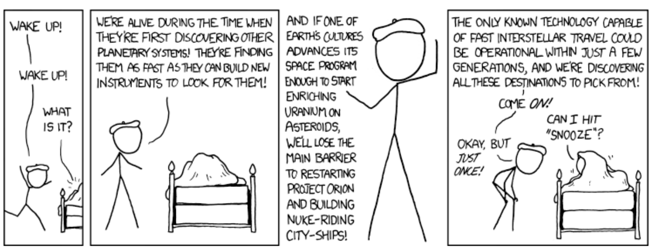
The History of the Universe in 200 Words or Less

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:

Extraterrestrial Life



<u>This class (Lecture 9):</u>

Origin of Planets

Jeff Lu

<u>Next Class:</u>

Exoplanets

Zachary Brewer
Quinn Calvert

Music: *Champagne Supernova* – Oasis

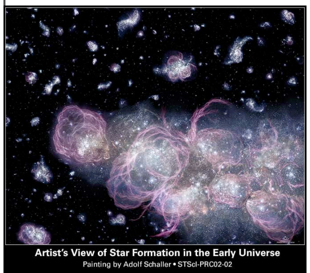
HW #3 due Sunday night.

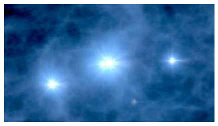
HW #2

- Cassandra Jensen
  http://www.aliens-everything-you-want-to-know.com/AlienAbductions.html
  Covered many topics thoroughly, but Men in Black are real

- Vincent Abejuela
  http://www.one-mind-one-energy.com/biocommunication.html
  Plants are sentient as an ancient defense mechanism behavior, but premise is flawed.

First Stars





First stars formed from primordial gas

Likely more massive (top heavy IMF)

Universe smaller, more dense

Increased production of heavier elements

Enrich Interstellar Medium

4

IMF = Initial mass function which is the distribution of stellar mass when stars are initially born in a molecule cloud

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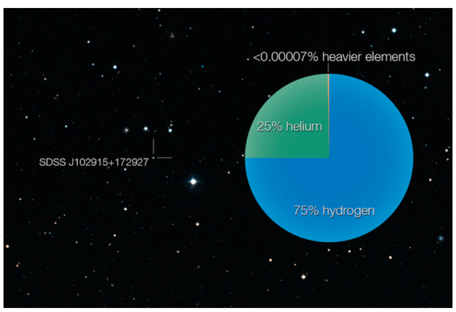
Second Stars

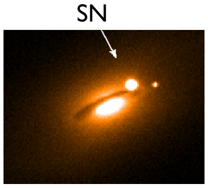
Made from the leftovers of the first generation of stars.
Enriched with new elements (still low numbers though)

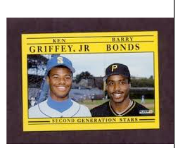


No significant source of nitrogen yet.

Second Generation

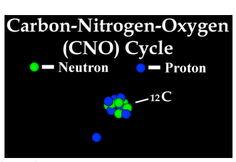
SN





Carbon and Oxygen provide alternate fusion pathways

CNO cycle more efficient than PP chain in stars more massive than the Sun

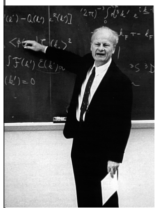


CNO produces most of the Nitrogen in the Universe

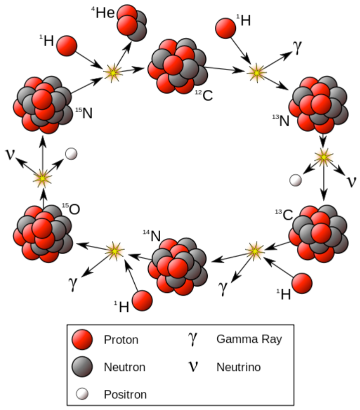
6

The first stars blew up their new elements into the proto-galaxy. Now, the second stars form in the ashes of the first. With C and N, the 2nd generation can form helium through the CNO cycle, in which most of the Universe's nitrogen is created. The 2nd generation also eventually explodes blowing nitrogen and the other elements into the galaxy.

CNO Cycle



Hans Bethe



Next Generations: Element Abundance

Percentage of heavier element increases towards center of MW galaxy

Sun is likely 3rd or later generation star given our Nitrogen abundance

Strong Nuclear force drives fusion

We are *STAR STUFF*!

The new atomic elements from the 1st and 2nd stars are spread out into the galaxy. The Sun must be at least a 3rd generation star as we have nitrogen in abundance. Indeed, the percentage of heavier elements is larger toward the center of the galaxy, where the first generation of stars probably formed. (Seen in ours and other galaxies.) Again, we are star stuff. Keep in mind that this is all from the nuclear strong force– fusion.

Are we alone?

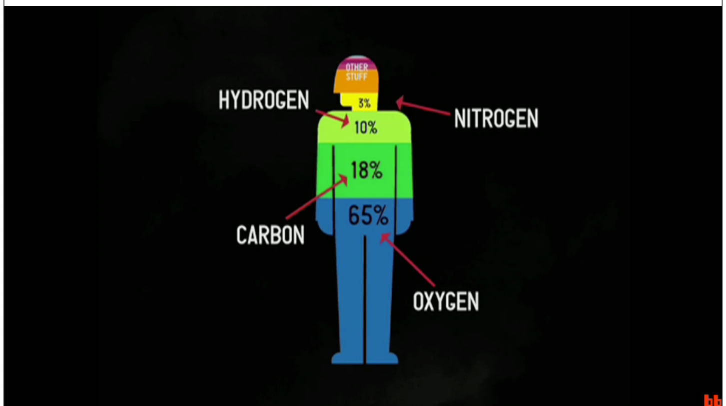
Life as we know it requires **HONC**

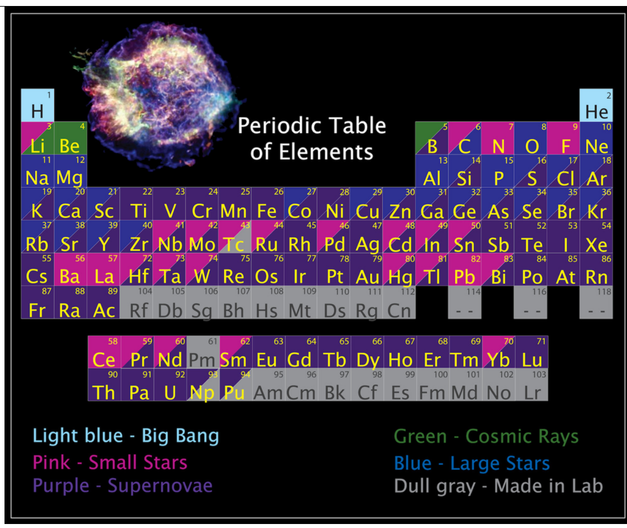
Big Bang 75% **H**ydrogen 25% **H**elium

Galaxies Star Factories Stars Carbon, Oxygen, Nitrogen, ...

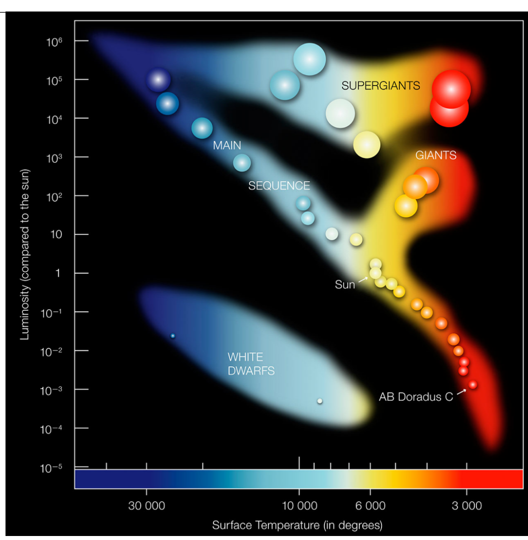
One slide to summarize this class

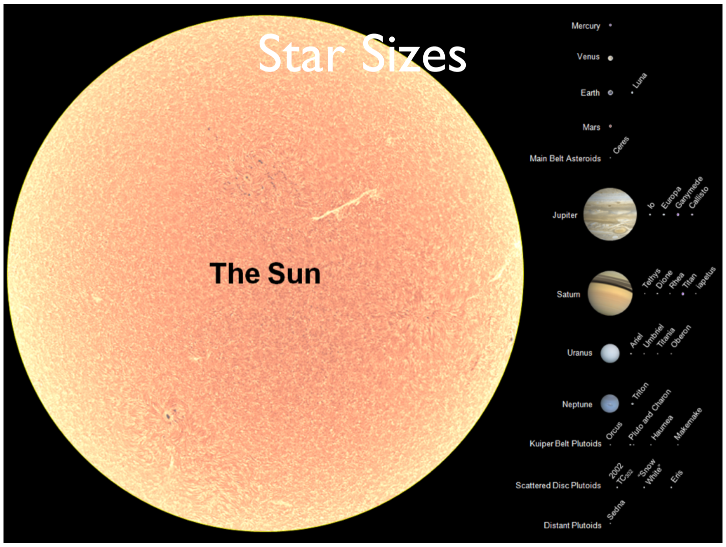
The Elements

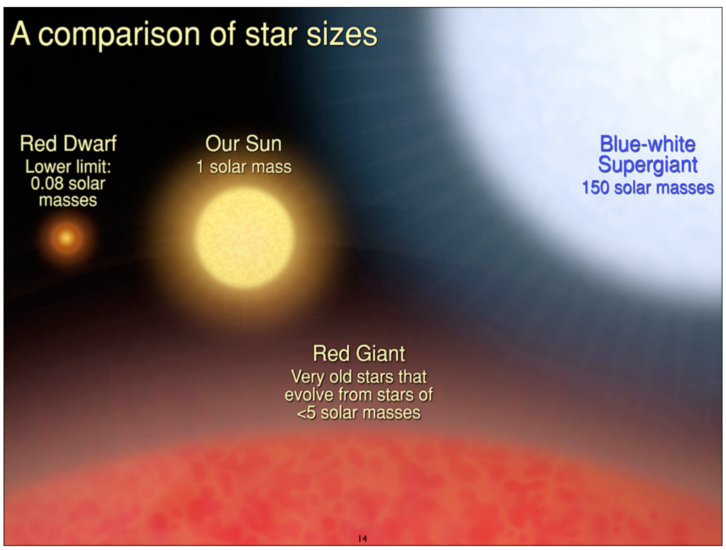




astronasty







http://www.youtube.com/watch?v=HEheh1BH34Q

Question

HONC is important for life. In which order did these elements first appear in the Universe?

a) H, O, N, C
b) All at once
c) H, C, O, N
d) N, O, H, C
e) C, O, N, H

Drake Equation

Frank Drake

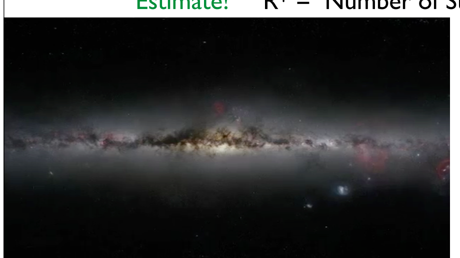
The class's first estimate is

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

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.

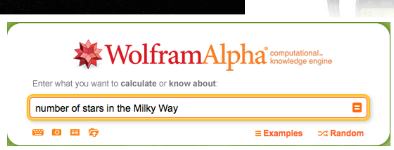
Counting Stars

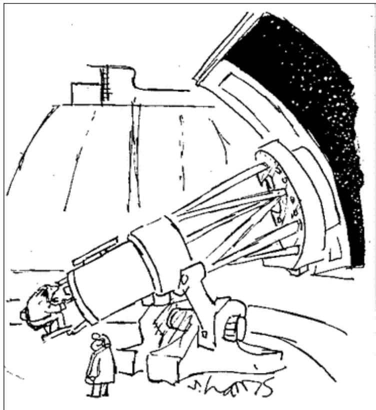
Estimate! R* = Number of Stars / Age of Galaxy



How old is Galaxy?

How many stars?





"Let's see, now ... picking up where we left off ... one billion, sixty-two million, thirty thousand, four hundred and thirteen ... one billion, sixty-two million, thirty thousand, four hundred and fourteen ... "

Counting Stars

Star Formation Rate

How many stars?

$$N_* = 2 \times 10^{11} - 4 \times 10^{11}$$

All stars of any mass.

How old is Galaxy?

$$13.7 \times 10^9 \longrightarrow 10 \times 10^9$$

$$R_* = \frac{2 \times 10^{11} - 4 \times 10^{11}}{10 \times 10^9} = 20 - 40$$

within a factor of ten

Best estimate for a term in Drake Equation!

Estimate of R_*:
Discuss

Counting Stars

Age of stars

Unknowns

Stellar Mass & Life

Dust

Binaries

$$R_* = \frac{2 \times 10^{11} - 4 \times 10^{11}}{10 \times 10^9} = 20 - 40$$

Galaxy Age

1. Discuss the calculation of this value.
2. Choose a lower/higher number if you think that the star formation rate was biased by non-uniform star formation.
   - Did the early galaxy produce more stars in the past than it does now? Was there a starburst long ago?
   - But remember that we are constantly obtaining new gas from our satellite galaxies (around 1 solar mass per year). It might average out.

Drake Equation

Frank Drake

The class's first estimate is

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

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

WWPC?

Why would **Paul** care?

Life Requirements?

How did our solar system form?

How rare is our system?

Is our system unusual?

Fraction with Planets

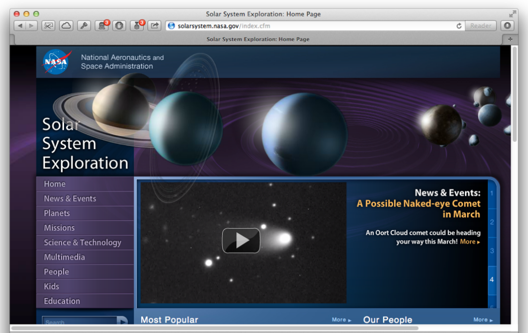
We need to understand how star systems formed!

Theory!

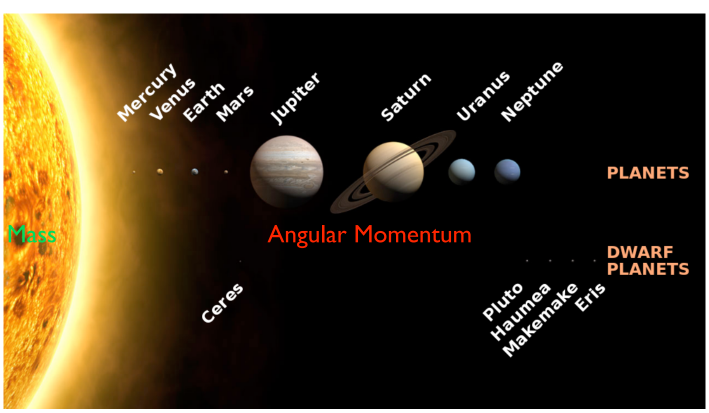
1) Explain present day solar system data.
2) Predict new solar system data.
3) Explain and Predict data from other stars.

Fraction with Planets

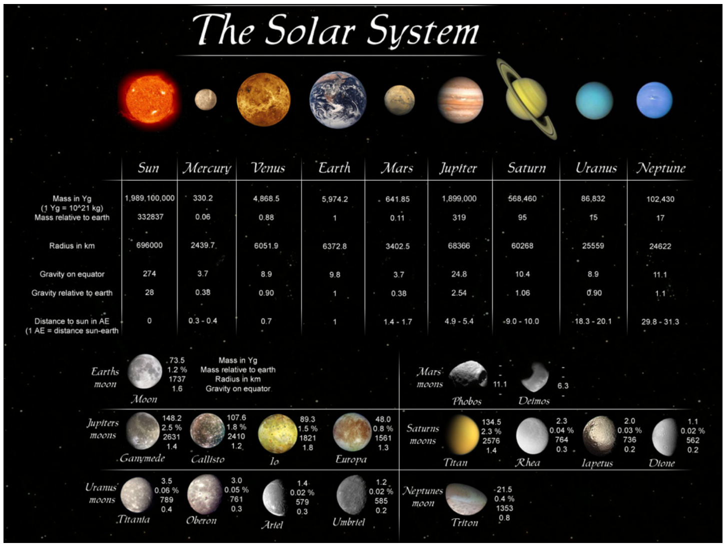
Where do we start?



Our Neighborhood



Most of mass in sun
Most of angular momentum in planets
Jupiter twice as massive as rest of planets combined.

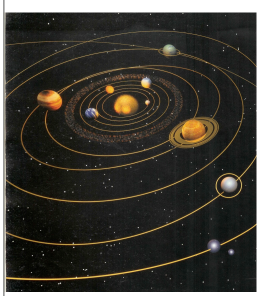


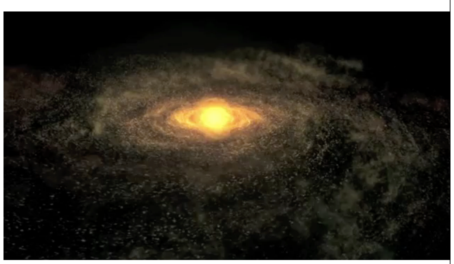
	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Mass in Yg (1 Yg = 10^21 kg)	1,989,100,000	330.2	4,868.5	5,974.2	641.85	1,899,000	568,460	86,832	102,430
Mass relative to earth	332837	0.06	0.88	1	0.11	319	95	15	17
Radius in km	696000	2439.7	6051.9	6372.8	3402.5	68366	60268	25559	24622
Gravity on equator	274	3.7	8.9	9.8	3.7	24.8	10.4	8.9	11.1
Gravity relative to earth	28	0.38	0.90	1	0.38	2.54	1.06	0.90	1.1
Distance to sun in AE (1 AE = distance sun-earth	0	0.3 - 0.4	0.7	1	1.4 - 1.7	4.9 - 5.4	9.0 - 10.0	18.3 - 20.1	29.8 - 31.3

Our Solar System

Coplanar planets

Ecliptic!





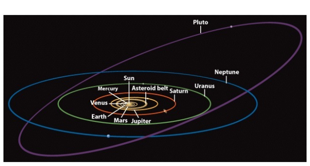
4 rocky planets close to sun

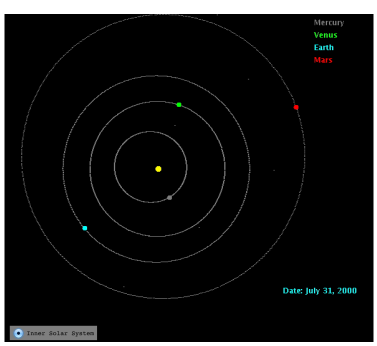
4 gas giants farther from sun

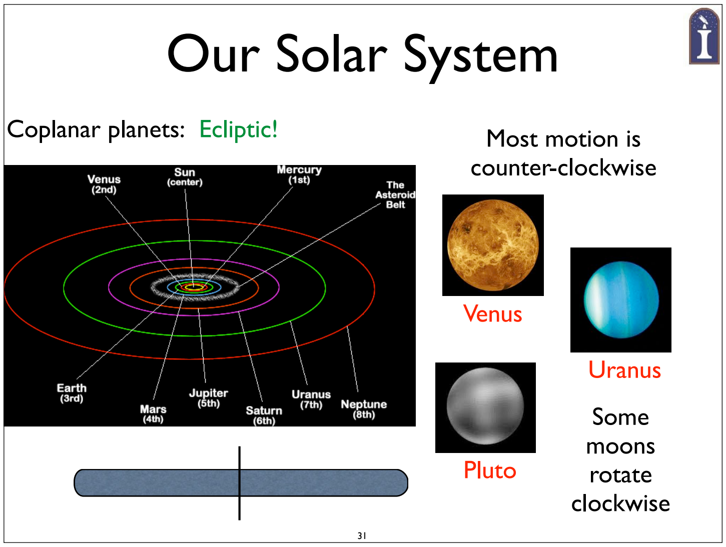
10 planets on average?

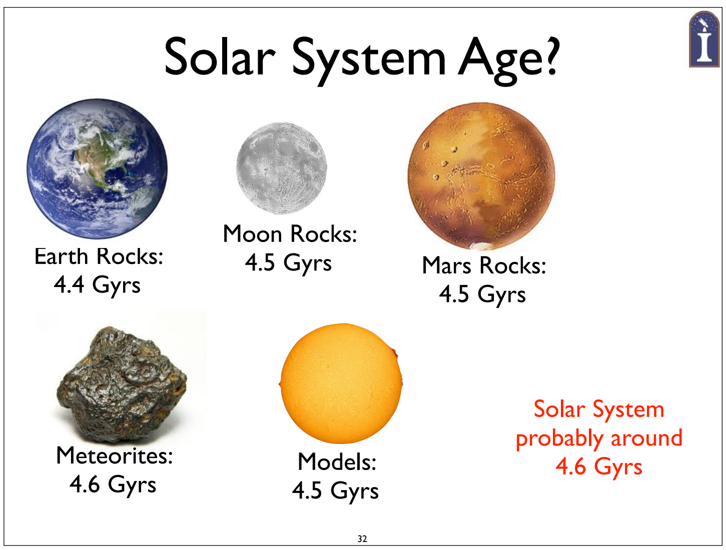
Our Solar System

Coplanar planets



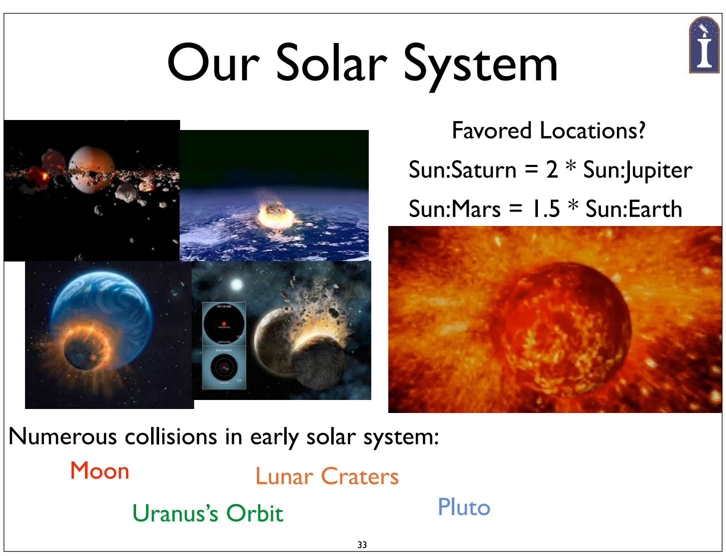


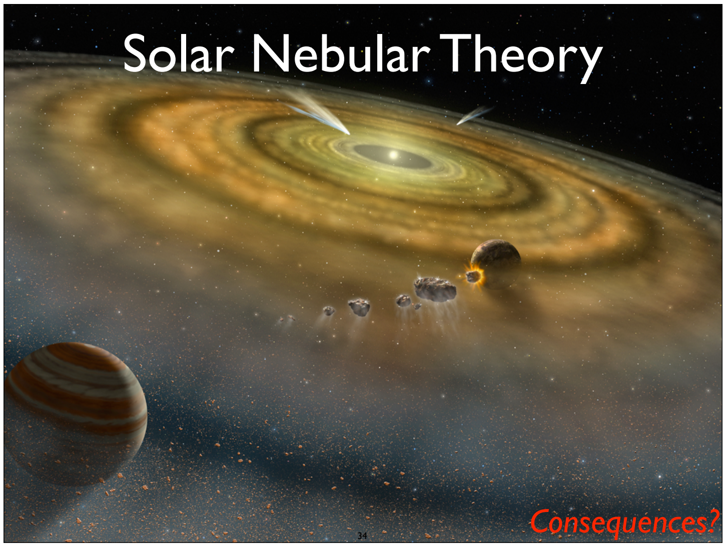




Earth: oldest rocks are 4.4 billion yrs
Moon: oldest rocks are 4.5 billion yrs
Mars: oldest rocks are 4.5 billion yrs
Meteorites: oldest are 4.6 billion yrs
Sun: models estimate an age of 4.5 billion yrs

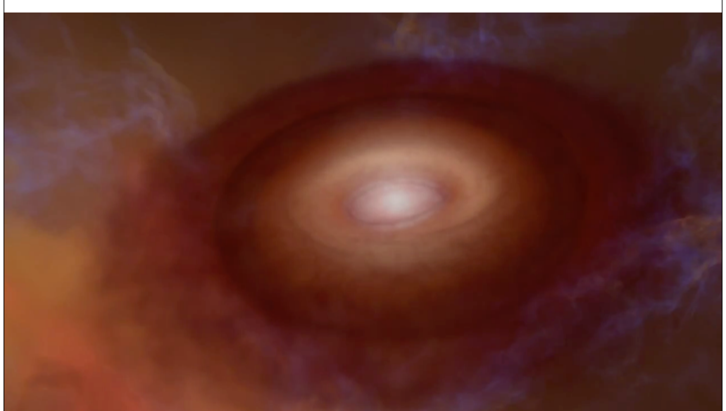
Age of Solar System is probably around 4.6 billion years old





http://astrobiology.gsfc.nasa.gov/mandell/images/mandell/BetaPic_fromNASA.jpg

Solar Nebular Theory



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The basic idea was put forth by Immanuel Kant (the philosopher)- Solar System came from a Gas Nebula.
4.6 billion years ago: a slowly spinning ball of gas, dust, and ice with a composition of mostly hydrogen and helium formed the early Solar System.
This matches nearly exactly with the modern idea of star formation.

Solar Nebular Theory

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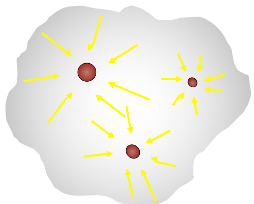
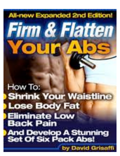
Stephen Hawking - Formation of the Solar System
https://www.youtube.com/watch?v=Uhy1fucSRQI&index=5&list=PLH37S3BiEx34x_Ybnmx-BD5fjeLFobBtN

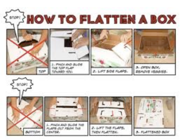
Cloud Contraction



Cloud Contraction

Not all mass falls radially. Spin leads to flattened structure.

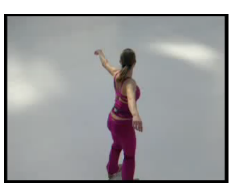


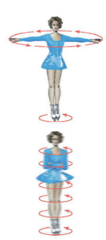


Angular Momentum

Spinning or orbiting objects in closed system have *angular momentum*

Angular momentum is a single, **constant** number.





Distance to axis constant: → Constant speed

Distance to axis decreases: → Increasing speed

Angular Momentum

Question

If a skater extends her arms while spinning, she will

a) slow down her rotation.

b) speed up her rotation.

c) experience no change.

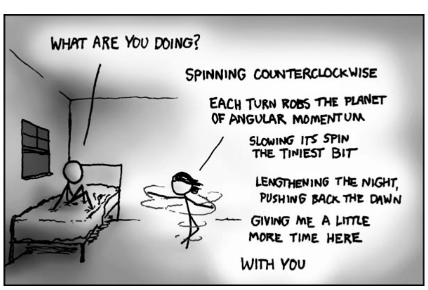
d) marry an alien.

e) fall over.

iClicker

A

Angular Momentum



Hmm ... Why Not?

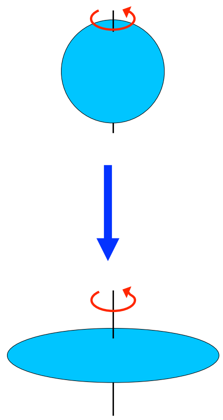
Solar Nebular Theory

Gravity versus ***Angular Momentum***

Collapse towards rotation axis:
matter must speed up
resistance from centrifugal force

Collapse parallel to rotation axis:
no resistance

Forms protoplanetary disk



Solar Nebular Theory

Predictions:

Young stars have disks

Disks contain gas & dust

Solar System should contain disk remnants