Radio Astronomy

$$\lambda_{max} T = 2.9 \text{ mm K}$$
$$= 2900 \text{ } \mu\text{m K}$$

Microwave background - T = ~~2.7~~ 3 K,
so

$$\lambda_{max} = 1 \text{ mm}$$

Thus, it is unusual to expect to see any thermal emission from "normal objects" in radio.

What can be detected?

- Rayleigh-Jeans tail of hot objects
- Non thermal emission, ~~from~~ like synchrotron, or coherent emission from pulsars
- HI, molecules, masers, etc.
  - can be in emission, or absorption.

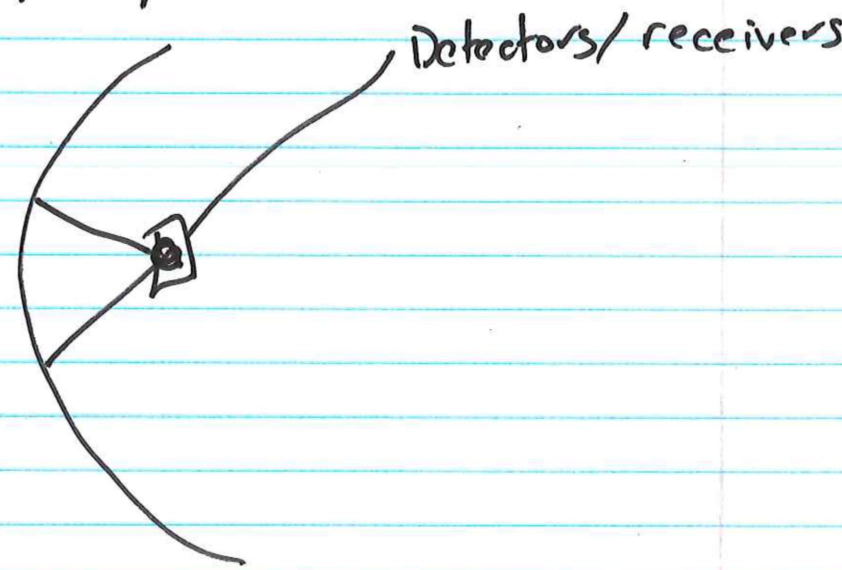
Radio Telescopes

- Single dishes
- Interferometers

Single dishes

- Pulsar Timing, and especially searching.
- Mapping out large structures

Single dishes more easily have multiple pixel detectors.



Receivers - use electronics to convert the frequency down to a lower one.

Then, record the voltage in each frequency channel as a function of time.

- Not all that different from what an AM/FM radio does, except that instead of going to a speaker, power is recorded.

Then, to make images, this can be done in a multibeam receiver, or ~~to make time series,~~ the sky can be scanned.

Bolometers sometimes used at high freq.

Key sources of noise

1) thermal ("system temp." often a unit of sensitivity)

2) sky

3) other sources due to confusion limit

4) RFI!

Angular resolution of radio telescopes

Green Bank - goes from 300 MHz to 90 GHz.

300 MHz = 1 m
90 GHz = 3 mm

Huge range in wavelengths!

GBT is 100 m dish

$\Delta\theta = 1.22 \frac{\lambda}{D}$ in rad if parabolic (and it's nearly parabolic).

$\Delta\theta = 42'$ at 300 MHz

$\Delta\theta = 7.5''$ at 90 GHz

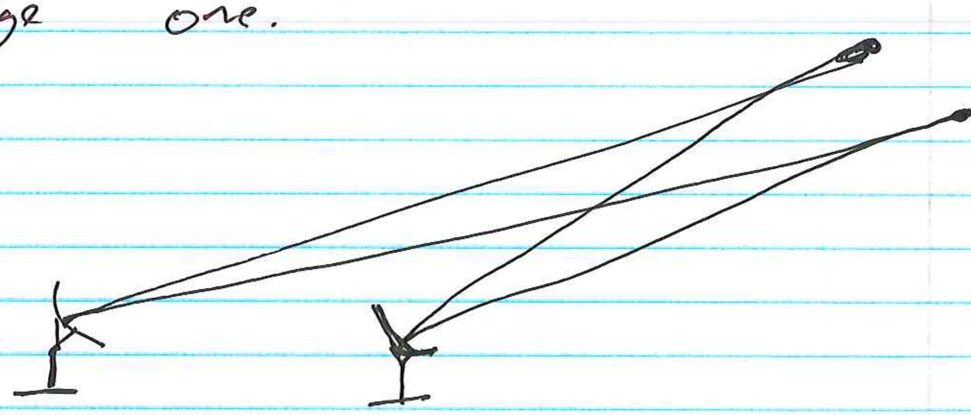
Still worse than good optical telescopes.

Advantage: big field of view per beam for pulsar searches

Interferometers!

- Physical limits to building large enough radio telescopes to match optical image quality (or exceed it!)
  Green Bank is taller than tallest building in WV, 485ft
- Receivers are expensive, and having good angular resolution <u>and</u> field of view is impractical because of cost.

Solution — combine multiple small telescopes into one large one.



The path length difference to the two telescopes from the source will depend slightly, but measureably on their position.

So, what we can do is measure the phases at each telescope of all the radio emission in their beams.

This introduces some new challenges:

(1) must know relative positions of the telescopes precisely - a quarter of a wavelength.

(2) must have excellent clocks on all the telescopes (~~masers~~ atomic clocks used), or the phase differences cannot be measured.

(3) Atmospheric effects - low frequency, the ionosphere causes time delays because of scattering of radio waves by free electrons. This is dispersive.

High frequency - the troposphere causes radio waves to move more slowly than in a vaccum. Clouds can cause rapid fluctuations.

Solution:

Phase calibration

- Must chop the telescope back and forth between a source of interest and a nearby "phase calibrator".

- The phase calibrator's position is well known, so it is then known what the delays should be between different antennae.

So, then, just the difference in phase is used.

~~Solution~~ Problem 2:

Complicated images

A single point source is easily located by interferometry.

To map out complicated structures, need to look at more "baselines". The phase differences on different baselines can be used to break things up into "pieces" - multiple sources. Helps to know some source positions ahead of time.

This is fine for point sources, but for smoothly extended sources, it's harder.

If the largest angular scale of a source is too big, then, the interferometer cannot distinguish it from higher thermal noise.

Partial solutions - VLA train tracks, rotation of the sky above sources.

Problem cannot be fully solved. Old array patterns not optimal, but easier to deconvolve.

Angular resolution of an interferometer:

~~$\Delta\theta \approx 1.22 \frac{\lambda}{B_{max}}$~~

~~B_{max} is largest separation.~~

VLA:

	A	B	C	D
B_{max}	36.4 km	11.1	3.4	1.03
B_{min}	0.68 km	0.21	0.035	0.035

If looking at bad angles, near horizon, need to correct a bit.

Synthesized beam: $\Delta\theta \sim \frac{\lambda}{B_{max}}$

Largest angular scale: $\Delta\theta \sim \frac{\lambda}{2 B_{min}}$ (not exactly)

Primary Beam (FOV) $\Delta\theta \sim \frac{\lambda}{D_{ant.}}$

VLBA: ~ 5000 km max, 100 km min.