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FS AUR AS A PERMANENT SUPERHUMP SYSTEM

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RESUMEN

Descubrimos que la Variable Cataclismica FS Aur de corto periodo orbital muestra periodo fotométrico cercano a orbital. El exceso de periodo coincide con lo que se espera de un sistema que cuenta con la presencia de superjorobas permanentes. Esto puede ser resultado de que FS Aur posea un disco grande y estable. Sin embargo el sistema sigue mostrando persistentemente un periodo mucho más largo que el orbital y los nuevos datos no alteran las explicaciones previas de este periodo.

ABSTRACT

We discovered that the short period cataclysmic variable FS Aur at some epochs shows a photometric period close to the orbital. It exceeds the orbital period by ∼2%, which is a sign of the presence of a permanent superhump in the system. Superhumps tend to appear near short, low amplitude outbursts. We assume that FS Aur possesses a large thermally stable accretion disc and that the outburst may be due to the variable mass transfer rate. This, however, does not alter our previous explanation of yet another, 2.4 times longer than orbital, photometric period of FS Aur, found earlier, and persistently observed in its light curves.

Key Words: **BINARIES: CLOSE — NOVAE, CATACLYSMIC VARIABLES — PHOTOMETRY**

1. INTRODUCTION

FS Aur is a short period Cataclysmic Variable (CV), with a spectroscopically established period of 85.7 minutes (Thorstensen et al., (1996), Neustroev(2002),Tovmassian et al., (2003)(T03)). It is on the short side of the Period Gap (PG) and, thus, is expected to have a mass ratio between components of q≤ 0.33 suitable to produce superhumps as a result of an apsidal precession of the elliptically distorted accretion disk grown out of the resonance radius (3.1) (Whitehurst 1988). Most of the Dwarf Novae (DN) systems below the PG belong to the SU UMa subclass known to undergo superoutbursts, during which superhumps develop. Basically, there are two requirements that should be satisfied for the presence of superhumps: the above mentioned mass ratio and sufficiently large disc radius. While SU UMa stars reach the latter condition only during superoutburst, the theory that allows for the existence of systems that may have large enough discs in the quiescence and show so-called permanent superhumps. Not accidentally, more than 20 such systems were discovered in the last decade (Patterson 1999). The amplitudes of superhumps in these systems is highly variable and sometimes disappears altogether from the light curves. Osaki (1996) suggested that only the orbital period and mass transfer rate determine the behavior of the system, and thus its classification (Retter & Naylor 2000). So far, FS Aur has been never detected in superoutburst.

Another more bizarre peculiarity of FS Aur is that it shows a 205 min photometric period which more than two times exceeds its orbital period. After lengthy discussion of possible causes of such peculiar behavior, T03 suggested a new possible mechanism to explain observed periods. It may be caused by the rapid rotating magnetic white dwarf (WD) with a period of the order of 50 - 100 sec, which in addition precesses. According to existing models, the precession period for a rigidly rotating WD would be in order of the observed period. In order to see this precession period in optical wavelengths, the collimated beam from the magnetically accreting white dwarf, the rotational axes of the white dwarf and the binary plane where the disc is located should have certain angles relative to each other. This could explain the uniqueness of FS Aur and why we do not observe such periods in other systems. This hypothesis remains, however, highly debatable until firm evidence is not found of the fast rotating WD in this system.

Motivated by this unique and unexplained behavior, we kept monitoring the star. Here we report on new findings suggesting that FS Aur is a permanent superhump system, which in turn may explain why we have never observed it in the superoutburst.

2. PHOTOMETRY AND PERIODS

A new set of observations of FS Aur using 1.5m telescope of OAN at SPM was obtained on 13-15

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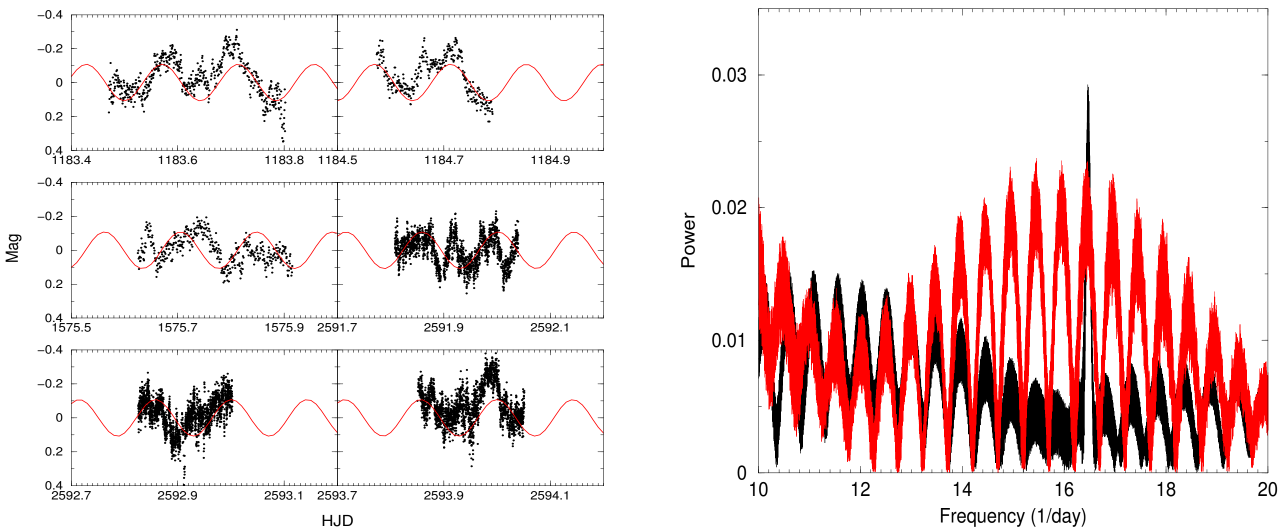

Fig. 1. The light curves of FS Aur. Left panel: selection of nights where the superhump period appears (the last 3 sub-panels contain new data; Right panel are nights where predominant period in the light curves is the long photometric period. The sin curve is a fit to the long photometric period over a 4 year period of monitoring.

Nov. 2002. The CCD was binned 2×2 and trimmed in size to accommodate the object and at least 2 comparison stars for a rapid differential photmetry in R band. The new light curves are highly variable and on first glance look sporadic. The clear sinusoidal variation with 205 min period observed before is replaced with a more complex pattern. However, the period search reveals a few dominating frequencies. One of them remains the mysterious long photometric period of 205 min. Another strong peak appears at the period close to the orbital. It is broad in the single night periodograms and it is difficult to tell if it coincides with the orbital period or not. Even combining the data of 3 nights does not satisfactorily resolve the emerging period. Therefore, we selected additioanal data from previous observations (T03), where similar variability was seen. In the Figure 1 on the left panel the selected observations are presented, including the new ones at the bottom. In the right panel the observations where the long photometric period clearly dominates are presented for comparison. The Fourier transform on the selection of data presented in the left panel reveals multiple peaks due to the alias periods appearing because of uneven distribution of data. The strongest peak drifts away from the value corresponding to the orbital period, toward longer periods. The CLEAN procedure (Roberts et al. 1987) encounters the peak centered on 16.46 day^{-1}, which corresponds to the 87.5 min period. The power spectrum of the selected set of data, as well as its CLEANed counterpart are presented in Figure 2. Folding the data by periods corresponding to the peaks in the Power Spectrum also clearly favors the 87.5 min period. This period exceeds the orbital period of the system by 2.06%.

There is an empirical relation between superhump period excess and the orbital period of superhump systems (Patterson 1998) supported by the theory (e.g. Murray 2000). According to that relationship the 2% value of period excess is what one would expect for FS Aur with the orbital period of 85.7 minutes. This indirectly confirms our derived period. On the other hand, it explains why FS Aur has not been seen in the superoutburst. The systems that are found to have permanent superhumps possess thermally stable large discs as a result of higher mass transfer rates than in SU UMa systems.

2.1. *Outbursts and long-term behavior*

The scenario discribed above would be not very surprising or rare at all if not for the history of cycli-

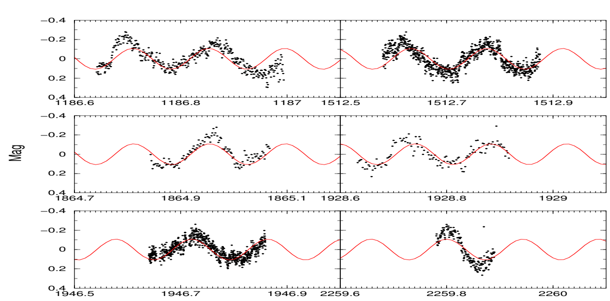

Fig. 2. The power spectrum of selected data (see text) and its CLEANed counterpart

a **b**

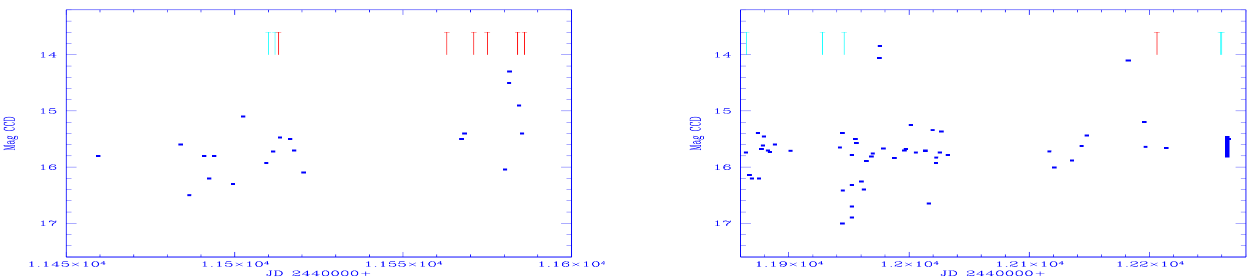

Fig. 3. The long-term light curve of FS Aur. The arrows mark the epochs where we obtained high time resolution photometry. The thick arrows indicate nights when superhumps were detected.

cal outbusrts of FS Aur. The problem is that the thermally stable disc in a high state should not produce outbursts in the way we used to explain them. The Dwarf Nova outbursts by widely accepted models are a product of thermal instability and require lower mass transfer rate to maintain the temperature/viscosity in a range where a jump is possible from one state to another (Osaki 1989). We examined all publicly available light curves of FS Aur from the archives of AAVSO. Only CCD measurements were taken into consideration. First we checked the correlation with the occurence of the superhumps in the system with its long term behavior. In the Figure 3 the long-term light curve of FS Aur is presented from AAVSO archives. The dates when superhumps were observed in the light curves are marked by long arrows. The nights when light curves were predominantly displaying the long photometric period without significant interference of short period modulation are marked by small arrows. While data is scarse and it is difficult to quantify, the overall impression is that superhumps mostly occur near/around the outbursts. If we amplify the outburst profile as, in the Figure 4, we can note that the duration of the flare, its amplitude and shape do not exactly fit the description of Dwarf Nova outburts. The short DN outbursts last on average 4 days, have a steep rise, plateau and slow decline and generally reach larger amplitudes (Warner 1990). While some frequent outburst systems exist (ER UMa type; Kato & Kunjaya 1995), FS Aur by no means belongs to them. The quiescence of FS Aur lasts long enough to accumulate power for a descent DN outburst.

We suppose that the flares (as opposed to the outbursts in DN) in FS Aur are rather a result of a varying mass transfer rate, which may cause the observed pattern. There exists a large number of models trying to explain DN outbursts by a variable mass transfer rate or its combination with thermal instability model (eg Bath et al. 1983, Smak 2000). In such case, we can also argue that the increased mass transfer pushes the disc in the FS Aur beyond resonance radius limits and it starts to apsidally precess, producing the permanent superhumps.

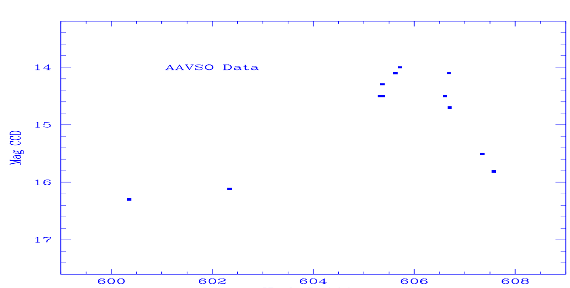

Fig. 4. The outburst profile of FS Aur.

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