

ET Life



HW 2



- Stefanie Pansch
<http://www.alienshift.com/id53.html>
- Matthew Zettinger
<http://truthism.com/>

This class (Lecture 8):

Planet Formation

Seth Orr

Next Class:

Exoplanets

Paritosh Gangaramani

HW 3 is due Thursday

Music: *Why Does the Sun Really Shine?* – They Might Be Giants

Presentations



- Seth Orr
[Culture Clash](#)

Outline



- How did our solar system form?
- Circumstellar disks are the birth place of planets
- Circumstellar disks are common!

Groups

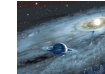


On Tuesday, we discussed the origins of the elements for life. In a few sentences, explain to your non-science major friends how HONC (the elements of life) were created.

Drake Equation

The class's first estimate is

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

20
stars/
yr

systems/
star

planets/
system

life/
planet

intel./
life

comm./
intel.

yrs/
comm.

So, Why would Spock Care?



If we are to suppose that ET life will be based on a planet orbiting a star, then we need to know

- How did our solar system form?
- How rare is it?
- Is our solar system unusual?



http://homepage.smc.edu/balm_simon/images/astro%205/spock.jpg

3 Lessons of Interstellar Molecules



1. Molecules with as many as **60 atoms** have evolved in places other than Earth.
 - In our Galaxy and beyond.
 - Hard thing is getting the lab data for searching for more complicated bio-molecules.
2. Dominance of **carbon** in interstellar chemistry. So perhaps carbon based life forms is not just Earth chauvinism.
3. Study of molecules in space illustrates the problems of molecules getting **more and more complex** and not being destroyed by UV light. That's why it wasn't expected.

Question



The molecules that life uses on Earth are complex.
In space

- a) no one can hear you scream.
- b) complex molecules can not be created. The environment is too harsh.
- c) complex molecules, up to 60 atoms, have been detected in large quantities.
- d) the only kind of molecules detected are missing C.
- e) all molecules are detected.

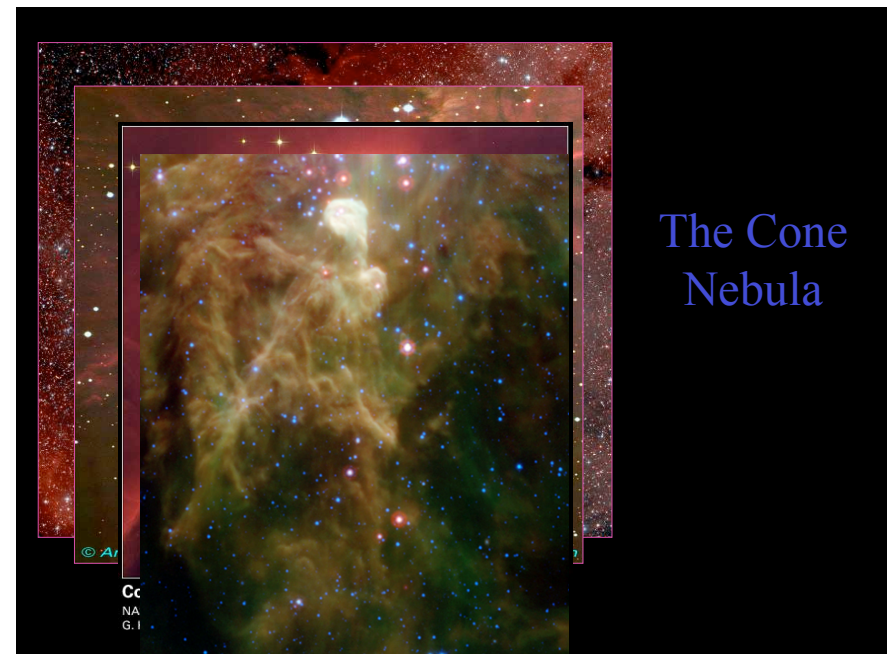
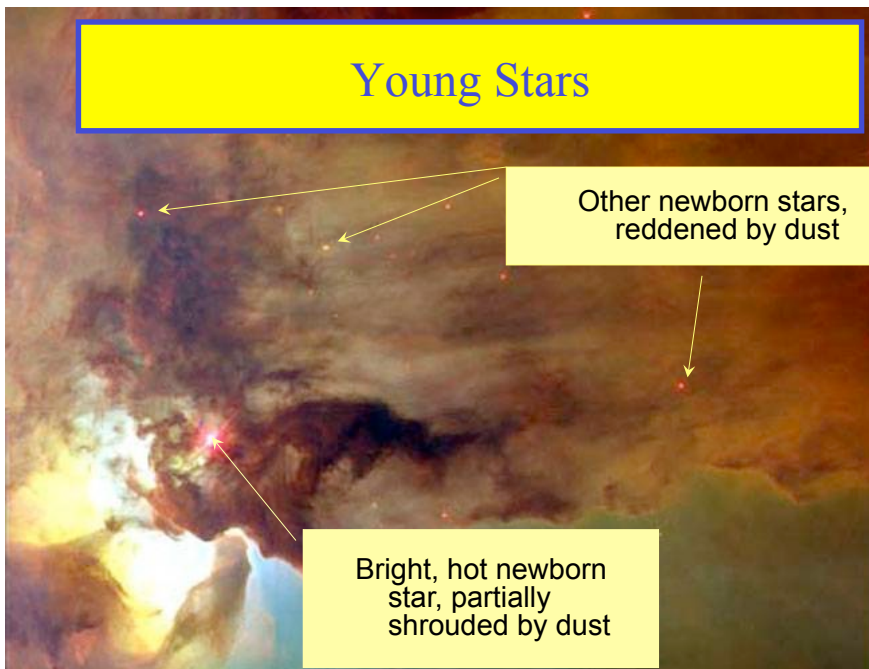
How Do We Know that Stars Form in Molecular Clouds ?



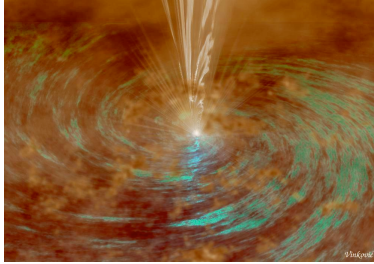
- Young stars are seen near molecular clouds.
- In infrared light, we can see into the deeper regions of clouds, and see clusters of young stars with circumstellar material (dust and gas) surrounding them.
- Stars are continuously being formed in our galaxy.



<http://antwrp.gsfc.nasa.gov/apod/ap030630.html>



Star Formation



Stars are born in cold, dense interstellar clouds

- Cold gas
- Dust grains

Star formation is probably triggered by

- Cloud turbulence
- Collision with another cloud
- Nearby supernova explosion
- Nearby hot star wind
- Disturbance from the Galaxy

Question



Stars are born

- a) in molecular clouds.
- b) in supernovae.
- c) in black holes.
- d) on Broadway.
- e) in empty space.

What is the origin of the Solar System?



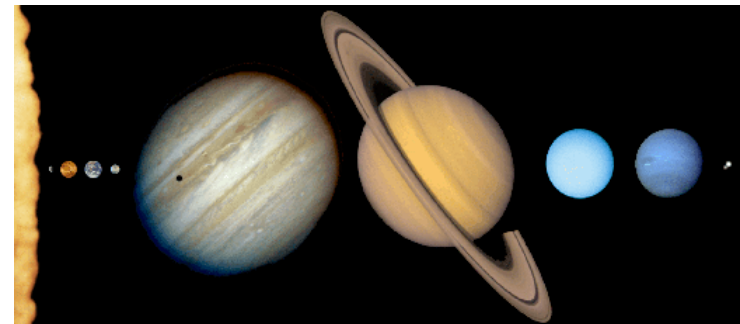
- Explain present-day Solar System data.
- Predict results of new Solar System data.
- Should explain and predict data from other stars!

What are clues to solar system origins?

Some Facts of the Solar System



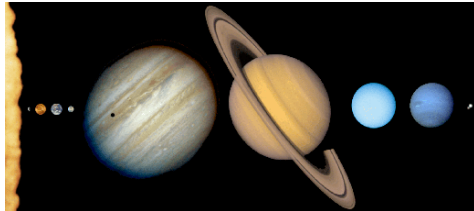
- We have 8 or 9 planets.
- So perhaps the average extrasolar system has about 10 planets (rounded off).



Some Facts of the Solar System



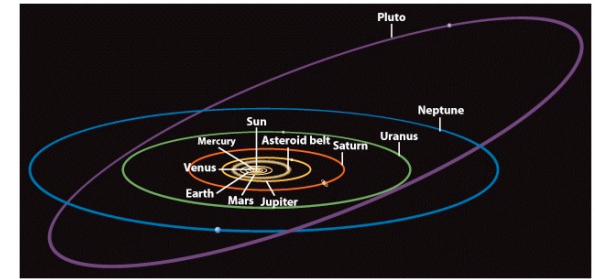
- Mass of solar system
 - 99.85% in the Sun (planets have 98% of ang. mom.)
 - Outer planets more massive than the inner ones
 - Jupiter is more than twice as massive as the rest of the planetary system combined!
- The inner planets are rocky and the outer planets are gaseous



Planetary Orbits



Most of the motions in the Solar System are counter clockwise in a flat system (pancake-like)



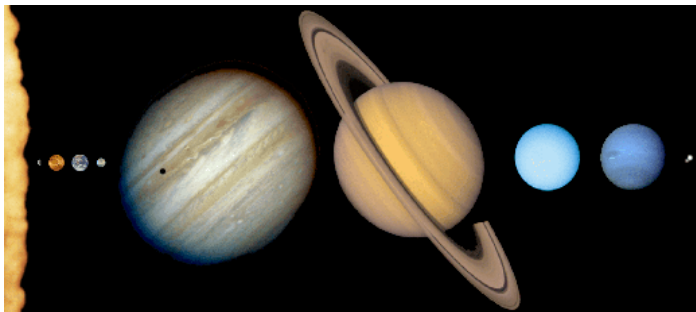
- There are some exceptions
- Venus, Uranus, and Pluto rotate clockwise (orbits are still clockwise)
- Some moons orbit backwards

<http://janus.astro.umd.edu/javadir/orbits/ssv.html>

Some Facts of the Solar System



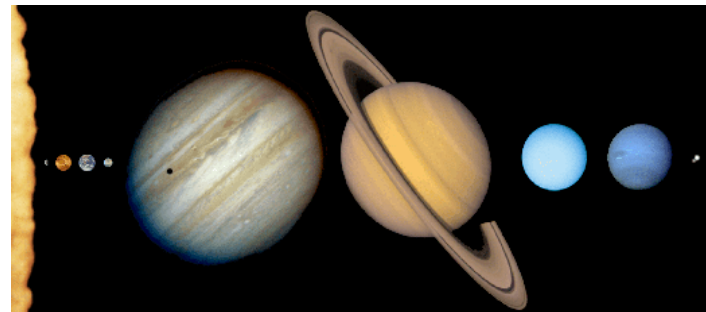
- Outer planets more massive than inner planets.
- The inner planets are rocky and the outer planets are gaseous.



Some Facts of the Solar System



- Numerous collisions occurred in the early Solar System
 - Origin of Moon, Lunar craters, Uranus's orbit, and Pluto
- Planets are not evenly spaced– factors of 1.5 to 2.
 - Sun/Saturn distance is 2x Sun/Jupiter distance
 - Sun/Mars distance is 1.5x Sun/Earth distance



What is the Age of the Solar System?



- 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**

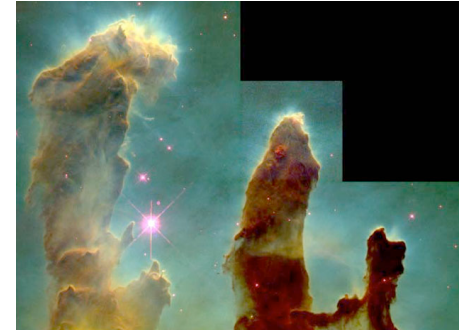
Origin of Solar System: Solar Nebula Theory



Gravitational Collapse

- 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.

“nebula” = cloud



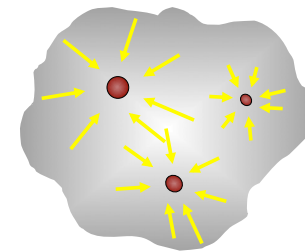
Gravitational Contraction



- As we discussed for the first stars, the gravity of the gas and dust clumps push the clumps together, but there is some resistance from pressure and magnetic fields to collapse.
- Probably as the cloud core collapses, it fragments into blobs that collapse into individual stars.
- Cloud becomes denser and denser until gravity wins, and the clumps collapse under their own mass– a protostar.



Cloud Contraction



But..



- Not all mass falls in directly (radially). Why?
- All gas has a small spin that preferentially causes the formation of a flattened structure
 - time for an interlude.



<http://homepages.igra.co.nz/morewa/Pages/>

Interlude: Angular Momentum



Spinning or orbiting objects in closed system have angular momentum.



Angular momentum is a single, *constant* number = *conserved*!

Keep same dist. to axis → velocity same

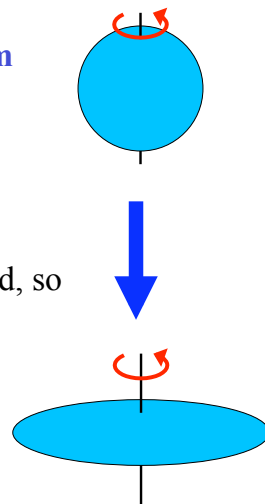
Move closer to axis → speed up!

When Doves Cry and Stars Form



Solar nebula competition: Gravity vs Angular Momentum

- If fall perpendicular to spin axis
 - Needs to speed up
 - resistance centrifugal force
- If fall parallel to spin axis same speed, so no resistance
 - forms *protoplanetary disk*
 - Origin of planet's orbits!
 - Organizes spins along initial spin axis



Question



Since a collapsing cloud is spinning, the cloud will form

- a) a spherical cloud
- b) a star
- c) a flattened disk
- d) a planet
- e) a galaxy

The Protostar Stage



Gravity, Spin, & Magnetic Fields

