X-ray Point Source Population of the Region Southeast of 30 Doradus in the LMC

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Abstract

We present the initial results of an X-ray point source population survey of a ~7 deg^2 region southeast of 30 Doradus in the Large Magellanic Cloud (LMC) using archival *XMM-Newton* data. We have retrieved and reduced relevant data from the XSA to characterize the X-ray emission from each of the detected point sources. We will determine candidate counterparts to the X-ray sources using primarily optical, UV and IR catalogues. In addition we will assess and remove the contribution of contaminating extragalactic Active Galactic Nuclei (AGN) to the detected population, as well as likely foreground Galactic sources, to obtain a purely LMC sample. Our ultimate goal is to construct an X-ray Luminosity Function for the X-ray binaries (XRBs) in this region of the LMC to compare to the results of a galaxy scale XRB population simulation code. which, along with the known stellar population from optical studies, will allow us to determine the likely evolutionary history of this region of the LMC and compare it to other regions of this galaxy.

Introduction

The Large Magellanic Cloud (LMC) is a vitally important laboratory for astrophysical research. Due to its location in the sky, its small relatively small distance (48 kpc, Macri et al. 2006), small inclination and low obscuration, the stellar content of the entire LMC can be resolved in multiple wavelength regimes.

These multiwavelength data can be used to investigate the physical properties of the detected X-ray sources allowing classification of the X-ray emitting source population. Thus, the global properties of the source classes can be investigated in the galaxy as a whole. Such an analysis of a nearby and complete population is important for the understanding of the unresolved X-ray emission of more distant galaxies as well as the understanding of the population of the Milky Way.

Past studies of the LMC X-ray population have been performed with several X-ray observatories including *Einstein* (Long et al. 1981, Wang et al. 1991), *Exosat* (Jones et al. 1985, Pakull et al. 1985, Pietsch et al. 1989) and *ROSAT* (Haberl & Pietsch 1999, Sasaki et al. 2000), which have incrementally increased the total number of X-ray sources in the direction of the LMC to ~1000 by the end of the *ROSAT* era. Due to the small FOV of both the *Chandra* and *XMM-Newton* observatories in relation to the LMC, a survey of the entire galaxy has yet to be performed with either of these instruments. Because of this, *Chandra* and *XMM-Newton* X-ray population studies focus on sub-regions of the LMC (see Shtykovskiy & Gilfanov 2005, for example).

We present the initial results of the analysis of the region southeast of and including 30 Doradus which has been relatively well observed with *XMM-Newton*. This region hosts the most active star forming region in the local group (30 Doradus), several known X-ray binaries, pulsars, supernova remnants, stellar clusters, superbubbles and a supergiant shell making it one of the most interesting regions in the LMC.

Data Reduction & Analysis

The observational datasets retrieved from the XSA and are listed in Table 1 with the FOVs of the *XMM-Newton* observations plotted over the MCELS[1] LMC image in Figure 1.

Table 1: XMM-Newton Observation Datasets

Obs. ID	Exp. time (ks)	Obs. ID	Exp. time (ks)
0112900101	7	0023940401	40
0104660301	27	0144530101	133
0083250101	41	0201030201	12
0113000401	48	0201030101	12
0094410101	12	0201030301	12
0094410201	12	0402000201	25
0094410701	12	0406840301	111
0113020201	38	0506220101	119
0094410401	12	0556350101	102
0094411101	13	0601200101	92
0094411401	12		

We reduced each of the datasets using SAS 10.0.0, filtering for periods of high particle background. We created OoT and exposure corrected images in the 0.3-1 keV, 1-2 keV and 2-8 keV to produce the false colour X-ray image of the region, shown in Figure 2.

Source detection was performed using the SAS task `emosaicproc` to achieve the maximum possible detection sensitivity in the overlapping regions of the exposures. False detections due to stray light and sources due to obvious diffuse emission structures were removed after visual screening.

In the preliminary analysis presented here we only consider the source statistics from the PN camera. Merging of MOS and PN source data for each observation, spectral analysis and variability analysis between observations will be performed in due course.

As a precursor to the more rigorous multiwavelength source identification to be performed, we cross-correlated our X-ray catalogue with the SIMBAD[2] astronomical database.

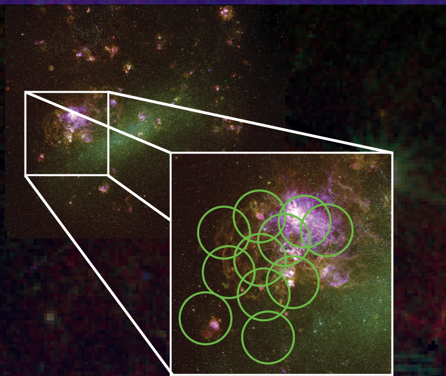

Figure 1: MCELS[1] colour image of the LMC with red corresponding to Hα, green to SII and blue to OIII. Also shown are the *XMM-Newton* observation FOVs plotted on the MCELS close-up image of the 30 Dor region.

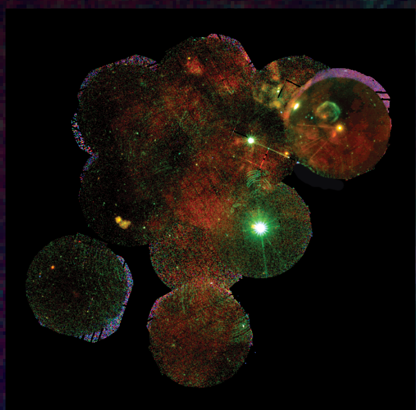

Figure 2: Combined false colour image of the *XMM-Newton* observations. Red corresponds to the 0.3-1 keV energy range, green to 1-2 keV and blue to 2-8 keV.

PN count rates were calculated for each of the detected sources taking into account the variation in exposure across the FOVs. Hardness Ratios (HRs) were also calculated, defined as:

$$HR1 = \frac{M - S}{M + S} \qquad HR2 = \frac{H - M}{H + M}$$

with S, M and H corresponding to the count rates in the 0.3-1 keV, 1-2 keV and 2-8 keV energy bands, respectively.

We separated the detected sources based on their SIMBAD counterparts to create one HR diagram for sources with multiwavelength counterparts and another for sources with either no counterparts or only previous X-ray counterparts (see Figure 3). To indicate the location of detected source spectral characteristics in HR parameter space we have generated absorbed power law and absorbed thermal plasma (APEC) HR grids using the PIMMS[3] tool, which are also included in Figure 3. We note that these two examples are insufficient to describe the spectra of all of our detected sources (with some requiring more advanced models), so the grids should only be considered as a guide. To reduce clutter in each plot we only include the sources with HR1 and HR2 errors < 0.25.

Post supernova objects are distributed as expected in the HR diagram. Both SNRs are located in the 'soft' region of the diagram, with the PWNe location indicated moderately hard spectra and the HMXB location indicating a hard spectrum.

Stellar counterparts are located throughout the diagram. However, we note that it is unclear as to whether these counterparts are truly the source of the X-ray emission (and not some unknown background sources) given the lack of information on spectral types, etc., in the SIMBAD database. Only after a more detailed analysis can we verify these as counterparts.

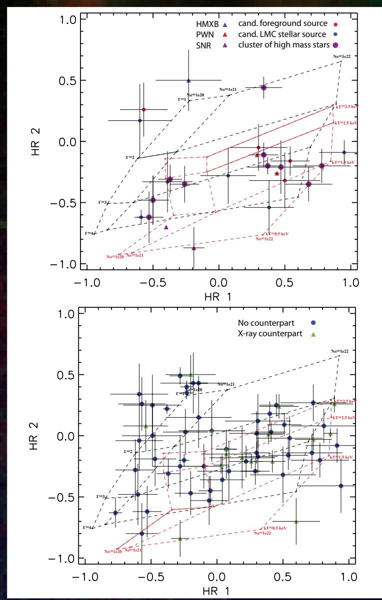

Figure 3: *XMM-Newton* PN HR plots. Top - sources with multiwavelength SIMBAD counterparts. Bottom - sources with either no counterparts or previously identified X-ray sources of unknown type. Object classes are indicated in each of the plots with HMXB = High Mass X-ray Binary, SNR = Supernova Remnant, PWN = Pulsar Wind Nebula. The black and red grids represent absorbed power law and absorbed thermal plasma models of varying spectral parameters (indicated in the plots), respectively.

The clusters of high mass stars are located in two groups, with one group suffering from higher foreground absorption (HR1 > 0). This is because of the presence of Wolf Rayet (WR) stars in these clusters, whose dominant X-ray emission (likely due to colliding wind binaries in these cases given their moderate spectral hardness) suffer from increased absorption due to their dense stellar winds.

The majority of the brightest sources in the PN data are of an unknown nature. Given the location of many of the unknown sources on the absorbed power law grid ($1.5 < \Gamma < 2.5$, Ishibashi & Courvoisier 2010, and references therein) it is likely that some are background AGN. However, many are also located in similar regions as those sources with multiwavelength counterparts. Only after a more complete source identification analysis can we begin to discern the source classes for this sample.

Summary

We have presented here the initial stages of an X-ray point source population study of the region southeast of and including 30 Doradus in the LMC using archival *XMM-Newton* data. We have detected several hundred sources in the region, many of which are bright enough to allow detailed spectral and temporal analysis to be performed. Preliminary source identification was carried out by cross-correlation with the SIMBAD database, identifying many sources including SNRs, PWNe and HMXBs.

Thus far we have only considered the source statistics from the PN data. As the analysis progresses, merging of MOS and PN source data for each observation, photometric, spectral and temporal analysis for each source will be performed, as well as much more rigorous source identification using multiwavelength catalogues.

References

Haberl & Pietsch 1999, A&AS,139,277

Ishibashi & Courvoisier 2010, A&A, 512,58

Long et al. 1981, ApJ,248,925

Macri et al. 2006 ApJ,652,133

Pakull et al. 1985,SSRv, 40,379

Sasaki et al. 2000, A&AS,143,391

Shtykovskiy & Gilfanov 2005, A&A, 431, 597

Wang et al. 1991, ApJ,374,475

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2 - This research has made use of the SIMBAD data base operated at CDS, Strasbourg, France.

3 - Found at http://heasarc.nasa.gov/docs/software/tools/pimms.html

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