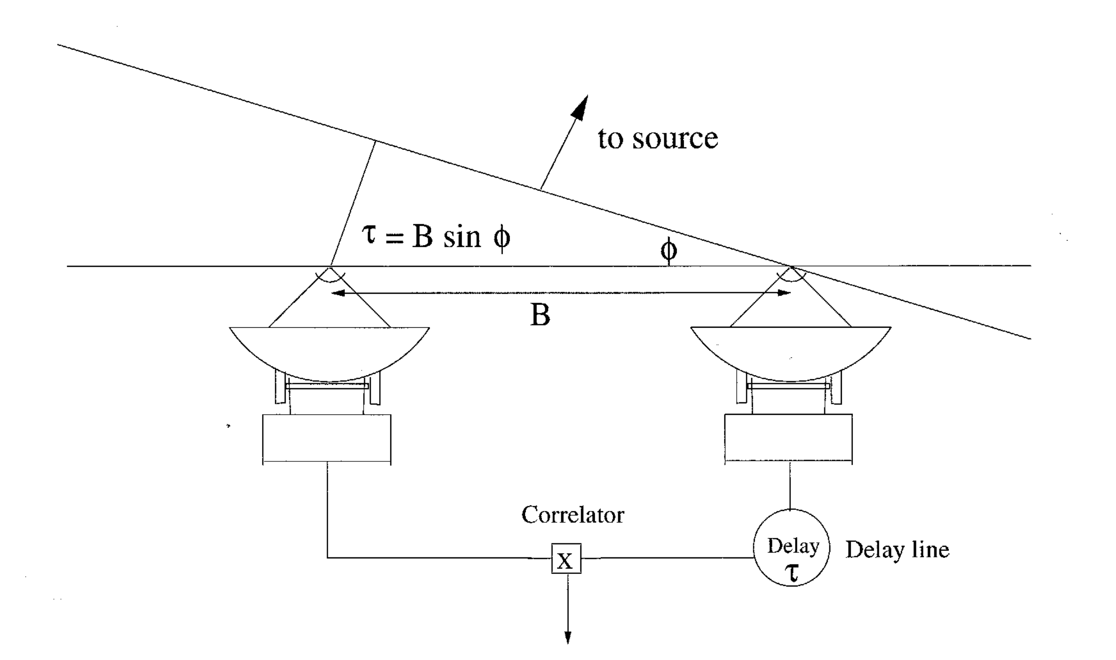
e-VLBI

- Radio interferometers
- How does VLBI work?
- What science do we do with VLBI?
- How has the technology changed?
- Advantages of e-VLBI
- e-Astronomy

Simple interferometer

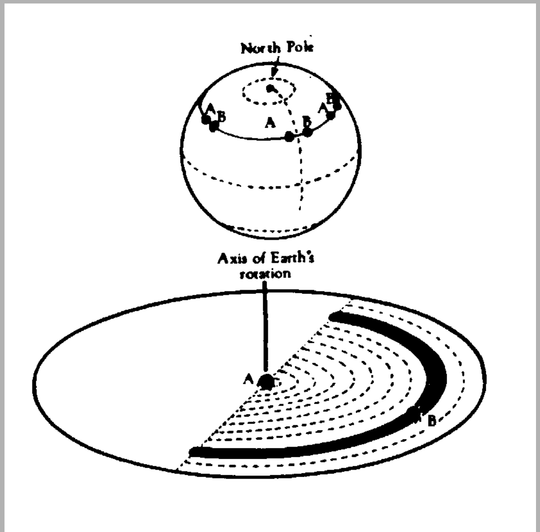


In a simple interferometer, two telescopes act as one with a diameter of B.cosΦ

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

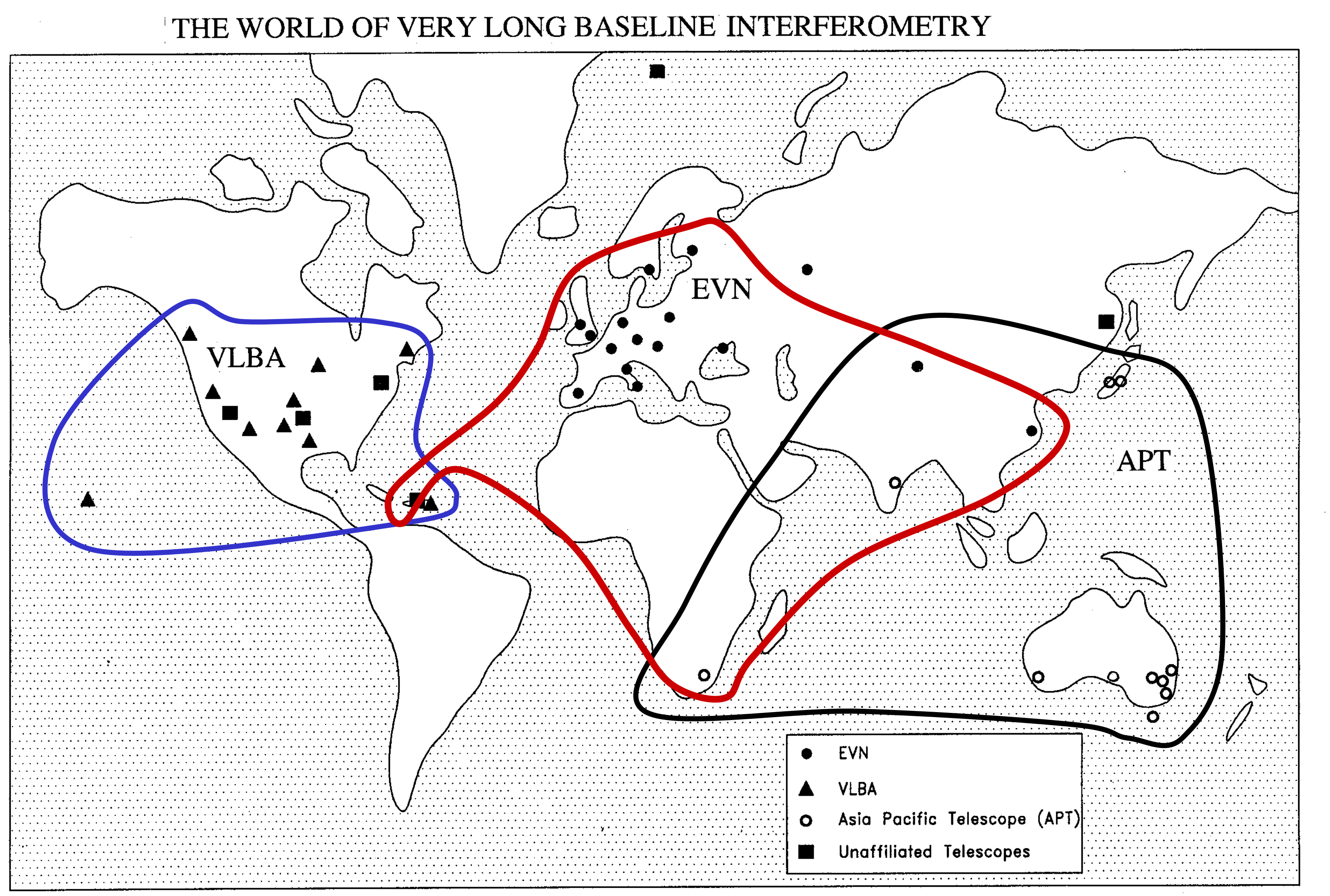
- the more telescopes simultaneously in the array, the better the image quality
- the greater the bandwidth detected, the higher the sensitivity
- data transported is incompressible “white” noise
- →24x365 operation

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

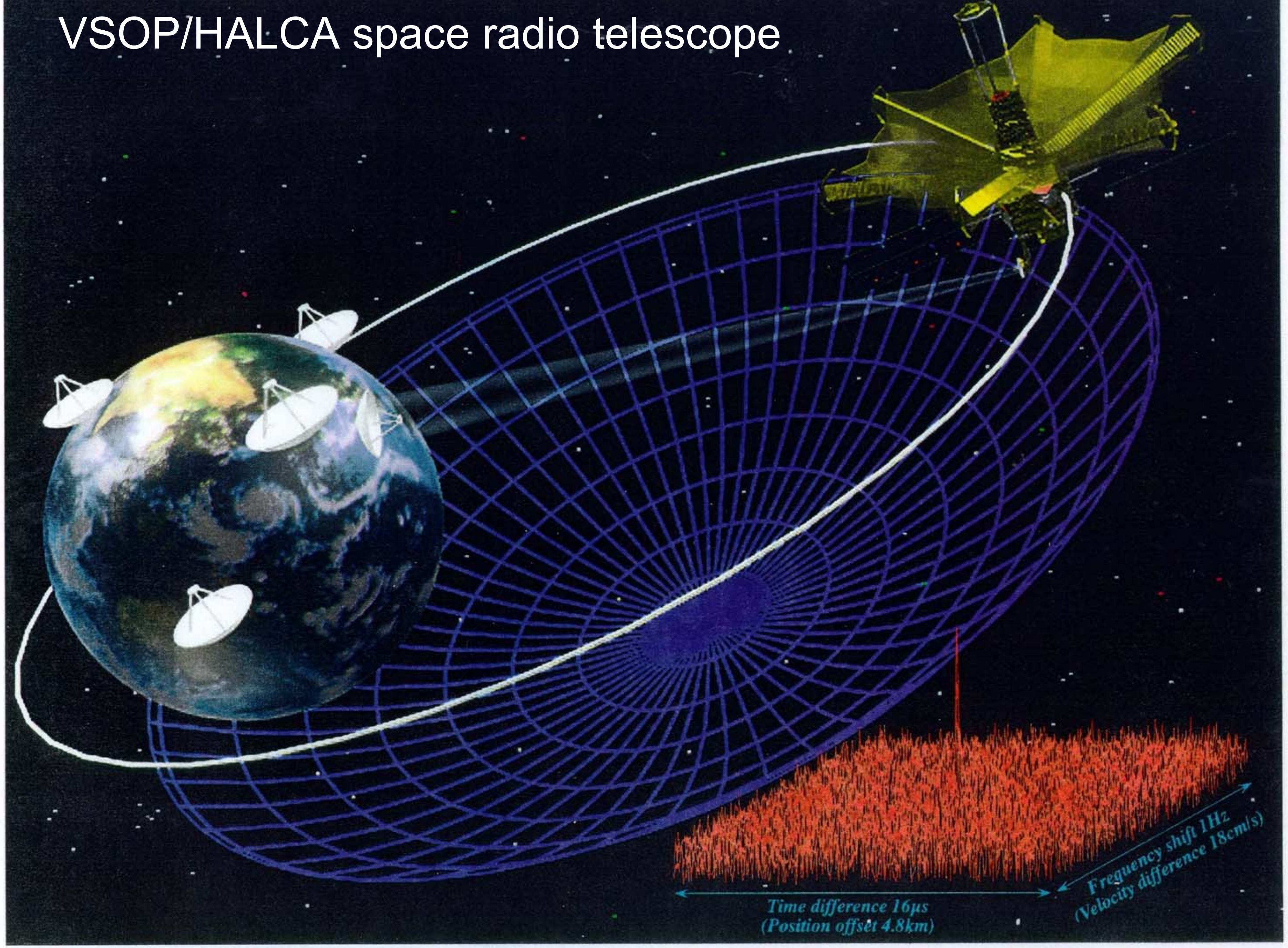
Short baseline interferometers

Longer baseline interferometers

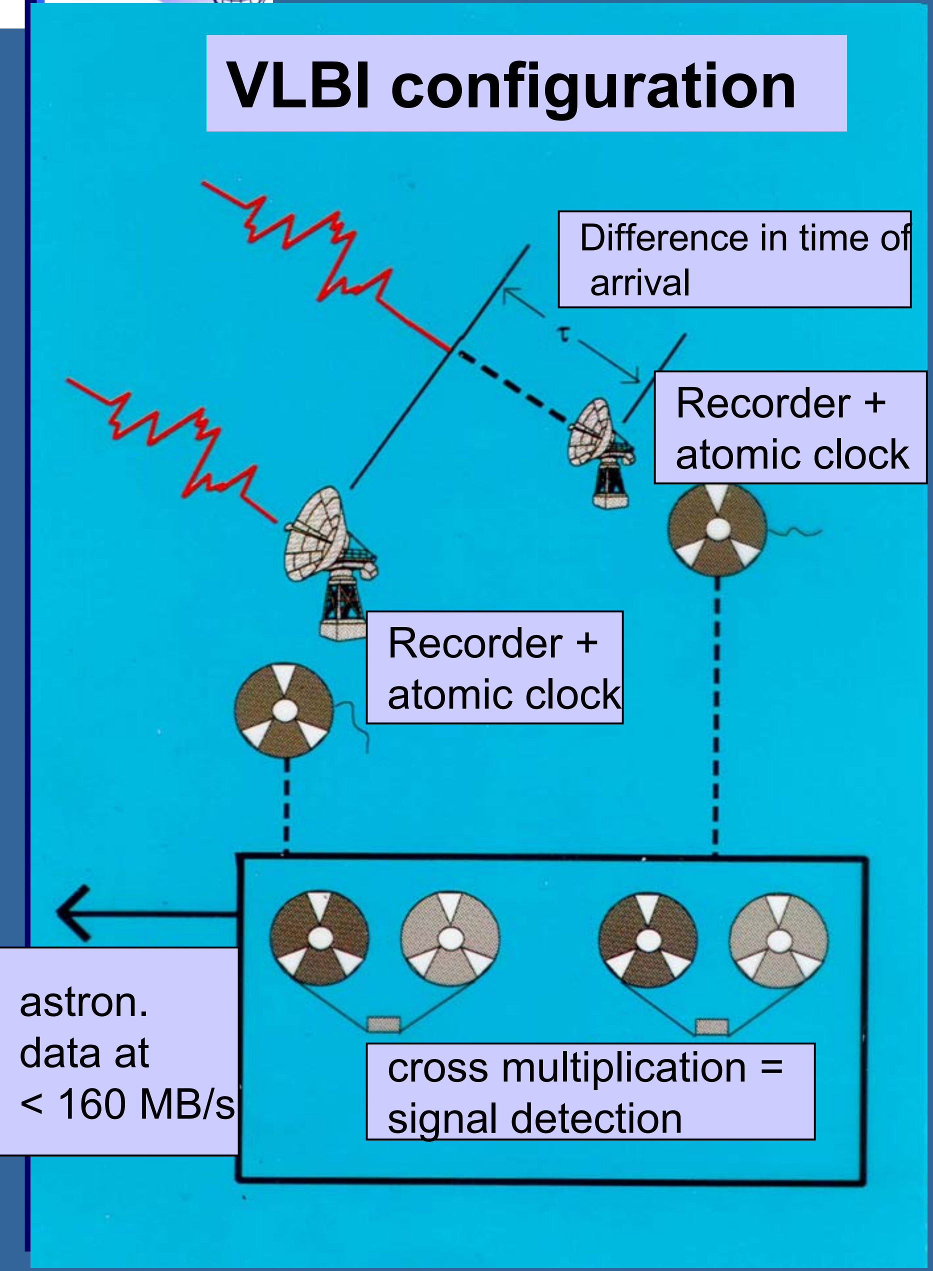
Very Long Baseline Interferometers



VSOP/HALCA space radio telescope



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?

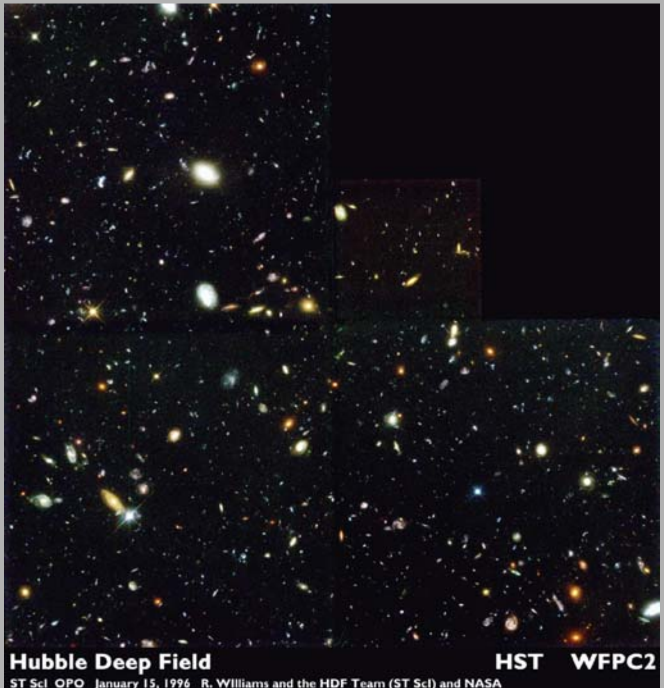
⇐ widely separated telescopes

⇐ data recorded on tape/PC disk at <=1 Gbps and transported to a central location (300 tera-bytes/day)

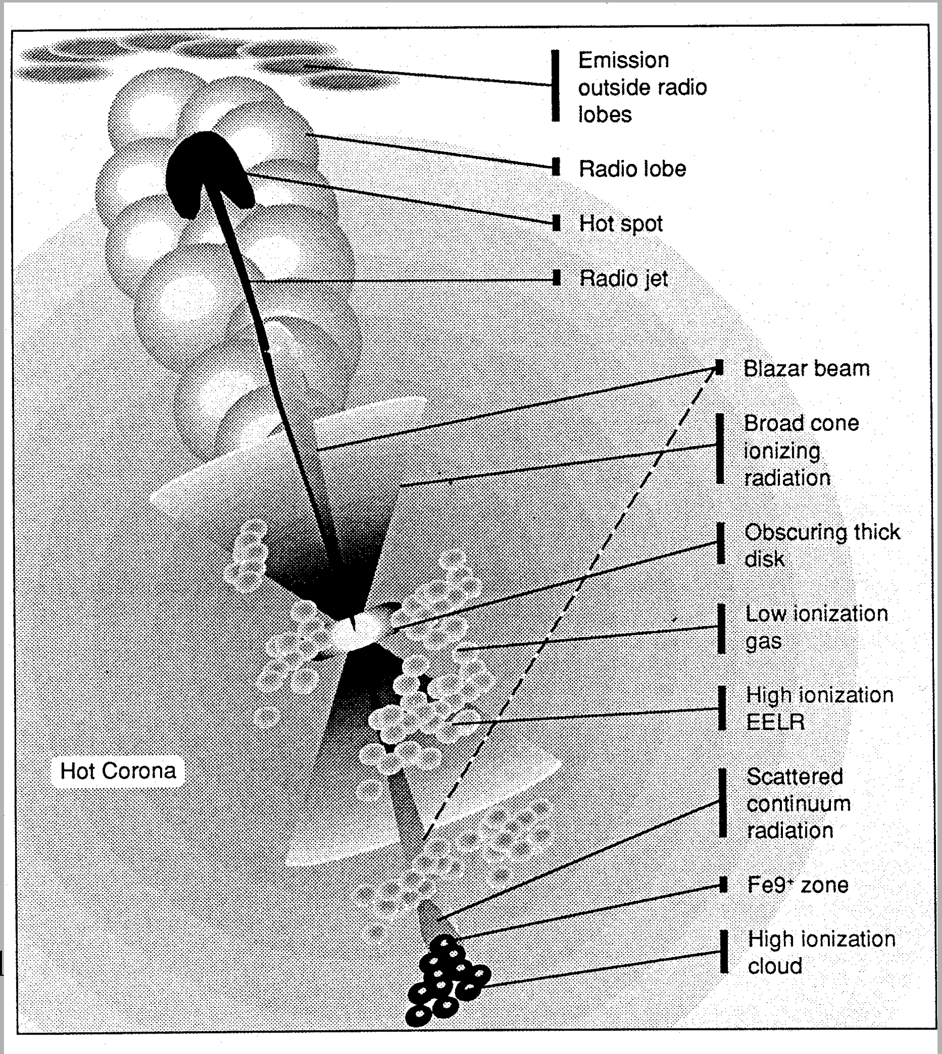
⇐ data processor multiplies and adds at a rate of 10^{14} ops/sec

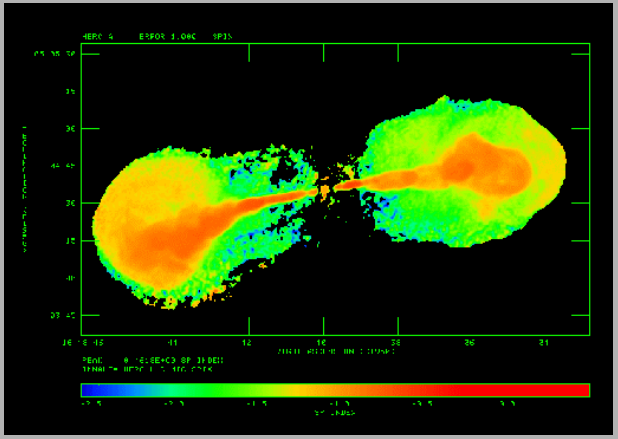
VLBI: the sharpest view of the universe

measuring the very small and the very mobile

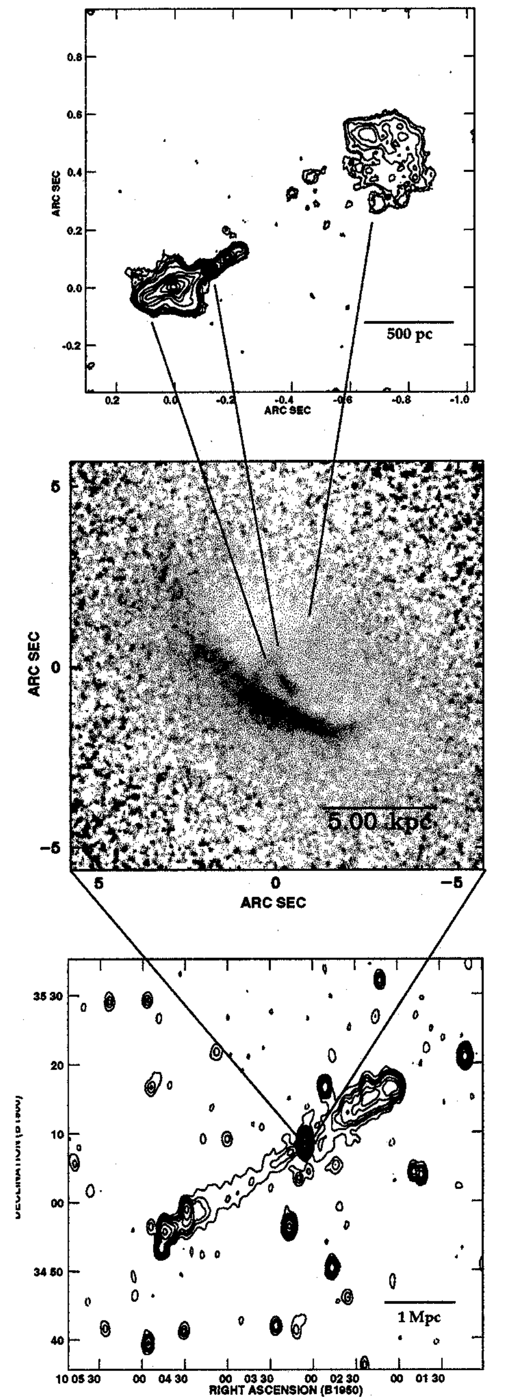


Model of an Active Galactic Nucleus





Hercules A



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

VLBI at 18 cm. Note alignment with bottom panel

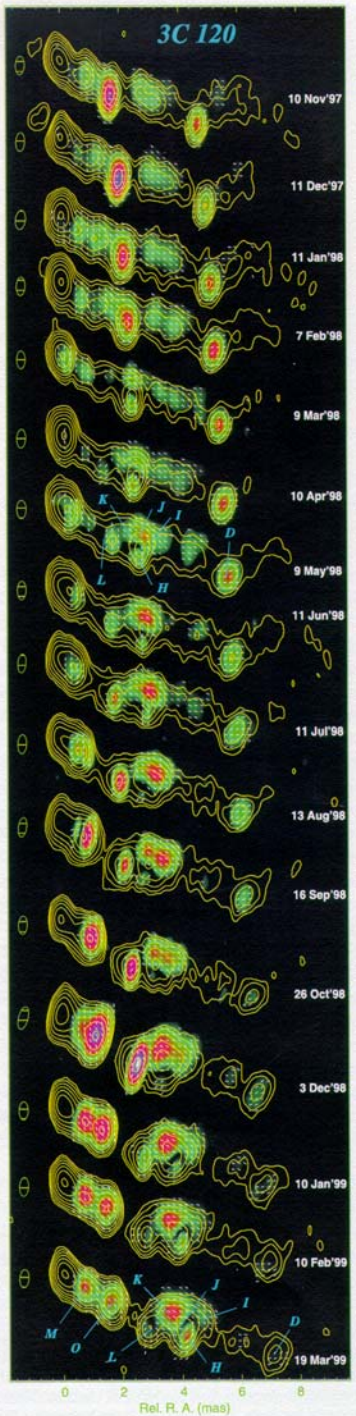
zoom=10

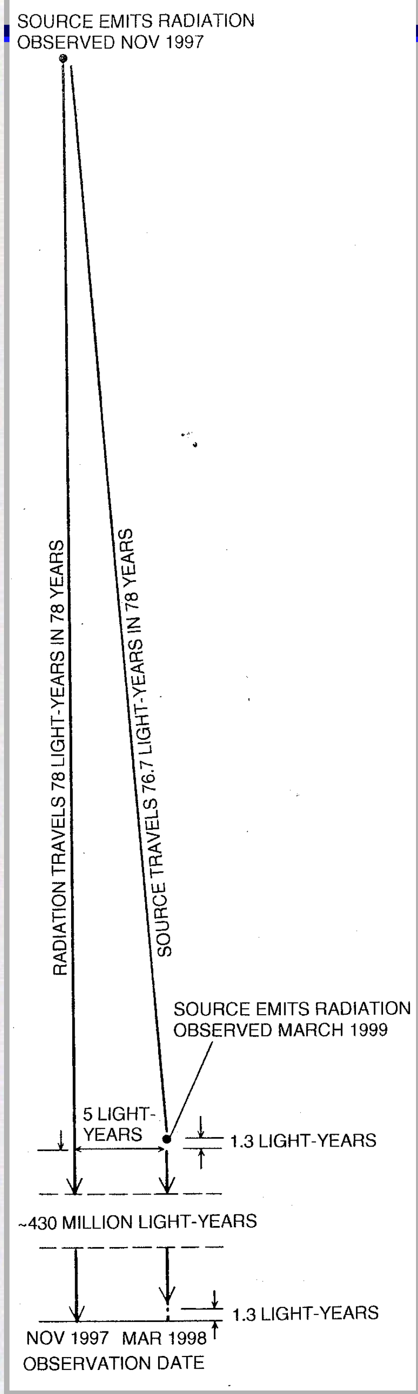
Hubble Space Telescope at 7000 Å (dust disk in centre)

zoom=200

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

(Schilizzi et al)





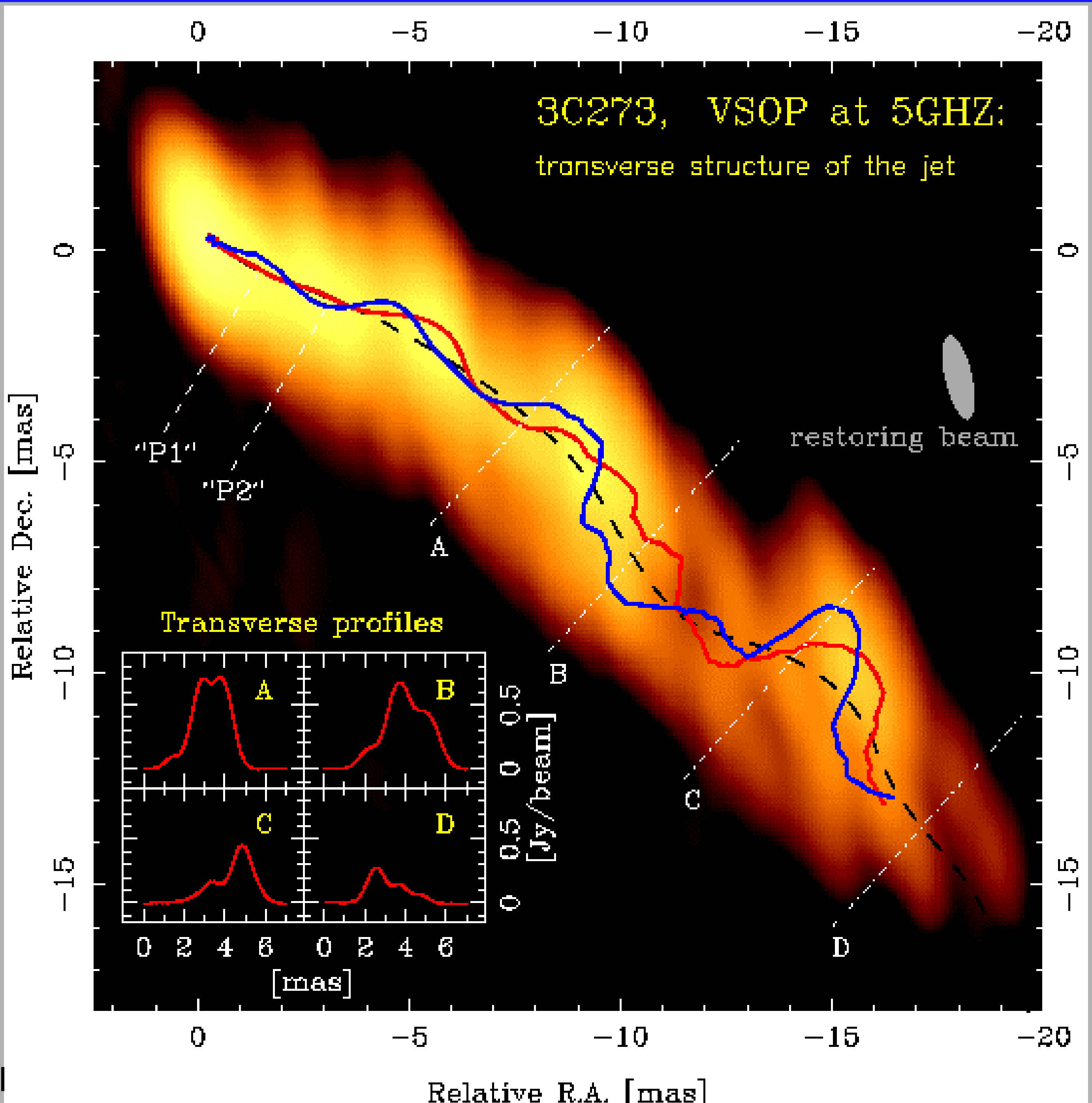
Super-luminal motion in the galaxy 3C120 at 22 GHz

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^o 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

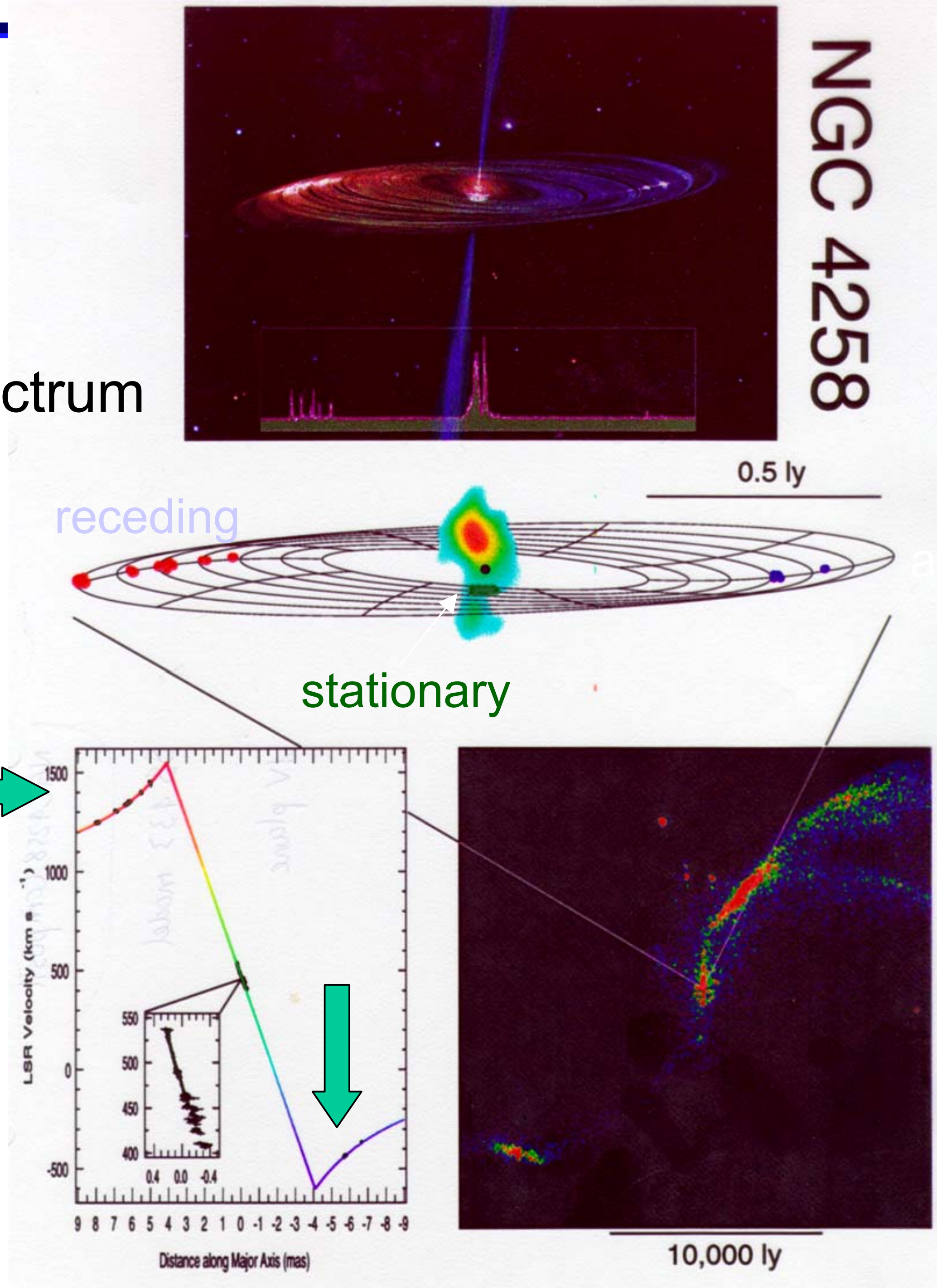
José–Luis Gómez	IAA (Spain)
Alan P. Marscher	BU (USA)
Antonio Alberdi	IAA (Spain)
Svetlana Marchenko–Jorstad	BU (USA)
Cristina García–Miró	IAA (Spain)



Lobanov et al

(Greenhill et al)

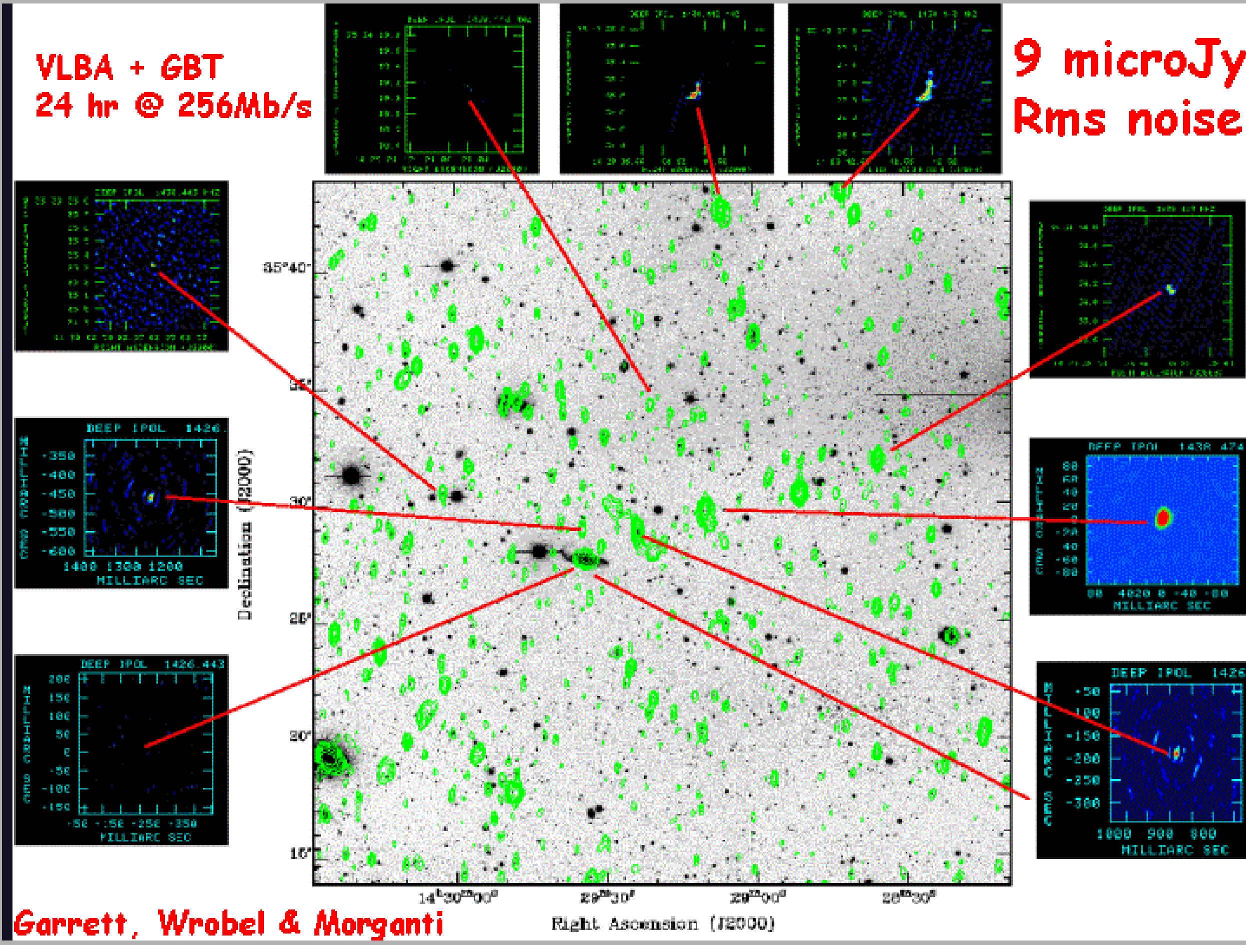
H_2O maser spectrum



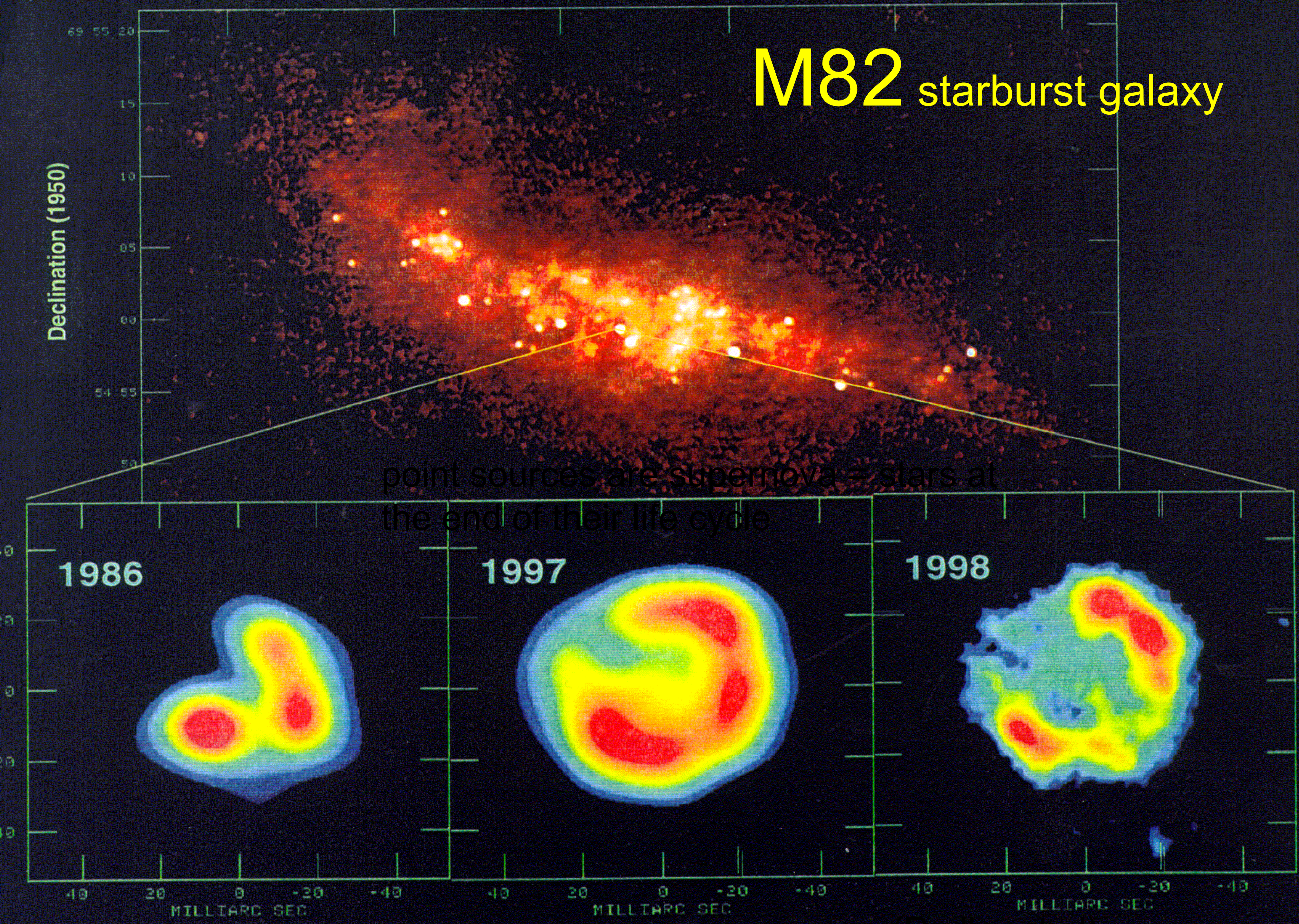
Keplerian motion of high velocity masers

Does every galaxy contain a massive black hole or are starburst galaxies more common?

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



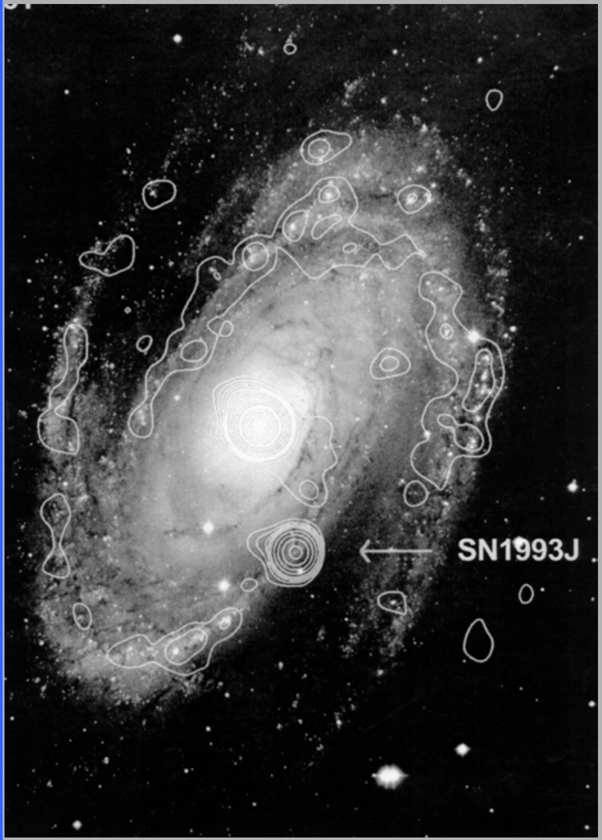
M82 starburst galaxy



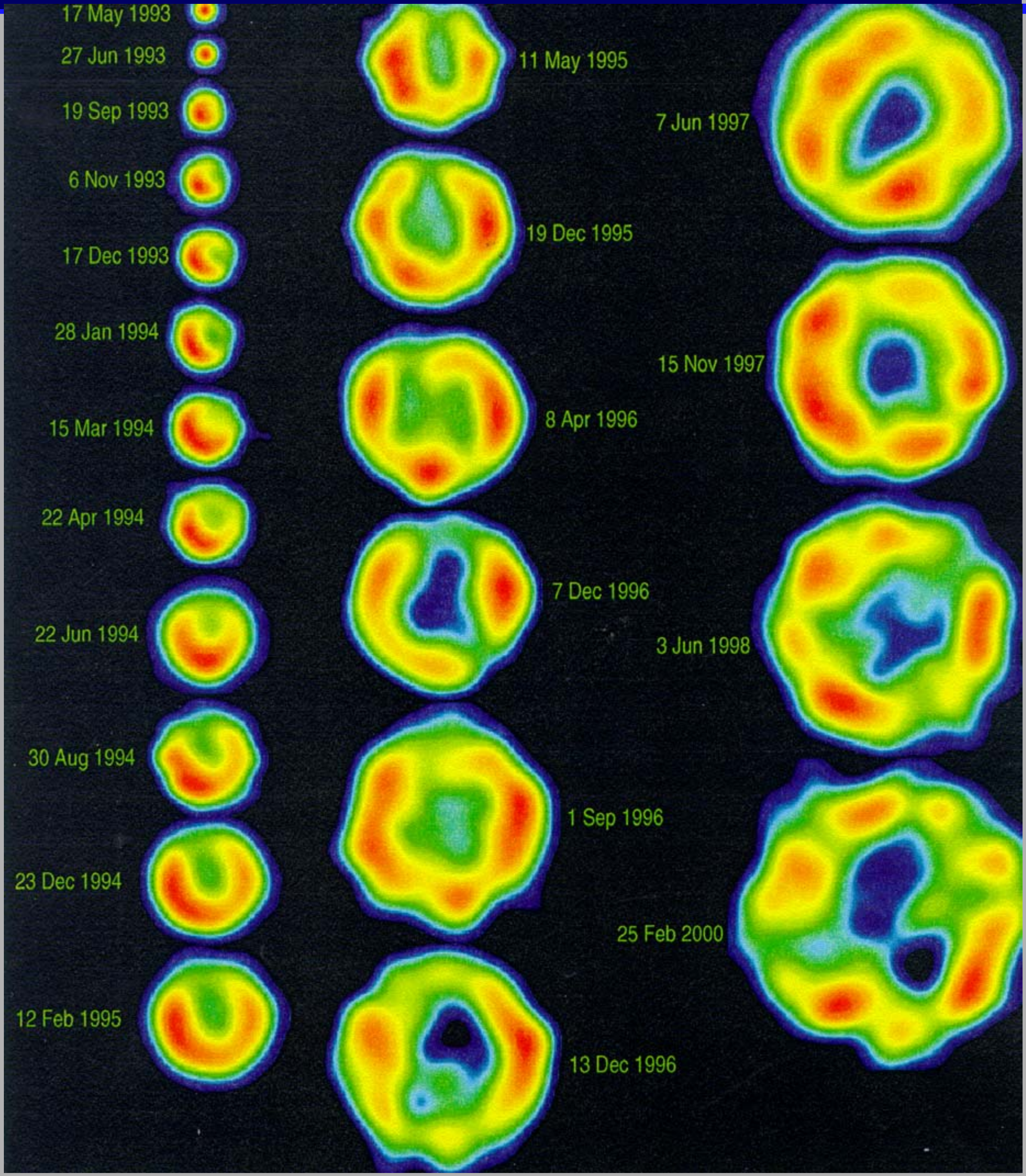
point sources are supernova = stars at the end of their life cycle

(Pedlar et al)

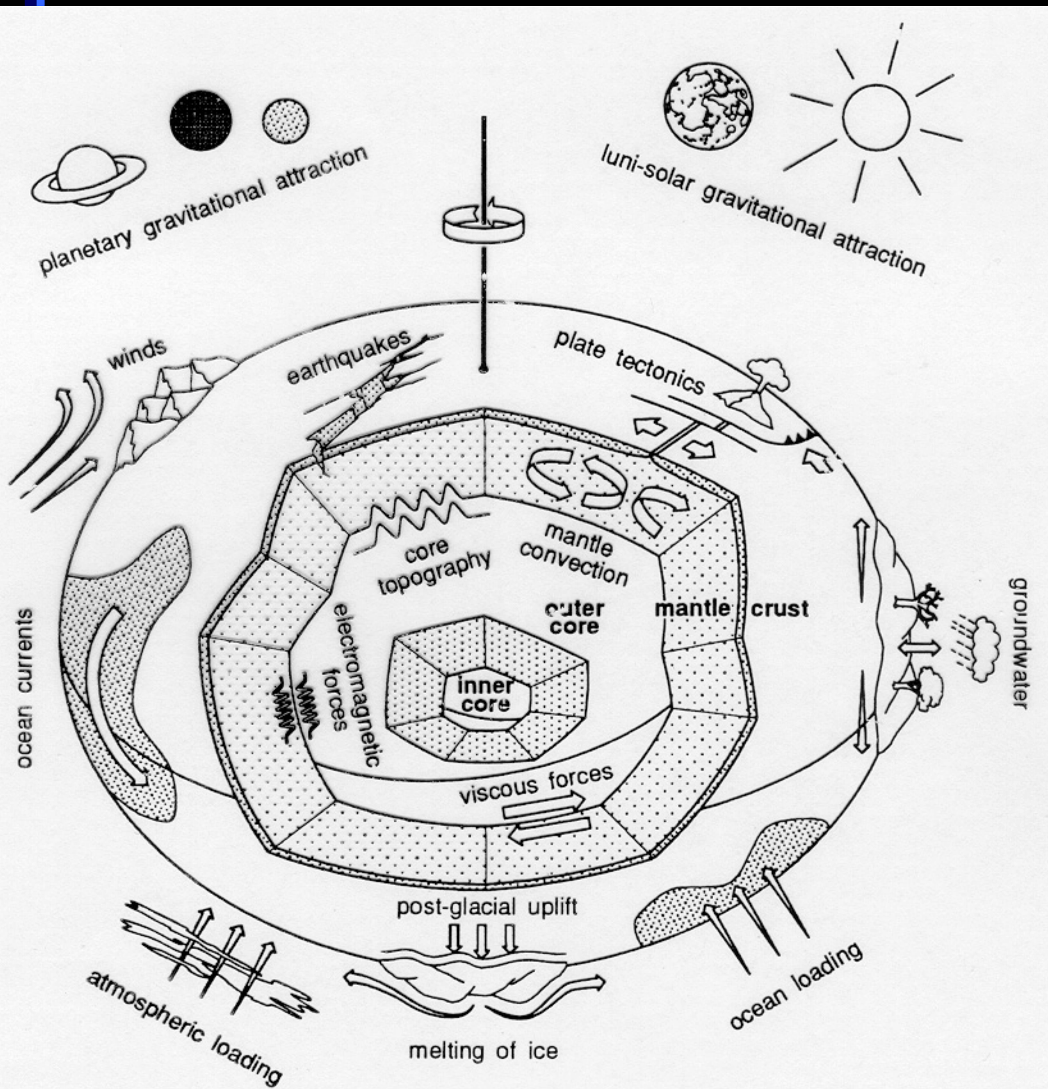
supernova in M81in 1993

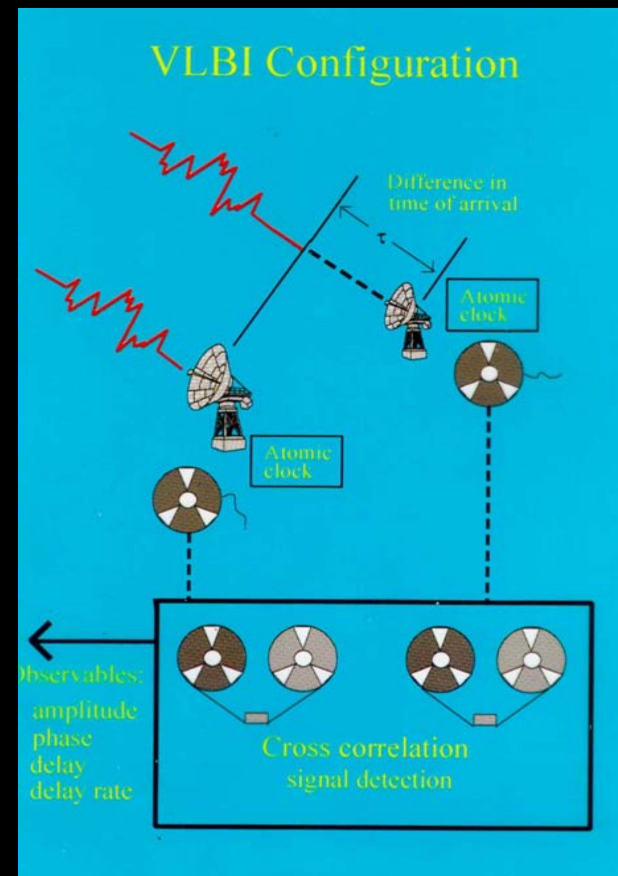


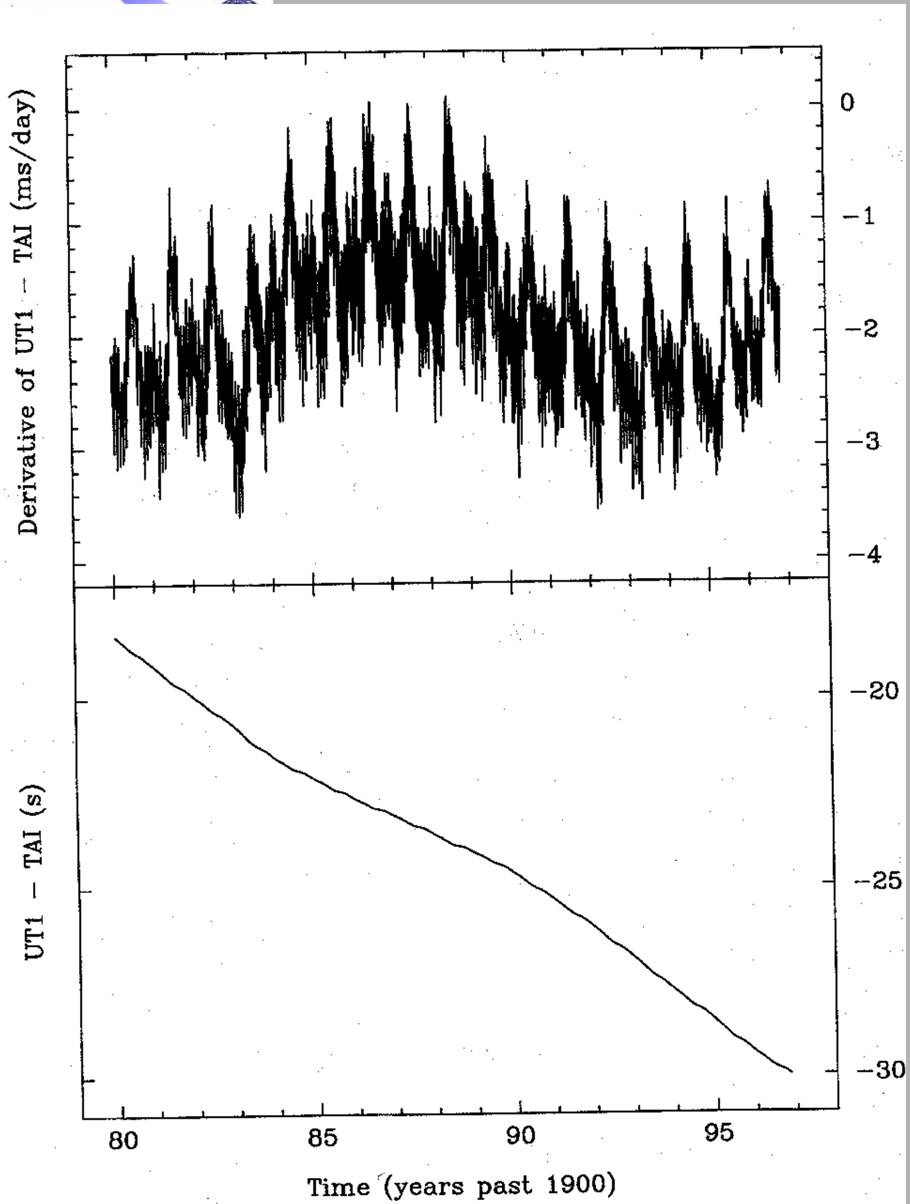
(Bietenholz et al)



geodesy


planetary gravitational attraction
luni-solar gravitational attraction
winds
earthquakes
plate tectonics
core topography
mantle convection
outer core
mantle
crust
inner core
electromagnetic forces
ocean currents
groundwater
viscous forces
post-glacial uplift
atmospheric loading
melting of ice
ocean loading


VLBI Configuration
Difference in time of arrival
τ
Atomic clock
Atomic clock
Observables:
amplitude
phase
delay
delay rate
Cross correlation
signal detection



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

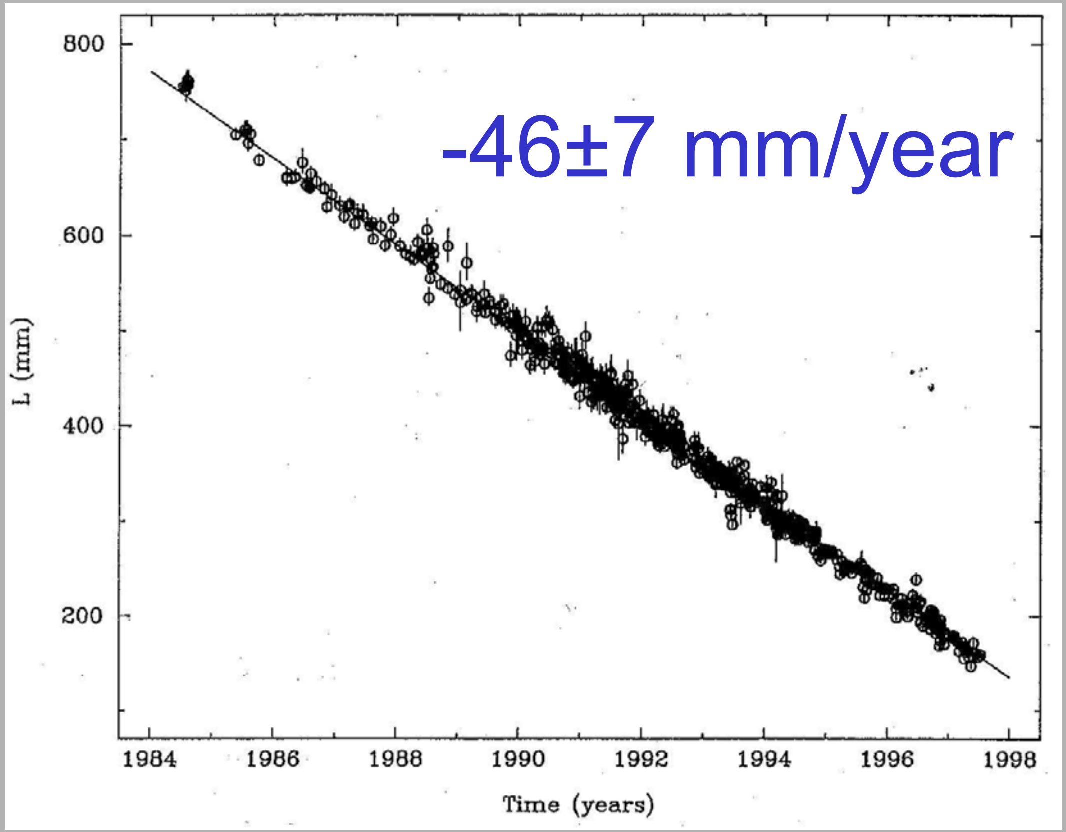
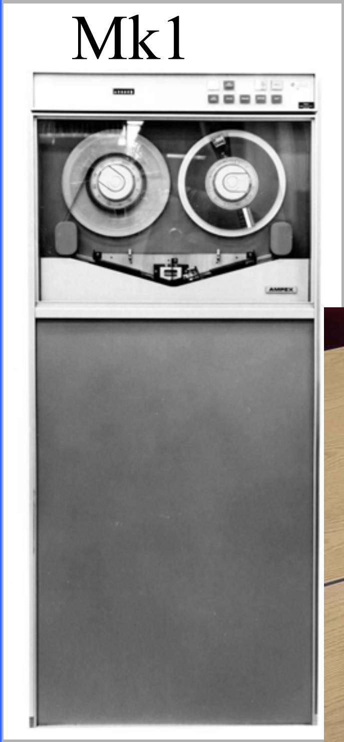


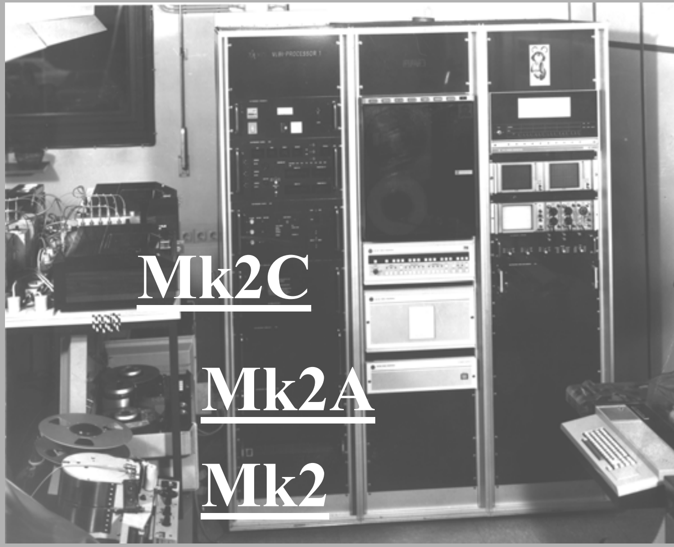
Plate motion 1984-1996

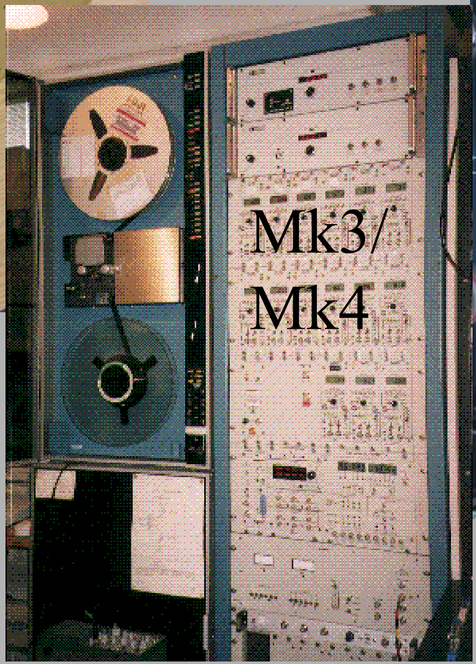
Alaska-Hawaii

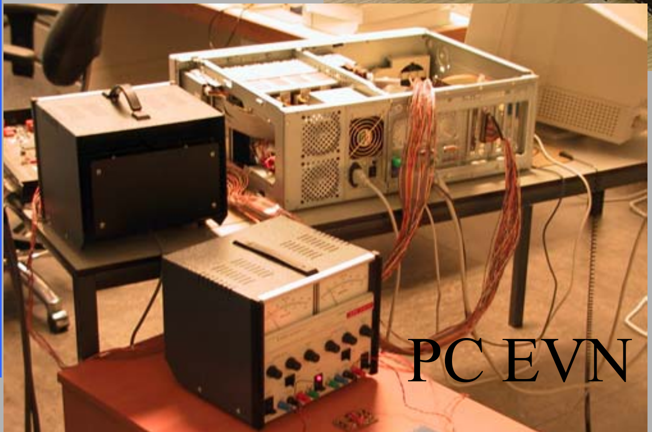
VLBI recording technology

SKA
SQUARE KILOMETRE ARRAY





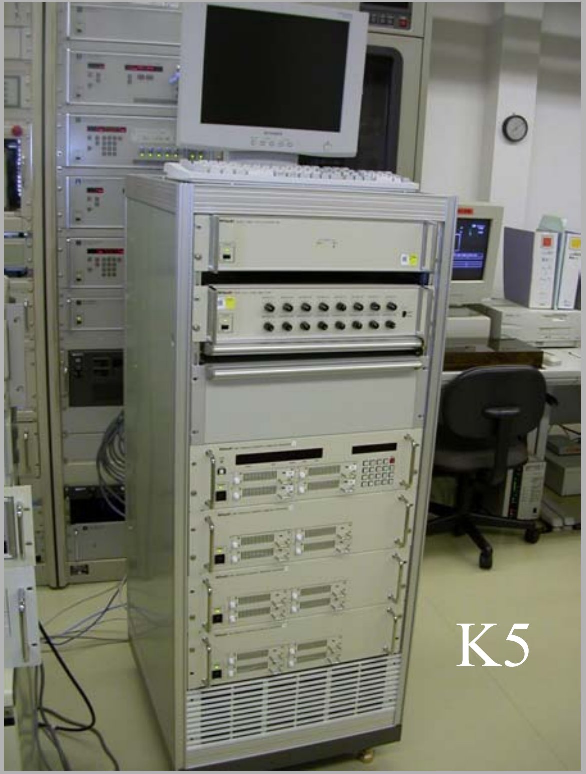





K3


K4/VSOP


PCVLBI


K5


K1

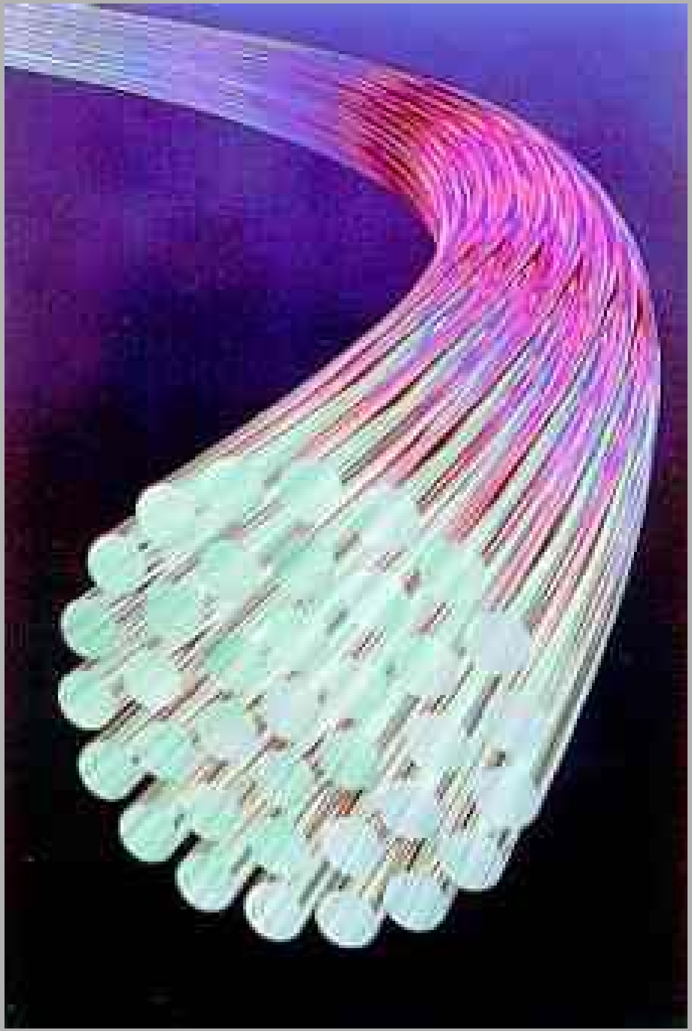

GBR2000


VDR2000

The S-series: S1, S2, S3

No pictures available

The future!



In astronomy, five types of use of wide bandwidth links are envisaged

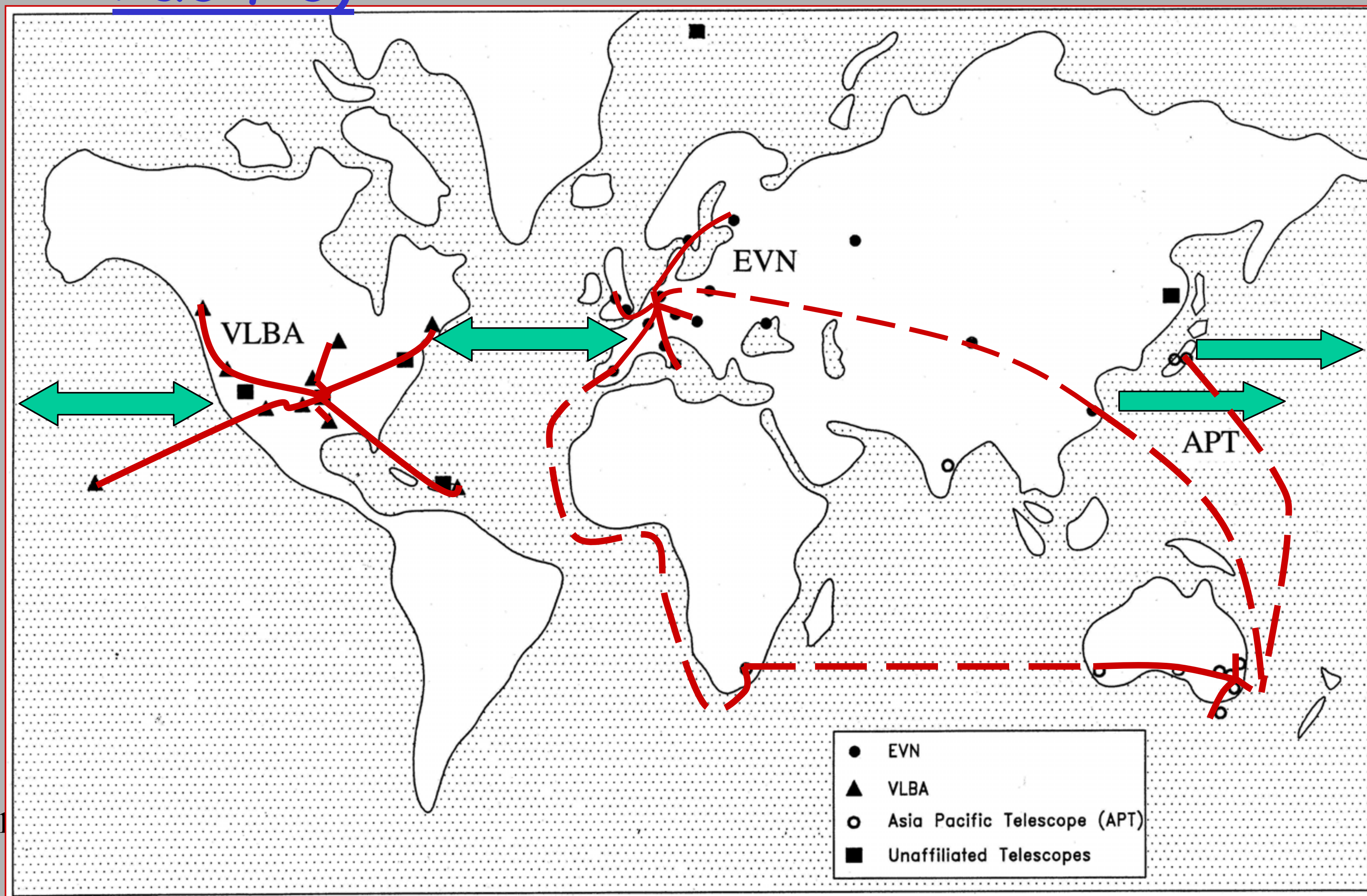
- Transport of raw data from telescope(s) to data processing facility
- Distribution of data from processing facility to users
- “Mining” of databases
- Remote data analysis
- Real-time remote control of telescopes

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

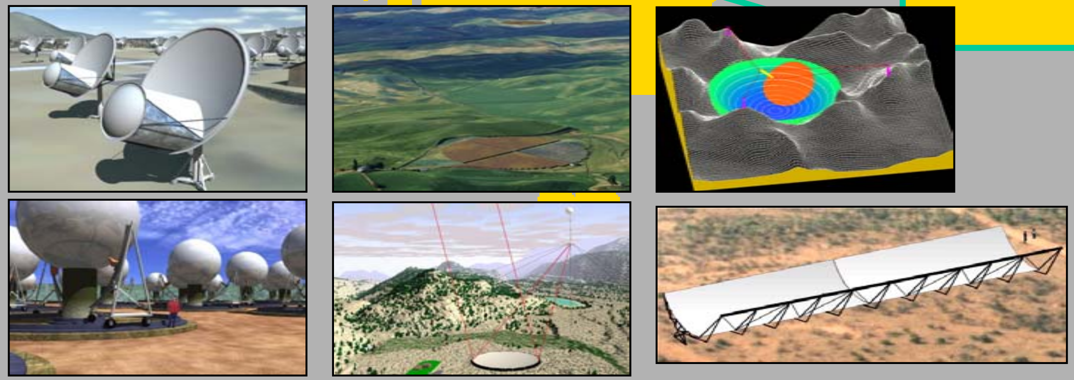
•high data rate that is always available ➡ major increase in sensitivity for radio sources at the edge of the universe

•high data rate ➡ very high quality imaging using bandwidth synthesis

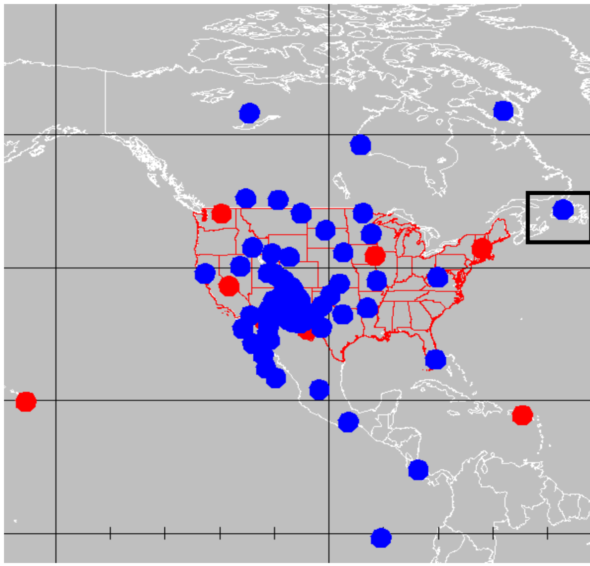
Operational impact on VLBI

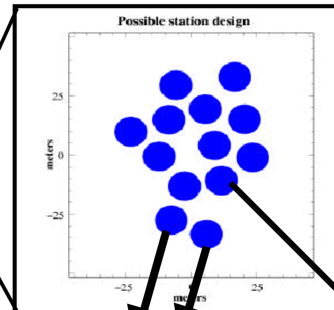
- more robust operation
- easier data transfer logistics
- flexible scheduling
- lower operating costs (?)
- more effective network monitoring

Potential site for the SKA



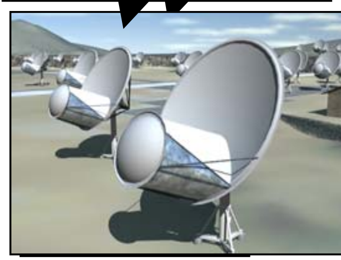
Potential site for the SKA

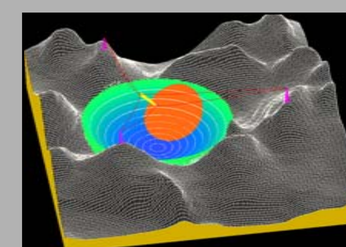




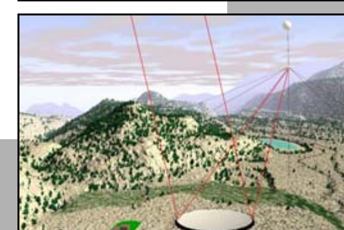
84 stations
35-350 km

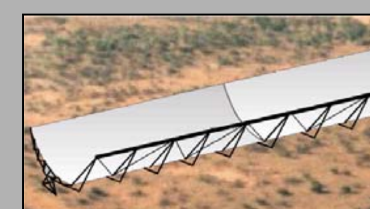
76 stations
350-3500 km





2320 12m antennas within 35 km core





The end