PLANETARY PERTURBATIONS, DYNAMICAL ENERGY AND EVOLUTION OF ORBITAL ELEMENTS OF PERIODIC COMETS.

A. MANARA - L. BUFFONI - M. SCARDIA
Osservatorio Astronomico di Brera
20121 MILANO
Italy

ABSTRACT. Planetary perturbations, dynamical energy and orbital evolution of the elements of three comets are calculated. This paper presents a part of the catalogue that will be issued in the next year.

1. INTRODUCTION

This paper presents a part of the catalogue that will be finished about the end of 1985.

The catalogue will contain a chronological list of planetary perturbations, dynamical energy (Buffoni et al., 1982a), orbital evolutions (Buffoni et al., 1982b) of 83 short-period comets that have at least a perihelion passage from 1968 through 1996.

The evolution of orbital elements is calculated only for those comets that show strong planetary perturbations and the dynamical energy for those comets that can have a doubtful orbit after a strong perturbation.

In addition the catalogue contains the orbital elements approximately at the epoch of the perihelion passage.

As an example we study P/Whipple (1978 VIII) and the planetary perturbations on P/Borelly (1981 IV), a comet with very short period (about 6.8 years), and P/Crommelin (1956 VI), a comet with only one perihelion passage in the period considered (period of the comet about 27.9 years).

The nongravitational forces are not taken into account in our calculations. These forces, probably random and impulsive in nature, are of small value, and in the graphs of planetary perturbations would not cause significant changes. They would have more importance in the calculation of the orbital energy of those comets with dubious orbit, but also in this case, due to their small intensity, there would not be definitive results.

For the computation of orbits Encke's method (Buffoni et al.,1971) has been used.

The time step of integration can be changed from many days to 1 day. For the three comets under examination it was taken constant,

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namely 7 days.

Machine time for each planetary perturbation graph is about ten minutes; for orbital energy and elements variation is about three hours.

Computations have been made by PDP 11/34 computer of Brera Astronomical Observatory of Milan.

2. SOURCES OF STARTING ORBITS

Osculating elements, from which we started, have been taken from Marsden (1982). As a rule, they correspond to the last apparition.

A few orbits were taken from D.F. Bender (1981) because more accurate orbits were available. We must remember that in Encke's method the choice of reference orbit is very important.

3. AIM OF THE WORK

The purpose of this work is to have at hand a quick reference from which the dynamical characteristic of any short period comet in the near future be ready available.

Our work stands out from the other similar works owing to the short period considered, which permits to study in detail the single comets passages.

The graph of planetary perturbations gives an immediate image of the epoch of possible "close encounters" with the planets. The graph of orbital energy is very interesting to see if the perturbations by the planets on the comet can change the sign of the energy; in fact if the energy remains negative the orbit will be elliptical, if the energy becomes positive the orbit will be hyperbolic. Orbital elements variations can be used to study the nature and origin of comets.

The present paper is only a section of our complete research about a sistematic calculation of comet orbits from observations published in Smithsonian Astrophysical Observatory and MPC circulars, conducted from 1980 by the Astronomical Observatory of Brera (Buffoni et al.,1981, 1983).

From its birth our Observatory had a real interest about comets and astronomers like Boscovich, Oriani, Carlini and Schiaparelli studied these celestial objects; we have especially to mention G. Celoria (1921) a pioneer of determination of comet orbits of Brera Observatory (Marsden, 1982). Both from sistematic study of comet orbits and from an analysis of the results of this paper, our purpose is to study those comets particularly useful for an appreciable improvement of the understanding of cometary evolution.

4. P/WHIPPLE

Fig. 1 shows planetary perturbations on comet Whipple. The perturbing forces that the individual planets exert on the comet are shown on logarithmic scale as the ratio R between the modules of perturbing force and the solar attractive force.

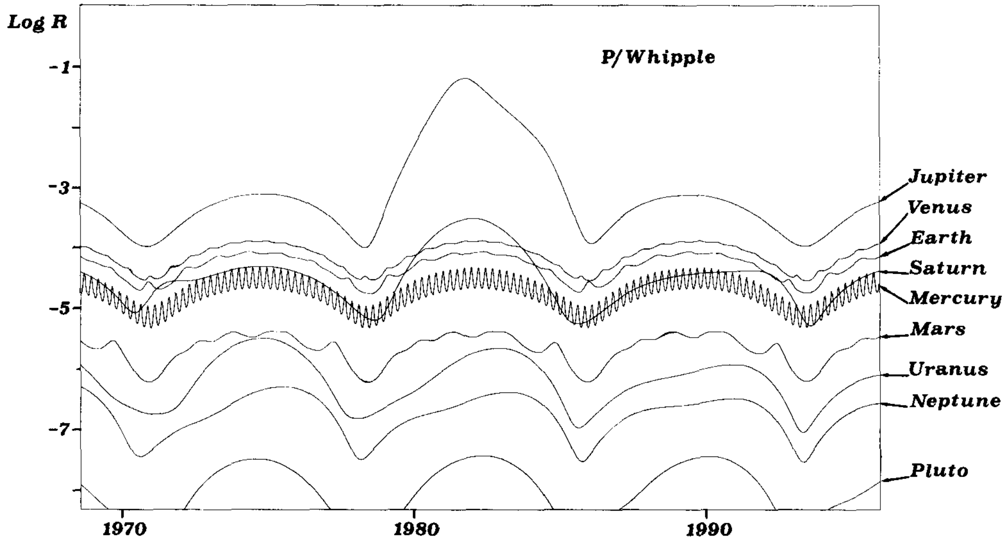

Figure 1. Planetary perturbations on P/Whipple

From an examination of the graph, it appears that in the period considered the planet which exerts the greatest perturbing force on the comet is always Jupiter and the maximum of this force is about 6% of the of the Sun in May 1981. We can see also the perturbing forces of the other eight planets.

We can see in Fig. 2 the orbital energy of Whipple's comet

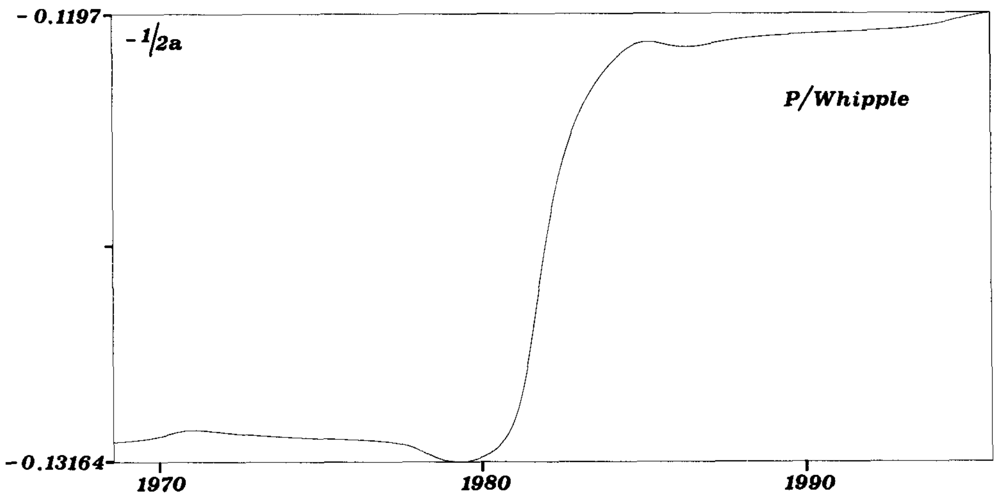

Figure 2. Mechanical energy of P/Whipple

expressed in units of -1/2a . The Jupiter perturbation is also well shown in this graph. Even though the perturbation is large, the comet energy always remains negative, consequently the comet orbit is elliptical. The evolution of inclination, in degrees, is shown in Fig. 3 . All sudden changes of the elements are due to close approaches to Jupiter. As it can be seen, the inclination exibits a sudden decrease in

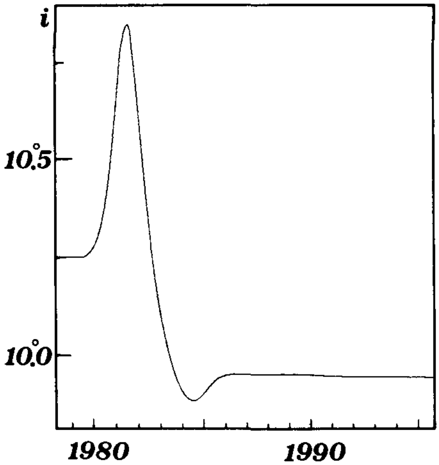

Figure 3. Orbital evolution of inclination

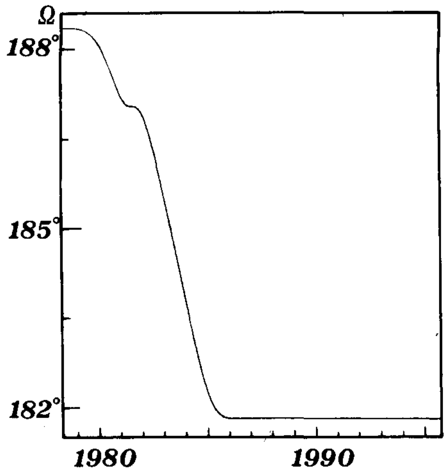

Figure 4. Orbital evolution of node

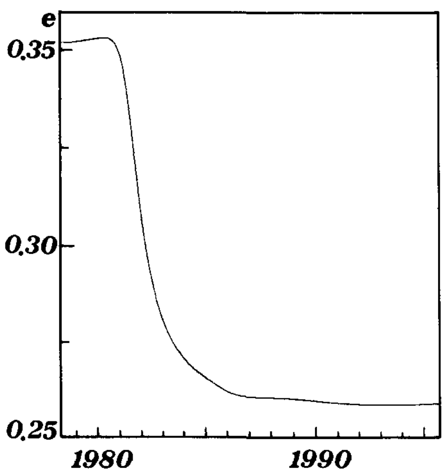

Figure 5. Orbital evolution of eccentricity

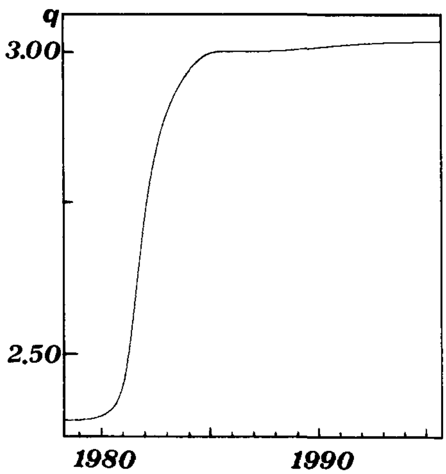

Figure 6. Orbital evolution of perihelion distance

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1981 after which the inclination remains constant.

The node (Fig. 4) and the eccentricity (Fig. 5) both also decrease suddenly and, after 1985, reach a constant value.

The perihelion distance (Fig. 6), also in 1981, grows suddenly when the comet is approaching Jupiter and, after 1985, reaches a constant value.

The argument of perihelion (Fig. 7) shows a sudden increase and finally reaches a nearly constant value.

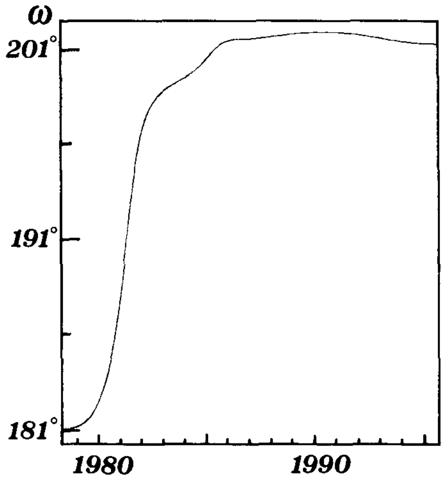

Figure 7. Orbital evolution of argument of perihelion

From the changes of times T of perihelion passage and of true anomaly of comet P/Whipple, which we calculated for the period 1978-1995, we found that the orbital period increases due to Jupiter's perturbation. We do not give the graph of perihelion passage variation because it is difficult for a graphical representation since our computations refer to several passages.

The minimum approach distance to Jupiter is 0.631 AU (1981, July 9). In this case the perturbation time step of integration is one day. Fig. 8 shows the projection of the orbits of Jupiter and P/Whipple into ecliptic plane for an interval of 5500 days around the epoch of approach to Jupiter.

The position of the comet and of Jupiter are given at corresponding epochs every 30 days starting from 1979, May 7 to 1983, June 15.

We can see in Table 1 the orbital elements approximately at the epoch of the perihelion passage. The epoch is given in year, month, day.

For the time of perihelion passage T one decimal of the day is added; the perihelion distance is given in AU.

All the angular elements are in degrees and their fractions, and referred to the mean equinox and ecliptic of 1950.0 .

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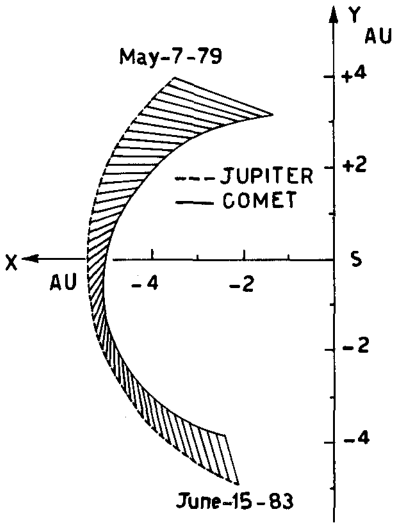

Figure 8. Projection of Jupiter and P/Whipple orbits into ecliptic plane

Table 1

Orbital elements of P/Whipple approximately at the epoch of perihelion

Epoch	T	q	e	i	Per.	Node
1978.0402	1978.03275	2.468633	0.352244	10.246	189.976	188.339
1986.0629	1986.06250	3.077550	0.260582	9.943	202.047	181.800
1994.1218	1994.12224	3.093882	0.258705	9.934	201.881	181.792

5. P/BORELLY

Planetary perturbations on P/Borelly are shown in Fig. 9 . In the graph we can see the very strong perturbation by Jupiter in 1972; the perturbation by the Earth in 1988 (the planet which exerts the greatest perturbing force in that short period) and the perturbation by Mars in 1994.

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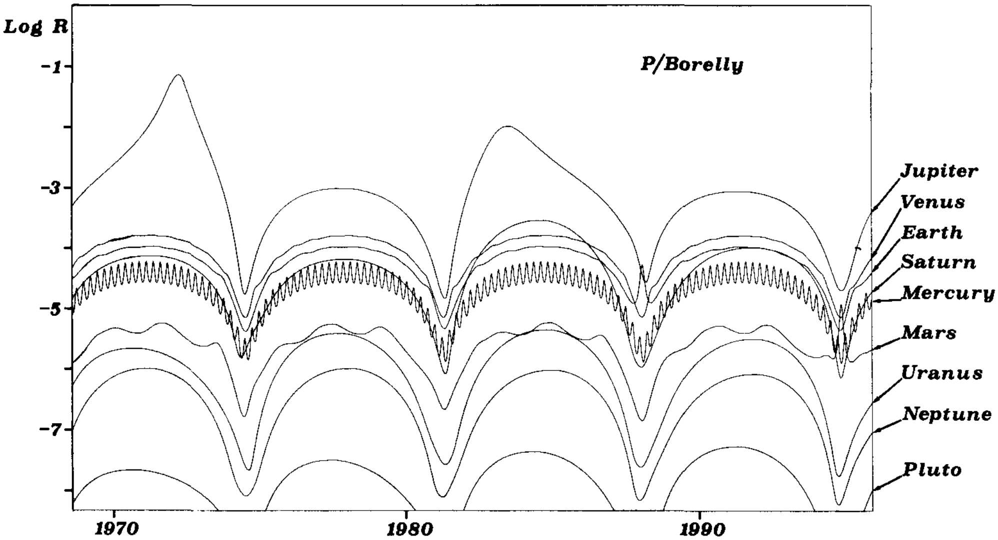

Figure 9. Planetary perturbations on P/Borelly

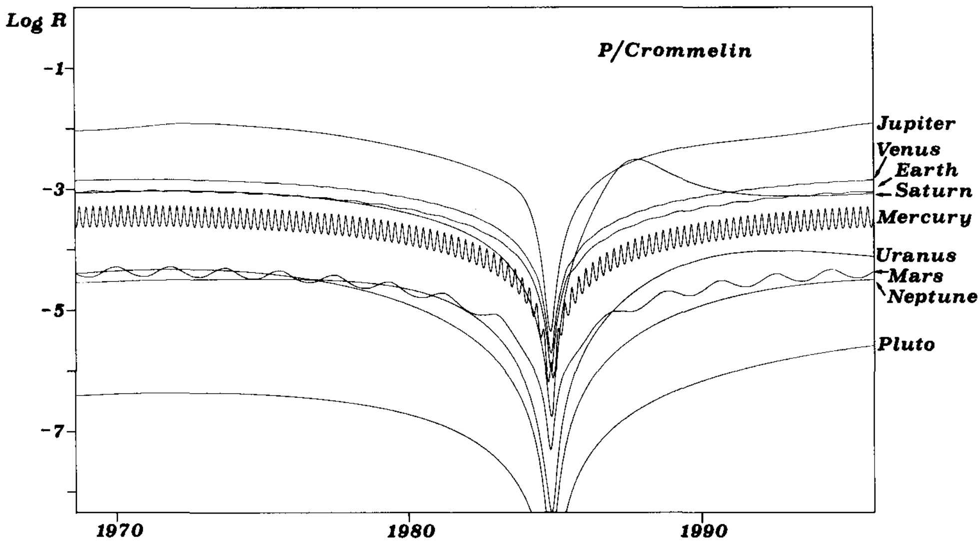

Figure 10. Planetary perturbation on P/Crommelin

6. P/CROMMELIN

The perihelion passage in 1984 and the largest perturbation due to

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Saturn around 1987-1988 are clearly shown in the diagram of planetary perturbations on P/Crommelin (Fig. 10). It is very interesting to observe that for P/Crommelin and generally for most of the comets the Mercury's perturbation is larger than that of Mars, Uranus and Neptune, planets which have a much greater mass; the explanation is that generally the comets pass much closer to Mercury than to Mars, Uranus and Neptune.

7. ACKNOWLEDGMENTS

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