THE CLASS OF RADIO-EMITTING MAGNETIC B STARS AND A WIND-FED MAGNETOSPHERE MODEL

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ABSTRACT We have detected a total of 16 magnetic Bp–Ap stars at 6 cm out of 61 observed, including both He-strong and He-weak/Si-strong stars with \(\log L_6 = 14.7\) to 17.9, but none of the classical (SrCrEu-type) Ap stars at a detection limit of \(\log L_6 < 14.9\). We believe that the radio-emitting CP (chemically peculiar) stars form a distinct class of radio stars that differs from both the hot star wind sources and the active late-type stars. For the detected CP stars we find that \(L_6 \propto M_\odot^{0.5} B_{\text{rms}}\), produced by optically thick nonthermal gyrosynchrotron emission. In our model the electrons are accelerated in current sheets located 10-20 radii from the star.

Keywords: Magnetic fields; radio sources, identifications; stars, coronae; stars, peculiar A

OBSERVATIONS

In five VLA observing runs we have extended the initial survey of radio emission from magnetic Bp–Ap stars by Drake et al. (1987) to include a total of 16 sources detected at 6 cm. The 11 new stars detected as radio sources have spectral types B5–A0 and are He-weak and Si-strong. We have not yet detected any of the classical (SrCrEu-type) Ap stars with detection limits of 0.2 – 0.5 mJy corresponding to \(\log L_6 < 14.9\) for some stars, despite many attempts. The 16 detected sources show a wide range of radio luminosities with the early-B He-S stars on average 20 times more radio luminous than the late-B He-W stars and 1000 times more luminous than \(\theta\) Aurigae, the field star with both the lowest radio luminosity and the lowest effective temperature. Multifrequency observations indicate flat spectra in all cases. Four stars have a detectable degree of circular polarization at one or more frequencies. For a full description of the observations and our model see Linsky et al. (1991).

We believe that the radio-emitting CP (chemically peculiar) stars form a distinct class of radio stars. For the detected CP stars we find that \(L_6 \propto\)

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\( \dot{M}^{0.5} B_{rms} \), where \( \dot{M} \) is the mass loss rate and \( B_{rms} \) is the rms value of the observed longitudinal field strength. The dependence on \( \dot{M} \), the rapid increase in \( L_6 \) with \( T_{eff} \), and the absence of obvious flares distinguishes the CP stars from the active cool stars. The radio emission from the CP stars is several orders of magnitude larger than the predicted thermal and nonthermal wind emission from the hot stars, and therefore not an extension of this class of radio emitters.

A WIND-FED MAGNETOSPHERE MODEL

We argue that the observed properties of radio emission from these stars may be understood as optically thick gyrosynchrotron emission from a nonthermal distribution of electrons produced in a current sheet far from the star. Our model (see Fig. 1) consists of a rotating dipolar magnetosphere in which stellar wind plasma flows out from near the magnetic poles along the field lines. Far from the star \( (r \geq 10 R_\ast) \), the gas pressure exceeds the magnetic pressure and the field lines near the equator are drawn out into current sheet configurations (see Havnes and Goertz 1984), in analogy to planetary magnetotails. These current sheets are likely locations of plasma heating and of particle acceleration. In our "direct injection" scenario the electrons return to near the star by traveling along magnetic fields, where they mirror and radiate in the strong fields near the poles.

![Diagram of a CP star and its magnetosphere](image)

Fig. 1: A cartoon showing a cross section through a CP star and its magnetosphere. For simplicity, an aligned rotator is shown. A dense stipple indicates the presence of dense, trapped thermal plasma. A light stipple indicates the possible presence of tenuous thermal plasma. The small dark circles indicate schematically where high frequencies originate; larger, lighter circles indicate the location of the source with decreasing frequency.

Our model accounts for time variability in terms of intrinsic variability in the acceleration process and rotational modulation of the projected area of the emitting region. The flat microwave spectra result from two factors: (i) a decrease in source size with increasing frequency; and (ii) a decrease in the effective temperature of the emitting electrons with increasing frequency.
The finite degree of circular polarization observed on some sources may be the result of an opacity effect resulting from the increasing magnetic field strength with decreasing radius. Finally, the decreasing radio luminosity with decreasing stellar effective temperature along the main sequence is explained primarily as a result of the decreasing mass loss rate.

While there is some overlap between the properties of the nonthermal radio emission from CP stars and those of the RS CVn binaries (Table 1), the physical basis of the radio emission is quite different in each case. For CP stars, the radio emission is intimately related to both the magnetic field and the mass loss rate while this does not appear to be the case for the RS CVn binaries. However, the model proposed here for the nonthermal radio emission from magnetic CP stars may have some relevance to certain of the weak T Tauri stars and other PMS objects (e.g., André et al. 1991).

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REFERENCES


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