POLARIMETRIC *VERSUS* PHOTOMETRIC VARIABILITY OF WOLF-RAYET STAR WINDS

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Abstract. Intensive broad band observations of WR stars by Moffat *et al.* reveals photometric and polarimetric variability on time-scales of hours, similar to that seen on narrow spectral features. The r.m.s. fractional photometric variation is found to be about 20 times the r.m.s. polarimetric variation whilst simple scattering theory predicts ratios of order unity. The possibility that this discrepancy is due to polarimetric cancellation of the Stokes parameters of light scattered from many dense blobs at random positions (known from spectrometric data to be present) is investigated analytically and by simulations. It is found that factors of 20 reduction in the polarimetric variability cannot be achieved for reasonable numbers of blobs and it is concluded that further polarimetric suppression by substantial blob optical depth and/or intrinsic blob emission must play a role. These results put further constraints on physical conditions in WR wind inhomogeneities.

Key words: stars: Wolf-Rayet – winds – polarimetry

1. Introduction

The presence of blobs (or inhomogeneities) in WR star winds has been deduced from the observation of transient narrow spectral features superposed on some broad emission lines together with the polarimetric variability of single WR stars. In general, about 10 narrow emission features can be observed at any one time, appearing and disappearing on timescales of about 10 hours. Transient features are also observed in

1. polarimetric light-curves — (having a 0.5% peak-peak variation) and
2. photometric light-curves — (having a 10% peak-peak variation)

For the purposes of this article we denote the variation in the polarisation by σ_P and the photometric variation by σ_{f_s}. We shall attempt to show the relationship between σ_P and σ_{f_s} with N, the number of blobs in the system.

2. The model and equations

We place N identical electron clouds, each with nV electrons, randomly around the star. The position of each blob is uniquely determined by its co-ordinates (r_j, θ_j, ϕ_j) where $1 \leq j \leq N$. Here r_j is the distance of the blob from the star, θ_j is the scattering angle and ϕ_j is the polarisation orientation angle. The distribution of the number of electrons, (nV), in a blob with the number of blobs, N, is given by $dN/d(nV) = A(nV)^{-(1+D/2)}$ where A is a constant and D is a variable parameter which we take as $= 2$. The number of electrons in the system is held constant at 10^{47} with 10^{44} being the minimum

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number of electrons contained in a blob. We denote the polarisation by P and the fractional light intensity by $f_s = I_s/(L/4\pi)$ where I_s is the intensity of the scattered light. The equations governing the system are then

$$P = \sqrt{Q^2 + U^2} \tag{1}$$

$$Q = \frac{3\sigma}{16\pi} \sum_{j=1}^{N} (nV)_j D_j \sin^2\theta_j \cos 2\phi_j \tag{2}$$

$$U = \frac{3\sigma}{16\pi} \sum_{j=1}^{N} (nV)_j D_j \sin^2\theta_j \sin 2\phi_j \tag{3}$$

$$f_s = \frac{3\sigma}{16\pi} \sum_{j=1}^{N} (nV)_j C_j (1 + \cos^2\theta_j) \tag{4}$$

where σ is the Thomson cross-section, n is the density of the scatterer, V is the volume of the scatterer and D_j, C_j are correction factors due to the finite size of the star. We have also assumed that $I_s \ll L/4\pi$. For each N we calculate an average polarisation $\bar{P}$ and intensity $\bar{f}_s$, together with the corresponding standard deviations. We also calculate $\alpha = P/f_s$, its average and standard deviation.

3. The results

First, we investigated the way in which the polarisation changed as the number of blobs increased. We found that as N increased, $\bar{P}$ decreased like $1/N^{1/2}$.

Secondly, we attempted to simulate the observed values of σ_P and σ_{f_s} which as stated earlier were 0.5% and 10% respectively, giving a ratio of 0.05. We found that the observed values of σ_P could be realised if the number of blobs ~ 20 but unfortunately, in order to reproduce the observations of σ_{f_s} more than 100 blobs were required. If we examine the ratio σ_P/σ_{f_s} then we find that a value of 0.05 cannot be achieved for a reasonable number of blobs. It is concluded that other mechanisms, *e.g.,* intrinsic blob emission must play a role.