THE RADIO LIGHT CURVE OF V471 TAURI

J.–P. Caillault*, J. Patterson†, and D. Skillman§

*Department of Physics and Astronomy, University of Georgia
Athens, GA 30607

†Department of Astronomy, Columbia University
New York, NY 10027

§Center for Basement Astrophysics, 9517 Washington Ave.
Laurel, MD 20707

ABSTRACT

We have observed the white dwarf – K dwarf eclipsing binary system V471 Tauri with the VLA[1]. We have detected in the radio flux an interesting dip centered near phase zero (the phase of white dwarf eclipse) and a 6 mJy flare shortly after mid–eclipse at phase 0.15. The best possible explanation for the dip is the self–eclipse of a large radio–emitting cloud anchored to a particular spot on the secondary, namely the sub–white dwarf point. The 6 cm flare observation and sudden variations seen in Hα suggest that this spot is an active flaring region.

INTRODUCTION

In the last 16 years one of the most extensively observed stars has been V471 Tauri (= BD+16° 516), the 9th magnitude eclipsing binary in the Hyades. Nelson and Young (1970) /1/ discovered that the star shows eclipses of a small, hot object, with the mass and radius of a white dwarf. Young and Capps (1971) /2/ demonstrated from proper motion data that it is almost certainly a member of the Hyades, and spectroscopic studies /3,4/ established the basic system parameters: a 0.7 $M_{\odot}$ K dwarf and a 0.8 $M_{\odot}$ white dwarf, with an orbital inclination of 80° and a period of 12.5 hours.

V471 Tau demonstrates many of the properties normally attributed to classical RS CVn stars /5/ and also exhibits flaring properties which characterize the BY Dra stars /6/. RS CVn–type binaries are probably the most common kind of radio–detected stars, with the possible exception of flare stars. Their radio emission is intense, highly variable, and often circularly polarized /7/. V471 Tau has been observed previously with the VLA, but only in a detection experiment; the observed quiescent flux was ~ 0.8 mJy /8/.

The photometric coverage of V471 Tau /9,10/ permits us to know the binary phase at which the magnetic starspot is face–on. Since the suggested mechanism for the quiescent emission of late–type stars observed by the VLA is thought to be magnetic in character, it is reasonable to expect V471 Tau to show similar modulation in the microwave region, unless the radio emission region greatly exceeds the star in size. In fact, the maximum microwave emission of the eclipsing binary system YY Gem (dM1e + dM1e) was seen to occur in phase with the meridian passage of the large starspot group and active region on the secondary star in this system /11/.

Finally, there are two additional major reasons for determining the microwave properties of V471 Tau: 1.) its large rotational velocity (84 km/sec) provides us with previously unattained access to the high–velocity regime for active K dwarfs, and 2.) the K dwarf will soon (in ~ 2 x 10^7 years) become the mass–losing secondary in a cataclysmic variable, having evolved from a "common envelope binary" phase of evolution, in which the K dwarf was spiralling through the outer atmosphere of a red giant /12/.

Hence, we have used the VLA to observe V471 Tau with the intention of using the high binary inclination to eclipse the region of radio emission, and thereby to learn its location and size.

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OBSERVATIONS AND RESULTS

We observed V471 Tauri for 8 consecutive hours on two separate days with the VLA in the C–D array. These 6 cm observations took place on 22–23 and 26–27 January 1987. The phase calibrator used was 0400+258; 3C48, with an assumed flux of 5.6 Jy, was used as the flux calibrator. The data were reduced in the standard manner, i.e., by making maps in each of the four Stokes' parameters I, U, V, and Q (no significant polarization was seen [<10%]). In order to obtain the 6 cm light curve discussed below, the reduction process was repeated for shorter sequential selected time segments.

The 6 cm light curve that we obtained is shown in Figure 1. On 22–23 January, the source was weak and slowly varying, but the 26–27 January observation showed a brighter source with an interesting dip centered near phase zero (the phase of white dwarf eclipse) and a 6 mJy flare shortly after mid–eclipse at phase ~ 0.15; this flare then decayed back down to its preflare level (~ 2–3 mJy) in about 2 hrs.

Our nearly simultaneous optical light curve (Figure 2) obtained with an automated 0.32 m telescope /13/ in early January 1987, showed the optical wave minimum to be near phase 0.5. The superposed smooth double sinusoid arises from the tidal distortion in the Roche lobe, hence the light curve suggests a dark spot face–on near phase 0.5.

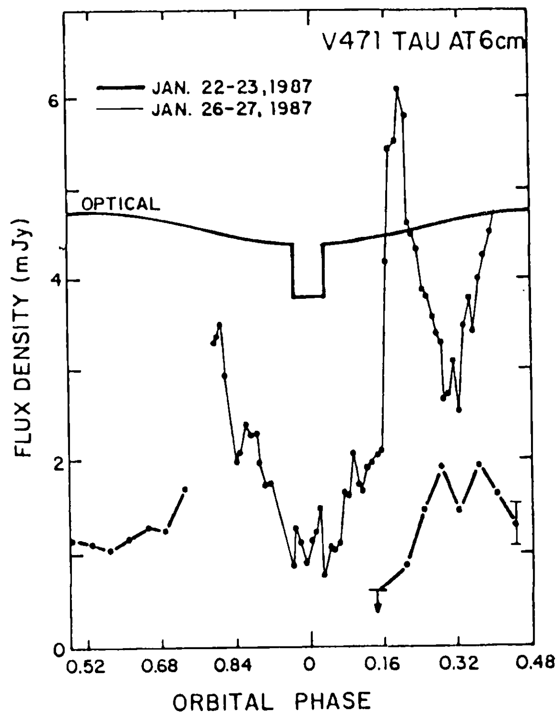

Fig. 1 The orbital light curve at $\lambda = 6$ cm, with the nearly simultaneous optical light curve superimposed, *sans* scaling. Note the dip in the radio light curve near phase zero.

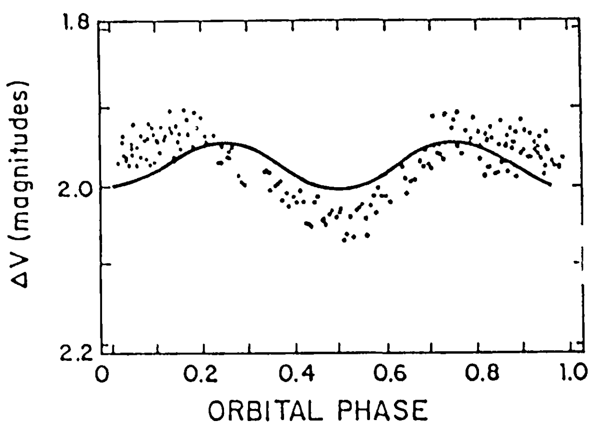

Fig. 2 Optical light curve of V471 Tau, obtained in early January 1987. The superposed smooth double sinusoid arises from the tidal distortion in the Roche lobe, so the light curve suggests a dark spot face–on near phase 0.5.

DISCUSSION

We have considered three possible explanations for the dip: (1) the eclipse of a large radio–emitting cloud centered on the presumably magnetic white dwarf; (2) the self–eclipse of a large radio–emitting cloud anchored to a particular spot on the secondary, namely the sub–white dwarf point; and (3) random variability.

We think that (2) is the leading possibility, because of the optical light curve. If, as is widely believed, the optical minimum is a result of the presence of a dark starspot, then the "spot", and any structures associated with it, would suffer a broad eclipse near phase zero – consistent with the radio light curve. The 6 cm flare observation and sudden variations seen in Hα /14/ suggest that this spot is an active flaring region.

In order to exclude (3) we simply need more data, and to exclude (1) we should obtain data when the spot is not nearly face–on to the white dwarf (*i.e.*, after it has drifted adequately in longitude). In order to guarantee that the latter does not occur, it is advisable to obtain two orbital light curves separated by ~ 60–90 days (to allow the spot to drift adequately in longitude).

Additional VLA time has been scheduled (separated by ~ 150 days) in order to verify if this eclipse of radio emission is a reproducible feature of the light curve. The favorable geometry and the very promising first observation makes it rather likely that we will really learn the size and location of the radio emission relative to the starspot – a crucial link that has not yet been securely established for any stellar radio source.

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