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Orbital period analyses for the CVs inside the period gap

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Abstract. All 13 eclipse CVs inside period gap are investigated. Considering that most CVs inside period gap lack the enough data accumulation, We only choose five objects to make orbital period analysis including a prototype polar AM Her and pre-CVs HW Vir. Although AM Her is not an eclipsing CVs, the facts that its orbital period locates in the upper edge of gap and it has a stable timing system suggest that AM Her should be a significant object for the study of period gap. All orbital period analyses for the CVs inside period gap never indicates any secular evolution information, which may suggest that the CVs inside period gap have a different evolution end. Moreover, the complex O-Cs variations can be explained by the light trave-time effect. It means that there are many substellar objects surrounding the CVs.

Key words. Stars: cataclysmic variables – Stars : binaries : close

1. Introduction

Cataclysmic variables(CVs) are short-period semidetached binary systems in which a white dwarf primary accretes matter from a Roche lobe-filling red-dwarf (Horne 1985). Due to the existence of mass transfer between two components and the angular momentum loss, the orbital period changes in CVs should be expected. Since the orbital period variation can reflect the dynamic alterations of binary system, the detection of orbital period variation in CVs is very important for the study of their evolution state. A traditional observation method that eclipse photometry can be used to measure the orbital motion of close binary. Therefore, the eclipsing CVs are particularly useful for the investigation of the orbital period changes, since the occultation of the bright primary or accretion disc by the secondary star can produce a significant luminosity dip in light curves. This offers a prior opportunity to accurately determine the orbital period. Depending on the seeing and time resolution in observation, the precision of the derived orbital period can almost reach up to 10^{-9}days (i.e. ∼ 0.1ms, Dai & Qian 2009; Dai et al. 2010). It means that a majority of tiny variations in CVs can be detected clearly, which may tell us lots of new and amazing information of CVs.

Robinson et al. (1981) has proposed a disrupted magnetic braking theory for the inter-

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Table 1. Eclipsing CVs inside period gap

Subtype	Eclipse CVs	Magnitude (mag)	Year of nova ouburst	Orbital period (days)
MCV	HU Aqr*	~15	-	.086820459 (2.08hr)
	DD Cir!	~20	-	.09746 (2.34hr)
	UZ For*	~18	-	.087865446 (2.11hr)
	V348 Pup*	~15	-	.101838933 (2.44hr)
	V597 Pup!	>18	-	.119583333 (2.67hr)
DN	DV Uma*	~19	-	.085852633 (2.06hr)
	IR Com*	~15	-	.087038644 (2.09hr)
	SDSS J170213!	~18	-	.100082090 (2.40hr)
	CTCV J1300-3052!	~16	-	.088850000 (2.13hr)
	TY Psa?	~14	-	.084100000 (2.02hr)
N/RN	V Per!	~18	1887	.107123474 (2.57hr)
	DD Cir!	~20	1999	.097460000 (2.34hr)
	V630 Sgr!	~18	1936	.118000000 (2.83hr)
	QU Vul!	~19	1984	.111764700 (2.68hr)
	V597 Pup!	>18	2007	.119583333 (2.67hr)

Note, * the CVs with enough data accumulation, ! the CVs lacking data accumulation ? the CVs with doubtable eclipse phenomenon.

pretation of period gap. This hypothesis has been accepted extensively to be a standard CVs evolution paradigm. Thus, period gap is a key factor for the study of CVs evolution scenario. At present, the new investigations of period distribution derived by Vojkhanskaja (2007) and Dai & Qian (2011) have found that the gap is weakening now. It means that more CVs inside period gap can be used to check out the standard paradigm. Moreover, the detailed investigations of period gap have pointed out that the profile of period gap has changed significantly (Katysheva & Pavlenko 2003; Dai & Qian 2011). Based on the orbital period analysis, we attempted to investigate the famous period gap phenomenon in CVs and discuss their possible dynamic characters.

In this paper, the investigations of orbital period variations for CVs inside period gap are discussed in sect. 2. And, Sect. 4 presents the primary discussions and conclusions.

2. Orbital period variations

In order to detect orbital period variations of CVs inside period gap, the eclipsing objects are used to analyze. A period distribution of eclipsing CVs from the catalogue of CVs (V/123A) derived by Downes et al. (2001) is carried out. This distribution in Fig. 1 clearly shows a deep gap between 2hr and 3hr, and a similar profile to that from all CVs. Thus, it is appropriate that the eclipsing CVs are chose to probe the period gap.

According to our statistics on the eclipsing objects, all 13 eclipsing CVs inside period gap are listed in Table 1. It is interested that no eclipsing nova-like is found inside gap, and the two nova outbursts DD Cir and V597 Pup in this century are from the subtype MCVs inside gap. Moreover, there are only five objects with good data accumulations for orbital period analysis. The other objects are either newfound or very faint with a magnitude of > 18^m. This may support the popular hypothesis that selection effect for observations (Rappaport 1983). Since Young & Schneider (1979) has pointed out that the photometric self-eclipse features in light curves of AM Her are stable enough for measuring its orbital motion, the prototype polar AM Her lacking normal eclipse is still a good object for the study of orbital period variations. Additionally, HW Vir-like eclipsing binaries are the progenitors of CVs (Shimansky et al. 2006). Since HW Vir is inside period gap, its evolution state should be critical for testing the standard evolution paradigm. Therefore, except as the CVs marked by asterisks in Table 1, the other two important objects that a pre-CVs HW Vir with the orbital period inside gap and a prototype polar AM Her with the orbital period on the upper edge of gap, are also discussed together. All investigated objects inside gap are listed in Table 2.

Although the CVs standard evolution paradigm has predicted that the orbital period should decrease, our orbital period analyses indicate that the orbital period variations in CVs are more complex and disunity. There are only three objects (i.e. AM Her, HU Aqr and HW Vir) with decrease trends in their O-C diagrams (Qian et al. 2008, 2011; Dai & Qian 2011). And the secular variation trend in polar UZ For is doubtable (Dai et al. 2010; Potter et al. 2011). Moreover, the intermediate polar V348 Pup is regarded as a special object with an increase trend (Dai et al. 2010). As for the three objects with decrease trends in O-C diagrams, pre-CVs HW Vir is regarded as the only object with a decreasing orbital period. The decreases in O-C diagrams of AM Her and HU Aqr may be just pseudo orbital period changes due to the suppression of magnetic braking by the strong magnetic white dwarf (King et al. 1994; Wickramasinghe & Wu 1994). On the other hand, based on the relationship between the variation rate of Roche lobe of secondary star $\dot{R}_{cr2}$ and of orbital period $\dot{P}_{orb}$,

$$\frac{\dot{R}_{cr2}}{\dot{P}_{orb}} \propto \frac{\lambda(q)}{q-1}, \tag{1}$$

the parameter $\lambda(q)$ is a function of mass ratio $q = m_2/m_1$ shown in Fig. 2, m_2 and m_1 are the masses of secondary star and white dwarf, respectively, the increase O-Cs in V348 Pup cannot be explained by the conservative mass transfer from the secondary star to the massive white dwarf. It means that this increase cannot reflect the true orbital period variation. Additionally, we also cannot know the definite evolution of polar UZ For from its vague variation in orbital period.

Except as the secular variation in orbital period, an interested phenomenon that periodic modulation is shown in the O-C diagram. But the periodic modulations in all investigated

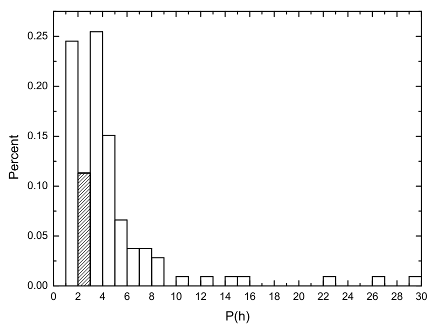

Fig. 1. The orbital period distribution of eclipsing CVs.

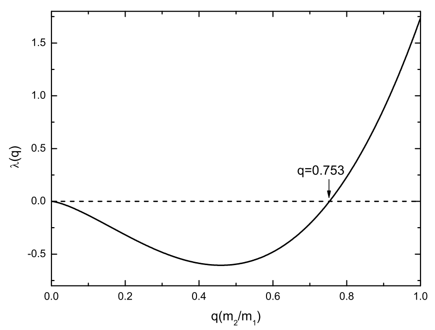

Fig. 2. The relationship between the function $\lambda(q)$ and the mass ratio q. The downward arrow points out that the critical point of function $\lambda(q)$ is at q ~0.753.

CVs cannot be explained by a solar-type magnetic activity cycle mechanism due to the large required energy beyond the support of the secondary star. Thus, the light trave-time effect suggests that the substellar objects including brown dwarfs and planets may be the tertiary components in CVs with high significant level. Moreover, Qian et al. (2011) found that circumbinary planets may orbit the polar HU Aqr.

3. Conclusions

Based on the investigation of CVs inside period gap, all 13 eclipsing objects are found.

Table 2. The details of investigated CVs inside period gap.

Object Name	Orbital period (hr)	Subtype	Ref.
AM Her*	3.09	Polar	(1)
HW Vir	2.80	Pre-CVs	(2)
V348 Pup	2.44	IP	(3)
UZ For	2.11	Polar	(3), (4)
HU Aqr	2.08	Polar	(5)

Note, * it is not eclipsing object. References: (1) Dai & Qian (2011); (2) Qian et al. (2008); (3) Dai et al. (2010); (4) Potter et al. (2011); (5) Qian et al. (2011).

However, since the data accumulations for the most of CVs inside gap are not enough for orbital period analysis, we only chose five objects including an eclipsing pre-CVs HW Vir and a prototype polar AM Her without eclipse, to analyze their orbital period. However, the orbital period analyses never give any certain secular evolutional information. Although this result is not expected, it may reveal that the evolution of CVs inside period gap can be slower and slower. Finally, they may have a different evolution end from the predicted one. This may support the hypothesis that the CVs below and above period gap originate from different progenitors (Vojkhanskaja 2007). On the other hand, the assumption of slow evolution for the CVs inside period gap would result in the accumulation of CVs inside the period gap, which obviously contradicts with the observation. However, a nonnegligible selection effect for observation has predicted that the CVs inside period gap should be faint objects. In fact, the most of eclipsing CVs listed in Table 1 have an magnitude larger than 18^m, which seems to support the selection effect. Additionally, the two dwarf novae IR Com and DV Uma are prepared for the further observations. The more interested and valuable results are expected for the study of orbital period gap.

4. Discussion

ELENA PAVLENKO: Does the list of eclipsing systems inside the gap consists of magnetic systems or includes both magnetic and dwarf novae?
ZHIBIN DAI: No, the list of eclipsing systems inside gap includes four subtypes: magnetic CVs, dwarf novae, novae and recurrent novae. But we combined novae and recurrent novae to be the one subject in this table. Moreover, we have found that there is no novae-like eclipsing object inside period gap. Maybe, the most of novae-like concentrate in the range of 3~4hr. This can be proved by the distribution of novae-like. Additionally, the more observations are needed to update this list.
KLAUS REINSCH: Can you comment on the long-term stability of the planetary orbits proposed for HU Aqr?
ZHIBIN DAI: Yes, we have estimated the stability of the planetary orbits with a simple point-mass model. And the distance between HU Aqr and planets are large enough for maintaining the stability of system. Additionally, we are also interested in the more detailed model for considering the system with a planetary system in the future. However, until now, there is little knowledge of extrasolar planetary system, which results in the fact that an ideal numerical simulation for such system only with several simple principles and conditions cannot correctly reflect the complex dynamic characters in a true system. Thus, we need to find the other direct observation evidences, for example, the transit of the planet as Kepler-16, to check out this result.

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