Line Intensity Mapping during the Epoch of Reionization

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Peering towards Cosmic Dawn
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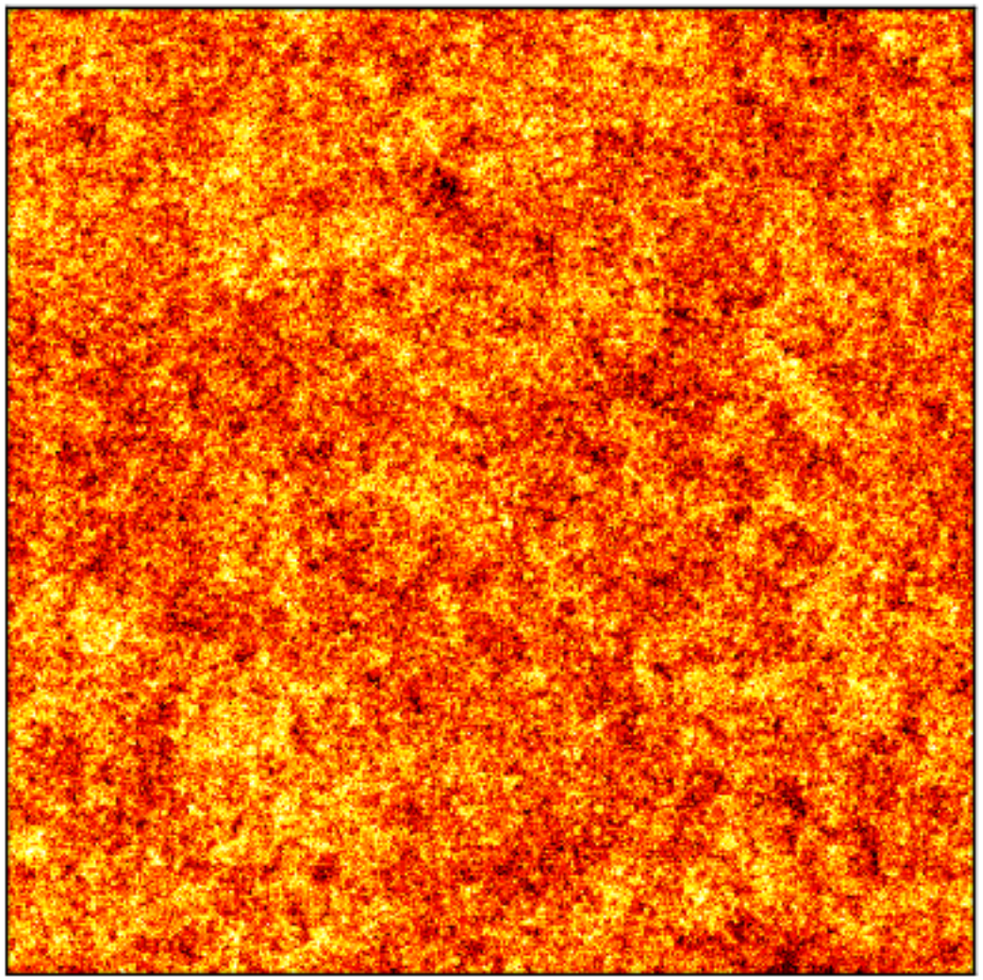
Line Intensity Mapping



Faint / Extended Sources

Good for high-z

Not selection biased

Probes all sources

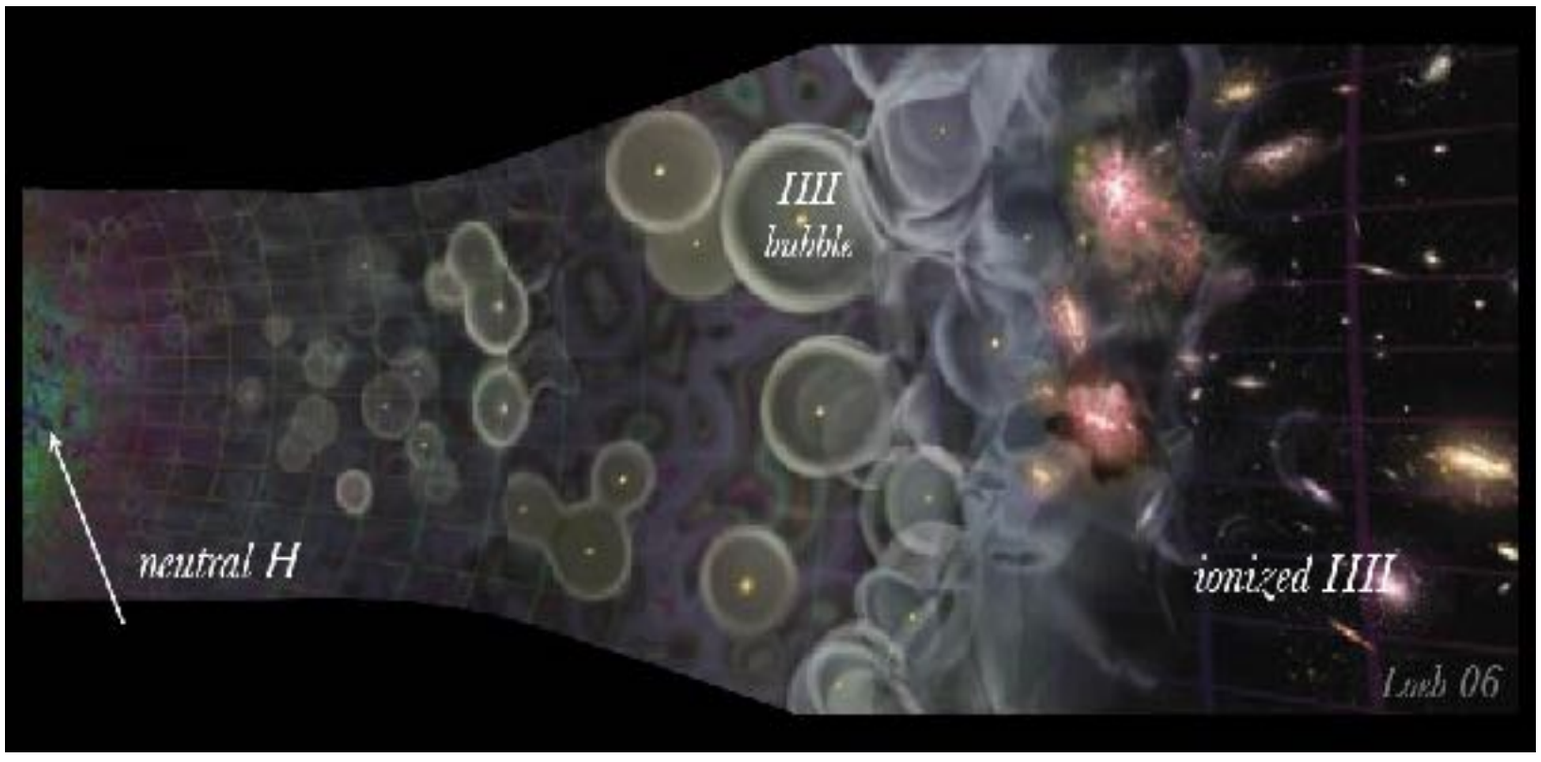
Redshift information

Allows probing time evolution of several quantities

Large volumes

Cosmology

Constraining the high-z Universe



- The **cosmic dawn**
  - First stars
  - IGM heating
- The **EoR**
  - The timeline
  - Main sources
  - Galaxy properties
- The **post-EoR**
  - Galaxies/IGM

- $z \gtrsim 10$ - Mostly 21cm signal
- $z \lesssim 10$ - Multiple options

Probing Galaxies and the IGM during the EOR

- Traditional galaxy surveys
  High-z gal. / Local analogs
- EBL surveys
- Line-Intensity Mapping surveys:
  Eg., CO, CII, Ly-alpha

Galaxies

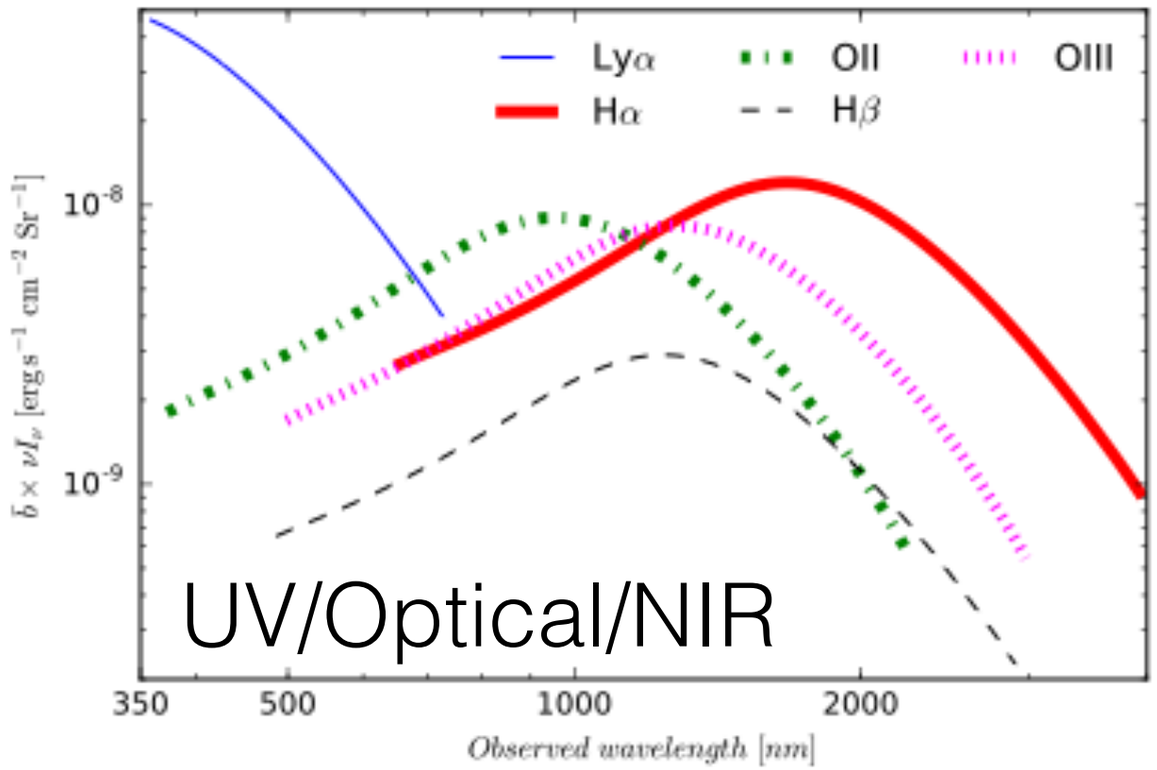
- Sky average 21cm signal
- 21cm Line-IM
- CMB

IGM

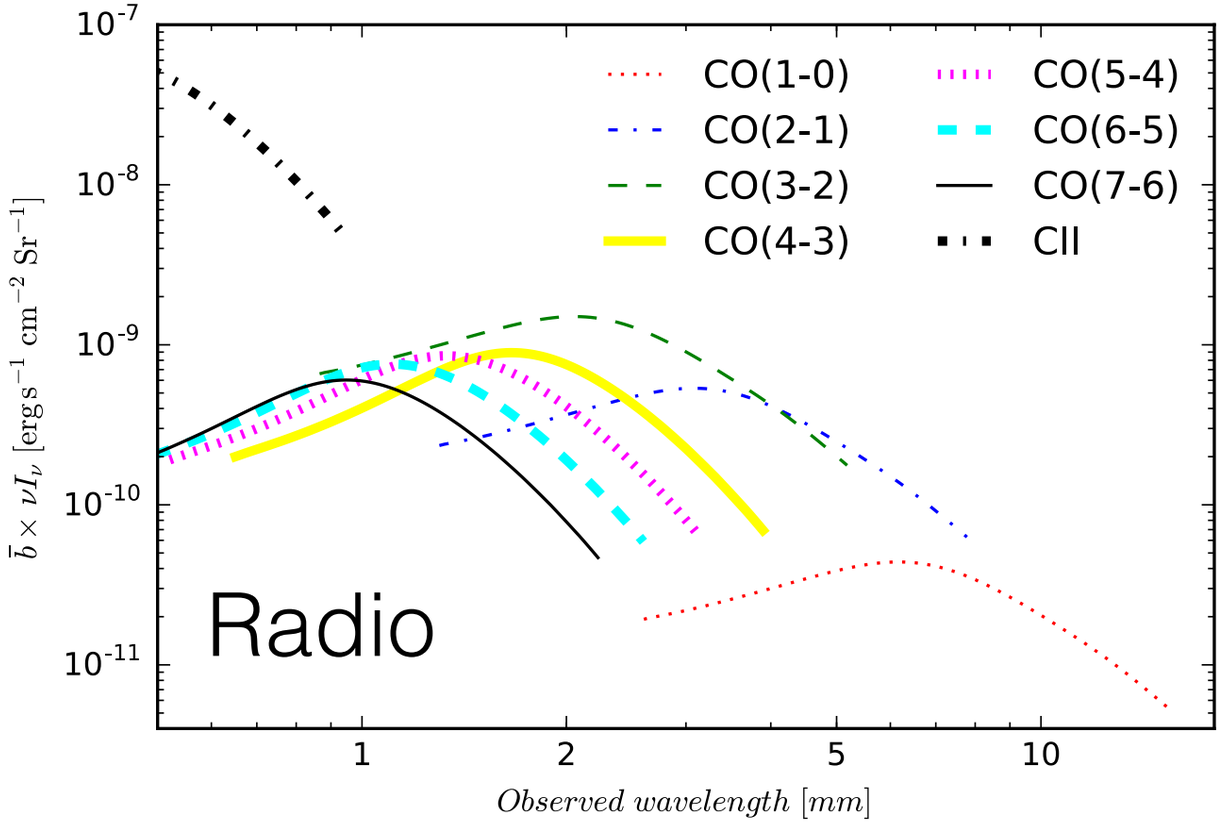
Connection

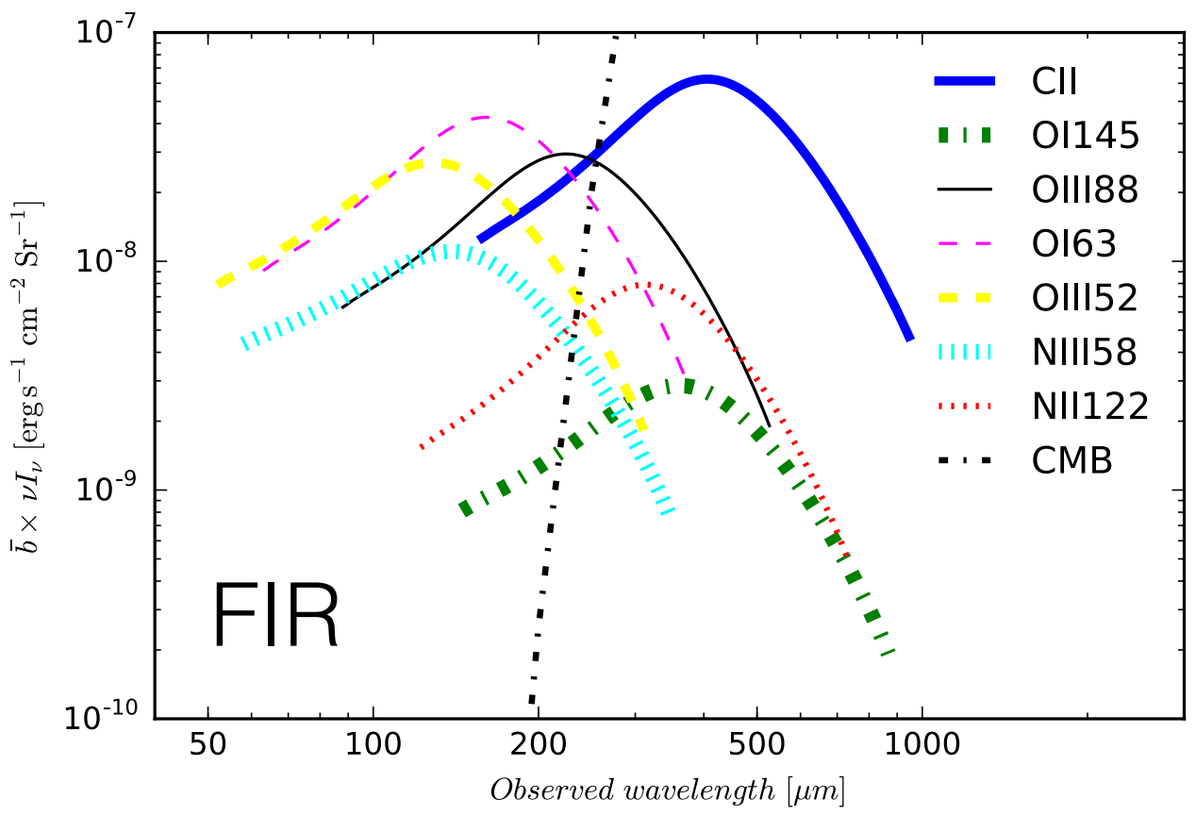
Underlying density field + Emissivity of light sources

Observing windows for line IM



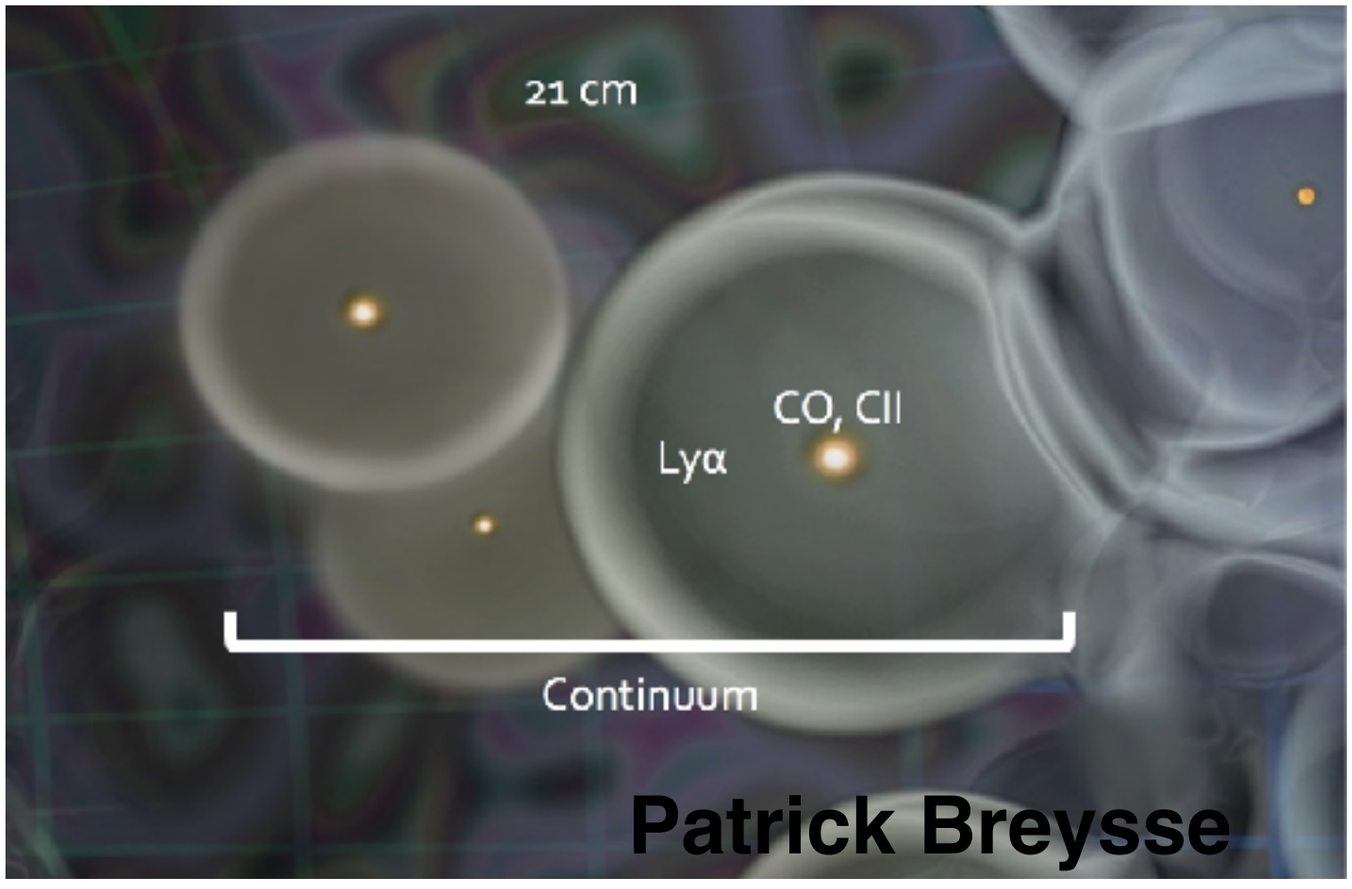
Fonseca et al. 2016





Galaxy constraints from Line-IM

- Molecular gas
- Neutral gas
- PDRs/Ionized gas
- Stellar mass
- SFR
- Line excitation
- Metallicity
- Dust extinction



Line IM instruments/ EOR surveys

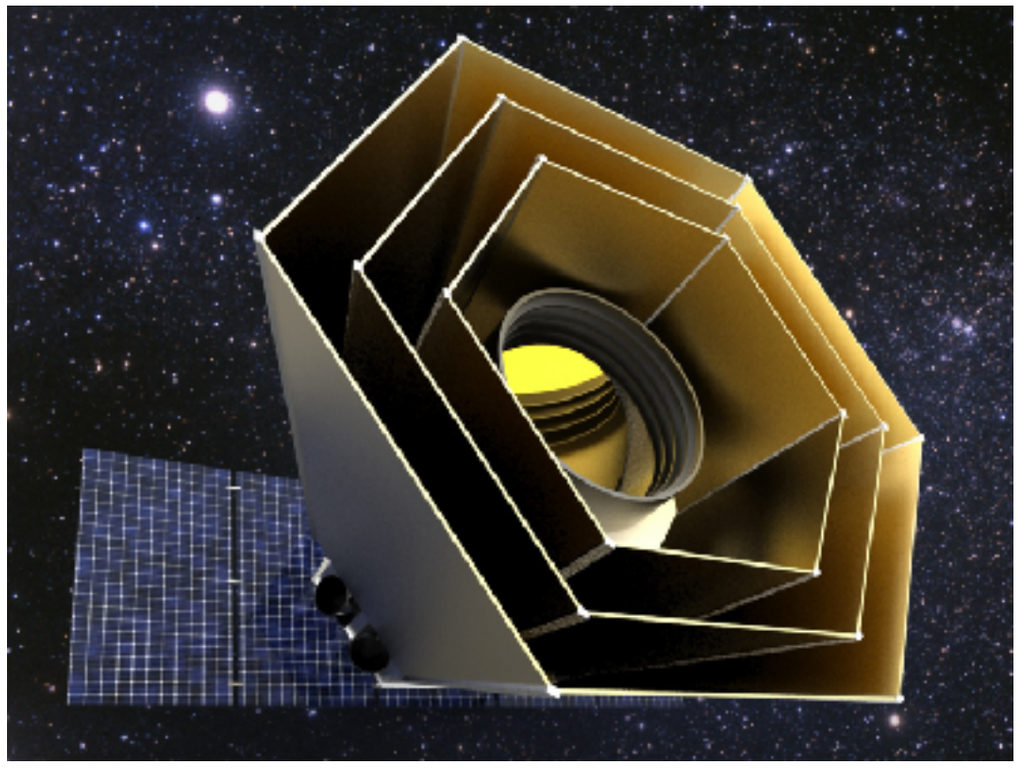
21 cm - LOFAR, SKA-low, HERA

Ly-alpha - SPHEREx, CDIM

H-alpha - CDIM, SPHEREx

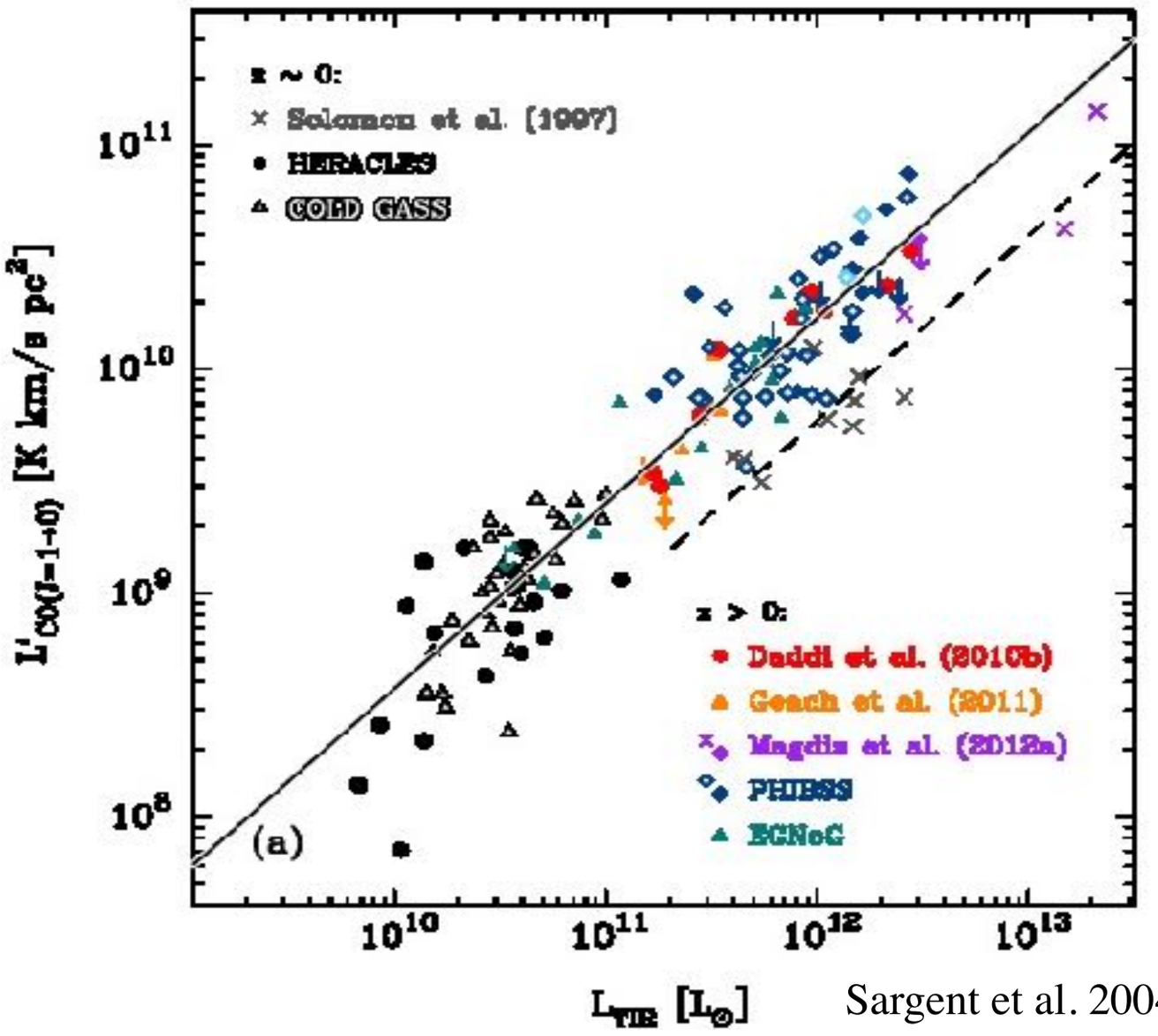
CO - COMAP

CII - TIME, CCAT-prime



CO Intensity Mapping

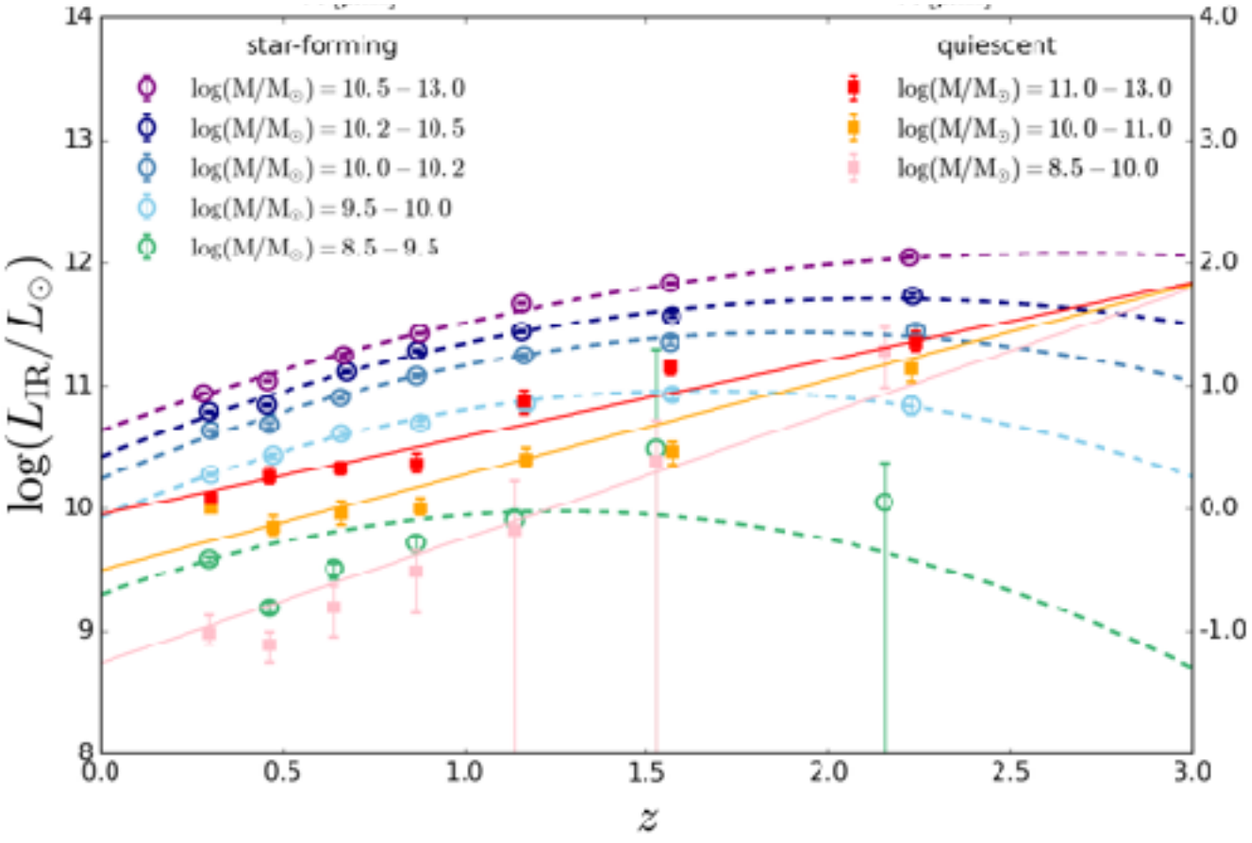
- Molecular gas (Fuel for SF)
- Line excitation
- Stellar mass
- Metallicity



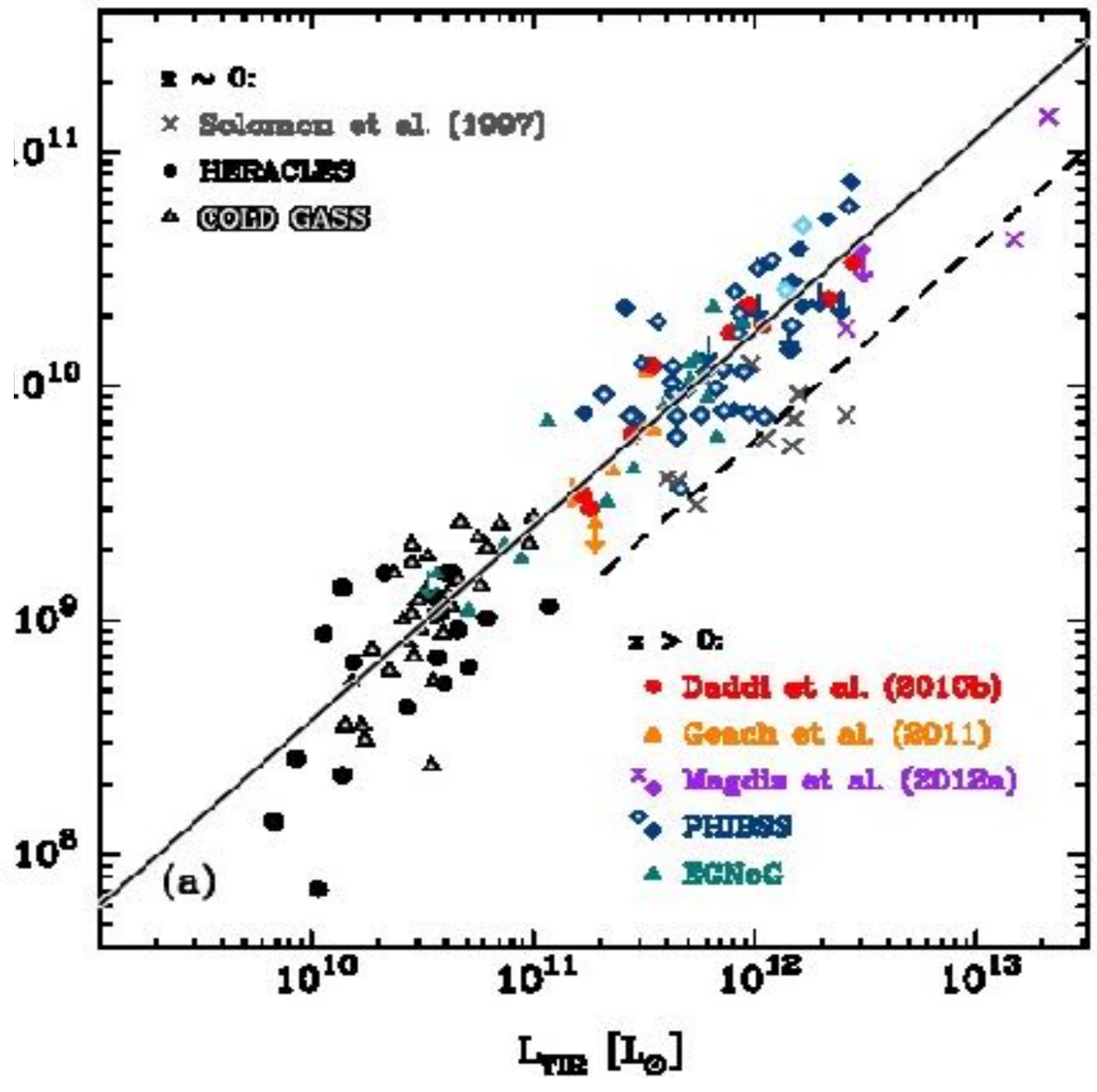
Sargent et al. 2004

See, e.g., Righi et al. 2008, Lidz et al. 2011, Gong et al. 2011

CO Intensity Mapping



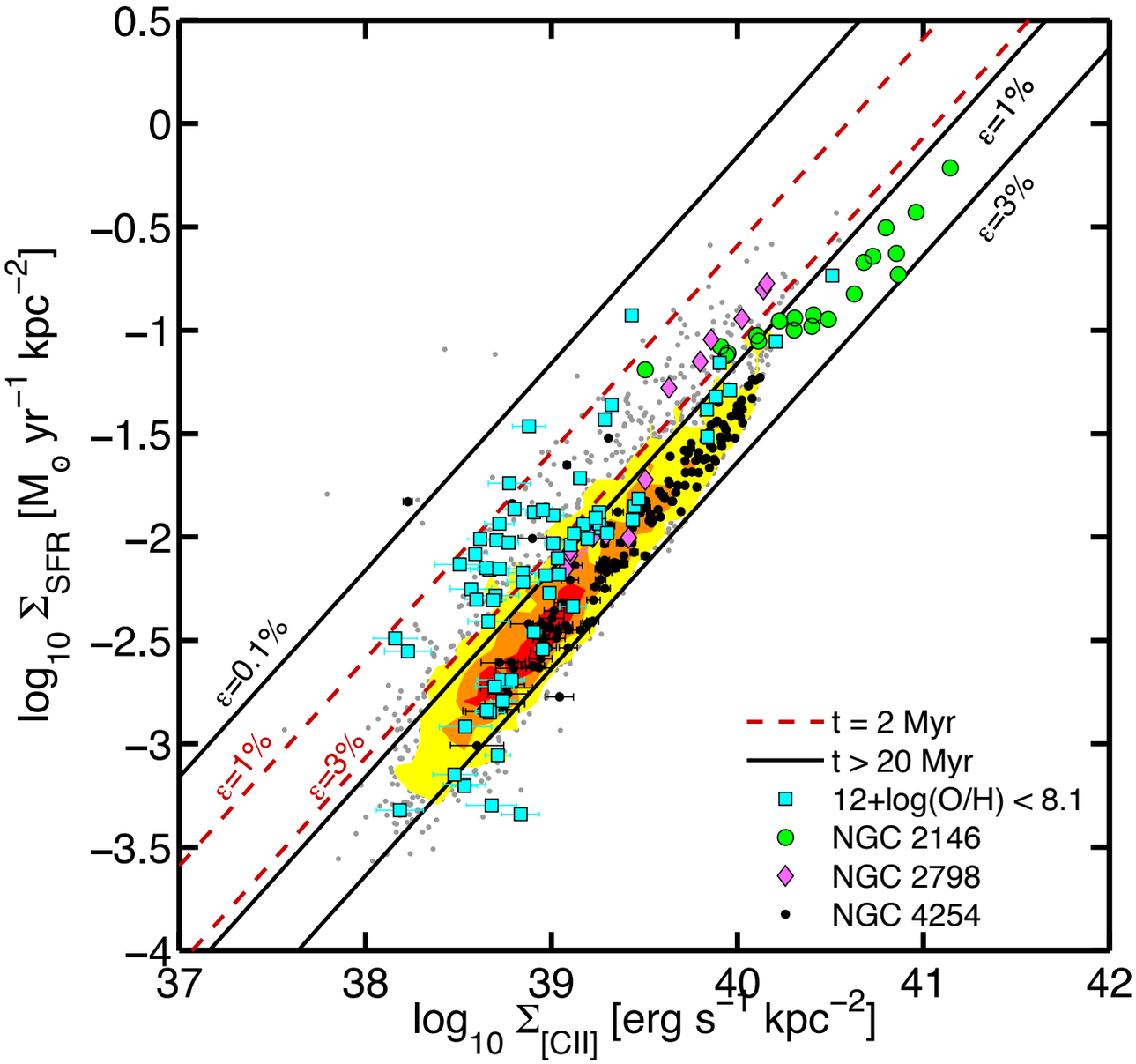
Guachau et al. (Arxiv:1610.10095)



Sargent et al. 2004

CII Intensity Mapping

- SFR/ Stellar mass
- Metallicity
- Major cooling ISM (neutral/Ionized gas and PDRs)



Herrera-Camus et al. 2014

See, e.g., Gong et al. 2012, Silva et al. 2013, Crites et al. 2014, Yue et al 2015

Ly-alpha Intensity Mapping

Intensity:

Galaxies/ IGM

Power spectra:

Galaxies

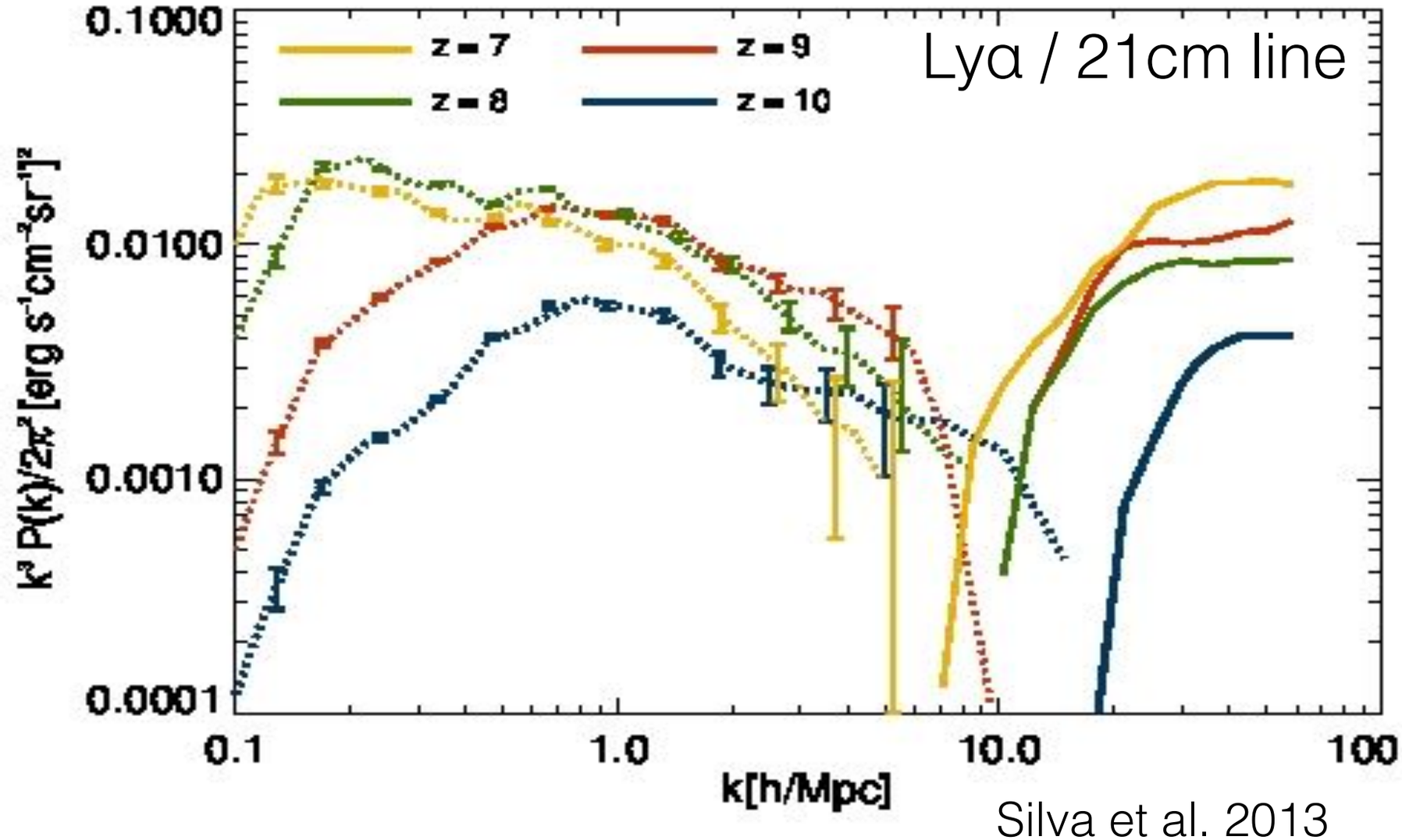
- Instantaneous SFR
- Ionizing recombining gas
- Lyα dust extinction
- IGM properties

See, e.g., Silva et al. 2013, Pullen et al. 2014, Gong et al. 2014, Comaschi et al. 2016

Cross correlating maps

CDIM/SKA-Low

Uncorrelated foregrounds



Silva et al. 2013

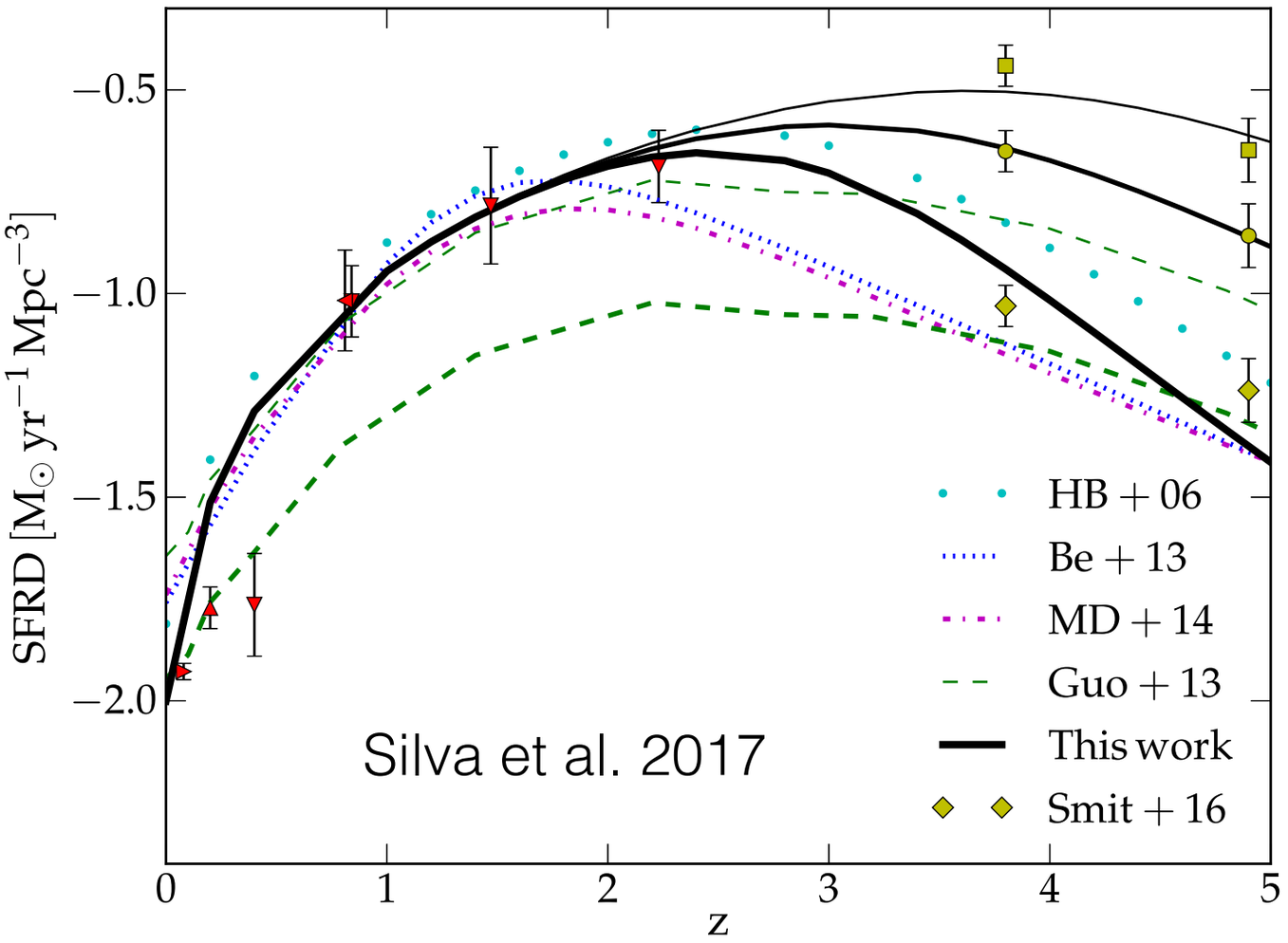
Galaxies and IGM anti-correlated

at scales larger than the typical ionised region

Line IM of Ly-alpha + H-alpha

CDIM/SKA-Low

Assuming
case B rec, Tk~10^4 K
n_e=350 cm^{-3}



lLyα_i/lHα_i = 8.7

A_Lyα >A_Hα

lLyα_o/lHα_o
traces ISM properties

These lines probe the instantaneous SFR

Summary

- **IM HI** - IGM state, Indirectly constrain overall galaxies ionising emissivity

- **IM Lyα/ Hα/ CO/ CII** - Molecular/neutral/Ionized gas, PDRs, instantaneous SFR, stellar mass, Metallicity, etc

- **IM of Multiple lines**
  - Cross-correlations: Avoid contamination
  - Constrain: ISM Temp/n_e, Line excitation, SFR, etc