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OBSERVATIONS OF A Z = 0.9 CLUSTER OF GALAXIES

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Abstract.
The cluster Cl 1257+4738 was found by comparing a ROSAT image with red ground based images, taken to determine if the red galaxies were young dusty ones or old early type galaxies. This adds another cluster to the handful of clusters with z larger than about 0.9. Each one provides new insights as to the relationship between the evolution of galaxies and the ICM. We acquired Chandra, XMM-Newton, Spitzer IRAC plus MIPS 24 data to study this relationship between galaxies and the ICM.

1 Introduction

It is becoming increasingly clear that the redshift range between ∼0.8 and 1.0 is particularly interesting for comparing star formation histories of galaxies in clusters and in the field, as well as studying relationship of galaxy infall and heating of the intracluster medium (e.g. Gilbank 2008).

Cluster formation is thought to start by $z = 2$ (e.g. Fassbender 2008). We might expect selection effects to favor finding the more X-ray luminous clusters when observing apparently faint clusters at high redshift. This is not the case, however. For example, the compilation by Ota et al. (2006) shows that 50% of the cluster sample between $z = 0.3$ and 0.56 have a bolometric X-ray luminosity ($L_{X,bol}$) greater than 10^{45} ergs s^{-1} compared to only 20% of the sample above $z = 1$ (e.g. Fassbender 2008). These X-ray luminosity observations suggest that in the redshift range between about 1 and 2, clusters are growing, but have not reached their peak X-ray luminosity even by $z \sim 1$.

In comparison, we estimate the free fall times for clusters (with a typical radius of 1 Mpc and masses between $0.5 - 5 \times 10^{14}$ $M_\odot$) of the order of 2.2 Gy − 0.7 Gyr (Sarazin 1986). The free fall time goes as the square root of the inverse of the cluster mass. In contrast, the elapsed time between $z = 2$ (the assumed initial infall epoch) and 1 is on the order of about 2.6 Gyrs (Ω_m=0.27, Ω_Λ=0.73, H_0=71 km/s/Mpc). Thus, the redshift range near 1 can be seen on theoretical grounds to favor finding clusters of $0.5 - 5 \times 10^{14}$ $M_\odot$ that have just completed their infall, while higher mass systems should be more mature.

In the process of our search for moderately distant (i.e. $z \sim 1$) clusters of galaxies that are detectable via their X-ray emission, we report here the discovery of a cluster with $z = 0.866$, RX J1257.2+4738 (hereafter for brevity referred to as RX J1257).

We report here a preliminar study based on extensive space-based and ground-based observations including Chandra, XMM, *Spitzer*, Gemini, Subaru, and ARC. That work will be reported in a forthcoming paper.

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2 Observations

We got Chandra (37 ksec) and XMM (15.94 ksec) X-ray data. These data allowed us to remove point sources and to fit a temperature of the intracluster gas ($3.6^{+2.9}_{-1.2}$ keV).

We got visible (i', z'), near infrared (J, Ks) and infrared (Spitzer: 4 IRAC bands and 24μ MIPS) data. This allowed us to compute photometric redshifts in order to discriminate between cluster members and field galaxies. We extracted a catalog of objects using Sextractor in double-image mode.

Finally, we measured 45 Gemini/Gmos spectroscopic redshifts along the cluster line of sight.

3 Cluster mass and substructures

We found a cluster mass of about $1 - 5 \times 10^{14}$ $M_\odot$. We also applied the SernaGerbal (SG: Serna & Gerbal 1996) method to our redshift catalog. The method reveals the existence of 2 groups, constituting independent structures inside the redshift catalog. The first group is a 3 galaxy low mass structure (4.5×10^{12} $M_\odot$) located beyond the cluster outskirts. The other group is located in the cluster center, roughly coincident with the X-ray emission, with a mass of $6.1 \times 10^{14} M_\odot$ (velocity dispersion of 598 km s^{-1} computed with 18 galaxies). Within this group, 2 other subgroups are detected, with masses of $\sim 10^{14}$ (velocity dispersion of 289 km s^{-1}) and 2.2 10^{13} $M_\odot$ (velocity dispersion of 255 km s^{-1}). These masses from X-ray and from galaxy velocity dispersion measurements are consistent and are in the correct range to call RX J1257 a rich cluster. However, since the velocity dispersion of the substructures are based on only 5 and 3 galaxies, respectively, these masses should only be taken to demonstrate the concistency between the X-ray estimated mass and the velocity dispersion mass.

4 Cluster collapse

We judge that this cluster is just in the process of formation and has not become relaxed because of: (a) the large fraction of galaxies that lie outside the core detectable X-ray emission or that lie inside and that are late type objects; (b) the bimodal nature of both the X-ray emission and the galaxy distribution; (c) the majority of the spectroscopically confirmed cluster members (more than 90%) were detectable in the MIPS 24 μm channel which suggest the presence of dust and star formation with some even being within the X-ray contours that indicates the system is young; (d) the detected level of substructures using the Serna-Gerbal method; (e) the kT on the high side relative to the predicted $L_{X,bol}$-kT relation line.

5 A comprehensive picture

The results briefly presented here combined with previous work on IR-X-ray observations of cluster of galaxies leads to a scenario in which the majority of the red galaxies in high z clusters are red due to dust rather than being red and dead. The less massive the cluster, the younger it will be in terms of having not yet completed infall, compared to more massive clusters. Then a system such as RX J1257 should, as we found here, have a high fraction of red dusty galaxies. Some of these will even be inside the core region as the cluster is still so young. The more massive the cluster, the fewer of these galaxies will be found in the core, and the more quickly the galaxies will progress from being red to blue to being red again.

References

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