# Prevelance & Effect of AGN in Clusters and Galaxies

R. J. H. Dunn[1], S. W. Allen[2], G. B. Taylor[3], G. Gentile[4], K. Shurkin[3], A. C. Fabian[5], C. Reynolds[6]

[1] Excellence Cluster "Universe", Munich; [2] SLAC-KIPAC Stanford; [3] UNM; [4] Ghent; [5] IoA, Cambridge, UK; [6] Maryland

## Introduction

With the advent of *Chandra* and *XMM-Newton* the dramatic effect of AGN on their host clusters and galaxies has become startlingly clear. The relativistic jets launched by the SMBH deposit large amounts of energy at great distances from the compact object. Although the clearest images show bubble like structures in the hot X-ray gas surrounding the central galaxy, the effect of this AGN heating is also observed in the lack of cool gas observed at the lowest X-ray temperatures (*e.g.* Peterson *et al.* 2003). As gas is being prevented from cooling onto the central galaxy, the injection of energy by the AGN has an impact on the growth and evolution of its host, restricting the stellar mass for the most massive galaxies (*e.g.* Croton *et al.* 2002). In order to investigate the AGN population in these structures we studied two well defined cluster samples and one galaxy sample.

## AGN in Clusters

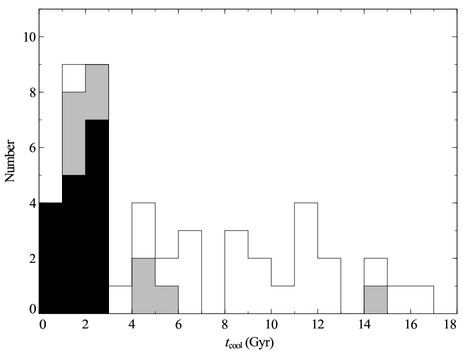


**Fig. 1**: The distribution of central cooling times of clusters in the Brightest 55 sample, using the *ROSAT* data of Peres *et al. 1998*. Clusters with clear bubbles are shown in black, and those with a central radio source (NVSS) in grey. The B55 sample is a well defined, flux limited sample, and most of its members had *Chandra* observations in the archive. We selected those clusters which had a short central cooling time (23/55), as well as those with a central temperature drop (21/55). Of the 20 which had both (and so require heating to prevent catastrophic cooling), 14 (70%) have clear X-ray cavities and only 1 has no central radio source.

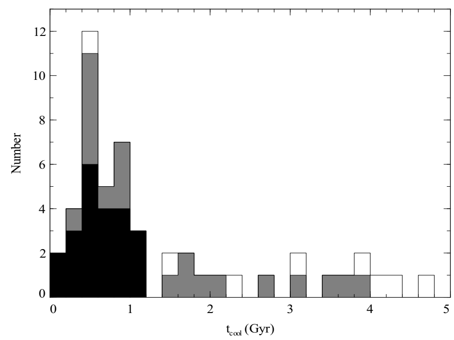


**Fig. 2**: To increase the sample size and the redshift range, we combined the B55 sample with the Brightest Cluster Sample (BCS) for $z > 0.1$. We performed the same selection proceedure, this time on the final combined sample of 71. No clusters with $t_{\rm cool} > 1.2\,{\rm Gyr}$ have clear X-ray bubbles. Only 5/47 (11 %) with $t_{\rm cool} < 4\,{\rm Gyr}$ have no central radio source. The AGN are found where they are "needed" to prevent cooling from occurring. This has been extended by Mittal *et al.* (2010) who find that of the strong cooling core clusters in the HIFLUCGS sample, 100% host a radio core. We note that using archival data and flux limited surveys induce biases (Hudson *et al.*, 2009).

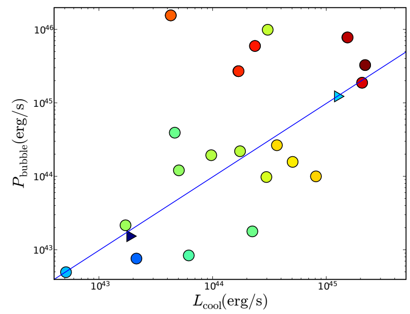


**Fig. 3**: We calculated the cooling luminosity between $0.5 - 7.0\,{\rm keV}$ and compared this to the kinetic power of the AGN. The line is to guide the eye, and the colour scale is the redshift. Although there is large scatter, as has been observed by others (*e.g.* Bîrzan *et al.* 2004, Rafferty *et al.*, 2006), the two luminosities are similar sizes. The large scatter is likely to arise from the way in which we measure the AGN power. The injection of a cavity is a discrete event and the cooling a continuous one. Therefore, depending when during the lifetime of the cavity, we observe it, we may infer different AGN powers. Also, if the duty cycle of the AGN is less than 100%, the cavities could "overheat" the gas during their active phase, and a build-up of cooling could occur inbetween.

## Radio AGN in Elliptical Galaxies

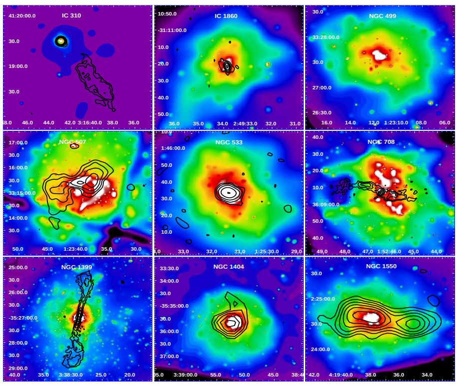


**Fig. 4**: We wanted to investigate the radio properties of a well defined, nearby sample of X-ray bright, massive, elliptical galaxies. We selected galaxies within 100Mpc with $S_{\rm X} > 3{\times}10^{-12}\,{\rm erg/cm^2/s^1}$. Nuclear radio activity is observed in 17/18 (94%), and extended radio emission in 10/18 (55%). Disturbed X-ray gas is seen in 12/18 (67%). Extending the sample to lower fluxes (and imposing a luminosity cut) increases the number of galaxies to 42, with at least 34 (81%) hosting a radio source.

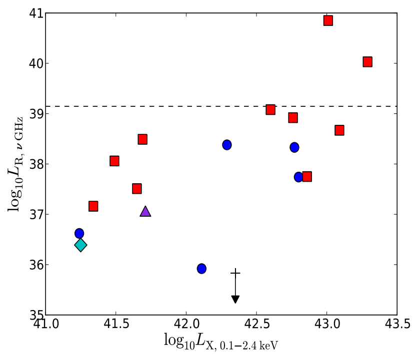


**Fig. 5**: Using a radio luminosity cut, Best *et al.* (2005) showed that the AGN fraction of their sample of SDSS galaxies was between 30 and 40 %. Only two (2/18, 11%) of the galaxies in this sample would be counted as radio loud using an equivalent cut. Although necessary in order to ensure completeness out to higher redshifts, using such a cut can be misleading when considering the AGN fraction of a population. Perhap a new definition of a "radio-AGN" is required to account for all active SMBHs.

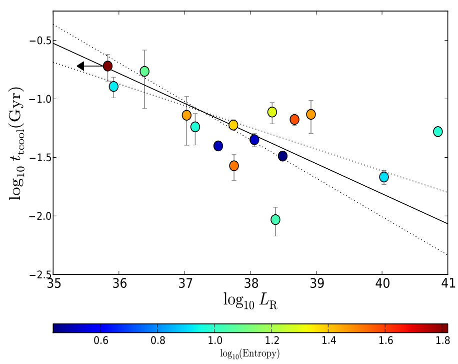


**Fig. 6**: The mass-weighted central cooling time within $1\,{\rm kpc}$ against the global radio luminosity of the galaxy (two galaxies have not been included as their X-ray emission is AGN dominated). The anti-correlation, albeit with large scatter, shows that the galaxies with short central cooling time ($\sim$ accretion rate) have a high radio luminosity ($\sim$ AGN output). Mittal *et al.* (2010) find a similar anti-correlation for their cluster sample, but also find that the galaxy sized structures do not fall on the relation.

## Summary & Further work

AGN play an important role in the evolution of the clusters and galaxies that host them. They are preferentially found in clusters which are actively cooling, and inject the "right" amount of energy, supporting the picture that the cooling gas and the AGN energy injection are part of a feedback mechanism stabilising the cluster and galaxy over time. Even in elliptical galaxies, where selecting the X-ray bright ones is likely to favour those with dense "cooling-core like" gas, AGN are found in a high proportion. This AGN fraction is much higher than the radio-loud fraction, possibly requiring a clearer classification structure for the AGN radio emission.

For further details and full references see Dunn, R.J.H. & Fabian, A.C., 2006, MNRAS, 373, 959, Dunn, R.J.H. & Fabian, A.C., 2008, MNRAS, 385, 757 and Dunn, R.J.H. et al. 2010, MNRAS, in press.