Analysis of Magnetic field Geometry and Its Interaction with Circumstellar Environment of HD 57682 by the MiMeS Collaboration

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Abstract. We 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. We 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, we report on our investigation of the magnetic field geometry and the effects of the field on the circumstellar environment.

Key words: 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 (see Fig. 1). Grunhut et al. also used IUE ultraviolet and ESPaDOnS optical spectroscopy to determine the following physical parameters using CMFGEN: $T_{\rm eff} = 34.5\,{\rm kK}$, $\log(g) = 4.0 \pm 0.2$, $R = 7.0^{+2.4}_{-1.8}\,R_\odot$, $M = 17^{+19}_{-9}\,M_\odot$, and $\log(\dot{M}) = -8.85 \pm 0.5\,M_\odot\,{\rm yr}^{-1}$. Of particular interest, we highlight the low mass-loss rate derived from UV wind diagnostic lines, which show variability characteristic of other magnetic OB stars (e.g. Schnerr et al. 2008), as shown in Fig. 1.

With only 7 observations of this star at our disposal at that time we employed a Bayesian inference method to determine the best-fitting dipole parameters to characterize the magnetic field (Petit et al. in prep). We concluded that the dipolar field of HD 57682 is characterized by a polar strength of ∼1.7 kG, and a magnetic axis aligned within 10 to 50° of the rotation axis, depending on the inclination of the rotation axis to our line of sight.

Since our original report of this star in 2009, we have obtained an additional 10 high-resolution spectropolarimetric observations with the ESPaDOnS instrument at CFHT.
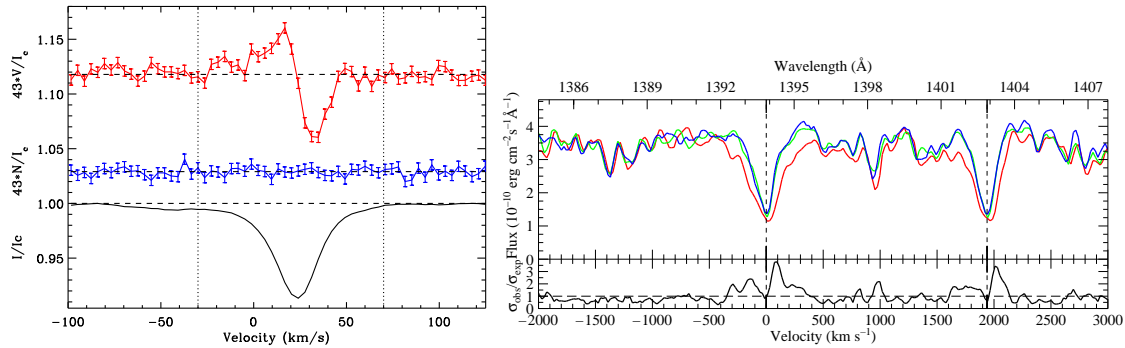
Figure 1: **Left:** Observed mean LSD Stokes V (top), diagnostic null (middle), and unpolarized Stokes I (bottom) profiles of HD 57682 from 2008-12-06. **Right:** Overplot of 3 IUE UV spectra of the Si IV line profiles (top). The significance of the variability is displayed at the bottom.
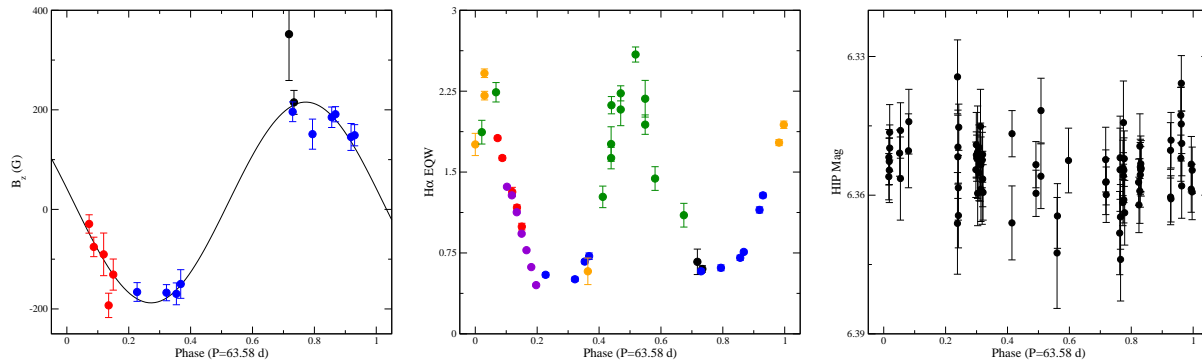

Figure 2: Phased longitudinal magnetic field measurements (left), Hα equivalent width variation (middle), and Hipparcos photometry (right), for HD 57682. Different colours indicate different epochs of observations.

2. Temporal Variability

Both the longitudinal magnetic field and Hα equivalent width of HD 57682 are strongly variable. In addition to our 17 ESPaDOnS observations, we've also utilized Hα observations from amateur spectroscopy from the BeSS database, as well as archival ESO UVES and FEROS observations dating back over a decade. A period search of these data resulted in a period of $\sim$31 d, consistent with the maximum original 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. 2.This period is inconsistent with the fundamental parameters derived by Grunhut et al., likely indicating that the $v \sin i$ is too high by nearly a factor of two.

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.
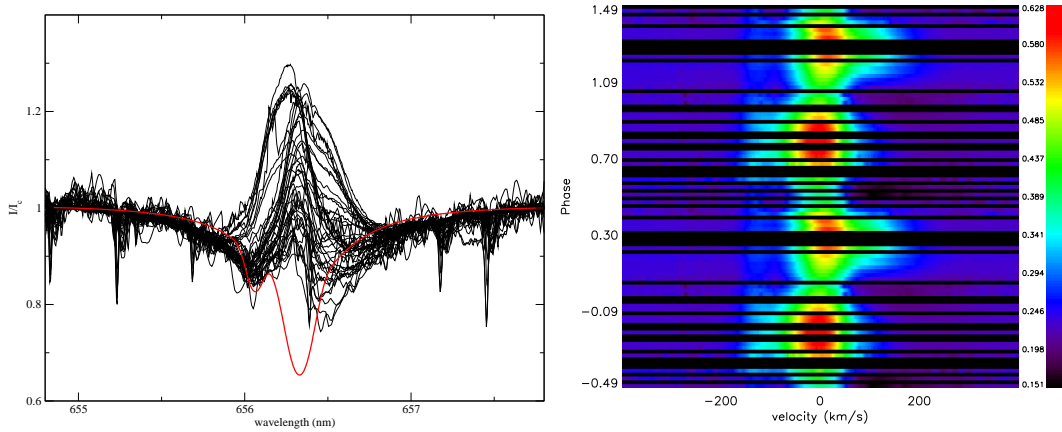
Figure 3: **Left:** Hα (black) profiles for different nights compared to a LTE model profile (red). **Right:** Phased Hα residual variations relative to an LTE model. Note the variability is likely due to a magnetically confined wind.

3. Magnetic Geometry and Circumstellar Environment

We are capable of fitting 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)) to the longitudinal component of the magnetic field, measured from the mean LSD Stokes V and I profiles. However, since we do not have any constraints on the inclination angle of the rotation axis, we can only estimate that $B_d = 1 - 3\,\mathrm{kG}$ and $\beta = 60 - 90°$.

In Fig. 3 we 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 observed 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.

References

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