VLBI in Europe

Huib van Langevelde
JIVE & Leiden
EVE: the European VLBI Network

- Big telescopes in number of European countries
- 20+ possible antennas
  - Ef, Mc, On, Jb, Nt, Tr, Wb, Sh, Ur, Hh, Ar, Mh, Ys, Sv, Ro, Ku, My, Wz, Sm, Ny, Ka
  - Ran by up to 14 different organizations
  - Can include MERLIN
  - And 12 more antennas for “Globals” with NRAO

- Covering range of frequencies
  - Workhorse frequencies 18cm, 6cm,
  - Also available: SX, 5cm, 1.2cm
  - And at limited stations 90cm, 21cm, UHF, 50cm, 2cm, 0.7mm

- Reaching mas resolutions
  - From 15mas for 1.4 GHz EVN (can add MERLIN for brightness sensitivity)
  - To 1 mas at 5GHz with Asian, African or American baselines

- Sensitivity of 5μJy in 8hr at 1.4 GHz
  - Combination of Big Antennas and 1 Gbps bandwidth
  - Big antennas also vital for spectroscopy (mJy sensitivity)

- Operational approximately 60 days/year
  - 3 sessions augmented with e-VLBI once a month
Donnerstag, 5. Juli 12
Joint Institute for VLBI in Europe

• Promote the use and advance of VLBI for astronomy
  • Central correlation; User services; Network support; Innovation; EC liaison/representation

• Founded in 1993

• South Africa joined in 2012
  • Base budget from partners in 8 countries:
    • China, France, Germany, Italy, Spain, Sweden, South Africa, United Kingdom, Netherlands
  • Large number of external projects
  • Hosted by ASTRON

• Just been reviewed
  • Next 5-year funding cycle
  • In a newly build wing

• Want to become an ERIC
  • European legal entity
JIVE: User hub of EVN

- User interfaces
  - Proposal tool
  - Sensitivity calculator
  - EVN observation scheduling
  - Data product
    - And related software interfaces
  - Archive
    - proprietary for one year after observation
    - Pipeline: calibration info & preliminary images

- User support
  - Offer help in all stages
  - Check the correlation of all user data
  - Pipeline calibration and imaging
  - Visitor facilities
    - EVN TransNational Access programme
      - Open for user visits
      - Point of contact various RadioNet funds

- Telescope support
• Went to disk in 21st century
  • Enormous boost in robustness
  • Correlator efficiency
• The EVN software correlator at JIVE (SFXC)
• 9 stations 1Gbps real-time
  • Pulsar gating
  • Space craft applications
  • Spectral polarimetry
  • Many field of views
- Connections work great!
  - often dedicated light paths
  - Use optimized protocols
- Closed feedback loop makes e-VLBI more robust
R+D: Introduced e-VLBI as operational facility:
Connections work great!

- often dedicated light paths
- Use optimized protocols
- Closed feedback loop makes e-VLBI more robust

R+D: Introduced e-VLBI as operational facility.

Donnerstag, 5. Juli 12
We detected a source with a peak brightness of 422 mJy using the e-VLBI technique (see also Supplementary Information). Improved the flexibility of the European VLBI network (EVN), baseline interferometry (e-VLBI) technique, which significantly improves the radio imaging. We observed SN 2007gr at 5 GHz with a subset of the EVN on 2007 August 15.51. Later optical observations revealed a radio jet from the otherwise quiescent SN2007gr on 2007 November 5–6. The off-source noise in the map is 13 mJy per beam. The VLBI location of RA 02 h 43 min 27.971 s, Dec. +37° 20′ 9.6 s indicates that at lower resolution there is a small apparent position shift of 6.85 mas at a position angle of 53.3 degrees.

We conclude that in SN 2007gr a small fraction of the ejecta produced a low-energy mildly relativistic bipolar radio jet, while the Gamma-ray burst (GRB) activity is related to a highly relativistic jet. The radio and optical data of SN 2007gr indicate a typical type Ic supernova with ejecta velocities ranging from 2,500 to 3,000 km s^{-1}.
Observations

• Now an operational facility
  • Guaranteed 10 x 24h per year
    • And quite bit more in practice (>30%)

• Flexible ways to get into e-VLBI
  • Request e-VLBI for fast response
    • Can be approved by PC for existing sessions
  • Or for triggered proposals
    • To be submitted at regular proposal dates
    • Requires specific trigger criteria
  • Short requests <2hr
    • e.g. calibrator checks
  • Target of Opportunities
    • EVN agreed to have substantially more of these
  • Or just because you prefer to e-VLBI
  • Or just because the EVN prefers to do e-VLBI
    • Because of logistics or (disk) resources
Observations

• Now an operational facility
  • Guaranteed 10 x 24h per year
    • And quite bit more in practice (>30%)
• Flexible ways to get into e-VLBI
  • Request e-VLBI for fast response
    • Can be approved by PC for existing sessions
      • Or for triggered proposals
        • To be submitted at regular proposal dates
          • Requires specific trigger criteria
            • Short requests <2hr
              • e.g. calibrator checks
• Target of Opportunities
  • EVN agreed to have substantially more of these
    • Or just because you prefer to e-VLBI
      • Or just because the EVN prefers to do e-VLBI
        • Because of logistics or (disk) resources

• Because of logistics or (disk) resources
New project: NEXPReS

- Correlate in real time what you can,
- Correlate later what you need

- Allow multiple correlator passes
- Continue to connect more telescopes
- Reliable operations
  - addressed by simultaneous recording
  - and get the best of both worlds
- NEXPReS maintains expertise
  - Collaborations with NRENs
  - 3.8 M€ for 3 years, 15 partners
Options for VLBI

- Improve imaging: more telescopes
  - New telescopes: Latvia, Sardinia, China, Ukraine
  - New locations: Africa, Goonhilly, Madeira, Brasil....
  - Joint observations with e-MERLIN

- Need for better sensitivity, more digital bandwidth
  - with more bit sampling against interference
  - Accommodating number of space applications

- Especially for higher frequencies
  - As dictated by science case

- Science synergy with new (survey) instruments
  - Apertif, LOFAR, MeerKAT, ASKAP
  - eMERLIN, EVLA, ALMA

...
VLBI future science case

• Science case has been developed
  • http://www.evlbi.org/publications/publications.html

• Fit well with scientific priorities
  A. Extremes of the universe
  B. Evolution of Galaxies
  C. Birth of stars and planets
  D. How do we fit in

---

Donnerstag, 5. Juli 12
Needed: next generation correlator

- Aiming for 32 station 10+ Gbps FPGA correlator
  - Flexibility of software correlator
  - Power consumption should be much better
  - Started in RadioNet::UniBoard, next step in RadioNet3

- Feeding into the SKA programme
  - As well as being used for EVN, LOFAR, WSRT, Effelsberg
Needed: next generation correlator

- Aiming for 32 station 10+ Gbps FPGA correlator
  - Flexibility of software correlator
  - Power consumption should be much better
  - Started in RadioNet::UniBoard, next step in RadioNet3

- Feeding into the SKA programme
  - As well as being used for EVN, LOFAR, WSRT, Effelsberg
VLBI for Space applications...

BepiColombo

ExoMars

MarcoPolo-R?

RadioAstron

Huygens

JUICE-Laplace?
User software

• User interfaces EVN include processing software
  • VLBI still largely dependent on AIPS

• JIVE managed RadioNet ALBUS, ALBiUS
  • Advanced Long Baseline interoperable User Software
    • Adopt new algorithms for RadioNet facilities
    • And make existing algorithms available for new facilities
  • Resulted in development of ParselTongue
    • “AIPS talking Python”: few hundred users
  • Work on interoperability and casa fringe fitting

• Continues in RadioNet3: HILADO
  • User models; casa VLBI pipeline
    • Warning: not the same as mm-VLBI processing

• Interest shared with other SKA pathfinders
  • Dutch collaboration with ALMA regional centre ALLEGRO
  • HPC processing of radio data
Interest in ALMA-VLBI

• Scientific interest among JIVE staff

• Expertise in real-time connectivity
  • Including to South America
  • Maybe not directly relevant at this time

• Familiar with (VLBI) correlators
  • Have expertise working with NRAO on correlator GUI

• User interfaces, scheduling, acquisition control
  • User software, casa for VLBI
    • Admittedly mm-VLBI can be different

• In addition to expertise around the EVN

• Serving European (cm) community
  • Large scale correlator operations
  • User support in all stages of process
  • Data curation, archive, access methods
JIVE Review

• public at http://www.jive.nl/

• Excellent marks in all areas
  • Only imperfection on spreading the VLBI gospel

• Endorsing JIVE strategy
  • Current SFXC processing
  • FPGA correlator
  • Space programme

• Good recommendations
  • VLBI can be more widely visible
  • Keep score on publications
  • Proceed careful with governance
Synergy with the SKA

• Lots of overlap with SKA technology
  • Benefit from digital components
  • Connectivity
    • Data en timing
  • Processing software
  • Maybe even antennas

• Important for SKA
  • Community building
  • Training aspects
  • Home telescope
  • Outreach
J2211-13, 0.17 Jy reference source at a distance of 2.5 deg from target.

VEX track

8.4 GHz
2011.03.28

3C446, 2.5 Jy Fringe Finder at a distance of 15 deg from target

09h05m TDB
OnWzMaMcMhSvZc +YS

09h30m TDB
OnWzMaMcYSsMhSvZc

09h55m TDB
OnWzMaMcYsMhZc

10h20m TDB
OnWzMaMcYsZc

10h45m TDB
OnWzMaMcYs

EM081c: On, Wz, Mc, Ma, Ys, Mh, Sv, Zc

Cimo, Duev, Molera et al. 2011, in preparation

Donnerstag, 5. Juli 12
New capabilities include 8192 spectral points on Orion KL water masers flare
First 3Gbps fringes with Chinese tels. Combining CDAS and Mk5

First correlation of European - Korean baselines at K-band
Future 2: clock distribution

• VLBI depends on availability of extremely accurate clock and frequency standard ($10^{-15}$)
  • All telescopes must have 100k€ maser clock
    • In principle can be distributed over dedicated fibre

• Investigate clock distribution on public network
  • Requires dedicated wavelength and stable amplification
  • To measure return loop

• Will improve stability, operations
• And many more VLBI sites!
Finally

• User community is the most precious asset
  • Make sure the interfaces are uniform and robust
    • User software, User support, Training, Proposal handling, Scheduling
  • Do not increase number of interfaces to different networks
    • but reduce and simplify
    • We do not have a user community to run 6 different networks
  • e-VLBI is helping us to foster user involvement
    • Gets the excitement of astronomical observation into VLBI

• Should build on these e-VLBI meetings
  • Could have a wider topic, they already have
  • BTW, next EVN symposium is in Bordeaux, October 2012

• Pushing technology is part of the mission
  • e-VLBI has helped keeping us visible

• Long-term common goal?
  • Global VLBI array which react flexible on user demands
    • Needed to satisfy scientists used to SKA/ALMA
First fringes to Irbene, near Ventspils, Latvia