PREDICTING DARK-MATTER HALO EVOLUTION WITH A MODIFIED PRESS-SCHECHTER MODEL

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The conventional Press-Schechter (PS) model for halo clustering evolution (see, e.g., Lacey & Cole[1]) treats any halo merger as equally significant when defining halo formation and destruction. The usual definition states that a halo of mass M at t was formed when half of its mass was assembled in a single halo, while its destruction time is defined as the time when it doubles its mass. This does not take into account that the halo mass could change either by a single major merger or by the continuous accretion of tiny halos. A consistent definition of halo formation time should rely on the relevance of the merger event experienced by the halo. In this sense, only major mergers can produce a substantial rearrangement of the halo internal structure and, hence, they are responsible of the formation of new halos and the destruction of the old ones. A modified PS clustering model has been developed in Salvador-Solé *et al.*[2] and Raig *et al.*[3] which is based on the distinction between halo major mergers and captures of small-mass halos. The latter are regarded as contributing to mass accretion. In the present work, the predictions of such modified PS model are compared with the results from N-body simulations of scale-free universes. A new semi-analytic model of galaxy formation based on the modified PS model is presently under construction in Barcelona.

1 Brief Description of the Model

Consider the instantaneous merger of two halos of mass M_1 and M_2, with $M_1 \geq M_2$. If $M_2/M_1 > \Delta_{\rm m}$ we say that a major merger has occurred causing the destruction of both halos and the formation of a new halo of mass $M' = M_1 + M_2$. Otherwise, if $M_2/M_1 \leq \Delta_{\rm m}$ we will regard the mass captured as a contribution to the mass accretion onto M_1. Then M_1 is not destroyed but simply evolves smoothly and its mass increases by an amount M_2.

The threshold in the captured mass, $\Delta_{\rm m}$, that separates major mergers from accretion is a free phenomenological parameter of the model. Its value must be determined by adjusting the predictions of the model to some empirical relationship related with the process of halo formation, such as the mass density relation of dark-matter halos found in N-body simulations. This has been done by Salvador-Solé *et al.*[2], who inferred that $\Delta_{\rm m} \approx 0.6$ by fitting the proportionality law between halo mass and characteristic density derived from high resolution N-body simulations performed by Navarro *et al.*[4]

It is quite natural in the modified PS model to define the halo formation time as the time when the halo experienced its last major merger. Conversely, the destruction time will be the time when the next major merger occurs. On the other hand, since instantaneous major mergers are essentially binary, one can consider that any halo has only two progenitors at his formation time. Given a population of halos with mass in an infinitesimal mass range around M_0 at t_0, the present model allows to derive an analytical expression for the distribution of formation times as well as the distribution function of progenitor masses of M_0. The median values of such distributions define the typical formation time and progenitor masses of a halo, respectively.

2 Implications for Semi-Analytic Modelling of Galaxy Formation

Semi-analytic models (SAMs) of galaxy formation rely on halo merger histories (so called merger trees) built from the usual PS model. Concretely, Monte Carlo realizations based on the conditional mass function are used to derive the mass of the progenitors of a halo. However, the number of progenitors can not be fixed with that function and some special procedure is also required to ensure that the sum of the progenitor masses obtained will be equal to the final halo mass. Additionally, in order to avoid merger trees with an infinite number of branches one is forced to set a minimum value of the halo mass that can be represented in a merger tree. Also the time step between consecutive merger nodes must be selected small enough, but the selected value depends mostly on memory requirements and is not connected with the evolution of the baryonic content of halos as computed from the SAM. For example, the amount of gas cooled or the number of galaxy mergers during the life-time of a halo can not depend on the time-step chosen for the merger tree.

Instead, the modified PS model is free from the above limitations. All quantities can be computed as continuous functions, and there is no need of introducing any mass or time resolution when computing halo merger histories. A merger tree computed from the modified PS model will only have merger nodes when a major merger takes place. Then, only two branches per merger node are present. Between successive major mergers, the evolution of the halo mass is described by a typical accretion track computed from the mass accretion rate function, which in turns is derived by integrating the usual PS merger rate function (Lacey & Cole[1]) over the range of final masses obtained after minor mergers (i.e., mergers with $M_2/M_1 \leq \Delta_{\rm m}$).

3 First Results

Predictions of the modified PS model are compared with the output from N-body simulations of three scale-free, flat $\Omega = 1$ universes, with initial power law power spectra with $n = 0$, -1 and -2. The comparison includes the different halo growth rates (destruction rate, formation rate and mass accretion rate) and the distributions of halo formation times and progenitor masses. Preliminary results show that model and simulations agree reasonably well. The plots for the case $n = -1$ (fig1.ps and fig2.ps) can be found at the following ftp site: pcess1.am.ub.es / pub.

References

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