ENVIRONMENTAL EFFECTS ON GALAXIES IN CLUSTERS

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This study is part of a program to investigate consequences to a galaxy of its orbiting within a cluster of galaxies. Numerical experiments have been conducted to study the tidal influences on the internal dynamics of a galaxy (Miller and Smith 1982). The present first cut at the general problem treats effects of the cluster's tidal potential on the pattern motion and observable properties of a galaxy (shape, density contours, velocity fields, velocity dispersions) for a fixed external potential. The first-order cluster force field is balanced by the galaxy's acceleration in the real cluster, leaving tidal terms as the leading terms in a Taylor series expansion of the cluster force field about the center of the galaxy. The cluster tidal force field is usually stretching along a line toward the cluster center and compressive at right angles.

The external potential used for the numerical experiments has the form $V_{ext} = (k_L x^2 + k_T y^2 + k_T z^2)$. This potential represents the dominant part of the potential seen by a galaxy orbiting in a cluster, with the cluster center located at some distance along the x-axis. The experiments were run with a barlike galaxy placed in this external field, and the initial bar rotates about the z-axis. The non-symmetrical tidal forces affect the galaxy's rotation if the galaxy's rotation axis is not toward or away from the cluster center. The difference $k_{ext} = /k_T - k_L/$ represents the anisotropy of the tidal force. Experiments were run with $/k_T - k_L/$ calibrated in terms of the galaxy's self-consistent potential: $k_L = \partial^2 V_{ext}/\partial x^2$; $k_{sc} = \partial^2 V_{sc}/\partial x^2$; etc. for the initial galaxy. Four different experiments were run with $k_{ext}/k_{sc} = 0.02, 0.05, 0.1$, and 0.2.

Although weaker than the galaxy's internal force field, the tidal field continues to act over long periods of time so significant cumulative effects can build up. The time scale on which cluster influences act is the cluster crossing time, typically a few by 10^9

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years (Gott and Turner 1977). The ratios, k_{ext}/k_{sc}, are roughly the squares of the ratios of crossing times: $(T_{sc}/T_{cluster})^2$. The ratios tested are somewhat on the high side so the experiments will run in a reasonable time, but they are in the observed range $(T_{sc}/T_{cluster}) \sim$ 1/10 to 1/20. More importantly, the experiments confirm that internal responses scale as expected (linearly in k_{ext}/k_{sc}). Results can be confidently extrapolated to weaker external fields with this scaling rule.

Results from these experiments were analyzed by means of motion pictures and by means of numerical summaries. The motion picture was used to analyze the way in which pattern motion of the galaxy responds to the external tidal field. Two possible consequences have been checked by these numerical experiments. (1) Observable rotation is reduced so initially rapidly rotating galaxies can be slowed to low values of (V/σ) compatible with observation for giant elliptical galaxies. The shapes of the galaxies were not significantly changed through tidal braking. (2) Pattern rotation is affected such that galaxies tend to align pointing toward the cluster center with a weak secondary maximum perpendicular to the line between the galaxy and the cluster center. This pattern of alignment has been reported by Adams, Strom, and Strom 1980. The important conclusion to be drawn from these results is that galaxies in a cluster respond to, and are affected by, their surroundings in significant, observable ways. The rotation of a galaxy may have been strongly braked in a cluster environment.

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