New powerful outburst of the unusual young star V1318 Cygni S (LkH α 225)[★]

T. Yu. Magakian, T. A. Movsessian, H. R. Andreasyan, and M. H. Gevorgyan

Byurakan Observatory NAS Armenia, Byurakan, Aragatsotn Prov. 0213, Armenia
e-mail: tigmag@sci.am

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ABSTRACT

Aims. Young double star V1318 Cyg, which is associated with a small isolated star-forming region around HAeBe star BD+40°4124, has very unusual photometric and spectral behavior. We present results of photometric and spectroscopic observations in the optical range.

Methods. We carried out BVRI CCD photometric observations of V1318 Cyg from 2015 Sept. to 2017 July. For the same period we acquired medium- and low-resolution spectra. Observations were performed with the 2.6 m telescope of the Byurakan observatory. We also analyzed the images of this field in IPHAS and other surveys.

Results. We analyze the historical light curve for V1318 Cyg and demonstrate that the southern component, V1318 Cyg S, after being rather bright in the 1970s ($V \sim 14$ mag) started to lower its brightness and in 1990 became practically invisible in the optical. After its reappearance in the second half of the 1990s the star started to become very slowly brighter. Between 2006 and 2010 V1318 Cyg S started brightening more quickly, and in 2015 had become brighter by more than five magnitudes in visible light. Since this time V1318 Cyg S has remained at this maximum. Its spectrum shows little variability and consists of a mixture of emission and absorption lines, which has allowed for estimates of its spectral type as early Ae, with obvious evidence of matter outflow. We derive its current $A_V \approx 7.2$ and $L = 750 L_\odot$ thus confirming that V1318 Cyg S should belong to the Herbig Ae stars, making it, along with BD+40°4124 and V1686 Cyg, the third luminous young star in the group. It is very probable that we observe V1318 Cyg S near the pole and that the inclination of its dense and slow ($\approx 100 \text{ km s}^{-1}$) outflow is low.

Conclusions. The unusual variability and other features of V1318 Cyg S make it difficult to classify this star among known types of eruptive young stars. It could be an extreme, higher-mass example of an EXor, or an object of intermediate class between EXors and FUors, like V1647 Ori.

Key words. stars: pre-main sequence – stars: variables: T Tauri, Herbig Ae/Be – stars: individual: V1318 Cyg S

1. Introduction

In 1960 George Herbig published his classic paper about the Ae/Be stars connected with nebulae (lately designated as HAeBe stars; Herbig 1960), which were suggested to represent the more massive and luminous young stellar objects in comparison to T Tauri stars. Among them he listed the bright BD+40°4124 star, surrounded by several stellar objects with fainter emission lines. One of them was designated as LkH α 225. Only H α emission lines of moderate intensity were found in its medium-resolution spectrum. A general view of this group is presented in Fig. 1.

This star attracted further attention when significant variability was found (Romano 1967, 1969; Wenzel 1972). As a variable star it received V1318 Cyg designation. At the same time, the area around BD+40°4124 was recognized as a star-forming region, where several bright IR sources were discovered. Among them, LkH α 225 was also listed (Strom et al. 1972). This object demonstrated prominent variability even in K band (Allen 1973).

It is nearly impossible to draw certain conclusions about the photometric behavior of V1318 Cyg from early brightness estimations, as was pointed out by Wenzel (1980). Usually the object demonstrated erratic variations around $V = 17.0$, with occasional brightening up to 2^m (Wenzel 1972). One cannot exclude

the longer period of high brightness in the 1950s, as such a level can be seen on POSS-I plate (1953) (Fig. 2a) and on the plate shown in Herbig (1960) obtained in 1956. In both cases LkH α 225 is equal in brightness to or brighter than nearby LkH α 224.

In the 1980s, studies of the variability of V1318 Cyg continued in a more organized way, including systematic electrophotometric observations (Ibragimov et al. 1988; Shevchenko et al. 1991, 1993). It was shown that the star fluctuated near a certain mean brightness level, sometimes demonstrating deep minima. The mean level itself was slowly decreasing from year to year, and in 1987–1988 the star brightness was always lower than $V = 17$ (Shevchenko et al. 1991).

Even in the DSS-I images one can see that the shape of LkH α 225 is slightly elongated in the north–south (N–S) direction (Fig. 2a). However, the probable duplicity of this object was mentioned for the first time only by Ibragimov et al. (1988). After the deep decline in brightness, the study of the inner structure of LkH α 225 became easier. As was shown by Aspin et al. (1994), the object actually consists of two stars – V1318 Cyg N and V1318 Cyg S – and a nebulous knot between them, all placed in the N–S direction, with a total separation of $5''$. This discovery immediately raised a question about the role of both components in the high-amplitude variations of visible brightness. Below we consider this point in detail.

Spectral data presented by Hillenbrand et al. (1995) and Magakyan & Movsesyan (1997) confirmed that both objects

[★] The reduced spectra are only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/625/A13>

Fig. 1. Direct image of the BD+40°4124 region in POSS-1 red plate (14.06.1953), taken from SuperCOSMOS sky survey.

belong to the young stars of A-F spectral type with specific emissions, including prominent forbidden lines produced by Herbig–Haro type outflow, which was found by Magakyan & Movsesyan (1997). Pronounced differences between the spectra of V1318 Cyg S in maximal and minimal brightness levels were pointed out in the same study.

2. Observations and data reduction

We restarted our observations of V1318 Cyg in 2015, after the end of the refurbishing works on the 2.6 m telescope at the Byurakan observatory. The SCORPIO spectral camera in the prime focus (Afanasiev & Moiseev 2005) was used to obtain both direct images and long-slit spectra. It was equipped with TK SI-003A 1044 × 1044 CCD matrix and after 2016 August with E2V CCD42-40 2080 × 2048 CCD matrix.

The field of view in the imagery mode was 11.5′ (with 0.68″ pix^{−1}) and 13′ (with 0.38″ pix^{−1}) with TK and EEV detectors, respectively. Direct CCD images were obtained in *BVR* bands, usually with two or three exposures for each color. The seeing was 2.5–3″.

In the long-slit mode the width of the slit was 1.5″ and the length was about 5′. As dispersive elements, the grism with 600 g mm^{−1} as well as two grisms equipped with volume phase holographic gratings with 1200 and 1800 g mm^{−1} were used. For the calibration of wavelengths the comparison spectra of Ne+Ar lamp were used. In the time period from 2015 Sept. to 2016 Dec. fourteen spectra were obtained. A full log of the spectral observations is presented in Table 1. Exposure times were selected to provide a signal-to-noise ratio of about 50–100 in the final spectra after the processing and optimal extraction.

The direct images were processed in the standard way; after that the aperture photometry of stars was performed with the aid of the ESO-MIDAS system. For the data calibration we used several stars in the field, covering various magnitude ranges to avoid the effects of saturation. Stars were selected from the papers of Hillenbrand et al. (1995) and Shevchenko et al. (1991), and in

Fig. 2. Enlarged direct images of V1318 Cyg field. (a): POSS-1 red plate (14.06.1953), SuperCOSMOS sky survey. (b): Quick-V plate (3.09.1983), STScI digitized sky survey. (c): POSS-2 red plate (29.06.1992), SuperCOSMOS sky survey. (d): IPHAS survey image in *R* band (11.10.2006), objects discussed here are marked by arrows. (e): ZTA-2.6 image in *R* band (22.09.2015). BD+40°4124 is hidden under the bright reflection nebula in the upper-right corner of all images.

some cases also the magnitudes from USNO-B1 catalogue were used. A special comparison confirmed that the magnitudes of calibration stars had good internal consistency. For each date the brightness of the objects was estimated separately for all exposures, after which results were averaged to obtain mean magnitudes. Typical internal scatter of results is 0^m005–0^m01, and typical errors of final estimates are about 0^m02–0^m03. In several cases, especially for *I* band, we excluded from the calibration partially saturated images of standard stars; this raised errors up to 0^m07–0^m08.

The processing of spectral data was done with the ESO-MIDAS system, following the classical procedures of long-slit spectrophotometry. All data in the paper are presented either in arbitrary flux units or are normalized to the continuum.

3. Results

3.1. Photometric history and the new outburst of V1318 Cyg

As mentioned above, at the end of the 1980s the total visible brightness of V1318 Cyg started descending and at the beginning of the 1990s its visible brightness fell rapidly. This fading can be seen very well in Fig. 14 of Herbst & Shevchenko (1999). The question regarding which of the stars in the pair is responsible for such high-amplitude variations can be solved by comparison of the images of the object on DSS-1 and DSS-2 plates (see Fig. 2a and c), and the data of Aspin et al. (1994). Obvious differences in morphology even on half-resolved survey images point to the significant variability of V1318 Cyg S. Its low brightness in the 1990s, confirmed by observations of Hillenbrand et al. (1995) and Magakyan & Movsesyan (1997), allowed for photometric and spectral observations to be performed for both stars separately. In particular, the brightness of both stars was estimated by Hillenbrand et al. (1995) as $V = 18.58$, $R_c = 16.88$, $I_c = 15.41$ (V1318 Cyg N) and $V = 19.17$;

Table 1. Log of the V1318 Cyg spectral observations.

Date	Spectral range (in Å)	Resolution ($\lambda/\Delta\lambda$)	Total exposure (min)	Label
22.09.2015	5880–6740	2500	60	A
18.11.2015	5785–7315	1500	60	B
22.11.2015	5785–7315	1500	60	C
16.05.2016	5880–6880	2500	30	D
10.06.2016	5890–6795	2500	40	E
08.08.2016	5780–7300	1500	30	F
23.08.2016	4120–6810	800	60	G
24.08.2016	5895–6795	2500	40	H
29.08.2016	4070–7055	800	20	I
30.08.2016	5870–6875	2500	40	J
06.11.2016	5695–7360	1500	45	K
28.11.2016	4025–6995	800	30	L
20.12.2016	4025–6995	800	45	M
21.12.2016	5850–6850	2500	30	N

Notes. Spectra A–H were acquired with TK SI-003A CCD matrix, and spectra I–N with E2V CCD42-40 matrix.

$R_c = 17.34$; $I_c = 15.68$: (V1318 Cyg S). This corresponds to an integral brightness of the double star of about $V = 18.1$. Such a value is in good compliance with the measurements of [Shevchenko et al. \(1991\)](#) for 1987–1988, which in turn means that by the end of the 1980s V1318 Cyg S has possibly reached a minimal level of brightness.

One cannot exclude the variability of V1318 Cyg N however, and indeed the extreme faintness of V1318 Cyg in the falls of 1995 ($V \approx 21$) and 1997 ($V \approx 24$), according to the estimates of [Herbst & Shevchenko \(1999\)](#) is evidence supporting this statement.

Beginning new observations of V1318 Cyg field in 2015 September, we immediately found that the star underwent a new powerful outburst and its brightness reached the level of the 1960s or even higher (Fig. 2e). The position of the photometric peak of the image was pointing to V1318 Cyg S as the outbursting star. The faint northern star was lost in its glare in our very short (to avoid saturation effects) exposures.

To find precise coordinates of both stars we consulted the *Gaia* DR2 catalogue ([Gaia Collaboration 2016, 2018](#)), where both V1318 Cyg N and V1318 Cyg S stars are resolved and listed (DR1 did not include these objects). We performed the astrometric calibration of our images, obtained within the years of 2015–2017, with the aid of the *astrometry.net* system ([Lang et al. 2010](#)), and measured the position of the outbursting star. All images demonstrated very good internal agreement and the dispersion of stellar position was $\approx 0.27''$ (which is about half a pixel) in both coordinates, for V and I colors. Our coordinates agree with the *Gaia* DR2 position of the V1318 Cyg S star within $0.3''$. *Gaia* DR2 photometry also confirmed the outburst of the southern star: G magnitudes are 13.23 for the southern star and 18.92 for the northern star, that is, they currently differ in brightness by about 6^m .

Though we have found on our exposures the faint trace of V1318 Cyg N near the northern edge of the bright southern star, it was not possible to resolve both objects to measure them separately. Therefore, the photometry presented below is related to both stars and the nebula between. Photometric data are presented in Table 2. Their errors do not exceed 0^m02 – 0^m03 , as was already noted above; if errors are higher (up to 0^m08), values are marked with “.”. In any case, taking into account the *Gaia* magnitude for V1318 Cyg N, it is easy to estimate that its contamination affects the values in Table 2 no more than 0^m01 .

Table 2. V1318 Cyg (LkH α 225) photometry.

Date	B	V	R	I
22.09.2015	16.95	14.61	12.53	11.06
18.11.2015	17.18	14.76	12.72	11.16
31.03.2016	17.38	14.98	12.95	11.20:
10.06.2016	16.78	14.40	12.43:	10.85:
23.08.2016	16.77	14.38	12.49	10.96:
20.12.2016	16.81	14.46	12.59	10.92
20.07.2017	17.48	15.03	13.12	11.29

As can be seen from our photometric data, the star presently remains at an almost constant level of brightness. To find an answer to the immediate question of when this new large-amplitude increase of the brightness of V1318 Cyg S started, we checked various surveys and found the images of IPHAS survey ([Drew et al. 2006](#)), obtained from 2003 to 2006, where both stars are resolved and V1318 Cyg S in R band is already brighter than V1318 Cyg N by at least one magnitude. We performed photometry for both stars using all suitable IPHAS images. Because of the relative faintness of the stars, the influence of the central nebular knot (Fig. 2d) on the photometric results was significant. This fact as well as the varying quality of IPHAS exposures led to significant measurement errors, reaching several tenths of a magnitude. We tried to minimize these errors as much as possible, and present the best of our estimates in Table 3.

These data, when we compare them with the measurements of [Hillenbrand et al. \(1995\)](#), lead us to two important conclusions. On the one hand, V1318 Cyg N became about two magnitudes fainter in comparison with 1993 Jan. This confirms the appreciable variability of the northern star. On the other hand, we see that the brightness of V1318 Cyg S in 2003–2006 also is lower than in 1993 Jan by several tenths of a magnitude. This means that after the great minimum of the second half of the 1990s its level of brightness was restored to the values observed at the end of the 1980s, and until the end of 2006 there was no further increase.

The V1318 Cyg field was also observed on 2003 Sept. 20 in the SDSS survey – see Data Release 12 ([Alam et al. 2015](#)). We do not show this image here, because the appearance of the object does not significantly differ from IPHAS images. SDSS

Table 3. V1318 Cyg S and V1318 Cyg N brightness on the IPHAS images.

Date	<i>R</i>	<i>I</i>
V1318 Cyg S		
09.08.2003	17.66	16.45
10.08.2003	17.67	16.45
18.10.2003	18.01	16.04
08.08.2004	17.72	16.23
11.10.2006	17.86	15.94
V1318 Cyg N		
09.08.2003	18.48	17.44
18.10.2003	19.17	17.58
08.08.2004	18.93	18.02
11.10.2006	18.79	17.21

photometric data related to V1318 Cyg S do not exist, since the image-recognizing program mistook the pair of stars with the middle nebula for a galaxy and integrated all their fluxes.

The most recent images of the region around BD+40°4124 that precede our new observations are available in the Pan-STARRS1 data archive (Chambers et al. 2016). They show both the N and S stars resolved, and V1318 Cyg S seems definitely brighter than in IPHAS images. In view of the “stacked” nature of DR1 images (i.e., they represent co-added images made from the multiple exposures taken over the survey), only the mean epoch of observations for V1318 Cyg (May 2012) was given. But while the current paper was in preparation, the new data release (DR2) of the Pan-STARRS survey became available, which contains the separate images of this area, and the dates of observations span 2010 Aug.–2014 Oct. Analyzing these images, we found that even in 2010 the star V1318 Cyg S was brighter than on SDSS images of 2003, and a further perceptible increase in its brightness took place in the middle of 2013. Photometric estimates (magnitudes in *grizy* bands) provided by Pan-STARRS DR1 were converted to *BVRi* magnitudes using the transformations suggested by Jester et al. (2005), which resulted in the following values for the brightness of both stars: V1318 Cyg S – $B = 18.73$; $V = 16.38$; $R = 14.57$; $I = 12.90$; V1318 Cyg N – $B = 21.14$; $V = 19.65$; $R = 17.91$; $I = 16.30$. One can see that these R and I magnitudes are brighter than IPHAS values by more than 3^m for V1318 Cyg S and by about 1^m for V1318 Cyg N. On the other hand, they are still about 2^m lower than the present level. These estimates however should be used with some caution because as we found by comparison with other available photometric data, highly variable emission background in the central part of BD+40°4124 cloud can introduce serious systematic errors in Pan-STARRS photometry.

We placed all measurements of V1318 Cyg S on the light curve (Fig. 3). Taking all results into account, we come to the following conclusions. Somewhere between 2000 and 2003 V1318 Cyg S came out of its minimum and returned to the mean brightness level of 1988. This star then remained at the same brightness for at least three years without pronounced changes. In the time period between 2006 and 2010 the brightness of V1318 Cyg S started to raise to more than 5 mag (at an unknown speed), reaching a maximum by the second half of 2015, and remaining at this level for at least two years¹. Another long max-

Fig. 3. *BVRi* light curve of V1318 Cyg S for the period of 1991–2017. Filled symbols show our measurements for IPHAS and Byurakan images; open symbols show data of Aspin et al. (1994) and Hillenbrand et al. (1995); half-open symbols show mean estimates for the four-year period of time from PanSTARRS survey (see text); and the line bounded by asterisks shows the level in *G* magnitude and time period of observations from *Gaia* DR2.

imum possibly took place in the 1950s, but no systematic observations were performed at that time (see above). We also see that small fluctuations near the present maximum do not lead to noticeable changes of color indices of the star, in contrast with its behavior at the lower level of brightness in the 1980s (Ibragimov et al. 1988; Herbst & Shevchenko 1999).

3.2. Spectrum of V1318 Cyg S at its maximum

3.2.1. General appearance

All our spectrograms of V1318 Cyg at maximal brightness are remarkably similar and do not show any prominent changes during the 1.5 year time interval of observations. Furthermore, they resemble the star spectrum during its previous maximum in the 1970s, which was briefly described by Magakyan & Movsesyan (1997), but on the other hand noticeably differ from the spectrum at minimum brightness (Hillenbrand et al. 1995). The general appearance of the V1318 Cyg spectrum is shown in Figs. 4 and 5. Due to the difference of almost six magnitudes in brightness, the influence of V1318 Cyg N should be negligible; in any case, slit width was significantly lower than the distance between the stars. In the following discussion we consider these data as the V1318 Cyg S spectra.

One can see a very red continuum with both emission and absorption features. The only line with a complex profile is $H\alpha$. More detail is shown in Fig. 6 where we present $H\alpha$ profiles obtained from all our better-resolution spectra. To compensate small positional differences between spectra introduced by rebinning, for some of them we added slight (≤ 0.1 Å) shifts to adjust all spectra by two nearby Fe emission lines. Iron emission in T Tau and HAe/Be stars usually has low variations in radial velocity, with one being close to stellar velocity (see, e.g. Petrov & Babina 2014). As one can see, this profile has the typical appearance of rather broad (nearly 800 km s⁻¹ in total width) $H\alpha$ emission, divided by a blue-shifted, relatively narrow absorption component, which goes well down the continuum; we did not find any significant changes in its structure or in radial velocities, though the equivalent widths (EWs) of both red-shifted and blue-shifted emission components vary to some extent. Such double-peaked $H\alpha$ profiles are common in young

¹ When this paper was ready for publication, we obtained new images of the region under study, which show that V1318 Cyg S retains its brightness; thus, the duration of the maximum is already three years or even more.

Fig. 4. Low-dispersion spectrum of V1318 Cyg, obtained with the 2.6 m telescope. Main features are identified.

Fig. 5. Red part of V1318 Cyg spectrum with better dispersion. The spectrum was obtained with the 2.6 m telescope. P Cyg profile of H α line and strong NaD absorptions are prominent. Several other features, including forbidden lines, are also identified. A part of this spectrum is shown in more detail in Fig. 7.

active stars, but their central absorptions often do not reach the continuum level.

Besides the P Cyg component of the H α line, we see prominent absorptions of NaD and, in the blue part of the spectrum, strong absorptions of H β , Fe II (42), and (48), Mg I (2) as well as several weaker ones (Fig. 4; at the shorter wavelengths weakness of continuum prevents detection of any lines except for the trace of H γ absorption). These lines are typical for the early A spectral type but, having negative radial velocities (see details below), they definitely belong to the outflowing envelope of the star. In addition, we detected a prominent diffuse interstellar band (DIB) λ 6284 Å, which easily resolves from the nearby atmospheric absorption λ 6278 Å, and is among the strongest ones (Herbig 1995). In the red part of the spectrum the only undoubtedly observed metallic absorption is λ 6456 of Fe II (74); there is no convincing evidence of the existence of the famous Li I λ 6707 absorption.

In fact, with our resolution we did not detect any photospheric absorption lines, which makes the spectral type of V1318 Cyg S difficult to estimate. This question is discussed in detail in the following section.

Fig. 6. H α line in V1318 Cyg spectrum: comparison for various dates.

3.2.2. Emission lines

Virtually all emission lines in the spectrum of V1318 Cyg S in maximal brightness, covered by our spectrograms, are located in the λ 6000–7000 Å range (see Fig. 5). They can be divided in three groups: H α (the only hydrogen line with an emission component), which was described above, forbidden lines of [O I] and [S II], and a large number of low-excitation Fe I and Fe II lines.

Forbidden emissions are contaminated not only by night sky lines of [O I], but also by lines of the diffuse emission background. Lines belonging to the star itself are not especially prominent and are produced in the HH outflow originating from V1318 Cyg S or perhaps from both stars in the pair (Magakian & Movsesyan 1997). It is worth mentioning that [S II] lines are wide and probably consist of two poorly resolved components, though they do not show particularly conspicuous variations as in PV Cep (Magakian & Movsesyan 2001; but the time period, encompassed by present observations of V1318 Cyg S, is also shorter).

Nearly all other emissions in the red range of the V1318 Cyg S spectrum belong to iron, especially Fe I, which makes it similar to T Tau-type stars. We show this in more detail in Fig. 7, with matched spectra of well-known eruptive young stars PV Cep and V350 Cep, obtained in Byurakan with the same equipment on 24.08.2016 and 22.09.2015, respectively. All emission features seen in this range were identified with lines of Fe I and Fe II using the spectrum of VY Tau at maximum brightness for reference (Herbig 1990).

One can see the remarkable similarity between the spectra of both active stars, which closely resemble each other even in fine detail (though V350 Cep presumably belongs to T Tau-type with spectral type M2, while the probable spectral type of PV Cep is A5); on the other hand, V1318 Cyg S differs from its counterparts in that it has significantly lower EWs of emission lines and obviously lower excitation level. Especially spectacular is the absence of intense emissions of λ 6456.38 Å Fe II (74) (this line is actually seen in absorption) and of the strong blend of λ 6493.78 and λ 6499.65 Å Ca I (18). Beyond the range shown in Fig. 7, the spectra of the three stars completely differ: for example, both V350 Cep and PV Cep demonstrate rich emission spectra also at shorter wavelengths.

Fig. 7. Emission lines in V1318 Cyg, PV Cep and V350 Cep: comparison. All main features are identified; lines, marked only by arrows, belong to Fe I.

3.2.3. Equivalent widths and radial velocities

Estimations of EWs of selected emission and absorption lines were performed using the best 12 spectra from our data set. In Table 4 we present their averaged values, taking into account that the spectrum of V1318 Cyg S at maximal brightness has not significantly changed in two years. Especially noteworthy is the almost constant strength of the NaD doublet, which is the most intense absorption in the star spectrum. Significant variations of intensities (which can also be seen from the standard deviations from Table 4) were only detected in the components of the H α line: their EWs were changing in the range of 4–10 Å (emission) and 1–3 Å (absorption).

In general the strength of emission spectrum of V1318 Cyg S is not high. For comparison we present in Table 4 the EW values for typical lines in the spectra of PV Cep and V350 Cep, shown also in Fig. 7. As one can see, they vastly exceed those of V1318 Cyg S.

We also estimated the heliocentric radial velocities of strong and well-defined lines in the V1318 Cyg S spectrum, separately measuring emission and absorption components of Balmer lines, the NaD pair, the forbidden lines of [OI] and [S II], the four strongest Fe II lines and λ 5183 Mg I, observed in absorption in the blue range, and λ 6456 Fe II observed in red range, as well as selected unblended emissions of Fe I (λ 6137, 6191, 6393, 6400) and Fe II (λ 6432, 6516). We would like to mention that for the measurements of lines in the red range we used 0.80 and 0.50 Å pix⁻¹ resolution spectra; on the other hand, we had only 1.50 Å pix⁻¹ spectra to measure H β and metallic absorptions in the blue spectral range. Radial velocities, averaged over all available measurements, are collected in Table 5. Standard deviations of mean radial velocities of hydrogen lines are clearly larger than observational errors (which are about 15–20 km s⁻¹), definitely confirming some variations in time. However, within the accuracy of our data we did not find any reliable trends in such variations. We further discuss radial velocities in the following section.

4. Discussion and conclusions

Starting from the paper of Aspin et al. (1994), V1318 Cyg S was considered a luminous ($L_{\text{bol}} \approx 1600 L_{\odot}$) and strongly reddened object. However, all these estimates are based on the studies in infrared and sub-millimeter range (Palla et al. 1995;

Table 4. Equivalent widths of selected V1318 Cyg S spectral lines.

Line	EW, Å	Spectra ^(a)	PV Cep ^(b)	V350 Cep ^(b)
λ 6731 [S II] (2F)	-0.36 ± 0.11	A-F,H,J-K		
λ 6717 [S II] (2F)	-0.25 ± 0.06	A-F,H,J-K		
H α (em)	-6.86 ± 1.50	A-F,H,J-K		
H α (abs)	1.91 ± 0.61	A-F,H,J-K		
λ 6517 Fe II (40)	-0.55 ± 0.13	A-F,H,J-K	-2.34	-1.23
λ 6456 Fe II (74)	0.43 ± 0.14	A-F,H,J-K		
λ 6430 Fe I (62)	-0.72 ± 0.10	A-F,H,J-K	-1.99	-1.27
λ 6300 [O I] (1F)	-1.28 ± 0.20	A-F,H,J-K	-5.26	-3.92
λ 6278 DIB	0.64 ± 0.10	A-F,H,J-K		
λ 6137 Fe I (207)	-0.69 ± 0.08	A-F,H,J-K	-1.69	-1.61
Na D	8.44 ± 0.23	B-C,F-G,J-M		
λ 5018 Fe II (42)	2.47 ± 0.07	G,L-M		
λ 4923 Fe II (42)	1.89 ± 0.18	G,L-M		
H β	4.26 ± 0.38	G,L-M		

Notes. EW values of emission lines are negative. ^(a)Spectra, used for averaging, are indicated by letters, which correspond to the Table 1. ^(b)PV Cep was observed at 24.08.2016 and V350 Cep at 22.09.2015.

Table 5. Mean heliocentric radial velocities of V1318 Cyg S spectral lines.

Line	V_R km s ⁻¹	Dates ^(a)
H α (em)	$+107 \pm 30$	A,D,E,H,J,K,N
H α (abs)	-150 ± 29	A,D,E,H,J,K,N
Na D (abs)	-81 ± 16	J,K,N
H β (abs)	-90 ± 41	I,L,M
Fe II, Mg I (abs, blue range)	-45 ± 23	I,L,M
Fe II (abs, red range) ^(b)	-68 ± 32	A,E,H,J,N
Fe I (em)	-14 ± 17	A,E,H,J,N
Fe II (em)	-21 ± 22	A,E,H,J,N
λ 6300 [O I] (em)	-89 ± 22	A,D,E,H,J,K,N
[S II] (em)	-127 ± 20	A,D,E,H,J

Notes. ^(a)Spectra used for measurement and averaging are indicated by letters, which are the same as in Table 1. ^(b)Only λ 6456 Fe II (74) line.

van den Ancker et al. 2000). On the other hand, spectral classification of HAeBe stars may encounter problems, which can lead to serious discrepancies in spectral types (see Hernández et al. 2004, for detailed discussion).

Comparing the optical spectra of V1318 Cyg S during the period of maximal brightness with spectral atlases and surveys of HAeBe stars, we found that in the blue spectral range well noticeable Fe II (42) absorptions and several other features make its spectrum remarkably similar to that of XY Per Herbig Ae star (A5), shown in the atlas of Gray (2009), as well as to such HAeBe stars as UX Ori (A3) (Hernández et al. 2004) and RR Tau (A0) near the maximum (Cohen & Kuhl 1979; Rodgers et al. 2002) (spectral classes are given according to work of Hernández et al. 2004). On the other hand, typical HAeBe stars have more prominent broad absorption wings of Balmer lines, and certain details, especially the powerful NaD absorptions, seem to contradict the early spectral type. However, such “anomalous” (Hernández et al. 2004) NaD and Fe II absorption features in some HAeBe stars have a non-photospheric origin, being caused by material surrounding the star. In the case of V1318 Cyg S, high negative radial velocities of these lines (see Table 5) confirm their formation in the envelope or in the dense stellar wind.

Assuming that V1318 Cyg S indeed belongs to HAeBe stars, it should be noted that given the strength of spectral lines it is

not similar to the majority of these stars. Comparing equivalent widths from Table 4 and corresponding values from Table 8 from the study of [Hernández et al. \(2004\)](#), one can see that the greatest resemblance (both in strength of Fe II absorptions and weakness of H α emission) to V1318 Cyg S demonstrate XY Per, UX Ori, RR Tau, BF Ori and LkH α 208 stars. As one can see, all these stars belong to the group of so-called UX Ori-type variable stars (UXors). We return to this topic below.

On the other hand, emission lines in the red part of the spectral range and strong NaD absorption make V1318 Cyg S somewhat similar to T Tau-type stars, though there is no evidence for a later-type spectrum, at least at maximal brightness. In fact, the observed combination of Fe absorption in the blue spectral range and Fe emissions in the red is quite unusual. The key to the problem could be the difference between their radial velocities (Table 5). Taking into account the heliocentric velocity of the BD+40°4124 molecular cloud (-9 km s^{-1} ; [Loren 1977](#)), one can see that low radial velocities of Fe emissions (which very probably originate near the stellar surface) are close to this value. In fact, it is reasonable to consider their mean value of -18 km s^{-1} as the systemic radial velocity of V1318 Cyg S. Consequently, the higher negative values from Table 5 will correspond to the speed of various layers of the expanding envelope and collimated outflow.

The existence and features of the matter outflow near V1318 Cyg S were studied in detail in the optical ([Magakyan & Movsesyan 1997](#)), the infrared, the sub-mm ([van den Ancker et al. 2000](#); [Davies et al. 2001](#); [Looney et al. 2006](#); [Sandell et al. 2012](#)), and in radio ([Palla et al. 1995](#); [Matthews et al. 2007](#)). All studies of CO emission confirm the existence of a molecular outflow, oriented close to the line of sight, though there is ambiguity about its possible source: it could be V1318 Cyg S ([Matthews et al. 2007](#)) or could be heavily embedded and non-detectable in the optical range protostar located nearby ([Looney et al. 2006](#)). In any case, the presence of high-velocity wind from V1318 Cyg S itself is obvious in view of many shock-excited spectral lines detected in optical ([Magakyan & Movsesyan 1997](#)) and infrared ([van den Ancker et al. 2000](#)) ranges. One can assume that V1318 Cyg S, like a great number of HAeBe and T Tau stars, is driving a more or less collimated outflow, creating Herbig-Haro-type emission in its vicinities. Indeed, forbidden emissions in the nebula between both stars have radial velocities of about -80 km s^{-1} ([Magakyan & Movsesyan 1997](#)), which agrees well with results from Table 5 (one should keep in mind that other measurements from this latter paper refer in fact to V1318 Cyg N, because the southern star was very faint during that period). Absence of [N II] lines and moderate equivalent widths of outflow emissions point to the low excitation level, corresponding to a shock velocity about 100 km s^{-1} or lower. Low inclination of the V1318 Cyg S flow to the line of sight is also corroborated by the shape of stellar H α line profile: as is shown by [Kurosawa et al. \(2006\)](#), such kinds of profiles (Type III-B by the classification of [Reipurth et al. 1996](#)) require slow accelerating wind viewed near pole-on. The significant equivalent width of blue-shifted absorption lines, which presumably arise in dense wind or/and envelope, should also be taken into account.

Independent evidence for a near pole-on orientation of V1318 Cyg S is provided by a high-resolution polarization map obtained by [Perrin et al. \(2004\)](#), showing low polarization at the position of V1318 Cyg S and the centrosymmetric pattern of polarization vectors around it, without any traces of a circumstellar dust disk.

To understand the main parameters of the star we should first of all find the amount of interstellar extinction toward V1318 Cyg S

as well as toward two other more massive members of this small association, namely BD+40°4124 and V1686 Cyg (LkH α 224). However, up to now almost all such estimates have been indirect and uncertain. For example, analysis of the molecular emissions in the infrared and radio ranges resulted in improbably high values of A_V of 25 ([Aspin et al. 1994](#)) and even 50 ([Palla et al. 1995](#)), which contradict the direct visibility of V1318 Cyg S in the optical range. The estimation of $A_V = 10$, based on the approximation of the spectral energy distribution ([Aspin et al. 1994](#)) is more reliable. In the same way, [Hillenbrand et al. \(1995\)](#) estimated $A_V > 8$ and $A_V > 7$ for V1318 Cyg S and V1318 Cyg N, respectively. However, in the same work the extinction values for the brightest stars were calculated in a straightforward way on the basis of established spectral types and previously observed ($B - V$) colors. These latter authors found $A_V = 3.6 - 3.8$ for BD+40°4124 and $4.2 - 6.7$ for V1686 Cyg, that is, much lower values. In the same way, the value of $A_V = 3.0$ for these stars was obtained in the comprehensive paper of [van den Ancker et al. \(2000\)](#); but for V1318 Cyg S they get $A_V = 15.4$, again based on the analysis of the features in the infrared spectrum.

Presently, while V1318 Cyg S remains at a stable maximum, its spectral type could be more or less reliably assigned as early A. Furthermore, since the current colors are well determined, we can directly derive A_V . We computed mean ($B - V$) and ($R - I$) from Table 2 and compared them with intrinsic colors of A2V and A5V stars from the tables of [Johnson et al. \(1963\)](#) and [Johnson \(1966\)](#), following the procedure and corrections described by [Hillenbrand et al. \(1995\)](#). As a result we derived $A_V = 7.22$ (for A2V star) or 7.00 (for A5V star) using ($B - V$), and 7.57 or 7.38 , respectively, using ($R - I$). The excellent agreement of these values however contradicts the larger estimates listed above. It is possible to assume that after prominent brightening, some amount of absorbing dust was cleared from the line of view. Thus, it will be interesting to repeat the observations of the object in the infrared range and to compare them with previous data.

Gaia project DR2 allows for reliable estimates to be made of the V1318 Cyg group distance. Indeed, one should assume that at least BD+40°4124, the brightest star in this small cluster, V1686 Cyg, and both stars of V1318 Cyg are close neighbors in space. The trigonometric parallax of BD+40°4124, taken from *Gaia* DR2, is $1.092 \pm 0.031 \text{ mas}$, which corresponds to a distance of 916 pc . V1686 Cyg, as well as V1318 Cyg S and V1318 Cyg N, were also detected and measured by *Gaia*, but with errors one order higher, probably due to their relative faintness. For completeness we list these data here: 0.785 ± 0.122 , 1.393 ± 0.292 , and $1.490 \pm 0.735 \text{ mas}$, respectively. It seems reasonable to use the value of 920 pc for the distance of the group, which is also in excellent agreement with the value of 980 pc estimated by [Shevchenko et al. \(1991\)](#) and used by other researchers. With $\bar{V} = 14.66$, $A_V = 7.2$, and this new distance, one can derive for V1318 Cyg S at maximum $M_V = -2.36$ and $L = 750 L_\odot$ in the optical range. This value, though naturally higher, agrees reasonably well with $590 L_\odot$ estimated by [van den Ancker et al. \(2000\)](#), and confirms that V1318 Cyg S should be a sufficiently massive YSO. The value of bolometric luminosity is of course at least two times larger according to the previous estimates.

It is not easy to attribute V1318 Cyg S to one of the known types of erupting medium-mass young stars. Let us discuss the existing options.

FUor-type star. FUors and FUor-like stars are very rare. Their specific features are now well-defined, being described in recent reviews ([Audard et al. 2014](#); [Connelley & Reipurth 2018](#)). The star V1318 Cyg S cannot be considered as a FUor,

or even an unusual one, because its spectrum in both optical and infrared range is not similar to typical FUors; besides, it is definitely a more massive object.

EXor-type star. EXors are usually considered to be lower-scale versions of FUors, but this class is loosely defined and probably not homogeneous (Audard et al. 2014; Lorenzetti et al. 2012). The light curve of V1318 Cyg S bears a resemblance to those of some EXors; another young eruptive star with developed FeI emission spectrum at maximum brightness is VY Tau (Herbig 1990), also an EXor. However, the high luminosity of V1318 Cyg S rules out such a classification: the luminosity of all known and probable EXors is lower by at least in one order of magnitude even in outburst.

Intermediate (V1647 Ori-like) object. This is a poorly defined and yet-to-be properly characterized class of young eruptive objects. However, they have some common features, namely they are connected with small nebulae and collimated outflows (like FUors); show outbursts with durations of several years (in between FUors and EXors); have T Tau-type spectra (like EXors); and their bolometric luminosities are moderate. In fact, V1318 Cyg S satisfies the first two criteria, and its emission spectrum shows a partial similarity to T Tau type. However, the bolometric luminosity of V1318 Cyg S cannot be considered as moderate. It could be a larger-mass member of this class (if such a class indeed exists); one should keep this option in mind.

HAeBe/UXor-type variability. We mentioned above that the intensity of the main emission and absorption lines in the V1318 Cyg S spectrum resemble those of known UXors. However, many arguments suggest that V1318 Cyg S is observed close to polar regions; thus, UXor-type occultations by clumps, moving close to the equatorial plane, are impossible. Naturally, one cannot exclude a role of another kind obscuration event in the unusual photometric behavior of V1318 Cyg S.

In any case, when considering possible explanations for the variability of V1318 Cyg S, one should take into account such features as a very large brightness amplitude in the optical range (more than 5 mag, possibly even more than 7 mag), large amplitude variations even in near-infrared, very long duration minimum (10 years or more), and pronounced spectral changes between minimum and maximum. The duration of the recent outburst, which is still in progress, should also be regarded as unusual, comparing it to previous, though incomplete photometric data for this star.

We hope that continued observations, especially collecting and analyzing high-resolution optical spectroscopic data, will shed more light on the nature of this star.

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