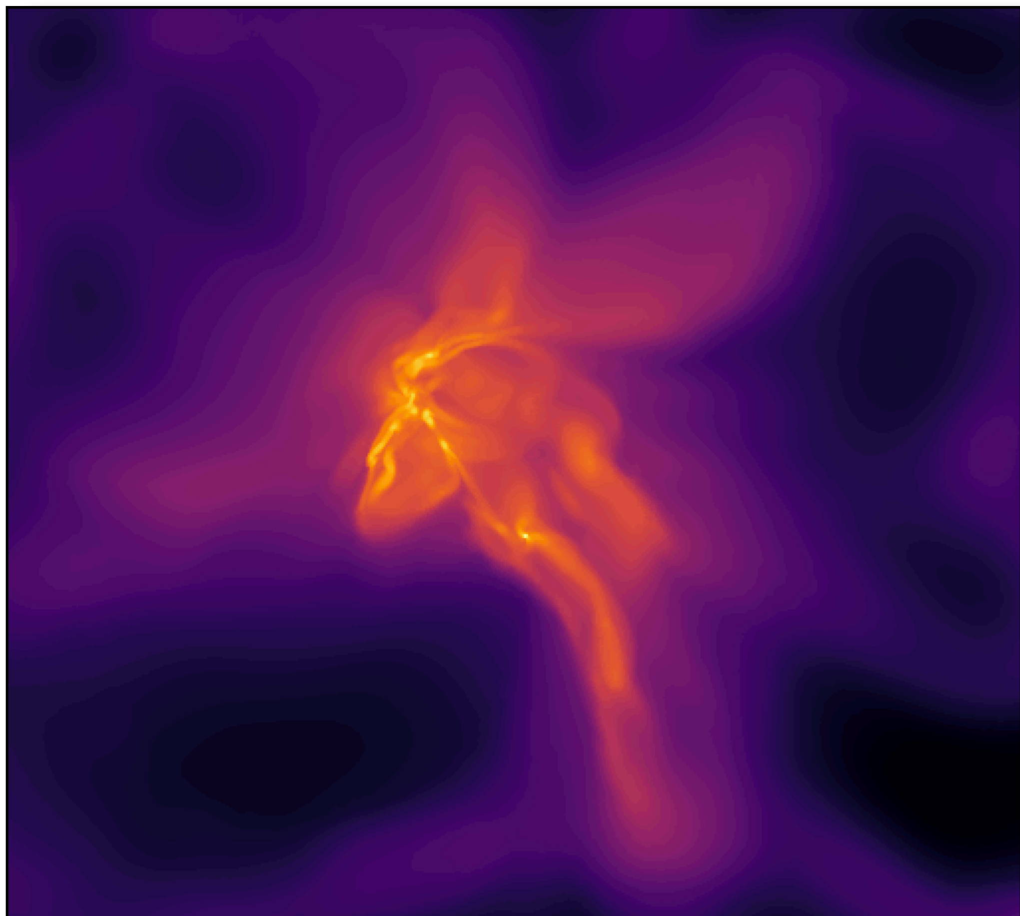
Protoplanetary disks population formation in massive clumps.



Ugo Lebreuilly

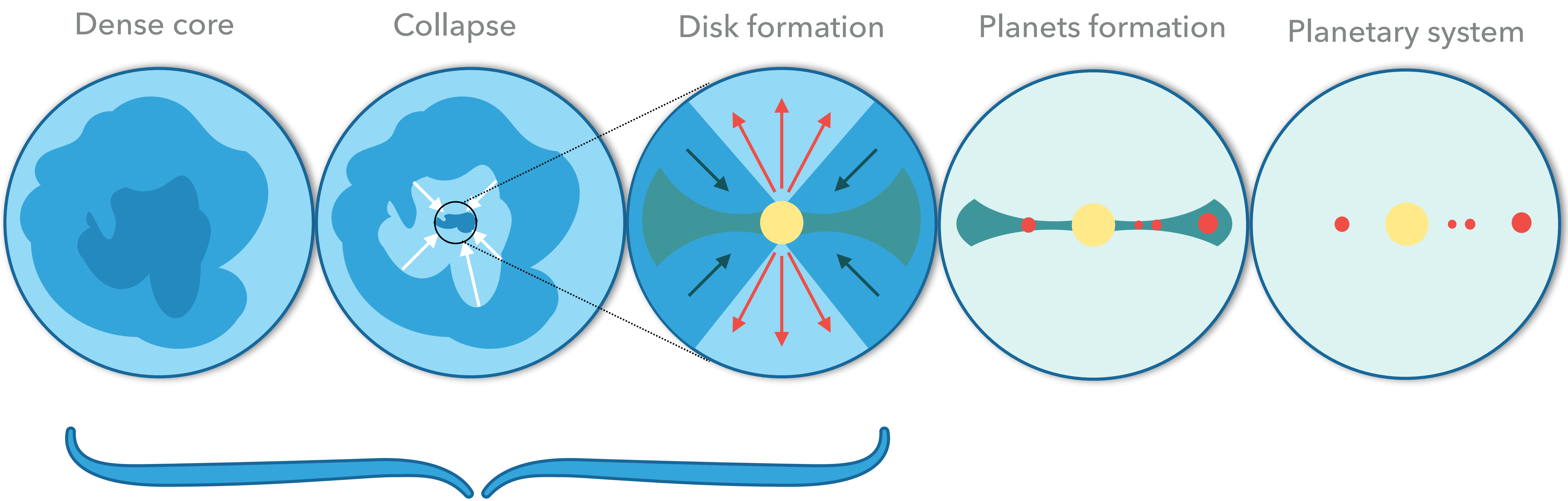
Webpage : https://ulebreui.github.io/

Contact : ugo.lebreuilly(at)cea.fr

RAMSES USER MEETING - 27/09/2021

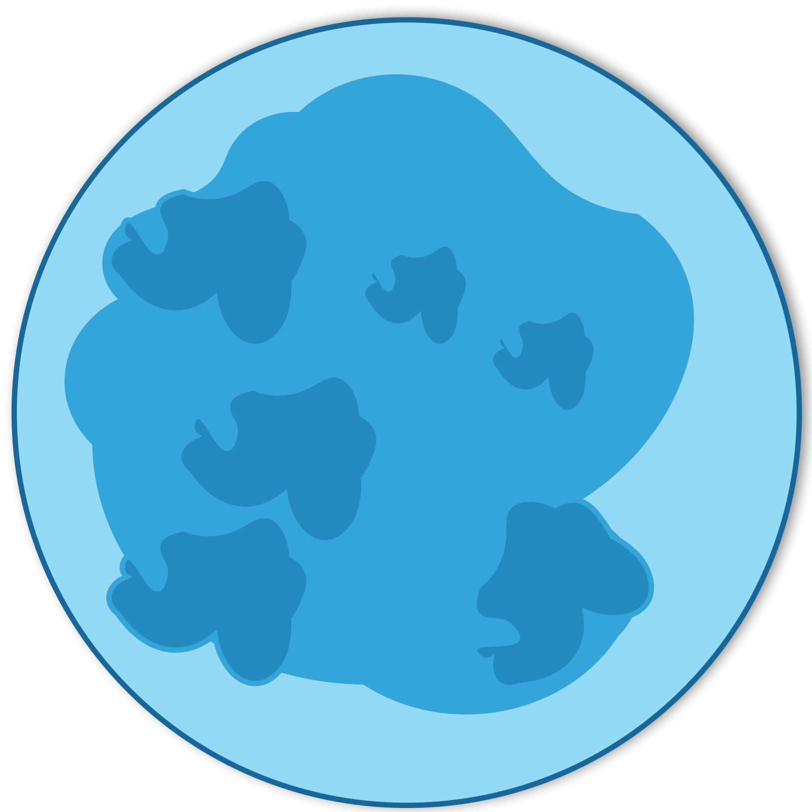
Collaborators :
Tine Colman, Benoît Commerçon, Patrick Hennebelle, Annaëlle Maury, Leonardo Testi, Sergio Molinari & Ralf Klessen

STAR FORMATION (SIMPLIFIED PICTURE)

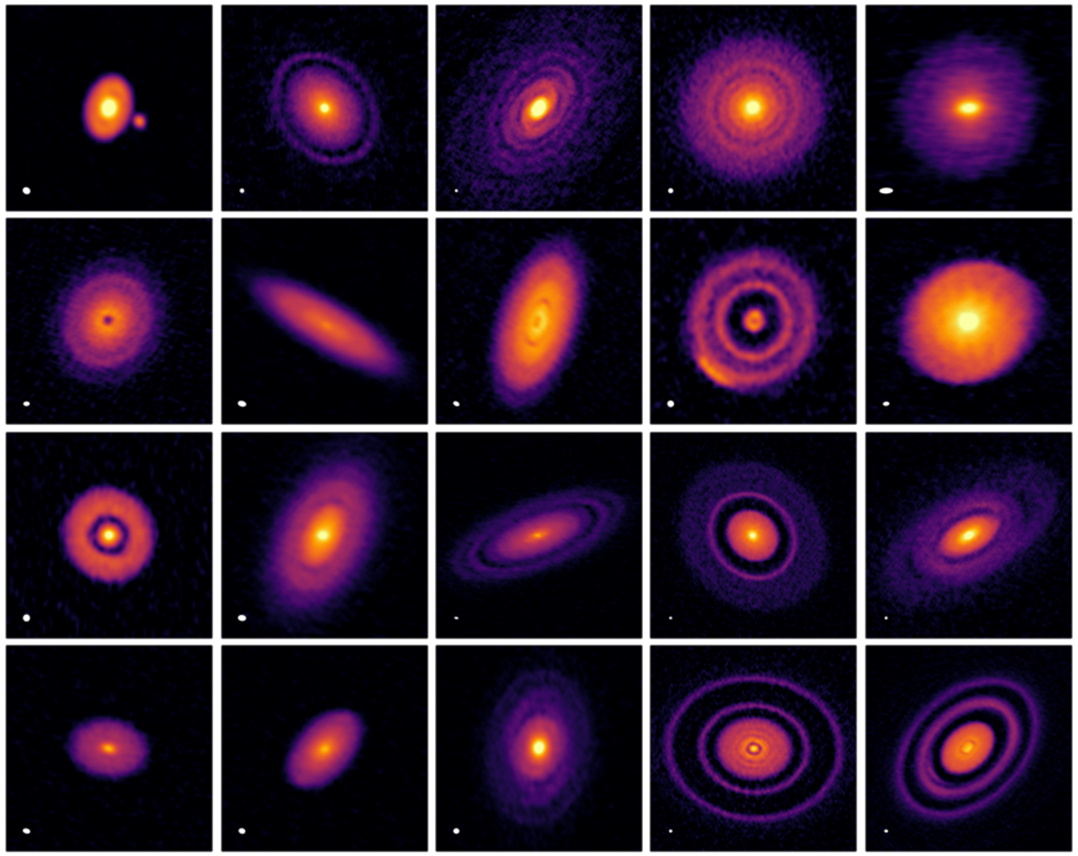


We will focus on the collapse part

.... and try to generalise the picture to star and disk formation in a population.



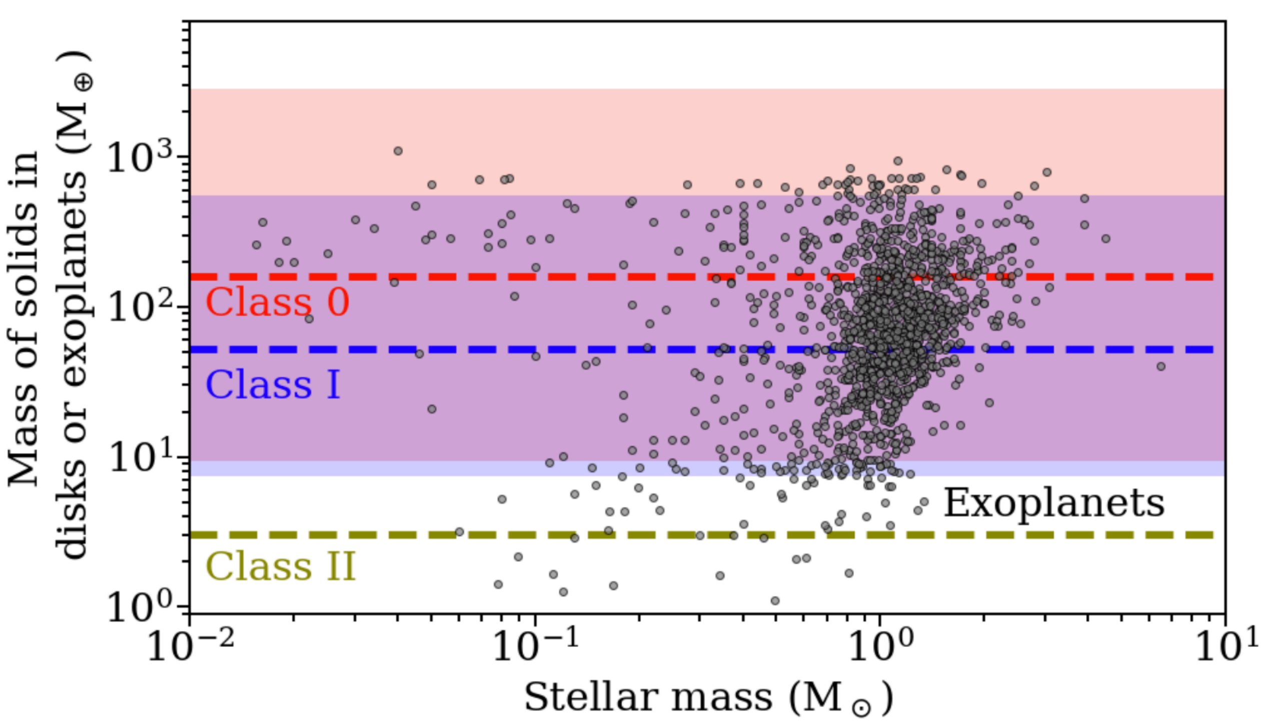
A WIDE DIVERSITY OF DISKS IN REAL LIFE



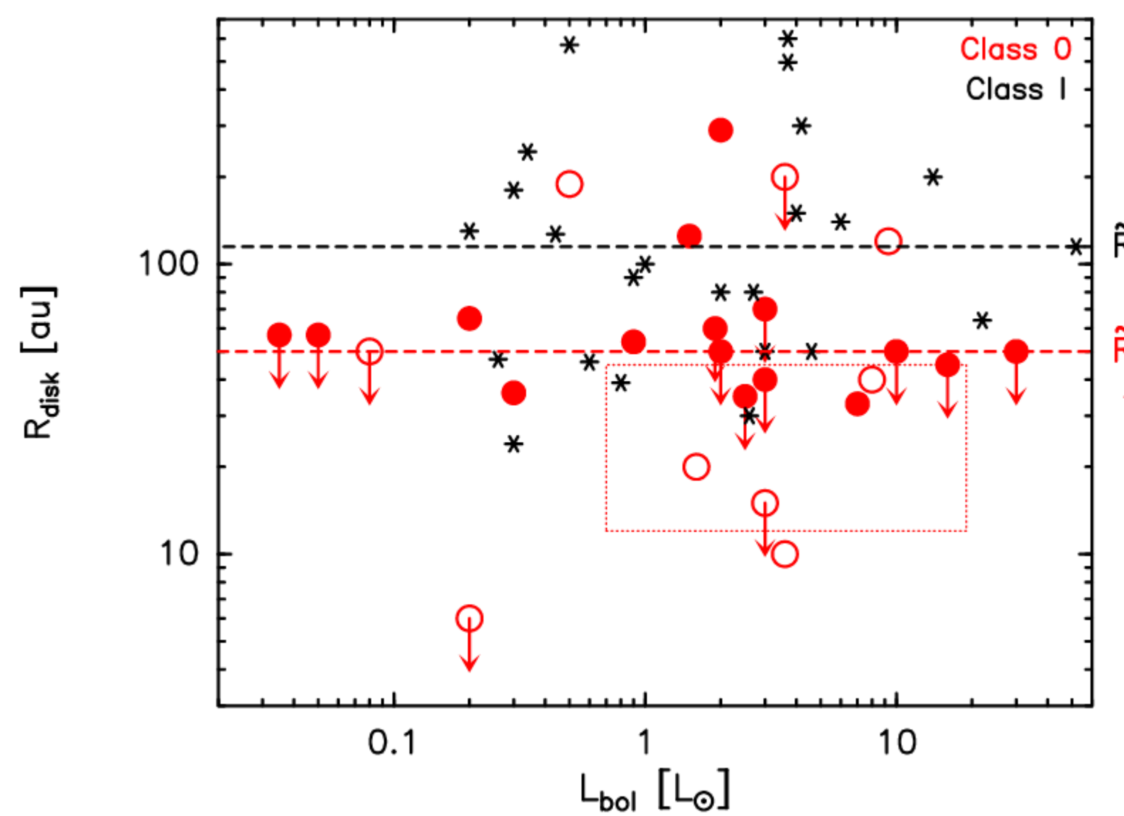
DSHARP survey : Andrews et al., 2018

/!\ These are 'old' class II disks ! /!\

Young Class 0-I disks are still difficult to observe with such resolution but we are beginning to be able to measure their properties statistically (see 2 bottom plots)



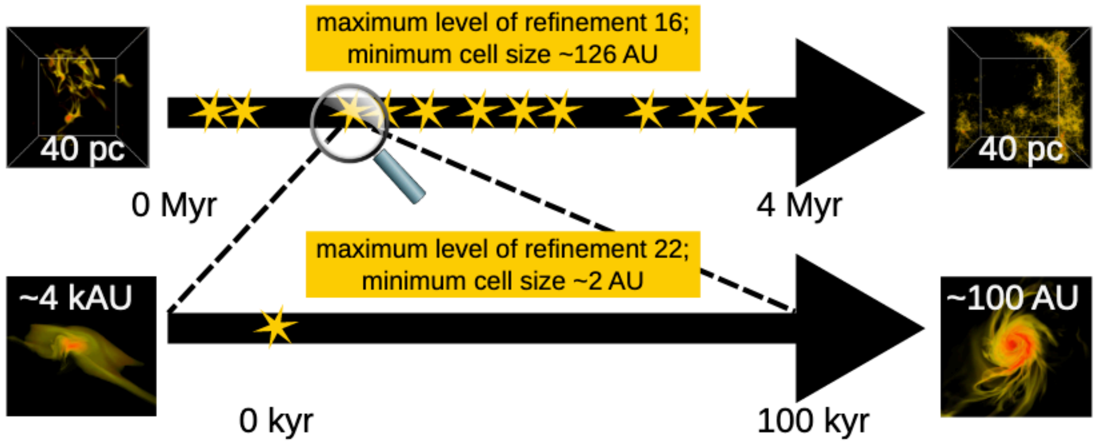
Tychoniec et al., 2020



Calypso: Maury et al., 2019

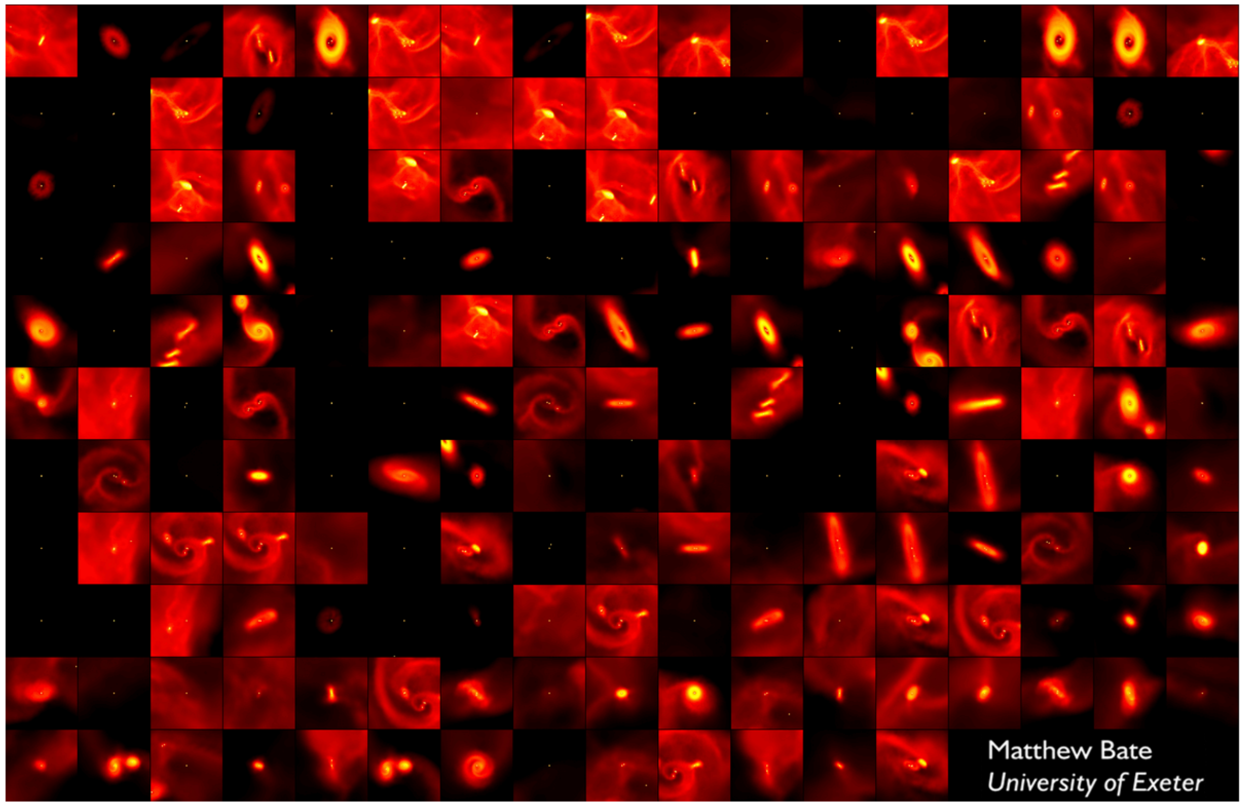
PRIOR STUDIES

Ideal MHD zoom in calculations on a few individual objects (with RAMSES)



Kuffmeier et al., 2017; 2019

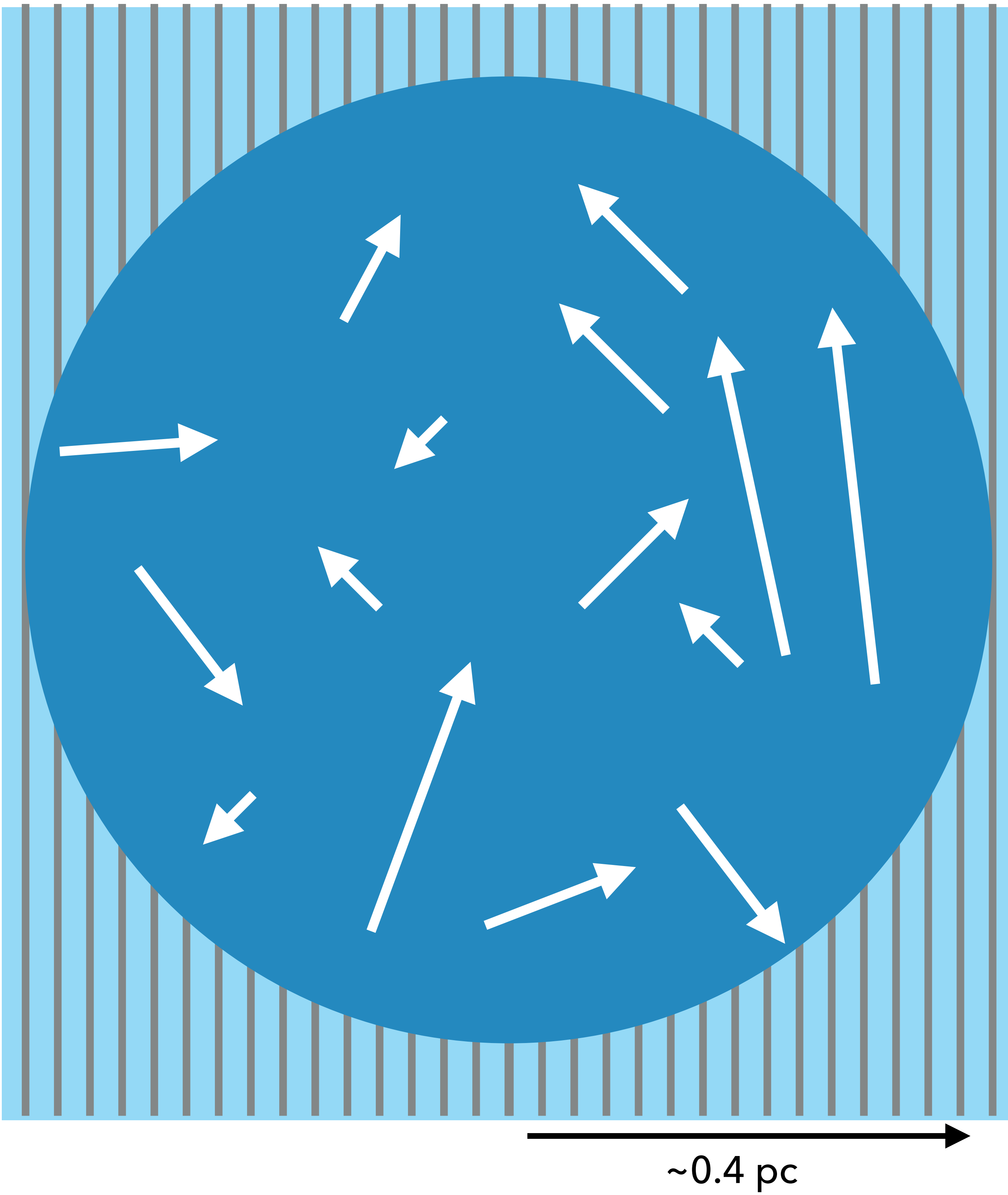
Population formation (without B-field and with SPH)



Bate 2018

STAR FORMING CLUMP COLLAPSE (WITH RAMSES)

Teyssier 2002, Fromang et al., 2006



We use : Sink particles (Bleuler & Teyssier 2014); Non-ideal MHD (Masson et al., 2016); radiation (FLD) (Commerçon et al., 2011); stellar feedback (as in Hennebelle et al., 2020b)

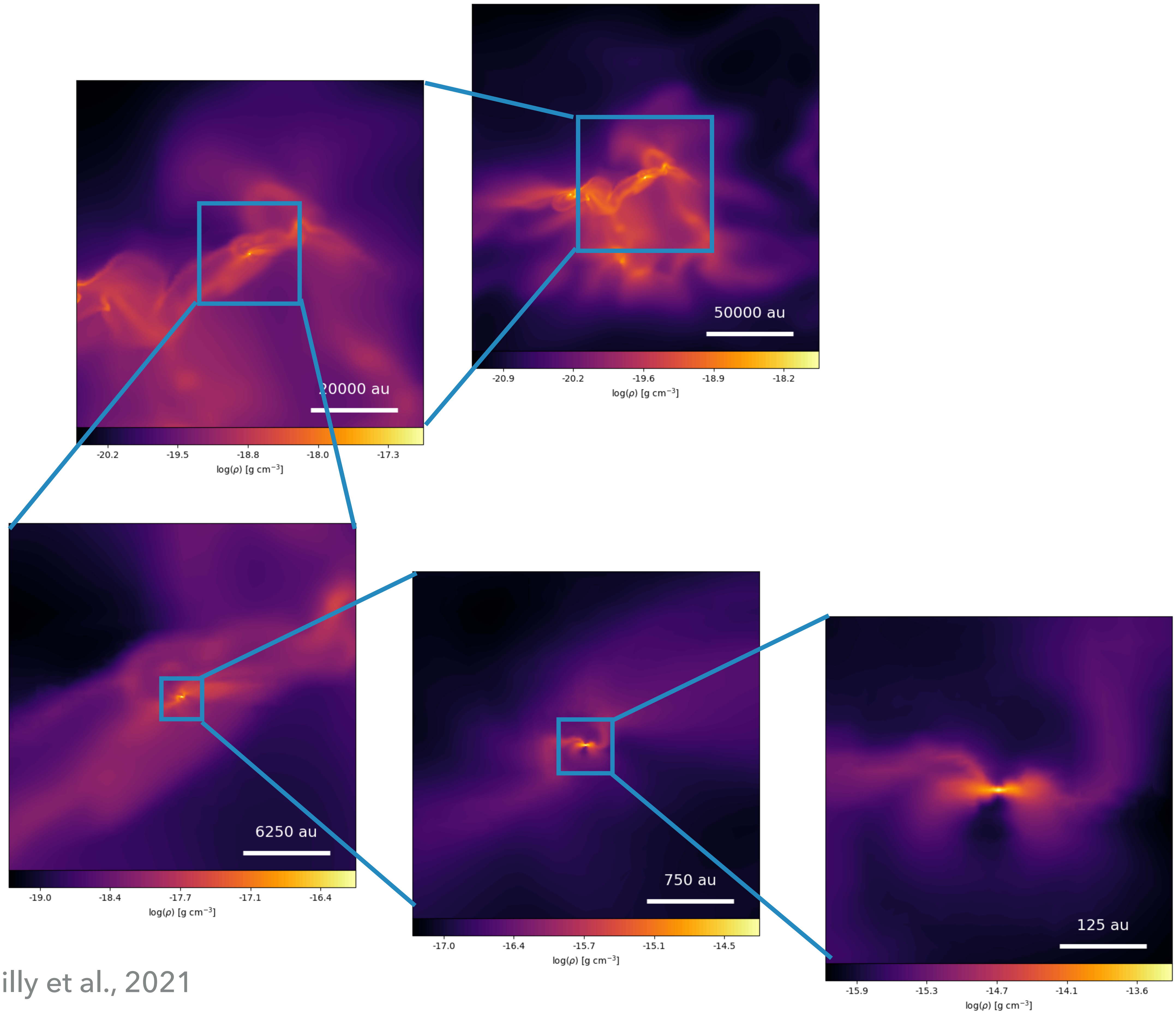
ICs : $1000 M_\odot$, ~0.4 pc cloud, turbulent ICs at Mach 7

3 models :

NIMHD IMHD HYDRO

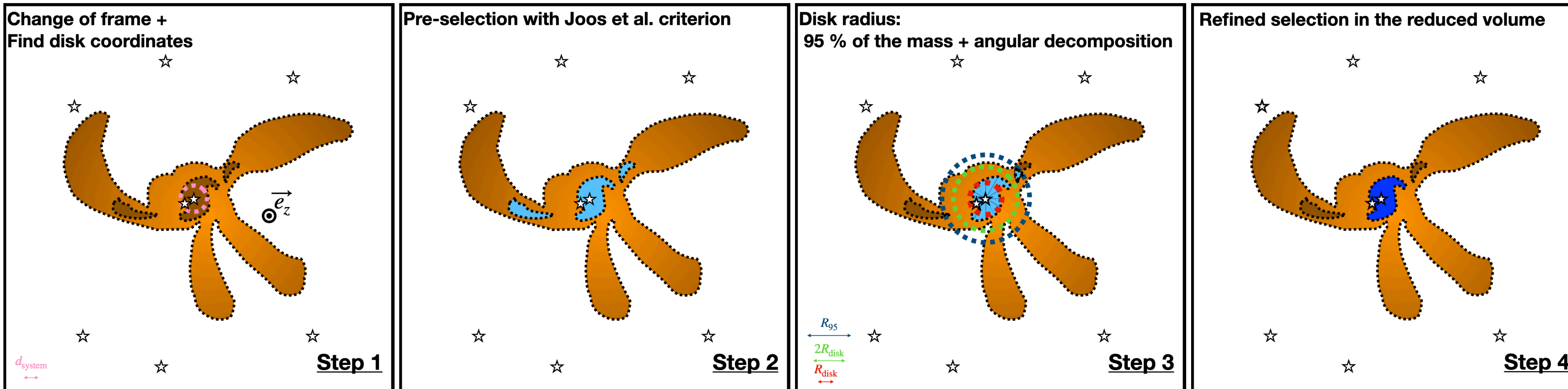
Maximal resolution of ~1 au
11 levels of refinement between low and max res.

FROM THE LARGE PC SCALE DOWN TO THE AU



Lebreuilly et al., 2021

DISK DETECTION



$$v_\phi > 2v_r$$

$$v_\phi > 2v_z$$

$$\frac{1}{2}\rho v_\phi^2 > 2P_{\text{th}}$$

$$n > n_{\text{thre}} = 10^9 \text{ cm}^{-3}$$

Joos et al., 2012

Q : How does that compare with the disk definition in observations ?

Lebreuilly et al., 2021

DISK POPULATIONS

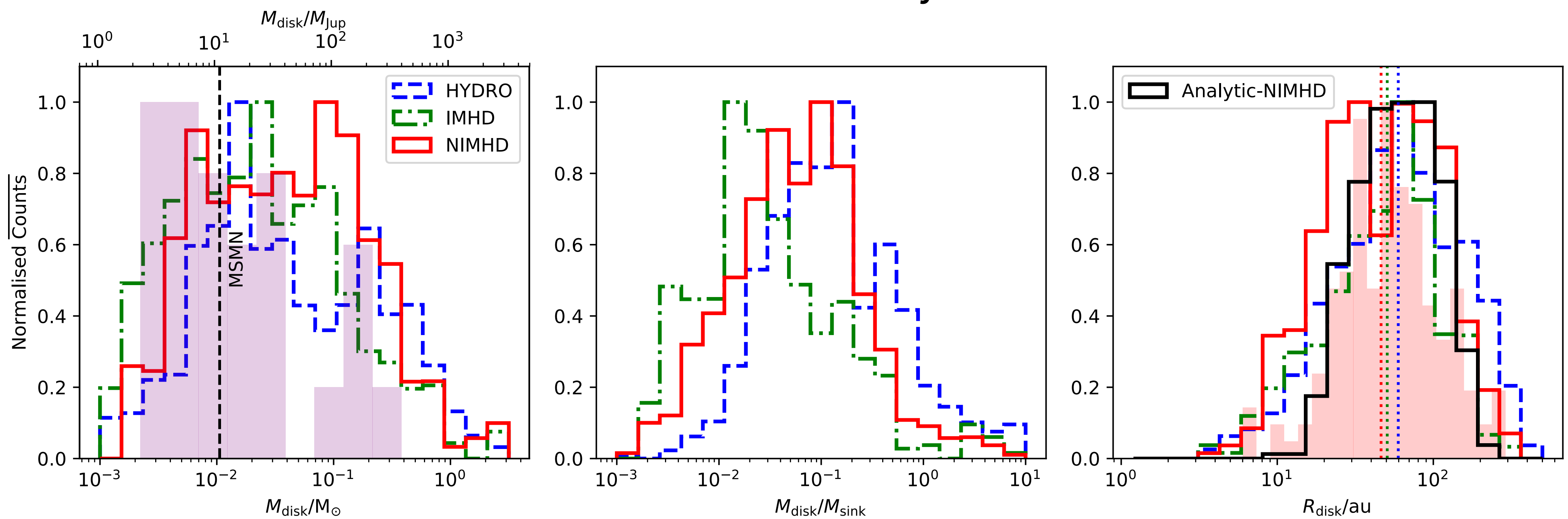
NIMHD IMHD HYDRO

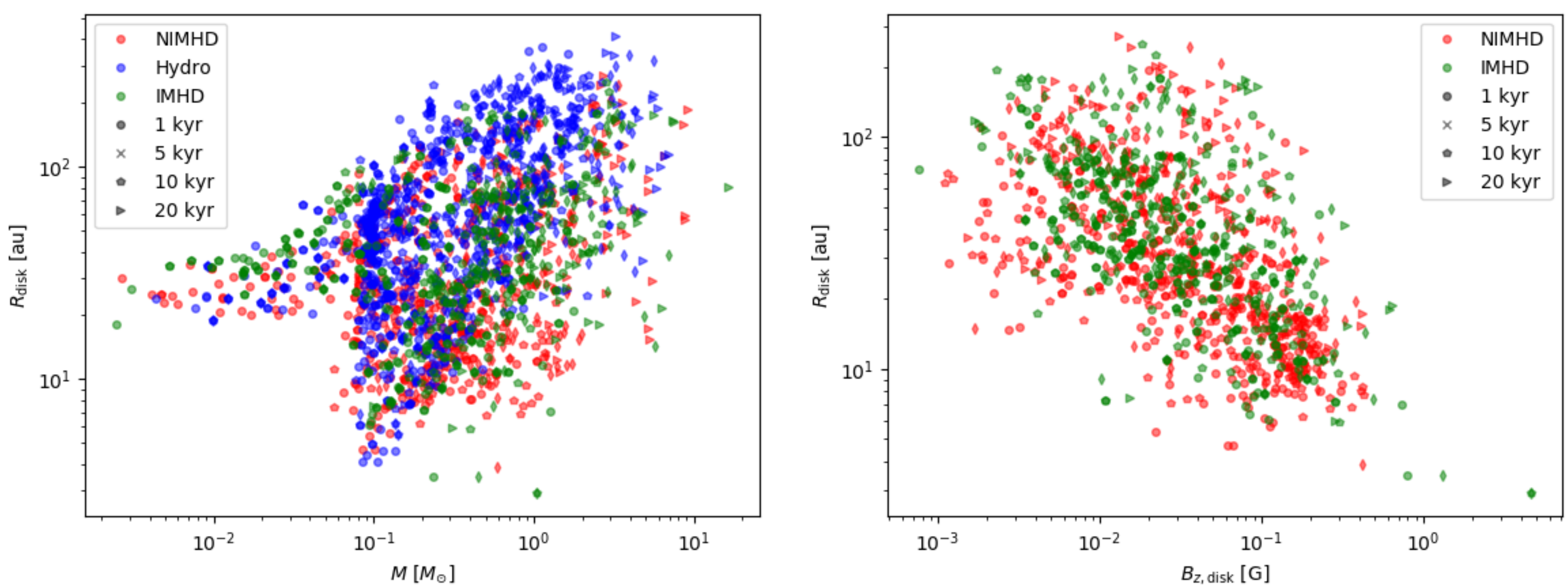
Class 0 Tychoniec et al., 2020

Class 0

Maury et al., 2018 + Tobin et al., 2020

NIMHD : analytical estimate from Hennebelle et al., 2016

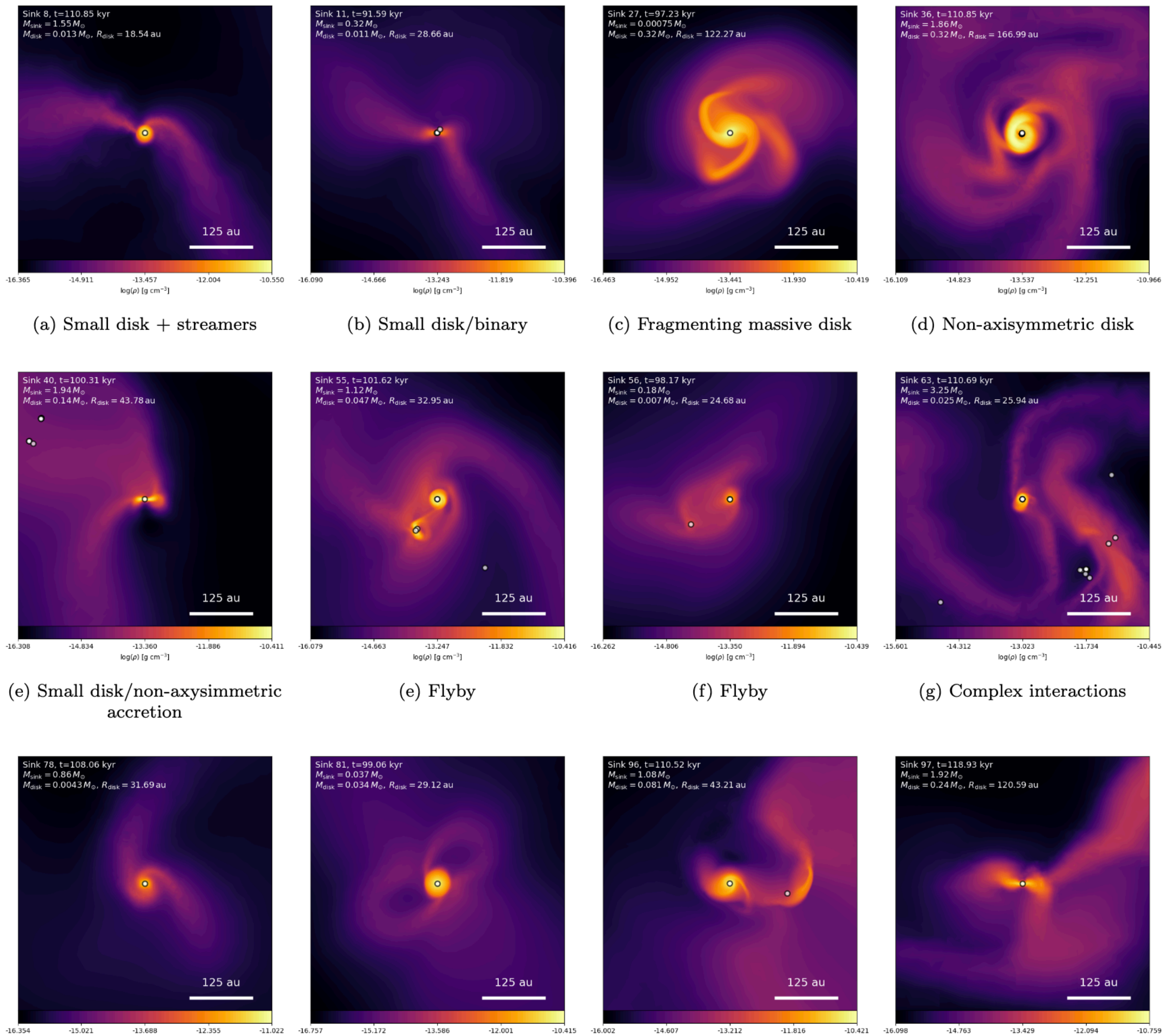




Lebreuilly et al., 2021

A WIDE VARIETY OF DISKS as in real life ?

NIMHD



(a) Small disk + streamers (b) Small disk/binary (c) Fragmenting massive disk (d) Non-axisymmetric disk

(e) Small disk/non-axysimmetric accretion (e) Flyby (f) Flyby (g) Complex interactions

(h) Small disk (i) Interchange instability (j) Flyby (k) Non-axysimmetric accretion

Lebreuilly et al., 2021 & in prep.

TAKE AWAY

What we have

- Disks, as a self-consistent population.
- Magnetic field tends to produce (at least at the time of formation) smaller disks (>50% of the disks are smaller than 50 au)
- <u>Many features:</u> streamers, spirals, flybys, cavities

The catalogues of disks will soon be made available to the public on the Galactica database : http://www.galactica-simulations.eu/db/ (Dr. Damien Chapon)

Snapshots

NIMHD disks a t =102.29 kyr ($t=102.286\ \mathrm{kyr}$)

Disks obtained for the model NIMHD

Catalogs :

- Protoplanetary disk catalog (41 protoplanetary disk objects)

Datafiles:

- Colum density (xz)
- Colum density (xy)
- Histogram B vs density
- Histogram T vs density
- Histogram beta vs density

NIMHD disks a t =103.40 kyr ($t=103.4\ \mathrm{kyr}$)

Disks obtained for the model NIMHD

Catalogs :

- Protoplanetary disk catalog (34 protoplanetary disk objects)

Datafiles:

- Colum density (xz)
- Colum density (xy)
- Histogram B vs density
- Histogram T vs density
- Histogram beta vs density

WHAT'S NEXT?

Challenges :

- We need better statistics: more disks i.e. more massive clouds or longer integration of the clouds.
- We need a better resolution in the disks.
- A wider span of the parameter space
- Synthetic observations of these disks (PHD thesis of Ngo Duy Tung, Dir Pr. Testi and Pr. Hennebelle)