Physical properties of cometary analogue materials

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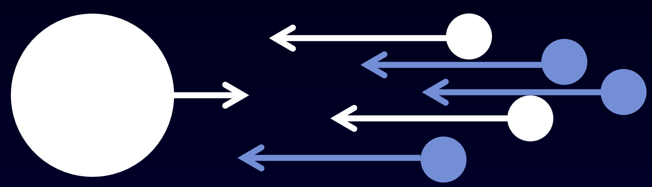
Formation scenarios

Mass transfer (MT)



(Windmark et al., 2012; Garaud et al., 2013)

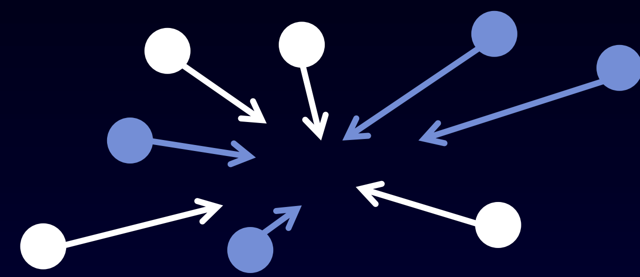
-> Collision of the formed ~ cm-sized aggregates with „lucky winners"

-> High impact velocities

-> Fragmentation of impacting aggregates

-> Mass transfer leads to growth

Gravitational instability (GI)



(Johansen et al., 2007)

-> Concentration of an ensemble of ~ cm-sized aggregates by, i.e., streaming instability*

*: (Youdin and Godman, 2005)

-> Ensamble becomes gravitational unstable -> collapse

-> Relatively low collision velocities**

-> ~ 0.01 m/s – 0.1 m/s**

-> Aggregates are not destroyed**

**: (Wahlberg and Johansen, 2014)

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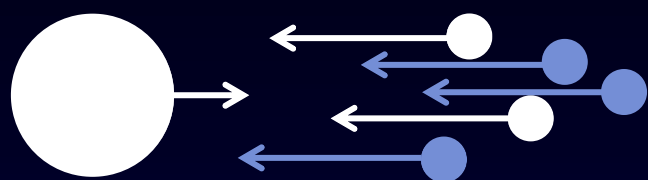
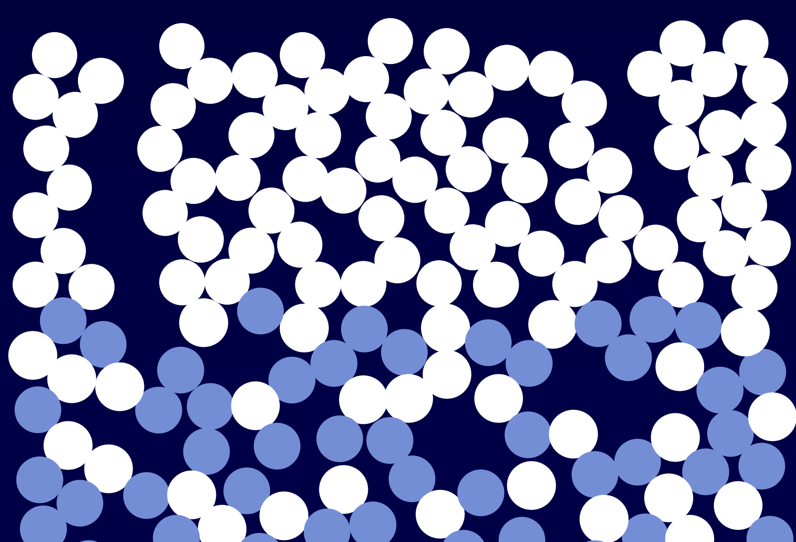


Cometary surface:

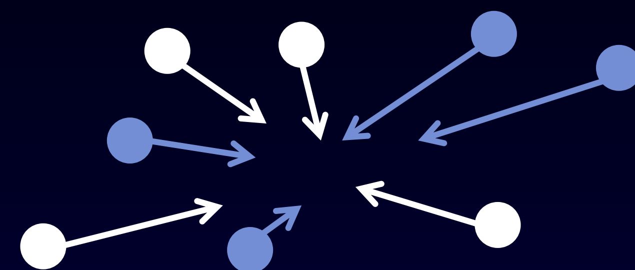
-> Relatively compact

-> Volume Filling Factor: ~ 0.4

-> µm-sized monomers



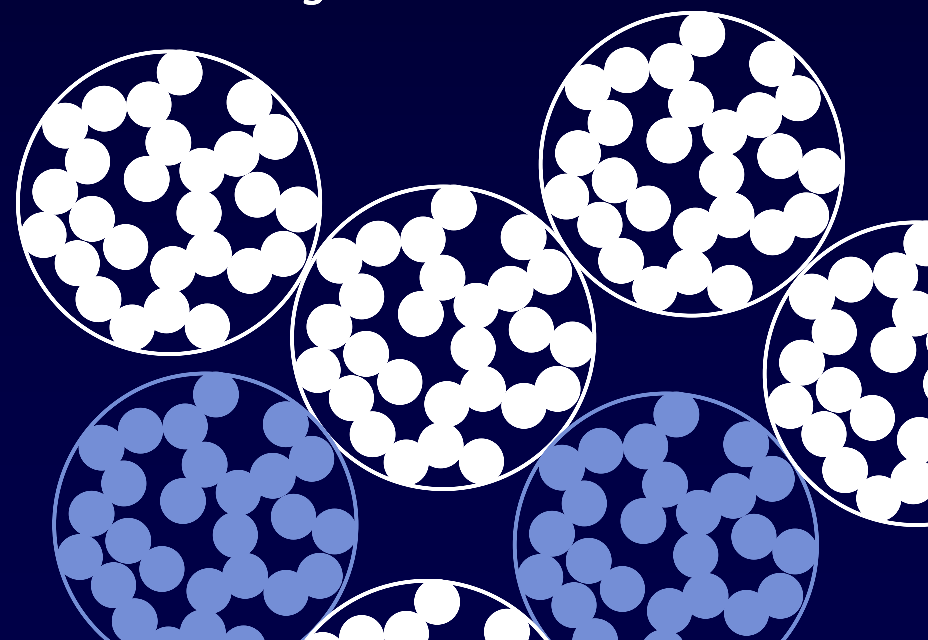
Gravitational instability (GI)



Cometary surface:

-> Loose arrangement of aggregates

-> Vol. filling factor: ~ 0.35 x 0.6 ≈ 0.2



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Formation scenarios

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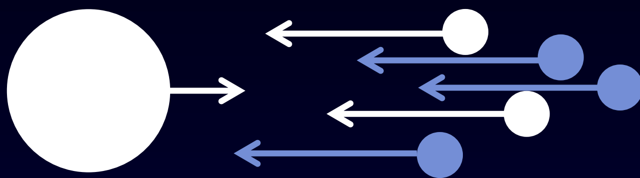
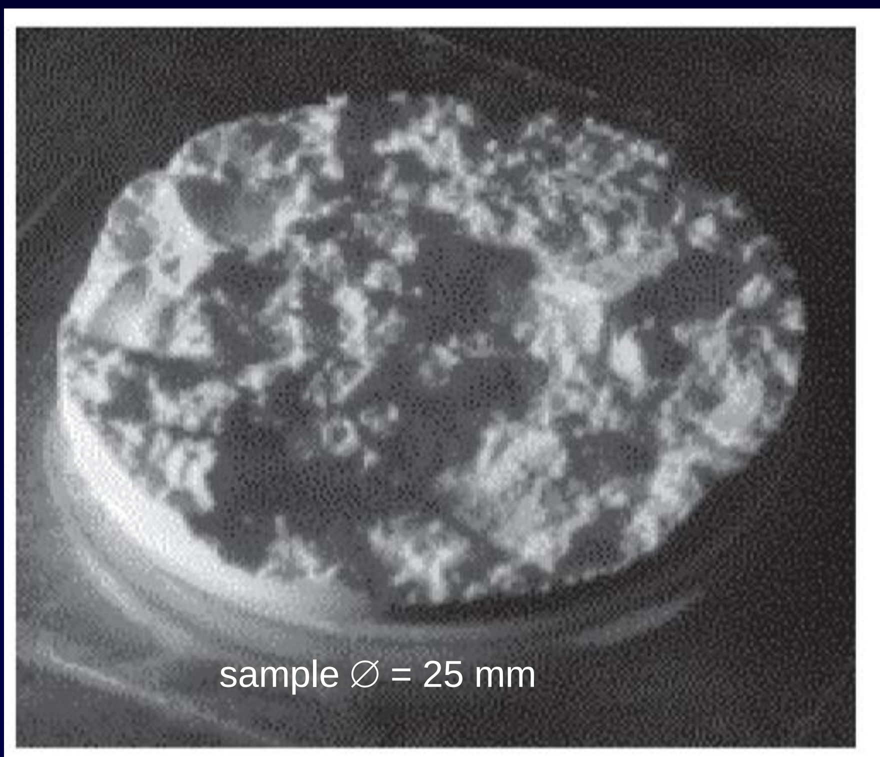
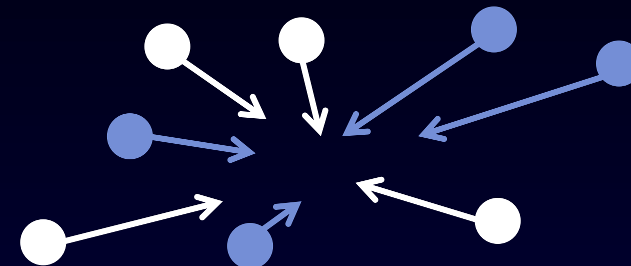
Mass transfer (MT)



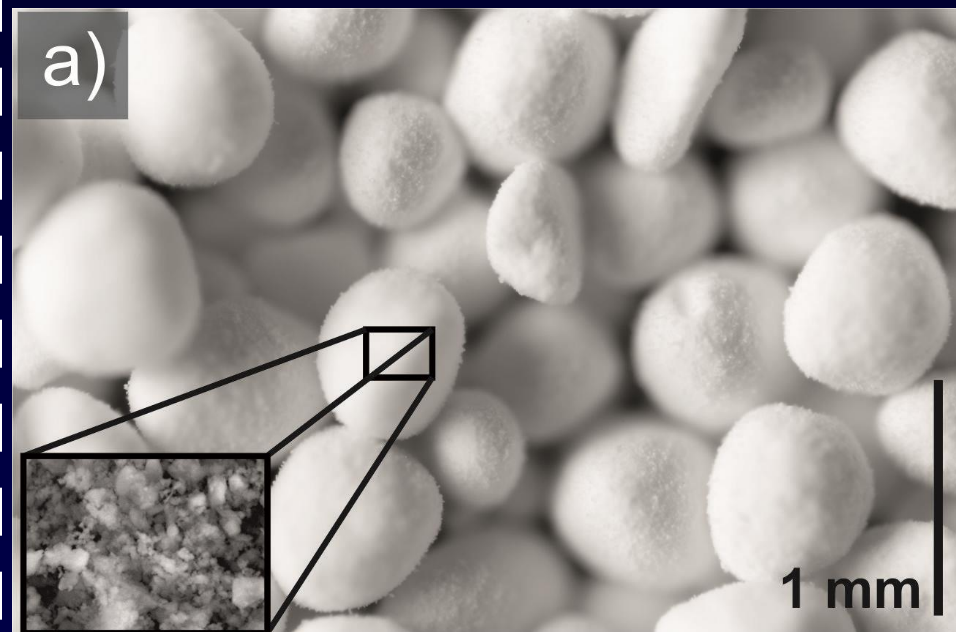
Cometary surface:



Gravitational instability (GI)



Cometary surface:



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Tensile Strength

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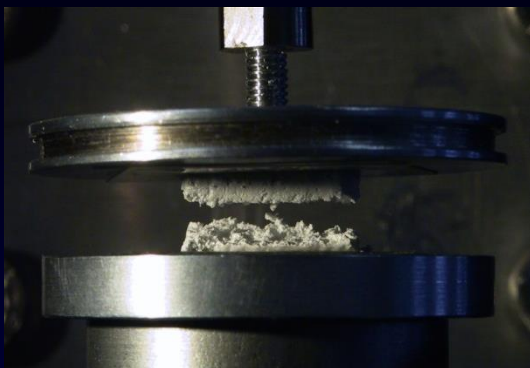
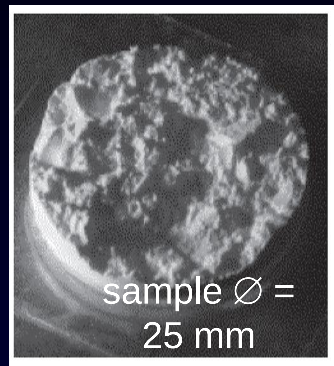
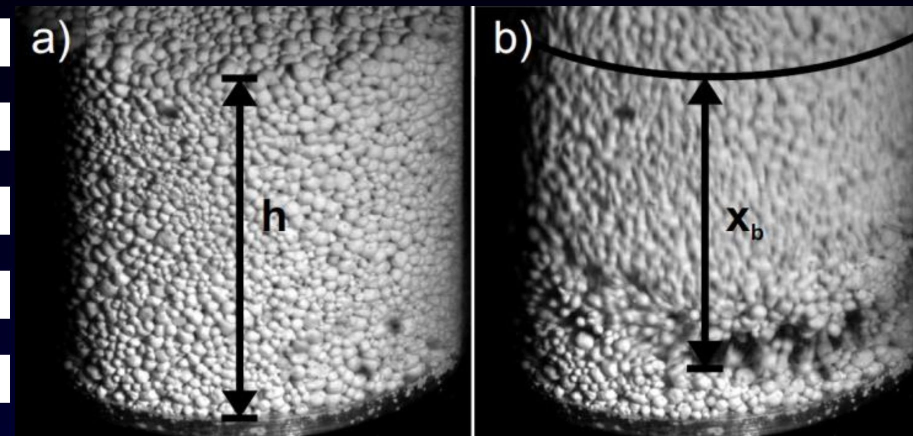


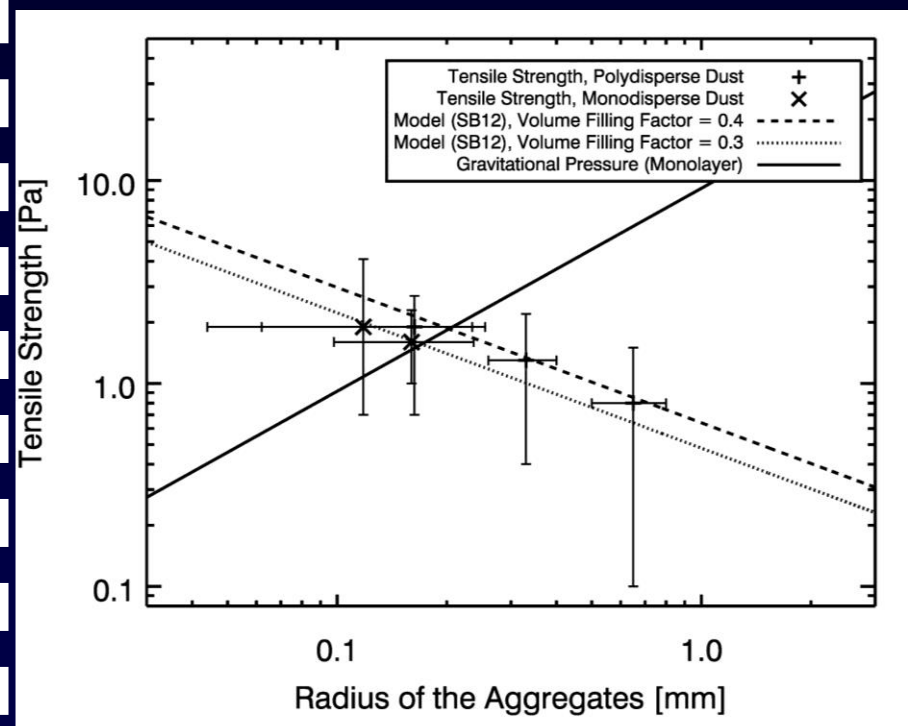




$$T(\phi) = 2400 \text{ Pa } (\phi = 0.41)$$

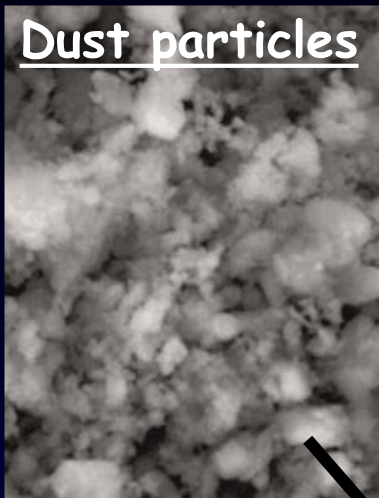
$$T(\phi) = 10^{2.8 + 1.48\,\phi} \quad (\text{Pa})$$

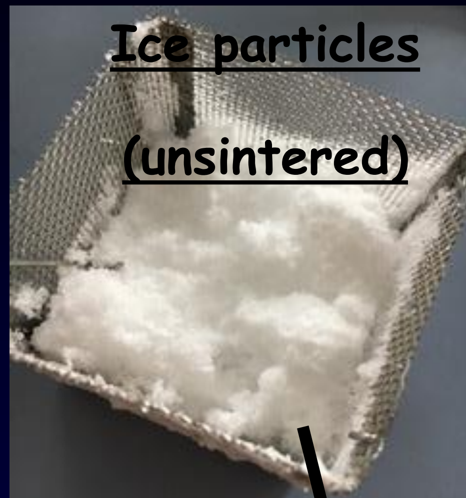
(Güttler et al., 2009)



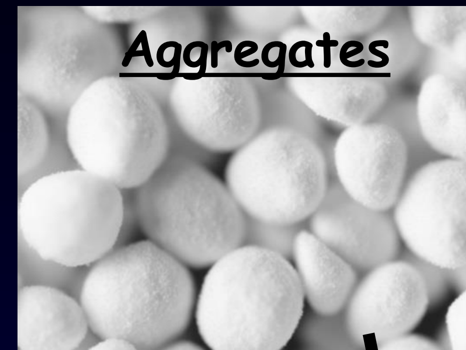
(Data from Blum et al., 2014; Brisset, 2014)

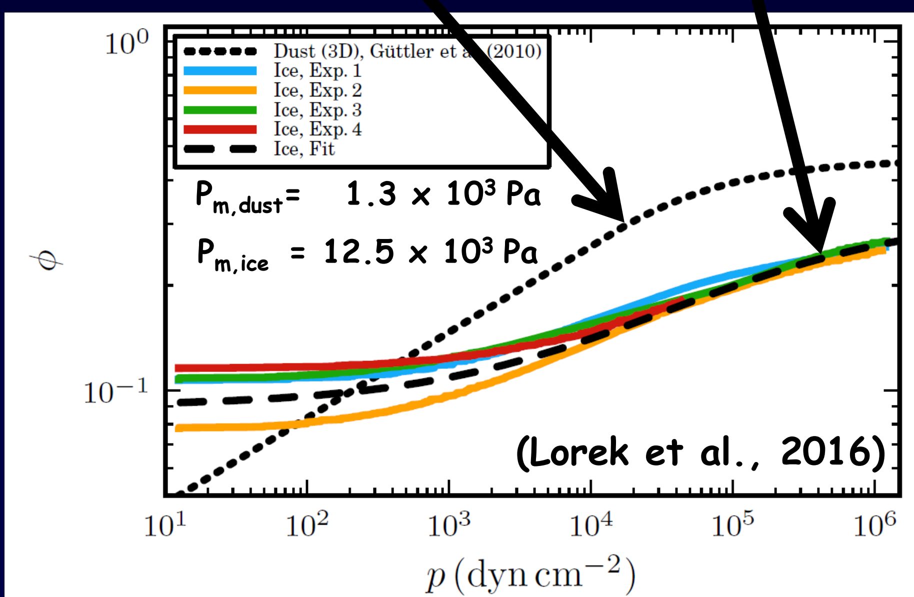
Compressive Strength

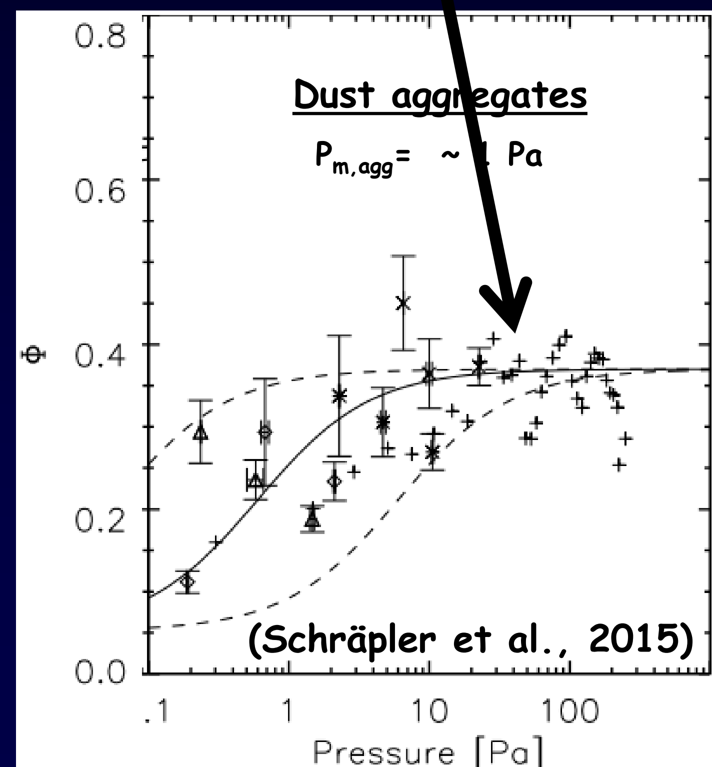




Granular H_2O ice







1 dyn cm^{-2} = 0.1 Pa ...

Overview (dust)

	Mass transfer (**MT**)	Gravitational instability (**GI**)
Volume filling factor	~ 0.4	~ 0.35 x 0.6 ≈ 0.2
Tensile strength (surface)	~ 1000 Pa	~ 1 Pa
Compression curve (p_m @ $\Phi \approx 0.25$)	~ 1300 Pa (up to 10^6 Pa) *no ice (MUPUS: > MPa)	~ 1 Pa (up to 10^3 Pa) (MUPUS: > MPa)
Gas permeability	~ 1×10^{-9} $m^4 s^{-1}$	~ 1×10^{-6} $m^4 s^{-1}$
Thermal conductivity	10^{-2} – 10^{-1} W $m^{-1} K^{-1}$ (conduction)	10^{-3} – 1 W $m^{-1} K^{-1}$ (conduction/radiation)

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And KOSI…?

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- The measured heat conductivity of the sample material (1×10^{-1} W m^{-1} K^{-1} to 6×10^{-1} W m^{-1} K^{-1}; Spohn et al., 1989) is lower than the bulk heat conductivity of water ice. However, the heat conductivity of the KOSI samples is much higher than the heat conductivity estimated for the surface material of Comet 9P/Tempel (heat conductivity: $\lambda \approx 1 \times 10^{-3}$ W m^{-1} K^{-1}; Groussin et al., 2007).

- Irradiated ice-dust mixtures form a non-volatile dust layer, which decreases the gas production rate of the sample (see Fig. 1.12; Lämmerzahl et al., 1995).

- The compressive strength of the sample material is very low and increases during the experiment from $\sim 1\times10^5$ N m^{-2} to $\sim 5\times10^6$ N m^{-2} (Colangeli et al., 2004). The increase of the compressive strength is probably caused by mass transport inside the sample due to the outgassing of the icy materials, or by sintering[18] of the sample material.

- The activity of the icy constituents causes the emission of particles (Lämmerzahl et al., 1995).

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Water ice

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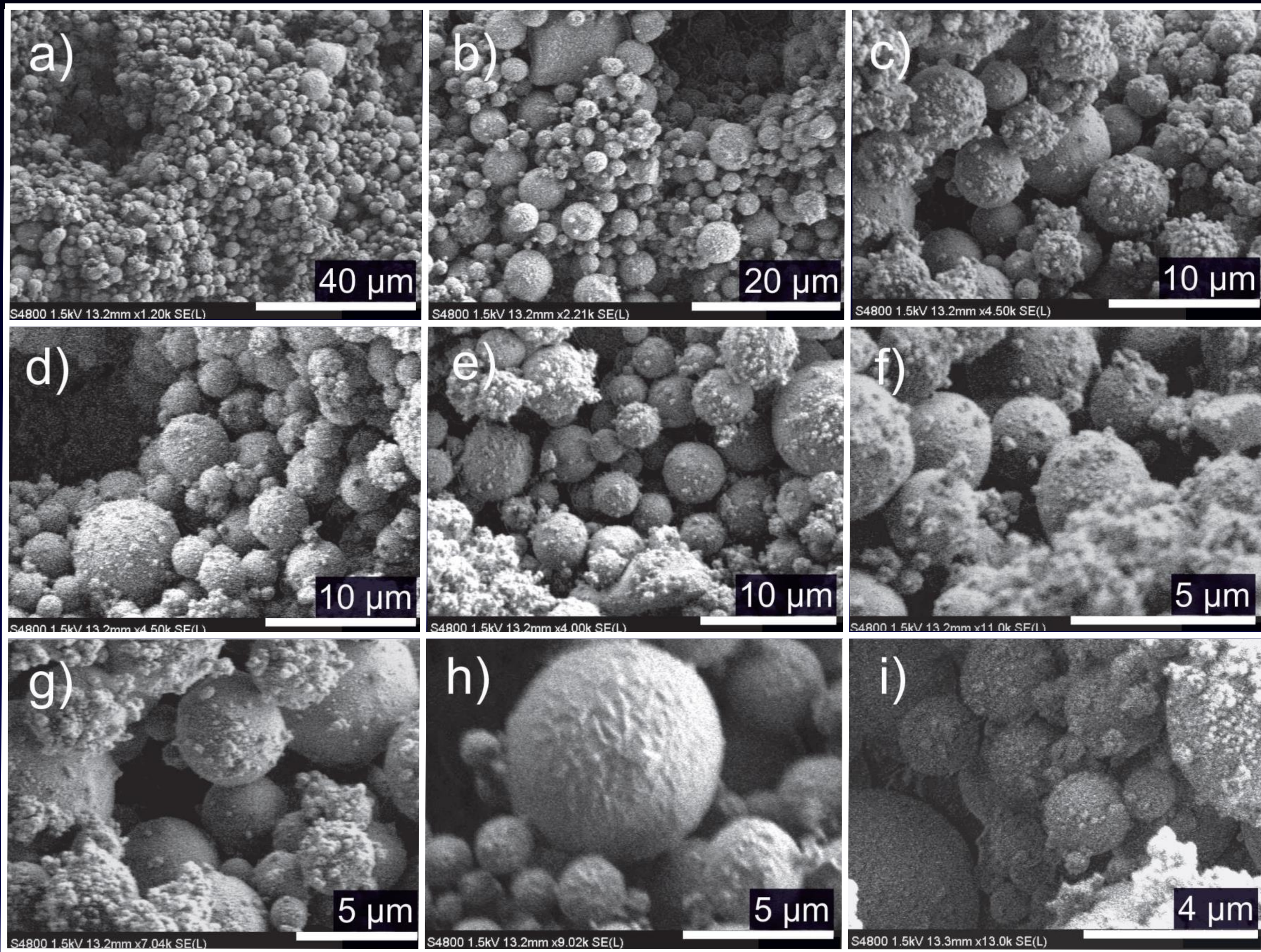

(Jost et al., 2013)

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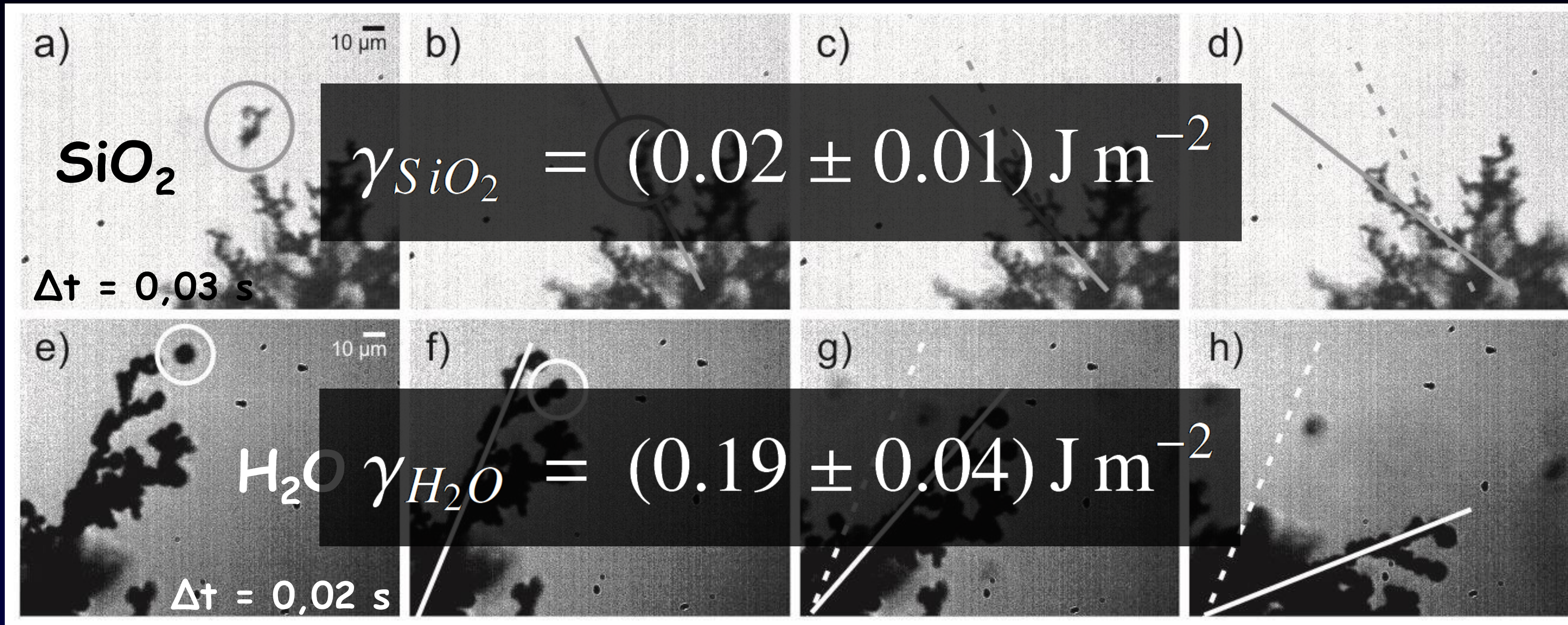

$$\gamma_{SiO_2} = (0.02 \pm 0.01)\,\mathrm{J\,m^{-2}}$$

$$\gamma_{H_2O} = (0.19 \pm 0.04)\,\mathrm{J\,m^{-2}}$$

(Gundlach et al., 2011b)

$$F_{Roll} = m\,g_0\,\frac{a_{cm}}{r} \quad \longleftrightarrow \quad F_{Roll} = 6\pi\gamma\xi$$

(Blum and Wurm, 2000) (Dominik and Tielens, 1995)

m: Mass of the Aggregate
a_{cm}: Lever Arm (Horizontal Projektion)
r: Particle Radius

γ : Specific Surface Energy
ξ : Critical Rolling Distance

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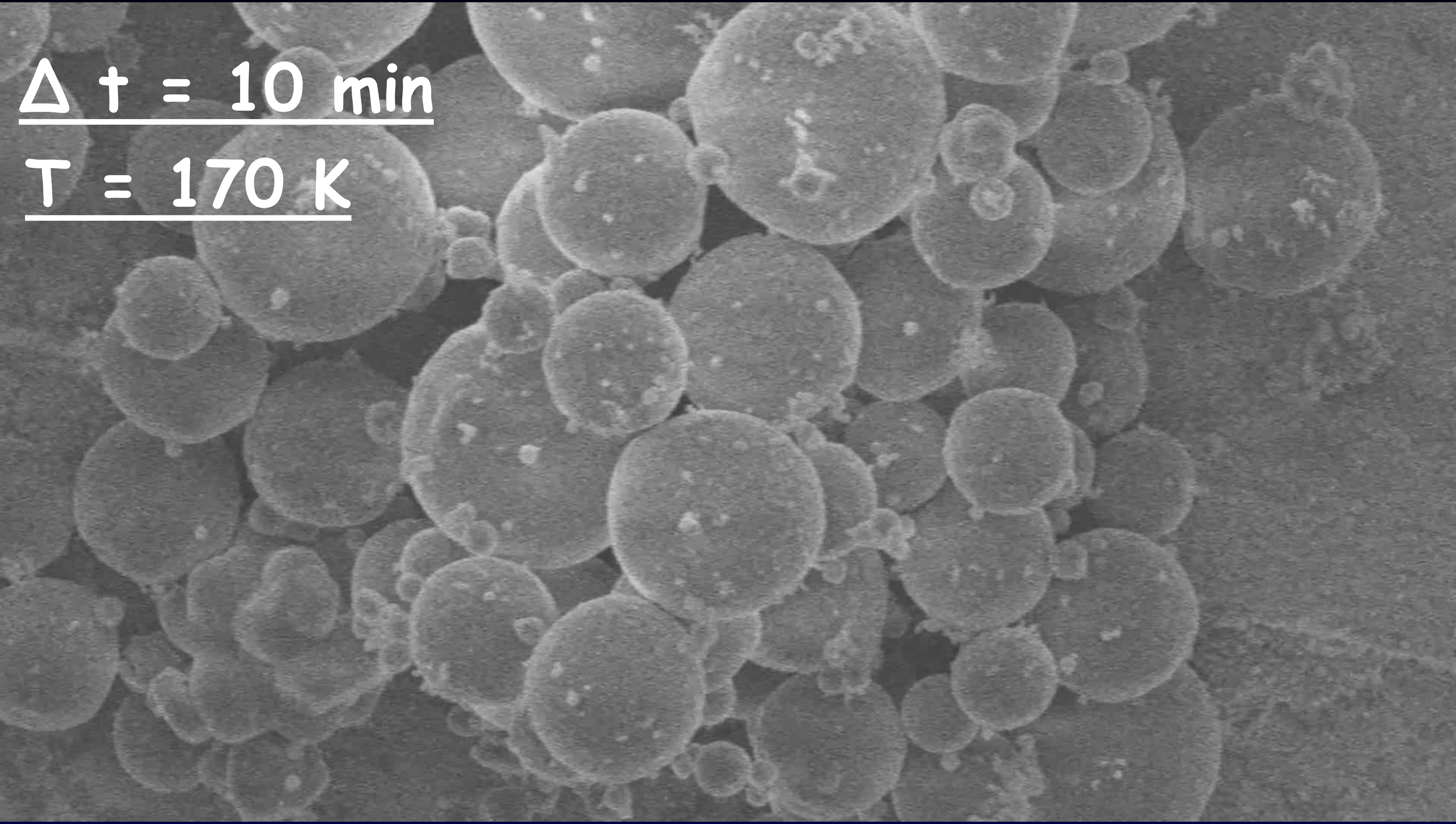
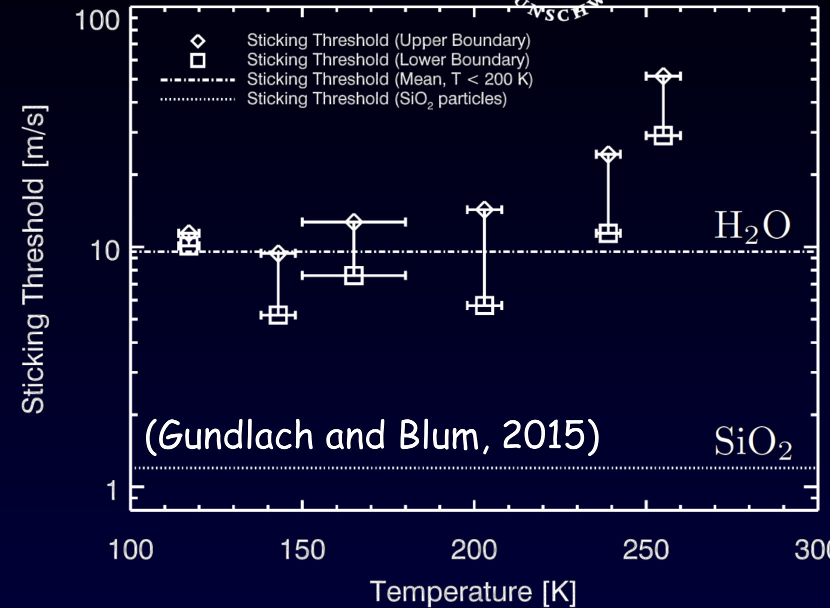
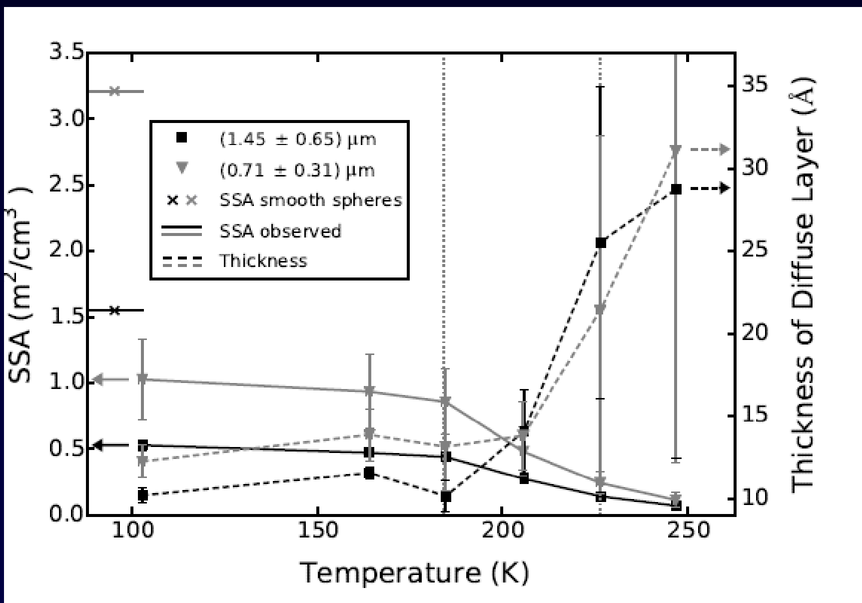


Water ice (@ 200 K)



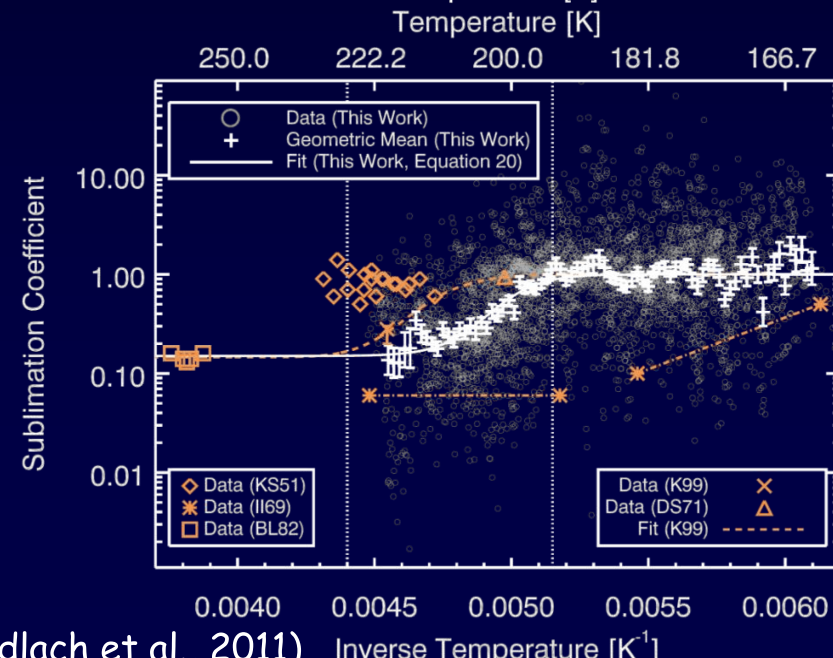
(Gundlach and Blum, 2015)



(Gärtner et al., submitted)

↓

Formation of a solidified layer on comets?



(Gundlach et al., 2011)