The Seyfert-LINER Galaxy NGC 7213: An *XMM-Newton* Observation

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Abstract. We examine the *XMM* X-ray spectrum of the LINER-AGN NGC 7213, which is best fit with a power law, Kα emission lines from Fe I, Fe XXV and Fe XXVI and a soft X-ray collisionally ionised thermal plasma with $kT = 0.18^{+0.03}_{-0.01}$ keV. We find a luminosity of $7 \times 10^{-4} L_{\text{Edd}}$, and a lack of soft X-ray excess emission, suggesting a truncated accretion disc. NGC 7213 has intermediate X-ray spectral properties, between those of the weak AGN found in the LINER M 81 and higher luminosity Seyfert galaxies. This supports the notion of a continuous sequence of X-ray properties from the Galactic Centre through LINER galaxies to Seyferts, likely determined by the amount of material available for accretion in the central regions.

Keywords: X-rays: galaxies - galaxies: active - galaxies: Seyfert - galaxies: individual: NGC 7213

1. Introduction

Low-ionisation nuclear emission-line region (LINER) galaxies are characterised by optical emission-line ratios which indicate a low level of ionisation (Heckman, 1980). The origin of these emission lines is still the subject of debate: the lines are attributed either to shock heating (Baldwin, Phillips and Terlevich, 1981) or to photoionisation by a central AGN (Ferland and Netzer, 1983; Halpern and Steiner, 1983). NGC 7213 is a nearby ($z=0.006$) S0 galaxy with AGN and LINER characteristics. It is clear that there is an AGN in this source, classified as a Seyfert 1 (Phillips, 1979). Optical emission lines are observed from this galaxy with velocities ranging from 200 to 2000 km s$^{-1}$ FWHM (Filippenko and Halpern 1984, hereafter FH84). FH84 argue that this emission comes from photoionisation by the AGN of clouds spanning a range of densities and velocities.

Since its discovery as a low luminosity X-ray source (Marshall et al., 1978) NGC 7213 has been observed with several X-ray missions, showing a power law shaped spectrum with an Fe I Kα line. Excess...
emission has been detected at higher energies, best explained as weak narrow emission lines from highly ionised iron. The same data have no significant reflection hump, suggesting that the Fe I Kα line originates in Compton-thin material (Bianchi et al., 2003, hereafter B03, BeppoSAX PDS+XMM pn). The presence of a soft X-ray excess in NGC 7213 was also inferred by those observations and EXOSAT results (Turner and Pounds, 1989).

Here we present the full XMM observation of NGC 7213 including high resolution spectra from the RGS instruments. Identifying the physical mechanisms producing the X-ray emission may help to reveal the origin of the optical emission lines where at present neither shock heating nor photoionisation by the AGN can be ruled out. We also discuss the relationship between Seyfert galaxies and LINERs.

2. XMM observations and spectral fitting

NGC 7213 was observed on 2001 May 28/29 with XMM in the RGS GT Programme. The exposure times are 46448s for MOS1, 42201s for pn and 46716s for each RGS instrument. The source is piled-up in MOS2. The MOS1 and pn spectra were combined using the method of Page, Davis and Salvi (2003). The data were processed with XMM SAS versions 5.2 and 5.4, and analysed using XSPEC v11.2. The Galactic column used in all fits is $N_H = 2.04 \times 10^{20}$ cm$^{-2}$ (Dickey and Lockman, 1990), errors are 90% confidence for 1 interesting parameter and line energies are rest frame values.

RGS: The RGS spectrum of NGC 7213 is dominated by continuum emission, but emission lines are present, particularly from O VII and O VIII. No significant absorption lines or broad absorption features are observed. The features at 13.08Å and 16.43Å are low signal to noise data points coinciding with chip-gaps in the first order spectra. To model the RGS spectrum we began with a power law, which is rejected at >99.5% confidence. To improve the fit we added a MEKAL thermal plasma component, and obtain an acceptable fit with a best fit plasma temperature of $kT = 0.18^{+0.02}_{-0.01}$ keV and $\chi^2/\nu = 554/496$. Addition of a second thermal plasma component improves the fit only slightly. The O VII lines are reproduced well by the 0.18 keV thermal plasma component, but there appears to be some emission adjacent to O VIII Lyα in excess of the model prediction, perhaps indicating that the higher temperature component is broadened by Doppler motions. There is no significant blackbody-like soft-excess emission above the power law. The model and data are shown in Fig. 1.
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The ‘G’ ratio of the intercombination (x+y) and forbidden (z) line strengths to the resonance (w) line strength in the He-like triplet of O VII allows us to discriminate collisionally ionised and photoionised emission (Porquet and Dubau, 2003). We obtained the G ratio by fitting the 21-23Å region with a power law and 3 emission lines (Fig. 2). Collisionally ionised plasmas have $G \approx 1$, consistent with that observed in NGC 7213 while photoionisation dominated plasmas have $G \geq 4$, which is excluded at $>95\%$ confidence. A photoionised plasma that does not lie along the line of sight could have $G < 4$ if the resonance line is enhanced by photoexcitation (Coupé et al., 2004). But the 3d–2p lines of Fe XVII at $\sim 15\text{Å}$ should then also be enhanced relative to the 3s–2p lines at $\sim 17\text{Å}$, as is observed in NGC 1068 (Kinkhabwala et al., 2002). This is not the case in NGC 7213, and so we conclude that the emission lines in the RGS spectrum are predominantly from collisionally ionised gas.

EPIC: A power law is clearly a poor fit to the 2-10 keV EPIC data. The presence of reflection has been ruled out in B03, and these authors conclude that the excess emission is explained with three Fe emission lines. Combination of the EPIC pn and MOS1 data provides better statistics than pn alone. We fit a power law plus 3 Gaussian lines of fixed narrow width ($\sigma = 1\text{ eV}$) to the 2-10 keV combined pn-MOS1 spectrum. The best fit ($\chi^2/\nu=212/169$) has a power law photon index of $\Gamma = 1.73 \pm 0.01$, consistent with that found in the RGS soft X-ray data.
Figure 2. Upper panel: close up of the He-like O VII triplet with best fitting power law plus 3-Gaussian model. Wavelength in Å. Lower panel: confidence contours for the strengths of the forbidden and intercombination lines (x+y+z) and the resonance line (w). The solid, dashed and dotted contour lines correspond to 68, 90 and 95% respectively for two interesting parameters. $G=1$ is expected for a collisionally ionised plasma; a photoionised plasma should lie to the left of the $G=4$ line.

The centroid energies of the emission lines in the fit to the combined EPIC data are indeed consistent with iron fluorescence in low ionisation material, Fe XXV and Fe XXVI. We find equivalent widths of Fe I (which will include a small contribution from Fe II-XVII), XXV and XXVI Kα emission lines of $82^{+10}_{-13}$, $24^{+9}_{-11}$ and $24^{+10}_{-13}$ eV, respectively.

3. Discussion

NGC 7213 resembles a typical Seyfert galaxy, in that its 2-10 keV spectrum is dominated by a $\Gamma \sim 1.7$ power law and a 6.4 keV Fe Kα emission line. Significant emission from Fe XXV and Fe XXVI is also present, which are not normally observed in the classical luminous
Seyfert galaxies (e.g., NGC 5548, Pounds et al., 2003; NGC 7469, Blustin et al., 2003), but appear to dominate the Fe Kα emission in the nearby LINER M 81 (Page et al., 2004). The Fe XXV and Fe XXVI lines may be produced by photoionisation of Compton-thin material by the nuclear X-ray source (Bianchi et al., 2004), or may be collisionally ionised like the soft X-ray thermal plasma. The soft X-ray emitting gas in Seyfert galaxies is usually found to be photoionised (e.g., IRAS 13349+2438, Sako et al., 2001), but unlike typical Seyferts, the soft X-ray spectrum of NGC 7213 is more consistent with the emission from a collisionally ionised plasma.

Many Seyfert galaxies show compelling evidence for an accretion disc surrounding the black hole in their X-ray spectra. The main indicators are a soft excess, reflection, and broad Fe Kα line emission, all of which originate from the inner parts of the accretion disc. None of these indicators are present in the XMM spectra of NGC 7213. There is no evidence for an optical/UV bump and consequently the AGN bolometric luminosity does not appear to be dominated by emission from an optically-thick, geometrically-thin accretion disc. From combining our $L_{\text{bol}}$ estimate from the XMM+archival data SED with the mass estimate of $M_{\text{BH}}=10^{8.0} M_{\odot}$ (Nelson and Whittle, 1995), we find that the luminosity of NGC 7213 is low, at approximately $7 \times 10^{-4} L_{\text{Edd}}$. Therefore it is likely that if there is an accretion disc in NGC 7213, its inner edge is truncated at a larger radius than is typical in Seyfert galaxies. This could be via an ADAF-type flow (Narayan and Yi, 1995), or the disc may be in a ‘low state’ (Siemiginowska, Czerny and Kostyunin, 1996).

The lack of reflection (B03) implies the Fe I Kα line arises in Compton-thin material. Thus the central region of NGC 7213 appears to be deficient in the dense, cool material. That LINERs have gas-poor central regions relative to Seyferts has also been proposed by Ho, Filippenko and Sargent (2003) on the basis of their optical emission line properties. It appears then that the low luminosities and therefore accretion rates of LINER-AGN are a consequence of a shortage of material in their central regions. In this case LINERs are just fuel-starved AGN.

If we compare the XMM X-ray spectra of NGC 7213 and the nearest LINER galaxy, M 81 (Page et al., 2003, 2004), the broad-band X-ray spectra of these two galaxies look remarkably similar. Whilst the continua are comparable we find substantial differences in the emission line parameters. The X-ray spectrum of NGC 7213 is much more Seyfert-like than that of M 81, owing to the stronger Fe I Kα line and weaker soft X-ray lines. Therefore NGC 7213 appears to bridge the gap between ‘normal’ Seyfert galaxies and LINER galaxies such as M 81.
It appears that there is likely a continuous distribution of galaxy nuclei between the LINERs and 'normal' Seyfert nuclei, over which the X-ray spectral features characteristic of Seyferts such as the neutral Fe Kα line, become successively more prominent, while characteristic LINER features such as soft X-ray emission lines diminish in significance. Accretion rate onto the black hole with respect to the Eddington rate is likely to be the overriding factor, with LINER galaxies accreting at much lower rates than Seyfert galaxies (Ho et al., 2003) and containing truncated discs. In fact, if we look at the observational properties of the Galactic Centre we see that it may also fit into this continuous distribution since it contains a low-mass black hole with an extremely low accretion rate: the emission from this region comes predominantly from thermal plasmas with strong soft X-ray emission (Baganoff et al., 2003), and the strongest Fe Kα emission is observed at 6.7 keV (Tanaka et al., 2000).

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