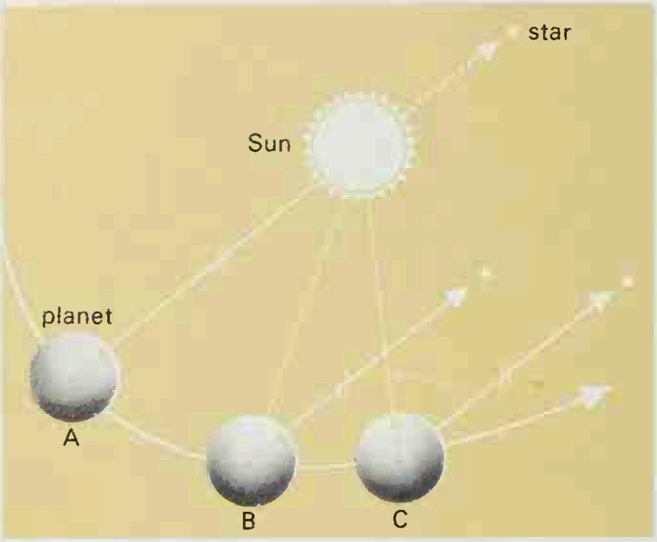

Fig. 2·7 right: Due to the motion of a planet in its orbit (from A to B and B to C), the sidereal rotation period (A to B) with respect to the stars, may be shorter than the synodic period (A to C) relative to the Sun.

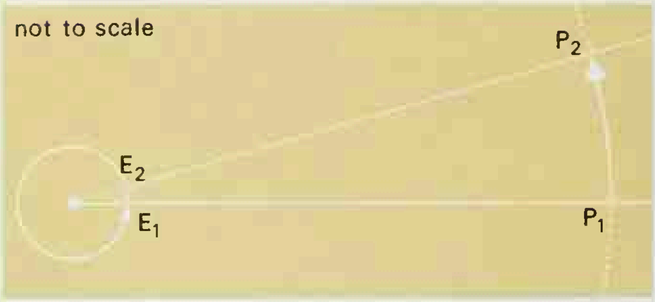

Fig. 2·8 right: The synodic period of a planet. In the time a distant planet takes to orbit from P_1 to P_2, the Earth completes one orbit from E_1 to E_1 and must travel on to E_2 to give the same position relative to the Sun.

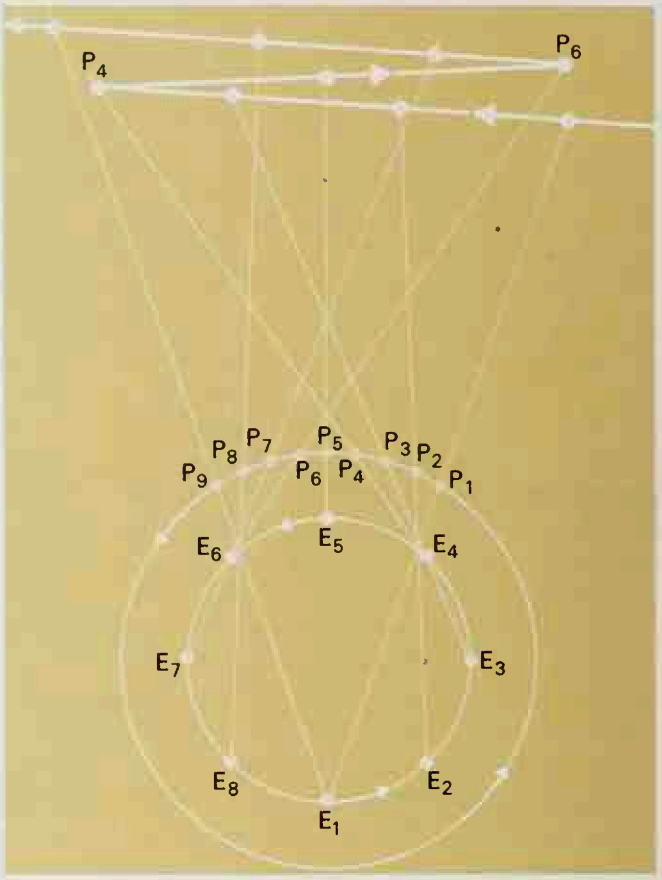

Fig. 2·9 top right: As seen from the Earth (E_1 . . . E_9) a planet moves against the background stars, appearing to retrograde from P_4 to P_6. Although the path is shown open for clarity, depending upon the orbital inclinations and positions, it may form a loop.

149 597 870 km (Fig. 2·11). Once one planetary distance has been established all of the others follow from the application of Kepler's theory.

The Titius-Bode 'law'

An attempt to explain the distances of the planets was made by Johann Titius in 1772 and this was publicized by Johann Bode, with whose name alone the idea was linked for a considerable time. It is now generally known as the Titius-Bode 'law' although it was only obtained by fairly arbitrary numerical manipulation. The figures obtained are given in Table 2·2 together with the actual planetary distances. It will be seen that, with the exception of the value of 2·8 au, the agreement is good for the planets which were known at the time – that is, out as far as Saturn. The discovery of Uranus in 1781 seemingly confirmed the 'law' and encouraged the search for the 'missing' planet at 2·8 au. Ceres, which was discovered accidentally, and other minor planets apparently filled this gap. When the search began for the planet which was perturbing Uranus, the Titius-Bode relation was used to indicate the distance at which it would be found. In the event, however, Neptune's distance of 30·06 au does not agree well with the predicted 38.8 au, and the discrepancy in the case of Pluto is too great (approximately 39·5 au against 77·8) for the 'law' to be any longer accepted. Various attempts have been made to suggest alternative relations, but as yet no satisfactory theory has been devised to account for the formation of the planets at specific distances. However, the Titius-Bode relationship served a useful purpose, as it encouraged the search for other objects.

Table 2·2 **The Titius-Bode 'law'**

planet	**distance (au) from Sun** 'predicted'	actual
Mercury	0·4	0·39
Venus	0·7	0·72
Earth	1·0	1·00
Mars	1·6	1·52
—	2·8	—
Jupiter	5·2	5·20
Saturn	10·0	9·54
Uranus	19·6	19·18
Neptune	38·8	30·06
Pluto	77·2	39·4

Table 2·1 **Planetary orbits**

planet	**mean distance** (millions of km)	**sidereal period** (d)	**inclination to ecliptic**	**eccentricity**
Mercury	57·91	87·969	7°00′15·6″	0·2056302
Venus	108·21	224·701	3°23′39·9″	0·0067835
Earth	149·60	365·256	—	0·0167184
Mars	227·94	686·980	1°50′59·3″	0·0933847
Jupiter	778·34	4 332·59	1°18′15·6″	0·0484648
Saturn	1 427·01	10 759·20	2°29′21·2″	0·0556194
Uranus	2 869·60	30 684·9	0°46′23·4″	0·0472585
Neptune	4 496·67	60 190·3	1°46′19·5″	0·0085888
Pluto	5 900·22	90 470	17·2°	0·25

(The values given for Pluto are approximate: inclinations and eccentricities are exact for 1978)