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Plasma Leakage from the Centrifugal Magnetospheres of Magnetic B-Type Stars

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Abstract. Magnetic B-type stars are often host to *Centrifugal Magnetospheres* (CMs). Here we describe the results of a population study encompassing the full sample of known magnetic early B-type stars, focusing on those with detectable CMs. We present revised rotational and magnetic parameters for some stars, clarifying their positions on the rotation-confinement diagram, and find that plasma densities within their CMs is much lower than those predicted by centrifugal breakout.

Keywords. plasmas, stars: circumstellar matter, stars: magnetic fields, stars: rotation

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Magnetic confinement of the winds of magnetic OB stars is explained by ud-Doula *et al.*, (this volume) while for a description of CMs and the Rigidly Rotating Magnetosphere (RRM; Townsend *et al.* 2005) model we refer to Oksala *et al.* (this volume).

It is not known how plasma escapes from CMs. The leading proposal is violent ejection in a so-called 'centrifugal breakout' (CB) event (Townsend *et al.* 2005; ud-Doula *et al.* 2008): plasma density increases beyond the ability of the magnetic field to confine the wind, thus rupturing the magnetic field structure. However, no direct evidence of CB has been found (e.g. Townsend *et al.* 2013), motivating a deeper examination of the properties of CMs.

We are conducting a population study of the magnetic B-type stars presented by Petit *et al.* (2013) (see also Fig. 1), aimed at studying the dependence of CM emission on stellar, magnetic, and rotational properties. We are performing systematic follow-up observations of newly discovered or poorly studied magnetic B-type stars, with the intent of determining rotational periods (and hence Kepler radii $R_{\rm K}$) and dipolar magnetic field strengths (and hence Alfvén radii $R_{\rm A}$) for all stars. We also measure the emission strengths and plasma densities of the sub-set of stars with CMs via Hα emission (about 25% of the magnetic B-type population: filled symbols in Fig. 1).

We have measured the emission equivalent width (EW) of CM host stars, in both Hα and UV resonance lines, by subtracting model photospheric spectra from observed spectra. We find clear thresholds dividing stars with and without Hα emission ($R_{\rm A} > 20R_*$, $R_{\rm K} < 3R_*$, $\log R_{\rm A}/R_{\rm K} > 1$), however, beyond these thresholds there are no clear trends. In contrast to Hα, UV line emission is generally stronger, and more widely distributed in the rotation-confinement diagram (outlined symbols in Fig. 1).

Using EWs for Hα, Hβ, and Hγ, we measured the circumstellar plasma density via Balmer decrements (Williams & Shipman 1988) at emission maximum (corresponding to the rotational phase at which the line-of-sight is closest to perpendicular to the

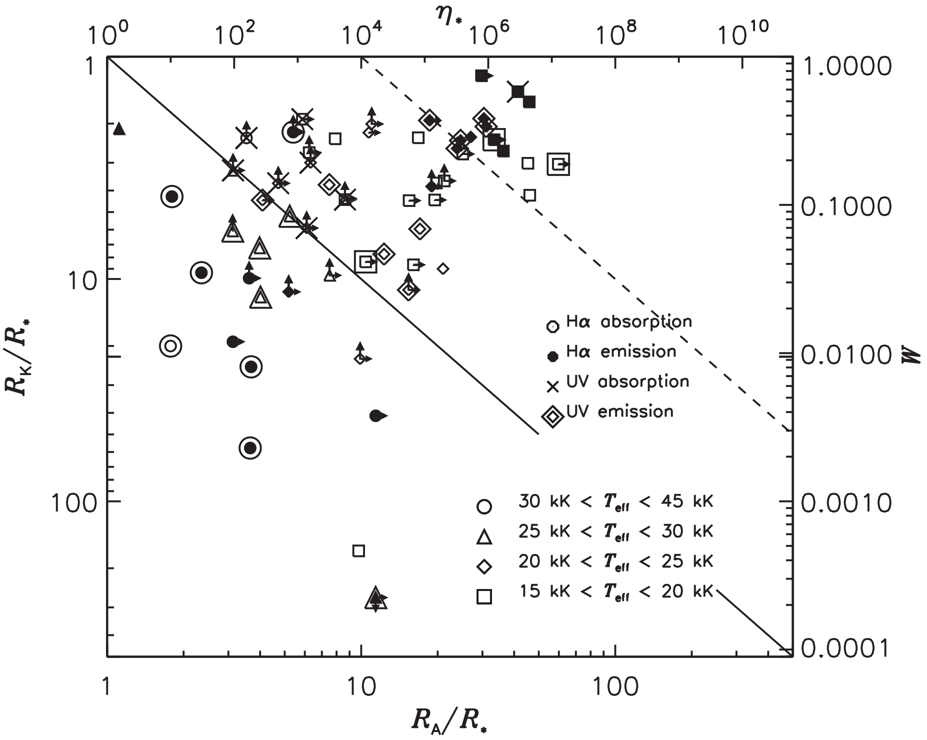

Figure 1. An up-dated rotation-confinement diagram, first presented by Petit *et al.* (2013). Stars are organized by magnetic confinement radius, the Alfvén radius $R_{\rm A}$, and the radius at which centrifugal and gravitational forces balance, the Kepler radius $R_{\rm K}$, both in terms of the stellar radius R_*. These are respectively proportional to the magnetic wind confinement parameter η_* and the rotation paramter W. Closer analysis of sample stars has moved some stars with Hα emission above $R_{\rm A} = 10R_{\rm K}$ (the diagonal dashed line), while some stars with Hα in absorption have been moved below this line. One Hα absorption star, HD 35912, has been removed entirely, due to non-detection of a Zeeman signature in 11 ESPaDOnS observations with $< \sigma_B > \sim 40$ G. A new Hα emission star, ALS 3694, has been discovered with new ESPaDOnS data. Finally, $R_{\rm K}$ of the early-type β Cep star ξ^1 CMa has been revised sharply upward to $>270\ R_*$ (see Shultz *et al.*, this volume).

plane of the magnetosphere). There is no significant variation from the mean density, $\log N \sim 12.5$, with $0.15 < \sigma_{\log N} < 0.7$ dex. CB predicts both substantially higher plasma densities, and clear, strong trends in plasma density, increasing with increasing $R_{\rm A}$ and decreasing $R_{\rm K}$. Furthermore, CB predicts that plasma density should be high enough for Hα emission in numerous stars for which no such emission is detected.

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