HST spectral mapping of V2051 Ophiuchi in a low state

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Abstract.
We report a study of the spectra and structure of the accretion disc of the V2051 Oph while the star was in an unusual, faint brightness state during 1996.

1. Observations and data analysis

V2051 Oph ($P_{\text{orb}} = 90\text{ min}$) belongs to a small group of ultrashort period eclipsing dwarf nova together with Z Cha, OY Car and HT Cas. During 1996, it was seen at a low brightness state ($B \simeq 16.2$), in which mass accretion was reduced to a minimum (Baptista et al. 1998).

High-speed ultraviolet and optical spectroscopy was secured with the Faint Object Spectrograph onboard the Hubble Space Telescope on 1996 Jan 29 (UV: G400H grating, $\lambda = 3226 - 4781\ \text{Å}$, $\Delta \lambda = 1.5\ \text{Å pixel}^{-1}$; optical: G160L grating, $\lambda = 1150 - 2507\ \text{Å}$, $\Delta \lambda = 3.5\ \text{Å pixel}^{-1}$) at a time resolution of 3.4 s. The runs cover the eclipse cycles 109988 (UV) and 109989 (optical), according to the ephemeris of Baptista et al. (2003).

The out-of-eclipse UV spectra show prominent Ly$\alpha$ $\lambda 1216$, C II $\lambda 1323$, Si IV $\lambda 1394, 1403$ and C IV $\lambda 1549, 1551$ emission lines as well as broad absorption bands possibly due to Fe II. The optical spectra show the Balmer continuum in emission as well as He emission lines and strong Balmer emission lines.

The UV spectra were divided into 34 narrow passbands (19-60 $\text{Å}$ wide in the continuum and velocity-resolved bins of 2000 km/s or 3000 km/s for the lines) while the optical spectra were divided into 68 passbands (15-42 $\text{Å}$ wide in the continuum and velocity-resolved bins of 1000 km/s for the lines) and light curves were extracted for each one. Maximum-entropy eclipse mapping techniques (Baptista & Steiner 1993) were used to solve for a map of the disc brightness distribution and for the flux of an additional uneclipsed component in each band.

2. Results

The line centre maps show broad brightness distributions from an extended and optically thick region, possibly ionized by the boundary layer. Velocity-resolved H$\gamma$ line light curves show the expected behavior for the eclipse of gas rotating in prograde sense (rotational disturbance), with the blue wing ($-1000\ km/s$) being eclipsed earlier than the red wing ($+1000\ km/s$). Net line emission maps show that the Balmer lines are in absorption at the disc centre, and that there is also
little contribution from the bright spot at the disc rim. In contrast with the observed in the line maps, the continuum maps show pronounced emission from the compact white dwarf and bright spot sources as well as enhanced emission along the ballistic stream trajectory of gas stream, an evidence of gas stream overflow.

We sliced the disc into concentric annular regions of width $0.1 R_{L1}$ to compute disc spectra as a function of distance. Motivated by the asymmetric emission patterns observed in the eclipse maps, we extracted spatially resolved spectra for three distinct disc regions: “front” (the disc side closest to the secondary star), “back” (the side disc farther away from the secondary star) and “gas stream” (a thin slice around the stream trajectory in each annular region).

The disc (front and back) spectra show that the Balmer decrement becomes shallower and the lines are more prominent and narrower with increasing radii. The “front” side is systematically brighter than the “back” side in agreement with the results of Vrielmann et al. (2002). The difference becomes more pronounced as the radius increases. The comparison of the “front” and “back” spectra show that the latter contain broad absorption bands, possibly due to Fe II, that become more conspicuous in the outer parts of the disc – suggesting that they arise from absorption along the line of sight in a vertically extended region above the disc (e.g. Horne et al. 1994). The spectrum of the central pixel shows a continuum filled with broad and shallow absorption lines and a Balmer jump in absorption, and resembles that of a DA white dwarf.

We computed the ratio between the spectrum of the “gas stream” and that of the “front” side at the same radius to investigate the emission along the gas stream trajectory. The spectrum of the gas stream is clearly distinct from the disc spectrum for a large range of radii. In contrast to the observed in the disc spectra, the lines appear in absorption. The distinct emission along the gas stream trajectory underscores the evidence of gas stream overflow. The fact that the lines appear in absorption in the stream spectra suggest the presence of matter outside of the orbital plane (e.g. a chromosphere + wind).

The uneclipsed component is dominated by the Balmer continuum and strong Balmer emission lines in the optical and by resonant emission lines in the UV, suggesting that it arises in a vertically extended region. The strong lines in the optical and UV spectra as well as the Balmer continuum accounts for $\sim 5 - 10$ per cent of the total light at the respective wavelength. The continuum in the uneclipsed spectrum yield negligible fractional contributions to the total light at the corresponding wavelengths.

We are fitting LTE atmosphere models to the spatially resolved disc spectra to derive the radial run of the temperature, surface density, turbulent mach number and vertical scale height.

References

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