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An X-ray study of the dwarf nova candidate OGLE-BLG-DN-0064 using Chandra data

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Abstract. OGLE-BLG-DN-0064 (hereafter, OGLE-64) has been identified as a possible dwarf nova candidate due to the optical outburst activity recorded by the Optical Gravitational Lensing Experiment (OGLE) survey. We study the X-ray properties of OGLE-64 using the Chandra archival data. OGLE-64 shows an X-ray luminosity of $L_X \approx 1.5 \times 10^{32}$ erg/s in the 0.5–7 keV energy band and a high ratio of X-ray flux to optical flux $F_X/F_{\rm opt} \approx 1.5$. We found no significant optical and X-ray periodicity with the timing analyses. The X-ray spectrum of OGLE-64 can be approximated by a power-law model with a photon index of $\Gamma \approx 1.9$ and an optically thin plasma model with a temperature of $kT \approx 6.4$ keV. The isobaric cooling flow model gives an accretion rate in the system of about $\dot{M}_{\rm acc} \approx 5.4 \times 10^{-11}\, M_\odot$/yr and the white dwarf mass of $M_{\rm WD} \approx 0.8\, M_\odot$. The X-ray properties and the optical outburst activity suggest that OGLE-64 is a dwarf nova.

Keywords: stars: cataclysmic variables, dwarf novae, binaries, white dwarfs; X-ray: general

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1 Introduction

Cataclysmic variables (CVs) are close binary systems consisting of an accreting white dwarf and a donor star, filling its Roche Lobe (Warner 1995). Dwarf novae are CVs that exhibit regular outbursting activity, best described by the disk instability model (Lasota 2001). CVs typically show X-ray luminosities in the $L_X \sim 10^{30}$–10^{33} erg/s range (Mukai 2017).

We found OGLE-64 as an X-ray source (2CXO J173917.7−214735) while searching for new CV candidates in the Chandra Source Catalog v2.0 (Evans et al. 2010), cross-matched with Gaia DR3 (Galiullin et al., submitted to A&A). OGLE-64 shows a high ratio of X-ray flux to optical flux, $F_X/F_{\rm opt} \approx 1.5$, compared to other objects in the catalog. OGLE-64 matches with a Gaia DR3 object (id: 4117235609421426560) within a 2 arcsec search radius, having a distance to the object of 872 ± 126 pc (Eyer et al. 2023). OGLE-64 is a variable object, which was first noted as a possible dwarf nova candidate in 2015 due to its outbursting behavior detected by the Optical Gravitational Lensing Experiment (OGLE) survey (Mróz et al. 2015). Fig. 1 shows the Chandra false-color X-ray image (Obsid: 12945) of OGLE-64 and the optical image of the same sky region from Pan-STARRS (Chambers et al. 2016).

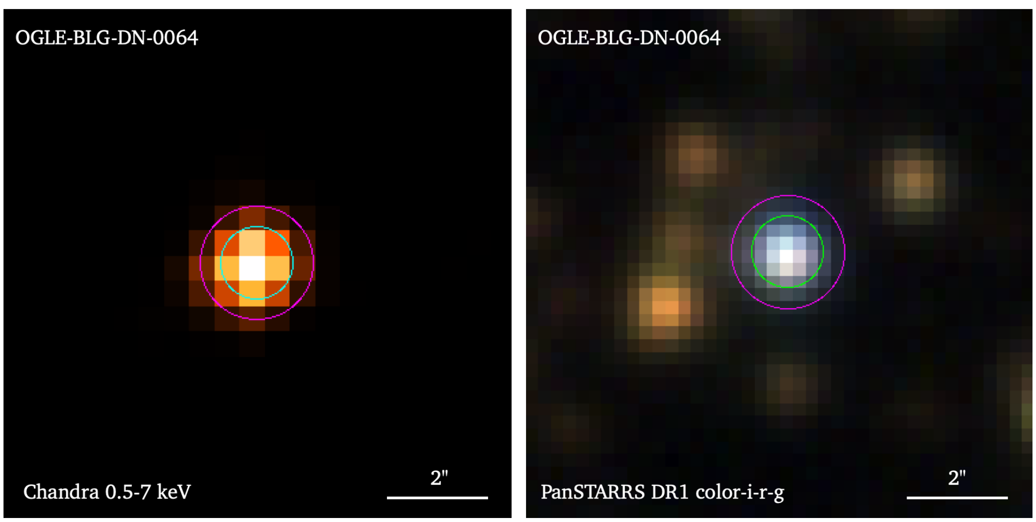

Fig. 1. Left panel: The Chandra X-ray image of OGLE-64 in the 0.5–7 keV energy band. Right panel: Color image of OGLE-64 obtained by combining Pan-STARRS gri images. The inner circle corresponds to the error region for the X-ray source detection, and the outer circle represents the region containing 90% of the counts from the X-ray source.

2 Analysis and Results

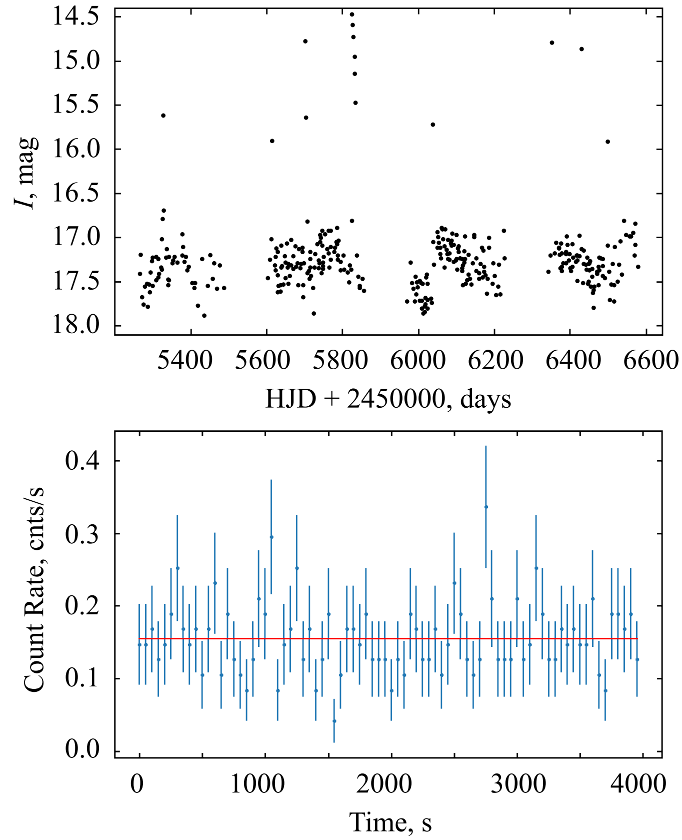

Fig. 2. Top panel: OGLE light curve of OGLE-64 on I band. Bottom panel: Chandra X-ray light curve of OGLE-64 in the 0.5–7 keV energy band. The red solid line shows the mean count rate.

We used a pre-calibrated optical light curve from the OGLE survey to search for possible periodic signals with timing analysis. We extracted the X-ray spectrum and light curve from the Chandra archival data (Obsid: 12945) using the `Chandra Interactive Analysis of Observation` (`CIAO`) (Fruscione et al. 2006) package. We analyzed the X-ray spectrum of OGLE-64 in the 0.5–7 keV energy band using the `XSPEC` package (Arnaud 1996). We grouped the X-ray spectrum of OGLE-64 to have at least three counts per spectral channel. We applied C-statistics (Cash 1979) to find the best-fit parameters and compute the errors at the 90% confidence level. We used the Tuebingen–Boulder interstellar absorption model with abundances from Wilms et al. (2000) to include a Galactic absorption component.

2.1 Timing analysis

We used the Lomb–Scargle periodogram (Lomb 1976; Scargle 1982) and Fast Fourier Transformation (using `XRONOS` sub-package in `FTOOLS`, HEASARC[1]) to search for periodic signals in the optical and X-ray light curves, respectively. We applied a sigma-clipping technique to the optical light curve to remove all data points caused by an outburst. To statistically estimate the significance of the peaks in the periodogram, we simulated 2000 nonperiodic light curves with constant fluxes. We generated the distribution of the maximum power of peaks in periodograms for nonperiodic light curves and obtained the values corresponding to the 3σ confidence level. The top panel of Fig. 2 shows the optical light curve with an outburst of about 3 mag. The bottom panel of Fig. 2 shows the X-ray light curve from the Chandra data. We found no significant periodicity neither for the optical nor the X-ray light curves.

2.2 X-ray spectrum, luminosity, and accretion rate

The top panel of Fig. 3 shows the X-ray spectrum of OGLE-64 along with the different models used in the fit. Initially, we approximated the X-ray spectrum of OGLE-64 by a power-law model. The fitted parameters are $N_{\rm H} = 3.3^{+1.1}_{-2.3} \times 10^{21}$ cm^{-2} for a hydrogen column density and $\Gamma = 1.85 \pm 0.22$ for a photon index (C-stat/dof: 118.82/124). The fit with an optically thermal plasma emission model gives a temperature of $kT = 6.44^{+3.62}_{-1.79}$ keV and $N_{\rm H} = (2.1 \pm 0.7) \times 10^{21}$ cm^{-2} (C-stat/dof: 122.81/124). We computed the absorption-corrected X-ray flux of OGLE-64 by integrating the power-law model. Using the distance to the object, we computed the X-ray luminosity of the OGLE-64 in the 0.5–7 keV (2–10 keV) energy band to be $L_X = (1.50 \pm 0.48) \times 10^{32}$–$(1.07 \pm 0.35) \times 10^{32}$ erg/s.

We used the isobaric cooling flow model to compute the accretion rate of OGLE-64. The fitted parameters are $N_{\rm H} = (2.8 \pm 1.0) \times 10^{21}$ cm^{-2}, $kT_{\rm max} = 18.93^{+28.92}_{-8.32}$ keV, and $\dot{M}_{\rm acc} = 5.37^{+3.60}_{-2.65} \times 10^{-11}\, M_\odot$/yr for the accretion rate (C-stat/dof: 119.27/122). To compute the white dwarf's mass, we used the relation between the shock temperature and mass, $kT_{\rm max} = (3/16) \times (GM_{\rm WD} \times m_{\rm H} \times \mu)/R_{\rm WD}$ (Frank et al. 2002), where $m_{\rm H}$ is the mass of hydrogen atom, μ is the mean molecular weight (here we use $\mu = 0.615$), G is the Newton's gravitational constant, $M_{\rm WD}$ and $R_{\rm WD}$ are the white dwarf's mass and radius respectively. Using the WD mass-radius relation (Nauenberg 1972), we computed the white dwarf's mass to be $M_{\rm WD} \approx 0.81^{+0.38}_{-0.23}\, M_\odot$.

3 Discussion and conclusion

The X-ray properties and the observed optical outbursts of about 3 mag suggest that OGLE-64 is a dwarf nova. OGLE-64 shows an accretion rate of $\dot{M}_{\rm acc} \approx 5 \times 10^{-11}\, M_\odot$/yr

[1] https://heasarc.gsfc.nasa.gov/

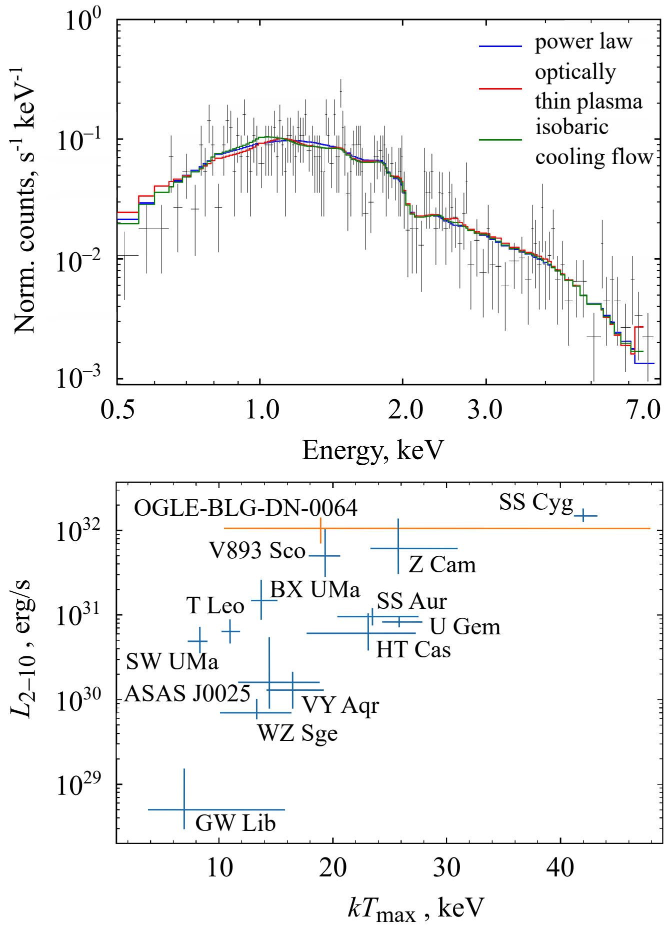

Fig. 3. Top panel: The Chandra X-ray spectrum of OGLE-64 along with the different models used in the fit. Bottom panel: The X-ray Luminosity L_X (2–10 keV)—maximum temperature $kT_{\rm max}$ diagram for some of the known dwarf novae (Byckling et al. 2010). OGLE-64 shows a relatively high X-ray luminosity, compared to other dwarf novae.

and a WD mass of $M_{\rm WD} \approx 0.8\,M_\odot$. The bottom panel of Fig. 3 shows the X-ray luminosity (2–10 keV energy band) versus the temperature $kT_{\rm max}$ (from the isobaric cooling flow model) diagram for some known dwarf novae (Byckling et al. 2010). OGLE-64 shows a relatively high X-ray luminosity of $L_X \approx 10^{32}$ erg/s, compared to some known dwarf novae. Such a high X-ray luminosity is mostly typical of magnetic systems. However, the photon index $\Gamma \sim 2$ and the temperature $kT \sim 6$ keV are typical for non-magnetic CVs in a quiescent state (see e.g., Galiullin & Gilfanov 2021). Our preliminary analysis shows no significant periodicity in the X-ray and the optical light curves. The absence of X-ray variability disagrees with the possible magnetic nature of OGLE-64 but might be explained by the almost face-on inclination angle ($i \sim 0^{\circ}$) of the system. The non-detection of the orbital period in the optical OGLE light curve also hints at the system's low inclination angle. OGLE-64 requires future spectroscopic follow-up observations. The presence of Balmer emission lines might confirm the object as a CV, and the presence of the high-excitation He II λ4686 emission line might imply a magnetic nature of the white dwarf.

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