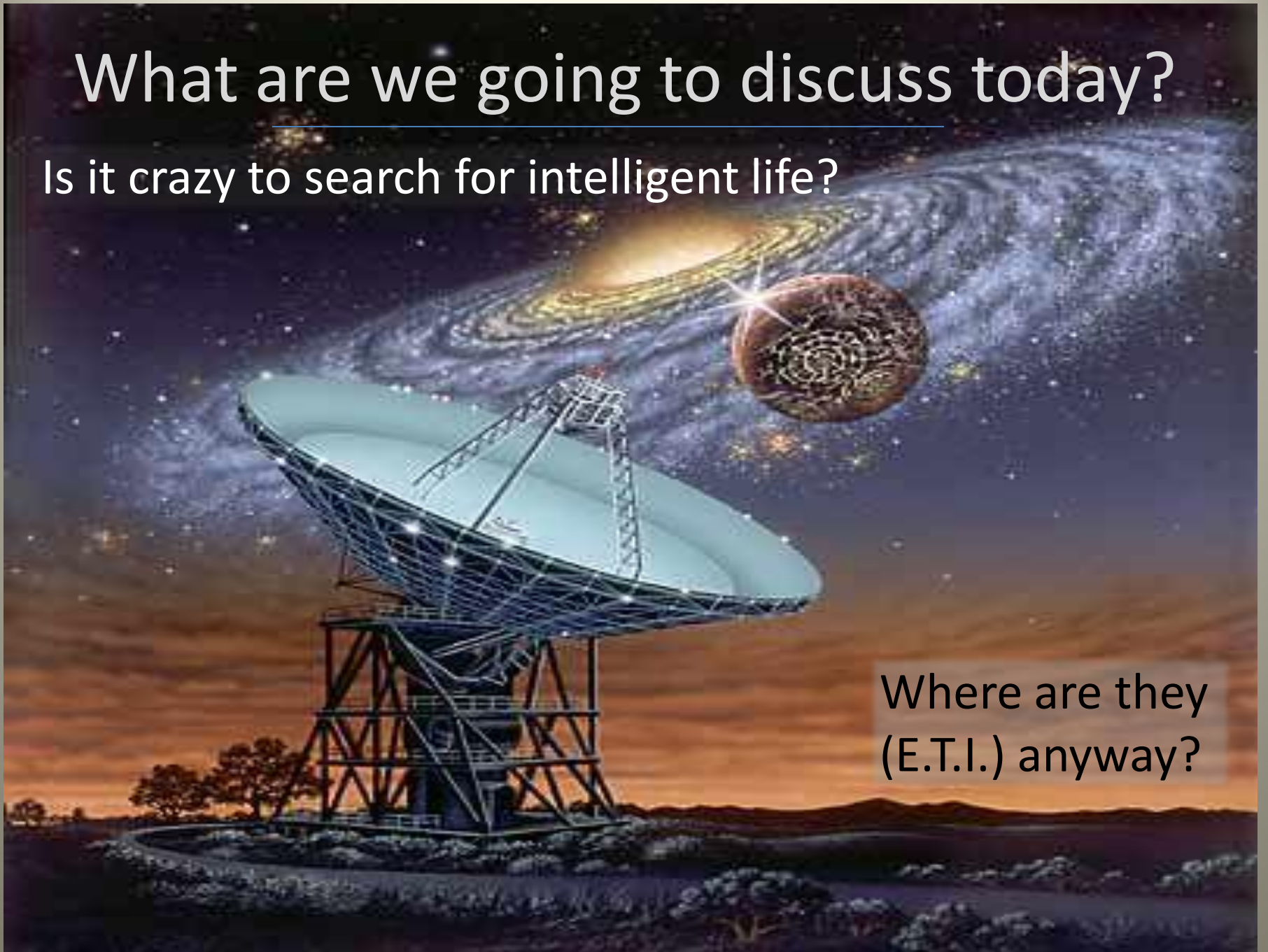


Welcome to Class 15:  
Drake Equation, SETI & Fermi  
Paradox

# What are we going to discuss today?

Is it crazy to search for intelligent life?

Where are they  
(E.T.I.) anyway?



# Opinion Question (with PRS): Has this class changed your view on life elsewhere?

1. I am a stronger believer in extraterrestrial life.
2. I am still a strong believer in extraterrestrial life.
3. I did believe, but now I am not so certain there is life elsewhere.
4. I never believed and still don't believe in ET life.
5. I didn't believe, but I think I do believe in ET life now.

Remember to set your channel to 80!

# Who is this man?

He designed an equation to estimate:

**Number of Civilizations in the Milky Way capable of interstellar communication NOW.**

Your book has simplified the Drake Equation to:

$$\# = \mathcal{N}_{\text{hp}} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}}$$

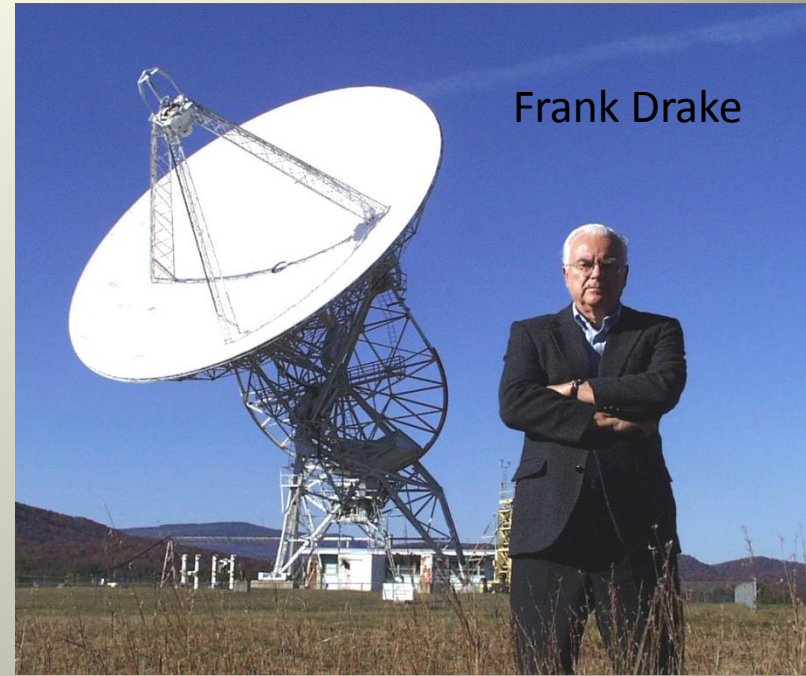
$\mathcal{N}_{\text{hp}}$  = Number of habitable planets in the Milky Way.

$f_{\text{life}}$  = Fraction of those planets which will develop life.

$f_{\text{civ}}$  = Fraction of those which develop Civilized life.

$f_{\text{now}}$  = Fraction of those planets with Civilized life NOW.

Let's consider some possible values for the Drake Equation..



Frank Drake

Frank Drake also designed the *first contact message* sent to nearby stars. He was director of Arecibo Radio Telescope, and sent the message from there in 1974. (36 yrs ago)

$\mathcal{N}_{\text{hp}}$  : How many habitable planets are in the Milky Way presently? (recall, there are a *few 100 billion* stars in the M.W.)

1. 200 billion
2. 1 billion
3. 1 million
4. 1,000

$\mathcal{F}_{\text{life}}$  : What fraction of those planets develop life (of any kind)?

1. All (1)
2. 1/10th
3. 1/100th
4. 1/million
5. None

$\mathcal{F}_{\text{civ}}$  : What fraction of life-bearing planets developed civilizations capable of communication at SOME time?

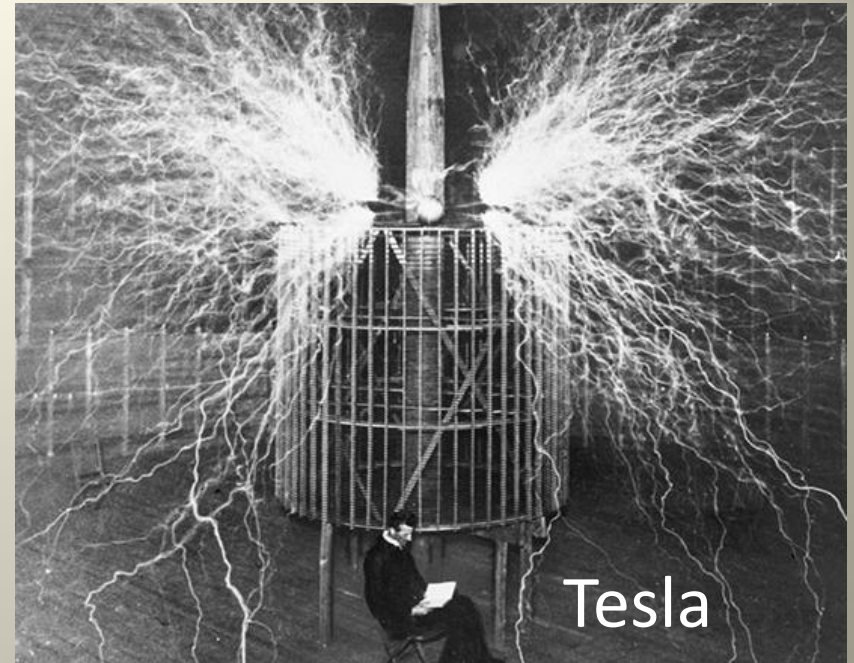
1. All (1)
2. 1/10th
3. 1/100th
4. 1/million
5. None

$\mathcal{F}_{\text{civ}}$  : What fraction of those life-bearing planets capable of communication exist NOW?

1. All (1)
2. 1/10th
3. 1/100th
4. 1/million
5. None

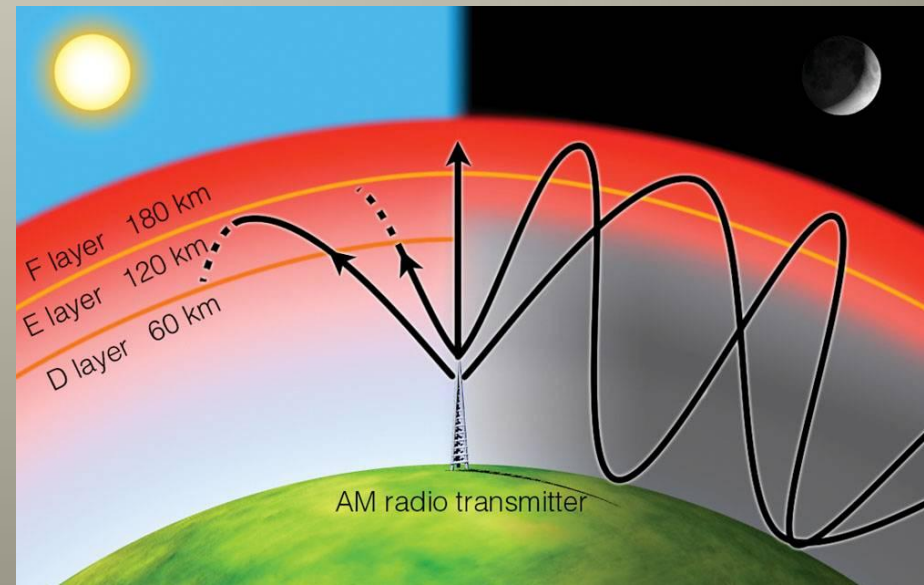


# Early claims to communicate with E.T.I.



Early pioneers of electricity, Marconi and Tesla, also introduced 'radio' (electromagnetic radiation) communication. They both thought they were hearing E.T.I.

Unfortunately, the radio wavelengths they were working at (AM radio, kHz) can not pass through Earth's ionosphere.



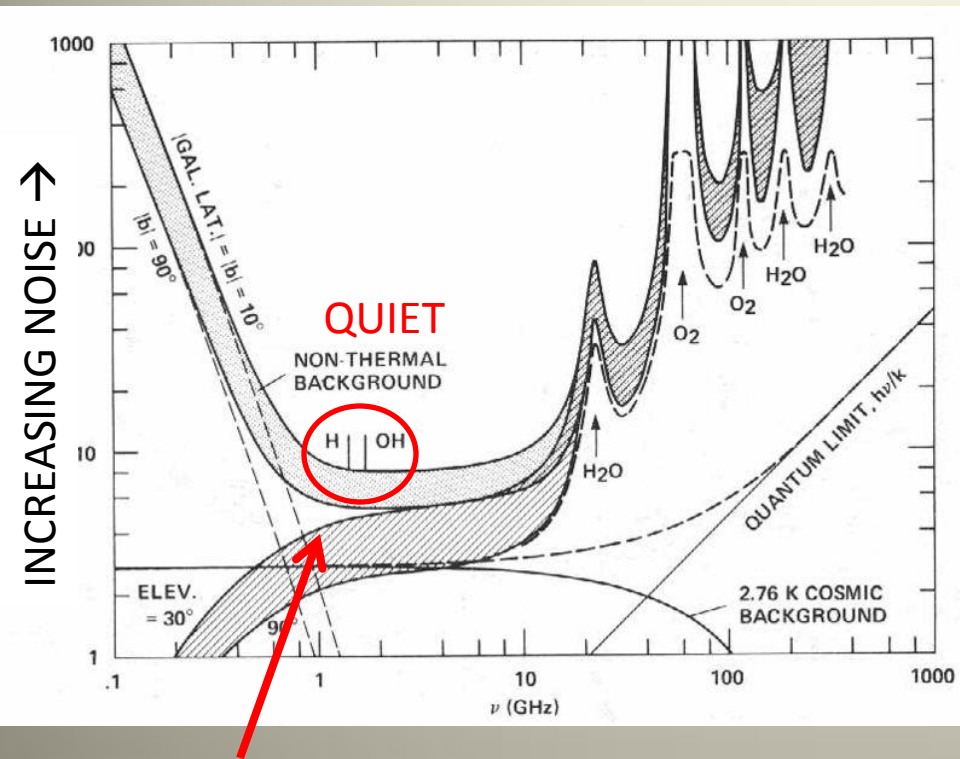
# PRS : Why do we listen rather than send out a signal?

1. Stay hidden from E.T.
2. Faster
3. Easier
4. Cheaper
5. All of the above

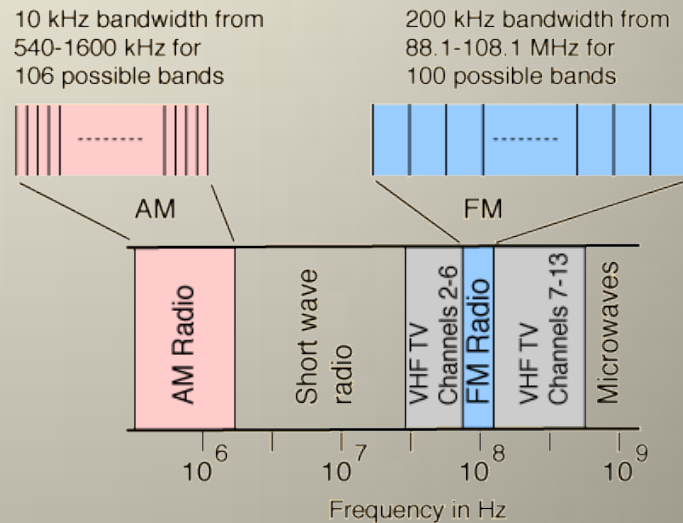
# Are we missing signals from E.T.I.?

1. We don't know which direction in the sky they are.
2. We assume they'd use `light', but we don't know what kind of electromagnetic radiation they are using.
3. We don't know how strong those signals are, or how far away they are coming from.
4. Is the signal continuous, or does it stop and start every year, every minute?
5. Do we need to go back and re-observe all directions?

# What FREQUENCY should we be listening?



Where the universe is most quiet!  
 But WHERE.. There is an infinite number of 'stations':



A civilized life would have astronomers who have built radio telescopes to observe H (hydrogen) and OH in the Galaxy.

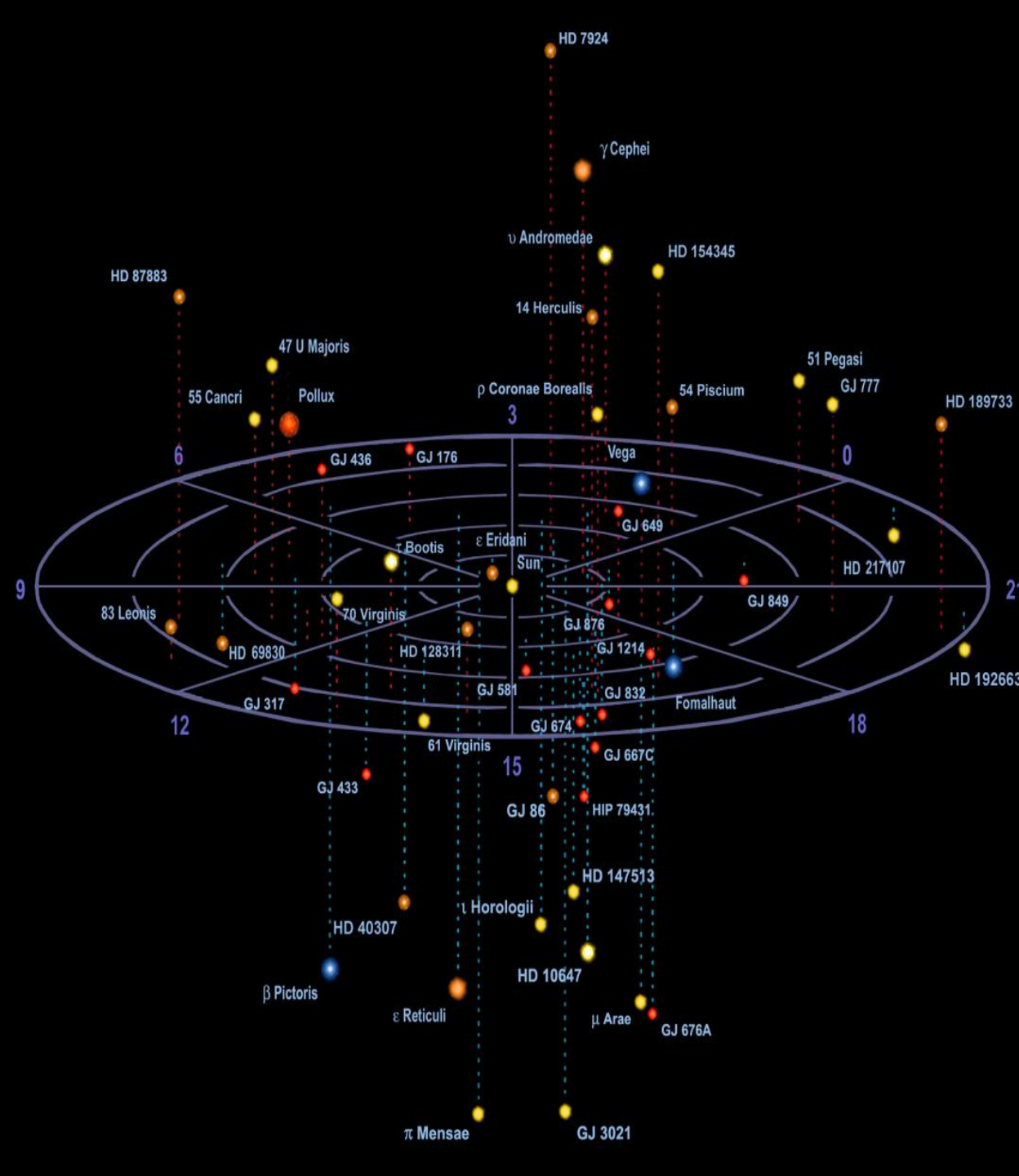
Even in this range, there exists an infinite number of FREQUENCIES to listen, depending on how broad a band (the 'bandwidth') you will consider to 'listen'. There is also the amount of TIME you listen, and which DIRECTION you listen.

# What DIRECTION should we be listening?

How about starting with nearby stars with planets?

All the stars listed here have exoplanets and are within 60 light years of Earth. This would be a **TARGETED** search

A **SURVEY** search would sweep the sky randomly.



# Challenges constraining SETI searches

SETI scientists design unique radio receivers to work with astronomical radio telescope from 1-20 GHz.

Problem 1: SETI gets little time to do *targeted* searches. Most time is looking where the telescopes happen to be looking (piggy backing other programs).

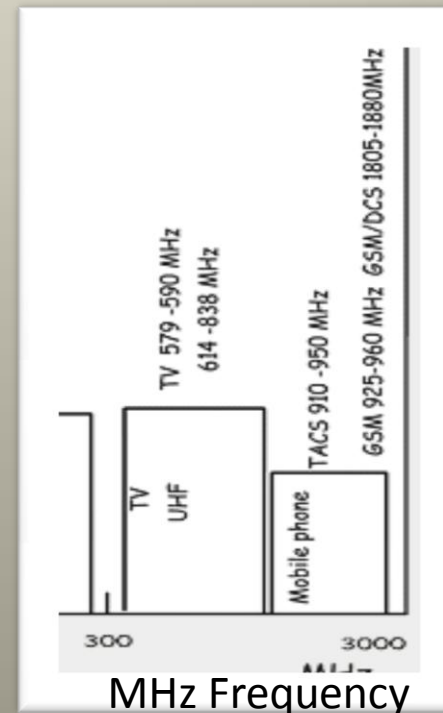


The Allen Telescope Array

The FIRST, high-powered, DEDICATED, SETI-search radio telescopes. Funded by Paul Allen (Microsoft co-founder). This allows for deeper, significant, TARGETED searches for E.T.I.

## Problem 2: NOISE

Man-made noise from radio transmitters is getting louder and covering a greater and greater amount of the frequency range.




Little can be done. SETI may need to move to the far side of the Moon.



# The Search for Extraterrestrial Intelligence at HOME


Press F1 for info

Version 1.06


<http://setiathome.ssl.berkeley.edu>**Data Analysis**Doing curve-fitting 44% 

Doppler drift rate: 0.0000 Hz/sec

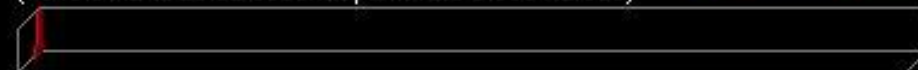
Frequency resolution: 1.192092 Hz

Strongest Peak: power 860.94 

(7545.1 Hz at 26.84 seconds, drift rate 0.000 Hz/sec)

Strongest Gaussian: power 2.69, fit 11.803 

(7545.9 Hz at 28.52 seconds, drift rate 0.000 Hz/sec)



Overall: 0.070% done

CPU time: 0 hr 01 min 59.0 sec

**Data Info**

From: 3 hr 50 min 27 sec RA, + 17 deg 28 min 11 sec Dec

Recorded on: Mon May 17 16:44:59 1999 GMT

Source: Arecibo Radio Observatory

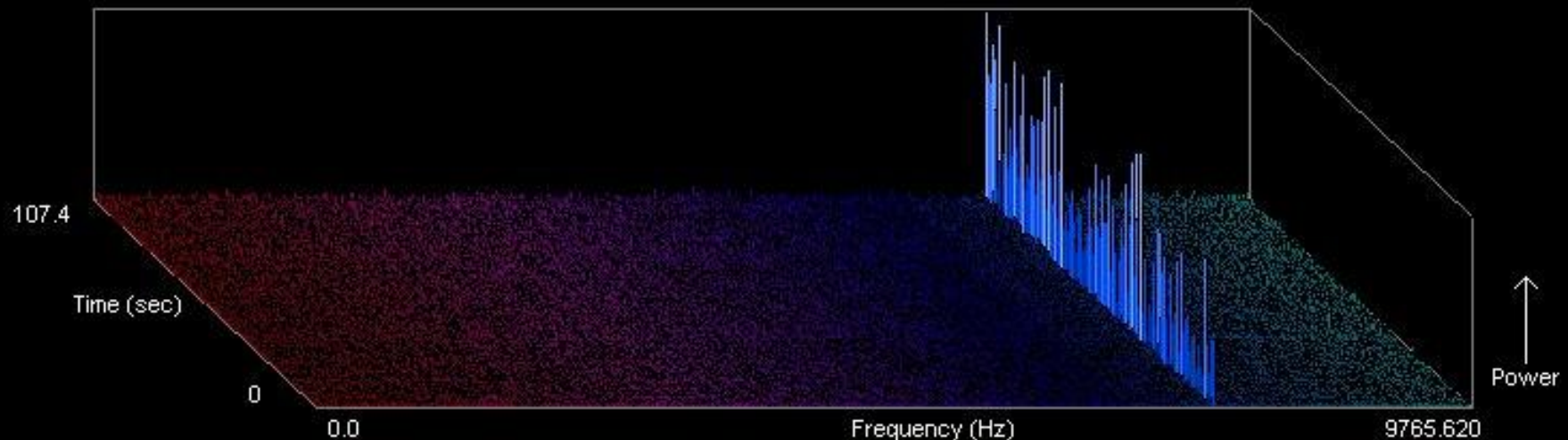
Base Frequency: 1.420791014 GHz

**User Info**

Name: Dr. H. Paul Shuch

Data units completed: 241

Total computer time: 10176 hr 26 min 27.1 sec



This is what a signal would look like above.  
However, this one is due to terrestrial transmitters

$\mathcal{F}_{\text{civ}}$  : fraction of life-bearing planets  
developing communicating civilizations =  
INTELLIGENCE.

1. All (1)
2. 1/10th
3. 1/100th
4. 1/million
5. None



# A philosophical argument about E.T.I.

We are NOT special



Intelligence is an 'observed phenomenon' which came about through natural causes.

Intelligence has occurred elsewhere in our Galaxy



Given the vast age and number of planets in the Galaxy, intelligent civilization, likely more sophisticated than us, exists and would have colonized the entire Galaxy by now.

We should be surrounded by evidence of this intelligence (civilizations)

We have no credible evidence that such a civilization exists in the Galaxy.



Is this because there IS NO E.T.I.?  
This is known as **Fermi's Paradox**

# What is a paradox?

---

*Def.* An argument that apparently derives self-contradictory conclusions by valid deduction (through reasoning) from acceptable **premises**.

## Critical premises leading to Fermi's Paradox

Intelligent civilizations exist through out the Galaxy and have colonized the Galaxy by now.



Those intelligent civilizations would communicate to us in such a way that we would know of their existence.

# PRS: Premise 1. How sure are we that intelligent civilizations would have 'colonized' the entire Galaxy?

1. Given the size and age of the Galaxy, absolutely yes.
2. The size and age of the Galaxy suggests its likely.
3. Even with the size and age of the Galaxy, it is unlikely.
4. I vote no. I don't believe any civilization has ever existed that can colonize the Galaxy.

PRS: Premise 2: Provided such a colonizing civilization *does* exist, how sure are we it would communicate itself to us?

1. Absolutely
2. Probably
3. Maybe
4. No, probably not.

# Possible solutions to Fermi's Paradox

---

## 1) **We are alone.**

Humans are unique (or at least the first).



## 2) **We aren't alone, but nobody has colonized the Galaxy**

Why? Colonization of the Galaxy isn't so easy either for:

a) Technological reasons (space is simply too big)

b) Sociological reasons (they don't want to, waste of resources)

or

c) Civilizations destroy themselves or die out before they get that far.

## 3) **They have colonized the Galaxy, but they are hiding it from us.**

# PRS: What do YOU think is the solution to Fermi's Paradox?

1. No E.T.I. exist.
2. Civilizations exist, but none have colonized the entire Galaxy yet.
3. The Galaxy HAS been colonized, but we've not been asked to join the `club' yet..

Put all your materials on the floor and  
place your PRS clicker in front of you.

---

Please: use just one clicker for yourself.

---

Take care that others can not  
view your selection

1. The Drake equation tells us how many civilizations in the Milky Way \_\_\_\_\_

1. are trying to communicate with us.

2. are capable of communicating with us.



## 2. We know Marconi & Tesla were not hearing E.T.I. because

1. Their receivers were not sensitive enough.
2. They were hearing lightning.
3. The atmosphere blocks the radio waves where they were listening.
4. The noise in their system was too high.

### 3. SETI scientists selected radio frequencies to listen because

1. The receivers are most sensitive there
2. They can build big radio telescopes
3. We know E.T.I. would be sending signals there.
4. It is the quietest part of the electromagnetic spectrum.

4. SETI scientists often piggyback on telescopes used by astronomers. What does this mean?

1. They obtain the same data as the astronomers.
2. They are looking in the same direction as the astronomers.
3. They use the same detectors as the astronomers.
4. All of the above.

5. The Fermi Paradox can be resolved by attacking/falsifying the \_\_\_\_\_

1. conclusions
2. contradiction
3. deduction
4. premises

# For Exam 3

- I will post later today the list of 6 essay questions.
- But be sure to study and be able to answer ALL learning objectives (there are only 16 this time!) for the multiple choice section.