FROM COSMIC DUST TO PLANET FORMATION : BUILDING NEW DUST MODELS

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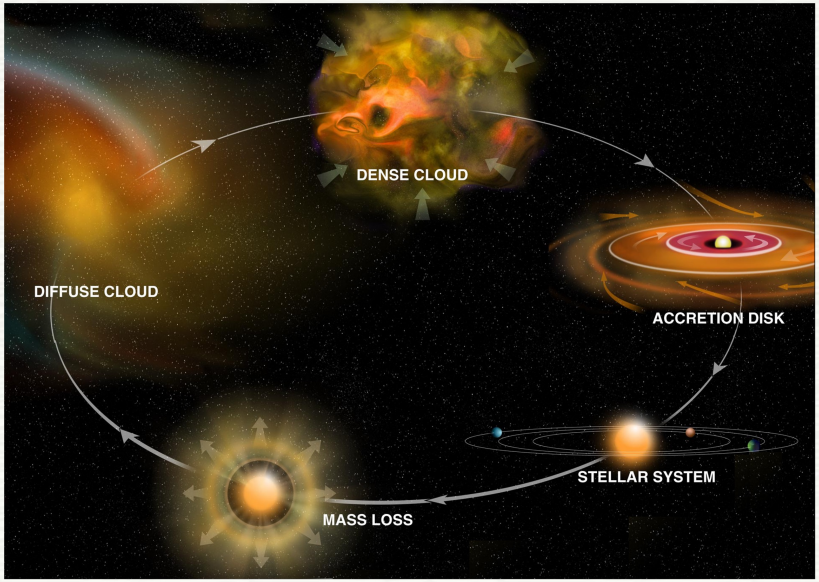
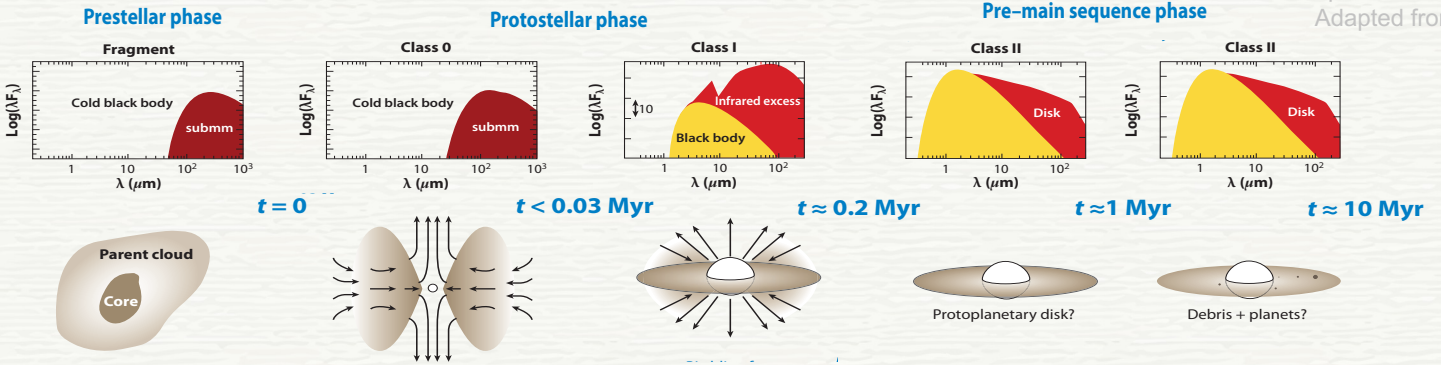
Interstellar dust play multiple major roles



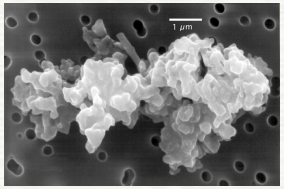
- Planet Formation
- Mass inference
- Chemistry
- Coupling with B-field

Interstellar dust has to grow fast



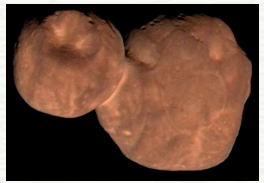
Dauphas & Chaussidon 2011
Adapted from André 1994,
Lada 1987

100 nm



Dust growth
$\times 10^{10}$

10km



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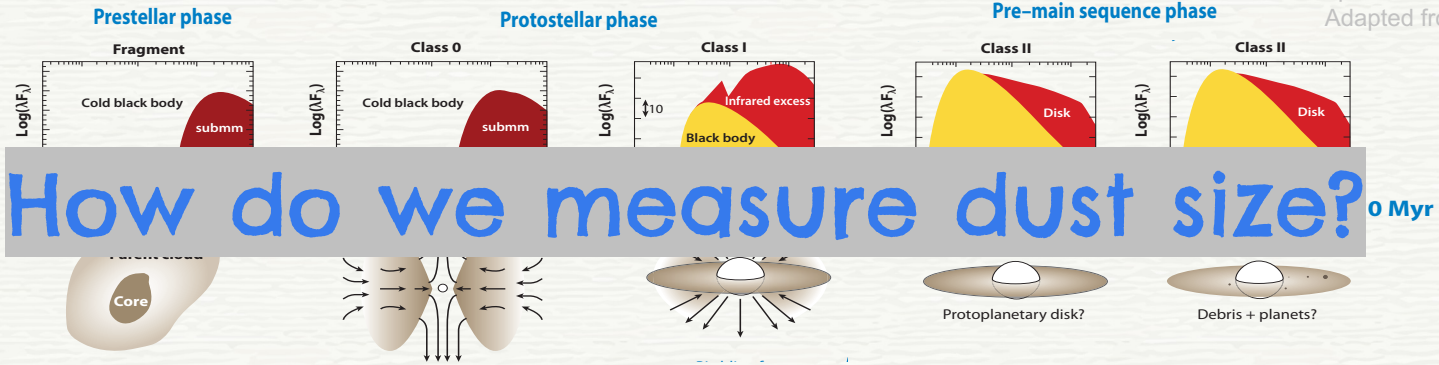

Dauphas & Chaussidon 2011
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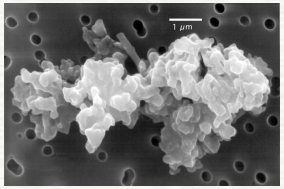
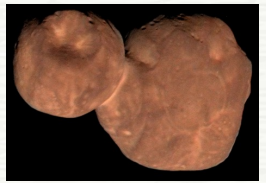
How do we measure dust size?

100 nm

Dust growth
$\times 10^{10}$

10km





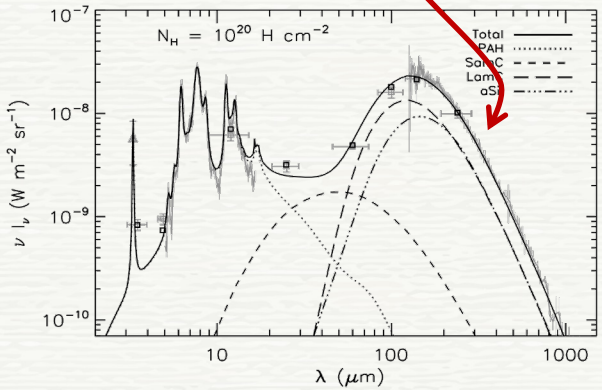
Emissivity index β as a dust size tracer

Modified black body

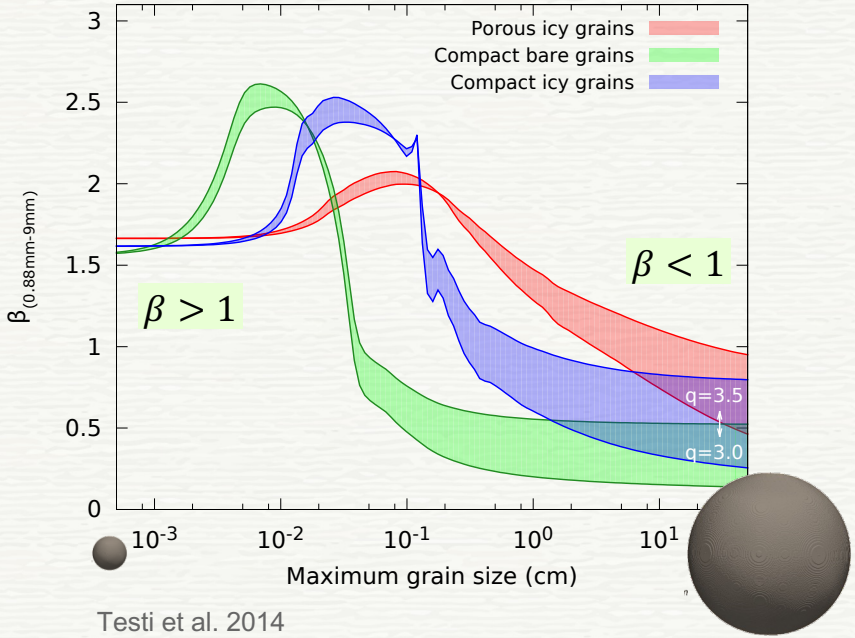
$$I_\nu \approx B_\nu(\mathrm{T})(1-e^{-\tau_\nu})$$
$$\approx B_\nu(\mathrm{T})\tau_\nu$$
$$\propto B_\nu(\mathrm{T})\kappa_\nu$$

$$I_\nu \propto \kappa_0 \left(\frac{\nu}{\nu_0}\right)^{\beta} B_\nu(\mathrm{T})$$

(sub-mm/mm regime)



Compiègne et al. 2011



Testi et al. 2014

Emissivity index β as a dust size tracer

Dauphas & Chaussidon 2011
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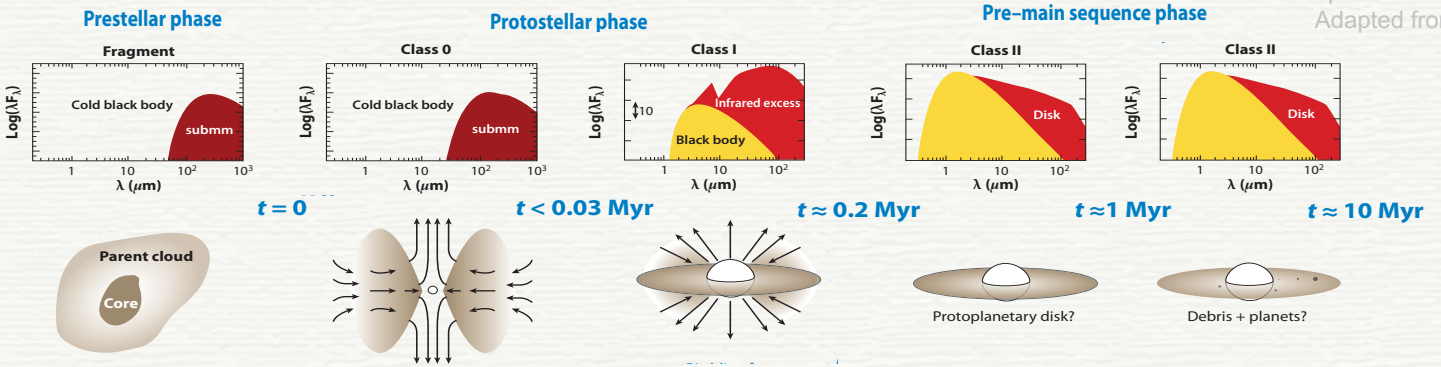
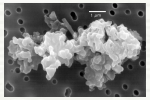


$\beta > 1$

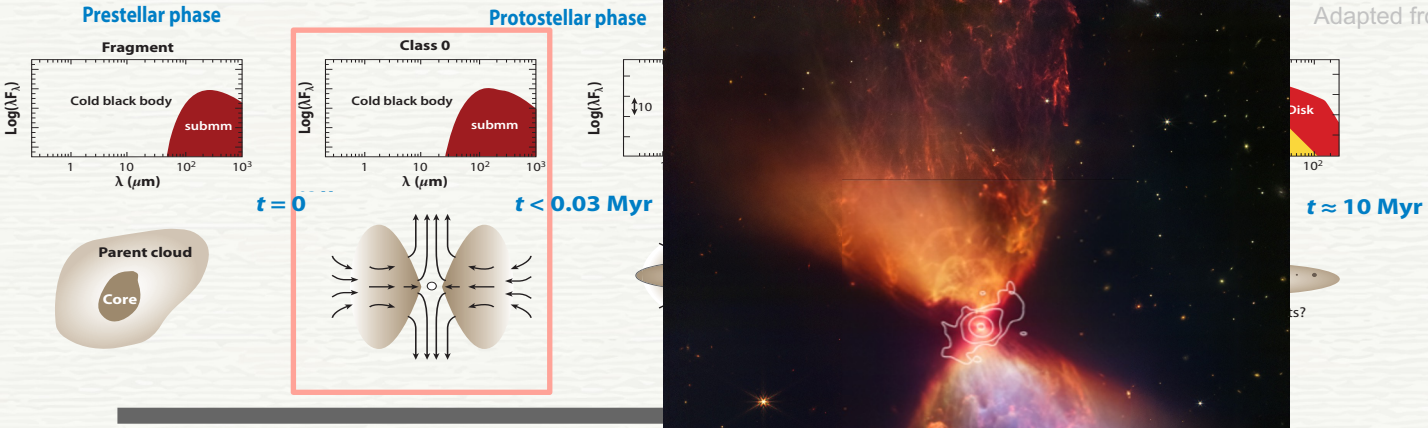
100 nm



$\beta < 1$

10km

What dust size in protostars ?



Dauphas & Chaussidon 2011
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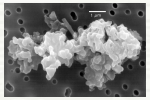
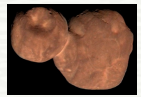
100 nm



$\beta > 1$

km



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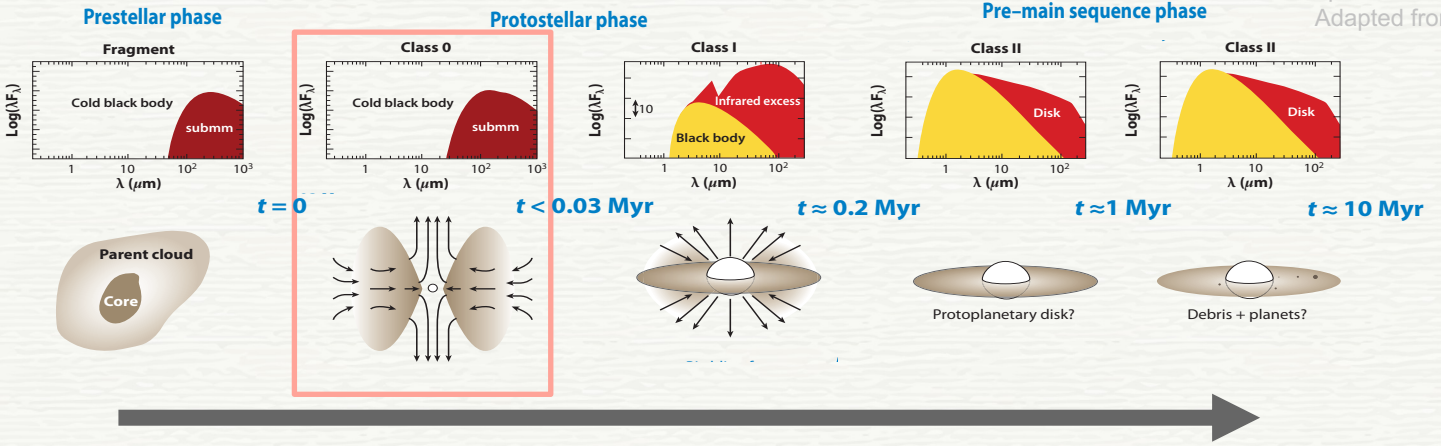

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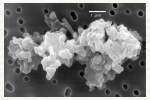
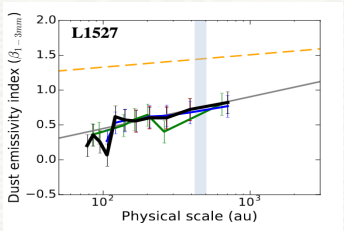
$\beta > 1$

100 nm



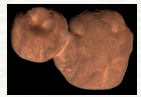
$\beta < 1$

Galametz et al. 2019



$\beta < 1$

10km



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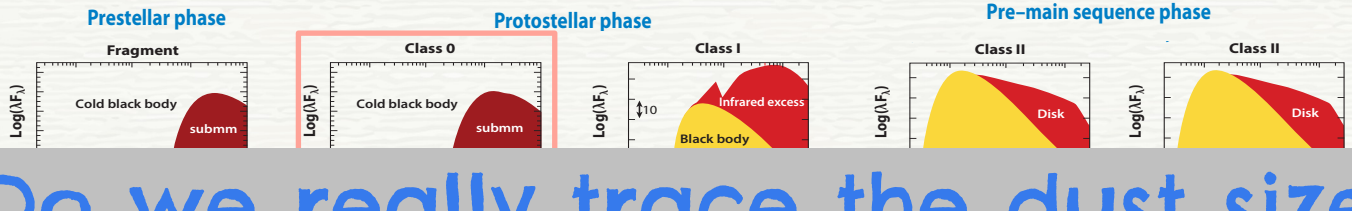
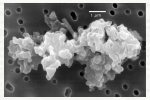


Do we really trace the dust size with β ? -> Need for realistic dust models

André 2000, ada & Lada

100 nm



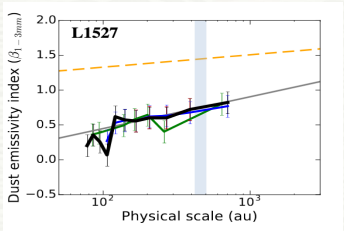
10km

$\beta > 1$

$\beta < 1$

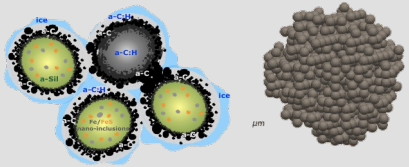
$\beta < 1$

Galametz et al. 2019



Dust models are the start of synthetic observations

MHD Simulations from Hennebelle et al. 2020



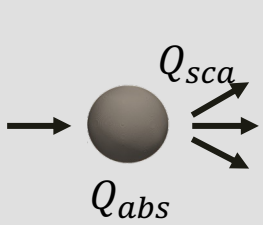
Dust Model

ADDA

Yurkin & Hoekstra 2011

TGCC

Très Grand Centre de calcul du CEA



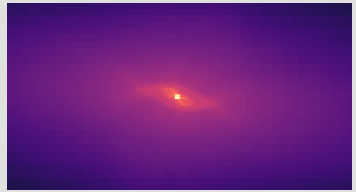
Opt. properties

Dullemond et al. 2012

RADMC-3D

POLARIS

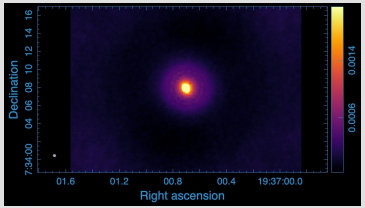
Reissl et al. 2016



Sky model

CASA

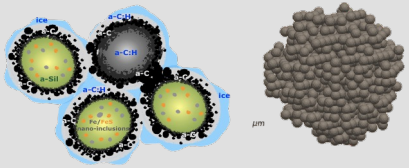
The CASA Team et al. 2022



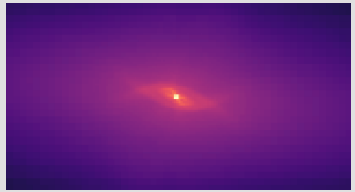
Synthetic obs.

Dust models are the start of synthetic observations

MHD Simulations from Hennebelle et al. 2020



Dust Model



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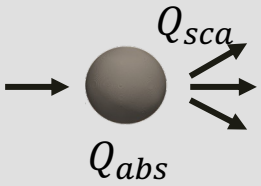

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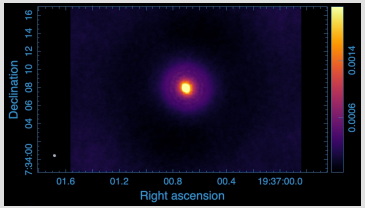
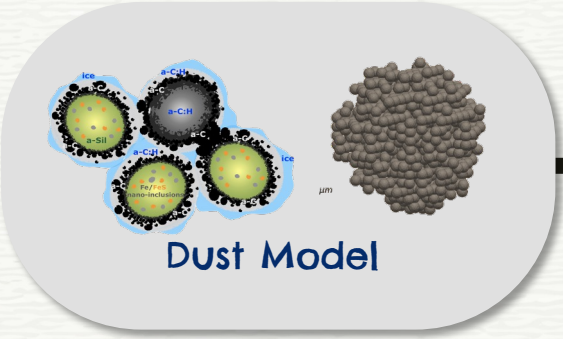


Synthetic obs.

Running dust model

Discrete Dipole Approximation



ADDA

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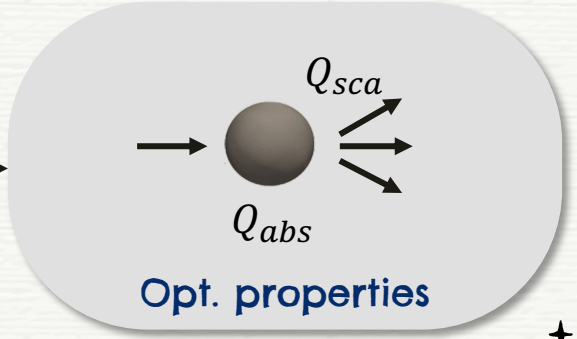
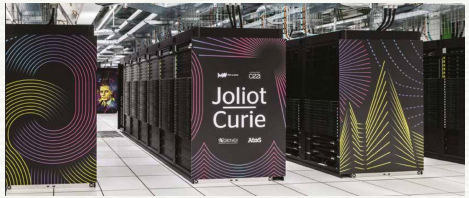


Yurkin & Hoekstra 2011

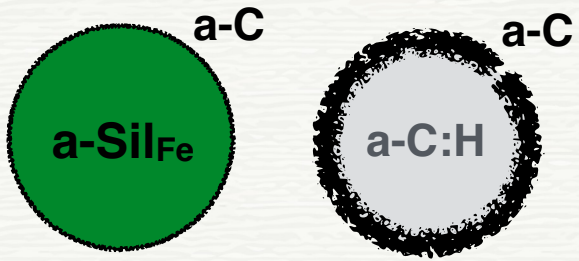


Pilot sample for new dust model

Themis 2.0 optical constants (a-Sil grains)

Jones et al 2014, Ysard et al. 2024

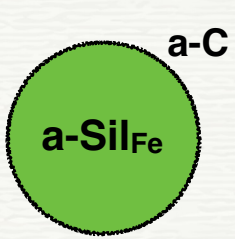
core/mantle grains (**CM**)



Laboratory-measured optical properties

Demyk et al. 2022

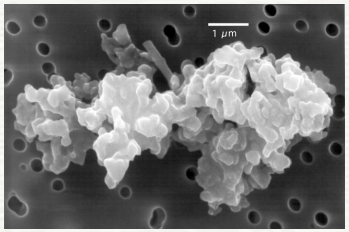
Pilot sample for new dust model

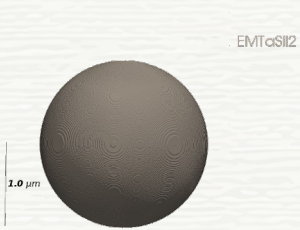


Themis 2.0 optical constants

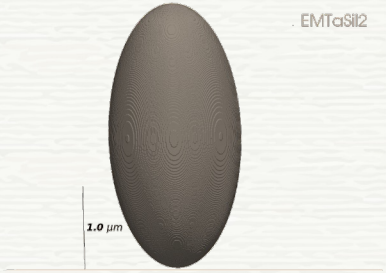
Jones et al 2014, Ysard et al. 2024

(a-Sil grains)

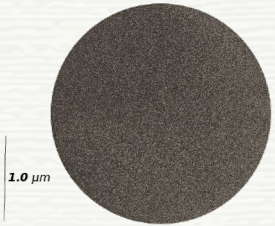




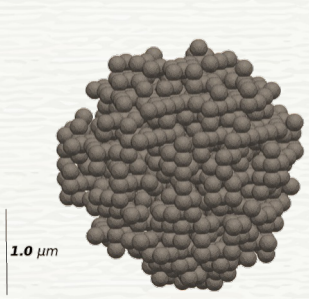
Sphere



Spheroid

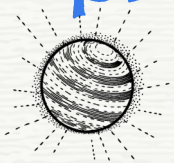


Porous sphere



Aggregate

Porosity has a major effect on IR properties.

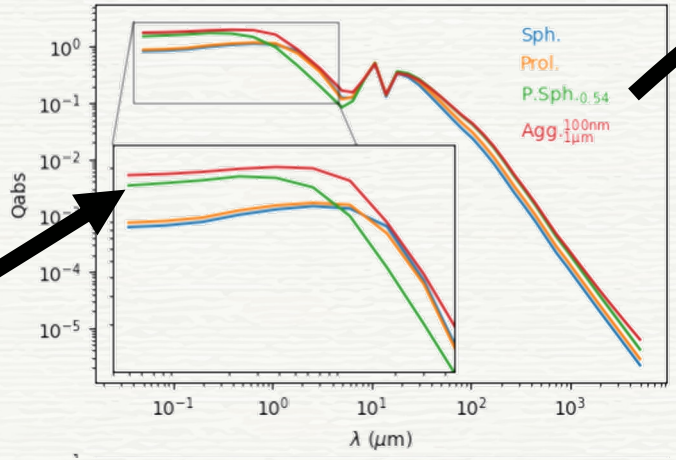


Q_{sca}

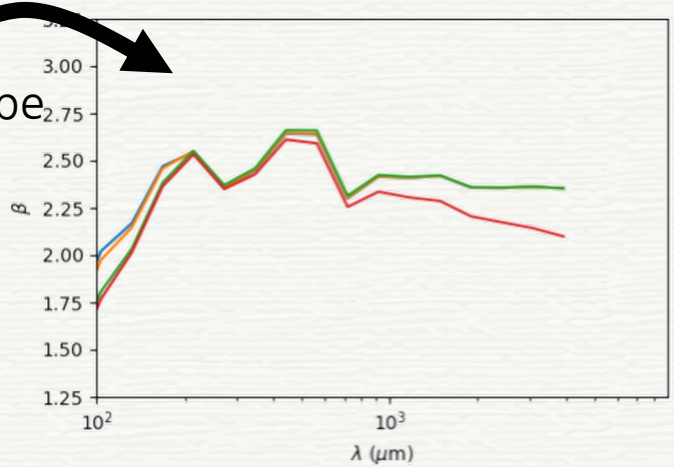
Q_{abs}

$$Q_{ext} \propto \kappa_\nu = \kappa_0 \left(\frac{\nu}{\nu_0}\right)^\beta$$

Porous = more emissive



Slope

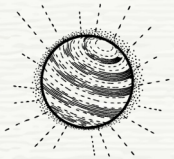


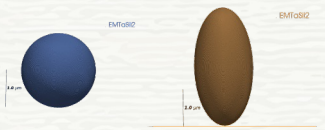
Carpine et al. 2025a

Emisivity

Emisivity index

β doesn't depend only on grain size





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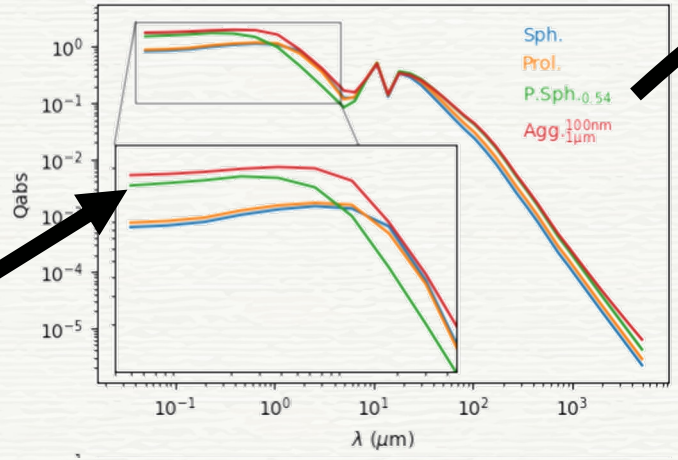
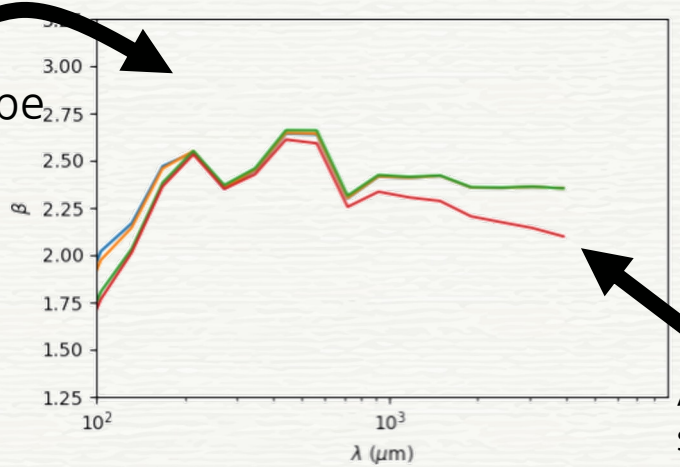


Emisivity

Slope



Emisivity index

Aggregate stands out !

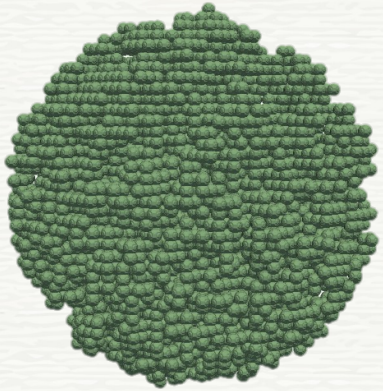
Carpine et al. 2025a

Pilot sample – iced grain

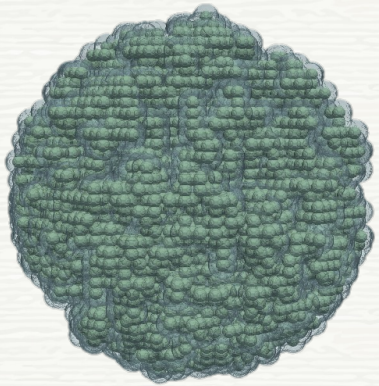
Themis 2.0 optical constants

Jones et al 2014, Ysard et al. 2024

(a-Sil grains)

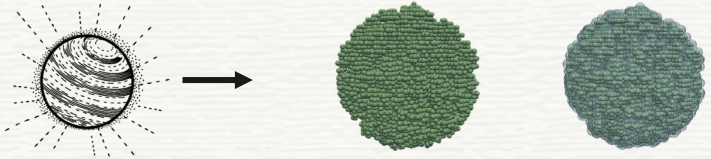


Aggregate



Aggregate + H2O ice

Ice coating also has an impact on β



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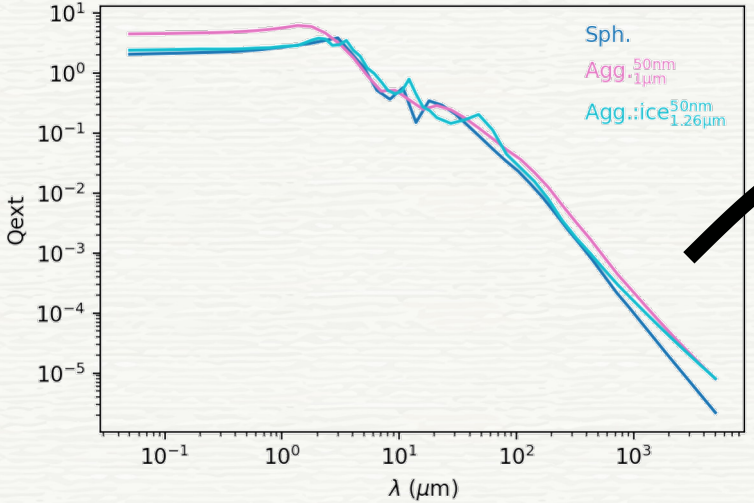
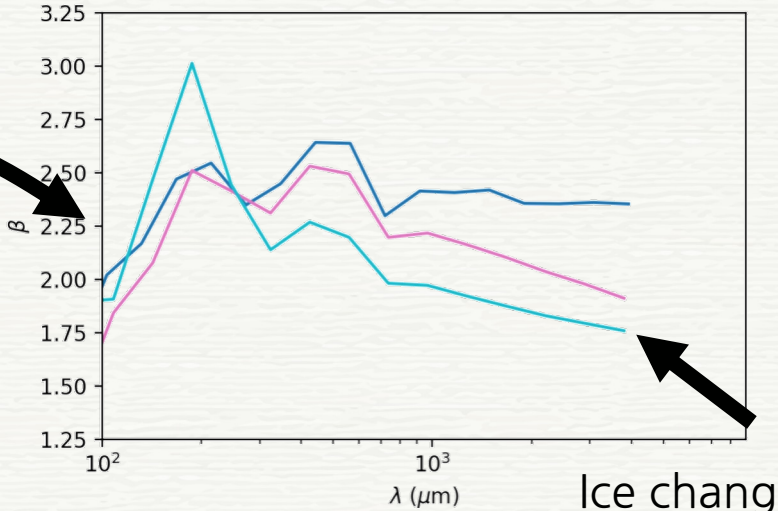


Emisivity

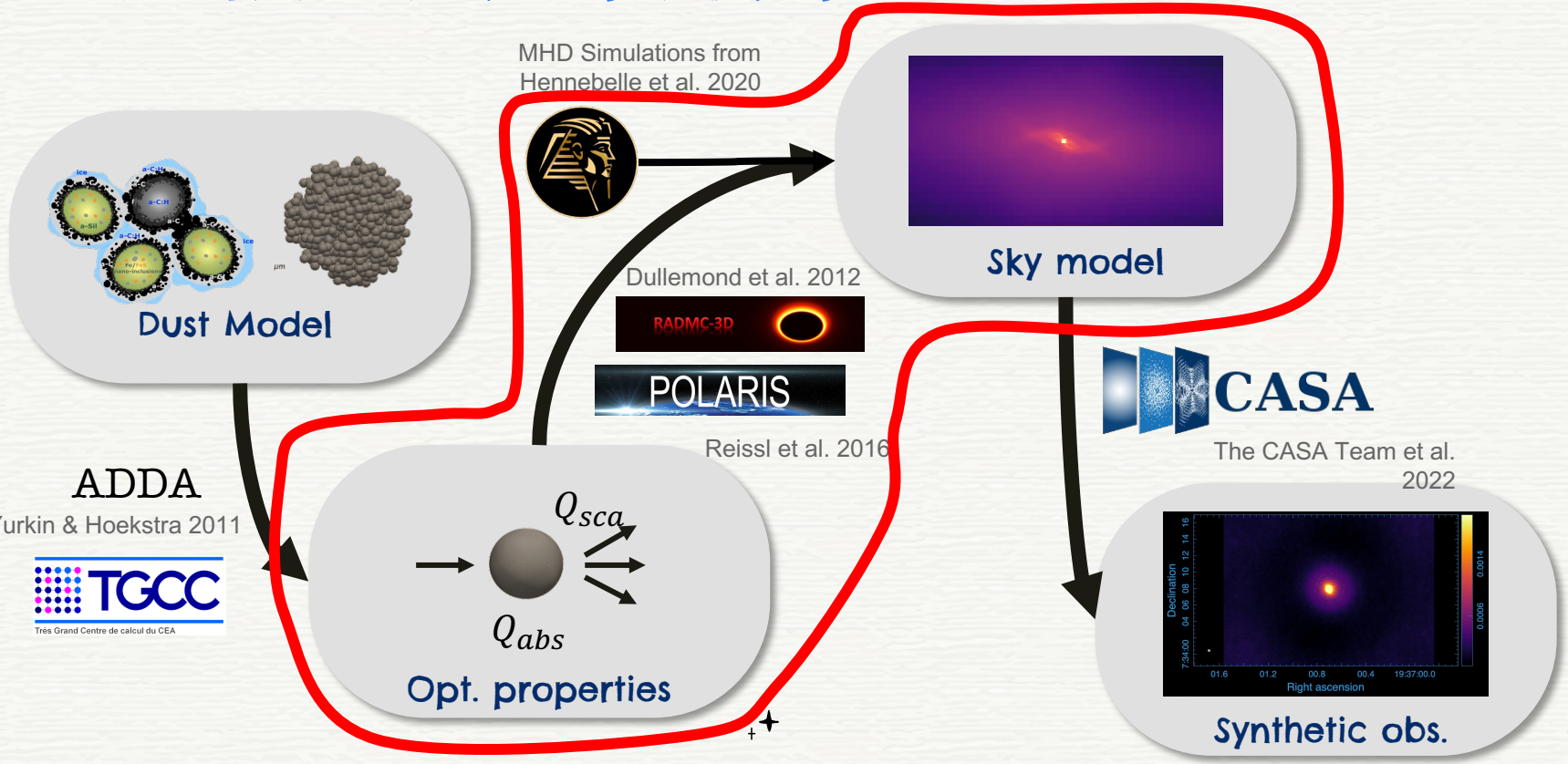
Slope



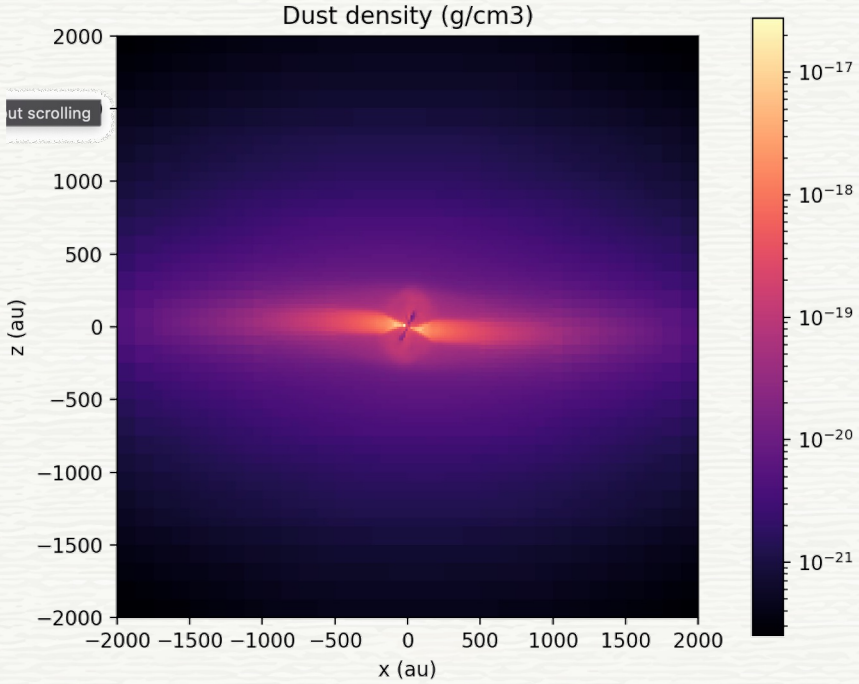
Emisivity index

Ice changes β

Dust Radiative transfer



MHD protostar simulation



MHD Simulations from
Hennebelle et al. 2020

POLARIS

Reissl et al. 2016,
Brauer et al. 2017

Source : $1\,L_{\odot}$

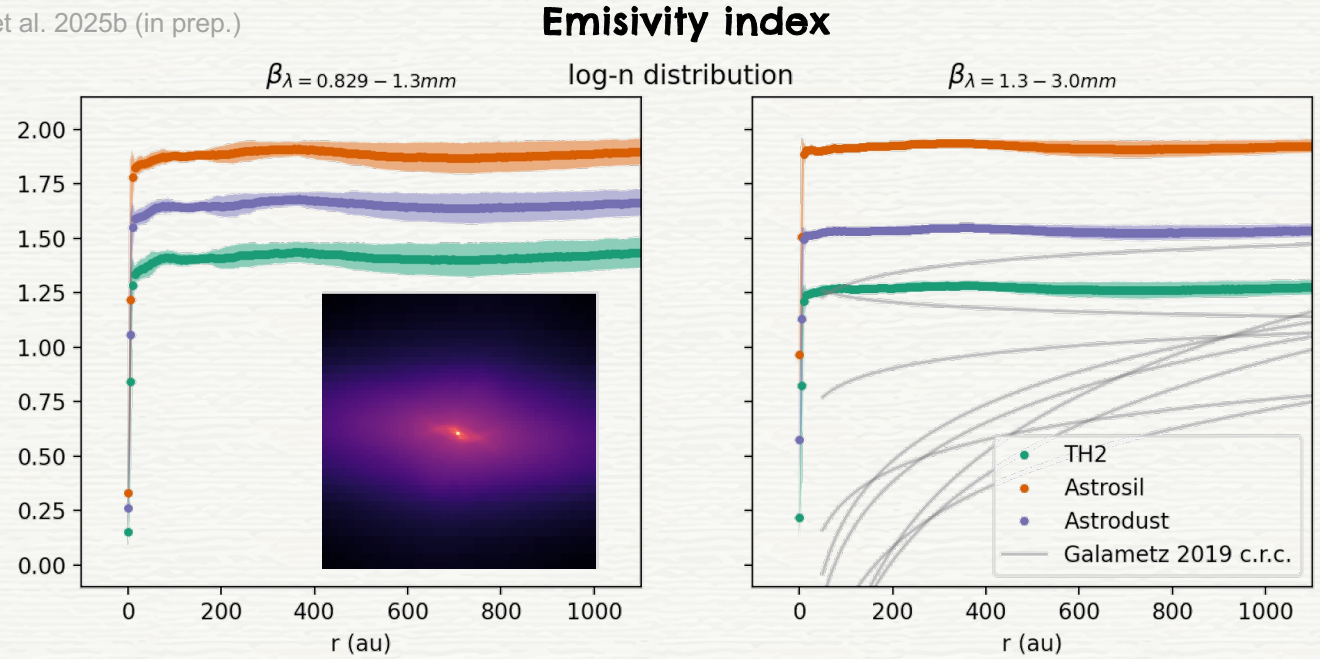
Dust

aC	45 nm - 700 nm	(37.5%)
aSil	10nm - 370nm	(62.5%)

Log-n distribution

Dust models influence index β

Carpine et al. 2025b (in prep.)



Weingartner & Draine 2001

Hensley & Draine 2023

Ysard et al. 2024

Same MHD simulation, same dust size distribution, compact grains.

Reissl et al. 2016,
Brauer et al. 2017

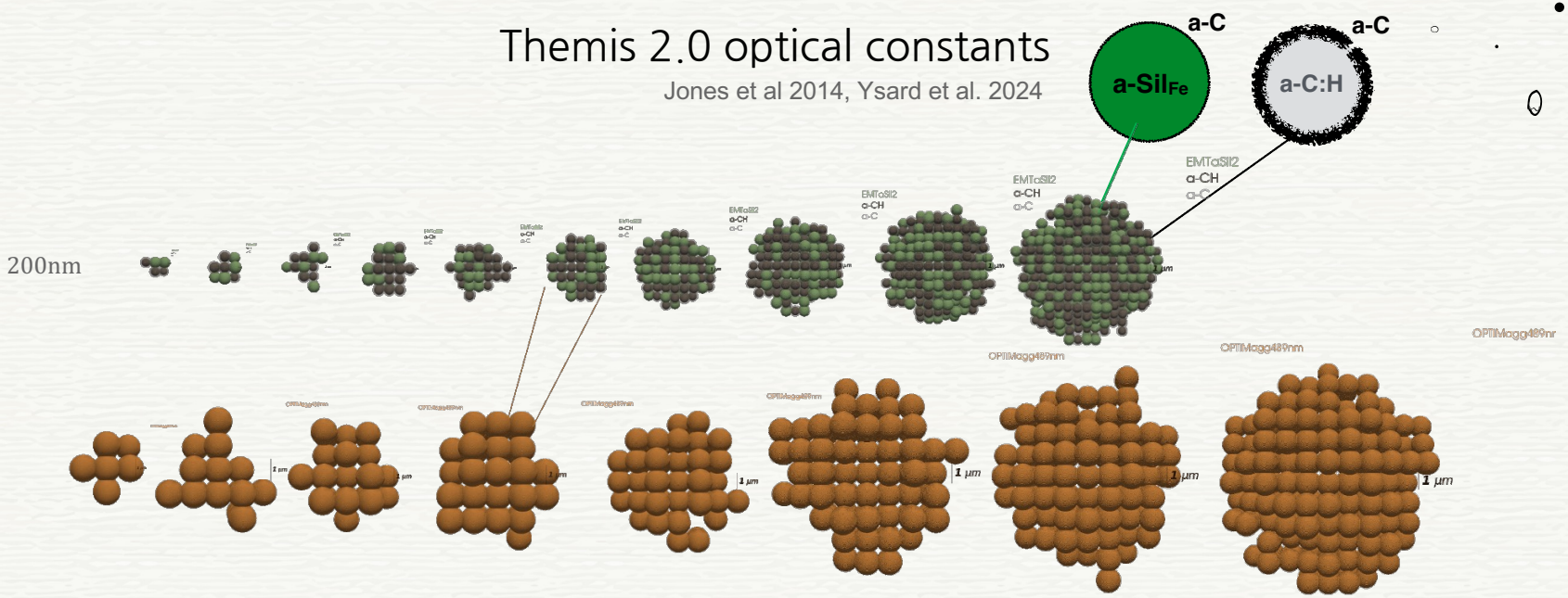
POLARIS

Perspective for complete database of dust aggregates

core/mantle grains (**CM**)

Themis 2.0 optical constants

Jones et al 2014, Ysard et al. 2024



Take home messages

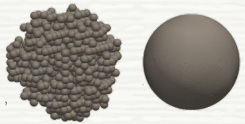
Need for realistic dense medium dust models

Dust optical properties depend on shape, porosity and structure of the grains.

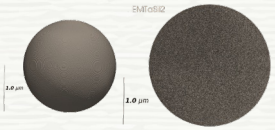
Dust composition will highly impact dust emission properties

New dust models can bring major contribution for interpretation of observations from ALMA, JWST

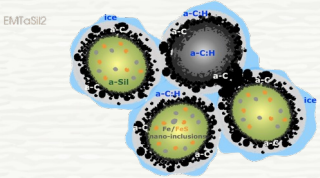
Size (distribution),



Structure,



Porosity,



Composition,

Ice mantle