ET: Astronomy 230

HW 10 due Friday!

EC HW due Dec 7th

This Class (Lecture 38):
Future of Civilization

Next Class:
Travel

Music: *Baby, Now That I've Found You–* Alison Krauss

Outline

- Needle in a haystack.
- Sensitivity of telescope– Does size matter?
- The history of SETI.
- The future?

= **12556**

Civilizations!

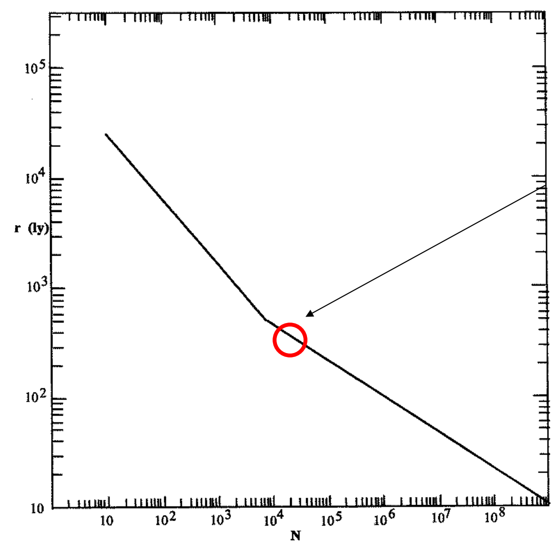
Drake Equation

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	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
	10 stars/ yr	**0.38 systems/ star**	**0.11 planets /system**	**0.5 life/ planet**	**0.75 intel. /life**	**0.801 comm./ intel.**	**100000 yrs/ comm.**

The Neighbors

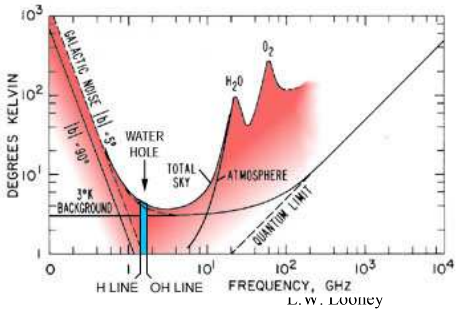


We need to look at every star within ~ 350 lyrs for one detection!

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

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.

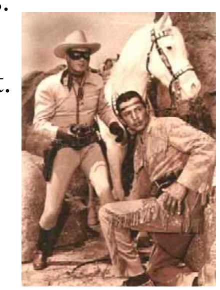
Does ET Love Lucy?

- 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. → $N_{required} = 10^7$
- So probably ET does not love Lucy, at least yet.



Problems…Problems

- Assume that an advanced civilization is broadcasting either in all directions or toward us.
- Where and when do we listen?
- Which frequency?
- Which channel?
- Which polarization?
- What is the code?

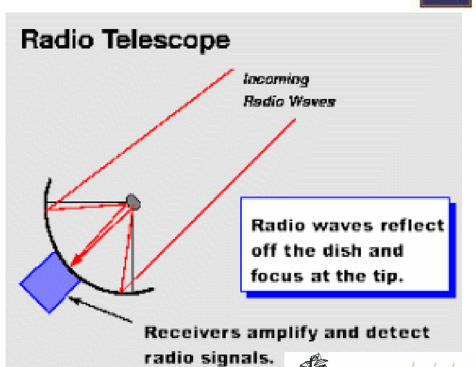
Problems…Problems

- 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.
- Have to make the needle bigger!

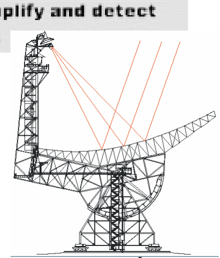
http://nl.ijs.si/et/talks/esslli02/metadata_files/Haystack-FINALb.jpg

Sky Dishes

- Radio telescopes are similar to optical telescopes.
- Most radio telescopes are Parabolic Cassegrains.
- Radio telescopes measure the source intensity– flux density– in W m^{-2} Hz^{-1}.
- The bigger the dish, the more sensitive.
- So a big dish is best, right?



http://www.nrao.edu/whatisra/radiotel.shtml



Unblocked Aperture

Haystack: Sensitivity

- Sensitivity of a radio telescope:
- We have to detect a weak signal in the presence of noise.
- So, ideally look in a fixed direction for a long time– better sensitivity to weak signals.
- But it may be the wrong direction.
- And a big dish is best, right?

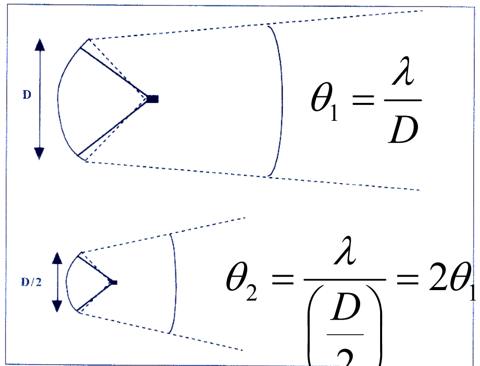
Channel size — time

$$S \propto D^2 \sqrt{\Delta \upsilon \times t}$$

Dish diameter

Haystack: Direction

- We can not *a priori* know which direction to look, so we must look in many directions.
- Tradeoff: The most sensitive radio telescope has the largest diameter but the smallest field of view.
- Beam size decreases as the diameter increases.
- The number of times you have to point to cover a certain area of the sky increases as diameter squared.



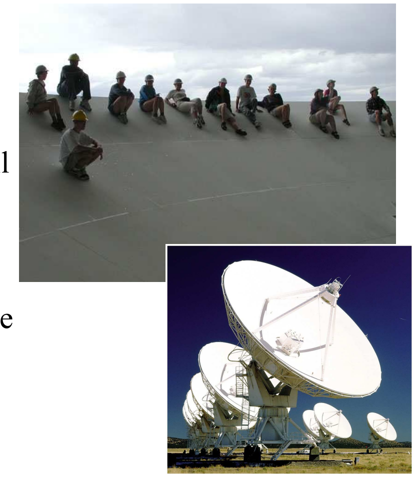
$$\theta_1 = \frac{\lambda}{D}$$

$$\theta_2 = \frac{\lambda}{\left(\frac{D}{2}\right)} = 2\theta_1$$

θ is in radians.

Dish Decision

- If ET signals are a few strong signals, we can use a small telescope and listen for a short time in any direction. The small diameter dish covers more area.
- If ET signal is many weak signals, we can use a bigger telescope and observe in a single direction for a long time. A weak signal requires a big dish.



http://www.noao.edu/staff/mighell/sacpeak/jpina/VLA%20in%20dish%204.jpg

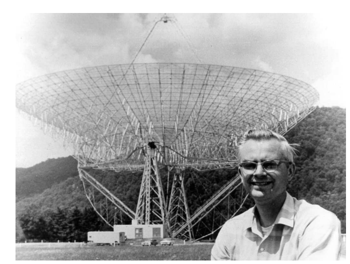
Haystack: Frequency

- Would the signal be concentrated in a small range of freqs?
- What size should a channel be?
- Could argue that the best choice is around 1 Hz.
- Then in the 1-10 GHz band there are 9×10^9 channels!
- With modern electronics we can survey large numbers of channels, but not that many.
- What's the history of SETI?

Project Ozma

- The first look for ET radio signals by Frank Drake in 1960.
- Used a 26 meter telescope in W.V. using the H atom frequency band of 1.42 GHz.`
- Targeted search of 2 nearby stars that are the same age as our Sun: Tau Ceti in the Constellation Cetus (the Whale) and Epsilon Eridani in the Constellation Eridanus (the River), both around 11 lyrs away.
- 200 hours over 3 months.
- A single 100 Hz channel scanned 400 kHz.
- 1 false alarm due to a secret military experiment.
- Nothing detected at a sensitivity of 10^{-22} W m^{-2} Hz^{-1}

http://www.angelfire.com/pa/maryanne/images/ozma.jpg



http://216.120.234.103/setiprime/setiprime/images/images-2003.html

Ozma II

- Ben Zuckerman and Pat Palmer used the 91m telescope in W.V. to survey the 670 nearest "suitable" stars.
- Targeted Search of stars with low mass and binaries that allowed stable planet orbits.
- Also observed at 1.42 GHz with 192 channels of 4 kHz and 192 channels of 52 kHz.
- Could have detected a 40 MW transmitter on a 100m telescope.
- Observed for 500 hours.
- No detection at a sensitivity of 10^{-23} W m^{-2} Hz^{-1} (10 times better than Ozma)

Ohio State

- In 1973 by F. Dixon and D. Cole.
- Used Ohio State radio telescope for a continuous survey of sky.
- Not steerable– sort of like Arecibo, so cuts a swath through the sky: A Sky Survey
- Searched overhead for signals.

http://www.bigear.org

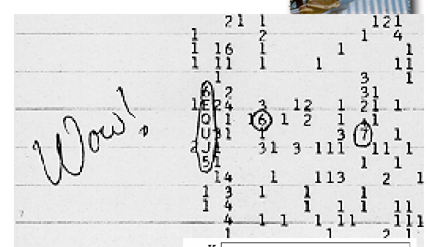
Ohio State

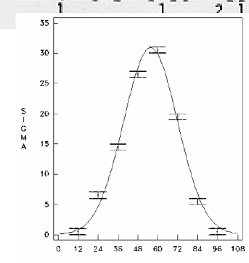
- Modest sensitivity 10^{-21} W m^{-2} Hz^{-1}
- 100 times worse than Ozma II
- But not just looking at stars.
- Could only detect extremely strong transmissions.
- Again, 1.42 GHz with 50 channels of 10 kHz.
- Land was sold to a golf course development.

http://www.bigear.org

The Wow Signal

- Aug. 15, 1977, Jerry Ehman was looking through the data when he recorded the Wow! signal.
- A major signal in the telescope– 30σ detection!
- Stayed around for >72 seconds.
- Unlikely to be noise, but never seen again.
- "Even if it were intelligent beings sending a signal, they'd do it far more than once."
- http://www.bigear.org/xfiles.ram





http://www.bigear.org/wow.htm

Gray & Marvel 2001, ApJ 546, 1171

Paul Horowitz Searches 1.42 GHz

- Paul Horowitz moved from a small number of channels to many many many channels.
- 1983 Sentinel: 128,000 channels covering 6 kHz each
- 1985 META: 8 million channels with 400 kHz bandwidth.
- 1993: Horowitz and Sagan reported 8 unexplained signals that did not repeat.
- 1995 BETA: Nearly a billion channels (2.5×10^8) covering 2 GHz, 10 kHz channels. Windstorm blew the telescope over in late 1990s.

The NASA Search

The most ambitious search was planned by NASA on the 500th anniversary of the *Discovery* of America– Oct 12, 1992.

Christopher Columbus (1451 – 1506)

http://www.teslasociety.com/exposition2.jpg
http://www.sailtexas.com/columbusships.html

The NASA Plan

- 2 prong approach using both Targeted Search and Sky Survey
- Sky Survey:
  - NASA's 34 m tracking telescopes in CA and Australia.
  - 6 year plan covering 1-10 GHz with 16 million channels of 20 Hz each and 30 different settings.
  - Would only detect very strong signals.
- Targeted Search:
  - Cover 800 suitable stars within 75 lyrs.
  - 16 million channels with 1 Hz bandwidth
  - 1-3 GHz range and 10^{-27} W m^{-2} Hz^{-1} sensitivity!

The NASA Search

- "In 1993, Nevada Senator Richard Bryan successfully introduced an amendment that eliminated all funding for the NASA SETI program. The cost of the program was less than 0.1% of NASA's annual budget, amounting to about a nickel per taxpayer per year. The Senator cited budget pressures as his reason for ending NASA's involvement with SETI."
- "The Great Martian Chase may finally come to an end. As of today millions have been spent and we have yet to bag a single little green fellow. Not a single Martian has said take me to your leader, and not a single flying saucer has applied for FAA approval."

http://www.planetary.org/html/UPDATES/seti/history/History12.htm
http://www.seti.org/about_us/faq.html

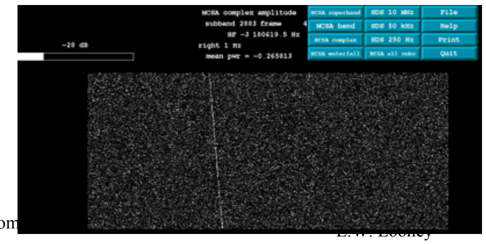
The SETI Institute

- An independent institute that was working with NASA on their SETI project.
- Once NASA cut funding, they went ahead with a more modest version of the Targeted Search–Project Phoenix.
- Now funded by private donors.
- Initially a search of 200 stars within 150 ly younger than 3 x 10^9 yrs using an Australian 63 m telescope for 5 minutes on each target.
- Scanned 28 million channels each 1 Hz wide, used multiple settings to scan 1.2 to 13.0 GHz

http://www.seti.org/seti/our_projects/project_phoenix/oveview/overview.html

Project Phoenix

- Still operating, but now at Arecibo (http://www.seti.org/seti/our_projects/project_phoenix/oveview/Welcome.html).
- About 2-3 weeks a year of telescope time to scan a total of 1000 stars.
- They are about ½ way through their list.
- As of yet, no ET signals.
- Proof of concept was shown by tracking the Pioneer 10 spacecraft (launched in 1973) that is 6 billion miles away and broadcasting with a few Watts of power.
- The signal was detected.
- As the Earth and object are moving, there is a small Doppler shift in the frequency of the light received over time.



Allen Telescope Array

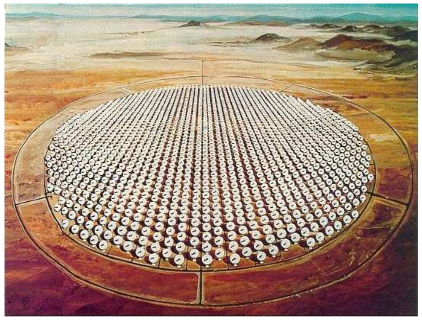
- At the BIMA site, UC Berkeley and the SETI Institute with majority of funding from Paul Allen are building the ATA.
- 350 antennas that are 6.1 m in diameter.
- Area comparison: Arecibo (70650 m^2) & ATA (10200 m^2) but still > 100 m single dish.
- And small dishes– larger field of view.
- With advanced electronics it will cover 1-10 GHz with many channels.
- Can image a few stars per field.
- 100% SETI
- Will increase search to 100,000 or 1 Million stars.

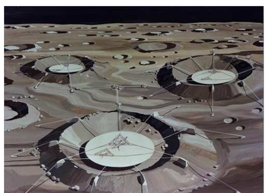
End All

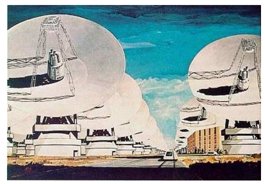
- The modern SETI searches are really expanding the frequency range in which we search, but we are still sensitivity limited.
- In any SETI experiment, what does a null result mean?

The Future?

- Cyclops – 1000 telescopes each 100 m in diameter.
- Resembles a giant eye.
- Could detect leakage transmission at 100 ly.
- Could detect a 1000 MW transmission at 1000 lyrs.
- Bucco Bucks– $50B and 10-20 yrs to build.







http://www.astrosurf.com/lombry/owni-bioastronomie-et.htm

Interstellar Travel

- The distances are freaky huge!
- Nearest star is 4.3 ly away or around 4 x 10^{13} km!
- 40,000,000,000,000 km! 40 TRILLION km!!!
- But, what if all communication with ET fails?
  - Wrong frequencies.
  - Everyone is listening and no one is broadcasting.
  - We fail to recognize the signal.
- We can go visit them or the microbes. “To boldly go…”
- Human colonization of the Galaxy has to start somewhere. Our own backyard!

Humans Spreading Out

- If we assume that no life is found in our solar system, we have multiple options.
  - Seed other planets with genetically engineered life or terraform the planet for terrestrial life.
  - Colonize the planets or asteroids.
  - Send robots to exploit solar system resources.

GELFs

- Genetic engineering techniques might allow us to develop organisms suitable for life on Mars, in the clouds of Venus, or the upper atmosphere of Jupiter.
- But the most likely organism would be those that are part of a larger plan to transform an environment into one suitable for human colonization.
- Terraforming– forming a planet or moon into something like the Earth conditions.

Spider genes being injected into a goat egg. Goat produces spider silk protein in milk– Biosteel.

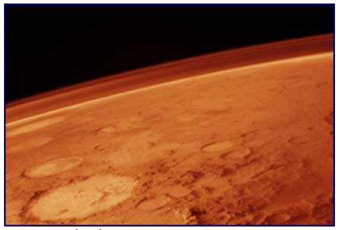
http://science.howstuffworks.com/designer-children3.htm

http://www.nexiabiotech.com

Terraforming Mars

- Mostly envision Mars for terraforming.
- Comparison:

Mars:		Earth:	
– 95.3%	carbon dioxide	– 78.1%	nitrogen
– 2.7%	nitrogen	– 20.9%	oxygen
– 1.6%	argon	– 0.1%	carbon dioxide + trace
– 0.2%	oxygen		



- Why terraform?
  - In 1-2 x 10^9 yrs, Earth will get hot.
  - Other economical possibilities.
- What are the essential ingredients?
  - Water, Oxygen, and Ozone.
- The bacteria that can build up oxygen need the water.

Or Aliens?

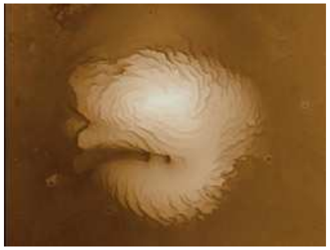
- Sometime movies are full of errors.

- But what can you do?

http://www.geocities.com/mattcash777/gallery4frames.html

Wet Mars

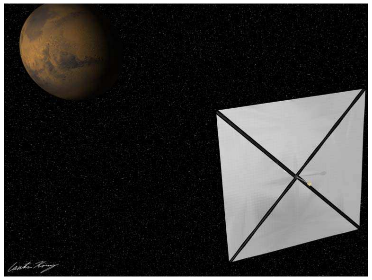
- There is clearly water on Mars frozen in the permanent ice caps or in icy deposits below the surface.
- Probably 10^{14} tons of ice in the caps, but how to melt it?
- Spread a layer of dark soil, which will sublimate the water to water vapor.
- Water vapor is a greenhouse gas, so eventually pressure and temperature goes up and liquid water can exist.
- Would take about 10,000 yrs to melt.



http://www.ucl.ac.uk/GeolSci/MITC/marsinfo/icecap.jpg

Solar Mirror?

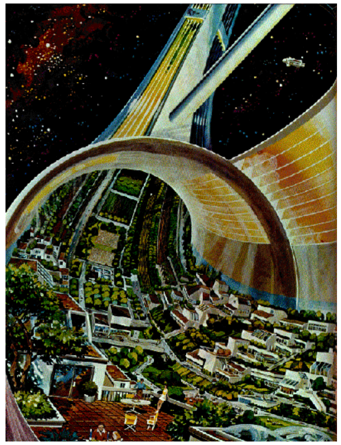
- Could build huge solar mirrors in space to add light to mars– size of Texas for 2% increase.
- Power needed to melt the icecap (remember only first step) is equivalent to 2500 yrs of the US energy output!
- A solar sail satellite (diameter of 125 km) above the pole should melt the icecap in 10 yrs.
- Other options: GE bacteria to add greenhouse gases, nanobots, etc.
- Bottom line, at this time it would be very costly and time consuming to terraform Mars.



http://www.futurespace.de/gallery/pictures/sail-mars1.jpg

Space Colonies?

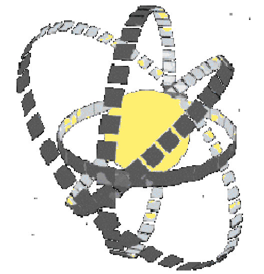
- Super-duper version of the Space Station.
- Collect materials from Moon, and make a large space structure.
- Artificial gravity from rotation– life could exist.
- But why?
- Hard to justify the expense.
- Maybe solar power collector– beaming microwaves back to Earth.



http://static.howstuffworks.com/gif/space-station-space-settlement.gif

Dyson Spheres– Recap

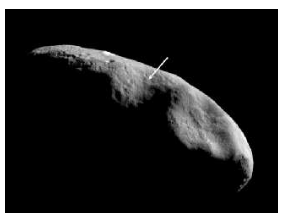
- Again, one could imagine a Dyson Sphere around the Sun to collect the sunlight.
- If other advanced civilizations built one, could we detect it?
- If at 1AU, the sphere would be about 300 K and emit in the IR.
- But if we detected it, we would think it was a star surrounded by dust-- a circumstellar disk of a young star or a blown out shell of dust from an old star.



http://www.homoexcelsior.com/omega.db/datum/megascale_engineering/dyson_sphere/237

Asteroid Living and…

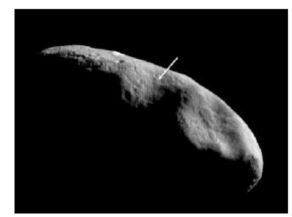
- Mining the Apollo (near Earth) asteroids for metals is a possible economical driver for life in space.
- But all of this requires moving machines, humans, or material around the solar system.
- Today, if there were piles of gold lying on the Moon, it would not be cost effective to go get it.



http://apollo-society.org/images/near_arrow_sm.jpg

Asteroid Living and…

- But, remember to date human space travel has cost 10 times as much as remote "robot" travel.
- Probably devise ways to mine remotely.
- Efficient mining requires more and more intelligent robots.
- What if they get too smart?
- Still self-replicating space probes could be result of such advances.



http://apollo-society.org/images/near_arrow_sm.jpg

Space Probed

- A single probe is constructed and dispatched to a nearby star system
- It surveys the system in an intelligent and exhaustive manner
- After which, the probe uses the energy and available raw materials of the system to reproduce itself .

Space Probed

- Dispatches its “children” onwards to repeat its mission in other star systems
- The parent probe is then able to choose whether it wants to stay in the system or not, depending on what it found
- Still need a way to get to other worlds.

http://www.biochem.wisc.edu/wickens/meetings.html