CRIRES Science Verification Proposal

Can IR solved the wind clumping question? ζ Pup as a test case.

Investigators	Institute	EMAIL
H. Sana	ESO	hsana@eso.org
M. De Becker	Liège University	debecker@astro.ulg.ac.be
F. Martins	Max-Planck	f.martins@mpg.de
Y. Nazé	Liège University	naze@astro.ulg.ac.be

Abstract:

We propose to perform the first self-consistent multiwavelength (visible-IR) analysis of the O-type star ζ Pup in order to quantitatively investigate one of the most crucial nowadays question related to massive stars : what is the degree of clumping of their winds and how does this affects our estimate of the mass loss rate. In this purpose, we will make use of the CMFGEN atmospheric code to simultaneously adjust the optical and IR spectrum of ζ Pup. Extension of the adjustment towards the UV domain will be further considered using archive IUE data. We emphasize that this work will be the first of its kind on an O-type star.

Scientific Case:

Several works have recently presented hints that the mass-loss rates from massive stars have been dramatically overestimated (Fullerton et al. 2006, ApJ 637, 1025; Martins et al. 2005A&A, 441, 735). The main cause for this is that the wind of massive stars might not be homogeneous as previously thought, but could be strongly clumped. This question has implications largely beyond the stellar physics of these objects, and seriously affects our understanding of their evolution as well as of their quantitative feedback on their surroundings.

As explained below, a multiwavelength detailed analysis has the potential to bring a direct answer to this question. The required wavelength range unfortunately is rather large and extends from the UV to the IR. While the archives contains a large amount of UV and visible data on the early-type stars and, in particular, on ζ Pup, the equivalent in the IR domain is still lacking. Fortunately, the advent of instrument such as CRIRES, that combines sufficient resolution, sensitivity and wavelength coverage, provides a unique opportunity to tackle this problem.

The need to go to IR : While the visible domain alone can constrain the temperature and gravity and while the UV domain gives us access to the wind terminal velocity, the mass loss rates are often estimated from the sole Hα line. Going to the IR will not only multiply by a significant factor the number of lines indicative of the wind structure and of the mass-loss rates (thus allowing to adjust with a larger confidence more sophisticated models), but it potentially give us access to several lines that, according to pioneering studies, might be particularly sensitive to the wind properties (Conti & Howarth 1999, MNRAS 302, 145 ; Hanson et al. 2005, ApJSS 161, 154 ; Lenorzer et al. 2005, A&A 384, 473; limited to the I, H and K, and L' band respectively): Br 10 and Br 11 seem to be excellent indicators of the gravity, though the rotation rate should be known for ultimate accuracy (which can be obtained through the fitting of the optical line), Brα shows a strong dependency with the wind density while the wings of Brγ might give direct indication of the degree of clumping (Hanson et al. 2005). Finally, as in the optical, the HeI and HeII lines are the main indicator for temperature.

So far, only Repolust et al. (2005, A&A 440, 261) have attempted to perform a quantitative analysis using a sub-sample of Hanson et al. data in the H and K bands. Their analysis, using FASTWIND (Puls et al. 2005, A&A 435, 669), was however limited to eight lines including only H, HeI and HeII species. In addition, FASTWIND did not account for the possible wind clumping.

Henceforth, we propose to acquire one high quality spectrum of one of the closest and brightest O-type stars, ζ Pup. Using CMFGEN (e.g. Martins et al . 2005, A&A 441, 735), an atmospheric code that includes metallic species and wind clumping, this data set will allow us to quantitatively investigate one of the most important nowadays question on the massive stars : what is the degree of clumping of their winds and how does this affects our estimate of their mass loss rate. The domain required for this study has been selected as to contain most of the H, HeI, HeII, CIV and OIII lines in the IR domain. This will ensure the highest accuracy in the adjustment of the spectrum.

Notes : (i) One IR ISAAC spectra of ζ Pup exists in the ESO data base. The resolution is however limited to about 10000 and covered only the H and K band. As in the optical, the need for higher resolution (over 30000) is justified by the need to resolve certain complex (e.g. HeI/NIII at 2.112 micron), as well as to accurately sample the line profiles of low surface gravity objects (supergiants, such as ζ Pup). Still this ISAAC spectrum will allow us to search for possible variability. **(ii)** The high S/N required by this program (around 200 in order to feed the atmosphere model with unambiguous data) will allow us to test the reduction software and to search for systematic errors that might be hidden in the photon noise at lower S/N. **(iii)** Finally, we emphasize that this source is particularly bright and might probably be observed even if the atmospheric condition are not good. **(iv)** Given the brightness of the target, the observations can be tempted even if no NGS star can be found.

Required observing time : 1.5 hour

Target	RA	DEC	Wavelength Band	Magnitude	DIT	NDIT
Zet Pup	08 03 35	-40 00 11	56/0/i	K=3	3	5
Zet Pup	08 03 35	-40 00 11	55/0/i	K=3	3	5
Zet Pup	08 03 35	-40 00 11	52/0/i	K=3	3	5
Zet Pup	08 03 35	-40 00 11	52/0/n	K=3	3	5
Zet Pup	08 03 35	-40 00 11	33/-1/n	K=3	3	9
Zet Pup	08 03 35	-40 00 11	33/-1/i	K=3	3	9
Zet Pup	08 03 35	-40 00 11	33/1/i	K=3	3	9
Zet Pup	08 03 35	-40 00 11	27/-1/n	K=3	5	9
Zet Pup	08 03 35	-40 00 11	27/-1/i	K=3	5	9
Zet Pup	08 03 35	-40 00 11	27/1/n	K=3	5	9
Zet Pup	08 03 35	-40 00 11	27/1/i	K=3	5	9
Zet Pup	08 03 35	-40 00 11	26/-1/i	K=3	5	9
Zet Pup	08 03 35	-40 00 11	26/-1/n	K=3	5	9
Zet Pup	08 03 35	-40 00 11	26/1/n	K=3	5	9
Zet Pup	08 03 35	-40 00 11	23/-1/i	K=3	5	9
Zet Pup	08 03 35	-40 00 11	15/-1/i	K=3	10	22
Zet Pup	08 03 35	-40 00 11	14/1/i	K=3	10	22
Zet Pup	08 03 35	-40 00 11	13/-2/n	K=3	10	22

To reach the desired wavelength coverage, one needs to observe ζ Pup using at least 25 different settings. Given the ETC, a high S/N (around 200) should be attain in a reasonable amount of time (see the estimates in the above table). Summing these estimates, accounting for the additional 0.25% read-out, the 0.2min overheads required to change settings, the 0.25 min per nodding cycle and the 5 min acquisition time yields a total of about 1hour30.