

Online course evaluations

Final Exam: **Wednesday, December 18; 4:30-6:30** ; review and practice exam posted

Room assignment for final: MacKay 0117

**ESSAY/SHORT ANSWER QUESTION**

### Last time: Life beyond Earth: The Drake Equation

$$N = R_s \times f_p \times n_p \times f_L \times f_i \times f_c \times L$$

- [Parameterizing our ignorance](#)
  - breaking one big question into many small ones
- [Astronomical, Biological, and Sociological factors](#)

### Today: Searching for Extraterrestrial Intelligence

- [Refine the Drake Equation by measuring N](#)
- [Contact vs. Communication](#)
- [Search strategies](#)
- [Results and prospects](#)

## Putting it all Together:

$$N \approx 8 \times 0.9 \times 1 \times 0.5 \times 0.5 \times 0.5 \times L$$

$$N \sim L$$

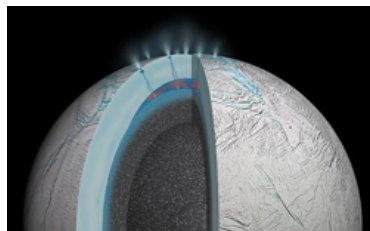
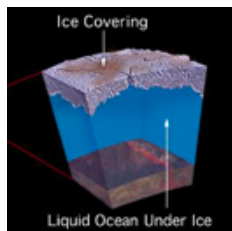
The number of other technical civilizations **in our galaxy** equals the number of years that they are able (and willing) communicate

**Could be ~ 80 in our galaxy right now!**



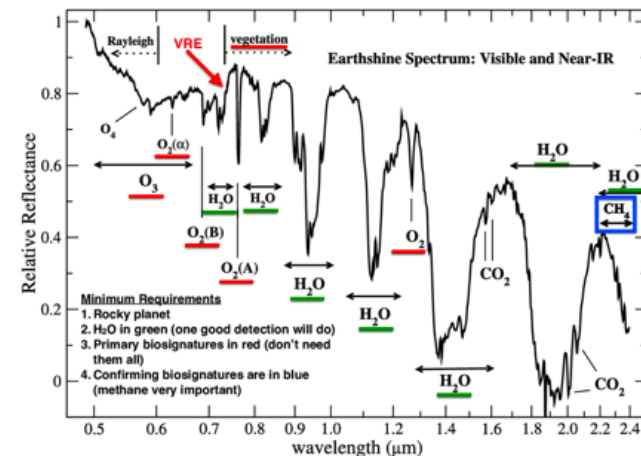
## Prospecting for life in our Solar System ( $f_L$ )

- **Mars**
  - once had liquid water on surface
  - possible fossil evidence or maybe extremophiles survived
  - no evidence from Viking and other landers / orbiters
  - Mars 2020 rover (launch in summer 2020)
- **Europa / Enceladus**
  - ample evidence of subsurface liquid salt water
  - energy source from tidal flexing
  - water (and organics) in 'spray' from Enceladus & Europa
  - Europa Clipper mission (launch in mid 2020s)



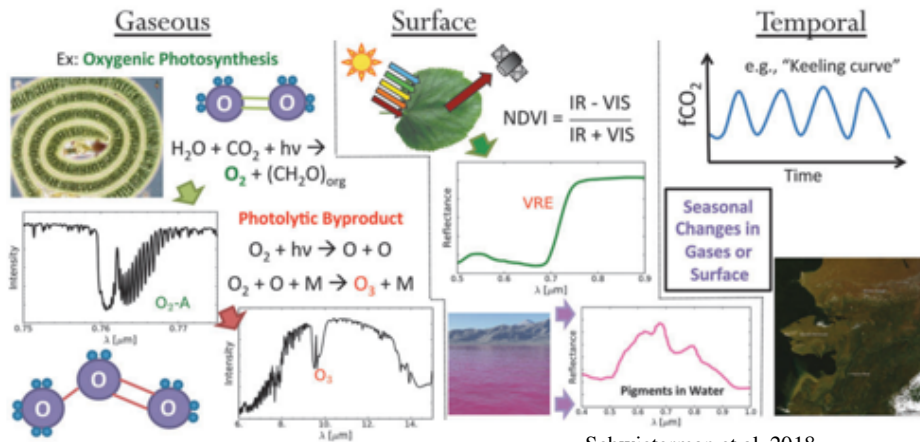
## Prospecting for life on exoplanets ( $f_L$ )

- **Exoplanet biosignatures**
  - observe exoplanets in transit across host star, or directly.
  - use spectroscopy to look for 'non-equilibrium' molecules of biological origin
  - Oxygen, ozone, chlorophyll pigmentaiton, methane, ...



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**Contact or 'just' communication ?**

- To go to a star 10 light years away ... and back in one (long) lifetime:
  - need  $6 \times 10^{28}$  ergs (20 years of Earth's total energy production!)
  - most efficient fuel: matter+antimatter (100 tons each way)
  - shielding against gamma rays...
  - nah...
- **Contacting and communicating with other civilizations must be a generation-to-generation effort**

**Communication?**

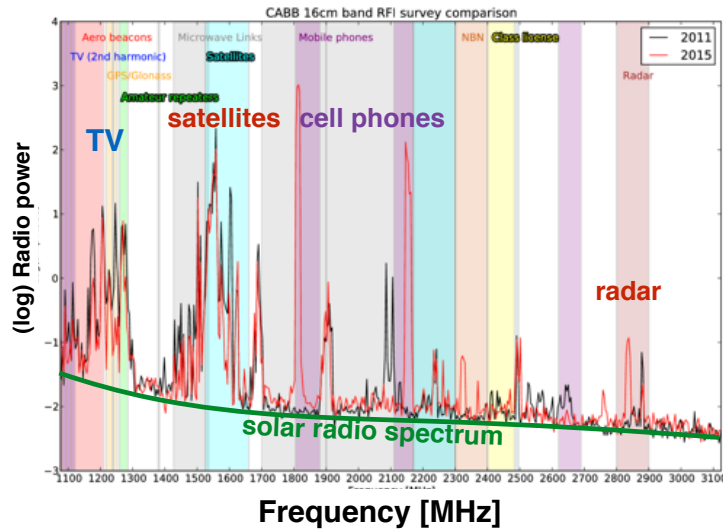
consider... value in one-way communication

Culture	separation in	common language	medium	an example
	time (4000 years)	hieroglyphics	tomb carvings papyri	
	space (light years)	universal truths: science, math	light, radio, sentinel spacecraft	

**SETI: Search for Extraterrestrial Intelligence**

- (Radio) Searches for narrowband signals
  - narrow band = non-natural origin
- need to scan billions of frequencies
  - we don't know their "standards"
  - FM radio - only 200 indep. frequencies
- need to point at LOTS of solar-type stars

# SETI: Why Radio?



- can detect “earthly” signals across the Milky Way
- scan thousands of nearby stars

# SETI: Why Radio?

- **cheap** to produce high-power beam
- **easy** to detect with simple technology
- **long-range**
  - Galaxy transparent to radio waves
  - Galaxy relatively noise-free at useful wavelengths

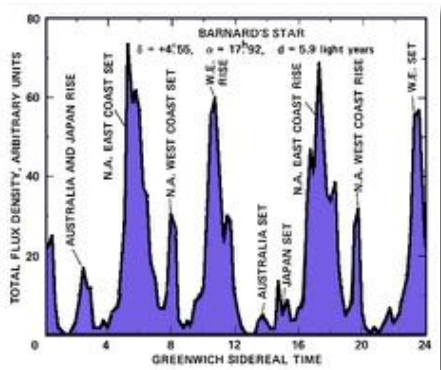


Arecibo Observatory

And we already have some huge radio telescopes!

- can detect “earthly” signals across the Milky Way
- scan thousands of nearby stars

# Unintentional Signals



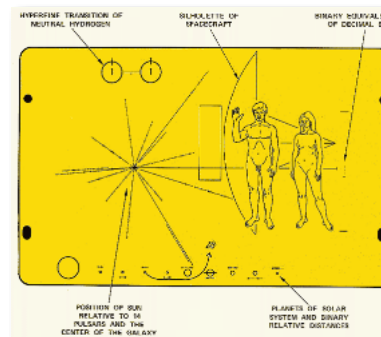
Earth UHF/VHF TV, viewed from Barnard's star  
(Sullivan et al. 1978)

- most radio signals will be unintentional
- Earth example -
  - TV broadcasts
  - Cell Phones
  - Military Radar
- **all spilling out into interstellar space**

**Discovery would be profound even if never decoded**

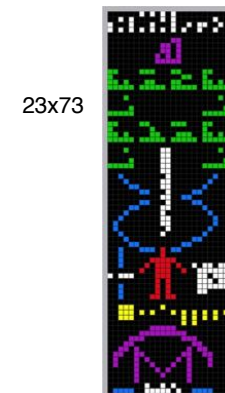
# Examples: intentional messages

The plaque aboard Pioneers 10 and 11



now over 7.5 billion miles away

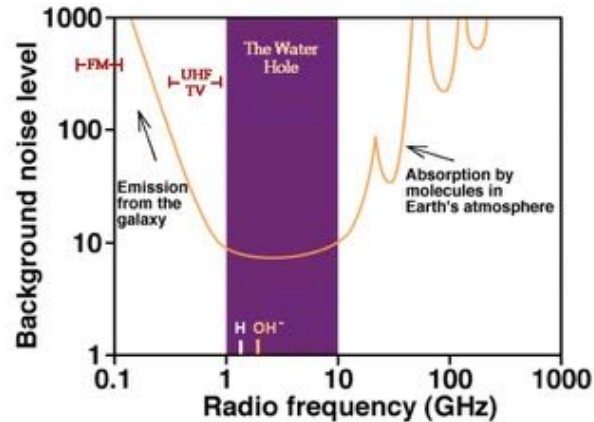
The Arecibo Message (1974)



now 45 light-years away

# What frequencies?

## the “Water Hole”



“Magic” frequencies: 1.42 GHz, 2.84, GHz ...

# How alone are we?

## How many stars to search?

L	nearest civilization	number of stars to search
75	3,600 ly	365,000,000
1000	1,500 ly	100,000,000
1,000,000	150 ly	100,000

# Project Ozma:

## the first search, 1960

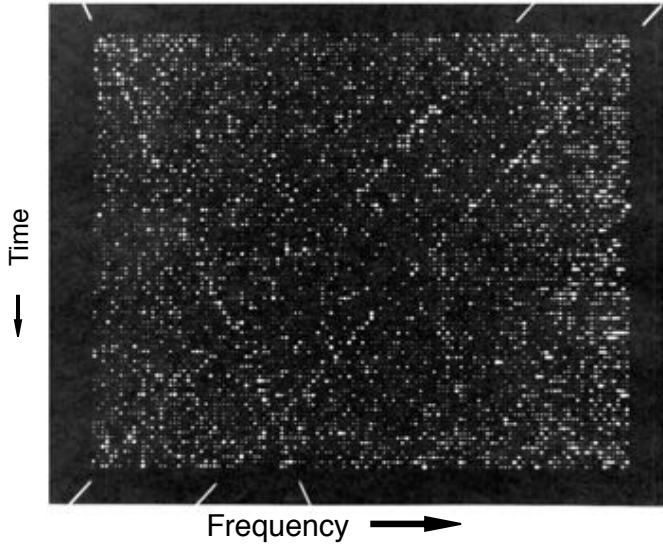


- Frank Drake (again!)
- 85ft Green Bank Telescope
- 3 months, 6h/day
- 2 stars
- monitored 1 frequency
  - 1420 MHz, HI line
- found nothing
  - except a secret military radar

# Modern Searches



- The more frequencies, the better
- **Project Phoenix**,  
@The SETI Institute  
(Frank Drake is Chair of the Board)
  - Paul Horowitz @ Harvard, project BETA
- Look for narrow bandwidth, pulsed signals
- Search LOTS of stars
- Automated data analysis
- Independent verification (lots of false alarms)





Each line of raster shows the power in each output channel, or "bin," for 120 adjacent channels during one sample. Ninety successive samples are shown. There is a general field of noise in which the probability of a given brightness falls off exponentially with brightness. Included are three drifting CW signals. The two with a slope of 45° represent signals decreasing in frequency 1 bin per sample. The right-hand signal is always centered in the bin at the middle of the sample. The left-hand signal straddles two bins at the middle of the sample. The resulting loss in detectability is evident. The third signal is increasing in frequency 1/2 bin per sample and is alternately at bin center and at bin edge. For all the signals, the SNR is 2; that is, the signal power is twice the average noise power per bin.

FIGURE 4. Detection of CW Signals

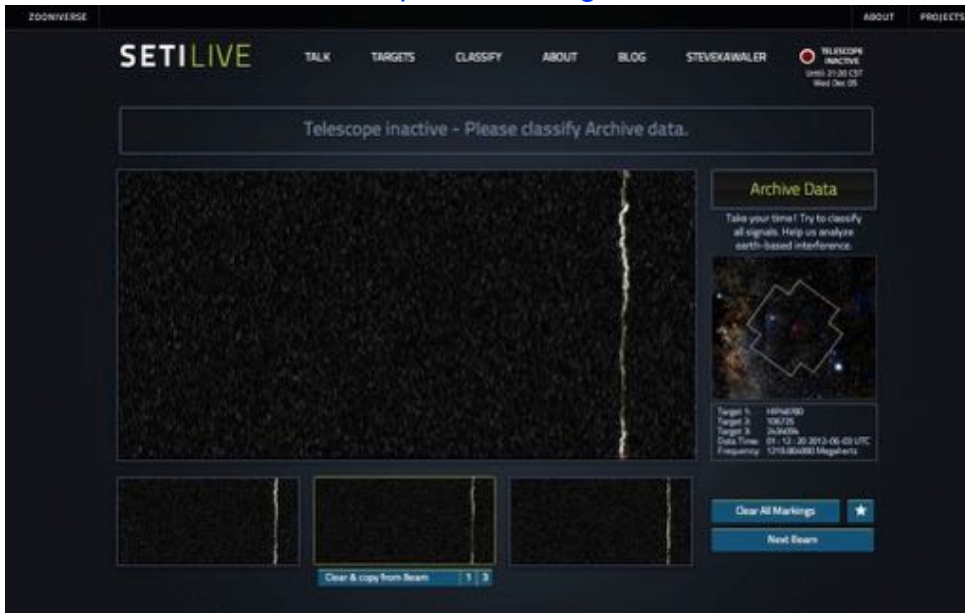
## Voyager 1 Signal from 106 AU Away

106 AU = 7.5 billion miles  
a 5 watt transmitter (walkie-talkie)

from Jill Tarter - SETI institute

## Data analysis example : SETILive.org

<http://setilive.org>

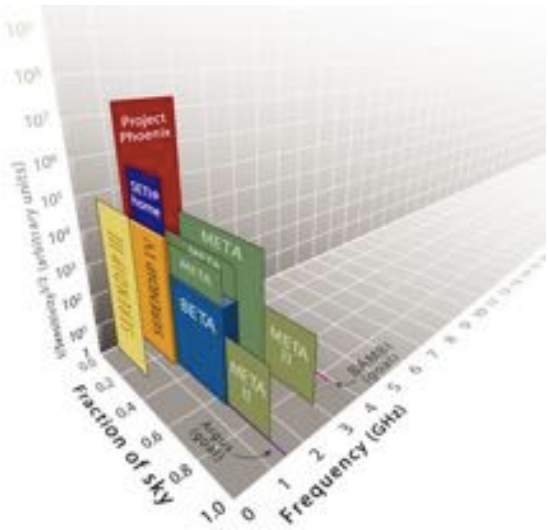


## Now: The Allen Telescope Array

- A large array of ~350 20 ft. radio telescope dishes
- work together as a single telescope
- cover the whole sky at all frequencies
- funded by Paul Allen (Microsoft Gazillionaire)
- **400,000,000 stars within 30 years - with software!**



# The Cosmic Haystack



- "(Current status is like) looking for a fish, any fish, in all of Earth's oceans by examining a single drinking glass of sea water"  
Jill Tartar, 2010
- "Our current search completeness is extremely low, akin to having searched something like a large hot tub or small swimming pool's worth of water out of all of Earth's oceans."  
Jason Wright, 2018

# Conclusions

- It's hard to avoid the conclusion that life is abundant in the Universe
- It's easy to suppose that intelligent life is common in our Galaxy
- We already have the technology to detect other intelligent civilizations at interstellar distances
- People are looking for them right now and will continue
- We may never succeed but we can't afford not to try

Messages from other stars are coming through this room, and they have been doing so for literally millions and billions of years. And nobody sensed it, no creature sensed it. You need special technology to do it but it is there, right here in this room.

Look around. Where is it?

It's here.

It's just that we're not using the right sensors, we're not looking in the right direction, we're not tuning to the right channel. But let's work on it and someday, we'll join the galactic internet, and learn a lot of good, fun things.

Frank Drake,  
Mountain View, California  
November 5, 2013

**"How unreasonable it would be to suppose that, besides the Earth and sky which we can see, there are no other skies and no other Earths"**

**Teng Mu  
13th Century**

You are here

**"Through the vast reaches of space and time, part of the matter of the Universe has evolved into living matter, of which a tiny part is in the form of brains capable of intelligent reasoning. As a result, the Universe is now able to reflect upon itself. In this respect, at least, the whole evolutionary chain is endowed with meaning."**

**National Academy of Science  
Astronomy Survey Committee, 1970**