30. Asteroids and TNOs
Overview: Structure

Inner system: terrestrial planets, asteroids.

Outer system: giant planets and moons, “TNOs”.

Oort Cloud: comets.
Giant Asteroids
Giant Asteroids

“Leftovers” from planet formation.

Differentiated structure!

Vesta

- Basaltic crust
- Mantle
- Iron-Nickel core

530 km

PIA14321: Vesta Full Rotation Movie
PIA15510: Vesta’s Internal Structure

Ceres

- Thin, dusty outer crust
- Water-ice layer
- Rocky inner core

975 km

PIA19547: Ceres Rotation
Largest Asteroid May Be 'Mini Planet'
Pluto and Charon

Double planet + 4 small moons; possibly formed by giant impact (similar to Earth-Moon system).

- Orbit $\Rightarrow$ mass: $M_P = 0.0022 \, M_E$; $M_C = 0.00027 \, M_E$
- Density: $\sim 1860 \, \text{kg/m}^3$
- Composition: rock + ices
- Thin atmosphere: $\text{N}_2$, $\text{CH}_4$, $\text{CO}$

Pluto has probably differentiated; Charon may be too small to melt.
Pluto: Norgay Montes
Largest Known TNOs (and Satellites)
Asteroid Light Curves

Period
Most asteroids are **rubble piles**: loose collections of fragmented rock held together by self-gravity.
Asteroid Belt Structure

- Trojans
- Hildas
- Mars
- Jupiter

Wikipedia: Asteroid belt
Asteroid Belt Structure

Inner Belt: $a < 2.5$ AU
Mid Belt: $2.5$ AU < $a < 2.8$ AU
Outer Belt: $a > 2.8$ AU
Asteroid Belt Structure

Resonances with Jupiter create gaps between belts.
Asteroid Belt Structure
Trojan Asteroids

- Jupiter
- Mars
- Hildas
- L₄
- L₅

Wikipedia: Asteroid belt
Orbits starting near L₄

\[ \frac{m_a}{m_b} = 49 \]
Orbits starting near $L_1$

$m_a/m_b = 49$
Points 4 and 5 are usually stable.

They are unstable in:
(a) Pluto-Charon system \((M_C / M_P > 0.04)\)
(b) Earth-Moon system (other planets perturb)
Hilda Asteroids

2:3 MMR; stable since they avoid Jupiter ($e \sim 0.3$).

Small inclinations ($i \approx 20^\circ$).
Pluto’s Orbit

Pluto is in a \textit{3:2 resonance} with Neptune. This is stable since Pluto avoids Neptune.

Pluto’s orbit is highly tilted (inclination $i = 17^\circ$) to the rest of the solar system.
TNO Orbits

- Classical: outside Neptune's orbit
- Resonant: like Pluto's orbit
- Scattered: highly elliptical
Orbital Populations

Resonant KBOs (plutinos) avoid Neptune’s influence.

Scattered KBOs which cross Neptune’s orbit are easily perturbed.

These scattered KBOs become short-period comets.