ET: Astronomy 230

This Class (Lecture 33):
Communication

Next Class:
Brian Fields:
"Killer Supernovae!"

Monday Class:
Julianne Fisette
Caitlin Ford
Jamal Reece

HW 9 due Friday!

Music: *I Still Haven't Found What I'm Looking For–* U2

Outline

- So how far do we have to look to find ET?
- Radio seems the best choice.
- But what frequency?
- Our best message to ET.
- Needle in a haystack.

Drake Equation

= **12556**

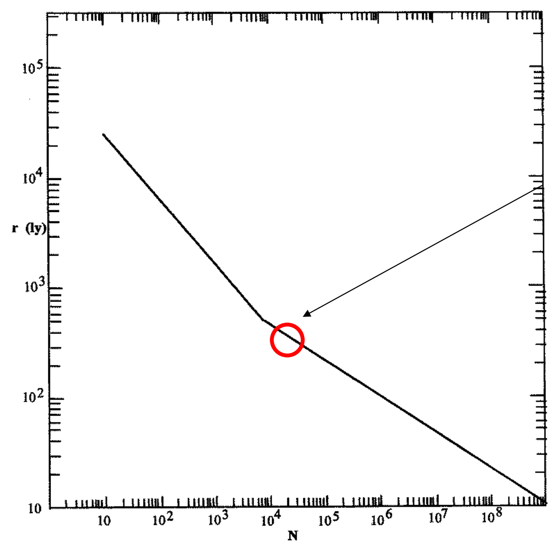
Civilizations!

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!

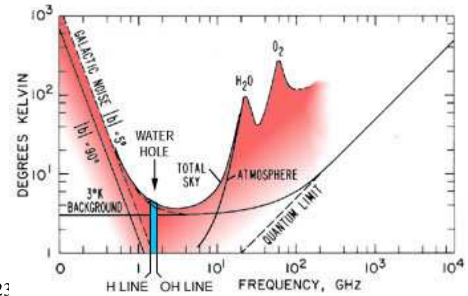
Interesting Points

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 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?

<u>Radio is probably best.</u>

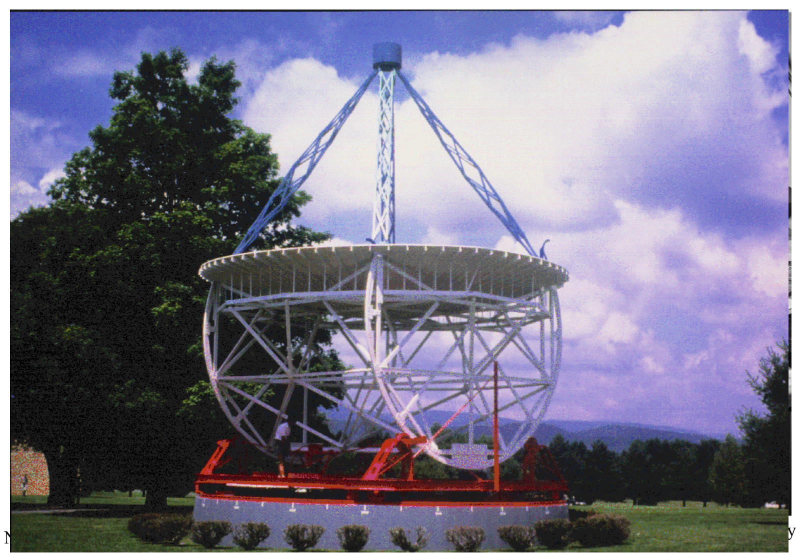
1. Dust extinction is reduced.
2. Lower frequency means less energy/photon, so cheaper.
3. There is a natural dip from about 1 to 10 GHz in the radio where the atmosphere and the galaxy are the quietest.



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

Radio telescopes

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



Arecibo Observatory, Puerto Rico

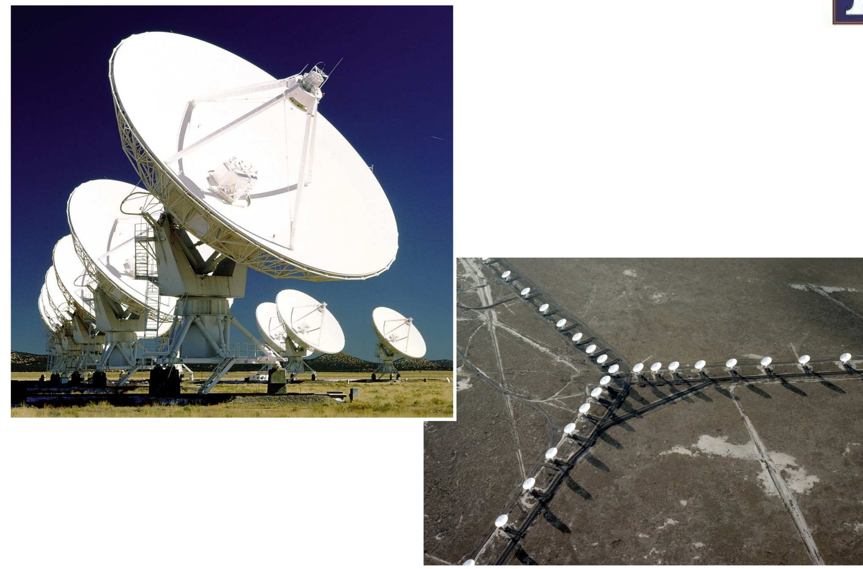
Largest radio telescope– 300 meters.

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

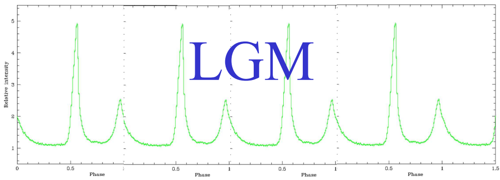
- After receiving and amplifying the signals, one has to decode the signals.
- Naturally created signals do not usually vary with time and are unpolarized.
- This is non-trivial.

http://theimaginaryworld.com/box678.jpg

Decoder Ring

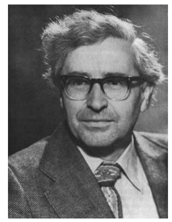
- Normally, artificial signals encode data:
  - FM : frequency modulation (frequency varies with time)
  - AM : amplitude modulation (brightness varies with time)
    - Usually analog, but digital is more robust
    - Can turn on/off to signify 1 or 0 (most likely for ET)
- Note, <u>most</u> astronomers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

http://theimaginaryworld.com/box678.jpg



LGM

Jocelyn Bell Burnell



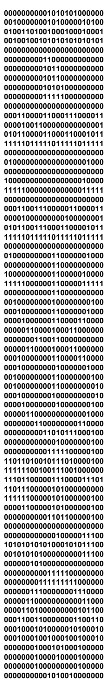
Anthony Hewish

- 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.
- Eventually realized to be from neutron stars (pulsars).
- The lighthouse beam from the rapid rotator sometimes intersecting the Earth.

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.



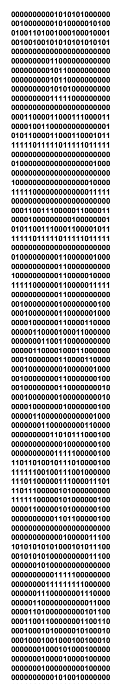
Can you Figure it out?

See if you can decode anything.

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

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

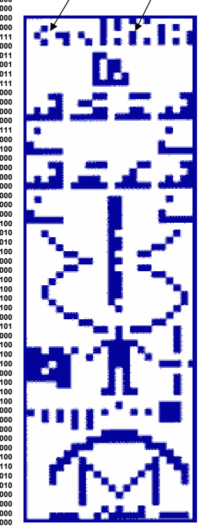
ET should be able to try arranging them into a picture.



We attempted Contact

a zero

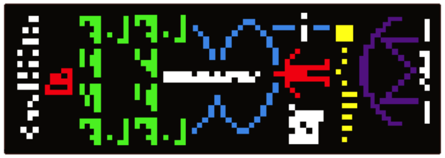
a one



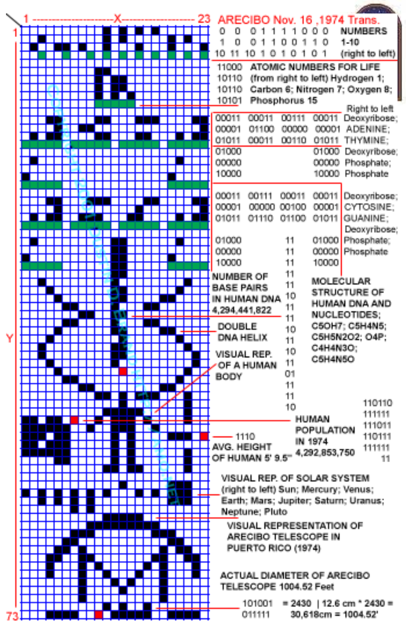
- Now, we wait.
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- Used the Arecibo telescope with a large transmitter– 20 trillion watts of power.
- If they're looking, any SETI experiment will detect this.

Decode what?

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



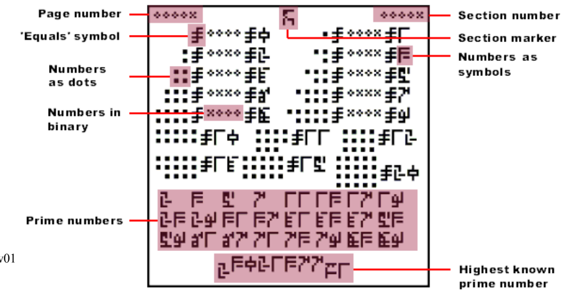
http://antwrp.gsfc.nasa.gov/apod/ap970717.html



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.



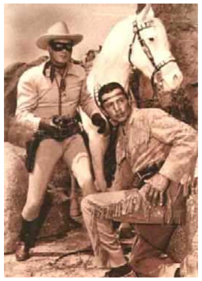
http://www.ibiblio.org/astrobiology/index.php?page=interview01

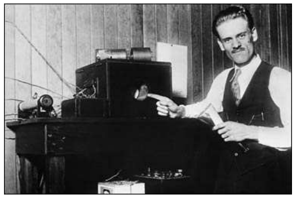
Contacting Us

- 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

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.

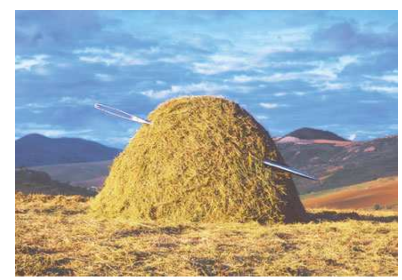
http://www.space.com/searchforlife/seti_shostak_aliens_031023.html

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, at least yet.

Problems…Problems

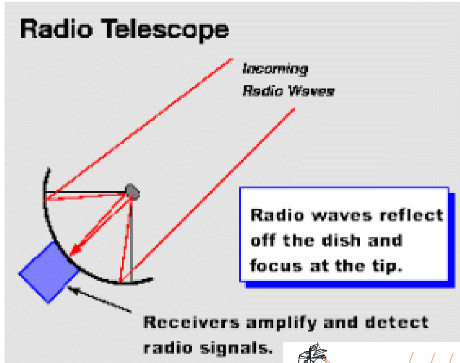
- Assume that an advanced civilization is broadcasting either in all directions or toward us.
- Where and when do we listen?
- Which frequency?
- Which channel?
- Which polarization?
- What is the code?
- The problem is worse than searching for a needle in a haystack.
- We have to assume that they are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



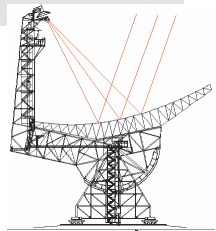
http://nl.ijs.si/et/talks/esslli02/metadata_files/Haystack-FINALb.jpg

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

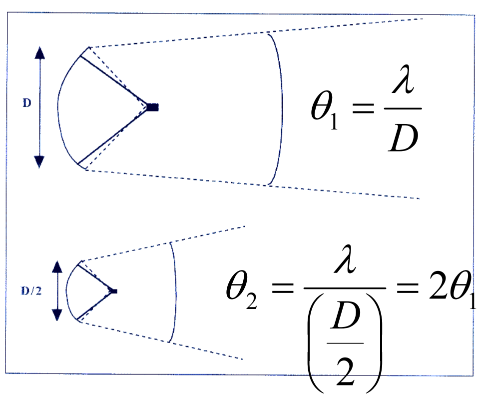
Haystack: Sensitivity

- Sensitivity of a radio telescope:
- The smaller the sensitivity the better.
- 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?

$$S \propto \frac{1}{D^2\sqrt{\Delta \upsilon \times t}}$$

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 increase as diameter squared.



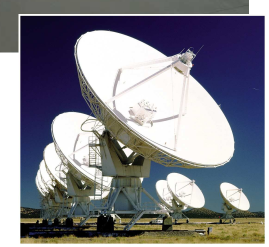
$$\theta_1 = \frac{\lambda}{D}$$

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

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 <u>big</u> dish.



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

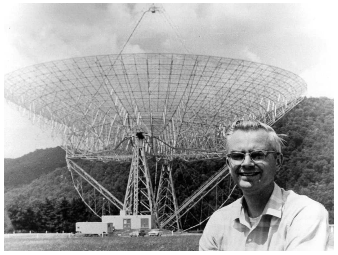
Haystack: Frequency

- 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

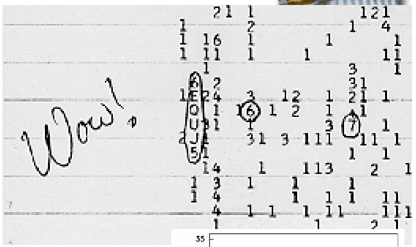
Ohio State

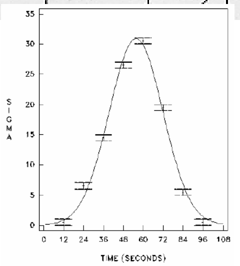
- Modest sensitivity 10^{-21} W m^{-2} Hz^{-1}
- 100 times worse than Ozma II
- But not just looking at stars.
- Could only detect extremely strong transmissions.
- Again, 1.42 GHz with 50 channels of 10 kHz.
- Land was sold to a golf course development.

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

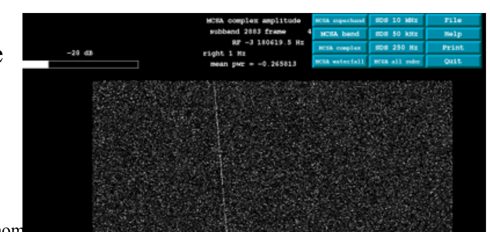
The SETI Institute

- 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

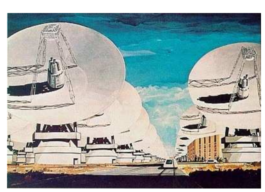
- At the BIMA site, UC Berkeley and the SETI Institute with majority of funding from Paul Allen are building the ATA.
- 350 antennas that are 6.1 m in diameter.
- Area comparison: Arecibo (70650 m^2) & ATA (10200 m^2) but still > 100 m single dish.
- And small dishes– larger field of view.
- With advanced 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