LHA 115-S 23, from B[e] to A[e]: A highly precessing system or a chemically peculiar object?

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Abstract: We report on the variation of the rapidly rotating SMC supergiant star LHA 115-S 23 (AV 172) for which we found a decrease in effective temperature from 11000 K to 9000 K and a simultaneous increase in rotation velocity from 19 km/s to 25 km/s (the latter corresponding to 75% of its critical velocity) within a period of 11 years. Such a behaviour cannot be explained by stellar evolution, especially not the fast cooling of the star. We therefore discuss possible scenarios that can lead to both, an apparent cooling and a speed up of the rotation velocity. The most plausible ones are either a highly precessing system, or a star with an inhomogeneous surface abundance distribution due to e.g. hot spots. If the latter scenario is true, our target would be the first post-main sequence object with such a peculiar surface abundance pattern.

According to the presence of forbidden emission lines of [FeII] and [OI], we derived the interstellar extinction and also the luminosity. Photometric data in the literature, we saw that UBV data changed substantially from similar to ZSW data. We convolved the FEROS data to a resolution of R=4900 taken on 14/10/2000, covering a sky area of 2 arcsec and a wavelength range from 4800 Å to 6400 Å. The B[e] phenomenon was defined by the presence in the optical spectra of B-type stars (Conti, 1997) of:

(a) Strong Balmer Emission Lines;
(b) Permitted emission lines of mainly low ionization metals, e.g. FeII;
(c) Forbidden emission lines of [FeII] and [OI];

and also a strong near or midinfrared excess due to hot circumstellar dust. Based on Lamers et al. (1998), there are different types of objects presenting the B[e] phenomenon: pre-main sequence HAB[e] stars, compact planetary nebula, symbiotic objects, hot supergiants – the most popular class with confirmed members in Magellanic Clouds – and finally unclassified objects whose evolutionary stage is still unknown.

LHA 115-S 23, hereafter S 23, is a SMC star and was classified as a B8 supergiant by Azzopardi & Vigneau (1982). Later Zickgraf et al. (1992), hereafter ZSW, included this star in the group of B[e] supergiants and derived its parameters. In this work, we are presenting, based on new spectroscopic data, a revised analysis of this object (more details can be seen in Kraus, Borges Fernandes, Kubát & de Araújo, 2008, astroph/0806.3208, in press A&A).

Observations

We obtained optical spectra with the ESO 1.52-m telescope in La Silla (Chile) using the high-resolution spectrograph FEROS (R=55000, around 6000 Å). The spectra were taken on 14/10/2000, covering a sky area of 2 arcsec and a wavelength range from 3600 Å to 9200 Å.

Spectroscopic Analysis of LHA 115-S 23

From our high-resolution FEROS spectra, we have derived:

(a) Spectral type and effective temperature, based on the line strength ratio of MgII (A4481) over Hα (M472). Since the Hα lines are not present in our spectra (Fig. 1), different temperature estimates in the spectra of ZSW have derived a lower limit for this ratio and compared to the value from ZSW data. We have found a spectral type A0 or later for this star (Fig. 2).

(b) Interstellar and Circumstellar Extinction plus the Luminosity Class: from photometric data in the literature, we saw that the UV fluxes have changed substantially from 1972 until 1999. We decided to use the data taken in 1999 (only one year earlier than our FEROS spectra) to derive the interstellar extinction and also the luminosity class considering the spectral type obtained from our spectra. However, we got different values of E(B-V) from (BV) and (U-B). The explanation is:

Extinction and emission from the stellar wind!

We test the influence of this wind to the UV band fluxes by modeling a spherically symmetric isothermal wind (Kraus et al. 2008b). We have found the best fit scenario for an A11b star – the first A[e] star identified - with T_e* ≈ 9000 K, mass loss rate of 3 x 10^{-8} M_/yr and interstellar extinction with E(B-V) = 0.03. It seems that within 11 years, the star has cooled ≈ 2000 K.

Table 1 – The set of parameters derived from our analysis compared to the ZSW ones. From the comparison with stellar evolutionary tracks for SMC stars (Charbonnel et al., 1993), an initial mass of 9.5-11 M_☉ is estimated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ST and LC</th>
<th>T_e* (K)</th>
<th>E(B-V)</th>
<th>Log (L/☉)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSW</td>
<td>B8-9.5 Ib</td>
<td>11000</td>
<td>0.1</td>
<td>4.46</td>
</tr>
<tr>
<td>Our Analysis</td>
<td>A1 Ib</td>
<td>9000</td>
<td>0.03</td>
<td>4.30</td>
</tr>
</tbody>
</table>

(c) Projected Rotational Velocity: modeling the line profile of the MgII (A4481) line using the FWHM method, we could estimate v sin i considering the presence of macro-turbulence, from our spectrum (Fig. 3) and also from the ZSW data.

1 - Stellar Evolution: NO!

The stellar evolution theories predict cooling associated to decreasing of v sin i or when the star contracts, heats up and increases v sin i. In addition, it takes 5000 yr for such a star to cool from 11000K to 9000K (Meynet, private communication).

2 - Precession of the star related to the line of sight: POSSIBLE!

Due to a rapid stellar rotation, the stellar surface suffers from a deformation in the form of flattening (Fig. 4). Thus, the polar regions become much hotter than the equatorial region (depending on the fraction of the rotation velocity to the critical velocity). Other stellar parameters will also change from one region to other.

3 - A Rapidly Rotating Star with Surface Inhomogeneities: POSSIBLE!

It is known that chemically peculiar (CP) stars at or close to the main sequence present surface abundance inhomogeneities or spotty surface patterns. Since the decay time of B[e] is longer than the rotation periods in the hot regions, we can see contributions from hotter regions, but it was seen a lower v sin i.

How can we explain the cooling and the increasing of projected rotational velocity in just 11 years?

- Possible!

References: