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DUAL-STAR PHOTOMETER AT THE TALLINN OBSERVATORY

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Abstract. We briefly describe the dual-star photometer designed by P. Kalv, a former director of Tallinn Observatory (1934–2002) for multicolor photometry of close binaries and intrinsic variable stars.

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While single-channel systems have achieved a high degree of operational efficiency, they are severely limited on nights of poor transparency. Dual-channel systems have been designed to circumvent this handicap. However, these systems tend to be very complex and prone to various subtle systematic errors and should not be considered until one has considerable experience with single-channel systems.

Apparently, atmospheric conditions are far from ideal in Estonia as in a number of other observatories in Europe. Changes in the sky transparency between successive observations are a predominant source of errors in photoelectric photometry of stars. By making simultaneous or nearly simultaneous observations of the variable and comparison stars, the dual-star system is able to eliminate the effects of changes in the sky transparency, which affect both stars by practically the same amount at virtually the same time. If the angular distance to a suitable comparison star is small, it is possible to observe both the variable and comparison stars without slewing the telescope.

At small angular separations, changes in atmospheric transparency affecting one star are bound to affect another star almost equally and nearly simultaneously. The advantage of using a single sensor is that the peculiar response of the sensor will be applied equally to both the variable and the comparison star, thus minimizing any effect on the differential measurement. The disadvantage of using a single sensor is that a somewhat complex electro-mechanical device must be made to switch the sensor back and forth rapidly between the variable and the comparison star.

The general principle of our photometer was described by Kalv (1984). The Fabry lens projects upon the PMT photocathode the image of the objective mirror, which is uniformly illuminated by the star located on the optical axis of the telescope. If we use the large Fabry lens such that it is able to embrace the entire field-of-view or the exit-pupil of the telescope, all the stars in the field-of-view will illuminate the photocathode, each creating an image of an evenly illuminated mirror on one and the same area of the photocathode. Using three apertures, we let the light of the two stars and the sky background pass to the photocathode. With the help of a shutter we can cover the diaphragm in pairs and measure intermittently the variable star, the comparison star and the sky.

In the focal plane of our reflector the diameter of the field in use is 75 mm, which corresponds to $27'$ in the sky. Since the loss of light in the Fabry lens is high, we replaced the lens with a mirror. We have a 105 mm diameter spherical mirror which provides an acceptable spot of 10 mm on the photocathode. The angle of the Fabry mirror must be at least 20 degrees to avoid the usage of an additional flat mirror. In this case we must deal with the so-called Herschel's asymmetric optical system, in which we observe coma, spherical aberration and astigmatism. We studied the quality of the image with the help of the Fabry mirror in the photometer model which was attached to the telescope. When we place a screen, which imitates the photocathode at the proper angle, we can incline the Fabry mirror by 30 degrees without any appreciable image distortion.

One may intuitively think that the quality of the image on the photocathode is not critically important. The main concern is that all photons fall on the photocathode and that the position of the image would always be in the same place. As to the latter, the described optical system is very sensitive. The photocathode must be positioned exactly in the focus of the Fabry mirror, and if not, the images of the two stars will not coincide. However, it is easy to measure the accuracy of the adjustment of the entire system by measuring the sky through all the apertures.

In the given optical system it is hard to find a proper place for filters. Since the light paths follow different angles, if the filter were located close to the photocathode, there would be a considerable shift in images due to double refraction. Thus the filters must be placed near the focal plane of the telescope in the shape of long, narrow strips. The shutter may either be in the shape of a revolving disc or a cylinder, in which cuts alternately let through the light either of the star or the sky. Since the scintillation of the atmosphere does not allow to use very high modulation frequencies, we used a shutter with two relays in the first version of the photometer. It was easy to control the relays, but vibration generated by the relays forced us to take in use a revolving cylinder shutter. A diaphragm strip holder is placed in the center of the revolving cylinder shutter. The main difficulty in observing with the dual-star photometer is related with centering of both stars precisely in their diaphragms. In the given version, we can view the entire field-of-view in the eyepiece and see stars behind the diaphragms in the control eyepiece.

With this publication the authors pay a tribute to a former director of Tallinn Observatory and a senior research associate of Tartu Observatory Dr. Peep Kalv (1934–2002). P. Kalv was a devoted investigator of the long-period eclipsing binaries and intrinsic variable stars for more than thirty years.

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