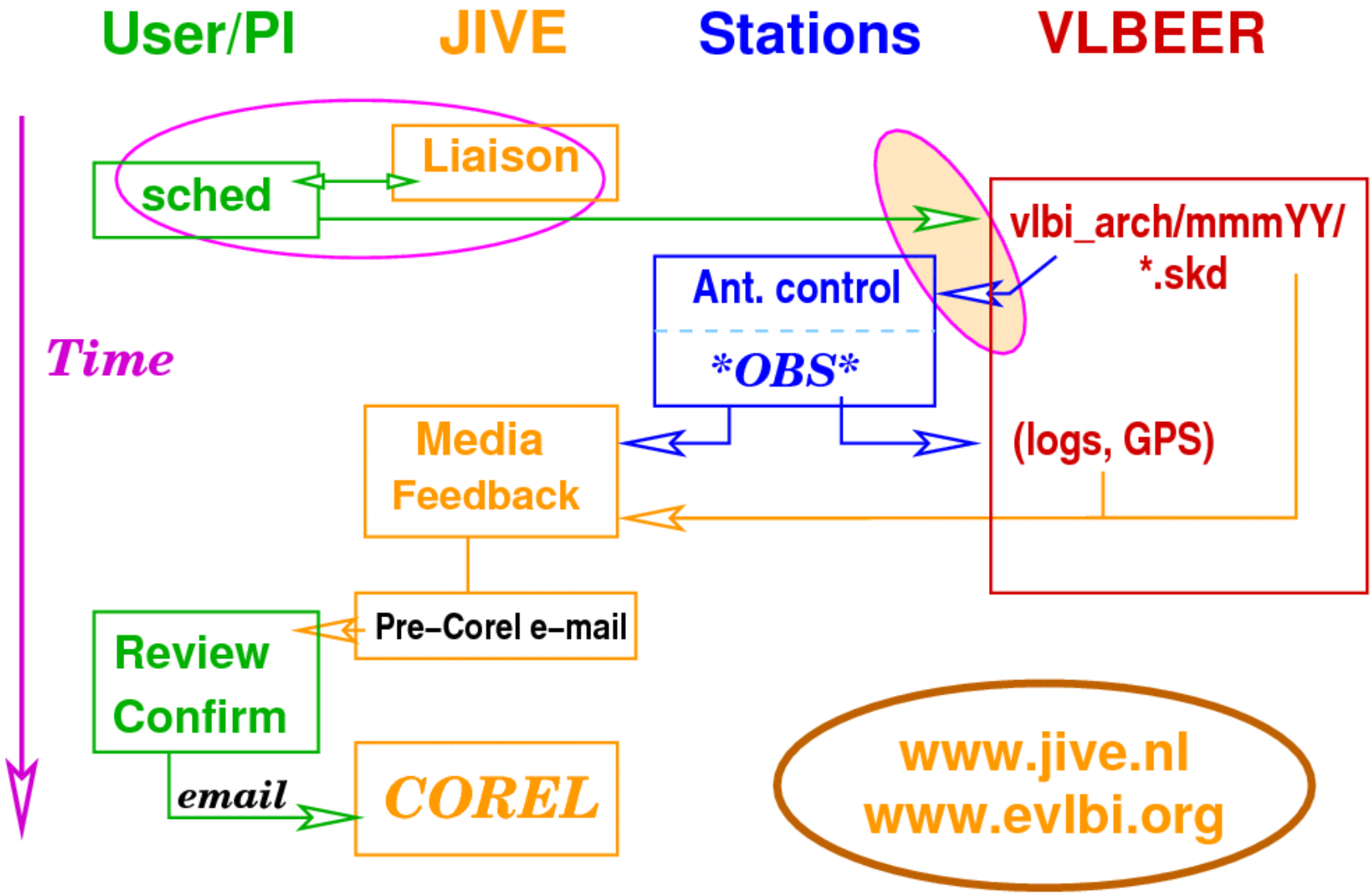
e-EVN & other Developments at the EVN MkIV Data Processor at JIVE

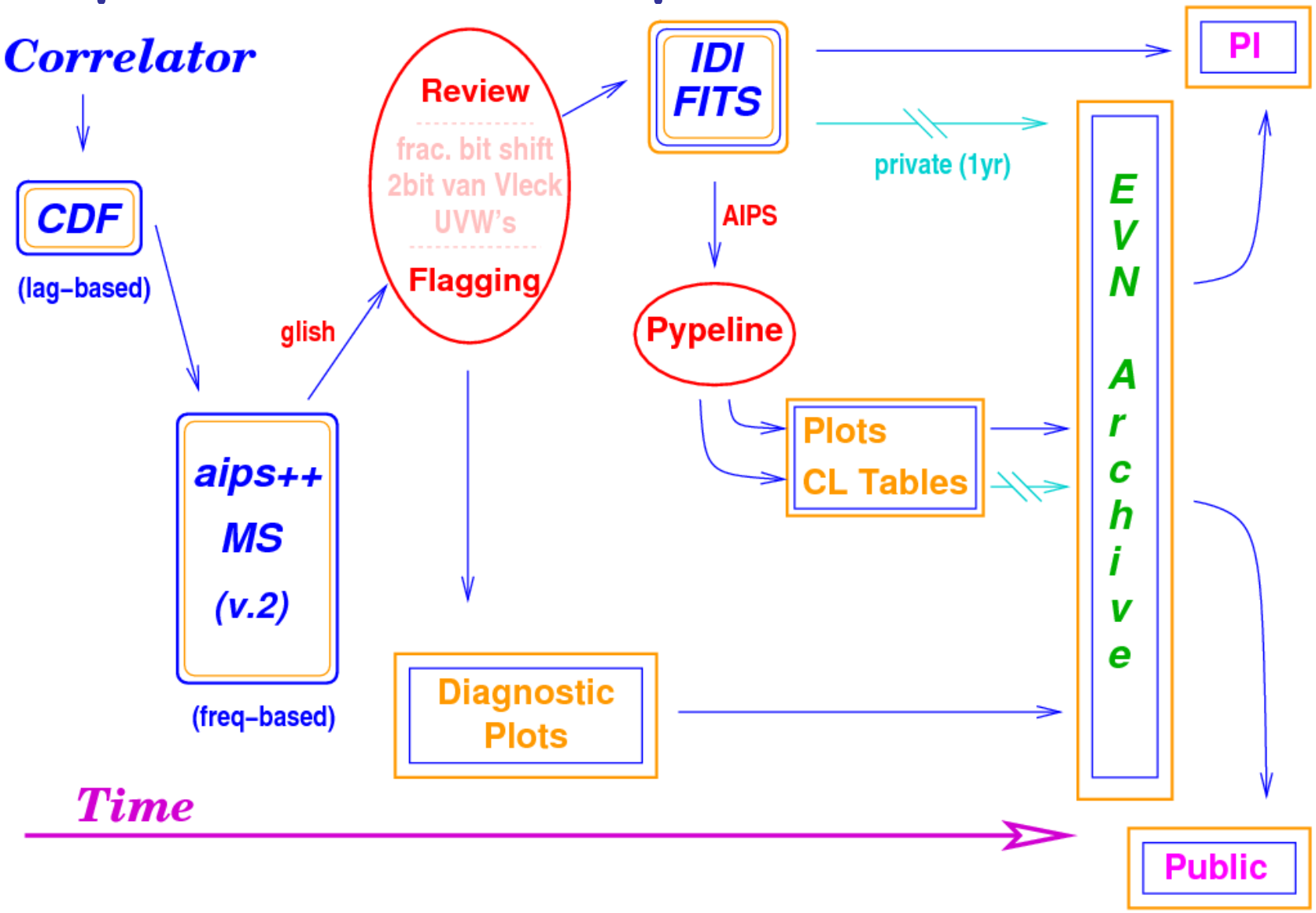
Bob Campbell, JIVE

- Operations and PI Interaction
- Correlator (MkIV) Capacities
- Real-time e-EVN Astronomy
- Software Correlation at JIVE
- EVN Trans-National Access

Ops Flowchart (≤ Correlation)



Ops Flowchart (post-Correlation)



Specific Correlator Capabilities

- Total observed rates up to 1 Gbps (max. sampling = 32Mb/s)
- 1-, 2-bit sampling (e.g., include VLBAs at 512 Mbps in Gbps obs)
- Full-Stokes polarization output
- Up to 2048 frequency points per SB/polarization
- Full-correlator $t_{int} \geq \frac{1}{4}$ sec (half-corr $t_{int} \geq 1/8$ sec)
- Oversampling (2, 4x Nyquist $\longrightarrow$ 500kHz filters)
- >16 stations through multiple passes
- Improved UVWs; 2-bit van Vleck, frac. bit shift comp.
- Multiple MERLIN out-stations as separate EVN ants.
- Recirculation (time-sharing correlator in low-BW obs)
- Real-time e-VLBI operation

Correlator Capacity (Spectral Resolution)

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

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

Recirculation: $\mathcal{R} \le 16\text{MHz}/BW_{sb}$; N_{frqmax} still 2048

Examples:

	5—8 Sta	1 SB	1 Pol	2048 Frq	
	9—16 Sta	1 SB	1 Pol	512 Frq	($\mathcal{R}$ = 1)
(if 8 MHz SB)	9—16 Sta	1 SB	2 Pol	512 Frq	($\mathcal{R}$ = 2)
(if 2 MHz SB)	9—16 Sta	1 SB	2 Pol	2048 Frq	($\mathcal{R}$ = 8)
	9—16 Sta	8 SB	4 Pol	16 Frq	

Maximal Spectral Resolution (N_{frq}=2048, Δv in [m/s])

BW_{sb} [MHz]	$\Delta\nu$ [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

But no Recirc.

Correlator Output Capacity

Raw output (local validity):

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

Approximate FITS-file growth rate:

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

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

- {2MHz SBs && t_{int} <2s} may well imply no recirculation

New Stations (KVAZAR)

Svetloe

Zelenchukskaya

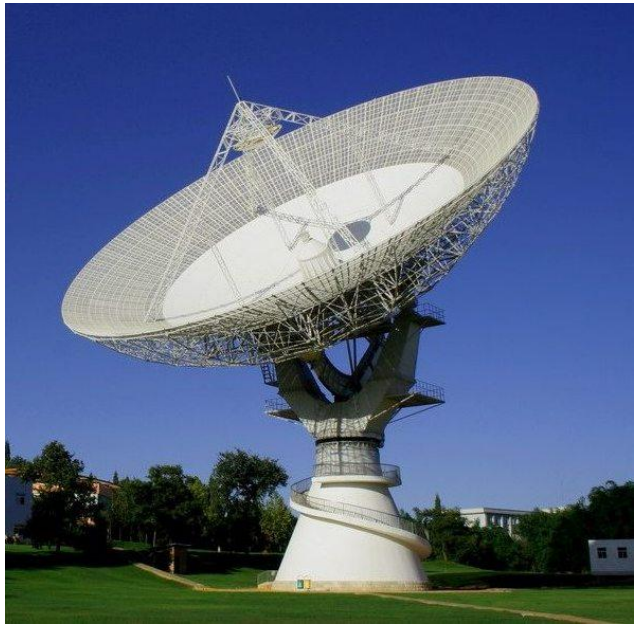
Badary

movie: www.ipa.nw.ru/PAGE/ENG/film/film.htm

- 1st EVN experiments = EK028A-C (Oct'08)
- Officially joined EVN in Nov'09
- Regular user experiments since Mar'10 session

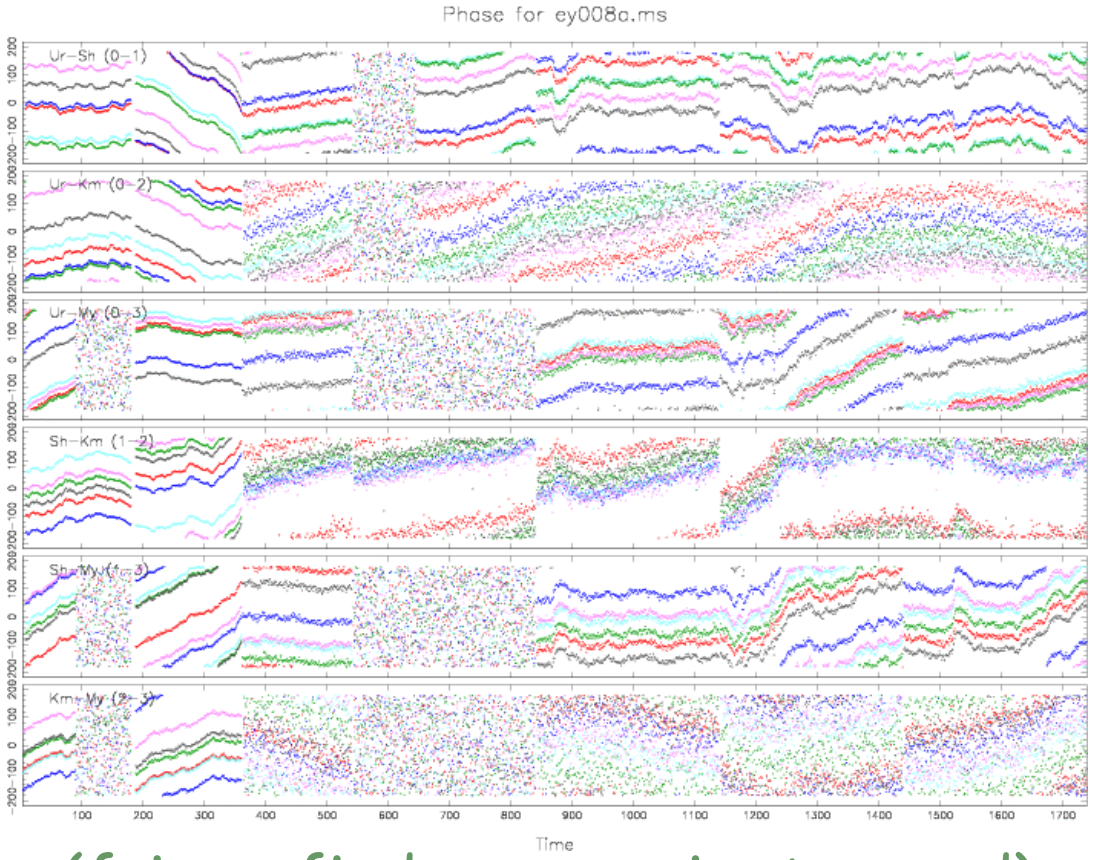
New Stations (Miyun, Kunming)

My



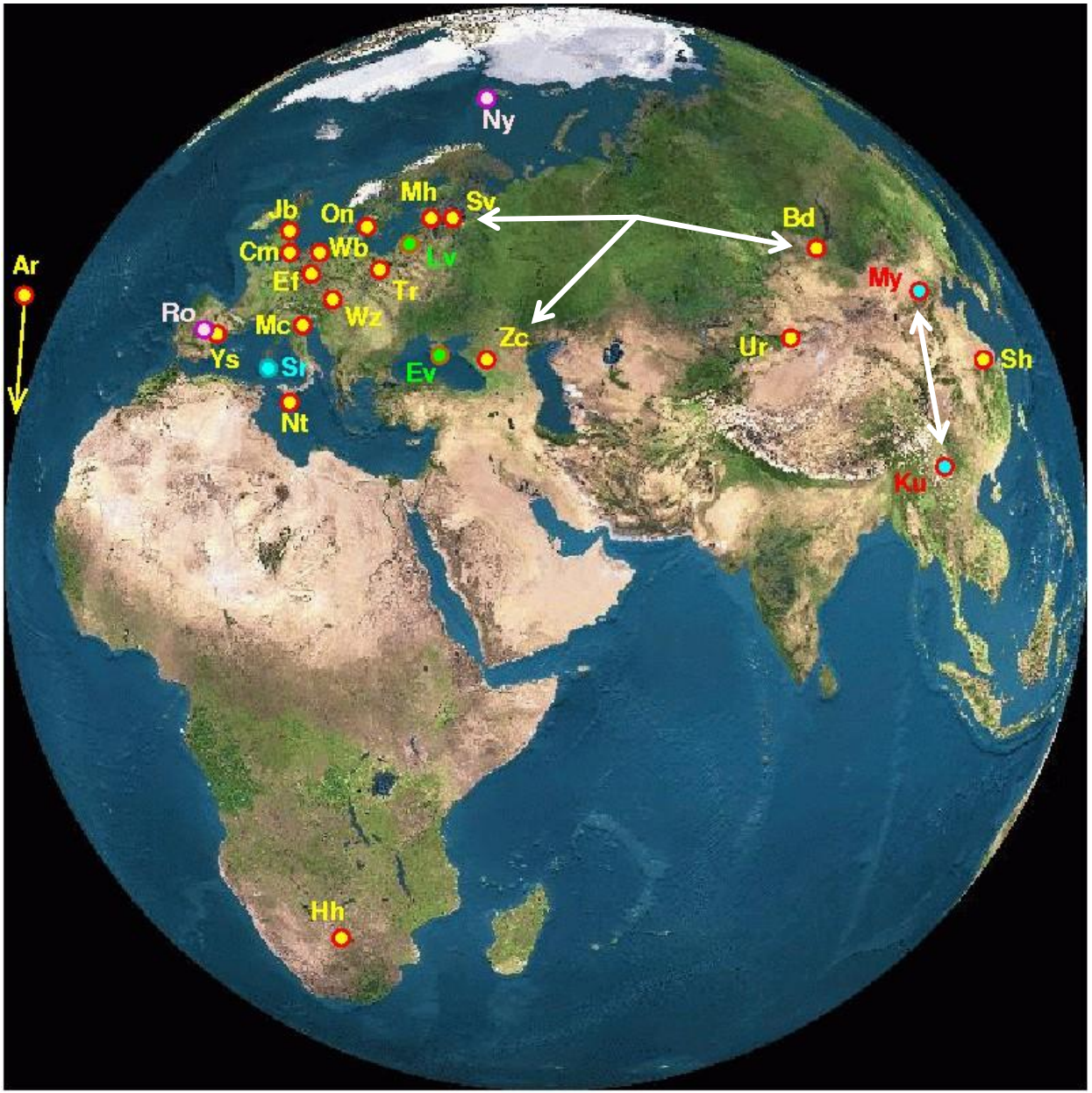
Km

phs(t) for F.F.'s in EY008A (X-band): Ur-Sh-Km-My



(fringe-finder scans juxtaposed)

The EVN


Ny
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Zc
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Hh

Real-time e-EVN Science (I)

- Proposal-driven e-VLBI science observations
  - 1st observation = 16 Mar 2006 (6 stations at 128 Mb/s)
  - 88 observations from 60 proposals (717.5 hours)
  - 30 different PIs
- Topics (rapid turn-around; urgency; denser time-sampling):
  - X-ray binaries in flaring states
  - Just-exploded GRBs, SNe, Novae
  - Binary stars at specific orbital phases
  - Monitoring SNe population/birth in starburst galaxies
  - AGN γ-ray outbursts — locus of VHE emission
  - Gravitational lenses // AGN in a sub-mm galaxies
  - High-z sources: UL galaxies, core-dominated triples
  - Seeking IMBH via compact radio emission in ULXs
  - Pre-proposal detection exp. // reference-source search

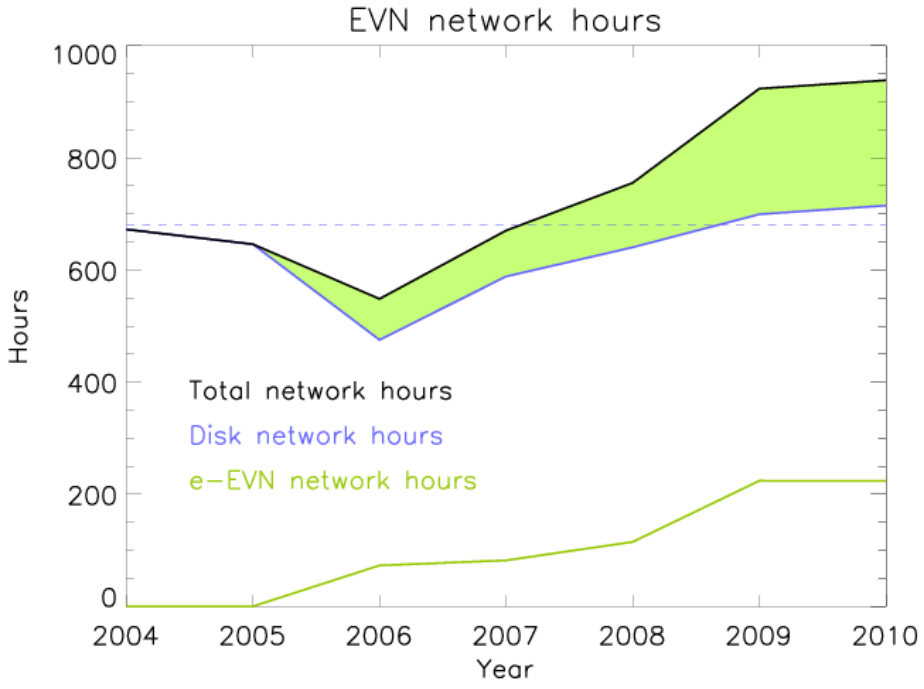
Real-time e-EVN Science (II)

- Evolution of e-EVN procedures
  - 24-hour periods run on fixed dates (fit to station commitments)
  - Proposals now within standard proposal-submission cycles
    - Proposal Class for "**triggered**" observations (5 since 2008)
    - Proposal Class for "**short**" observations
  - Target of Opportunity Observations (e-EVN + disk)

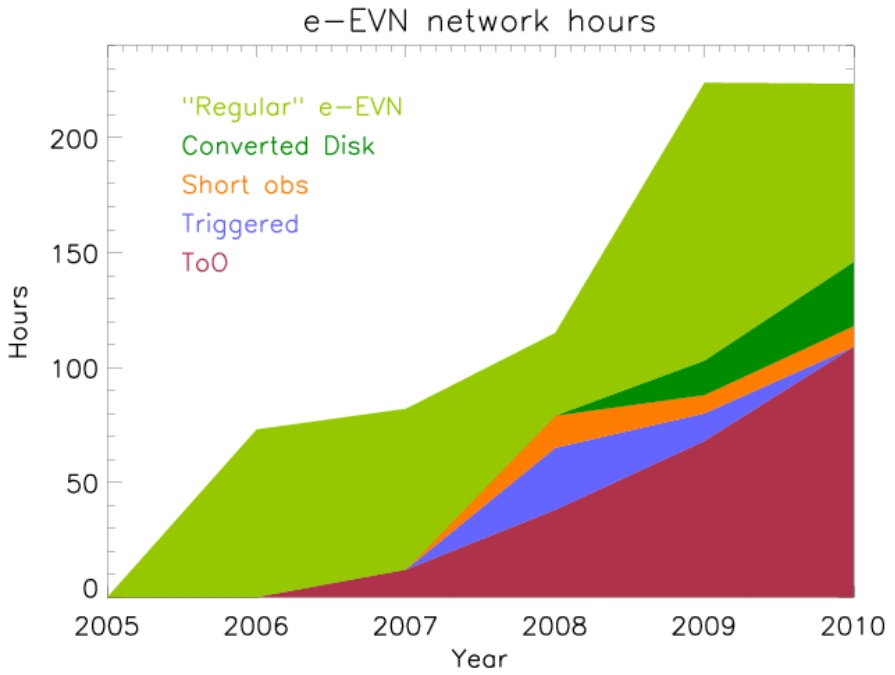
	N_{proj}	N_{obs}	N_{hour}
2007	1	1	12
2008	2	4	38
2009	3 + 1	6	68
2010	8 + 2	11 + 5	109 + 43

    - Growth rate in each e-EVN ToO stat. ≥ Fibonacci
    - Some e-EVN ToOs have included Australian stations

e-EVN: Growth / Composition



- Disk-based network hours roughly constant
- 2010 e-EVN network hours now at 223.5 (& counting)



ToOs: almost half the total of e-EVN observing time in 2010 so far (48.8%)

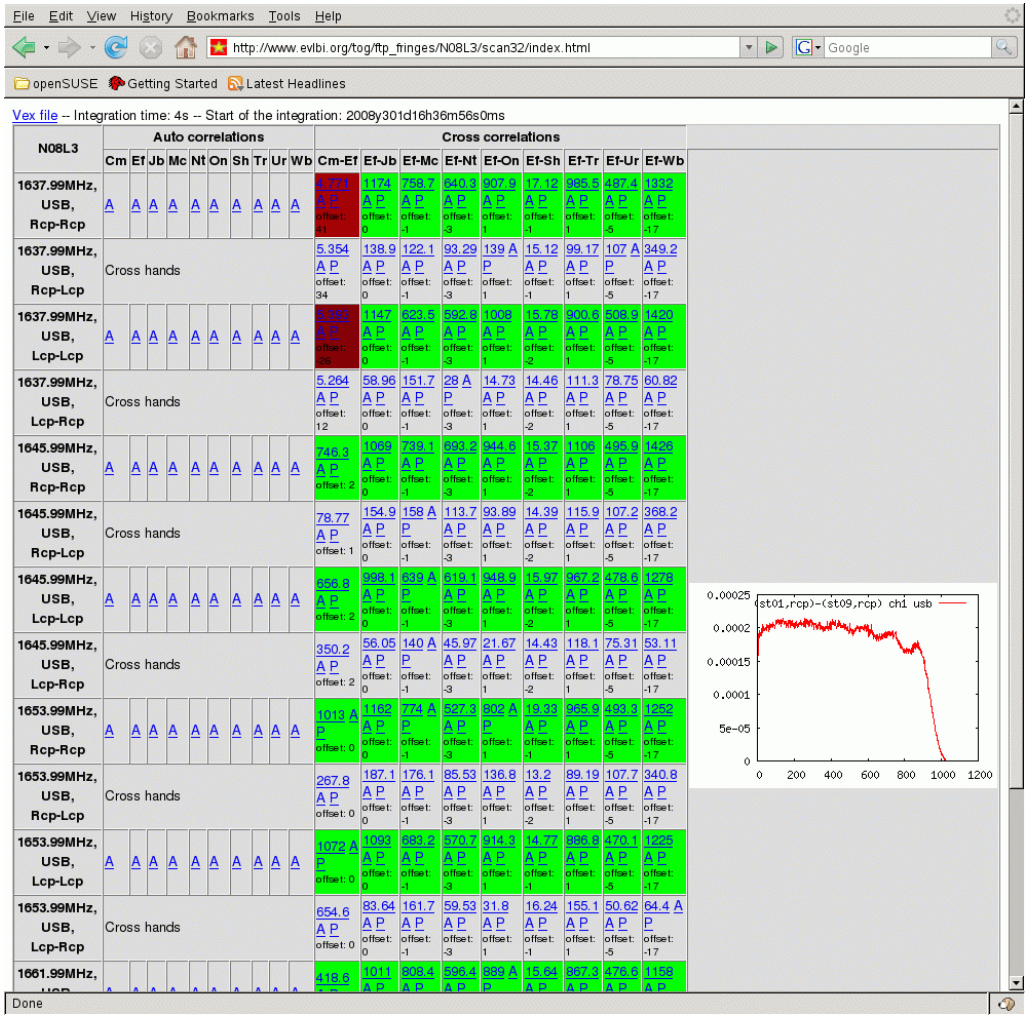
Software Correlation at JIVE (I)

- SFXC (based on correlator for tracking Huygens descent*)
  - VEX-driven + simple config. file with correlation parameters
  - Mark 5A, 5B, VLBA, and VDIF support (thus 5C-ready)
  - Post-correlation processing → IDI-FITS as for Mk IV
  - Essentially unlimited N_{frq} / t_{int} (wider-field mapping)
- Now running on a dedicated 16-node, 128-core cluster
  - "Real-time" processing currently = 9 stations at 512 Mb/s
  - Benchmarks summary on **SFXC Poster**
- Used for ftp fringe-tests in NMEs since 2007
- NEXPReS: integration of SFXC with e-EVN(+)
  - Globally distributed correlation (dynamic resource demand)

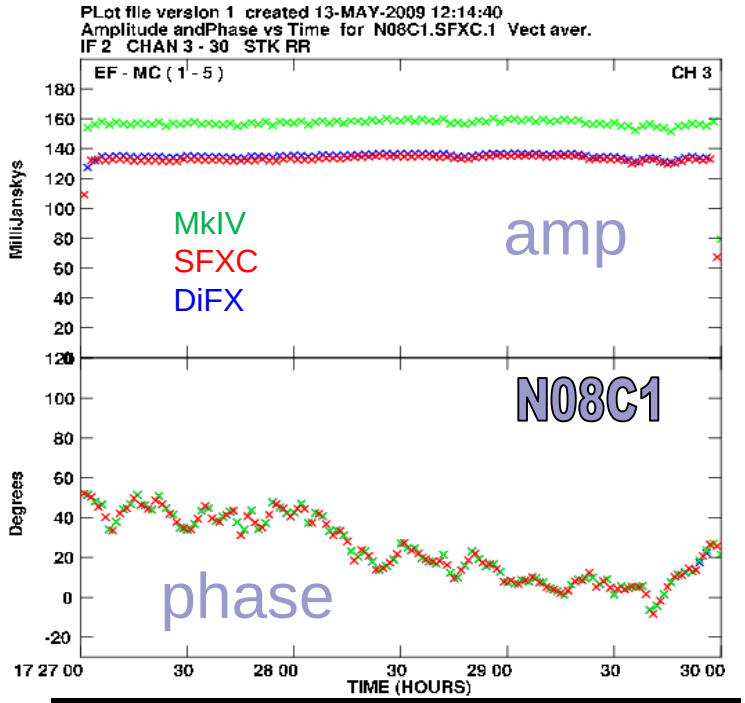
•www.jive.nl/jive-research-notes (R.N #4, 5, 11)

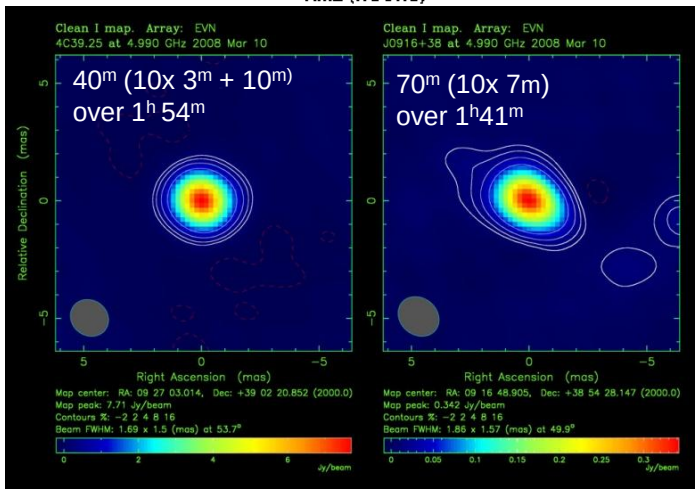
•www.mrc.uidaho.edu/entryws/full/programme_detailed.html (C-4.6)

Software Correlation at JIVE (II)



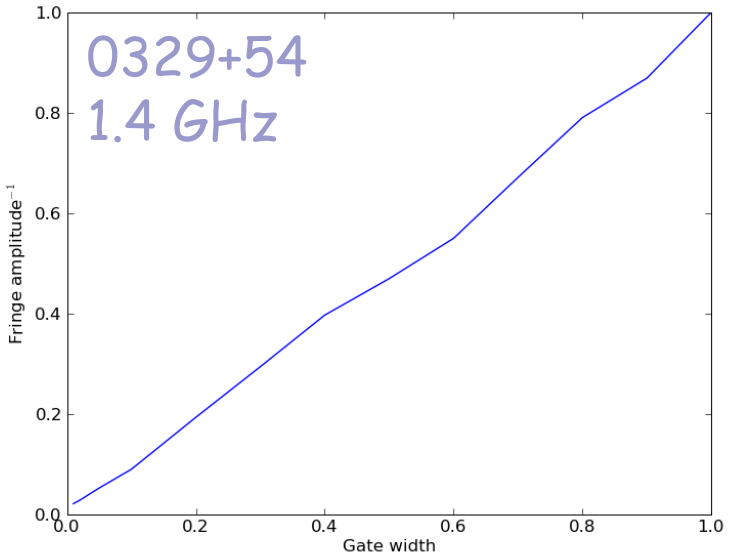
ftp fringe-test results web interface



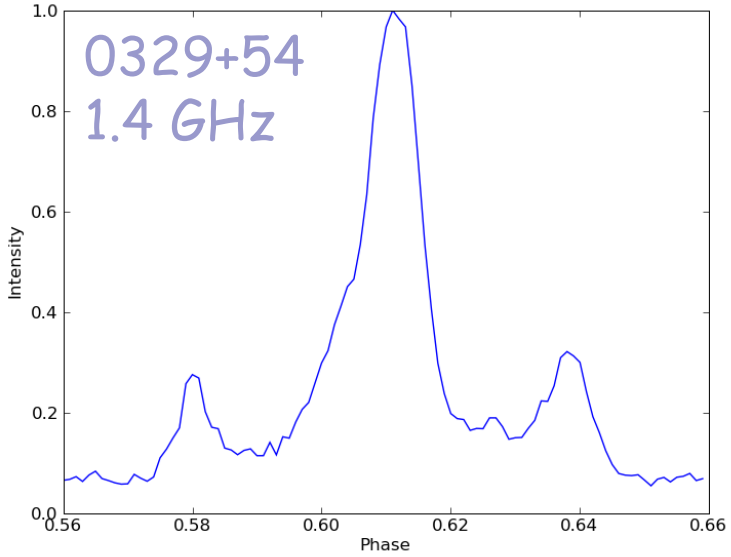


SFXC Pulsar Gating/Binning

- 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)

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- Binning = arbitrary number of bins within the gate

Sieber et al 1974

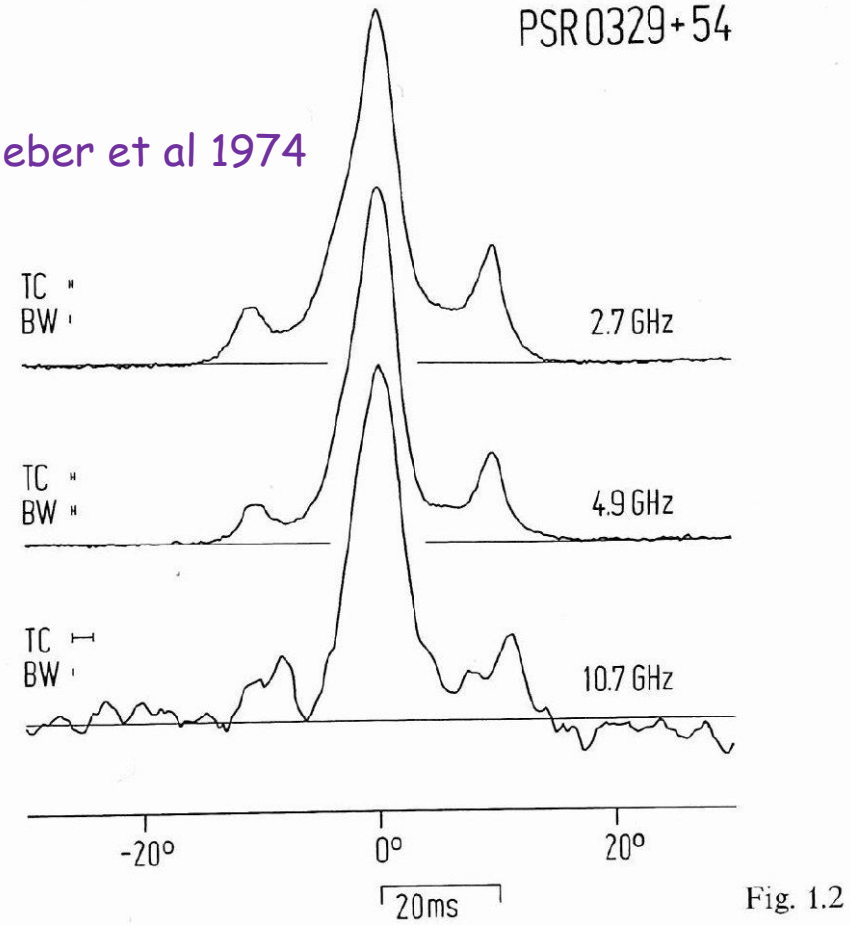
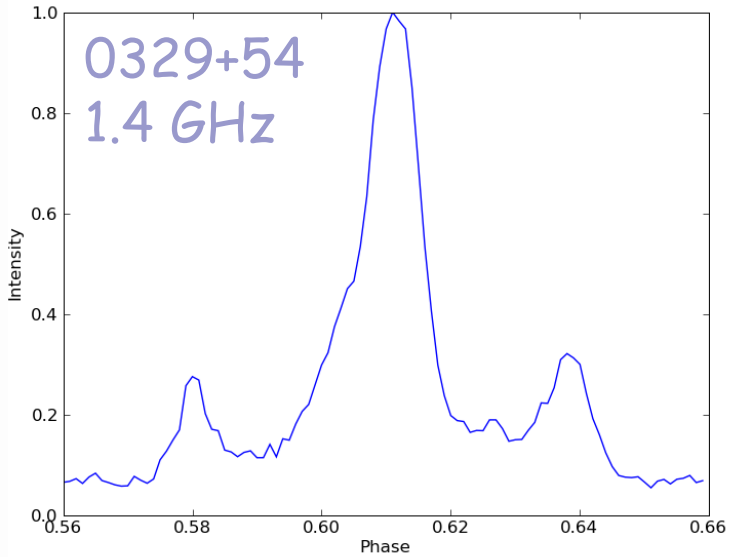


Fig. 1.2

ation / output IDI-FITS file

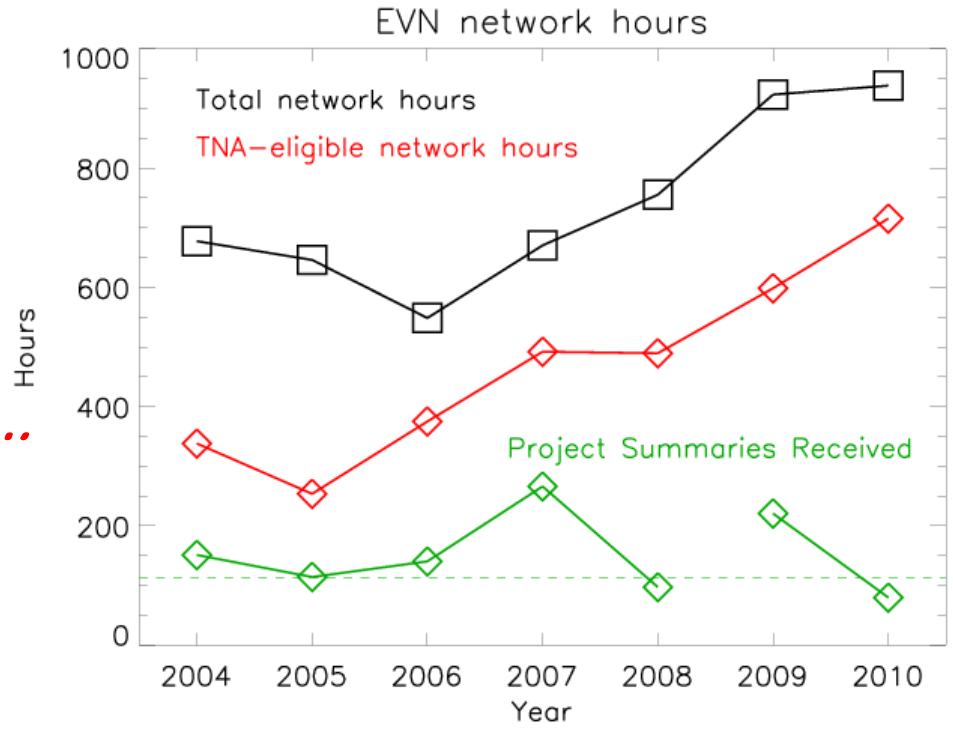


Pulse profile (1 gate, 100 bins)

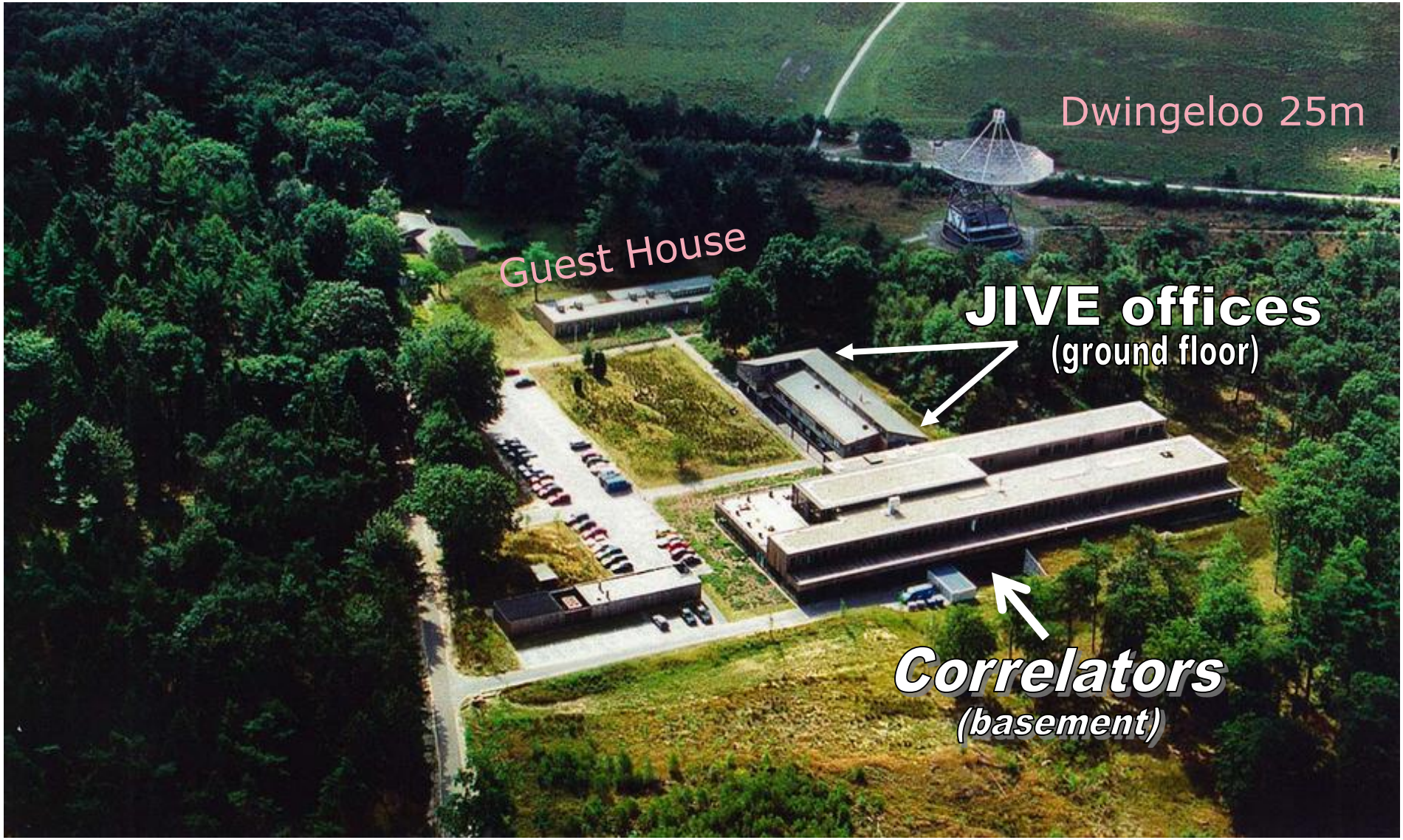
EVN Transnational Access (+)

- TNA eligibility rule:
  - {PI && ≥½ team members} from institutes in {EU && .not.NL}
- TNA "bennies": reimbursement of travel costs to JIVE or other EVN institute(s) for a member of the team

People seem to be learning the system……



JIVE in Dwingeloo



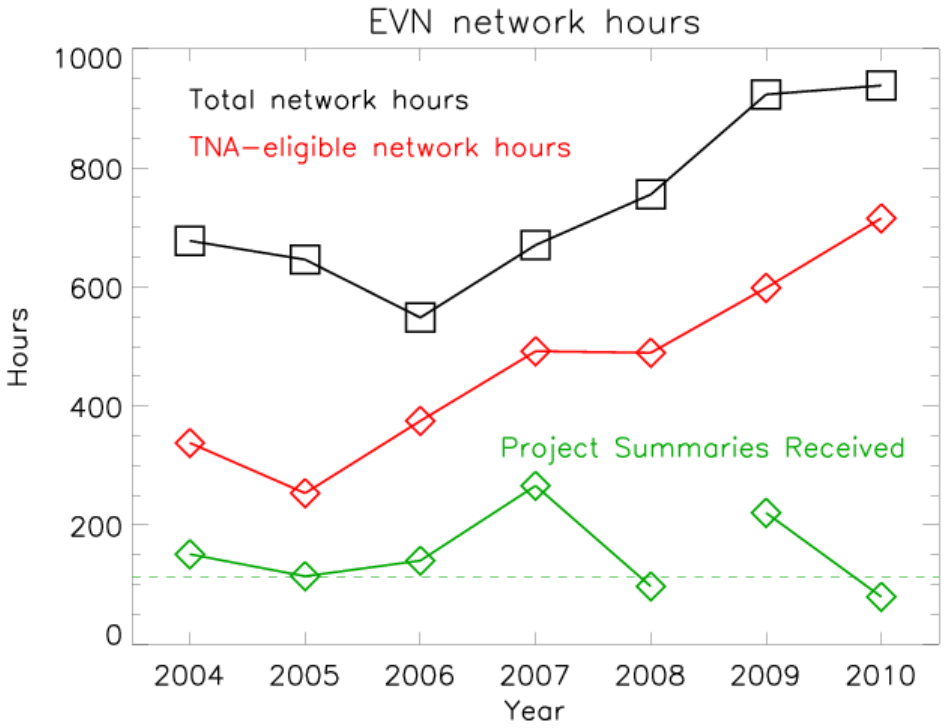
EVN Transnational Access (-)

- TNA responsibilities:
  - Project Summary (prior to travel reimbursement)
  - Questionnaires (2 similar ones: RadioNet office, EC)

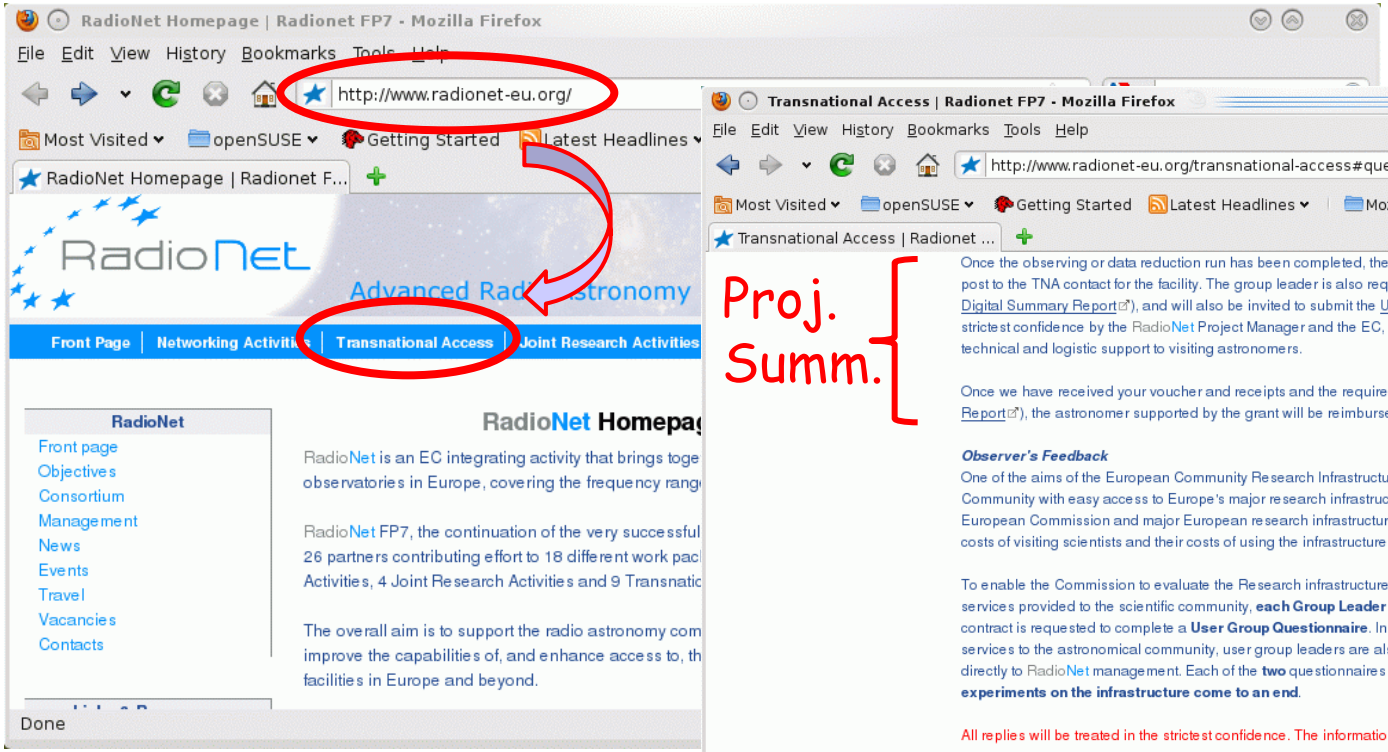
FP6: 2004—2008
FP7$_a$: 2009—2011

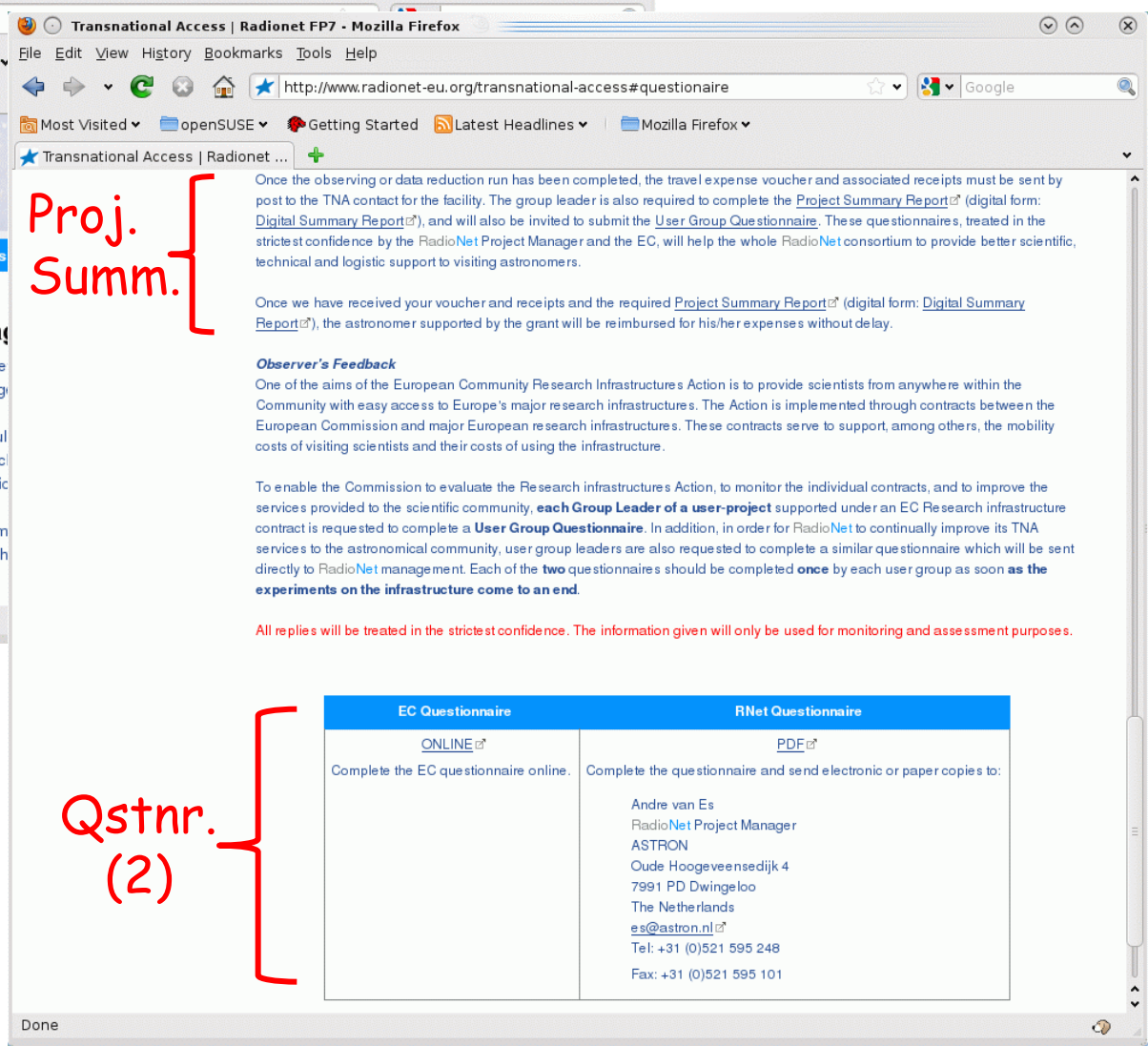
Ideally, all eligible projects submit their reports — **Must have enough to account for contracted number of acces hours**

-> KEEP BRUSSELS HAPPY!!



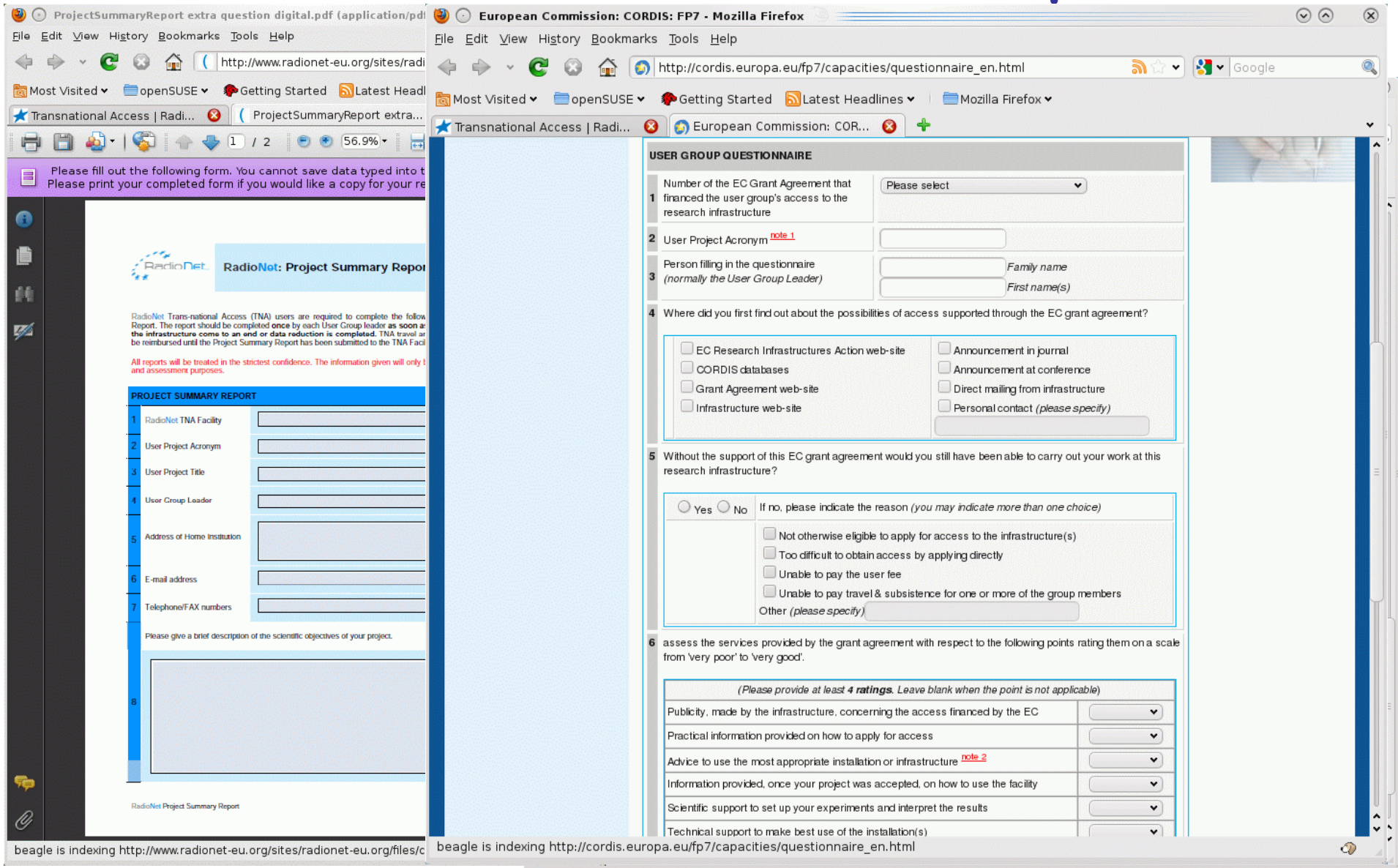
Where are these TNA Reports?





2nd half of an animated slide

Where are these TNA Reports?



Summary

- Pre-/Post-correlation PI Support
  - Help available — not required to wait until last minute
  - Archive: feedback, standard plots, FITS, pipeline
  - EVN Trans-national access
- MkIV Correlator Capabilities
  - ≤ 2048 freq.pts per SB/pol; $t_{int} \geq \frac{1}{4}s$ ($\frac{1}{8}s$, half-corr.)
  - Recirculation: spectral resolution boost if $BW_{SB}<16MHz$
  - e-EVN & new kinds of astronomy enabled
- Software correlation at JIVE
  - Applications beyond MkIV correlator
  - Capacity to grow with increased hardware base