Kinematical analysis of the ejecta created after a catastrophic collision

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The creation of an asteroid dynamical family as the outcome of a high-energy collision is essentially a two-step process: (1) the hydrodynamical phase, when the colliding system (projectile+target) is partially or completely shattered and the fragments are ejected (with several side effects, such as the creation of a plasma cloud, usually not relevant for the final observable properties); (2) the ballistic phase, when the ejecta collide or are reaccumulated due to the mutual gravity. At the end of this phase, the asteroid family is established, and its observable properties, also after a long time interval of dynamical evolution (including Yarkovsky-driven acceleration of the small members), have significant footprints of this original structure. In turn, this structure depends on the overall properties (mass and velocity distributions) in the beginning of the ballistic phase (D'Abramo et al. 1999, Michel et al. 2004).

According to the results of hydrodynamical simulations, most of the ejecta entering the ballistic phase are small (their size is essentially limited by the resolution of the code). A kinematical analysis of their properties may be helpful to clarify several points:

1) How can these small fragments reaccumulate into larger bodies, to create an observable family? If one starts from an expanding field and a set of small fragments, it is not easy to obtain a significant reaccumulation into many bodies; simple kinematical models, such as spherical expansion, but also the less symmetrical geometries defined from the semiempirical models of the 90's, allow essentially a more or less massive reaccumulation into very few bodies (sometimes only the largest remnant). What are the general properties of an ejection field causing a process of reaccumulation able to produce the observational evidence?

2) May some significant results be resolution-dependent?

3) Is it possible to define a general qualitative pattern of the ejecta field, allowing, in principle, to avoid huge computations, whenever one is interested in the general properties of the process, and not in the details?

In this preliminary analysis, we have studied a pair of ejecta fields produced by old SPH computations (Michel et al., 2001). The most surprising and significant indication is that, at least in these cases, about 20 % of the original ejecta appear to have initially crossing trajectories forcing them to have necessarily mutual impacts, without any role played by the mutual gravity. This property marks a significant difference with respect to the "simple" models, usually allowing collisions only as a consequence of the gravity, and might be important to shape the reaccumulation properties. It has to be noted that this property is not resolution-independent (in principle, for a given total volume of the ejecta, a larger number of smaller ejecta with similar kinematical properties should entail a larger collision probability).

We also discuss the possibility of identifying in these ejection fields an analogue of the "irradiation point" usually defined in the semiempirical models.

References: D'Abramo G., Dell'Oro A., Paolicchi P. 1999. Gravitational effects after the impact disruption of a minor planet: geometrical properties and criteria for the reaccumulation. Planetary and Space Science, 47, 975–986; Michel P., Benz W., Tanga P., Richardson D.C. 2001. Collisions and Gravitational Reaccumulation: Forming Asteroid Families and Satellites. Science, 294, 1696–1700; Michel P., Benz W., Richardson D.C. 2004. Catastrophic disruption of pre-shattered parent bodies. Icarus, 168, 420–432.