SETI

With current technology, difficult to detect unintentional leakage from other civilizations at useful distances

An advanced civilization could choose to construct "beacons" that *would* be detectable today

Search needs to target:

- many stars
- at high sensitivity
- with narrow frequency channels

Depending upon the nature of the signal being sought, can be advantageous to trade off these factors (e.g. one super-powerful beacon in the Galaxy would best be found with a low sensitivity all-sky survey)

SETI searches: Project Phoenix

Search between 1995-2004 on large radio telescopes:

- 700 nearby stars surveyed
- 1.2 - 3 GHz, in 0.7 Hz frequency channels
- 2-10 minutes observing time per star
- sensitivity 10^{-26} W / m^2

•Used a pair of widely separated dishes to allow for a
•determination that sources were actually coming from the
•sky and were not radio frequency interference

- ~1,000,000 candidate signals
- ~1,000 that appeared to be from the sky
- none that survived further examination

"SETI at home"

Distributed computing project to analyze passively acquired data from Arecibo (primarily in a 2.5 MHz band centered on 1420 MHz)

Due to Doppler shift, frequency of a narrowband artificial signal will drift due to the changing motion between the Earth and another planet - rate of ~0.1 Hz / s

Computational task is to search across many frequency channels and all possible drift rates

About 3 million PCs participating in the effort

Allen Telescope Array

New array of radio telescopes under construction in California

First 42 dishes were activated last October: goal is 350 dishes each of 6.1m diameter

Frequency coverage 1-10GHz (~10 billion 1 Hz channels)

Each antenna is small (so wide field of view): within this field multiple targets can be identified in software post-processing of the data.

ATA search strategy

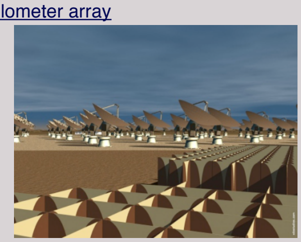
- Search ~100,000 stars for artificial signals. Sensitivity good enough to detect the equivalent of the Arecibo planetary radar out to ~1000 light years in the frequency band 1-10 GHz
- Survey ~ 4 x 10^{10} stars in the Galactic plane toward the center of the Galaxy for super-powerful beacon transmissions

Telescope will also be the best instrument for some non-SETI radio astronomy - searches for radio counterparts to gamma-ray bursts, timing of pulsars…

Square kilometer array

Proposed next generation radio telescope, to be sited either in Western Australia or South Africa

1 square km of collecting area - similar all-digital design to Allen telescope



For SETI, could survey ~1,000,000 stars for signals of comparable strength to current terrestrial emission

Null results and the Drake equation

$$N_{civ} = N_* \times f_{HP} \times f_{life} \times f_{civ} \times f_{alive}$$

Suppose we search 1,000,000 stars and find no evidence for artificial signals. If we assume that any presently alive civilization would send signals, then estimate:

$$N_{civ} < \frac{N_*}{10^6} \approx 10^5$$

Could write this as a limit on the product $f_{life} f_{civ} f_{alive}$

Clearly current and planned searches do not place very strict limits on the number of intelligent civilizations in the Galaxy (especially since it's not clear other civilizations *would* send signals).

Interstellar travel

Could we send a probe to nearby stars?

Example: Voyager 1 probe has a current velocity of ~17,000 km per hour = 4,700 ms^{-1}

Distance to the nearest star is about 3 light years: 3 x 9.5 x 10^{15} m ~ 3 x 10^{16} m

Travel time: $$t = \frac{3 \times 10^{16} \text{ m}}{4{,}700 \text{ m/s}} = 6 \times 10^{12} \text{ s} = 200{,}000 \text{ years}$$

Need to do much better if interstellar travel is ever to be practical!

Fundamental limitations

All evidence suggest that the speed of light c is the absolute upper limit for the propagation of any material object, signal or information transfer (Einstein's special theory of relativity)

As seen from Earth, cannot make it to the nearest stars (d ~ 3 light years) in less than 3 years unless there are fundamental errors in our understanding of physics

However, as **seen from an astronaut on board** a craft, time is slowed by a factor:

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

Relativistic phenomenon called time dilation

Time dilation only becomes significant at velocities close to the speed of light:

e.g. v = 0.1 c: γ = 1.005

1 year of Earth time = 0.995 years on spacecraft

v = 0.99 c: γ = 7

1 year of Earth time = 1.7 months on spacecraft

If we could accelerate spacecraft to very close to the speed of light, would be possible to make trips to the nearby stars within human lifetimes.

Energy requirements

For non-relativistic speeds (v << c), the kinetic energy of a spacecraft of mass m traveling at speed v is:

$$E_{KE} = \frac{1}{2} m v^2$$

e.g. to accelerate a probe of mass 100 kg to 10% of the speed of light energy requirement is:

$$E_{KE} = 0.5 \times 100 \text{ kg } \times \left(3 \times 10^7 \text{ m/s}\right)^2 = 4.5 \times 10^{16} \text{ Joules}$$

Not a crazy number - about the energy output of a 1 GW power station for one year

Problem is that the fuel required to yield that much energy is very heavy…

e.g. liquid hydrogen has an energy density of about 140 MJ per kg: 1.4 x 10^8 Joules / kg

To supply the energy requirements of our hypothetical 100 kg probe, would need ~300,000 *tonnes* of fuel!

Ways around this problem…

- discard the fuel tanks as you go (the principle of "staging" used for all current rockets)
- use more efficient fuel (higher energy density)
- don't carry the fuel with you
- accept extremely long journey times (energy goes as the square of the velocity, and even a million years is very short compared to lifetime of Galaxy)