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The Be Phenomenon in A-type Supergiants

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Abstract. Multiwavelength observations of a large sample of A-type supergiants reveal that these stars display several features associated with the classical Be phenomenon.

1. Introduction

One of the long standing problems of the variability of the winds of Be stars has been the V/R variability (e.g. Telting et al. 1994) mostly observed in the Hα profiles. The V/R variations can occur on timescales of years to a decade and they reflect the global oscillations of a flattened and axially symmetric disk. Rapid variations have also been observed on a time scale of hours to a few days (e.g. Rivinius et al. 1998) associated with outbursts. Another remarkable property of classical Be stars spectra is the formation of variable *discrete-absorption-components*, DACs, in the UV resonance lines.

Multiwavelength observations in the visible and ultraviolet spectral ranges of a sample of 41 A-type supergiants (Verdugo, Talavera, & Gómez de Castro 1999a) reveal that these stars display several features associated with the classical Be phenomenon. In this contribution the variability of the observed visible and ultraviolet profiles is described. Relevant periods of these stars (e.g. rotation periods) related to the different models proposed to explain the observed variations are also presented.

2. Visible observations

We found variations of the Hα profiles in almost all A-supergiants of our sample which show asymmetric or emission profiles ($M_V < -6$). The strongest variations are detected on timescales of days and most of them are due to a variable double-peaked emission (see Fig. 1). The observed V/R variability is

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highly indicative of non-spherical circumstellar envelopes and, comparing with the classical Be phenomenon, an equatorial concentration of the outflow can be inferred. Moreover, two stars of our sample show temporarily pure emission Hα profiles which points to the presence of density clumping structures in the wind.

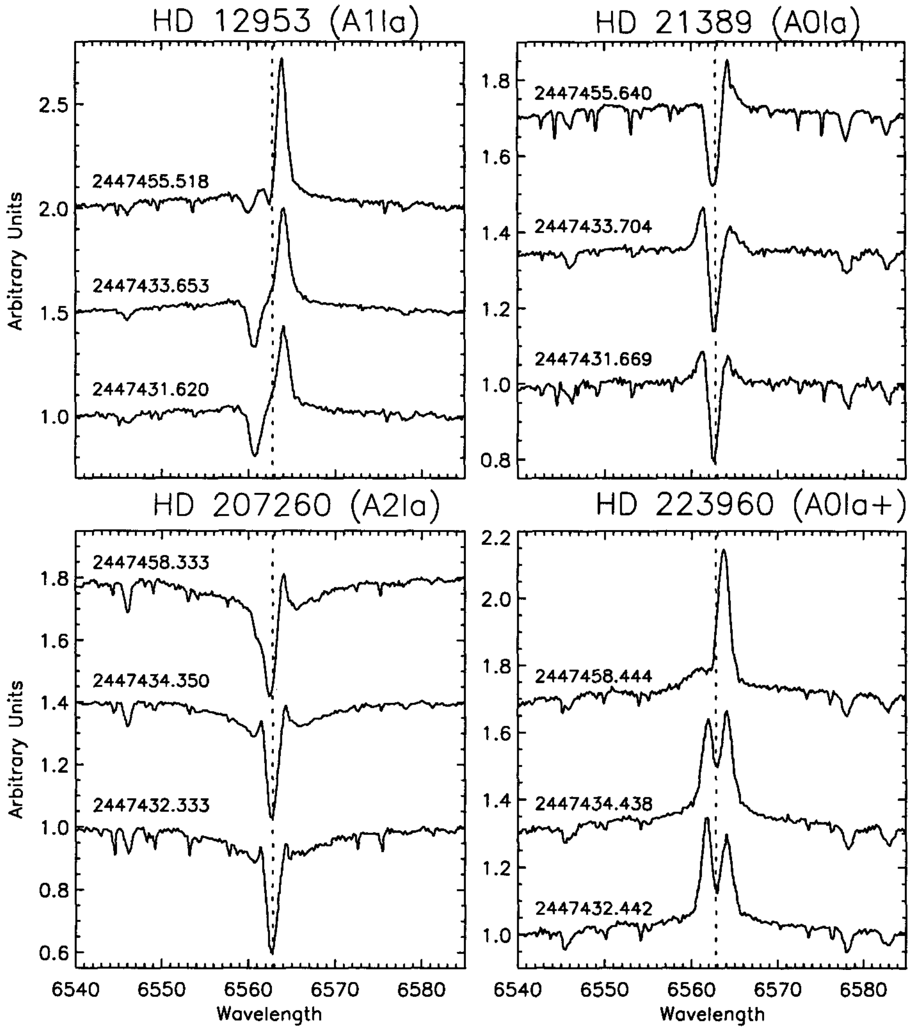

Figure 1. V/R variability in the Hα profile of four A-supergiants of our sample. The rest wavelength is marked with a dashed line. The Julian Date for each observation is indicated.

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3. Ultraviolet observations

The formation of DACs in two different timescales has also been detected in the UV spectra of A-type supergiants (Verdugo et al. 1999a). In the most luminous stars (Ia and Iab) the DACs are detected in the resonance lines of several Fe II multiplets (uv1, uv2, uv3, uv62, uv63) and seem to remain stable during years (see Fig. 2). However, in the less luminous stars (Ib stars with $M_V > -6$) we have detected the appearance and evolution of a blueshifted component in the non-saturated profiles of the Mg II resonance lines. This component migrates through the profile from $v = 0$ km s^{-1} to $v \sim -200$ km s^{-1} on a timescale of days (Fig. 2). This component is the unique spectral evidence of mass outflow in both visible and UV ranges in the AIb stars of our sample.

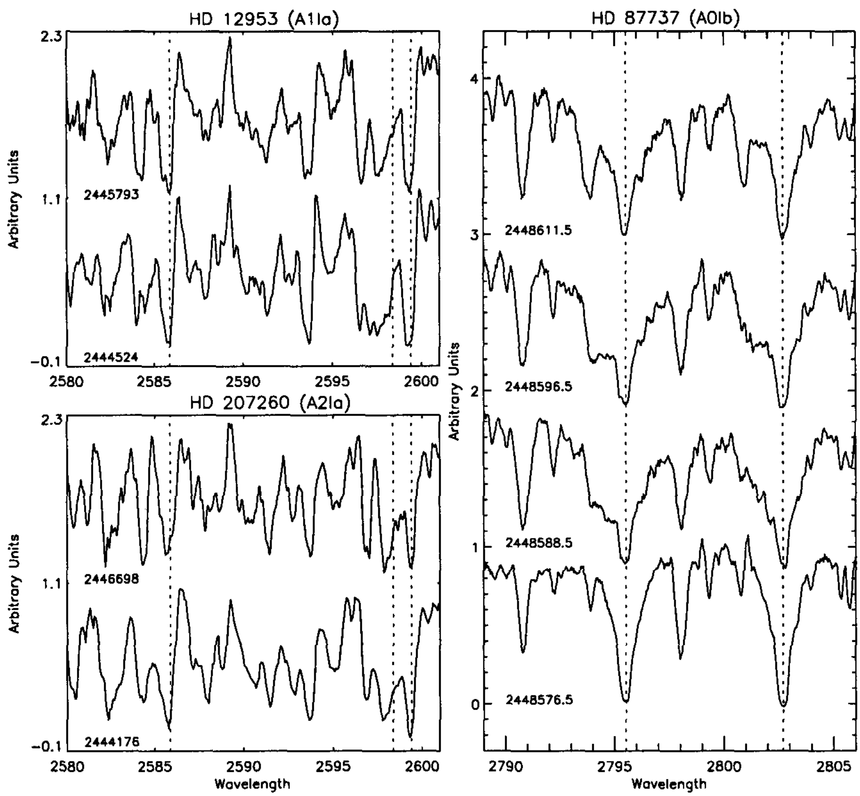

Figure 2. Variable DACs in the Fe $\text{II}_{[\text{uv1}]}$ lines of two A Ia stars (left) and in the Mg II lines of one A Ib star (right). As in Fig. 1 the rest wavelength and the Julian Date are marked.

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4. Rotation

Radiation pressure is accepted as the dominant driving mechanism in the mass-loss phenomenon of A supergiants. There is now, however, increasing evidence that in addition to radiation pressure also rotation plays an important role in the winds of hot stars. Kaufer et al. (1996) give strong evidence for a rotational modulation of the lower envelope of BA supergiants.

We have calculated an upper limit for the true rotation velocity of the stars of our sample (for detailed calculation see Verdugo, Talavera, & Gómez de Castro 1999b). The corresponding rotation periods ($P_{\rm rot}/\sin i$) are compared in Fig. 3 with those calculated from the critical or break-up velocity ($v_{\rm crit} = v_{\rm esc}/\sqrt{2}$) and with the radial fundamental pulsation periods ($P_{\rm rad}$) computed according to Lovy et al. (1984) using a pulsation constant of -1.4.

The lower limit for the true rotation periods given by the critical velocity is up to a factor of 3 longer than the pulsation period of the radial fundamental mode. This difference allows to discriminate between rotation and pulsation as sources of spectral variability. In this respect, we found that the Hα variability and the observed time-life of the UV blueshifted components is much longer than pulsation periods and consistent with rotation periods. Moreover, we have not detected significant variations in the observed photospheric lines. These clues point to a model of corotating clouds of gas and the existence of a weak magnetic field on the surface, corotating with the star. Henceforth the possible detection of a weak surface magnetic field in these objects must be investigated.

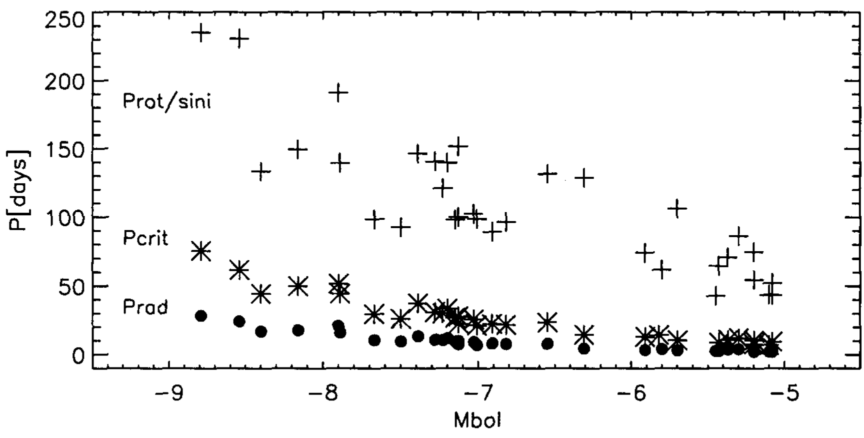

Figure 3. Rotation periods (crosses) compared with those calculated from the critical velocity (asterisks) and with the radial fundamental pulsation periods (points).

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5. Conclusions

Several lines of evidence point to a non-spherical circumstellar envelope for A-type supergiants with an equatorial concentration of the outflow caused by rotation which is suggested as the most plausible source of variability. However, the rich variety of wind activity in these stars with very different spectral features and timescales of variability indicates that this activity should not be interpreted in terms of a single process or at least, the same process occurring in all the stars of our sample.

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Discussion

H. Henrichs: How strong a magnetic field do you expect might cause the effects you mentioned?

E. Verdugo: We are now studying the dynamics but maybe a magnetic field of just ~50 G could account for the observed effects.

H. Henrichs: I am worried about such high values because these supergiants must then have had much stronger fields when they were on the main sequence.

L. Balona: Only for fossil fields.

H. Henrichs: This excludes then fossil fields for A stars.

A. Dudorov: A comment about magnetic fields of normal A stars. There are two types of A stars. Magnetic Cp stars have usually strong dipolar magnetic fields with intensity $B \simeq 10^3 - 10^4$ G. According to the observations the upper limit of the magnetic field intensity of normal A stars is $B < 100$ G. These types of field are quite feeble with respect to other dynamical processes.

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