Isolated Elliptical Galaxies

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Introduction

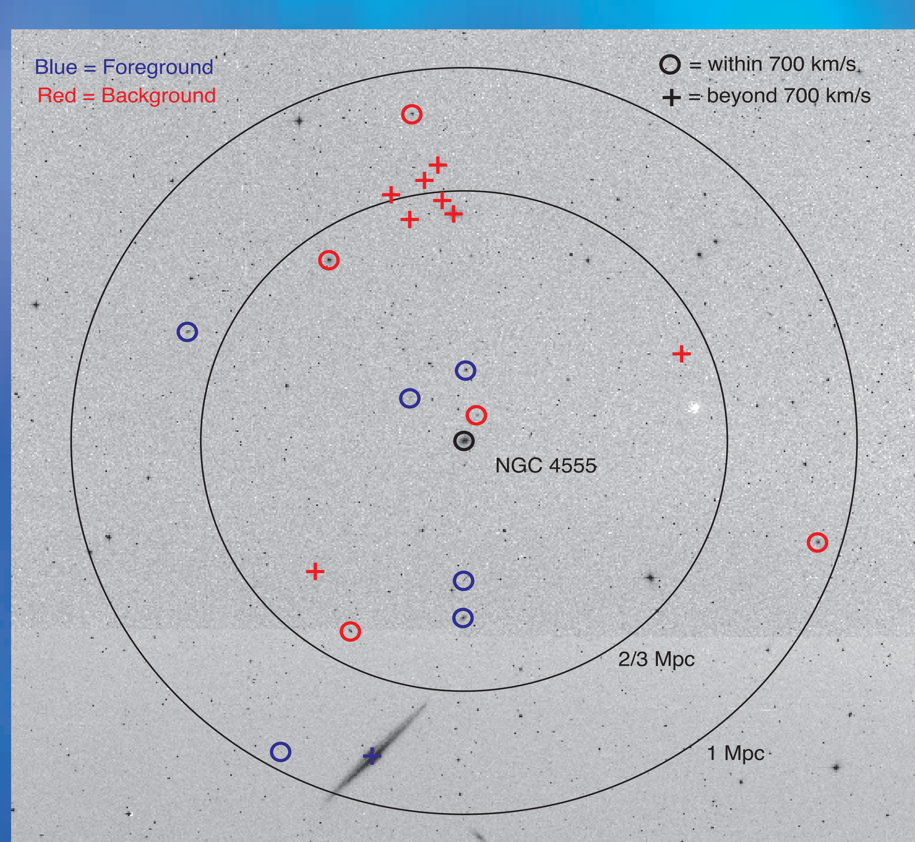
Almost all elliptical galaxies thus far observed in the X-ray reside in groups or clusters. There are two reasons for this bias:

1) Ellipticals are most common in dense environments (Tully 1987), and
2) Group and cluster dominant ellipticals are much more X-ray luminous than other ellipticals (Helsdon et al 2001).

However, the location of these galaxies in dense environments, surrounded by larger dark matter potentials, reservoirs of hot gas, and vulnerable to interactions with other galaxies, makes them a poor choice for the study of the intrinsic properties of ellipticals.

The importance of this issue has recently increased, owing to reports that some ellipticals may contain little or no dark matter (Romanowsky et al 2003, and speaking at this workshop). This raises the questions of whether ellipticals can form without dark matter or whether it is stripped in groups, whether they can build and retain gaseous haloes outside groups and clusters, and whether the scatter in the L_X:L_B relation is governed by the range of dark matter properties, by environmental influences, or perhaps by galaxy age or AGN activity cycle.

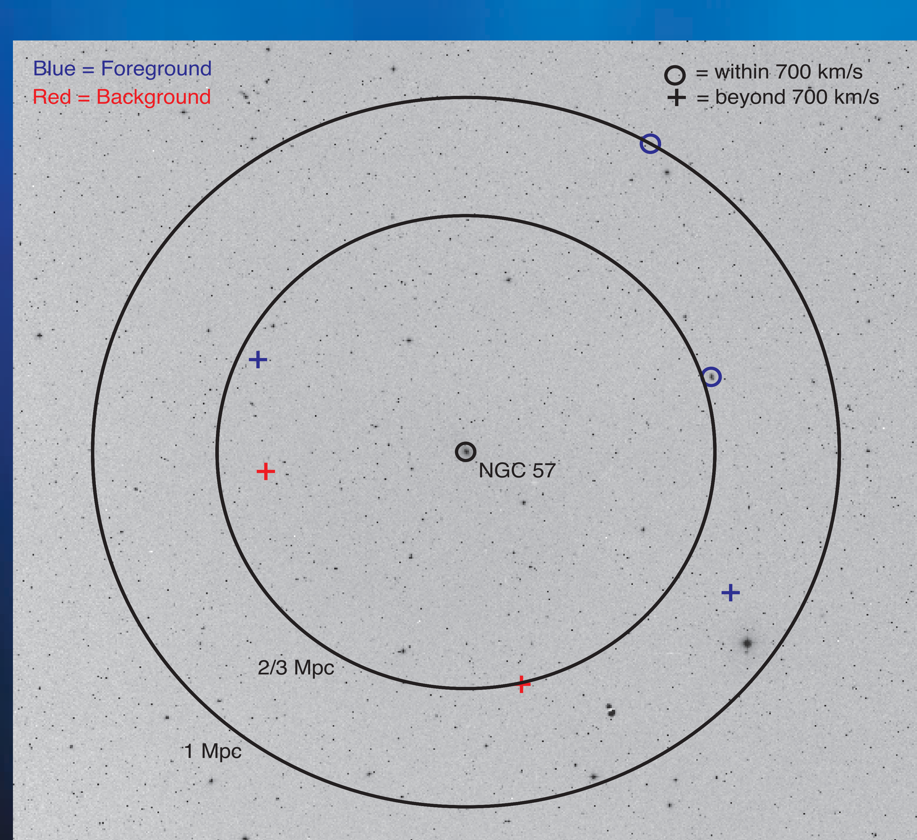
In order to investigate these questions, we have observed two highly isolated ellipticals: NGC 4555, observed with *Chandra*, and NGC 57, observed with *XMM-Newton*.

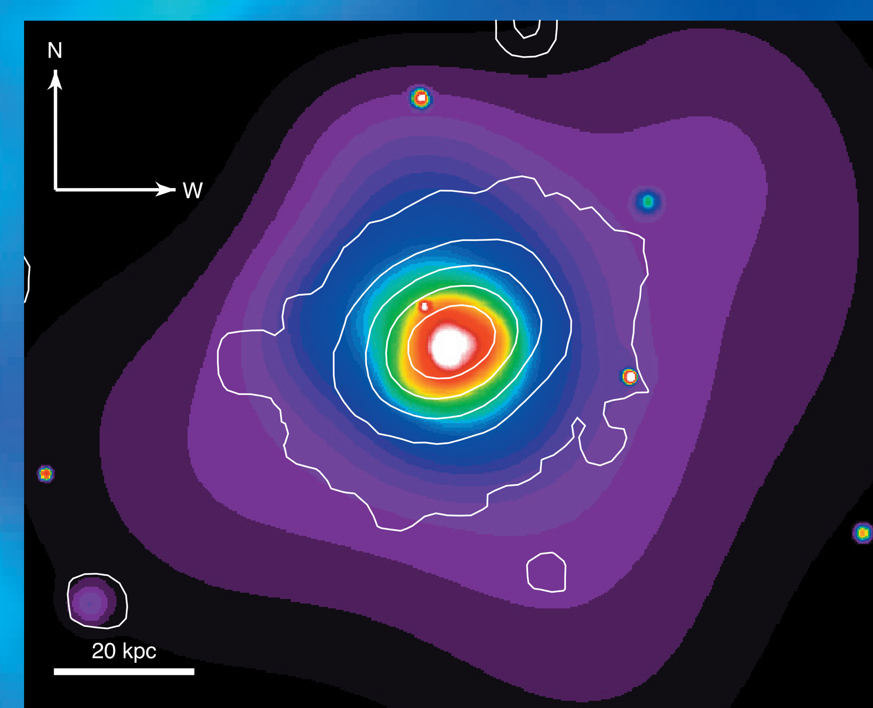


Isolation

Our galaxies are selected from the LEDA catalogue, to have no neighbours within 0.67 h_{75}^{-1} kpc, 700 km s^{-1} and 2 B-band magnitudes. This should ensure that any neighbouring galaxies are too small to significantly influence the development of the candidate isolated elliptical.

The plots above and below show the positions of all galaxies with measured redshifts within 1 Mpc of our two targets. NGC 57 is clearly extremely isolated. NGC 4555 does not appear to be part of a bound group, but may be in the process of falling into a structure centred on the galaxies to its north.



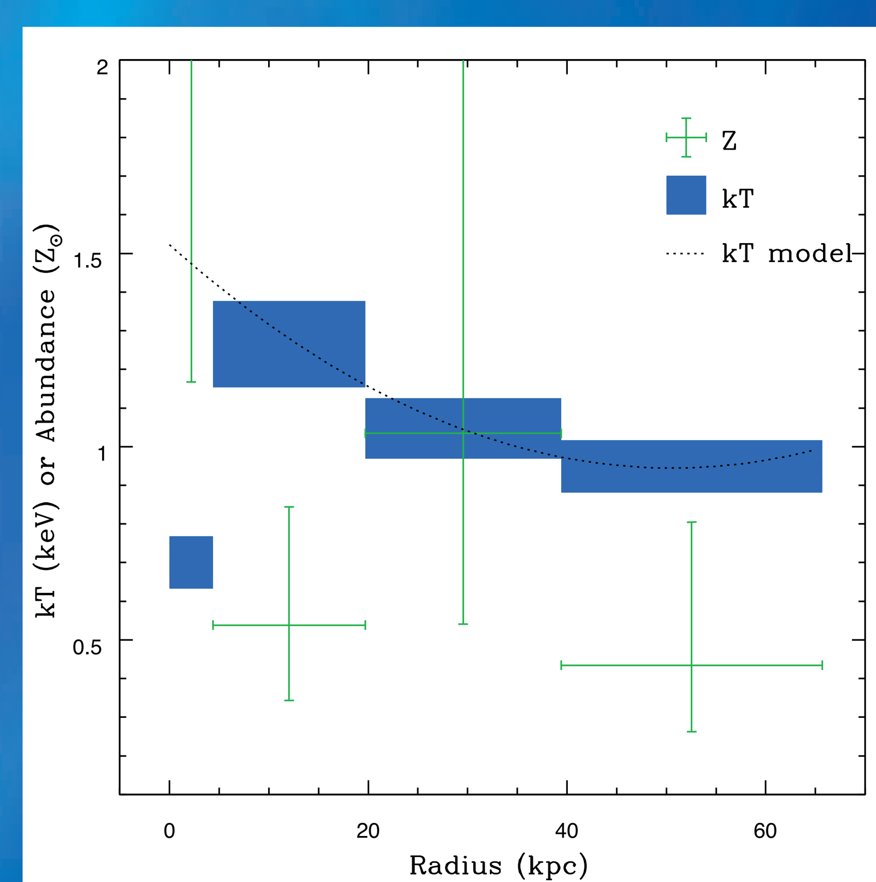


Adaptively smoothed image of NGC 4555 created using CSMOOTH with a signal to noise range of 3-5. Optical contours from the DSS are overlaid

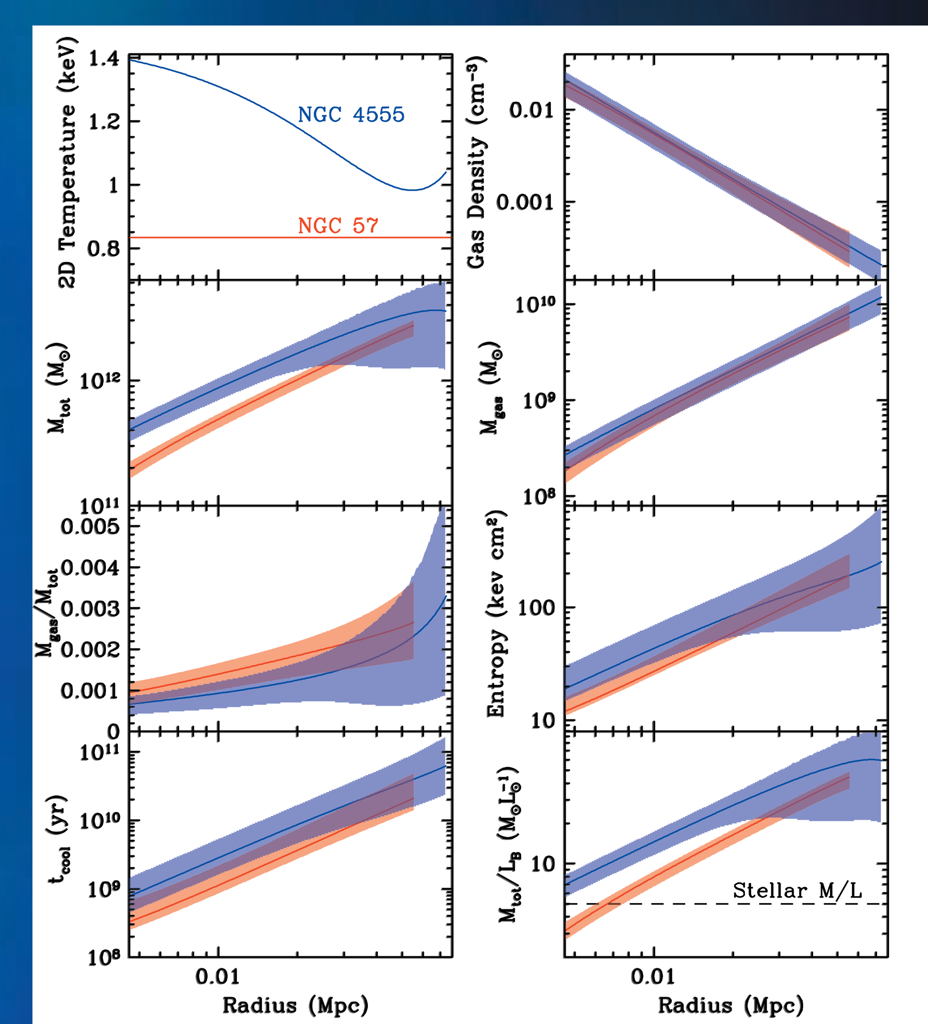
NGC 4555

NGC 4555 (D=90.3 Mpc, L_B=6x10^{10} $L_\odot$) was observed with the ACIS-S3 chip for ~30 ksec, yielding 23.3 ksec of useful data. We were able to fit a 2D surface brightness model and radial kT profile (shown below left), and used these to estimate the total mass and other properties of the system. The halo of NGC 4555 extends to ~60 kpc, and the galaxy clearly possesses a large dark matter halo. The total X-ray luminosity is ~5x10^{41} erg s^{-1}, too low for the galaxy to be a fossil group. See O'Sullivan & Ponman 2004 for more details.

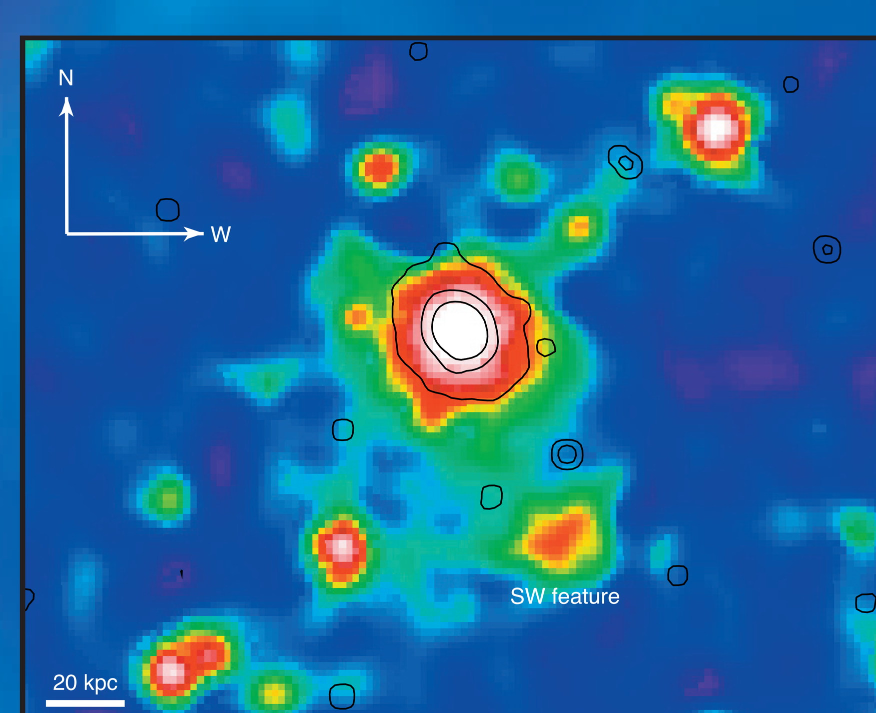
At present, the only other isolated elliptical to have been observed by *Chandra* is NGC 821, which is exceptionally faint and dominated by an AGN, making an analysis of its gas content difficult (Fabbiano et al 2004).



Best fit projected temperature and abundance for four radial bins in the halo of NGC 4555. 90% error regions are shown. The dotted line shows the temperature model used to estimate system mass, entropy, etc.



Projected Temperature and deprojected Gas Density, Gravitational and gas mass, gas fraction, entropy, cooling time and M/L ratio for our galaxies. Hatched regions show 1σ errors, and the dashed line the assumed stellar M/L ratio. Note that M/L falls below this line for NGC 57, indicating our assumption of isothermality may be faulty.



Adaptively smoothed *XMM-Newton* image of NGC 57, created by ASMOOTH with minimum SNR of 10. Optical contours from the DSS are overlaid.

NGC 57

NGC 57 (D=76.6 Mpc, L_B=6x10^{10} $L_\odot$) was observed by *XMM* for ~28 ksec, yielding ~21 ksec of useful data. Mosaicing all three cameras, we fit a 2D surface brightness model, but the large PSF and high background make a spectral profile difficult. We assume an isothermal halo in order to estimate mass, with kT=0.84±0.01 keV and Z=0.31±0.08 $Z_\odot$. Although a central point source dominates the emission, the halo is clearly extended, and there is evidence for a dark matter halo. The extended feature to the SW may be related to the galaxy or may be a background group.

Dark Matter

As shown above, both our isolated ellipticals show evidence of significant X-ray and dark matter (DM) halos. However, NGC 821 is known to be isolated and X-ray faint, and dynamical analysis suggests it has M/L=13-17 $M_\odot/L_\odot$ (Romanowsky et al). Our results suggest that ellipticals can form with significant DM halos outside galaxy groups, but whether DM content varies intrinsically or because of tidal stripping in denser environments is unclear.

Optical data

We have a sample of ~30 candidate isolated ellipticals, and have confirmed the status of ~50% of these using wide-field optical imaging (Reda et al 2004). Fine structure observed in these galaxies suggest they formed either through merger of near-equal mass progenitors or multiple dwarf galaxies. Formation as a fossil group or via merger of gas clouds is unlikely. We intend to complete the imaging and acquire spectra for the ellipticals and their neighbours so as to provide a complete picture of their environment, and perhaps confirm X-ray DM estimates through dynamical modeling.

XMM and *Chandra*

Although *XMM-Newton*'s larger effective area provides more counts, its higher and more complex background and larger PSF make *Chandra* the best choice for studying isolated ellipticals, which are relatively small and faint. Unfortunately this requires longer exposures, but it is worth considering that only *Chandra* can perform this study properly. If we wish to understand the processes by which elliptical galaxies form and evolve, observing isolated ellipticals is a necessary prerequisite.

References

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