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# The Chemical Evolution of the Intra-Cluster Medium

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**Abstract.** We present numerical simulations of the dynamical and chemical evolution of galaxy clusters. From X-ray spectra it is evident that the Intra-Cluster Medium (ICM) is abundant in metals. As heavy elements are only produced in stars the processed material must have been ejected by cluster galaxies into the ICM. Several different mechanisms for interaction between the cluster galaxies and the ICM are possible but their efficiency of metal enrichment of the cluster and their time evolution are still not known. Suggested processes which remove enriched material from the galaxies are ram-pressure stripping, galactic winds, superwinds driven by starburst activity and jets from active galaxies. First results of high resolution hydrodynamic simulations on cluster scales are presented to investigate the effect of these different pollution mechanisms.

## 1. Numerical Method

We present combined N-body and hydrodynamic simulations of the interaction between the ICM and the cluster galaxies. These simulations are performed on cluster scale (20 $h^{-1}$ Mpc) to investigate the chemical evolution of the ICM. Large-scale structure formation is simulated using an 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 (Collela & Woodward, 1984) hydrodynamic simulation is performed including the effect of ram-pressure stripping using the criterion of Gunn and Gott (1972). The hydrodynamic simulation is computed on four nested grids (Ruffert, 1992) which allows to cover the cluster center where most of the stripping is expected to happen with high resolution as well as to investigate the effect of gas-rich galaxies falling in towards the cluster center. Metallicity is used to trace the stripped material.



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## 2. Interaction between Galaxies and the ICM

As the total amount of metals in the intra-cluster gas is about the same as in all galaxies together, a lot of gas must have been transported from the galaxies into the ICM. A closer look at the different metal enrichment processes is therefore very important for the understanding of cluster formation and galaxy evolution. We expect that different enrichment mechanisms will lead to different distributions and different concentrations of metal rich material.
First results of the simulation with galactic mass loss due to ram-pressure stripping show that the amount of stripped material increases when a galaxy approaches regions with higher density close to the cluster center. The enriched material is not uniformly distributed and we see an influence of subcluster mergers. An example of such a simulation is shown in fig.1. We also model well-known clusters (e.g. Coma). From these calculations we make simulated X-ray temperature and metallicity maps to compare our calculations with observations.

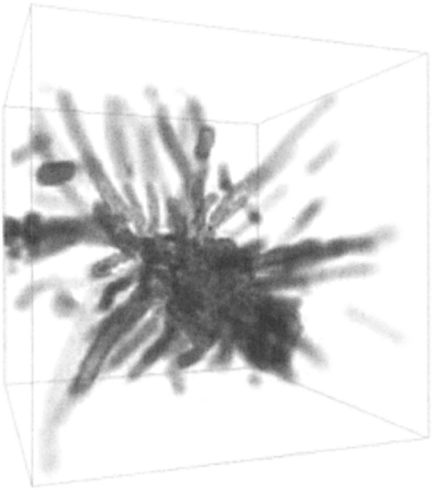

Figure 1. Distribution of enriched material in a simulated galaxy cluster. The volume shown here extends over $(5\ h^{-1})^3\ Mpc^3$.

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