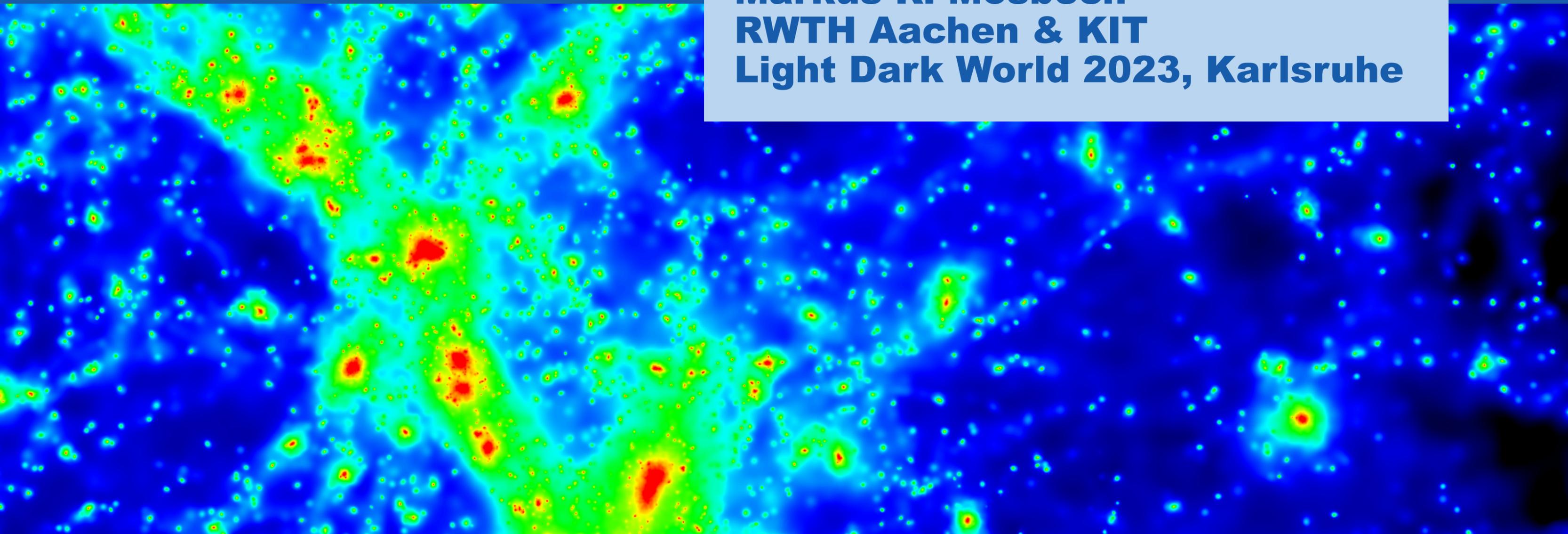


Probing dark matter microphysics with gravitational waves and 21cm emission

Markus R. Mosbech
RWTH Aachen & KIT
Light Dark World 2023, Karlsruhe



Dark Matter?

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- **Makes up the majority of the universe's matter budget**
- **Has only very limited interactions with standard model particles**
- **Clusters gravitationally, at least on large scales**

- **Surveys and experiments have ruled out, or constrained many models: we know a lot about what dark matter is not, but not what it is!**

Relevant papers:

[2207.03107](#)

[2207.14126](#)

[2011.04206](#)

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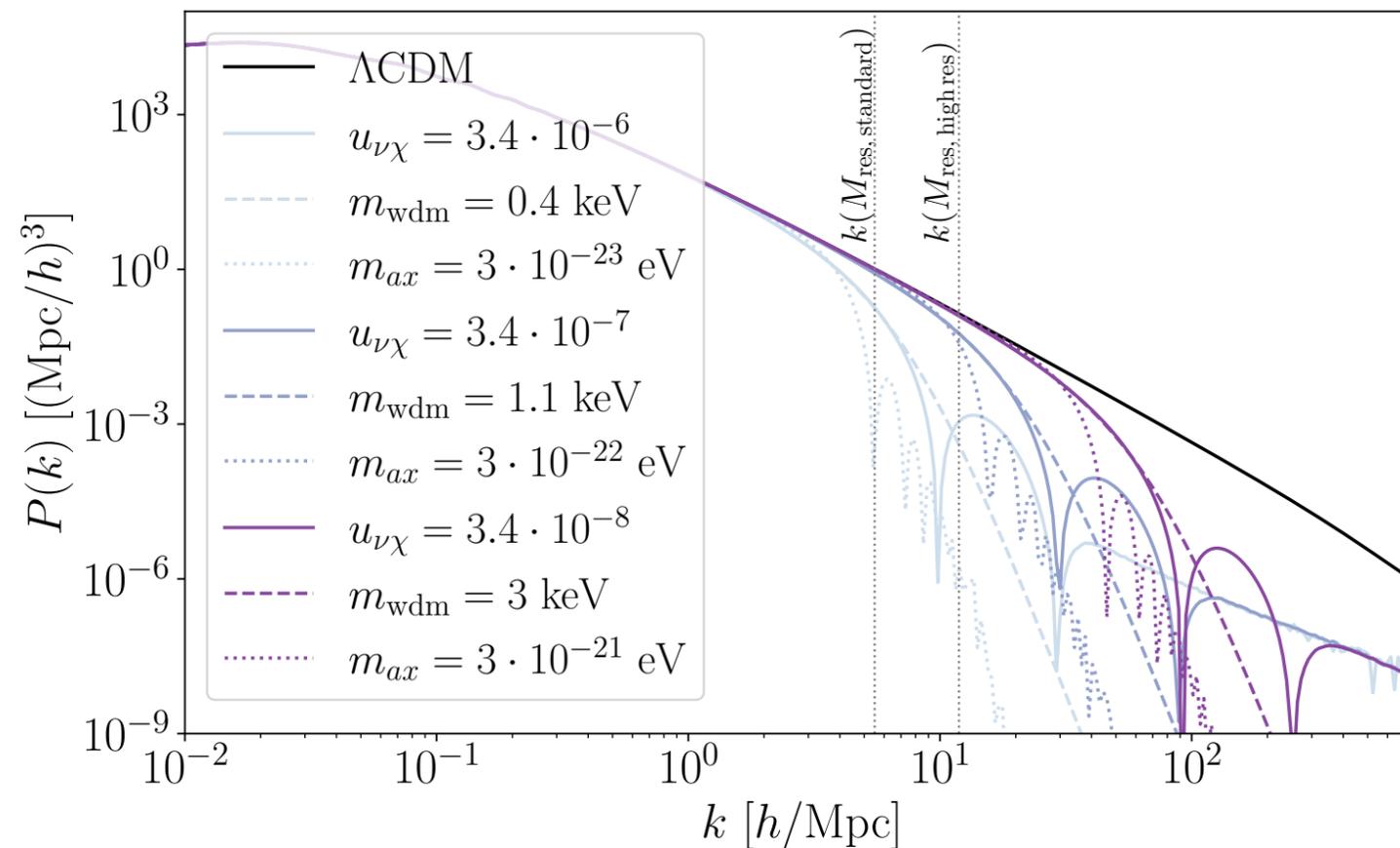
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‘All roads lead to Rome’?

- Several types of dark matter models lead to suppressed structure at small scales - this can give similar observational signatures despite different origins.



Relevant papers:

[2207.03107](#)

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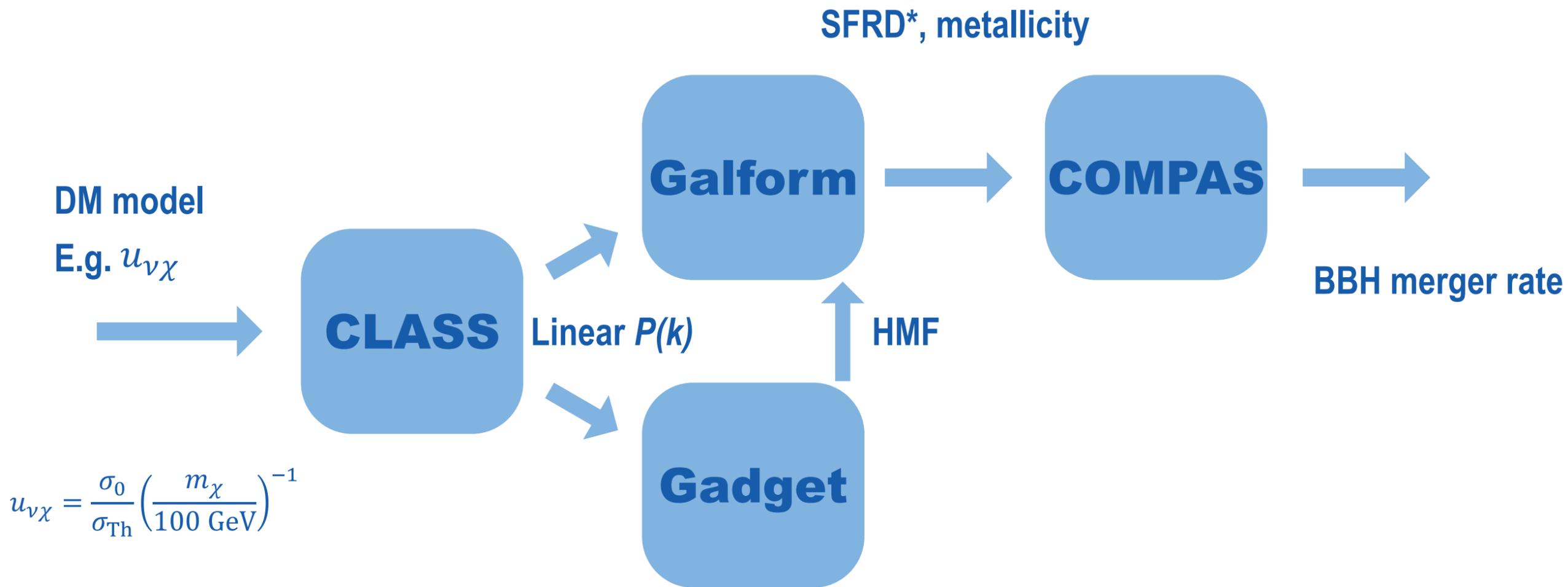
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From DM interactions to GWs



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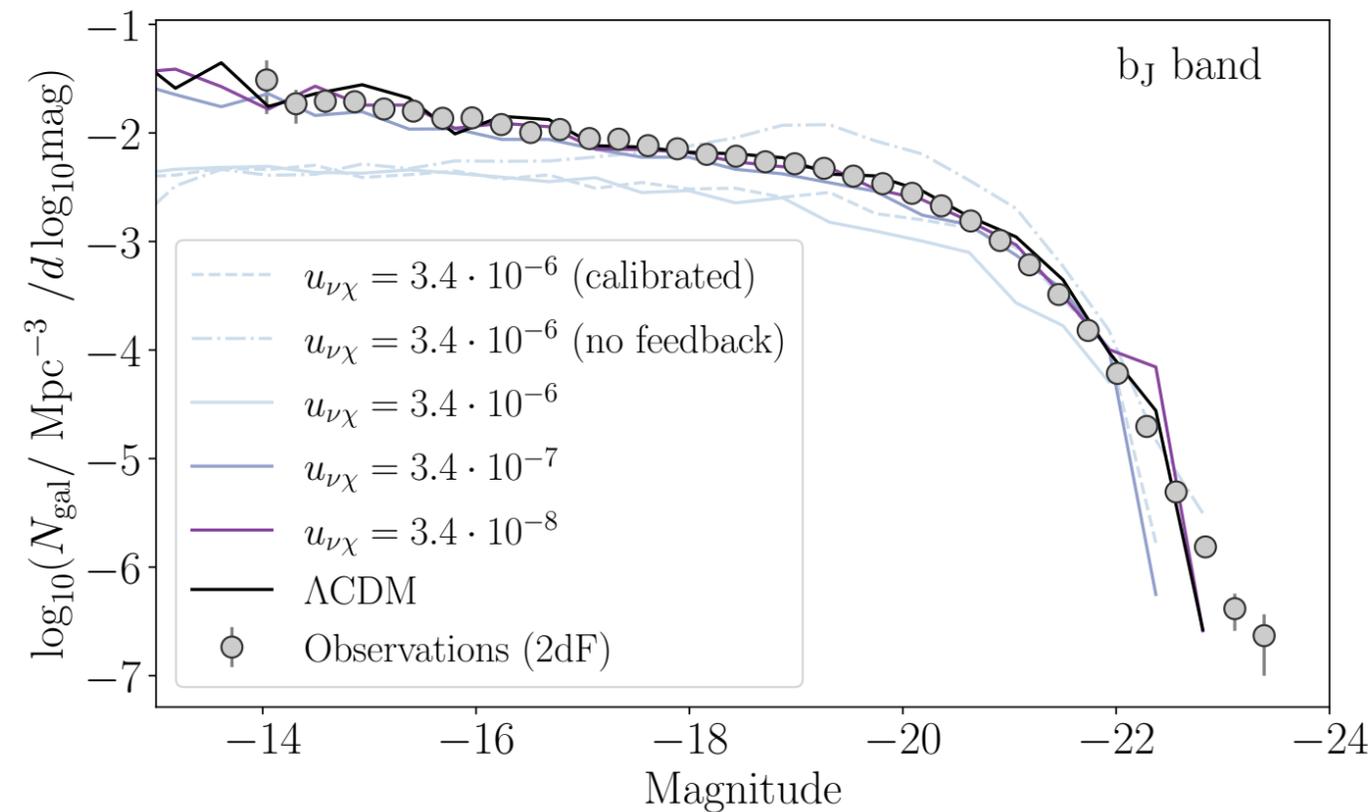
A similar analysis of host galaxies was later done by [Rauf et al. '23](#)

*Star formation rate density



Sidebar: Galaxy constraints

- Observed galaxy populations offer a strong constraint on DM-neutrino interactions
- Rules out previous hint (Hooper & Lucca '22) + improves bounds.



Relevant papers:

[2207.03107](#)

[2207.14126](#)

[2011.04206](#)

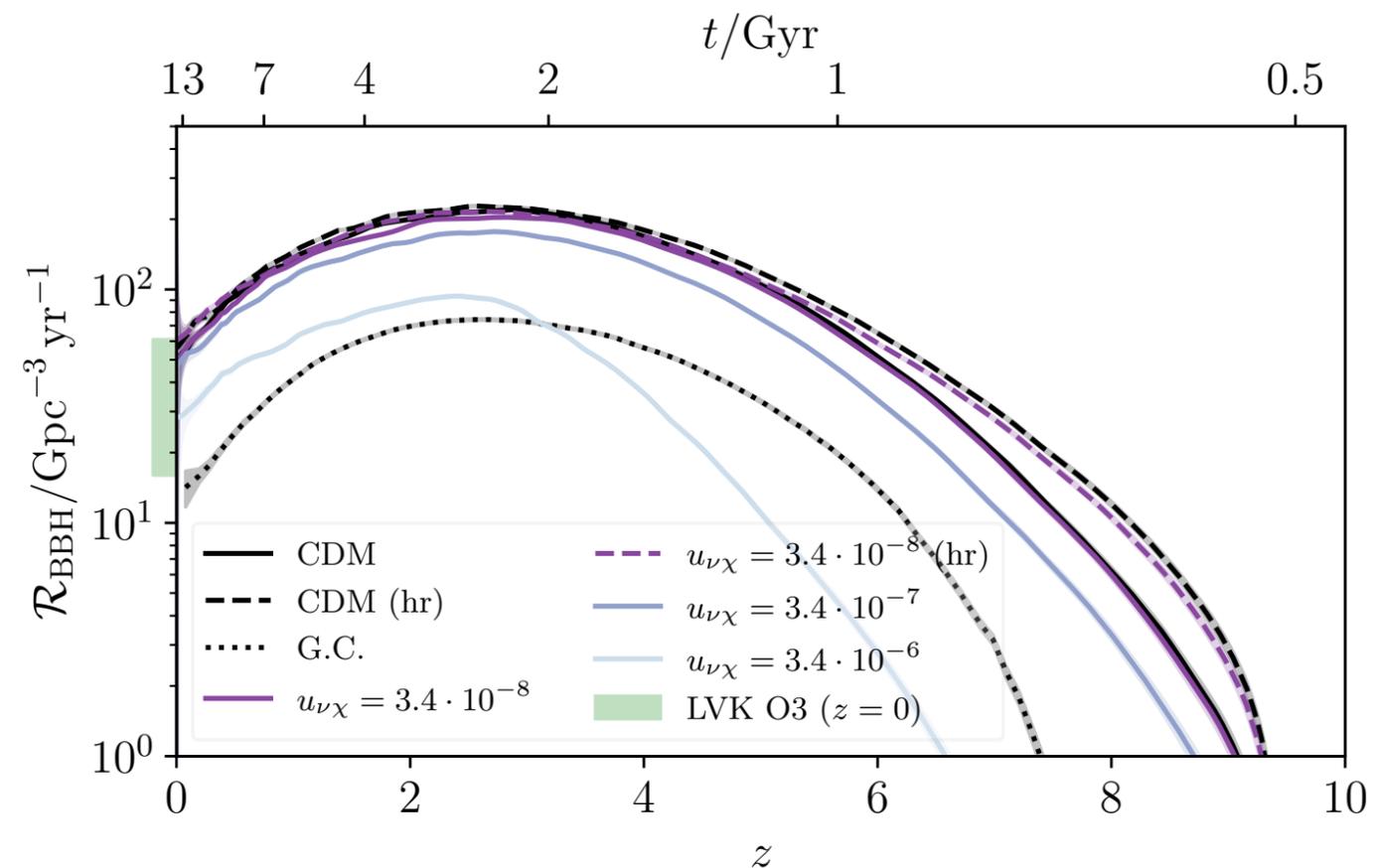
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The GW signal

- Effect of suppressed structure is largest at early times
- LVK bounds on BBH rate can not yet improve dark matter bounds.



Relevant papers:

[2207.03107](#)

[2207.14126](#)

[2011.04206](#)

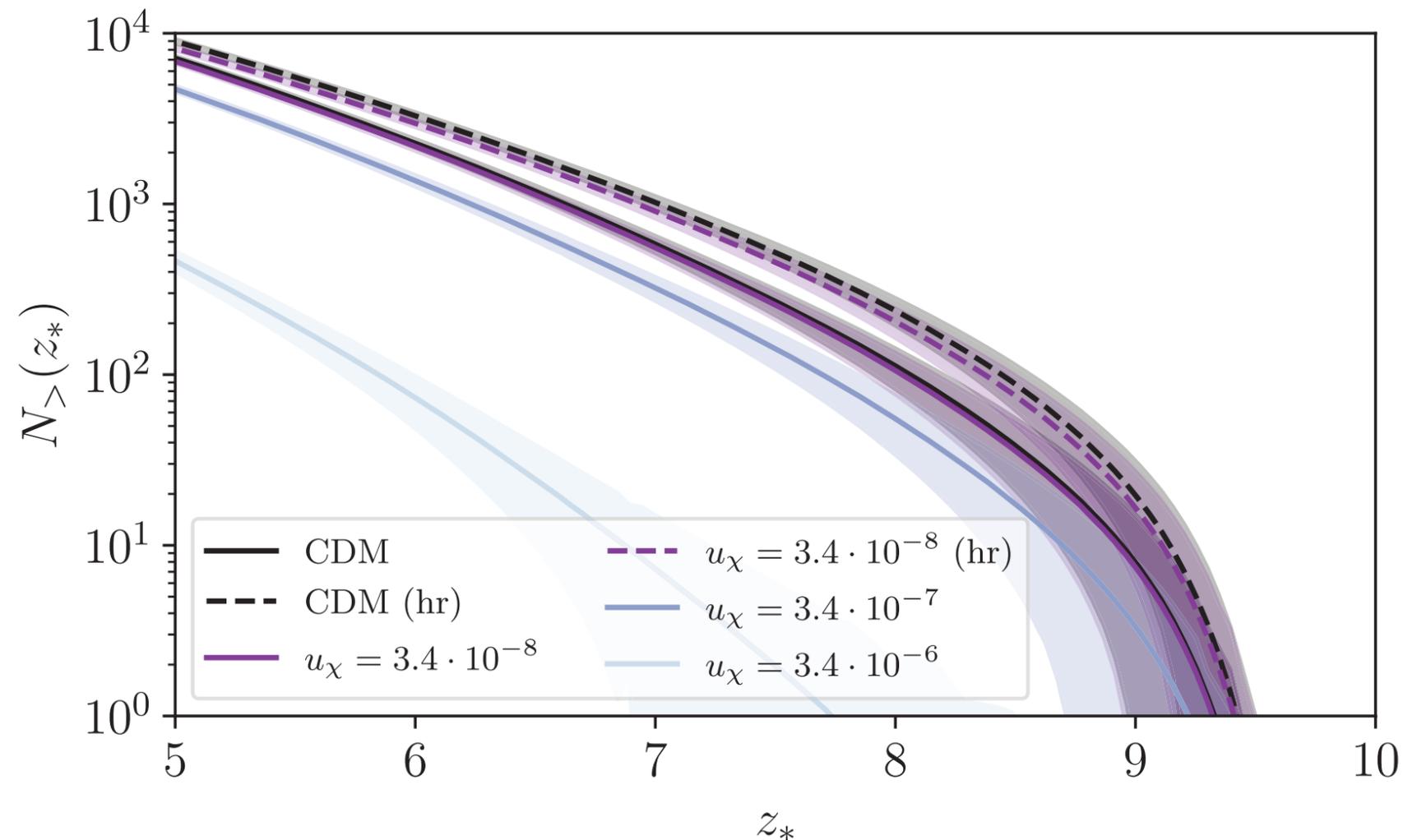
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The next generation

- The next generation of GW detectors (Einstein telescope + Cosmic explorer) has much improved redshift range, allowing improved constraints.



Relevant papers:

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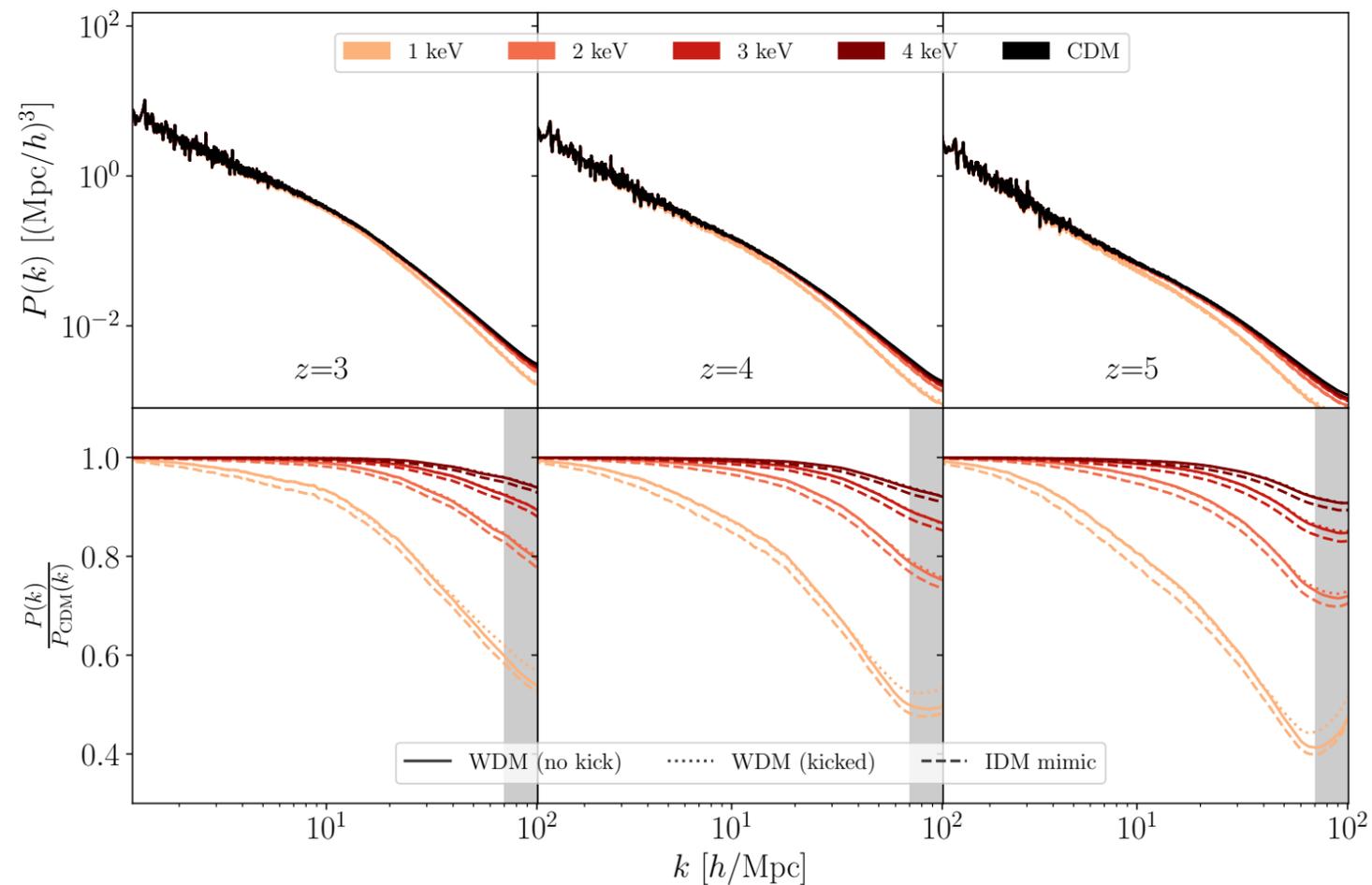
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IDM vs WDM

- Differences between interacting and warm dark matter are erased by non-linear structure formation
- Good: constraints universal; Bad: cannot distinguish at low z
- Warm dark matter constraints will apply to DM-neutrino interactions
- SKA-low can potentially constrain to $u_{\nu\chi} \sim 4 \times 10^{-8}$.



Relevant papers:

[2207.03107](#)

[2207.14126](#)

[2011.04206](#)

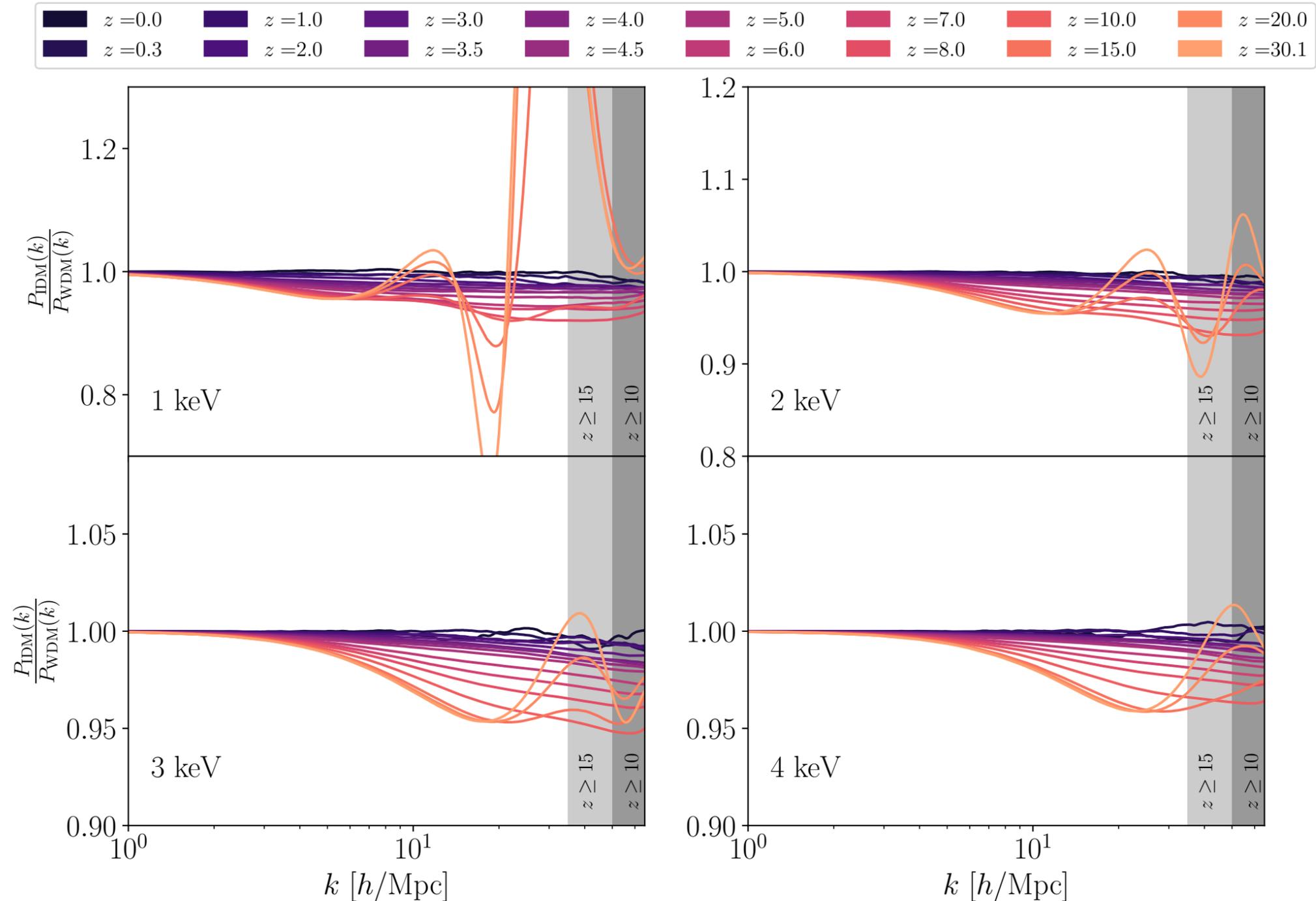
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Identifying differences

- Differences exist at high redshift.
- Percent-level measurement of $P(k)$ required
- Further studies required to determine feasibility



Relevant papers:

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Conclusions and Overview

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- **Gravitational waves offer a new and exciting probe of structure formation - also at early times.**
- **Upcoming radio telescopes can provide powerful constraints with 21cm line intensity mapping.**
- **High precision measurements of the matter power spectrum at high redshift is crucial to distinguish between dark matter models with suppressed small scale structure.**
- **Thanks for listening!**

Relevant papers:

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Bonus slide: Numbers

Relevant papers:

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m_{wdm}	$u_{\nu\text{DM}}$	$u_{\gamma\text{DM}}$
1 keV	8.5×10^{-7}	4.0×10^{-7}
2 keV	1.75×10^{-7}	9.0×10^{-8}
3 keV	7×10^{-8}	3.5×10^{-8}
4 keV	3.6×10^{-8}	1.8×10^{-8}

Data	Max $u_{\nu\text{DM}}$	Source
Planck + SDSS	$\sim 3 \times 10^{-4}$	Mosbech et al. arXiv:2011.04206
Planck + SDSS+Ly α	$\sim 10^{-5}$	Hooper & Lucca arXiv:2110.04024
SKA 21cm line intensity map	$\sim 4 \times 10^{-8}$ *	Mosbech, Boehm, & Wong arXiv:2207.03107
2dF galaxy counts	$\sim 3 \times 10^{-6}$ - 10^{-7}	Mosbech et al. arXiv:2207.14126
Einstein Telescope + Cosmic Explorer	$\sim 4 \times 10^{-7}$ *	Mosbech et al. arXiv:2207.14126

*: Forecast – constraint assuming non-detection