CHIRON, the mythological quadruped, half man, half horse, and a descendant of the gods Saturn and Uranus, is the name given by Charles T. Kowal to the fast moving object he discovered on 1 November, 1977 (see *Nature, News and Views* **270**, 385; 1977). In common with many other 'new' discoveries in the Solar System Chiron had been observed before. Knowing roughly where it was helped enormously. Careful sifting of the astronomical photographic plate collections have brought to light over 30 images, the oldest dating back to 1895. These images have been used to obtain an accurate orbit, which, unlike the preliminary orbit given in the reference above, now has a perihelion distance of 8.51 AU, a whole astronomical unit within the orbit of Saturn. Chiron passed perihelion in 1895 and 1945 and will pass again in February 1996. At perihelion it has a photographic magnitude of 14.5, 40 times brighter than it is at present. The orbit is inclined at 6.923° to the ecliptic plane and at aphelion Chiron is 18.9 AU from the Sun, only about two astronomical units from Uranus.

There has been some discussion as to whether Chiron is an asteroid or a comet, the majority opinion favouring the former. Most comets far from the Sun show little or no nebulosity and are virtually indistinguishable from minor planets on an observational basis. However, Chiron's estimated radius lying as it does between 50 and 320 km makes it larger than all known comets but well within the range of observed asteroids.

Assuming it is an asteroid still leaves us with a fascinating problem—where did it come from? There are two simple possibilities, first it originated near its present orbit and is a prominent member of an asteroid belt that has always existed between Saturn and Uranus. There is a discontinuity in planetary masses here just as there is between the planets Mars and Jupiter which bound the inner asteroid belt. In the second theory asteroids have at some time been perturbed from the inner belt into orbits between Jupiter and Saturn and Saturn and Uranus. This latter theory is favoured by Robert C. Smith of the Astronomy Centre at the University of Sussex and is dis-

Chiron's origin

from David W. Hughes

cussed by him on page 229 of this issue of *Nature*. Smith follows R. B. Hunter's hypothesis that the original spatial distribution of asteroids was roughly Gaussian, the maximum number having semi-major axes of about 3.1 AU spacial density values of half this maximum value occurring at around 3.5 and 2.8 AU (see *Mon. Not. R. Astr. Soc.* **136**, 267; 1967). Smith calculates that 330 of the original assumed total of nearly 2,000 would have had mean solar distances between 3.7 and 5.2 AU, this latter value being the semi-major axis of Jupiter's orbit. There are only 50 in this range at present. He concludes that the missing 280 asteroids have been transported outwards by Jovian gravitational perturbations.

The sphere of influence of a planet is defined as the volume around the planet in which the planet's gravitational field has more effect on the orbit of a satellite or passing space probe, asteroid or comet than the gravitational field of the Sun. Inside this sphere the Sun is just regarded as a perturbing influence. Jupiter's sphere has a radius of 0.32 AU, Saturn's is 0.36 AU. Interestingly the ratio between the radius of the Jovian sphere of influence and the distance between the orbits of Jupiter and Mars is nearly the same as the ratio between the radius of Saturn's sphere of influence and the Jupiter-Saturn orbital distance. So Saturn will have a similar influence on the asteroid belt between Jupiter and Saturn as Jupiter has on the belt between itself and Mars. The end product of these gravitational perturbations will be a series of asteroid belts with relative populations in the ratio 1720 : 240 : 40 these belts occupying the regions between the orbits of Mars and Jupiter, Jupiter and Saturn and Saturn and Uranus.

As the observed brightness of asteroids is roughly proportional to the inverse fourth power of their heliocentric distance the magnitude

of the brighter members of each group will be approximately 10, 14 and 18.

The faintness of the trans-Saturnian group coupled with their low orbital angular velocities makes them extremely difficult to detect, a fact which helps to explain why Chiron is the only one to come to light so far.

All asteroids with semi-major axis greater than 3.9 AU will have their orbits greatly perturbed by the attraction of Jupiter. According to Hunter some of these asteroids can suffer temporary capture by Jupiter. Most of these will eventually be dispersed into heliocentric orbits well outside and inside that of Jupiter's. Occasionally a capture by Jupiter could become permanent due to successive solar perturbations decreasing the semi-major axis of the captured asteroid's orbit around the planet until this orbit became stable. The eight outermost satellites of Jupiter, together with Phoebe, the outermost satellite of Saturn seem to be captured asteroids. Smith points out that numbers of captured asteroids orbiting the major planets give a crude indication of the number of asteroids available for capture in the asteroid belt just inside the planets orbit.

So the asteroids according to the work of Smith and Hunter are not just confined to the regions of the Solar System interior to Jupiter's orbit. There are asteroids throughout the Solar System and individual asteroids can be quite easily moved from orbit to orbit by gravitational perturbation. They can also spend some of their life orbiting the major planets and a percentage of the asteroids that do this end up as permanently captured satellites.

A preliminary report by Brian G. Marsden of the Smithsonian Astrophysical Observatory of a detailed celestial mechanical analysis of the effect of Jupiter and Saturn on the orbit of Chiron, indicates that it passed within 0.1 AU of Saturn in 1664 and within 0.6 AU of Jupiter sometime in the latter part of the second millennium BC.

David W. Hughes is a lecturer in the Department of Physics, University of Sheffield.

simulation to a system for which infinite dilution is meaningful, and have chosen as solute N-acetyl alanyl N'-methylamide ($\text{CH}_3\text{CO.NH.CH.CH}_3\text{CO.NH.CH}_3$) which may be considered as a model of the smallest possible 'protein'. On the other hand, Hagler and Moulton exploit the resemblance of

the model to the structure of a crystal, and thus chose two hydrated crystal systems. These are the cyclic peptide cyclo-(L-Ala-L-Pro-D-Phe) $_2$ and the enzymically active protein lysozyme. Their study thus has the advantage of involving more typical biological peptide molecules, and further, since the

positions of the more ordered water molecules in these crystals is known by X-ray crystallographic analysis, it can be checked against experiment.

Briefly, the studies of both groups support the experimental evidence that there are several water molecules strongly bound to the peptide so that