Announcements

- Today: Chapter 18, Life in the Universe
- Wednesday: review for final exam
- Quizzes
  - **Quiz 13 on Chapter 17 due tonight**, last regular quiz
  - **Extra credit quiz** with math problems, now through May 12
  - **Extra credit quiz on Ch 18** now through May 12
- Extra credit research paper due Wednesday
- **Problem sets are due Monday May 12**
  - Best 12 count for final grade (10% of grade)
- **Final exam Monday May 12, 10 am**

Astronomy 103

Life in the Universe

Please read chapter 18

Is there life in the Galaxy?

- Liquid water may exist on Europa, used to exist on Mars…
- And Kepler now tells us that planets are common
- Amino acids are available in the interstellar medium
- So the ingredients for life seem common.

- What is the likelihood that life will develop?

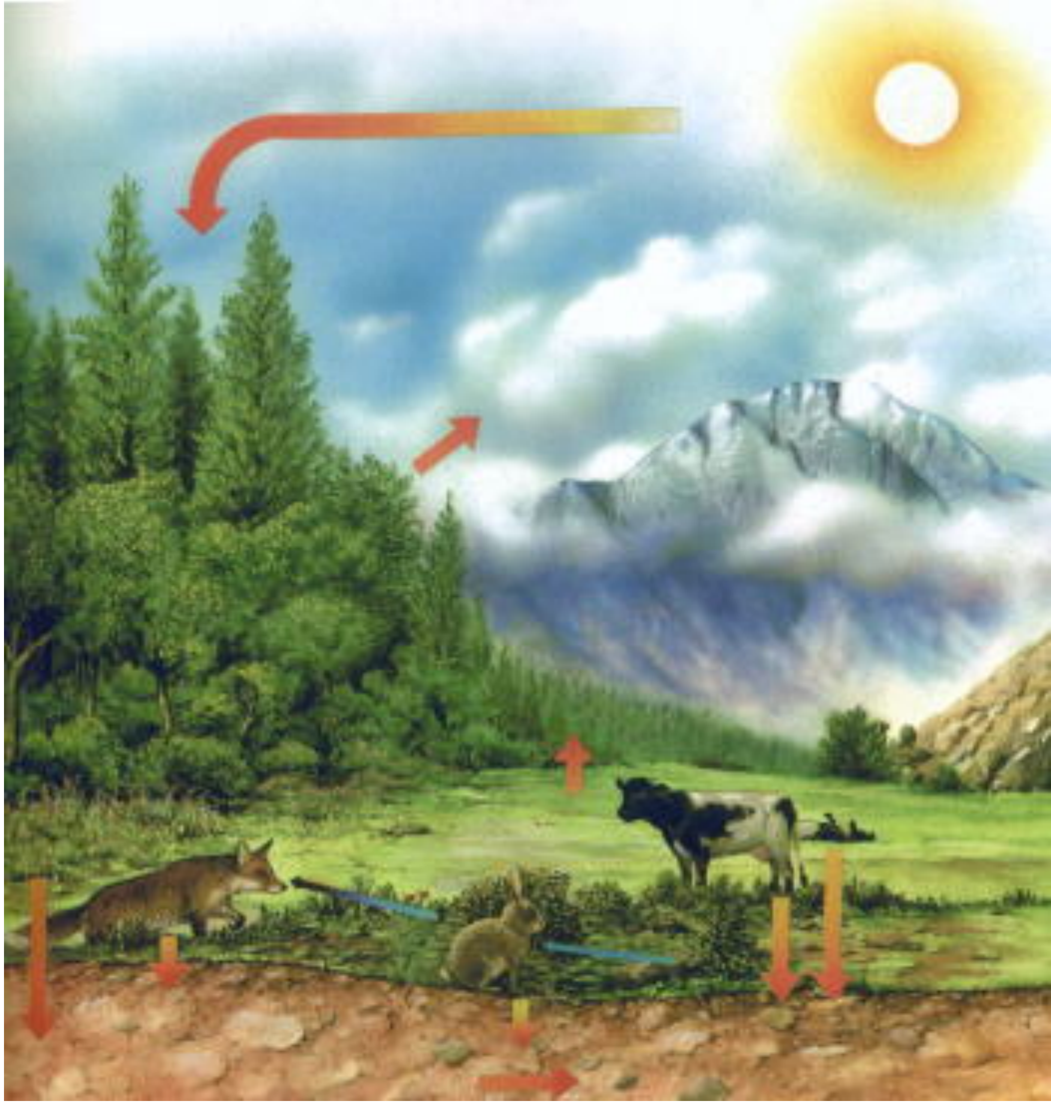
- And how do we detect it?

How do we detect life?

- To detect life, we have to understand how life interacts with its environment – the presence of life may affect a planet in ways we could detect

One Example: Carbon Cycle

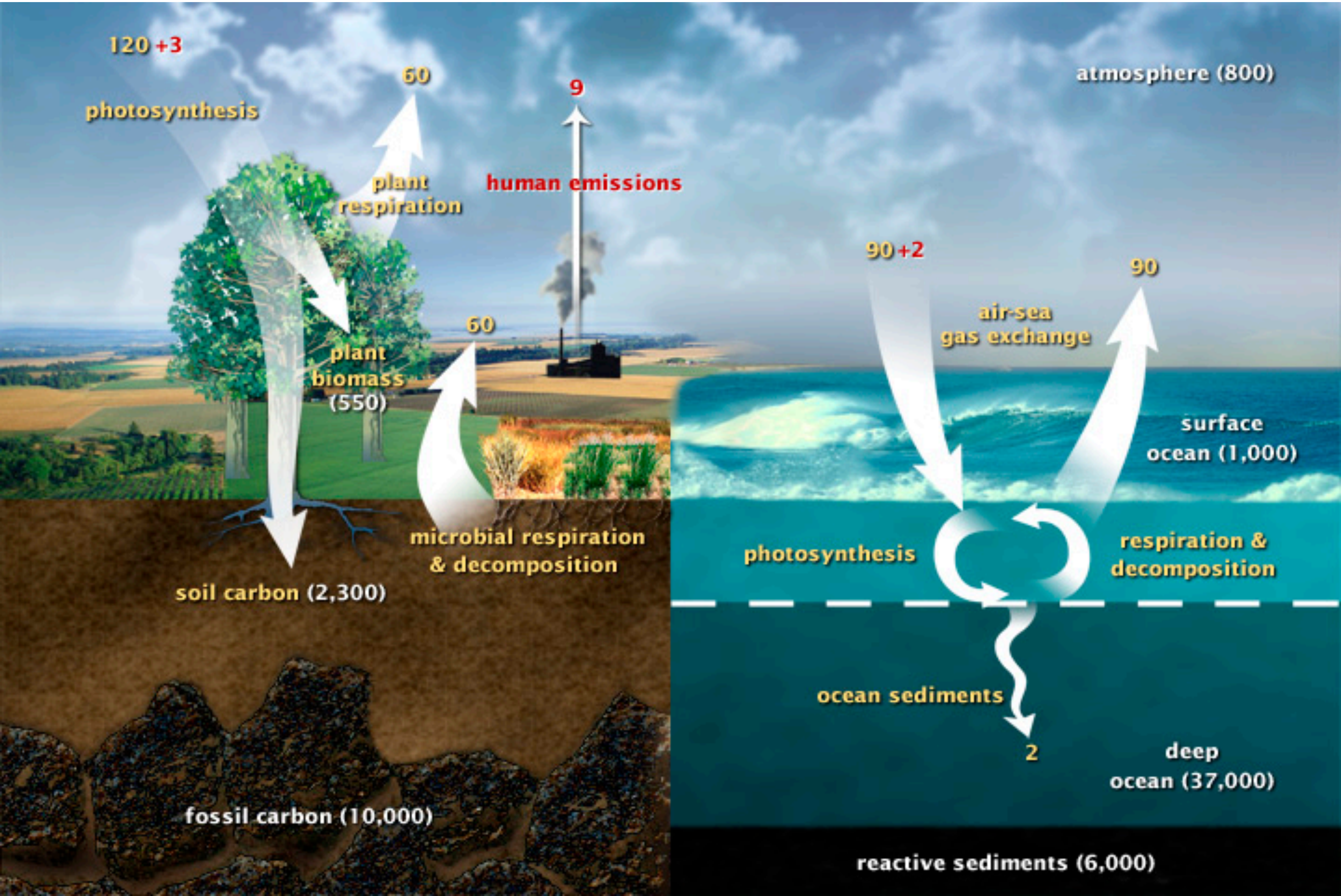
- One example of how life on Earth interacts with the environment is the carbon cycle: the movement of carbon as it's reused and recycled throughout Earth's biosphere
- Plants take sunlight and consume carbon dioxide (CO_2) while animals eat the plants and release CO_2
- The cycle maintains levels of CO_2



The Carbon Cycle

- The full carbon cycle is much more complicated
- Not just plants and animals
  - Volcanoes produce CO_2
  - Carbon is trapped in rocks and released through weathering
  - Weathering on rocks is aided by plants such as lichen
  - Carbon enters the oceans from the atmosphere and through rivers
  - Sea life uses carbon in shells
- And a later effect: carbon stored in coal, petroleum, natural gas released by human burning of fossil fuels, significantly increasing CO_2 in atmosphere
- **Life is a key part of the carbon cycle**

Carbon Cycle

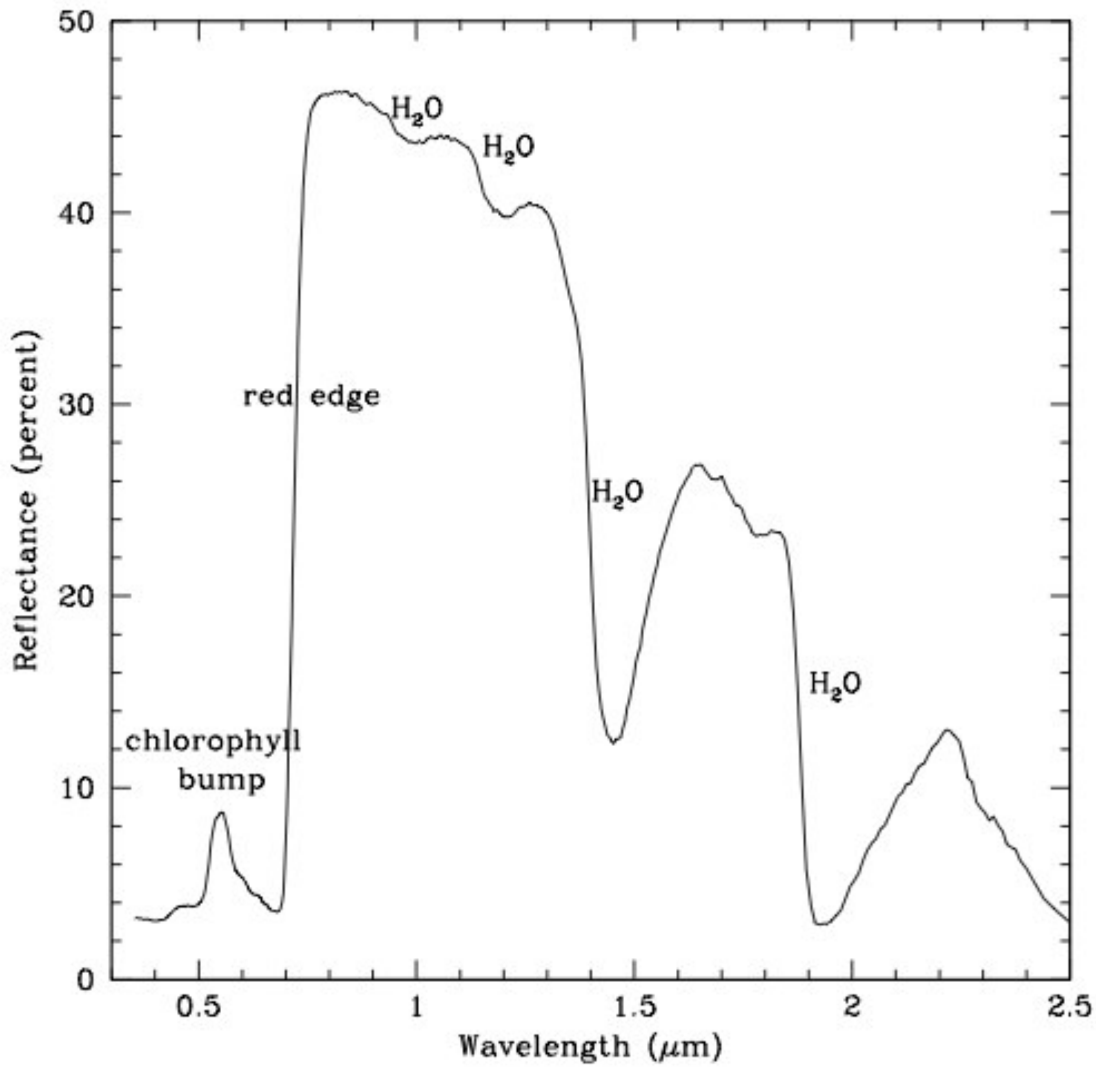


How can we use this to look for life?

- Life alters the environment: look for planets with lots of oxygen and planets that show lots of photosynthesis

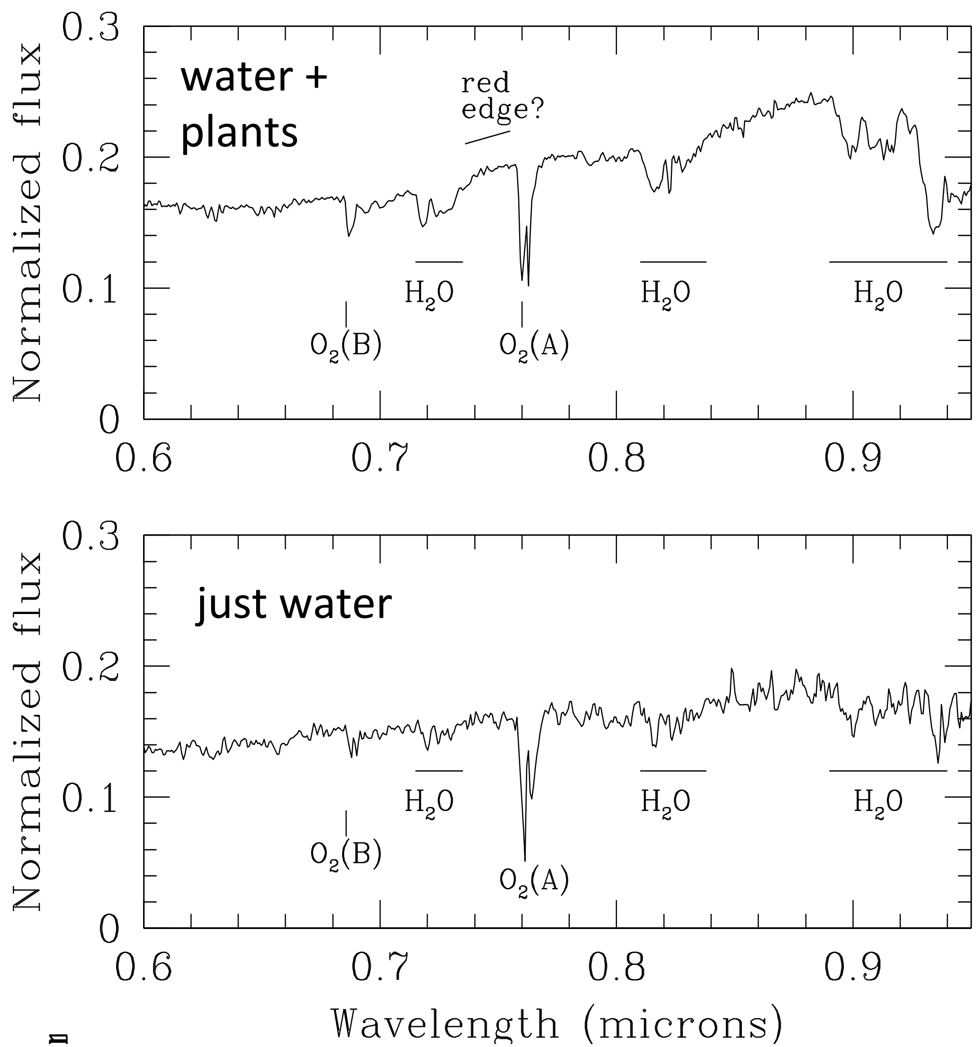
Photosynthesis and the red edge

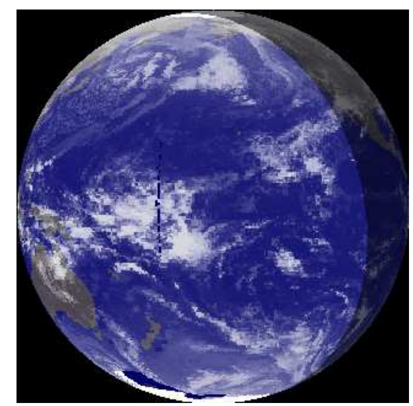
- Plants on Earth are optimized to absorb sunlight – they absorb most visible light
- So the reflected light from Earth in the visible wavelength range has a ``red edge'' inside of which plants absorb all the light



Looking for Life

We can test this by looking at the Earth – we can see light from Earth by looking at the reflected light from the Moon.





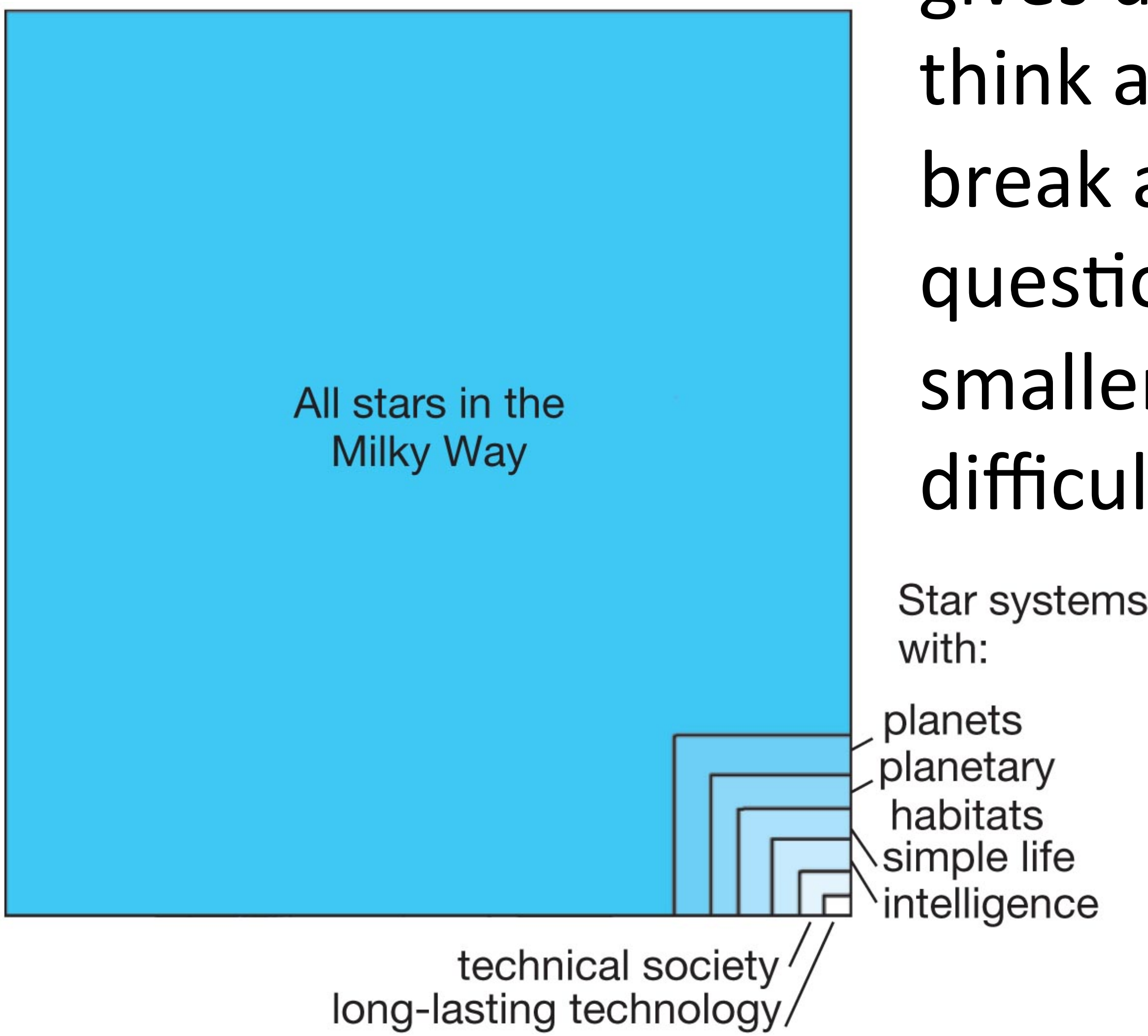
Measurements show the detection of a red edge for Earth's reflection, but not yet possible for other planets.

Intelligent Life in the Galaxy

- Life may develop elsewhere, but we really want to know…
  - Is that life is intelligent?
  - And able to communicate?

The Drake Equation

The **Drake equation** gives us a good way to think about this – lets us break a complicated question into lots of smaller (but still difficult!) questions



The Drake Equation

number of technological, intelligent civilizations now present in the Galaxy = rate of star formation, averaged over the lifetime of the Galaxy × fraction of stars having planetary systems × average number of habitable planets within those planetary systems × fraction of those habitable planets on which life arises

× fraction of those life-bearing planets on which intelligence evolves × fraction of those intelligent-life planets that develop technological society × average lifetime of a technologically competent civilization.

The Drake Equation

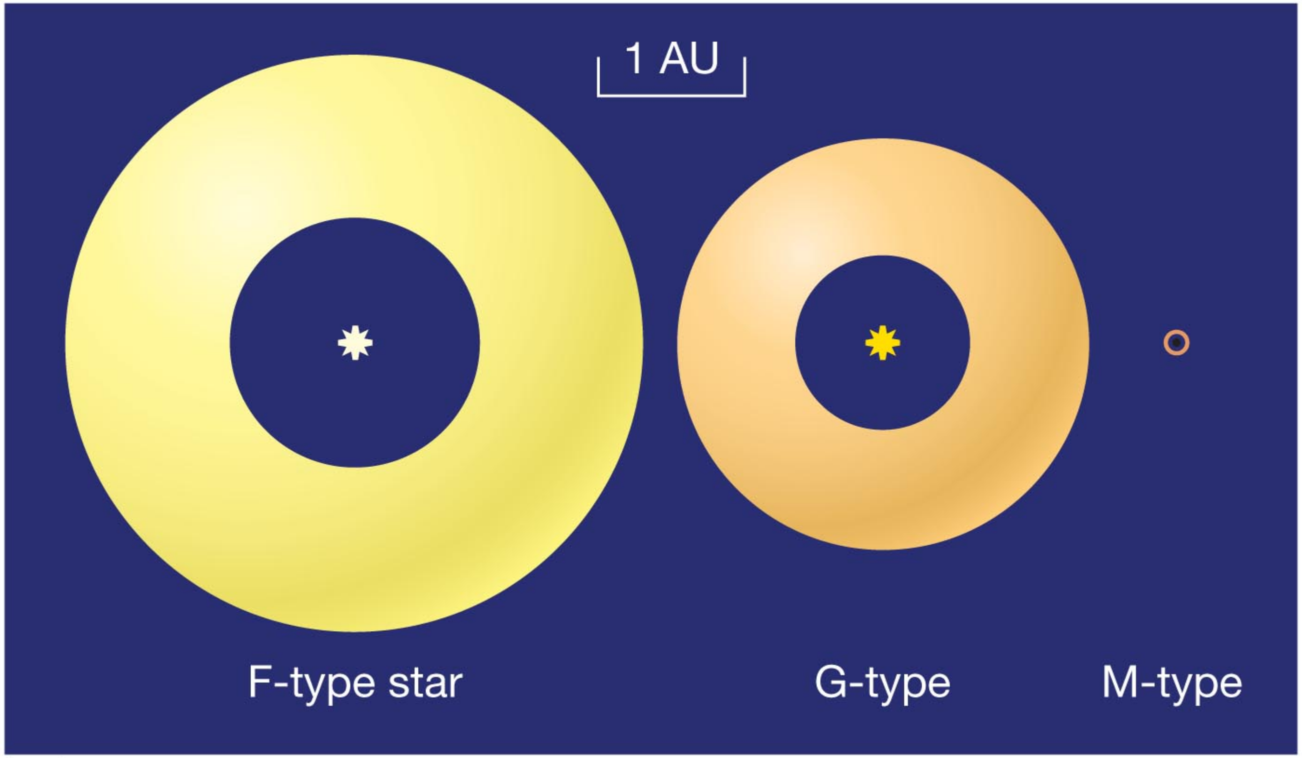
First: the rate of star formation: estimate 10 stars per year (dividing population of Milky Way by its present age)

Second: Fraction of stars having planetary systems.

Our model for the formation of the solar system suggests that planetary formation is a part of star formation, and Kepler is finding that planets around other stars are common. This fraction is probably high. We'll guess 1.

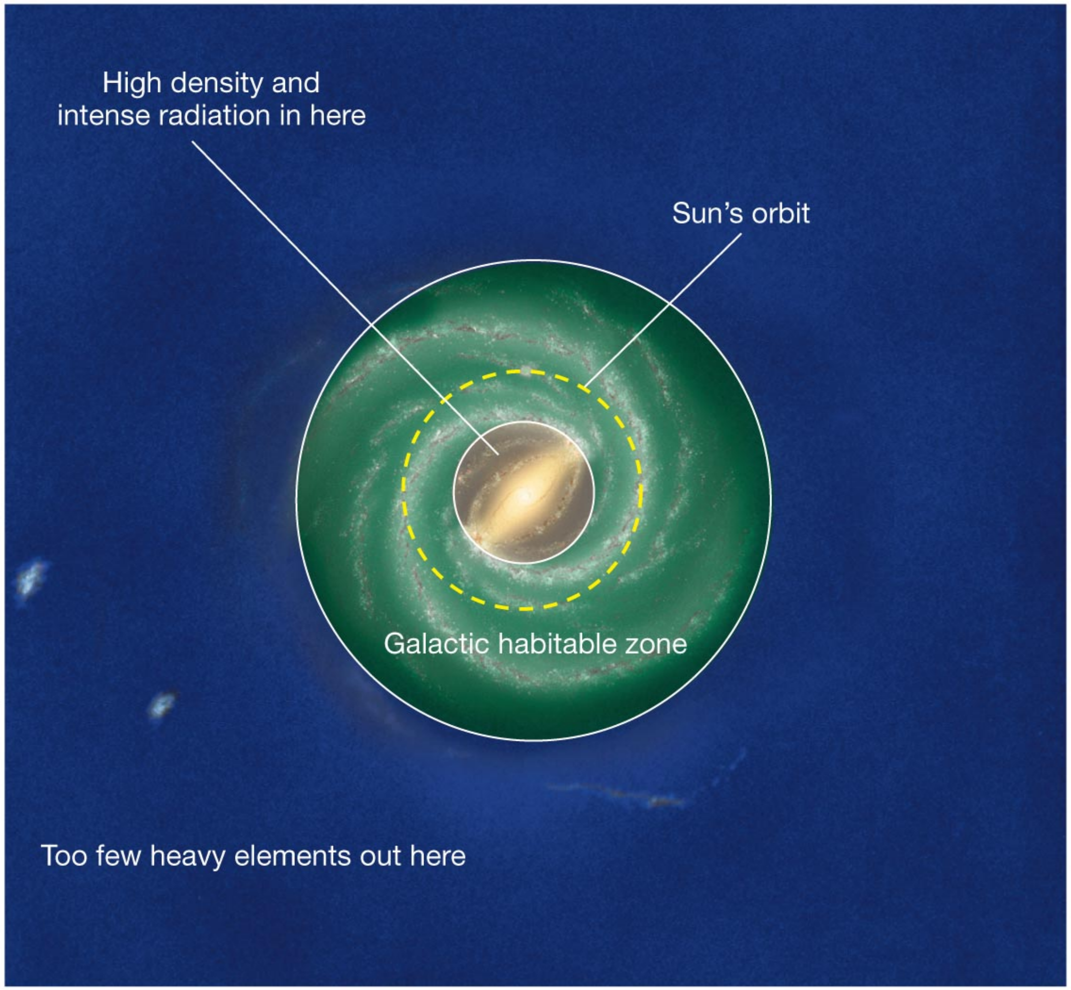
The Drake Equation

Number of habitable planets per planetary system: Probably only significant around A-, F-, G-, and K-type stars. Smaller stars have a too-small habitable zone, and larger stars a too-short lifetime.



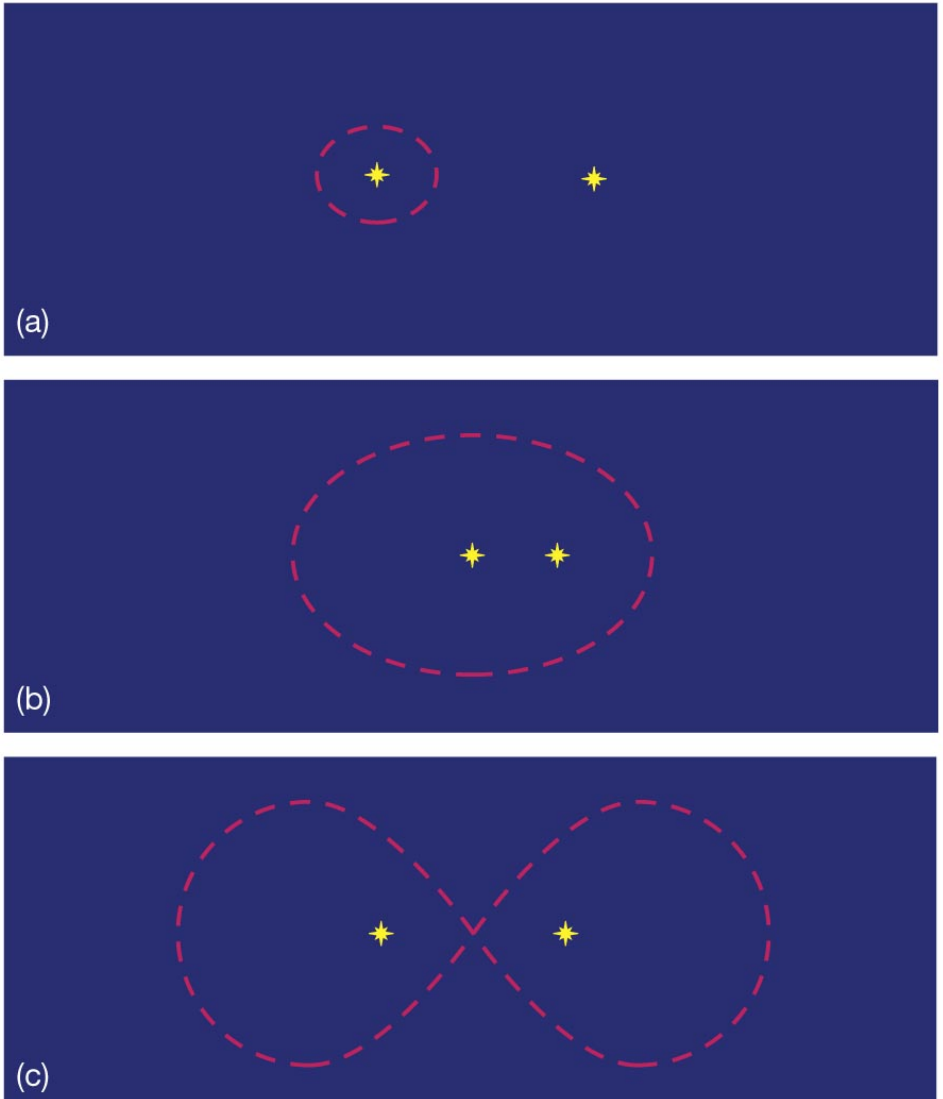
The Drake Equation

In addition, there are galactic habitable zones –



there must not be too much radiation, or too few heavy elements.

The Drake Equation



Finally, it is very unlikely that a planet in a binary system would have a stable orbit unless it is extremely close to one star, or very far away from both.

Give this factor a value of 1/10: one habitable planet in every 10 planetary systems.

The Drake Equation

Fraction of habitable planets on which life actually arises:

This is harder. Life arose very quickly on Earth, and experiments suggest that this may be quite likely. On the other hand, maybe we're just lucky, and it might be extremely improbable.

We'll be optimistic, and give this factor a value of 1.

The Drake Equation

Fraction of life-bearing planets where intelligence arises:

Here we have essentially no facts, just speculation and opinion.

We'll continue being optimistic, and assign this factor a value of 1.

The Drake Equation

Fraction of planets where intelligent life develops and uses technology:

Again, we have no facts, but it does seem reasonable to assume that intelligent life will develop technology sooner or later.

We'll give this factor a value of 1 also.

The Drake Equation

A reminder of the first six factors:

number of technological, intelligent civilizations now present in the Galaxy = rate of star formation, averaged over the lifetime of the Galaxy × fraction of stars having planetary systems × average number of habitable planets within those planetary systems × fraction of those habitable planets on which life arises × fraction of those life-bearing planets on which intelligence evolves × fraction of those intelligent-life planets that develop technological society × average lifetime of a technologically competent civilization.

The values we've assigned to them give

10 x 1 x 1/10 x 1 x 1 x 1 = 1

The Drake Equation

So, according to our estimate:

number of technological, intelligent civilizations now present in the Milky Way Galaxy	=	average lifetime of a technologically competent civilization, in years

The Drake Equation

How long is that?

For the average lifetime of a technological civilization, we can't even use ourselves as an example – our civilization has been technological for about 100 years, but who knows how long it will last?

Also, we assigned a value of one to several very uncertain factors; even if only one of them is low, the number of expected civilizations drops quickly.

The Drake Equation

If we optimistically suppose that the average lifetime of a technological civilization is 1 million years, there should be a million such civilizations in our Galaxy, spaced about 30 pc, or 100 ly, apart on average.

This means that any two-way communication will take about 200 years (if there is in fact a technological civilization 100 light-years or less away from us).

The Fermi Paradox, or "Where is everybody?"

- **If there are indeed many long-lived civilizations, there would have been many more in the past – even a million years is very very short compared to the lifetime of the galaxy**
- **Even if it takes millions of years for these civilizations to spread across the galaxy, they should be here already**
- **Where are they?**

- **This is called the Fermi Paradox**

Solutions to the Fermi Paradox

- **They are already here**
- **Maybe they just haven't made it to Earth yet**
- **Few civilizations have ever existed**
- **We are the first and alone**
  - **Rare Earth hypothesis: conditions for advanced life to arise are very rare**
- **Intelligent life destroys itself (at least as far as reverting to a non-technological state)**
- **Intelligent life destroys others**
  - **Do civilizations regard other civilizations as a threat?**
- **Life is destroyed by natural events**

Solutions to the Fermi Paradox

- They are too far away
  - It is too hard or expensive to travel between the stars
  - It takes too long to communicate
  - Civilizations may not exist at the same time
- They are avoiding us or don't care
- They are too advanced technologically
- Their communications are too alien for us to recognize
- We are in a zoo (i.e. the Prime Directive)

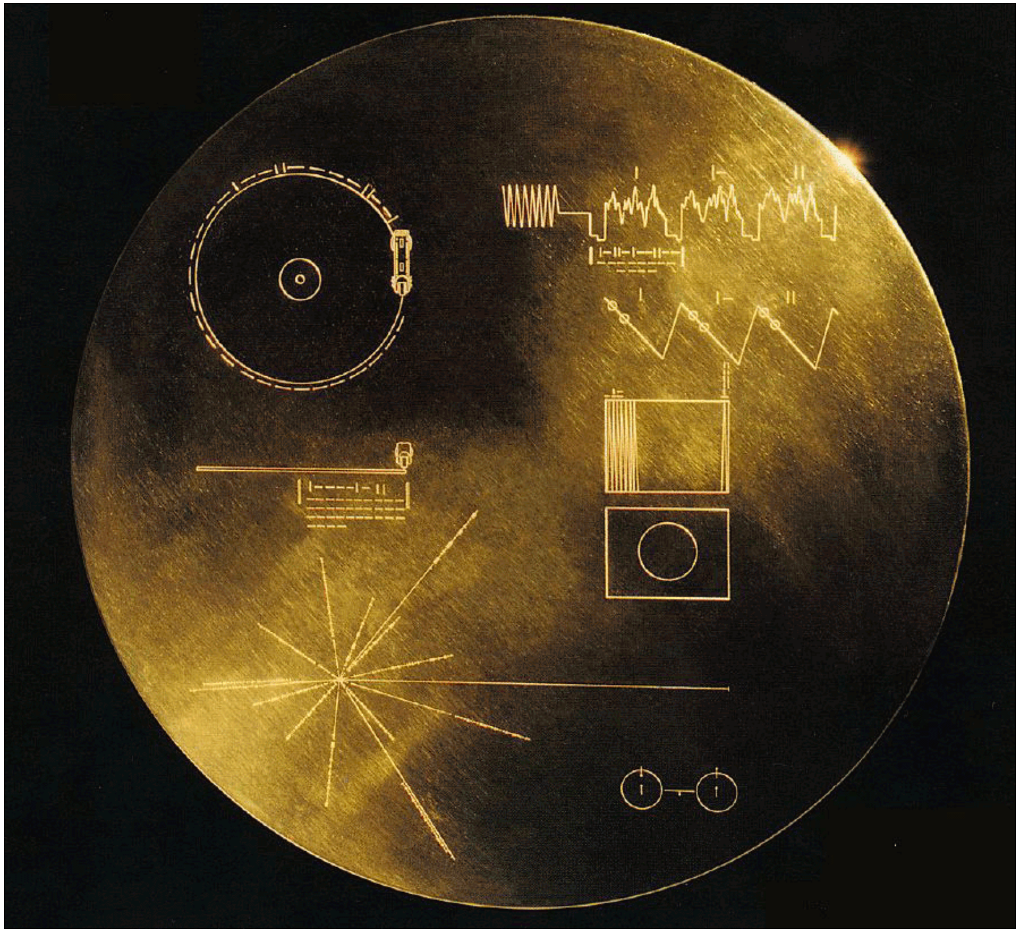
Detecting Extraterrestrial Intelligence

- **How can we find intelligent life in the universe?**

  - **Send space probes**
    - **Slow – fastest space probes will take 76,000 year to the *nearest* star**
    - **Expensive – lots of stars in the galaxy**

  - **Look for signals**
    - **Cheap – the power costs are minimal**
    - **Fast – nothing travels faster than light**
    - **But where to look?**

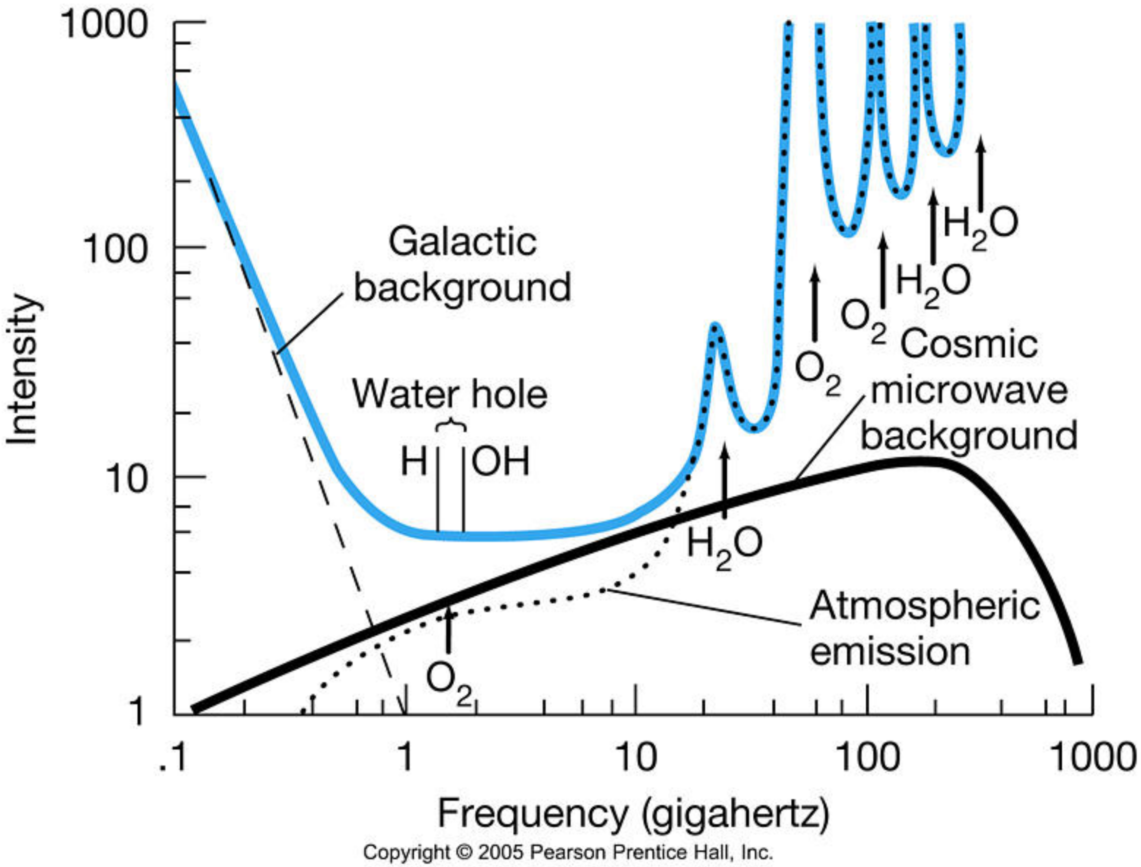
Space Probes



- Voyager I will come close to another star in about 40,000 years
- It carries a message from Earth called the golden record
- But this isn't really a serious attempt to communicate

Looking for Signals

- Radio is the easiest technology to use
  - But what frequency?
- There is a range of frequencies between 1420 and 1660 MHz which is especially quiet – "water hole"
- H emits in this frequency so it might be a good choice



Detecting Extraterrestrial Intelligence

SETI: Search for Extraterrestrial Intelligence
One search is conducted with the Arecibo Observatory

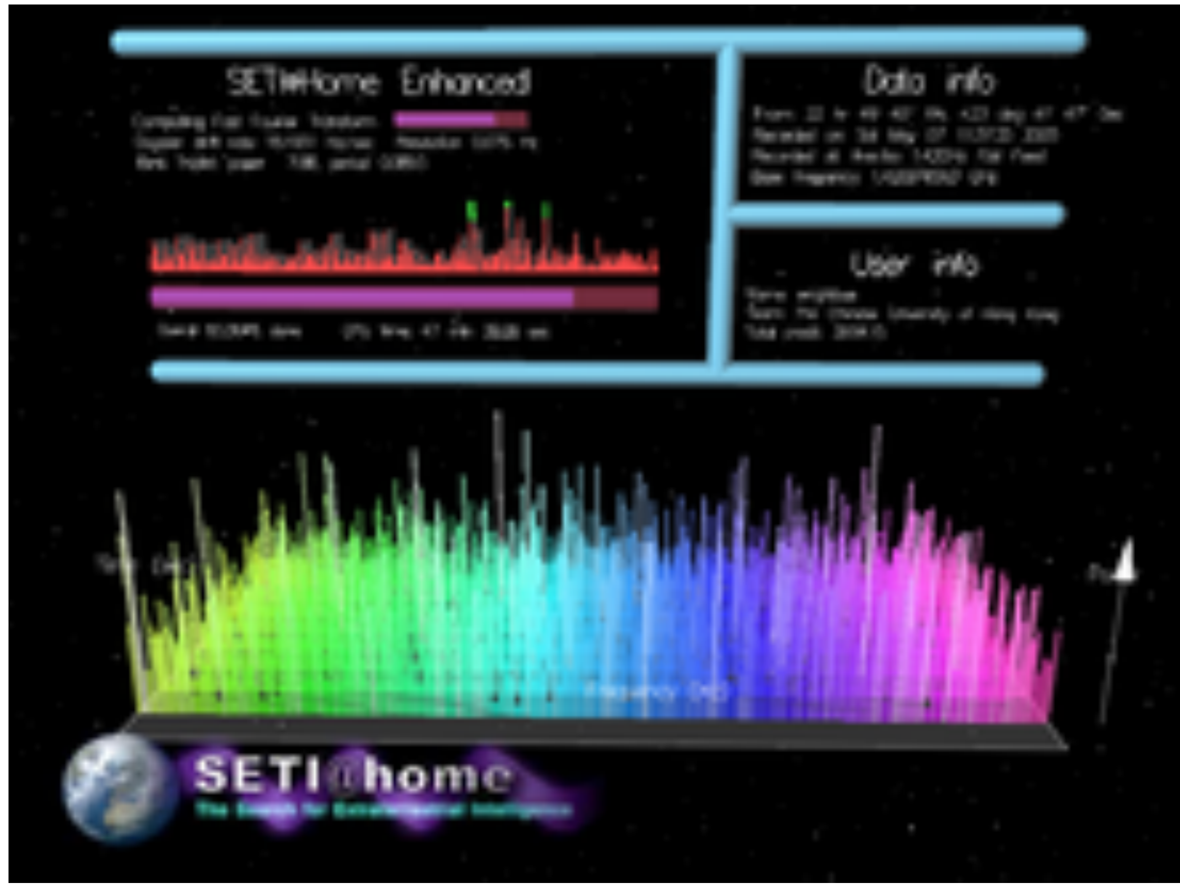
Generates about 35 Gigabytes of data per day

Detecting Extraterrestrial Intelligence

To analyze this data requires a lot of computers.

- Solution: Outsource it to volunteers

SETI@home uses computer idle time to process radio data



No conclusive signals yet

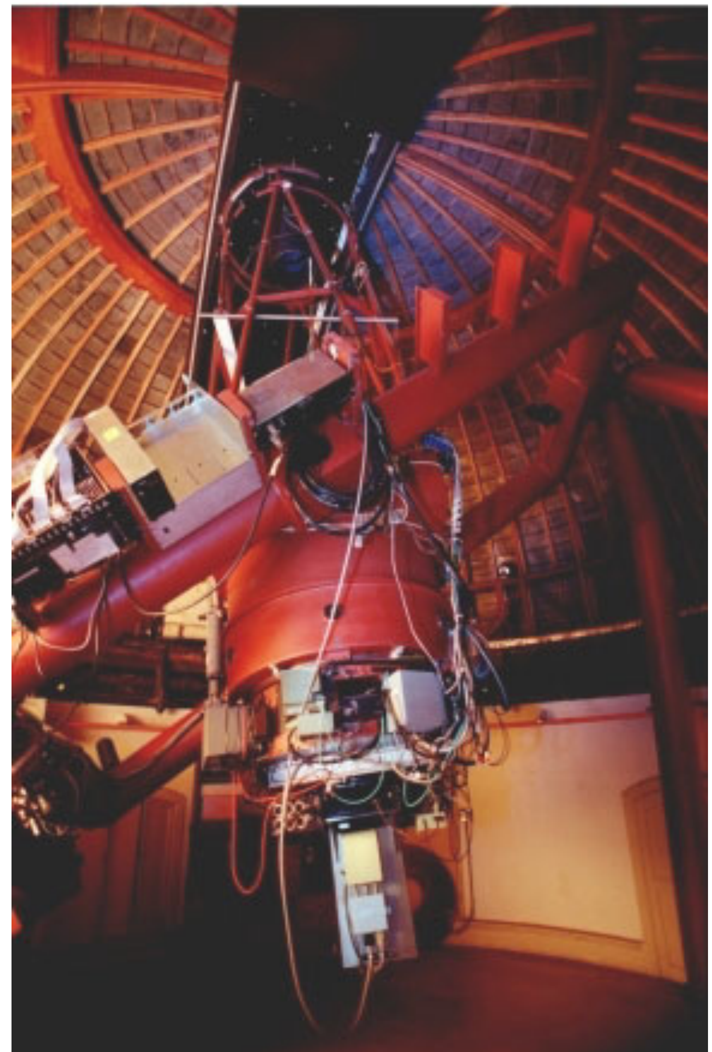
Looking for Signals

- But the phase of using radio to communicate may be short – even now on Earth we're moving toward fiber optics, away from undirected radio broadcasts

- Maybe alien civilizations don't use radio anymore
- Lasers? Look for optical signals?

Optical SETI

- A few searches underway – piggybacking on other observations



Communicating with ET?

- Use universal languages – like mathematics
- One example – in 1974, Arecibo sent a message to the globular cluster M13 consisting of 1679 bits

- Why 1679? Because 73x23=1679, and 73 and 23 are prime numbers

- Arranging the bits as 73x23, you get a picture

Life in the Universe: Summary

- Living organisms should be able to react to their environment, grow by taking in nutrients, reproduce, and evolve
- Amino acids could have formed in the conditions present on the early Earth, or in space
- The necessary ingredients for life may be common

Life in the Universe: Summary

- Other places in our solar system that may harbor life are Mars, Europa, and Titan

- Planets in the habitable zones around other stars may have liquid water – the Kepler satellite is now finding these

- The Drake equation can be used to estimate the total number of intelligent civilizations in our Galaxy, although a number of its factors are extremely uncertain

- Even using optimistic assumptions, the next nearest technological civilization is likely to be hundreds of pc away

Life in the Universe: Summary

- We have sent probes that will get to interstellar space eventually; they include information about us
- We also "leak" radio signals, which to an outside observer would exhibit a 24-hour periodic variation
- The "water hole" – a frequency around the hydrogen and OH frequencies – is a good place both to broadcast and to seek messages
- We are listening (SETI, the Search for Extraterrestrial Intelligence), but no confirmed signals yet