e-VLBI

- Radio interferometers
- How does VLBI work?
- What science do we do with VLBI?
- How has the technology changed?
- Advantages of e-VLBI
- e-Astronomy
In a simple interferometer, two telescopes act as one with a diameter of $B \cos \Phi$.

We measure a fringe pattern whose amplitude and phase information on the structure and position of the radio source.
Earth rotation helps

• As the Earth rotates, the apparent separation of the telescopes and their orientation changes as a function of time as seen from the radio source.

• At each instant, an effectively different telescope observes the source giving new information on its structure.
Radio telescope arrays

create images by interferometry

• the more telescopes simultaneously in the array, the better the image quality
• the greater the bandwidth detected, the higher the sensitivity
• data transported is incompressible “white” noise
• → 24x365 operation

networks of radio telescopes spread over distances up to 1000’s of km provide zoom lenses for astronomers
Short baseline interferometers

Very Large Array

Westerbork Synthesis Radio Telescope
Longer baseline interferometers
Very Long Baseline Interferometers

THE WORLD OF VERY LONG BASELINE INTERFEROMETRY

- EVN
- VLBA
- Asia Pacific Telescope (APT)
- Unaffiliated Telescopes
The ISAS satellite HALCA and the Usuda 64m antenna conducted their first successful interferometric test on 7th May 1997 during observations of the quasar PKS1519-273 at a wavelength of 18cm. The spike shows the first 'fringes' --- the coherent combination of the signals from the two
how do we currently do this?

\[ \Rightarrow \text{widely separated telescopes} \]

\[ \Rightarrow \text{data recorded on tape/PC disk at } \leq 1 \text{ Gbps and transported to a central location (300 tera-bytes/day)} \]

\[ \Rightarrow \text{data processor multiplies and adds at a rate of } 10^{14} \text{ ops/sec} \]
VLBI: the sharpest view of the universe
measuring the very small and the very mobile

15 May 2003
Model of an Active Galactic Nucleus

- Emission outside radio lobes
- Radio lobe
- Hot spot
- Radio jet

- Blazar beam
- Broad cone ionizing radiation
- Obscuring thick disk
- Low ionization gas
- High ionization EELR
- Scattered continuum radiation
- Fe9+ zone
- High ionization cloud

Hercules A
Radio galaxy 3C236: the largest known object in the universe

- VLBI at 18 cm. Note alignment with bottom panel

- Hubble Space Telescope at 7000 Å (dust disk in centre)

- Local radio interferometry (Westerbork) (size of radio source ~ 13 million light years)

R. T. Schilizzi

(Schilizzi et al)

e-VLBI Workshop
Super-luminal motion in the galaxy 3C120 at 22 GHz
Nov 97 – March 99

• Proper motion: 1.6 - 2.0 mas/yr
• Apparent transverse motion: 4 - 6 c
• Physical velocity ~ 0.98 c (i.e relativistic) at ~20° to line of sight
• Jets are apparently one-sided due to Doppler boosting (factor of 1000)
• Jet may interact with an inter-stellar cloud about 24 light years from the nuclear black hole
VLBA 22 GHz Observations of 3C120

José–Luis Gómez IAA (Spain)
Alan P. Marscher BU (USA)
Antonio Alberdi IAA (Spain)
Svetlana Marchenko–Jorstad BU (USA)
Cristina García–Miró IAA (Spain)
3C273, VSOP at 5GHz: transverse structure of the jet

Transverse profiles

Lobanov et al.
H$_2$O maser spectrum

Keplerian motion of high velocity masers

(Greenhill et al)
Does every galaxy contain a massive black hole or are starburst galaxies more common?

Need more sensitivity to answer question (e-VLBI, SKA)
M82 starburst galaxy

Point sources are supernovae, stars at the end of their life cycle.

(Pecklar et al)
supernova in M81 in 1993

(Bietenholz et al)
geodesy
rate of rotation of the Earth 1980-1997

Annual and semi-annual terms

Earth is currently slowing down at a rate of 2ms/day

LOD was 18 hours 900 million years ago

Dominant oscillations due to annual interchange of atmospheric angular momentum with the solid Earth
Plate motion 1984-1996
Alaska-Hawaii

-46±7 mm/year
VLBI recording technology
The S-series: S1, S2, S3

No pictures available
The future!

15 May 2003
In astronomy, five types of use of wide bandwidth links are envisaged:

- Transport of raw data from telescope(s) to data processing facility
- Distribution of data from processing facility to users
- “Mining” of databases
- Remote data analysis
- Real-time remote control of telescopes
Transport of raw data in radio astronomy arrays

Examples:

• local scale  ALMA

• regional scale  e-MERLIN, LOFAR, E-VLA

• global scale  e-EVN, e-VLBA, Global VLBI
  Square Kilometre Array (SKA)
Transport of raw data on a global scale: VLBI arrays (Europe, USA, Asia-Pacific)
Science impact of e-VLBI

• real-time operation allows flexible dynamic scheduling to respond to “targets of opportunity” like exploding stars

• high data rate that is always available → major increase in sensitivity for radio sources at the edge of the universe

• high data rate → very high quality imaging using bandwidth synthesis
Operational impact on VLBI

- more robust operation
- easier data transfer logistics
- flexible scheduling
- lower operating costs (?)
- more effective network monitoring
Potential site for the SKA
Potential site for the SKA

2320 12m antennas within 35 km core

84 stations
35-350 km

76 stations
350-3500 km

Inexpensive, hydroformed dishes

Potential site for the SKA
The end