The new control system of the 2-meter telescope of the Rozhen National Astronomical Observatory: Status in November 2009

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Abstract. This paper gives several results from tests obtained with the 2-meter telescope of the National astronomical observatory - Rozhen, in November 2009. The aims of the tests are to show the quality of tracking of the 2-m telescope with the new control system, to derive quantitative parameters, describing some errors of the tracking and to discuss the reasons for these errors by relating them to details in the mechanical design of the sensor coupling to the telescope's hour axis.

Key words: telescope control system, 2-meter RCC, NAO Rozhen

Новата система за управление на 2-метровия телескоп на Националната астрономическа обсерватория - Рожен: Статус през ноември 2009 г.

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В тази статия са представени резултати от тестове на 2-метровия телескоп на Националната астрономическа обсерватория - Рожен получени през ноември 2009 г. Целите на тестовете са да се покаже качеството на водене на 2-метровия телескоп с новата система за управление, да се получат количествени оценки на параметри, описващи някои грешки на воденето и да се дискутират причините за тези грешки, свързвайки ги с детайли на механичния дизайн на куплирането на датчиците към часовата ос на телескопа.

Introduction

On March 26, 2009, a contract was signed between the Institute of Astronomy (www.astro.bas.bg) and the company Projectsoft (www.projectsoft.cz) for the design and manufacturing of a new control system for the 2-meter telescope of the Rozhen National Astronomical observatory. The new system will fully replace the 30 years old telescope electronics and will guarantee for more effective conduction of the astronomical observations. After several months preparation of the new system in the labs and workshops of Projectsoft, the mounting of the new system started on site begin of August, 2009. By the end of August the telescope was already operational with the new system. The first results showed an excellent improvement of the telescope pointing accuracy, after application of the TPOINT model (http://www.nao-rozhen.org/news/fr9_en.htm).

Further tests showed periodic fluctuations of the telescope during tracking. The oscillations had a characteristic period of about 103 seconds and were related to the mounting of the incremental sensor on a second axis, coupled to the first one by an additional gear, having 105 teeth. In order to remove the observed periodic terms, the mounting of the incremental sensor at the hour axis was modified. Now, the sensor is mounted at the first axis, which is directly connected to the large gear of the hour axis. The connection is realized by a 39 teeth gear which is clutched to the 312 teeth gear of the hour axis. Here we describe the results of tests of the telescope tracking after the remake of the sensor mounting.

1 Methods of testing

Two different approaches were applied to test the tracking quality of the telescope. First, analysis of star tracks with the telescope moving in declination. For these tests the telescope was forced to move in delination with a prescribed user speed. Thus, the distance along the star track (along declination) is a measure for the time, elapsed after start of an exposure. This means that the measuring of displacements perpendicular to the star track at different positions along the track is equivalent to measuring the variations along the hour angle as a function of time. The second approach is based on analysis of long sequences of short exposure images, without user speeds. The positions of several stars in the field of view are measured and their displacements from one image to the next are stored. The displacements are fitted with polynomials to determine the parameters of the low frequency variations. The parameters describing the high frequency errors are found by Fourier analysis of the residuals = displacements - (low frequency trends).

2 Tracks of stars obtained with user speed

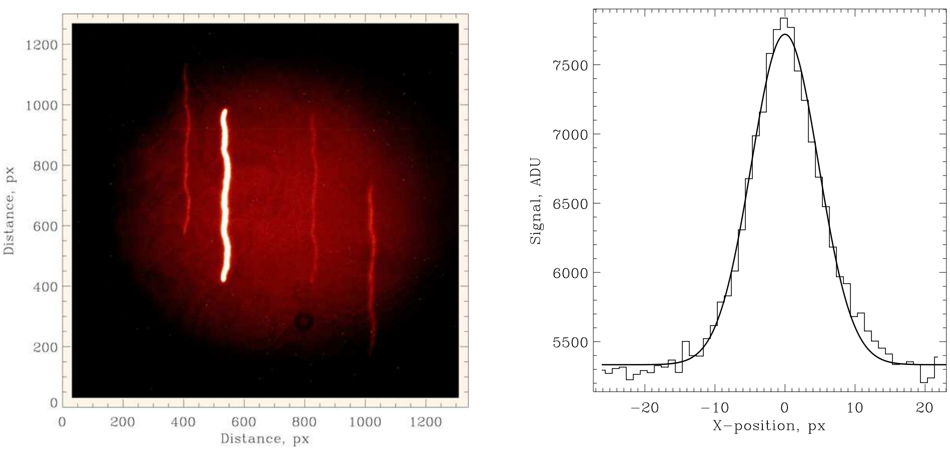

Fig. 1. Left: The result of a 600 sec exposure, with user speed of 0.25”/sec only in declination. Right: Slice taken perpendicular to the star track, i.e. along the X-direction.

Figure 1 shows an image exposed 600 sec with user speed 0.25 "/sec, only in declination. The brightest worm which is located around the center was extracted and analyzed. Profiles perpendicular to the star track are considered. One example profile is shown in the right panel of fig. 1. Dashed line is the extracted profile, the full thick line is a fit to the measured data with a gaussian function. The full width of half maximum of the profile is about 10 pixel which corresponds to a seeing of about 2.5 arcsec.

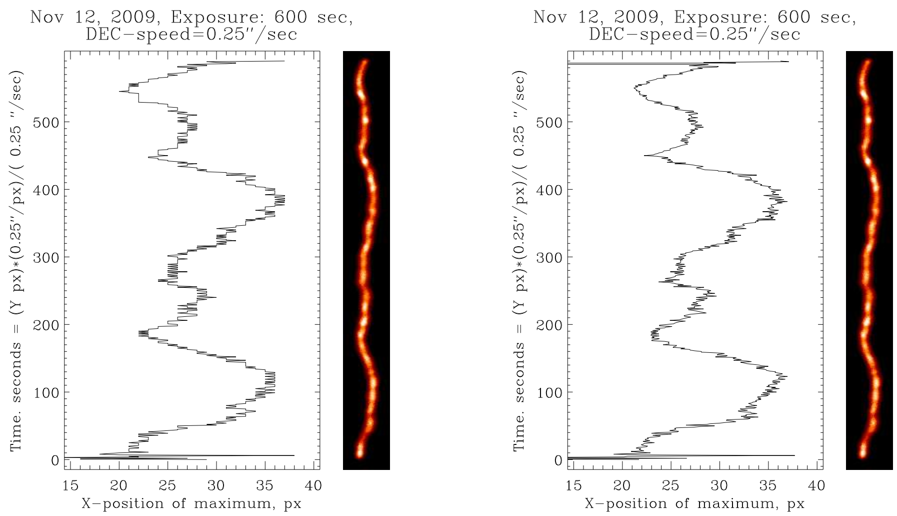

Fig. 2. Left: Changing positions of the maxima in profiles taken perpendicular to the star track. Right: The same as in the left panel, but the positions of the maxima are found with sub-pixel accuracy by the Gaussian fit to the profile.

In all profiles, extracted at consecutive Y-positions, the positions of the maxima were found, stored, and compared. Figure 2 shows how the found X-coordinates of these maxima change with time. The time starts with the start of the exposure (begin of the star track) and increases along the Y-axis. The exposure is 600 sec. In the left panel the maxima are given at the pixel where they appear. In the right panel the position of the maximum is given with subpixel accuracy, as obtained from the gaussian fit of the profile. The only difference between the left and right panel is the slightly decrease of the low scale noise (pixel-to-pixel) in the right panel, compared to the left one, caused by the more precise derivation of the position of the maxima. In both figures minima/maxima appear with an amplitude ¿ 10 pixels and repetition in intervals of 250 - 300 sec. In order to get more reliable and quantitative information about these fluctuations the method described in the next section was applied.

3 Long exposure series: displacements and Fourier analysis

The images considered so far give information on the telescope behavior over a time interval limited to 600 seconds. To get deeper insight into the situation over longer time ranges, we obtained 1000 short exposure (10 sec) images in one observation run on Nov. 12, 2009. No user speed were used and the telescope was not touched during the time of the experiment (about 4 hours), excepting corrections in several cases when the stars would leave the field of view due to a permanent drift in one direction. For the analysis the positions of a set of stars were measured in every image and the differences of the positions in every pair of subsequent images were derived. The measured X-coordinates (the X-axis is aligned to HA) are shown in the upper panel of the left side in Figure 3. The middle panel in the same figure shows the mean trend and in the lower panel the mean trend is removed from the data. The interval between the two peaks to the left and to the right is 3 hours, equal to one full rotation of the gear with 39 teeth.

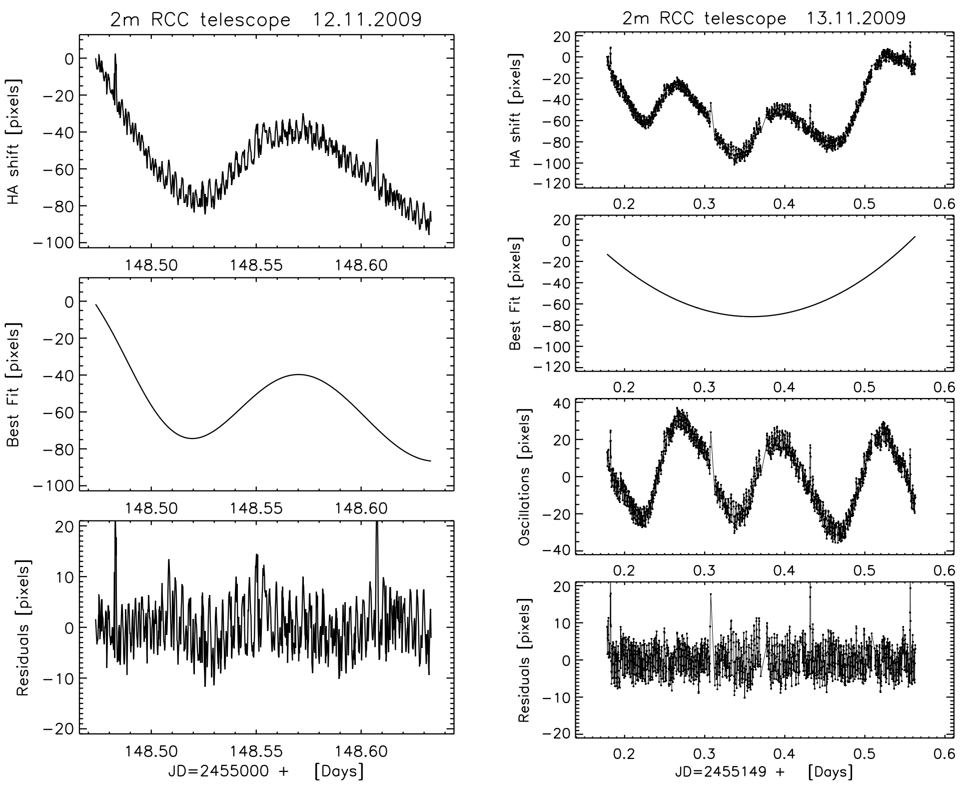

Fig. 3. Measured displacements of stars in direction along the hour angle in a series of images. The differences of X-coordinates measured in pairs of two consecutive images are shown. Left: Measurements obtained on Nov. 12. Right: Measurements from Nov 13.

A longer sequence of images was obtained during the night starting on Nov. 13. The whole night only one field was observed, again with short exposures. The measured positions (X-cord. = HA) of that one star are shown in the upper panel, right side of fig. 3. The total duration of the sequence is more than 9 hours. The mean panel is a fit to the large scale changes. In the third panel the large scale drift is removed. The most prominent feature in the residuals is the periodic change of the star position with an amplitude of almost 70 pixel and a period of about 3 hours. Inside of the 3 hours period, the star oscillates around its current position with a higher frequency. The lowest panel of the right part of fig 3 shows the residuals of the data after removing the 3 hour periodicity.

Even after removal of the large scale trend and of the 3 hour periodicity, the residual data are exhibiting well expressed periodic features. To derive the frequencies of these oscillations Fourier analysis of the sequences was applied. The spectral power distributions of the Fourier transform is shown in figure 4, left and right for the sequences obtained on Nov 12 and Nov 13, respectively. The frequency has dimension Cycles/(24 hours).

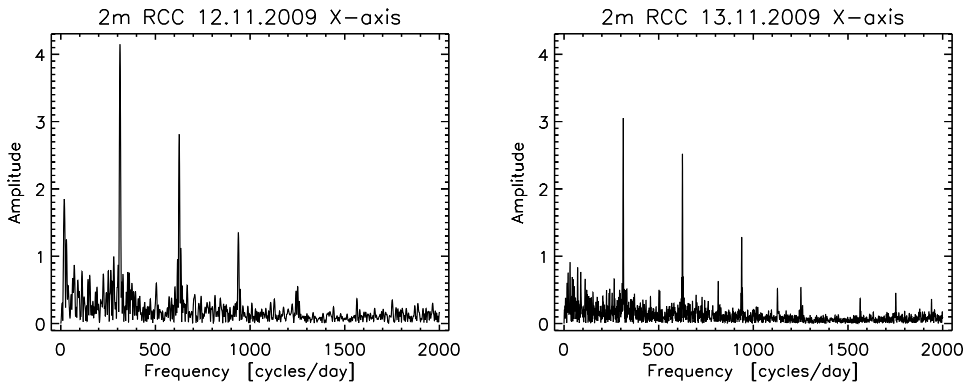

Fig. 4. Spectral power distribution of the Fourier transform of the residuals after removal of the low frequency displacements. Left: Nov 12, right: Nov 13

The most prominent frequency in both sequences is close to 312 cycles/day, which is equivalent to the number of teeth on the large hour axis gear. Recalculating this in seconds yields 276.221 sec, very close to the time of transition from one tooth to the next on the 39 teeth gear. Of course, this is not surprising, as both gears, the large one with 312 teeth and that with 39 teeth are mutually clutched.

Conclusion

After the remake of the gearbox the oscillations with period about 103 seconds disappeared. Now, several other oscillations can be identified, the strongest one having a period of 3 hours and an amplitude of about 70 px (=

approx. 18 arcsec, see fig. 3). During each particular 3 hour cycle the telescope makes oscillations with an amplitude > 10 px and with a higher frequency, corresponding to a period of 276.2 sec., which is practically equivalent to the transition time from one tooth to the next on the clutched gears. Additional fluctuations are also present, e.g. with amplitudes > 20 px. These oscillations are superimposed on a large scale trend which causes the observed object to be displaced over the field of view to a position about 80 px (= 20 arsec) away from the initial position in a time interval of about 4 hours (fig. 3, left part, middle panel).

Stabilization of the tracking quality of the 2-meter telescope will be achieved by several means. To remove the high frequency oscillations the sensors mounted in the drives at the hour and declination axis will be used during tracking. The middle frequency (with period 3 hours) and the low frequency errors can be accounted for by different terms in the TPOINT model. To find the corresponding coefficients the TPOINT model should be feed with sufficient number of measurements after the remake of the control system.

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