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X-ray Archaeology of Galaxy Groups

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Abstract

We have assembled a sample of 60 galaxy groups in order to study the hot intragroup medium and better understand the processes by which it formed. We have analysed ROSAT data for all 60 groups and have obtained XMM data for a small subset. Here we present an initial analysis of the XMM data for NGC 5171, and a comparison with the ROSAT data. This provides some indication of the reliability of the GEMS ROSAT data as well as demonstrating the additional power of XMM.

We find that NGC 5171 consists of two sub-groups with a bright ridge of emission between the centre of the larger component and a bright optical galaxy. Spectral mapping reveals the gas in this ridge to be hot and bright which may be the result of shock heating following a group merger.

A comparison between results from the two instruments reveals the X-ray temperature and large scale morphology are both reliably determined using ROSAT. However, the low spectral resolution leads to a poorly determined metallicity and the low spatial resolution leads to a poor understanding of the point source contamination, and a corresponding inaccuracy in the group luminosity.

1.1 Introduction

Galaxies are most often found in gravitationally bound groups (Tully 1987) which in many cases exhibit hot, X-ray emitting gas at the centre of the potential well (Price et. al. 1991). The intergalactic medium retains material ejected from the member galaxies and can tell us much about the evolution of these galaxies as well as the group itself. To explore this in detail, we have assembled a sample of 60 groups with $z < 0.03$ which have a pointed ROSAT observation of $t > 10000$ s. ROSAT PSPC data were analysed and the results correlated to reveal trends within the X-ray parameters (Osmond & Ponman 2004). The results of this analysis will be combined with optical and radio studies as well as the results of hydrodynamical simulations (e.g. Miles et. al. 2004, Pearce et. al. 2004).

In addition to the ROSAT data, XMM and Chandra observations will eventually be available for most of the groups in the GEMS sample. Here we present an initial analysis of the XMM data for NGC 5171, and compare the results with those derived from a ROSAT observation of the same group. In this way we hope to demonstrate the accuracy of the GEMS ROSAT data as well as the additional precision of XMM.

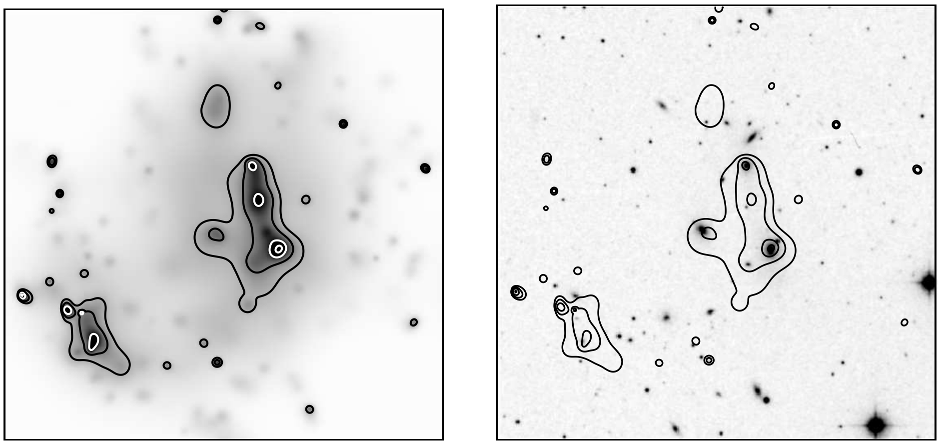

Fig. 1.1. The image on the left shows an adaptively smoothed XMM mosaic with logarithmically spaced contours. The image on the right shows the same contours overlaid on an optical DSS image.

NGC 5171 is a group of 12 optical galaxies comprising 5 lenticulars and 7 of unknown type. It is situated at a redshift of 0.023 (107 Mpc), with a total optical luminosity of 1.90 $\times 10^{11}$ $L_{\odot}$, a velocity dispersion of 494 km s^{-1} and an optical radius (r_{500}) of 0.58 Mpc. The X-ray emission observed with ROSAT is of an unusual morphology, in that no bright, central galaxy resides at the centre of the emission.

1.2 Results

1.2.1 Spatial Analysis

Data taken with the EPIC-PN and both EPIC-MOS cameras have been combined to create an adaptively smoothed X-ray mosaic (Figure 1.1.) Individual images were particle subtracted, exposure corrected and background subtracted and contours added to denote logarithmically spaced surface brightness isophotes. Two distinct regions of X-ray emitting gas are visible, with a ridge of bright X-ray emission at the centre of the larger component.

Figure 1.1 also shows the same contours overlaid onto an optical DSS image. The smaller emission region to the east has only a dim optical counterpart, and the ridge of emission in the brighter region appears to join two galaxies, and may represent a wake left by the brightest galaxy as it moves through the intra-group medium.

1.2.2 Spectral Analysis

We have extracted a spectrum from EPIC-PN data within 0.08deg of the group position and fitted a multi-temperature cemekl plasma model (Figure 1.2). A background spectrum was estimated from data within an annulus between 0.08° and 0.12° of the group position and contaminating emission from point sources was removed to a radius of 0.003°. Point sources conincident with the bright ridge (Section 1.2.1) were believed to be erroneous and were reintroduced into the data. The model describes gas with temperatures ranging up to 1.93±0.32 keV and a metal abundance of 0.13±0.02 $Z_{\odot}$. The fit has a reduced χ^2=1.01

which is a significant improvement on the value of 1.11 obtained when fitting a single temperature model (T = 1.05 keV). This suggests that either there are spatially separated regions of different temperature gas or that the group contains multiphase gas.

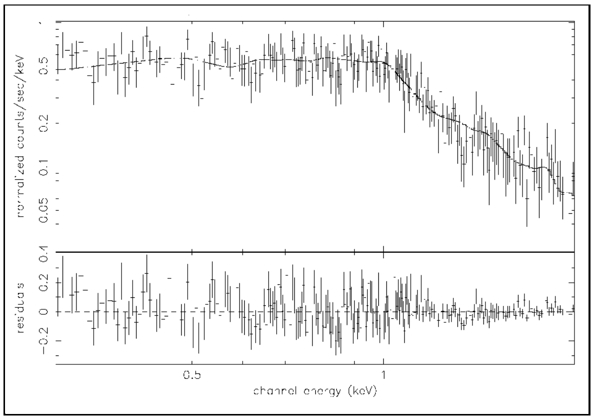

Fig. 1.2. An EPIC-PN spectrum fitted with a differential cemekl plasma model.

To investigate this further we have created spectral maps from data taken with the EPIC-PN camera (Figure 1.3). Adaptively sized bins containing $\geq$ 1000 counts are fitted with a single temperature mekal plasma model, and contours of X-ray surface brightness are overlaid. In the temperature map lighter shades represent higher temperatures and values range from $\sim$ 1.3 keV at the northern end of the bright ridge to $\sim$ 0.6 keV in the surrounding emission. In the map of metal abundance, lighter shades represent higher metallicities and values range from $\sim$ 0.35 $Z_{\odot}$ at the northern end of the bright ridge to $\sim$ 0.05 $Z_{\odot}$ in the surrounding emission. These maps show a hot, metallic feature consistent with a shock front or galaxy wake existing between the northern most galaxy in the ridge and the centre of the group emission. The position of this region is also coincident with a peak in the X-ray emission. Such a feature may be the result of a merger where the two bright galaxies represent the centres of two individual groups, and the bright, hot region is produced by a shock which forms at the interface between the two colliding systems.

1.2.3 ROSAT Comparison

We have attempted to investigate the quality of our ROSAT data as well as demonstrate the superior capabilities of XMM by performing a comparison between the two instruments. Figure 1.4 shows a DSS image overlaid with ROSAT PSPC X-ray contours and scaled such that it covers the same area as the XMM equivalent. Although the general morphology of the group is apparent, the PSPC instrument is too insensitive to detect either the subgrouping or bright ridge found within the XMM data.

Table 1.1 shows the results of fitting a single component mekal plasma model using both XMM and ROSAT. ROSAT data were analysed according to Osmond & Ponman (2004) but extracted to the same radius used in the XMM analysis. Whilst values of temperature agree well between instruments, both metal abundance and luminosity are inconsistent. The discrepancy in metal abundance is most likely a result of the poor spectral resolution of the

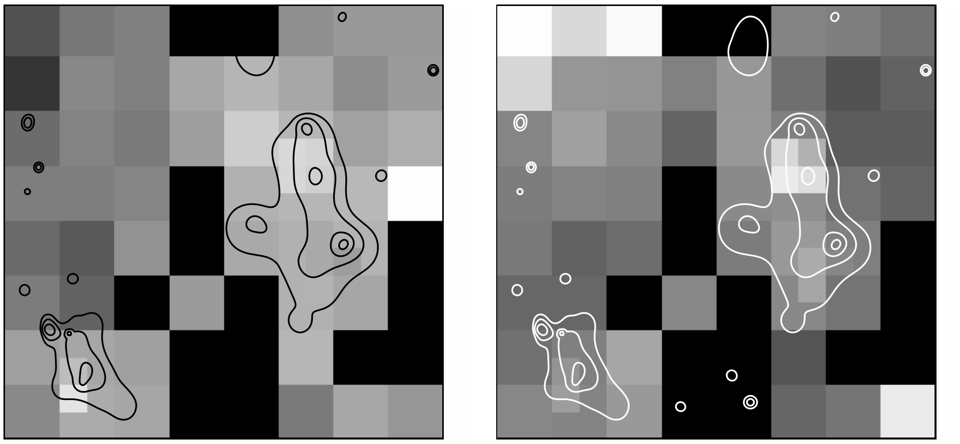

Fig. 1.3. The spectral maps. On the left is the temperature map where lighter shades represent higher temperatures. Values range from $\sim$ 1.3 keV at the northern end of the bright ridge to $\sim$ 0.6 keV in the surrounding emission. On the right is the metal abundance map where lighter shades represent higher metallicities. Values range from $\sim$ 0.35 $Z_{\odot}$ at the northern end of the bright ridge to $\sim$ 0.05 $Z_{\odot}$ in the surrounding emission. Black bins are unconstrained and contours represent X-ray surface brightness.

ROSAT-PSPC. The values of luminosity quoted here exclude point sources, and the greater sensitivity and spatial resolution of XMM has resulted in the removal of 38 sources compared to the 5 found using ROSAT. However Table 1.1 shows that the total area of point sources removed from the XMM data is $\sim \frac{1}{2}$ of that removed from ROSAT. Reincluding point sources gives total group luminosities which are essentially identical between instruments (final column of Table 1.1).

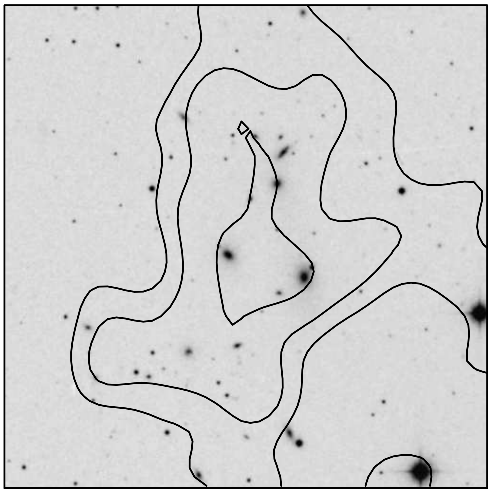

Fig. 1.4. ROSAT-PSPC contours, with point sources removed, overlaid on an optical DSS image.

Table 1.1. *Spectral properties of NGC 5171 using the EPIC-PN compared with those using ROSAT-PSPC. All data are extracted from within 0.08° of the group position.*

Ins.	T_X (keV)	Z ($Z_\odot$)	L_X (erg s^{-1})	N_{ps}	A_{ps} (*amin*^{2})	L_{tot} (erg s^{-1})
ROSAT	1.10±0.15	0.76±0.63	1.26×10^{42}	5	8.50	1.98×10^{42}
XMM	1.05±0.03	0.06±0.06	1.88×10^{42}	38	3.87	1.97×10^{42}

1.3 Conclusions

The unusual morphology of NGC 5171 found in previous ROSAT data has been confirmed using XMM. Furthermore we find significant substructure in the form of two subgroups, with a bright central ridge in the larger component which was not apparent in the ROSAT data. Spectral mapping reveals the presence of a hot, bright feature between the two brightest galaxies in the X-ray ridge. Such a feature may be the result of a merger shock, or possibly gas compression in a galaxy wake.

We have shown that the X-ray temperature and large scale morphology of the system inferred from ROSAT data agree well with higher quality XMM results. However the higher quality of the XMM data result in a much more constrained and reliable measure of metal abundance. Furthermore the lower spatial resolution of ROSAT results in a poor determination of both the number and size of contaminating point sources, and a corresponding inaccuracy in the value of diffuse X-ray luminosity.

References

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