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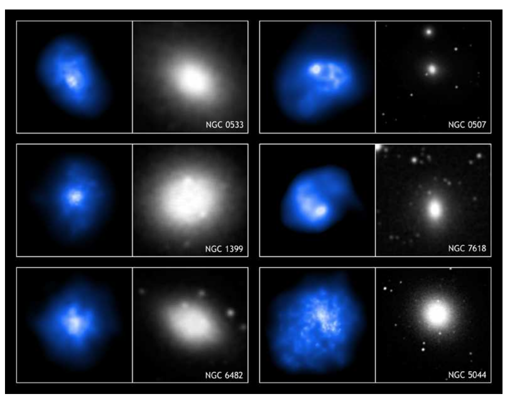
Preface

The physical properties of the hot interstellar matter in elliptical galaxies are directly related with the formation and evolution of elliptical galaxies via star formation episodes, environmental effects such as stripping, infall, and mergers, and growth of super-massive black holes. The recent successful Chandra and XMM-Newton X-ray space missions have provided a large amount of high spatial/spectral resolution observational data on the hot ISM in elliptical galaxies. At the same time, theoretical studies with numerical simulations and analytical modeling of the dynamical and chemical evolution of elliptical galaxies have made a significant progress and start to predict various observable quantities.

As an example of rich sub-structures in the hot ISM, Chandra X-ray (blue & white) and optical (grey & white) images of a few elliptical galaxies are shown below (taken from http://chandra.harvard.edu/photo/2006/galaxies; Credit X-ray: NASA/CXC/U. Ohio/T. Statler & S. Diehl; Optical: DSS). In contrast to the stellar optical light which is smoothly distributed as known for elliptical galaxies, the shapes of the massive clouds of X-ray emitting gas reveal complex structures, indicating that a powerful source of energy must be pushing the hot gas around and stirring it up.



This Joint Discussion between "Galaxies" and "ISM" divisions/commissions was organized during the IAU General Assembly to bring together both observers and theorists in the field. Throughout this JD, we have discussed recent results on the hot interstellar matter in elliptical galaxies to identify important, but unsolved problems for further investigations with special emphasis on the spectral and spatial properties of the hot ISM and the comparison with the state-of-the-art theoretical models. During the one and a half day session, 23 speakers, including 4 reviewers, presented their recent achievements.

We thank all the speakers for their excellent presentations, 3 session chairs for timely managing talks and Q/A, the SOC members for their help in various organizational issues and the local organizers for their supports throughout the preparation.

Dong-Woo Kim and Silvia Pellegrini, SOC co-chairs,
Cambridge and Bologna, November 30, 2009

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The hot ISM of early-type galaxies

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Abstract. This talks reviews the history of the discovery of the hot ISM in elliptical galaxies, and the ensuing debate on the suitability of X-ray observations of these galaxies for mass measurements. How much of the X-ray emission is truly from a hot ISM, and is this ISM in hydrostatic equilibrium? While the debate went on, a deeper understanding on the evolution of the halos was generated. High resolution *Chandra* observations are providing an answer.

Hot extended halos trapped in cluster potentials were discovered early in the history of X-ray astronomy (Kellogg & Murray 1974). It was soon realized that these halos provided a means for measuring the mass of the associated self-gravitating body, leading to huge amounts of dark matter (e.g. in the central Virgo Cluster galaxy M87, Mathews 1978; later confirmed with the first X-ray imaging telescope, the *Einstein X-ray Observatory*, Fabricant, Lecar & Gorenstein 1980). With *Einstein*, hot halos were also discovered in several early-type galaxies (Forman et al. 1979), leading to the realization that if the X-ray emission of E and S0 galaxies were dominated by hot halos in hydrostatic equilibrium, these observations could provide a ready means for measuring their masses (Forman, Jones & Tucker 1985). However, this assumption took a considerable leap of faith, because with the quality of these first X-ray images one could not disentangle a truly diffuse gaseous emission from the unresolved contribution of populations of low-mass X-ray binaries (LMXBs). Moreover, even if the emission was largely thermal, it could not be proved from the data that the hot halo was indeed in equilibrium (e.g., Trinchieri & Fabbiano 1985, hereafter TF85; see review Fabbiano 1989, hereafter F89). This debate is in part still ongoing and has contributed to a deeper understanding of the evolution of early-type galaxies, and their stellar and gaseous components.

The X-ray (L_X) and B-band luminosity (L_B) are correlated, with a large scatter (the $L_X - L_B$ diagram; TF85; Forman et al. 1985). The interpretation of this diagram has been central to the 'halo' debate (see other talks in this meeting). Is the $L_X - L_B$ diagram the expression of halo evolution and physics, or is it 'biased' by the contribution of unresolved LMXB populations? TF85 first raised the LMXB problem, based on a comparison with the bulge of M31 and the integrated emission properties of bulge-dominated galaxies, which have L_X/L_B ratios consistent with those of 'X-ray faint' ellipticals. This hypothesis was confirmed by the spectral characteristics of the X-ray emission: harder X-ray emission was found in X-ray faint galaxies with *Einstein* and *ROSAT* (e.g., Kim, Fabbiano & Trinchieri 1992), and the CCD spectra of ASCA found the signature of a hard LMXB emission also in halo-dominated galaxies (Matsushita et al. 1994). With the sub-arcsecond telescope of the *Chandra X-ray Observatory*, populations of LMXBs are now obvious in the images of elliptical galaxies, and in some cases account for the bulk of the X-ray emission (e.g. NGC 3379; Brassington et al. 2008).

There is sufficient material from stellar outgassing to account for the hot halos. These halos may be further heated by SNIa and by gravity (if they slowly accrete to the center via cooling flows; see F89). AGN feedback may also be an important energy source (e.g. Tabor & Binney 1993). Given all this ready energy input, can we be sure that the halos are in hydrostatic equilibrium? Or are they in an outflow or wind state? Indeed, hydrodynamical modeling of the $L_X - L_B$ diagram suggested that winds, partial outflows and cooling flows could naturally explain the placement of galaxies in this diagram (Ciotti et al. 1991). Now, with *Chandra* we have set stringent limits on the amount of diffuse emission in some X-ray faint galaxies, demonstrating the presence of winds. In NGC 3379, for example, we find residual evidence of non-stellar diffuse emission in the 0.7-1.5 keV band, which is well reproduced by independent hydrodynamical modeling of the hot halo (Trinchieri, Pellegrini et al. 2008).

Optical indicators of large galaxy potentials and primordial merging are correlated with the presence of large X-ray halos (e.g., Eskridge, Fabbiano & Kim 1995; see Kormendy et al. 2009), suggesting that these halos are gravity-held. These hot halos are likely to be experiencing cooling flows, because the denser central regions would cool faster than the outer shells. There is an entire literature on cooling flows (see F89), which I will not explore here, except to say that there are two key observational diagnostics: (1) central colder gas; (2) central star formation. Neither have been detected to the amount expected. What stops the cooling flows? Radio-emitting AGN are frequently found in elliptical galaxies, and a first inkling of the interplay between these nuclear sources and the hot halos was suggested by the *Einstein* results (Fabbiano, Gioia & Trinchieri 1989). *Chandra* observations convincingly prove that AGN feedback is at play (e.g., Finoguenov et al. 2008). The evolution of the hot halos is the result of a tug of war between the pull of gravity and the push of feedback from stellar evolution (SNIa) and AGNs.

The above discussion demonstrates that caution must be used when approaching X-ray based mass measurements. In the case of 'dominant' extended hot halos hydrostatic equilibrium is probably a good approximation. However, for less X-ray luminous galaxies the halo may be far from equilibrium, and careful analysis of high resolution X-ray data (*Chandra*) and hydrodynamical modeling is required to understand the physical state of the halo.

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References

Brassington, N. et al. 2008, *ApJS* 179, 142
Ciotti, L. et al. 1991, *ApJ* 376, 380
Eskridge, P. B., Fabbiano, G., Kim, D.-W. 1995, *ApJ* 442, 523
Fabbiano, G. 1989, *ARAA* 27, 87 (F89)
Fabbiano, G., Gioia, I. M., Trinchieri, G. 1989, *ApJ* 347, 127
Fabricant, D., Lecar, M., Gorenstein, P. 1980, *ApJ* 241, 552
Finoguenov, A. et al. 2008, *ApJ* 686, 911
Forman, W. et al. 1979, *ApJ* 234, L27
Forman, W., Jones, C., Tucker, W. 1985, *ApJ* 293, 102
Kellogg, E. & Murray, S. 1974, *ApJ* 193, L57
Kim, D.-W., Fabbiano, G., Trinchieri, G. 1992, *ApJ* 393, 134
Kormendy, J. et al. 2009, *ApJS* 182, 216
Mathews, W. G. 1978, *ApJ* 219, 413
Matsushita, K. et al. 1994, *ApJ* 436, L41
Tabor, G., Binney, J. 1993, *MNRAS* 263, 323
Trinchieri, G., Fabbiano, G. 1985, *ApJ* 296, 447 (TF85)
Trinchieri, G., Pellegrini, S. et al. 2008, *ApJ* 688, 1000

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XMM-Newton observations of elliptical galaxies in the local universe

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XMM-Newton is well suited to the study of the X-ray properties of early-type galaxies: the wide energy band allows a characterization of the different components of the X-ray emission in galaxies, separating the gas from the compact source component through their spectral characteristics, and identifying low-luminosity absorbed AGNs; the large field of view allows a proper understanding of the large scale emission, and the separation between the galaxy and the surrounding group. Nonetheless, in spite of the much improved understanding of the X-ray characteristics of this class of sources, much of the original questions on the global X-ray properties of early-type galaxies remain. One in particular: how can we predict how much gas is there in any given galaxy? We have learned that the individual sources are tightly linked to the stellar component, both field stars and relative frequency of globular clusters. We have also learned that the central group galaxies, brighter and more extended, might represent a specific class of early-type galaxies, rather than the population as a whole. Yet we have not learned how to predict, from the stellar properties, how much hot gas a galaxy will have. Even a well selected class of sources, namely early type galaxies in isolation, where we can exclude the influence of the environment, appear to retain different amounts of the hot ISM produced by the stellar population, and display a wide range of L_x for their gaseous component for a relative narrow range of L_b, or mass [measured through L_K], as shown by Fig. 1.

Keywords. galaxies: halos;elliptical and lenticular; intergalactic medium

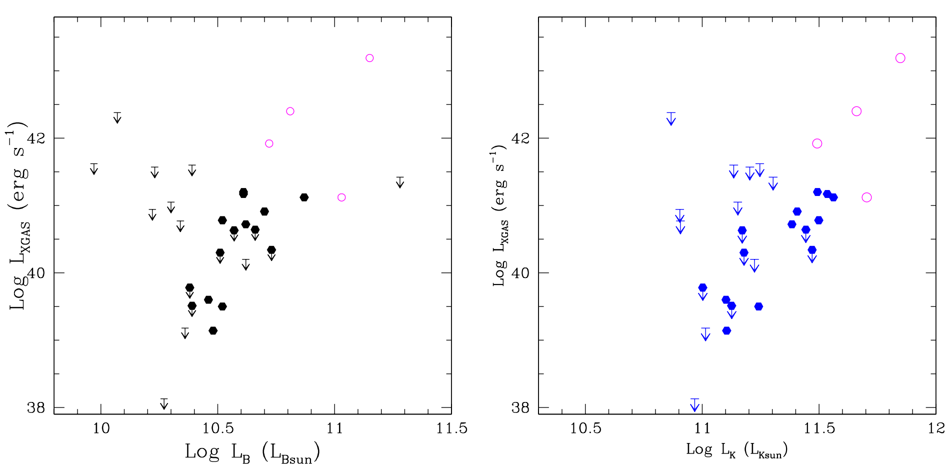

Figure 1. Comparison between the hot gas X-ray luminosity and B-band (left) or K-band (right) luminosity for isolated galaxies. "Fossil groups", namely isolated galaxies that have been found associated to a large, group-size halos, are identified by open circles. Arrows identify upperlimits to the total emission, or gas emission when associated with a symbol.

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Suzaku observations of early-type galaxies

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The metal abundances in the hot X-ray emitting interstellar medium (ISM) of early-type galaxies give us important information about the present metal supply into the ISM through supernovae (SNe) Ia and stellar mass loss. In addition, O and Mg abundances should reflect the stellar metallicity and enable us to directly look into the formation history of these galaxies. The XIS instrument onboard the Suzaku satellite has an improved line spread function due to a very small low-pulse-height tail below 1 keV coupled with a very low background.

We derived abundance pattern of O, Ne, Mg and Fe of ISM of four elliptical galaxies, NGC 720 (Tawara et al. 2007), NGC 1399 (Matsushita et al. 2007a), NGC 1404 (Matsushita et al. 2007a), NGC 4636 (Hayashi et al. 2009), and two S0 galaxies, NGC 1316 (Konami et al. 2009), and NGC 4382 (Nagino et al. 2009) observed with Suzaku, and compared with those of two cD galaxies, M 87 (Matsushita et al. 2003), and NGC 4696 (Matsushita et al. 2007b) observed with XMM.

The Fe abundances of the ISM of these galaxies are about 0.5–1 solar, indicating that the present SN Ia rate is low. The O, Ne and Mg abundances are consistent with stellar metallicity. The abundance patterns of the ellipticals and cDs, and NGC 1316 are not so different from the solar pattern, using new solar abundance by Loddars (2003), and consistent with a mixture of SNe Ia and metal-poor Galactic stars. These galaxies are giant galaxies and their ISM temperatures are 0.6∼1 keV. In contrast, a S0 galaxy, NGC 4382, with an ISM temperature of 0.3 keV, has a smaller O/Fe ratio in the ISM. This result means that the ISM in this galaxy contains more SNIa products.

References

Hayashi, K., Fukazawa, Y., Tozuka, M., Nishino, S., Matsushita, K., Takei, Y., & Arnaud, K. A. 2009, *PASJ* in press, arXiv:0907.2283

Konami, S., in preparation

Lodders, K. et al. 2003, *ApJ* 591, 1220

Matsushita, K., Finoguenov, A., Böhringer, H. 2003, *A&A* 401, 443

Matsushita, K. et al. 2007a, *PASJ* 59, 327

Matsushita, K., Böhringer, H., Takahashi, I., & Ikebe, Y. 2007b, *A&A* 462, 953

Nagino, R., & Matsushita, K. in preparation

Tawara, Y., Matsumoto, C., Tozuka, M., Fukazawa, Y., Matsushita, K., & Anabuki, N. 2008, *PASJ* 60, 307

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Hot gas morpoloy, thermal structure, and the AGN connection in elliptical galaxies

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Abstract.
Recent studies of the hot interstellar medium in normal elliptical galaxies have shown that (1) the gas is only approximately hydrostatic; (2) morphological disturbances are corrleated with radio and X-ray signatures of AGN; and (3) temperature gradients in the main bodies of the galaxies are correlated with nuclear activity but not with environment. An X-ray Gas Fundamental Plane (XGFP), unrelated to the stellar fundamental plane, links the global gas properties in a relation whose origin is not yet understood.

Keywords. cooling flows; galaxies: elliptical and lenticular, cD; galaxies: ISM—X-rays: galaxies

1. Introduction

Current questions regarding the X-ray gas in elliptical galaxies concern modes of heating, coupling to central AGN, and even whether the gas is hydrostatic. This last is nothing new; even in the *Einstein* era Trinchieri et al. (1986) noticed the asymmetry of NGC 4472, and argued that the gas is not hydrostatic at large radii.

The early years of *Chandra* saw several in-depth studies of single, interesting, usually luminous, objects that quickly became "poster children" for AGN-driven feedback. Jones et al. (2002) argued that features in NGC 4636 are shocks created by intermittently-fueled AGN. Finoguenov & Jones (2001) observed a striking H-shaped structure in NGC 4374, correlated with, and likely created by, expanding radio lobes.

In one of the few early studies of an X-ray faint system, Sarazin et al. (2001) demonstrated that low-mass X-ray binaries (LMXBs) contribute much of the total emission from NGC 4697. After removing the resolved sources, a diffuse component remained, apparently flatter than the starlight; however these authors emphasized that the gas morphology was uncertain because of the unknown contribution from unresolved LMXBs.

2. Hot ISM Properties of Normal Ellipticals

Diehl & Statler (2007) (hereafter DS1) demonstrate that the emission from gas *alone* can be isolated by taking a suitably chosen scaled difference of hard-band and soft-band images. DS1 produce gas-only images for 54 normal ellipticals observed by *Chandra*, and obtain isophotal ellipticity and position angle profiles for each system as well as an "asymmetry index" measuring the deviation from a smooth elliptical model.

The angular resolution of *Chandra* allows measurement of gas ellipticities inside the optical effective radius (R_e), where elliptical galaxies are stellar-mass dominated, offering a chance to test the assumption of hydrostatic equilibrium. DS1 find (their Fig. 6) that, contrary to this assumption, there is no correlation between optical and X-ray ellipticities. After extensive modeling, they conclude that the gas may be hydrostatic enough for radial mass profiles to be extracted, but it is not, in general, sufficiently hydrostatic for the *shape* of the gravitating mass to be inferred—as attempted by, e.g., Buote & Canizares (1994) and Buote et al. (2002).

The origin of morphological disturbances in the gas is addressed by Diehl & Statler (2008a). They find that the asymmetry index η is strongly correlated with the NVSS 20 cm luminosity and the X-ray luminosity of the central point source—signatures of AGN—and with the gas temperature gradient beyond $2R_e$—an indicator of environment (their Fig. 11). Since η measures small-scale asymmetries as well as large-scale lopsidedness, DS2 conclude that gas morphology is influenced in comparable measure by ram pressure in cluster environments and by AGN.

Unlike in galaxy clusters, gas temperatures in normal ellipticals do not always increase outward. Fukazawa et al. (2006) argue that positive radial temperature gradients indicate a transition to a hotter intragroup or intracluster medium. Humphrey et al. (2006) suggest that the gradient distribution is actually bimodal. Diehl & Statler (2008b) show that there is no evidence for bimodality, and that the gradients inside $2R_e$ are not affected by environment (as measured by the number density of neighbor galaxies), whereas the gradients outside $2R_e$ are (their Fig. 5). They suggest that the change from positive to negative gradients reflects a change in the role or mode of AGN heating.

3. X-Ray Gas Fundamental Plane

The global properties of the stellar distribution in elliptical galaxies follow the well known Fundamental Plane: a 2-dimensional locus in the space of effective radius, surface brightness, and velocity dispersion that is primarily a consequence of the virial theorem. Diehl & Statler (2005) find that, if one takes the analogous properties for the X-ray gas alone—half-light radius, X-ray surface brightness, and temperature, elliptical galaxies again delineate a plane, albeit a totally different one. The X-Ray Gas Fundamental Plane (XGFP) is not a consequence of the virial theorem, but is as tight as the stellar Fundamental Plane. Its origin has yet to be explained.

Acknowledgements

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References

Buote, D. A., & Canizares, C. R. 1994, *ApJ* 427, 86
Buote, D. A., Jeltema, T. E., Canizares, C. R., & Garmire, G. P. 2002, *ApJ* 577, 183
Diehl, S. & Statler, T. S. 2005, *ApJ* 633, L21
Diehl, S. & Statler, T. S. 2007, *ApJ* 668, 150
Diehl, S. & Statler, T. S. 2008a, *ApJ* 680, 897
Diehl, S. & Statler, T. S. 2008b, *ApJ* 687, 986
Finoguenov, A. & Jones, C. 2001, *ApJ* 547, L107
Fukazawa, Y., Botoya-Nonesa, J. G., Pu, J., Ohto, A., & Kawano, N. 2006, *ApJ* 636, 698
Humphrey, P. J., Buote, D. A., Gastaldello, F., Zappacosta, L., Bullock, J. S., Brighenti, F., & Mathews, W. 2006, *ApJ* 646, 899
Jones, C., Forman, W., Vikhlinin, A., Markevitch, M., David, L., Warmflash, A., Murray S., & Nulsen, P. E. J. 2002, *ApJ* 567, L115
Sarazin, C. L., Irwin, J. A., & Bregman, J. N. 2001, *ApJ* 556, 533
Trinchieri, G., Fabbiano, G. & Canizares, C. D. 1986, *ApJ* 310, 637

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Hot gas flows on global and nuclear galactic scales

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Abstract. One of the most significant observational improvements allowed by the high quality *Chandra* data of galaxies is the measurement of the nuclear luminosities down to low values, and of the hot ISM properties down to very low gas contents. I present here some recent developements concerning the possibility of accreting and outflowing gas, based on modeling results that take into account the role of a central supermassive black hole (MBH).

Keywords. galaxies: elliptical and lenticular, cD – galaxies: evolution – galaxies: ISM – X-rays: galaxies – X-rays: ISM

Recently, the interaction of the energy output from a central MBH with the interstellar medium (ISM) has been studied with high resolution 1D hydrodynamical simulations, including a detailed treatment of the radiative energy output and its transfer within the ISM, and of the mechanical energy output from AGN winds and jets (Ciotti, Ostriker & Proga 2009). We briefly report here the observational properties of this class of models in the X-ray band at the present epoch from a preliminary investigation (see also Pellegrini, Ciotti & Ostriker 2009).

For a bright ($L_B = 5\times10^{10} L_{B,\odot}$) isolated galaxy and standard assumptions concerning the stellar mass loss and SNIa rate, and the stellar and dark mass profiles, the radiative and AGN winds feedback lead to a hot ISM luminosity on the lower end of the large range observed. An external medium, as that of the outer regions of the Virgo cluster, can increase this luminosity by a factor of a few. It also causes (brief) nuclear outbursts to repeat until present epoch. The gas is inflowing within $\sim$ 100 pc, producing a mass accretion rate on the MBH within the low radiative efficiency ADAF regime ($\dot{M}/\dot{M}_{Edd} \sim 10^{-4}$); the nuclear luminosity though ($L_{bol,nuc} \sim$ few$\times10^{41}$ erg s^{-1} at the present epoch) is quite higher than typically observed (Pellegrini 2005a,b). Mechanical feedback from a jet can lower $L_{bol,nuc}$ to values common for early type galaxies of the local universe ($L_{bol,nuc}/L_{Edd} \sim 10^{-7} - 10^{-8}$). It also makes the nuclear outbursts less strong and rarer. The brightness profile of the hot gas can have a variety of shapes, depending on the recent flow history, the external medium and the jet heating. The temperature profile has a negative gradient, the external medium and the jet both make this profile flatter.

References

Ciotti, L., Ostriker, J.P., Proga, D. 2009, *ApJ* 699, 89
Pellegrini, S. 2005a, *MNRAS* 364, 169
Pellegrini, S. 2005b, *ApJ* 624, 155
Pellegrini, S., Ciotti, L., Ostriker, J. P. 2009, *Adv. Sp. Res.* 44, 340

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Hyperfine structure radio lines from hot ISM in elliptical galaxies

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Abstract. Hyperfine structure (HFS) line of ^{14}N VII ion with rest frequency of $\nu = 53.04$ GHz should be detectable from the interstellar medium in some of the densest and coolest cores of elliptical galaxies at redshifts exceeding 0.15 or so.

Keywords. galaxies: elliptical, galaxies: ISM, radio lines: ISM

Hyperfine structure (HFS) lines of highly-charged ions may open a new window in observations of hot plasmas, as first discussed by Sunyaev, R.A., Churazov (1984). Some of the relevant isotopes and ions are abundant at temperatures around $10^5 - 10^7$ K, characteristic of the hot interstellar medium (ISM) in elliptical galaxies, as well as many other types of astrophysical objects. Observations of these lines might complement soft X-ray observations with micro-calorimeters, but, in contrast to soft X-rays, they are not attenuated by the Galactic ISM and Earth atmosphere (except for the ^{14}N VII line), and allow to study observed target bulk and turbulent motions with much higher spectroscopic and angular resolution, provided that the radio telescope has sufficient sensitivity.

We estimate feasibility of HFS emission and absorption line observations from this astrophysical source type using simple theoretical estimates of spectral line absorption cross-section and emissivity (see Sunyaev & Docenko (2007), Docenko & Sunyaev (2007a) and Docenko & Sunyaev (2007b) for more details).

These estimates show that the most promising HFS line to be detected on modern instruments is one of the ^{14}N VII (rest wavelength $\lambda = 5.652$ mm) at redshifts $z > 0.15$. Using planned radio telescopes and interferometers it appears possible to observe also HFS lines of several other Mg, Si and Fe ions, including ^{57}Fe XXII line at 1.05 cm.

Acknowledgements

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References

Docenko, D., Sunyaev, R.A. 2007a, in: H. Böhringer, G. W. Pratt, A. Finoguenov, & P. Schuecker (eds.), *Heating versus Cooling in Galaxies and Clusters of Galaxies*, ESO Astrophysics Symposia (Berlin, Heidelberg: Springer), p. 333

Docenko, D., Sunyaev, R.A. 2007b, in: *From Planets to Dark Energy: the Modern Radio Universe*, Published online at SISSA, *Proceedings of Science*, p.90

Sunyaev, R.A., Churazov, E.M. 1984, *Soviet Astron. Lett.* 10, 201

Sunyaev, R.A., Docenko, D.O. 2007, *Astron. Lett.* 33, 67

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Cool gas in brightest cluster galaxies

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Abstract. Gas in galaxy clusters requires re-heating. We study the re-heating of the cool gas phases. Ionized and molecular gas is traced out to 20 kpc and found to be strongly coupled. The observed line emission may in part be explained by excitation due to hot, young stars.

Keywords. galaxies: galaxies: cooling flows, cD, clusters: general

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Relaxed clusters of galaxies contain large quantities of gas at a variety of temperatures within their cores. To avoid catastrophic cooling, this gas needs to be re-heated. The details of this re-heating process are currently not understood.

To study the distribution and condition of the cool gas, HII and H_2, we performed deep K-band IFU observations of two clusters Abell 2597 and Sersic 159-03 with SINFONI on the VLT. These observations enable us, for the first time, to map this gas in the cores of these clusters. The distribution of the gas is filamentary and correlates well with the X-ray emission. Ionized and molecular gas is found to co-exist in both intensity and dynamics and is detected out to 20 kpc from the nucleus of the brightest cluster galaxy.

The gas near the nucleus partakes in rotation and shows a sharp increase in its velocity dispersion along the current radio axis, indicating that the gas here is stirred up by AGN outflows. Deep 5 GHz radio observations furthermore show that non-thermal plasma is spread throughout the cluster core on short timescales, $t \lesssim 10^7$ yr.

The H_2 lines are everywhere well fit by a single temperature LTE model, implying that this gas is warm, T$\sim$2300 K. The total warm H_2 mass is $\sim 10^5$ $M_\odot$ and the total HII mass is $\sim 10^7$ $M_\odot$. The ratio of the Pa α to H_2 lines indicate a source of UV excitation rich in EUV to FUV photons (Jaffe *et al.* 2005 and Oonk *et al.* in prep.).

To study the source of excitation for the cool gas we performed deep FUV imaging with ACS-SBC on the HST and U imaging with FORS on the VLT for two clusters, Abell 2597 and Abell 2204. FUV and U continuum emission is found to exist in clumps and filaments out to 25 kpc from the nucleus of the brightest cluster galaxy. Comparing the FUV/U ratio to a black body curve we find a temperature $T_{BB} \sim 50000$ K for the young stars in cores of these clusters. Preliminary analysis suggests that the UV emission can account for the ionization seen in the Hα emission, but detailed analysis of optical line ratios indicates the need for additional heating mechanisms (Voit *et al.* 1997).

Acknowledgements

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References

Jaffe, W., Bremer, M.N. & Baker, K. 2005, *MNRAS* 360, 748
Voit, G. M. & Donahue, M. 1997, *ApJ* 486, 242

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A multi-instrument comparison of the hot ISM in elliptical galaxies

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Abstract. Consistent metallicities are now obtained in X-ray bright galaxies, using the Chandra ACIS and XMM PN, MOS and RGS detectors. With two temperature models, the Fe metallicity of the gas is typically solar, similar to Mg, Si, and S, but the O abundance is about half solar. These values are in conflict with models, which predict a metallicity 3-5 times higher and a Fe to O ratio near unity. This suggests that a significant fraction of metals are not becoming mixed into the hot galactic atmosphere.

Keywords. X-rays: galaxies, galaxies: ISM

We appear to be reaching an observational consensus for the metallicity of the hot gas. The metals enter the hot gas through mass loss from AGB stars plus the metals from Type Ia supernovae, which should lead to a hot ambient medium with a metallicity of 3-5 times the solar value of Fe. Supernovae should heat the gas to temperatures above the velocity dispersion temperature, an observational feature that has been known for some time. However, measuring the metallicity has been problematic and has depended upon whether one adopts one or two temperature components for the hot plasma. We used four instruments to determine the temperature for the same X-ray bright galaxies: the Chandra ACIS-S; the XMM-Newton Epic (PN and MOS); and the XMM-Newton Reflection Grating Spectrometer (RGS).

As shown in Ji et al. (2009, *ApJ*, 696, 2252), there is good consistency in the fits for NGC 4649 from all instruments. The abundances for Mg, Si, S, and Fe are about the same, with a value near 1.4 times the solar value, using the metallicity calibration of Grevesse and Sauval (1998). The O and Ne values are about 0.7 solar, about half that of the heavier elements. There is a discrepancy between the Chandra ACIS-S and XMM-Newton values for O, with the Chandra abundance being lower. For nine bright galaxies, we fit two-temperature models and find that he median abundances, relative to solar are 0.86 (Fe), 0.79 (Si), 0.81 (Mg), and 0.44 (O). No galaxy has a metallicity exceeding about 1.5 solar in Fe. The 2:1 ratio of Fe to O, seen in all objects with good data, has been reported previously. This distribution of metal enrichment is consistent with 65-85% of the metal enrichment coming from Type Ia SNe.

The results are in conflict with basic expectations. The metallicity is low by at least a factor of three, and this problem worstens for the lower L_X galaxies. This conflict might be removed if somehow supernovae ejecta did not mix effectively. In this case, one would expect the abundance ratios to be like that of the stars, but the O/Fe and O/Mg ratios are half that of the stars. Furthermore, there is no correlation between the stellar Fe abundance and the hot gas Fe abundance, which would be expected if the hot gas metallicity were dominated by the AGB mass loss phase. Perhaps some of this can be resolved with models that restrict the mixing of metals, and there are some presentations at this meeting that address these issues.

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Abundance ratios in stars vs. hot gas in elliptical galaxies

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Abstract. I present predictions from a chemical evolution model for a self-consistent study of optical (i.e., stellar) and X-ray (i.e., gas) properties of present-day elliptical galaxies. Detailed cooling and heating processes in the interstellar medium are taken into account and allow a reliable modelling of the SN-driven galactic wind. The model simultaneously reproduces the mass-metallicity, colour-magnitude, L_X - L_B and L_X - T relations, and the observed trend of [Mg/Fe] with σ. The "iron discrepancy" can be solved by taking into account the dust presence.

Keywords. galaxies: elliptical and lenticular, cD - galaxies: abundances - X-rays: ISM

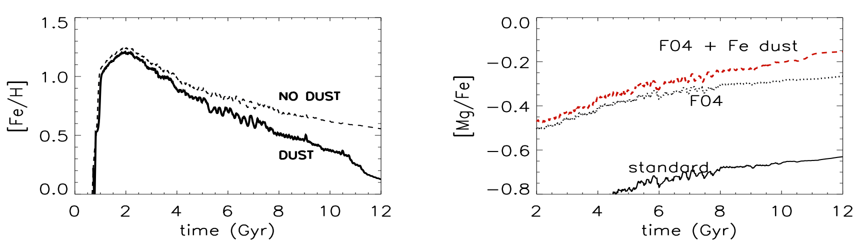

Figure 1. Predicted abundance ratios as a function of time by different models (see text).

Monolithic collapse models featuring a SN-driven galactic wind (Pipino et al. 2008) are shown to reproduce the largest number of observables in the optical spectrum of elliptical galaxies (e.g. Pipino et al. 2005, P05). Here, I made use of the P05 chemical evolution code in order to present preliminary attempts to overcome long lasting problems such as the discrepancy between the expected high Fe abundance in the post-wind phase and the observed one, as well as to explain the observed abundance ratio pattern (see Bregman, Humphrey, this Conference).

In particular, in Calura et al. (2008) we showed that the most recent estimates of the diffuse dust in ellipticals is enough to hide a suitable amount of Fe and reduce the gas phase abundance to the required solar value (Fig. 1, left panel). The empirical yields by François et al. (2004), instead, may make the predicted [Mg/Fe] closer to the observed solar value (Fig. 1, right panel). The same yields may explain why the observations hint to an under-solar [O/Mg] ratio.

I acknowledge support from the AAS and the IAU travel grants.

References

Calura, F., Pipino, A., Matteucci, F., 2008, *A&A* 479, 669
François, P., Matteucci, F., Cayrel, R., Spite, M., Spite, F., Chiappini, C., 2004, *A&A* 421, 613
Pipino, A., Kawata, D., Gibson, B. K., Matteucci, F., 2005, *A&A* 434, 553
Pipino, A., D'Ercole, A., Matteucci, F., 2008, *A&A* 484, 679

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Numerical simulations of elliptical galaxies

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For the formation of elliptical galaxies, two scenarios, monolithic collapse vs. major merger, have been debated. We simulate the formation and chemodynamical evolution of 128 Es from the CDM initial fluctuations, using the GRAPE-SPH code that include star formation, supernovae feedback, and chemical enrichment. In our CDM-based scenario, galaxies form through the successive merging of subgalaxies with various masses.

The metallicity gradient gives one of the most stringent constraints on the galaxy formation. Kobayashi (2004) showed that gradients are destroyed by mergers and are not enough regenerated by induced star formation. In observations, there is a significant scatter (Kobayashi & Arimoto 1999), which is reproduced with our simulations (Fig.1a). The scatter stems from the difference in the merging histories. Galaxies that form monolithically have steeper gradients, while galaxies that undergo major mergers have shallower gradients. For less-massive galaxies, Spolaor et al. (2009) showed that the gradients become flatter, which cannot be reproduced.

This scenario does not conflict with the observed scaling relations. The mass-metallicity relation (Fig.1b) and the fundamental plane are also reproduced (Kobayashi 2005). An intrinsic scatter exists along the fundamental plane, and the origin of this scatter lies in differences in merging history. Galaxies that undergo major mergers tend to have larger effective radii r_e and fainter surface brightnesses, which result in larger masses, smaller surface brightnesses, and larger mass-to-light ratios M/L.

Mass-to-light ratios and baryon fractions (Fig.1c) will be important constraints on the origin of elliptical galaxies. Our simulations are roughly consistent with the available observations with X-ray (Nagino & Matsushita 2009), optical measurements (Gerhard et al. 2001), and gravitational lensing (Treu et al. 2006). The stellar M/L correlates with the stellar mass, which can be the origin of the tilt of the fundamental plane. The total M/L does not correlate with the stellar M/L, which is contrary to the optical observations. The total M/L are almost constant as $\sim 18-28$ in $2r_e$ for $M_* \gtrsim 10^{10}M_\odot$, which is consistent with the X-ray observations, and increases upto ~ 100 for dwarf ellipticals. Thus, the baryon fraction is larger for massive galaxies.

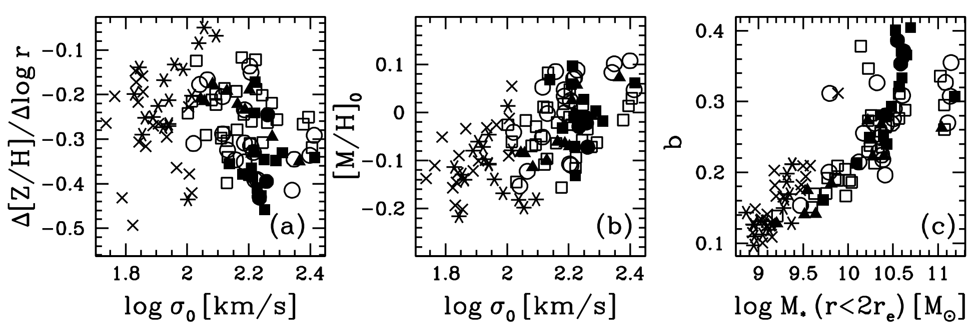

Figure 1. (a) Metallicity gradients and (b) central metallicities against central velocity dispersions for monolithic-like (filled symbols), major merger (open symbols), and dwarf ellipticals (crosses). (c) Baryon fractions against stellar mass within $2r_e$ of the simulated galaxies.

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Metal abundances in the hot ISM of early-type galaxies

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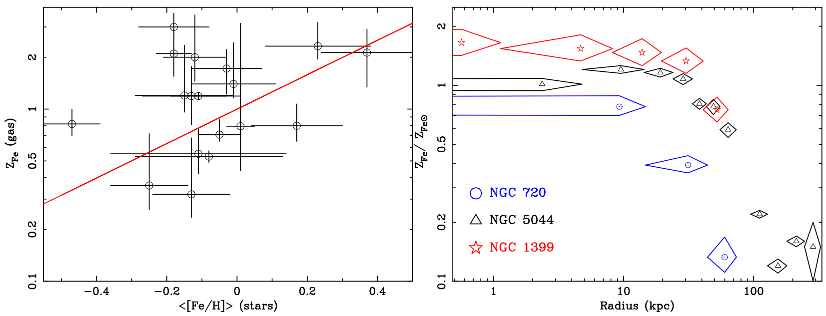

Figure 1. Left: Comparison of the ISM and stellar abundances for a sample of early-type galaxies (Humphrey & Buote 2006, P. Humphrey et al., in prep.). The solid line denotes “y=x”. **Right:** Radial abundance gradients for the galaxy groups NGC 1399 and NGC 5044 (Buote et al. 2003, 2004) and the isolated elliptical galaxy NGC 720 (P. Humphrey et al., in prep.).

Understanding the process of metal enrichment is one of the key problems for our picture of structure formation and evolution, in which early-type galaxies are a crucial ingredient. X-ray observations provide a powerful tool for measuring the metal distributions in their hot ISM, which is shaped by their entire history of star-formation, evolution and feedback. In Fig 1 (left panel), we summarize the results of a Chandra survey of metals in early-type galaxies, supplemented with Suzaku data (Humphrey & Buote 2006, P. Humphrey et al., in prep.). Chandra is particularly suited to this study, as it enables temperature gradients and X-ray point sources to be resolved, mitigating two important sources of bias (e.g., Buote & Fabian 1998; Fabbiano et al. 1994). We found on average that the ISM is at least as metal-rich as the stars, and we did not find the problematical, highly sub-solar, abundances historically reported. The abundance ratios of O, Ne, Mg, Si and S with respect to Fe are similar to the centres of massive groups and clusters, suggesting homology in the enrichment process over a wide mass range. Finally, using high-quality Suzaku data, we were able to resolve, for the first time in a galaxy-scale ($\lesssim 10^{13} M_{\odot}$) object, a radial abundance gradient similar to those seen in some bright galaxy groups (Fig 1, right panel).

References

Buote, D. A., Fabian, A. C. 1998, *MNRAS* 296, 977
Buote, D. A., et al. 2003, *ApJ* 595, 151
Buote, D. A., Brighenti, F., Mathews, W. G. 2004, *ApJL* 607, L91
Fabbiano, G., Kim, D.-W., Trinchieri, G. 1994, *ApJ* 429, 94
Humphrey, P. J., Buote, D. A. 2006, *ApJ* 639, 136

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Confronting feedback simulations with observations of hot gas in elliptical galaxies

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Keywords. X-ray, elliptical galaxies, hot gas, galaxy evolution

Elliptical galaxies comprise primarily old stars, which collectively generate a long-lasting feedback via stellar mass-loss and Type Ia SNe. This feedback can be traced by X-ray-emitting hot gas in and around such galaxies, in which little cool gas is typically present. However, the X-ray-inferred mass, energy, and metal abundance of the hot gas are often found to be far less than what are expected from the feedback, particularly in so-called low L_X/L_B ellipticals. This "missing" stellar feedback is presumably lost in galaxy-wide outflows, which can play an essential role in galaxy evolution (e.g., explaining the observed color bi-modality of galaxies). We are developing a model that can be used to properly interpret the X-ray data and to extract key information about the dynamics of the feedback and its interplay with galactic environment.

First, we have constructed a 1-D model of the stellar feedback in the context of galaxy formation and evolution. The feedback is assumed to consist of two primary phases: 1) an initial burst during the bulge formation and 2) a subsequent long-lasting mass and energy injection from stellar winds and Type Ia SNe of low-mass stars. An outward blastwave is initiated by the burst and is maintained and enhanced by the long-lasting stellar feedback. This blastwave can heat the surrounding medium not only in the galactic halo, but also in regions beyond the virial radius. As a result, the smooth accretion of hot gas can be completely stopped. The long-lasting feedback can form a galactic bulge wind, which is reverse-shocked at a large radius, and can later evolve into a subsonic quasi-stable outflow as the energy injection decreases with time. The two phases of the feedback thus re-enforce each-other's impact on the gas dynamics. Present-day elliptical galaxies with significant amounts of hot gas are most likely in subsonic outflow states. The exact properties of such an outflow depend on the galaxy formation history and environment. This dependence and variance may explain the large dispersion in the L_X/L_B ratios of elliptical galaxies.

Second, to quantitatively compare the simulations with X-ray observations, we have conducted various 3-D hydrodynamical simulations with the adaptive mesh refinement code FLASH to investigate the physical properties of hot gas in and around elliptical galaxies. We have developed an embedding scheme of individual supernova remnant seeds, which allows us to examine, for the first time, the effect of sporadic SNe on the density, temperature, and iron ejecta distribution of the hot gas as well as the resultant X-ray morphology and spectrum. We find that the SNe produce a wind/outflow with highly filamentary density structures and patchy ejecta. Compared with a 1-D spherical wind model, the non-uniformity of simulated gas density, temperature, and metallicity substantially alters the spectral shape and increases the diffuse X-ray luminosity. The differential emission measure as a function of temperature of the simulated gas exhibits a log-normal distribution, with a peak value much lower than that of the corresponding 1D model. The bulk of the X-ray emission comes from the relatively low temperature and low abundance gas shells associated with SN blastwaves. SN ejecta are not well mixed with the ambient medium and typically remain very hot in the central region. Driven by the buoyancy, the iron-rich gas on average moves substantially faster than the medium and only gradually mixes with it on the way out. As a result, apparent increasing temperature and metal abundance with off-center distance can arise in the region, mimicking what have been observed in elliptical galaxies. These results, at least partly, account for the apparent lack of evidence for iron enrichment in the soft X-ray-emitting gas in galactic bulges and intermediate-mass elliptical galaxies.

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Hot ISM in young elliptical galaxies

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Abstract.
Using Chandra and XMM-Newton X-ray observations of young, post-merger elliptical galaxies, we present X-ray characteristics of age-related observational results, by comparing with typical old elliptical galaxies in terms of X-ray properties of their low-mass X-ray binaries (LMXBs) and hot interstellar matter (ISM).

Keywords. galaxies: elliptical and lenticular, cD, X-rays: galaxies, X-rays: ISM

Stellar age in an elliptical galaxy has been measured and there are now a handful of elliptical galaxies with intermediate stellar age (< 5 Gyr) which could link between Antennae-like merging systems and typical old elliptical galaxies (e.g,. Thomas et al. 2005). We find that young elliptical galaxies host more luminous (> 5 x 10^{38} erg s^{-1}) LMXBs which are often distributed in a non-uniform way, indicating a possible connection with recent mergers (Kim et al. 2009, in preparation). Young elliptical galaxies tend to have a small amount of hot gas, with Lx(gas) comparable to or smaller than Lx(LMXB). By comparison, old elliptical galaxies have a wide range of Lx(gas) and some of them (e.g., group or cluster dominant galaxies) have Lx(gas) 10 or 100 times higher than Lx(LMXB).

One of the key observables to address the age effect is the abundance ratio of Fe to α elements, because of different production yields of SNe Ia and II. In the merger scenario of young elliptical galaxies, we would expect an enrichment of α-elements from SN II, associated with the recent star formation. Based on the SN yields, [Si/Fe] would be close to 0.5 if SNe Ia are dominating, while the ratio would be close to 2.5 if SNe II are dominating. Typical old giant elliptical galaxies have [Si/Fe] close to solar (e.g., Kim & Fabbiano 2004), indicating that the ejecta from both SNe II (from the early star formation) and SNe Ia (continuously added later) are well mixed. With added contribution from SNe II in young elliptical galaxies, we expect [Si/Fe] to be between 1 and 2.5 solar. By carefully selecting young and old samples (e.g, similar σ* to avoid different $[\alpha/Fe]$*; weak AGN; deep Chandra observations to effectively remove LMXBs) and by rigorously analyzing the data (extracting X-rays only from r < 30" to avoid a background problem; do not arbitrarily tying different elements), we find that [Si/Fe] is close to 1.5-2 solar in young E's (NGC 720 and NGC 3923), while [Si/Fe] is very close to solar in old E's (e.g, N4472, N4649). Given the limited sample and related uncertainties, our result is consistent with the expectation.

Finally, we note that while for X-ray faint galaxies the absolute abundances of individual elements are uncertain and controversial, the abundance ratio is better constrained because of strong correlations between errors of different elements.

References

Kim, D.-W. & Fabbiano, G. 2004, *ApJ* 613, 933
Thomas, D. Maraston, C., Bender, R., & de Oliveira, C. M. 2005, *ApJ* 621, 673

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Suzaku observation of the metallicity in the interstellar medium of NGC 1316

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Metal abundances of the hot X-ray emitting interstellar medium (ISM) include important information to understand the history of star formation and evolution of galaxies. The metals are mainly synthesized by Type Ia (SNe Ia) and stellar mass loss in elliptical galaxies. The productions of stellar mass loss reflect stellar metallicity. SNe Ia mainly product Fe. Therefore, the abundance pattern of ISM can play key role to investigate the metal enrichment history.

S0 galaxies, which are intermediate between ellipticals and spirals, are similar to elliptical galaxies in their optical spectra. Nevertheless, S0's in the cluster environment may have been changed from spiral galaxies when falling into clusters. X-ray observations are expected to provide a clue to this issue, because we can measure the metals accumulated over the Hubble time.

We investigated metal abundances of the hot ISM in the nearby S0 galaxy, NGC1316 (Fornax A), in the Fornax group. According to Goudfrooij et al. (2001), several galaxies may have merged into this galaxy 3 Gyr ago. We used a 43.9 ks of archival data achieved with the Suzaku satellite, because the XIS instrument of Suzaku is particularly suitable for the spectroscopy of extended X-ray emission with a low surface brightness.

The derived abundance pattern of O, Ne, Mg, Si against Fe of the ISM is close to that of new solar abundance of Lodders (2003). Furthermore, the abundance pattern of NGC 1316 is consistent with those of elliptical galaxies measured with Suzaku. This result indicates that the total amount of present stellar mass loss and SN Ia is similar between NGC 1316 and elliptical galaxies. In contrast, the abundance pattern of the ISM in NGC 4382, a S0 galaxy with an ISM temperature of 0.3 keV, is different from that of NGC 1316 (Nagino et al. in prep). These difference may be attributed to morphology types or system masses. We need more sample of S0 and elliptical galaxies to investigate the difference.

References

Goudfrooij, P., Mack, J., Kissler-Patig, M., Meylan, G., & Minniti, D. 2001a, *MNRAS* 322, 643
Hayashi, K., Fukazawa, Y., Tozuka, M., Nishino, S., Matsushita, K., Takei, Y., & Arnaud, K. A. 2009, arXiv:0907.2283
Lodders, K. 2003, *ApJ* 591, 1220
Matsushita, K., et al. 2007, *PASJ* 59, 327
Tawara, Y., Matsumoto, C., Tozuka, M., Fukazawa, Y., Matsushita, K., & Anabuki, N. 2008, *PASJ* 60, 307

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Fossil groups of galaxies: Are they groups? Are they fossils?

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Abstract. Fossil groups present a puzzle to current theories of structure formation. Despite the low number of bright galaxies, their high velocity dispersions and high T_X indicate cluster-like potential wells. Measured concentration parameters seem very high indicating early formation epochs in contradiction with the observed lack of large and well defined cooling cores. There are very few fossil groups with good quality X-ray data and their idiosyncrasies may enhance these apparent contradictions. The standard explanation for their formation suggests that bright galaxies within half the virial radii of these systems were wiped out by cannibalism forming the central galaxy. Since dry mergers, typically invoked to explain the formation of the central galaxies, are not expected to change the IGM energetics significantly, thus not preventing the formation of cooling cores, we investigate the scenario where recent gaseous (wet) mergers formed the central galaxy injecting energy and changing the chemistry of the IGM in fossil groups. We show a test for this scenario using fossil groups with enough X-ray flux in the *Chandra X-ray Observatory* archive by looking at individual metal abundance ratio distributions near the core. Secondary SN II powered winds would tend to erase the dominance of SN IA ejecta in the core of these systems and would help to erase previously existing cold cores. Strong SN II-powered galactic winds resulting from galaxy merging would be trapped by their deep potential wells reducing the central enhancement of SN Ia/SN II iron mass fraction ratio. The results indicate that there is a decrement in the ratio of SN Ia to SN II iron mass fraction in the central regions of the systems analyzed, varying from $99\pm1\%$ in the outer regions to $85\pm2\%$ within the cooling radius (Figure 1) and would inject enough energy into the IGM preventing central gas cooling. The results are consistent with a scenario of later formation epoch for fossil groups, as they are defined, when compared to galaxy clusters and normal groups.

Keywords. galaxies: clusters: general, X-rays: galaxies: clusters, surveys

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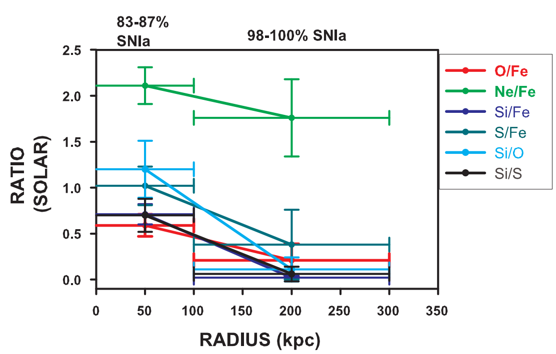

Figure 1.

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A large X-ray sample of fossil groups

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Abstract. We present Chandra snapshot observations of the first large X-ray sample of optically identified fossil groups. For 9 of 14 candidate groups, we are able to determine the X-ray luminosity and temperature, which span a range typical of large ellipticals to rich groups of galaxies. We discuss these initial results in the context of group IGM and central galaxy ISM evolution, and we also describe plans for a deep X-ray follow-up program.

Keywords. galaxies: clusters: general, X-rays: galaxies: clusters, surveys

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Fossil groups (FGs) are systems dominated by a single, giant elliptical galaxy, yet their X-ray emission indicates a deeper cluster-scale gravitational potential. They are thought to be old, undisturbed galaxy groups, however these systems may be younger or more active than previously thought (see Dupke et al. in these proceedings). These results are complicated by the small number of FGs with deep X-ray data.

To address this, we have constructed a sample of 15 FG candidates from the maxBCG cluster catalog (Koester et al. 2007), using the criteria $0.09 < z < 0.15$, $L_{\rm BCG} > 9 \times 10^{11} L_\odot$, and $\Delta i > 2.0$ between the BCG and second ranked galaxy within $R_{200}/2$ (see Figure 1). We have obtained 5–10 ksec *Chandra* snapshot observations of 14 targets, and we detect diffuse X-ray emission from 11 of them at $> 90\%$ confidence, measuring T_X for 9 of these. One detection is shown in Figure 2. The measured L_X and T_X are similar to what is expected for groups of galaxies. Deep follow-up with *XMM* is necessary to measure T_X profiles, surface brightness profiles, concentration, and abundances, thereby constraining the formation mechanism of these peculiar but numerous systems.

References

Koester, B.P. 2007, *ApJ*, 660, 239

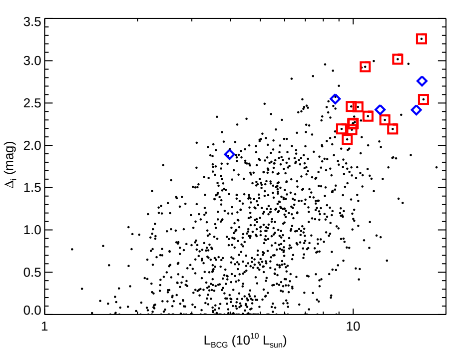

Figure 1. Magnitude differential vs. BCG luminosity for all maxBCG clusters with $9 < N_{200} < 25$; open squares identify the 15 FG candidates. Diamonds show known FGs.

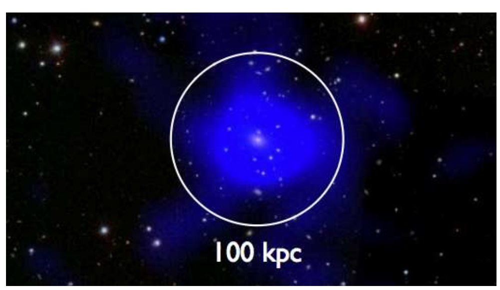

Figure 2. SDSS J0856+0553, a $z = 0.09$ FG candidate. The X-ray image is plotted over the SDSS g, r, i composite image.

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Feedback and environmental effects in elliptical galaxies

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Abstract. The role of the environment of an elliptical galaxy on its hot interstellar gas is discussed. In general, the X-ray halos of early-type galaxies tend to be smaller and fainter in denser environments, with the exception of group-central galaxies. X-ray observations show many examples of nearby galaxies which are undergoing gas stripping. On the other hand, most bright galaxies in clusters do manage to retain small coronae of X-ray emission. Recent theoretical and observational results on the role of feedback from AGN at the centers of elliptical galaxies on their interstellar gas are reviewed. X-ray observations show many examples of X-ray holes in the central regions of brightest-cluster galaxies; in many cases, the X-ray holes are filled with radio lobes. Similar radio bubbles are seen in groups and individual early-type galaxies. "Ghost bubbles" are often seen at larger radii in clusters and galaxies; these bubbles are faint in high radio frequencies, and are believed to be old radio bubbles which have risen buoyantly in the hot gas. Low frequency radio observations show that many of the ghost bubbles have radio emission; in general, these long wavelength observations show that radio sources are much larger and involve greater energies than had been previously thought. The radio bubbles can be used to estimate the total energy output of the radio jets. The total energies deposited by radio jets exceed the losses from the gas due to radiative cooling, indicating that radio sources are energetically capable of heating the cooling core gas and preventing rapid cooling.

Keywords. galaxies: clusters: general — cooling flows — galaxies: elliptical and lenticular, cD — galaxies: halos — galaxies: ISM — X-rays: galaxies — X-rays: galaxies: clusters

1. Environmental Effects on X-ray Emission

Given the wide range in X-ray luminosities of early-type galaxies of a given optical luminosity, the question naturally arises as to whether part of this dispersion might be due to the effects of environment on their X-ray emission. White & Sarazin (1991) suggested that elliptical galaxies in dense environments were fainter than those in sparse regions. In this and most subsequent studies, the local density was characterized by the projected galaxy density in the region around the target galaxy. Brown & Bregman (2000) argued that early-type galaxies in dense regions were more luminous; their sample included a number of group-center ellipticals. Some studies, mainly using ROSAT data, found no correlation (e.g., O'Sullivan *et al.* 2001). More recent Chandra studies of groups and clusters (e.g, Jeltema *et al.* 2008; Sun *et al.* 2007) seem to confirm a general anti-correlation of local density and X-ray luminosity. Observations of several galaxies in nearby clusters show evidence for ram pressure stripping; examples include M86 (Randall *et al.* 2008) and NGC 4552 (Machacek *et al.* 2006). However, despite the efficiency of stripping, most bright early-type galaxies in clusters do retain small coronae (Sun *et al.* 2007).

2. AGN Feedback in Early-Type Galaxies

In recent years, evidence has been found for a coupling between supermassive black holes (SMBHs) in the centers of galaxies, and their galaxy hosts. First, the masses of the SMBHs are proportional to the bulge mass of the host, suggesting that star formation and SMBH accretion are connected. Second, the luminosity function of galaxies falls below that expected for dark matter halos at high masses in a way that can be understood if AGN suppress star formation in massive galaxies. Finally, less gas cools to low temperatures at the centers of cool core clusters, groups, and individual ellipticals than expected unless something heats the gas, and AGNs are the leading candidates. In cool core clusters, X-ray deficits ("radio bubbles") have been found at the locations of the lobes of the radio sources associated with the brightest cluster galaxies (BCGs; Fabian *et al.* 2006; Blanton *et al.* 2001); similar radio bubbles are seen in groups and individual elliptical galaxies. "Ghost bubbles"' at larger radii are also seen which lack high frequency radio emission. These are thought to be older radio bubble which have risen buoyantly through the hot gas. Recent low frequency radio observation often show that the ghost bubbles are filled with long wavelength radio emission. Recent examples include Abell 2597 (Clarke *et al.* 2005) and Abell 262 (Clarke *et al.* 2009).

Radio bubbles in clusters and ellipticals allow the determination of the total kinetic energy output of the radio jets. The energy injected by the jets must at least equal the work needed to inflate the bubbles plus the internal energy associated with their pressure plus any energy in shocks in the surrounding medium. In general, these energies greatly exceed the synchrotron radio emission from the AGN, and the energies in the radio lobes are much greater than the values expected from equipartition. These estimates indicate that radio jets in cluster BCGs and ellipticals deposit enough energy to balance radiative cooling in these systems (Dunn & Fabian 2006; Rafferty *et al.* 2006). The mechanisms by which the radio sources heat the X-ray gas are uncertain, although heating by sound waves and weak shocks is a possibility. Recent observations of Abell 2052 (Blanton *et al.* 2009) show X-ray ripples which are similar to the features seen in the Perseus cluster.

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References

Blanton, E. L., Sarazin, C. L., McNamara, B. R. & Wise, M. W. 2001, *ApJ* 558, L15
Blanton, E. L. *et al.* 2009, *ApJ* 697, L95
Brown, B. A. & Bregman, J. N. 2000, *ApJ* 539, 592
Clarke, T. E. *et al.* 2009 *ApJ* 625, 748
Clarke, T. E. *et al.* 2009 *ApJ* 697, 481
Dunn, R. J. H. & Fabian, A. C. 2006, *MNRAS* 373, 959
Fabian, A. C., *et al.* 2006, *MNRAS* 366, 417
Jeltema, T. E., Binder, B., Mulchaey, J. S. 2008, *ApJ* 679, 1162
Machacek, M., Nulsen, P. E. J., Jones, C. & Forman, W. R. 2006 *ApJ* 648, 947
O'Sullivan, E., Forbes, D. A. & Ponman, T. J. 2001, *MNRAS* 328, 461
Randall, S., *et al.* 2008, *ApJ* 688, 208
Rafferty, D., McNamara, B. R., Nulsen, P. E. J. & Wise, M. W. 2006, *ApJ* 652, 216
Sun, M., Jones, C., Forman, W., Vikhlinin, A., Donahue, M. & Voit, M. 2007, *ApJ* 657, 197
White, R. E. III & Sarazin, C. L. 1991, *ApJ* 367, 476

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Scaling properties of the hot gas in early-type galaxies

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Abstract. We examine the processes responsible for the large scatter in the X-ray/optical luminosity scaling relation of early-type galaxies.

1. The L_X-$L_{\rm opt}$ relation in early-type galaxies

Optically brighter galaxies tend to have higher X-ray luminosity. The largest sample yet presented, by Ellis & O'Sullivan (2006), is shown in Fig.1. It is apparent that: (a) there is a factor ∼100 scatter in L_X around the mean relation; (b) the relation steepens at high L_B, where most galaxies lie well above the discrete source line – their X-ray emission dominated by a diffuse hot gas component; (c) many of these luminous galaxies are the bright central members of groups or clusters (BGGs or BCGs). Here we briefly examine a number of possible causes for the large scatter apparent in this relation.

2. Sources of scatter in L_X-$L_{\rm opt}$

Star formation history – Recent star formation can considerably raise the blue luminosity of a galaxy, at a given stellar mass. However, Ellis & O'Sullivan (2006) showed that replacing L_B by K-band luminosity in Fig.1, results in a very similar scatter.

X-ray data quality – The X-ray data used by Ellis & O'Sullivan (2006) came from ROSAT. However, smaller samples of higher quality datasets from Chandra and XMM (e.g. Diehl & Statler (2007), Sun (2009)) show similar scatter in the relation.

Galaxy age – It has been recognised for some years (e.g. O'Sullivan et al (2001)) that spectroscopically young ellipticals have low X-ray luminosity. The compilation of Sansom et al (2006) shows a decline in L_X/L_B for 1-2 Gyr after a substantial burst of star formation (e.g. following a galaxy merger), presumably due to hot gas being dispersed by the energetic galaxy winds known to be associated with starbursts. However, galaxies with larger spectroscopic ages show no age trend, and a wide scatter in L_X/L_B.

Galaxy environment – Ellis & O'Sullivan (2006) found no clear environmental trend in L_X/L_B, apart from the high values apparent in BGGs and BCGs. However, recent studies with Chandra, which is better able to resolve galaxy emission, show that L_X/L_B is suppressed by a factor ∼3-4 in non-central galaxies within both clusters (Sun et al (2007)) and groups (Jeltema et al (2008)). This presumably results from stripping of hot gas within dense environments. The properties of *isolated* early-type galaxies provide a probe of whether environmental effects can account for the bulk of the scatter in L_X/L_B. Memola et al (2009) assembled L_X-L_B data for 27 isolated ellipticals, and found a good deal of scatter. However, excluding probable 'fossil groups' (Ponman et al (1994)) and upper limits, the remaining sample is small. Preliminary results from a Chandra study of

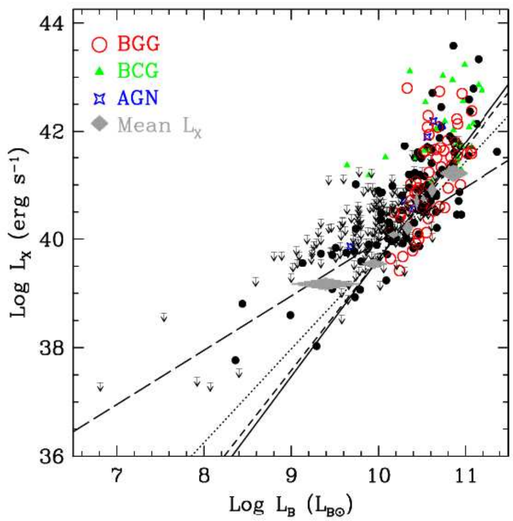

Figure 1. L_X-L_B plot for 401 early-type galaxies from Ellis & O'Sullivan (2006). The long dashed line is the discrete source contribution estimated by Kim & Fabbiano (2004), other lines show fits to various subsets of the sample, and the grey diamonds represent the mean L_X in a series of L_B bins.

isolated ellipticals currently underway indicate (Humphrey private communication) that significant L_X/L_B scatter is still present, but may be limited to a factor ∼10.

Halo mass – Mathews et al (2006) suggested that the primary factor driving L_X is the mass of the dark halo surrounding a galaxy. For a sample of ellipticals (mostly BGGs) they found that L_X/L_K increased with X-ray derived virial mass. This is consistent with the earlier result , that BGGs have L_X/L_B ratios much higher than other elliptical galaxies. The study of NGC 4555 by O'Sullivan & Ponman (2004) shows that isolated ellipticals can also possess substantial dark matter halos.

Feedback – For a given dark halo mass, the gas content can be affected by feedback processes. Injection of energy raises the entropy, resulting in low density and X-ray luminosity. The low L_X/L_B ratio seen in ellipticals with recent star formation is probably an example of this. AGN feedback may have similar effects, if it can couple effectively to the surrounding gas. Sun (2009) finds that all radio-bright elliptical galaxies contain hot gas coronae – either compact or extensive. He postulates that AGN jets can couple to the extended hot halos found in groups or clusters, but not to compact gas cores.

References

Diehl S. & Statler T.S. 2007, *ApJ* 668, 150
Ellis S.J. & O'Sullivan E.J. 2006, *MNRAS* 367, 627
Jeltema T.E. et al 2008, *ApJ* 679, 1162
Kim D-W. & Fabbiano G. 2004, *ApJ* 611, 846
Mathews W.G. et al 2006, *ApJ* 652, L17
Memola E. et al 2009, *A&A* 497, 359
O'Sullivan E.J., Forbes D.A. & Ponman T.J. 2001, *MNRAS* 324, 420
O'Sullivan E.J. & Ponman T.J. 2004, *MNRAS* 354, 935
Ponman T.J. et al 1994, *Nature* 369, 462
Sansom A. et al 2006, *MNRAS* 370, 1541
Sun M. et al 2007, *ApJ* 657, 197
Sun M. 2009, *arXiv:0904.2006*

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AGN feedback in numerical simulations

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Abstract.
The passively evolving stellar population in elliptical galaxies (Es) provides a continuous source of fuel for accretion on the central supermassive black hole (SMBH), which is 1) extended over the entire galaxy life (but declining with cosmic time), 2) linearly proportional to the stellar mass of the host spheroid, 3) summing up to a total gas mass that is > 100 times larger than the currently observed SMBH masses, 4) available independently of merging events. The main results of numerical simulations of Es with central SMBH, in which a physically based implementation of radiative and mechanical feedback effects is considered, are presented.

Keywords. X-rays: ISM - Galaxies: cooling flows - Galaxies: active

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In a series of papers (Ciotti & Ostriker 2007; Ciotti, Ostriker & Proga 2009; Pellegrini, Ciotti & Ostriker 2009; Shin, Ciotti & Ostriker 2009; Jiang *et al.* 2009; see also Ciotti 2009) we study, with a high-resolution 1-D hydrodynamical code, the evolution of the ISM in Es under the action of SNIa heating, thermalization of the stellar mass losses, and feedback from the central SMBH. The cooling and heating functions include photoionization and Compton effects, radiation pressure is evaluated by solving the transport equation, mechanical feedback is produced by a physically based luminosity-dependent nuclear wind and jet, and star formation is also allowed. The recycled gas from the aging stars of the galaxy cools and collapses towards the center, a star-burst occurs and the central SMBH is fed. The energy output from the central SMBH pushes matter out, the accretion rate drops precipitously and the expanding matter drives shocks into the ISM. Then the resulting hot bubble ultimately cools and the consequent infall leads to renewed accretion; the cycle repeats, with the galaxy being seen alternately as an AGN/starburst for a small fraction of the time and as a "normal" elliptical hosting an incipient cooling catastrophe for much longer intervals. No steady flow appears to be possible for Eddington ratios above $\simeq 0.01$: whenever the luminosity is significantly above this limit both the accretion and the output luminosity are in burst mode. Strong intermittencies are expected at early times, while at low redshift the models are characterized by smooth, very sub-Eddington mass accretion rates punctuated by rare outbursts. One of the general consequences of our exploration is the fact that the recycled gas from dying stars can induce substantial QSO activity, even in the absence of external phenomena such as galaxy merging, while accretion feedback can be strong enough to solve the "cooling-flow" problem and to maintain the mass of the SMBH on the observed range of values.

References

Ciotti, L. 2009, *La Rivista del Nuovo Cimento* 32, n.1, 1
Ciotti, L. & Ostriker, J.P. 2007, *ApJ* 665, 1038
Ciotti, L., Ostriker, J.P., Proga, D. 2009, *ApJ* 699, 89
Pellegrini, S., Ciotti, L., Ostriker, J.P. 2009, *Advances in Space Research* 44, 340
Shin, M.-S., Ostriker, J.P., Ciotti, L. 2009, *arXiv0905.4294*
Jiang, Y.F., Ciotti, L., Ostriker, J.P., Spitkovsky, A. 2009, *arXiv0904.4918*

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Effects of environment on the properties of cluster galaxies via ram pressure stripping

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Abstract. We study the effect of ram pressure stripping (RPS) on the colours, cold gas content and star formation of galaxies in clusters, using a combination of N-Body/SPH simulations of galaxy clusters and a semi-analytic model of galaxy formation that includes the effect of RPS.

Keywords. Galaxies: clusters: general, galaxies: evolution, intergalactic medium

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In the local universe, galaxy clusters have larger fractions of red, early-type galaxies than the field (Baldry *et al.* 2006) and star formation is suppressed in denser environments (Kauffmann *et al.* 2004). This could be caused by removal of cold gas from galaxies via ram pressure stripping (RPS) by the intracluster medium (ICM) (Gunn & Gott 1972).

We have studied the influence of RPS on galaxy properties using a hybrid model that combines non-radiative N-Body/SPH cosmological simulations of clusters with masses in the range $10^{14} - 10^{15} h^{-1}$ M$_\odot$ (Dolag *et al.* 2005) and a semi-analytic model of galaxy formation (Lagos *et al.* 2008) in which we implement the RPS process. We use the information provided by the gas particles in the simulations to obtain the properties of the ICM and the velocities of galaxies relative to it. This results in a more self-consistent method than previous works, which relied on analytical approximations.

We have run two sets of models, with and without RPS, with all the parameters involved in other physical processes remaining unchanged. Our results show that RPS is more important in the more massive haloes, but becomes significant only at $z \lesssim 0.5$. In the RPS model, star formation activity is strongly suppressed in dwarf galaxies ($M_* < 10^{10} h^{-1}$ M$_\odot$), which lose most of their ISM and become red and passive on a shorter timescale. RPS could then be responsible for the loss of gas in cluster dE galaxies (Boselli *et al.* 2008). Mean colours of the red and blue sequences do not change significantly, but the number of faint red galaxies increases in the RPS model for $z < 1$. The fraction of gas poor galaxies in regions around clusters increase from ~5% to ~20%, indicating that RPS acts to some degree in group environments prior to cluster infall.

References

Baldry, I. K., *et al.* 2006, *MNRAS* 373, 469
Boselli, A. *et al.* 2008, *ApJ* 674, 742
Dolag, K. *et al.* 2005, *MNRAS* 364, 753
Gunn, J. E., Gott, J. R. 1972, *ApJ* 176, 1
Kauffmann, G. *et al.* 2004, *MNRAS* 353, 713
Lagos, C. D. P., Cora, S. A., Padilla, N. D. 2008, *MNRAS* 388, 587

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AGN feedback in details and in surveys

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Abstract. I will review the new details on AGN feedback revealed by recent Chandra observations of M84 and present its theoretical modeling. Using the results of COSMOS survey I will present the direct measurement of halo occupation statistics for radio galaxies.

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Warm ionized ISM in the bulge of Andromeda galaxy

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Abstract. We demonstrate that unresolved X-ray emission from the bulge of M31 is composed of at least three different components: (i) Broad-band emission from a large number of faint sources – mainly accreting white dwarfs and active binaries, associated with the old stellar population, similar to the Galactic Ridge X-ray emission of the Milky Way. (ii) Soft emission from ionized gas with temperature of about ~ 300 eV and mass of $\sim 4 \times 10^6$ $M_\odot$. The gas distribution is significantly elongated along the minor axis of the galaxy suggesting that it may be outflowing in the direction perpendicular to the galactic disk. The shadows cast on the gas by spiral arms and the 10-kpc star-forming ring confirm large off-plane extent of the gas. (iii) Hard unresolved emission from spiral arms, most likely associated with protostars and young stellar objects located in the star-forming regions.

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Constraints on turbulent pressure in the X-ray halos of giant elliptical galaxies from resonant scattering

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Abstract.
The dense cores of X-ray emitting gaseous halos of large elliptical galaxies with temperatures below about 0.8 keV show two prominent Fe XVII emission features, which provide a sensitive diagnostic tool to measure the effects of resonant scattering. We present here high-resolution spectra of five bright nearby elliptical galaxies, obtained with the Reflection Grating Spectrometers (RGS) on the XMM-Newton satellite. The spectra for the cores of four of the galaxies show the Fe XVII line at 15.01 Angstrom being suppressed by resonant scattering. The data for NGC 4636 in particular allow the effects of resonant scattering to be studied in detail. Using deprojected density and temperature profiles for this galaxy obtained with the Chandra satellite, we model the radial intensity profiles of the strongest resonance lines, accounting for the effects of resonant scattering, for different values of the characteristic turbulent velocity. Comparing the model to the data, we find that the isotropic turbulent velocities on spatial scales smaller than about 1 kpc are less than 100 km/s and the turbulent pressure support in the galaxy core is smaller than 5% of the thermal pressure at the 90% confidence level, and less than 20% at 99% confidence. Neglecting the effects of resonant scattering in spectral fitting of the inner 2 kpc core of NGC 4636 will lead to underestimates of the chemical abundances of Fe and O by about 10-20%.

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"My god, It's full of stars": Separating stars and gas in X-ray observations of elliptical galaxies

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Abstract.
We are peering into an isolated elliptical galaxy's past when we measure its hot gas component, as these galaxies are not expected to be sites of active star formation. Measuring gas temperatures and abundances versus location in the galaxy is difficult because blended populations of active binaries (such as LMXBs, CVs, and RS CVn) can be confused with gas emission. We can estimate stellar contributions from Milky Way sources and from nearby dim galaxies expected to have little hot gas. We apply this method to a sample of elliptical galaxies observed with *Chandra* and *XMM*, playing special attention to be self-consistent.

Keywords. galaxies: ISM, galaxies: elliptical and lenticular, CD, galaxies: fundamental parameters, X-rays: galaxies

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Towards a larger sample of fossil groups and their luminosity functions

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Abstract.
Fossil Groups are groups (or clusters) of galaxies optically dominated by an elliptical galaxy immersed in an extended and luminous X-ray halo, in which the magnitude gap between the two brightest galaxies within half of the virial radius is greater than 2 in the r-band. Recent studies suggest that the central galaxies in Fossil Groups are most likely formed by mergers of galaxies that had lost energy by dynamical friction, and that the velocity dispersion and X-rays properties of these systems are reminiscent of those of clusters, more than of groups of galaxies. Here we report on the preliminary results of our search for new fossil groups and confirmation of candidates suggested in the literature by acquiring spectroscopy of the member galaxies. We also present a photometric study of the luminosity function of a sample of 10 group candidates using the SDSS database. A Schechter function describes well the individual luminosity functions, with an alpha parameter ranging from 0.5 to -1.5. Our fossil groups have a range of masses and properties ranging from groups to clusters.

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The mass distribution of massive, X-ray luminous, elliptical galaxies

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Abstract.
The advent of Chandra with its high resolution and XMM-Newton with its large collecting power and field-of-view have enabled the temperature and density profiles of massive nearby ellipticals to be reproduced to unprecedented detail. This allows the derivation of reliable mass profiles to large radii. We use temperature and density profiles derived from Chandra and XMM-Newton observations for a sample of nearby, X-ray luminous elliptical galaxies (NGC 5846, NGC 1399 and NGC 4649) whose X-ray maps are relatively quiescent. We then assume hydrostatic equilibrium and apply a non-parametric method to obtain the mass profile out to at least ten times the half-light radii. This requires a determination of the local gradient in the pressure, and we believe our method is preferable to the more traditional parametric methods, as the latter commonly underestimate the true error. We fit two-component mass models to probe the stellar and dark matter contributions to the total mass content. Then, using optical photometric data and kinematic constraints provided by long-slit kinematics, integral-field kinematics and radial velocities of planetary nebulae, we create dynamical models in the derived mass profile to probe the orbital structure deep into the halo. The orbital structure serves as an imprint of the formation channels of the galaxy thus throwing light on their evolution history.

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