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The recurrent ultra-luminous X-ray transient NGC 253 ULX1

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Abstract. We present the results of *ROSAT* and XMM-Newton observations of the recurrent ultraluminous X-ray source (ULX) NGC 253 ULX1. This transient is one of the few ULXs that was detected during several outbursts. The luminosity reached 1.4×10^{39} erg s^{-1} and 0.5×10^{39} erg s^{-1} in the detections by *ROSAT* and XMM-Newton, respectively, indicating a black hole X-ray binary (BHXRB) with a mass of the compact object of >11 $M_{\odot}$. In the *ROSAT* detection NGC 253 ULX1 showed significant variability, whereas the luminosity was constant in the detection from XMM-Newton. The XMM-Newton EPIC spectra are well-fit by a bremsstrahlung model (kT= 2.24 keV, $N_H = 1.74 \times 10^{20}$cm^{-2}), which can be used to describe a comptonized plasma. No counterpart was detected in the optical I, R, B, NUV and FUV bands to limits of 22.9, 24.2, 24.3, 22 and 23 mag, respectively, pointing at a XRB with a low mass companion.

Keywords. X-rays: binaries – X-rays: individuals: (NGC 253 ULX1) – black hole physics – accretion, accretion disks.

1. Introduction

ULXs are extra-nuclear compact X-ray sources with luminosities considerably exceeding the Eddington luminosity for stellar mass X-ray binaries of $\sim 2 \times 10^{38}$ erg/s (Makishima *et al.* 2000). ULXs obtain special attention as they may indicate the existence of intermediate mass black holes (100–1000 $M_{\odot}$, IMBHs). The ULX presented here, NGC 253 ULX1, was found by Liu & Bregman (2005) searching for ULXs in ROSAT HRI observations of 313 nearby galaxies. We analysed the source for variability (Fig. 1) and extracted the first spectrum from XMM-Newton data. For a more extensive report on NGC 253 ULX1 see Bauer & Pietsch (2005).

2. Properties of NGC 253 ULX1

NGC 253 ULX1 showed two outburst. The first was observed by ROSAT with $L_X = 1.4 \times 10^{39}$ erg/s (0.3–10keV), the second was detected by XMM-Newton with $L_X = 0.5 \times 10^{39}$ erg/s (0.3–10keV). From the first outburst we determined a lower mass limit of the compact object to 11 $M_{\odot}$. We were able to obtain the first spectrum of this source from the second outburst. It was best fitted with a bremsstrahlung model (kT = 2.24 keV, $N_H = 1.74 \times 10^{20}$ cm^{-2}, $\chi^2_{\rm red} = 0.961$). The brightness of the source varies by at least a factor of 500 ($L_{X,\rm min} = 0.003 \times 10^{39}$ erg/s). Its fastest change in luminosity ($L_{\rm max}/L_{\rm min}$) is greater than 71 in 120 days. In the ROSAT observation, NGC 253 ULX1 showed significant variability by at least a factor of 2 during 8 days. No short term variability was detected in the XMM-Newton observation.

3. Optical counterpart

We checked images taken with the Wide Field Imager (WFI) on the MPG-ESO 2.2m telescope at La Silla in the R-, I- and B-band (limiting magnitudes 24.2, 22.9 and 24.3,

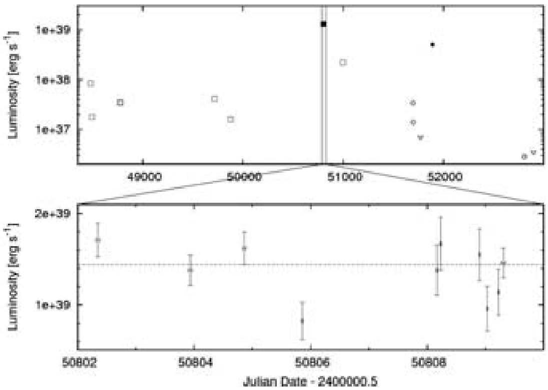

Figure 1. NGC 253 ULX1 light curves. Upper panel: solid symbols represent detections, open symbols 3σ upper limits of NGC 253 ULX1. Different symbols represent observing instruments: *ROSAT* (squares), XMM-Newton (diamonds) and *Chandra* (triangles). Lower panel: Luminosities of individual *ROSAT* HRI exposures from observation 601111h. In contrast to the upper panel, in the lower panel the plot is linear in luminosity.

respectively) and images taken with the Galaxy Evolution Explorer (GALEX, a space telescope from NASA observing in the ultraviolet) in the NUV and FUV (limiting magnitudes 22 and 23, respectively), but no counterpart could be detected.

4. The nature of NGC 253 ULX1

The best fitting bremsstrahlung spectrum indicates that NGC 253 ULX1 is a XRB system. We determined the lower mass limit of the compact object from its ROSAT luminosity to 11 $M_\odot$, typical for a stellar mass black hole. If we assume a multicolour disk blackbody model (XSPEC model *diskbb*, fitted with $N_H = 1.30 \times 10^{20}$ cm^{-2}, kT = 0.62 keV, $\chi^2_{\rm red} = 1.671$) then NGC 253 ULX1's position in the luminosity-disk temperature diagram (Fig. 2 in Miller *et al.* 2004) also indicates that NGC 253 ULX1 is a stellar mass black hole. The lack of an optical counterpart points at a low mass companion in the system. A high mass XRB should have been detectable in the WFI images (see Sect. 3) at about 22 to 24 mag (extrapolating V magnitudes from high mass XRBs in the Magellanic Clouds, Liu *et al.* 2000).

The recurrent outbursts exclude that the source is the luminous remnant of a recent supernova, like e.g. SN1993J in M81 (Zimmermann & Aschenbach 2003). We can also exclude that NGC 253 ULX1 is either a foreground object or a background active galactic nucleus (AGN) based on three arguments: (i) Its $\log(f_{\rm x}/f_{\rm opt})$ value of >3.2 exceeds that expected for galactic sources (−4.6 to −0.6) as well as AGNs (−1.2 to +1.2) (Maccacaro *et al.* 1988). (ii) The variability of NGC 253 ULX1 is by far larger than typically observed for AGNs (∼10–60) and (iii) NGC 253 ULX1 shows a bremsstrahlung spectrum, whereas spectra of AGNs above 2 keV are typically fitted by a power law.

We conclude that NGC 253 ULX1 is a low mass XRB with a stellar black hole as compact companion.

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