Preplanetary Scavengers: Growing Tall in Dust Collisions

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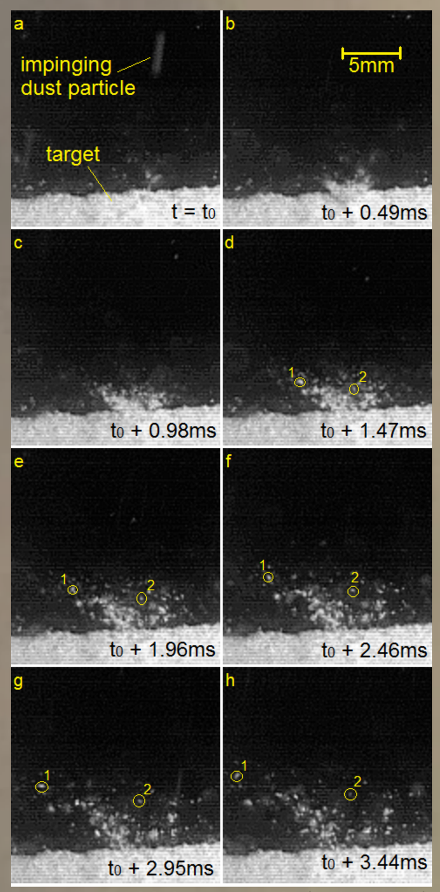
Open-Minded

Introduction:

Dust collisions are one possibility to grow planetesimals. In protoplanetary disks relative velocities of dust aggregates can reach 60m/s (Weidenschilling & Cuzzi 1993). For this reason we study the destructive or constructive nature of high speed dust collisions in laboratory experiments. We extend previous work of Teiser, J. et al. 2011a and Teiser, J. 2011b to model the self consistent evolution of a target upon continuous impacts of submm dust aggregates at collision velocities up to 71m/s. Existing large bodies grow further by scavenging smaller aggregates with high efficiency.

II Coefficient of restitution (CoR):

Dust particles with velocities up to 50 m/s hit a target placed at the bottom of the vacuum chamber. Dust accumulates on the target due to direct sticking and reaccretion of ejecta by gravity. Gravity is a substitute for gas re-accretion.



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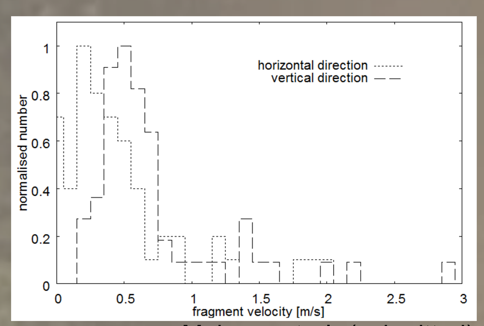

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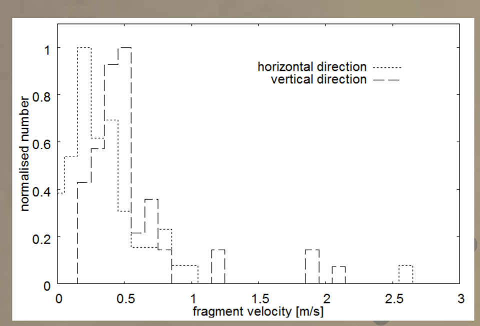

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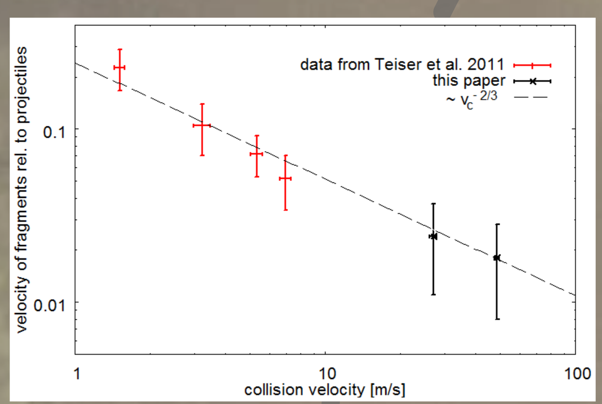
By measuring trajectories of single fragments shown above and their velocity distribution, an average velocity of the fragments relative to the projectile velocity can be calculated and defined as coefficient of restitution.



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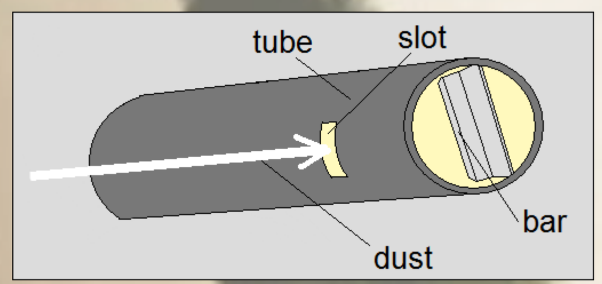
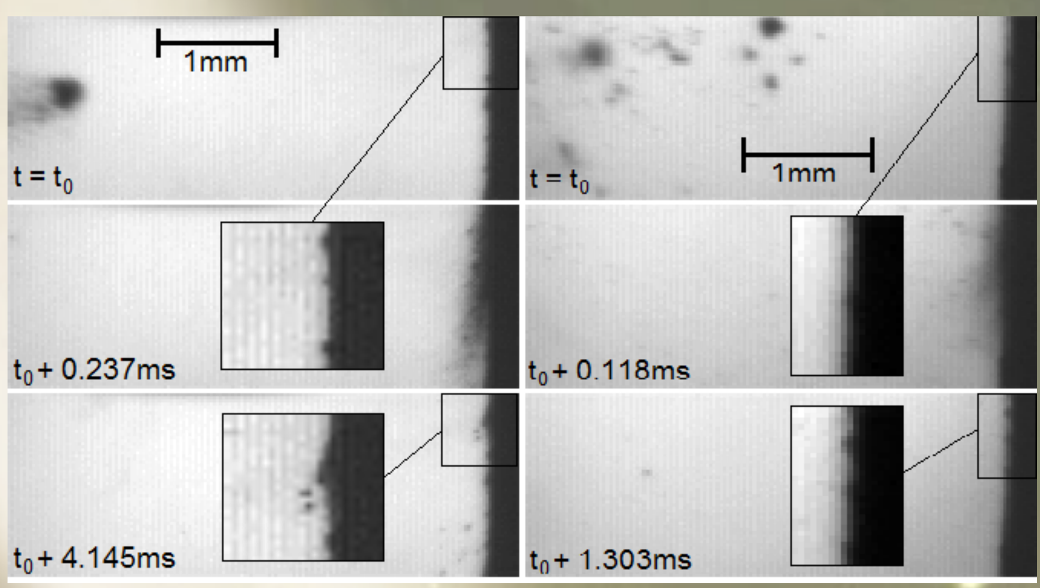
We compare the values to previous measurements with larger projectiles and at lower collision velocities. On first order the data can be described as a power law with $v_c^{-2/3}$

III Evolution of dust targets in a sequence of individual collisions



The dust projectiles enter a small aperture within a tube and impact onto a thin bar. Growth and erosion of a target in indivdual collisions can be detected. To prevent particles to return by gravity the targets are inclined and placed higher than the centrifuge.

On the left an example for simultaneous mass accretion and erosion is shown. As can be compared in the highlighted frames before and after an impact of a fast dust particle (v = 48.7m/s) 225µm in diameter, the small hill on top is lost. At the same time a new small hill is built up again, where the particle impacted the target. On the right an example for mass accretion is also shown. After a multiple impact of dust particles < 110µm in diameter (v = 48.7m/s), new small hills are built up.



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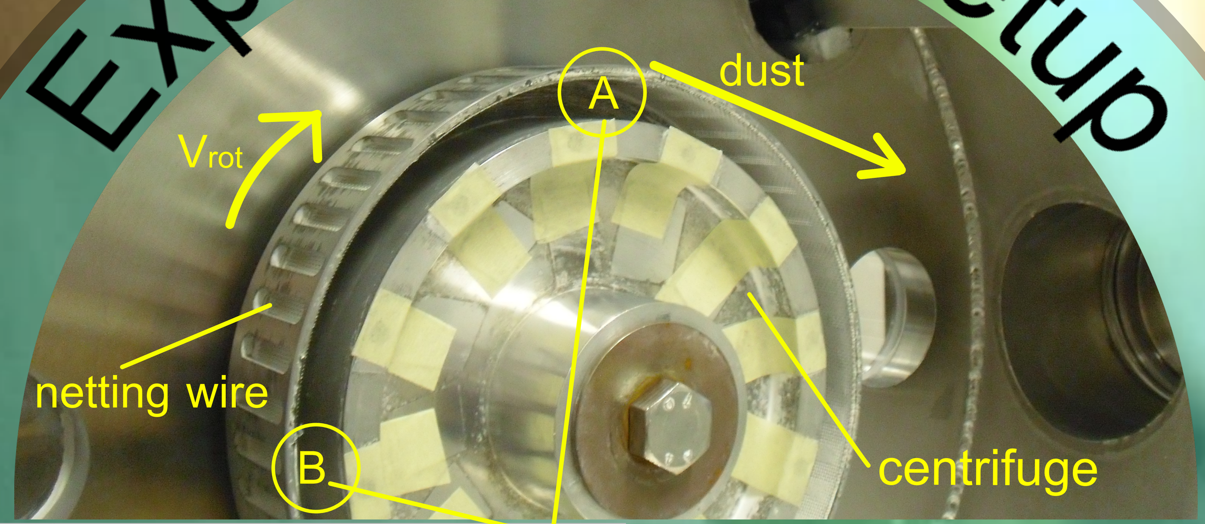
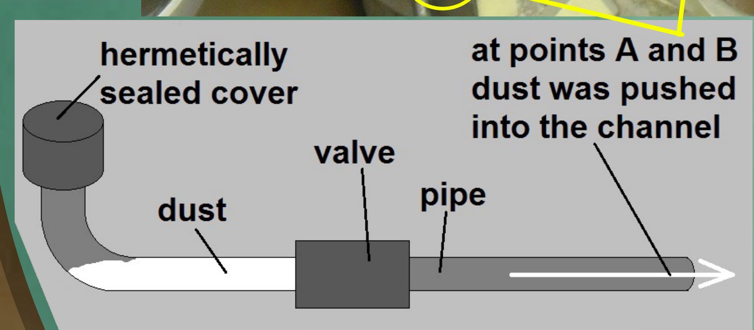
Scan the QR-Code to watch the videos of the impacts, which are analysed in sections II and III. In addition you can find this poster and my previous papers on the linked URL.

Results

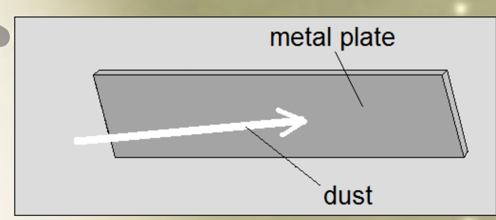
Experimental setup





Basic element of the setup is a fast rotating centrifuge placed in a vacuum chamber (P=30-80Pa). Dust is injected into the narrow channel of the centrifuge in a sequence of filling a dust reservoir at the outside of the chamber which is sucked in if a valve is opened. The dust is moving toward the mesh where it is tangentially ejected towards the inner surface of the vacuum chamber. At some positions windows or targets can be placed to observe the impacts.

IV Growing targets at high speed



Dust aggregates are build up on a metal plate with and without reaccreted ejecta.

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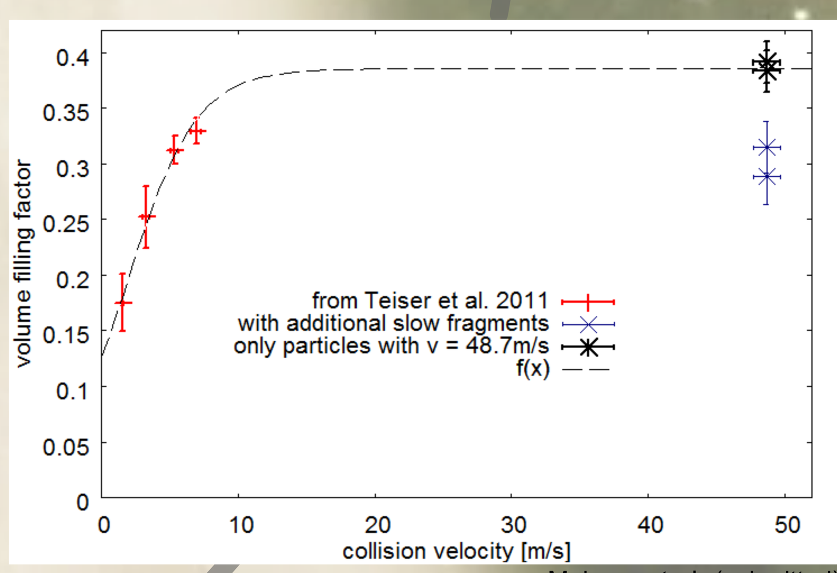
They have sizes of about 3cm in length and 0.6cm in height. The volume filling factors have values between 0.383 and 0.391 for the accumulations without reaccreted dust material and 0.28 and 0.32 for the accumulations with reaccreted material. The volume filling factor increases only slightly from 0.32 to 0.38 between 7m/s and 49m/s.



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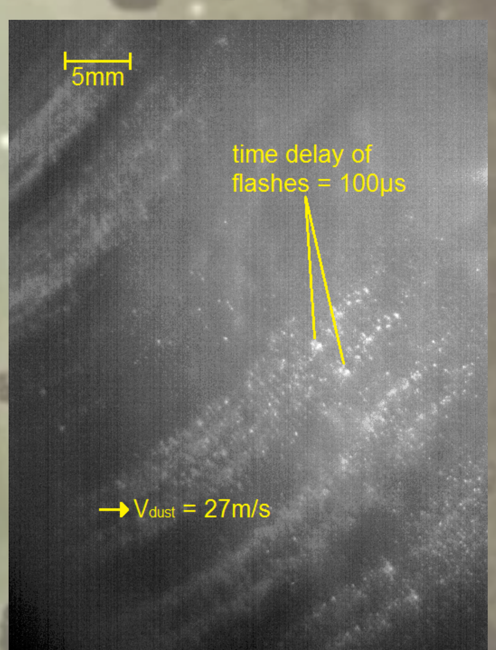
I Calibrations:



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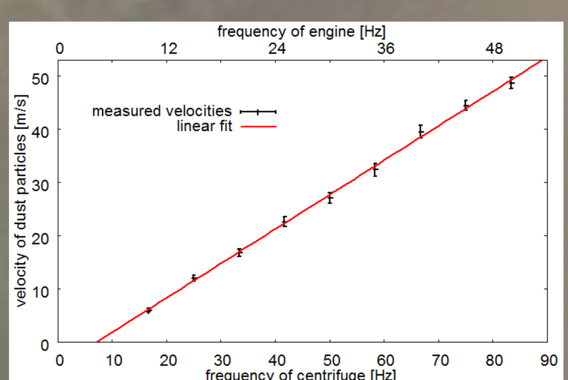
The ejected dust volleys are observed with a high speed camera. With the help of known double exposure times and a length reference velocities of the dust particles can be determined. To analyse the sizes of the particles a microscope lens is used. Images are binarised and the particle cross sections are determined.

Velocity calibration shows a linear increase in measured velocities of the ejected dust with frequency of the centrifuge.



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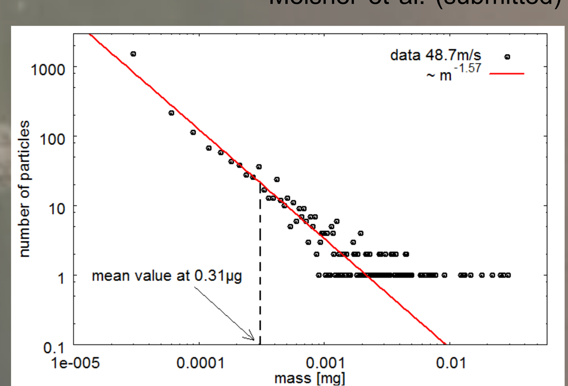
The size distribution is roughly proportional to $m^{-2/3}$. A systematic change of the sizes with velocity could not be seen. In this example the average value for the particle mass is 0.31µg which corresponds to the average radius of 45µm.



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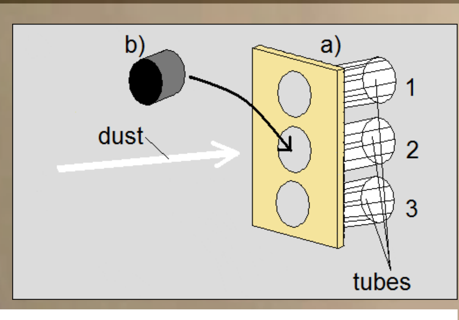
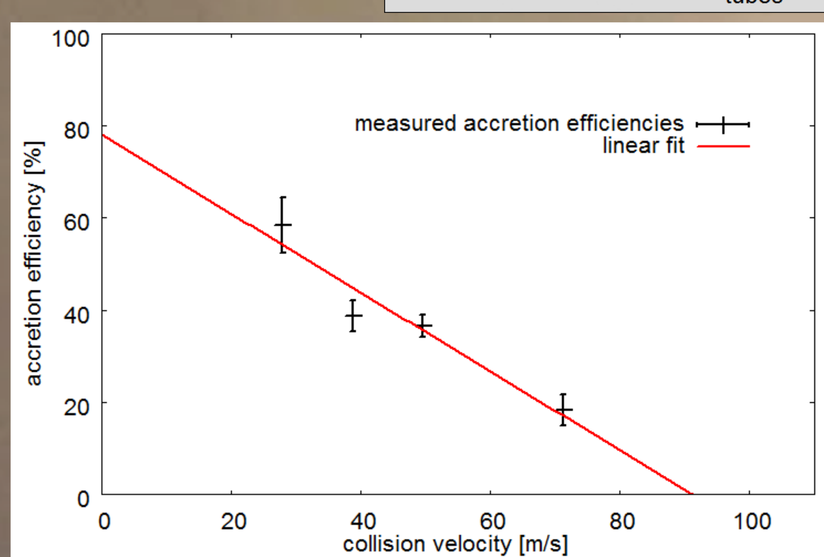
V Accretion efficiencies of dust targets with impinging dust particle cloud





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The accretion efficiency is the ratio m_{stick} / m_{total} with m_{stick} as mass sticking to the target and m_{total} being the total mass that impacted. To measure the total impacting dust we placed 3 tubes in a row next to each other (see left above, step a). In a number of experimental runs we measured the ratio of masses between the different tubes to calibrate the difference of impacting mass with varying tube location. This way, the mass in one tube gives a measure of the total impacting mass in the other tubes or m_{total}. In a second set of runs the center tube was replaced by a small target (step b) with the same diameter as the original tube opening. An aggregate grows on the target and its mass m_{stick} is measured after a certain time. The accretion efficiency drops with increasing collision velocity.

References:

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