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THE COUNTLESS ASTEROIDS

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THE sun's family of planets is divided according to size into three natural groups: the four major planets, Jupiter, Saturn, Uranus, and Neptune; the five terrestrial planets, Mercury, Venus, Earth, Mars, and Pluto; and the countless minor planets or asteroids. The asteroids are so small relative to the other planets that their admission to planetary rank is generally qualified by reservations that are almost apologetic. On the basis of apparent brightness rather than size, however, no apologies are necessary. Under favorable conditions when closest to the earth the asteroid Vesta is just visible to the unaided eye. The planet Uranus is no brighter. At opposition both Ceres and Vesta are brighter than Neptune and at least a thousand asteroids are brighter than Pluto.

However, it is not in brightness but in sheer numbers that the asteroids excel. Even before Uranus, Neptune, and Pluto were known, astronomers suspected the presence of an undiscovered planet between the orbits of Mars and Jupiter because the definite regularity in the distances of the known planets from the sun was interrupted by a gap between Mars and Jupiter. The suspicion that something belonged in this gap was greatly strengthened in 1781 by the discovery of Uranus whose distance from the sun was found to fit in the sequence with the other planets. In order to settle the question a group of astronomers was organized to search for

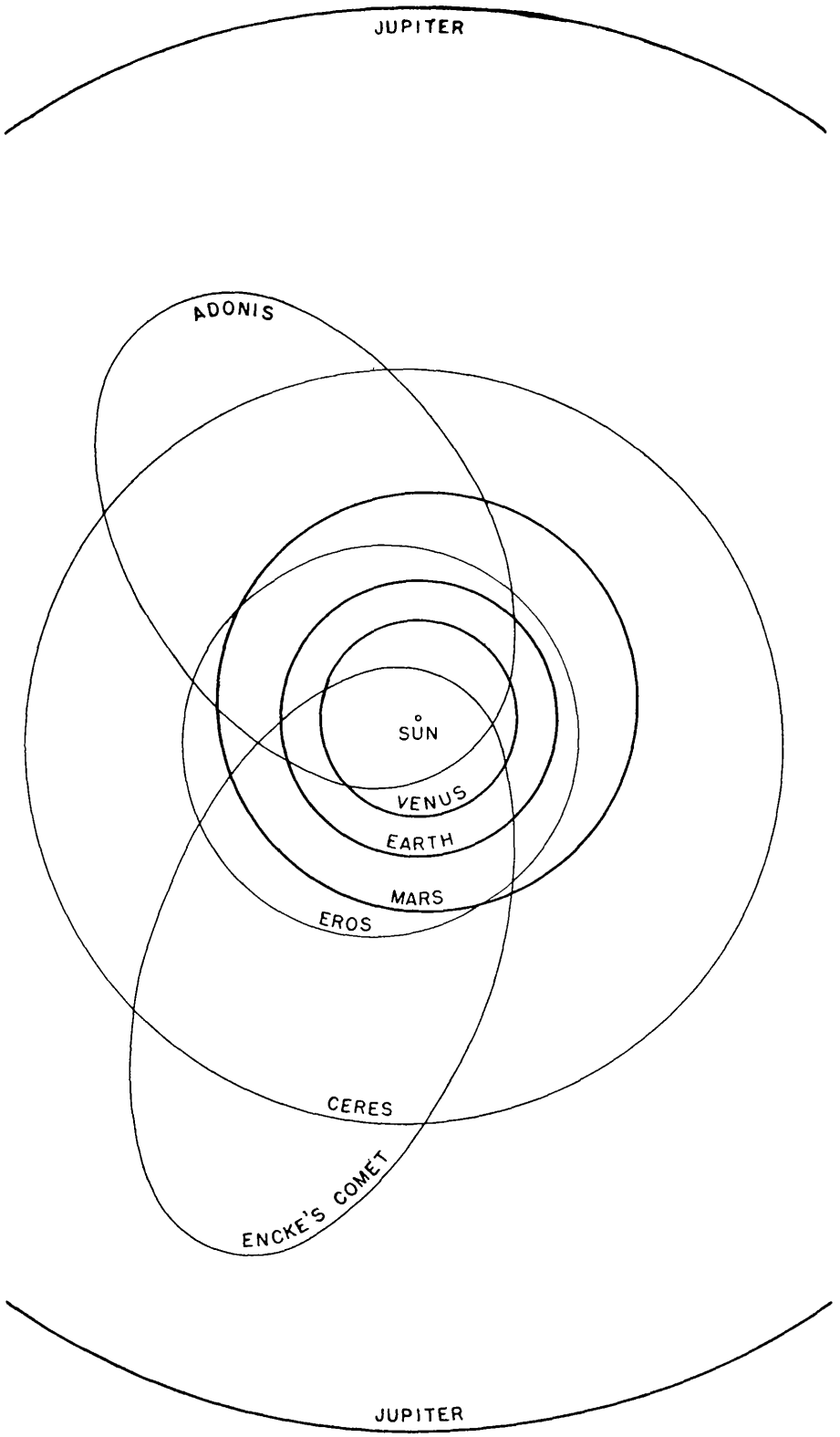

Figure 1.—The orbits of Venus, Earth, Mars, Ceres, Jupiter and the exceptional asteroids Eros and Adonis with the orbit of Encke's Comet for comparison.

the suspected planet. The first asteroid was not discovered by a member of this group, however, but quite accidentally by Piazzi on January 1, 1801, when he was looking in the constellation of Taurus for a star which he could not find because its catalogue number had been erroneously recorded. The new planet was named Ceres, and its distance from the sun fitted so well into the gap between Mars and Jupiter that it was heralded as the one for which astronomers were searching. When in the next few years three additional similar objects were discovered, all at approximately the same distance from the sun, astronomers realized that the gap was occupied not by one planet but by a group of planets. After the discovery of the first four, Ceres, Pallas, Juno, and Vesta, 37 years passed before another was found. During this interval no one suspected the existence of the enormous number of objects later discovered in the group.

The fifth asteroid was discovered in December 1845. Since then, 1846 is the only year that has not added at least one new member to the known asteroid family. Perhaps astronomers felt that the discovery of Neptune in 1846 was enough of a contribution to the solar system for one year. Since that time the number of recognized asteroids has increased year by year. Probably the discovery of Neptune stimulated the search for new planets and may well have been responsible for the number of asteroids discovered in the years that followed. Finding a new asteroid was an astronomical achievement in those days and a certain amount of rivalry existed among asteroid hunters. The first one discovered in America was 31 Euphrosyne, discovered by Ferguson in 1854 at Washington. By the end of November 1891, 322 asteroids had been found, all by laborious visual searching which

necessitated the tedious comparison, star by star, of the telescope field with a star chart. In December 1891, Wolf started a new era in asteroid history by discovering one by photography. It was number 323 and was called Brucia. In the 46 years from 1845 to 1891, 318 asteroids had been discovered visually, an average of 6.9 per year. In the 48 years from 1891 to 1939, 1191 were added, an average of 24.8 per year.

An asteroid is usually not named until its orbit is well determined; the name is then assigned by the discoverer or by the orbit computer. The first few names were selected from mythology, but this source was soon exhausted and even recourse to more modern literature was inadequate to keep up with the rate of discovery. Generally, feminine names were selected, except for objects with outstanding orbital characteristics which were deemed worthy of masculine names. Many of the names have been artificially feminized by an appropriate ending while some have been coined outright. Asteroids 1000, 1001, and 1002 are named Piazzia, Gaussia, and Olbersia in honor of Piazzi, who discovered Ceres, Gauss who computed its orbit, and Olbers who rediscovered it with the aid of Gauss's ephemeris and who also independently discovered 2 Pallas and 4 Vesta. 620 Drakonia and 694 Ekard were so named in honor of Drake University where their orbits were first computed, the name Ekard being coined by spelling Drake backwards. The names of many asteroids have obviously been assigned to honor persons, places, or institutions, and it is probable that many others serve the same purpose less obviously. The result of this heterogeneous system of naming is a roster surpassing in variety and individuality that of the names of Pullman sleepers.

Now that photography is so universally used in astronomy it is no longer an achievement to find new asteroids. At most observatories no attention at all is given to them, in fact they are often a nuisance and have more than once been called "vermin of the sky." They have been mistaken for variable stars, comets, satellites, novae, and supernovae; and many an extra photograph has been hopefully taken to check some interesting new discovery only to find that the object was just another of those—asteroids.

With the 100-inch reflector an exposure of one hour near the ecliptic will usually record at least one new asteroid. In the search for new satellites of Jupiter made in 1938 at Mount Wilson, 32 asteroids were photographed close to Jupiter on plates which showed only six satellites. Of the six satellites two were new, four were already known; of the 32 asteroids, however, 31 were new, only one having been previously catalogued. If only one of the 32 asteroids photographed was among the 1400 for which orbits were known in 1938, the total number bright enough to be photographed without difficulty with the 100-inch telescope (about magnitude 19) is probably many thousand. From his photographs Hubble has estimated the number as 30,000. From a more complete statistical study, Baade concluded that at least 44,000 are brighter than 19th magnitude at opposition.

The diameters of only four asteroids have been measured. They are: Ceres, 480 miles; Pallas, 304 miles; Vesta, 240 miles; and Juno, 120 miles. The diameters of the others can be estimated from their brightness if we assume that they reflect as much light per square mile of surface as these four. With this assumption we find that 500 are

larger than 30 miles in diameter. Most of those discovered in recent years are between five and 20 miles in diameter, and a new one larger than 30 miles is so rarely found that the count is essentially complete down to that size.

The density of an asteroid is probably about like that of the moon; if so, the mass of Ceres is 125 millionths (0.000125) the mass of the earth and that of Pallas 30 millionths. These two asteroids combined have more mass than all the others together. The total mass of the 500 largest asteroids, exclusive of Ceres and Pallas, is 120 millionths that of the earth. The remaining 1,000 whose orbits are known contribute 8 millionths, while the 40,000 or more as yet uncatalogued contribute only 7 millionths. The total mass of all the asteroids is therefore only 290 millionths (0.000290) of the earth's mass. One small planet only 630 miles in diameter could contain all the mass now scattered among the asteroids.

The herculean task of keeping track of so many asteroids is accomplished under the supervision of the Copernicus-Institute (Astronomisches Rechen-Institut) with the cooperation of individuals and universities all over the world. In its publication for the year 1941, the orbits of 1513 asteroids are catalogued. In addition, three unnumbered objects named Apollo, Adonis, and Hermes are listed. They remind one of the extra pig belonging to the farmer who, when asked how many pigs he had, replied, "Fifty-nine and one that runs around so fast I can't count it." That is the trouble with these asteroids, they moved so fast that only a few observations of them could be obtained, so few that only the general features of their orbits are known.

Hermes has the shortest period of all the asteroids, 1.47 years; the orbit of Adonis has the

greatest eccentricity, 0.78. At perihelion Apollo, Adonis, and Hermes all come inside the orbit of Venus, Adonis almost to the orbit of Mercury. They are closest to the earth, therefore, not when at opposition like the other asteroids but when they pass the earth's orbit on the way to and from perihelion. Unless these objects are reobserved soon it will be very difficult to find them again and their rediscovery will be a matter of chance. Asteroids have been lost before. For example, 132 Aethra was observed for only 22 days after discovery in 1873, and in spite of much work by computers and observers was not seen again until it was rediscovered 49 years later in 1922.

433 Eros has a period of 1.76 years, shortest of all the asteroids with well-determined orbits, and at perihelion comes within 13,840,000 miles of the earth's orbit (Leaflet No. 31). 944 Hildalgo has the longest period, 13.7 years. Next to Hildalgo the most distant asteroids are members of a group all of which have the same distance and the same period as Jupiter. They are affected by the action of Jupiter in such a way that they always stay about 60° ahead of Jupiter or 60° behind it. They have all been given names of Greek or Trojan heroes and are known as the Trojan Group (Leaflet No. 114).

The orbit of Hildalgo is so eccentric, $e = 0.65$, that it goes out as far as Saturn, yet at perihelion is only one astronomical unit from the earth's orbit. In fact its orbit is so much like that of a comet that there is some question about its identifition as an asteroid. Long exposures with the 100-inch telescope have, however, failed to show any coma around it.

Although it is quite probable that some of the objects now identified as asteroids may in reality

be comets that have lost their coma, it is hardly probable that all the asteroids are converted comets. The origin of the asteroids has been the subject of much speculation ever since the discovery of the second asteroid by Olbers, who suggested at once that the two might have once formed a larger planet which exploded. If a planet were to explode into many small pieces, their orbits would for a while intersect near the point where the explosion occurred. As time elapsed the orbits would be disturbed by the attraction of the large planets, particularly by Jupiter, until eventually all trace of the common point of explosion might be lost. There are, however, certain orbital characteristics which would change very slowly, and an investigation reveals no evidence of a common origin for the asteroids as a whole. Five small groups are known, with from 16 to 81 members apiece, for which a common origin is indicated. It has been suggested that these groups are the results of five separate explosions, but since only 192 out of 1500 asteroids are in such groups, it seems probable that most of the material in the asteroid zone has, since the formation of the solar system, been scattered much as it is today.