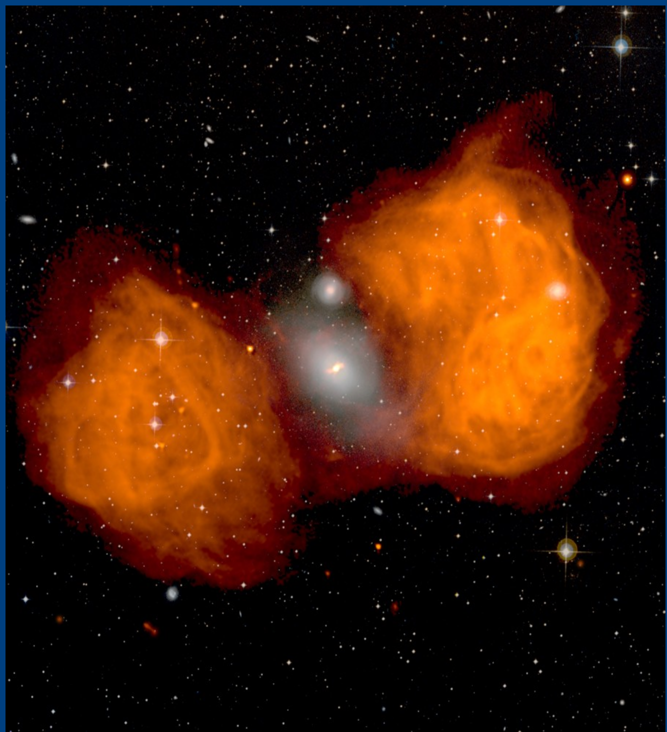
Studying the Relativistic Jets of Active Galactic Nuclei

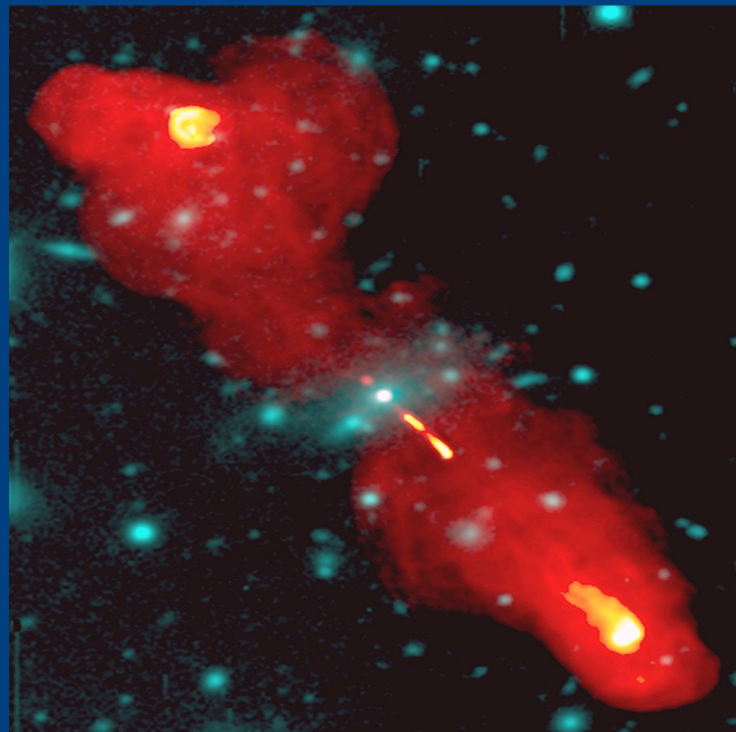
Denise Gabuzda
Radio Astronomy Group

Active Galactic Nuclei (AGN): extremely compact, generate much more energy than a normal galaxy.

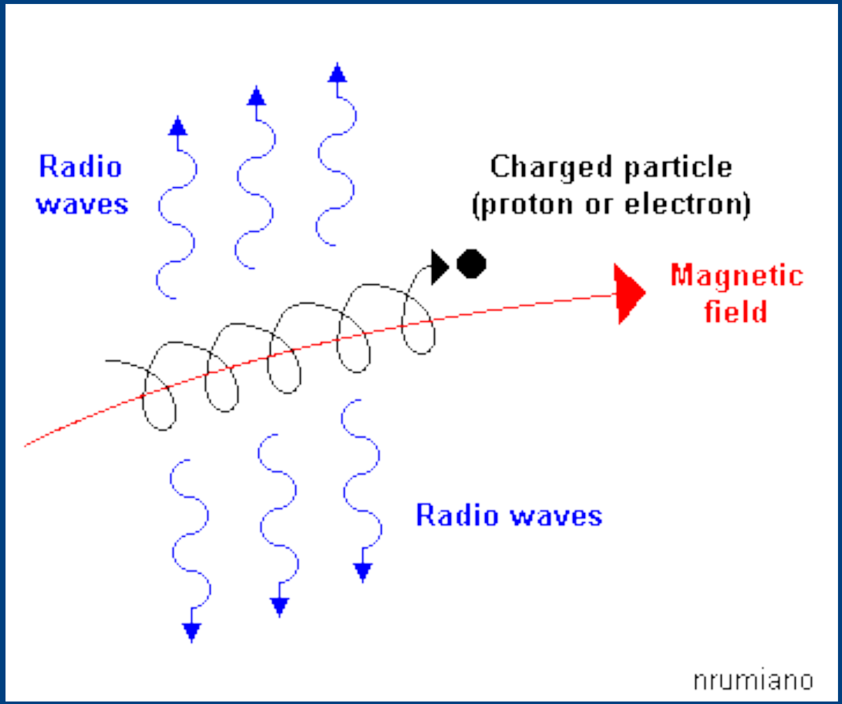
Activity due to accretion onto a supermassive (~10^9 solar masses!) black hole

Sometimes eject "jets" of radio-emitting plasma extending far beyond optical (visible) galaxy.





This radio emission is SYNCHROTRON RADIATION — electromagetic radiation given off by energetic electrons during their acceleration by local magnetic fields. Intrinsically linearly polarized up to 70%.



Radio Interferometry – using an array of radio telescopes with synchronized signals, provides resolution

$$R \sim \lambda/D$$

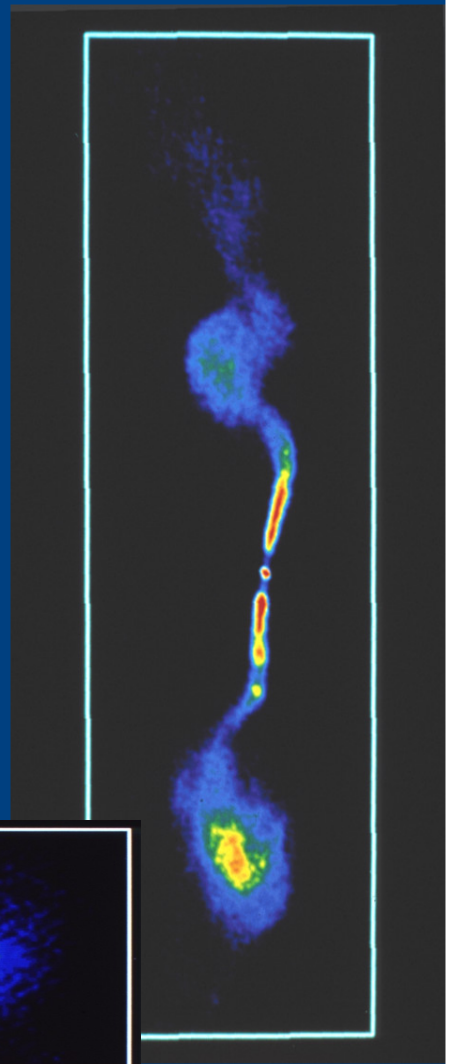
Where D is maximum distance between telescopes used.

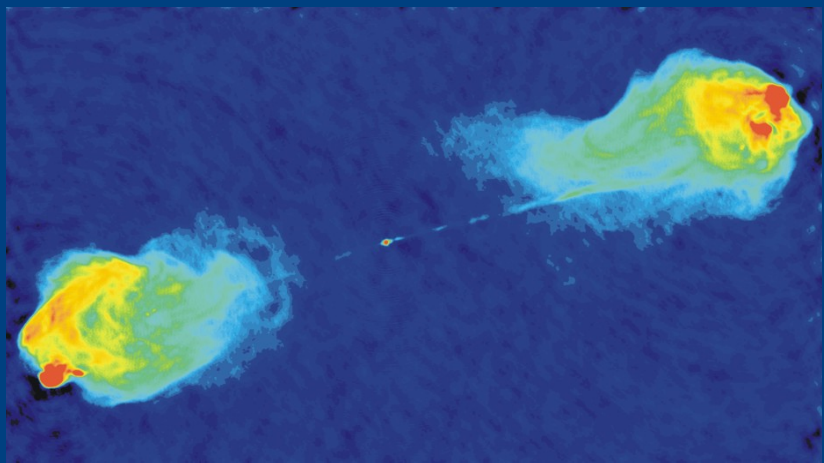
Can use different radio telescope arrays to study jets on different scales.

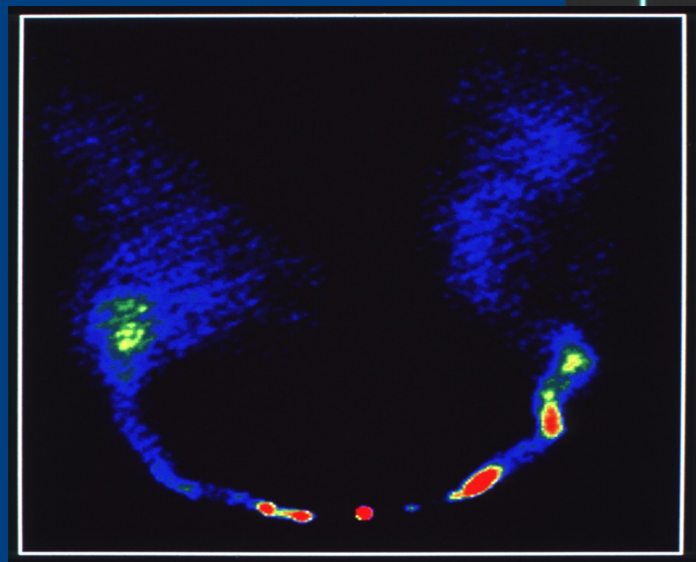
In connected-element arrays, the telescopes are linked electronically

Very Large Array (VLA), max baseline 36 km

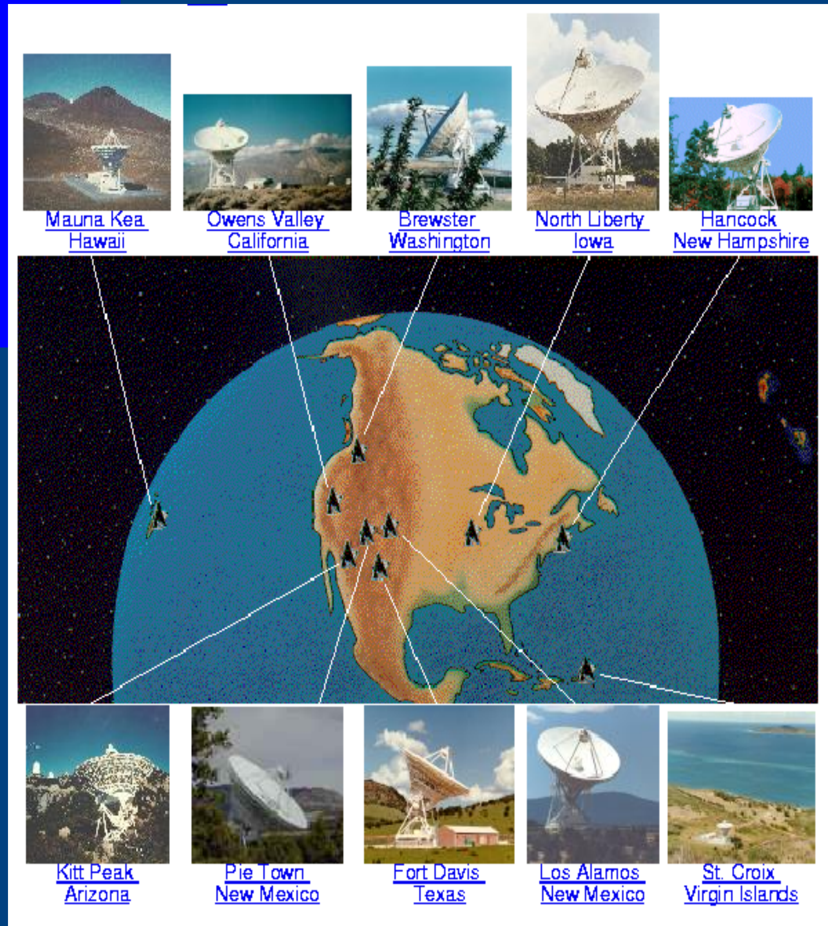
Images of AGN jets obtained with the VLA, scales of kiloparsec (1000’s of light years)





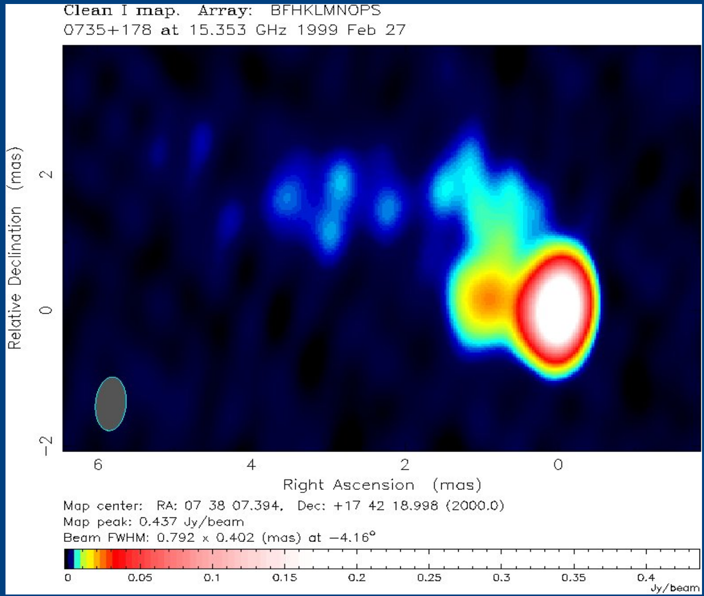


Very Long Baseline Array (VLBA)



In Very Long Baseline Interferometry, the data are usually recorded on disc and processed after the observations

Images of AGN jets obtained with the American VLBA — one-sided structure due to Doppler beaming



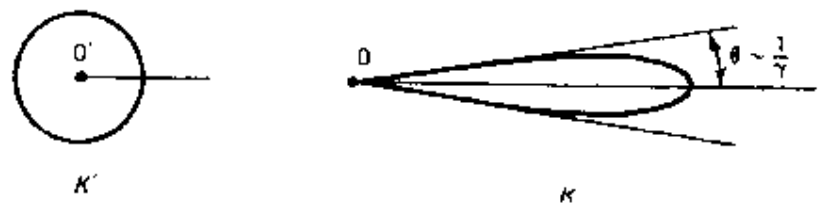
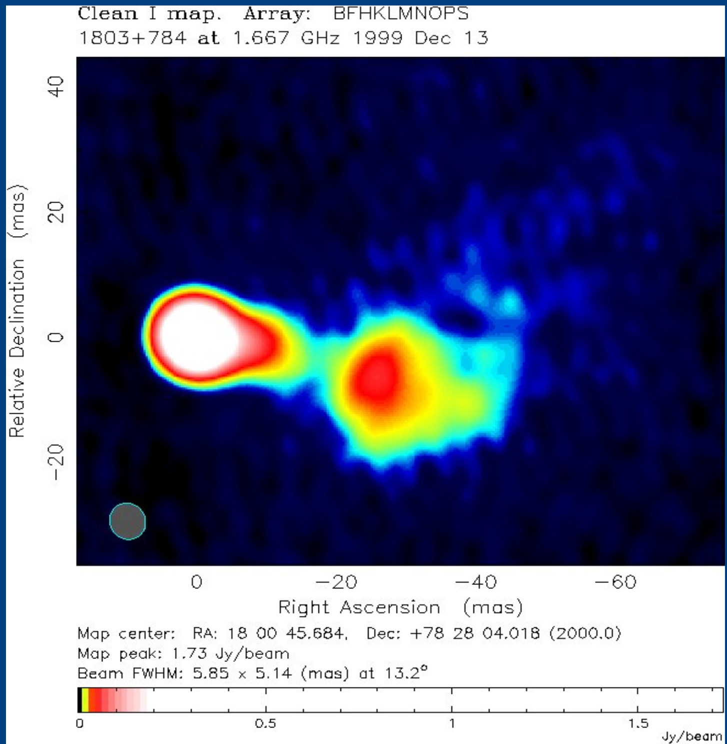
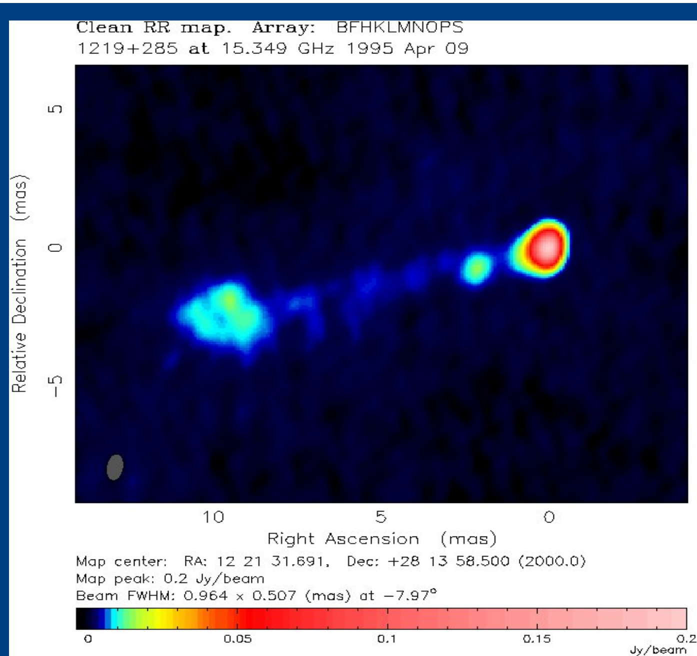
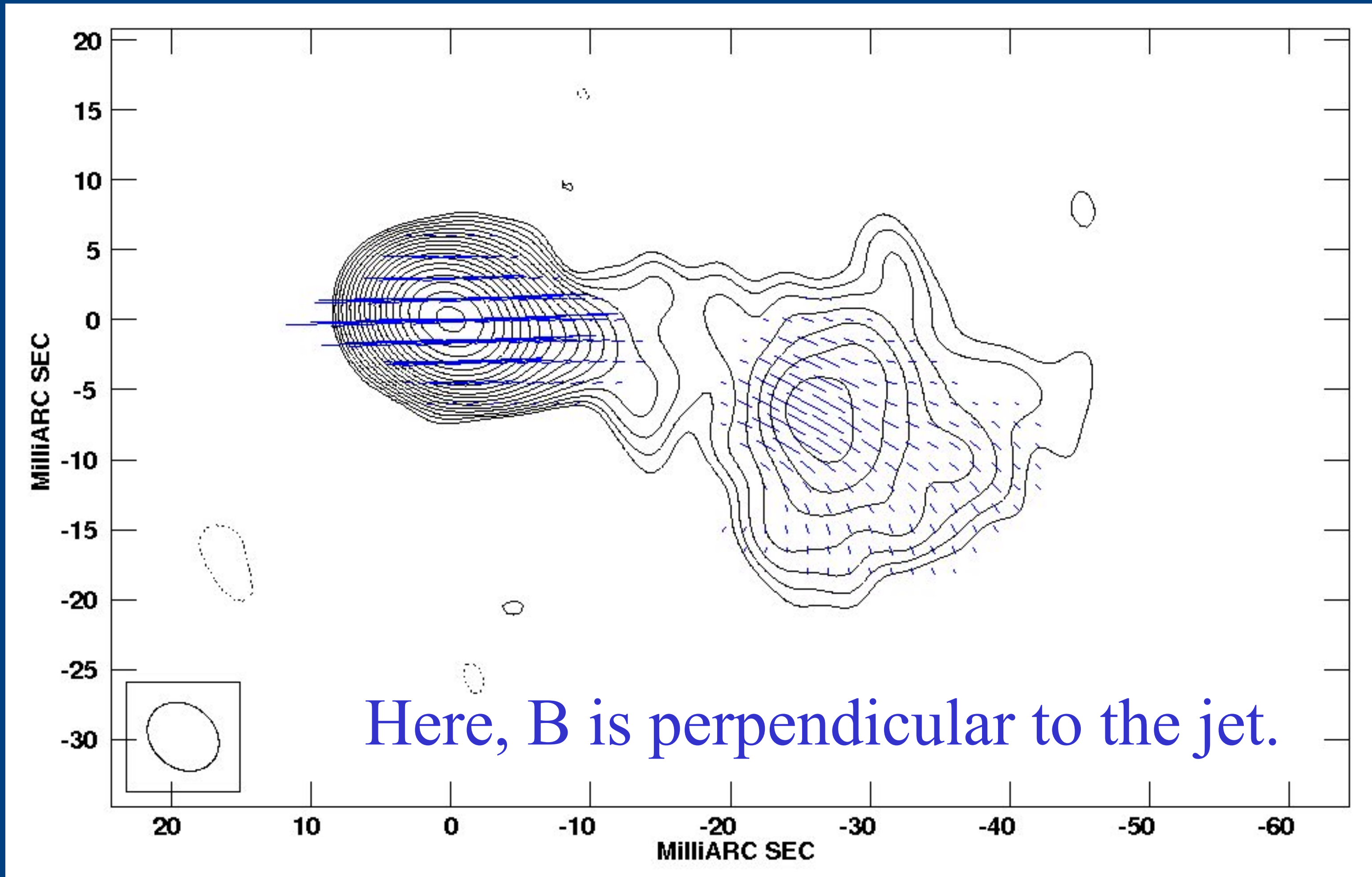


Figure 13: Relativistic beaming

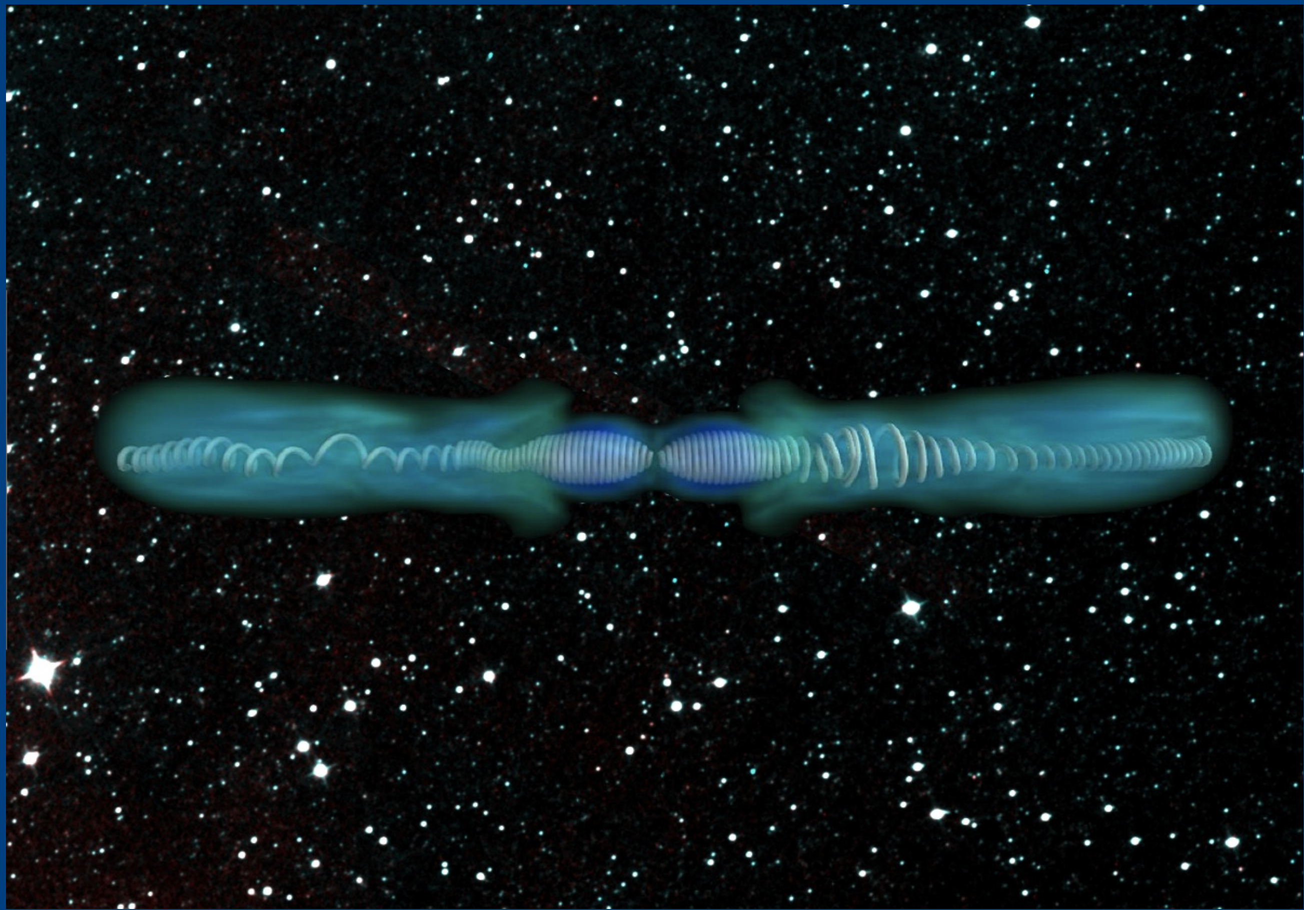




The linear polarization of the radio emission is perpendicular to the B field giving rise to the synchrotron radiation.



Such perpendicular B fields may represent the toroidal component of an intrinsic underlying helical B field, due to rotation of the central supermassive black hole and its accretion disc + relativistic jet outflow.



Recent simulation by A. Tchekovskoy

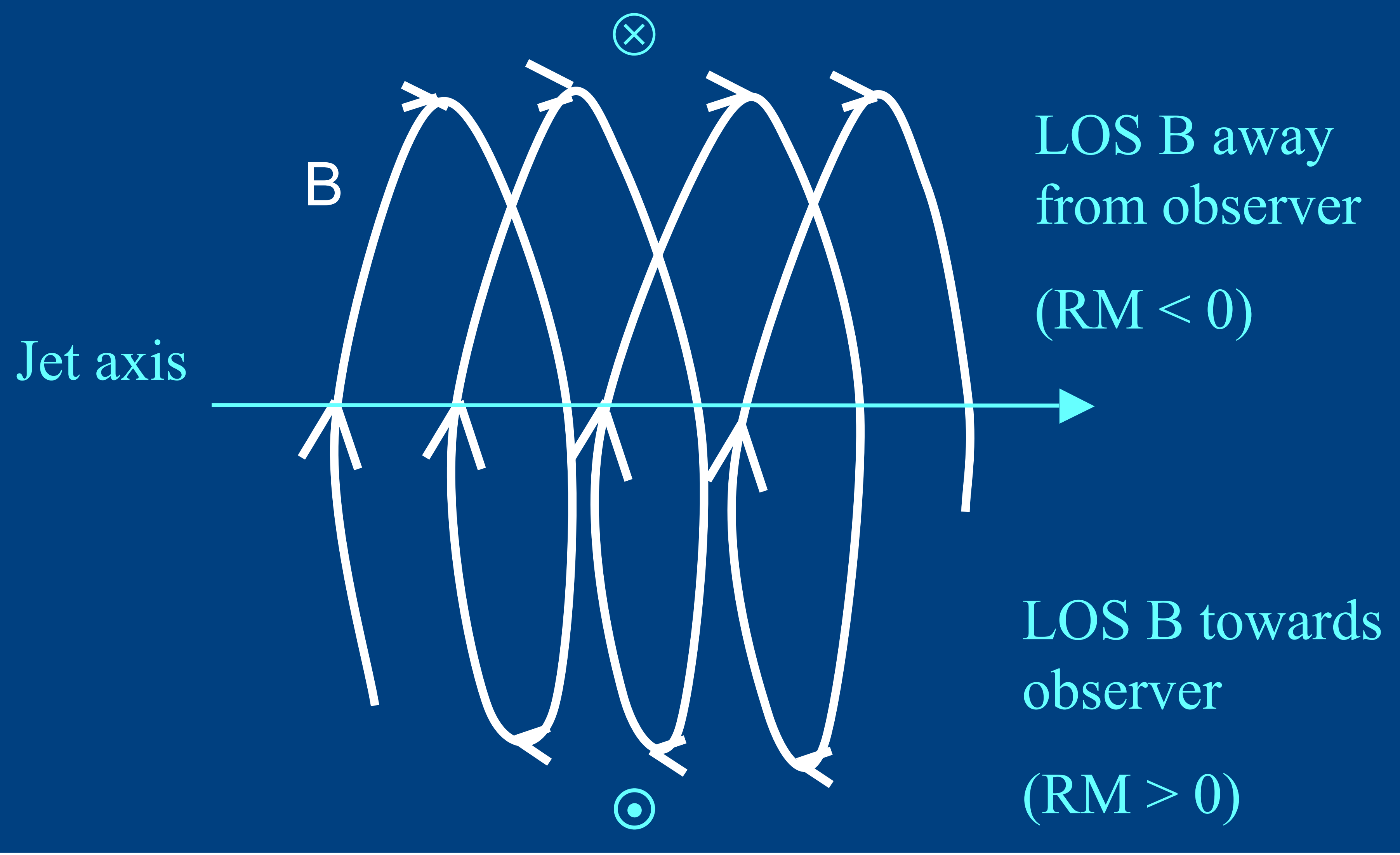
Faraday rotation of the direction of polarisation occurs when an EM wave passes through a magnetised plasma, due to different propagation velocities of the right- and left-circularly polarized components of the EM wave in the plasma.

The rotation is proportional to the square of the wavelength, and its sign is determined by the direction of the line-of-sight B field:

$$\chi = \chi_o + RM\,\lambda^2$$

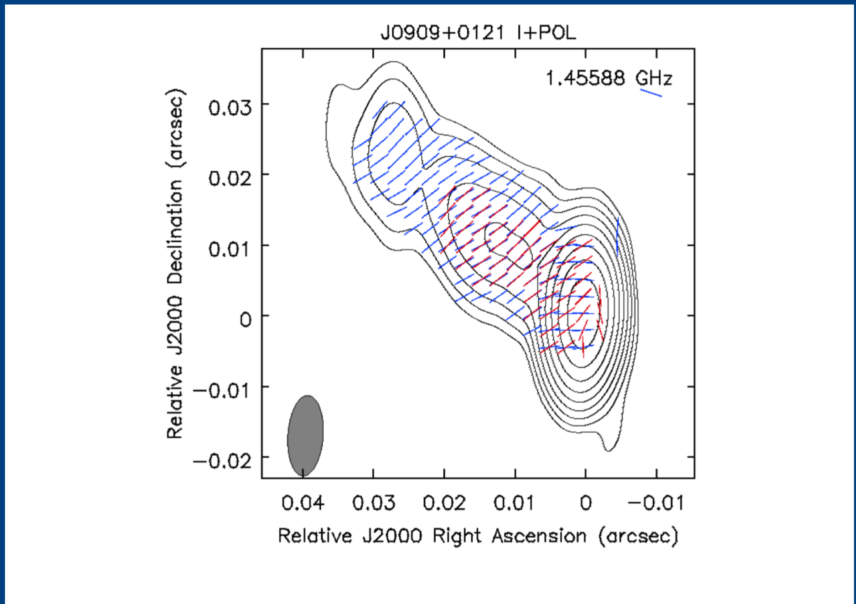
$$RM = (\text{constants}) \int n_e\, \mathbf{B} \cdot d\mathbf{l}$$

A helical jet B field should give rise to a gradient in the Faraday rotation across the jet, due to the systematic change in the line-of-sight (LOS) component of the helical field.

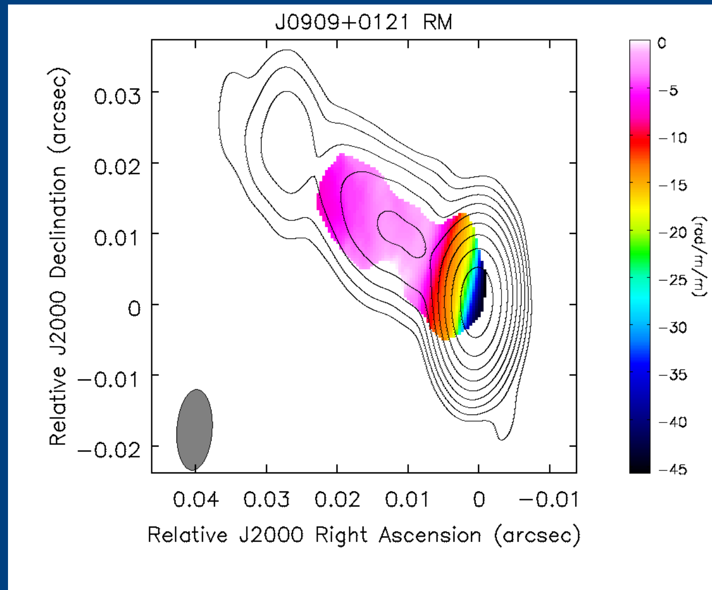


Project: AGN jets on parsec to decaparsec scales

Making 6, 13, 18 and 22 cm intensity, linear polarization, spectral index and Faraday rotation maps, to study the jet structures & B fields and look for transverse RM gradients (evidence of helical B fields)



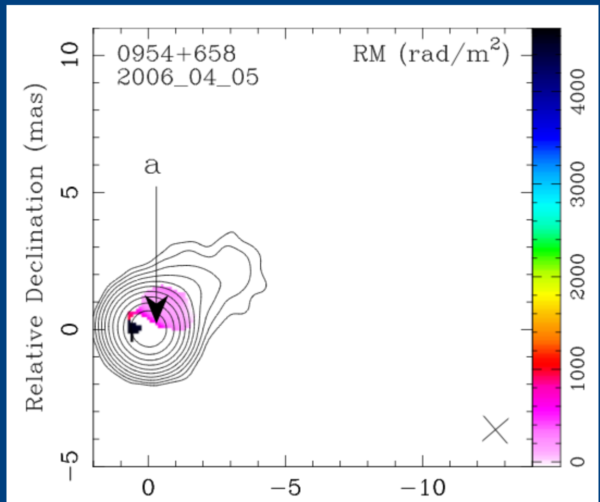
Intensity contours with polarization as observed (blue) and corrected for Faraday rotation (red)

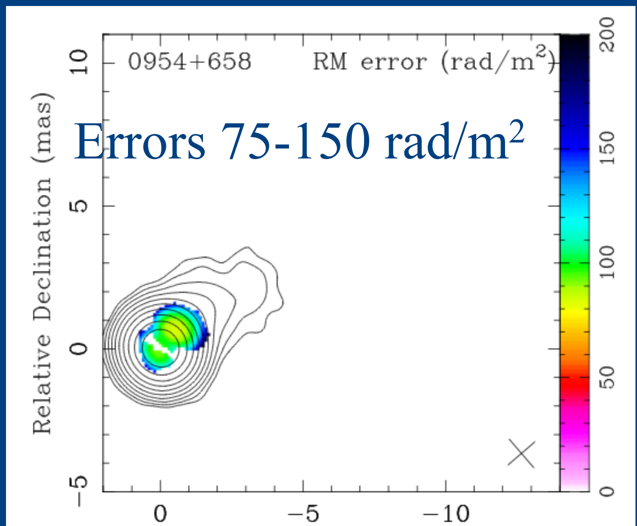


Intensity contours with Faraday rotation map in colour

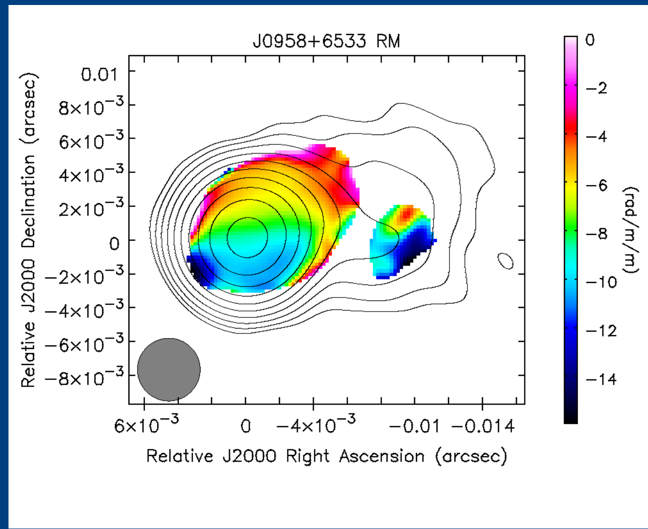
These data are designed to give very sensitive Faraday rotation maps due to the large range of λ^2 encompassed.

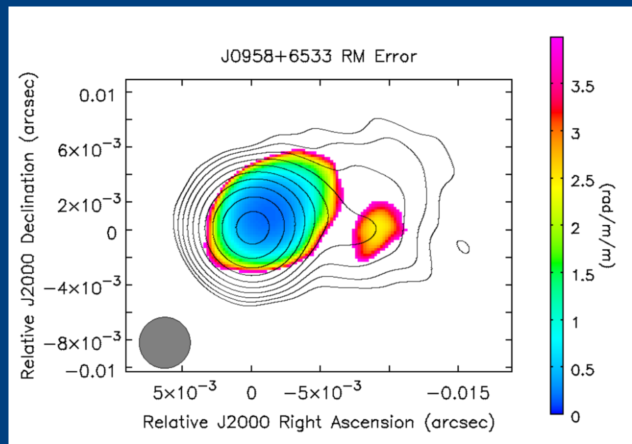
2-4cm RM map





6–22cm RM map





Errors 0.3-3 rad/m^2 !

Peering into the heart of an AGN