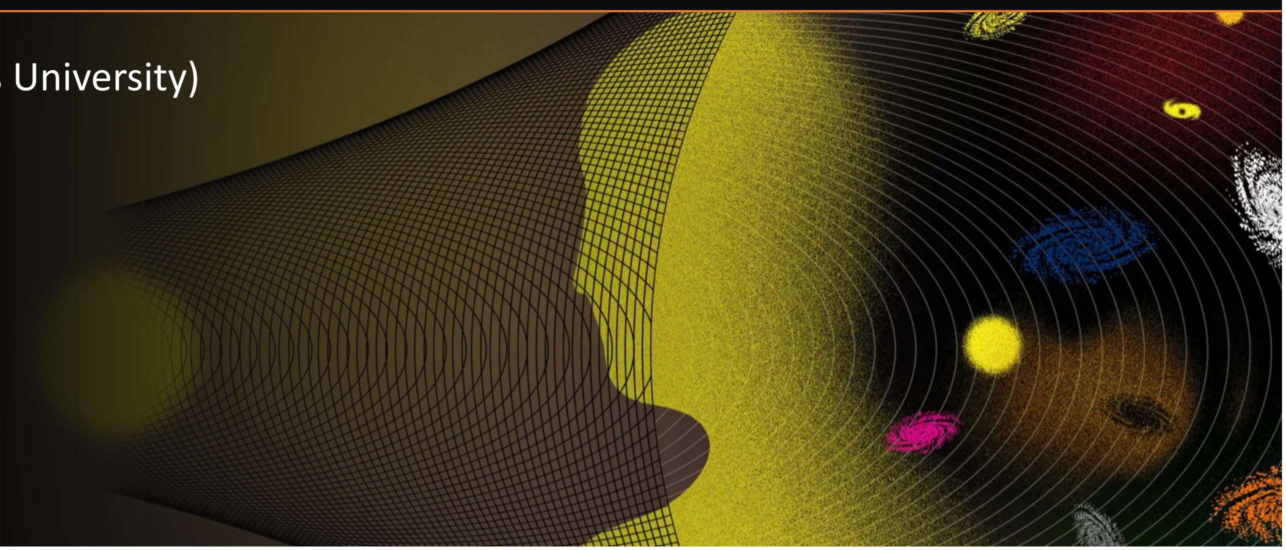
The cosmic optical background excess, dark matter, and line intensity mapping

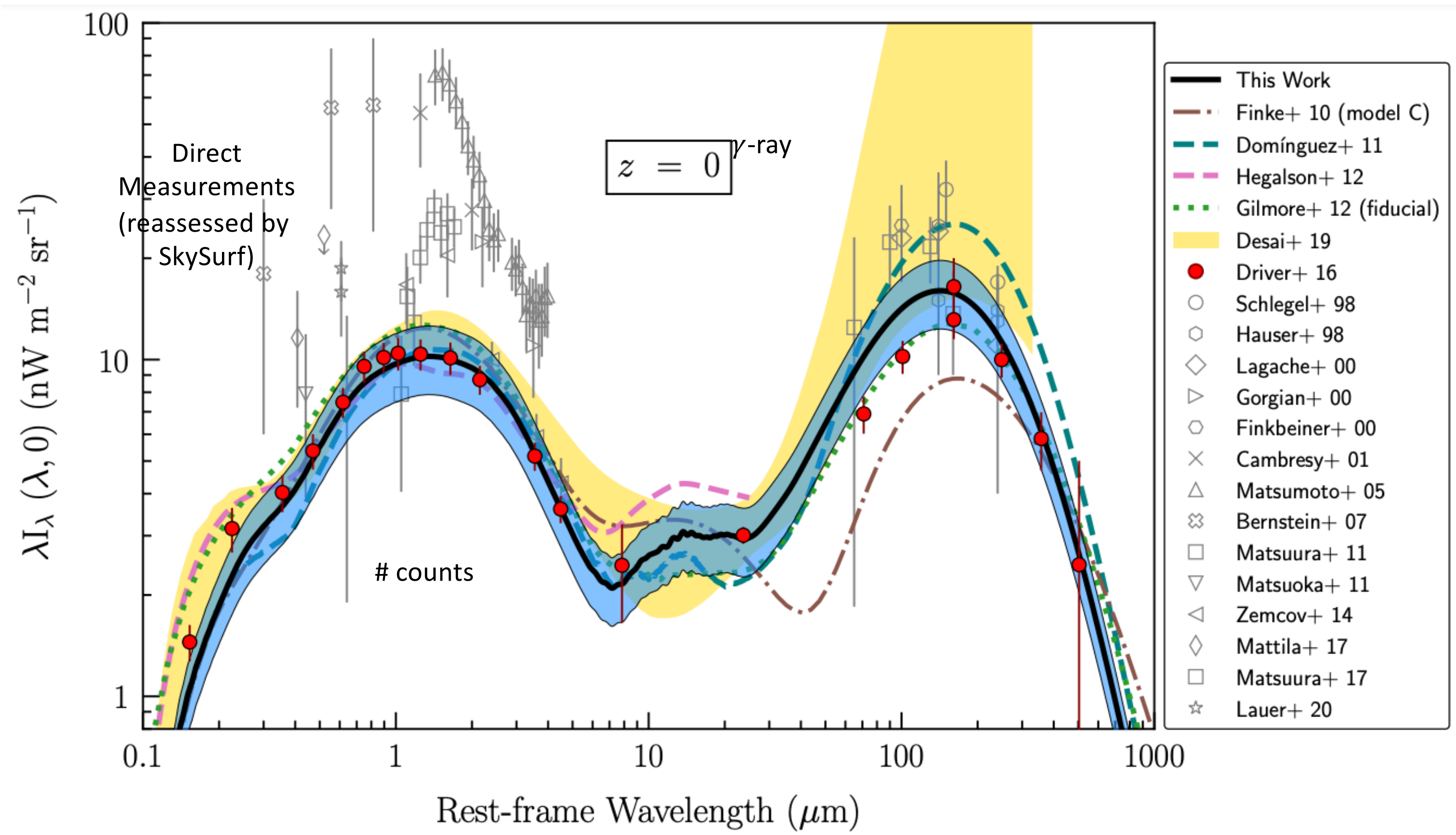
Marc Kamionkowski (Johns Hopkins University)



Collaborators

- Gabriela Sato-Polito
- Jose Luis Bernal
- Andrea Caputo
- Jordan Mirocha
- Patrick Breysse
- Ely Kovetz
- Francisco Villaescusa-Navarro

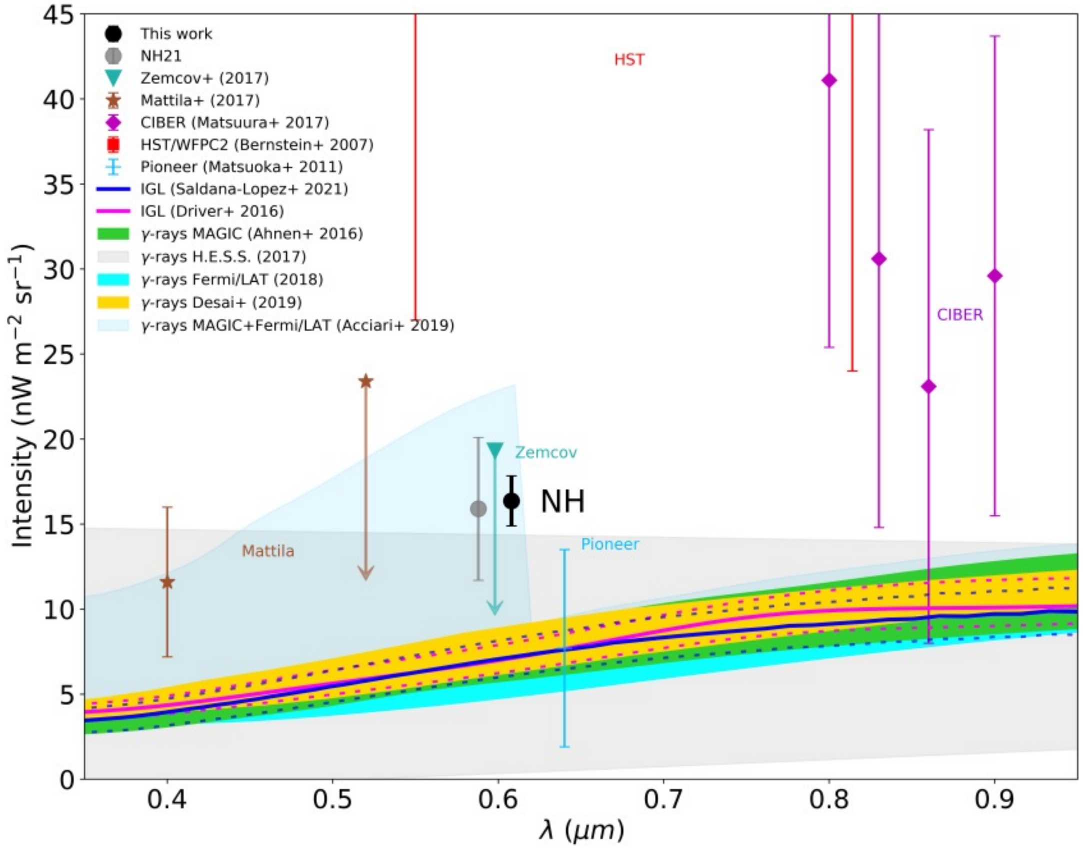
Extragalactic Background Light



Saldana-Lopez+(2021)

- Aggregate of *all* emitted radiation

COB excess



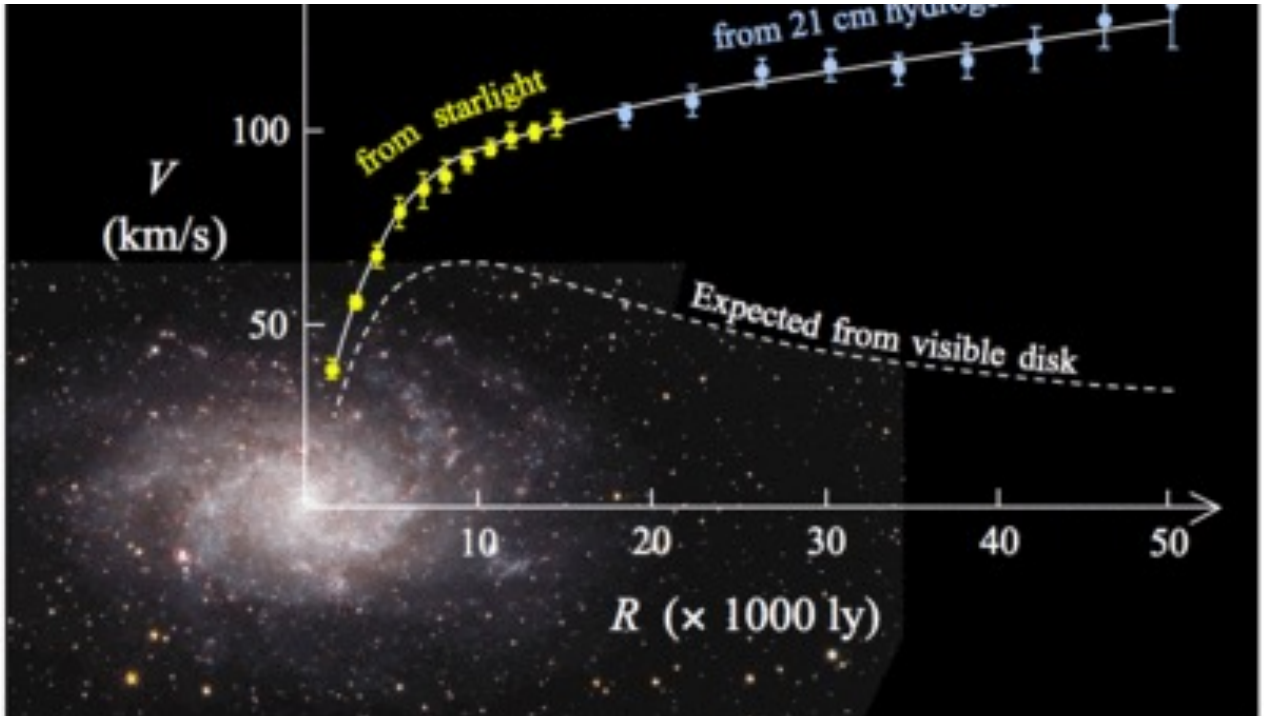
- New direct observations from New Horizons (> 50 AU) at 0.61 microns
- 1st high significance detection ($> 8\sigma$)
- $> 4\sigma$ excess wrt estimation from IGL

Lauer+(2022)

COB Excess: What could it be?

Possibility 1: unaccounted for light from unresolved galaxies

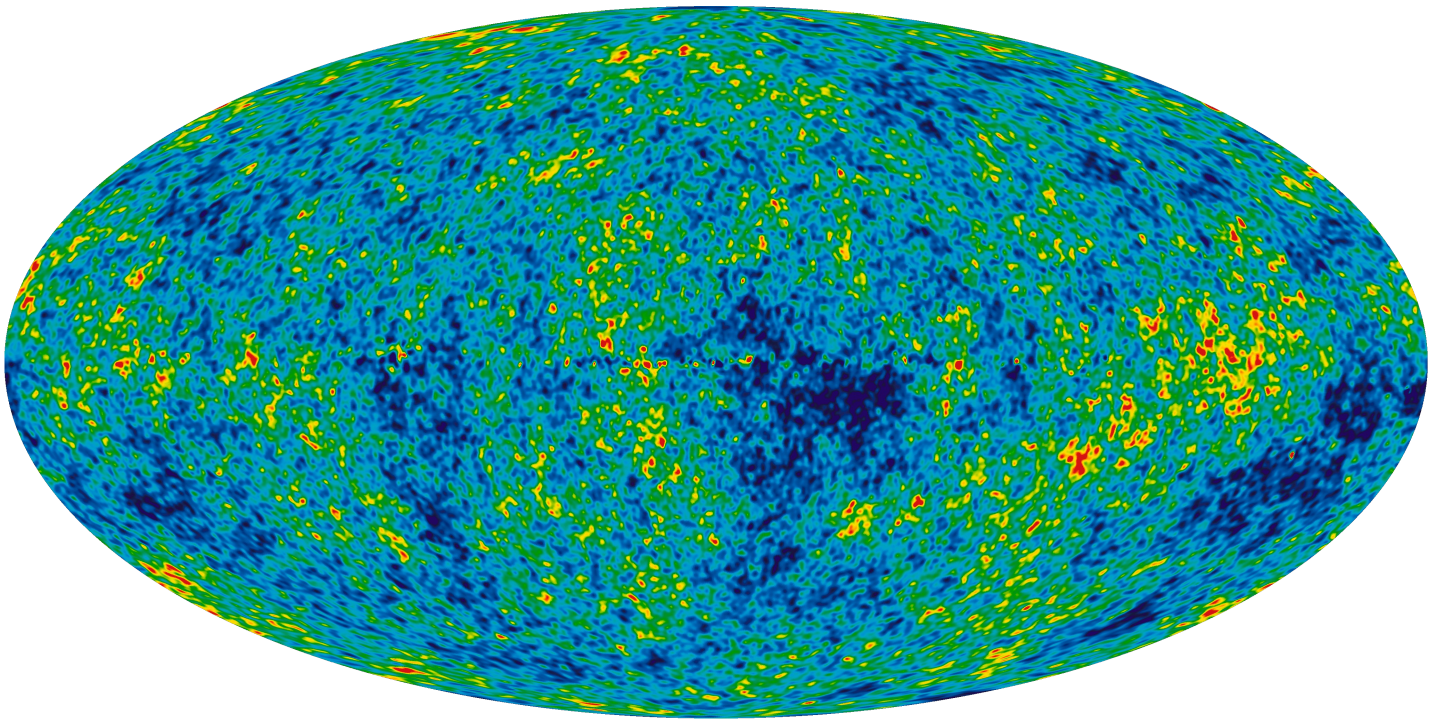
Possibility 2: extra photons from DM decay



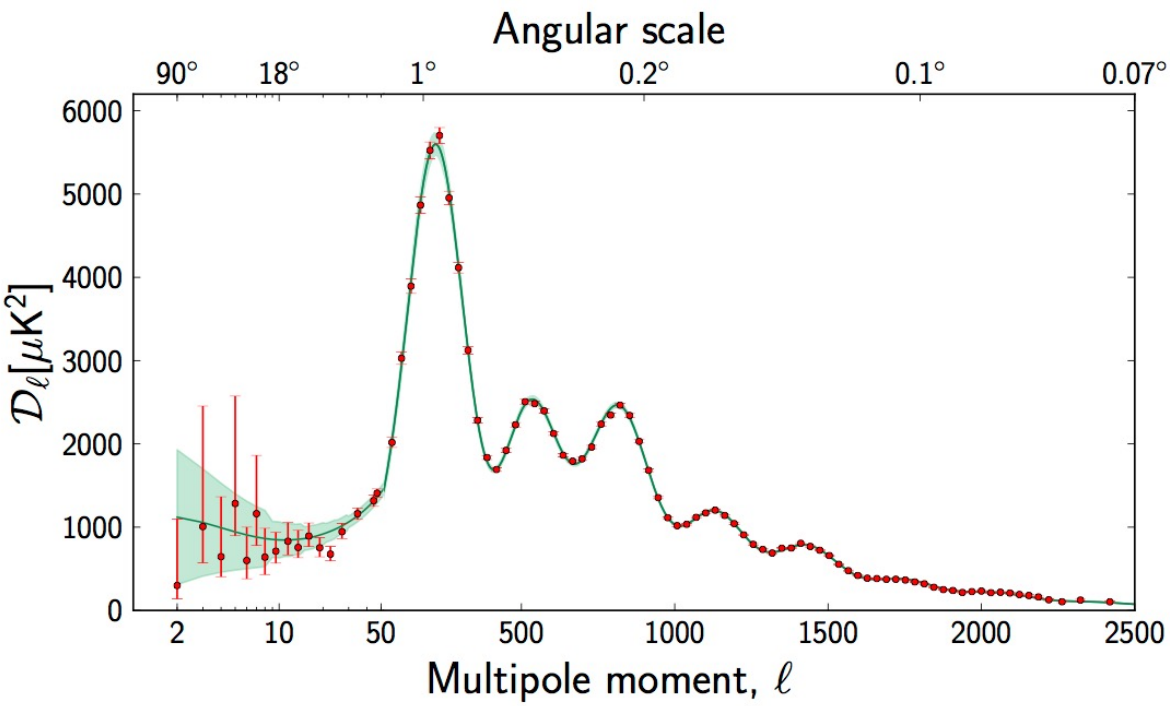
Dark matter: A Cosmic mystery

Dark Matter

What is it?



Cosmic microwave background

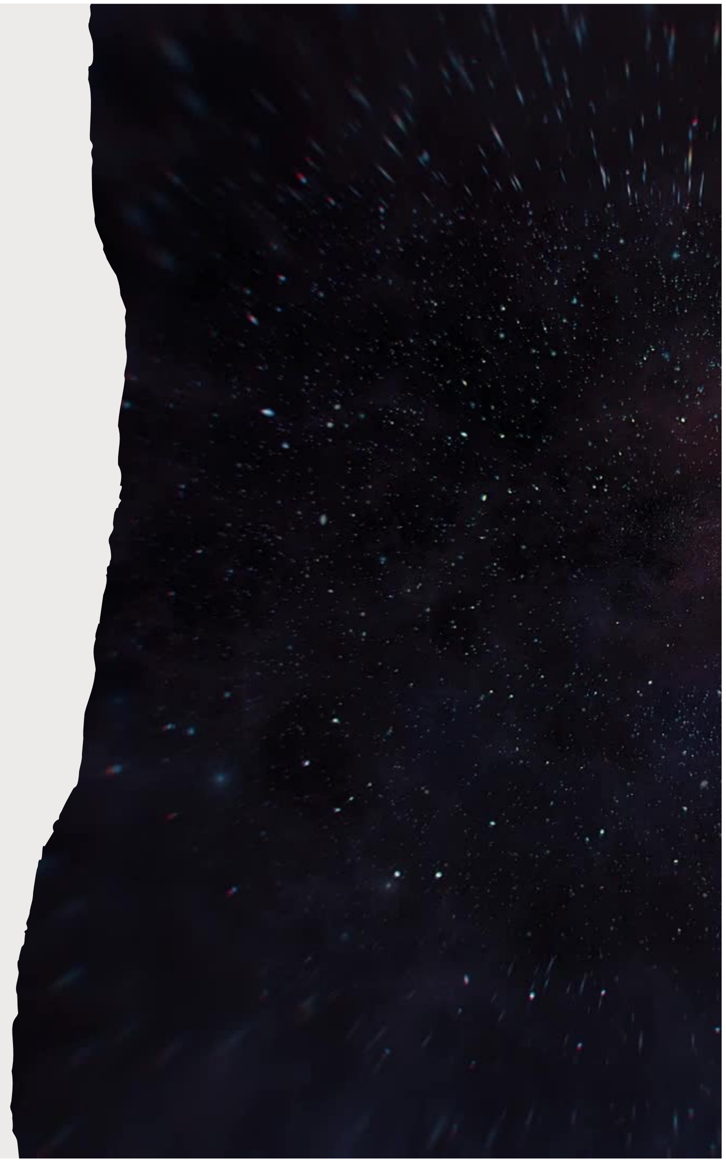


Cosmic microwave background

Cosmic microwave background

Dark matter cannot be baryons

Some collisionless nonrelativistic particle or object

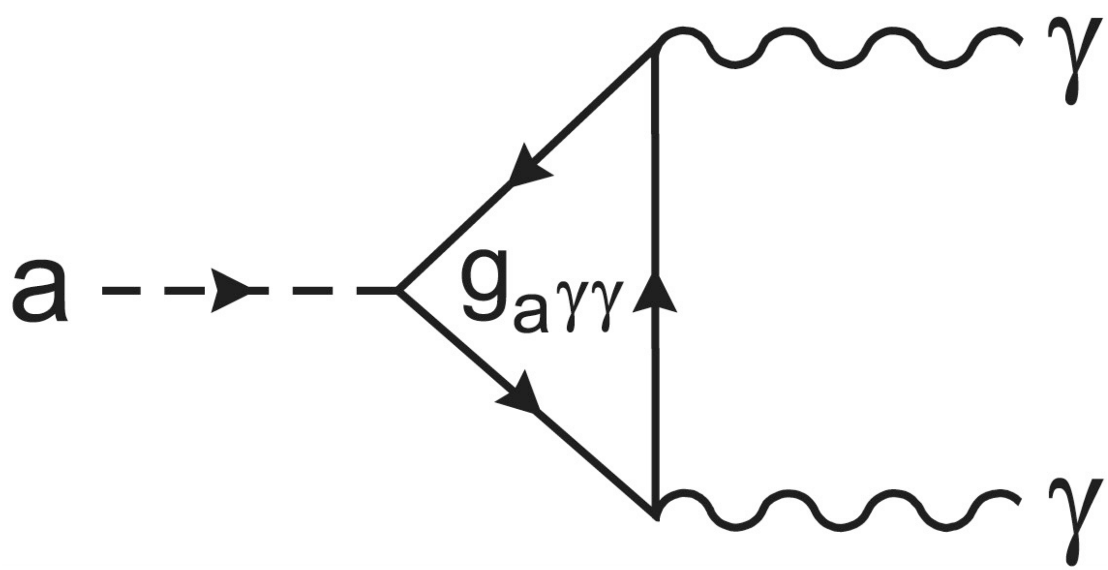


Axions (and or ALPS: ”axion-like particles”)

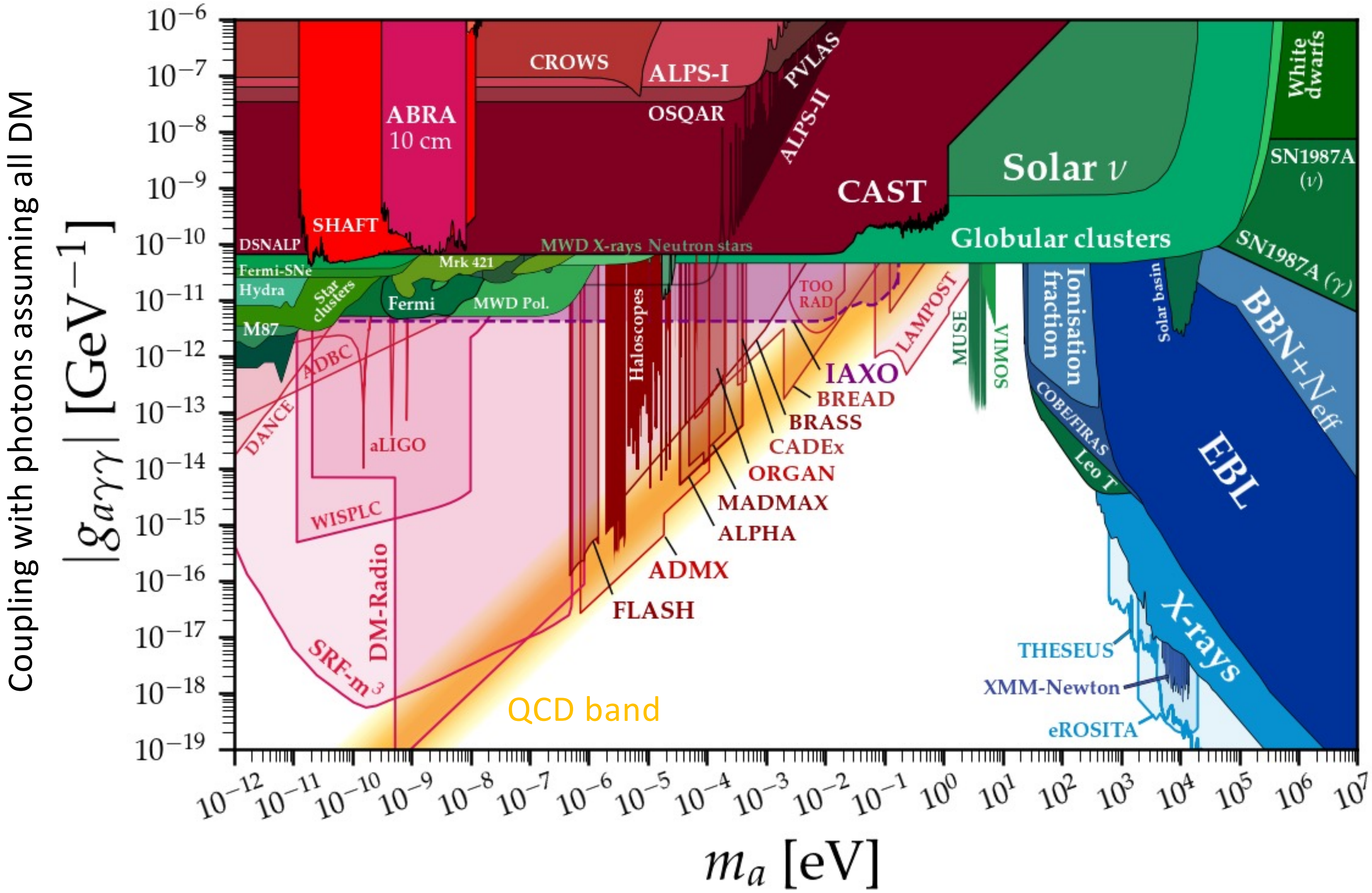
- New elementary particle postulated to explain why the strong interactions seem to be time-reversal invariant
- Also appear generically in string theories
- Are parameterized by their mass m_a and coupling to photons
- Can be long-lived and have extremely weak interactions with ordinary matter and are thus candidates for DM

Axions (and or ALPS: ”axion-like particles”)

- They can also decay to two photons, each with energy equal to half the axion rest-mass energy $m_a c^2$



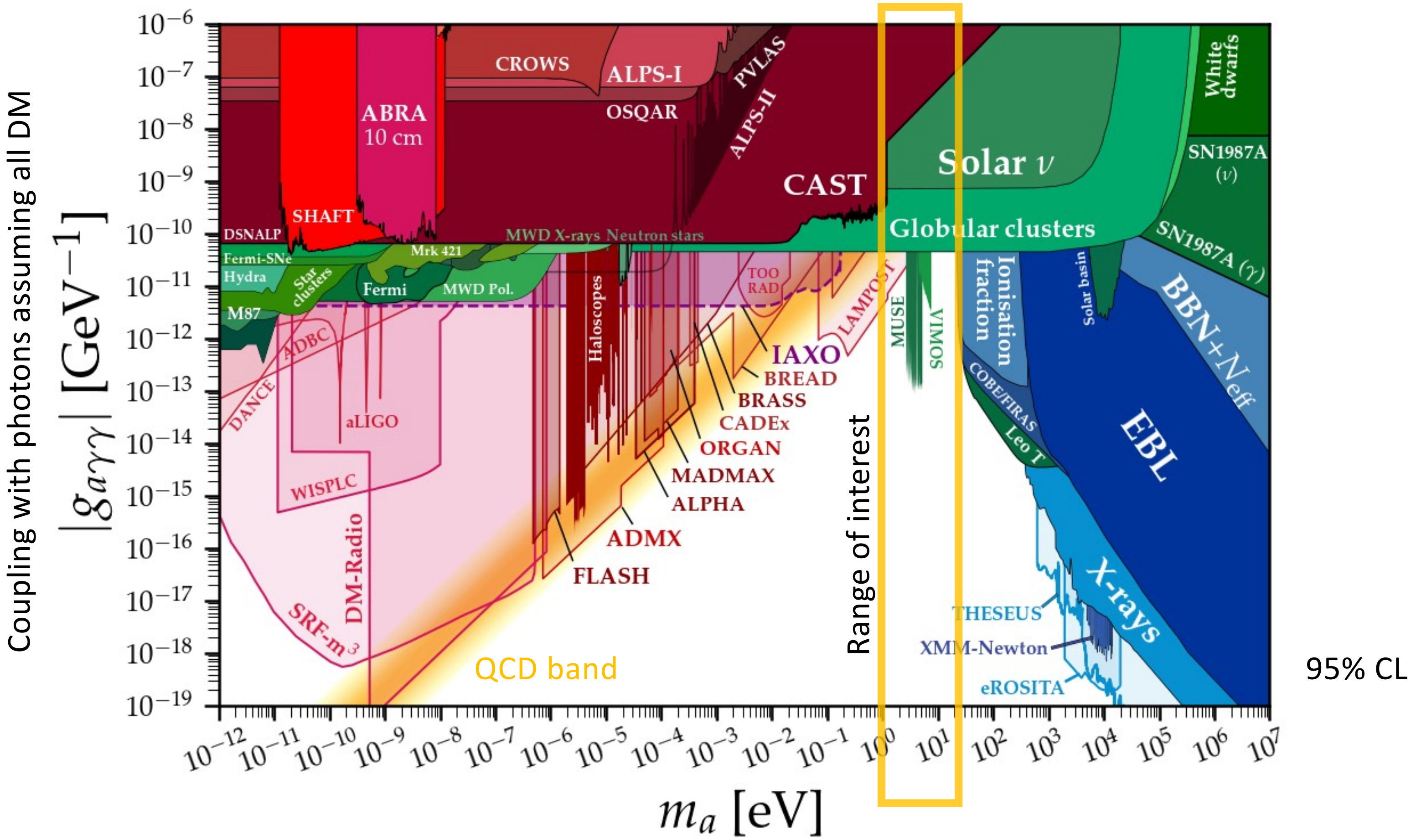
Axion and ALPs



95% CL

Adams+(2022); Snowmass

Axion and ALPs



Adams+(2022); Snowmass

PHYSICAL REVIEW D **75,** 105018 (2007)

Telescope search for decaying relic axions

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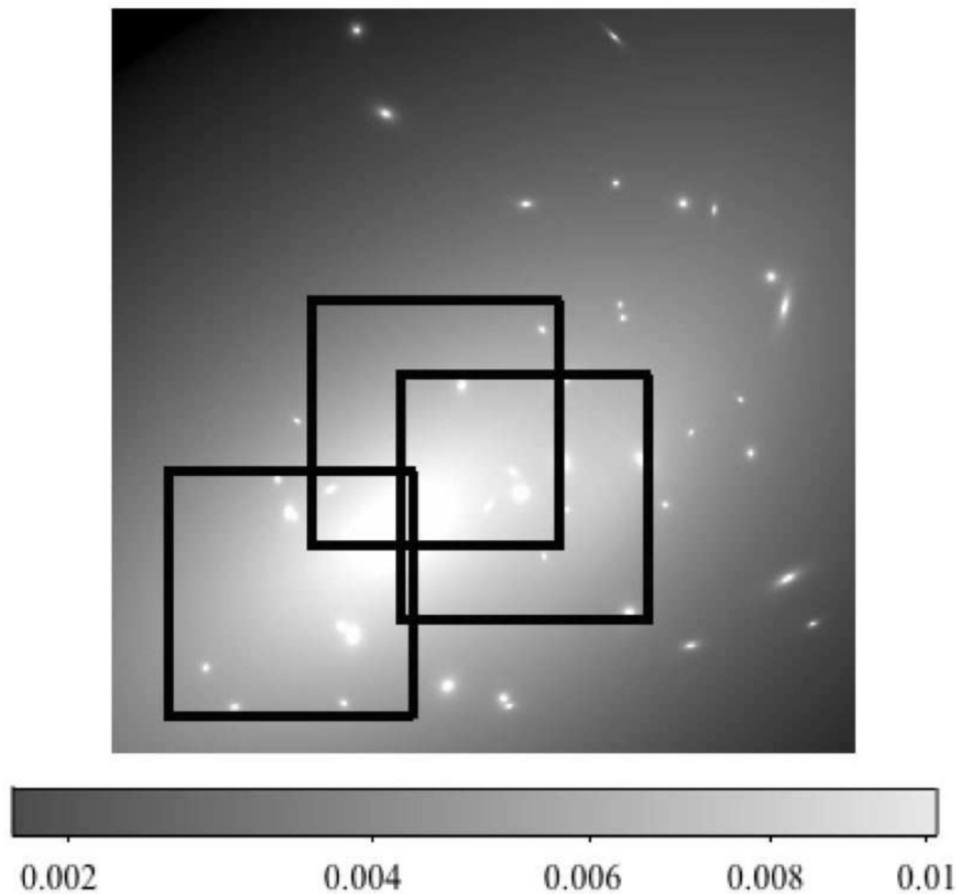
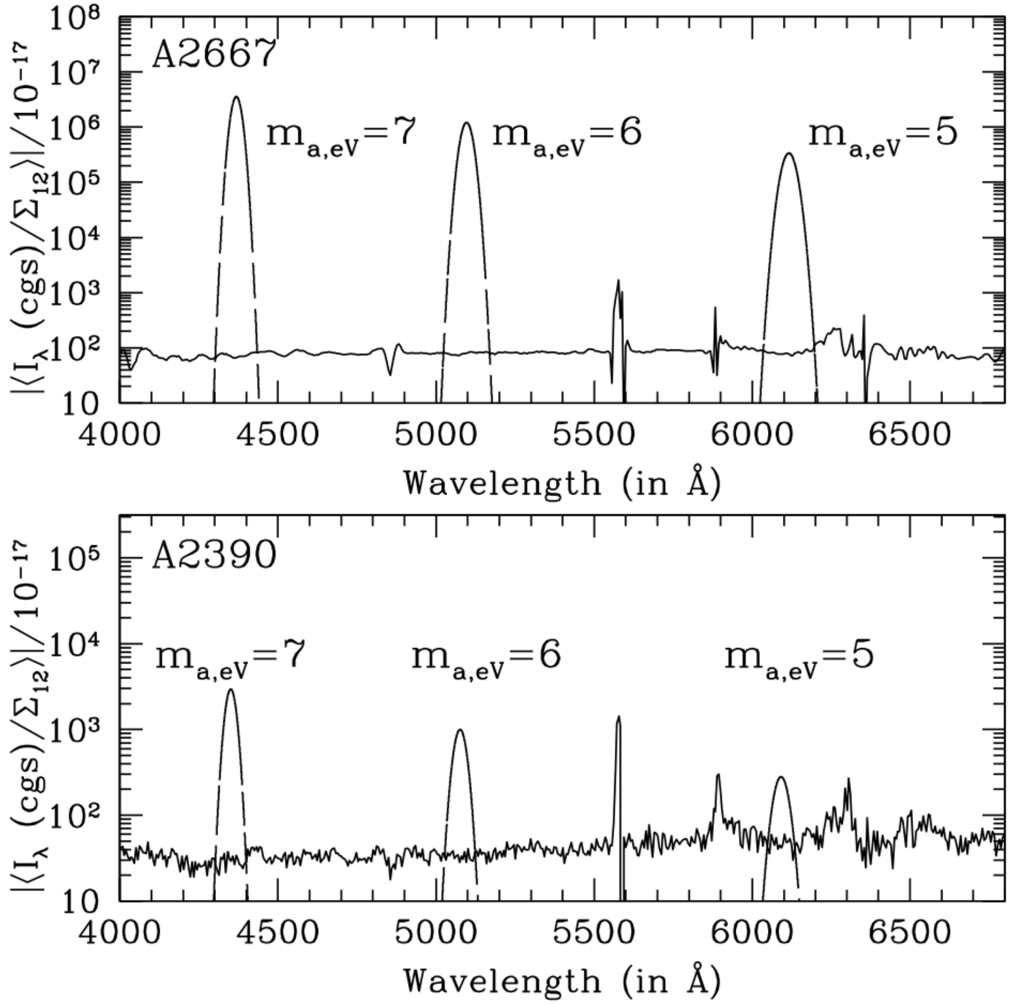
(Received 14 November 2006; revised manuscript received 27 March 2007; published 25 May 2007)

A search for optical line emission from the two-photon decay of relic axions was conducted in the galaxy clusters Abell 2667 and 2390, using spectra from the VIMOS (Visible MultiObject Spectrograph) integral field unit at the Very Large Telescope. New upper limits to the two-photon coupling of the axion are derived, and are at least a factor of 3 more stringent than previous upper limits in this mass window. The improvement follows from a larger collecting area, integration time, and spatial resolution, as well as from improvements in signal to noise and sky subtraction made possible by strong-lensing mass models of these clusters. The new limits either require that the two-photon coupling of the axion be extremely weak or that the axion mass window between 4.5 eV and 7.7 eV be closed. Implications for sterile-neutrino dark matter are discussed briefly also.

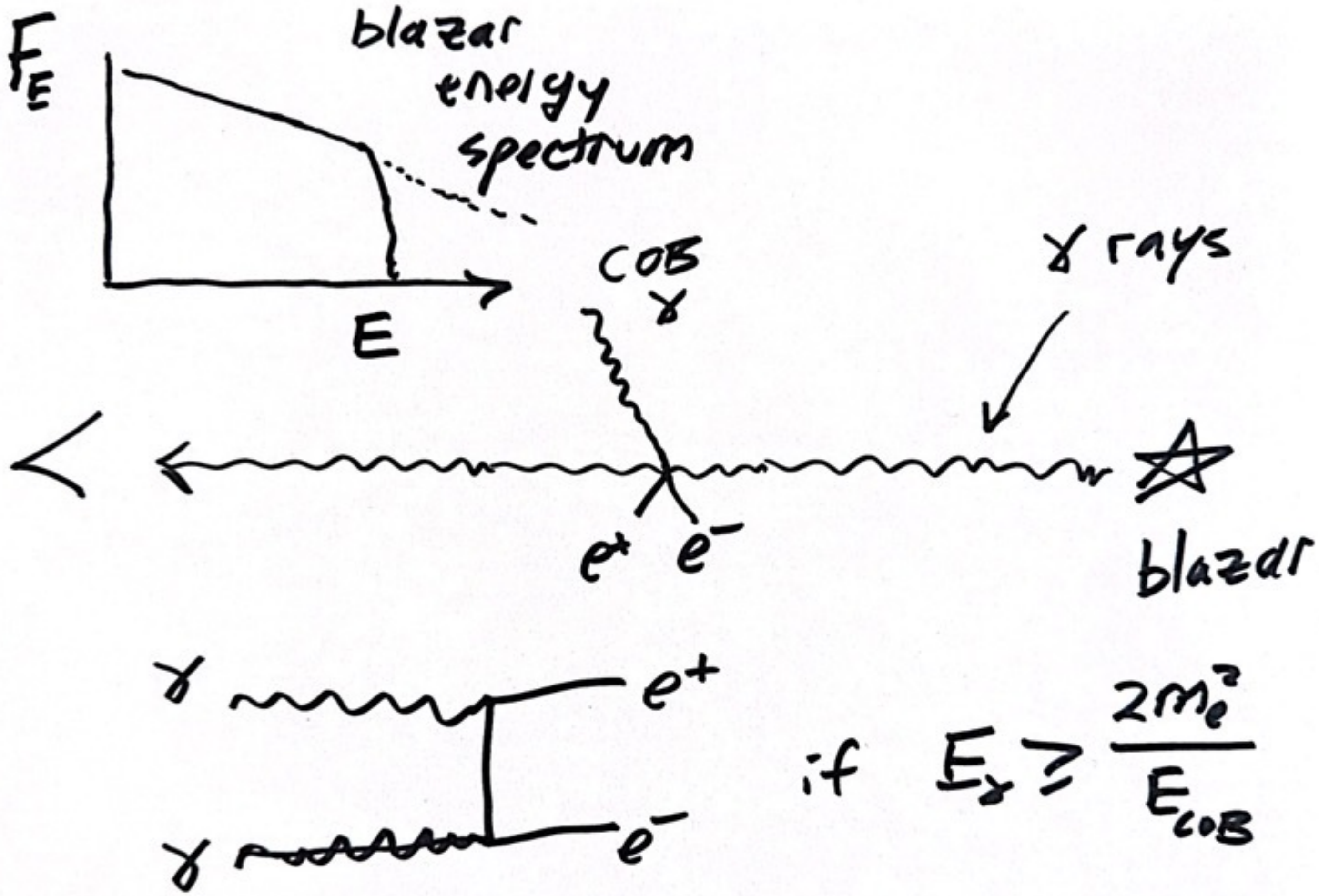
DOI: 10.1103/PhysRevD.75.105018 PACS numbers: 14.80.Mz, 98.62.Sb, 98.65.Cw, 95.35.+d


0.002
0.004
0.006
0.008
0.01


A2667
$m_{a,eV}=7$
$m_{a,eV}=6$
$m_{a,eV}=5$
$|\langle I_\lambda \text{ (cgs)}/\Sigma_{12}\rangle|/10^{-17}$
Wavelength (in Å)
A2390
$m_{a,eV}=7$
$m_{a,eV}=6$
$m_{a,eV}=5$
$|\langle I_\lambda \text{ (cgs)}/\Sigma_{12}\rangle|/10^{-17}$
Wavelength (in Å)

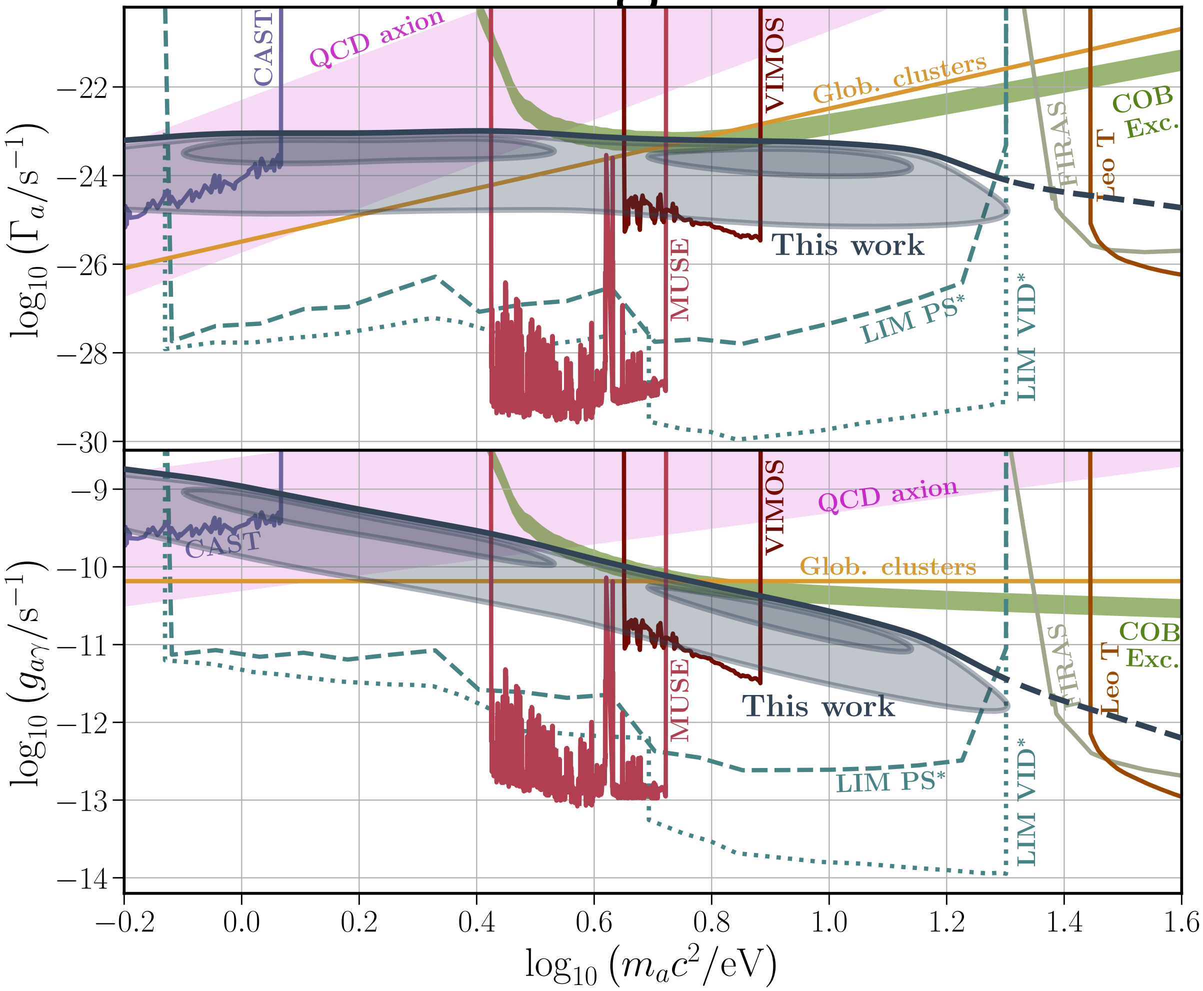
Gamma-ray attenuation: another probe of the cosmic optical background

- Fermi Telescope has gamma-ray spectra from ~800 blazars
- Air Cherenkov telescopes also see many
- Look for attenuation of high-energy gamma rays from blazars



if $E_\gamma \geq \frac{2m_e^2}{E_{COB}}$

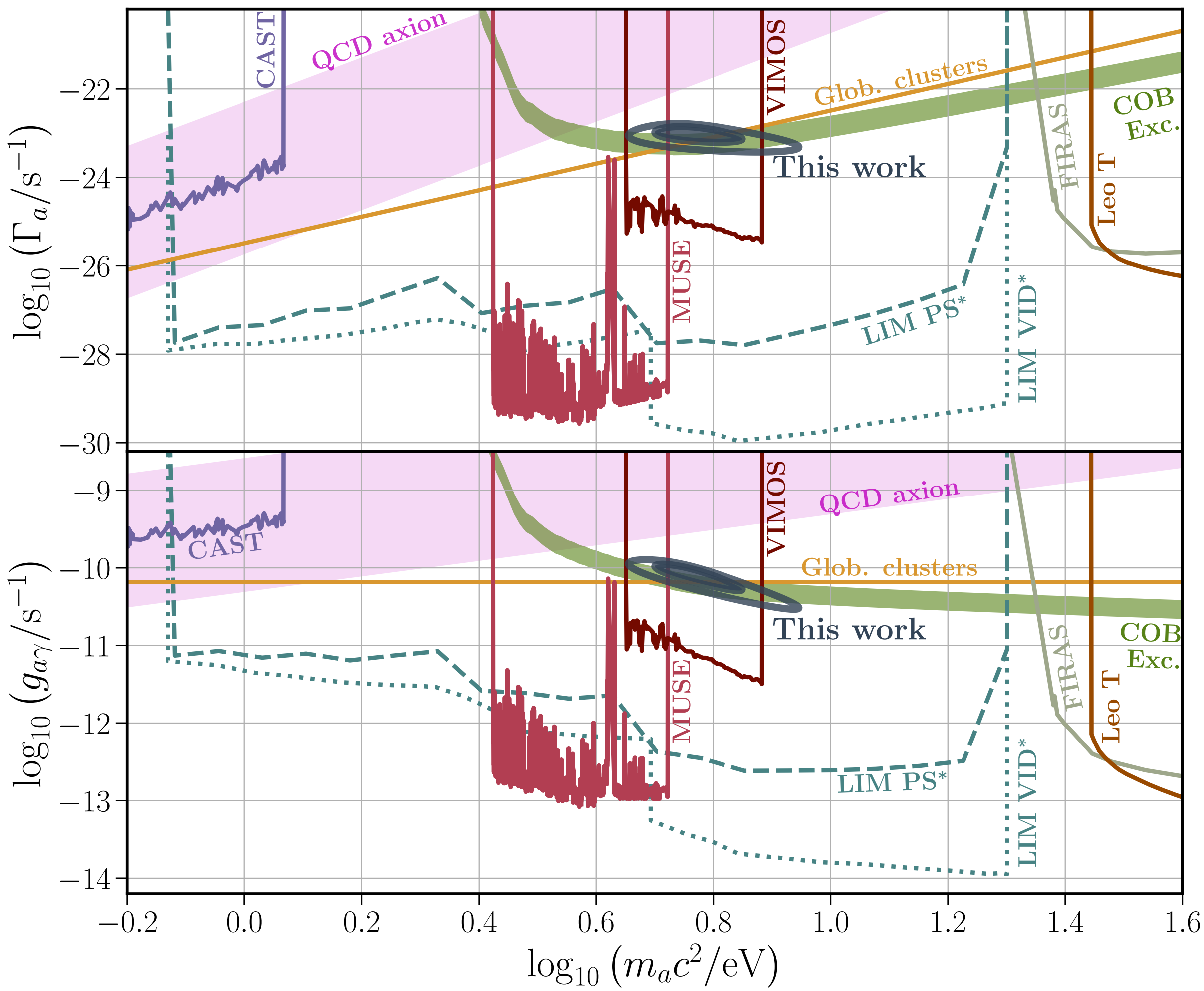
Understanding the axion hint



Bernal+(2022b)

95% CL

Understanding the axion hint



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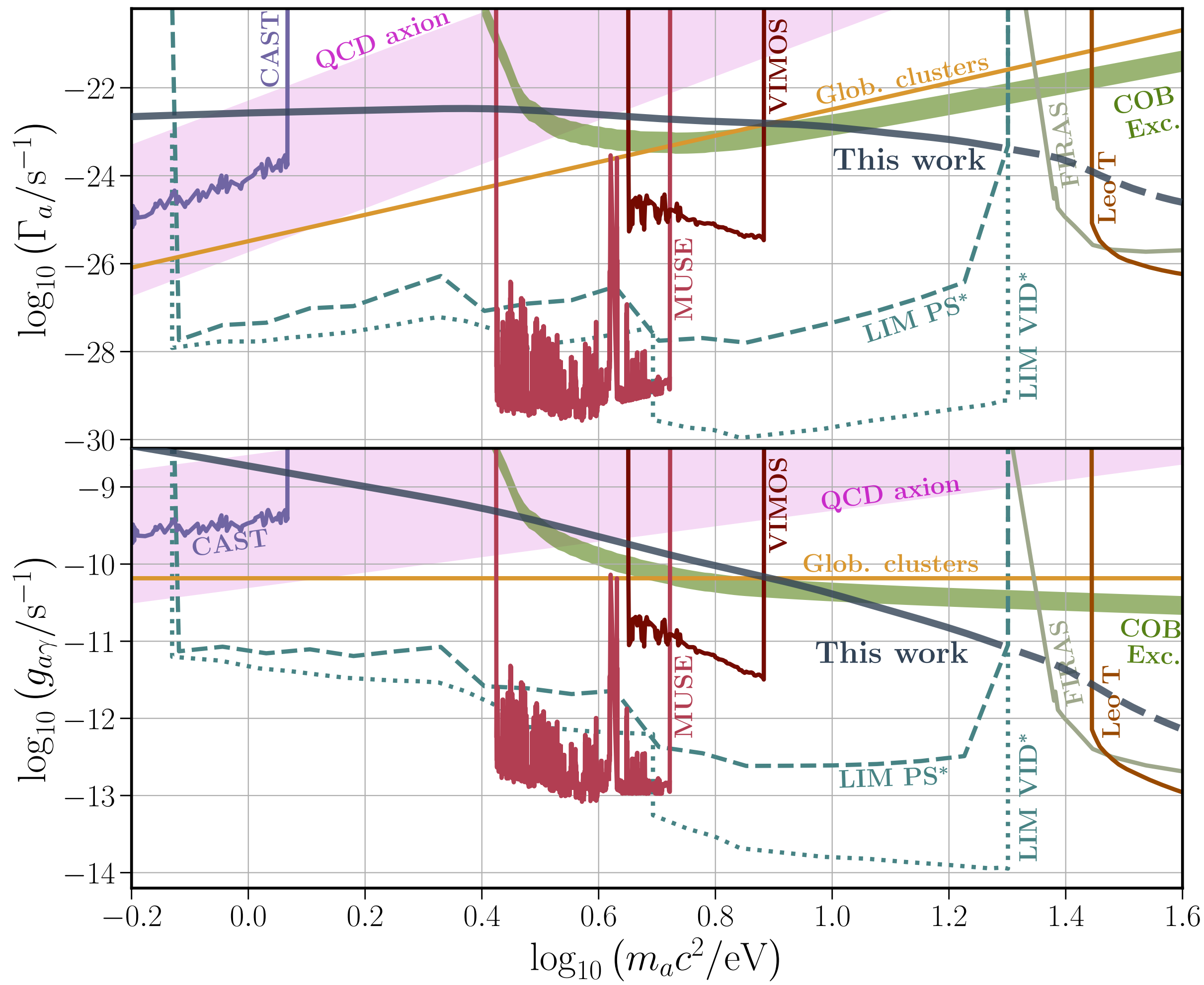
Bernal+(2022b)

Null case B



95% CL

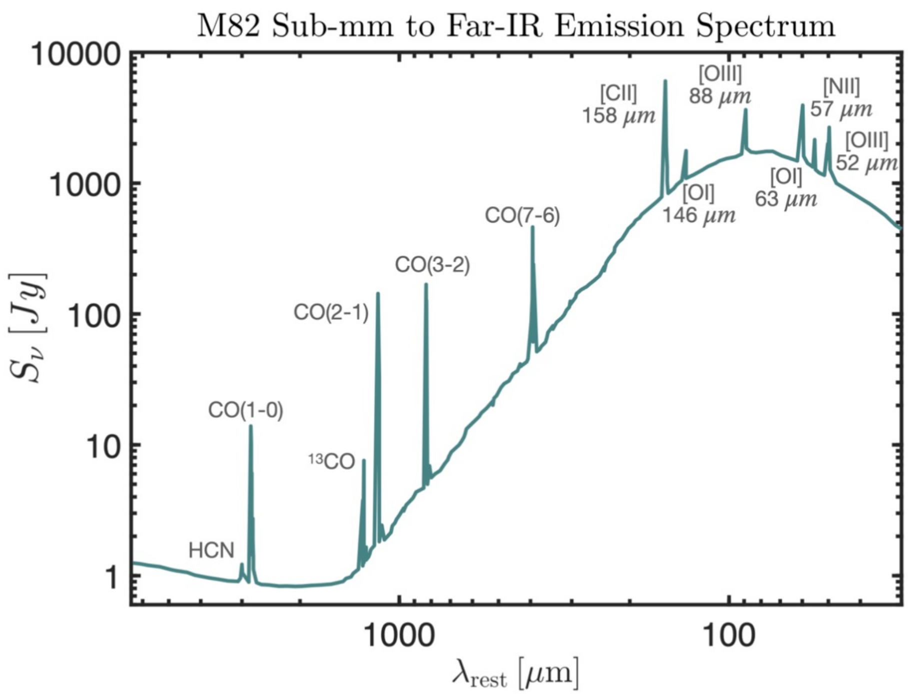
Bernal+(2022b)

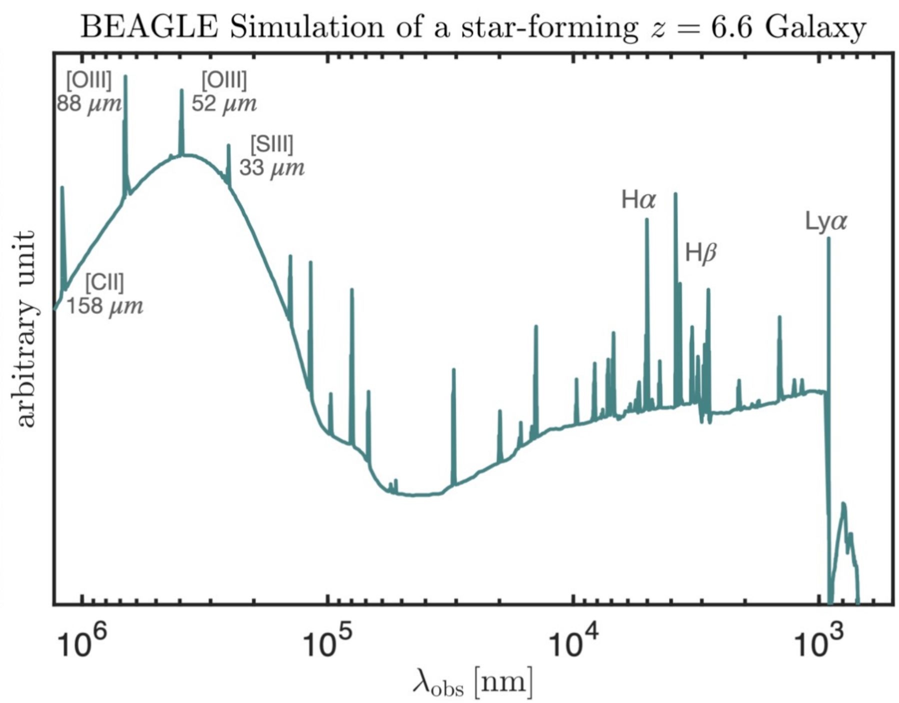
II. Line-Intensity Mapping

- 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 → 3D

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

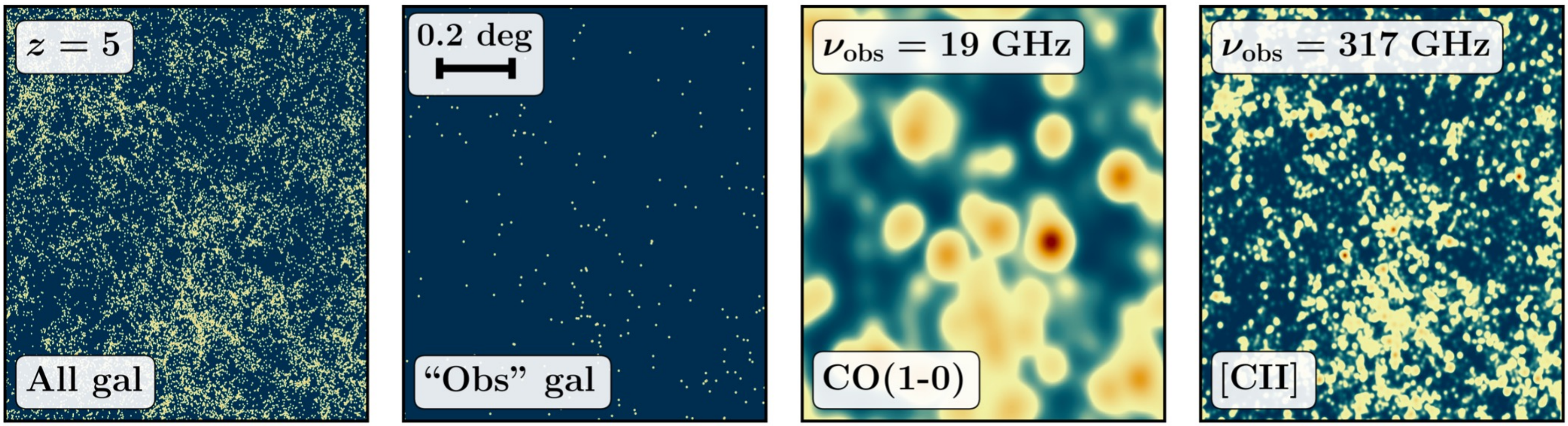
Emission lines



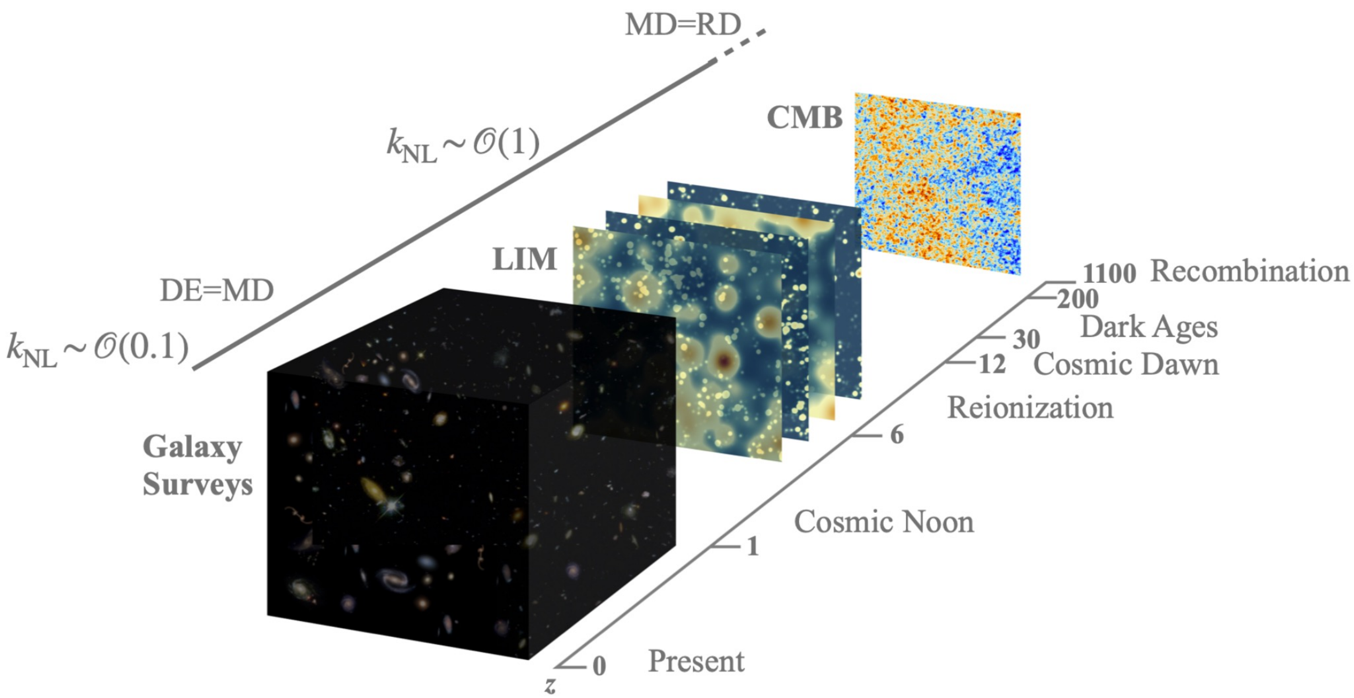


Galaxy surveys: detailed distribution of brightest galaxies

Intensity maps: noisy distribution of all galaxies and IGM

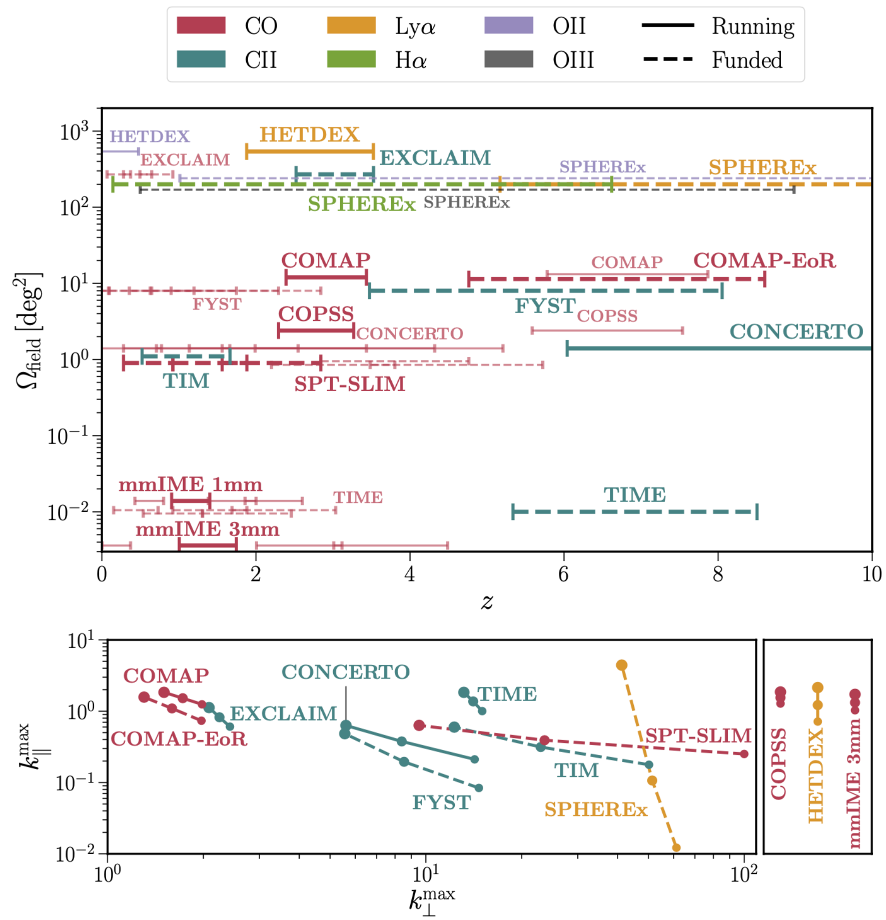


Probing the Universe



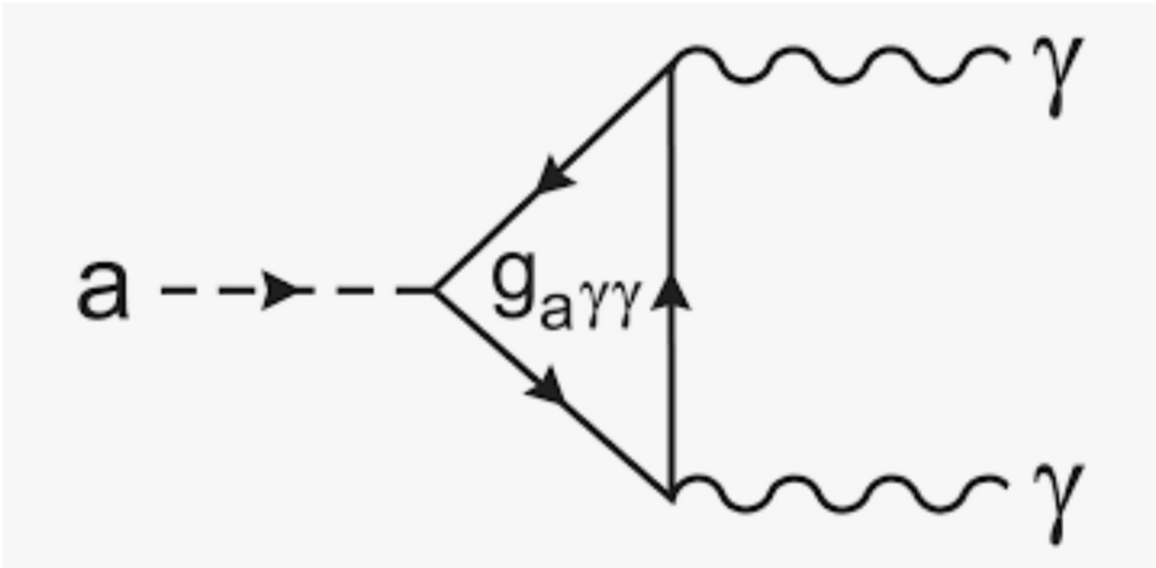
Probing the Universe with LIM

- Exciting experimental landscape!



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

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



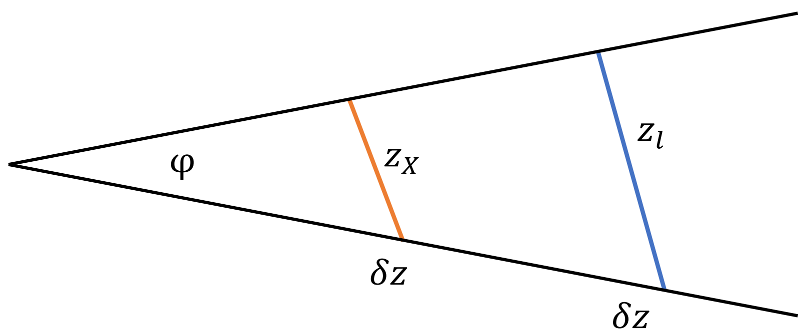
- Axion decay

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

→should cross-correlate with LSS

How to distinguish from astrophysical line

- Clustering anisotropy



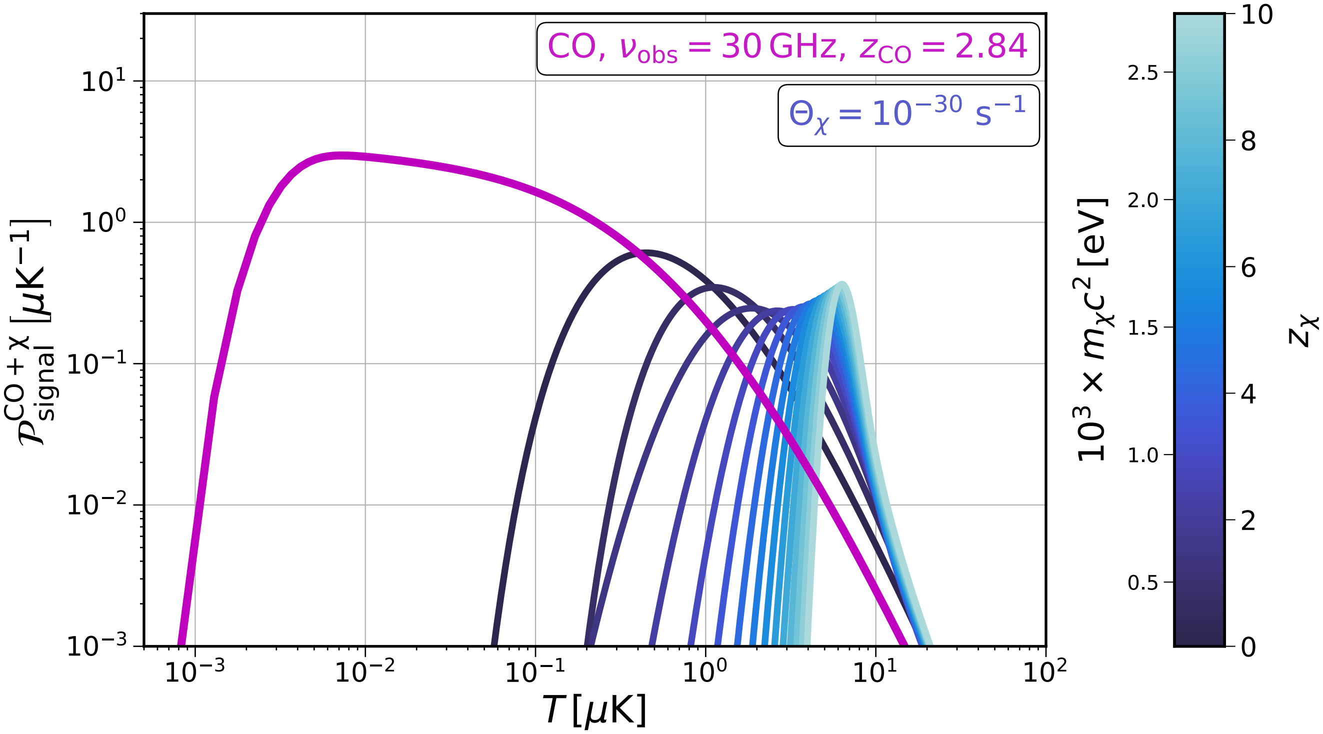
$$x_\perp = D_M(z)\theta$$

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

Voxel intensity distribution (VID)

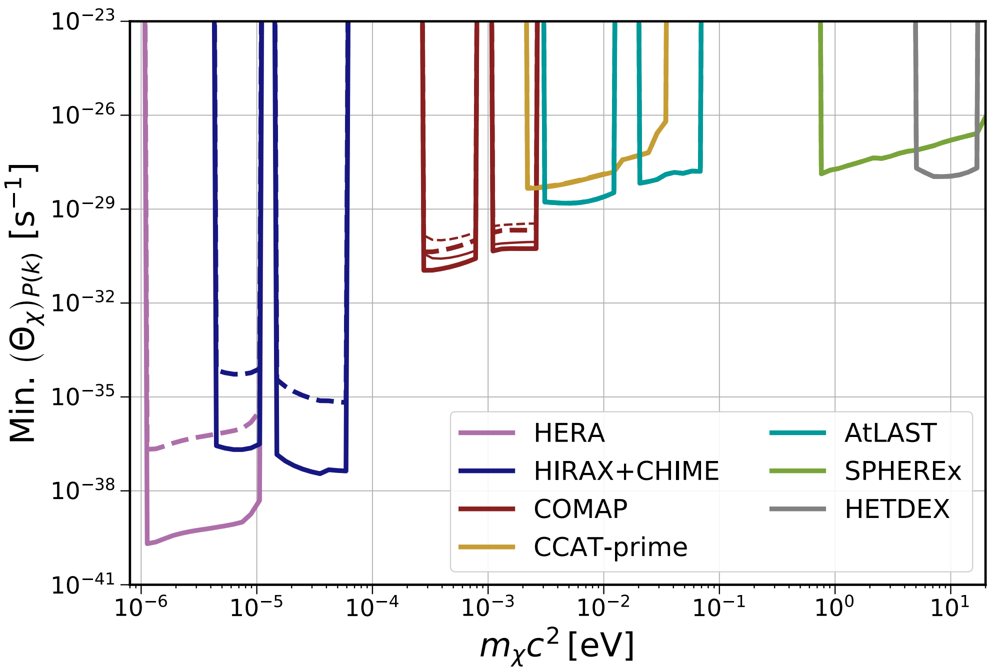
- PDF of luminosity density in each pixel

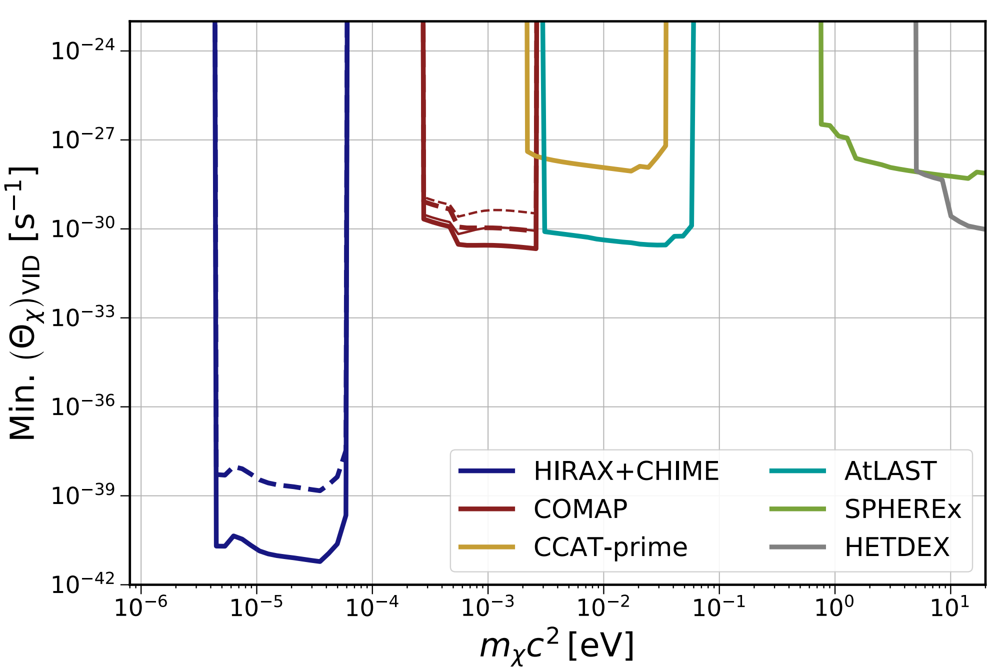
Effect in VID



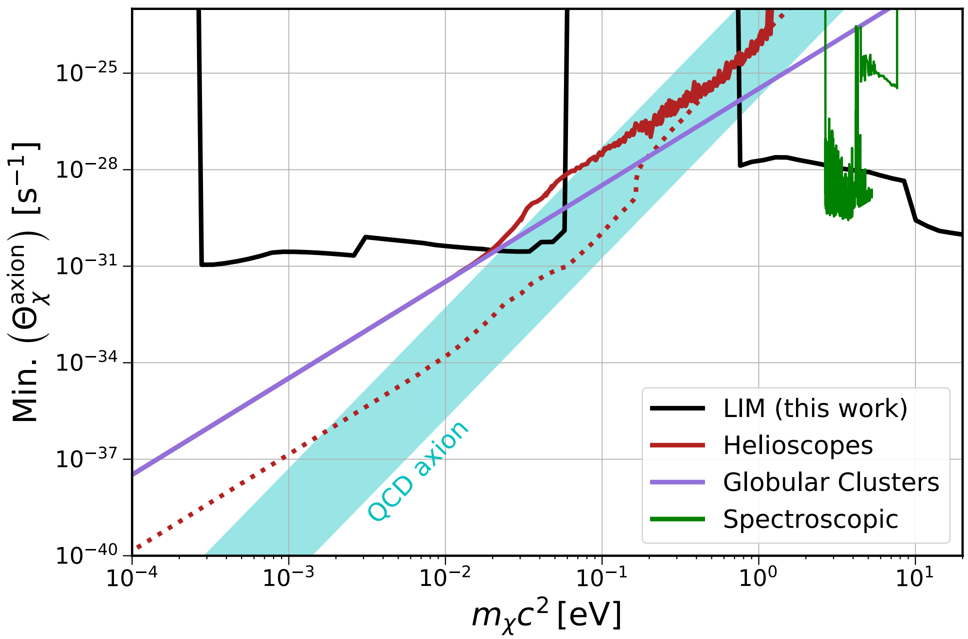
Sensitivity to DM decays

- After marginalizing over astrophysical uncertainties of the target emission line





Sensitivity to axions



Summary

- New Horizons sees ~two optical photons for every photon expected from known galaxy populations
- Excess is consistent with constraints to optical background from gamma-ray absorption
- Axion-decay explanation for excess to be tested with high significance with line intensity mapping with SphereX
- Line intensity mapping provides new tool to study dark matter, neutrinos, dark energy and more