Polarization study of massive binaries with 1.04-m ARIES telescope

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Abstract

We present preliminary results obtained from optical (B, V, R, and I) linear polarimetric observations of an O+O massive binary DH Cep. The observations were made on six nights in 2017 with Aries IMaging POLarimeter mounted at the back of 1.04-m Aries telescope. The average intrinsic linear polarization in each of the B, V, R, and I photometric bands is found to be less than 1%. The degree of polarization as well as polarization angle appear to be binary phase dependent. The significant polarization variability noticed towards shorter wavelengths (*i.e.* B and V bands) is indicative of the asymmetric circumstellar envelope.

1. Introduction

Massive stars (O type and Wolf-Rayet stars) are hot and luminous objects which are characterized by their huge stellar winds that lead to high mass loss rates (10^{-6} to 10^{-4} $M_{\odot}$ per year). These stellar winds are dense and strongly ionized abundant in free electrons and ions. This fact opens the door to a promising way of systematically probing the wind structure of these stars, namely via the polarization of starlight. In particular, it is the free electrons that can lead to linear polarization of light through single Thomson scattering in an ionized and optically thin plasma envelope co-rotating with the star.

Most stars have a spherically symmetric circumstellar envelope, and therefore no intrinsic linear polarization is observed. However, for massive stars, which are known to have anisotropic winds as a result of the inherent instability of their line-driven mass loss, this is not the case. Further, this effect is even more significant in the case of short-period massive binaries, where the close companion acts like a probe and modulates the linear polarization as it orbits around the primary star and illuminates different regions of the electron-rich wind.

Some of the massive binaries have also been identified as dust producers despite of their strong radiation fields. Their dust formation is associated with the presence of the strong colliding winds. Hence, these are expected to be highly polarized due to the free-free scattering. Polarimetry is, therefore, an important observational technique to study the dust formation and stellar winds of massive binaries. We are making polarimetric observations of a sample of 12 massive binaries consisting of WR+O as well as O+O systems. Here, we will present preliminary results obtained from an O+O binary DH Cep.

2. Observations and data reduction

The optical polarimetric observations of massive binaries were acquired using AIMPOL (Aries IMaging POLarimeter) mounted at the Cassegrain focus of the 1.04-m Sampurnanad telescope of ARIES. The telescope is an RC reflector with a focal ratio of f/13. AIMPOL is coupled with a TK 1K×1K CCD camera which is cooled by liquid-N_2. AIMPOL consists of an achromatic half-wave plate (HWP) modulator and a Wollaston prism beam-splitter. Hence, for each object within a field of view, two images (ordinary and extra-ordinary) are formed. After alignment of the optical axis of AIMPOL with the North-South (NS) direction of the telescope, observations were done at four positions of HWP ($\alpha = 0^{o}$, 22.5^{o}, 45^{o}, and 67.5^{o}).

The standard aperture photometry technique was used to estimate fluxes of the ordinary and extraordinary beams of the target at each position of HWP in IRAF package. We calculated the four Stoke's parameters at four positions of HWP according to the procedure mentioned in Rautela et al. (2004).

DH Cep was observed in B, V, R, and I photometric bands having λ_{eff}= 0.44, 0.55, 0.61, and 0.80 μm, respectively, on the nights of 15, 16 October; 12, 20, 21 November, and 14 December, 2017. Polarized and un-polarized standard stars from Schmidt et al. (1992) were also observed to perform zero point calibration of the estimated polarization angles of the target and correction for instrumental polarization, respectively.

3. DH Cep (HD 215835)

DH Cep (HD 215835) is an O+O double lined spectroscopic as well as the eclipsing binary system. It is a member of the cluster **NGC 7380** (distance = 3.7 kpc, age = 10 Myr) and has an orbital period of **2.11 d** (Lata et al. 2016). The main orbital parameters of DH Cep are listed in Table 1.

This binary star is also an X-ray source with ***log*(L_X/L_{bol}) of -6.7** in 0.3 - 7.5 keV energy band, perhaps attributed to colliding winds. The presence of the cool (< 1 keV) and hot (> 1.89 keV) temperature components in X-ray spectra of DH Cep could possibly be associated with the instabilities in radiation-driven wind shocks (Bhatt et al. 2010). A polarimetric study of DH Cep has been carried out to understand its stellar wind dynamics deeply.

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Table 1: Basic Parameters of HD 215835 binary system

Parameter	Value	Reference	Parameter	Value	Reference
Period (days)	2.11095	5	Spectral Type	O5.5V-III + O6V-III	5
e (°)	0.0	5	*q* (M_1/M_2)	1.15 ± 0.02	5
V (mag)	8.61	5	Dist. (kpc)	3.24 ± 0.37	4
$T_{\circ}$ (HJD)	2456525.56± 0.006	5	Inclination (*i*)	47° ± 1	5
a sin*i* ($R_{\odot}$) (primary)	9.79 ± 0.17	5	Mass ($M_{\odot}$) (primary)	38.4 ± 2.5	5
a sin*i* ($R_{\odot}$) (secondary)	11.24 ± 0.19	5	Mass ($M_{\odot}$) (secondary)	33.4 ± 2.2	5

Note: Here e is the eccentricity, $T_{\circ}$ refers to the time of the conjunction, a sin *i* is the projected separation between the centre of the star and the centre of mass of the binary system.

4. Preliminary Results

The variation of the degree of polarization and polarization angle from DH Cep with the orbital phase is shown in Fig. 1. The phase dependent modulations are clearly visible in these light curves which may be arising due to any of the following reasons:

(i) asymmetric circumstaller/binary envelopes
(ii) dust formation due to colliding winds
(iii) inhomogeneities in O-star winds (e.g blobs)
(iv) the orbital phase for binary systems.

Significant polarization variability is seen in B and V bands probably due to the asymmetric circumstellar/binary envelopes.

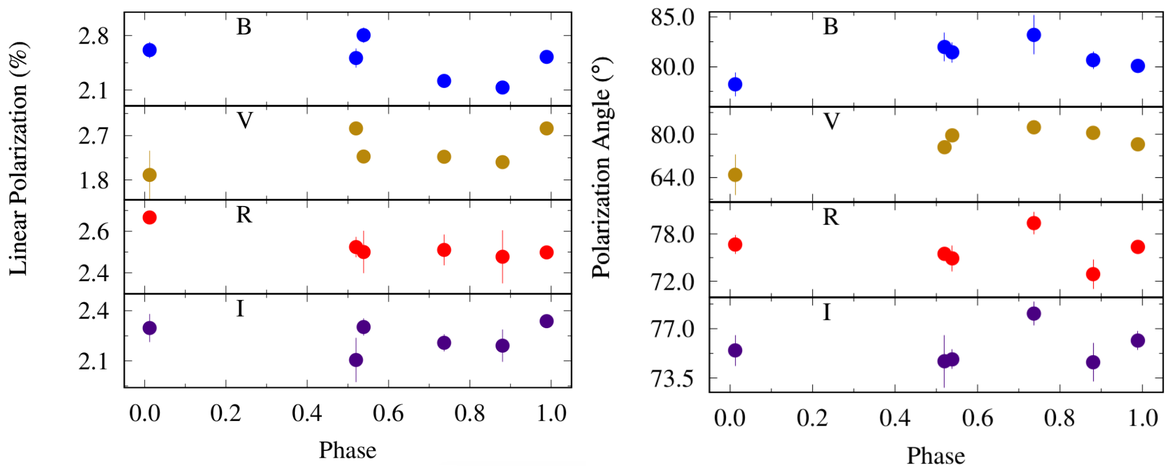

Figure 1. Linear polarization (left) and polarization angle (right) variation of DH Cep with the orbital phase in B, V, R, and I filters (top to bottom).

In order to estimate the interstellar linear polarization (*p*) towards DH Cep, we have plotted *p* with distance in Fig. 2. The *p* values of the stars lying within 2 deg field of DH Cep were taken from Heiles (2000) while their distances were noted from Gaia DR2 archive (Lindegren et al. 2018). It is anticipated that *p* increases linearly with the distance because of the presence of the interstellar medium. At the location of DH Cep (distance=3.24 kpc), *p* value is ~2%. Therefore, the intrinsic polarization of DH Cep is less than 1% in all optical bands, but the variation trends of Fig. 1 will remain same.

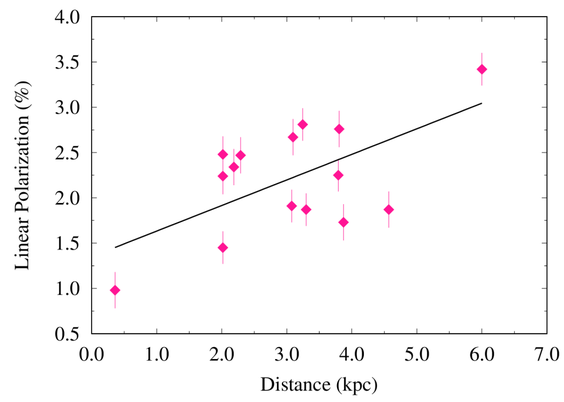

Figure 2. Linear polarisation as a function of distance towards the direction of DH Cep.

Until now, the phase coverage of DH Cep is sparse. We will observe this source again during the coming observation cycles to complete its polarization light curve. Our next aim is to fit these light curves with the available standard models and estimate the parameters like mass loss rate etc. for this binary system (-Louis *et a*l. 1988).

5. References

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