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New CCD positions of Triton and a comparison with the theoretical predictions*

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Abstract. Astrometric observations of Triton are given for the oppositions of Neptune on 1995, 1996 and two nights in 1997. In this period, 759 frames were obtained during 35 nights at the Cassegrain focus of the 1.6 m and the 0.6 m reflectors of the LNA-Brazil. The comparison with calculated positions gives residuals with standard deviation of the order of $0\overset{''}{.}09$[1].

Key words: astrometry — planets and satellites: Triton

1. Introduction

We initiated an astrometric program of observations of natural satellites in 1982. Considering that, up to accuracies better than $0\overset{''}{.}15$, only a few hundred positions of Triton, were published since the discovery of this satellite by Lassel in 1846 (see for instance Jacobson et al. 1991), we began our observations of this satellite in 1985.

The first results of our observations, presenting 53 photographic positions distributed along 13 nights, between 1985 and 1988, were presented in Veiga et al. (1995). A second paper with 433 CCD observations of Triton obtained in the period 89-94 over 29 nights was published in the following year (Veiga & Vieira Martins 1996, hereafter called Paper I).

In this paper we present 759 CCD observations obtained in 1995, 96 and 97, distributed over 35 nights. We then compare the whole set of our measured positions of Triton related to Neptune to the positions calculated using the parameters given by Jacobson et al. (1991). The distribution of our CCD observations of Triton are presented in Fig. 1. In Sect. 2 of this paper we describe the observations, the measures and the reduction procedures. In Sect. 3 we compare our results with theoretical calculated positions and in Sect. 4 a conclusion is presented.

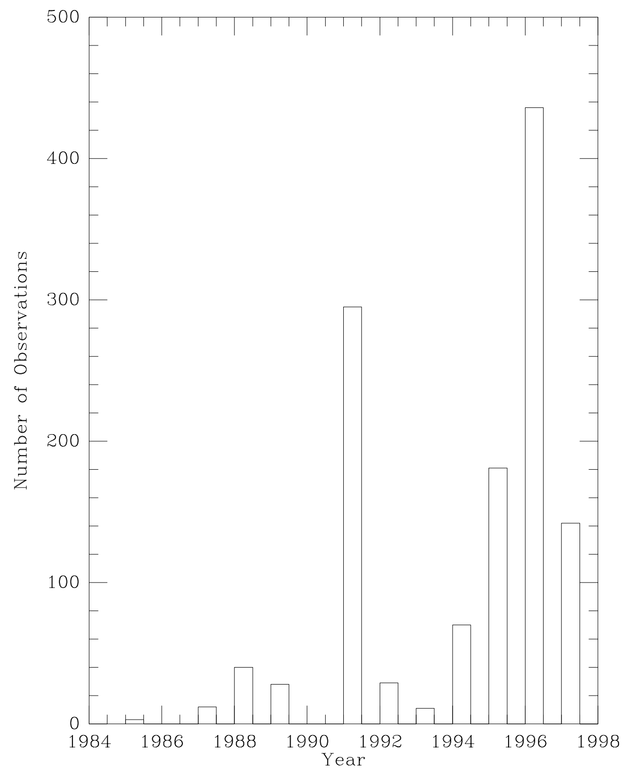

Fig. 1. The distribution of the observations, both photographic and using CCDs

2. The observations, measures and data reduction

The observations were carried out at the Cassegrain focus of two telescopes at the Observatório do Pico dos Dias (OPD) of the Laboratório Nacional de Astrofísica - Brazil. About 70% of these observations were made at the 1.6 m Perkin-Elmer reflector for wich the scale at the focal plane

* Based on observations made at Laboratório Nacional de Astrofísica/CNPq/MCT-Itajubá-Brazil. Please Send offprint requests to C.H. Veiga.

[1] Table 1 is only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

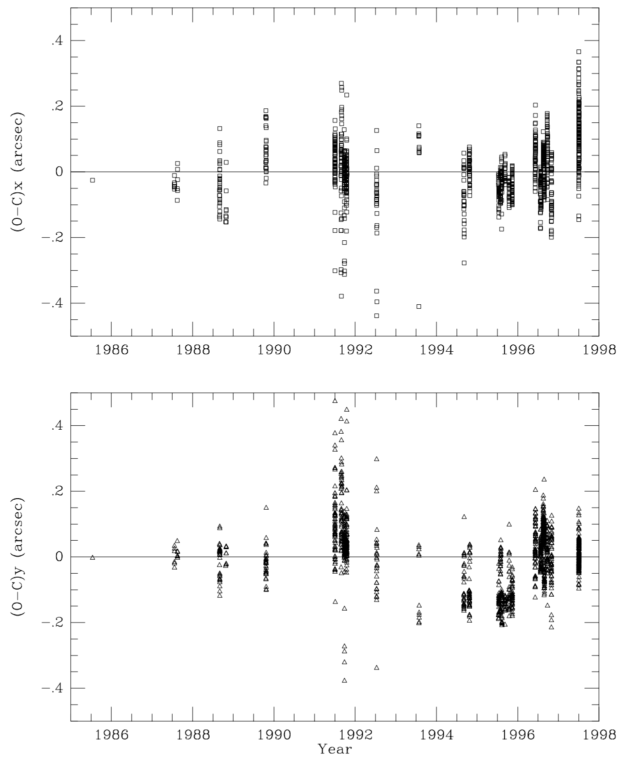

Fig. 2. The (O−C) of Triton as function of time

is 13″/mm and 30% at the 0.6 Zeiss Jena reflector for wich the scale is 27.″5/mm. The latitude of the observatory is $\phi \approx -23°$ and so Neptune's culmination is near the zenith of those years. For details about the telescopes we refer to Veiga et al. (1987).

For all of the 229 observation made at the 0.6 m telescope we used the CCD EEVP8603A which is an array with 385×578 square pixels, each measuring 22 μm, which corresponds to 0.″605. The 530 observations made at the 1.6m telescope used the EEV CCD-05-20-0-202 which has an array of 770×1152 square pixels with 22.5 μm or 0.″293 (for 319 observations) and the CCD SITe SI003AB wich is a square with 1024×1024 square pixel with 24 μm corresponding to 0.″312 (for 211 observations). No filter was used for most of the observations. However, for 53 observations made in 1997, an Johnston R filter was used.

The exposure time varied from 1 to 5 seconds depending on the meteorological conditions and on the utilized devices.

We use the program ASTROL (Colas & Serrau 1993) to find the centers of the planet, satellite and stellar images. For the determination of each center we take a small area containing the image and a bi-dimensional Gaussian is fit to this image. The Gaussian is added to a second degree polynomial as to remove the sky background. The errors upon the centering procedure were 0.″04 for Neptune and 0.″02 for Triton. For a discussion on the determination of astrometric centers see Veiga & Vieira Martins (1995).

For the astrometric calibration we made an adaptation of the method of the secondary catalog to the special conditions of the small CCD fields. This method, which is presented and tested in Vieira Martins et al. (1996) (see also Assafin et al. 1997a,b), consists on the setting of an astrometric catalogue for the stars on the CCD, using their images in the Digitized Sky Survey and the positions of nearby stars from the Guide Star Catalog corrected by the PPM Catalog.

To correct the systematic errors due to the color difference between Neptune and Triton for the frames took without filter, we computed the total astronomical refraction separately for Neptune and Triton following the procedure presented in Paper I. In few words, we considered a difference of 0.″19 for the planet and the satellite refraction constants which corresponds to 0.″15 after the corrections due to the usual values for the pressure and the temperature during our observations. This value corresponds to a difference of 0.07 μm between the effective wavelength observed for Neptune and Triton. No correction was made for the observations taken with the R filter.

In Table 1 (accessible in electronic form) we list the observed positions of Triton relative to Neptune. The data are presented in the following form: the first line gives the year, month and day and decimal fractions of UTC days, corresponding to the mean instant of the observation. In the next line we list the name of the satellite followed by $X(\Delta\alpha\cos\delta)$ and $Y(\Delta\delta)$ in arcseconds, referred to Neptune. The reference system is referred to the equator and equinox of J2000.

3. Comparison with theoretical positions

We compared our complete set of measured positions with those calculated using the parameters given by Jacobson et al. (1991) (in their Table 5). The positions of Neptune were obtained from the ephemeris DE403 (Standish et al. 1995). These positions are related to J2000 reference system. However, the Jacobson parameters give rise to positions of Triton related to Neptune in the B1950.0 reference system. So we must transform the positions of the planet from J2000 to B1950.0 and, after we calculate the positions of the satellite, and convert these positions to J2000. To perform these convertions we used the procedure described in Aoki et al. (1983), Appendix 2. To add the E-Term of the aberration in the inverse transformation (J2000 to B1950.0) we used a process of successive approximations (Rapaport 1996).

Our positions (for all observations) have the following (O−C) residuals: $\overline{x} = 0.''014$, $\overline{y} = -0.''007$, $\sigma_x = 0.''086$ and $\sigma_y = 0.''082$. These values are slightly better than those presented in Paper I, probably due to the fact that the images for each frame were obtained with an accurate determination of the good exposure time.

In Fig. 2 we present the (O−C) of the positions of Triton related to Neptune as function of the observational

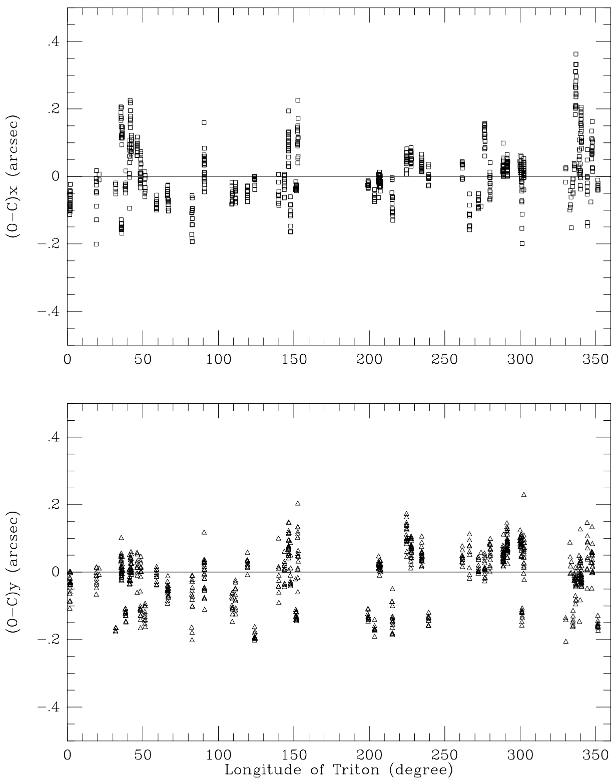

Fig. 3. Residuals for Triton referred to Neptune versus the longitude

dates. The photographic and the previous CCD observations are also plotted. We can see that the residuals are almost uniform for these 13 years. Some $(\mathrm{O-C})_x$ values for 1997 are larger than $\overline{x} + 3\sigma$ probably due to the bad meteorological conditions in the two considered nights.

The (O−C) for the positions of Triton related to Neptune as function of the longitude of the satellite for the observations of this paper (1995-1997) are presented in Fig. 3. We can see that the distribution of the residuals is approximately uniform.

4. Conclusion

We presented 759 positions of Triton distributed over 35 nights. Putting these observations together with those which we published in the two previous papers, we have observed 1245 positions of Triton distributed between 77 nights, with an accuracy of the order of $0\farcs1$.

A conclusion that is reached from our results is that the parameters of Jacobson et al. are very good to describe the orbit of Triton considering the present accuracy of the observations of this satellite. On the other hand, the little accuracy of the majority of the old observations allows to conclude that only large number of new precise observations distributed over many nights will be important in a future study of a more accurate orbital evolution of Triton.

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