SPACE · ART
SPACE ADVANCED RESEARCH TEAM

2010 European Planetary Science Congress

Kinematic Impacts – Improved Modeling of Asteroid Deflection
Experimental and Numerical Approach

Rome, Italy, 19^{th}-24^{th} September

Alison Gibbings
Eirini Komninou
Massimiliano Vasile

Space Advanced Research Team
Dept. of Aerospace Engineering
University of Glasgow,
Scotland, UK

CONTENTS

MOTIVATION

Aims to model the kinematic impact asteroid deflection scenario….long-term impact evolution of the solar system

Limited by:

- Kinematic impacts that occur at the Centre of Mass of the asteroid
- Characterisation of the asteroid (analogue) physical/material characteristics
- Assumptions regarding the ejecta distribution and profile

agibbing@eng.gla.ac.uk

MODELLING – APPROACH

Developing a model to account for:

- Impacts onto non-spherical, initially rotating bodies
- Occur from a given proximity to the CoM
- Variation in impact geometry
- Variation in asteroidal composition (Athen, Apollo etc)

Provide a realistic and improved deflection and cratering response of (kinematic) impacting events

Support this development, wished to provide validation data through experimental cratering events

agibbing@eng.gla.ac.uk

EXPERIMENT - APPROACH

ESA Education Office – 2010 Spin Your Thesis! Campaign

8 m Large Diameter Centrifuge, with a payload capability of 80 kg

<u>Intended to:</u>

- Reproduce and investigate impact cratering events onto porous asteroid analogue bodies
- Provide cratering response data – validation and advancement of numerical models

Assess projectile density and target material (asteroid analogue) porosity as a function of crater formation and ejecta distribution

University of Glasgow | SPACE ART
Space Advanced Research Team
agibbing@eng.gla.ac.uk

SIMILARITY ANALYSIS

(Schmidt & Holsapple, 1987; Housen & Holsapple 2002)

Crater's volume can be expressed as:

$\text{Projectile's}:$

$a = Radius$

$\delta = Density$

$U = Velocity$

$g = Gravity$

Target Material

$\rho = Density$

$Y = Strength$

$n = Porosity$

$$V = f\left[a, U, \delta, \rho, Y, g, n\ldots\right]$$

Standard tools of dimensional analysis:

$$\frac{\rho V}{m} = f\left[\frac{ga}{U^2}, \frac{Y}{\rho U^2}, \frac{\rho}{\delta}, n, \pi_M\right]$$

Further reduced to:

$$\left[\frac{ga}{U^2}\right]$$

$$\frac{(g_C)(a_C)}{U_C^{\ 2}} = \frac{(g_A)(a_A)}{U_A^{\ 2}}$$

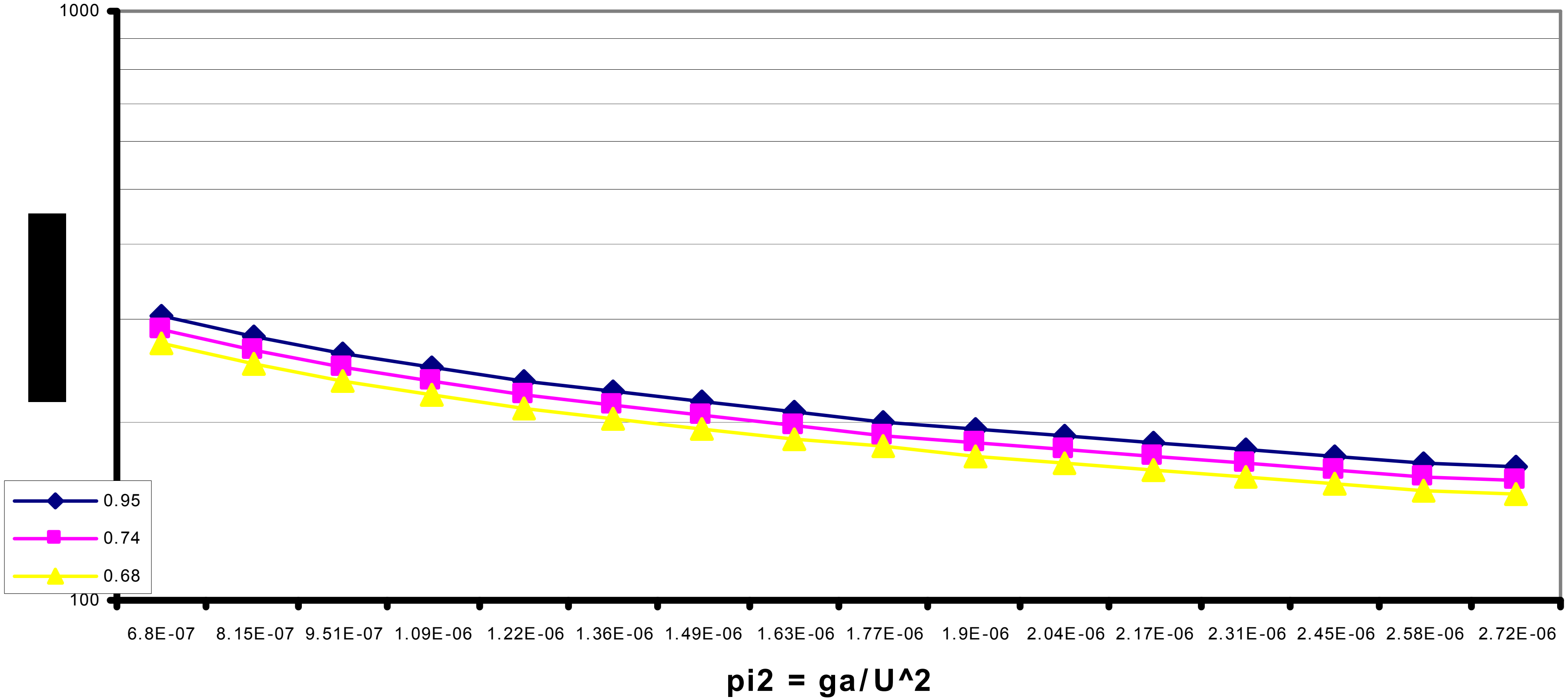
$$a_A = a_C\left(\frac{g_C}{g_A}\right)\left[\left(\frac{U_A}{U_C}\right)^2\right]$$

'Gravity regime' dominates the cratering process

agibbing@eng.gla.ac.uk

SIMILARITY ANALYSIS

Increasing role of gravity



University of Glasgow
SPACE ART
Space Advanced Research Team
agibbing@eng.gla.ac.uk

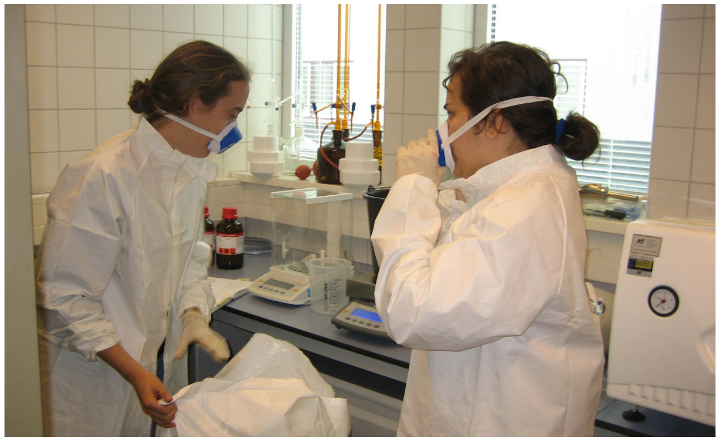
EXPERIMENT

Target material - mixture of quartz sand and expanded perlite

Table 2: Target Material Mixture

(Similar, but not identical to Housen & Holsapple 2002)

Mixture (Percentage by Mass)				
Expanded Perlite	Quartz Sand	Water	Average Density (g/cm^3)	Average Porosity (%)
100	0	0	0.103	96
21	27	52	0.443	74
11	59	30	0.668	68



agibbing@eng.gla.ac.uk

EXPERIMENT

For each sample, impact events occurred at increasing levels of acceleration

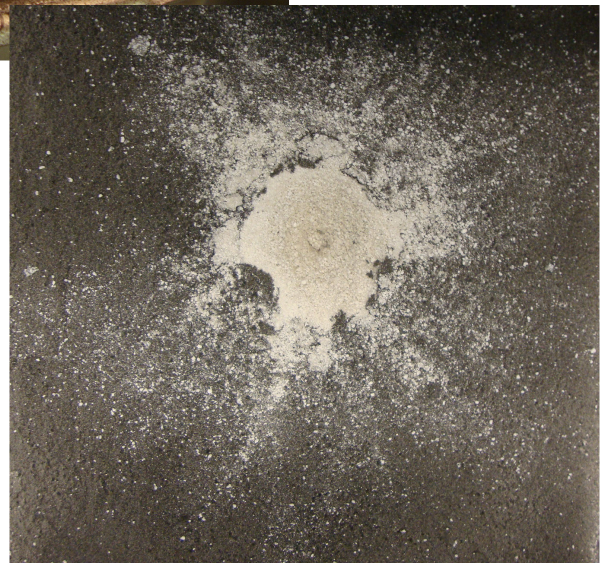
- Recorded each impact onto high speed cameras
- Measured the crater diameter, shape, cross-section depth
- Preserved selected samples through application of a epoxy resin

Enable later topographical scans

Analysis of possible microscopic compaction as a function of distance via a SEM

agibbing@eng.gla.ac.uk

EXPERIMENT AT ESA/ESTEC

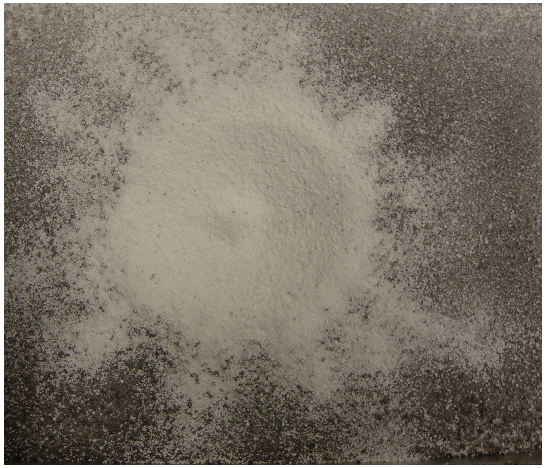


University of Glasgow | SPACE ART
Space Advanced Research Team

agibbing@eng.gla.ac.uk

OBSERVED TRENDS

- With very high porosity samples (96 %), under increasing acceleration:
  - More ejecta remained within the crater bowl.
  - Noticeable & increasing central peak
  - Crater becomes smaller, with some irregular impact craters.



University of Glasgow | SPACE ART
Space Advanced Research Team

agibbing@eng.gla.ac.uk

OBSERVED TRENDS

- At high porosity (approx 70 %) sample, under increasing acceleration:
  - Crater becomes slightly wider, with an decreasing depth.
  - Much less ejecta escapes the crater rim.

- At mid porosity (approx 60 %) under increasing acceleration:
  - Crater shape is far more coincident between tests
  - Decreasing crater size, with less ejecta

agibbing@eng.gla.ac.uk

CLOSING REMARKS & FUTURE WORK

- Ongoing analysis will provide data for the advancement and validation of numerical code

  - Include detailed material characterisation of the asteroid-analogue target material and cratering response
  - Analysis is ongoing – data was collected last week!

- 2010 Spin Your Thesis! Campaign provided a solid foundation, and prove of concept for the experimental design

University of Glasgow | SPACE ART
Space Advanced Research Team

agibbing@eng.gla.ac.uk

Thank you for your Time

ANY QUESTIONS?

agibbing@eng.gla.ac.uk