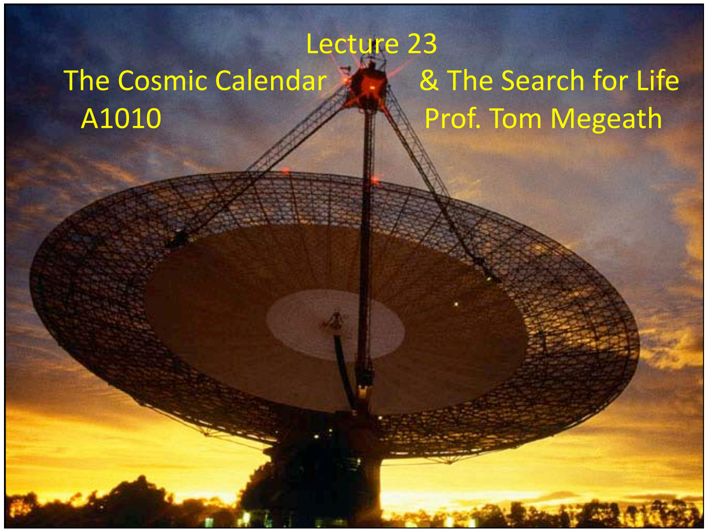
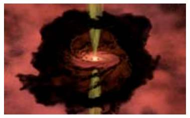
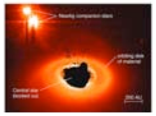


Review: The Scientific Search for Origins
How did our world come to be?

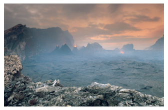
The formation of stars



The formation of planets



The origin and evolution of life



Journey Back in Time

Astronomy, Physics, Geology and Biology have extended the history of our planet and universe back to the beginning time.

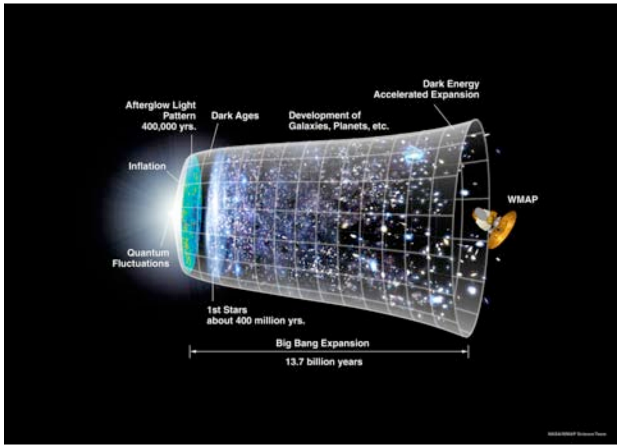
The cosmic calendar:

Midnight January 1st - the beginning of the universe.

12:59:59 PM December 31st - today

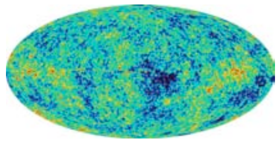
Compresses all of cosmic evolution into a single year

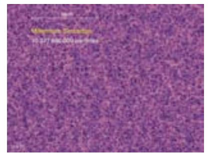
January-December



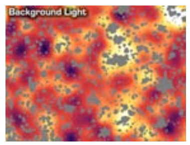
January

January 1st: The Big Bang 13.7 billion years ago – leaving the cosmic microwave background.



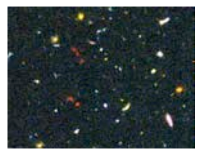


Early January: Dark ages - no stars just gas (first 400,000 years). Cosmic web forms and concentrates matter.

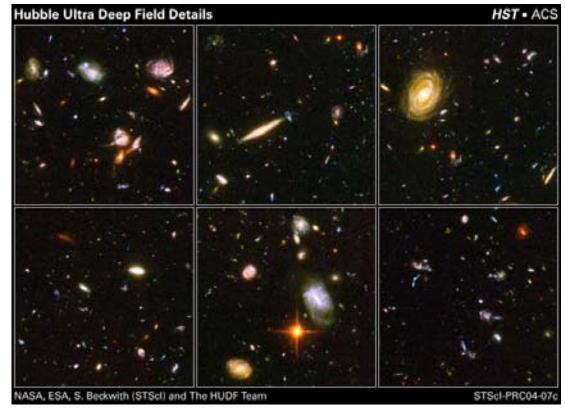


Mid January: The first stars (400 million years)

By end of January: The first galaxies formed (< 1 billion years)



February – December (1 Billion years to present) Galaxies continue to form, stars continue to form and die in galaxies



January to December

The Creation of the Elements

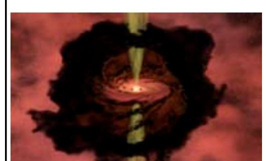
Elements heavier than hydrogen and helium created in the centers of stars (Carbon, Oxygen, Nitrogen, Iron, Aluminum)

When stars die, they release some of these elements into the universe.

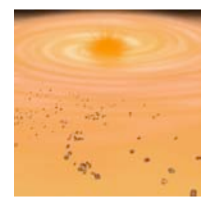
New stars form from the gas with the new elements.

Artist conception of supernovae explosion.

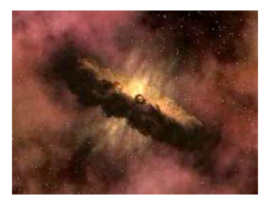
September 3rd (9 billion years): Our Solar System Forms



Protostar 300,000 years

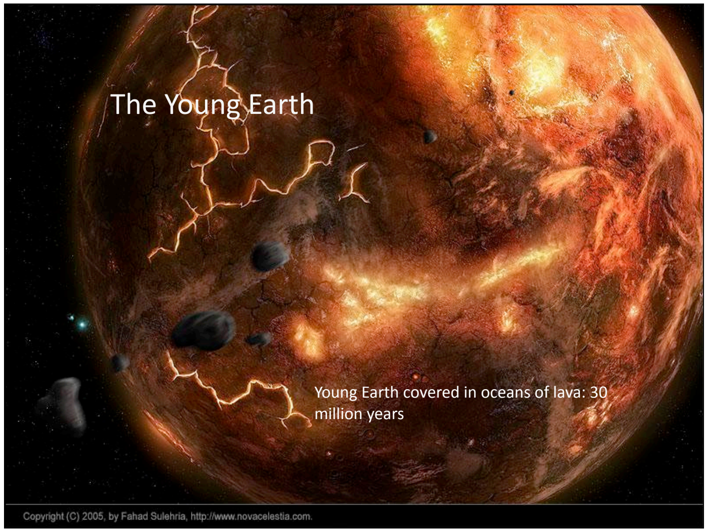


Dust collects into planetesimals and eventually planets: 3 million years



Sun surrounded by disk of gas and dust: 1 million years

Planetesimals collide to form planets: 1-30 million years



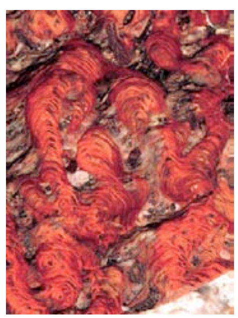
The Creation of the Terrestrial Planet Atmosphere Through Outgassing

After 500 Myr, the crust cools enough to solidify, and an atmosphere and oceans can begin to form. Atmosphere probably came from outgassing.

September 22nd: 11billion years

First Single Cell Life - Bacteria

Layered rocks thought be mats of fossilized bacteria are found on the Canadian shores of Lake Superior

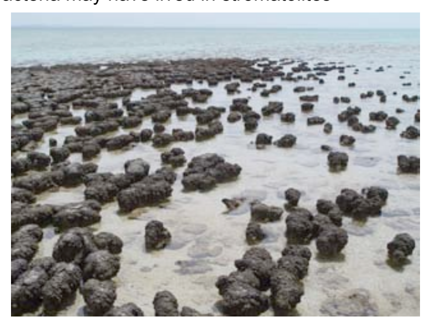


October - November (11.5-12.5 billion years)

Life Alters Earth's Atmosphere and produces Oxygen

Bacteria convert CO_2 in O_2 through photosynthesis

Bacteria may have lived in stromatolites



Shark's bay Australia

December: last billion years

December 8 - single cell animals (Eukaryotes)
December 13 - Jellyfish
December 20 - Fish first appear
December 22 - Animals first take to land
December 26 to December 29 - Dinosaurs
December 31, 9 PM - early hominids
December 31,11:58 PM - modern Humans
December 31, 11:59:35 PM - Agriculture begins
December 31, 11:59:49 PM - Pyramids
December 31, 11:59:59 PM - Galileo, Copernicus and Kepler show how the planets go around the sun

Why do we think there *could* be life elsewhere in the universe?

The Copernican Principle: we do not occupy a special position in the Universe.

Since there is abundant life on Earth, there should be life elsewhere in the Universe.

But to this day, scientist have found no evidence for life around other planets. Due to the vastness of space, detecting life around other planets is difficult.

Is there Life on Other Planets in our Solar System

In 1950s, there was optimism that life may exist elsewhere in our solar system - perhaps Venus or Mars.

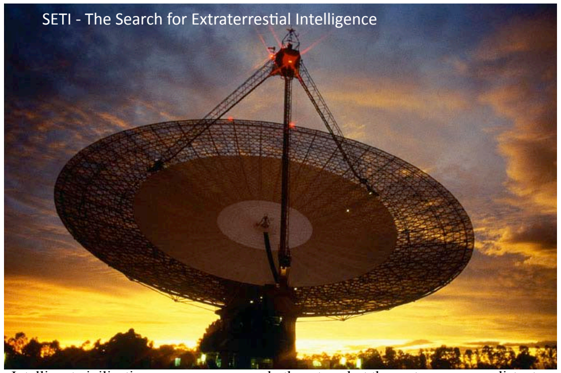
Starting in the 1960, NASA began to explore the solar system with unmanned space probes.

Venus far to hot (800 Kelvin)

Mars cold and dry (but may have microbial life hidden somewhere).

Moons of Jupiter and Saturn may have oceans below their surfaces - could potentially harbor life.

Some possibility of life - but not of intelligent life.



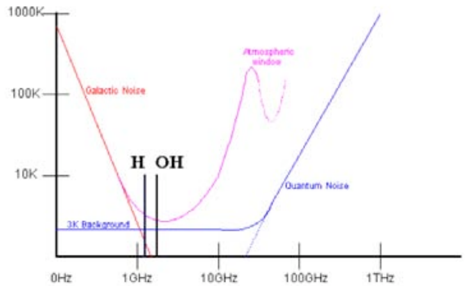
Intelligent civilizations may occur around other stars, but those stars are very distant.

Proposed by Cocconi and Morrison in 1959 that radio waves can be used to communicate across the Galaxy.

SETI experiments look for either deliberate signals sent by other civilizations or leakage from radar, radio, television.

The difficulty is where to look and at what frequency.

The Galactic Water Hole



Frequencies between 1 and 8 GHz show lowest noise from atmosphere and galactic sources.

Since any civilization with radio telescopes should know at the the atomic Hydrogen line at 21 cm, another civilization might choose a frequency close to the 21 cm line.

Other approaches have been suggested.

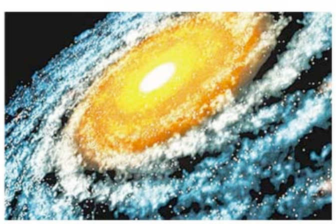
Deliberate Signals

In 1974, a message was sent to the Globular Cluster M13
Coded 1679 bits (1 and 0) - designed to be a 23 x 73 picture.
M13 is 25,000 light years away
Globular clusters poor places for life to exist.

Leakage

Aliens Mourn As Final Cheers Episode Reaches Alpha Centauri | The Onion -

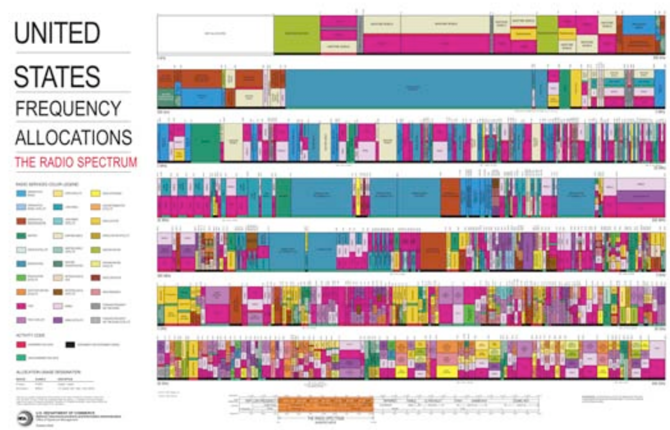
Aliens Mourn As Final *Cheers* Episode Reaches
Alpha Centauri



Leakage is hard to detect since the signal is spread out over a larger range of frequencies.

Leakage from Earth:

- Radar
- Television (60-600 Mhz)
- Radio (FM is 78-105 Mhz)
- Leakage is perhaps only 60-70 years old.



The atomic Hydrogen HI line is at 1423 MHz

SETI Searches to Date

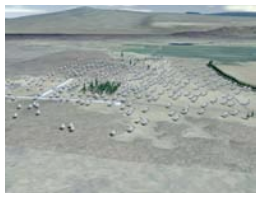
SERENDIP (II - IV) - receiver piggy backs on radio telescope.

META and BETA - Million/Billlion Channel ExtraTerrestrial Assay (1995-1999) scanned 1400 to 1720 MHz

Project Phoenix - scanned 800 stars at frequencies from 1200 MHz to 3000 MHz, could pick up leakages from nearest star (150 light years)

Under consruction:

Allen Telescope Array



Optical SETI

In 1961, Schwartz and Townes suggested that optical pulses from lasers are a viable means of interstellar communication.

Advantages are that a precise frequency is not necessary.

Disadvantage is that the light would have to compete with light from the central star.

However, a high powered lasers coupled to a large telescope could create a pulses which could briefly be 10,000 times brighter than the Sun.

A number of optical SETI searches are underway.

1.5 Meter Oak Ridge Observatory

To date nothing has been found

What does this mean?

How many civilizations would we expect?

The Drake Equation

Number of civilizations of which we might contact us:

$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$

R = rate of star formation in the Milky Way
f_p = fraction of stars with planets
n_e = number of habitable planets per star
f_l = fraction of planets that develop life
f_i = fraction of planets with life that develop intelligent life and civilizations
f_c = fraction of civilizations that can communicate with us
L = lifetime of civilizations

The Drake Equation

Number of civilizations of which we might contact us:

$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$

Example:
R = 10 stars form per year in our Galaxy
$f_p = 0.5$
$n_e = 1$
$f_l = 0.01$
$f_i = 0.001$
$f_c = 0.0001$
L = 10,000 years

$N = 10 \times 0.5 \times 0.01 \times 0.001 \times 0.0001 \times 10^4$ years $= 5\times10^{-5}$

The Drake Equation

Number of civilizations of which we might contact us:

$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$

Example:
R = 10 stars form per year in our Galaxy
$f_p = 0.5$
$n_e = 2$
$f_l = 0.1$
$f_i = 0.1$
$f_c = 0.1$
L = 1,000,000 years

$N = 10 \times 0.5 \times 0.01 \times 0.001 \times 0.0001 \times 10^4$ years $= 5000$

Megeath Equation

Number of left handed, near sighted, red haired optometrist in Ohio:

$N = R \times f_p \times f_n \times f_l \times f_o \times L$

R = rate of people born in Ohio
f_p = fraction of people with red hair
f_n = fraction which are nearsighted
f_l = fraction which are left handed
f_o = fraction which become optometrist
L = average lifespan

The Drake equation is just a standard approach of breaking the problem into smaller pieces.

The Drake Equation

Number of civilizations of which we might contact us:

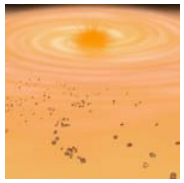
$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$

R = rate of star formation in the Milky Way — We know this fairly well
f_p = fraction of stars with planets — We are on our way to measuring this
n_e = number of habitable planets per star — This is the next big step
f_l = fraction of planets that develop life
f_i = fraction of planets with life that develop intelligent life and civilizations
f_c = fraction of civilizations that can communicate with us
L = lifetime of civilizations

What Fraction of Stars Have Planets: First approach: how many have disks capable of forming planets

Start: disk of gas and dust

3,000,000 years

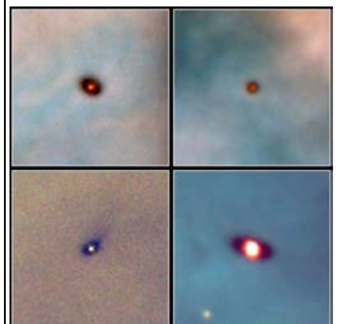


Dust grains start sticking together to form larger and larger objects.

Planets form in disk, the larger planets accreting gas and forming gas giants.

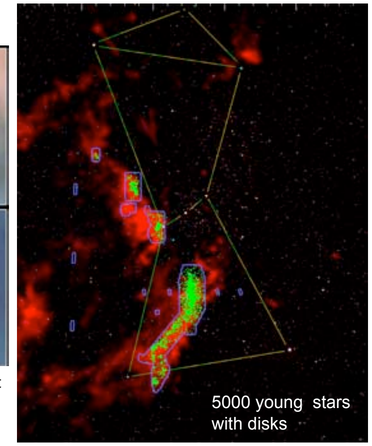
Around 75% of all young stars have disks

Shillouette Disks in Orion (Hubble)



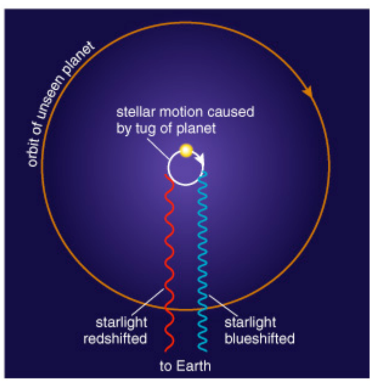
Dust in disk absorbs and scatters visible light from nebula, creating shillouette.

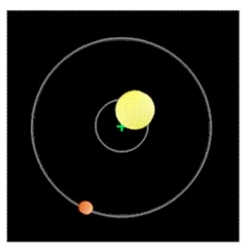
McCaughrean & O'Dell



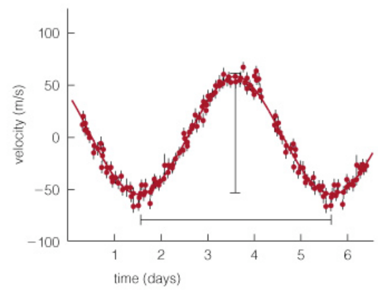
Second Approach: Detecting Planets Detecting Planets by Watching Stars Wobble

- Measuring a star's Doppler shift can tell us its motion toward and away from us
- Current techniques can measure motions as small as 1 m/s (walking speed!)



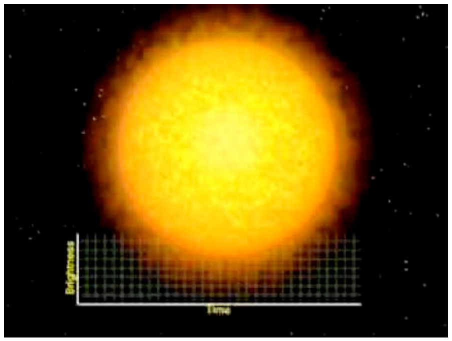


First Extrasolar Planet

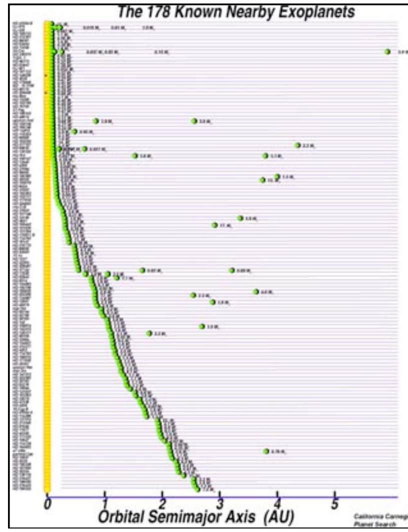


- Doppler shifts of star 51 Pegasi indirectly reveal a planet with 4-day orbital period
- Short period means small orbital distance: 0.05 AU (same as Mercury)
- But mass = 0.5 $M_{Jupiter}$
- First extrasolar planet to be discovered (1995) Mayor & Queloz

Second Approach:
Detecting Planets with Planetary Transits



Known Exoplanets to Date

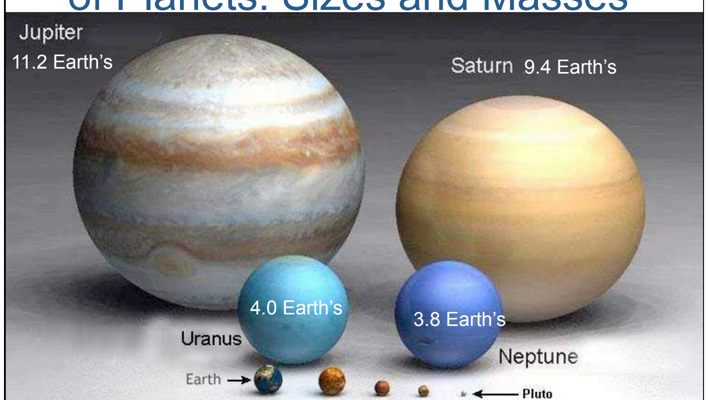


This figure is out of date, now there are 346!!

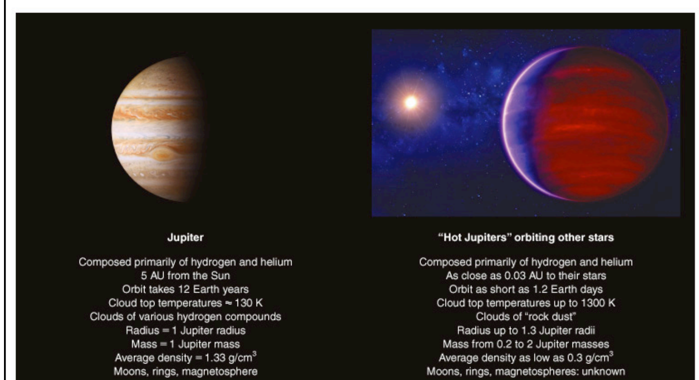
Most found by measuring the motions of stars being tugged by planets.

You can find lists of exoplanets at:
http://exoplanets.org
http://exoplanets.eu

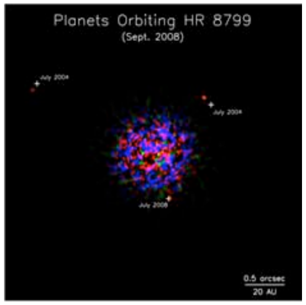
What are the Characteristics of Planets: Sizes and Masses

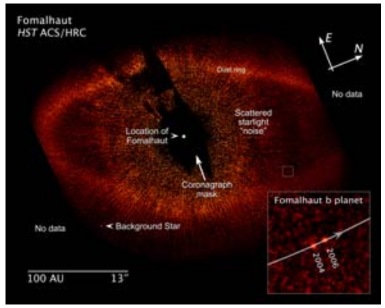


But many (all?) of these are not habitable: Many are too big and hot

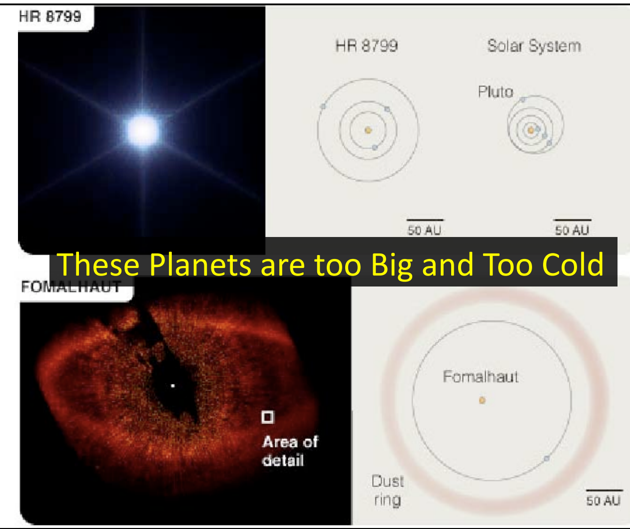


Second Approach:
Direct Imaging of Planets





Astronomers have measured their orbital motions!



These Planets are too Big and Too Cold

Current status:

About 75% of young stars have the raw material needed to make planets.

12% of stars have giant planets

So there are a large number of stars with planets!!

What is the number of habitable planets per planetary system?

Where can life survive?

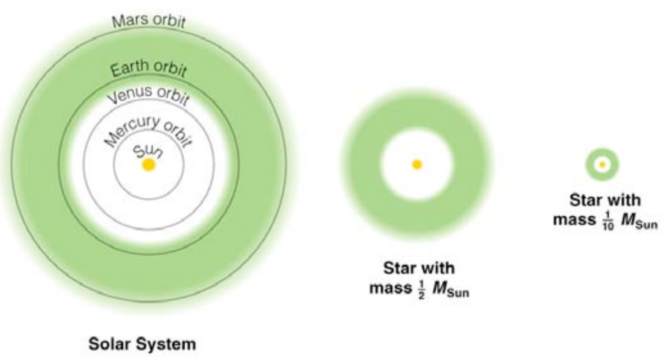
Earth is only planet in our solar system with abundant life

Three requirements for life on Earth

1. A source of nutrients
2. Energy from sunlight, chemical reactions, or from the Earth itself
3. Liquid Water - water important solvent and plays an essential role in the chemistry of life.

The presence of liquid water is perhaps the most stringent of the requirements.

Are habitable planets likely?



The Habitability Zone (HZ)

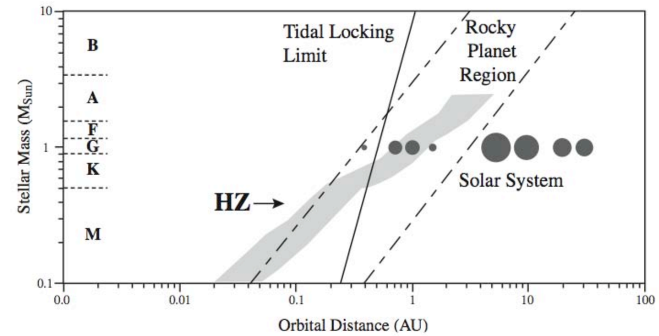
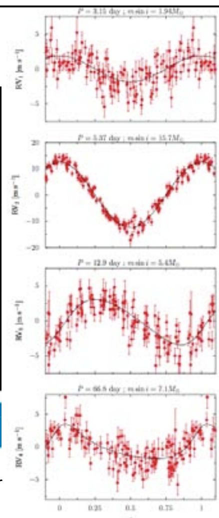


FIG. 5.2. The habitable zone (HZ) around main sequence stars.

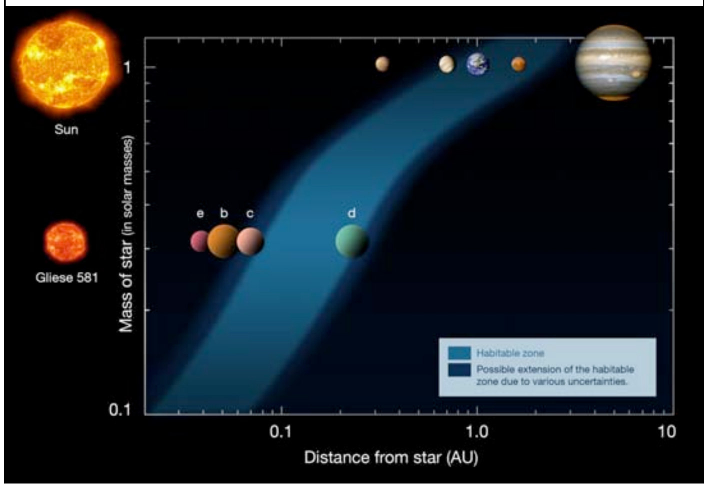
Gliese 581 bcde



M3 stars only 20 light years from Earth. Stars is 0.013 solar luminosities. Two planets of edge of habitable zone.

Gliese 581 bcde

Gliese 581 bcde

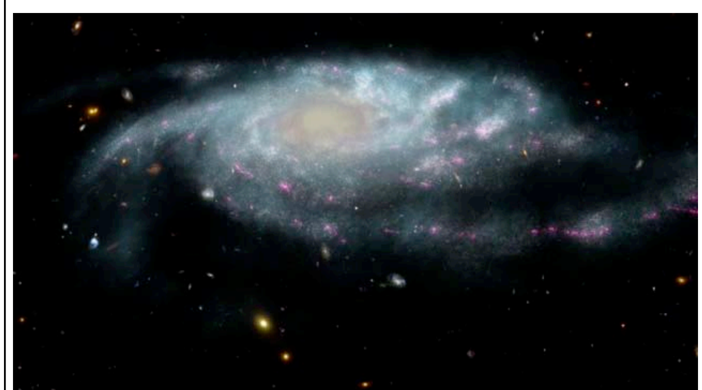


Detecting Earth-like Planets with Kepler

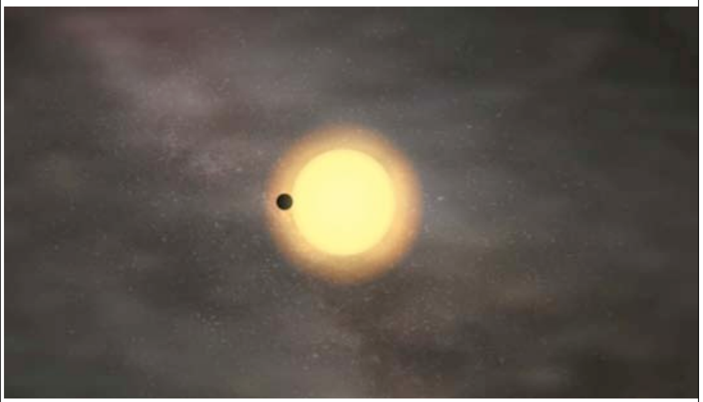
Will watch 100,000 stars for changes in brightness of 1/10,0000 Expect 50 earth-like planets in 1st year

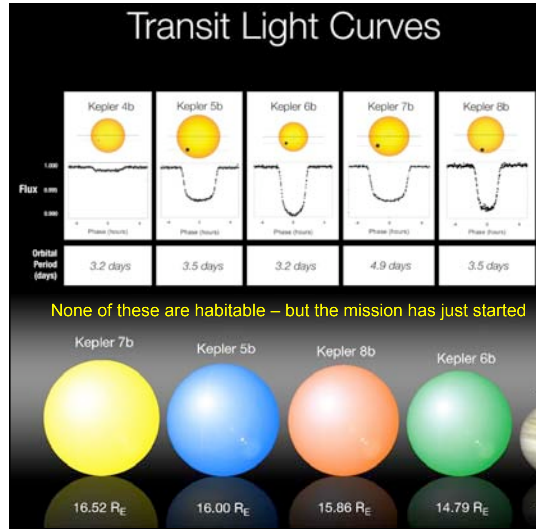
Launch of Kepler Satellite on March 6, 2009

Where Kepler will look…



Kepler Mission





Kepler Planets So Far

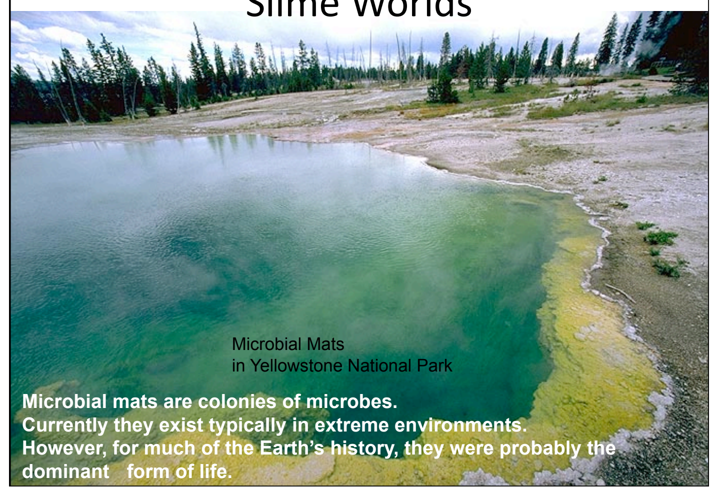
If we find planets, will they have life?

What kind of life will it have?

Can we determine the fraction of planets with life?

Or at least, can we determine the fraction of planets with slime.....?

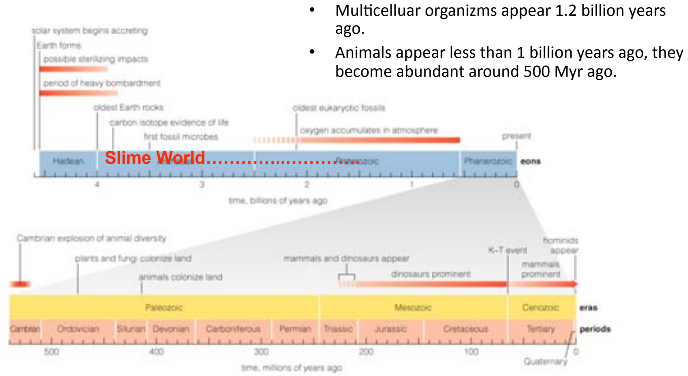
Slime Worlds



The Earth was a Slime Worlds

The History of Life

- Cyanobacteria paved the way for more complicated life forms by releasing oxygen into atmosphere via photosynthesis
- Oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago
- About 2.4 billion years ago, Oxygen became abundant.
- Multicelluar organizms appear 1.2 billion years ago.
- Animals appear less than 1 billion years ago, they become abundant around 500 Myr ago.



Origin of Oxygen

- Cyanobacteria paved the way for more complicated life forms by releasing oxygen into atmosphere via photosynthesis
- Oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago
- Carbon isotope evidence pushes origin of life to more than 3.85 billion years ago
- About 2.4 billion years ago, Oxygen became abundant.

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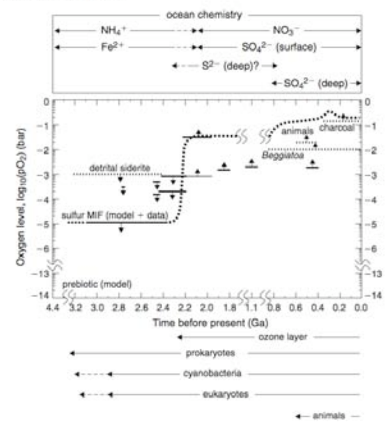
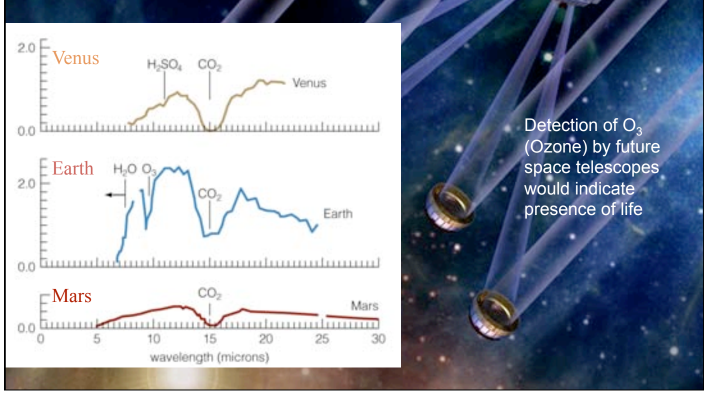


FIG. 2.3. The history of atmospheric O_2. The thick dashed line shows a possible evolutionary path of atmospheric O_2 that satisfies biogeochemical data. Dotted horizontal lines show the duration of biogeochemical constraints. Downward-pointing arrows indicate upper bounds on the partial pressure of oxygen (pO_2), whereas upward-pointing arrows indicate lower bounds. Unlabeled solid horizontal lines indicate the occurrence of particular paleosols, with the length of each line showing the uncertainty in the age of each paleosol. See Catling and Claire (2005) for description/references for the constraints. Ga, billions of years ago; MIF, mass-independent fractionation.

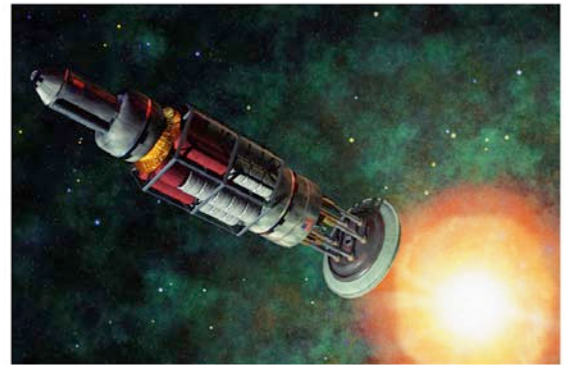
Measuring the Fraction of Planets with Life: The Transformation of Earth's Atmosphere

It may be possible to search for life on other planets by using spectroscopy looking for Oxygen.

Spectral Signatures of Life on Exoplanets



How difficult is interstellar travel?

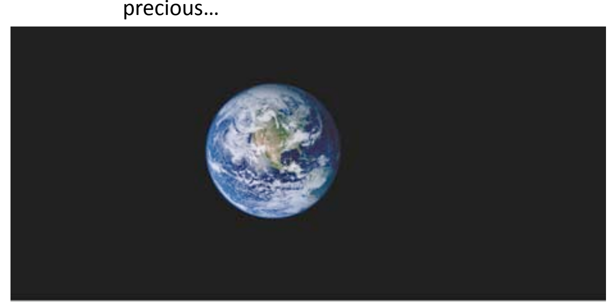


Fermi's Paradox

- Plausible arguments suggest that civilizations should be common, for example:
- Even if only 1 in 1 million stars gets a civilization at some time ⇒ 100,000 civilizations
- Many should be more advanced than we (?)
- So why we haven't they contacted us?

Possible solutions to the paradox

1) We are alone: life/civilizations much rarer than we might have guessed.
   - Our own planet/civilization looks all the more precious…



Possible solutions to the paradox

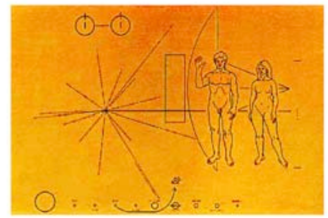
2) Civilizations are common but interstellar travel is not. Perhaps because:
   - Interstellar travel more difficult than we think.
   - Desire to explore is rare.
   - Civilizations destroy themselves before achieving interstellar travel

3) Interstellar Nature Reserve hypothesis

4) We will contact a civilization in the future.

Current Spacecraft

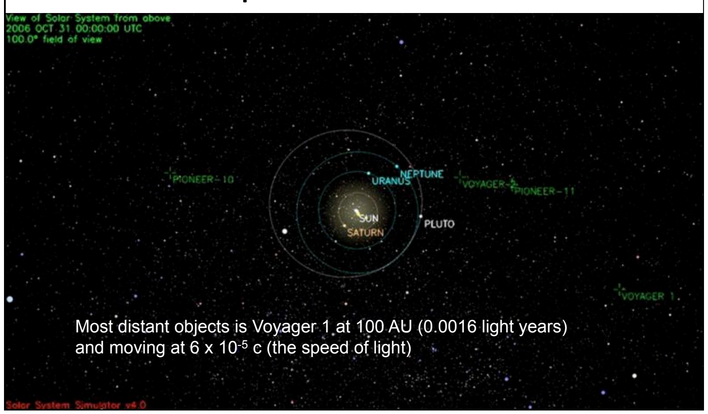
- Current spacecraft travel at <1/10,000 c; 100,000 years to the nearest stars.



Pioneer plaque

Voyager record

Where are Voyager and Pioneer Spacecraft Now?

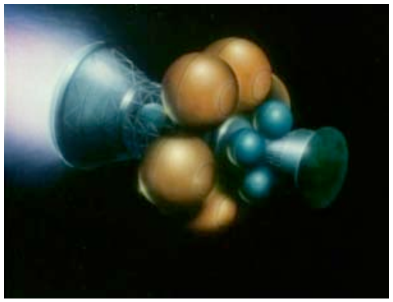


Most distant objects is Voyager 1 at 100 AU (0.0016 light years) and moving at 6×10^{-5} c (the speed of light)

Difficulties of Interstellar Travel

- Far more efficient engines are needed
- Energy requirements are enormous
- Ordinary interstellar particles become like cosmic rays
- Time dilation makes space travel possible in a human lifetime, but with social complications.

Project Daedalus



Concept for unmanned probe to Banard's star (5.9 light years away).

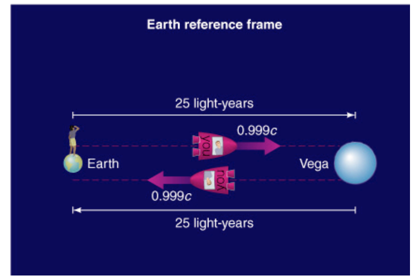
Fusion Rocket

50 year flight time

12% speed of light

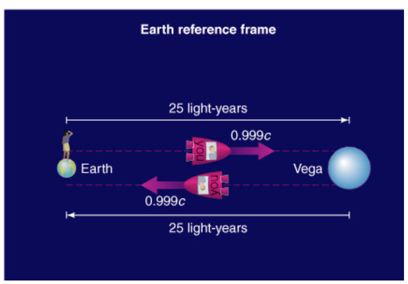
Would send probes in advance to search for planets around Banard star.

Time Dilation: A Result of Einstein's Theory of Relativity



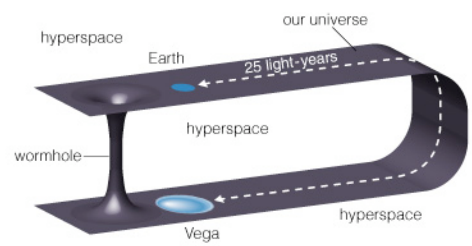
- The distance to Vega is about 25 light-years
- But if you could travel to Vega at 0.999*c*, the round trip would seem to take only two years!
- At that speed, the distance to Vega contracts to only 1 light-year in your reference frame
- Going even faster would make the trip seem even shorter!

A Journey to Vega



- However, your twin on Earth would have aged 50 years while you aged only 2
- Thus, it is possible to travel to the stars, but you would leave behind everyone you knew on Earth.
- We don't possess the technology to travel near the speed of light.
- Accelerating the space shuttle to 0.999 speed of light would require 40,000 times the total amount of energy produced in one year in the U.S.

Shortcut through Spacetime



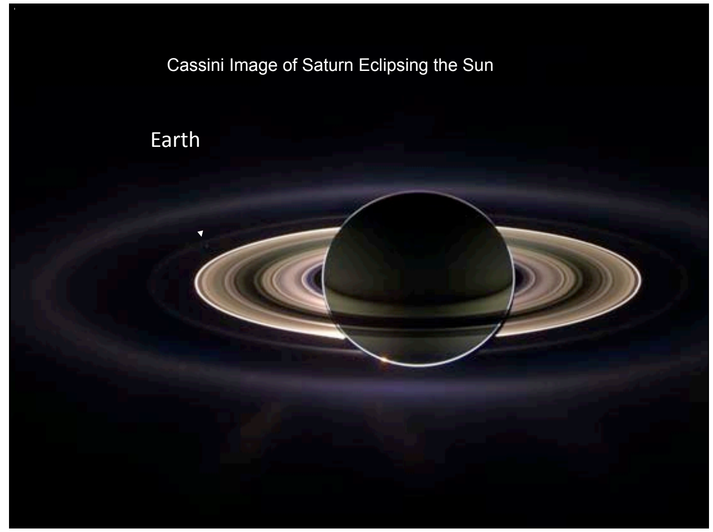
- Some mathematical solutions of the equations of general relativity allow for shortcuts called *wormholes* that are tunnels through *hyperspace*
- *We have no idea how to build one!!*

But we can’t leave now….

--and the earth is getting more crowded:

there are 50 people per square kilometer of non-ice covered land

(that is 128 people per square mile)



Pale Blue Dot

Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there-on a mote of dust suspended in a sunbeam.

Carl Sagan
1934-1996

Summary

Events leading up to life on Earth

SETI - search for radio signals and light pulses from other civilizations (no signals yet).

Drake equation - simple method for quantifying the uncertainties in estimating the number of civilizations. We don’t know all the terms in this equation, but we are improving our knowledge by:

Determining the number of stars with planets by searching for planets and nascent planetary systems (in progress – 75% of young stars have material needed to make planets – 12% of stars have giant planets)

Determining the number of planets in the habitable zone – i.e. at the right distance where liquid water can exist (some larger planets in habitable zones have been detected – but the detection of Earthlike planets in habitable zones has not yet been achieved. Kepler mission may detect such a planet in the next year).

Determining the planets with life (may be done by detecting oxygen in atmosphere)

Most planets may be slime worlds without animal life (our planet was a slime world for most of its lifetime).

Travel to other star systems very difficult (but not impossible).