

## Strathprints Institutional Repository

Gibbins, Alison and Komninou, Eirini and Vasile, Massimiliano (2010) *Kinematic impactors : Improved modelling of asteroid deflection from an experimental and numerical approach*. In: European Planetary Science Congress, 2010-09-19 - 2010-09-24, Rome.

Strathprints is designed to allow users to access the research output of the University of Strathclyde. Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. You may not engage in further distribution of the material for any profitmaking activities or any commercial gain. You may freely distribute both the url (<http://strathprints.strath.ac.uk/>) and the content of this paper for research or study, educational, or not-for-profit purposes without prior permission or charge.

Any correspondence concerning this service should be sent to Strathprints administrator: <mailto:strathprints@strath.ac.uk>

SPACE · ART

SPACE ADVANCED RESEARCH TEAM



**2010 European Planetary Science Congress**

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

**Alison Gibbings**

Eirini Komninou

Massimiliano Vasile

Space Advanced Research Team

Dept. of Aerospace Engineering

University of Glasgow,

Scotland, UK

Rome, Italy, 19<sup>th</sup>-24<sup>th</sup> September

# CONTENTS

---



Motivation and requirement for modelling

Newly adopted approach

Numerical and Experimental design

Preliminary Results

Closing remarks

Future Work



University  
of Glasgow

SPACE ART  
Space Advanced Research Team

[agibbing@eng.gla.ac.uk](mailto:agibbing@eng.gla.ac.uk)

# 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



University  
of Glasgow

SPACE ART  
Space Advanced Research Team

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

# EXPERIMENT - APPROACH

---



ESA Education Office – 2010 Spin Your Thesis! Campaign

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

Intended to:

- 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**



# SIMILARITY ANALYSIS

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



Crater's volume can be expressed as:

Projectile's : 
$$V = f[a, U, \delta, \rho, Y, g, n...]$$

$a = \text{Radius}$

$\delta = \text{Density}$

$U = \text{Velocity}$

$g = \text{Gravity}$

Standard tools of dimensional analysis:

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

Target Material

$\rho = \text{Density}$

$Y = \text{Strength}$

$n = \text{Porosity}$

Further reduced to:

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

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

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

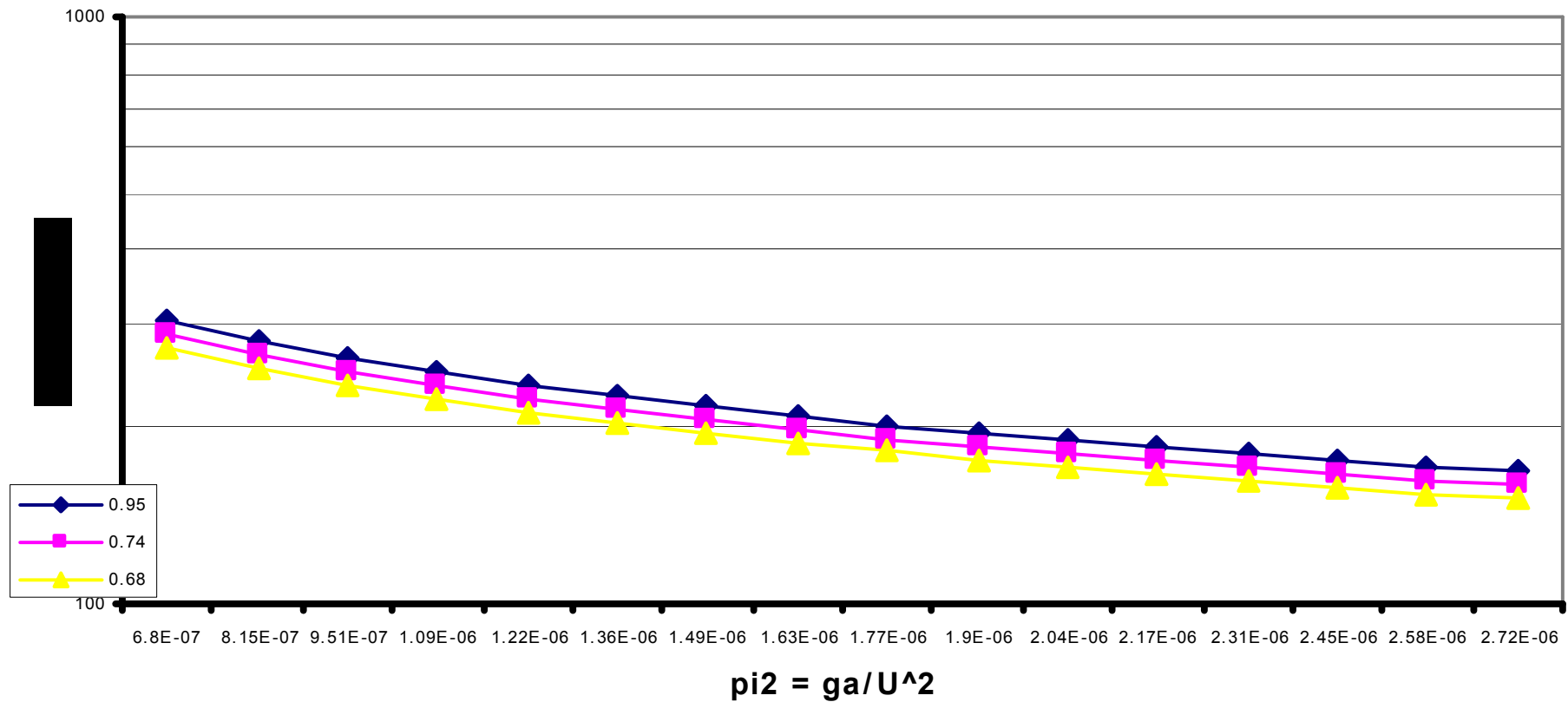
'Gravity regime' dominates the cratering process



# SIMILARITY ANALYSIS



Increasing role of gravity





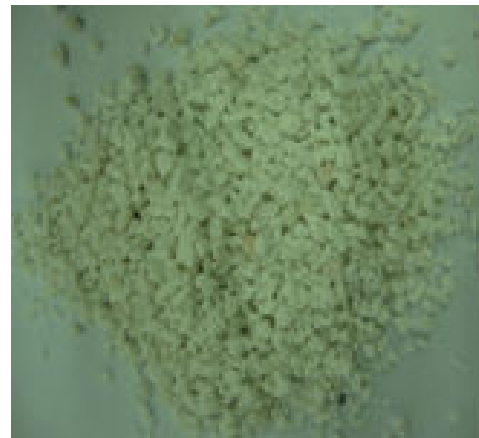
# EXPERIMENT



Target material - mixture of quartz sand and expanded perlite

Table 2: Target Material Mixture

Mixture (Percentage by Mass)			(Similar, but not identical to Housen & Holsapple 2002)	
Expanded Perlite	Quartz Sand	Water	Average Density (g/cm <sup>3</sup> )	Average Porosity (%)
100	0	0	0.103	96
21	27	52	0.443	74
11	59	30	0.668	68



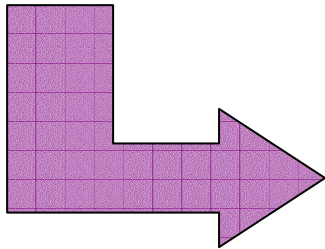
# EXPERIMENT

---



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

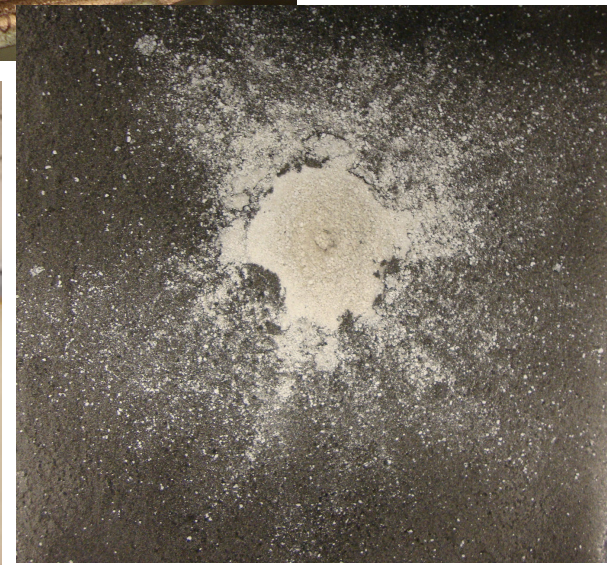


Enable later topographical scans

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



# EXPERIMENT AT ESA/ESTEC



University  
of Glasgow

SPACE ART  
Space Advanced Research Team

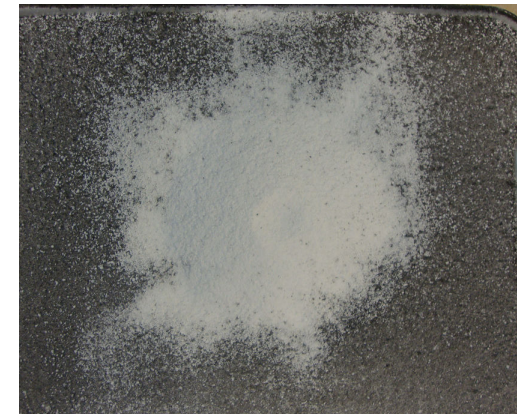
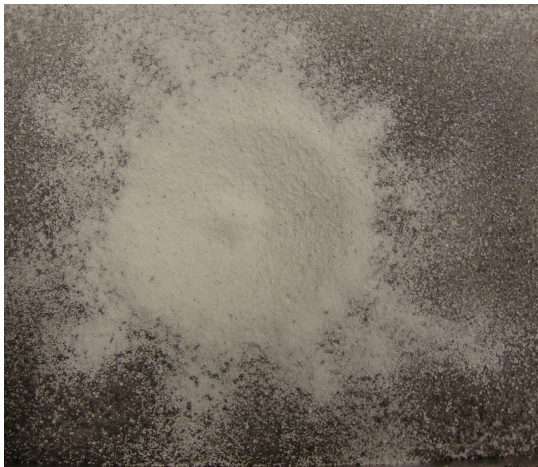
[agibbing@eng.gla.ac.uk](mailto:agibbing@eng.gla.ac.uk)

# 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.



# 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



# 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





---

Thank you for your Time

**ANY QUESTIONS?**



University  
of Glasgow

SPACE ART  
Space Advanced Research Team

[agibbing@eng.gla.ac.uk](mailto:agibbing@eng.gla.ac.uk)