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THE REVISED POLE MODEL AND NEW OBSERVATIONS OF TRITON

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RESUMEN

En este trabajo usamos 3108 observaciones astrométricas hechas desde tierra por más de 30 años, desde 1975 hasta 2006, obtenidas del Centro de Datos de Satélites Naturales (NSDC, siglas en ingés), para determinar los vectores de estado de Tritón, el satélite más grande de Neptuno. Para integrar la ecuación de perturbación, adoptamos el sistema de referencia baricéntrico del sistema Neptuno-Tritón, y considerando la perturbación por el achatamiento de los polos de Neptuno, usamos un modelo revisado que describe la precesión del polo del planeta, en nuestros cálculos. Adicionalmente, un total de 1095 nuevas posiciones observadas de Tritón fueron recolectadas de 46 noches de observación en 2007, 2008 y 2009. Nosotros comparamos nuestras observaciones con dos efemérides de Tritón y con la mayoría de las efemérides planetarias disponibles de Neptuno.

ABSTRACT

We used 3108 Earth-based astrometric observations from the Natural Satellite Data Center (NSDC) over more than 30 years time span from 1975 to 2006 for determining the epoch state vectors of the Neptunes largest satellite Triton. In integrating the perturbation equation, the barycentric frame of Neptune-Triton system is adopted, and in considering the oblateness perturbation due to Neptune, a revised pole model describing the precession of the Neptune's pole is used in our calculation. Moreover, a total of 1095 new observed positions of Triton were collected during 46 nights of observations in 2007, 2008 and 2009. We compared our observations to two ephemerides of Triton and most of the available planetary ephemerides of Neptune.

Key Words: astrometry — planets and satellites: Triton

1. INTRODUCTION

The giant planets Jupiter, Saturn, Uranus and Neptune with their respective satellites form micro-solar systems. These small solar systems constitute natural laboratories for the study of the formation and evolution of the Solar system. In addition, research on the motion of the natural satellites can improve the ephemerides of the major planets.

We initiated an astrometric observing program of natural satellites in 1985. Some results of our observations have been already used to develop new orbits for satellites, such as the eight main satellites of Saturn (Dourneau 1993), Phoebe the ninth satellite of Saturn (Shen et al. 2005), the major satellites of Uranus (Emelyanov & Nikonchuk 2013) and Triton, the main satellite of Neptune (Jacobson 2009; Zhang et al. 2014). Triton, the largest satellite of Neptune, was discovered by the British astronomer William Lassell using a telescope on October 10, 1846.

To date, the best available orbit of Triton was computed by Jacobson (2009) and by Jacobson, Riedel & Taylor (1991) by employing a precessing pole model of Neptune (Jacobson 1990b). In the Neptunian system, the oblateness force depends upon the orientation of the pole of Neptune. The polar motion is driven primarily by the torque due to the gravitational attraction of Triton on the planets equatorial bulge, which causes the orbit to precess at a constant inclination to a plane about the Neptune pole. This perturbational model of Triton complicates the calculations more than for other satellites.

2. DYNAMICAL MODEL

We have included the following forces in the model: the central force of the primary; the perturbing force due to the Sun, Saturn, Jupiter and Uranus; the perturbation due to the Neptunian oblateness.

In this work, we use a revised pole model presented here for a better representation of the pole direction with time. Here, we derive the accelerations and partial derivatives of the acceleration upon a satellite due to the oblateness of Neptune in an arbitrary planetocentric reference system.

We suppose that the direction cosines of the pole vector of the planet are defined as (γ_1,γ_2,γ_3), and that the planetocentric coordinates of the satellite

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are x_1,x_2,x_3, then

$$r^2 = x_1^2 + x_2^2 + x_3^2$$

$$\zeta = \frac{\gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3}{r} \tag{1}$$

The potential function for the effect of the n-th zonal harmonic of the planet's gravity field upon the satellite is

$$\begin{aligned}\phi &= -\frac{k(\mu_0+\mu)}{r}\sum_{n=2}^{4} J_n\left(\frac{a_0}{r}\right)^n P_n(\zeta)\\ &= K\frac{1}{r^{n+1}}\sum_{n=2}^{4} J_n P_n(\zeta)\end{aligned}$$

where $K = -k(\mu_0+\mu)J_n a_0^n$, μ_0 is the mass of the planet, a_0 is the mass of satellite, r is the equatorial radius of the planet and J_n is the coefficient of the n^{th} zonal harmonic. The acceleration component of coordinate x_i is

$$F_i = \frac{\partial\phi}{\partial x} = \frac{K}{r^{n+2}}\Big(-\frac{x_i}{r}P'_{n+1}(\zeta) + \gamma_i P'_n(\zeta)\Big) \tag{2}$$

where we have used the identity

$$(n+1)P_n(x) + xP'_n(x) \equiv P'_{n+1}(x) \tag{3}$$

3. COMPARISON BETWEEN TWO EPHEMERIDES WITH THE NEW OBSERVATIONS (2007-2009)

As a continuation of our previous observing campaign of 1996-2006 (Qiao, et al. 2014), we present here another 1095 new observed positions of Triton which were obtained by using three different telescopes at two different stations during the period 2007-2009, spread over 46 nights involving eight missions.

Our results show that both of the orbits by Jacobson (2009) and by Zhang et al. (2014) can be considered as equivalent for the recent period of our observations from 2007 to 2009.

4. CONCLUSIONS

We have presented a new determination of the orbit of Triton. The orbit has been checked with some comparisons from Jacobson (2009) with all the available observations spread over the period 1975-2006, and then with the recent period of our observations. They provide the same values of mean residuals, within 1 mas, corresponding to only 20 km in the position of Triton.

Moreover, we analyzed our observations by comparing them to the ephemeris positions. This analysis has shown that our observations present a high level of accuracy, barely higher than 50 mas, which is the standard deviation of the residuals. However, the mean residuals are smaller, less than 30 mas in both coordinates, showing the very high accuracy.

For the planet Neptune, the ephemeris DE431 appears to be the most homogeneous and accurate as it is the only one presenting mean residuals lower than 30 mas in both coordinates, just followed by INPOP06, nearly as accurate as DE431 in both coordinates, within less than 10 mas. Also DE421, which we have shown to be equivalent to EPM2011m, is in very good agreement with DE431, within less than 20 mas. The other planetary ephemerides, such as DE405, that we have shown to be equivalent to DE406, INPOP08 and INPOP10 present slightly higher residuals but remain in rather good agreement with DE431, within about 50 mas. Finally, DE200 and VSOP82, the oldest ephemerides, present the highest residuals, up to 900 mas, showing a significant drift of their positions for the recent period of our observations.

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