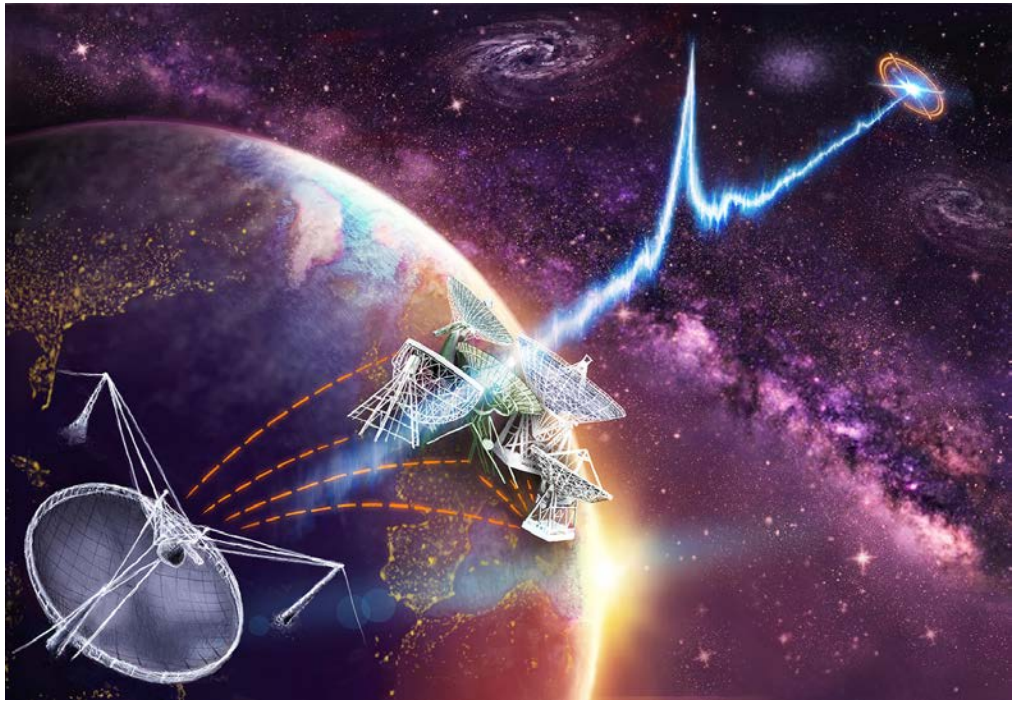
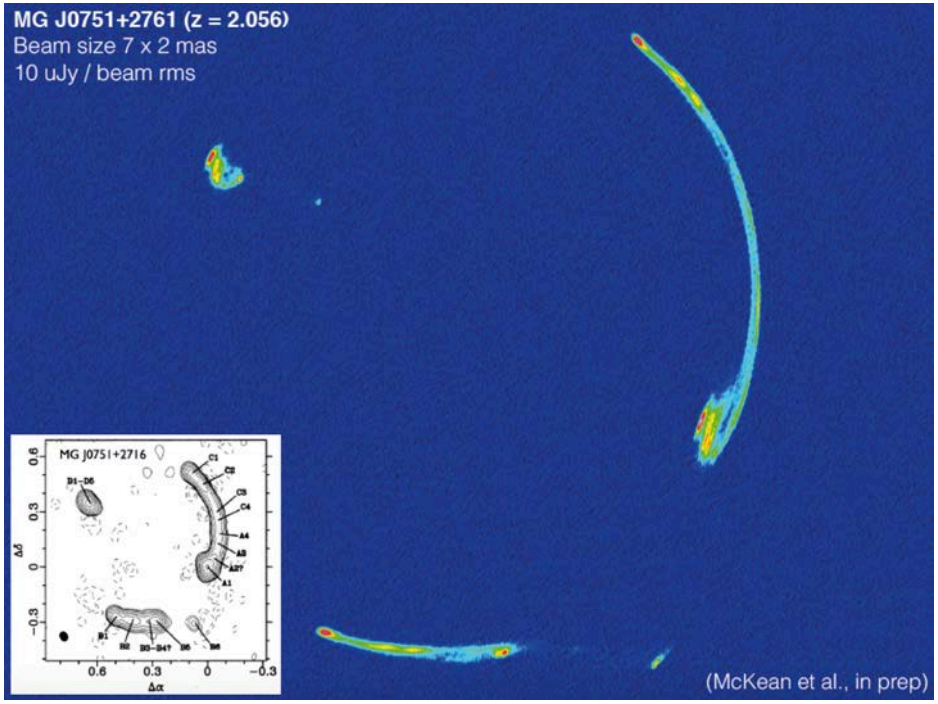
Present status and future directions of the EVN



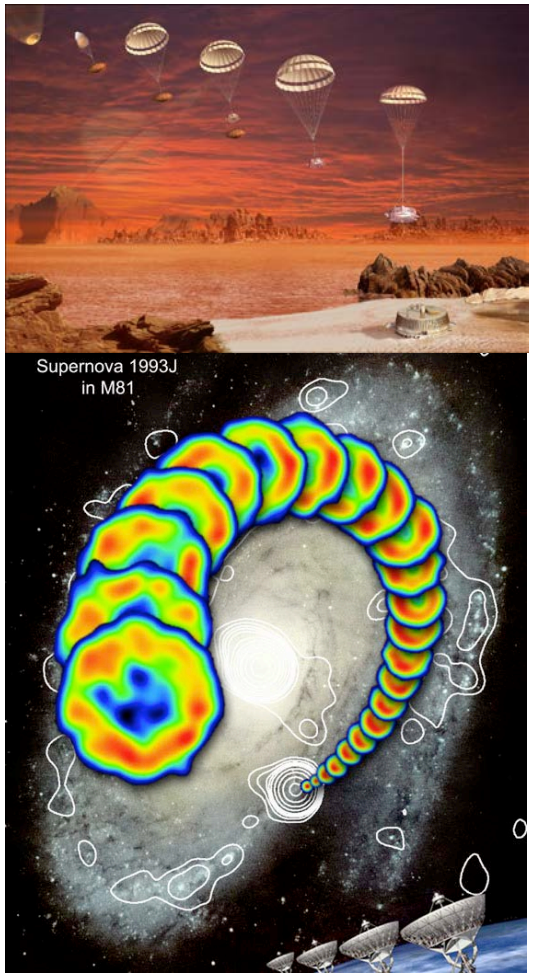


Michael Lindqvist, Onsala Space Observatory
Zsolt Paragi, JIVE

Thanks Tasso!

VLBI science

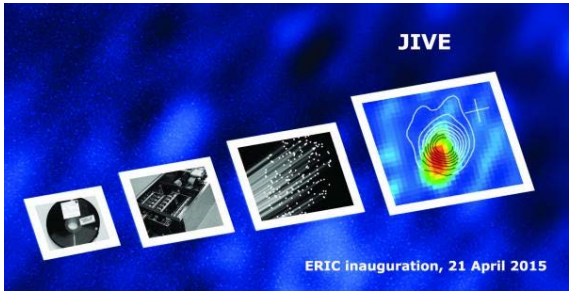
- Radio jet & black hole physics
- Radio source evolution
- Astrometry
- Galactic and extra-galactic masers
- Gravitational lenses
- Supernovae and gamma-ray-burst studies
- Nearby and distant starburst galaxies
- Nature of faint radio source population
- HI absorption studies in AGN
- Space science VLBI
- Transients
- SETI



Description of the EVN

- The European VLBI Network (EVN) was formed in 1980. Today it includes 15 major institutes, including the Joint Institute for VLBI ERIC, JIVE

- JIVE operates EVN correlator. JIVE is also involved in supporting EVN users and operations of EVN as a facility. JIVE has officially been established as an European Research Infrastructure Consortium (ERIC).



- The EVN operates an “open sky” policy

- No standing centralised budget for the EVN - distributed European facility

The network


JIVE
Joint Institute for VLBI ERIC
EUROPEAN VLBI NETWORK
Metsähovi
Onsala
JIVE
WSRT
Torun
Svetloe
Jodrell Bank
Zelenchukskaya
Badary
Irbene
Yonsei
Cambridge
Wettzell
Effelsberg
Tamna
Medicina
Yebes
Urumqi
Sardinia
Noto
Ulsan
Tianma
Arecibo
Hartebeesthoek
Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

EVN and e-VLBI

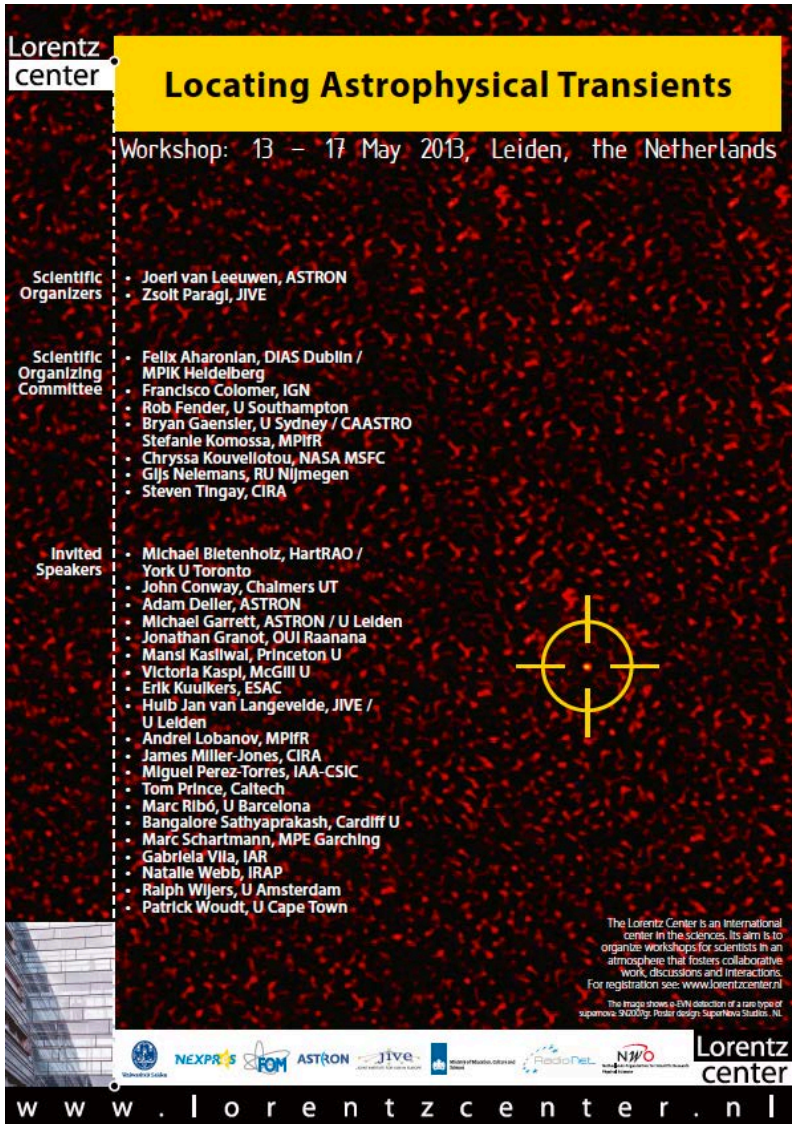
From tape reel to intercontinental light paths

- Pieces falling into place around 2003:
  - Introduction of Mark5 recording system (game changer) by Haystack Observatory
  - Emergence of high bandwidth optical fibre networks

e-VLBI

- The development of e-VLBI has been spearheaded by the JIVE/EVN (EXPReS, Garrett)
- In this way, the EVN/JIVE is a recognized SKA pathfinder

e-VLBI - rapid turn-around



- e-VLBI has made rapid turn-around possible
  - X-ray, γ-ray binaries in flaring states (including novae)
  - AGN γ-ray outbursts — locus of VHE emission
  - Other high-energy flaring (e.g., Crab)
  - Outbursts in Mira variables (spectral-line)
  - Just-exploded GRBs, SNe
  - Binaries (incl. novae, XRBs) at specific orbital/outburst phases
  - FRB
  - follow-up of Gravitational Wave events

From triggers to (early) results

e-EVN observations of V404 Cyg in outburst

ATel #7742; *V. Tudose (ISS), Z. Paragi (JIVE), J. C.A. Miller-Jones (ICRAR-Curtin), A. Rushton (Oxford), J. Yang (Chalmers), R. Fender (Oxford), S. Corbel (CEA), M. Garrett (ASTRON/Leiden), R. Spencer (Manchester)*
on 1 Jul 2015; 16:43 UT
Credential Certification: Valeriu Tudose (tudose@spacescience.ro)

Subjects: Radio, Binary, Black Hole, Transient

Referred to by ATel #: 7959

Tweet Recommend 20

Following the outburst of the transient X-ray binary V404 Cyg, we observed the system at 1.6 GHz on 2015 June 23/24 between 22:08-07:58 UT with the European VLBI Network (EVN), using the e-VLBI technique. The participating radio telescopes were Effelsberg, Hartebeesthoek, Jodrell Bank MkII, Medicina, Onsala85, Shanghai, Torun, Westerbork (5 telescopes of the phased-array).

Due to the heavy scattering towards the target, the longer baselines with Shanghai were significantly affected and had to be deleted. Significant variations in the flux density of the source (by a factor 1.5) also influenced the quality of the radio image. However, we clearly detected V404 Cyg as a point-like source (beam FWHM: 30 x 13 mas; PA: 83 deg) with a peak brightness of 166 +/- 5 mJy/beam at the position (J2000):

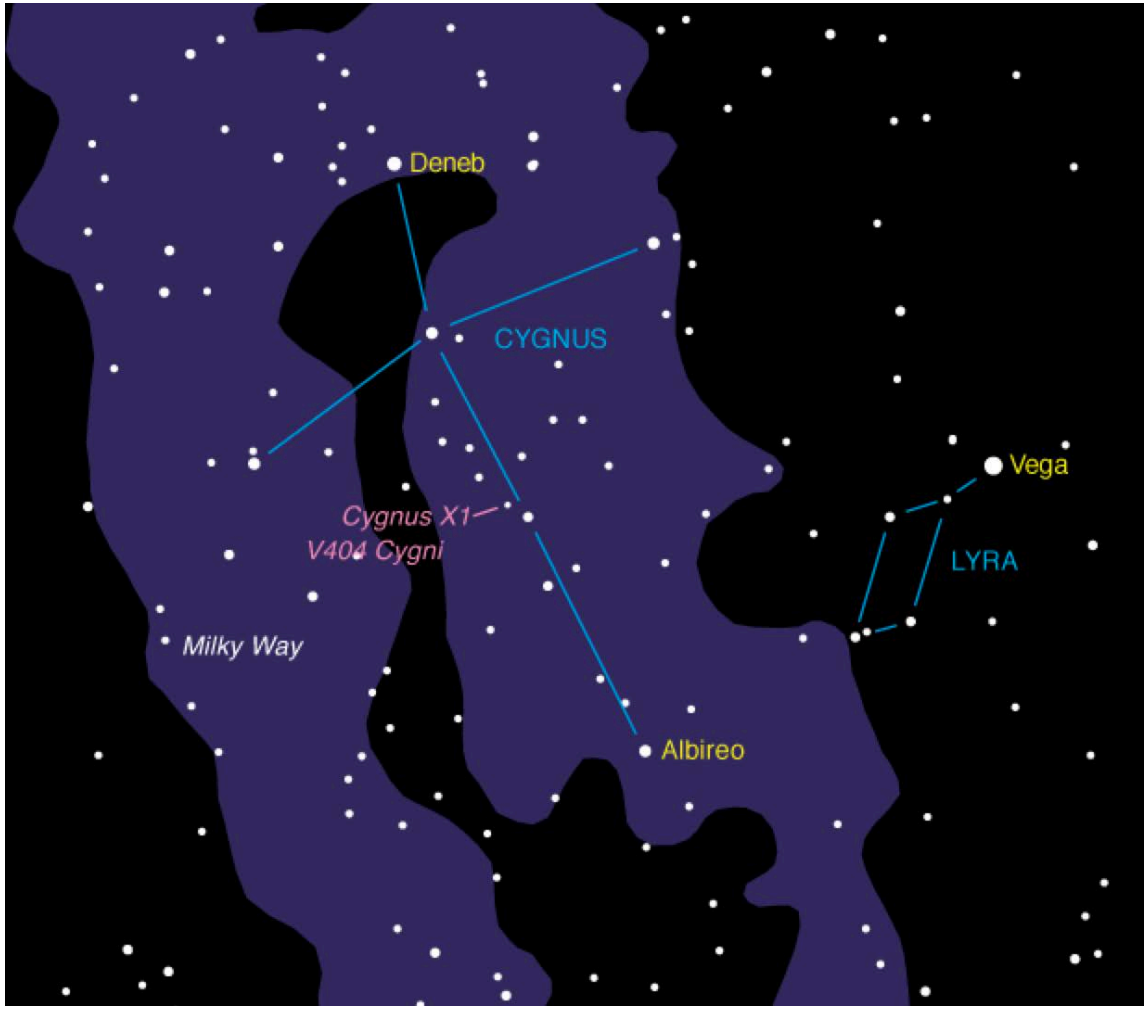
RA: 20h24m03.8183983
Dec: +33d52m01.840768"

We estimate the systematic error in astrometry to be of a few mas due to poorly modeled ionosphere and large line-of-sight scattering.

We do not see any evidence for extended radio emission above a 3-sigma rms noise level of 0.5 mJy/beam, at scales from 5 mas up to 200 mas.

We take the opportunity to note that these observations represent the last occasion on which the MFFE receivers and TADU system were used to form the Westerbork tied array. We thank the "old" Westerbork for the excellent VLBI science it has generated over the last few decades and look forward to the "new" Westerbork system employing the APERTIF Phased Array Feeds.

The European VLBI Network (EVN) is a joint facility of European, Chinese, South African, and other radio astronomy institutes funded by their national research councils. The observations presented here were obtained under the project code ET031A.



e-VLBI: Delivering the most sensitive VLBI array in a flexible way…

From triggers to (early) results

e-EVN observations of V404 Cyg in outburst

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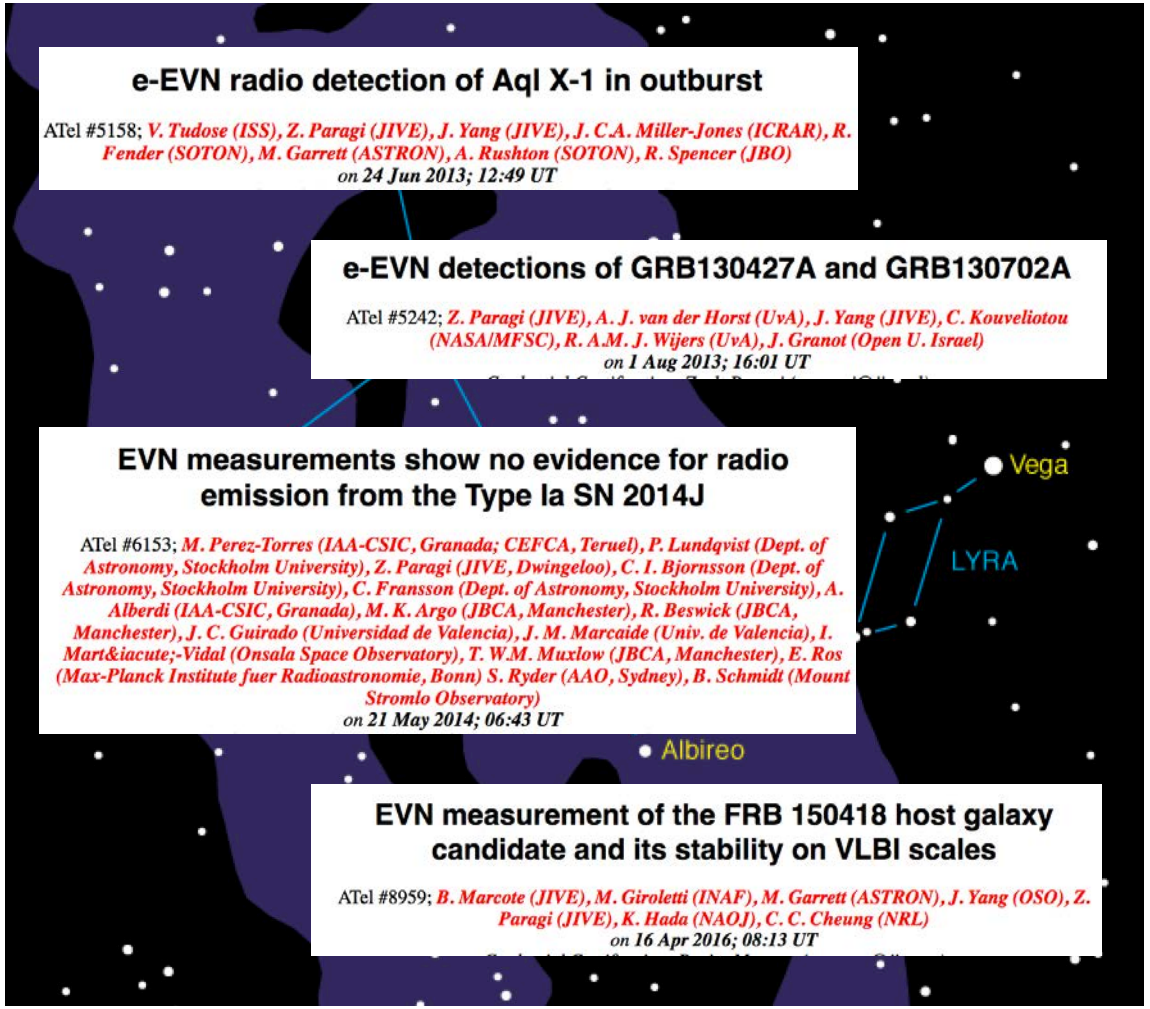


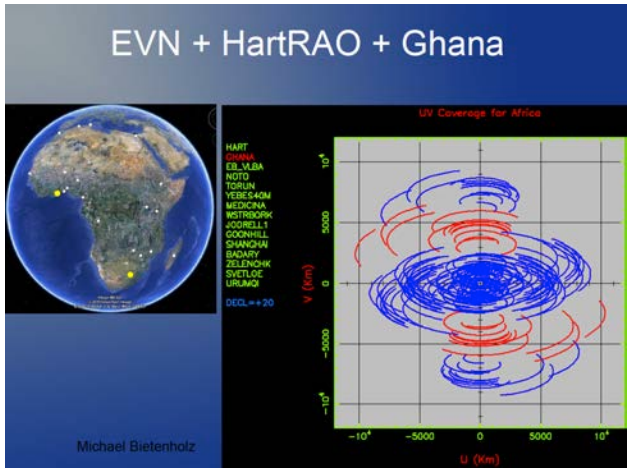
e-VLBI: Delivering the most sensitive VLBI array in a flexible way…

EVN - current status

- **Call for proposals:** 3 times per year: (February 1, June 1, October 1)
- **Wavebands:** 90, 18, 6, 5, 3.6, 1.3, 0.7 cm
- **Maximum Angular Resolution in milliarcseconds:** 5 mas (18 cm), 1.5 mas (6cm)
- **Not a full time array, the EVN observes during "sessions":**
  - **3 EVN disk sessions (3x3 weeks)**
  - **10 e-VLBI sessions (10x24 hours)**
  - **Target of Opportunity and Out-of-Session**
- **Disk recording and e-VLBI simultaneously**
- **Automated trigger e-VLBI**
- **Most data correlated at JIVE**
- **Collaborations:** EVN+NRAO/GBO/LBO, EVN+RadioAstron, EVN+LBA

Enhancing EVN capabilities

- **New telescopes and collaborations**
  - e-MERLIN with all out stations at 1 Gbps (and beyond)
  - KunMing, African VLBI Network (AVN), FAST, MeerKAT, TNRT
  - SKA



Enhancing EVN capabilities

- **Next generation receivers, backends and recording systems**
  - DBBC3: More bandwidth (2x4 GHz)
  - RadioNet: BRoad BAND EVN, 1.5 – 15.5 GHz
  - 100 Gbps technology rolled out – but not all stations are e-connected
  - **…**
- **New observing modes**
  - Commensal surveys: fast transient signals (< 2 s) in EVN data (LOCATe)
  - Open for suggestions!

Automated generic triggers

- Goal
  - Interrupt/trigger a new observation within 10 minutes (e-VLBI)
- Why?
  - Probe a new transient parameter space in the EVN
- (Almost) entirely automated
  - From trigger (e.g. via VOEvent) to observation & correlation
  - PI needs to work with JIVE
- Offered from 2015

Exploit a potential ’EVN-lite’

- Lesser-used telescopes
- Long-term monitor programs
- Would make automated trigger really useful
- Need pressure from the community

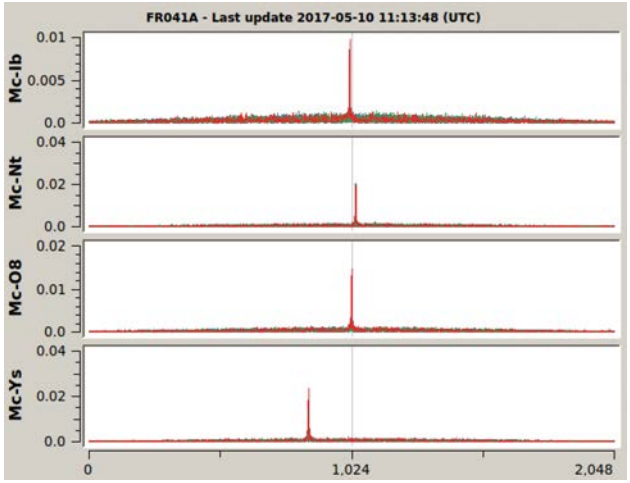
Correlator - hardware or software?

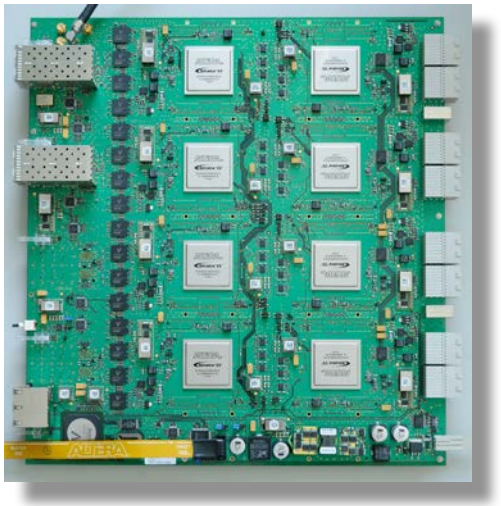
EVN Software Correlator at JIVE (SFXC):

- Fantastically flexible
- “Easy” to modify, improve, extend, expand, upgrade
- Hardware gets cheaper as time goes by
- Definitely not suited for heavy lifting
- 6-7 stations at 2 Gbps + 3-4 at 1 Gbps
- Successful tests at 4 Gbps

JIVE UniBoard Correlator (JUC)

- Once it works, it goes like the clappers
- Perfect for “simple” operations
- Not nearly as flexible
- Hard(er) to develop/debug/modify/upgrade firmware
- 16 stations on 2 available UniBoards at 2 Gbps





EVN in the SKA era

- The two instruments are complementary because the angular resolution of the EVN is better
- EVN also observes at shorter wavelength not available to SKA1
- Very-high-sensitivity VLBI observations will be possible using SKA1-MID acting as a single phased-up element
- Interest in the EVN will increase further in the SKA era as there will be increasing demand for follow-up VLBI observations at high resolution

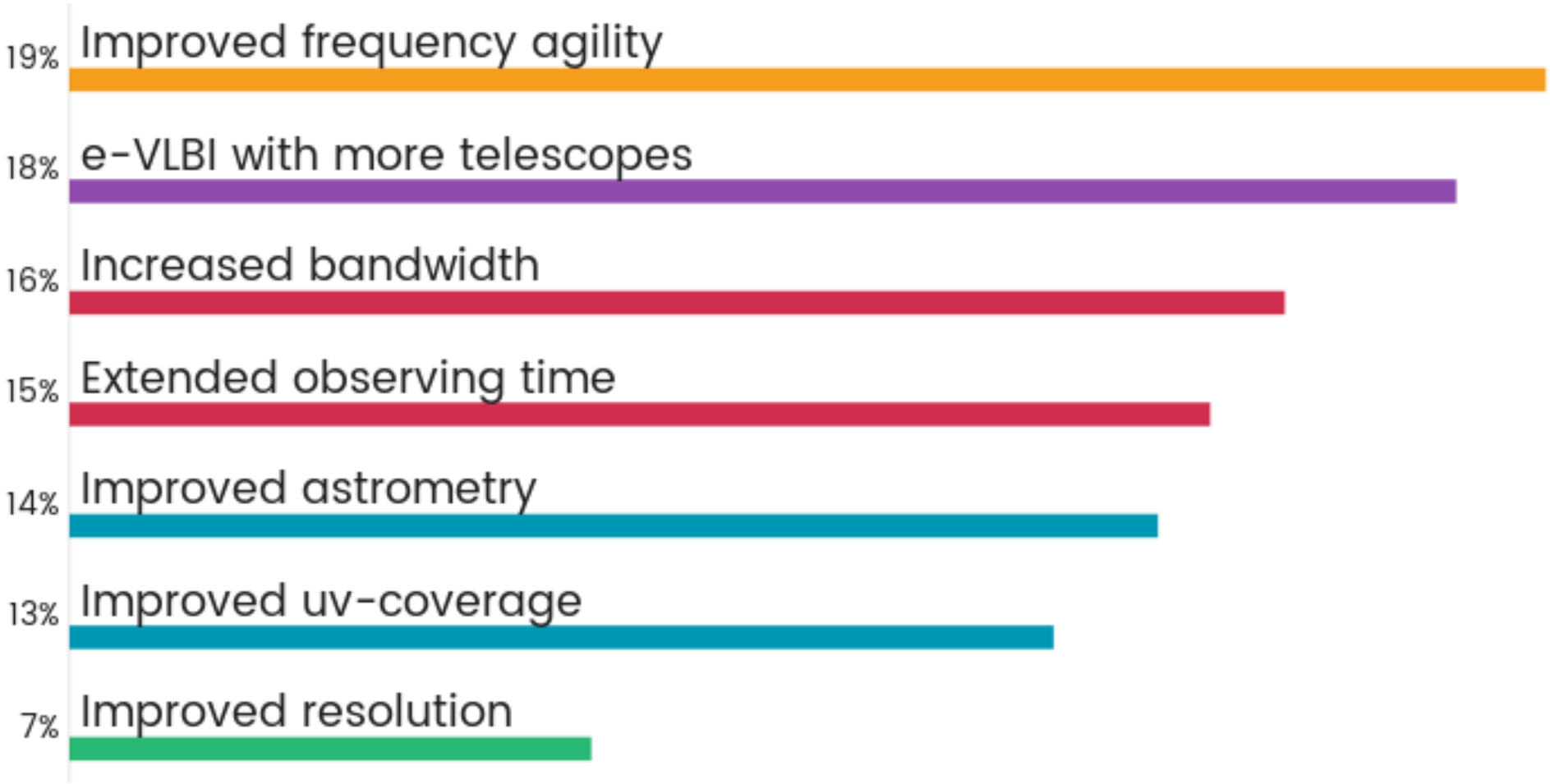
Max-Planck-Institut für Radioastronomie

VLBI with Solar Power Towers as SKA?

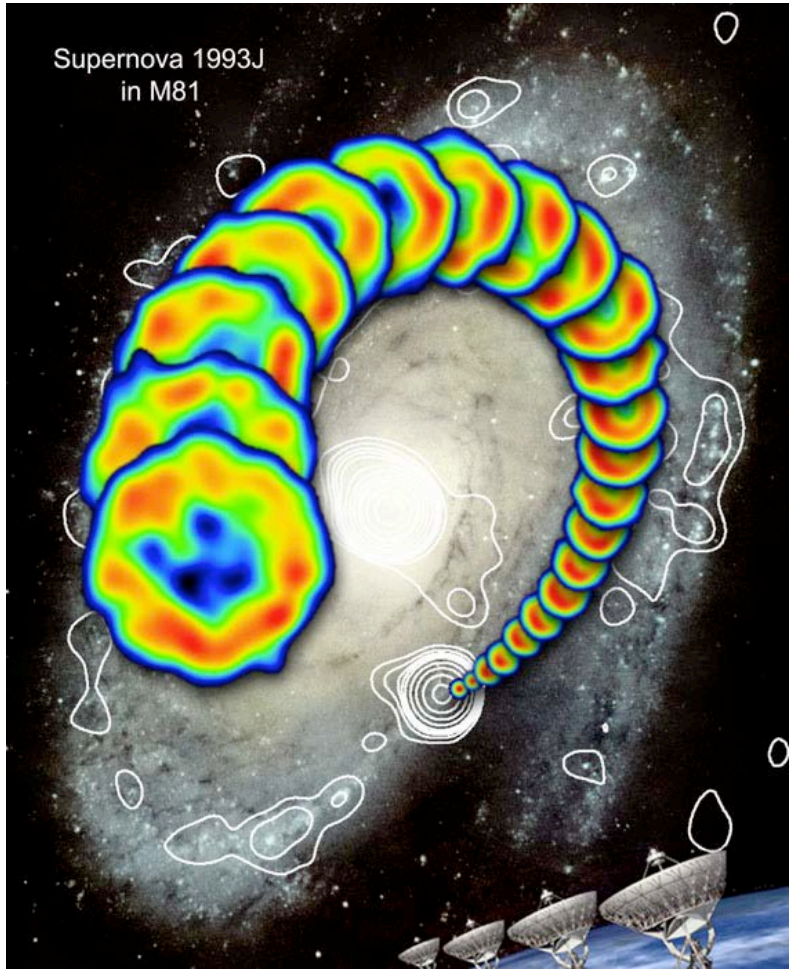
Alan Roy, Olaf Wucknitz, Ivan Camara,

Most important – the users!

In which way should the EVN develop?



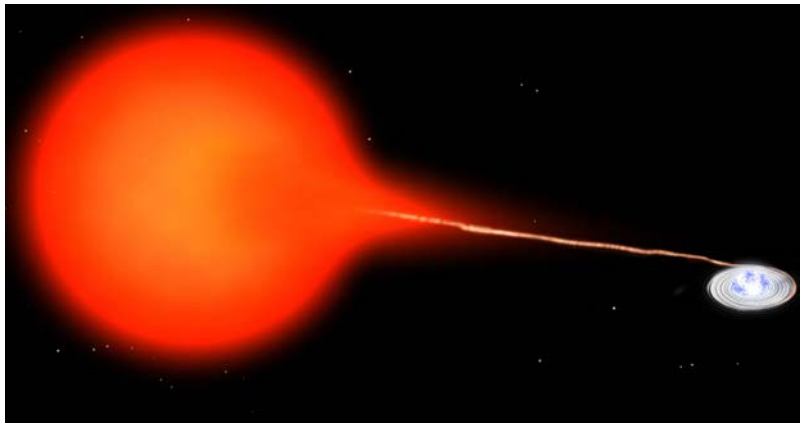
Supernova 1993J in M81

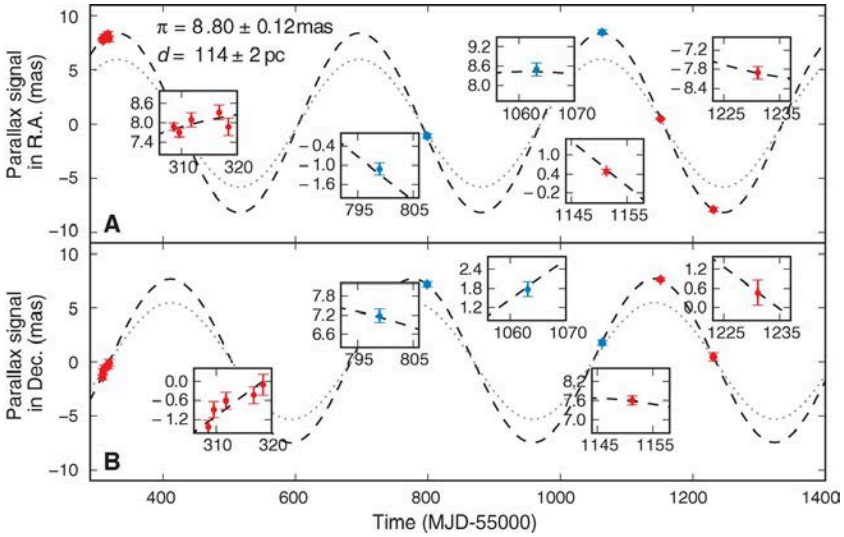


Bartel et al.; Marcaide et al.

- SN 1993J is a textbook example where one can trace the physical and structural evolution of an supernova, an exploding star
- From 1993 it has been the subject of intense studies

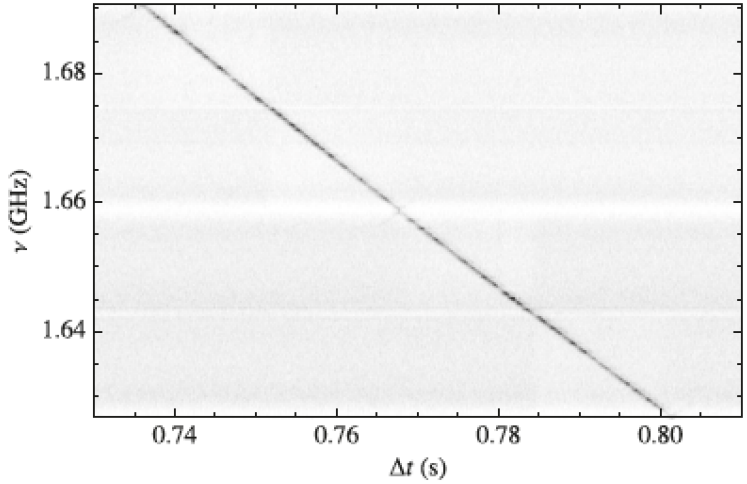
The dwarf nova SS Cygni

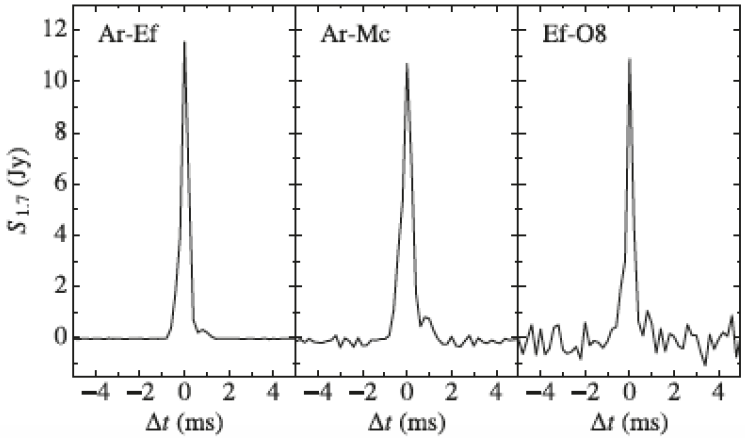




- SS Cyg is perhaps the prototype dwarf nova, the outbursts result from changes in the rate at which matter moves through the disk onto the white dwarf
- Using VLBA and the EVN, Miller-Jones et al., (2013) were able to accurately measure the distance to SS Cyg
- VLBI data places SS Cyg substantially closer, 114±2 pc, than HST data, 159±12 pc
- The new distance measurement has solved the puzzle of SS Cygni's brightness, it fits the theories after all

The Repeating Fast Radio Burst FRB 121102 as seen on milliarcsecond angular scales





SETI experiment with EVN/VLBI

- So far, few reported VLBI projects
- Using the LBA, Rampadarath et al. (2012) observed the M-dwarf star Gliese 581
- Demonstrated the efficiency of VLBI at discriminating between SETI signals and RFI
- Monitor potential habitable planets with EVN-lite?

The Astronomical Journal, 144:38 (8pp), 2012 August doi:10.1088/0004-6256/144/2

THE FIRST VERY LONG BASELINE INTERFEROMETRIC SETI EXPERIMENT

H. Rampadarath, J. S. Morgan, S. J. Tingay, and C. M. Trott[1]
International Centre for Radio Astronomy Research, Curtin University, GPO Box U1987, Perth, WA, Australia; hayden.rampadarath@icrar.org
Received 2011 November 28; accepted 2012 May 24; published 2012 June 28

ABSTRACT

The first Search for Extra-Terrestrial Intelligence (SETI) conducted with very long baseline interferometry (VLBI) is presented. By consideration of the basic principles of interferometry, we show that VLBI is efficient at discriminating between SETI signals and human generated radio frequency interference (RFI). The target for this study was the star Gliese 581, thought to have two planets within its habitable zone. On 2007 June 19, Gliese 581 was observed for 8 hr at 1230–1544 MHz with the Australian Long Baseline Array. The data set was searched for signals appearing on all interferometer baselines above five times the noise limit. A total of 222 potential SETI signals were detected and by using automated data analysis techniques were ruled out as originating from the Gliese 581 system. From our results we place an upper limit of 7 MW Hz^{-1} on the power output of any isotropic emitter located in the Gliese 581 system within this frequency range. This study shows that VLBI is ideal for targeted SETI including follow-up observations. The techniques presented are equally applicable to next-generation interferometers, such as the long baselines of the Square Kilometre Array.

Key words: radio continuum: planetary systems – stars: individual (Gliese 581) – techniques: interferometric

Summary

- Development can come either bottom-up (new technology looking for astronomical uses) or top-down - (defining astronomical problems first and finding technical solutions afterward). EVN does both.
- Continuously being upgraded, new telescopes, hardware, network, correlators, observing modes
- The future for the EVN is looking bright also when we enter the SKA era
- EVN - formed in 1980, still ready for the unexpected!

Thank you for your attention! Any questions?