New Horizons in Time-Domain Astronomy
Proceedings IAU Symposium No. 285, 2011
R.E.M. Griffin, R.J. Hanisch & R. Seaman, eds.

doi:10.1017/S1743921312000774

Investigating the Sources of Flickering and Superhumps in the Dwarf Nova V4140 Sgr

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Abstract. We report the results of maximum entropy eclipse-mapping analysis of an ensemble of light curves of the dwarf nova V4140 Sagitarii (V4140 Sgr) with the objective of studying the spatial distribution of its steady-light and flickering sources in quiescence, and the changing disk structure during an outburst.

Keywords. accretion, accretion disks, stars: dwarf novae, stars: imaging, novae, cataclysmic variables, binaries: eclipsing, stars: individual (V4140 Sagitarii)

1. Context

In dwarf novæ, mass is transferred from a late-type star to a companion white dwarf via an accretion disk. Recurrent outbursts occur on time-scales of days or months, when the disk brightens by a factor of 20–100 for about 1–10 days. Outbursts are explained in terms of either a thermal-viscous disk-instability (DIM; Lasota 2001) or a mass-transfer instability (MTIM; Bath 1975). DIM predicts that matter accumulates in a low-viscosity disk ($\alpha_{\rm quies} \sim 10^{-2}$) during quiescence, whereas in MTIM the disk viscosity is always large ($\alpha \sim 10^{-1}$). Measuring α in a quiescent disk is therefore critical for inferring which model is the more realistic for a given dwarf nova.

"Flickering" refers to the intrinsic brightness fluctuation of 0.01–1 mag on time-scales of seconds to dozens of minutes which are seen in dwarf-novæ light curves (Bruch 2000). Flcikering might arise at the stream-disk impact region (because of unsteady mass inflow, or post-shock turbulence; Warner & Nather 1971) and/or in turbulent inner-disk regions. If the disk-related flickering is caused by magneto-hydrodynamic (MHD) turbulence, it is possible to infer α from the relative flickering amplitude (Geertsema & Achterberg 1992).

V4140 Sgr is an 88-min period eclipsing SU UMa-type dwarf nova showing 1–2 mag, 5 to 10-day outbursts recurring every 80 to 90 days, and longer, brighter super-outbursts when superhumps appear in its light curve (Borges & Baptista 2005).

2. Data Analysis and Results

An ensemble of 22 B-band light curves of V4140 Sgr was obtained with the SOI optical camera on the Southern Astrophysical Research 4.1-m telescope during 2006. The object was observed during two nights during the decline of what seemed to have been a super-outburst in 2006 September 12–24. The outburst light curves show pronounced superhumps, with maximum light occurring at different binary phases at each night.

We applied 3D eclipse-mapping techniques to locate the source of the superhump and to follow the evolution of the disk's surface brightness distibution during the outburst decline. An entropy landscape method was used to derive the disk radius R_d and opening angle β. The disk shrank from $0.34\,R_\odot$ at outburst maximum to $0.21\,R_\odot$ in quiescence, and was geometrically thin both in outburst ($\beta = 1^\circ\!.0$) and in quiescence ($\beta = 0^\circ\!.5$). The surface brightness distribution was asymmetric towards the L1 point at outburst maximum, suggesting that the disk was elliptical at that stage. Wide (in azimuth) regions of enhanced emission at the disk rim are responsible for the orbital modulation observed during outburst maximum and decline. The quiescent disk map shows enhanced emission ahead of the stream-disk impact point, and maximum emission along the disk rim coinciding with the predicted azimuth of impact point (bright spot).

The remaining 15 light curves in quiescence were combined to derive the orbital dependency of the steady-light components and of the low- and high-frequency flickering ones (Baptista & Bortoletto 2004). Eclipse mapping of those curves indicate that the steady-light phase is dominated by emission from an extended asymmetric source with negligible contribution from the white dwarf, indicating that in quiescence efficient accretion is taking place through a high-viscosity disk. Flickering maps show an asymmetric source at the disk rim (stream-disk impact flickering) and an extended central source (disk-related flickering) several times larger in radius than the white dwarf at disk centre.

If the disk-related flickering is caused by fluctuations in the energy dissipation rate induced by MHD turbulence in the disk's atmosphere, its relative amplitude will yield a direct measurement of the disk viscosity parameter α and its radial dependency (Geertsema & Achterberg 1992). With that assumption, we find that the inner disk regions of V4140 Sgr have a high viscosity of $\alpha \sim 0.15$–0.3 but which decreases with increasing radius—a similar behaviour to that previously found for the similar dwarf nova HT Cas (Baptista *et al.* 2011). The inferred high disk viscosity is in agreement with the observed surface brightness distribution of the disk, and is inconsistent with the expectations from the DIM.

These results suggest that the outbursts of V4140 Sgr are powered by bursts of enhanced mass transfer rates from the donor star.

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