Top Ten Signs
Your Astronomy Instructor May Be Nuts
***as** enumerated by Prof. Lee Carkner, Augustana College*

10) The title of every lecture is: "Man, Them Stars is Hot!".
9) His so called "telescopes" are really just paper towel rolls covered in aluminum foil.
8) To illustrate the vastness of the universe, he makes everybody walk to Des Moines.
7) Thinks he's married to the projector.
6) Your grade is based entirely on how many ping-pong balls you can fit in your mouth.
5) His so called Drake Equation video is really just an old episode of Alf.
4) He makes everyone wear a soup pot on their head to protect the class from "Klingon mind control lasers".
3) About 90% of all classes involve dressing monkeys up to look like Frank Drake.
2) When you go to his office hours he is always hiding under the desk so that the "space squirrels" can't get him.
1) The only observing advice he ever gives is, "Keep an eye out for the mothership."

Astronomy 230

Section 1– MWF 1400-1450
106 B1 Eng Hall

This Class (Lecture 34):

Communication

Astronomy Public Lecture Nov 17th!

Next Class:
Communication 2

HW #6 is due on Nov 19th!

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

Outline

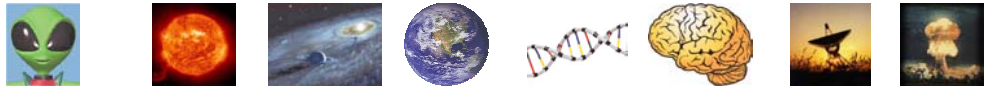
- Recap of our value of N.
- So how far do we have to look to find ET?
- And how can we communicate with ET?
- Radio seems the best choice.
- But what frequency?
- Our only message to ET.
- Needle in a haystack.

Drake Equation

= 69,525

Civilizations

Birthrate of 0.7/year!



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

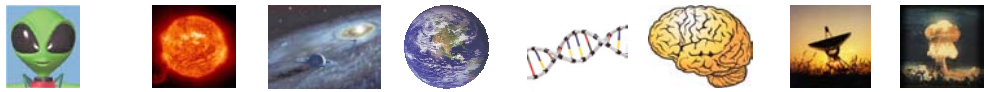
R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact	Rate of star formation	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
25	**0.34**	**.396**	**0.54**	**.425**	**0.9**	**100000**
stars/ yr	systems /star	life planets /system	life /planet	intelligence /life	life /comm.	years

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	5×10^9

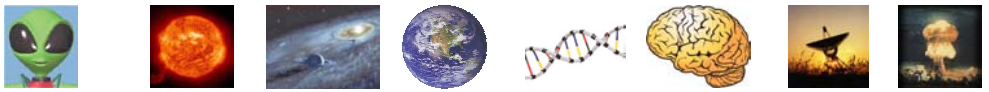
Birthrate of 50/year!

Drake Equation For Pessimist

= 0.0000075

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 7.5×10^{-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	1×10^6

Birthrate of 0.93 /year!

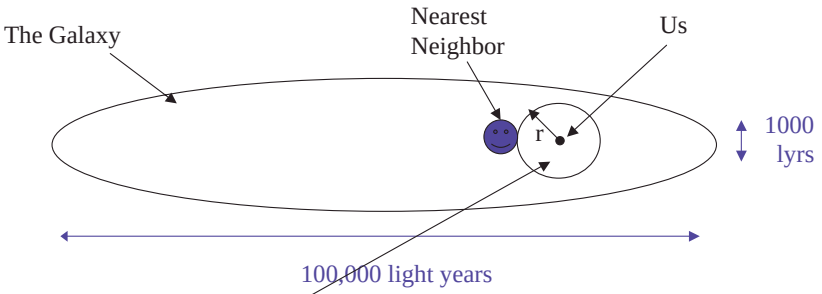
Hmm..

- None of these results are wrong.
- The average results 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 lifetimes greater than around 275 years, that's more than 10 civilizations with which to talk.
- Our number was 100,000 years.

Distance to Nearest Neighbor

Assume that the alien civilizations are uniformly scattered in our galaxy and N > 8000.

$$Average\ Volume = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N}$$

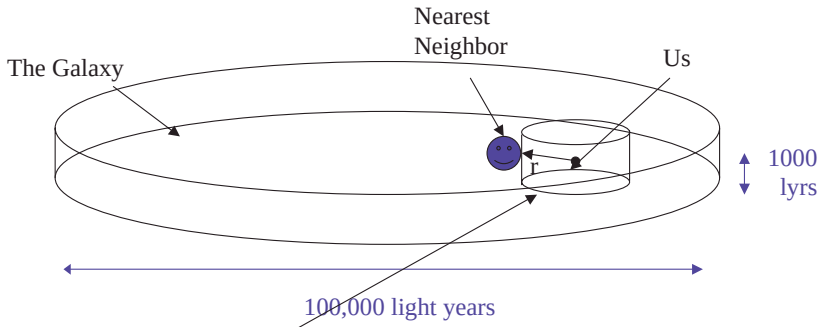


$$search\ volume = \frac{4}{3}\pi\, r^3 \qquad \text{Then} \qquad r \approx \frac{12000\ ly}{N^{\frac{1}{3}}}$$

Distance to Nearest Neighbor

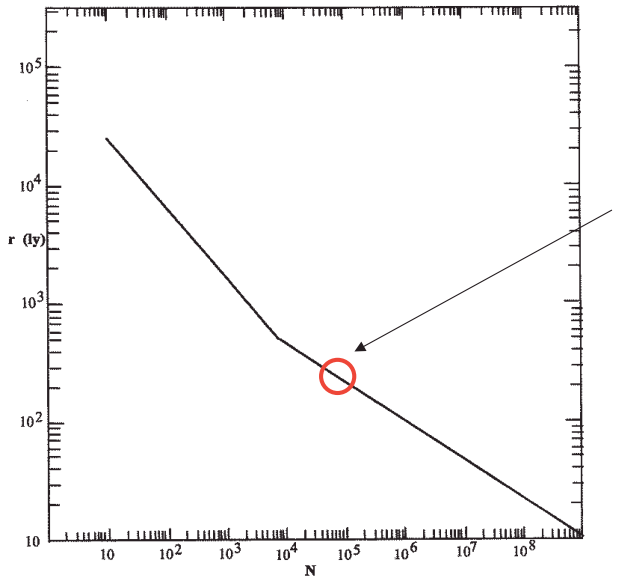
Assume that the alien civilizations are uniformly scattered in our galaxy and N < 8000.

$$Average\ Volume = \frac{\pi\, r_{galaxy}^2 h_{galaxy}}{N}$$



$$search\ volume = \pi\, r^2 h_{galaxy} \qquad \text{Then} \qquad r \approx \frac{50000\ ly}{N^{\frac{1}{2}}}$$

The Neighbors



We need to look at every star within ~ 300 lyrs for one detection!

Interesting Points

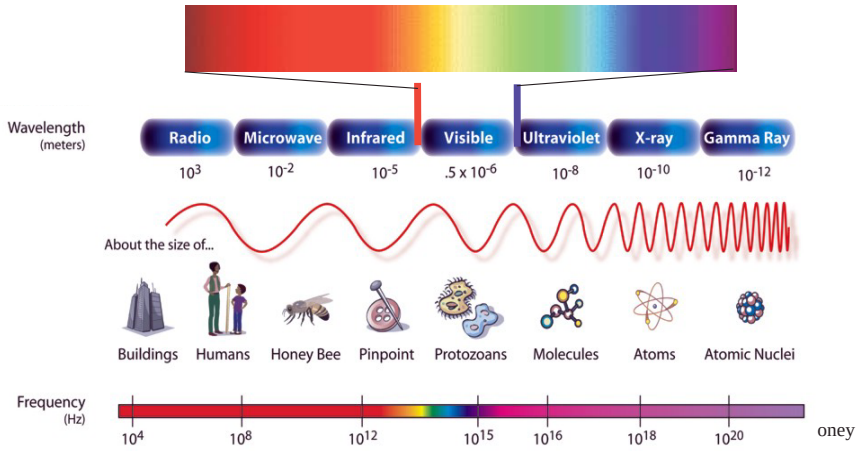
1. We assumed uniform density of civilizations.
   - Underweights the galactic center, but maybe that's okay– supernovae.
2. Distance away is the average.
   - Could be closer, but unlikely to be much closer.
3. Note that r is better defined that N.
   - R depends on $N^{1/2}$ or $N^{1/3}$.
   - If we 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?

- Okay, our estimate is optimistic.
- So, how do we go about detecting our neighbors?
- Are we seriously sending out messages now?
- No.
- 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?

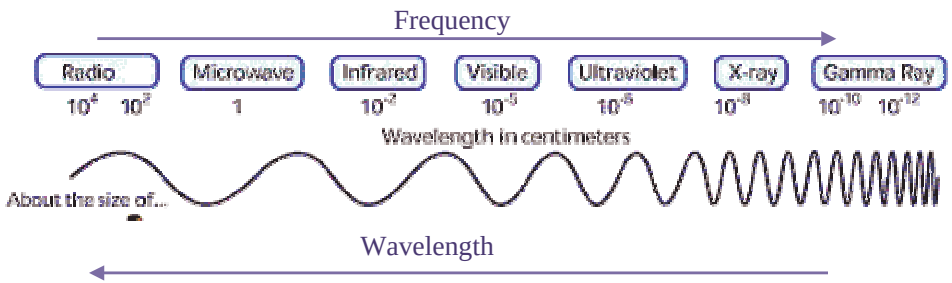
Light me up

- 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.



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



What’s the Frequency Kenneth?

- We can’t broadcast over the whole range– too 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.
- Interstellar dust attenuates light that is shorter than infrared wavelengths– a few microns.
- Energy required for the photon increases with frequency.
- Argues for low frequency or long wavelength operation– radio.

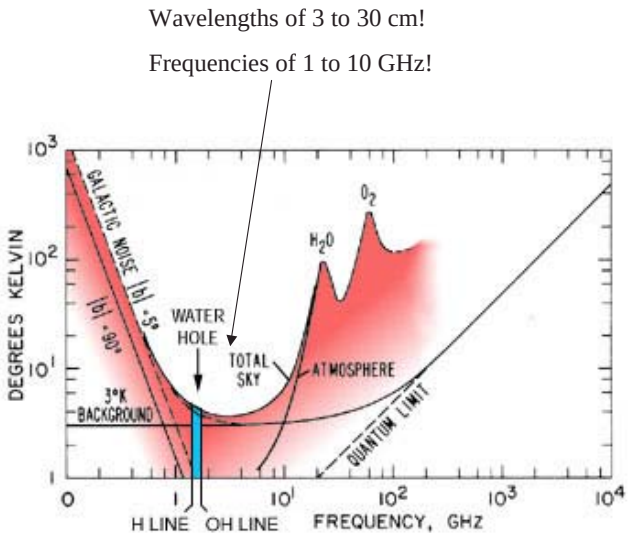
Freq Show

- Keep in mind that radio stations fade as you get further away.
- In fact, light decrease 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.

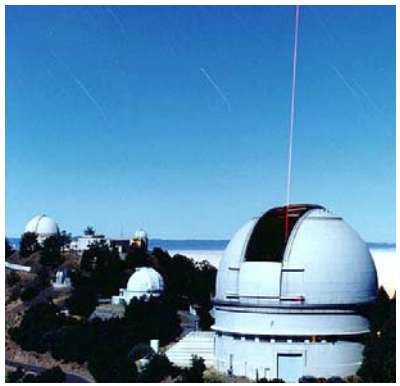
- The best place to listen– in the "quiet" part of the spectrum
1. The galaxy emits lots of emission at low frequencies.
2. The Big Bang background noise– CMB.
3. Noise of receivers. The perfect receiver has a quantum limit of one photon noise.
4. The Earth's atmosphere blocks many frequencies.



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.
- Powerful lasers have a certain defined wavelength.
- Reines and Marcy in 2002 searched 577 nearby stars with sensitivity to detect >60 kW lasers focuses from a 10m telescope.
- Nothing was detected.
- Seems unlikely as the laser is a very small beam of light, only a few stars in transmission, so back to radio.



Laser for adaptive optics, not optical SETI.

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

Big Band

- Still, 1-100 GHz or even 1-10 GHz is a lot of frequency to search.
- Is there a magic frequency that advanced civilizations would choose?
- 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.
- 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.

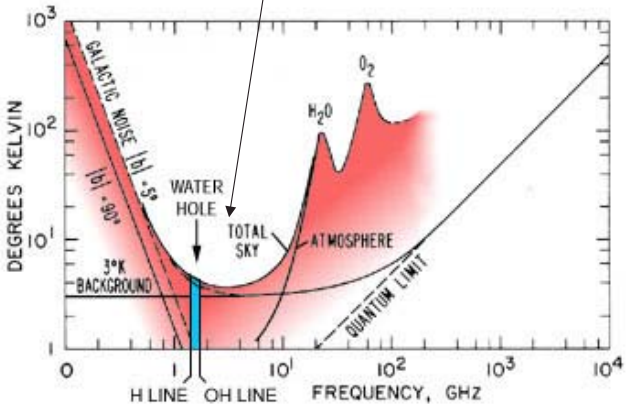
http://www.stamps.net/40band.jpg

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 time as necessary to get a frequency in the radio range.
- In that case you get 2.5568 GHz.
- First suggested by Kuiper and Morris.

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

http://astronomy.swin.edu.au/sao/guest/davis/eqn_a.gif

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.
- 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

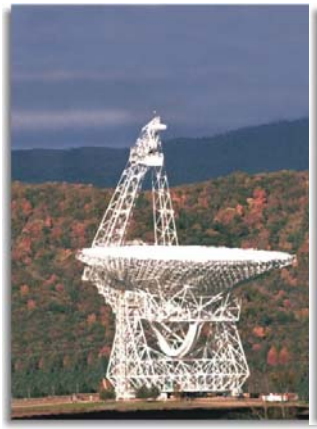
Pioneering work by Grote Reber in back yard, Wheaton, Illinois. (He died in 2002).

Arecibo Observatory, Puerto Rico

Largest radio telescope– 300 meters.

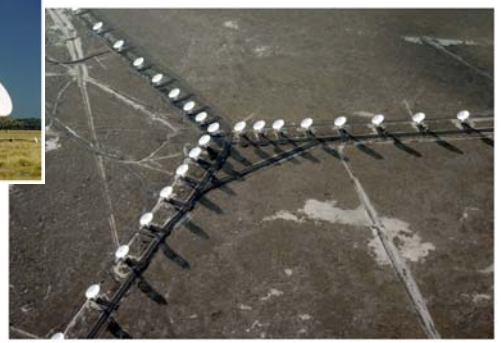
The Green Bank Telescope– W.V.

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



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

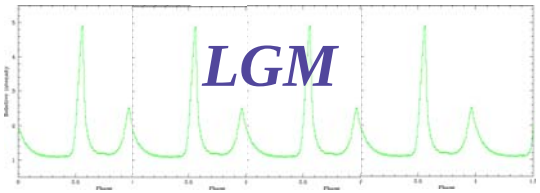
Very Large Array, near Magdalena, NM



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.
- Normally, artificial signals encode data:
  - FM : frequency modulation (the frequency varies with time)
  - AM : amplitude modulation (the 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.

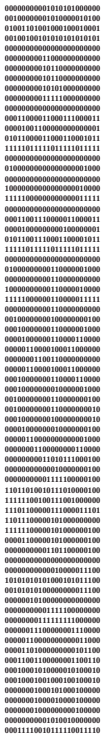
Jocelyn Bell Burnell

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 direct message sent from Earth.
- On November 16, 1974 Carl Sagan and Frank Drake sent a message for 3 minutes. Then repeat.



Can you Figure it out?

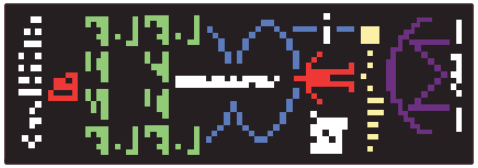
See if you can decode anything.

We attempted Contact

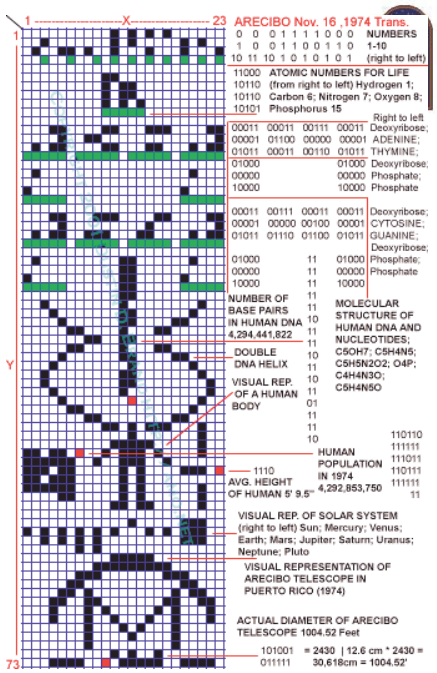
- Now, we wait.
- By frequency modulation, they sent 1679 bits of 1/on and 0/off.
- 1679 is the product of 2 prime numbers– 23 and 73.
- ET should be able to try arranging them into a picture.
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- Used the Arecibo telescope with a large transmitter– 20 trillion watts of power.
- If they're looking, any SETI experiment will detect this.

Decode what?

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



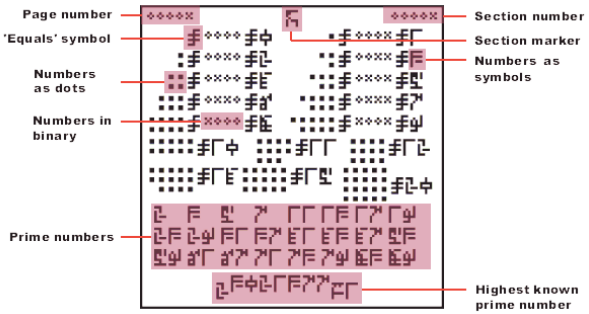
http://antwrp.gsfc.nasa.gov/apod/ap970717.html



http://amo.net/Contact/

Encounter 2001/2003 Message

- Sent by commercial company based in Houston, Texas using the Evpatoriya Deep Space Center radio telescope in Ukraine to 4 nearby stars less than 50 lyrs.
- Drake's message had 1,679 bits of information. This has 300,000 bits, with built-in redundancy. If some bits are lost to noise en route, ET might be able to decode.
- Canadian astronomers derived code:Dutil & Dumas
- Included names and address of 2000 donors and personal messages.



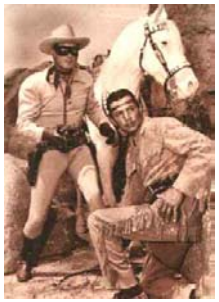
http://www.ibiblio.org/astrobiology/index.php?page=interview01

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

L.W. Looney

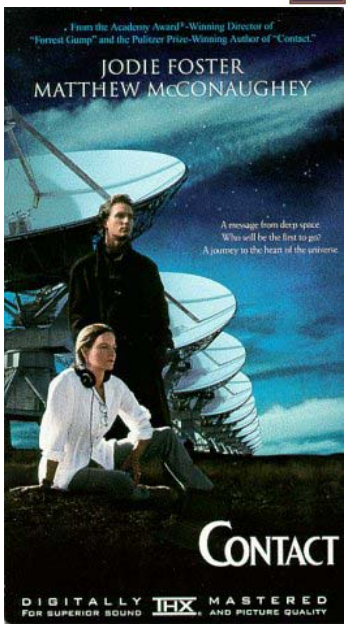
Contact

http://www.jurassicpunk.com/movies/contact.shtml

"If humans were the only life in the Universe it would be a terrible waste of space."

Vega calls us back, but how can we be sure that we're listening?

Our leakage radiation is actually decreasing with cable, fiber optics, direct satellite, etc. Civilizations may not spend much time in that phase.



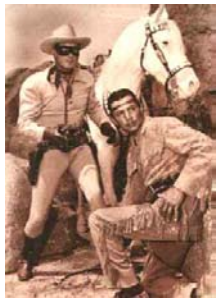
Does ET Love Lucy?

- ET would be unable to really distinguish individual stations due to the rotation of the Earth.
- To detect early carrier signals at 50 lyrs, need 3000 acres of antenna.
- To watch the TV show, need antenna the size of Colorado. It is possible.
- Still Earth would produce a regular 24 hour pattern for the last 60 years.
- Military radar is more promising. Highly focused and powerful.
- Only requires a 1000 foot antenna.

http://www.space.com/searchforlife/seti_shostak_aliens_031023.html

Does ET Love Lucy?

- As radio travels at speed of light, our leakage signals have reached the nearest 5000 stars!
- Still, this is way too few for our estimate.
- It is unlikely that a civilization is within 50 lyrs. → $N = 10^7$
- So probably ET does not love Lucy.



Problems…Problems

- Assume that an advanced civilization is broadcasting either in all directions or toward us.
- Where and when do we listen?
- What frequency?
- What polarization?
- What is the code?
- The problem is worse than searching for a needle in a haystack.
- We have to assume that they are constantly broadcasting, or the problem is impossible.

http://nl.ijs.si/et/talks/esslli02/metadata_files/Haystack-FINALb.jpg