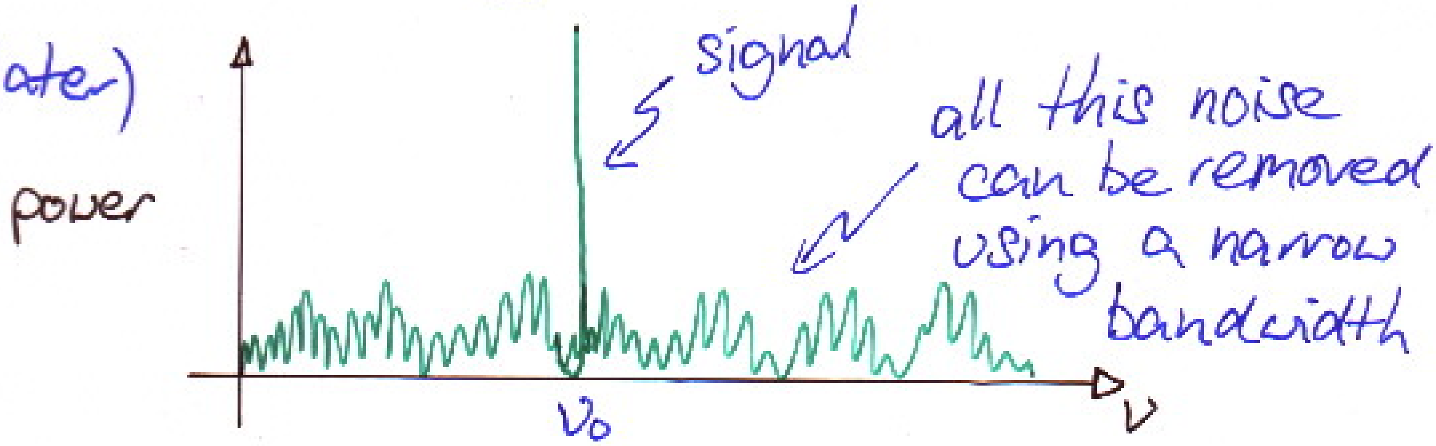
# S.E.T.I.

- The search for extraterrestrial intelligence
- Radio because:

  Galactic emission is a minimum at certain radio wavelengths + the waves can travel without strong absorption (unlike light)

- Best at $\lambda \sim$ mm to $\lambda \sim 30$cm

- Narrow band signals travel furthest (see later)




How do we choose $\nu_0$?

- Perhaps choose one close to a natural emission line, eg H (21cm) or OH (18cm)

The zone $18\,cm < \lambda < 21\,cm$ is called the water hole

## Communication

Take a transmitter, output power $P$
bandwidth $\Delta\nu$

Distance $r$ from transmitter:

Flux density $$S = \frac{P}{4\pi r^2 \Delta\nu}$$

Take a receiver, effective area $A_e$, also with bandwidth $\Delta\nu$. Received power $W$ is

$$W = S A_e \Delta\nu = \frac{P A_e}{4\pi r^2}$$

If the transmitting antenna is pointing our way with a beam solid angle $\Omega_A$. $\Rightarrow$

transmitting area

power increased by $\dfrac{4\pi}{\Omega_A} = \dfrac{4\pi A_t}{\lambda^2}$

Giving

Tx power

$$w = \frac{P A_e A_t}{\lambda^2 r^2}$$

the Friis transmission formula

received power

- What about the noise?

Noise power $= k T_s \Delta\nu$

system temperature

Boltzmann constant

So signal-to-noise ratio is

$$SNR = \frac{P A_e A_t}{\lambda^2 r^2} \cdot \frac{1}{k T_s \Delta\nu}$$

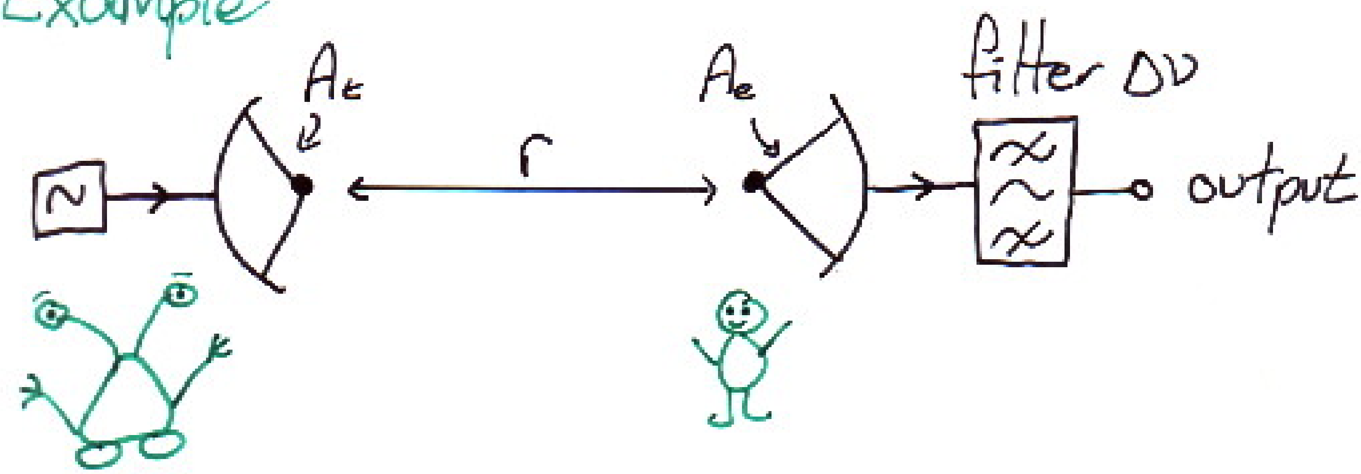
(ie SNR ↑ when $\Delta\nu$ ↓)

- For a constant signal, we can integrate, so that SNR ↑ by $\sqrt{(\Delta\nu\,\tau)}$

integration time

But maximum data throughput when $\Delta\nu\,\tau = 1$

Example




Take both dishes as 100m diameter

$$\Rightarrow \quad A_t = A_e \simeq \pi\left(\frac{100}{2}\right)^2 \simeq 8000\,m^2$$

Alien transmits $10^6$ W for 10s

$\Delta\nu = 0.1$ Hz (min. useable due to interstellar scattering)

$\nu = 5$GHz $\Rightarrow \lambda = 6$cm

$T_s = 3$K (Noise dominated by microwave background)

$\Rightarrow$ (for an SNR of 3):

$$r = \left(\frac{PA^2}{3\lambda^2 k T_s \Delta\nu}\right)^{1/2} = \left(\frac{10^6 \pi^2 50^4}{3 \cdot 0.06^2 \cdot 1.38\times10^{-23}\, 3\, 0.1}\right)^{1/2}$$

i.e. $r \simeq 4\times10^{19}\,\mathrm{m} \simeq 1{,}200\ \mathrm{pc}$

$[1\,\mathrm{pc} \simeq 3\times10^{16}\,\mathrm{m}]$

$\Rightarrow$ we are sensitive to a volume of

$$\tfrac{4}{3}\pi r^3 \simeq 7.2\times10^{9}\ \mathrm{pc}^3$$

Star density in solar neighbourhood

$$\rho \sim 1/20\ \mathrm{pc}^{-3}$$

$\Rightarrow$ N° of stars in range $\sim 3\times10^{8}$

- Receiver beam solid angle $\Omega_A = \dfrac{\lambda^2}{A_e} \simeq 4\times10^{-7}\ \mathrm{sr}$

$\Rightarrow$ only see $\dfrac{4\times10^{-7}}{4\pi}$ of the sky at any one time. $\Rightarrow$ about $\dfrac{10^{-7}}{\pi}\cdot 3\times10^{8} \sim$ 10 stars in the beam at any one time.

- How long to survey the sky?

N°. of beams in $4\pi \simeq \dfrac{4\pi}{4\times10^{-7}} \simeq 3\times10^{7}$

(Time per beam = 10s) $\Rightarrow 3\times10^{8}\,\mathrm{s}$ = 10 years

# Present Searches

Justification is flaky ⇒ no NASA support.

Biggest present effort: SERENDIP

University of California (Berkeley)

- Serendip IV began summer 1997
- "Piggyback" on Arecibo
- Observing frequency centred on 1·42 GHz (HI line)
- 100 MHz bandwidth
  samples 168 million 0·6 Hz channels in 1·7 s
- $2 \times 10^{11}$ flops (floating point operations / s)