asteroids I Most asteroids orbit between Mans & Jupiter's orbits. But two are known that travel at least as far out as Saturn's orbit : · 944 Hidalgo : eccentric abit from Fijust part Mars to near Satura about 40 km across; extenct comet? (desc 1920) · 2060 Chiron : arbit ranges from just inside Satura to rear Uranus. (disc. 1977) ~180 km across Both arbits are inclined to ecliptic

Q What distinguishes asteroids

from comets ?

In the minor planet center animation, Rere seen to be more asteroids close to the Earth in its orbit than, say, 180° away. What do you Think causes This ?

A It's hard to think of a physical reason for this, but easier to think of a sociological one. Human beings are concerned about a possible direct hit on the Earth by an large object. We search harder for objects whose orbit may cross the Earth's, and work harden to derive the orbit of such objects. This causes an artificial enhancement on the maps, which are only of course, of <u>known</u> objects.

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7.3 Asteroids

Asteroids are by far the most abundant named objects in the Solar System. Over one hundred thousand asteroids have been detected, with over thirty thousand having well determined orbits, most of these occupying the asteroid belt between about 2 and 4 AU from the Sun (between the orbits of Mars and Jupiter, Figure 7.7). The total mass of all the bodies in the current asteroid belt is only about one-thousandth of an Earth mass, although originally, a few Earth masses of material would have been available in the solar nebula in the region. In the 19th and early 20th centuries, astronomers thought that the asteroid belt represented fragments of a single planet which had somehow disintegrated catastrophically. However the asteroids are now thought to represent fragments of many small planetary bodies that never managed to accrete into one single body. This is due to the strong gravitational influence of the newly formed Jupiter 'stirring up' the asteroid population, causing collisions which would repeatedly break up the bodies and so impede the formation of one single large object.

Figure 7.7 (a) A representation of the asteroid belt. It is seen that the asteroid belt is actually a diffuse cloud, or swarm of orbiting bodies. (b) A crosssection through the belt, shown on the same scale. Each individual asteroid shown moves in an orbit inclined to the ecliptic plane, so that sometimes it is above it, and sometimes below. You can imagine that collisions between asteroids will be quite common.



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AN INTRODUCTION TO THE SOLAR SYSTEM

Figure 7.9 The orbits of known Potentially Hazardous Asteroids (PHAs). The orbit of Earth is also shown.



The very fact that we see NEAs today means that the NEA population is being continually replenished, and this happens because of the orbital evolution of objects in the inner asteroid belt. The long-term gravitational effects of Jupiter (and even Mars) give rise to a slow 'conveyor belt', which delivers bodies to the inner Solar System (although you should also appreciate that it can be a two-way process – bodies that are already in the inner Solar System can evolve outwards again). Some of the objects that make it into the inner Solar System might eventually hit one of the terrestrial planets.

7.3.1 Asteroid sizes

The largest main belt asteroid, discovered in 1801, is (1) Ceres (pronounced 'series') which has a diameter of 913 km. The next biggest is (2) Pallas, with a diameter of 523 km. (Note that the asteroids are numbered, and so the full name is, for example, (1) Ceres, although often, you will see only the name being used.) As we go smaller and smaller, the asteroids become more numerous. So while there is only 1 asteroid larger than, say, 600 km (i.e. Ceres), there are 7 larger than 300 km, 81 larger than 150 km, and so on. Note that for each reduction in size the number rises steeply. This behaviour is described by a size distribution. This concept will sound familiar to you after considering impact crater size—frequency distributions in Chapter 4 (Box 4.1). It is exactly the same concept, except we are now thinking in terms of asteroid diameter rather than crater diameter.

Figure 7.10 shows the cumulative size distribution of known asteroids in the asteroid belt. We see that there are many more small asteroids than large ones. The data 'flattens out' at small sizes (10 km or smaller) but this partly due to observational selection; we simply have not yet discovered all the small asteroids. The gradient of the dashed line in Figure 7.10 is significant when considering where most of the material in the asteroid belt is concentrated. In other words, we could ask, is most of the material (i.e. the mass) to be found in the few largest asteroids, or is most of it distributed amongst the numerous small bodies? It turns out that, if all the data followed the same slope as the dashed line shown in Figure 7.10, the total mass of objects contained in each logarithmic diameter step would be approximately the same. For example, the total mass of all asteroids with diameters between 1 and 10 km would be the same as those with diameters between 10 and 100 km. If however the slope of the data was shallower than the dashed line (i.e. more towards the horizontal), this would indicate that the largest bodies accounted for most of the mass contained in the asteroid belt. Conversely, if the data were steeper than the dashed line, most of the mass would be contained in the smaller bodies. The data in Figure 7.10 lies close to the dashed line in the middle region of the plot, but if we were to take all the data together, a best fit straight line would be somewhat shallower than the dashed line. Thus most of the mass in the asteroid belt is concentrated in the few largest asteroids.

As many of the impact craters seen on planetary bodies are caused by the impact of asteroids, it follows that the impact crater size distribution must broadly reflect the asteroid size distribution in some way. So if we expect a large asteroid to make a large crater, and a small asteroid to make a smaller crater, then because there are far more small asteroids, we would expect to see far more small impact craters on planetary surfaces. Indeed, this is what you found in Chapter 4, with the crater size–frequency distribution.



Figure 7.10 The cumulative size distribution of the known bodies in the asteroid belt, plotted logarithmically. The graph tells us the number of asteroids that have diameters greater than a given value.

Why are there so many more small asteroids? 9

It is relatively simple to derive the orbit of an extrasolar planet (ance the observations are accurate enough) But calculating the orbit of a rewly discovered asteroid is Taugher. Generally they are too faint to obtain velocities, so the data are simply a number of positions in the sky with times of abservation. Q How do you think astronomers

actually calculate (estimate) The

orbit of a new asteroid?

Comets

Most have orbits that look parabolic hard to measure exact orbit. Some do return Halley (1986) Enche etc

When a long way from Sun, balls of ice

& dust 1-10 km across

at ~ 3 AU, heat from Sun eugeorates some of carnet, forming coma (~10,000 km size)

lonized a edges, formes tail by interaction with solar (10' km in size)

Dust Tail, rediction solar wind, radiation

points in different direction

Complex structure of ion tail from interaction. with magnetic field dust tail moother





b

Figure 7-10. (a) Nomenclature of a comet. (b) Comet Kohoutek, showing the same features, with minimal separation of Type I and Type II tails. (NASA, Lunar and Planetary Laboratory, University of Arizona)



a



Figure 7-11. Spiral and fountainlike jet forms are seen near the nucleus of Halley's comet as jets of gas and dust are emitted from the rotating nucleus and blown back (to the right) by the solar wind. These photos were made on different days as the comet passed near Earth in 1910, but the jets were revealed only in 1984 when astronomers Z. Sekanina and S. M. Larson used modern image processing techniques to enhance low contrast detail. Streaks are star images, trailed by long exposure. (Courtesy S. M. Larson, Lunar and Planetary Laboratory, University of Arizona)

carbon and probably organic compounds (Sagdeev and others, 1986), though no life is expected to have evolved there.

In summary, a typical comet nucleus is now believed to be mostly ice by composition (frozen H_2O and other volatiles) but impregnated with black sooty carbonaceous and CHON particles. Just a small percentage of the sooty material, scattered through the comet ice, could make even the "fresh ice surfaces" appear very black. As the ice sublimes at the surface of a comet, during passes near the sun, the ice/soil ratio in the surface layers probably decreases, leaving an even darker surface regolith of

Spectrum of ian tail complex

Ionized by radiation from Sur +

collisions with particles in solar wind

Problem

It is observed that comets tend to become tainter & fainter with successive returns rear the Sur. Can you explain this ?

Motions of comets can be erratic.

· perturbations from planets etc

. jets of gas from interior the crust

A On each perihetion passage, the comet loses more volatiles to its coma & tail. Some of these will remain strung out along the comet's arbit. after several passages there will be les volatiles available to contribute to the coma & tail so the comet appears fainter.