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SEARCHING EVIDENCES FOR SPIRAL SHOCKS IN THE QUIESCENT ACCRETION DISK OF U GEM

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RESUMEN

Encontramos que el disco de acreción en la etapa de quietud de U Gem, tiene una estructura complicada. A lo largo de la mancha brillante originada en la región de interacción entre el chorro y las partículas del disco, hay también indicaciones de choques espirales. El mapa Doppler y las variaciones en las separaciones del pico de las líneas de emisión son indicativos de ello.

ABSTRACT

We find that the quiescent accretion disk of U Gem has a complicated structure. Along to the bright spot originating in the region of interaction between the stream and the disk particles, there are also explicit indications of spiral shocks. The Doppler map and the variations of the peak separation of the emission lines are indicative.

Key Words: **ACCRETION, ACCRETION DISKS — LINE: PROFILES — NOVAE, CATACLYSMIC VARIABLES — SHOCK WAVES — STARS: INDIVIDUAL (U GEM)**

Although indications for spiral shocks in the hot accretion disks during an outburst have already been found (Steeghs et al. 1997), the problem on the spiral structure of the quiescent accretion disks still remains unsolved. The observational detection of spiral shocks in such disks would be very important since spiral arms are very efficient in transporting angular momentum into the outer part of the disk (Boffin 2001). However if existing, spiral shocks would be much more difficult to detect than the strong shocks in the hot accretion disk during outburst. Nevertheless, first steps towards an observational confirmation have been started. Neustroev & Borisov (1998) and Neustroev et al. (2002) have found some evidences for spiral structure of the quiescent accretion disk of U Gem and IP Peg. Further investigations in this area are strongly required.

Here we present new evidences for spiral shocks in the quiescent accretion disk of U Gem. High signal-to-noise and medium resolution (∼3Å) optical spectra of U Gem were obtained on the 2.12-m telescope of the *Observatorio Astrofisico"Guillermo Haro"* (AOGH), Cananea, México, during 2000 November 17, with a total coverage of 4.3 hours. A total of 24 spectra were taken in the wavelength range 3900-5400 Å with exposures of 600 s, covering one orbital period.

The distribution of the accretion disk's emission

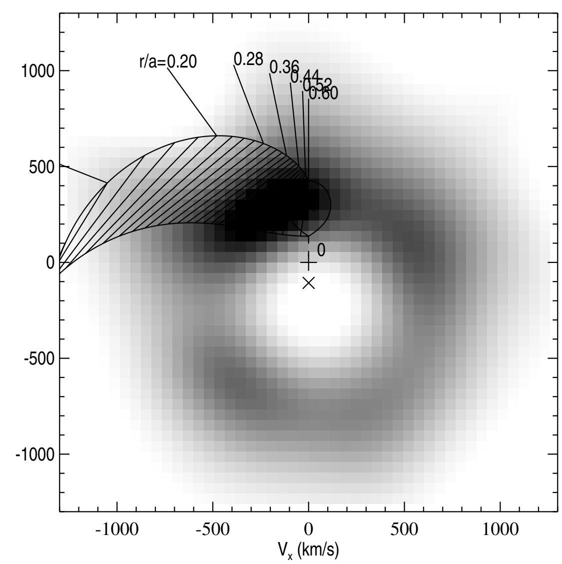

Fig. 1. The Doppler map of the Hβ emission from U Gem in quiescence.

was explored by computing a Doppler map, using the method of Doppler tomography (Marsh & Horne 1988). The Hβ tomogram shows the bright emitting region superposed on the typical ring-shaped emission of the accretion disk. This bright region can be unequivocally contributed to emission from the bright spot on the outer edge of the accretion disk. Note that the emission from the secondary is completely absent.

Disk emission is centered on the white dwarf and has small, but well noticeable azimuthal asymmetry

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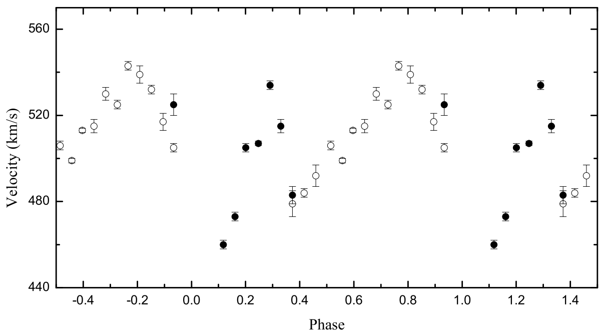

Fig. 2. The modulation of the double peak separation of the Hβ emission across the binary period. Filled and open circles correspond to the velocity difference between the center of the line and the blue and red peak respectively. These velocity differences were determined during orbital phases when the emission component from the bright spot was on the opposite peak of the line.

in the form of a two armed pattern. The line flux in the arms is about a factor of $\sim$1.4 stronger than that of the disk emission outside these areas, pointing to some heating and density enhancement. Note that the marked areas of increased luminosity are not perfectly symmetric. The arm in the upper right of the tomogram is slightly stronger.

These arms are located too far from the region of interaction between the stream and the disk particles. None of the theories predict the presence of any bright spots here, which are connected with such an interaction. However, exactly in these areas of the Doppler maps there should be spiral shocks predicted numerically by a number of researchers (Sawada et al. 1986). Furthermore, very similar two-armed structure was detected by Groot (2001) in the accretion disk of U Gem and by Steeghs et al. (1997) in IP Peg, when both systems were in outburst.

However, unlike Steeghs et al. (1997) and Groot (2001), we cannot confidently assert that the form of both arms is spiral. The reason of it can be the fact, that spiral shocks in quiescence should be tightly wrapped (Steeghs & Stehle 1999). Hence, the areas on the tomograms corresponding to the spirals will little differ from a ring. In addition this difference will be difficult for detecting, taking into account low brightness of these shocks.

As additional observational evidence for spiral shocks in the accretion disk can be regarded the modulation of the double peak separation of the emission lines across the binary orbit in a particular way (Neustroev & Borisov 1998). The detection of such modulation is complicated by presence of the s-wave component distorting the lines. To remove this influence, the spectra of U Gem were corrected

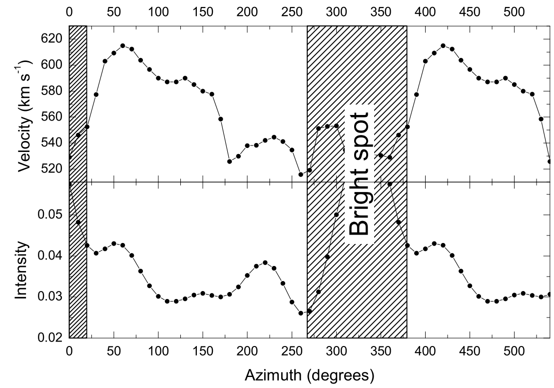

Fig. 3. Variation in the velocity and emission strength of the spiral arms as a function of azimuth.

for wavelength shifts due to orbital motion. After that, we have determined, using gaussian fitting, the radial velocities of only such line peaks that are not garbled by the s-wave component. We have taken the absolute values of these velocities as the half of the double peak separations, and in Fig. 2 we show their dependence on the orbital phase. One can see that the double peak separation varies during the orbital period, at a first approximation as $\sin 2\varphi$. These variations are the signature of a m=2 mode in the accretion disk of U Gem. This mode can be excited by the tidal forcing and the detected variations can be explained by the presence of spiral shocks in the disk, confirming the results of Neustroev & Borisov (1998). Additionally, we have also determined the variation in the velocity and emission strength of the (spiral) arms as a function of azimuth (Fig. 3). The obtained plot is qualitatively similar to Fig. 4 that has been presented by Harlaftis et al. (1999) for spiral shocks in the accretion disk of IP Peg during outburst.

Thus, we find that the quiescent accretion disk of U Gem has a complicated structure. Along to the bright spot originating in the region of interaction between the stream and the disk particles, there are also explicit indications of spiral shock waves.

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