RevMexAA (Serie de Conferencias), **35**, 259–260 (2009)

GANAS: A HYBRID ANASTIGMATIC ASPHERICAL PRIME-FOCUS CORRECTOR

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RESUMEN

La configuración óptica del Telescopio Reflector Cassegrain-Coudé del Observatorio Astronómico Nacional venezolano incluye 6 elementos. Con la remoción del espejo secundario se tiene acceso al foco primario del espejo principal de 1 metro de diámetro, el cual posee una distancia focal de 5 metros. Sin embargo, el espejo principal esferoidal no es capaz de proporcionar imágenes aceptables debido a su aberración esférica. Además, las aberraciones extra-axiales de coma, astigmatismo y curvatura de campo, contribuyen a degradar ulteriormente las imágenes. Con la finalidad de minimizar todas las aberraciones principales presentes en un campo útil circular de 30′, se ha diseñado un Grupo óptico de corrección Anastigmático Asférico (GAnAs), el cual consta de dos placas asféricas delgadas y un menisco.

ABSTRACT

The Cassegrain-Coudé 1 meter Carl Zeiss telescope at the Venezuelan National Astronomical Observatory uses six optical elements. Removal of the secondary convex mirror gives access to the focal plane of the primary f/5 spheroidal mirror, but spherical aberration, coma, astigmatism and field curvature severely hamper its imaging capabilities. In order to carry out prime-focus imaging, we designed and manufactured a corrector group, called GAnAs, to minimize these aberrations over a circular field of 30′. The corrector group is a hybrid configuration with two thin aspherical 4th-order plates and a meniscus lens.

Key Words: instrumentation

1. INTRODUCTION

The Venezuelan National Observatory is located in the Andes at almost 9 degrees north of the equator at an elevation of 3600m. Four telescopes, made in Germany in late fifties by Carl Zeiss (Oberkochen) and Askania Werke, are at present active. The 1 meter Zeiss reflector has a peculiar configuration with a spheroidal primary, a special hyperbolic secondary, and two correcting lenses to give a f/21 focal ratio (Köhler 1960). Two plane mirrors fold the light path inside the polar axis. At f/21, the field covered by the CCD is about 5′×5′. In order to use the prime-focus capabilities of the 1 meter f/5 primary, a 3-element corrector group has been designed and manufactured at CIDA to minimize spherical aberration, coma, astigmatism and field curvature over a useful circular field of 30′. This prime-focus corrector has been dubbed GAnAs, from the spanish acronym for Anastigmatic Aspherical Group.

2. DESIGN

Prime-focus correctors have been well known for many years and successfully used to dramatically increase useful fields of large paraboloidal mirrors of short focal length. A good example is the all-spherical prime-focus Ross corrector for the 200-inch Hale telescope at Palomar Observatory (Ross 1935). Meinel (1953) gives a good theoretical approach to a general 3-element aspherical prime-focus corrector group while Wynne (1949) combines both spherical and aspherical elements (hybrid configurations). Schulte (1966) gives a special review of prime-focus correctors involving aspherics. GAnAs also combines two relatively large thin aspherical plates and one small meniscus (all-spherical) lens, the latter placed just in front of the focal plane (Figure 1). The two aspherical plates cancel spherical aberration and coma, the meniscus flattens the field and almost eliminates astigmatism. The larger element is a 330mm-diameter classical Schmidt plate while the second aspheric is a 290mm-diameter plate with a reverse-Schmidt profile. K5 crown glass was selected for the three optical elements. While generation, polishing and figuring of precision aspherics can be very difficult, we choose this solution because we had a modest experience in Schmidt-plate fabrication (Della Prugna 1991) and also because no special thick glasses are needed. The design was ray-traced and optimized using BEAM 3 (Stellar Software). Polychromatic spot diagrams showed that

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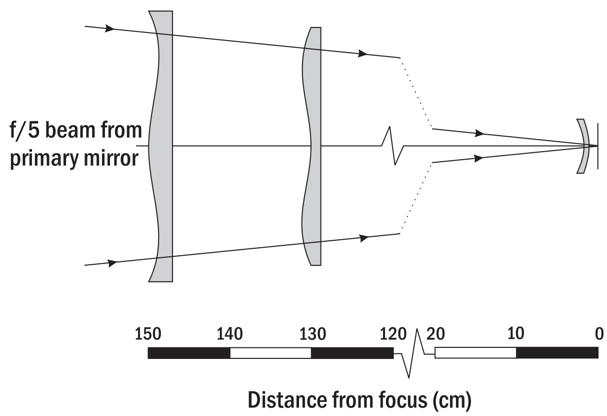

Fig. 1. Optical layout of GAnAs. Aspherical profiles are greatly exaggerated.

over a 30′ circular field, images were smaller than the typical long-exposure best-seeing FWHM (∼1.″5) measured at the Observatory.

3. FABRICATION

To carry out the optical work, we first made a simple machine. This uses an electric motor and a variable-speed gear to spin a rotating base onto which the glass plate is firmly placed. Starting with Carborundum 400, both surfaces of each plate were first ground flat against a larger plane glass. Generation of the aspherical profile was carried out using Cox's method of fine grinding (Cox & Cox 1938). To measure to a fairly good level (∼5%) the profile, we put the plate on an graduated stage with a precision (0.001mm) dial gauge, attached on top, and set its tip in contact with the aspherical surface. After levelling, readings were taken radially at 5mm steps, starting from the center of the plate to the edge. Several runs were carried out at different position angles of the plate and the mean calculated. When both profiles were within tolerances, the polishing process begun. The flat surfaces resulted an easy task and were polished flat to within 20 fringes of visible light by means of a sub-diameter pitch tool. Polishing the aspherical surfaces was first carried out by using flexible pitch polishers as described by De Vany (1981). However, we weren't able to produce smooth surfaces with such tools and we were forced to try a different approach. After several prototypes, we found an adequate flexible tool made by sticking to a rigid disk three equally-spaced petals made from 25mm-thick expanded polystyrene slab (styrofoam). The petals were glued to the disk and their shapes and channels were easily cut by using a sharp knife. We usually cut a 25mm-square channel pattern. Because styrofoam didn't hold well the polishing compound (Cerium oxide), we covered the squares with 1-inch-wide self-adhesive Micropore^{TM} (3M) medical paper tape. This polisher, although very slow, gave good control and surface smoothness. The small meniscus lens was easily made by standard techniques employed to produce spherical surfaces.

4. TESTING

We optically tested the aspherical plates as follows. First, a 250mm-diameter f/5 precision spherical mirror was made. This allows to explore the plates from center to edge but not the whole surface. A 2-lines/mm Ronchi grating was attached on a graduated stage and set at the mirror's center of curvature. A rig was made to hold the plates between grating and mirror at specific positions. We first placed one plate at a time and measured its spherical aberration by sliding along the optical axis the Ronchi grating used as a Wire test. When both plates, separated by the right distance, are placed on the rig, a null must be observed. Because light passes twice trough the plates, the observed amplitude of defects is doubled. Using only one line of the ruling, it is possible to mimic the Foucault test and assess smoothness.

5. CONCLUSIONS

A prime-focus hybrid corrector has been designed and manufactured by using conventional methods and tools. GAnAs will allow direct f/5 imaging over a useful circular field of 30′ with a 17-fold increase of field coverage for a given imaging device compared to the original f/21 focal ratio, and also less elements in the optical train. Hence, we expect to reach fainter objects with shorter exposures.

We wish to thank Pedro Ramírez and Luis Plaza for the machining of the mechanical assembly and also Santiago Barboza for 3-D modelling.

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