Astron. Astrophys. 313, 363–376 (1996)

ASTRONOMY
AND
ASTROPHYSICS

Dynamical evolution of galaxy groups. A comparison of two approaches

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Received 4 August 1995 / Accepted 15 January 1996

Abstract. In this paper we test the performance of explicit simulations of groups of galaxies, (i.e simulations in which each galaxy is treated as a mass point and the physics of the interactions is modelled by specific analytical prescriptions for merging conditions), by comparing them with fully self-consistent simulations starting from identical initial conditions. The quality of the explicit simulations is very unequal. For some prescriptions the results are in complete disagreement with the self-consistent simulations. The inclusion of other dynamical effects like dynamical friction gives, in some cases, better agreement. We also propose a new merging criterion, which, combined with dynamical friction, gives much better agreement with self-consistent simulations in a variety of initial conditions, but even this criterion has a limited range of applicability.

Key words: galaxies: kinematics and dynamics – galaxies: interactions – methods: numerical

1. Introduction

Fully self-consistent N-body simulations, where each galaxy is represented by a large number of particles, are a useful, albeit expensive, tool for studying the evolution of galaxy groups and clusters. However, for simulations of large clusters of galaxies, like the Coma cluster, the necessary computing time is prohibitive. As a substitute people have considered explicit simulations, in which each galaxy is represented by a single point and the physics of the interactions is modelled by explicit prescriptions for merging conditions. In particular, a variety of recipes are explored for the conditions the two galaxies must fulfil in order to merge. In general, these merging conditions are based on self-consistent simulations of two-galaxy collisions, and do not include the tidal forces between the galaxies or collisions involving more than two galaxies. It is thus not a priori certain that they will perform well in simulations of group or cluster evolution. In some cases (Merritt 1983; Richstone & Malumuth 1983; Mamon 1987), the authors also introduce other effects like dynamical friction and tidal forces from the background. The main advantage of this type of approach is that it is inexpensive in computing time and therefore allows one to explore a wide parameter space. In any case, a considerable fraction of the results on the dynamics of galaxy groups are based on the explicit approach. We may cite works by Jones & Efstathiou (1979), Roos & Norman (1979), Aarseth & Fall (1980), Cooper & Miller (1981), Roos (1981), Roos & Aarseth (1982), Merritt (1983), Richstone & Malumuth (1983), Malumuth & Richstone (1984), Saarinen & Valtonen (1985), Mamon (1987), Navarro et al. (1987) and Schindler & Böhringer (1993).

Not many self-consistent simulations of groups with more than 10 galaxies can be found in the literature. We can cite the articles by Carnevalli et al. (1981), Ishizawa et al. (1983), Ishizawa (1986), Rhee & Roos (1990), Barnes (1992), Funato et al. (1993) and Bode et al. (1994). The first works of this kind used Aarseth's (1971) N-body code and a limited number of points, typically 10–20, to represent each galaxy, and only recently it has become possible to use the order of 1000 particles per galaxy.

Our aim is to compare the two approaches to see whether, and under what conditions, one can use explicit simulations and have confidence in the results. For this purpose, we have evolved a set of initial conditions in two different ways. One way is to use an N-body code where physics is included explicitly, the other, to use self-consistent simulations and a treecode (Barnes & Hut 1986, Hernquist 1987 for a vectorised version), representing each galaxy either by 100 or by 900 points. In Sect. 2 we describe our initial conditions and the different merging criteria used so far in the literature. In Sect. 3 we compare the results of fully self-consistent numerical simulations to those of explicit simulations made with the various merging criteria, both without (Sect. 3.1) and with dynamical friction (Sect. 3.2). This comparison led us to propose a new merging criterion (Sect. 3.3), whose performance we also compare with the fully self-consistent simulations. In this section we consider only groups with no common all-encompassing dark matter halo. Simulations including such a halo are presented in Sect. 4, where again we compare

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