Astronomy 405
Solar System and ISM

Lecture 15
Asteroids

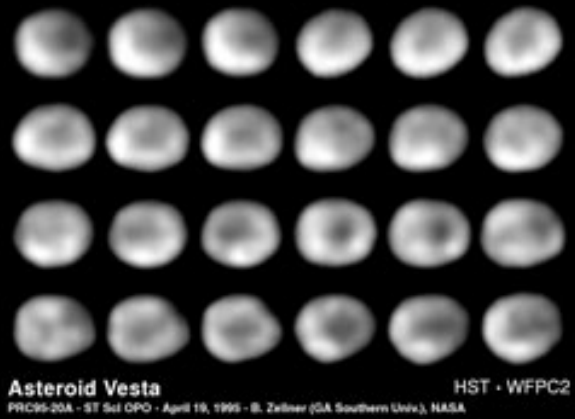
February 18, 2013

Asteroids (minor planets)

1 Ceres - discovered in 1801

334 Chicago - 154 km, 7.7 yr

Several 10^5 asteroids known. Total number may be 10^7, but the total mass is only $5 \times 10^{-4}\ M_\oplus$.



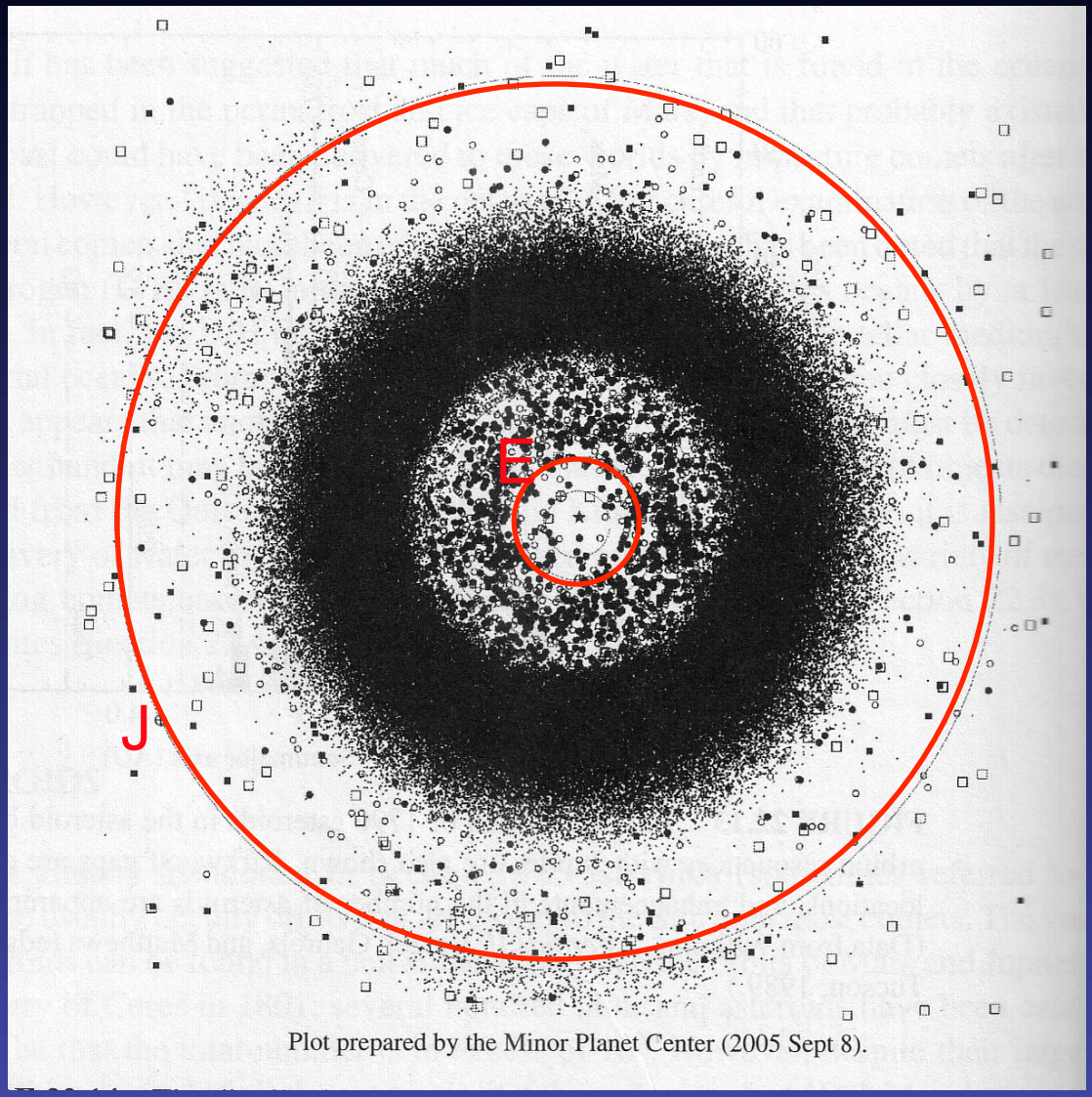
Hubble Follows the Rotation of the **Asteroid Vesta**
This is a NASA Hubble Space Telescope series of 24 images showing the full 5.34-hour rotation of the 325-mile diameter (525 kilometre) asteroid Vesta.

243 Ida
55 km long

Dactyl
1.6x1.2 km^2

Diemos Phobos

237,000 objects plotted in the figure



Plot prepared by the Minor Planet Center (2005 Sept 8).

Distribution of 1796 Asteroids in the Asteroid Belt

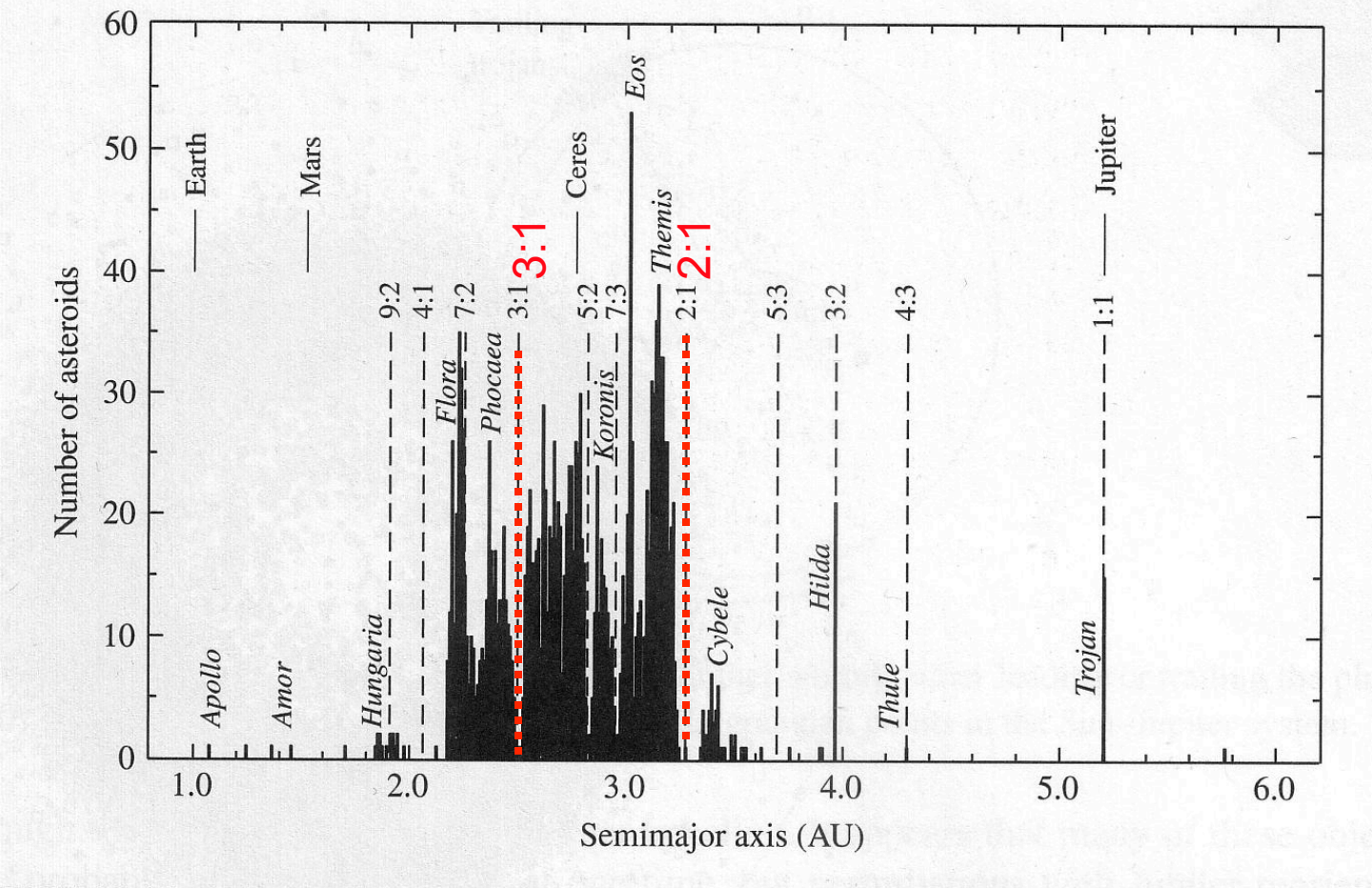
The distribution of asteroids is not uniform.

Kirkwood gaps - orbital resonance with Jupiter

2:1 resonance at 3.3 AU; 3:1 resonance at 2.5 AU

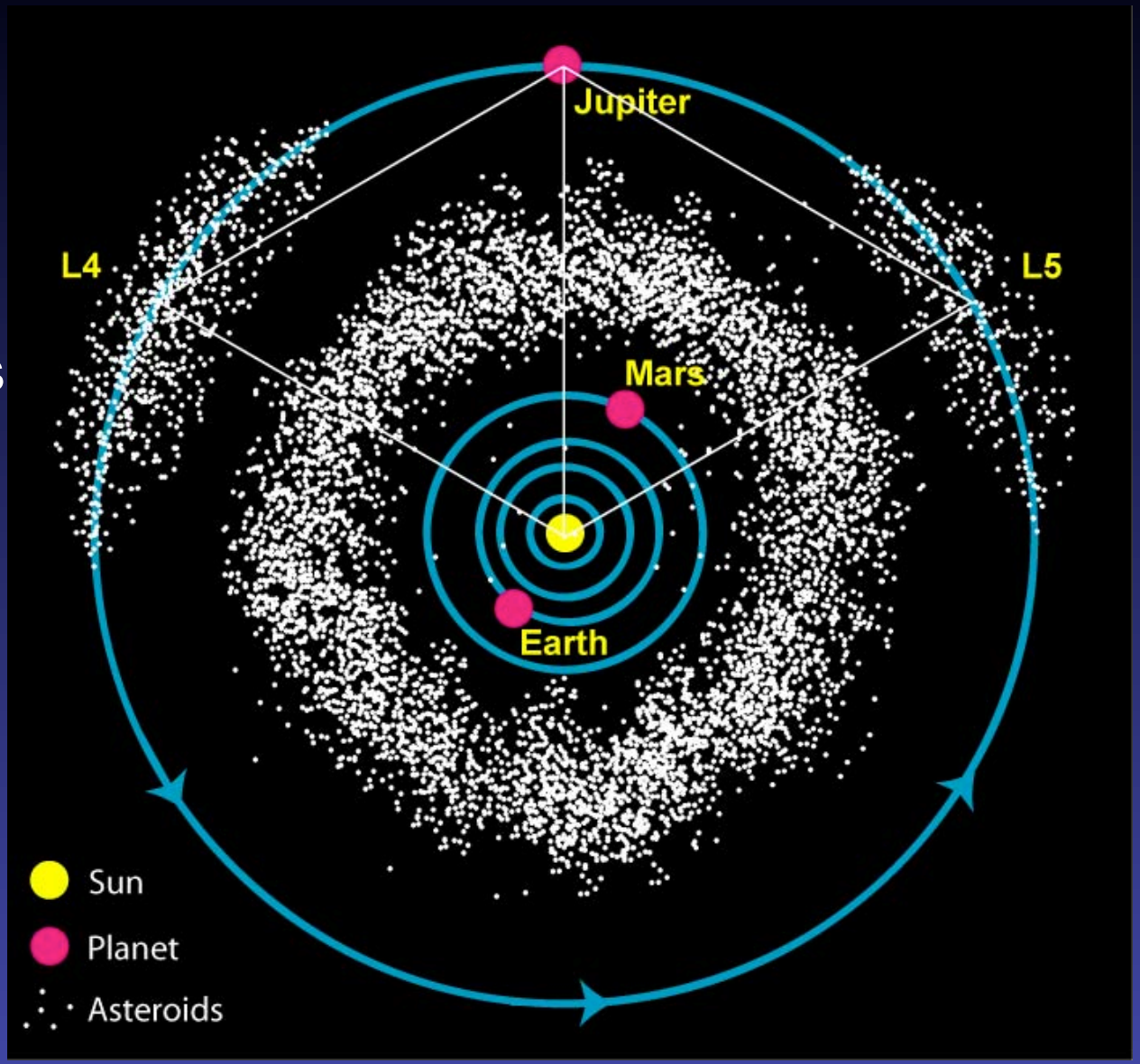
Not empty in gaps; similar to gaps in Saturn's rings.

Tidal interaction => elliptical orbits => move out of gap



Distribution of Asteroids

Trojan Asteroids

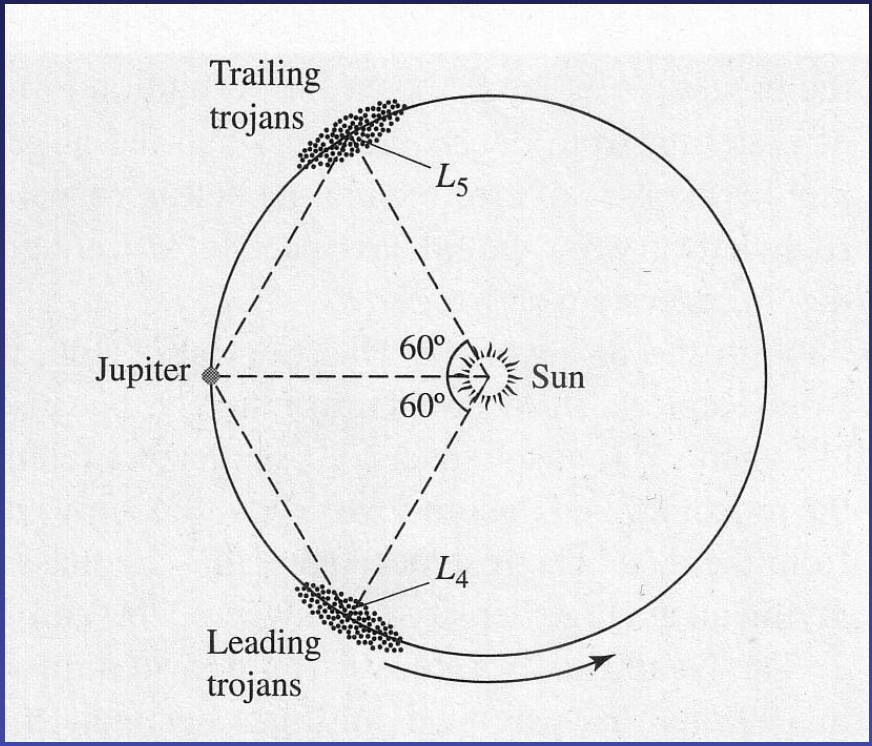


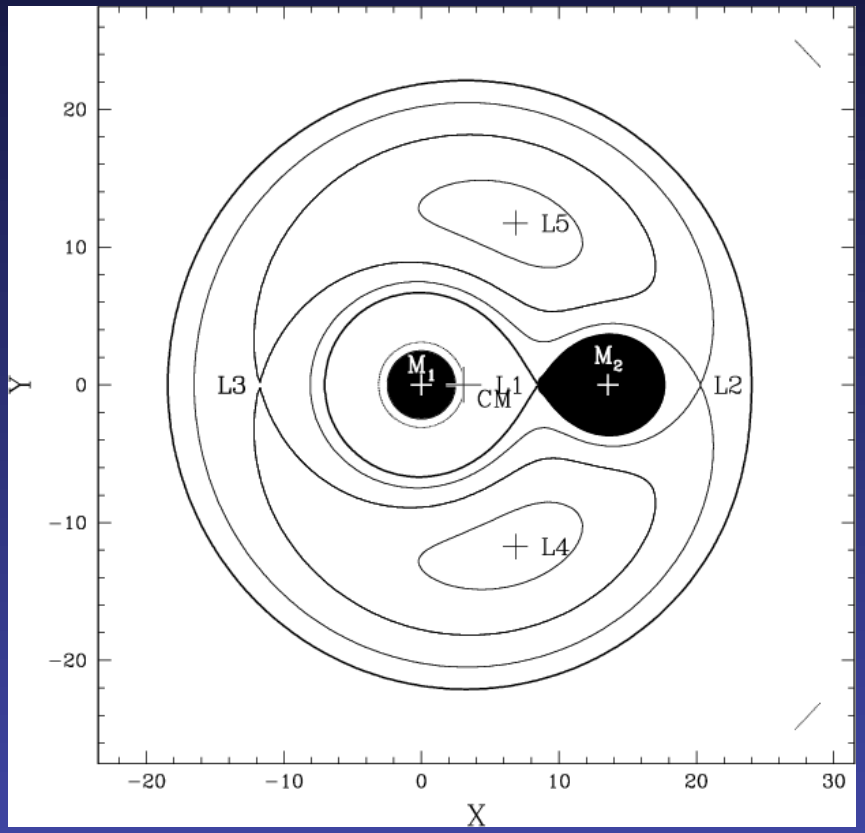
Asteroid Belt

Trojan Asteroids

1:1 resonance with Jupiter. Gravitational wells that provide unusual stability. Mars and Neptune also have their own 1:1 resonant asteroids

Lagrangian points - no force on the test mass.
L4, L5 (each) form equilateral triangles with M_1 and M_2





Asteroids with Orbits Crossing the Terrestrial Planets

Amors - between Mars and Earth

Apollos - cross Earth orbit approaching perihelion

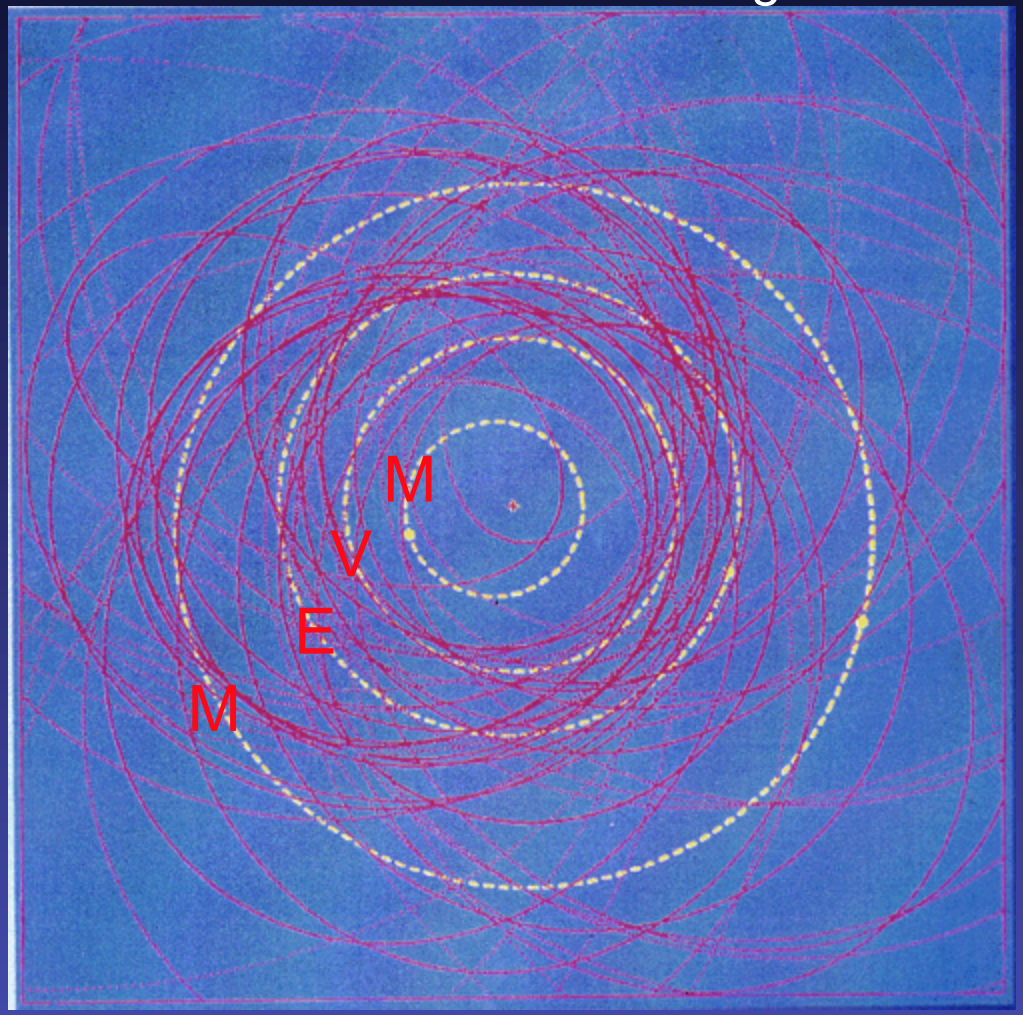
Atens - orbital semimajor axis < 1 AU

Earth-crossing asteroids were in the main belt at one time, but were perturbed by Jupiter and reoriented their orbits.

Some might be extinct cometary nuclei.

Collisions with Earth are Possible!!!

Earth-crossing asteroids



Collisions among asteroids can shatter a large asteroid into an “asteroid family” that occupy near identical orbits.

Kiyotsugu Hirayama first pointed this out in 1918.
More than 100 Hirayama families (asteroid failies) are known.

Some less powerful collisions only produce dust.

P/2010 A2: Unusual Asteroid Tail Implies Powerful Collision

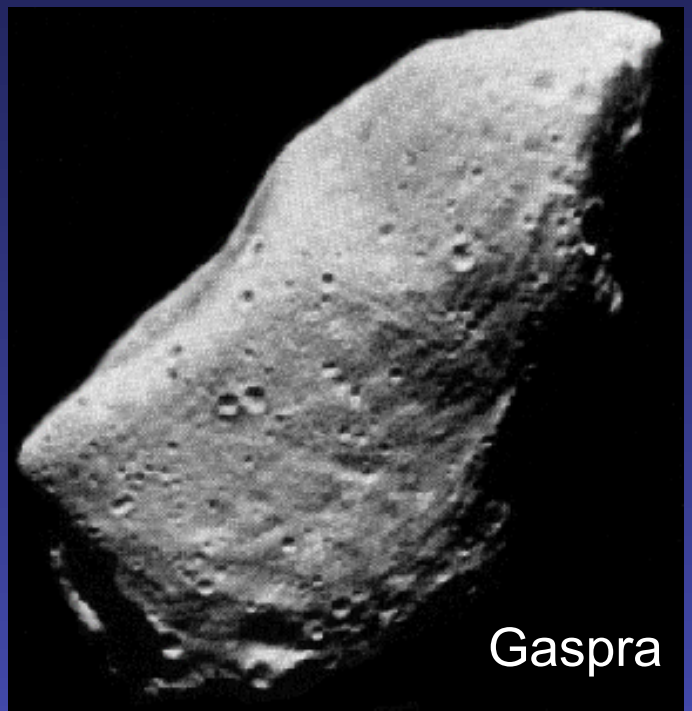
Rendezvousing with Asteroids

Galileo flybys of 951 Gaspra and 243 Ida.

Gaspra (in the Flora family) was broken off from a larger Asteroid ~200 Myr ago.

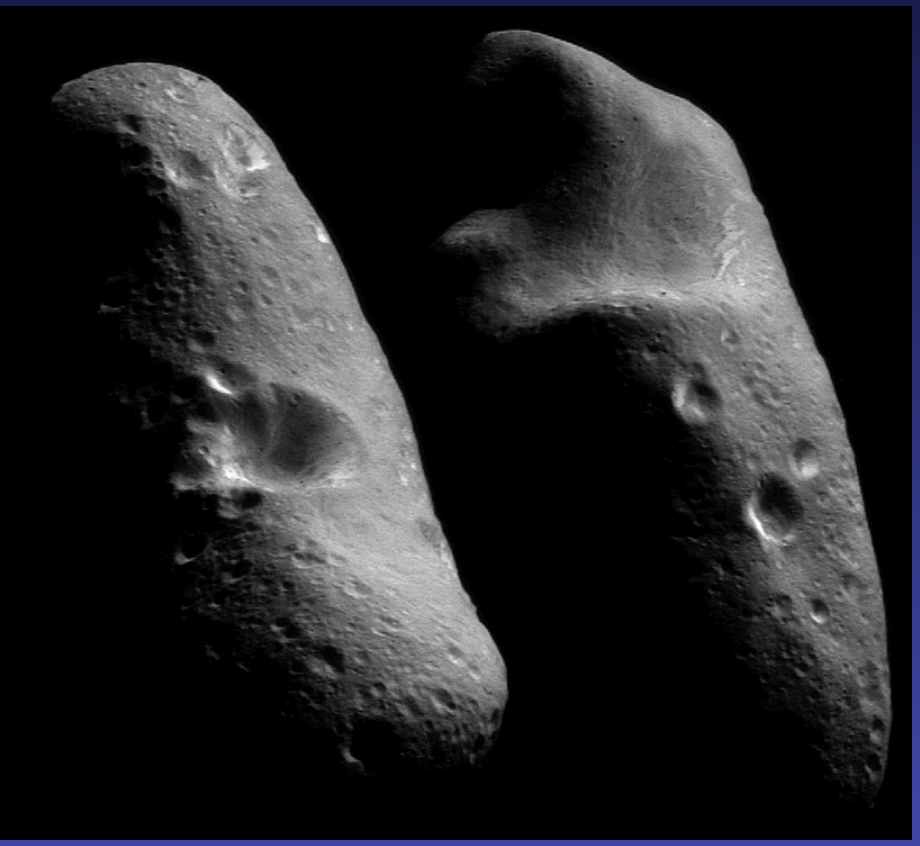
Ida (in the Koronis family) may be as old as 1 Gyr, based On its crater density.

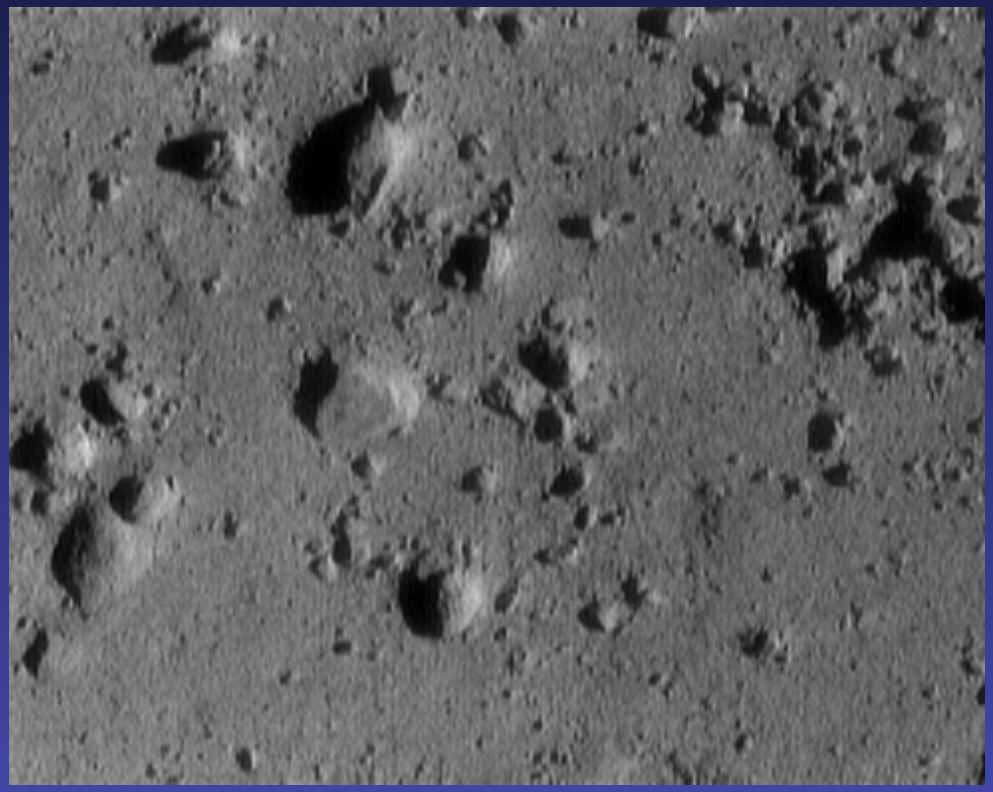
Dactyl's orbit => Ida 3-4x10^{16} kg, 2.2-2.9 g/cm^3

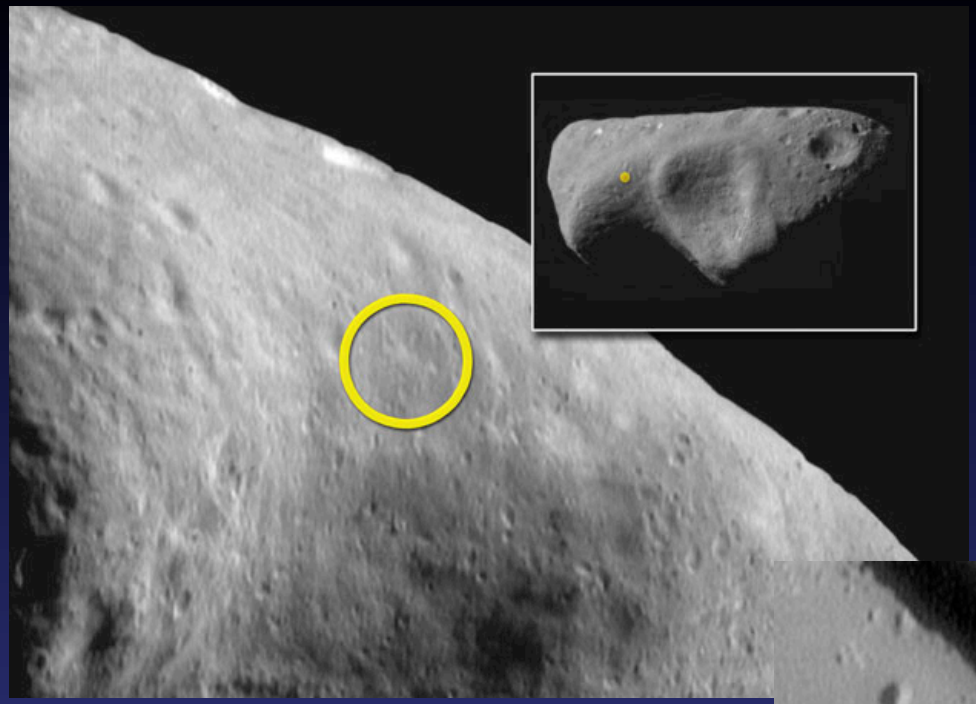


The Near Earth Asteroid Rendezvous Mission NEAR-Shoemaker

Launched in 1996, destination 433 Eros (means love)
Arrived on Feb 14, 2000 (Valentine's Day)
Orbited around it for a year, landed at a speed of 1.6 m/s.



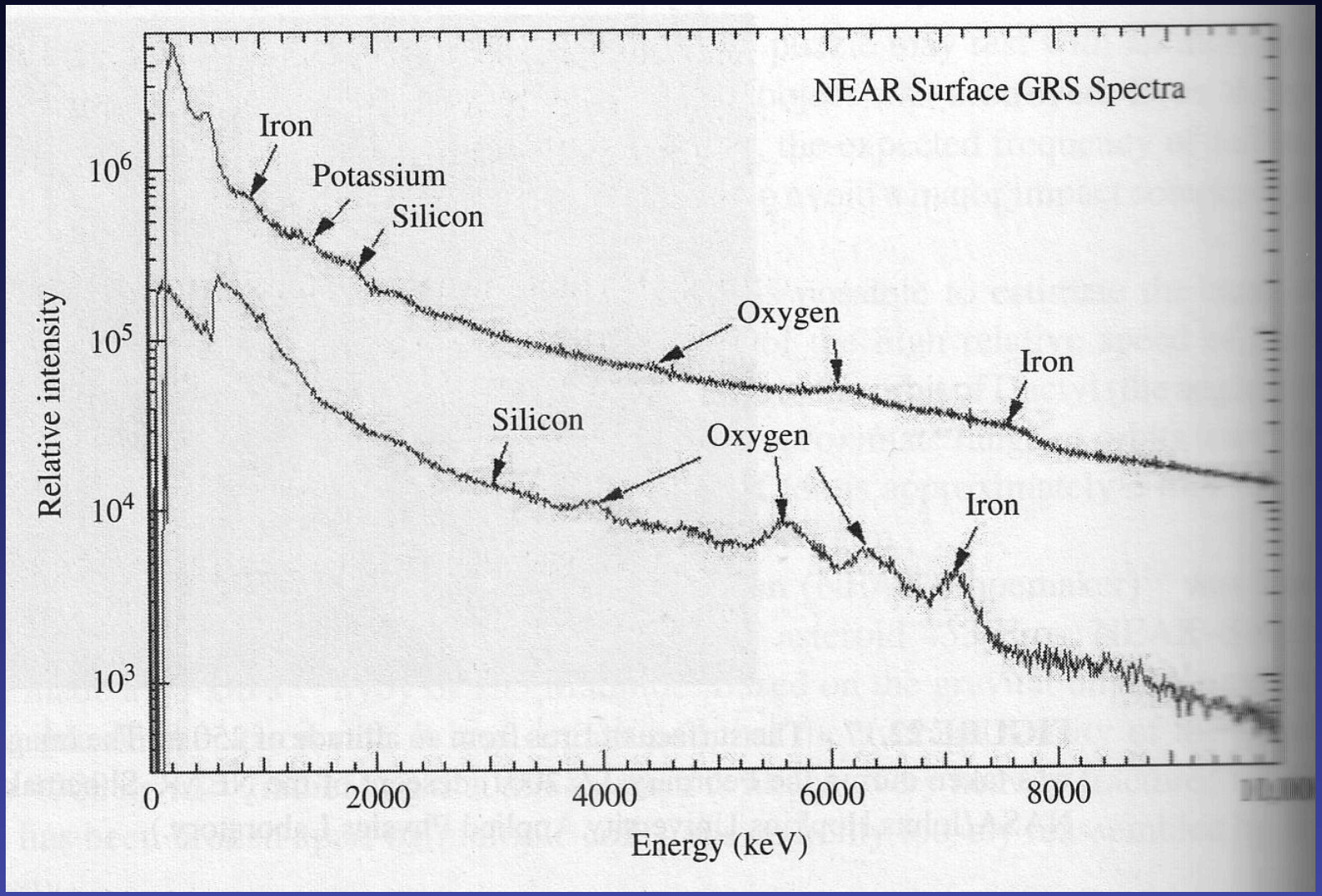




Density of Eros 2.67 g/cm^3
25% porosity

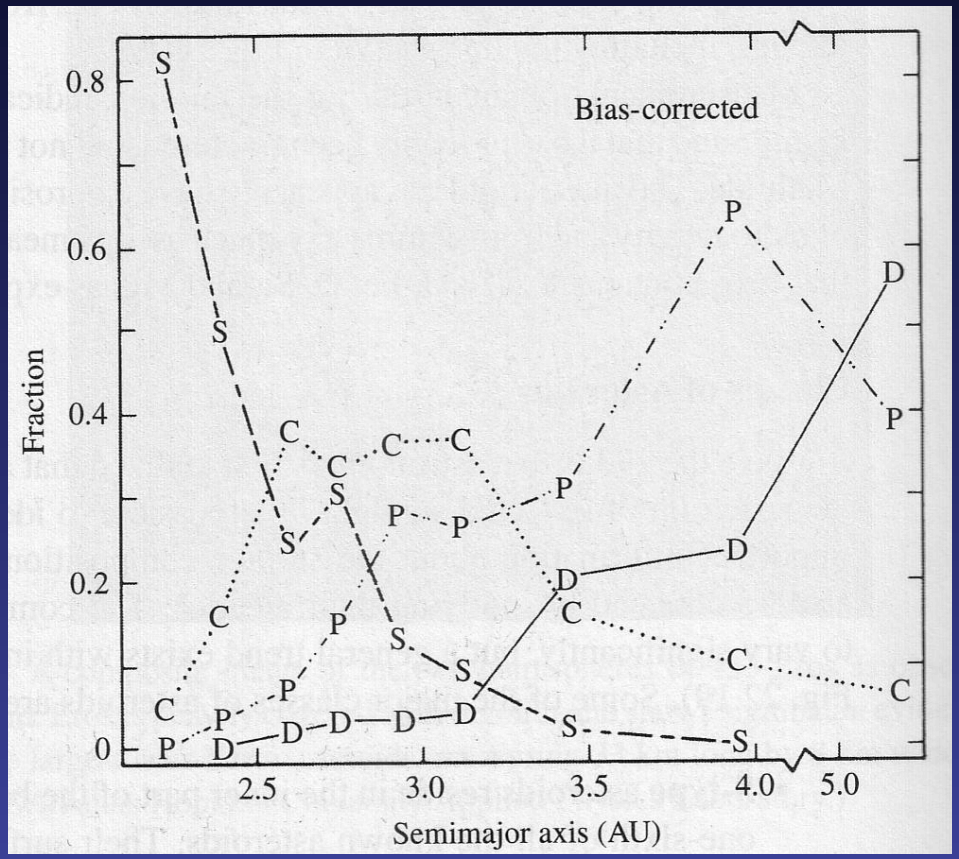
After landing, transmitted signals for another week.

Gamma-ray spectra of Eros show presence of metals (obtained by two gamma-ray detectors that landed on Eros)



Classes of Asteroids

Spectra of asteroids (reflected sunlight) show absorption bands that give information about the surface compositions. Albedos also provide information about surface meterial.



Differences are caused by temperature gradient in the solar nebula.

S-type (1/6 of all asteroids)
2-3.5 AU, Fe- or Mg-rich silicates,
Albedos 0.1-0.2; Gaspra, Ida, Eros

M-type
2-3.5 AU, very metal rich,
Albedos 0.1-0.18

C-type (3/4 of all asteroids)
Peak near 3 AU, carbonaceous,
Albedos 0.03-0.07; Mathilde

P-type
3-5 AU, reddish, organic compounds,
Albedos 0.02-0.06

D-type
Similar to P, redder and farther out
Trojan asteroids

Internal Heating

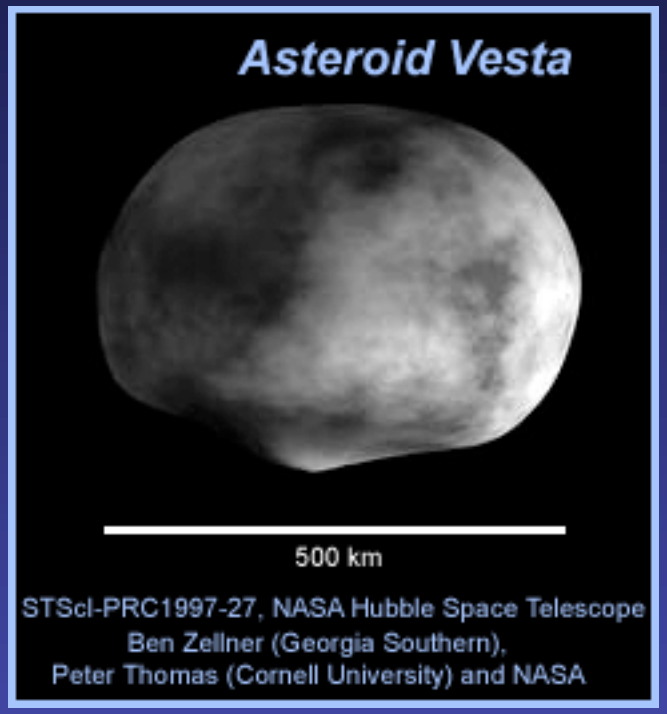
The metal-rich S- and M-type asteroids suggest molten interiors that allowed gravitational separation. Collisions removed the outer layers and exposed the metal cores.

Vesta's surface appears to be covered with basalt (form from lava flows). With its small size (R=250 km), Vespa's interior has been heated by the decay of radioactive Al:

$$^{26}_{13}\mathrm{Al} \rightarrow {}^{26}_{12}\mathrm{Mg} + e^{+} + \nu_e$$

e^+, e^- annihilation generate energy

Where did the radioactive Al come from? A nearby supernova.



Give a quantitative example of rate of energy generation by radioactive decay of Al.
(Do this on blackboard.)