EPSC Abstracts
Vol. 10, EPSC2015-373, 2015
European Planetary Science Congress 2015

Survival of the impactor during hypervelocity collisions. An analogue for icy bodies.

Ch. Avdellidou (1), M.C. Price (1) and M.J. Cole (1)
(1) Centre for Astrophysics and Planetary Science, University of Kent, Canterbury, CT2 7NH, UK (ca332@kent.ac.uk)

Abstract

The majority of laboratory and simulation studies of hypervelocity impacts are dedicated to the investigation of the fate of the target bodies. However interest has increased in the fate of the projectile, as a result of several observational findings on asteroid surfaces, indicating the presence of material which does not match the overall lithology of the body. A possible explanation is that these materials are products of inter asteroid impacts in the Main Belt. Additionally, during the dynamical studies of asteroids collisions, the fate of the impactor was mainly neglected. We present the results of our laboratory programme devoted to measuring the survivability, fragmentation and state of the impactor, along with an estimation of the mass that was implanted on the target body, over a speed range of 0.38 - 3.5 km/s. Forsterite (Fo) projectiles were fired onto low porosity, water-ice targets, using the University of Kent's Light Gas Gun (LGG).

1 Introduction

Impacts have shaped asteroids, and their size frequency distribution, through 4.5Ga of Solar System evolution. The appearance and morphology of asteroidal surfaces are also the result of impact processes, which are responsible, for instance, for the formation of craters and the production of regolith. Over the last four decades, a plethora of laboratory experiments and computer simulations have provided insights into collision processes, but our understanding of the fate of the impactor at impact speeds of several km/s is still poorly understood. The fate of the projectile and projectile debris will potentially explain phenomena such as the source of the olivine and dark material deposits observed on Vesta [1] and the "Black Boulder" on (25143) Itokawa [2]. Asteroid 2008 TC3 consists of a peculiar case of a multi-lithology body whose origin is still unknown. A recent study [3] has shown that there is a little chance that foreign material remained on the surface of the body after low speed collisions with asteroids which orbits lay in a limited area in a-e space. There have been performed several laboratory experiments firing onto water-ice and regolith [4], studying the collision, as result from the aspect of the impactor. However, the collisional speed range that was tested was too low to simulate asteroid collisions. Considering an average impact speed of v = 5.3 km/s for Main Belt asteroid collisions [5], we show that material can be embedded on the target body at higher speeds.

2. Experiments

The gun used to perform these experiments is the horizontal two-stage LGG of the Impact Lab of the University of Kent. We used 3mm diameter Mg-rich peridots (Fo) as projectiles, fired with speeds 0.38-3.50 km/s onto low porosity (<10%) water-ice targets. As one of the aims of this project is to measure the size distributions of the projectile's fragments after the impact we built a set up with a water-ice layer to collect all the ejecta.

2.1 Fragment identification

After melting and filtering the ice from the target and the ejecta collecting set up, we ended up with filters that contain the projectile's fragments mixed with contaminating material from the gun. The majority of the contaminating material is C, Fe and Si. This led us to develop a different way to count and measure the olivine fragments. By using a Scanning Electron Microscope (SEM) and performing Energy-dispersive X-ray spectroscopy (EDX) we obtained raw images from scanning the filters that contained the projectile's fragments. Considering that (i) Fo projectiles have a very strong Mg signal and (ii) there is no Mg contamination from the gun, we used the EDX maps of Mg to identify the projectile fragments.

2.2 Photometry with Source Extractor

We applied a photometry technique to each image using the Source Extractor (SExtractor) open source software for astronomical photometry. SExtractor is able to extract every "light source" from the image and returns information about each source (such as the total number and the detected area of each fragment, major and minor axes, etc.).

3. Results

3.1 Size distribution of the ejecta

Following the procedures described above we constructed size frequency distributions for the range of speeds 0.92-3.50 km/s. The size frequencies follow log-normal distributions with a noticeable shift of the mode towards smaller sizes as the impact speed is increased.

3.2 Examination of the largest fragments

After each shot we collected the biggest fragment of the impactor found in the ejecta. The energy density at the time of the impact is Q [J/kg], and its general form is given by:

$$Q = \frac{1}{2}\frac{M_{im}}{M_t + M_{im}}v^2 \tag{1}$$

where M_{im} is the mass of the impactor and M_t the mass of the target, and represents the kinetic energy of the impactor divided by the total mass of the system (see Fig. 1). Raman spectra were obtained of recovered fragments to ascertain whether the shock caused a shift in the olivine lines. Changes in the Raman spectra may also be indicative of changes to the crystallisation and/or the elemental composition of the olivine [6]. By comparing the spectra we collected before and after each shot we noticed a small shift of the two prominent olivine lines which increased with increasing collisional speed (approximate maximum shift 3 cm^{-1}). Additionally, simulations performed with AUTODYN hydro-code giving pressure and temperature values at the moment of the impact.

3.3 Contamination of the target

The general method we applied in order to estimate the mass of the impactor on the target filters is similar to the one described in §2. The goal was to calculate the volume of each fragment and derive its mass.

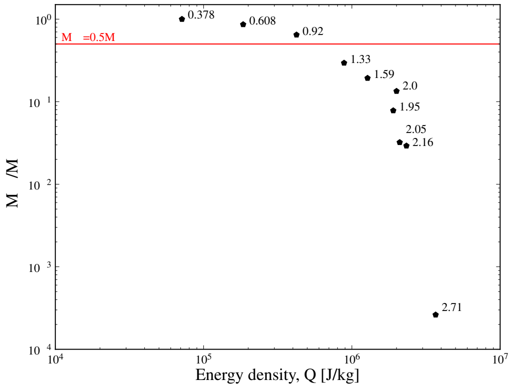

Figure 1: Mass ratio of the largest surviving fragment of the impactor versus the energy density Q_{im}. Catastrophic disruption occurred, when $M_{l,f}/M_{im}$=0.5 [numbers denote impact speed].

After having extracted the 2D area of each fragment, as projected on the detector, we had to estimate a z-axis that corresponds to the fragment's height. Tests were performed in order to show the randomness of the way that each fragment sits on the filter. By proving that there is not a preferable position of the fragments we were able to adopt simple estimations of the z-axis which had to follow similar distributions as x and y axes.

References

[1] V. Reddy et al. Delivery of dark material to Vesta via carbonaceous chondritic impacts. *Icarus*, 221:544–559, 2012.

[2] N. Hirata and M. Ishiguro. Properties and Possible Origin of Black Boulders on the Asteroid Itokawa. In *LPSC*, volume 42, page 1821, 2011.

[3] J. Gayon-Markt et al. On the origin of the Almahata Sitta meteorite and 2008 TC_3 asteroid. *MNRAS*, 424:508–518, 2012.

[4] H. Nagaoka et al. Degree of impactor fragmentation under collision with a regolith surface. Laboratory impact experiments of rock projectiles. *MAPS*, 49:69–79, 2014.

[5] W. F. Bottke et al. Velocity distributions among colliding asteroids. *Icarus*, 107:255–268, 1994.

[6] K. E. Kuebler et al. Extracting olivine (Fo Fa) compositions from Raman spectral peak positions. *GCA*, 70:6201–6222, 2006.