Formation of solar system—11 Feb

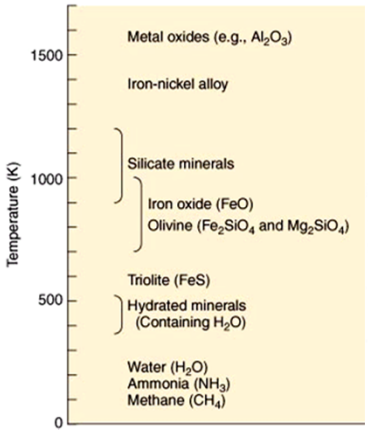
- Homework 4
- Preparation for Midterm exam (4 March)
  - Identify the main ideas for each class.
  - Make certain you understand the reasoning to answer the clicker questions.
  - Understand the homework.
  - There will be a cheat sheet for the entire class. Send me equations to put on the cheat sheet.
- Formation of the solar system
- Comets

Protosolar cloud

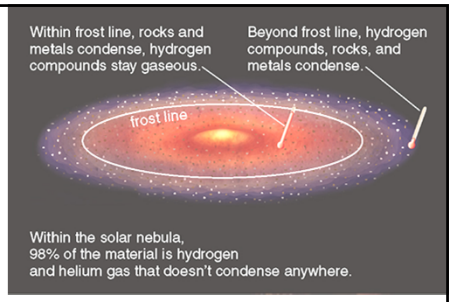
- Protosolar cloud collapses because of its own gravity.
- The inner part moves faster than the outer part because ___. (7 Feb) The inner part is hotter.
- Cloud radiates energy and shrinks more.
- Inner part remains hotter than outer parts.

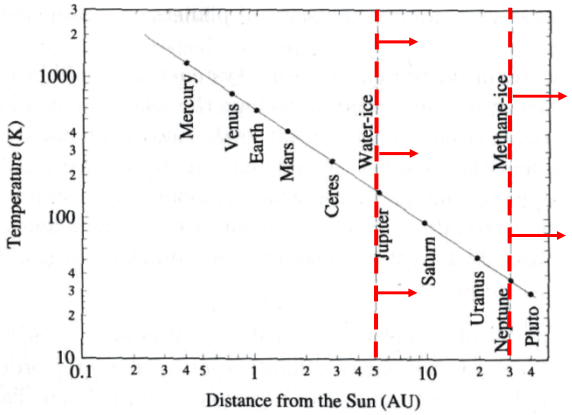
Thermal history of the Solar System

- Terrestrial vs. giant planets
- Asteroids vs. comets



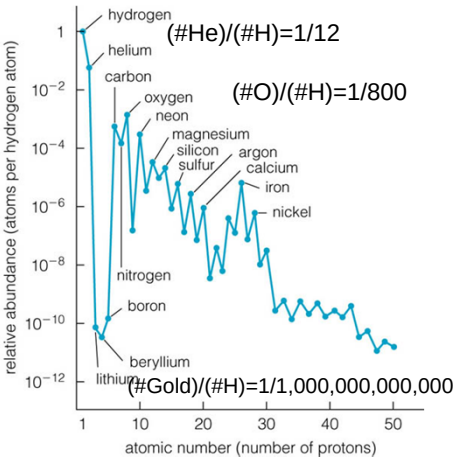
Evaporation Temperatures





Abundances of elements

- Composition of the gas from which the solar system formed
  - Mostly hydrogen
  - Helium is less by factor of 12
  - Carbon, nitrogen, & oxygen are less by 1000 to 10,000.
  - Mg, Si, S, Fe less by 100,000
- Inner planets are made of rare stuff.

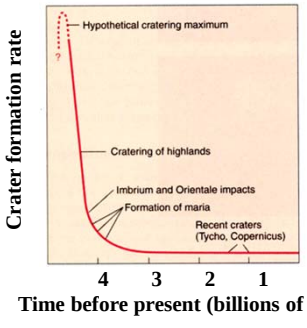


1. Why was it cooler in the outer parts of the solar system at the time of formation of planets?
   A. The material fell into a shallower gravitational potential.
   B. The radiation of the sun is less.
2. Why are the outer planets more massive than the inner planets?
   A. There is more material in the outer parts of the solar system.
   B. A larger fraction of the material could condense.

Giants vs. Terrestrials

- Inner solar system.
  - Lighter elements could not condense.
  - Planetesimals contained only heavy elements.
  - Growth stopped at Earth-sized planets.
  - Continuing impacts with planetesimals altered the planets
    - Earth's moon
    - Reversal of Venus' rotation, etc.
    - Dumped much of atmospheres onto planets
- Outer solar system.
  - Ices as well as silicates available for solid bodies.
  - Larger protoplanets resulted.
  - These cores able to attract surrounding H & He gas in order to build giant planets.
  - Gravitational field of giant planets perturbed orbits of remaining planetesimals.

Progressive Buildup of the Planets



Before the Sun started to produce its own energy:

- Small "dust" grains condensed from nebula.
  - mm-sized.
- Clumped up into *planetesimals*
  - 10's of km in diameter.
  - comets and asteroids.
- Run away growth into *protoplanets*
  - larger bodies had more gravitational attraction
    - collected lots of smaller bodies.
  - ➔ a few Mercury/Mars-sized objects.
    - rapidly accreted further planetesimals.
  - Impacts heated interior of growing planet.
    - ➔ differentiation in molten interiors.

The End Game

- The Sun became a star.
  - *Solar wind* = high velocity particles streaming outwards from Sun.
  - Solar wind blew away the remaining H, He gas.
  - Left just protoplanets + remaining planetesimals to finish up their interactions.
  - Timescale to this point: only ~ 10 million years.

Composition of comets

1. From what we know about the formation of the solar system, we can deduce that the composition of asteroids to vary with distance from the sun. Asteroids with more carbon should be found ___ and asteroids with more silicon should be found ___.
   A. closer to sun & closer to sun
   B. farther from sun & closer to sun
   C. closer to sun & farther from sun
   D. farther from sun & farther from sun
2. Small objects in the outer part of the solar system (beyond Saturn) are likely to be made primarily of
   A. Hydrogen and helium
   B. Water, ammonia, and methane
   C. Rock

Comets

- Small objects (~10km) with periods of 100's years to 1000's years.
- Visible when near the sun. Sunlight boils off gas and frees dust.

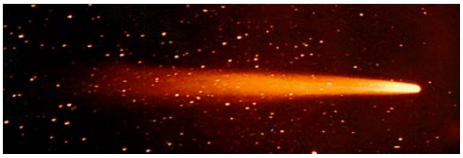
Comet Hale-Bopp (1997)

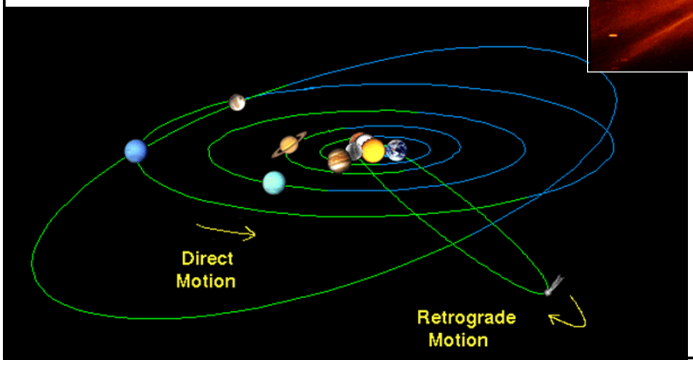
Comet Hale-Bopp February 7, 2000
This fading super comet continues to be visible in small telescopes almost 5 years after it was discovered. Despite now being out beyond the orbit of Saturn, the comet continues to display a strong coma.
The image is a combination of 3, 3-minute exposures using a 416xt CCD and a 12" f/6 newtonian telescope at prime focus. Taken by Maurice Clark

Comet Hale Bopp (1995 o1)
april 9, 1997

Halley's Comet

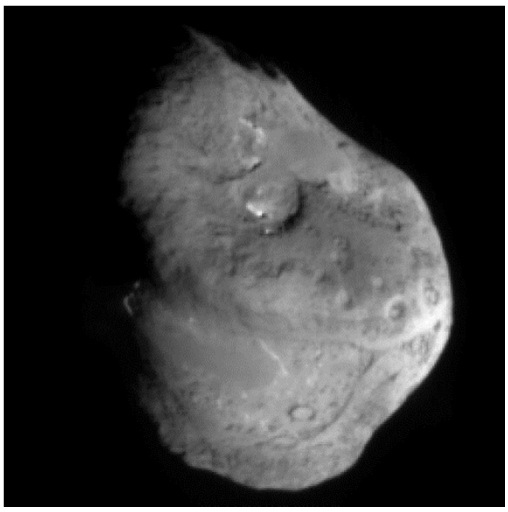
- first observed 239 BC
- 76 year average period
- most recent visit 1986





Dirty snowballs

- Small icy nucleus.
- "Dirty snowball" model
  - mostly water ice
  - + other ices
  - mixed with silicate grains and dust
- Outer layers of nucleus vaporize when comet approaches sun.
  - Little geysers and eruptions observed.
  - Comet's head (Coma) often as large as Jupiter
    - up to 250,000 km diameter.
    - Primarily H_2O gas.
    - + few percent CO, CO_2 and hydrocarbons.
  - Huge hydrogen clouds around head can get bigger than sun.

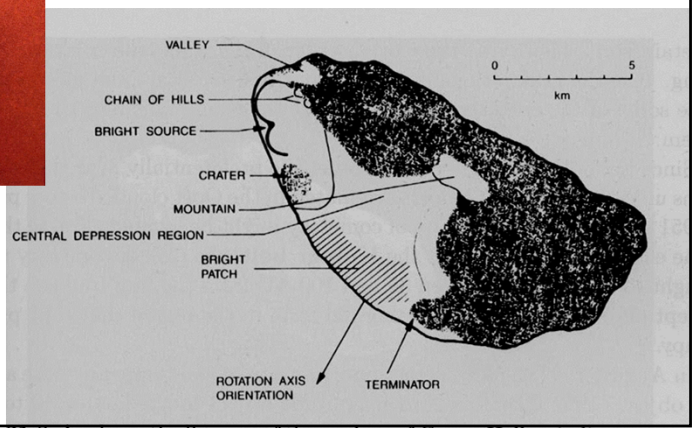


Comet Tempel 1. NASA Deep Impact

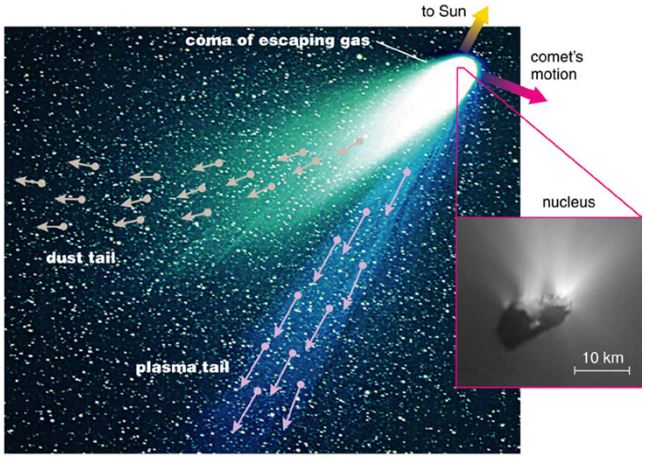
Halley's nucleus.

Picture taken by Giotto. Sun is at lower left.

- Nucleus is 10×15 km (6×10 mi)
- Nucleus is irregular in shape
- Nucleus is jet black
- Evaporation is confined to small regions



Comets: Dirty Snowballs



- In what direction is the force on a proton moving in a magnetic field?
- What is a photon?
- Light carries energy.
- Light carries momentum.