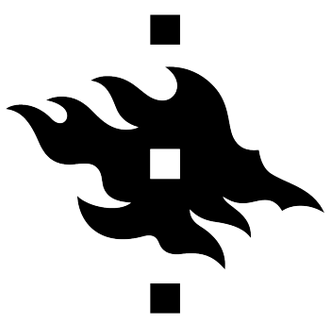
Cosmological probes of particle dark matter

Deanna C. Hooper

(they/them)

News from the Dark

12th September 2023



HELSINGIN YLIOPISTO
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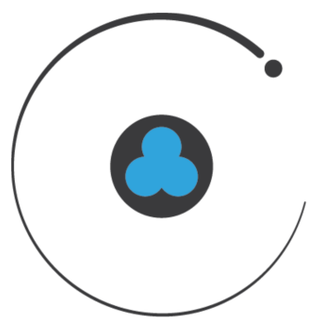
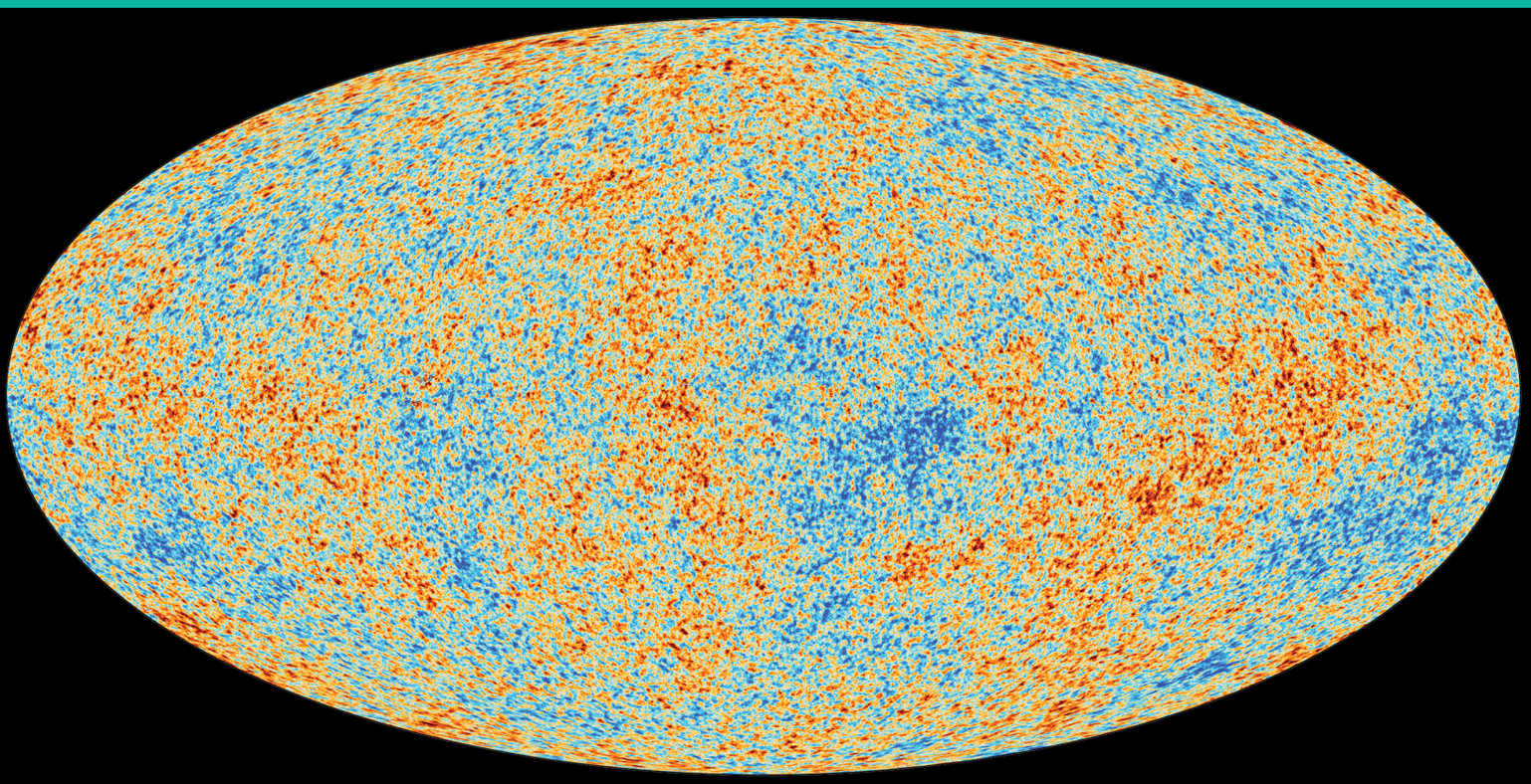
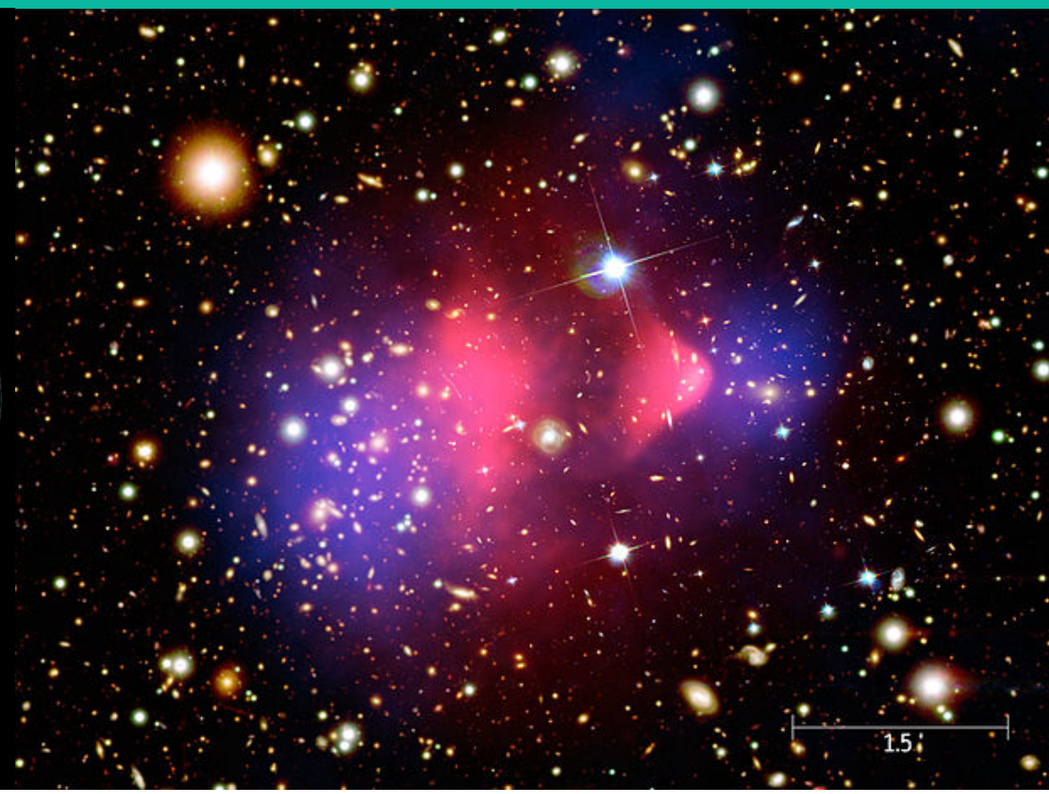
UNIVERSITY OF HELSINKI

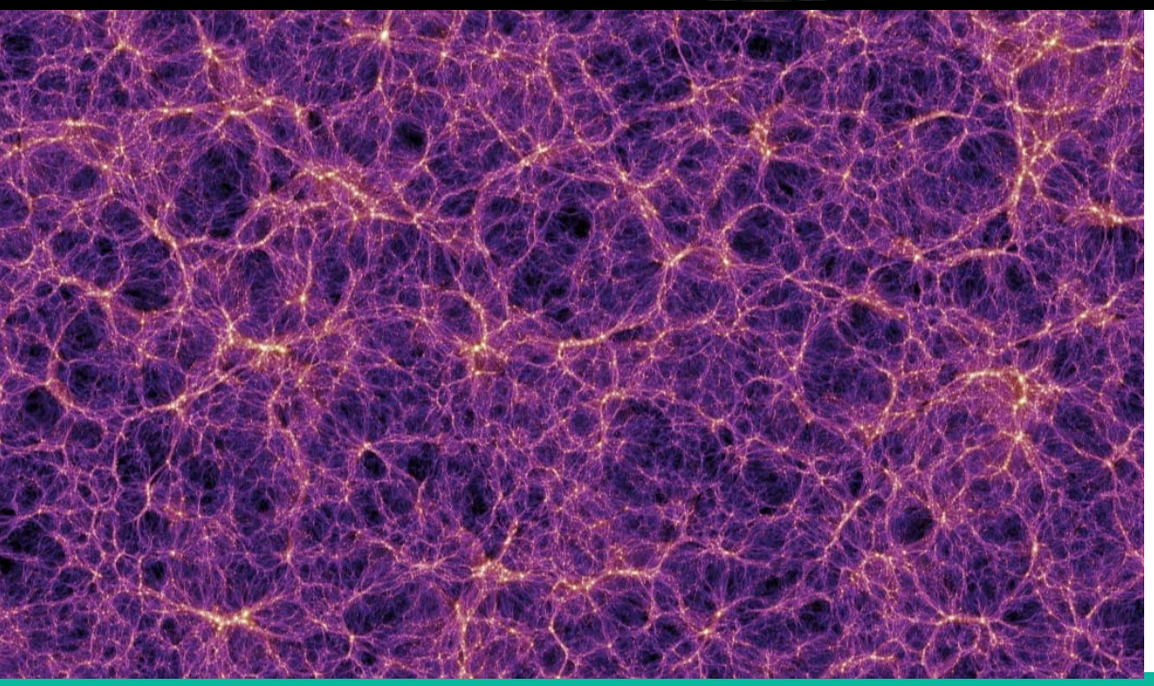


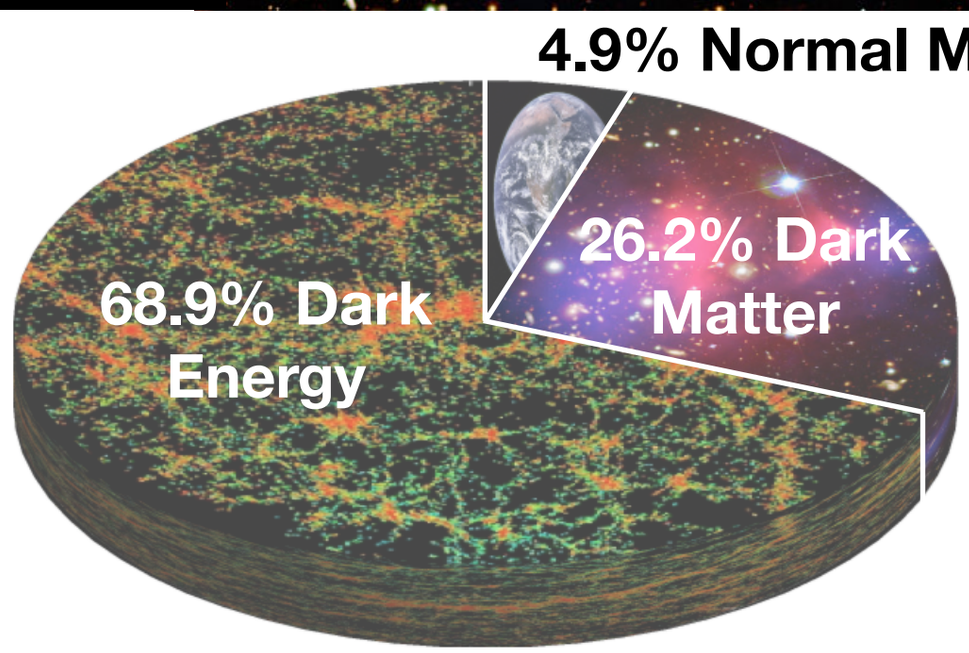
HELSINKI INSTITUTE OF PHYSICS

Cosmology tells us that dark matter is abundant in the universe, but what is it?

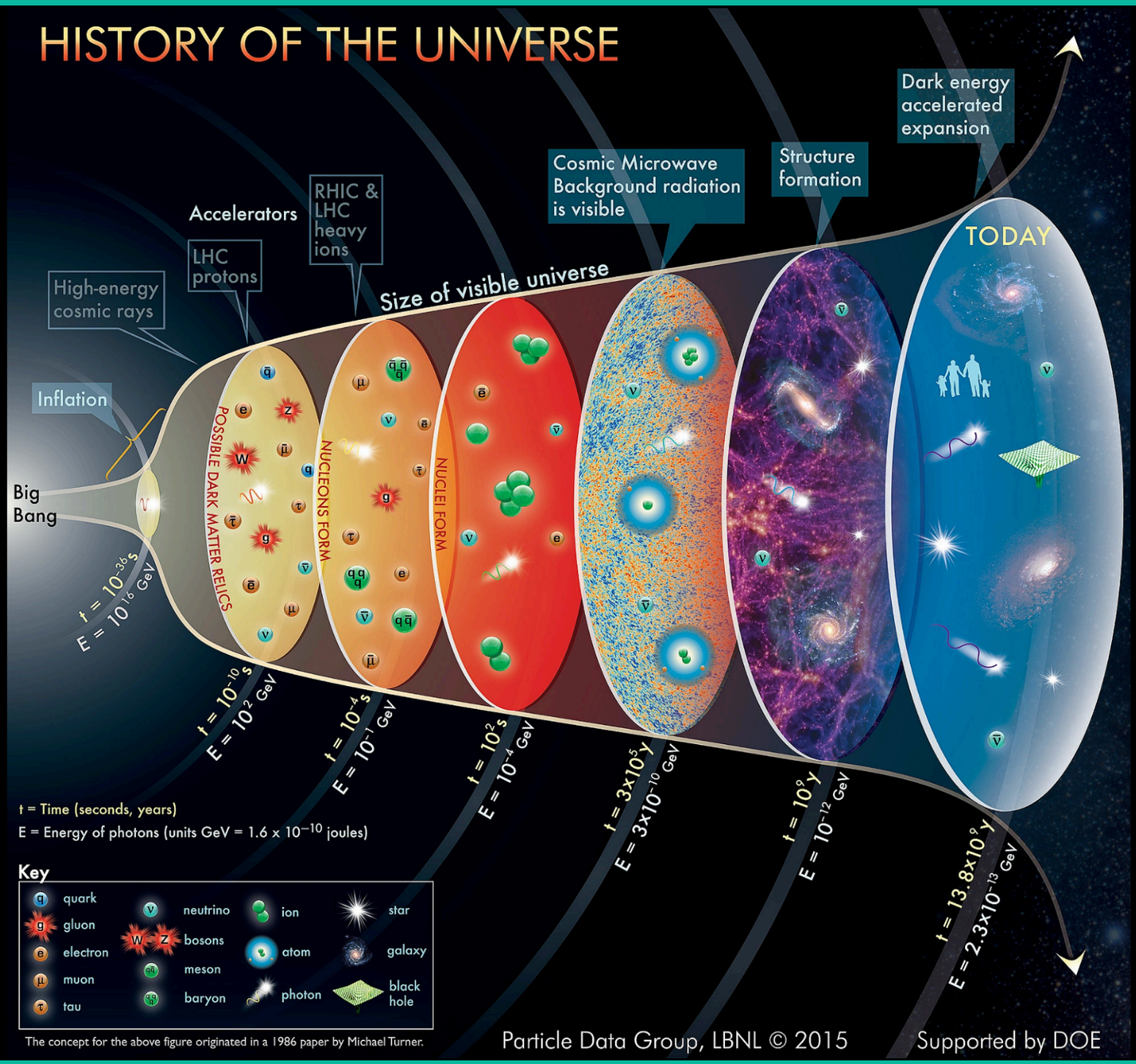








The nature of dark matter can be probed by many cosmological observables



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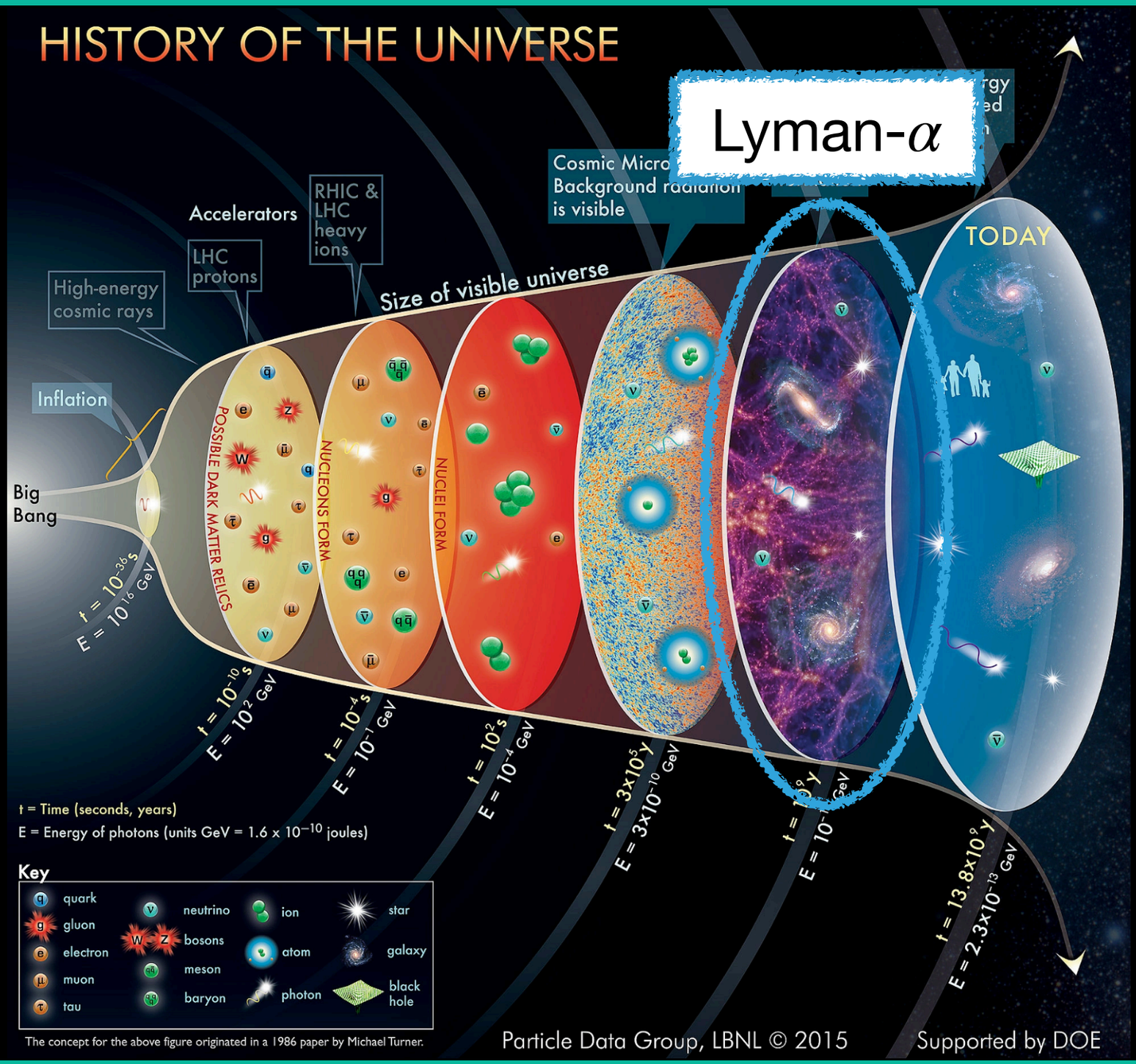

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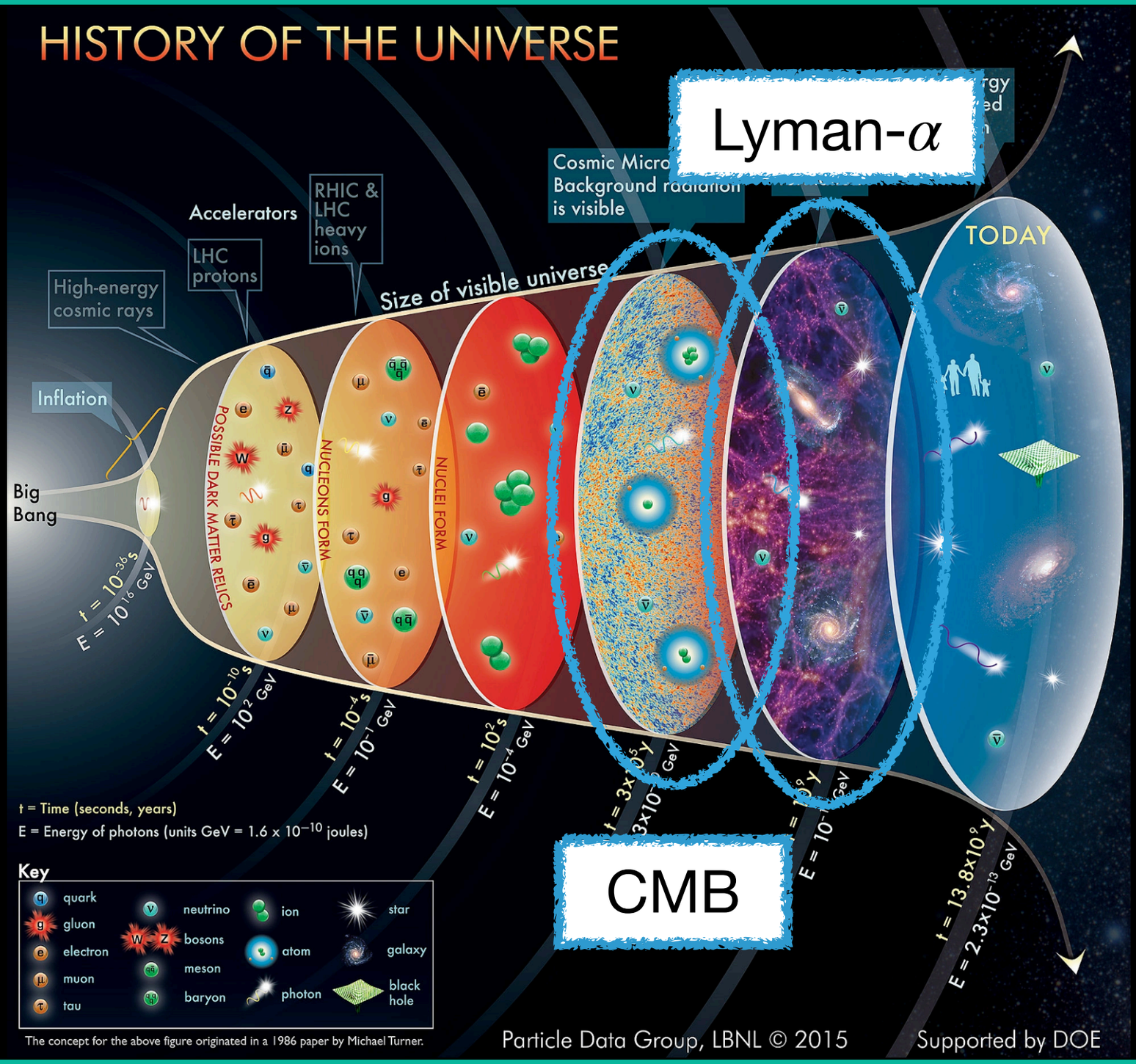

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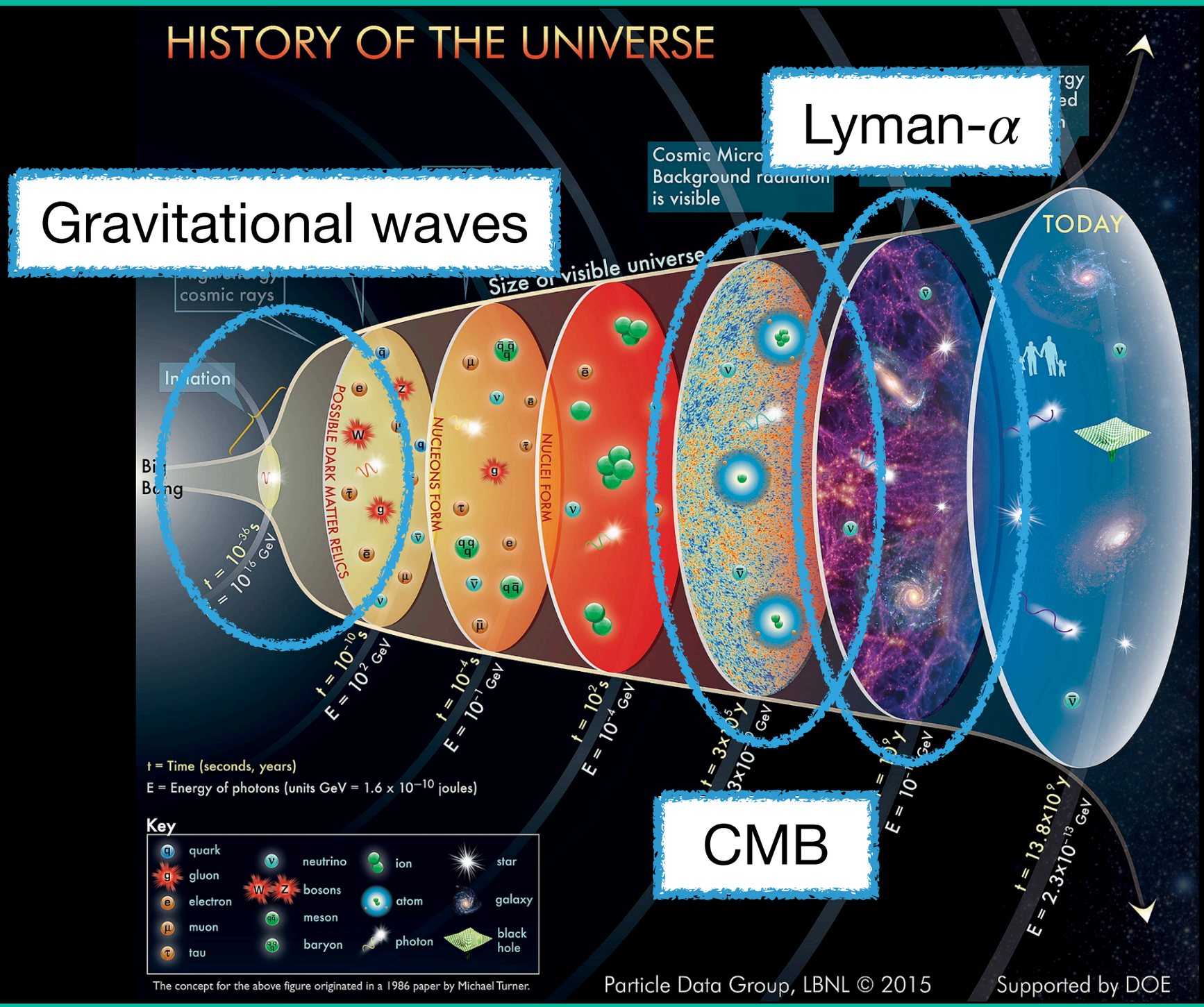
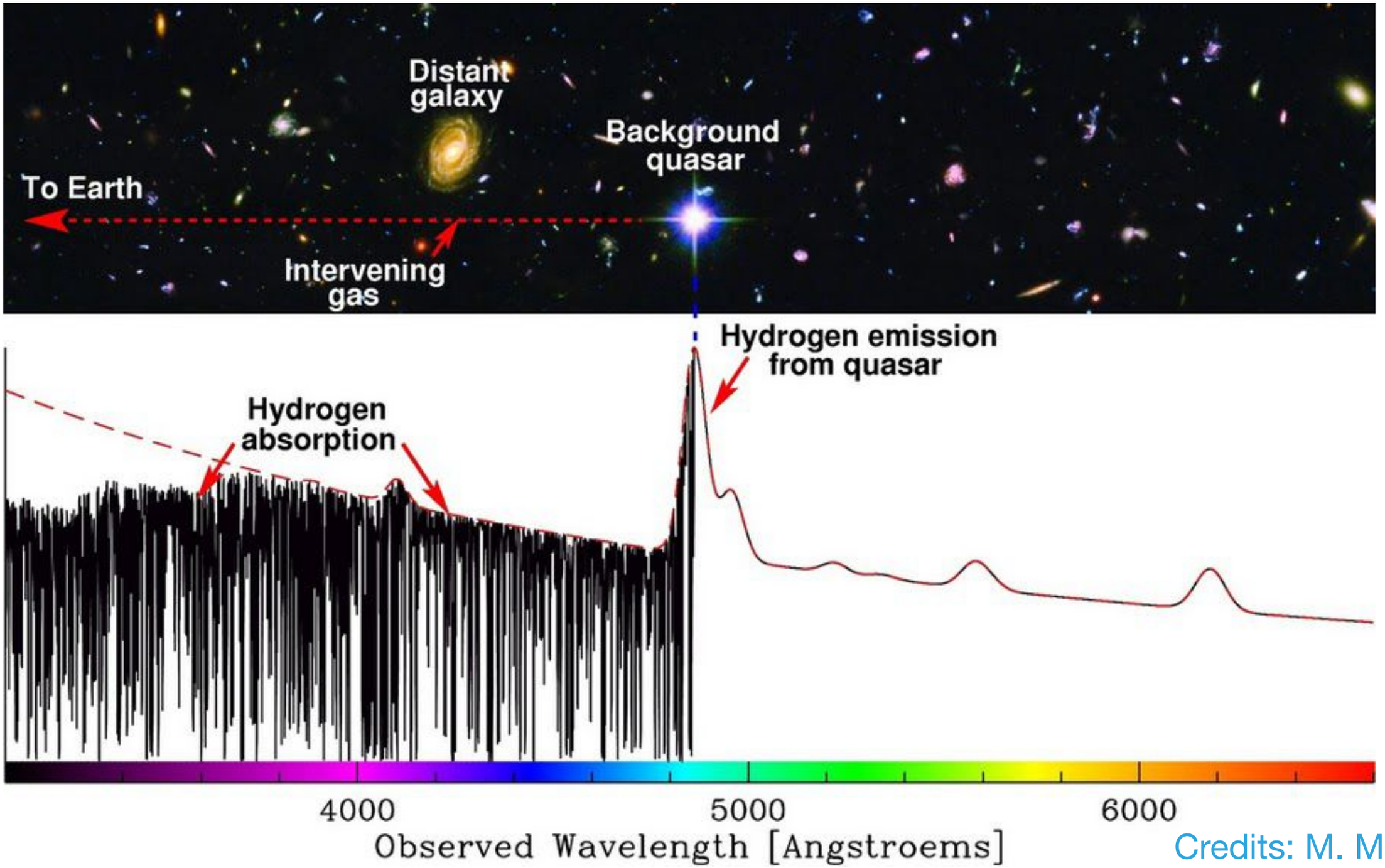


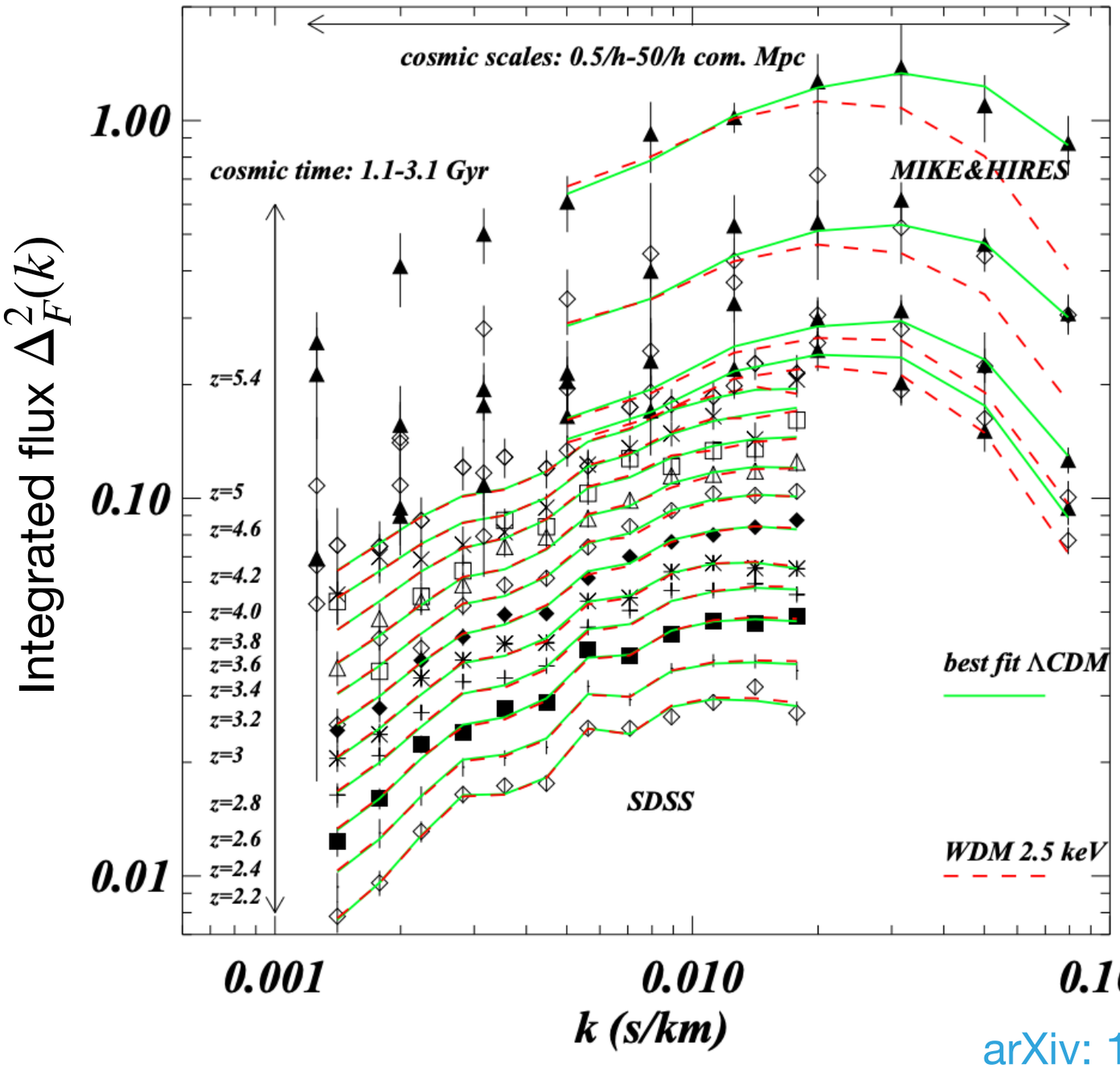
Lyman-α data

Lyman-α: absorption lines in quasar spectra produced by the intergalactic medium



Credits: M. Murphy

Lyman-α traces the matter power spectrum at high redshifts and small scales

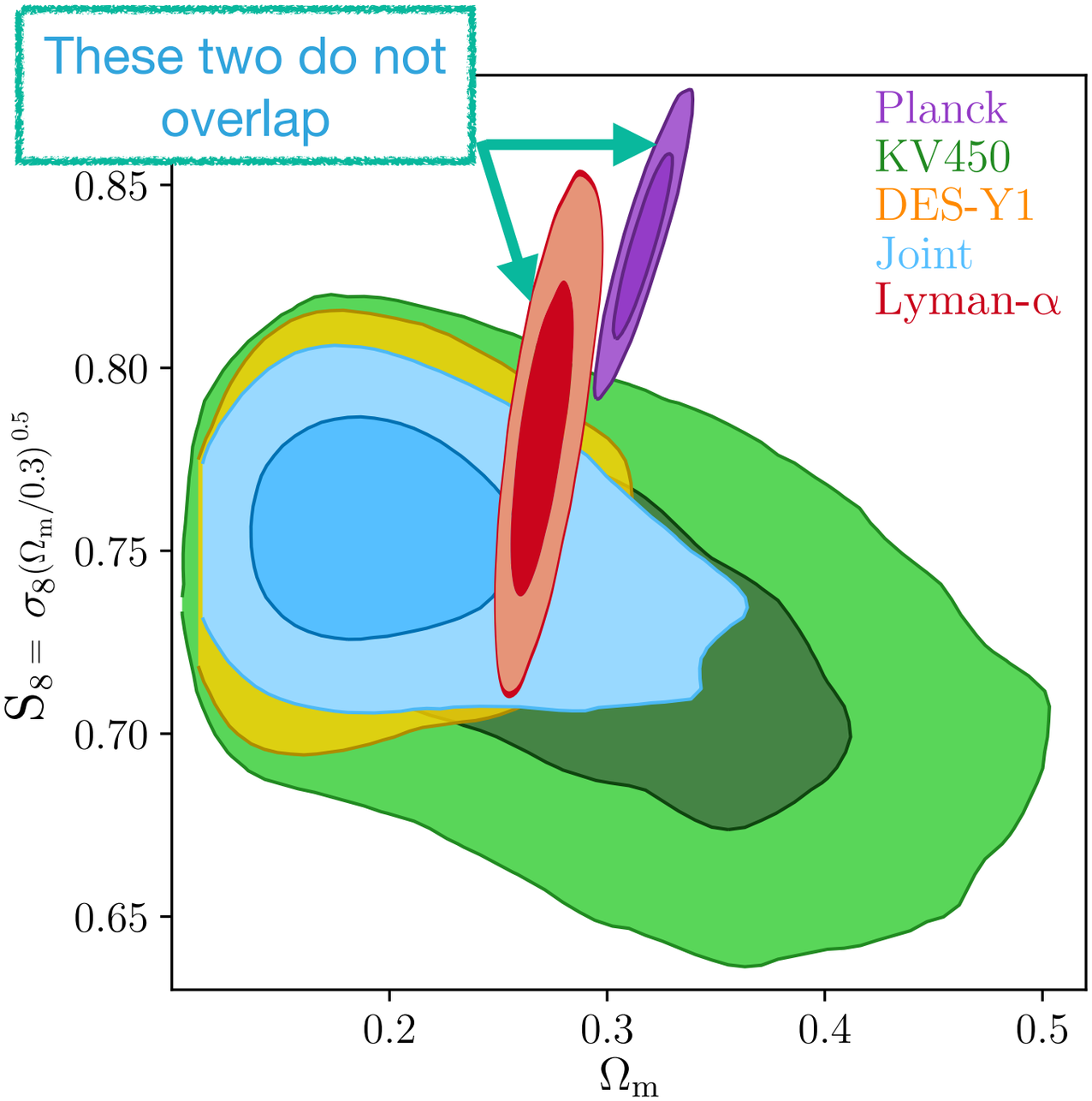


Can constrain models that affect structure formation, such as warm dark matter

arXiv: 1306.2314

Lyman-α data requires computationally expensive hydro simulations

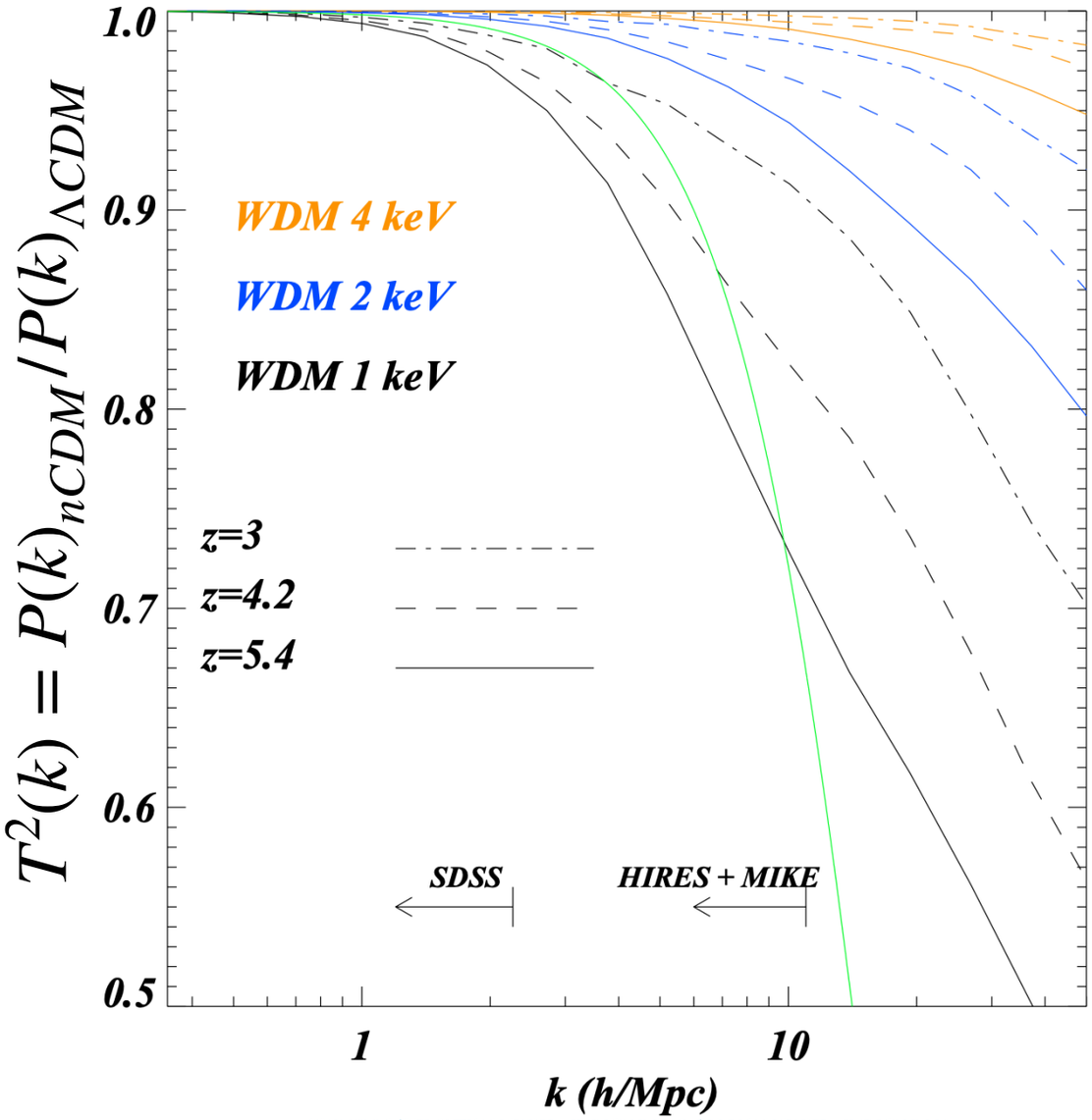
- Lyman-α is non-linear, we need hydro sims
- A lot of astrophysical foregrounds
- In slight tension with Planck (is this a problem?)



arXiv: 1911.09073

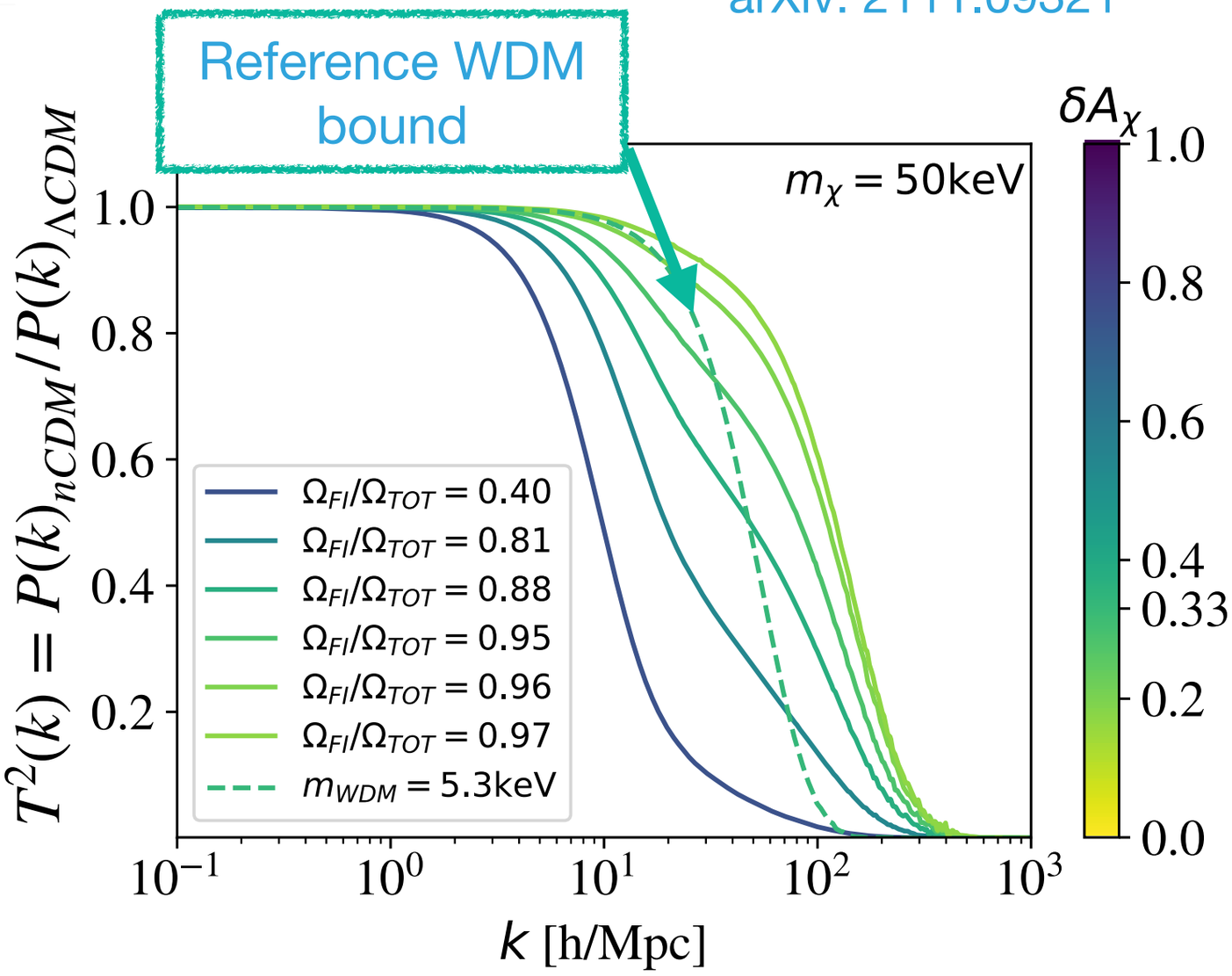
We can use full simulations or remappings to constrain dark matter

arXiv: 1306.2314



Warm Dark Matter

arXiv: 2111.09321

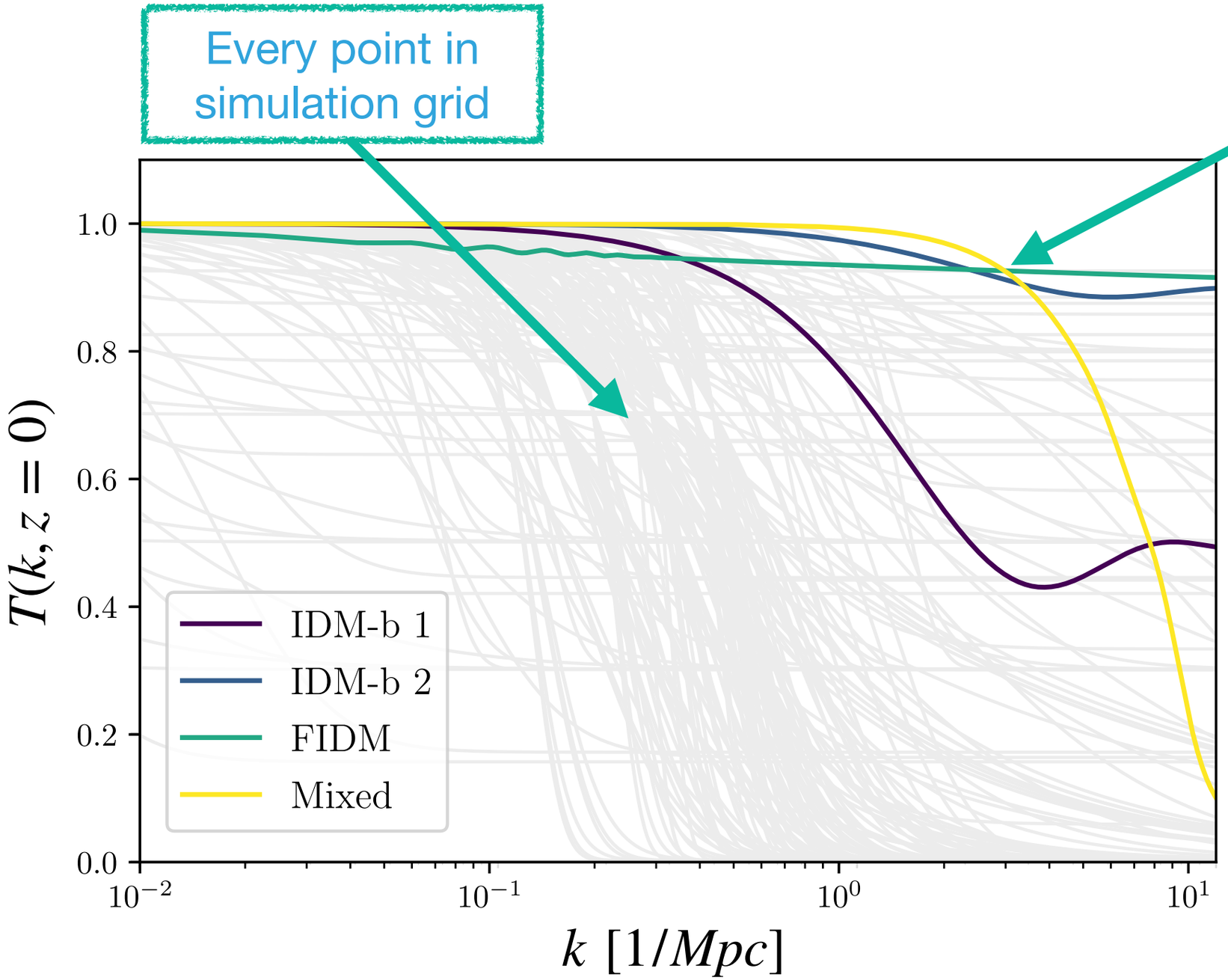


FIMPs+SuperWIMPs

Or we can use alternative approaches to constrain dark matter

Every point in simulation grid

Example models

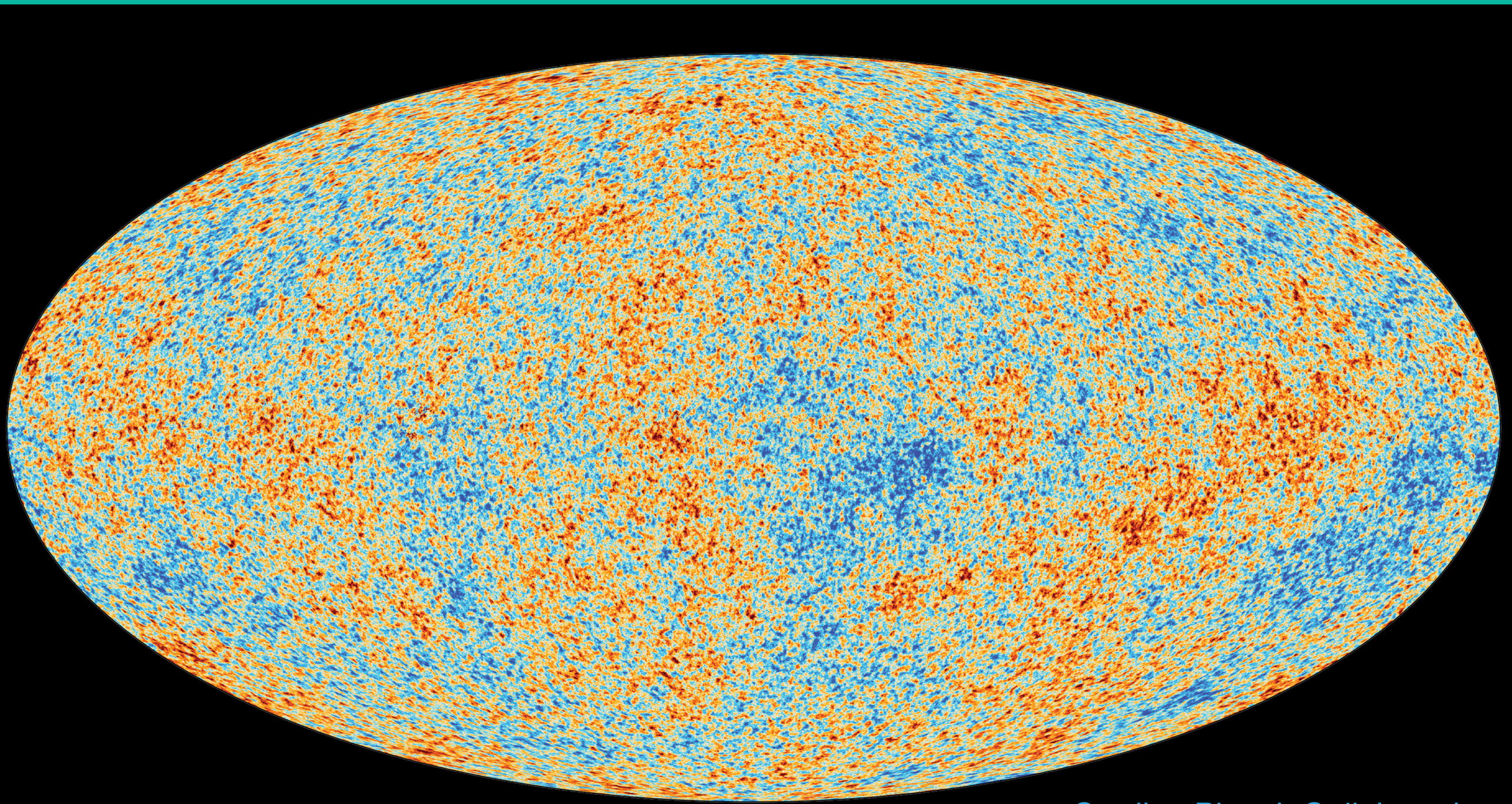


- Grid of simulations
- Used for different interacting and warm dark matter models

arXiv: 1907.01496, arXiv: 2206.08188

Cosmic Microwave Background

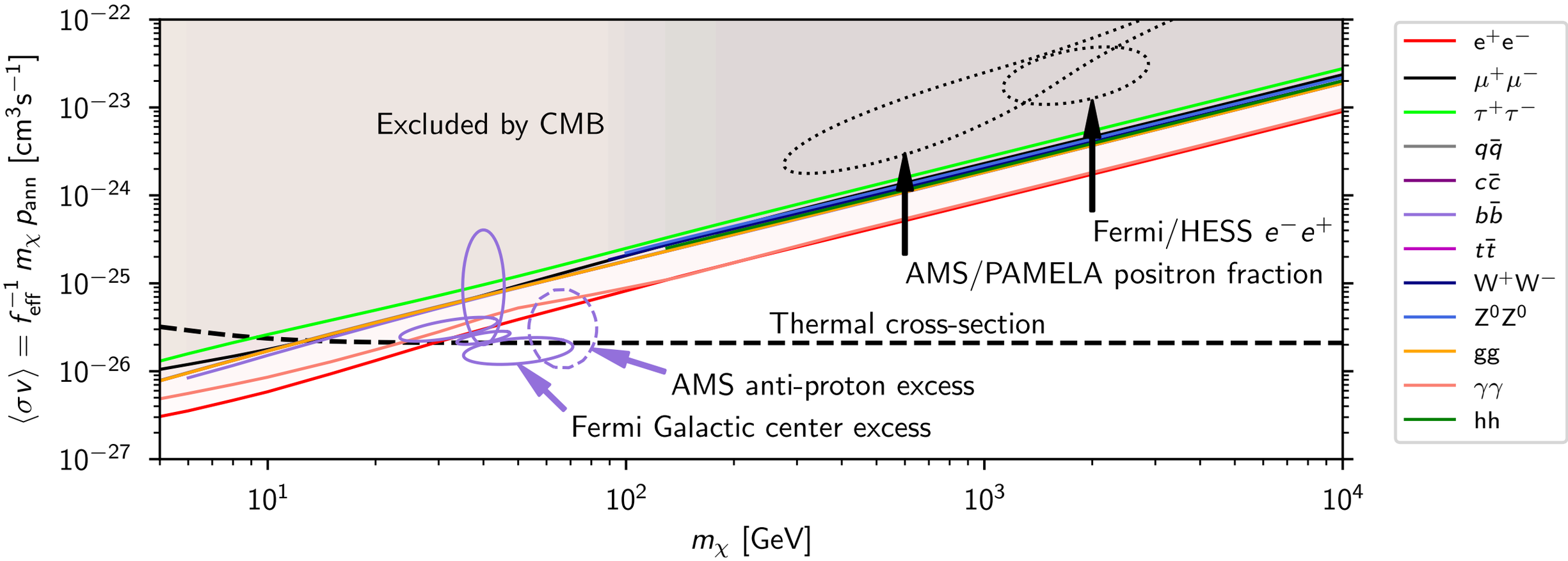
Decoupled photons provide a snapshot of the early universe



Credits: Planck Collaboration

Dark matter annihilations can affect the energy of the CMB

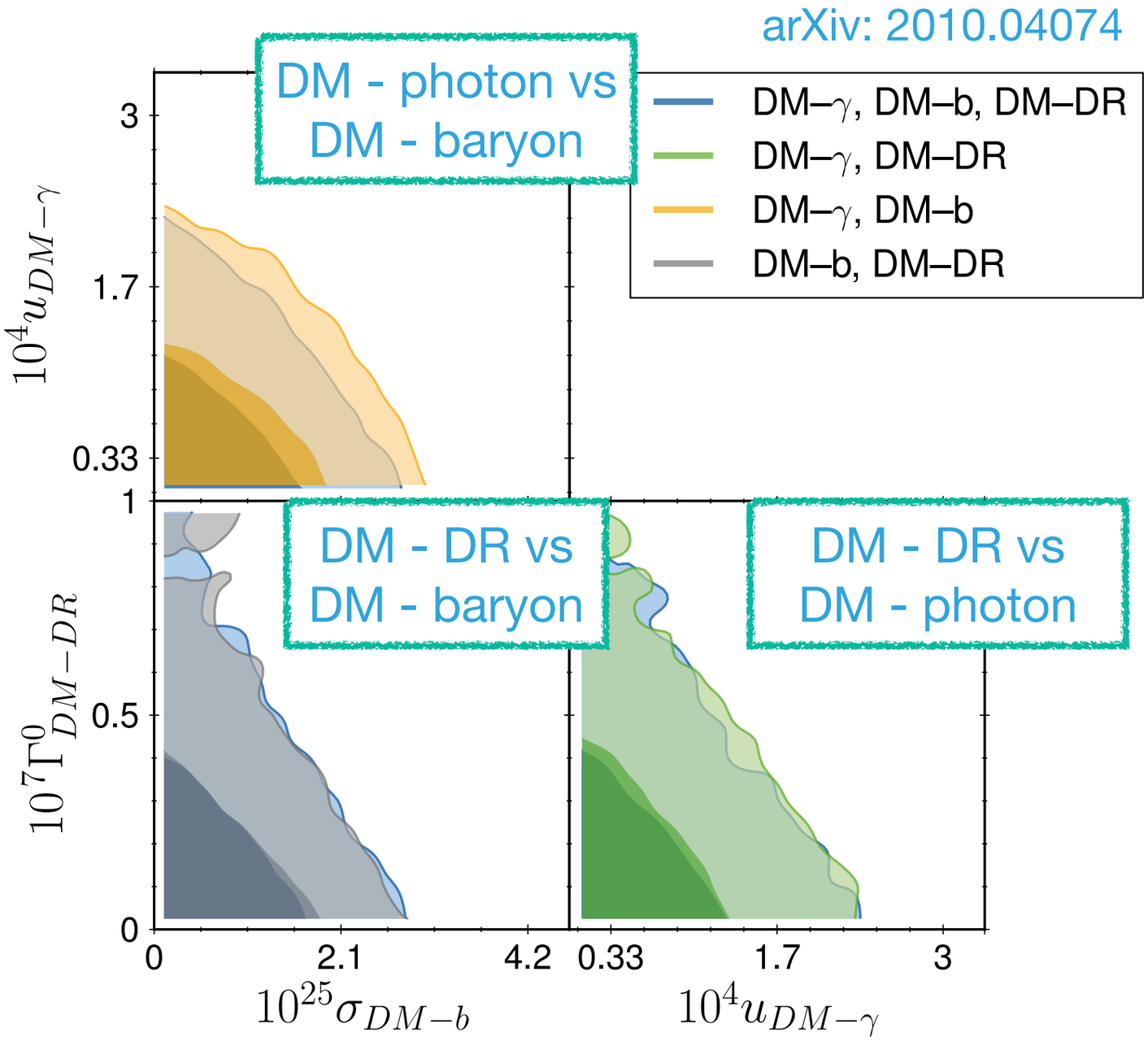
arXiv: 1807.06209



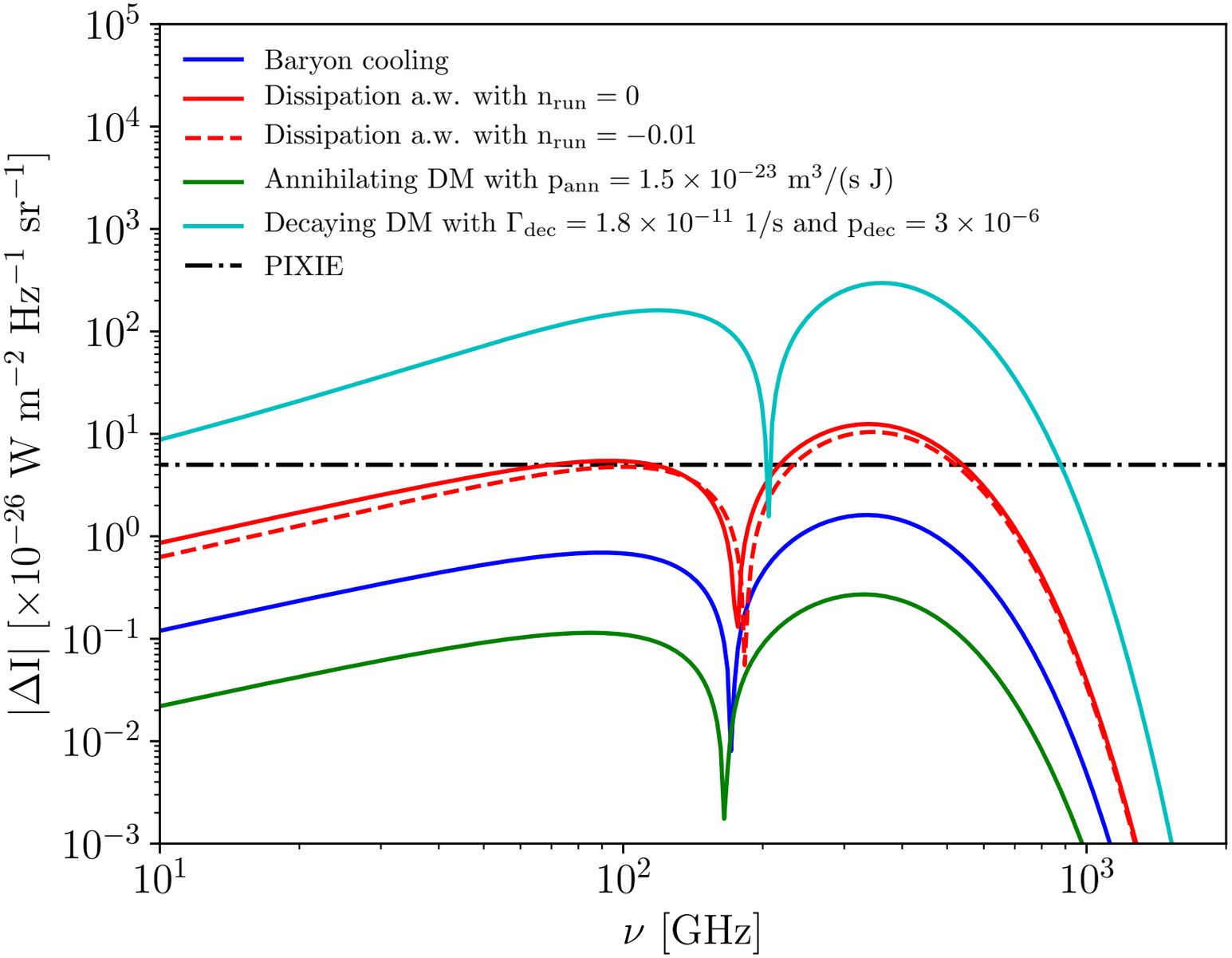
Assuming WIMPs, CMB bounds are competitive with and complementary to indirect DM searches.

Various dark matter couplings can be studied with the CMB anisotropies

- Spin-independent interactions, complementary to other probes
- Few assumptions about underlying model needed



Spectral distortions are deviations from a perfect black body in the CMB



- Predicted in standard and non-standard models
- Only constraints we have so far are from FIRAS
- Future missions could measure them

arXiv: 1910.04619

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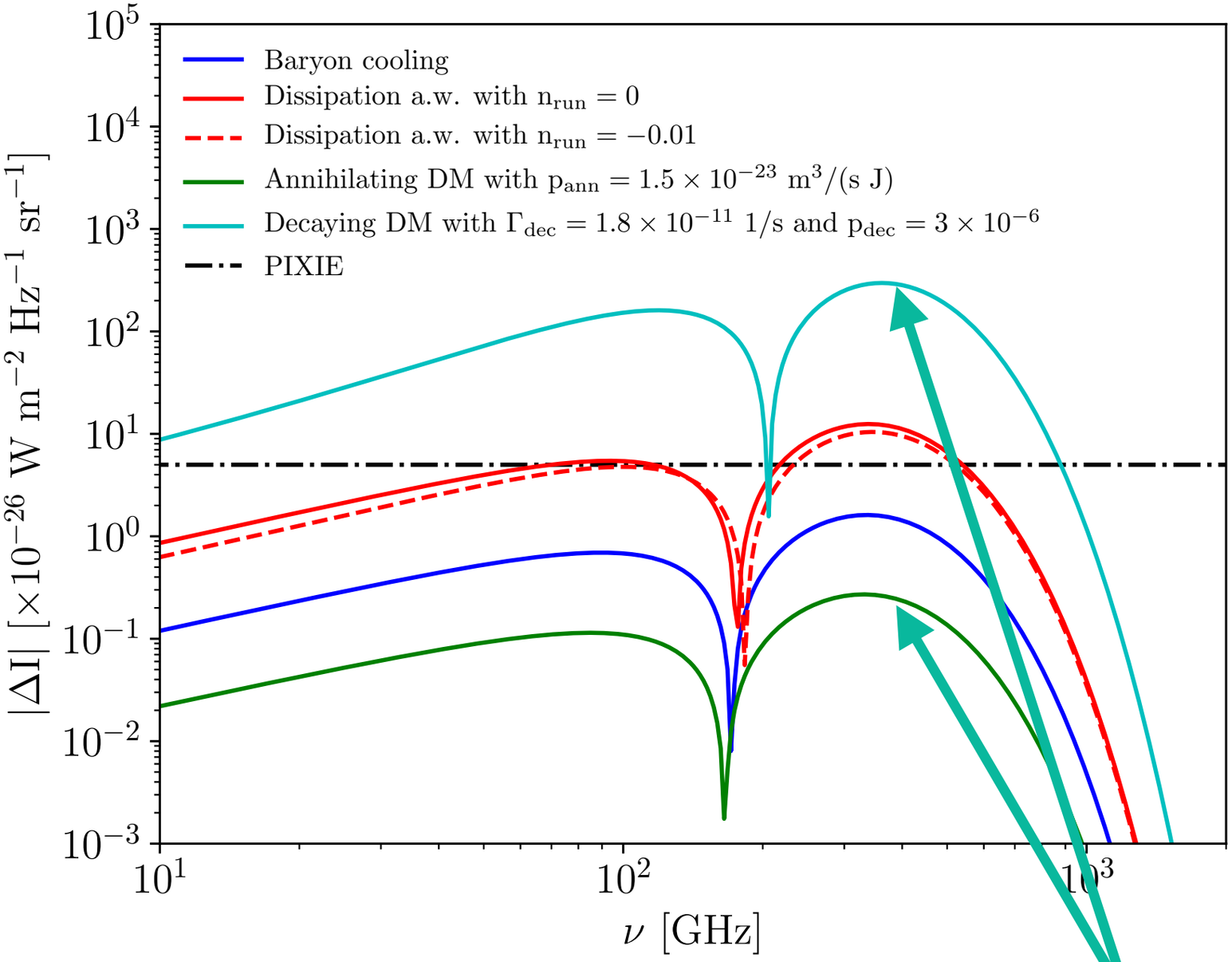

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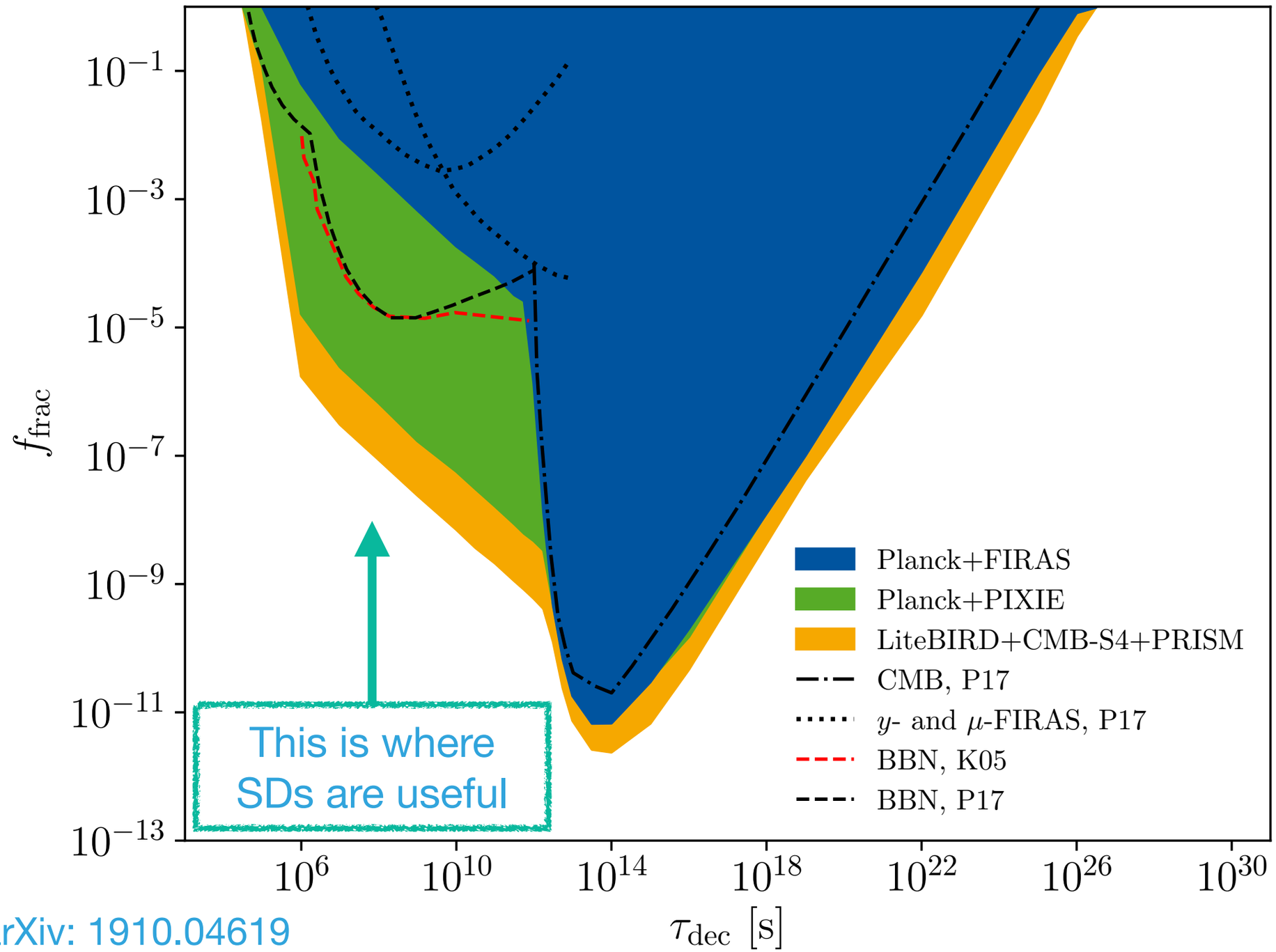
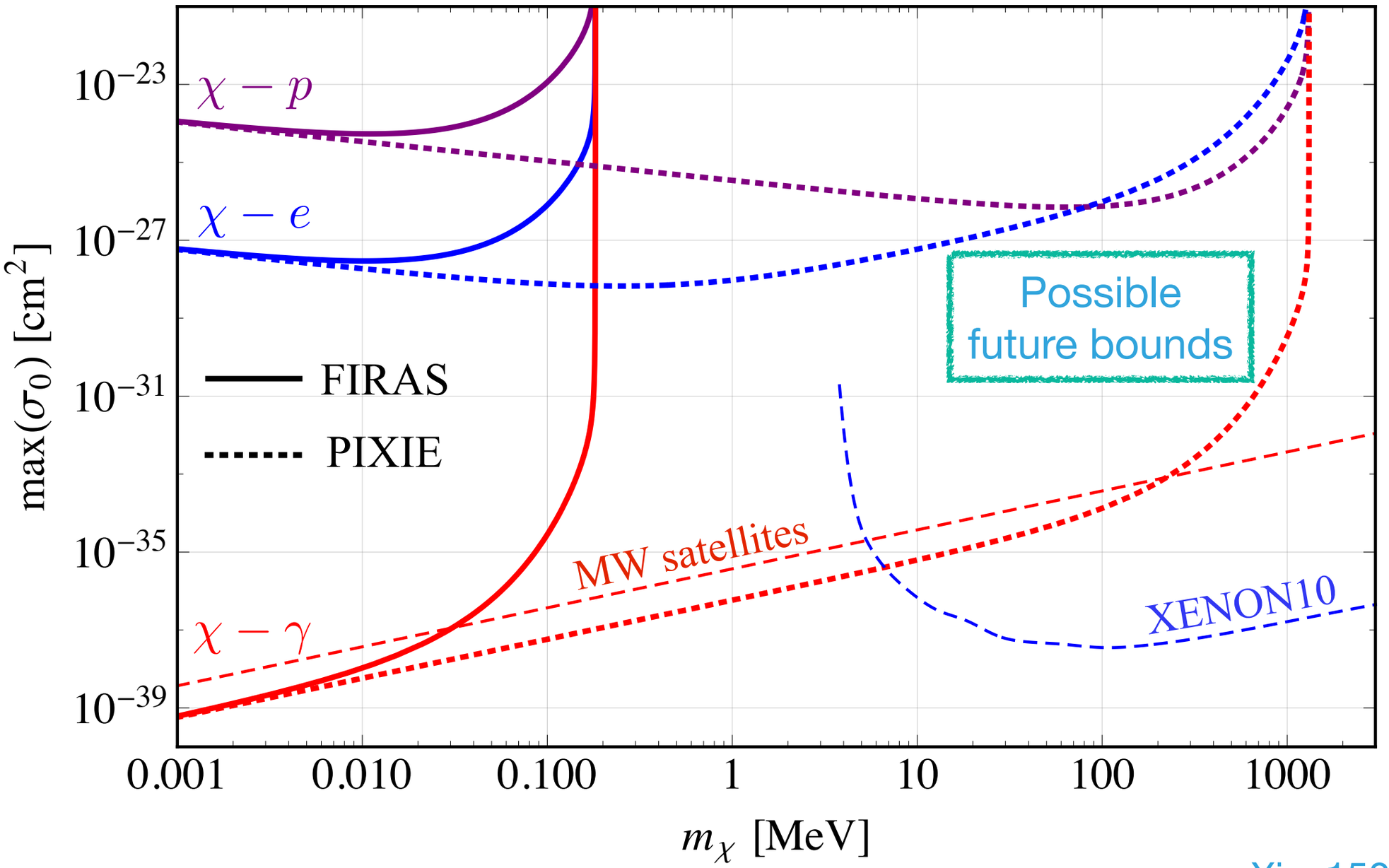
Can improve constraints on decaying dark matter by 3-4 orders of magnitude



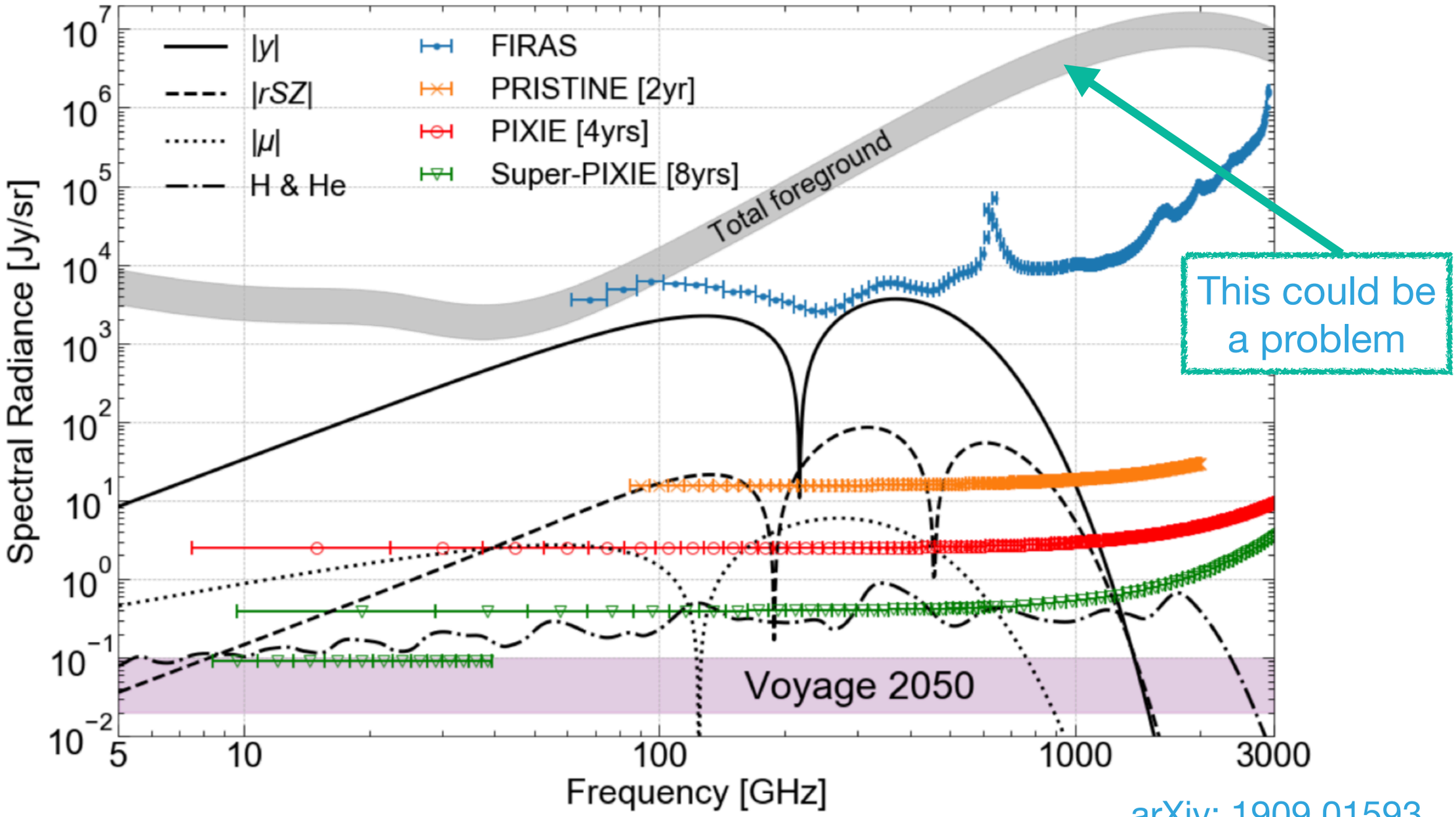
arXiv: 1910.04619

Can probe lower-mass regions than anisotropies for DM interactions



arXiv: 1506.04745

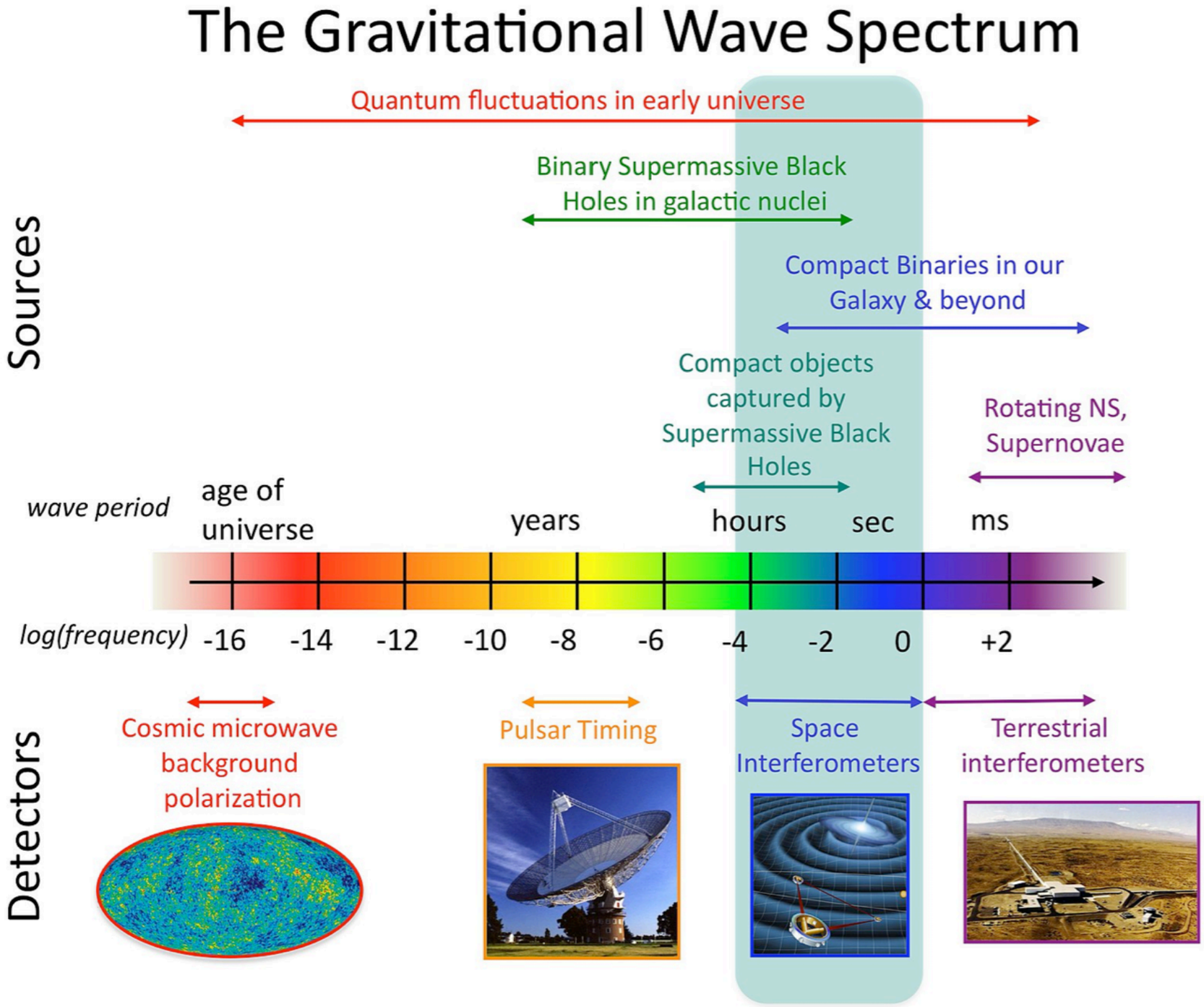
We expect the foregrounds to be much larger than a spectral distortion signal



arXiv: 1909.01593

Gravitational Waves

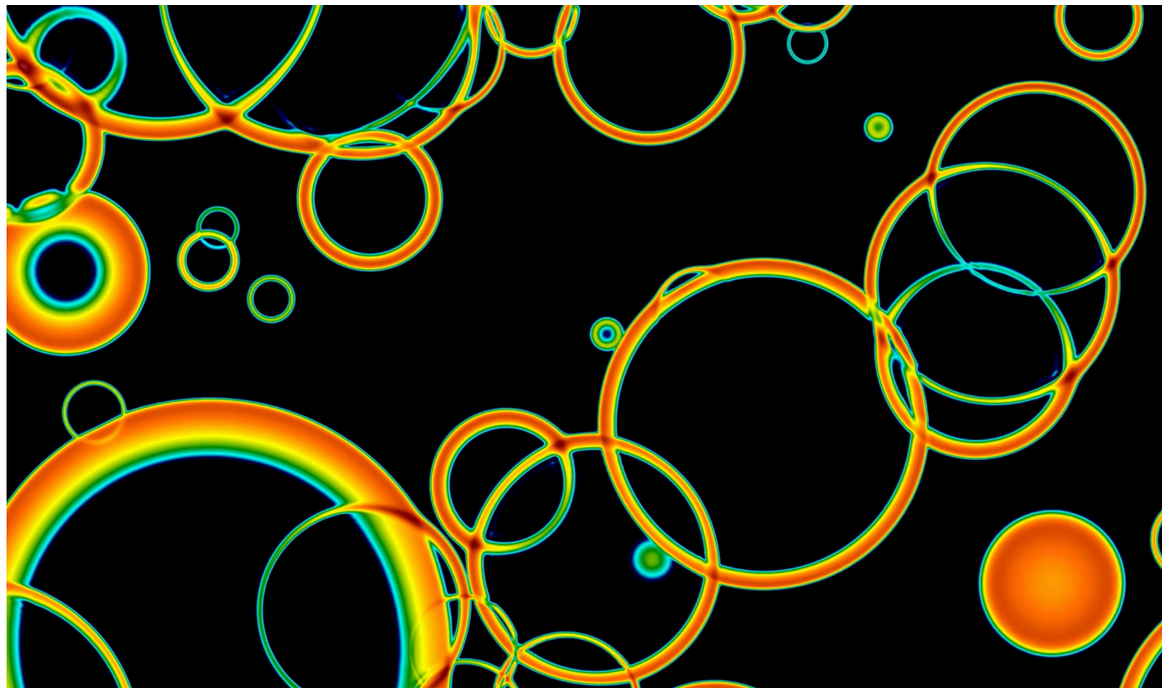
Gravitational waves can probe vastly different cosmological epochs



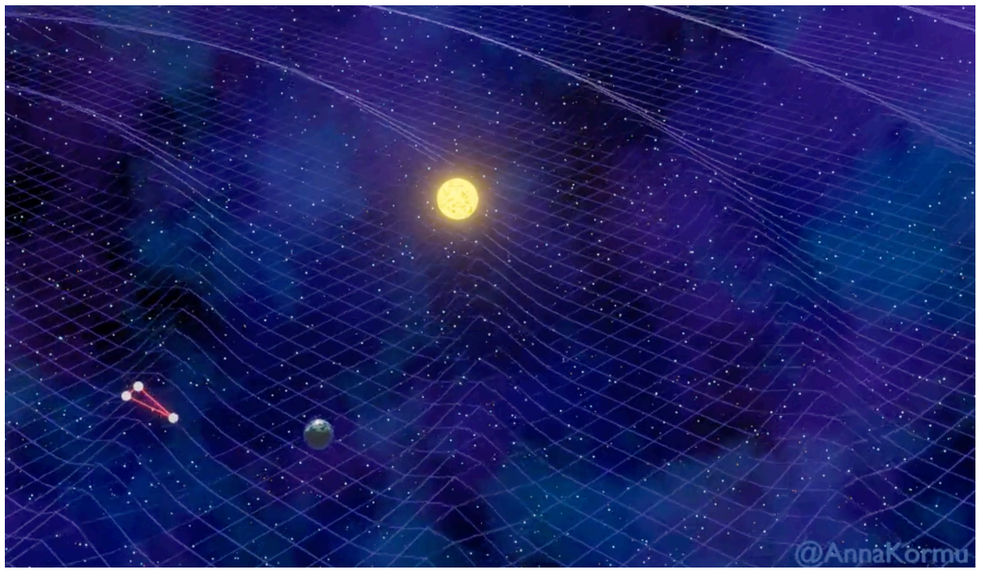
See talks on Wednesday for more GW!

Phase transitions in the early universe can source gravitational waves

- Many BSM models predict first-order phase transitions
- Bubbles of new phase nucleate and grow



Credits: D. J. Weir

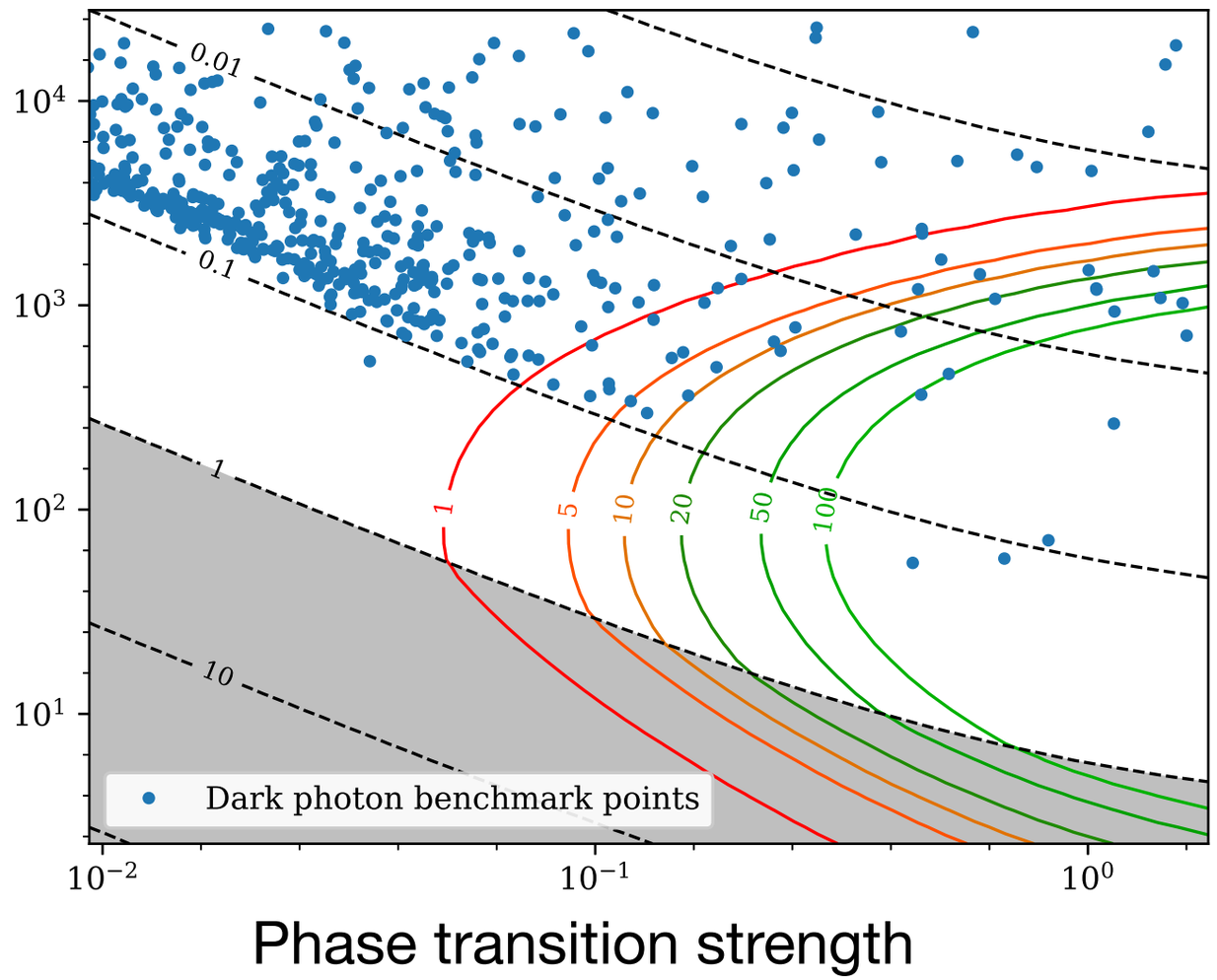


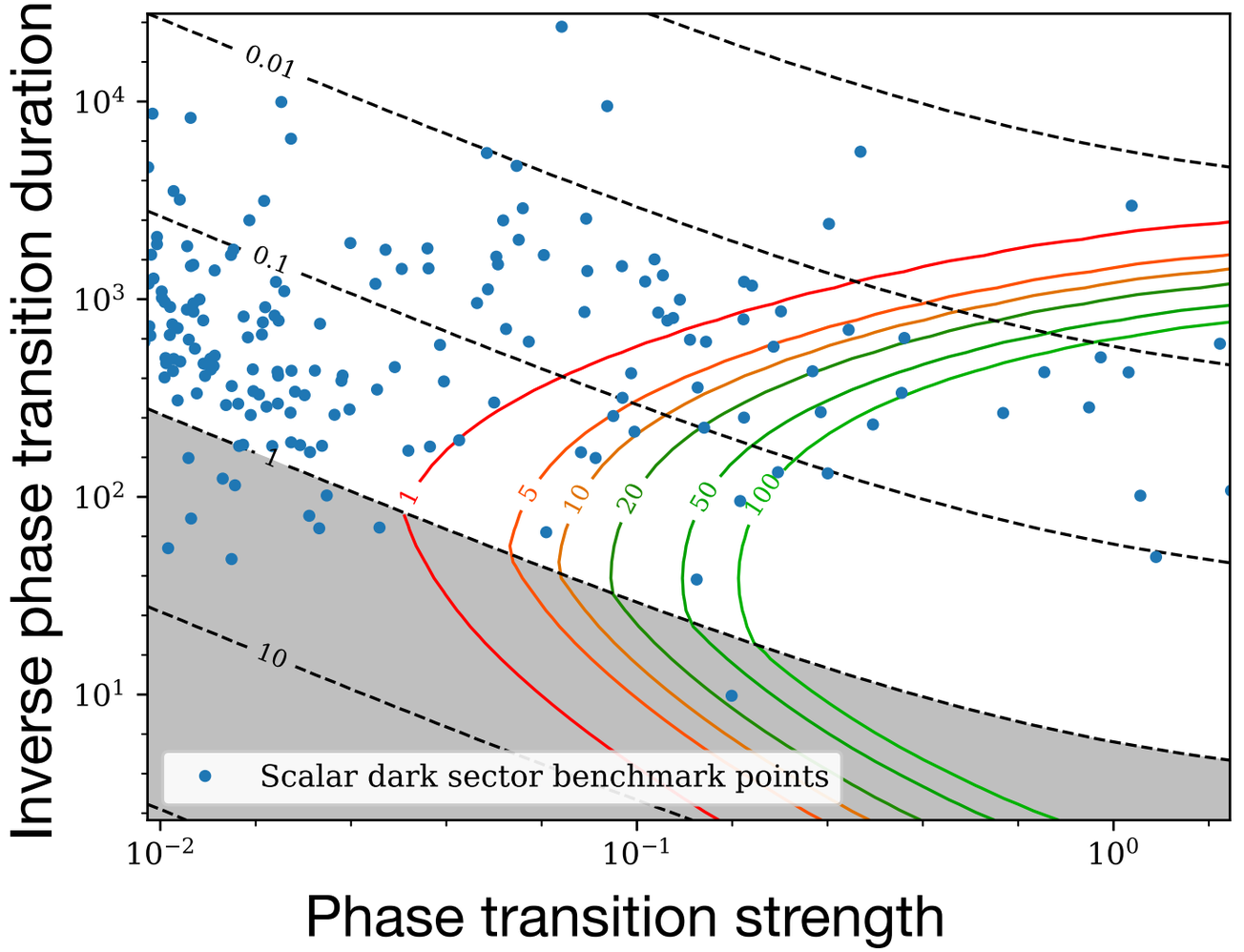
Credits: A. Kormu

- Bubble collision, sound waves, and turbulence make gravitational waves
- Target for LISA: future space-based gravitational wave mission (203X)

Dark matter models can be involved in or produced by phase transitions

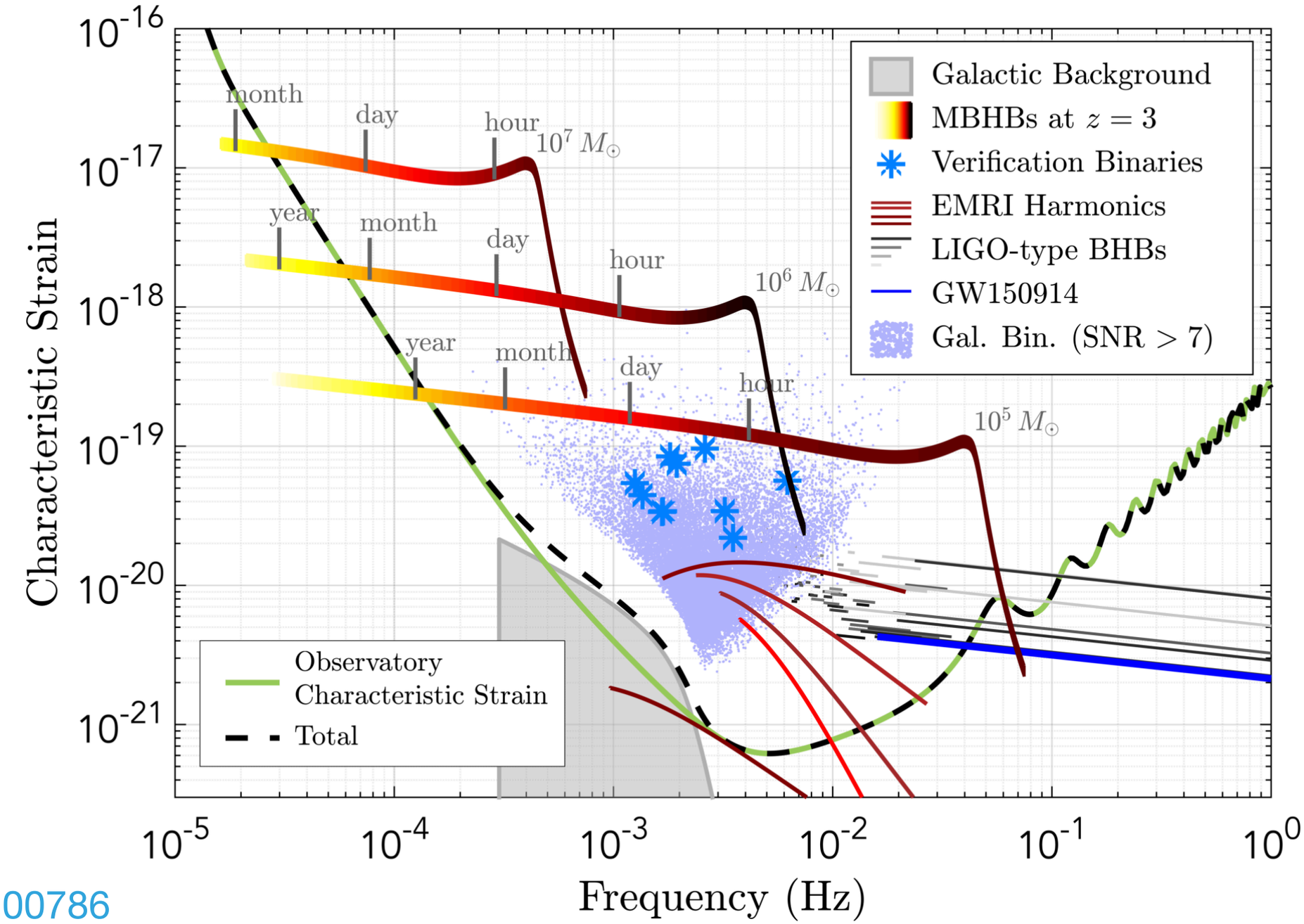
Model data from arXiv: 1811.11175





Figures made with PTPlot, doi:10.5281/zenodo.6949107

Measuring a SGWB coming from a phase transition will be difficult



arXiv:1702.00786

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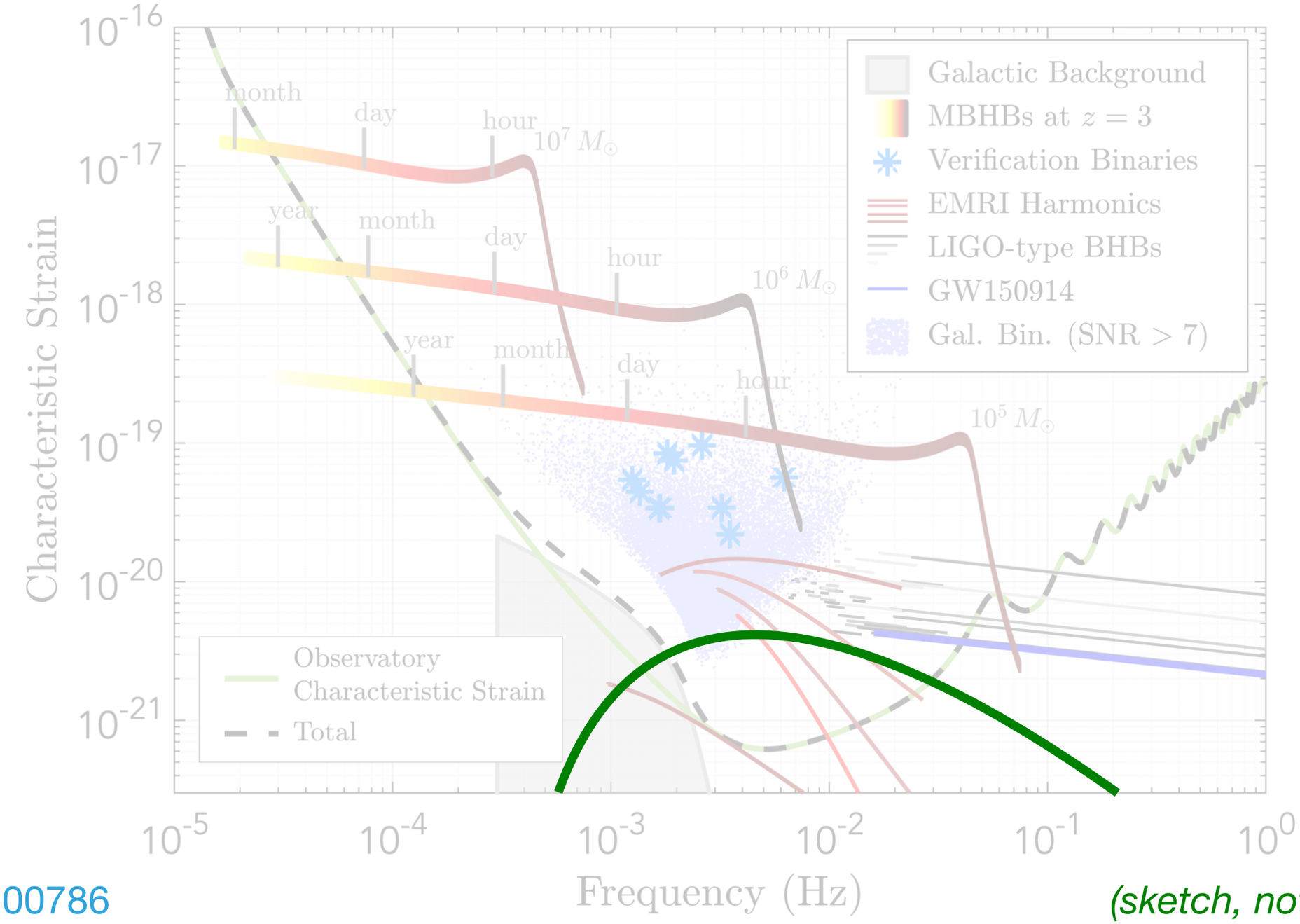
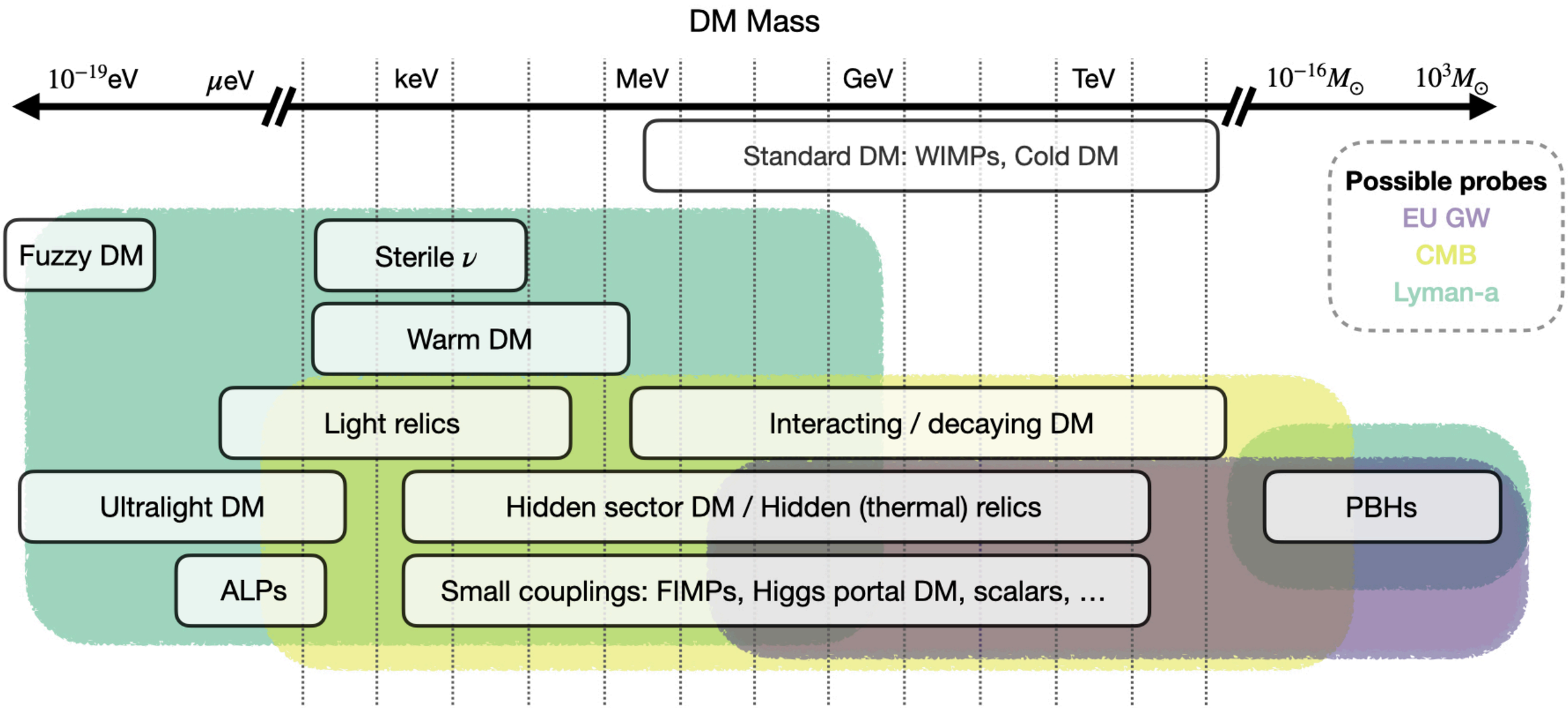


arXiv:1702.00786

(sketch, not a real model)

Combining probes might disentangle models with similar signatures



Credits: D. C. Hooper

Cosmology can offer a lot of insight into the particle nature of dark matter

Summary

- Cosmology can probe dark matter on many different scales
- CMB, Lyman-α and gravitational waves can cover many dark matter models

Questions

- Can LISA actually find a phase transition signal compatible with dark matter?
- How will we deal with all the foregrounds?
- Can we combine all of these probes to get more information?

Thanks for listening!

Get in touch!

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