ALMA DISK SURVEYS

WHAT DOES CO TELL US ABOUT?

COLLABORATORS

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DIAS : A. Natta

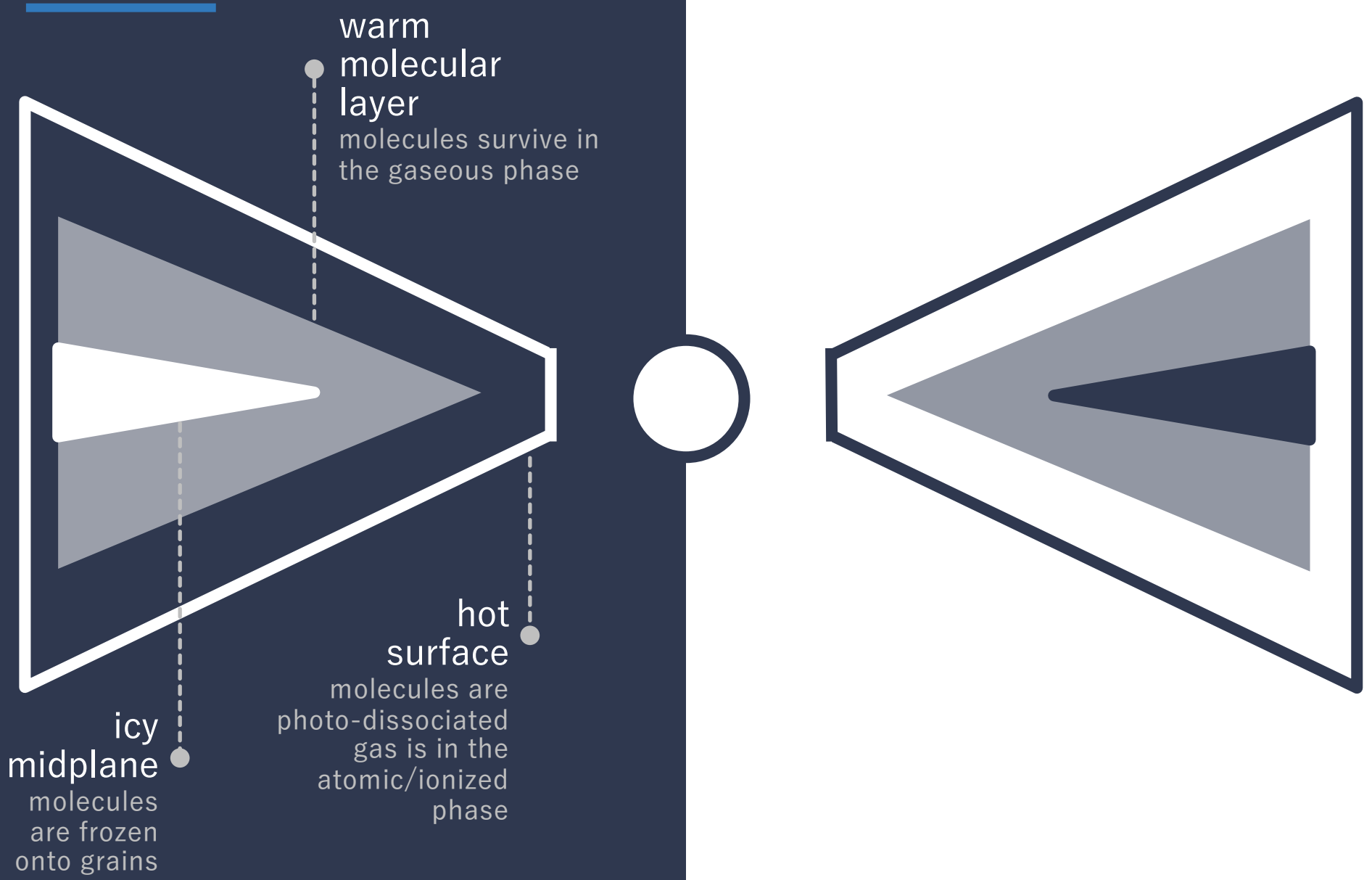
INAF : J. M. Alcalá

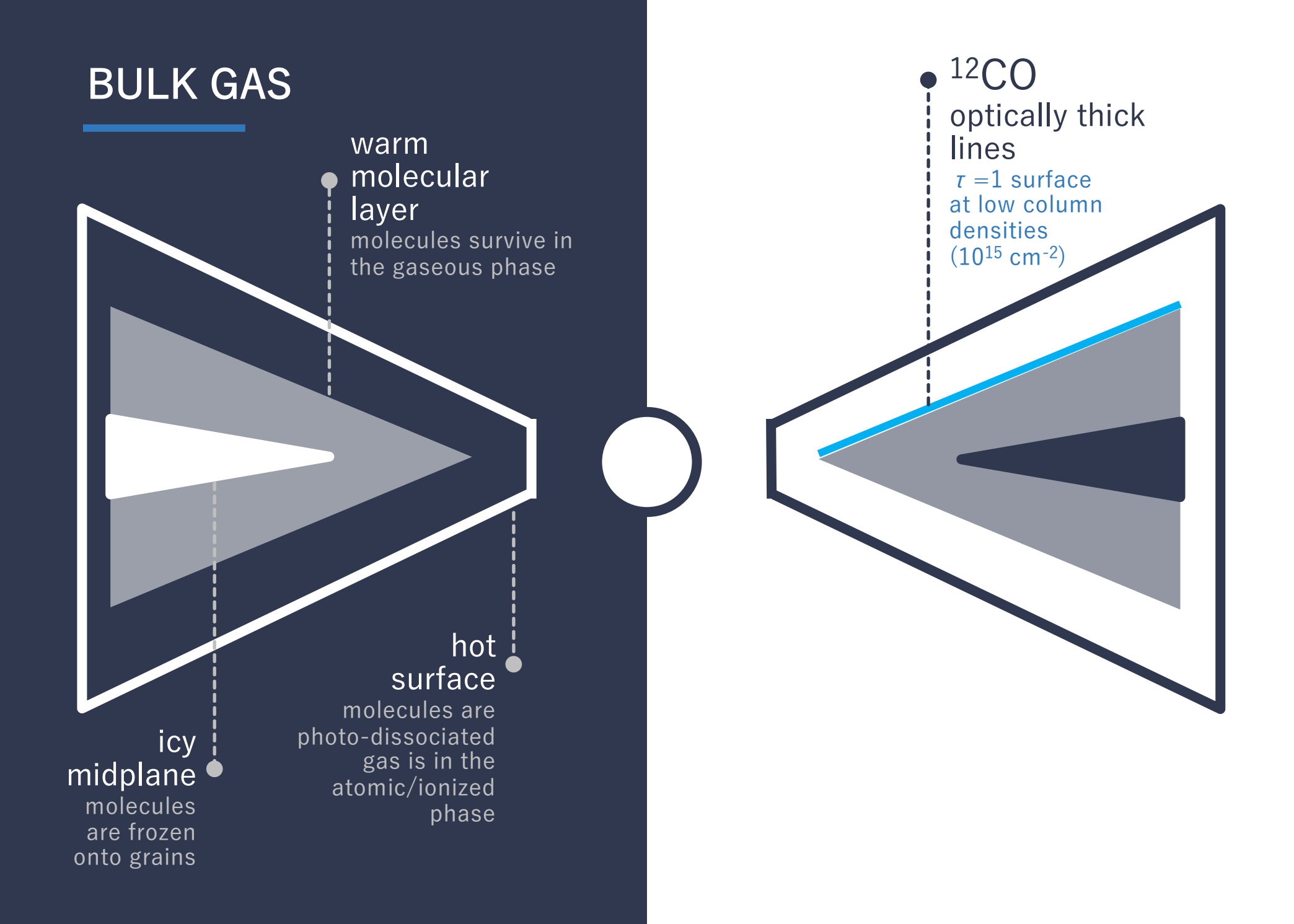
Anna Miotello
ESO Fellow

GAS MASS & DISTRIBUTION

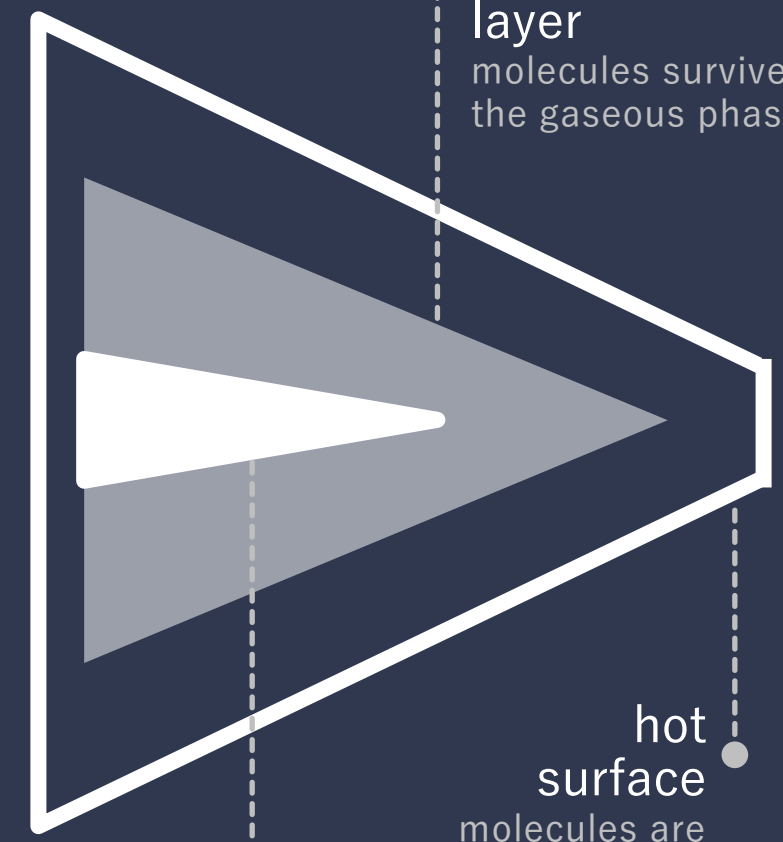
disk dynamics
and evolution

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
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
^{12}CO
optically thick lines
τ =1 surface at low column densities (10^{15} cm^{-2})

BULK GAS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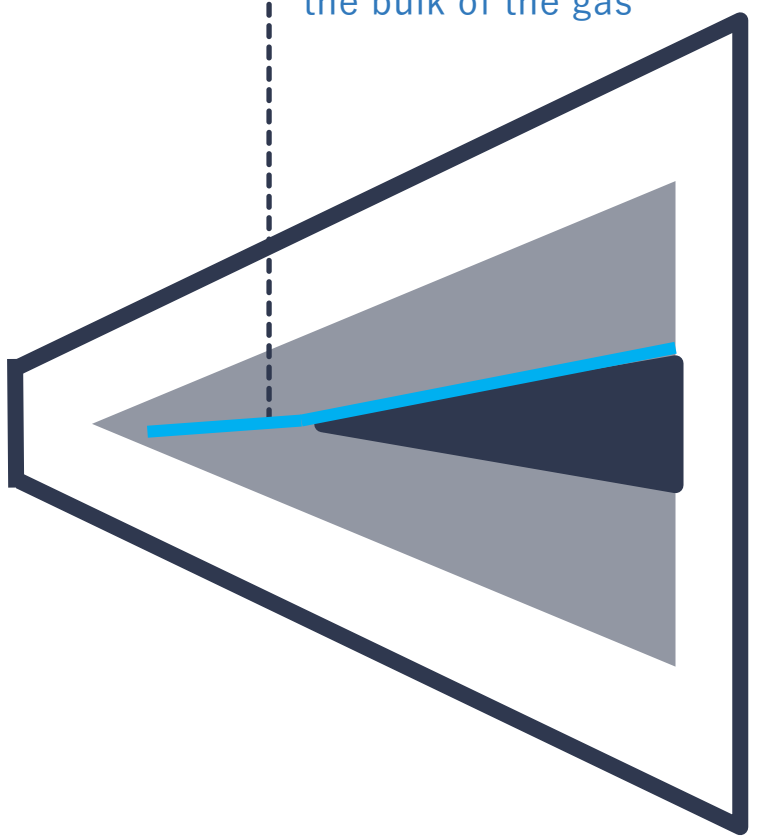
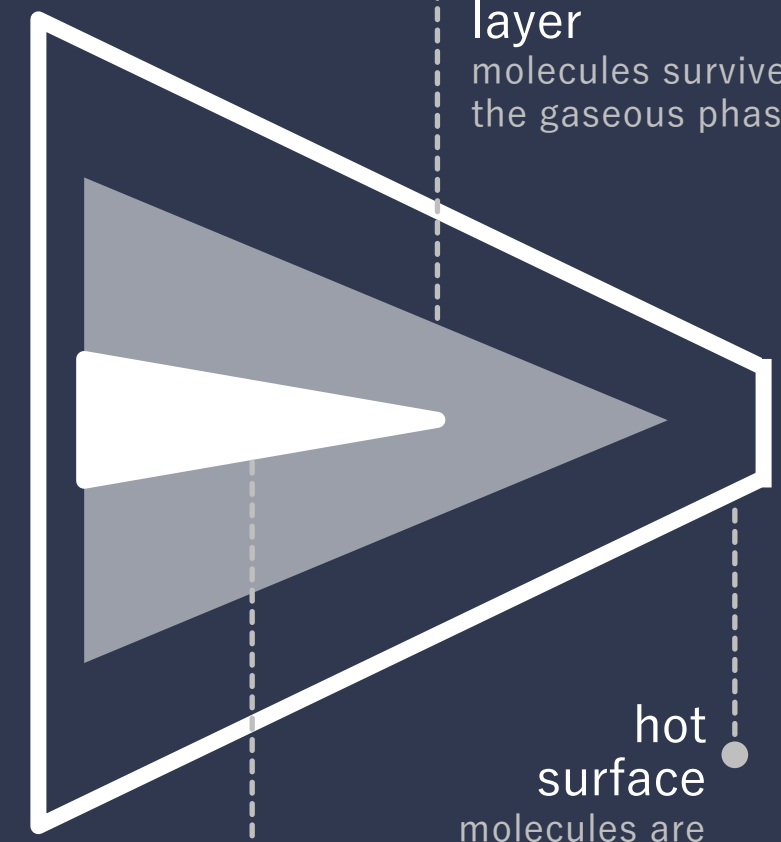
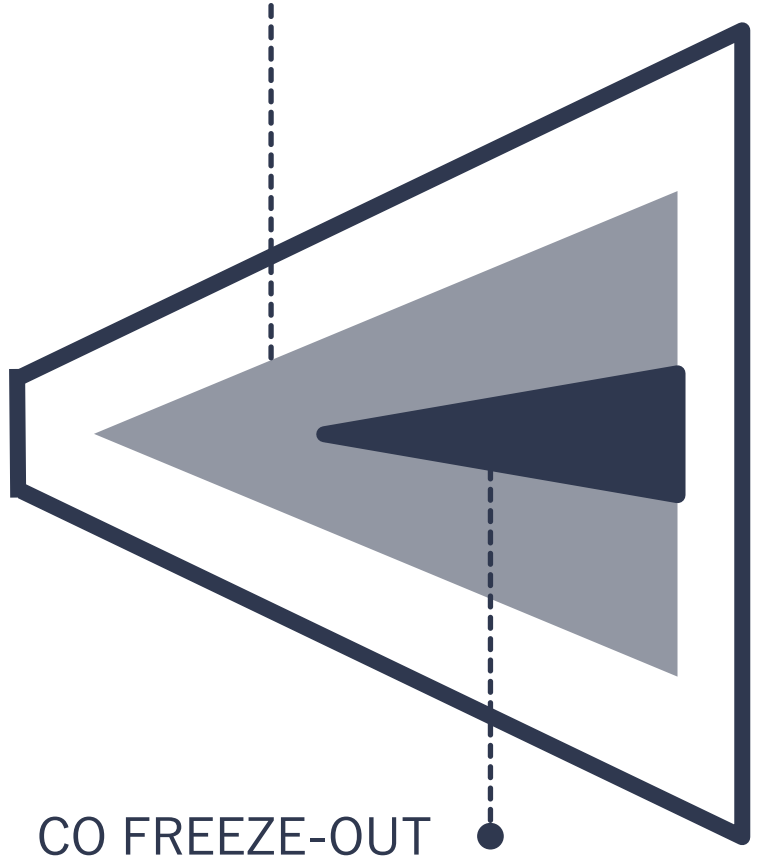

^{13}CO and $C^{18}O$
optically thin lines
their detection allows us to trace the bulk of the gas

BULK GAS - MASS





Phisical-chemical models - DALI

Bruderer et al. 2012; Miotello et al. 2014;2016

Visser et al. 2009; Williams & Best 2014;
Woitke et al. 2016

LUPUS

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

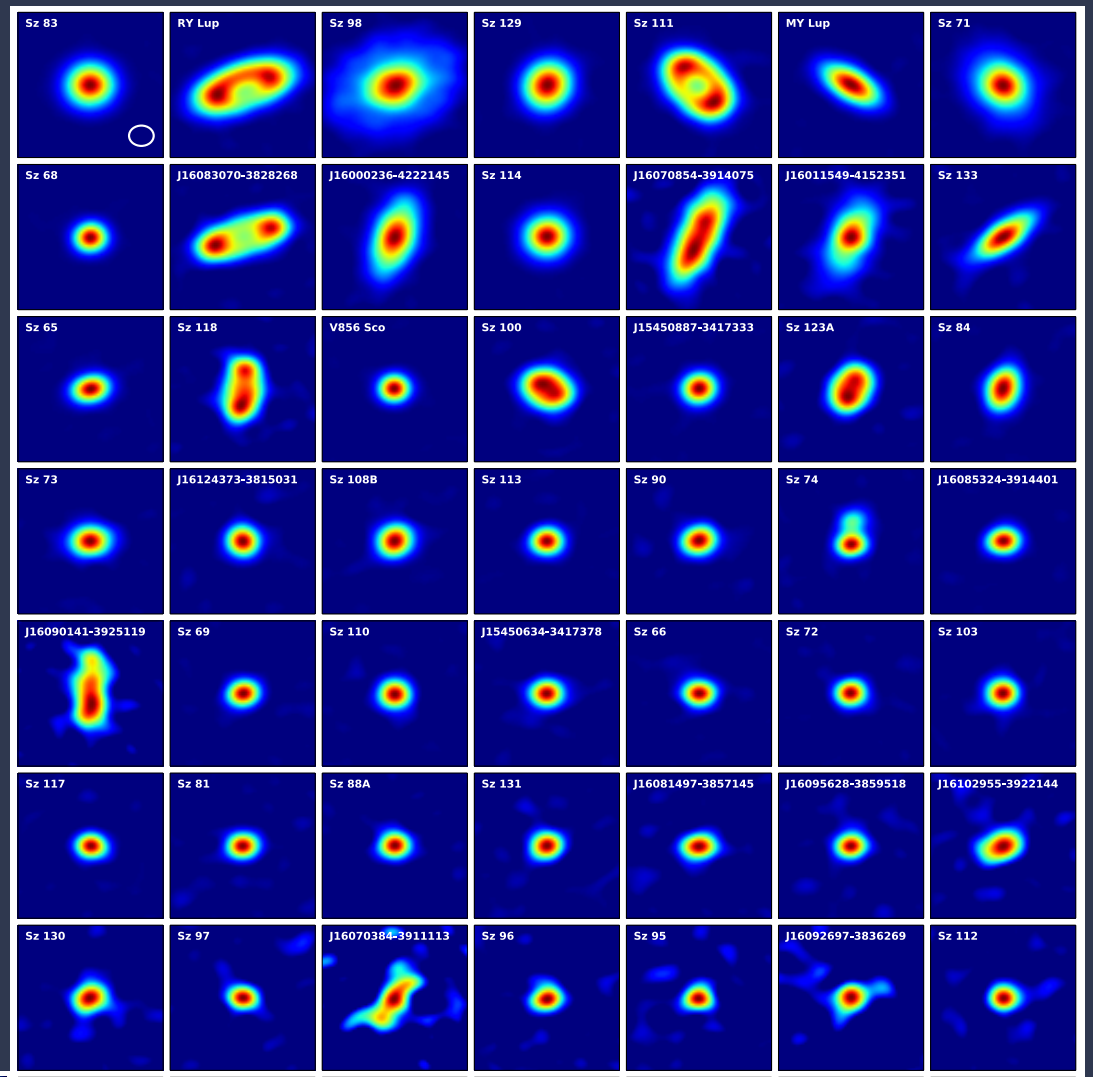
88 sources

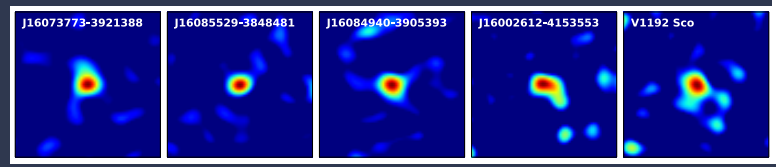
61 detected in the continuum (890 μm)

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

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

Ansdell et al., 2016;2018





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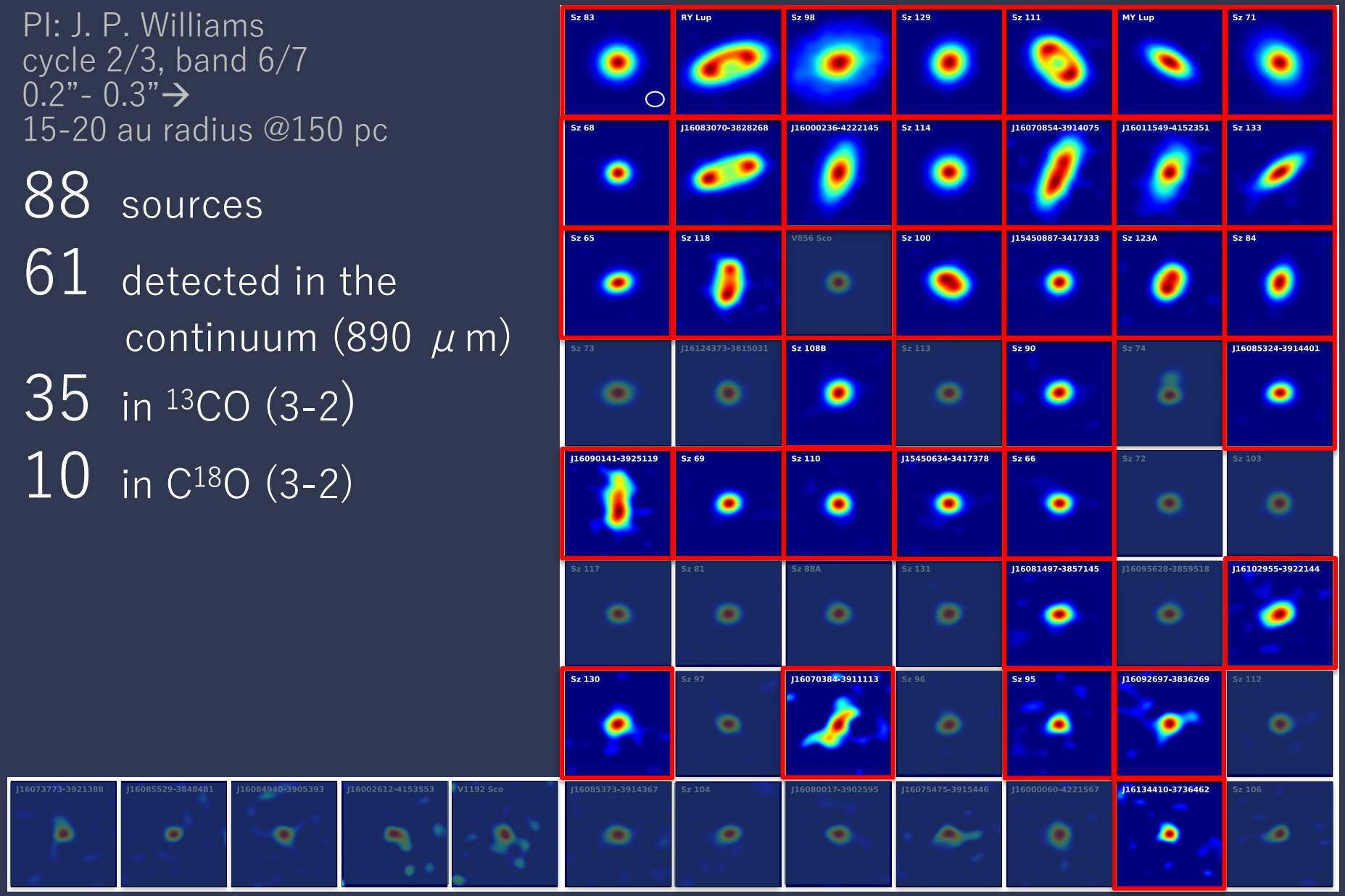

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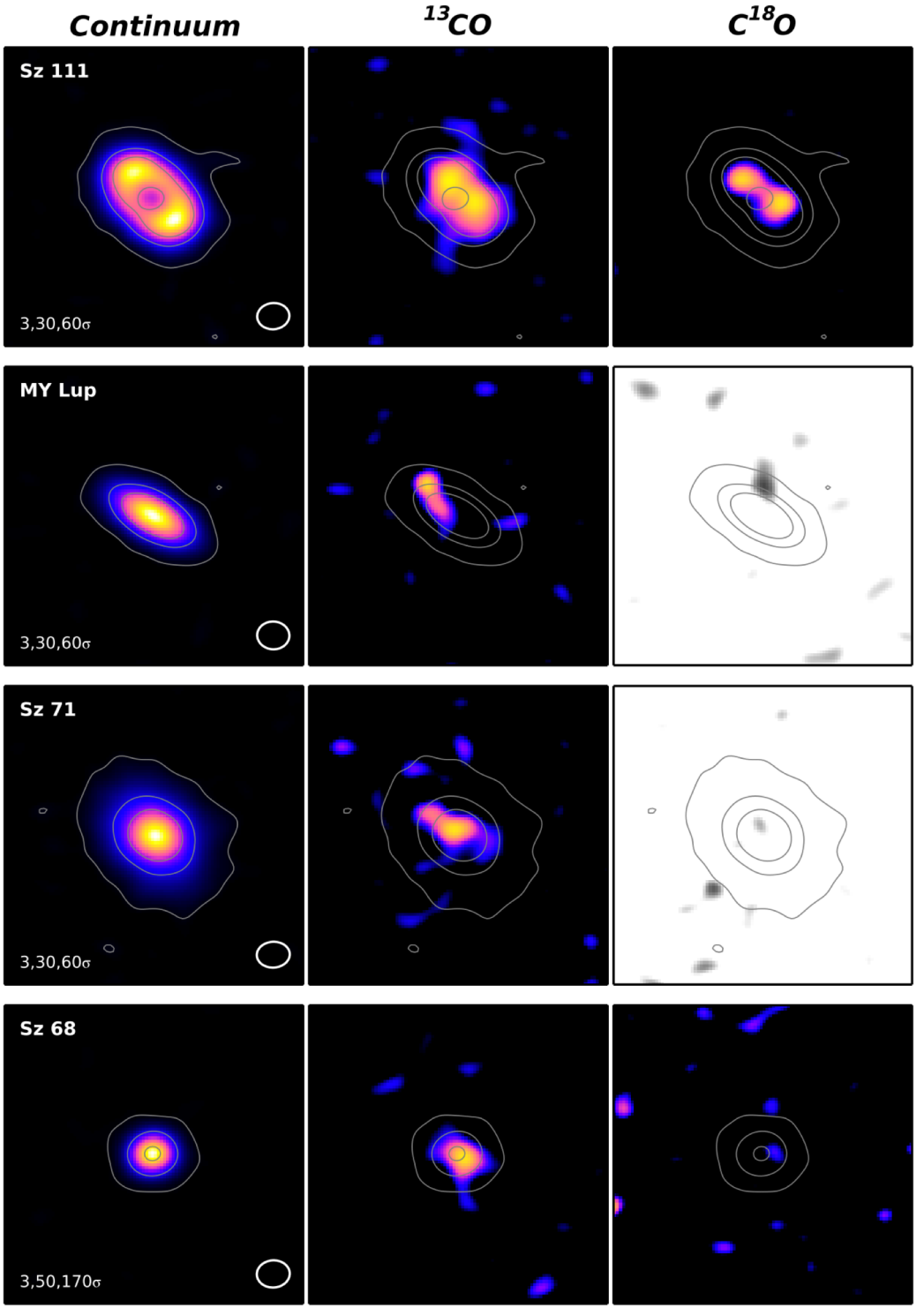
Resolution
0.2” - 0.3” beam

Sensitivity
0.2 -0.4 mJy beam^{-1}

On source integr. time
30 sec – 1 min

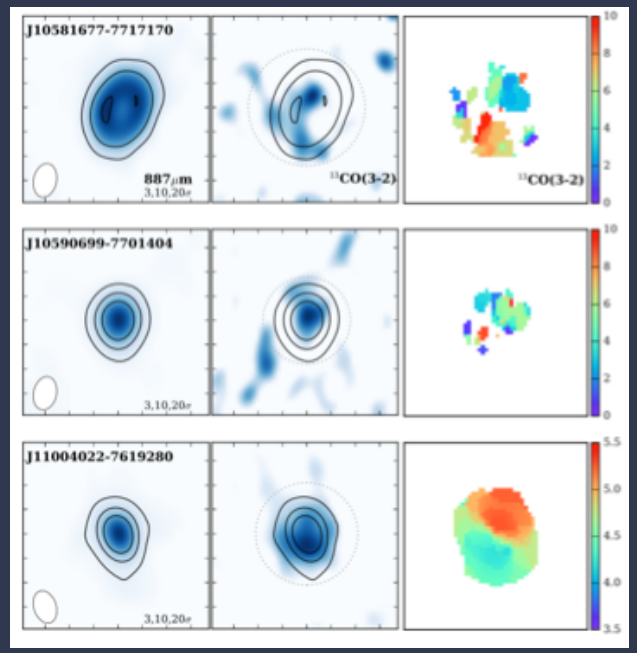
Ansdell et al., 2016;2018



CHAMAELEON I

PI: I. Pascucci
cycle 2, band 7
0.7”- 0.5”

Pascucci et al., 2016
Long et al. 2017

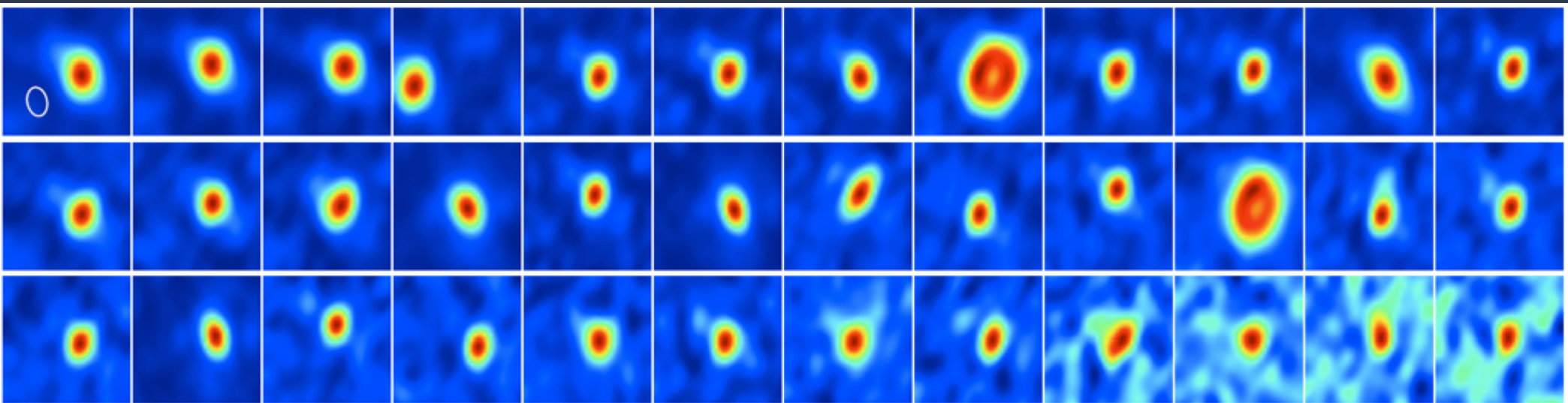


93 sources

66 detected in the continuum (890 μm)

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

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



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Pascucci et al., 2016
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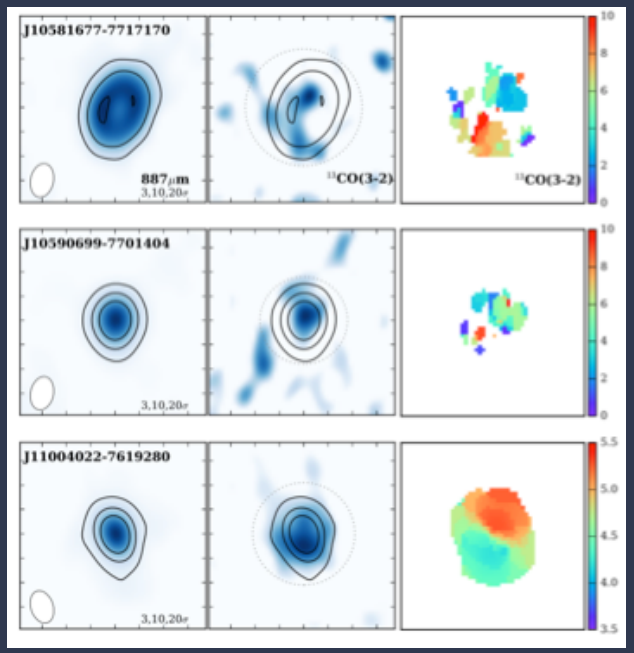
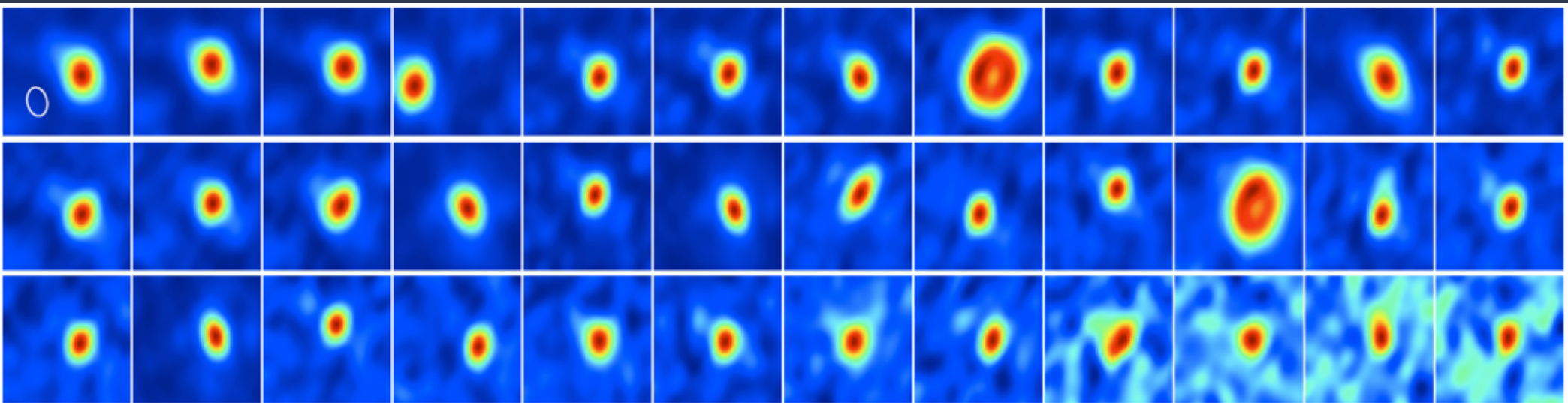


Resolution
0.7” - 0.5” beam
Sensitivity
0.2 -1 mJy beam^{-1}



σ-ORIONIS

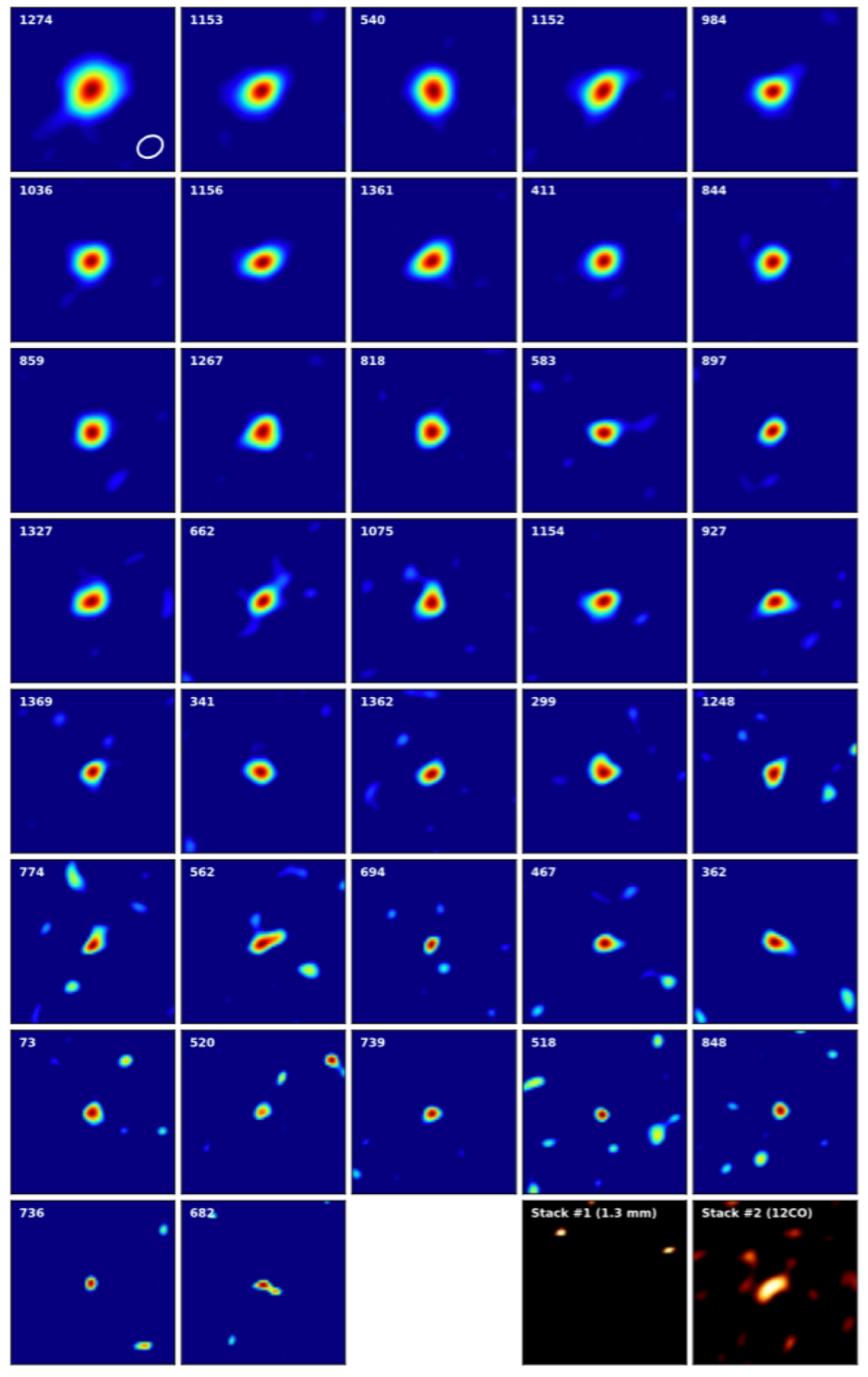
PI: J. Williams
cycle 3, band 6
0.31”x 0.25”→
120-95 au radius @385 pc

92 sources

37 detected in the continuum (890 μm)

6 in ^{12}CO (3-2)

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



Ansdell et al., 2017

σ-ORIONIS

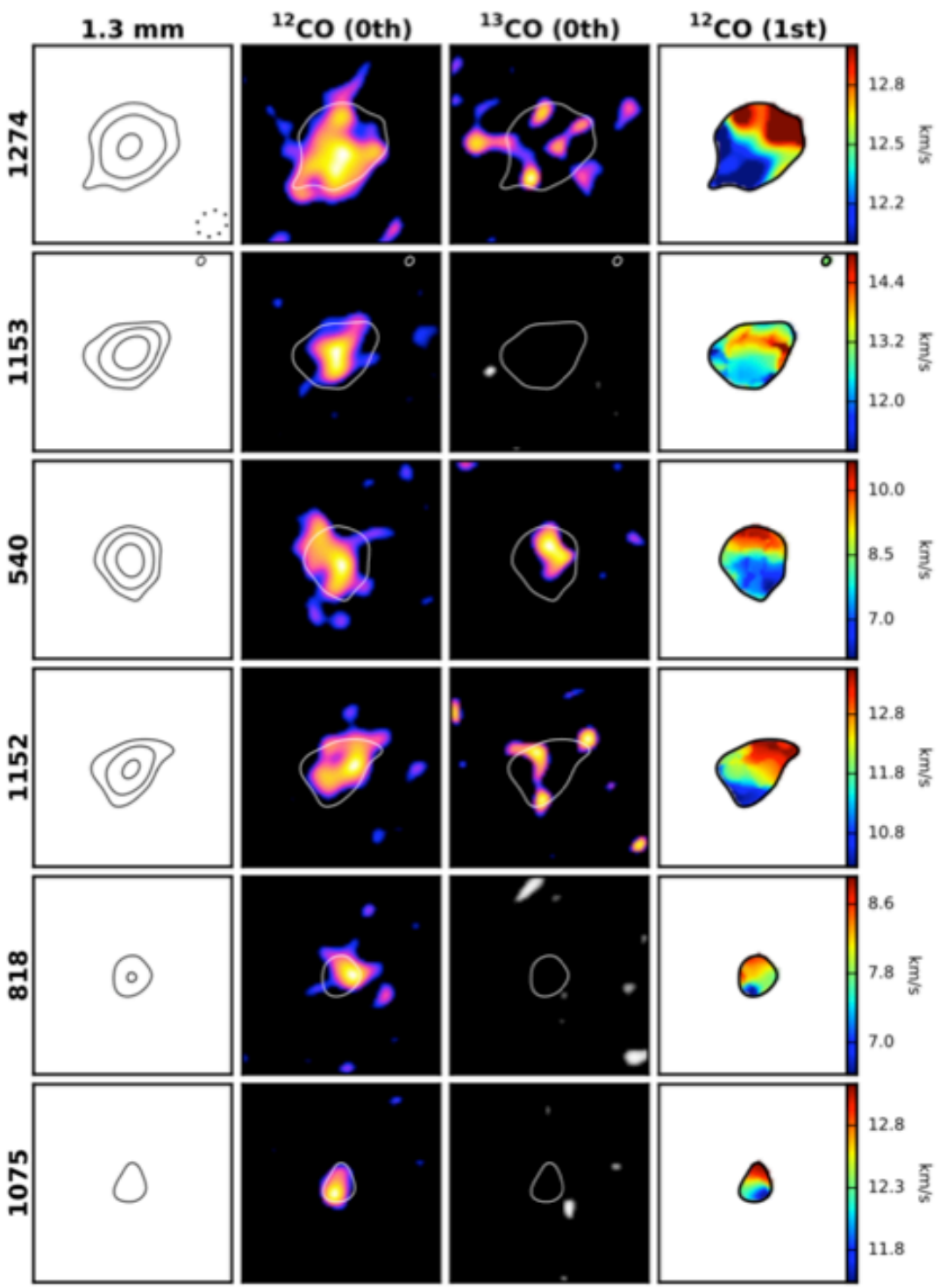
PI: J. Williams
cycle 3, band 6
0.31”x 0.25”→
120-95 au radius @385 pc

Resolution
0.31” x 0.25” beam

Sensitivity
0.15 mJy beam^{-1}

On source integr. time
1.2 minutes

Ansdell et al., 2017



TAURUS

PI: G. Herczeg

Resolution
0.1” beam

Sensitivity
10 mJy beam^{-1}
(0.2 km/s)

On source integr. time
4-10 minutes

32 targeted disks

11 clear detections down to ^{13}CO

3 sources affected by cloud contamination

Long et al., in prep.

CHA I → deeper observations

PI: G. Rosotti

Resolution
0.3” x 0.2” beam

Sensitivity
~ 1 mJy beam^{-1}
(0.7 km/s)

On source integr. time
20 minutes

6 targeted disks

4 clear detections down to $C^{18}O$

2 sources affected by cloud contamination

Rosotti, Miotello, et al., in prep

1 ALMA surveys were too shallow

1 ALMA surveys were too shallow

2 CO is much fainter than expected

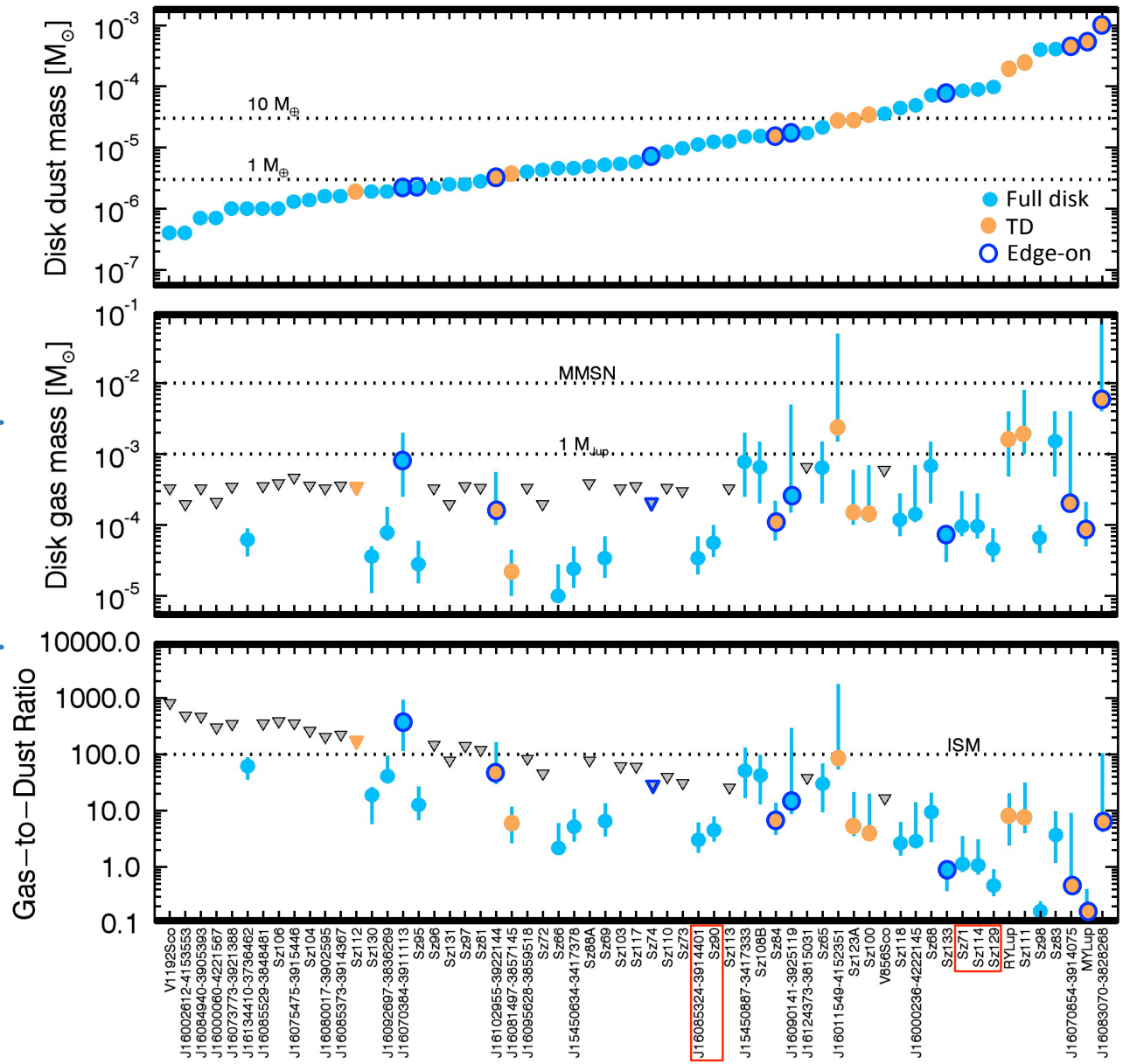
DISK MASSES

LUPUS

dust masses

gas masses

^{13}CO-based gas/dust ratio



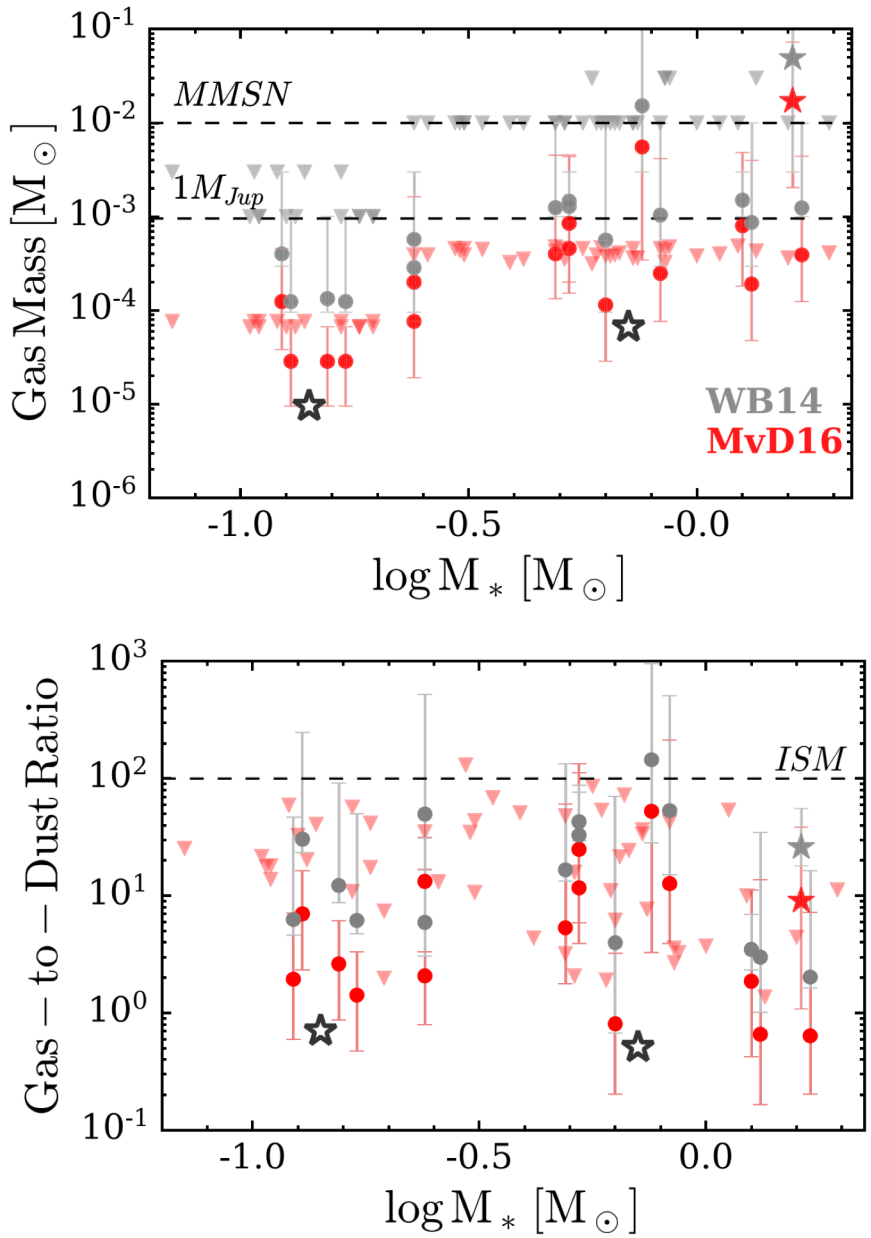
Miotello et al., 2017

DISK MASSES

CHAMAELEON I

gas masses

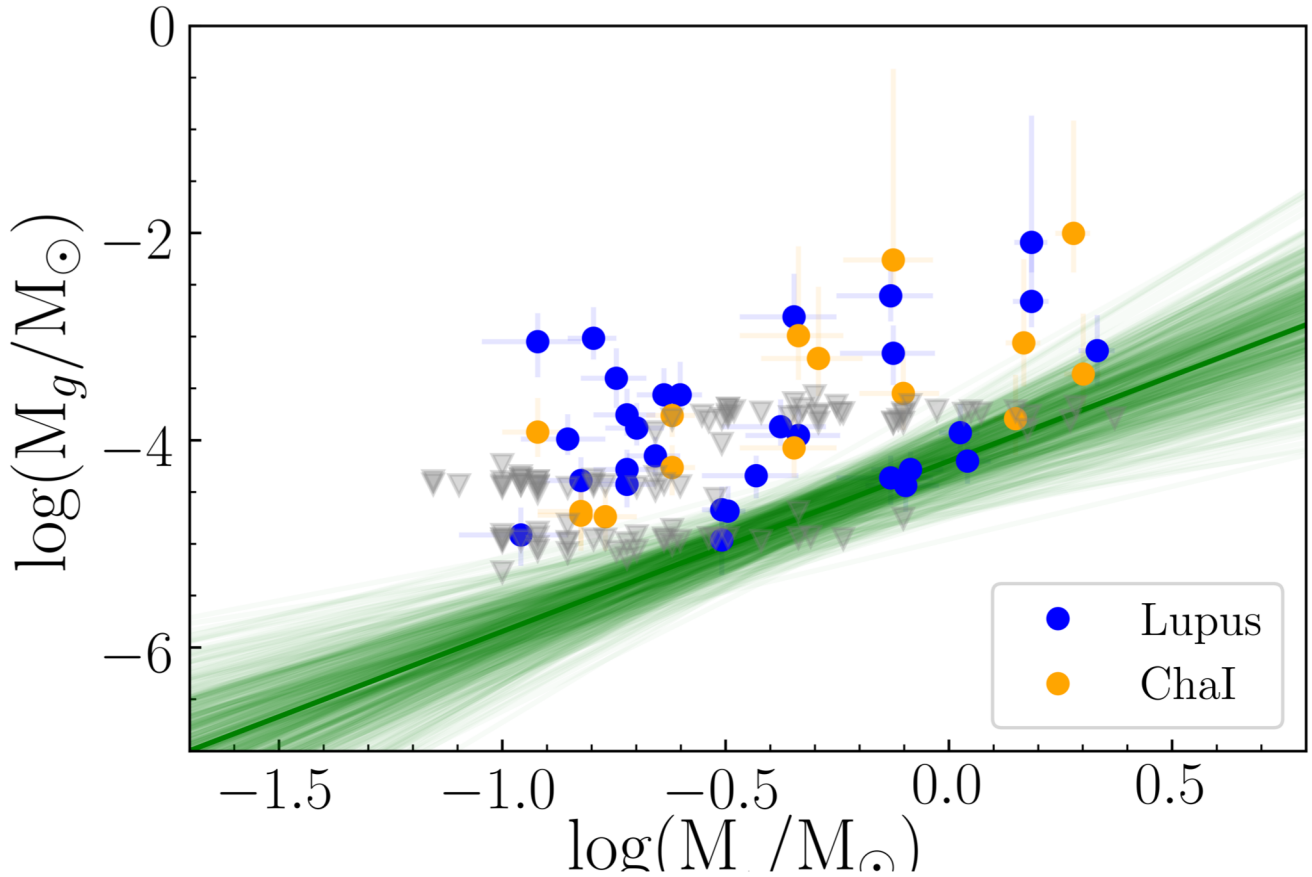
^{13}CO-based gas/dust ratio



Long et al., 2017

DISK MASSES

CHAMAELEON I + LUPUS



De Simone, Miotello & Testi
(in prep.)

LOW GAS/DUST OR HIGH VOLATILE 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

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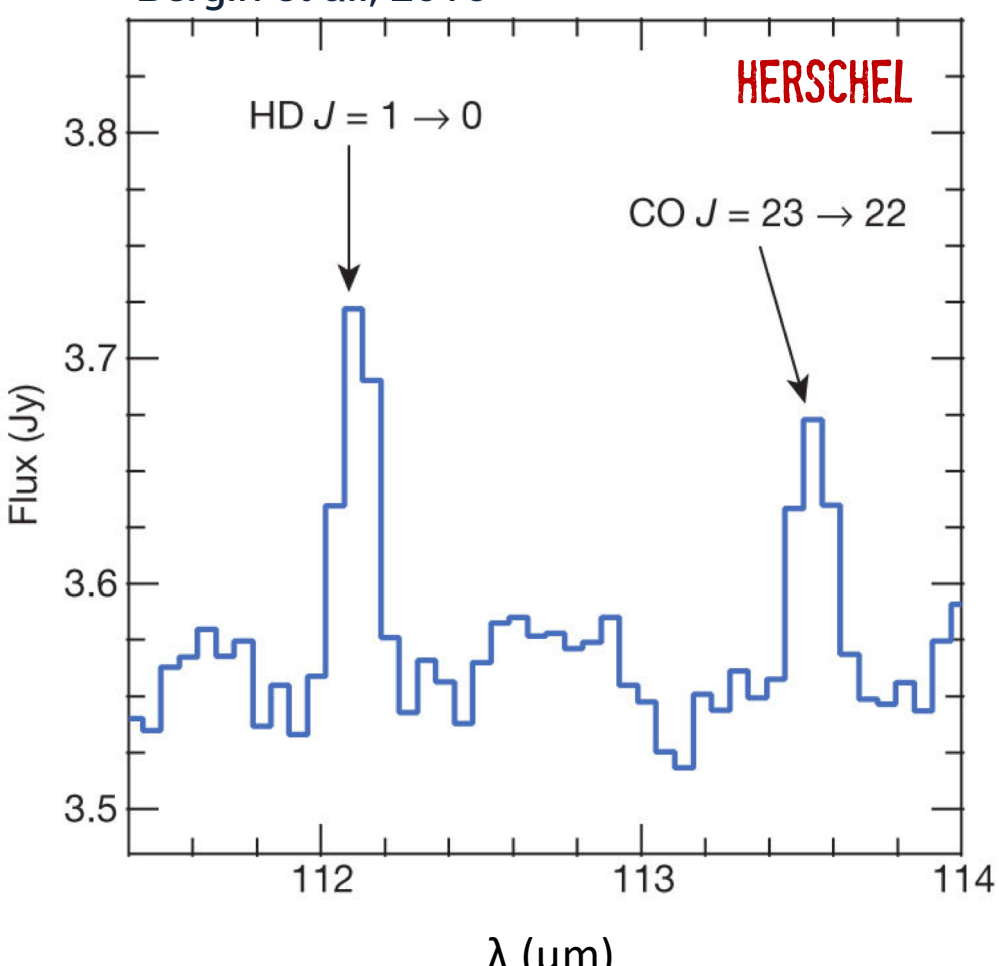
HYDROGEN DEUTERIDE

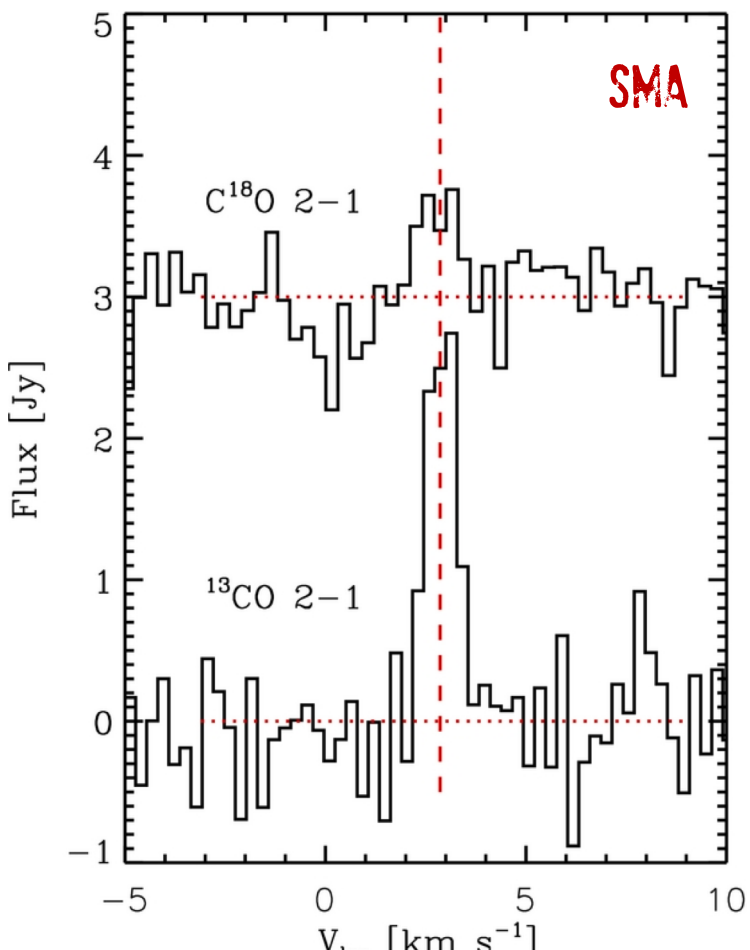
An alternative to measure disk masses
(Bergin et al. 2013; McClure et al. 2016)

TW HYA

Bergin et al., 2013



Favre et al., 2013



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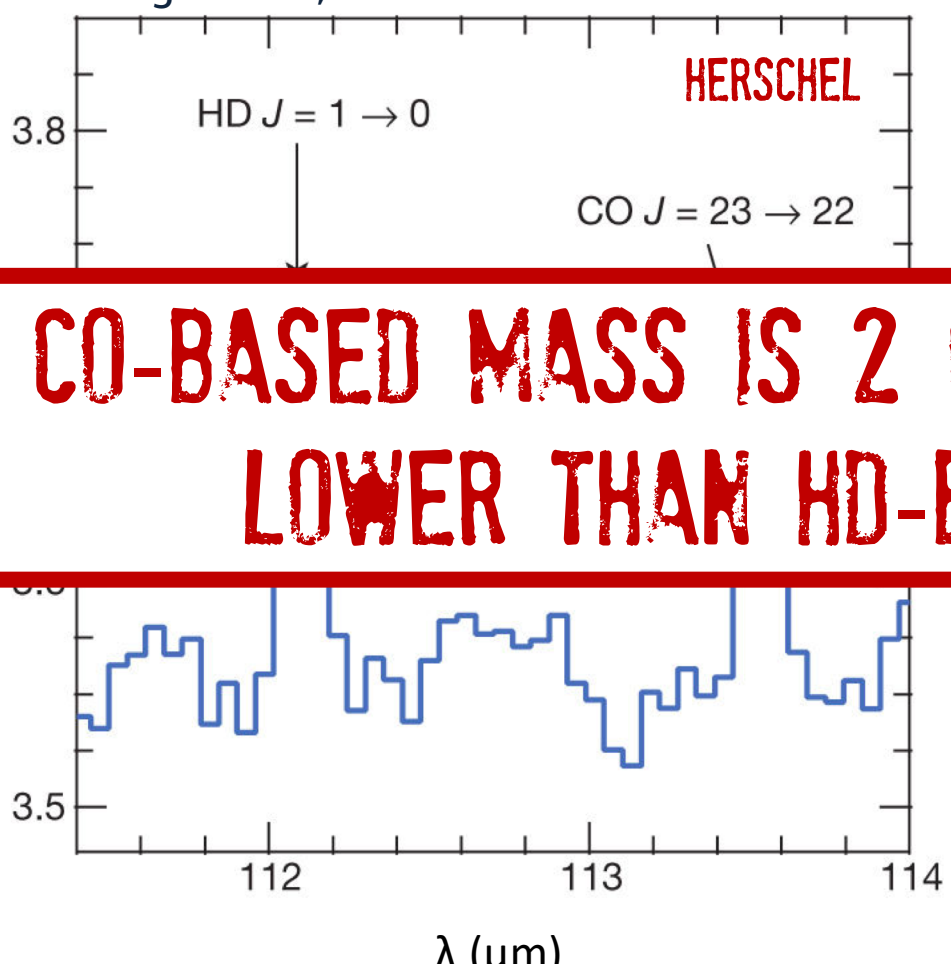
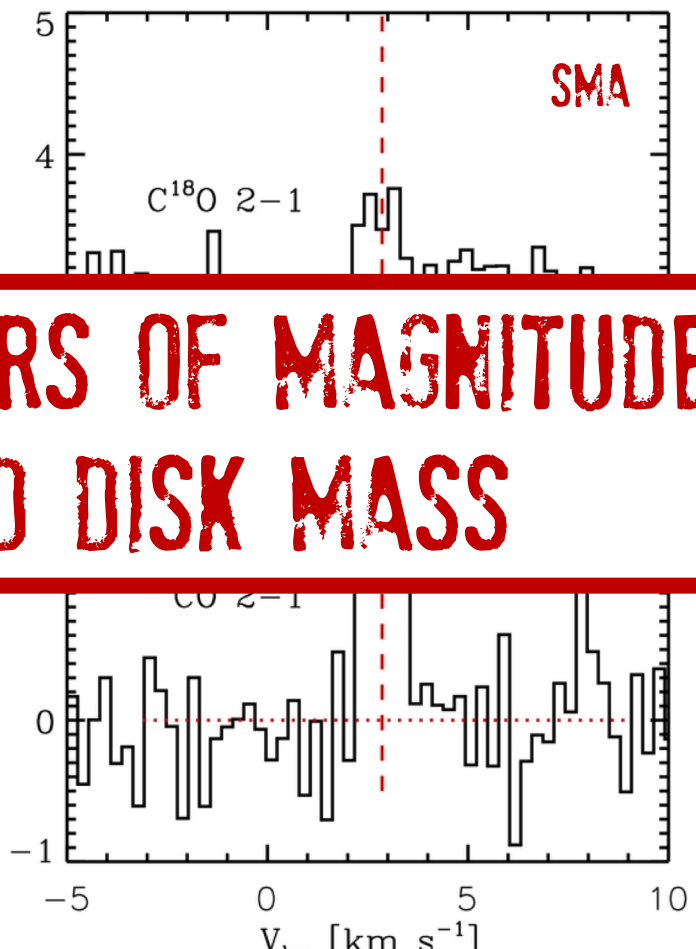


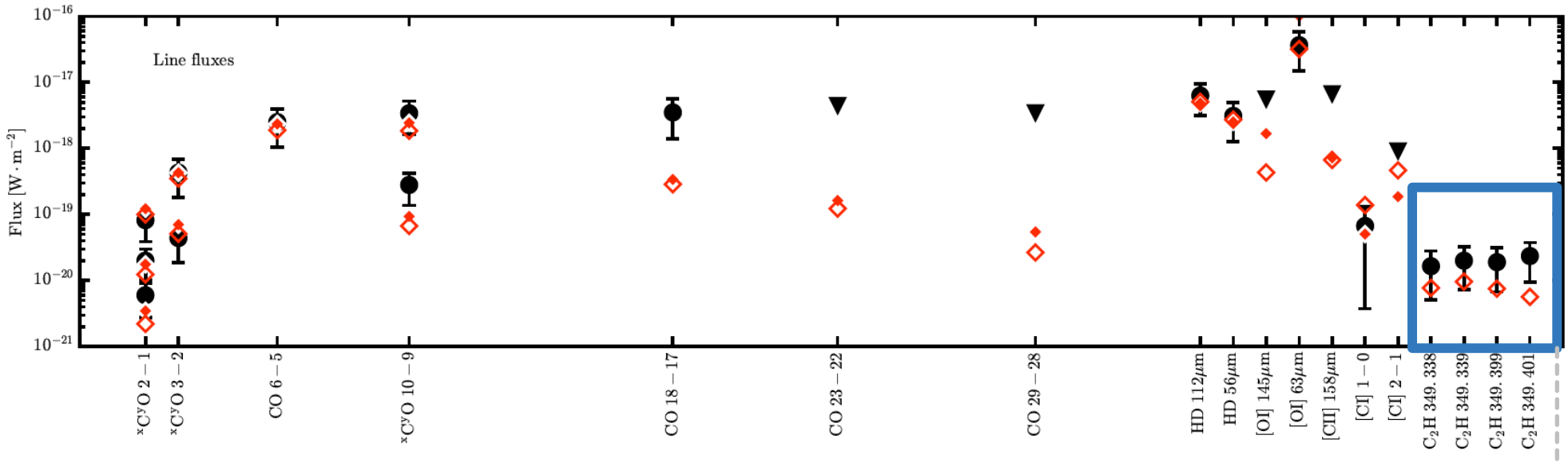
Favre et al., 2013



CO-BASED MASS IS 2 ORDERS OF MAGNITUDE LOWER THAN HD-BASED DISK MASS

C_2H in TW Hya

strong emission lines

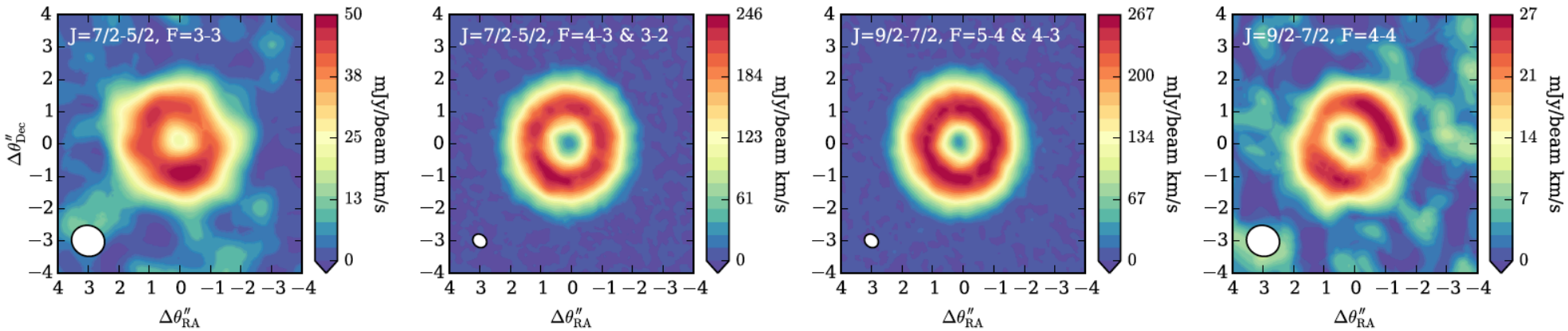


Kama et al., 2016
Trapman, Miotello, et al., 2017

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

C_2H rings

Hydrocarbons in TW Hya



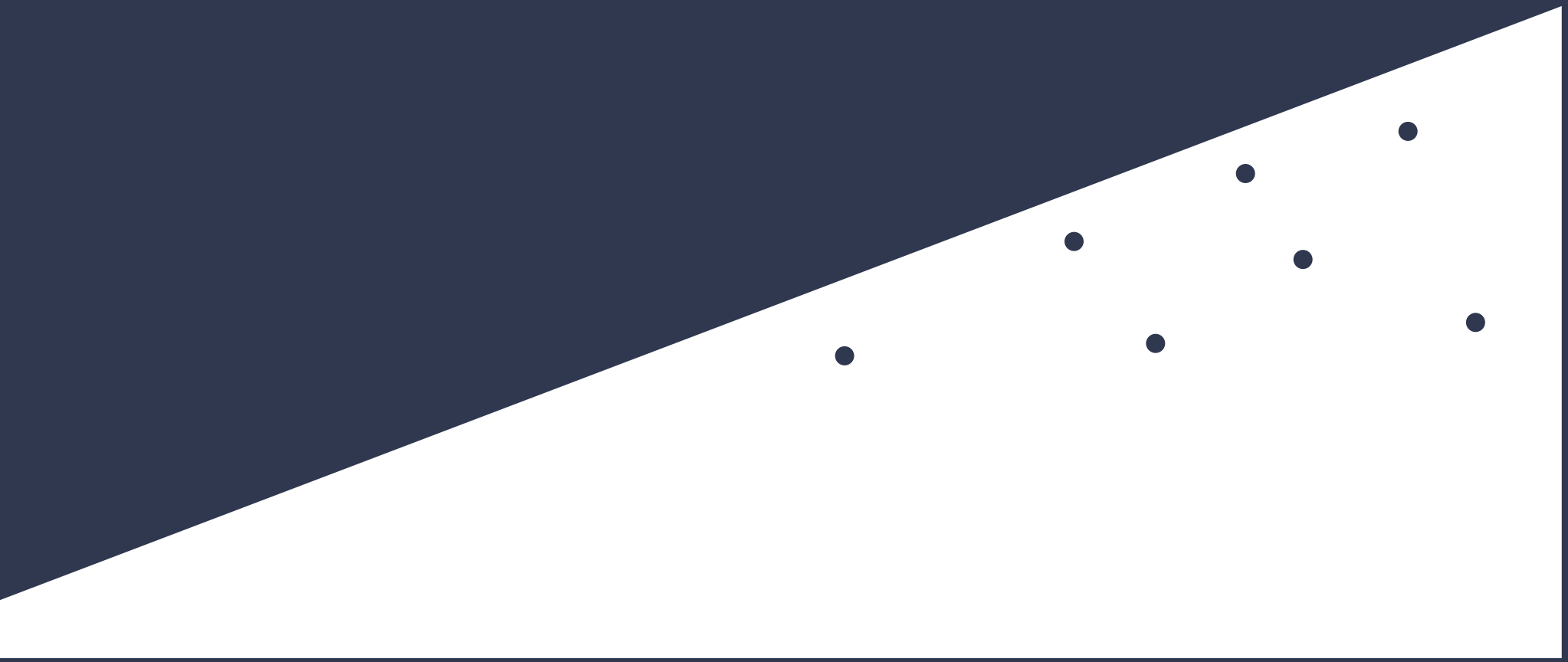
Bergin et al. (2016)
Kastner et al. (2015)

IM Lup (Cleeves et. al 2018)

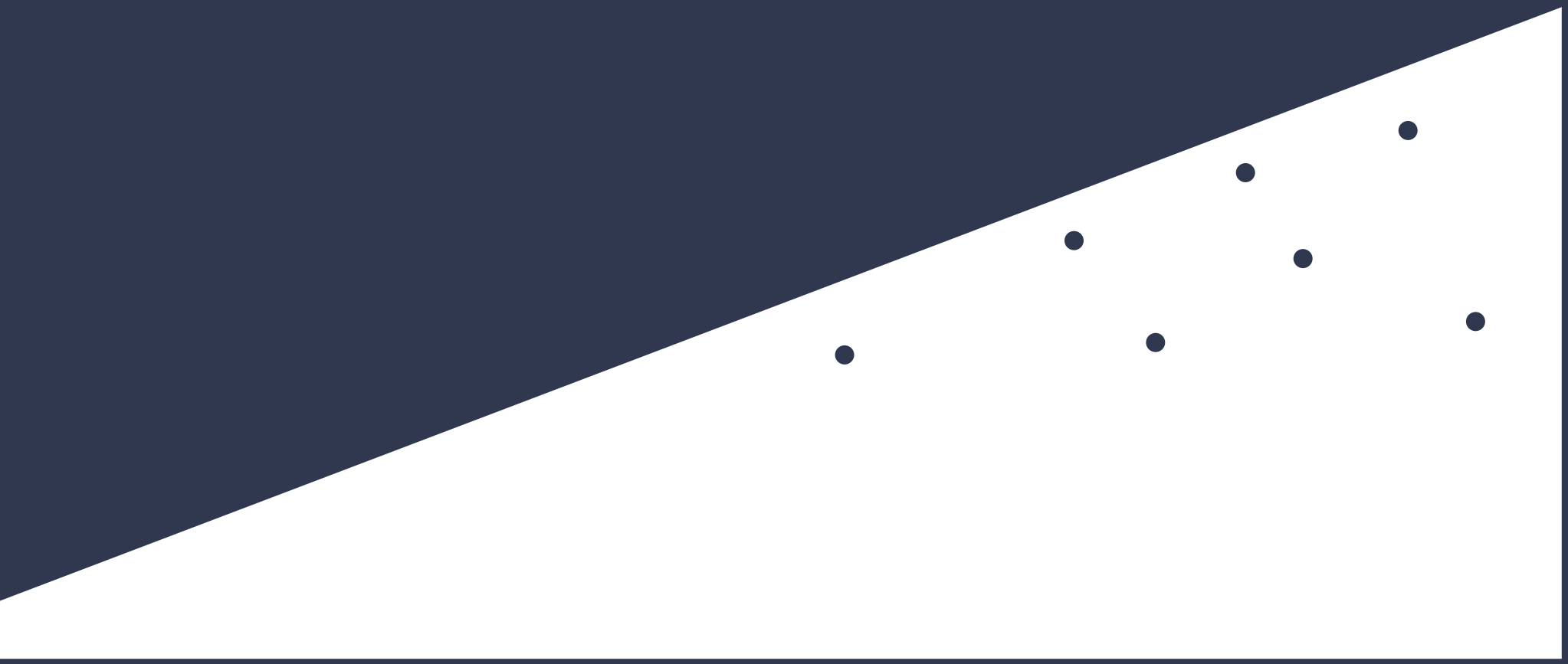
TW Hya

- C_2H strong emission
- CO fainter than expected

Bergin et al. (2016)



Bergin et al. (2016)



settling

Bergin et al. (2016)

C and O volatile depletion

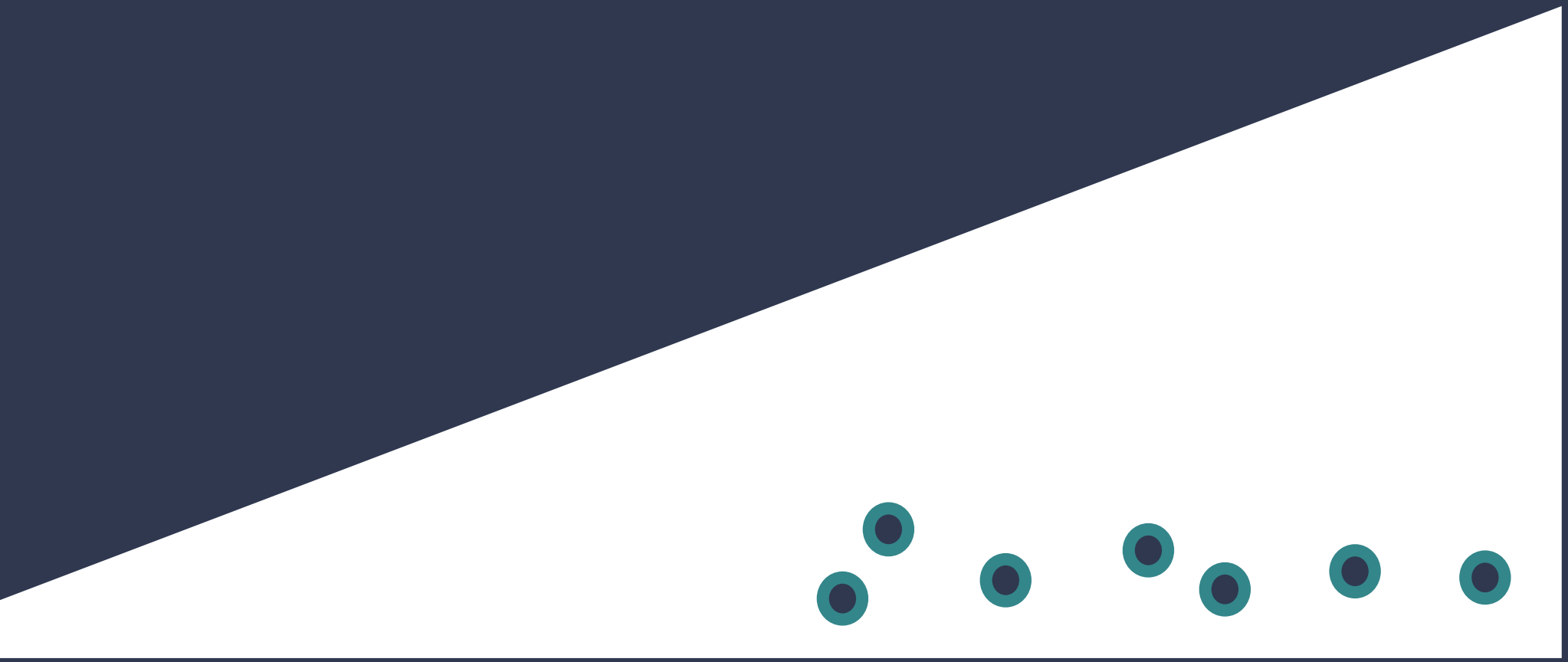
[C]/[O] > 1

(CO_2, CH_3OH ices large bodies)

ice coating

Hogerheijde et al. 2011; Du et al. 2017; Krijt et al. 2018
Eistrup et al. 2016; 2018; Yu et al. 2017a,b; Bosman et al. 2017, 2018; Schwarz et al. 2018

Bergin et al. (2016)



radial drift

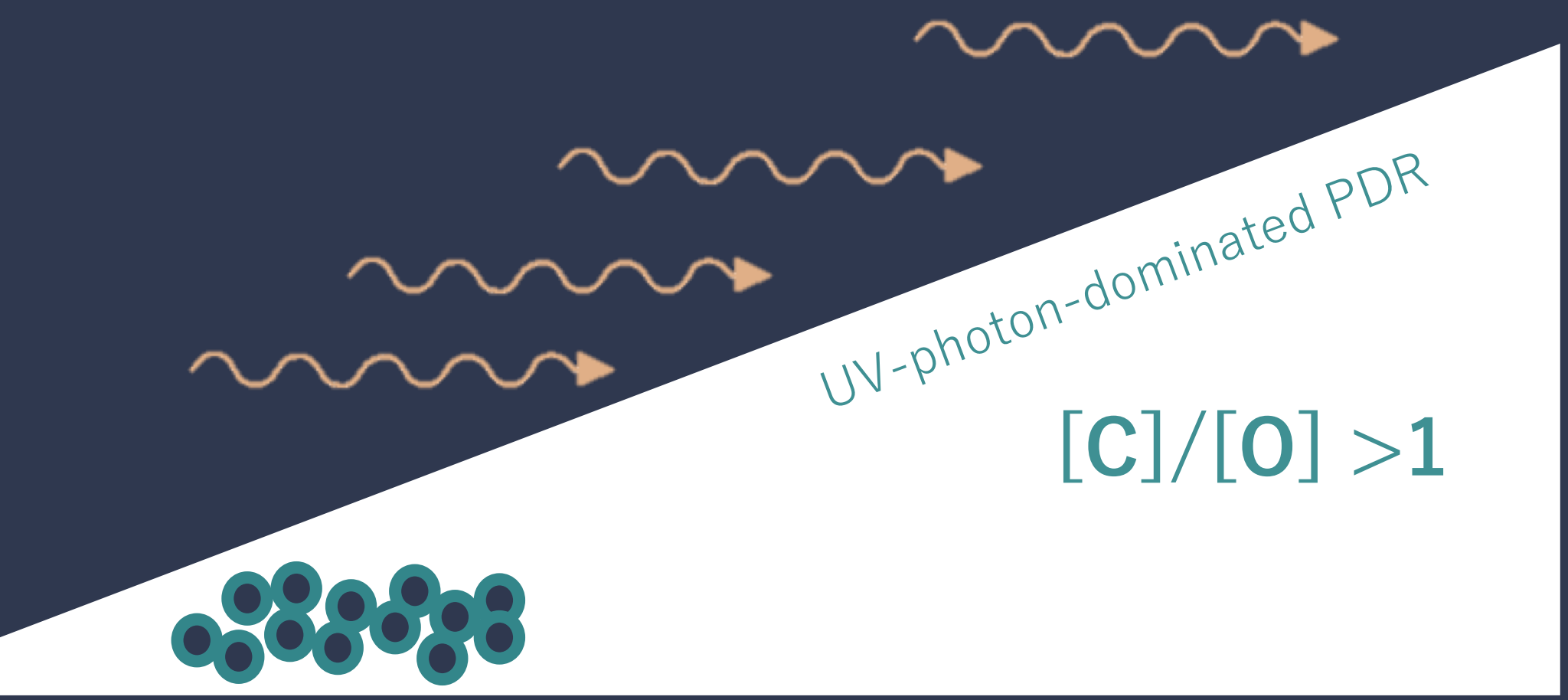
Bergin et al. (2016)

[C]/[O] >1

Some free C
not in CO

hydrocarbon chemistry starts

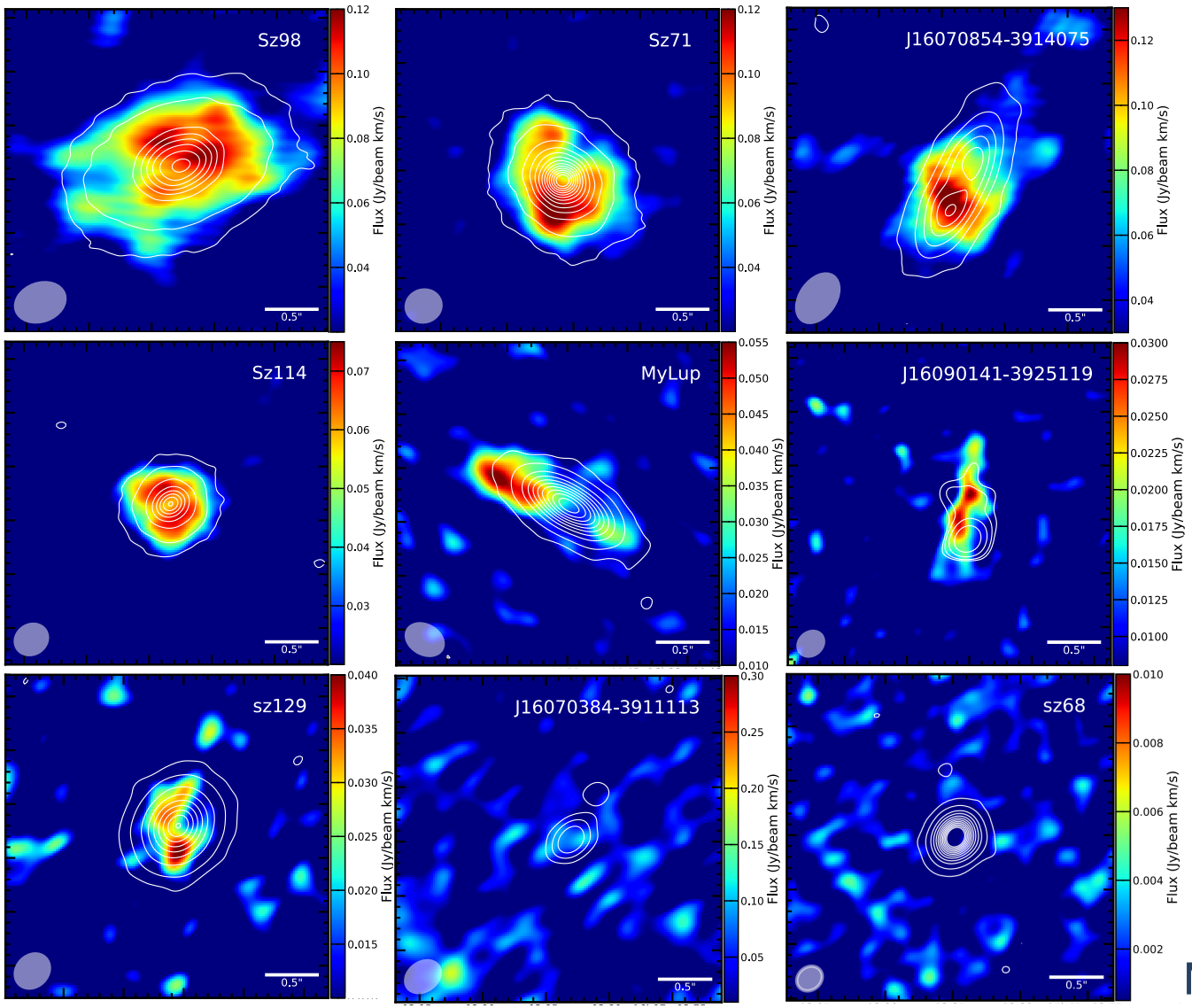
Bergin et al. (2016)



hydrocarbon emission is boosted

C_2H in Lupus

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



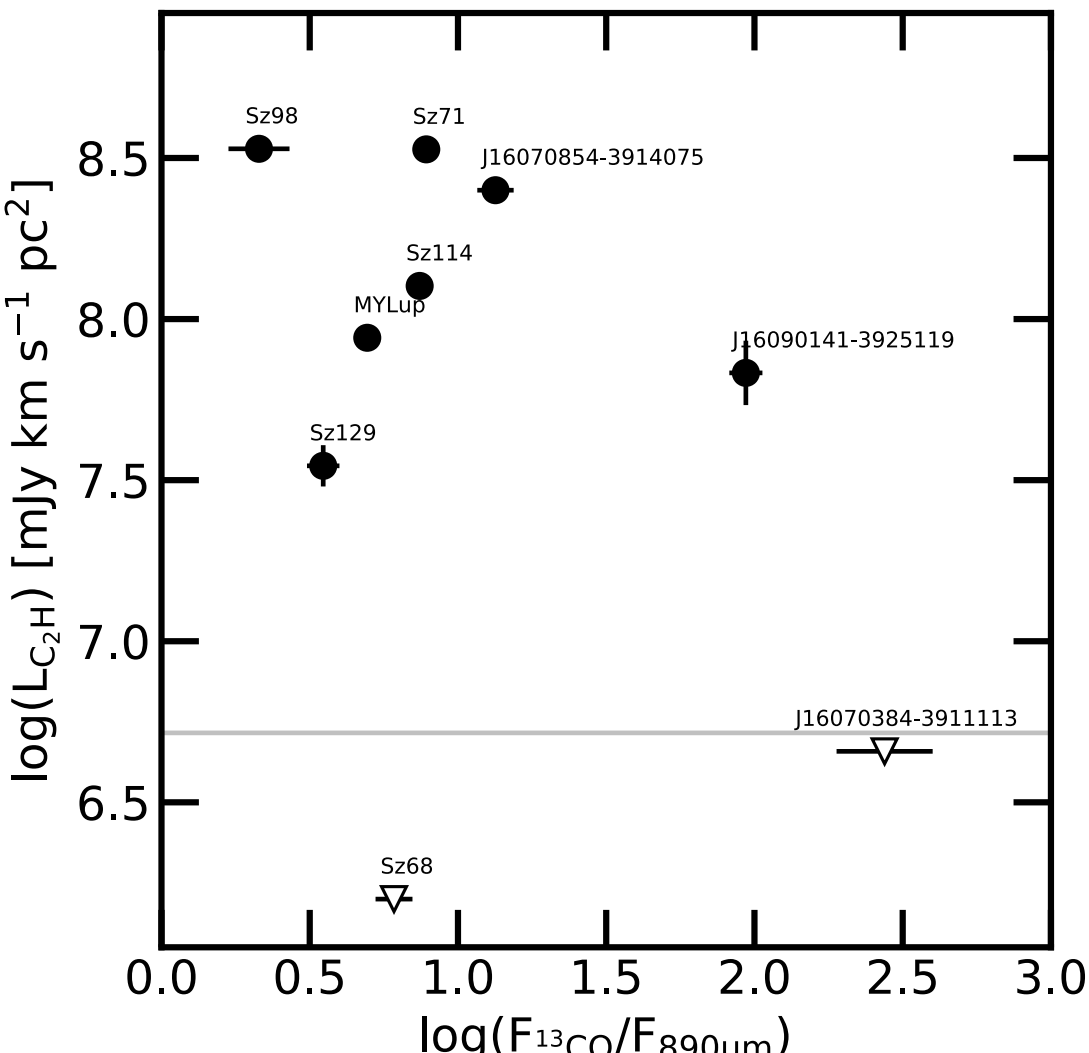
search for anti-correlation

of C_2H and ^{13}CO line luminosity in a subsample of Lupus disks with CO-based g/d ratios between 1 and 100

Miotello et al., to be submitted

C_2H in Lupus

Possible ON/OFF switch of hydrocarbon emission led by C/O ⩾1



Step-function

Led by C/O ratio

Miotello et al., to be submitted

C_2H in Lupus

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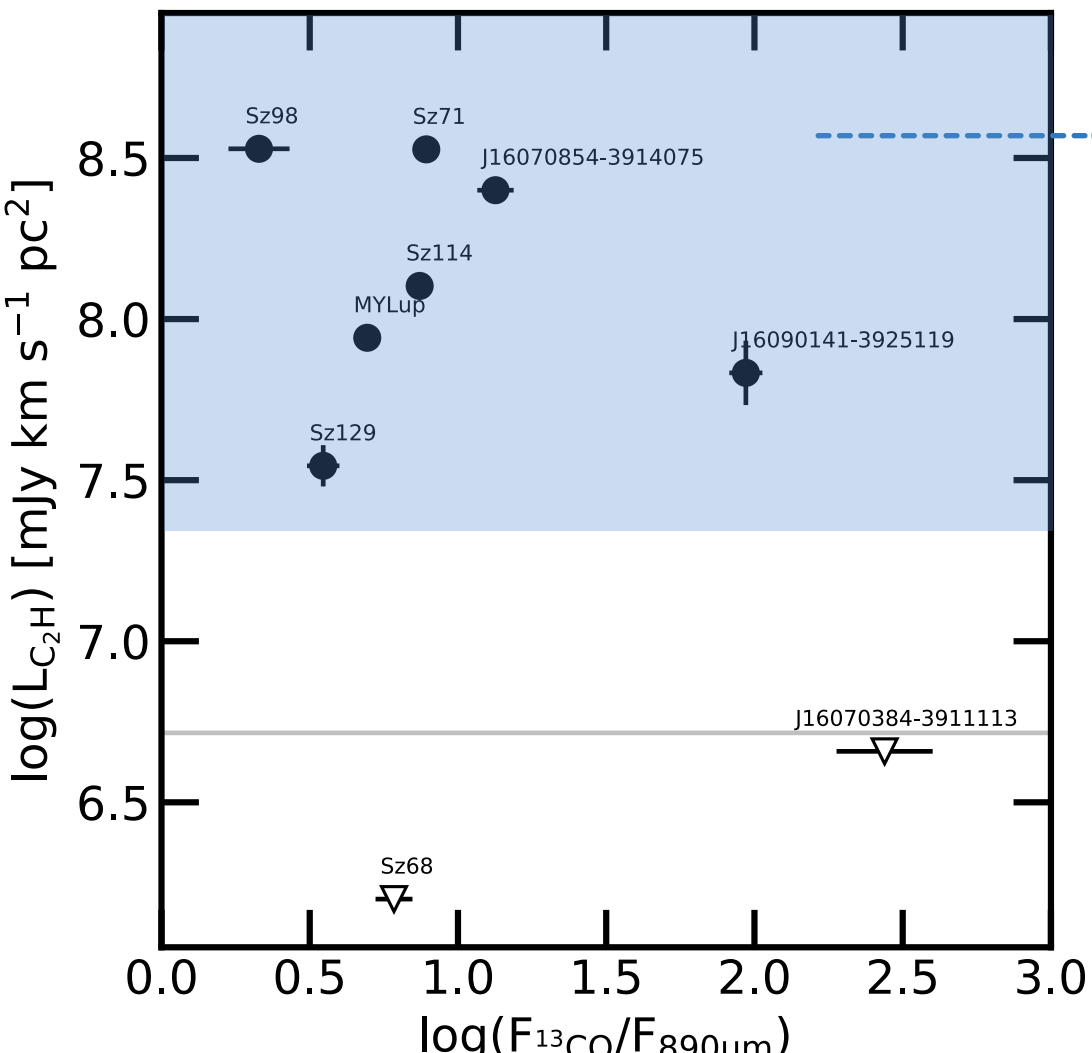


C_2H is bright

as bright as ^{13}CO when it is detected

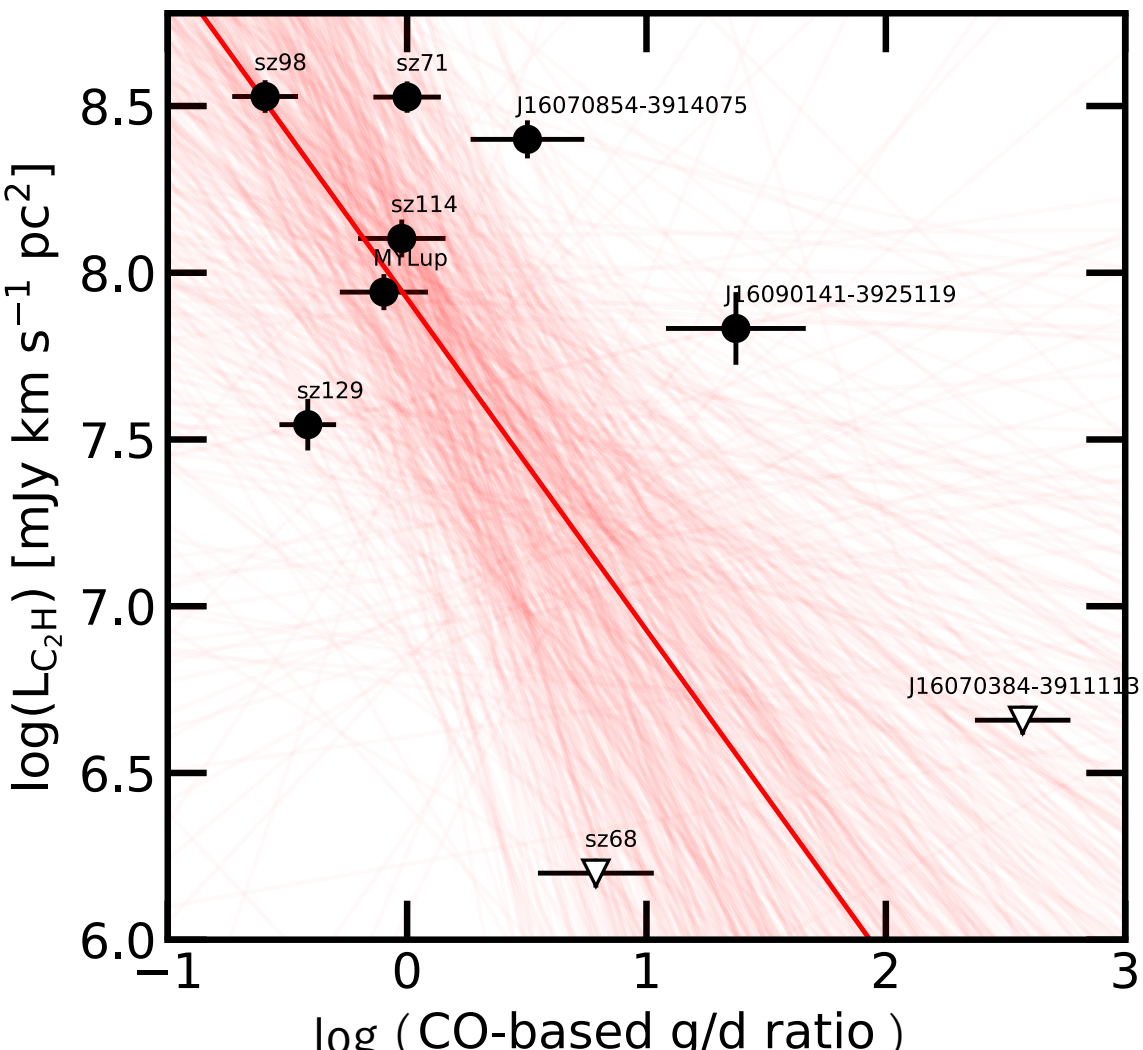
Step-function

Led by C/O ratio

Miotello et al., to be submitted

C_2H in Lupus

tentative anticorrelation between C_2H emission and CO-based g/d ratio



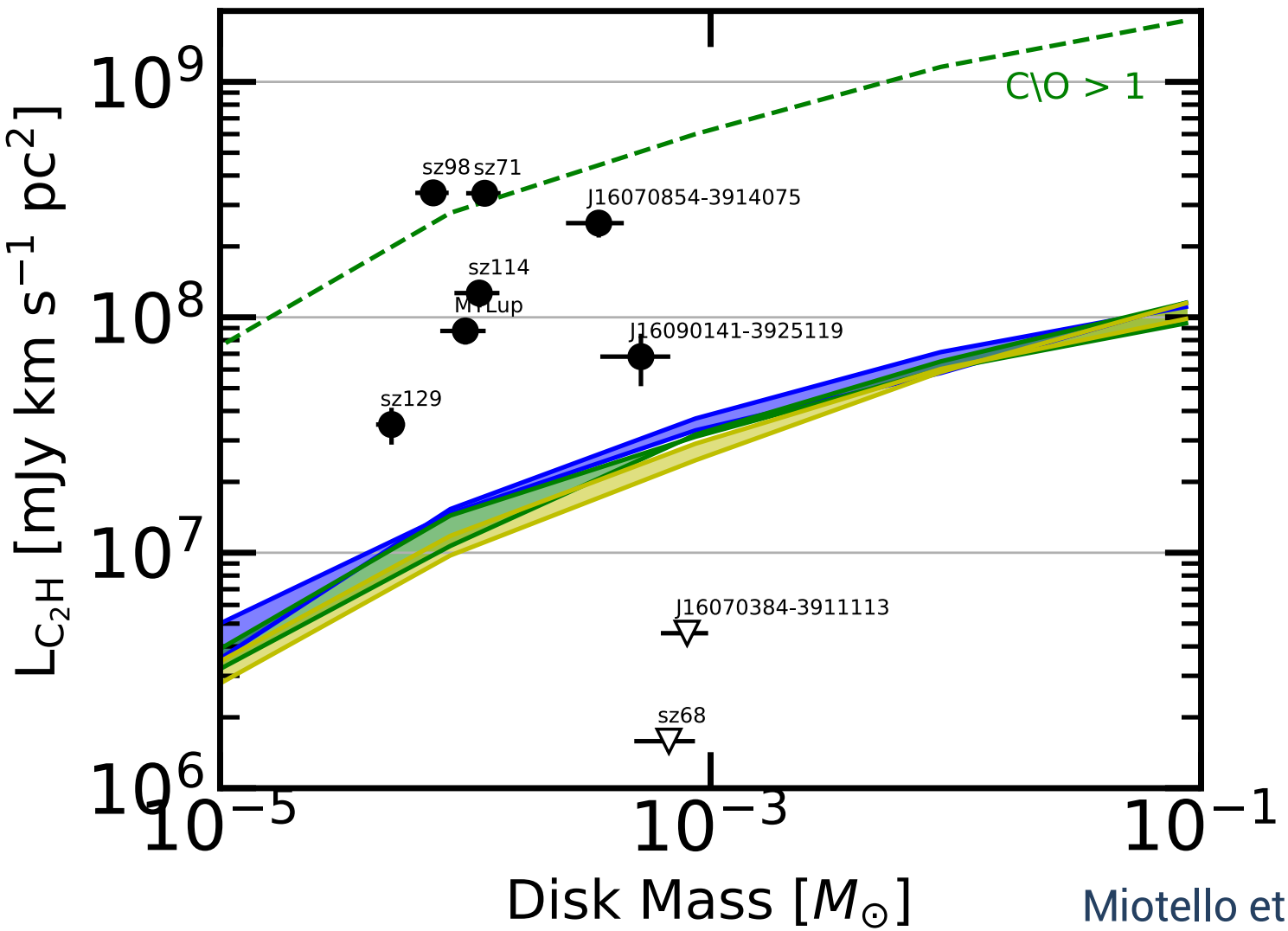
anti-correlation

Limited by low-number statistics

Miotello et al., to be submitted

C_2H in Lupus

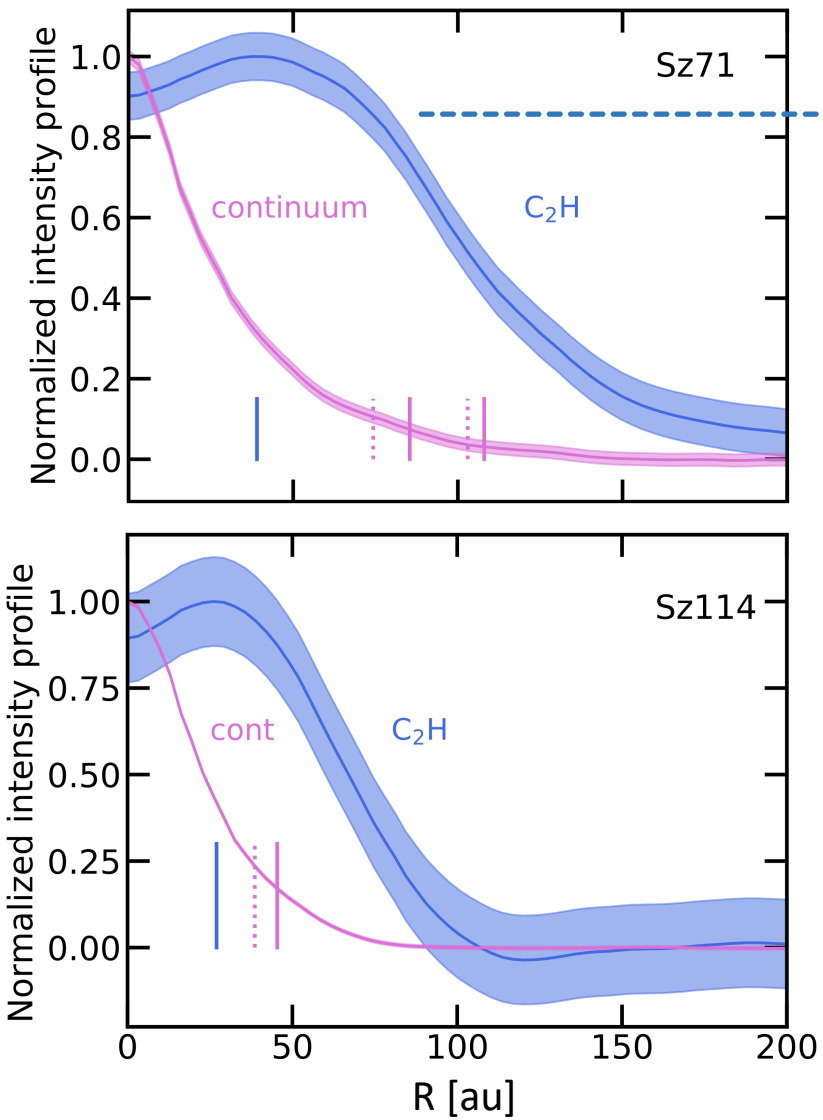
Volatile C and O depletion and C/O>1 can explain the observed ^{13}CO and C_2H fluxes



Miotello et al., in prep.
Cazzoletti et al., 2018

C_2H in Lupus

C_2H ring-like emission seems disconnected from continuum substructures



C_2H rings

Two sources in common with DSHARP.

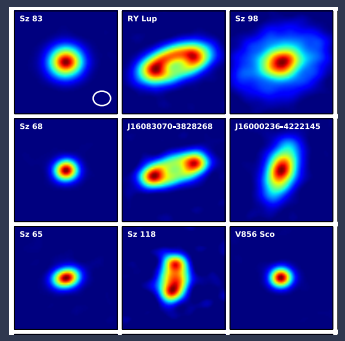
Similarly to CN, location of C_2H rings is not connected either with continuum rings or dips

Miotello et al., in prep.
DSHARP - Huang et al., 2018
Cazzoletti et al., 2018
van Terwisga et al. 2018

TAKE HOME MESSAGE

CO emission is faint

sign of disk evolution



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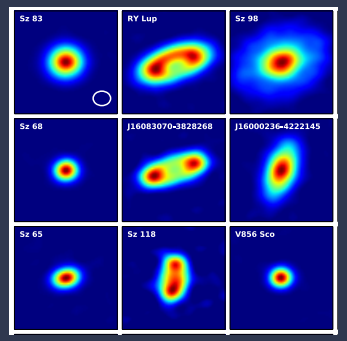
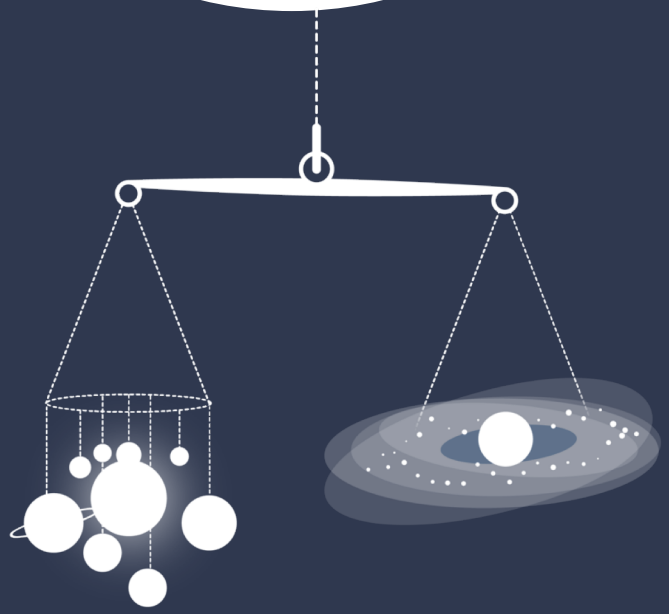


Physical or chemical evolution?

TAKE HOME MESSAGE



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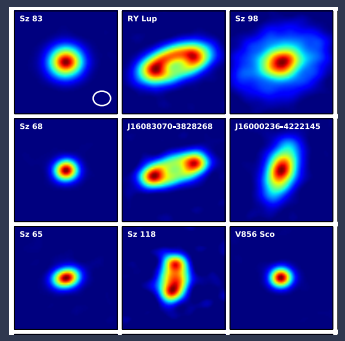

C_2H hints at chemical evolution

fast gas dispersal is not yet ruled out