Collision simulation of sintered icy aggregates

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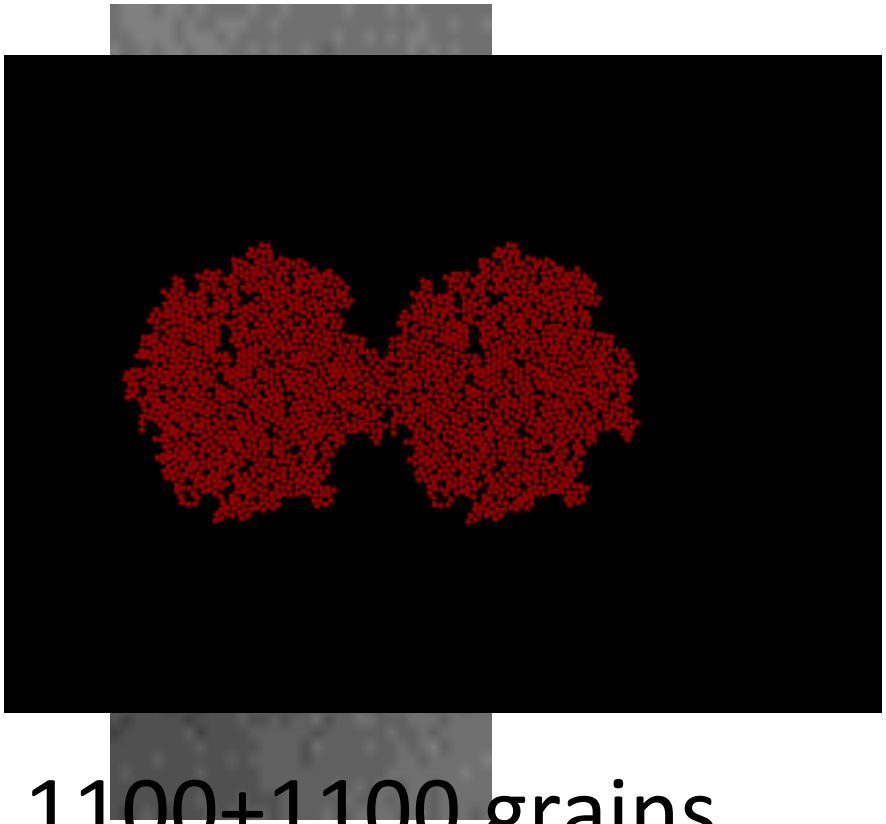
3rd DTA Symposium 2015/6/2 NAOJ

Coagulation of dust aggregates

- Dust grain (0.1μm) => Aggregate (1m)
  => Planetesimal (1km) => Planet (1000km)
- Aggregate infalls（~50m/s）
  - 100 yr Infalling problem
  - Disruption @ 50m/s? Disruption problem
- Sticking @ 50m/s Wada et al.(2009)
  Numerical simulation with H_2O ice
- Sticking @ ~ m/s

Laboratory experiment : SiO_2 Blum (2010)

Rolling of grains



1100+1100 grains,

V=50m/s, 0.1μm H_2O

Chain of 1 μm

SiO_2 grains

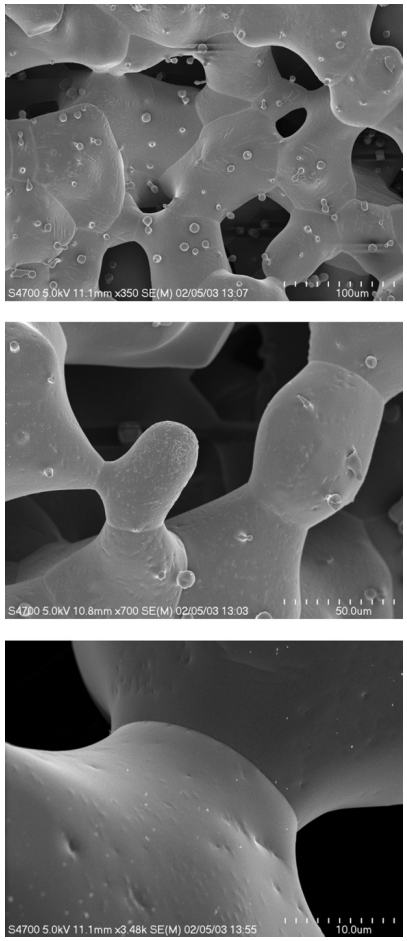
Heim et al.(1999)

- Rolling without splitting of grains
- Rolling => Deformation of grain aggregate

⇒Sticking

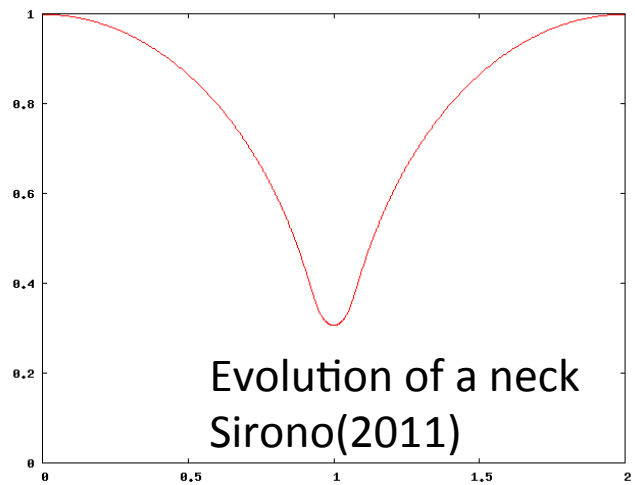
⇒Planetesimal formation?

Sintering of H_2O ice



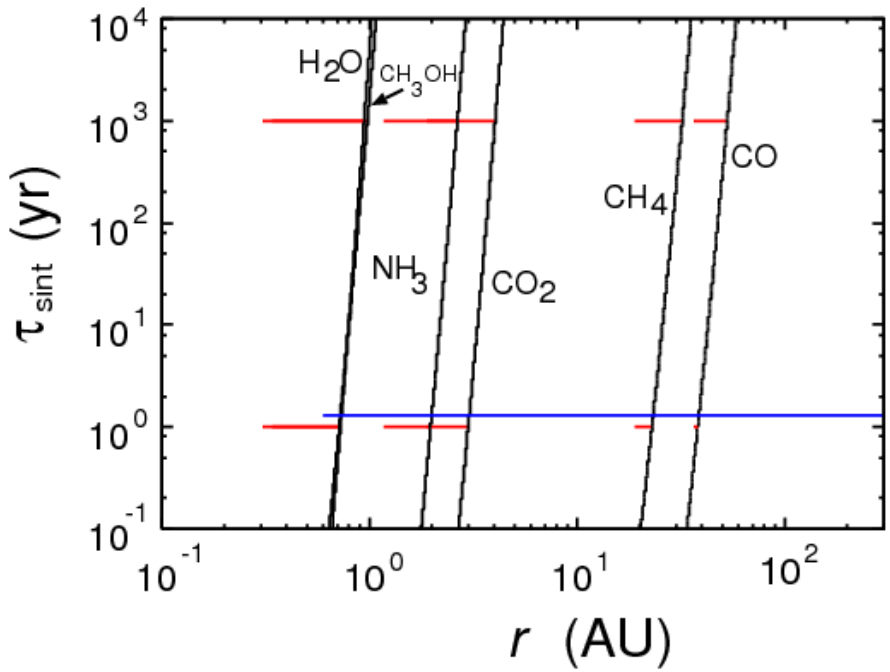
Blackford (2007)

- High T ➡ Sintering
  - Growth of a neck
- Mechanical properties
  - Increase in strength
  - Breakup by rolling



Evolution of a neck
Sirono(2011)

Sintering regions



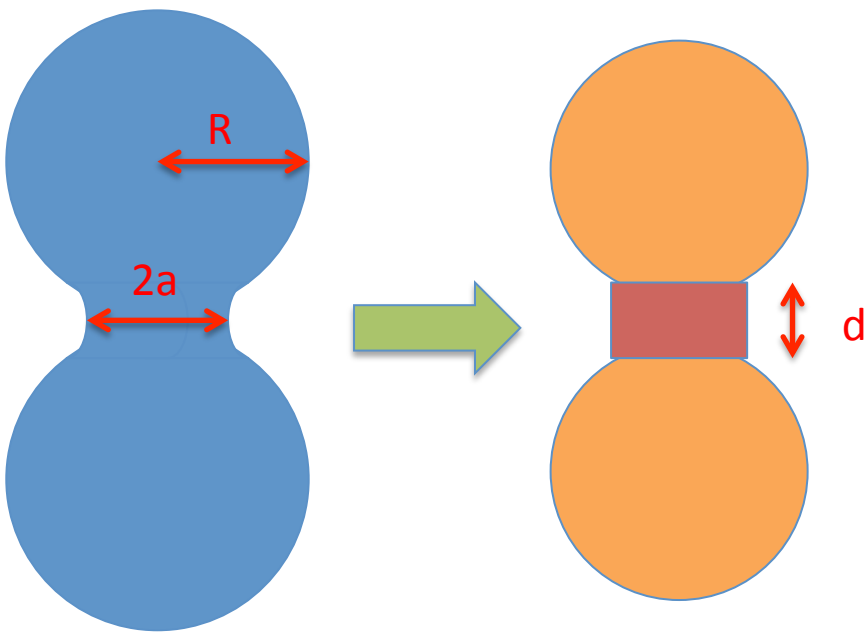
Sirono (2011)

- Sintering proceeds around a snow line
- Various ice species

Aim of this study

- 2-D collision simulation of sintered aggregates
  - Effects of sintering on collisional outcomes
  - Sticking velocity

Model of a sintered neck



- Cylindrical rod
  - Elastic deformation
- Breakup when elastic energy reaches surface energy
- No sintering case: Domink&Tielens(1997)

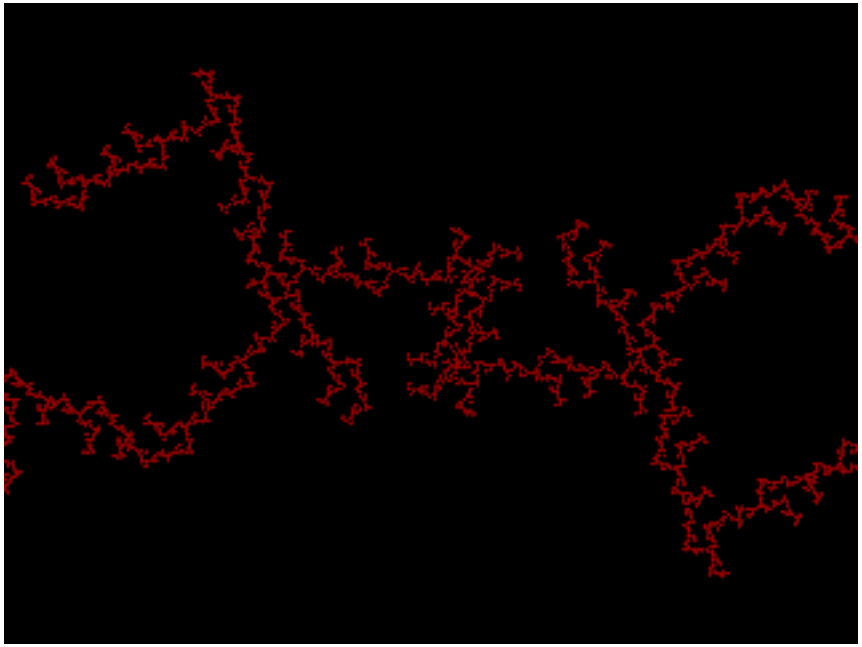
$$k_{\mathrm{ss}} = \frac{\pi a^2 E}{d} \quad k_{\mathrm{sl}} = \frac{\pi a^2 G}{d} \quad k_{\mathrm{ro}} = \frac{\pi a^4 E}{16} \quad \beta = \frac{a}{R}$$

Collision simulation

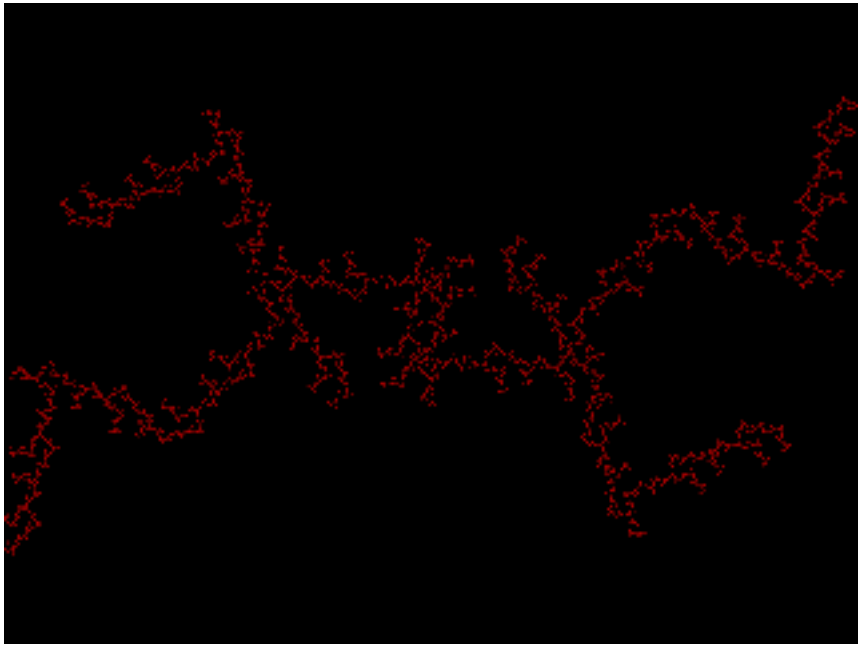
- 2-D DEM Simulation（Dominik&Tielens 1997)
- Number of grains: 128 => 256 => 512 =>...
- Material properties：H_2O ice, 0.1 μm radius
- BCCA aggregate，５ runs
- Head-on collision
- Parameters:
  - β=Neck radius/Grain radius 0.7, no sintering
  - Collision velocity 10 m/s - 60 m/s

Collisional outcomes

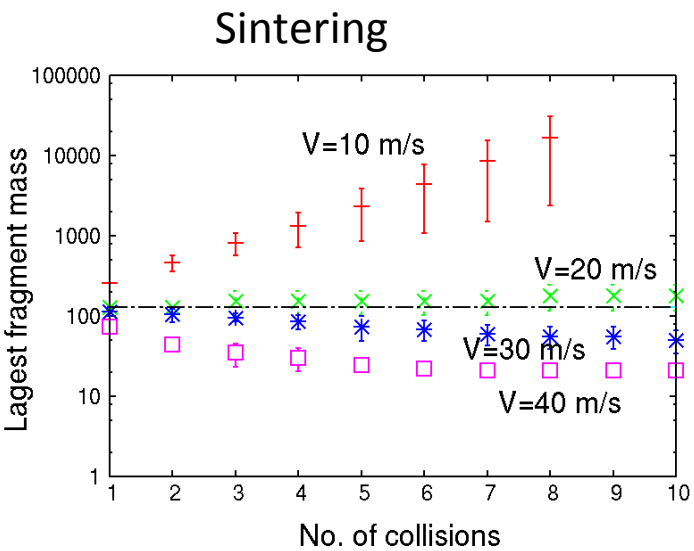
- 1024 grains, V=32 m/s
- No sintering (left), Sintering (right)

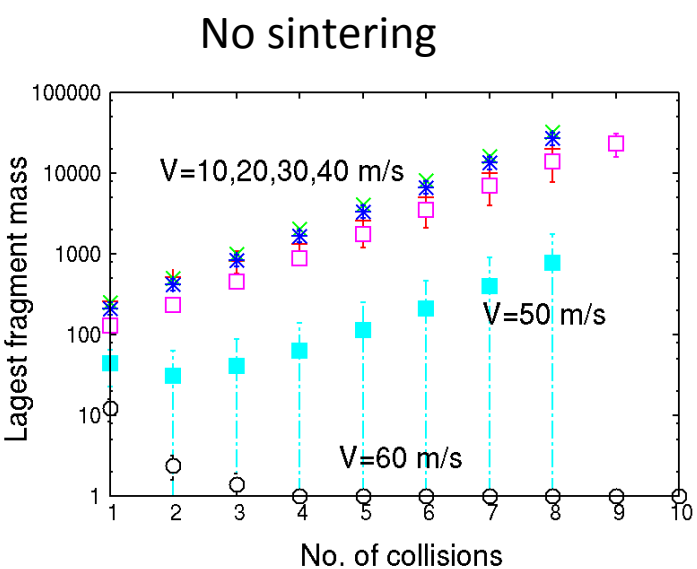


β=0.7



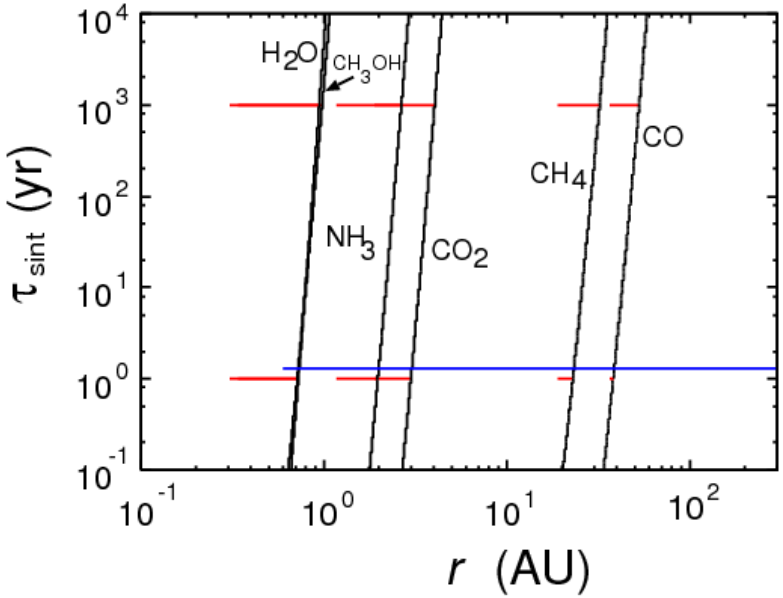
Sticking velocity





- Sintering V_s=20m/s
- No sintering V_s=50m/s
- Bouncing due to large strength
- Rolling Breakup decreases V_s

Discussion: Sintering regions



Sirono (2011)

- Various ices: Many sintering regions
- Inside sintering region: Sintering proceeds => Low sticking velocity => No planetesimal formation by collisional sticking

=> Production of fragments

Summary

- Collision simulation of sintered icy aggregates
- Sintering => Breakup by rolling
  - Low sticking velocity
- Sintering decreases sticking velocity
  - Planetesimals might not be formed inside sintering region
  - Axisymmetric pattern of HL Tau?