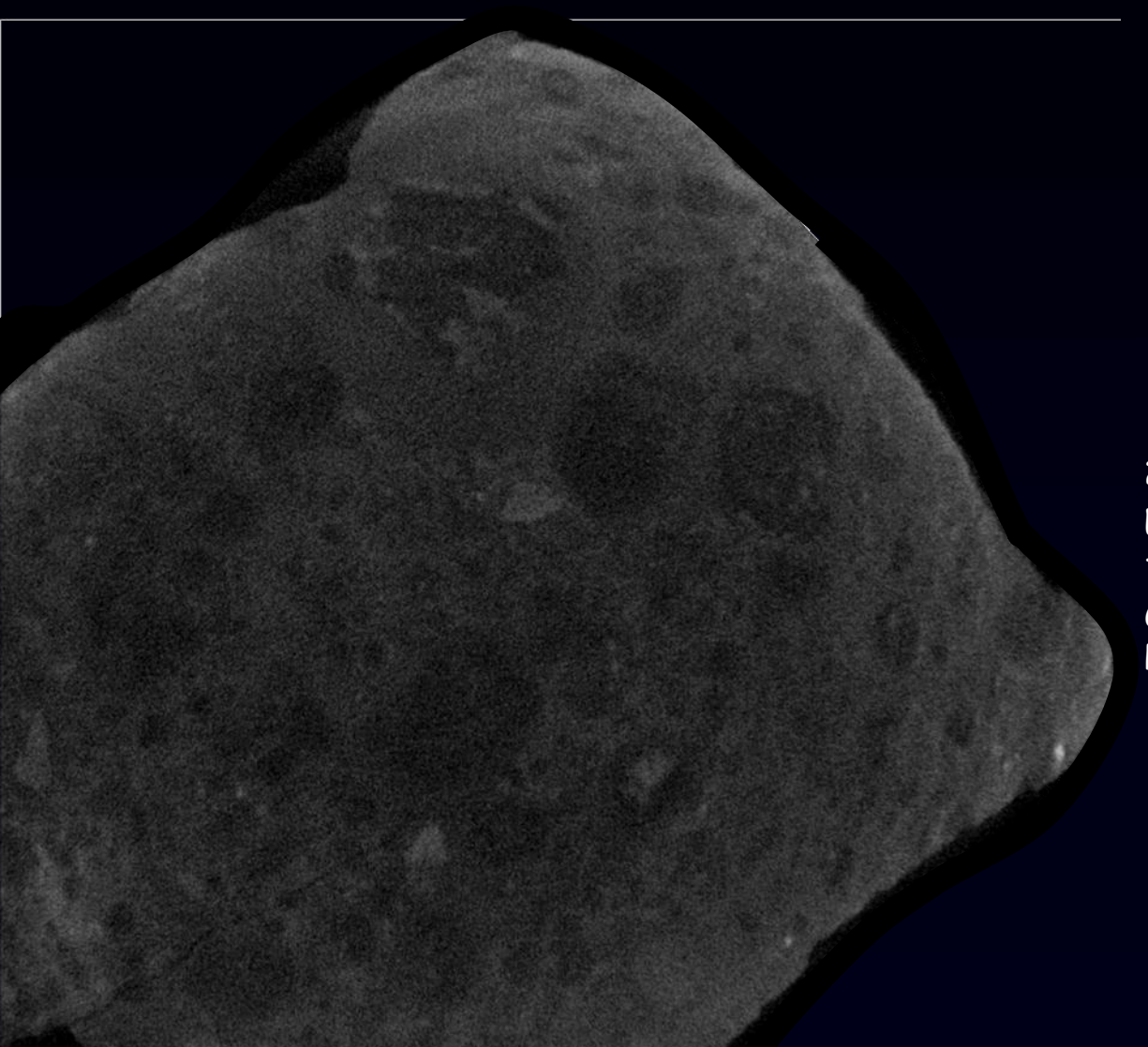
Formation of chondrule dust rims and their influence on the formation of chondrites



24.04.2012

Eike Beitz & Jürgen Blum

TU Braunschweig - Institut für Geophysik und extraterrestrische Physik

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Outline

- Introduction / Motivation
- Experiments
  - Coating Experiments – Cold
  - Coating Experiments – Hot
  - Collisions Experiments
  - Impact Experiments
- Conclusions

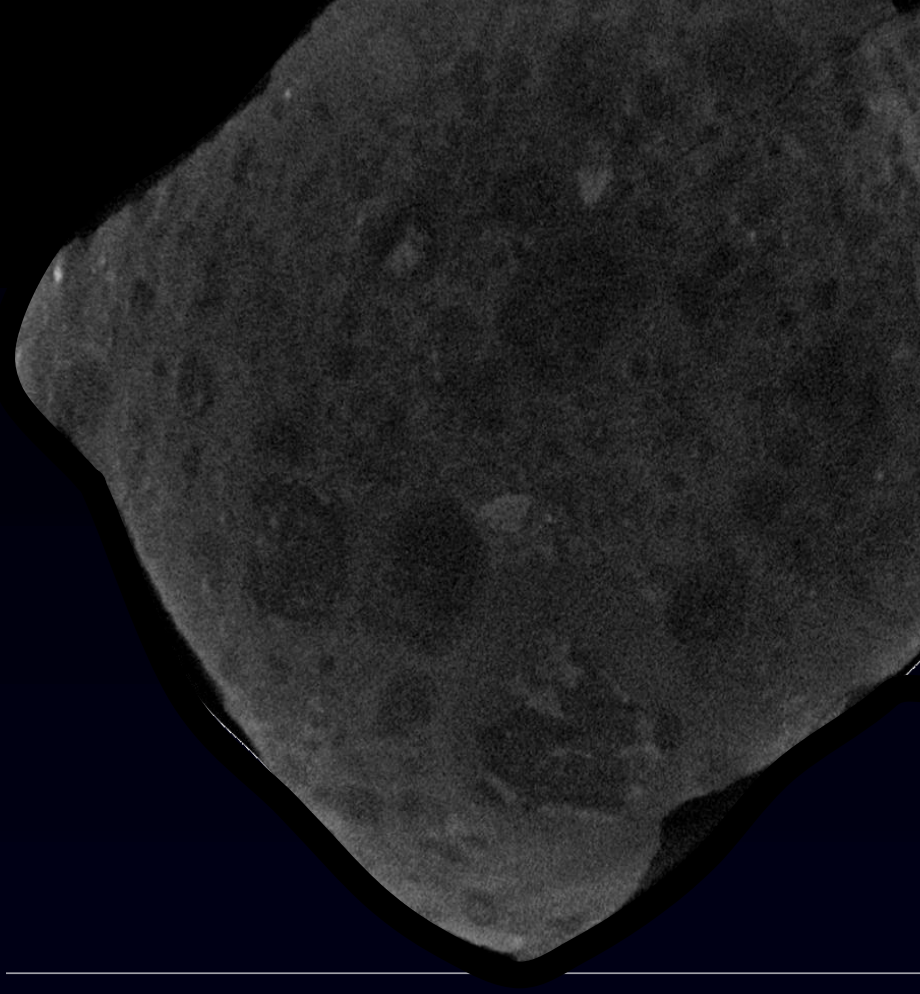
Meteorites

- 86.2 % of the meteorites are undifferentiated and are called chondrites

- these are unmolten witnesses of the early stages of planet formation

- consisting of chondrules (0 – 80 vol.%), matrix (0 – 100 vol.%), an opaqe phase (0 – 70 vol.%), and CAIs (up to 9 vol.%)

- formed 2.5 Myrs afer the CAIs over a time span of 2 Myrs



Type: CM2 (Murchison)

Fall : 1969

Age : 4.567 billion years (Bouvier et al. 2007)

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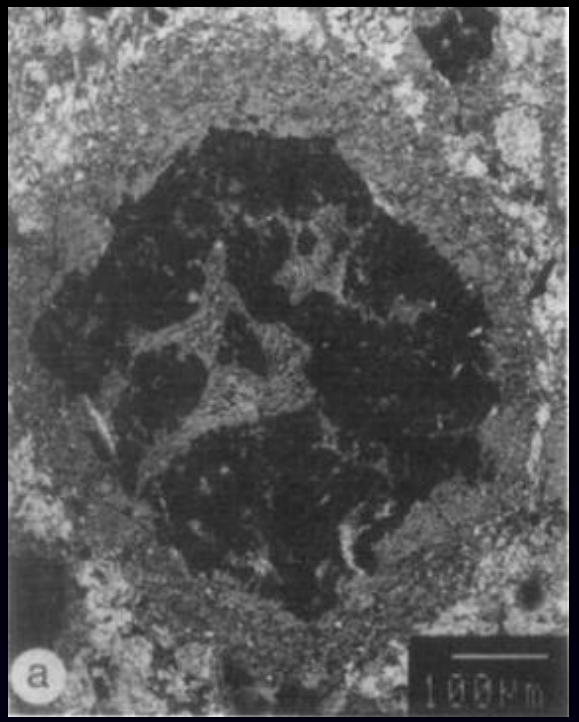
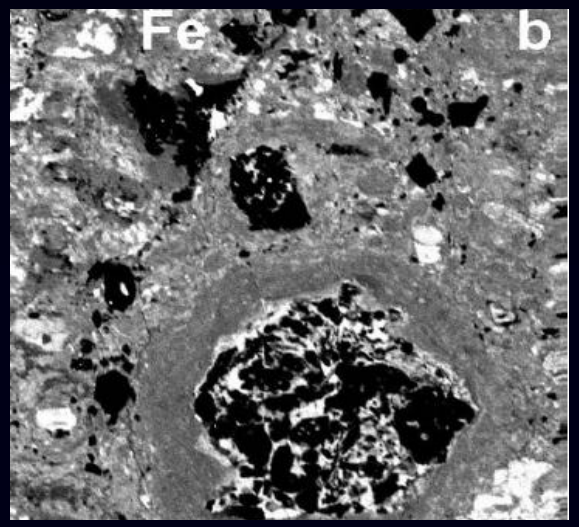
Properties of chondrule fine grained rims

- Dusty envelope surrounding chondrules
  - All larger particles are covered with dust and more than 50 vol.% of not chondrule fraction are rim material.
- Low porosity (Wasson et al. 2005) ~ 6-15%
- Chondrule, rims, and matrix consist of similar material (Palme et al. 1993)
- Volatile elements that are depleted in chondrules are enriched in rim and matrix
- Rim thickness proportional to chondrule size (Metzler et al. 1992)





top: Metzler et al. 1992

bottom: Trigo-Rodriguez et al. 2006

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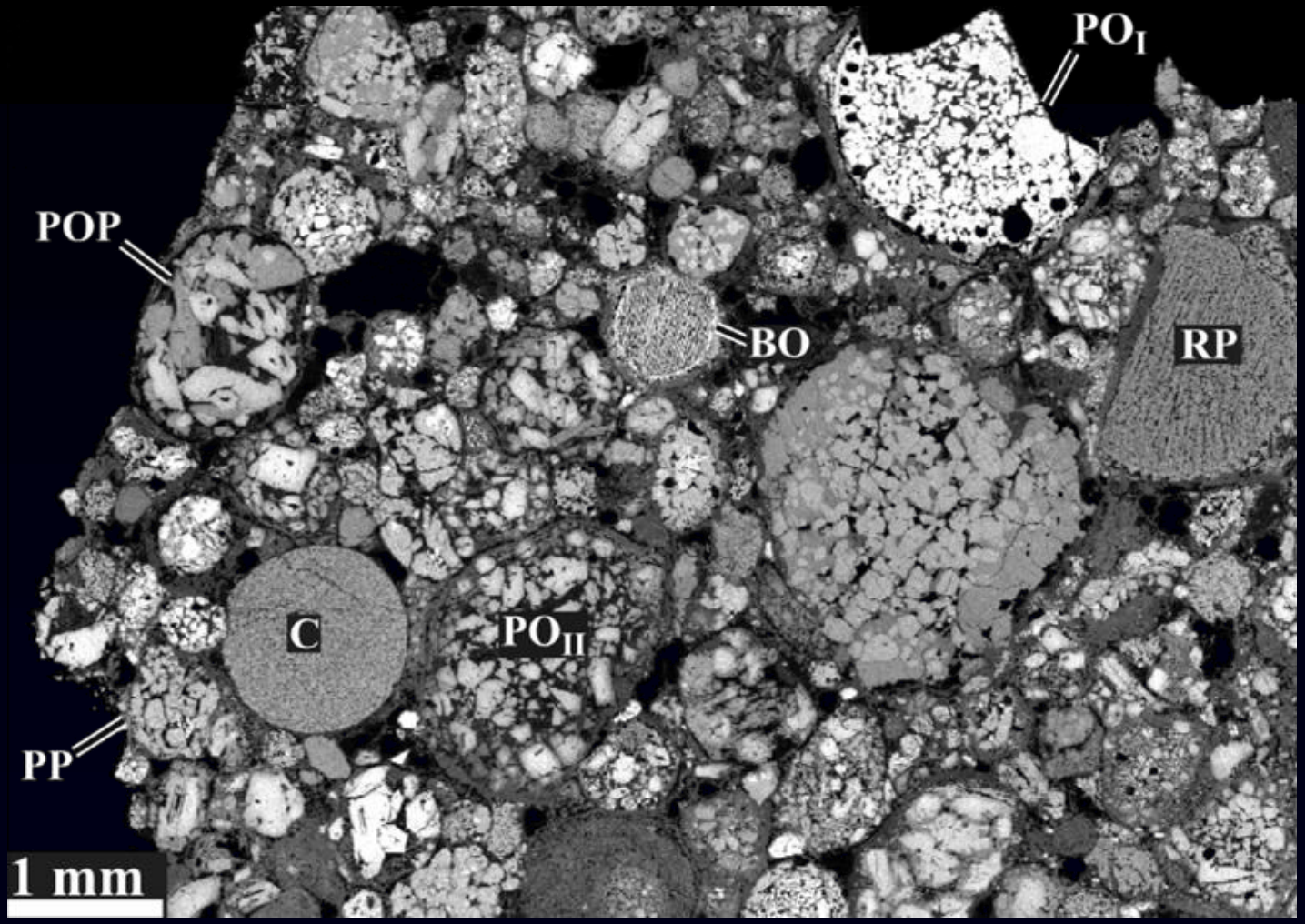
Chondrule - Textures



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Scott & Krot 2005

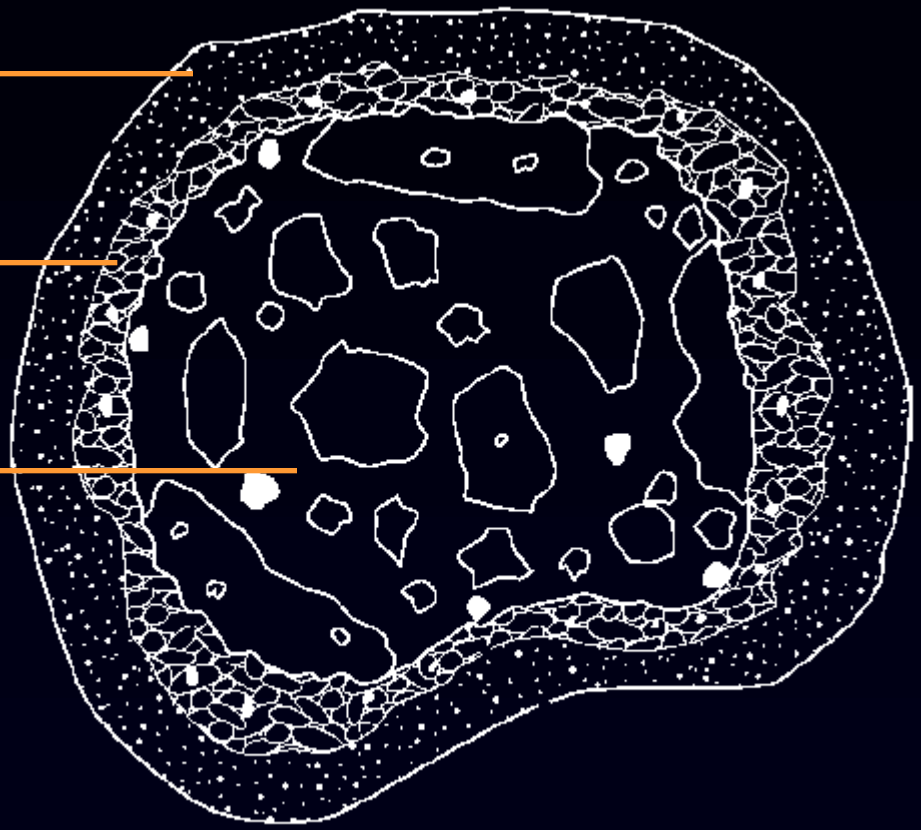
Tieschitz ordinary chondrite H3

Chondrule - Sketch

fine-grained matrix rim

coarse grained rim

chondrule



after: Scott & Krot 2005

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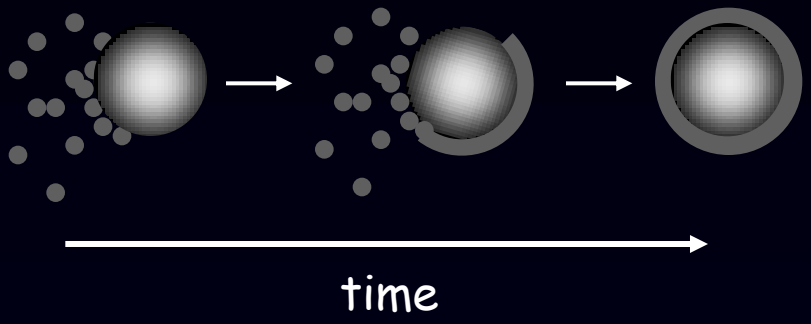
Formation Theories on Chondrule Rims

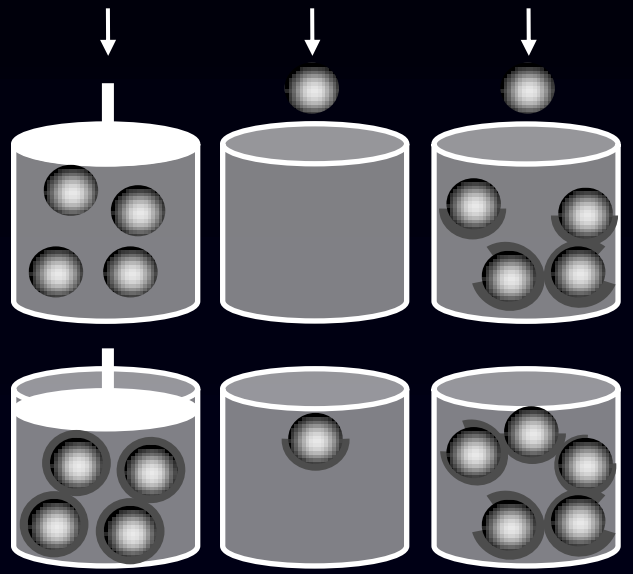
Accretion of dust rims in solar nebula

- Cold accretion
- Hot accretion



Formation of rims due to compression of / shock within parent body

- Dynamical parent-body compression
- High-velocity



A combination of both hypothesis ?

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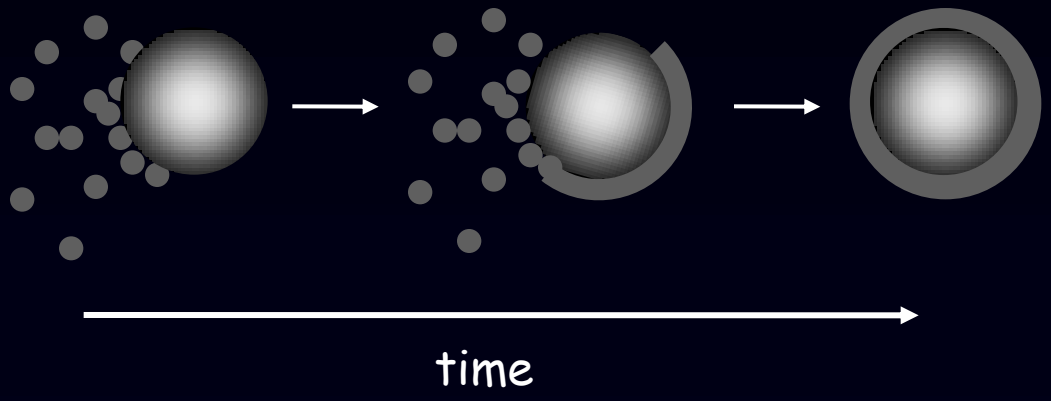
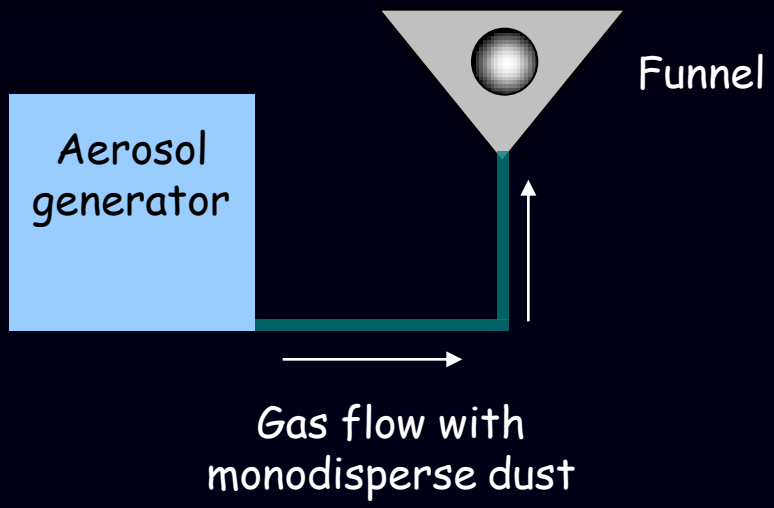
Coating Experiments Cold

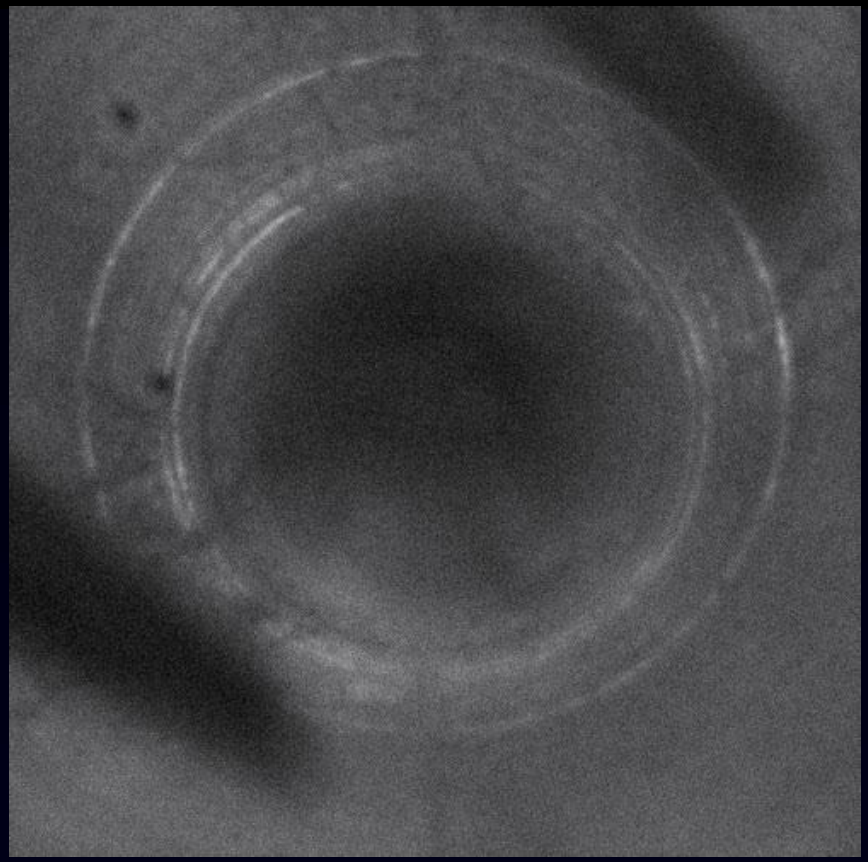


Particle Coating – Cold
(referring to nebular accretion)

Accretion of µm-sized dust on chondrule analogs – formation of fluffy accretionary rims in the laboratory

Levitating glassbead





Beitz et al. 2012

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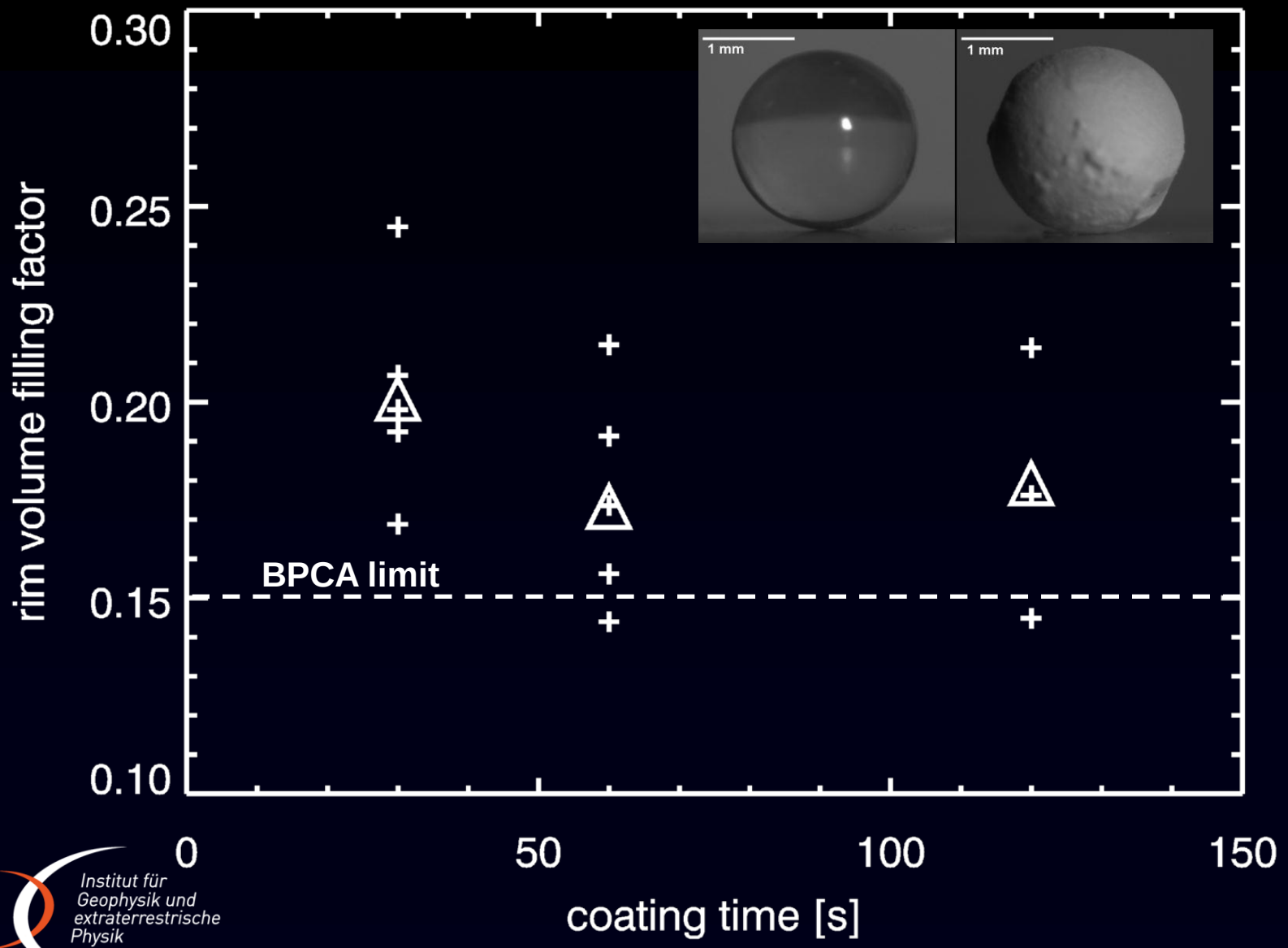
Results – Particle Coating



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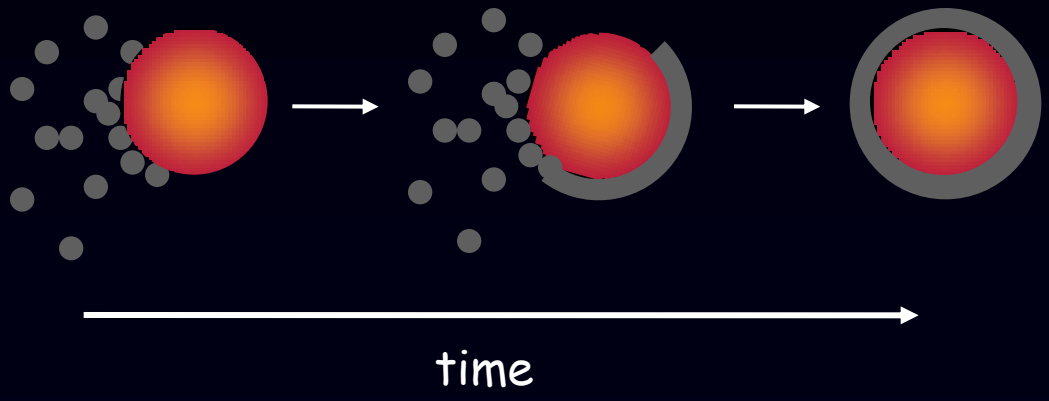
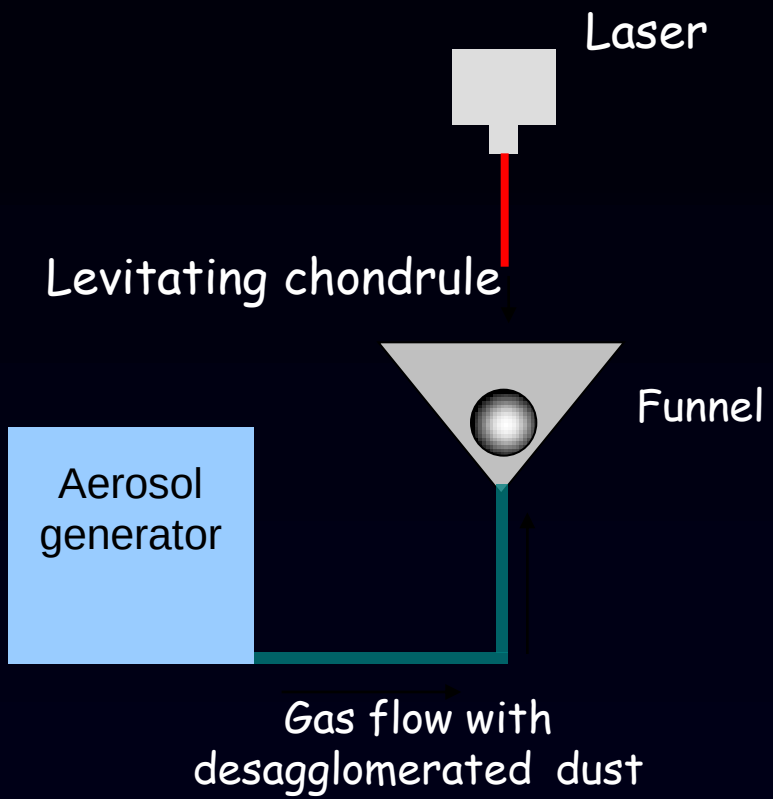
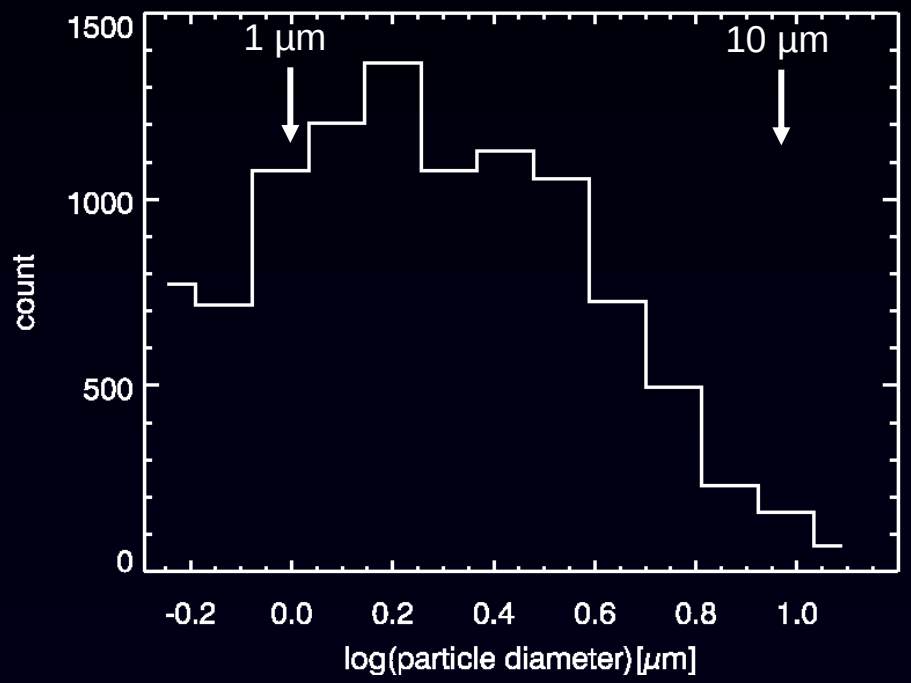
Coating Experiments
Hot



Particle Coating – Hot



Size Distribution of Olivine Dust



Colaboration with A. Pack and R. Mathieu U Göttingen and Dominik C. Hezel U Köln

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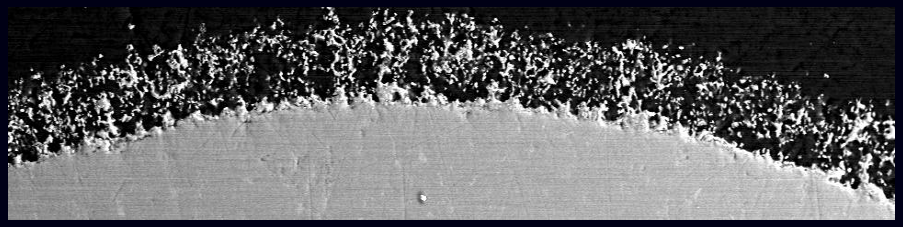
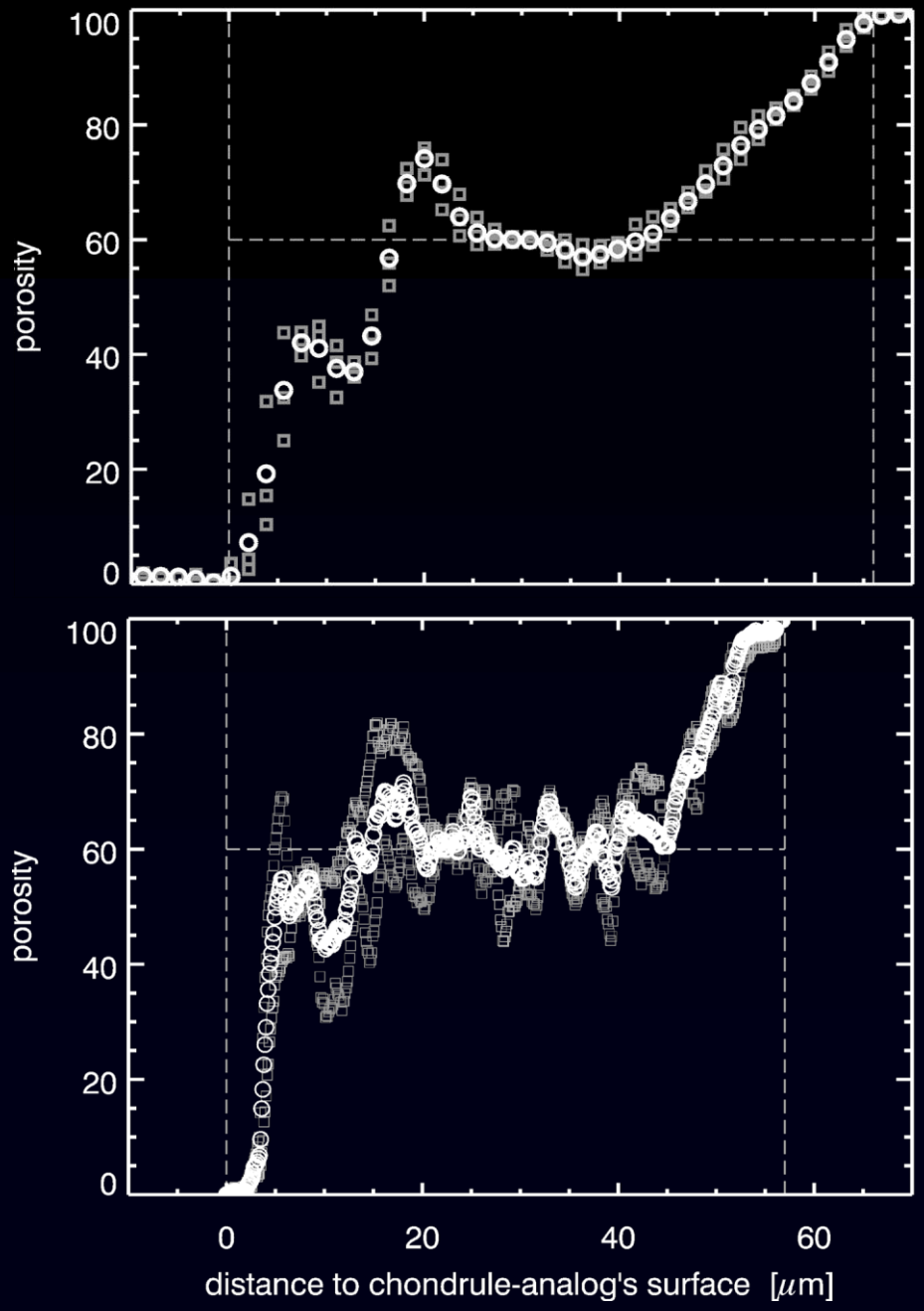
Particle Coating – Hot



T ~ 1100 °C Coating time 120 s



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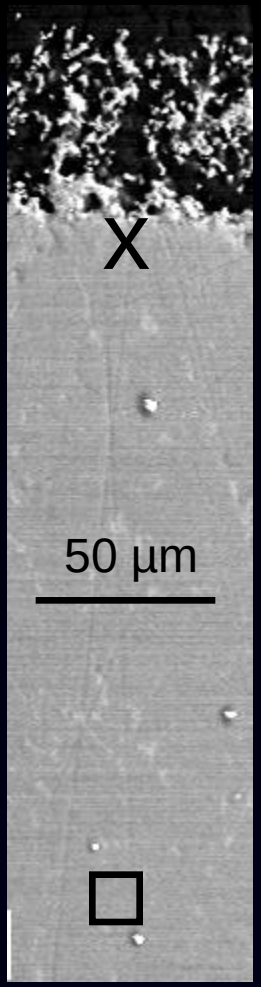
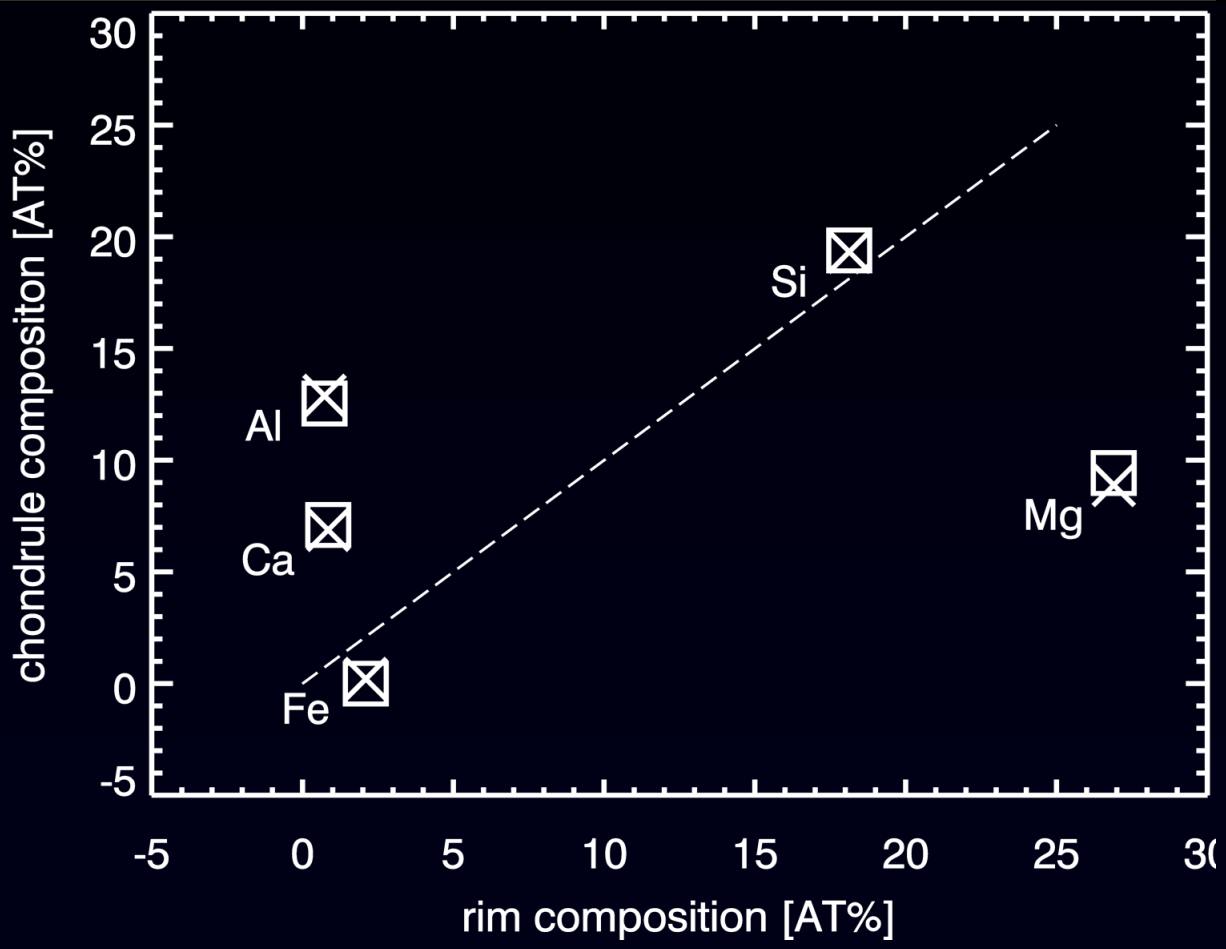
Sharp Boundary between Chondrule and Rim





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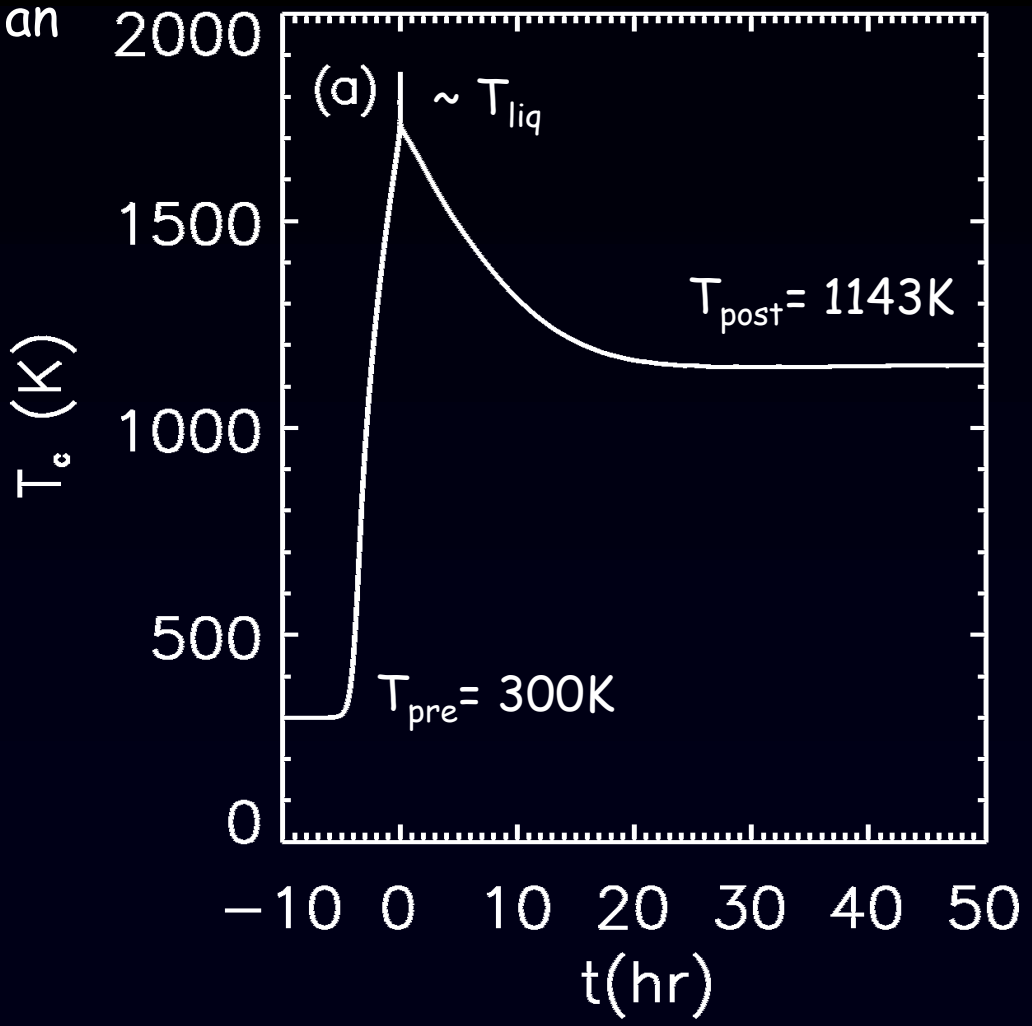
Beitz et al. submitted

Temperature Profiles of Chondrule Formation Processes

- Chondrules are formed by an energetic process
  - nebula shock waves
  - accretion shocks
  - x- wind
  - nebula lightning
  - impact melting
  - magnetic flares
  - …



Morris et al. 2010

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Nebula Shocks

46.6 % SiO_2

40.4 % MgO

4.5 % CaO

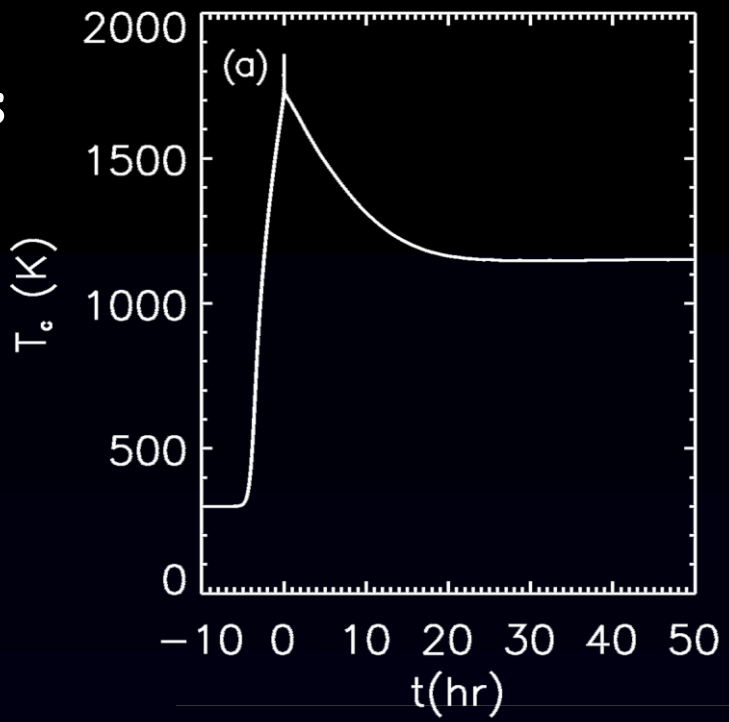
0.5 % TiO_2

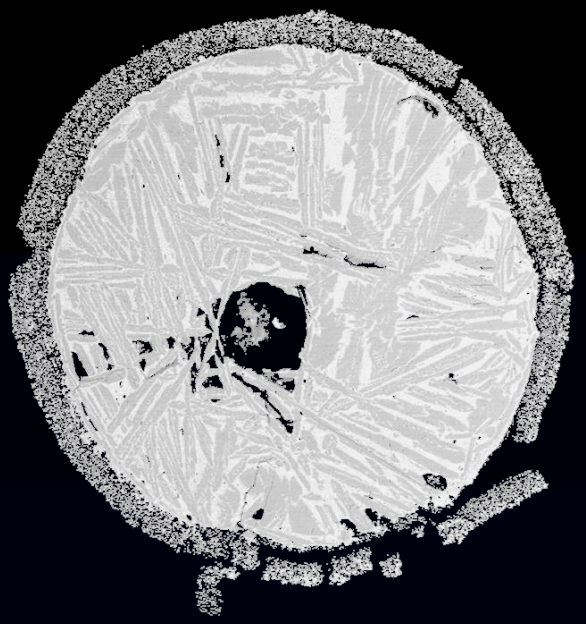
2.8 % FeO

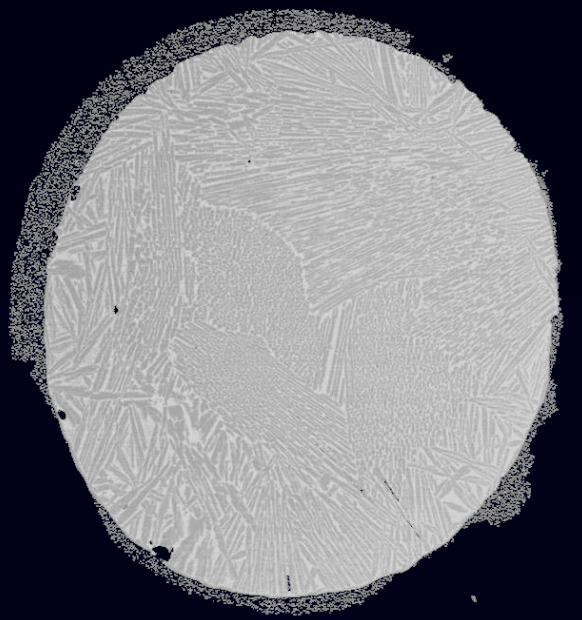
4.7 % Al_2O_3

0.5 % MnO

T_{liq} = 1723°C







Olivine $(Fe,Mg)_2SiO_4$

Pyroxene $(Fe, Mg,Ca)_2Si_2O_6$

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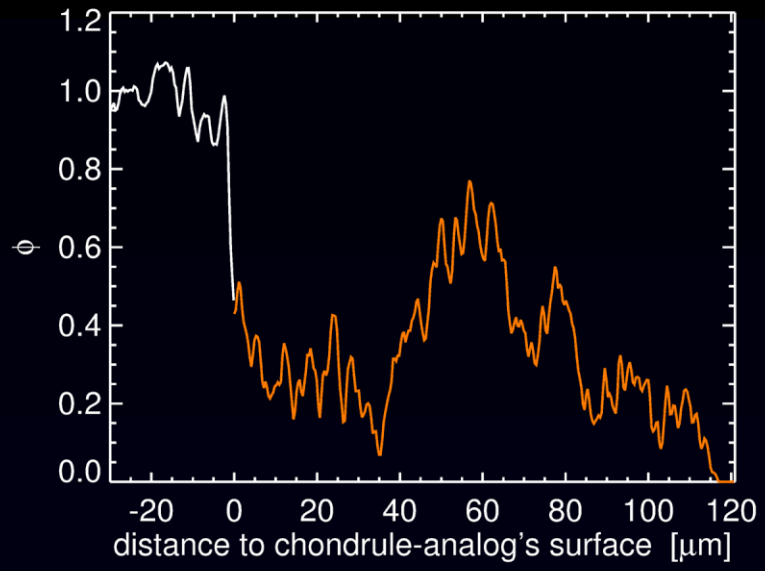
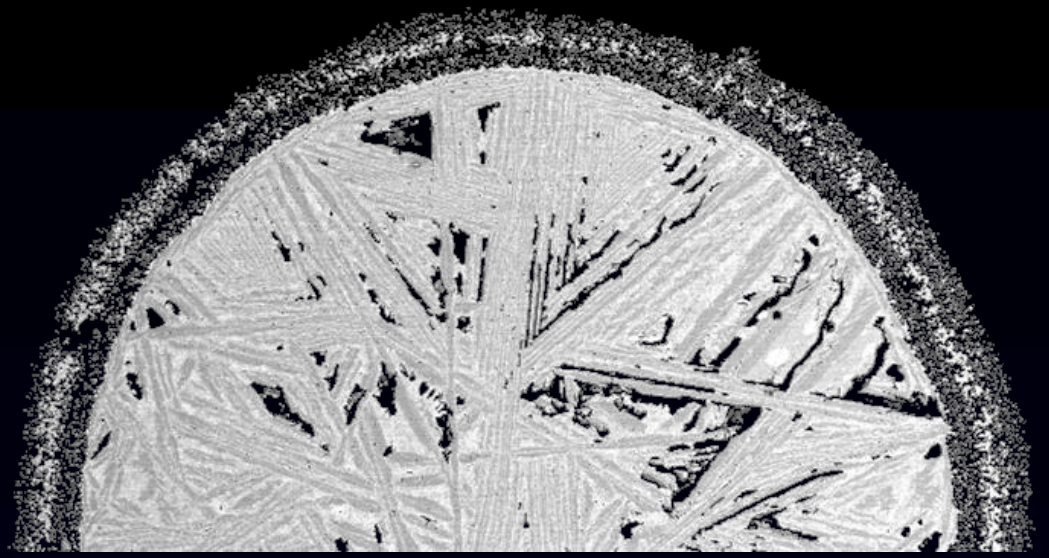
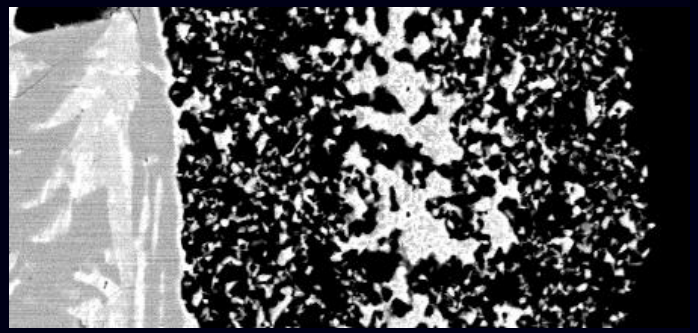
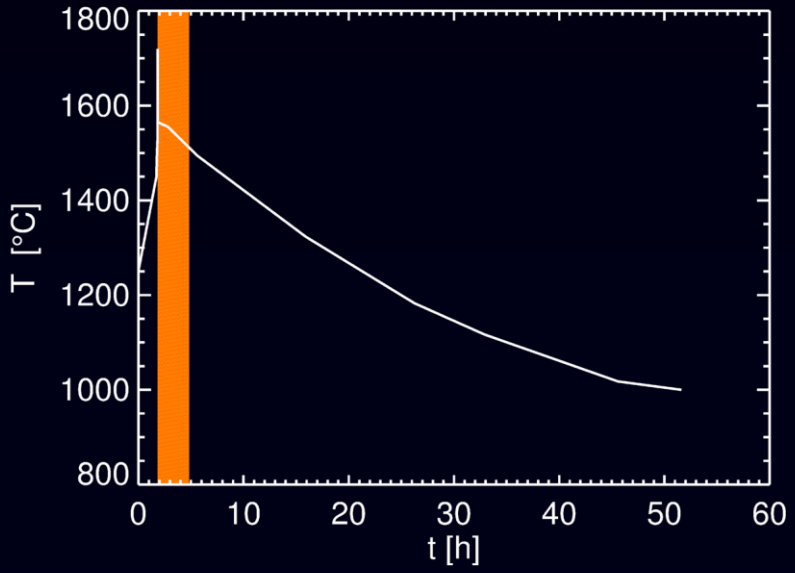
Temperature Profile of Shock Waves









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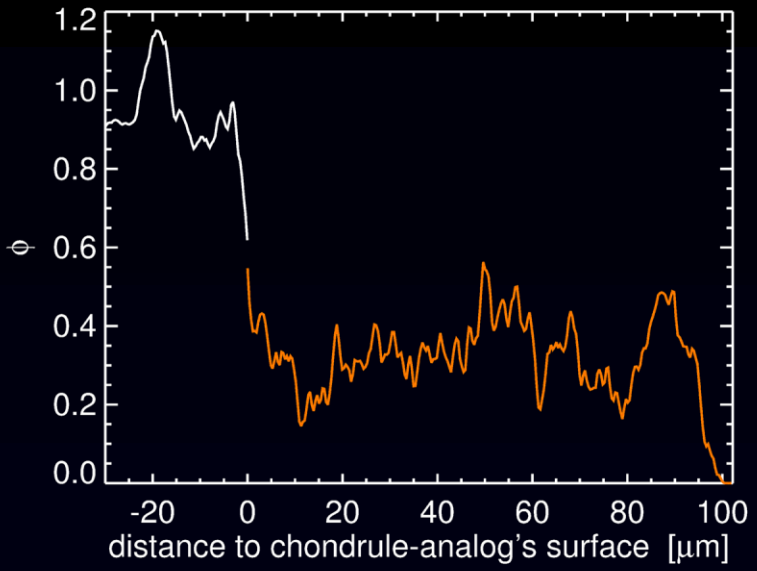
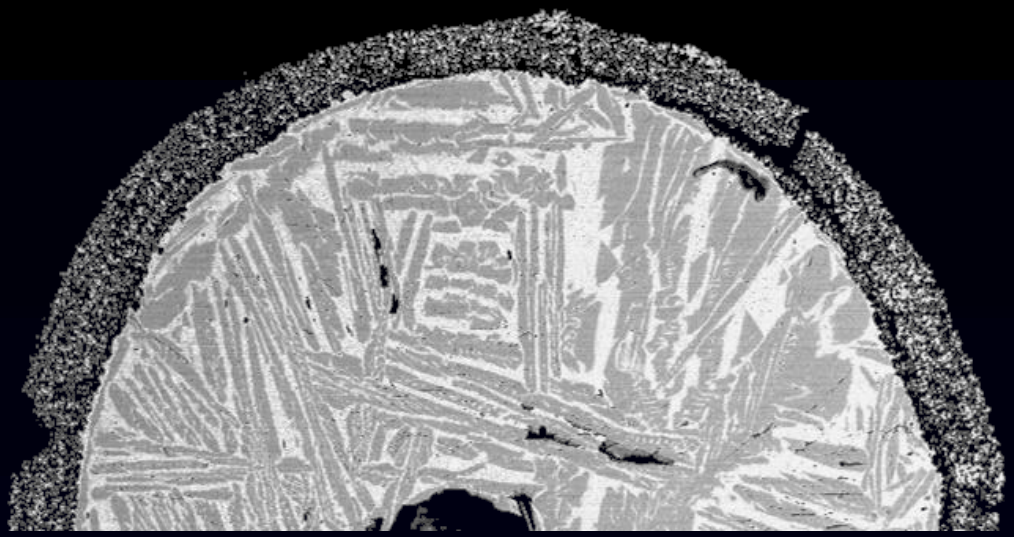
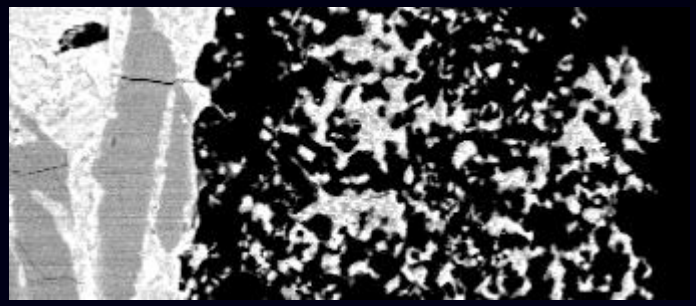
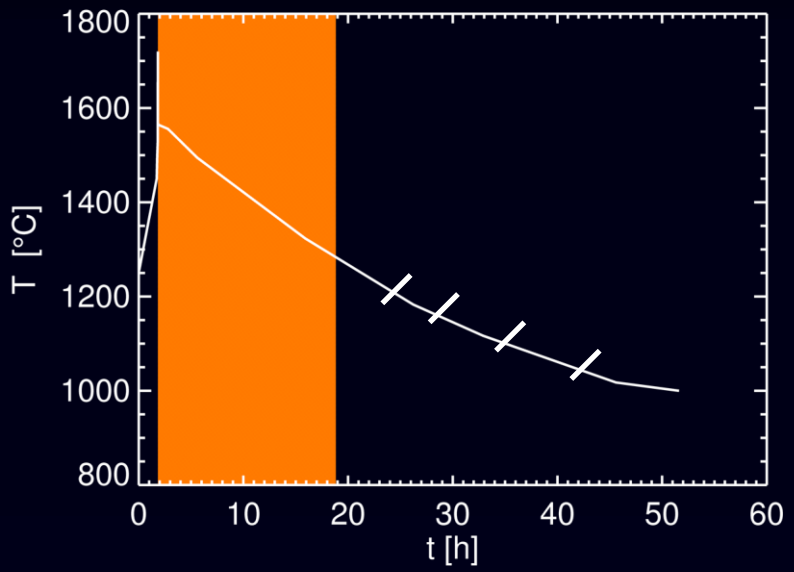
Temperature Profile of Shock Waves









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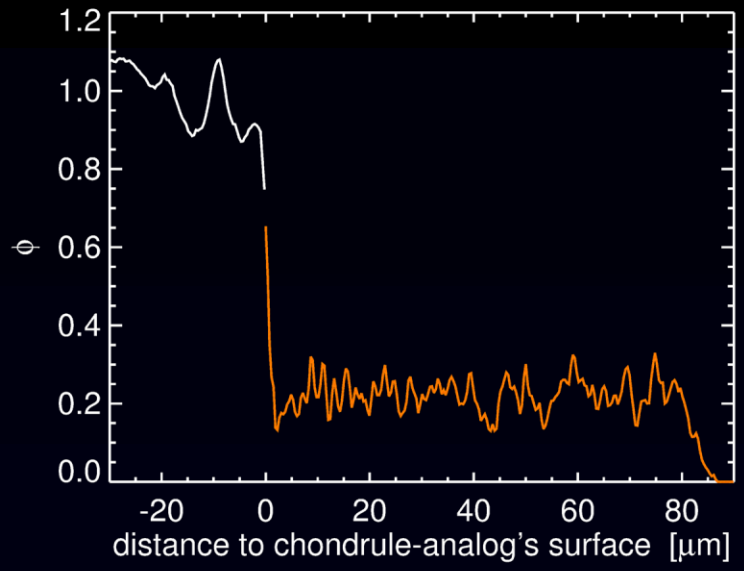
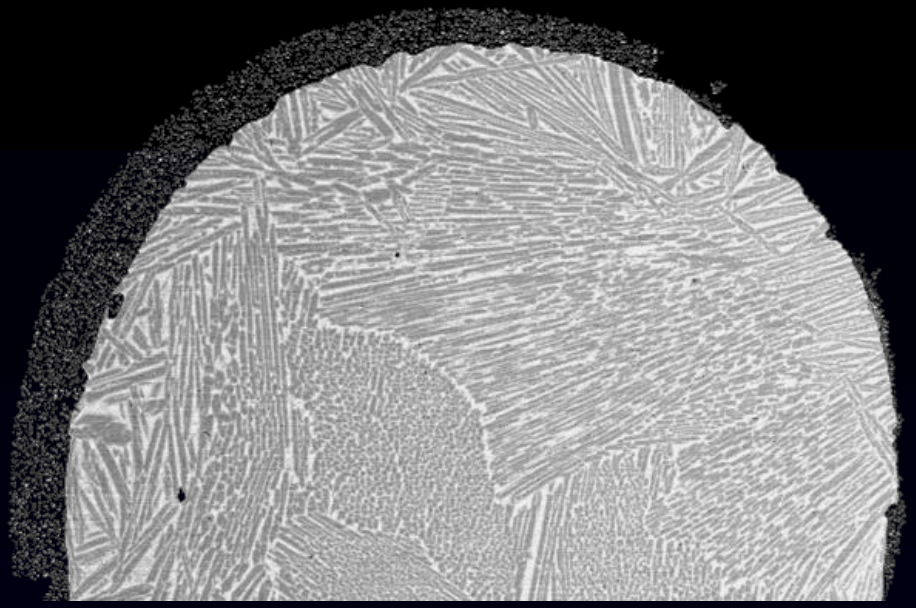
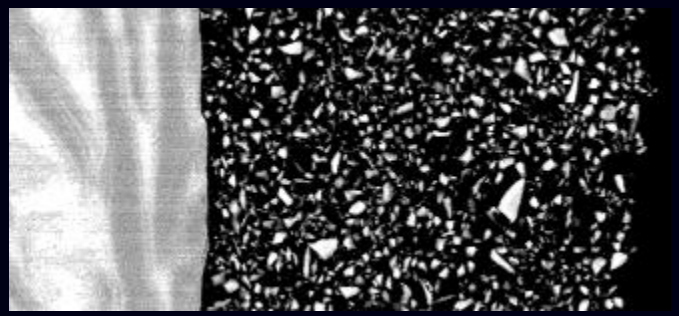
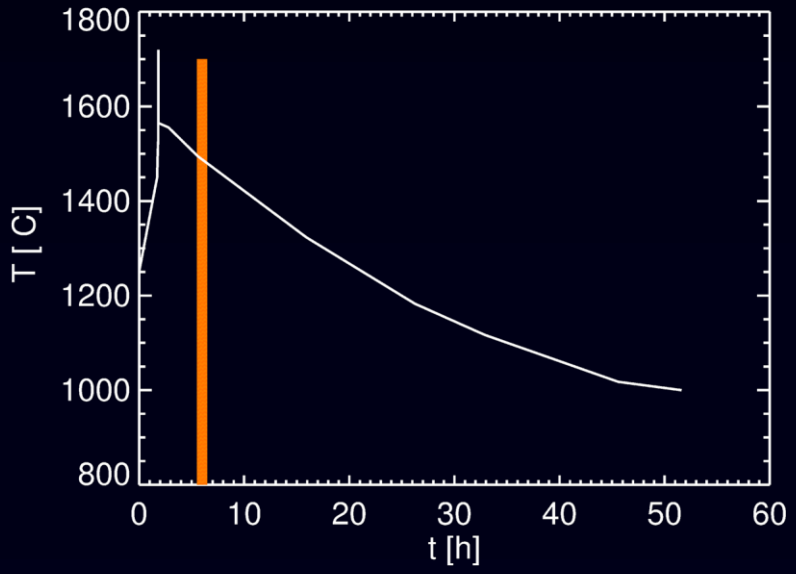
Temperature Profile of Shock Waves









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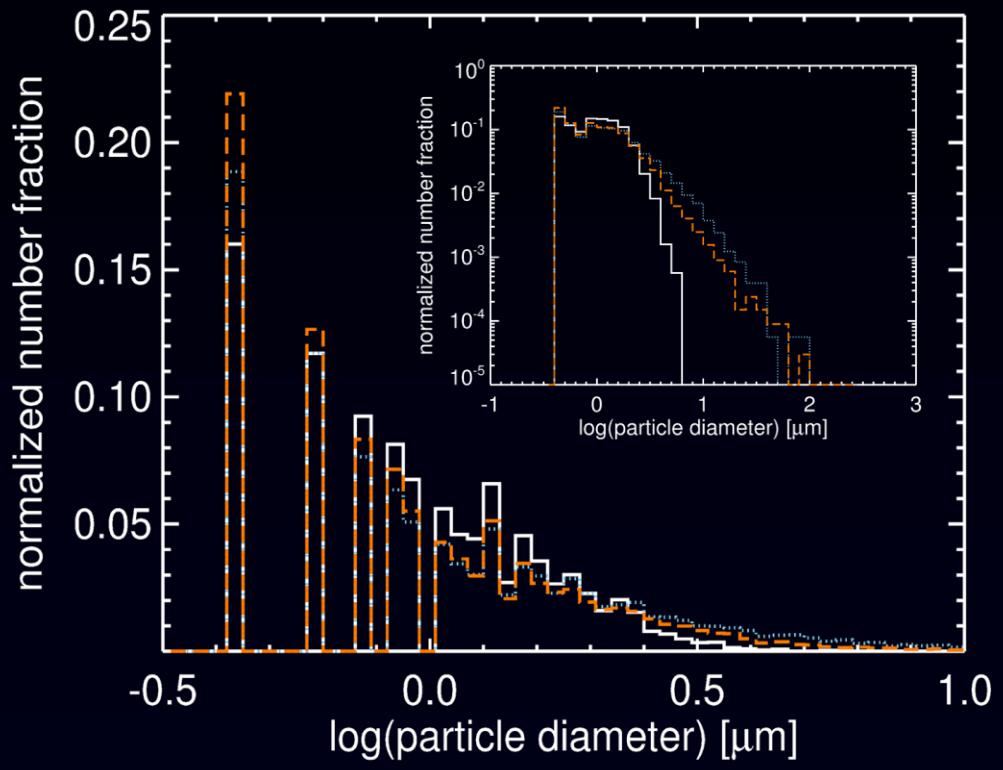
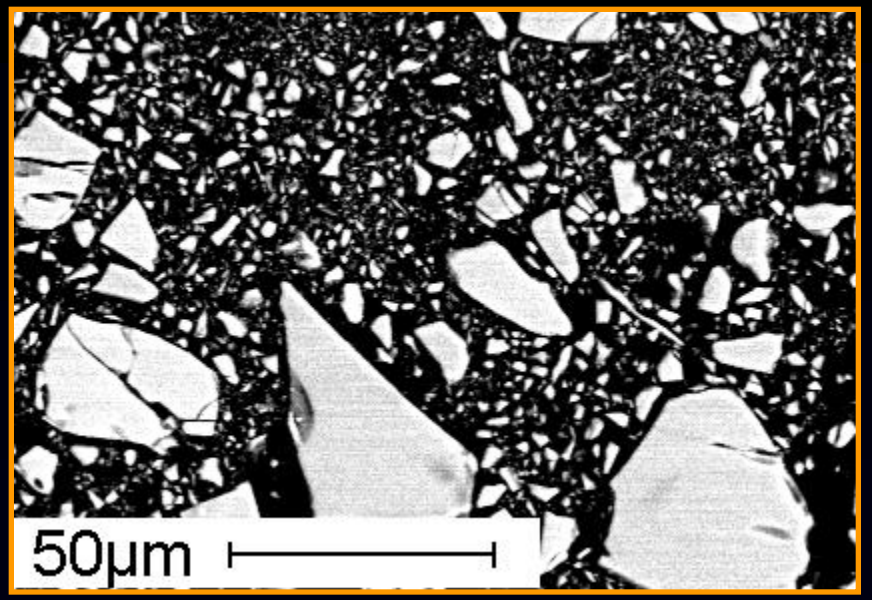
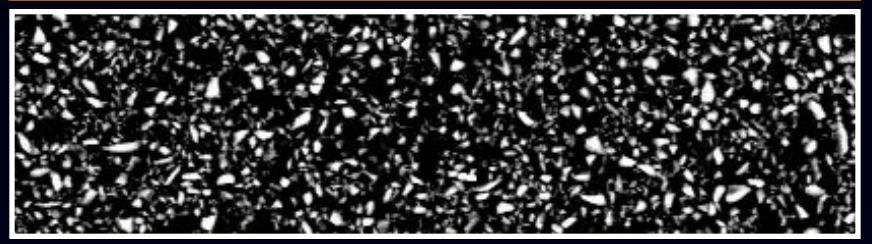
Size Distribution of Milled San Carlos Olivine







- evaporation of dust grains
- larger particles are unlikely to stick

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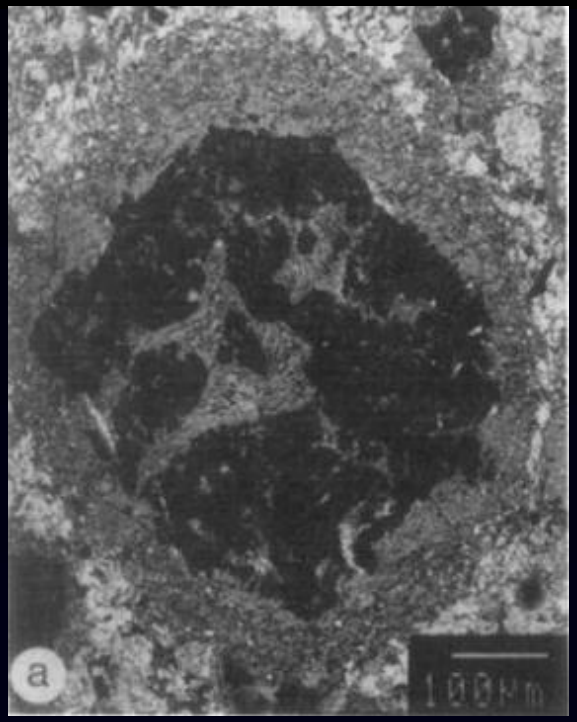
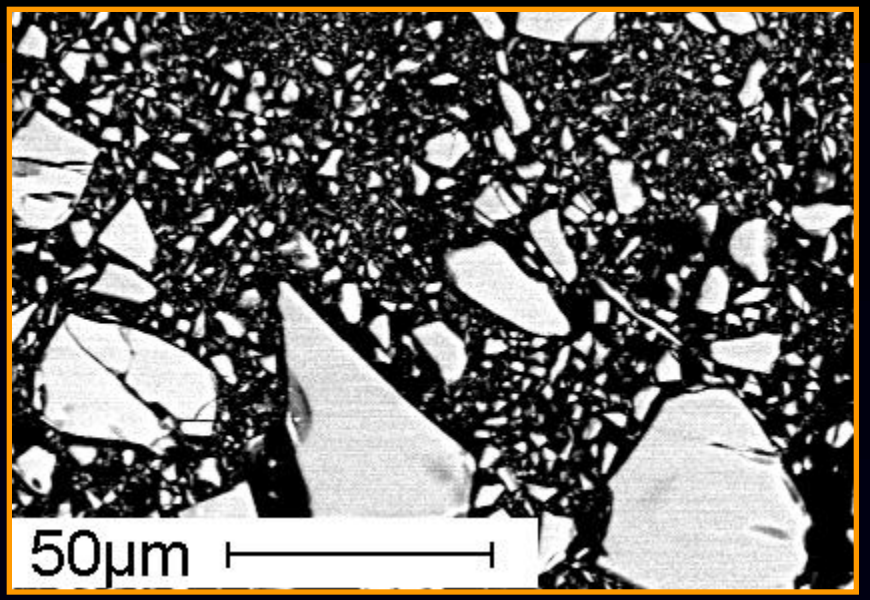
Size Separation Corresponds to CM2 Chondrites



Metzler et al. 1992



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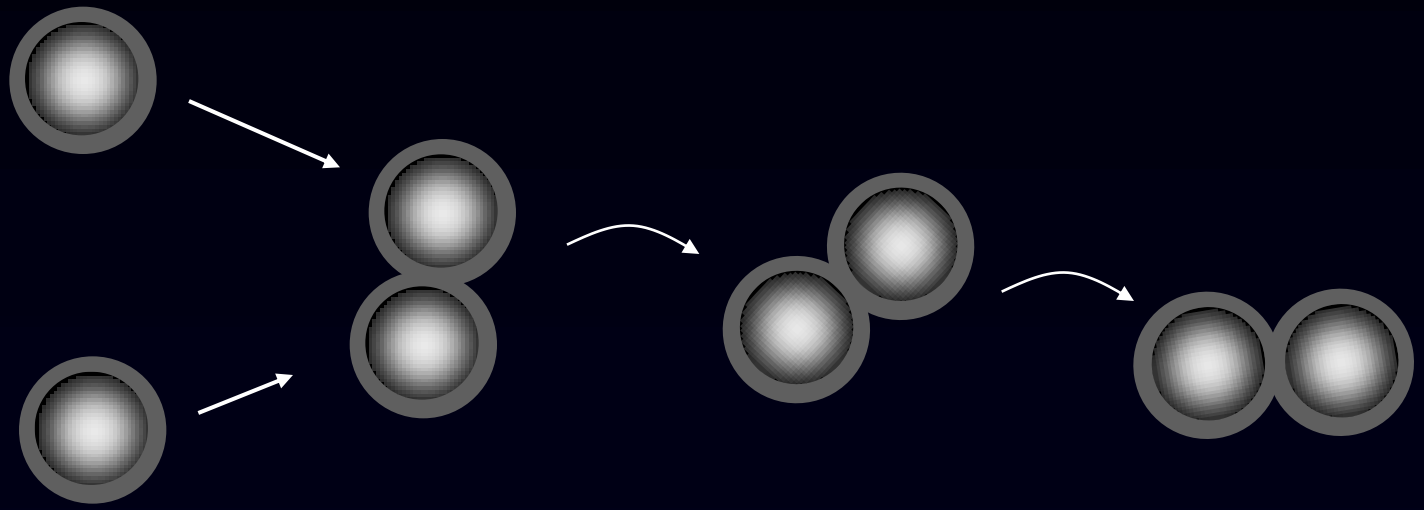
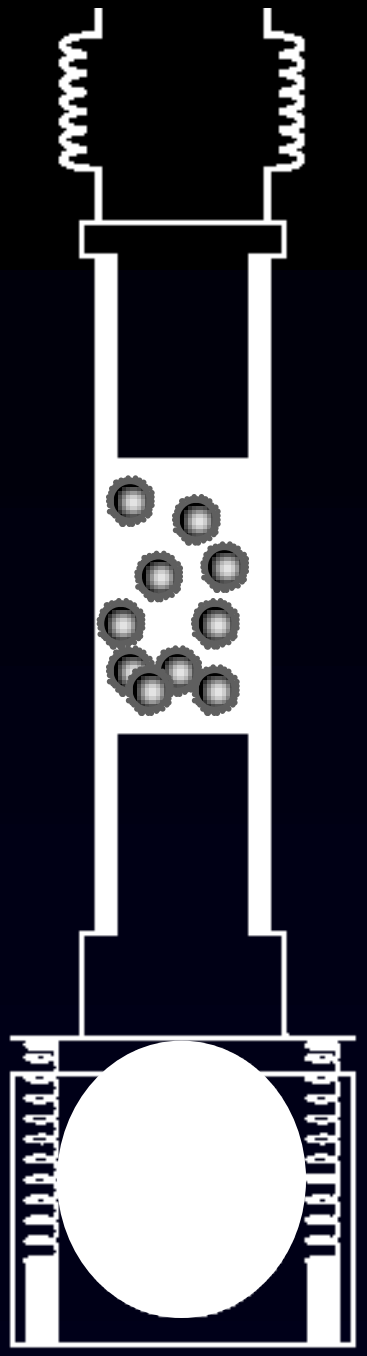
Collision Experiments



Multiple-Collision Experiments

- MEDEA setup on a drop-tower campaign in Bremen
- low-velocity multiple collision experiment
- coated glass beads with different rim morphologies
- mixtures of dust agglomerates and glass beads
- artificial chondrules



Weidling et al. 2012

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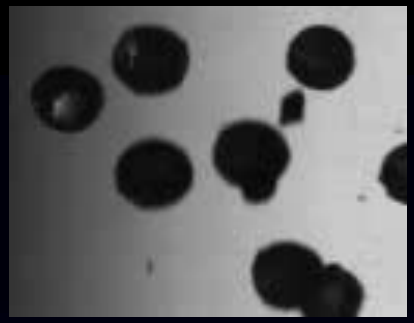
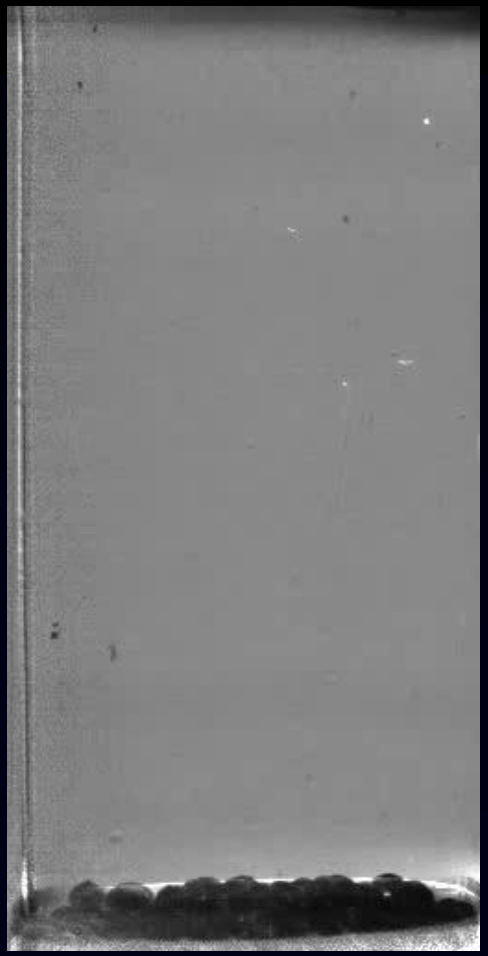
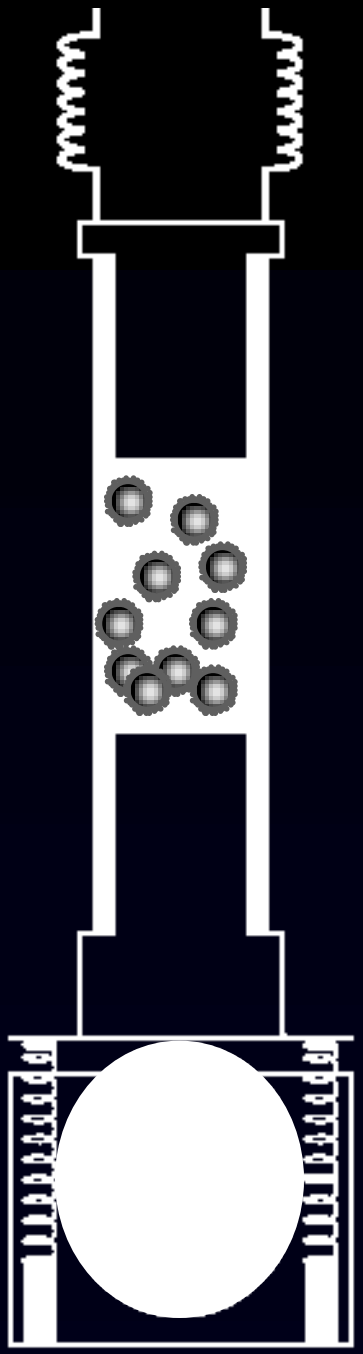
Multiple-Collision Experiments



1 cm/s

2.7 cm/s





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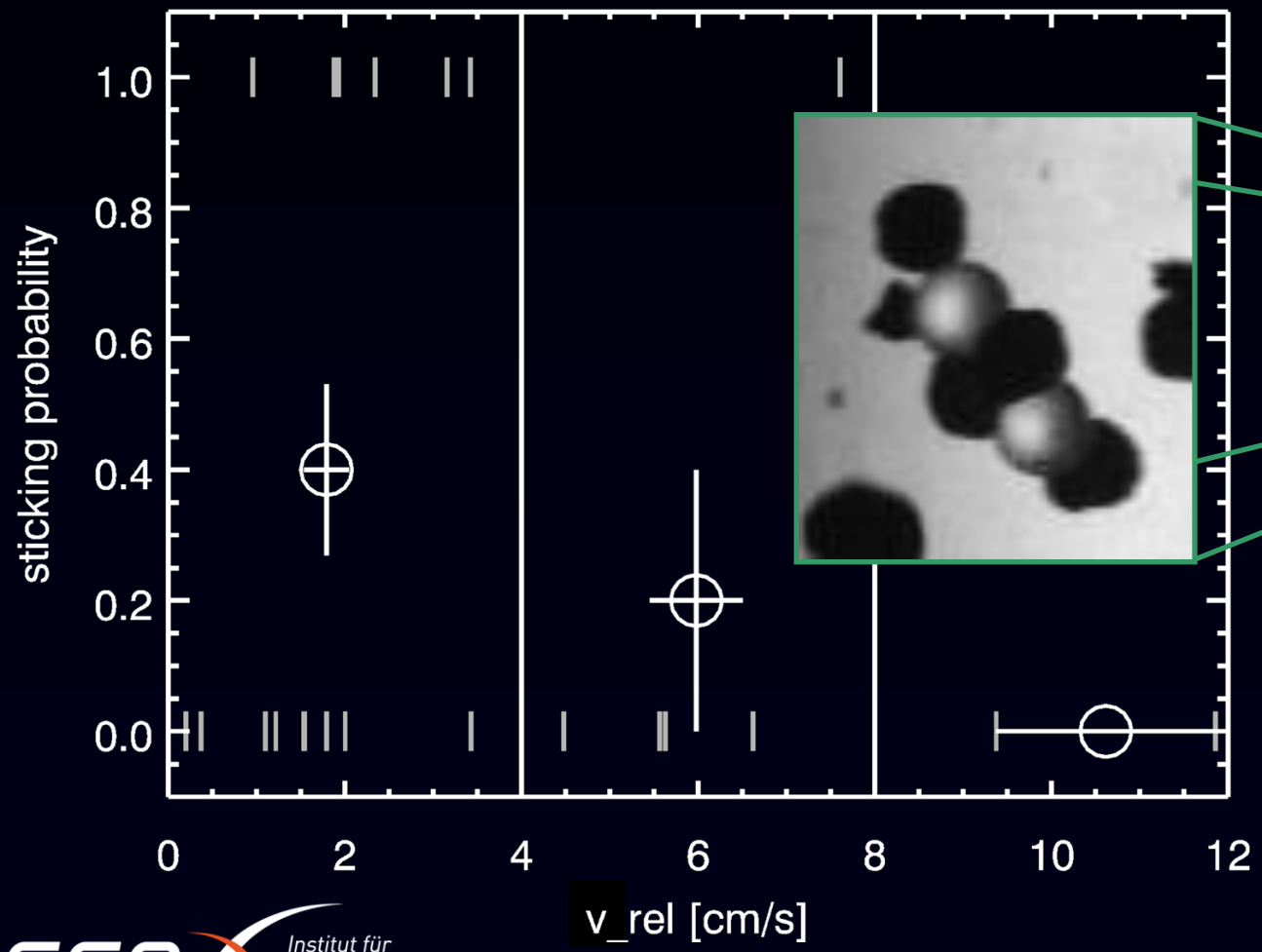
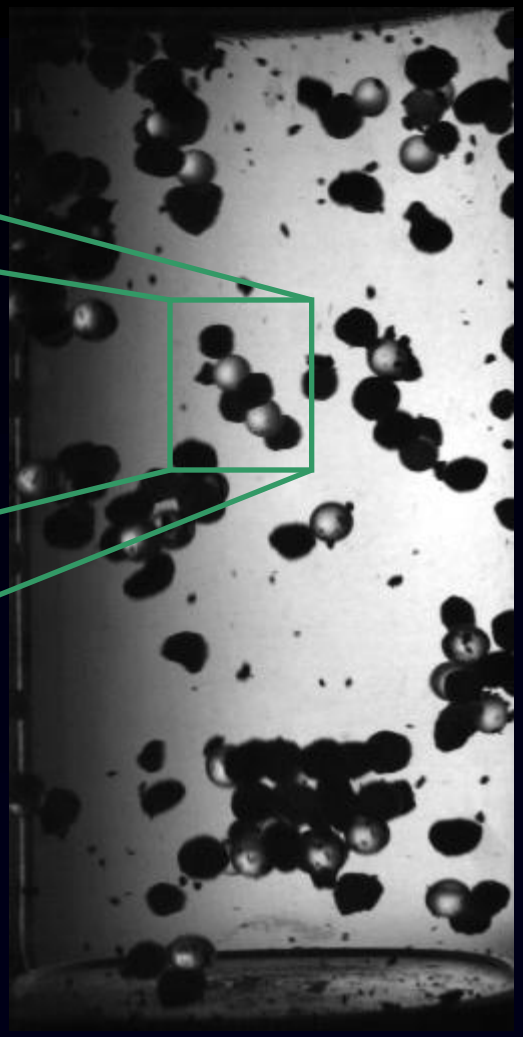
Multiple-Collision Experiments

2 mm glass beads with dust aggregates of the same size





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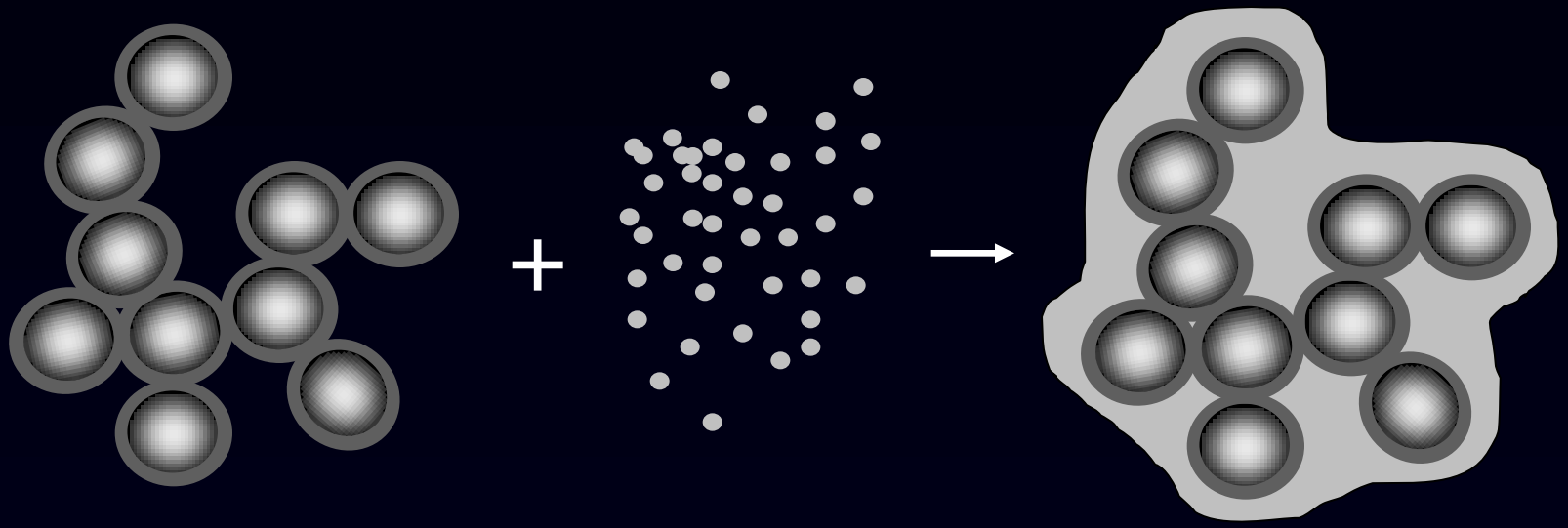
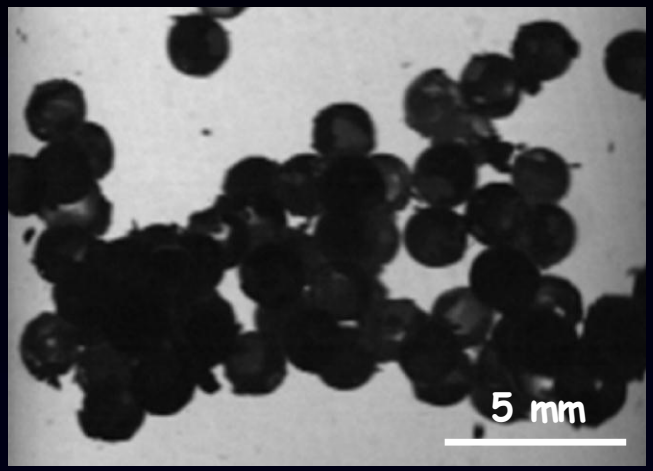
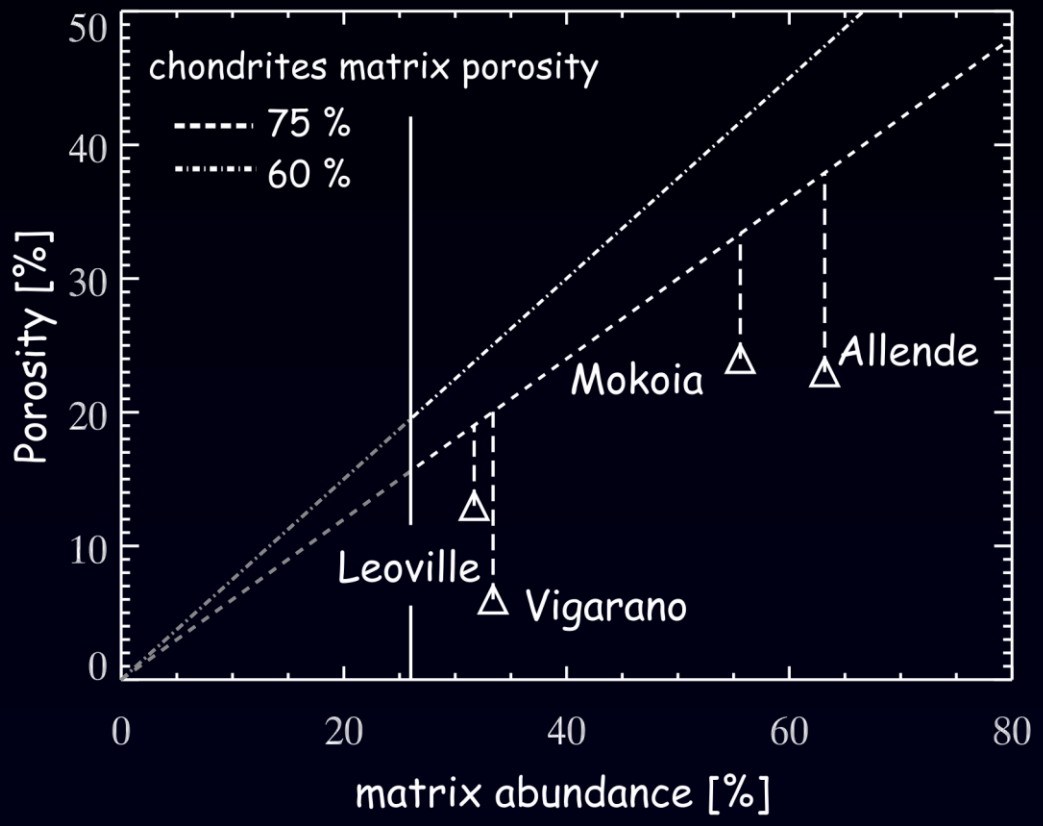
Chondrite Formation



Compaction of Chondrites





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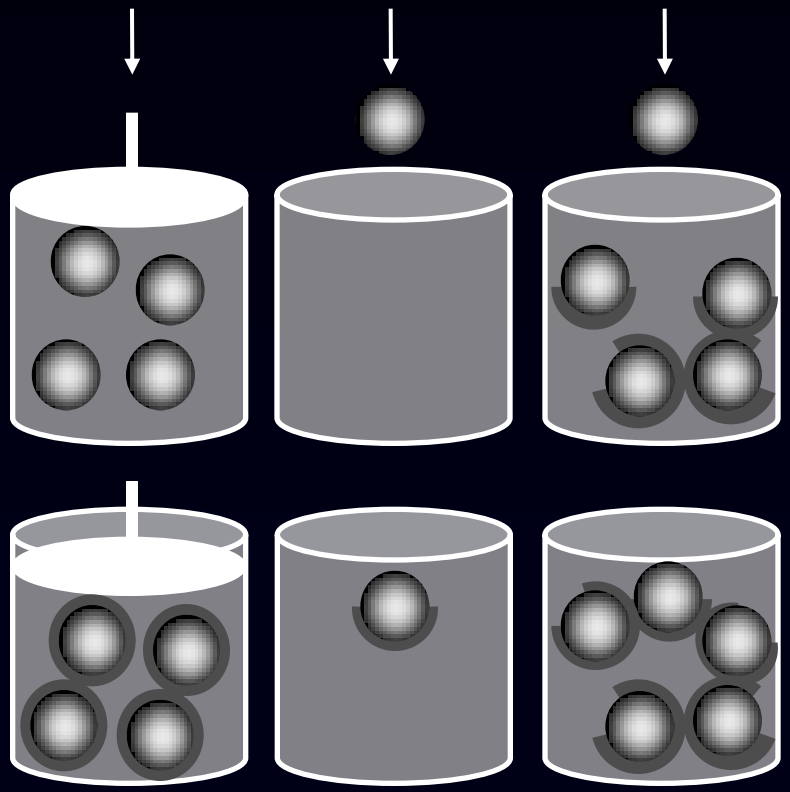
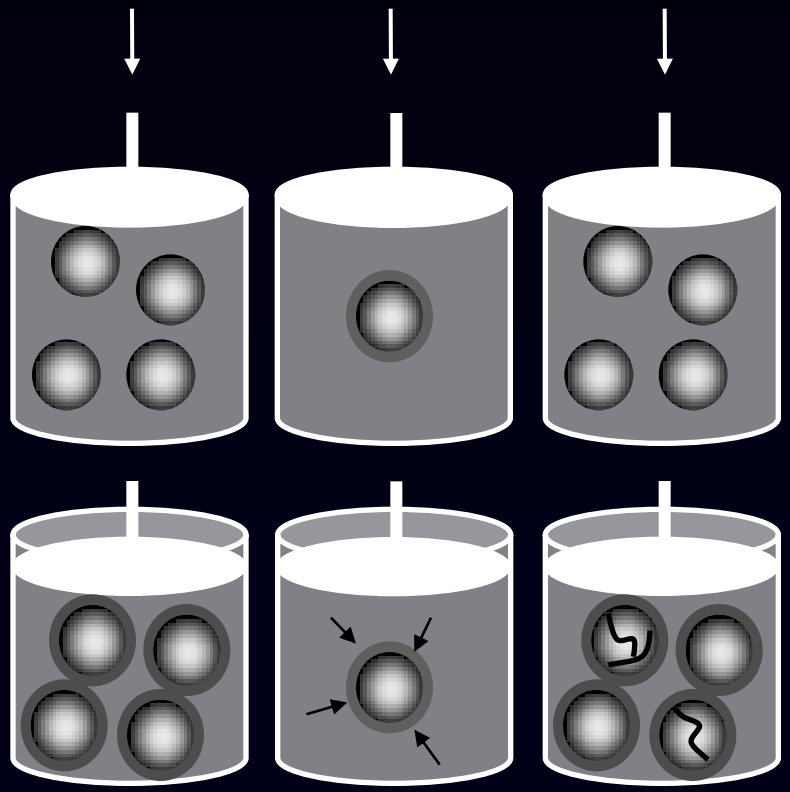
Beitz et al. submitted

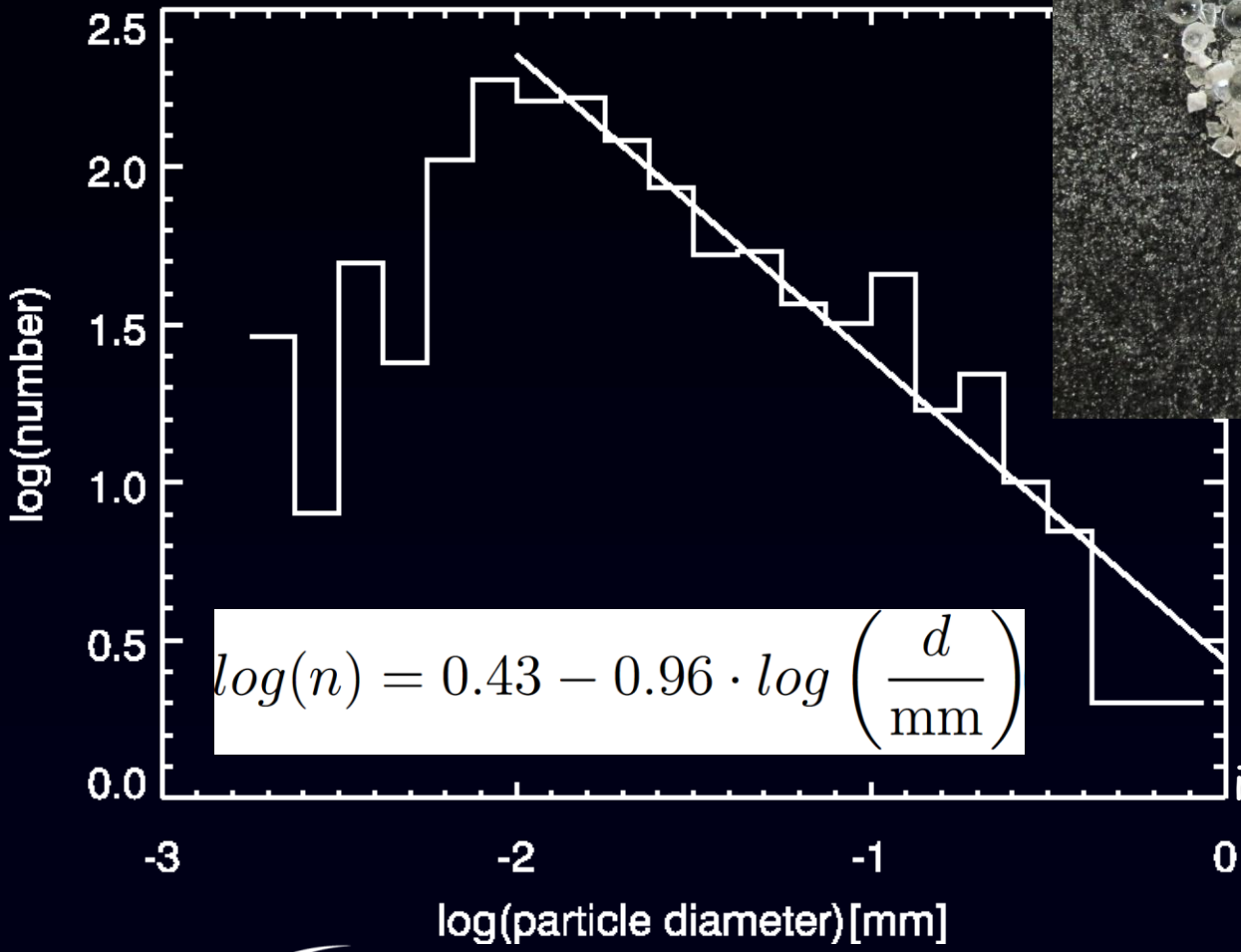
Impact Experiments

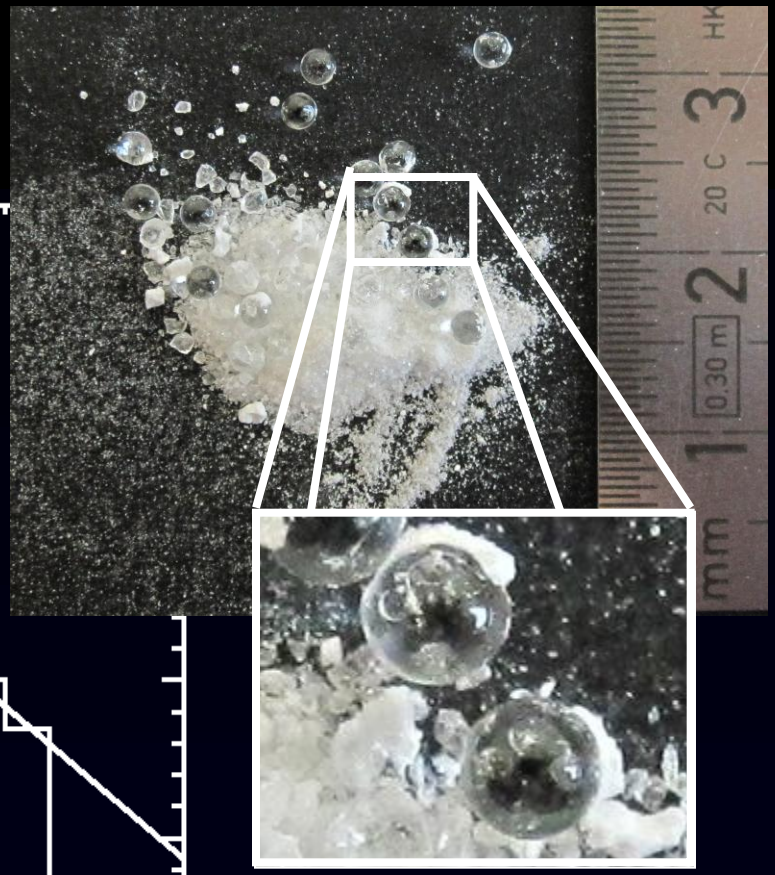


Impact Experiments



Glass bead Experiments





impact velocity v=75 m/s

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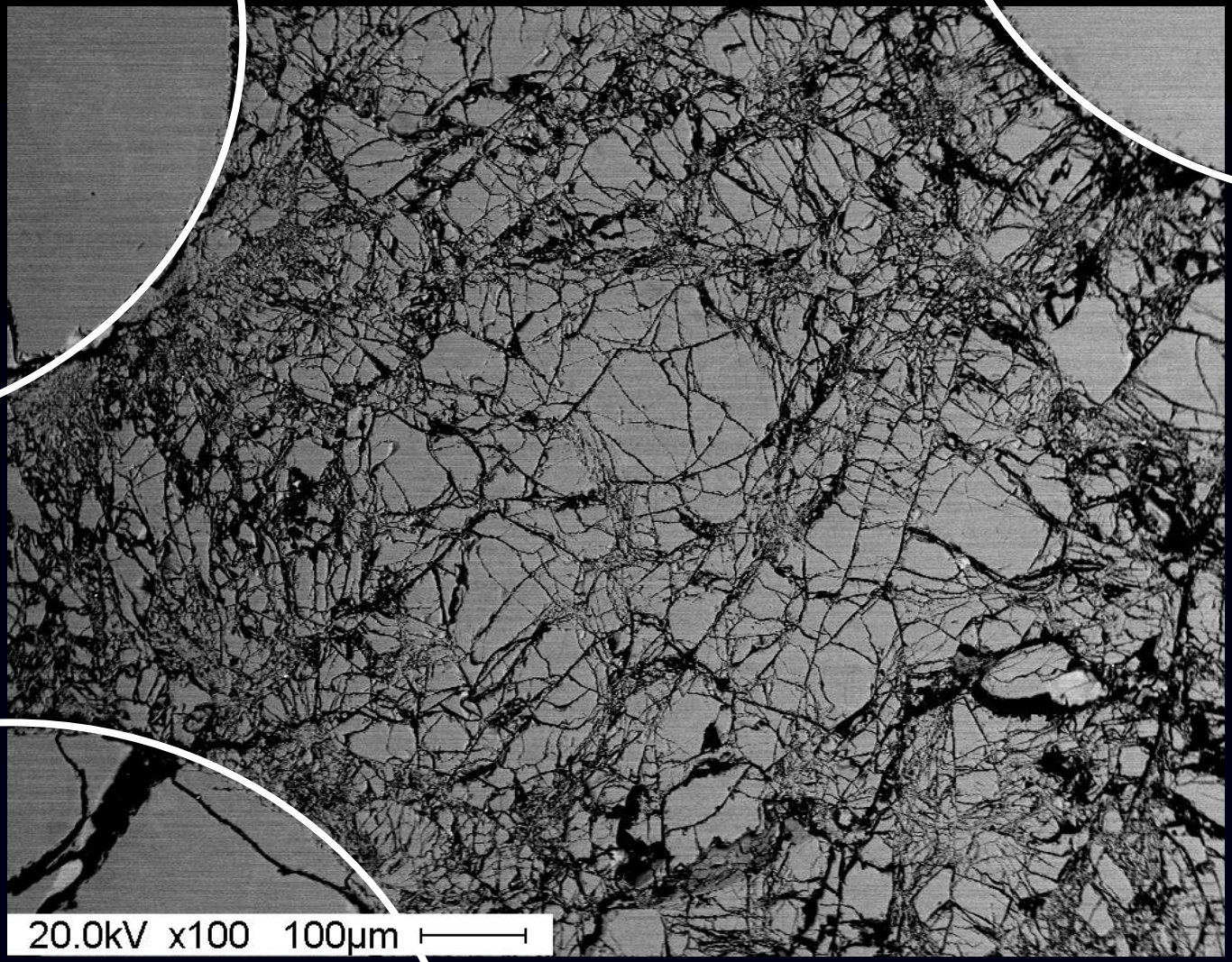
Glass bead Experiments - fast



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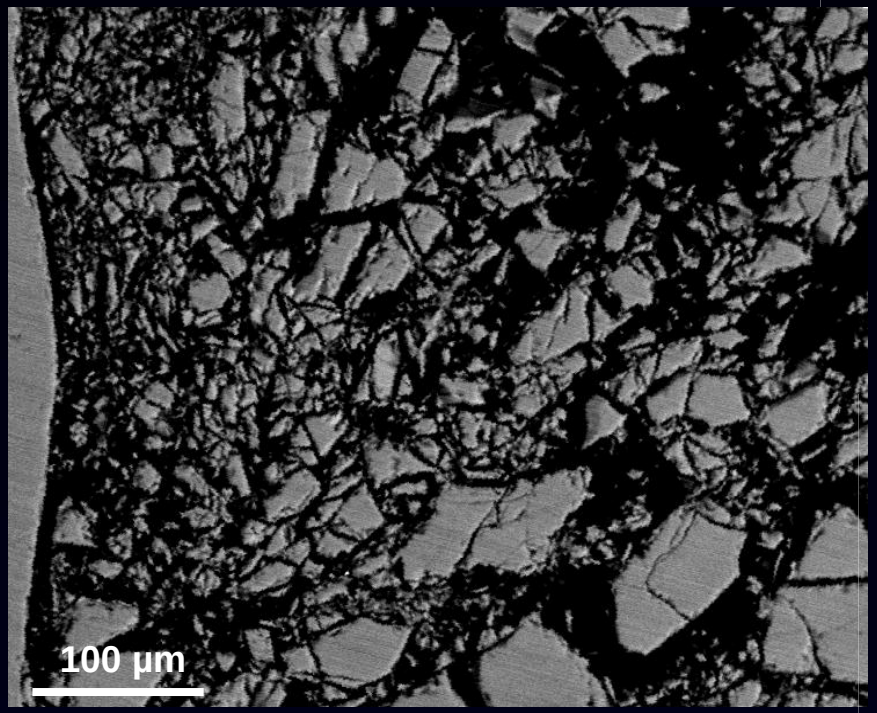
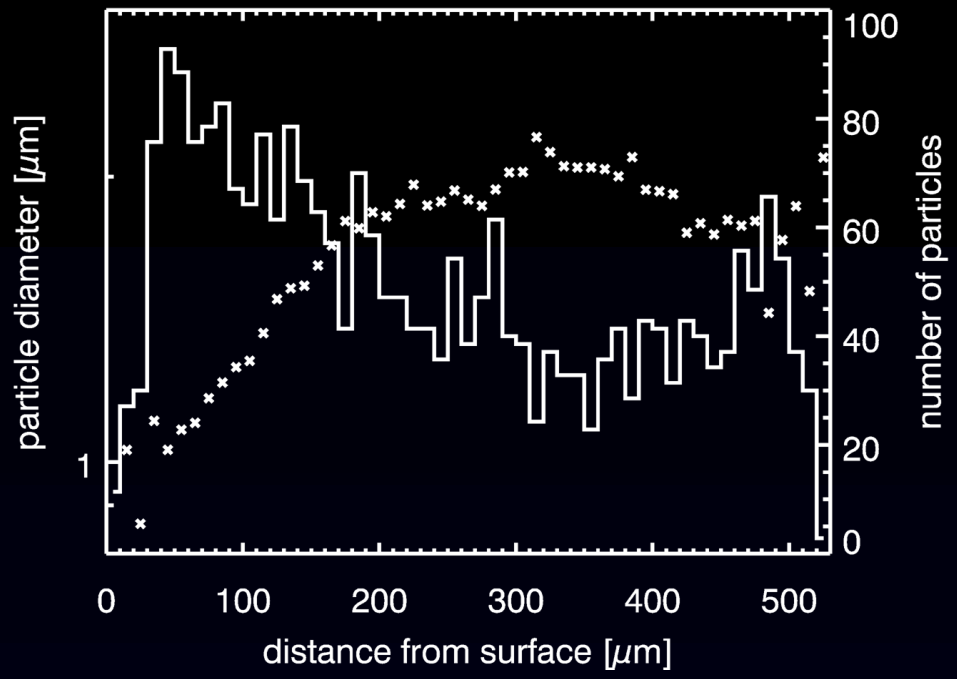
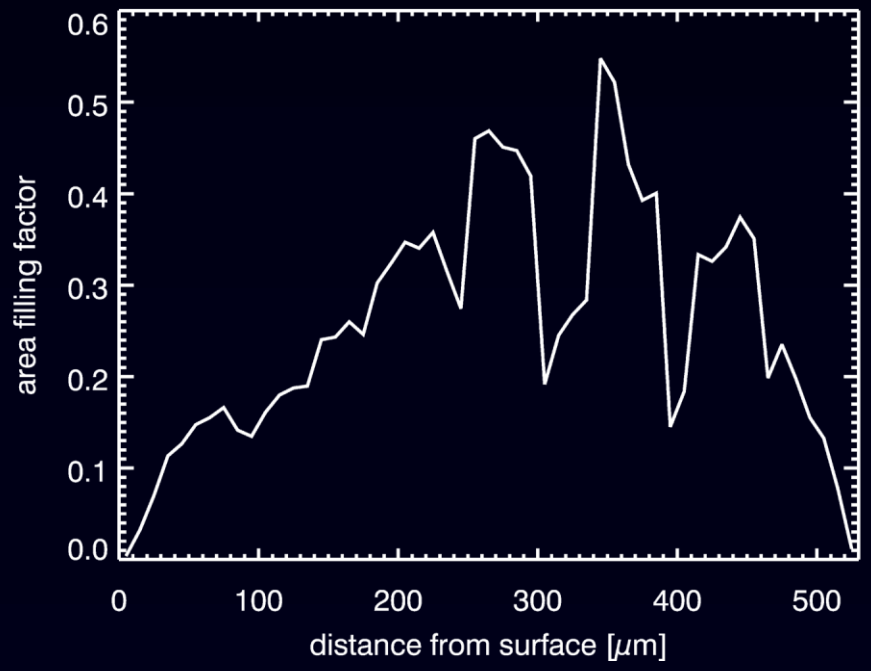
v ~ 450 m/s; 50 glass beads

Glass bead Experiments II



v ~ 450 m/s; 50 glass beads





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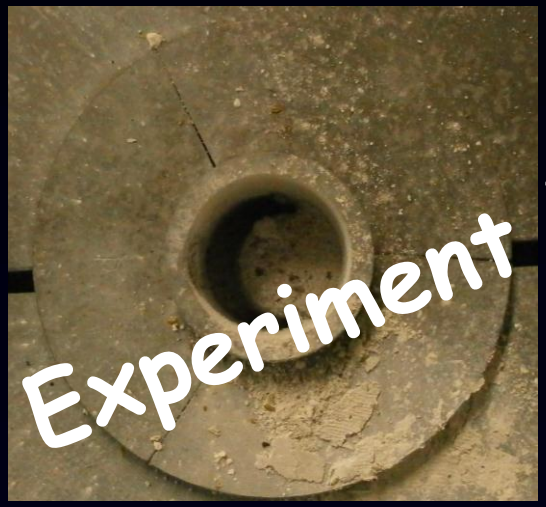
High Velocity Impact Experiments (last week)



Sucessfull Experiment !!!

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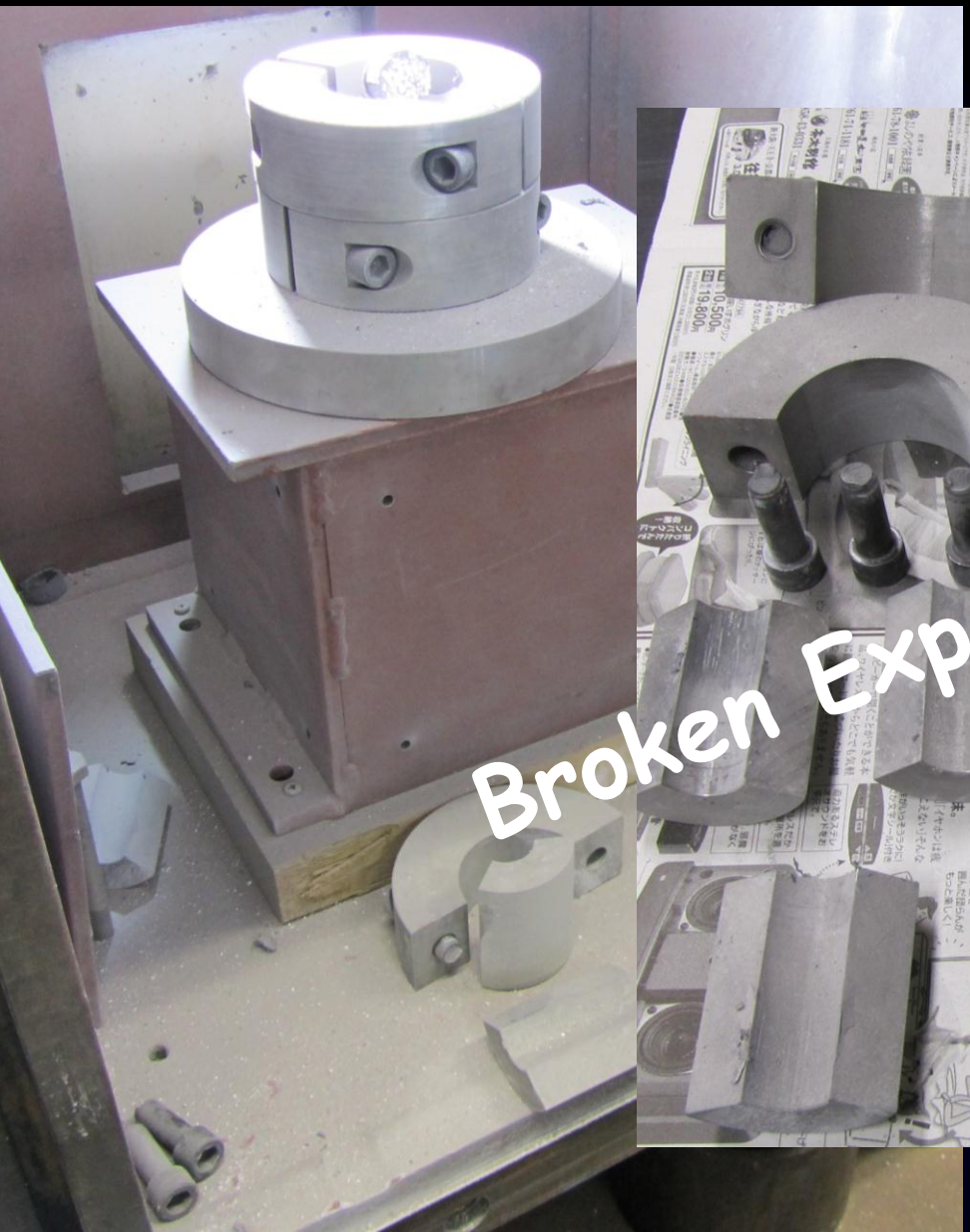
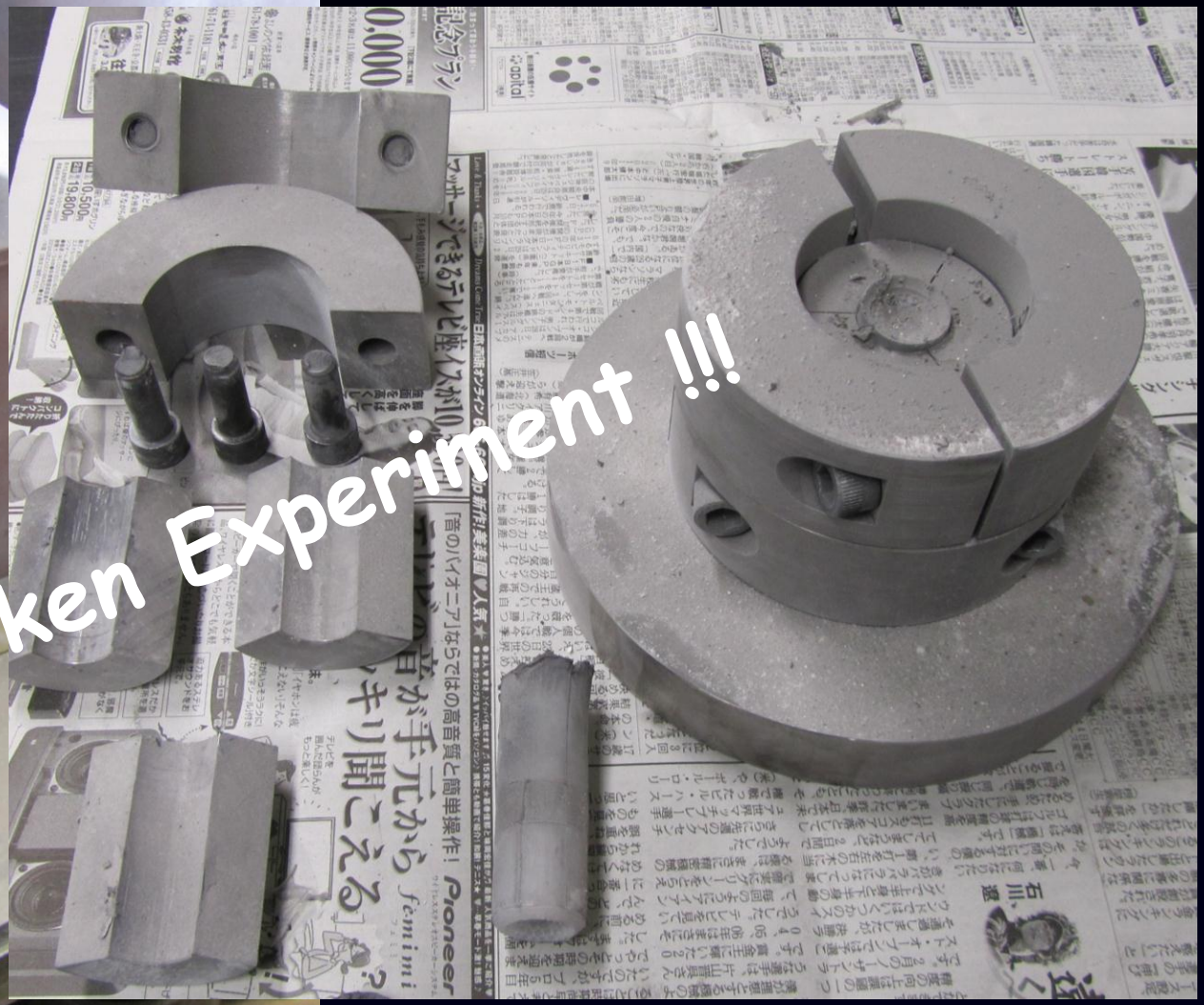
High Velocity Impact Experiments (last week)





Broken Experiment !!!

High Velocity Impact Experiments (last week)

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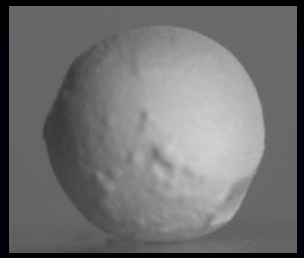
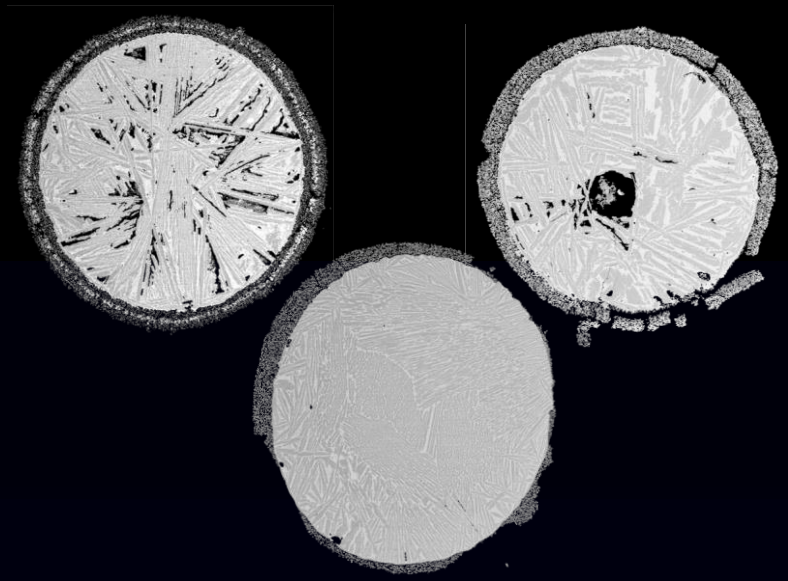
Conclusion

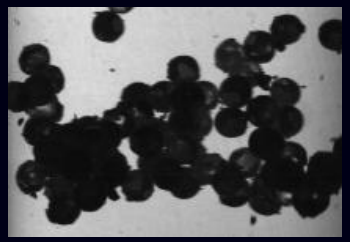


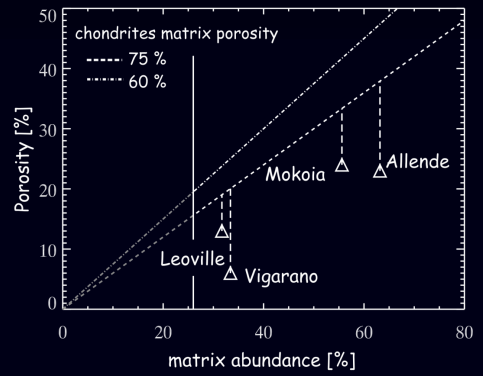


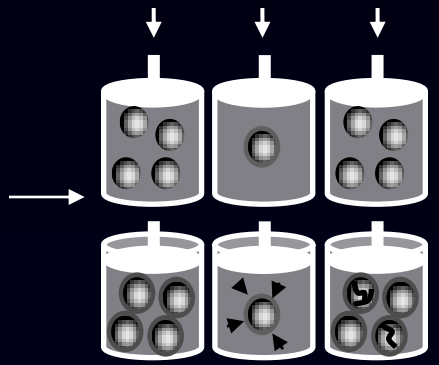
cold

hot

temperature profile







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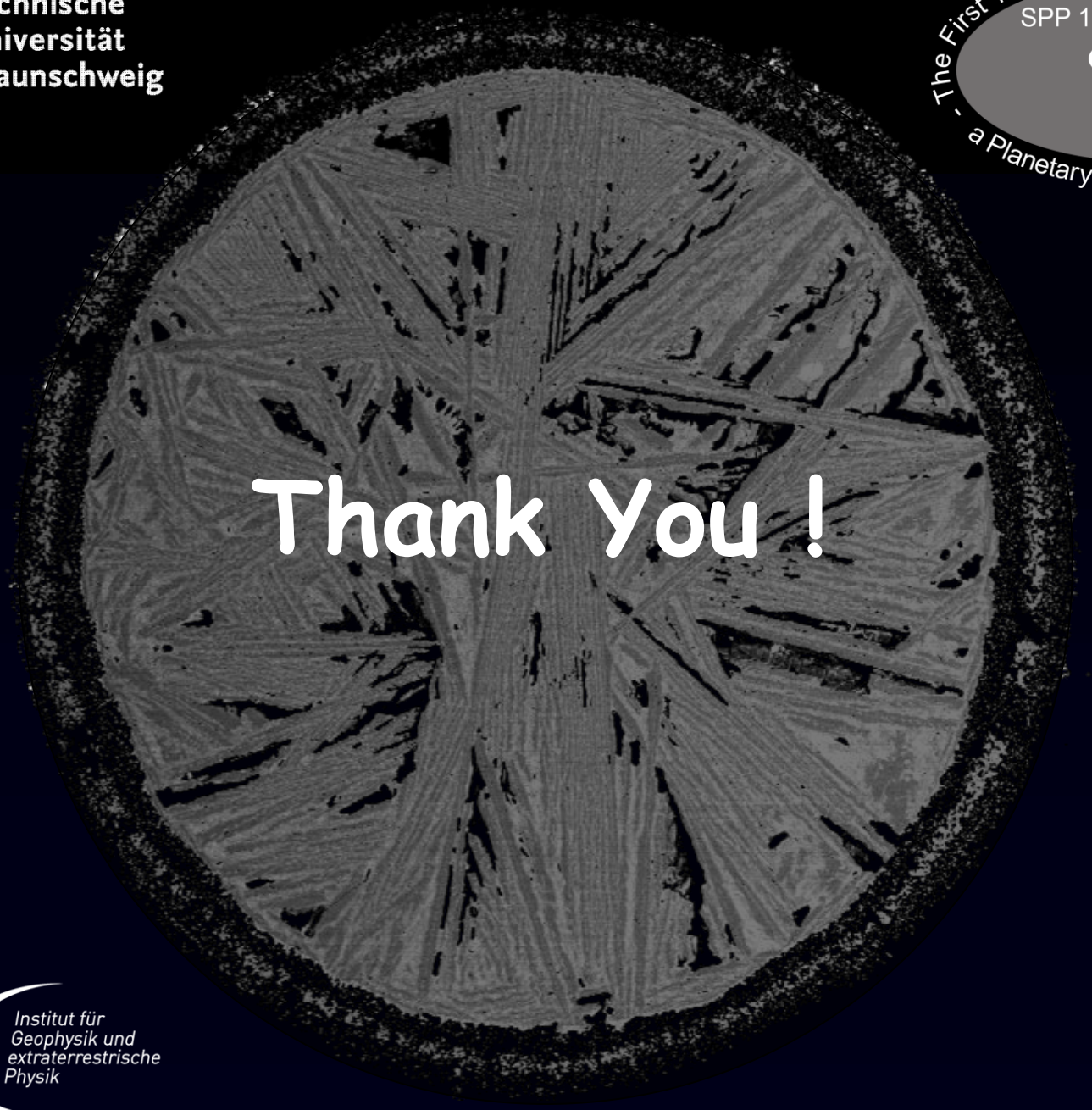
SPP 1385 - The First 10 Million Years of the Solar System - a Planetary Materials Approach - DFG



Thank You !

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