although it may possibly be feasible to detect any gravitational influence on the two Pioneer spacecraft (in particular) which are now heading out into interstellar space in approximately opposite directions. For as long as they continue to operate it will be possible to determine from the Doppler shift of their radio signals whether they are being subjected to any additional gravitational influences.

The Minor Planets

The minor planets are probably the least generally known members of the Solar System. Only one body, Vesta, occasionally becomes bright enough to be seen by the naked eye, and nearly all the remainder are very small faint objects, which have been found photographically. However, the earlier members were discovered visually, the first being Ceres, noted on 1 January 1801 by Piazzi, who was compiling a star catalogue. Its orbit fitted in with the 'missing' planet of the Titius-Bode 'law' (see p. 28), but it was soon realized that it was very small and another three objects had been found by the end of 1807. The term 'asteroid' was introduced by William Herschel in 1802 to describe their star-like appearance, and this word has continued in use, although 'planetoid' and 'minor planet' describe them more correctly.

About 2 000 orbits are sufficiently well-known for the objects to have received permanent identification numbers and names, and there are some 1 000 others which have temporary designations. The latter consist of the year of discovery followed by two letters (and occasionally an additional number). Examples are 1976 AA (a planetoid which crosses the orbit of the Earth) and 1977 UB (Chiron, which will be discussed later). When positive identification is certain, they are given individual numbers and usually named by their discoverers. Examples are 1 Ceres, 4 Vesta and 1566 Icarus. Statistical calculations based upon the observed sizes suggest that the total number runs into several hundreds of thousands.

Orbits

The majority of the minor planets have orbits which lie between those of Mars and Jupiter (Fig. 5·20), in a belt from 2·2–3·3 au. Some significant groups lie outside this belt, but within it the distribution is uneven (Fig. 5·21), with distinct peaks and depressions at particular distances. The dips are known as Kirkwood gaps after their discoverer and are due to gravitational perturbations by Jupiter.

Under certain circumstances, groups of planetoids can be locked into simple orbital relationships with Jupiter. The most important of these is the group which has the same orbital period as Jupiter itself; its members are known as the Trojan planetoids. Their stable positions are 60° ahead of, and 60° behind Jupiter, positions which are known as Lagrangian points after the mathematician who predicted their existence. Since the minor planets do not have completely negligible masses, they are perturbed by the planets and one another, so that they actually oscillate about the theoretical positions (Fig. 5·20). For some unknown reason the Achilles group, which leads Jupiter, has about twice as many members as the Patroclus group, which follows the planet.

All the minor planets show direct orbital motion (unlike the comets, many of which have retrograde orbits), but they generally have greater eccentricities and orbital inclinations than the major planets. Table 5·20 gives data on some of their orbits. A few planetoids have very large orbits; 944 Hidalgo, for example. The object known as 1977 UB (Chiron) is truly remarkable as its orbit ranges from 8·5 au (inside that of Saturn) to 18·9 au (close to Uranus' mean distance of 19·2 au). The nature of this object is obscure, as its distance and orbit might suggest a cometary nature but its apparent size is rather too great for this. However, investigations of Chiron's orbit by means of computer modelling have shown

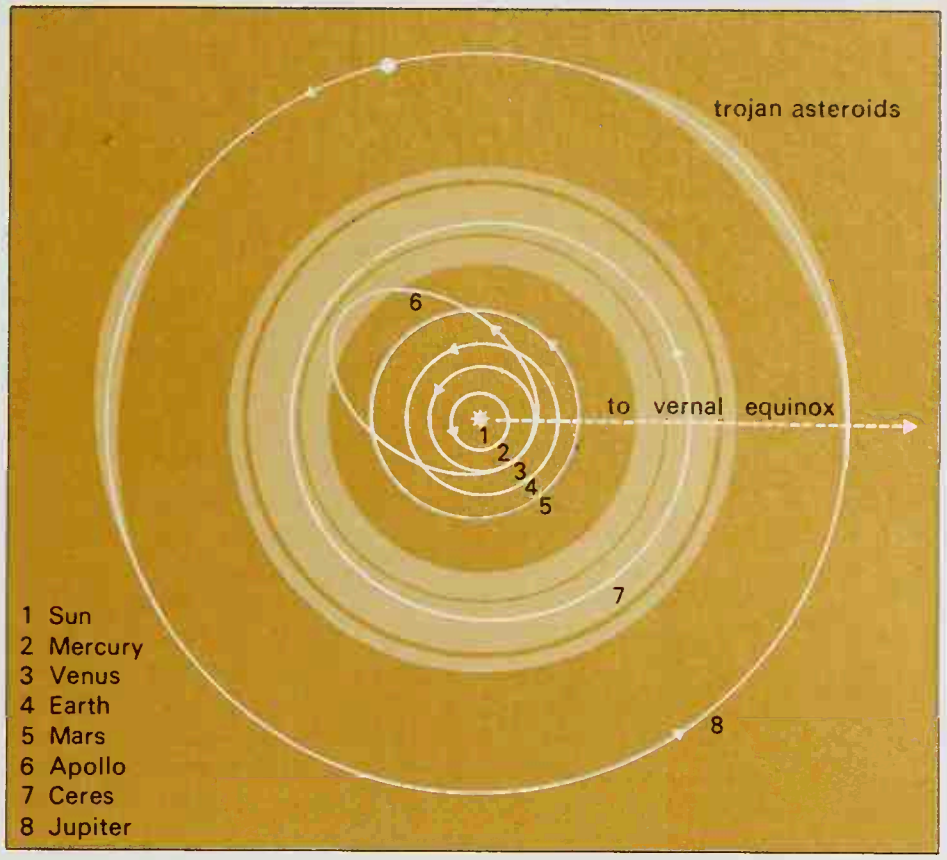

Fig. 5·20 The minor planet belt, showing the main concentration of orbits. Although nominally orbiting 60° in front of, and behind Jupiter, the Trojan planetoids actually oscillate within the elongated regions shown.

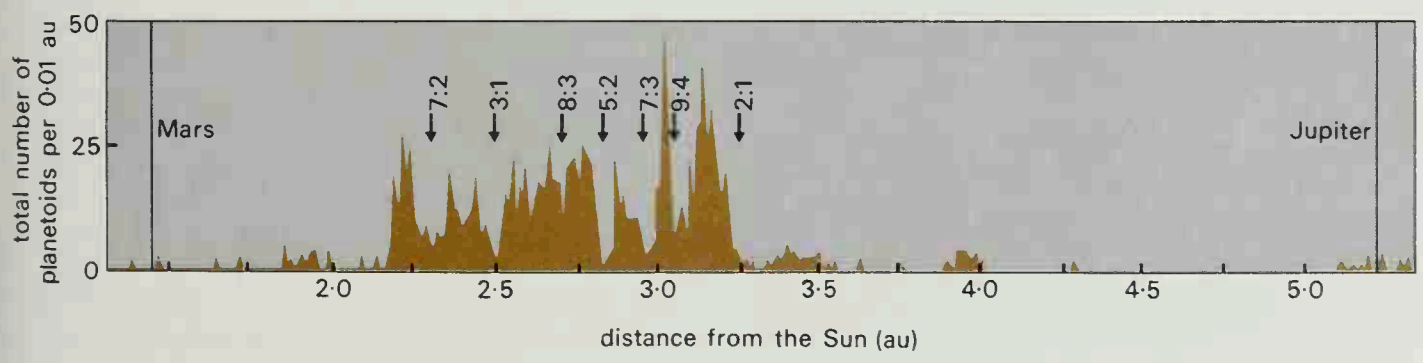

Fig. 5·21 The distribution of the minor planets. The arrows indicate distances at which bodies have orbital resonances with Jupiter, the number of orbits made by the planetoid being given first. The Trojan objects cluster about Jupiter's orbital distance.