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A catalog of secondary photometric standard stars around gravitational lenses⋆,⋆⋆

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Abstract. We present a catalog of secondary photometric standard stars in the neighborhood of 14 gravitationally lensed quasars. These stars were verified to be non variable using long-term monitoring. The instrumental magnitudes of the new standard stars have been transformed to the Johnson-Cousins $BV(RI)_c$ photometric system. For ten gravitational lenses (GLs) we also provide the $BV(RI)_c$ mean magnitudes of the integrated flux of all the lens components, for the epochs of the photometric calibration.

Key words. techniques: photometry – gravitational lensing – quasars: general

1. Observations

In this work we present a list of secondary standard stars in the fields of 14 gravitationally lensed systems. Since 1999, 27 known gravitational lenses and lens candidates are being monitored at the Wise Observatory (Israel). The observations are being performed on a weekly basis in the standard Cousins R_c band, with partial coverage in the I_c or V band. The data obtained at the Wise observatory have been used for selecting several non-variable stars in each field. We used additional observations made at Skinakas Observatory (Greece) and at SAAO (South Africa) to perform the photometric calibration.

The basic characteristics of the telescopes and CCDs used are:

(a) Wise Observatory: the observations are being carried out with a 1 m (f/7) Ritchey-Chrétien telescope using a cryogenicaly-cooled Tektronix back-illuminated CCD (1024 × 1024 pixels, 24 × 24 μm^2). The pixel scale is 0.″7 pixel.$^{-1}$.

(b) Skinakas Observatory: observations were conducted during the period August to November 2001 and in May 2002, using a 1.3 m (f/7.7) Ritchey-Chrétien telescope. We used a SITe CCD detector (1024 × 1024 pixels, 24 × 24 μm^2), giving a scale of 0.″5 pixel^{-1}.

(c) Sutherland Observatory: the observations were carried out with a 1.9 m telescope (f/18), during the period 14–21 May 2002. A STE4 CCD was used (1024×1024 pixels, 23×23 μm^2) giving a scale of 0.″14 pixel^{-1} .

2. Data reduction and results

2.1. Selection of the non-variable stars, photometry and calibration to the Johnson-Cousins $BV(RI)_c$ system

The images obtained at the Wise observatory are being reduced automatically on a daily basis and the light curves of the sum of the lensed components are posted on the web[1]. We used the

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⋆ Based on observations made with a) the 1.0 m telescope at Wise Observatory, Israel, b) the 1.3 m telescope at Skinakas Observatory, Crete, Greece, and c) the 1.9 m SAAO telescope, Sutherland Observatory, South Africa.

⋆⋆ Tables 1–3 and Fig. 1 are only available in electronic form at http://www.edpsciences.org

[1] http://wise-obs.tau.ac.il/~eran/LM/

IRAF package[2] to perform aperture photometry for all sources in each field. The standard stars in each field were selected in an iterative process. In the first iteration, the relative zero point of the images was derived from the mean magnitude of the stars that appear in all frames. Then, in each iteration, stars that have a large scatter about the mean (based on their χ^2, standard-deviation and skewness) were removed. For UM 673, the selection of the non-variable stars was based on work by Sinachopoulos et al. (2001). For PMNJ 1838−3427 we had no monitoring data at our disposal, and we therefore observed several of the field stars presented by Winn et al. (2000). Finding charts for all the systems are shown in Fig. 1.

The data obtained for the photometric calibration were processed using the ESO-MIDAS software package with the standard aperture-photometry procedures. Due to the high density of stars in the field of PMNJ 1838−3427, we used the DAOPHOT package (Stetson 1987) and applied aperture correction to the PSF photometry.

The extinction and the zero point at the different wavebands were computed by observing several Landolt (Landolt 1983, 1992) stars, at a wide range of airmasses, each night of observations. The color terms applied to the observations obtained between August to November 2001 were computed by observing 12 Landolt stars on the night of 27 August 2001. For both May 2002 Skinakas and SAAO observations, about nine photometric standard stars were observed during each night. As the color term we used the mean value of the daily measurements of the color terms in each run. The final calibrated photometry for the secondary standard stars is given in Table 2.

The errors presented correspond to the standard deviation of the mean (i.e. the unweighted standard deviation of the sample divided by $\sqrt{N}$, where N is the number of observations) and do not include any systematic errors (e.g. Landolt errors, RMS of fitting of the equation used for the calibration to the standard system), which are of the order of 0.02 mag. Note that the photometric calibration in the fields of APM 08279+52 and SBS 0909+53, which was separated by several months and was performed using different sets of Landolt standards, gave consistent results. For the field of PMNJ 1838−3427, some systematic differences ($\Delta I \approx 0.11, \Delta R \approx -0.11$) between our measurements of the field stars and the ones presented by Winn et al. (2000) seem to exist.

In Table 3 we list the calibrated photometry for ten gravitational lenses.

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