THE ULTRALUMINOUS X-RAY SOURCE IC 342 X-1 AND ITS ENVIRONMENT

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ABSTRACT

We present optical observations of a ULX in the nearby spiral galaxy IC 342. This variable source has an average X-ray luminosity of some 10^{40} erg/s. At the position of the source there is an ionized nebula (the "Tooth") having huge dimensions (280 x 130 pc), much larger than normal supernova remnants. Our optical spectra reveal highly supersonic expansion velocities and emission line ratios typical of SNRs. It has been claimed that two [OIII] λ5007 bright regions in the nebula might be indicative of excitation by non-isotropic emission from the ULX. However, our continuum subtracted [OIII] λ5007 image reveals that O^{++} ions are rather smoothly distributed in the nebula, fully consistent with shock excitation. Within the nebula we find two candidate stars (V=24.0 & 24.6) in the Chandra X-ray error circle. Both are substantially reddened being consistent with the patchy interstellar absorption. We will discuss the nature of this source in the framework of what is currently known about optical counterparts of ULXs.

Key words: galaxies: individual (IC 342), ISM: supernova remnants, X-rays: galaxies, X-rays: binaries.

1. INTRODUCTION

The two main hypotheses put forward to explain the high X-ray luminosities of ULXs are intermediate mass black holes (IMBHs) having 10^2 to 10^5 solar masses (Colbert & Mushotzky, 1999) or non-isotropic emission from a stellar mass black hole beamed into our line-of-sight (King et al., 2001).
We present optical observations of one of these sources, carried out in 2003 and 2004 with the 8.2m SUBARU telescope. This ULX is located in the spiral galaxy IC 342, at a distance of some 4.0 Mpc, although the distance is not precisely known due to high foreground obscuration. Previously detected in an Einstein observation (Fabbiano & Trinchieri, 1987), IC342 X-1 was seen several times with ROSAT and ASCA, and later with Chandra and XMM-Newton, but in different states.

The first optical observation was done by Pakull & Mirioni (2002), revealing the presence of a nebula coincident with the ROSAT position of the ULX, which was named the "Tooth" nebula, descriptive of its morphology.
Another optical study made independently by Roberts et al. (2003), has obtained results consistent with the previous one, e.g, a [SII]/H_α emission-line flux ratio of 1.1 consistent with a supernova remnant.

2. RESULTS

At the position of the X-ray source there is an ionized nebula having huge dimensions (280 x 130 pc), much larger than normal supernova remnants (Fig. 1).
Inside the Chandra error circle of the X-ray source, there are two possible optical counterparts (astrometrical error $\sim 0.2''$) :

- candidate 1 at $03^h45^m55.60^s$, $+68°04'55.3''$ with a magnitude V=24.0 (V-I=1.5). Absolute magnitude M_V=-6.5 $\pm$ 0.5
- candidate 2 at $03^h45^m55.70^s$, $+68°04'54.5''$ with a magnitude V=24.6 (V-I=1.3). Absolute magnitude M_V=-5.9 $\pm$ 0.5

These two possible counterparts have V-I consistent with the extinction E(B-V)=0.8$\pm$0.1 towards the nebula in IC 342, so they are both likely members of the galaxy.

Unlike the study made by Roberts et al. (2003), the [OIII] emission seems to closely follow that of H_α (Fig. 1). Accordingly, we do not confirm the presence of high excitation [OIII] blobs which could have been suggestive of anisotropic X-ray emission (and ionisation) by the X-ray source.

Figure 2 presents the low resolution spectrum of the nebula around IC 342 X-1 (slit orientation is north-south) which confirms the previous studies with a high [SII]/H_α emission line flux ratio of 1.1, constant along the nebula. We can also note a high [OI]λ6300/H_α flux ratio of 0.26, all these ratios being typical of SNRs. Our [OIII]/H_β ratio, with a value of 1.0, does not show strong variations in

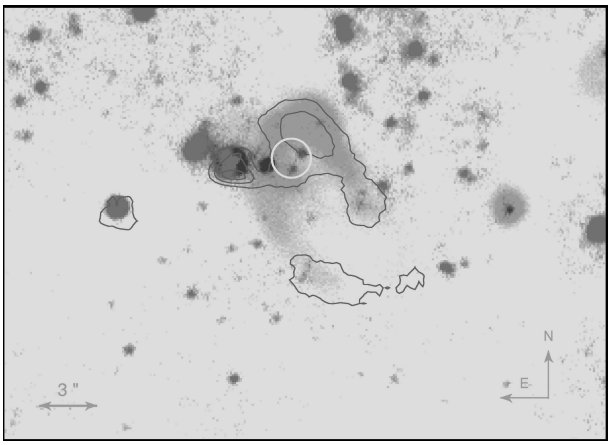

Figure 1. Structure of the "Tooth" around IC 342 X-1. The image shows the continuum subtracted H_α and V band representing the continuum. The continuum subtracted [OIII] emission is shown with contours. The uncertainty in the position of the X-ray source is indicated by an error circle with a 90% confidence radius of 1.2''.

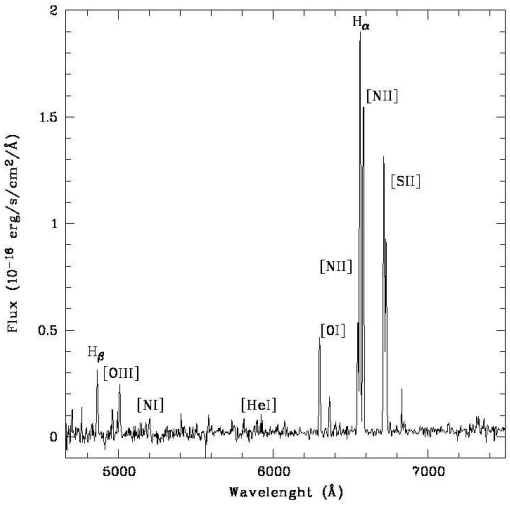

Figure 2. Low resolution spectrum of the nebula around IC 342 X-1. Emission features other than annotated are residuals of telluric lines or cosmic rays.

the main body of the nebula in agreement with our continuum subtracted [OIII] image. Table 1 presents the emission line flux ratios (vs. H_β) of the nebula, corrected for reddening.

Candidate 1 is present in our long slit spectrum. Unfortunately, the continuum of the star is not visible in the blue end of the spectrum because of the high reddening (Galactic extinction : E(B-V)=0.56). It seems that there is in addition a local extinction with E(B-V)=0.26 deduced from the H_α/H_β ratio. We have carefully searched for the HeIIλ4686 emission line present in some other ULXs and revealing X-ray ionization, but the spectrum is not sufficiently sensitive in this wavelength domain. We derive an upper limit for an emission line flux ratio [HeII]λ4686/H_β of about 0.1.

Element	λ(Å)	I(λ)/I(H_β)
H_β	4861	1.0 ± 0.1
[OIII]	4959	0.3 ± 0.08
	5007	0.7 ± 0.09
[NI]	5198+5200	0.3 ± 0.08
[HeI]	5876	0.1 ± 0.05
[OI]	6300	0.8 ± 0.1
	6363	0.3 ± 0.08
[NII]	6548	0.7 ± 0.15
	6583	2.4 ± 0.25
H_α	6563	2.9 ± 0.3
[SII]	6717	1.8 ± 0.25
	6731	1.3 ± 0.2
[ArIII]	7136	0.05 ± 0.03
[OII]	7320+7330	0.10 ± 0.07

Table 1. Emission line flux ratios of the nebula surrounding IC 342 X-1, corrected for reddening. c(H_β)=1.13 corresponding to E(B-V)=0.82

3. CONCLUSION AND PERSPECTIVES

IC 342 X-1 is one of the most studied ULX, and it starts to reveal some of its secrets. We conclude that the nebula is mainly shock-ionized, with no or little X-ray ionization. Like other ULX bubbles, the Tooth is probably either a supernova remnant that reflects tfhe formation of the compact star in the ULX or it is inflated by relativistic wind/jets as in the system W50/S433.
We have found in the Chandra error circle two possible optical counterparts. Their absolute visual magnitude is consistent with the X-ray heated accretion disk counterparts of ULXs Holmberg IX X-1 and NGC 1313 X-2. Much fainter candidates, including the possible presence of a poor cluster as observed in these archetypal ULXs, cannot presently be excluded for IC 342 X-1. Future optical observations will be crucial to reveal nature and evolutionary state of the exciting class of ultraluminous X-ray emitters.

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