Astrometry of the Neptune-Triton System

Altair Ramos Gomes Júnior

April 27, 2016

Introduction

In this report I present the preliminary results of the astrometric reductions of the images from the Observatório do Pico dos Dias (OPD) in Brazil. The aim is to obtain precise positions for the Neptune - Triton system. The telescopes used was the Perkin-Elmer (160) with a diameter of 1.6m, the Boller & Chivens (IAG) with a diameter of 0.6m, and the Zeiss telescope with a diameter of 0.6m.

The observations were carried out since 1992 when a CCD big enough was installed in the OPD. The planet and satellite have been constantly observed, and still are, by our group. There were many CCDs (IKON, IXON, CCD101, CCD106, ...) and many filters (V, R, I, No Filter, ...) utilized.

In Table 1 it is summarized the final number of images for Neptune and Triton for the 3 telescopes. It is also shown the number of positions where Neptune and Triton were identified automatically in the same image.

Table 1: Number of positions by object by telescope

Telescope	Neptune	Triton	Matches
160	610	1154	547
IAG	2381	2659	1888
Zeiss	258	345	222
Total	3249	4158	2657

Number of positions identified of Neptune and Triton by telescope. In parentheses the number of nights where the observations are distributed. Matches: Number of positions where Neptune and Triton were identified automatically in the same image.

There were a total of 9942 images from June 1992 to September 2015. Many of the oldest images had no coordinates in header or they were wrong. Sometimes the filter was missing. Many nights had two exposure sets. The first one with low exposure time so Neptune were not saturated, but there were few reference stars in the field. The second one with higher exposure time so Triton were brighter and had more reference stars the the previous exposure, but the image of Neptune were saturated.

Fig. 1 shows the distribution of positions identified for Neptune and Triton over the years.

Reduction

The images were reduced using PRAIA, developed by Marcelo Assafin. To avoid the missing or wrong coordinates I used the coordinates of the ephemeris as input. This way PRAIA could identify reference stars in the images. The reference catalogue used was UCAC4. The ephemeris used to identify Neptune and Triton in the images was DE430+NEP081. The positions where the image of Neptune were saturated was removed of the results.

We applied the digital coronagraphy technique to test if the scattered light of Neptune would influence in the Triton's photocenter. No influence was identified in the 1 mas range.

From the offsets in the sense "position minus ephemeris" identified I made statistics night by night to eliminate discrepant positions with a sigma-clip procedure where offsets (modulus) larger than 80 mas or 2-sigma discrepant from the mean offset were removed.

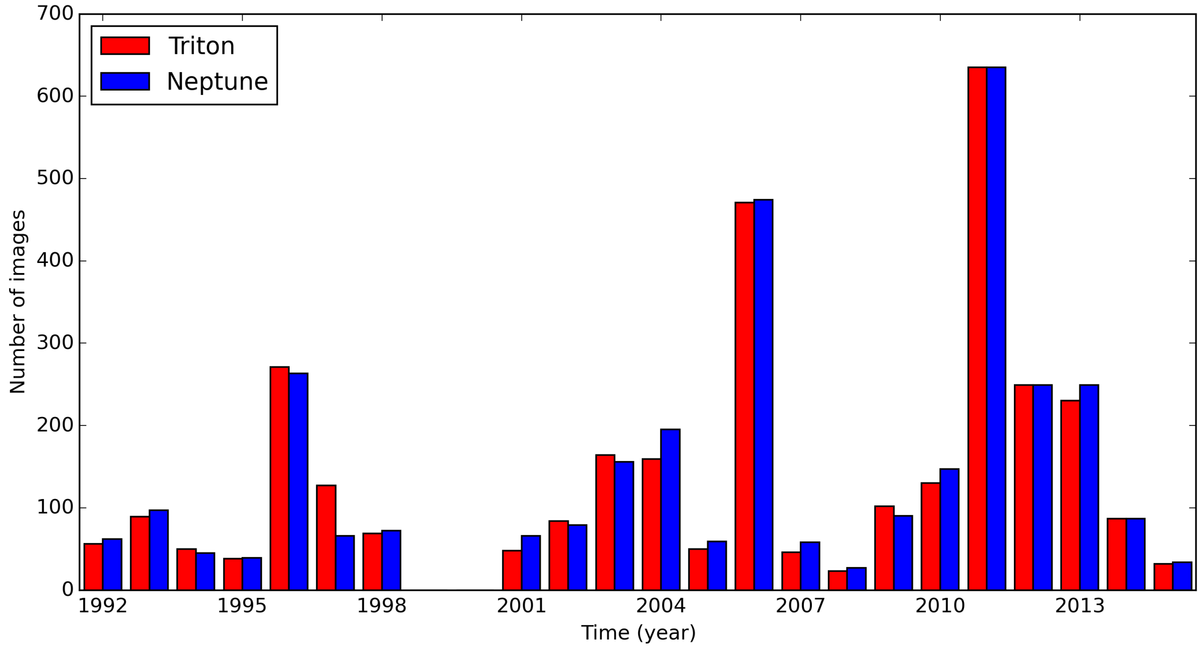

Figure 1: Distribution of positions for Neptune and Triton by year

We also tested two other process of reduction in the nights with two different exposure sets. The first one is the uniform reduction where only stars presented in all fields were used to represent the reference system. The second one is the global reduction where all the stars presented in all fields are used within a unique least-square procedure to obtain the reference system. With this, four situations were considered.

1. The standard procedure of astrometric reduction.

2. The uniform reduction of the fields.

3. The global reduction over the identified stars in the procedure 1.

4. The global reduction over the identified stars in the procedure 2.

For each situation we tested two sets of positions. The first one with the positions of Neptune and Triton within the same exposure set as explained above. The second one with the positions of Neptune in the smallest exposure set and the positions of Triton in the biggest exposure set (where Neptune were saturated).

For each night tested, we obtained the mean difference in the offsets of Triton-Neptune for the 4 situations and the 2 sets of positions. The dispersion of the 4 situations for the set where Neptune and Triton have the same exposure is in majority smaller than the set where they have different exposures.

Figs 2 e 4 show the offsets of Neptune and Triton, respectively, in RA e DEC for all the positions not eliminated in the previous procedure. Figs 3 e 5 show the mean offsets of each night and respective discrepancy (error bars).

Fig 6 shows the difference between the relative observed positions and the relative ephemeris positions of Triton and Neptune in the sense Triton - Neptune where they were identified in the same frame and not eliminated by the sigma-clip procedure.

Fig 7 shows the difference in the mean offsets night by night for all matched nights and not eliminated by the sigma-clip procedure in the sense Triton - Neptune. The dispersions (error bars) is the mean value of the dispersion in the night for each satellite.

We plan to do the following:

- Separate images by filter.
- Study the effects of chromatic refraction in the offsets (difference of offsets Triton - Neptune). I already have nights separated with observations distributed over six hours during the night.
- It may be required the use of a specific PSF for Neptune due to its large size.
- Further refinements in the data may be needed as we further investigate these position sets.

Figures 8-10 summarizes the distribution of positions by filter obtained in the Perkin-Elmer , the Boller & Chivens and the Zeiss telescopes, respectively.

In Table 2 it is presented the mean errors in X and Y of the bidimensional Gaussian used to fit the PSF of the objects.

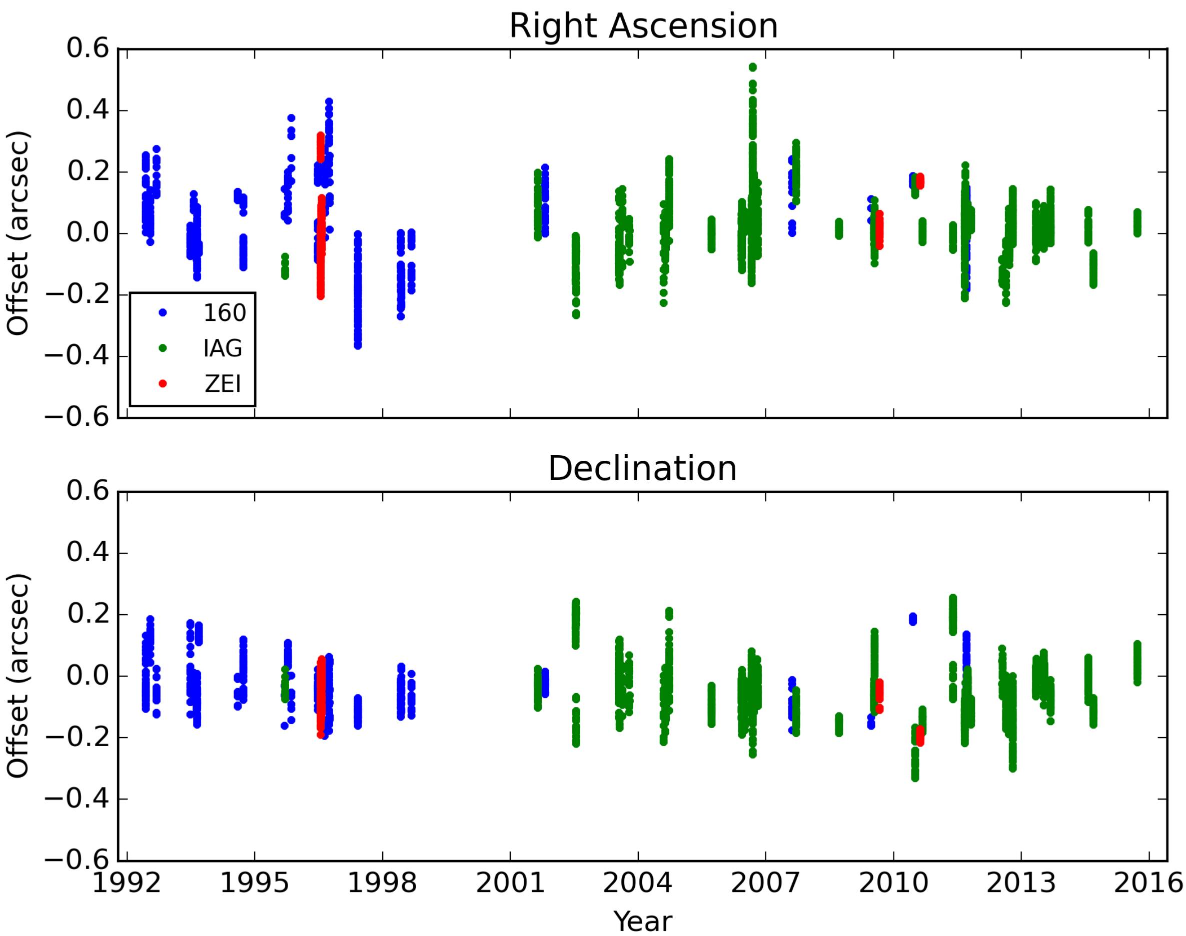

Figure 2: Neptune - All Offsets

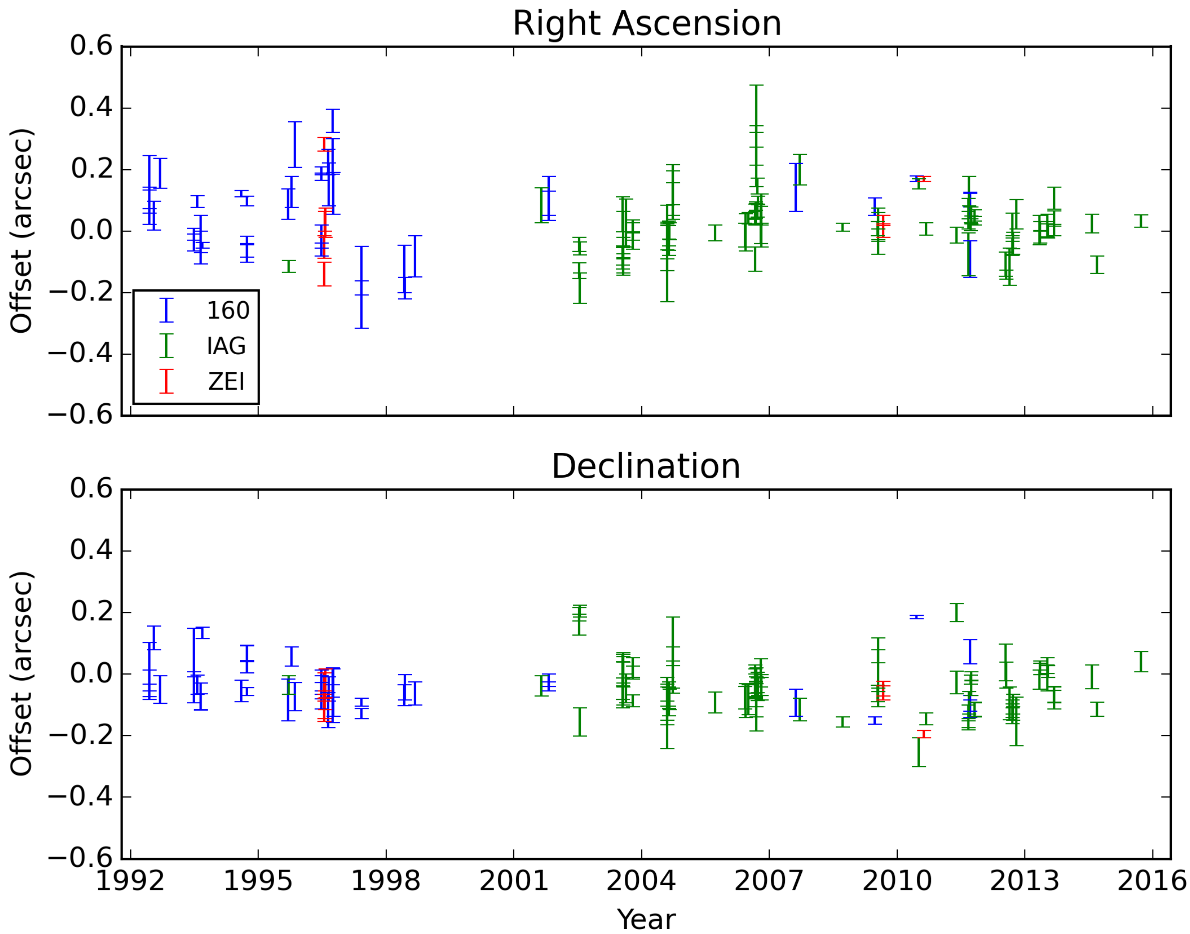

Figure 3: Neptune - Mean offsets by day

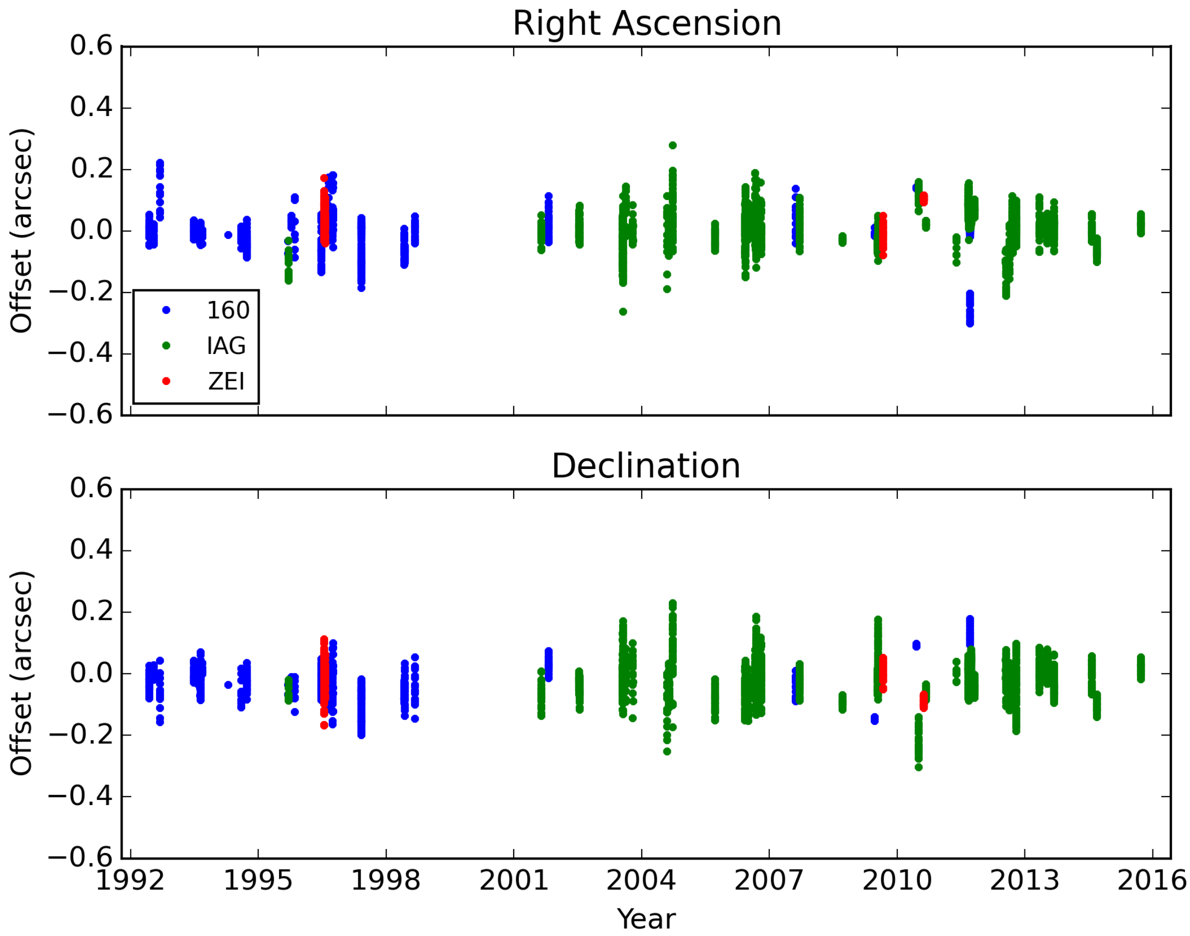

Figure 4: Triton - All Offsets

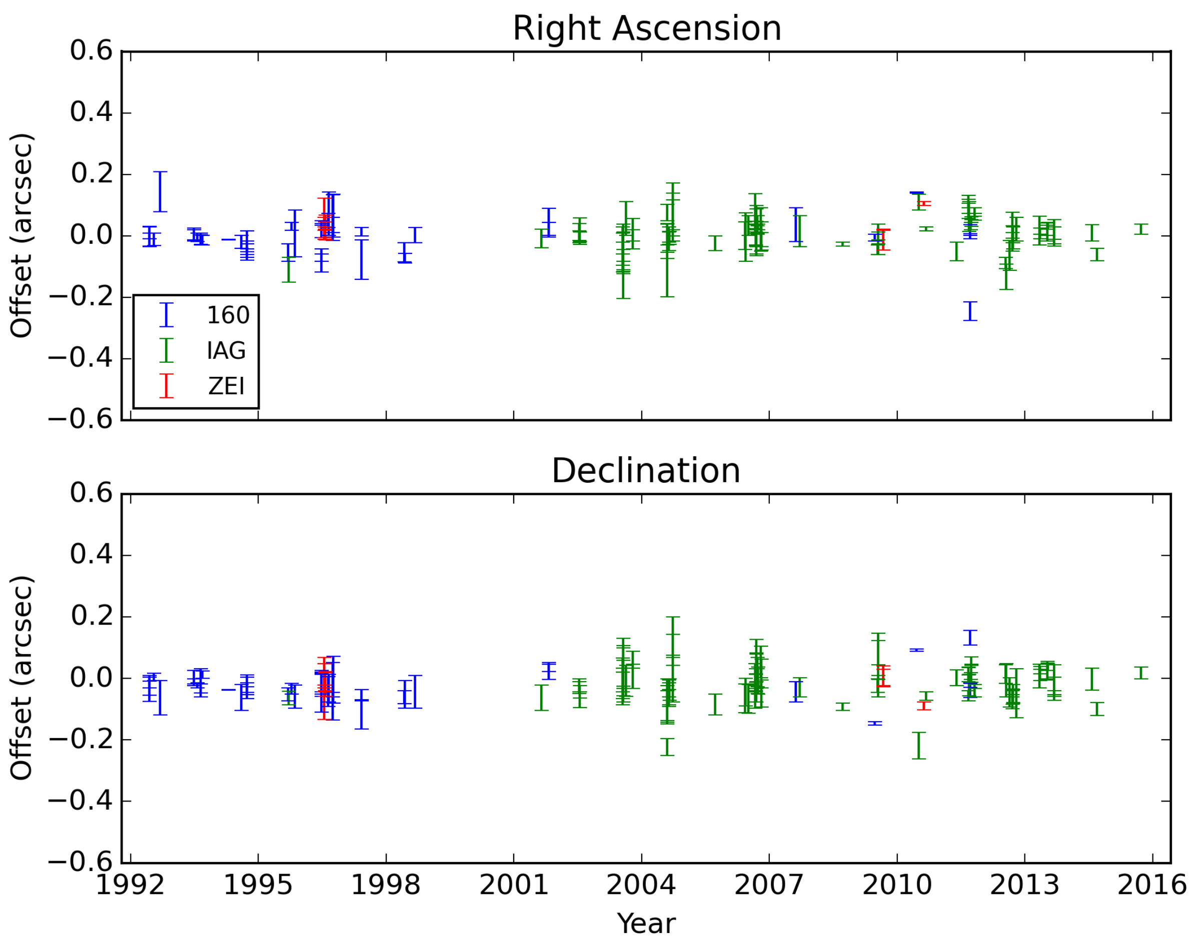

Figure 5: Triton - Mean offsets by day

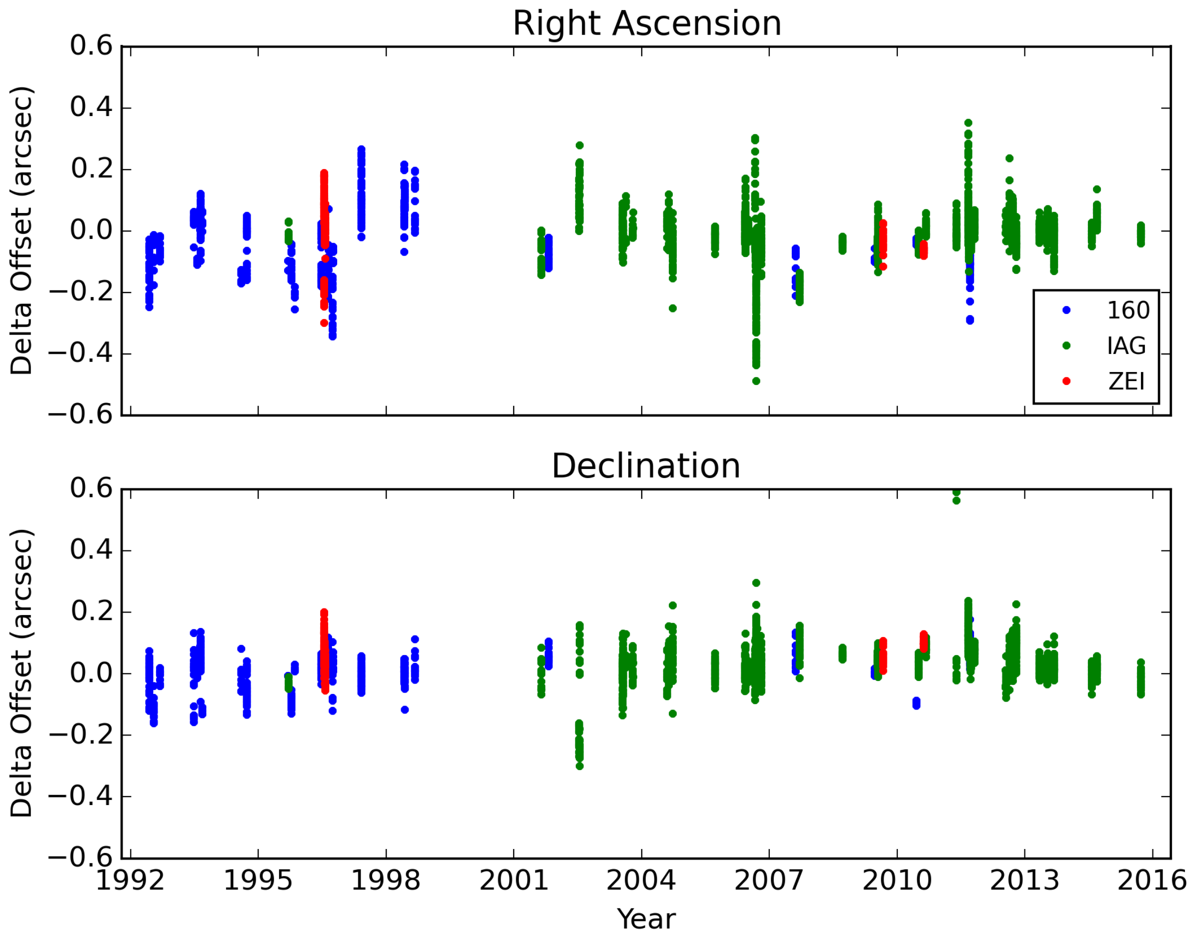

Figure 6: Difference between the offsets of Triton and Neptune - All data

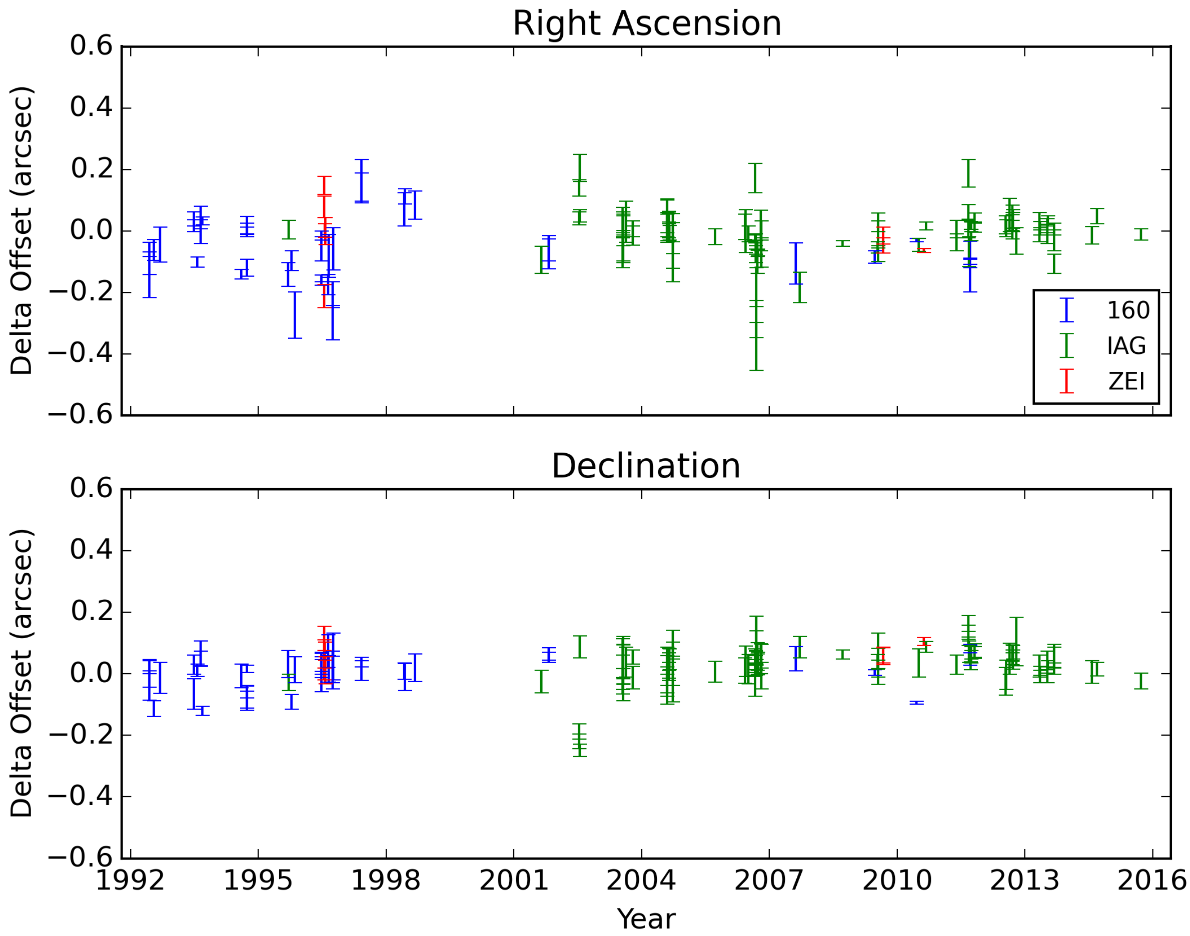

Figure 7: Difference between the offsets of Triton and Neptune - Mean offset by day

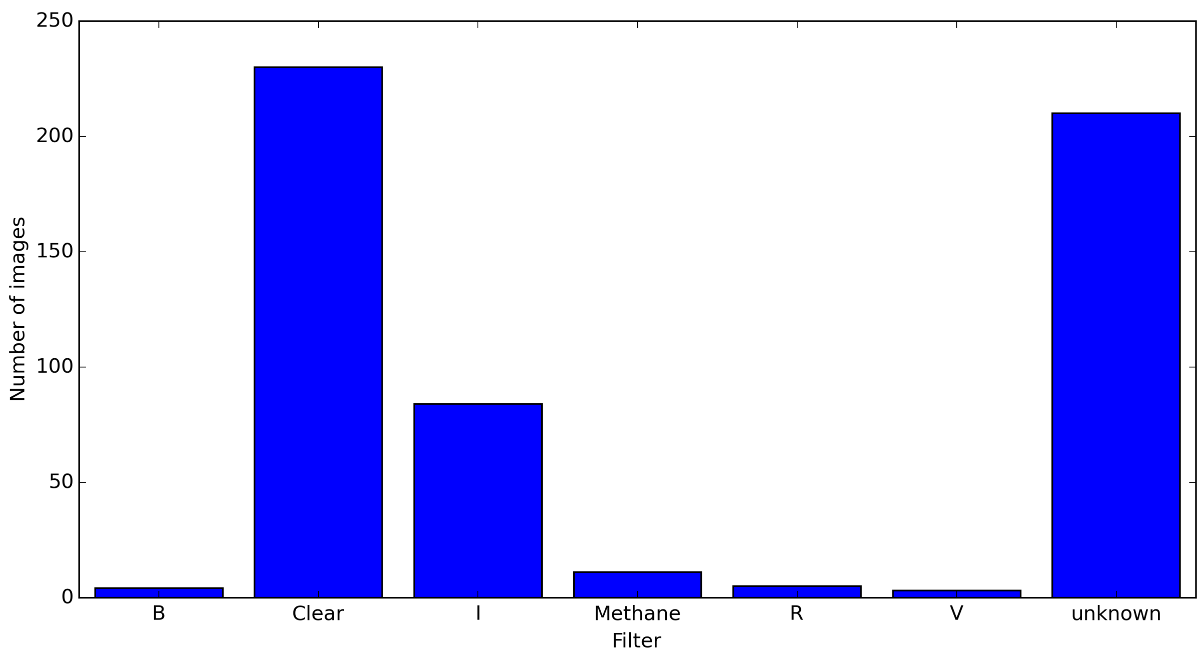

Figure 8: Distribution of positions by filter for the Perkin-Elmer telescope.

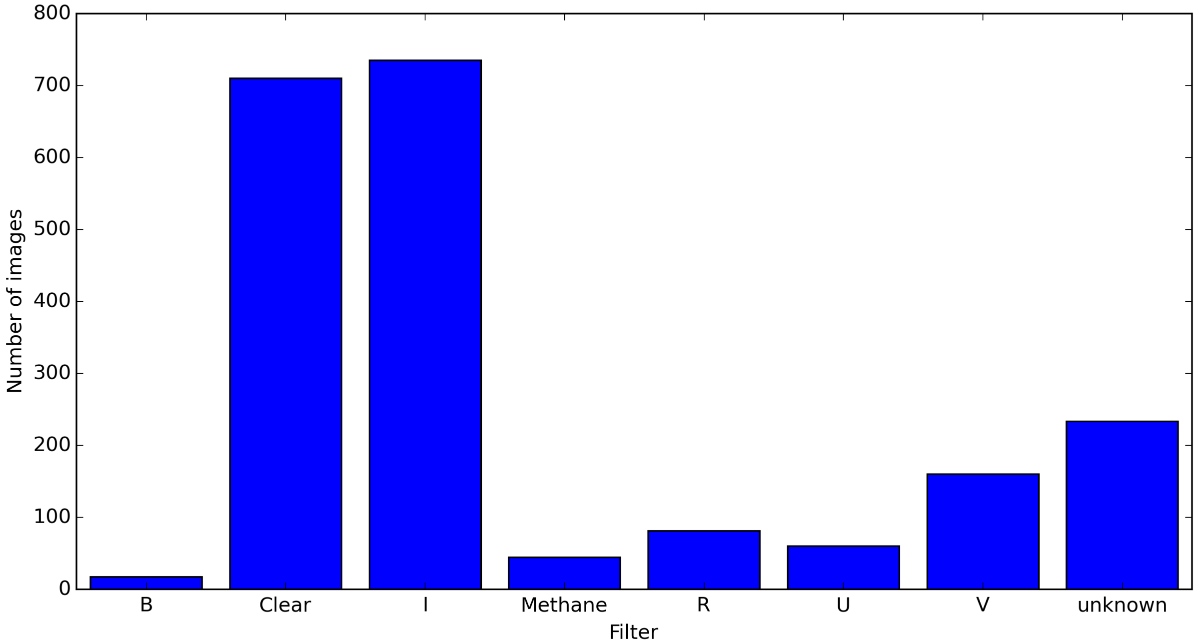

Figure 9: Distribution of positions by filter for the Boller & Chivens telescope.

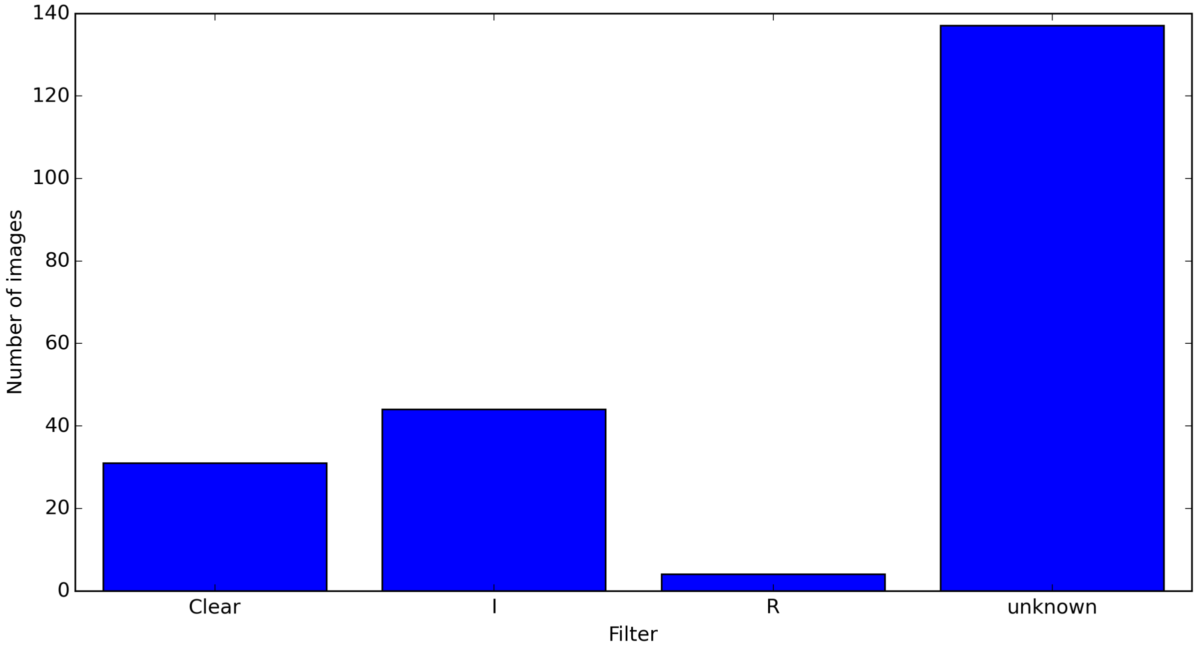

Figure 10: Distribution of positions by filter for the Zeiss telescope.

Table 2: Table of erros of the reduction. Gaussian error stands for the error in X and Y of the bidimensional Gaussian used to fit the PSF. Mean offset errors is the average dispersion of the positions of each night.

Telescope/Satellite	Gaussian error		Mean offet errors	
	X (mas)	Y (mas)	RA (mas)	DEC (mas)
160/Neptune	8	8	42	37
160/Triton	14	14	28	29
IAG/Neptune	9	9	36	38
IAG/Triton	20	20	34	37
Zeiss/Neptune	9	9	28	32
Zeiss/Triton	27	27	28	35