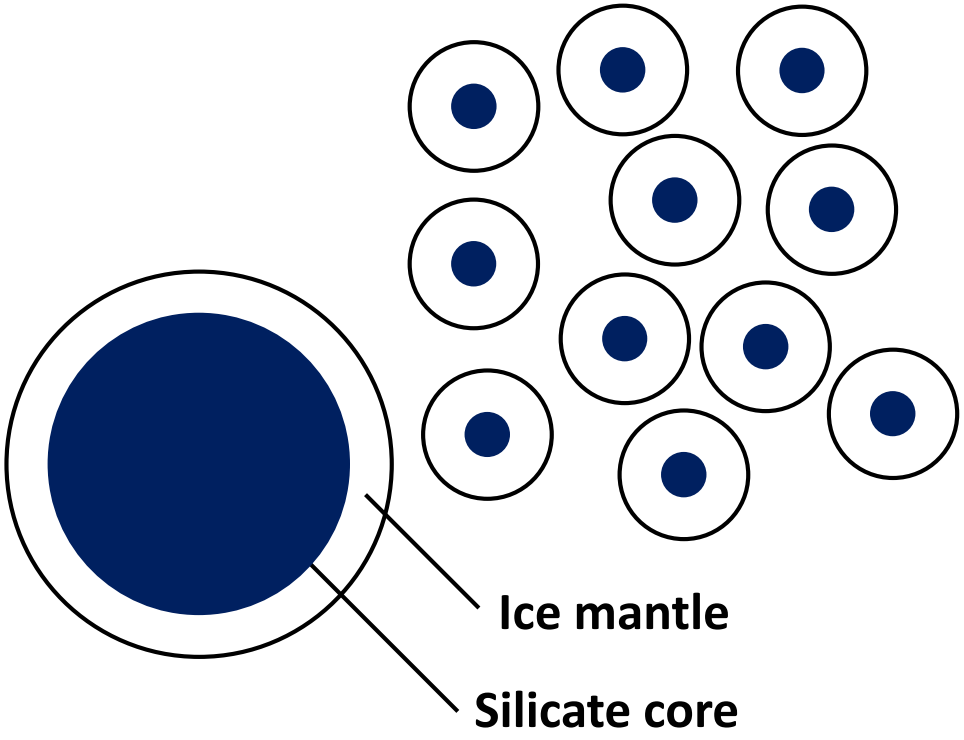
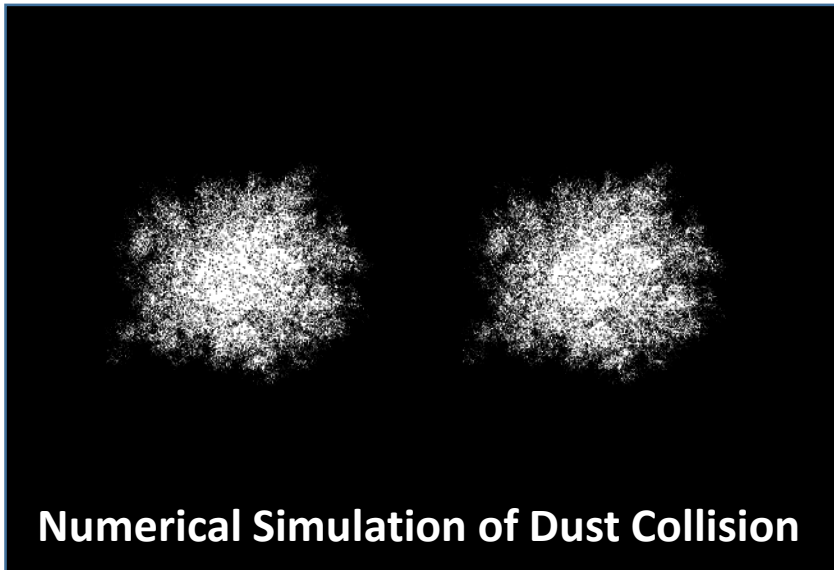
Size Distribution of Ice-mantled Grains and Its Effect on Dust Growth

Hidekazu Tanaka (Tohoku University)

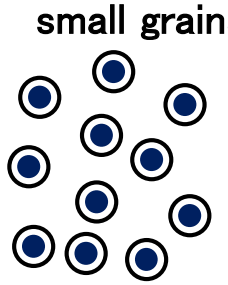




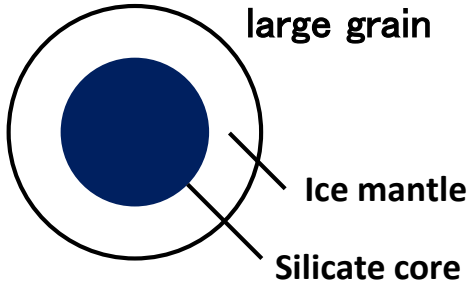
Evolution of Cosmic Dust

1. Grain formation around Stars

2. **Silicate grains (& graphite) in molecular clouds**
   - Size distribution $N(a)\,da = A\,a^{-3.5}\,da$ (MRN 1977)
   - Upper limit ~ 0.1μm (which determines total grain mass)



3. **Ice-mantled grains in Cloud Cores**
   - **Is their size distribution MRN? (This work)**
   - Chemical reaction at grain surface



4. **Dust aggregates in Protoplanetary Disks**
   Smaller initial grains make the aggregates more sticky!

Growth Equation of Ice-mantled grains

- **Assumption: Temperature is low enough to neglect evaporation.**
- **Growth Equation of Ice-mantled grains** (*a* : grain radius)

$$\frac{da}{dt} = \beta n_{\mathrm{H2O}} v_{\mathrm{H2O}} \frac{m_{\mathrm{H2O}}}{\rho_{\mathrm{ice}}}$$

n_{H2O} : number density of H_2O mol.
m_{H2O} : molecular mass of H_2O
v_{H2O} : thermal velocity of H_2O
ρ_{ice} : density of ice
β : sticking probability

Thickness of ice-mantle is NOT dependent on size of silicate cores!

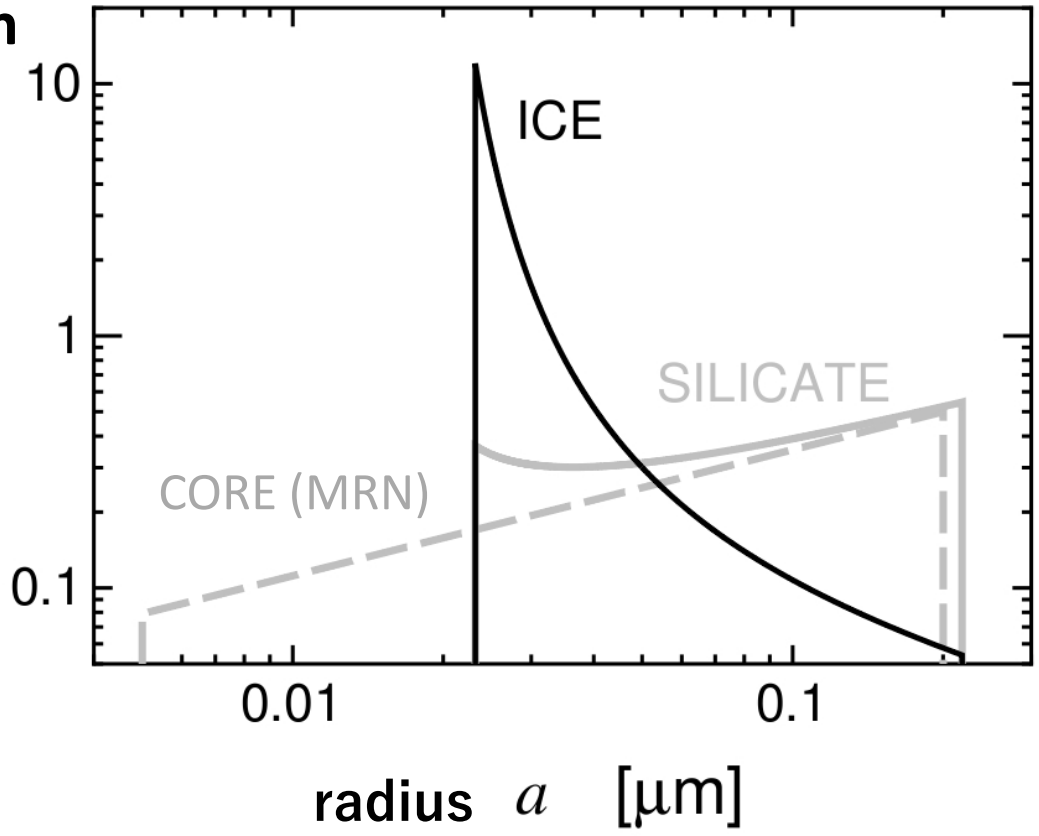
- **LARGE** silicate cores have relatively **THIN** ice-mantle.
- **SMALL** silicate cores have relatively **THICK** ice-mantle.

Size Distribution of Ice-mantled Grains

distribution of MASS

$n(a)\ m\ a$

$[\rho_{core}]$



Size distribution function

$n(a)$ [number/cm^4]

Parameters

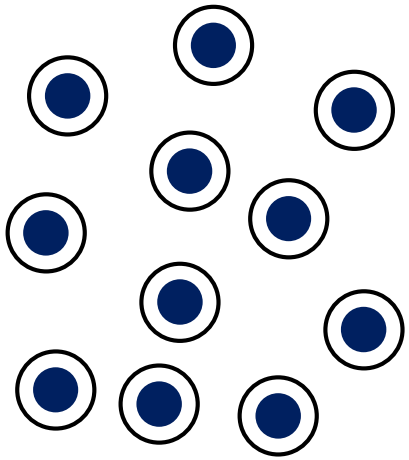
- lower limit of cores
  $a_{min,core}$ = 5nm
- abundance ratio
  ice/silicate =2
- ratio of the density
  ice/silicate =1/3

Ice is condensed mainly on small silicate cores!

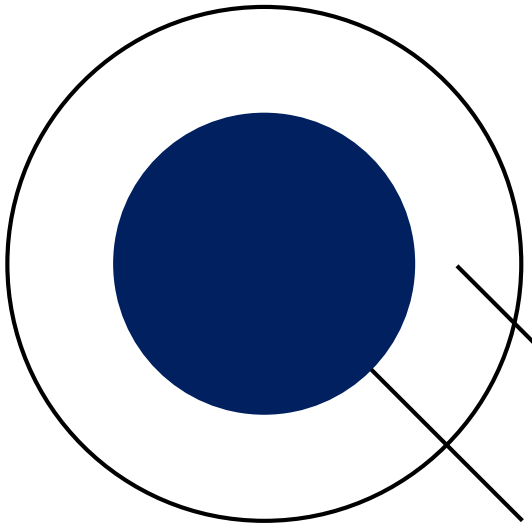
Summary on Ice-mantled Dust Model

Simple model

Similarity growth



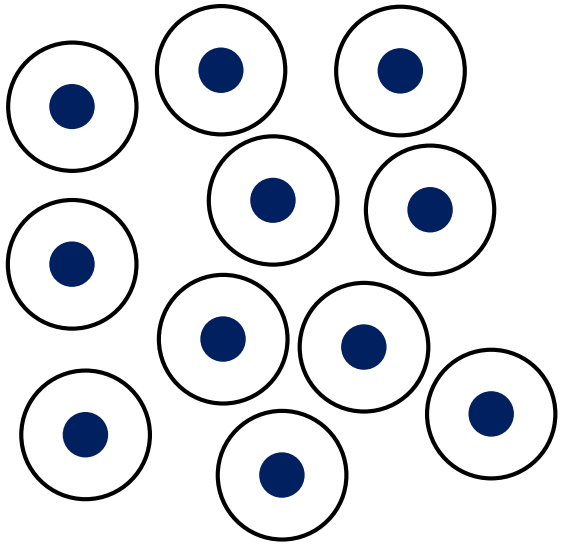
~0.02μm

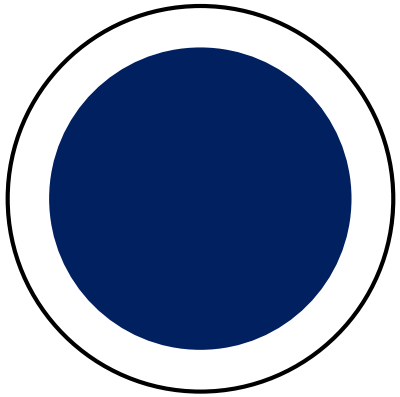


~0.1μm

This Work

Ice-mantle grows mainly on small cores.





Numerical Simulation of dust collisions

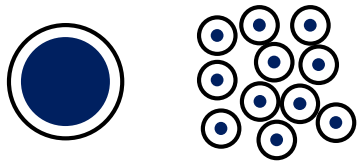
- fragmentation velocity $v_{\mathrm{crit}} \propto a_0^{-5/6}$ (a_0 : monomer radius)

Wada+09,13

- Monomer size distribution used in this simulation

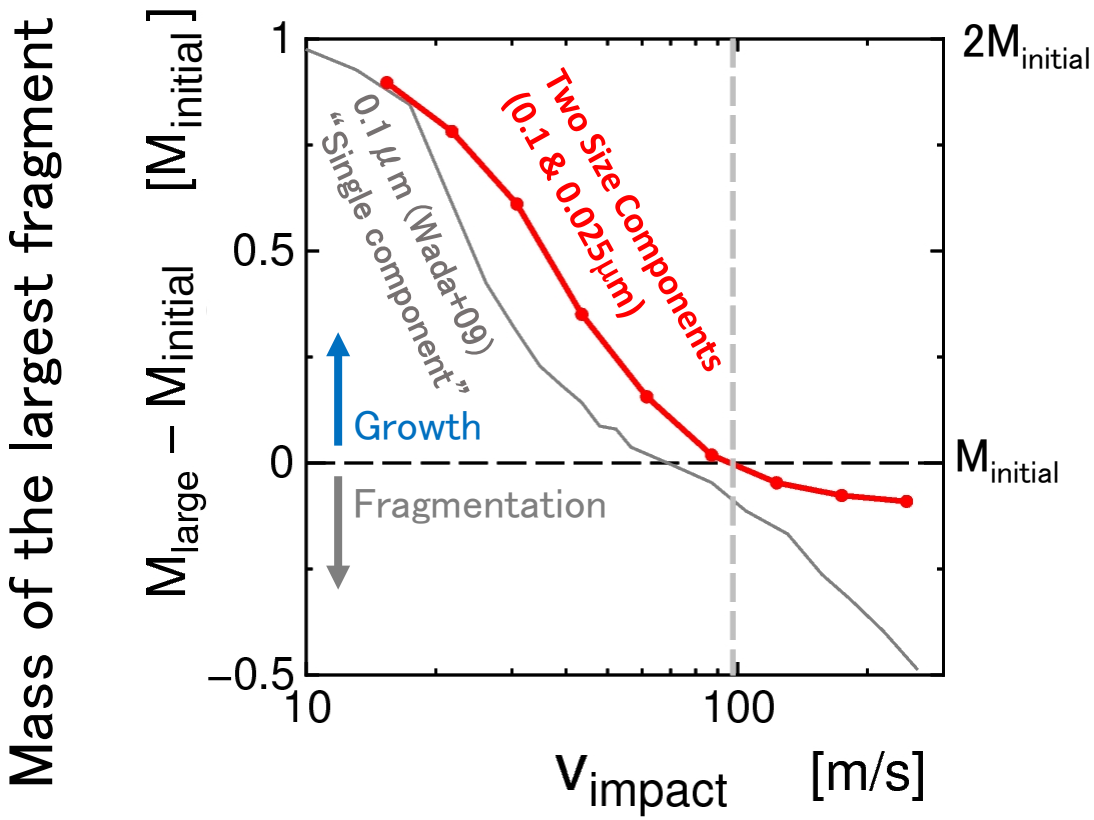
Two size components

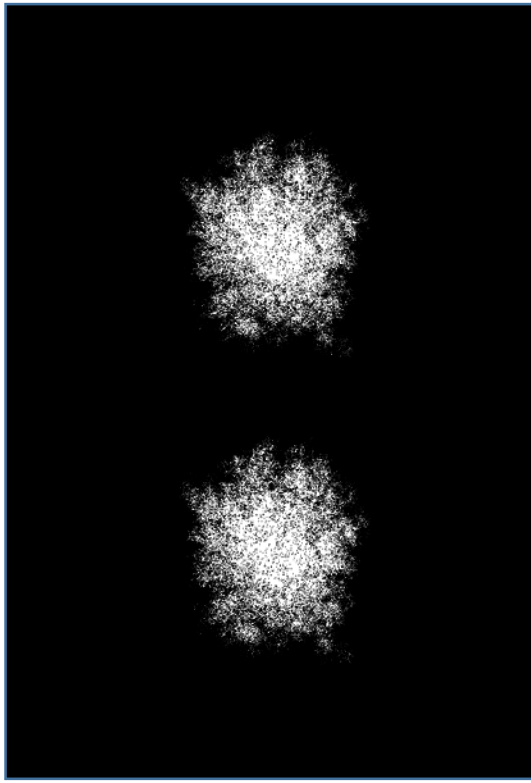
	radius	total mass ratio
large monomers	0.1 μ m	1
small monomers	0.025 μ m	2



- **Number of monomers in two aggregates = 1.5x10^6**
- **200 runs for various collision speeds and impact parameters**

Numerical Simulation of dust collisions

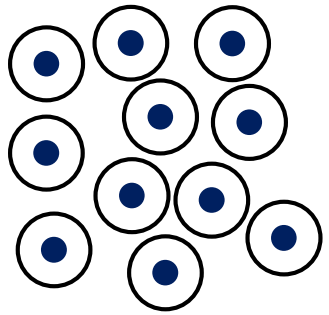




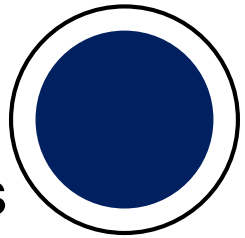
Small ice-mantled grains make
dust aggregates more sticky!

Summary

1. Small ice-mantle grains are formed (~0.02μm)
   - Ice is condensed mainly at small silicate cores.
   - Grain size distribution is “two size components”.
   - A great increase in total grain surface area



2. Numerical simulation of aggregate collisions with two size components of ice-mantled grains



Small ice-mantled grains makes dust aggregates more sticky!

Future work:

Effect on the extinction curves of the inter-stellar dust grains