EPSC Abstracts
Vol. 6, EPSC-DPS2011-880, 2011
EPSC-DPS Joint Meeting 2011

Had they a rubble-pile parent body?

Paula G. Benavidez (1,2,3), Daniel D. Durda (3), Brian L. Enke (3), William F. Bottke, Jr. (3), David Nesvorný (3), Derek C. Richardson (4), Erik Asphaug (5), William J. Merline (3).

(1) Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal, Universidad de Alicante. P.O. Box 99, 03080 Alicante (Spain), paula.benavidez@ua.es; (2) Instituto Universitario de Física Aplicada a las Ciencias y la Tecnología; (3) Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302; (4) University of Maryland, College Park MD 20742; (5) University of California Santa Cruz, Santa Cruz CA 95064.

Abstract

We present the main results obtained of a study of the size-frequency distributions (SFDs) from impact simulations. We systematically studied a complete grid of rubble-pile and monolithic impact simulations and compared their SFD with actual asteroid families to decide if for some cases rubble-pile SFDs achieve a better match.

1. Introduction

As a natural consequence of collisional evolution in the main asteroid belt, many asteroids have undergone a series of battering impacts that likely have left their interiors substantially fractured, if not completely rubblized. Evidence supporting the existence of objects with a rubble-pile internal structure in the main-belt and near-Earth asteroid populations comes from observations, experiments and simulations [11].

Understanding the formation mechanisms of asteroid families can lead to a better understanding of the collisional evolution of the main-belt. Recent simulations of collisional destruction of asteroids reproduce quite well the main features of the size-frequency distributions (SFDs) of some asteroid families [6,7,9]. However some families remain poorly represented, as pointed out [3] (e.g., the Eos and Astrid families).

Smoothed-Particle Hydrodynamics/N-body codes have become the techniques of choice to study large-scale impact outcomes, including both the fragmentation of the parent body and the gravitational interactions between fragments. It is now possible to apply this technique to targets with either monolithic or rubble-pile internal structures.

Significant debate and examples can be found in the literature about matching the size distribution of asteroid families with modeled SFDs by means of computer simulations. Most of the studied cases consider different internal structures (solid, shattered or porous targets) but for limited impact conditions, restricted to reproduce the SFD of a specific family [3,4,5].

Here, we report our systematic study of a set of 175 new impact simulations considering a rubble-pile target. Simulations cover a range of collision speeds, impact angles, and impactor sizes. A more extended description of this work can be found in [1].

2. Impact simulations

First, the SPH code is used to model the actual impact [2]. Then, when the impact simulations are sufficiently complete the outcomes of the SPH models are handed off as the initial conditions for N-body simulations, which follow the trajectories of the ejecta fragments for an extended time to search for the formation of bound satellite systems [10]. This is essentially the same numerical scheme utilized by [4,5,6] to study the formation of asteroid families.

3. Results and Discussion

First we compared rubbe-pile and monolithic modelled SFD. For rubble-pile targets, as was true for monolithic targets, low-energy impacts (produced by small impactors and/or oblique impacts) result in sub-catastrophic events, while high-energy impacts (mainly large impactors) result in catastrophic or super-catastrophic events. No significant changes are observed in the general morphology of the SFDs by varying the impact speed for a given size impactor and angle (except for a minor features discussed below). In particular, for an impact angle of 75º, the

shape of rubble-pile SFDs remains quite similar even varying the impact speed and impactor size, becoming steeper and more continuous (smaller size ratio between the two largest remnants) than the monolithic ones. This implies that at some point, more energy does not translate into a significantly different fragment SFD.
Our results show that low-energy impacts into rubble-pile and monolithic targets produce different features in the resulting SFDs and that these are potentially diagnostic of the initial conditions for the impact and the internal structure of the parent bodies of asteroid families. In contrast, super-catastrophic events (i.e., high-energy impacts with large specific impact energy) result in SFDs that are similar each other.

Second, compared the modeled SFD with actual families. We considered the same families studied by [3] (see their Table 1), who applied the procedure detailed in [8] to determine families. Some of the families analyzed are suspected to have interlopers among the larger members, which can affect the shape of the observed family SFDs. When possible, such interlopers have been removed from the SFD before comparison with the modeled SFDs (see Table 1 in Durda et al. for more details about interlopers).

Our results suggest that some families in the asteroid belt could come from a rubble-pile parent body. The asteroid families that best fit with a rubble-pile parent body are Meliboea, Erigone, Misa, Agnia, Gefion and Rafita. In general, the parent-body size estimated for these families is smaller than the one previously estimated from monolithic targets. All of theses families (except Gefion) were produced by sub-catastrophic impacts. According to the results of the comparison of SFDs, the impact conditions for these families are in the parameter space that allows us to infer physical properties of the parent body. In contrast, Gefion is a family produced by a catastrophic disruption event. For this kind of high-energy impact, the monolithic and rubble-pile SFDs are usually similar, but in this case the SFD of a rubble-pile parent body leads to a better match than the monolithic one. Note that [3] showed that they could not find a good fit for this family with monolithic parent bodies.

Acknowledgements

This project is supported by National Science Foundation grant AST0708517. P.G.B. acknowledges to the Generalitat Valenciana (Consellería de Educación) for providing the financial support for this long-term visit. D.C.R. was supported by the National Aeronautics and Space Administration under Grant Nº NNX08AM39G issued through the Office of Space Science. E.A. thanks to NASA Planetery Geology and Geophysics Program. W.J.M. acknowledges the NASA and NSF Planetary Astronomy Programs.

References

[1] Benavidez, P. G., Daniel D. Durda, Brian L. Enke, William F. Bottke Jr., David Nesvorn, Derek C. Richardson, Erik Asphaug, William J. Merline, (submitted 2011).

[2] Benz, W., & Asphaug, E., Phys. Commun., 87, 253, 1995.

[3] Durda, D. D., Bottke, W. F., Nesvorný, D., Enke, B. L., Merline, W. J., Asphaug, E., & Richardson, D. C., Icarus, 186, 498, 2007.

[4] Michel, P., Benz, W., Tanga, P., & Richardson, D. C., Science, 294, 1696, 2001.

[5] Michel, P., Tanga, P., Benz, W., & Richardson, D. C., Icarus, 160, 10, 2002.

[6] Michel, P., Benz, W., & Richardson, D. C., Icarus, 168, 420, 2004a.

[7] Michel, P., Benz, W., & Richardson, D. C. , Planet. Space Sci., 52, 1109, 2004b.

[8] Nesvorný, D., Jedicke, R., Whiteley, R. J., & Ivezic, Z , Icarus, 173, 132, 2005.

[9] Nesvorný, D., Enke, B. L., Bottke, W. F., Durda, D. D., Asphaug, E., & Richardson, D. C., Icarus, 183, 296, 2006.

[10] Richardson, D. C., Quinn, T., Stadel, J., & Lake, G., Icarus, 143, 45, 2000.

[11] Richardson, D. C., Leinhardt, Z. M., Melosh, H. J., Bottke, W. F., Jr., & Asphaug, E., Asteroids III, Univ. of Arizona Press, Tucson, pp. 501-515, 2002.