# ASTROMETRIC OBSERVATIONS OF FAINT SATELLITES

R. VIEIRA MARTINS, C. H. VEIGA
*Observatório Nacional*
*Rua General José Cristino 77, CEP 20921-030 Rio de Janeiro, RJ - Brazil. E-mail: rvm@on.br or cave@on.br*

AND

M. ASSAFIN
*Observatório do Valongo/UFRJ*
*Ladeira Pedro Antônio 43, CEP 20080-090 Rio de Janeiro, RJ - Brazil. E-mail: massaf@vms1.nce.ufrj.br*

**Abstract.** We present a method to obtain the reference system for isolated observations of faint satellites made with CCD[1]. The method consists in the construction of a secondary catalogue of faint stars using 'The Digitized Sky Survey' and 'The Guide Star Catalogue' corrected by modern astrometric catalogues.

## 1. Introduction

In 1982, we started a systematic program of astrometric observations of faint satellites. From 1982 to 1988, all observations were made using photographic plates and, since then, CCD devices have been used.

For the reduction of our observations, some methods were developed. The center positions for the images were determined using special photometric methods (Veiga and Vieira Martins,1995) and the reference system was obtained through the method described by Veiga and Vieira Martins (1994) which uses the apparent motion of the planet.

Nevertheless, the method of the motion of the planet cannot be used for all observations. This happens if, between the first and the last frame

[1] Based on observations made at Laboratório Nacional de Astrofísica/CNPq/MCT-Itajubá-Brazil.



*S. Ferraz-Mello et al. (eds.), Dynamics, Ephemerides and Astrometry of the Solar System,* 419–422.

of a observations mission, the planet do not cover an arc longer than the distance between the satellite-planet or satellite-reference satellite and also for isolated observations.

So, we have now developed a method for isolated observations of faint satellites with small CCD fields. This method is similar to the classical one which consists in the construction of secondary catalogues. However, in our method, we make use of 'The Digitized Sky Survey of the Space Telescope Science Institute' in the place of the astrographic plate.

Next, we present some data about our observations, the general idea of the method of astrometric calibration and, as an example, an application to observations of Nereid (magnitude 19).

## 2. Observations

The faint satellites observed in our program are: the Martian satellite Deimos; the Jovians Amalthea, Thebe and the eight outer satellites; Helene, Calypso, Telesto and Phoebe of Saturn; the satellites Miranda, Ariel Umbriel, Titania and Oberon of Uranus; Triton and Nereid of Neptune.

The observations were made at the Cassegrain focus of the 1.6 m reflector of the Laboratório Nacional de Astrofísica, Brazil ($\phi \approx -23°$). This telescope has a focal distance equal to 15.8 m which gives the scale of $13''.0$/mm at focal plane (Veiga et al.,1987).

The CCD used was a EEVP 88231 of $770 \times 1152$ square pixels with $22\mu$m. No filter was used. As the image of the planet is always saturated, the diffraction spikes were avoided by placing a mask with 8 circular apertures between the secondary mirror vanes. To avoid the saturation due to the light of the planets (Mars, Jupiter and Saturn), circular masks with appropriate diameter are placed on the CCD window. The distance from the window to the chip is 10mm and so we can observe faint satellites when the distance from the edge of the planet is greater than $13''$.

So, we have images of the satellites surrounded by a small field ($5'30'' \times 3'40''$) of stars whose magnitudes are smaller than or equal to the satellites magnitudes.

## 3. Astrometric Calibration

The usual method to obtain positions of satellites in an equatorial reference system is the same used in astrometric reductions of faint objects. It consists in the construction of a secondary astrometric catalogue of faint stars in the neighborhood of the satellites using high quality astrometric plates taken by telescopes with small focal distance. This procedure presents two problems: first, it is necessary to have an astrometric plate of the field and second, we must measure this plate carefully.

To avoid these problems we developed a variation of this method using facilities available in almost all observatories. The method consists in the following steps:

1. We take a field with about $4° \times 4°$ centered in the satellite position using a good astrometric catalogue and the Guide Star Catalogue (GSC) (Russel et al.,1990). We correct the GSC positions using a third degree plate model. So, we arrive to a local version of the GSC corrected by a selected astrometric catalog.

2. Using the Digitized Sky Survey (DSS), we determine the center of GSC stars in a field with $30' \times 30'$ surrounding the CCD frame. We determine also the center of some stars on the CCD.

3. With the corrected GSC positions and using a first degree polynomial, we obtain a catalog for the CCD stars.

4. Using the CCD images, we measure the center of the stars and the satellites.

5. With the catalogue constructed for the CCD stars, we calculated the positions of the satellite using a polynomial of degree one or two. The degree of the polynomial depends on the relative positions of the satellites in the CCD matrix.

The astrometric details of the method which was used for many extragalactic radio sources are given in Assafin and Vieira Martins (1995).

In order to present an example we give the results of the application of the method for 7 observations of the system Triton-Nereid. The observations were made in two nights and Triton and Nereid are near opposite edges of the CCD matrix (their distance was about $310''$).

The astrometric catalogue used was the Carlsberg Automatic Meridian Circle Catalogue-4 (CAMC-4) (1990). For the first step, the GSC correction was made with 23 CAMC-4 stars in a field $4° \times 4°$ with a third degree polynomial and the adjustment yielded $\sigma_x = 0''.22$, $\sigma_y = 0''.20$. For the step 2, the error in the center process were typically $0''.04$. The step 3 was done with 11 stars from a field $12' \times 12'$ with a first order plate model and the standard errors were $0''.11$ for $x$ and $0''.09$ for $y$.

The center of the CCD images (step 4) were reduced using the program ASTROL (Colas and Serrau,1993) and the errors were typically $0''.03$ for the two directions. The catalog for CCD stars (step 5) was calculated with a second order polynomial with 14 stars and the typical errors were $0''.11$ for $x$ and $y$. Finally, the O-C for the relative positions Triton-Nereid are $\bar{x} = 0''.06$ ($\sigma_x = 0''.03$) and $\bar{y} = -0''.01$ ($\sigma_y = 0''.09$) for 7 images taken in two nights. The theoretical positions of Triton and Nereid were calculated following Veiga et al. (1995).

## 4. Conclusion

We presented a method to obtain the reference system for isolated observations of faint satellites. It presents some advantages:

- large field plates are not required;
- it can be used for small CCD fields;
- as the method provides the equatorial coordinates of satellites, it works well to obtain positions of satellites far from the planets.

## Acknowledgements

This work was concluded while the authors (Roberto Vieira Martins and Carlos Henrique Veiga) were visiting scientists at Bureau des Longitudes. This work was partially supported by CNPq-Brazil.

## References

Assafin, M., Vieira Martins, R.: 1995, in preparation.

*Carlsberg Meridian Catalogue* No.4, 1990, Copenhagen University Observatory, Royal Greenwich Observatory and Real Instituto y Observatório de la Armada en San Fernando.

Colas, F., Serrau, M.: 1993, *ASTROL et INTERPOL*, version 3.10, Edition du Bureau des Longitudes. Paris.

Russel, J.L., Lasker, B.M, Macleau, B.J., Sturch, C.R., Jenkner, H.: 1990, *Astron. J.* **99** 6, 2059.

Veiga C.H., Vieira Martins, R., Veillet C., Lazzaro D.: 1987, *Astron. Astrophys. Suppl. Ser.* **70**, 325.

Veiga, C.H., Vieira Martins, R.: 1994, *Astron. Astrophys. Suppl. Ser.*,**107**, 551.

Veiga, C.H., Vieira Martins, R.: 1995, *Astron. Astrophys. Suppl. Ser.* **111**, 387.

Veiga, C.H., Vieira Martins, R., Le Guyader, Cl., Assafin, M.: 1995. *Astron. Astrophys. Supp. Ser.* in press.