Subclustering in the Hierarchical Model of Galaxy Formation

N93-26734

Satoshi Yoshioka

Department of Physics, Tokyo University of Mercantile Marine
Etchujima, Koto, Tokyo 135, Japan

ABSTRACT

We investigate the process of subclustering in the hierarchical model of galaxy formation. We construct density field around peaks of density fluctuations using the path integral method and investigate their nature.

I. INTRODUCTION

Methods studying formation process of individual galaxies particularly numerically are so far divided into two types. First, galaxy-scale density perturbations are assumed and their gravitational collapses are followed. However, assumed density perturbations are usually top-hat models, and then unrealistic. In the second type galaxy-scale objects are chosen from large-scale simulations and their evolution is followed. This method is in principle the best. We must however represent an individual galaxy by at most several hundred meshes or particles owing to present limitation of computational ability, which leads to low resolution of computations. Therefore, we study galaxy formation basing upon a more realistic model.

In clustering model of galaxy formation galaxies are thought to form at or near peaks of density fluctuations. We construct density field around peaks of density fluctuations using path integral method (Bertschinger 1987) and investigate their nature. Advantage of this method is that it can produce density fields satisfying certain constraints, *e.g.*, a density peak with a given amplitude at a given position.

II. SUBCLUSTERING

We investigate the process of subclustering in galaxies by applying an object search algorizm to the density field produced by the path integral method.

The algorizm of searching objects from a given density field is a modified version of Press and Schechter (1974) method. First, the density field produced by the path integral method is smoothed using Gaussian filter with the scale R_f: $\tilde{P}(k) = P(k)\exp(-R_f^2 k^2)$. R_f is made gradually smaller from a sufficient large value. When the value of a peak of the smoothed density field reaches a critical value ($\delta_c \approx 1$), we identify it as an object corresponding to such a scale. We can find objects with various mass by applying this algorizm for the density field with various R_f. In addition, we can investigate the history of subclustering in galaxies by comparing the objects found from density fields at different epochs.

We here present the results of three-dimensional simulation. We take a cube whose length of sides is l. The cube is divided into 32^3 meshes. We assume the power spectrum obeys power law: $P(k) \propto k^n$. As a constraint, we put a peak with $\delta/\sigma(< 0.5\mathrm{Mpc}) = 3$ in the center of the cube. In the simulation, we took l as 2.5Mpc. Thus, this peak corresponds to an object with the mass of $M \simeq 3 \times 10^{11} \mathrm{M}_\odot$ in the cosmology of $\Omega = 1$ and $h = 0.75$.

Number evolution of subclumps in the case of $n = -2$ is shown in Fig. 1. From considerably early epoch the clumps form, which is natural in the clustering models. Since star formation can occur in these clumps, the formation epoch of these stars will be much earlier than those of galaxies to which the stars will belong at the late epoch.

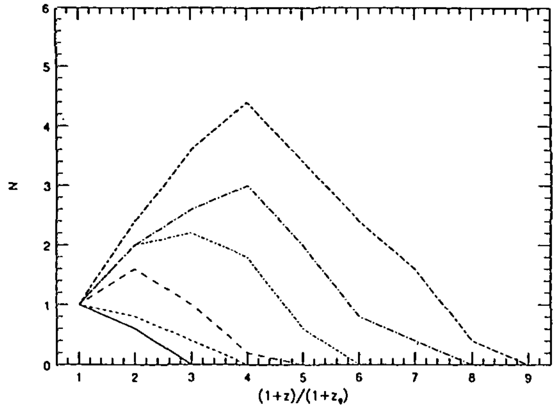

Fig. 1.–number evolution of subclumps. $n = -2$ case. Six lines indicate number of subclumps with mass larger than $10^9 M_\odot$, $10^{9.5} M_\odot$, $10^{10} M_\odot$, $10^{10.5} M_\odot$, $10^{11} M_\odot$, and $10^{11.5} M_\odot$ from the top. z_g is the epoch 0.5Mpc perturbation goes nonlinear, *i.e.*, the perturbation becomes an isolate galaxy.

III. N-BODY SIMULATIONS

We perform N-body simulations whose initial conditions are given by the density field produced by the path integral method. The density field is translated into particle distribution using the Zeldovich approximation. We follow gravitational evolution of particles using the tree code.

As a constraint, we put a peak with $\delta/\sigma(< 0.2L) = 3$ in the center of the cube as section 2. Initial redshift is $z_i = 20$. We scale amplitudes of perturbations in the way the density perturbation goes nonlinear at $z = 5$.

An example of calculations is shown in Fig. 2. This is the case that $n = -2$. The number of particles is $N \simeq 2 \times 10^4$. First, several clumps form, which merge into a single galaxy.

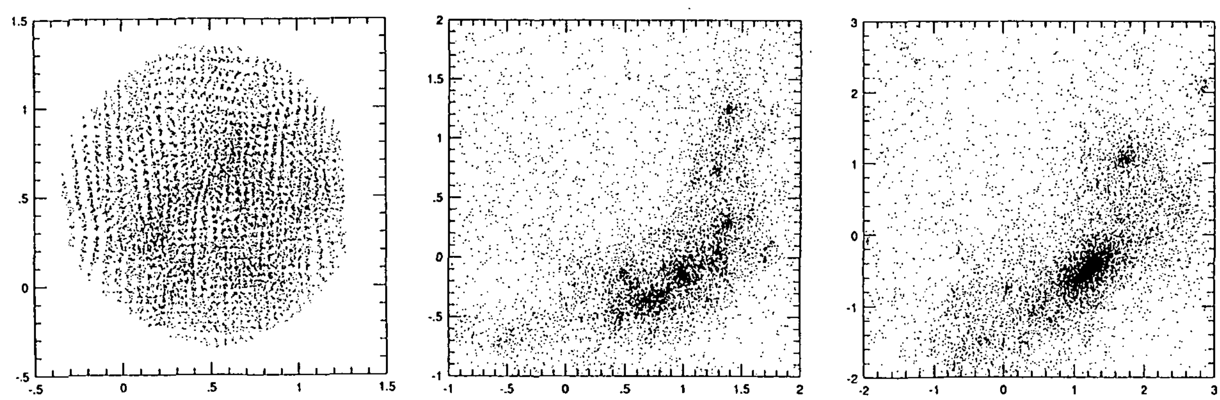

Fig. 2.–Result of N-body simulation. $n = -2$ case. $z_i = 20$, and $z_{nl} = 5$. Particle number is $N \simeq 2 \times 10^4$. From left to right, $z = 3.95$, $z = 1.70$, and $z = 0.70$.

References

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