THE RADIO SPECTRA OF WEAK-LINED T TAURI STARS

S. M. WHITE
Dept. of Astronomy, Univ. of Maryland

R. PALLAVICINI
Arcetri Observatory, Florence, Italy

J. LIM
Solar Astronomy, Caltech

ABSTRACT The weak-lined T Tauri stars have been found to be amongst the most radio-luminous of all active stars, although their distance (> 150 pc) makes them difficult to study. Here we present observations of the radio spectra and circular polarization of a number of these objects, and compare their properties with those of other classes of active stars.

THE RADIO SPECTRA OF WEAK-LINED T TAURI STARS

Weak-lined (also known variously as post- or naked-) T Tauri stars (WTTs) are thought to be low-mass pre-main-sequence objects (Herbig 1978) which have passed beyond the T Tauri phase in which the stars themselves are surrounded by dense circumstellar material. In the "naked" phase the circumstellar material has been blown away, and WTTs lack the extreme Hα emission and infrared excess associated with the circumstellar material in classical T Tauris. However, they have been found to be strong radio (Feigelson & Montmerle 1985, Andrè, Montmerle & Feigelson 1987, White, Pallavicini & Kundu 1992a) and X–ray sources (e.g., Walter *et al.* 1988).

There have been few dedicated studies of the radio spectra and polarization of these stars, since most observations of weak–lined T Tauris have been surveys. Knowledge of these properties is necessary to study the physics of the radio emission and its relationship to the other forms of activity on WTTs. We have carried out observations with the *Very Large Array* to study the spectrum and the polarization of several stars. For the spectral study we observed WTT stars in Taurus and Ophiuchus known from previous single-frequency surveys to be amongst the strongest radio sources: ROX 31, Oph 2, Oph 3 and DoAr21 in Ophiuchus, and HD283447, HD283572, V826 Tau, and 045226+30 in Taurus. Each was observed briefly during several periods in 1991 at 1.5, 5, 8 and 15 GHz. The resulting spectra are plotted in Figure 1. All sources except 045226+30 were detected. ROX 31 is possibly weakly positively polarized.

The spectra are consistently flat from 5 to 8 GHz, and seem to rise from 1.5

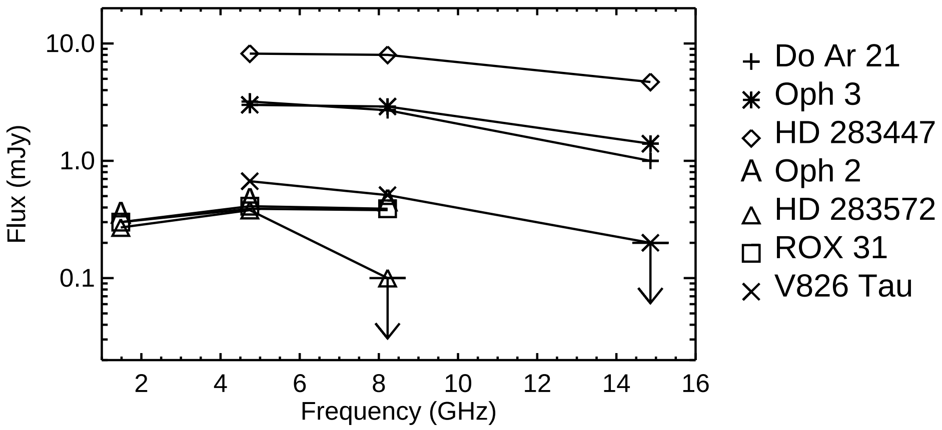

FIGURE I Radio spectra of weak-lined T Tauri stars.

to 5 GHz and fall from 8 to 15 GHz. In its stronger state (see below) HD 283447 has a flat spectrum from 5 to 15 GHz, so the high-frequency spectral shape may well depend on the flux level.

CIRCULAR POLARIZATION

Since all other active stars show significant degrees of circular polarization in their radio emission, the lack of detections of circular polarization in the early radio surveys of WTT's was a puzzle (Phillips, Lonsdale & Feigelson 1991). Longer, more sensitive, observations have since shown that there is measurable circular polarization present, but generally only at levels of several percent (White, Pallavicini & Kundu 1992b, Phillips 1992). Only one WTT has been detetected at a degree of polarization above 10% (Hubble 4 at $\sim$ 18%: Skinner 1993). We have carried out two further observations to both search for circular polarization, and to test whether there is a reversal in the sense of polarization between the low-frequency and high-frequency sides of the spectral peak. Such a flip is seen in RS CVn systems, and is well understood in terms of nonthermal gyrosynchrotron theory. The two stars chosen were the two most "radio-active" WTT's, DoAr 21 and HD 283447.

Both were observed in 1992, at 5 and 15 GHz. We picked these frequencies because the observations of V410 Tau suggested that the spectral peak was above 5 GHz (Bieging & Cohen 1989), so that 5 GHz would be on the optically-thick side of the spectrum. Given the variability of these stars, we were fortunate that both were detectable at both frequencies: HD 283447 was steady at 15 mJy at both frequencies, while DoAr 21 showed a flux of 1.6 mJy at 5 GHz and 1.0 mJy at 15 GHz. The sense of circular polarization of HD 283447 was negative at both frequencies as in previous detections, reaching 3% at 5 GHz and 5% at 15 GHz. However, Do Ar 21 was positively polarized at 5 GHz (10%; $<$ 15% at 15 GHz), whereas in its previous detection it was negatively polarized.

DISCUSSION

Let us compare the radio properties of WTTs with the well-studied radio properties of RS CVns:

- WTTs can reach luminosities of order 10^{18} ergs s^{-1} Hz^{-1}, which is only matched by RS CVns in their most active states.
- In RS CVns the spectrum depends on the flux level, being flat instead of falling at high frequencies as the flux level rises (Morris, Mutel & Su 1990). Comparing the two observations of HD 283447 in this paper suggests that this property may well be shared by WTTs.
- WTTs have smaller degrees of circular polarization than RS CVns. Unfortunately our statistics on the degree of polarization of WTTs at low flux levels are poor, so while the two detections of circular polarization in stars in a low state both have relatively high degrees of polarization (Hubble 4 in Skinner 1993, and DoAr 21 here), we cannot yet tell if, like RS CVns, the degree of polarization rises as flux decreases.
- Variability seems to occur on longer timescales on WTTs than on RS CVns: as yet no radio variations with doubling times much less than 1 hour have been seen on WTTs.

Some of these properties (e.g., slow variability, low polarization) could be explained if radio source sizes tend to be larger for WTTs, which VLBI observations suggest may be the case (Phillips, Lonsdale & Feigelson 1991). We have no explanation for the seemingly remarkable radio luminosities.

ACKNOWLEDGMENTS

Research in stellar radiophysics at the University of Maryland is supported by NSF grant AST 92–17891.

REFERENCES

Andrè, P., Montmerle, T., & Feigelson, E. D. 1987, *AJ*, **93**, 1182.
Bieging, J. H., & Cohen, M. 1989, *AJ*, **98**, 1686.
Feigelson, E. D., & Montmerle, T. 1985, *ApJL*, **289**, L19.
Herbig, G. H. 1978, in *Problems of Physics and Evolution of the Universe*, ed. L. V. Mirzoyan (Armenia: Armenian Academy of Sciences), p. 171.
Morris, D. H., Mutel, R. L., & Su, B. 1990, *ApJ*, **362**, 299.
Phillips, R. B. 1992, in *Cool Stars, Stellar Systems and the Sun (7th Cambridge Workshop)*, ed. M. S. Giampapa & J. A. Bookbinder (San Francisco: Astron. Soc. Pacific Conf. Ser. **26**), p. 309.
Phillips, R. B., Lonsdale, C. J., & Feigelson, E. D. 1991, *ApJ*, **382**, 261.
Skinner, S. L. 1993, *ApJ*, **408**, 660.
Walter, F. M., Brown, A., Mathieu, R. D., Myers, P. C., & Vrba, F. J. 1988, *AJ*, **96**, 297.
White, S. M., Pallavicini, R., & Kundu, M. R. 1992a, *A&A*, **257**, 557.
White, S. M., Pallavicini, R., & Kundu, M. R. 1992b, *A&A*, **259**, 149.