Coagulation of Dust - Collisions in the Decimetre Range

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Introduction

- Planets form by accretion of km size protoplanetary bodies
- these planetesimals grow from dust particles
- different models of growth
  - coagulation of dust agglomerates
  - gravitational clumping of solids
  - combination of both
- decimetre size bodies important in both models
  - direct precursors of metre size bodies
  - can easily be trapped in vortices where gravitational collapse can occur

Introduction

- collision properties of decimetre size agglomerates important
- threshold conditions for fragmentation crucial for coagulation models

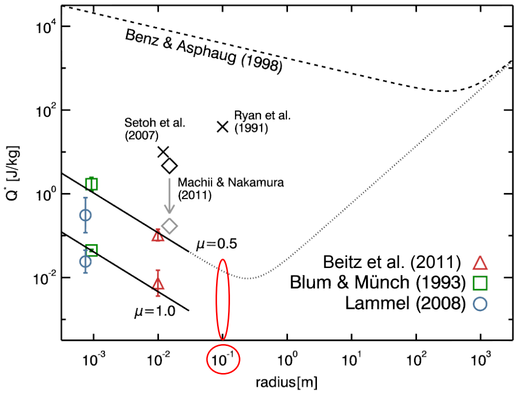


Figure : Critical fragmentation strength Q^* [Beitz et al. (2011)]

Experiment

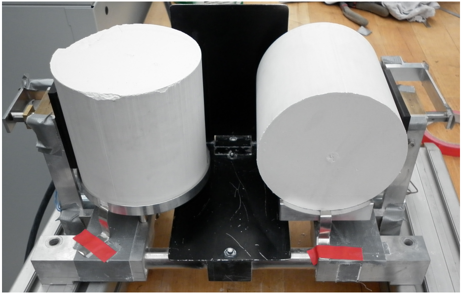
Pressing of the Dust Agglomerates

- used analogue material:
  Quartz ($\mathrm{SiO_2}$), irregular grains
- grain size: 0.1 to 10 $\mu\mathrm{m}$, 80% of mass are in 1-5 $\mu\mathrm{m}$ (producer: Sigma-Aldrich)
- volume filling factor and grain size relevant for mechanical properties (Meisner et al. (2012), Schräpler et al. (2012), Blum et al. (2006))
- agglomerates with the same size ($\varnothing$=12cm) and volume filling factors ($\phi \approx 0.44$)
- mass of each agglomerate is $\approx$1.5 kg

Experiment

Collision Setup

- experiment in a vacuum chamber in the drop capsule (p $\lesssim 10^{-2}\mathrm{mbar}$)
- carried out at drop tower in Bremen (4.7 s of microgravity)
- acceleration by a linear motor
- observation with two high speed cameras (500 fps)



Collision Videos

Example for Bouncing

- collision velocities between 0.8 and 7 $\frac{\mathrm{cm}}{\mathrm{s}}$

Collision Videos

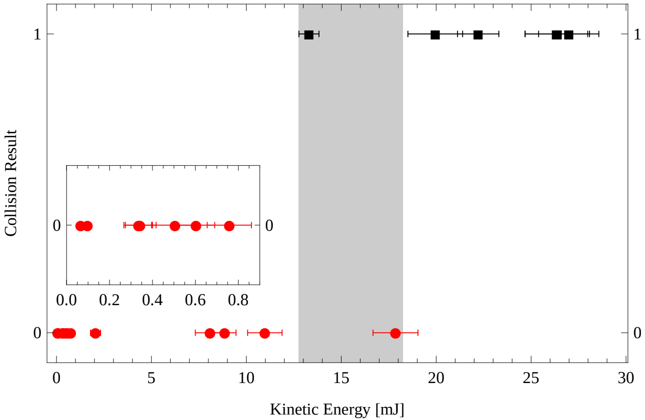
Example for Fragmentation

- collision velocity at $\approx 25.7\ \frac{\mathrm{cm}}{\mathrm{s}}$

First Results

Critical Collision Velocities

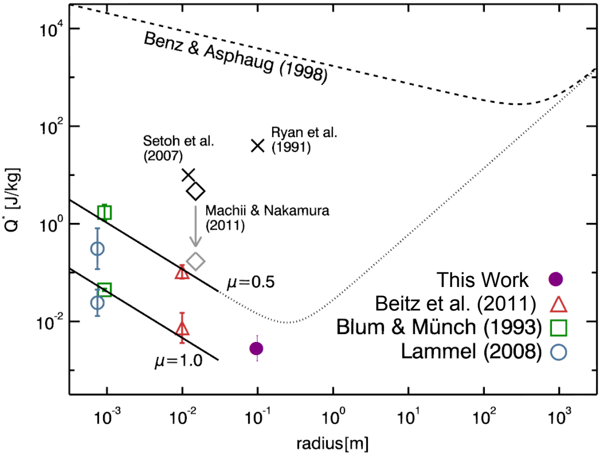
- Bouncing = 0, Fragmentation = 1
- critical fragmentation velocity at about 16 $\frac{\mathrm{cm}}{\mathrm{s}}$



First Results

Critical Fragmentation Strength

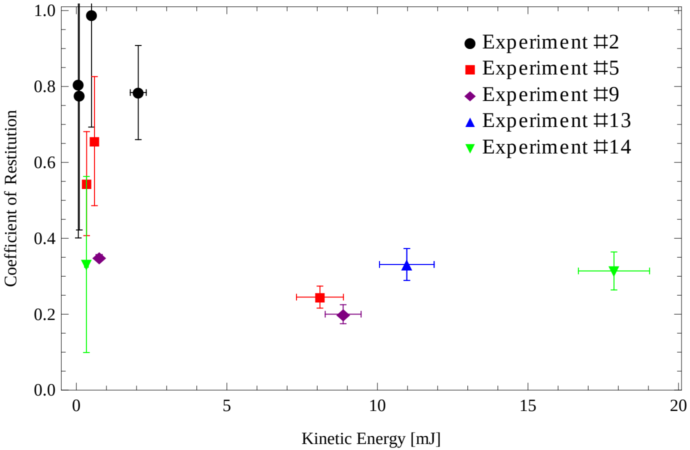
- μ=1: boundary between bouncing and fragmentation
- critical fragmentation strength $Q^* \approx (5 \pm 0.6) \cdot 10^{-3} \frac{J}{kg}$



First Results

Coefficient of Restitution

- ratio of kinetic energy after and before the collision
- decreases with increasing collision energy
- dependend on primary collision energy



Conclusions

- critical fragmentation velocity at $\approx$ 16 $\frac{\mathrm{cm}}{\mathrm{s}}$ $\left(\mathrm{Q}^* \approx (5 \pm 0.6) \cdot 10^{-3} \frac{\mathrm{J}}{\mathrm{kg}}\right)$
- elastic behaviour at low collision velocities
- coefficient of restitution decreases with increasing collision energy