Jet Propulsion Laboratory
California Institute of Technology

TIME: [CII] Intensity Mapper
Tomographic Ionized-C Mapping Experiment

Tzu-Ching Chang

on behalf of

TIME Collaboration

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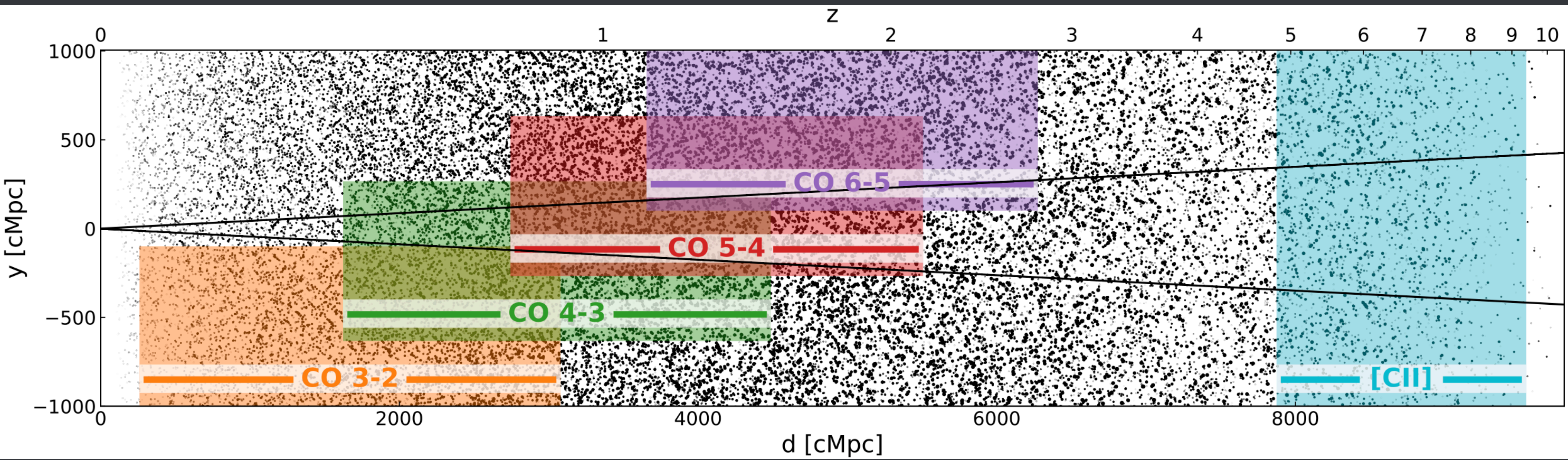
TIME in a nutshell

- A [CII] Intensity Mapper for EoR at $5.3 < z < 8.5$
  - Covering 195-295 GHz at R~100 (183-326 GHz including atmosphere monitoring channels)
  - 32 grating spectrometers (2 polarizations)
  - 1920 TES bolometer detectors
  - 16 spatial pixels and 60 spectral channels
  - FoV: 11 arcmin x 0.4 arcmin
  - Nominal survey: ~1 deg x 0.4 arcmin
  - Engineering run now: Jan-March 2019
  - 1000 hours of winter observing time at the Kitt Peak ALMA 12-m Prototype Antenna, starting winter 2019

TIME Lightcone

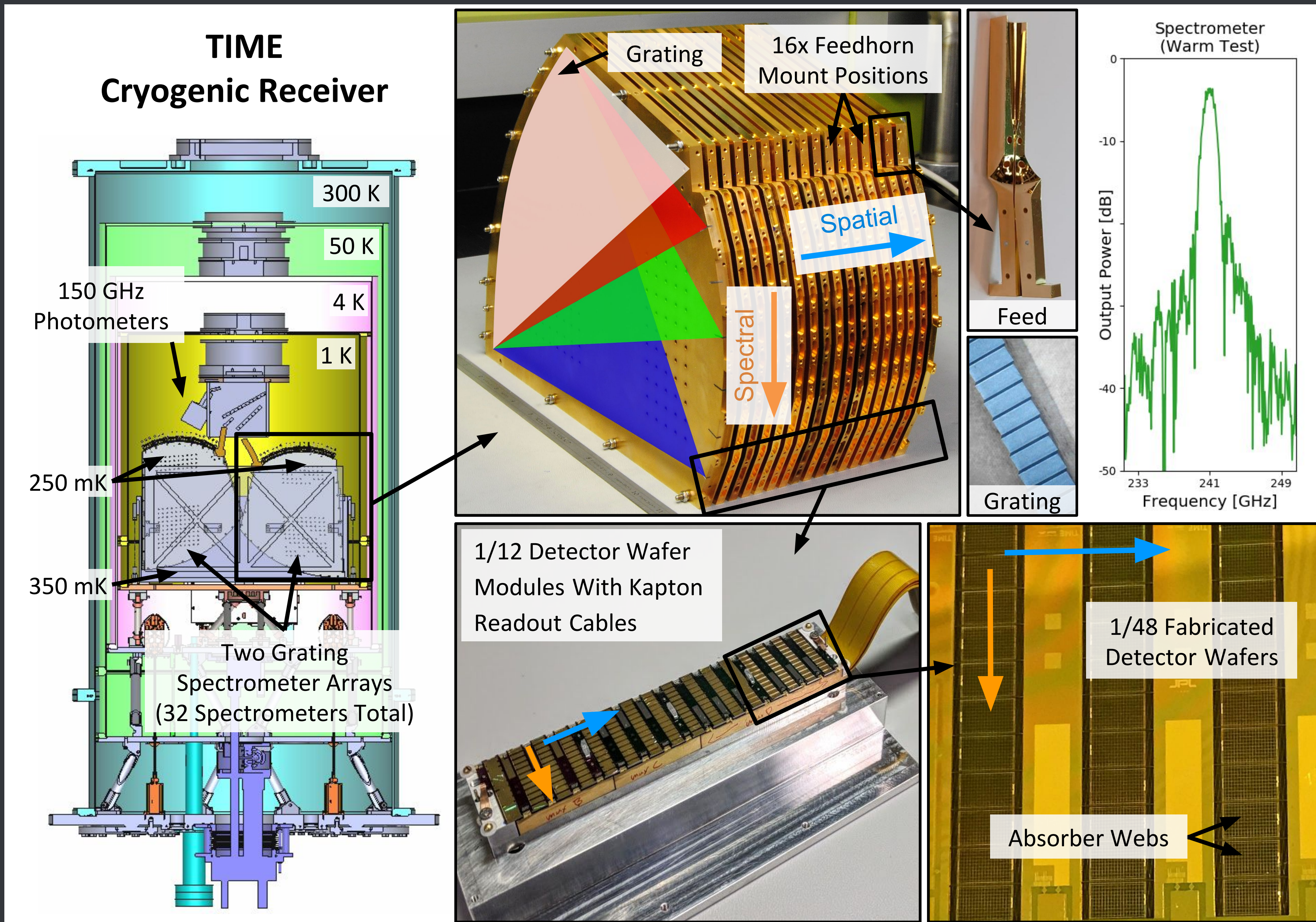


TIME collaboration

TIME traces the 3D large-scale cosmic structures via [CII] and CO and measures the luminosity-weighted density field

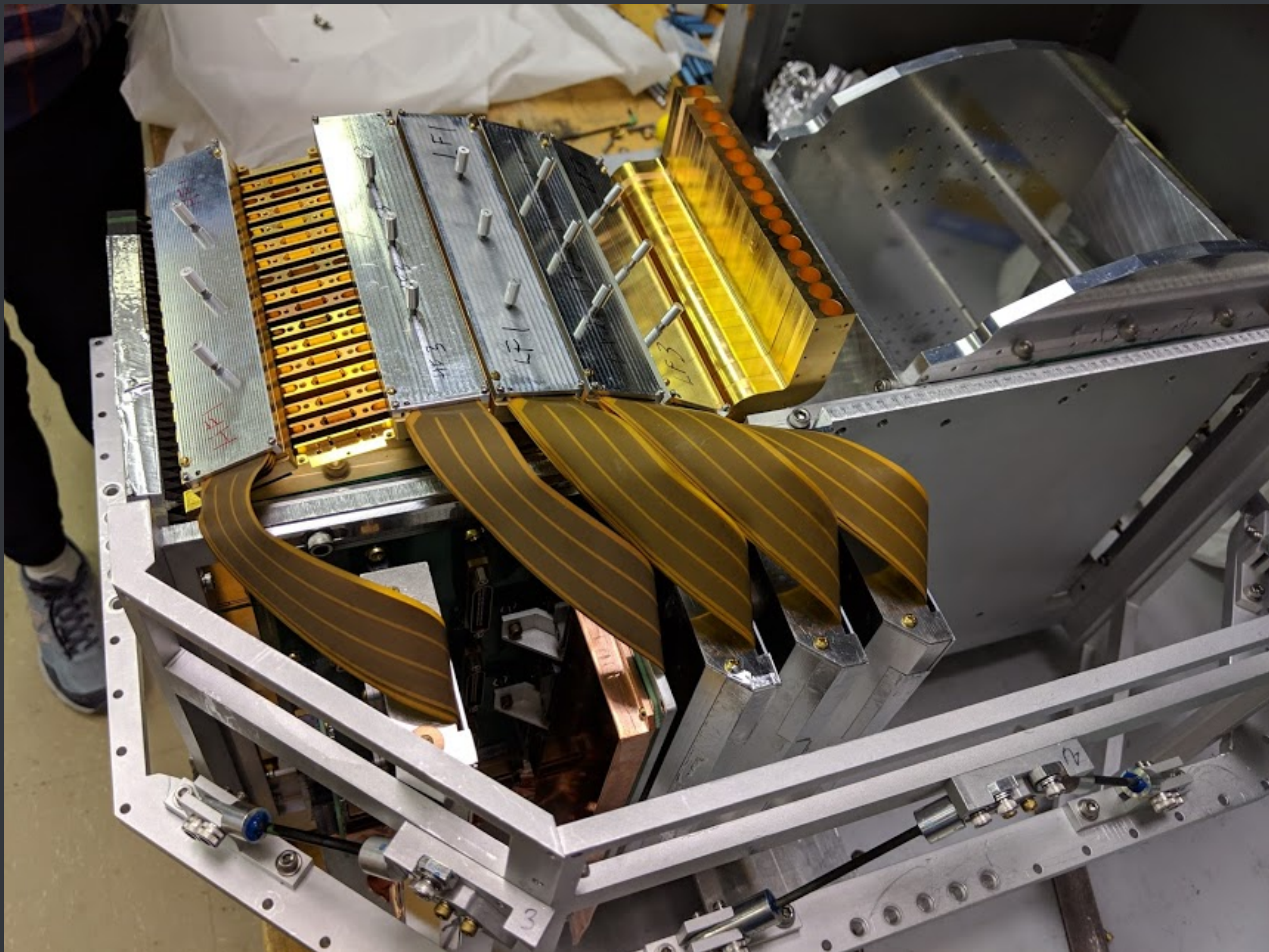
Astrophysics: L(M)
Cosmology: $P_L(k, z)$

TIME Instrument



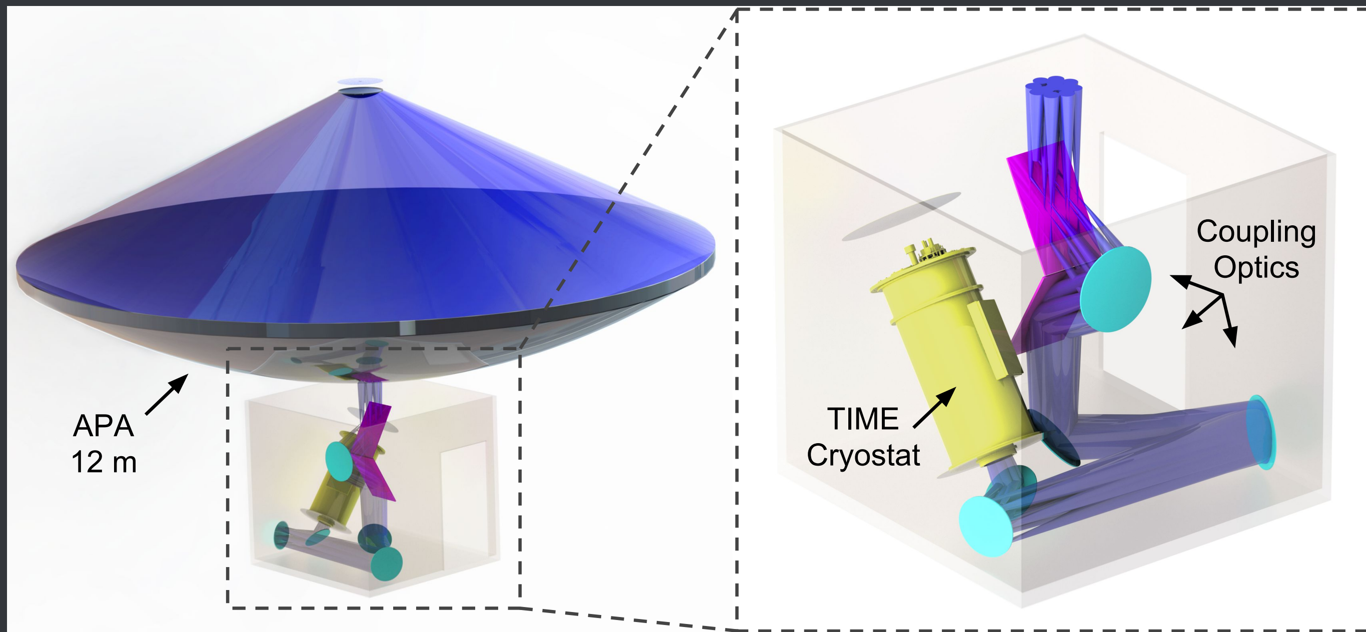
TIME collaboration

TIME focal plane



Courtesy Abby Crites

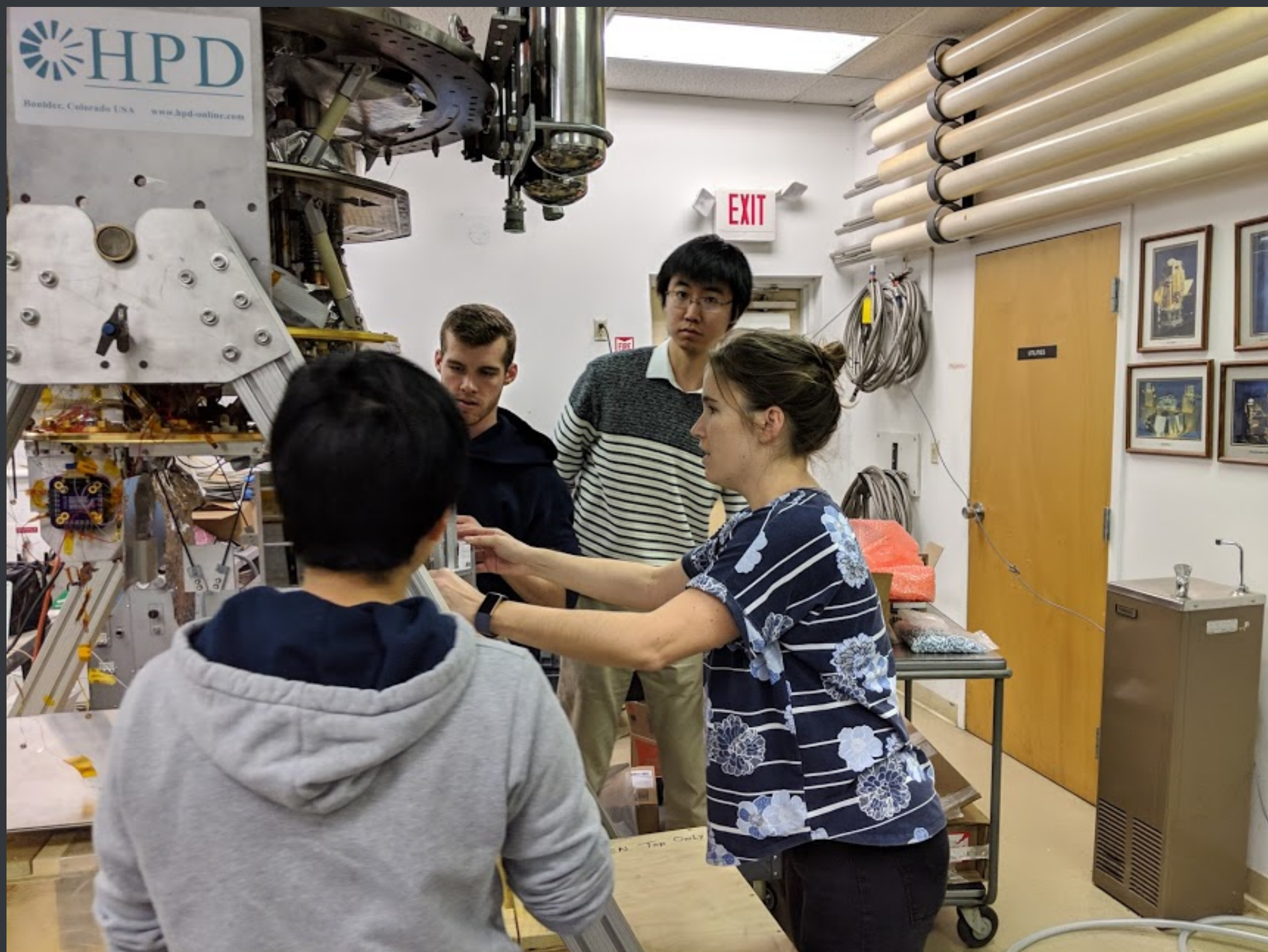
TIME @APA



TIME collaboration

TIME engineering run @APA

January - March, 2019



Courtesy Abby Crites

TIME engineering run @APA

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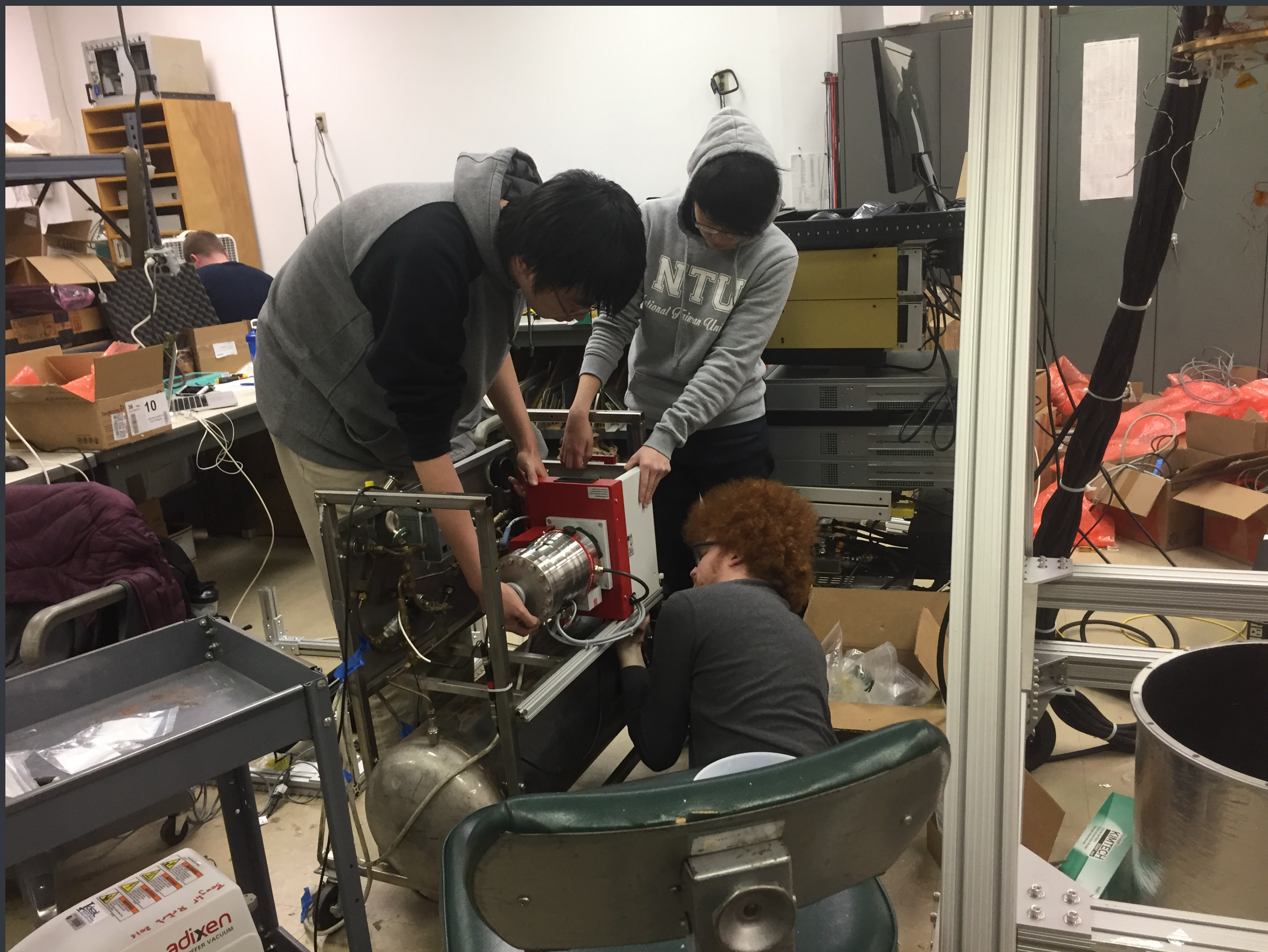


Courtesy Abby Crites

TIME engineering run @APA

January - March, 2019

Courtesy Abby Crites

TIME engineering run @APA

TIME assembled

Courtesy Abby Crites

TIME engineering run @APA

TIME cold, lab testing

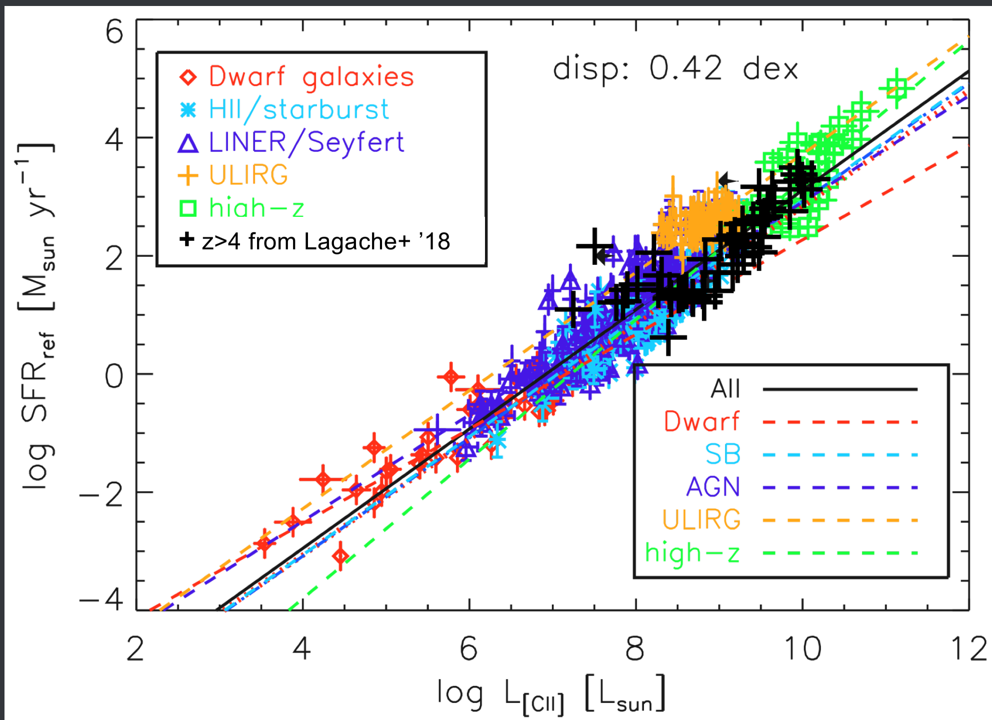
Courtesy Abby Crites

TIME engineering run @APA

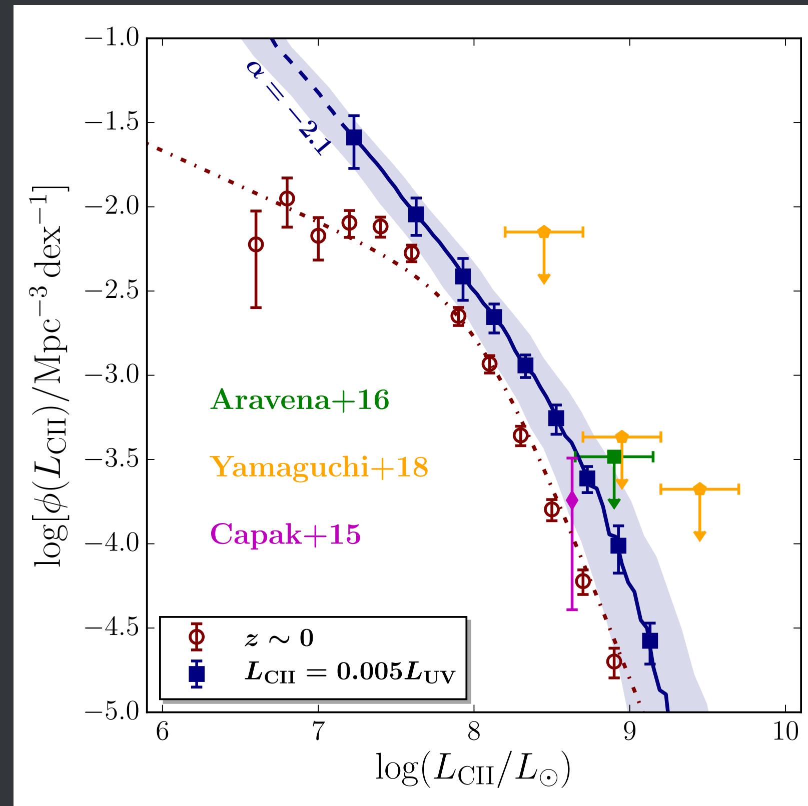
TIME on APA!

Courtesy Jonathan Hunacek

[CII] at high-z



De Looze et al. 2014

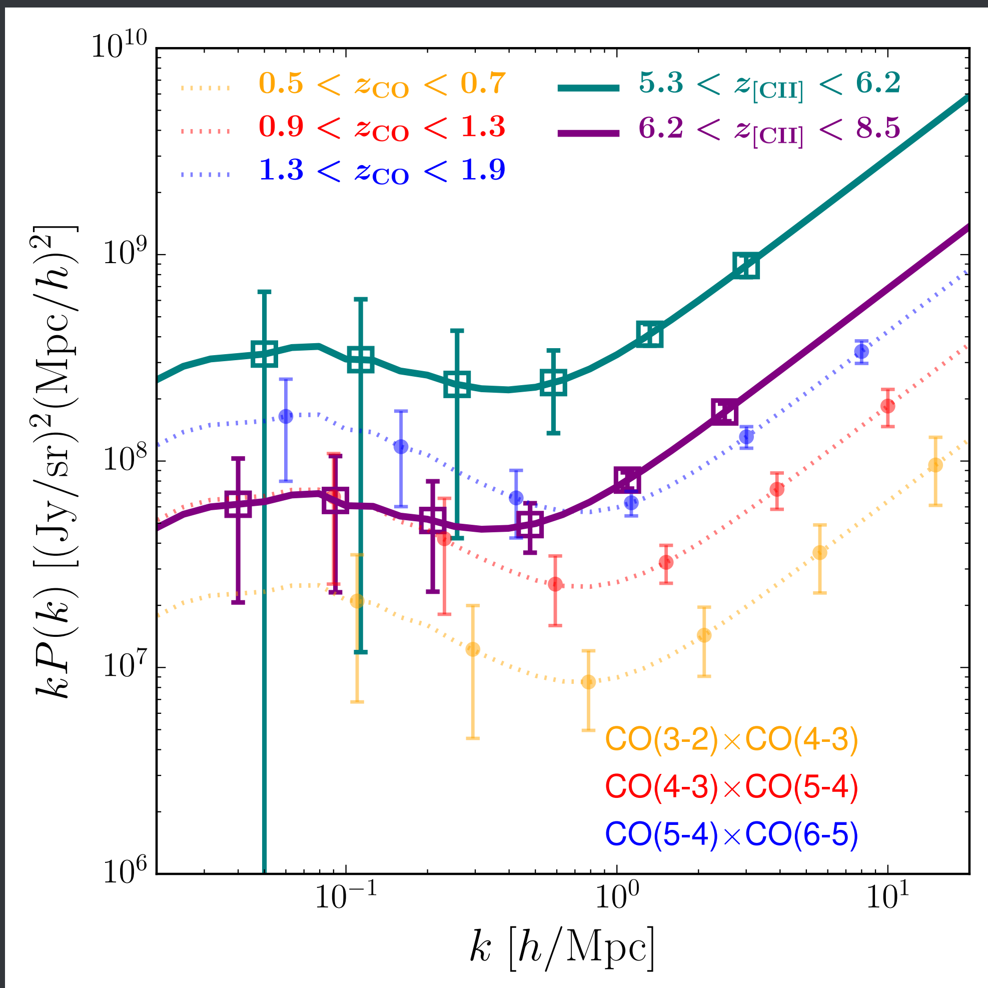


TIME collaboration

- [CII] is a major coolant in ISM, a tracer of Star formation activities.
- $L_{[CII]}/L_{FIR}$ appears to be ~0.001 - 0.01 at high-z from recent ALMA observations (Aravena et al. 2016, Capak et al. 2015)
- ALMA starts to constrain $10^{8.5-9}$ L_{sun} systems (Aravena et al. 2016, Hayatsu+17)

TIME forecast:

[CII], CO Power Spectra

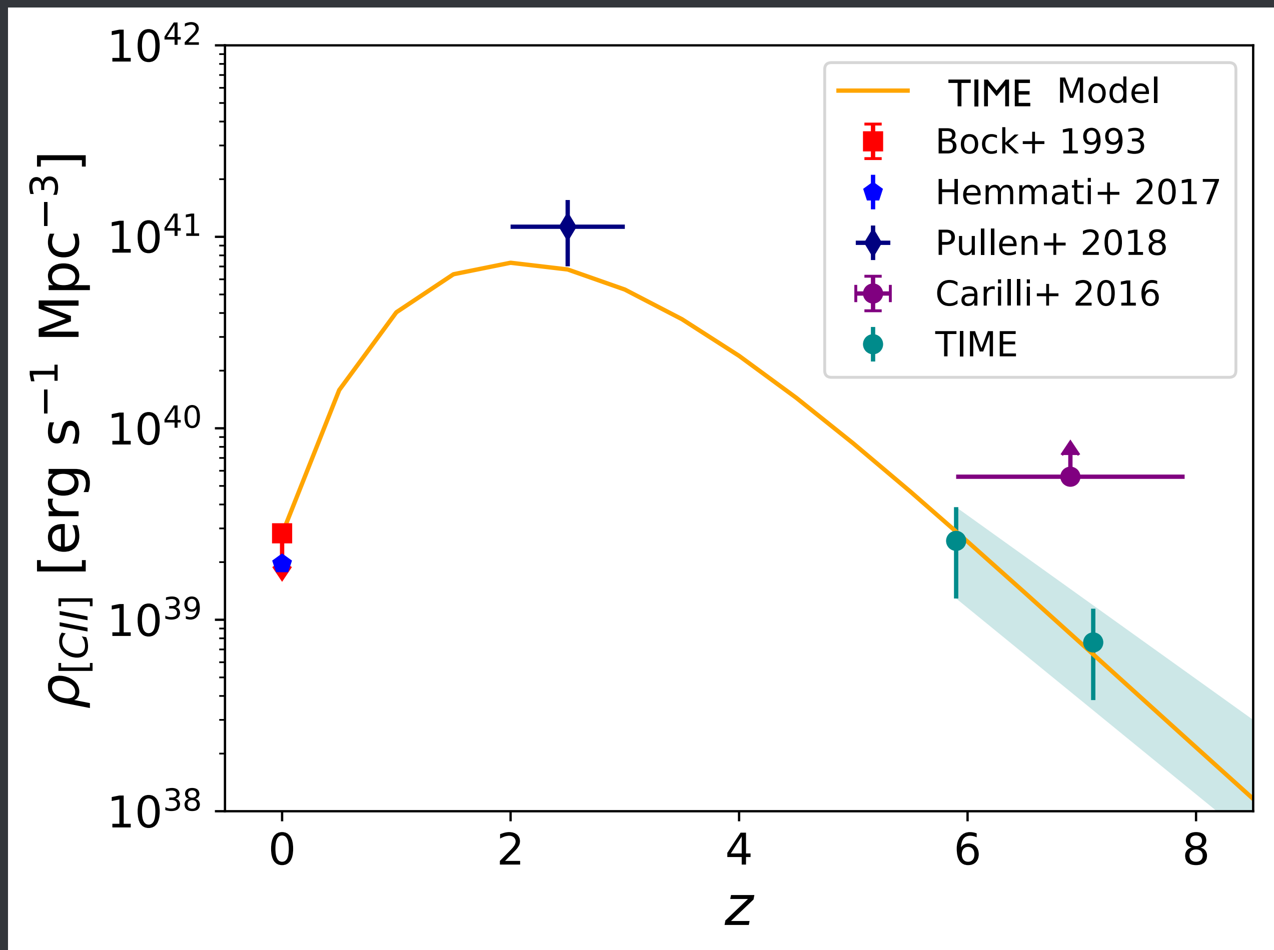


TIME collaboration (Sun et al., in prep)

- [CII]/CO intensity mapping constrains the integral of luminosity function via clustering and shot-noise power spectrum
- Power spectra SNR ~ 10, including estimated signal reduction due to observing strategy, survey geometry, atmospheric and continuum contaminations.

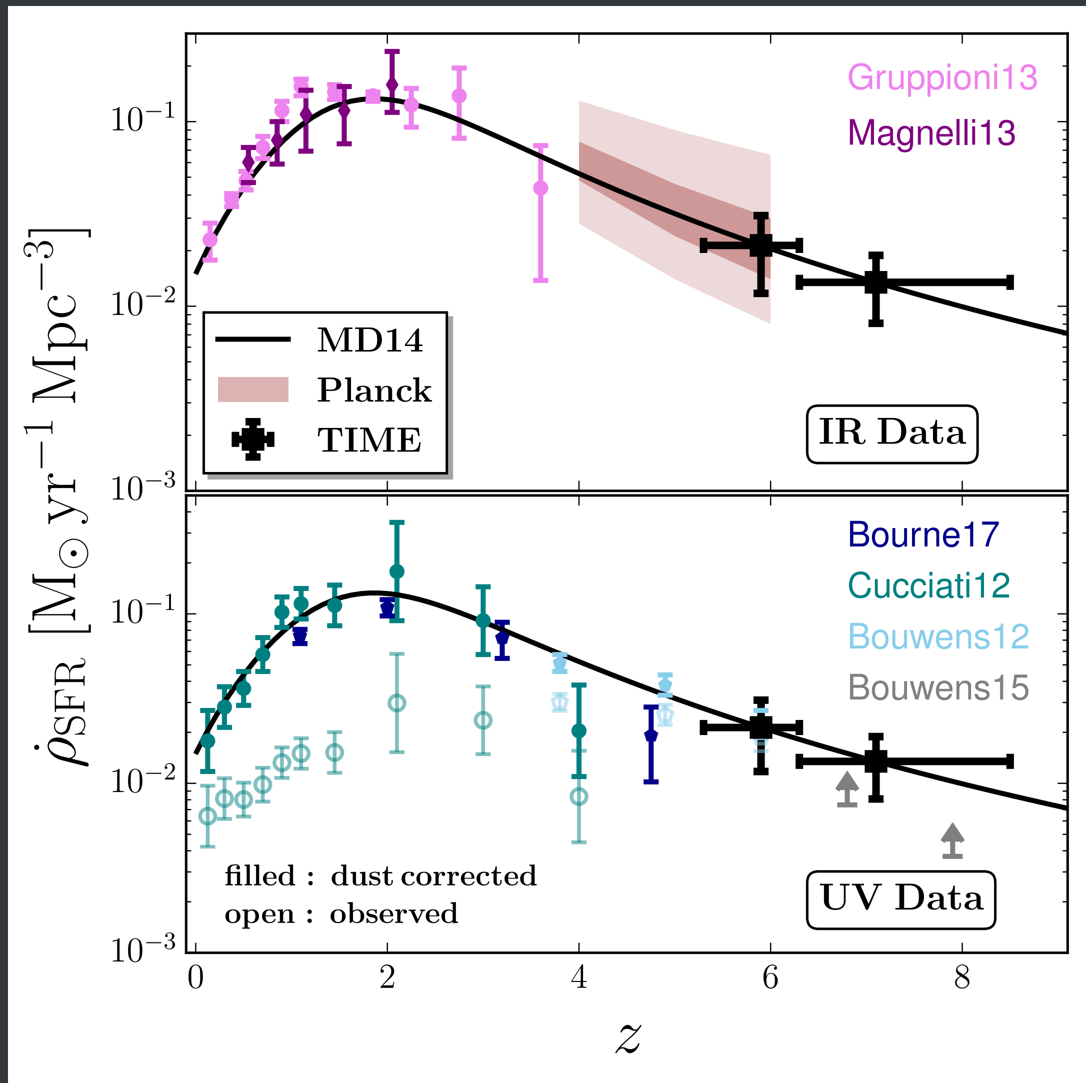
TIME forecast:

Cosmic [CII] abundance



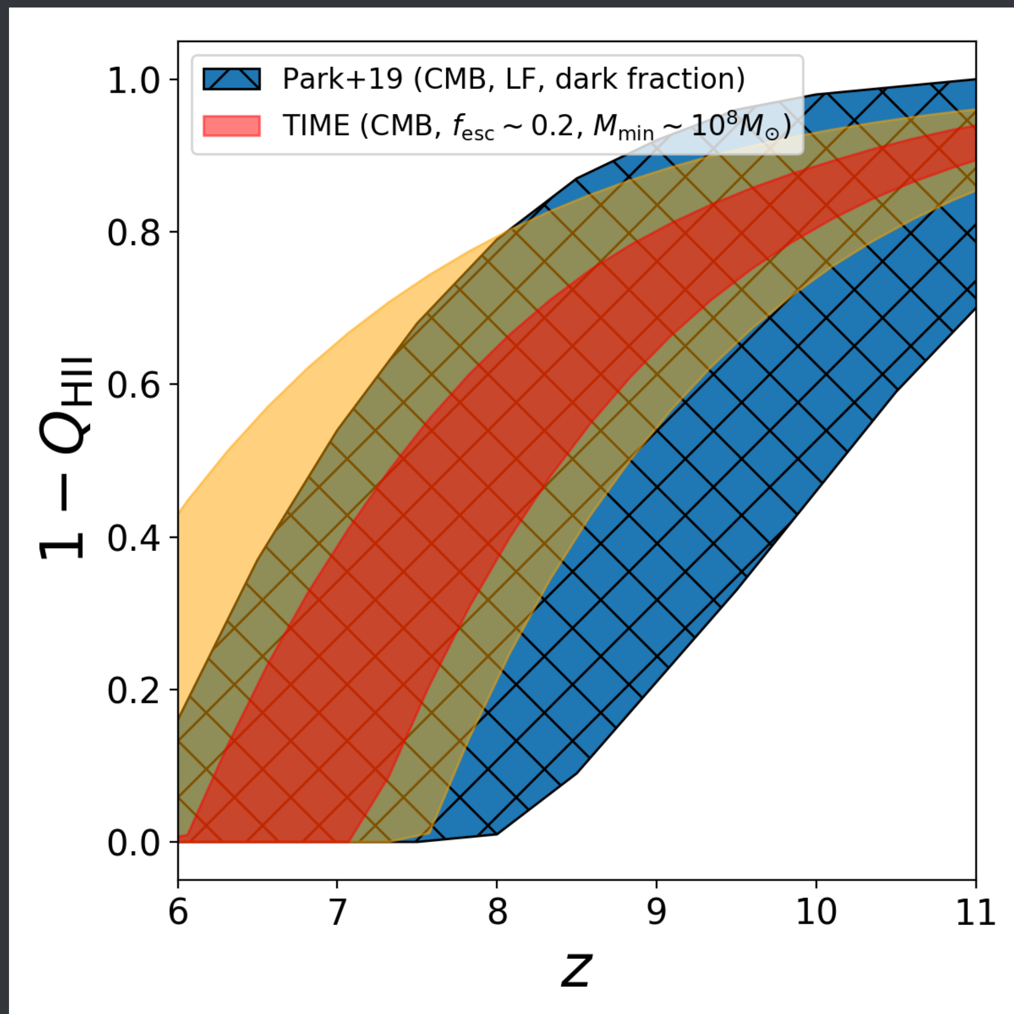
TIME collaboration (Sun et al., in prep)

TIME forecast:
SFR constraints at high-z



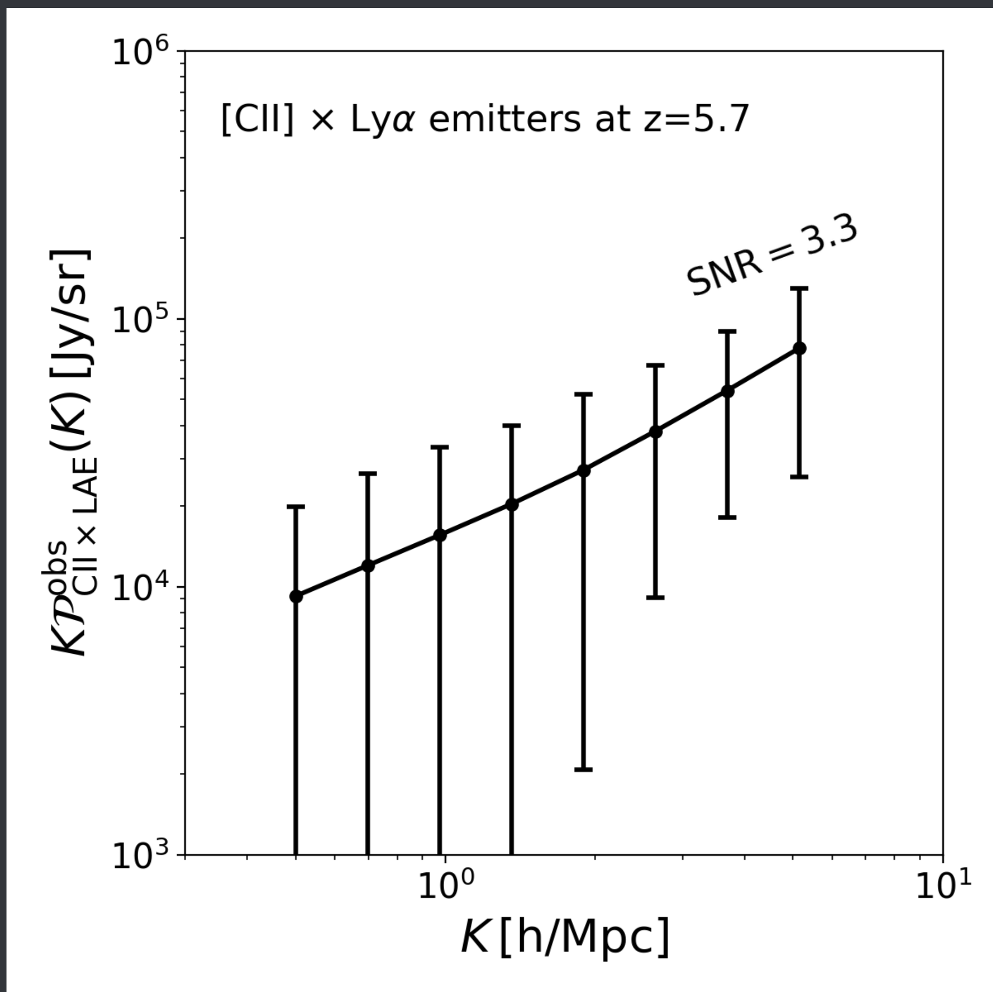
TIME collaboration (Sun et al., in prep)

TIME forecast: Reionization history



TIME collaboration (Sun et al., in prep)

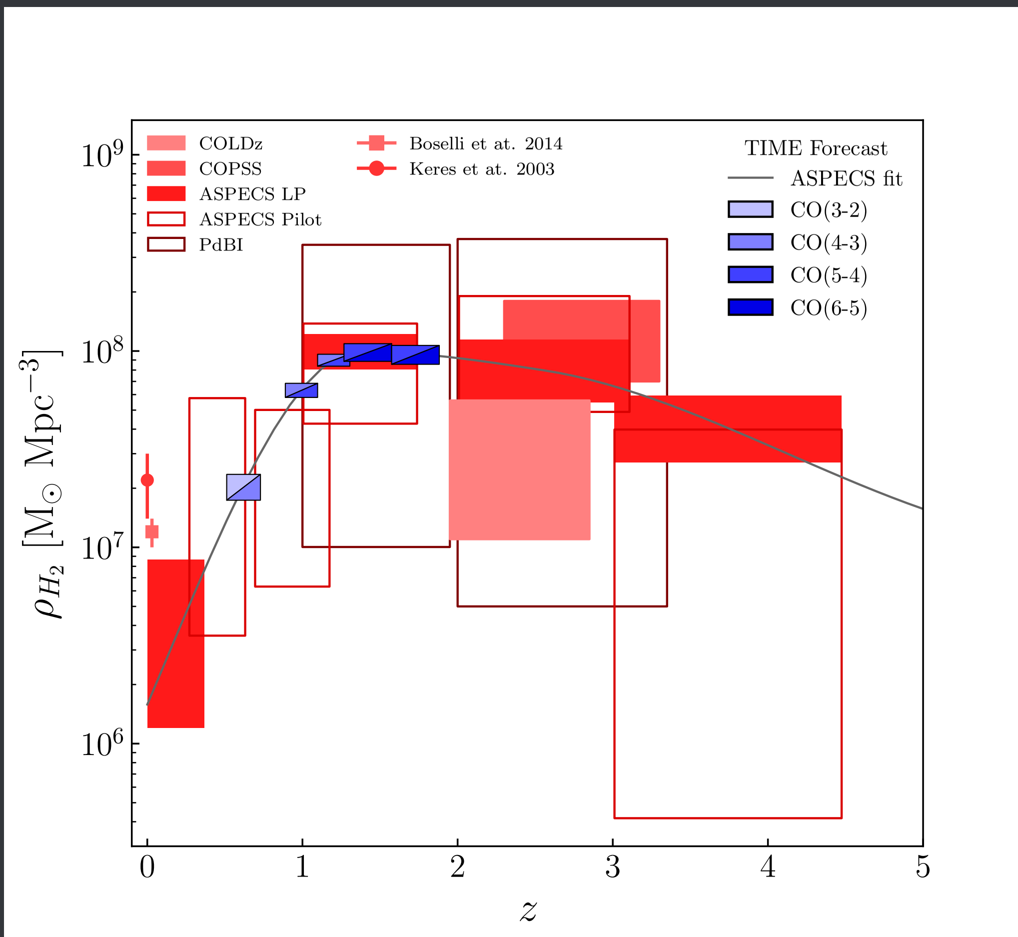
TIME forecast: [CII] x LAE cross correlation



TIME collaboration (Sun et al., in prep)

- [CII] x LAEs from the HSC SILVERRUSH survey at z=5.7
- Currently optimizing the survey depth and geometry for CO, [CII] and [CII]xLAE power spectra

TIME forecast: CO/H_2 abundance at z=0.5-2



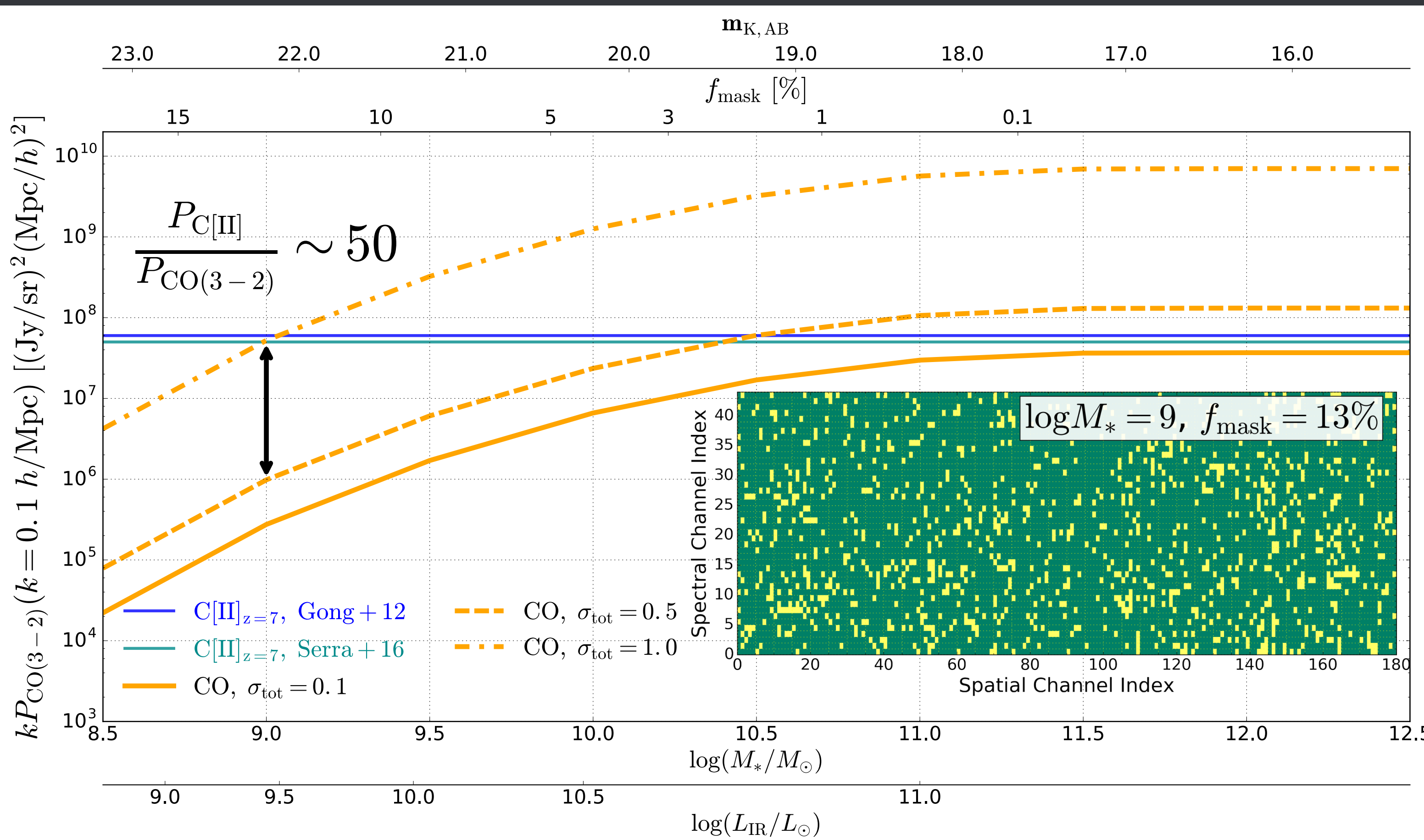
TIME collaboration (Sun et al., in prep)

- TIME will measure multiple CO J rotational transitions at 0.5 < z < 2
- Can be achieved via in-band cross-correlations of different J lines
- TIME will constrain the cosmic molecular hydrogen abundance across redshifts

Line de-confusion

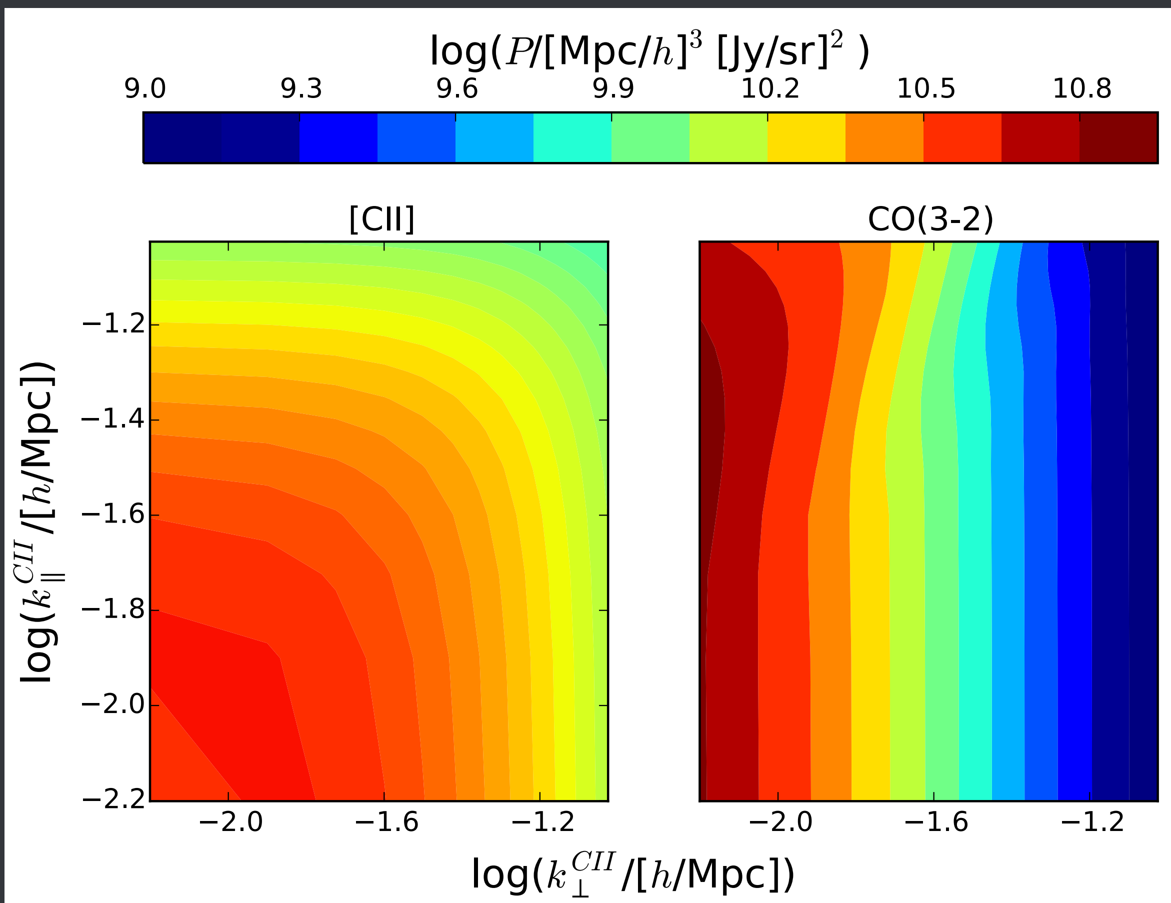
- High-z [CII] and low-z CO lines can be confused in TIME.
- We are planning to use a combination of well-demonstrated techniques:
    - Masking bright, low-z sources: employed in CMB, CIB, EBL and studied for IM (e.g., Sun+18, Silva+17).
    - Use the anisotropic power spectrum shape of [CII] and CO (from observing to comoving coordinates) to distinguish the lines (Visbal & Loeb 2010; Gong+14; Lidz & Taylor 2016; Cheng+ 2016).
    - Cross-correlations of different lines at same redshift (e.g., Visbal & Loeb 2010; Gong+12, +17).
    - Cross-correlations with galaxy tracers (e.g., Chang+10, Masui+13, Pullen+13, +18).

CO, [CII] signal de-confusion: source masking



TIME collaboration (Sun et al. 2018)

CO, [CII] signal de-confusion: Anisotropic power spectrum



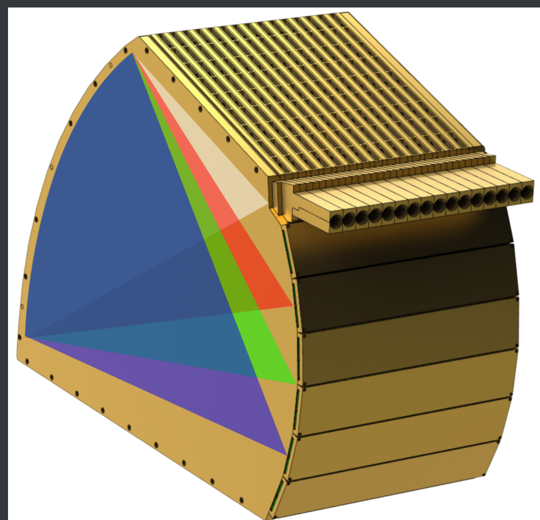
Cheng et al. 2016

- High-z [CII] and low-z CO rotational lines can be confused in TIME
- Use the redshift-dependence of CO and [CII] from observing to comoving coordinates to distinguish the lines (Lidz & Taylor 2016; Cheng et al. 2016).

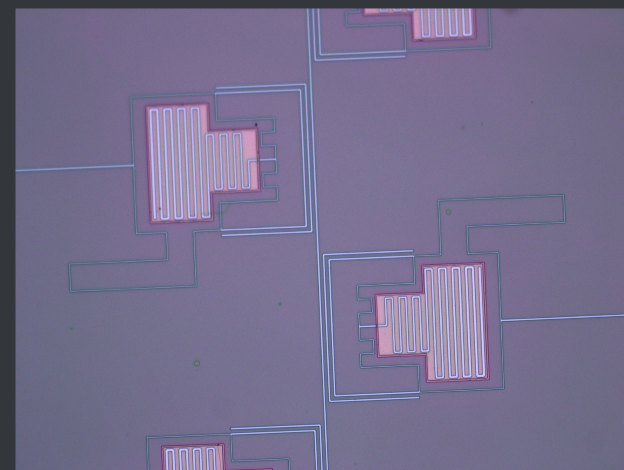
Next-gen [CII] intensity mapper

See Kirit's talk

Grating spectrometer



On-chip spectrometer



(O'brient et al. 2014)

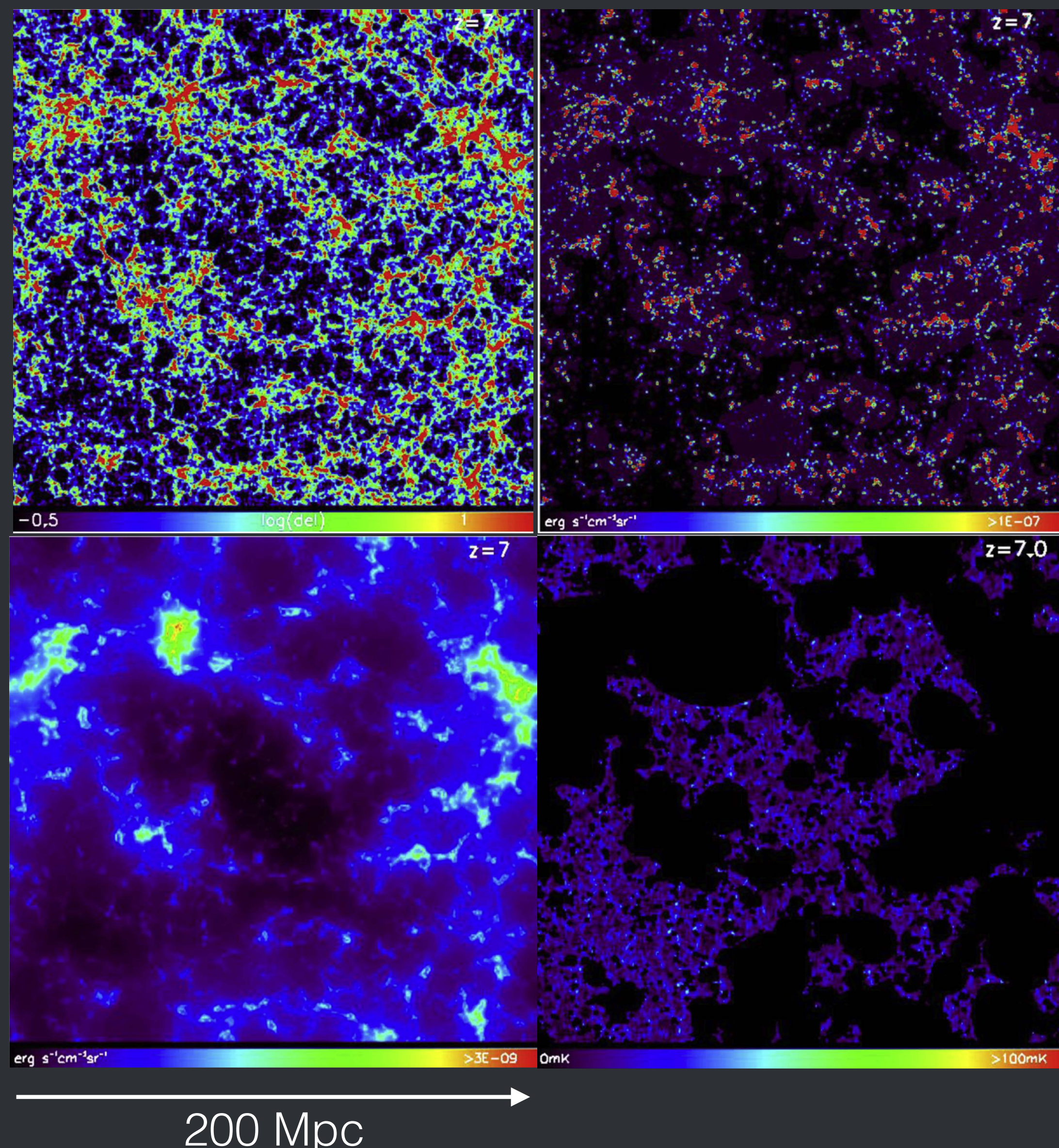
- Better Sensitivity. Scale up to 10,000 detectors.
- Better site. CSO proposed move to the Chile ALMA site (NSF MRI proposal by Golwala)

Courtesy Abby Crites

[CII], Lya, Ha, 21cm Intensity Mapping: large-scale, 3D EoR probes

Density fluctuation
z~7

Ionizing sources
(traced by Ha, [CII])



Ionized IGM
(traced by
scattering Lya,
[CII]?)

Neutral IGM
(traced by 21cm)

Heneka et al., 2017