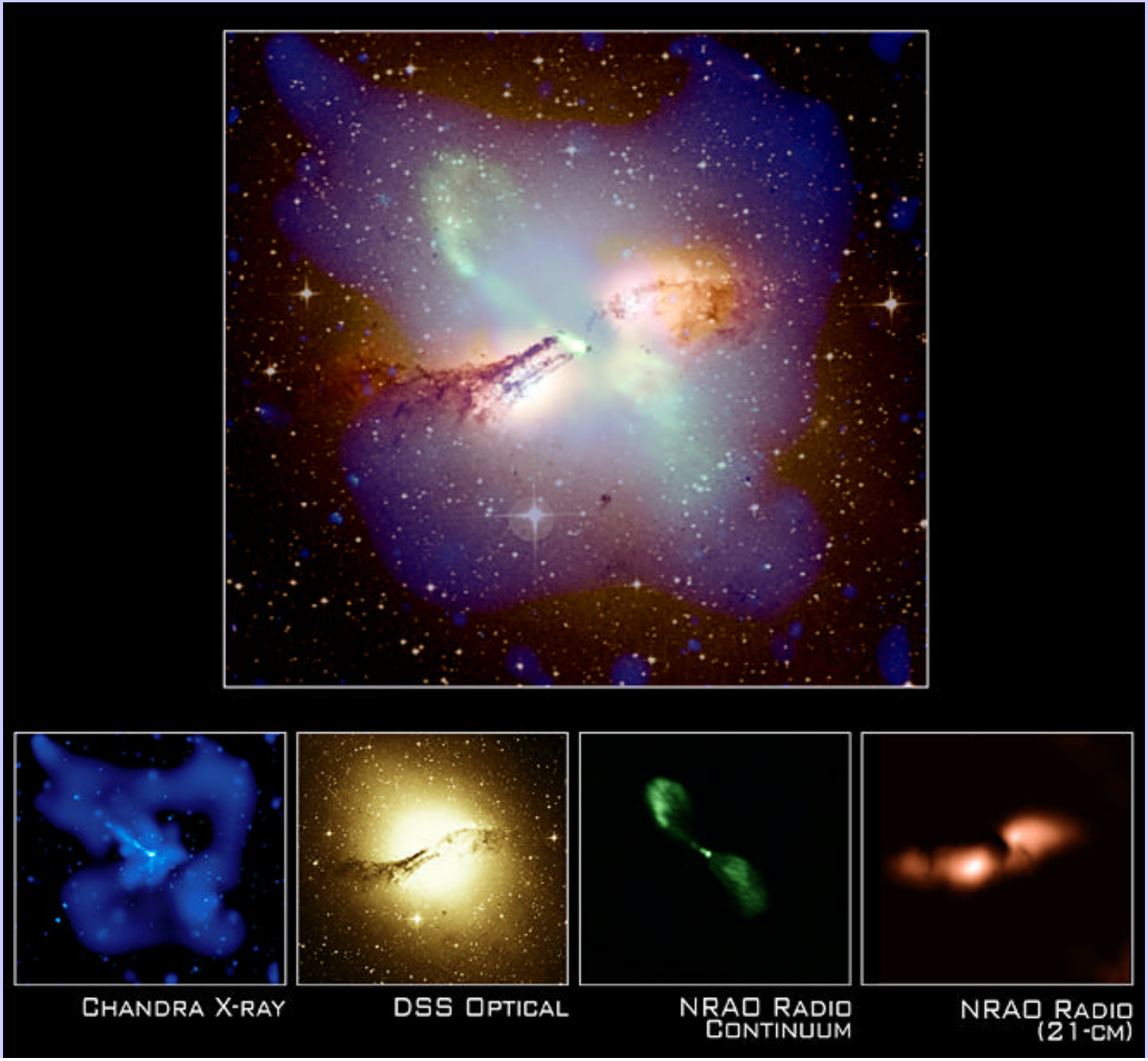
Multi-Wavelength Astrophysics

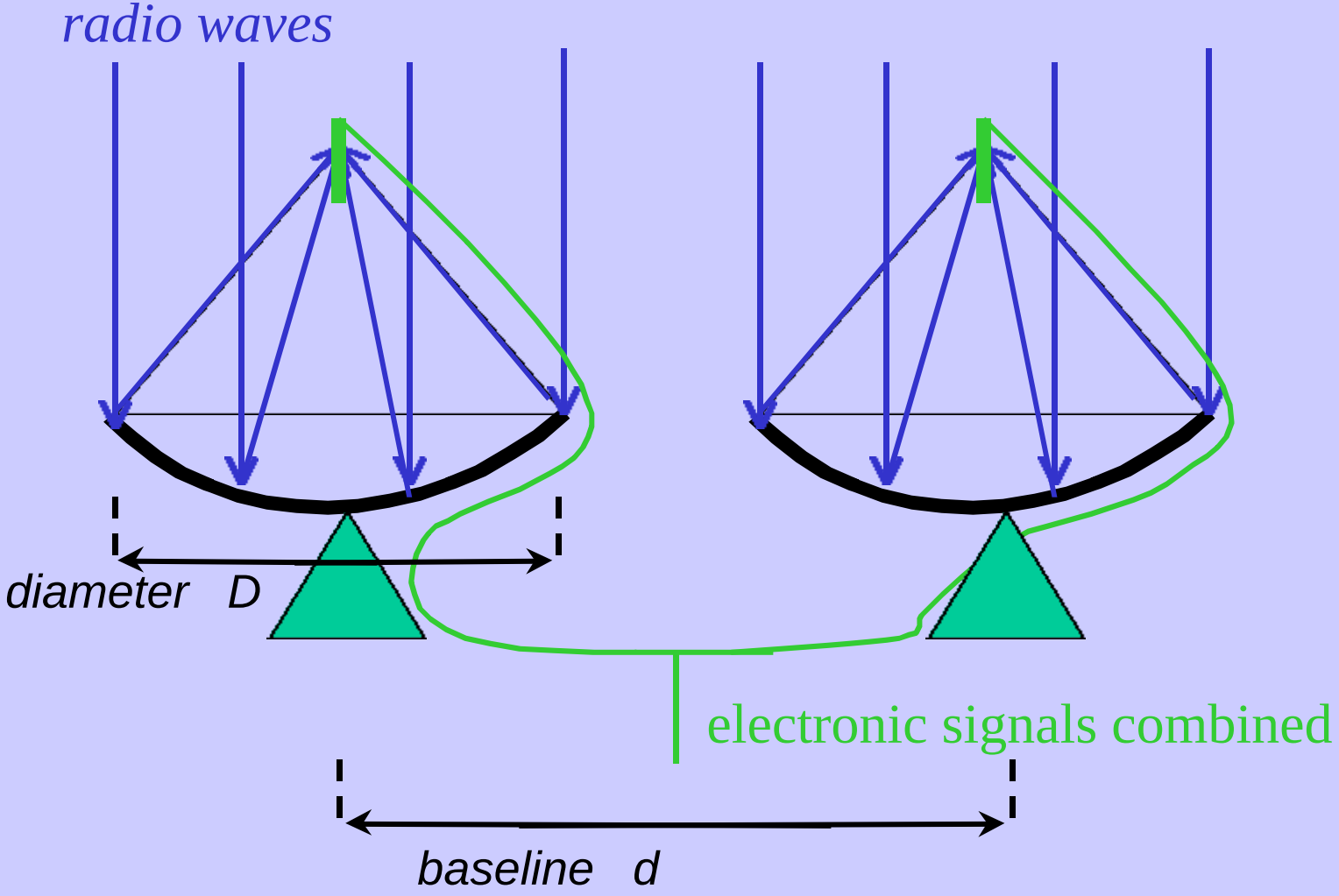
- gamma-ray --- relativistic gas $(>10^9\ \mathrm{K})$
- x-ray ---------- hot gas $(10^{6-8}\ \mathrm{K})$
- ultraviolet ------ hot stars $(10^{4-5}\ \mathrm{K})$
- optical ---------- cool stars $(10^{3-4}\ \mathrm{K})$
- infrared --------- cool gas,dust $(10-100\ \mathrm{K})$
- millimetre ------ Big Band afterglow $(3\ \mathrm{K})$
- radio ---------- non-thermal radiation

Each wavelength gives a different picture


CHANDRA X-RAY
DSS OPTICAL
NRAO RADIO CONTINUUM
NRAO RADIO (21-CM)

The Very Large Array (VLA) Radio Interferometer

Radio Telescopes and Interferometry



Resolution of Radio Telescope

diameter $D = 20\ \mathrm{m}$

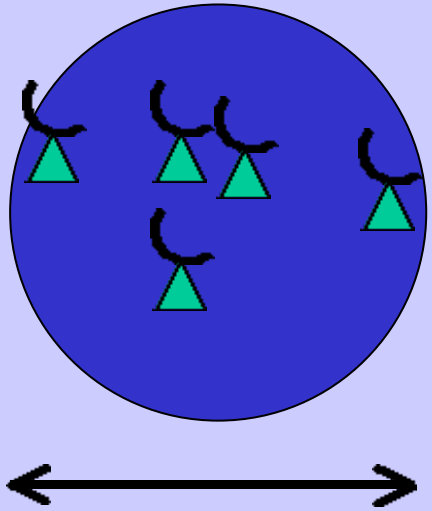
$$\frac{l}{D} \approx \frac{20\ \mathrm{cm}}{20\ \mathrm{m}} \times \frac{1\ \mathrm{m}}{100\ \mathrm{cm}} \times \frac{180°}{p\ \mathrm{radian}} = 0.6°$$

Resolution of Radio Interferometer

base line $d = 20\ \mathrm{km}$

$$\frac{l}{d} \approx \frac{20\ \mathrm{cm}}{20\ \mathrm{km}} \approx \frac{0.6°}{1000} \times \frac{3600\ \mathrm{arcsec}}{1°} = 2\ \mathrm{arcsec}$$

Very Long Baseline Interferometry
VLBI



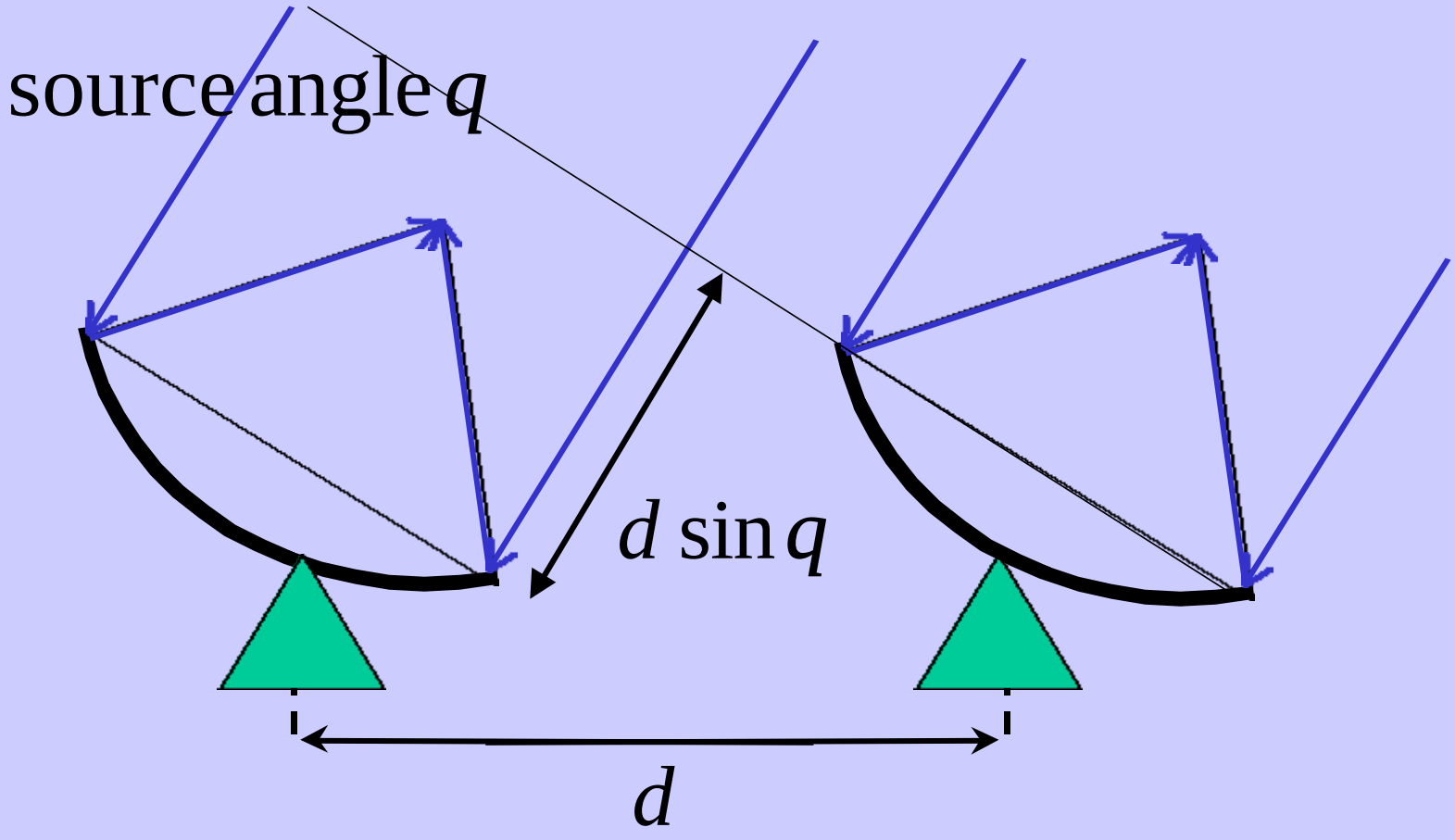
Linked Radio Telescopes across the Globe

longest baseline $d \approx 10^4$ km

$$\frac{l}{d} \approx \frac{20\text{ cm}}{10^4\text{ km}} \times \frac{1\text{ km}}{10^5\text{ cm}} \times \frac{180°}{p\text{ radian}} \times \frac{3600\text{ arcsec}}{1°}$$

$$= 0.004\text{ arcsec} = 4\text{ milliarcsec}$$

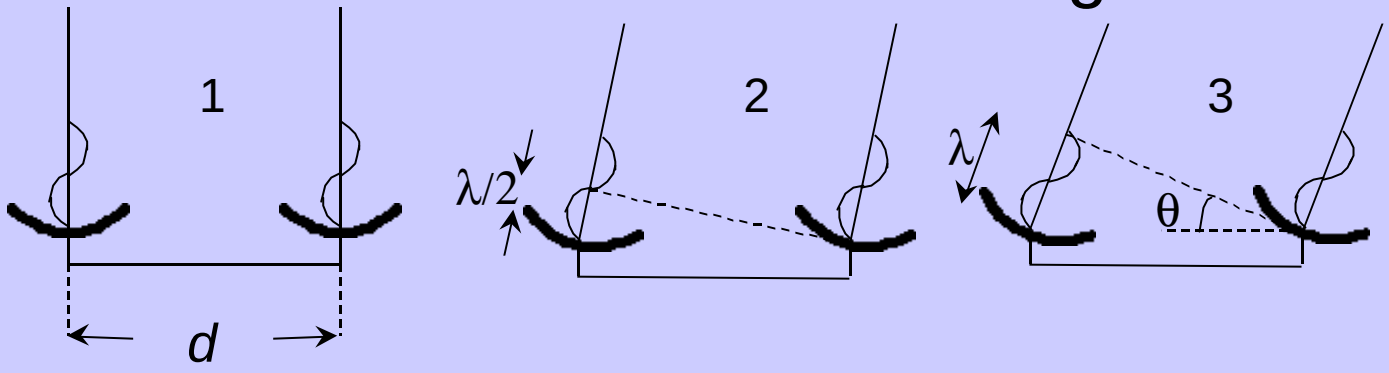
Radio Interferometry



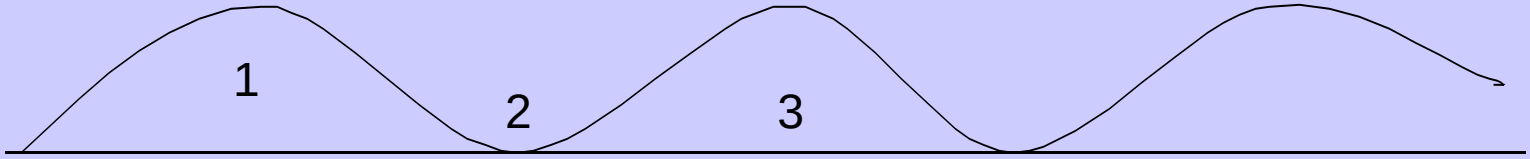
constructve interferen ce when $d \sin q = n l$

Radio Interferometry

two radio antennas on rotating Earth



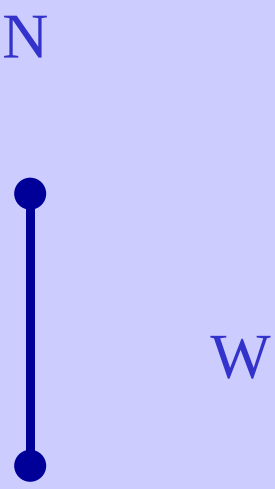
constructive interference when $d \sin q = n l$



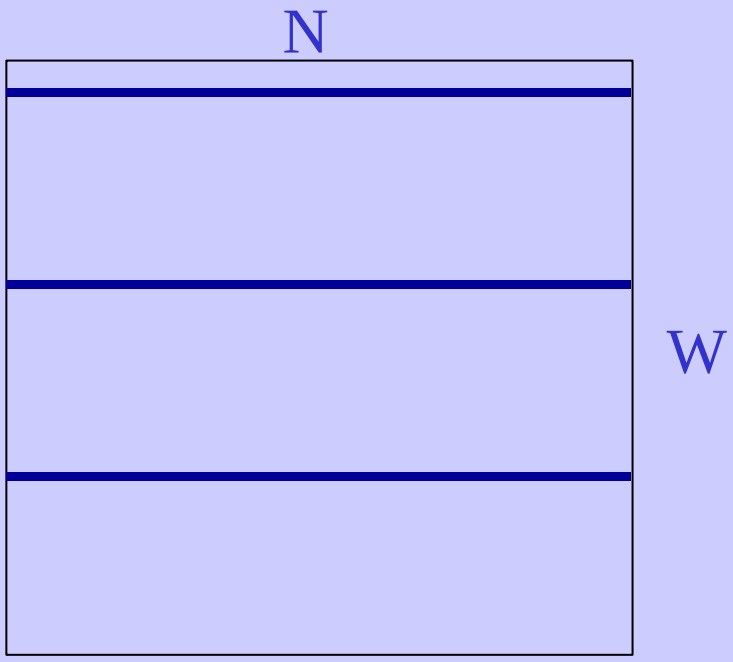
Interference pattern recorded as angle changes in time

Aperture Synthesis

2 telescopes
1 baseline



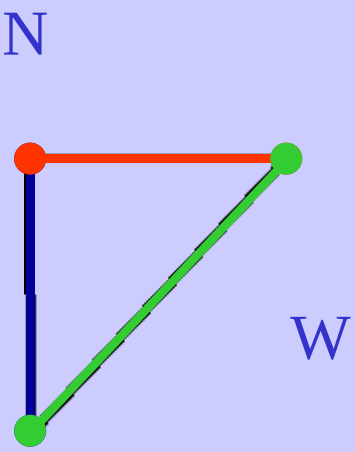
possible source directions



$$\sin q = n l / d$$

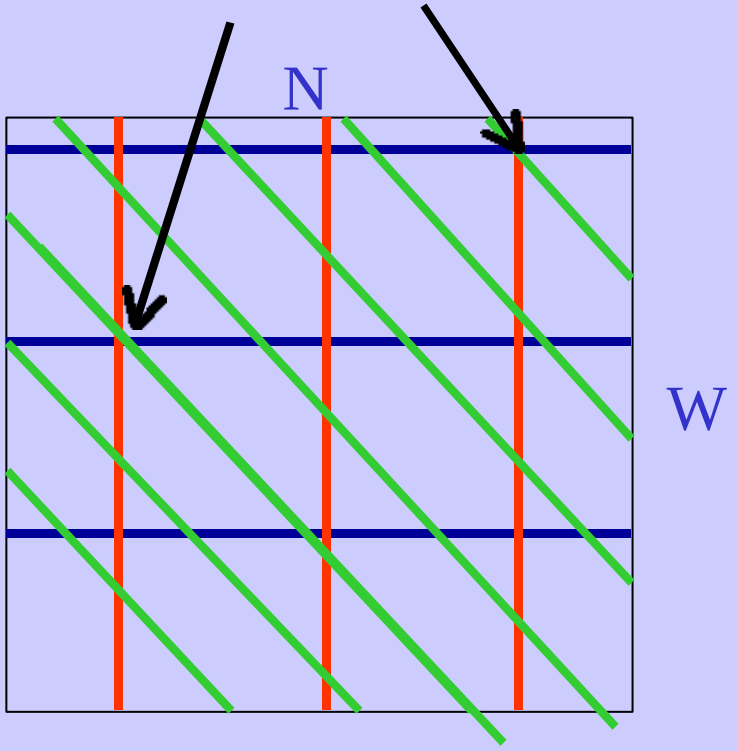
Aperture Synthesis

3 telescopes
3 baselines



N telescopes
N(N-1)/2 baselines
less and less ambiguity

possible source locations



$$\sin q_{1,2,3} = n l / d_{1,2,3}$$

examples:

- UK MERLIN
  (Jodrell Bank, Cambridge, Rutherford Lab.)
  - resolution ~ 0.01 arcsec
- USA Very Large Array (VLA)
  - Y-shaped array, each arm up to 21 km long, effective diameter 35 km
  - ~ 0.1 arcsec
- Very Long Baseline Interferometry (VLBI)
  - (Australia, Europe, USA, ...)
  - needs synchronised, highly accurate timing, major data storage and computer processing
  - ~ 0.1 milliarcsec

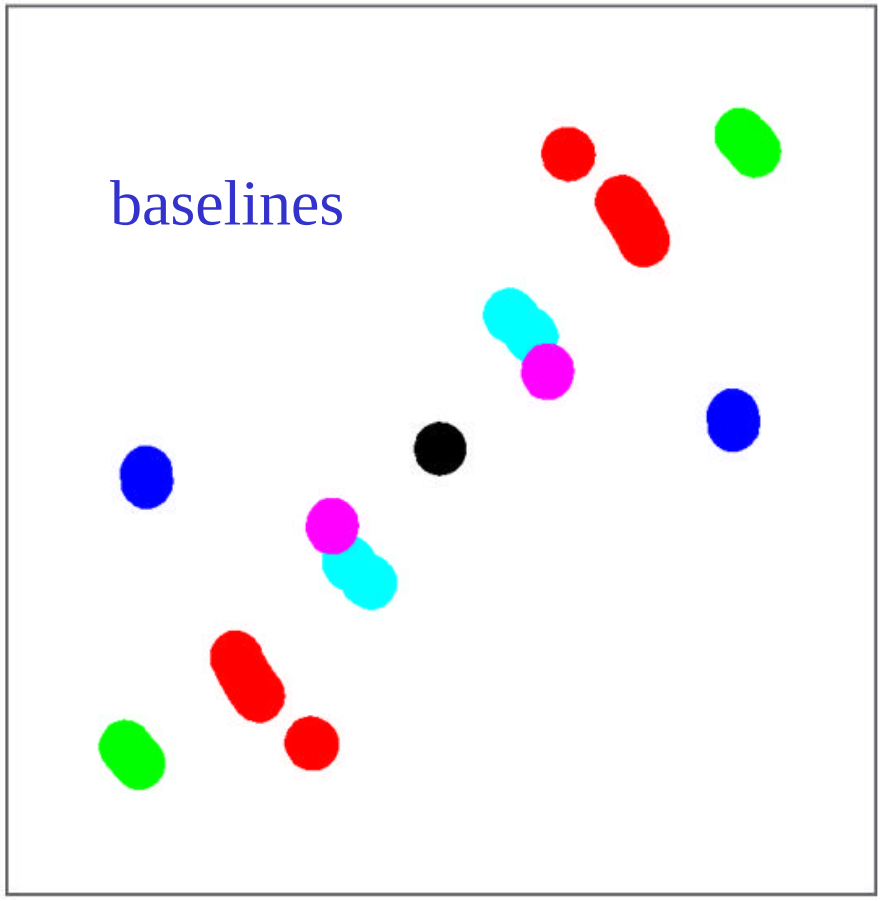
Optical /Infrared Aperture Synthesis

very difficult because wavelengths much shorter.

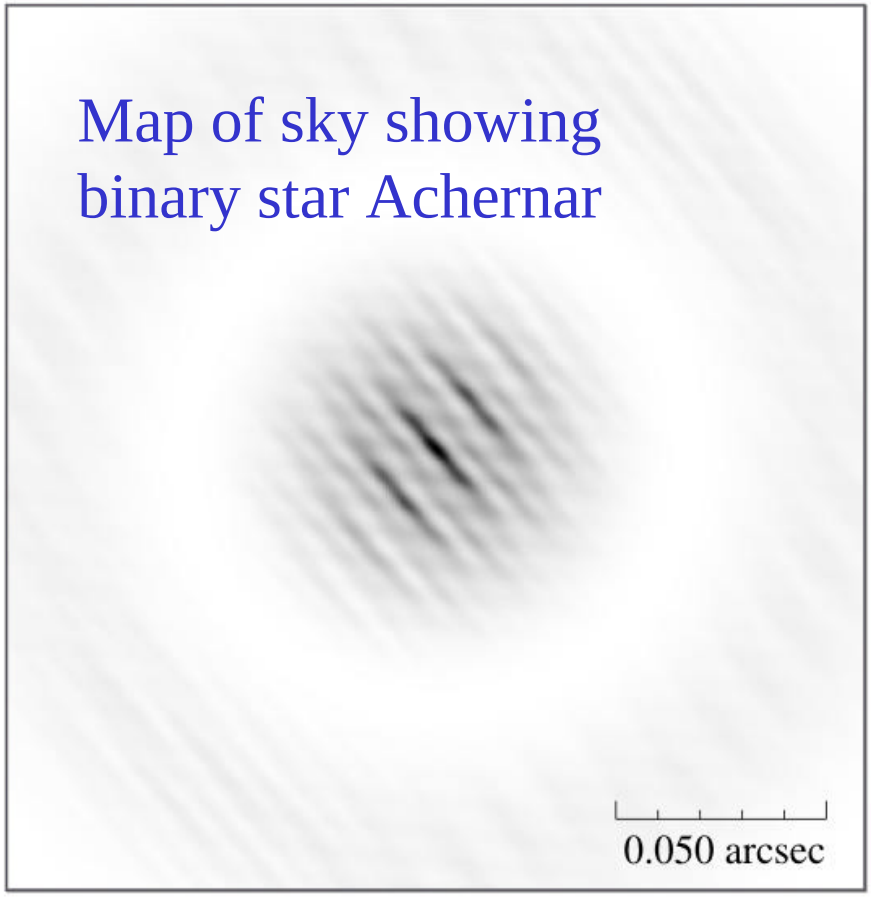
$$\frac{l}{d} \approx \frac{5\times10^{-7}\,\mathrm{m}}{100\,\mathrm{m}} \times \frac{2\times10^{5}\,\mathrm{arcsec}}{\mathrm{radian}} = 0.001\,\mathrm{arcsec}$$

European Southern Observatory (ESO)

- Very Large Telescope Interferometer (VLTI)
  - Four 8 metre telescopes (now)
  - + many 1.5m telescopes (soon)



UV Plane Coverage



Fringe Pattern of Achernar

First Steps towards a 2D Interferometric Image
(VLT ANTU/KUEYEN/MELIPAL/YEPUN + VINCI)

ESO PR Photo 22b/02 (26 September 2002)