

Astronomy 330



This class (Lecture 23):
Communication

Next Class:
Future of Civilization
Joshua Brickman

HW10 is due Thursday in class.

Music: *What's the Frequency Kenneth?*– REM

Outline

- We have a number!
- What does it mean?
- Okay, now how to communicate with them?



Presentations



- **Raeed Chowdhury:** [The Science of AVATAR](#)

Drake Equation

Frank Drake



That's 190,540 advanced civs!!!



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

# of advanced civilizations we can contact 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 communicate	Lifetime of advanced civilizations
	10 stars/yr	0.75 systems/star	$1.5 \times 0.11 = 0.165$ planets/system	0.47 life/planet	0.42 intel./life	.78 comm./intel.	1×10^6 yrs/comm.

= 2.5 x 10¹¹
Communicating Civilizations

Drake Equation For Optimist



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 communicate	Lifetime of advanced civilizations
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50 1 1 1 1 1 5 x 10⁹

Birthrate of 50/year!

= 7.5 x 10⁻⁶
Communicating Civilizations

Drake Equation For Pessimist



Must wait 10⁷ 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 communicate	Lifetime of advanced civilizations
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5 0.1 0.15 0.01 0.01 0.01 100

Birthrate of 7.5 x 10⁻⁸ / year!

= 930,000
Communicating Civilizations

Drake Equation For Average



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

# 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 communicate	Lifetime of advanced civilizations
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10 0.5 0.89 0.5 0.7 0.6 1x10⁶

Birthrate of 0.93/year!

Hmm..

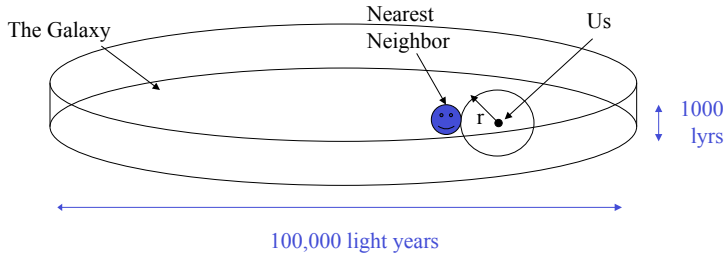


- None of these results are wrong.
- The average birthrate result of around 1/year would suggest that any life that is contacted is presumable older and therefore more advanced.
- It is interesting to note that for our values, lifetimes greater than around 100 years give about 2 civilizations with which to talk.
- Our total number was **190,540** years.

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.

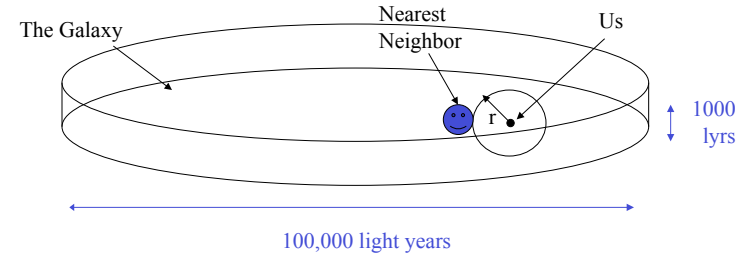


Distance to Nearest Neighbor



- Assume $N > 8000$

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

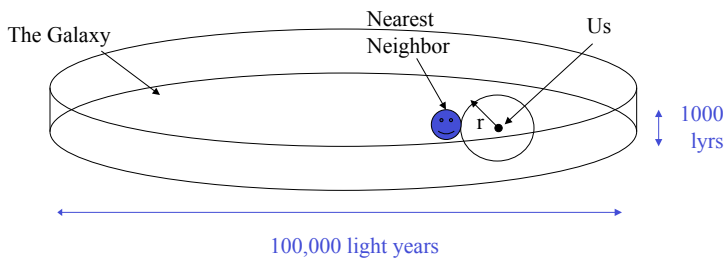


Distance to Nearest Neighbor



- Assume $N > 8000$

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

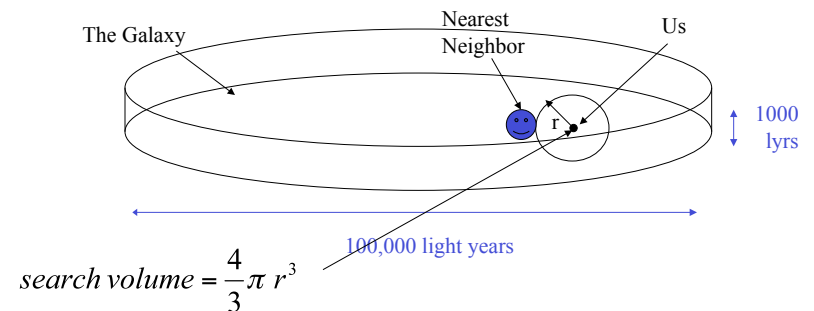


Distance to Nearest Neighbor



- Assume $N > 8000$

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

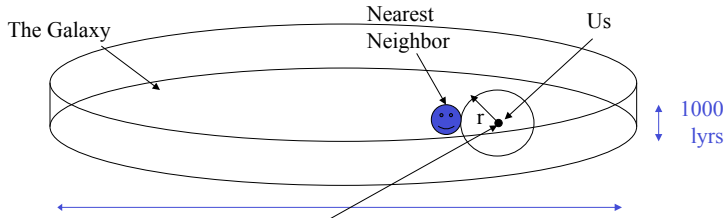


Distance to Nearest Neighbor



- Assume $N > 8000$

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



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

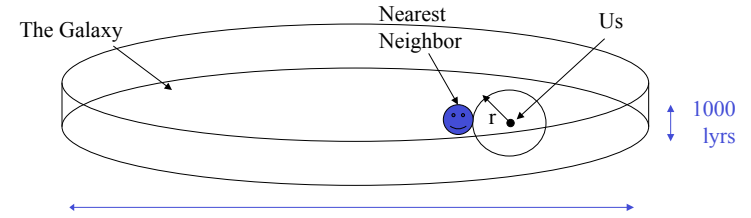
$$\text{alien volume} = \frac{\pi r_{\text{galaxy}}^2 h_{\text{galaxy}}}{N}$$

Distance to Nearest Neighbor



- Assume $N > 8000$

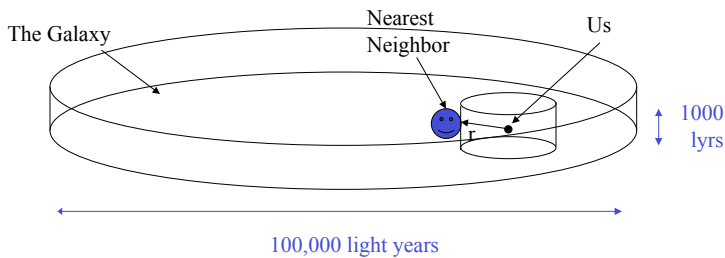
$$\text{Then } r \approx \frac{12000 \text{ ly}}{N^{1/3}}$$



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.

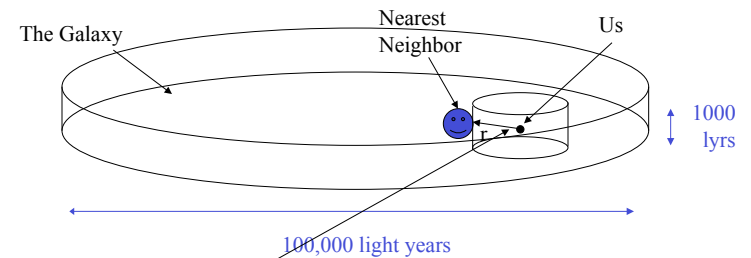


Distance to Nearest Neighbor



- Assume $N < 8000$

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



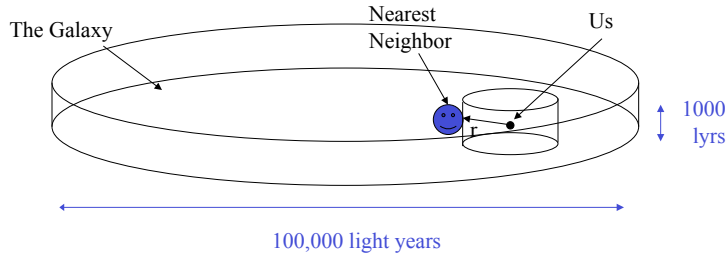
$$\text{search volume} = \pi r^2 h_{\text{galaxy}}$$

Distance to Nearest Neighbor



- Assume $N < 8000$

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

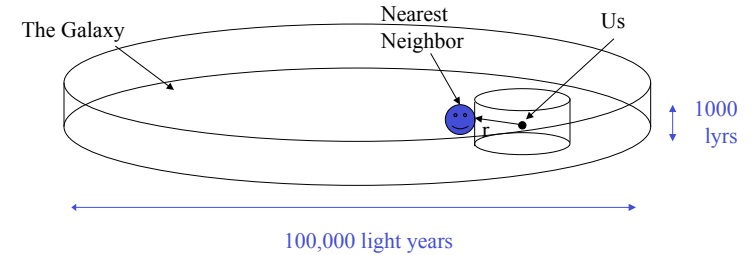


Distance to Nearest Neighbor

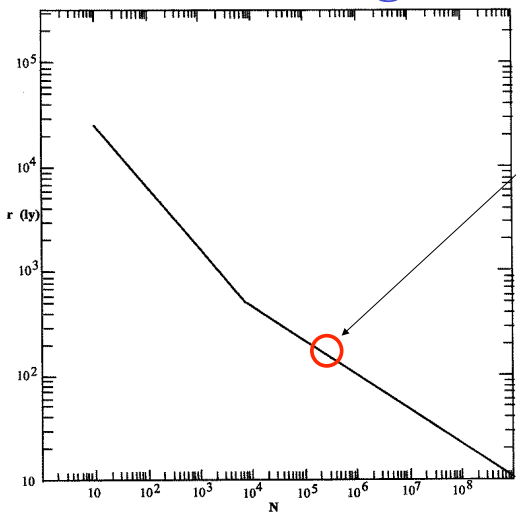


- Assume $N < 8000$

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



The Neighbors



We need to look at every star within ~200 lyrs for one detection!

Using $N=190,540$

Interesting Points



- We assumed uniform density of civilizations.
 - Underweights the galactic center, but maybe that's okay- supernovae.
- Distance away is the average.
 - Could be closer, but unlikely to be much closer.
- 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.
- For communication, it may be that the distance there and back is longer than L .

How to Communicate?



- Okay, our estimate is optimistic.
- So, how do we go about detecting our neighbors?
 - About 200 lyrs away (maybe... perhaps...)
- Are we seriously sending out messages now?
- No.

How to Communicate?

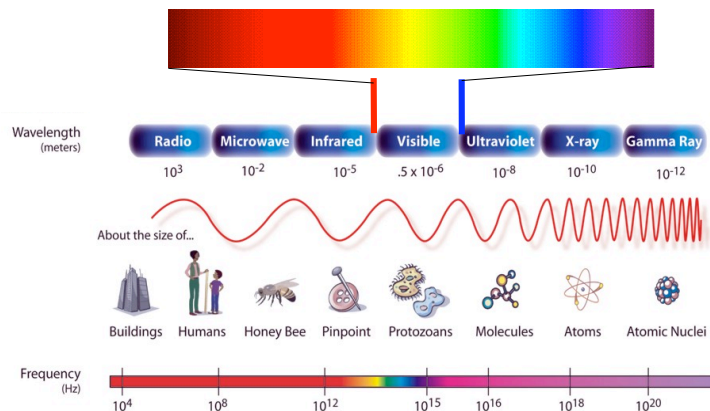


- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive “lurker” civilization.
- Okay, so what will an advanced civilization use?
- Hard to figure out.. They are aliens!

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



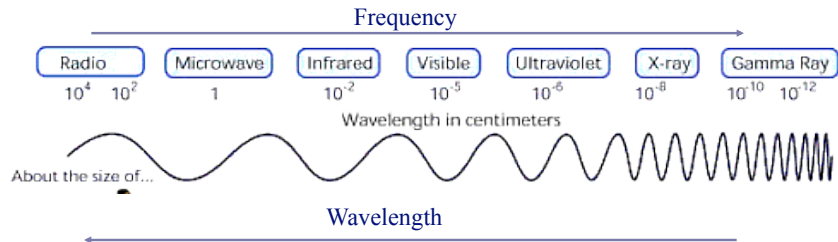
I want to communicate with aliens at a distance of 100 light years. What is the fastest way to do that?

- 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 has the longest wavelength?

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

Question



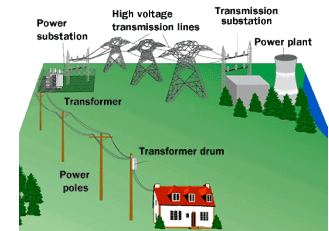
Which of the following is the highest frequency?

- 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.



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 high frequency.
- Energy required for the photon increases with frequency.
- Argues for low frequency or long wavelength operation— radio.

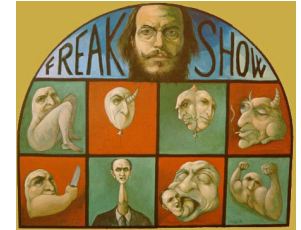


<http://www.beautydish.com/>

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.



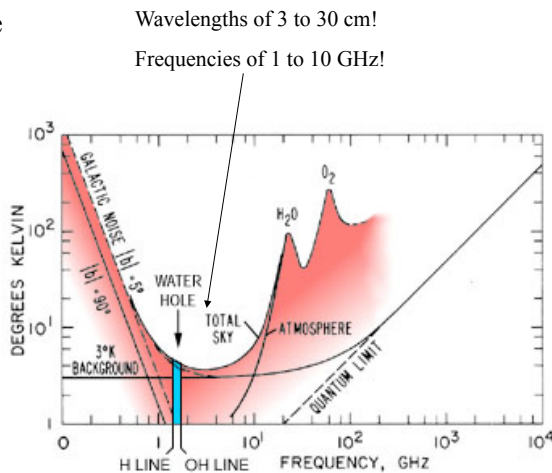
<http://www.micka.cz/f8.jpg>

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.



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?

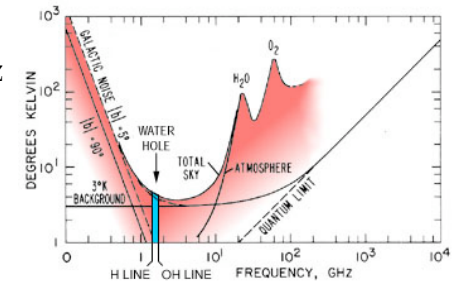
http://www.insomniacmania.com/news/news_771_1.jpg

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 9×10^9 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.

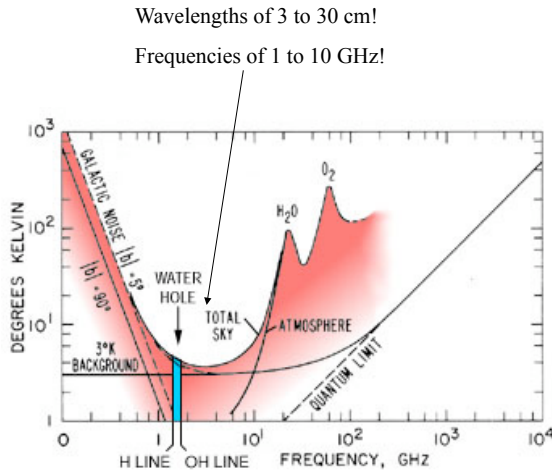


<http://www.leapsecond.com/pages/univ/>

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.



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.itrealstuff.com/assets/images/antenna.jpg>

Radio



- How does the antenna on your car work?
- The electro-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

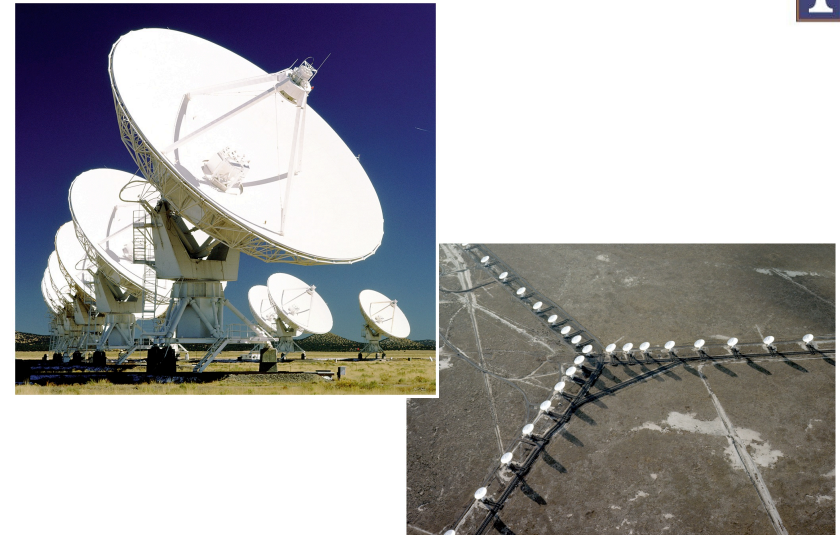


<http://www.gb.nrao.edu/epo/GBT/gbtpix.html>

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, most astronomers do not look for fast varying signals, but weak non-varying signals.

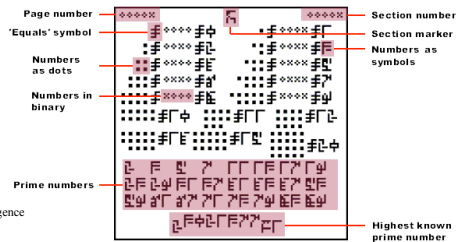


<http://theimaginaryworld.com/box678.jpg>

Encounter Messages



Name	Designation	HD	Constellation	Date sent	Arrival date	Message
16 Cyg A	HD 186408		Cygnus	May 24 , 1999	November 2069	Cosmic Call 1
15 Sge	HD 190406		Sagitta	June 30 , 1999	February 2057	Cosmic Call 1
	HD 178428		Sagitta	June 30 , 1999	October 2067	Cosmic Call 1
Gl 777	HD 190360		Cygnus	July 1 , 1999	April 2051	Cosmic Call 1
	Hip 4872		Cassiopeia	July 6 , 2003	April 2036	Cosmic Call 2
	HD 245409		Orion	July 6 , 2003	August 2040	Cosmic Call 2
55 Cnc	HD 75732		Cancer	July 6 , 2003	May 2044	Cosmic Call 2
	HD 10307		Andromeda	July 6 , 2003	September 2044	Cosmic Call 2
47 UMa	HD 95128		Ursa Major	July 6 , 2003	May 2049	Cosmic Call 2



http://en.wikipedia.org/wiki/Communication_with_Extraterrestrial_Intelligence

Contacting Us



- What does an advanced civilization that wants to contact us do?
- Could set-up radio beacons
 - Broadcast in all directions.
 - Broadcast at several frequencies.
 - Would require enormous energy sources.
- Would be much better if they could use directional messages.
- Existing transmitters on Arecibo are strong enough to communicate across the galaxy with similar telescopes, but with a very small beam.
- The problem is where to look or to transmit.

Does ET Love Lucy?



- One solution is to look for unintentional leakage signals.
- Leakage, as it “leaks” from the planet’s ionosphere.
- We can not currently detect this, but maybe other civilizations can.
- This is the scenario explored in the novel *Contact* by Carl Sagan and the movie based on the novel.
- What leakage do we have? TV, FM Radio, radar
- Television transmission exceeds 10^7 watts (10 MW).



<http://www.time.com/time/time100/scientist/profile/farnsworth.html>