The chemo-dynamical simulations of molecular cloud collapse: why dust properties define the size of circustellar disks.

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The bumpy path from star birth to planets

2*10^6 yrs

Star formation stages:

Fragmentation of large gravo-turbulent cloud („pillars of creation“)

Blob collapses to the first core →
second core collapse →
flattened disk forms – OR NOT?

10^5 yrs

10^7 yrs

Planet formation:

Gas and dust material is processed:
→ accretion of matter on star
→ material loss through winds → [… very long story …]
→ Growth of dust, pebbles, planetesimals
→ Debris disk

Circumstellar disk formation:
(1) Observations of Class 0 disks within 500 pc

From over 4800 'nearby' YSOs,

there are 4 known Class 0 YSOs with <u>rotationally-supported</u> disks:

	M_central	M_disk	M_env	R_disk
L 1527 **VLA 1623A** **RCrA IRS7B** **HH212 MMS**	0.2M☼	0.02M☼	1M☼	50AU

(Tobin+ 2012, Murillo+ 2013,
Codella+ 2014, Lindberg+ 2014)

2 more candidates (ALMA, VLA):

L 1448 IRS2
Rer-emb-14

(Perseus cloud, *Tobin+ 2015*)

75 % infant disks are small or undetectable: R ≤ 10 AU !

Circumstellar disk formation:
(2) Collapse simulations

Physics in collapse simulations:

hydro-dynamics (HD)
+ radiative transfer (RHD)
+ magnetic fields (RMHD)

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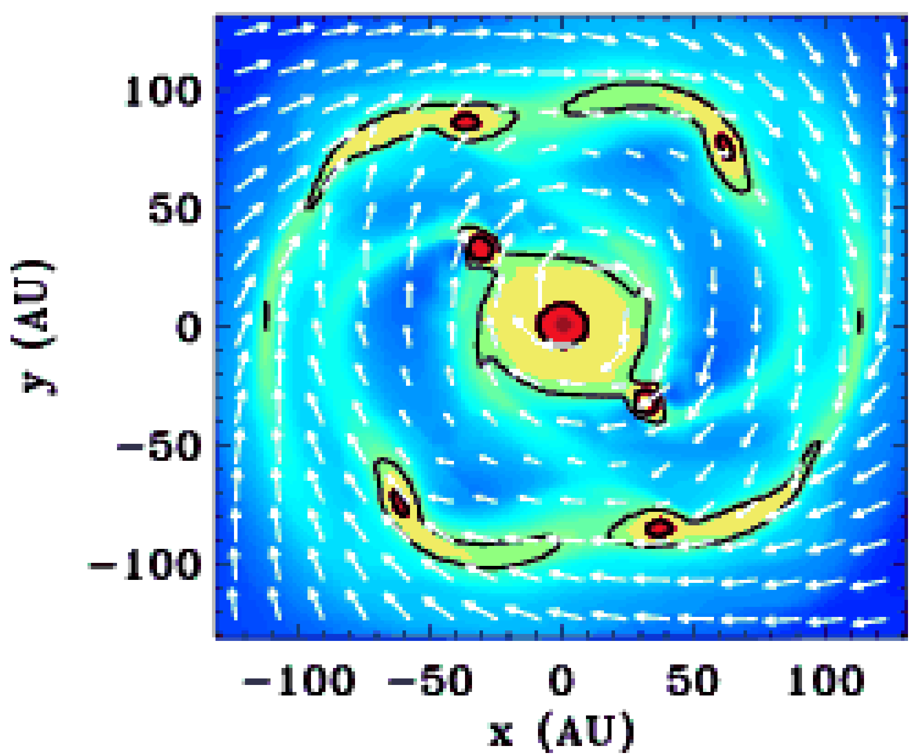
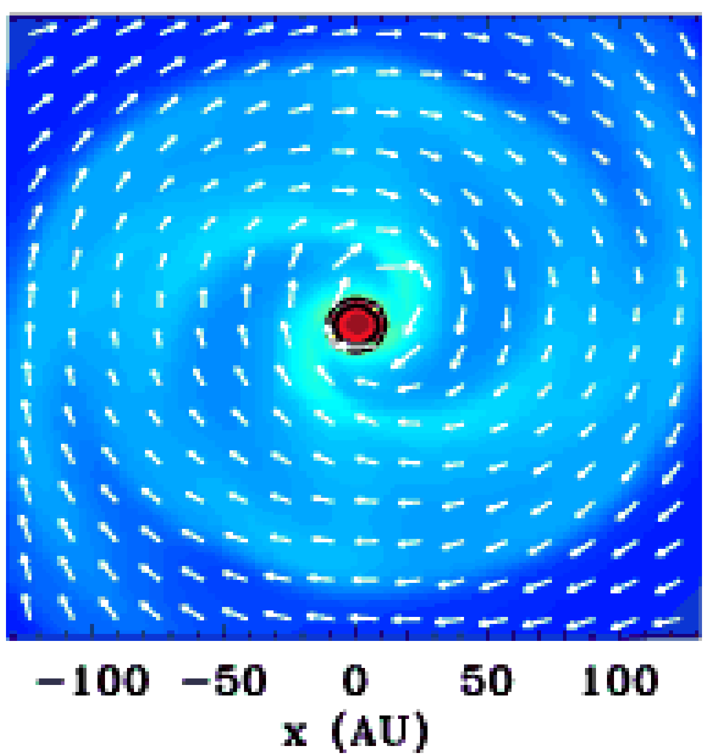
a) RHD collapse of isolated cloud

b) Magnetic braking
Catastrophe: *Commercon+ 2008*





Circumstellar disk formation:
(2) Collapse simulations

Physics in collapse simulations:

hydro-dynamics (HD)
+ radiative transfer (RHD)
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c) RMHD + magnetic dissipation terms:

Ohmic (RMHD + OD)
Ambipolar (RMHD + AD)
Hall effect (RMHD + HE)

Magnetic dissipation effect → to reduce magnetic flux

Circumstellar disk formation:
(2) Collapse simulations

RMHD +OD	***RMHD+OD+AD***	***RMHD+OD+AD+HE***
Dapp & Basu 2010 (*etc.*) Machida+ 2007 Tomida+ 2017	Tomida+ 2012 Masson+ 2016 Tsukamoto+ 2015a Zhao+ 2017	Tsukamoto+2015c
Resulting disks:		
1 -- 5 AU	***1 – 20 AU***	***1 – 10 AU***

Disagreements are due to : ***- inputs to adopted chemistry / ionization ;***
- numerical issues.

Chemo-dynamical model of collapsing cloud:

Codes: **RAMSES (AMR , R-HD) + PDS code (chemistry) merged;**

Basic grid: 64^3,
10 levels of mesh refinement

Domain:

4.d+4 AU, 1 M☼, T=10K
E_th/E_grav=0.44
n_c = 4.4d+5 cm^3

Aims *Part I:*

*P*arameter study (core size, free-fall time, dust size) for chemistry,
arXiv:1605.08032;

Part II:

How the magnetic dissipation depends on mean dust size in the cloud?

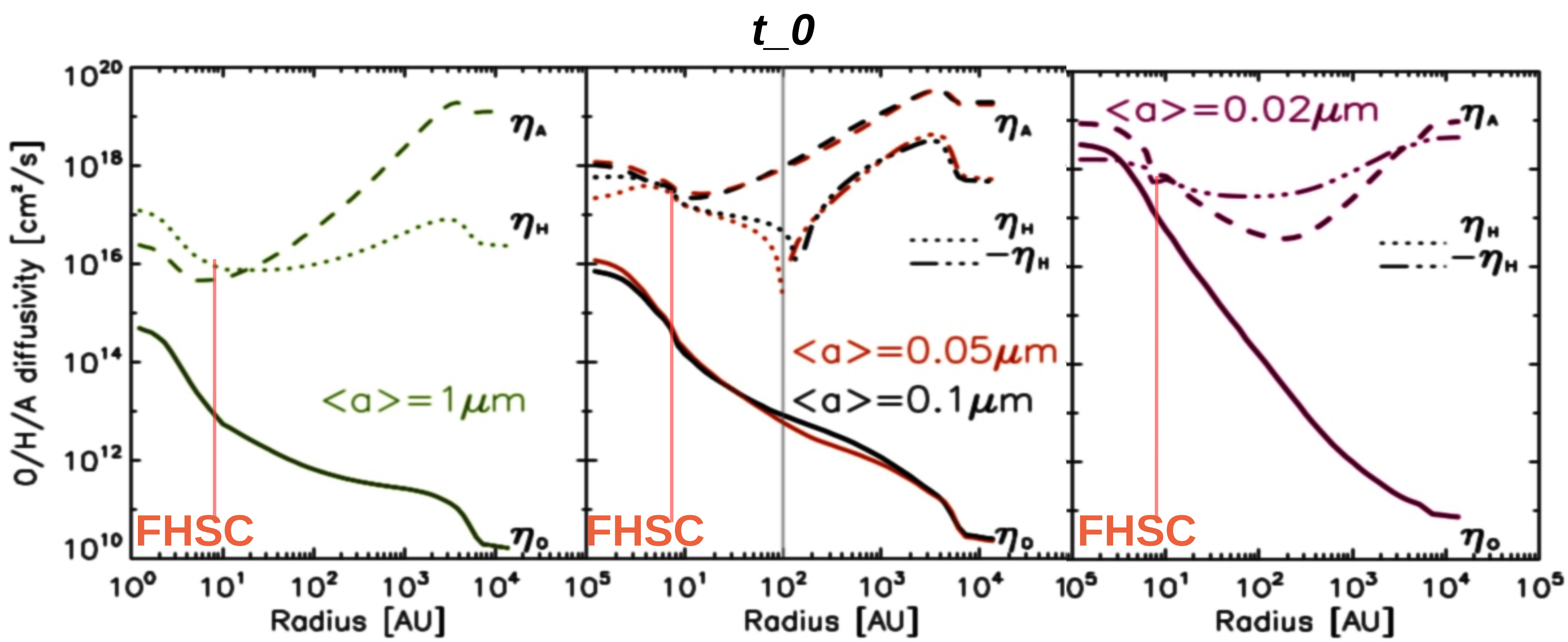
arXiv:1702.05688

The ParisDurhamShock code merged in RAMSES: The network of H–C–O & metals

Table 1: Chemical species.

Neutral species														
H	H_2	He	C	CH	CH_2	CH_3	CH_4	O	O_2	OH	H_2O	CO	CO_2	Fe
Ionized species														
H^+	H_2^+	H_3^+	He^+	C^+	CH^+	CH_2^+	CH_3^+	CH_4^+	CH_5^+	O^+	O_2^+	OH^+	H_2O^+	H_3O^+
CO^+	HCO^+	Fe^+												
Core species														
O^{**}	Si^{**}	Mg^{**}	Fe^{**}	C^{**}										
Mantle species														
C^*	CH^*	CH_2^*	CH_3^*	CH_4^*	CO^*	CO_2^*	Fe^*	H_2O^*	O^*	O_2^*	OH^*	H^*	H_2^*	He^*
Grains														
G	G^+	G^-												

Chemo-dynamical model of collapsing cloud:



<u>Large dust:</u>

- η_H and η_A are low

<u>Intermediate dust sizes:</u>

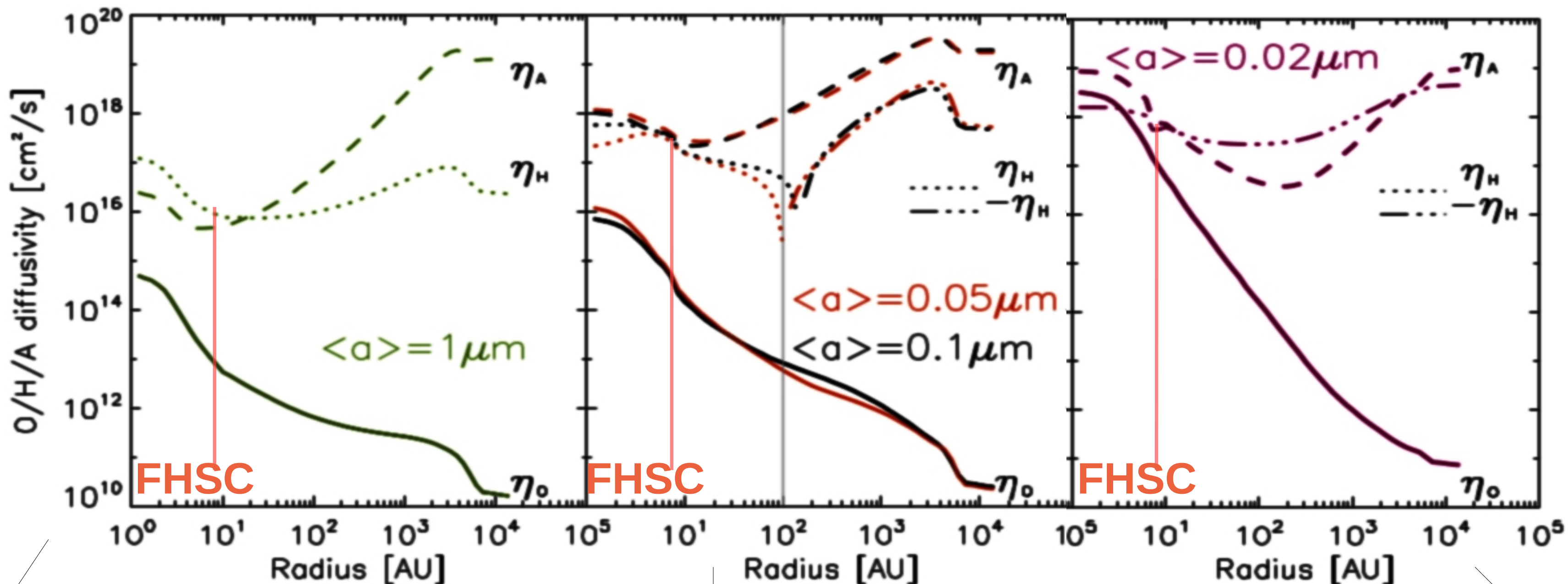
- η_A is high, dominates at all radii

<u>Tiny dust:</u>

- η_H dominates large radial domain outside of FHSC

Chemo-dynamical model of collapsing cloud:

t_0



NO disks !

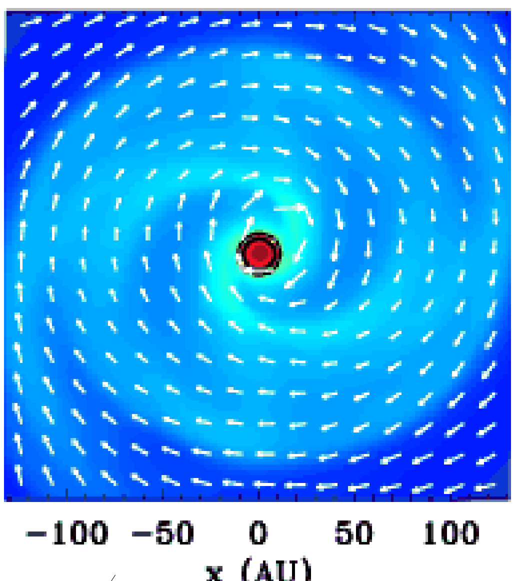
18-20 AU disk

growing / failing

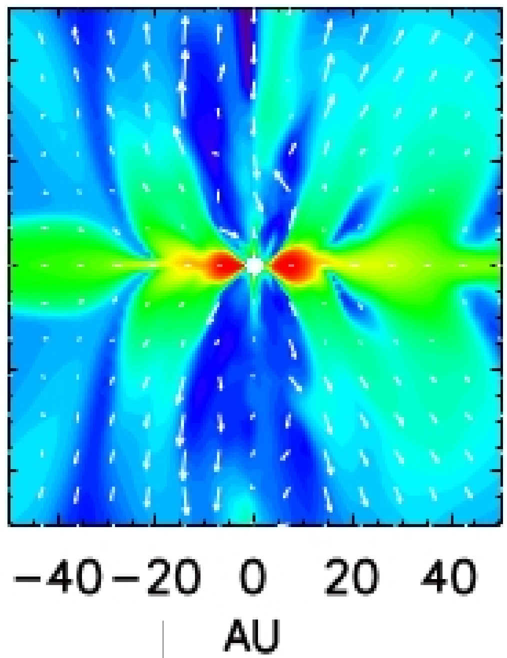
Tiny Disk
(< 10AU)
+
Counter-rotating envelope

Comparing to previous models of collapsing cloud:

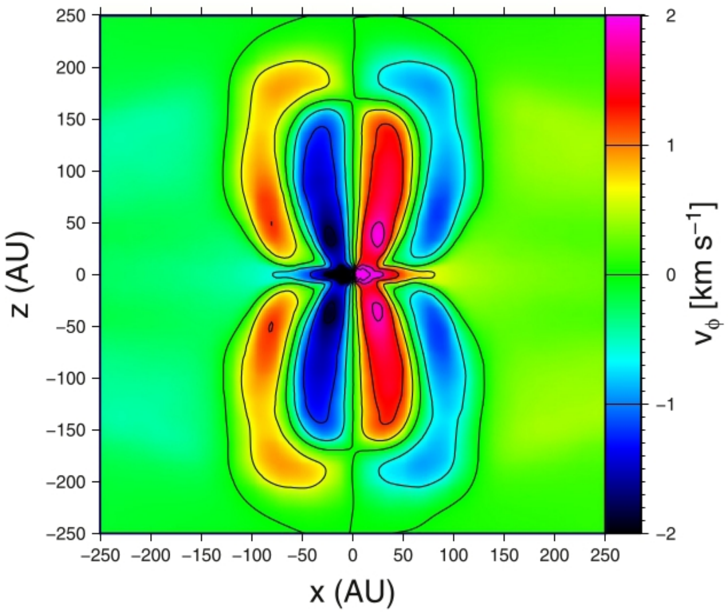
Commercon+ 2008



Zhao+ 2017



Tsukamoto+ 2015



<a> ≥ 1μm

NO disks !

18-20 AU disk

growing / failing

<a> ≤ 0.02 μm

Tiny Disk
(~ 10AU)
+
Counter-rotating envelope

Class 0 disks as initial condition for Proto-Planetary Disks

- **Large diversity already in Class 0 disks !**

- ***We propose:***

  dust size measurements *for Class 0 objects with disks (or disk candidates) to* ***probe the link between dust size and disk radius!***