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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 magnetic properties of the O9IV star HD 57682, using spectropolarimetric observations obtained with the 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)

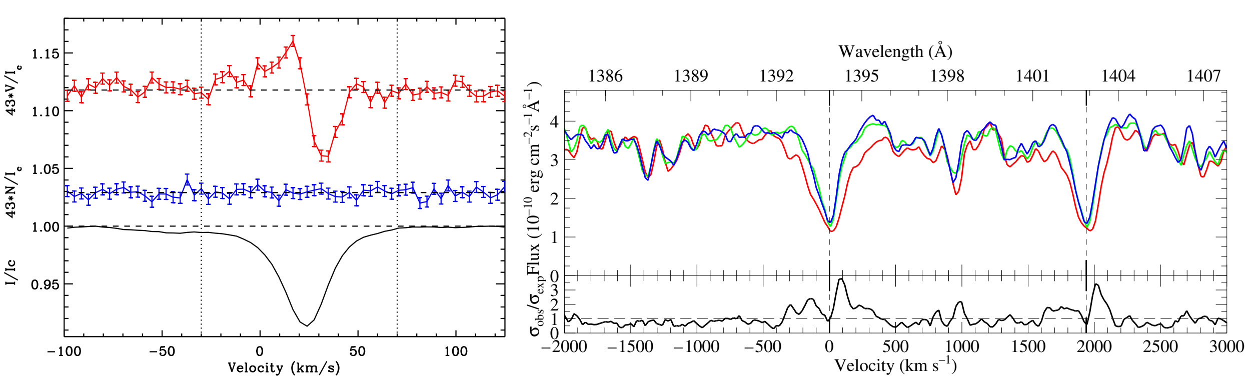

Figure 1: **Upper:** The observed mean LSD Stokes V (top), diagnostic null (middle), and unpolarized Stokes I (bottom) profiles of HD 57682 from 2008–12–06. **Lower:** Overplot of 3 *IUE* UV spectra of the Si IV line profiles (top). The significance of the variability is displayed at the bottom.

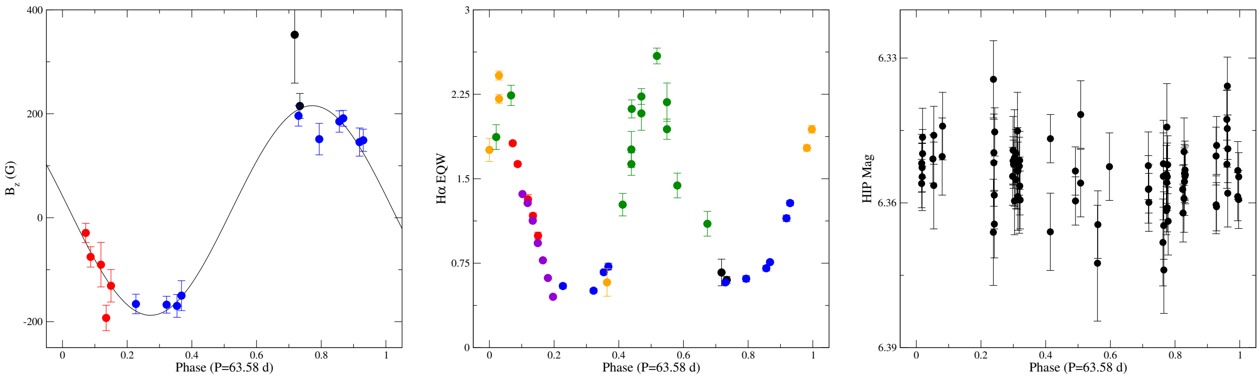

Figure 2: Phased longitudinal magnetic field measurements (left), Hα equivalent width variation (middle), and Hipparcos photometry (right), for HD 57682. Different colours indicate different observational epochs.

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 the mean Least–Squares Deconvolution (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 the CMFGEN: $T_{\rm eff} = 34.5$ 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 mark the low mass-loss rate, derived from the UV wind diagnostic lines, which show the 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 preparation). 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 on this star in 2009, we have obtained 10 additional high–resolution spectropolarimetric observations with the ESPaDOnS instrument at the CFHT.

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 have also utilized the Hα amateur spectroscopy observations from the BeSS database, as well as the archive ESO UVES and FEROS observational data dating back over a decade. A period search of these data resulted in the period of ~ 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., indicating that the $v \sin i$ is likely 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 a peak emission occurring at the magnetic crossover phases (i. e. when the longitudinal field is

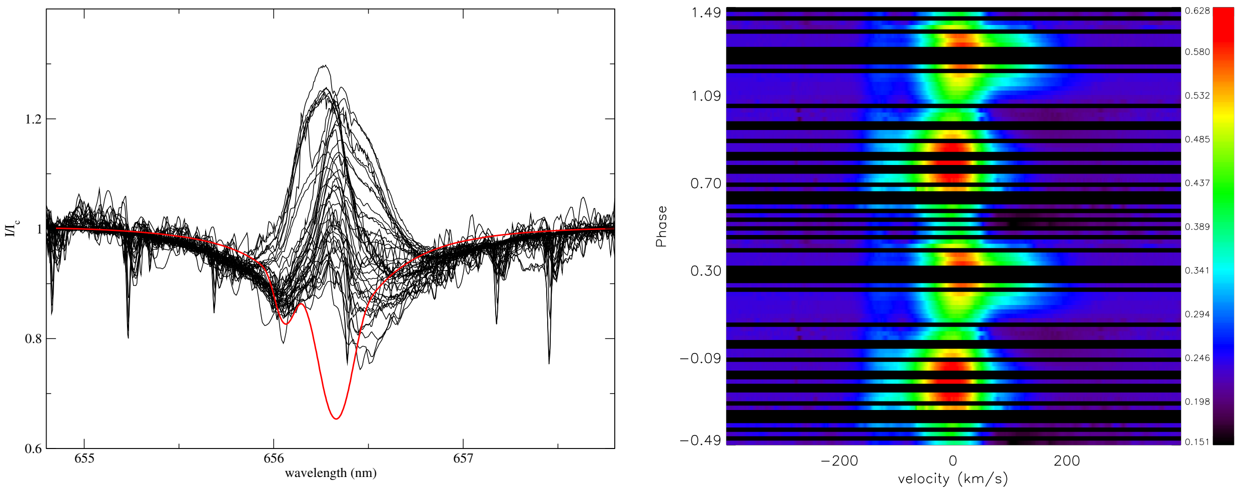

Figure 3: **Left:** Hα (black) profiles for different nights compared to the LTE model profile (red). **Right:** Phased Hα residual variations relative to the LTE model. Note that the variability is likely due to a magnetically confined wind.

null).

The photometric light curve from the Hipparcos shows no apparent variability. This likely indicates that the column density of the magnetically confined plasma is relatively low at the eclipse phases.

3 Magnetic Geometry and Circumstellar Environment

We are capable of fitting a dipole model (characterized by 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 $\beta = 60 - 90°$.

Figure 3 presents residual variations of Hα phased with the adopted rotational period. Based on the characteristics of this dynamic spectrum we conclude that the magnetic field exerts a 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, slow rotation is likely unable to centrifugally support a stable magnetosphere. Therefore, the plasma that is present possibly has a relatively short residence time in the magnetosphere, and must therefore be continually replenished.

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