SOLAR SYSTEM OBJECTS OBSERVED BY HIPPARCOS.

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Abstract. The ESA satellite Hipparcos provides valuable photometric and astrometric results on minor planets and natural satellites. Observations of 48 asteroids, J II-Europa, S VI-Titan and S VIII-Iapetus were made from November 1989 to March 1993. A twenty seconds averaged normal place is constructed, providing thus positions accurate to a few hundredths of arcseconds and relative to a very precise and homogeneous reference frame.

1. Introduction

The systematic scanning of the sky by Hipparcos from November 1989 to March 1993 yields accurate astrometric parameters for about 120 000 stars. It will provide an homogeneous optical counterpart of the ICRS's reference frame (ICRF). Because the Hipparcos sphere has no orientation, it is tied to the reference frame of extra-galactic objects. It can also be tied to the dynamical reference frame defined by the motion of solar system objects. Three natural satellites and 48 minor planets have been added to the list of stars to be observed by the Hipparcos satellite (they are listed on Table 1 and 2). These are small and bright objects not larger than ≈ 1", and with magnitude lower than 12.5.

2. Observations

The payload design of the instrument and the global reduction of the FAST consortium are described in (Perryman *et al.*, 1992) and (Kovalevsky *et al.*, 1992); the reduction procedure of the astrometric data for minor planets is described in (Hestroffer *et al.*, 1995).

S. Ferraz-Mello et al. (eds.), Dynamics, Ephemerides and Astrometry of the Solar System, 437–442.

TABLE 1. Solar system objects observed by Hipparcos
Asteroids

N°	Name	Nbr	N°	Name	Nbr	N°	Name	Nbr
1	Ceres	67	18	Melpomene	103	63	Ausonia	13
2	Juno	62	19	Fortuna	31	88	Thisbe	36
3	Pallas	63	20	Massalia	61	115	Thyra	32
4	Vesta	51	22	Kalliope	64	129	Antigone	43
5	Astraea	80	23	Thalia	66	192	Nausikaa	32
6	Hebe	93	27	Euterpe	36	196	Philomela	16
7	Iris	66	28	Bellona	36	216	Kleopatra	20
8	Flora	57	29	Amphitrite	63	230	Athamantis	35
9	Metis	47	30	Urania	48	324	Bamberga	66
10	Hygiea	47	31	Euphrosyne	15	349	Dembowska	96
11	Parthenope	67	37	Fides	33	354	Eleonora	97
12	Victoria	24	39	Laetitia	103	451	Patientia	29
13	Egeria	36	40	Harmonia	105	471	Papagena	108
14	Irene	47	42	Isys	50	511	Davida	65
15	Eunomia	87	44	Nysa	53	532	Herculina	38
16	Psyche	46	51	Nemausa	15	704	Interamnia	72

TABLE 2. Solar system objects observed by Hipparcos
Satellites

Jupiter			Saturn		
N°	Name	Number	N°	Name	Number
J II	Europa	88	S VIII	Titan	111
			S VIII	Iapetus	65

Due to the particular scanning law of the Hipparcos satellite, the amount of observations varies between the different objects (columns 'Nbr' and 'Number' of Tables 1 and 2). Moreover the observation of a solar system body occurs in a 86° wide zone around the quadratures, which can yield a photocentre offset of a few mas for the largest planetoids.

Because the fundamental measure is a photon count, Hipparcos not only provides positions of the observed objects, but also magnitudes with a precision of a few 0.01 mag (Mignard *et al.*, 1992), (Morando and Mignard, 1993). So, reduced light curves for a few objects and phase curves between 15° and 25° can be constructed.

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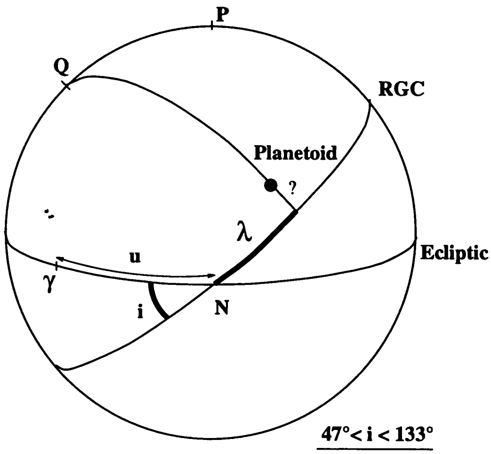

Figure 1. Position of a planetoid given by Hipparcos

3. Astrometry

As the measures are made through a modulating grid with parallel slits, Hipparcos observations only provide a one-dimensional abscissa λ on a reference great circle (RGC) as shown on Figure 1. This precessing great circle oscillates, with a period of 57 days, around a plane perpendicular to the ecliptic, yielding thus more information on the planetoids latitude than on their ecliptic longitudes.

The reduction procedure takes into account effects of the order of 1 mas. Care has also been taken to avoid modelisation errors of such an amplitude so that no correction of the photocenter offset has been added. The given abscissa corresponds then to the astrometric direction of the planet photocentre for each transit in the field of view. In general, this normal point is distant to the center of mass by only a few 0.1 mas. The accuracy of the position obtained depends on the body's magnitude and size, it is of the order of $0\overset{''}{.}015$.

The O–C's obtained, for the satellite S VI-Titan and for all the minor planets, from the comparison to the Hipparcos observations are shown on Figure 2. These are differences on the great circles; the dispersion present on these graphs arises from the measurement noise, the variation over successive transits on a same great circle, and, on a larger time scale, from the geometry of the scanning direction relative to the planets' orbit.

The calculated places for the minor planets were obtained by numerical integration with initial conditions taken from the "Ephemerides of minor planets, 1992". The O–C's depend on a rotation of the Hipparcos sphere

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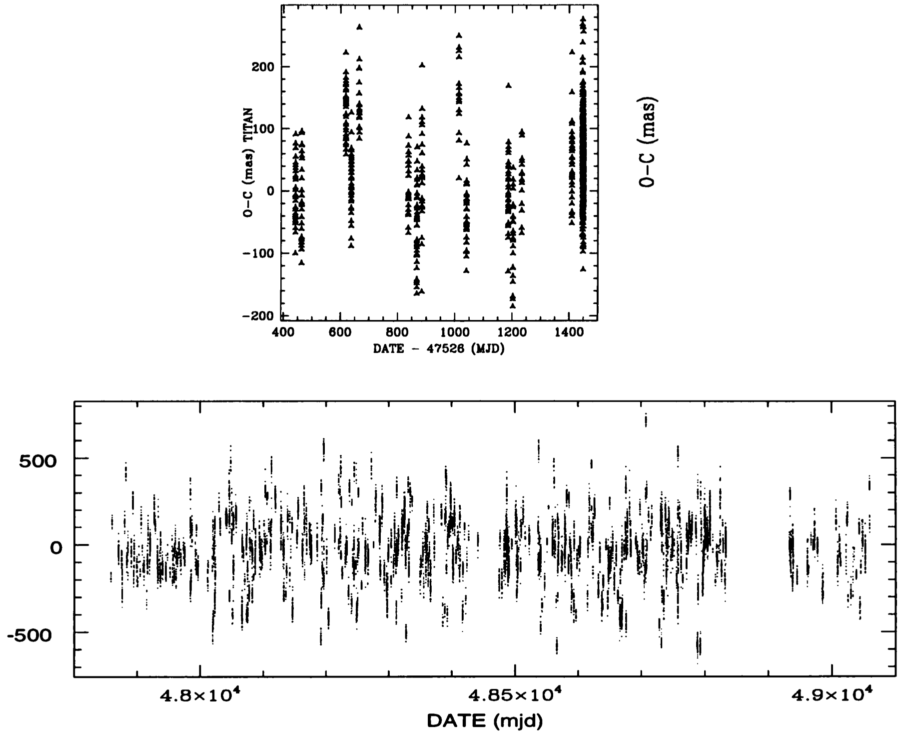

Figure 2. O–C's for S VI-Titan (*top*) and for the 48 minor planets (*bottom*).

relative to the dynamical reference frame, on the systematic errors due to phase effect, on errors of the Earth's ephemerides; but mostly on the initial conditions from the minor planets' ephemerides. For Titan the ephemerides were taken from the theory of Dourneau (1987) and the ephemerides of DE200 for Saturn, the O–C's are then in the range $\pm 0\overset{''}{.}2$; next step will be to compare these observations to the more recent theories TASS (Duriez and Vienne, 1991) or of Dourneau (1993), with improved ephemerides of Saturn.

4. Reference Frame

The link of the Hipparcos sphere to the dynamical frame – defined by the minor planets' motions – is given by an infinitesimal time dependant rotation: $\mathbf{W} = \mathbf{W}_o + (t - t_o) \cdot \mathbf{W}_1$. Other parameters outlined in Section 3 are the initial conditions of the minor planet ephemerides. With 3 years of observations it is not possible to determine the whole set of initial conditions. Parameters such as eccentricity, semi-major axis or mean longitude are not or are poorly determined; nevertheless, the orientation of the osculating plane can be provided to an accuracy of a few mas.

Correction to the orientation of the Earth's osculating plane can not be determined simultaneously with those of the minor planets and the orientation of the sphere (Hestroffer *et al.*, 1995). The orientation $\mathbf{W}_o$ and the rotation rate $\mathbf{W}_1$, given with respect to the DE 200 system, are provided with an accuracy of 1–2 mas and 1–3 mas/year respectively; where the orientation of the ecliptic is better determined than the position of the equinox (Hestroffer, 1994).

5. Conclusion

Hipparcos observations of minor planets and natural satellites, made over a period of 3 years, yield magnitude determination with a precision of a few 0.01 mag and astrometric positions accurate to about 0".015. From the minor planets' astrometric data, it is possible to obtain a partial improvement of their ephemerides. These observations can however profitably complete the ground-based observations made on a wider time span. It is also possible to determine the rotation of the Hipparcos sphere relative to a dynamical reference frame with a precision of 3 mas and 3 mas/year.

Hipparcos observations of solar system objects are of great value for orbital improvement or frames linking, but they are spread over a short time span when compared to the minor planets' sidereal periods. These observations will be advantageously completed by high precision observations from ground (CCD observations of occultations or close approaches) or by astrometry from space (HST, Struve, GAIA).

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