

## Astronomy 330



This class (Lecture 23):  
Communication

Next Class:  
Communication

**HW10 is due Wed night. Not multiple choice.**

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

## Question



How many questions would you like for section 3 of the final (the new stuff)? (Sections 1 and 2 will be  $\frac{1}{2}$  the length.)

- a) 25
- b) 30
- c) 35
- d) 40
- e) 45

## Online ICES



- ICES forms are available online.
- I appreciate you filling them out!
- Please make sure to leave written comments. I find these comments the most useful, and typically that's where I make the most changes to the course.

## Outline



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

# Drake Equation

Frank Drake



That's 2,759 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
9	stars/yr	0.29 systems/star	$1.03 \times 0.22 = 0.23$ planets/system	0.46 life/planet	0.3 intel./life	.52 comm./intel.	65,000 yrs/comm.

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 our values, lifetimes greater than around 100 years give more than 4 civilizations with which to talk.
- Our number was 2,759 years.

# Drake Equation For Average

= 930,000

Communicating Civilizations

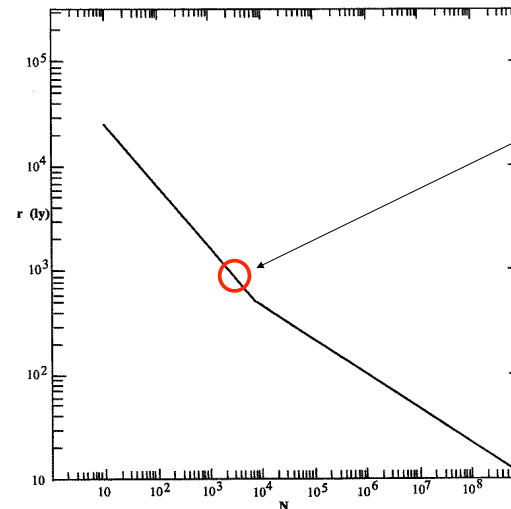


$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# 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 communicate	Lifetime of advanced civilizations
10	10	0.5	0.89	0.5	0.7	0.6	$1 \times 10^6$

Birthrate of 0.93/year!

# The Neighbors



We need to look at every star within ~850 yrs for one detection!

Using  $N=2,759$

# How to Communicate?

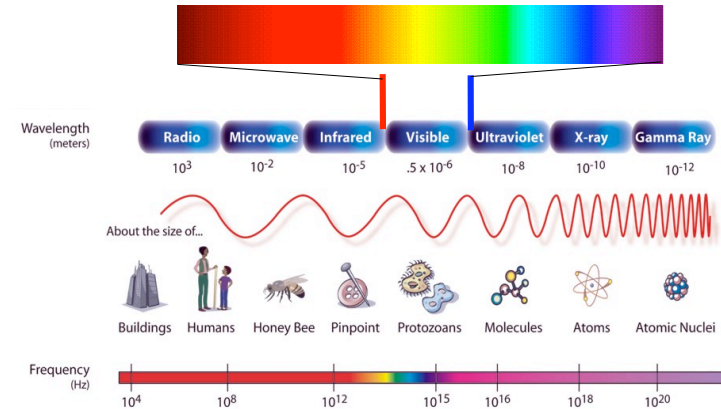


- Okay, our estimate is optimistic.
- So, how do we go about detecting our neighbors?
  - About 850 lyrs away (maybe... perhaps...)
- Are we seriously sending out messages now?
- No.

# 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.

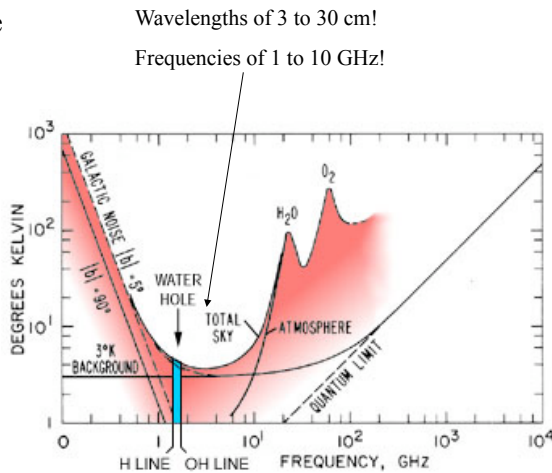


# Freq-ing Out.



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](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](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?

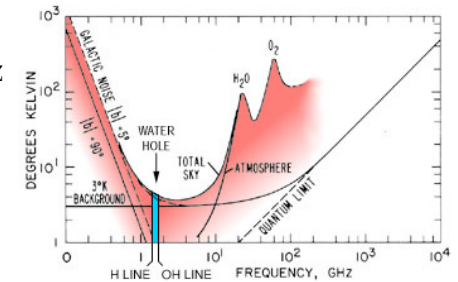
[http://www.insomniacmania.com/news/news\\_771\\_1.jpg](http://www.insomniacmania.com/news/news_771_1.jpg)

## 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](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  $9 \times 10^9$  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.

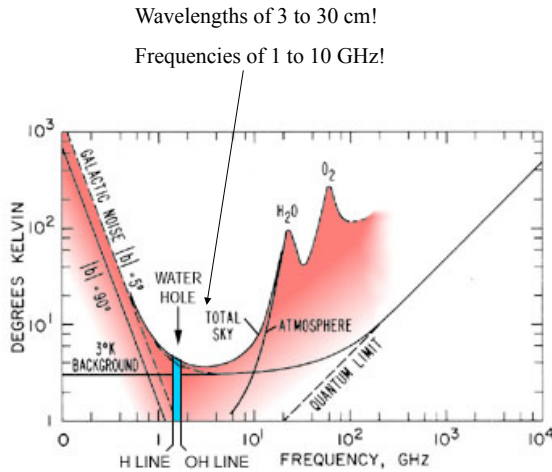


<http://www.leapsecond.com/pages/univ/>

## 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](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

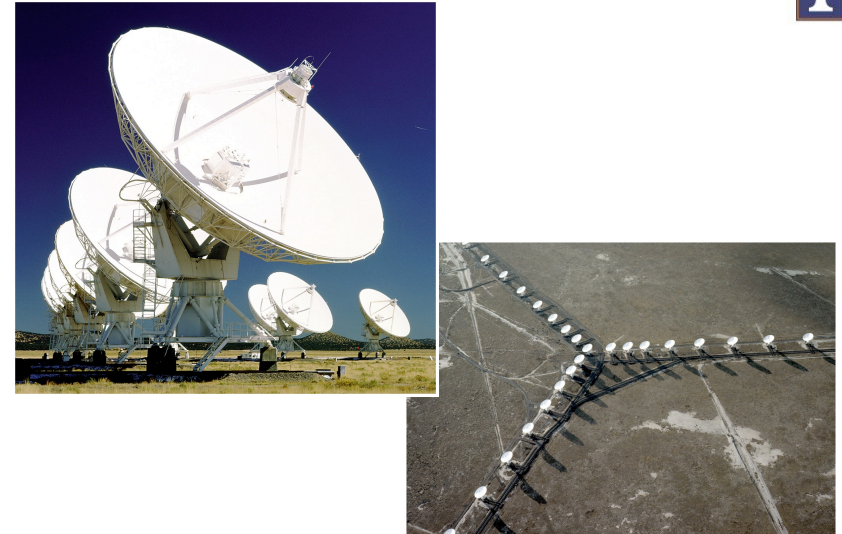


<http://www.gb.nrao.edu/epo/GBT/gbtpix.html>

## Greenbank WV



## Very Large Array, near Magdalena, NM



## Question



What is the radio frequency we use to try to contact ET?

- a) 1.42 GHz (H atom)
- b) 2.5568 GHz (using the constants)
- c) Between 1.612 and 1.720 GHz (the OH lines)
- d) 22 GHz (the water line)
- e) There is no magical frequency, so we aren't sure what frequency is best.

## 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.

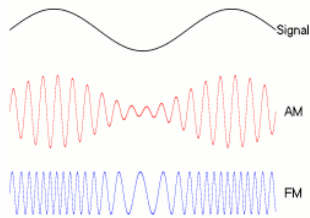


<http://theimaginaryworld.com/box678.jpg>

# 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)



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

[http://en.wikipedia.org/wiki/Frequency\\_modulation](http://en.wikipedia.org/wiki/Frequency_modulation)

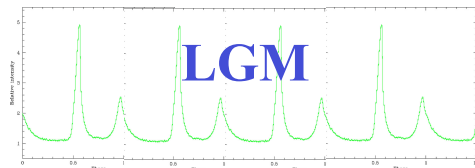
# Decoder Ring



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



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



- But, astronomers studying the short variations in the interstellar medium did look at fast varying signals.
- Jocelyn Bell Burnell 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.





## Question



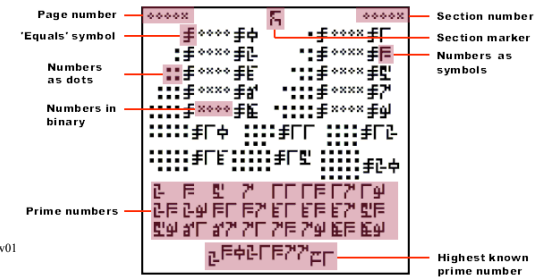
In 21,000 years, when the Drake message gets to M13

- The aliens will be able to decode it, and enjoy images and sounds of the people of Earth.
- The aliens may not be able to decode it.
- The aliens will not be able to decode it, but with the additional hints sent afterwards, they will figure it out.
- The aliens will be able to decode it and build their own telescope with the knowledge.

## Encounter Messages



- Sent by commercial company based in Houston, Texas using the Eupatoriya Deep Space Center radio telescope in Ukraine to 5 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.
- Astronomers derived code: Dutil & Dumas
- Included names and address of 2000 donors and personal messages.

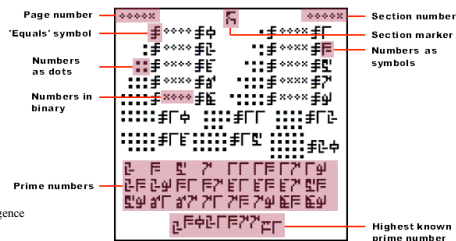


<http://www.ibiblio.org/astrobiology/index.php?page=interview01>

## 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](http://en.wikipedia.org/wiki/Communication_with_Extraterrestrial_Intelligence)

## Contacting Us

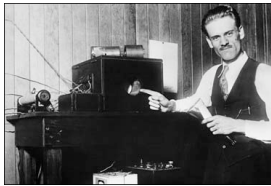


- What does an advanced civilization that wants to contact us do?
- Could set-up radio beacons (assumes cheap energy?)
  - Broadcast in all directions.
  - Broadcast at several frequencies.
  - Would require enormous energy sources.
- Would be much better if they could use directional messages (assumes cheap energy?).
- 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



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

Vega (25lyr) 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.

<http://www.youtube.com/watch?v=ZF3IZzXZ6lg>



## 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?



[http://www.space.com/searchforlife/seti\\_shostak\\_alien\\_031023.html](http://www.space.com/searchforlife/seti_shostak_alien_031023.html)

## Does ET Love Lucy?



- 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\\_alien\\_031023.html](http://www.space.com/searchforlife/seti_shostak_alien_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.  
→  $N_{\text{required}} = 10^7$
- So probably ET does not love Lucy, at least yet.

