Changes in the structure of the accretion disc of V2051 Ophiuchi through the outburst cycle

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Abstract.

We present the results of the analysis of light curves of V2051 Oph through an outburst with eclipse mapping techniques.

1. Introduction

Dwarf novae show recurrent outbursts (of 2-5 mags on timescales from weeks to months) powered by a sudden increase in mass inflow in the accretion disc around the white dwarf. Currently, there are two competing models to explain the cause of the sudden increase in mass accretion. In the mass transfer instability model (MTIM), the outburst is the time dependent response of a viscous accretion disc to a burst of matter transferred from the secondary star. In the disc instability model (DIM), matter is transferred at a constant rate to a low viscosity disc and accumulates in an annulus until a critical configuration switches the disc to a high viscosity regime and the gas diffuses rapidly inwards and onto the white dwarf. Tracking the evolution of a dwarf nova accretion disc along an outburst cycle with eclipse mapping techniques (EMT) provides a valuable opportunity to test these models against observations.

2. Observations and data analysis

V2051 Oph is a short period dwarf nova ($P_{\text{orb}} = 90 \text{ min}$) with deep eclipses ($B \simeq 2.5 \text{ mag}$). It went in outburst between the nights of 2000 July 30 and 31.

B band light curves of V2051 Oph were obtained with the 1.60 m telescope of Laboratorio Nacional de Astrofisica (LNA/Brazil) on 2000 July 28/August 02 covering the nights before the onset of the outburst, the short ($\approx 1 \text{ day}$) outburst maximum and 2 days along the decline from maximum.

The disc radius shrinks from 0.47 $R_{L1}$ in quiescence to 0.40 $R_{L1}$ at the night before maximum, in agreement with the expectation of the MTIM ($R_{L1}$ is the distance from the disc centre to the inner Lagrangian point).

3. Results

EMT were used to solve for a map of the disc brightness distribution and for the flux of an additional uneclipsed component (Baptista & Steiner 1993).
The sequence of eclipse maps reveal that the outburst starts with a decrease in the brightness of the disc and confirms that the disc shrinks at the night before maximum. The map of this night is dominated by emission along the gas stream with no evidence of an increase in the brightness of the bright spot. The brightness of the inner disc regions remains constant during outburst maximum and along decline, while the brightness of the outer disc regions progressively decreases with the inward propagation of a cooling wave. The disc becomes fainter through the decline phase, leaving the bright spot progressively more perceptible at the outer edge of the disc.

The maximum fractional contribution of the uneclipsed component (9% of the total flux in the B band) occurs on the night before outburst maximum. This suggests the development of a vertically-extended disc wind before outburst maximum.

We quantify the changes in disc size during outburst by analyzing the radial intensity distribution of the total map. We define the outer disc radius in each map as the radial position at which the intensity distribution falls below a reference level corresponding to the intensity of the bright spot in the eclipse map in quiescence. The disc expands from 0.40 $R_{L_1}$ at the night before maximum to 0.76 $R_{L_1}$ at outburst maximum. Two days after maximum, the disc radius reduces to 0.67 $R_{L_1}$. The radial intensity distribution of the symmetric disc component shows an outward moving heating wave at the rise to outburst maximum with a speed of $v_{f(hot)} \geq 1.73 \text{ km s}^{-1}$. The speed of the inward moving cooling wave are $-0.24 \text{ km s}^{-1}$ and $-0.91 \text{ km s}^{-1}$, respectively 1 and 2 days after maximum. We observe an acceleration of the cooling wave as it travels across the disc, in contradiction with the prediction of the DIM. From $v_{f(hot)}$ we derive a viscosity parameter $\alpha_{hot} \simeq 0.14$, comparable to the derived viscosity in quiescence $\alpha_{cool} \simeq 0.16$ (Baptista & Bortoletto 2004).

The radial brightness temperature distribution is flatter than the $T \propto R^{-3/4}$ law expected for steady-state discs both in quiescence and in outburst, leading to larger mass accretion rates in the outer disc ($0.3 - 0.4 R_{L_1}$) than in the inner disc regions ($0.1 R_{L_1}$). If we assume a distance of 146 pc to the binary (Vrielmann, Stiening & Offutt 2002), the brightness temperatures in quiescence range from 5800 K in the outer disc to 9200 K in the inner disc; at outburst maximum the temperatures range from 9600 K at 0.4 $R_{L_1}$ to 12200 K in the inner disc. The inferred temperatures of the outbursting disc are higher than the critical temperature $T_{crit}$ above which the disc gas should remain while in the high viscosity branch of the thermal-viscous limit cycle of the DIM. However, if the distance is 100 pc (see Baptista & Bortoletto 2004), the inferred disc temperature are lower and do not exceed $T_{crit}$ even at outburst maximum.

Our next step is to derive the distance to the binary from the measured B and V white dwarf fluxes in quiescence.

References
Baptista, R. & Bortoletto, A. 2004 AJ, 411, 128
Baptista, R. & Steiner, J. E. 1993, A&A, 277, 331
Vrielmann, S., Stiening, R. F., & Offutt, W. 2002, MNRAS, 334, 608