METAL ENRICHMENT OF THE INTRA-CLUSTER MEDIUM: RAM-PRESSURE STRIPPING OF CLUSTER GALAXIES

W. DOMAINKO, W. KAPFERER, S. SCHINDLER, E. v. KAMPEN, S. KIMESWENGER, M. MAIR & M. RUFFERT

1 Institut für Astrophysik, Leopold-Franzens-Universität Innsbruck
Techniker Straße 25, A-6020 Innsbruck Austria

http://astrouibk.ac.at/astroneu/hydroskiteam/index.htm

2 Department for Mathematics and Statistics, University of Edinburgh
JCMB, Mayfield Road, Edinburgh, EH9 3JZ, UK

Abstract

We present numerical simulations of the dynamical and chemical evolution of galaxy clusters. X-ray spectra show that the intra-cluster medium contains a significant amount of metals. As heavy elements are produced in the stars of galaxies material from the galaxies must have been expelled to enrich the ambient medium. We have performed hydrodynamic simulations investigating various processes. In this presentation we show the feedback from gas which is stripped from galaxies by ram-pressure stripping. The efficiency, resulting spatial distribution of the metals and the time dependency of this enrichment process on galaxy cluster scale is shown.

1 Introduction

Clusters of galaxies contain a hot and thin plasma inbetween the cluster galaxies – the Intra-Cluster Medium (ICM) which can be observed in X-rays. X-ray spectra of the ICM show metal lines (Fukazawa et. al. 1998) which indicates that the gas is not only of primordial origin as metals are generally produced in stars. The amount of metals in the ICM is of the same order of magnitude as the amount of metals found in the cluster galaxies. This means that processed material from stars and supernovae must have been ejected into the ICM. Possible enrichment mechanisms of the ICM are the feedback from Intra-Cluster Supernovae (Domainko et al. 2004) and material expelled by cluster galaxies. Processes which can remove gas from cluster galaxies are ram-pressure stripping (Gunn & Gott 1972), galactic winds (De Young 1978), galaxy-galaxy interactions and jets from active galaxies. Two of these processes (ram-pressure stripping, galaxy-galaxy interactions) are triggered by
their surroundings whereas the other two processes (galactic winds and jets) are triggered by violent internal processes. The efficiency, time dependences and spatial distributions of these mechanisms are poorly understood. In this paper we investigate the effect of ram-pressure stripping on the chemical evolution of the ICM.

2 Numerical Method

We use combined N-body and Hydrodynamical simulations to compute the effect of different enrichment processes on the ICM. The simulations are performed on galaxy cluster scale to investigate the efficiency, time dependence and spatial distribution of the chemical evolution of the ICM. Large-scale structure formation is derived with a N-body tree code with an additional semi-numerical model for galaxy formation (van Kampen et al. 1999). On this background potential a shock capturing grid based PPM (Colella & Woodward 1984) hydrodynamic simulation is performed. The effect of ram-pressure stripping according to the local properties of the ICM and the properties of the galaxies as well as the effect of galactic winds (see Kapferer et al. this volume) are included in the calculations. The hydrodynamic simulation is obtained on four nested grids (Ruffert 1992). This technique allows to cover the cluster center where most of the stripping is expected to happen with high resolution (cell size comparable to galaxy size) and also to investigate the effect of gas rich galaxies falling in towards the cluster center (in e.g. hierarchical merger events). Metallicity is used as a tracer to follow the enriched material.

3 Ram-pressure stripping

Galaxies moving fast through an ambient medium (in galaxy clusters the ICM) can suffer from environmental interactions. In particular the Inter-Stellar Medium (ISM) of the galaxy is effected by the ram-pressure of a surrounding medium when its host galaxy moves with a sufficiently high velocity. Additionally the value of the ram-pressure also depends on the properties (density) of the ICM (the environmental influence will increase with increasing density). If the force due to the ram-pressure exceeds the restoring gravitational acceleration the gas in this region will be stripped away from the affected galaxy. This can influence both the stripped galaxy and the stripping initiating ICM. On the one hand a depletion of ISM leads to a decreased star formation rate which may explain the Butcher-Oemler effect (Butcher & Oemler 1984) and the formation of S0 galaxies (Dressler et al. 1997). On the other hand the stripped material will enrich the surrounding medium with heavy elements. This is the effect we study with our simulations.

4 Dynamical State

Mergers of galaxy clusters have strong effects on the physical quantities of the ICM. The most prominent features of merger events are shock waves which we also clearly see in our simulation (due to good shock resolution of our hydrodynamic treatment). Shock waves represent a step in the density distribution of the cluster. A sudden increase in the surrounding density will also result in an increased stripping rate due to ram-pressure stripping in an affected cluster galaxy. Mergers also change the density and temperature distribution of the ICM which then obviously influences environmental dependent enrichment mechanisms like ram-pressure stripping. During and after merger events the ICM is mixed due to turbulent gas motions. This can result in a significant change of the metallicity distribution in such systems. We ran several models with different merger scenarios to investigate the above mentioned effects.

5 First Results

In first simulations we investigate the chemical evolution of the ICM from redshift $z = 1$ to $z = 0$. In the case of ram-pressure stripping we clearly see that the process is getting more efficient when moving closer to the cluster center. This can be understood in terms of higher
velocities and higher ambient densities strip galaxies more efficiently as discussed above. We also study different merger events and their influence on the properties and the distribution of the enriched material in the ICM. In the central region of the cluster some mixing due to merger events can be seen. For a better interpretation of cluster observations we model specific clusters (e.g. Coma). From this simulations constraints on the merger history of the modeled systems can be made. Additionally we produce X-ray brightness maps, temperature maps and metallicity maps which can directly be compared to X-ray observations.

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Figure 2: The distribution of stripped, enriched material which is produced since redshift $z = 1$. The lower image is a projection along the X-axis. Some mixing at the cluster center can be seen.