New windows on massive stars: asteroseismology, interferometry, and spectropolarimetry
Proceedings IAU Symposium No. 307, 2014
G. Meynet, C. Georgy, J. H. Groh & Ph. Stee, eds.

doi:10.1017/S1743921314007169

Multiple, short-lived "stellar prominences" on O stars: the supergiant λ Cephei

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Abstract. Many OB stars show unexplained cyclical variability in their winds and in many optical lines, which are formed at the base of the wind. For these stars no dipolar magnetic fields have been detected. We propose that these cyclical variations are caused by the presence of multiple, transient, short-lived, corotating magnetic loops, which we call "stellar prominences". We present a simplified model representing these prominences as corotating spherical blobs and fit the rapid variability in the HeII λ4686 line of the O supergiant λ Cep for time-resolved spectra obtained in 1989. Our conclusions are: (1) From model fits we find that the life time of the prominences varies, and is between 2–7 h. (2) The adopted inclination angle is 68° with a rotation period of $\approx$ 4.1 d (but not well constrained). (3) The contribution of non-radial pulsations is negligible (4) Similar behavior is observed in at least 4 other O stars. We propose that prominences are a common phenomenon among O stars.

Keywords. line: profiles, stars: magnetic fields, stars: winds, outflows, stars: individual (λ Cep)

1. Introduction

Wind variability in massive OB stars is a wide spread phenomenon. This variability is not periodic, but cyclic (like sunspots) with often a dominant quasi period which scales with the estimated rotation period (days to weeks), or perhaps an integer fraction thereof, see for instance references in Henrichs & Sudnik (2014), also for the remainder of this contribution. The cause or trigger is unknown. The major time-variable wind features that are observed in the UV (the so-called DACs, discrete absorption components), must start from very near, or at the stellar surface. Possible explanations include non-radial pulsations and/or bright magnetic star spots. Pulsations have been found only for a few O stars, mostly from optical studies but also from space-based photometry. Magnetic dipole fields in such stars (except for the CP stars) have been found since 1998. Both phenomena are expected, however, to cause periodic variations, and are therefore unlikely the cause of the observed cyclical behavior (David-Uraz *et al.* 2014).

New developments in this field are twofold. First, Cantiello *et al.* (2009) showed that in the sub-surface convective layers in massive stars magnetic fields can be generated with a short turnover time (Cantiello *et al.* 2011). Second, space-based photometry of the O giant ξ Per showed rapid variations at the 1 mmag level, incompatible with the known pulsations, but compatible with the presence of a multitude of corotating bright spots, which live only a few days (Ramiaramanantsoa *et al.* 2014). These spots are suggested to be of magnetic origin as described above.

To understand the role of magnetic fields in OB stars is a major challenge. Here we present a simplified model to explain optical wind-line variability in the O star λ Cep.

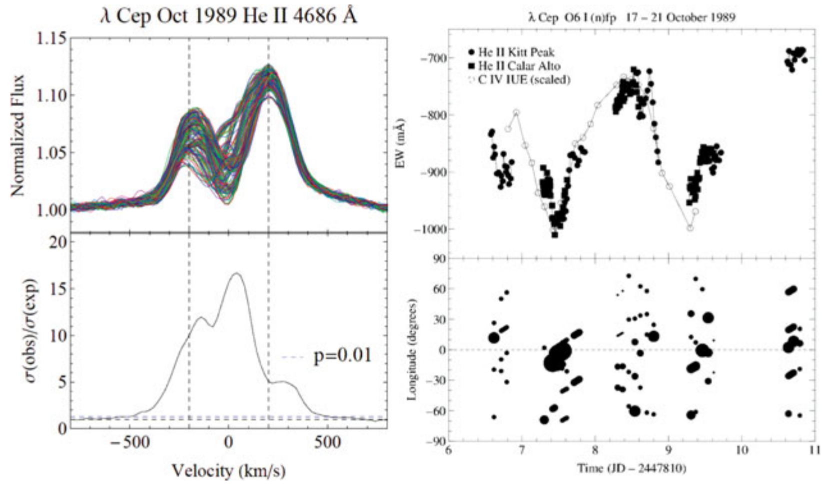

Figure 1. *Left, top:* Overplot of He II 4686 profiles during 5 days. *bottom:* TVS and significance level. *Right:* EW of He II lines and wind C IV blue edge variability (*top*) plotted along with properties of the blobs, with symbol size proportional to optical thickness (*bottom*).

2. Optical wind-line variability in the O6I(n)fp star λ Cep

The bright runaway star O6I(n)fp star λ Cep ($v\sin i \simeq 214$ km s^{-1}, $\log(L/L_\odot) \simeq 5.9$, $T_{\rm eff} \simeq 36000$ K, $R \simeq 17.5R_\odot$, $M \simeq 60M_\odot$), is a nonradial pulsator ($l = 3, P = 12.3$ h; $l = 5, P = 6.6$ h), and shows cyclical DACs in the UV resonance lines. Rapid variability (timescale 10 min) have been observed in the He II emission line in 1989 (and other years as well). The dominant period in the UV and optical lines is $\simeq 2$ d. Only redward moving NRP features have been observed, implying an inclination angle greater than, say, 50°. With the adopted radius, the likely rotation period is then $\simeq 4.1$ d.

The observed optical profile changes extend far beyond $v\sin i$, which requires emitting gas above the surface. We therefore consider the most simplified model to represent a "stellar prominence" by a sphere corotating and touching the surface. The model properties are described by Henrichs & Sudnik (2014). Essential in our procedure is that quotient spectra are fitted, such that the overal shape of the profile cancels out. The procedure is to adopt a fixed inclination angle (matching $v\sin i$ and R_*) which was 68°, and put a number of blobs around the star to fit the first quotient, which is determined by an assumed rotation period. A least-squares fit gives the best parameters. The optical thickness of the fitted blobs are plotted in Fig. 1 (right). The number of blobs needed is between 2 and 6, with typical lifetime in the order of several hours. No clear correlation is apparent. The He I 4713 photospheric line shows only pulsations. Several other data sets of this star, which include other optical lines as well, show very similar behavior. We note that quotient spectra of most lines behave rather similarly. Similar behavior is also observed in other O stars (in progress). This suggests a common phenomenon in O stars.

References

Cantiello, M., Braithwaite, J., Brandenburg, A., *et al.* 2011, in C. Neiner, G. Wade, G. Meynet, & G. Peters (eds.), *IAU Symposium*, Vol. 272 of *IAU Symposium*, pp 32–37

Cantiello, M., Langer, N., Brott, I., *et al.* 2009, *A&A* 499, 279

David-Uraz, A., Wade, G. A., Petit, V., *et al.* 2014, *MNRAS* 444, 429

Henrichs, H. F. & Sudnik, N. P. 2014, in *IAU Symposium*, Vol. 302 of *IAU Symp.*, pp 280–283

Ramiaramanantsoa, T., Moffat, A. F. J., Chené, A.-N., *et al.* 2014, *MNRAS* 441, 910