

The outcome of protoplanetary dust growth: pebbles, boulders or planetesimals?

Andras Zsom

MPIA, Heidelberg

Collaborators:

Chris Ormel, MPIA

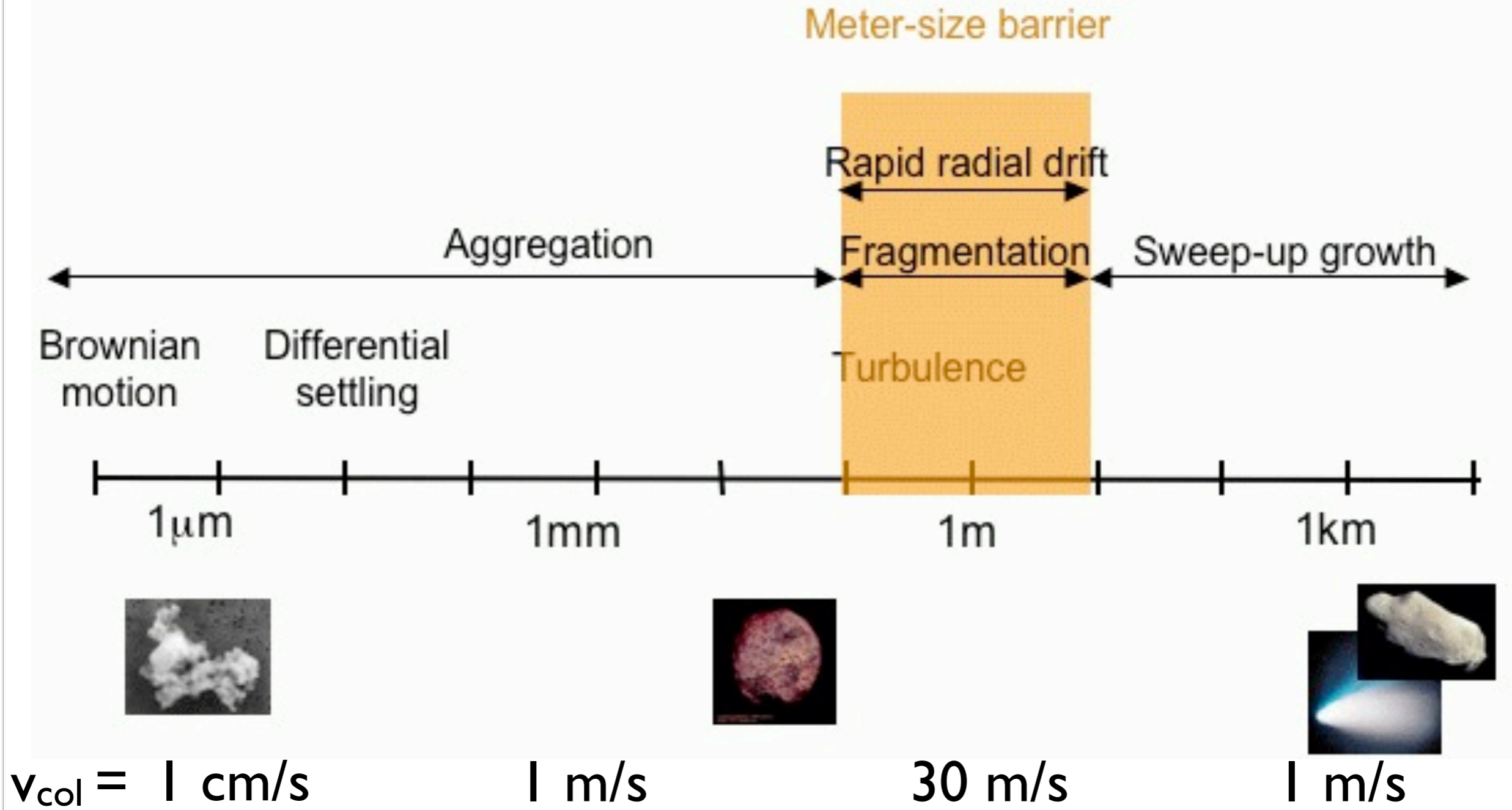
Carsten Güttler, Braunschweig

Jürgen Blum, Braunschweig

Cornelis Dullemond, MPIA

INTRODUCTION

Growth from 'dust' to planetary building blocks



OUR GOAL

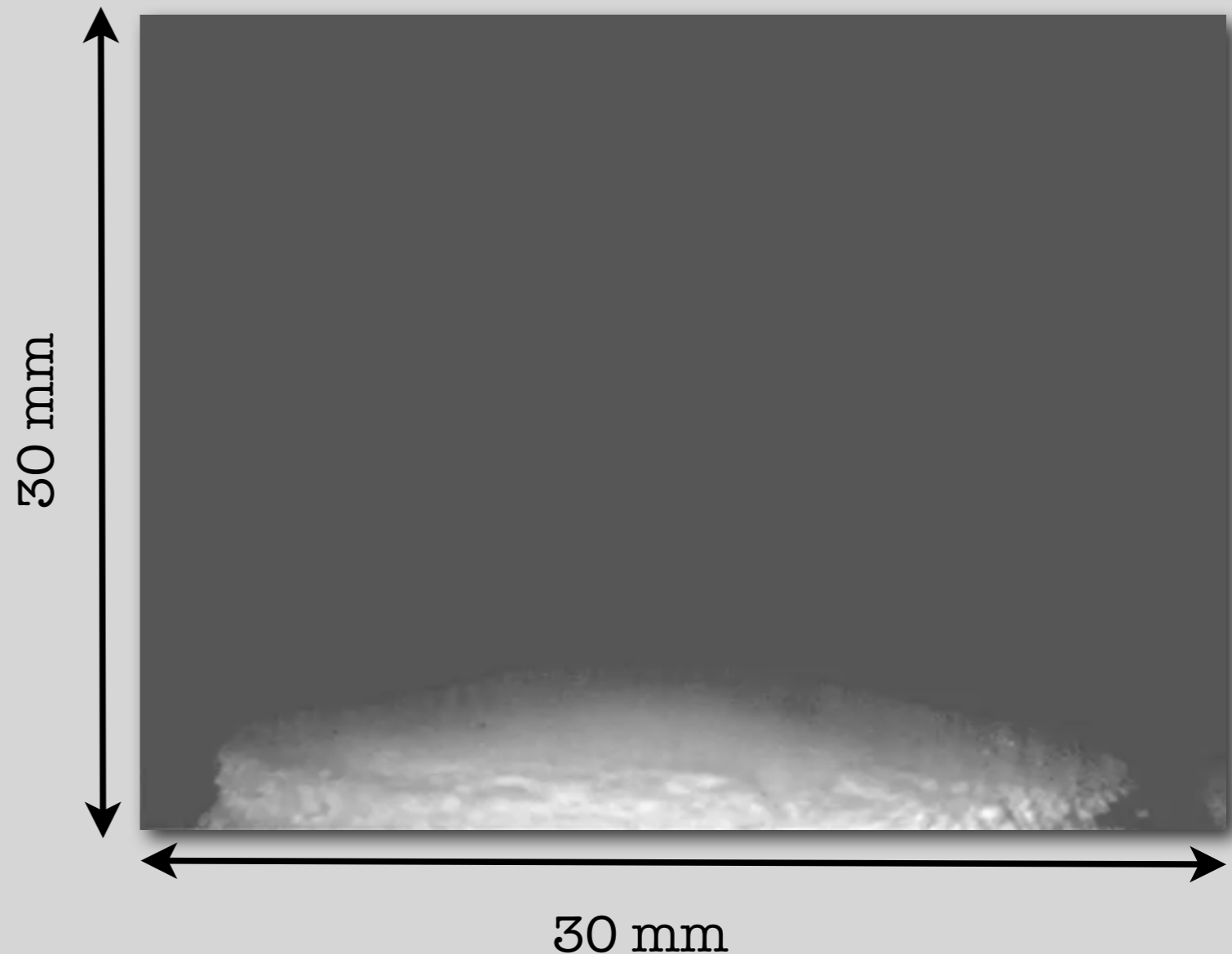
Understand better the initial growth,
coagulation process:

1. Use all available laboratory experiments for silicates
2. Construct a collision model
3. Implement this into a numerical code

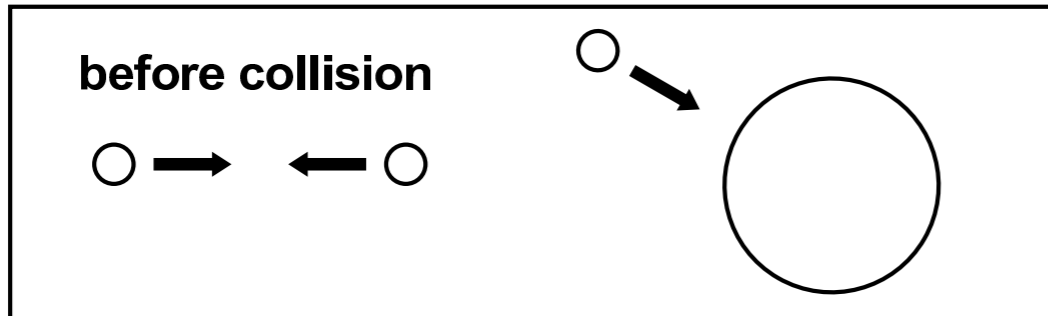
LAB EXPERIMENTS

An example (1 out of 19):

- dust cake + projectiles
- $v_{\text{col}} = 1 \text{ m/s}$
- slow motion movie
- free-fall conditions in the Bremen drop tower
- penetration (1 out of 9 collision types)
- Langkowski et al. 2008



COLLISION TYPES



S1 (*hit & stick*)



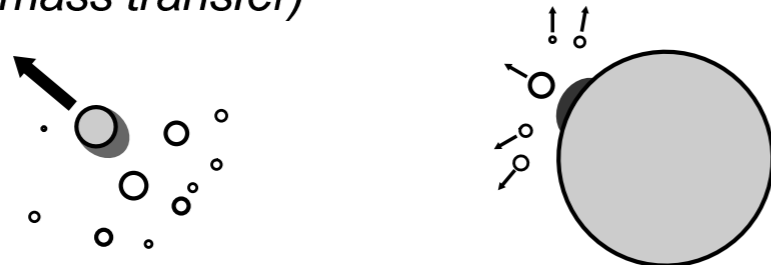
S2 (*sticking through surface effects*)



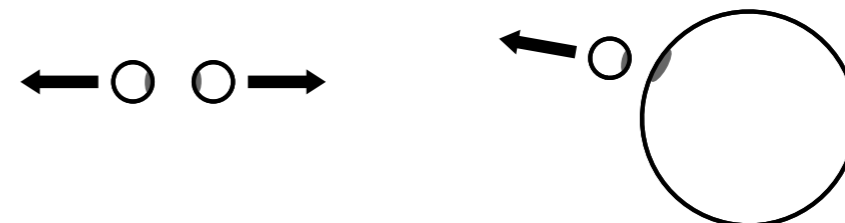
S3 (*sticking by penetration*)



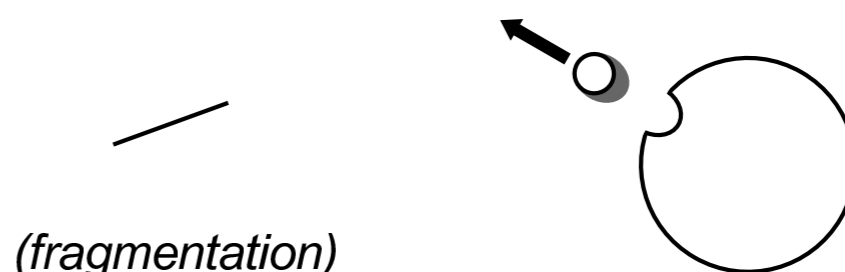
S4 (*mass transfer*)



B1 (*bouncing with compaction*)



B2 (*bouncing with mass transfer*)



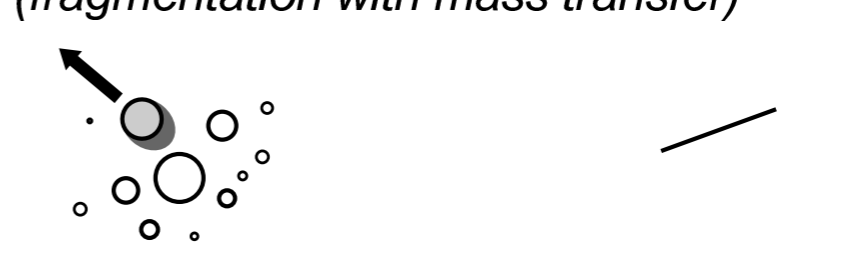
F1 (*fragmentation*)



F2 (*erosion*)



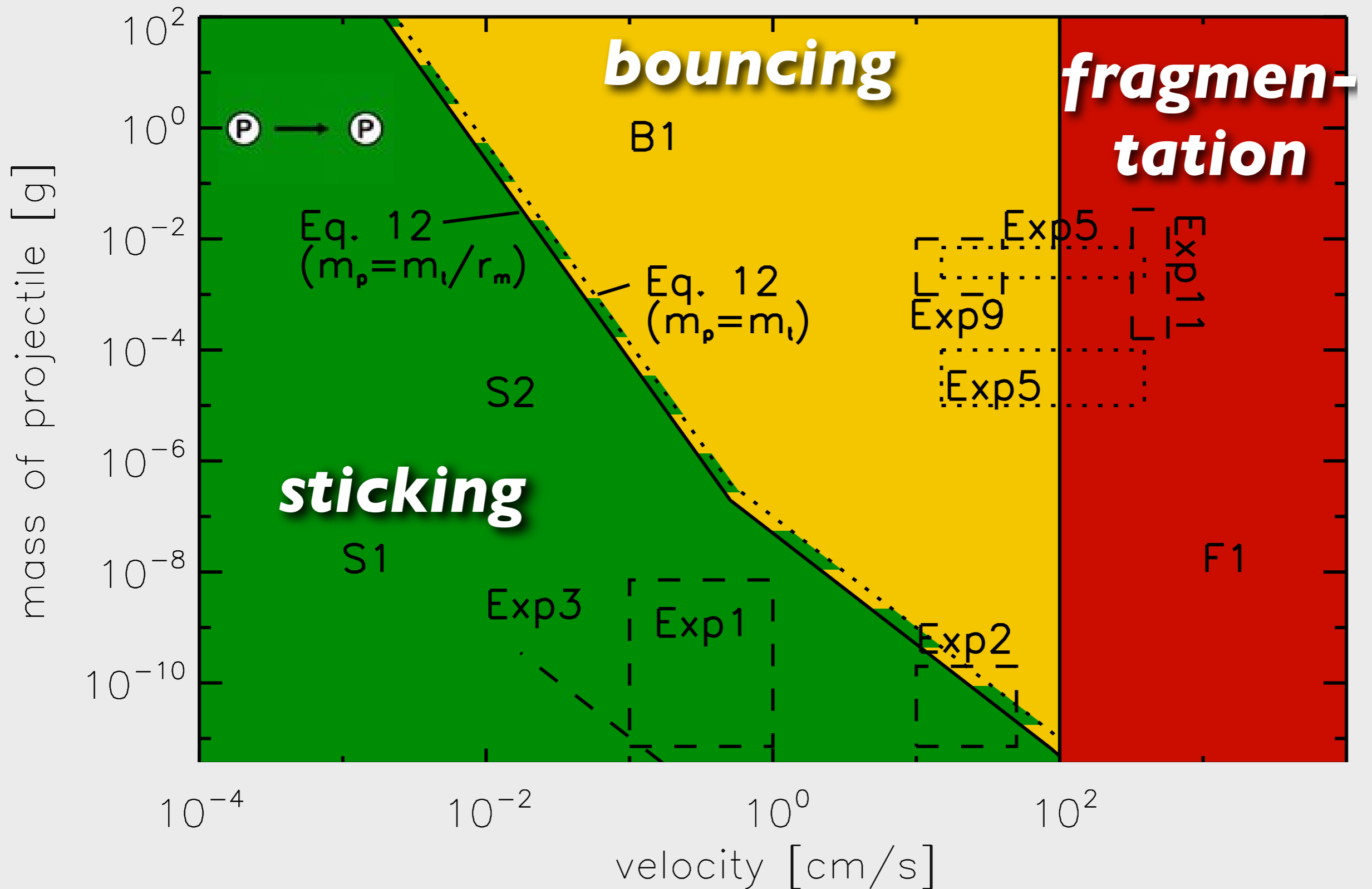
F3 (*fragmentation with mass transfer*)



THE COLLISION MODEL

- Güttler et al, accepted in A&A
 - 19 experiments
 - 9 different collision types
 - the experiments do not cover the whole parameter space => extrapolation
 - the parameters are:
 - masses
 - porosities
 - collision velocity

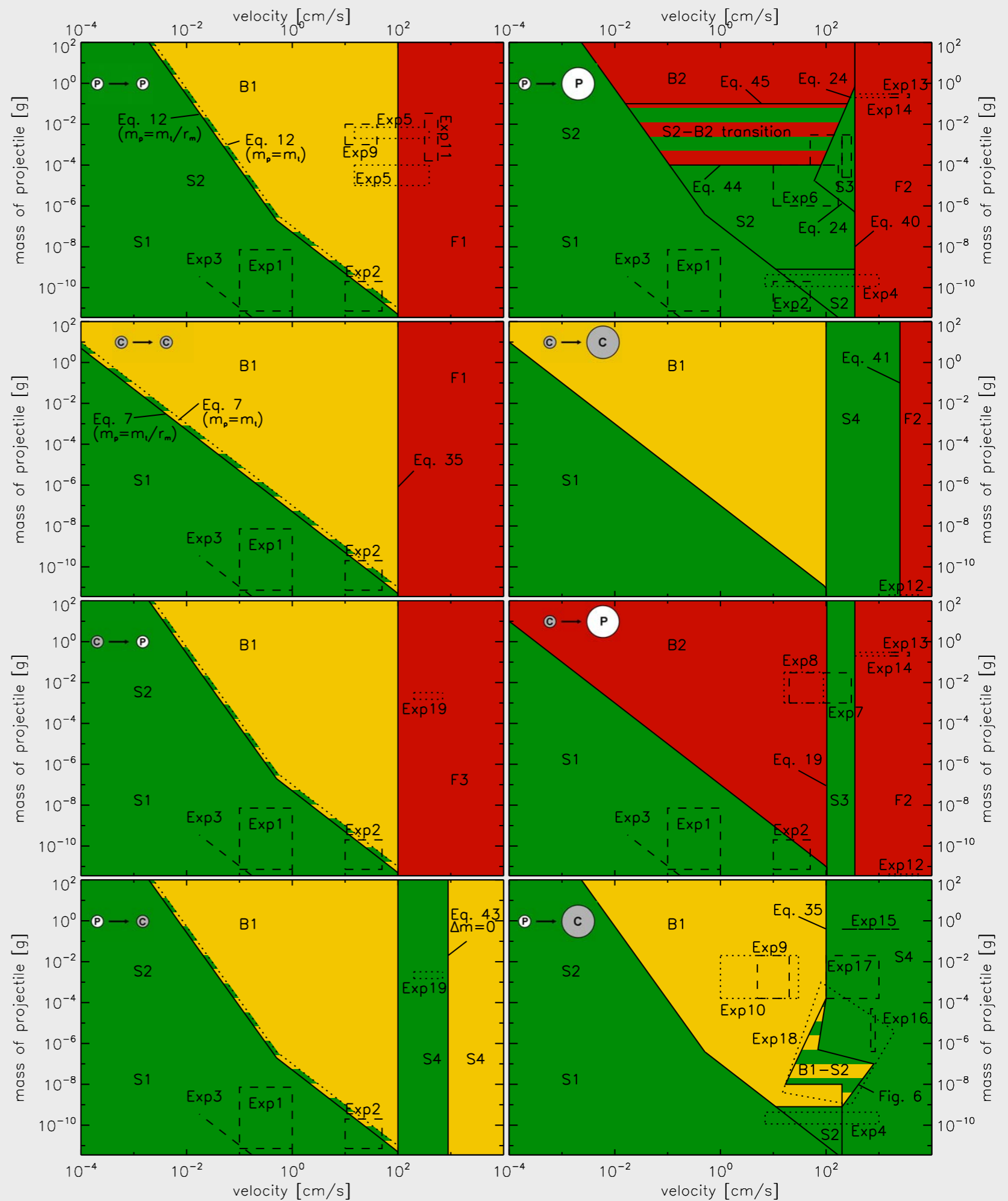
The parameter space



The parameter space

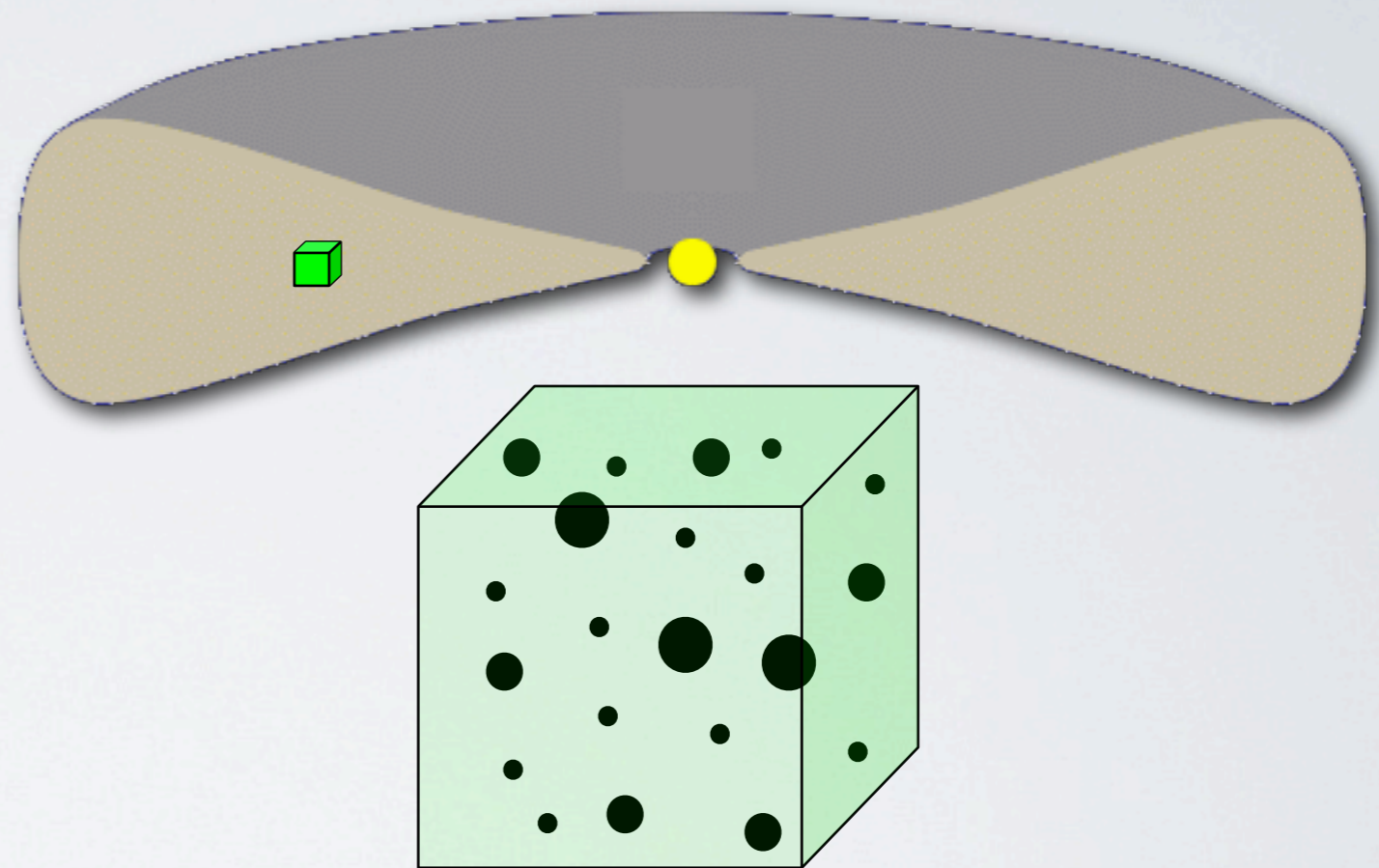
Güttler et al,
accepted in A&A

mass increase
bouncing
mass decrease



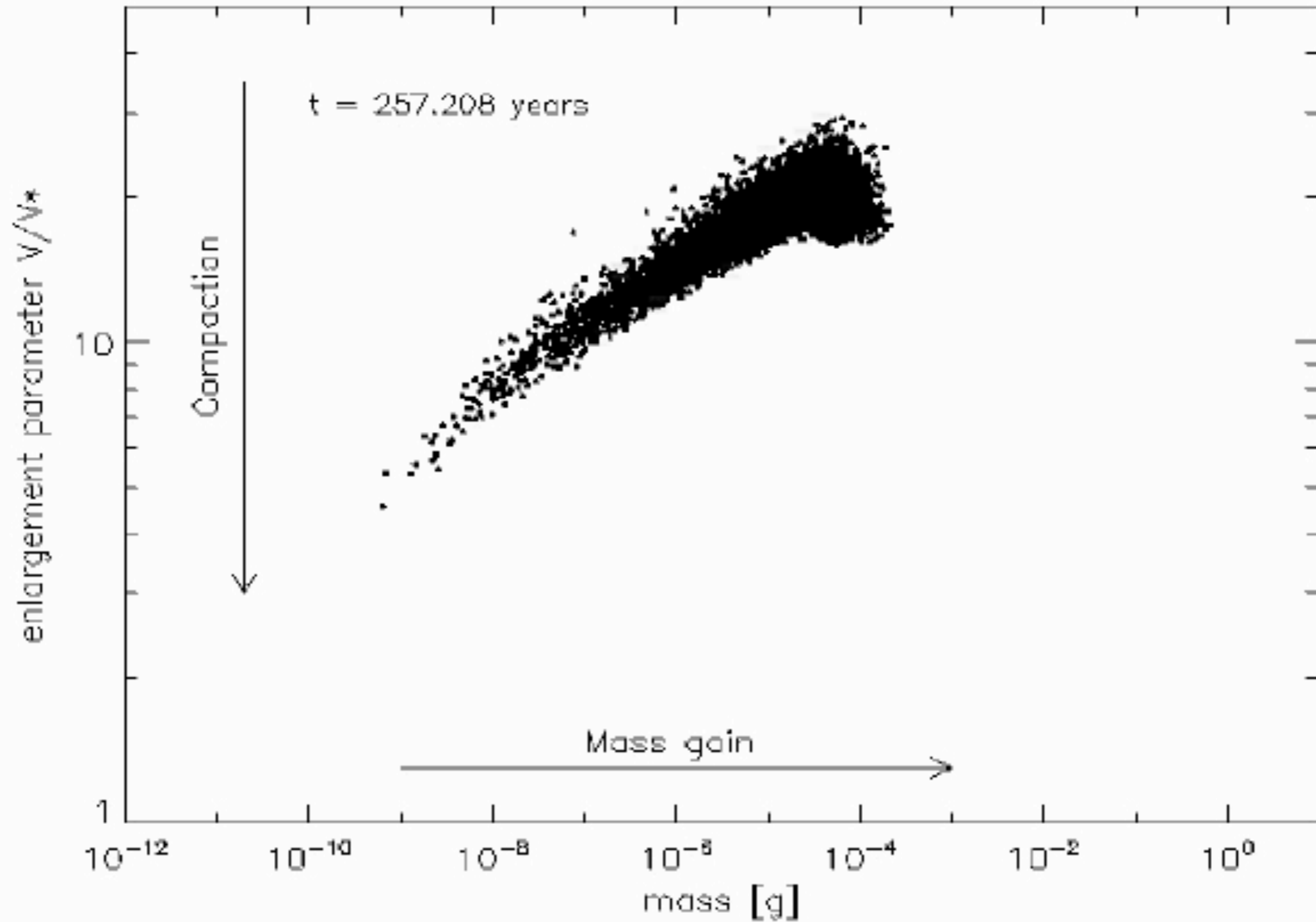
SIMULATIONS

- Local box approach
- 1 AU at the midplane of the MMSN disk
- $\alpha = 10^{-4}$



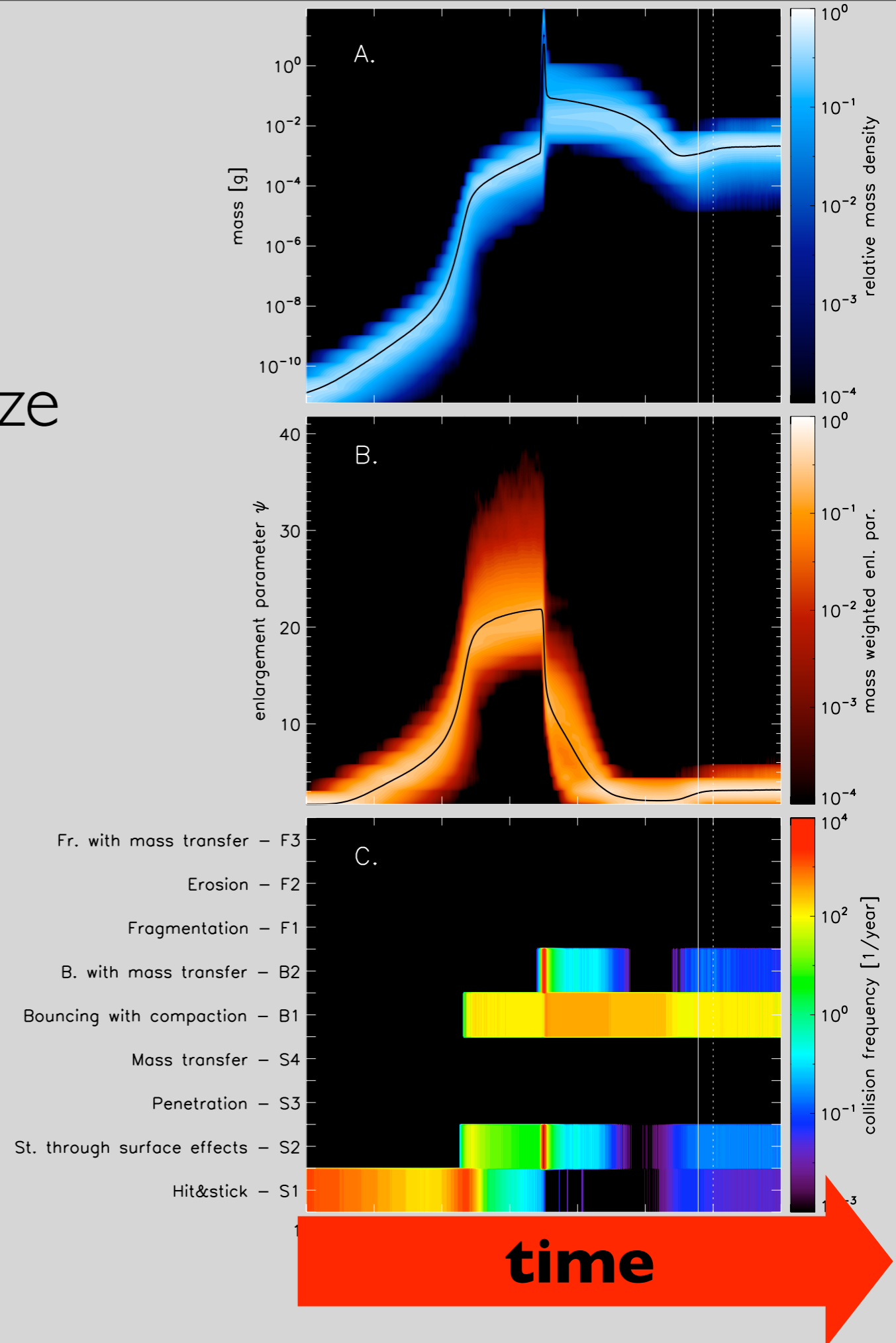
Results

Zsom et al, submitted to A&A



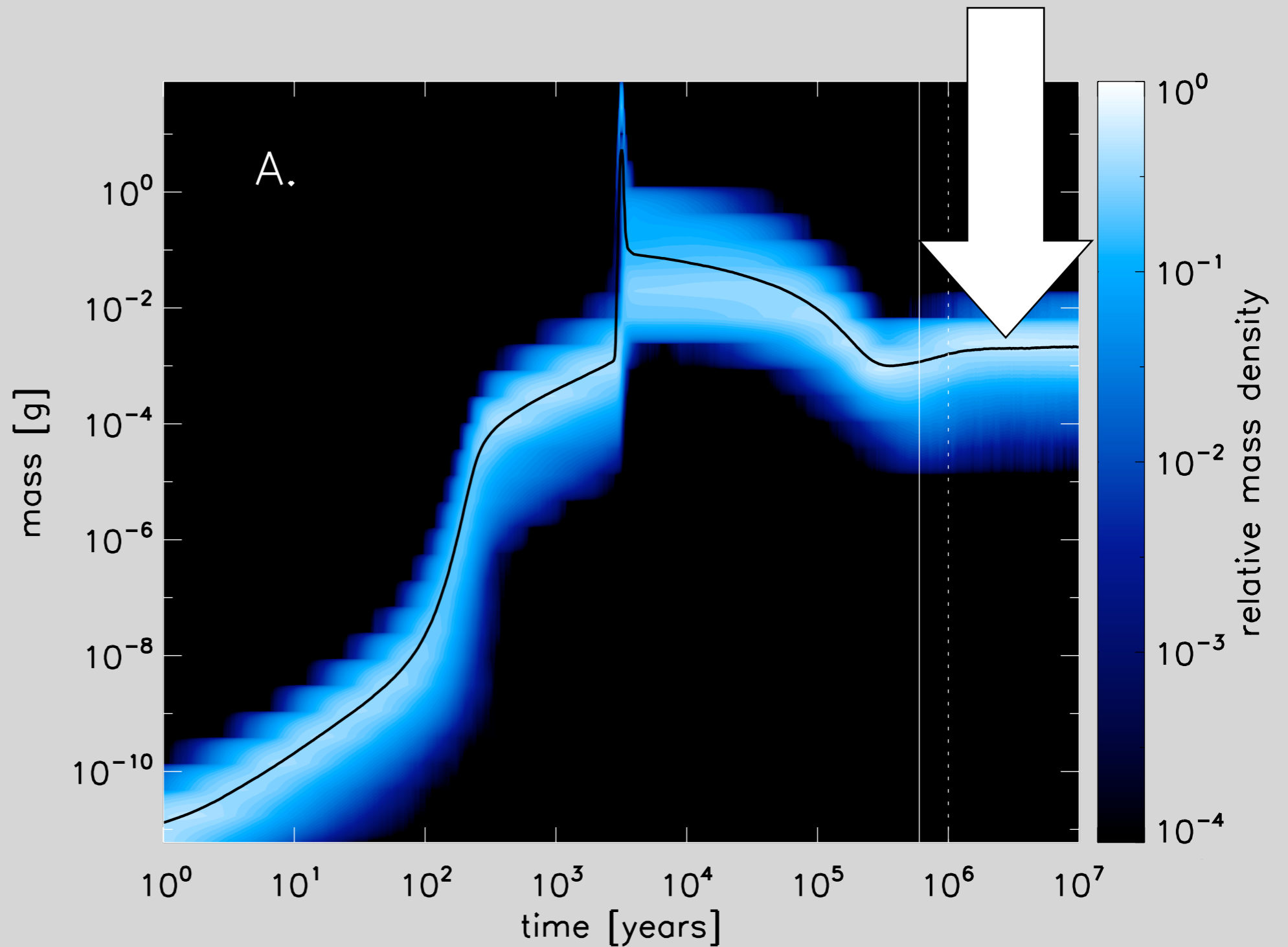
Results

Another way to visualize the results



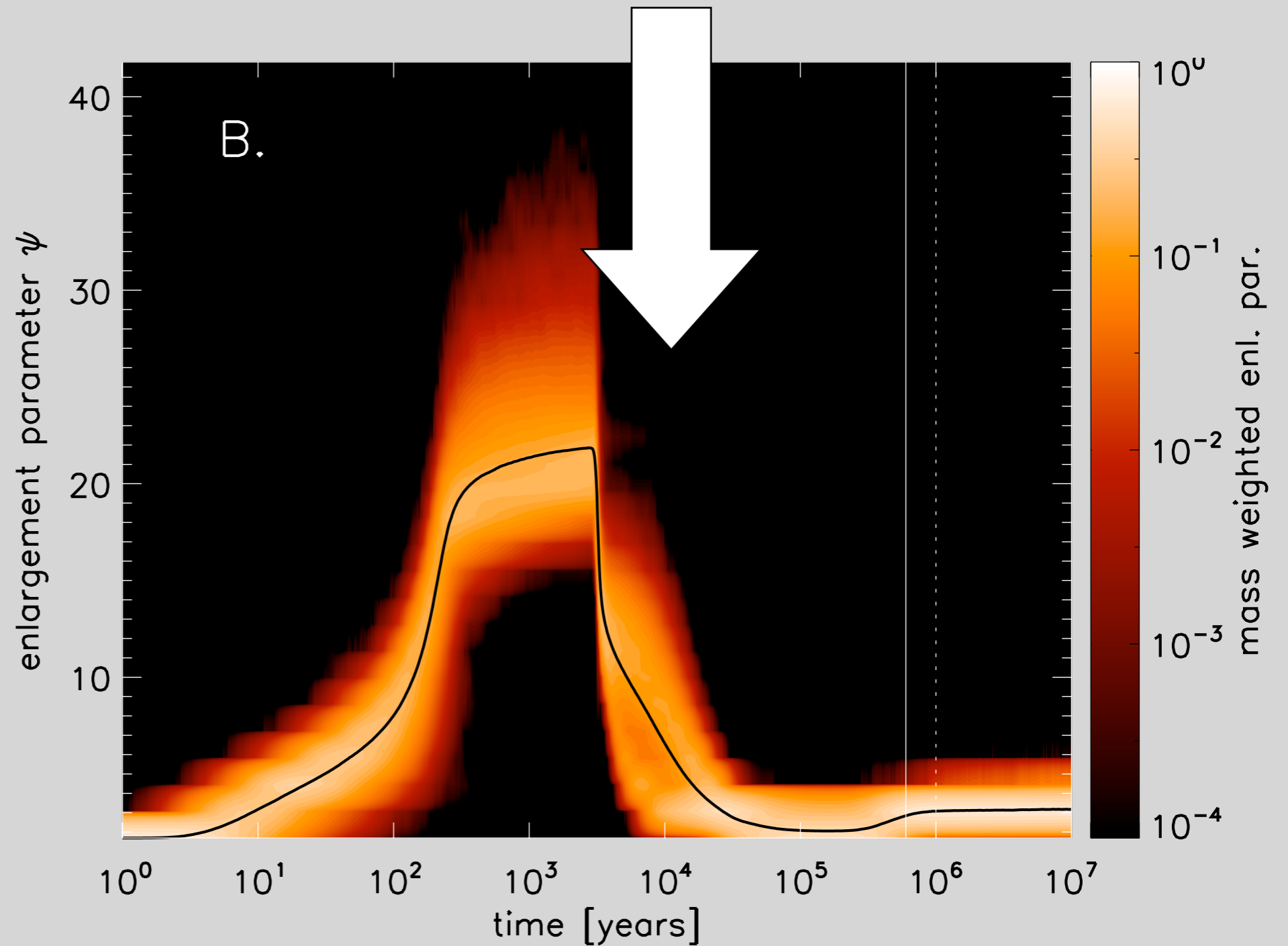
Results

Millimeter sized particles



Results

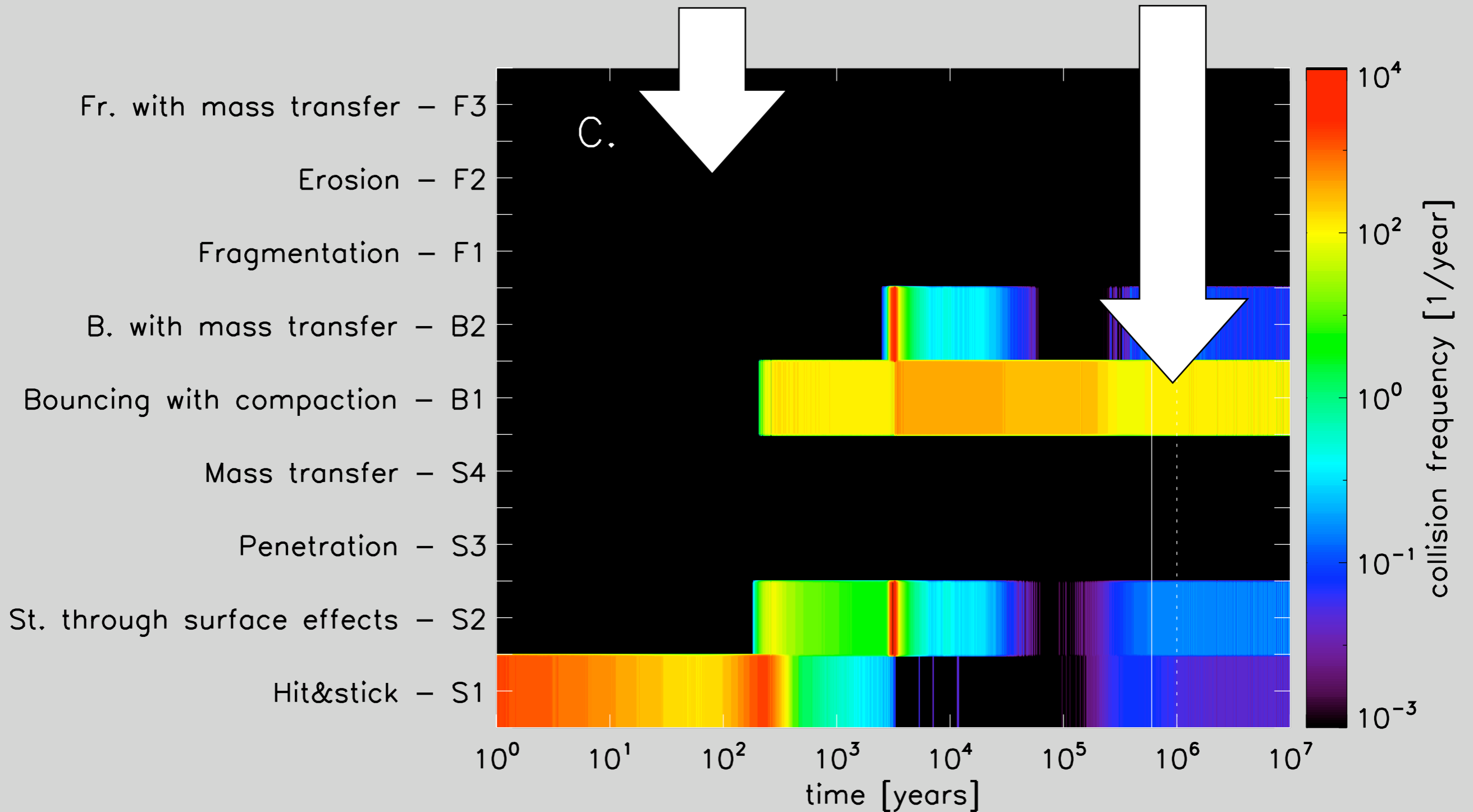
Compaction



Results

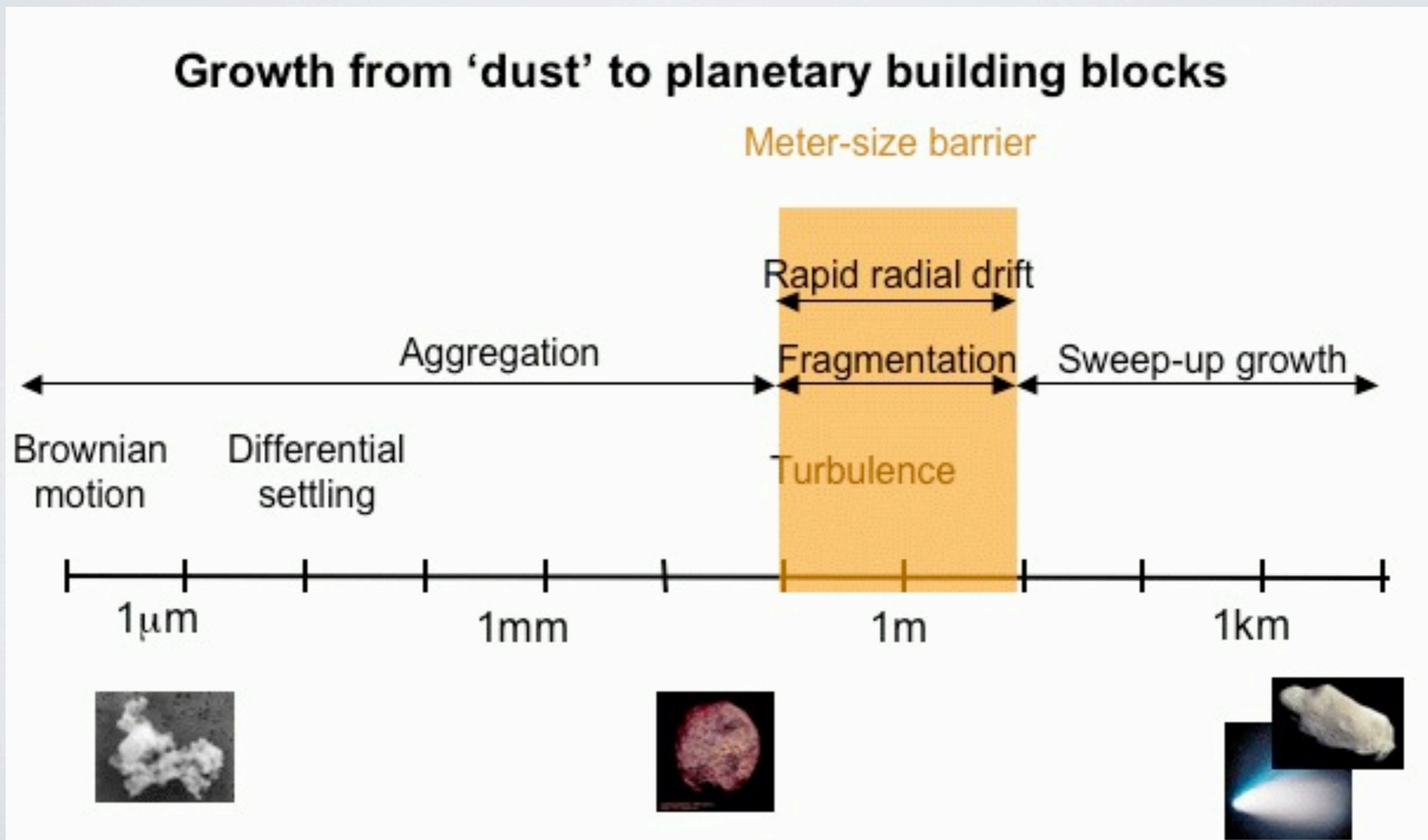
No fragmentation

Bouncing



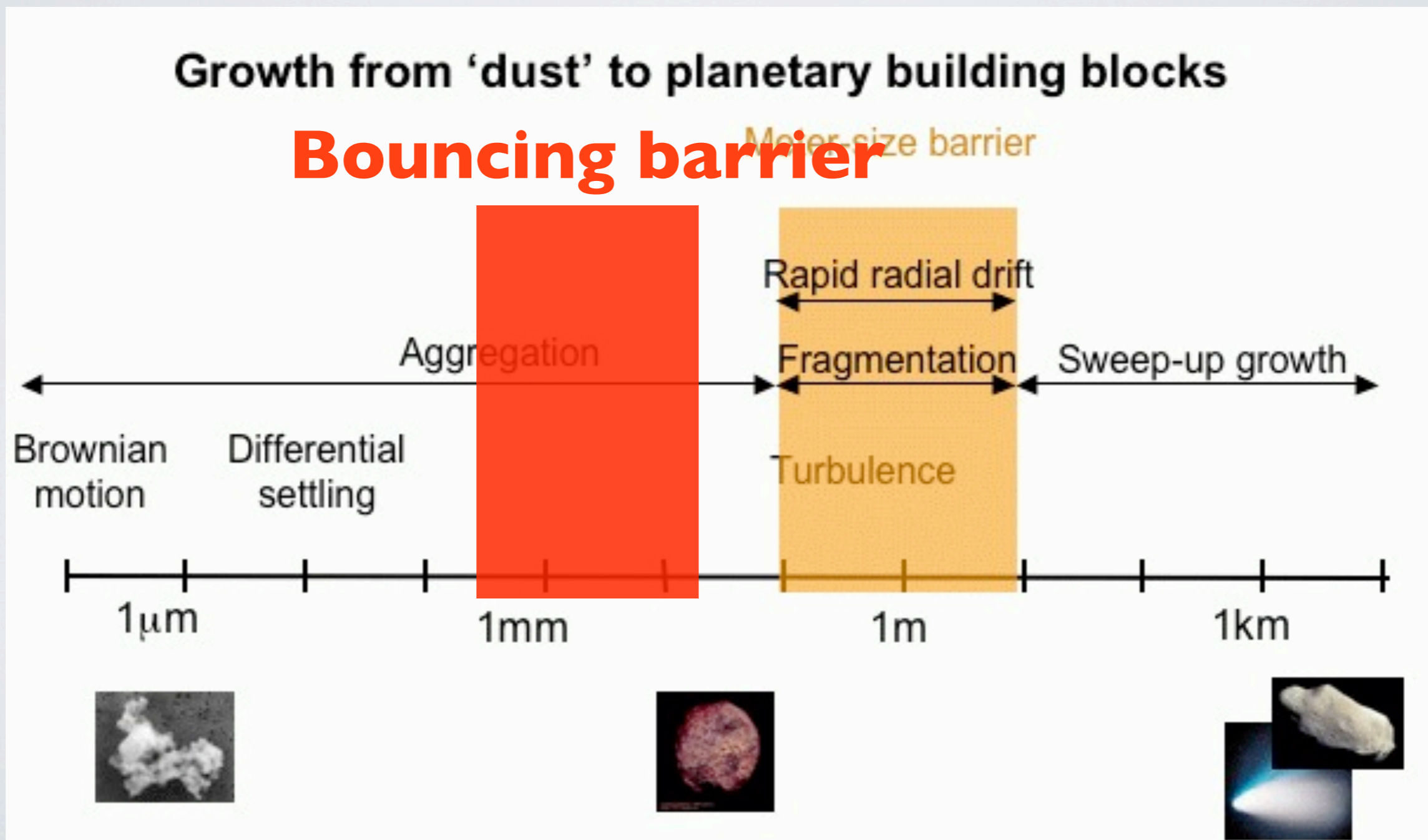
CONCLUSIONS

- Growth is halted earlier because of bouncing (sizes of ~ 1 mm)
- Fragmentation barrier (sizes of ~ 1 m) is not reached



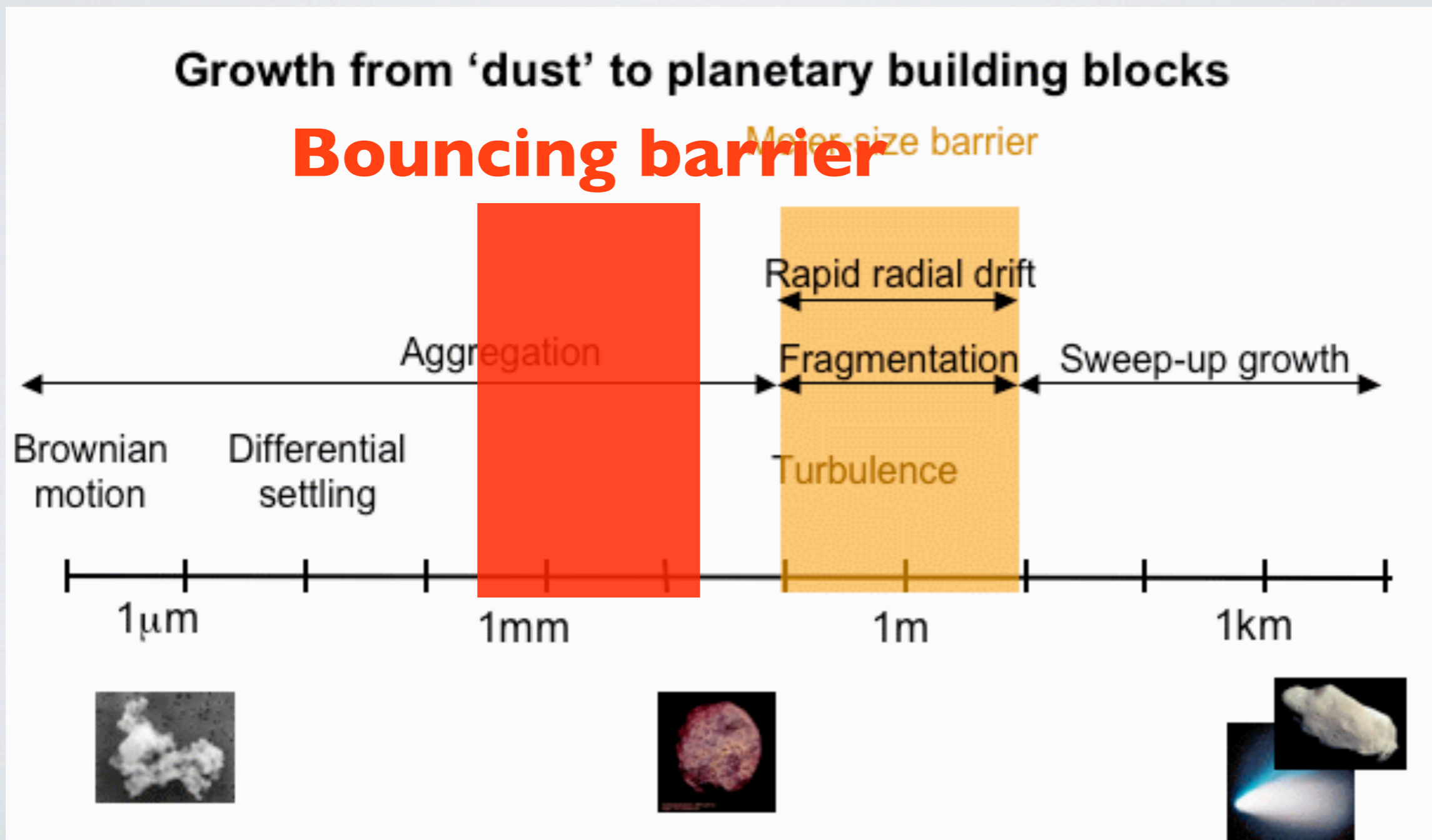
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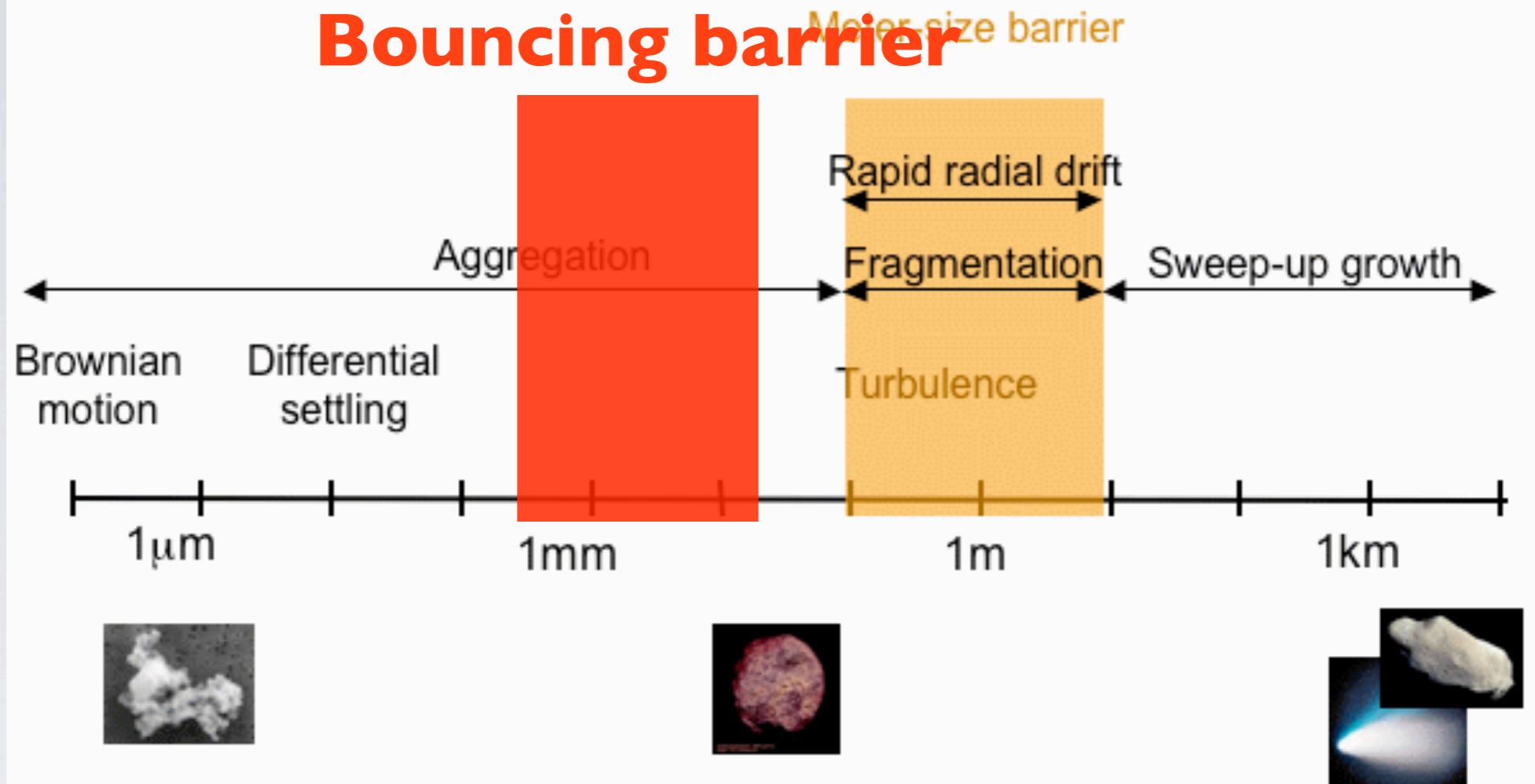
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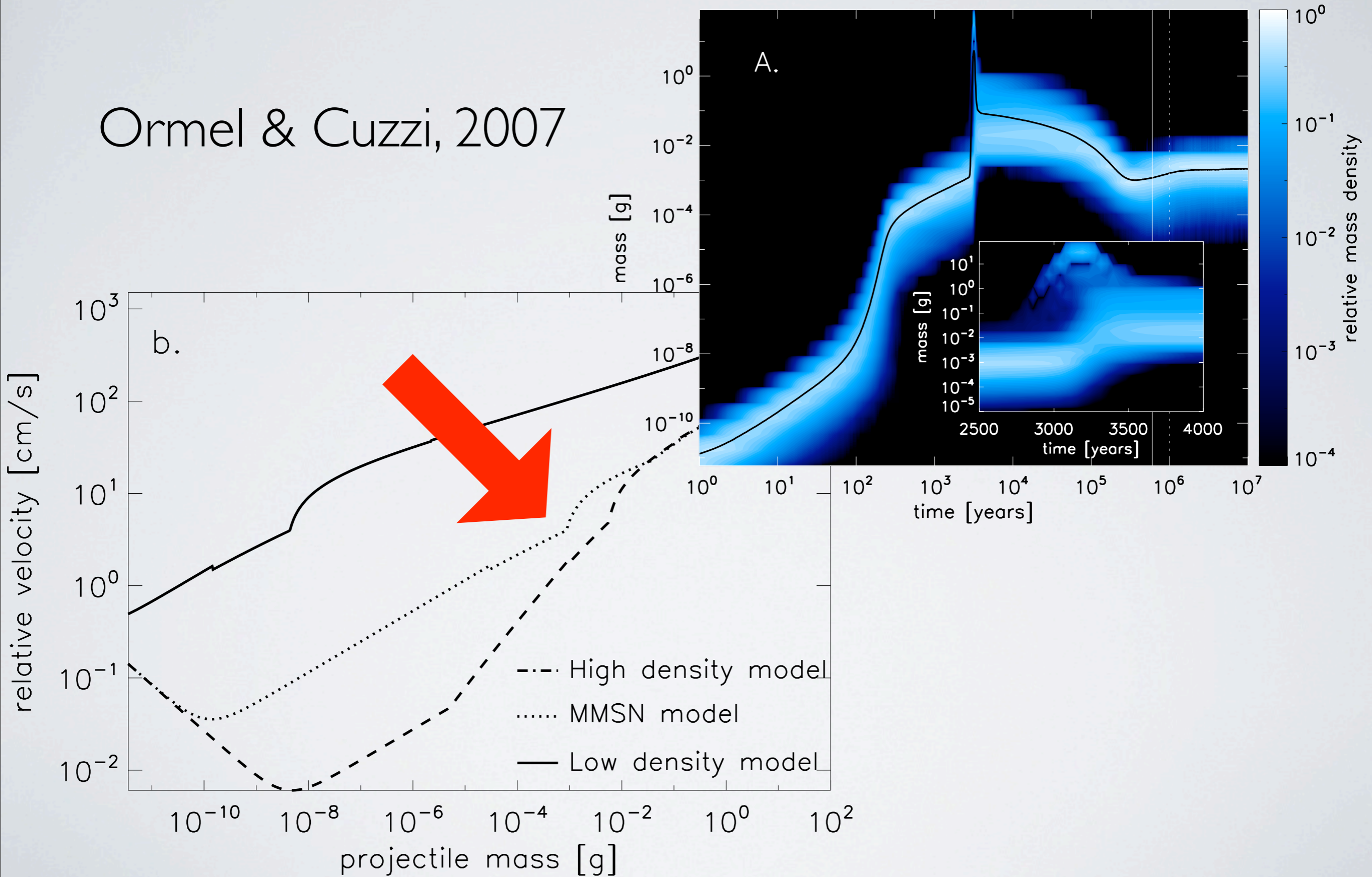
Bouncing barrier



- Possible ways to overcome the barriers:
 - Cuzzi et al, 2008 - 'sandpile' planetesimals
 - Johansen et al, 2007 - gravitationally unstable clumps
 - Using stickier materials? Ices, monomers with organic mantel?

COLLISION SPEEDS

Ormel & Cuzzi, 2007



Results

