Brooks Observatory telescope observing

Mon. - Thurs., March 22 – 55, 8:30 to about 9:45 PM

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

Present your blue ticket with your name and my name written on it, or a sheet of paper.

Please attend one session during the semester. You may also satisfy this requirement by attending a regular observing session after a Friday evening public planetarium show.

If you attend this week, a 1/2 to 1-page report/journal is due Wednesday, March 31.
Quiz 4 is available for pickup in front

Extra credit corrections: 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, March 29.
- Or by email until midnight that night. If possible, please avoid attachments.

Distribution of scores

The last day for students to withdraw from classes is Friday, March 26.
Extra credit assignment 5 is now online at Mastering Astronomy

Covers this week’s material: asteroids, meteor(ite)s, comets, the Sun

Due this Friday, 5:30 PM (can still work it after that but no credit)

Extra credit offered

• Up to 10 points toward the 200 for the course (same as planetarium & observatory requirement)
• Partial credit available

Two more will be posted, due April 9 and 23
Small bodies of the solar system: debris from planet building

Meteorites
Asteroids
Kuiper Belt Objects
Comets

Importance of small bodies: compared to planetary rocks, small bodies are less likely to have been heated and modified during their history.

Therefore, more likely to preserve a record of conditions at their formation.
Meteorites

Terminology

- **Meteors**
  - Short-lived trails of light — “shooting stars”
  - Produced when small interplanetary particles enter the Earth’s atmosphere and vaporize because of frictional heating
  - Called “meteor showers” when they come in bunches
  - The **Orionids** are a shower that occurs in October each year.
Showers are named after the constellation from which the meteors appear to come; owing to a perspective effect, they *radiate* away from a point.
• Meteoroids: chunks of rock in space, which may or may not strike a planet

• Meteorites: chunks of rock that have struck a planet
Meteorites: two main types

- Processed meteorites: stones, stony irons, irons
  - Iron meteorites easily identified. Example:
– Solidified from liquid, similar to planetary rocks
– Broken fragments of a planet-sized, differentiated parent body: stones from mantle/crust, irons from core

• Primitive meteorites. Example:

Detail view
– Made of tiny grains stuck together
– Appear to have formed by condensation directly from gas phase; never liquid
– Compared to planetary rock, rich in substances that are easily driven out by heating
– Rich in water of hydration
– Some are rich in carbon-bearing compounds, even including amino acids (non-biological origin)
– Never have been subjected to heating or processing of any kind; were never part of a larger parent body
– Preserve record of conditions at their formation
Radioisotope ages

- All primitive meteorites: $4.56 \pm 0.01$ billion years
- Evidence for solar-system-wide condensation event, supports nebular theory
- Interpreted as age of solar system, meaning date of first formation of solid material in primordial cloud surrounding infant Sun
- Processed meteorites are slightly but definitely (up to 0.1 billion years) younger. They came from parent bodies that underwent subsequent evolution. Implies rapid formation of planets.
Where meteorites come from

When a meteorite is seen to fall, its path can often be traced backwards, and its prior orbit around the Sun can be calculated.

In all such cases, the far end of the ellipse is in the asteroid belt, between the orbits of Mars and Jupiter.

Implication: meteorites originally were chunks of asteroids that were broken off in collisions.

There is also other evidence that meteorites are chunks of asteroids.
Meteorites from Mars

During formation of an impact crater, a small portion of the ejected material can reach escape speed from the planet and go into orbit around the Sun. Eventually, a few fragments may reach Earth.

About 20 meteorites are thought to have come from Mars in this way.

Evidence:

- Mineral makeup suggests formerly belonged to a planet’s crust
- Trapped gases correspond precisely to composition of Mars’s atmosphere.
Asteroids

Location

- Most are in *main belt* between orbits of Mars & Jupiter (Fig. 9.3)
- A few are in orbits that cross that of Earth or Mars; collisions theoretically possible

Characteristics

- Largest asteroid: *Ceres*, diameter about 600 miles
- Most are much smaller; likely collision fragments
- The largest ones are spherical, while smaller ones have irregular shapes
– Gravity pulls large, massive objects into a spherical shape
– For small objects, gravity too weak to overcome native strength of rock

– Transition from spherical to irregular shapes at diameters between 300 & 600 miles
Comets

Visible appearance

- Tail
- Head

Motion

- Rise and set with the stars, move against the stars slowly, night to night
- Visible for days or weeks
Spectrum of light from a comet

- **Emission lines** from low-density gases energized by sunlight
- Sunlight reflected from solid particles (rock powder or dust)

Model: “dirty snowball” or “icy dirtball”

- Nucleus up to about 10 miles across made of ices, rock powder (dust), possibly chunks of rock
- When comet approaches Sun, ices vaporize, dust particles released from ice, atmosphere develops, hides nucleus
Nature of tail

- Always points away from Sun (Fig. 9.9)
- Dust pushed by sunlight, forms dust tail
- Gas pushed by solar wind, forms ion tail or plasma tail
- Thus, these forces produce two tails. (Fig. 9.8)
Nucleus hidden by atmosphere or *coma*; size estimated indirectly, typically a few miles
Nucleus of Comet Halley: image from *Giotto* spacecraft

- Surprisingly dark
- Spacecraft particle sensors found carbon-rich material

General remark: dark, carbon-rich material is abundant in outer asteroid belt and beyond.

- Dark, carbon-rich, primitive meteorites
- Asteroids with similar darkness, coloration
- Dark surfaces of some moons of Jupiter, Saturn
Deep Impact mission to Comet Tempel 1

- Flew by the comet
- Released a “smart” probe designed to impact the comet
- Obtained images, spectra of the flash of light from the impact; also observed from Earth, space telescopes
- Comet “ingredients” found: water ice, silicate minerals, carbonate minerals (surprise)

Comets originate in two solar system regions or “reservoirs”
Kuiper Belt

- More than 800 objects now known
- Extends from Pluto’s orbit (40 AU) to 50 AU
- Pluto is 2nd largest object known in Kuiper Belt; largest is called Eris
- Circular or somewhat elliptical orbits
- Occasionally, the gravitational pull from Neptune deflects a comet into a highly elliptical orbit that plunges into inner solar system
- Origin of most comets with periods less than about 200 years
Oort Cloud

• Spherical cloud containing billions of comets
• About 50,000 to 100,000 AU from Sun, essentially at rest there
• Occasionally, gravitational pull from a passing star nudges a comet toward the Sun (or ejects it from solar system)
• Comets enter inner solar system on orbits that have shapes of extremely long, narrow ellipses
Short-period comets: after many passages close to the Sun, the comet’s ices eventually vaporize.

Only a cloud of rock powder and chunks remains, continuing to orbit the Sun and gradually spreading out along the orbit.

When the Earth passes through such a cloud of debris, we experience a meteor shower.
Distribution of Quiz 4 Scores

Median = 13

Number of Students

Score

Number of Students

Score

Median = 13