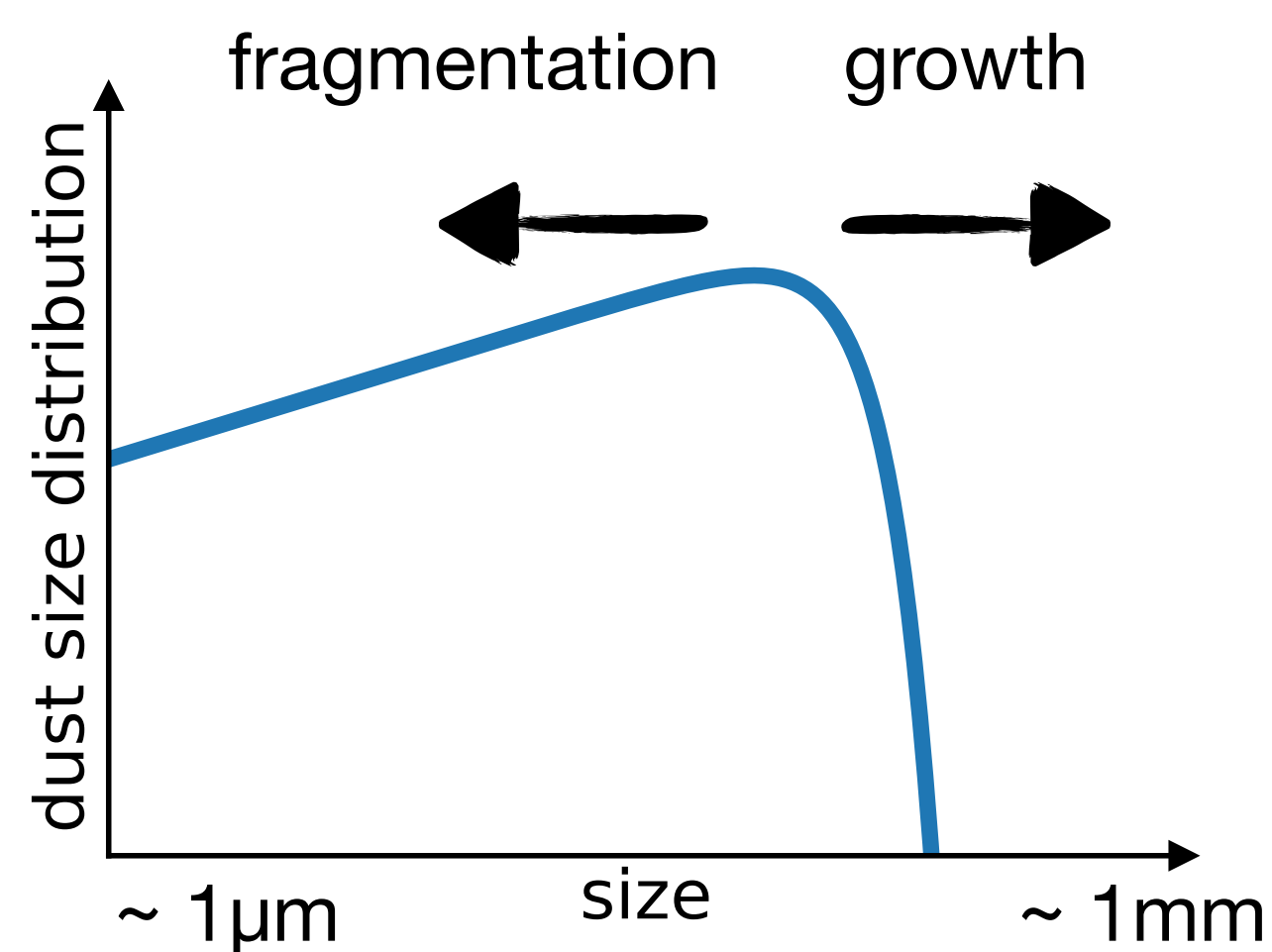


Models of dust evolution in the disk-building stage

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Need realistic dust growth and fragmentation in 3D hydrodynamics simulations



- 3 orders of magnitude in size (1μm - 1mm)
⇔ 9 orders in mass
- Size discretization
~ 20 size bins
(low numerical cost)

Numerical requirements

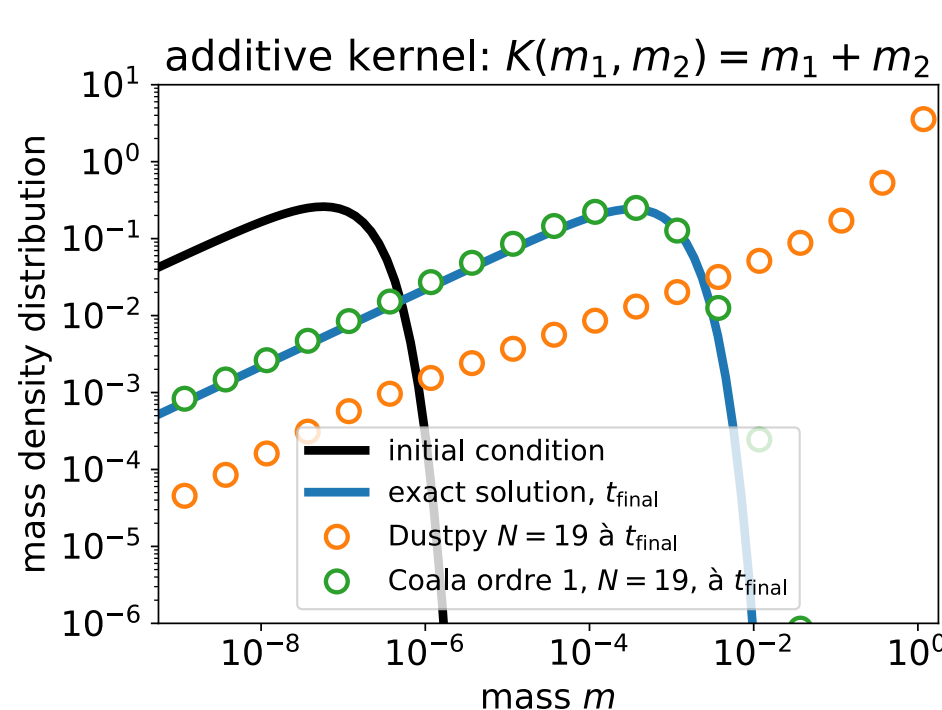


Dust size evolution model

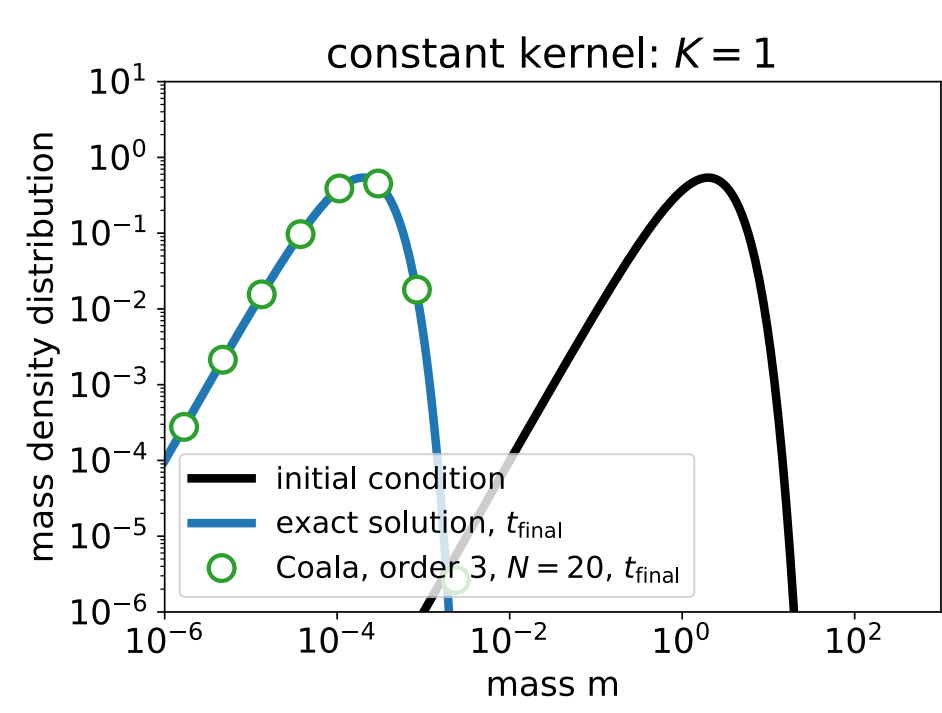
Code COALA

Solve conservative form of the growth and fragmentation equations

$$\frac{\partial g(m, t)}{\partial t} + \frac{\partial F[g](m, t)}{\partial m} = 0$$



Benchmarking for growth



Benchmarking for fragmentation

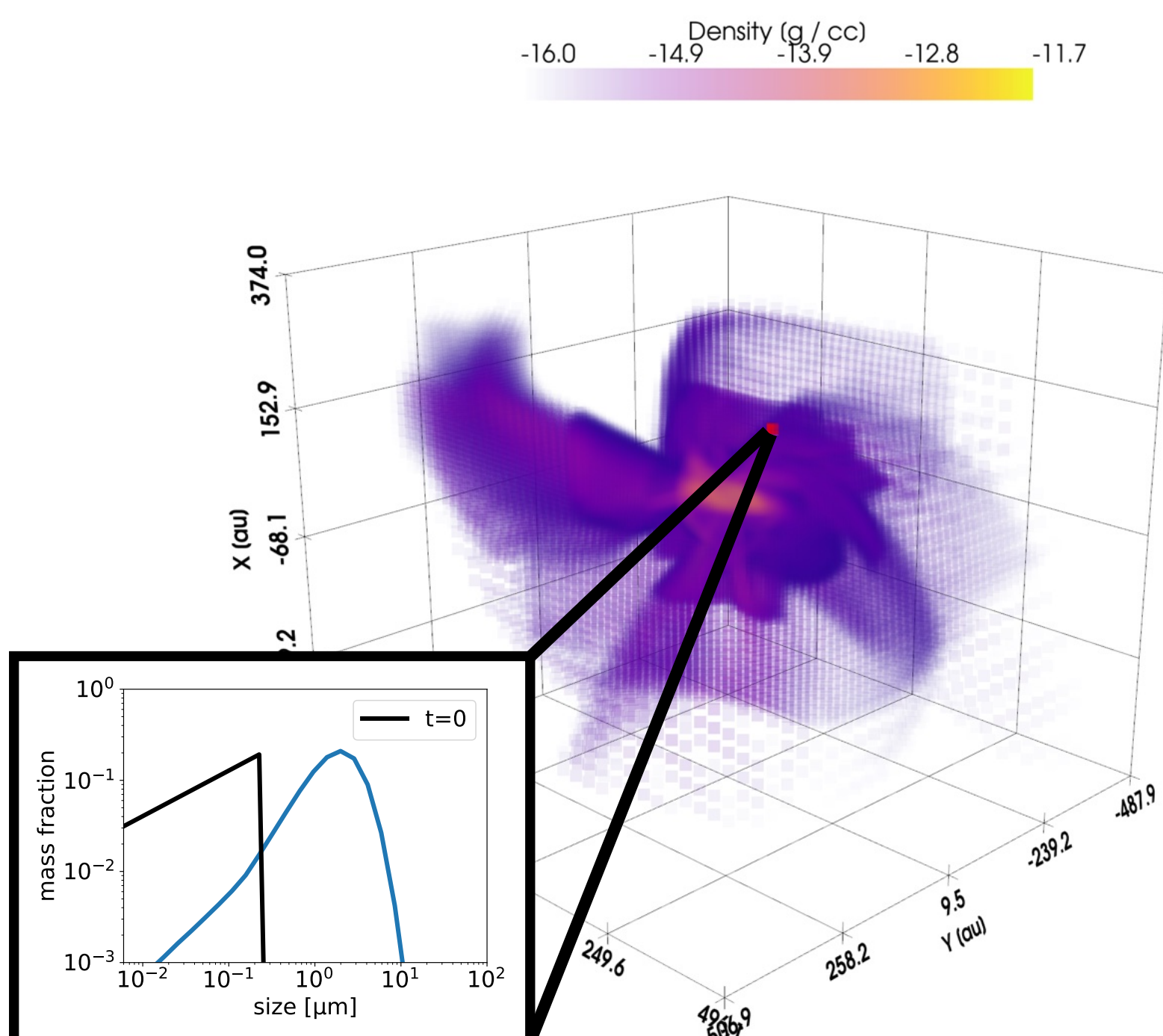
Dust growth and fragmentation in 3D hydrodynamics simulations



Dust growth in protostellar collapse

3D MHD model of B335-like protostar (Maury+2018) with grain growth

RAMSES + COALA



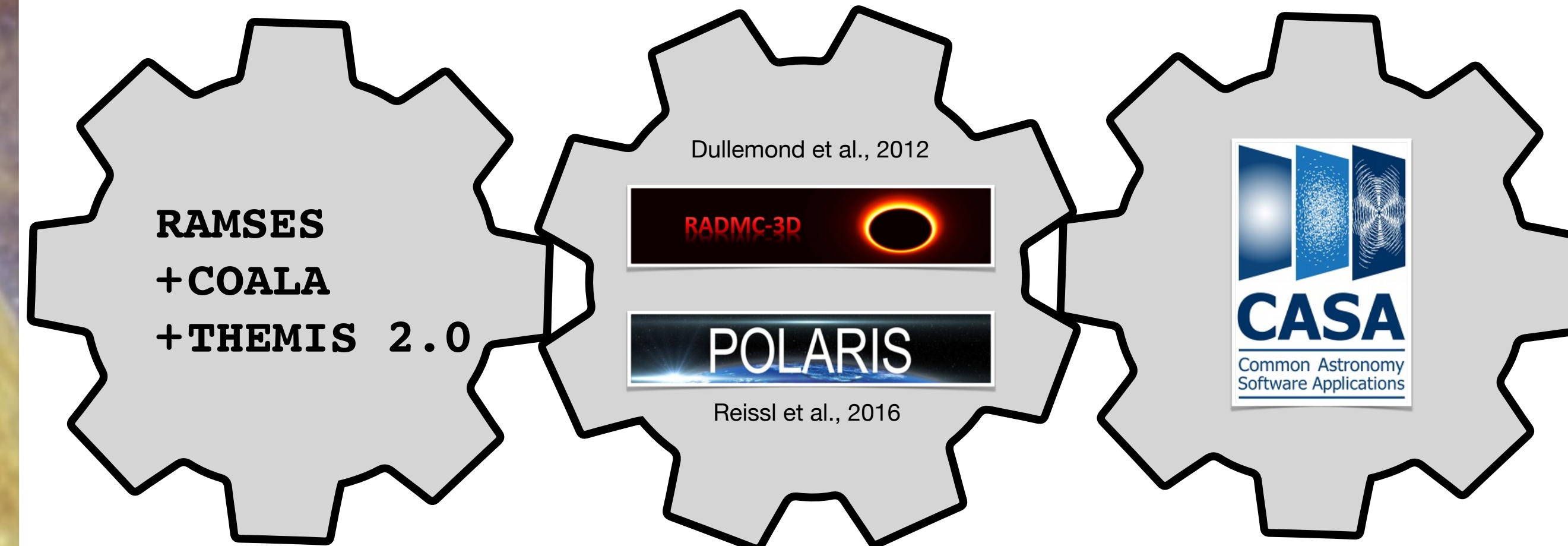
Mass of grains in the envelope (in % of total dust mass)

- Initially (MRN distribution):
- ~ 0,25 μm → 20%
 - ~ 5 μm → 0%
- After 100 kyrs:
- ~ 0,25 μm → 13%
 - ~ 5 μm → 1%

MHD simulations + Realistic dust model

Radiative transfer

Synthetic observations

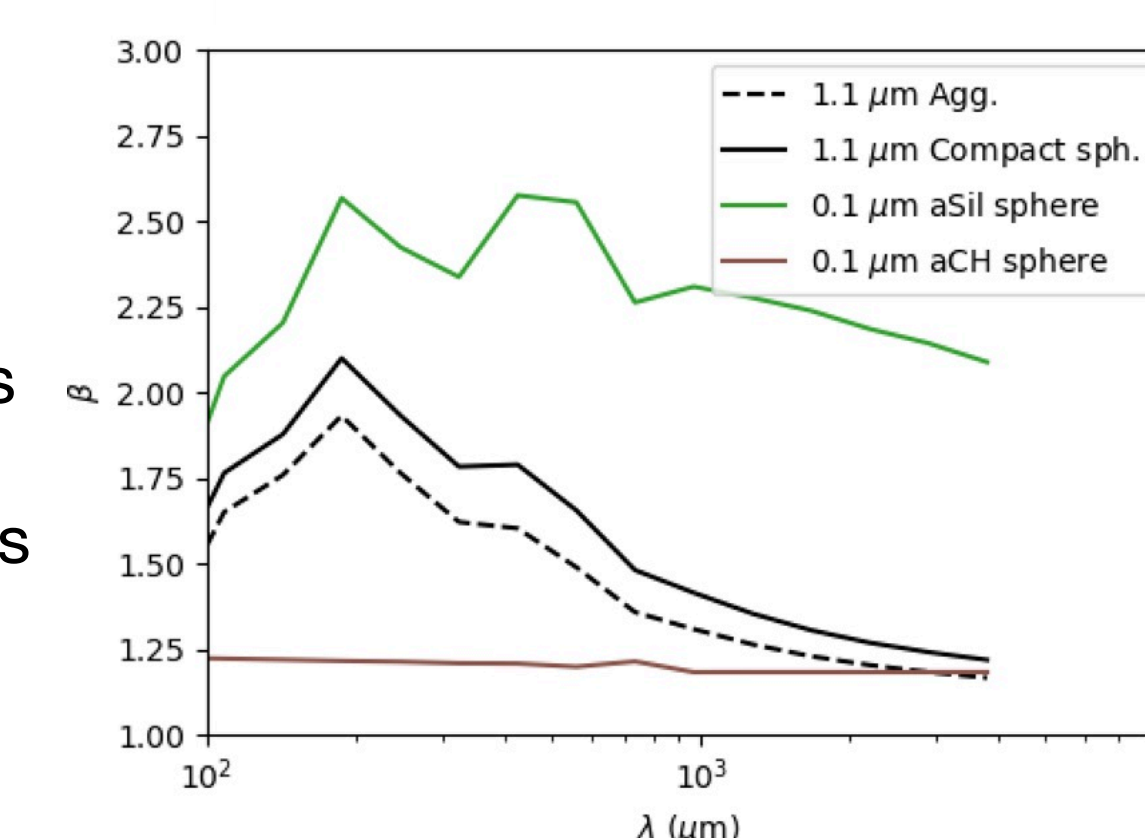


Full process for characterizing the dust evolution during the disk-building stage

Synthetic observations

Optical properties

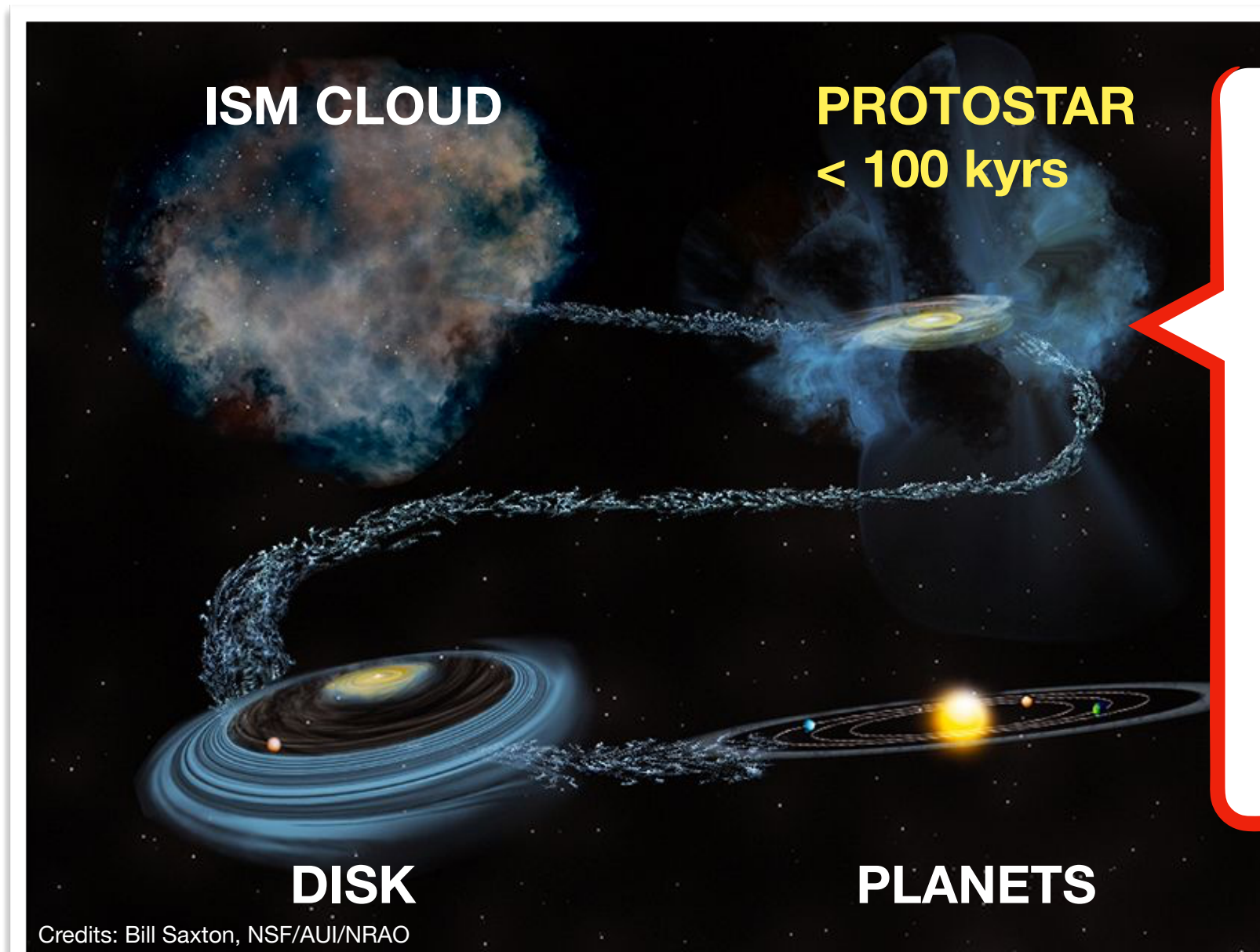
Computation of optical properties by discrete dipole approximation with the code ADDA (Yurkin & Hoekstra 2011)



emissivity index for monomers and aggregates

- β varies with grain porosity
- Up to 20% of difference in range of wavelengths 0.1 - 1 mm
- Up to 10% of difference in range of wavelengths 1 - 3 mm

How early do pebbles form around YSOs ?



What are the dust properties in protostellar environments ?

Size ?
Shape ?
Composition ?

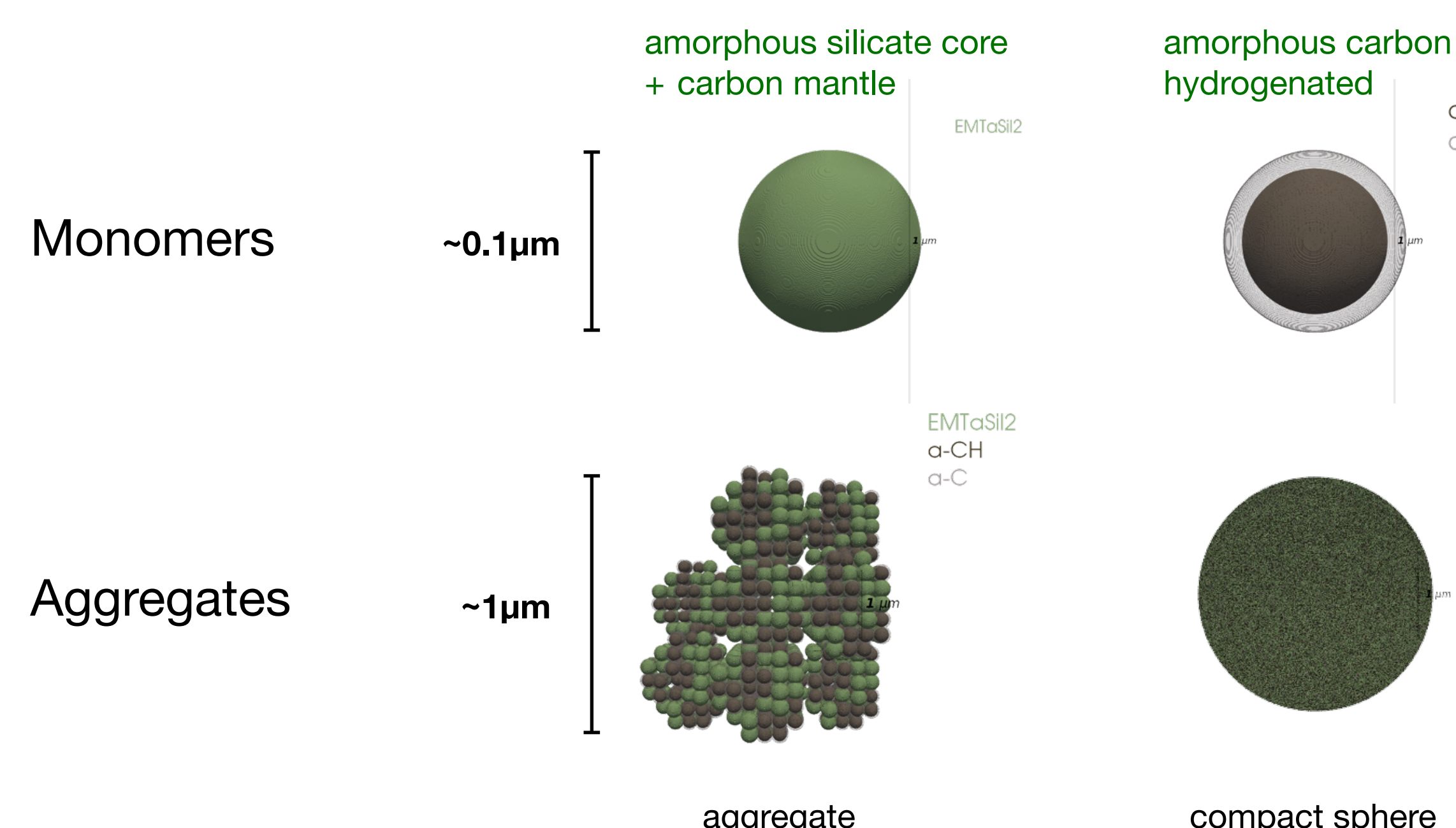
PEBBLES project: Characterizing dust properties in protostars with new observations and new dust models



Ysard et al., 2024



Need realistic dust optical properties for micrometer aggregates



PEBBLES project aims to characterize dust properties to determine how large grain can be in protostellar envelope. New models are developed based on 3D MHD models of protostellar collapse with dust evolution associated with realistic optical properties.

Lombart, M. et al., 2025 (submitted A&A)
Carpine, M.-A. et al., A&A, 698, A200, 2025
Lombart, M. et al., MNRAS, 533, 2024
Lombart, M. et al., MNRAS, 517, 2022
Lombart, M., Laibe, G., MNRAS, 501, 2021

