

CIRCUMSTELLAR RADIO EMISSION FROM PRE-MAIN SEQUENCE STARS

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ABSTRACT. VLA radio continuum observations have been obtained for a number of pre-main sequence (PMS) stars in Corona Australis, Lupus, Scorpius and Taurus. A variety of PMS sources were detected and for other stars upper limits to the ionized mass loss rates were determined. A strong double source, showing two radio jets, was found associated with an embedded infra-red source in the R CrA molecular cloud. Some of the PMS stars show extended radio emission associated with ionized circumstellar envelopes, even though photoionization by EUV photons is not sufficient to produce the ionized regions.

Five fields in Corona Australis, Scorpius and Lupus, centered on R CrA, TY CrA, CrA X-1, HR 5999 and RU Lup, were observed using the VLA* in C and C/D array during 1985 September and October. Eleven 6 cm radio continuum sources were found in the CrA molecular cloud; the only sources with optical counterparts were TY CrA (1.2 mJy) and the Herbig Haro object HH 101 (0.24 mJy). For the other sources near R CrA there was exceptionally good correlation between the detected 6 cm sources and the positions of 2 μ infrared sources from the mapping of Taylor and Storey (1984). The strongest source in this field, first detected by Brown and Zuckerman (1975), is a double source coincident with the 2 μ source IRS7. The double source has two extended radio "jets" and an integrated flux density of 21.7 mJy. The radio jets show internal structure and appear to be inclined to the plane of the sky. IRS7 is the most deeply embedded IR source of Taylor and Storey with $A_V = 20-25$ magnitudes. Table 1 presents data on six stars which were not detected but for which interesting upper limits result. The case of RU Lupi is particularly interesting because the upper

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TABLE 1. Some PMS stars for which only 6 cm upper limits were obtained.

Star	Spectral Type	Distance (pc)	3σ Upper Limit (mJy)	Ionized \dot{M} (M_{\odot}/yr)*	Comment
R CrA	F0e	130	0.18	$\leq 1 \times 10^{-8}$	PMS F star
T CrA	F0e	130	0.18	$\leq 1 \times 10^{-8}$	PMS F star
CrA X1	K0	130	0.16	$\leq 1 \times 10^{-8}$	Naked T Tauri star
RU Lup	---	150	0.13	$\leq 1 \times 10^{-8}$	Extreme T Tauri star
HR 5999	A7 IIIe	270	0.15	$\leq 3 \times 10^{-8}$	Herbig Ae star
HR 6000	B6 Vp	270	0.15	---	Young Bp star

* Assuming wind velocity of 200 km/s. For HR 5999 $v_{\text{wind}} \sim 100$ km/s is a better estimate giving $\dot{M} < 1.5 \times 10^{-8} M_{\odot}/\text{yr}$.

limit to the ionized mass loss is an order of magnitude smaller than that suggested by the models of Lago (1984), but consistent with that of Kuin (1986). Both these models are based on Alfvén wave-driven wind theory.

VLA observations of HL and XZ Tau have shown evidence for extended radio emission. These stars show spectral indices of 1.0 ± 0.3 and 0.9 ± 0.3 , respectively, based on 6 cm and 2 cm data (Brown, Drake, and Mundt, 1986). These values suggest that the emission is free-free emission from their stellar winds.

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