

First Detection of the Cosmic CO and [CII] Backgrounds



Academia Sinica
Institute of Astronomy & Astrophysics

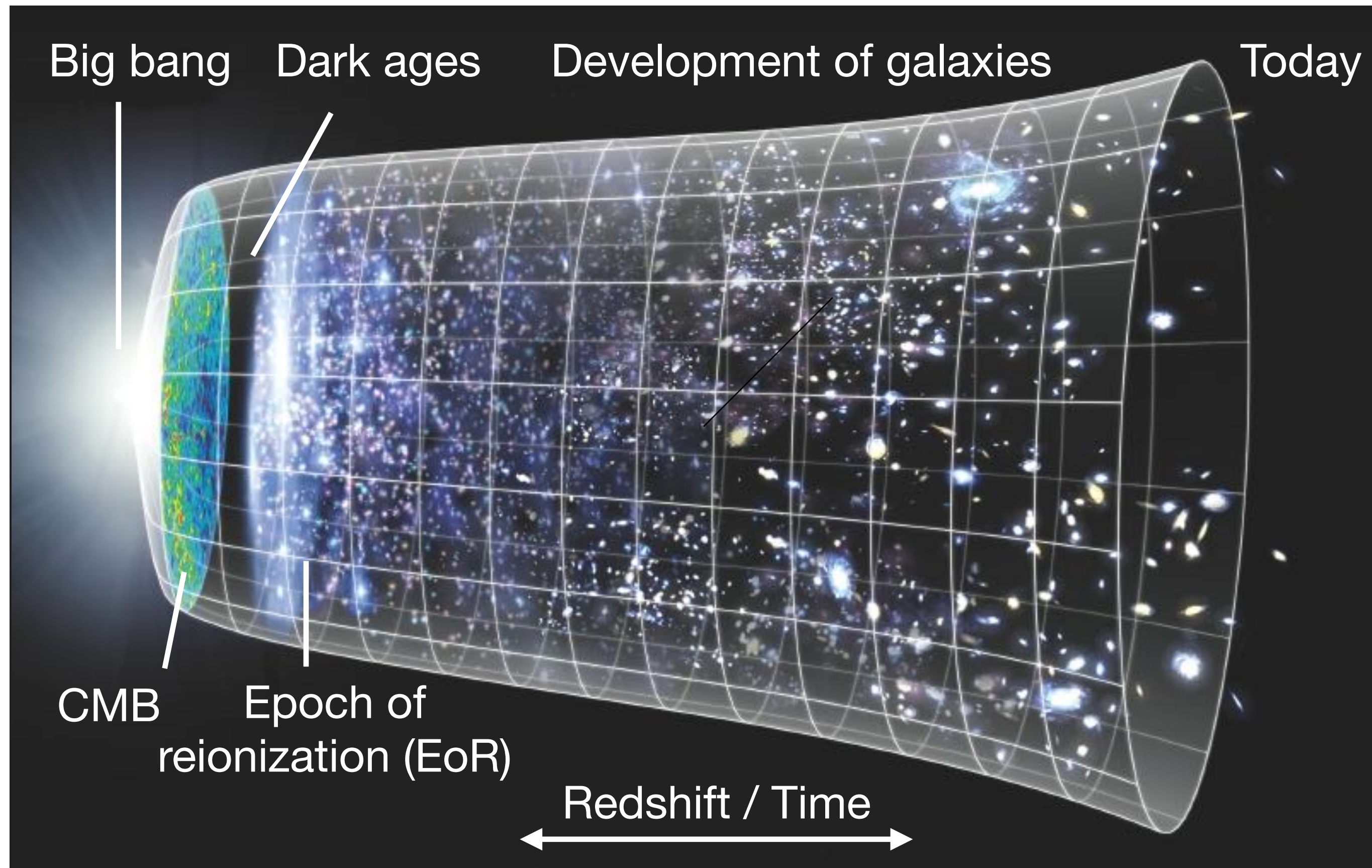
Yi-Kuan Chiang

Former CCAPP Fellow (2019-2021)

CCAPP's 20th Anniversary, 6/10/2026

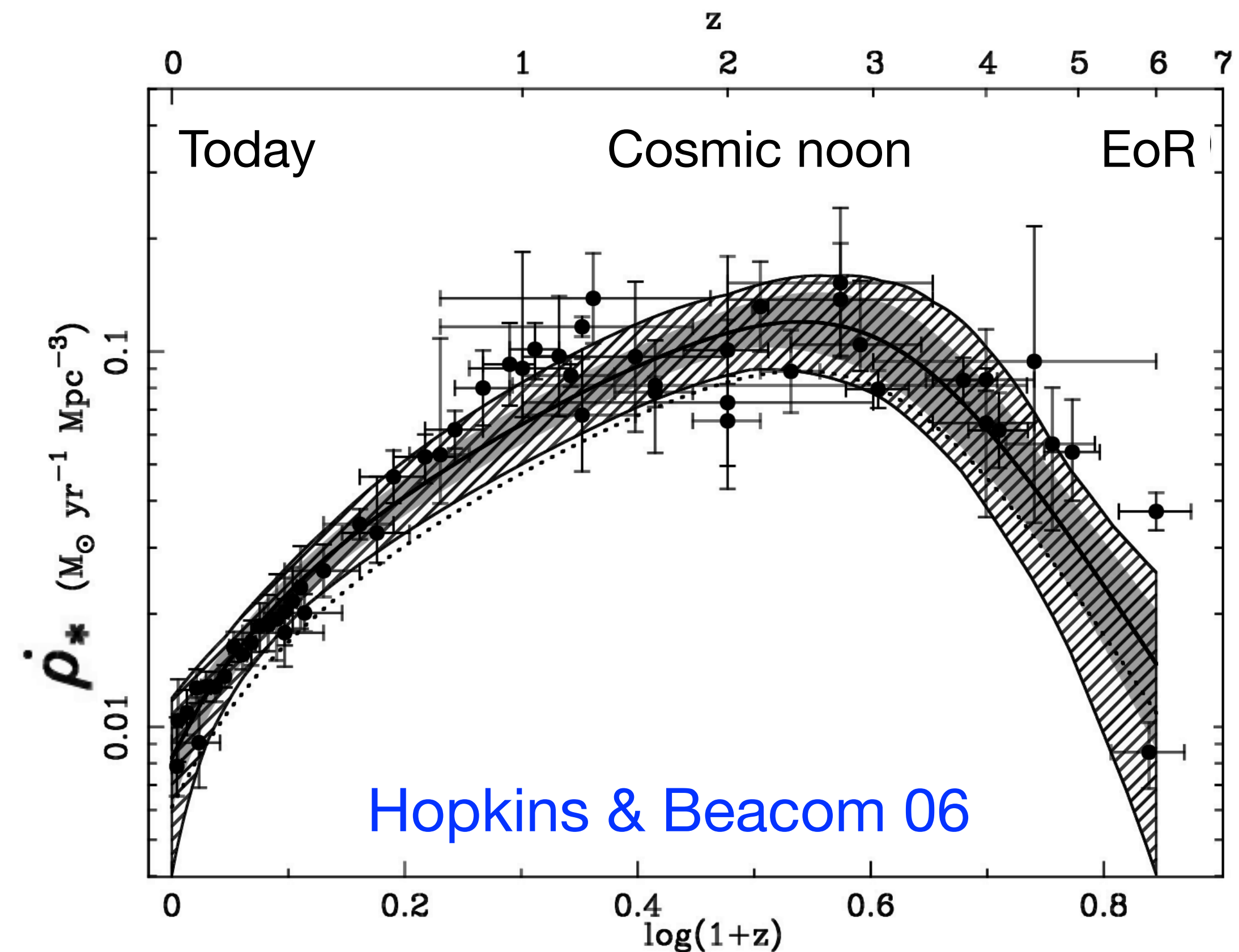
How does the Universe evolve?

Key phases of cosmic history



NASA/WMAP Science Team

Cosmic star formation

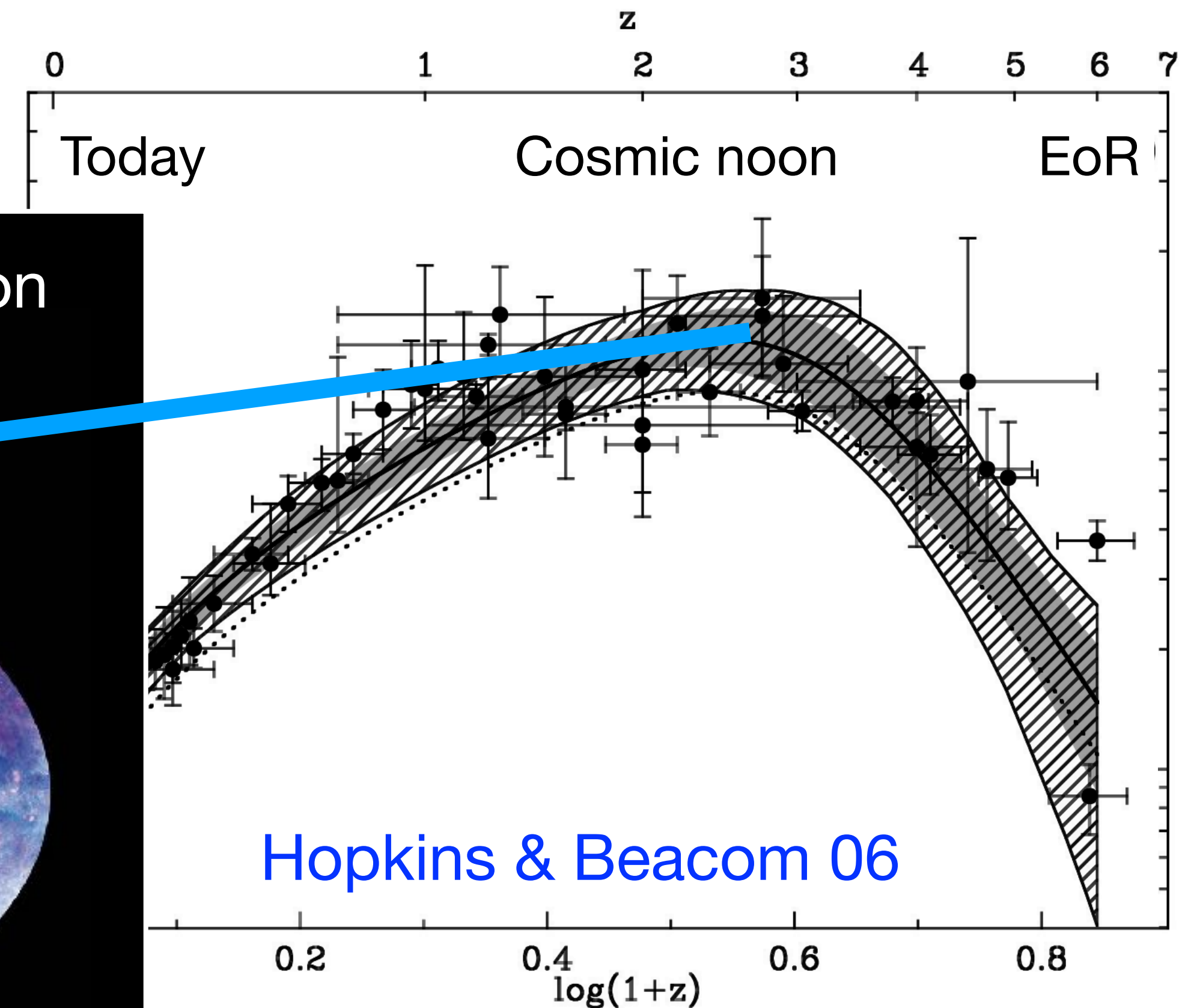
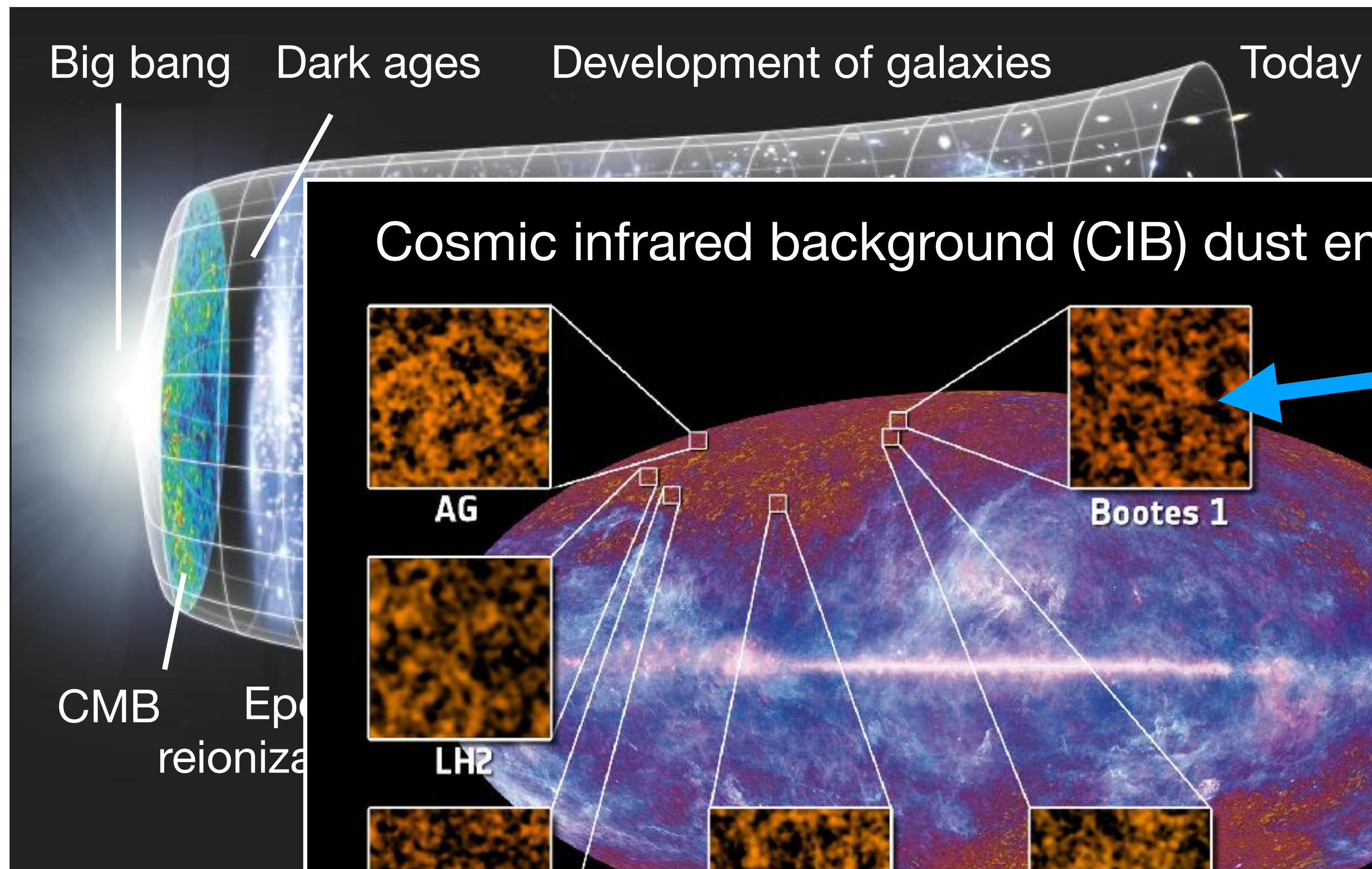


(See also Madau & Dickinson 14)

How does the Universe evolve?

Key phases of cosmic history

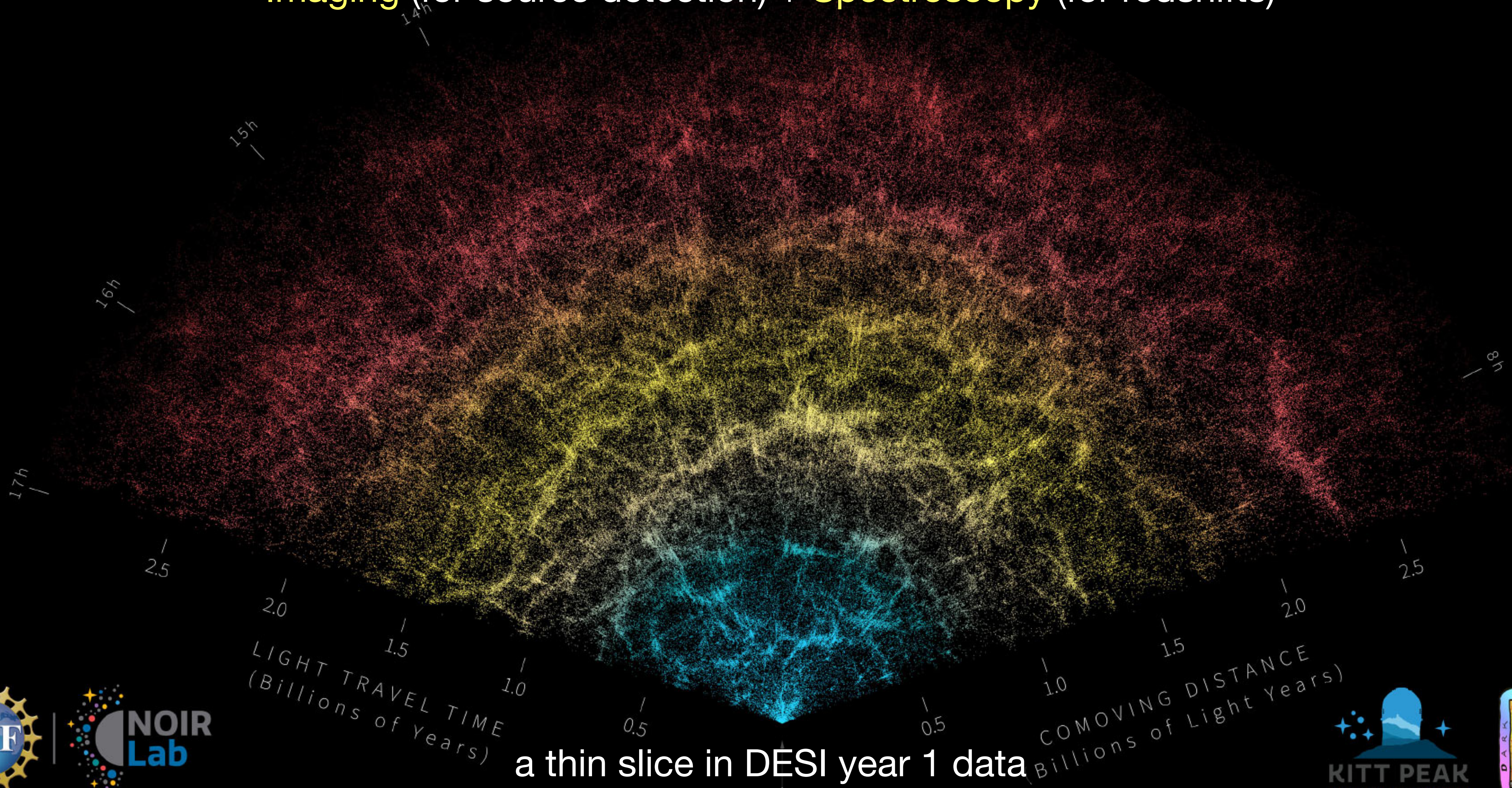
Cosmic star formation



See also Madau & Dickinson 14)

The origins of structure with galaxy surveys

Imaging (for source detection) + Spectroscopy (for redshifts)



a thin slice in DESI year 1 data

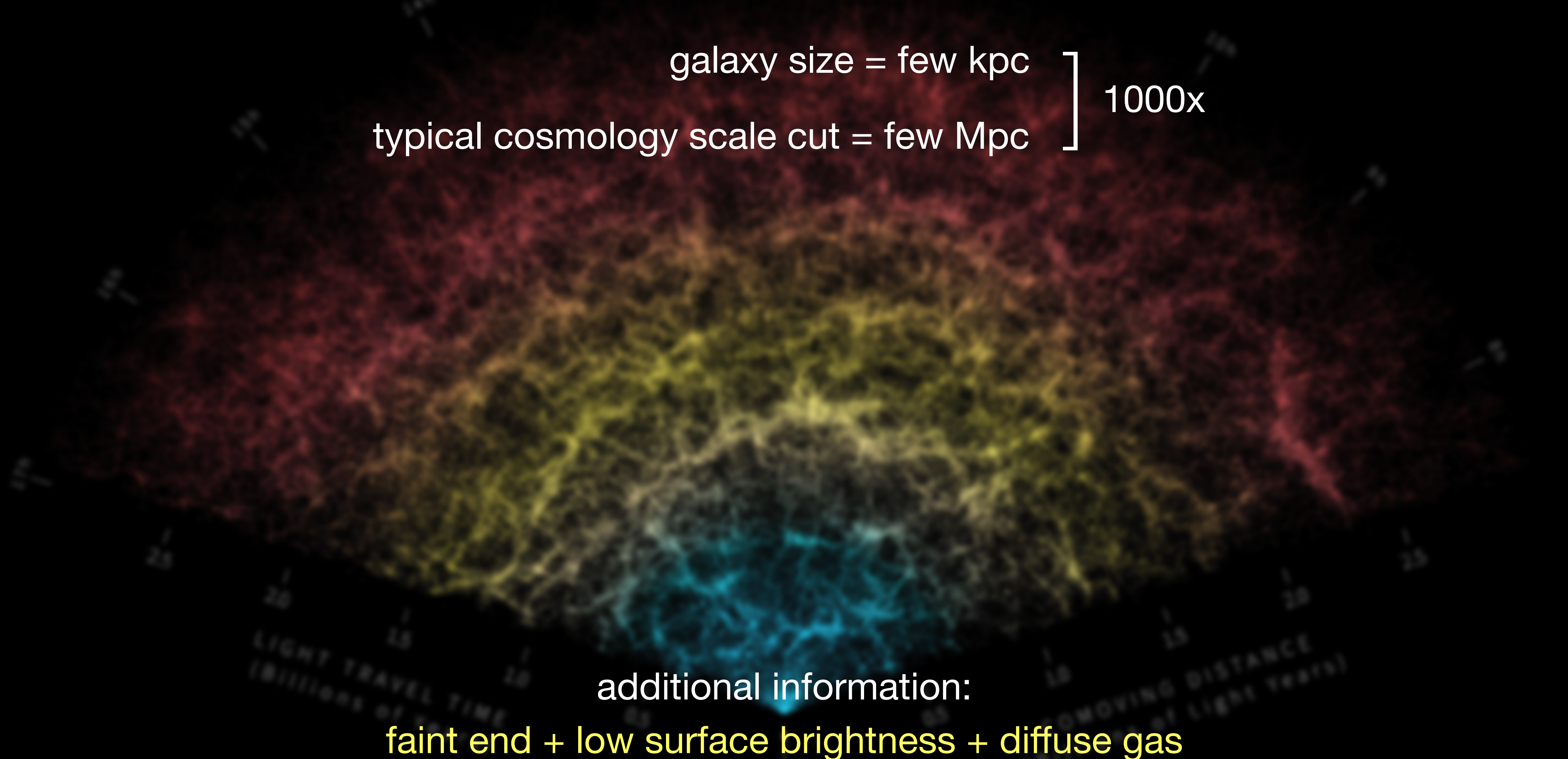
The origins of structure with **intensity mapping**

use all photons, bypass source detection, **trade resolution for efficiency** in volume & depth

galaxy size = few kpc
typical cosmology scale cut = few Mpc] 1000x

additional information:

faint end + low surface brightness + diffuse gas

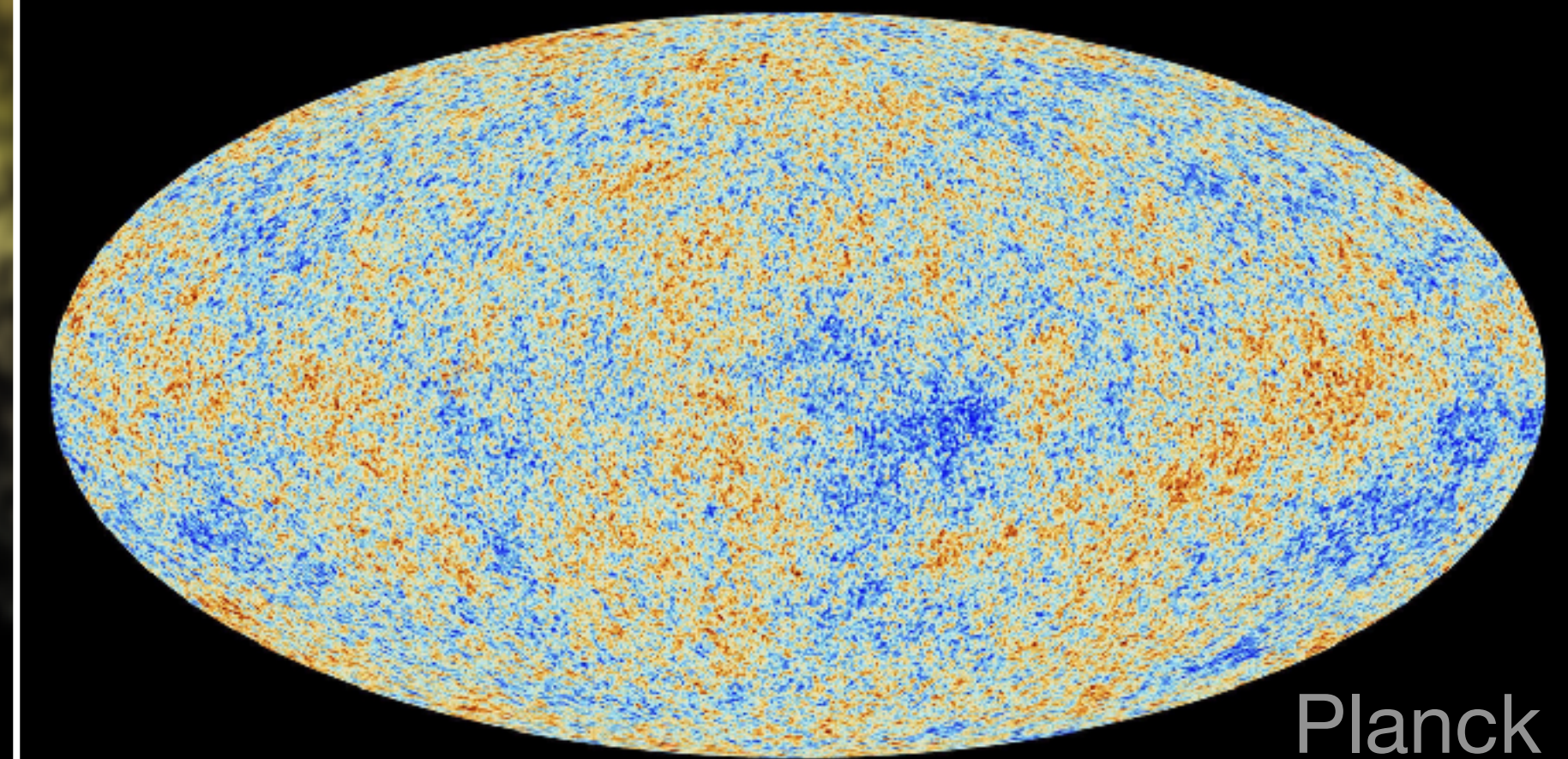


The origins of structure with **intensity mapping**

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CMB as a 2D example

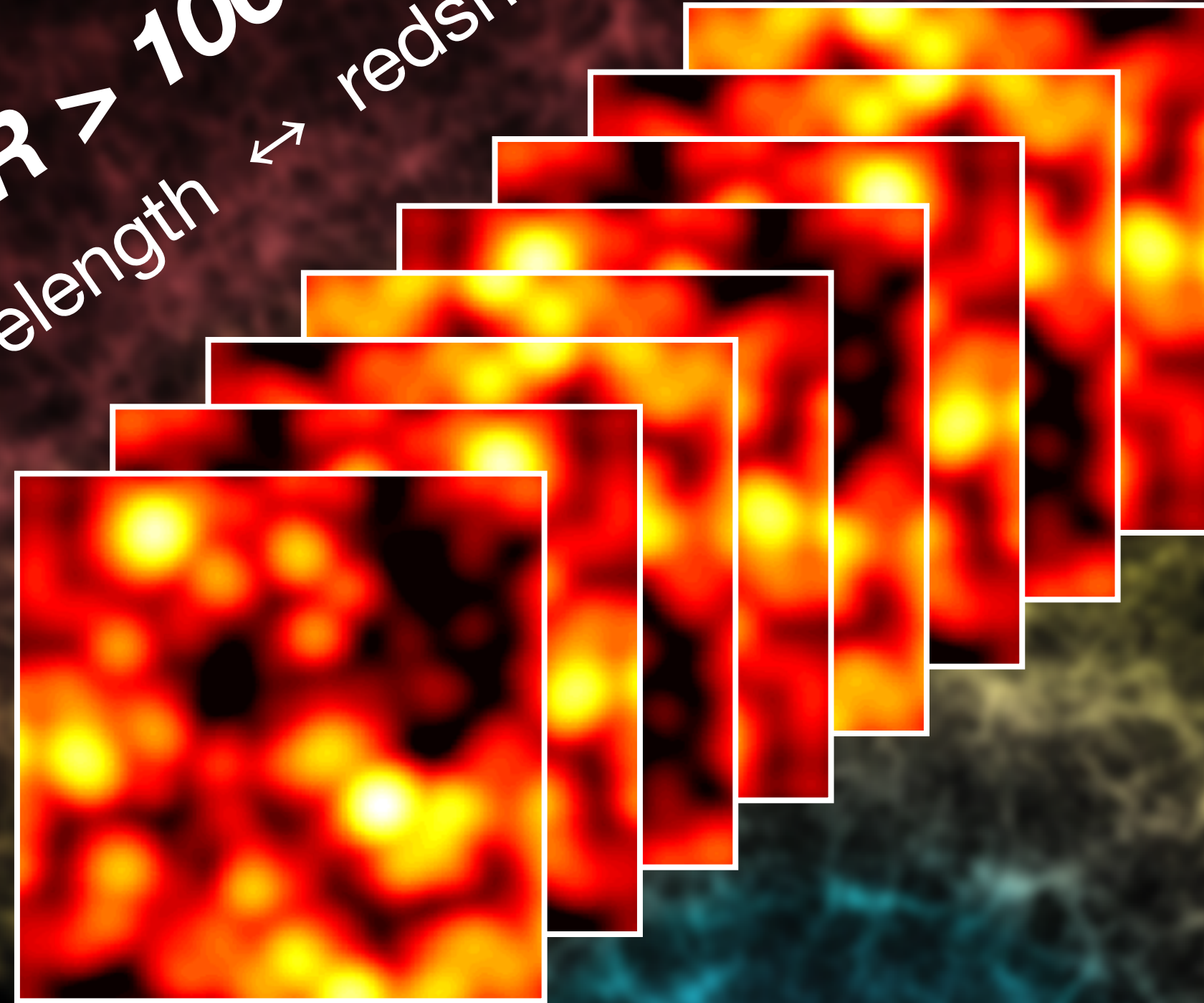


additional information:

faint end + low surface brightness + diffuse gas

Line intensity mapping (LIM) for a 3D view

$R > 100$
wavelength $\leftrightarrow$ redshift



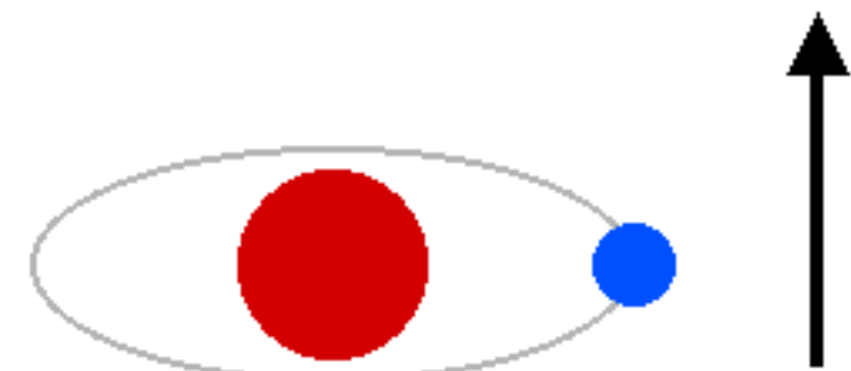
CO: traces fuel of star formation

CO rotational transition



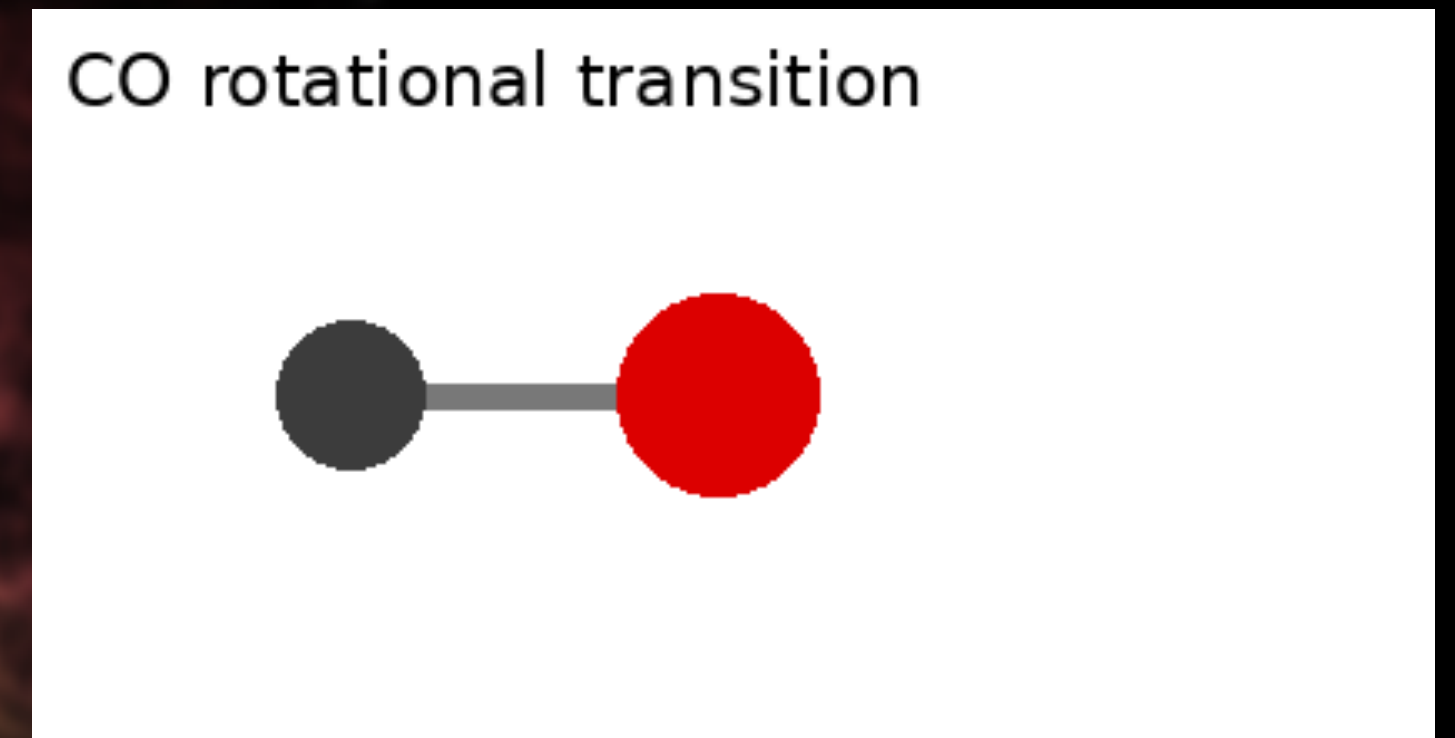
[CII]: traces star formation rates

[CII] excited state

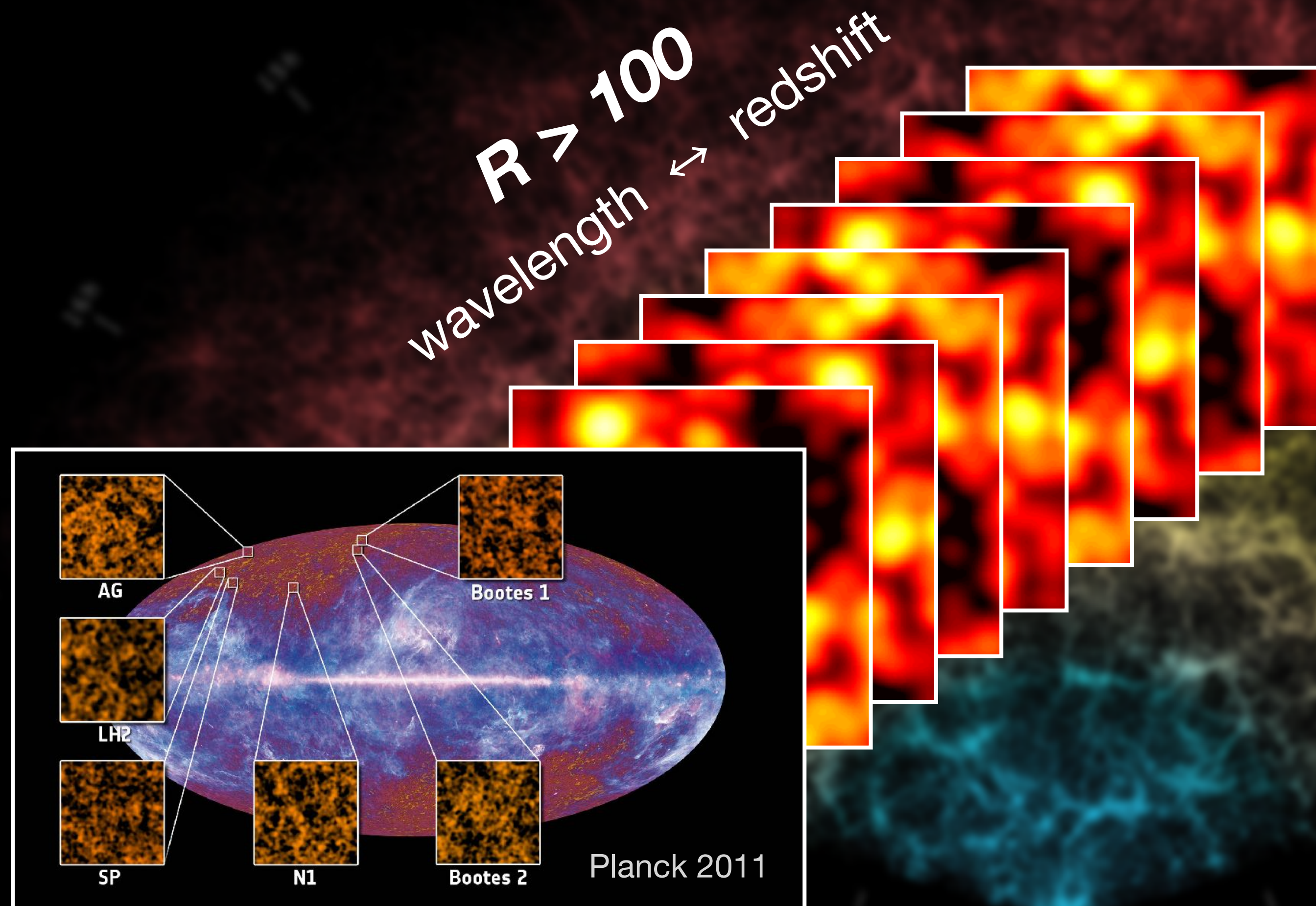
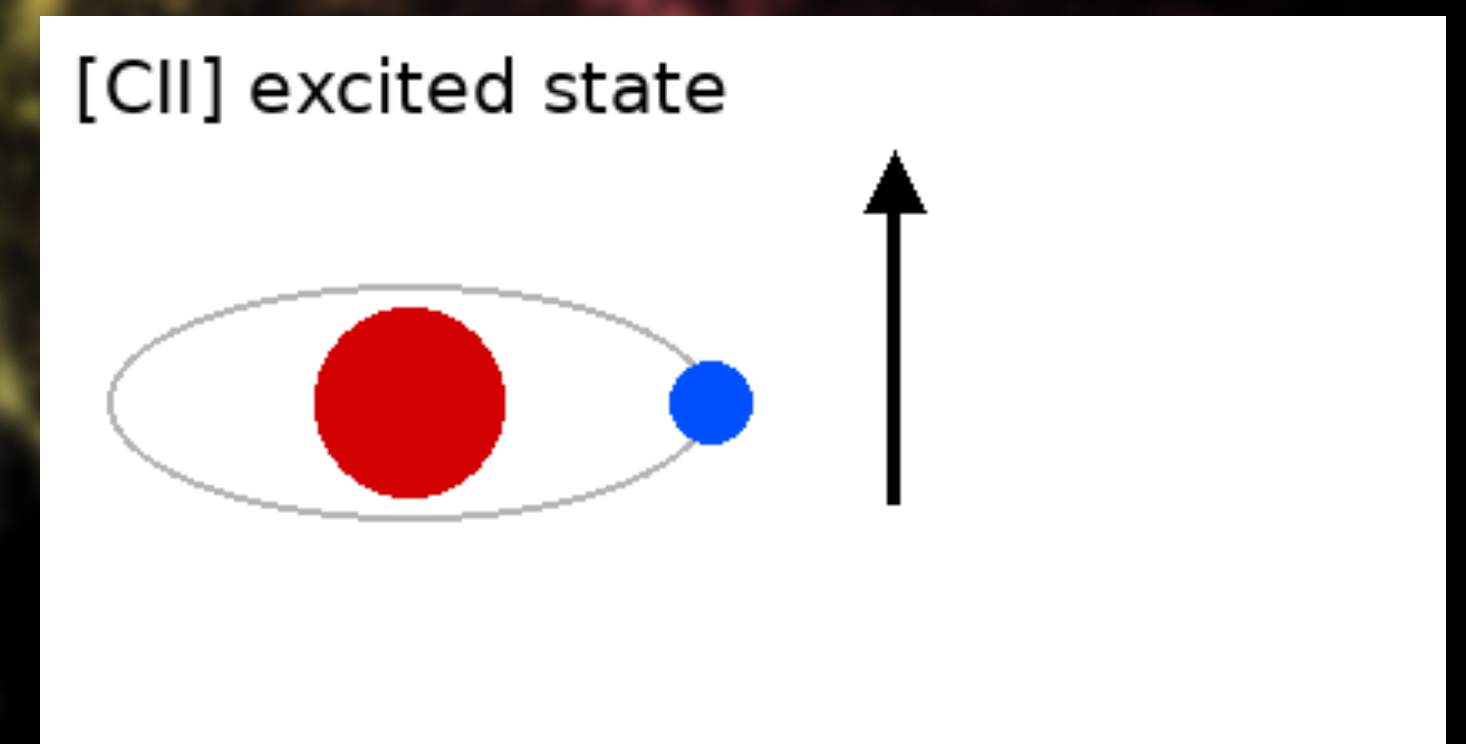


Line intensity mapping (LIM) for a 3D view

CO: traces fuel of star formation

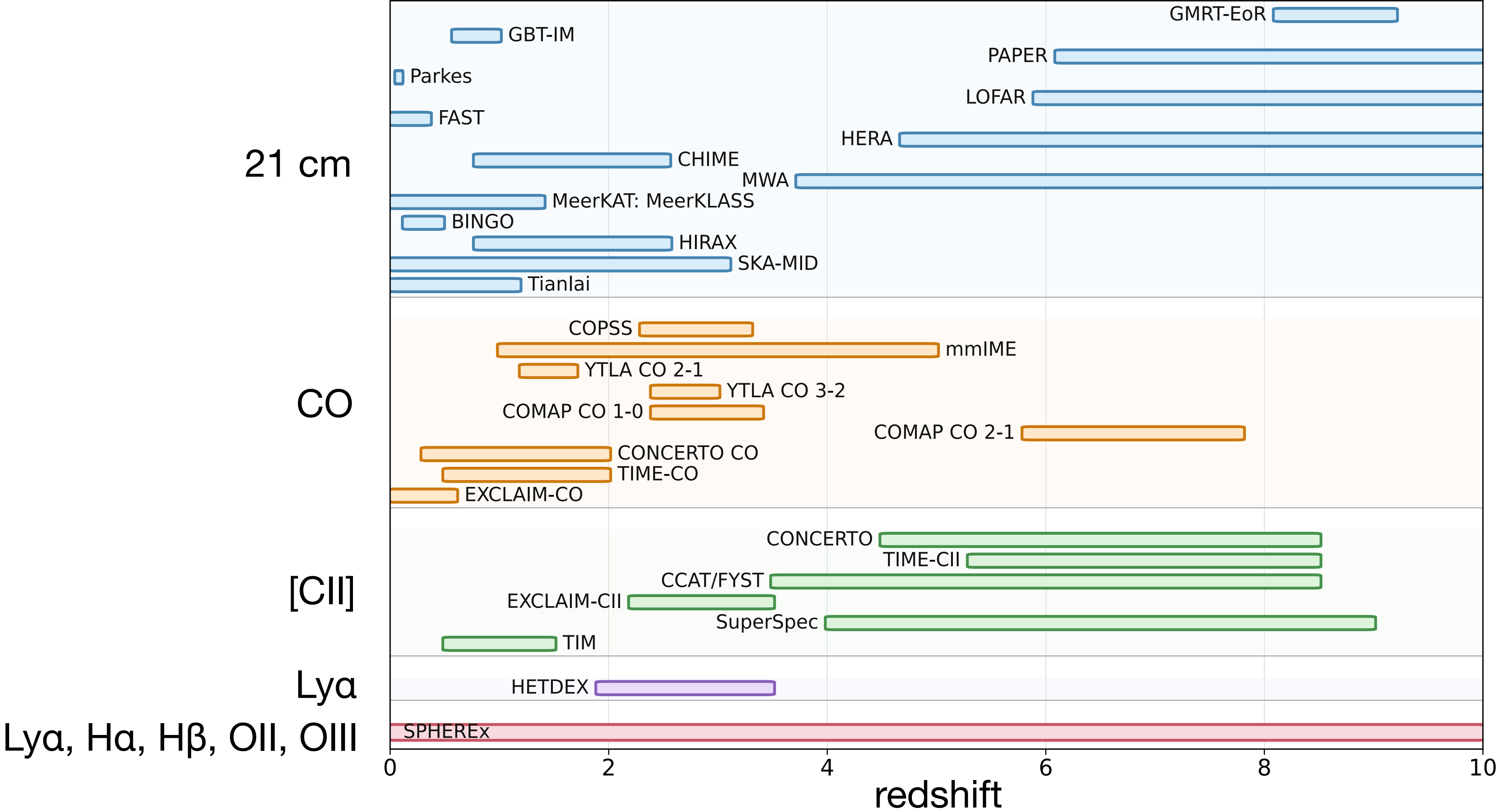


[CII]: traces star formation rates



Foreground + coeval continuum (e.g., CIB)

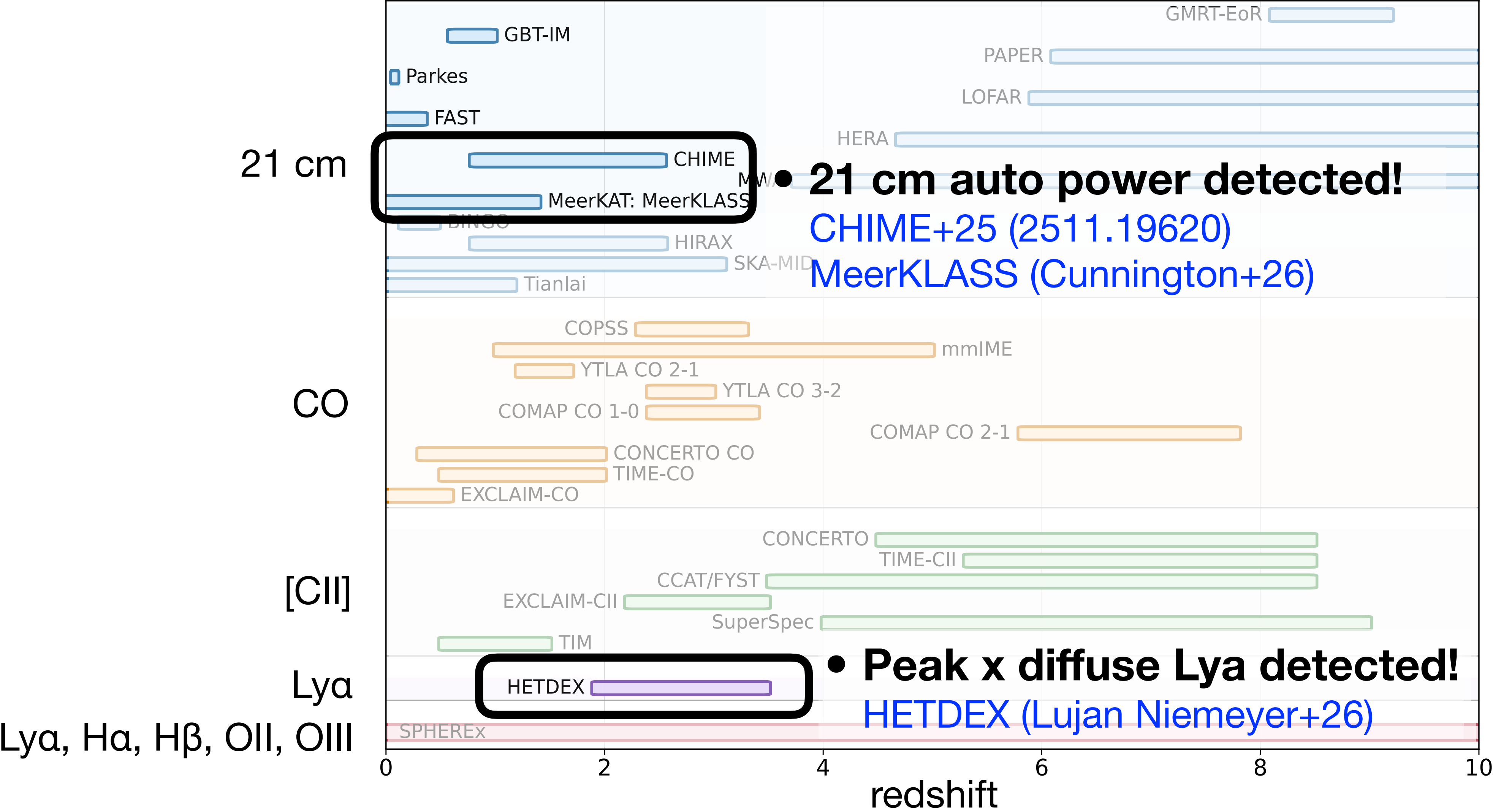
Experimental landscape and exciting recent progress



List of
LIM experiments



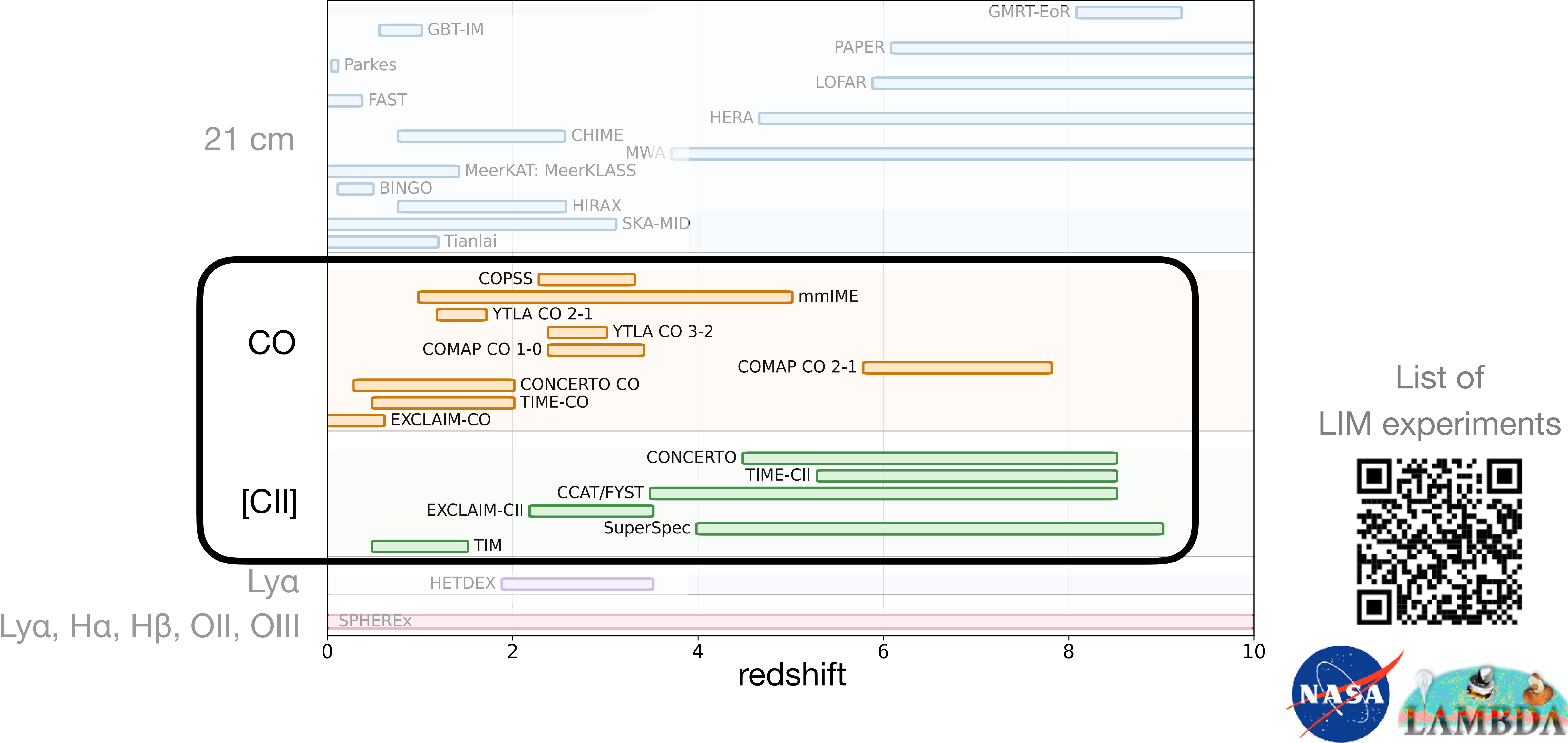
Experimental landscape and exciting recent progress



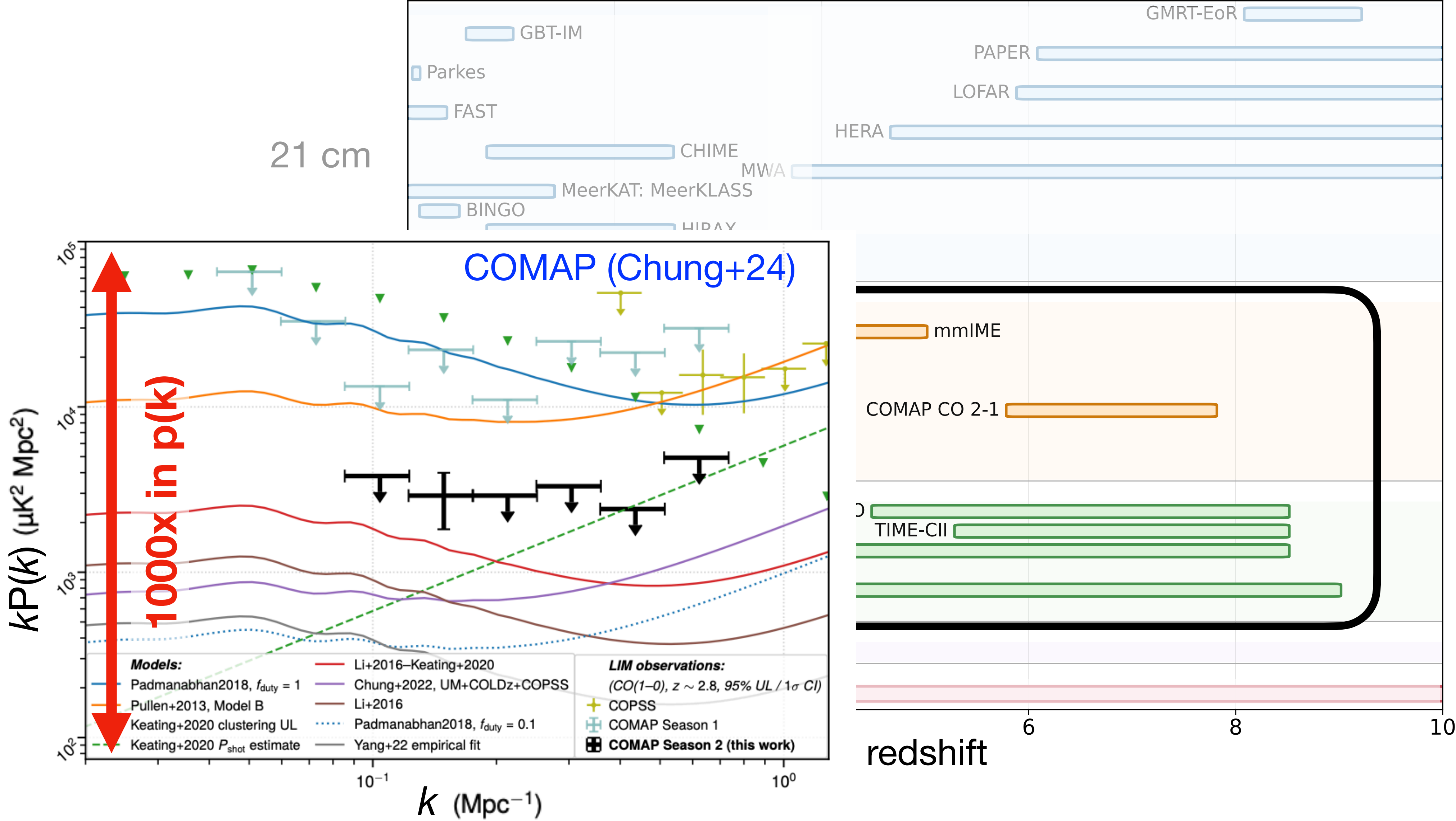
List of
LIM experiments



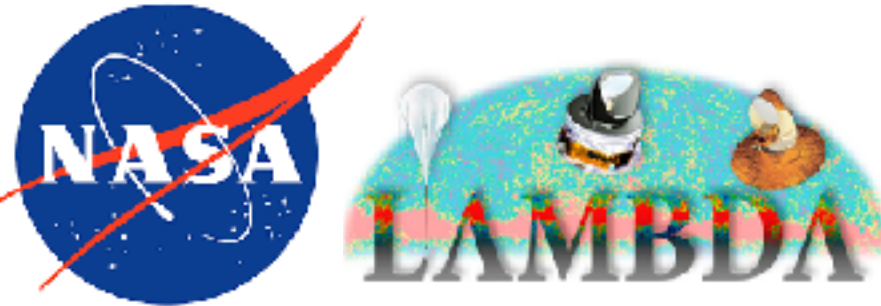
Experimental landscape and exciting recent progress



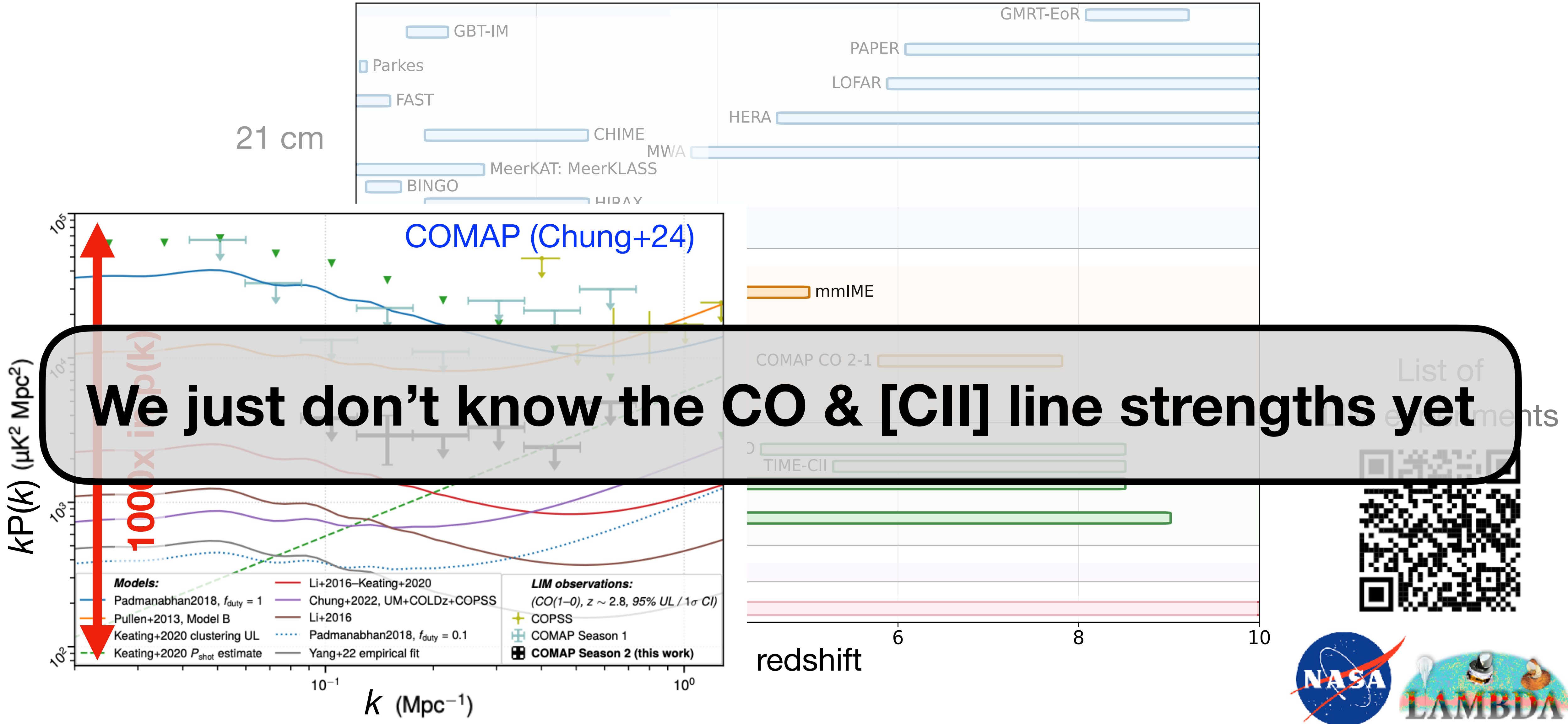
Experimental landscape and exciting recent progress



List of
LIM experiments



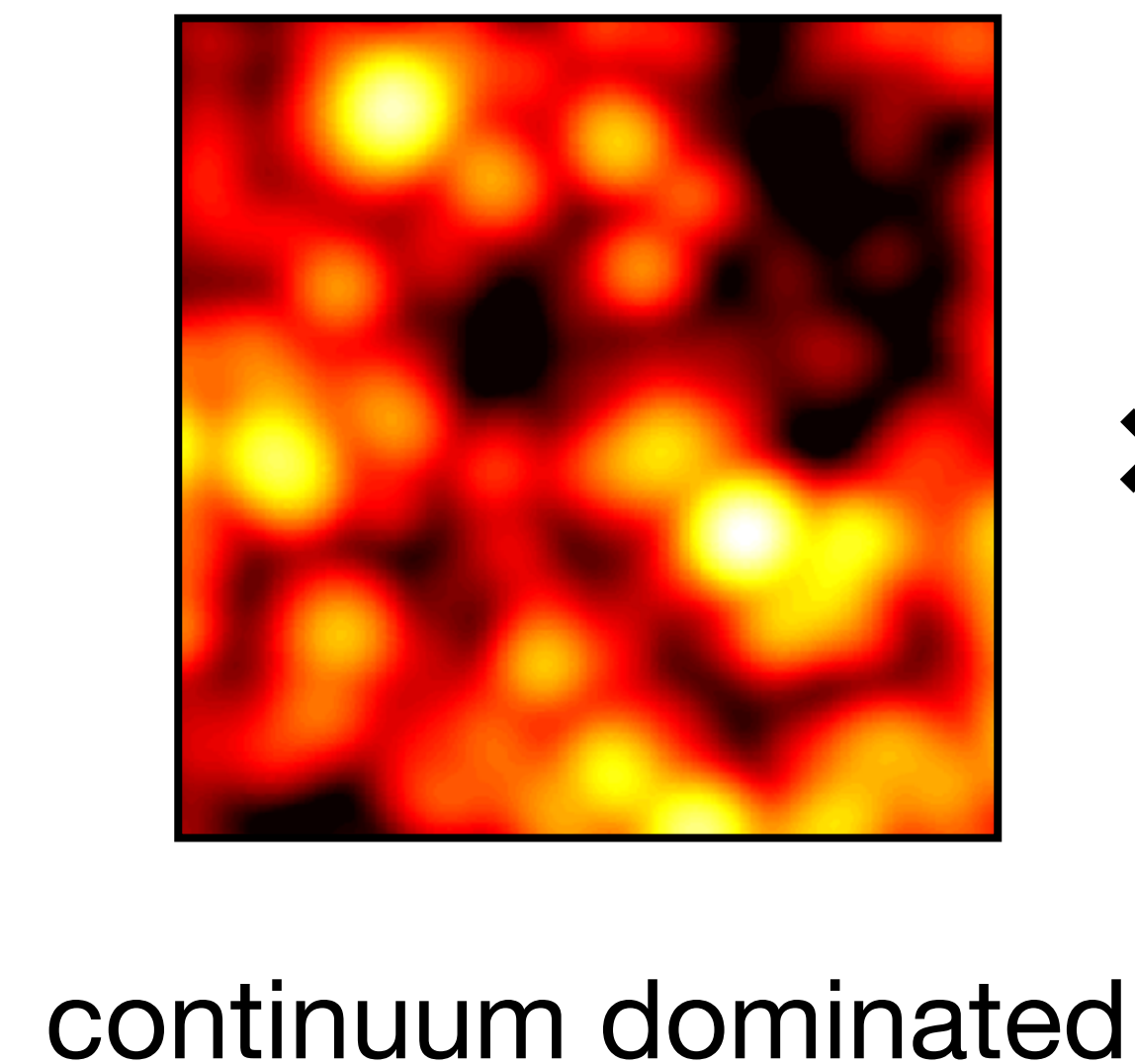
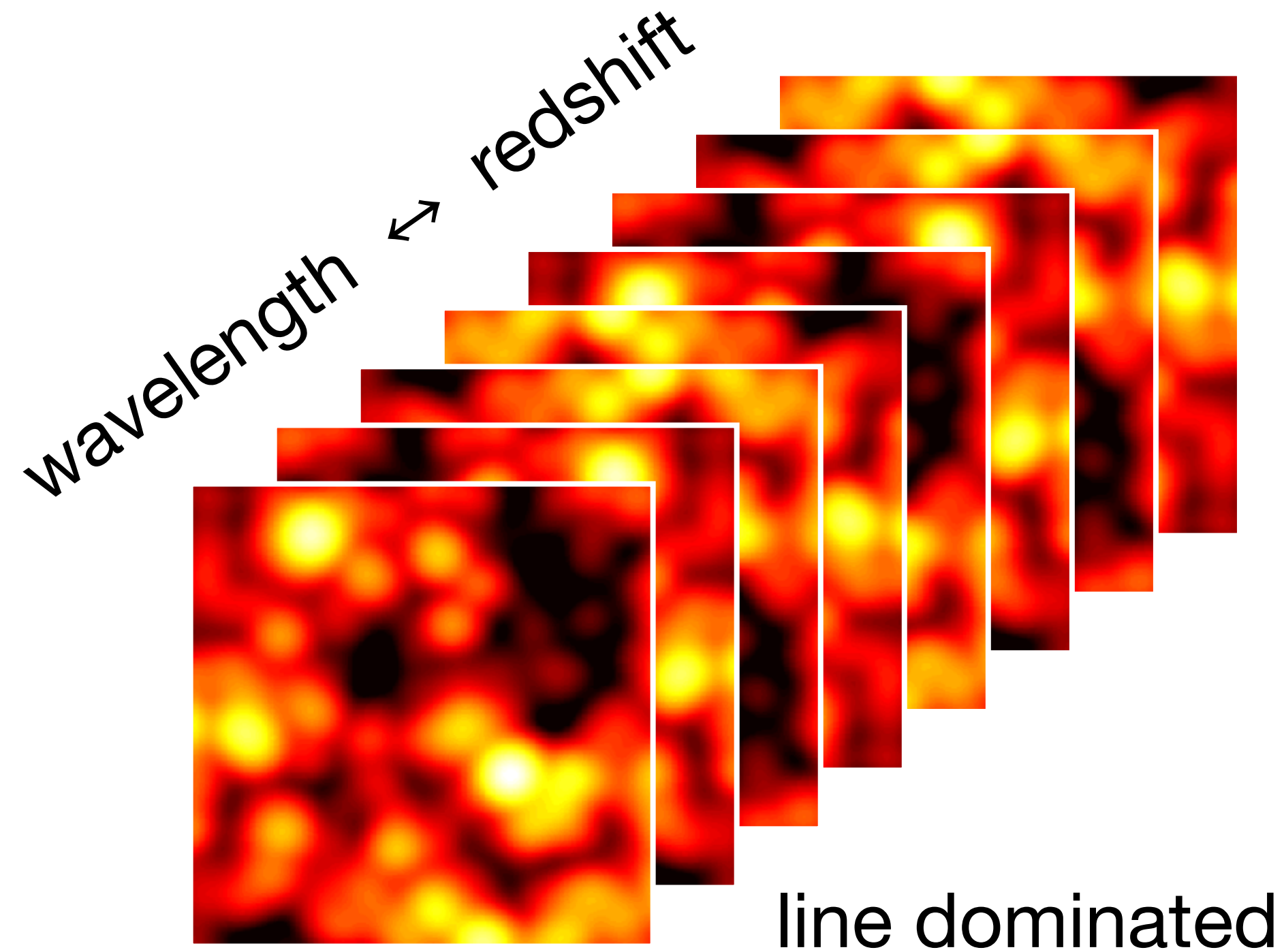
Experimental landscape and exciting recent progress



Best bet for a first CO / [CII] detection?

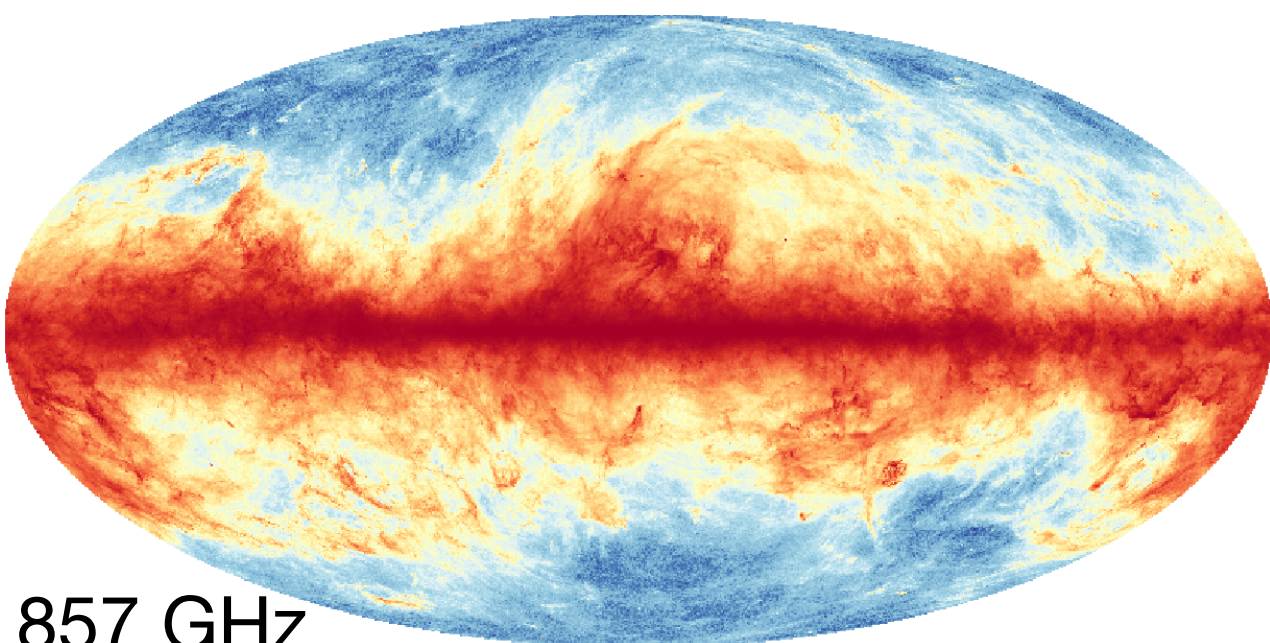
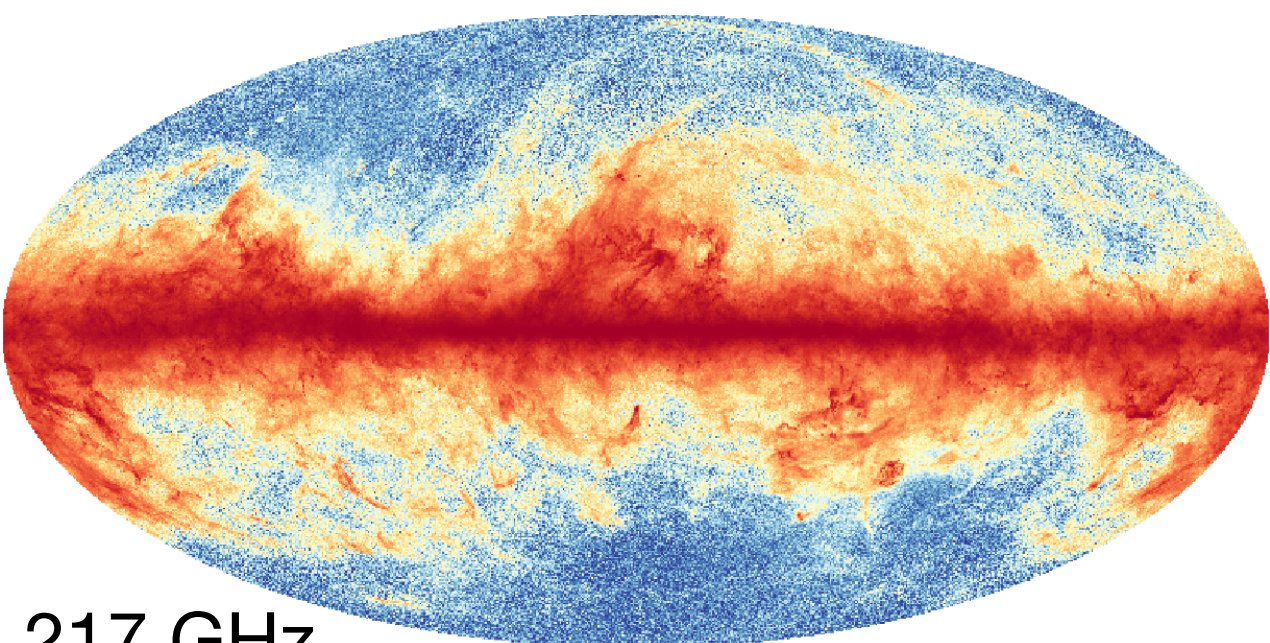
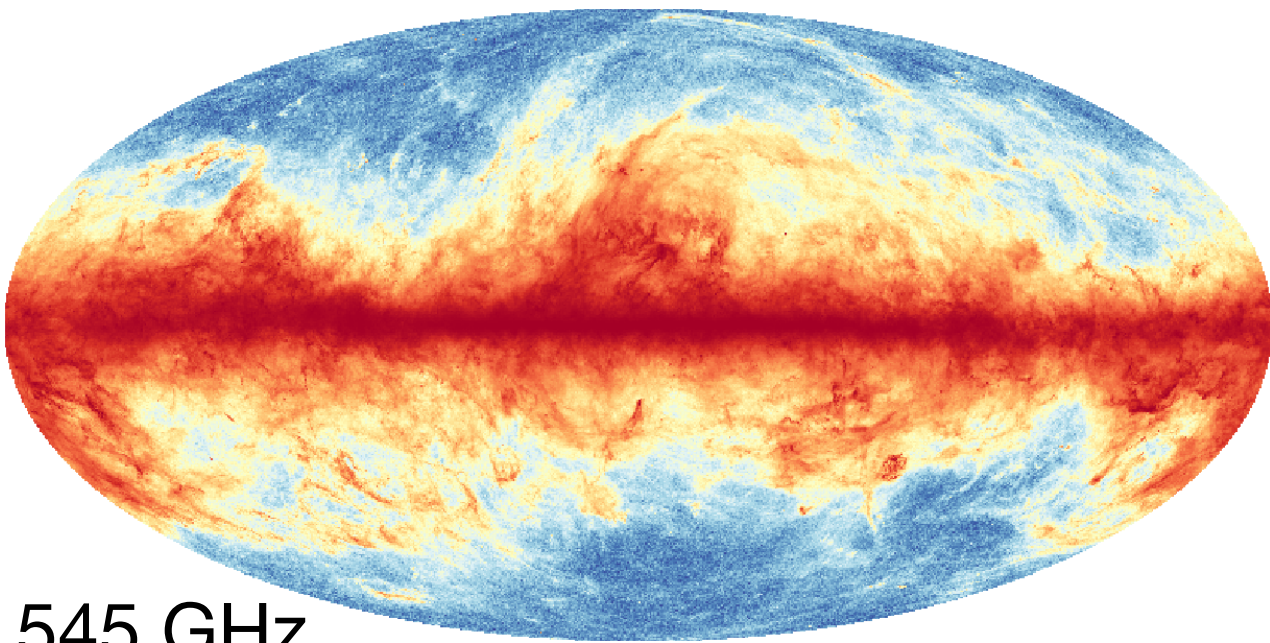
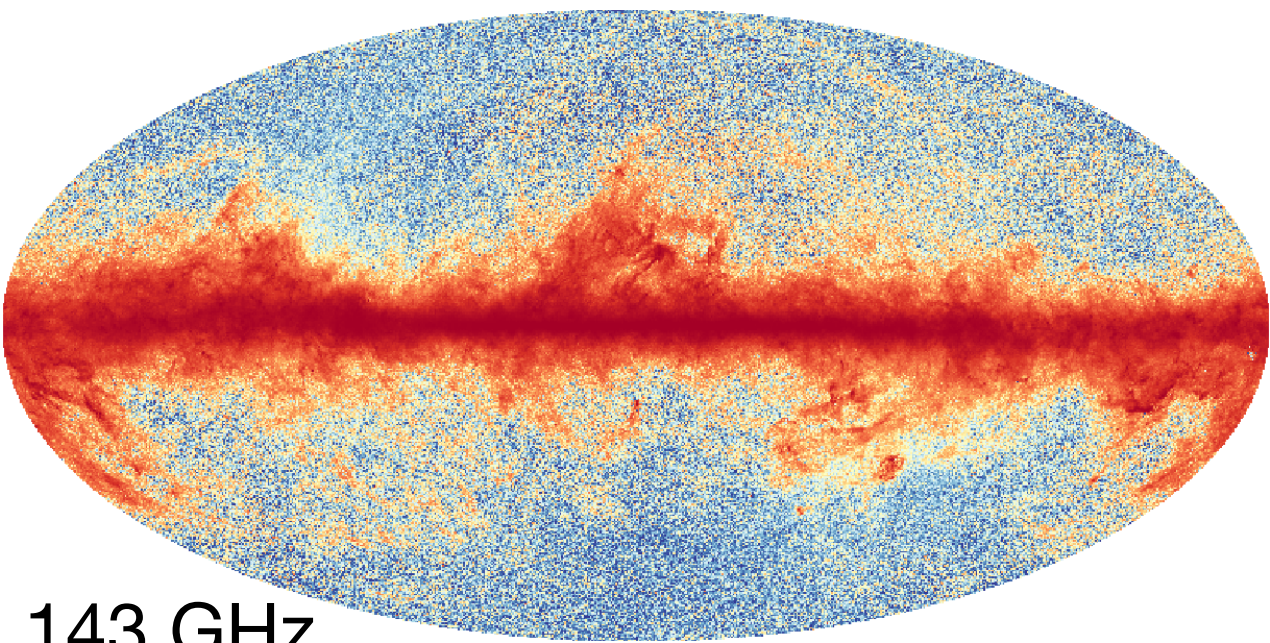
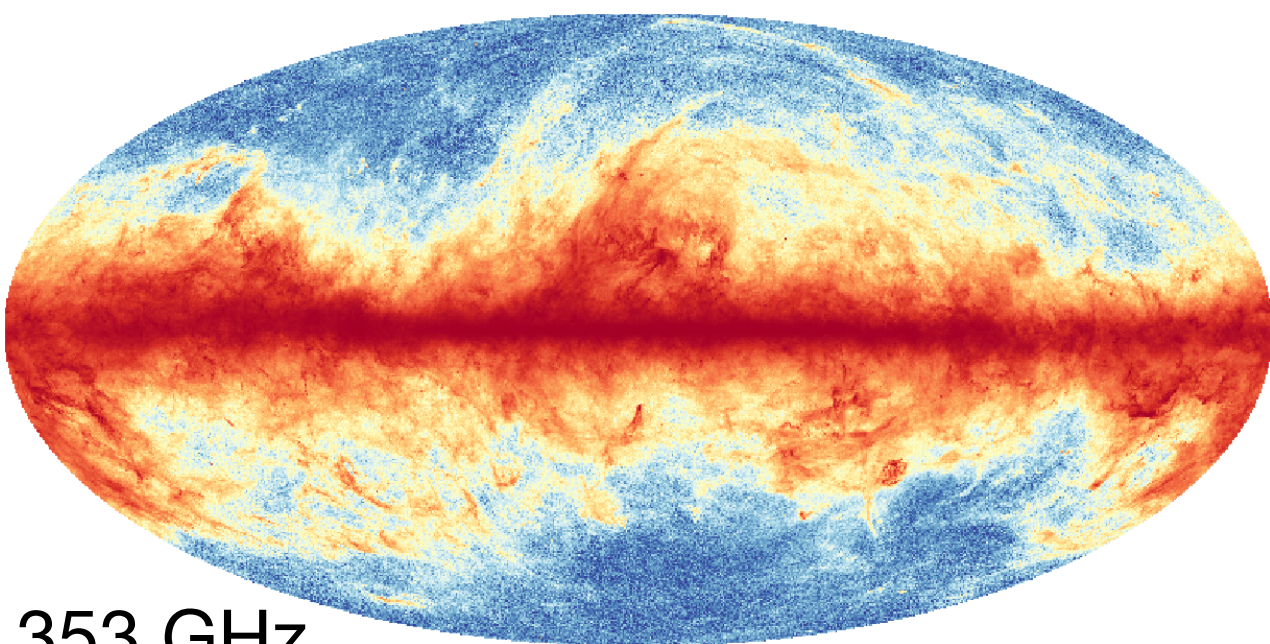
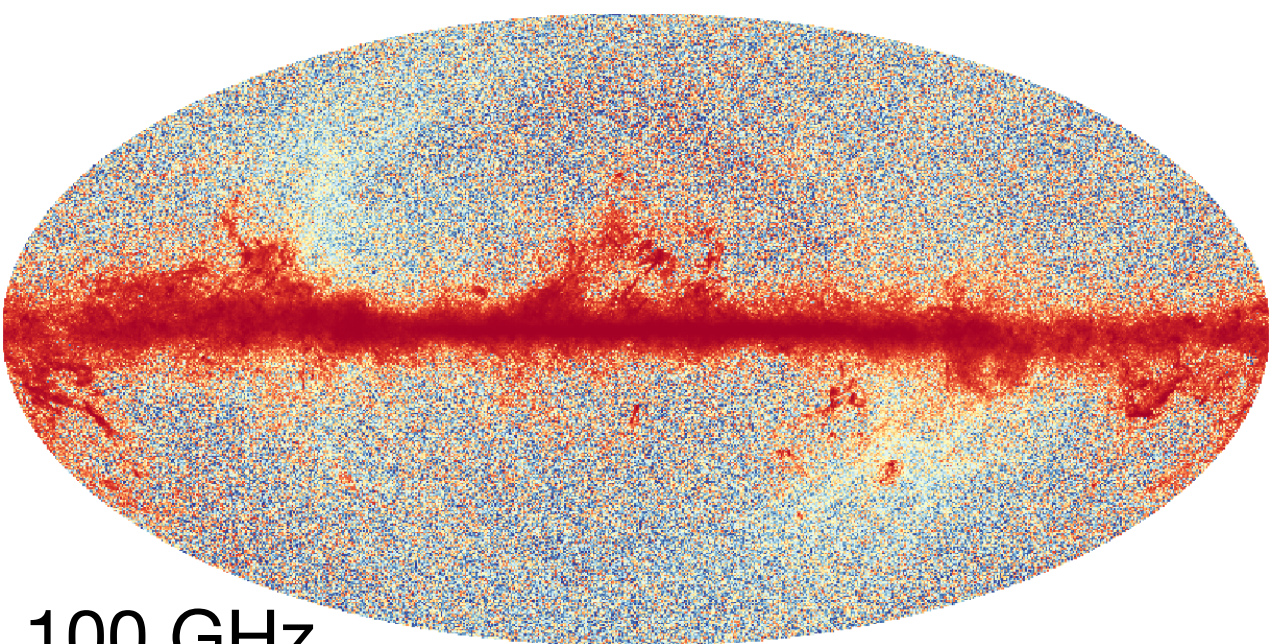
1 Spectroscopic, $R > 100$ LIM surveys are not yet deep or wide enough

2 How about $R \sim 3$ maps × galaxy surveys?

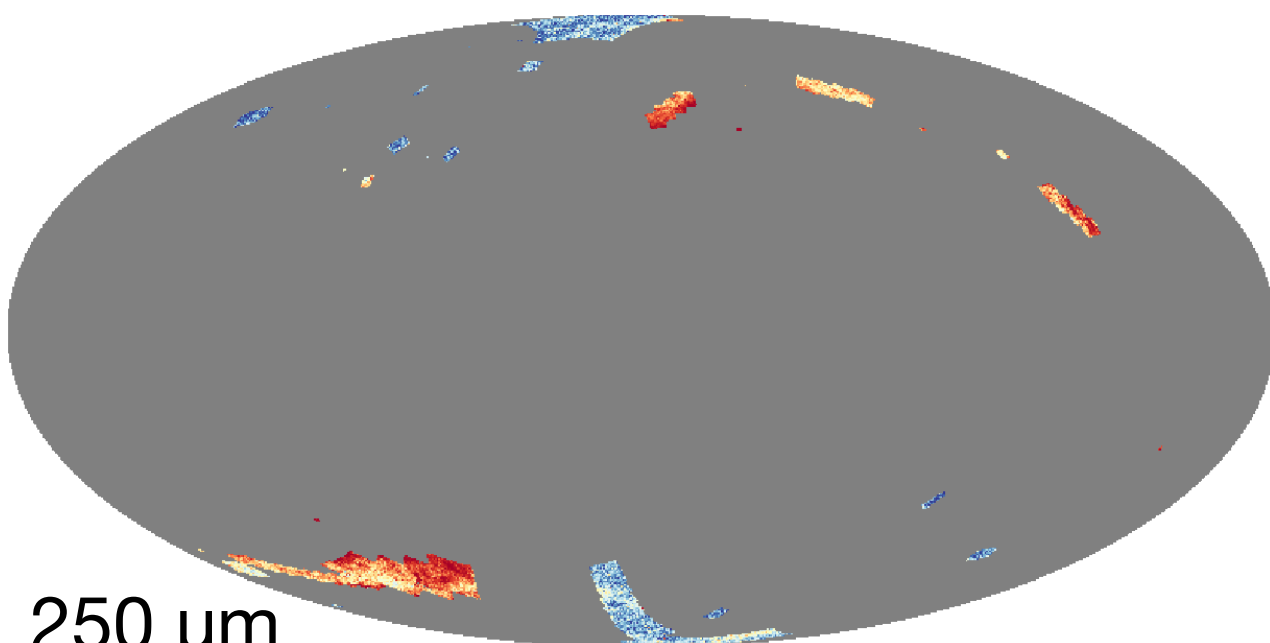
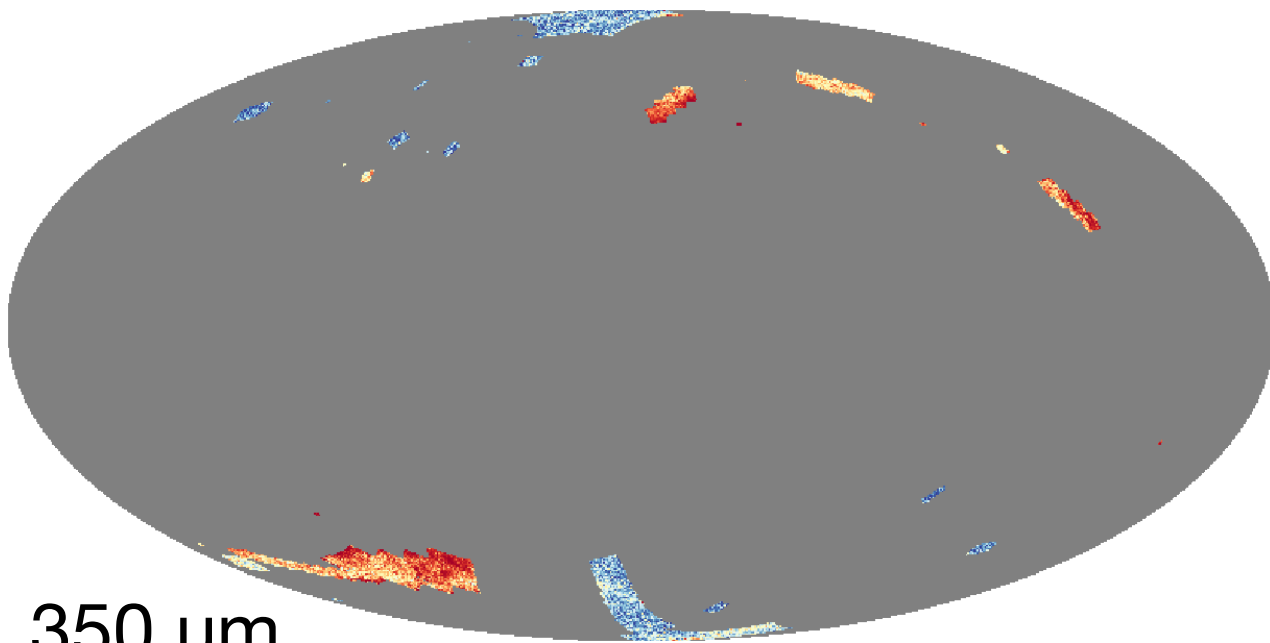
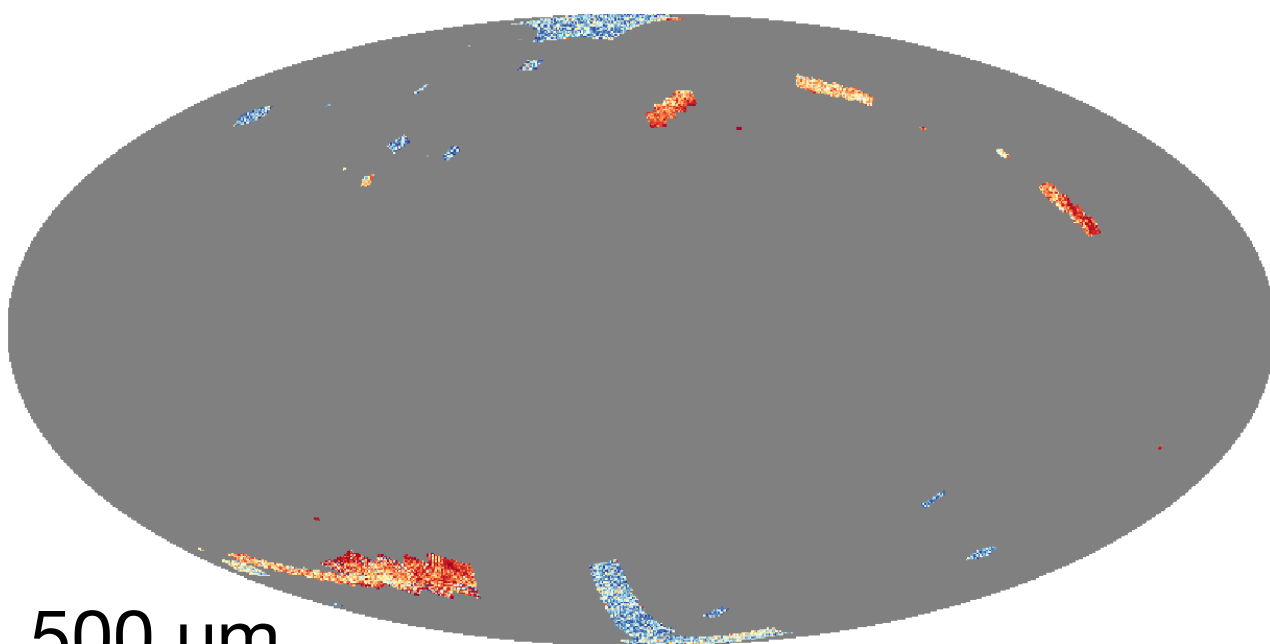


11 broadband mm-FIR maps covering 50-fold frequencies

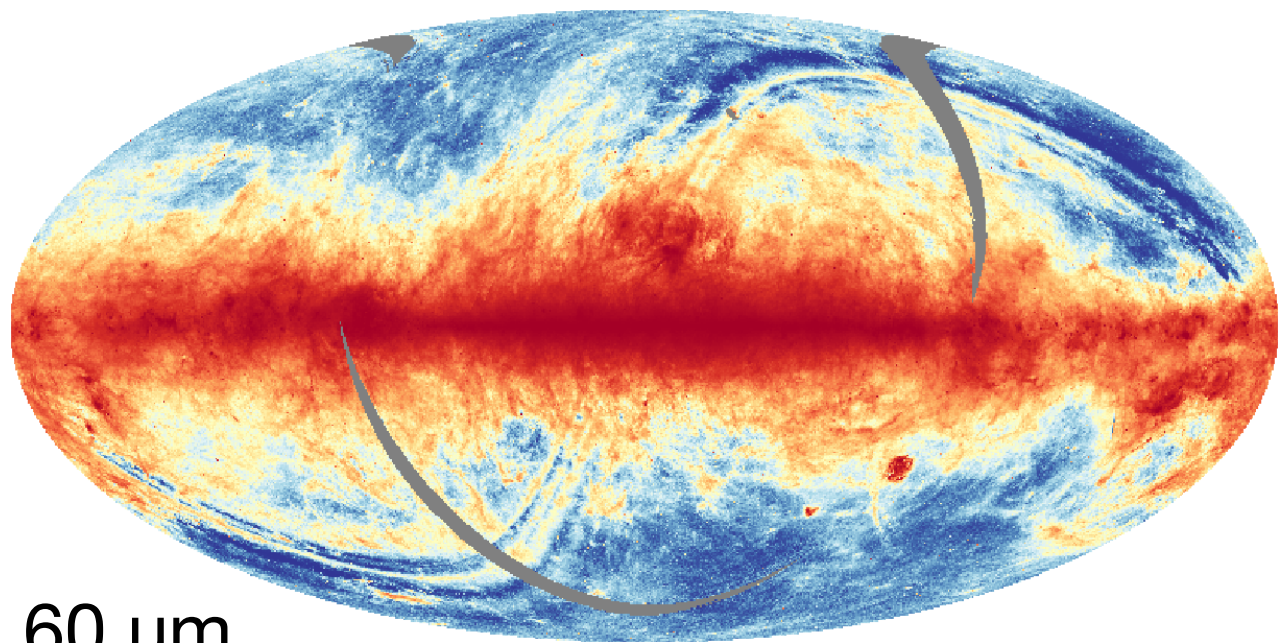
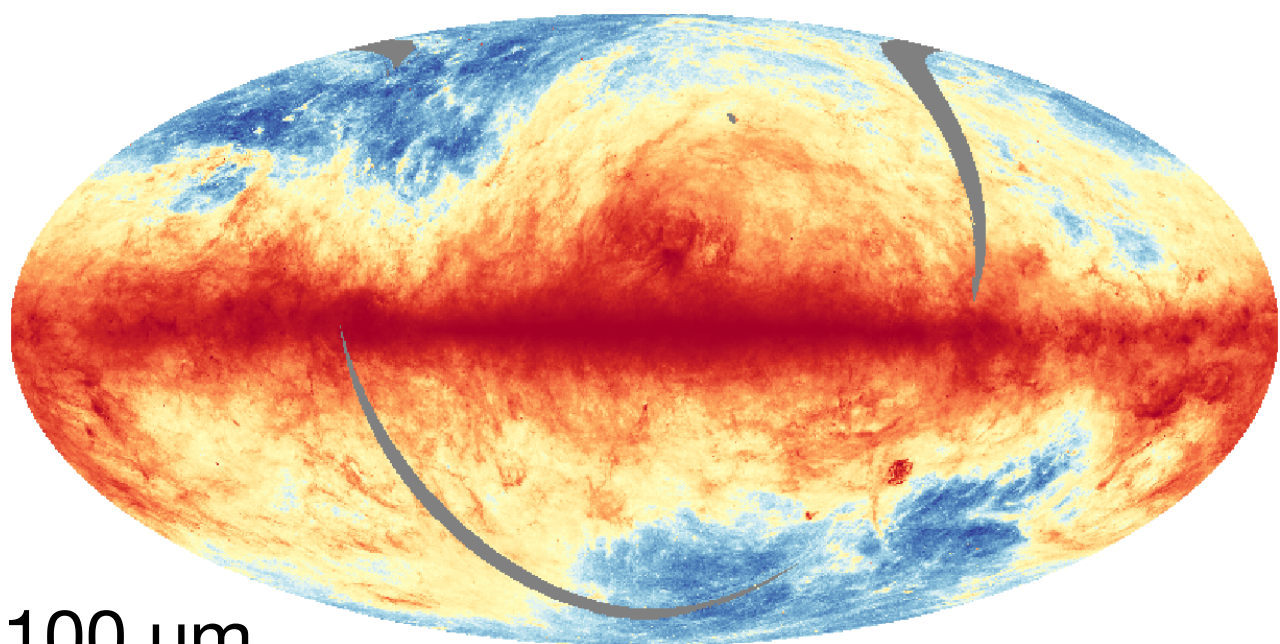
Planck



Herschel



IRAS



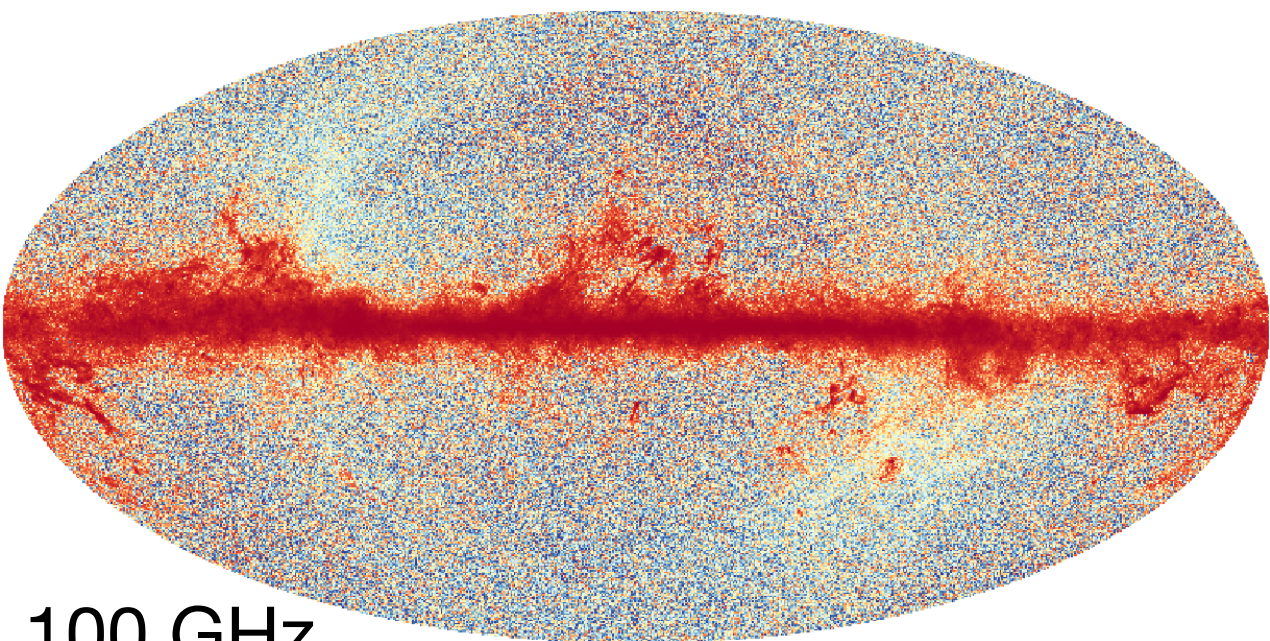
YKC+ 2025 ApJ
YKC 2026 Nat. Astron

11 broadband mm-FIR maps covering 50-fold frequencies

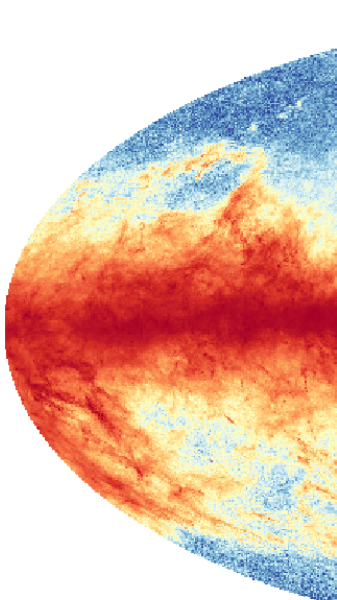
Planck

Herschel

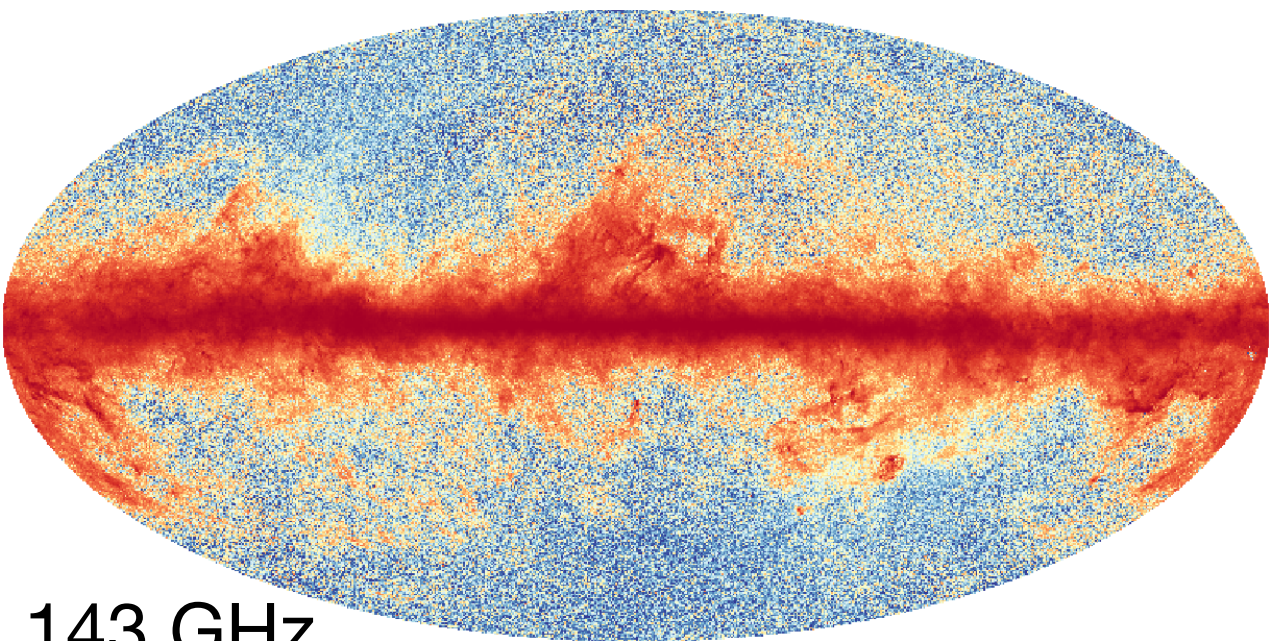
IRAS



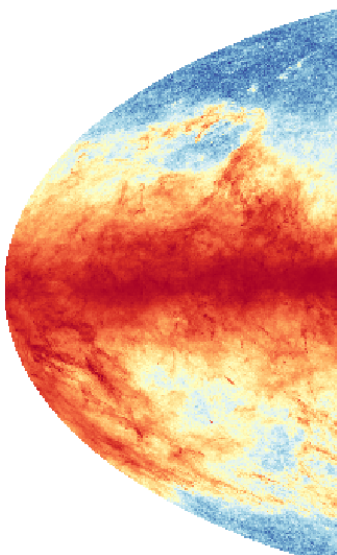
100 GHz



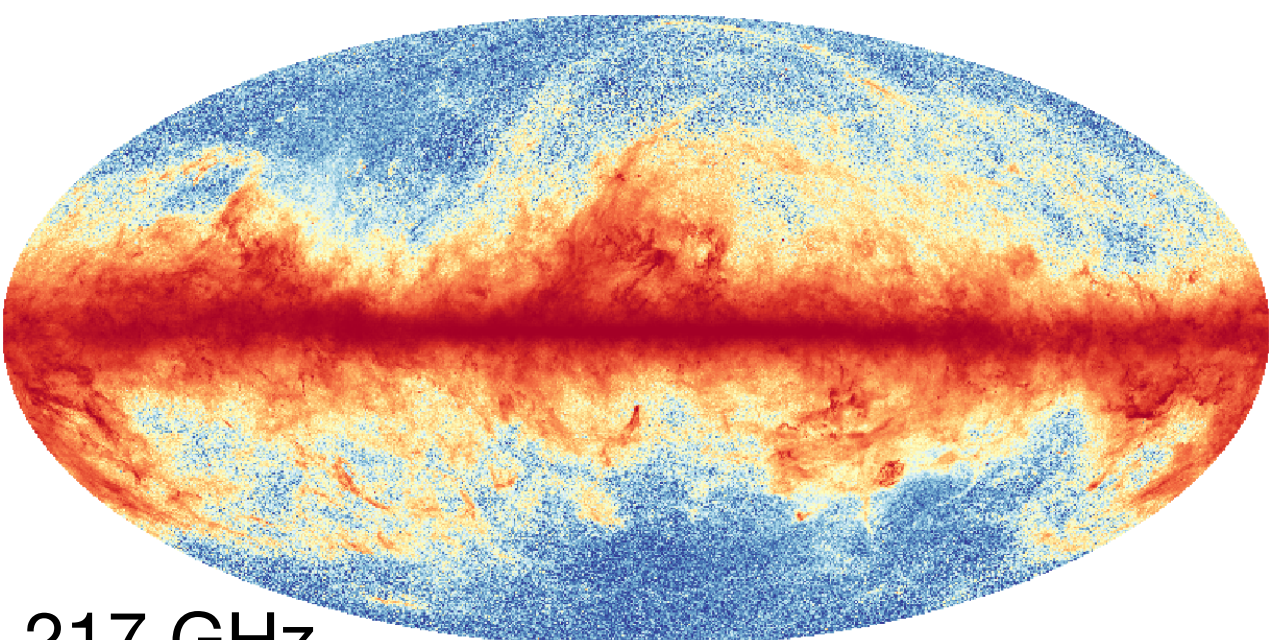
353 GHz



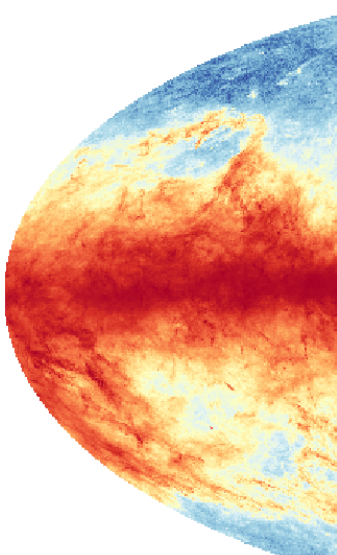
143 GHz



545 GHz

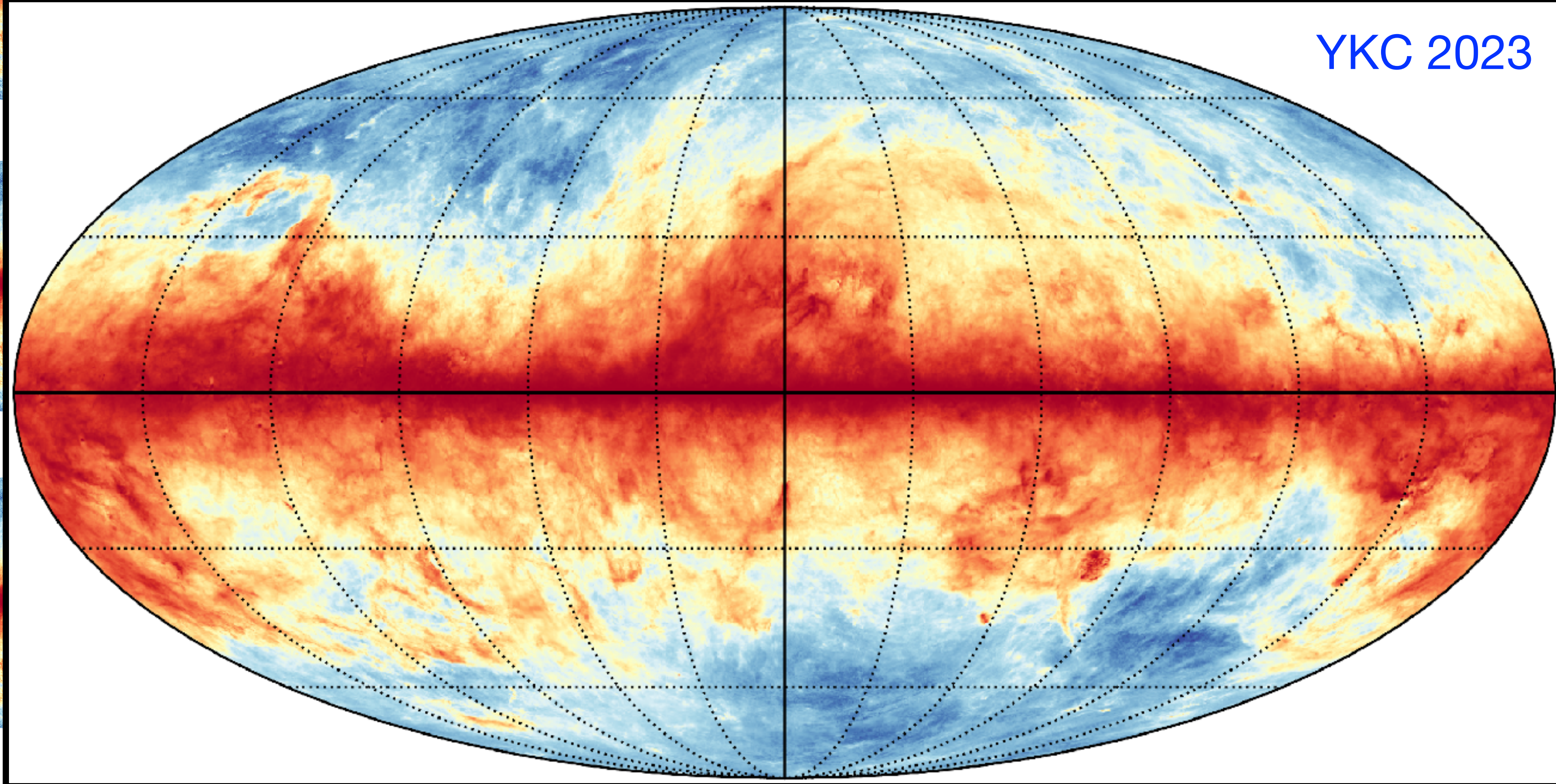


217 GHz



857 GHz

Foreground cleaned using CSFD dust map



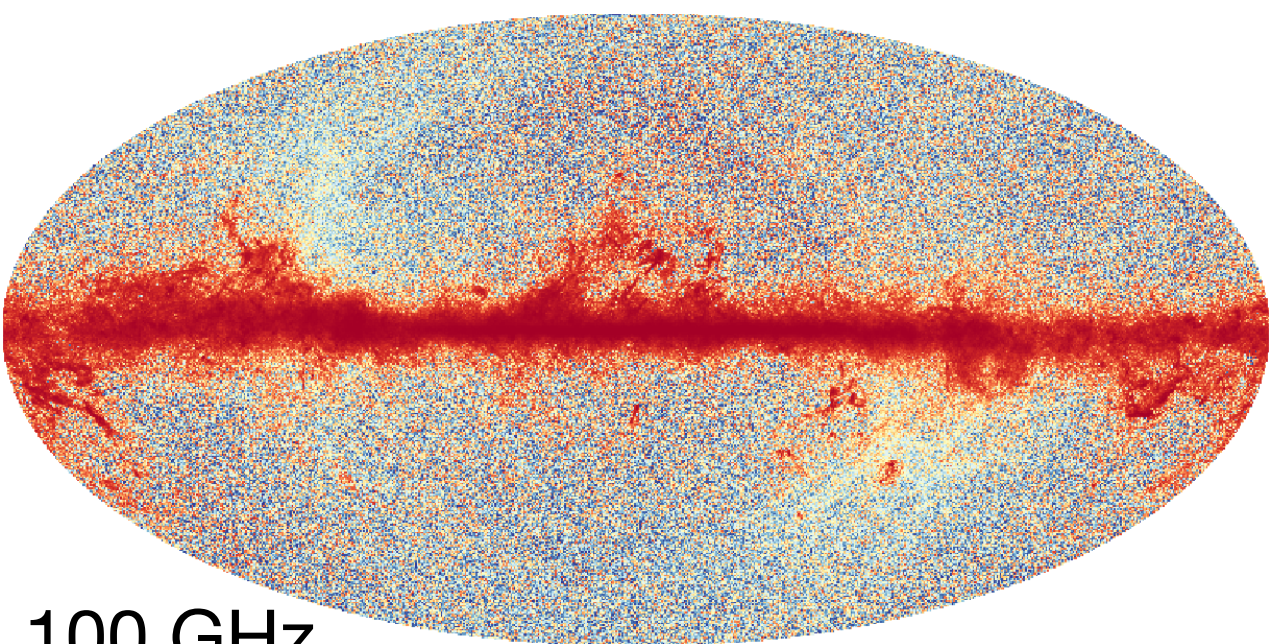
YKC 2023

11 broadband mm-FIR maps covering 50-fold frequencies

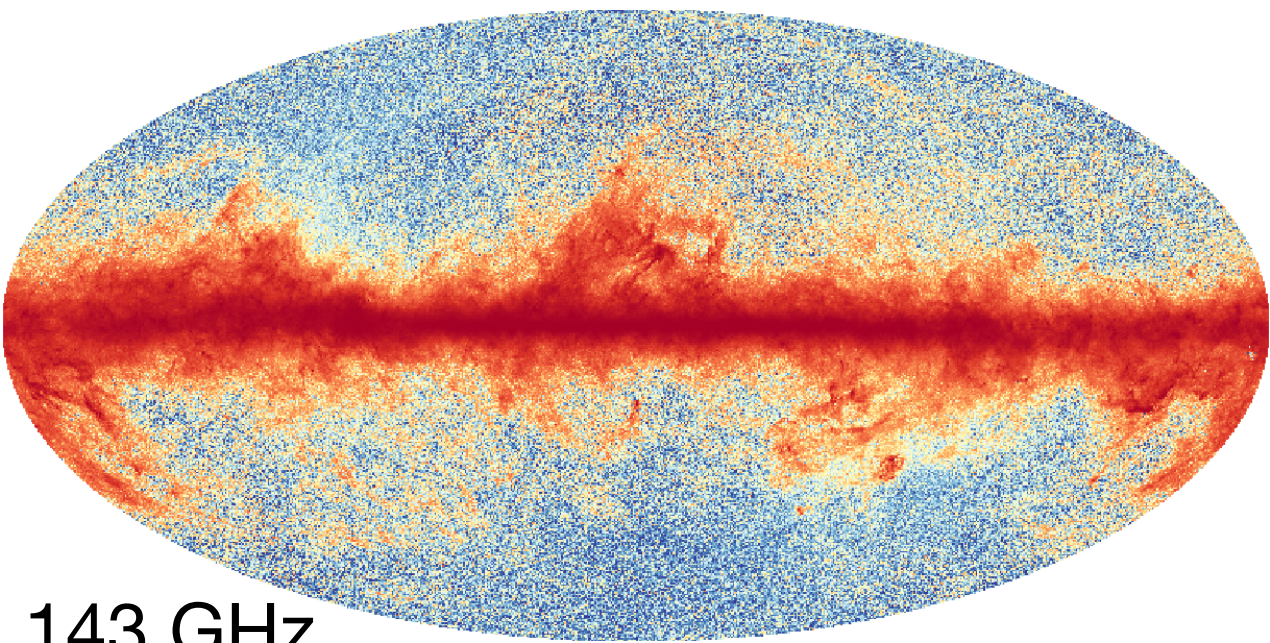
Planck

Herschel

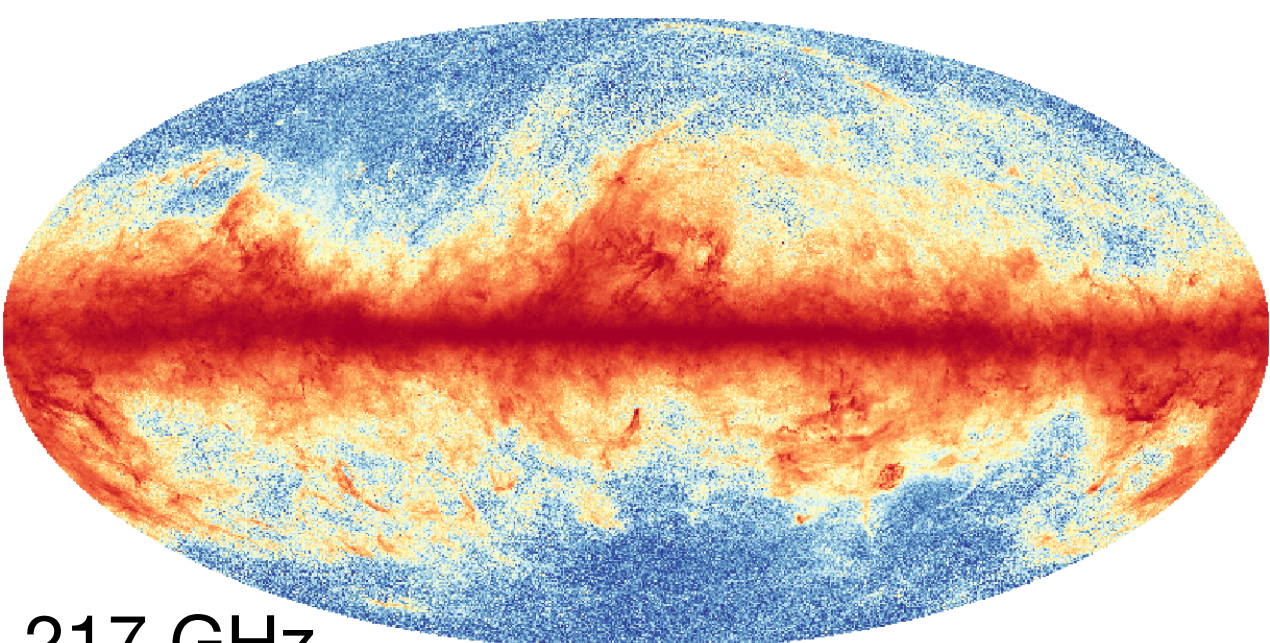
IRAS



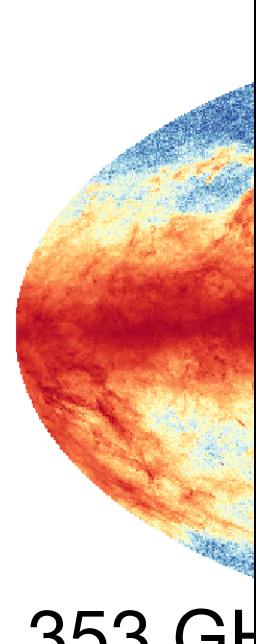
100 GHz



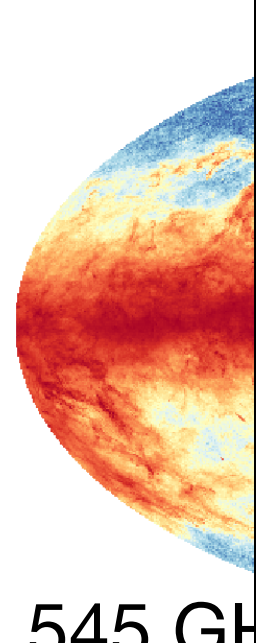
143 GHz



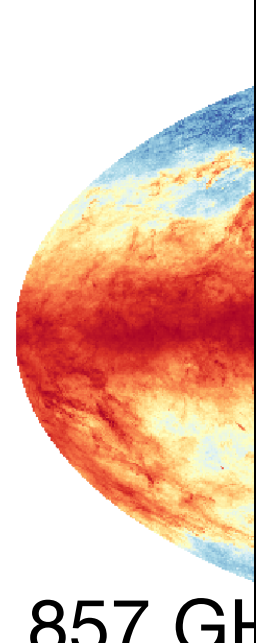
217 GHz



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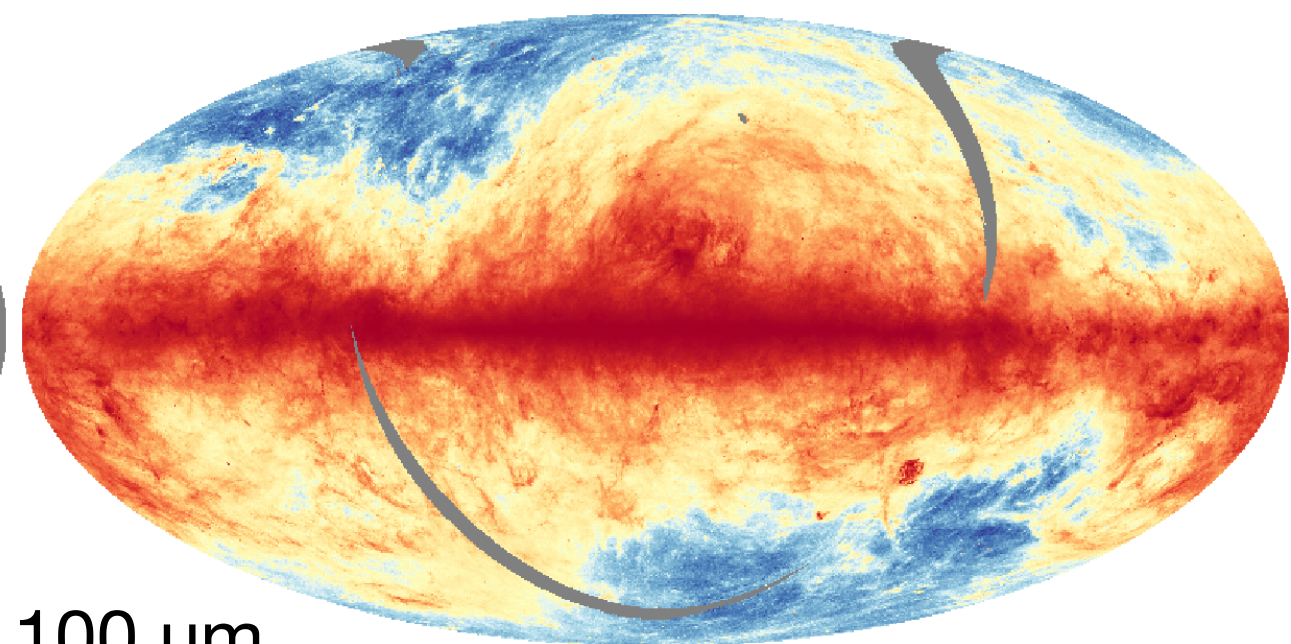
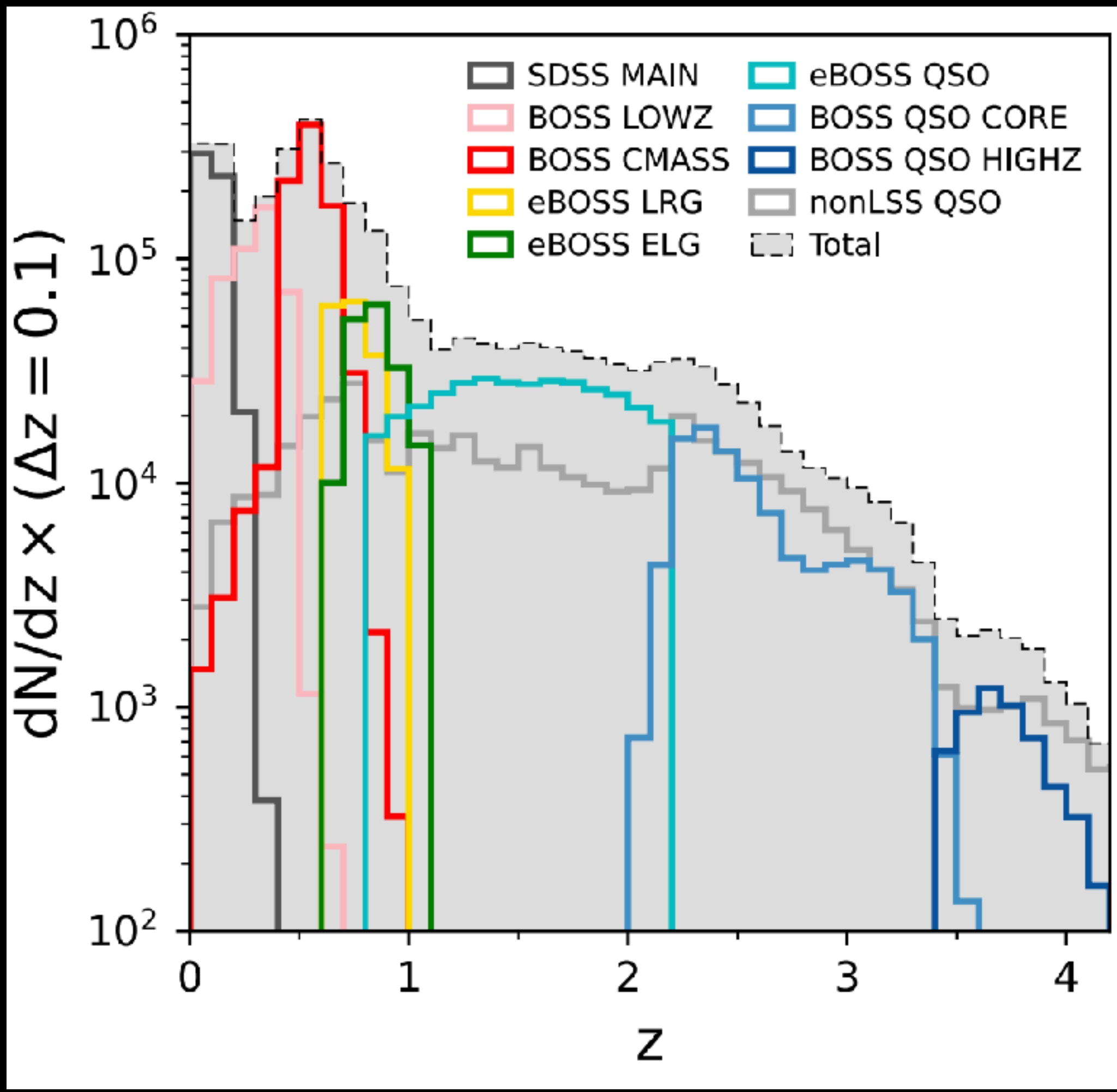


545 GHz

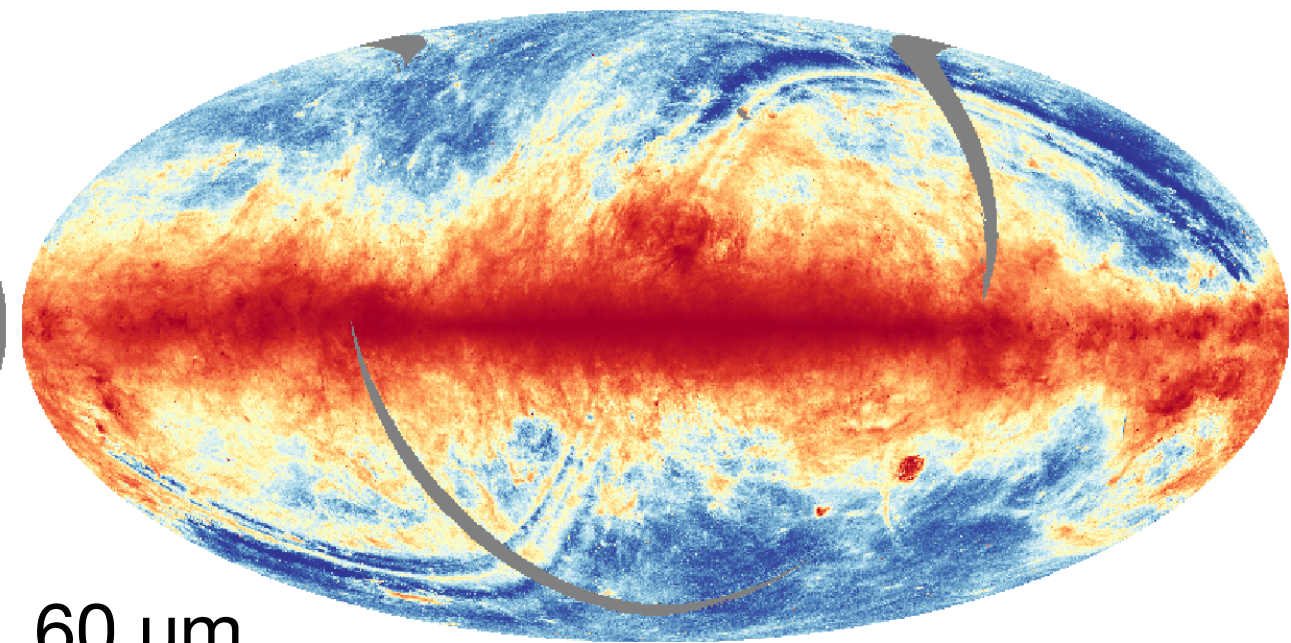


857 GHz

Cross 3M SDSS galaxy redshifts



100 μm

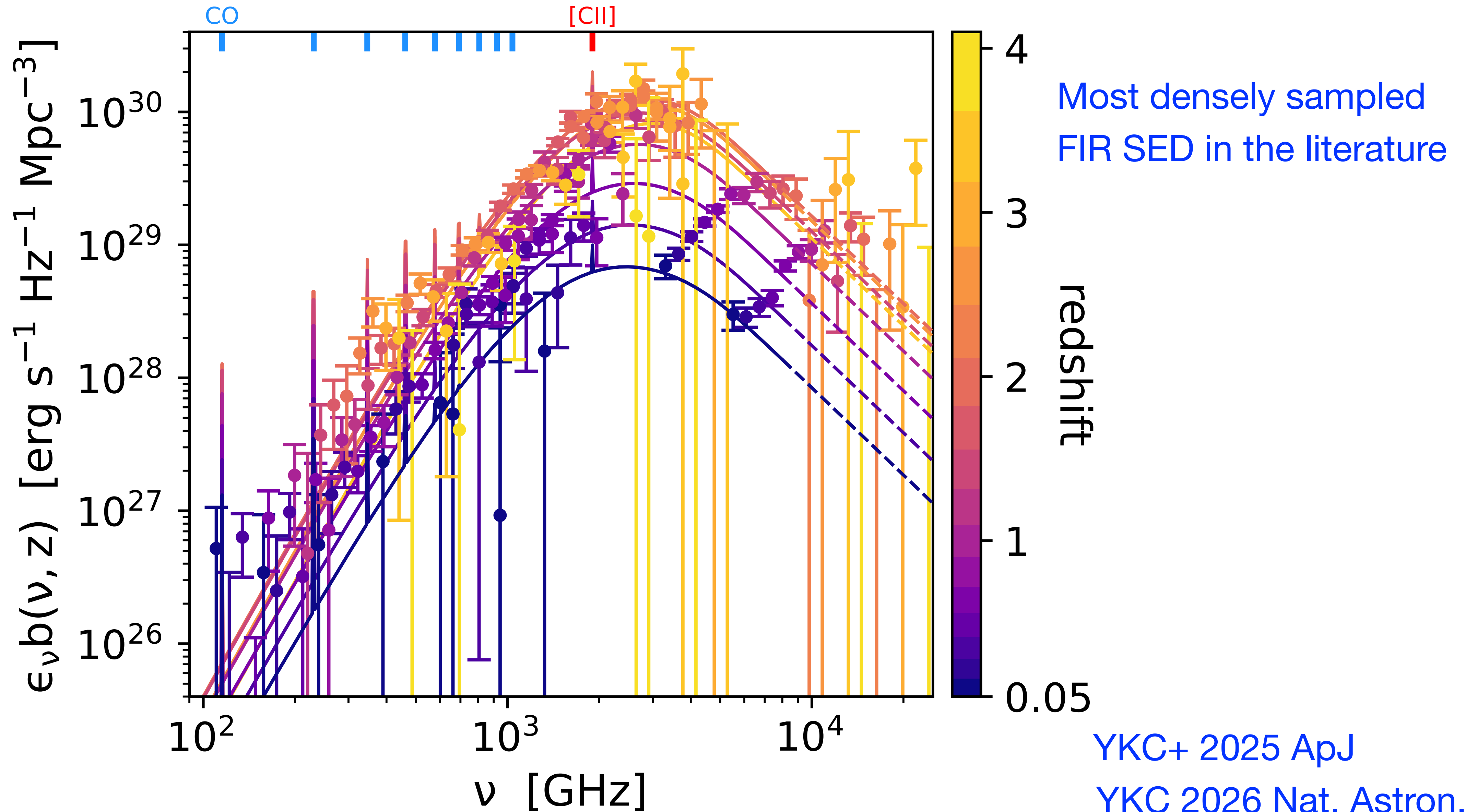


60 μm

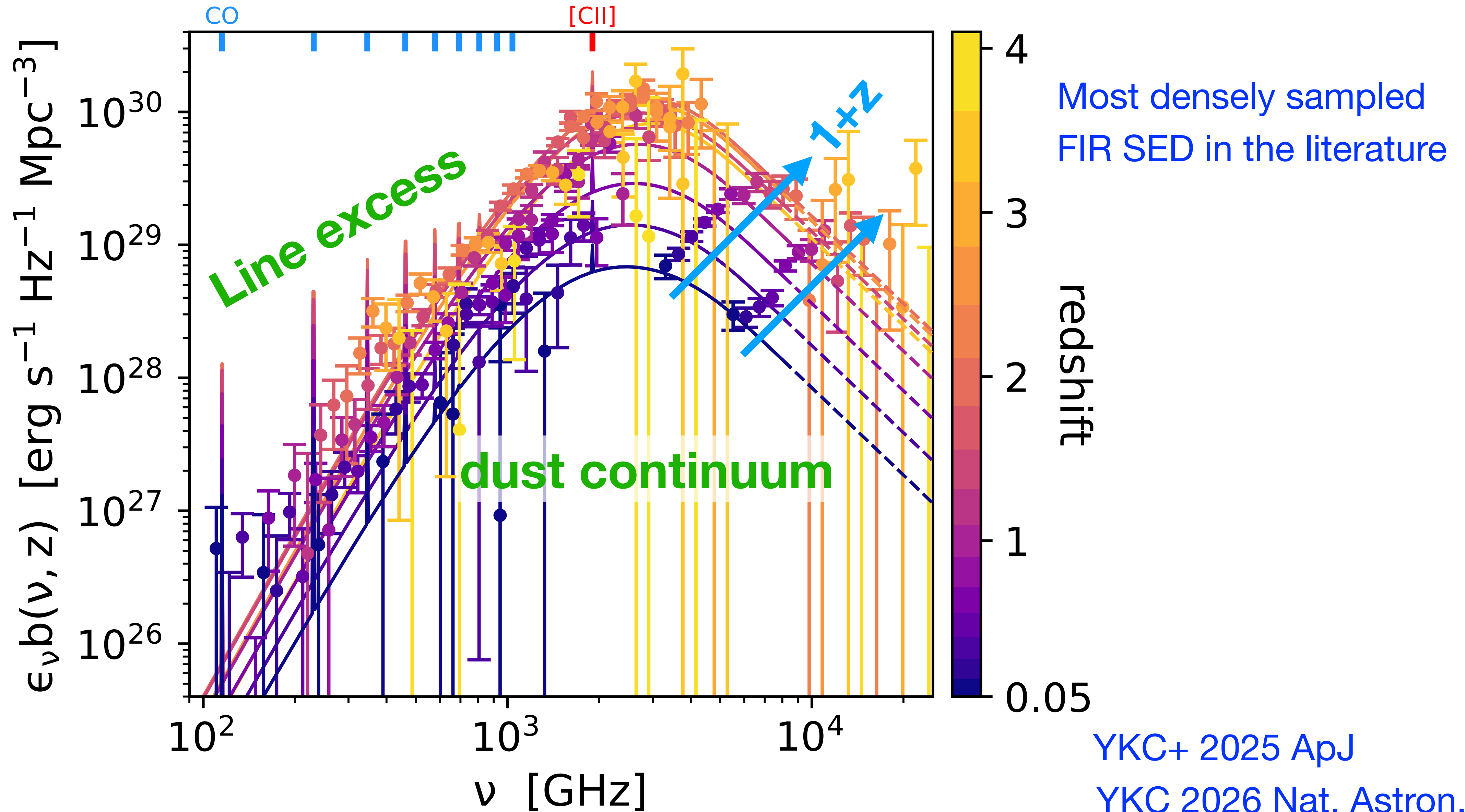
YKC+ 2025 ApJ

YKC 2026 Nat. Astron

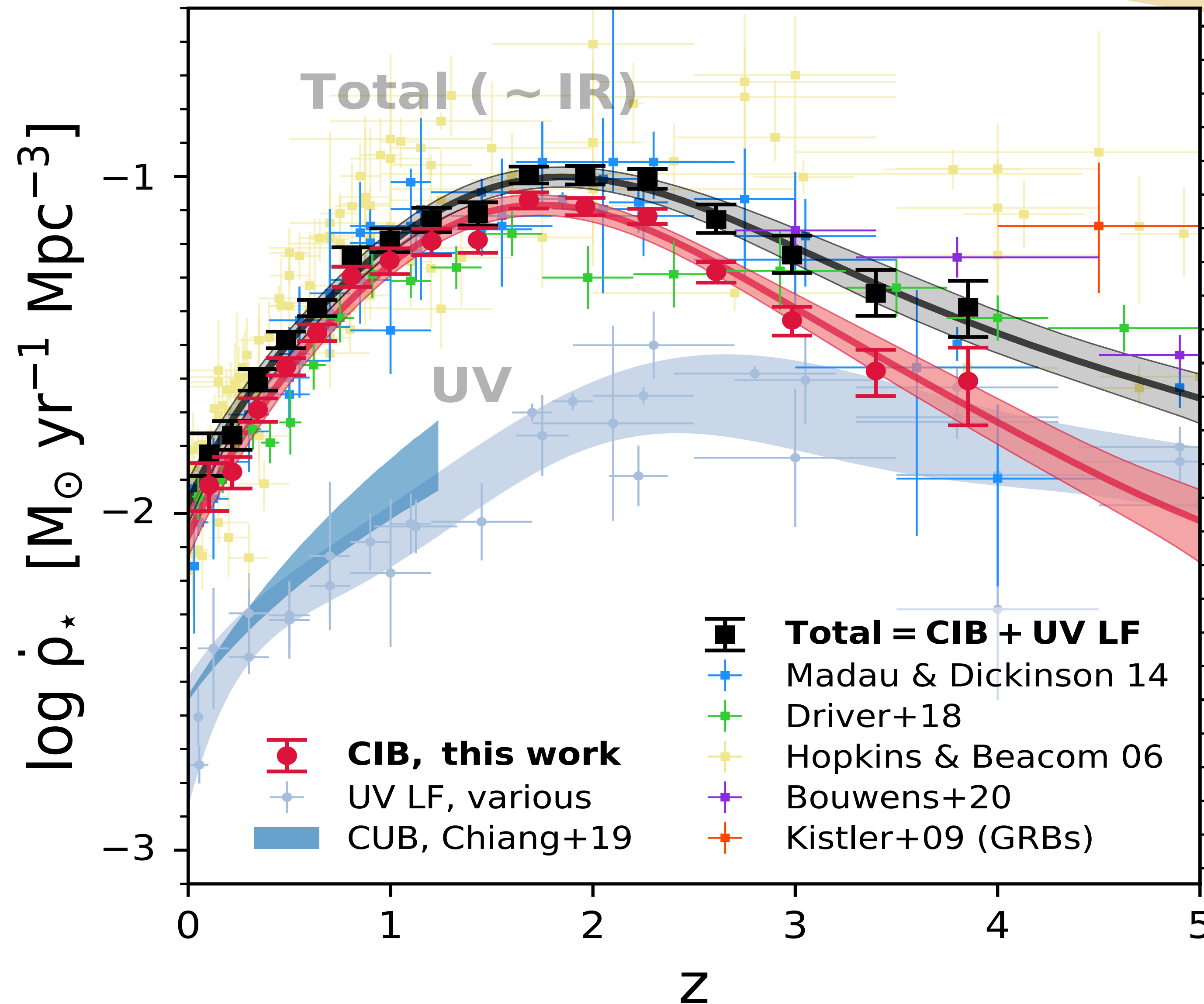
Tomographic CIB spectrum + small line excess



Tomographic CIB spectrum + small line excess



Cosmic star formation is 80% dust-obscured



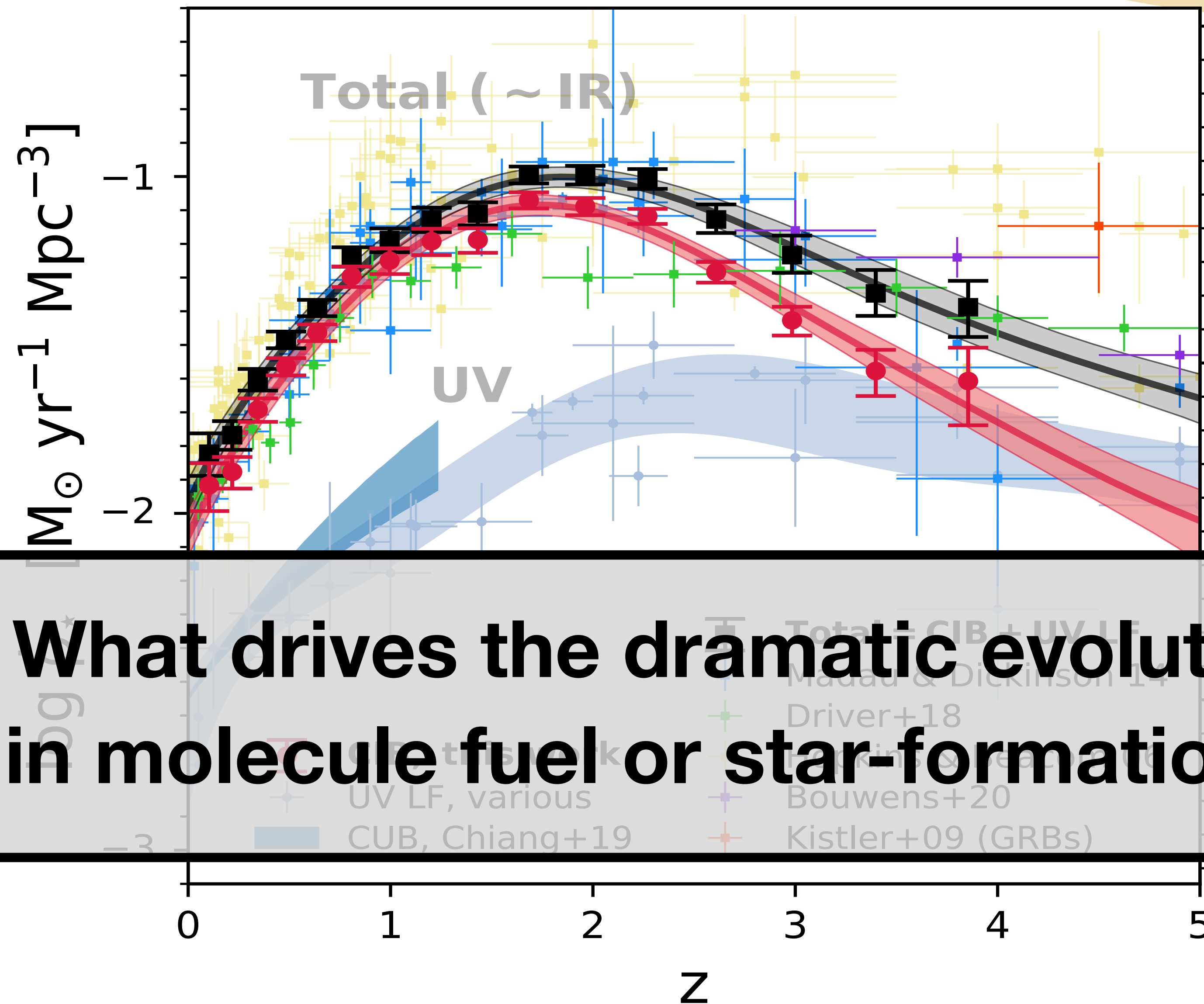
Tightest CSFR
constraint

No cosmic variance
No SED systematic

Complete to the
faintest galaxies

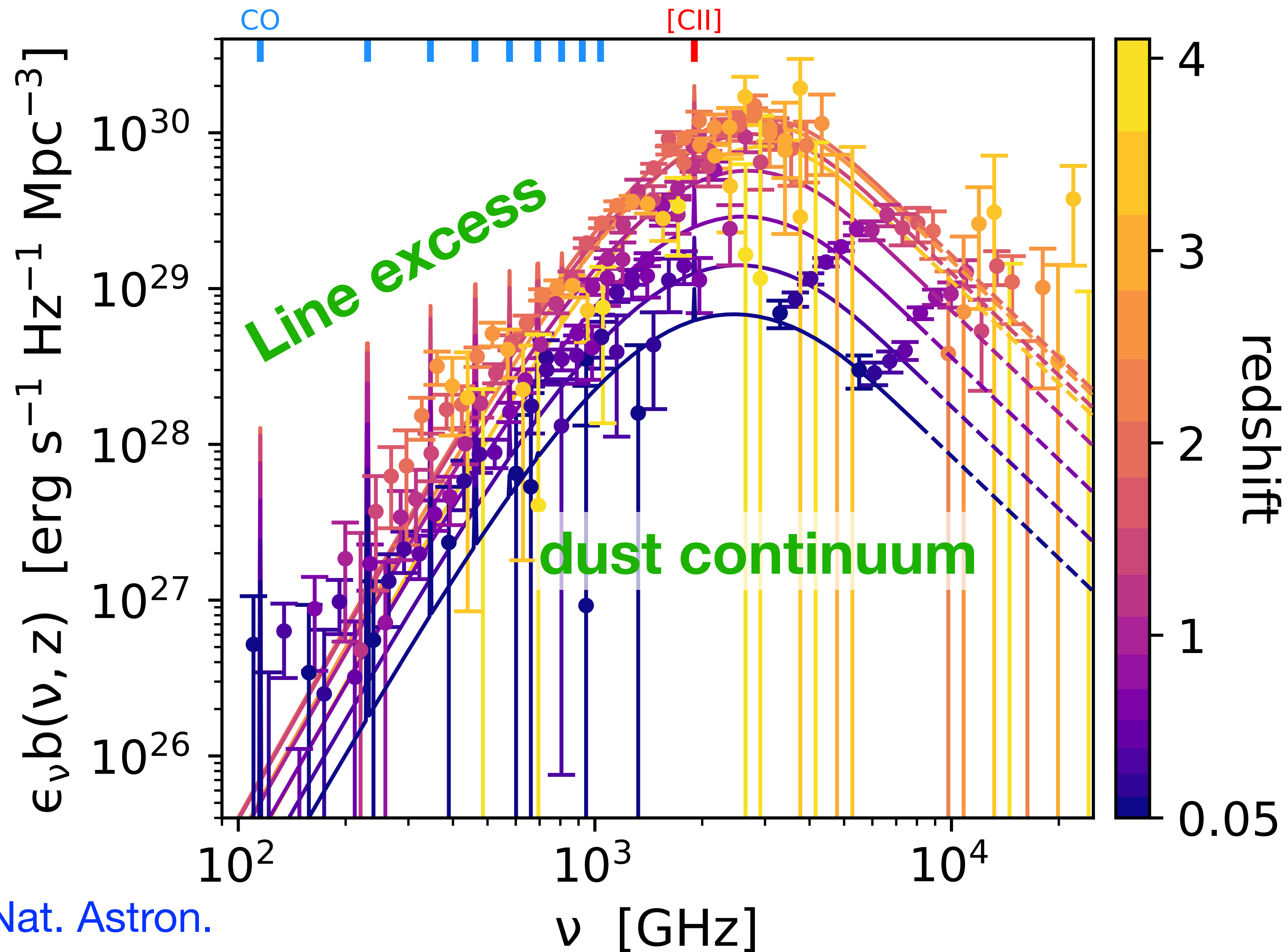
YKC+ 2025

Cosmic star formation is 80% dust-obscured



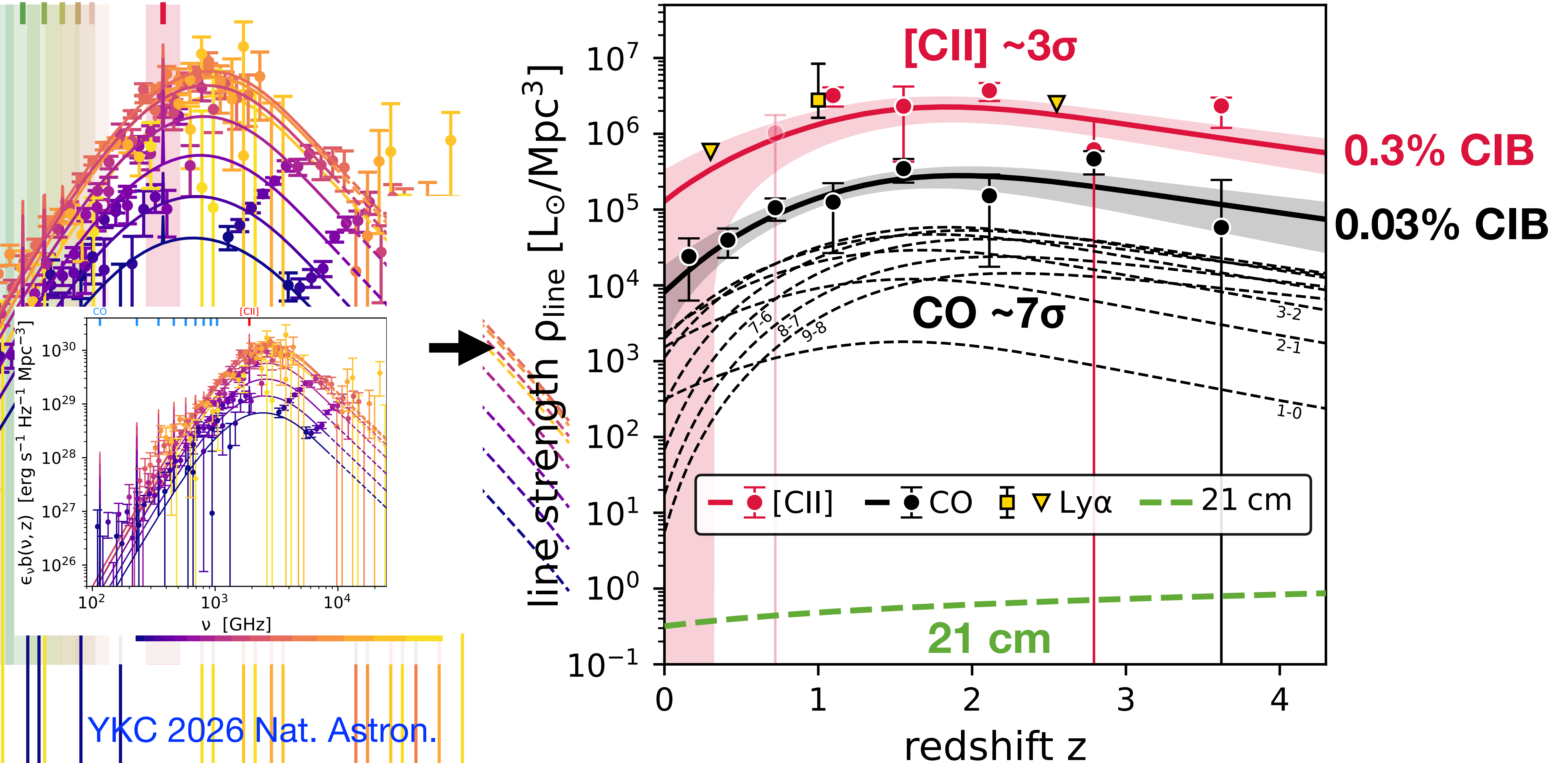
YKC+ 2025

Fit δ functions for lines, jointly with the continuum

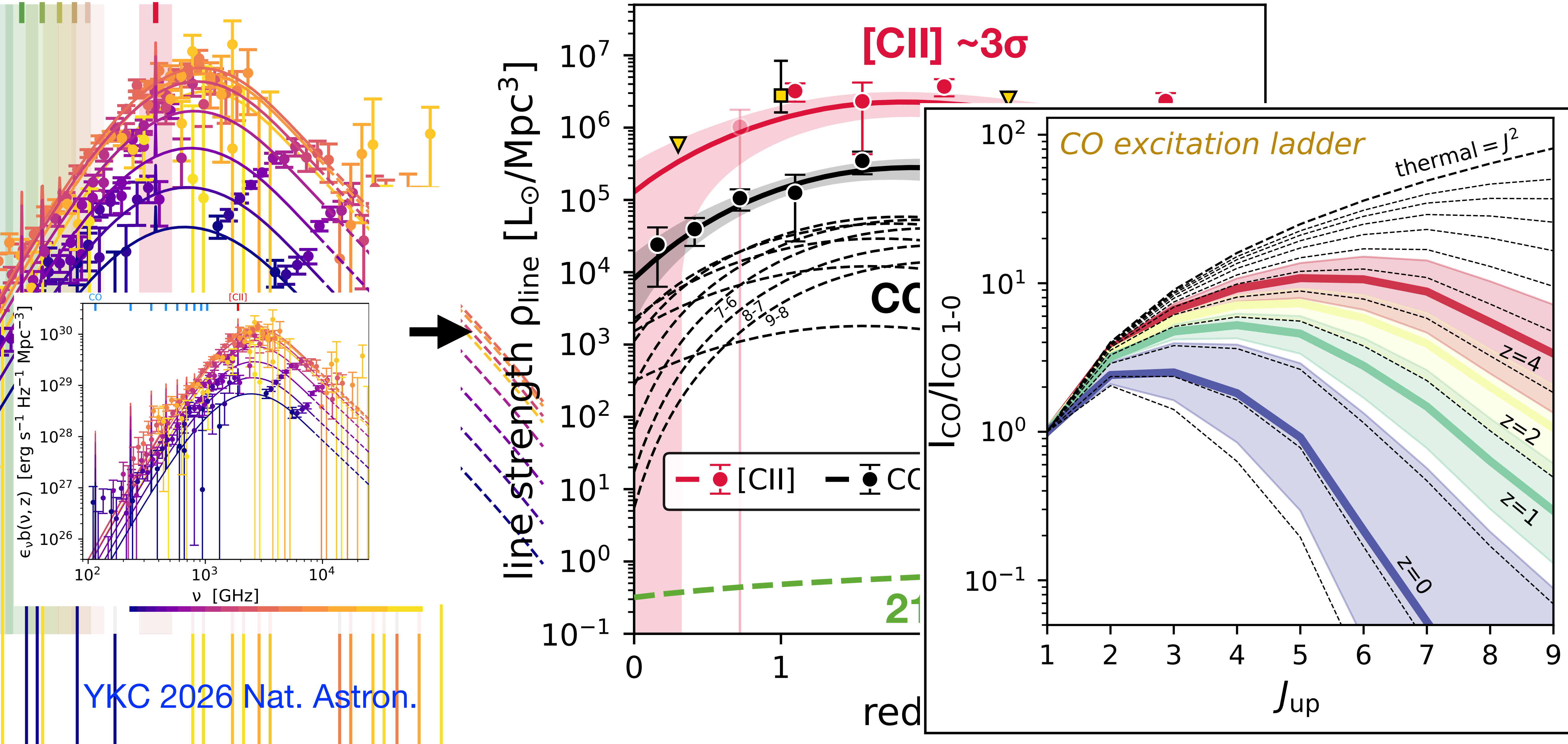


YKC 2026 Nat. Astron.

First cosmic mean CO & [CII] detections

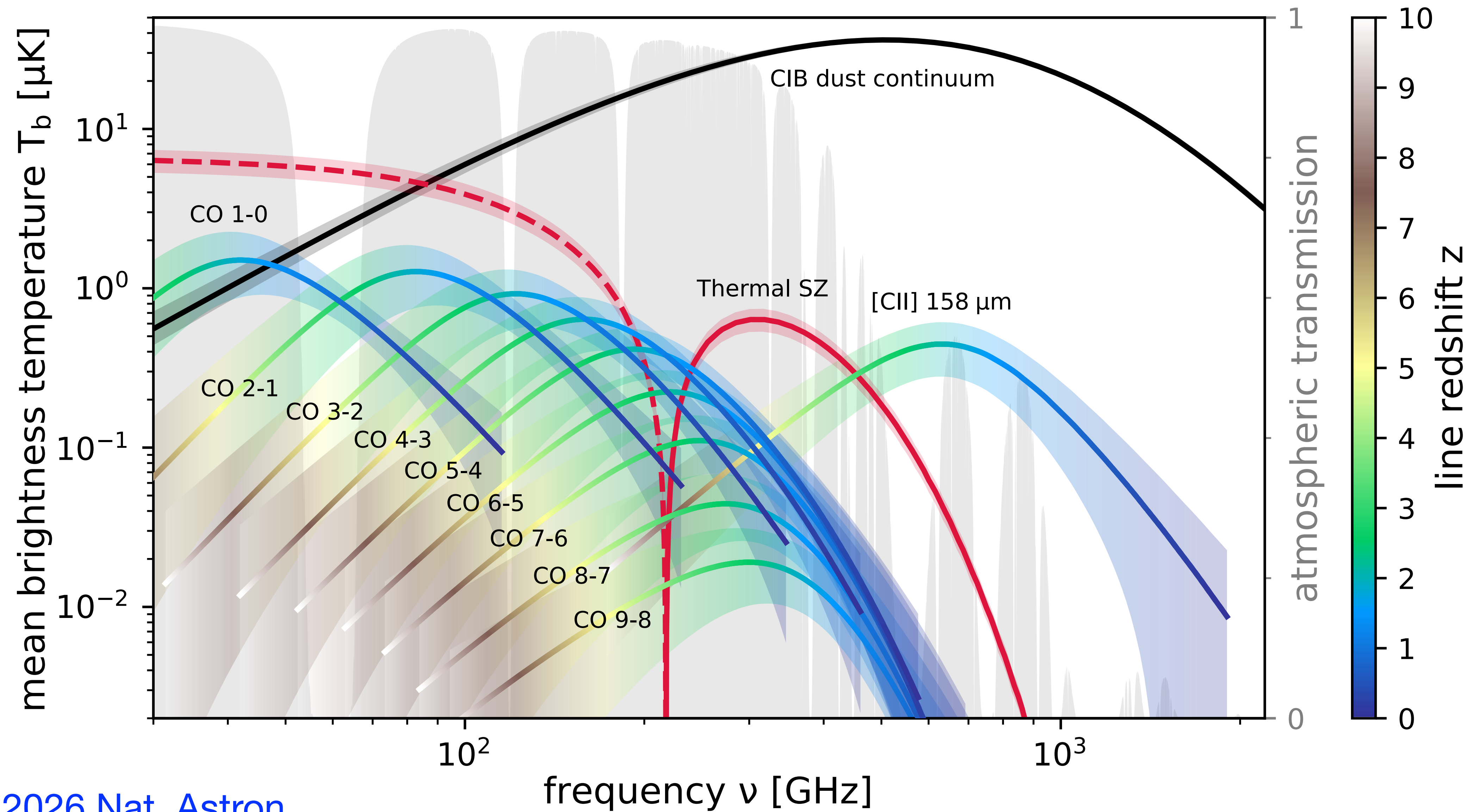


First cosmic mean CO & [CII] detections



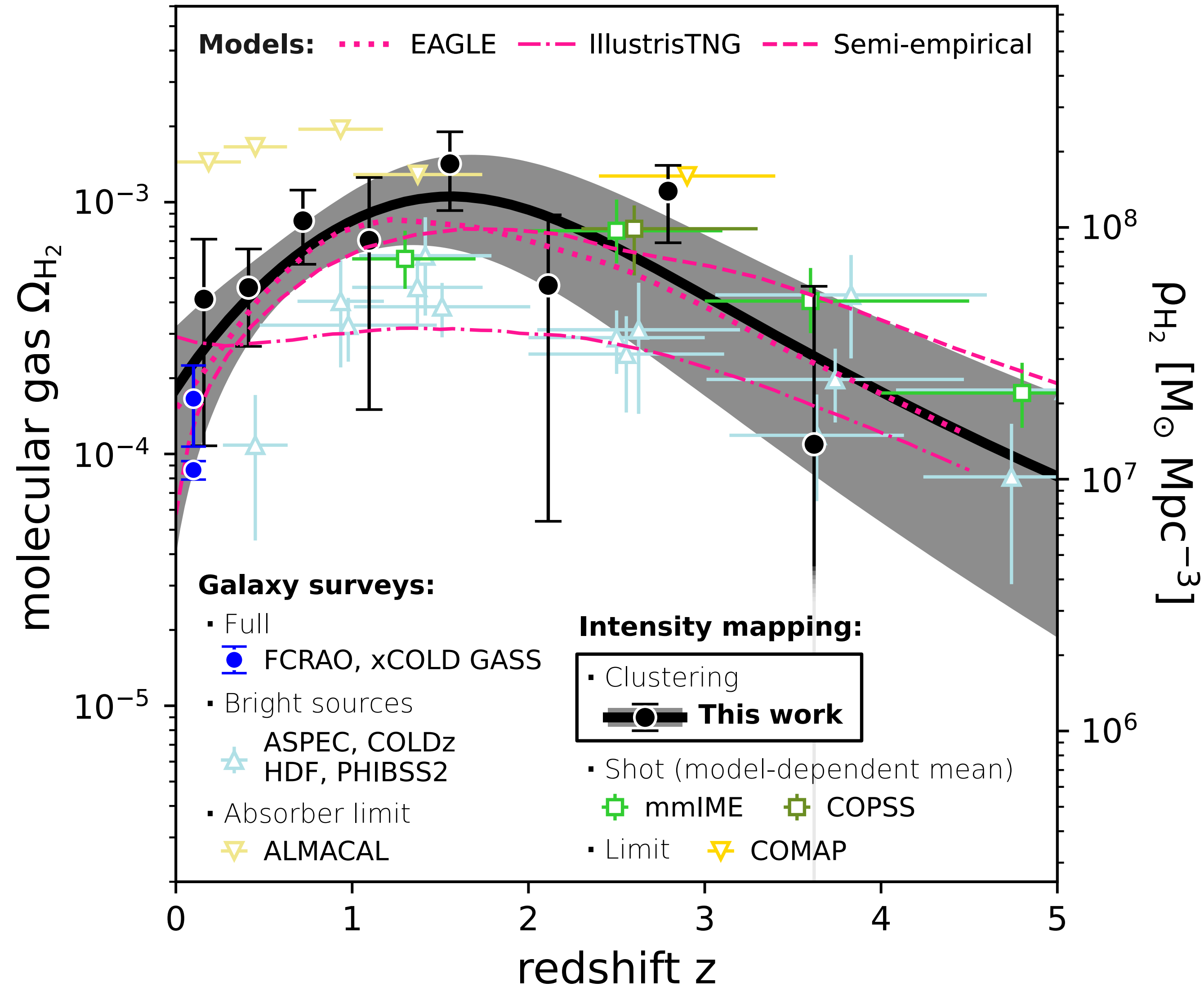
YKC 2026 Nat. Astron.

Mean CO & [CII] anchors 3D LIM and CMB foreground



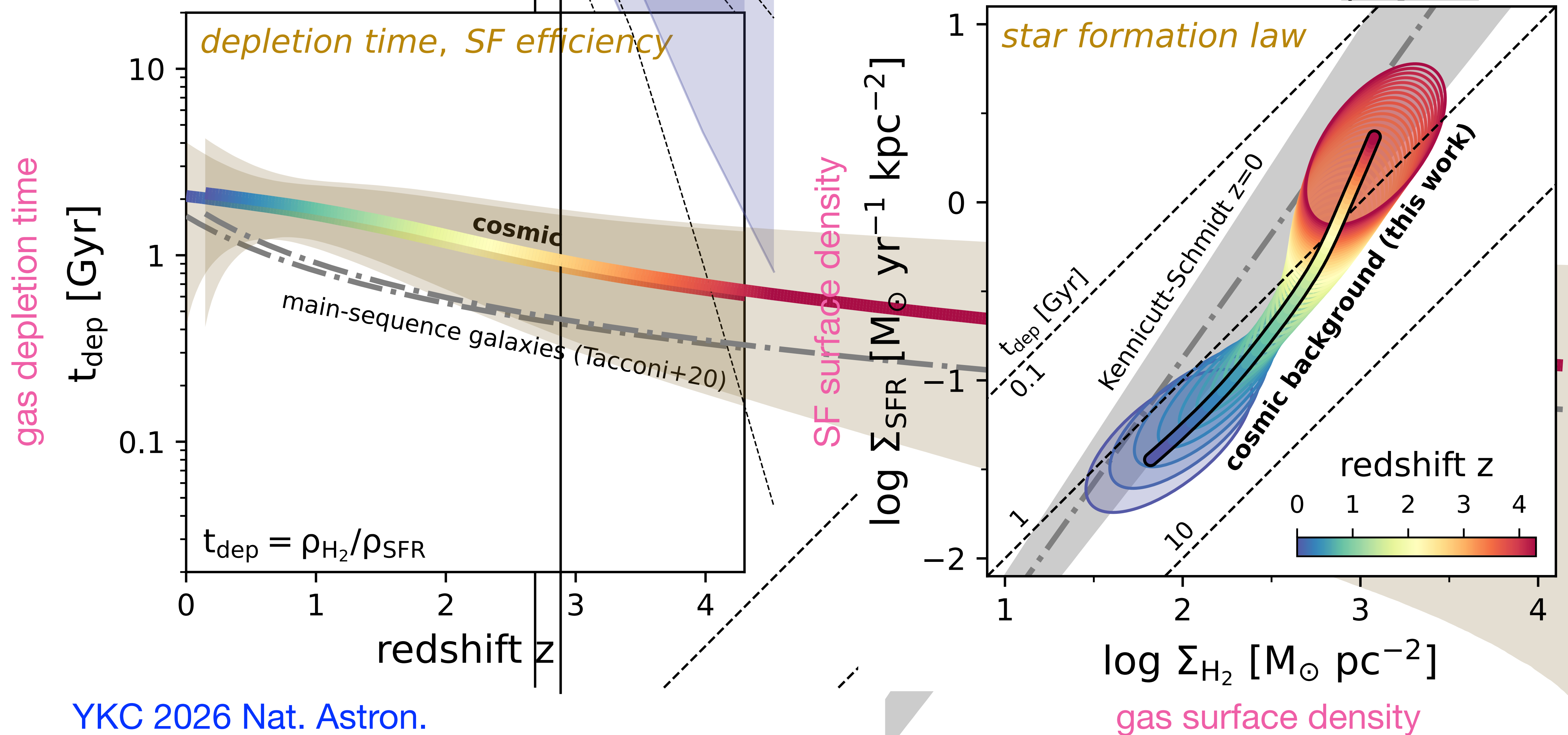
YKC 2026 Nat. Astron.

Molecular gas fueling as driver of cosmic star-formation

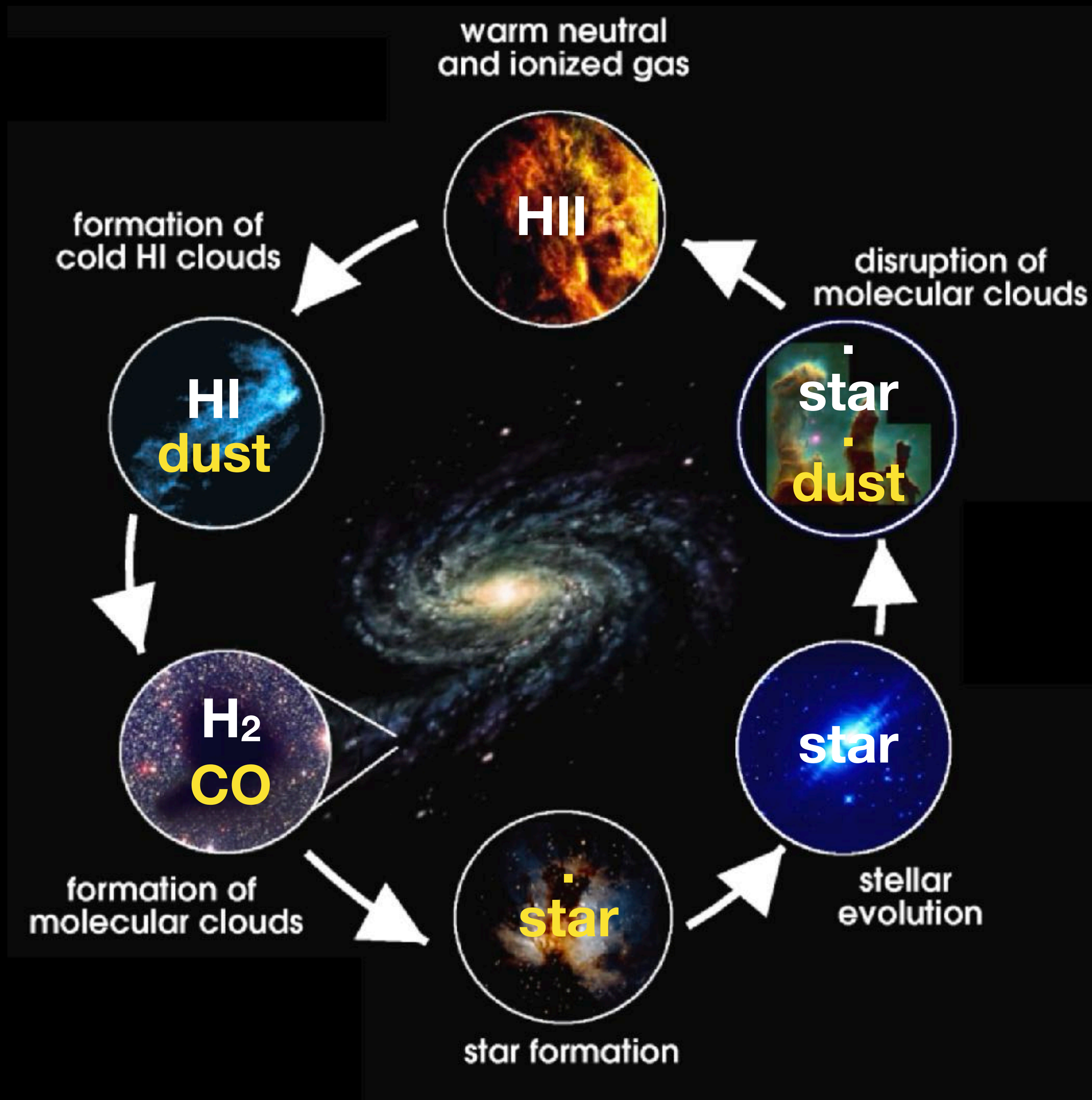


YKC 2026 Nat. Astron.

Depletion, replenishment, & universal star-formation law



YKC 2026 Nat. Astron.



Summary

intensity mapping

11 R=3 FIR to mm maps (10^8 pixels)

×

galaxy surveys

3 million galaxy redshifts

- First detection of the cosmic CO and [CII] backgrounds
- Empirical anchors for future 3D line intensity mapping surveys
- Revealing a large but limited molecular reservoir regulating cosmic star formation

