Astro 102/104

Lecture #22: Asteroids

• Discovery/Observations
• Where are they?
• How many are there?
• What are they like?
• Where did they come from?

Reading: Chapter 12.1

The Main Points

Asteroids are small, rocky objects that exhibit surprisingly diverse compositions and surface geologies.

Most asteroids are found in the Main Belt between Mars and Jupiter or in the Kuiper Belt beyond Neptune, but many exist in near-Earth space too.

Asteroids

• "Asteroid" is Greek for "star-like"
• Asteroids are small, rocky objects that look star-like in telescopes, except they move across the sky like the planets do
• The first asteroid was discovered in 1801 – Ceres, about 940 km diameter
• There may be 1,000,000+ >1 km diameter

Asteroids are discovered in telescopic images because they move at a different speed across the sky than the stars.
The Largest Asteroids

- **1 Ceres**: Diam. = 940 km, a = 2.77 AU
  - Discovered by Guiseppe Piazzi in 1801
  - Piazzi was searching for a "missing planet" between Mars and Jupiter
- **2 Pallas**: D=540 km, a=2.77 AU, disc. 1802
- **4 Vesta**: D=510 km, a=2.36 AU, disc. 1807
- **13 main belt** asteroids have D > 250 km

Where are the Asteroids?

- Asteroids can be found throughout the solar system, but there are two main populations:
  - The **Main Belt** between Mars and Jupiter
  - The **Kuiper Belt** beyond Neptune's orbit
- Most of the asteroids with well-determined orbits are in the main belt
- Other smaller populations exist too
  - Trojans, Apollos, Amors, Centaurs, ...

The Main Asteroid Belt

- The main belt extends from about 2.2 to 3.3 AU
- Most of the orbits lie at or near (±10° to 20°) the plane of the ecliptic
- As of 2008, almost 200,000 main belt asteroids have well-known orbital parameters
- The number has been recently increasing by a few thousand per year because of new telescopic search programs

A snapshot of the locations of all known inner solar system asteroids as of March 2007 (outer circle is the orbit of Jupiter)

Gaps in the Belt...

- Astronomer Daniel Kirkwood (1886) noticed that the main belt is not uniformly populated.
- Asteroids "missing" from places where disturbances by Jupiter are strongest.
- These places are where resonances with Jupiter's orbit occur.
- May explain why no planet here: Jupiter only allowed small bodies to coalesce.

Other Asteroid Groups

- Trojans
  - About 1000 asteroids leading and trailing Jupiter by 60°.
- Centaurs
  - About 100 asteroids found between Jupiter & Neptune.
- Kuiper Belt Objects
  - More than 1000 large asteroids beyond Neptune.
- Near-Earth Asteroids (NEAs)
  - Atens (6%): orbits interior to Earth's.
  - Apollos (62%): orbits that cross Earth's.
  - Amors (32%): orbits exterior to Earth's (e.g. 433 Eros).
- All these populations are incompletely counted.

How Many Asteroids are There?

- The number of asteroids of a given diameter D is proportional to 1/D^2: a collisional distribution.
- For example:
  - 3 > 500 km
  - 13 > 250 km
  - hundreds > 100 km
  - 10,000+ > 10 km
- Total: >1,000,000 > 1 km
- Most of the MASS is in the largest few asteroids.
- Total mass of all asteroids is only ~ 5-10% mass of the Moon.
Discovering Asteroids

- For many years, most discoveries were random
- Within the past decade, dedicated surveys have begun in response to the possible threat of asteroid and comet impacts on the Earth
  - NASA Spacewatch Program
  - Air Force Near Earth Asteroid Tracking Program (NEAT)
  - Lowell Observatory Near Earth Object Survey (LONEOS)
  - Lincoln (MIT) Near Earth Asteroid Research Project (LINEAR)
  - Catalina (Arizona) Sky Survey
- Tens of thousands of objects discovered, many NEAs...

Dedicated search programs started in the last few years have located perhaps 70% of the >1 km Potentially Hazardous Asteroids (PHAs) that could pose a threat to life on Earth.

Asteroid Physical Properties

- Many diagnostic properties can be determined by telescopic remote sensing:
  - Albedo (% of reflected sunlight)
    - darkest are 1% to 2%, brightest are 40% to 50%
  - Spin period (length of an asteroid "day")
  - Shape (from radar & variations in the light curve)

Asteroid Composition

- Spectroscopy and radar observations of asteroids reveal four main classes:
  - C Type: dark, "carbon rich", albedo ~5%
  - S Type: brighter, "stony", albedo ~20%
  - D Type: dark, very red spectra
  - M Type: rare "metallic" type, very radar bright
- C,S,D Types probably all primitive (?)
- M Types and other anomalous classes (like Vesta) from differentiated parent bodies
• Composition varies systematically with distance from the Sun
• Implies that asteroids preserve the conditions of planetary formation in the early solar system
• But primitive vs. differentiated issue is controversial!

Asteroid Geology

• 4 asteroids visited up close by spacecraft
  – 951 Gaspra: Galileo flyby in 1991
  – 243 Ida: Galileo flyby in 1993
  – 253 Mathilde: NEAR flyby in 1997
• Also: Spacecraft images of Martian moons Phobos and Deimos: captured asteroids?
• Abundant evidence for impacts, and surprising evidence for erosion and tectonism on these bodies

951 Gaspra
S Type
16 x 11 x 10 km

253 Mathilde
C Type
66 x 48 x 46 km (large!)
Many large craters
Density only 1.3 g/cm³
May be 50% "empty"

433 Eros
S Type
31 x 13 x 13 km
Many large craters
Density about 2.6 g/cm³
Geology?
Summary

- Asteroids are small, rocky, primitive objects thought to be remnants from the formation of the solar system
- There are probably more than 1 million asteroids > 1 km in size in the solar system, but their total mass is only a small fraction of the mass of the Moon
- Remote sensing shows that not all asteroids are alike
  - Different compositional classes (C, S, D, M)
  - Some asteroids have had complex internal histories
- Spacecraft observations show that asteroids have interesting and complex geologic histories: impacts, tectonics, erosion

Next Lecture...
- Meteorites: Samples from the Early Solar System
  - Classification
  - Parent Bodies: Asteroids & Planets
- Reading: 12.1