MERGER RATES AND GALAXY FORMATION

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Introduction and Theory

Observations indicate that the frequency of merging galaxies in the present epoch is ≈0.3%, and an extrapolation to past yields a frequency ≈5% (Toomre, 1977, Tremaine, 1980). Loosely bound pairs of galaxies that had separated to great distances in the general cosmic expansion and have lately fallen together again in comet-like plunging ellipses seem to be the most lucrative candidates for mergers. But could all ellipticals be merger remnants ? To study this problem we have determined the frequency of merging galaxies on the basis of the collision theory, by studying many collisions with different collision parameters and progenitor pairs (using the impulsive approximation) and compared the values so obtained with the observational ones. The mean values of the collision parameters favourable for mergers for different types of progenitor pairs are segregated from a statistical study of many collisions and are compared to the corresponding values in dense regions where a galaxy and its nearest neighbour can be visualised to form a loosely bound pair, to determine the corresponding frequencies. The theory and method is described in detail in Chatterjee, 1987, 1990, except that subsequently we have studied disk-disk mergers by using basically the same method.

Results and conclusions

The main results can be summed up as follows :

(i) The frequency of mergers involving all the three type of progenitor pairs (sphere-sphere, disk-sphere, disk-disk) is of the same order of magnitude (10^{-3}% for mergers taking place in a single crossing time and 10^{-2}% for mergers taking place in several orbital periods, not considering models with massive halos).

(ii) On the average ≈85% of the mergers take place in several orbital periods (as compared to mergers taking place in a single crossing time).

(iii) Among mergers taking place in a single crossing time, those which are due to central impacts are underabundant by an order of magnitude. This implies that ≈ 1% of mergers are due to central impacts.

As the frequency of mergers with different pairs of progenitors is of the same order of magnitude, there is bound to be many subtle kinematical differences between remnants ofdifferent pairs of progenitors. In the case of disk-disk (or disk/halo) mergers the flatness of the remnant depends upon the inclinations of the initial disks (less inclined disks produce flatter remnants) and the kinematics of the remnant depends upon the

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magnitude and direction of the angular momentum with respect to the relative velocity (White, 1982). Villumsen (1983) finds that the density profiles of the remnants, when the progenitors have a mass ratio of 3:1 (compact secondary) are inconsistent with an r^{-2} projected density profile. Since an overwhelming majority of mergers are achieved in several orbital periods, and only ≈ 1% of mergers are due to central impacts, most of the remnants originate in high angular momentum collisions and will have a high rotation as compared to the low rotation rates of elliptical galaxies. These results are strongly indicative of the fact that all elliptical galaxies are not the products of mergers, but a percentage of them must have formed in this way, leading to the conclusion of the existence of two racially different types of ellipticals (with subtypes in each family). In addition to the main properties which show a marked variance for the two racial varieties (rotation, surface brightness, globular cluster content), there are strong breaks in many of the properties of ellipticals as the transition between the two races seemingly takes place. Bright cluster members have the general appearance of normal ellipticals, but have properties that do not fall in line with bright ellipticals ; but they are more close to falling in line with N-Body simulations leading to merger remnants (cf. Schombert, 1987). On the other hand the prominence of the colour-magnitude effect in the ellipticals (and lenticulars) is indicative of factors determining the intrinsic development of these galaxies, independent of the environment and shape, which is further reinforced by correlations between physical properties and intrinsic shape of these galaxies (cf. Terlevich et al., 1981). The projected density profile with power law r^{-2}, which is considered as proof of the universality of ellipticals, may be an effect of forcing the particular fitting function on the observed and simulated profiles; the goodness of the fit could very well be due to the fact that it is the only power density law which allows non-homologous behaviour found in merger remnants, since it is divergent at both small and large radii.

A comparison of the expected merger frequencies with the observational values shows that the expected frequency of mergers, not considering massive halos, is about an order of magnitude less than the observed value. Preliminary calculations show that we can increase this frequency by embedding the galaxies in massive halos. But a dynamical study of the properties of mergers remnants, as compared to normal ellipticals, argues against the universality of ellipticals.

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