COLLISION AND TIDAL INTERACTION BETWEEN PLANETESIMALS

Sei-ichiro WATANABE, *Geophisical Institute, University of Tokyo, Tokyo 113, Japan*
AND
Shoken M. MIYAMA, *National Astronomical Observatory, Mitaka 181, Japan*

Introduction: In the study of planetary accretion it is very important to clarify the effective coalesence cross section. Recently Ida and Nakazawa [1] have calculated collisional probability of rigid planetesimals taking the effect of the solar gravitational field into account. In order to further the development, we have investigated the mutual tidal interactions between solid planetesimals, which may enlarge the effective coalesence cross section and thus the collisional probability. There are several works related to this subject: Mizuno and Boss [2] have calculated tidal disruption of dissipative planetesimals; Benz *et al.* [3] have simulated an impact between the protoearth and an object about 0.1 of its mass and shown that the Moon could be made from a single-impact event. However, these works are restricted within narrow renge of parameters such as the minimum distance during encounter, mass ratio, and equation of state. Thus, we have done systematic simulation about the collision and close encounter between planetesimals taking the effect of solar gravity into account, in order to clarify the effective coalesence cross section of planetesimals.

Numerical procedure: We consider two planetesimals with mass M_1 and M_2 revolving around the Sun. We neglect the shear strength of the material and all heating or cooling mechanisms other than shock heating and the PdV work. We introduce local Cartesian coordinates (x, y, z) with x taken along the radial direction, y along the tangential direction, and z perpendicular to the orbital plane of the center of mass of two planetesimals, and rotating with Keplerian angular velocity at the center of mass, Ω_0. Then the mass, momentum, and energy conservations are described as

$$\frac{d\rho}{dt} + \rho\nabla\cdot\mathbf{v} = 0, \tag{1}$$

$$\frac{d\mathbf{v}}{dt} = 3\Omega_0^2 x\hat{\mathbf{i}} - \Omega_0^2 z\hat{\mathbf{k}} - 2\Omega_0\hat{\mathbf{k}}\times\mathbf{v} - \frac{1}{\rho}\nabla(P+\Pi) - \nabla\phi, \tag{2}$$

$$\frac{du}{dt} = -\frac{P+\Pi}{\rho}\nabla\cdot\mathbf{v}, \tag{3}$$

where $\hat{\mathbf{i}}$ and $\hat{\mathbf{k}}$ are unit vectors in x- and z-directions, respectively, Π the viscous stress, u the specific internal energy, and ϕ the gravitational potential of planetesimals. According to the equation of state, we examined two extreme cases: barotropic ideal fluid and pulverulent body composed of N-rigid pieces. We used three dimensional smoothed particle method with artificial viscosity.

Results: We will show here preliminaly results for the case of initial polytropic structures and the equation of state of ideal gas. Random velocity of planetesimals is determined mainly by the mutual gravitational scattering and is estimated less than one third of the escape velocity of the planetesimals [4]. Thus we put heliocentric eccentricity and inclination of planetesimals to be zero in order to reduce the number of the parameters. In this case the important parameters are polytropic index N, mass ratio M_2/M_1, and near point distance of an initial orbit r_{min}. Figure 1 is a sequence of snapshots from a collision in which $M_2/M_1 = 1$, $r_{min} = 0.75R$ (where R is the radius of the planetesimal). Kinetic energy loss due to shock dissipation and orbital angular momentum transfer due to rotation of deformed planetesimals determine the collisional product: coalesence, binary formation, or scattering. From this we can estimate an effective coalesence cross section as a function of M_2/M_1 and N. In the case of $M_2/M_1 = 1$ two bodys finally coalesence into one if $r_{min} < 2.6R$ for $N = 1$ and $r_{min} < 3.1R$ for $N = 0.5$. We also determined excited spin due to tidal interaction.

COLLISION BETWEEN PLANETESIMALS: S. Watanabe and S. Miyama

References

[1] Ida, S., and K. Nakazawa (1989) *Astron. Astrophys*, **224**, 303-315.
[2] Mizuno, H., and A. P. Boss (1985) *Icarus* **63**, 109-133.
[3] Benz, W., W. L. Slattery, and A. G. W. Cameron (1986) *Icarus* **66**, 515-535.
[4] Ida, S., (1990) in preparation.

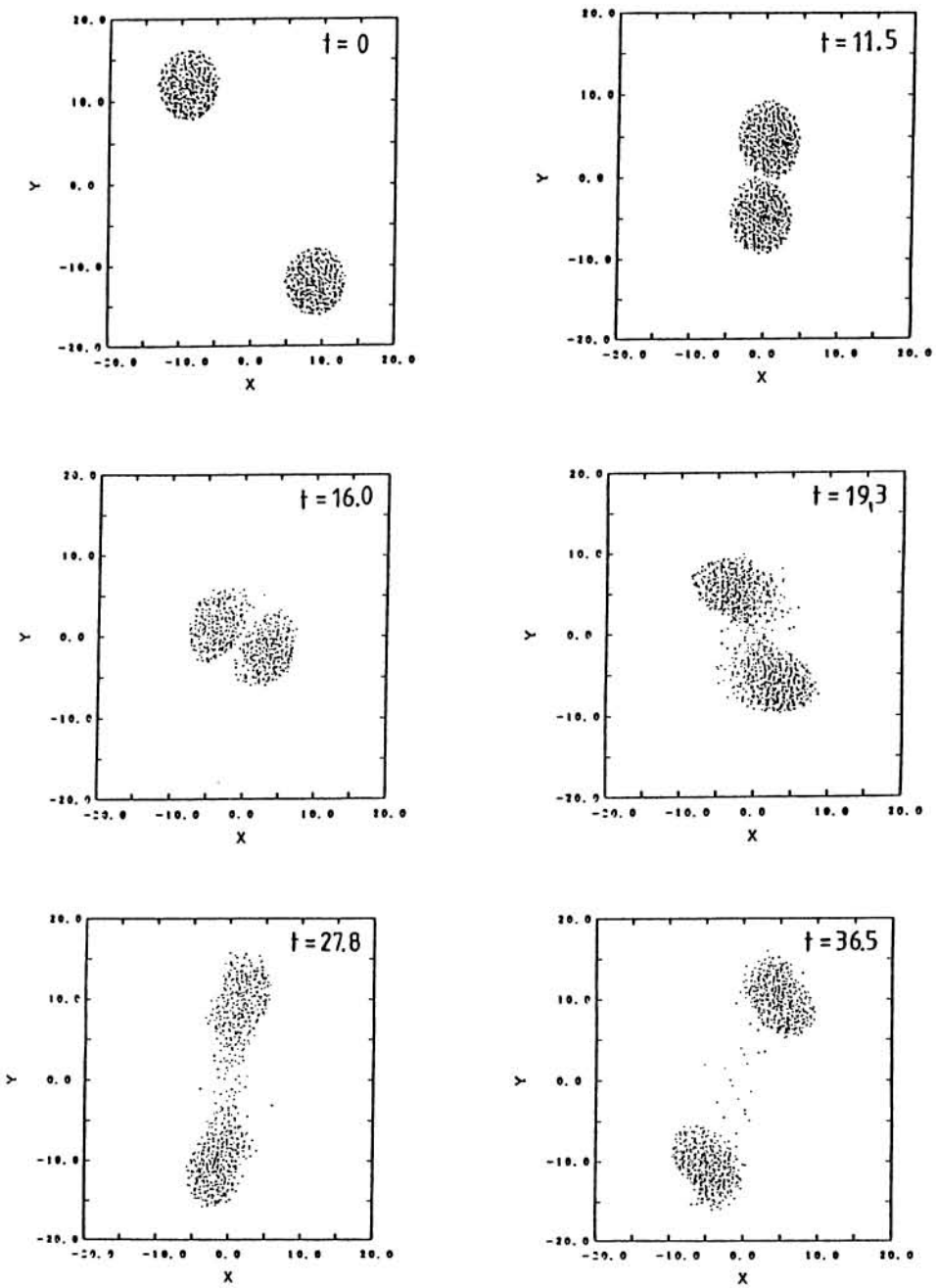

Fig. 1