N93-26827

DISSIPATIVE MERGING OF GALAXIES

M. UMEMURA
Princeton University Observatory /
National Astronomical Observatory of Japan

ABSTRACT. The galaxy merging is investigated with hydrodynamical processes taken into account. For this purpose, the 3D calculations are performed by the use of a smoothed particle hydrodynamics (SPH) scheme combined with an N-body sheme. In these calculations, we find a new merging criterion and the dependence of the central phase space density of merger remnants upon the gas fraction in progenitors. It is concluded that ellpticals can be formed just by merging of fairly gas rich primordial galaxies, not ordinary spiral galaxies.

1. Introduction

The calculations for galaxy interaction have been performed so far mainly by the N-body simulations of collisionless particles. They have succeeded in accounting for some properties of elliptical galaxies such as the $r^{1/4}$ law of surface density profiles. On the other hand, one physical problem has not been solved, that is, the problem of central phase space density. In purely collisionless merging, the phase space density should be perfectly conserved, while that in elliptical galaxies is by about two orders higher than in spirals.

Focusing on this problem, I've performed 3D hydrodynamical calculations of galaxy merger, using an SPH scheme combined with N-body scheme, and pursued the dynamical evolution of both collisionless stellar component and gaseous matter.

2. Model Galaxies

I assume exponential disks for progenitors: $I(r) = I_0 \exp(-r/r_d)$, $r_d = 5$kpc. The total mass of a progenitor is $10^{10} M_\odot$. And I consider the gaseous mass fraction of 0.01, 0.1, or 0.5. The gas is postulated to be isothermal with $T_g = 2 \times 10^4$K. At present the progenitors are composed just of stars and gas, not including dark halos. As for the kinematics inside a progenitor, the rotational velocities are decided so that the centrifugal force balances to the gravitational field at each point. These progenitors encounter each other in a parabolic orbit.

3. Numerical Results

i) Merging Criterion

It is a intuitive way to use the impulse approximation for a merging criterion taking into account dissipative effect. Then the change of total energy is

$$\frac{\Delta E}{E} = \frac{32 G^2 M^2 R_G^2}{3 r_p^4 v^4} + \beta \frac{M_g}{M}, \tag{1}$$

where M, M_g, and R_G are the total mass, gaseous mass, and radius of a progenitor, respectively, r_p is the pericentric distance, and v is the relative velocity at r_p. When we adopt the condition

$\Delta E/E \geq 1$ as a conventional merging criterion, we get, using the virial theorem,

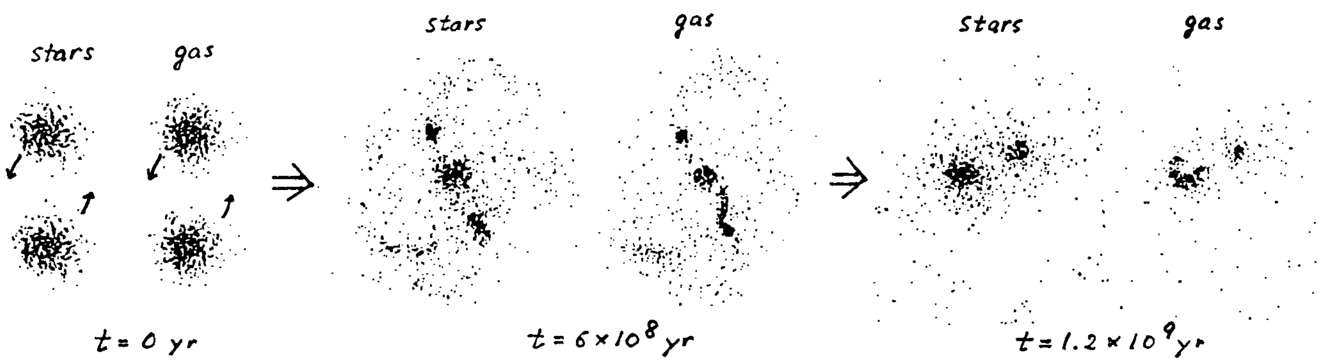
$$\alpha \gtrsim 1 - \beta \frac{M_g}{M}, \quad \alpha = \frac{32}{3} \left(\frac{R_G \sigma_*}{r_p v} \right)^4, \tag{2}$$

where σ_* is the stellar velocity dispersion or rotational velocity in a progenitor. The β is an unknown parameter which comes from dissipative effect, and should be determined in numerical simulations.

In numerical simulations, I adopted $r_p = 4.53$ kpc and $v = 200$ km s^{-1}, which corresponds to $\alpha = 0.75$. This means that this encounter doesn't satisfy the merging criterion without the dissipative effect. The simulations with 1% gas fraction have shown several clumps left after the collision. In the case of 10% gas fraction, there were two remnants left finally. And the progenitors with 50% gas fraction merge into one big remnant. Therefore, we obtain an empirical criterion for dissipative merging;

$$\alpha \gtrsim 1 - \frac{1}{2} \frac{M_g}{M}. \tag{3}$$

And also, progenitors with $M_g/M = 0.5$ merge three times faster than those with $M_g/M = 0.1$. The merging process is shown below for the case of $M_g/M = 0.5$.



ii) Central Phase Space Density

The central phase space density is defined as

$$f_c = \frac{\rho_c}{(2\pi\sigma_c^2)^{3/2}}, \tag{4}$$

where ρ_c is the central density, and σ_c is the velocity dispersion. The f_c is significantly raised through the dissipative merging. The numerical results show that the amplification factor is 8, 14, and 90, respectively for $M_g/M = 0.01$, 0.1, and 0.5. These results can be compared to the observational ones in spiral or elliptical galaxies (see right). So, we can conclude that if there is as large an amount of gas in progenitor as 50% of total mass, the central phase space density can be accounted for by merging. This means that the merger remnant of ordinary spirals cannot be ellipticals, but gas rich primordial galaxies possiblly merge to form ellipticals.

Data: Carlberg (1987)