

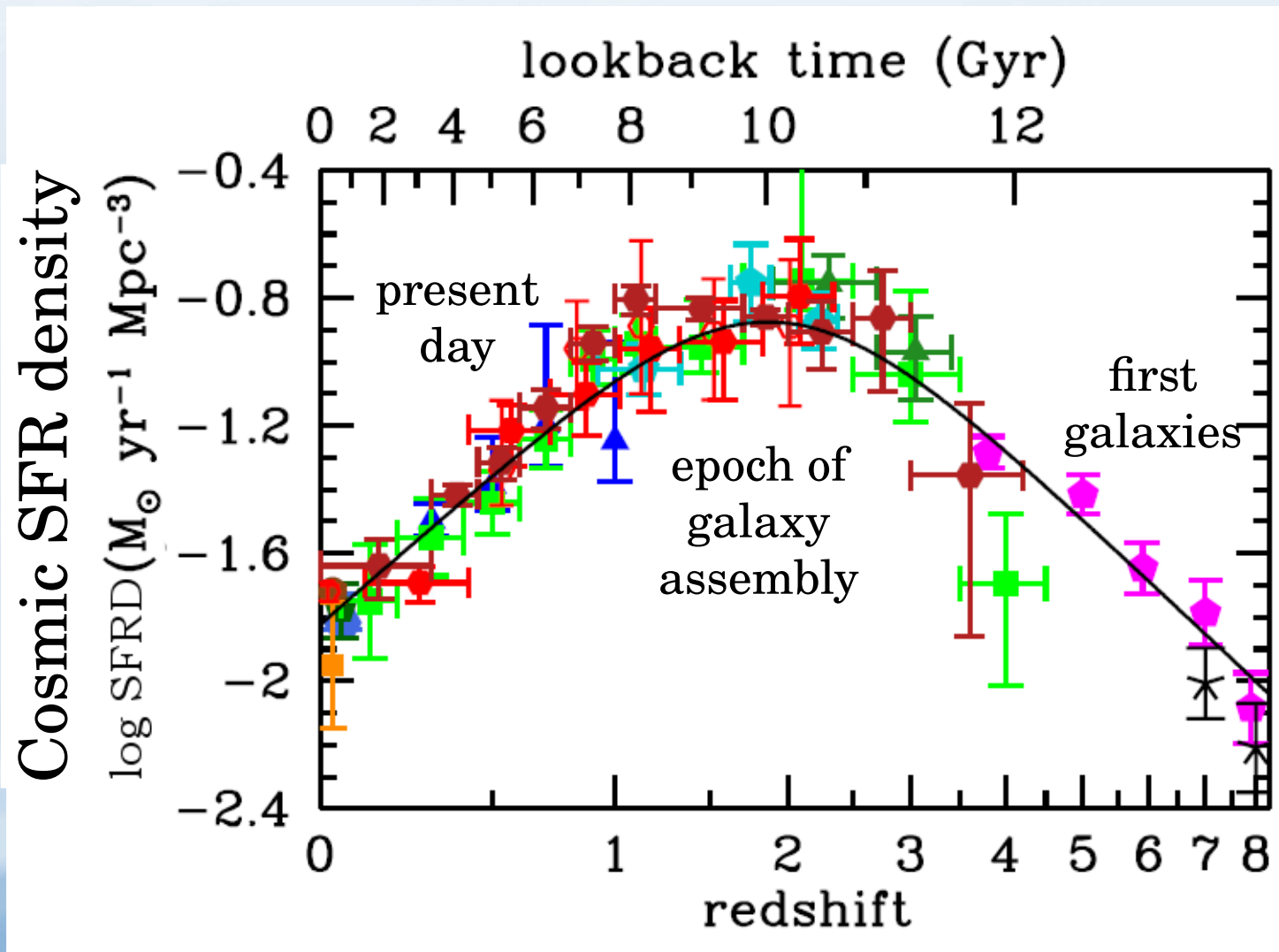


# The interstellar medium at high redshift

Roberto Decarli

INAF Osservatorio Astronomico di Bologna

# We now know the Cosmic Star Formation History

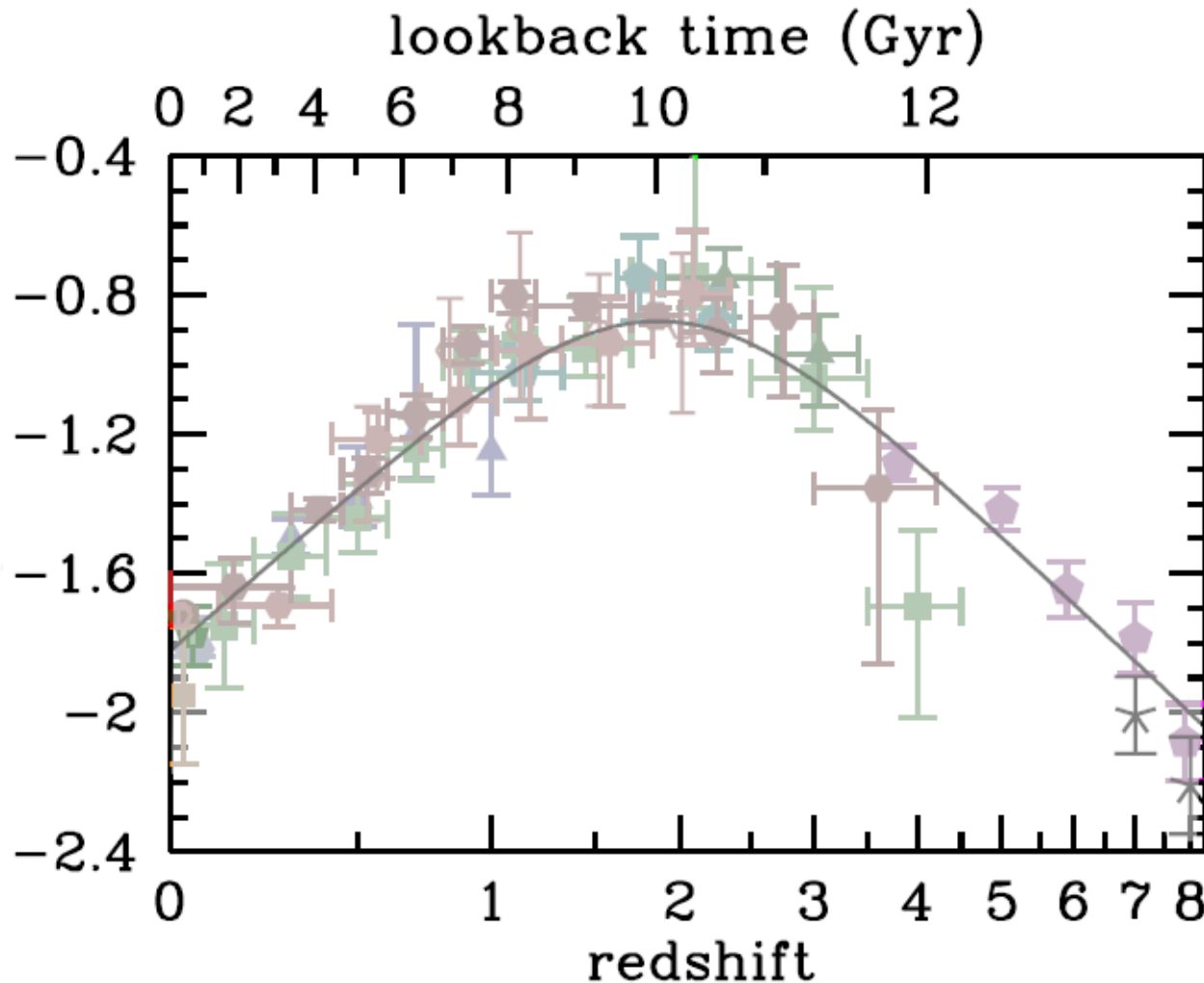


“Lilly-Madau”  
plot

# What drives the Cosmic Star Formation History?

# What drives the Cosmic Star Formation History?

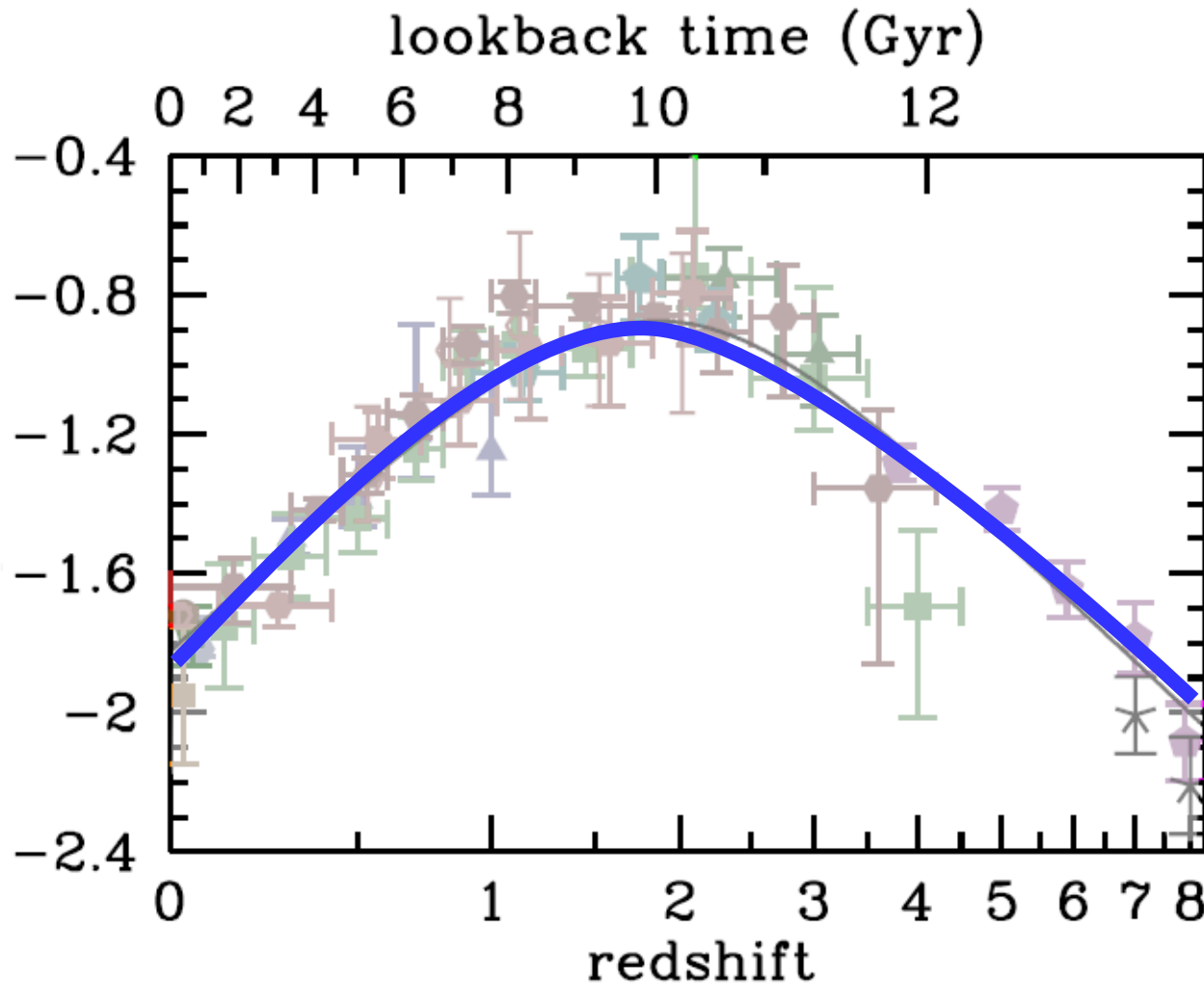
Gas cosmic density



“Lilly-Madau”  
plot, for gas

# What drives the Cosmic Star Formation History?

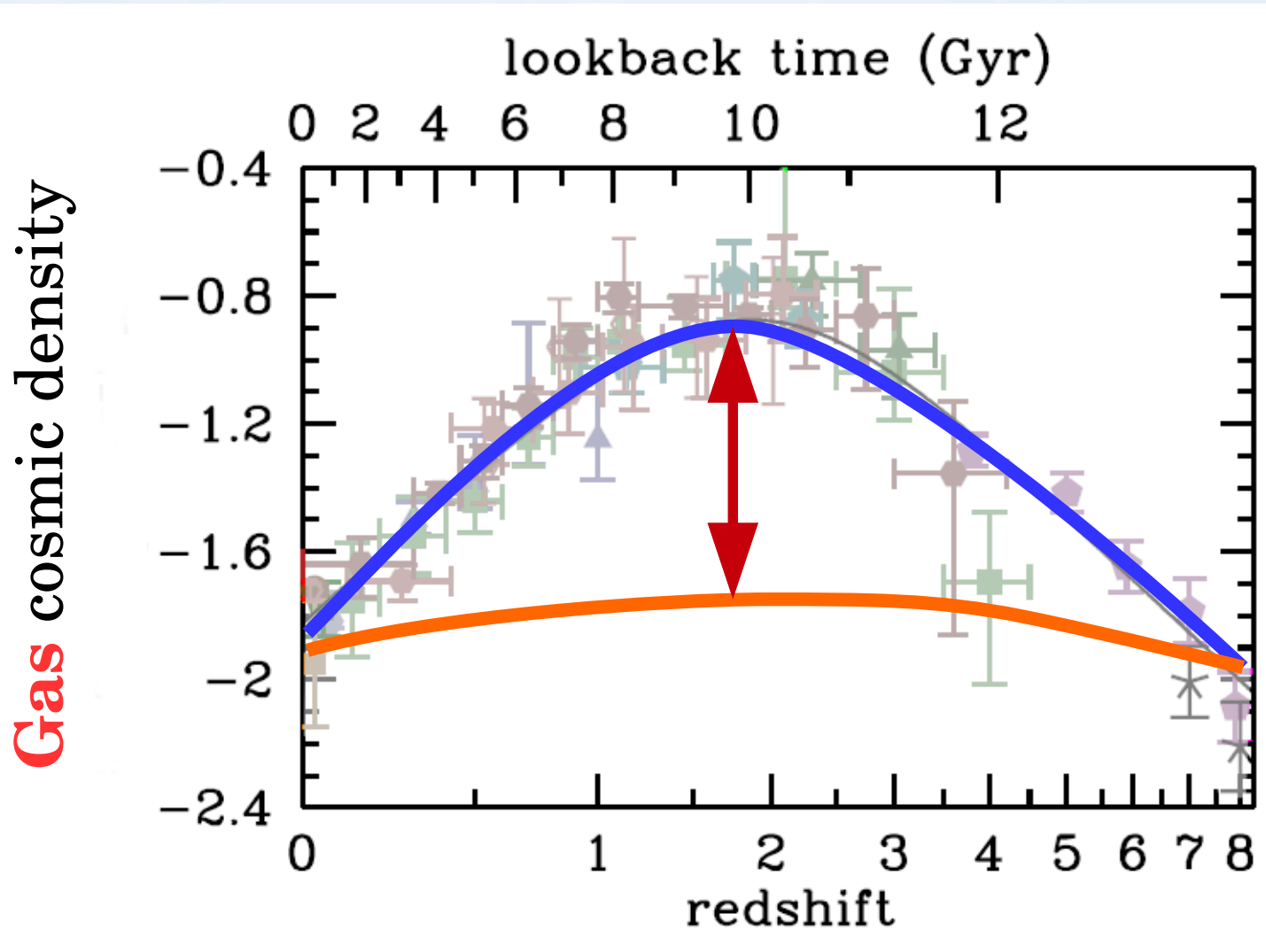
Gas cosmic density



“Lilly-Madau”  
plot, for gas

Does the  
gas supply  
evolve?

# What drives the Cosmic Star Formation History?



“Lilly-Madau”  
plot, for gas

Does the  
gas supply  
evolve?

Does the  
star  
formation  
efficiency  
change?

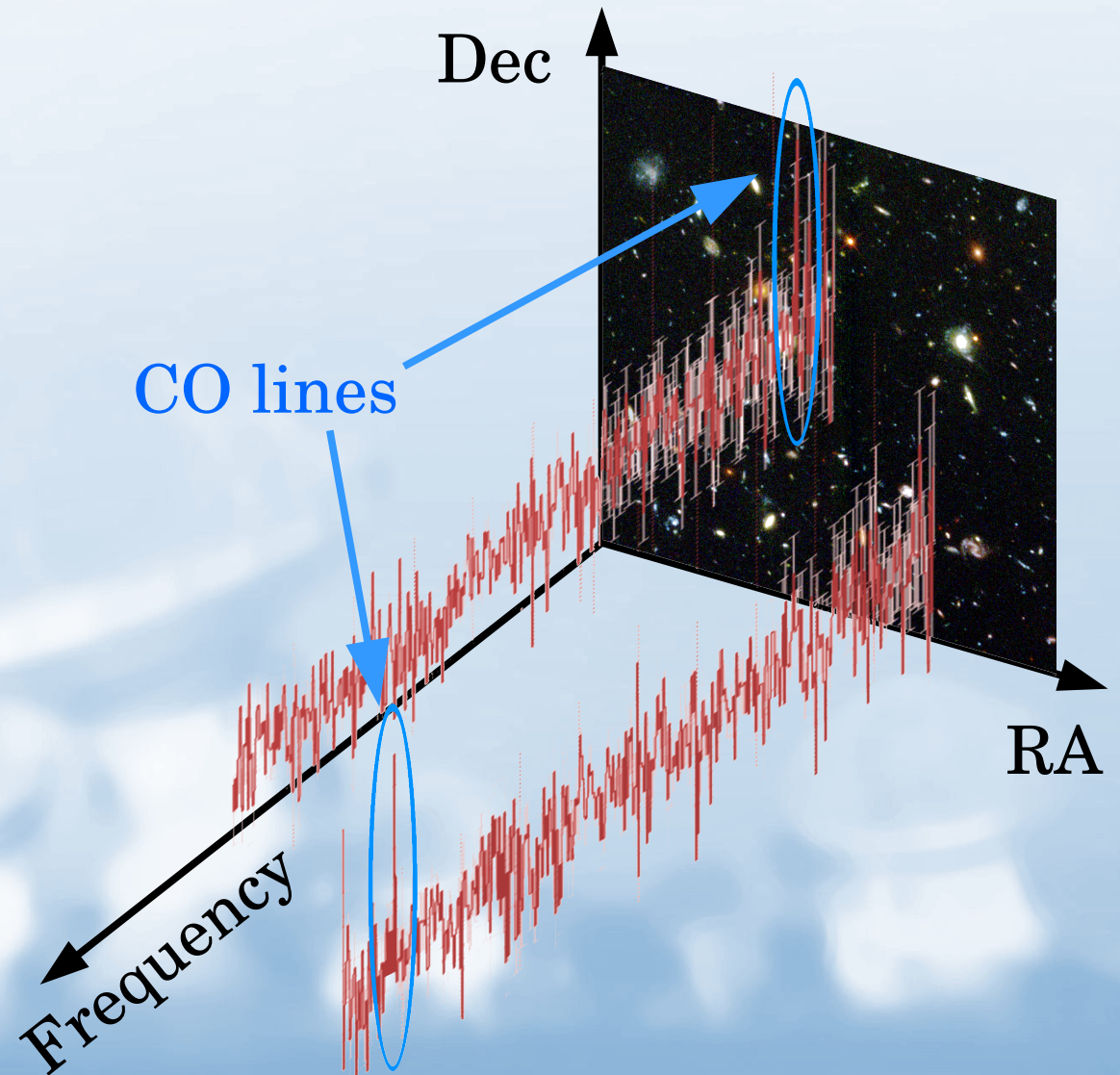
# A change of gear in ISM studies at high $z$



# A novel approach: Molecular Deep Fields

Deep field strategy,  
but for gas

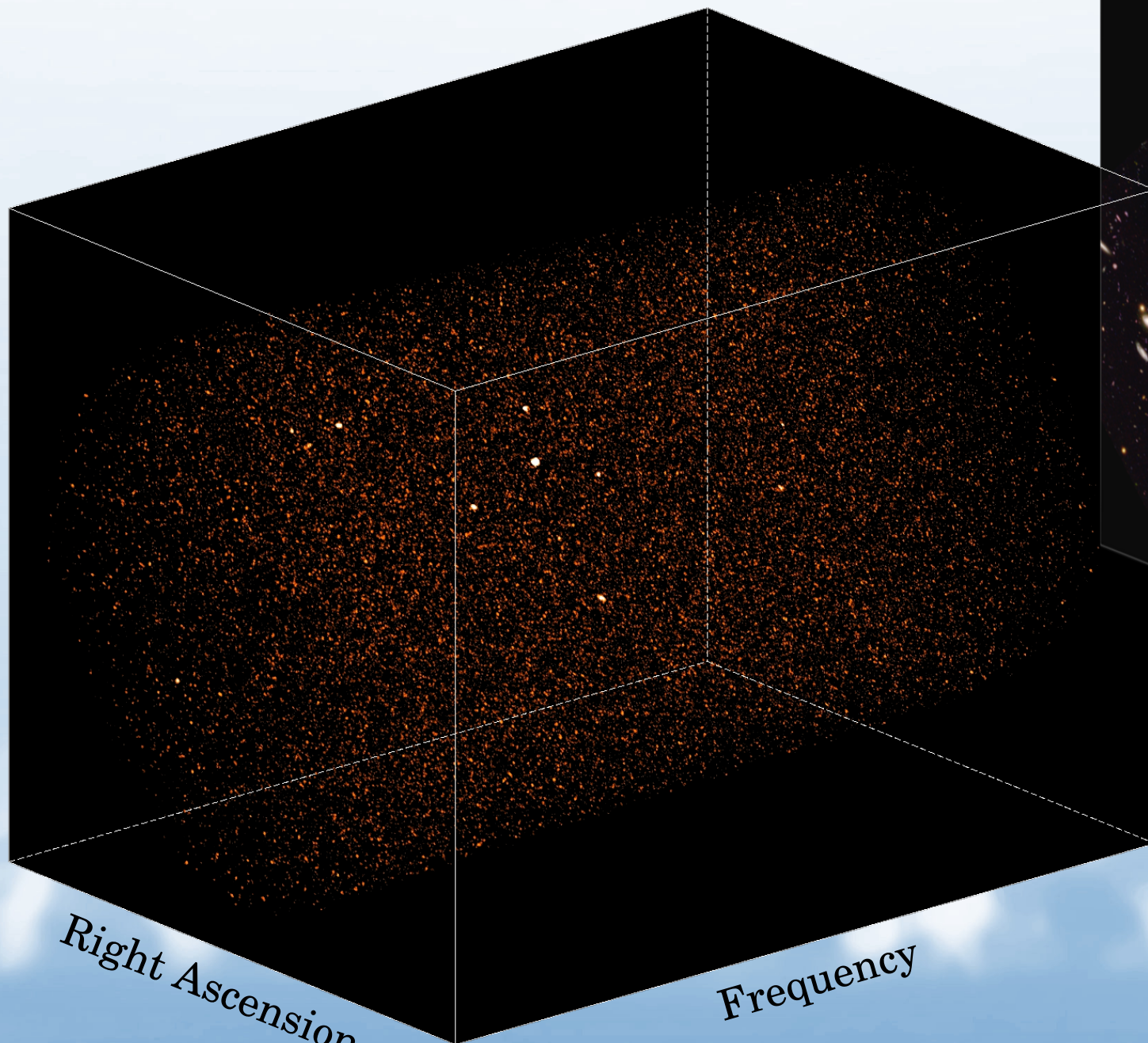
Blind search  
=  
no pre-selection



adapted from Decarli et al. (2014a)

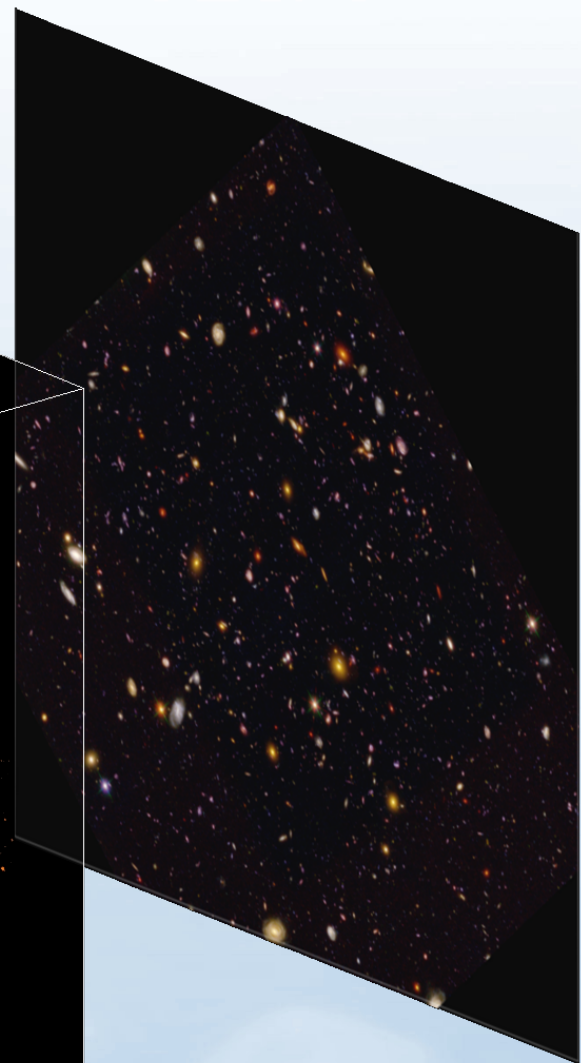


Declination



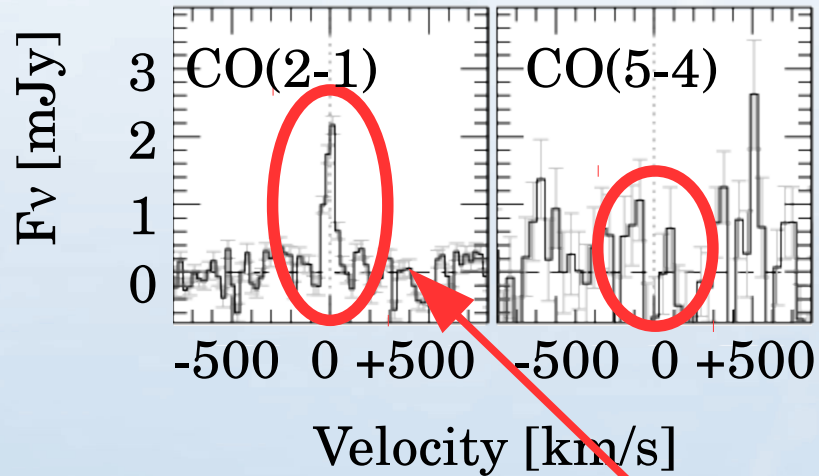
Right Ascension

Frequency



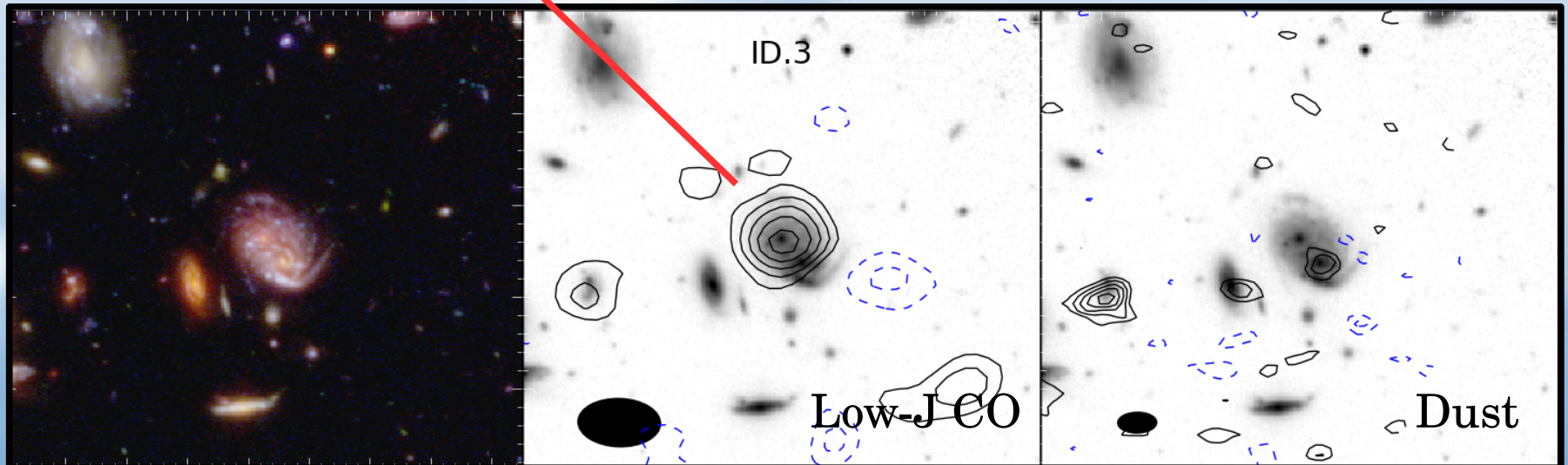
# Molecular Deep Fields

CO line emission:



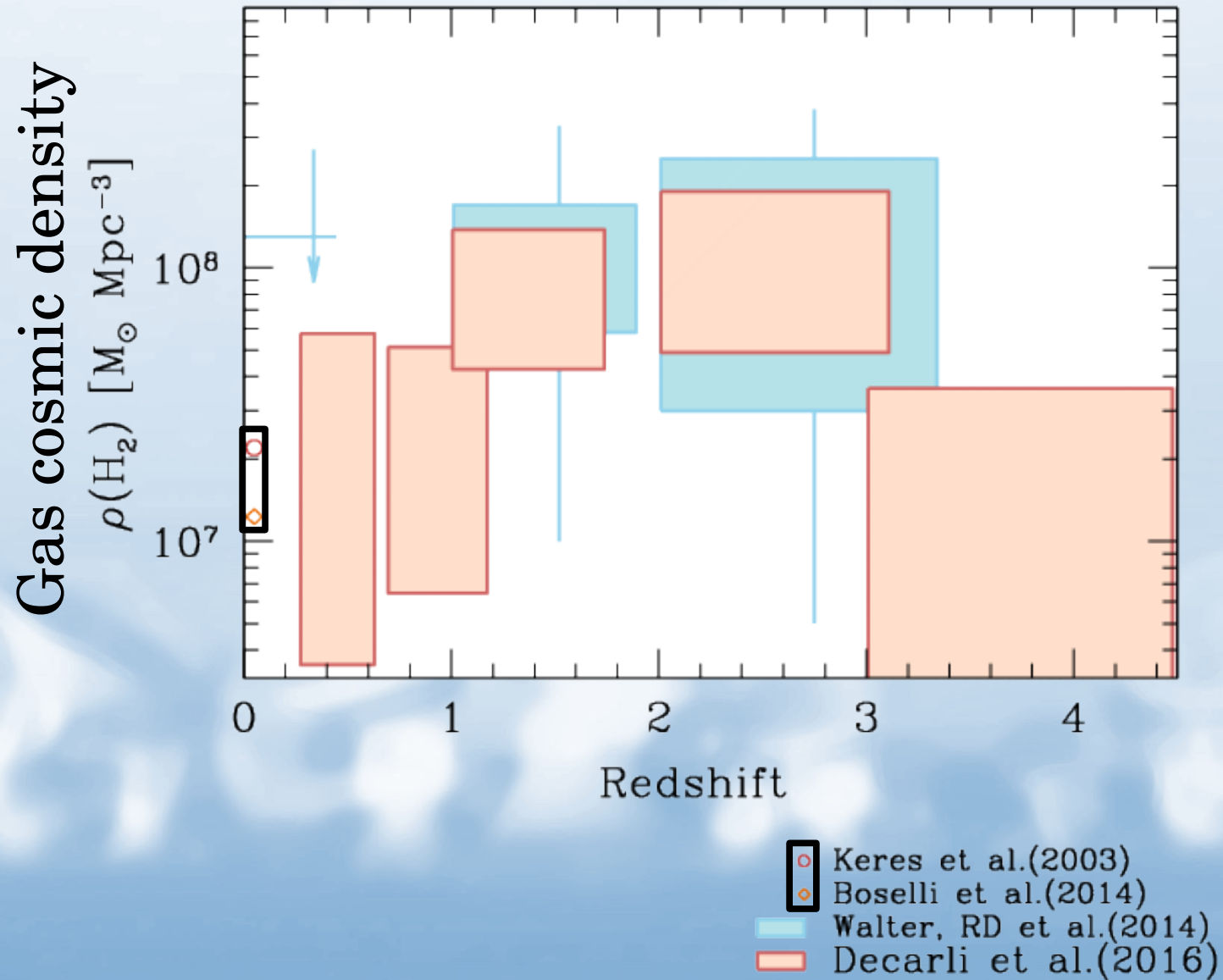
- Gas content
- CO excitation
- Gas fraction, depletion time, role of AGN, etc

Decarli et al. (2016b)



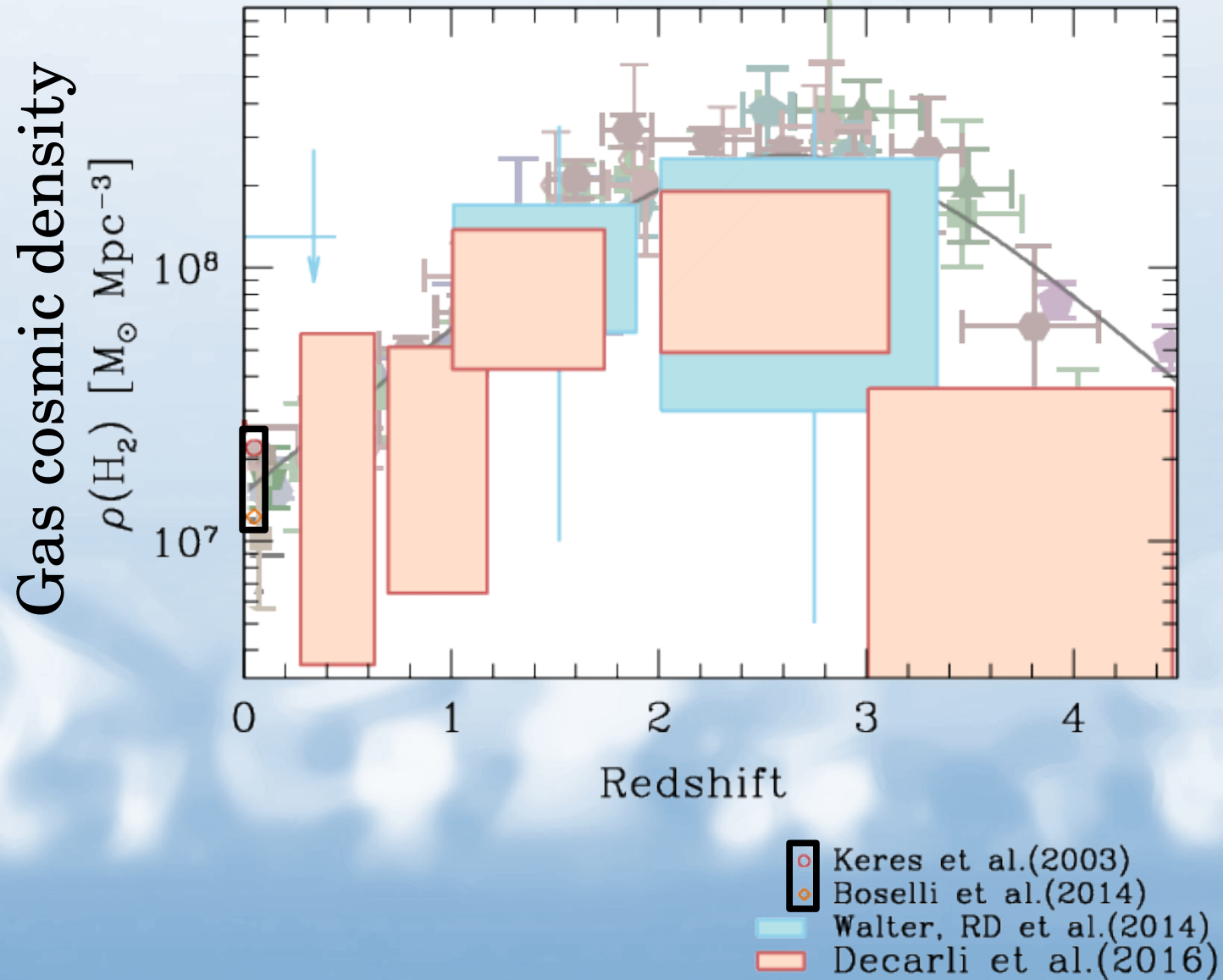
# Molecular Deep Fields

Decarli et al. (2016a)

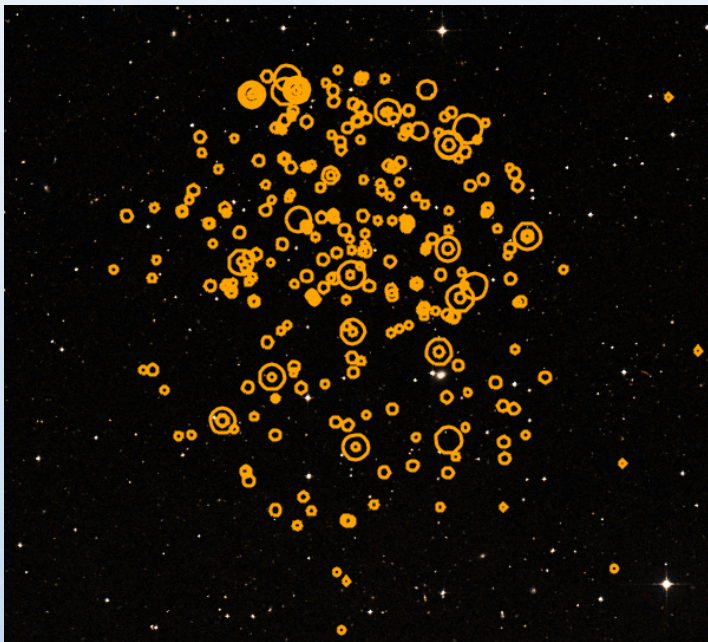


# Molecular Deep Fields

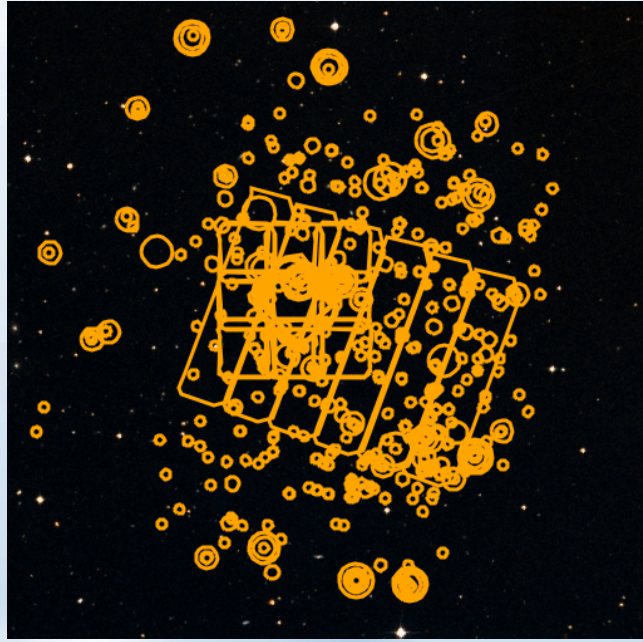
Decarli et al. (2016a)



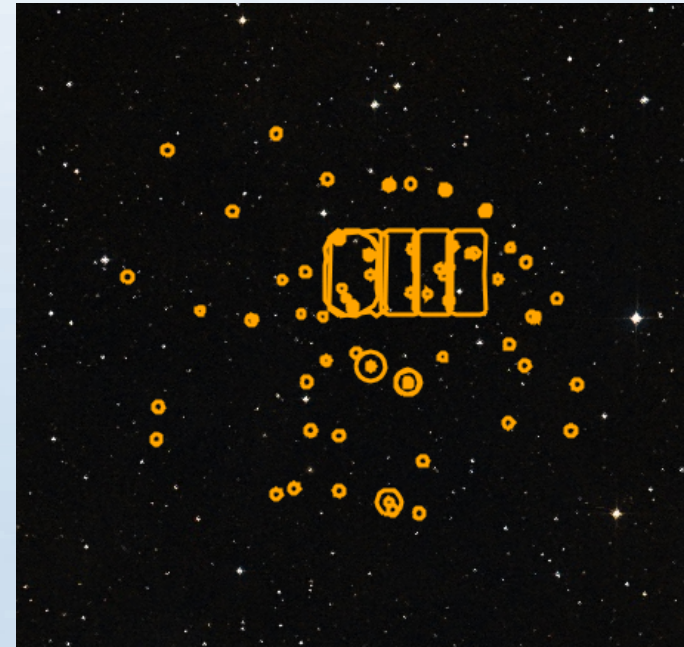
# Molecular Deep Fields



COSMOS



GOODS-South



SSA22

# The physics of the ISM at high $z$

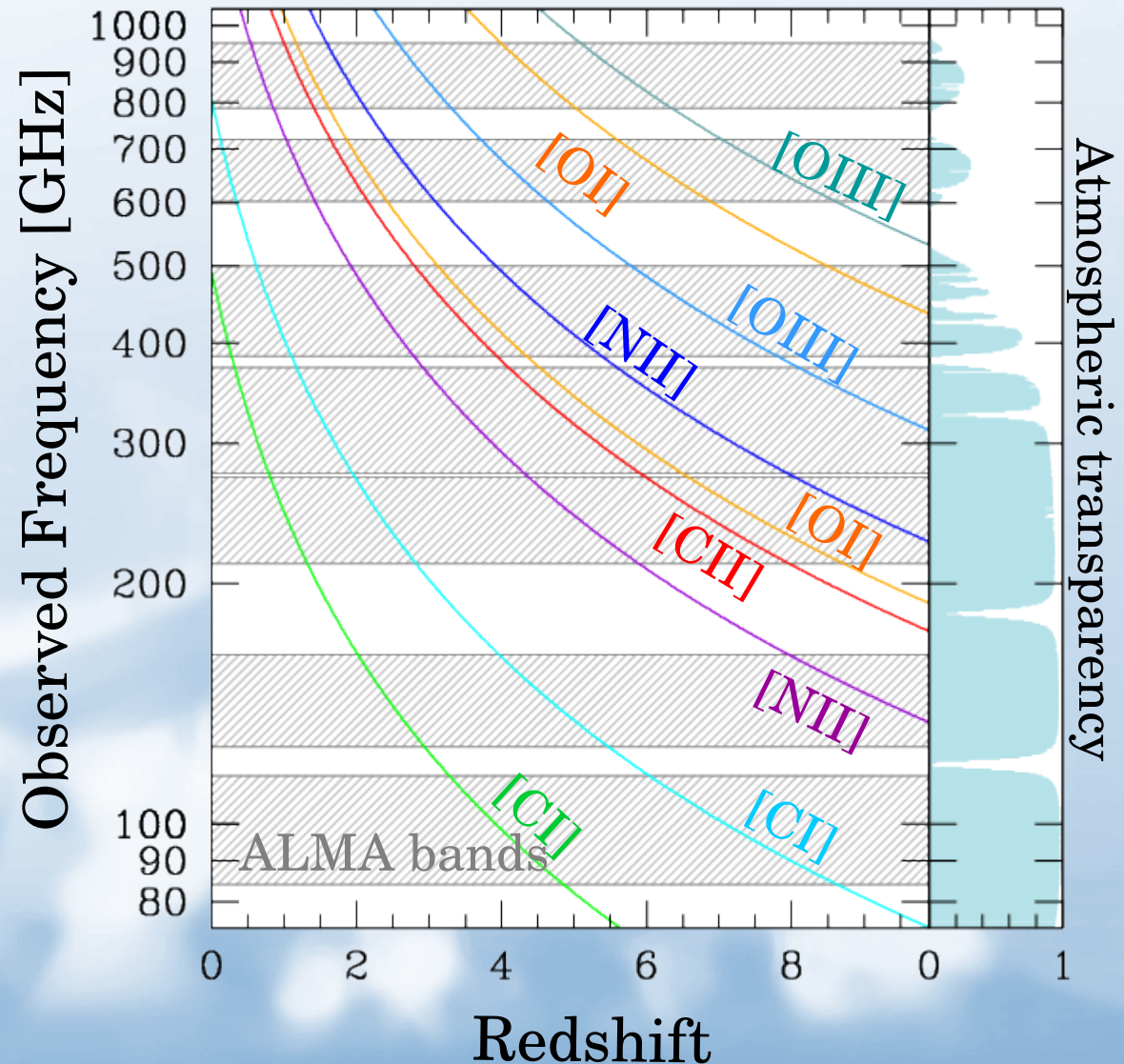
Nebular lines  
(rest-frame optical)  
are out of reach  
at high  $z$



# The physics of the ISM at high $z$

Nebular lines  
(rest-frame optical)  
are out of reach  
at high  $z$

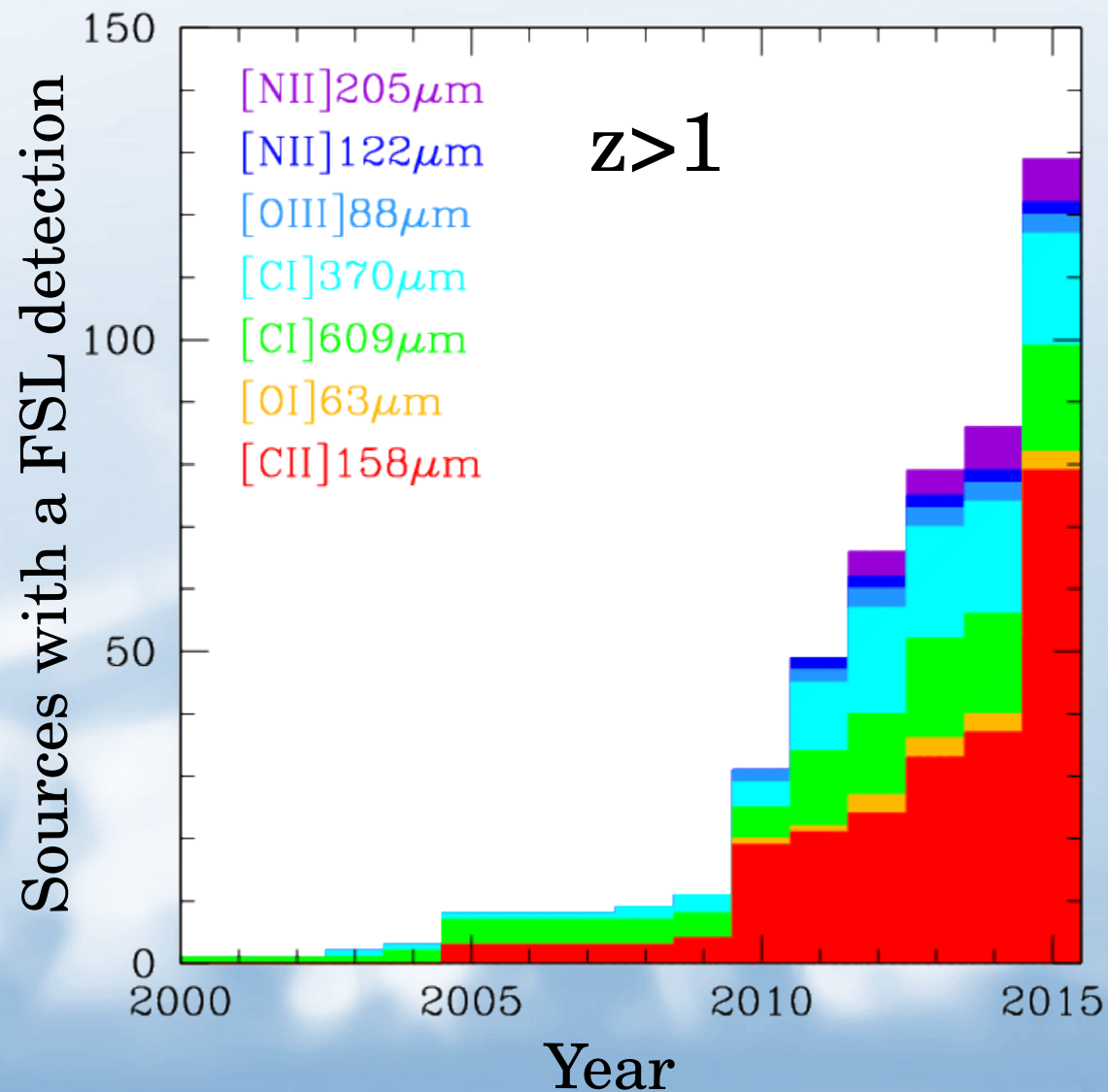
Fine-Structure Lines:  
- main coolant  
of the cold ISM  
- accessible at  
[sub-]mm wavelengths



# The physics of the ISM at high $z$

Nebular lines  
(rest-frame optical)  
are out of reach  
at high  $z$

Fine-Structure Lines:  
- main coolant  
of the cold ISM  
- accessible at  
[sub-]mm wavelengths





# ISM in quasar hosts at $z > 6$

6 lines detected

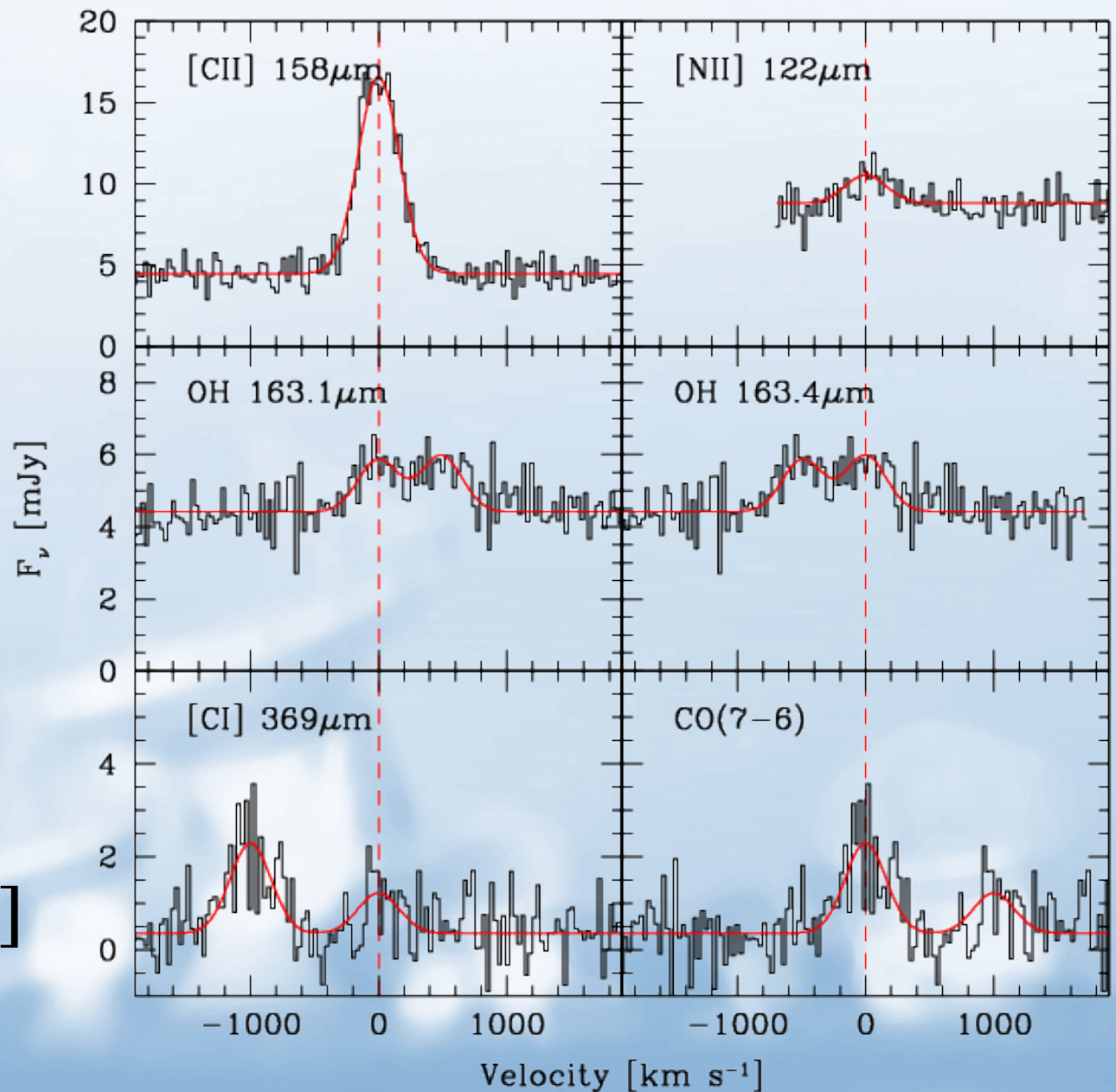
No detection of:

$\text{H}_2\text{O}$

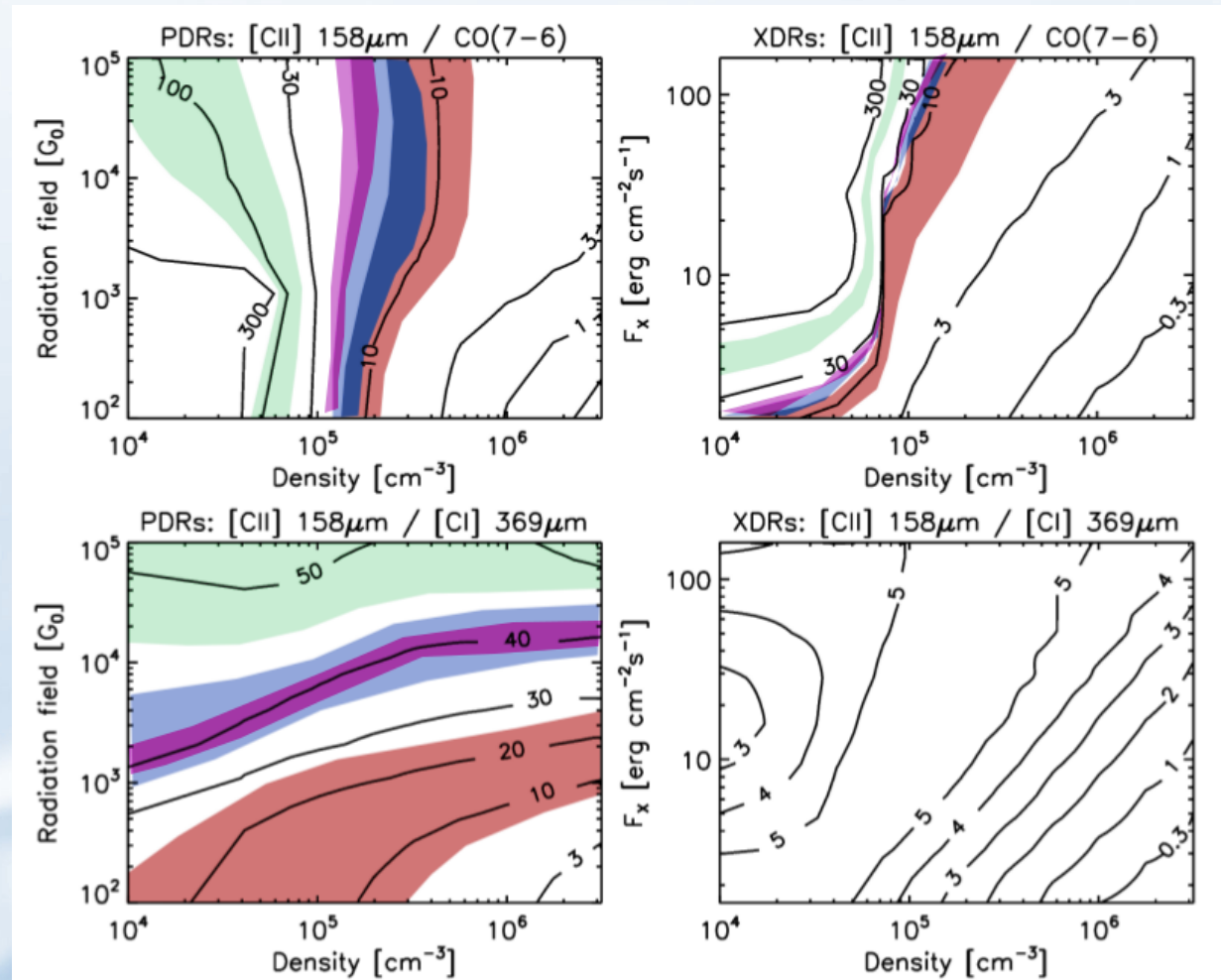
High-J CO

(contrary to  
J1148+5251, P036+03)

No [OI] nor [OIII]  
data yet



# So, what did we learn?

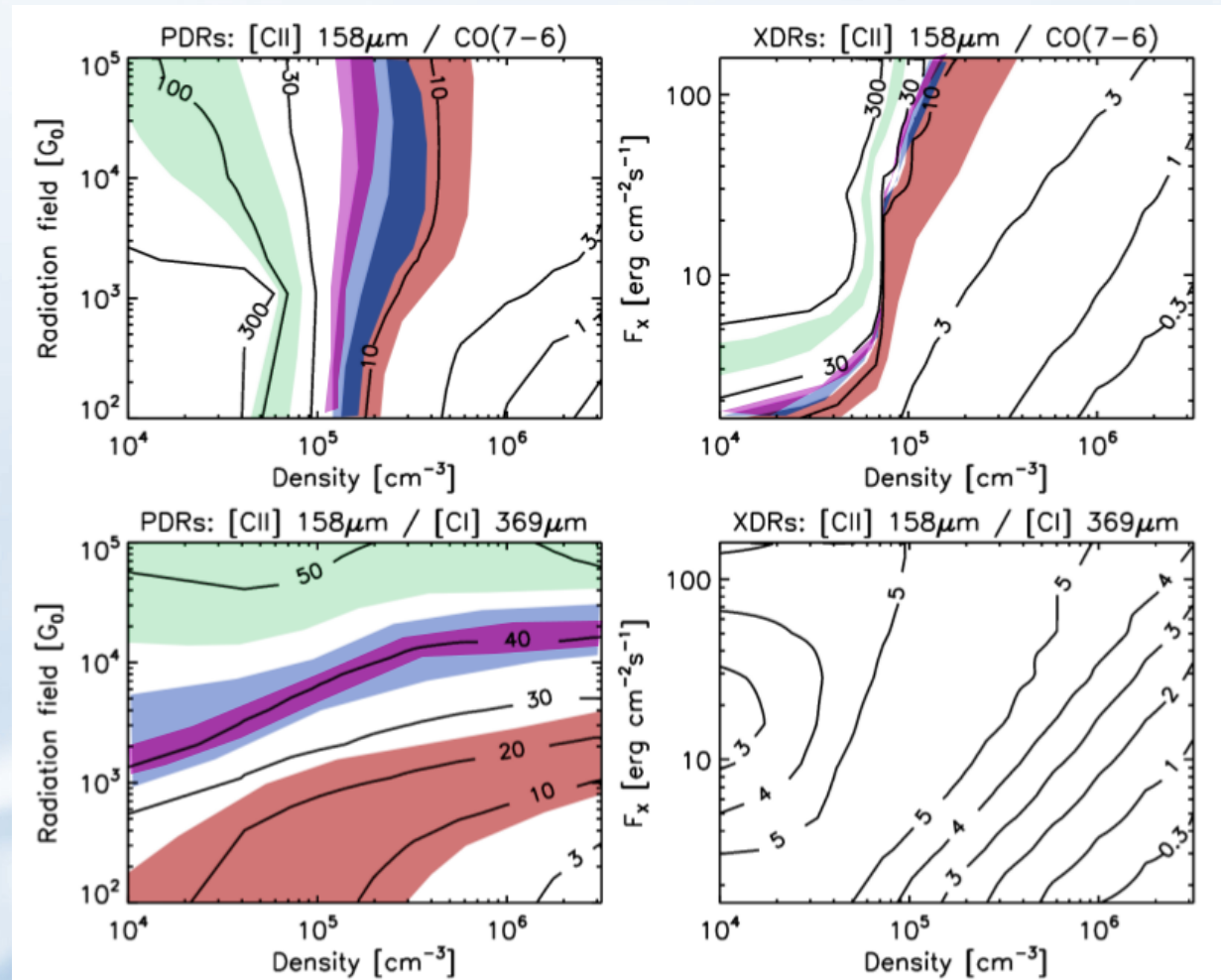


P183+05, P036+03, J1148+5251, J2348-3054

Adapted from Meijerink et al. 2007

# So, what did we learn?

From [CII]/CO(7-6):  
 $n_{\text{gas}} \sim 2e5 \text{ cm}^{-3}$



P183+05, P036+03, J1148+5251, J2348-3054

Adapted from Meijerink et al. 2007

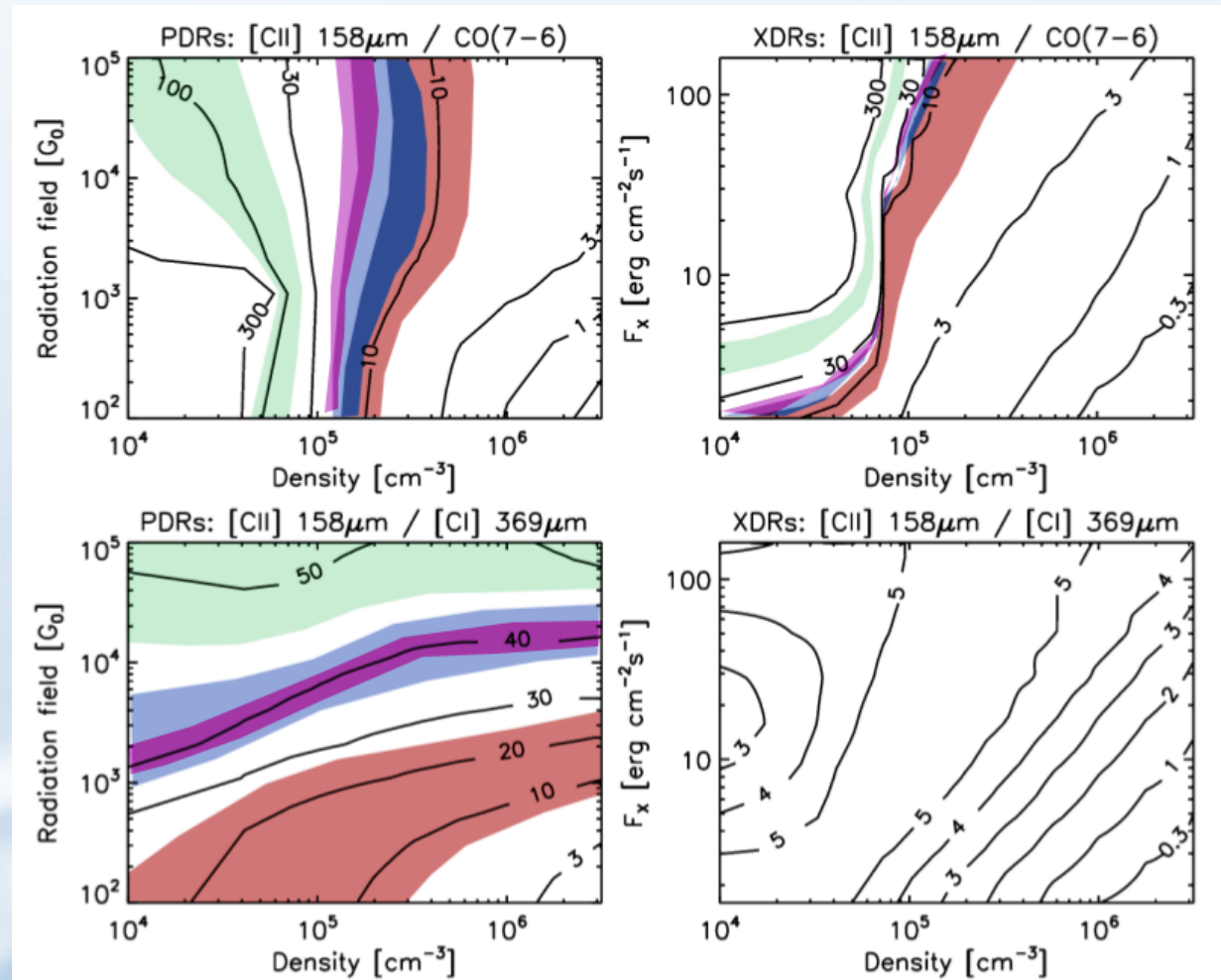
# So, what did we learn?

From [CII]/CO(7-6):

$$n_{\text{gas}} \sim 2e5 \text{ cm}^{-3}$$

From [CII]/[CI]:

$$G \sim 8e3 G_0$$



P183+05, P036+03, J1148+5251, J2348-3054

Adapted from Meijerink et al. 2007

# So, what did we learn?

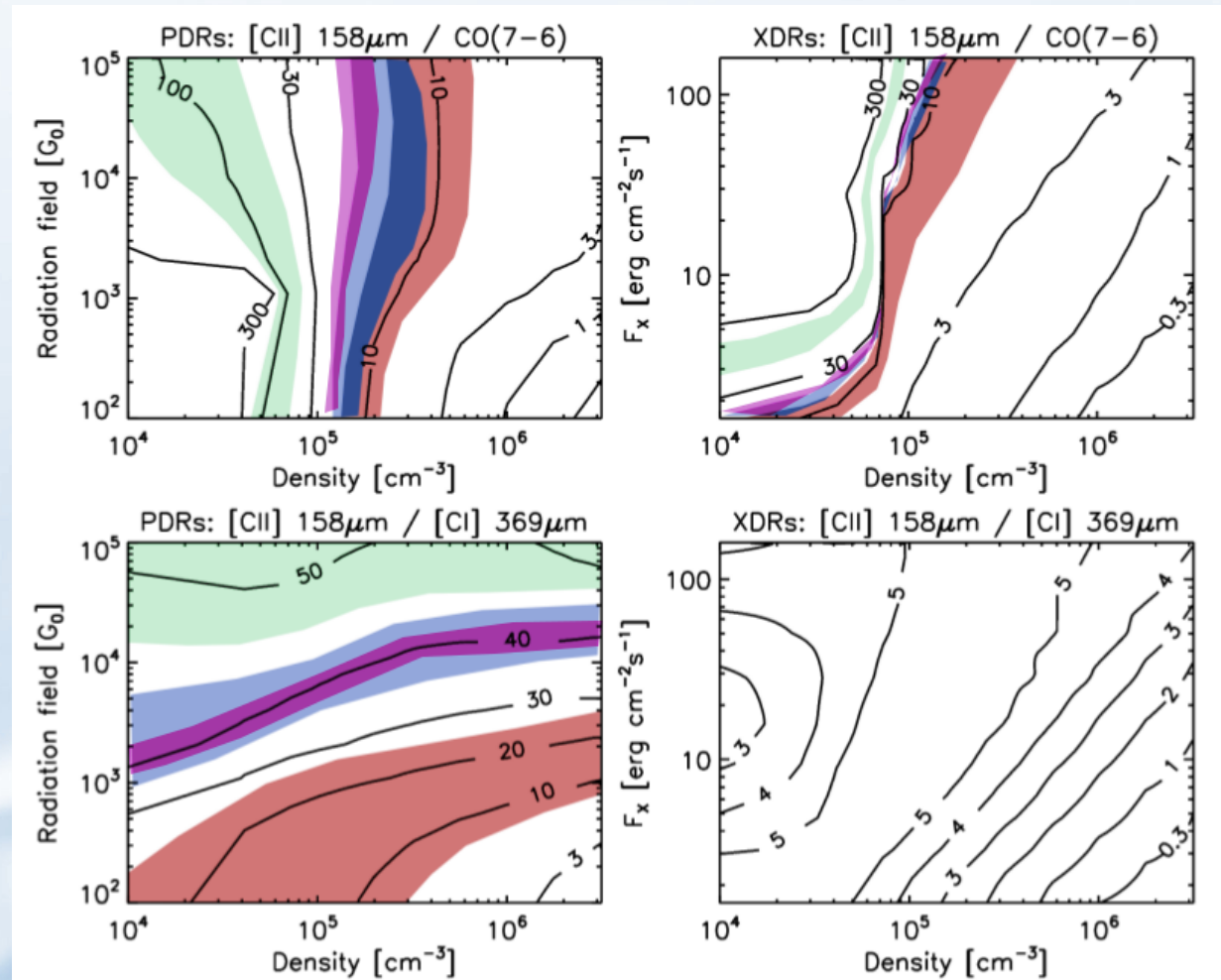
From [CII]/CO(7-6):

$$n_{\text{gas}} \sim 2e5 \text{ cm}^{-3}$$

From [CII]/[CI]:

$$G \sim 8e3 G_0$$

X-ray powering is unlikely



P183+05, P036+03, J1148+5251, J2348-3054

Adapted from Meijerink et al. 2007

# So, what did we learn?

From [CII]/CO(7-6):

$$n_{\text{gas}} \sim 2e5 \text{ cm}^{-3}$$

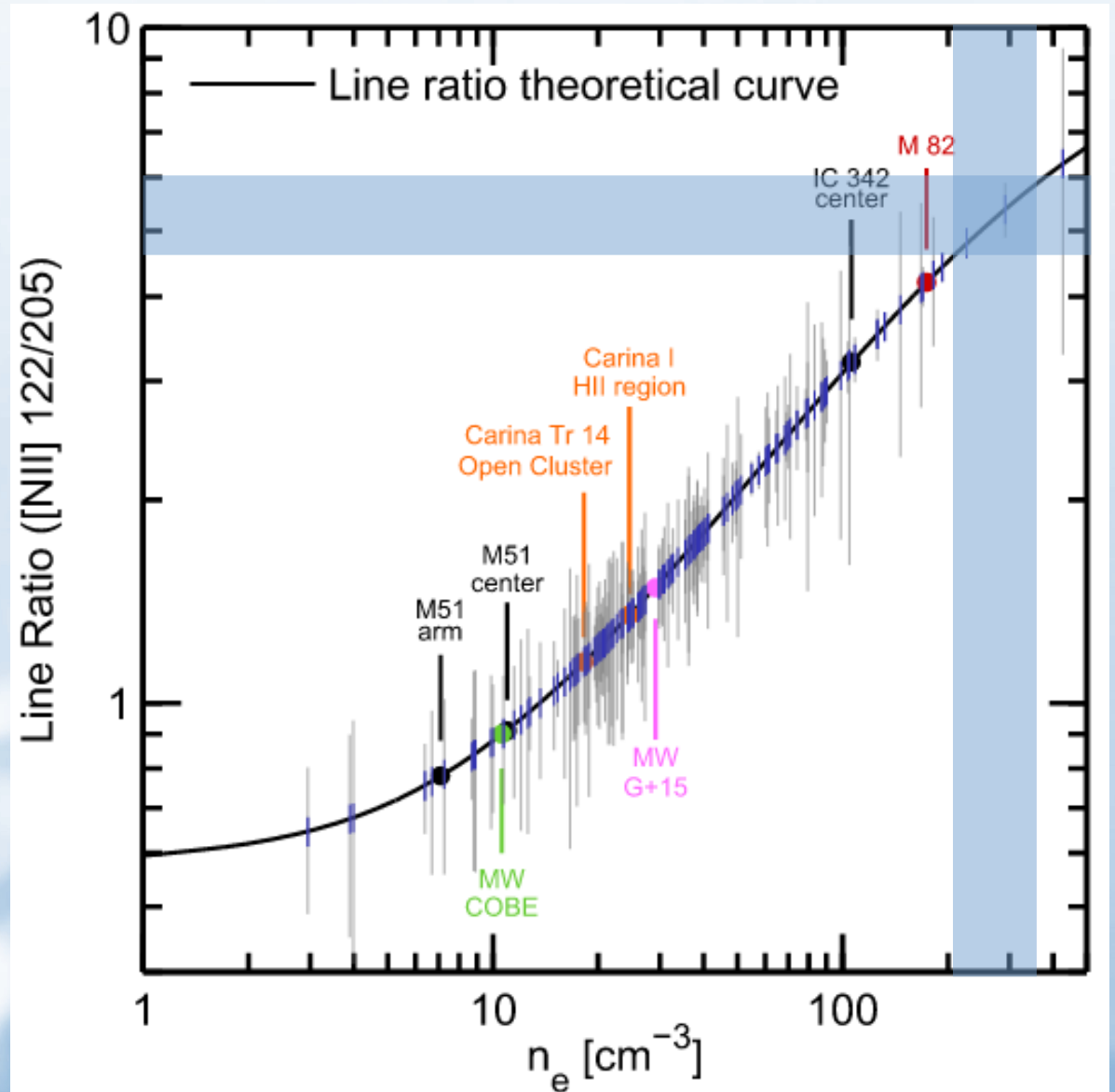
From [CII]/[CI]:

$$G \sim 8e3 G_0$$

X-ray powering is unlikely

[NII] 122/205:

$$n_{e^-} \sim 300 \text{ cm}^{-3}$$



Adapted from Herrera-Camus et al. (2016)

In brief



# In brief

Molecular Deep Fields:  
the evolution of molecular gas content

Dedicated follow-up studies:  
the physics of the star-forming ISM



# Opportunities for the Italian community

<b>Facility</b>	<b>Access</b>	<b>Archive</b>
ALMA	30% through ESO	Open
IRAM 30m + NOEMA	15% open time	Headers; Contact PIs
JVLA	Open	Open
... SRT, SKA, ...?		

