
In the simulation experiments of jet stream formation, there are two factors crucial to the orbital evolution of the colliding particles; they are (a) initial orbital distribution of the particles and (b) collisional model adopted in the computation. In the following we will briefly discuss their effects in the light of Trulsen's calculation (1972a, b) and the recent Monte Carlo calculation (Ip, 1976).

Assuming the initial orbital distribution of the particles to be similar to that of the Saturnian rings, namely, a thin disk of particles in near-circular orbit, it is easily seen that, even considering the extreme case of a perfectly inelastic collision with the sticking coefficient \(\approx 1\), the end result of the collision process could only be a system of circular jet streams well separated from each other. For continuous coagulation and hence orbital focusing of matter, an additional perturbation mechanism is required to pump the particles in circular orbits into eccentric ones such that they could interact effectively. If the eccentricity and inclination of the particles are reduced to near-zero the focusing (or dispersing) will essentially stop.

If we start with a system of particles with orbital distribution similar to that of the main belt asteroids, in the simulation experiment assuming the absence of fragmentation and coagulation, we find that as a rule the eccentricity and inclination of the particles are reduced to small values after 5 to 10 collisions per particle. Therefore, the inelastic collision process has no problem in producing orbital focusing in the latitudinal direction. However, the radial focusing effect of the particle system depends critically on the collisional model adopted.

In Trulsen's beta model, because of the small degree of kinetic energy dissipation during inelastic collision, coupled with the transfer of kinetic energy into the radial kinetic energy, the particles will be scattered into orbits of large and small \(\text{a}\) values. In the three-dimensional beta model, this radial dispersion is especially important in the first few collisions with large impact velocity. As the relative velocity \(\Delta v\) is reduced, the scattering effect would also decrease. After 20 collisions per particles the ratio \((f_{20})\) of the initial radial dispersion \(\Delta a_0\) to the final value \(\Delta a_f\) is 1.60. Therefore, a net radial dispersion is produced.
At this point, the $\langle e \rangle$ and $\sin \langle i \rangle$ are both reduced to small values such that the whole system would have the configuration of a flat disk similar to the Saturnian rings.

One of the methods to reverse the radial dispersion effect is to increase the chance of a head-on collision in the model calculation (Trulsen, 1972a, b). This could be achieved by limiting the angle $\alpha$ between the impact vector $\hat{k}$ and the relative velocity unit vector of $\hat{g}$, (i.e. $\alpha = \cos^{-1} (\hat{g}, \hat{k})$) to be $> 90^\circ$. In a way this is similar to the snowflake model suggested by Alfvén.

In the snowflake model with $\beta = 1.5$ and $\alpha_{\text{min}} = 150^\circ$, the first few collisions are observed to disperse the jet stream system; but in the later stage the radial scattering process is replaced by a slight focusing. As we have mentioned before the dynamical evolution of the particle system more or less stops when $\langle e \rangle$ and $\sin \langle i \rangle$ reach small values (0.05, say). The value of $f_{20}$ is estimated to be $\approx 0.90$. To decrease the value of $\alpha_{\text{min}}$ even further, for example, $\alpha_{\text{min}} = 170^\circ$, orbital focusing could be achieved right at the start and $f_{20}$ could be as small as 0.65.

Finally we consider another collisional model different from the beta model and snowflake model. Here we assume the components of the post-encounter relative velocity $\Delta v_a$ of the colliding bodies to be always smaller than the corresponding pre-encounter values ($\Delta v_b$). In this inelastic "rebound" model no transfer of kinetic energy from one direction to another is possible. Consequently, the colliding particles always could be focused not only in the latitudinal direction but also in the radial direction. The ideal case, of course, is when $\Delta v_a = 0$, in which case the collision is perfectly inelastic with the sticking coefficient equals to 1. Under this condition $f_{20} = 0.6$. But even if we relax the condition to be just $\Delta v_a < \Delta v_b$ we would still obtain an $f_{20}$ value on the order of $0.7 - 0.8$.

In principle, the above collision model is only a variant of the snowflake model since it also reduces the tendency of transfer of kinetic energy from the ordered motion (along the azimuthal direction) to the random motion (in the radial direction). The numerical results from the simulation calculations using the snowflake and inelastic rebound models are consistent with jet stream theory (Alfvén, 1970; Alfvén and Arrhenius, 1975, 1976; Trulsen, 1971). However, the basic problem in jet stream simulation is that it is by no means certain whether any of these collision models are characteristic of the hypervelocity collision process. In any case, in the
second part of this report we will explore the growth of a pre-planetary (or pre-satellite) jet stream via capture of interplanetary matter assuming the validity of the snowflake model. The accretion effect of lunar size objects in the jet stream will also be studied.

REFERENCES