The History of the Universe in 200 Words or Less

Quantum fluctuation. Inflation. Expansion. Strong nuclear interaction. Particle-antiparticle annihilation. Deuterium and helium production. Density perturbations. Recombination. Blackbody radiation. Local contraction. Cluster formation. Reionization? Violent relaxation. Virialization. Biased galaxy formation? Turbulent fragmentation. Contraction. Ionization. Compression. Opaque hydrogen. Massive star formation. Deuterium ignition. Hydrogen fusion. Hydrogen depletion. Core contraction. Envelope expansion. Helium fusion. Carbon, oxygen, and silicon fusion. Iron production. Implosion. Supernova explosion. Metals injection. Star formation. Supernova explosions. Star formation. Condensation. Planetesimal accretion. Planetary differentiation. Crust solidification. Volatile gas expulsion. Water condensation. Water dissociation. Ozone production. Ultraviolet absorption. Photosynthetic unicellular organisms. Oxidation. Mutation. Natural selection and evolution. Respiration. Cell differentiation. Sexual reproduction. Fossilization. Land exploration. Dinosaur extinction. Mammal expansion. Glaciation. Homo sapiens manifestation. Animal domestication. Food surplus production. Civilization! Innovation. Exploration. Religion. Warring nations. Empire creation and destruction. Exploration. Colonization. Taxation without representation. Revolution. Constitution. Election. Expansion. Industrialization. Rebellion. Emancipation Proclamation. Invention. Mass production. Urbanization. Immigration. World conflagration. League of Nations. Suffrage extension. Depression. World conflagration. Fission explosions. United Nations. Space exploration. Assassinations. Lunar excursions. Resignation. Computerization. World Trade Organization. Terrorism. Internet expansion. Reunification. Dissolution. World-Wide Web creation. Composition. Extrapolation?

Astronomy 330

This class (Lecture 10):

Origin of the Moon

Next Class:

Our Planet
Daniel Miller-McLemore
Alexandra Timm

HW 4 is due Wednesday!

Music: *3rd Planet* – Modest Mouse

HW 2

- **Janet Pauketat**
  http://www.abduct.com/features/f49.php
- **Joshua Brickman**
  http://www.greatdreams.com/end-world.htm

Presentations

- **Joshua Beckman**
  Alien Communication Past, Present, Future
- **Christopher Bisom**
  Extraterrestrials: Through the Looking Glass

Outline

- f_p
- n_e
- What's up with the Earth?
- What do we need for a life-suitable planet?

Drake Equation

Frank Drake

That's ? planetary systems/year

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

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
	10 stars/yr	? systems/star	planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

What Are We Looking For?

General Predictions of Solar Nebula Theory

- ☺ Are interstellar dust clouds common? ***Yes!***
- ☺ Do young stars have disks? ***Yes!***
- ? Are the smaller planets near the star?
  - *Not the ones found so far! Haven't found smaller planets yet!*
- ? Are massive planets farther away?
  - *Not most of the ones found so far!*

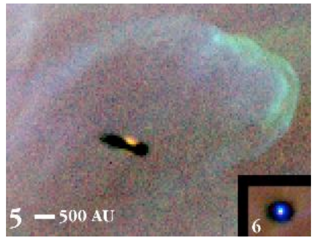
Disks in Binary Systems

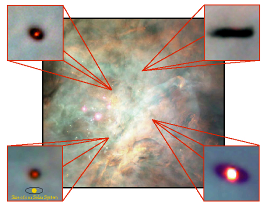
- >60% of all stars are in binary or multiple systems.
- We do see circumstellar disks in binary systems
- We do see exoplanets in binary systems.

- But we also see effects of the binary on the disk.
  - Still unclear how large of an effect.

Now, for f_p

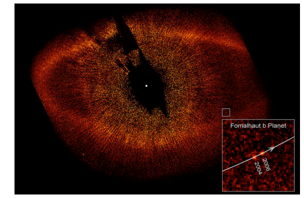
- About 2/3 of all stars are in multiple systems.
  - Is this good or bad?
- Disks around stars are very common, even most binary systems have them.
- Hard to think of a formation scenario without a disk at some point– single or binary system.
- Disk formation matches our solar system parameters.
- We know of many brown dwarfs, so maybe some planets do not form around stars.
  - There might be free-floating planets, but…

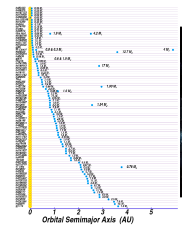


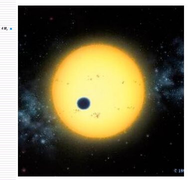


Now, for f_p

- Extrasolar planet searches so far give about $f_p \sim 0.03$, but not sensitive to lower mass systems.
- Maximum is 1 and lower limit is probably around 0.01.
- A high fraction assumes that the disks often form a planet or planets of some kind.
- A low fraction assumes that even if there are disks, planets do not form.
- <u>This is not Earth-like planets, just a planet or many planets.</u>







Drake Equation


Frank Drake

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 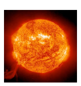 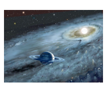     

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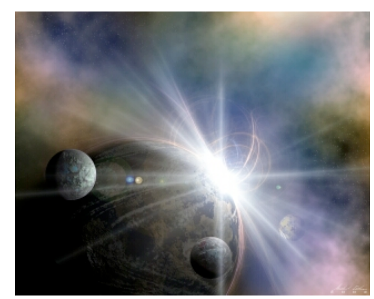
n_e

Complex term, so let's break it into two terms:

- n_p: number of planets suitable for life per planetary system
- f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

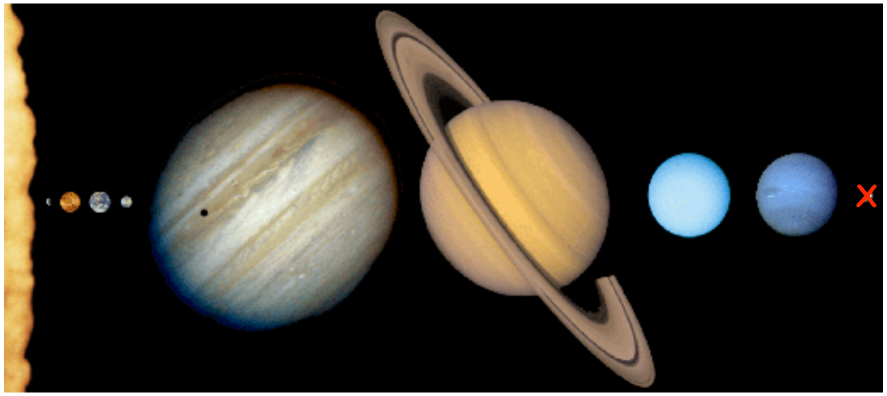
$$n_e = n_p \times f_s$$

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg



Our Solar System

Terrestrial planets and Gas Giants… but how many are valid planets/moons for n_p?



Earth-Moon Comparison

Radius	6378 km	Radius	0.272 Earth
Surface gravity	9.8 m/s^2	Surface gravity	0.17 Earth
Mass	6.0x10^{24} kg	Mass	0.012 Earth
Distance to Sun	1.5x10^8 km	Distance to Earth	384,000 km
Year	365.2422 days	Orbital Period	27.3 days
Solar day	1 day	Solar day	27.3 days

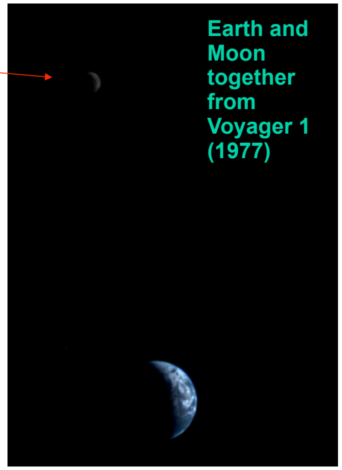
Formation of the Earth

- Earth formed from planetesimals in the circumstellar disk.
- Was hot and melted together.
- The biggest peculiarity, compared to the other planets, is the large moon.

A Double World

Why a "double world"?

- Most moons are tiny compared to the planet
  - The Moon is over 25% the diameter of Earth
  - Jupiter's biggest moons are about 3% the size of the planet
- The Moon is comparable to the terrestrial planets
  - About 70% the size of Mercury
  - Nearly the same density as Mars



The Moon

The Moon's surface is barren and dead

- No water, no air, some water ice.
- No life!!

Formation of the Moon: Smack

- Collision of Earth with a Mars-sized body early in the solar system's history
- Iron-rich core of the impactor sank within Earth
- Earth's rotation sped up
- Remaining ejecta thrown into orbit, coalesced into the Moon
- http://www.youtube.com/watch?v=ibV4MdN5wo0&feature=related

Why is this a good hypothesis?

- The Earth has a large iron core (differentiation), but the moon does not.
  - The debris blown out of collision came from the rocky mantles
  - The iron core of the impactor merged with the iron core of Earth
- Compare density of 5.5 g/cm^3 to 3.3 g/cm^3— the moon lacks iron.

http://www.flatrock.org.nz/topics/odds_and_oddities/assets/extreme_iron.jpg