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Research on Europa's dust cloud at The Open University's Hypervelocity Impact (HVI) Laboratory

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Space in the vicinity of Europa is populated by dust originating from the lunar surface. Fragments of the surface are ejected due to meteoroid hypervelocity impacts (but also may originate from sub-surface layers such as found on Enceladus). It is assumed that orbit-based detection and analysis of material ejected from the Europan surface may provide an alternative method for sampling Europan material without landing on the surface. Relative impact speeds from these dust sources onto an in-orbit detector would, typically, be about 2 km/s. This impact speed is generally too low for complete vapourisation of the impactor/target and the ejecta material could be captured in-situ for further analysis. Our current work is aimed at the development of a new hybrid dust detector for any Europa orbiter as well as understanding of Europa's dust cloud by mimicking micrometeorite impact into simulated European regolith/ice. In this paper we present our latest research as well as the facility we have developed as a new laboratory in the field of HVI physics.

Key Words: Europa, dust detector, hypervelocity, laboratory

1. Introduction

The aim of this research is better understanding of the Europan environment in order to allow the fine tuning of the dust instrument that may go to orbit around Europa within ESA Cosmic Vision programme 2015-2025 (LaPlace mission). The more we understand the dust cloud environment the more compatible we could make the dust instrument with the encountered dust. It is important to investigate the fragment size–velocity distribution of the solid ejecta fragments as well as angles at which the fragments are launched in order to profile the Europan dust cloud population.

Depending on the target material (its strength and density) the fragment size distributions are different but yet have similar trends. Here we investigate how those distributions as well as the material ejection angles vary with different projectile incidence angles. We also compare our results with the results derived from impacts into other materials made by other authors.

2. The Open University's HVI Laboratory

The Open University (OU)'s Hypervelocity Impact Laboratory has been developed to support planetary and space science and engineering activities of the OU's Centre for Earth Planetary Space and Astronomical Research (CEPSAR), incorporating the well-known Planetary and Space Sciences Research Institute (PSSRI). The laboratory contains a two stage Light Gas Gun (LGG), with horizontal, vertical and oblique firing configurations, a Van de Graaff (VdG) dust accelerator, as well as a range of planetary environmental chambers and impact target chambers. Following development over the period 2001-2005, and further improvements, in 2005-2007, the OU LGG is now recertified for operation.

The OU's light gas gun (LGG) consists of 0.5" diameter pump tube and .17 cal rifled barrel (can fire projectiles up to 4.3 mm in diameter). It works in the range up to 5 km/s impacting velocities (*E A Taylor, 2006; K Miljkovic et al, 2007*).

Since its re-commissioning, our recent experimental LGG work encompass impacts into sandstone, sandstone doped with cyanobacteria, little porous gypsum rock, porous gypsum plaster block and gypsum plaster powder. Some impacts are imaged using the ultra high speed camera (DRS Ultra 8), others are used for ejecta fragments profiling using the foam coated with 15 m thick aluminium foils.

3. Experimental Method and Results

Using the Open University's light gas gun we simulate impacts into the Europan surface analogue. This time the analogue for the surface was gypsum polycrystalline rock. The projectiles were 1 mm Stainless Steel ball bearings launched at 2 km/s. The impacts are done at 30°, 60° and 90° incidence angles.

Aluminium foil was used to characterize the cumulative mass distribution of the solid ejecta material. The IDL script was written for reading the hole features off the images and calculate the size and spatial distribution of the holes therefore mass as well. The hole are approximated to be circular and by comparing the size-velocity distribution by *Nakamura et al, 1994* with our data set and taking into consideration the mass-velocity ballistic limit for foil penetration (*McDonnell and Sullivan, 1992*) and the hole growth factor (as calculated by *Carey et al, 1985, Grun et al, 2001*) we estimate the size of the fragments that penetrated the foil.

3.1. Total number of ejecta fragments as the function of projectile incidence angles

On the Fig. 1 the total number of holes is plotted against the projectile incidence angle. Our results are compared with *Yamamoto et al, 2002* and *Yamamoto et al, 2003* but rescaled on the Y axis in order to show the functional trend and dependence of the total number of ejected fragments on the projectile incidence angle.

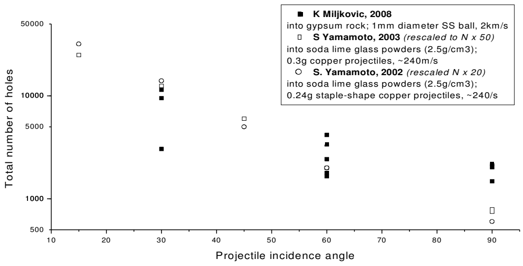

Fig. 1

3.2. Cumulative fragment mass distribution

The Fig. 2, 3 and 4 represent cumulative fragment mass distributions from impacts done at 30º, 60º and 90º. Between three and five shots are repeated for the same experimental setup. Therefore, the Y axis error was estimated to be the standard deviation from the mean value. Mass on the X axis is represented in bins where the bin size is translated from 1 pixel size (because the holes are read from the images).

Cumulative mass distribution is represented by a power-law function ($N=Ad^B$, d is a dust fragment diameter). In the Table 1 our results are compared with other authors that did similar study on different target materials with different projectiles. The total ejecta count presented at Fig. 1 is not comparable with other authors but the slopes of the cumulative power law distributions are (parameter B).

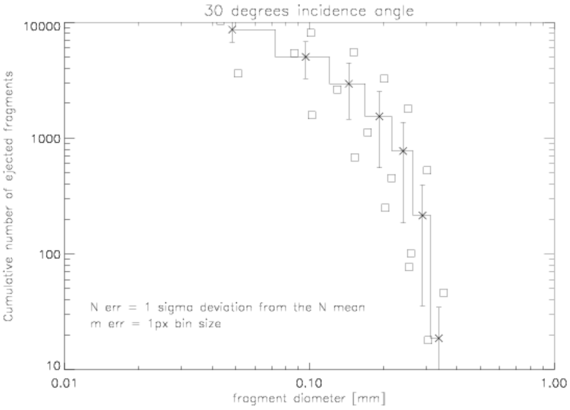

Fig. 2

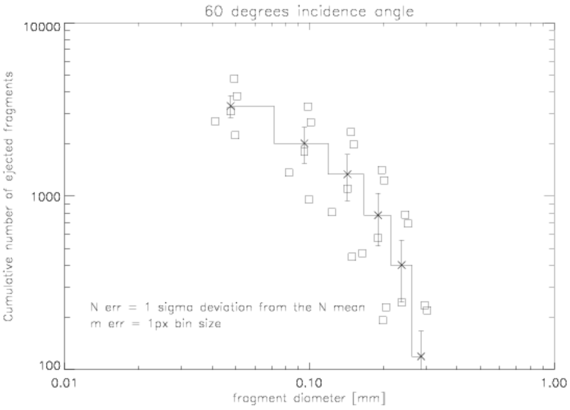

Fig. 3

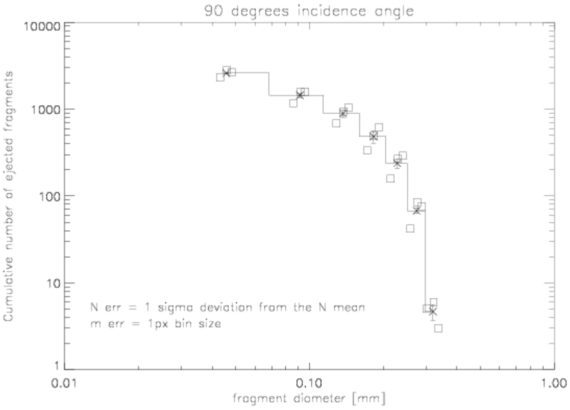

Fig. 4

Table 1.

Target material	Author	B
Water ice	Frisch (1990, 1992)	-1.7
Porous ice-silicate mixture	Frisch (1990, 1992)	-1.2
Compact ice-silicate mixture	Koschny, Grun (2001)	-1.6±0.3
Polycrystalline little porous gypsum	This work	30º: -1.3±0.2 60º: -1.2±0.2 90º: -1.25±0.05

4. Conclusions

The impacts at shallower angles show higher deviation in ejecta count that at higher impacting angles. Most fragments are ejected at 55°-65° angles from the horizontal regardless of the projectile incidence angle. However, at 30° and 60° incidence the ejecta cone was separated into cone with smaller and cone with larger fragments. At 90° this division wasn't noticed. These results agree with *Gault et al, 1963, Evans et al, 1994, Koschny and Grun 2001, Polanskey and Ahrens, 1990, Michikami et al, 2007 etc.*

Future work with include the same set of experiments but on icy targets which should be closer to the real Europan conditions.

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References

1) Evans, N. J. et al *Hypervelocity impact: Ejecta velocity, angle, and composition*, Geological Society of America, Special paper 293, 1994
2) Grun, E et al *Interplanetary Dust*, Springer, 2001
3) Koschny, D. Grun, E. *Impacts into ice-silicate mixtures: Ejecta mass and size distributions*, Icarus, 402-411, 2001
4) McDonnell, J. A. M. and Sullivan, K. *Hypervelocity impacts on space detectors: decoding the projectile parameters,* Hypervelocity impacts in Space, Uni Space Kent, pp. 39-47, 1992
5) Michikami, T. et al, *Ejecta velocity distribution for impact cratering experiments on porous and low strength targets*, Planetary and Space Science 55, 70-88, 2007
6) Miljkovic, K et al, The First Vertical Firing and Ultra High Speed Impact Imaging at the Open University's HyperVelocity Impact Facility, *Proc. 58th ARA Meeting, NM, USA, 2007*
7) Nakamura, A. M. et al, *Velocity of finer fragments from impact*, Planet. Space Sci., Vol. 42, No. 12, pp. 1043-1052, 1992
8) Polanskey, C. A. and Ahrens, T. *Impact Spallation Experiments: Fracture Patterns and Spall Velocities*, Icarus, 87, 140–155, 1990
9) Taylor, E. A. *et al.*, The OU HVI Laboratory, *Proc. 57th ARA Meeting*, Italy, Sept. 2006.
10) Yamamoto, S et al. *Measurements of ejecta distribution from regolith targetrs in oblique impacts*, LPSC XXXIV, 2003
11) Yamamoto, S *Measurements of Impact Ejecta from Regolith Targets in Oblique Impacts*, Icarus 158, 87-97, 2002