Astronomy 330

This class (Lecture 24):
Communication
Adam Flanders
Stefanie Pansch

Next Class:
Interstellar Travel

HW10 is due Thursday.

Music: *Aliens Exist*– Blink 182

Presentations

- Adam Flanders
  Water on Earth
- Stefanie Pansch
  Life Around Gas Giants

Outline

- How to communicate with ET.
- What makes a radio telescope so cool.
- SETI experiments
- Speed of light– it's the law.

Drake Equation

That's 500 million advanced civs!!!

Frank Drake








$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	20 stars/ yr	0.8 systems/ star	2 x 0.11 = 0.22 planets/ system	0.775 life/ planet	0.505 intel./ life	.7 comm./ intel.	500M yrs/ comm.

Drake Equation For Optimist

= 2.5 x 10^{11}

Communicating Civilizations

62.5% of all stars in our Galaxy.

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact	Rate of formation of Sun-like stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	50	**1**	**1**	**1**	**1**	**1**	**5 x 10^9**

Birthrate of 50/year!

Drake Equation For Pessimist

= 7.5 x 10^{-6}

Communicating Civilizations

Must wait 10^7 years for one!

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact	Rate of formation of Sun-like stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	5	**0.1**	**0.15**	**0.01**	**0.01**	**0.01**	**100**

Birthrate of 7.5 x 10^{-8} / year!

Drake Equation For Average

= 930,000

Communicating Civilizations

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

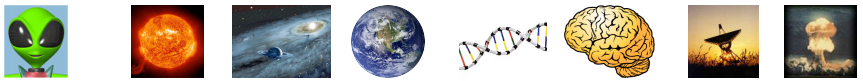
# of advanced civilizations we can contact	Rate of formation of Sun-like stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	10	**0.5**	**0.89**	**0.5**	**0.7**	**0.6**	**1x10^6**

Birthrate of 0.93 /year!

Drake Equation For me

= 1,800

Communicating Civilizations



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact	Rate of formation of Sun-like stars	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	10	**0.8**	**1**	**0.5**	**0.5**	**0.9**	**1000**

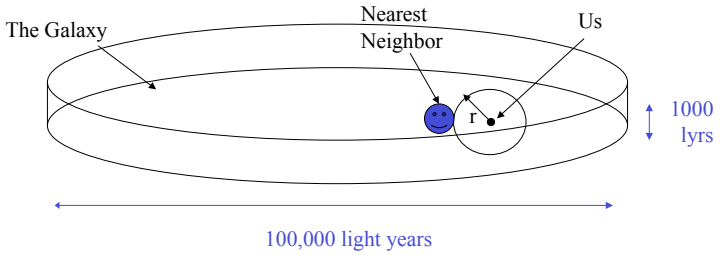
Birthrate of 1.8 /year!

Hmm..

- None of these results are wrong.
- The average birthrate result of around 1/year would suggest that any life that is contacted is presumable older and therefore more advanced.
- It is interesting to note that for our values, lifetimes greater than around 10 years give about 10 civilizations with which to talk.
- Our total number was **500 million** civs.

Distance to Nearest Neighbor

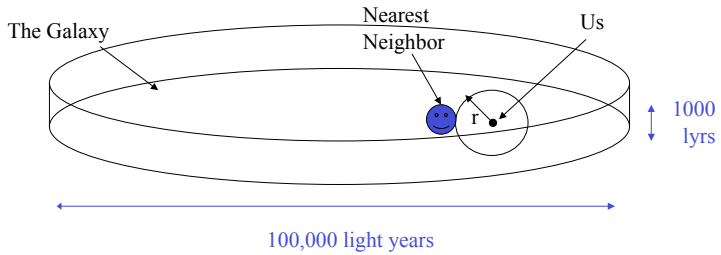
- Assume that the alien civilizations are uniformly scattered in our galaxy and N > 8000.
- We can then assume spherical volume to find ET, i.e. flatness of Galaxy not an issue.



Distance to Nearest Neighbor

- Assume N > 8000

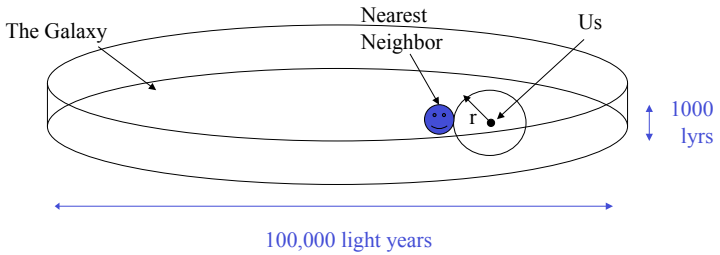
$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi r_{galaxy}^2 h_{galaxy}}{N} = \text{alien volume } (\text{lyr}^3/civ)$$



Distance to Nearest Neighbor

- Assume N > 8000

$$alien\ \text{volume} = \frac{\pi r_{galaxy}^2 h_{galaxy}}{N} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{\text{N}}$$



Distance to Nearest Neighbor

- Assume N > 8000

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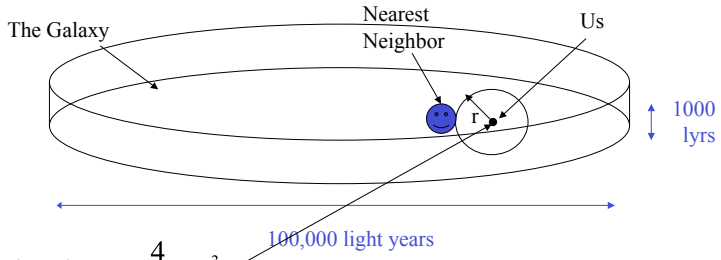
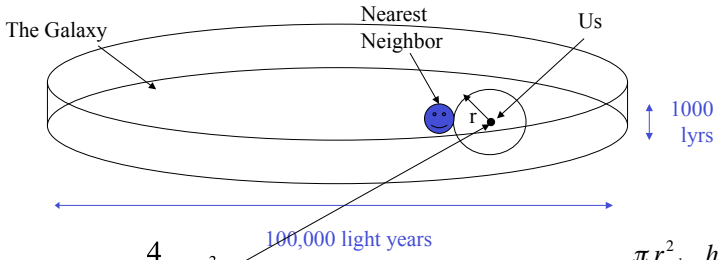


$$search\ volume = \frac{4}{3}\pi\ r^3$$

Distance to Nearest Neighbor

- Assume N > 8000

$$\frac{4}{3}\pi r^3 = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{N}$$



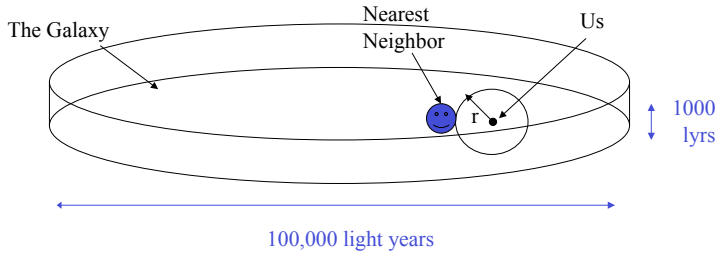
$$search\ volume = \frac{4}{3}\pi\ r^3$$

$$\text{alien volume} = \frac{\pi r_{galaxy}^2 h_{galaxy}}{N}$$

Distance to Nearest Neighbor

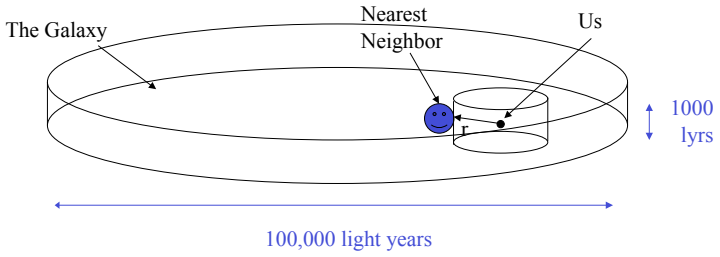
- Assume N > 8000

Then $$r \approx \frac{12000\ ly}{N^{\frac{1}{3}}}$$



Distance to Nearest Neighbor

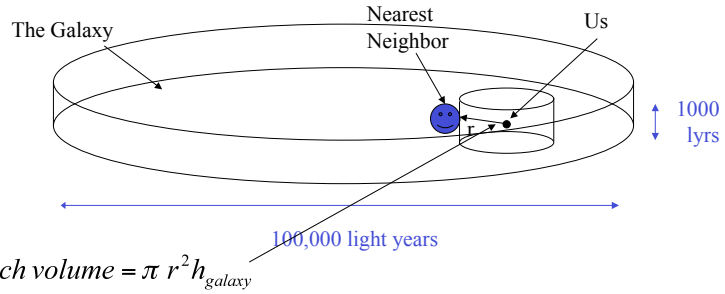
- Assume that the alien civilizations are uniformly scattered in our galaxy and N < 8000.
- Then, the flatness of Galaxy is an issue.



Distance to Nearest Neighbor

- Assume N < 8000

$$\frac{Average\ \ Galactic\ Volume}{Number\ of\ Civilizations} = \frac{\pi r_{galaxy}^2 h_{galaxy}}{N} = \text{alien volume}$$

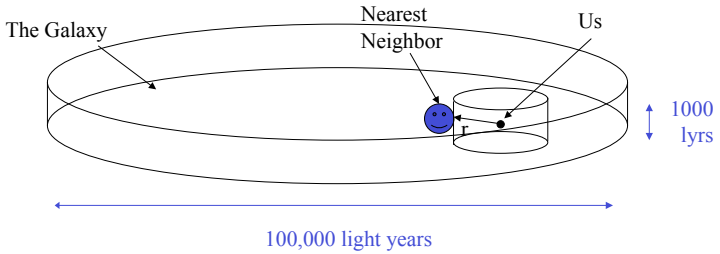


$search\ volume = \pi\ r^2 h_{galaxy}$

Distance to Nearest Neighbor

- Assume N < 8000

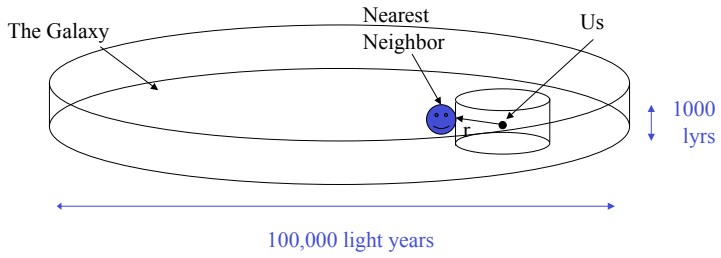
$$\pi r^2 h_{galaxy} = \frac{7.85 \times 10^{12}\ \text{lyrs}^3}{N}$$



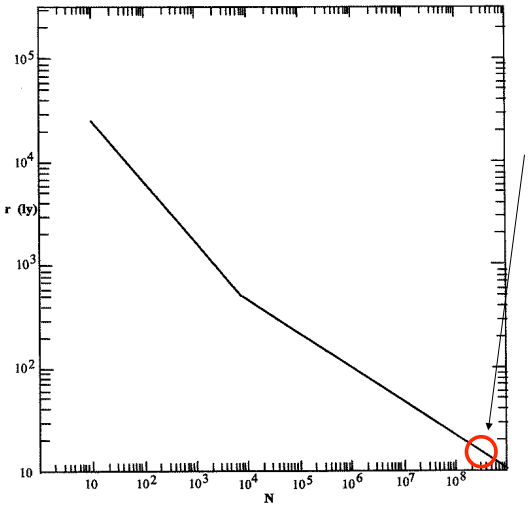
Distance to Nearest Neighbor

- Assume N < 8000

Then $r \approx \frac{50000\ ly}{N^{\frac{1}{2}}}$



The Neighbors



We need to look at every star within ~15 lyrs for one detection!

Using N=**500 million**

How Many Stars?

- How many stars in our distance?
- Let's use an average of 1 star/pc^3
  - 15 light years is 4.6 parsecs
- So 4/3 π (4.6^3) = 400 stars
- But, about 50% of stars are multiple, so we need to correct for that.
- 400 + 400/2 =
  600 stars

How Many Stars?

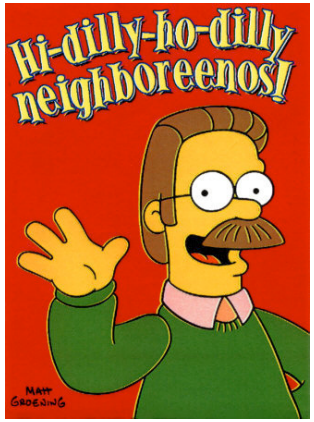
- Or, 500 million stars out of 100 billion
- **Or 1 in every 200 stars or so**
- **Too many?**

Interesting Points

1. We assumed uniform density of civilizations.
   - Underweights the galactic center, but maybe that's okay– supernovae.
2. Distance away is the <u>average</u>.
   - Could be closer, but unlikely to be much closer.
3. Note that r is better defined than N.
   - R depends on N$^{1/2}$ or N$^{1/3.}$
   - If we are wrong in N by a factor of 100, then only off in r by factors of 10 or 4, respectively.
4. For communication, it may be that the distance there and back is longer than L.

How to Communicate?

- So, how do we go about detecting our neighbors?
  - About 15 lyrs away (maybe… perhaps…)
- Are we seriously sending out messages now?
- No.

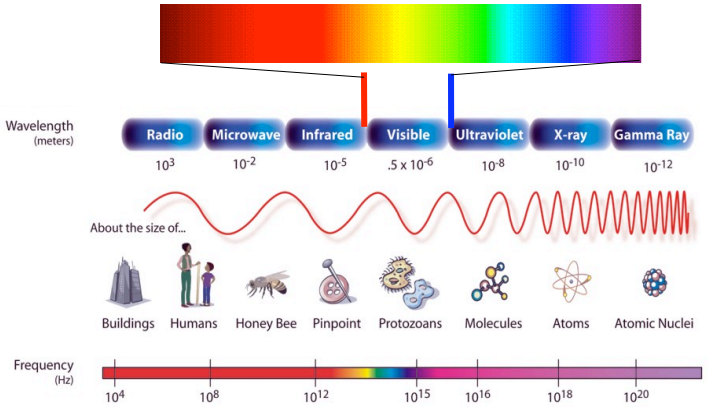


How to Communicate?

- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive "lurker" civilization.
- Okay, so what will an advanced civilization use?
- Hard to figure out.. They are aliens!

Light me up

- Visible light is only a tiny portion of the full electromagnetic spectrum
- Red light has longer wavelength and lower frequency than blue light.
- Divisions between regions are from biology or technologies.



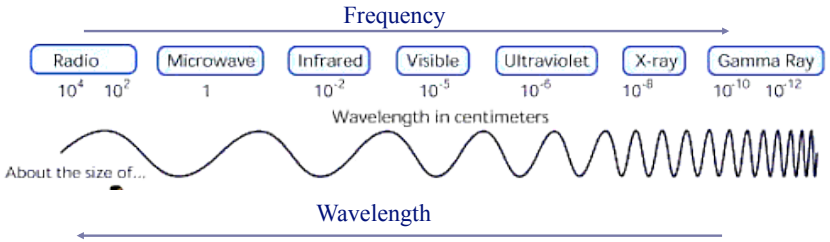
Question

I want to communicate with aliens at a distance of 100 light years. What is the fastest way to do that?

a) X-rays
b) Radio
c) Visible light
d) Gamma-rays
e) All of the above are light, so travel the same speed.

Frequency

- The frequency of light depends on its color.
- The unit is Hertz, equivalent to 1 cycle a second.
- For radio waves, we normally use larger units
  - 1 kHz = 1000 Hz
  - 1 MHz = 10^6 Hz
  - 1 GHz = 10^9 Hz



Question

Which of the following is the highest frequency?

a) 100 Hz
b) 100 kHz.
c) 100 MHz
d) 100 GHz

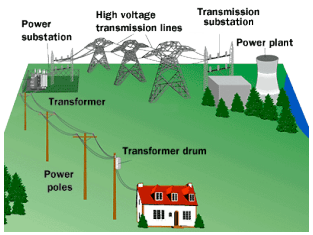
Question

Which of the following has the longest wavelength?

a) 100 Hz
b) 100 kHz.
c) 100 MHz
d) 100 GHz

What's the Frequency Kenneth?

- We can't broadcast over the whole range– too much power = expensive.
- So what kind of reasoning can we use to limit our search or any broadcasts?
- Keep in mind that ET must make the same decisions.
- May be very alien decisions.



http://http://science.howstuffworks.com/power.htm

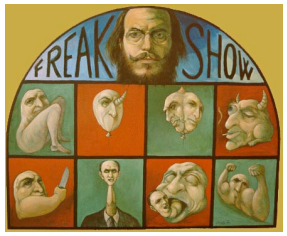
What's the Frequency Kenneth?

- Want biggest bang for the buck.
- Interstellar dust is in the Galactic plane
- Attenuates light that is shorter than infrared wavelengths– a few microns.
- Or need very very high frequency.
- But, energy required for the photon increases with frequency– not good.
- Argues for low frequency or long wavelength operation– radio.

http://www.beautydish.com/

Freq Show

- Keep in mind that radio stations fade as you get further away.
- In fact, light decreases in amplitude as the square of the distance traveled.
- And like your radio, there can be noise from competing stations or noise from the radio receivers.
- The Galaxy emits lots of emission at low frequencies.



http://www.micka.cz/f8.jpg

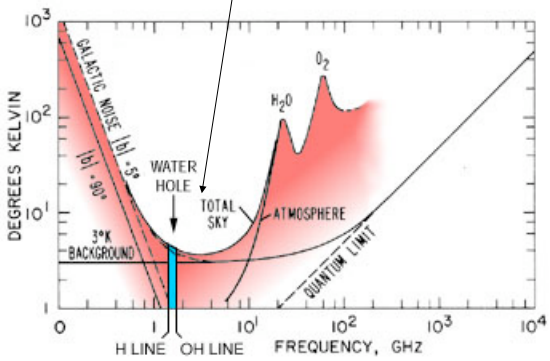
Freq-ing Out.

The best place to listen– in the "quiet" part of the spectrum

1. The galaxy emits lots of emission at low frequencies.
2. The Big Bang background noise– CMB.
3. Noise of receivers. The perfect receiver has a quantum limit of one photon noise.
4. The Earth's atmosphere blocks many frequencies.

Wavelengths of 3 to 30 cm!

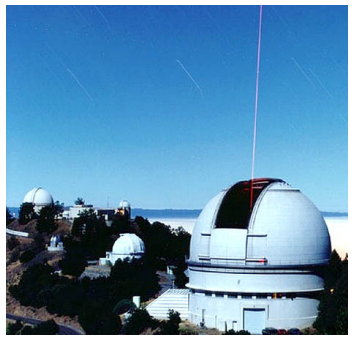
Frequencies of 1 to 10 GHz!



http://setiathome.ssl.berkeley.edu/about_seti/radio_search_2.html

Or Lasers?

- Charlie Townes has pointed out that sending pulses of laser light could be competitive.
- A number of searches are now underway using visible light– optical SETI.
- The light must be distinguishable from the star.
- It is easy for planets to overwhelm their suns in radio waves, but not visible.
- But, powerful lasers have a certain defined wavelength.



Laser for adaptive optics, not optical SETI.

http://www.ucsc.edu/news_events/download/images/laser-lg.jpg

ETs with Lasers?

- Reines and Marcy in 2002 searched 577 nearby stars with sensitivity to detect >60 kW lasers focused from a 10m telescope.
- Nothing was detected.
- Laser is a very small beam of light, only a few stars in transmission beam.
- But strength of laser does not decrease as quickly as radio.
- Laser seems an unlikely communication tool though.

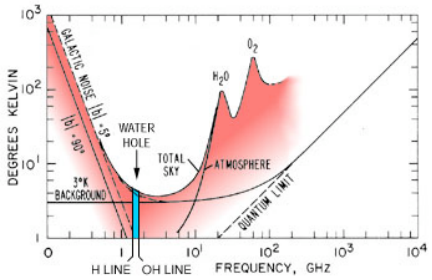
Are aliens trying to contact us with LASERs?

http://www.insomniacmania.com/news/news_771_1.jpg

How to Communicate?

Radio is probably best.

1. Dust extinction is reduced.
2. Lower frequency means less energy/photon, so cheaper.
3. There is a natural dip from about 1 to 10 GHz in the radio where the atmosphere and the galaxy are the quietest.



http://setiathome.ssl.berkeley.edu/about_seti/radio_search_2.html

Big Band

- Still, 1-100 GHz or even 1-10 GHz is a lot of frequency to search.
- Remember, we have to tune to the proper "radio station".
- What's the right channel size?
- Many argue that we should use 1 Hz channels, then in the 1-10 GHz band there are 9 x 10^9 channels!
- Is there a magic frequency that advanced civilizations would choose?

http://www.stamps.net/40band.jpg

The Magical 1420

- Morrison and Cocconi (1959) suggested the first magical frequency of 1420 MHz or 1.420 GHz.
- It's the frequency at which H atoms in space emit and absorb radiation (21 cm line).
- Not a bad choice as H is the most abundant atom in the Universe.
- But, now we have detected over 100 molecular transitions, some crucial to life, so maybe not as an important argument as it once was.

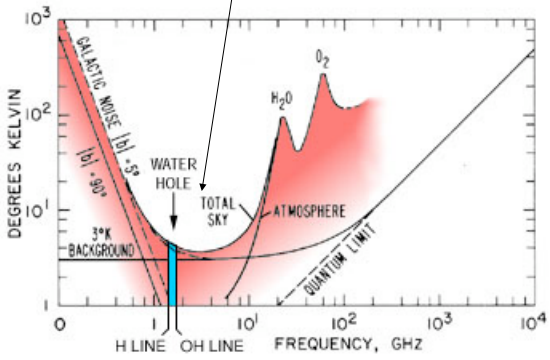
http://www.leapsecond.com/pages/unix/

The Water Hole?

- Carl Sagan and Frank Drake suggested that species on Earth always gathered around the water hole.
- There is a molecular fragment of OH that absorbs at 4 frequencies between 1.612 and 1.720 GHz.
- These molecules were well studied at the time, so it was biased.
- And, now we know about more exciting transitions at higher frequencies.

Wavelengths of 3 to 30 cm!

Frequencies of 1 to 10 GHz!



http://setiathome.ssl.berkeley.edu/about_seti/radio_search_2.html

Fundamental Freqs

- What are constants that every civilization would be aware of?
- Speed of light
- Fine structure constant (1/137)
- Divide the speed of light as many times as necessary to get a frequency in the radio range.
- In that case you get 2.5568 GHz.
- First suggested by Kuiper and Morris.

$$\alpha = \frac{e^2}{\hbar c}$$

Magical Frequency?

- No.
- Nothing is really obvious.
- So, we're screwed.
- We have to look through a lot of radio frequencies.
- So, we better understand radio techniques a little.

http://www.funbrain.com/guess/magic.gif

Radio

- The basic concept of radio astronomy, radio communications, television, mobile phones, etc. is the same.
- Information is transmitted by low energy light.

http://www.itsrealstuff.com/assets/images/antenna.jpg

Radio

- How does the antenna on your car work?
- The electo-magnetic wave cause electrons to move up and down in your antenna.
- That signal is amplified and decoded.
- For frequencies in the band of interest, parabolic antennas are common used.

http://www.itsrealstuff.com/assets/images/antenna.jpg

Radio telescopes

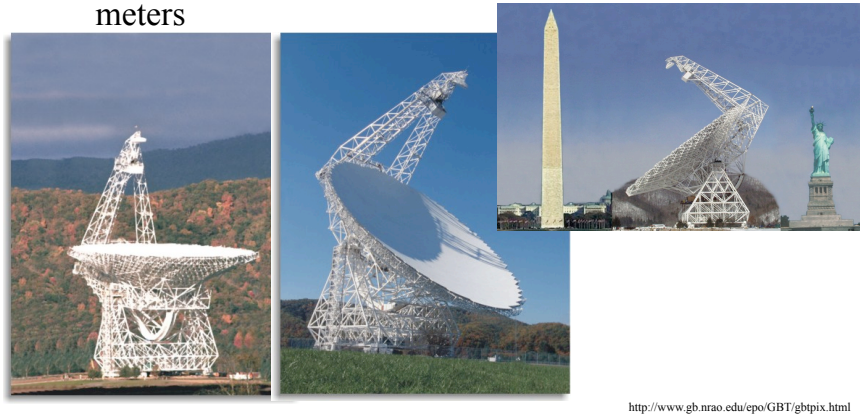
Pioneering work by Grote Reber in back yard, Wheaton, Illinois. (He died in 2002).

Arecibo Observatory, Puerto Rico

Largest radio telescope– 300 meters.

The Green Bank Telescope– W.V.

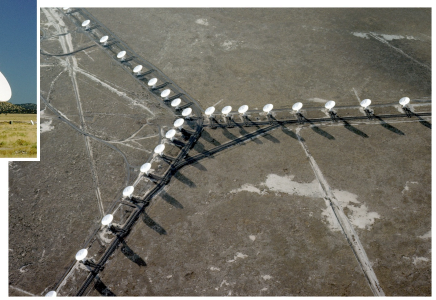
- The largest fully steerable dish in the world– 100 meters



http://www.gb.nrao.edu/epo/GBT/gbtpix.html

Greenbank WV

Very Large Array, near Magdalena, NM



Decoder Ring

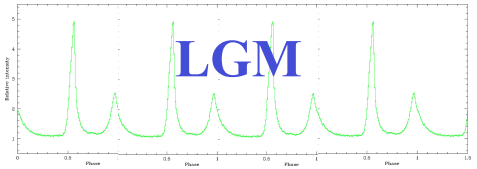
- After receiving and amplifying the signals, one has to decode the signals.
- Naturally created signals do not usually vary with time and are unpolarized.

http://theimaginaryworld.com/box678.jpg

Decoder Ring

- Normally, artificial signals encode data:
  - FM : frequency modulation (frequency varies with time)
  - AM : amplitude modulation (brightness varies with time)
    - Usually analog, but digital is more robust
    - Can turn on/off to signify 1 or 0 (most likely for ET)
- Note, <u>most</u> astronomers do not look for fast varying signals, but weak non-varying signals.

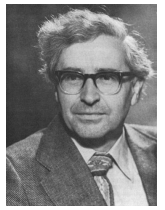
http://theimaginaryworld.com/box678.jpg



LGM

- But, astronomers studying the short variations in the interstellar medium did look at fast varying signals.
- Jocelyn Bell noticed a regularly repeating signal.
- Perfect timing, but no real encoding.
- Jokingly called LGMs, then Pulsars.
- Eventually realized to be from neutron stars.
- The lighthouse beam from the rapid rotator sometimes intersecting the Earth.

Jocelyn Bell Burnell



Anthony Hewish

http://www.radiosky.com/rspplsr.html

Built to be Decoded

- If a signal is found, how do we decode it?
- Most coding is meant to hide the signal, but in this case we want it to be decoded by any intelligence.
- Obviously this is not trivial.
- Many suggestions that revolve around mathematics have been made.
- To date there has only been one serious message sent from Earth.

The Arecibo Message

- On November 16, 1974 Carl Sagan and Frank Drake sent a message for 3 minutes
- Frequency used was 2380 MHz, with frequency modulation (10 Hz)
- Used the Arecibo telescope with a large transmitter– 100 kw beamed or 20 trillion watts of power if omni-directional.
- Strongest man-made signal ever sent.

Can you Figure it out?

See if you can decode anything.

By frequency modulation, they sent 1679 bits of 1/on and 0/off.

1679 is the product of 2 prime numbers– 23 and 73.

ET should be able to try arranging them into a picture.

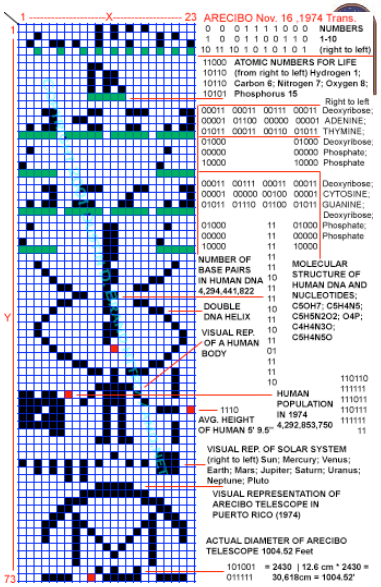
We attempted Contact

- Now, we wait.
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- If they're looking, any SETI experiment will detect this.
- But do we expect anyone?

Decode what?

- An amazing amount of information in 1679 bits.
- But human experts had trouble decoding it.

http://antwrp.gsfc.nasa.gov/apod/ap970717.html



http://amo.net/Contact/

Question

In 21,000 years, when the Drake message gets to M13

a) The aliens will be able to decode it, and enjoy images and sounds of the people of Earth.

b) The aliens may not be able to decode it.

c) The aliens will not be able to decode it, but with the additional hints sent afterwards, they will figure it out.

d) The aliens will be able to decode it and build their own telescope with the knowledge.