TIME-SERIES ANALYSIS OF THE O4 SUPERGIANT ζ PUPPIS

ANDY REID
Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom.

Abstract. Preliminary results of a time-series analysis on a sequence of high dispersion, high-signal-to-noise, optical echelle spectra of the O4 supergiant, ζ Puppis (HD 66811), are presented. Lines of He I λ5876Å, He II λ5411Å, N IV λ6381Å and C IV λλ5801, 5812Å are analysed; they show variations in line shape and equivalent width, with 'bumps' and 'dips' seen moving from blue to red within the line profile. The qualitative pattern of variability seen in all these lines is similar.

A Fourier technique, incorporating the iterative CLEAN algorithm, was used on the individual wavelength samples. A periodicity of 8.5-hrs was detected in He II, and strongly suspected in the remaining absorption lines. This periodicity seems to rule out wind variability as the principal origin for the optical line profile variations seen in ζ Puppis.

1. Summary of the Time-Series Analysis

The technique of Baade (1988) and Gies & Kullavanijaya (1988), which includes the CLEAN algorithm of Roberts et al. (1987), is applied to time-series spectra constructed from the individual wavelength samples. The resultant CLEANed power spectra are assembled into data cubes of line velocity (x-axis) *vs.* frequency (y-axis) *vs.* power (z-axis). Although the periodograms show considerable aliasing structure, a period of 8.5-hrs is found across the line profile of He II λ5411Å. In addition, the alias frequencies either side of this 8.5-hr period are detected across the line profiles of the remaining lines of study. This indicates that the 8.5-hr modulation may be present within all the lines presented here, but that the sampling pathology has caused the CLEAN algorithm to 'lock' onto the alias frequency, giving erroneous periods.

Plotting the sinusoid half-amplitude of the 8.5-hr period as a function of line velocity, shows that the strength of the variation is concentrated in the line wings with the exception of N IV λ6381Å, where power is spread about the line profile more evenly. This pattern of variability suggests a strong azimuthal component within the origin of the 8.5-hr modulation.

2. Origin of the Variations

The origin of the line profile variations (lpv) seen within the optical absorption lines of ζ Puppis is controversial. Baade (1986, 1991) has attributed these variations to photospheric non-radial pulsation (NRP). However,

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Fullerton (1990) attributes much of the lpv of the O supergiants to variability within the stellar wind.

The coherent periodicity across the line profile would rule out stochastic variations in the wind as the cause of the lpv. Moreover, the period indicated in this study, which Baade (1986) also found, is much shorter than the estimated rotation period of ζ Puppis (5.075-days, Moffat & Michaud 1981; 5.21-days, Balona 1992), and indeed, is shorter still than the critical rotation period of 3.4-days (estimated in the Roche approximation using stellar parameters given by Prinja et al. 1992, and accounting for radiation pressure). Evidently, the apparent 8.5-hr modulation does not represent the corotation of a single wind inhomogeneity about the star. This short period does not rule out the possibility of a cylindrical pattern of features within the wind or photosphere which would then produce the regular variation within the line profiles as the star rotates. This would mean inhomogeneities spaced at regular intervals, which whilst highly unlikely, cannot be entirely ruled out. The NRP hypothesis is a much more attractive explanation; cylindrical symmetry of both velocity and temperature variations upon the photosphere is a natural consequence of NRP. In addition, the appearance of strong amplitude in the line wings, can be explained as a pulsation mode possessing a significant horizontal pulsation velocity.

Further analysis, which is in progress, is required to identify if the frequencies found in the line profiles are due to a combination of a 8.5-hr modulation and temporal sampling. The analysis presented here is preliminary and caution is therefore advised in the interpretation of these findings.

References

Baade D.: 1986, 'Observational properties of non-radial oscillations in early-type stars and their possible effect on mass loss: the example of ζ Puppis (O4 If)' in D.O. Gough, ed(s)., *Seismology of the Sun and the Distant Stars*, Reidel: Dordrecht, p. 465

Baade, D.: 1988, 'Doppler imaging of variable early-type stars' in G. Cayrel de Strobel & M. Spite, ed(s)., *IAU Symposium 132: The Impact of Very High S/N Spectroscopy on Stellar Physics*, Kluwer: Dordrecht, p. 193

Baade, D.: 1991, 'Regular variability of optical lines in ζ Pup' in D. Baade, ed(s)., *ESO Workshop Proceedings No. 36, Rapid Variability of OB-Stars: Nature & Diagnostic Value*, ESO: Munich, p. 21

Balona, L. A.: 1992, *MNRAS* **254**, 404

Fullerton, A. W.: 1990, *Ph.D. Thesis*, University of Toronto: Toronto

Gies, D. R., & Kullavanijaya, A.: 1988, *ApJ* **326**, 813

Moffat, A. J., & Michaud, G.: 1981, *ApJ* **251**, 133

Prinja, R. K., et al.: 1992, *ApJ* **390**, 266

Roberts, D. H., Lehár, J., & Dreher, J. W.: 1987, *AJ* **93**, 968