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Electron Cyclotron Maser Emission phenomenon in hot magnetic stars

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Abstract

It was discovered in 2000 that magnetic Bp main sequence star CU Vir exhibits remarkable coherent radio emission identified as electron cyclotron maser emission (ECME). It remained the only known star to do so until 2015 when Chandra et al. (2015) identified a similar ECME behaviour in HD 133880, which was later confirmed by Das et al. (2018). In the past one year, 3 more stars have been discovered to exhibit this phenomenon, making a total of five hot magnetic main sequence stars to display ECME phenomenon.

1 Introduction

Roughly 10% of the Galactic hot stars with spectral type O, B and A are known to be magnetic (Wade & Neiner, 2018). While the radio emission from non-magnetic hot stars is expected to be thermal free-free emission, one expects a significant contribution from the non-thermal gyrosynchrotron emission due to acceleration of electrons in the presence of magnetic fields. However, a rare phenomenon of electron cyclotron maser emission (ECME) in radio bands was identified in CU Vir (Trigilio et al., 2000). It remained the only known star to exhibit ECME for more than 15 years. However, in recent years, due to sensitive low frequency surveys, stars with ECME phenomena have increased five folds. Below we summarize the stars in which ECME has recently been discovered.

2 HD 133880

HD 133880 is a young Bp type star with a rotation period of ~ 0.88d and an unusual magnetic topology with a non-dipolar longitudinal (line-of-sight) magnetic field (B_z) variation (Kochukhov et al., 2017). Chandra et al. (2015) reported large flux enhancements in Giant Metrewave Radio Telescope (GMRT) 1390 and 610 MHz observations at magnetic nulls and speculated their origin to be ECME in nature. However, they did not have polarization information to conclusively ascertain it. Later Das et al. (2018) carried out GMRT observations covering the full rotational cycle of the star and found flux density enhancements near the magnetic nulls with nearly 100% right circular polarization (RCP; Fig. 1). They detected no enhancements in the left circular polarization (LCP), and attributed this to the star's complex magnetic geometry.

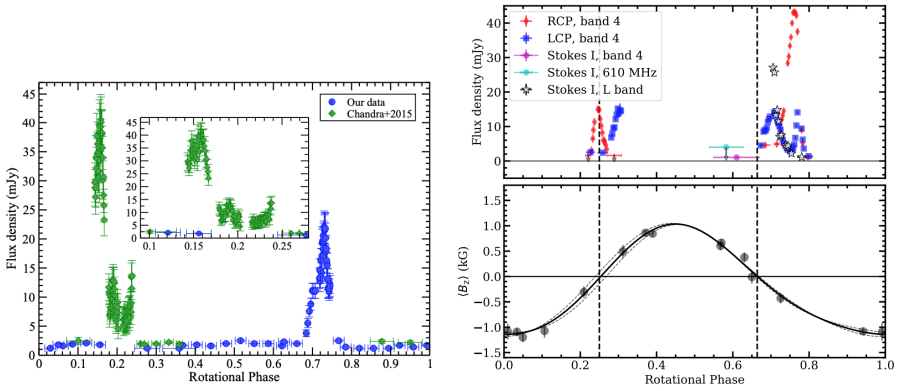

Figure 1: Left: Variation of the 610 MHz flux of HD 133880 with rotational phase for RCP (Das et al., 2018). Right: ECME phenomenon in HD 142990 (Das et al., 2019a).

3 HD 142990

HD 142990 is a Bp-type star with a nearly dipolar surface magnetic field of kG strength, and a rotation period of ~ 0.98 d (Shultz et al., 2018). Lenc et al. (2018) speculated the presence of ECME from highly circularly polarised emission detected in an all sky circular polarisation survey with the Murchison Widefield Array at 200 MHz. Independently Das et al. (2019a) found flux enhancements with the upgraded GMRT (uGMRT) in band 4 ($550 - 804$ MHz) near the magnetic nulls in both circular polarisations (Fig. 1). Surprisingly they observed enhancements with opposite circular polarisations from the same magnetic pole in one of the observations. They suggested a scenario that involves a transition of the dominant mode of ECME between the two magneto-ionic modes.

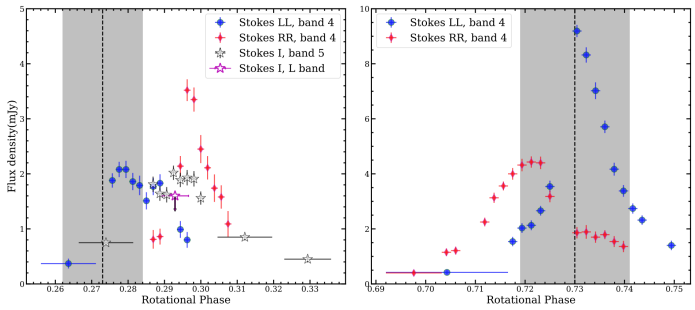

Figure 2: Lightcurves of HD 35298 near the magnetic null phases. (Das et al., 2019b).

4 HD 35298

HD 35298 is a Bp star with a rotation period of $\sim$ 1.85d (Shultz et al., 2018). Das et al. (2019b) observed flux density enhancements in both polarisations near magnetic nulls in bands 4 and one of the nulls in band 5 (1000-1450 MHz) uGMRT observations. Based on the high circular polarization combined the flux enhancements near magnetic nulls, they concluded this to be an ECME phenomenon (Fig. 2). From the arrival sequence pulses in both polarizations, they deduced the mode of emission to be ordinary mode.

In addition, Leto et al. (2019) also reported ECME in Bp type star HD 142301.

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