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Cataclysmic Variables as Radio Emitters

Deanne L. Coppejans[*]
Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA) and Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208
E-mail: `deanne.coppejans@northwestern.edu`

Only recently have we had telescopes with sufficient sensitivity to detect cataclysmic variables (CVs) at radio wavelengths. I briefly review the properties of the observed radio emission of non-magnetic CVs and discuss the possible emission mechanisms. Furthermore, I highlight cases where CV radio studies could enable progress on broader astrophysical contexts. Given the sensitivity of new and planned radio telescopes, CVs are likely to make a significant contribution to the population of galactic radio transients in future surveys.

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[*] Speaker.

1. Introduction

Radio surveys of Cataclysmic Variables (CVs) in previous decades resulted in few detections. This was particularly the case for the non-magnetic[1] systems (hereafter referred to simply as CVs[2]), of which only three were detected [2, 3, 4]. A hiatus in radio observations of CVs followed, which was broken with the detection of radio emission from SS Cyg, which the authors found was best explained as synchrotron emission from a transient jet [5, 6, 7, 8, 9]. Following this, three more systems were observed at GHz frequencies but only one was detected [10] and it appeared that SS Cyg was unusual in its radio emission. Crucially, it was at this point that the Very Large Array (VLA) was upgraded. Subsequent observations showed that CVs as a class are significant radio emitters and the previous non-detections were due to insufficient sensitivity [11, 12]. In particular, of the nine CVs observed with the upgraded Karl G. Jansky VLA, eight were detected. In Section 2 I briefly describe the properties of the observed radio emission from CVs and in Section 3 I discuss the possible emission mechanisms and open questions, before concluding with the future prospects for this field in Section 4.

2. Radio Emission Properties

The specific radio luminosity at 10 GHz of the observed CVs (TT Ari, RW Sex, V603 Aql, U Gem, Z Cam, SU UMa, YZ Cnc and RX And[3]) was in the range $L_{10} \sim 4 \times 10^{15} - 4 \times 10^{16}\,\mathrm{erg\,s^{-1}\,Hz^{-1}}$ [11, 12]. These observations were taken while the novalikes[4] were in the high state and the dwarf novae were in outburst. The emission was highly variable, with measured variability time-scales of ∼200s to days, and did not appear to be dependent on the orbital phase. In the dwarf novae systems the emission was too faint to constrain the spectral indices. The novalike spectral indices were consistent with steep to inverted (see Table 4 in [11]). In the majority of cases, no linear or circular polarization was detected (with typical 3σ upper-limits of $\sim 10\%$). One system, however, did show a highly circularly polarized flare of duration 10 minutes. This flare in TT Ari, had a lower-limit on the circular polarization fraction of 75%. Currently there is no indication of a correlation between the radio luminosity and the optical luminosity[5], orbital period, outburst type or CV subclass. Given the variable nature of the emission and the short observations, this can be attributed to sampling effects and such correlations cannot be ruled out.

3. Radio Emission Mechanism

The observed radio emission in CVs in non-thermal, based on the variability time-scales, brightness temperatures and flux densities [5, 6, 10, 11, 12, 8, 9]. In all cases except for TT Ari, the emission was consistent with synchrotron or gyrosynchrotron emission, although the emission

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[1] CVs where the magnetic field strength of the white dwarf exceeds 10^6 G

[2] See [1] and the talk by Paul Mason in this proceedings for radio observations of magnetic CVs

[3] V1084 Her was not detected.

[4] Note that V603 Aql is an old nova, as it experienced a nova eruption in 1918. It had returned to pre-eruption brightness by 1937 and has subsequently been declining in brightness by 0.44 mag century^{-1} [13]. As it has a high accretion rate [14] and does not show outbursts, I include it in the discussion of the novalikes.

[5] Note that the optical and radio observations were not taken strictly simultaneously

mechanism is not yet known. As discussed in [12], the luminosity, variability time-scales and outburst behaviour (in the dwarf novae systems) are consistent with that of SS Cyg and hence with a transient jet. Higher resolution imaging and better sampling in time over the course of an outburst are required to definitively test this model however. If CVs as a class are launching jets, contrary to previous belief, then there will be significant implications for jet-launching models in compact accretors, as CVs have been used to constrain these models (e.g. [15, 16]). As CVs are non-relativistic, they could potentially offer a means to constrain jet-physics without the need to disentangle relativistic effects as in the X-ray binaries.

The flare observed in TT Ari was too highly circularly polarized to be consistent with this scenario. It was coherent emission, likely cyclotron-maser emission. The emission properties bring up two tantalizing, and currently untested, possibilities. First, the emission is similar to that seen in the magnetic CVs, where flaring highly polarized emission is common (see [1]). There is no definitive evidence that the white dwarf in TT Ari is strongly magnetic however, and a similar flare was observed in the non-magnetic CV EM Cyg in early radio observations [4]. Given the current observations it is not clear how common these flares are in the non-magnetic CVs. Does the radio behaviour indicate a magnetic white dwarf and could this be used as a means to identify such systems? The second possibility stems from the fact that the flare is reminiscent of stellar flares. The secondary star in TT Ari is a M3.5 type [17] , a class that is known to flare (e.g. [18]). Although the emission in TT Ari is brighter than that of normal flare stars, the rotation period of the tidally locked secondary (which is equal to the 3.3 hour orbital period, [19]) is significantly higher than that of isolated flare stars. If the secondary star is flaring, then radio observations of CVs might be able to probe a rotation regime that is currently unaccessible in traditional stellar dynamo studies.

4. Conclusion

Recent improvements in the sensitivity of radio telescopes have allowed us to detect non-magnetic CVs at radio wavelengths. The radio emission mechanism is not currently known, although it is consistent with synchrotron or gyrosynchrotron emission in the majority of cases. A highly circularly polarized (coherent) flare was also detected in the novalike system TT Ari that is best explained as cyclotron maser emission.

To determine the radio emission mechanisms in non-magnetic CVs we need more sensitive and higher resolution observations, with better multi-wavelength coverage of the outbursts. The MeerKAT radio telescope in South Africa will allow us to make significant progress on this front. In particular, the ThunderKAT (The hunt for dynamic and explosive ratio transients with MeerKAT, [20]) project will focus on CVs as one of its main science programmes, and strictly simultaneous optical data from the MeerLICHT telescope [21] will be available for all radio observations. This significantly improved sampling is necessary to determine the radio emission mechanism in this new class of radio transient.

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DISCUSSION

DAVID BUCKLEY: Can you confirm that within error, the circular polarization is greater than 70%, which I understand is the maximum expected of synchrotron emission?

DEANNE COPPEJANS: Yes, the flare in TT Ari had a circular polarization fraction of greater than 75% so it was not synchrotron emission.