A WISE-Chandra view of baryon content evolution in clusters

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abstract

We study the relationship between two major baryonic components in galaxy clusters, namely the galaxies and the intracluster medium (ICM), using 94 clusters that span the redshift range 0-0.6. Accurately measured total and ICM masses from Chandra observations, and stellar masses derived from Wide-Field Infrared Survey Explorer (WISE) and Two-Micron All-Sky Survey (2MASS) allow us to trace the evolution of cluster baryon content in a self-consistent and self-contained fashion.

We find that the evolution of the ICM mass–total mass relation is consistent with the expectation of self-similar model, while there is no evidence for redshift evolution in the stellar mass–total mass relation. This suggests that the clusters acquire their gas and galaxy contents in different ways.

introduction

There have been many studies of cluster baryon content at z > 0. Many such studies use large cluster samples at high redshifts in short supply. The first attempt has been made with the X-ray selected clusters at z > 0.1-0.2 detected in COSMOS field (Giordani et al. 09). Our analysis is complementary in the sense that we probe the high mass end, with accurate X-ray measurements.

For k-correction, we use the updated version of Bruzual & Charlot (03) model to obtain predictions for a single population formed in a burst at z=3, with Kroupa initial mass function (IMF). The model is normalized such that it gives adequate description for the evolution of m* (characteristic magnitude in luminosity function, LF) at 2.2, 3.6, and 4.5 microns (blue, green, and red points below; data from Mancone et al. 10).

stellar mass

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scaling relations

Our dataset allows us to examine three scaling relations with a large cluster sample across a wide redshift range:
- stellar mass vs total mass
- ICM mass vs total mass
- stellar mass vs ICM mass

We show below the total baryon fraction, stellar mass fraction, and the M500–M500 correlation. In these figures, green points are z < 0.1 clusters, while blue ones are at z = 0.1-0.6 (solid: Maughan sample; open: Vikhlinin sample).

discussion

evolution of baryons in clusters

The evolution of ICM mass–total mass relation can be understood in the context of self-similar evolution (SSE, see Vikhlinin et al. 09). Let us denote MICM–M500, where w = 0.14 based on our data. Introducing the nonlinear mass scale σ500, at which the rms fluctuation of linear power spectrum equals to 5σ(d), where δ = 0.68 and D(z) is the growth factor, we expect the ICM mass fraction fICM to be the same for systems of the same M500, at different redshifts under SSE. We then have fICM(M500,σ500).

We have thus shown that the two main baryonic components in clusters appear to evolve differently: while the ICM evolve according to self-similar expectation, the stellar mass–total mass relation remains similar up to z = 0.6 (that is, γ2 is consistent with zero). The latter behavior is consistent with the finding of Giordani et al. (09).

On the face value, this may indicate that clusters acquire their gas and galaxy content in different ways. Or, it implies strong dynamical evolution (e.g., tidal stripping) of galaxies once they become cluster members. It is thus critical for future studies to include the contribution from intracluster stars (e.g., Gonzalez et al. 07). Unfortunately, with the depth of WISE all-sky survey, we would not be sensitive to this stellar population. Dedicated observations with HST WFC3, or with the upcoming Subaru HyperSuprime Cam survey should be able to address this issue.

systematics

The greatest systematic uncertainty in our analysis is the choice of IMF. For example, using the Chabrier IMF would result in stellar mass-to-light ratio that is 40% lower, thus affecting the total stellar mass fraction measurements. Any systematic variation of IMF with galaxy mass or morphology would also affect the slope of the M500–M IC M correlation.

references


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