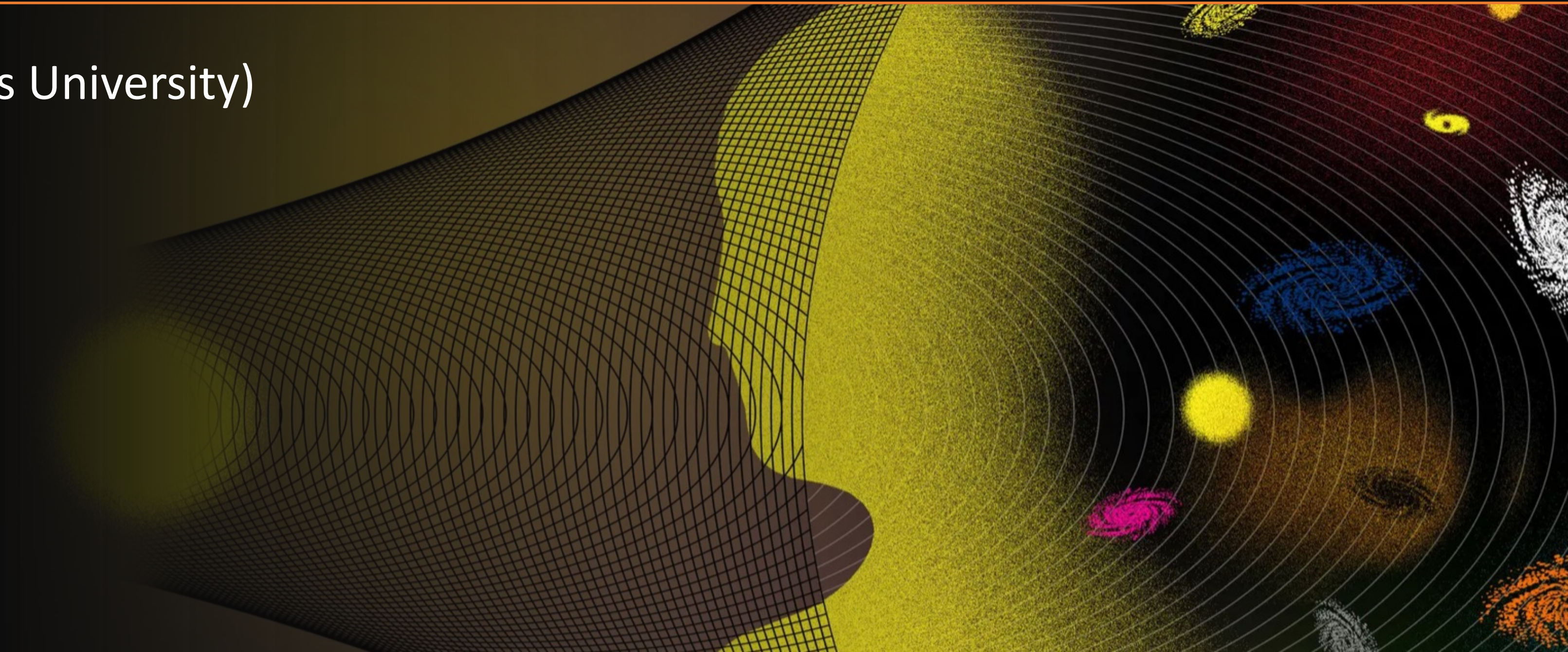
Line-Intensity Mapping (and kSZ tomography) and dark matter

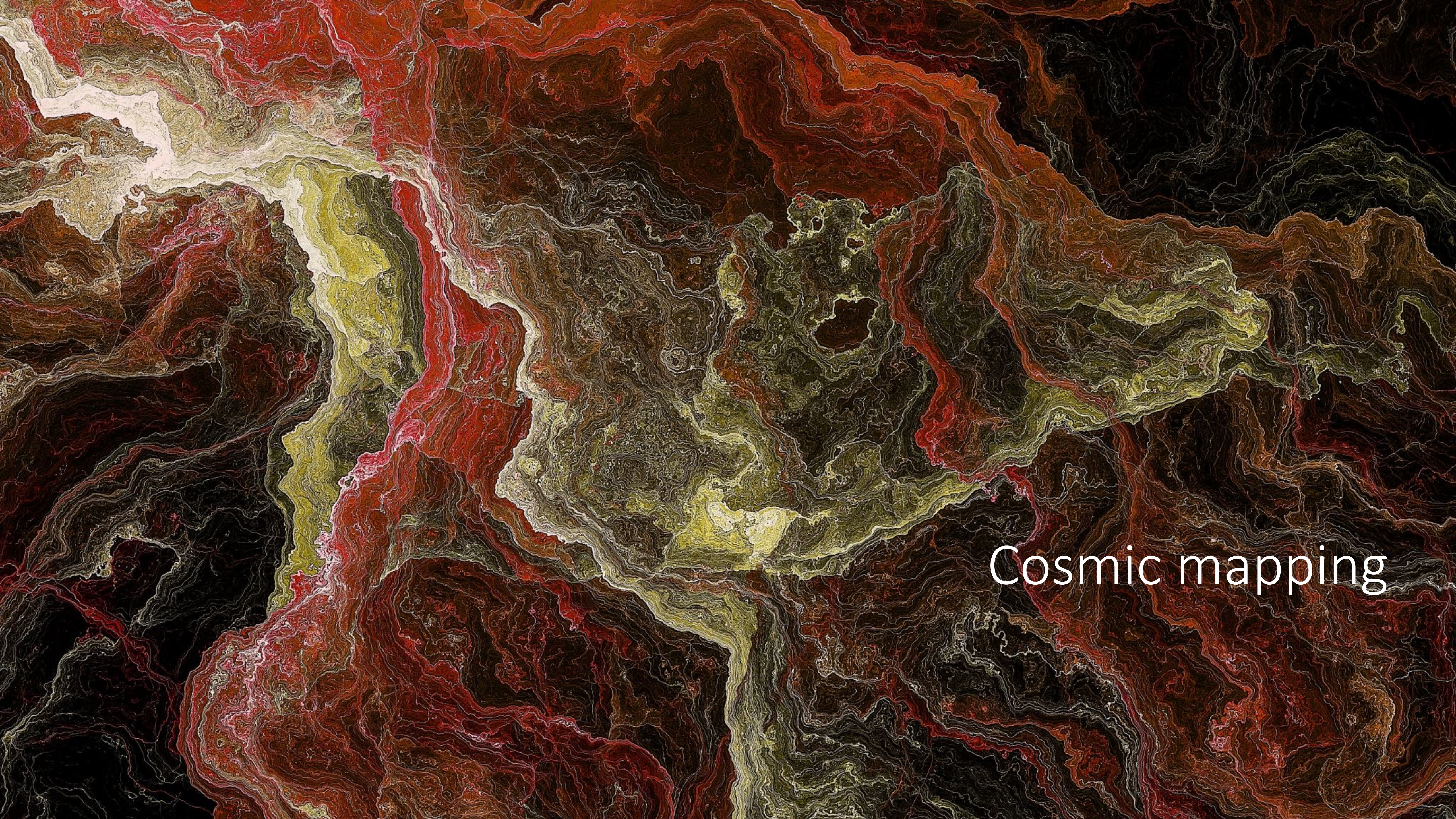
Marc Kamionkowski (Johns Hopkins University)

7 June 2022

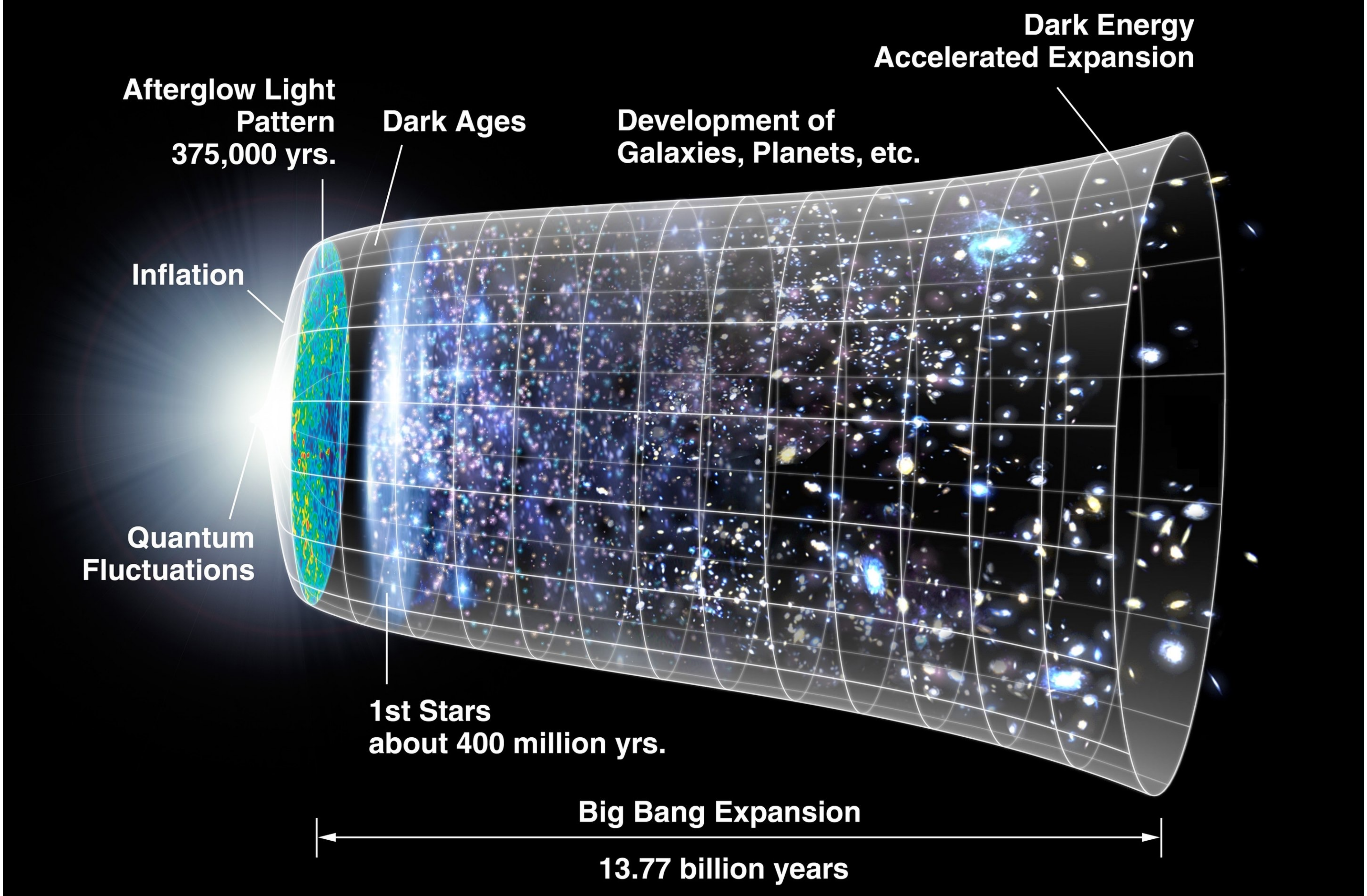


Outline

- CMB, galaxy surveys, and cosmology
- Line-intensity mapping
- kSZ (kinematic Sunyaev-Zeldovich) tomography

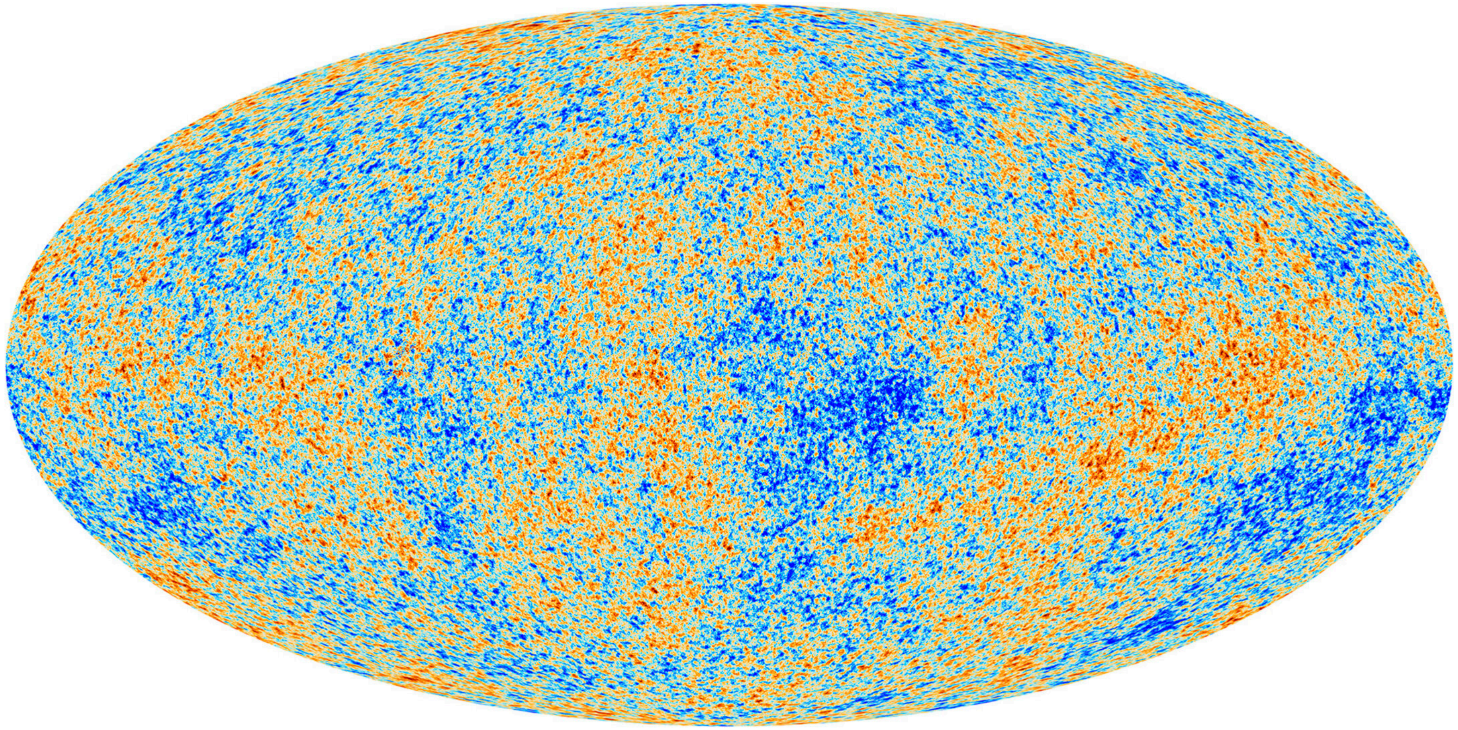


Cosmic mapping

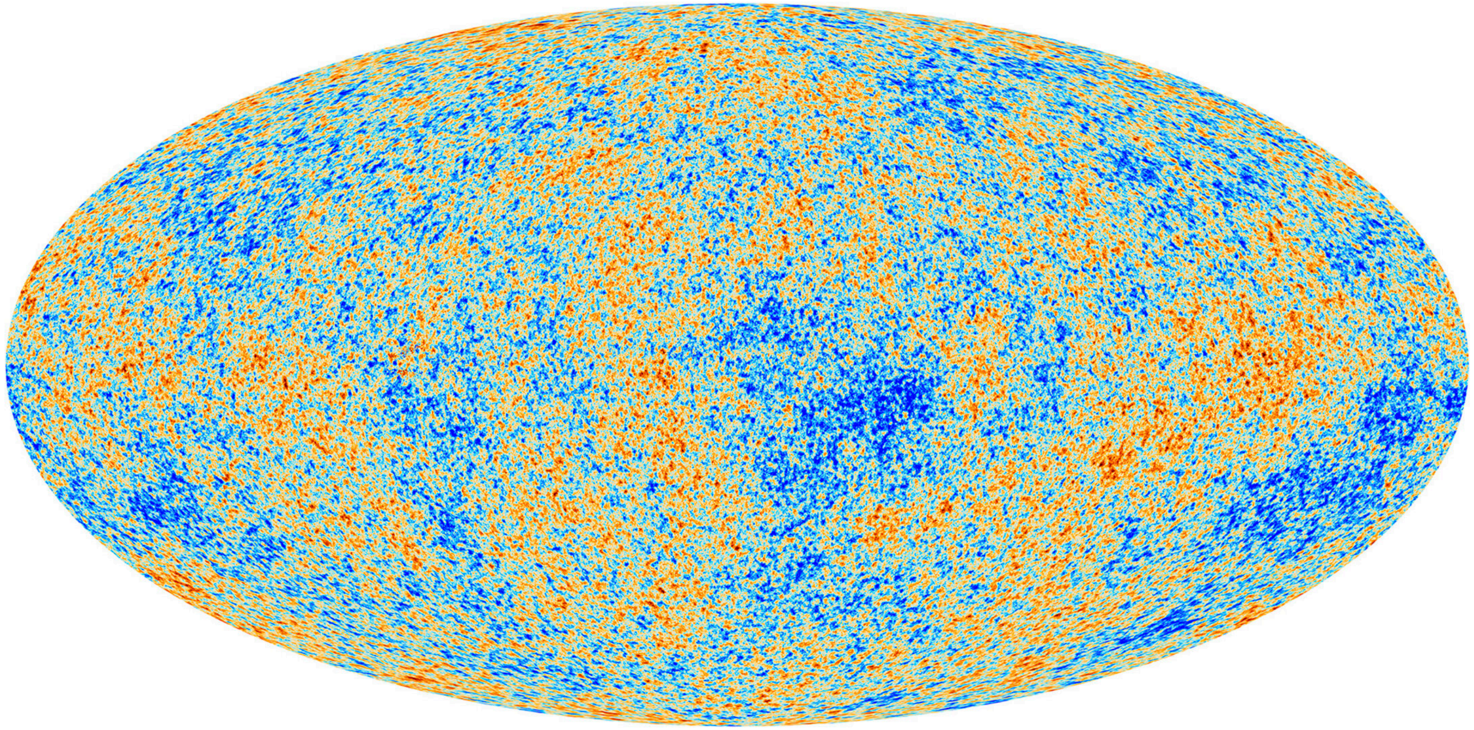

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

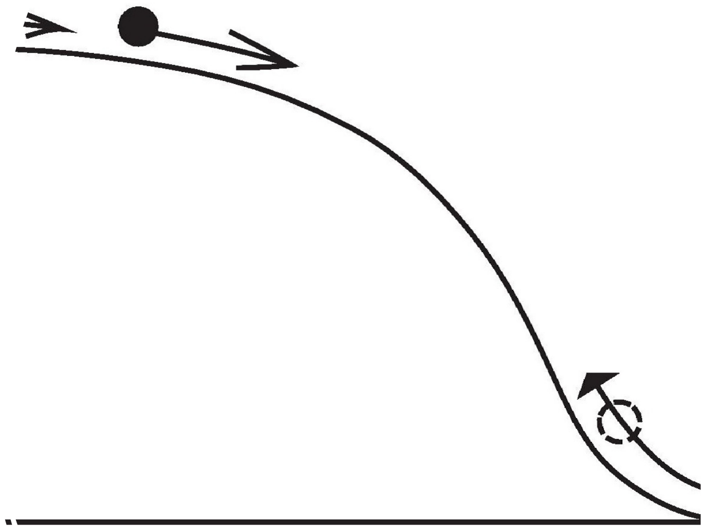
Cosmic microwave background (CMB)

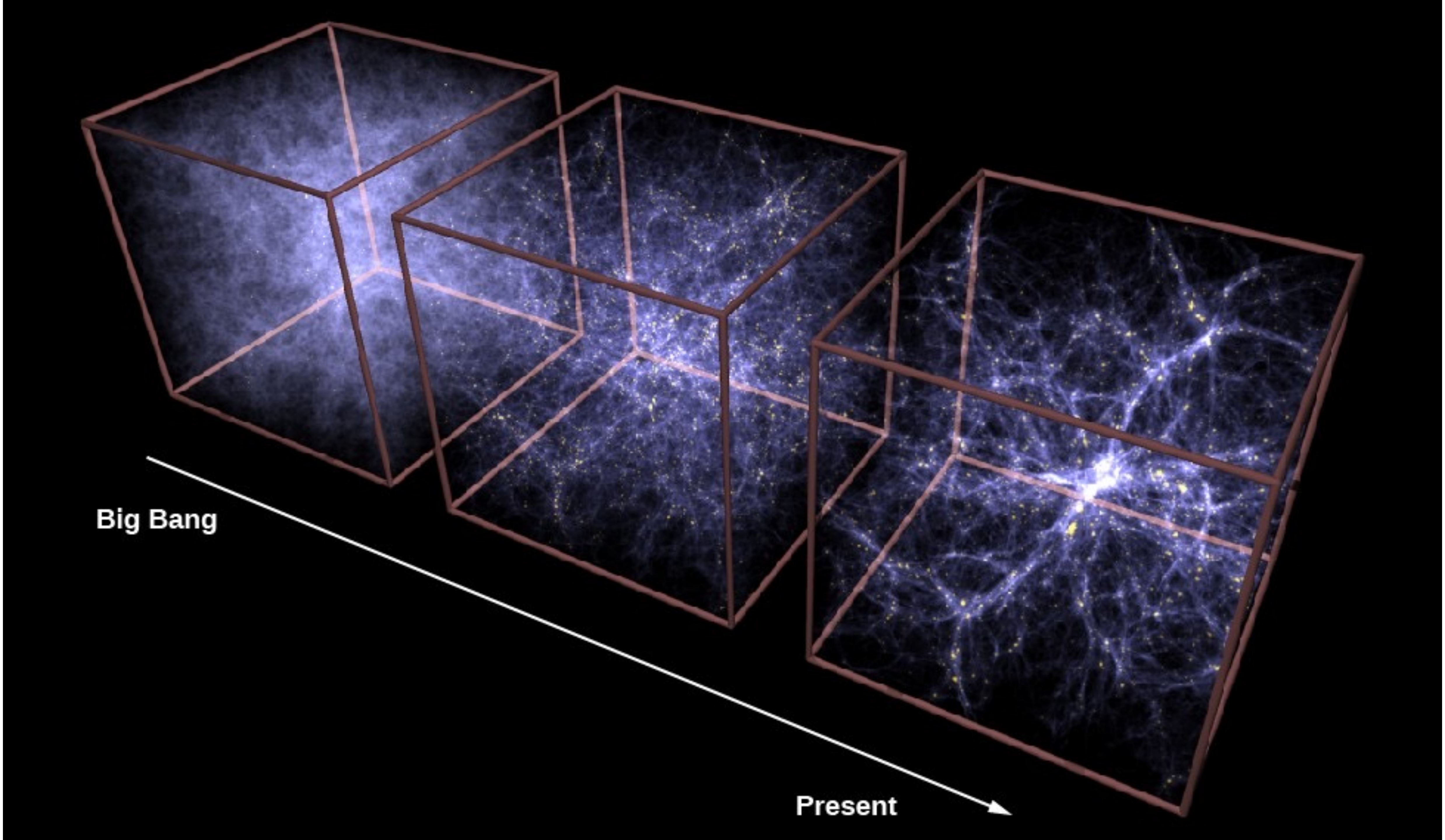
- Provides primordial perturbations
- Backlight for later Universe
  - Weak gravitational lensing
  - Sunyaev-Zeldovich (SZ) effect



Inflation






Big Bang
Present

Evolution of perturbations

- "Linear-theory growth factor": *D(z)*
  - dark energy
- Small-scale perturbations
  - Neutrino masses
  - ULAs (ultra-light axions)
- Baryon acoustic oscillations (BAOs) and redshift-space distortions (RSDs)
  - Anisotropy in clustering along/transverse to line of sight
    → dark energy, Hubble parameter, modified gravity

Cosmology and new physics

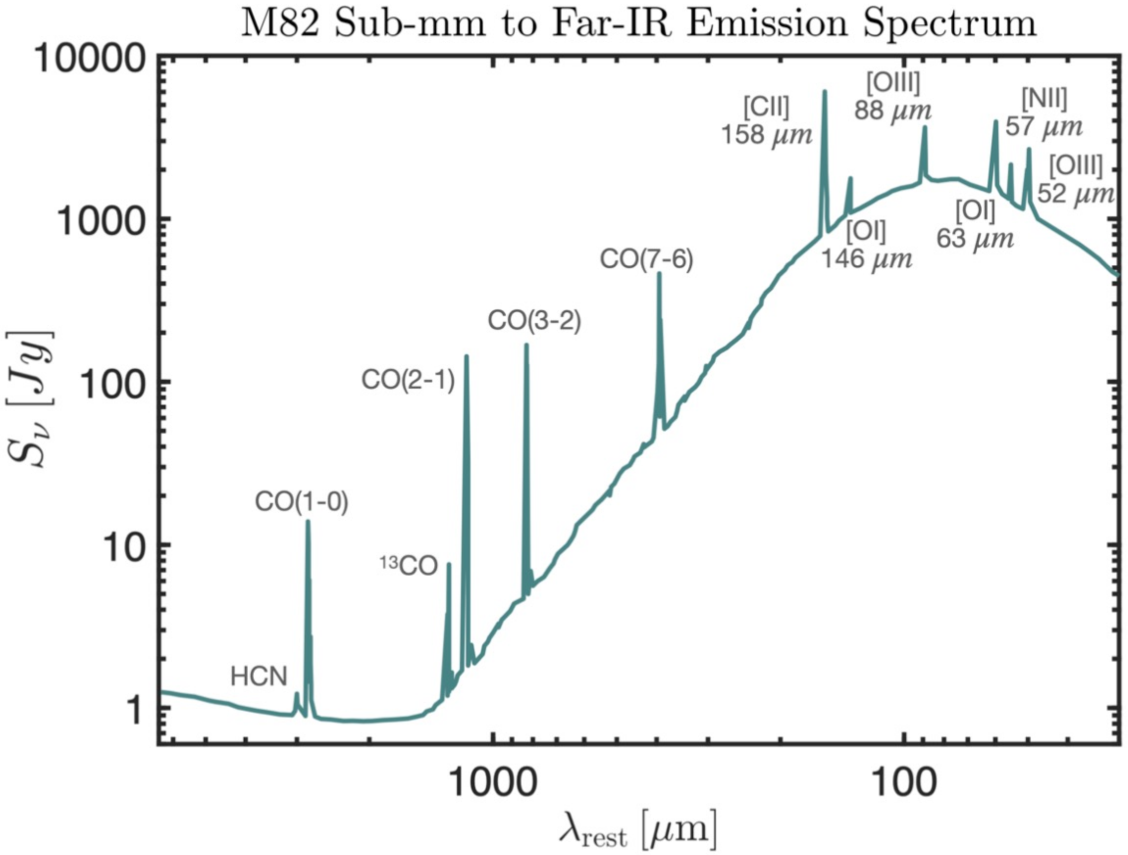
- Dark matter
- Dark energy
- Hubble tension and early dark energy
- inflation
- Neutrinos
- baryogenesis

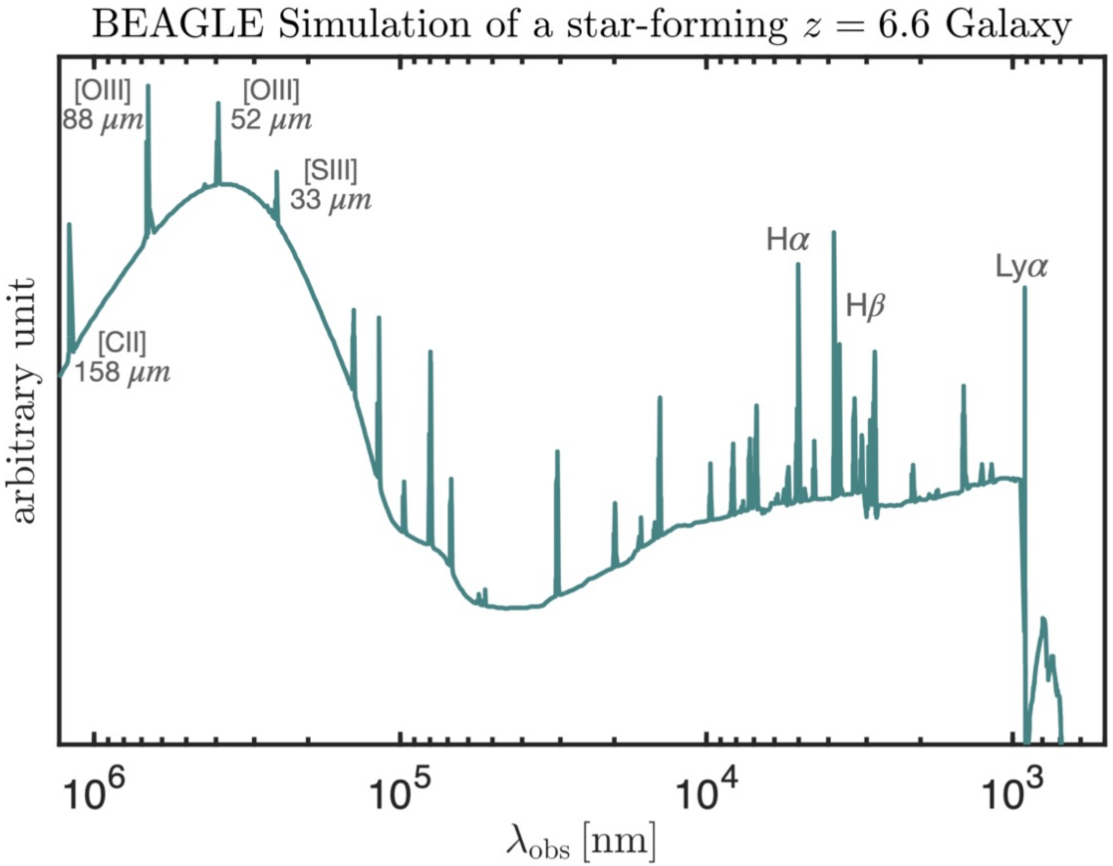
II. Line-Intensity Mapping

- New way to study large-scale structure
- LIM: use integrated light in given pixel on sky
- Information from all galaxies and IGM along LoS
- Use redshift of identifiable spectral line $\rightarrow$ 3D

Reviews/refs: Kovetz et al., 1709.09066; Bernal, Breysse, Gil-Marin, Kovetz, arXiv:1907.10067; *Bernal & Kovetz, in preparation*

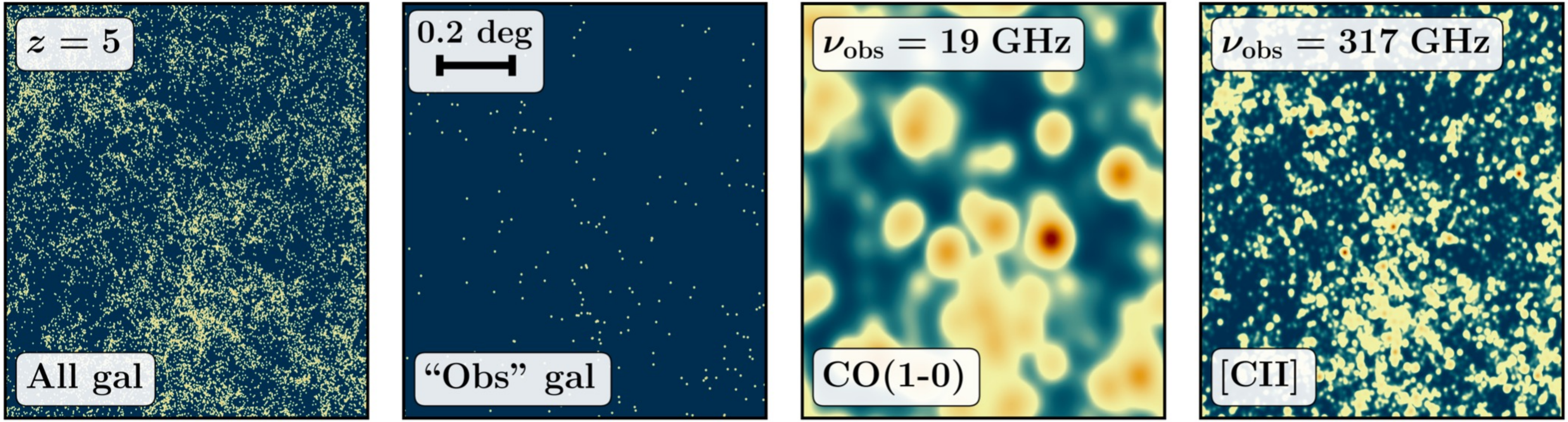
Emission lines



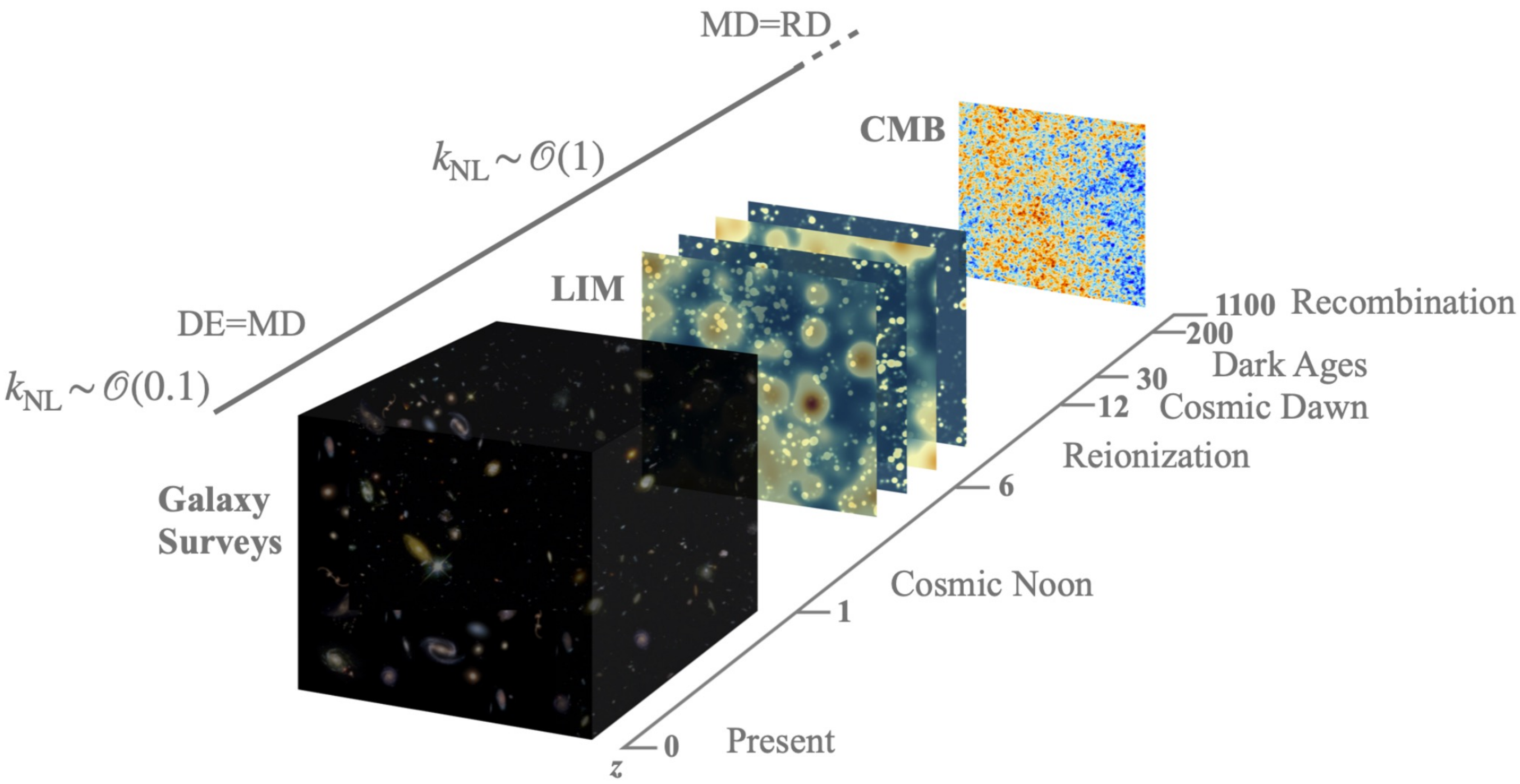


Galaxy surveys: detailed distribution of brightest galaxies

Intensity maps: noisy distribution of all galaxies and IGM

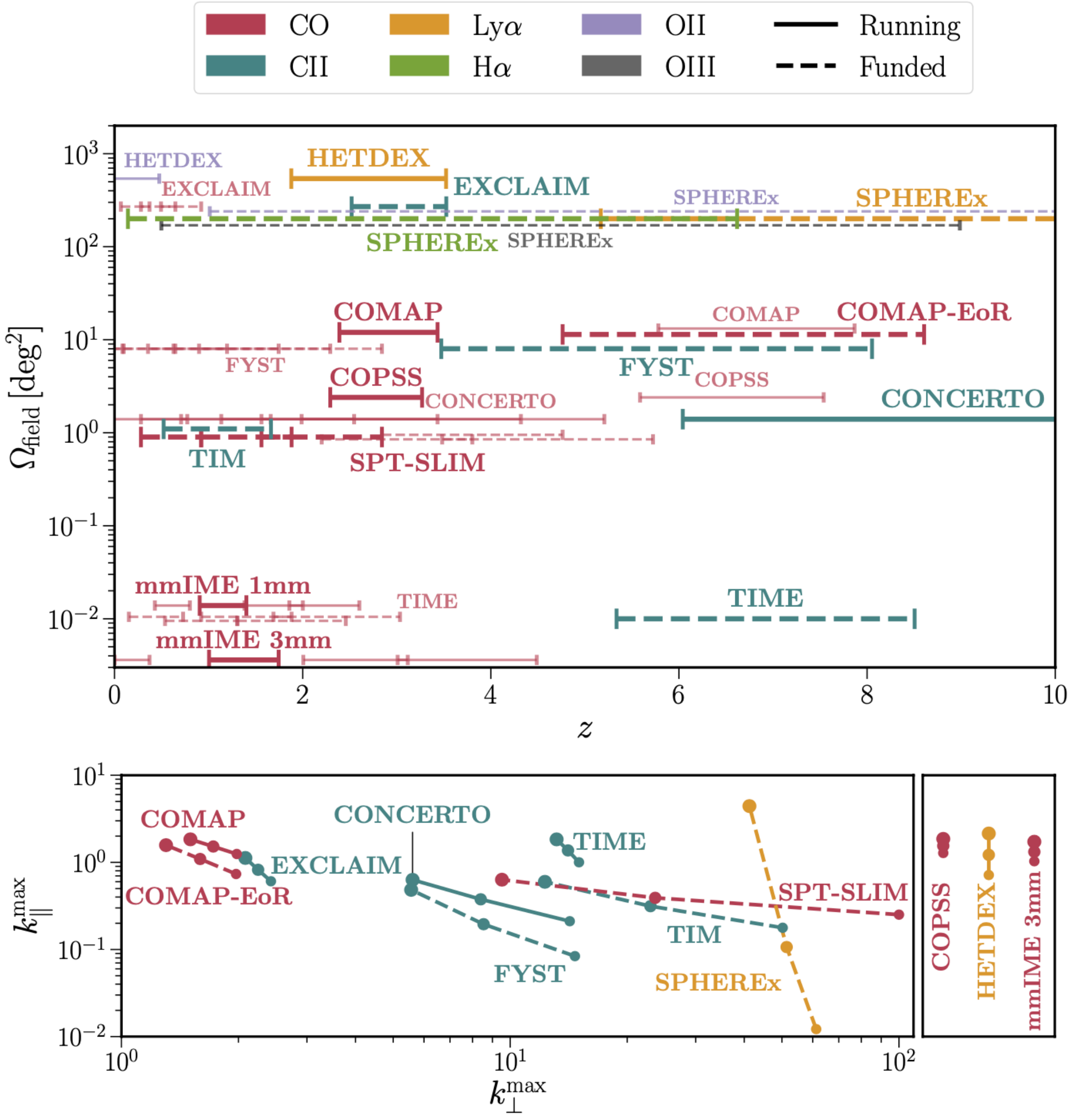


Probing the Universe



Probing the Universe with LIM

- Exciting experimental landscape!



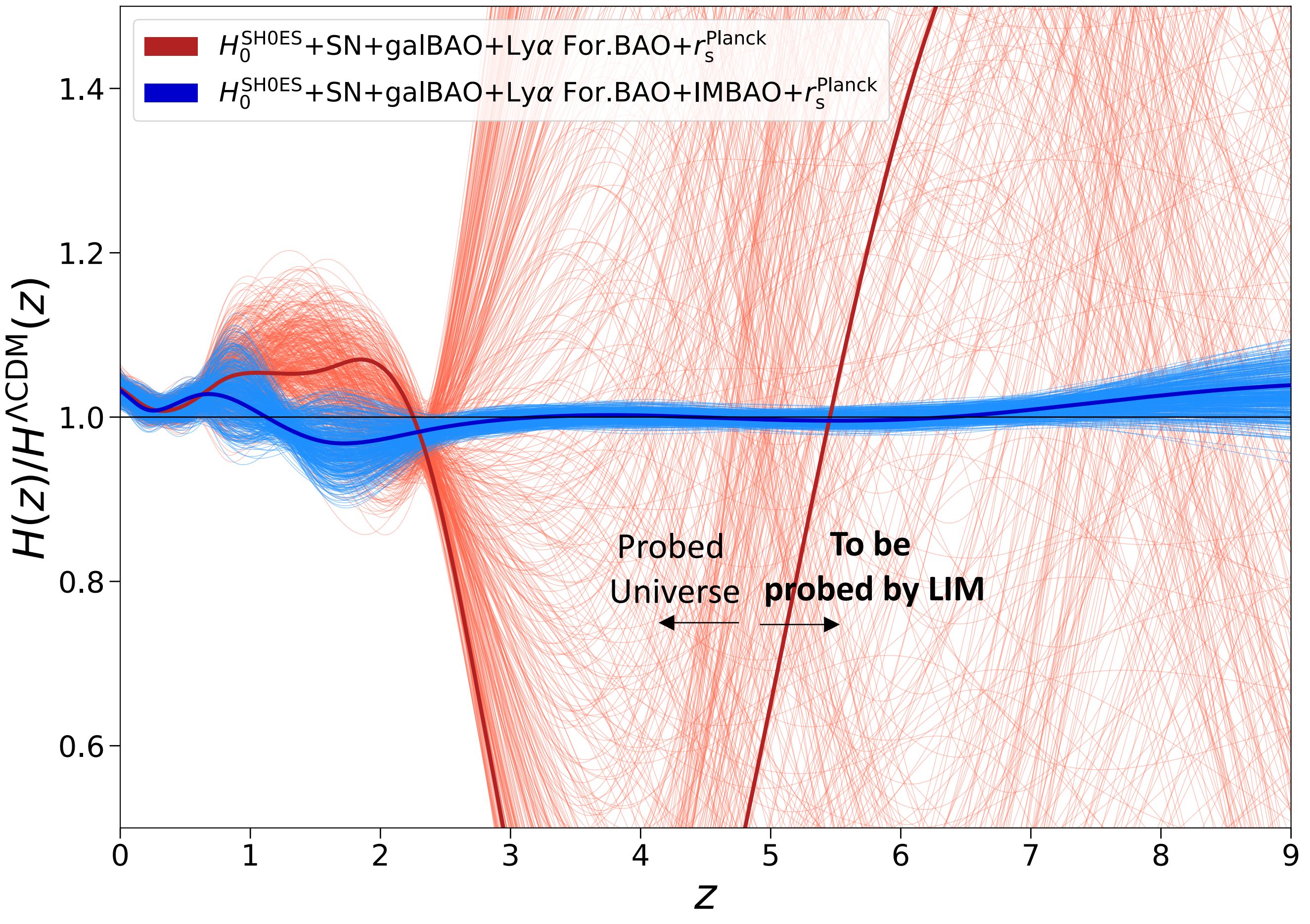
Probes LSS, extending galaxy-survey wavelength/redshift range

Dark energy

Inflation

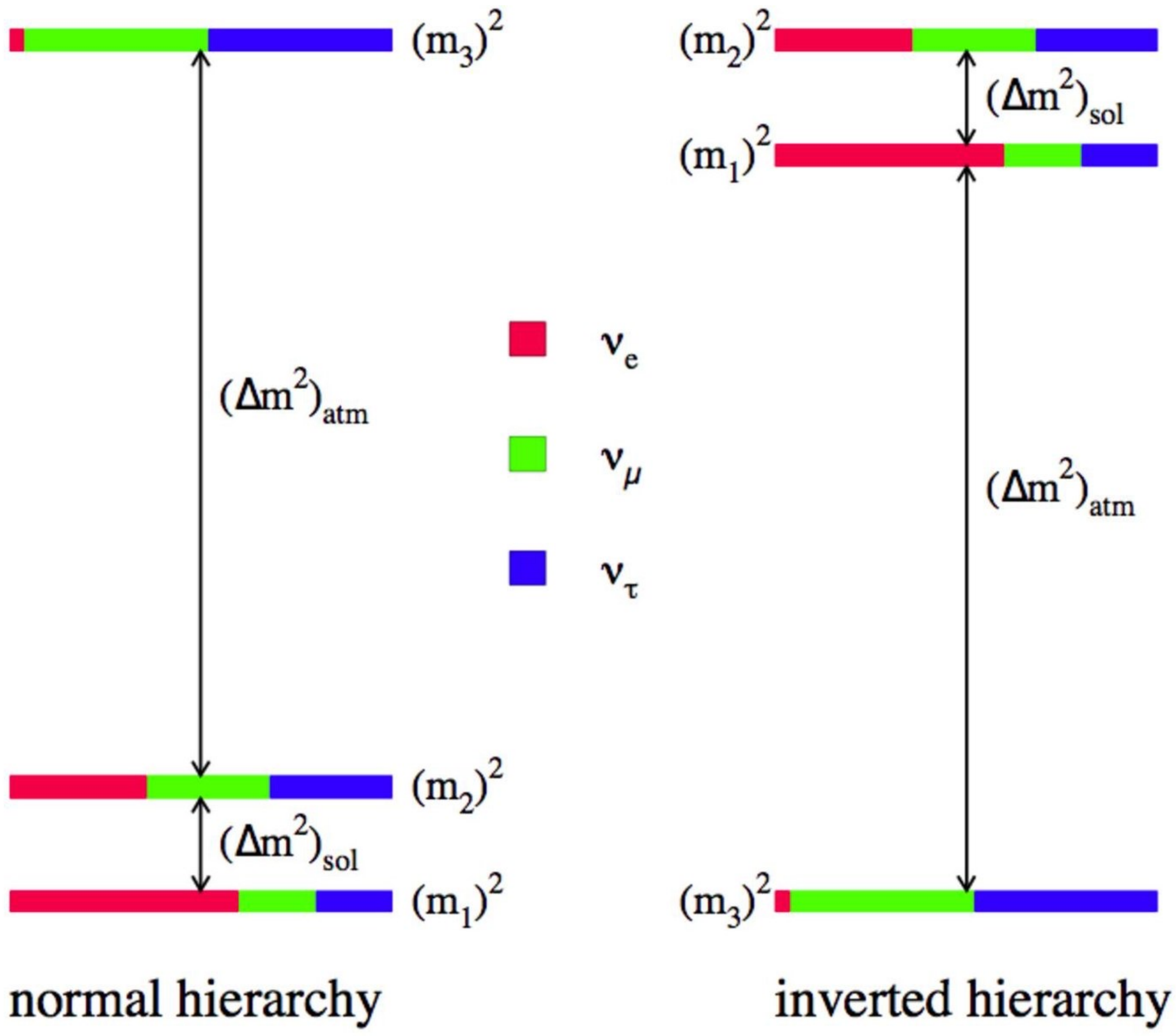
Dark-matter physics

Hubble tension: $H(z)$ beyond the reach of galaxy surveys



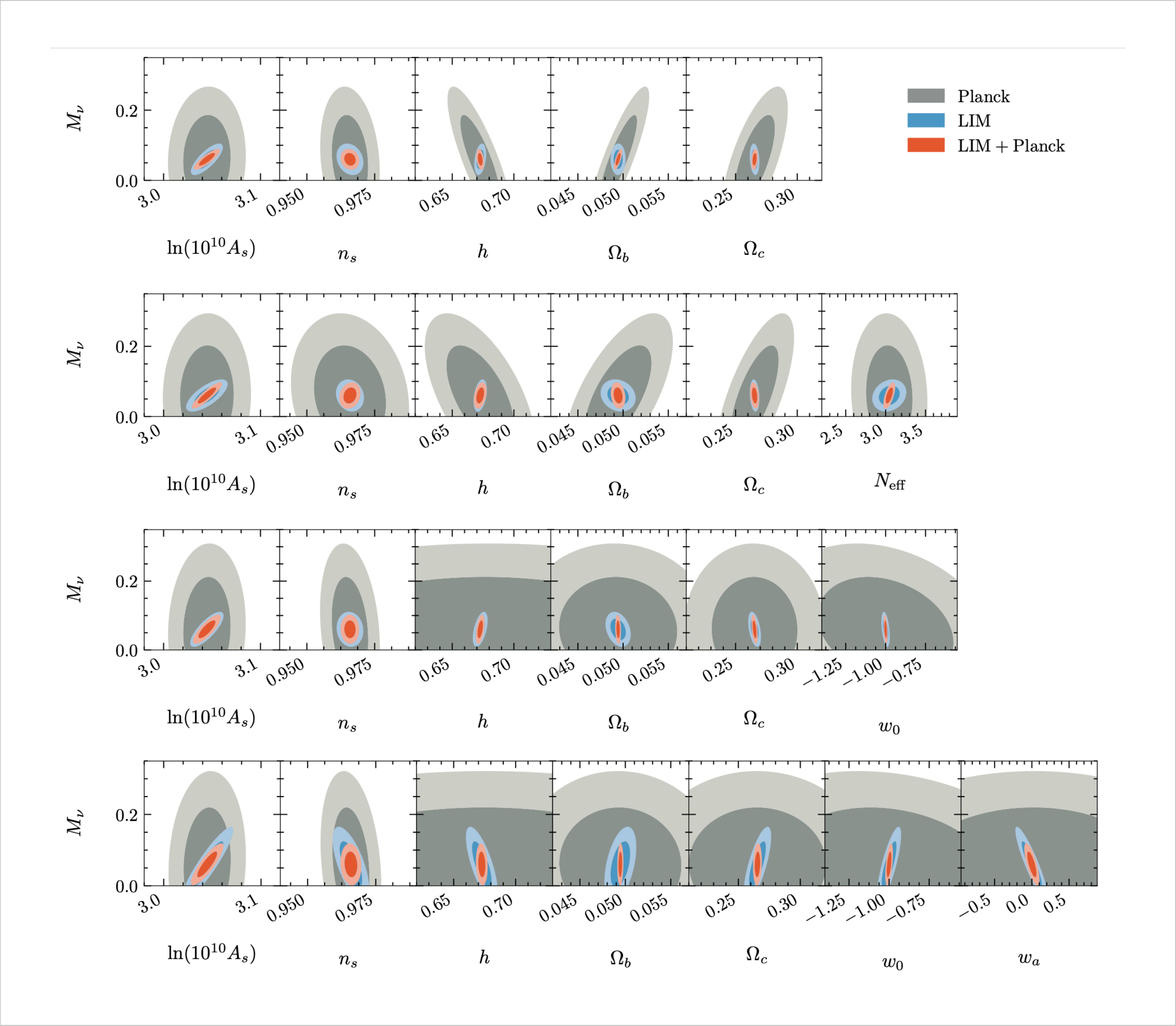
Bernal, Breysse, Kovetz 2019

Neutrino masses



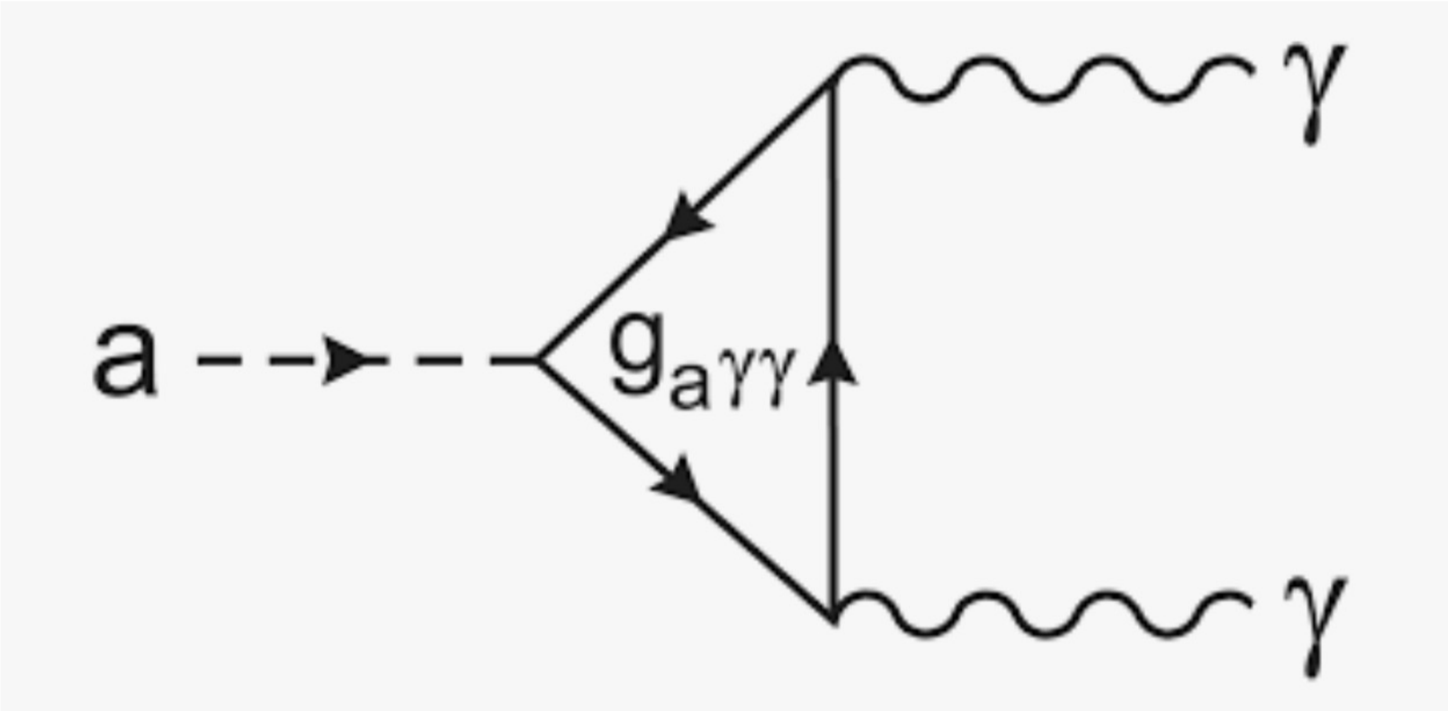
Neutrino masses:

- Dizgah et al., arXiv:2110.00014



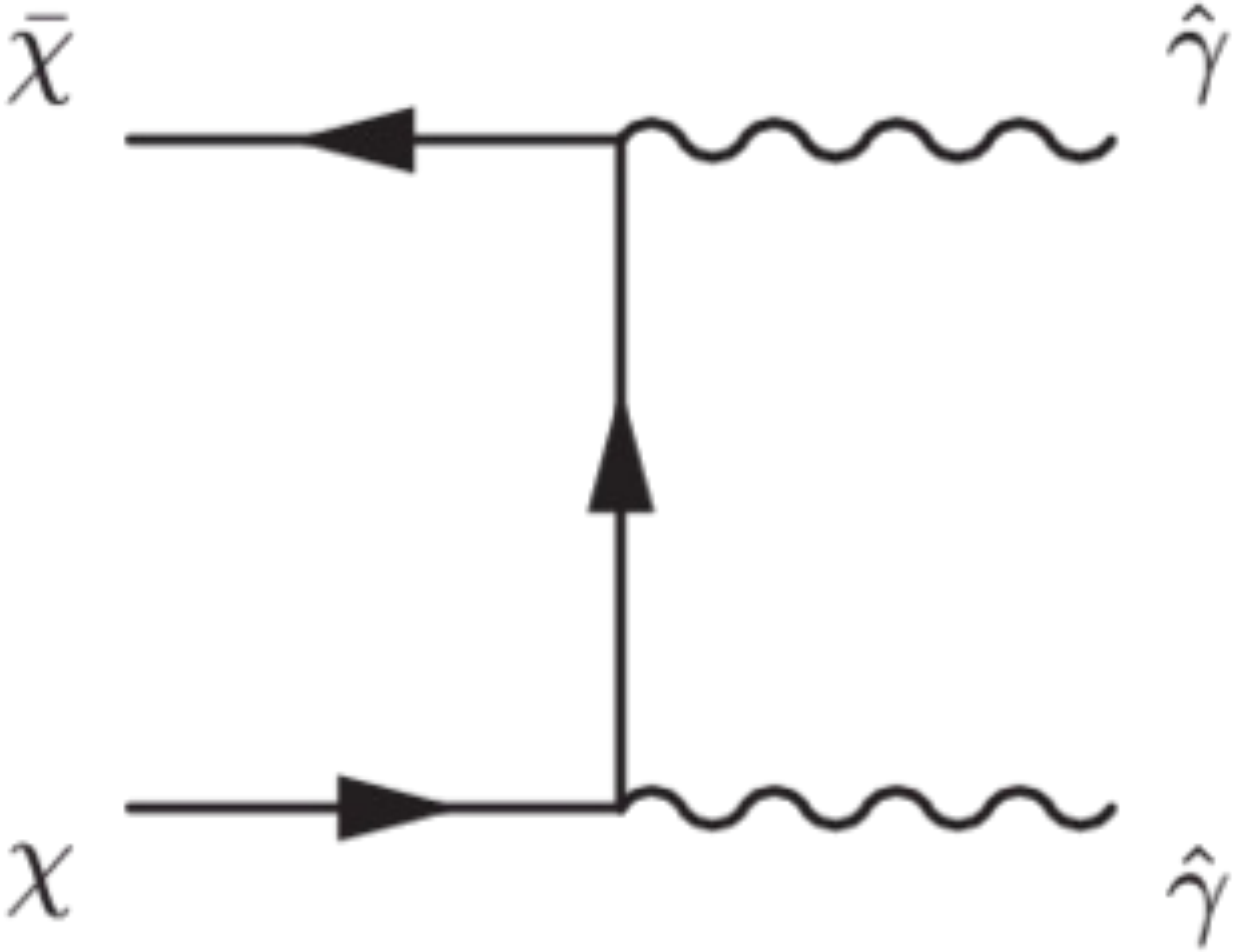
photon lines from radiative dark-matter/neutrino decay/annihilation

(Creque-Sarbinowski, MK 2018; Bernal, Caputo, MK 2021; Bernal, Caputo, Villaescusa-Navarro, MK 2021)



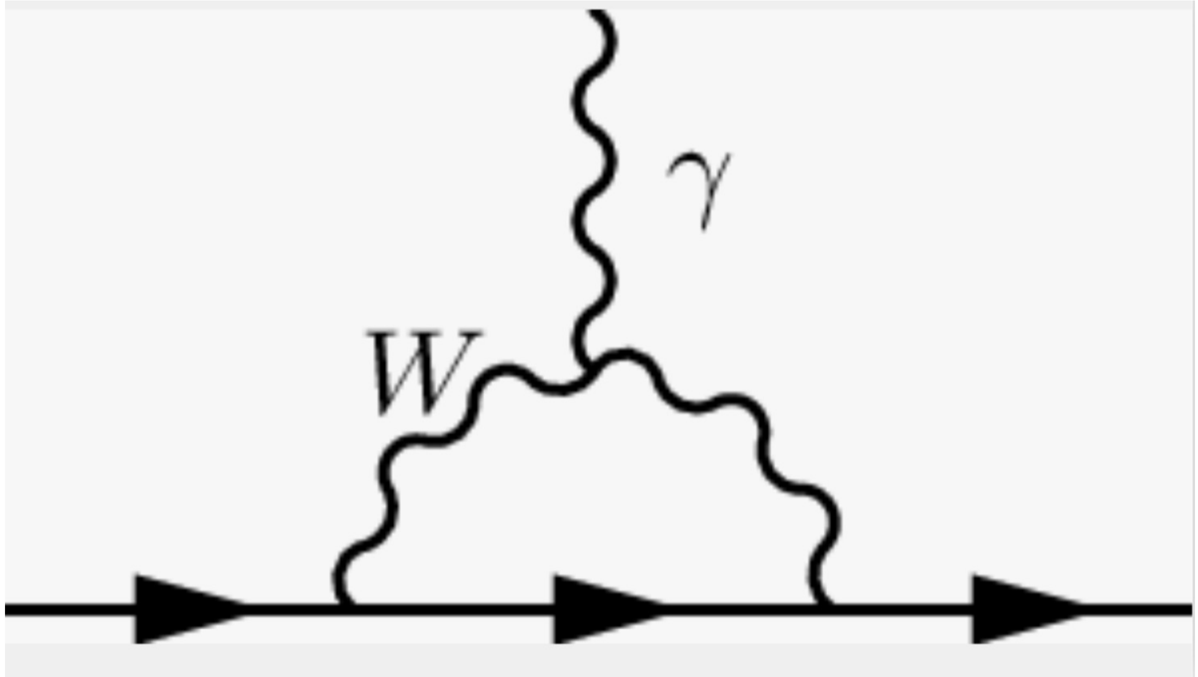
- Axion decay

- Dark matter annihilation



Neutrino decay

Heavier neutrino mass eigenstate



Lighter neutrino mass eigenstate

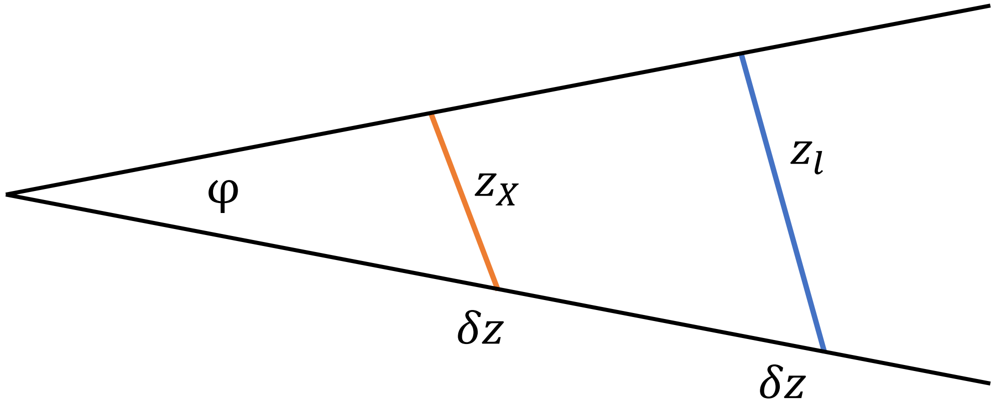
Parameterized by (transition) magnetic moment

Decay/annihilation line is unbiased/biased tracer of dark-matter distribution

→should cross-correlate with LSS

How to distinguish from astrophysical line

- Clustering anisotropy



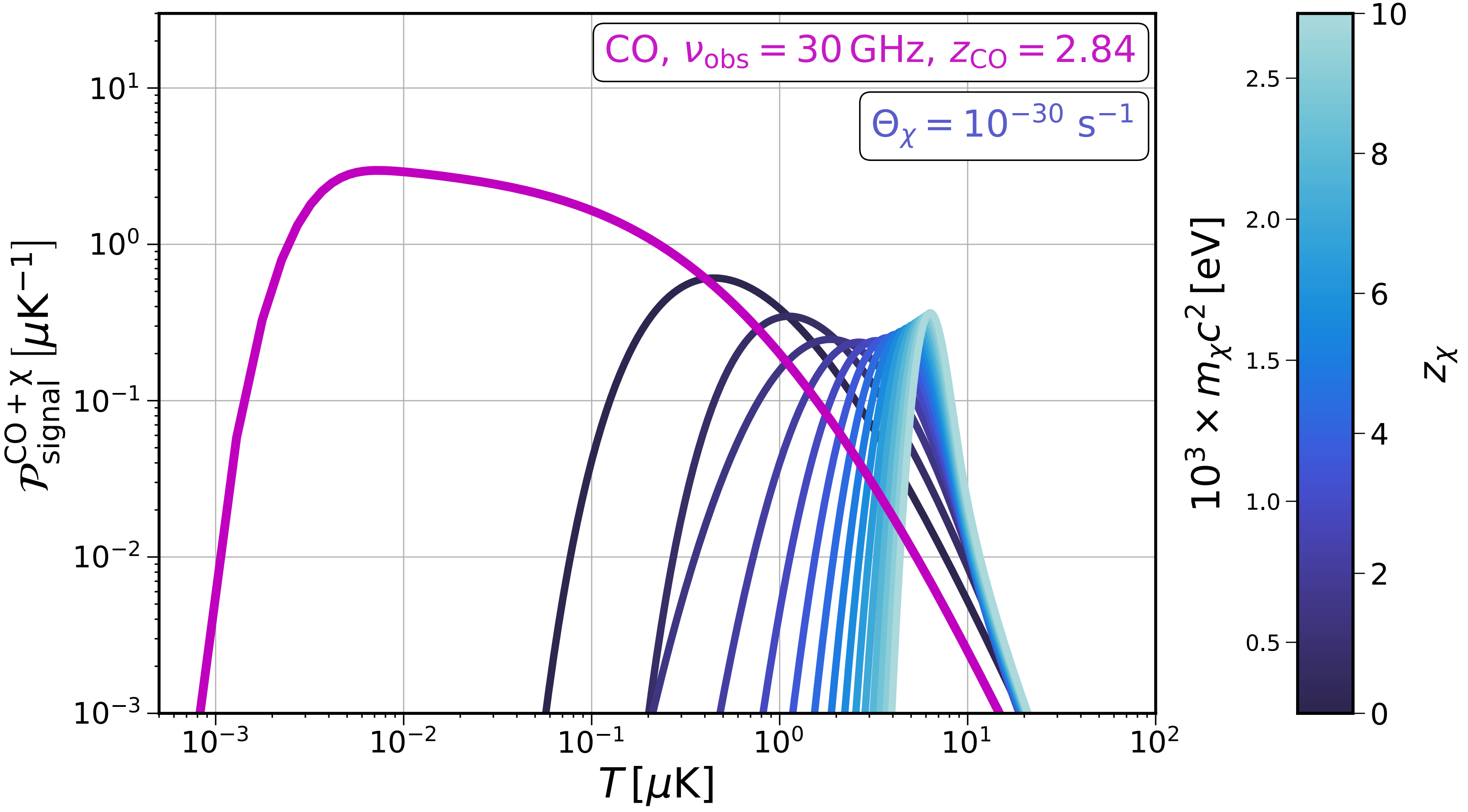
$$x_\perp = D_M(z)\theta$$

$$x_\parallel = \frac{c\delta z}{H(z)}$$

Voxel intensity distribution (VID)

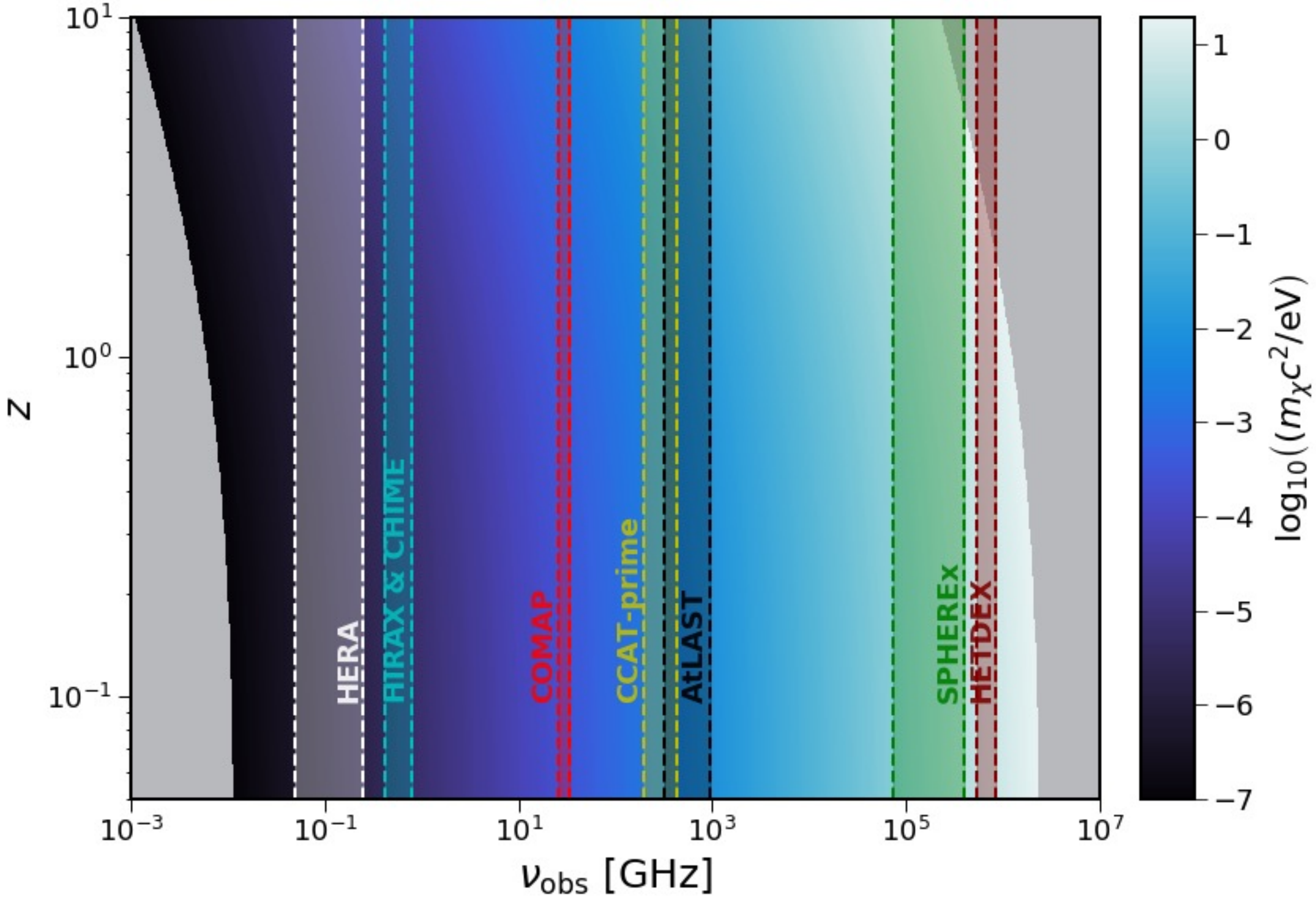
- PDF of luminosity density in each pixel

Effect in VID



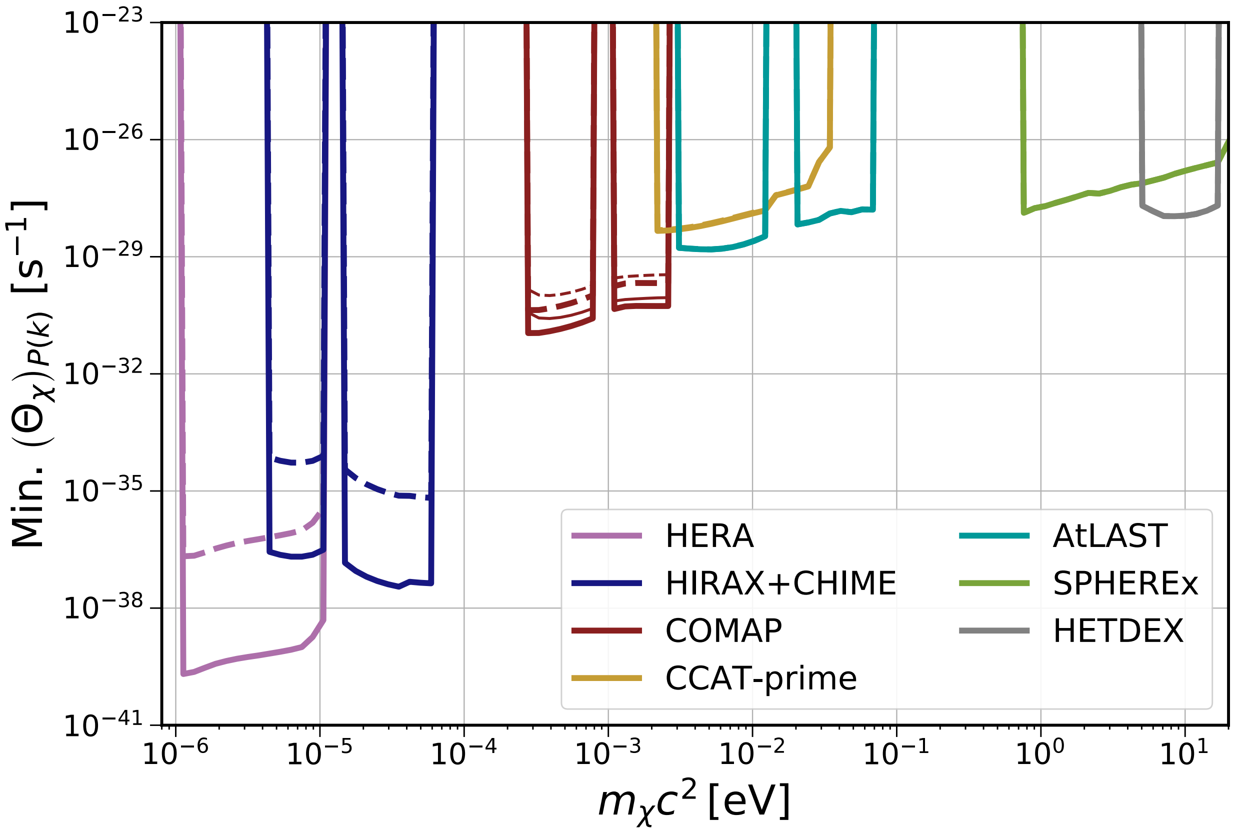
Exotic radiative decays

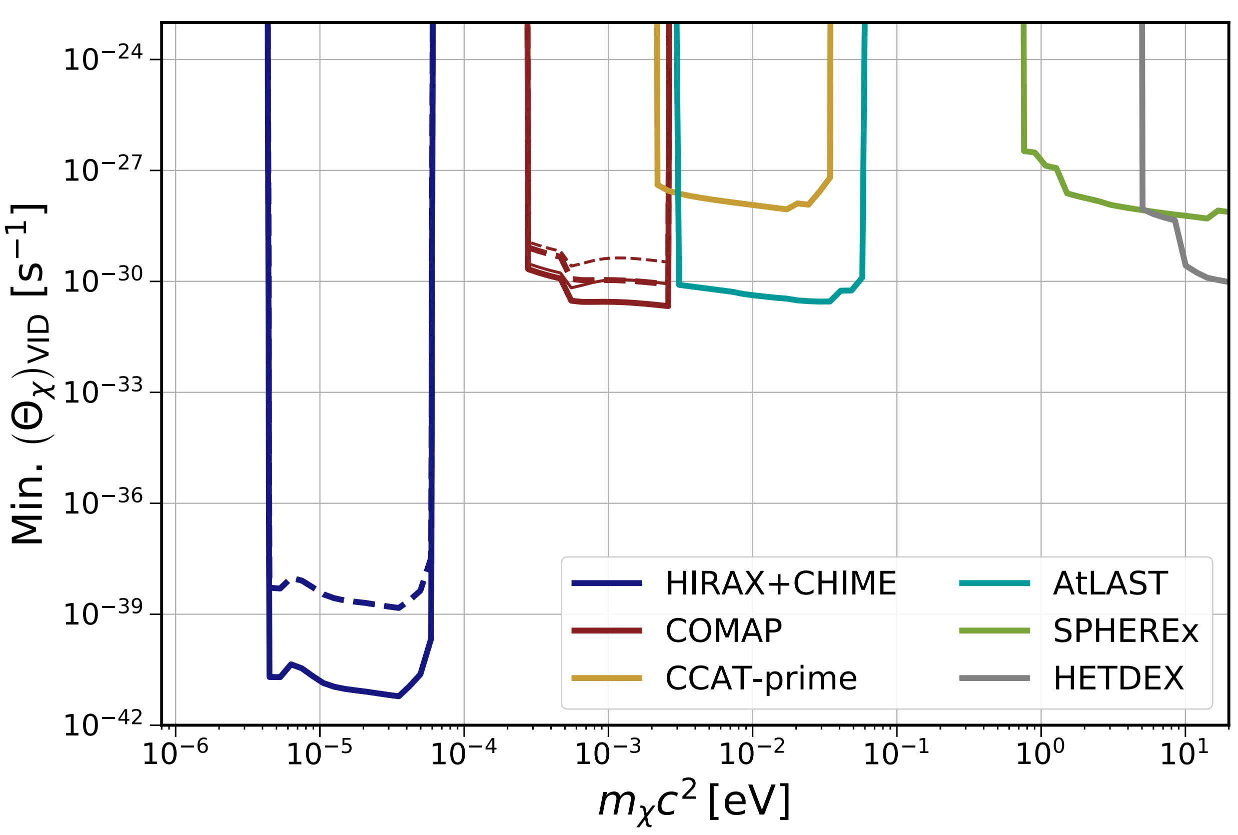
- Decaying dark matter: $\chi \to \gamma + \gamma$ $\nu_\gamma = m_\chi c^2 / 2h_P$



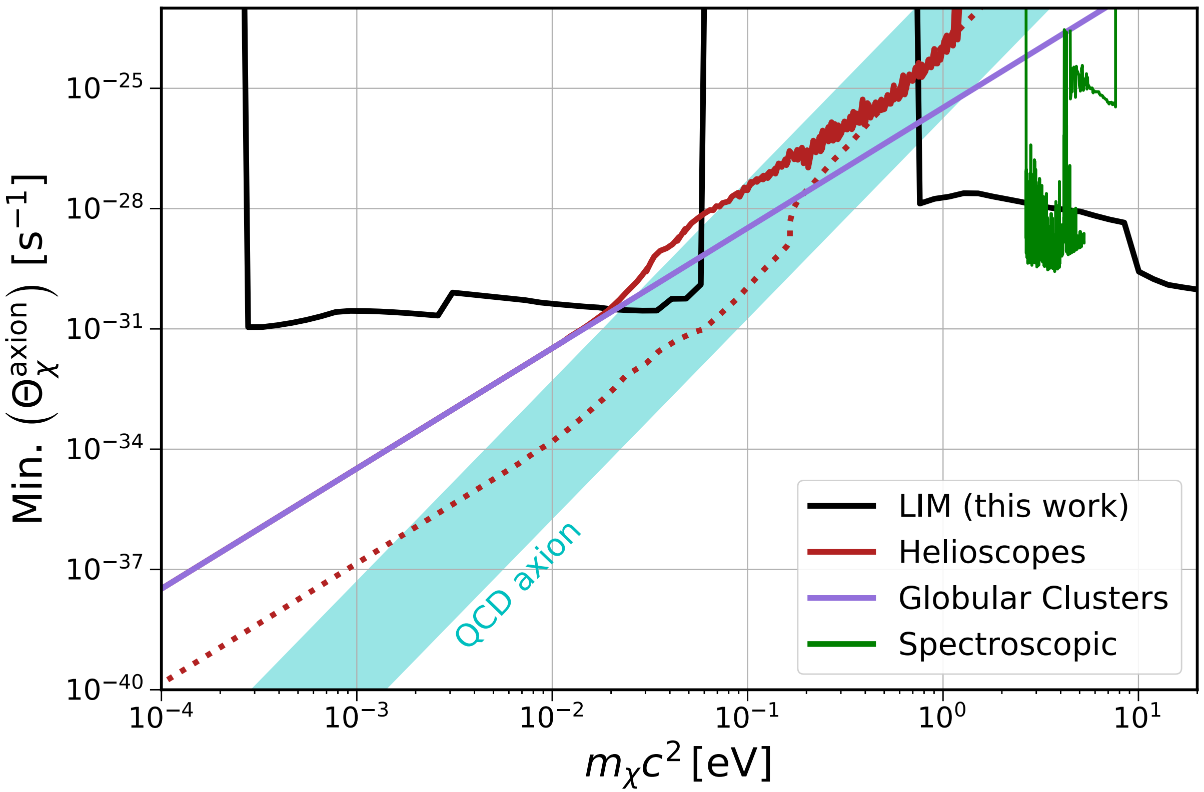
Sensitivity to DM decays

- After marginalizing over astrophysical uncertainties of the target emission line

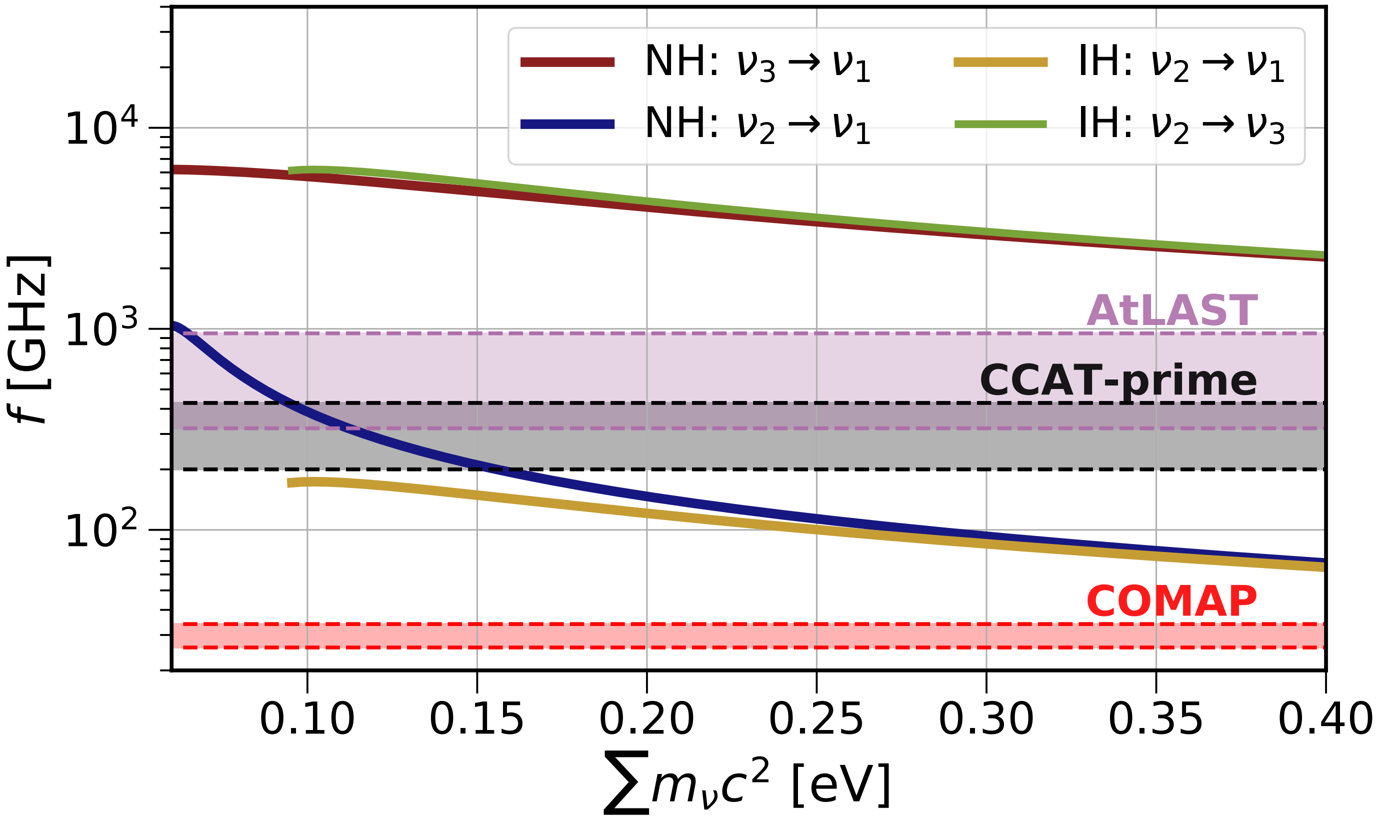




Sensitivity to axions



Exotic radiative decays

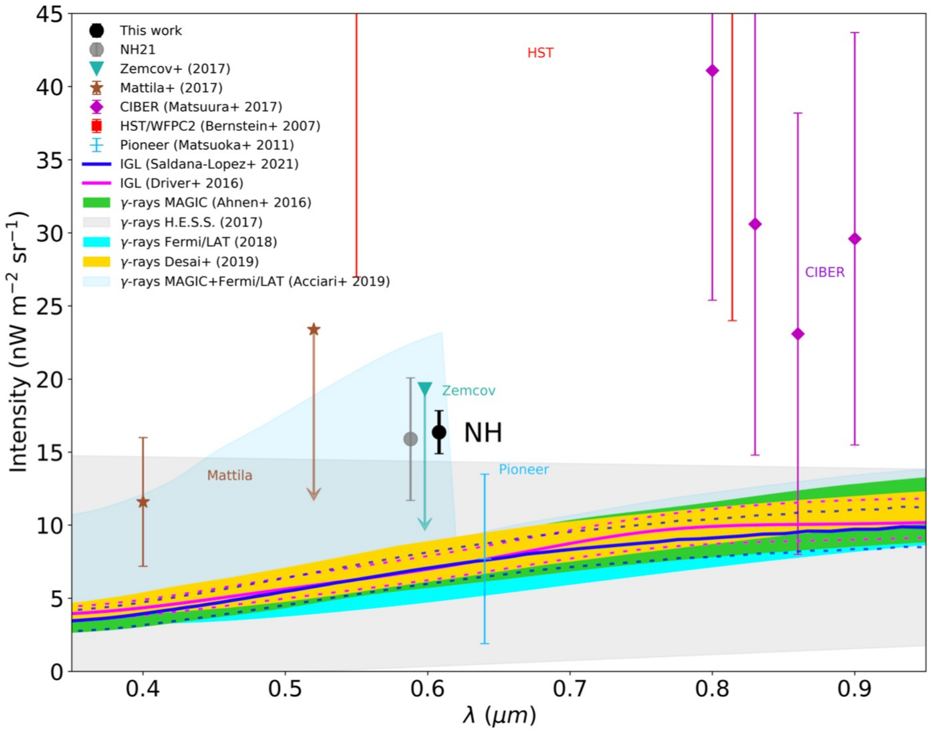


- Neutrino decay: $\nu_i \rightarrow \nu_j + \gamma$

$$f_{ij} = (m_i^2 - m_j^2)c^2/2h_P m_i$$

- Traces directly the cosmic neutrino density field

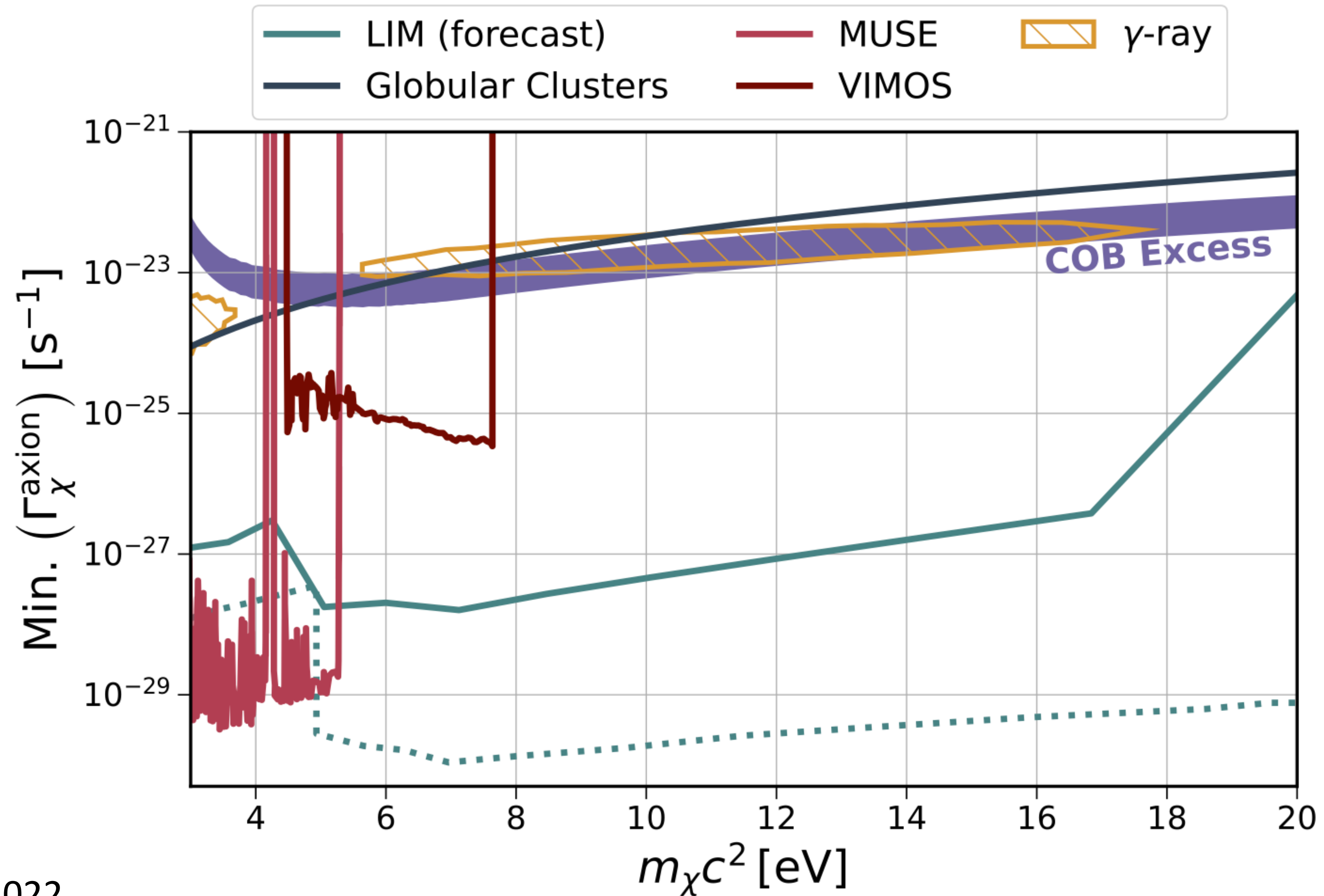
Recent development…..



DRAFT VERSION FEBRUARY 10, 2022
Typeset using LATEX **twocolumn** style in AASTeX63

Anomalous Flux in the Cosmic Optical Background Detected With New Horizons Observations

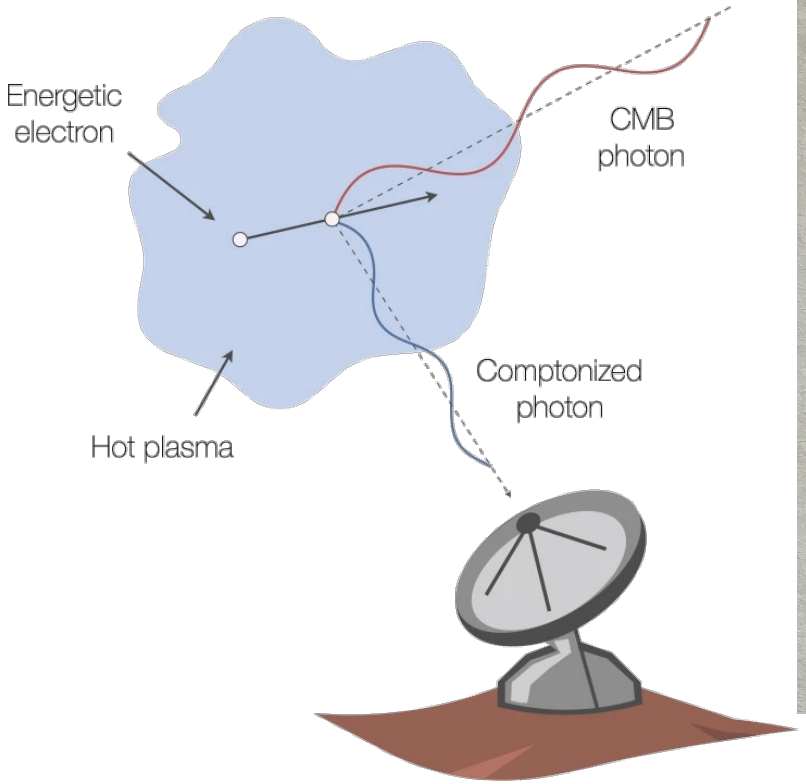
TOD R. LAUER,[1] MARC POSTMAN,[2] JOHN R. SPENCER,[3] HAROLD A. WEAVER,[4] S. ALAN STERN,[5] G. RANDALL GLADSTONE,[6,7] RICHARD P. BINZEL,[8] DANIEL T. BRITT,[9] MARC W. BUIE,[3] BONNIE J. BURATTI,[10] ANDREW F. CHENG,[4] W.M. GRUNDY,[11] MIHALY HORÁNYI,[12] J.J. KAVELAARS,[13] IVAN R. LINSCOTT,[14] CAREY M. LISSE,[4] WILLIAM B. MCKINNON,[15] RALPH L. MCNUTT,[4] JEFFREY M. MOORE,[16] JORGE I. NÚÑEZ,[4] CATHERINE B. OLKIN,[3] JOEL W. PARKER,[3] SIMON B. PORTER,[3] DENNIS C. REUTER,[17] STUART J. ROBBINS,[3] PAUL M. SCHENK,[18] MARK R. SHOWALTER,[19] KELSI N. SINGER,[3] ANNE. J. VERBISCER,[20] AND LESLIE A. YOUNG[3]

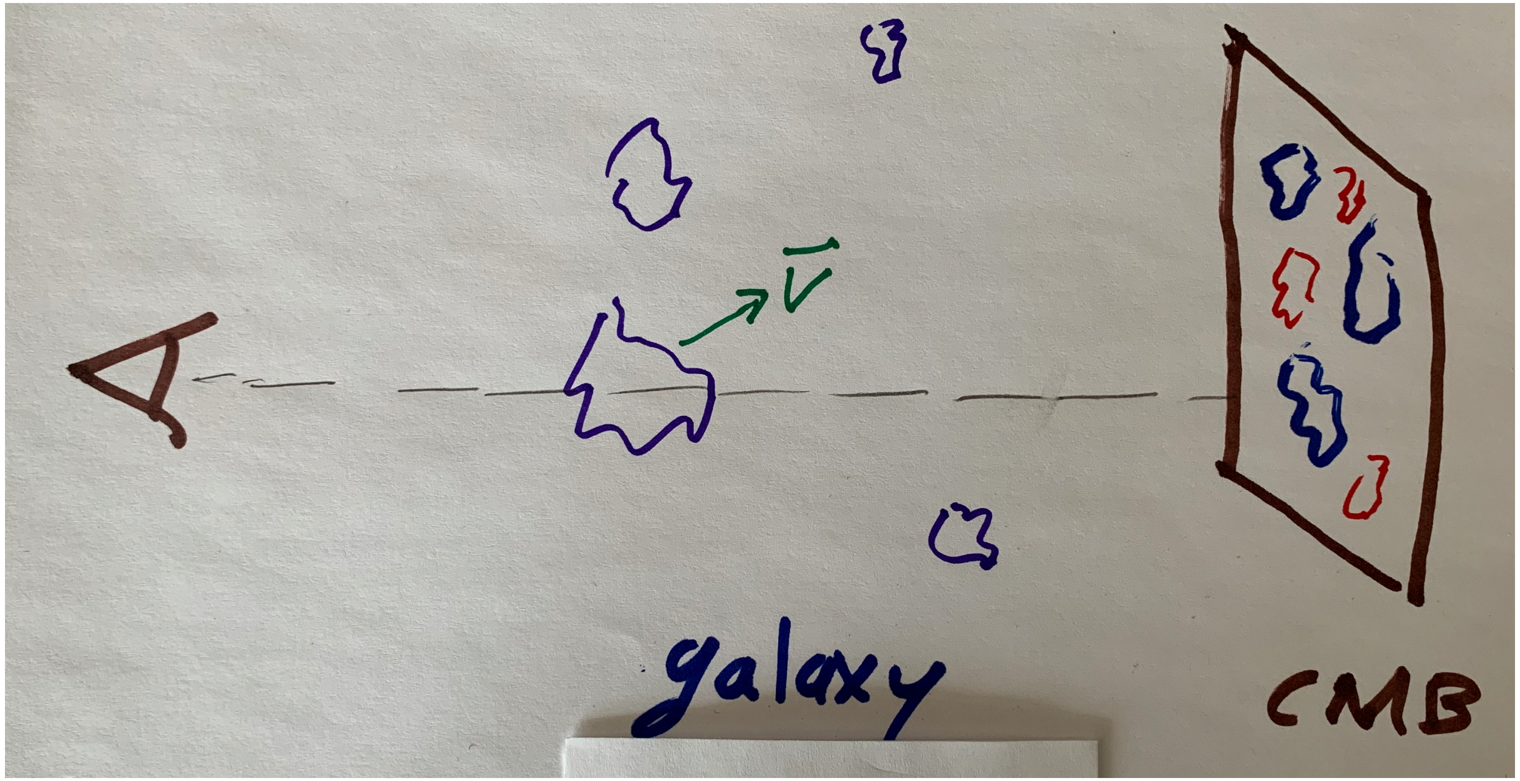


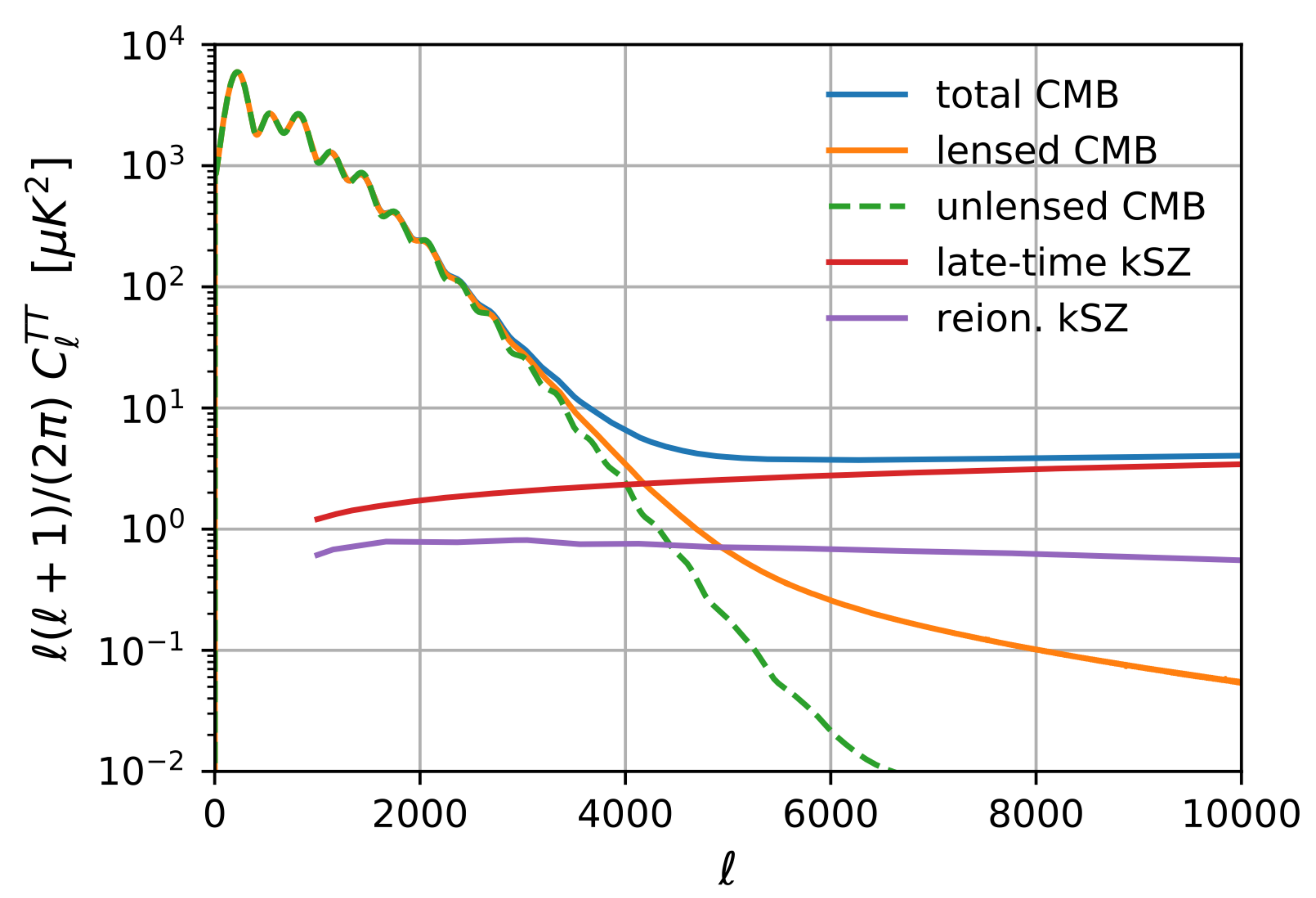
Bernal, Sato-Polito, MK, 2022

III. Kinetic-Sunyaev-Zeldovich tomography: new probe of 3d *mass* distribution

- Cross-correlate CMB and galaxy distribution to get cosmic velocity field

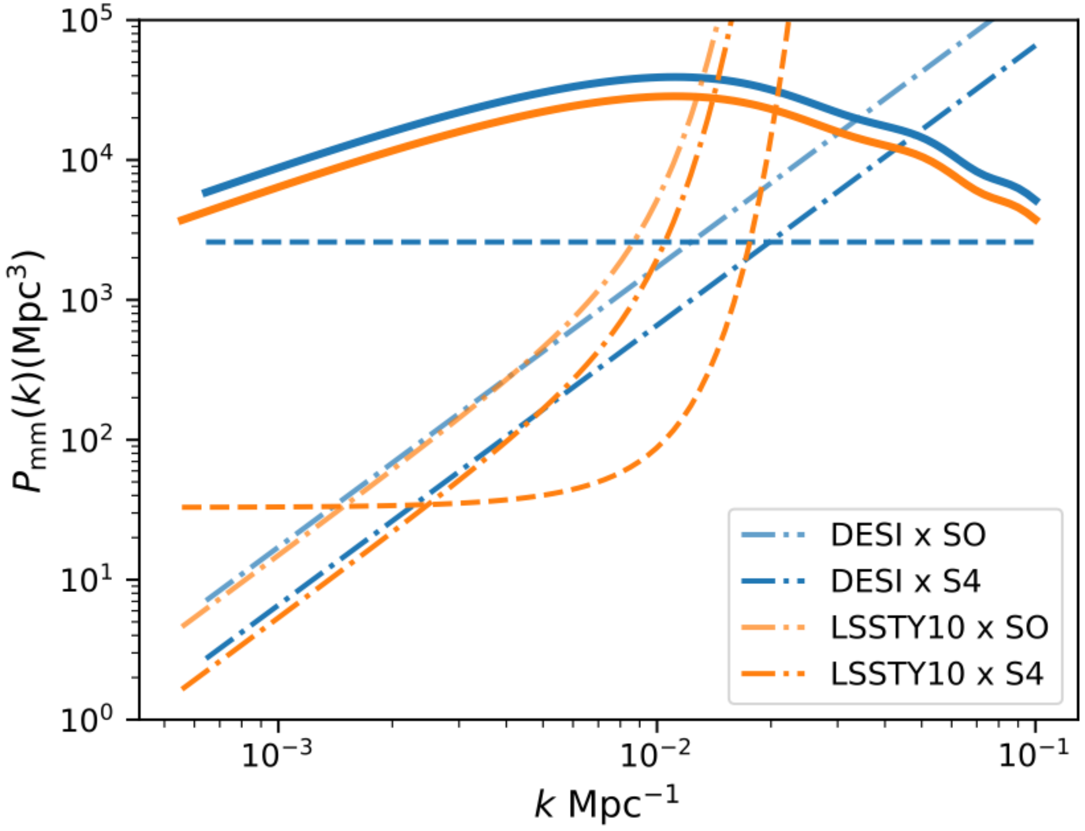


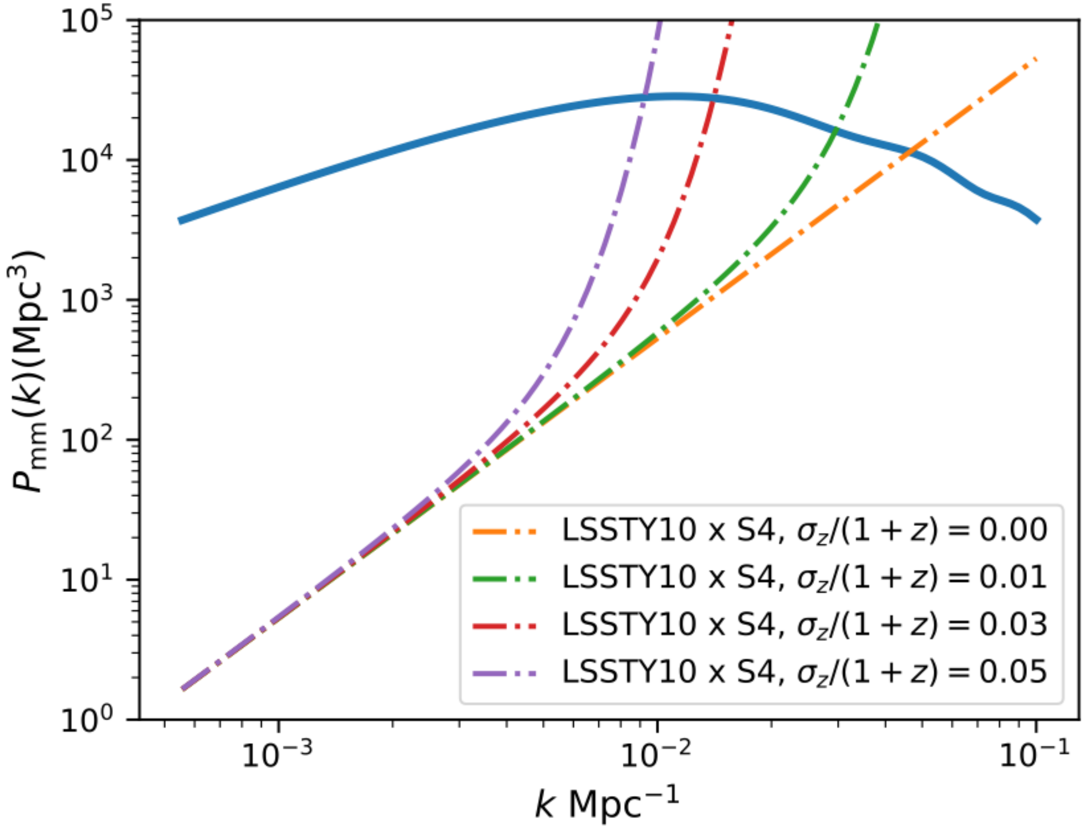




Smith et al. arXiv:1810.13423

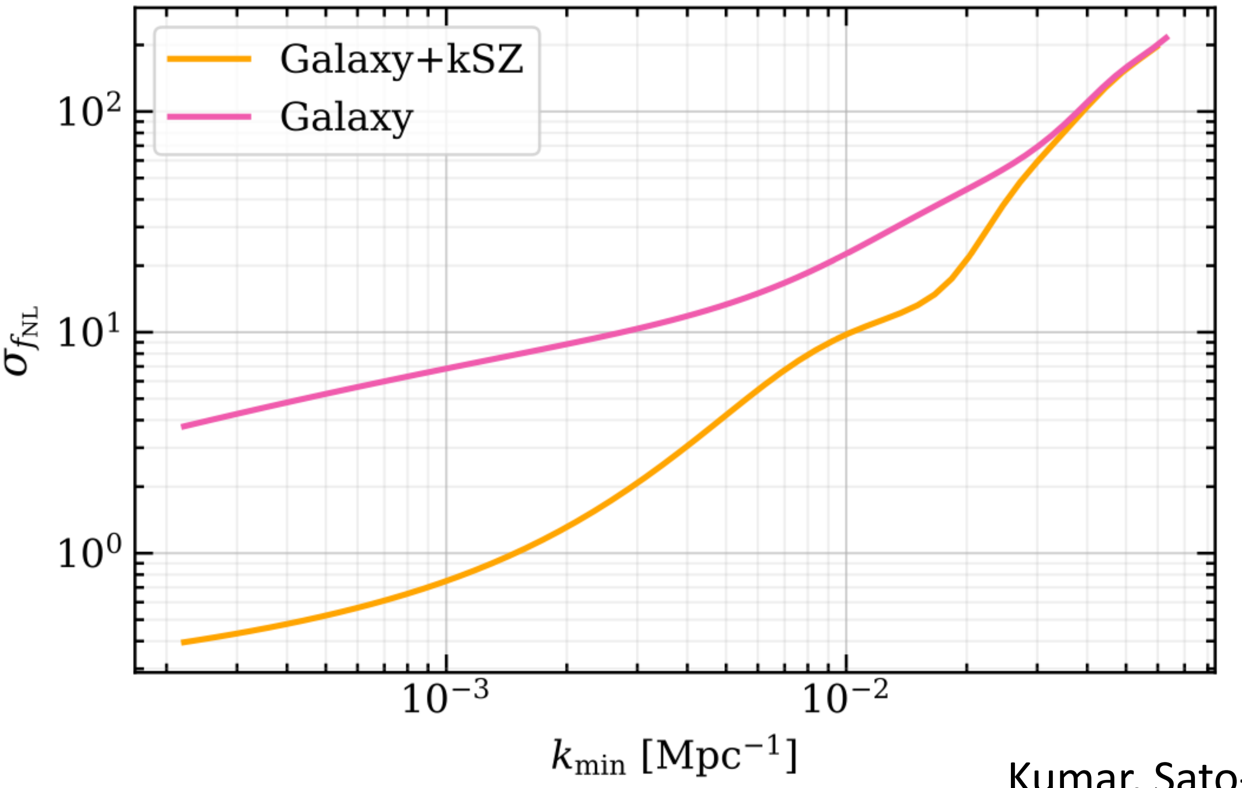
matter power spectrum (Smith et al. arXiv:1810.13423)

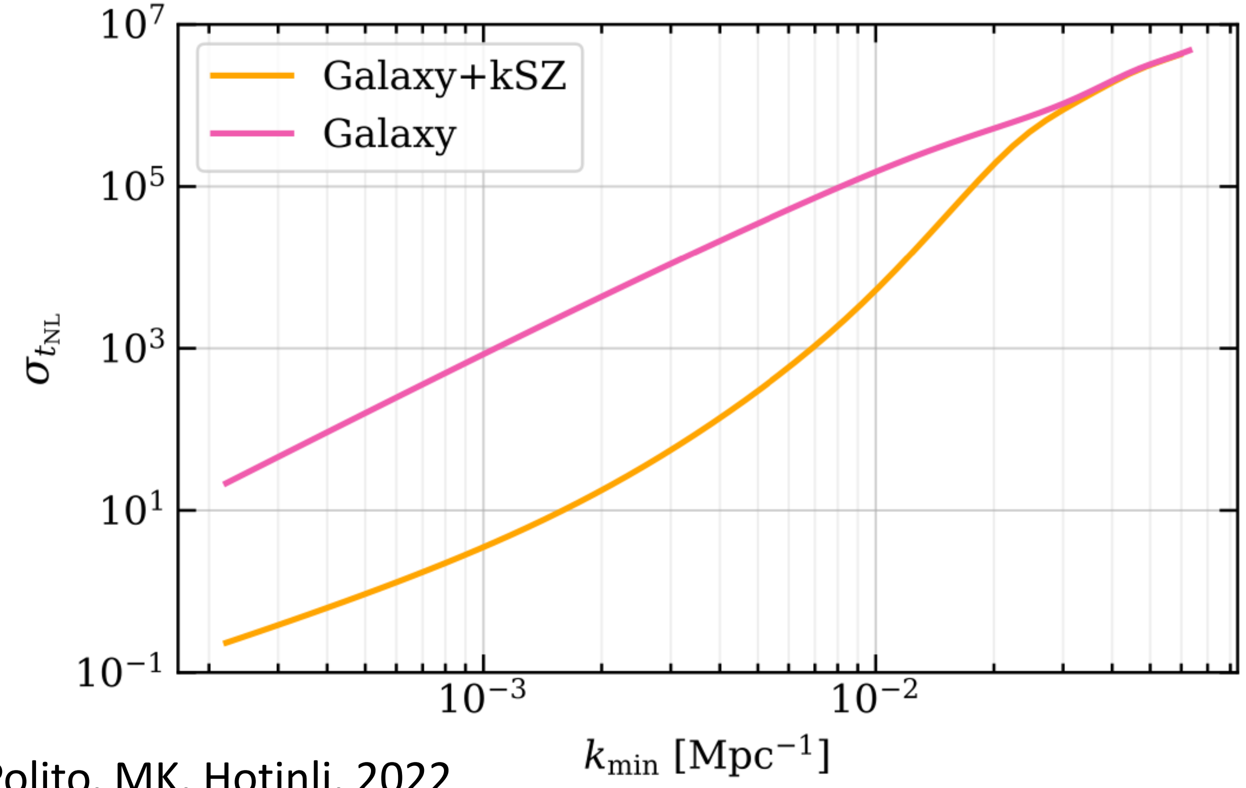




Can compare matter and galaxy distributions *independently*

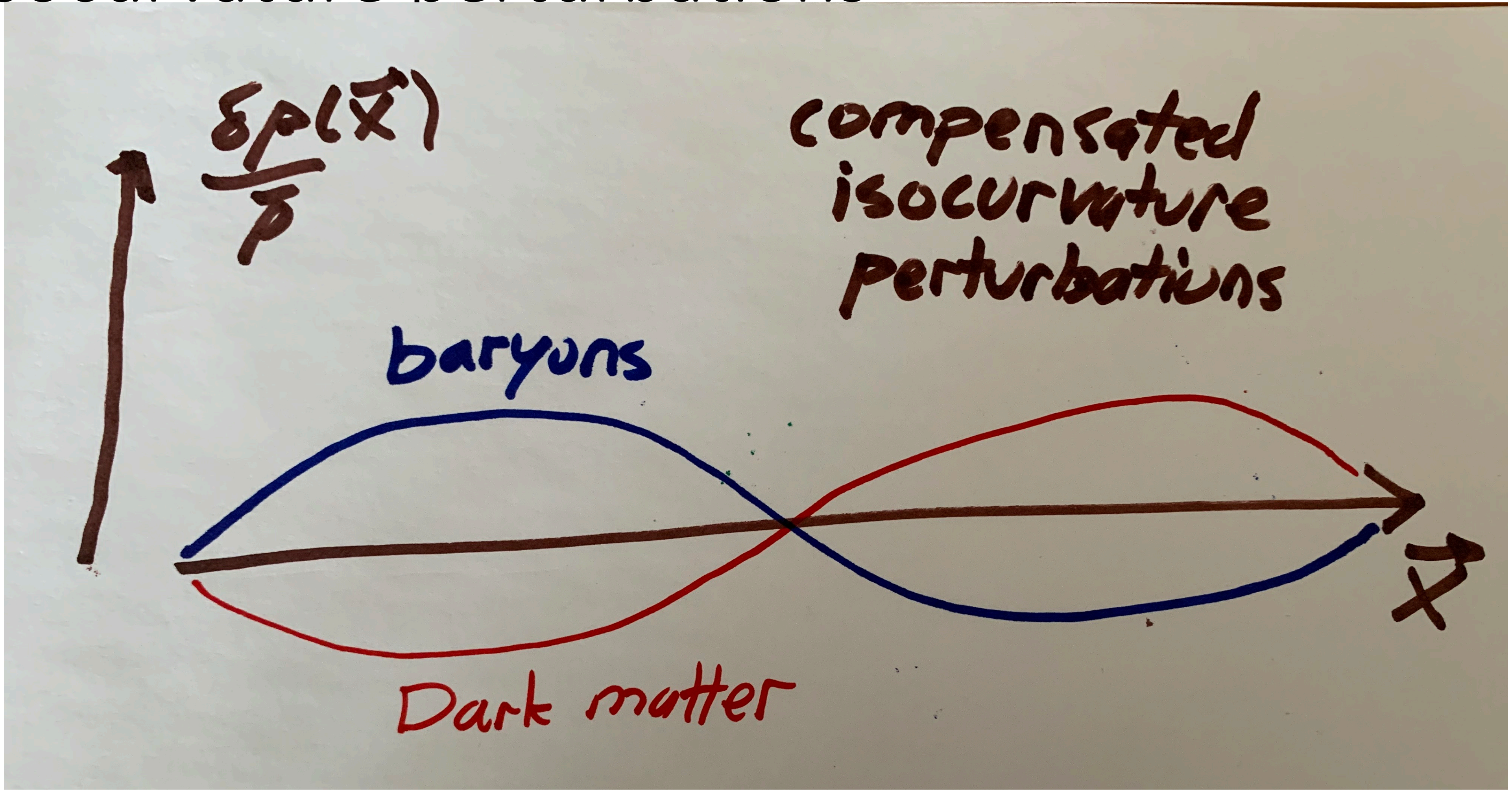
- E.g., scale-dependent bias from local-model non-Gaussianity; not cosmic-variance limited (Munchmeyer et al. 1810.13424)





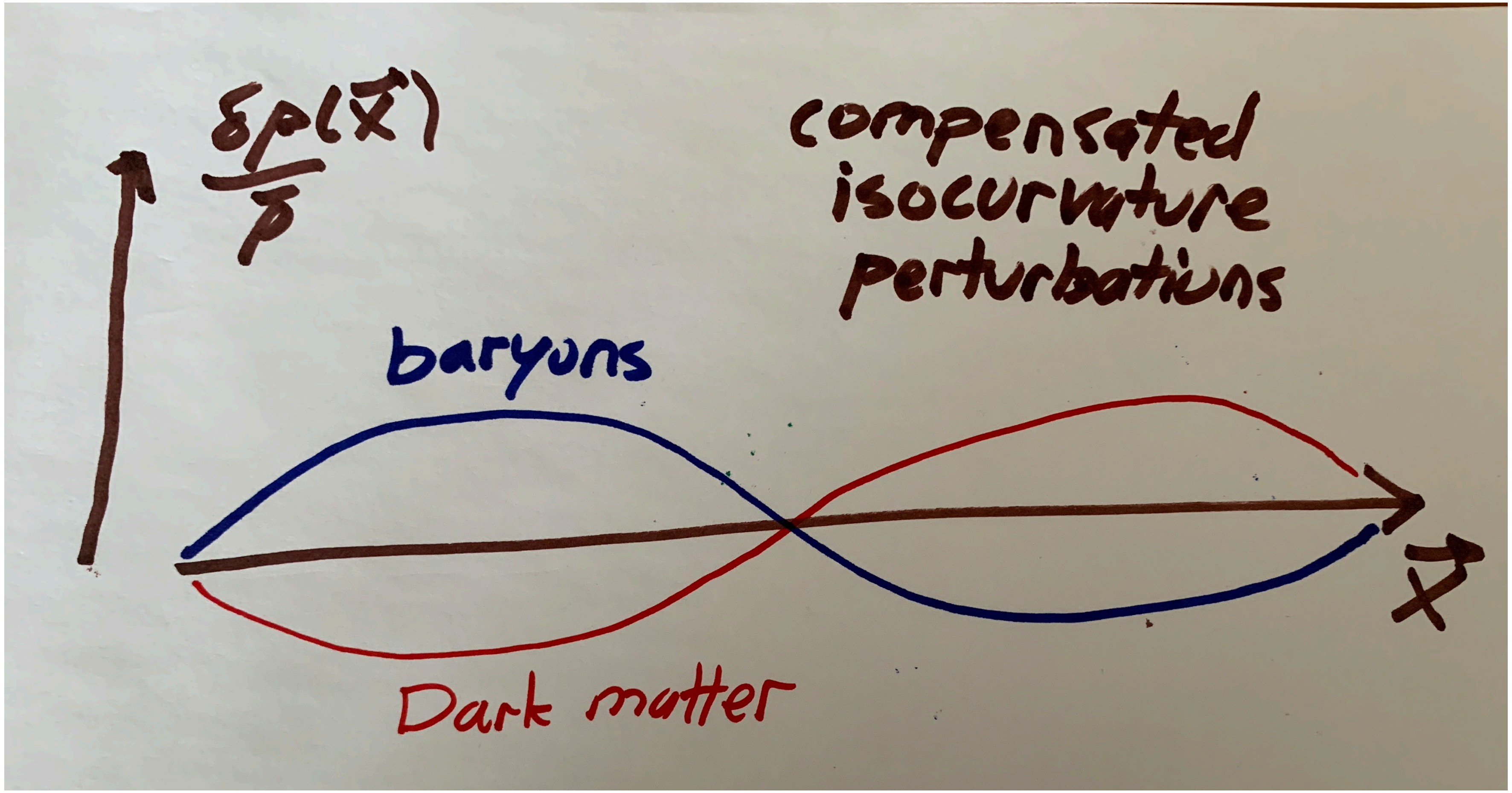
Kumar, Sato-Polito, MK, Hotinli, 2022

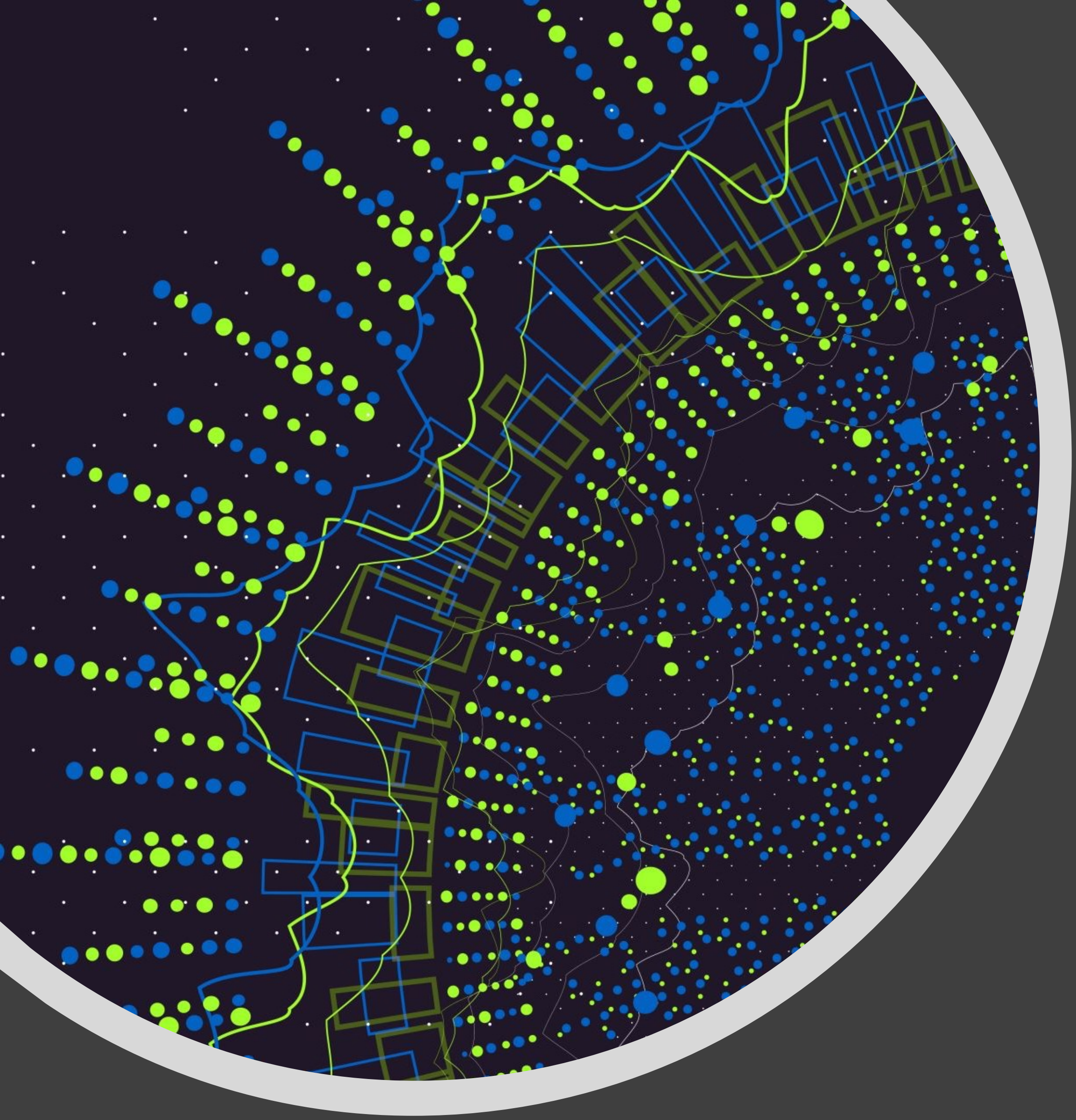
Useful if primordial baryon and dark-matter distributions differ; e.g., compensated isocurvature perturbations



Hotinli, Mertens, Johnson, MK 2019; N. Kumar et al., in prep

IM can provide foreground density field at high redshifts and large angular scales (Sato-Polito, Bernal, Boddy, MK 2021)





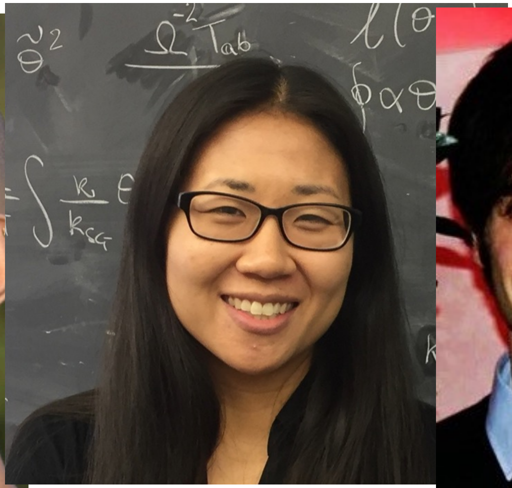
Conclusions

- New tools (LIM and kSZ tomography) in physical cosmology can be re-purposed to learn about the dark sector and other new physics

Neha Kumar

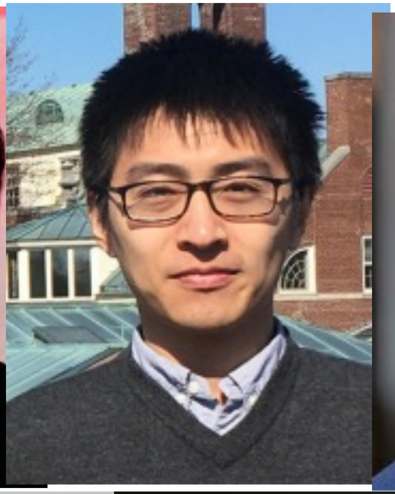
Cyril
Creque-Sarbinowski

Kim Boddy

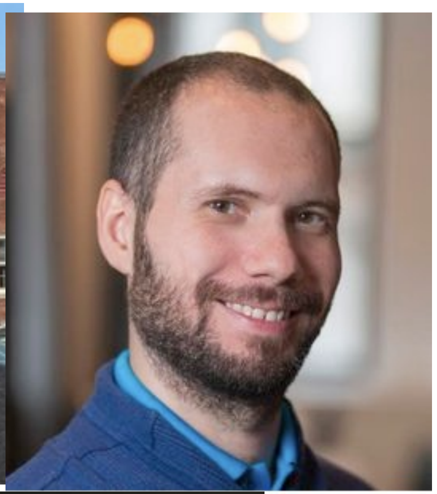


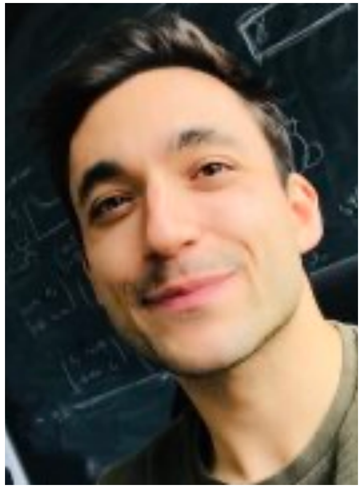
Andrea
Caputo

Liang Dai



Franciso
Villaescusa-Navarro





Selim Hotinli

Gabriela
Sato-Polito

Jose Luis Bernal

Ely Kovetz

Patrick Breysse