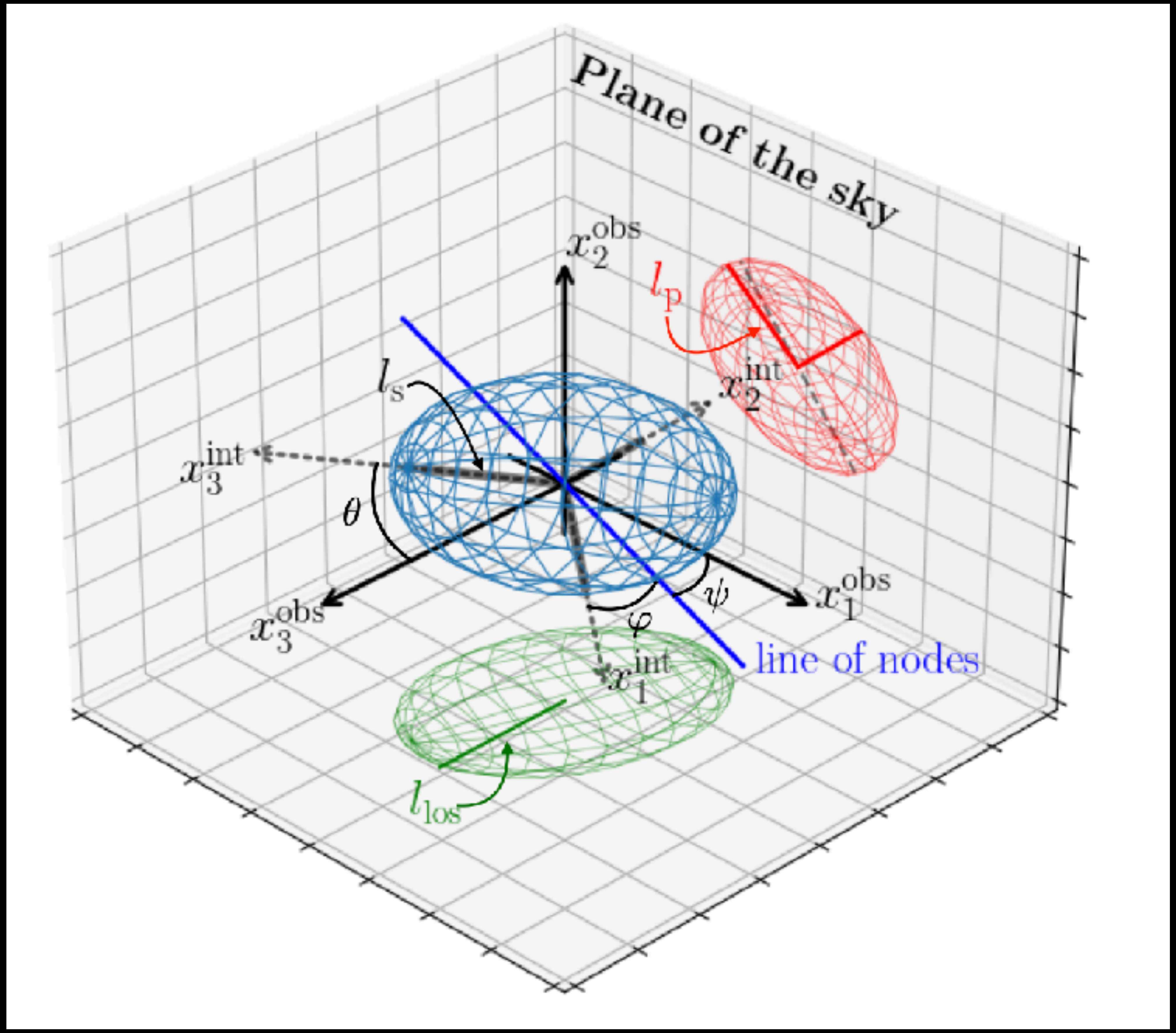
PSZ2 G313.33+61.13 (Abell 1689): Model Fit

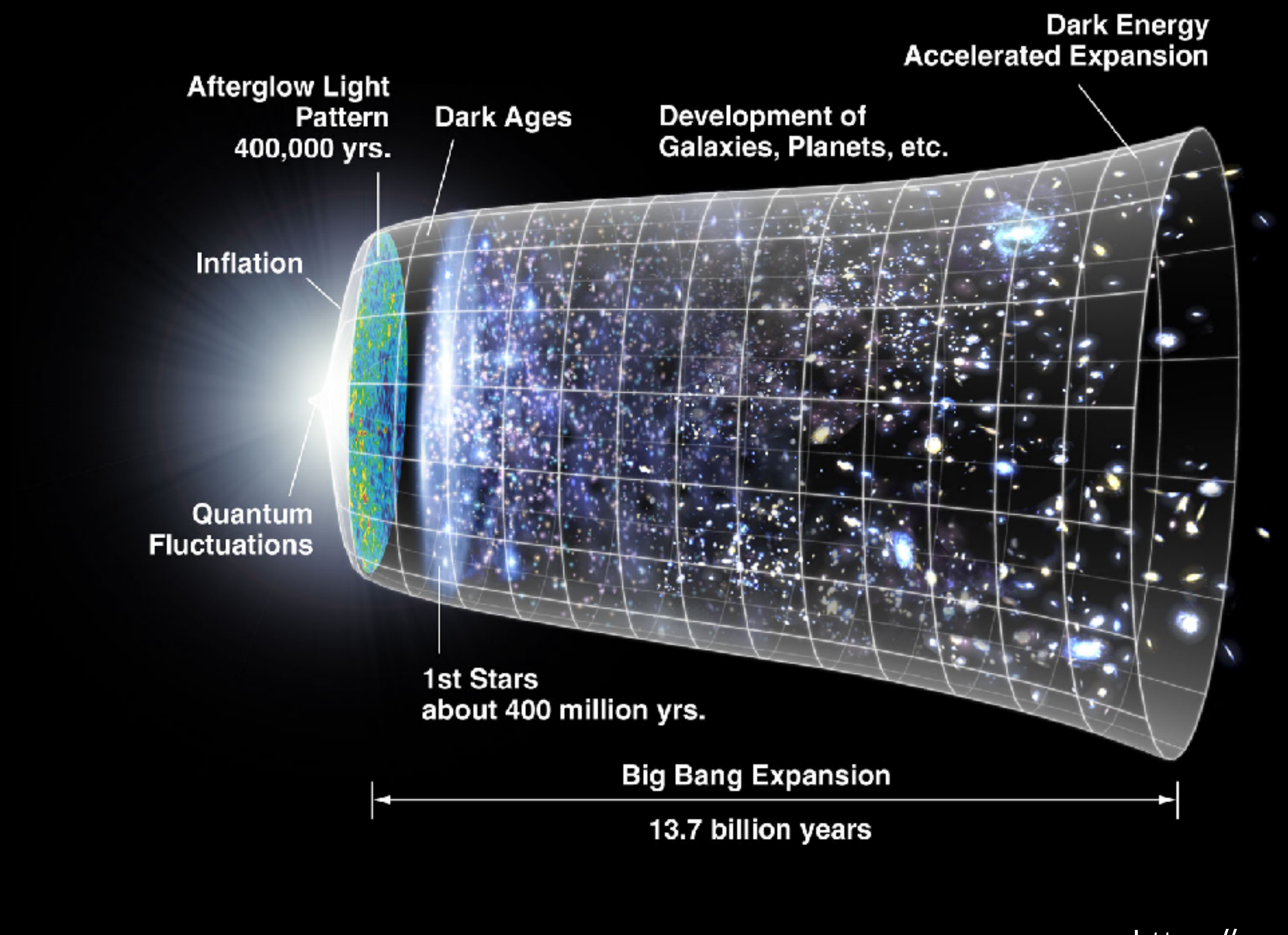
- The analysis effectively constrains the model geometry at the few percent level.
- Compared to the similar gas-only analysis using X-ray and SZ data presented in Sereno et al. (2012), the axial ratios and elongation parameters in our study demonstrate a substantial improvement, with uncertainties an order of magnitude lower.

$q_{\mathrm{ICM},1}$	$q_{\mathrm{ICM},2}$	$\cos\theta$	$e_{\parallel}$	Reference
0.70 ± 0.15	0.81 ± 0.16	0.70 ± 0.29	1.68 ± 0.53	Sereno et al. (2012)
0.63 ± 0.14	0.70 ± 0.16	0.93 ± 0.06	1.16 ± 0.10	Umetsu et al. (2015)
0.65 ± 0.02	0.79 ± 0.02	≥ 0.96	1.24 ± 0.03	This work



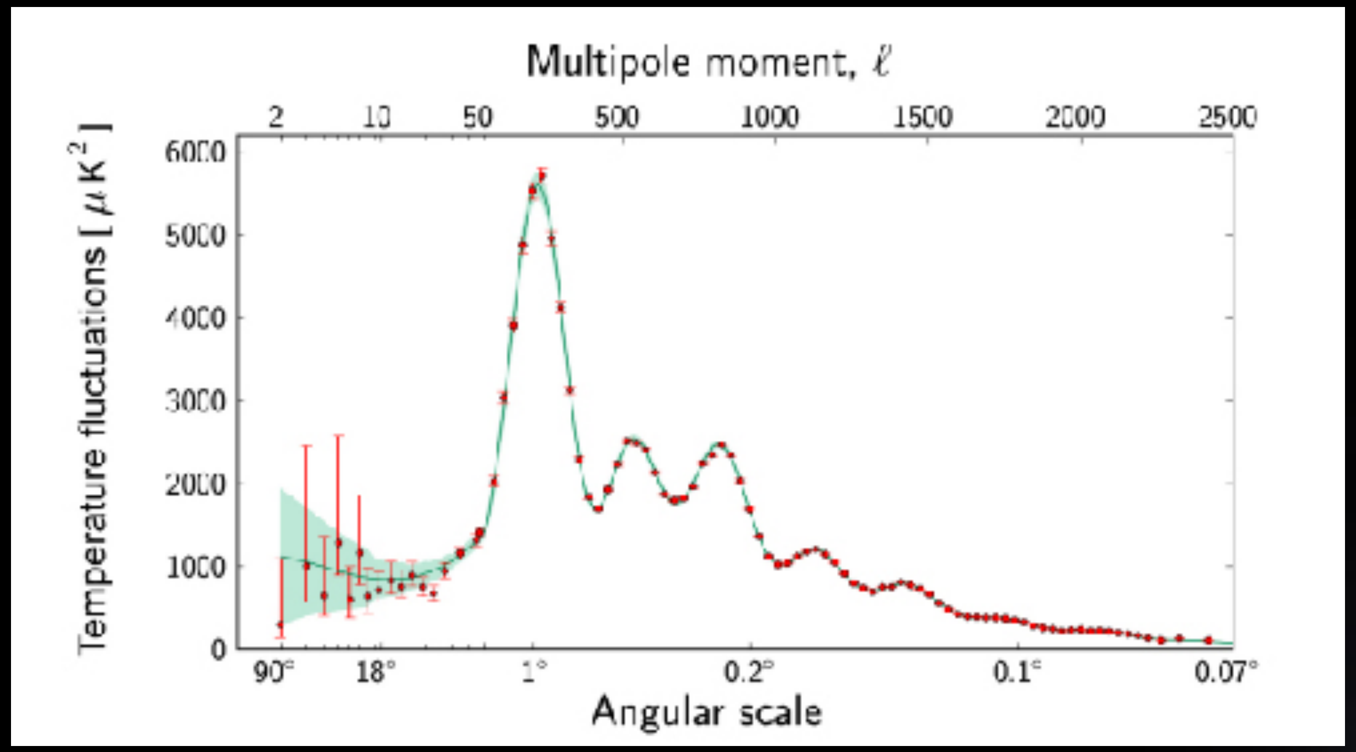

CO Intensity Mapping for Capturing
Star-formation History in the Early Universe

History of the Universe

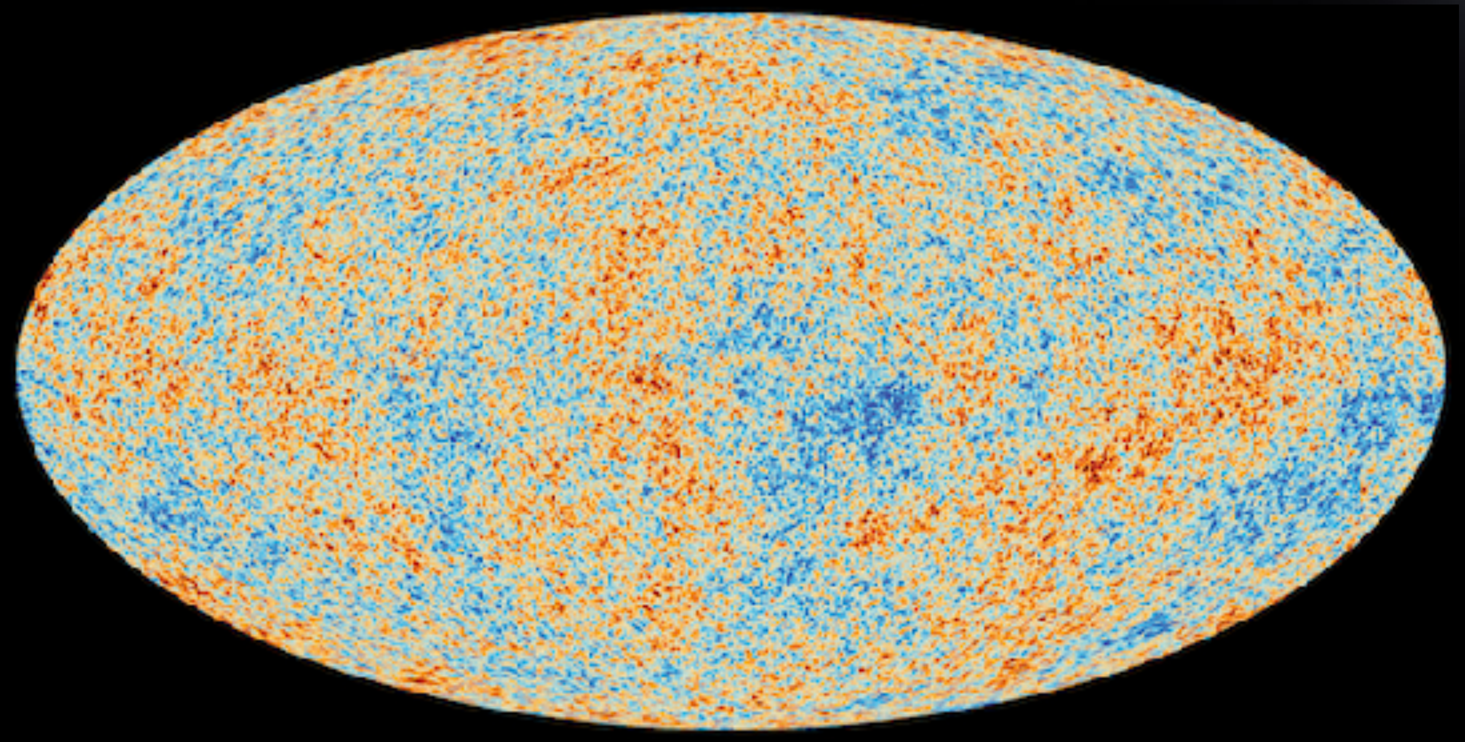


https://map.gsfc.nasa.gov/media/060915/index.html

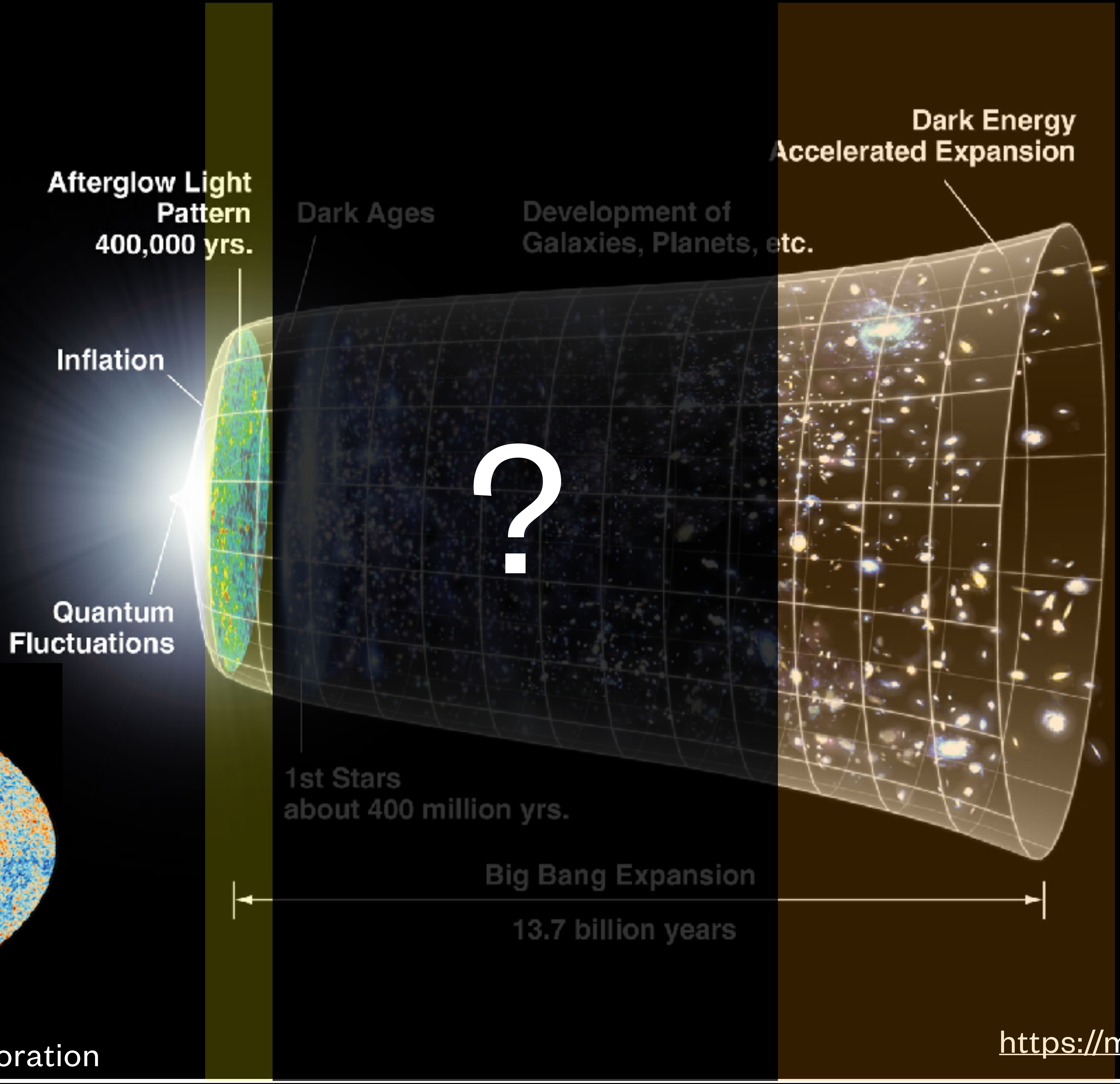
History of the Universe

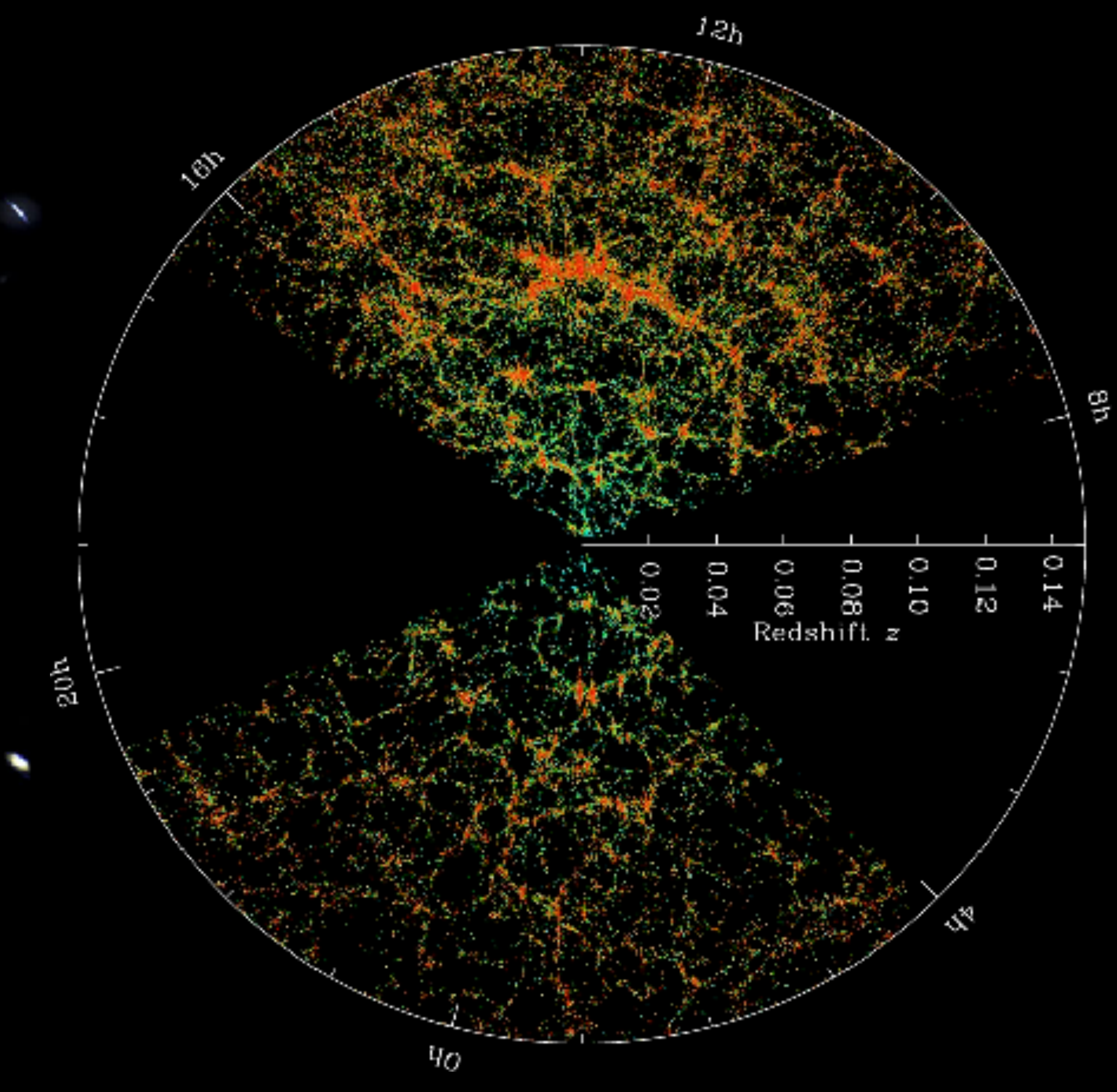


Cosmic Microwave Background (CMB)



ESA/Planck Collaboration





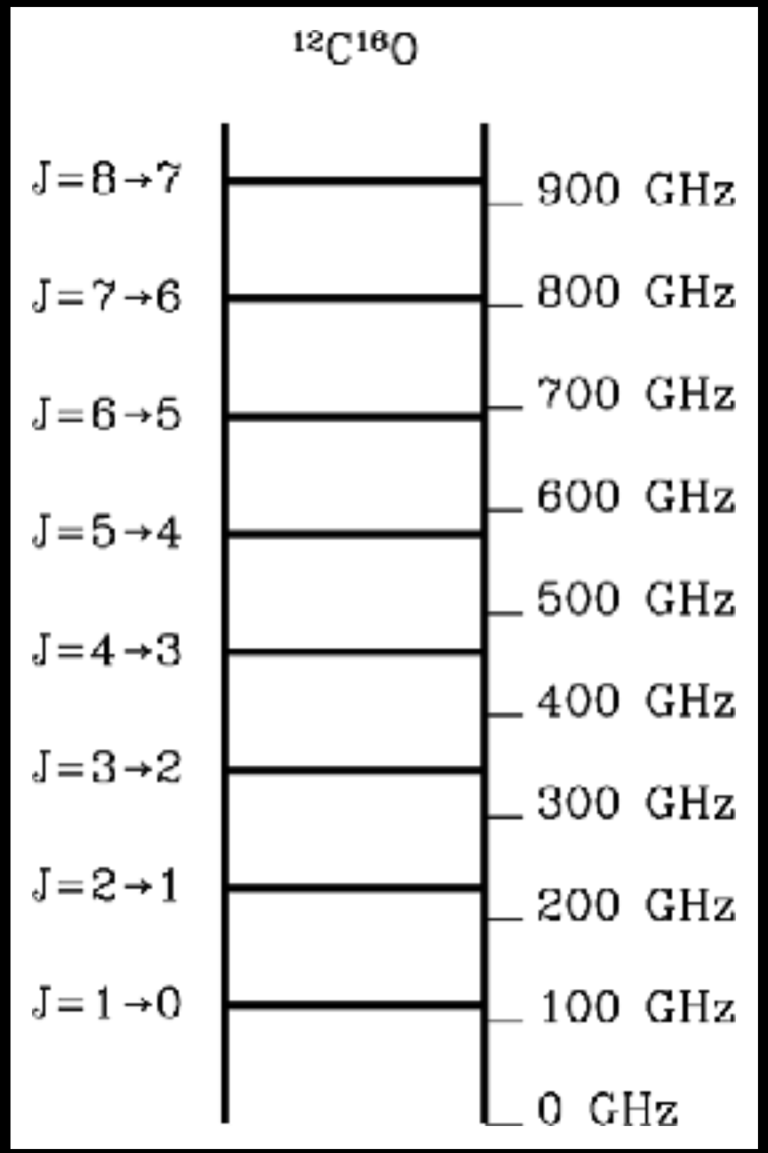
Galaxy surveys
z = 0-1+

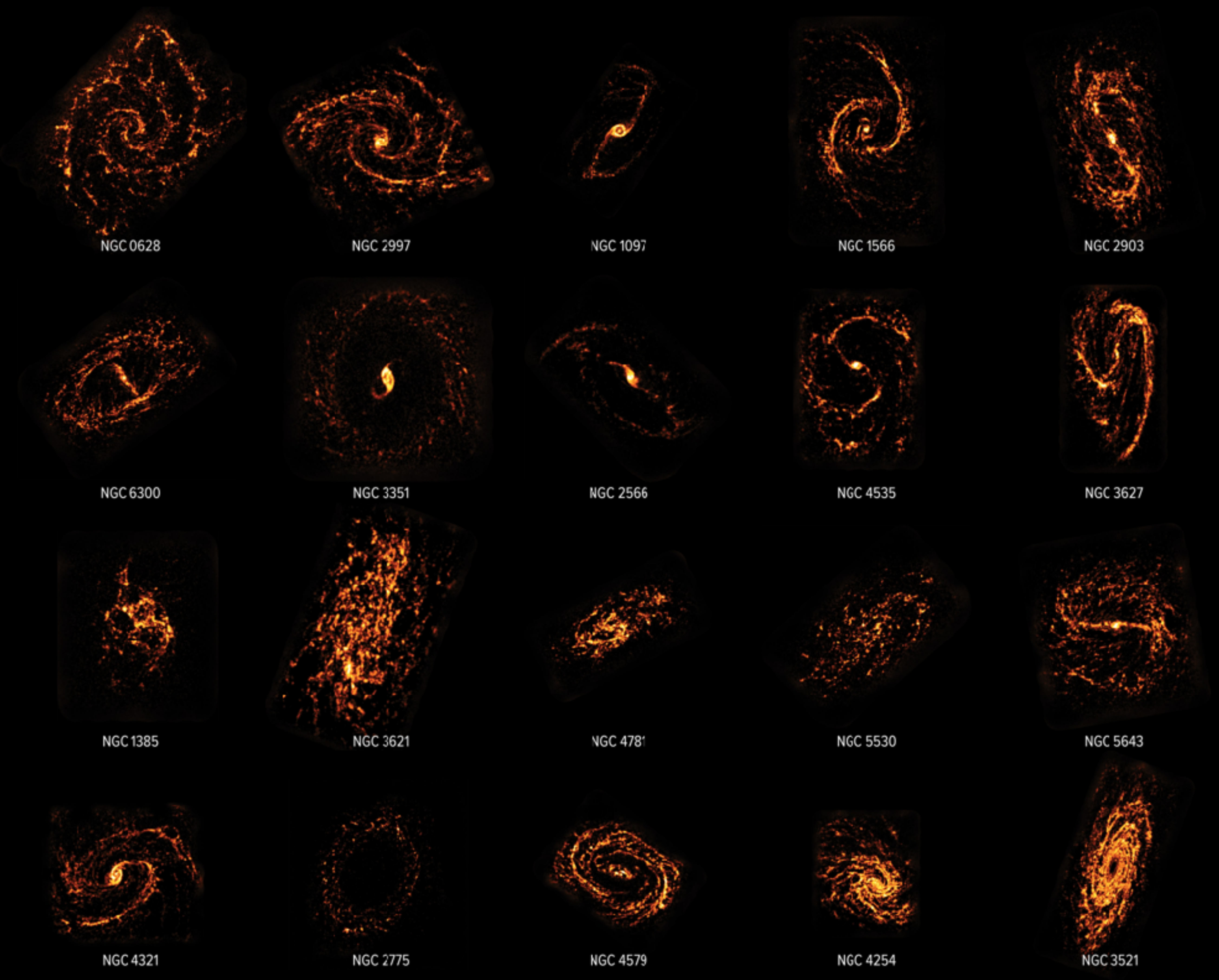
https://map.gsfc.nasa.gov/media/060915/index.html

KAIST Korea Advanced Institute of Science and Technology

Carbon Monoxide (CO)

- Tracer of cold molecular gas, the fuel for star formation.
- The second most abundant molecule in the gas phase.
- Line emissions at multiples of ~115 GHz.

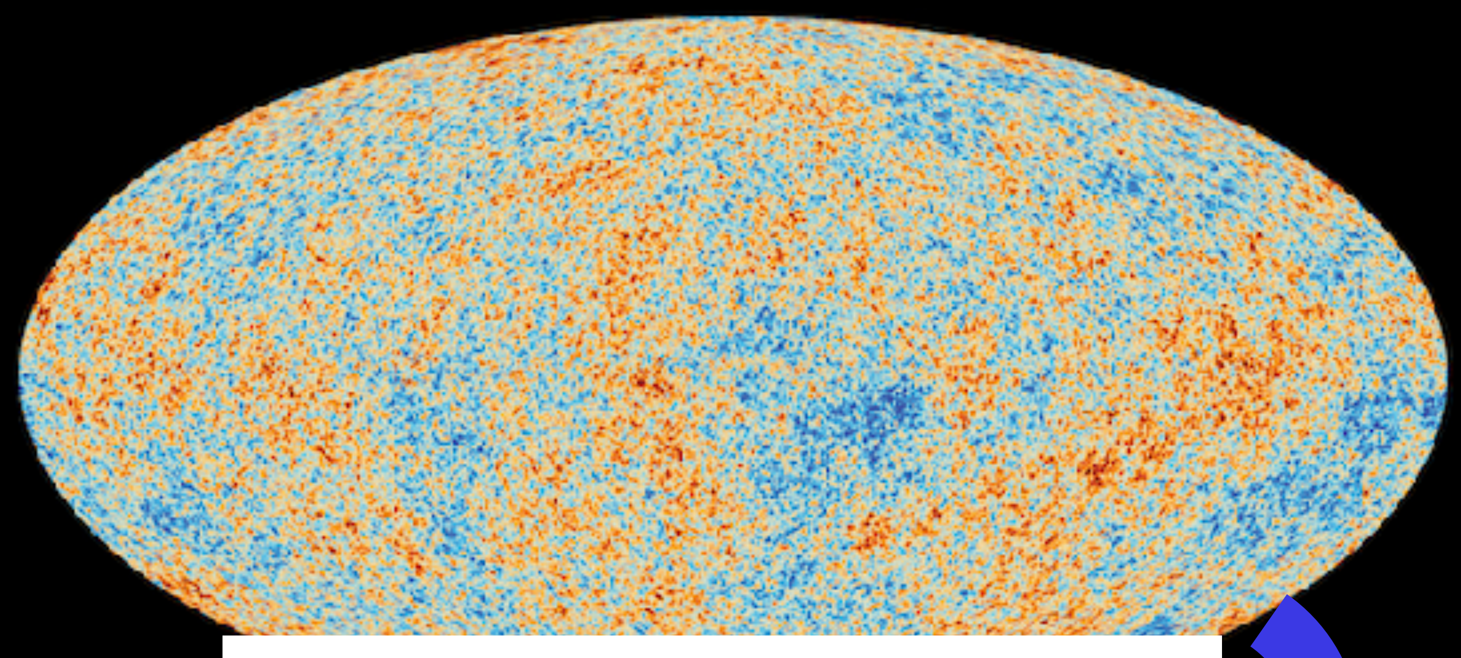




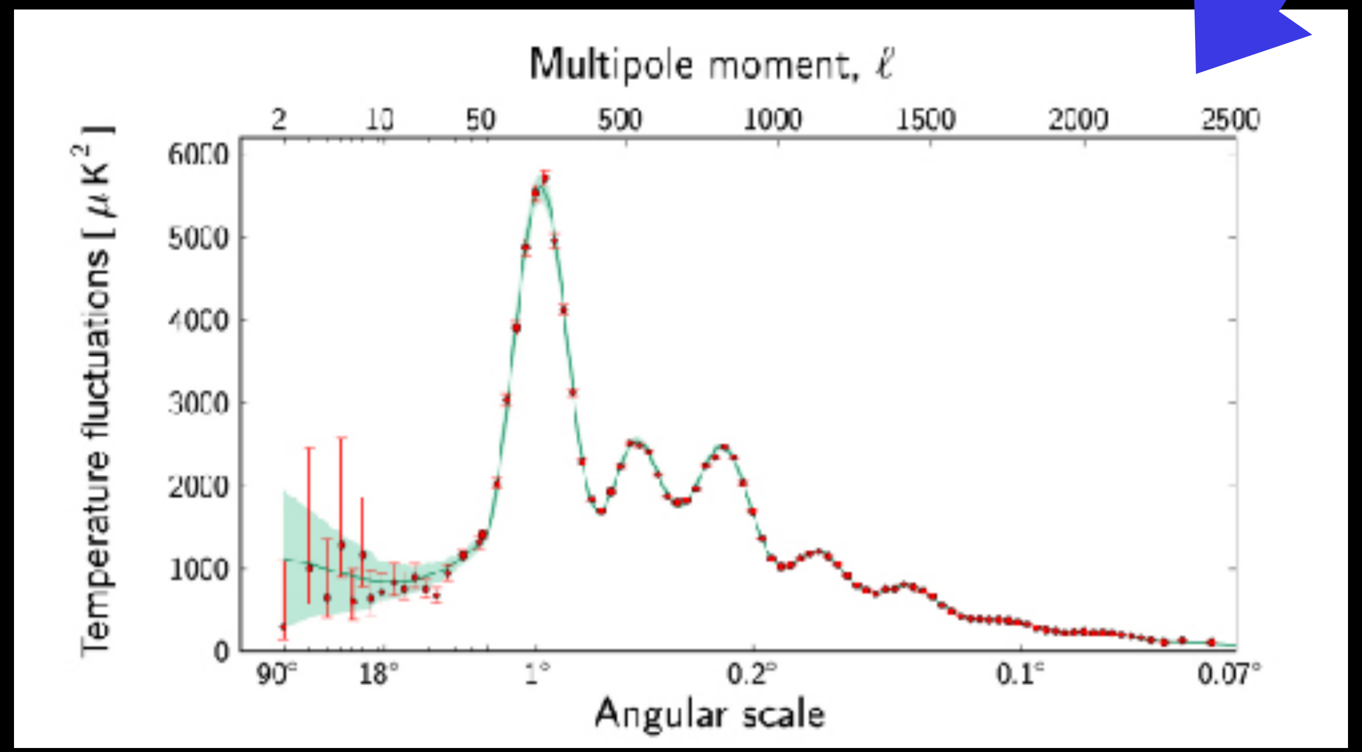
Credit: ALMA (ESO/NAOJ/NRAO)/PHANGS, S. Dagnello (NRAO)

Line Intensity Mapping (LIM)

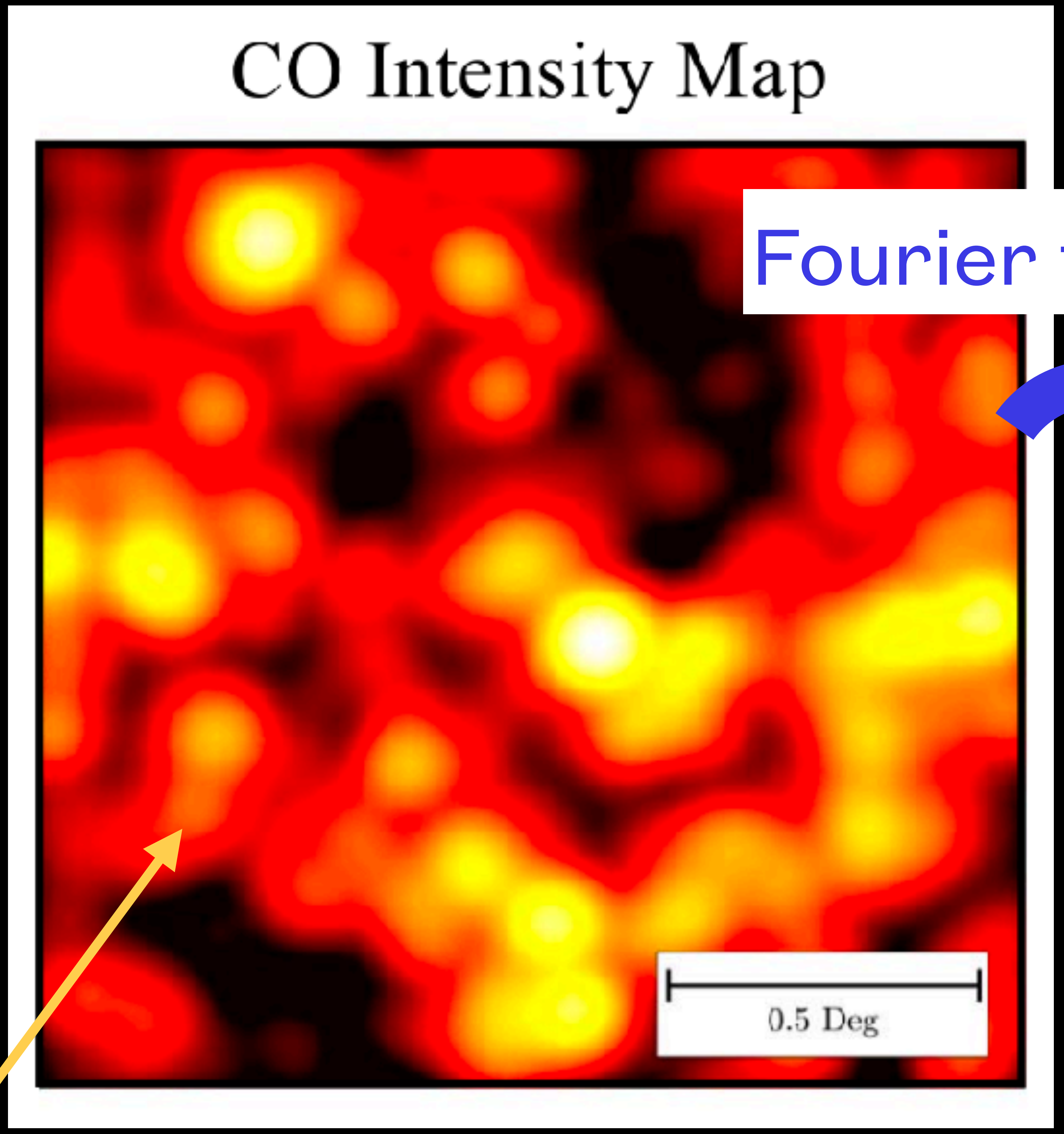
- LIM is sensitive to the "aggregate line emission from all galaxies in the line of sight".



Fourier transform

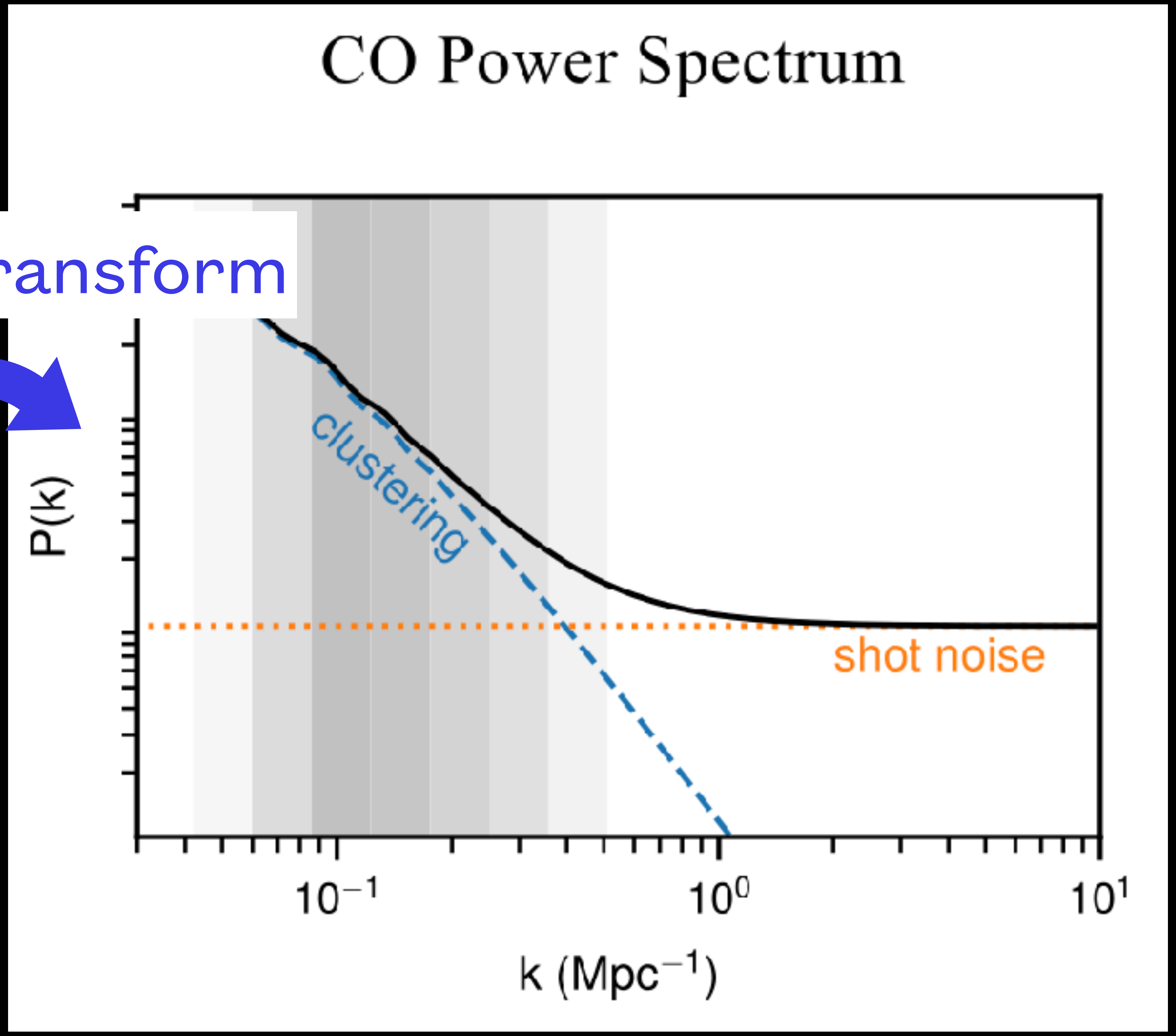


(convolved with ~5 arcmin beam)



all of the photons!

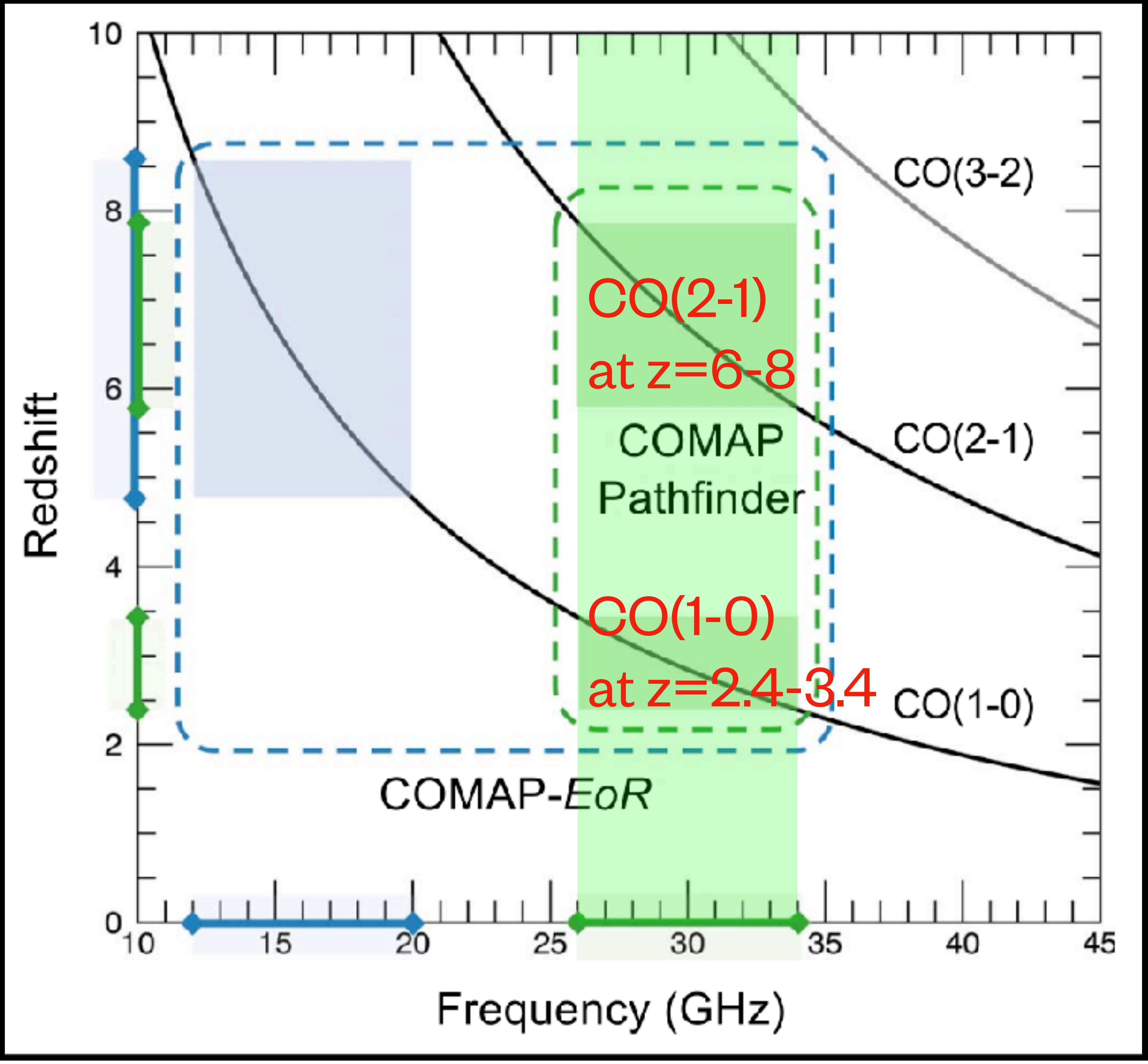
Fourier transform



Kovetz et al. (2017), Cleary et al. (2022), Credit: Patrick Breysse & Dongwoo Chung

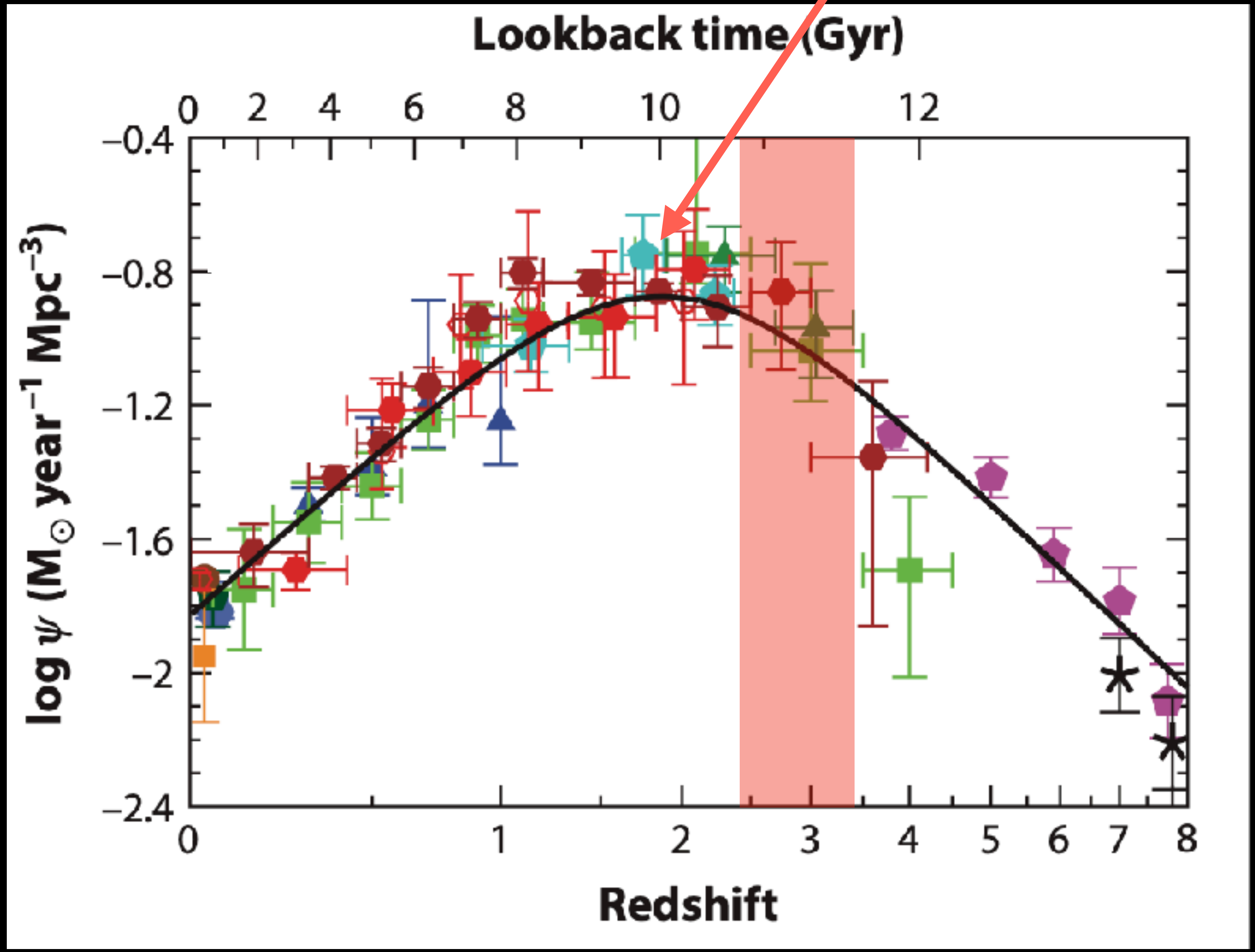
CO Mapping Array Project (COMAP)

- CO probes cold molecular gas, the fuel for star formation.



Cleary et al. (2022)

Peak of the
Star-formation History



Madau & Dickinson (2014)

KAIST Korea Advanced Institute of Science and Technology

CO Mapping Array Project (COMAP)

Caltech
Kieran Cleary (PI)
Delaney Dunne
Rick Hobbs
James Lamb
Timothy Pearson
Anthony Readhead
David Woody

NYU
Patrick Breysse

MANCHESTER 1824 The University of Manchester
Clive Dickinson
Stuart Harper

KAIST
Junhan Kim

UiO : Universitetet i Oslo
Ingunn Wehus
Hans Kristian Eriksen
Jonas Lunde
Nils-Ole Stutzer

UNIVERSITY OF MARYLAND
Andrew Harris

UNIVERSITY OF MIAMI
Joshua Gundersen

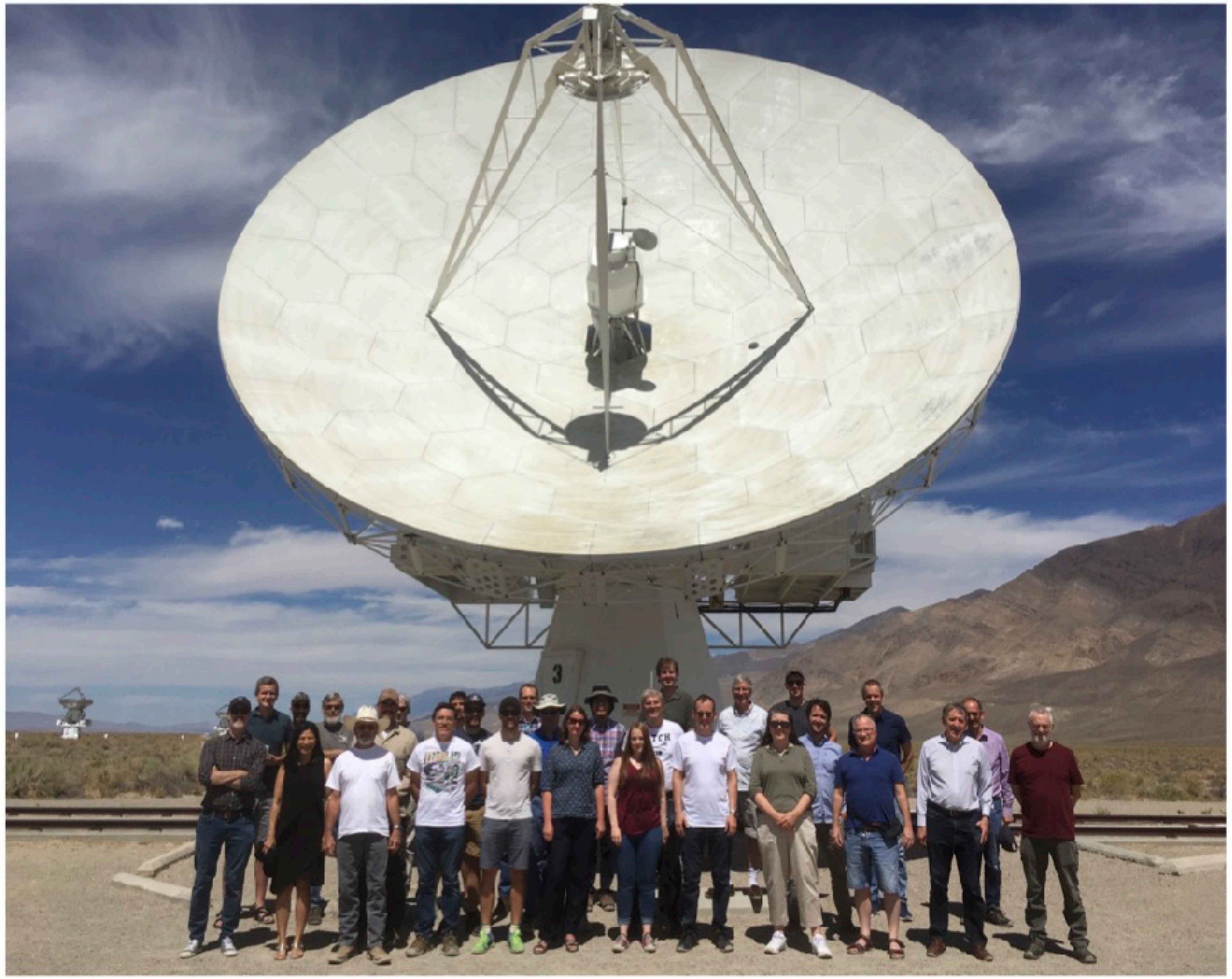
Stanford
Sarah Church
Risa Wechsler

CITA ICAT
Richard Bond
Dongwoo Chung
Norman Murray

JPL Jet Propulsion Laboratory, California Institute of Technology
Charles Lawrence
Todd Gaier
Brandon Hensley
Joseph Lazio

UNIVERSITÉ DE GENÈVE
Hamsa Padmanabhan

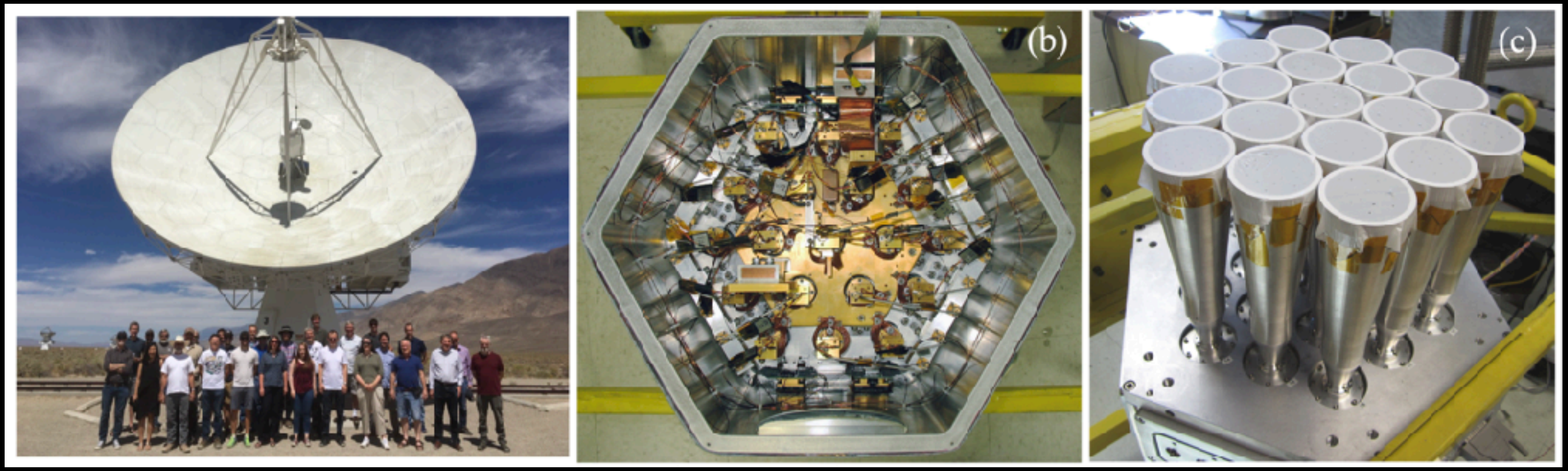
UBC THE UNIVERSITY OF BRITISH COLUMBIA
Thomas Rennie



https://comap.caltech.edu/team.html#

COMAP Pathfinder

- Site: Owens Valley Radio Observatory (OVRO), CA
- Telescope: “Leighton” dish (10.4 m)
- Receiver: 26-34 GHz (z=2.4-3.4)
  - 19-pixel, single-polarization focal plane array
- Backend digitization
  - 38 ROACH2 spectrometers, 2 MHz resolution



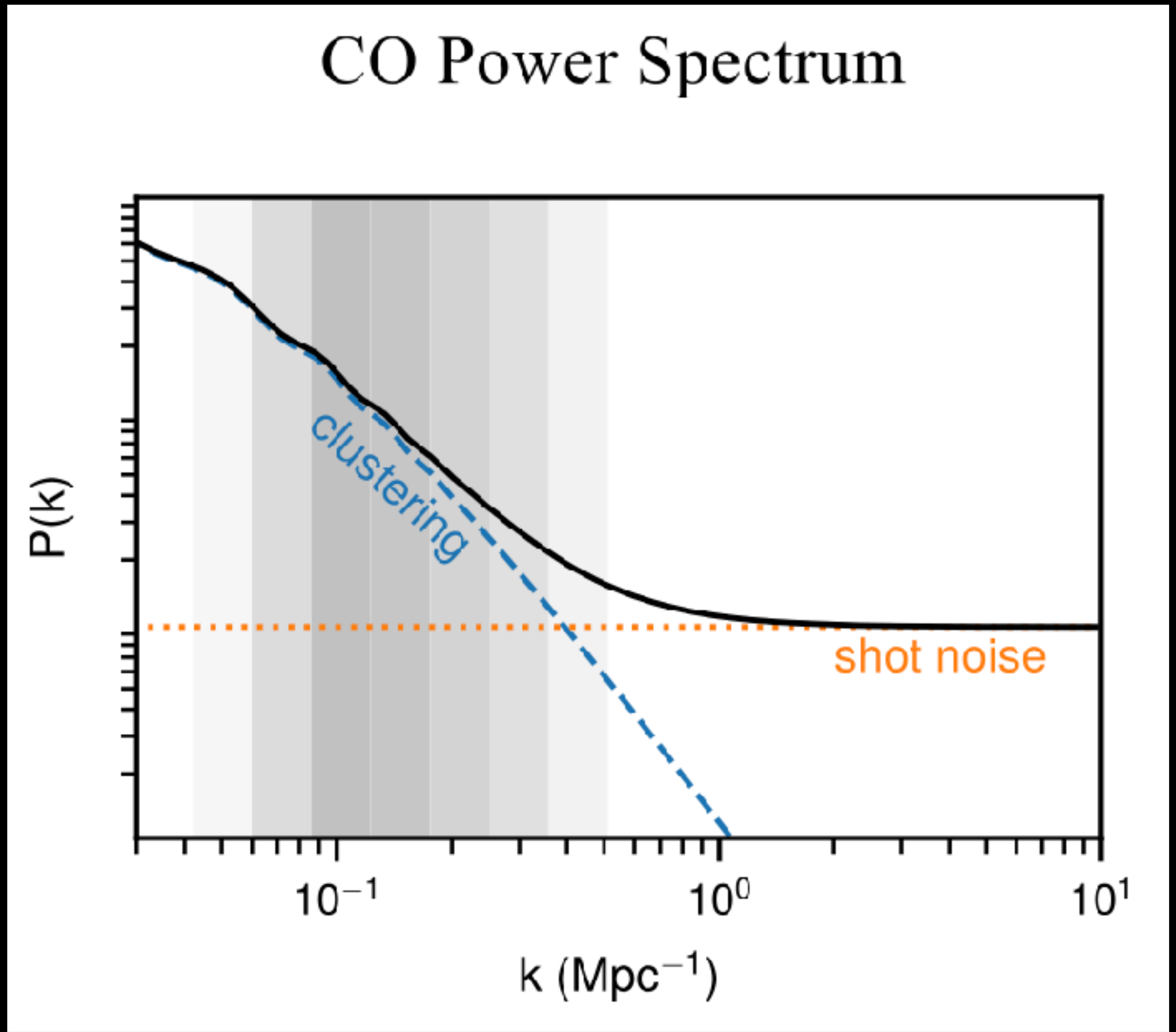
Cleary et al. (2022)

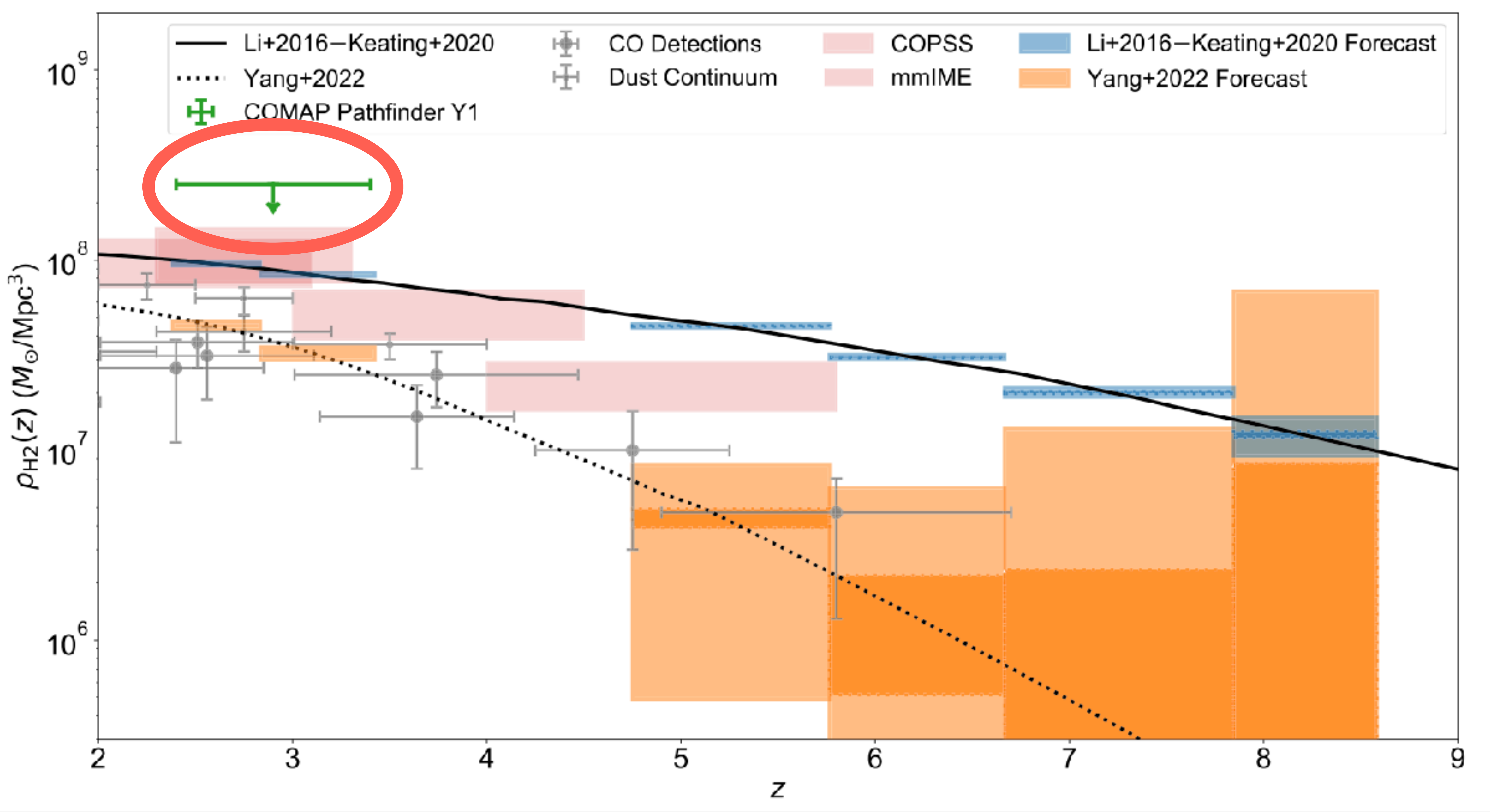
COMAP Pathfinder: Season 1 Results

$$\frac{L'_{\mathrm{CO}}(M_h)}{\mathrm{K\,km\,s^{-1}\,pc^2}} = \frac{C}{(M_h/M)^A + (M_h/M)^B}$$

Cleary et al. (2022), Chung et al. (2022)

COMAP Pathfinder: Season 1 Results





Clustering amplitude × (Underlying matter power spectrum) + shot noise

$$\langle T_{CO} \rangle < 3.6\mu K \xrightarrow{\alpha_{CO}} \rho_{H_2} < 2.5 \times 10^8 M_\odot \text{ Mpc}^{-3}$$

(mean CO temperature) (molecular gas abundance)

COMAP Early Science Papers (2022)

THE ASTROPHYSICAL JOURNAL

Focus on Early Science Results from the CO Mapping Array Project (COMAP)

Editor: Professor Christopher Conselice

PI: Kieran Cleary, California Institute of Technology

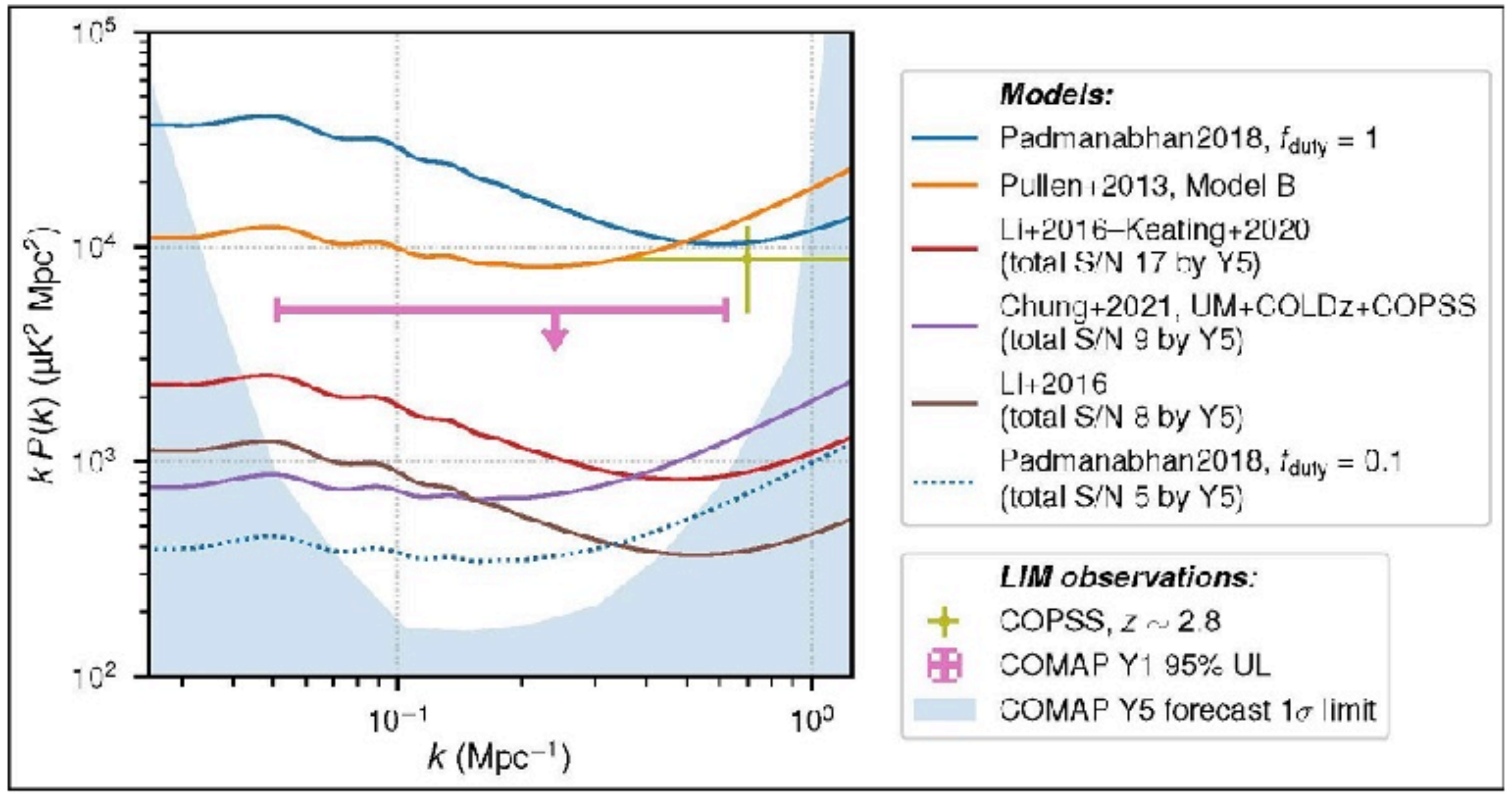


Figure 1. COMAP Pathfinder Season 1 constraint (pink) on the redshift-space CO(1–0) power spectrum at $z \sim 3$, alongside the predictions from various models and our Year 5 Pathfinder sensitivity forecast (blue shaded area). The models include (i) the fiducial COMAP data-driven model from Chung et al. (2021) ("UM+COLDz+COPSS"), (ii) an alternative model from Keating et al. (2020) ("Li+2016–Keating+2020") with emission from faint galaxies that may be missed by the surveys informing the fiducial model, and (iii) models based on $L(M_h)$ relations from Padmanabhan (2017), Pullen et al. (2013), and Li et al. (2016). Also shown is the result from another CO LIM experiment, COPSS, that targeted the shot-noise component of the power spectrum (Keating et al. 2016). For each, the legend indicates the expected signal-to-noise ratio with which we would reject the null hypothesis (i.e., excluding sample variance from the calculation).