INVESTIGATIONS OF ENVIRONMENTAL EFFECTS IN CLUSTERS OF GALAXIES USING N-BODY SIMULATIONS

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In order to investigate cluster evolutionary effects we present a new chemo-dynamical model. The model takes into account N-body simulations, modified for galaxy-galaxy binary encounters. The model incorporates also the codes for spectrophotometric and chemical evolution of galaxies. In the same time the calculations include the interaction between two merging subclusters.

As initial parameters, the model uses $[(M_{\rm i}, \mathbf{x}_{\rm i}, \mathbf{v}_{\rm i}), (T_{\rm i}, Z_{\rm i})]$, taking into account different scales of interactions: galaxy–galaxy, galaxy–cluster and subcluster–subcluster (or cluster–cluster). The model is of N-body type, with normal collisions for $d > d_0$ and close binary interactions for $d \leq d_0$. The parameters of interactions are represented by $[\Delta M_{\rm i}(\Delta Z_{\rm i}), \Delta \mathbf{v}_{\rm i}, \Delta E_{\rm i}]$. In our simulations for the momentum transfer we use a simple Chandrasekhar formula with a constant $\mathcal{K}$ input parameter. Different types of interactions were taken into account: mergers and cannibalism ($|v| \leq V_0$), tidal stripping and harassment ($|v| > V_0$), tidal shaking ($T = T(M, Z)$), blocking of SFR ($M_{\rm g} = 0$), cool fluxes ($+\Delta M$), and evaporation (galactic winds).

The calculations have been done for *a Coma-like cluster, composed of two interacting substructures.* The initial configuration used in our calculations consists of 173 galaxies in two nucleated subclusters (A,B) with 119 galaxies and 54 galaxies, respectively. The initial cluster diameter was chosen to be ~3 Mpc. The two interacting substructures consist of 119 E+S galaxies in subcluster A: 40 galaxies in the nucleus (50% E galaxies) and 79 galaxies in the envelope (31% E galaxies). The subcluster B is composed of 54 E+S galaxies: 30 galaxies in the nucleus (50% E galaxies) and 24 galaxies in the envelope (45% E galaxies). The initial masses for galaxies were chosen to be 100×10^{10} $M_\odot$ for E-galaxies and 30×10^{10} $M_\odot$ for S-galaxies. The parameters for interactions where chosen as: $d_{\rm o} = 0.15$ Mpc; $\mathcal{K} = 0.001$, $\Delta M = 0.3 M_\odot$.

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The chemo-spectro-photometric model is a Stellar Population Synthesis model, which takes into account supernova I and II rates, galactic winds and chemical mass transfer $\Delta M_{\rm i}(Z_{\rm i}(t))$.

The results of our simulations are compared with the observational data in the field of:

1. intrinsic galactic evolution (galactic tracks in C-C and C-M diagrams);
2. cluster evolution:

   (a) photometric evolution (Suran, Popescu this volume): C-R effect; photometric evolution of first galaxies in cluster;

   (b) dynamical evolution: existence of binary clusters with dumbbell galaxies; dependence of the properties of first galaxies on compactness and richness classes; profile and dynamics of cD and D galaxies;
3. complex chemical evolution: $SFR = SFR[Z(z)]$, $IMF = IMF[Z(z)]$;
4. morphological evolution: $T = T(z)$.

In our simulations, after a frontal interaction between the two subclusters, the core of the merged cluster contains two D or cD galaxies (which are the remnants of each central galaxy). This mode results in a cluster with dumbbell galaxies (separation $< 0.2h^{-1}$ Mpc).

We identify three different time scales: the interaction time scale between subclusters ($\sim 1-2$ Gyr); the relaxation time scale for the whole system ($\sim$ 10 Gyr) and the post-relaxation time scale (from which, up to now were inferred fortuitous interactions). The number of interactions for the entire process ($0 < z < 4$) increases as $\sim A \times (1+z)^{\gamma}$, where $A = 0.03, \gamma = 3.6 \div 4$. For short time scales, both A and γ depend on z.

The model can also reproduce colour-colour, colour-magnitude diagrams and chemical abundances in concordance with observations for all z ranges.

The time scale inferred in these effects (photometric time scale + abundance time scale + dynamical time scale) are of the same order ($\sim$ 10 Gyr), much higher than the needed time scale for the cluster evolution in the Standard Cold Dark Matter model (SCDM).

The estimated stellar mass for a D or cD galaxy has grown by a factor $\sim$ 3.2 for $z < 1$, in good agreement with other results (see Aragon-Salamanca et al., this volume, model with $\Omega_0 \sim 0.5$).