A MiMeS analysis of the magnetic field and circumstellar environment of the weak-wind O9 sub-giant star HD 57682

Jason H. Grunhut[1], Gregg A. Wade[1], Wagner L. F. Marcolino[2], Véronique Petit[3], and the MiMeS Collaboration

[1]Kingston, Canada; [2]Marseille, France; [3]West Chester, USA

Abstract. I will review our recent analysis of the magnetic properties of the O9IV star HD 57682, using spectropolarimetric observations obtained with ESPaDOnS at the Canada-France-Hawaii telescope within the context of the Magnetism in Massive Stars (MiMeS) Large Program. I discuss our most recent determination of the rotational period from longitudinal magnetic field measurements and Hα variability - the latter obtained from over a decade's worth of professional and amateur spectroscopic observations. Lastly, I will report on our investigation of the magnetic field geometry and the effects of the field on the circumstellar environment.

Keywords. instrumentation: polarimeters, techniques: spectroscopic, stars: magnetic fields, stars: rotation, stars: individual (HD 57682)

1. Introduction

The presence of strong, globally-organized magnetic fields in hot, massive stars is rare. To date, only a handful of massive O-type stars are known to host magnetic fields. In 2009, Grunhut *et al.* reported the discovery of a strong magnetic field in the weak-wind O9IV star HD 57682 from the presence of Zeeman signatures in mean Least-Squares Deconvolved (LSD) Stokes V profiles. Their analysis of the IUE and optical spectra determined the following atmospheric and wind properties: $T_{eff} = 34.5\,\text{kK}$, $\log(g) = 4.0 \pm 0.2$, $R = 7.0^{+2.4}_{-1.8}\,R_{\odot}$, $M = 17^{+19}_{-9}\,M_{\odot}$, and $\log(\dot{M}) = -8.85 \pm 0.5\,M_{\odot}\,\text{yr}^{-1}$.

2. Temporal Variability

Both the longitudinal magnetic field and Hα equivalent width of HD 57682 are strongly variable. In addtion to our 17 ESPaDOnS observations, we've also utilized Hα observations from amateur spectroscopy from the BeSS database, as well archival ESO UVES and FEROS observations dating back over a decade. A period search of these data resulted in a period of ∼31 d, consistent with the rotational period estimated by Grunhut *et al.* (2009). However, the magnetic data could not be reasonably phased with this period. Ultimately, adopting a period of 63.58 d (twice the period obtained from the Hα data) resulted in a coherent phasing of all the data at our disposal, as shown in Fig. 1.

The longitudinal magnetic field appears to vary sinusoidally, consistent with a magnetic field dominated by a strong dipolar component. The Hα equivalent width shows a double-wave pattern with peak emission occurring at the magnetic crossover phases (i.e. when the longitudinal field is null).

The photometric light curve from Hipparcos shows no apparent variability. This likely indicates that the column density of the magnetically confined plasma is relatively low at eclipse phases.
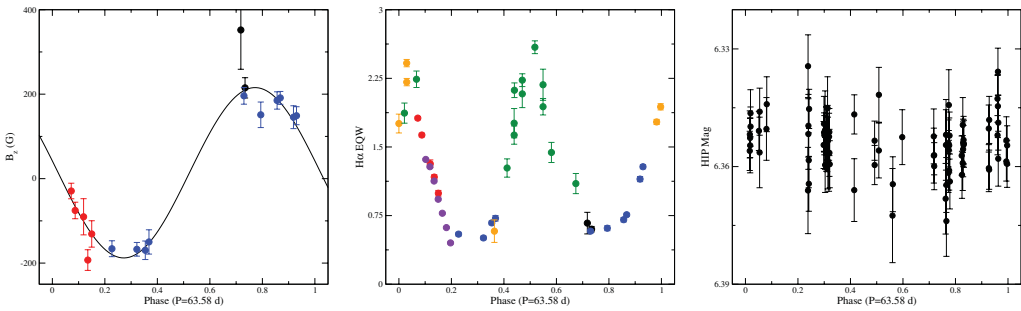
Figure 1. Phased longitudinal magnetic field measurements (left), Hα equivalent width variation (middle), and Hipparcos photometry (right), for HD 57682. Different colours indicate different epochs of observations.
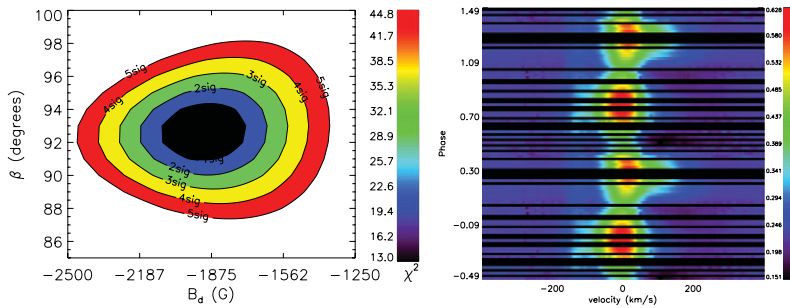

Figure 2. Left: χ^2 landscape as a function of dipole field strength (B_d) and obliquity angle (β). Shown are the intervals corresponding to 1, 2, 3, 4, and 5σ using $i = 22°$. **Right:** Phased Hα residual variations relative to an LTE model. Note the variability is likely due to a magnetically confined wind.

3. Magnetic Geometry and Circumstellar Environment

Using the longitudinal component of the magnetic field, measured from the mean LSD Stokes V and I profiles, we are able to fit a dipole model, characterized by the magnetic field strength at the poles (B_d) and the angle of obliquity of the magnetic axis relative to the rotation axis (β). Using the $v \sin i$ and radius as determined by Grunhut *et al.* (2009) and assuming rigid rotation, we can infer an inclination angle $i = 22^{+17}_{-9}$°. Using this value we obtain the χ^2 landscape as a function of B_d and β shown in Fig. 2. Taking into account the range of possible inclination angles, we find that $B_d = 1 - 3\,\mathrm{kG}$ and $\beta = 94° \pm 5°$.

In Fig. 2 we also show the residual variations of Hα phased with the adopted rotational period. We conclude based on the characteristics of this dynamic spectrum that the magnetic field is exerting strong confinement (confinement parameter $\eta* \sim 10^3 - 10^5$; ud-Doula & Owocki 2002) on the weak wind of HD 57682, resulting in the Hα variability. However, the slow rotation is likely unable to centrifugally support a stable magnetosphere. Therefore, the plasma that is present likely has a relatively short residence time in the magnetosphere, and must therefore be continually replenished (see Townsend *et al.* these proceedings).

References

Grunhut, J. H., Wade, G. A., Marcolino, W. L. F., Petit, V. *et al.* 2009, *MNRAS*, 400, L94
ud-Doula, A. & Owocki, S. P. 2002, *ApJ*, 576, 413