DWARF PLANETS AND ASTEROIDS:
MINOR BODIES OF THE SOLAR SYSTEM

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**NAMES:** Asteroids named for a person will be noted with the person’s dates, and any other associations they may have with asteroids. Ordinary asteroids’ names are printed in italics on their first appearance. Dwarf planet names are in bold.

**SEARCHES:** Several deliberate searches have been made for asteroids. The first was organized around the year 1800 by German astronomers seeking a presumed planet between Mars and Jupiter. They succeeded in finding the second, third, and fourth asteroids. More recent efforts include the Deep Ecliptic Survey to seek small objects beyond Neptune, which was run by the National Optical Astronomy Observatory; LINEAR (the Lincoln Near Earth Asteroid Research) run by the United States Air Force, NASA, and MIT’s Lincoln Laboratory; NEAT (Near Earth Astronomical Tracking), operated at Mount Palomar by NASA and Jet Propulsion Lab from December 1995 to April 2007; the Catalina Sky Survey with Siding Spring Survey, operating under a Congressional mandate of 1998 to find ninety percent of potentially hazardous asteroids or comets within ten years; and LONEOS, the Lowell Observatory Near Earth Object Search.

These searches used a variety of instruments. LINEAR, for example, used two one-meter telescopes and a 0.5 meter telescope, and found over 240,000 objects. Catalina/Siding Spring has sixty inch and twenty-seven inch telescopes near Tucson and a twenty inch telescope at Siding Spring in Australia.

**DEFINITION**

The term **asteroid** was invented by William Herschel (1738-1822; asteroid 2000 Herschel) in 1802. It referred to the star-like appearance of the recently discovered objects. Others have used planetoid or have fudged the issue by calling Ceres a dwarf planet. In this book, asteroid will refer to any object in orbit around the Sun that is less than 1500 kilometers in diameter, more than 0.1 kilometer across, and not a comet. Smaller objects are meteors and not included here. Moons go around planets, and are in a different book, *Moons of the Solar System*, 2013.

**DISCOVERY**

The existence of asteroids was first suspected by astronomers starting in 1596 with Johannes Kepler (1571-1630), who noted that there seemed to be a large gap among the planets between Mars and Jupiter. In the eighteenth century, German astronomers Johann David Titius (1729-1796) and Johann Elert Bode (1747-1826) noted that each planet going outward from the Sun, seemed to double the distance from the Sun of its predecessor, except between Mars and Jupiter, where the gap more than tripled. Following up on this in 1781 after the discovery of Uranus by William Herschel at what both Titius (asteroid 1998 Titius) and Bode (asteroid 998 Bodea) said was the right distance beyond Saturn, a group of German astronomers organized a committee to search the region between Mars and Jupiter for a dim planet.

While the Germans were still organizing, the Director of Palermo Observatory in Sicily, Giuseppe Piazzi (1746-1826, asteroid 1000 Piazia), discovered the first asteroid, *Ceres*, on January 1, 1801. Piazzi was checking the accuracy of a recently received catalog and noted an unlisted item, which he soon realized was moving, and, like Herschel with Uranus, initially reported it to be a comet, although, unlike Herschel, he suspected it was something **better**.
Over the next four years following the discovery of Ceres, three more asteroids were discovered, all by the Germans, who had initiated the search. These asteroids were given the names of Pallas, Juno, and Vesta, and, to this day, Ceres, Pallas, and Vesta remain the three largest known asteroids (although Ceres is now classified as a dwarf planet and Vesta’s status is disputed).

No further asteroids were discovered until 1845, which inspired new searches, and from 1847 onward, more asteroids were found every year. By the end of the nineteenth century, over 450 asteroids had been found. An astronomer, uninterested in them, described their frequent appearance on his photographs as (translated from German) a plague of minor planets. By the end of the twentieth century, over 7,000 had been catalogued.

**DESIGNATIONS AND NAMING**

Piazzi chose the name of Ceres for his discovery. Ceres was the patron goddess of Sicily, an agricultural goddess from whom we derive the word cereal. The next few asteroids were all named for similar Graeco-Roman mythological females (e.g. Vesta), establishing the rule that asteroids have feminine names. This rule resulted in later asteroids named for countries getting names such as Germania. When asteroids’ names began to honor astronomers and other real people, those names would be feminized, such as eminent astronomer Jacobus Kapteyn (1851-1922), whose name was feminized to Kapteynia, as was Piazzi’s own asteroid, 1000 Piazzia. After the 1850s, asteroids were given a number also, which was supposed to be sequential in order of discovery. Thus, Ceres became 1 Ceres, while Kapteyn’s became 818 Kapteynia.

The first asteroid not to have a feminine name was 433 Eros. In addition, Eros was the first discovered asteroid to have an orbit that was not completely between Mars and Jupiter, which created a new custom of giving asteroids with unusual orbits a masculine name. The entire practice of worrying about the gender of asteroidal names was dropped after World War II. Today, an asteroid named for a woman, regardless of location, has a feminine name, and asteroids named for a man have a masculine name, regardless of orbital characteristics.

The first couple thousand asteroids all received names given either by their discoverer, the person who worked out their orbit, or someone given the right by the discoverer (one American astronomer was rumored to sell some naming rights). At some observatories, the directors demanded naming rights, regardless of who at the observatory made the discovery. As astronomers began to honor friends and colleagues by naming an asteroid for them, someone commented that the sky was being turned into a cemetery for astronomers.

Gradually, more people began to receive naming honors, including musicians, philosophers, athletes, and other scientists. Rules were imposed limiting asteroids to one word names of not more than sixteen letters. Those with reasonably unusual names found their last names used with the number; thus, 2308 Schilt for astronomer Jan Schilt of Columbia University (a former student of Kapteyn). Anyone with a fairly common last name would find some version of their first name melded into the last name as a single word, e.g., 4897 Tomhamilton (a former student of Schilt). Very few asteroids slipped through before these rules were imposed.

Following the discovery of a new asteroid, even before it gets a number (which under the rules requires knowing its orbit), it receives a designation that combines the year of discovery with letters and numbers. Thus, Asteroid 2012DA15 indicates that the asteroid was discovered in the year 2012, during the period from February 16 to the end of the month, and was the fifteenth asteroid discovered during that two-week period. Each month is divided in two, with the first fifteen days getting a certain letter (A in January, C
in February, E in March, etc.) while the remainder of the month gets the letter that follows (B for January 16 to 31, D for February 16 to 28 or 29, F for March 16 to 31, etc.). The asteroids discovered in the time period are given letters A through Z, and if more are found, numbers are used. (The letter J is never used.)

**ORBITS**

Any orbit can be defined numerically by six characteristics of the orbit. Certain values of three of these tend to be seen only in the orbits of asteroids, so these are the ones we will discuss here, and include many of the asteroids mentioned below.

First is the semimajor axis. One can think of this as being approximately the average distance of an object from the Sun, or as \((\text{aphelion} + \text{perihelion})/2\). Of course, averages can be misleading. Halley’s Comet ranges from inside the orbit of Venus (perihelion of about 66 million miles) to outside the orbit of Neptune (over 2 billion miles for the aphelion), giving an average of over a billion miles, but a distance from the Sun that is actually rare for this comet during its 76 year period. With asteroids, the semimajor axis determines the asteroid’s status as a member of the Main Belt of asteroids, those between the orbits of Mars and Jupiter, or a member of less frequently seen groups such as Amors, Atens, Apollos, Trojans, centaurs, etc. Each of these will be discussed.

The semimajor axis is directly related to how long an object takes to complete one orbit around the Sun, using Kepler’s Third Law, \(ka^3=P^2\). The \(k\) just tells us to use the correct units (the year and the Astronomical Unit, usually). The \(a\) is the semimajor axis in Astronomical Units (1 AU = 92,955,807 miles, or 149,597,870 kilometers). The \(P\) is the orbital period around the Sun in Earth years. All distances in this book are quoted in Astronomical Units, or AU.

The second number is the orbital eccentricity, which defines how much the orbit deviates from a perfect circle. Asteroids tend to have orbits more elliptical than the orbits of planets, but there are plenty of exceptions. An eccentricity of 0 is a perfect circle. An eccentricity of 1 would be a parabola, which would mean that the object is on its way out of the Solar System, never to return. Eccentricities greater than 1 are hyperbolas, leaving the Solar System fast. The eccentricity is based on the ratio between the semimajor axis and the orbit’s closest approach to the Sun. The semimajor axis and eccentricity together define the size and shape of an orbit.

For a semimajor axis \(a\) and eccentricity \(e\) perihelion (the point nearest the Sun) is at a distance of \(a(1-e)\), while aphelion (furthest from the Sun) is at \(a(1+e)\). An ellipse, of course, has two focuses (or foci). The Sun is at one focus, the other is empty space and of no particular importance. In this book, we give the aphelion and perihelion for each asteroid in Astronomical Units (AU), which may be converted to miles or kilometers if readers wish. The eccentricity is also given, and is always less than 1.

The third number is the inclination, the tilt of the orbit with respect to the Earth’s orbit (technically known as the ecliptic). Asteroids tend to have orbits inclined to the ecliptic more than orbits of planets, but there are plenty of exceptions.