Anomalous eclipses of the young star RW Aur A

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Abstract

Results of $UBVRIJHKLM$ photometry, $VRI$ polarimetry and optical spectroscopy
of a young star RW Aur A obtained during 2010-11 and 2014-16 dimming events are
presented. During the second dimming the star decreased its brightness to $\Delta V > 4.5$
mag, polarization of its light in I-band was up to 30%, and color-magnitude diagramm
was similar to that of UX Ori type stars. We conclude that the reason of both dimmings
is an eclipses of the star by dust screen, but the size of the screen is much larger than in
the case of UXORs.

Introduction

RW Aur is a young binary [8] with current separation between components $\approx 1.5''$. The
primary of the system RW Aur A is a classical T Tauri star, i.e. low mass pre-main-
sequence star, which accretes matter from a protoplanetary disk [11]. [8] found a spiral
arm of molecular gas going out from the disk and concluded "that we are witnessing
tidal stripping of the primary disk by the recent fly-by of RW Aur B". Hydrodynamical
simulations of [8] confirm this tidal interaction hypothesisis.

Recently RW Aur A has undergone two major dimming events with unprecedented
parameters. The first one has occured in 2010-11 ($\Delta t \sim 150^d$, $\Delta V \sim 2$ mag) and the
second even deeper dimming was from summer 2014 to summer 2016 [12, 13]. Non-trivial
behavior of the star during these events was discussed in a number of papers – see e.g.
[1], [10], [14], [15], [2], [5], [16] and references therein. There are no doubts now that both

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dimming events were due to eclipse of the star by dust screen, but the nature of the screen is a matter of debates: a tidal arm between components of the binary, dusty disk wind or/and warped inner disk regions.

We present here preliminary results of our observations during both dimming events and some general conclusions.

Observations and Results

Our observations of RW Aur were carried out at Crimean Astrophysical Observatory (CrAO, 1.25-m telescope), Special Astrophysical Observatory (SAO, 6-m telescope), and at two observatories of Lomonosov Moscow State University: Caucasus Mountain Observatory (CMO, 2.5-m telescope) and Crimean observatory (CO, 1.25-m telescope). Photometric and polarimetric data in optical band were obtained at CrAO (2010-2011, non-resolved) and CMO (2014-2016, resolved). Medium ($R \approx 15000$) resolution spectra in 5850-6600 Å band were observed at SAO in November 2014 and December 2015. Infrared photometric data were obtained at CO (2010-2016, $JHKLM$, non-resolved) and CMO (2015-2016, $JHK$, resolved). Details of the observations and data reduction will be presented in forthcoming paper.

It can be seen from Figure 1 that 2014-16 dimming of RW Aur A occurred in all spectral bands from $U$ to $K$. The larger wavelength the smaller an amplitude $\Delta m$ of the dimming: if values $V = 10.5^m$ \cite{7}, $K = 7.2^m$ \cite{15} are adopted as an average values before 2010, then $\Delta V \approx 4.6^m$, $\Delta K \approx 2.8^m$. Minimal brightness was reached near the end of 2015 and then there was a period of almost constant brightness (plateau), which was shorter in NIR band than in optical one.

As follows from Figure 2 a color-magnitude diagramm of the star during 2014-16 dimming is similar to that of so called UXORs \cite{6}: initially RW Aur A becomes redder when it fades, but at $V \geq 13.5^m$ its colors become bluer when the star dims further. Note that colors during engress are redder than during ingress.

Optical ($UBVRI$) radiation of the star during 2010-11 and 2014-16 dimmings was strongly linearly polarized as in the case of UXORs \cite{6}. The degree of polarization increases when the star fades and rises with wavelength: at the plateau phase it reached 30% in $I$ band (see Figure 3), but was < 1% before 2010 \cite{17}. Position angle of polarization during both dimmings was parallel to that of major axis of RW Aur A’s disk, while radiation transfer modelling of protoplanetary disks predicts that they should be perpendicular \cite{9}.

\cite{15} observed increase of the 3-5 $\mu$m flux of RW Aur at the beginning of 2014-2016 dimming at wavelength $\lambda \leq 2.2$ $\mu$m. We report that brightness of the star returned back to pre-dimming level in both these spectral bands by the end of summer 2016.

We found from our spectra that equivalent width of iron emission lines increased only in a few times when observed continuum flux decreased dozens of times. Note also that profiles of these lines during ingress and plateau phases of 2014-16 dimming were asymmetric: their redward part was stronger than blue one.

Our results confirm that both dimming events were due to eclipse of RW Aur A by dust cloud, grains of which produce selective absorption. In some respects the behavior of the star reminds that of UXORs, but duration and amplitude of 2014-16 eclipse are
Рис. 1: $UBVRcIcJHK$ light curves of RW Aur A during the second dimming event. Filled triangles – resolved measurements of the binary, open circles – non-resolved data corrected for average contribution of RW Aur B.
Рис. 2: Color-magnitude diagramm of RW Aur A during 2014-2016 dimming. Filled triangles refer to ingress and plateau phases, open circles – to egress phase. Cross and solid circle represent data before 2010: non-resolved photometry of [7] and resolved photometry of [18], respectively.

Рис. 3: Polarization in $V$, $R_c$ and $I_c$ bands vs $V$-magnitude. Filled squares – resolved polarimetry of RW Aur A during the second dimming, open squares – unresolved polarimetry of both components during the first dimming with subtracted contribution of RW Aur B.
much larger, linear polarization of light is much stronger and has another orientation. In our case dust screen eclipses not only the star, but also significant part of scattering disc and a region where iron emission lines are originated. We don’t know the nature of the dust screen (a tidal arm, dusty disk wind etc.), but its origin undoubtedly connected with tidal disturbance of RW Aur A disk by recent fly-by of the companion.

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