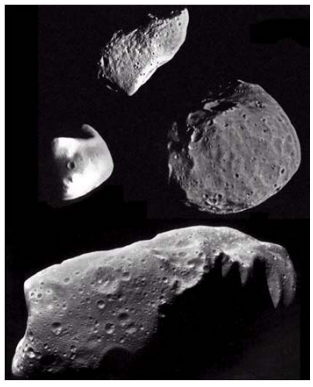
# Asteroids—4 Feb

- Asteroids, Comets, Minor Planets
  - Asteroids today
  - Comets & minor planets next week
- Understanding composition of solar system
  - Read for next week: Chapter 8, Formation of the solar system

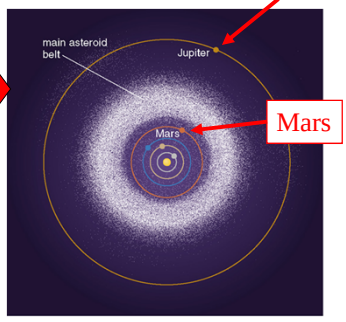


## Asteroids

- Small, rocky objects in orbit around the Sun.
  - Sizes up to 940 km. (Detroit to Boston)
  - 26 known with sizes > 200 km (width of MI).
- 250,000 currently have designations.
  - + estimated > 1 million asteroids < 1 km in size.
- But total mass probably less than mass of Moon.

### Asteroid Belt

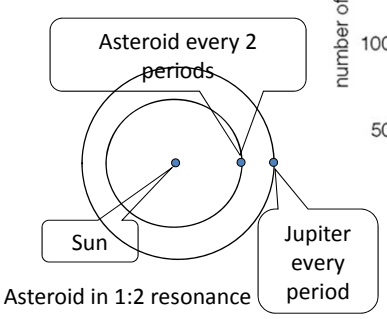
- semi-major axis 2.2 - 3.3 AU.
- Between orbits of Mars and Jupiter
- Includes 75% of known asteroids.
- Mostly orbiting sun in same direction of planets, and in plane of solar system.

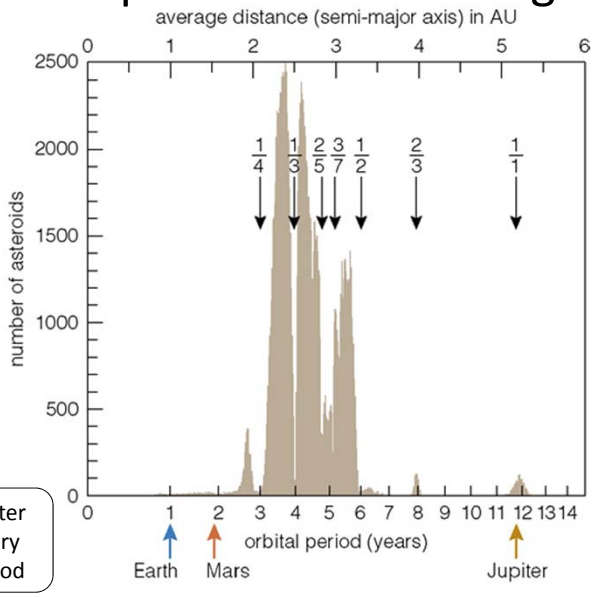



[Fig. 9.3]

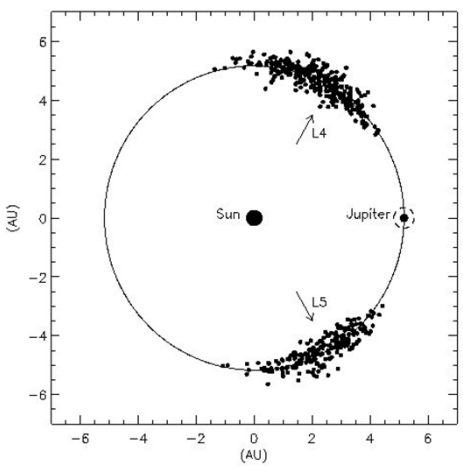
# Jupiter prevented planet from forming

- Gaps in asteroid belt correspond to resonances with orbit of Jupiter
  - In a resonance, pulling by Jupiter adds over & over.



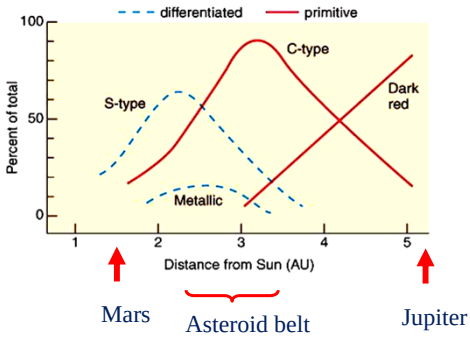

# Trojan Asteroids



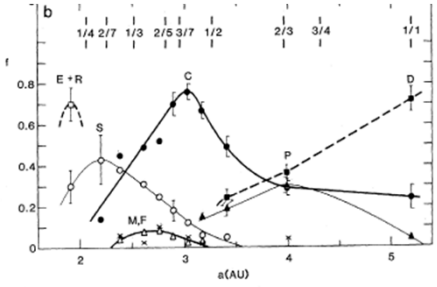
# Asteroids

- Most are carbon-rich “C-type.” Low albedo
- Stony “S-type”,
  - dark carbon compounds missing. Redder.
- A few metal-rich “M-type”
  - Mostly iron & nickel
  - Especially reflective at radar wavelengths.

Where Different Types of Asteroids are Found




# Distribution of asteroid types

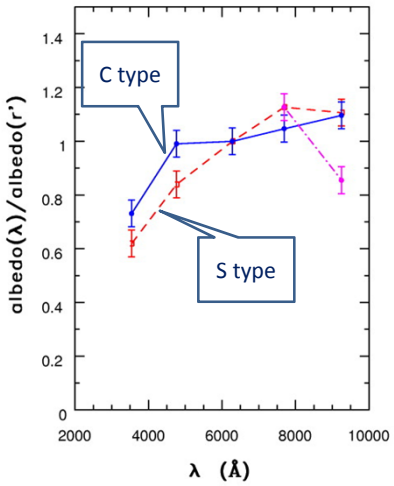



Relative number of asteroid type vs location
J. Gradie and E. Tedesco
Compositional Structure of t
1982, Science, 216, 1405

| Type | Visual geometric albedo | Spectral reflectivity (0.3 to 1.1 μm) |
|---|---|---|
| C | Low (< 0.065) | Neutral, slight absorption blueward of 0.4 μm |
| S | Moderate (0.07–0.23) | Reddened, typically an absorption band ~ 0.9 to 1.0 μm |
| M | Moderate (0.07–0.23) | Featureless, sloping up into red |
| F | Low (< 0.065) | Flat |
| P | Low (< 0.065) | Similar to M, hence pseudo-M or P |
| D | Low (< 0.065) | Very red longward of 0.7 μm |
| R | Very high (> 0.23) | Very red, bands deeper than S |
| E | Very high (> 0.23) | Featureless, flat or sloping up into red |
| U | | Unclassifiable in this system* |

# Measuring composition

- Materials have characteristic reflectance as a function of wavelength.
- Colors of asteroids & meteors are similar.



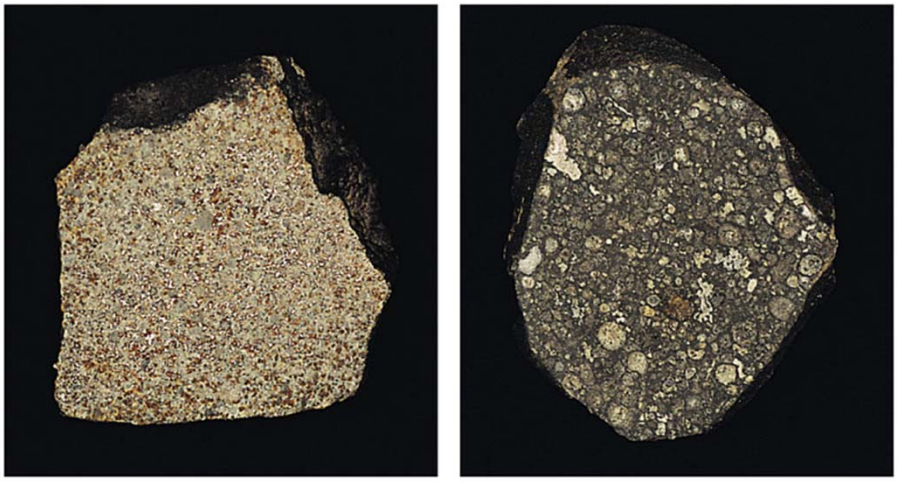

IVEZI, et al, 2001, AJ 122, 2749

# Carbonaceous chondrite

# Stony meteorite

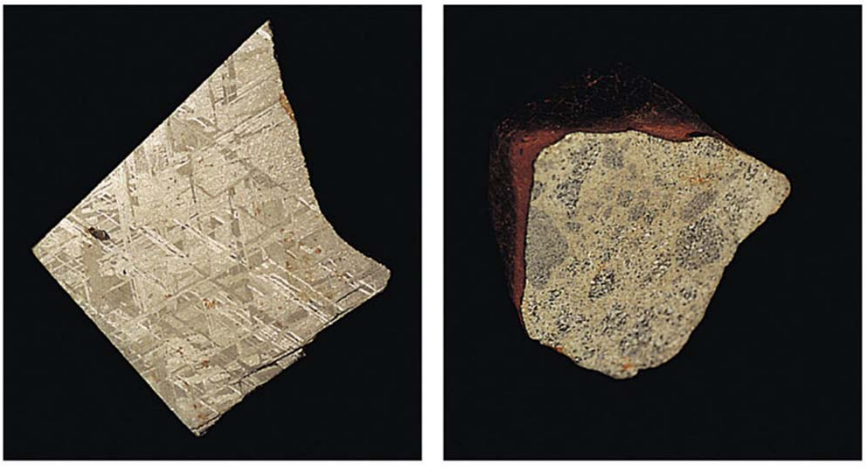
Note fusion crust

# Iron-nickel meteorite



- Primitive meteorites (not melted)
  - Stony (left). Formed in inner asteroid belt
  - Carbon-rich (right). Formed in outer asteroid belt

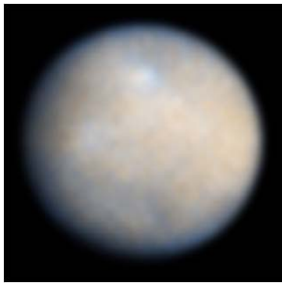




- Processed meteorites (melted)
  - Iron (left). Large iron crystals => cooled very slowly =>part of a large object
  - Stony (right).

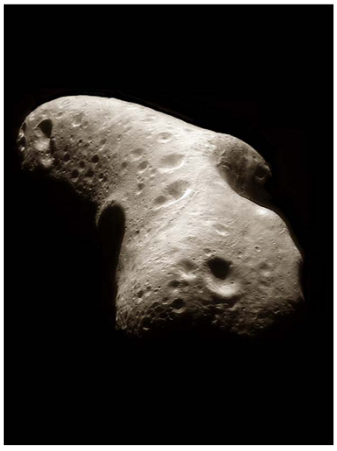
# Ceres

- The largest asteroid
  - 940 km diameter.
- Estimated to contain ~ 1/3 of the total mass of the asteroids.
- Orbit: 2.8 AU
- C-type.



HST

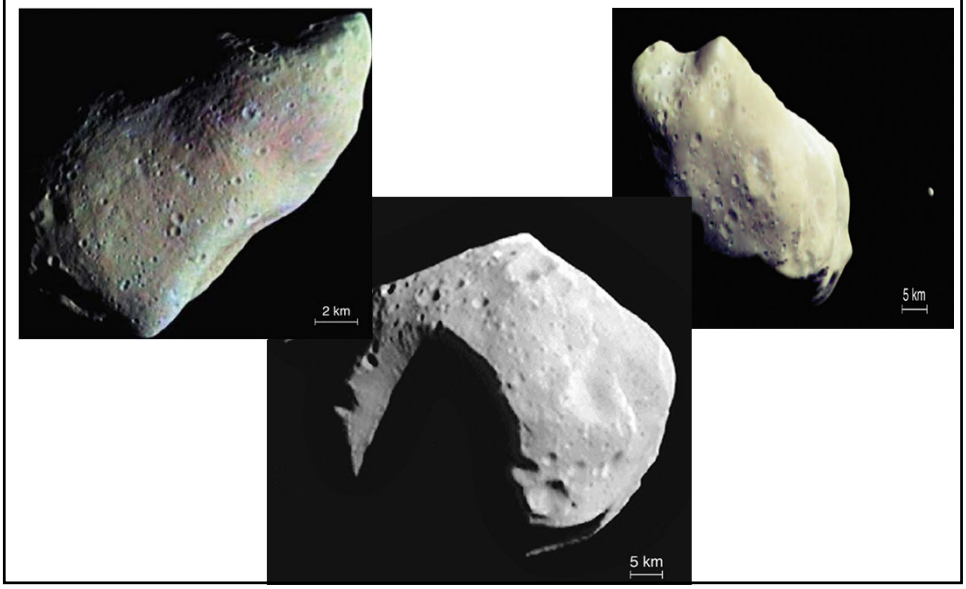
# 433 Eros



- Near Earth asteroid
- S-type
- 35 x 15 x 13 km (size of Lansing)
- Density: 2.4gm/cm3 (rock)
- You would weigh 3 oz on Eros (little bag of potato chips)
- 20 mph speed limit
- NEAR spacecraft orbited for 1 year, then landed Feb. 2001.
  - NEAR found that Eros is not differentiated.

124 km orbit movie

## Gaspra, Mathilda, and Ida (& Dactyl)




## Asteroid families

- Asteroid families have similar orbits and compositions
  - 1/3 of asteroids belong to families
- Orbital elements
  - Semi-major axis
  - Eccentricity
  - Inclination

# Orbital elements

- If the gravity of the was the only force on the asteroid, then the orbital elements do not change.
- Eccentricity and semi-major axis do not change because of Kepler's Law.

1. What powerful principle prevents the inclination from changing?
   A. Conservation of angular momentum
   B. Conservation of energy
   C. Conservation of momentum
2. What can cause the orbital elements to change?
   A. Collisions with another asteroid having the same orbital elements.
   B. Gravity of other planets.
   C. Both A and B