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An XMM-Newton view of the luminous X-ray source population of M101

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Abstract.
We present the first results of an *XMM-Newton* EPIC observation of the luminous X-ray source population in the face-on supergiant spiral galaxy M101. We have studied the X-ray spectral and temporal properties of the most luminous sources in M101 at the time of the *XMM-Newton* observation, and our results suggest that they are all accreting systems associated with M101. The majority of sources show short and/or long-term variability, while their spectral shapes are consistent with X-ray binaries (XRBs) in the high/soft state. We have compared the spectral shapes of nine sources covered by both this observation and an archival 100 ks *Chandra* observation of M101, and the majority show behaviour typical of Galactic XRBs.

Key words. galaxies: spiral – X-rays: galaxies – X-rays: binaries

1. Introduction

M101 (NGC 5457) is a nearby (D=7.2 Mpc) grand-design supergiant spiral galaxy. Its face-on aspect and low line-of-sight Galactic hydrogen column density provide an ideal opportunity to study the discrete X-ray source population in a galaxy similar to the Milky Way, away from the obscuration instrinsic to our Galactic plane. The brightest discrete sources detected in local galaxies are the ultraluminous X-ray sources (ULXs), possessing X-ray luminosities $> 10^{39}$ erg s^{-1} (e.g. Roberts & Warwick 2000). If powered by accretion onto compact objects, ULXs must either be accreting at a super-Eddington rate, have anisotropic (beamed) emission (King et al. 2001), or constitute examples of the new class of "intermediate mass" ($10^2 - 10^5 M_{\odot}$) black holes (IMBHs, e.g. Colbert & Mushotzky 1999; Kaaret et al. 2001). Prior to *XMM-Newton*, X-ray studies of such sources were unable to provide sufficient detail with which to investigate their nature. Here we present the first results of an *XMM-Newton* EPIC X-ray observation of M101, with which we have been able to study the X-ray spectral and temporal properties of the fourteen most luminous sources in the galaxy at the time of the observation, a subset of which are in the ULX regime.

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2. Results

The locations of the fourteen sources are shown in Fig. 1. One source is coincident with the optical nucleus, while the majority of the others are firmly associated with spiral arm

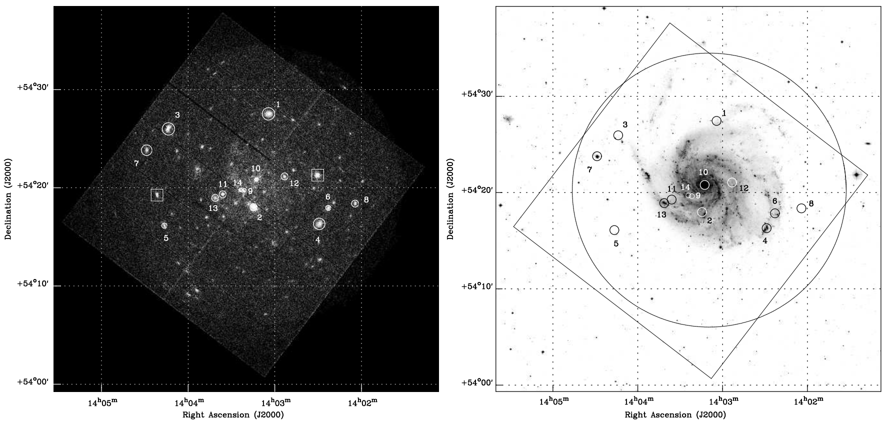

Fig. 1. [Left] *XMM* image of the M101 field (stacked MOS & PN). The 14 luminous X-ray sources are marked with circles, and 2 bright foreground stars are marked with squares. [Right] *XMM* source positions overlaid on a DSS2 optical image.

structure/HII regions, suggesting a link with young stellar populations. Eleven sources show evidence of short-term variability during the *XMM* observation. In addition, archival data from *ROSAT* and *Einstein* show that most vary by a factor of ~2–4 over a baseline of 11–24 years, providing strong evidence that these sources are accreting X-ray binaries (XRBs). The X-ray spectra of nine sources are well-fit with either simple absorbed disc blackbody or powerlaw models. However for three of the four sources best-fit with powerlaw models, we cannot exclude the disc blackbody fits and therefore conclude that, coupled with their high luminosities, eight out of nine single-component sources are possibly high/soft state XRBs. The nuclear source has the only unambiguous powerlaw spectrum ($\Gamma \sim 2.3$), which may be evidence for the presence of a low-luminosity AGN. The remaining five sources require at least two-component spectral fits, with an underlying hard component that can be modelled by either a powerlaw continuum or, in three cases, a hot disc blackbody (T_{in}=0.9–1.5 keV), plus a soft component modelled as a cool blackbody/disc blackbody/thermal plasma. Our results demonstrate that while these sources show a variety of spectral shapes, there is no apparent spectral distinction between those above and below the ULX luminosity threshold.

We have compared the spectral shapes of nine sources covered by both this observation and an archival 100 ks *Chandra* observation of M101 conducted ~2 years previously. Eight show behaviour typical of Galactic XRBs (i.e. softening with increasing luminosity), the only exception being a transient source which shows little change in spectral hardness despite a factor of ~30 increase in luminosity. We find no definitive observational signatures to indicate that these sources contain neutron star primaries. We therefore conclude that they are likely to be stellar-mass black hole XRBs, with black hole masses of ~2–23$M_\odot$ if accreting at the Eddington limit, leaving no requirement to invoke accretion onto an IMBH.

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