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INVESTIGATION OF THE 1-M TELESCOPE GUIDING AT THE OAN-TONANTZINTLA

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RESUMEN

Se presentan los resultados de investigaciones experimentales del guiado del telescopio 1-m en el Observatorio Astronómico Nacional (OAN), Tonantzintla, México. Las observaciones se llevaron a cabo con el instrumento Dragon, el cual permite grabar conjuntos de imágenes de corta exposición. El análisis de los datos obtenidos ha mostrado que hay 3 tipos de errores de guiado en el telescopio: tendencia lineal, vibraciones del telescopio y saltos de telescopio.

ABSTRACT

The results of experimental investigations of the 1-m telescope guiding at the Observatorio Astronómico Nacional (OAN), Tonantzintla, México are presented. The observations have been carried out with the Dragon instrument which allows to record sets of short-exposure images. The analysis of the data obtained has shown that there are three types of telescope guiding errors: linear trend, telescope vibrations, and telescope jumps.

Key Words: **INSTRUMENTATION: MISCELLANEOUS — TELESCOPES**

1. INTRODUCTION

There are several factors, both natural and technical ones, which affect the quality of images obtained from astronomical observations: the atmospheric turbulence, the telescope mirror quality, the errors of the telescope guiding, etc. So, if one wants to reach the best image quality, one needs to minimize the influence of the above factors. However, before proceeding with improvements it is necessary to investigate how strongly each factor degrades the image.

In this paper we describe the method used to investigate telescope guiding and the results obtained for the 1-m telescope at the OAN - Tonantzintla, México, on the nights of February 15 and 16, 2006.

2. METHOD, EXPERIMENTAL SETUP AND DATA REDUCTION

Let us assume that we have a set of short-exposure images $I(x, y, t)$, where x, y stand for the spatial coordinates, and t denotes the temporal one. Then, let us consider the time-dependent image centroids $x_c(t)$ and $y_c(t)$ defined as

$$x_c(t) = \int xI(x,y,t)dxdy / \int I(x,y,t)dxdy \quad ,$$

$$y_c(t) = \int yI(x,y,t)dxdy / \int I(x,y,t)dxdy \quad . \quad (1)$$

Since the telescope guiding moves the observed images as a whole, a proper statistical analysis of the movements of the image centroids can be used for the estimation of the guiding quality. So, if some instrument is able to record sets of short-exposure images, its output can be used for such an investigation.

In our observations we have used the Dragon instrument (Voitsekhovich et al. 2005) which was designed for different types of experimental investigations related to high-resolution astronomy. The Dragon instrument allows various experimental configurations. The one that was implemented in our observations is as follows.

The light from a star is collected by the telescope, is amplified by the image intensifier, and the set of focal images is grabbed by the CCD-camera. The objective is used to fit the image scale in the focal plane to the pixel size of the detector, which allows to increase the accuracy of spatial measurements. During the experiment, the digitalized images are stored by the frame accumulator. The frame recording is performed with a speed of 25 frames/sec. After the

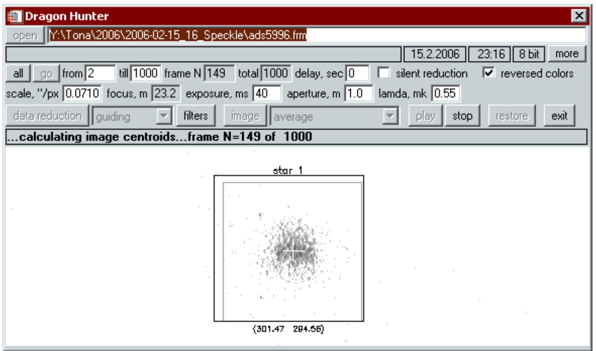

Fig. 1. Dragon Hunter data reduction: program window.

experiment the digitalized images are copied to hard disk in a PC.

A special program named Dragon Hunter has been written to perform the fast reduction of data obtained with the Dragon instrument. Dragon Hunter is a multi-purpose, easy-to-use interactive program allowing for the input of Dragon data, different types of data processing, data fitting, interactive image analysis, statistical, spectral and correlation analysis, etc.

The Dragon Hunter data reduction program window is shown in Figure 1.

One of the functions of the Dragon Hunter program is the reduction and analysis of the data related to the telescope guiding. The whole procedure consists of the following main steps.

1. As a first step the program calculates the spatial scaling of the observational data. The calibration procedure assumes that there is a set of images for the stars with well-known separations. In our observations we have recorded the Orion Trapezium which has four bright stars. The program averages the set of images over time, cuts the noise, calculates the image centroids and the six separations in pixels. Comparing the separations in pixels to the known ones in arcsec, the program calculates the spatial scaling in arcsec per pixel. Because we have six separations, the scaling error is also evaluated (in our data this error does not exceed 1%).

2. The program inputs a file with the observational data chosen by the researcher. As soon as the data are loaded, the researcher can estimate the entire set visually by pushing the "play" button. Such a visual estimation is convenient, for instance, for finding telescope jumps.

3. Next, the program calculates image centroids for a chosen data set. Figure 1 shows a screen shot of the program window when the image centroid calculation is in process. The calculated image centroids are recorded for future analysis.

4. As soon as the calculation and recording of image centroids is finished, the program shows their temporal dependencies in graphs, and makes a chosen type of analysis. The following types of analysis are available.

- Linear approximations (to estimate the linear trend of the telescope guiding).
- Polynomial filtering.
- Correlation analysis.
- Spectral analysis.
- Peaks analysis (to get the frequencies and amplitudes of the spectral peaks related to the telescope vibrations).

3. OBSERVATIONS AND RESULTS

The observations were performed at the Tonantzintla observatory (Latitude = $19°01'58''$ (N), Longitude = $98°18'50''$ (W), Altitude=2147m) at the 1-m telescope (F/15, polar mounting).

During our observations the data for 15 stars were recorded. Each data set consists of 1000 short-exposure (40 ms) frames with a scaling equal to 0.07 arcsec/pixel. Because only bright stars were chosen, the images were recorded in the analog mode that allows to neglect the influence of the photon noise on image centroids. Under the above conditions, the main error of image centroid measurements is determined by the ratio of the image size to the pixel size. Since in our experiments this ratio was large enough (≈10-15), we can estimate the accuracy of image centroid measurements to be of order of 0.01 arcsec (Thomas et al. 2006).

The analysis of the data has allowed to distinguish the three types of guiding errors: linear trend, telescope vibrations and jumps. In what follows we consider each type of these errors in detail.

3.1. *Linear trend*

Figure 2 presents a typical example of telescope linear trend (for the object ADS 5996; the results for this object are plotted in all the following figures). Figure 2 shows the temporal dependencies of image centroids and their linear approximations along the x (upper graph) and the y (bottom graph) axes. The speed of the linear trend along the y-axis is higher because in our observations the guiding direction was practically along the y-axis.

In what follows we calculate the magnitude of the linear trend as $(trend_x^2 + trend_y^2)^{1/2}$ which corresponds to the speed of the linear trend along the guiding direction.

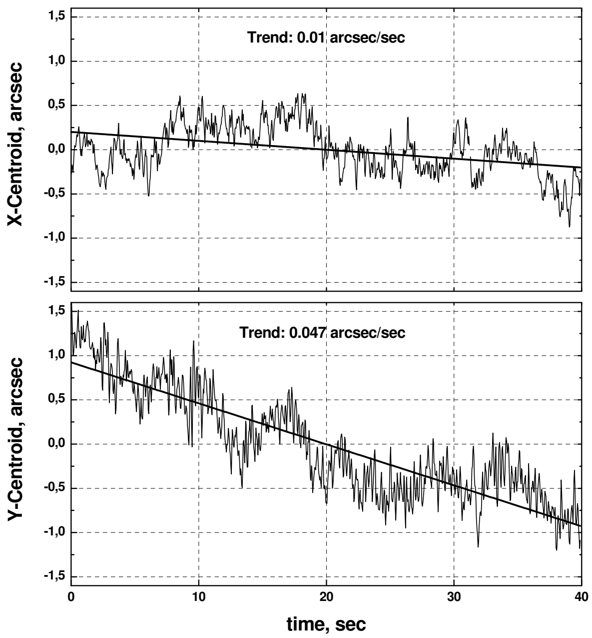

Fig. 2. Linear trend: data and their linear approximations.

TABLE 1

LINEAR TREND: ALL OBJECTS

Object	Date	Time	Trend arcsecsec	Zenith Angle deg
M42	15.02.2006	22:09	0.029	35
BD23	15.02.2006	22:22	0.027	20
ADS4728	15.02.2006	22:34	0.033	24
ADS4841	15.02.2006	22:48	0.017	25
ADS5871	15.02.2006	23:05	0.031	17
ADS5996	15.02.2006	23:16	0.047	25
ADS7152	15.02.2006	23:35	0.021	17
ADS7187	16.02.2006	00:21	0.028	7
ADS7186	16.02.2006	00:35	0.016	26
ADS7674	16.02.2006	00:52	0.053	17
BD11	16.02.2006	01:12	0.023	33
ADS8086	16.02.2006	01:41	0.046	38
ADS7769	16.02.2006	02:03	0.021	20
ADS8094	16.02.2006	02:17	0.034	4
ADS7780	16.02.2006	02:44	0.035	26

Table 1 shows the speed of the linear trend for all our data.

Analyzing the data presented in Table 1, one can conclude the following about the minimum, maximum and mean magnitudes of the linear trend: minimum: $0.016''/\text{sec}$, maximum: $0.053''/\text{sec}$, mean: $0.031''/\text{sec}$.

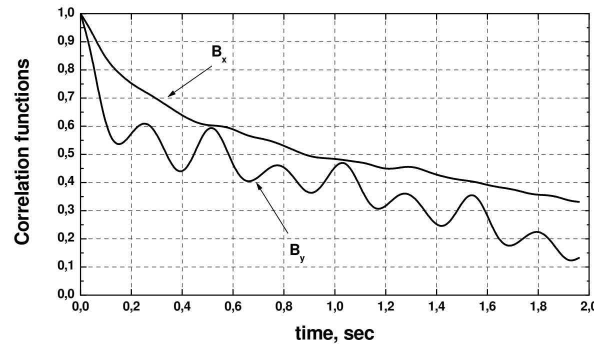

Fig. 3. Telescope vibrations (autocorrelation functions).

3.2. *Telescope vibrations*

The second type of guiding errors which we have found in our data are telescope vibrations. The effect of telescope vibrations has been noticed before on different telescopes (Voitsekhovich 1988; Balega et al. 1990; Altarac et al. 2001).

In order to estimate numerically the magnitude of the effect we have extracted first the linear trend from our data and then we have applied correlation and spectral analyses.

The autocorrelation functions B_x and B_y of the image centroids illustrating telescope vibrations are shown in Figure 3.

The autocorrelation functions shown in Figure 3 are affected by two factors: the atmospheric turbulence (random component), and the telescope vibrations (regular harmonics). One can notice the effect of telescope vibrations on the function B_y, where two regular frequencies can be distinguished. To estimate the frequencies and the amplitudes of regular harmonics we have performed spectral analysis of our data (an example is shown in Figure 4).

Analyzing the Y-spectrum in Figure 4, one can see two narrow peaks located at the frequencies 2 and 4 Hz. (note that in all our data consisting of the 15 sets the peaks appear at the same frequencies). The amplitude of these peaks allows us to estimate the magnitude of the telescope vibrations. In what follows we define the magnitude of telescope vibrations as $2(amplitude_x^2 + amplitude_y^2)^{1/2}$.

Table 2 shows the magnitude of the telescope vibrations for all our data.

Analyzing Table 2, one can get the minimum, maximum and mean magnitudes of the telescope vibrations, which are shown in Table 3.

3.3. *Jumps*

The third type of the guiding errors that we noticed during our observations were telescope jumps.

TABLE 2

TELESCOPE VIBRATIONS: ALL OBJECTS

Object	Date	Time	Vibrations (2 Hz) arcsec	Vibrations (4 Hz) arcsec	Zenith angle deg
M42	15.02.2006	22:09	0.15	0.19	35
BD23	15.02.2006	22:22	0.11	0.17	20
ADS4728	15.02.2006	22:34	0.11	0.09	24
ADS4841	15.02.2006	22:48	0.10	0.16	25
ADS5871	15.02.2006	23:05	0.13	0.20	17
ADS5996	15.02.2006	23:16	0.12	0.22	25
ADS7152	15.02.2006	23:35	0.10	0.34	17
ADS7187	16.02.2006	00:21	0.09	0.45	7
ADS7186	16.02.2006	00:35	0.07	0.18	26
ADS7674	16.02.2006	00:52	0.08	0.44	17
BD11	16.02.2006	01:12	0.10	0.28	33
ADS8086	16.02.2006	01:41	0.10	0.30	38
ADS7769	16.02.2006	02:03	0.14	0.15	20
ADS8094	16.02.2006	02:17	0.08	0.38	4
ADS7780	16.02.2006	02:44	0.11	0.21	26

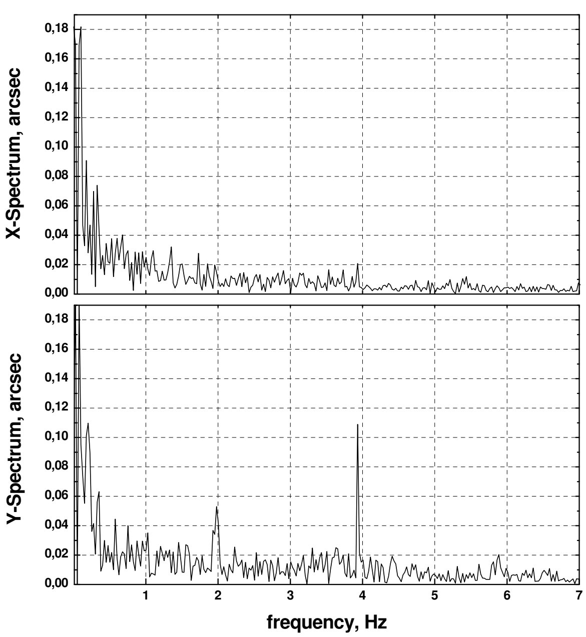

Fig. 4. Telescope vibrations (spectra).

These jumps appear as fast image movements with a magnitude of up to ten arcsec. The effect is rather odd; we noticed it visually only a few times, but the corresponding data were recorded only once. The data illustrating the telescope jumps are plotted in Figure 5.

TABLE 3

MINIMUM, MAXIMUM AND MEAN MAGNITUDES OF TELESCOPE VIBRATIONS

Frecuency Hz	Min arcsec	Max arcsec	Mean arcsec
2	0.07	0.15	0.11
4	0.09	0.45	0.25

4. CONCLUSIONS

In a previous paper (Orlov et al. 2007) we have shown that the Dragon instrument can successfully be used for speckle-interferometry of binary stars. In this paper we have demonstrated another type of usage: the investigation of telescope guiding. In order to simplify and accelerate the data reduction, a special program named Dragon Hunter has been written. Because the program works interactively, it is easy to use and allows to rapidly perform the data reduction and analyses.

Using the observational data obtained with the Dragon instrument and the above program, the OAN - Tonantzintla 1-m telescope guiding has been investigated. The analysis of the results obtained has allowed us to distinguish three types of guiding errors: linear trend, telescope vibrations and telescope jumps. The mean magnitudes of the linear trend and

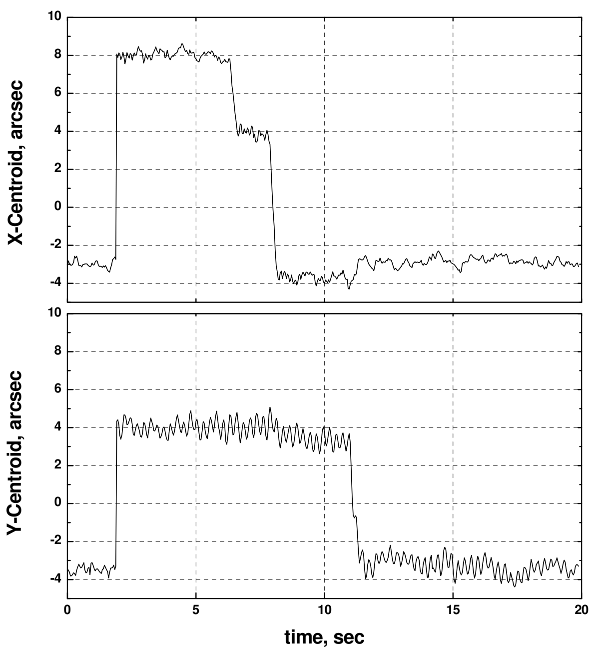

Fig. 5. Telescope jumps.

telescope vibrations calculated by averaging over 15 observations are as follows:

- Linear trend: 0.031 arcsec/sec
- Telescope vibrations (at 2 Hz): 0.11 arcsec
- Telescope vibrations (at 4 Hz): 0.25 arcsec

The telescope jumps occur quite seldom; however, their magnitude may reach up to ten arcsec.

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