

# Spectroscopy of the dwarf nova V2051 Oph between the maximum and decline of an outburst

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**Abstract.** We present an analysis of time-resolved spectroscopy of the eclipsing dwarf nova V2051 Oph covering the maximum and early decline of its 2002 outburst. By employing eclipse mapping techniques and gray atmosphere modeling, we derived spatially resolved spectra and physical parameters of the accretion disk. Our results show that the gas temperature decreases radially and the disk remains optically thin ( $\tau \sim 10^{-3}$ ) throughout the observed stages. We observed a disk expansion from  $0.48R_{L1}$  to  $0.58R_{L1}$  and a decrease in the accretion rate from  $\dot{M} \sim 10^{-9.4}$  to  $10^{-9.5}M_{\odot}\text{yr}^{-1}$ . The evolution of the radial profiles suggests a cooling wave propagating from the outer to the inner disk regions, supporting the Mass Transfer Instability Model (MTIM).

**Resumo.** Apresentamos uma análise de espectroscopia resolvida no tempo da nova anã eclipsante V2051 Oph cobrindo o máximo e o início do declínio de sua erupção de 2002. Empregando técnicas de mapeamento por eclipse e modelagem de atmosfera cinza, derivamos espectros espacialmente resolvidos e parâmetros físicos do disco de acréscimo. Nossos resultados mostram que a temperatura do gás diminui radialmente e o disco permanece opticamente fino ( $\tau \sim 10^{-3}$ ) durante os estágios observados. Observamos uma expansão do disco de  $0.48R_{L1}$  para  $0.58R_{L1}$  e uma diminuição na taxa de acreção de  $\dot{M} \sim 10^{-9.4}$  para  $10^{-9.5}M_{\odot}\text{ano}^{-1}$ . A evolução dos perfis radiais sugere uma onda de resfriamento se propagando das regiões externas para as internas, corroborando o Modelo de Instabilidade de Transferência de Massa (MTIM).

**Keywords.** Accretion, accretion disks – Stars: dwarf novae – binaries: eclipsing – Stars: individual: V2051 Oph – Techniques: spectroscopic

## 1. Introduction

Dwarf novae are a subclass of cataclysmic variables (CVs) consisting of a white dwarf accreting matter from a late-type companion via an accretion disk. These systems undergo recurrent outbursts, where the disk brightness increases by factors of 10-100. Two main models compete to explain these events: the Disk Instability Model (DIM), which attributes the outburst to thermal-viscous instabilities within the disk, and the Mass Transfer Instability Model (MTIM), which suggests a burst in mass transfer from the secondary star (Baptista 2012).

V2051 Oph is a short-period ( $P_{orb} \approx 90$  min) eclipsing dwarf nova that serves as an excellent laboratory for testing these models. Its high orbital inclination ( $i \approx 83^{\circ}$ ) allows the use of eclipse mapping techniques to spatially resolve the accretion disk structure without the need for model-dependent assumptions. In this work, we analyze time-resolved spectroscopic data obtained during the 2002 outburst to constrain the physical properties of the accretion disk and its evolution between the maximum and the onset of the decline.

## 2. Observations and Data Reduction

Time-resolved spectroscopy was obtained with the ESO 1.5m telescope between July 10 and 14, 2002. This dataset covers the rise, maximum, and decline of an outburst. In this proceeding, we focus on the data from July 12 (maximum) and July 13 (early decline). The spectra cover the range 3500–5800 Å.

The data reduction followed standard procedures. The spectra were phase-folded according to the ephemeris of the system. Light curves were extracted for 134 narrow wavelength bins using the JOIA software. To correct for orbital modulations outside the

eclipse, we fitted spline functions to the out-of-eclipse phases, normalizing the flux to isolate the eclipse profile.

## 3. Methods: Eclipse Mapping and Modeling

The light curves were analyzed using the eclipse mapping method with the PRIDA code to produce brightness distribution maps of the accretion disk for each wavelength bin. The reconstruction process utilized maximum entropy regularization to select the smoothest map consistent with the data ( $\chi^2 \approx 1$ ). Uncertainties in the eclipse maps were estimated using Monte Carlo simulations, generating randomized light curves consistent with the observational noise.

From the resulting monochromatic maps, we extracted spatially resolved spectra for concentric annuli centered on the white dwarf, with radial widths of  $\Delta R = 0.1R_{L1}$  (where  $R_{L1}$  is the distance to the inner Lagrangian point  $L_1$ ). This slicing technique allowed us to isolate the emission from different disk regions, from the inner boundary near the white dwarf to the outer edge.

To determine the physical properties of the gas, we modeled the extracted spectra using a grid of gray atmosphere models using the SPEC\_DR code (Schlindwein 2021). We employed a  $\chi^2$  minimization routine to fit the observed continuum spectra, deriving the gas temperature ( $T_{gas}$ ) and column density ( $\Sigma$ ) for each disk ring. Effective temperatures ( $T_{eff}$ ) were calculated using the Stefan-Boltzmann law, and optical depths ( $\tau$ ) were derived consistently from the best-fit model outputs.

## 4. Results

The spectral modeling provided satisfactory fits to the continuum emission across the disk radius (Fig. 1). The spectra show prominent emission lines (Balmer series, HeII 4686, and CIII/NIII

