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Systematic Detection of Magnetic Fields in Descendants of Massive OB Stars

Grunhut J. H.[1,2], **Wade G. A.**[1], **Hanes D. A.**[2], **Alecian E.**[3]

[1] Department of Physics, Royal Military College of Canada, Kingston, Ontario, Canada
[2] Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, Ontario, Canada
[3] LAOG, Laboratoire d'Astrophysique de Grenoble, Université Joseph Fourier, Grenoble, France

Abstract. We present the results of an ongoing survey of cool, late–type supergiants — the descendants of massive O and B–type stars — that has systematically detected magnetic fields in these stars using spectropolarimetric observations obtained with the ESPaDOnS at the Canada–France–Hawaii Telescope. Our observations reveal detectable, often complex Stokes V Zeeman signatures in the Least–Squares Deconvolution mean line profiles in a significant fraction of the observed sample of $\sim$30 stars.

Key words: instrumentation: polarimeters – techniques: spectroscopic – stars: magnetic fields – stars: supergiants

1 Introduction

Supergiants are the descendants of massive O and B–type main sequence stars. Unlike their main sequence progenitors, cool supergiants are characterized by a helium–burning core and a deep convective envelope.

Due to their extended radii, low–atmospheric densities, slow rotation and long convective turnover times, supergiants provide an opportunity to study stellar magnetism at the extremes of parameter space.

In fact, the observations of late–type supergiants show characteristics consistent with magnetic activity, such as luminous X–ray emission and flaring, and emission in the chromospheric UV lines — the phenomena suggesting the presence of dynamo–driven magnetic fields.

Motivated by the activity–related puzzles of late–type supergiants, a nearly complete lack of direct constraints on their magnetic fields, and recent success of measuring fields of red and yellow giants (e. g. Aurière et al., 2008), we have initiated a program to search for direct evidence of magnetic fields in these massive, evolved stars. Here we summarize the recent results of Grunhut et al. (2010).

2 Observations

Circular polarization (Stokes V) spectra were obtained with the high–resolution ($R \sim 68000$) ESPaDOnS and NARVAL spectropolarimeters at the Canada–France–Hawaii Telescope and Bernard Lyot Telescope as part of a large survey investigating the magnetic properties of late–type supergiants.

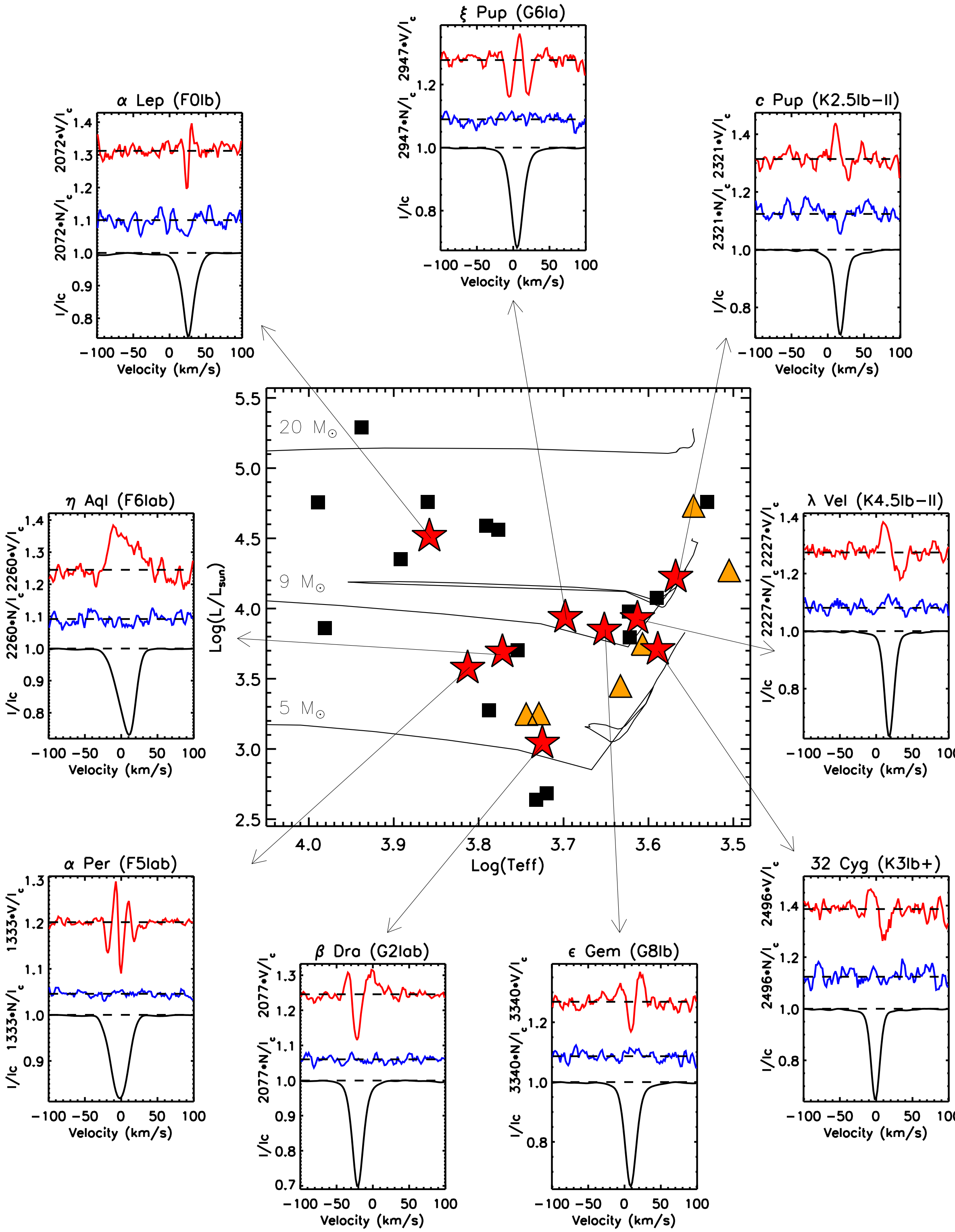

Figure 1: The HR diagram showing all observed supergiants. Black squares indicate stars for which no Zeeman signatures were detected, orange triangles indicate stars with presumable Zeeman signatures, while red stars represent supergiants with clear Zeeman signatures. Surrounding the HR diagram are illustrative mean Stokes V (top), diagnostic null (middle), and unpolarized Stokes I (bottom) LSD profiles of the 9 stars with clear detections.

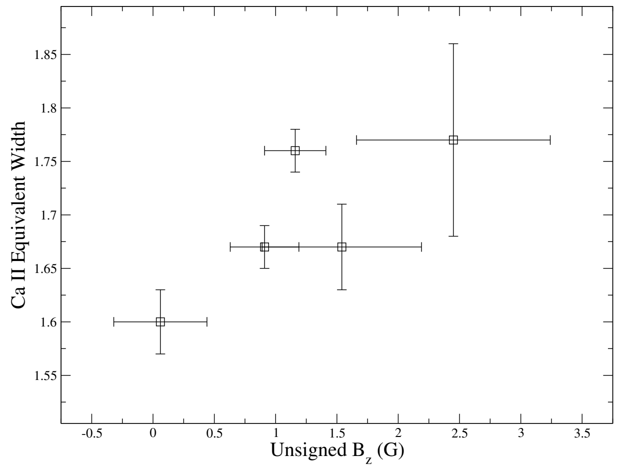

Figure 2: Ca II K line core equivalent width measurements for β Dra as a function of the unsigned longitudinal magnetic field B_z

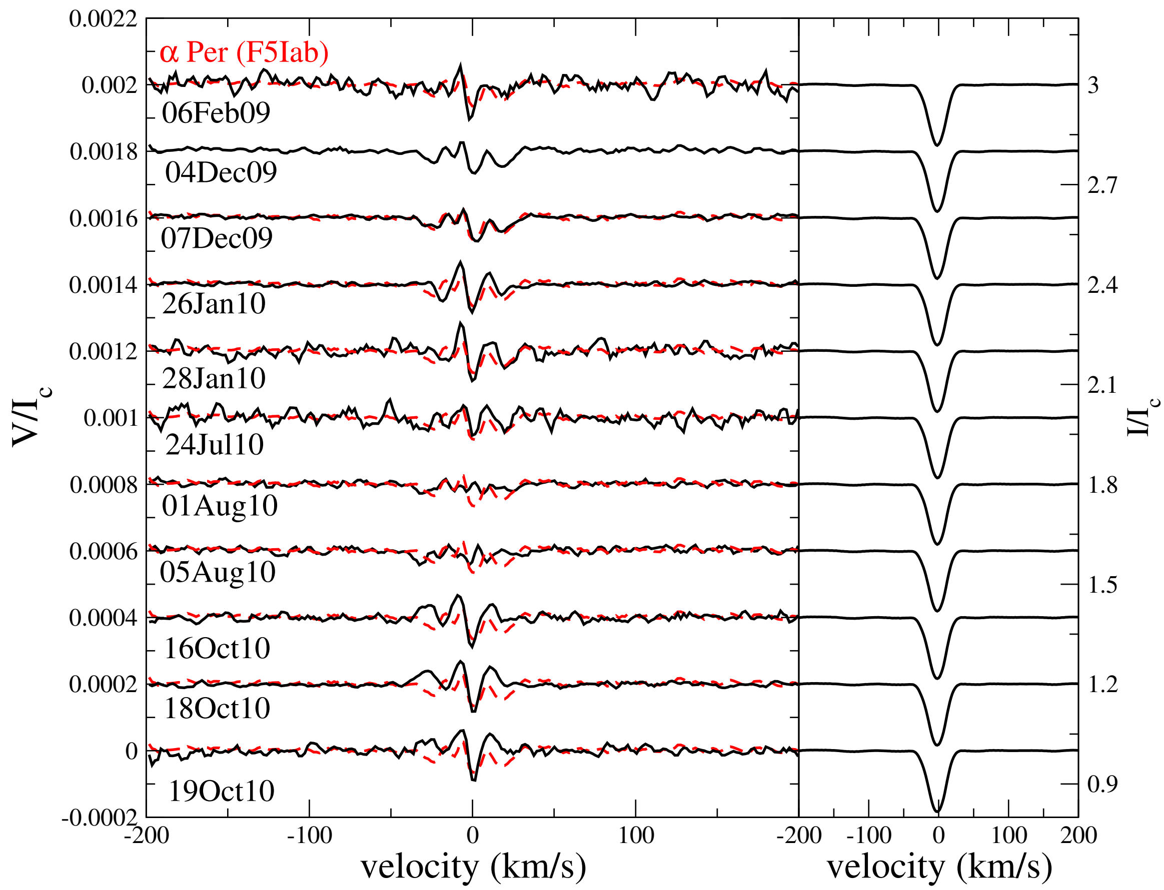

Figure 3: The stokes V profiles (left, solid lines) and Stokes I (right) of α Per for the nights indicated. The profiles are vertically offset for display purposes. The dashed line corresponds to the observational data obtained on 04 Dec. 2009, shifted to the position of each night in order to highlight the changes in the profile.

To date, we have observed more than 30 stars: 4 A–type stars, 8 F–type stars, 11 G–type stars, 7 K–type stars, and 3 M–type stars.

3 Magnetic Field Diagnosis

We applied the Least–Squares Deconvolution (LSD; Donati et al., 1997) technique to all our data in order to increase the S/N and detect weak Zeeman signatures.

In Fig. 1 we present all stars with clear Zeeman signatures detected in the Stokes V. Also shown in Fig. 1 is the placement of all the studied stars on the HR diagram.

4 Results

Our investigation shows that many late–type supergiants host detectable Stokes V Zeeman signatures, which are frequently complex. The detected stars span a large range of physical characteristics, with the most massive being α Lep ($\sim 15\,M_{\odot}$), which also happens to be the hottest star in our sample ($T_{\rm eff} \sim 7000$ K). The lowest mass detection is β Dra ($\sim 5\,M_{\odot}$), while the coolest star is either c Pup or λ Vel, depending on the adopted temperature (both ~ 3500 K).

Overall, we find that approximately 1/3 of our sample reveals detectable Zeeman signatures in the Stokes V. However, we find no clear differences between the classical activity indicators (such as Ca II H&K or Hα emission) of those stars with or without detections. However, we do find a weak correlation between the Ca II core equivalent width and the magnetic field strength for the stars with multiple observations, as displayed in Fig. 2. In addition, we also see clear temporal variability of the Stokes V profiles for the targets with multiple observations, as shown in Fig. 3.

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