Patchy dark screening

Junwu Huang
May 2024 @ Berkeley

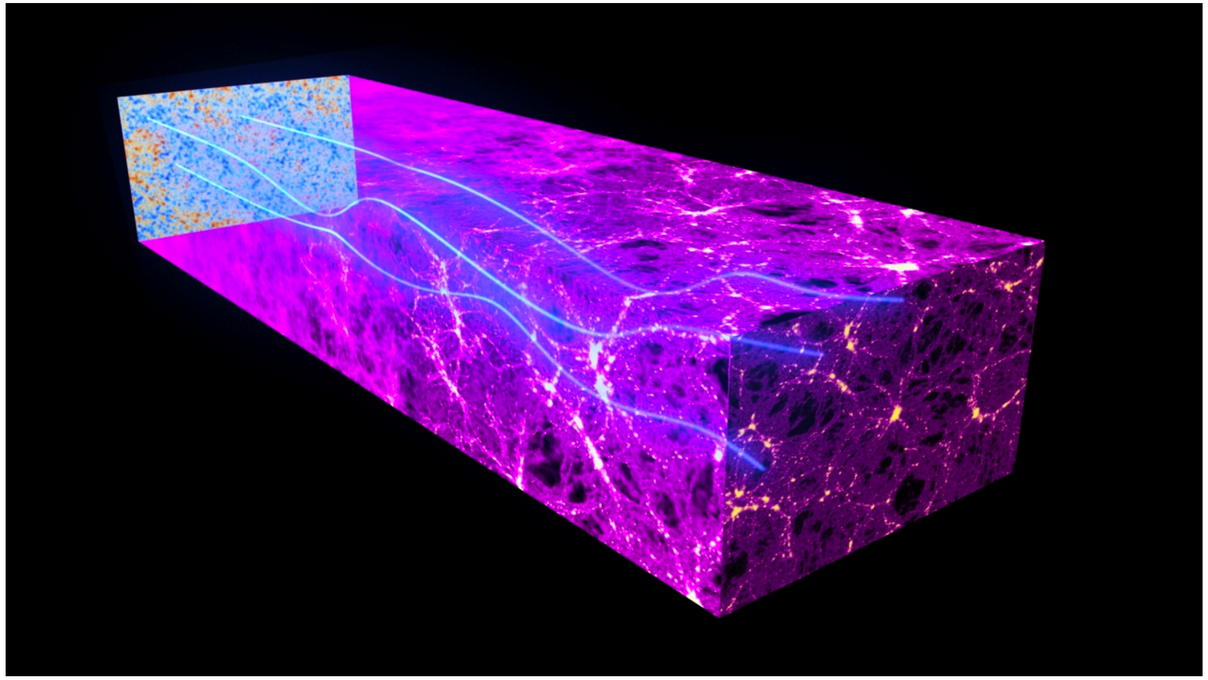
Dalila Pirvu, **Junwu Huang**, Matthew Johnson, 2307.15124
Dalila Pirvu, Cristina Mondino, **Junwu Huang**, Matthew Johnson, 2405.XXXXX
Fiona McCarthy, J. Colin Hill, Dalila Pirvu, **Junwu Huang**, Matthew Johnson,
Keir K. Rogers, 240X.XXXXX, and more ongoing studies



CMB secondaries

See Selim's Talk

Background light



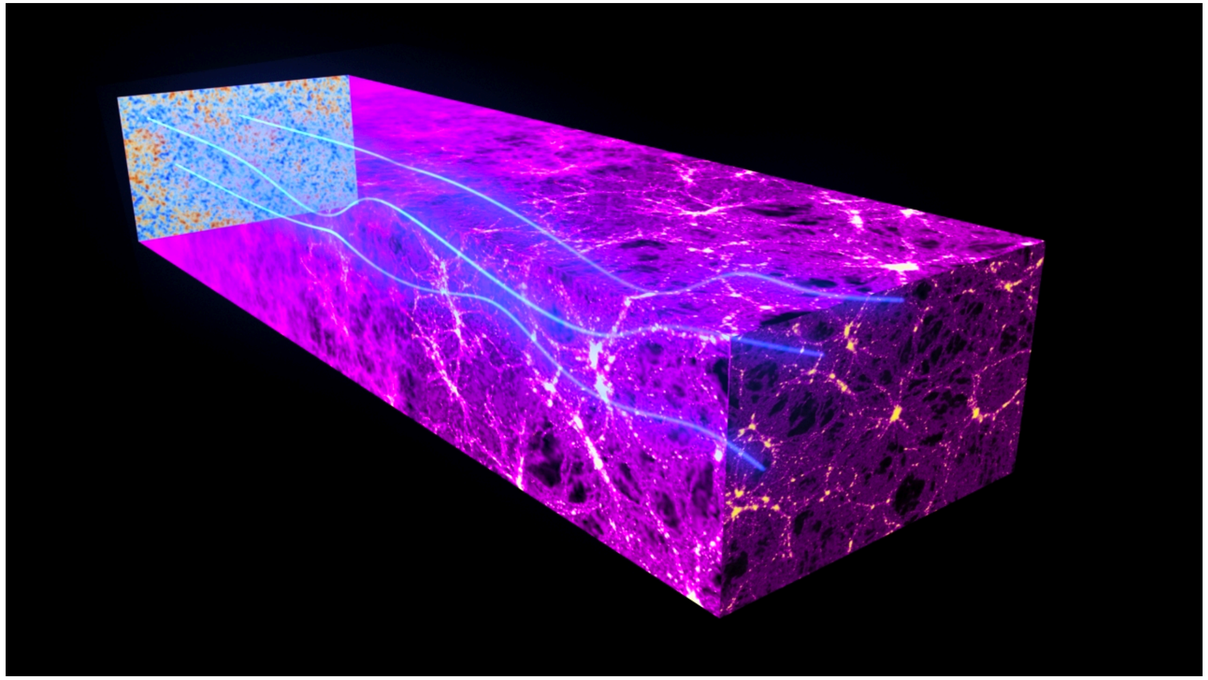
Observable

Large scale structure

CMB secondaries

See Selim's Talk

Background light



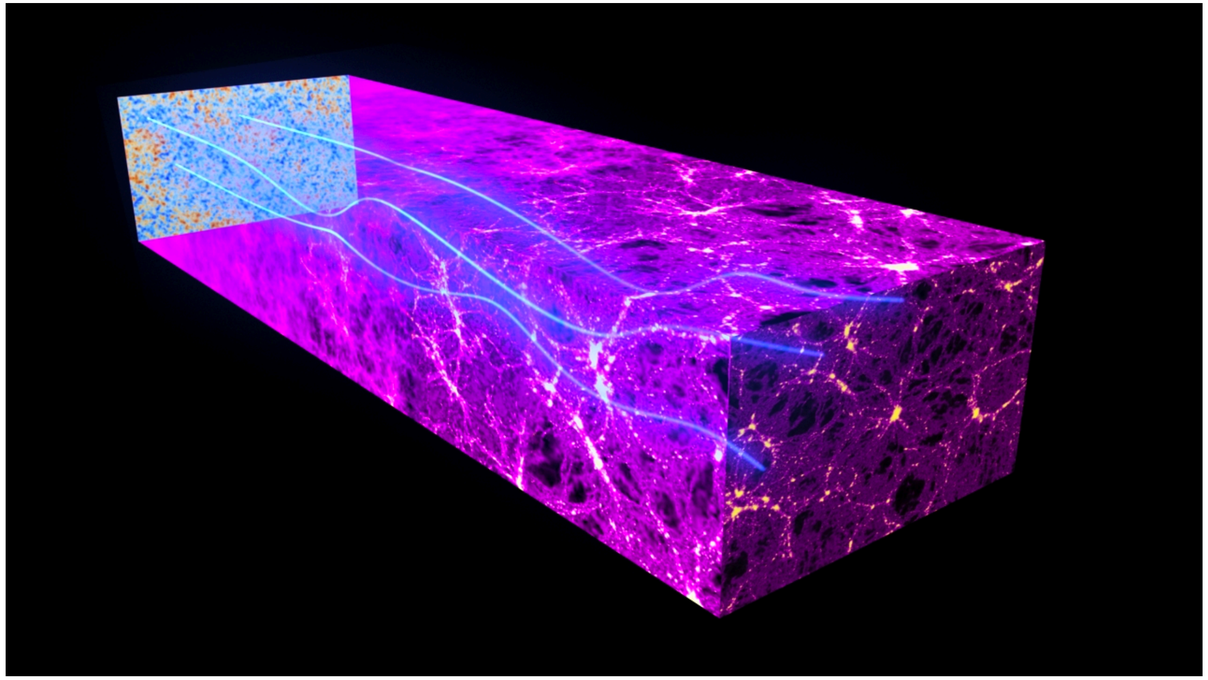
Observable

Known physics (unKnown physics)

Growth of structures

CMB secondaries

Background light



Observable

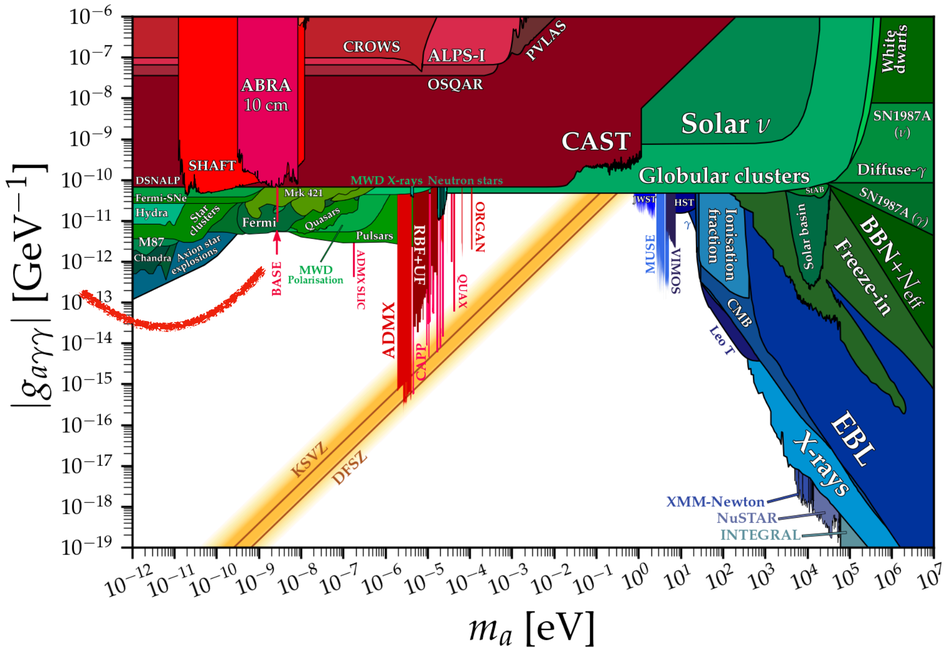
Tracer of structures

New physics
(Couples to photons)

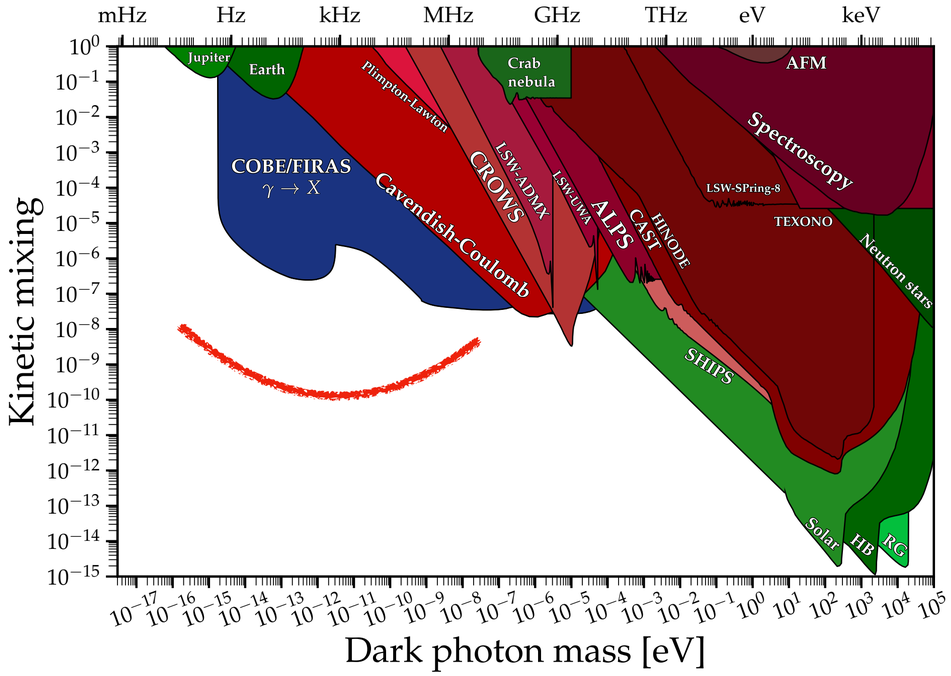
Axions & Dark photons

https://cajohare.github.io/AxionLimits/

Axion photon coupling: $g_{a\gamma\gamma} a F^{\mu\nu} \tilde{F}_{\mu\nu}$



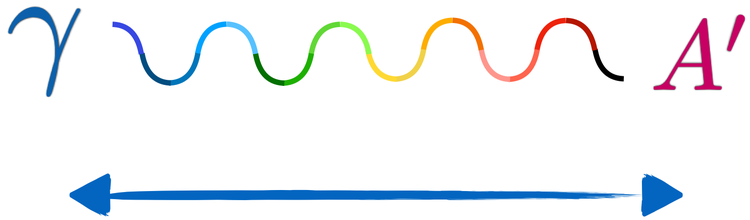
Dark photon kinetic mixing: $\varepsilon F^{\mu\nu} F'_{\mu\nu}$



See also Peter's Talk for motivation

Dark photon conversion

- Resonant conversion to search for photon to dark photon conversion

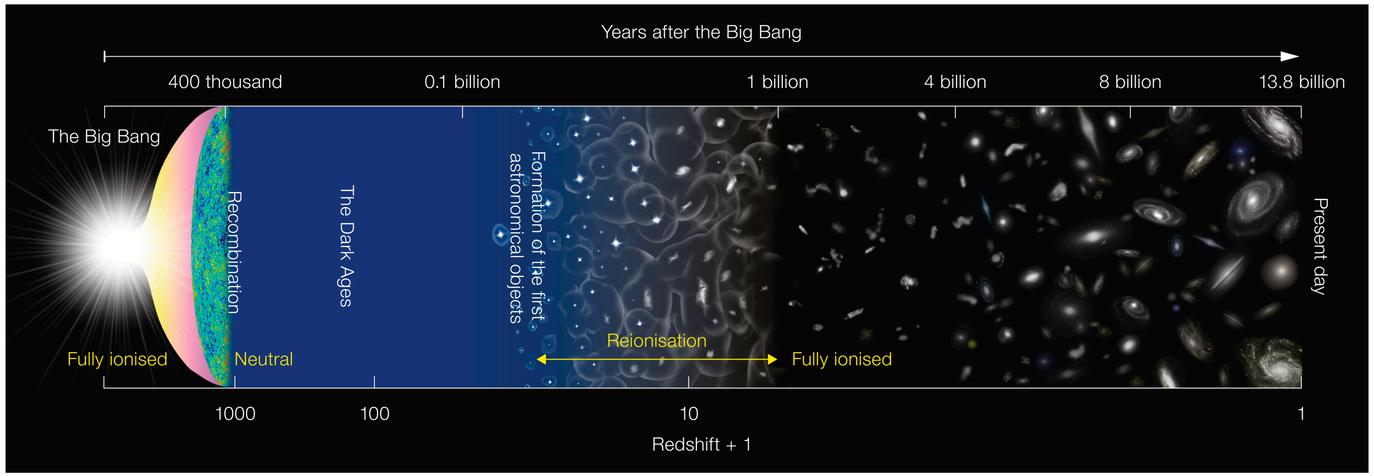


Conversion in cosmology

- Resonant conversion to search for photon to dark photon conversion
  - $\omega_p^2 = m_{A'}^2$

Cosmology provides natural scanners

$$\omega_p^2 = \frac{e^2 X_e n_e}{m_e}$$



Mirizzi, et. al., 0901.0014, Caputo, et. al., 2002.05165

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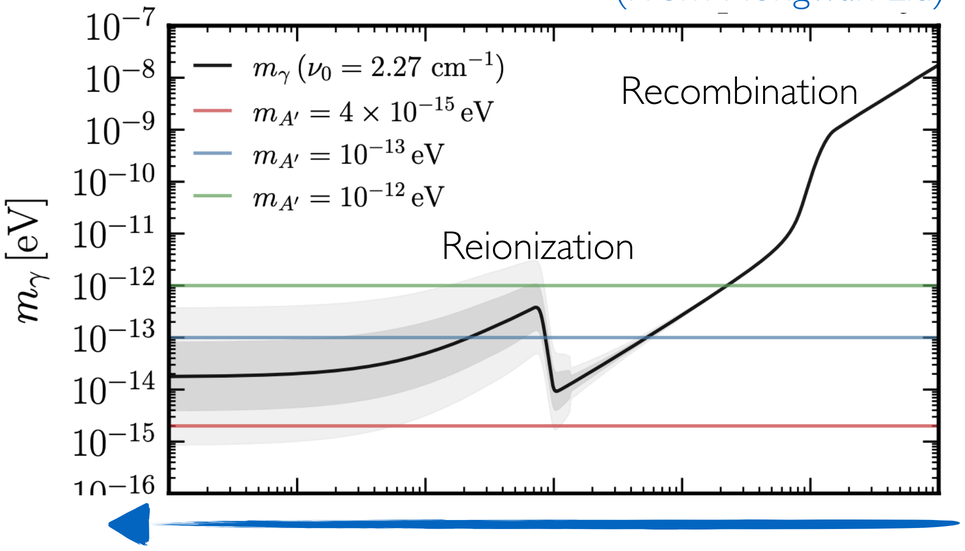
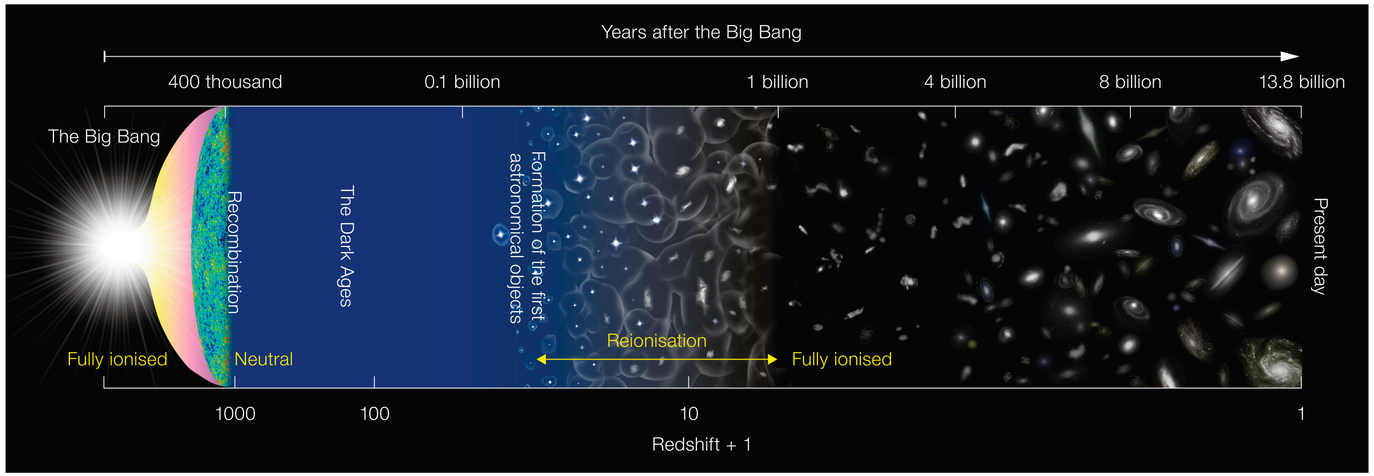
(From Hongwan Liu)



Time



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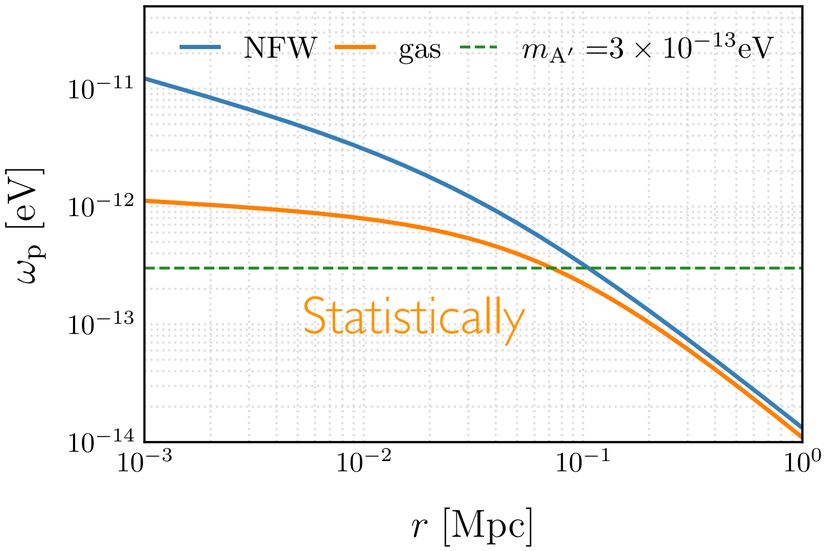
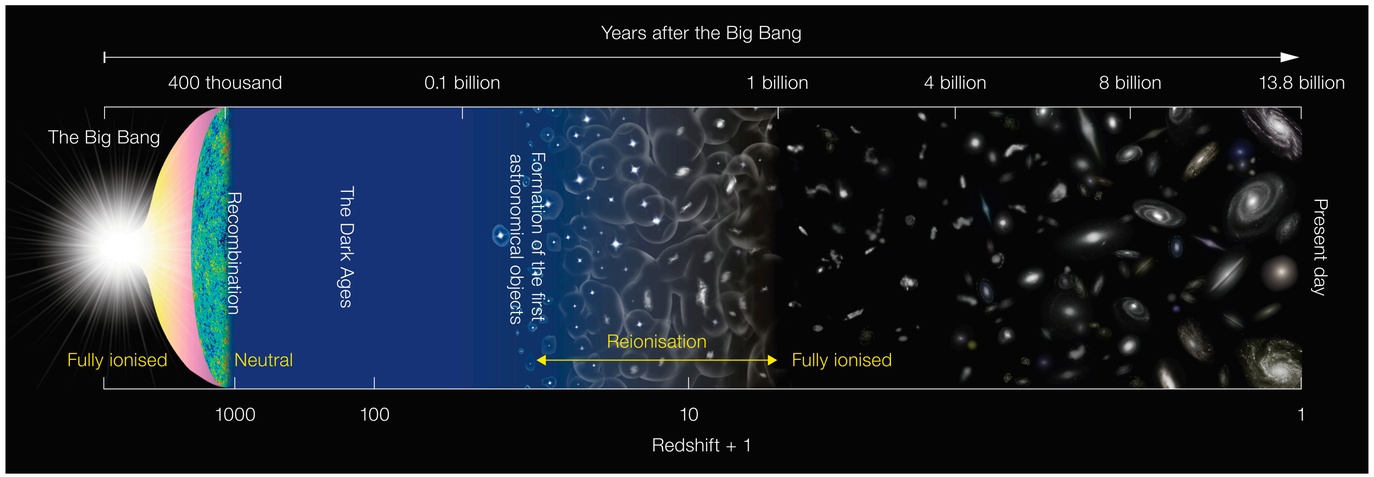
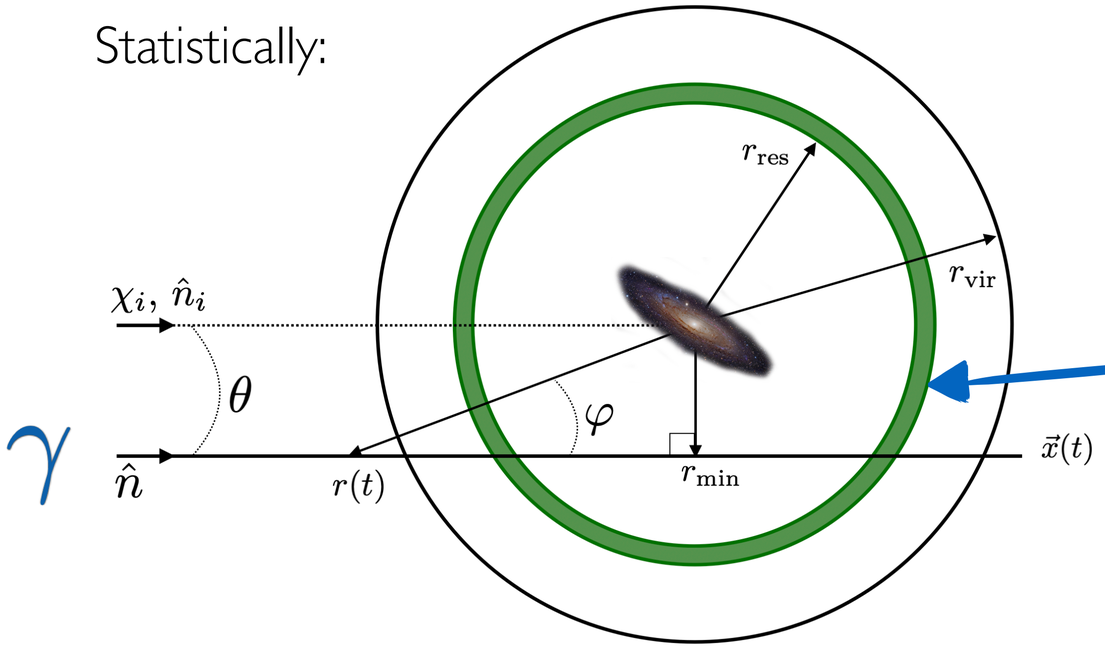
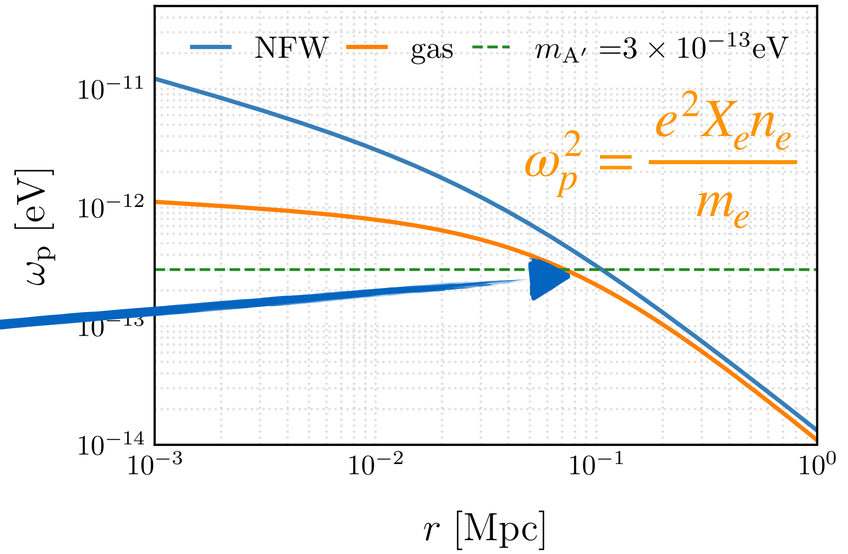




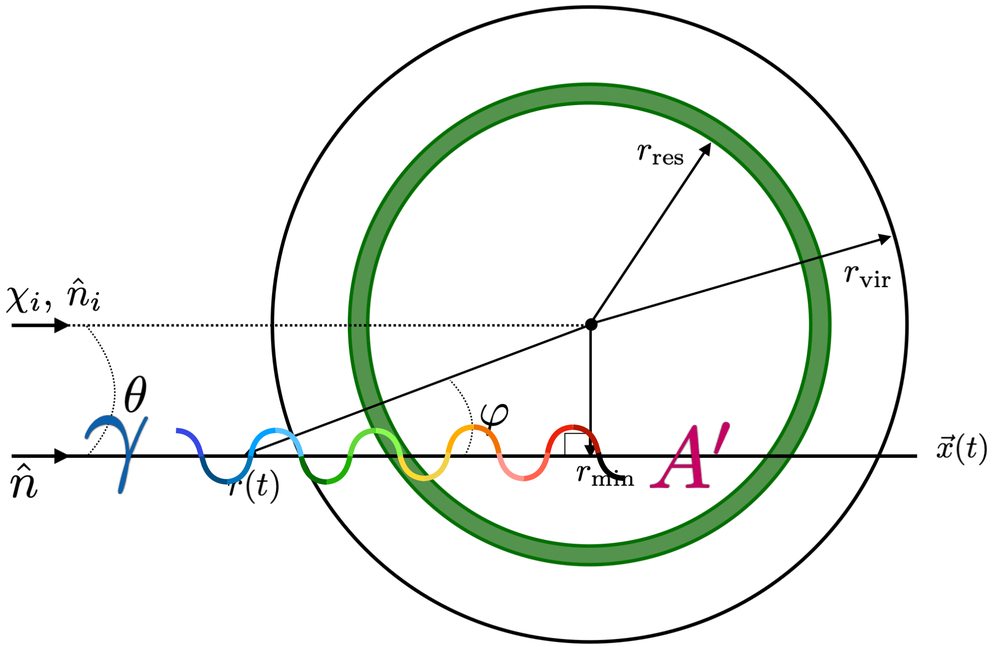
Inside a galactic halo

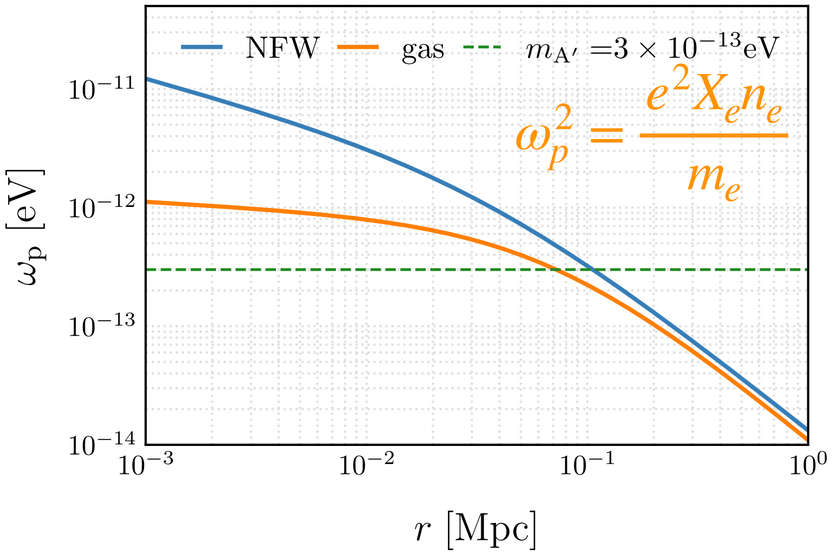
Statistically:





Inside a galactic halo



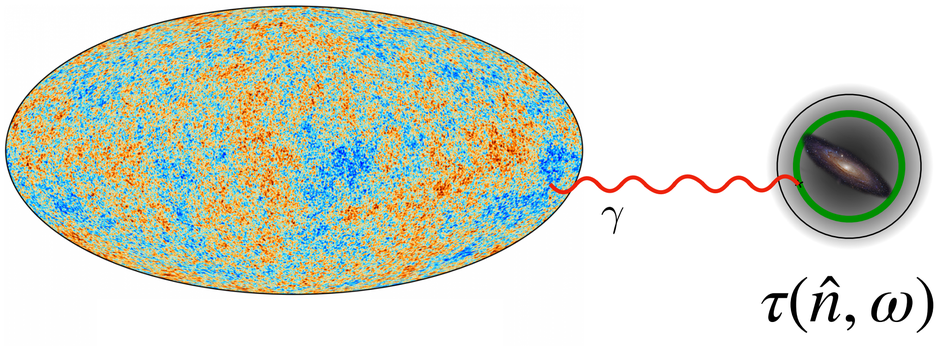


$$\tau(\hat{n},\omega) \equiv P_{\gamma\to A'} = \sum_{t_{\rm res}} \frac{\pi\varepsilon\, m_{A'}^2}{\omega(t_{\rm res})} \times \varepsilon \left|\frac{\rm d}{{\rm d}t} \ln m_\gamma^2(\vec{x}(t))\right|^{-1}_{t=t_{\rm res}}$$

Frequency dependence

Position/Angular dependence

Map of photon conversion



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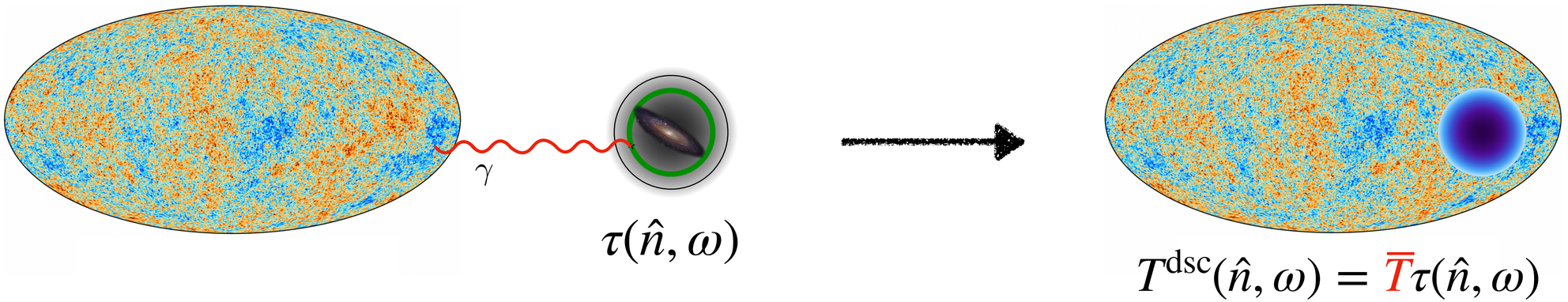

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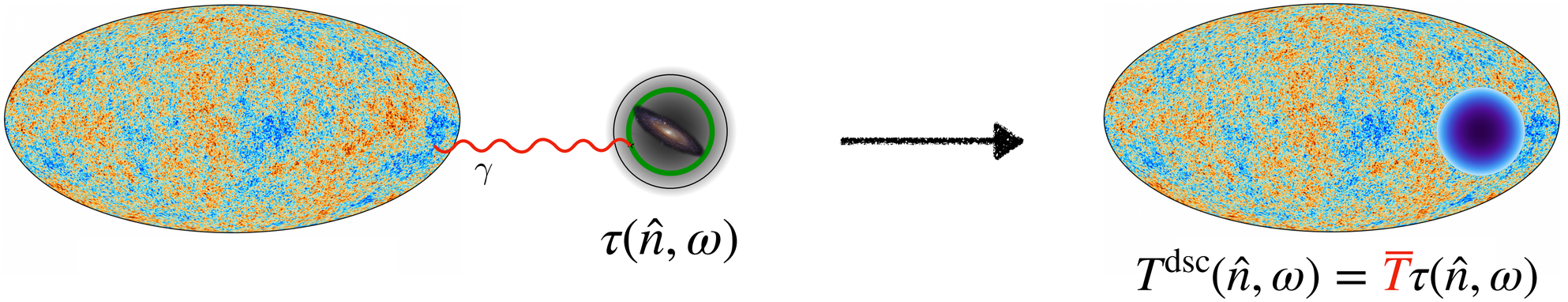

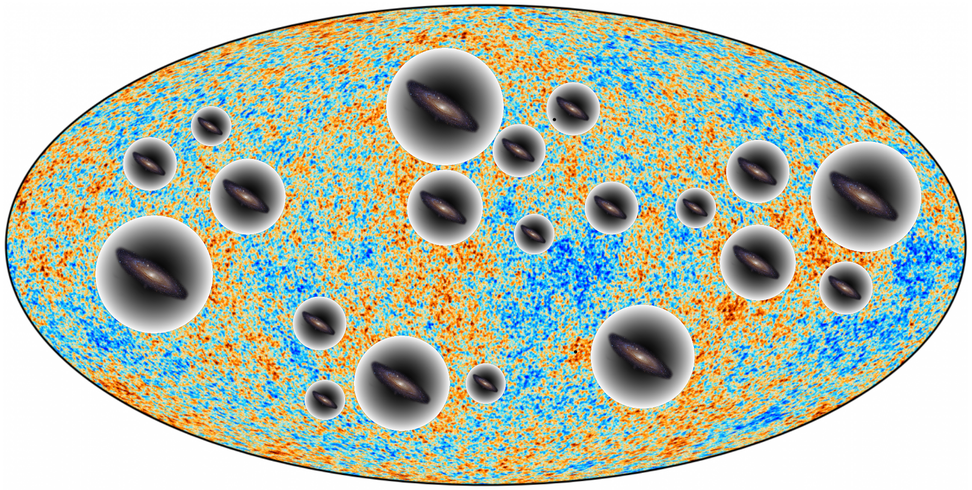

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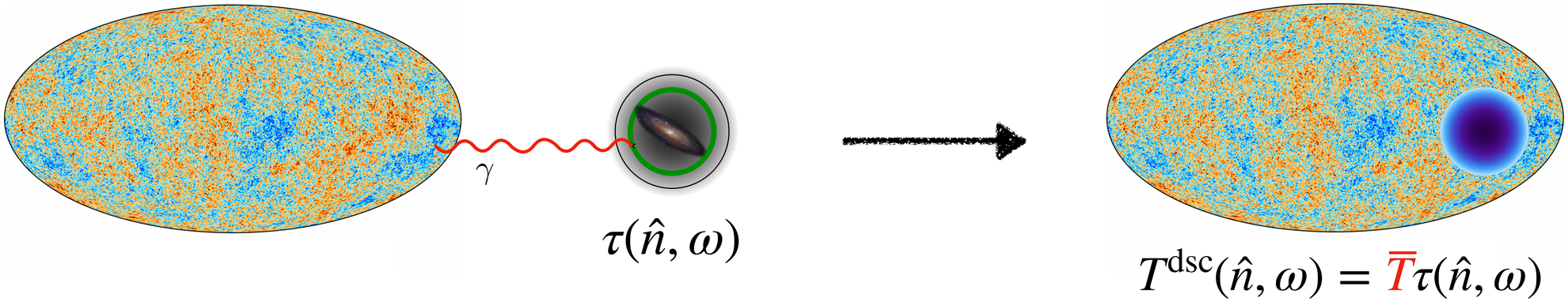
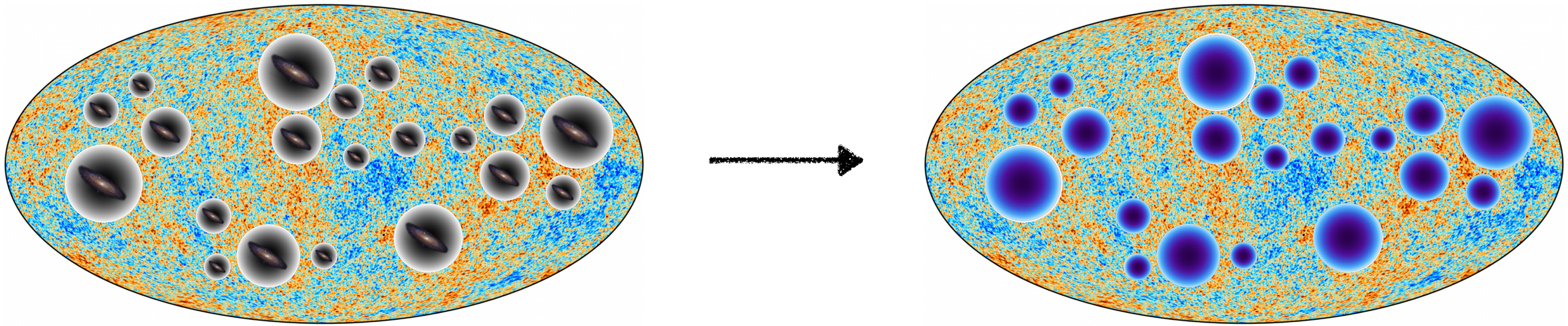
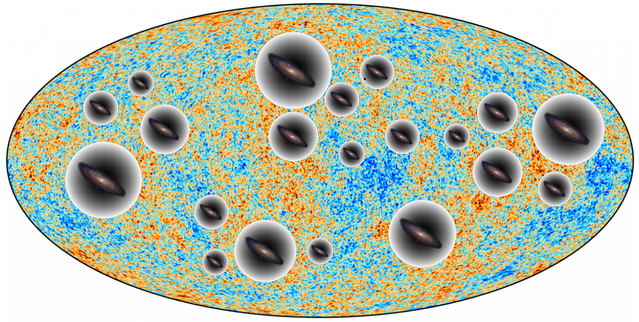
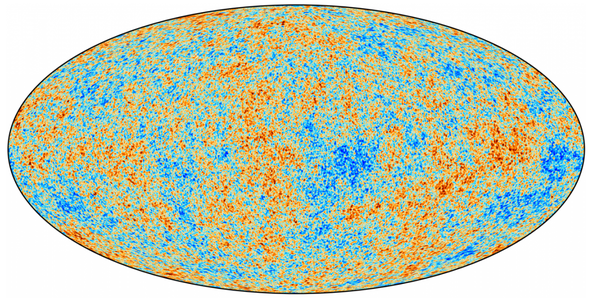




Screening and dark screening maps

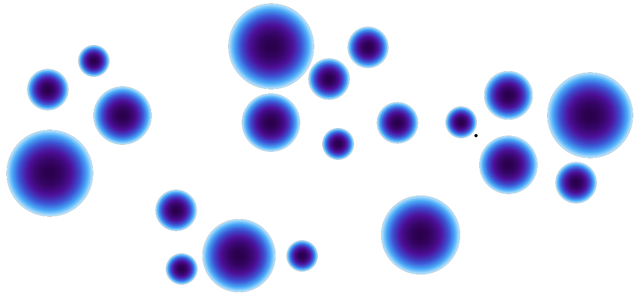


$\overline{T} + T^{\mathrm{CMB}}(\hat{n}) + \mathrm{halo}$



$T^{\mathrm{CMB}}(\hat{n})$

+

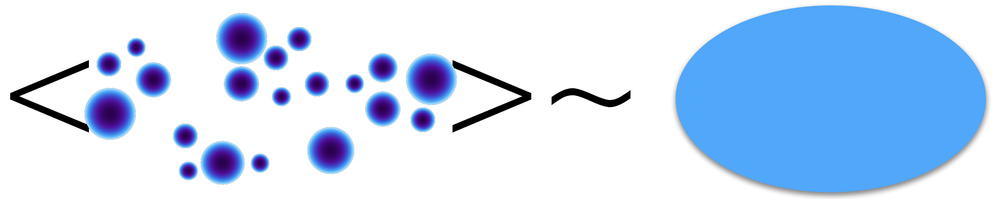


$T^{\mathrm{dsc}}(\hat{n}, \omega) = \overline{T}\tau(\hat{n}, \omega)$

- Map separation with ILC!

Monopole = Spectral distortion

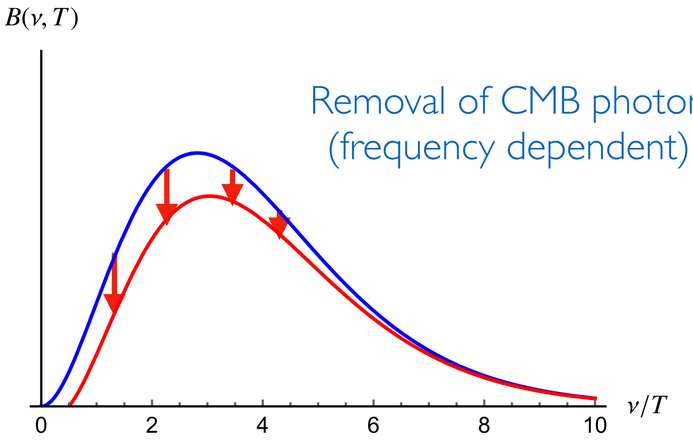
- Monopole:



$$T^{\mathrm{dsc}}(\hat{n},\omega)$$

- COBE/FIRAS constraints.

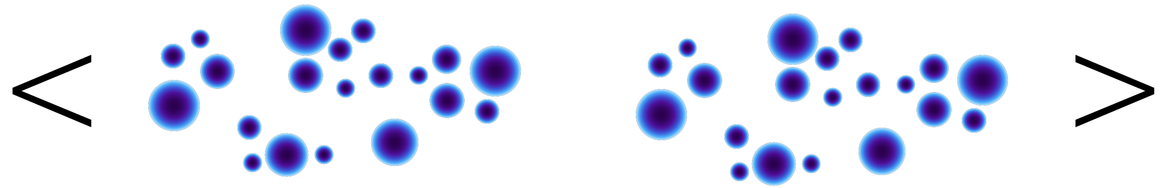
Mirizzi, et. al., 0901.0014,
Caputo, et. al., 2002.05165



Auto-correlation

- Auto-correlation $\langle T^{\mathrm{dsc}} T^{\mathrm{dsc}} \rangle = \bar{T}^2 C_\ell^{\tau\tau}$

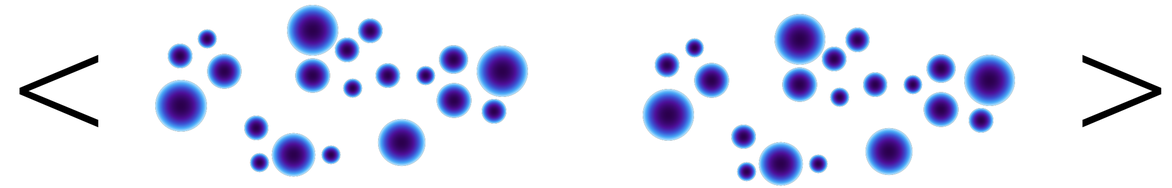
Scales as ε^4



Cross-correlation

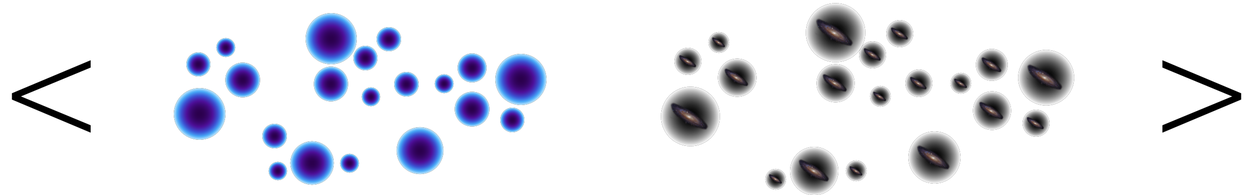
- Auto-correlation $\langle T^{\rm dsc} T^{\rm dsc} \rangle = \overline{T}^2 C_\ell^{\tau\tau}$

Scales as ε^4



- Cross-correlation with LSS survey $\langle T^{\rm dsc} \hat{\tau}_g \rangle = \overline{T} C_\ell^{\tau\hat{\tau}^g}$

Scales as ε^2



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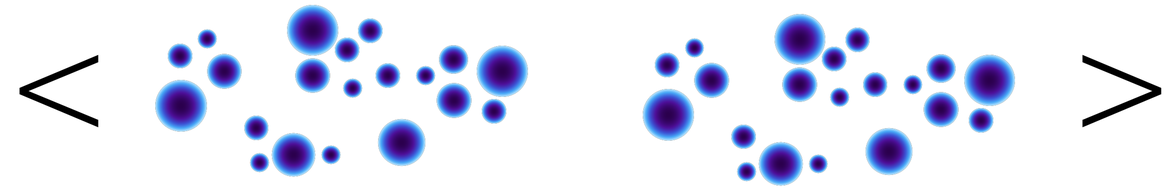


- Cross-correlation with LSS survey $\langle T^{\rm dsc} \hat{\tau}_g \rangle = \overline{T} C_\ell^{\tau\hat{\tau}^g}$

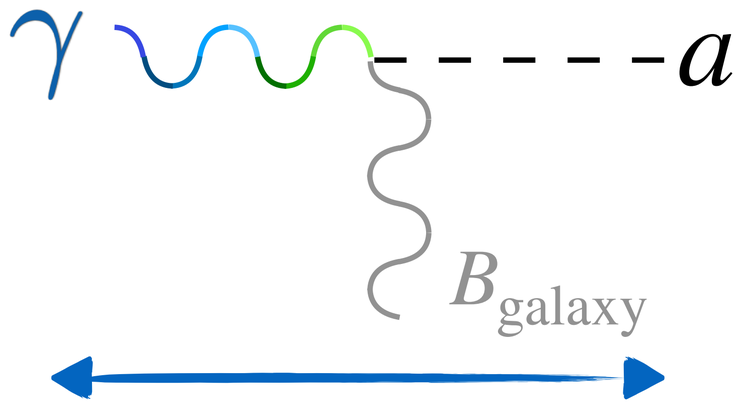
Scales as ε^2

$\langle \mathrm{BSM} \times \mathrm{SM} \rangle$ type operators

$\langle \mathrm{CMB} \times \mathrm{LSS} \rangle$

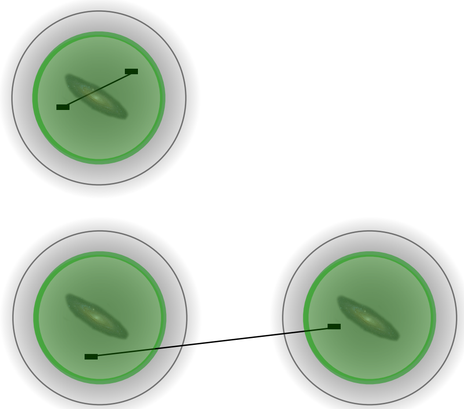
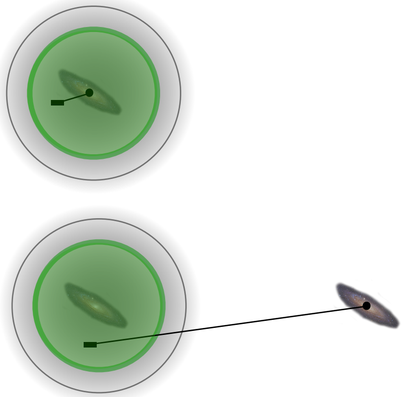
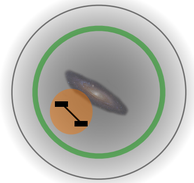
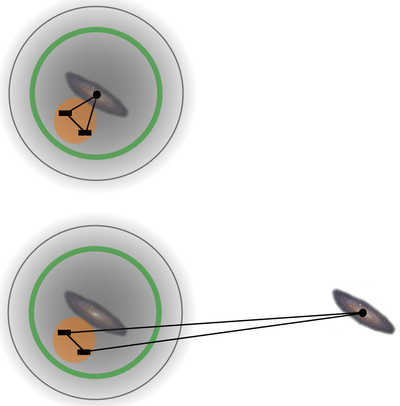
Axion conversion

- Resonant conversion to search for photon to dark photon conversion

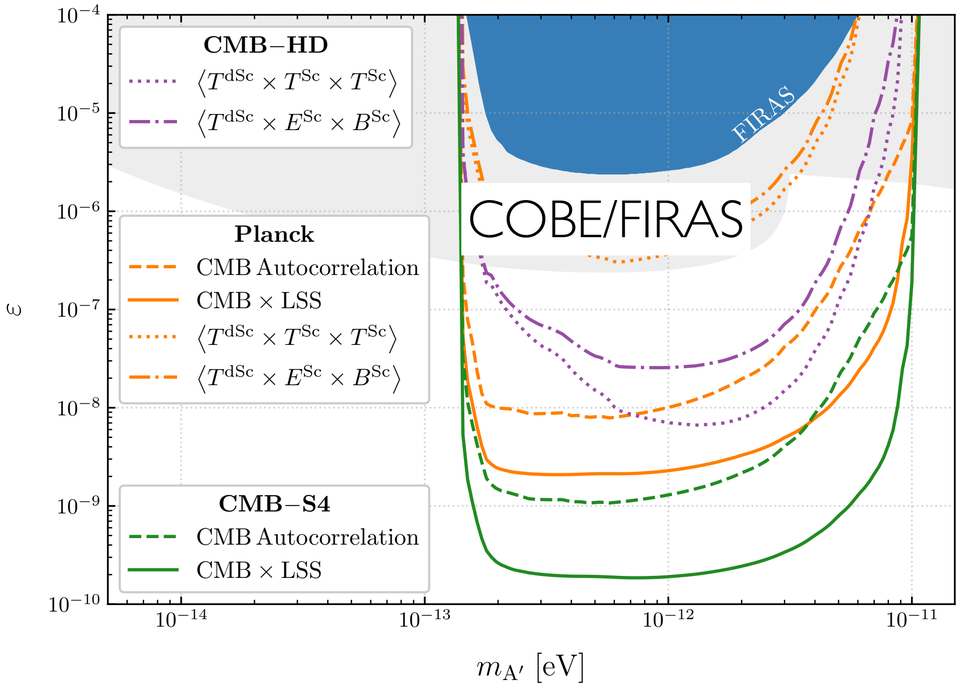


Axion screening

- Temperature and Polarization signal

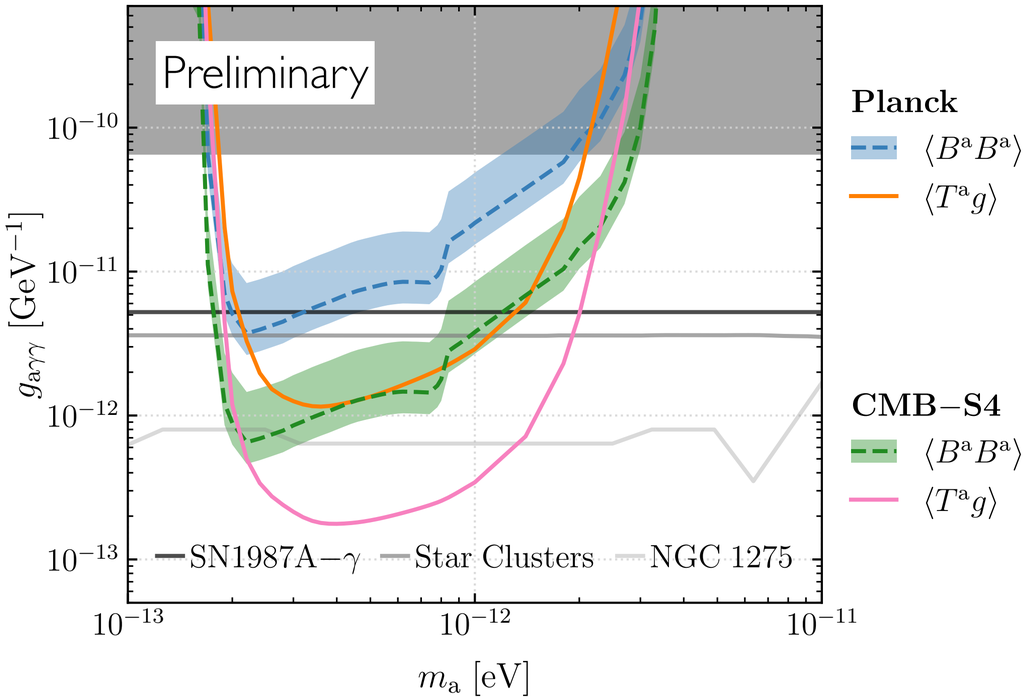
	Auto-correlation	Cross-correlation	Bispectrum
T			Higher point function
E, B	 X	= 0	

Dark photon



Pirvu, **JH**, Johnson, 2307.15124 + ongoing date analysis

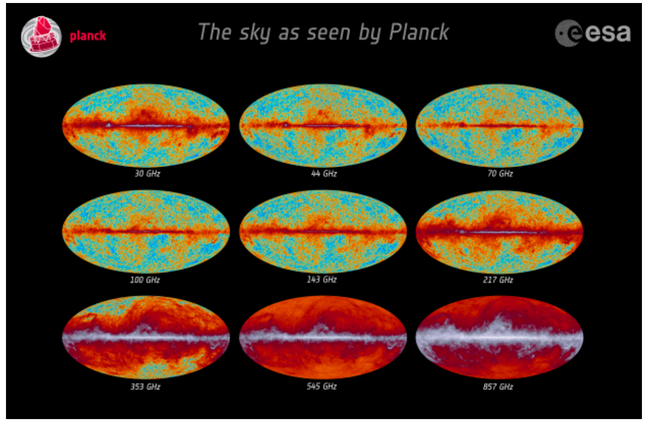
Axion



Pirvu, Mondino, **JH**, Johnson, 2405.XXXXX

Analysis (Planck x unWISE)

In collaboration with Fiona McCarthy & Colin Hill's group,
Also axion analysis+ Sam Goldstein



Extract a map with a particular spectral energy distribution (SED)
$(1/\omega, \omega, \omega^2)$

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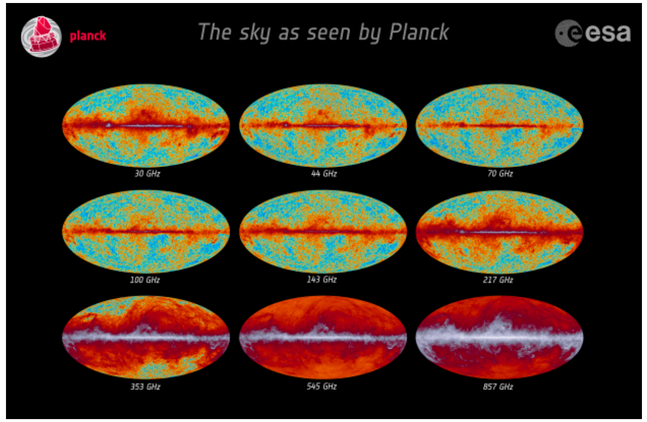

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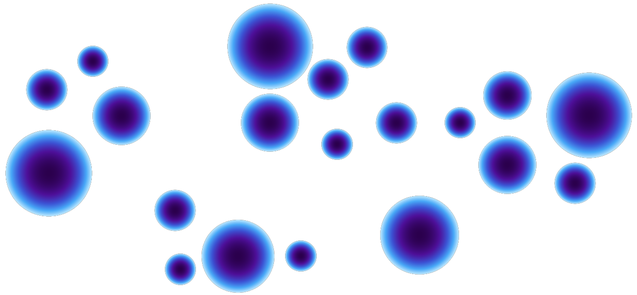

$T^{\rm dsc}(\hat{n},\omega), E^{\rm dsc}(\hat{n},\omega), B^{\rm dsc}(\hat{n},\omega)$

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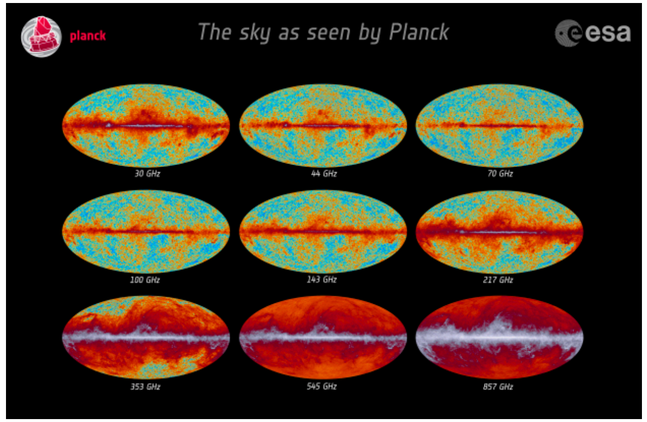

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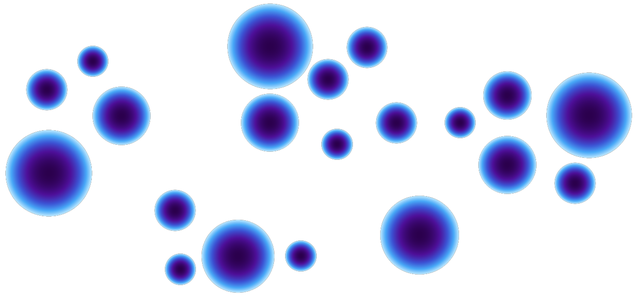
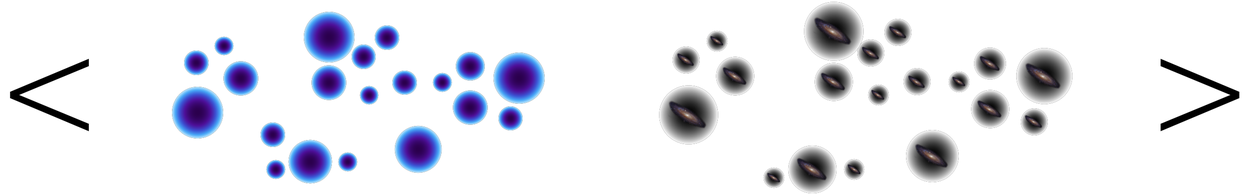


$T^{\rm dsc}(\hat{n},\omega), E^{\rm dsc}(\hat{n},\omega), B^{\rm dsc}(\hat{n},\omega)$

Compute correlation with unWISE



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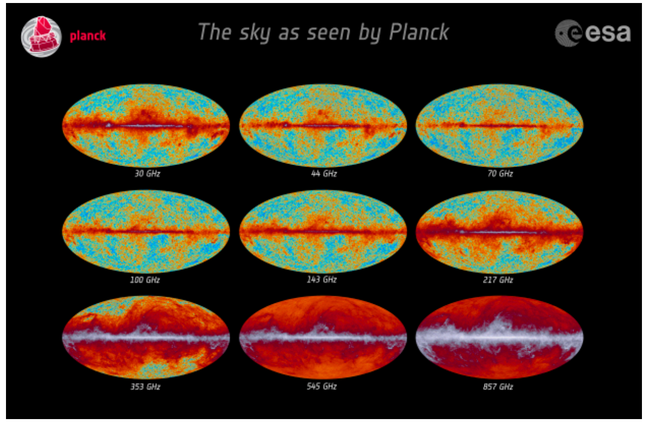

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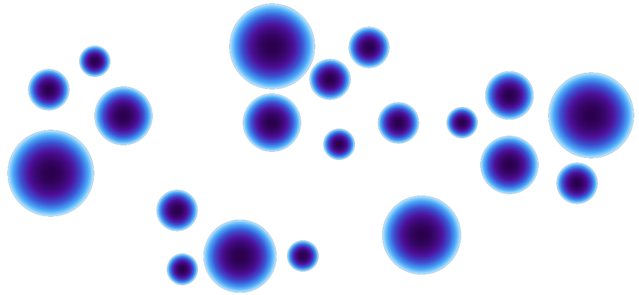

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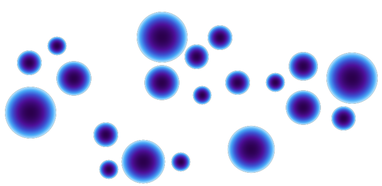

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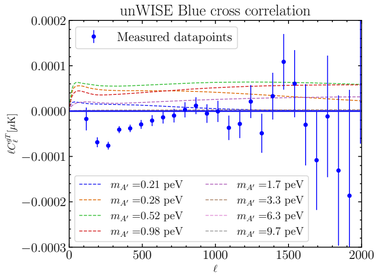

Compare to model

Analysis (Planck x unWISE)

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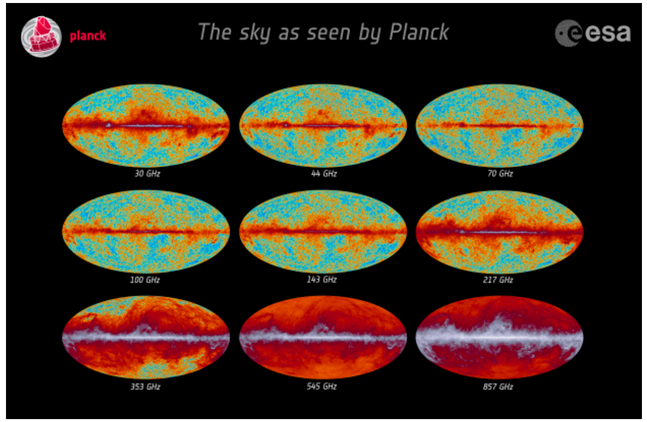

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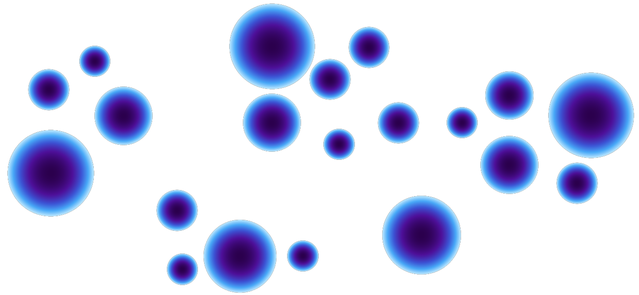
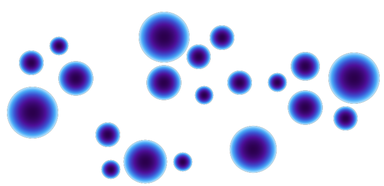


$T^{\rm dsc}(\hat{n},\omega), E^{\rm dsc}(\hat{n},\omega), B^{\rm dsc}(\hat{n},\omega)$

Compute correlation with unWISE



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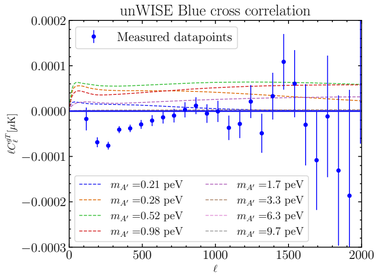
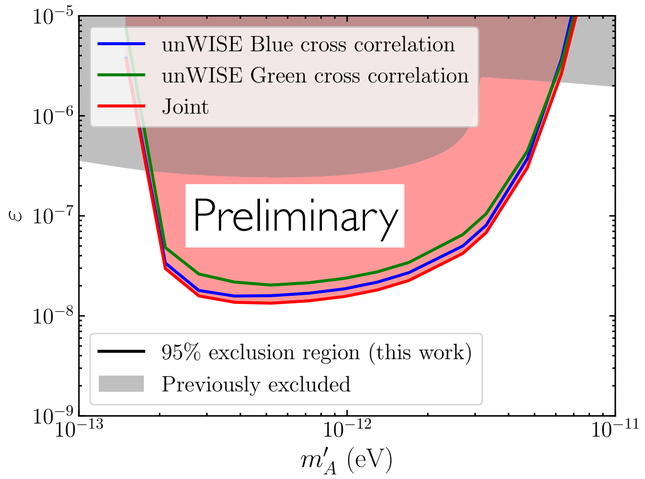
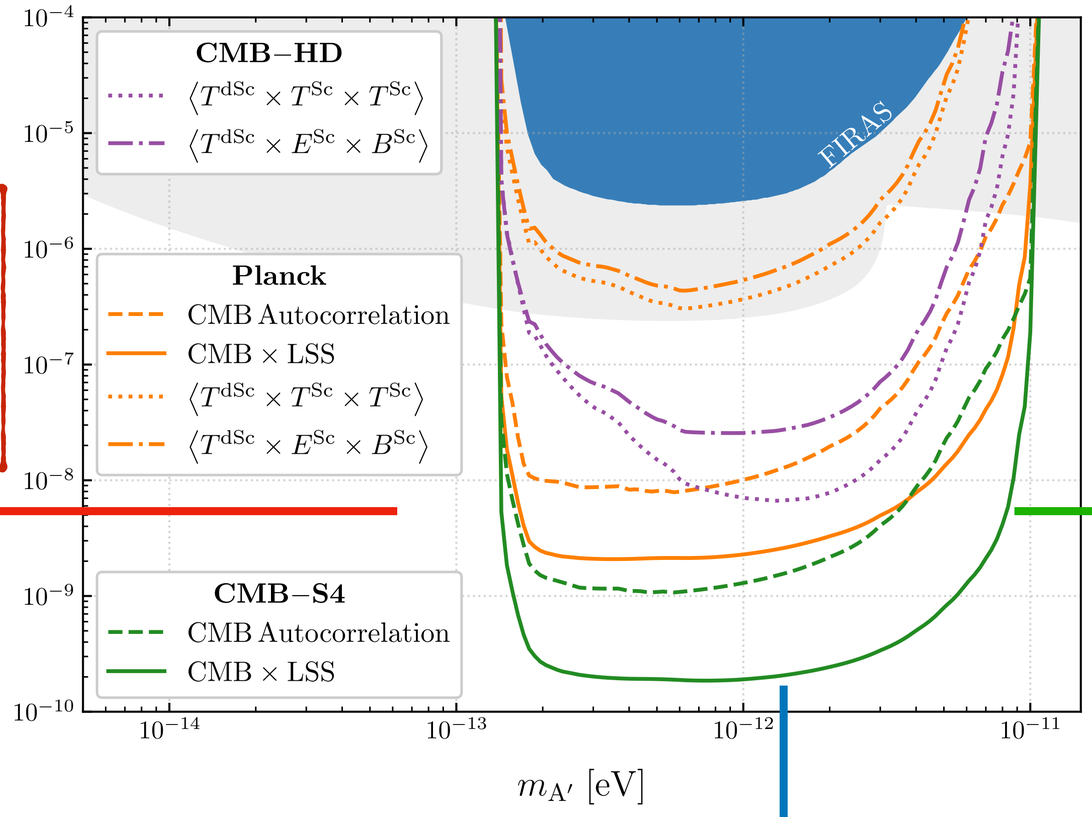


Compare to model



Short term wish list

Electron density profile prediction/measurement beyond the Virial radius, in Cosmic Voids, etc.



Higher redshift (Especially for Axion)

Galaxy catelog with as many galaxies as possible ($N_g^{1/4}$)

Redshift of galaxies

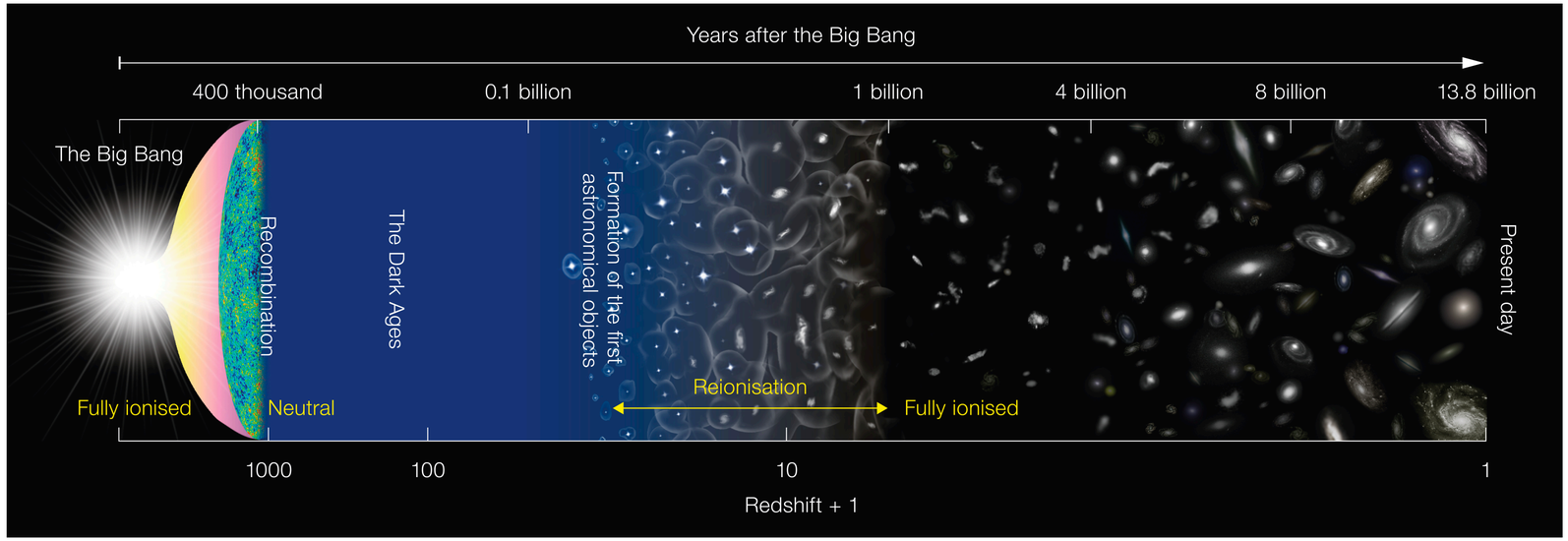
CMB Experiments with lower noise

Summary

Background light

Effect of Dark Sector

Observer



CMB, 21cm, LIM…

Dark photon, axion, freeze-in…

Linear perturbations, Halos, Voids, Bubbles…

$$\langle \mathrm{BSM} \times \mathrm{SM} \rangle$$

In collaboration with Cristina Mondino, Dalila Pirvu, Matt Johnson, and Hongwan Liu, Fiona McCarthy, Colin Hill, Selim Hotinli, Keir Rogers…