The development of global VLBI

Huib Jan van Langevelde, director of JIVE
Acronyms/Organizations involved

• **VLBI**: Very Long Baseline Interferometry
  - A radio-astronomical technique with telescopes thousands kilometres apart to obtain highest possible resolution

• **EVN**: European VLBI Network
  - Consortium of (European) Telescopes
    - 30 year of collaboration, open to global collaborations

• **AVN**: African VLBI Network

• **JIVE**: Joint Institute for VLBI in Europe
  - Funded by radio-astronomy institutes and research councils
    - NWO (NL), ASTRON (NL), STFC (UK), INAF (IT), ICN-IG (ES), OSO (SE), CAS (CN), CNRS (FR), MPG (DE), NRF (ZA)
  - Promote the use and advance of VLBI (for astronomy)
    - Central correlation; User services; Network support; Innovation R&D
    - Exemplary science; EC liaison/representation
    - With ambition to become ERIC (European Research Infrastructure Consortium)
Hartebeesthoek a very valued member of the EVN
- Now with 2 antennas on site
- North-south sensitivity on long baselines

South-Africa’s NRF joined JIVE foundation on May 10

Recognizing a joint interest:
- VLBI with KAT7 and MeerKAT
- The potential of the AVN
- Human capacity building
VLBI: make a giant telescope

- Radio interferometry measures Fourier components of sky
- Atmosphere transparent for radio emission 100M - 100GHz
- Big telescopes more sensitive, long baselines high resolution
- Sample, digitize and record and tag very accurate time
- Send to correlator, measure interference
- Compute image back from measurements

maser clock

correlator

weak radio source

recorder
The European VLBI Network

- Big telescopes in number of European countries
  - Run by national agencies
- Important partners outside EC countries

- Network defines telescope:
  - Resolution of astronomical picture depends on baseline length
  - Sensitivity depends on telescope size and digital equipment
  - Image quality on number and distribution of receptors

- Arranged in Consortium
  - No exchange of funds
  - Except central operations of JIVE
Sardinia 64m

Arecibo, Puerto Rico

Hartebeesthoek, South Africa

Irbene LV

3 telescopes in Russia

4 telescopes in China
The EVN in numbers

- EVN consortium with 20+ possible antennas
  - Ef, Jb, Cm, Wb, On, Mc, Nt, Tr, Ys, Ur, Sh, Hh, Ar, Sv, Zc, Bd, Wz, Ro, Km, My, Na, Sm
  - Ran by up to 14 different organizations
  - And 12 more antennas for “Globals” with NRAO
    - + other DSN (Go, Ti), Japanese (Ka, Ym, Vm, Vs), & Australian (Pa, Ho, At, Mp, Cd)

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

- Reaching mas resolutions
  - From 15mas for 1.4 GHz EVN (can add MERLIN for 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 75 days/year
  - 3 sessions augmented with e-VLBI once a month

- Typically 80 experiments per year scheduled
  - Quite competitive at factor 2 oversubscription
  - Serves European community and beyond (open skies)
  - Access for non-specialist through EC-funded RadioNet
• Requires correlators at JIVE
  • Dedicated supercomputer from 90s
  • Recently developed software correlator
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
  • Feedback on performance
Considerable R+D effort
- for VLBI innovations
- with important EC support
- together with (EVN) partners

Enhancing global e-VLBI

Defining many-station, large-bandwidth, economic correlators
Relation to the SKA

• The e-EVN is a recognized SKA pathfinder
  • For long-haul connectivity (on public fibre)
  • For real-time operations and science exploitation
  • For distributed computing issues

• Feeding into SKA technology and making use of it
  • Correlator programme (RadioNet)
    • also for Aperture Array beam-formers
  • Computing and data distribution (NEXPreS)

• Scientific synergy with other pathfinders:
  • Follow-up large scale surveys (cosmology, pulsars)
  • Transient science
  • Space applications

• Training and outreach, capacity building
  • Scientists and engineers for SKA era (RadioNet)
  • Educating general public about (radio) astronomy
    • Operational telescopes in populated regions
VLBI science case

• Recently reviewed
  • Review of JIVE
  • ASTRONET radio panel

• Recognized science priorities
  • Extremes of the universe
  • Evolution of Galaxies
  • Birth of stars and planets
  • How do we fit in
Opportunities for VLBI

- Science case calls for enhancements
  - Increase sensitivity
    - more digital bandwidth
  - Go to higher frequencies
  - Double number of stations
    - Joint observations with e-MERLIN
    - Others: Goonhilly, Portugal, Ireland, Ukraine, Brasil....
  - Preferably connected in real-time
- Stations in African VLBI Network
  Very relevant for this!
  - And MeerKAT connection too

- Science synergy with new technology (survey) instruments
  - e.g. Transients from LOFAR
  - or Pulsars from Apertif
  - MeerKAT Galactic surveys
Target AVN:

Necessary ingredients for VLBI:

- **A telescope**
  - They are already there!
  - Being retrofitted by African collaboration (?)
  - Including receivers for common frequencies

- **VLBI instrumentation**
  - Increasingly off-the-shelf, but compatibility required
    - Maser clock, digitization equipment, recorder, interface computer

- **Competent staff (technical & scientific)**
  - Training through workshops and exchange programmes
  - Means to operate
  - Man station, but also consumables (power, disks, connectivity, logistics)

- **Possibility for a win-win-win situation**
  - Attract local talent for science and engineering
  - Get everybody ready for SKA (involve Africans)
  - Enhance the scientific potential of the European research infrastructure
Target AVN:

Necessary ingredients for VLBI:

- A telescope
  - They are already there!
  - Being retrofitted by African collaboration (?)
- VLBI instrumentation
  - Increasingly off-the-shelf, but compatibility required
  - Maser clock, digitization equipment, recorder, interface computer
- Competent staff (technical & scientific)
  - Training through workshops and exchange programmes
- Means to operate
  - Man station, but also consumables (power, disks, connectivity, logistics)

Possibility for a win-win-win situation

- Attract local talent for science and engineering
- Get everybody ready for SKA (involve Africans)
- Enhance the scientific potential of the European research infrastructure
Target AVN:

Necessary ingredients for VLBI:

- **A telescope**
  - They are already there!
    - Being retrofitted by African collaboration (?)
    - But SKA programme also offers dish technology
  - Including receivers for common frequencies

- **VLBI instrumentation**
  - Increasingly off-the-shelf, but compatibility required
    - Maser clock, digitization equipment, recorder, interface computer

- **Competent staff (technical & scientific)**
  - Training through workshops and exchange programmes
  - Means to operate
  - Man station, but also consumables (power, disks, connectivity, logistics)

- **Possibility for a win-win-win situation**
  - Attract local talent for science and engineering
  - Get everybody ready for SKA (involve Africans)
  - Enhance the scientific potential of the European research infrastructure
Opportunity for collaboration

• EVN has expertise for this process
  • May offer partnership in commissioning VLBI elements
    • Has worked for China, Latvia
  • Training events already in place
  • Exchange programmes could be implemented
  • Advice on compatible equipment and components

• JIVE can assist
  • Correlation is the ultimate test
  • User training/schools/exchanges
  • Project coordination
    • EC funding?
    • Central equipment purchases
    • Science programmes

• VLBI offers a growth path
  • Complementary science to pathfinders
  • Partnership in all areas
    • Science and operations
    • Technology development
The future of VLBI in the SKA era

- Siting decision much welcomed
  - Allows for Africa-Europe synergy
- Global array with African dishes in SKA-1 era
  - Already ~10% of SKA-2 sensitivity
  - Complements SKA-1
    - with sensitive long baselines
    - at high frequencies
  - Team up with SKA-2
    - Joint operations/user support
- VLBI offers a growth path
  - Complementary science to pathfinders
  - Partnership in all areas
    - Science and operations
    - Technology development
- European radio astronomy
  - Has an open structure
  - RadioNet platform
Full information available, mailto: langevelde@jive.nl