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ICM METALLICITY EVOLUTION: EFFECTS OF DYNAMICAL PROCESSES

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RESUMEN

Presentamos un estudio sobre el origen de la evolución de la metalicidad del medio intracúmulo (MIC) mediante la aplicación de un modelo semi-analítico de formación de galaxias a simulaciones cosmológicas no-radiativas N-Body/SPH de cúmulos de galaxias. Los resultados obtenidos para un conjunto de cúmulos con masa virial de $\sim 1.5 \times 10^{15}\, h^{-1}\, M_{\odot}$ contribuyen a la interpretación teórica de recientes datos observacionales en rayos X, los cuales indican una disminución del contenido medio de hierro del gas intracúmulo al aumentar el corrimiento al rojo, z. Encontramos que esta evolución se debe principalmente a un aumento progresivo del contenido de hierro dentro de $\sim$ 15% del radio virial como resultado de procesos dinámicos. Los cúmulos han sido enriquecidos considerablemente a $z \sim 1$ con muy poca contribución por parte de formación estelar reciente. El gas de baja entropía que ha sido enriquecido a alto z converge hacia el centro del cúmulo contribuyendo a la evolución de los perfiles de metalicidad.

ABSTRACT

We present a study on the origin of the metallicity evolution of the intracluster medium (ICM) by applying a semi-analytic model of galaxy formation to N-Body/SPH non-radiative cosmological simulations of clusters of galaxies. The results obtained for a set of clusters with virial masses of $\sim 1.5 \times 10^{15}\, h^{-1}\, M_{\odot}$ contribute to the theoretical interpretation of recent observational X-ray data, which indicate a decrease of the average iron content of the intracluster gas with increasing redshift, z. We find that this evolution is mainly due to a progressive increase of the iron content within $\sim$ 15 per cent of the virial radius as a result of dynamical processes. The clusters have been considerably enriched by $z \sim 1$ with very low contribution from recent star formation. Low entropy gas that has been enriched at high z sink to the cluster centre contributing to the evolution of the metallicity profiles.

Key Words: cosmology: observations — galaxies: clusters: general — methods: numerical — X-rays: galaxies: clusters

1. INTRODUCTION

The intracluster medium (ICM) is a hot ($\sim 10^7$ K) and diffuse gas contained within the deep potential well of clusters of galaxies, which constitute the largest virialized structures of the Universe. This gas radiates energy through thermal Bremsstrahlung, which is detected in the X-ray band of the electromagnetic spectrum, characterized by the presence of emission lines from highly ionized iron (Fe XXV and Fe XXVI) at 6.6–7 keV. The average Fe abundance of the ICM is $\sim 0.5\, Z_{\odot}$ in the central regions of local X-ray clusters; we have used the more recent solar value of iron abundance by number $(\mathrm{Fe/H})_{\odot} = 2.82 \times 10^{-5}$ by Asplund et al. (2005). Observations of radial abundance profiles of different elements (Tamura et al. 2004; Vikhlinin et al. 2005) provide valuable constraints on the physical processes involved in the chemical enrichment of the ICM, being supernovae explosions the typical sources of metals that contaminate the intracluster gas (e.g., Renzini 1997).

A recent analysis of *Chandra* X-ray spectra of 56 clusters within the redshift range $0.3 \lesssim z \lesssim 1.3$ spanning temperatures $3 \lesssim k\mathrm{T} \lesssim 18$ keV allows to trace the evolution of the iron content of the ICM (Balestra et al. 2007). The results are based on the estimated average emission-weighted (EW) iron abundance of the ICM within the inner region delimited by $\sim 15-30$ per cent of the virial radius, R_{vir}. They find that, for $z \gtrsim 0.5$, the mean abundance of the ICM is approximately constant, with a

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value of $Z_{\rm Fe} \approx 0.4\ Z_{\odot}$. However, at lower redshifts ($0.3 \lesssim z \lesssim 0.5$), the EW iron abundance is significantly higher, reaching a value of $Z_{\rm Fe} \approx 0.64\ Z_{\odot}$.

Different theoretical approaches have been used so far aimed at studying the process of metal enrichment of the ICM (Ettori 2005; Loewenstein 2006; Calura et al. 2007). In order to interprete the current observed ICM metallicity evolution, we apply the hybrid model of chemical enrichment of the ICM described by Cora (2006).

2. MODEL

The hybrid model used for studying the chemical enrichment of the ICM combines non-radiative cosmological N-body/SPH simulations that contain galaxy clusters and a semi-analytic model of galaxy formation. The important feature of this hybrid model is the link between semi-analytic model results and the chemical enrichment of the diffuse gas component of the underlying N-body/SPH simulation. We pollute gas particles with metals ejected from the galaxies that have been generated by the semi-analytic model.

We consider a set of three simulated galaxy clusters (Dolag et al. 2005), with virial mass in the range $\simeq (1-2) \times 10^{15}\,h^{-1}\,M_{\odot}$. These clusters have been initially selected from a dark matter simulation of a cosmological box, having size of $479\,h^{-1}$ Mpc, for a cosmological model $\Omega_{\rm m} = 0.3$, $\Omega_{\Lambda} = 0.7$, $\rm H_o = 70$ km s^{-1} Mpc^{-1}, $\Omega_{\rm b} = 0.039$ for the baryon density parameter, and $\sigma_8 = 0.9$ for the normalization of the power spectrum. The simulation provides the merger trees of dark matter substructures used by the semi-analytic model to generate the galaxy population. The semi-analytic model includes gas cooling, star formation, and the contribution of energy and metals from supernovae type Ia and II. Some aspects of the semi-analytic model have been modified with respect to the version described in Cora (2006), specially those regarding the spreading of metals among gas particles (see Cora et al. 2008, for details).

3. RESULTS AND CONCLUSIONS

We evaluate the capability of our model to represent the chemical enrichment of the ICM by comparing the radial iron abundance profiles of the ICM constructed from simulated results at redshift $z = 0$ with a sample of nearby, relaxed galaxy clusters observed with *Chandra* (Vikhlinin et al. 2005). The local EW profiles show a good agreement with the trend traced by observations. The EW iron abundances become progressively lower with increasing redshift, with the main change occurring at radii $\lesssim 0.15\,R_{\rm vir}$, where the profiles become flatter.

Results on the evolution of iron content from Balestra et al. (2007) can be parametrized by a power law of the form $\sim (1+z)^{-1.25}$, which implies that the average iron content of the ICM at present epoch is a factor of ~ 2 larger than at $z \simeq 1.2$. Model results closely follow the trend denoted by this parametrization within the whole redshift range considered; mean EW iron abundances have been estimated from the iron content of gas particles contained within $0.15\ R_{\rm vir}$ from the centre of the cluster or of its progenitor, depending on the redshift considered. The observed mean metallicity evolution can be explained as being produced by the combination of an overall increase of the iron content within the virial radius of the main progenitor of the cluster, and the evolution of the slope of the central part of the iron abundance profiles ($\lesssim 0.15\ R_{\rm vir}$) since $z \sim 1$.

From the analysis of the relationships between iron abundances and entropy values of gas particles, we get a general picture on the development of metallicity profiles. Low entropy gas in infalling subgroups determine the maximum level of enrichment found in the cluster center at $z = 0$; it has been highly contaminated at high redshifts, when the metal ejecta from galaxies was considerably higher with respect to the present epoch. This dynamical process explains the evolution suffered by the metallicity profiles in their central parts, which cannot be accounted for by recent enhanced star formation activity.

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