Surviving the Storm

Are Planetesimals Safe from Protoplanetary Winds?

Tunahan Demirci, Jens Teiser, Maximilian Kruss, Niclas Schneider, Tobias Steinpilz, Tabea Bogdan, Felix Jungmann & Gerhard Wurm

University of Duisburg-Essen, Faculty of Physics, Experimental Astrophysics

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

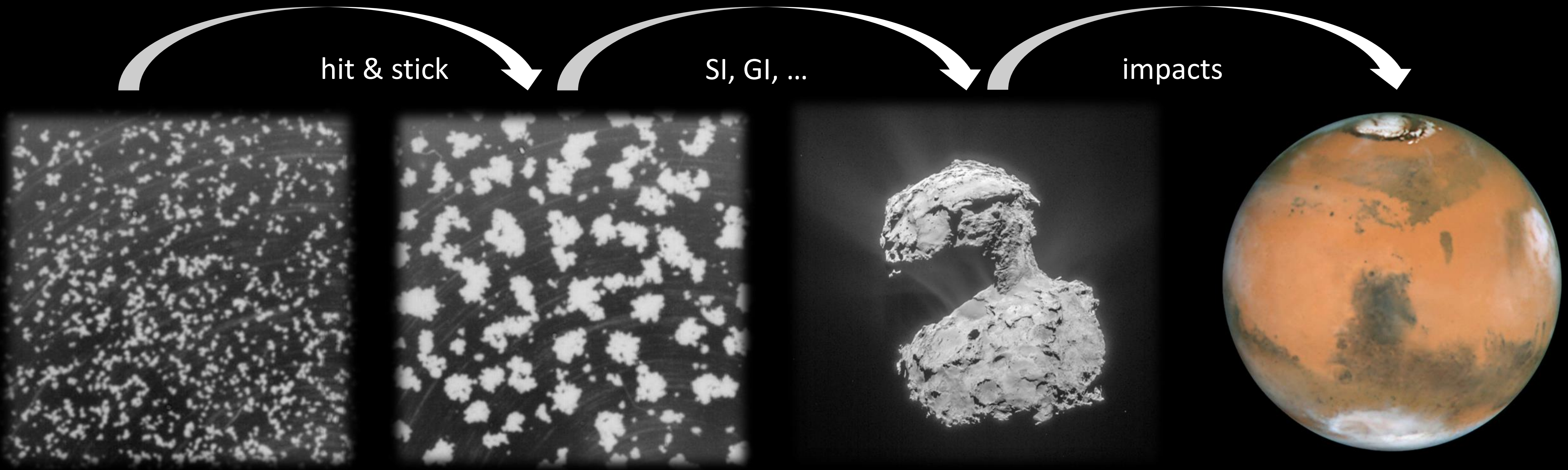
Great barriers in planet formation
Palm Cove - Australia

25.07.2019

This work is funded by DLR
under grant number 50 WM 1760

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Brief introduction to planet formation



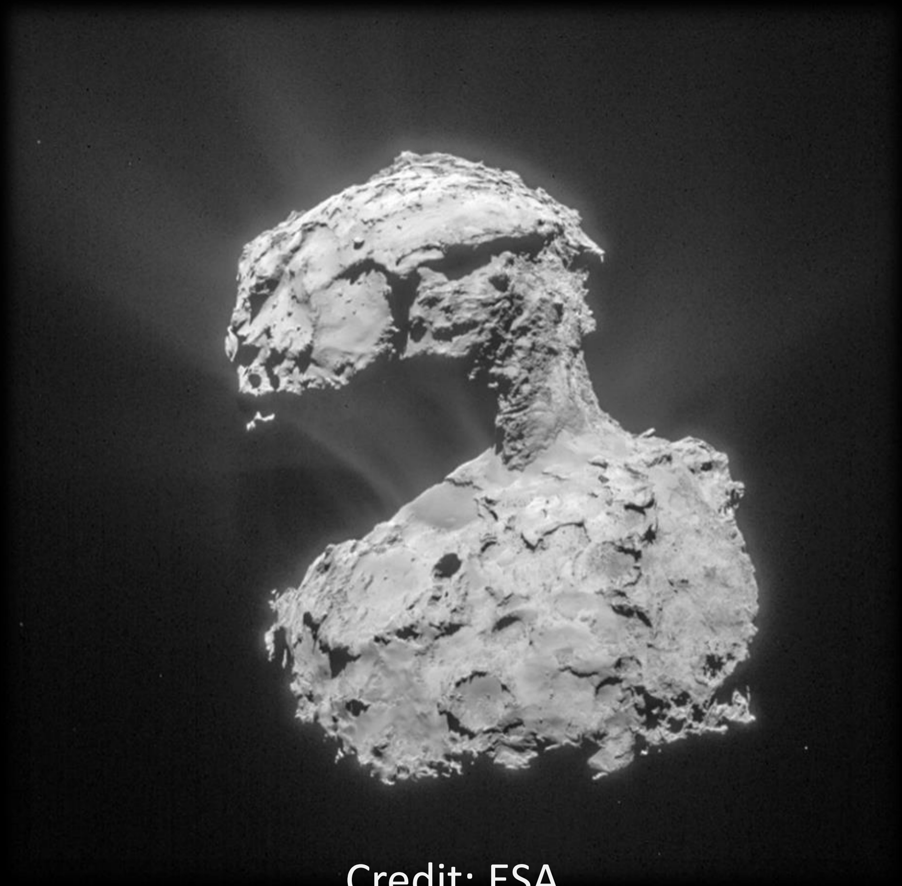
µm dust particle | mm dust agglomerates | km planetesimals | Mm terrestrial planets

Planetesimals

small planetesimals (< 30 km): porous pebble piles

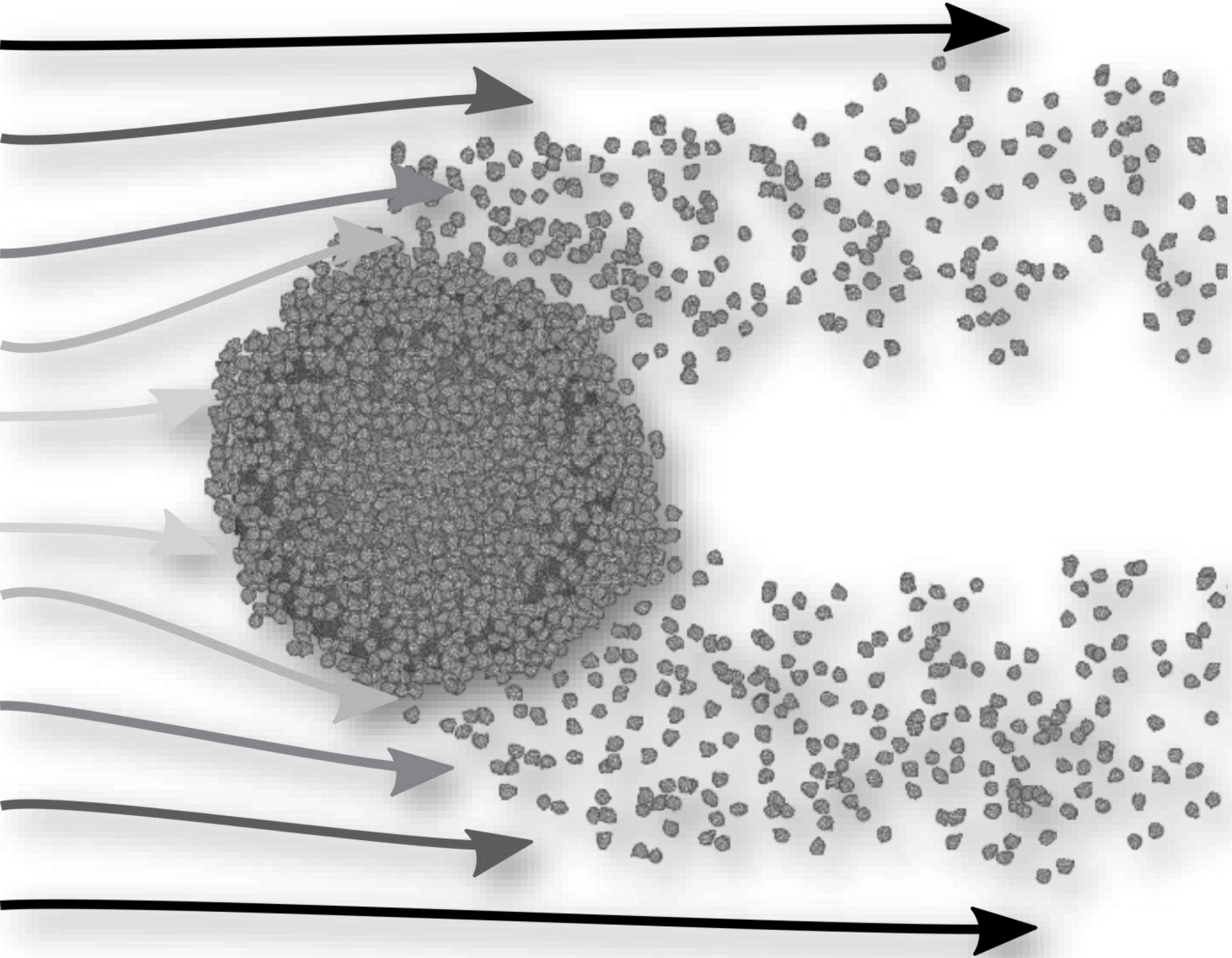
low tensile strength: only a few Pa

low gravitational acceleration on the surface



Credit: ESA

Wind erosion of planetesimals?



Kepler velocity of planetesimal $>$ azimuthal gas velocity

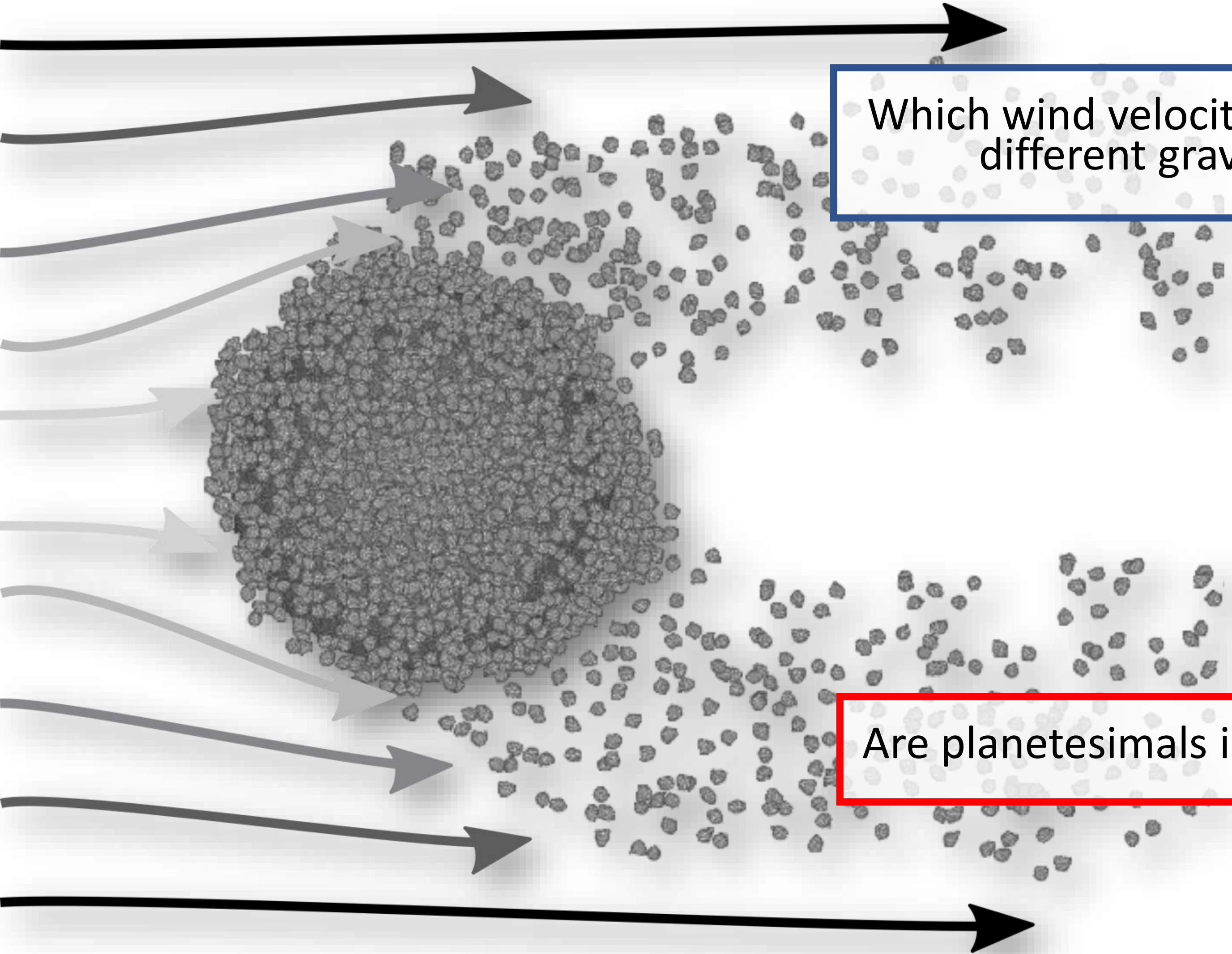
→ Relative velocity to the gas $\geq 50\ \frac{\mathrm{m}}{\mathrm{s}}$

"head wind" could erode planetesimal

→ depends on:

- ambient gas pressure
- pebble size
- cohesion between pebbles
- planetesimal gravity
- …

Objectives

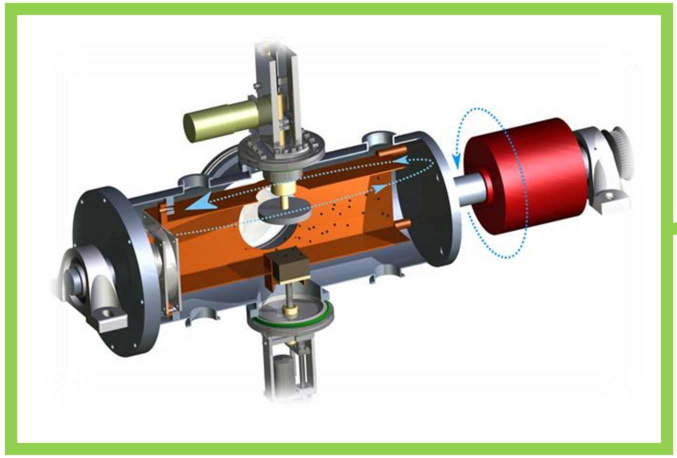


Which wind velocites are needed to erode a protoplanetary surface at different gravitational accelerations g and gas densities ρ?

experimental approach

Are planetesimals in Protoplanetary Disks stable against wind erosion?

What we are doing

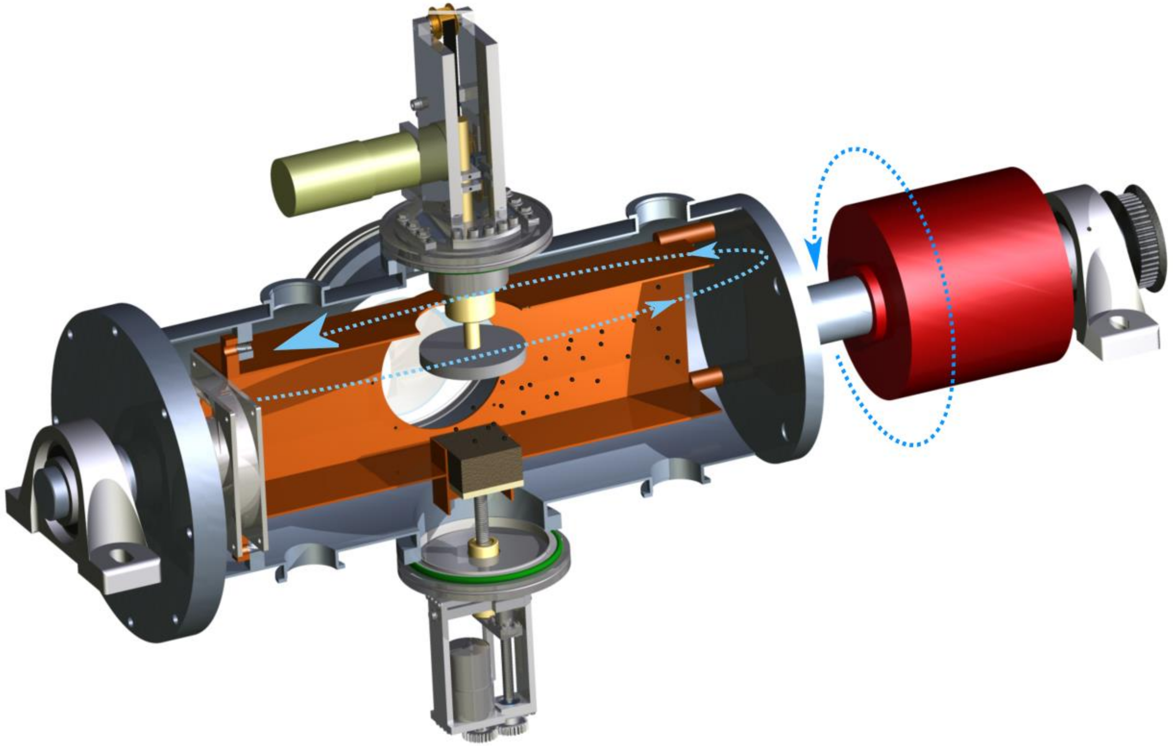


DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

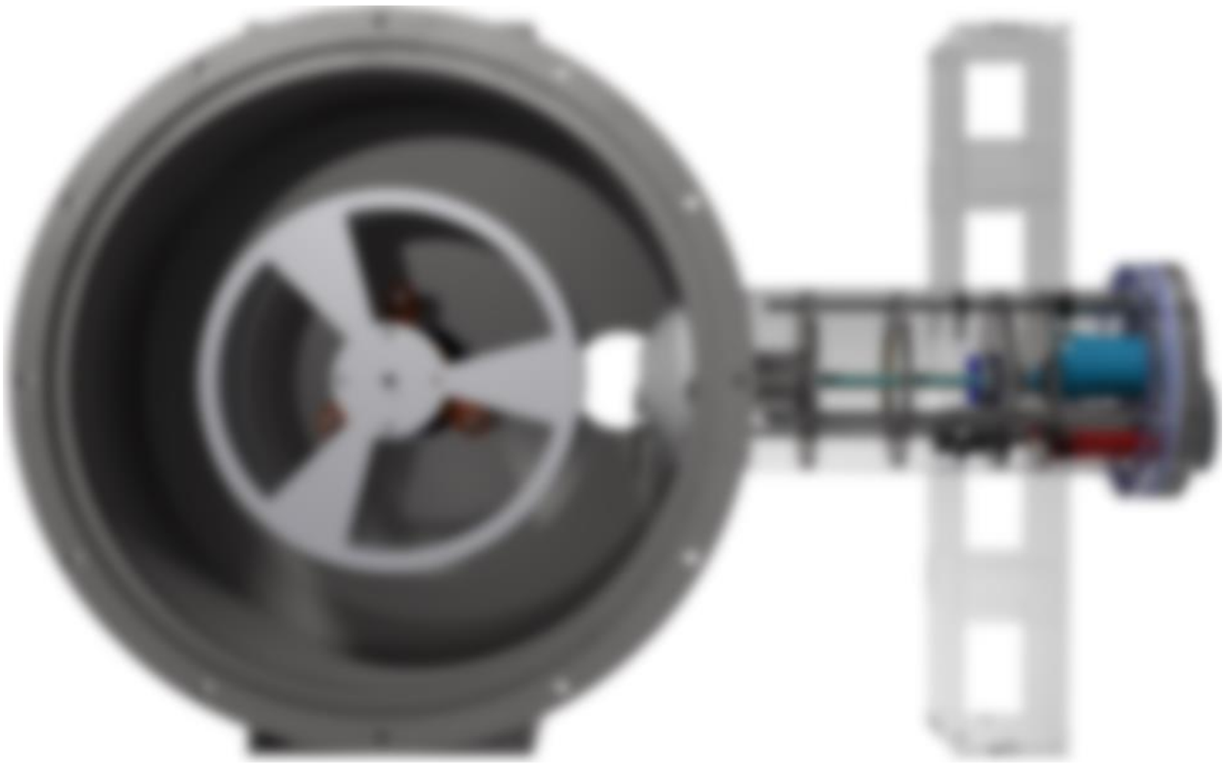
Parabolic flight campaign (31. DLR campaign)

Parabolic flight campaigns

31. DLR campaign
(March 2018)

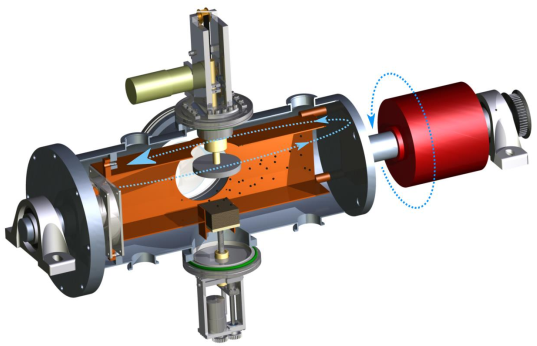


33. DLR campaign
(March 2019)



Parabolic flight campaigns

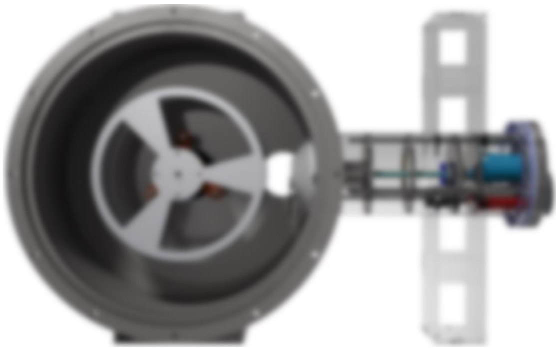
31. DLR campaign
(March 2018)



- 0.1 - 1 g
- wind speeds up to 15 m/s
- ambient pressures down to 300 Pa

Demirci et al. 2019 (MNRAS)

33. DLR campaign
(March 2019)

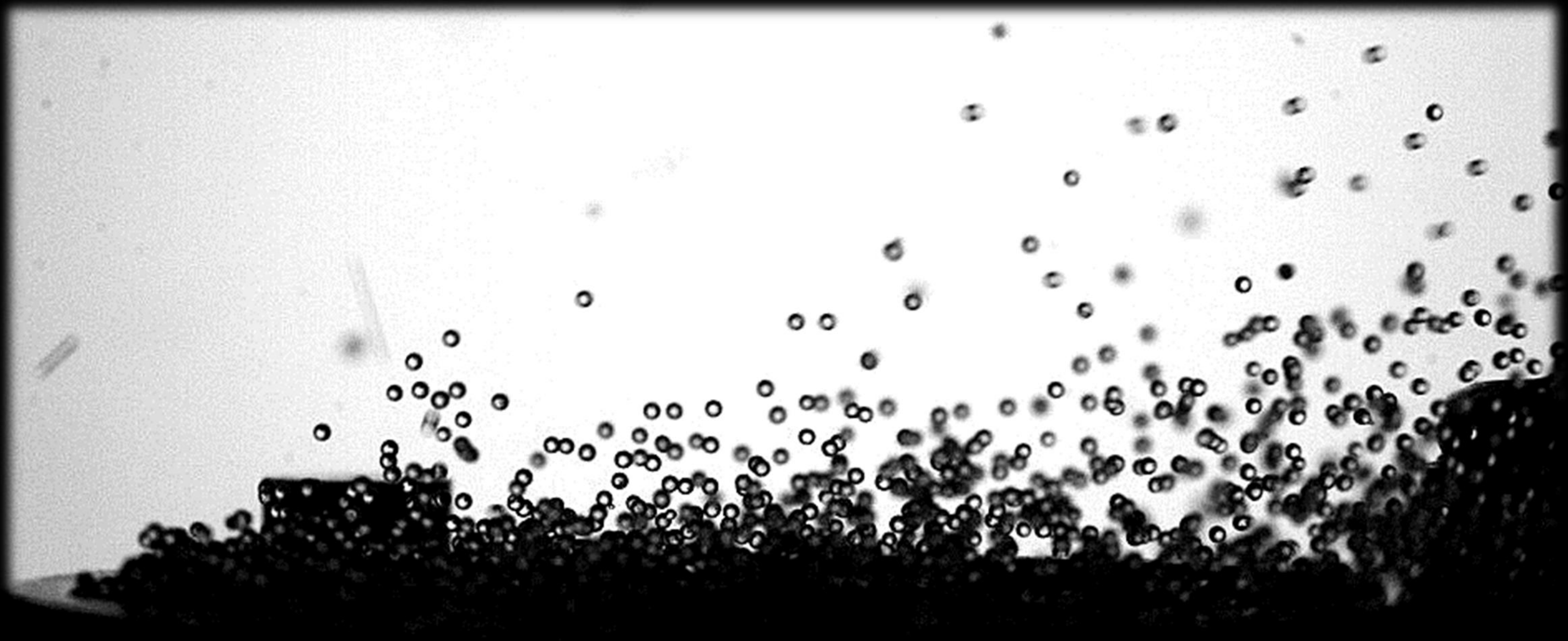


- approx. 0.02 g
- wind speeds up to 100 m/s
- ambient pressures down to 0.1 Pa

Demirci et al. (in prep.)

Experiment data

425 µm spherical glass beads
10 Pa ambient pressure
second setup

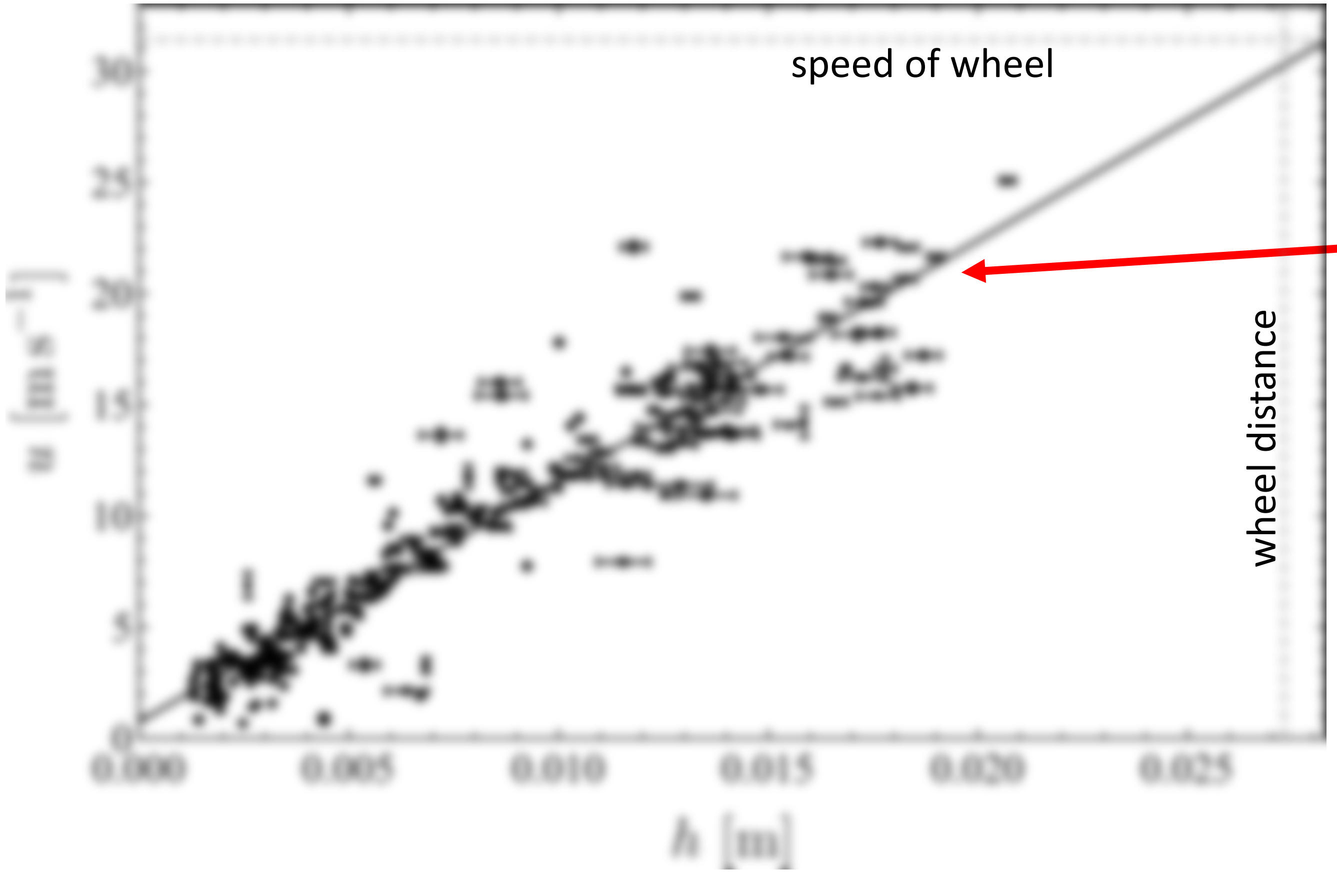


Demirci et al. (subm.)

frame rate: 939 fps

playback speed: 1/30

Wind profile



laminar flow (small Reynolds number)

linear wind profile

threshold shear stress

$$\tau = \eta \frac{\partial u(h)}{\partial h}$$

Schlichting & Gersten 2006

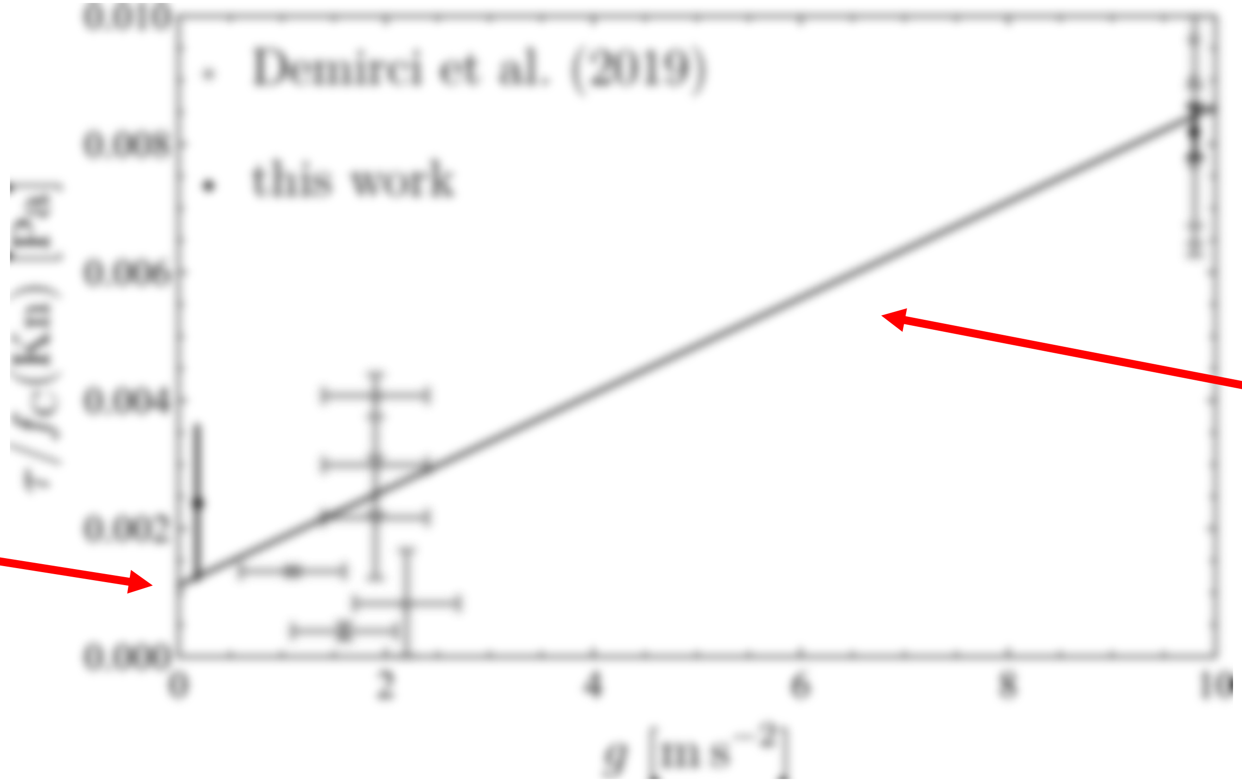
Demirci et al. (in prep.)

Gravity dependent erosion threshold

Shao & Lu 2000

$$\tau_{\text{erosion}} = \alpha\, f_{\text{C}}(\text{Kn}) \left(\frac{1}{9} \rho_{\text{p}} g d + \frac{\gamma}{d} \right)$$

The erosion model is applicable



gravity dependence is linear

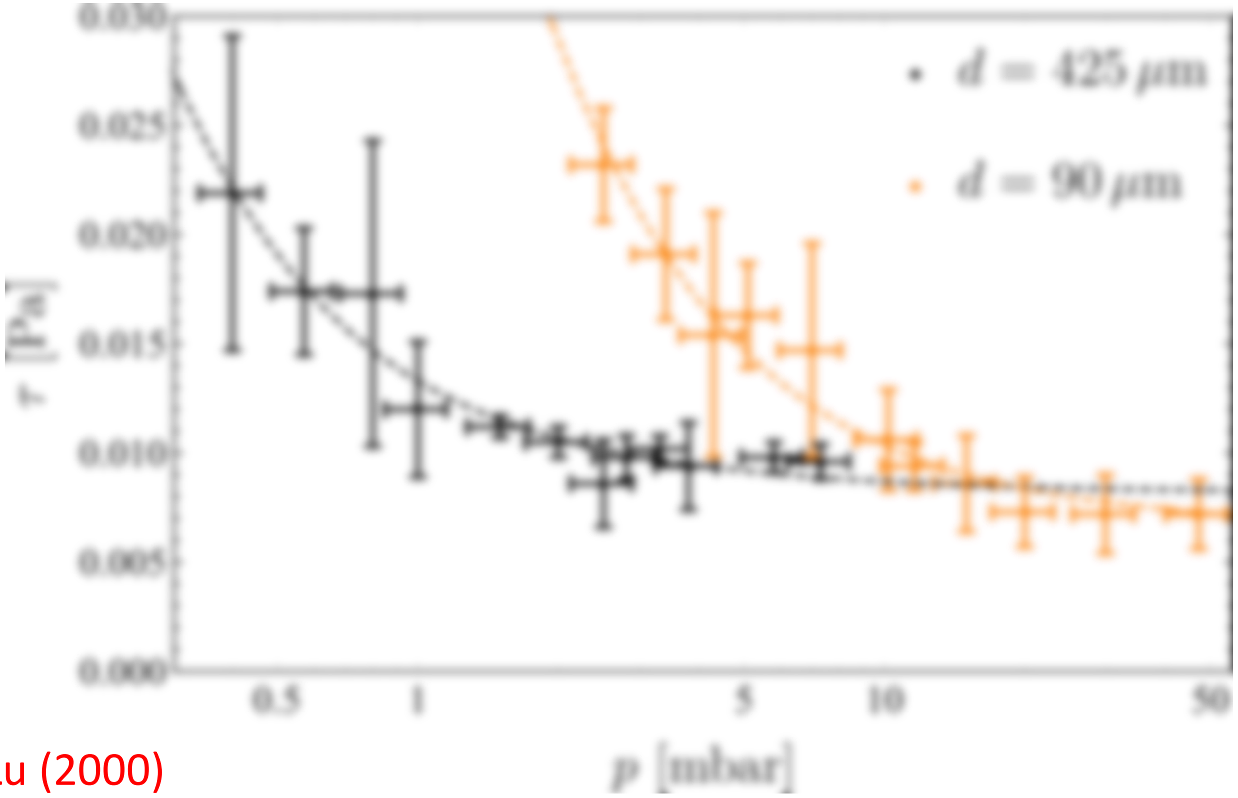
for spherical glass beads (425 µm) cohesion is almost negligible

Demirci et al. (in prep.)

Wind erosion in slip flow

@ 1g

additional ground based measurements



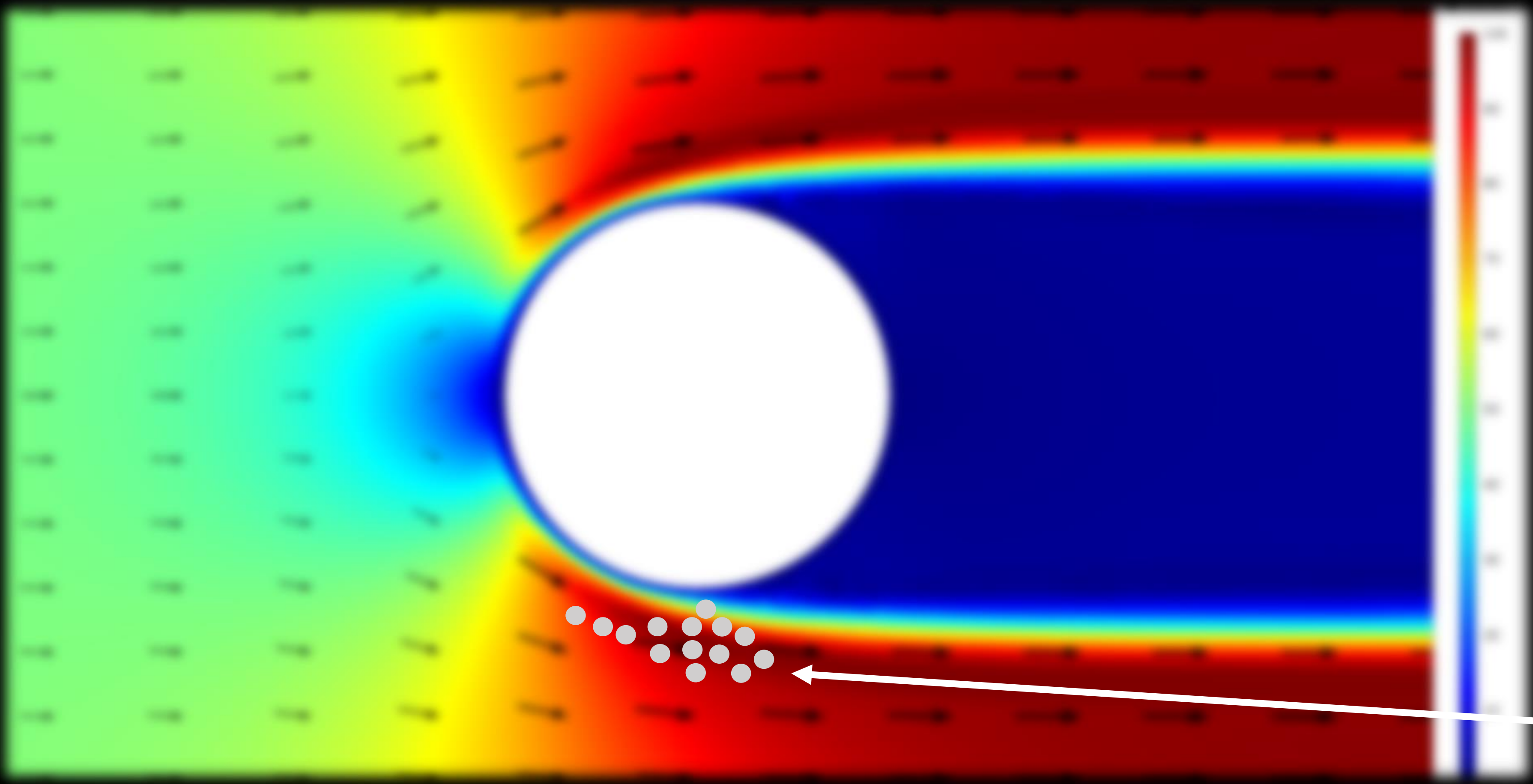
shear stress needed to erode a dust bed:

$$\tau_{\text{erosion}} = \alpha \, f_{\text{C}}(\text{Kn}) \left(\frac{1}{9} \rho_{\text{p}} g d + \frac{\gamma}{d} \right)$$

Cunningham correction for slip flow

(…) describes erosion model by Shao & Lu (2000)

Planetesimals and gas flow



hydrodynamic flow
around planetesimal
(small Knudsen number)

no-slip boundary condition
gas flow = 0 at surface

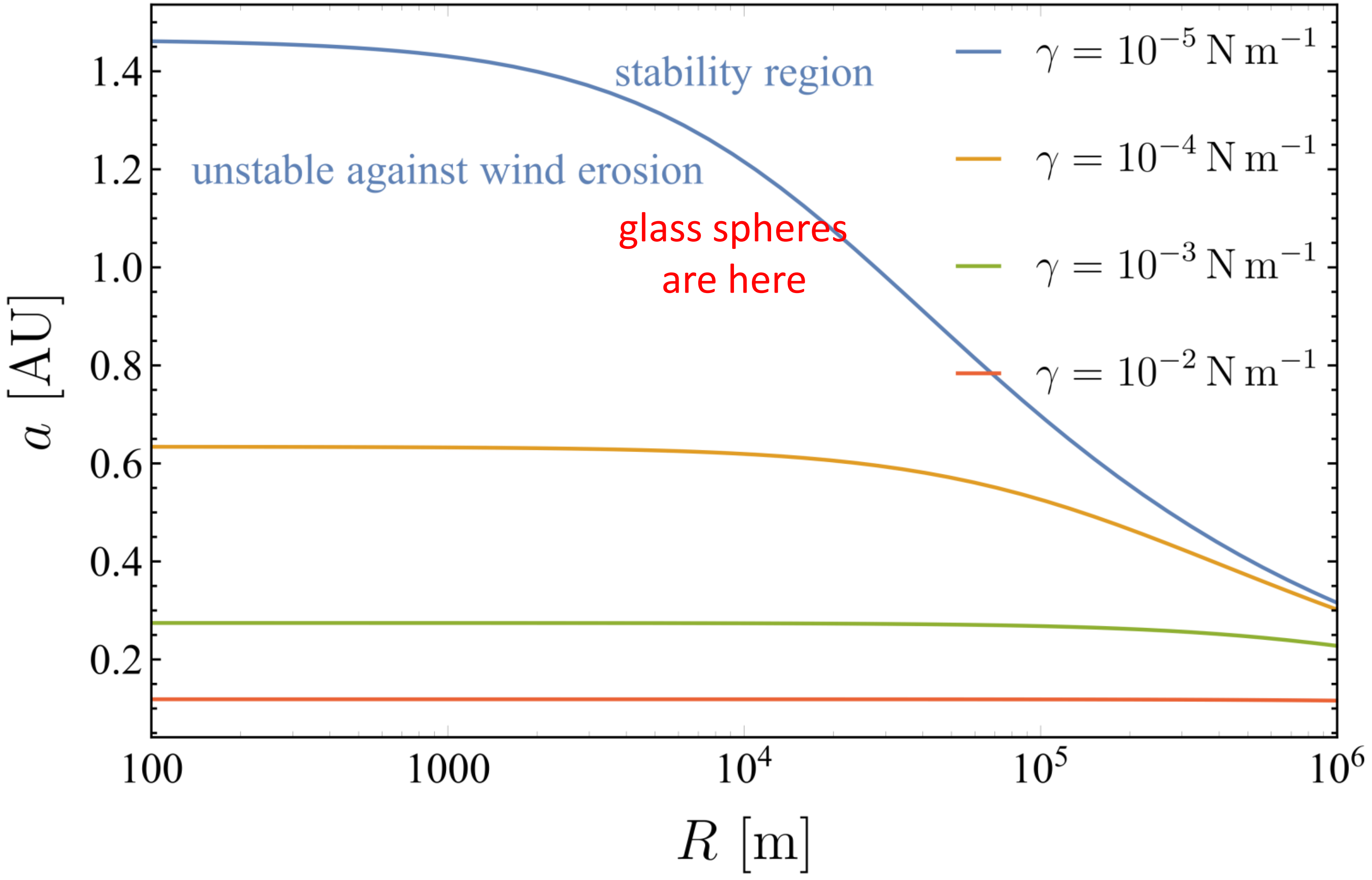
turbulent flow for
large Reynolds numbers

BUT:

slip flow around mm pebbles
(large Knudsen number)

COMSOL Multiphysics 4.3

Wind erosion of pebble pile planetesimals



$$U_{rel} = 50\,\frac{\mathrm{m}}{\mathrm{s}}$$

pebble pile planetesimals are only destroyed in the inner PPD

Demirci et al. 2019 (MNRAS)

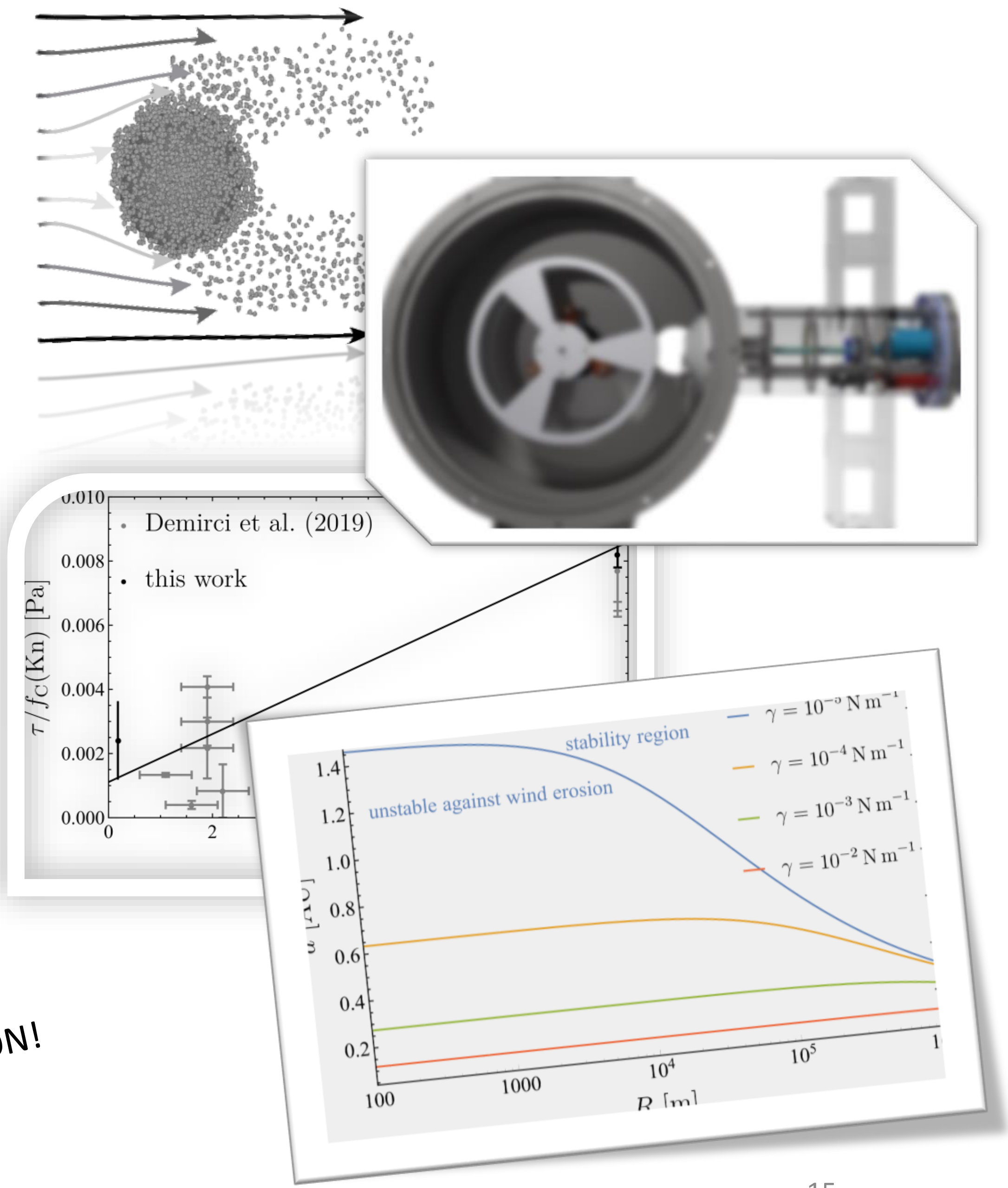
Conclusion

application of erosion model to the protoplanetary disk

→ stability regions in the protoplanetary disk

→ small planetesimal near star are unstable

This work is in preparation for submission to MNRAS



THANK YOU FOR YOUR ATTENTION!

tunahan.demirci@uni-due.de