THE OPTICAL PARAMETERS OF THE 2-m TELESCOPE AND SEEING AT THE PEAK TERSKOL OBSERVATORY

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We present the Hartmann images to attestate the Cassegrain focus optics of the 2-m telescope of the Peak Terskol Observatory of the International Center for Astronomical and Medico-Ecological Research of the NASU/RAS. The Cassegrain focus optics is a classical Ritchey-Chretien system with compensated coma and spherical aberration. The astigmatism corrector compensates for the system field astigmatism. Star images formed by the system with the astigmatism corrector are characterized by $d_{0.8} = 1''.3$, which does not meet the present-day requirements. The constant coma followed by the spherical aberration are dominating. The astigmatism is the least distortion of the image. Eliminating the Zeidel aberrations gives $d_{0.8} = 0''.7$, which coincides with manufacturer attestation. An additional adjustment should be made to achieve this image quality. Local wavefront errors including triangular astigmatism are small, which testifies that the unloading and fastening of the mirrors are of a high quality.

1. PROBLEMS AND INVESTIGATION PROCEDURE

Investigation of the optics of the 2-m mirror telescope constructed by “Carl Zeiss Jena” (FRG) and installed on the Peak Terskol was performed in accordance with the plan of joint ventures between the Special Astrophysical Observatory (SAO) of the Russian Academy of Sciences and the International Center for Astronomical and Medico-Ecological Research (IC AMER) of the NAS of Ukraine. The problem of a complete testing of the 2-m telescope optics in the Cassegrain focus is divided into the following parts:

– agreement between the actual optical system and the calculated one;
– position of the best image plane and the image quality in this plane throughout the whole field;
– the quality of adjustment of the optical system and possibilities of its further improvement;
– the estimate of the quality of unloading and fastening of the mirrors.

Hartmann's method [11]–[13] was chosen as a quantitative technique for optical investigation of the 2-m telescope.

The investigation and the attestation of the optics of the IC AMER 2-m telescope were performed by the procedure [2]–[10] developed beforehand and based on the simultaneous reduction of two extrafocal photographic films (the Hartmann images) obtained before and after the focus. This procedure has many advantages such as a lower requirement on the accuracy of coordinates of apertures of the Hartmann diaphragm, a lower effect of experimental systematic errors on the results of investigations together with the possibility for estimating the accuracy of the data obtained and the reliability of the wave front topography obtained.

2. OBSERVATIONAL DATA AND THE SOFTWARE

The observational data were obtained during three nights in 1998: June 19/20, June 29/30, June 30/July 01; and six nights in 1999: July 16/17, July 17/18, July 18/19, July 19/20, July 21/22, July 22/23. The established Hartmann diaphragm (156 nonvignetted apertures in rectangular grid nodes) and a special mounting for obtaining the Hartmann images with the “Zenit” photocamera instead of the established free-shot cassette were used for the test observations.

251 Hartmann images were obtained. The preliminary and final reductions of the Hartmann images were made using the two-coordinate measuring "Askorecord" machine and the automatic digital ADMP-XY microphotometer [1], respectively.

FORTRAN-, PASCAL- and MIDAS-programs were prepared for reduction of digital images.

Figure 1 gives an example of image reduction by program package MIDAS/ROMAFOT.

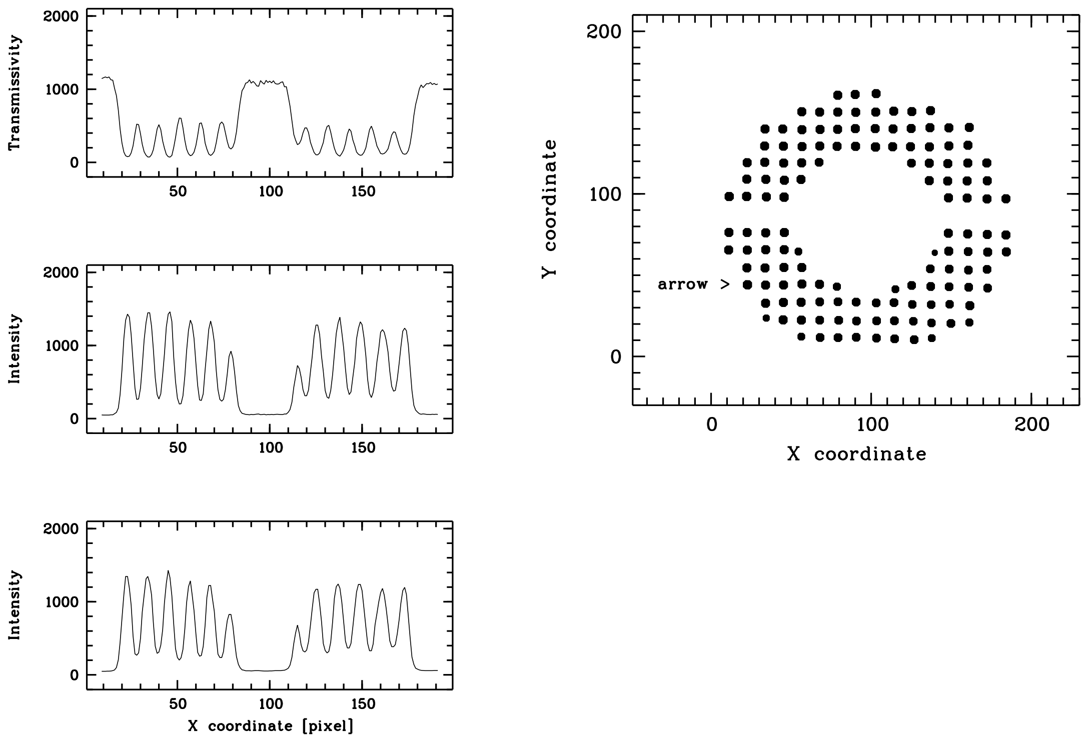

Figure 1: On the left: the section of one of serieses of the Hartmann diaphragm image on the photographic film after photometric measuring with the use of ADMF-XY (the upper row), after artificial spreading dynamical region of instrumental parameters (the mean row), as well as after filtering and smoothing (the lower row).
On the right: the restored Hartmann diaphragm after reduction with the use of MIDAS/ROMAFOT

3. THE SYSTEM WITHOUT THE ASTIGMATISM CORRECTOR

The optical system of the Cassegrain focus for the 2-m telescope is a simple two-mirror system in this case.

Figures 2, 4, 6 show the variations of the Zeidel aberrations throughout the system field for the secondary mirror position located by the focussing device reading equal to 37.45 mm.

The field astigmatism is characterized by the amplitude linear increase and by the position angle change with the point position varying in the field dominates in the wave front.

Figure 8 illustrates the variations of the Zeidel aberrations in the system without the astigmatism corrector in the field center for varying distance between the system mirrors. Figure 6 shows the constant coma A_{31} to dominate and the astigmatism A_{22} to be in the field center in the wave front (Figure 4). The variable spherical aberration A_{41} changing its sign at the focussing device reading equal to 33–34 mm is clearly seen. The coma amplitude is also minimized in this area (Figure 8).

So, Figures 2, 4, 6 show the aberration of a two-mirror system with the Cassegrain focus as a classical Ritchey-Chretien system with noncompensated astigmatism.

Initial distribution of energy throughout the image formed by the system without the corrector is characterized by $d_{0.8} = (1.34 \pm 0.05)''$. The image can be significantly improved by eliminating the constant coma, so that $d_{0.8} = (0.84 \pm 0.02)''$. The image is scarcely affected by astigmatism. All of the Zeidel aberrations being eliminated, the image size is $d_{0.8} = (0.79 \pm 0.02)''$. Therefore, having eliminated the Zeidel aberrations, we can obtain substantially the manufacturer value of the image quality.

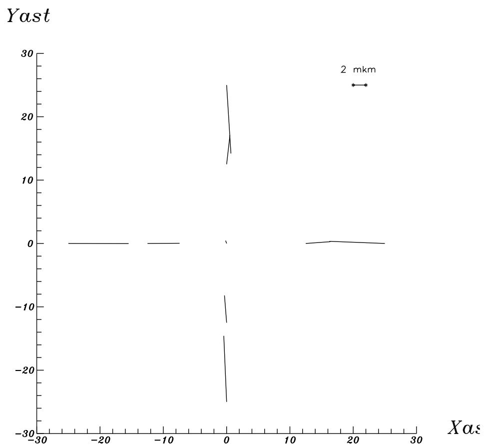

Figure 2: Astigmatism variations throughout the field in the system without the astigmatism corrector

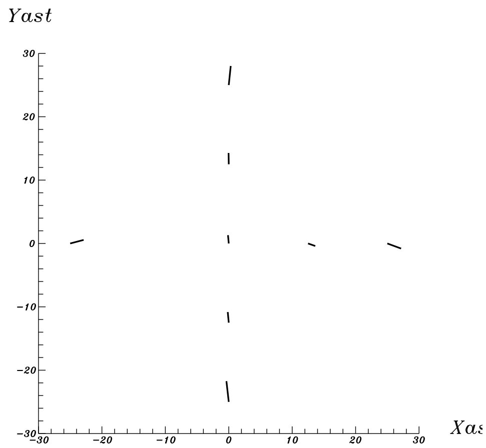

Figure 3: Astigmatism variations throughout the field in the system with the astigmatism corrector

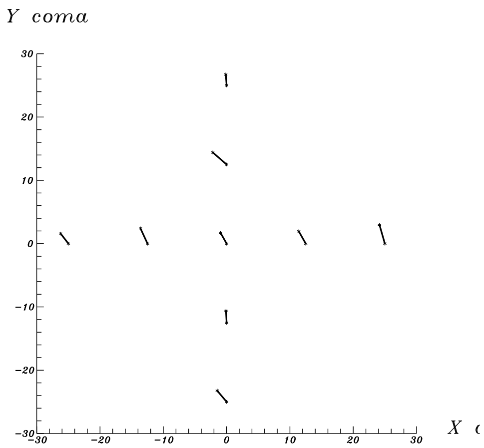

Figure 4: Coma variations throughout the field in the system without the astigmatism corrector

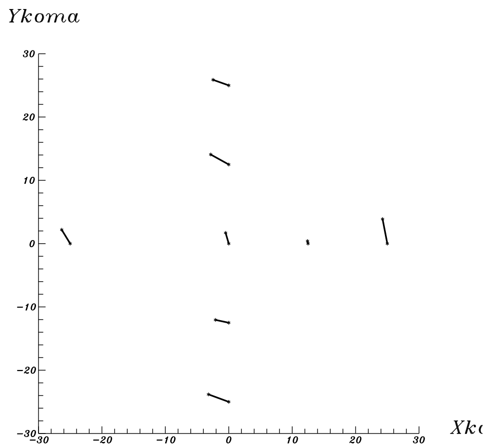

Figure 5: Coma variations throughout the field in the system with the astigmatism corrector

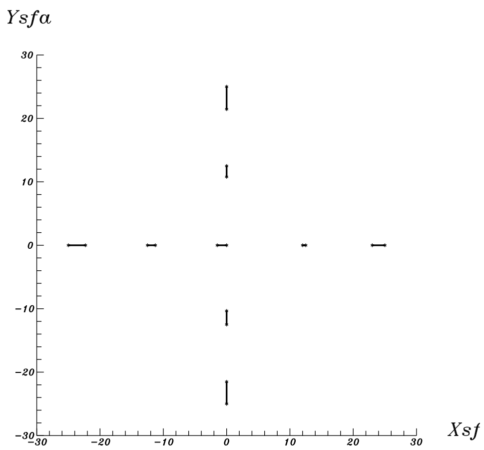

Figure 6: Spherical aberration variations throughout the field in the system without the astigmatism corrector

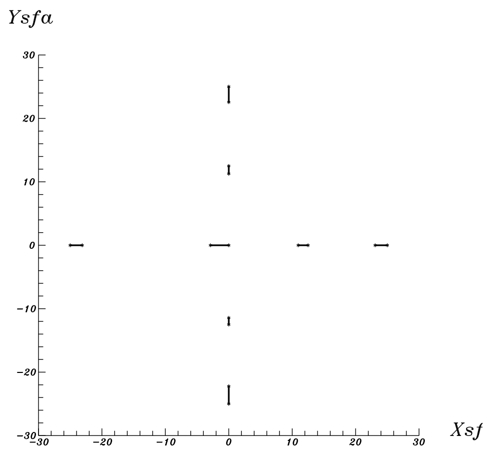

Figure 7: Spherical aberration variations throughout the field in the system with the astigmatism corrector

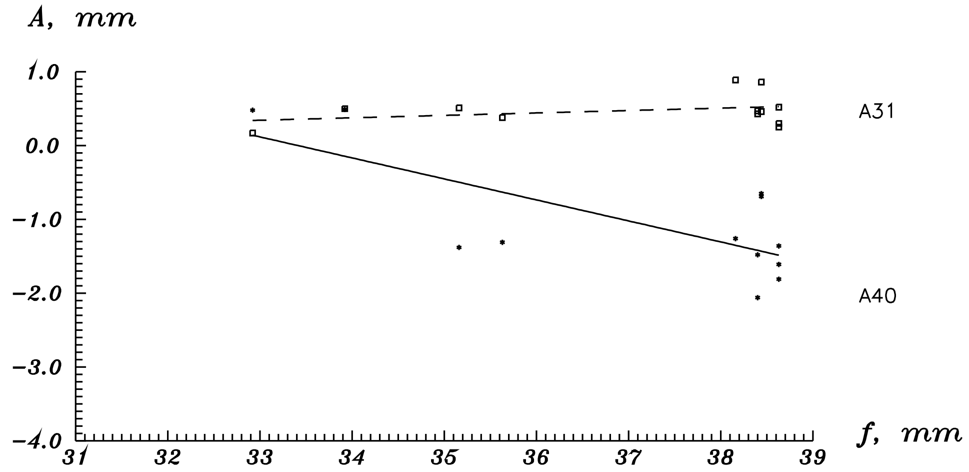

Figure 8: Dependence of amplitude of coma and spherical aberration on the focus position

In general, the investigation of the optical system without the astigmatism corrector by Hartmann's method proved the following:

– the system of the Cassegrain focus of the 2-m telescope is a Ritchey-Chretien system in which coma and spherical aberration are compensated and field astigmatism is present;

– the initial concentration of energy in the image on the axis is $d_{0.8} = 1''\!.3$, which does not meet the present-day requirements;

– we can reach the value $d_{0.8} = 0''\!.8$ by eliminating the Zeidel aberrations, primarily the constant coma and the spherical aberrations, which is in good agreement with the manufacturer attestation results.

4. THE SYSTEM WITH THE ASTIGMATISM CORRECTOR

Theoretically, the astigmatism corrector is a powerless element, that is why it is connected in the efficient paraboloid circuit when Hartmann's method is used.

Figures 3, 5, 7 show the variations of the Zeidel aberrations in the system field with the astigmatism corrector for the focusing device reading equal to 37.27 mm.

The following inferences can be made from the analysis of Figures 3, 5, 7:

– the field astigmatism is not revealed in the system with the astigmatism corrector, *i.e.*, the astigmatism corrector performs its functions;

– the amplitudes of the Zeidel aberrations in the system field with the astigmatism corrector do not exceed that for the field center;

– the constant coma A_{31} is the dominating aberration and astigmatism is minimal;

In all, the following conclusions can be made from the attestation of the system with the astigmatism corrector:

– the astigmatism corrector compensates for the field astigmatism completely;

– all of the Zeidel aberrations are present in the field center of the wave front; the wave aberrations in extraaxis points of the field do not exceed their values for the field center;

– the image produced by the optics is characterized by the low energy concentration, $d_{0.8} = 1''\!.3$. But the image can be drastically refined by eliminating the Zeidel aberrations, basically coma and spherical aberration, $d_{0.8} = 0''\!.7 - 0''\!.8$, which is in good agreement with the manufacturer attestation results.

5. ADJUSTMENT PROBLEMS

The constant coma is the principal cause of image degradation. It can be eliminated by the corresponding displacement/inclination of the system secondary mirror.

Figures 2–8 visualize the variations of the amplitudes of the coma and the spherical aberration for the axis motion of the mirror together with the field astigmatism in the system without and with the astigmatism corrector. The field astigmatism symmetry indicates that the system is centred quite well. The amplitudes of the variations A_{40} and A_{31} show that the spherical aberration and the coma caused by the astigmatism corrector can be compensated.

The results of our study testify that the additional adjustment of the Cassegrain focus system optics is necessary.

6. SEEING PROBLEMS

The photographic films with exposures less than 0.5 sec were obtained in the course of the Hartmann imaging and were reduced by the automated measurement procedure.

The trains of vibrations of aperture images are seen to be unaveraged in the Hartmann images of 0.5 sec exposures. They affect also the value of the Zeidel aberrations, especially astigmatism. In the course of the analysis of vibration of the aperture images the image quality was visually estimated by $5''$ and improved to $3''$ towards the end of the series of observations. This is caused by decrease in the difference in temperature between the observing hut space and environment. That is why before observational process the observing hut has to be ventilated for the time interval sufficient for the difference in these temperature values to get minimal.

7. CONCLUSION

We consider the attestation of the Cassegrain focus optics to be accomplished. The Cassegrain focus system is shown to be a classical Ritchey-Chretien system. The image quality estimate equal to $0''\!.7$ throughout the field can be reached by additional adjustment, which is in good agreement with the manufacturer attestation results.

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