Astronomy 150:

Killer Skies

This Class (Lecture 5):
Star Formation

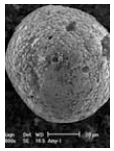
Next Class:
More Meteors

HW2 due next Monday. As you have to access Nat History Building, you can't wait until the last minute.

Music: ***Kelly Watch the Stars*** **– Air**

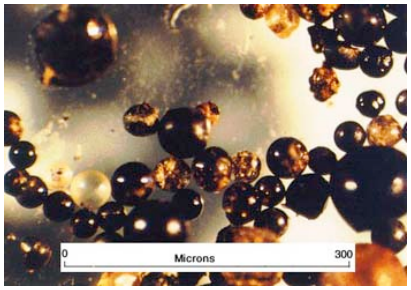
Micro-Meteorites

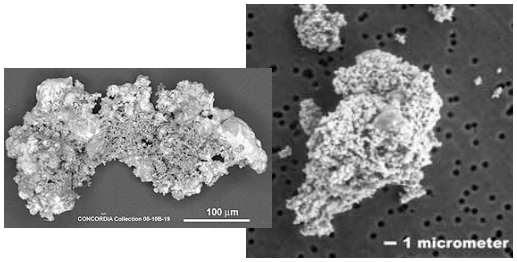
- Group project! (Due Oct 4th)
- Find a flat container– the bigger surface area the better.
- Fill with water and leave outside (away from buildings and tress), perhaps on a roof if possible, for a few weeks.
- Somewhere secure.
- Strain through a coffee filter or a few paper towels.



Micro-Meteorites

- Use a magnet to find the magnetic dust.
- Most of those are from space.
- So small, they fall to Earth unchanged.
- Estimate amount of micro-meteorites falling onto the Earth per year.





Night Obs

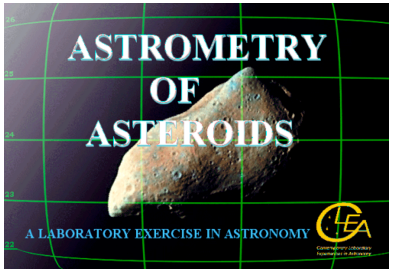
- Dates:
  - Monday, Oct. 4th
  - Tuesday, Oct. 5th
  - Wednesday, Oct. 6th
  - Thursday, Oct. 7th
  - Monday, Oct. 11th
  - Tuesday, Oct. 12th
  - Wednesday, Oct. 13th
  - Thursday, Oct. 14th

Go to assignment page on class website for more info.

You MUST download worksheet before you go.

Computer Labs

- Computer labs to assess the way we look for killer asteroids.



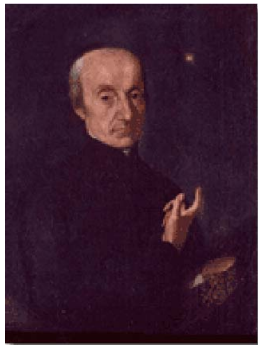
- See Assignments webpage for more info.
- Due Nov 12th.
- Lectures will not be held on Sept 13/15 to allow the class to work on the computer lab.

Outline

- What are asteroids?
- Where did they come from?
- How was the Sun born?

Discovery of the Asteroids

- In 1801, Giuseppe Piazzi noticed an uncharted "star" that shifted position among the stars over several nights
- Could it be another planet?
  - Its orbit was between Mars and Jupiter
  - Very dim, so it must be small
  - Too small to be a planet
- It was an *asteroid,* a "minor planet"



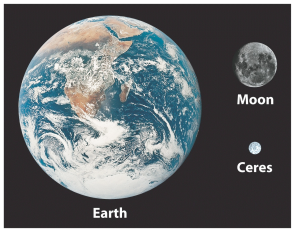
Question

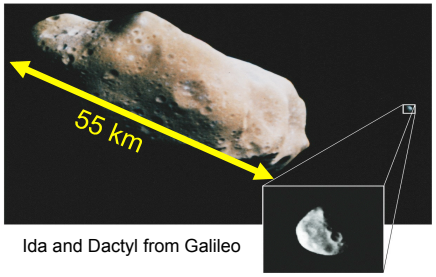
How did we discover the asteroids (i.e. non-planets)?

a) The objects were in the asteroid belt.
b) The objects were dim compared to their distance.
c) The objects had a large ^{17}O to ^{16}O ratio.
d) By using very large telescopes.
e) Echo sounding.

Asteroids

- Small sizes
  - Largest – Ceres: 940 km across
  - Only 3 more than 300 km
  - About 240 bigger than 100 km
  - Millions under 1 km
- Composition
  - Rocks (silicates) and iron/nickel

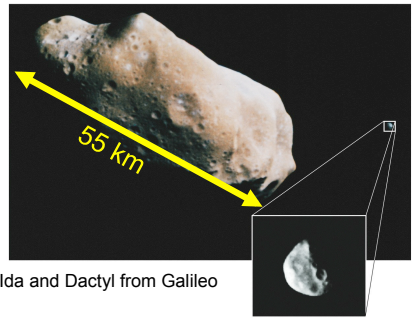




Ida and Dactyl from Galileo

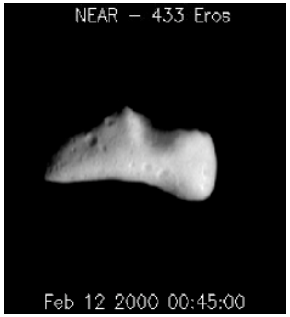
Asteroids

- Asteroids rotate– see Eros
- They can even have moons



Ida and Dactyl from Galileo

Eros from NEAR

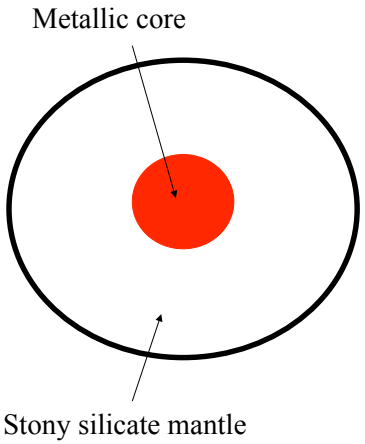


Asteroids

Eros from NEAR:http://near.jhuapl.edu/iod/20010205/index.html

Types of meteorites derived from asteroids

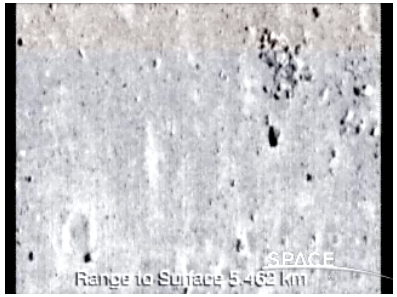
- Many asteroids have a metallic core and stony silicate mantle
- As asteroids fragment, both metallic and silicate pieces are produced



Asteroids

- Because they are small, they are pretty much the same as when they formed: ancient 4.6 billion years old.
- Have regolith, some craters, some boulder
- Heavily cratered surface.

NEAR landing on Eros

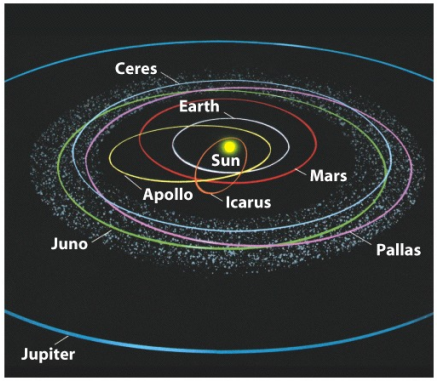


http://www.space.com/media/s010731_eros_landing_2.mov

http://www.youtube.com/watch?v=iiM7VHSRz4c

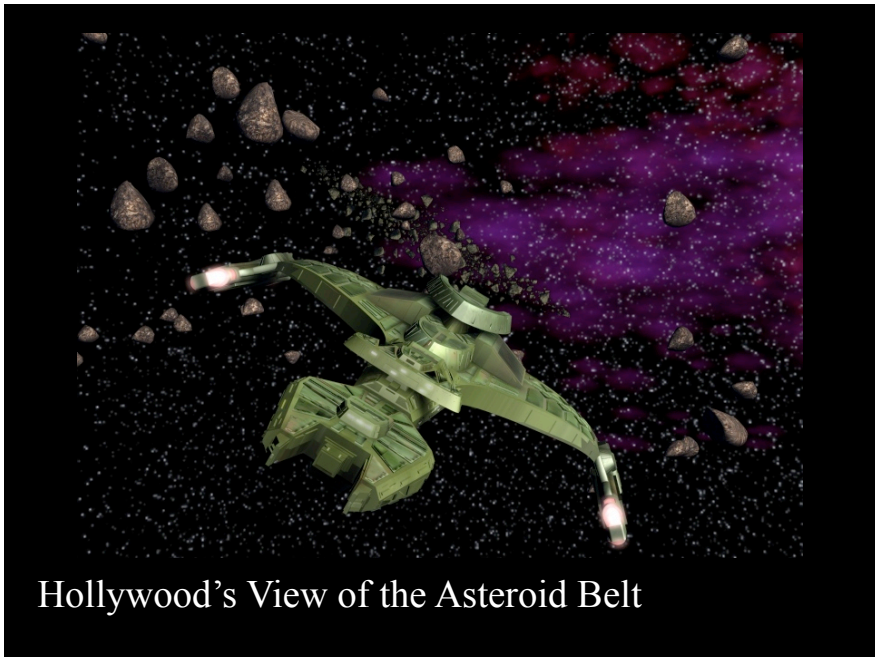
The Asteroid Belt

- Most, but not all, asteroids are found between 2-3.5 AU
  - Between Mars & Jupiter
  - Region is called the **Asteroid Belt**
- As asteroids collide with one another, they fragment and send pieces into near-Earth orbits

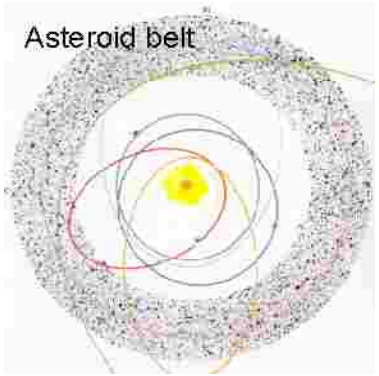


The possibility of successfully navigating an asteroid field…

- Actually, NASA has sent many space probes into and through the Asteroid Belt
- Unlike in Star Wars, the Asteroid Belt is not that crowded
- Average separation between sizable asteroids is 10 million km!



Hollywood's View of the Asteroid Belt

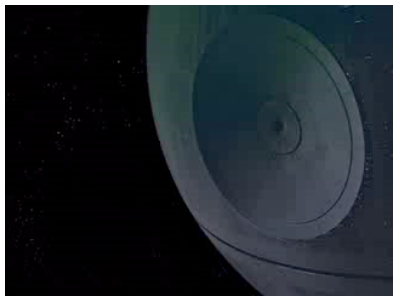


Thousands of asteroids …

On average, about a million miles apart!

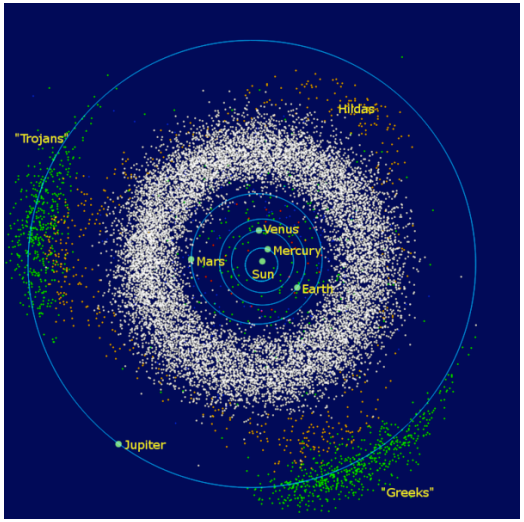
Scientific View of the Asteroid Belt

Destroyed… by the Empire



- Are the asteroids a destroyed planet? **NO!**
  - Combined, the asteroids have a mass about 0.1% that of the Earth
  - Less than 10% that of our Moon
- The asteroids might be a *failed* planet
  - Jupiter's gravity kept the asteroids from coalescing into a planet
  - Jupiter probably ejected many asteroids from the Solar System

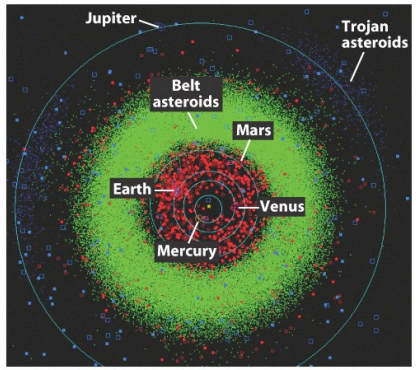
Asteroids and the Asteroid Belt



Apollos

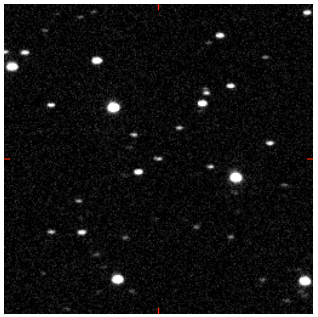
Some asteroids are on orbits that cross Earth's orbit

- Called *Apollo asteroids*
- At least 3000 are known
- In 1972, one skipped off the Earth's atmosphere



Near Earth Asteroids

- Short-lived (few million years)
  - Orbital decay and Sun accretion
  - Collision with inner planets
  - Ejected from system by interactions
- Must be replenished
- Gravity interactions with asteroids and Jupiter can send them Earth-ward



2004 FH (30 meter) passing 10% the Earth-Moon distance

Outer Solar System

THE MIDDLE SOLAR SYSTEM

This animation shows the motion of the middle part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth Mars and Jupiter are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

The individual frames were generated on an OpenVMS system, using the PGPLOT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.

http://www.cfa.harvard.edu/iau/Animations/Animations.html

Inner Solar System

THE INNER SOLAR SYSTEM

This animation shows the motion of the inner part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth and Mars are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

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Near Earth Asteroids

A Ride With The Earth

An animation centered on Earth showing the known objects that have approached to within 20 million km between July 2007 and June 2008. See the Animations Page on the MPC website for a description of the symbols used in this animation.

Some large asteroids have Earth-crossing orbits

Orbits cross but not necessarily collide… why?

Right now, over 3000 Earth-crossing asteroids are known.
And over 1000 potential dangerous ones.

http://cfa-www.harvard.edu/iau/Animations/Animations.html

Near Earth Asteroids

And we're still finding them!

http://www.youtube.com/watch?v=S_d-gs0WoUw

And since they are replenished, it is a never ending job!!!

Question

What can we say about the Near Earth Asteroids?

a) They have always orbited nearby the Earth.
b) They are all made of mostly iron.
c) They collide with the Earth every few hours.
d) They can only exist in near Earth orbit for a few million years and are replenished by asteroid belt objects.
e) They typical travel in unique orbits that move them from Mercury to Venus to Earth, and to Mars, with a 10% chance of collision at each body.

NEOs have Affected our Environment for Eons…and will Continue to do so

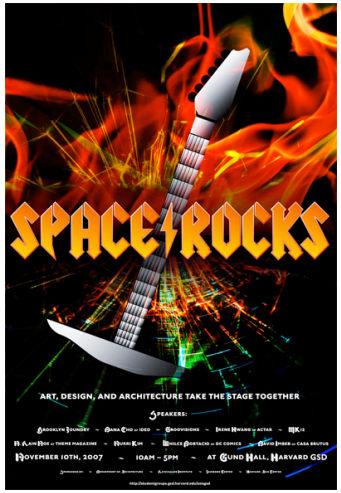
- Early sources of water, organic molecules on Earth
- Bombardment "blizzard": the Late Heavy Bombardment, ~3.9 BYA, which frustrated the origin of life
- External cause for "punctuated equilibrium" evolution, mass extinctions, rise of new species
- Rare, modern threat to humanity
- Future source of raw materials, spacefaring tourist destinations

Terms

- **Asteroid:** A relatively small, inactive, rocky body orbiting the Sun (>50 meters).
- **Comet:** A relatively small, at times active, object whose ices can vaporize in sunlight forming an atmosphere (coma) of dust and gas and, sometimes, a tail of dust and/or gas.
- **Meteoroid:** A small particle from a comet or asteroid orbiting the Sun (<50 meters).
- **Meteor:** The light phenomena which results when a meteoroid enters the Earth's atmosphere and vaporizes; a shooting star.
- **Meteorite:** A meteoroid that survives its passage through the Earth's atmosphere and lands upon the Earth's surface.

Where are These Rocks From?

- Asteroids
- Meteoroids
- Comets
- … yes, but why are they so old and where are they from?

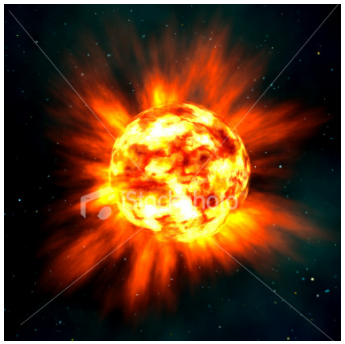


The Early Days

- We'll come back to this, but the Universe is around 13.7 billion years old.
- About 400,000 years after the Big Bang (we'll come back to this), the Universe was mostly hydrogen (92%)

Making Heavy Elements

- The first stars were born and died.
- When a massive star dies, it goes **supernova** and explodes. (We'll come back to this.)
- When it does this, the elements forged during its life enrich space.
- Supernovae provide much of the building blocks for planets… and us!
- **We are recycled supernova debris!**
- **We are Star stuff.**



The Interstellar Medium (ISM)

- Stuff between the stars in a galaxy.
- Sounds sort of boring, but
  - Actually very important
  - Features complex physical processes hidden in safe dust clouds
- Every star and planet, and maybe the molecules that led to life, were formed in the dust and gas of clouds.
- Exists as either
  - Diffuse Interstellar Clouds
  - Molecular Clouds

Keyhole Nebula

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

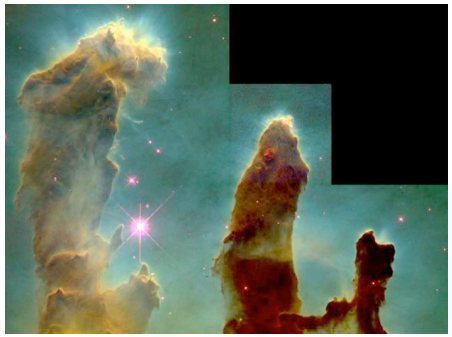
- **Age of Solar System is probably around 4.6 billion years old**

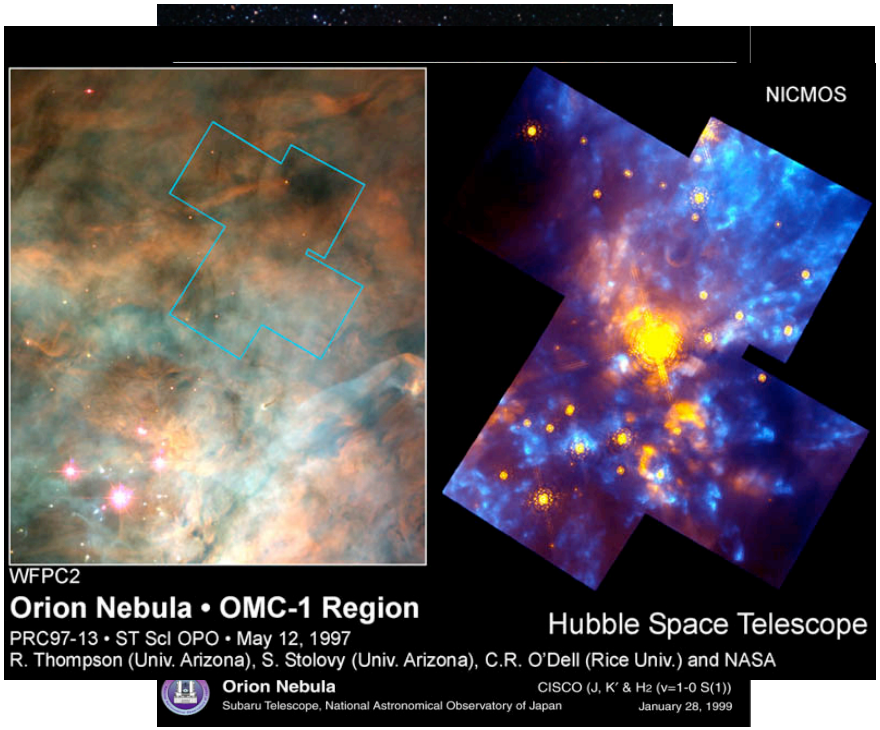
Origin of Solar System: Solar Nebula Theory

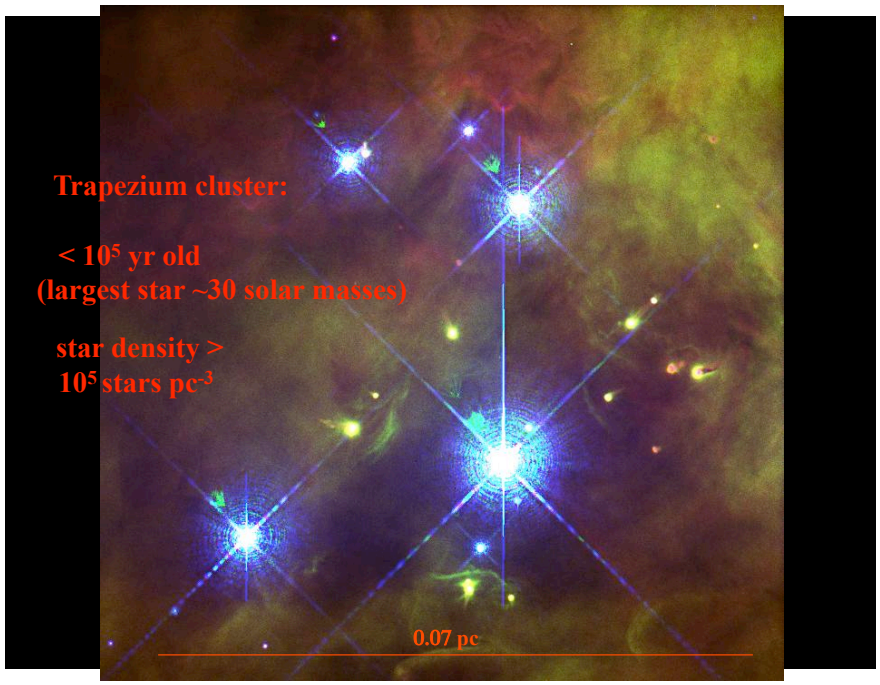
"*nebula*" = cloud

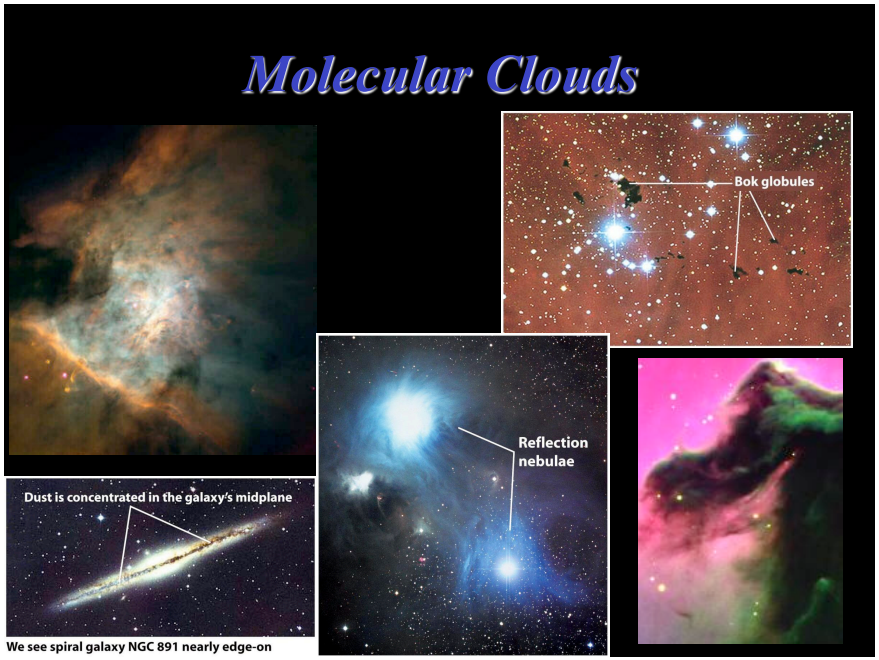
Gravitational Collapse

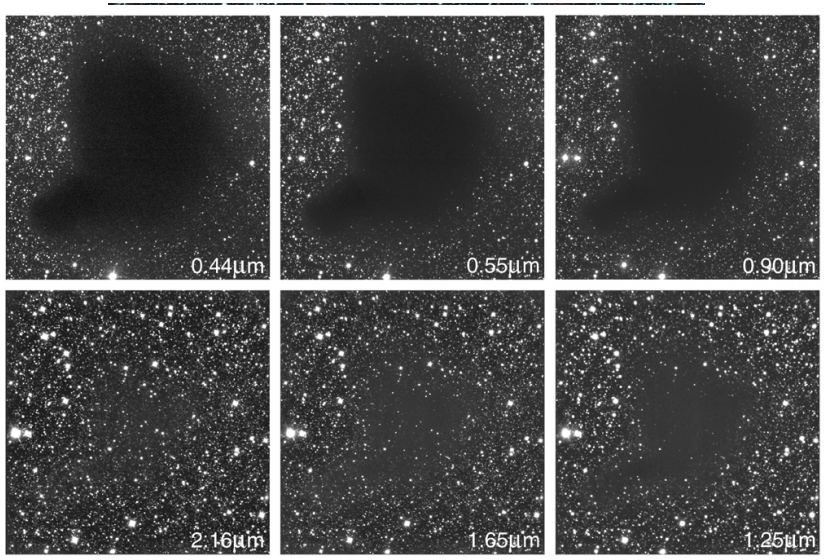
- The basic idea was put forth by Immanuel Kant (the philosopher)– Solar System came from a Gas Nebula.
- 4.6 billion years ago: a slowly spinning ball of gas, dust, and ice with a composition of mostly hydrogen and helium formed the early Solar System.
- This matches nearly exactly with the modern idea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





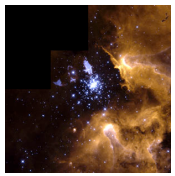




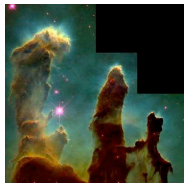


The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)

ESO PR Photo 29b/99 (2 July 1999)



Molecular Clouds



- Interstellar clouds are important molecular factories.
- Analogous to clouds in our atmosphere
- Primarily molecular hydrogen (~93%) and helium (~6%) with (~1%) heavy molecules– molecules or dust.
- H_2 is not good at emitting photons, so easier to see larger molecules emitting– especially CO (which tells the temperature of these clouds).