Stellar Rotation
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Apparent Variation of $v \sin i$ and Rotational Modulation in Be Stars

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Abstract. $v \sin i$ was determined by applying the Fourier transform method to the line profiles of two classical Be stars. A variation is observed in the apparent $v \sin i$ which corresponds to the main frequencies associated to *nrp* modes. Rotational modulation is observed in wind sensitive UV lines of the Be star ω Ori and is associated with an oblique magnetic dipole which is discovered for the first time in a classical Be star.

1. Introduction

Be stars are non-supergiant B stars that have displayed emission in their Balmer lines. This emission takes its origin in a non spherical circumstellar envelope. Be stars usually are rapid rotators and show light and line profile variations in time scale ranging from hours to years. The short-term variability could be explained by non-radial pulsations (*nrp*) and/or by rotational modulation.

2. $v \sin i$ Determination and its Apparent Variations

Two Be stars seen under a moderate inclination have been investigated: ω Ori (HD 37490, B 2-3IIIe, $v \sin i$ = 179 km s^{-1}) and 66 Oph (HD 164284, B 2Ve, $v \sin i$ = 280 km s^{-1}). Observations consist in high resolution, high S/N ratio spectra obtained during an international multi-site campaign MUSICOS held in 1998 for ω Ori (see Neiner et al. 2002) and in 2 sets of data obtained in 1998 and 2000 for 66 Oph (see Floquet et al. 2002). The determination of $v \sin i$ in Be stars is always a crucial problem due to the distortion of the star itself by rapid rotation and influence of *nrp*.

$v \sin i$ can be determined using the first minimum of a Fourier transform analysis (Gray 1976) performed on the mean available photospheric lines (He I, Si III, Mg II, ...) assuming a limb darkening coefficient of $\varepsilon = 0.4$ (Jankov 1995). It has also been applied to each individual spectrum to study the pulsational influence.

Line profile variations analysis of 66 Oph leads to the detection of 2 main frequencies: 2.25 and 4.05 c/d associated with mode degree l=2 and l=3 respectively. The $v \sin i$ value is found to be variable following the same frequencies as line profiles (see Floquet et al. 2002, their figs. 12 and 13).

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Line profile variation analysis of ω Ori leads to the detection of one frequency 1.03 c/d associated with l=2-3 and m=2. This frequency is also found in the variation of $v \sin i$ of all the studied lines (see Neiner et al. 2002, their fig. 9).

3. Rotational Modulation in ω Ori

The Be star ω Ori was found to be magnetic from spectropolarimetric observations obtained at TBL (Pic du Midi, France) (Neiner et al, 2003). The longitudinal component of the magnetic field varies periodically with P = 1.29 d. The profiles of the UV resonance lines of CIV, SiIV and NV, known to be sensitive to the stellar wind, are also rotationally modulated. The period found here is also P = 1.29 d. Other observables, such as the depth of optical lines and the peak separation of the emission components in Hβ, are also rotationally modulated. This is well described in the frame of the oblique magnetic rotator model: the axis of the magnetic dipole differs from the rotation axis and thus the dipole is seen with a different angle through a full rotational period. In the frame of this model, the wind, flowing away from the stellar surface at the magnetic poles is confined towards the magnetic equator.

4. Conclusion

In the case of ω Ori the rotational period has been constrained by the modulation of wind and magnetic field and the period of non-radial pulsation is different from the rotational one. The quasi-sinusoidal variation of $v \sin i$ observed in 66 Oph and ω Ori is modulated by the pulsational period in the same manner as in ζ Oph (Jankov et al. 2000). In a rapidly rotating star the pulsation velocity field acts as a small perturbation to the dominant rotational velocity field. Therefore the apparent variation of $v \sin i$ can result from an additional horizontal velocity field due to non-radial pulsations and/or from associated temperature oscillations at the stellar surface.

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