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RESOLVED PHOTOMETRY OF THE BINARY COMPONENTS OF RW Aur

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1 Introduction

RW Aur is one of the objects from the initial list of T Tauri type stars composed by Joy (1945). Joy & van Biesbroeck (1944) discovered that the star has a companion, RW Aur B, which was at that moment $1\overset{\mathrm{m}}{.}5$ fainter than the primary star RW Aur A. The current position of the companion RW Aur B is: $\rho \simeq 1.45''$, PA$\simeq 256°$ (Bisikalo et al. 2012). It was found later that both A and B components were classical T Tauri stars (Duchêne et al. 1999), i.e. pre-main sequence low mass stars surrounded by accretion disks. Spectral types of the main component and the companion are K1-K4 (Petrov et al. 2001) and K5 (Duchêne et al. 1999), respectively.

Variability of RW Aur was discovered more than a century ago by L.P. Ceraski (Ceraski 1906). Historical light curve of the star (Beck & Simon 2001; Grankin et al. 2007; Rodriguez et al. 2013) reflects the total brightness of both components due to their proximity. In $UBVRI$ bands the star demonstrates irregular variability, whose amplitude increases from I to U band, that is typical of classical T Tauri stars. In particular, average brightness of RW Aur during 1985-2003 in the V band was near $10\overset{\mathrm{m}}{.}5$ with an average amplitude of seasonal variations $\simeq 1\overset{\mathrm{m}}{.}4$ (Grankin et al. 2007).

It is commonly accepted to interpret the variability of RW Aur as that of the brighter component A. We found the only paper by White & Ghez (2001) where a quantitative information on the brightness of RW Aur B in the $UBVR_cI_c$ bands is presented (from November 9, 1994 HST observations).

Petrov & Kozack (2007) concluded that the brightness and color of RW Aur A are governed by variations of the circumstellar extinction rather than of the accretion. It looks strange because the inclination of RW Aur A disk midplane to the line of sight lies between 30° and 45° (Cabrit et al. 2006). Unexpected confirmation of Petrov & Kozack conclusion appeared in 2010 when a long and deep dimming of RW Aur happened. The dimming had a depth of 2 magnitudes, a duration of 180 days and presumably was due to occultation of RW Aur A by a dust cloud (Rodriguez et al. 2013).

The V magnitude of RW Aur during the dimming event fell down to $\simeq 13^{\mathrm{m}}$, that is close to brightness of RW Aur B, so it is not clear what was the real amplitude of RW

Aur A dimming. It was not possible to answer this question due to the lack of resolved photometry of this double system.

According to the AAVSO database (`http://www.aavso.org`), in a period from April 2011 to the end of April 2014 RW Aur demonstrated its usual (pre-dimming) behavior, e.g. its V magnitude varied in an irregular way around the average value of $10\overset{\rm m}{.}5$. Then the star was not observed till October, 23 when it appeared that RW Aur dimmed again down to $V \simeq 12.6^{\rm m}$.

2 Observations and results

Multicolor imaging of RW Aur was performed on November 13/14, 2014 with a newly installed 2.5 meter telescope ($F_{\rm equiv} = 20$ m) of the Caucasus observatory of Lomonosov Moscow State University at the mount Shatzhatmaz[1] in course of test precommissioning observations aimed at checking the image quality provided by the instrument. The telescope was equipped with a mosaic CCD camera manufactured by Niels Bohr Institute based on two E2V CCD44-82 detectors (pixel size 15 μm) and a set of standard Bessel $UBVR_{\rm c}I_{\rm c}$ filters from Asahi Spectra Co.

In course of observations the image quality with FWHM between 0.5 and 0.7 arcsec was routinely obtained confirming the excellent optics quality of the instrument, delivered by the REOSC company of Safran group, France (Poutriquet et al. 2012). The binary was clearly resolved (see Fig. 1): the wings of a brighter component image contribute $< 7\,\%$ to the central intensity of a fainter component in all bands. This time of year at the site is known to be characteristic of exceptionally stable atmospheric turbulence conditions (Kornilov et al. 2014), so this result was not unexpected. The exposure time varied from 5 sec in the $I_{\rm c}$ band to 300 sec in the U band, the middle date of measurements is JD 2456975.56.

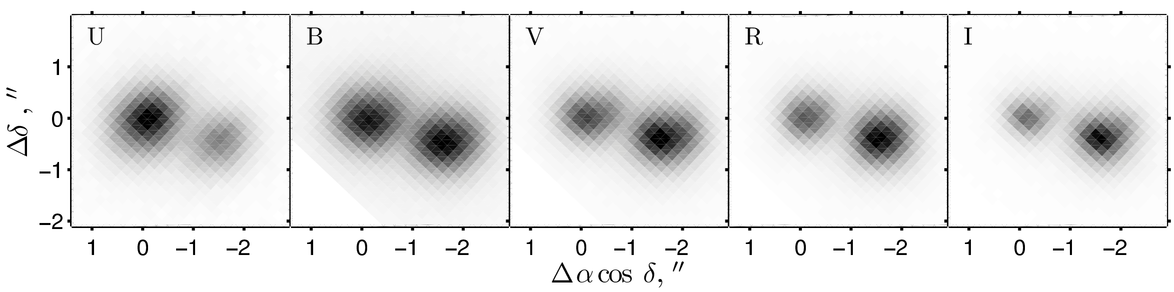

Figure 1. Images of RW Aur binary in the $UBVRI$ photometric bands. The primary component, RW Aur A, is placed in the origin of the coordinate system.

Primary data processing and PSF photometry were performed in a standard way in the ESO-MIDAS environment with the DAOPHOT program package (Stetson 1987). Stars 127 and 129 from the AAVSO chart for RW Aur were used as $BVR_{\rm c}I_{\rm c}$ photometric standards. The $U-B$ colors for these standards and transformation of magnitudes and colors from the instrumental to the standard $UBVR_{\rm c}I_{\rm c}$ system were made based on quasi-

[1]Webpage of the observatory, in Russian: `http://lnfm1.sai.msu.ru/kgo/`. An English report can be found at the following link:
`http://phys.org/wire-news/180021829/lomonosov-moscow-state-university-opens-new-observatory-in-the-c.html` .

simultaneous observations of Landolt standard fields (Landolt 2009) using formulae from Hardie (1964). The results of our measurements are presented in Table 1.

Table 1: $UBVRI$ photometry of RW Aur

	U	B	V	R_c	I_c
RW Aur A	14.26 ± 0.3	14.50 ± 0.06	13.80 ± 0.05	13.18 ± 0.07	12.46 ± 0.1
RW Aur B	14.97 ± 0.3	14.26 ± 0.05	12.92 ± 0.03	11.97 ± 0.07	11.01 ± 0.1

The results are non-trivial, as follows from the comparison of our data with that of White & Ghez (2001) obtained 20 years ago (see Fig. 2). First of all, during our observations RW Aur A became $\simeq 3^{\rm m}$ fainter in all spectral bands (the dot-dashed curve at the left panel of the figure) which may be interpreted as gray extinction. A better fit can be obtained assuming that the extinction is a sum of two components: a gray extinction with $A_V = 2.87$ and a selective standard one (Savage & Mathis, 1979) with $A_V = 0.44$ – see open circles in the panel. It seems natural to explain current RW Aur A dimming as a result of an eclipse of the star by dust particles, with predominantly large enough size r to produce gray extinctions up to at least 0.7 μm, which means that $r > 1$ μm (Krügel 2003).

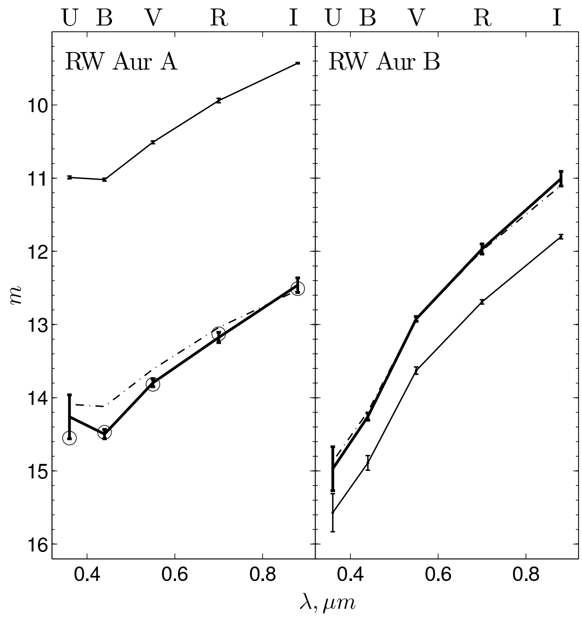

Figure 2. $UBVRI$-photometry for A and B components of RW Aur for two epochs: the thin lines are for HST observation (Nov. 1994), the thick lines are for our observation. The dash-dotted line corresponds to the HST data shifted down by $3\overset{\rm m}{.}1$ and up by $0\overset{\rm m}{.}7$ for A and B components, respectively. The circles are obtained from HST data by applying a sum of gray extinction with $\Delta m = 2.87$ and selective extinction with $A_V = 0.44$ using a standard reddening curve.

Our results indicate that RW Aur B is also a variable star: at the moment of our observations it was brighter than 20 years ago at $\Delta m \simeq 0\overset{\rm m}{.}7$ in each of $UBVRI$ band (gray brightening). Explanation is the same as for RW Aur A, but in the opposite sense: in 1994, RW Aur B was eclipsed by a cloud that consisted of dust particles with size $r > 1$ μm and now the cloud has passed away from the line of sight.

It follows also from our data that at the moment of observations the relative contribution of RW Aur B to the total brightness monotonically decreases from I to U band: it dominates at long wavelengths but becomes fainter than RW Aur A in the ultraviolet (see Fig. 1).

And last but not the least: our test observations indicate that the optics of the new 2.5 m telescope is good as well as the seasonal astroclimate at the site.

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