Clusters, Lensing, and the Future of the Universe
ASP Conference Series, Vol. 88, 1996
Virginia Trimble and Andreas Reisenegger (eds.)

Possible mechanisms of formation of clusters with "cD-galaxies" and gravitational lenses

J. Anosova[1]

Texas University at Austin, Dept. of Aerospace and Engineer.,Austin ,USA

P. M. S. Namboodiri[2]

Indian Institute of Astrophysics,Bangalore,India

M.R.Deshpande[3]

Physical Research Laboratory,Ahmedabad,India.

Abstract.

We study by computer N-body simulations tidal effects of disruption and merger, within a system consisting of a massive perturber and a galaxy cluster, have been studied by computer simulations using Aarseth's NBODY2 code. The model consists of a spherical N-body galaxy cluster and a point-mass perturber.

For small pericentric distances of the initial parabolic orbit of the perturber, and for values of the virial coefficient q greater than 0.5, collisions of objects can result in their merger, and the formation of products with properties of cD-galaxies. For the cases with large masses of a perturber we get final structures which are similar to observed galaxy clusters with big gravitational lenses.

Keywords: **interacting galaxies - perturbers, galaxy clusters - cD-galaxy - gravitational lenses**

1. Introduction

A distinctive feature of large clusters of galaxies is the presence of one or two highly luminous supergiant elliptical galaxies near the centres of the clusters. These galaxies, known as cD galaxies, are the most luminous galaxies in the universe and have extended amorphous stellar envelopes; they are the most massive stellar systems with masses of about 10^{12} M_o (Tonry 1987; Tremaine 1990). The potential associated with cores of clusters that contain cD-galaxies is 10 times deeper than that associated with normal galaxies; about 80% of these galaxies are located at surface density maxima. The envelopes of cD-galaxies may consist of debris stripped from cluster galaxies by the tidal field of a cluster or by collisions with other galaxies. Particles in such envelopes have a smaller velocity dispersion (about 300 km/s) than that of the cluster (about 800 km/s).

About 50% of cD-galaxies have close secondary companions or multiple nuclei. Sometimes we observe dumbell cD-galaxies with small separations between components, small differences of their magnitudes, and small rms velocities.

The Coma cluster is an example of a galaxy cluster containing a dumbell with two cD-galaxies.

Many authors try to explain properties of these galaxies by studying the dynamics with N-body computer simulations. Numerical investigations in this field were first performed by Toomre and Toomre (1972). At present there are several reviews of such investigations: see for example Barnes & Hernquist (1992), and the references therein. A model of the collision of two galaxies where the first one is a massive smoothed particle and the second an N-body system has been used by several authors (e.g. Tonry 1987 and Namboodiri & Kochhar 1993, and references therein).

Effects of collisions of these objects, such as disruption of the N-body cluster, tidal effects, formation of bridges and tails between the galaxies, and the structure of the surface density profile of the remnant, have been considered by these authors.

Many authors have discussed also possible mechanisms for the formation of cD-galaxies.

Our main aim is to determine initial conditions for a model of 'perturber/galaxy-cluster interaction' which will yield a final remnant with the properties of cD-galaxies. An explanation of the formation of these objects would be very important for our understanding of basic processes involved in the formation of spatial structure in the Universe (see for example recent reviews by Tremaine 1990, Barnes & Hernquist 1992, and references therein).

2. Method and general results.

In this paper, we study tidal effects of the collision of a perturber with a galaxy cluster. A perturber is treated as a smoothed particle; a galaxy cluster is treated as a spherical N=250-body system, and the individual galaxies have different masses.

We study collisions of these objects by computer simulations using Aarseth's NBODY2 code. We consider a wide range of initial conditions in which a perturber and cluster approach each other on parabolic orbits. We change the peri-

centric distance of the relative orbit of the objects, the mass of the perturber, and the initial parameters of the cluster.

We notice that when the pericentric distance is small, and the mass of the perturber and the virial coefficient q of the cluster are large, the collision results in a merger. For all models, about 30% of particles escape from the full system, other particles having been captured by the perturber. For our model with largest inititial virial coefficient, $q_0 = 0.90$, the final product has some properties similar dynamically for cD-galaxies.

For large mass of perturber, we obtain remnants with structure like that of clusters of galaxies with gravitational lenses. In these cases, the final remnant is a perturber surrounded by numerous faint dwarf galaxies; these galaxies form long arcs with large curvature and tangential elongations around the perturber.

Acknowledgments. We thank S. J. Aarseth for kindly sending us his NBODY2 code, P.Eggleton for correction of English and A.Toomre for very interesting discussions.

References

Barnes, J. E. , Hernquist, L. E. , 1992, Ann. Rev. Astron. Astrophys. 30, 705.

Namboodiri, P. M. S. , Kochhar, R. K. 1993, Mon. Not. Roy. Astron. Soc. 261, 855.

Tonry, J. L. 1987. In structure and dynamics of Elliptical galaxies, IAU Symp. No. 127, ed. T. de Zeew, Dordrecht; Reidel 89.

Toomre, A. , Toomre, J. 1972. Astrophys. J. 178, 623.

Tremaine, S. 1990. See Wielen 1990, p394.

Wielen. R. ed. 1990. Dynamics and Interactions of Galaxies. Berlin: Springer-Verlag.