The Eclipsing Radio Emission of the Precataclysmic Binary V471 Tau

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**Abstract.** We present confirming evidence for eclipses in the centimeter radio emission of the eclipsing binary V471 Tau, comprising a K2 dwarf and a white dwarf. The radio eclipse appears to be centered at orbital phase $\phi = 0$ when the white dwarf is eclipsed and directly behind the K dwarf, and has a full width of $\Delta \phi \approx 0.3$; by comparison, the optical eclipse of the white dwarf occupies only $\Delta \phi = 0.066$. The eclipse depth is $\sim 80\%$, implying that much of the radio emission of the system originates from between the two stars. We favour a model where the radio-emitting electrons are accelerated by the interaction (collision) between the magnetospheres of the K dwarf and the white dwarf. Because this region of interaction is likely to be located very close to the surface of the white dwarf, the radio emission probably originates from large magnetic structures associated with the K dwarf. Such structures may provide the means by which mass is transferred from the K dwarf to the white dwarf, accounting for the inferred accretion of the white dwarf.

1. Introduction

V471 Tau, a member of the Hyades cluster, is a binary system comprising a (degenerate) white dwarf and a (main sequence) K2 dwarf in a very close, eclipsing orbit. Figure 1 illustrates the geometry of the system, where the companion stars are separated by only $3.1R_\odot$. The system belongs to a class of detached binaries known as precataclysmic binaries, the presumed progenitors of cataclysmic variables. Their study is important for our understanding of the evolution of close binary systems, and of the progenitors of cataclysmic variables. Among known precataclysmic binaries, so far only V471 Tau has been found to exhibit detectable radio emission.
Figure 1: Geometry of the V471 Tau binary system to scale.

2. Observations and Results

As part of a campaign of coordinated observations in support of an EUVE program, we observed V471 Tau for two complete orbital periods ($P_{orb} = 12.4$ hrs) on 2 consecutive days on 1994 Dec 2 and 3. These observations are reported in full by Lim, White & Cully (1995); in the following we provide a brief summary. Our observations were made using the VLA\(^{1}\) mainly at 20 and 3.6 cm, with occasional short scans at 6 and 2 cm. The measured radio light-curves at 6, 3.6, and 2 cm are shown in Figure 2. The radio light-curves show periodic dips in intensity centered at or near $\phi = 0$; the 3rd eclipse, the only near-complete eclipse observed, has a full width $\Delta \phi \approx 0.3$. This is much wider than the photospheric optical eclipse of the white dwarf of $\Delta \phi = 0.066$. Note also the sharp ingress and egress phases of the eclipse.

Inside eclipse the total flux density of V471 Tau falls to a level $\sim 20\%$ of that outside eclipse, implying that a large fraction of the radio emission originates from the region between the two stars. Outside eclipse the radio emission varies slowly and follows, in large part, the same phase dependence over the two observed orbits (separated by one orbit). This suggests that much of the modulation observed outside eclipse may be due to an apparent change in the observed radiation pattern of the source with orbital revolution, rather than intrinsic variability in the radio emission process.

3. Discussion and Conclusion

A model in which the radio emission is identified with the white dwarf requires a very large source, and a surface magnetic field strength higher than the inferred upper limit (a few kilogauss; Sion 1995, personal communication). A model where the radio emission originates from compact active regions on the K dwarf requires the radio emission to be strongest at phase 0.5, contrary to

\(^{1}\)The Very Large Array is a facility of the National Radio Astronomy Observatory, which is operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation.
what is actually observed; it also requires a wide longitudinal distribution of radio-emitting regions to produce the wide eclipse observed, and this necessarily produces gradual ingress and egress phases, contrary again to observations. The alternative, that the electrons are in extended loops well above the surface of the K dwarf is a characteristic of the interacting stellar magnetospheres model (originally proposed by Patterson et al. 1993) discussed next.

The white dwarf probably has a dipolar–like magnetosphere, as evidenced by rotation modulation in its photospheric optical and soft X-ray emission (attributed to the accretion of elements at its magnetic pole). It is rotating with a period of 9.25 minutes (Jensen et al. 1986), and consequently its magnetic field must be whipping rapidly past the coronal field lines of the K dwarf (which is tidally locked into synchronous rotation with the orbital period). The region where this interaction takes place is an obvious plausible source of energy release, and hence acceleration of nonthermal electrons. For a plausible range of magnetic parameters, we find that this region of interaction lies very close to the surface of the white dwarf, leading naturally to a picture where the radio emission originates from extended magnetic structures associated with the K dwarf. Such structures can qualitatively explain many of the features observed in the radio light–curve. Mass from the K dwarf may be channeled directly to the white dwarf through these large-scale magnetic structures, explaining the inferred accretion onto the white dwarf.

References