Prospects for Intensity Mapping the [CII] Fine Structure Line during the Epoch of Reionization

Christos Karoumpis

WHO → Type of Ionizing Sources

Physical Processes in ISM/IGM ← WHY

WHEN → Time and duration of EoR

Details of bubble expansion ← HOW

WHERE → Underlying Structure Formation

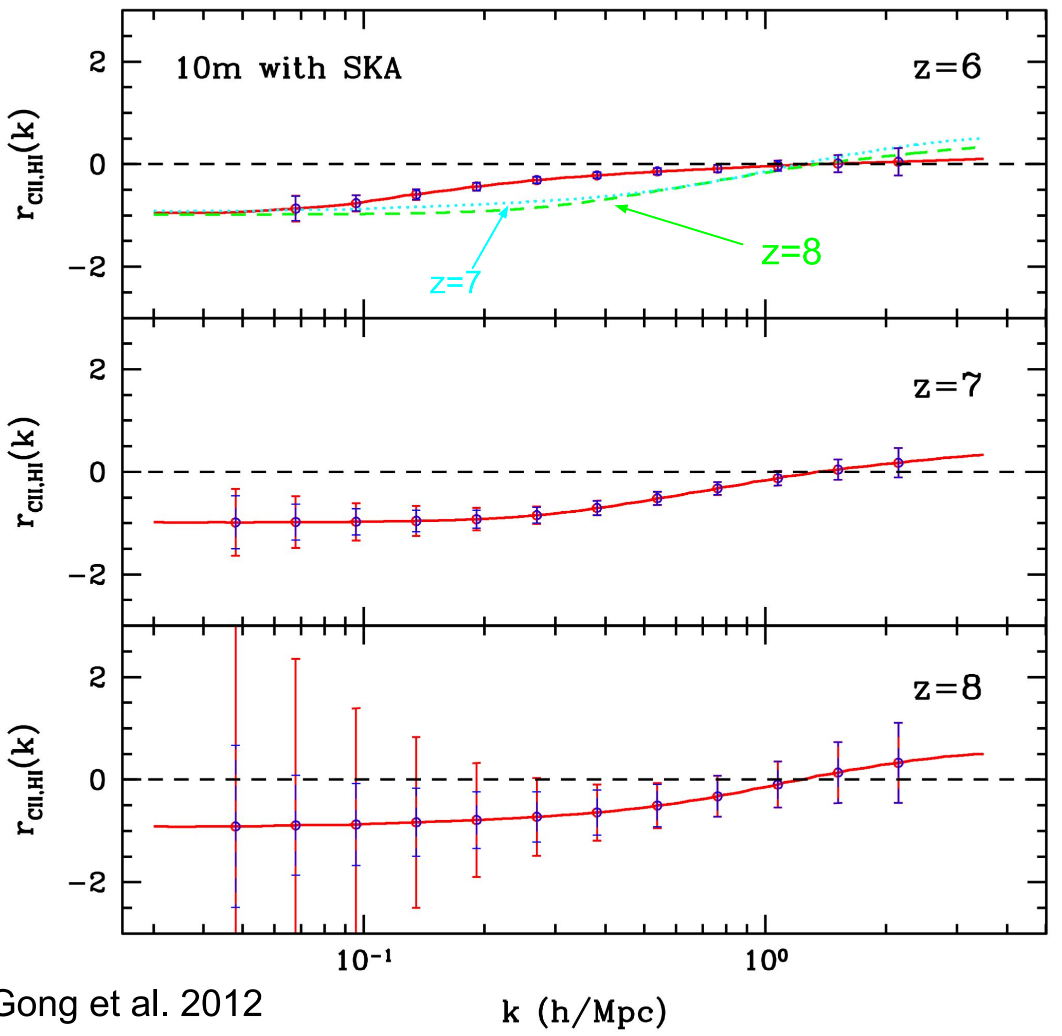
Sky average 21 cm , 21 cm IM, CMB → IGM

[CII] -CO -Lyman alpha LIM, EBL, Galaxy surveys → ISM, SFR, DM structure

Sky av... IGM

[CII] ... ISM, SFR, DM

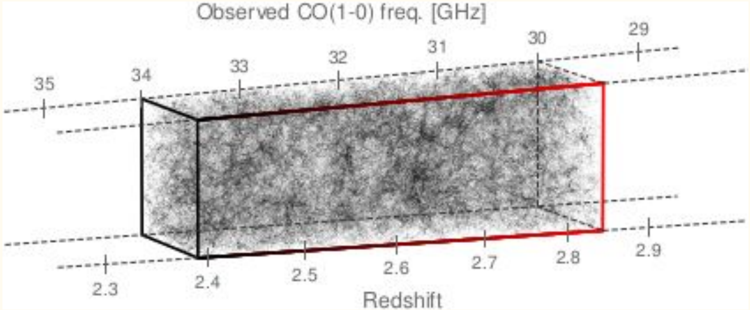
surve... structure



Gong et al. 2012

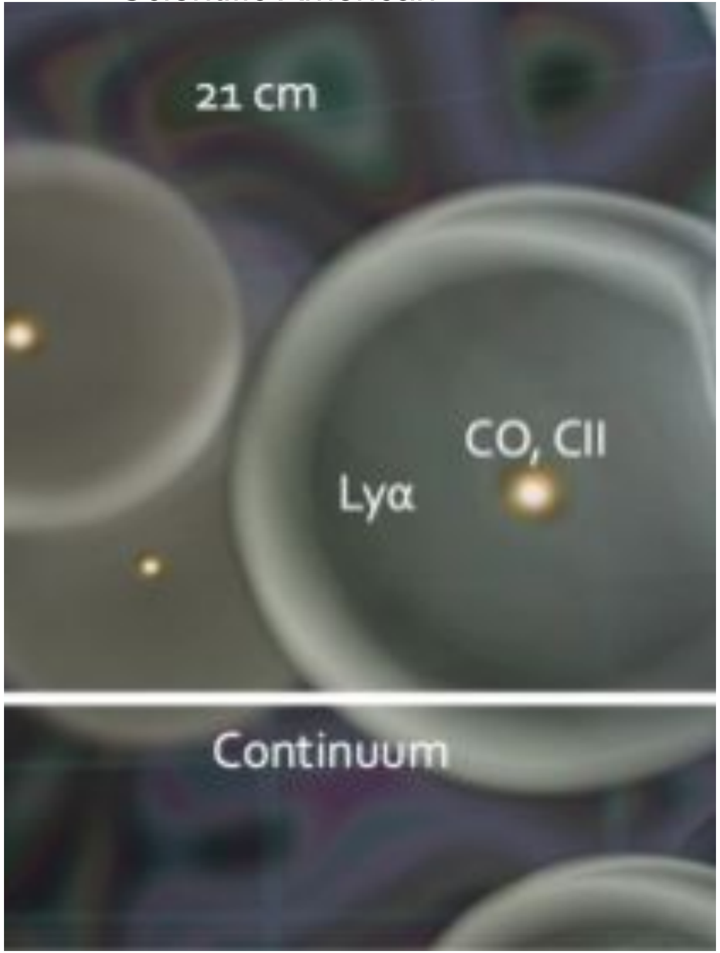
When it comes to high-redshift LIM is a nice idea!

Li et al 2015



- Allows access to high-z galaxies below detection limit (that will remain largely inaccessible to best optical tracers)
- Collects radiation from galaxies in a selected redshift range
- Spurious flux due to contaminating radiation and noise can be in principle removed or suppressed.
- If the galaxy luminosity function has a sufficiently steep faint end, the observed radiation is dominated by unresolved sources
- We can measure the clustering signal of galaxies
- We can check if there is enough star formation to produce enough UV photons to cause and maintain reionization

Scientific American



Why [CII] 158 micrometers?

Tracer of UV field in star-forming regions, redshifted to ~1 mm at EoR redshifts

Much stronger (brightest metal line) signal than HI 21cm and much simpler foregrounds

Not subject to IGM absorption like Ly-α 1216 A and others

Not subject to steep metallicity dependence like CO rotational lines

Complementary to Lyα line and other lines (e.g. 21 cm, HeII1640,..)

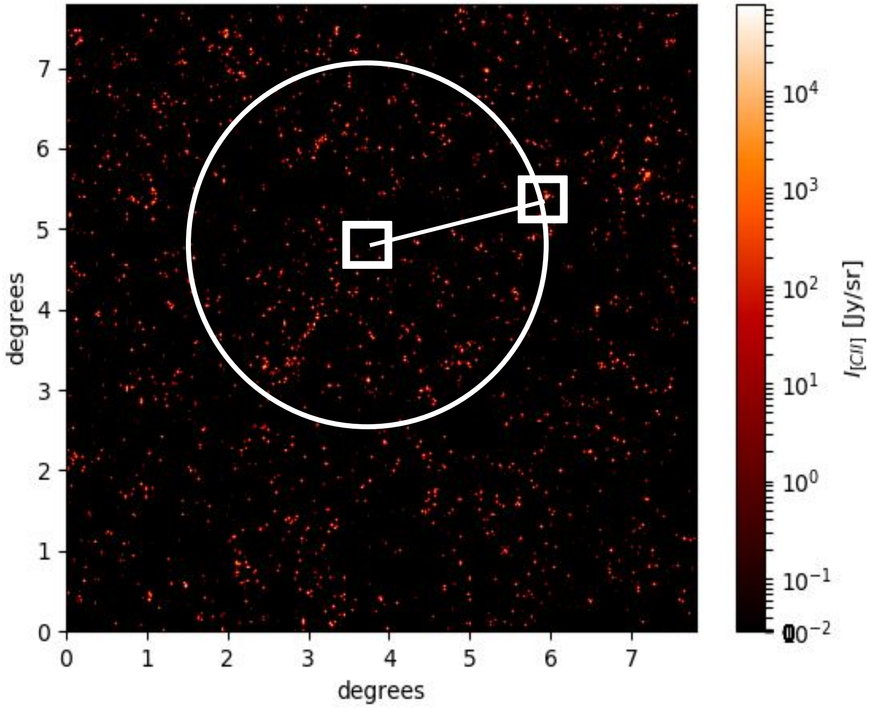
What do we need to detect it?

- 6-m telescope has ~1' = 45" beam for [CII] at z~7 (~240 GHz)
- ideal to probe few arcmin/Mpc clustering scales at EoR over >10 deg2
- Requirement:moderate spectral resolution (~0.5 GHz, dz~0.01), wide-bandwidth multi-element spectroscopy covering [CII] at z=6-8 (z=3.3-9.3): continuous coverage of 1mm (+760/850μm) atmospheric windows
- Rapid spectral+spatial mapping speed on deg-scales critical to be feasible Using Fabry-Perot Interferometer on 4000-pix quad-color TES camera
- Sensitivity at a premium: high site, very low emissivity telescope essential • ~1.5x reduced sky emissivity compared to ALMA site • <2% telescope emissivity with off-axis design " Overall ~20 – 100x mapping speed for EoR IM wrt. APEX, JCMT, LMT

CCAT-p Observatory

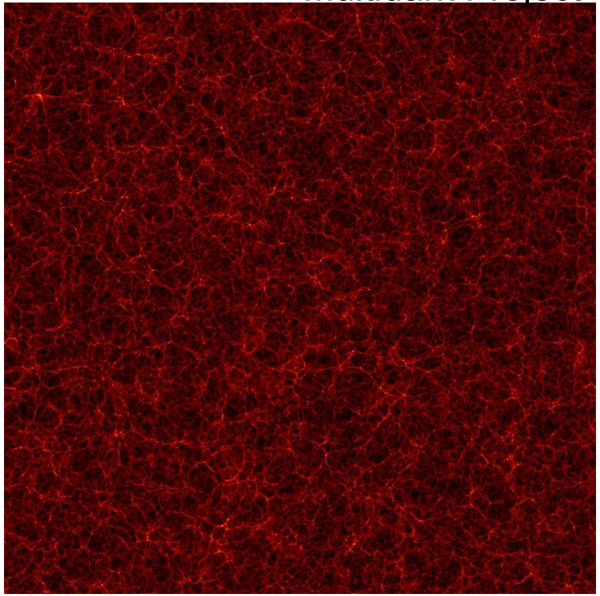
What do we need to analyze it?

- Detecting the signal is hardly the end of the story! We need to
- plan the optimal survey strategy depending on our scientific questions
- develop techniques of foreground and contamination removal
- produce methods of statistically analysing the targeted signal
- Find ways to combine it with auxiliary data
- To do this we need mock [CII] line intensity maps

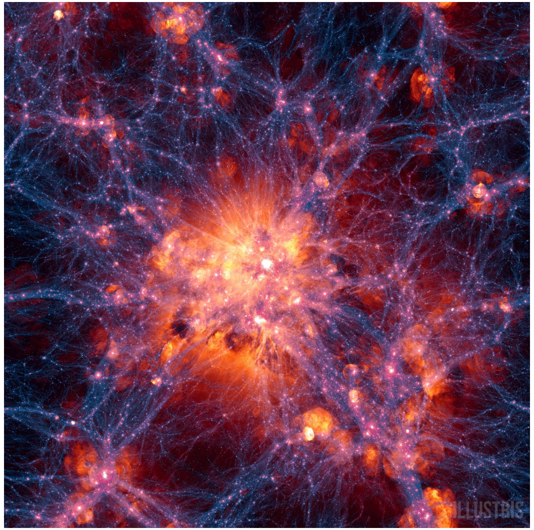


Creating the observational cone

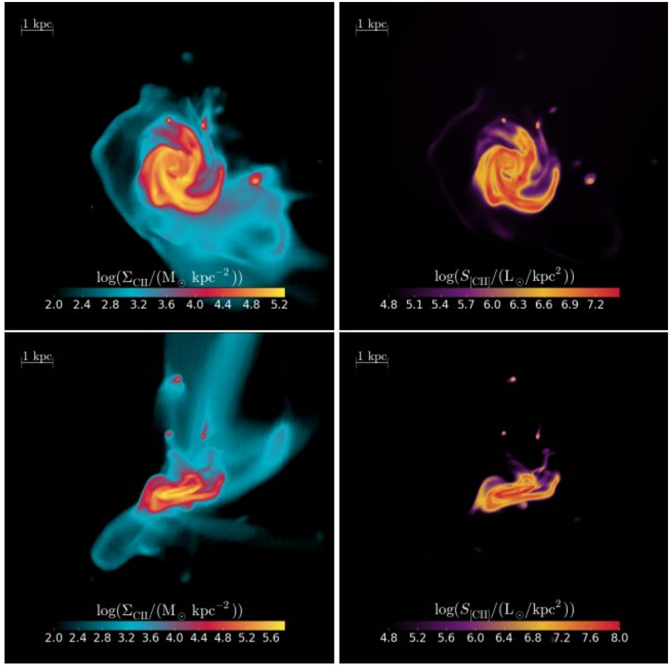
Multidark Project



Illustris Collaboration

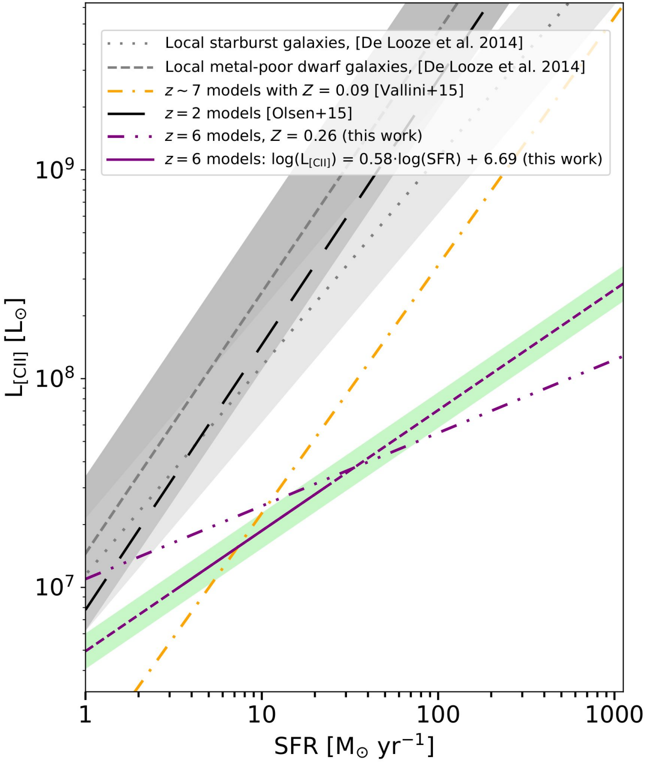


Pallottini et al 2017

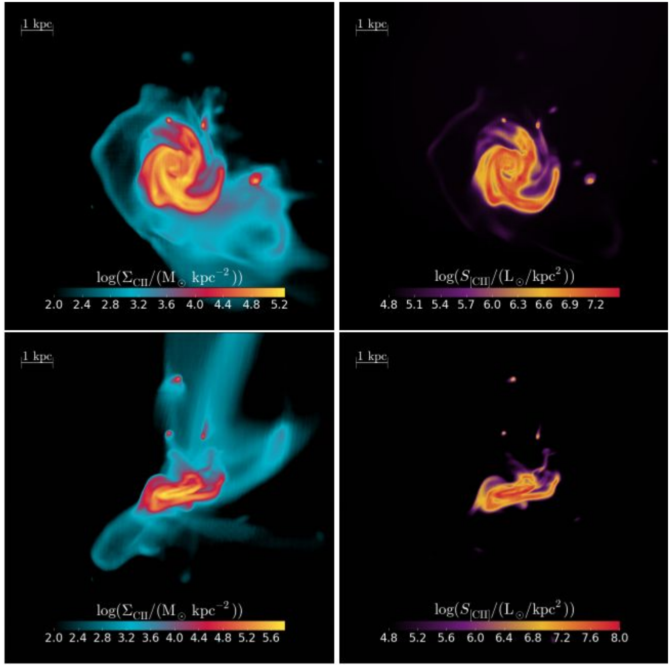


The [CII] line emission in high redshift galaxies

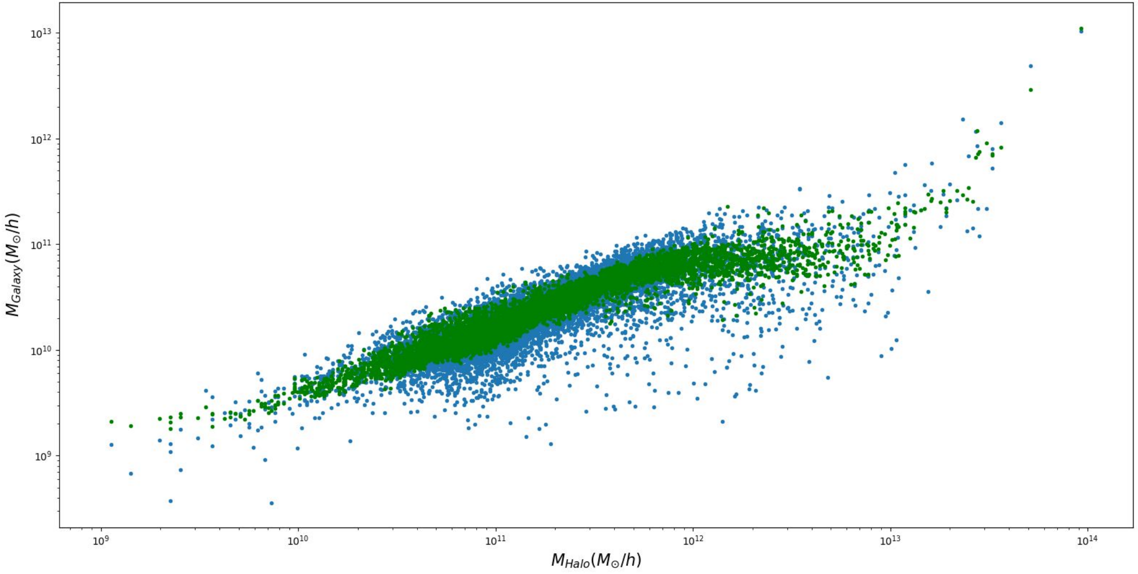
Olsen et al 2017



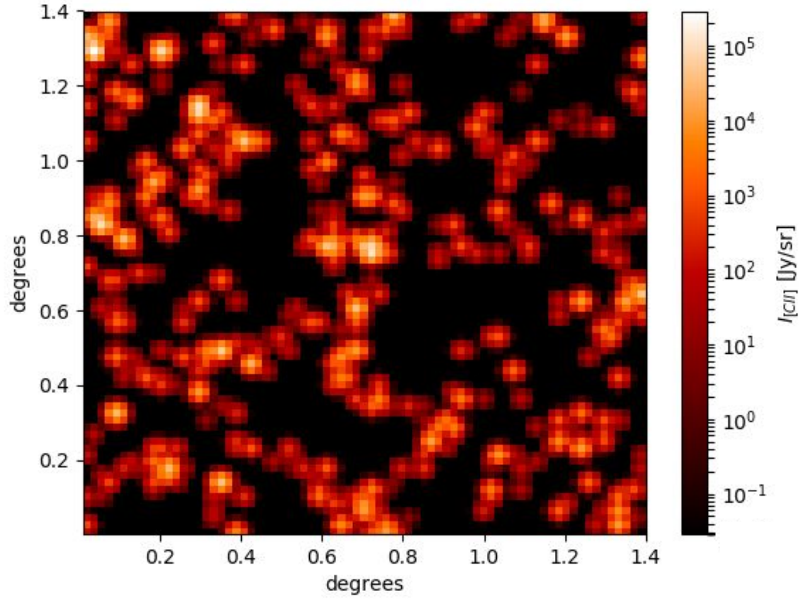
Pallottini et al al 2017

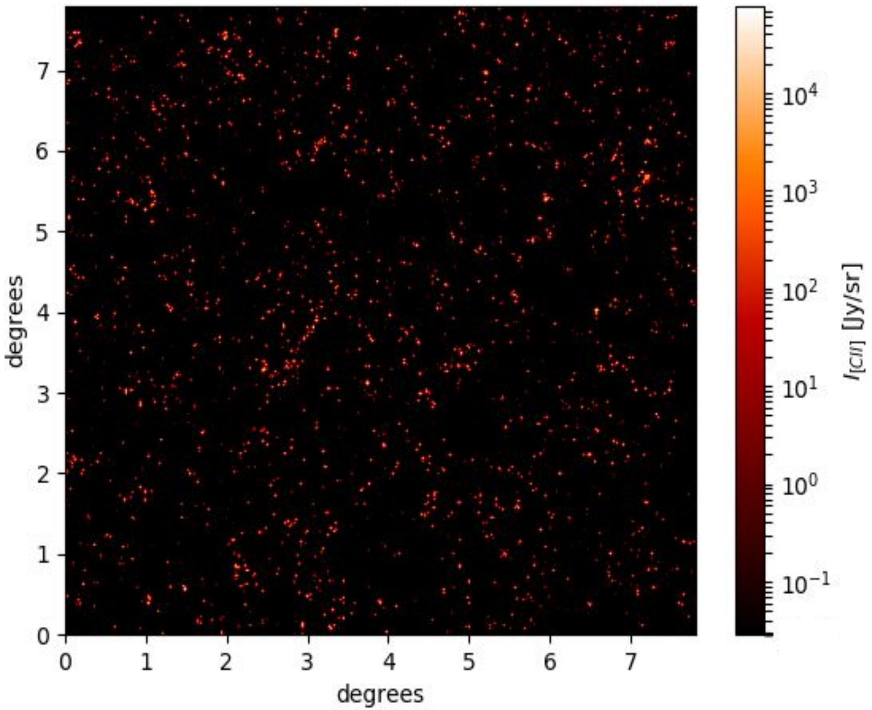


Painting Galaxies on Dark Matter with Machine Learning

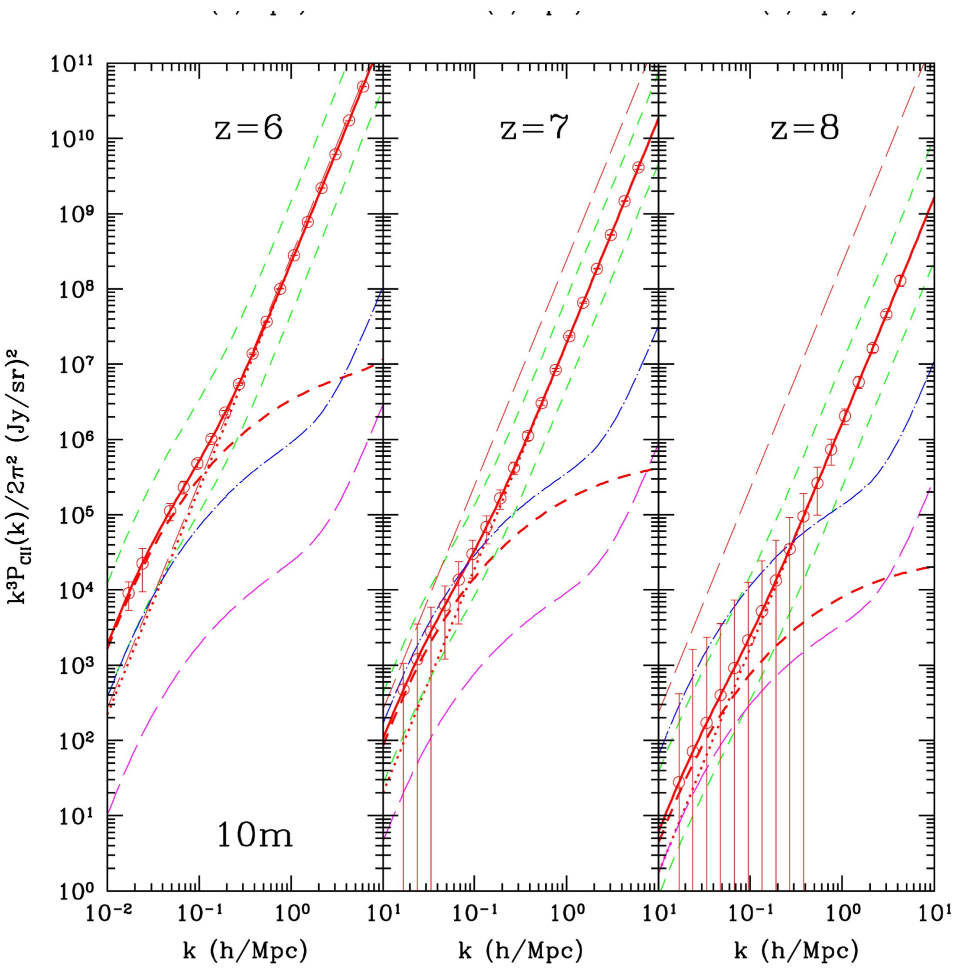


Mock Maps



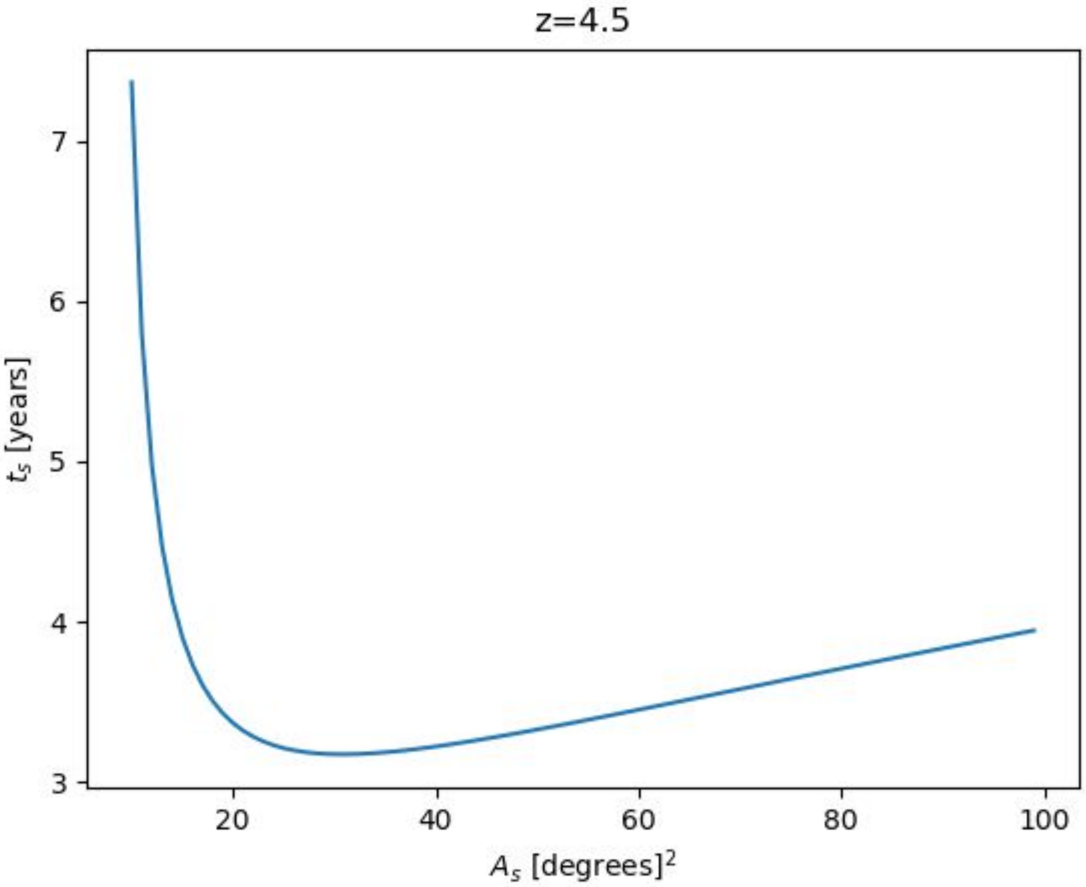


The 3D Power Spectrum



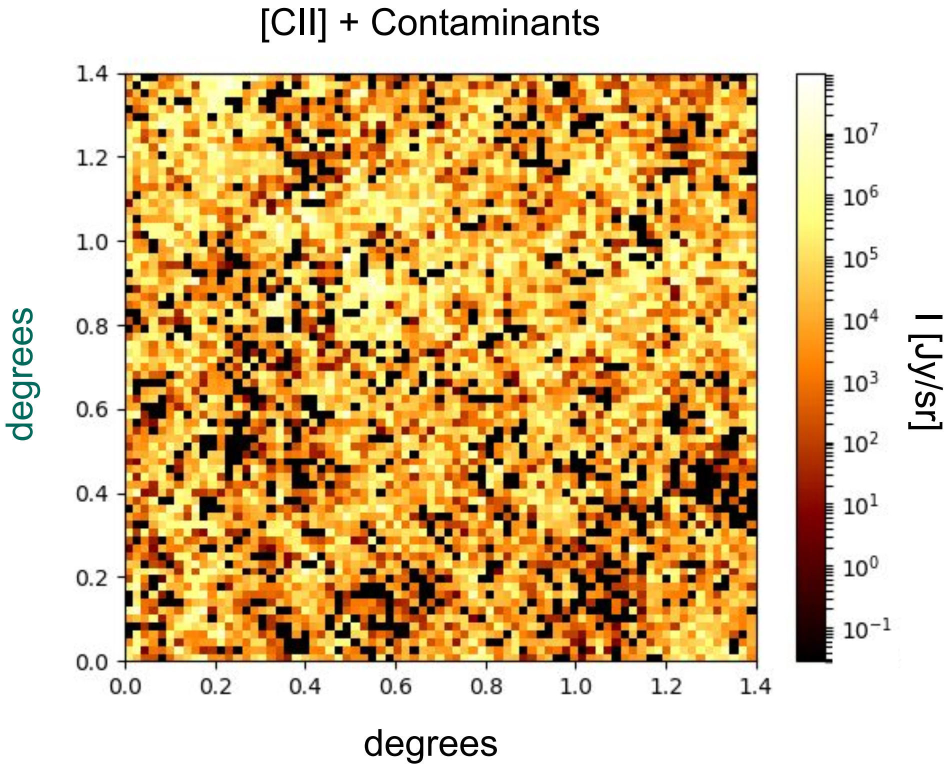
Gong et al. 2012

CCAT-p Survey



Contaminants

- In [CII] line intensity maps, the main contaminants are the FIR continuum foreground and FIR emission lines from lower redshifts, particularly the CO rotational transitions.
- The signal from the contaminants is integrated to our maps using the physical properties of galaxies (e.g., L CO -SFR relation) populating our DM halo catalogs.
- The resulting intensity of CO power spectra is of the same order of magnitude than that from the [CII] line (Fig. 3). This highlights the need for very efficient foreground removal techniques.



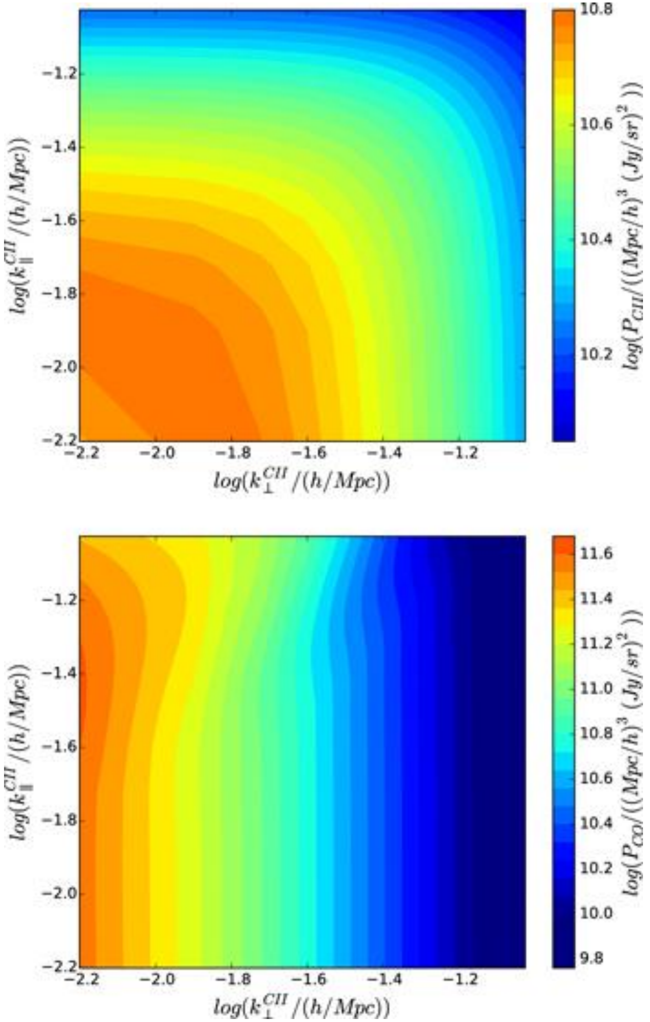
Cheng et al. 2016

Contaminant removal methods

There are two classes of foreground removal methods:

• those requiring ancillary data; like masking of pixels containing bright optical galaxies (e.g., Yue et al. 2015) or cross-correlating with intensity maps of other lines covering the same redshift (e.g., Serra et al. 2017)

• those using the signal itself; like removing the anisotropic component of the power spectrum coming from incorrect redshift projection (e.g., Cheng et al. 2016) or cross-correlating between two CO lines to distinguish them from [CII] line (e.g.,, Silva et al 2015).



Conclusion

[CII] line intensity mapping experiments can provide as with vital information over the sources that ionized the universe and their underlying DM structure

CCAT-prime will be an ideal observatory to contact this kind of observations

In order to find the optimal survey strategy, create foreground removal and statistical analysis methods and investigate ways the targeted signal can be combined with ancillary data I created mock [CII] line intensity maps

In order to acquire them we combine physics of three different scales: large scale only dark matter simulations, medium sized hydrodynamical simulation and high-redshift galaxy simulations