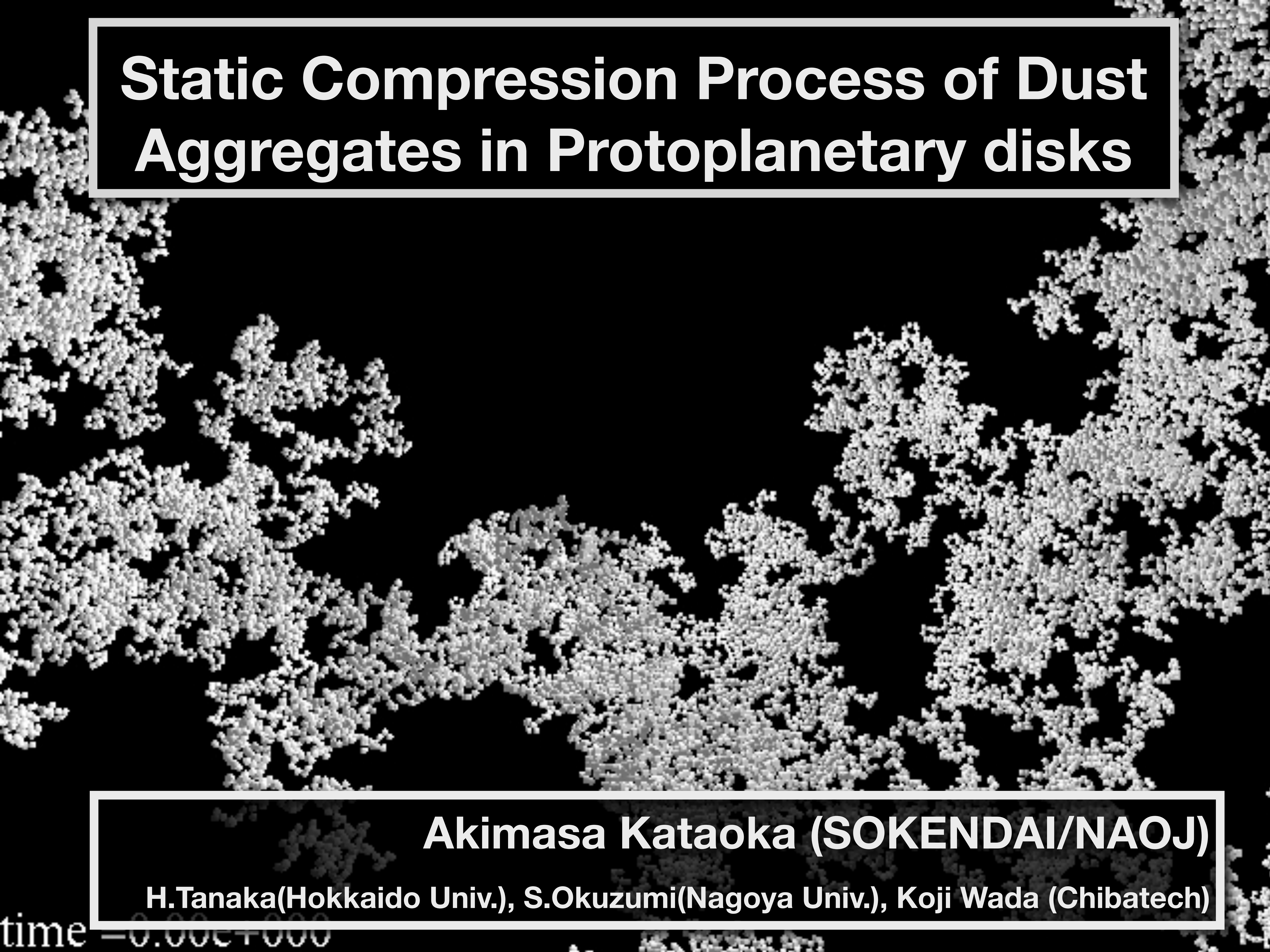
Static Compression Process of Dust Aggregates in Protoplanetary disks



Akimasa Kataoka (SOKENDAI/NAOJ)

H.Tanaka(Hokkaido Univ.), S.Okuzumi(Nagoya Univ.), Koji Wada (Chibatech)

Planet Formation Theory

Dust Coagulation

Jump?
(Self-gravity?)

Runaway
growth

Oligarchic
growth

Brownian
motion

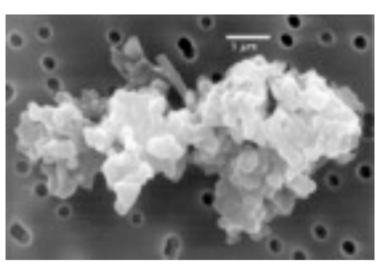
Differential
drift, settling,
&turbulence

0.1μm

1m

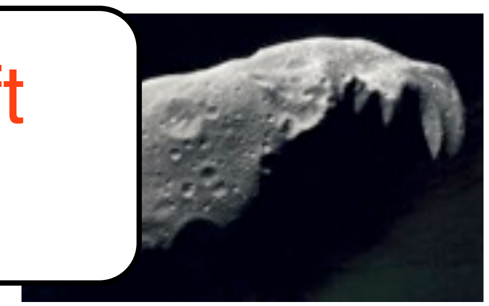
1km

$10^{2\text{-}4}$km

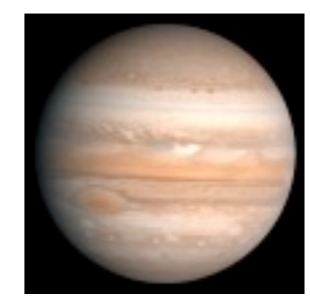


Interstellar Medium

Radial drift
barrier

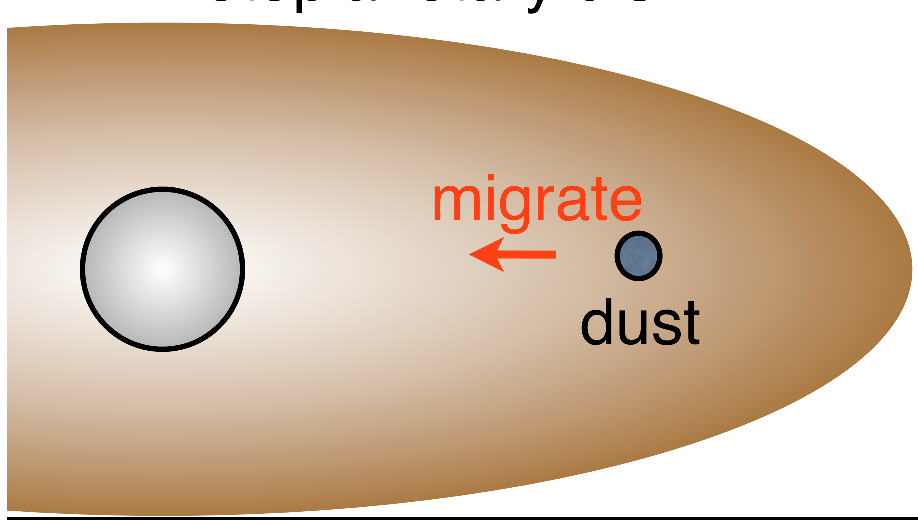


“Planetesimals”



Planets

Protoplanetary disk



Dust structure (size and density) is important!

Porosity

constant density

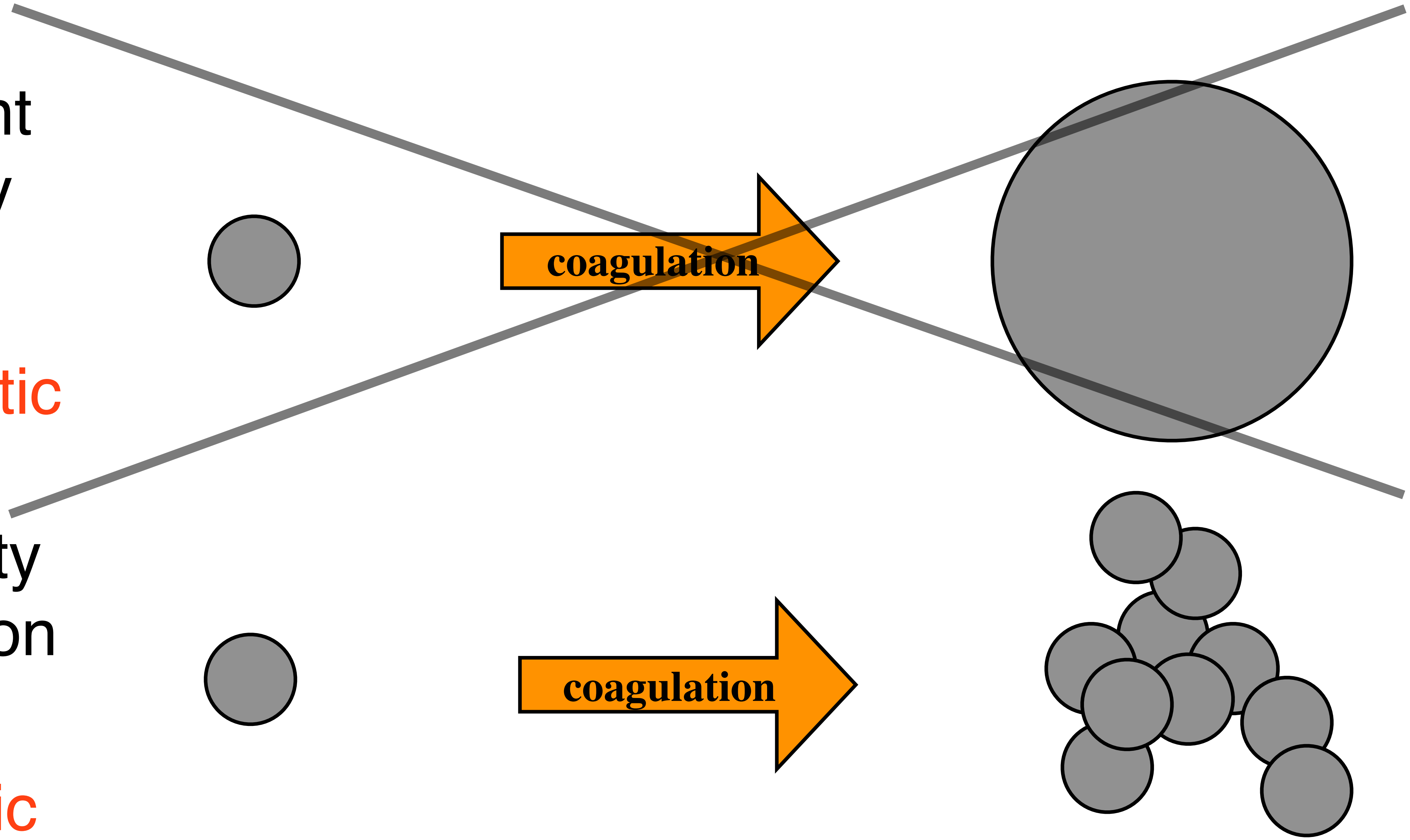
↓

unrealistic

porosity evolution

↓

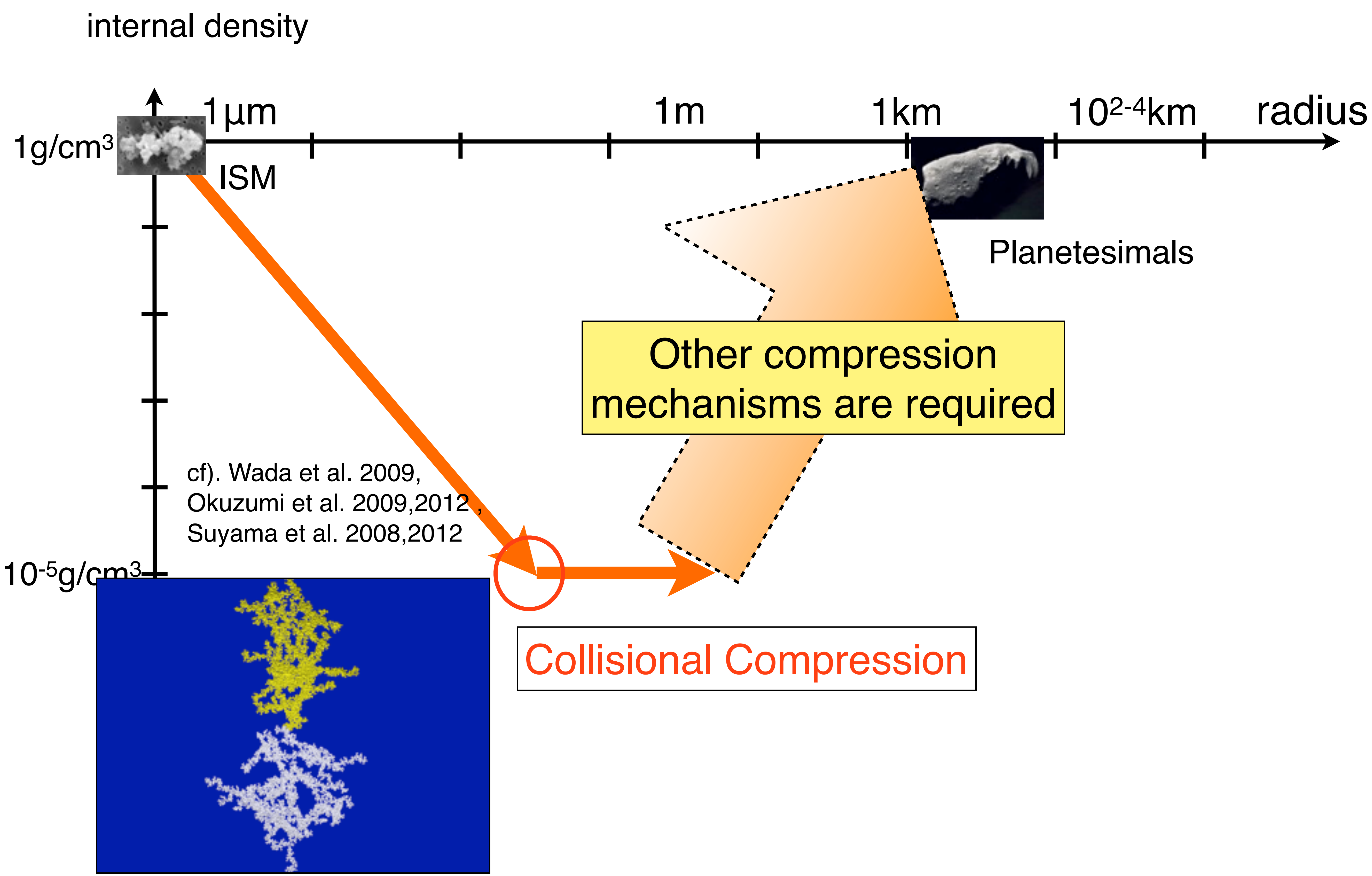
realistic



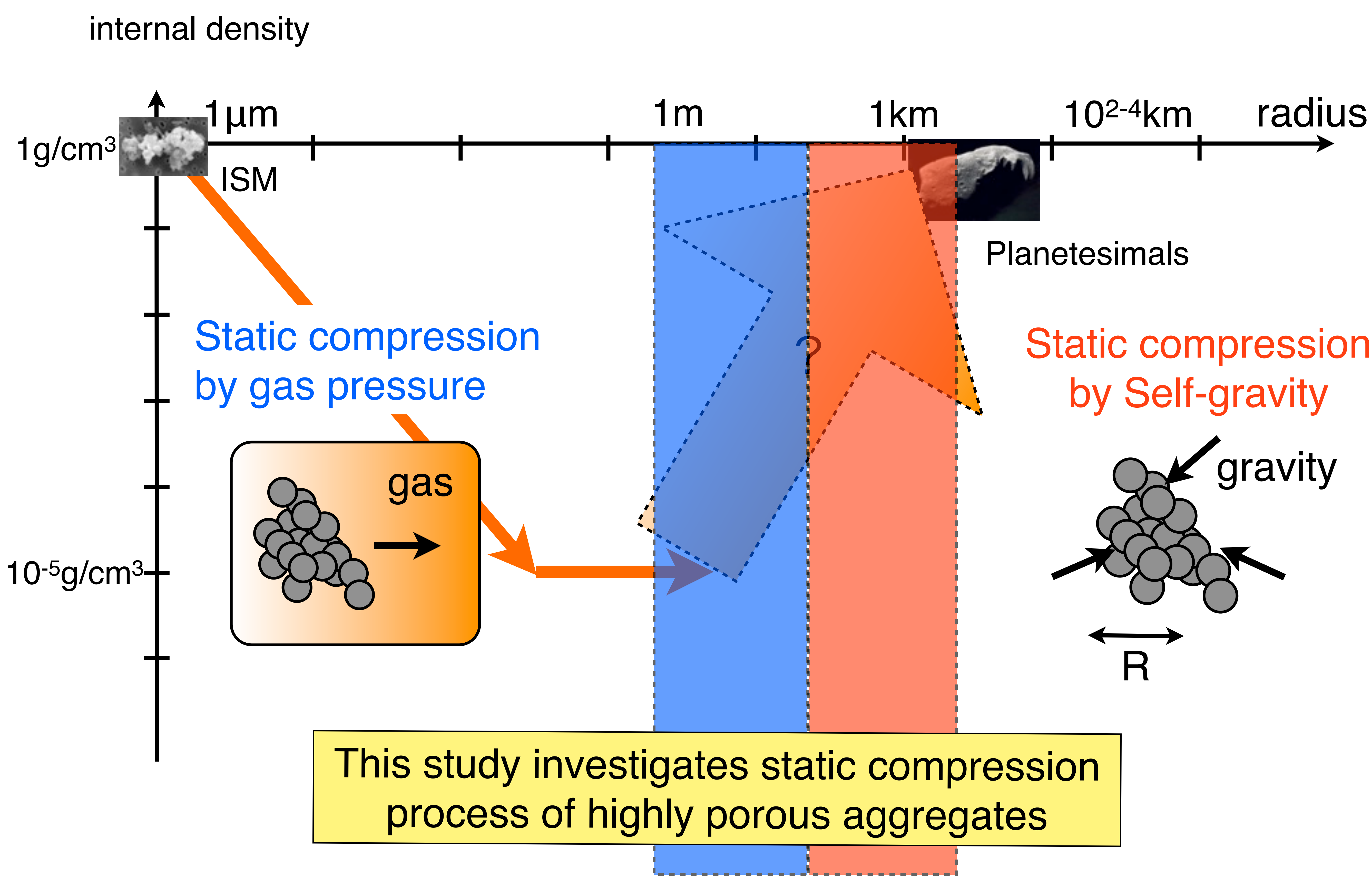
Recent studies have shown that dust grains grow to highly porous aggregates

cf). Wada et al. 2007, 2009, 2011, Suyama et al. 2008,2012, Okuzumi et al. 2009,2012

Planetesimal formation with fluffy aggregates

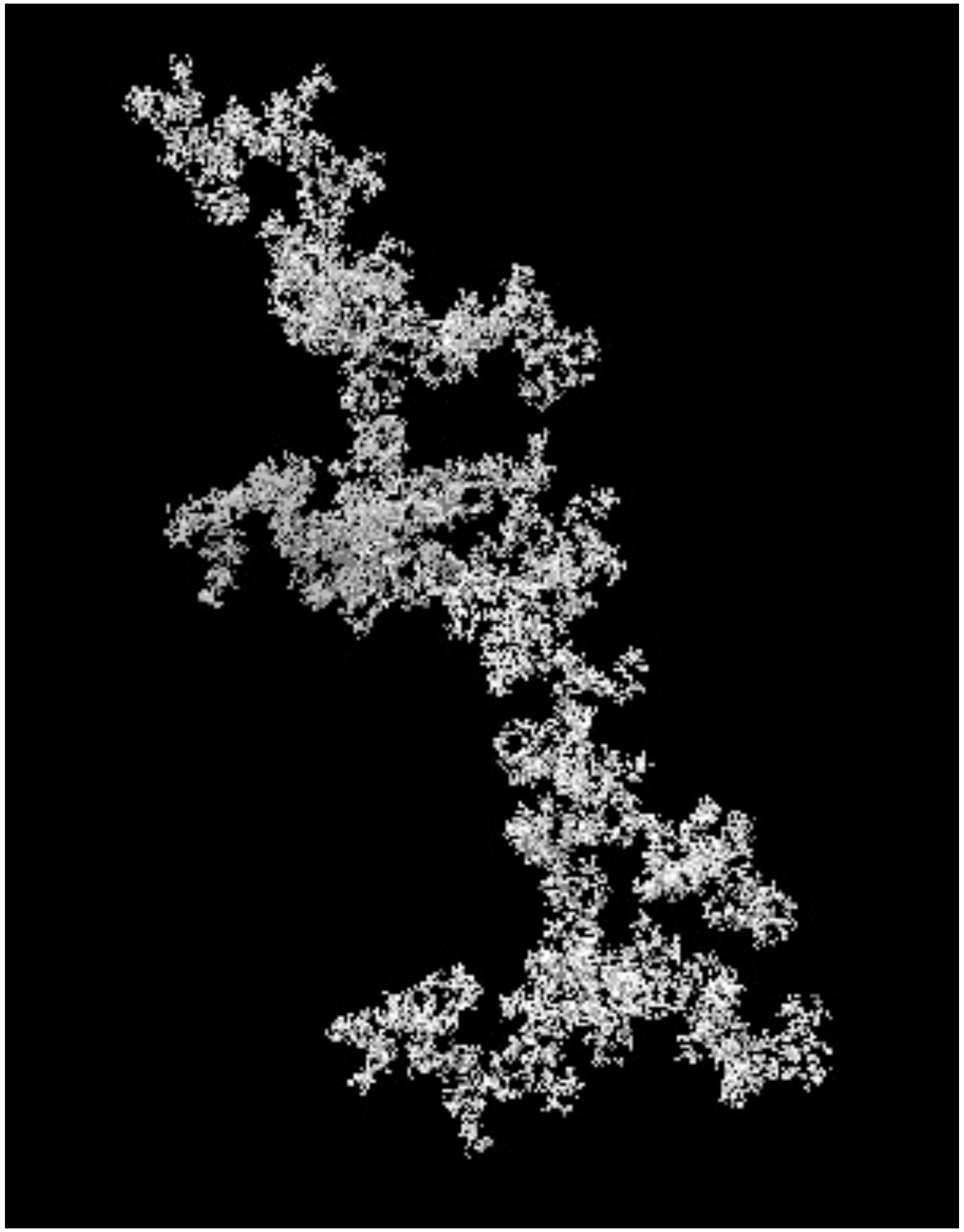


Aim of this work

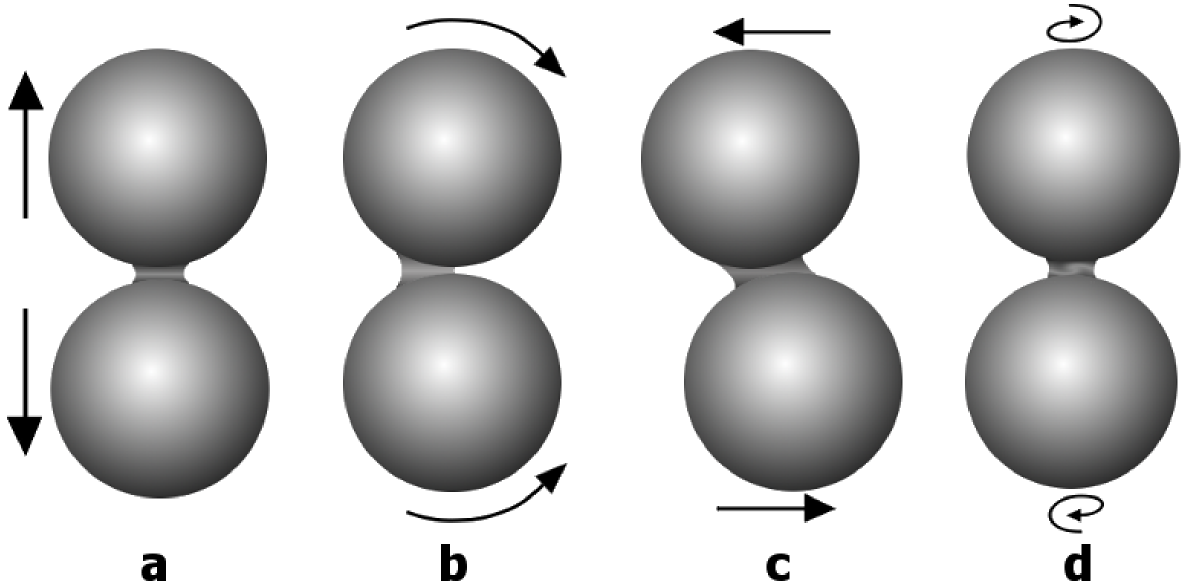


This study investigates static compression process of highly porous aggregates

Simulation model



Particle-particle interaction

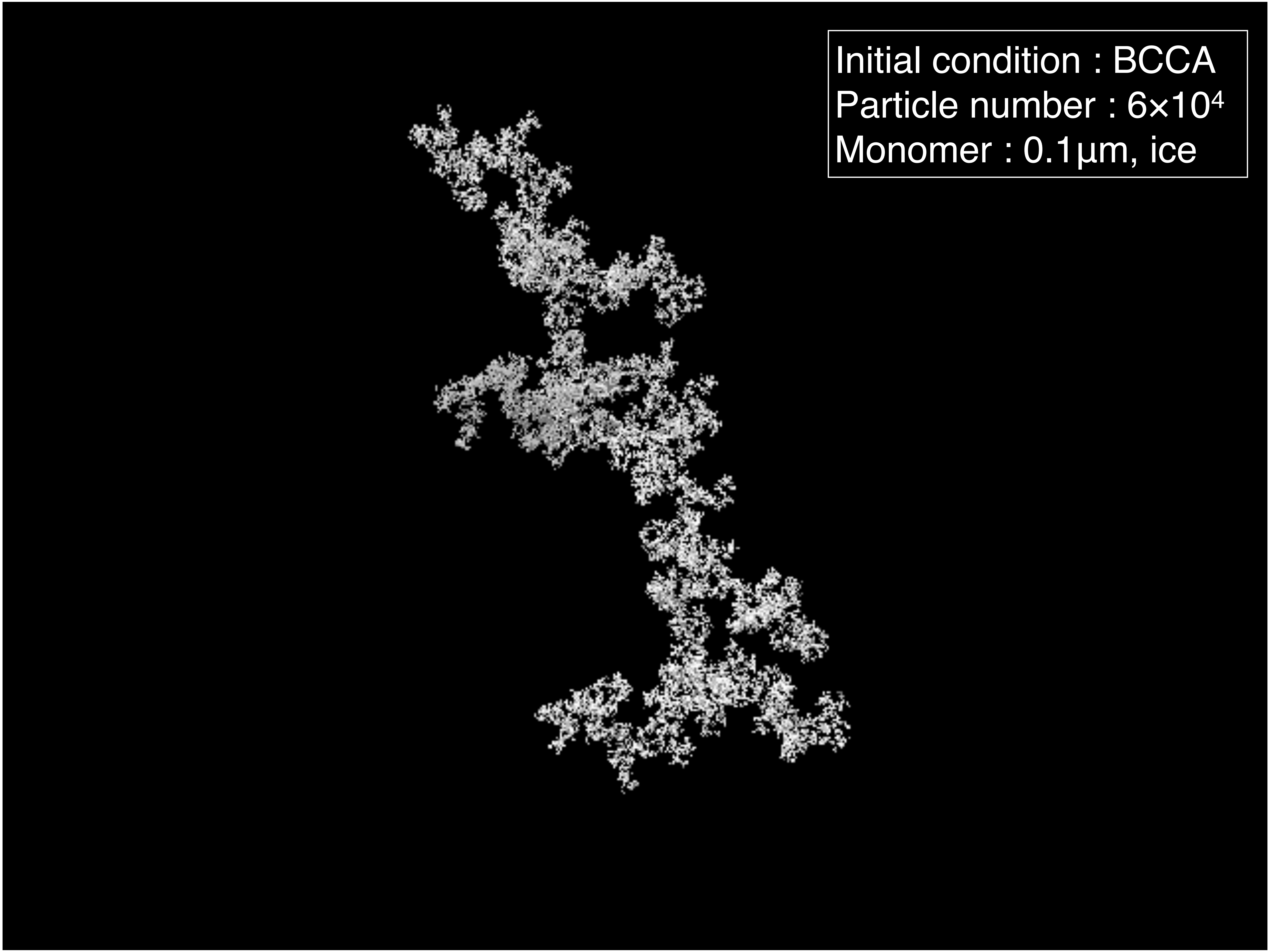


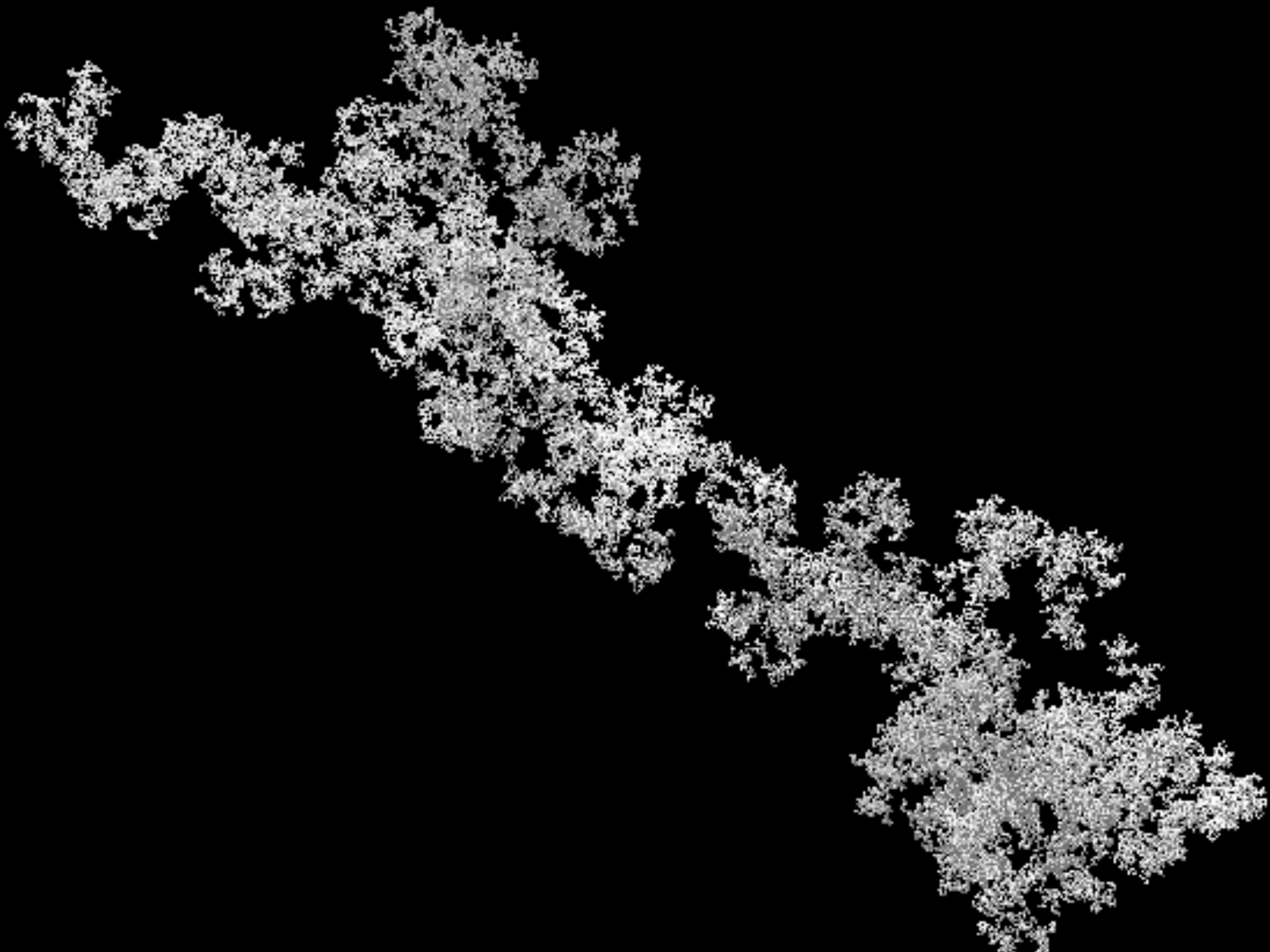
cf).Seizinger et al. 2012

(a) Repulsion / Adhesion
(b) Rolling
(c) Sliding
(d) Twisting

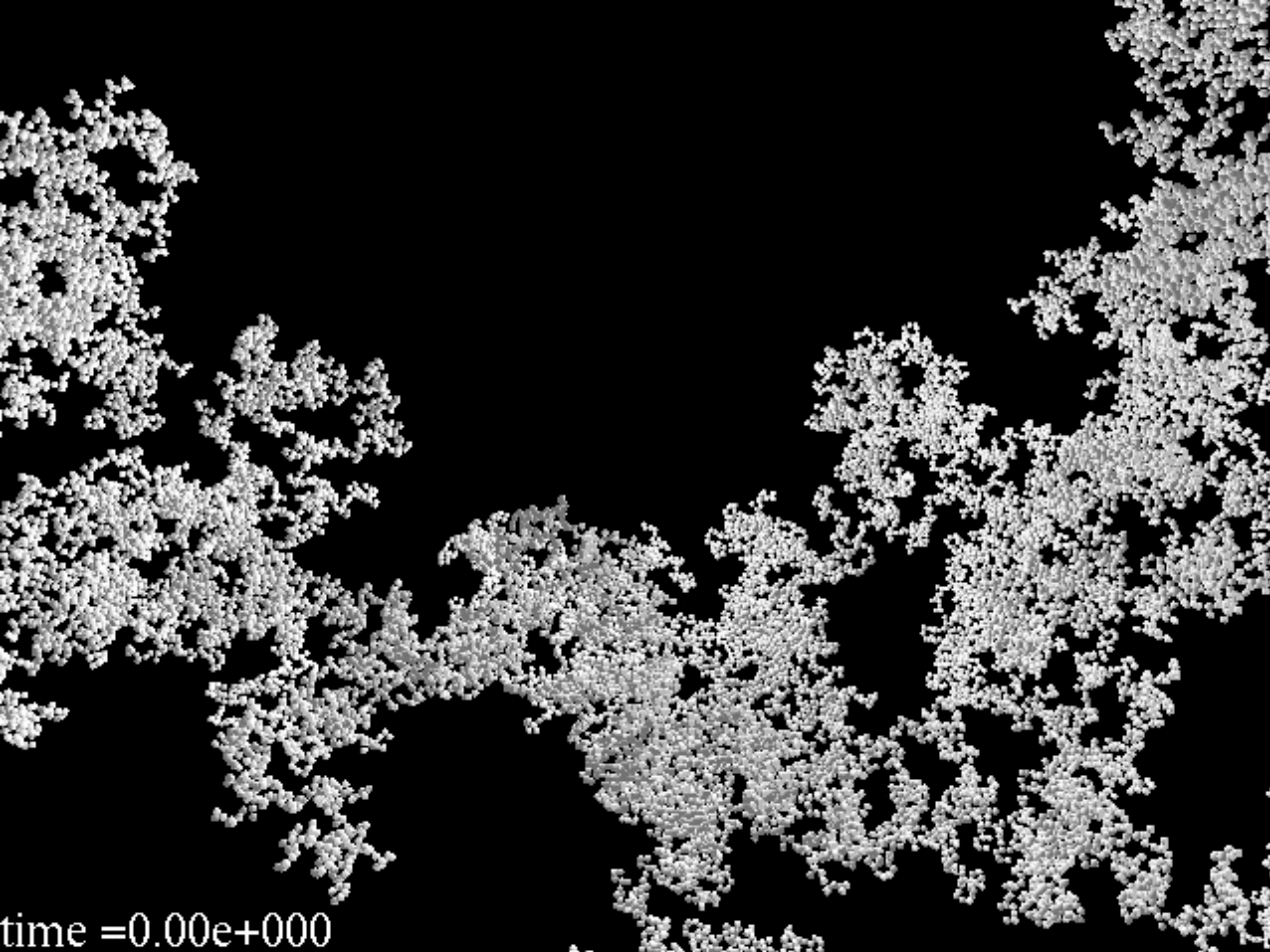
cf).Dominik & Tielens 1997, Wada et al. 2007

We use N-body simulation to investigate compression process


Initial condition : BCCA
Particle number : 6×10^4
Monomer : 0.1μm, ice

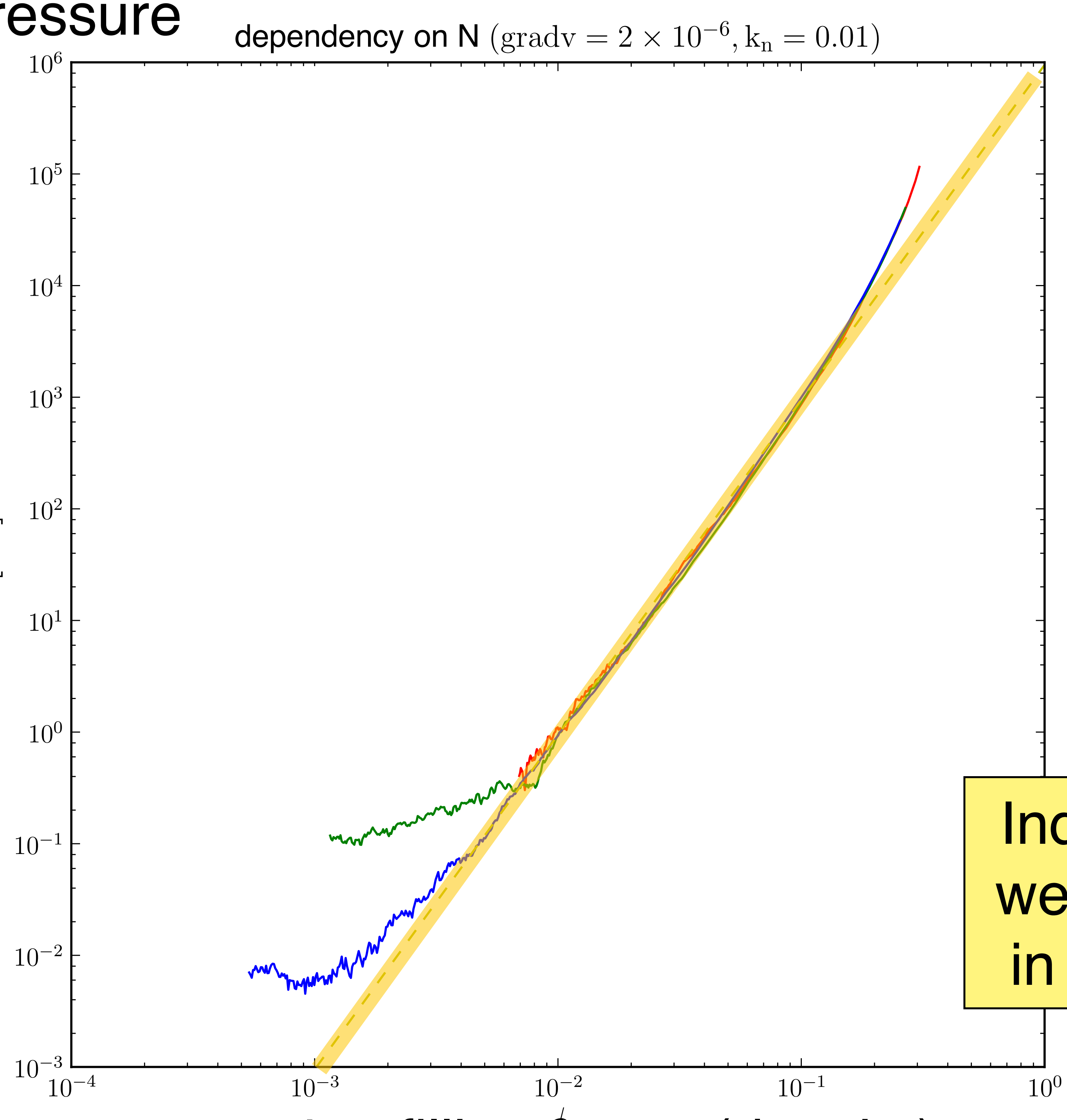


time = 0.000000


time =0.00e+000

Result

pressure

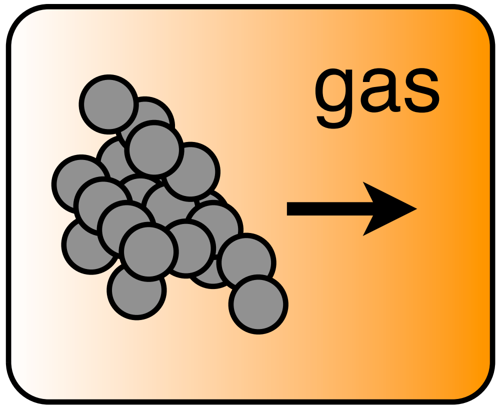


Φ = filling factor (density)

Independent from parameters, we derive the equation of state in static compression process

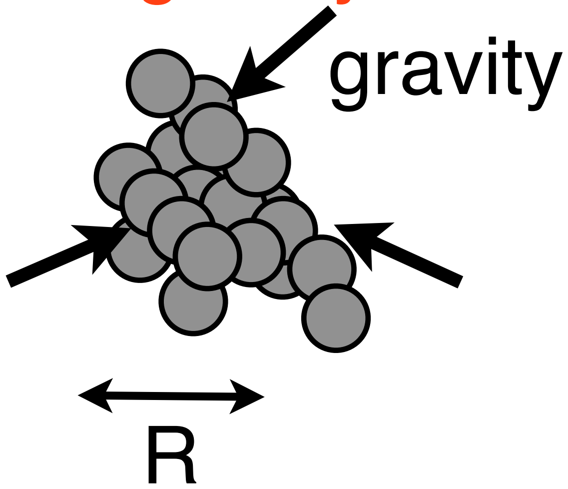
Pressure in protoplanetary disks

Gas pressure



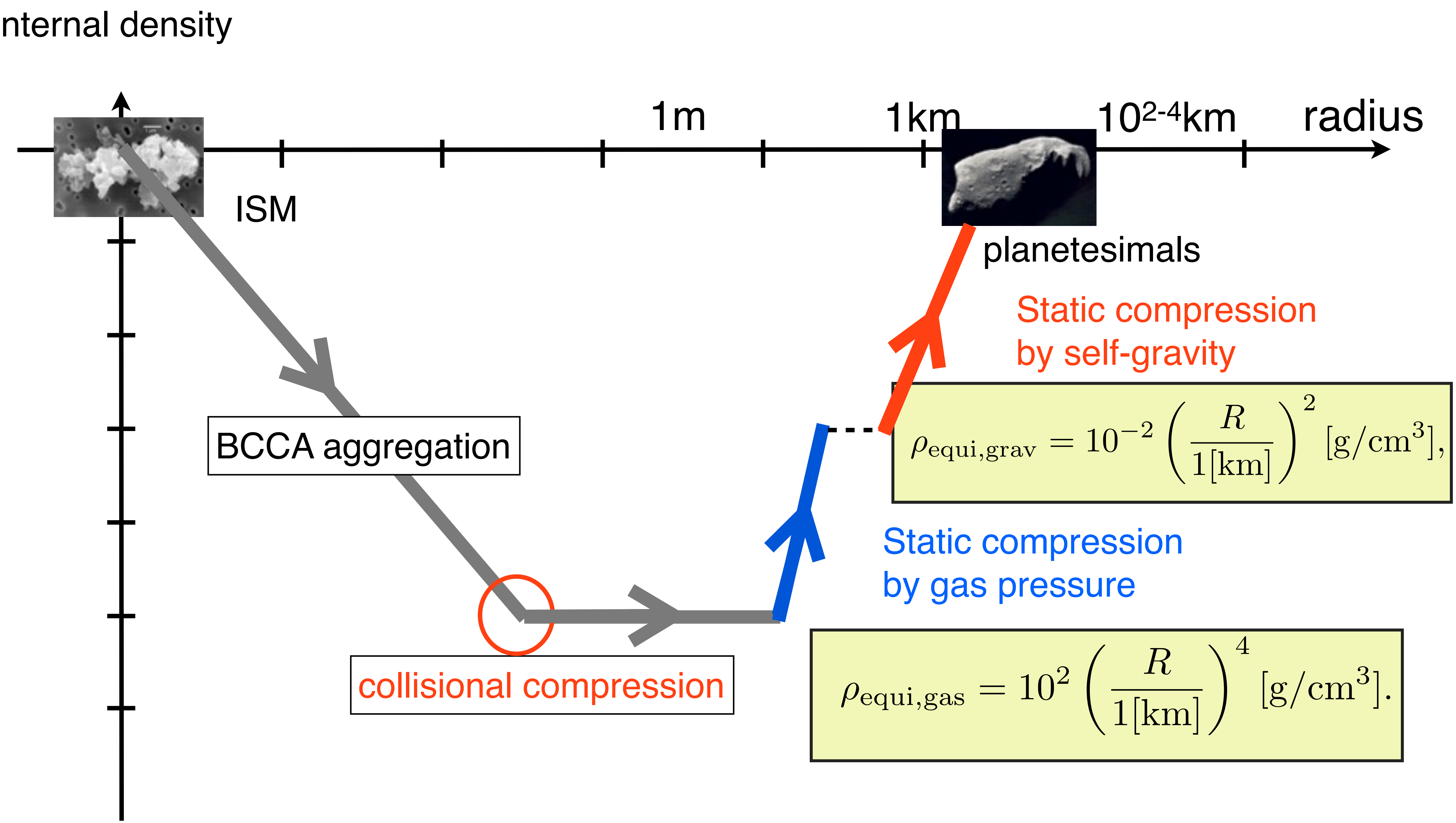
$$\rho_{\mathrm{equi,gas}} = 10^{2}\left(\frac{R}{1[\mathrm{km}]}\right)^{4}[\mathrm{g/cm^3}].$$

Self-gravity



$$\rho_{\mathrm{equi,grav}} = 10^{-2}\left(\frac{R}{1[\mathrm{km}]}\right)^{2}[\mathrm{g/cm^3}],$$

Planetesimal formation via fluffy aggregates



$$\rho_{\mathrm{equi,grav}} = 10^{-2}\left(\frac{R}{1[\mathrm{km}]}\right)^{2} [\mathrm{g/cm^3}],$$

$$\rho_{\mathrm{equi,gas}} = 10^{2}\left(\frac{R}{1[\mathrm{km}]}\right)^{4} [\mathrm{g/cm^3}].$$

Successful pathway of planetesimal formation

Conclusion

- We investigate the growth process from highly porous aggregates to planetesimals.
  - We perform N-body simulations with particle-particle interaction.
  - We derive the equation of state of dust aggregates in static compression process.
  - Using the equation of state, we showed the successful pathway from highly porous aggregates to planetesimals in protoplanetary disks.