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The formation of cD galaxies

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Abstract. We present N-body simulations of groups of galaxies with a number of very different initial conditions. These include spherical isotropic, nonspherical anisotropic collapses and virialised spherical systems. In all cases but one the merging instability leads to the formation of a giant central galaxy in the center of the group. The initial conditions of the exception are such that no galaxies are present in the central part of the group. Thus some central seed of material is necessary to trigger the formation of a giant central galaxy. We concentrate on the properties of these giant central galaxies. Spherical virialised systems give rise to relatively round and isotropic systems, while aspherical initial conditions give rise to triaxial objects with anisotropic velocity dispersion tensors. In the latter cases the orientation of the resulting central galaxy is well correlated with that of the initial cluster. We compare the projected properties of the objects formed with the properties of real brightest cluster member galaxies. The surface density profiles are in good agreement with the observed surface brightness profiles. In the case of extended virialised groups the projected properties of the giant central galaxy are the same as the properties of cD galaxies. These include a halo of luminous material and a nearly flat velocity dispersion profile.

Key words: galaxies: elliptical and lenticular, cD – galaxies: kinematics and dynamics – galaxies: interactions – methods: numerical

1. Introduction

The centers of galaxy clusters are usually dominated by very massive ($\sim\ 10^{13} M_{\odot}$) and extended ($\sim$ 300 kpc) galaxies, called brightest cluster members, or D or cD galaxies, whose particular physical properties require a distinct formation scenario. More detailed information on these objects is given in the reviews by Tonry (1987), Kormendy & Djorgovski (1989) and Schombert (1992). Four theories have been proposed so far to explain the properties of these central dominant galaxies.

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The first theory is related to the presence of cooling flows in clusters of galaxies (Cowie & Binney 1977; Fabian & Nulsen 1977). If the central cluster density is high enough, intracluster gas can gradually condense and form stars at the bottom of the potential well. Andreon et al. (1992), however, show that colour gradients are small or absent, while McNamara & O'Connell (1992) find colour anomalies only in the inner 5-10% of the cooling radii estimated by X-ray observations. Furthermore, they find that the amplitudes of these colour anomalies imply star formation rates that account for at most a few percent of the material that is cooling and accreting on the central galaxy, if the initial mass function is the same as that of the solar neighbourhood.

The second theory involves tidal stripping. Cluster galaxies that pass near the center of the cluster may be stripped by the tidal forces arising from the cluster potential or the potential of the central galaxy itself. The stripped material eventually falls to the center of the potential well, where the giant galaxy resides, and may be responsible for the halo of cD galaxies. This theory was first proposed by Gallagher and Ostriker (1972) and later developed by Richstone (1975, 1976). It can explain the halos of cD galaxies, but it is unable to explain the differences between D galaxies, which are central dominant galaxies with no halo, and cD galaxies. Moreover, observations show that the velocity dispersion of the stars in cD halos is three times smaller than the velocity dispersion of galaxies in the cluster, and so this theory should work out how tidally stripped material is slowed down as it builds up a cD halo.

The third theory links the formation of the central galaxy to progressive mergings or captures of less massive galaxies by the central object of a cluster. This theory is known as "galactic cannibalism" and was first proposed by Ostriker & Tremaine (1975) and later developed by Ostriker & Hausman (1977). Merging might account for the formation of the central parts of first ranked galaxies with a de Vaucouleurs profile, since such a profile is often found in the simulations of galaxy mergers (Barnes & Hernquist 1992 and references therein). Photometric observations (Schombert 1987) discard the analytical approach of Ostriker and Hausman (1977), which is based on homology. The observation of multiple nuclei in central galaxies is often