Brooks Observatory telescope observing this week

Mon. - Thurs., 7:30 – 9:15 PM MW, 7:30 – 8:45 PM TR

See the class web page for weather updates. This evening’s session is cancelled.

Present your blue ticket with your name and my name written on it. If you don’t have a blue ticket, use a sheet of paper.

You are required to attend one session during the semester. You may attend more if you like.

If you attend, a 1/2 to 1-page report/journal is due Wed., Mar. 3.
Extra credit corrections for Quiz 2

For up to 4 of the questions you missed:

• Look up or figure out the correct answer.

• Write a sentence or two explaining what you did wrong or why the right answer is correct. **Just giving the answer will not earn credit!**

• Turn it in on paper at the beginning of class Monday, Feb. 22 (today).

• Or by email until midnight tonight. If possible, please avoid attachments.
About Quiz 3
Wed., Feb. 24, 8:30 PM

Telescopes (chapter 5, last Monday)

Solar system overview (chapter 6, last Wednesday)

Solar system formation or origin (chapter 6, today, may be continued before the quiz on Monday.)
Origin of the Solar System: the Nebular Theory

Three stages in the formation of the solar system

1. **Nebula:** a cloud of gas & dust among the stars. Such clouds are common today.

Composition of gas: similar to that of the Sun’s atmosphere today: hydrogen, helium, traces of all others.

(Where did the elements come from? Another theory . . .)

Additional linked images of the Orion Nebula: (1) (2)
Isolation of a small portion of an interstellar cloud of gas and dust (a denser clump or core)

Gravitational contraction, in which gravitational potential energy is converted into thermal energy and radiation

Formation of a hot protostar in the center
Amplification of existing rotation of the clump (conservation of angular momentum as it contracts)

Formation of an *accretion disk* (Drawing at right is on an expanded scale)
The accretion disk is flat and thin. Here, it is shown edge-on.

Out of the rotating disk, the planets eventually formed.

The protostar in the center was to become the Sun. It was more luminous than the Sun today; its radiation vaporized most of the dust in the accretion disk as it formed.
2. Condensation: formation of liquid droplets or solid grains out of a gas because of cooling of the gas

- As the Sun contracted gravitationally, it gradually became dimmer.
- Solid grains were able to re-form.
- They gravitated toward the central plane of the accretion disk, forming a dense layer there.
3. Accretion: the gathering together of small solid grains into larger chunks, then into even larger chunks, which eventually grew into the planets.\(^4\)

Early stages

• Initially, slow, gentle collisions; all grains in circular orbits around the Sun
• Slowly colliding objects stuck together
• Formation of *planetesimals* — objects millimeters to kilometers in size
• Runaway growth; “the rich get richer;” large objects’ gravity attracted smaller objects.
• **Planetesimals** are estimated to have reached kilometer size in a few million years.
Later stages: gravitational pull of larger objects caused smaller ones to deviate from circular orbits around Sun; Figure 6.18

- Collisions became more violent
- Small objects broke up rather than sticking together
- Planets swept up most of remaining small objects

Final stages of accretion: *heavy bombardment* that led to formation of impact basins & craters still visible on old surfaces
Accretion required solid raw materials (Table 6.3).
Close to Sun, only rocky materials could be solid. Explains rocky composition of terrestrial planets.
Farther from the Sun, ices could exist as well as rock. They were more abundant because they are made of the most abundant elements.

Ice and rock formed large solid bodies, perhaps 20 times Earth mass.

Their gravitational pull attracted hydrogen and helium gas, and they grew very large. Jupiter became a giant ball of gas.

It began to contract under its own gravitation and grew hot. (Figure 6.20)
Origin of comets and asteroids

Asteroid belt: Gravitational pull from nearby Jupiter prevented formation of a full-sized planet because collisions fast, not slow

Kuiper Belt: Icy planetesimals formed in the same way as in the rest of the solar system. Difference: in outer parts of solar system, density of nebula low, not enough material available for large planets to form

Oort Cloud: Icy planetesimals that came near Jupiter were flung outward and came to rest far from the Sun.
General remark

The theory implies that the formation of the planets was a natural by-product of the formation of the Sun.

Therefore, it predicts that solar systems like the one we live in are fairly common.

Evidence for planets orbiting other stars has indeed been found by means of the star’s wobble in response to the planet’s gravitational pull.

However, in many cases a giant planet orbits close to the star, where it could not have formed by condensation and accretion.
Origin of Moon

- Current theory: Mars-sized asteroid from asteroid belt struck Earth about 4.5 billion years ago
- Both objects already differentiated - formed internal layers, core & mantle
- Cores intermingled
- Mantle material (mostly Earth’s) formed new object in orbit around Earth, by accretion of small chunks of debris from the collision

Other anomalies in the solar system are also thought to be due to severe collisions at early times: Uranus was “knocked over,” Venus suffered a crash.

Numerical simulations of Moon origin: (1) (2)

(2) is an image by Robin Canup, no longer found on the internet.