Modeling pattern formation in ejecta curtains by numerical and laboratory experiments

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Understanding the formation processes of impact craters is important for elucidating impacts that have occurred in the solar system throughout its history. In a crater-forming impact, ejecting particles form a structure called an ejecta curtain. Laboratory and numerical experiments show that ejecta curtains have a non-uniform particle mesh pattern. This pattern formation is thought to be induced by inelastic collisions between ejecta particles (Kadono et al. 2015). However, no theoretical model has been proposed that can quantitatively predict the time evolution of the patterns as a function of parameters, such as the coefficient of restitution and the initial velocity of particles.

The purpose of this study is to construct an analytical model that predicts pattern formation in ejecta curtains. To this end, we performed impact experiments using a vertical two-stage light-gas gun and particle collision simulations. The analytical model was constructed in two steps. In the first step, we simulated inelastic collisions of particles in a periodic box and analyzed the velocity dispersion of the particles and the Fourier spectrum of the pattern. In the second step, we simulated the motion of inelastically colliding particles with one-dimensionally expanding initial velocities and compared the results with the results of our laboratory experiments.

From the simulations in the first step, we find that a simple model that assumes perfect coalescence of particle clusters reproduces the time evolution of both the particle velocity dispersion and the cluster interval. The analytic model also reproduces the early evolution of the velocity dispersion of the particles in the simulations with one-dimensionally expanding initial velocities. Unlike the prediction from the analytic model, the velocity dispersion in the simulation deviates from the simple analytic solution at late times, suggesting that inelastic collisions are quenched be expansion. These results suggest that the time evolution of the mesh patterns in ejecta curtains can be divided into two stages: the early pattern formation through perfect cluster coalescence, and the later geometric expansion with no coalescence.

In conclusion, we found that pattern formation in ejecta curtains can be well described by the perfect coalescence of particle clusters. In future work, we plan to construct a model that smoothly connects the two stages of ejecta pattern formation.

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