INTRODUCTION

Why observe the planets?

Astronomy has always been a popular hobby with all kinds of people, especially since the arrival of the 'Space Age'. Telescope sales are brisk and books on astronomy abound. Astronomy is a hobby that can be enjoyed even if the only optical instrument that you have is a pair of binoculars or a very small telescope. Books have even been written on naked eye astronomy.

There is something for everyone in observational astronomy. Some like to study either the Sun or Moon, which are especially suitable for those owning only modest telescopic equipment. Others prefer 'deep sky' observing and love to probe the depths of space with the largest telescopes that they can afford and enjoy the satisfaction of locating and identifying bright and faint star clusters, galaxies and nebulae that abound in our universe. Still others like to hunt for comets or keep track of the brightness changes in variable stars, or plot the paths of meteors ('shooting stars'). Many who are also keen photographers couple their cameras to their telescopes and delight in taking portraits of their favourite celestial objects.

To those who enjoy deep sky observing and the mind-boggling immensities of outer space, planetary observing must seem a little tame. The planets of the Solar System must seem like mere pebbles in their back yards when compared to the immensities of the universe beyond the Solar System. So – why observe the planets? The simple answer to that question is that planetary observation has a fascination of its own just as stellar astronomy has its own peculiar appeal. There is no accounting for taste; we are all different and we must accept this. The telescopic observer who gets a thrill from glimpsing a faint stellar object for the first time after repeated unsuccessful attempts is not likely to get as excited over variable diffuse markings on the surface of a comparatively close planet – yet this is precisely what thrills a planetary observer, who is not likely to feel a strong emotional or other response to a tiny wisp of faintly luminous nebulous fluff just glimpsed at the eye end of a telescope even if it does have a 30-inch mirror or object glass or on being told that what is seen is so many millions of light years distant.

The special fascination of the planets of the Solar System is their nearness to us; they are our closest celestial neighbours. Also, they are worlds more or less like our own and so there is a feeling of intimacy and kinship. The distances and sizes of these bodies are much easier to grasp and visualise than the unthinkable immensities of the universe beyond the Solar System.

Another reason why planetary observation has a special appeal is that you are never quite sure about what you are going to see, for the planets exhibit a continually changing telescopic spectacle – the cloud belts of Jupiter, the rings of Saturn, the surface markings and atmospheric phenomena of Mars and the phases of Mercury and Venus to name the most prominent examples.

Observation of the planets is rewarding because there is always something new to see and record that may be added to the continually growing body of planetary knowledge. There is even a chance that a dedicated amateur may make a discovery. Stellar observation admittedly gives us a much greater variety and number of different objects to explore such as star clusters, double stars, galaxies, nebulae and so on, but apart from variable stars, novae and Solar System comets, the stellar heavens are virtually changeless, year after year, century after century. Deep sky observing can be frustrating too, because of the increasing problem of light pollution in and near urban areas so that enthusiasts are continually yearning for bigger and bigger telescopes to collect as much light, as possible from the remote faint objects that interest them so much. To avoid light pollution deep sky observers often put up with the inconvenience of driving with their telescopes into remote country areas at night in search of darker skies. Because of this and in spite of the enormous cost of purchase or the time and effort required to build them, reflecting telescopes of up to 30 inches of aperture are not uncommonly found in the observatories of amateur astronomical clubs and societies and occasionally found in the hands of private individuals. In contrast, excellent views of the planets are obtained with even quite small telescopes and light pollution poses no serious problems.

Observing versus sightseeing

Because of the essentially unchanging nature of the stars and galaxies, there is in one sense nothing new to see except the different appearances of this or that Messier object, say, in telescopes of different apertures under varying conditions of seeing and light pollution. To say that a given galaxy was barely visible with a particular telescope and that spiral arms were just glimpsed with a much larger telescope is interesting. However, this is not really observing. It is sight-seeing. Telescopic deep sky study thus tends to become a sport (except for supernova searches) perhaps even involving friendly rivalry, rather than being a scientific pursuit. Telescope owners are really only comparing the performances of their telescopes with those of others, rather than making genuine observations.

What exactly do I mean by 'observation'? When something is observed, we do much more than merely look at it. We scrutinise it carefully, noting every detail. We ask questions about it. Finally, the observation is not complete until we have recorded it either by taking notes, drawing it, or both and perhaps photographing it as well. It goes without saying that observation requires practice, patience and perseverance. It is hard work. Some of the best astronomical seeing conditions occur on clear intensely cold winter nights so that observation can be physically trying; observation under these conditions thus demands self-discipline. This book has been especially written for those prepared to go out and endure the rigours of winter evenings in devoting themselves to planetary observing.

No one actually seems to look through the big professional observatory telescopes these days; everything is automated, electronic and computerised and the photographic plate and charge-coupled device (CCD) replace the human retina. For the forseeable future these 'giant eyes' will be trained almost exclusively on stellar objects. No amateur with even a fairly big back-yard telescope can hope to compete with the observatory giants in the field of astrophysics and astrophotography or in attempts to contribute to stellar research. But those same big observatory telescopes which are hardly ever pointed to the planets can be overtaken by the modest telescopes of back-yard amateur planetary observers who have considerable potential to contribute to planetary knowledge in addition to enjoying their fascinating hobby.

For those amateur observers working with modest telescopes who wish to contribute something to our knowledge of the heavenly bodies, as opposed to merely enjoying themselves, planetary observation therefore offers the greatest opportunities. In addition to the sheer love of doing it, which is the best of all reasons for following any pursuit, the opportunity to contribute to astronomical knowledge afforded by planetary observation is my best answer to the question "Why observe the planets?"

1

The Solar System

General

The Solar System consists of a central hot, massive and very large body, the sun, which is a star, with numerous smaller bodies circling around it in orbits varying from nearly circular to very eccentric ellipses. The principal members of this family of bodies orbiting the Sun are the nine planets of which our Earth is one. All of them move in approximately circular orbits (actually ellipses which differ only slightly from true circles) around the Sun and all in the same direction which is the same as the direction in which the sun rotates on its axis (fig. 1.1). The orbits of the planets lie roughly in the same plane as the sun's equator.

The planets rotate on their own axes in the same direction as the sun's rotation, only the axis of the planet Uranus having an unusual tilt (see chapter 11).

It is convenient to express the distances of the planets from the sun in terms of astronomical units (AU). An astronomical unit is equal to the length of the semi-major axis of the Earth's elliptical orbit around the Sun which is 92.9 million miles (149.5 million km). The names of the planets, their distances from the sun and their astronomical symbols are shown in table 1.1.

Table 1.1. *The planets: names, symbols and distances from the sun (AU).*

Planet	Symbol	Mean distance from sun (AU)
Mercury	☿	0.4
Venus	♀	0.7
Earth	⊕	1.0
Mars	♂	1.5
Jupiter	♃	5.2
Saturn	♄	9.5
Uranus	♅	19.2
Neptune	♆	30.1
Pluto	♇	39.5

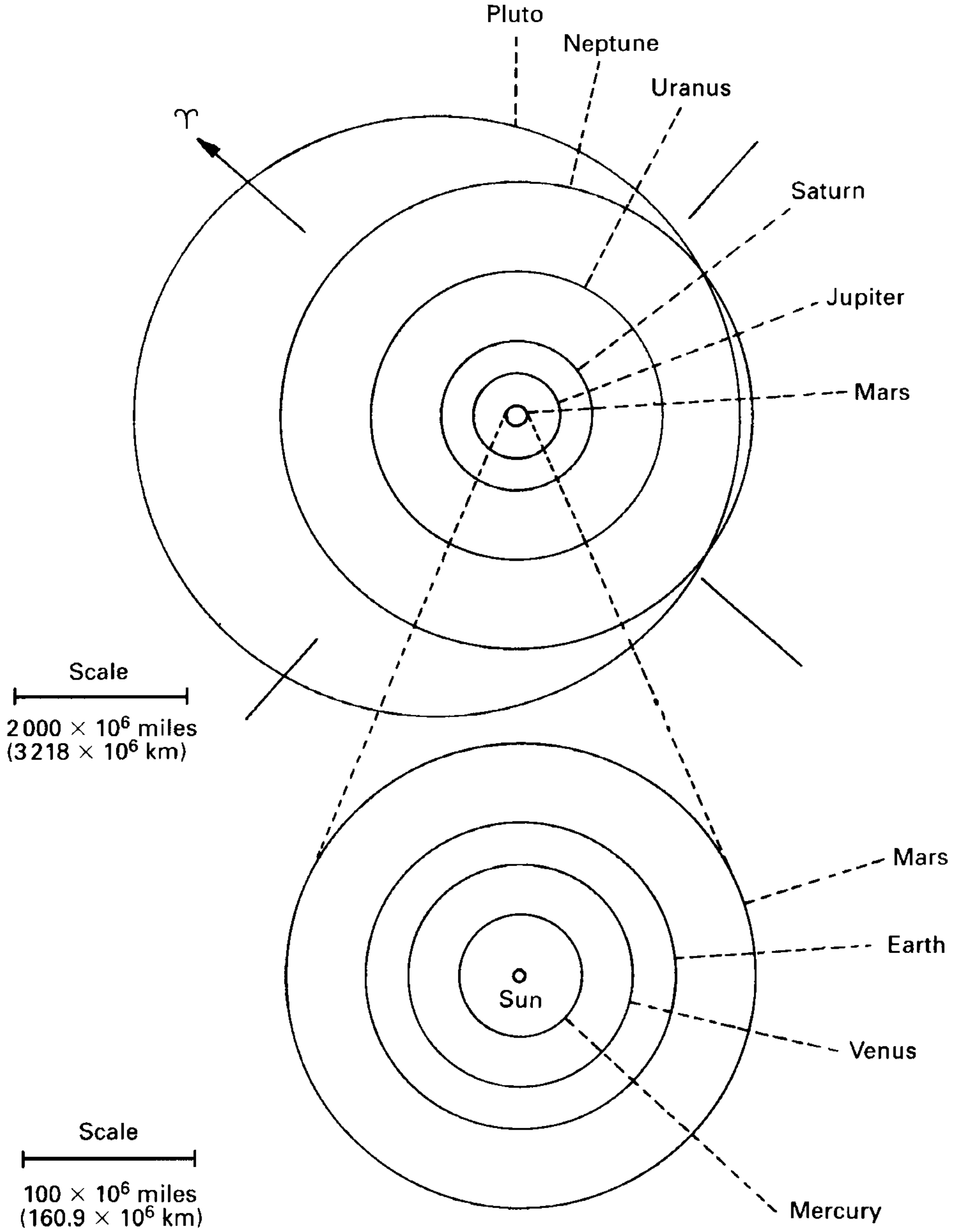

Fig. 1.1 The Solar System. For simplicity the planetary orbits are shown as circles. In reality they are slightly elliptical.

The largest planet is Jupiter with an equatorial diameter of 88 700 miles (142 718 km) and the smallest is Mercury, diameter 3010 miles (4878 km). Detailed data pertaining to each planet such as diameter, distance from the sun, orbital speed and so forth are given individually in the chapters devoted to each planet. The comparative sizes of the planets are shown in fig. 1.2.

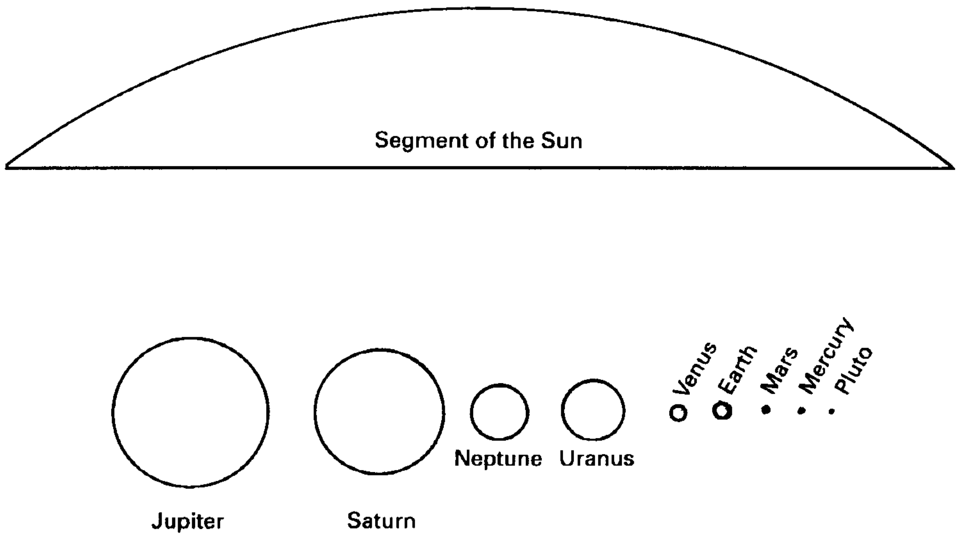

Fig. 1.2 Comparative sizes of the sun and planets.

Between the orbits of Mars and Jupiter is a large gap within which is a swarm of small bodies varying in size from a few hundred miles in diameter down to large boulders. These are the minor planets (planetoids) also known as the asteroids, because of their star-like appearance in the telescope. Most of them lie in a main belt with more or less circular orbits at mean distances from the sun of 2–4 AU but several of them have highly eccentric orbits which carry them out far beyond the confines of the main asteroidal belt (fig. 1.3).

The planets fall naturally into two groups of four each:

(1) *The terrestrial planets:* Mercury, Venus, Earth and Mars. They are all relatively small, have solid surfaces and are all of about the same order of size. Their chemical compositions are all more or less similar. Because they lie within the asteroid belt and are the planets nearest to the sun they are also called the inner planets.

(2) *The 'gas giants':* Jupiter, Saturn, Uranus and Neptune. These are all much larger than the terrestrial planets and do not have solid surfaces. What is seen of them in the telescope is the top of a cloud-laden atmosphere. Because they lie outside the asteroid belt and are the furthest planets from the sun they are (together with Pluto) also called the outer planets. Pluto doesn't seem to fit easily into either the gas giant or terrestrial planet category. It is more like an asteroidal body.

All of the planets except Mercury and Venus are attended by one or more satellites, most of these revolving around their primaries in the same direction. In addition to satellites the four large outer planets are surrounded by concentric rings consisting of swarms of countless small bodies ranging in size from kilometre-sized boulders to microscopic particles revolving around their primaries in the plane of the equator. The planet Saturn has the brightest and

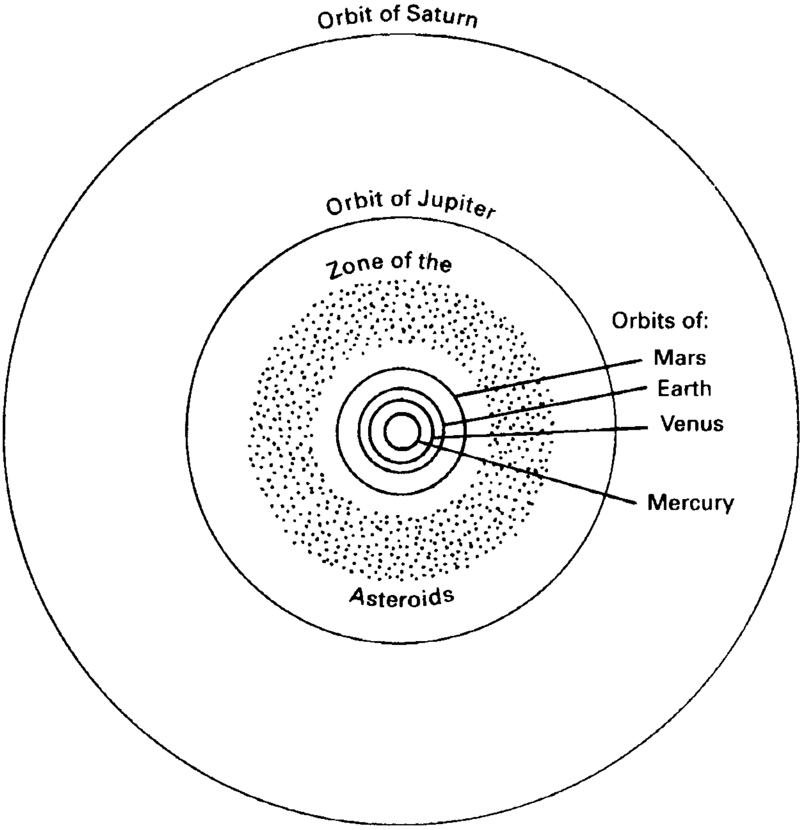

Fig. 1.3 The asteroids.

most prominent system of rings which have been known since telescopic observation of the planets began. Jupiter, Uranus and Neptune have much less well-developed faint rings that were finally detected and then photographed long after the 'Space Age' began.

The plane of the Earth's orbit is called the ecliptic and the orbits of the other planets are all nearly coplanar with it, the majority being tilted to the ecliptic plane by a few degrees at most. The planes of the planets' orbits will therefore intersect the plane of the ecliptic at two points. These are called nodes (fig. 1.4). The node where the planet passes from south to north of the ecliptic plane is called the ascending node and that where it passes from north to south of the Ecliptic plane is the descending node. The line joining them is called the line of nodes.

It would appear that the Solar System family of sun, planets and their satellites is not a chance assemblage of material bodies but that they all had a common origin. This would seem to be very probable in view of the extreme isolation of the Solar System; the nearest star is about 6000 times as far away as the outermost planet at its mean distance from the sun. Many ideas have been put forward to account for the origins of the Solar System. One of these is that it was formed by condensation from a nebula and another is that it arose from the

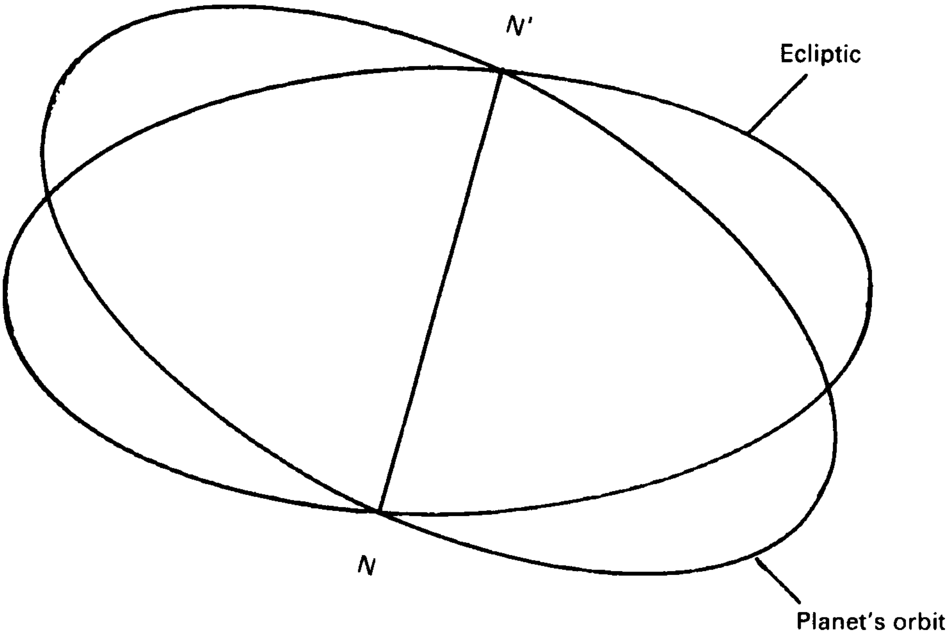

Fig. 1.4 The nodes.

condensation of myriads of small bodies into larger bodies – the process of accretion. A third theory pictures a close encounter of the sun with another star, with or without collision, in which a long filament of material from the sun was pulled out by the gravitational pull of the intruding star. This subsequently broke up and condensed into the planets. That this filament may have been spindle- or cigar-shaped is suggested by the size variation of the planets and their distances from the sun; those nearest and farthest (Mercury, Pluto) are smallest whereas those at middle distances are the largest. None of these and other theories that have been put forward to explain the origin of the Solar System is completely satisfactory.

In addition to the nine principal planets and the asteroids there are numberless other objects within the domain of the sun. Some of these are huge boulders – meteorites – that have fallen to Earth on rare occasions, and some are tiny particles the size of sand grains. Upon entering the Earth's atmosphere at high speed they burn up as a result of the frictional energy generated by flying through the Earth's gaseous envelope and we see them as 'shooting stars'. Then there are the comets, large bodies consisting of rock and ice and circling the sun, most of them in highly eccentric elliptical orbits. On approaching the sun the comet gives off gases and dust which stream away from it in a direction away from the sun as though blown by a wind originating in the sun and resembling in form a feathery tail. The comet looks like a 'hairy star,' from whence the name comet is derived (*comes* = hair). Perhaps the best known is Halley's comet. Its orbit is shown in fig. 1.5. Some comets have parabolic or hyperbolic orbits which are open curves. They approach the sun from the depths of space, recede from it and are never seen again.

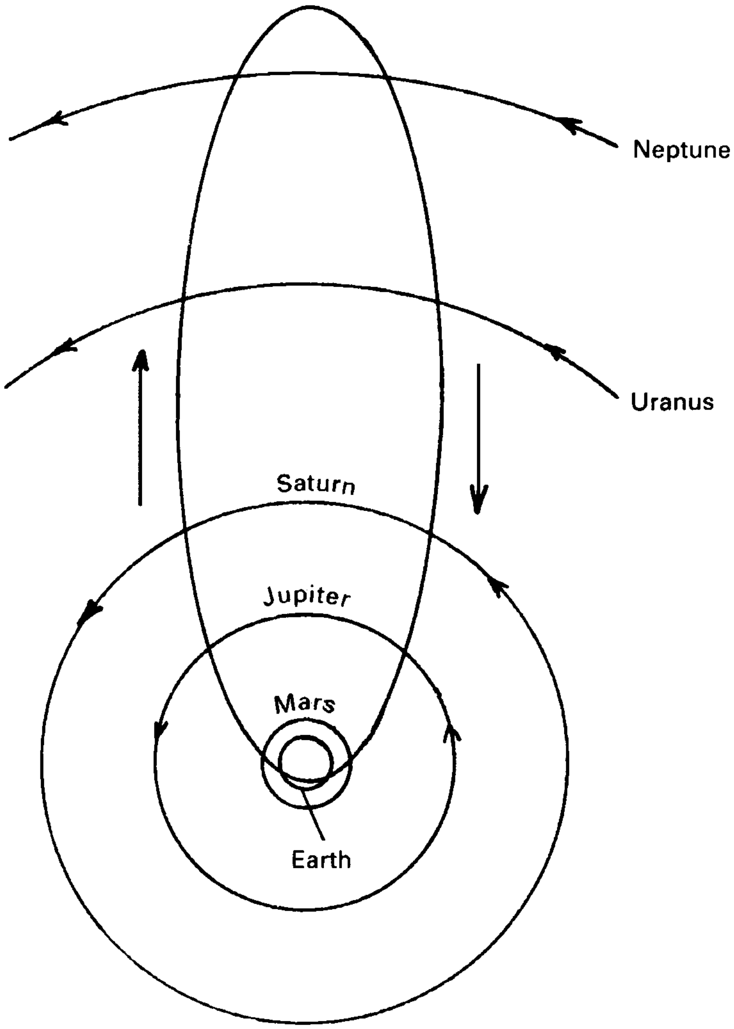

Fig. 1.5 The orbit of Halley's Comet.

A scale model of the Solar System

It is not possible to represent in a single diagram the relative sizes and distances from each other of the sun and planets because the distances are enormously greater than their sizes. The relative sizes of the sun and planets are shown in fig. 1.2 from which it will be appreciated that the sun is many times larger and more massive than all of the planets put together.

To gain a mental image of the size–distance proportions of the Solar System, first visualise a globe 2 feet (0.61 m) in diameter to represent the sun. On this scale, Mercury will be at an average distance of 83 feet (25.3 m) from it and in size will be represented by small shot or a good-sized pin head. Venus, represented by a small pea, will be at a distance of 156 feet (47.6 m) and the Earth will be another small pea at about 215 feet (65.6 m). Mars, a little larger than the shot representing Mercury, will be about 109 yards (99.7 m) from the ball representing the sun and Jupiter represented by a fairly large orange at a distance of about 373 yards (341.3 m). A large plum represents Saturn at a distance of about 0.38 mile (0.61 km). Two cherries at distances of 0.80 mile (1.29 km) and 1.22 mile (1.96 km) represent respectively Uranus and Neptune. Pluto will be a small pea at an average distance from the sun of slightly more than 1.6 miles (2.6 km). On the same scale, the nearest star would be at a distance of 10000 miles (16 090 km).

Bode's Law

The names of J. B. Titius of Wittenberg (1729–96) and J. E. Bode (1747–1826) are both associated with the formulation of an empirical law that seems to govern the distances of the planets from the sun. Bode and Titius both found that the mean distances of the planets from the sun are not distributed at random but follow a pattern. They derived a law such that the distance of a planet from the sun is given by the formula:

$$\text{distance} = 0.4 + 2^n \times 0.075$$

S. W. Orlow stated that if the constant 0.075 is incorporated in this formula as shown, then the exponent n is the planet's location in order from the sun corresponding to the distance given by the formula, i.e., Mercury = 1, Venus = 2 etc. If n is given whole number values from 1 to 10, then the values for the expression will give the distances of the planets from the sun in terms of astronomical units quite accurately except for Mercury, Neptune and Pluto (see table 1.2).

Another frequently quoted and simpler way to derive Bode's Law is, starting with zero, to write down the following numbers, each number being double the previous one:

0 3 6 12 24 48 96

Table 1.2. *Distances of the planets from the sun.*

Planet	Distance from sun (AU)	
	Bode's Law	Actual mean solar distance (AU)
Mercury	$0.4 + 2^1 \times 0.075 = 0.55$	0.4
Venus	$0.4 + 2^2 \times 0.075 = 0.70$	0.7
Earth	$0.4 + 2^3 \times 0.075 = 1.00$	1.0
Mars	$0.4 + 2^4 \times 0.075 = 1.60$	1.5
Asteroids	$0.4 + 2^5 \times 0.075 = 2.80$	2.8
Jupiter	$0.4 + 2^6 \times 0.075 = 5.20$	5.2
Saturn	$0.4 + 2^7 \times 0.075 = 10.00$	9.5
Uranus	$0.4 + 2^8 \times 0.075 = 19.60$	19.2
Neptune	$0.4 + 2^9 \times 0.075 = 38.8$	30.1
Pluto	$0.4 + 2^{10} \times 0.075 = 77.2$	39.1