Investigating Dark Matter with Gravitational waves and cosmology

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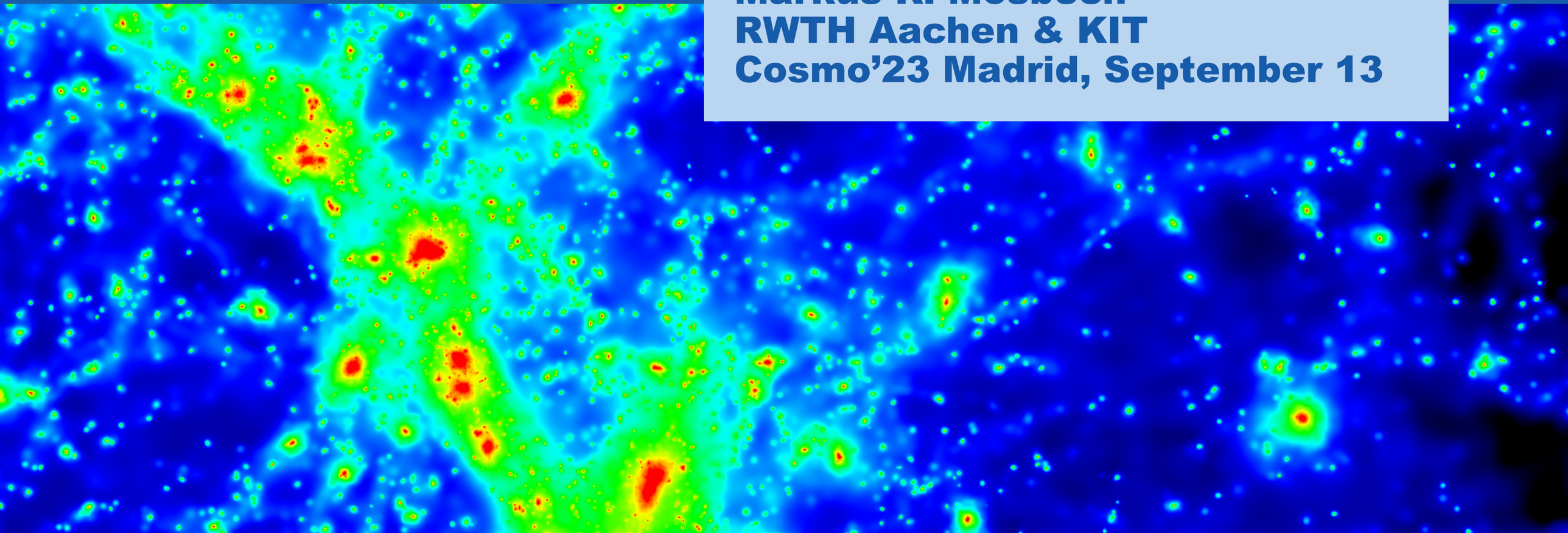
Cosmo’23 Madrid, September 13



Dark Matter?

- 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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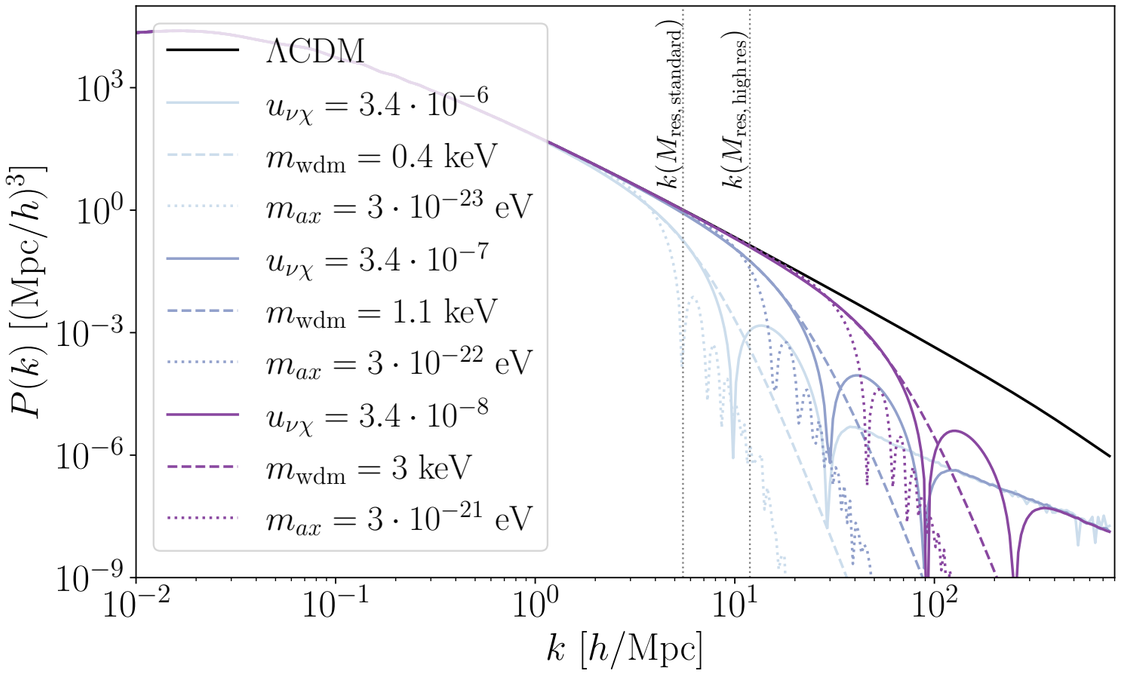
‘All roads lead to Rome’?

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



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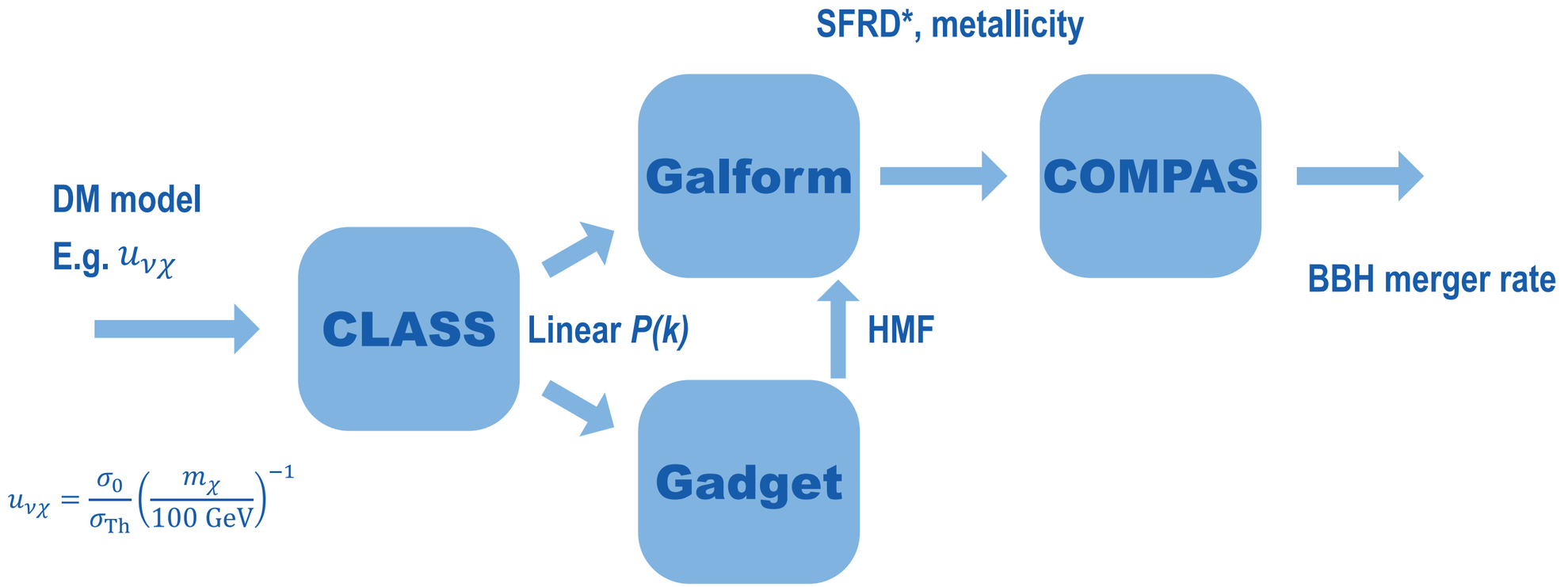
From DM interactions to GWs



A similar analysis of host galaxies was later done by Rauf et al. '23

*Star formation rate density

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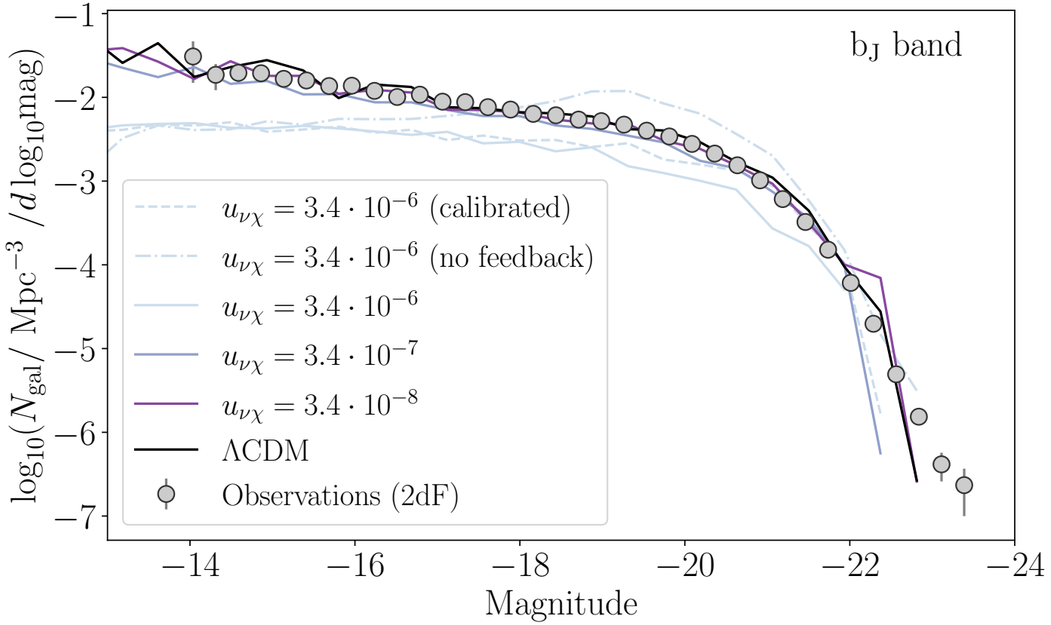
Sidebar: Galaxy constraints

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



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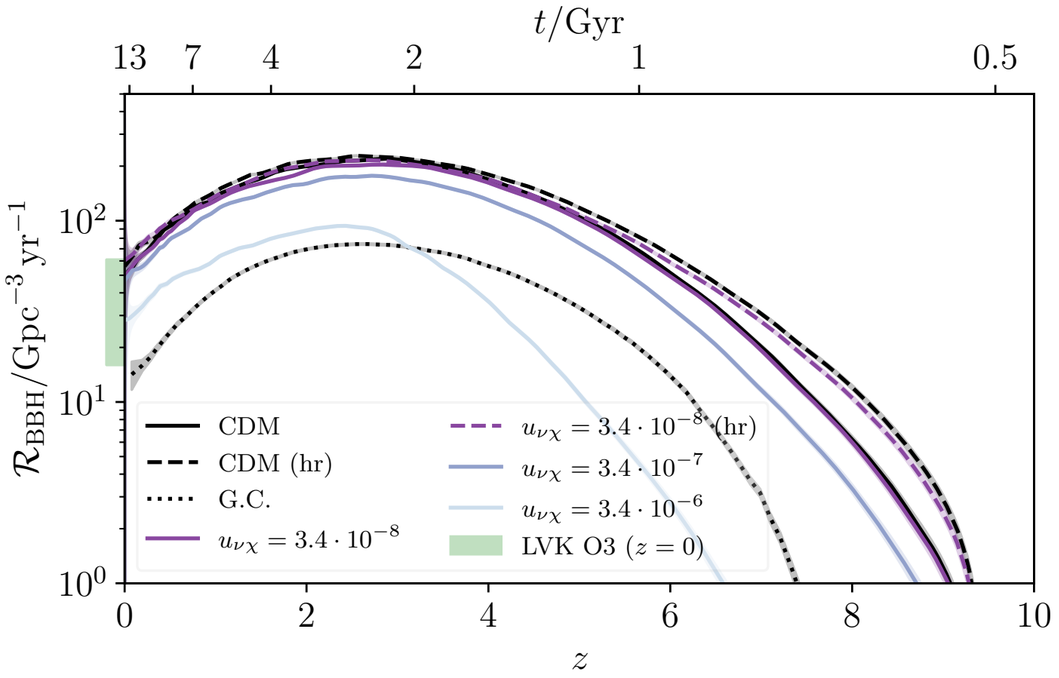
The GW signal

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



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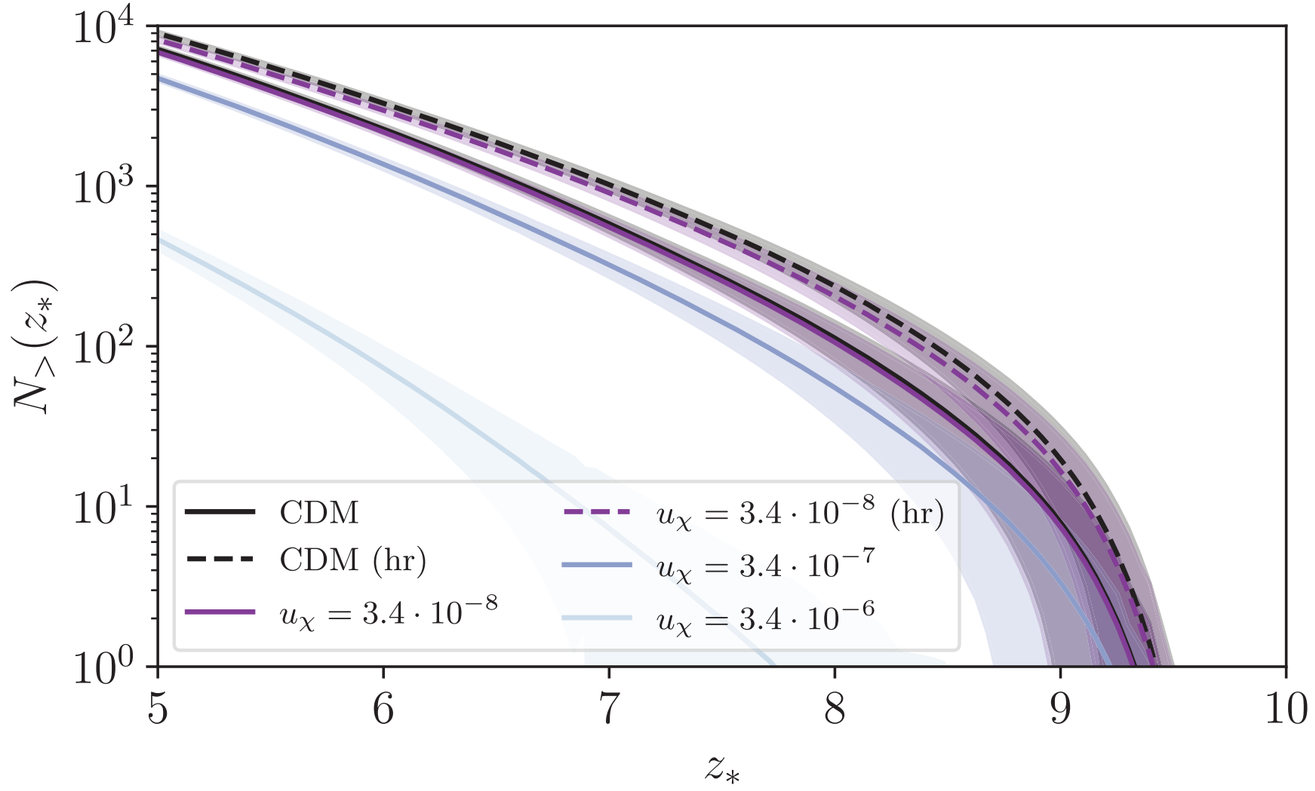
The next generation

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



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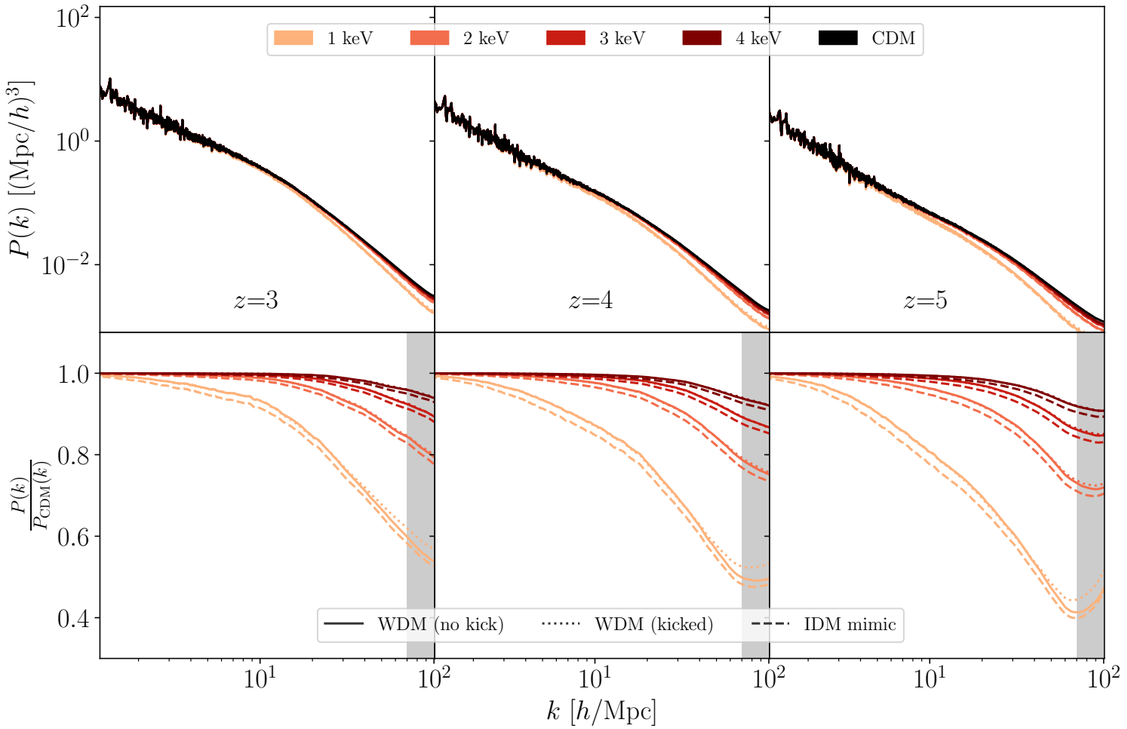
IDM vs WDM

- 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 $u_{\nu\chi}$~4x10^{-8}.



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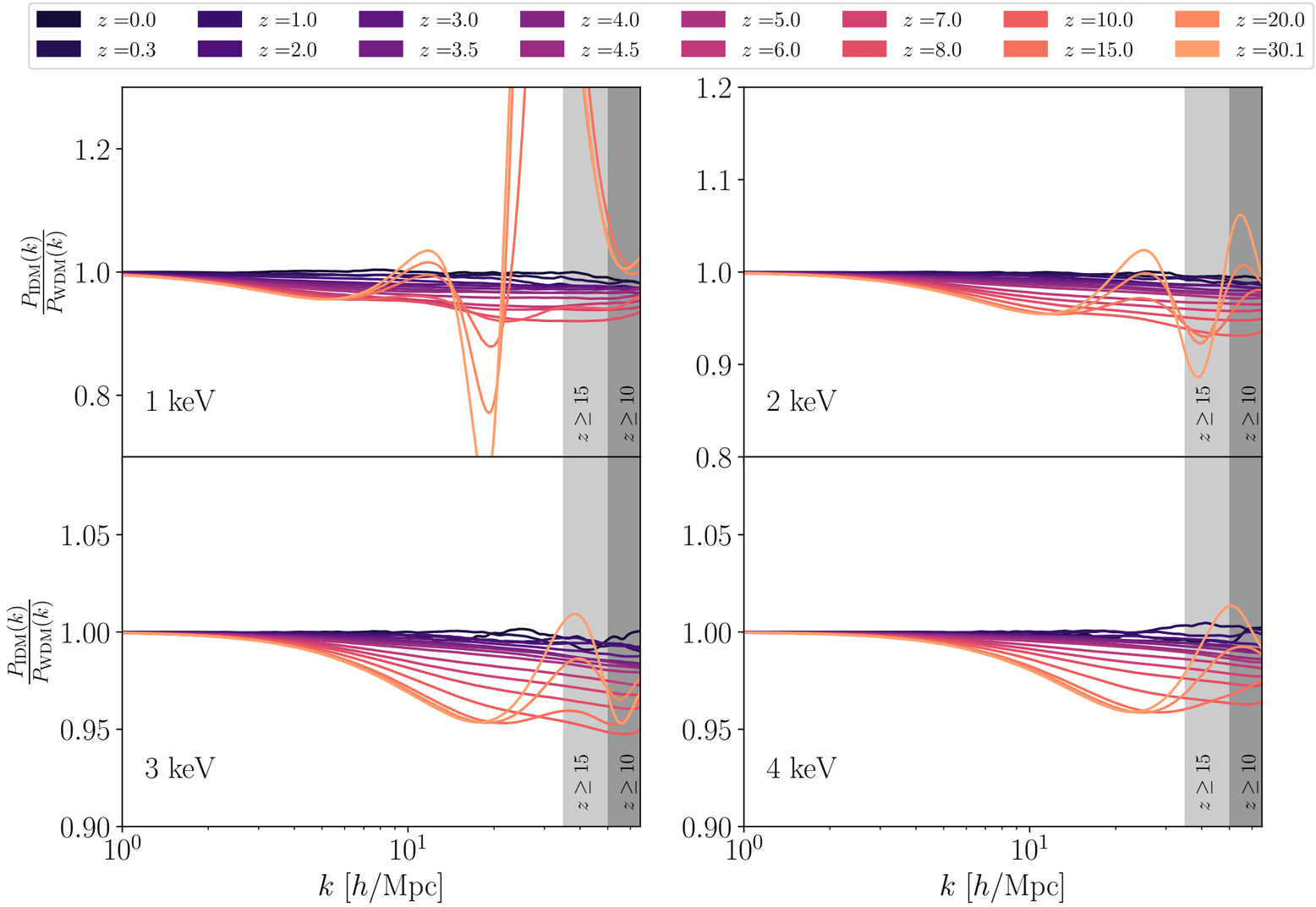
Identifying differences

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



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Conclusions and Overview

- 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!

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Bonus slide: Numbers

m_{wdm}	$u_{\nu DM}$	$u_{\gamma DM}$
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 $u_{\nu DM}$	Source
Planck + SDSS	$\sim 3 \times 10^{-4}$	Mosbech et al. arXiv:2011.04206
Planck + SDSS+Lyα	$\sim 10^{-5}$	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

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