New Evidence of the Diversity In Outbursting AM CVn Systems

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Abstract

We present results of out analysis of up to 15 years of photometric data from eight AM CVn systems with periods in the disc instability region. We find that systems in the previously identified disk instability region are not a homogenous group. Various members of the analysed sample show long super outbursts and standstills, others show shorter regular super outbursts, and a final group only appears in a high state with no apparent instability. Using TESS full frame images we find the first evidence of normal outbursts appearing as a precursor event to a super outburst in an AM CVn system.

Introduction

AM CVn systems are a relatively rare class of cataclysmic variable (CV) systems, with a known population of ~60 systems. They consist of a white dwarf which accretes matter from a hydrogen deficient low mass companion star which is either fully or partially degenerate. These systems are some of the shortest period CVs with orbital periods between ~5-65 minutes.

AM CVn systems with orbital periods between ~22-44 minutes have been observed to outburst, where they suddenly increase their brightness by 3-4 magnitudes. Two types of outbursts are seen, normal outbursts which last a few days and brighter super outbursts which last several weeks. There is an increasing body of evidence which suggests that amongst outbursting systems the behaviour can vary significantly.

We analysed photometry of 8 AM CVn systems with orbital periods between 22.5-26.8 minutes collected over up to 15 years in addition to high cadence TESS photometry of one of these systems to understand the behaviours of these systems.

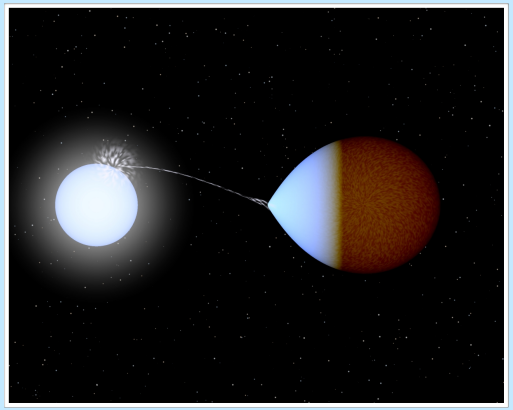

Fig.1 Artists Impression of an AM CVn system. Image Credit: D. Steeghs/R. Hynes

Data

We combined data of the 8 systems from a number of all sky surveys, such as GOTO (see fig. 2), as well as data gathered by citizen scientists. This gave us up to 15 years of photometry for each of the sources which we considered; we ensured the compatibility of these data by using photometry taken in the same or significantly overlapping wavelength ranges. We were primarily interested in identifying periodic behaviours in these lightcurves and searching for year to year variations.

We also studied observations of KL Dra from TESS which gave us access to photometry with a 30 minute cadence over ~9 months. Due to the faintness of KL Dra brightness measurements between outbursts were not possible, however we were able to identify the outbursts could be readily identified. This marks the first time that outbursts from an AM CVn system have been observed in such high cadence.

Results

We found looking at the combined data from the all sky surveys (fig. 3) three distinct behaviours in the AM CVn systems which we studied. This is somewhat unexpected as they all have similar orbital periods a property thought to govern outburst behaviour. This is in line however, with other findings. We identified a group of these systems, such as CR Boo, which spend years in high states interspersed with periods of regular super outbursts that last approximately half of the the recurrence time. Another group, such as KL Dra, show less frequent and shorter super outbursts interspersed with normal outbursts and no evidence extended bright states. The third group appears only a high state which is entirely unexpected as systems with this period are expected to outburst.

In the observations of KL Dra from TESS we are able to identify 5 super outbursts (see fig. 4). We have observed in these data a clear drop in flux around 1 day from the time of initial rise identified as the onset of the super outbursts. Such behaviour has been seen before in hydrogen dominated CVs and has been identified as normal outburst acting as the trigger to the subsequent super outburst. Due to the observed similarity we attribute to this finding to be the same feature. This would be the first time such a feature has been seen in AM CVn systems.

Fig.2 GOTO dome with 8 telescopes in La Palma. Image Credit: GOTO Consortium (**http://goto-observatory.org/**)

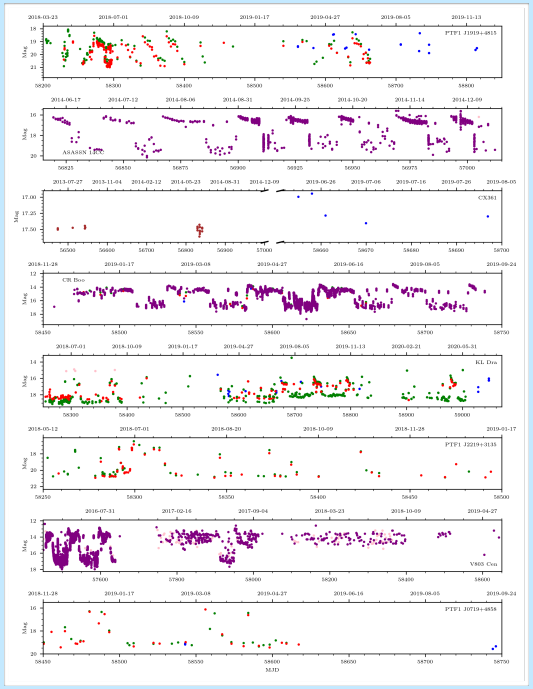

Fig.3 Representative lightcurves of each of the sources studied, different colours relating to different sources of data

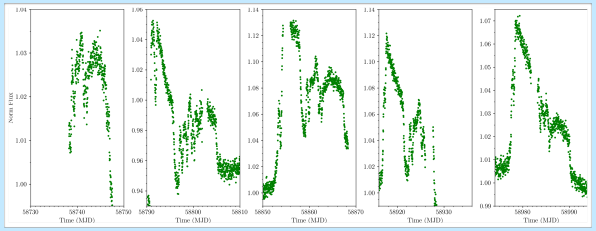

Fig.4 TESS data showing the profile of 5 super outbursts in KL Dra

Discussion

Our study is not the first to find significant differences in the behaviour of these systems, it is probable that the differing rate of accretion is the source of the different behaviours but why this arises is still an open question. We speculate that this could arise from:

- ➡Different mass ratios between the component stars
- ➡The type of secondary star
- ➡The formation channel of the AM CVn

These factors are not easily determined through observation and thus followup work, relying heavily on modelling will be needed.

CX 361 is something of an anomaly, only appearing in a high state, despite being in the period range to outburst. Recently another similar system, ZTF J2228+4949, has been identified. These findings put into doubt the current theory that systems with periods ~22-~44 minutes always outburst.

The precursor outburst feature is a new discovery in AM CVn systems and has likely not been seen before due to the relatively rarity of these systems and the requirement for high cadence observations. This discovery has significant implications for the models which govern AM CVn systems. In order to determine if these features are common to all outbursting AM CVn systems, or subset of them, further high cadence observations will be necessary.

Conclusions

- ➡We have identified that outbursting AM CVn systems do not all behave in the same way regardless of similar orbital period.
- ➡We have further identified the presence of systems with orbital periods which would be expected to outburst based on observations of other systems but show no evidence of outburst suggesting that the characterisation of AM CVn systems is more subtle than previously thought
- ➡We have presented the first evidence of a precursor outburst from an AM CVn system, a feature we believe to be common to all of these systems which if confirmed would prompt changes to existing models for AM CVn systems.

References and acknowledgments

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