SUPEROUTBURSTS AND SUPERHUMPS OF SU UMA STARS

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1. INTRODUCTION

SU UMa stars are one of subclasses of dwarf novae. Dwarf novae are semi-detached close binary systems in which a Roche-lobe filling red dwarf secondary loses matter and the white dwarf primary accretes it through the accretion disk. The main characteristics of SU UMa subclass is that they show two kinds of outbursts: normal outbursts and superoutbursts. In addition to the more frequent narrow outbursts of normal dwarf nova, SU UMa stars exhibit "superoutbursts", in which stars reach about 1 magnitude brighter and stay longer than in normal outburst. Careful photometric studies during superoutburst have almost always revealed the "superhumps": periodic humps in light curves with a period very close to the orbital period of the system. However, the most curious of all is that this superhump period is not exactly equal to the orbital period, but it is always longer by a few percent than the orbital period.

2. MODEL FOR SUPEROUTBURSTS AND SUPERHUMPS

One of the present authors proposed a model for superoutbursts and superhumps of SU UMa stars [1]. In this model, the normal outbursts of SU UMa stars are thought to be essentially the same as the ordinary outbursts of dwarf nova and they are supposed to be caused by the disk instability (see e.g., Smak [2]). Superoutbursts are explained in the following way. The heating of the secondary's atmosphere by strong far UV and soft X-ray radiation due to accretion and the resulting increase in mass-overflow rate from the secondary may lead to a positive feed back instability between accretion and mass overflow in a certain circumstance. This "irradiation-induced mass-overflow instability" is the suggested mechanism of "superoutburst" of SU UMa stars.

The "superhump" phenomenon may be explained by this model in the following way. It is hypothesized that a slowly precessing eccentric accretion disk develops during superoutbursts. (The eccentric disk was first proposed by Vogt [3] in a slightly different context with the present model). Irradiation on the secondary's atmosphere varies periodically because of varying shadow cast by the eccentric disk. Since mass overflow rate from the secondary is strongly influenced by irradiation effect during superoutburst, the mass transfer rate itself will also vary periodically. The superhump phenomenon may be caused by this periodic variation in the mass transfer rate. The period of this mass transfer variation (and therefore the period of superhump) is determined by the repetition period of the same secondary and eccentric disk configuration (i.e., the synodic period). The latter period is

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not exactly equal to the orbital period, but it is slightly longer than that, because the apsidal line of the eccentric disk is not fixed in space but it advances slowly in the same direction as the orbital motion of the secondary. This is the reason why the superhump period is slightly longer than the orbital period of the binary.

3. PRECESSING ECCENTRIC DISK AND LIGHT CURVE SIMULATION

If a precessing eccentric disk ever exists, its effects should show up in light curves for systems with high orbital inclination. That is, the light from accretion disk may vary with the precessing period because of the variable aspect of non-axisymmetric disk from the observer. Furthermore, if the system is an eclipsing binary, asymmetric eclipse light curves may result. Such effects have in fact been observed in an eclipsing SU UMa star called OY Car. Schoembs [4] has found that the brightness level of OY Car outside of hump and eclipse was modulated with a long period of about 3 days, which is the beat period between the orbital and superhump periods. Krzeminski and Vogt [5] have also found that OY Car during supermaximum exhibited asymmetric eclipse light curves and the sense of asymmetry oscillated with the beat period. These observations may most naturally be explained by the precessing eccentric disk.

In order to confirm this and to find the configuration of the eccentric disk, we have tried to simulate these observations by adopting a simple eccentric disk model and by calculating light curves. It is found that the basic feature of the two phenomena (i.e., brightness variation outside of eclipse and asymmetric eclipse light curves) can be reproduced with appropriate parameters describing the precessing eccentric disk and the secondary. However, it has turned out that the orientation of the apsidal line of the eccentric disk has to be chosen almost in the opposite direction for the two cases. In order to explain the timing of asymmetric eclipse observed by Krzeminski and Vogt [5], the supermaximum must occur when the apsidal line of the eccentric disk is directed to the secondary (consistent with Vogt's model). On the other hand, in order to explain the phase of the brightness modulation outside of eclipse observed by Schoembs [4], the superhump maximum must occur when the apsidal line is directed away from the secondary (consistent with Osaki's model). So far this kind of observations has been limited to the two observations mentioned above. More observations are clearly needed either to confirm or reject the existence of the eccentric disk during superoutbursts.

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