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Letter to the Editor

Deep transient optical fading in the WC9 Star WR 106

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Abstract. We discovered that the WR9-type star WR 106 (HDE 313643) underwent a deep episodic fading in 2000. The depth of the fading ($\Delta V \sim 2.9$ mag) surpassed those of all known similar "eclipse-like" fadings in WR stars. This fading episode was likely to be produced by a line-of-sight episodic dust formation rather than a periodic enhancement of dust production in the WR-star wind during the passage of the companion star though an elliptical orbit. The overall 2000 episode was composed of at least two distinct fadings. These individual fadings seem to more support that the initial dust formation triggered a second dust formation, or that the two independent dust formations occurred by the same triggering mechanism rather than a stepwise dust formation. We also discuss on phenomenological similarity of the present fading with the double fading of R CrB observed in 1999–2000.

Key words. stars: individual: WR 106 – stars: variables – stars: winds, outflows – stars: Wolf–Rayet

1. Introduction

Wolf–Rayet (WR) stars are massive, luminous stars which have blown away the hydrogen envelope, and are considered to be immediate precursors of some kinds of supernovae. WCL-type stars are a carbon-rich, late-type subclass of WR stars (for the definition of the subclasses of WC-type stars, see e.g. Smith & Shara 1990); more comprehensive information of WR stars can be found in the catalogue by van der Hucht (2001). WC9-type stars are the coolest WCL-type stars which are characterized by strong CIII and CII lines, and the weak or absent OV feature (Torres & Conti 1984). WC9-type stars have been receiving much astrophysical attention in that they are one of the most effectively dust-producing environments in stellar systems (for recent reviews, see Williams 1995, 1997).

The dust-forming process in WCL-type (especially in WC9-type) stars is known to be either continuous or episodic. The best-known continuous dust producer is a binary WR 104 (WC9+B0.5V), renowned for its "dusty pinwheel nebula" (Tuthill et al. 1999, 2002). Recently discovered large-amplitude optical variability even suggests the presence of a continuous "dust jet" in the direction of the rotation axis (Kato et al. 2002). WR 112 (WC9+OB?) has been also suspected to have a similar dusty pinwheel (Marchenko et al. 2002).

Another class of manifestation of dust production in WCL stars is episodic optical fading (Veen et al. 1998) or episodic infrared brightening (Williams et al. 1990), which are considered to arise from temporary condensations of dust clouds.

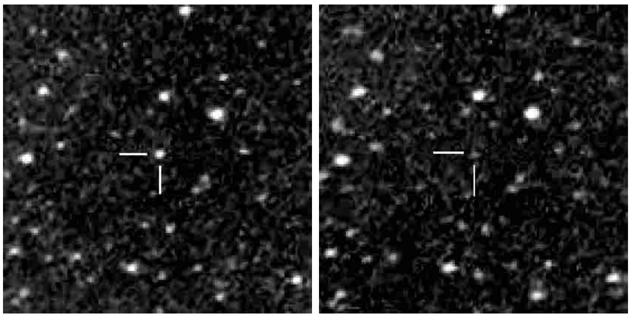

Fig. 1. Variation of WR 106 = Had V84, recorded with photographs taken by one of the authors (KH). Each panel shows 10 arcmin square, north is up and east is left. The left and right panels were taken on 2000 Aug. 22 and 2000 Apr. 28, when the object was at 12.0 mag and 14.1 mag, respectively. Such dramatic variability of a Wolf–Rayet star is quite exceptional.

In 2001 April, one of the authors (KH) serendipitously discovered a new variable star named Had V84 (vsnet-alert 5856)[1], which was subsequently identified with WR 106 = HDE 313643 (Fig. 1). WR 106 is known to show a strong infrared excess (Cohen & Vogel 1978; Cohen 1995; Kwok et al. 1997; Pitault et al. 1983), which indicates substantial dust formation. We also noticed that the object was listed as No. 15357

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[1] http://www.kusastro.kyoto-u.ac.jp/vsnet/alert5000/msg00856.html

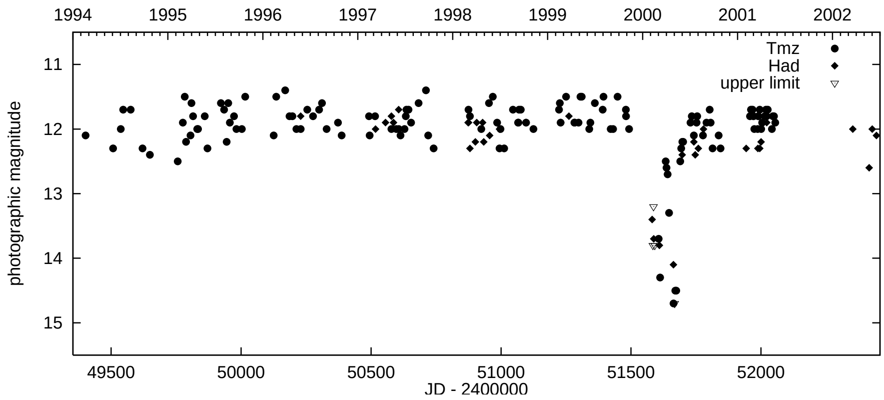

Fig. 2. Light curve of WR 106. The filled circles and squares represent observations by Takamizawa (Tmz) and Haseda (Had), respectively. The open triangles represent the upper limits. The most prominent fading was recorded in early 2000.

in FitzGerald (1973), who suspected 0.13 mag V-band variability based an analysis of past photoelectric archival data. The object was given a name for suspected variable star (NSV 10152), but the variability was not confirmed at that time.

2. Observation and results

A total of 177 observations were made between 1994 February 17 and 2002 June 18, with twin patrol cameras equipped with a $D = 10$ cm f/4.0 telephoto lens and unfiltered T-Max 400 emulsions, located at two sites in Toyohashi, Aichi (KH) and Saku, Nagano (KT). The passband of observations covers the range of 400–650 nm. Photographic photometry was performed using neighboring comparison stars, whose V-magnitudes were calibrated by T. Watanabe. The magnitudes were derived by a combination of image size and density. The overall uncertainty of the calibration and individual photometric estimates is 0.2–0.3 mag, which will not affect the following analysis. A scatter around the maximum light likely comes from statistical distribution of errors, although superposed intrinsic variations cannot be ruled out.

The resultant light curve is presented in Fig. 2. The star showed an overall range of variability of between 11.4 and fainter than 14.7 mag. Taking into measurement errors into consideration, the minimum full amplitude of the variation is 2.9 mag.

Figure 3 shows an enlarged light curve of the 2000 fading episode. This figure clearly demonstrates that the overall fading episode was composed of at least two distinct fadings. The two most prominent fadings were separated by ~55 d. In 2002 May, KH reported a marginal detection of another shallower ($\Delta V \sim 0.6$ mag).

An inspection of the available archived images at the USNOFS pixel server, 9 epochs during 1950–1996, has revealed no distinct fading of WR 106, suggesting that fadings are rather rare.

3. Discussion

WR 106 was studied for binarity by Williams & van der Hucht (2000). The lack of evidence for a companion and the apparent lack of photometric periodicity (Fig. 2) less favor the

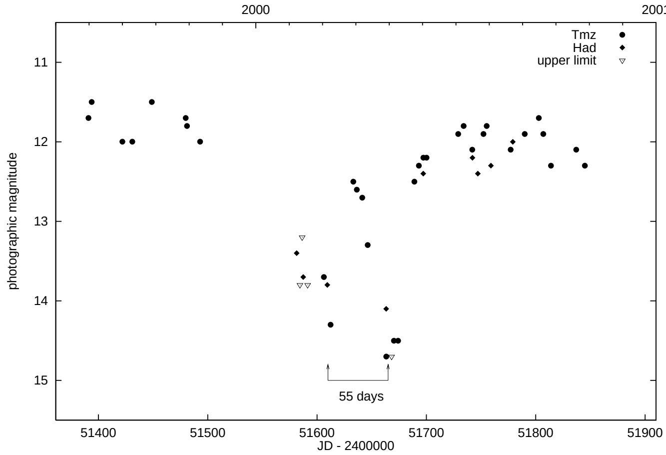

Fig. 3. Enlarged light curve of the 2000 fading episode. The episode is composed of at least two fadings. The two most prominent fadings was separated by ~55 d.

interpretation of a periodic enhancement of dust production in the WR-star wind during the passage of the companion star though an elliptical orbit, as has been proposed in WR 140 (Williams et al. 1990) and presumably WR 137 (Williams et al. 2001).

The present phenomenon seems to be better understood as an "eclipse-like", line-of-sight dust formation as proposed by Veen et al. (1998). The depth of the present phenomenon, however, far surpasses those (up to 1.2 mag in visual wavelengths) of the previously known similar phenomena in other stars. Following the interpretation by Veen et al. (1998), the production rate of the optical depth or the dust production rate in the present episode should be at least a few times larger than in the previously recorded phenomena. Furthermore, the observed depth severely constrains the amount of the unobscured scattered light to be less than 7%.

The present phenomenon is composed of at least two distinct fadings (Fig. 3). Veen et al. (1998) reported the presence of two-step fadings in some fadings. Veen et al. (1998) suggested several possibilities to explain the two-step fadings: (1) sudden enhancement of the dust production in response to an inflow of additional matter to the dust production area,

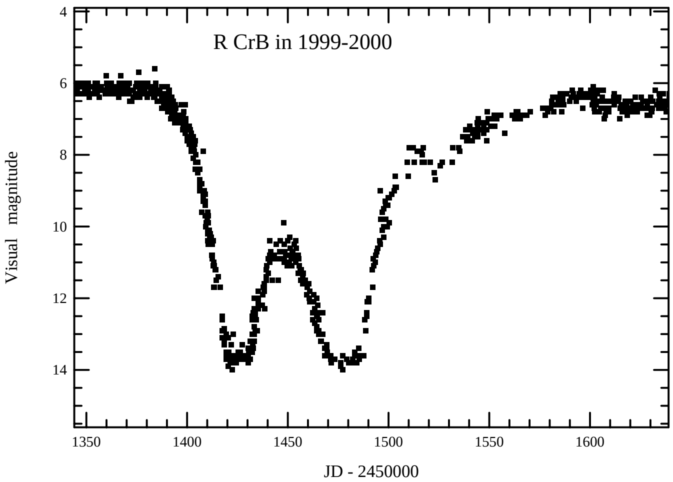

Fig. 4. Light curve of the "double fading" of R CrB in 1999–2000. The data are from VSNET.

(2) non-radial expansion of a neighboring cloud, or (3) formation of the second cloud in the shade of the first cloud. In the present case, the close occurrence of two rare fadings suggests that they are not a chance superposition of two independent phenomena, but are more physically related. The similar observed depths and durations of the two fadings do not seem to support a stepwise formation of the dust cloud, as represented by the possibilities (1) and (3). The present observation seems to more support that the initial dust formation somehow triggered a second dust formation in the proximity, or that the two independent dust formations occurred by the same triggering mechanism.

We also note phenomenological similarity of the present fading with the "double fading" of R CrB observed in 1999–2000 (Fig. 4, the data are from VSNET[2]). The fading mechanism proposed by Veen et al. (1998) being analogous to the fading mechanism of R CrB stars (for a review, see Clayton 1996), the analogy may suggest a common underlying dust production mechanism between R CrB stars and WR 106. Similar double fadings are also known in some [WC] stars (CPD−56°8032 = He3–1333 = V837 Ara: Pollacco et al. 1977; V348 Sgr: Heck et al. 1985), which are sometimes considered to be related to R CrB-type stars. It is widely believed that the dust formation in R CrB stars are associated with pulsation (Clayton 1996). Although the large difference of the gravity and temperature between WR stars and R CrB stars may make it difficult to directly apply the R CrB-type dust formation to a WR star, a pulsation-type instability similar to that of R CrB stars in the outer WR wind may have caused a similar sequence of fadings in a WR star.

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[2] `http://www.kusastro.kyoto-u.ac.jp/vsnet/`