Present status and future directions of the EVN

Michael Lindqvist, Onsala Space Observatory
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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

http://www.evlbi.org/
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

Image by Paul Boven (boven@jive.eu). Satellite image: Blue Marble Next Generation, courtesy of Nasa Visible Earth (visibleearth.nasa.gov).

http://www.evlbi.org/
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

- 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-VLBI observations of V404 Cyg in outburst

ATel #7423: V. Tadross (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: Valeria Tadross (vadross@spacescience.ru)

Subjects: Radio, Binary, Black Hole, Transient

Referred to by ATel #: 7959

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 22:08:07-07:58 UT with the European VLBI Network (EVN), using the e-VLBI technique. The participating radio telescopes were Effelsberg, Hartebeesthoek, Jodrell Bank MKII, Medicina, Onsala55, 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 MPH receiver 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

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We take the opportunity to note that these observations represent the last occasion on which the MFPE 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.

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e-VVLBI: 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 (6 cm)
- **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
VLBI with Solar Power Towers as SKA?

Alan Roy, Olaf Wucknitz, Ivan Camara,

Gemasolar, Spain
Most important – the users!
In which way should the EVN develop?

- Improved frequency agility: 19%
- e-VLBI with more telescopes: 18%
- Increased bandwidth: 16%
- Extended observing time: 15%
- Improved astrometry: 14%
- Improved uv-coverage: 13%
- Improved resolution: 7%
Supernova 1993J in M81

- SN 1993J is a textbook example where one can trace the physical and structural evolution of a supernova, an exploding star.

- From 1993 it has been the subject of intense studies.

Bartel et al.; Marcaide et al.
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?
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?