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# PERIOD VARIATIONS OF SUPERHUMPS IN SU UMA STARS

Akira Imada[1] & Taichi Kato[2]
[1]Tomominami, Asaminami 1-5, Hiroshima, Japan
[2]Department of Astronomy, Kyoto University, Kitashirakawa Oiwake-cho, Sakyo-ku, Kyoto, Kyoto 606-8502, Japan
*E-mail: imada@oao.nao.ac.jp*
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## ABSTRACT

We review recent results on superhump period variations in SU UMa-type dwarf novae. Our statistical studies have revealed that the evolution of the superhump period is basically composed of three stages: stage-A, during which the superhump period is long and constant, stage-B, during which the superhump period increases as the superoutburst proceeds, and stage-C, during which the superhump period is short and constant. We also introduce a new method of estimating a mass ratio using the stage-A superhump period. This method can extend to, for example, low mass X-ray binaries or AM CVn stars if the stage-A superhump period is well determined.

*Key words:* accretion disk, dwarf novae, star

## 1. INTRODUCTION

Dwarf novae are a subclass of cataclysmic variables that consist of a white dwarf primary and a late-type secondary (for a review, see e.g., Osaki (1996)). Dwarf novae are further divided into several subclasses according to their long-term light curves. One subclass is SU UMa-type dwarf novae. SU UMa-type dwarf novae show two types of outburst, a normal outburst and a superoutburst. During the superoutburst, quasi-periodic modulations called (positive) superhumps are observed. The period of the positive superhumps is a few percent longer than the orbital period of the system[1]. Superhump phenomena are understood as the tidal dissipation of a progradely-precessing eccentric disk (Whitehurst , 1988).

It is well known that the superhump period varies as the superoutburst proceeds. From a theoretical point of view, Osaki (1985) noted that mass depletion from the accretion disk results in a decrease of the superhump period. In the early 1990s, observations supported this; the decrease of the superhump period was reported in many SU UMa-type dwarf novae (Patterson et al. , 1993). But in the mid-to-late 1990s, an increase of the superhump period was reported in many SU UMa-type dwarf novae, particularly in short period systems (Nogami et al. , 1997).

Thanks to world-wide mailing lists (e.g., VSNET; Kato et al. (2004)) and automated telescopes (e.g., CRTS; Drake et al. (2009), ASAS; Pojmanski (2002)), we can obtain light curves of superhumps from the early onset of the superoutburst. This enables us to investigate the overall behavior of the evolution of the superhump period. After collecting extensive data for superhump light curves, we started a statistical study of the evolution of superhumps from 2009. We have analyzed more than 500 superoutbursts of SU UMa-type dwarf novae. These results have been published by T. Kato et al. (see Kato et al. (2009); Kato et al. (2010); Kato et al. (2012); Kato et al. (2013); Kato et al. (2014)).

[1] In some systems, there exist modulations shorter than the orbital period. These are called negative superhumps. Throughout this proceedings, the term superhump means positive superhump.

## 2. TEXTBOOK OF SUPERHUMP PERIOD CHANGE

One of the significant results of our statistical study is that we reformed the textbook of the evolution of the superhump period. Figure 1 shows light curves of a superoutburst and the O-C diagram of the maximum timings of the superhumps.

As can be seen in this figure, the evolution of the superhump period is composed of three stages. When the superhump appears near the bright maximum, the superhump period remains constant with a duration of typically 1-2 days. This stage is called stage-A, during which the mean superhump period is the longest and the amplitude of the superhumps is the largest. After the end of stage-A, the superhump period suddenly decreases by about 2 %, after which the superhump period gradually increases as the superoutburst proceeds. This stage is called stage-B. In most cases, the duration of stage-B is about a week. This means that the majority of a superoutburst in SU UMa-type dwarf novae is composed of stage-B. Near the end of the plateau phase of the superoutburst, the superhump period again remains

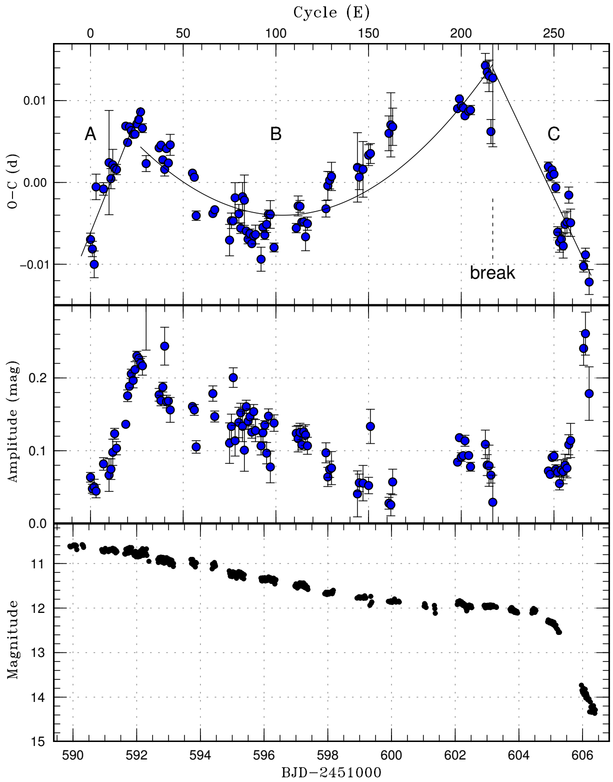


Figure 1. O-C diagram of the maximum timings of superhumps (top), amplitudes of superhumps (middle), and light curves of the superoutburst (bottom). Figure is taken from Kato & Osaki (2013).

constant. This is called stage-C. The mean superhump period during stage-C is shorter than that during stage-A. Sometimes stage-C continues even after the end of the plateau phase.

As mentioned above, we have studied more than 500 superoutbursts of SU UMa-type dwarf novae. The vast majority of O-C diagram of superhump maxima look like the top panel of Figure 1. However, there are some exceptions. For example, stage-A was absent during the 2005 superoutburst of V391 Cam (Imada et al., 2009), despite the fact that the observations started from the onset of the superoutburst. Another example is the 2006 superoutburst of EG Aqr which showed a decrease of the superhump period during stage-B (Imada et al., 2008). Our statistical study suggests that systems with a superhump period longer than 0.08 days tend to show negative period derivatives during stage-B.

## 3. A NEW ESTIMATION OF THE MASS RATIO USING STAGE-A SUPERHUMP

The working mechanism of the superhump evolution in each stage is still in debate.

However, our data for eclipsing SU UMa-type dwarf novae imply that the the stage-A superhump period may be associated with the dynamical precession rate at the 3:1 resonance radius (Osaki & Kato (2013); Kato & Osaki (2013)). By using the dynamical equations of the accretion disk, we can directly estimate the mass ratio

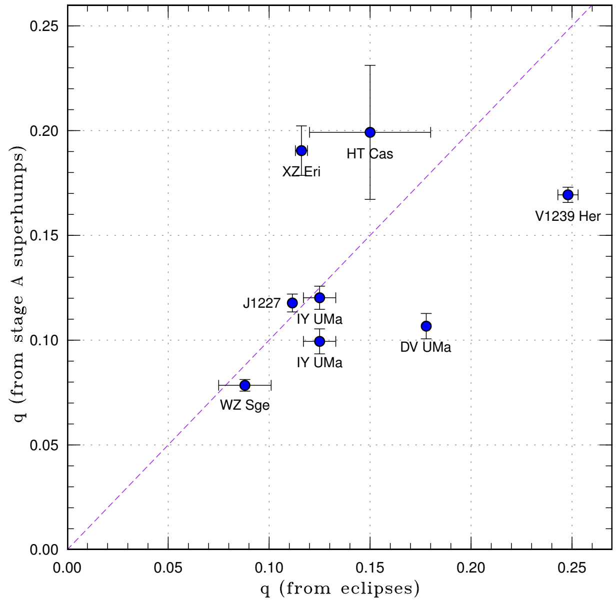


Figure 2. Comparison of mass ratios measured by eclipses (x-axis) and mass ratios measured by a new method using stage-A superhump period (y-axis). Figure is taken from Kato & Osaki (2013).

of the system if the stage-A superhump period and the orbital period of the system are well determined (for detailed equations, see Kato & Osaki (2013)). Figure 2 shows the result of mass ratio estimation of eclipsing SU UMa-type dwarf novae. Although there remains a large scatter in some SU UMa-type dwarf novae, systems with high quality data lie on the linear line. Such systems include SDSS J1227, IY UMa, and WZ Sge itself. For these systems, the mass ratio estimated by the eclipses corresponds to that estimated from the stage-A superhump period. Of course we should collect more samples during the stage-A superhump in order to firmly establish the new method, but we can fairly conclude that using stage-A superhump period is a powerful tool for estimating the mass ratio of the system.

As we noted above, this method is derived by dynamical equations. This implies that this method can be extended to other compact binaries such as black hole binaries and AM CVn stars. Indeed, our method applied to CR Boo results in a derived mass ratio consistent with previous results (Isogai et al. in prep.). As for black hole binaries, we particularly focus on KV UMa, a system which shows superhumps (Uemura et al., 2000). If we are successful in detecting the stage-A superhump of KV UMa in future observations, this may be the supreme opportunity for testing our method.

## 4. SUMMARY

In this proceedings, our main results are as follows:

- Our statistical study of superhumps in SU UMa-type dwarf novae has revealed that the evolution of the superhump period consists of three stages: long and constant (stage-A), increasing (stage-B), and short and constant (stage-C).

- Period analyses during stage-A superhumps suggest that the period of stage-A superhumps may be associated with the dynamical precession rate at the 3:1 resonance radius.
- We have established a new method of estimating the mass ratio using stage-A superhump periods. The mass ratio derived by the new method is consistent with that obtained by eclipses.
- This new method can extend to other compact binaries such as black hole binaries and AM CVn stars.

Finally, we note on what the speaker said at the conference: please email to us if you are interested in my talk. Everyone can start observations and research for dwarf novae if you have a small telescope. With the lowest cost, the greatest results.

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