RADIO INTERFEROMETRY

The angular resolution of a single radio telescope isn’t particularly good. Using the Rayleigh criterion for resolution, a telescope of diameter \( D \) observing at wavelength \( \lambda \) can resolve objects separated by an angle \( \theta \) given by

\[
\theta = 1.22 \frac{\lambda}{D} \tag{1}
\]

For example, if a telescope with \( D = 25 \) m observes at the 21 cm line of hydrogen, the resolution is

\[
\begin{align*}
\theta &= 1.22 \times \frac{0.21}{25} \\
&= 0.010248 \text{ rad} \\
&= 0.587^\circ
\end{align*} \tag{2}
\]

The resolution can be greatly improved by using interferometry. The idea behind interferometry is similar to that of the diffraction grating. Suppose we have two telescopes separated by a baseline distance \( d \), and both telescopes are observing an object that makes an angle \( \theta \) with the normal to the ground. The radio waves travelling to one telescope will go a distance \( L = d \sin \theta \) further than those to the other telescope. If \( L = (n - \frac{1}{2}) \lambda \) the signal at one telescope is exactly out of phase with the signal at the other. Since \( \lambda \) is known (it’s the wavelength at which we’re doing the observing), we can adjust the angle \( \theta \) of the telescopes until the combined signal vanishes.

The angle by which the telescopes must be changed to move from one minimum (or maximum) to the next is found from
\[
\sin \theta = \frac{L}{d} \quad (5)
\]
\[
\cos \theta \Delta \theta = \frac{\Delta L}{d} \quad (6)
\]
\[
= \frac{1}{d} \left( \left(n + 1 - \frac{1}{2}\right) \lambda - \left(n - \frac{1}{2}\right) \lambda \right) \quad (7)
\]
\[
= \frac{\lambda}{d} \quad (8)
\]
\[
\Delta \theta = \frac{\lambda}{d \cos \theta} \quad (9)
\]

If the two telescopes are separated by the diameter of the Earth, then for \(\lambda = 21\) cm and observations near \(\theta = 0\) we have

\[
\Delta \theta = \frac{0.21\ m}{1.2742 \times 10^7\ m} = 1.65 \times 10^{-8}\ \text{rad} \quad (10)
\]
\[
= 0.0034'' \quad (11)
\]

Thus the resolution is about a million times better than for a single telescope on its own.

Several arrays of radio telescopes have been built. The Very Large Array (VLA) in New Mexico consists of 27 dishes, each 25 m in diameter, spread over a circle 27 km in diameter. Along with the increased resolution, the VLA has a total collection area of \(27 \times \pi \times (12.5)^2 = 13253\ m^2\) which is equivalent to a single dish of diameter 130 m.

Another large array is situated at the Atacama Large Millimeter Array (ALMA) in Chile. It consists of 50 12 m diameter antennas with an additional 16 smaller dishes, and was completed in 2013. The 50 main dishes provide \((\binom{50}{2}) = 1225\) distinct baselines for pairs of telescopes.

**Pingbacks**

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