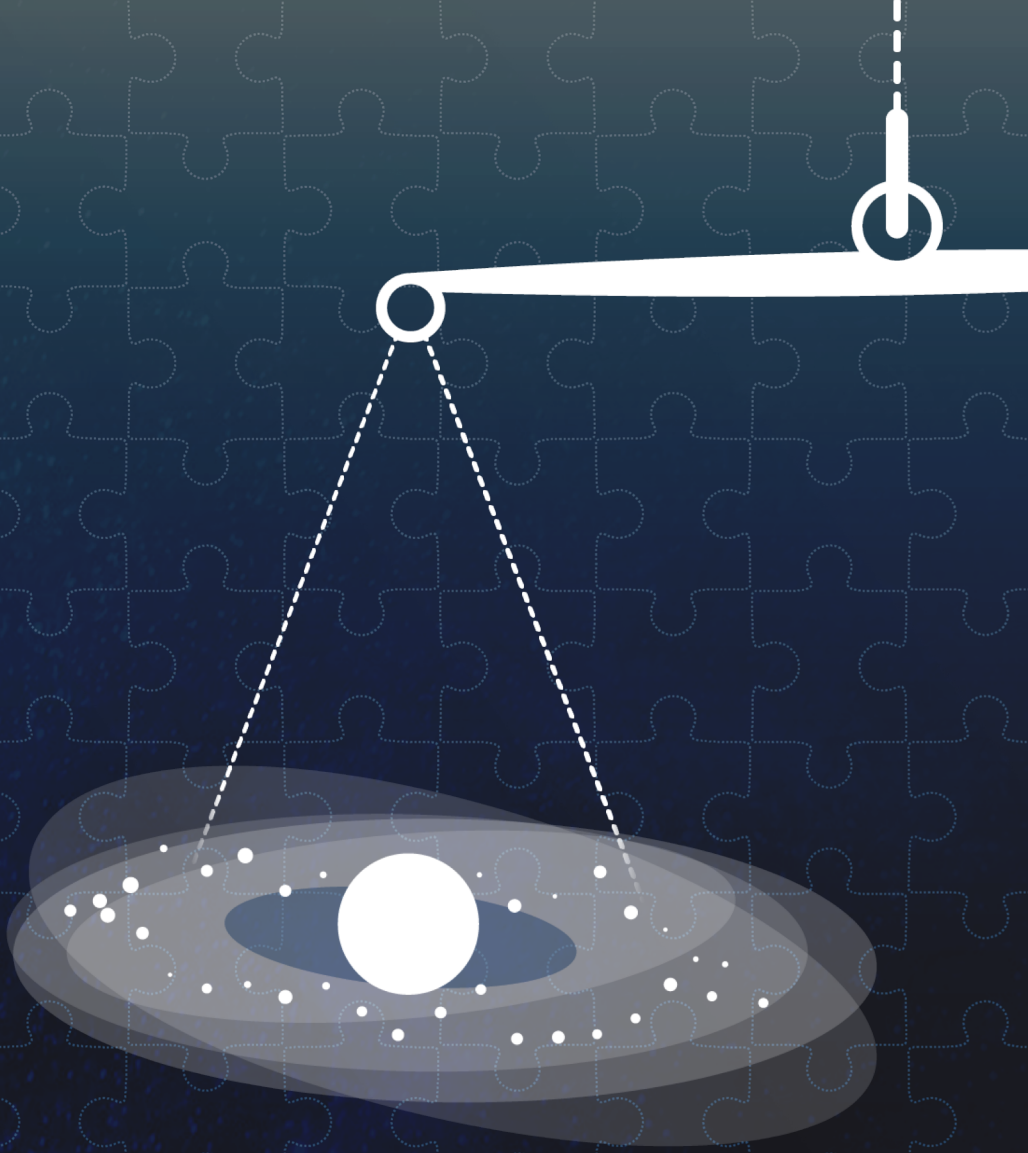
Gas & Dust

IN PROTOPLANETARY DISKS

Anna Miotello
ESO Fellow

ESO :	L. Testi
	C. F. Manara
	Hsi-Wei Yen
MPE :	S. Facchini
	P. Cazzoletti
	S. Bruderer
INAF :	J. M. Alcalá
	G. Guidi
	C. Codella
Leiden:	E. F. van Dishoeck
	L. Trapman
	S. van Terwisga
	M. Hogerheijde
IfA :	J. P. Williams
UCB:	M. Ansdell
IoA :	M. Tazzari
IPAG:	M. De Simone
DIAS :	A. Natta



Gas

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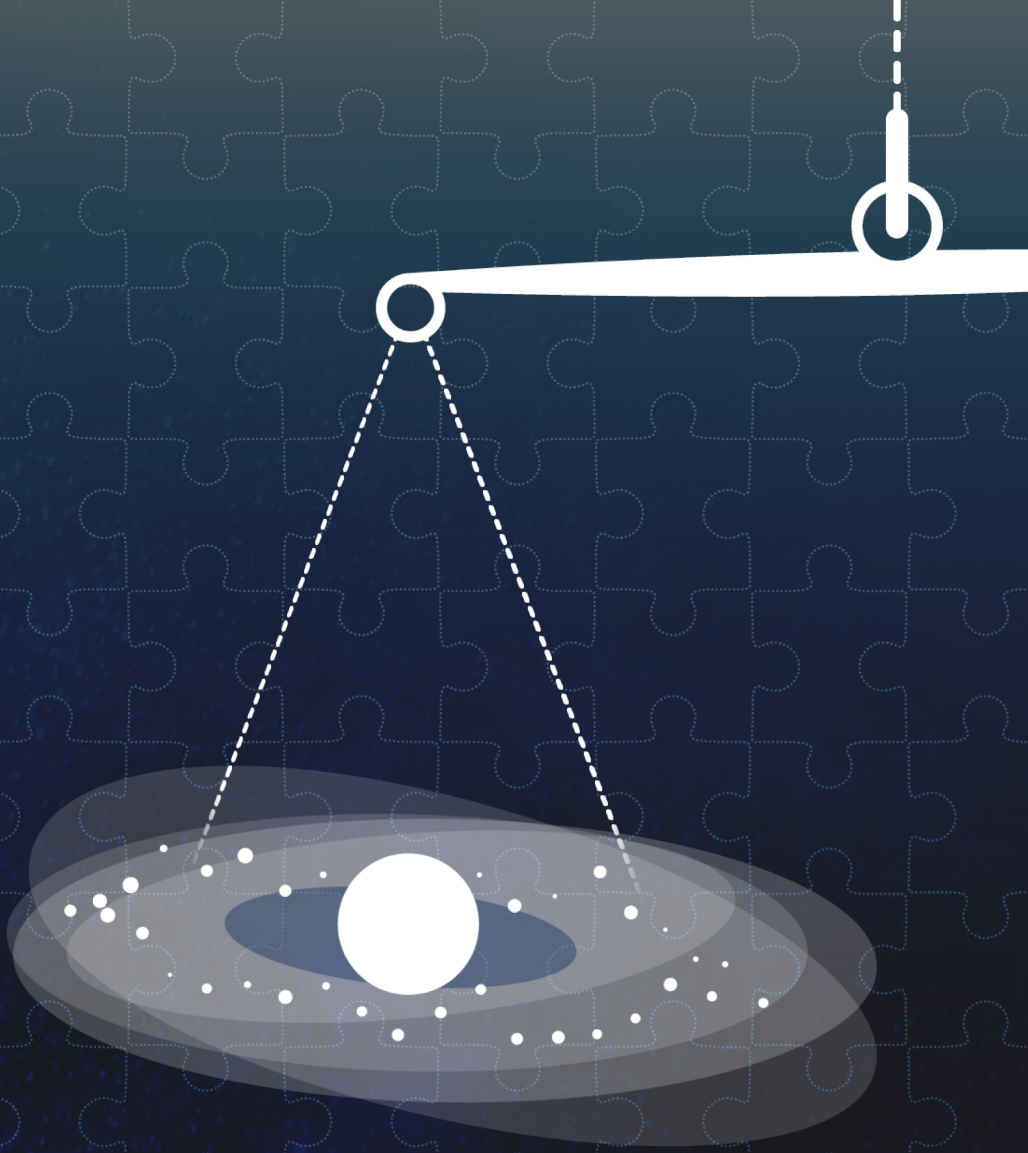
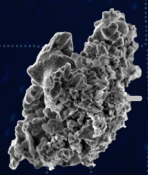
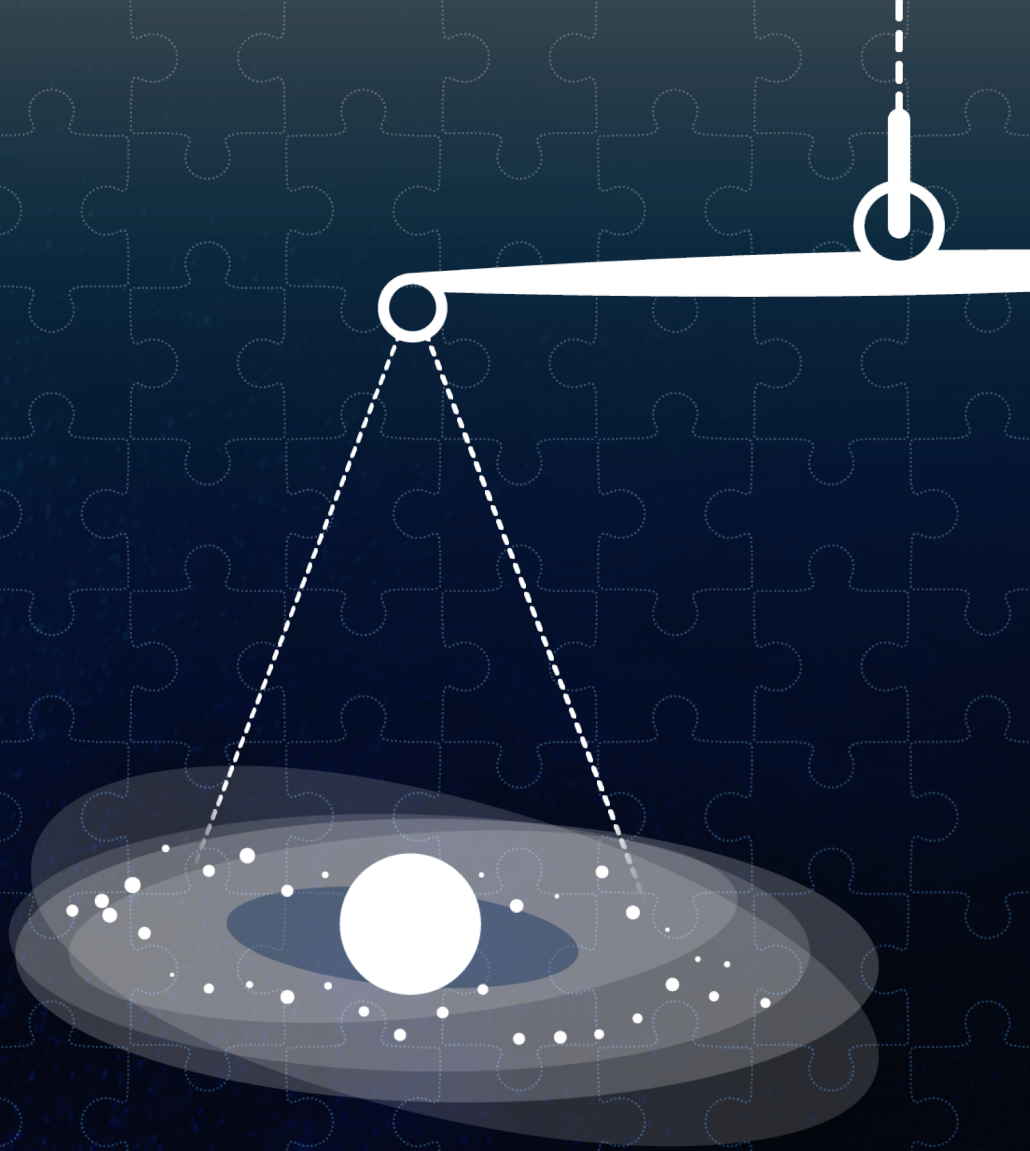


PROTOPLANETARY DISK

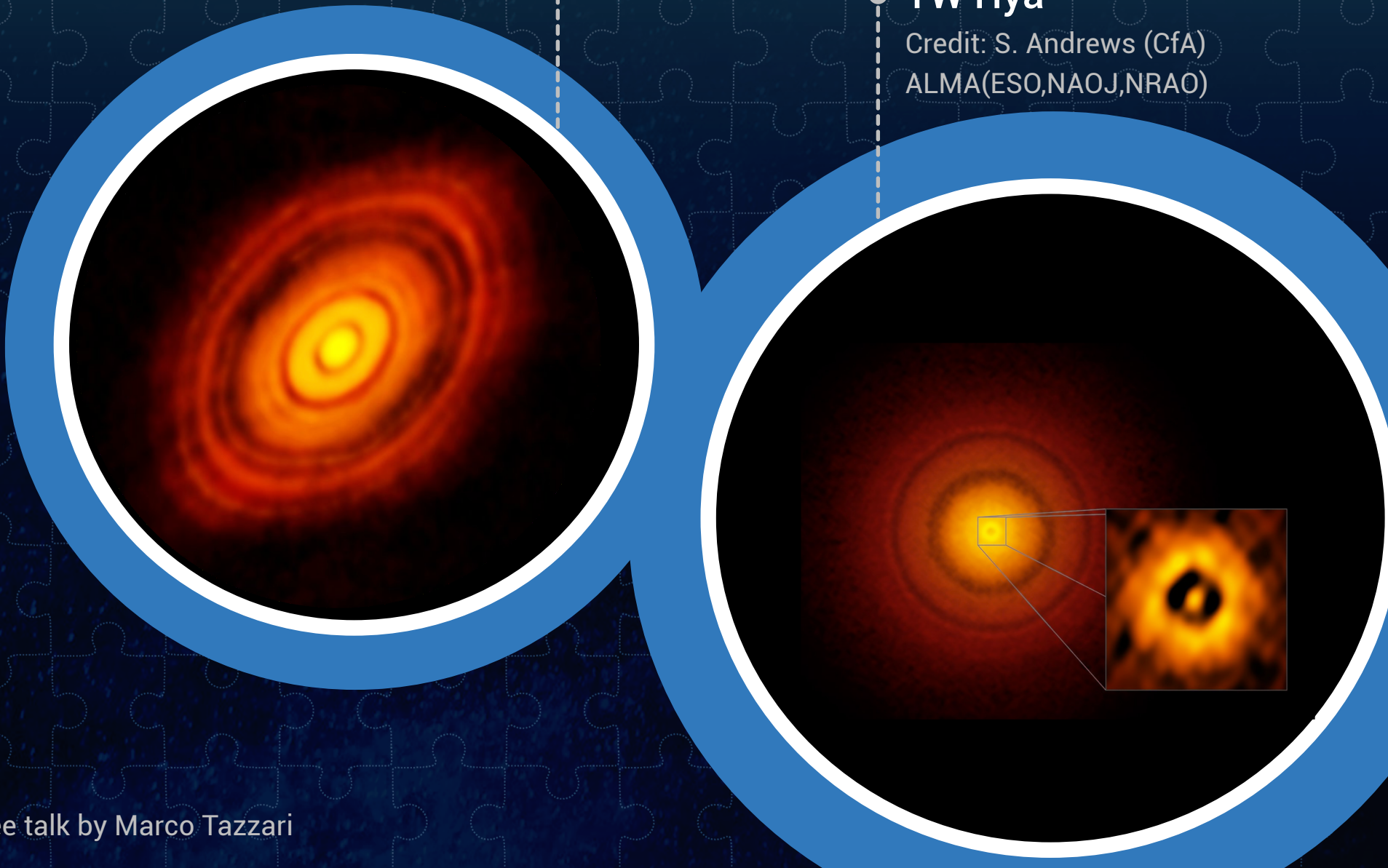


DUST
1%

GAS
99%



DUST DISTRIBUTION



HL Tau

Credit: ALMA(ESO,NAOJ,NRAO)

TW Hya

Credit: S. Andrews (CfA)
ALMA(ESO,NAOJ,NRAO)

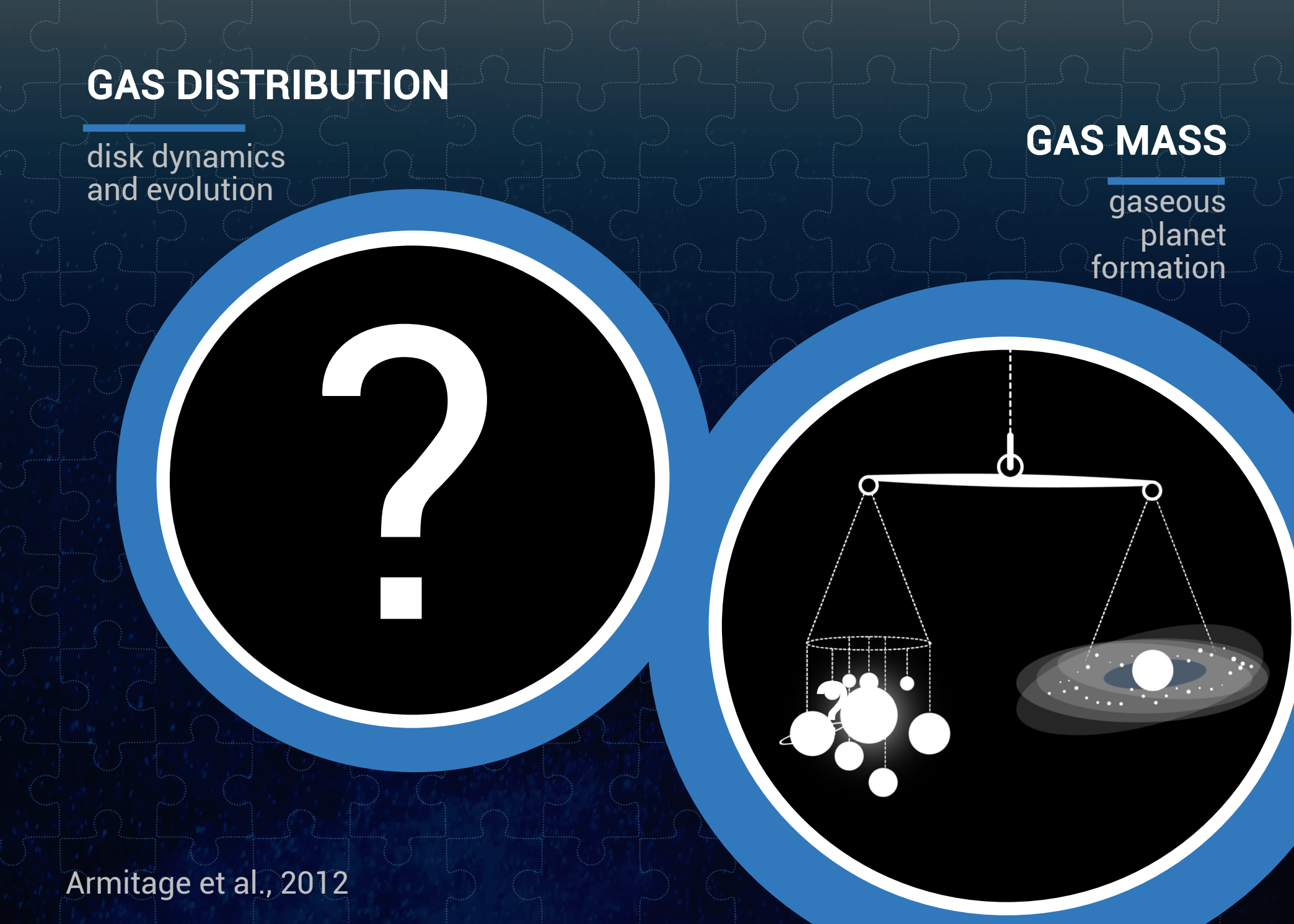
See talk by Marco Tazzari

GAS DISTRIBUTION

disk dynamics
and evolution

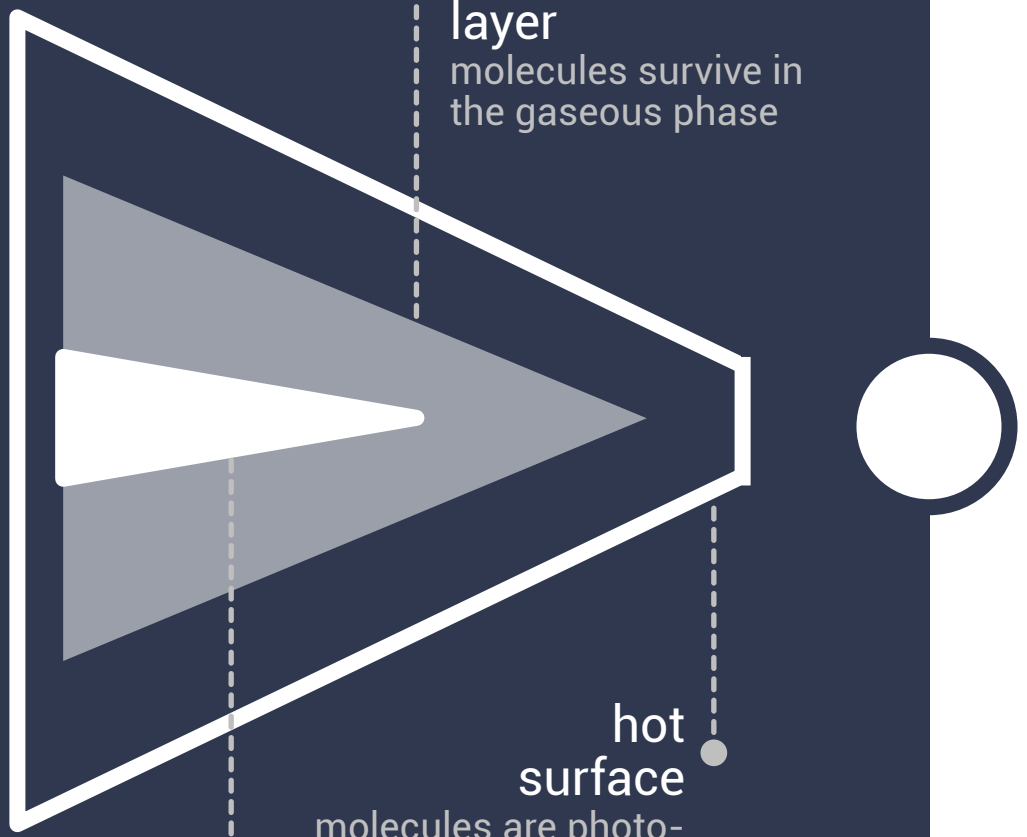
GAS MASS

gaseous
planet
formation

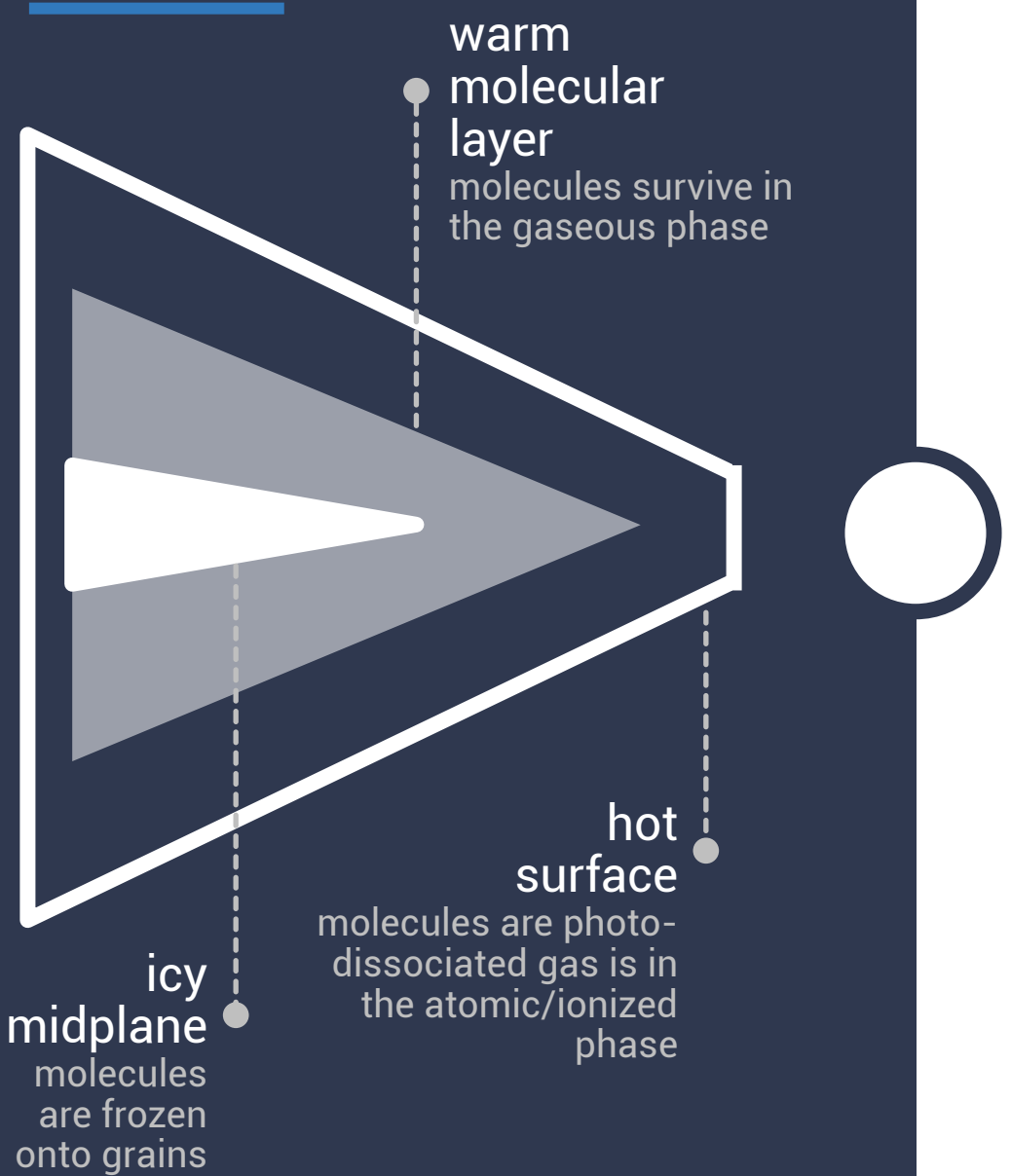


Armitage et al., 2012

BULK GAS


warm
molecular
layer
molecules survive in
the gaseous phase
hot
surface
molecules are photo-
dissociated gas is in
the atomic/ionized
phase
icy
midplane
molecules
are frozen
onto grains

BULK GAS

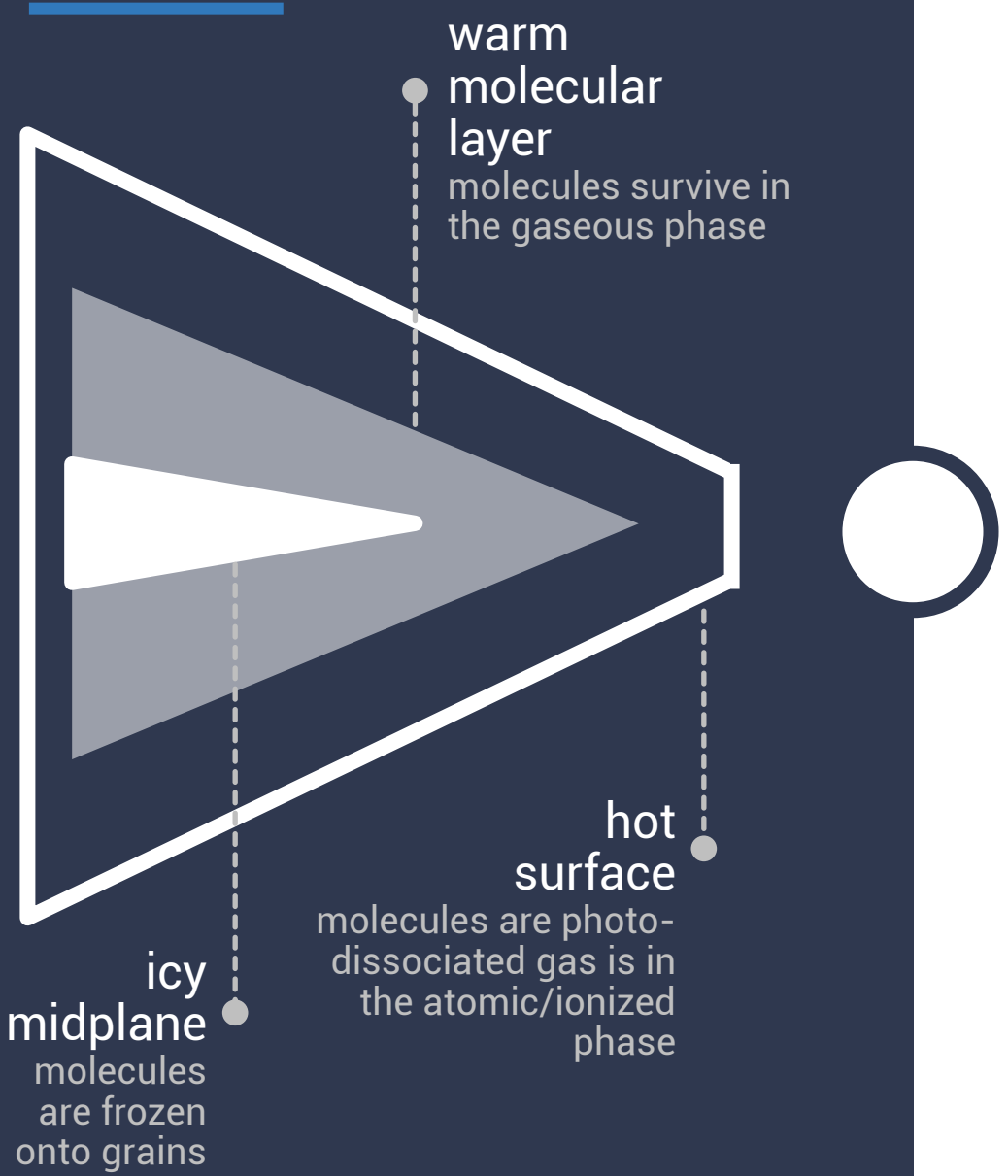


H_2

- most abundant constituent
- no permanent electric dipole moment:

very weak rotational and vibrational lines

BULK GAS



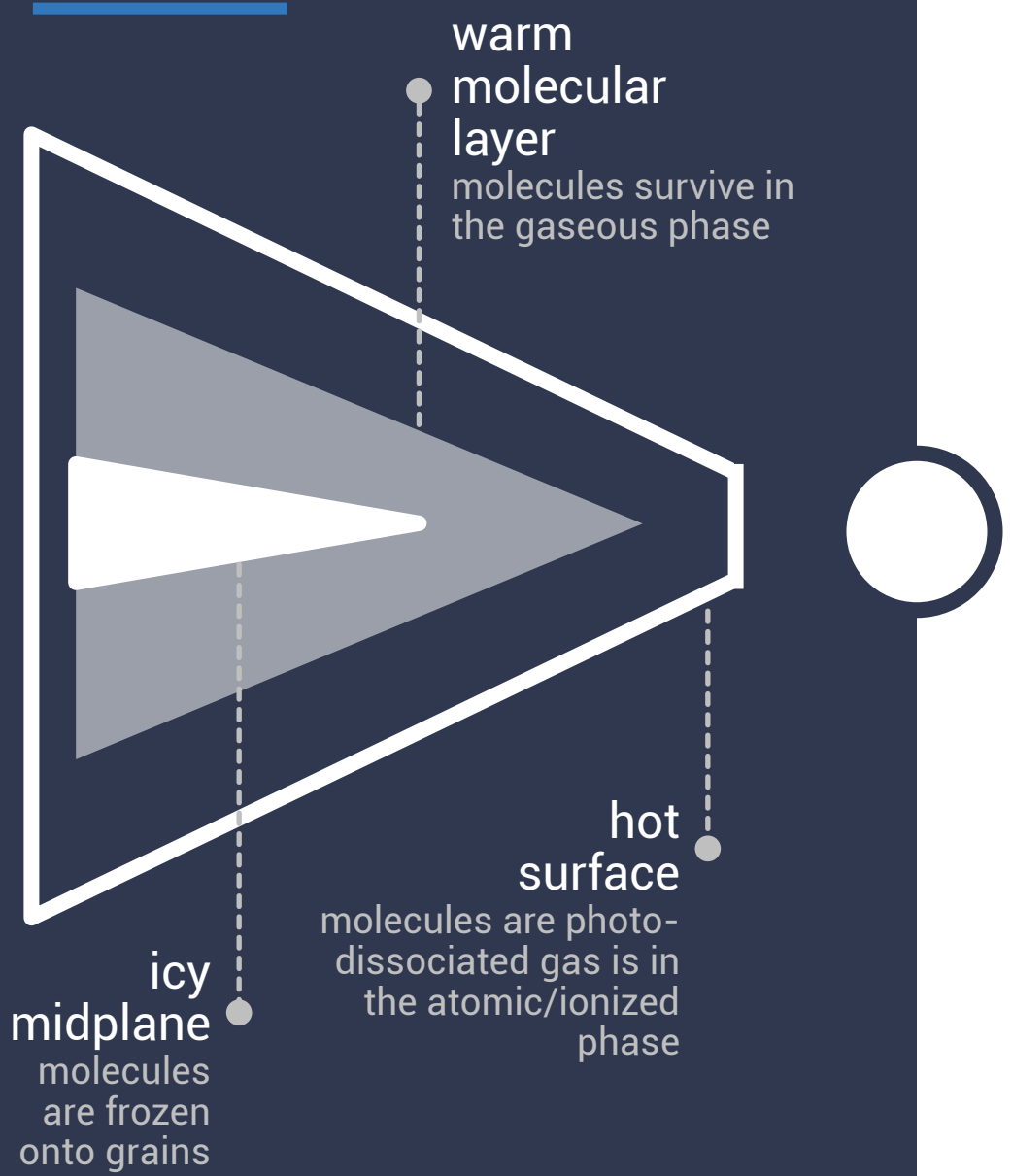
HD

- Less abundant isotopologue of molecular hydrogen

rotational transition $J(1\text{-}0)$
detectable with
Herschel Space Observatory
PACS instrument

only 3 detections in disks
Bergin et al. (2013); Favre et al. (2013); McClure et al. (2016)

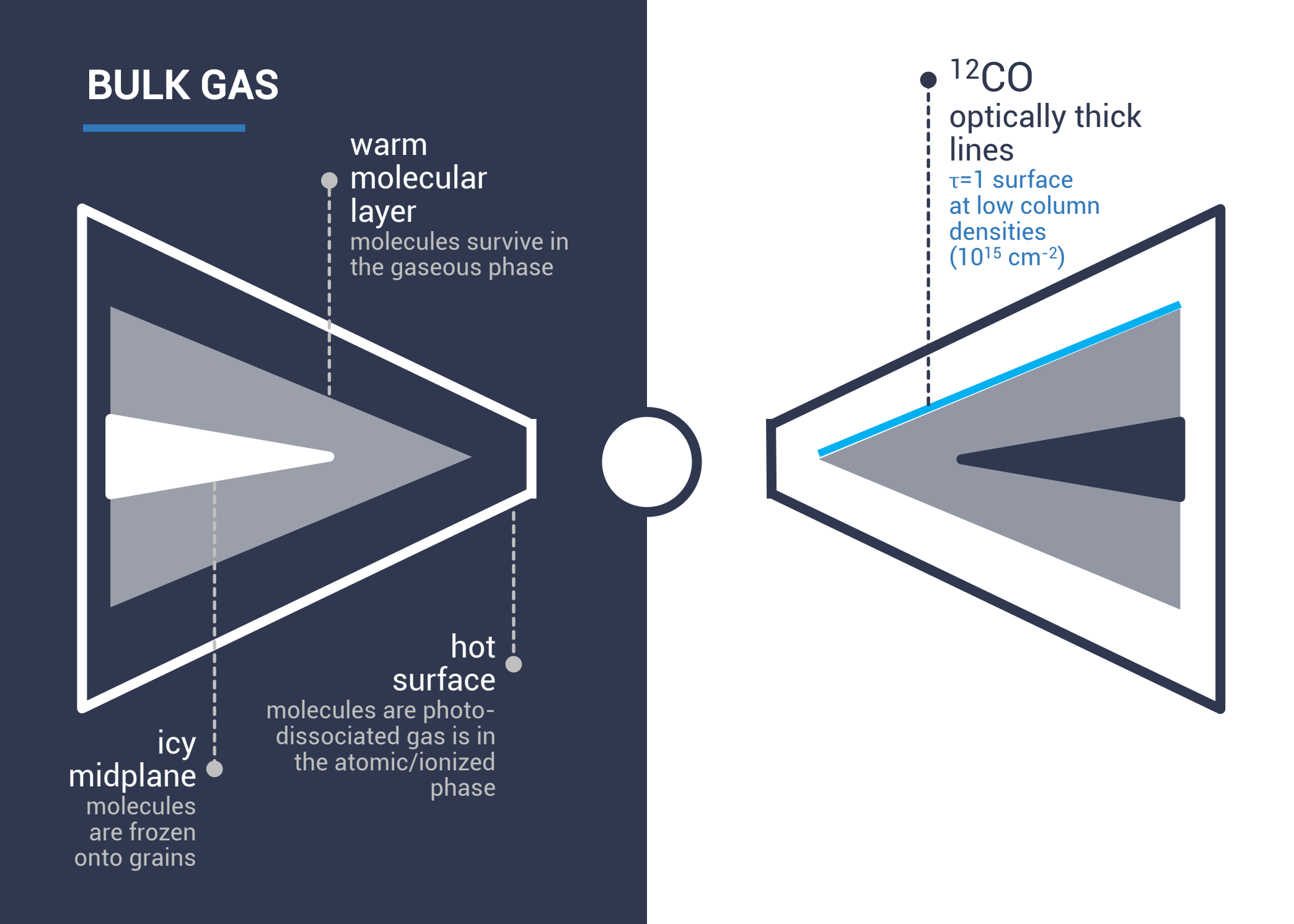
BULK GAS



CO

- second in abundance to H_2
- very well studied chemistry

readily detectable
pure rotational lines
at mm wavelengths

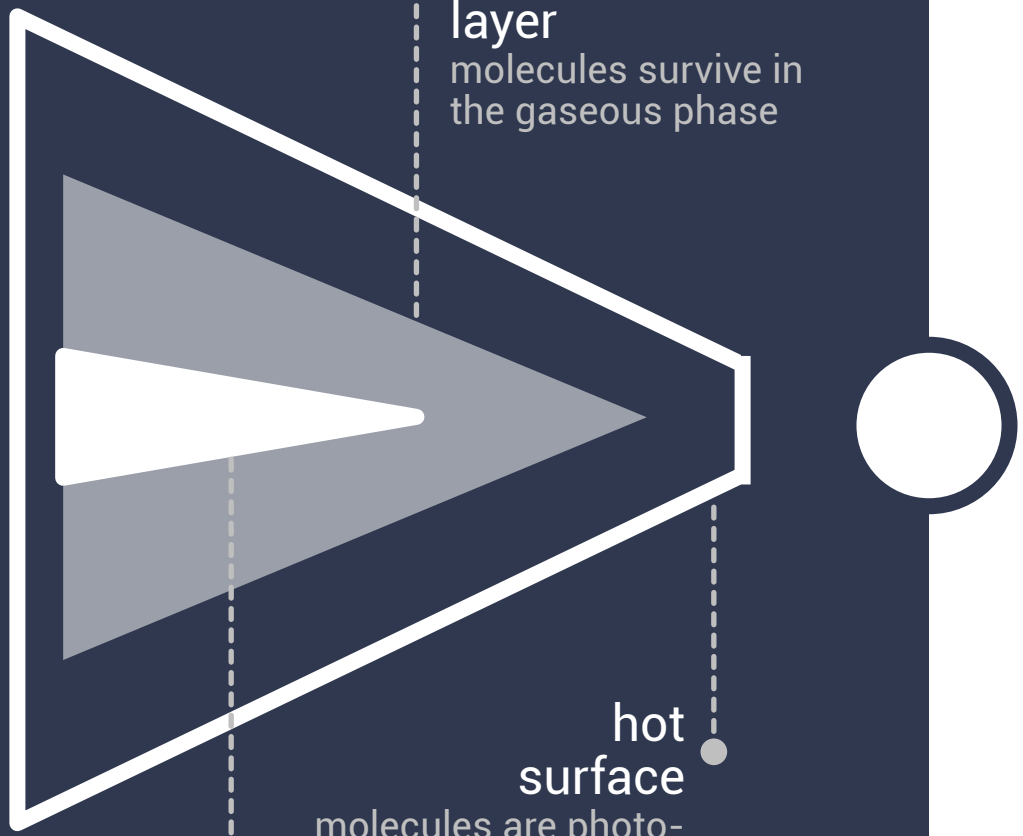

BULK GAS
warm molecular layer
molecules survive in the gaseous phase
hot surface
molecules are photo-dissociated gas is in the atomic/ionized phase
icy midplane
molecules are frozen onto grains
12CO
optically thick lines
τ=1 surface at low column densities (10^15 cm^-2)

BULK GAS

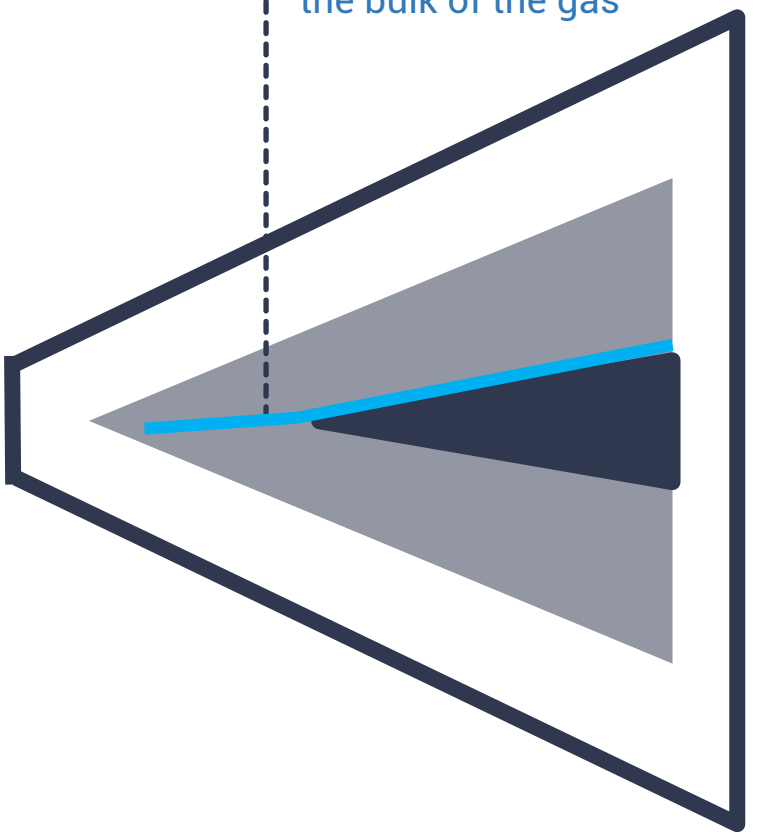
warm molecular layer
molecules survive in the gaseous phase

hot surface
molecules are photo-dissociated gas is in the atomic/ionized phase

icy midplane
molecules are frozen onto grains

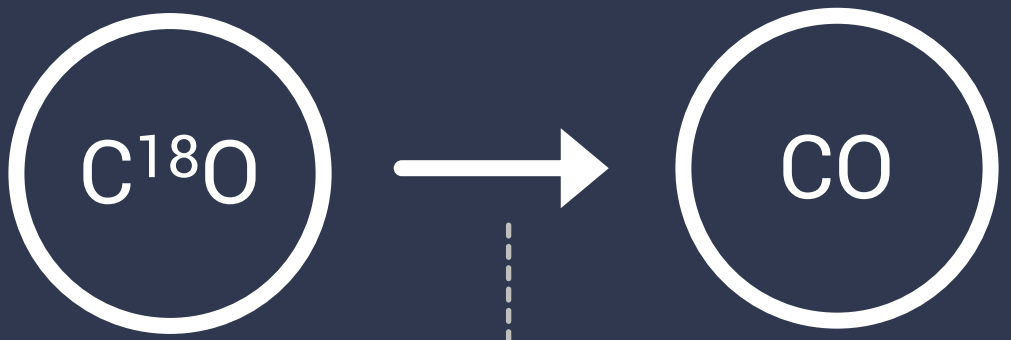


^{13}CO and $C^{18}O$ optically thin lines
their detection allows us to trace the bulk of the gas



CAVEATS

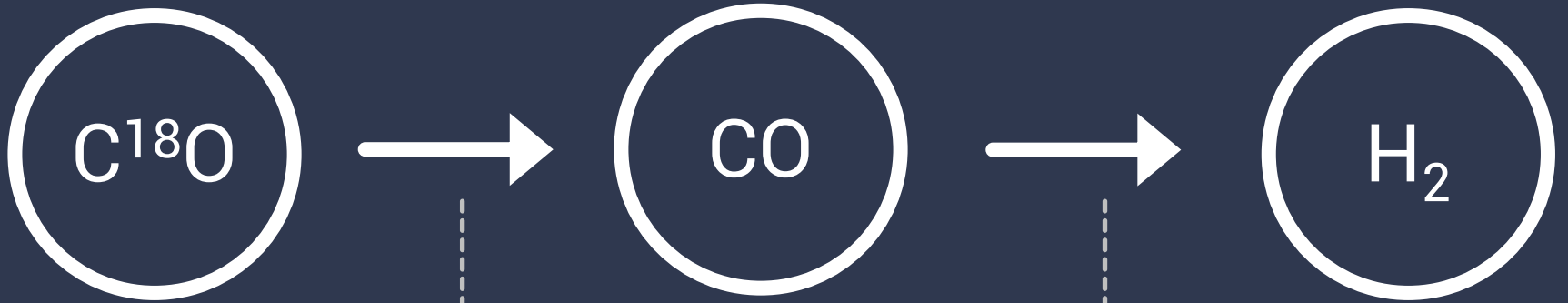
CAVEATS



isotope selective processes
taken into account with physical-chemical disk modeling

DALI, Bruderer et al. 2012
Miotello et al., 2014b; 2016

CAVEATS



isotope selective processes
taken into account with physical-chemical disk modeling

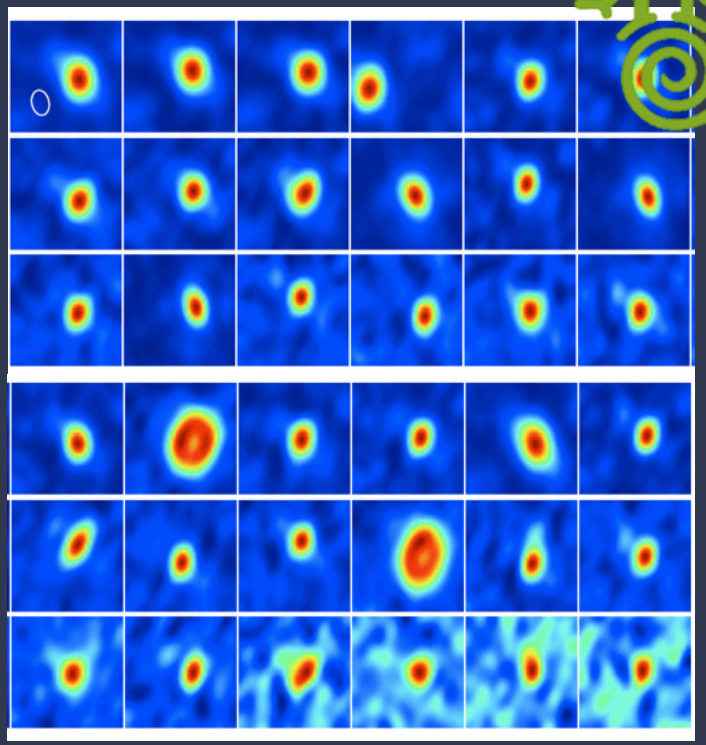
DALI, Bruderer et al. 2012
Miotello et al., 2014b; 2016

carbon abundance relative to H_2
difficult to quantify

TW Hya
Favre et al., 2013
Kama et al., 2016
Schwarz et al., 2016

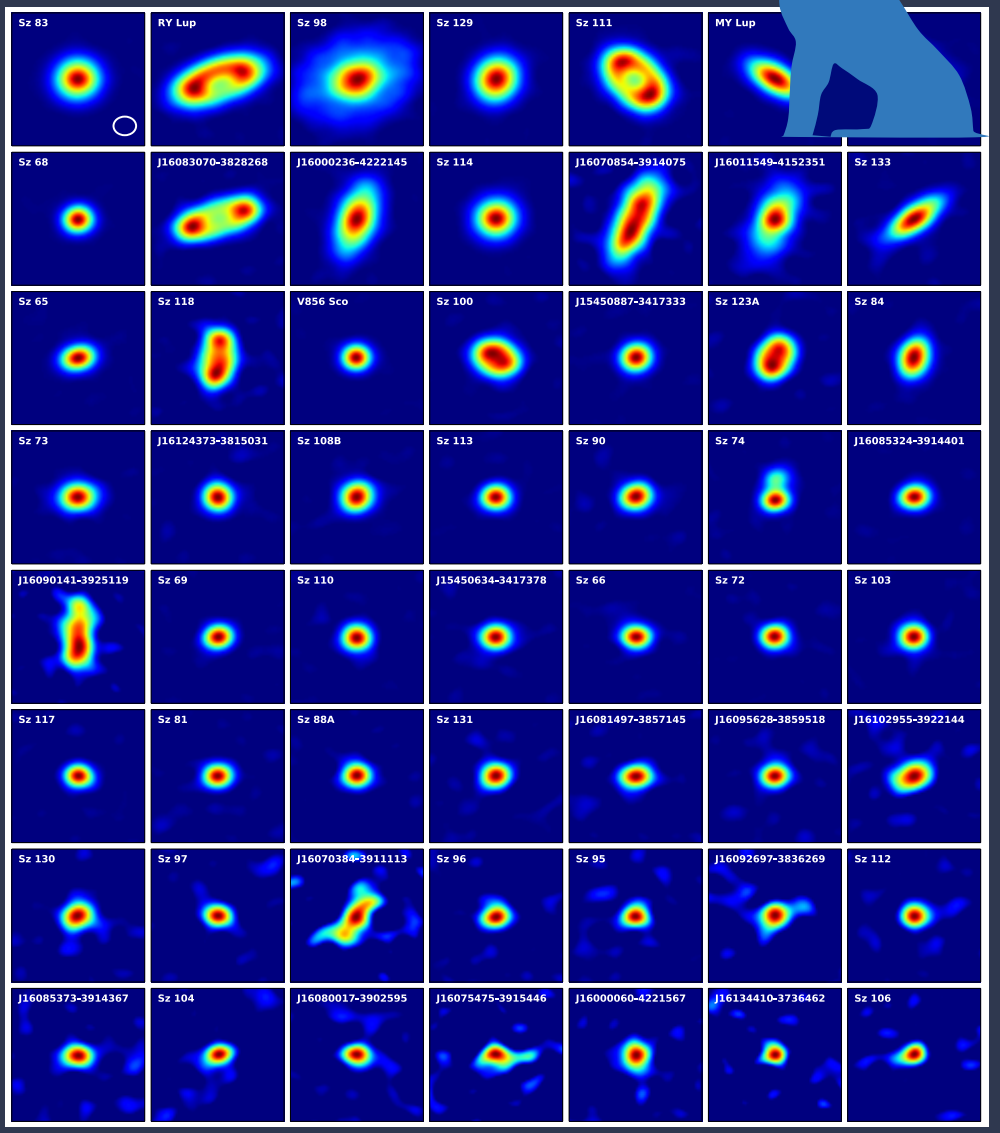
GAS IN DISKS WITH ALMA

Cha I



PI Ilaria Pascucci. 2017 - Pascucci et al. 2016; Long et al. 2016, …

Lupus



PI Jonathan Williams - Ansdell et al., 2016;2018; Miotello et al. 2016, Manara et al.2016; Tazzari et al. 2017 …

ALMA LUPUS DISK SURVEY

Ansdell et al., 2016;2018

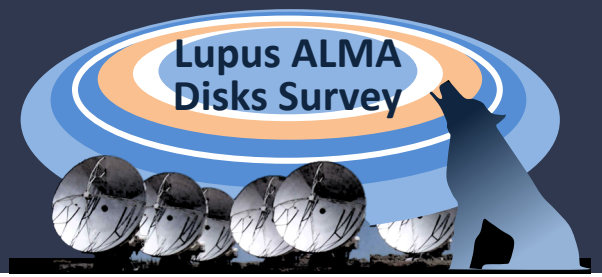
PI: J. P. Williams
cycle 2/3, band 6/7
0.2"- 0.3"→
15-20 au radius @150 pc

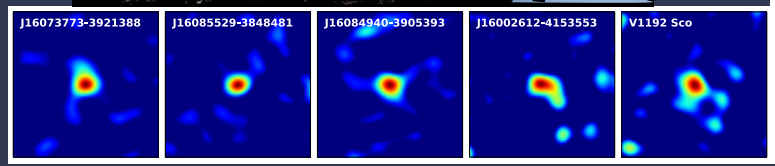
88 sources

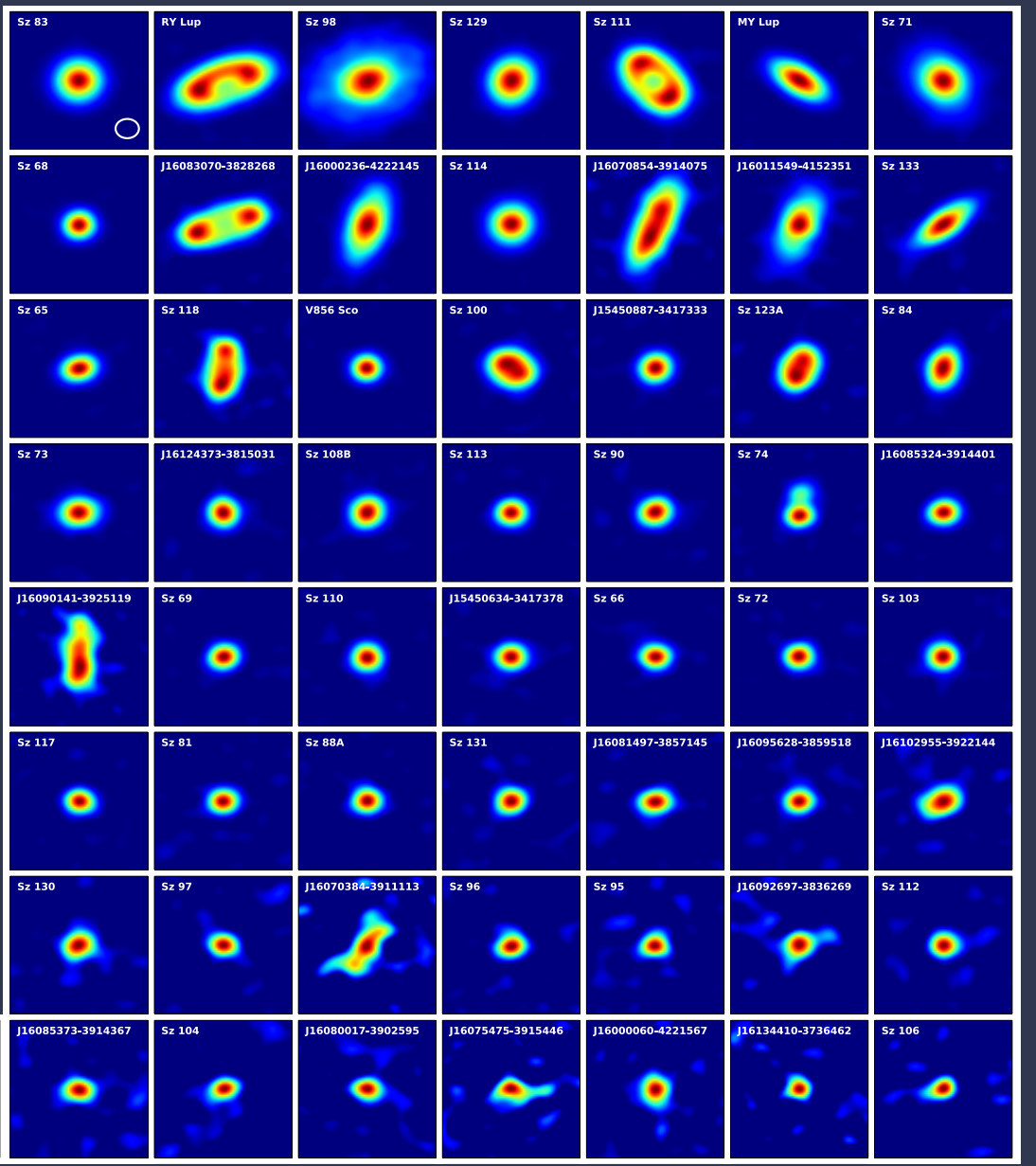
61 detected in the continuum (890 μm)

35 in ^{13}CO (3-2)

10 in C^{18}O (3-2)

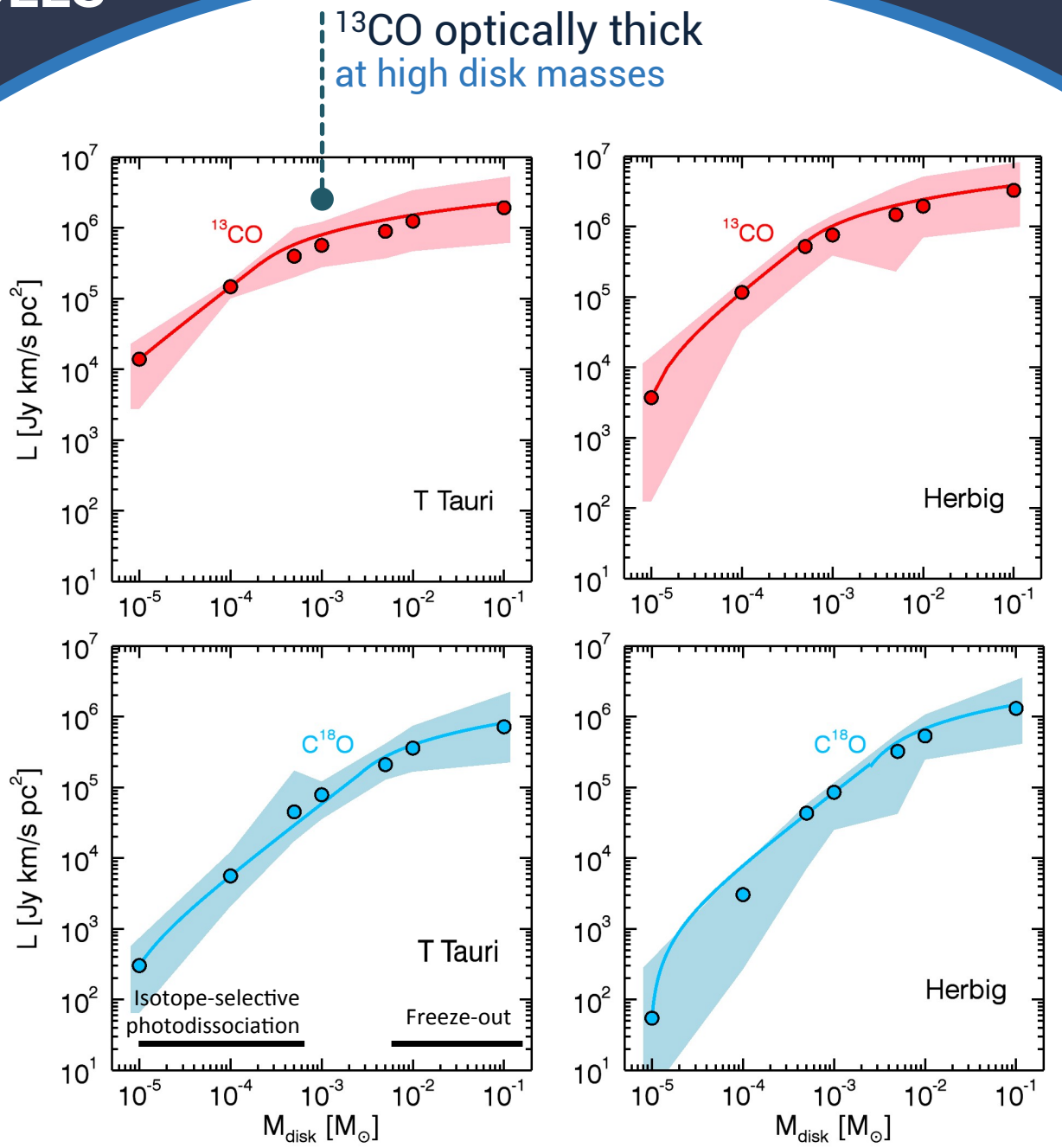






LARGE GRID OF MODELS

Analytic expressions of the line emission as function of the disk mass

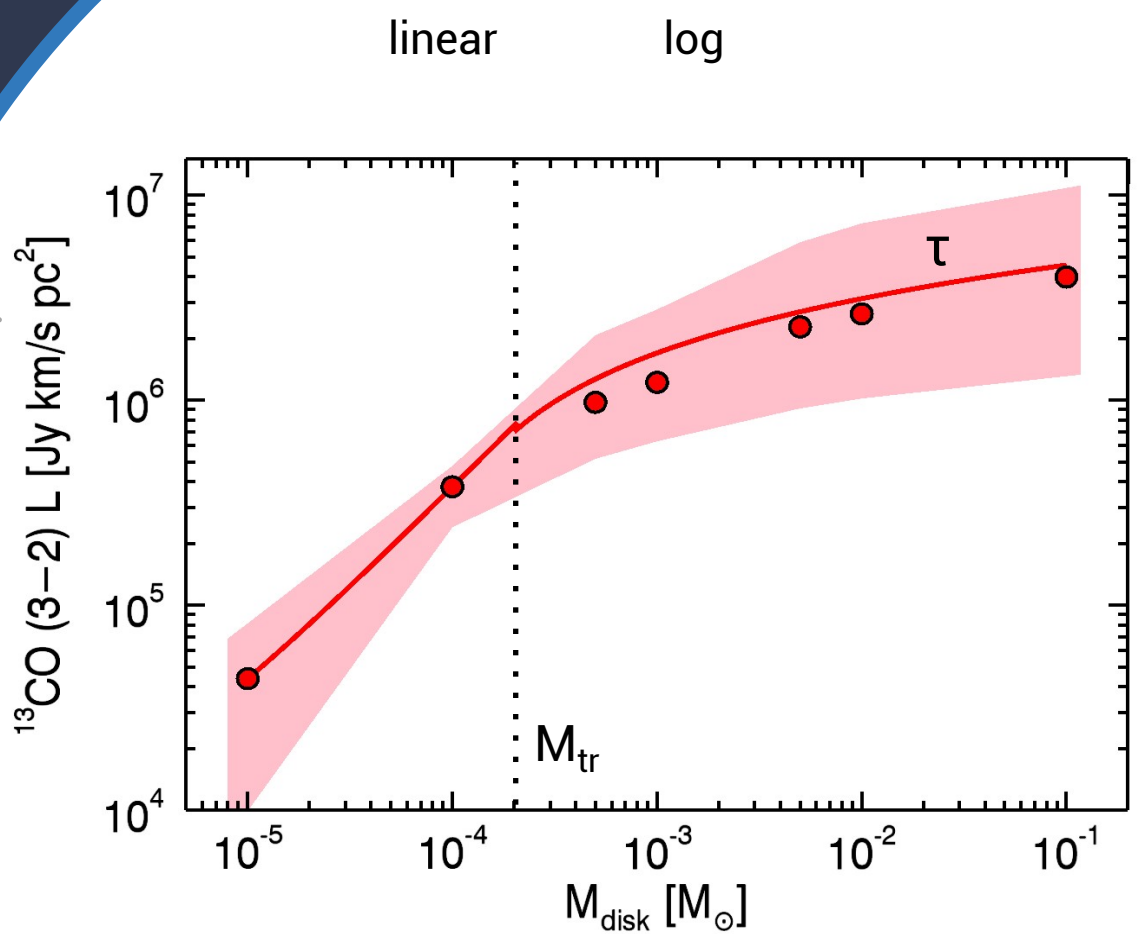


Williams & Best 2014
Miotello et al., 2016

CO ISOTOPOLOGUES

as gas mass tracers

^{13}CO



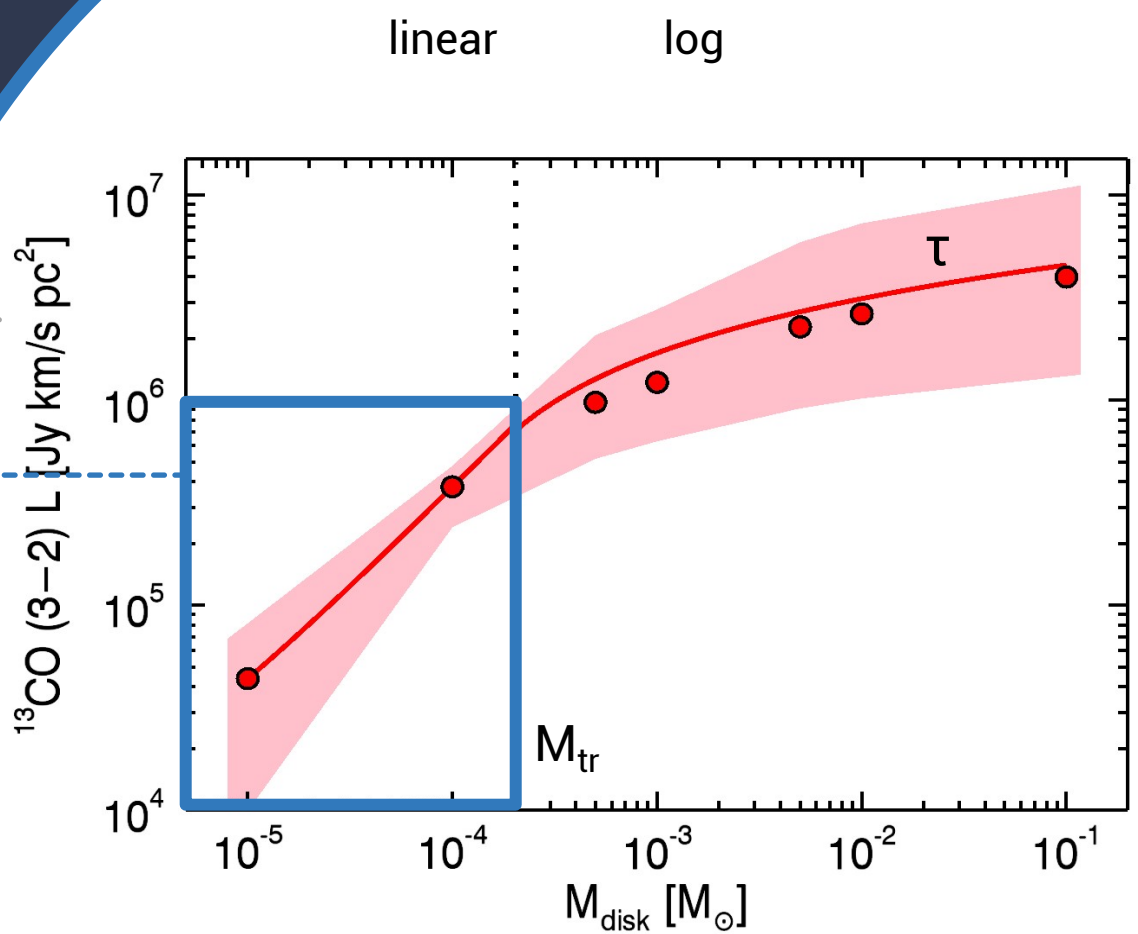
Miotello et al., 2017

CO ISOTOPOLOGUES

as gas mass tracers

^{13}CO

^{13}CO scales linearly with disk mass



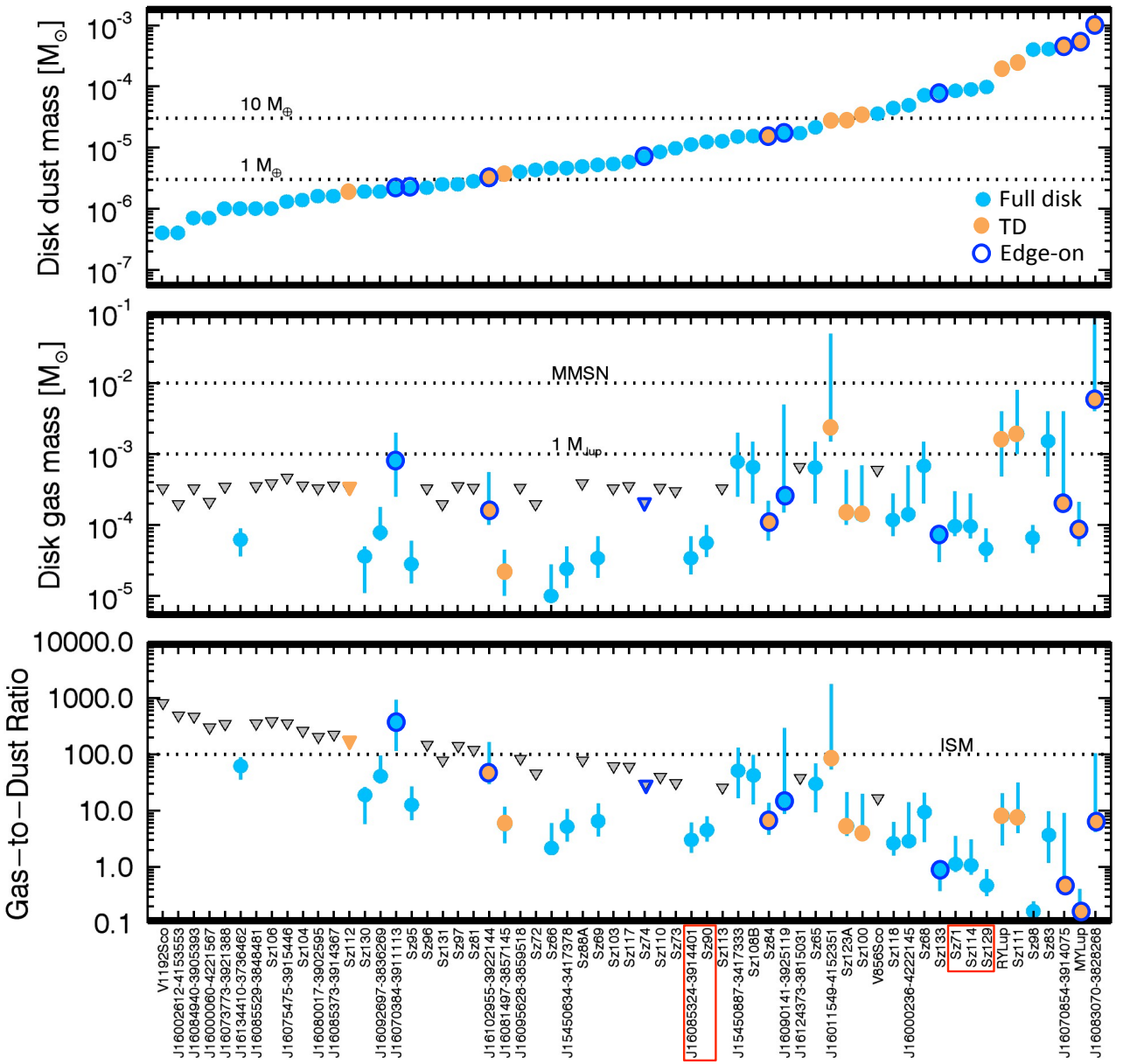
Miotello et al., 2017

DISK MASSES

dust masses

gas masses

gas/dust ratio



Miotello et al., 2017

LOW GAS/DUST OR HIGH C DEPLETION?

sign of disk evolution

1 physical evolution

gas is dissipated
$M_{gas} < M_{jup}$
giant planet
formation
is quick or rare

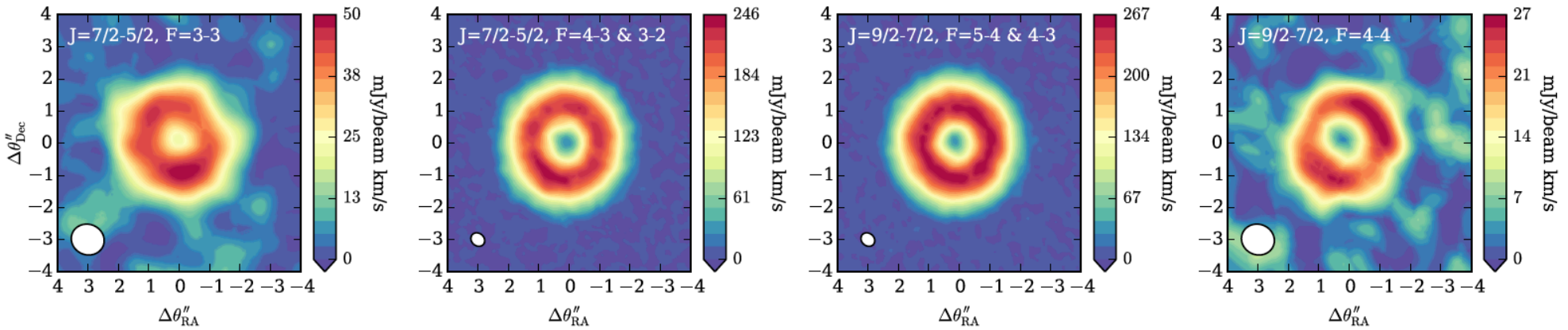
2 chemical evolution

volatile carbon
is locked up
in large icy bodies
or turned into
more complex species

Ansdell et al., 2016
Miotello et al., 2017
Manara et al., 2016

C_2H rings

Hydrocarbons in TW Hya



Bergin et al. (2016)
Kastner et al. (2015)

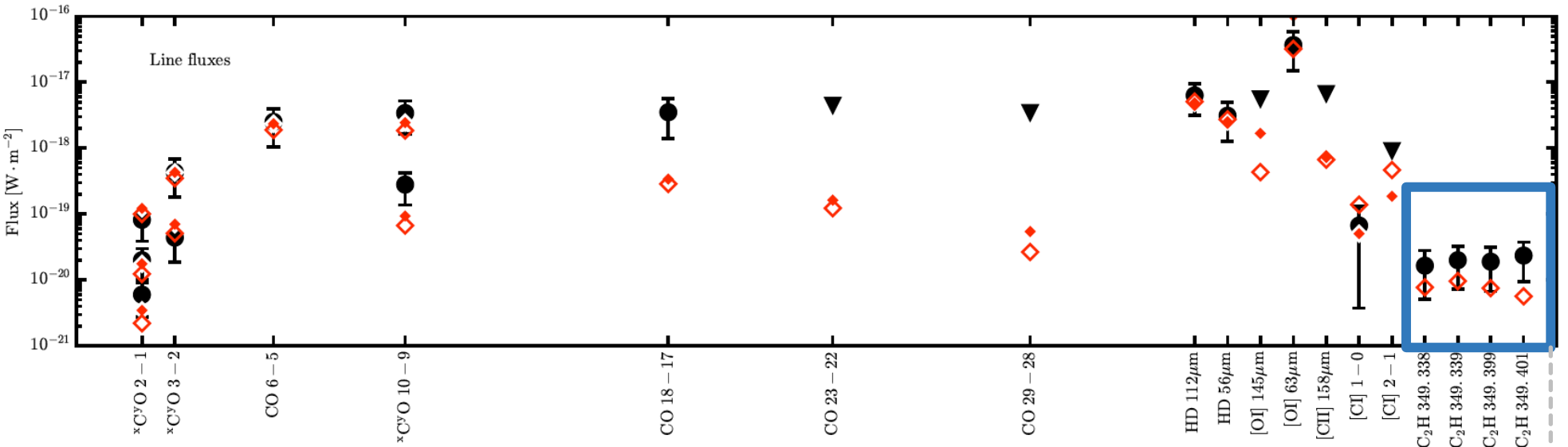
TW Hya

C_2H strong emission

CO fainter than expected

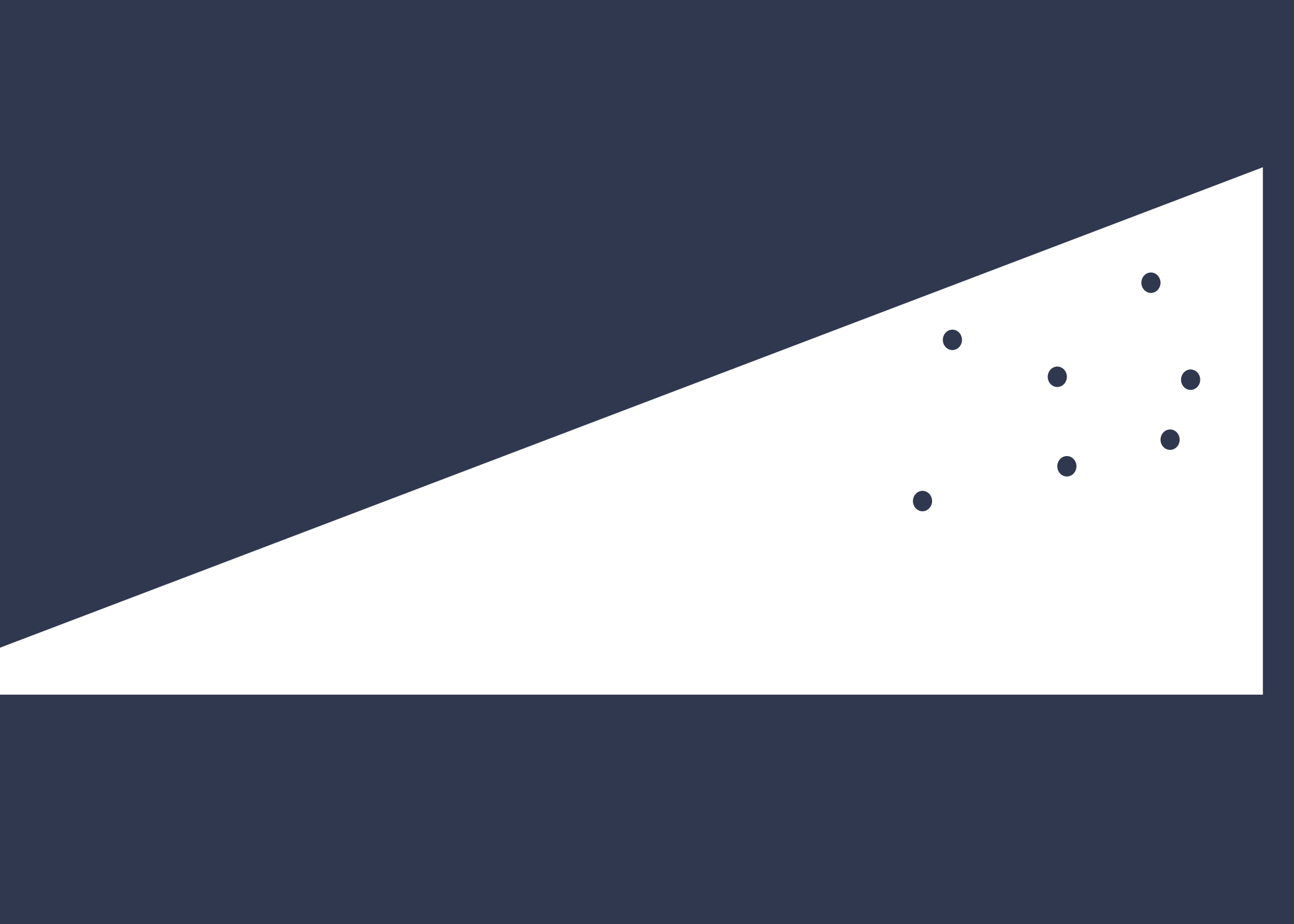
C_2H in TW Hya

strong emission lines



Kama et al., 2016
Trapman et al., 2017

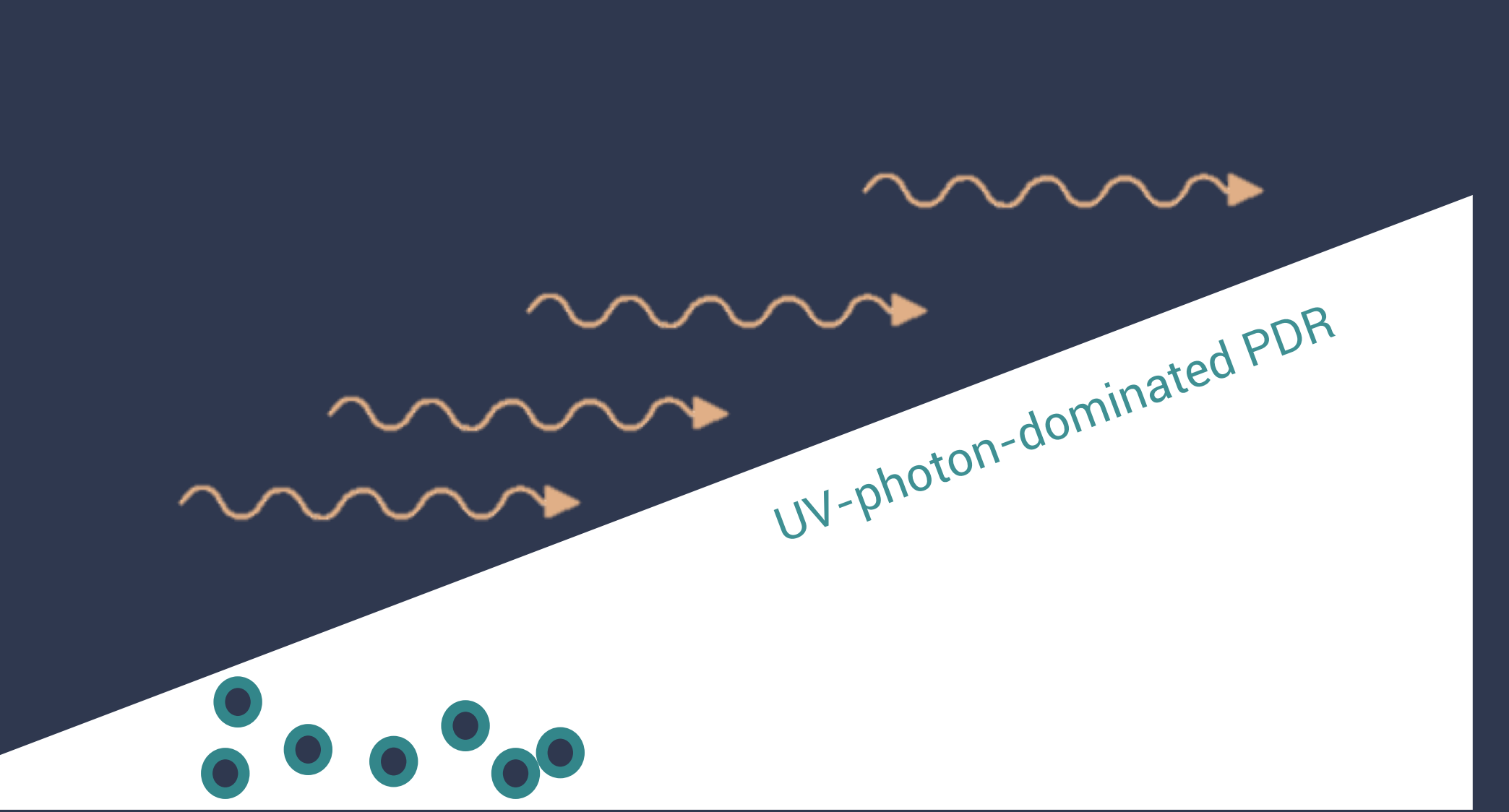
consistent
with two orders of
magnitude
carbon depletion
and C/O>1

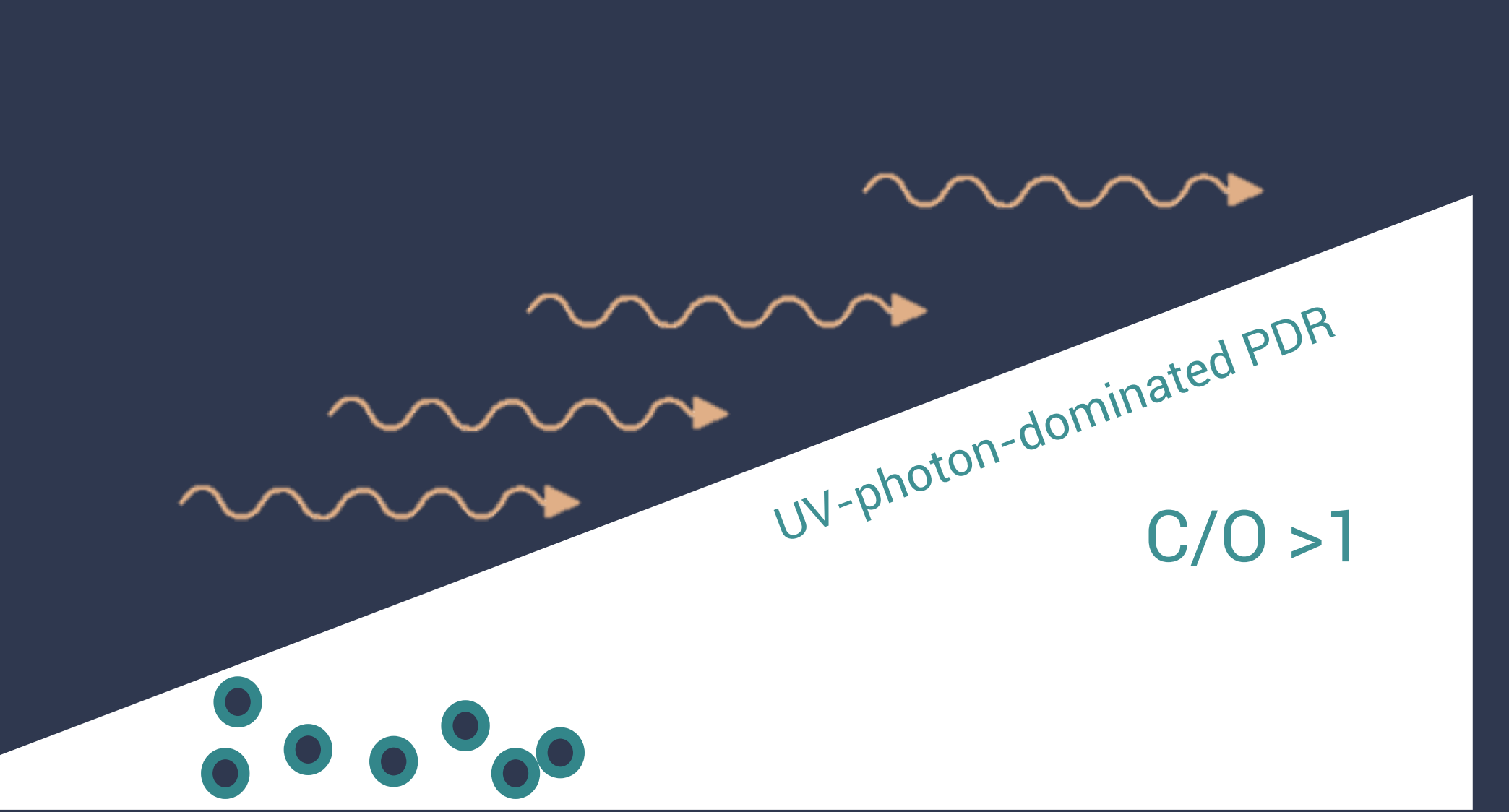


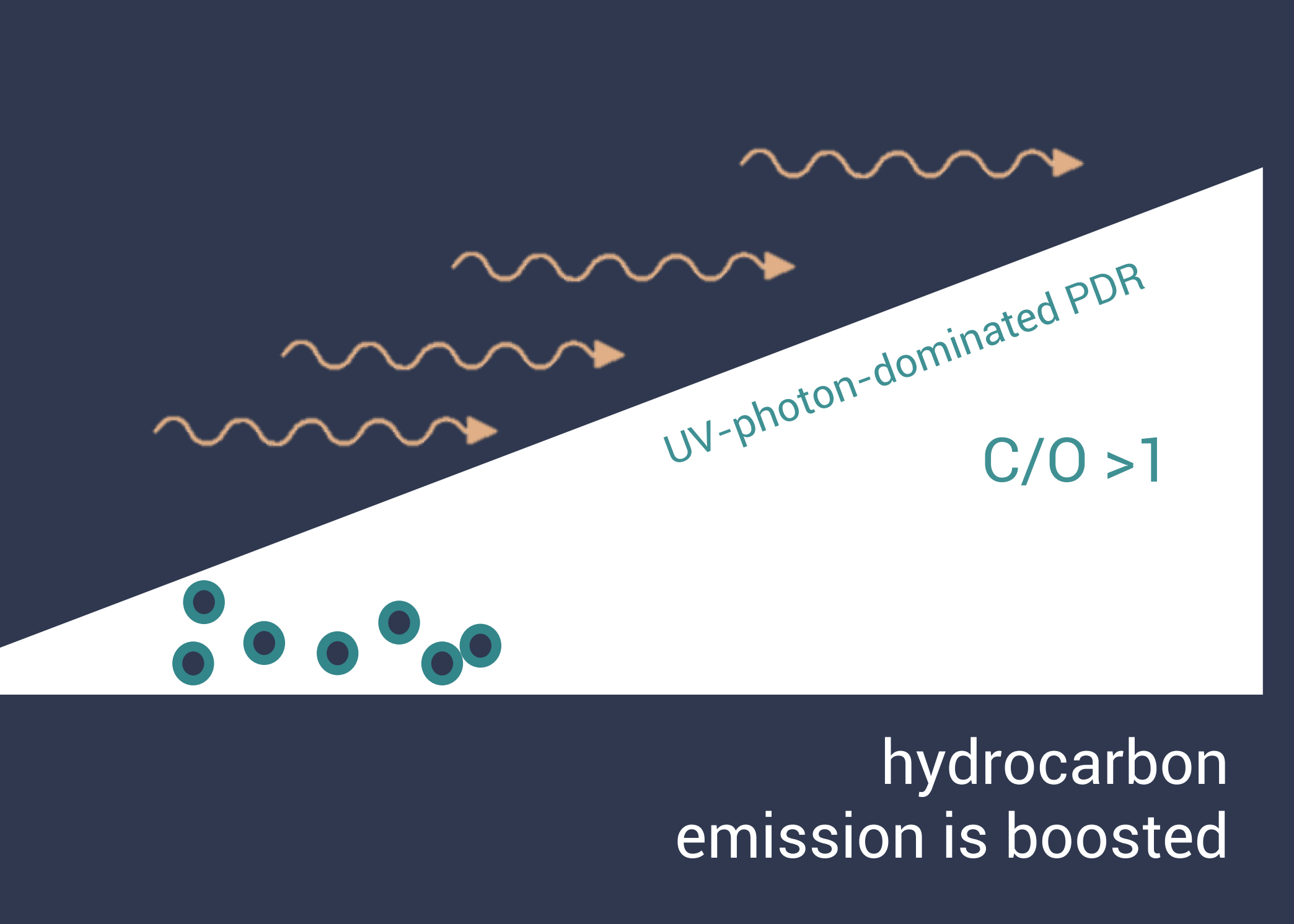
settling

Ice coating

Radial drift

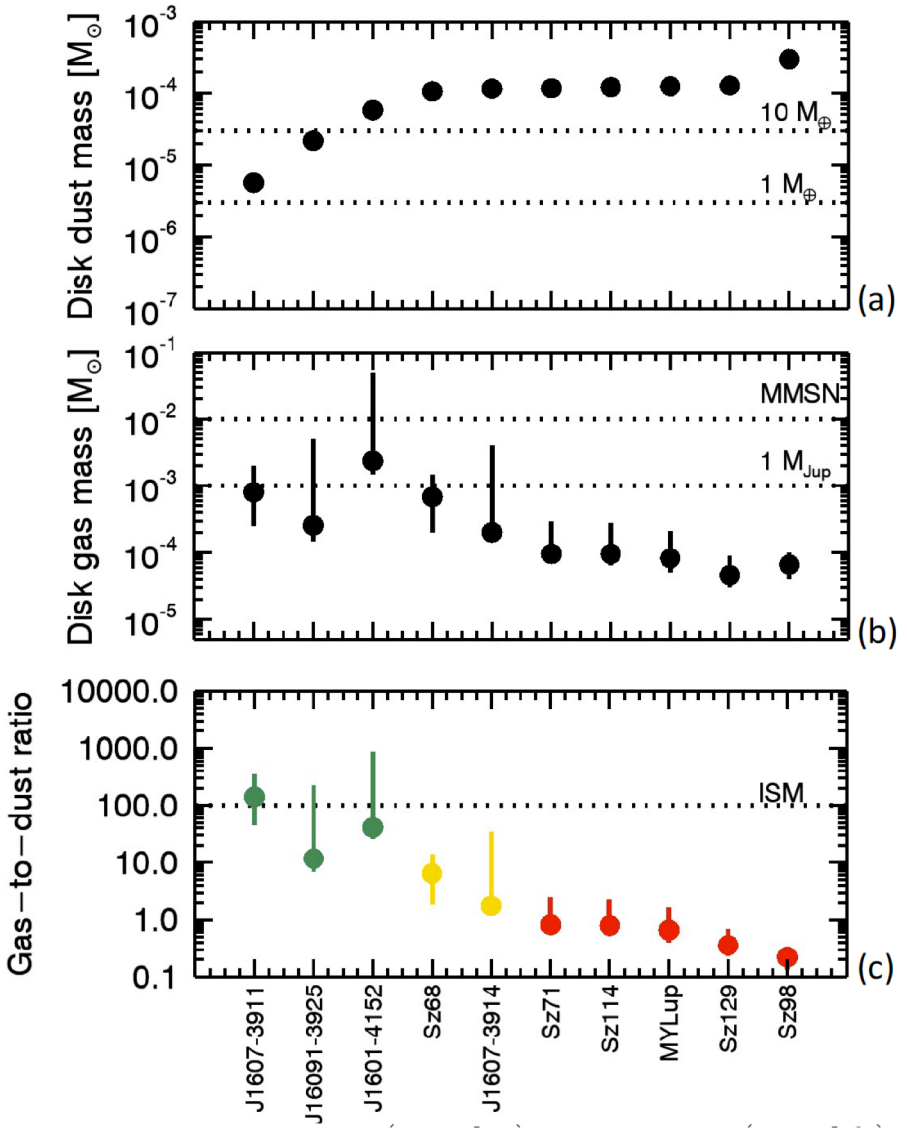

UV-photon-dominated PDR


UV-photon-dominated PDR
C/O >1


UV-photon-dominated PDR
C/O >1
hydrocarbon
emission is boosted

C_2H in Lupus

follow up ALMA Cycle 4 program in Band 6 (PI: Miotello)



search for anti-correlation

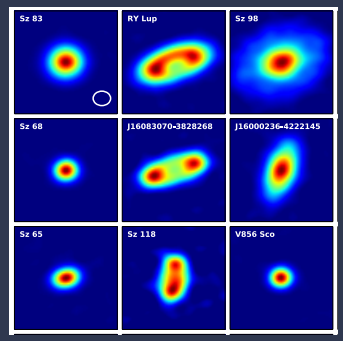
of C_2H and ^{13}CO line luminosity
in 10 of the brightest in continuum
g/d ratios between 1 and 100

gas/dust ratio

- **100**
- **10**
- **1**

TAKE HOME MESSAGE

Lupus and Cha disks
CO faint emission
may be explained by
carbon depletion



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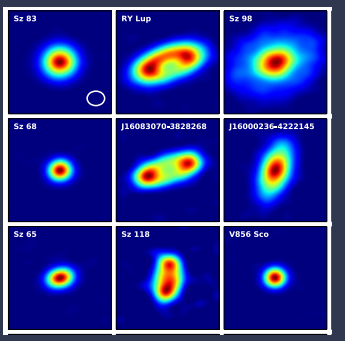

CO-based masses need
to be calibrated

TAKE HOME MESSAGE

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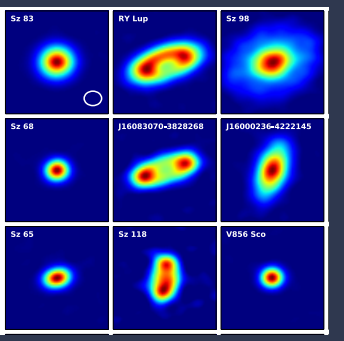

C_2H

Miotello et al. in prep.

- Larger sample
- Detailed modeling to constrain C abundance and C/O

TAKE HOME MESSAGE

Lupus and Cha disks
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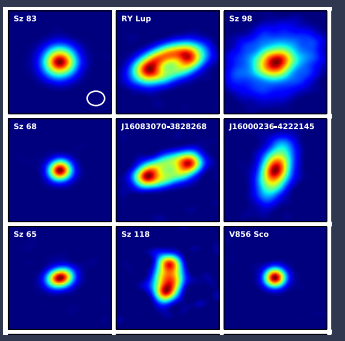

CI and HD lines
ALMA and SPICA (?)

See Trapman et al. (2018)
Kama et al. (2016)

TAKE HOME MESSAGE

Lupus and Cha disks
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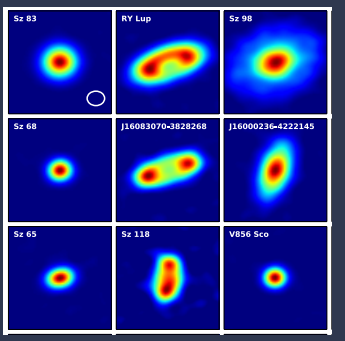

OUT OF THE BOX IDEAS?

Talk by Benedetta Veronesi