A Magnetic Confinement vs. Rotation Classification of Massive-Star Magnetospheres

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Building on results from the Magnetism in Massive Stars (MiMeS) project, this paper shows how a two-parameter classification of massive-star magnetospheres in terms of the magnetic wind confinement (which sets the Alfv'en radius RA) and stellar rotation (which sets the Kepler co-rotation radius RK) provides a useful organisation of both observational signatures and theoretical predictions. We compile the first comprehensive study of inferred and observed values for relevant stellar and magnetic parameters of 64 confirmed magnetic OB stars with Teff > 16 kK. Using these parameters, we locate the stars in the magnetic confinement-rotation diagram, a log-log plot of RK vs. RA. This diagram can be subdivided into regimes of centrifugal magnetospheres (CM), with RA > RK, vs. dynamical magnetospheres (DM), with RK > RA. We show how key observational diagnostics, like the presence and characteristics of Halpha emission, depend on a star's position within the diagram, as well as other parameters, especially the expected wind mass-loss rates. In particular, we identify two distinct populations of magnetic stars with Halpha emission: namely, slowly rotating O-type stars with narrow emission consistent with a DM, and more rapidly rotating B-type stars with broader emission associated with a CM. For O-type stars, the high mass-loss rates are sufficient to accumulate enough material for line emission even within the relatively short free-fall timescale associated with a DM: this high mass-loss rate also leads to a rapid magnetic spindown of the stellar rotation. For the B-type stars, the longer confinement of a CM is required to accumulate sufficient emitting material from their relatively weak winds, which also lead to much longer spindown timescales. Finally, we discuss how other observational diagnostics, e.g. variability of UV wind lines or X-ray emission, relate to the inferred magnetic properties of these stars, and prospects for future developments in our understanding of massive-star magnetospheres.

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