XMM-Newton study of the interacting galaxies NGC 1512 and NGC 1510

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Abstract

We present an analysis of an *XMM-Newton* observation of the interacting galaxies NGC 1512 and NGC 1510 with the aim of gaining information on the population of X-ray sources diffuse emission. Spectral analysis, hardness ratios, X-ray variability, and cross-correlations with catalogues in other wavelengths, allowed us to identify and classify the observed sources as X-ray binaries in the NGC 1512/1510 system, background objects and foreground stars. We detected 106 sources in the energy range $0.2-12$ keV, 15 within the D_{25} ellipses of NGC 1512 and NGC 1510. The properties of the most interesting sources are discussed.

Properties of NGC 1512/1510

- NGC 1512 (distance: 9.5 Mpc) interacts with the smaller galaxy NGC 1510 and shows a peculiar morphology: two extended arms immersed in an HI disc whose size is about four times larger than the optical diameter of NGC 1512.
- NGC 1510 is a blue compact dwarf galaxy separated by ∼14 kpc from NGC 1512. The blue colour and emission line spectrum are probably caused by the star formation activity produced by the interaction with NGC 1512 (Hawarden et al. 1979).
- the star formation activity in the outskirts of the disc as well as the distortion in the HI arms are the consequence of the interaction between the two galaxies that started ∼400 Myr ago (Koribalski & Lopez-Sanchez 2009).
- Using different methods at different wavelengths (from radio to UV), Koribalski & Lopez-Sanchez (2009) derived an average SFR of 0.22 $M_\odot$ yr^{-1} for NGC 1512 and $SFR = 0.07$ $M_\odot$ yr^{-1} for NGC 1510.
- There has been no detection of sources at the position of NGC 1512/1510 with X-ray telescopes to date. Therefore, the work described here represents the first report of significant X-ray emission in NGC1512/1510.

Observations and data reduction

- The galaxy pair NGC 1512/1510 has been observed with *XMM-Newton* in 2012 in a 63 ks exposure observation.
- The data analysis was performed through the *XMM-Newton* Science Analysis System software (version 12.0.1).
- After rejecting time intervals affected by high background, the net good exposure time was reduced to 26.0 ks for PN, 39.8 ks for Metal Oxide Semi-conductor 1 (MOS1), and 34.8 ks for MOS2.
- For each instrument, data were divided into five energy bands: B_1: 0.2–0.5 keV; B_2: 0.5–1 keV; B_3: 1–2 keV; B_4: 2–4.5 keV; B_5: 4.5–12 keV.
- We ran the source detection (SAS task `edetect_chain`) on the images corresponding to the five energy bands and three instruments (total of 15 images) simultaneously.
- To search for extended X-ray emission in the NGC 1512/1510 system we used the *XMM-Newton* Extended Source Analysis Software (XMM-ESAS), packaged in SAS 12.0.1.
- The system NGC 1512/1510 has been observed in radio (20-cm) with ATCA (see Koribalski & Lopez-Sanchez 2009). We used the 20-cm radio continuum maps with 8 and 15 arcsec resolution to find possible radio counterparts of the X-ray sources we detected with *XMM-Newton*.

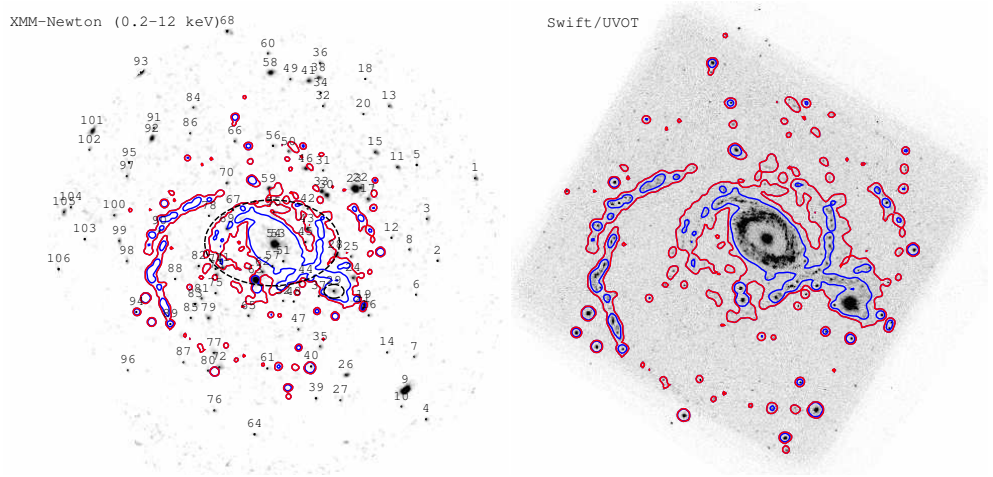

Figure 1: *Left panel:* combined PN, MOS1, MOS2 three-colour mosaic image of the NGC 1512/1510 field of view ($0.2-12$ keV). *Right panel:* Swift/UVOT image (uvm2 filter). The contour levels of UV emission, obtained from the Swift/UVOT image, show the regions of higher UV emission: 0.5σ (red line) and 1σ (blue line) above the background. Black-dashed lines are the D_{25} ellipses for NGC 1512 and NGC 1510.

Analysis

- We fitted the *XMM-Newton* spectra of eight sources. With the exception of source No. 9 (it is a foreground star), their spectra can be fitted with an absorbed power-law or an absorbed disc-blackbody model, with photon indices and $kT_{\rm in}$ compatible with either XRBs or AGNs.
- Hardness ratios can provide information about the X-ray properties of faint sources, for which the spectral fitting is not possible. We calculated the hardness ratios ($HR_i = \frac{B_{i+1}-B_i}{B_{i+1}+B_i}$ for $i = 1, ..., 4$) with the Bayesian method described in Park et al. (2006). The hardness ratios calculated using the Bayesian method are much more accurate than those calculated using the classical methods, especially for very faint sources.
- We compared the list of X-ray sources detected in the *XMM-Newton* observation with sources observed in other wavelengths (optical, infrared, radio) to find the counterparts.

Results: Point sources

- We detected 106 sources in the energy range 0.2−12 keV, out of which 15 are located within the D_{25} regions of NGC 1512 and NGC 1510 and at least six sources coincide with the extended arms.
- We identified counterparts for 37 sources. We found nine radio counterparts using ATCA data. We identified and classified six background objects and six foreground stars.
- XMMU J040400.9-432319 (No. 63 in Fig. 1), within the D_{25} ellipse of NGC 1512, shows properties of a quasi-stellar object (Atlee & Gould et al. 2007). We used the first deep X-ray observation of this region of the sky to investigate other possible classifications. We found that its properties are also consistent with an accreting black-hole in the galactic disc of NGC 1512, with an X-ray luminosity lying just below the conventional luminosity threshold of $\sim 10^{39}$ erg s^{-1} of ULXs.
- Nuclear source of NGC 1512 (XMMU J040354.2-432056): from the X-ray spectral analysis we found an acceptable fit ($\chi^2 = 0.90$, 65 d.o.f.) with an absorbed power-law plus thermal component. It describes the expected X-ray emission from the unresolved nuclear region of a galaxy, where a fraction of the X-ray emission is produced by point sources and the remaining emission comes from interstellar gas.
- The number of high-mass X-ray binaries detected within the D_{25} region of NGC 1512 is consistent with the star formation rate obtained in previous works based on radio, infrared, optical, and UV wavelengths.

Results: Diffuse emission

- We detected diffuse X-ray emission from the interior region of NGC 1512 with a plasma temperature of $kT = 0.68$ $(0.31-0.87)$ keV and a 0.3–10 keV X-ray luminosity of 1.3×10^{38} erg s^{-1}, after correcting for unresolved discrete sources.
- While the X-ray emission is most likely due to present and/or past stellar winds and supernovae, the derived electron densities and radiative cooling times seem to low and high, respectively, compared with those of other spiral galaxies (see Ducci et al. 2014).

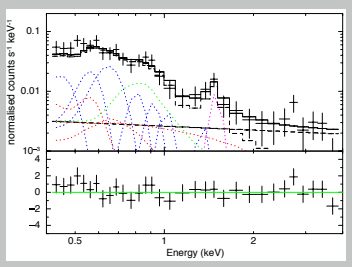

Figure 2: Fit to the EPIC-PN spectrum of the central diffuse emission in NGC 1512. Additive model components are indicated with astrophysical background in red, fluorescence line in magenta, SWCX lines in blue, and source emission in green. The black dashed line that follows the data more closely represents the combined additive model, while the straight dashed black line represents the residual SP contamination. The addition of these two provides the total model indicated by the solid black line.

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