

The Nature of the Evolution of Galaxies by Mergers

Tapan K. Chatterjee, Facultad de Ciencias, F.M., Universidad A. Puebla, Puebla, Mexico.

The merger theory for the formation of elliptical galaxies is examined by conducting a dynamical study of the expected frequency of merging galaxies on the basis of the collisional theory, using galaxy models without halos. The expected merger rates obtained on the basis of the collisional theory fall about a magnitude below the observational value in the present epoch. In the light of current observational evidence and the results obtained, a marked regularity in the formation of ellipticals is indicated, followed by secular evolution by mergers.

Brief Summary of Material to be Covered

Using basically the impulsive approximation and a modification of the method used by Alladin, 1965 (Astrophys. J. 141, 768) and described in detail in Chatterjee, 1990 (I.A.U. Col. 124, 519; "Paired and Interacting Galaxies"; NASA Publ. No. 3098), we study mergers between different types of progenitor pairs, each collision being characterized by the initial separation between the galaxies and the initial relative velocity therein. For each collision the change in relative velocity due to dynamical friction is taken into account. The merger takes place when the instantaneous relative velocity of the two galaxies equals the velocity of escape between the pair characterized at the instantaneous separation.

Results indicate that the expected frequency of merging galaxies, not considering the galaxies to be embedded in massive halos, is $\sim 10^{-2}\%$, which falls short of the observed value in the present epoch ($\sim 0.3\%$) by an order of magnitude and falls short of the extrapolated past value ($\sim 5\%$) by two orders of magnitudes. The frequency of different types of progenitor pairs in merger is of the same order of

magnitude. The majority of mergers are achieved in several orbital periods (2 to 3), and only about $\sim 10\%$ of them are achieved in a single orbital period; and about 1% of them are due to central impacts.

There are bound to be many subtle kinematical differences between the remnants owing their origin to different pairs of progenitors, and as the frequency of mergers with different pairs of progenitors is of the same order of magnitude, the frequency of these kinematical differences should be observationally significant. These results are reinforced by current observational evidence, indicating the existence of racially different types of ellipticals.

The existence of the fundamental parameter plane (on which the global properties of elliptical galaxies lie), is indicative of a strong regularity in the process of elliptical galaxy formation, with fluctuations about the main process as a function of mainly the initial conditions, and of subsequent evolution as a function of mainly the local conditions, accounting for the observed diversity in ellipticals. It is this subsequent evolution where the mergers seem to be a very prominent part. The virial theorem implies that any homologous family of self gravitating galaxies in dynamical equilibrium will define a plane, which will map into the fundamental plane if the mass to luminosity ratio is a unique function of the position of the plane; the mass to luminosity ratio for ellipticals seems to vary little.

The brightest cluster members and cDs even though sighted as evidence for the merger theory, have anomalous properties suggestive of an evolutionary history different from other ellipticals and modified by mergers.

This evidence is strongly indicative of the expected regularity in elliptical galaxy formation, and a secular evolution by mergers.