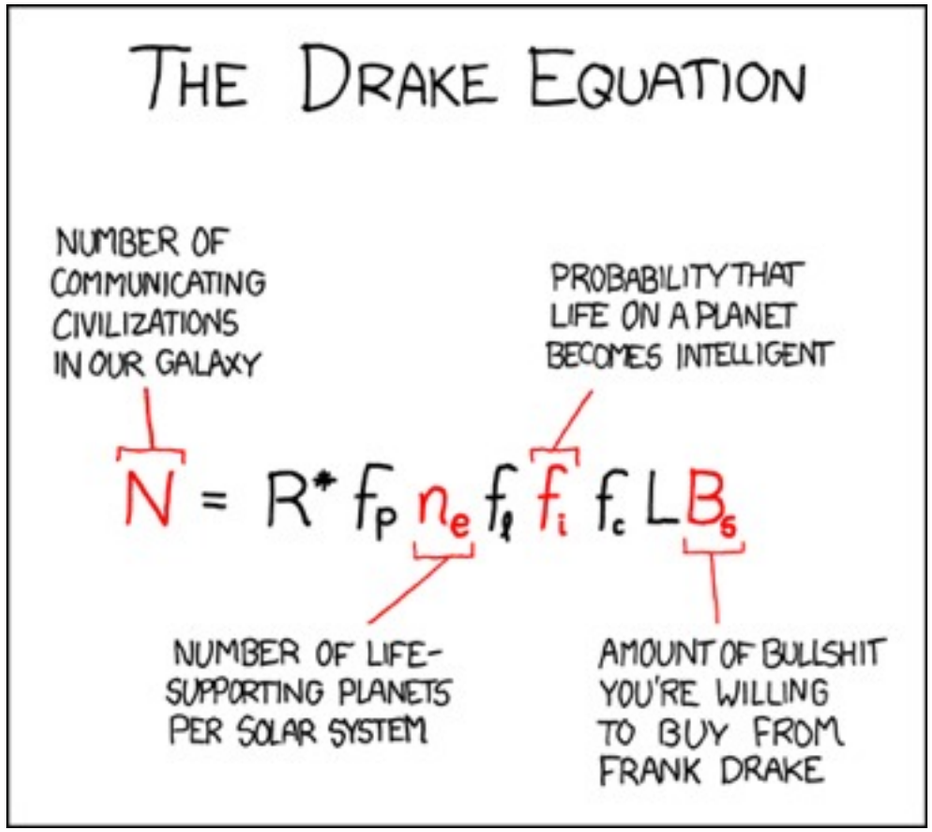
Killer Skies

- **HW 11** due tonight
- Exam 3, Dec 11
- Last time: End of the Universe
- Today: Aliens



Music: *Pets* – Porno For Pyros

Hour Exam 3

Hour Exam 3 Wed, Dec 11th, in class

- information on course website
- 40 questions (cover material from Nov 4 to Dec 9: Lect 25-36)

May bring 1-page of notes

- both sides
- printed, handwritten, whatever

Most useful study materials

- class notes
- iClicker questions
- study guide
- homework questions
- old exam

Focus on concepts, main ideas

Numerically Challenged

In the Universe, the number of stars is greater than the number of grains of sand on all of the beaches of the Earth.

Each of these stars probably have planets.

Is it sensible to think that life only exists on Earth?

Life?

Astronomically, we are not special.

So, we are probably typical in many ways to the other planets around other stars, in other galaxies.

So, the pre-biotic aspects of Earth is probably typical too.

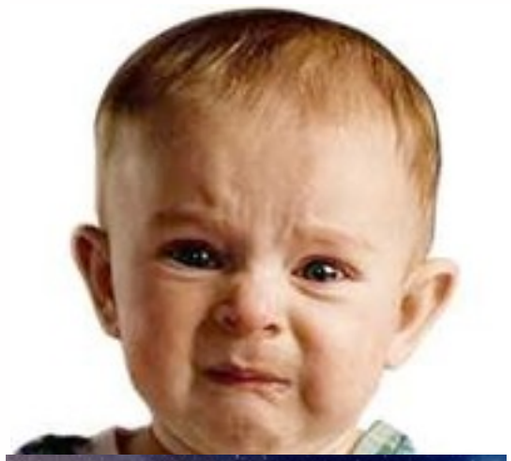
One aspect of the study of extraterrestrial intelligent life is to determine if life is a typical phenomenon.

Life?

At the very worst, we expect that most galaxies have at least one planet with intelligent life on it

- **As the Milky Way has at least one planet with Intelligent Life.**

So, there ought to be at least 100 billion intelligent civilizations in the Universe!



Aliens?

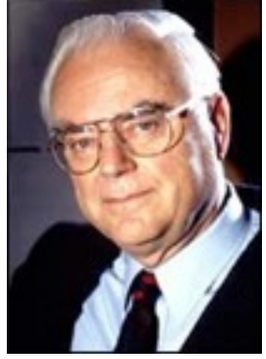
We have been bombarded by aliens in the media– all types.

No surprise that close to half of all Americans believe in aliens.

Have we been visited by ETs?

“Extraordinary Claims Require Extraordinary Evidence”

Drake Equation



Frank Drake








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

N	R_*	f_p	n_e	f_l	f_i	f_c	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 commun-icate	Lifetime of advanced civilizations
	stars/yr	systems/ star	planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Not a real equation, but a way to guide our thinking about the questions.

f_p: Other Planets, Other Stars

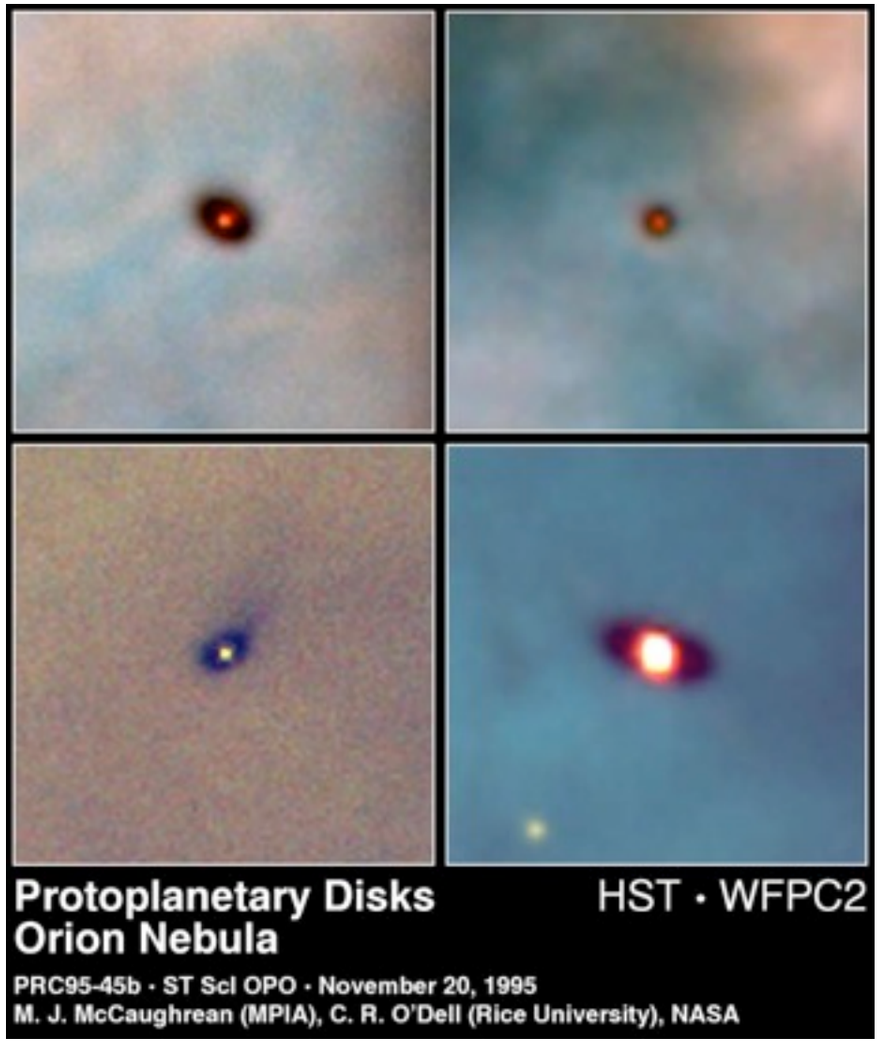
How common are planets? Are aliens everywhere or nowhere? Only in the last 15 years, have we gone from knowing about only the 8 planets in our Solar System to over 1050 known today (today) and thousands of candidates.

Every day, we learn about even more planets!

f_p: Other Planets, Other Stars

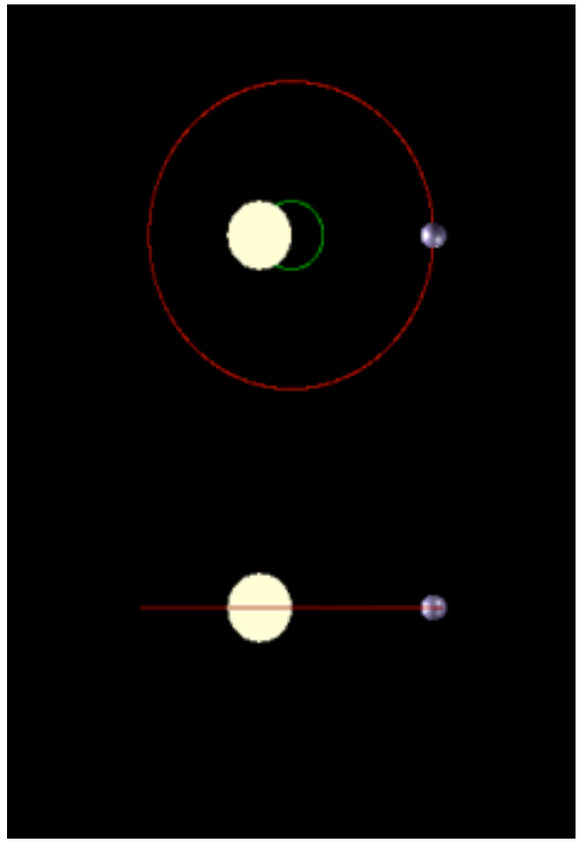
Remember the star formation process. Planets are a natural byproduct of star formation.

Stars are born with disks of material circling them. These disks are thought to produce planets. Nearly all protostars have disks. So, it seems planets should be common.



Wobbling Stars

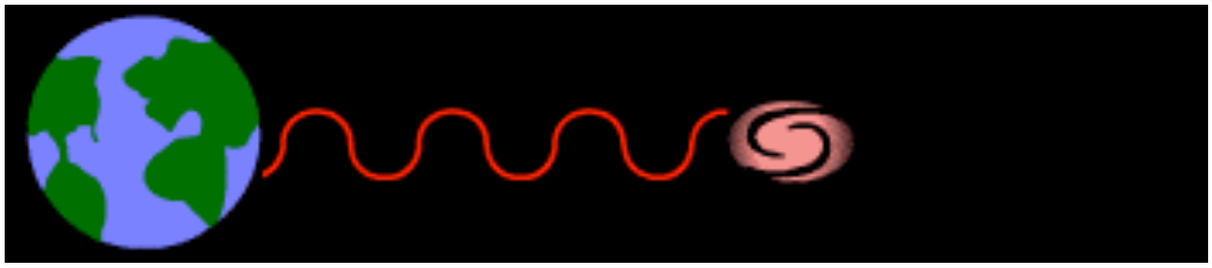
- Planet's gravity "tugs" the parent star
- As planet orbits the star, the tugs make the star "wobble"
- But how can we see this wobble?
  - Too small to see the back-and-forth motion of the star
  - Observe wobble by the **Doppler effect**



Star and planet each orbit around their mutual *center of mass*

Astronomers have generally had to resort to indirect methods. Instead of detecting the planet, they infer its existence by observing the effects that it has on its parent star.

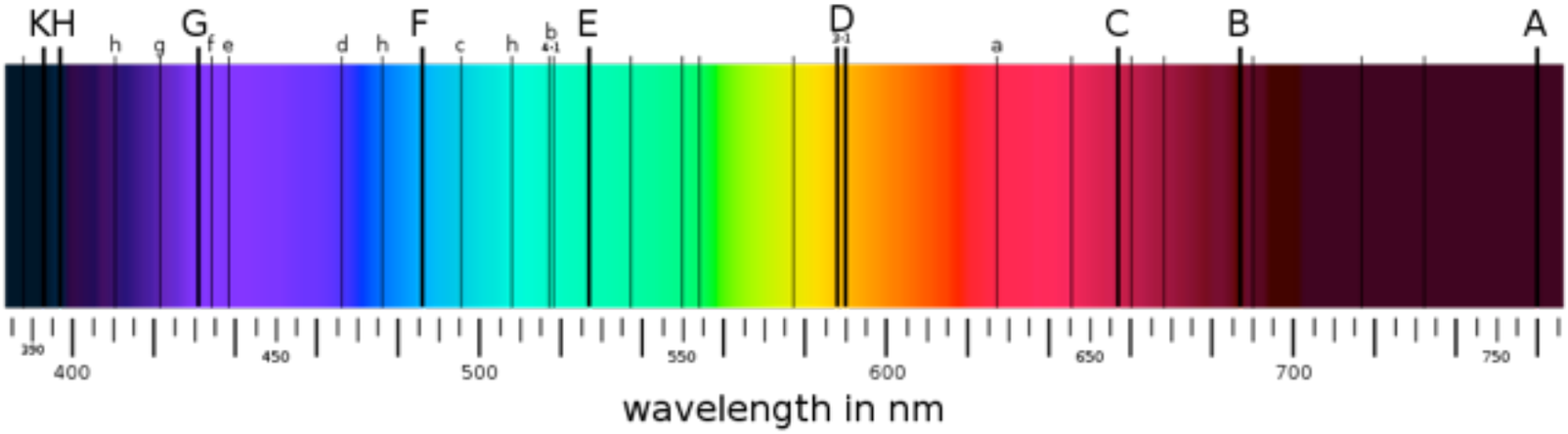
Remember: The Doppler Shift and Light



- **Redshift**: Motion away from the observer
  - Observed wavelength longer than emitted
- **Blueshift**: Motion towards the observer
  - Observed wavelength shorter than emitted

Greater shift ⇒ greater speed

Remember: Lines in a Star's Spectrum

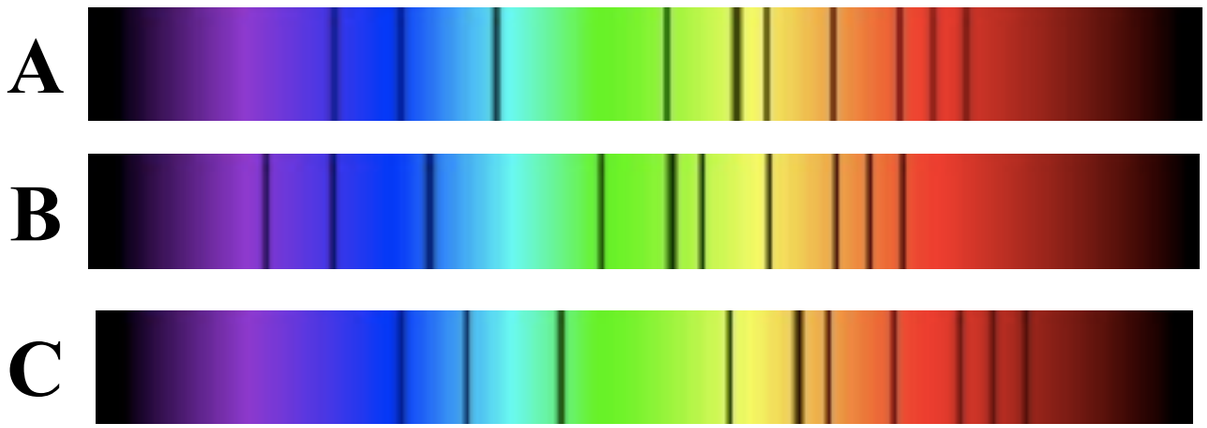


All stars have spectral lines that depend on the star's surface temperature.

Thought Question

For the spectra shown below, one is from a star that is not moving relative to you, one is from a star moving toward you, and one is from a star moving away from you.

Which of the three spectra is from the star moving toward you?

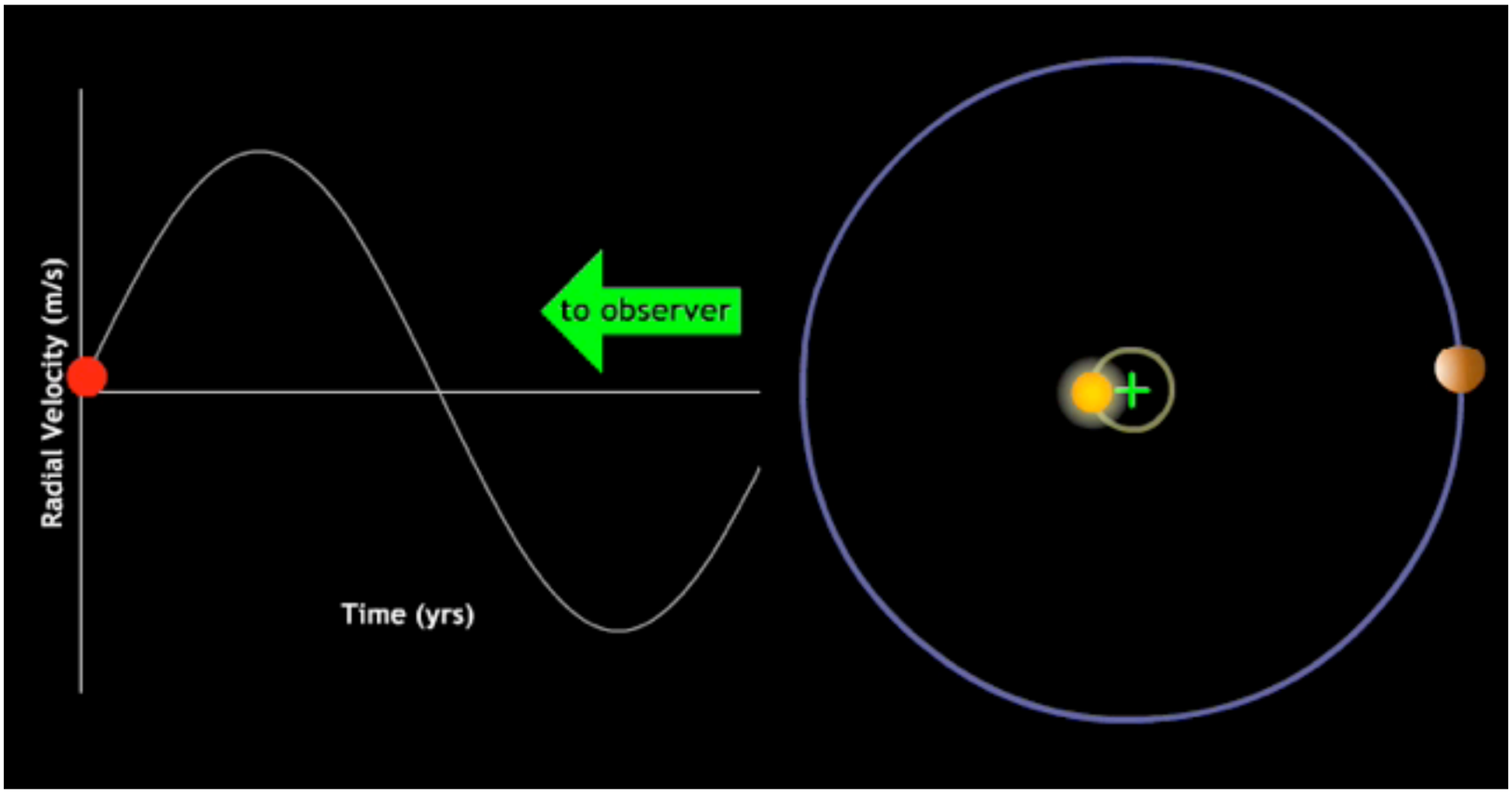


Answer B – the lines are blueshifted

A is not moving

C is moving away

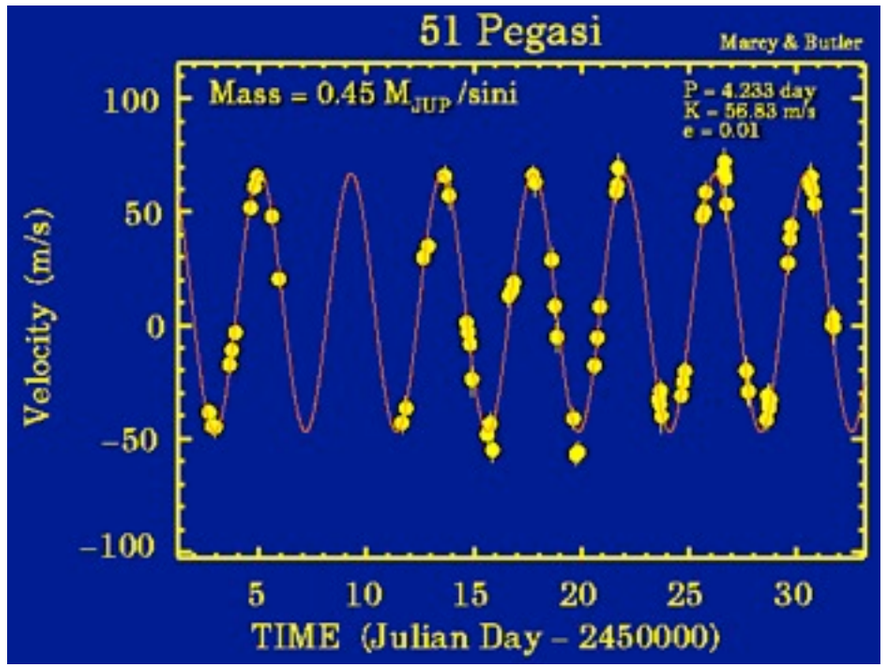
Radial Velocity



Astronomers plot a star's changing radial velocity over time (measured via the Doppler shift) to detect planets

First extrasolar planet around a Sun-like star

- Discovered in 1995 orbiting 51 Pegasi
  - Doppler shifts reveal a planet with 4.23 day orbital period
  - 0.5 M_{Jup} at 0.05 AU from its star!

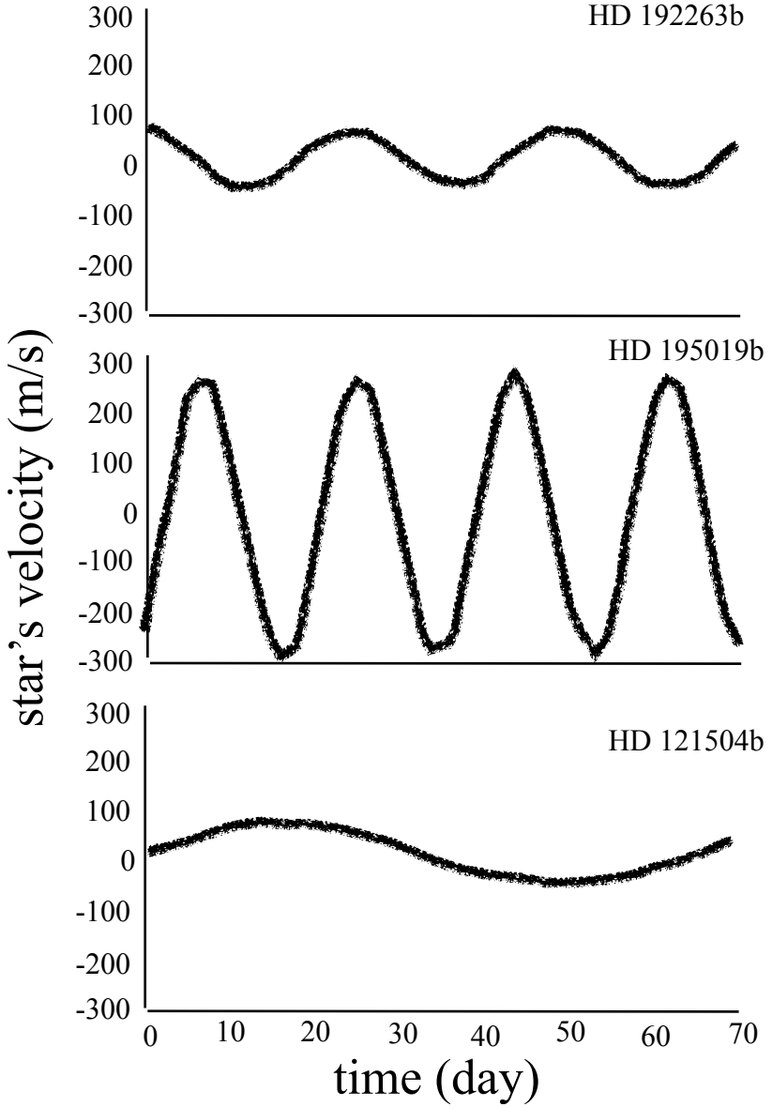


51 Pegasi b orbits it star every 4.23 days!

First extrasolar planet discovered was half Jupiter's mass (150 times the mass of Earth!) but only 1/8th the distance of Mercury from its star!

Doppler shift tells us about a planet's mass and orbit

- Top graph shows a 0.5 M_{Jup} planet in an orbit around a Sun-like star at 0.05 AU
- Middle graph - more massive planet in a 0.05 AU orbit
- Bottom graph - 0.5 M_{Jup} planet in more distant orbit



The amplitude of the wobble tells us the planet's mass. More massive planet in same orbit produces greater Doppler shift with same period around the star. The period of the wobble tells us the radius of its orbit (from Kepler's 3rd Law). Same mass planet in a more distant orbit produces a smaller Doppler shift with a longer period

Selection Effect

- Big planets make big wobbles
  - Bigger Doppler shift
  - Easier to detect
- Close planets make fast wobbles
  - Shorter period of Doppler shift
  - Less time to observe a full orbital period
- Think about it...
  - Jupiter's orbital period ~12 years
  - Saturn's orbital period ~30 years
  - Detecting extrasolar planets for 20 years
  - Enough time for 1 Jupiter orbit, but not Saturn

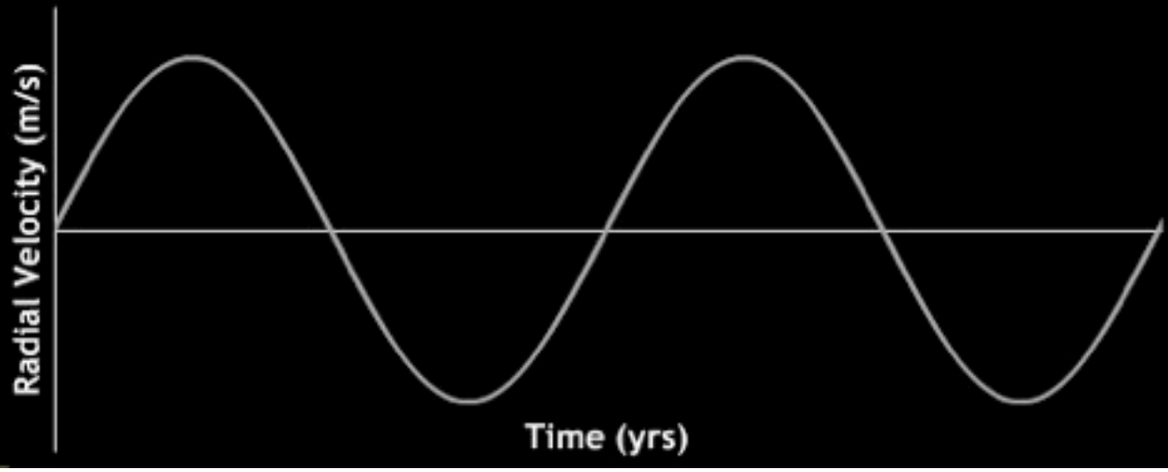
Thought Question

The graph below simulates the radial velocity curve for a star with a singular extrasolar planet in a circular orbit seen edge-on. If the mass of the **planet** were **increased**, then...

(A) the amplitude would increase

(B) the amplitude would remain the same

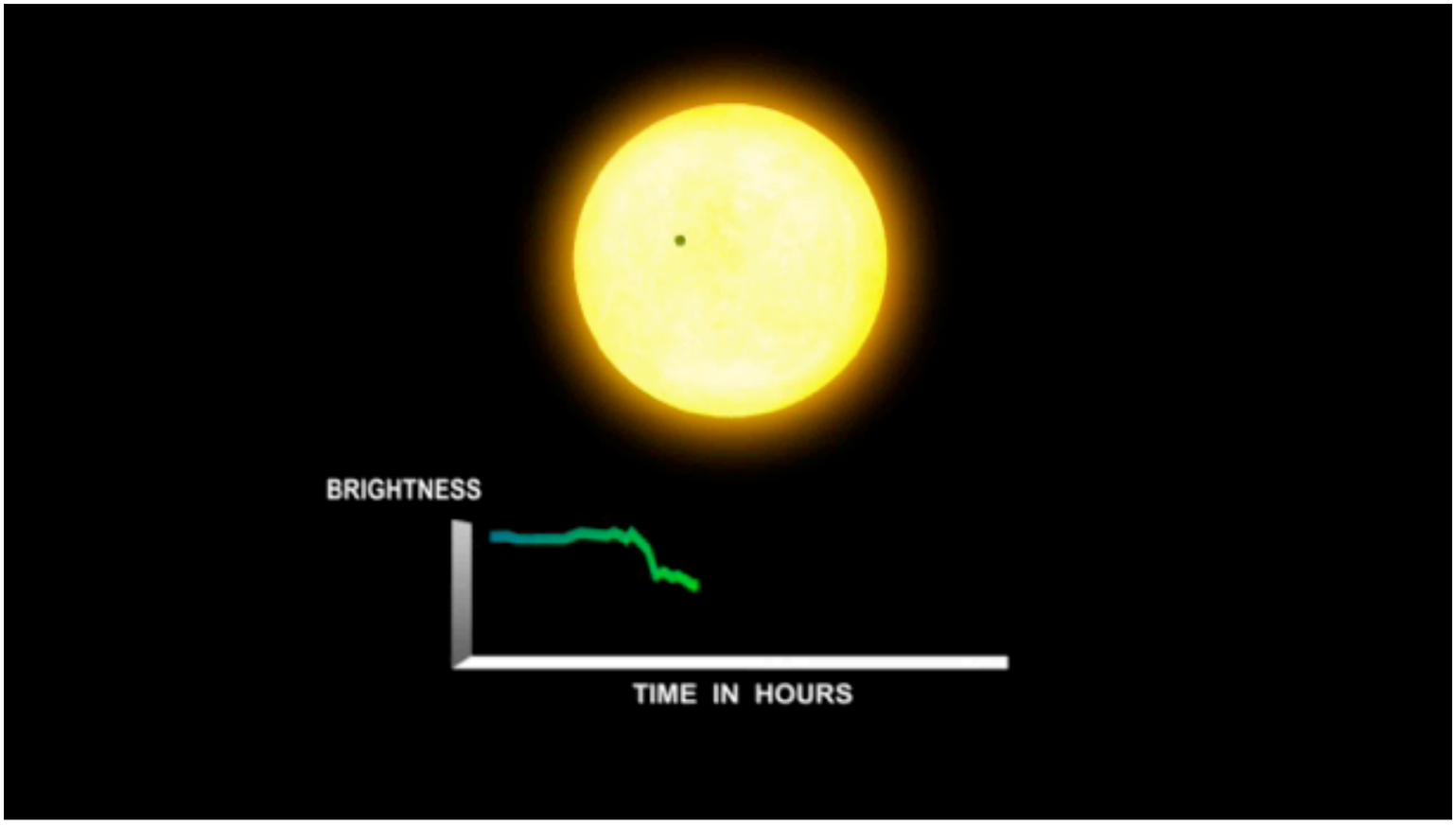
(C) the amplitude would decrease



Show A

Answer: A. Bigger planet bigger wobble.

The Transit Method



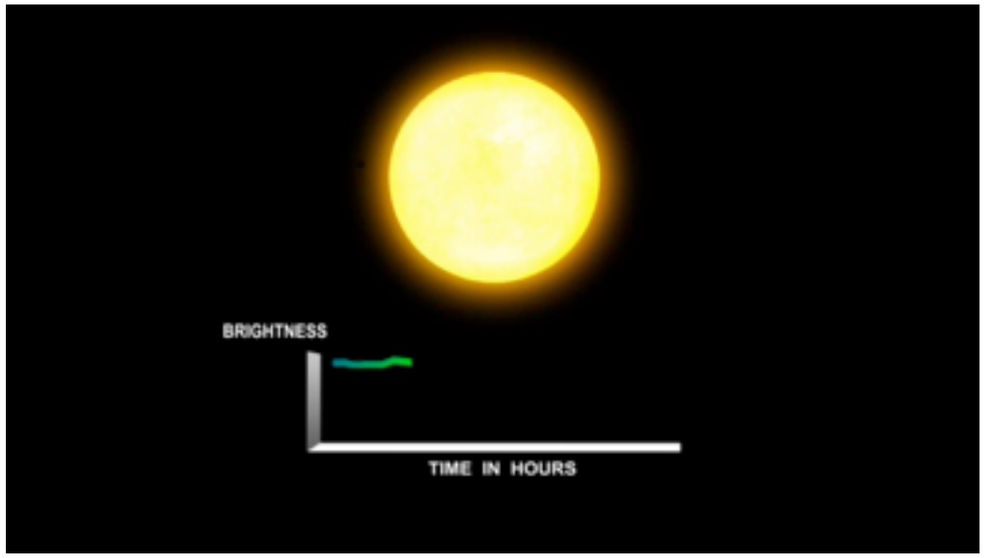
The effect on the observed brightness when a planet passes in front of the parent star

Look for regular dips in the brightness of a star as a large planet passes, or transits, in front of it. Requires the extrasolar planet's orbital plane to be pointed right at Earth. Fraction of starlight blocked tells us planet's size. Time between transits gives us orbit period.

Note that we need to observe the system edge on. The star must pass in front of the star to see the effect. Otherwise, we would not see it. This limits the number of stars you expect to see transits with, since there is no Galactic rotation preference.

Transits are the best chance to find Earth-like planets

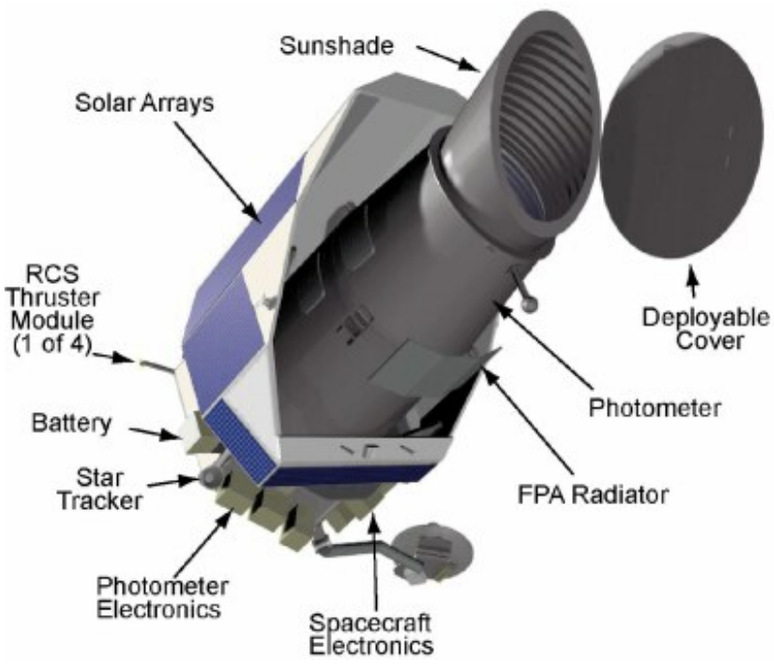
- Fraction of starlight blocked tells us planet's size
- Time between transits gives us orbit period
- A Jupiter-sized planet transiting a Sun-like star would cause a 1% brightness drop
- Best method to find Earth-like planets



Earth-sized planet would cause a 0.01% drop in brightness (1 in 10,000), but best instruments can measure 1 in 50,000 drop in brightness!

Kepler Mission

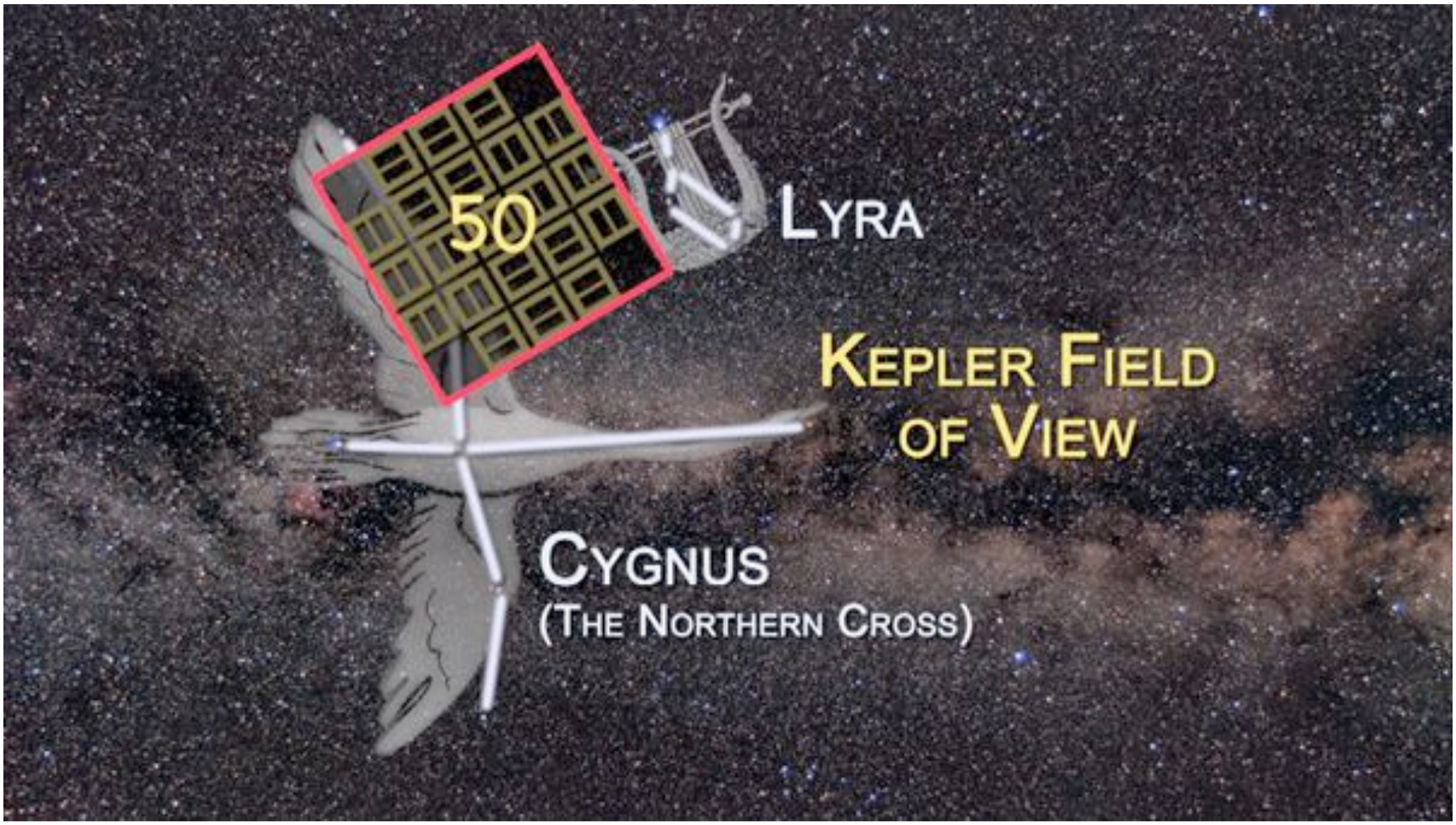
- Launched in 2009
- Monitoring 156,000 stars for 3.5 years
- Sensitive to 1 part in 50,000 (0.002%)!
  - Can detect Earth-size planets!
- To date (July 2013) :
  - 134 confirmed planets
  - 3277 candidates!
  - 350 Earth-sized candidates!



The Kepler Space Probe

In space, no atmosphere to limit sensitivity, only limits are from instruments. The probability of an Earthlike planet at 1 AU transiting its star is 0.47%, or about 1 in 210 – assuming it had one. If 100% of stars observed had Earthlike terrestrial planets, Kepler would find about 480 of them. The mission is therefore ideally suited to determine the frequency of Earthlike planets around other stars. 350 of Kepler's planet candidates (all sizes) are in the "habitable zone" (where water can be liquid-- see later slide).

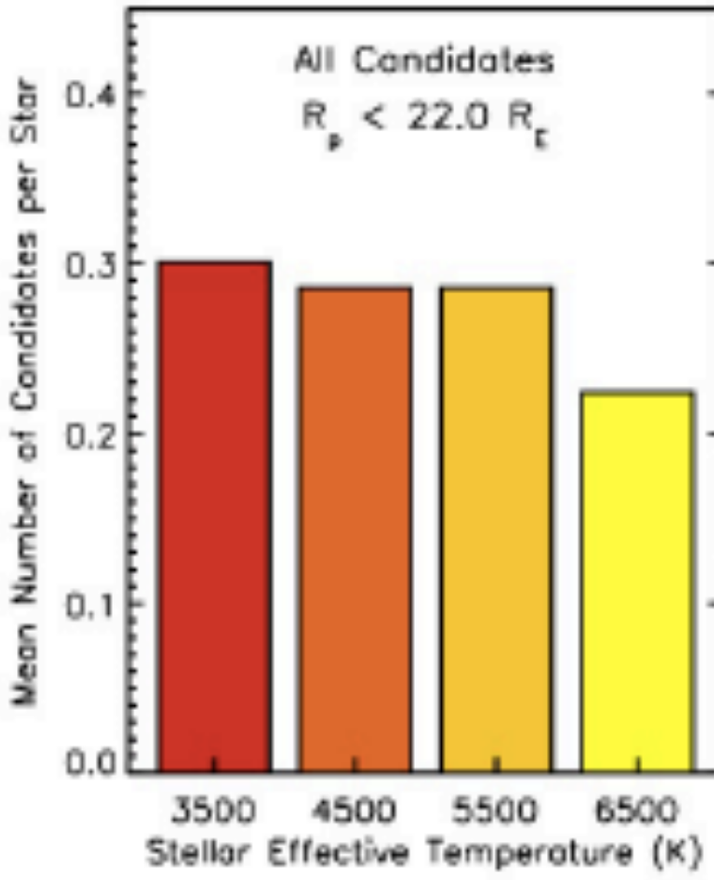
Right now there is problem on spacecraft, so future is unknown



The Kepler Space Telescope watches more than 156,000 stars in its field of view which covers approximately 1/400th of the sky

f_P: How many stars have planets?

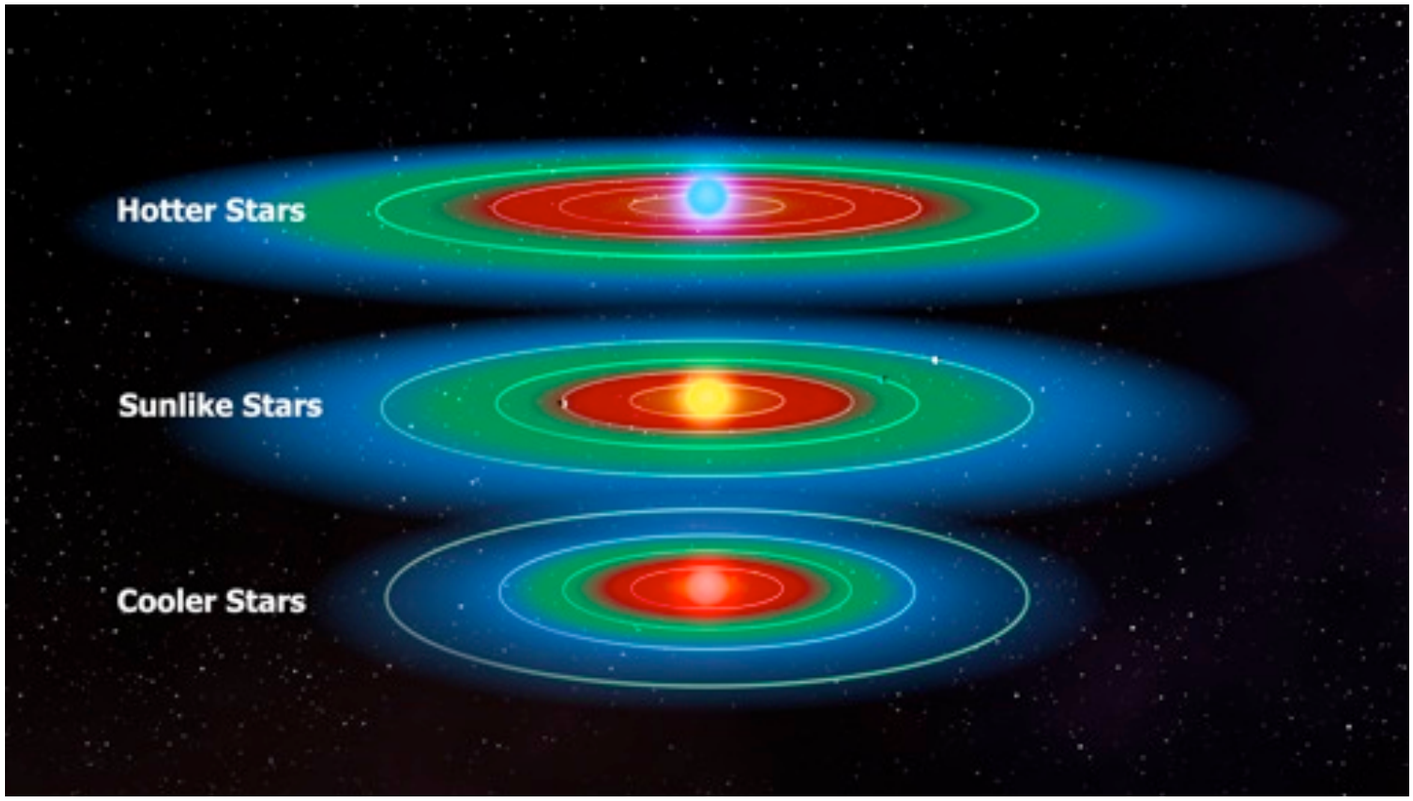
- Kepler team estimates there are at least **50 billion planets** in the Milky Way!
- From these results, f_P appears to be ≳ 30%
- First scientific estimate of f_P!
- A more recent study suggests over 100 billion planets with maybe $f_P = 1$!



http://arxiv.org/pdf/1102.0541v1

The Kepler team estimated at least 50 billion planets in the Milky Way. The 30% figure is lower limit, could be higher! In fact, a new study (Swift et al.) only looking at M stars, suggest that they all have multiple planets, which means f_p is close to 1.

n_e: # of Earth-like planets in the habitable zone per system

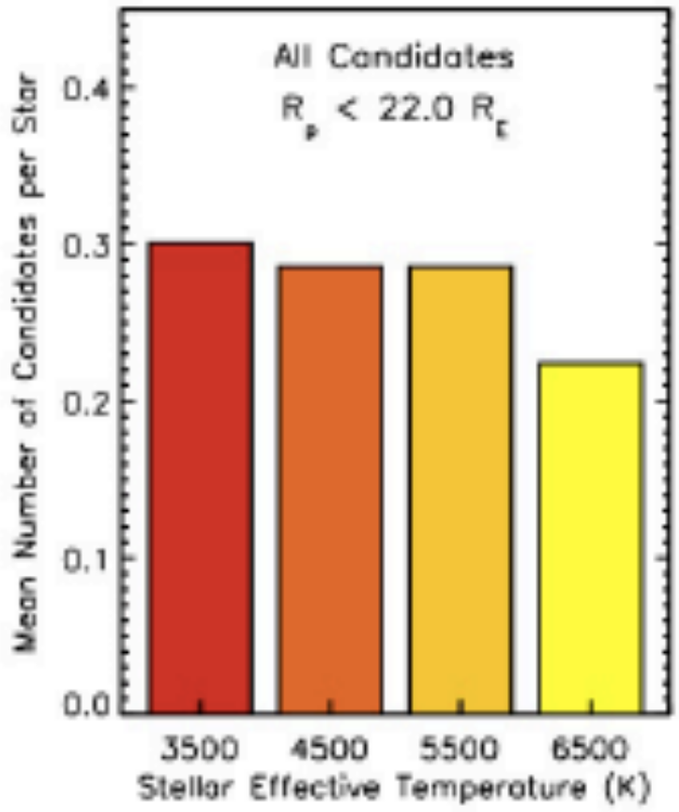


Habitable Zone: the region surrounding the star in which water can remain in its liquid state (green region in figure)

Habitable Zone: the region surrounding the star in which water can remain in its liquid state. The red region is too warm, the blue region too cool, and the green region is just right for liquid water. Notice, as expected, that for low mass, cool stars the region is closer to the star, and for higher mass, hotter stars, the region is more distant from the star.

n_e: How many Earth's?

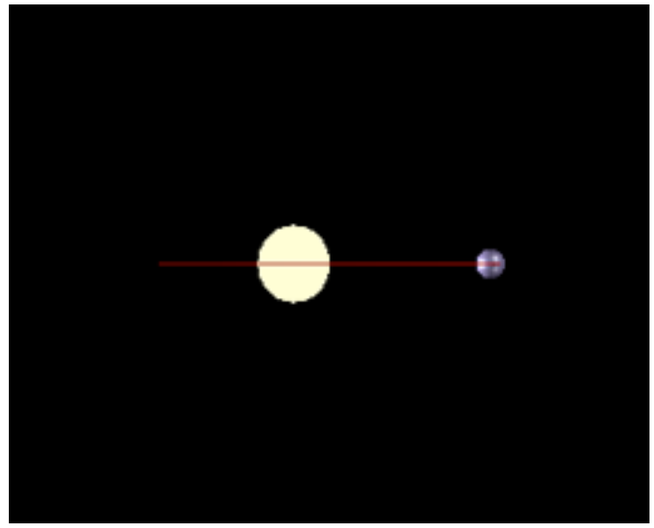
- Now we know that the most common planet is much less massive than Jupiter.
- Kepler team estimates 17% of the ~100 billion stars are Earth-like
- And in habitable zone
- That's 17 billion Earth's in the Galaxy!!!!

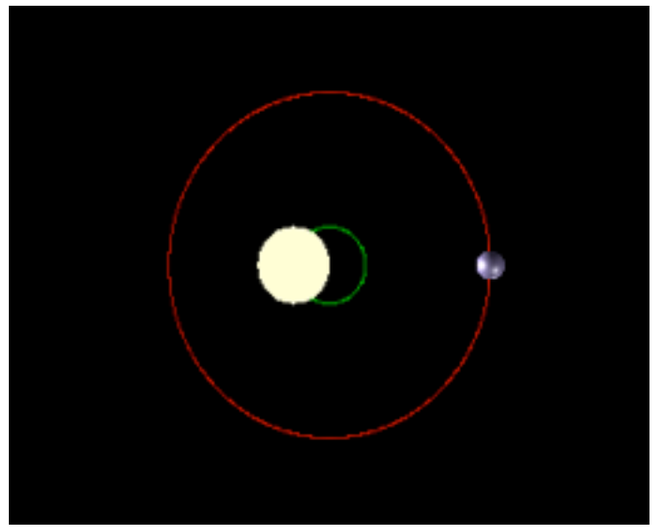


http://arxiv.org/pdf/1102.0541v1

Limitations of Doppler and Transit Methods

- In edge-on system (above)
  - Transits are possible
  - Doppler shift observed
  - Radial velocity is star's true motion
  - Doppler method gives planet mass
- In face-on system (below)
  - No transits, no Doppler shift

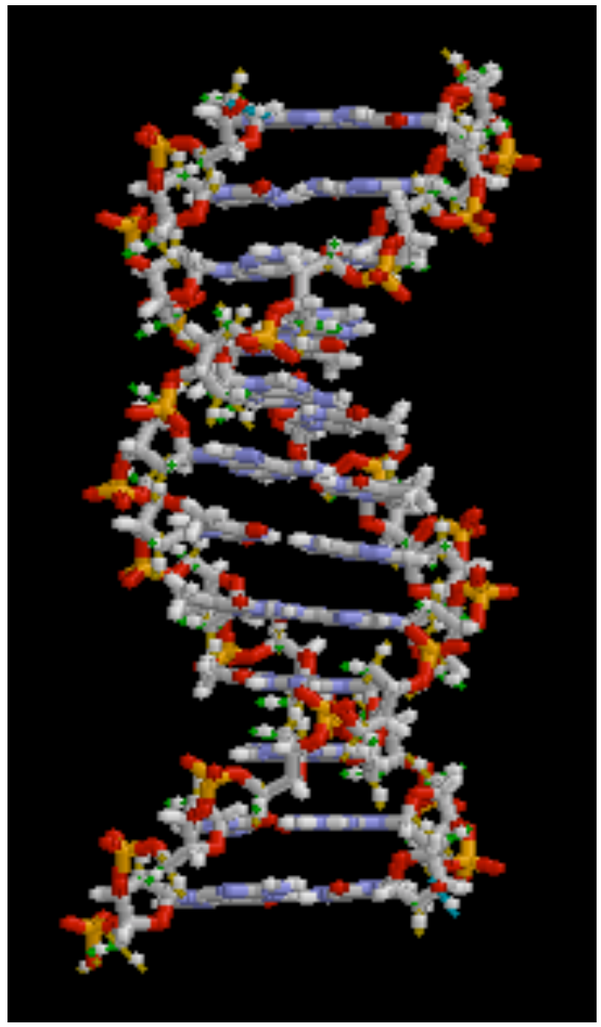




Planetary Good News

- Planets are common
- It looks like something like 5-17% of all stars have Earth-like planets!
  - High mass stars don't life long enough for life anyway
  - Very low-mass stars, the planet has to be too close to be in the habitable zone
- Very good news for life in the Galaxy and the Universe

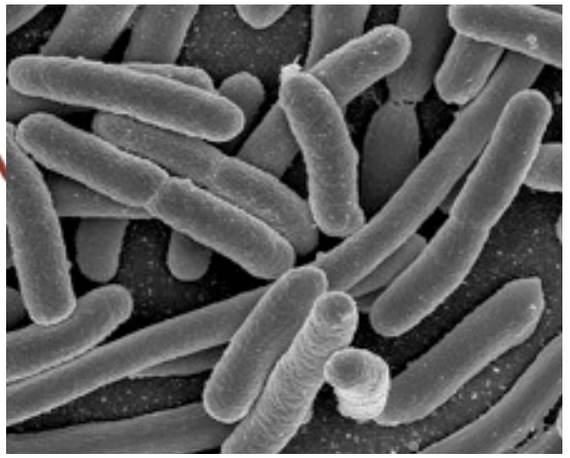
f_l: Fraction of planets on which life arises



- Life on Earth shares numerous characteristics
- For example:
  - All known life uses **DNA** as its genetic material
  - Builds proteins from the same set of building blocks, known as **amino acids**
- Otherwise, life on Earth is remarkably diverse

Yet, All Made from the Same Stuff

All life today uses the same processes and encoding of protein stored in DNA. Life came from a common ancestor.



How Old is Life?

- Earth formed 4.6 billion years ago
- Earth's early geologic record (first 1/2 billion years) is GONE (erosion, plate tectonics, etc.)
  - Clues to early stages of life formation are gone
  - Oldest rocks 4 billion years old
- Heavy bombardment prevented any life
  - Hard to have any permanent life, when big rocks keep falling on its head
- Evidence of life ~3.8 billion yrs ago!

But, we do have evidence for very early microbial life on Earth (about 3.8 billion yrs old). Really soon (astronomical speaking) after the bombardment

Early Fossils

Stromatolite fossils created by micro-organisms, especially blue-green algae

This Stromatolite estimated to be 2.3 billion years old!

Modern stromatolites in Australia on the left. Fossil stromatolite from Bolivia on the right

The oldest stromatolite fossils (found in Western Australia) are over 3 billion years old!

Making Oxygen: The First Air Pollution

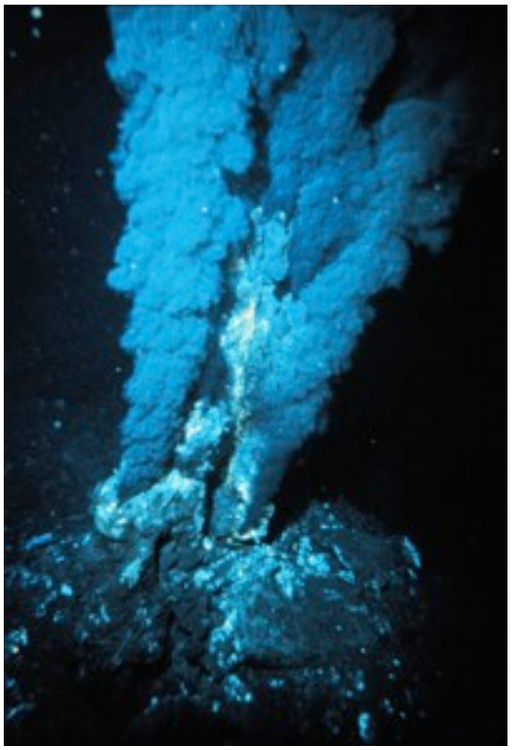
- The early Earth had no oxygen.
- Cyanobacteria changed the world!
- Created first environmental disaster!
- Oxygen rich atmosphere about 2 Byrs ago, allowing more complicated life.
  - Like you

Thought Question

You have a time machine with a dial that you can spin to send you randomly to any time in Earth's history. If you spin the dial, travel through time, and walk out, what is most likely to happen to you?

A. You'll be eaten by dinosaurs.
B. You'll suffocate because you'll be unable to breathe the air.
C. You'll be consumed by toxic bacteria.
D. Nothing: you'll probably be just fine.

Answer: B Most of the Earth's history, you would be unable to breathe. Free oxygen in the atmosphere is a new thing.



Genetic studies suggest that the earliest life on Earth may have resembled the bacteria today found near deep ocean volcanic vents (black smokers) and geothermal hot springs. These bacteria are called extremophiles.

Extremophiles are microbes that live in the most extreme places on Earth. Earth not fine-tuned for life, but life has been tuned for Earth.

Temperature extremes

- Boiling or freezing, 100C to -10C

Chemical extremes

- Vinegar or ammonia (<5 pH or >9 pH)
- Highly salty, up to ten times sea water

Exciting because they are the most likely candidate for extraterrestrial life

Building blocks for life from space?

- Some of life's ingredients were delivered to Earth long ago by meteorite and comet impacts
- Fundamental building blocks of life are prevalent in space
- Life in the universe may be common

Murchison meteorite has multiple amino acids.

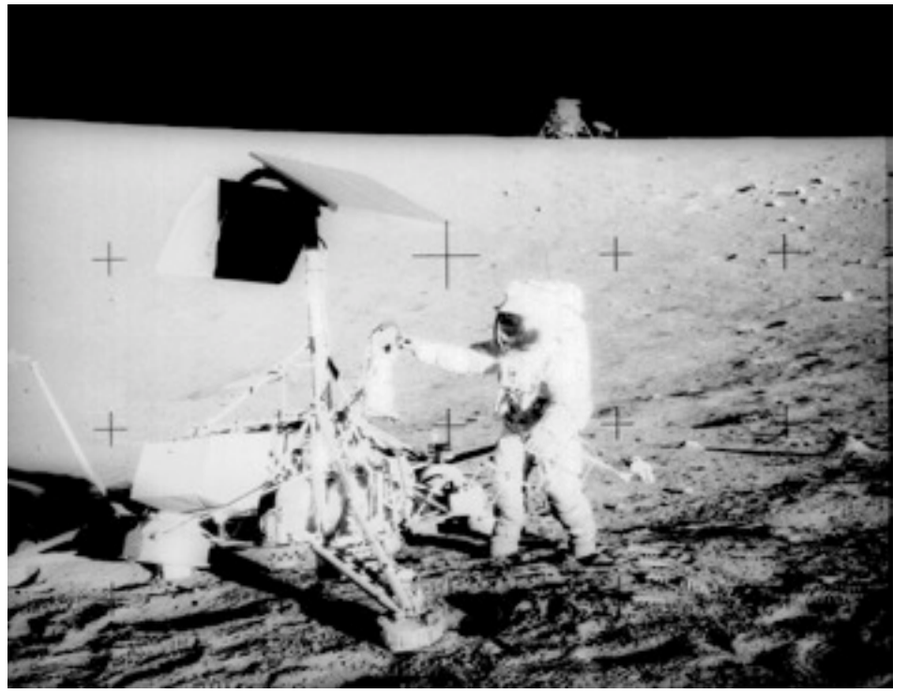
Panspermia

- Some have stated that perhaps life-important molecules formed in molecular clouds and spread to planets. **Infection!**
- Comets could have carried molecules to Earth's surface. Or ordinary meteors.
- Or some even claim that simple life came from the stars!

http://www.daviddarling.info/images/lithopanspermia.jpg

Panspermia: Case in Point

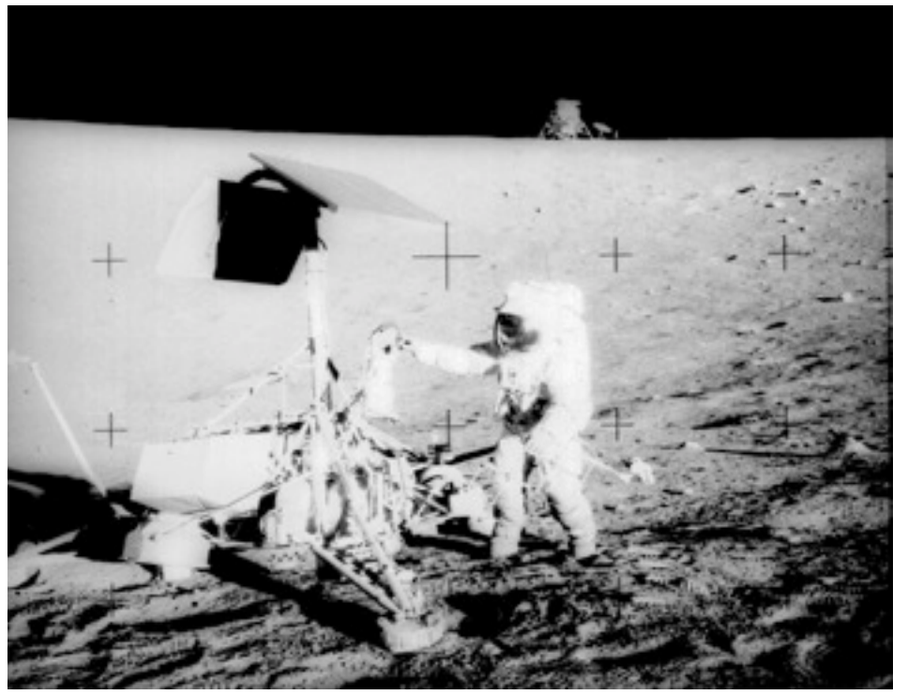
- Surveyor 3: unmanned lunar probe which landed in 1967.
- 2.5 years later, a camera was retrieved by Apollo astronauts.
- The camera had 50 to 100 viable specimens of *Streptococcus mitis*, a harmless bacterium commonly found in the human nose, mouth, and throat.



http://nssdc.gsfc.nasa.gov/planetary/news/image/conrad_19990709_c.jpg

Panspermia: Case in Point

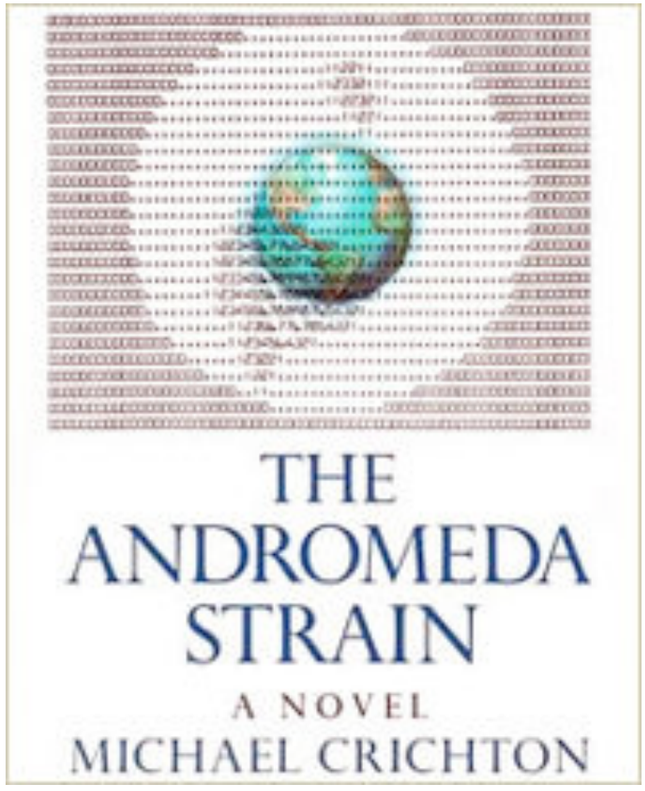
- The camera was returned under strict sterile conditions.
- The bacteria had survived 31 months in the absence of air or water!
- In SPACE!
- Was subjected to large monthly temperature variations and hard ultraviolet radiation from the Sun.



http://nssdc.gsfc.nasa.gov/planetary/news/image/conrad_19990709_c.jpg

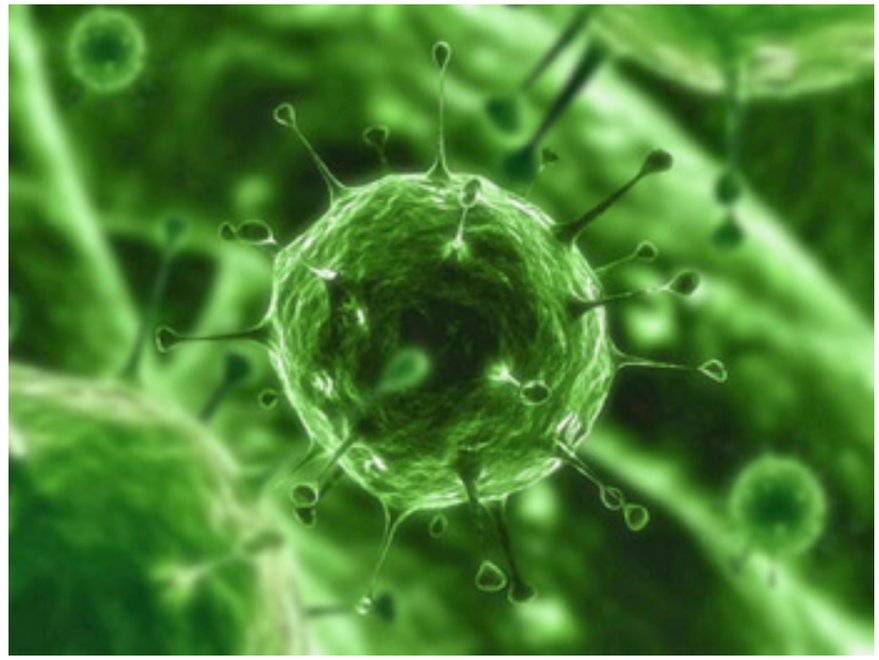
Panspermia: Alien Invaders

- If life on Earth came from Panspermia, what if “they” come back?
- Virus or bacteria inside a rock, could survive space travel and Earth landing.
- But, interstellar travel for micro-life is very, very unlikely.
- But even still, could they hurt us?



Alien Invaders: Viruses

- Viruses are simple; space travel would be easiest for them.
- Although simple, they are very specialized.
- A plant virus can not infect an insect.
- Too simple to change on quick timescales.
- So, likely can not hurt us.



Alien Invaders: Bacteria

- Bacteria are more complex.
- Able to survive in more "hosts"– worst guest ever!
- You already host many colonies on your skin and inside your body!
- But, remember fine-tuned: we evolved together: regular and extremes.
- Alien life would likely be killed off before major damage.

Question

If an alien bacteria or virus lands on Earth it is unlikely to be seriously dangerous to humans why?

a) No hands. No ray guns.
b) Terrestrial bacteria or viruses have evolved to become dangerous to humans.
c) They are too little to make any difference.
d) It is totally impossible for alien bacteria or viruses to land on Earth.
e) The Drake Equation proves that ET life can not exist.

Could there be life elsewhere in our solar system?

- Requirement for liquid water or some other liquid rules out the possibility of life on most worlds in our solar system
- Mercury and the Moon are barren and dry.
- Venus's surface is far too hot for liquid water.
- Pluto, Eris, and other dwarf planets are too small and too cold to harbor liquids
- Possible candidates for life: Mars, some moons of Jovian planets

Early in Mars' history it was likely more Earth-like

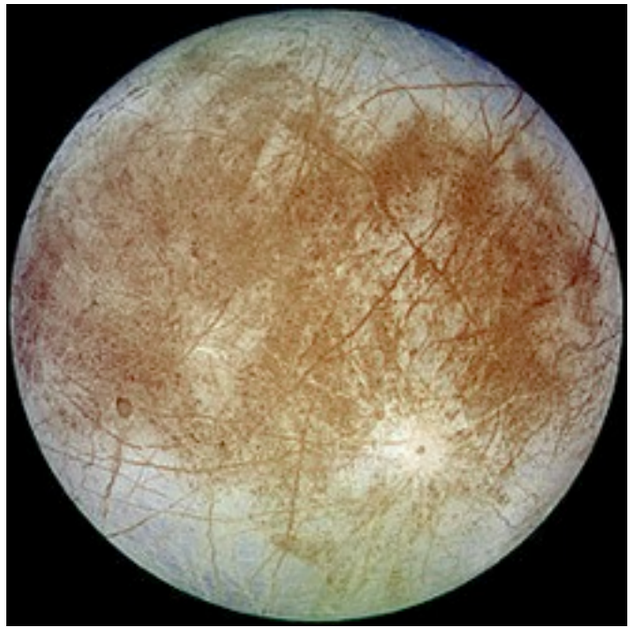
- Geologically active
- Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
- Greenhouse effect made it warm enough for liquid water
- More hospitable to life?

An ancient, wet Mars?

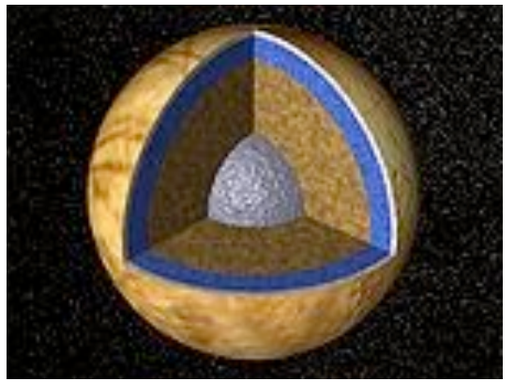
What Happened?

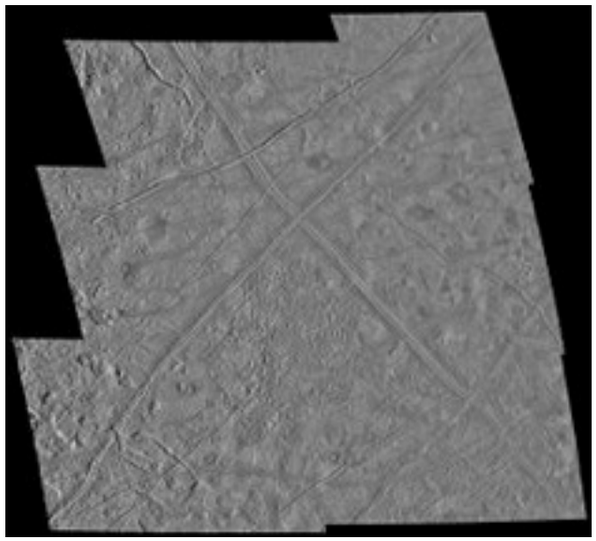
- Mars was too small
  - Not enough internal heat
- Plate tectonics stopped
  - Volcanoes sat over “hotspots” grew to immense sizes
- Volcanic activity slowed as the interior cooled
- The atmosphere escaped
- The planet froze
- Did life move underground?

Europa: Moon of Jupiter

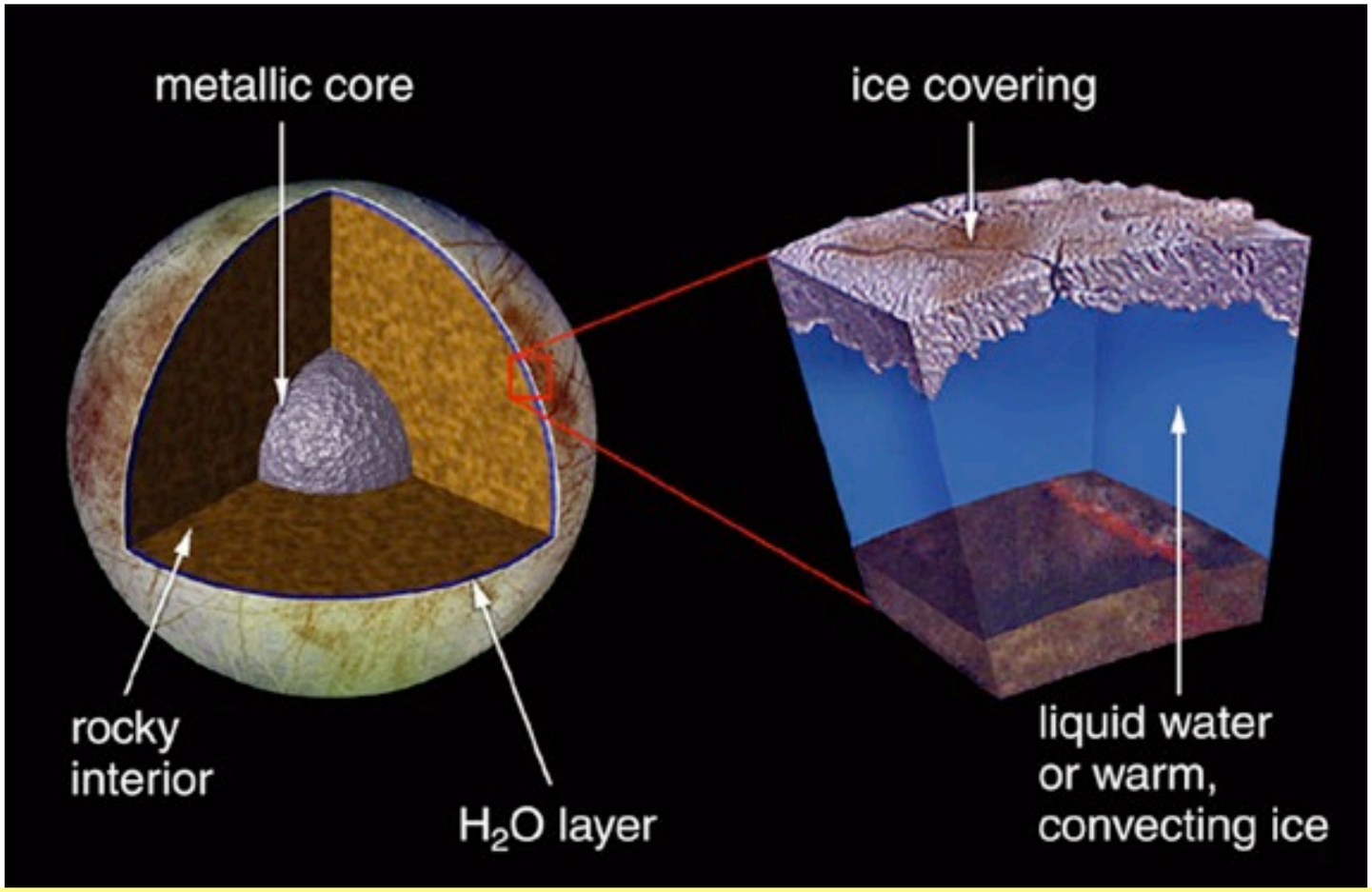


- The 6th moon of Jupiter
- Has an new, icy surface, suggested by cratering and the fracture lines
- Jupiter pulls and pushes, so interior is hot.
- New evidence of liquid water under the ice!





Could there be life on Europa?



Tidal heating from Jupiter produces geological activity and a deep ocean on Europa

Based on Galileo spacecraft measurements of the strength of gravity over different positions of Europa and theoretical modeling of the interior.

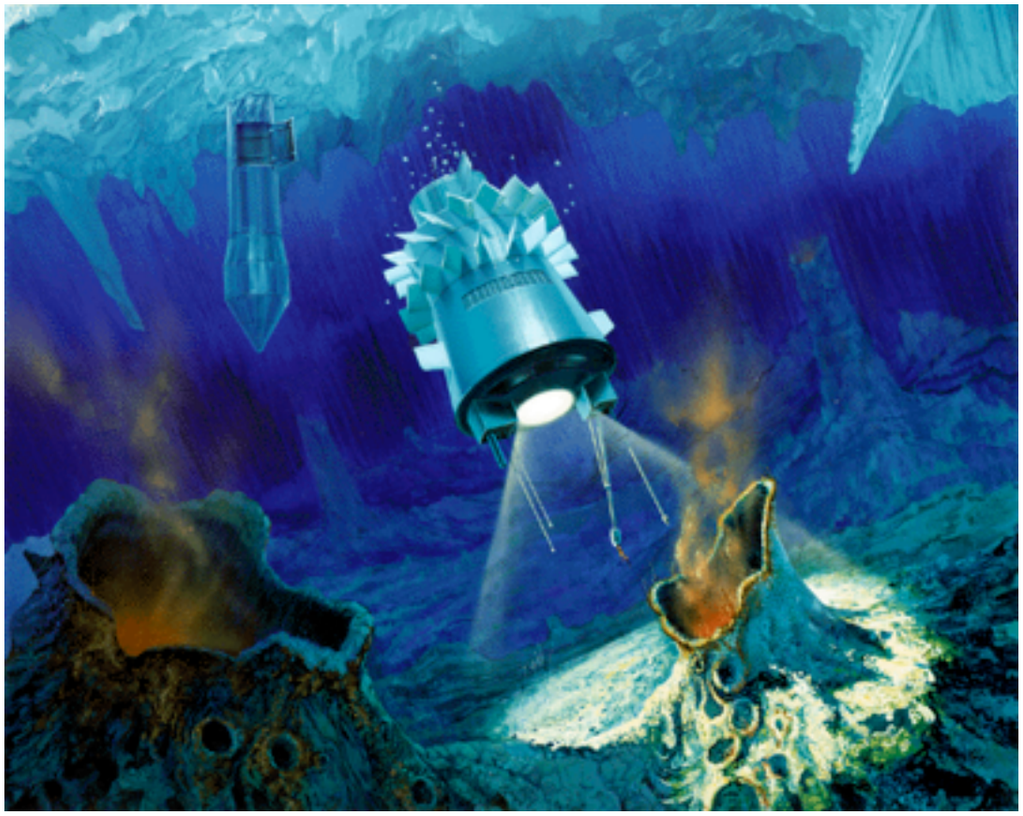
Icy crust 5 km thick

Cracks and fissures on surface – upwelling?

Evidence for deep (50 km!) liquid water ocean beneath crust

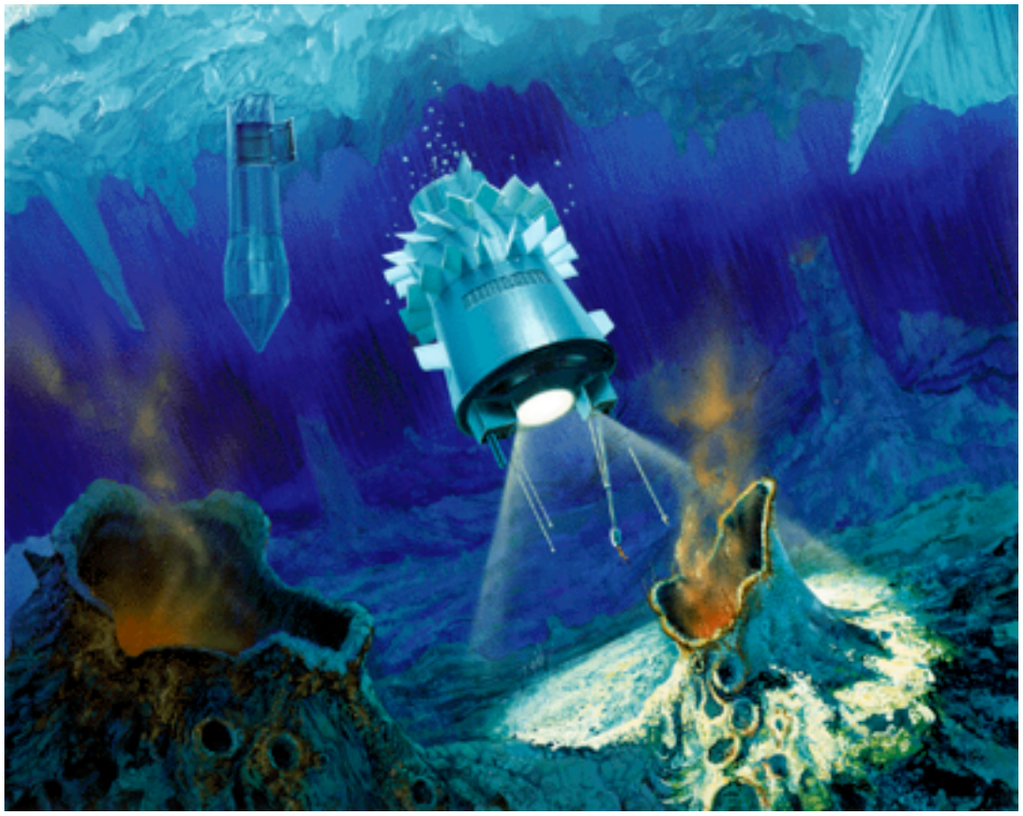
Tidal heating not as strong as on Io.

Europa could support life near geothermal vents



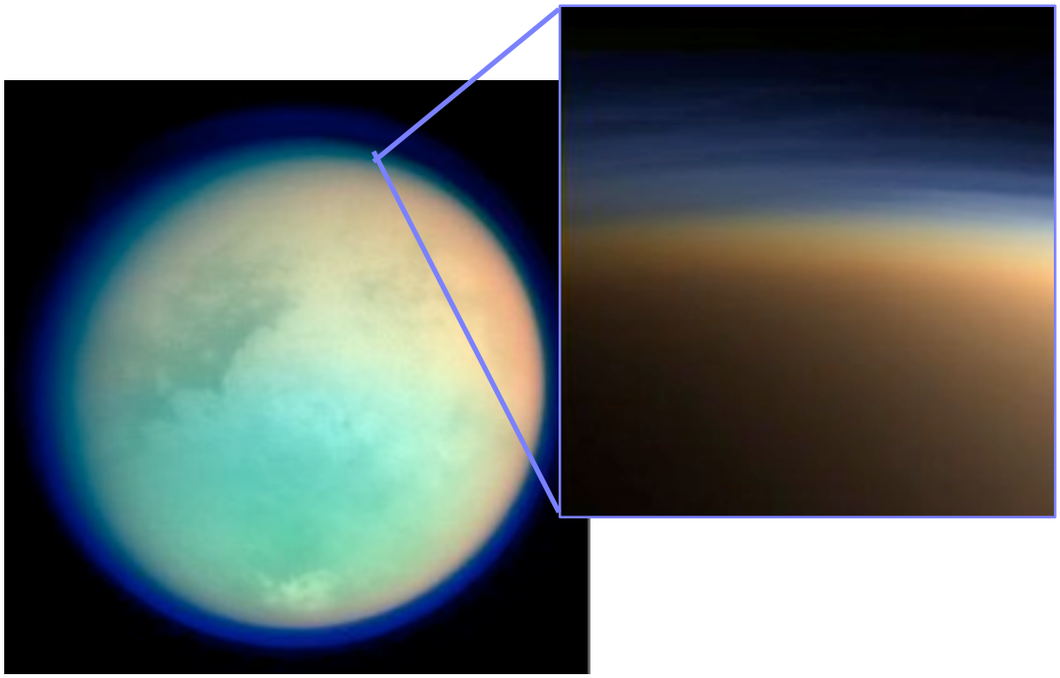
Could Europa have the equivalent of Earth's "black smokers" (right) on the floor of its ocean?

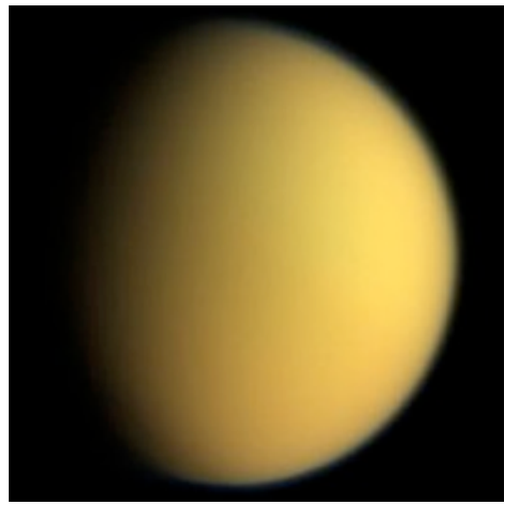
Europa could support life near geothermal vents

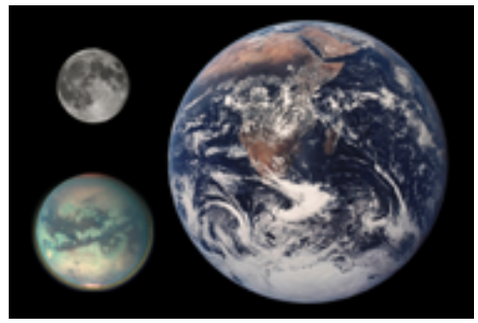


Best bet for seeing macroscopic life in Solar System

Could there be life on Titan?



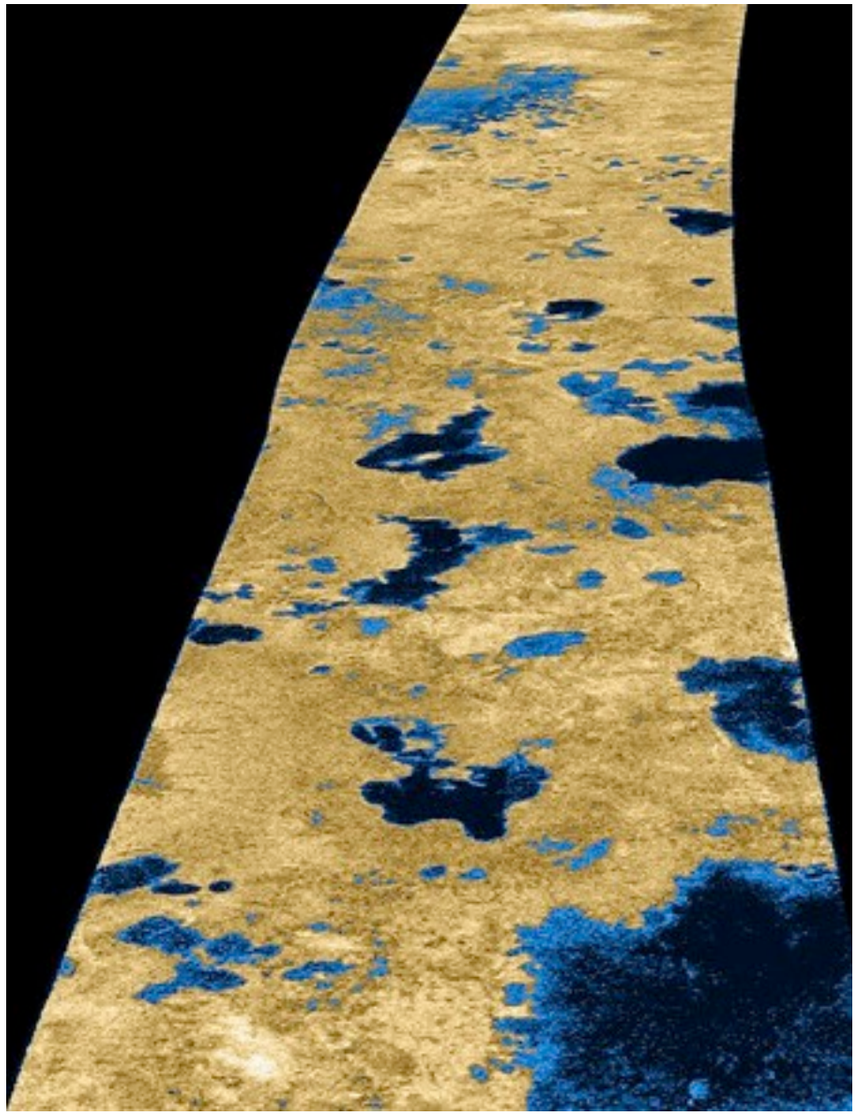




- Largest moon of Saturn
- Only moon with a thick atmosphere
- Surface freaky cold!
  - Too cold for liquid water

Could there be life on Titan?

- But Titan has liquid ethane/methane seas!
  - These are valid liquids for life, just life as we have never seen it.



Titan has something uniquely in common with the Earth. It has a liquid solvent on the surface! Sure, for the Earth it is water, but water on Titan is like a rock due to the low temperatures. (Literally like a rock as mountains are made from it and volcanoes on Titan spew a mixture of methane and water ices.)

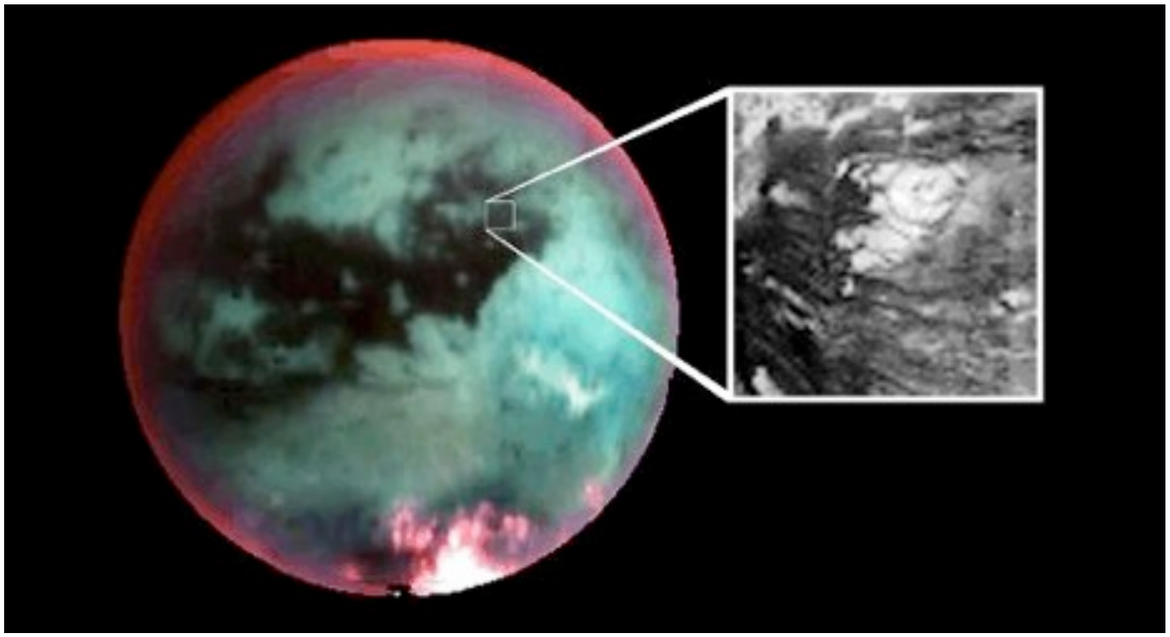
The liquid on Titan is liquid ethane/methane! That type of solvent does not work for Earth-like life, but who is to say that Earth-like life is the only type of life or even the most prevalent? The rich chemistry and the harsh conditions are some of the reasons that searching for life on Titan is so exciting. It will change the way we think about life.

Titan's "Great Ethane Sea"

This image shows a Cassini radar image of what is the largest body of liquid ever found on Titan, compared to Lake Superior

This feature on Titan is at least 39,000 square miles, which is greater in extent than Lake Superior 32,000 square miles, which is one of Earth's largest lakes. The feature covers a greater fraction of Titan than the largest terrestrial inland sea, the Black Sea. Because of its size, scientists are calling it a sea. These seas are most likely liquid methane and ethane.

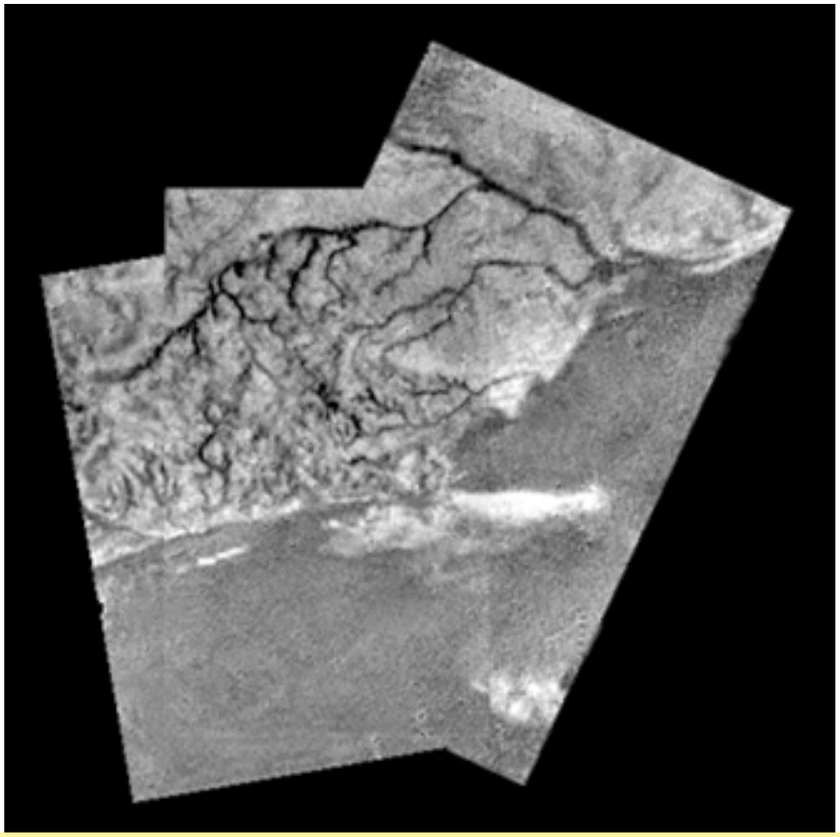
Titan is active



A circular feature about 30 kilometers in diameter that is most likely a volcano, spewing a mixture of methane and water ices. This is evidence of (cryo)volcanism suggesting Titan is geologically active

The left image shows a circular feature about 30 kilometers in diameter. That feature, scientists conclude, is most likely a volcano that spews a mixture of methane and water ices, perhaps mixed with other hydrocarbons.
The right image shows a river bed on Titan, likely made by liquid ethane/methane flows. So, titan has nutrients, energy, and liquid for life to evolve in!

Titan is active



A river bed on Titan, likely made by liquid ethane/ methane flows. So, Titan has nutrients, energy, and liquid for life to evolve in!

The left image shows a circular feature about 30 kilometers in diameter. That feature, scientists conclude, is most likely a volcano that spews a mixture of methane and water ices, perhaps mixed with other hydrocarbons.
The right image shows a river bed on Titan, likely made by liquid ethane/methane flows.
So, titan has nutrients, energy, and liquid for life to evolve in!

Life in the Solar System

No conclusive evidence exists for life in our solar system besides on Earth

But, possibilities exist for life

- Mars may have some microbial history linked to water, and perhaps some subsurface life.
  - Maybe Martian life seeded Earth?
- Europa's sub-crustal oceans may harbor life, even fish-like life.
- Titan is very interesting and could change how we view life
  - Thick atmosphere

fi: Evolution of intelligent life

- Life arose on Earth very quickly
- Intelligent life is a very recent development
- Does evolution naturally drive life to intelligence, or will most planets only develop simple, non-intelligent life?

Evan89/Wikimedia Commons

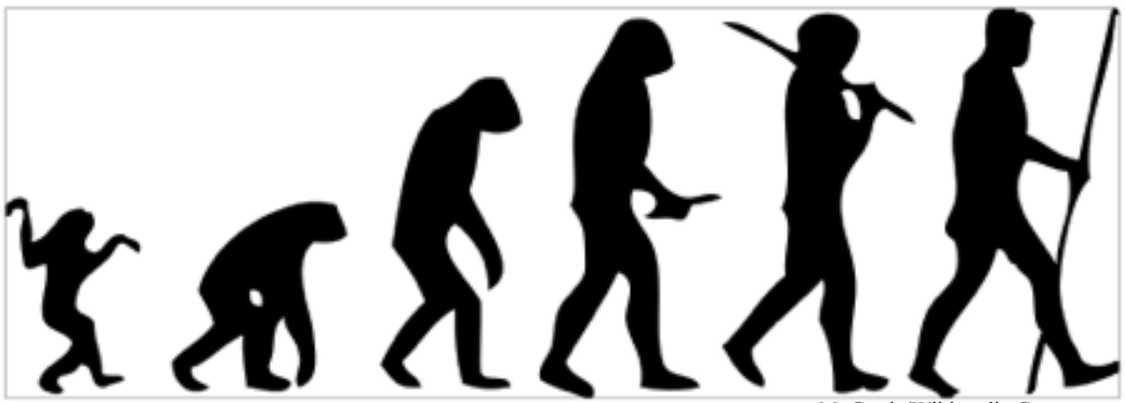
Optimists will tell you that evolution would naturally drive life towards intelligence, but this may not necessarily be true - a non-intelligent simple life form may be very well adapted to its environment and may not evolve significantly.

The fact that intelligent life has arisen once in the Galaxy does not, of necessity, mean that it must be common.

It is thus virtually impossible to make an accurate estimate for this factor and it could be the one, along with an estimate of L, that really determines how likely we are to come into contact with another civilization.

Intelligence is not the "goal" of evolution

- Intelligence is a natural outcome of diversity, filling a niche that is clearly very successful for humans and other species too.
- Intelligence is just one niche to fill, like wings or eyes or any other mutation.
- On Earth, it took billions of years to fill that niche. Will it happen easily on other planets? Not at all?



M. Garde/Wikimedia Commons

Evolution on Earth has the main objective of diversity in order to find a niche for species to flourish. So, intelligence is not the goal of evolution, it is a trait that fills a niche.

It is important to note that intelligence on Earth is a broad spectrum. Many animals exhibit intelligent behaviors, even utilizing many behaviors previously thought to belong only to humans for beneficial purposes.

Intelligent life is a very recent development on Earth, having taken billions of years to arise. Everyone agrees that Earth's particular evolution will not necessarily occur on other planets.

Optimist Drake Equation

Frank Drake








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

# 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 commun-icate	Lifetime of advanced civilizations
	10 stars/yr	1 systems/ star	0.2 planets/ system	1 life/ planet	1 intel./ life	1 comm./ intel.	1 billion yrs/ comm.

Optimist guess is about 2 billion alien civilizations!

The optimist would say that the Galaxy is teeming with advanced civilizations! So where are they?

Pessimist Drake Equation

Frank Drake








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

# 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 commun-icate	Lifetime of advanced civilizations
	1 stars/ yr	0.5 systems/ star	0.04 planets/ system	0.01 life/ planet	0.01 intel./ life	0.1 comm./ intel.	1000 yrs/ comm.

Pessimist guess is about 0.0002 alien civilizations!

The pessimist would look at the Drake Equation and say, we're likely the only intelligent civilization out there right now.

What's your answer?

There is no right answer. Even for the best guess answer, the nearest alien would be thousands of light years away – the Galaxy is big. The main point is that alien life is possible, maybe even probable.

My Drake Equation

Frank Drake








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

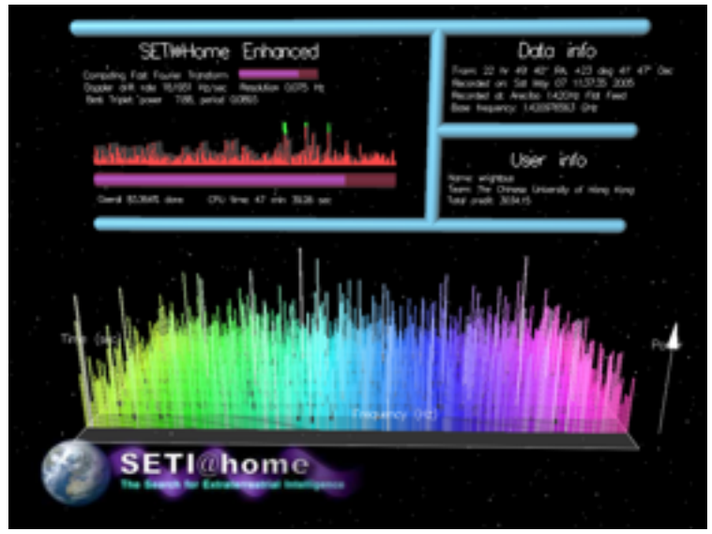
# of advanced civilizations we can contact in **our Galaxy** today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	5 stars/ yr	0.9 systems/ star	0.04 planets/ system	0.5 life/ planet	0.5 intel./ life	0.5 comm./ intel.	10,000 yrs/ comm.

My guess is about 225 alien civilizations!

No right answer. Even for the my best guess answer, the nearest alien would be **thousands** of light years away-- the Galaxy is big. The main point is that alien life is possible, maybe even probable. The next question is do we communicate with them?

How to Communicate with ET?

- If ETs are out there, how do we go about detecting our neighbors?
- Are we seriously sending out messages now?
- No.
- We are relatively a young civilization, with radio technology for only a hundred years.
- Right now, we are mostly a passive “lurker” civilization.



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We attempted Contact a few times

- The first real signal sent was in 1974 by the Arecibo telescope (20 trillion Watts of power).
- It was sent as a series of on/off signals that could be re-arranged into the series on the left.

We attempted Contact

- Or, if you colored in the ones, you can make an image.
- Sent toward the globular cluster M13 which is 21,000 lyrs away.
- Not very likely to have life.. too old, not enough heavy elements-- it was really a publicity stunt.

Now, we wait….. If they're looking, a SETI experiment will detect this. But human experts had trouble decoding it. There has been other attempts, with better encoding, but only a few nearby stars.

Interstellar Travel

- But, what if all communication with ET fails?
  - Wrong frequencies.
  - Everyone is listening and no one is broadcasting.
  - We fail to recognize the signal.

- We can go visit them or the microbes. "To boldly go…"
- BUT, the distances are huge!
- Nearest star is 4.3 ly away or around 4 x 10^{13} km!
- **40,000,000,000,000 km! 40 TRILLION km!!!**
- The fastest long-term spacecraft, Voyager, would take nearly 100,000 years

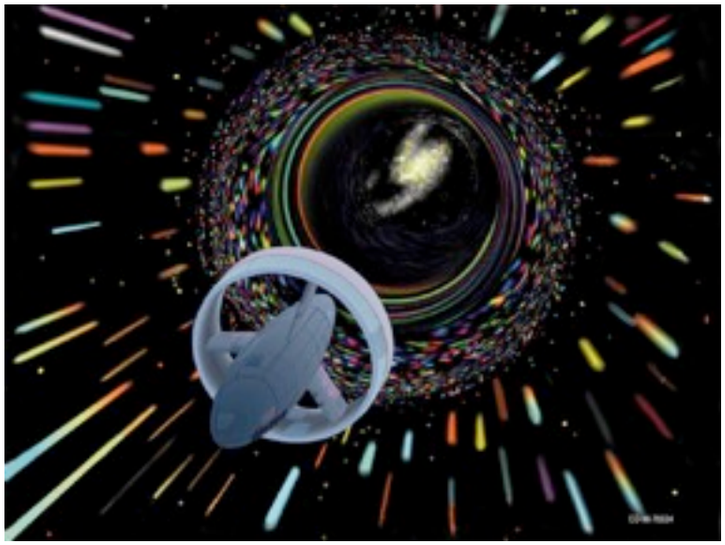
Problems to Overcome?

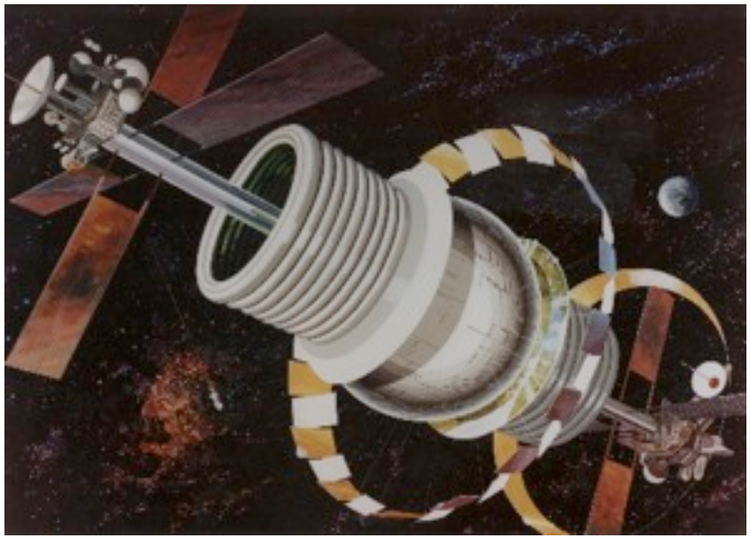
1. Space is Big.
   - Nothing we can probably do about this one.
2. Time.
   - Because of #1, interstellar travel would take a lot of time.
   - But arguably do-able.
     - Maybe lifetime is expanded, generation ships, suspended animation, or intelligent robots.
     - Might be able to reach 0.1c in the future, but unlikely to go faster than that.
3. Cost
   - Right now, colossal budget of a few trillion dollars. Impossible now, but in the future?
   - Medieval blacksmiths could have made an oil tanker, but too costly. 500 years later, piece of cake.
   - In future, cost of interstellar travel may also go down.

Due to great distance between the stars and the speed limit of light, sci-fi had to resort to "Warp Drive" that allows faster-than-light speeds. Currently, this is impossible. It is speculation that requires a revolution in physics. It is science fiction! But, we have been surprised before… Unfortunately new physics usually adds constraints not removes them.

Getting Out of Here

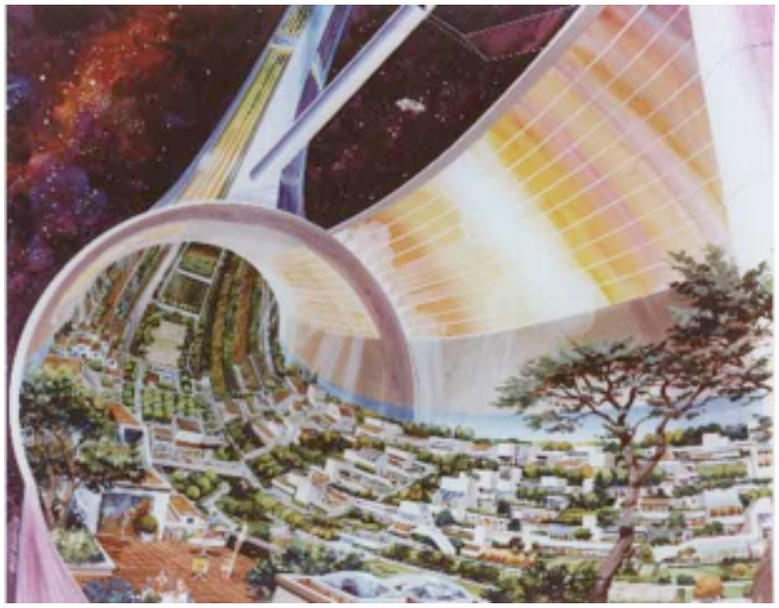
- Distances between stars are much greater than we can imagine– freaky big distances, plus difficult environment and the time required makes interstellar travel hard to conceive.
- Sci-fi books and movies have dramatized space travel to make it seem possible
  - But, interstellar travel may never happen

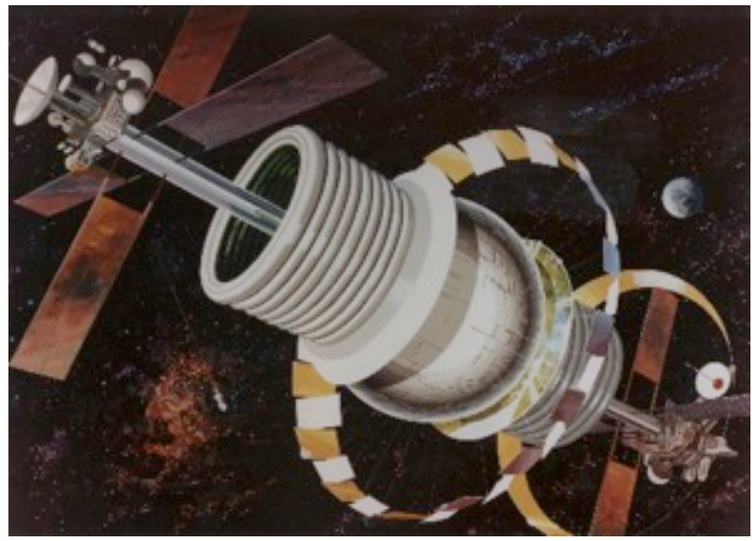


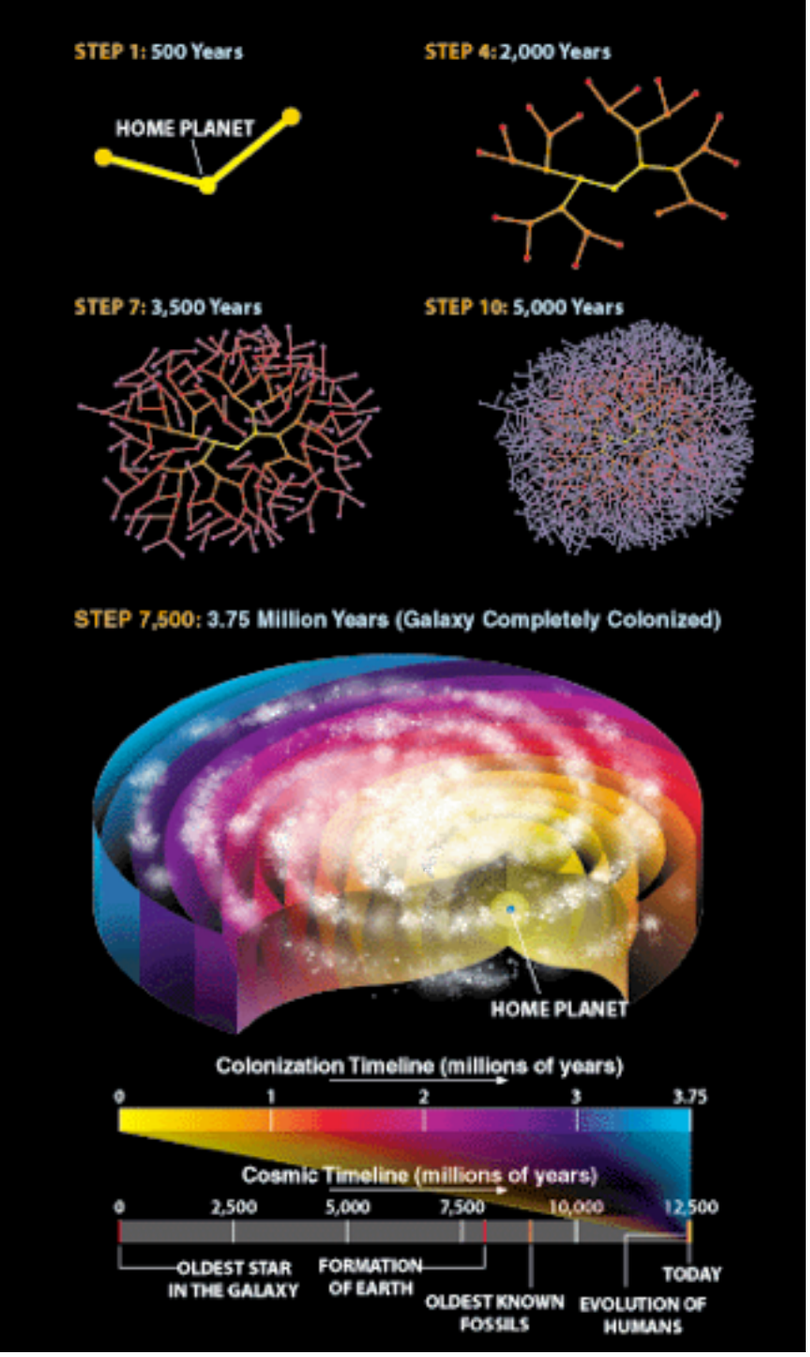


How long to colonize the Galaxy?

- With 0.1c, we can travel 10 light years in 100 years
- Can reach the nearest star in 43 years
- How long to colonize the Galaxy?



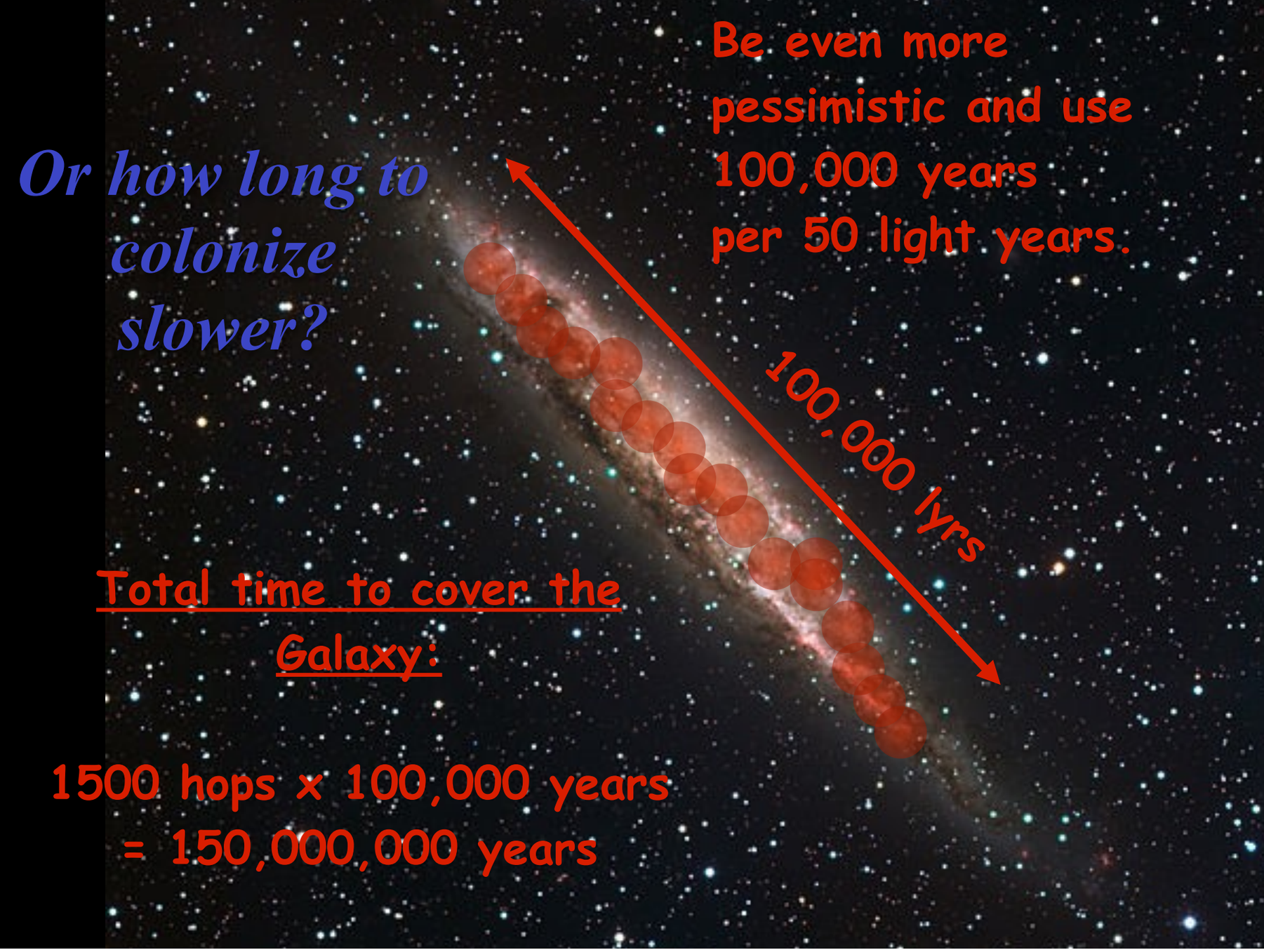




Optimistic

Every 500 years, the colonization craft makes it to the next suitable solar system– small delay.

Colonization only takes about 4 million years!



Or how long to colonize slower?

Total time to cover the Galaxy:

1500 hops x 100,000 years = 150,000,000 years

The Fermi Paradox

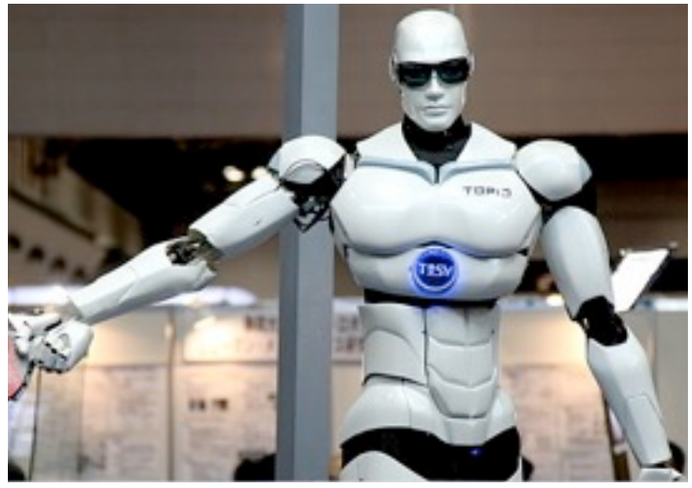
The Drake Equation – Even for a few hundred technical civilizations.

Only 150 million years to colonize the Galaxy.

WHERE IS EVERYBODY?????

The Fermi Paradox

- Given some ET civilizations, one of them must have developed earlier than we did.
- So "Where are they?"
- Even if interstellar travel is very slow and difficult, there has been a lot of time to do it.
- Furthermore, many of the objections to interstellar travel do not apply to artificial intelligence (intelligent robots.)



Timescales

- For pessimist: 150 million years to colonize the Galaxy.
- For optimist: 4 million years to colonize the Galaxy.
- This may seem like forever, but it is actually pretty tiny compared to the time it takes evolution (about 0.1%).
- So, if we believe our condition, there should only be one intelligent family of species in our galaxy - whoever reached intelligence first should have spread everywhere before anyone else reaches intelligence.
- This is the main point of the Fermi Paradox.
- Where are they?

Fact 1

It is possible that extraterrestrial intelligent (ETI) life is abundant in our galaxy

- With 100 billion stars and plenty of opportunities for life to develop.
- There are clear arguments for common life.

Fact 2

If ETI is abundant in our Galaxy, then we expect that, statistically, there exists or have existed ET civilizations that have achieved a technological capability greater than that which we now demonstrate– an advanced civilization!

- We took about 4.5 billion years on Earth, but it could easily be only 3.5 billion years somewhere else, then another civilization could easily have a 1 billion year jump on us.
- An intelligent civilization can do a lot in a billion years

Fact 3

The distances and times associated with interstellar travel are great, but as far as we know, it is conceivably possible that a civilization conducts significant interstellar exploration, especially with enough time.

- At very least, a more advanced civilization could have sent out self-replicating nanoprobes across the Galaxy.

Fact 4

It is possible therefore that an ET civilization has explored our region of the Galaxy, the Sun, and even our Earth at some point in its history

- This is not pseudo-science but real logical consequences of abundant ETI.

Fact 5

We have no reason to believe that this has not happened

- We also have no reason to believe that it has.
- It is an open question.

What are we left with?

- These are two distinct but still very significant claims
  - The Earth has been visited by ETs.
  - The Earth has not been visited by ETs.
- Neither of these statements has been validated.
- So, the only statement we can make is
  - We do not know whether or not the Earth has been visited by ETs.
  - Yeah, doesn't sound like a powerful statement, but if you think about it is

UFO Phenomenon

- Some argue that we have proof:
  - UFO sightings.
  - Strange historical accounts or grand technological accomplishments of humans in the past.
  - Alien abductions.
- This all falls into the realm of pseudo-science.
- There has never been any concrete evidence of extraterrestrials having anything to do with UFOs.
- UFOs could be so very many things. Why assume automatically that there is an otherworldly explanation? But those who want to believe will do so even despite evidence to the contrary.
- Remember that "**Extraordinary Claims Require Extraordinary Evidence**" - Carl Sagan.

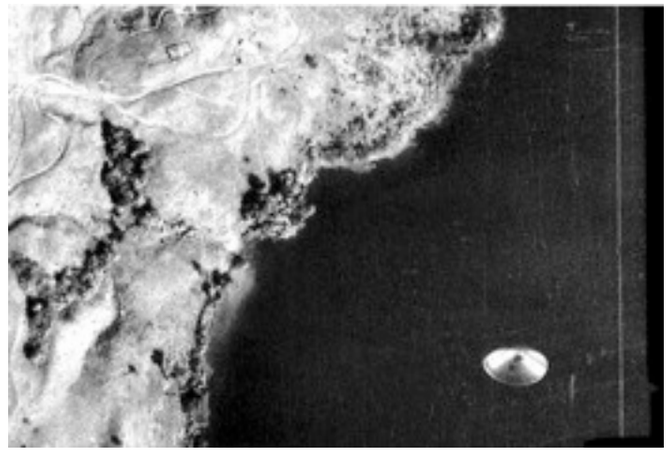
So far no reliable evidence exists for ET visitation. But, the idea that we have been visited and traces exist somewhere is a valid THEORY! (Here I even mean scientific theory.) Maybe it is improbable, but it is still valid

BUT, don't expect people to believe your theory unless it is substantiated with reliable evidence. It is what is expected of ANY scientific theory.

Problems?

Large number of sightings argues **against** alien spacecraft.

- Space is freaky big.
- There are extreme difficulties of interstellar space travel and the number of planets to explore.
- So, why would so many alien spacecraft be visiting the earth constantly?
  - There are other planets to check out.
  - What makes us so interesting?
  - We should not overestimate our significance.



So, where are the aliens?

Have we been visited by ETs?

Extraordinary Claims Require Extraordinary Evidence

UFO just means “Unidentified Flying Object”, nothing to do with aliens necessarily
When they are identified, they are normally weather balloons, 747s, Venus, etc…
Even after all you’ve heard and all you’ve read in the Enquirer, there is has been no reliable proof of any UFOs being ETs

Possible solutions to the Fermi Paradox

1. We are alone: life/civilizations much rarer than we might have guessed
2. Civilizations are common but interstellar travel is not. Perhaps because:
   - Interstellar travel too difficult
   - No desire to explore? - Not if they're like us!
   - Civilizations destroy themselves before achieving interstellar travel
3. There IS a galactic civilization…
   …and some day we'll meet them…

#1: Our own planet/civilization looks all the more precious…
#2: These are all possibilities, but not very appealing…
#3: A truly incredible possibility to ponder…

Give Me Real Evidence!

- Evidence:
  - A piece of a probe or spaceship
  - Some trace that can be uniquely linked to an ET probe
  - Biological material.
  - A reliable, logical calculation

- That is the same we require of ANY scientific investigation

http://www.alien-ufos.com/images/ufos/miscufo4.jpg

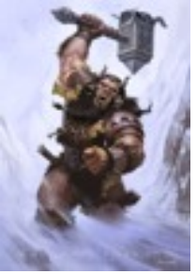
Other Ideas: Space Probed

- A single probe is constructed and dispatched to a nearby star system
- It surveys the system in an intelligent and exhaustive manner
- After which, the probe uses the energy and available raw materials of the system to reproduce itself .
- Often called a Neumann Space Probe

Neumann Space Probed

- Dispatches its “children” onwards to repeat its mission in other star systems
- The parent probe is then able to choose whether it wants to stay in the system or not, depending on what it found
- Armchair explorers

http://www.biochem.wisc.edu/wickens/meetings.html

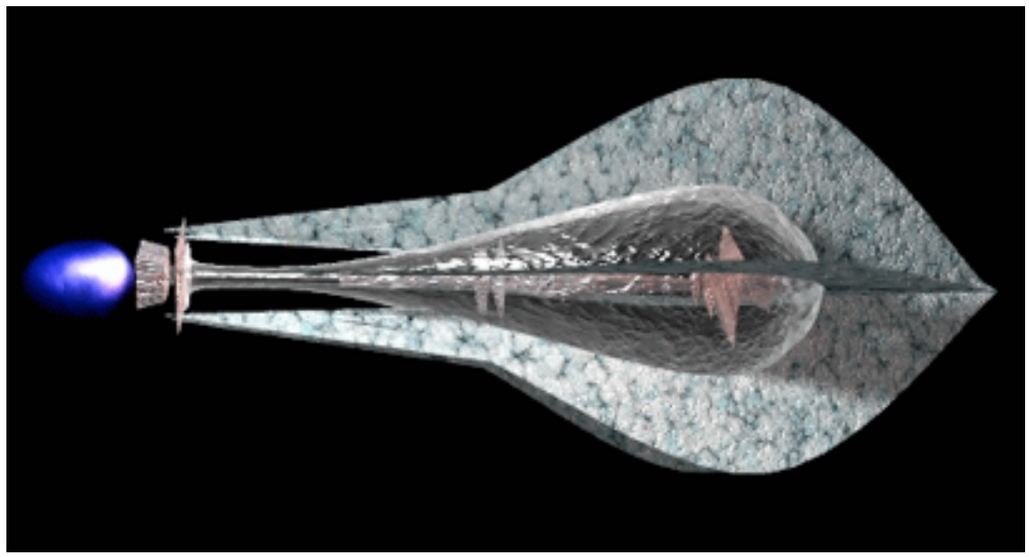


Neumann Space Probe BERSERKERS!!!!!!

- Self-Replicating Devices
- Openly hostile to life forms
- Out of control
- Probe ecosystem?
- Programmed to evolve?

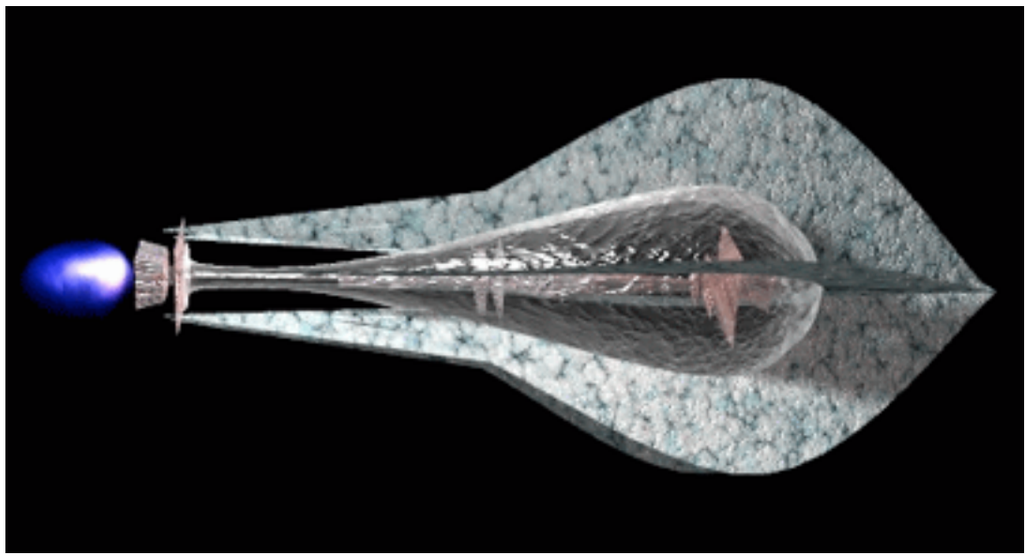
Neumann Space Probed

- What if it's armchair generals instead of explorers.
- Decide to change the galaxy by force?
- What if programming goes crazy, and the objects decide to ignore the explore part and focus on only the replicate part?
- Might be a larger possibility than we thought.



Mitigation

- I dunno.
- Send out our own probes?
- Make sure to get vaccinated for space flu?
- Destroy all life friendly planets in case they evolve after us?
- I prefer to just explore the Universe, and let's see what's out there!



Bottom-line

- We have probably not been visited by aliens; there is **no** evidence.
- To me, alien reports are images of human psyche.
- But, our Drake equation estimate suggest that extraterrestrial life is common.
- So the Fermi Paradox: “Where are they?”
- I would argue that we keep trying to figure out the Universe, look at the concept of extraterrestrial life with a critical eye, fill in our gaps of knowledge, and the search is on.

Imagine

- Astronomers notice something bright in gamma-rays moving into the Solar System.
- The object is changing course!
- Contact! But it isn't responding to our hails.
- The object passes by the asteroid belt, but then starts to move out of the Solar System.
- Excitement dies down, but a year later, an asteroid starts to change orbit and move toward Mars.
- The asteroid has factories and "lands" on Mars.
- Robotic spiders are building more and more factories, and with our orbiting spacecraft, we watch.

Imagine

- Within a few years, the surface of Mars is picked clean, as micro-factories replicate huge numbers of alien robot-like organisms and spacecraft.
- A year later, objects start to lift off from Mars, and they are coming toward Earth!
- As they land, there is nothing we can do.
- They begin to destroy the surface of the Earth, making more replicates of themselves.
- As you are ripped apart for your heavy elements, you wonder why you didn't pay attention during the last few days of Leslie's class.

The End May be in Sight!

There are real and cosmic hazards to life on earth.

- Some of which are unavoidable

We may have experienced them in the past.

- Could explain lack of evident life in galaxy.

Some of these will happen in the future, and we shall have to leave earth eventually to insure the further existence of humans in our Galaxy.

But for now, everything is fine

is fine...

is fine...

is fine..

is fine....


Thank You &
Good Luck! ☺