Advanced Workshop on Cosmological Structures from Reionization to Galaxies – Trieste, Italy

Probing the reionization process and its sources with Line Intensity Mapping

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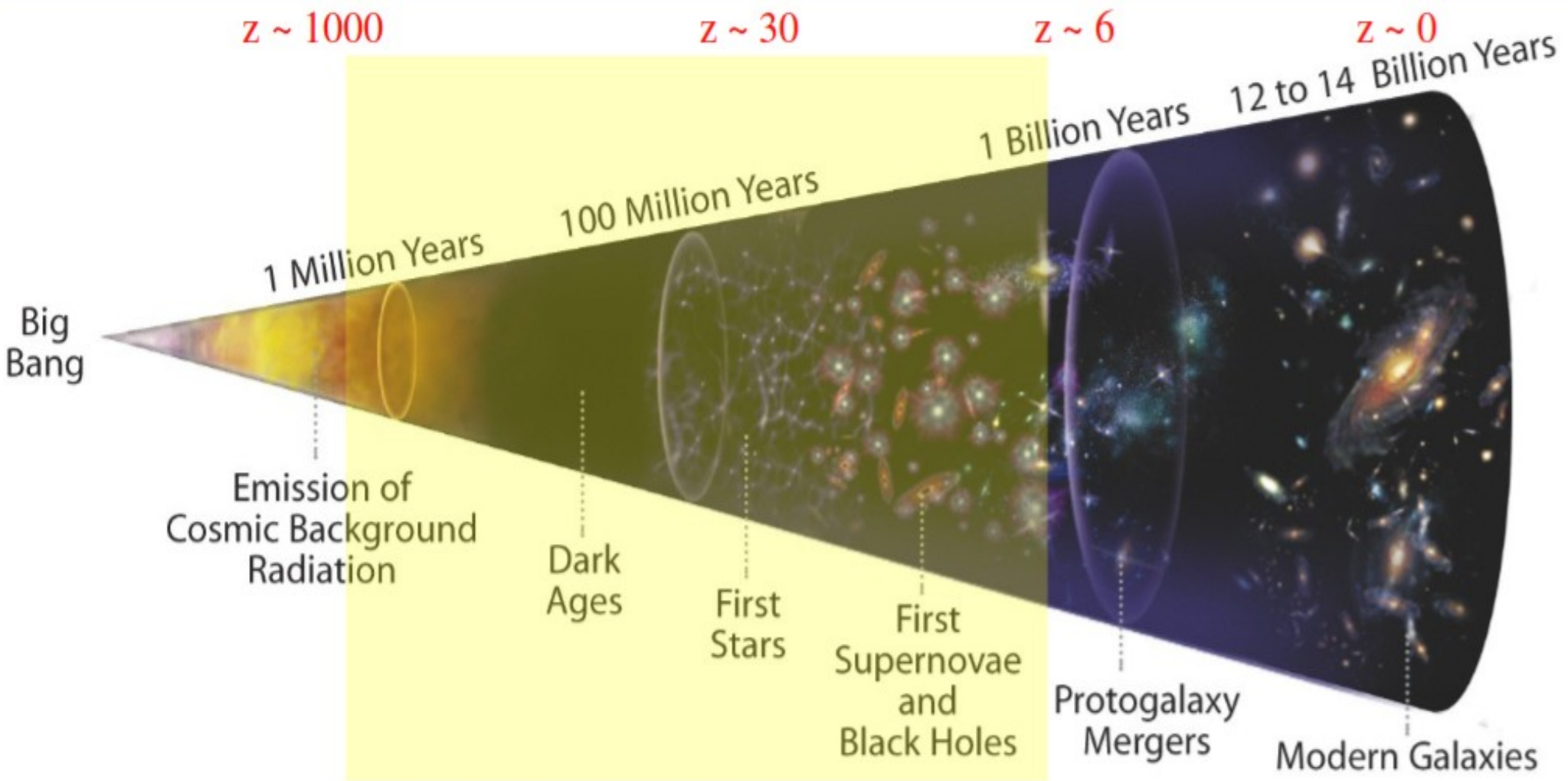
The high redshift Universe



Intensity mapping during the EoR

HI – 21cm line

Santos et al. 2010
(MNRAS, 46, 2421)

CO

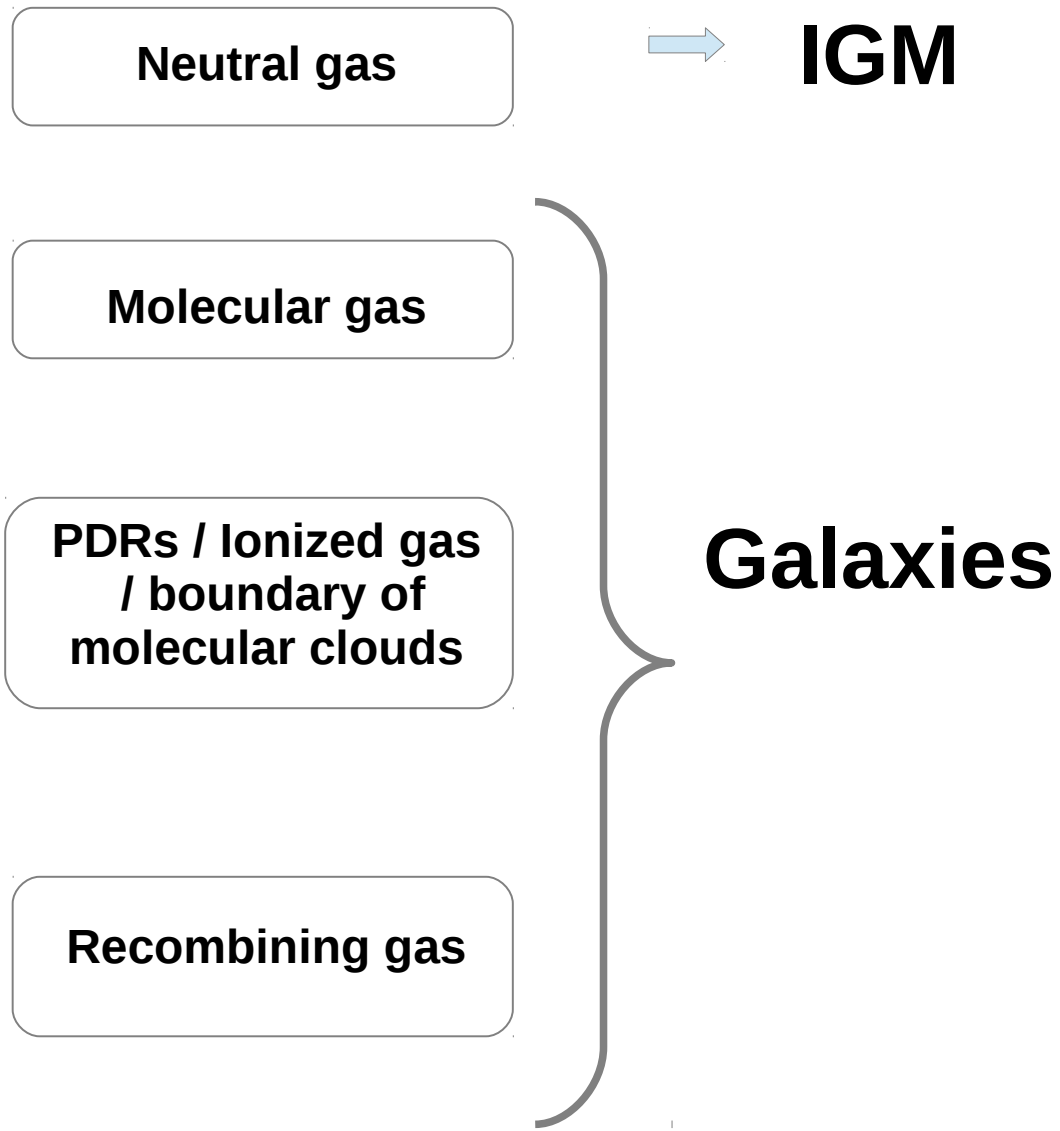
Gong et al. 2011
(ApJ, 726, L46)

CII

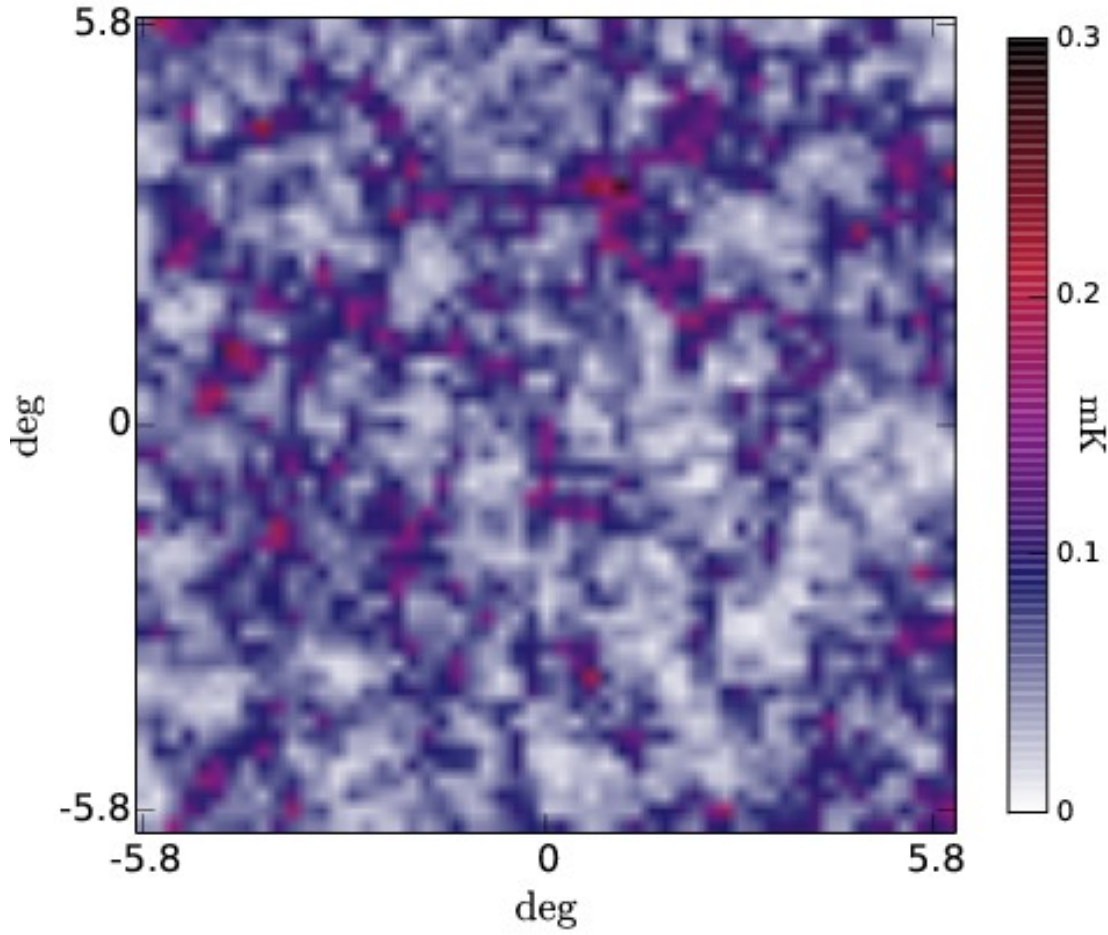
Gong et al. 2011
(ApJ, 745, 49)
Silva et al. 2014
(arxiv:1410.4808)

Lyα

Silva et al. 2012
(ApJ, 763, 2)
Gong et al. 2014
(ApJ, 785, 72)



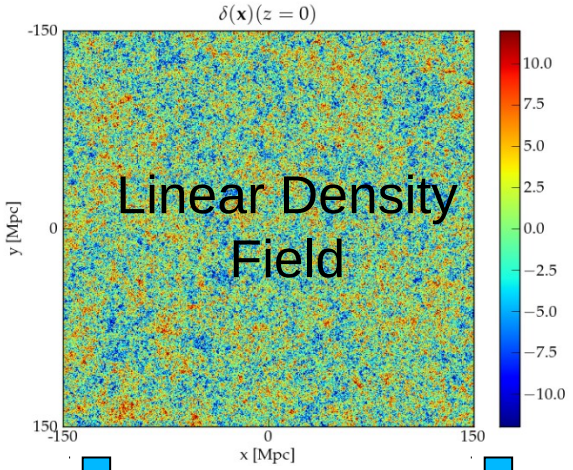
The intensity mapping technique



Galaxies

Line intensity map

The simulations: Simfast21 code



Non Linear Density Field

Halos

CO Intensity maps

Ionization Field

SFR

21 cm Intensity maps

Lyα Intensity maps

CII Intensity maps

Model and simulating [CII] 157.7 μm emission

Ionized carbon emission

$f_{CII} = 1900\text{GHz}$

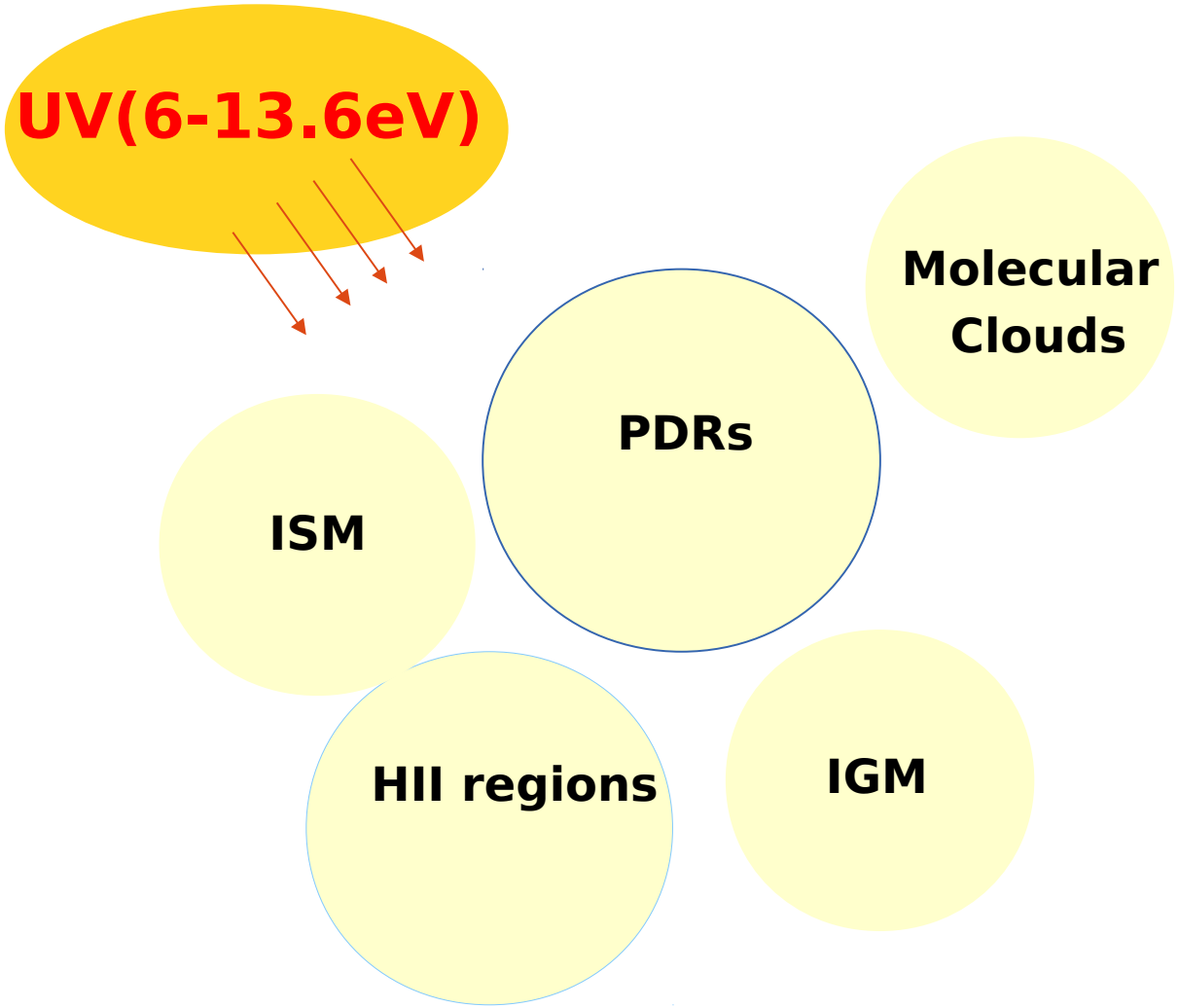
$(z \sim 8.5 \text{ to } 5.5) \rightarrow f_o \sim 200\text{–}300\ \text{GHz}$

PDRs/Ionized gas

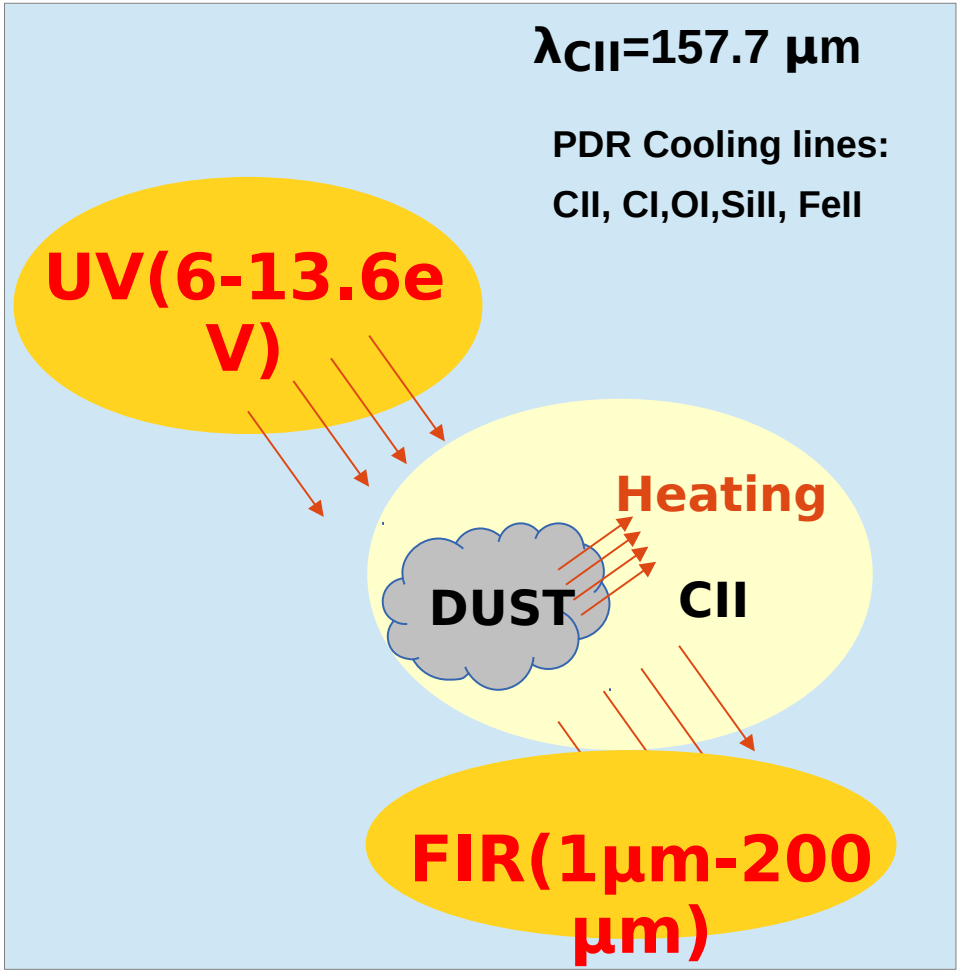
CII emission

λ_{CII}=157.7 μm

E_{ion}(C)=11.26 eV



CII intensity: PDRs



$$L_{\mathrm{CII(M,z)}}\,[\mathrm{L}_\odot] = 0.003 \times L_{\mathrm{FIR}}.$$

(Boselli et al. 2002)

Local Universe

$$\mathrm{L_{FIR}}[\mathrm{L}_\odot] = 3.07 \times 10^9 \mathrm{SFR}[\mathrm{M}_\odot \mathrm{yr}^{-1}]$$

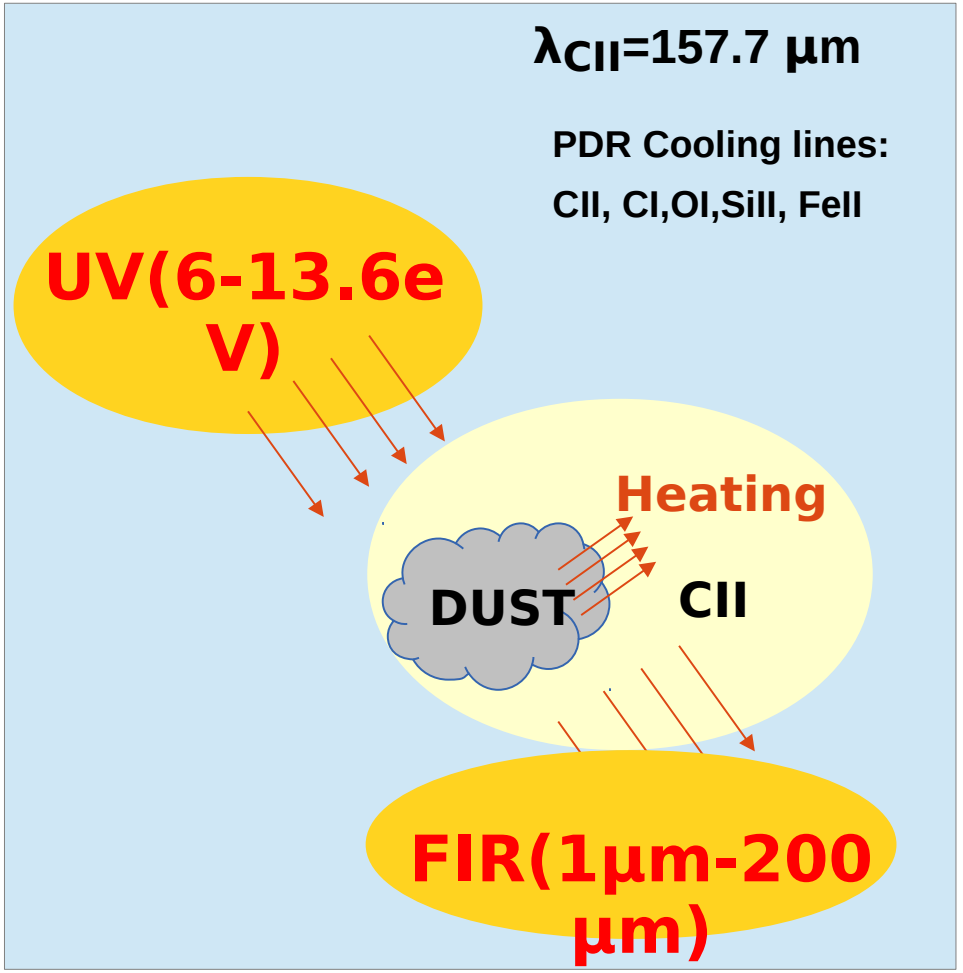
Kennicutt (1998) +Cardiel et al. (2003

CII luminosity

HII regions

Silva et al. 2014

CII luminosity: PDRs



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CII luminosity

Silva et al. 2014

$$\log10(L_{\rm CII}[{\rm L}_\odot]) = a_{\rm LCII} \times \log10(\psi[{\rm M}_\odot]) + b_{\rm LCII},$$

model	$a_{\rm LCII}$	$b_{\rm LCII}$
$\mathbf{m_1}$	0.8475	7.2203
$\mathbf{m_2}$	1.0000	6.9647
$\mathbf{m_3}$	0.8727	6.7250
$\mathbf{m_4}$	0.9231	6.5234

CII Intensity

$$\bar{I}(z) = \int_{\mathrm{M_{min}}}^{\mathrm{M_{max}}} dM \frac{dn}{dM} \frac{L(M,z)}{4\pi D_{\mathrm{L}}^2} y(z) D_A^2$$

HII regions

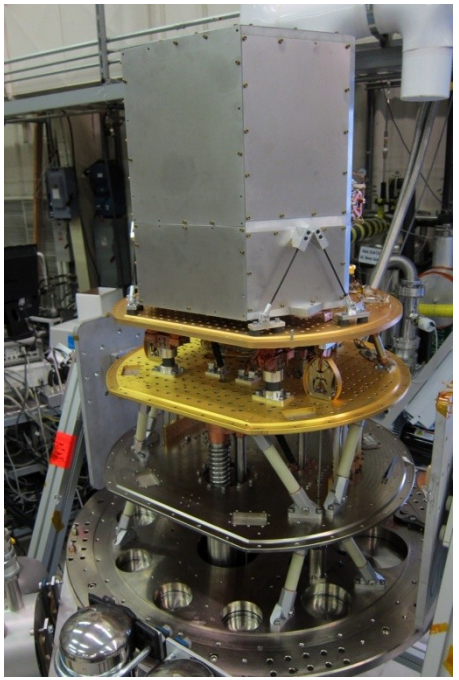
PDR

Silva et al. 2014

CII Intensity mapping experiment

CII

Gong et al. 2011 (ApJ, 745, 49)
Silva et al. 2014 (arxiv:1410.4808)

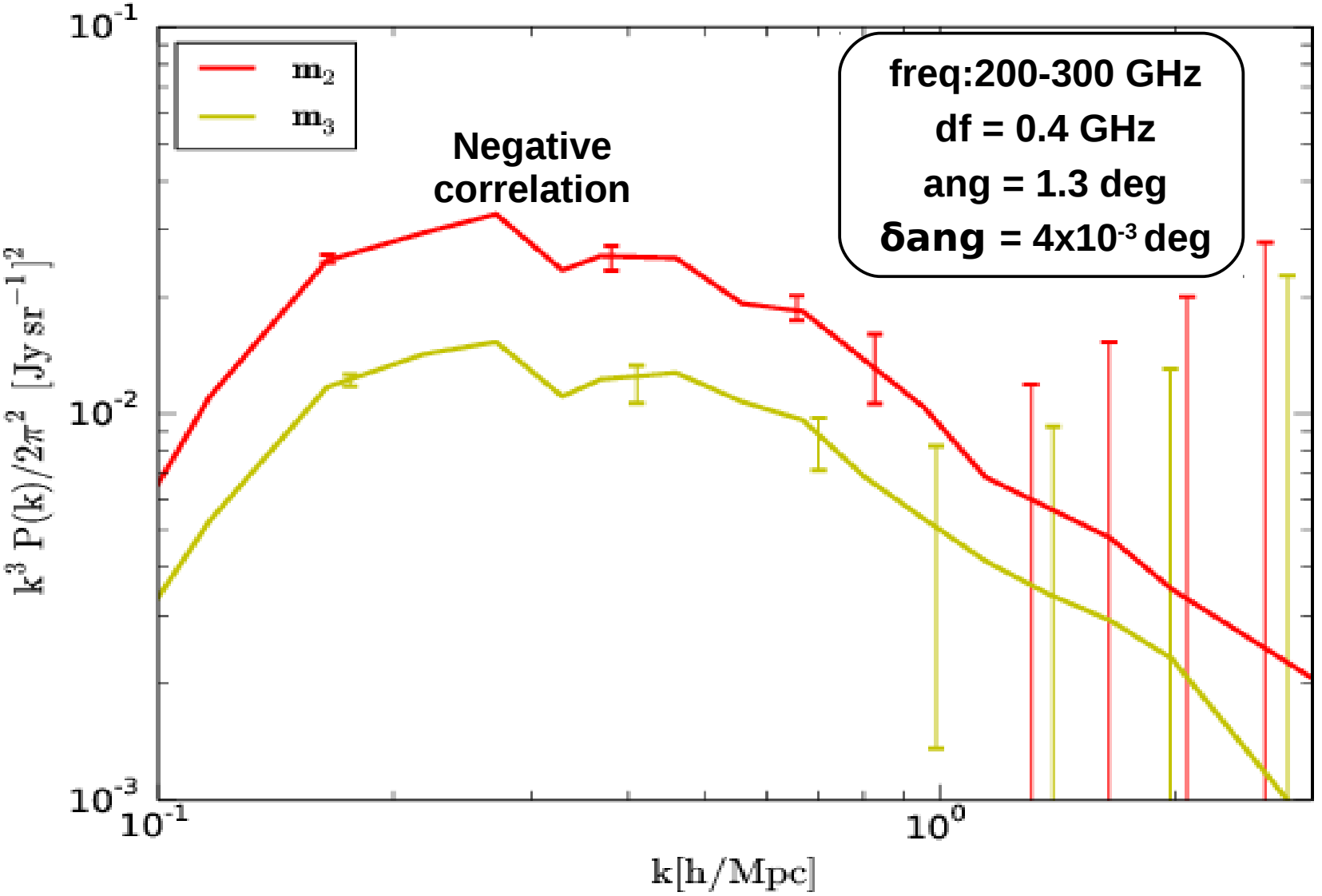


TIME

(Tomographic Ionized-carbon Mapping Experiment)

Wide-band imaging spectrometer using large arrays of direct detectors

21cm/CII cross correlation



21cm/CII cross correlation

$$P_{21,CII} = I_{21}\, I_{CII}\, b_{21}\, b_{CII}\, P_{\delta\delta}$$

Foregrounds in CII Intensity Maps:

$\nu_{CII} \approx 1900GHz$

Line emission:

CO(J=2-1),...,CO(J=10-9) → Intensity Larger than the CII signall

$\nu_{CO}(J=1-0) \approx Jx115GHz$

OI[145μm], NII[122μm], NII[205μm] and CI[610μm] → Intensity smaller than the CII signal

Continuum emission:

Stellar emission

Free-free

Free-bound

Two photon

Dust emission

Emission from the Milky Way

Spectraly smooth component can be removed along each line of sight

Yue et all. 2015

CO contamination in CII intencity maps

CO transitions:

$\upsilon(CO_{J\rightarrow J-1}) \approx J \times 115.271GHz$

$\upsilon(CII) \approx 1900GHz$

transition (J)	ν_{CO}^{J}(GHz)	z($\nu_o \approx 300$GHz)	z($\nu_o \approx 200$GHz)
2-1	230.542	0(1)	0.150
3-2	345.813	0.150	0.730
4-3	461.084	0.535	1.305
5-4	576.355	0.920	1.881
6-5	691.626	1.305	2.458
7-6	806.897	1.690	3.035
8-7	922.168	2.074	3.610
9-8	1037.439	2.458	4.186
10-9	1152.71	2.842	4.762

Molecular Gas/star formation

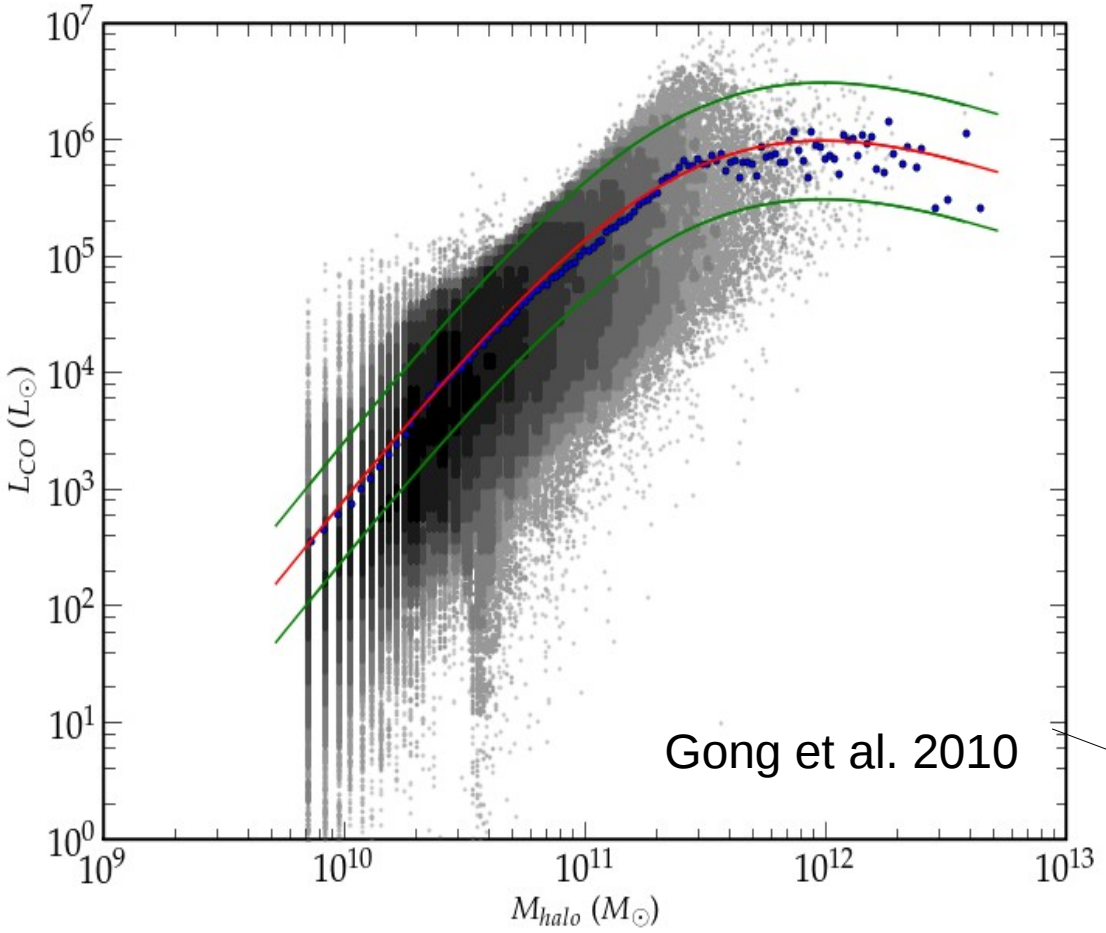
CO luminosity

Cold gas

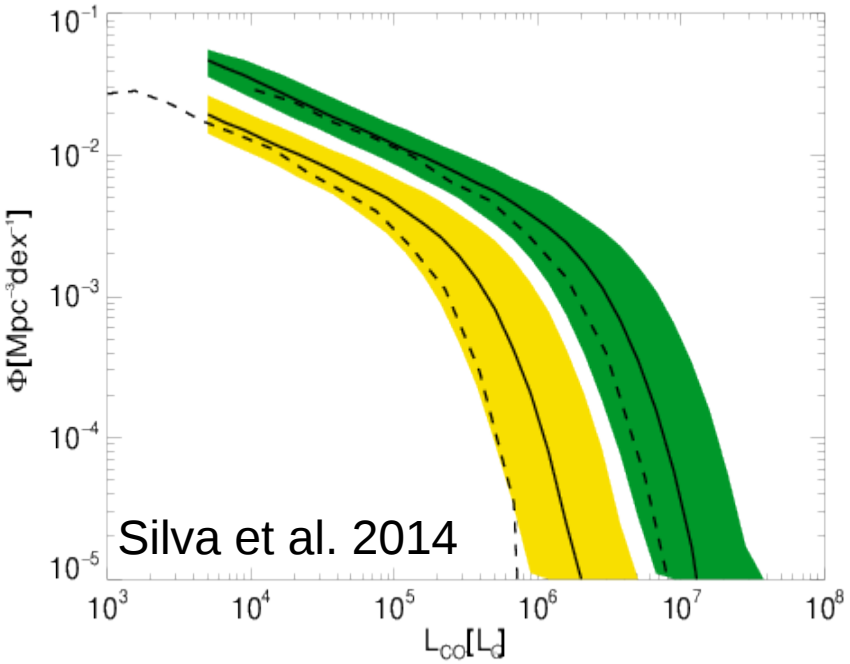
Helium

Hydrogen → HI

Hydrogen → H_2 → CO



Gong et al. 2010



Based in the galaxy catalogs from:

Obreschkow et al. 2009b,2009c

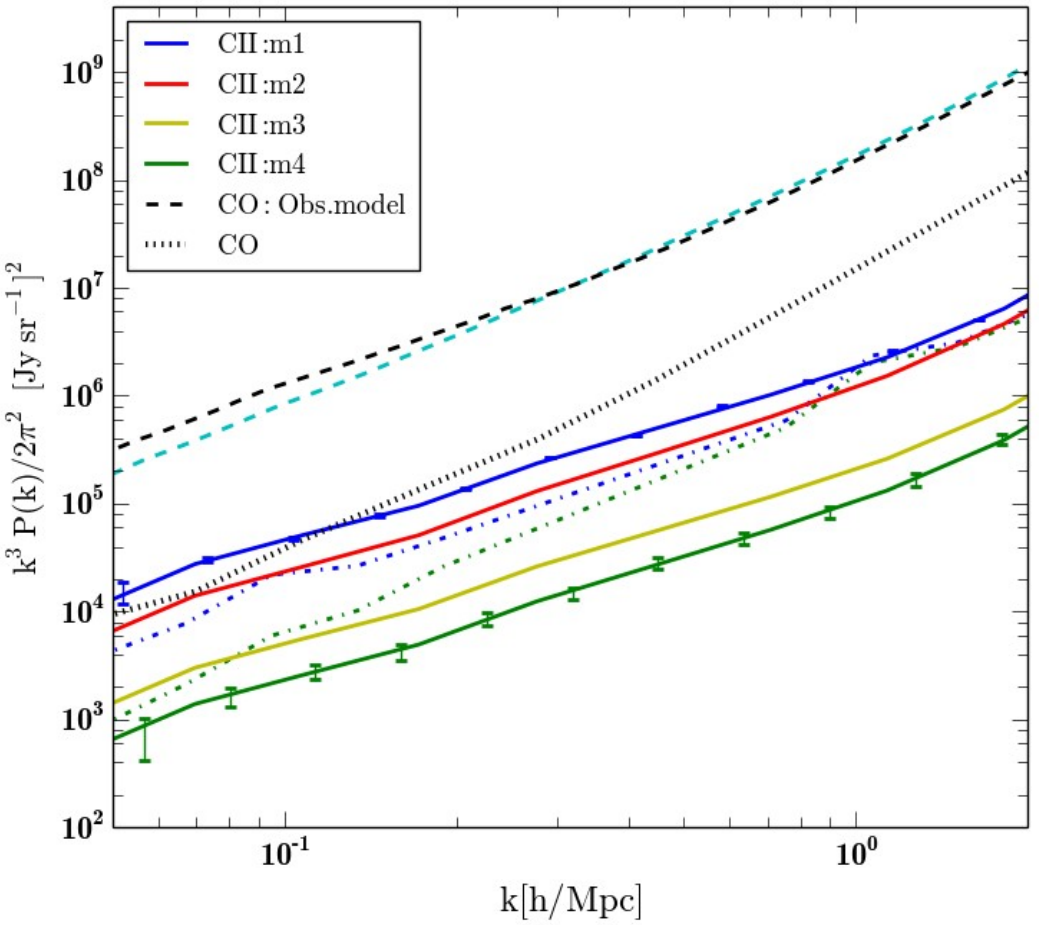
DeLucia et al. 2006

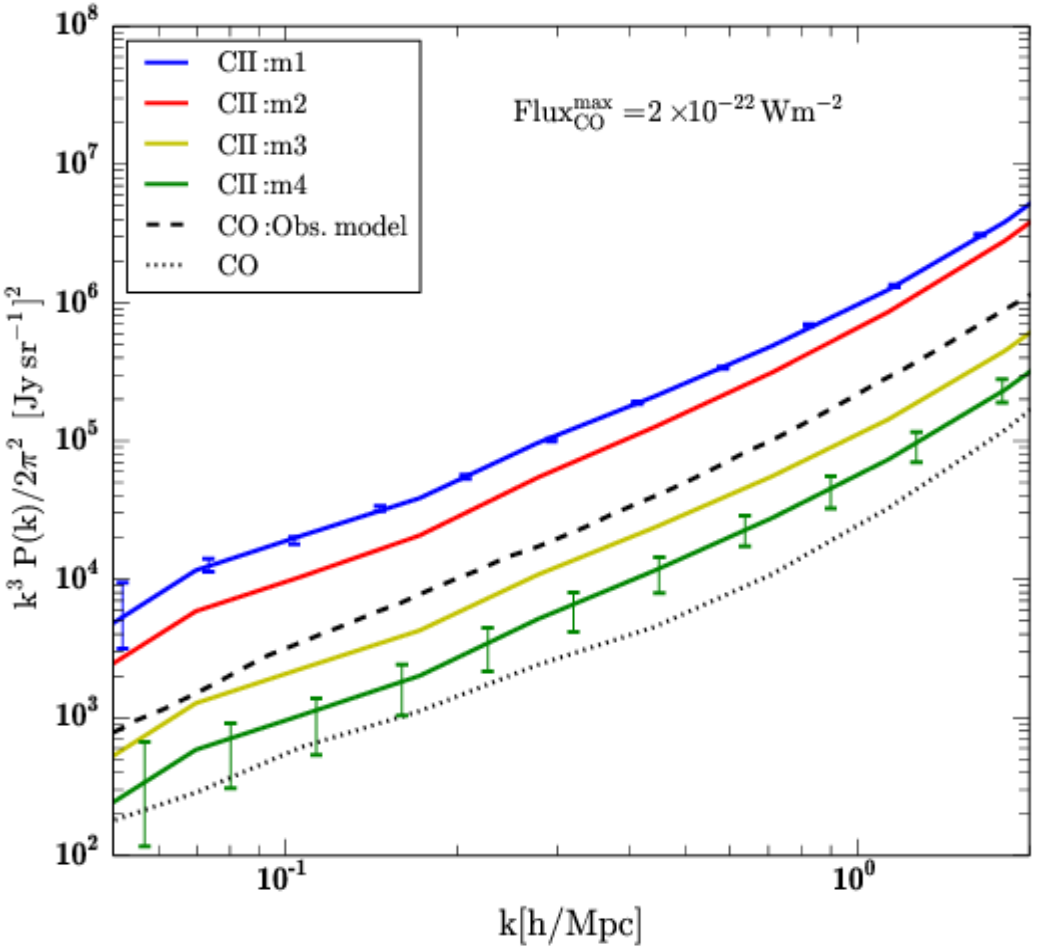
$\nu_{CII} \approx 1900$GHz

$\nu_{CO}(J=J-1) \approx J \times 115$GHz

CO(J=2-1),...,CO(J=6-5)

CII foregrounds: Removing CO contamination





Power spectra of CII emission assuming 4 observationally based models

freq:200-300 GHz
df = 0.4 GHz
ang = 1.3 deg
δang = 6.67x10^{-3} deg

<10% Masking

Summary

- Reionization can be probed with several emission lines ex: 21cm, CO , CII , Lyα, …
- Intensity mapping of emission lines may show to be a more promising tool to study the EoR than individual observations of galaxies
- Intensity mapping of several lines can be used to improve constrains on several astrophysical and cosmological parameters
- Cross-correlation of CO, Lyα or CII lines and the 21 cm linel can help with foregrounds and provide information about the ionization process