Astronomy 330:

Extraterrestrial Life

This class (Lecture 9):

Planet Formation
Zachary Brewer
Quinn Calvert

Next Class:

Exoplanets
Itamar Allali
Brian Campbell-Deem

Music: *Another Girl Another Planet* – Blink 182

HW #3 due Sunday night.

HW #2

- Saloni Sheth
  http://www.ufosightingsdaily.com/
  Collection of potential UFO sightings, but they aim to confuse readers
- Sean Sarcu
  http://www.ibtimes.co.uk/earth-sized-ufo-spotted-nasa-images-show-alien-mothership-blasting-out-sun-video-1480987
  An irregularity spotted near the Sun in a NASA satellite image, clearly an "alien mothership".

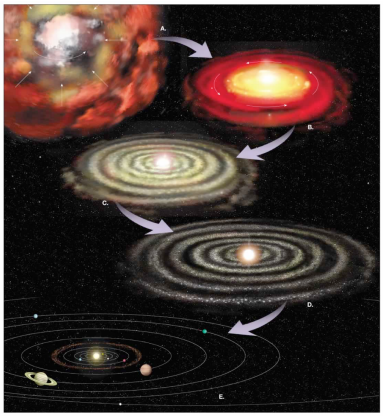
Solar Nebular Theory

Predictions:

Young stars have disks

Disks contain gas & dust

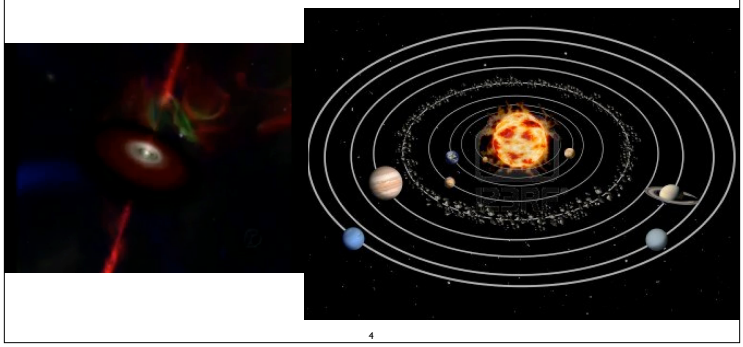
Solar System should contain disk remnants



Solar Nebular Theory

Predictions: Planar solar system

Coherent spins



4

Question

Which of the following are not a prediction of the Solar Nebulae Theory?

a) Disks around young stars.

b) Disk contains dust and gas.

c) Disk will be UV bright.

d) Coherent rotation.

e) Planar solar system.

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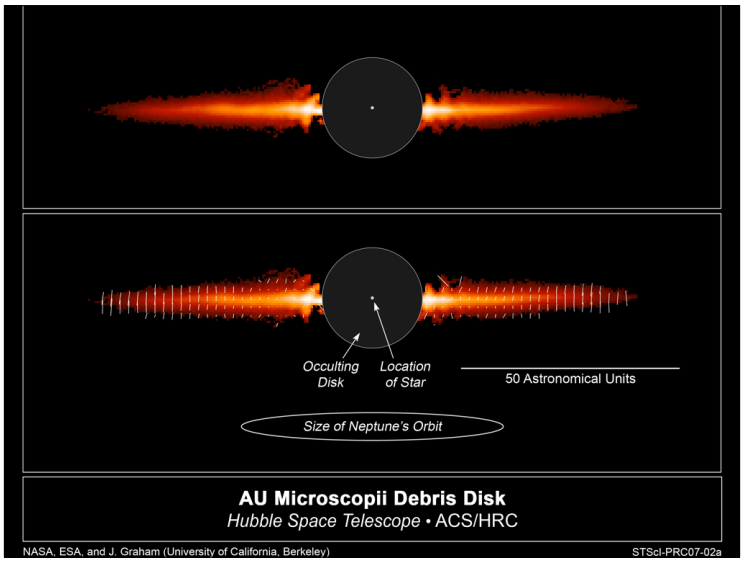
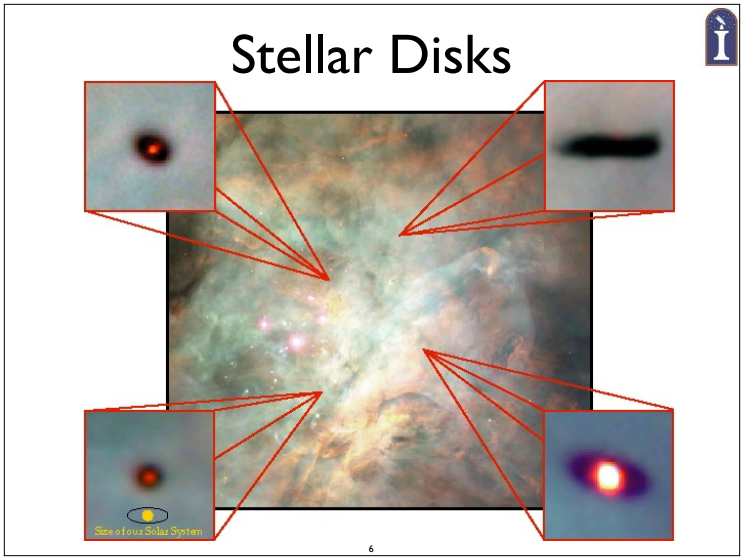
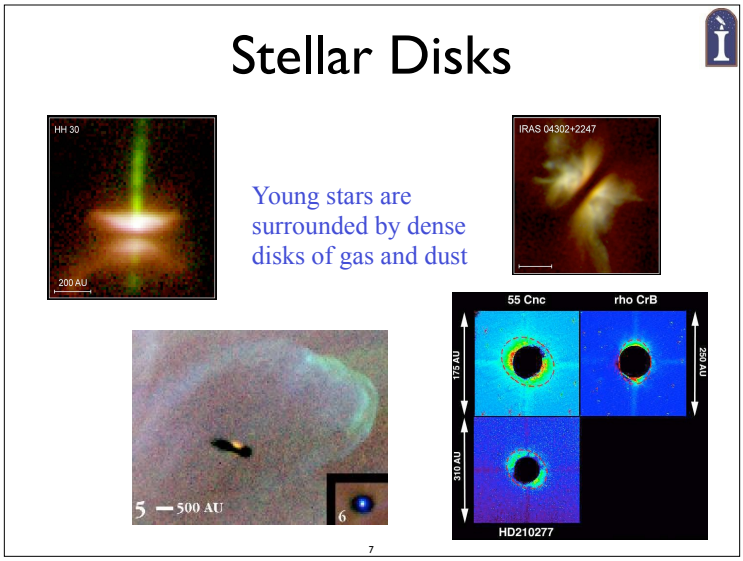
x

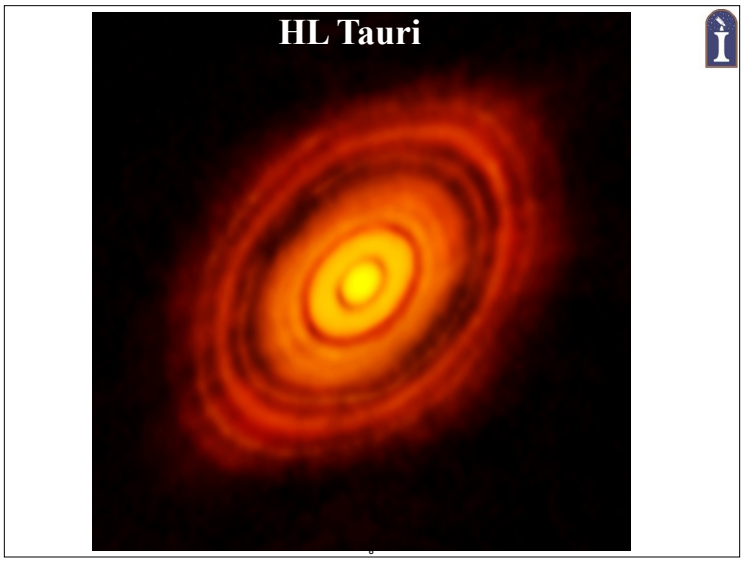
C







http://www.ifa.hawaii.edu/users/tokunaga/SSET/SSET.htm

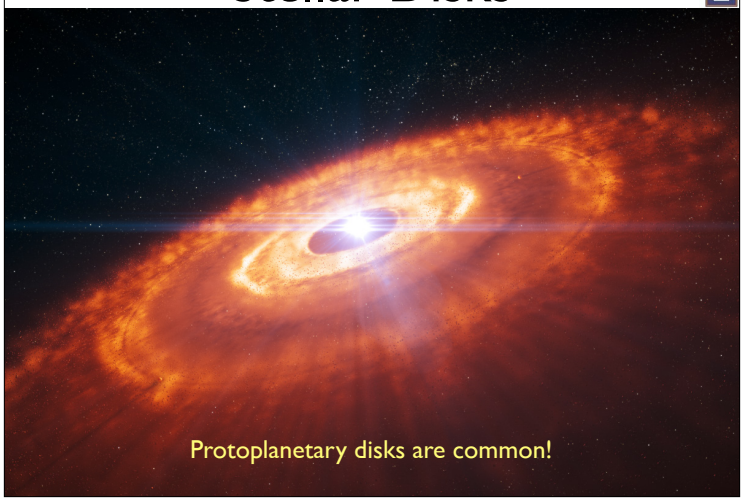


The protostar HL Tau.

My mouth has been open for months now. Amazing!

http://www.almaobservatory.org/press-room/press-releases/771-revolutionary-alma-image-reveals-planetary-genesis

Stellar Disks



I think the real data is more interesting than the artist drawing!

Question

The disks around young stars are best viewed in the

a) gamma-ray

b) neutrinos

c) optical

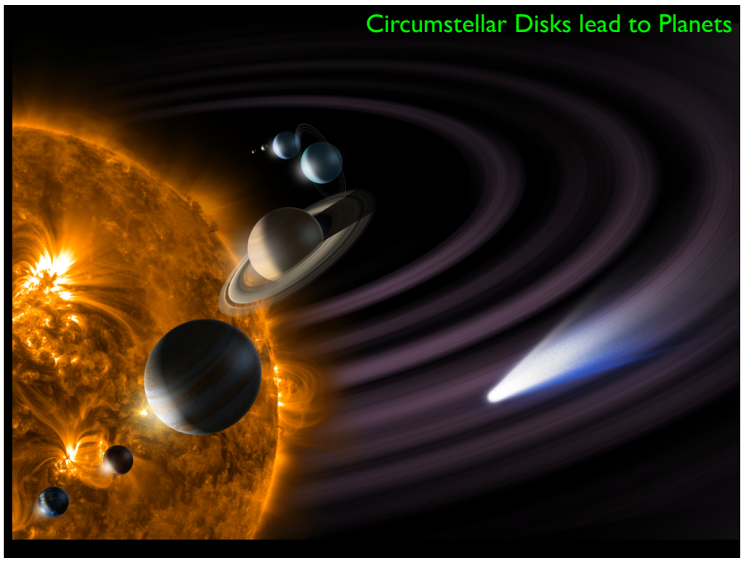
d) infrared

e) ultraviolet

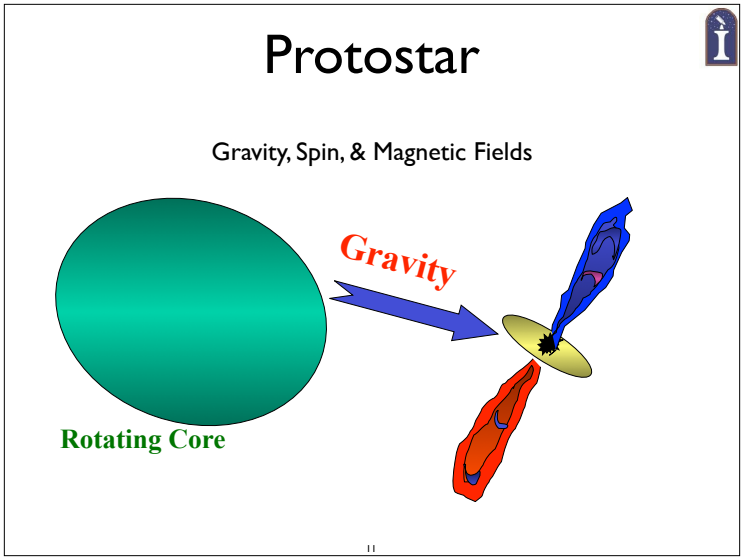
iClicker

x

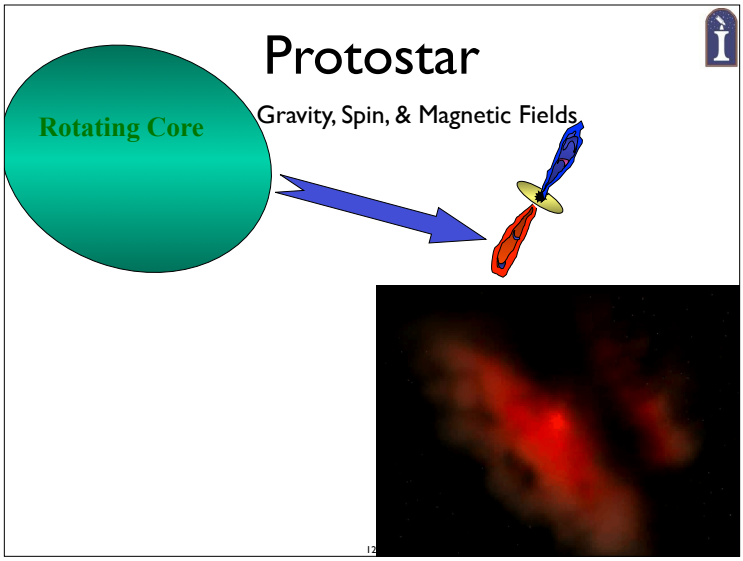
D



http://solarsystem.nasa.gov/multimedia/gallery/EotSS_intro_graphic_large.jpg



A massive cloud of gas and dust
Seeded with elements from
Big Bang (hydrogen, helium, etc.)
Elements from planetary nebula pushed into space by red giant.
Elements blown from across galaxy by supernovae.



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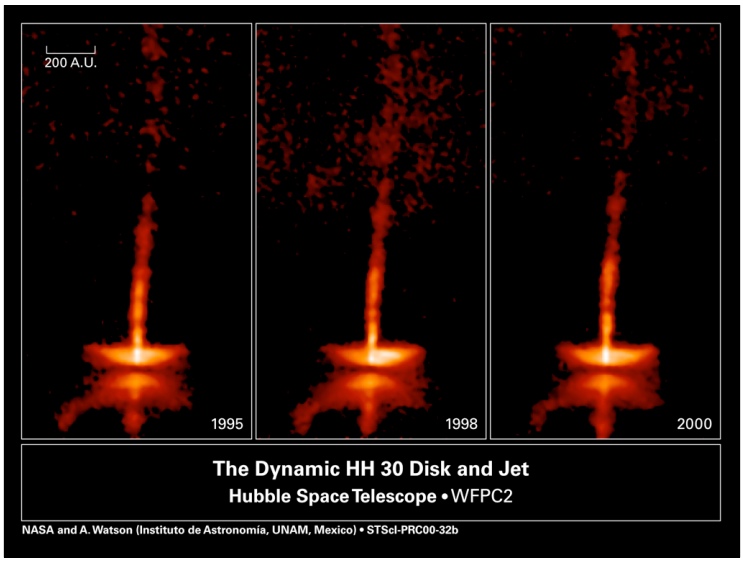
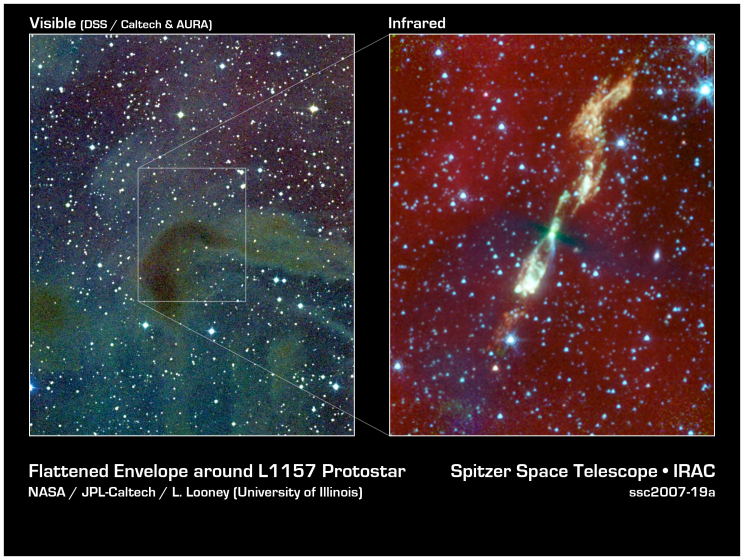
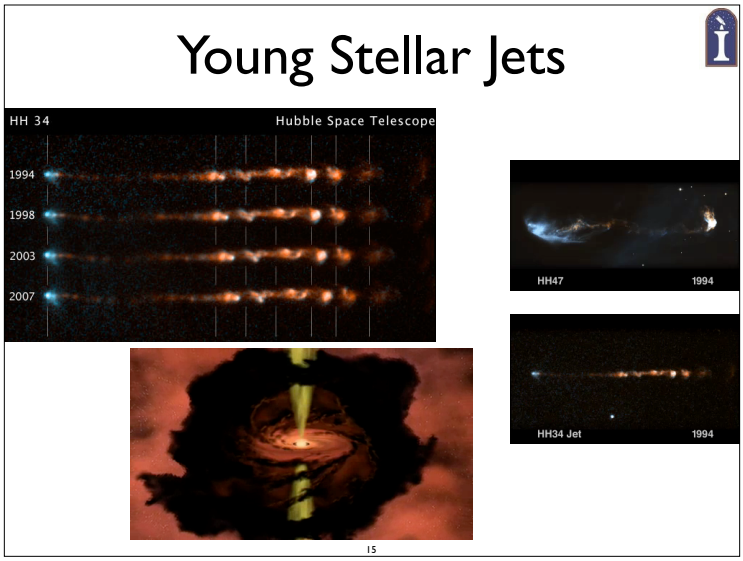
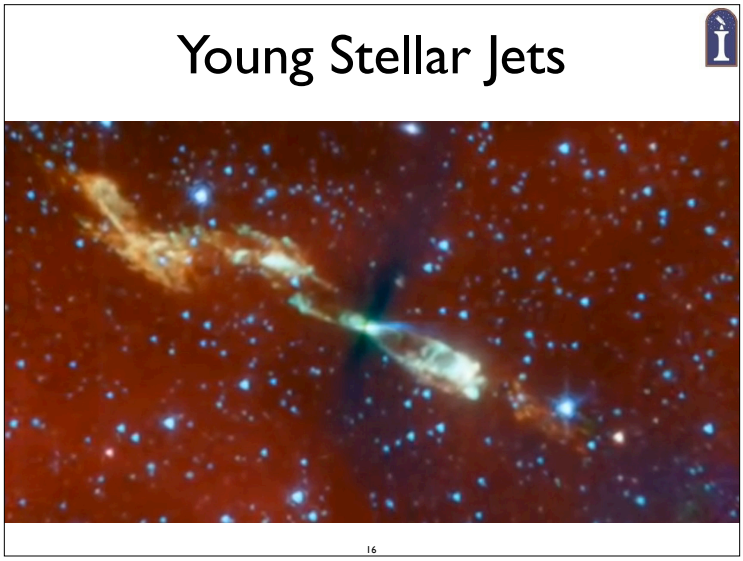


http://imgsrc.hubblesite.org/hu/db/images/hs-2000-32-c-print.jpg





NASA's Hubble Space Telescope saw how a bright, clumpy jet called Herbig-Haro 34 (or HH 34) that was ejected from a young star has changed over time. Several bright regions in the lumpy gas signify where material is slamming into each other, heating up, and glowing. Red areas indicate where heated material cooled. Two regions at left, indicate fresh collision sites. A small knot of material within the blue feature (left) is either a new jet or magnetic energy being emitted by the star. Credit: NASA/ ESA/P. Hartigan (Rice University)



https://www.youtube.com/watch?v=Rm3Sj8qAaWg&NR=1

Young Stellar Jets

https://www.youtube.com/watch?v=1Swmddp6GKg&index=18&list=PLH37S3BiEx34x_Ybnmx-BD5fjeLFobBtN

Question

Why do young stars show jet structures?

a) Gravitational Contraction

b) Nuclear Fusion

c) Strong Nuclear Force

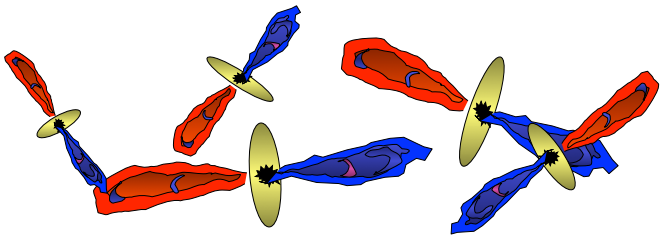
d) Angular Momentum

e) Magnetic Fields

iClicker

D

Young Star Groups?



Most stars are born near other stars.

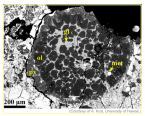
What about the Sun?

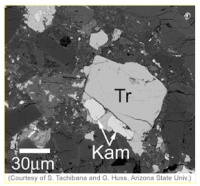
Pre-Solar Dust Grains

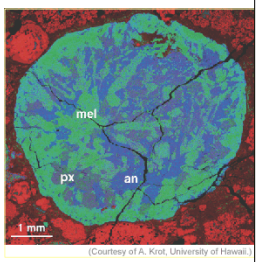
Formed 4,700,000,000 years ago

CAIs: Calcium-Aluminum Rich Inclusions

Chondrules: Grains found in primitive meteorites







CAIs radioactive date via ^{60}Fe and ^{26}Al

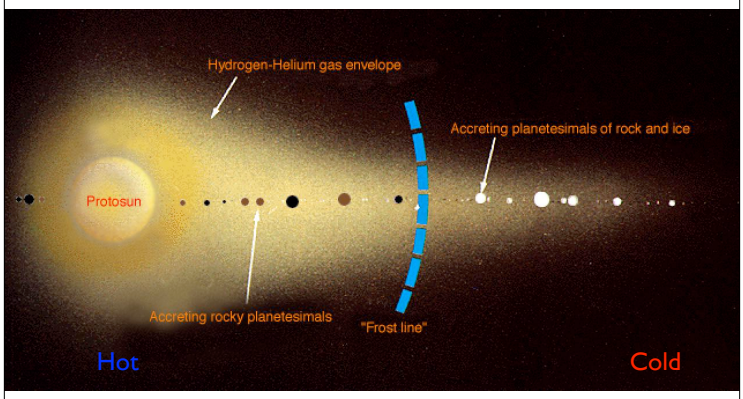
Supernovae progenitor: 0.1 1.6 pc away.

20

- Contain decay products of ^{60}Fe and Al
- As seen by an excess of nickel
- Most likely produced by nearby supernova explosion!

- Can use the ensemble of all radioactive elements to estimate distance to the supernova
  - 0.1 to 1.6 pc away

Frost Line



21

Temperature is the key factor. Inner Solar System: Hot. Light gasses (H, He) and "ices" vaporized. Blown out of the inner solar system by the solar wind. Only heavy elements (iron & rock) left. Outer Solar System: Cold. Too cold to evaporate ices to space. Rock & ice "seeds" grew large enough to pull gasses (H, He) onto themselves

Everyone Loves Disks

As the star forms, the inner region of the disk gets much hotter than the outer regions, creating a temperature gradient.

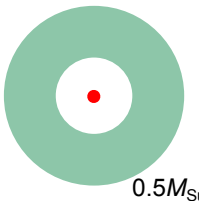
The inner part of the disk had a higher density than the outer regions.

Icy mantles of dust grains (NH_3, CH_4, etc.) evaporated at varying distances.

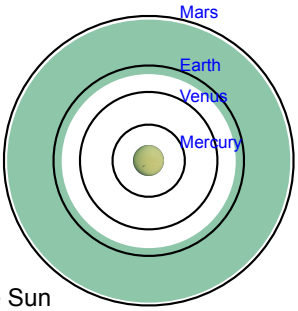
Planets in the Habitable Zone: Would be nice for life

Distance from the star such that liquid water can exist on planet

Will depend on the star's temperature



$0.5M_{Sun}$ star



The Sun

Solar System History

GMC

Big Bang + PN + SN

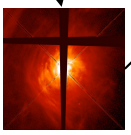
Planet Formation

0.1-1 M_{sun} in Disk

Heavy Bombardment

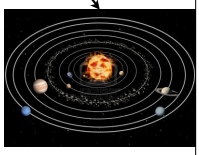
10^8 years

10^7 years



Dust grains combine into planetesimals

Planetesimals merge into inner planets and outer planet cores



Main Sequence

24

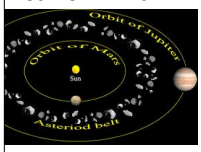
Heavy elements clump

1. *Dust grains* collide, stick, and form planetesimals– about 10^{12} of them, sort of like asteroids! All orbit in the same direction and in the same plane.
2. Gravity Effects: Big planetesimals attract the smaller planetesimals. So, fewer and fewer of large objects (100's). Collisions build-up inner planets and outer planet cores.
3. Collisions can also account for odd motions of Venus (backwards), Uranus (rotates on its side), and Pluto (high inclination of orbit). Proof of period of high collision evident on moon
4. There were billions of planetesimals in the early solar system

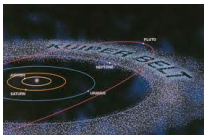
Many collided with the young planets. Look at the Moon & Mercury! Period of **heavy bombardment** Lasted for about the first 800 million years of the Solar System. Others were ejected from the solar system…

Planetesimal Remnants

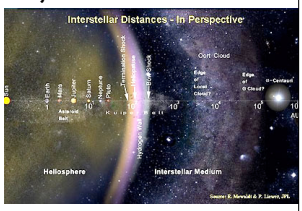
Asteroid Belt

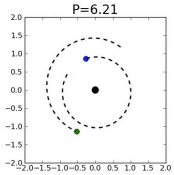


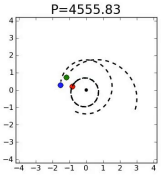
Kuiper Belt (TNOs)



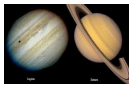
Near Uranus and Neptune: Ejected to Oort Cloud







Jupiter & Saturn Eject from Solar System



25

Between Mars and Jupiter— Remain as the asteroids
Near Jupiter & Saturn— Ejected from the solar system
Near Uranus & Neptune— Ejected to the Oort Cloud
Beyond Neptune— Remain in the Kuiper Belt

Formation of the Moon