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DETECTION AND CORRECTION OF SCATTERED LIGHT IN THE 2.1-m SAN PEDRO MÁRTIR TELESCOPE

L. Gutiérrez, J.A. López, E. Luna, J. Valdéz,
J.M. Murillo, G. Sierra, F. Grundhal[1], and W.J. Schuster

Instituto de Astronomía
Universidad Nacional Autónoma de México

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RESUMEN

Se ha utilizado el método de *Camera Obscura* (Grundhal & Sørensen 1996) para evaluar la presencia de luz dispersa en la pupila de salida del telescopio de 2.1-m de San Pedro Mártir en su configuración f/7.5. Se encontró presente una cantidad importante de luz dispersa originada por reflexiones múltiples sobre las paredes internas de los *baffles* del cielo; esta componente dispersa puede afectar directamente la calidad de los campos planos de calibración, lo cual se refleja a su vez en la precisión de la fotometría bidimensional sobre un detector CCD. Se implementaron acciones correctivas en los *baffles* de cielo del espejo primario, las cuales eliminaron casi en su totalidad la componente dispersa espuria.

ABSTRACT

We have used the pinhole camera method (Grundhal & Sørensen 1966) to evaluate the amount of scattered light present at the exit pupil of the f/7.5, 2.1-m San Pedro Mártir telescope. A substantial amount of scattered light, originating from multiple reflections off the inner walls of the sky baffles was found to be present; this scattered component directly affects the quality of the flat-field calibration frames, which is in turn reflected on the accuracy of CCD bidimensional photometry. Corrective action has been performed on the primary's sky baffle, successfully eliminating most of the spurious scatterea component.

Key words: **TELESCOPES**

1. INTRODUCTION

The motivation for this work arose from the need to evaluate the performance of the 2.1-m SPM telescope to achieve high quality bidimensional CCD photometry required by some research programs. In observational programs of this nature, one of the main elements that may hinder a good photometric calibration is the reliability of the flat-fields. Contributions of scattered light along the optical path of a telescope can have a serious effect on data calibration, particularly when the calibration frame is acquired by exposing to a bright light source. Thus, flat-field exposures that are obtained to compensate for pixel to pixel sensitivity variations may be substantially affected if the optical system relays scattered light by introducing spurious intensity variations not present in the target observations and, of course, not inherent to the response of the detector. This effect would yield intrinsic flux calibration errors beyond the expected accuracy corresponding to a given instrumental set up and/or observing conditions.

Although the ultimate effects of contributions from scattered light may be severe in the calibration of photometric data, its presence is difficult to detect and diagnose, particularly in telescopes with equatorial mountings, where the CCD is rarely rotated in imaging programs involving calibrated, bidimensional photometry. Grundhal & Sørensen (1996) have extensively discussed this problem, in particular with regard to the Nordic Optical Telescope, which has an alt-azimuth mounting where field ro-

[1] Institute of Physics and Astronomy, Univ. of Aarhus, DK-8000, Denmark.

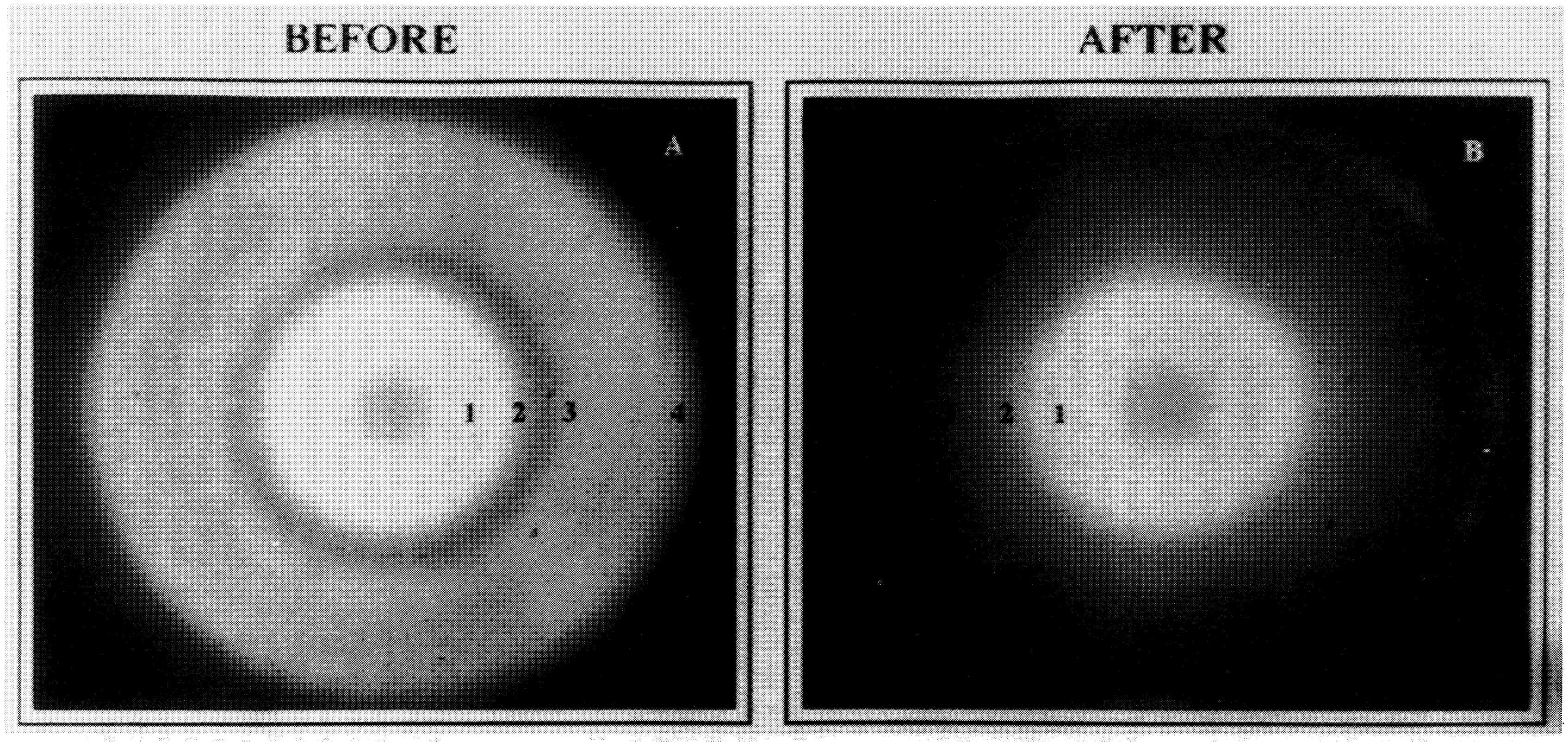

Fig. 1. Images obtained through a 50 μm pinhole placed in front of the CCD window. Fig. 1*a* corresponds to the image before any corrective steps were performed. The regions labeled indicate: 1) image of the secondary mirror, 2) inner wall of the secondary baffle, 3) top of the primary baffle, and 4) bottom of the primary baffle at the Cassegrain hole. Fig. 1*b* corresponds to the same image after the corrections, numbers indicate regions as in Figure 1*a*. The display for both images is logarithmic.

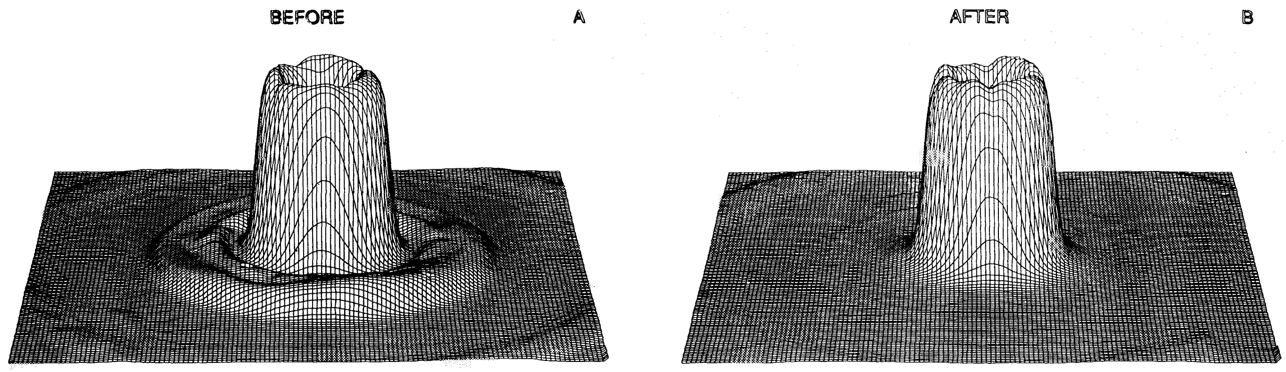

Fig. 2. Figures 2*a* and 2*b* are surface plots of the images in Figures 1*a* and 1*b*, respectively. The scattered component present in 2*a* is apparent, this has disappeared after modification of the primary mirror sky baffle in Fig. 2*b*. The intensity display in these plots is linear.

tation constantly varies the orientation of the CCD with respect to the field of view; they have worked out a relatively simple, yet efficient method to diagnose and correct for this hidden but potentially damaging effect. We have followed their method to detect and correct the spurious scattered component in the f/7.5 configuration of the 2.1-m SPM telescope. In § 2 we describe the methodology to detect the scattered component and in § 3, the corrective steps and results are described and discussed. Section 4 contains the conclusions.

2. DETECTION OF THE SCATTERED COMPONENT

Detection of the scattered component involves turning the telescope into a *Camera Obscura.* For this purpose we have used an industrial —high quality pinhole— 50 μm in diameter, with a conic shaped entrance face for our diagnostic tests. This mask was placed in front of the CCD window, about 5 cm ahead of the chip, on a specially built mounting that kept it firmly in position and centered. We used a CCD Tektronix 1024^2 with square 24 μm size pixels each $\equiv$ $0.3'' \times 0.3''$. The nominal field of the CCD on the sky is $5.12' \times 5.12'$ (López, Gutiérrez, & Valdéz 1995). The optical path is left free from any other interference and an integration is taken in a similar way as a dome flat-field to image the telescope's exit pupil on the CCD. Figure 1*a* contains the image obtained under the conditions described above, before any corrective action was taken. The display is in a logarithmic scale. The different sections of the image are labeled and described in the legend to the figure. The main components to notice are the image of the secondary mirror at the center of the figure and outside of it the substantial and uneven illumination, corresponding to scattered light, present on the inner wall of the primary mirror baffle. The tests and modifications described here were performed on 1995, May 29.

3. CORRECTION OF THE SCATTERED COMPONENT

Correction of the scattered light is performed by placing a series of rings on the inner side of the sky baffle to block out the spurious component. Five annuli were installed, separated by approximately 23 cm each and with progressing widths from top to bottom. The first ring has a width of 1.87 cm and the last one, next to the Cassegrain aperture, of 6.99 cm. Before these modifications, the telescope's f/7.5 beam had an unvignetted field of 68.3 arcmin (Malacara & Cornejo 1970), after the installation of the annuli the field was reduced to 59.7 arcmin. Figure 1*b* contains the image obtained after modifying the baffle. An outstanding improvement over Figure 1*a* is readily appreciated. Figures 2*a* and 2*b* are linear surface plots of Figures 1*a* and 1*b*, respectively. These plots allow a good visualization of the information contained in Figures 1*a* and 1*b*. The scattered component is apparent in Figure 2*a* as the irregular pedestal at the base of the light cone corresponding to the secondary mirror. In order to show the importance of the scattered component, Figure 3*a* contains plots across the entire diameter of Figure 1*a*, along both, the central column (dashed line) and along the central line (solid line). It is apparent from this figure that outside the inner region corresponding to the secondary mirror, the intensity distribution of light is severely uneven and asymmetric in both di-

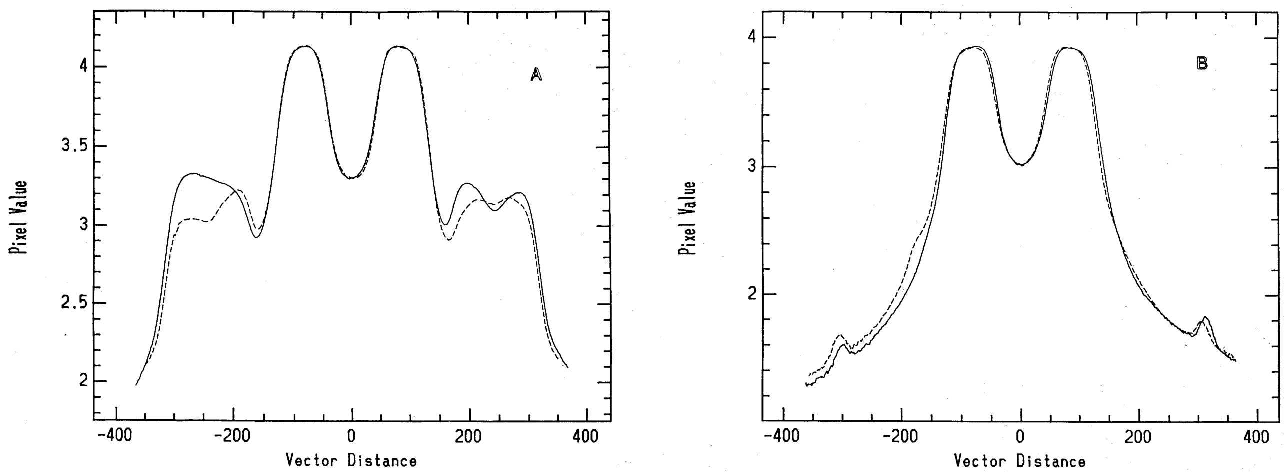

Fig. 3. Figure 3*a* are plots across the entire diameter of Figure 1*a* both, along the central column (dashed line) and along the central line (solid line). The presence of substantial, uneven and asymmetric illumination is apparent. Figure 3*b*, as Figure 3*a*. Plots corresponding to scans for Figure 1*b*, after correction. The spurious component has been clearly removed and both scans are now nearly symmetric in this figure. Intensity scale in both figures is logarithmic.

rections. The scale is logarithmic here with peak values near 10 000 counts, typical of flat-fields. It is clear from this figure that the amount of scattered light present can reach values in excess of 10% of the peak intensity in some directions. In Figure 3*b*, the corresponding scans for Figure 1*b*, after correction, are presented; the scattered component, represented by the "shoulders" of the plots in Figure 3*a*, has now disappeared and it can be seen that both scans in Figure 3*b* are nearly symmetric. Finally, Figure 4 contains the normalized radial profiles, across columns in the X+ direction —for the two pinhole images— before and after correction that further exemplifies the improvement achieved after the installation of the annuli in the baffle. The little peak in intensity for the corrected plot, near vector position 310 corresponds to the Cassegrain ring at the base of the primary baffle.

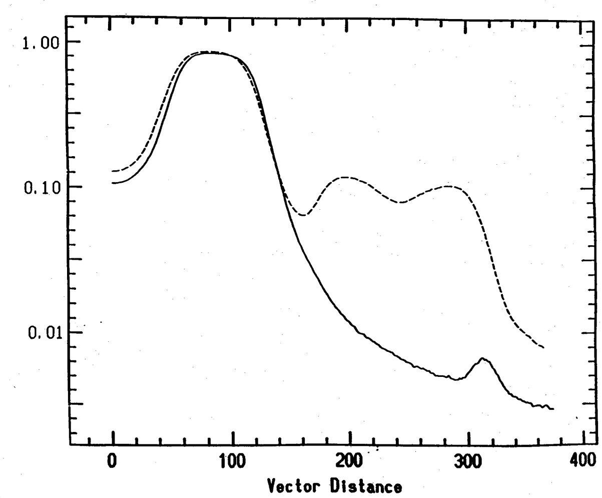

Fig. 4. Normalized radial profiles, across columns (X+ direction), for both pinhole images, before and after modifications. Intensity scale is logarithmic.

4. CONCLUSIONS

We have successfully applied the *Camera Obscura* method (Grundhal & Sørensen 1996) to detect and eliminate the scattered component previously present in the 2.1-m (f/7.5) telescope of SPM originating from multiple reflections off the inner wall of the primary sky baffle. The method has proven to be very effective and simple to implement. Observers that in the past have obtained bidimensional photometry in this telescope, for programs that require high accuracy, are warned that their results should be used with caution. Similar tests and corrective steps are planned for the other two telescopes at the OAN-SPM. Finally, it is worth mentioning that this method can be used as a helpful tool for a variety of tests in a telescope, for instance, possible vignetting of the field of view by mechanical parts by off-set guiders, can be tested easily following this procedure.

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L. Gutiérrez, J.A. López, E. Luna, J.M. Murillo, W.J. Schuster, G. Sierra, and J. Valdéz: Observatorio Astronómico Nacional, I. Astronomía, UNAM, Apartado Postal 877, 22830 Ensenada, B.C., México. (jal@bufadora.astrosen.unam.mx)
F. Grundhal: Institute of Physics and Astronomy, University of Aarhus, DK-8000 Denmark.