University of Zurich[UZH]

Institute for Computational Science

Nonlinear modelling and constraints from dark matter decays and implications on S_8 tension

Jozef Bucko

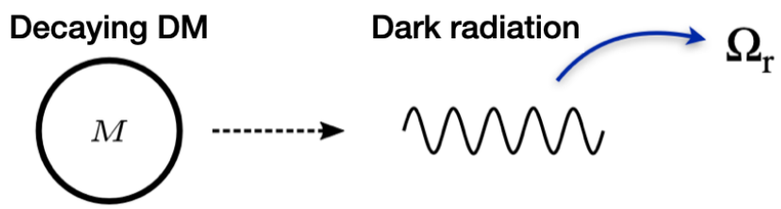
Institute for Computational Science

University of Zurich

Together with: Aurel Schneider, Sambit K. Giri, Fabian Hervas Peters,…

One-body (late-time) decays of dark matter

Bucko et al. 2023a



$\longrightarrow$ suppression of matter $P(k)$

Model parameters

- $\Gamma \equiv 1/\tau$ - decay rate of DM particles or lifetime
- f - fraction of decaying DM

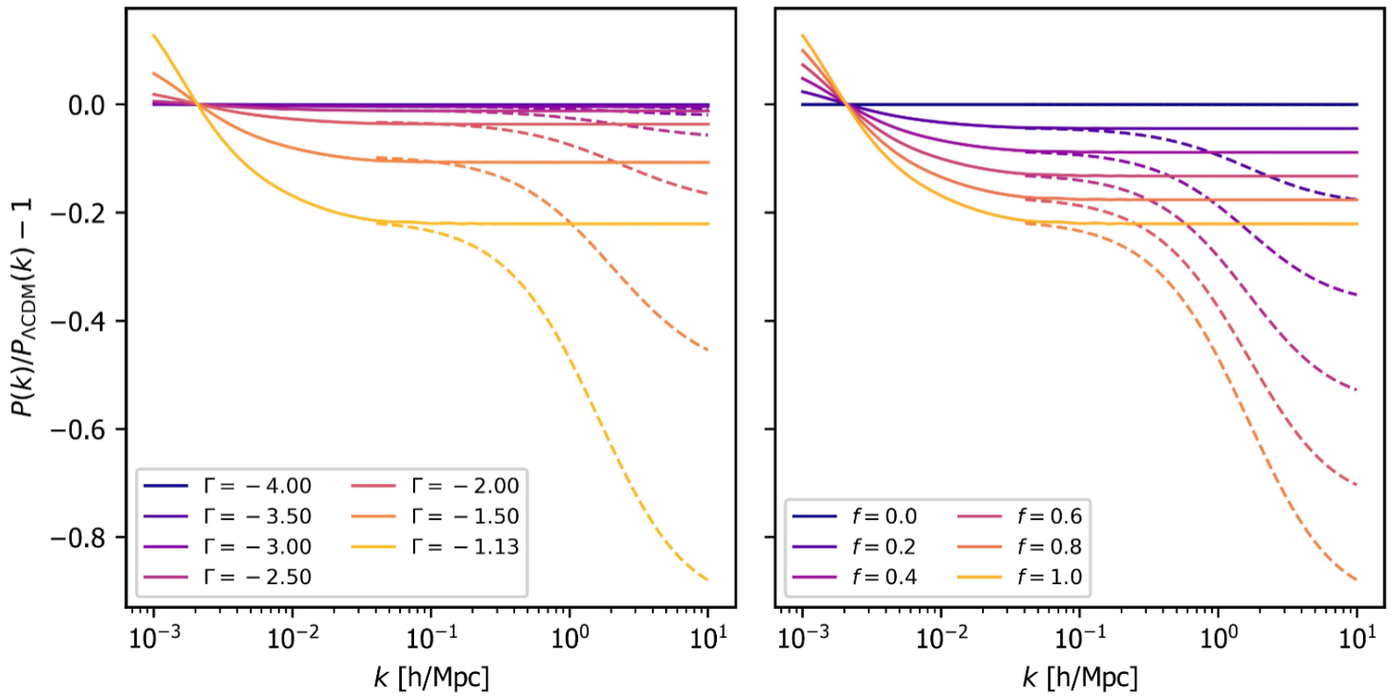
Fitting formula from N-body simulations

$$P_{\rm DDM}(k,z)/P_{\Lambda\rm CDM}(k,z) = 1 - \varepsilon_{\rm nonlin}(k,z)$$

$$\frac{\varepsilon_{\rm nonlin}(k,z)}{\varepsilon_{\rm lin}} = \frac{1 + a(k/{\rm Mpc}^{-1})^p}{1 + b(k/{\rm Mpc}^{-1})^q} f,$$

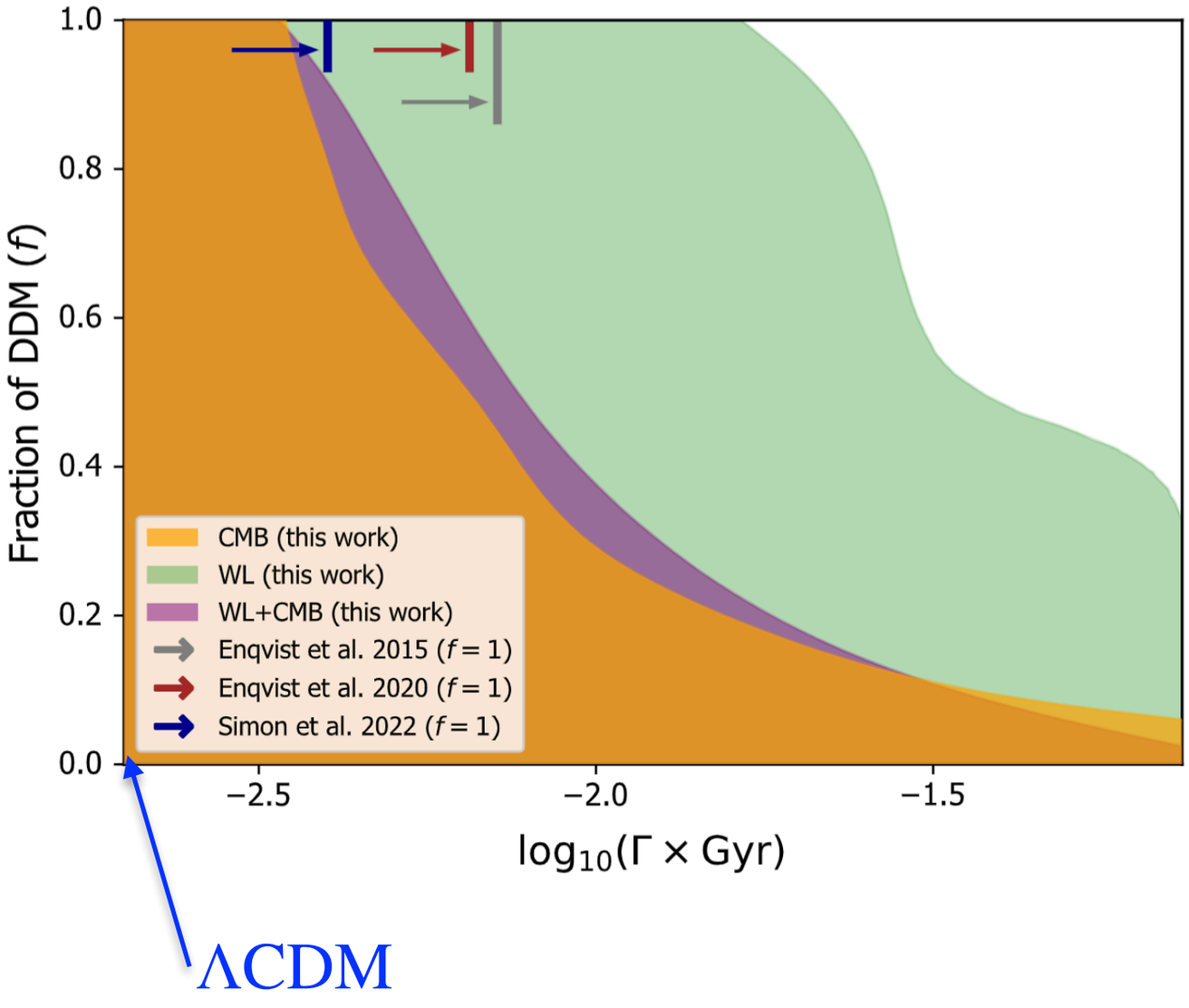
with the factors a, b, p, and q given by

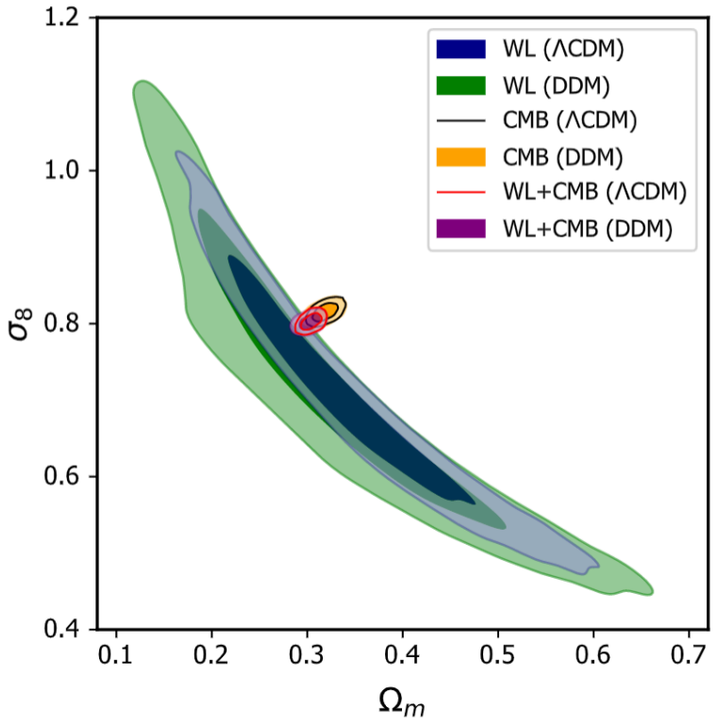
$$a(\tau,z) = 0.7208 + 2.027\left(\frac{\rm Gyr}{\tau}\right) + 3.031\left(\frac{1}{1+1.1z}\right) - 0.18,$$
$$b(\tau,z) = 0.0120 + 2.786\left(\frac{\rm Gyr}{\tau}\right) + 0.6699\left(\frac{1}{1+1.1z}\right) - 0.09,$$
$$p(\tau,z) = 1.045 + 1.225\left(\frac{\rm Gyr}{\tau}\right) + 0.2207\left(\frac{1}{1+1.1z}\right) - 0.099,$$
$$q(\tau,z) = 0.992 + 1.735\left(\frac{\rm Gyr}{\tau}\right) + 0.2154\left(\frac{1}{1+1.1z}\right) - 0.056.$$



One-body decays of dark matter

- Cosmic shear (*KiDS-1000)* and CMB (*Planck 2018)*
- Nonlinear alignment, baryonic feedback (BCemu)



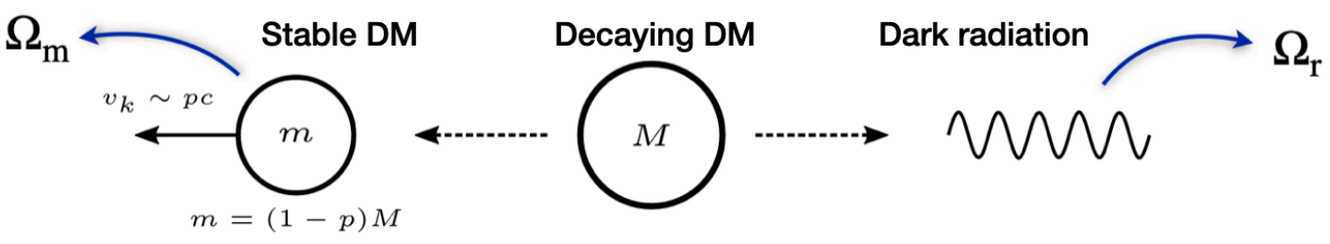


Takeaway:

- One-body decays strongly constraint by *Planck* data (ISW effect), not that much by weak lensing from KiDS
- Constraints in **agreement with ΛCDM**
- Strongest constraints up-to-date for decay rate Γ and fraction of decaying dark matter f
- One-body decays **cannot explain** S_8 **tension**

Two-body (late-time) decays of dark matter

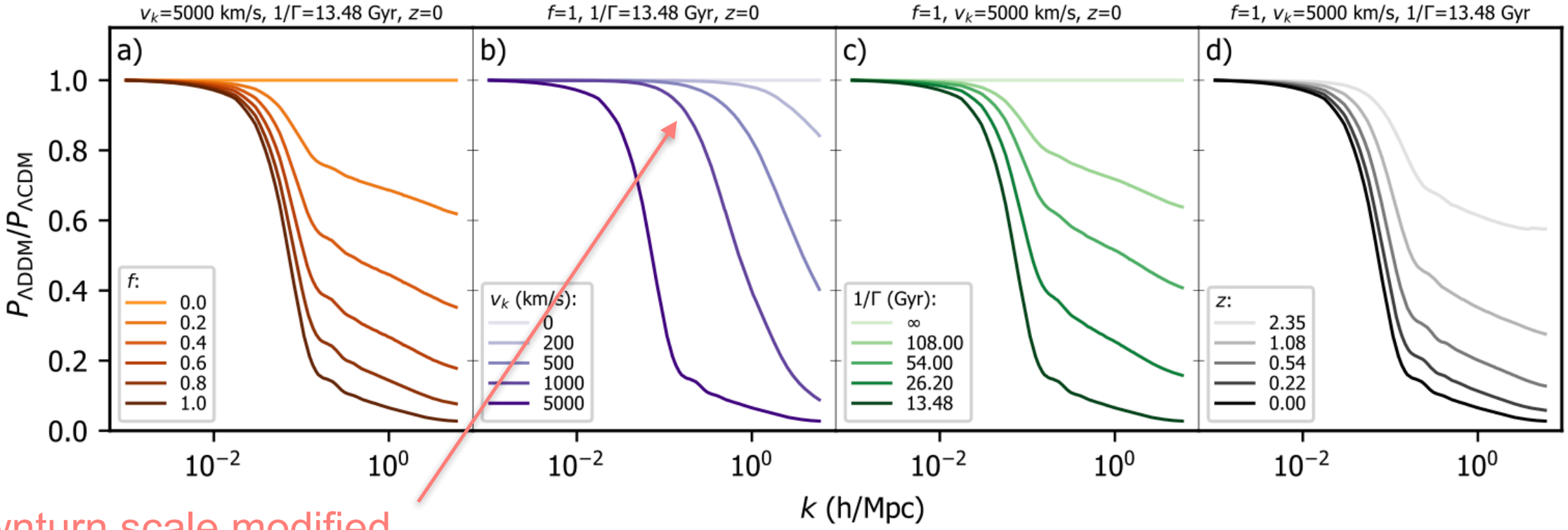
Bucko et al. 2023b (in prep.)



Model parameters

- $\Gamma \equiv 1/\tau$ - decay rate of DM particles or lifetime
- v_k - velocity kick magnitude
- f - fraction of decaying DM

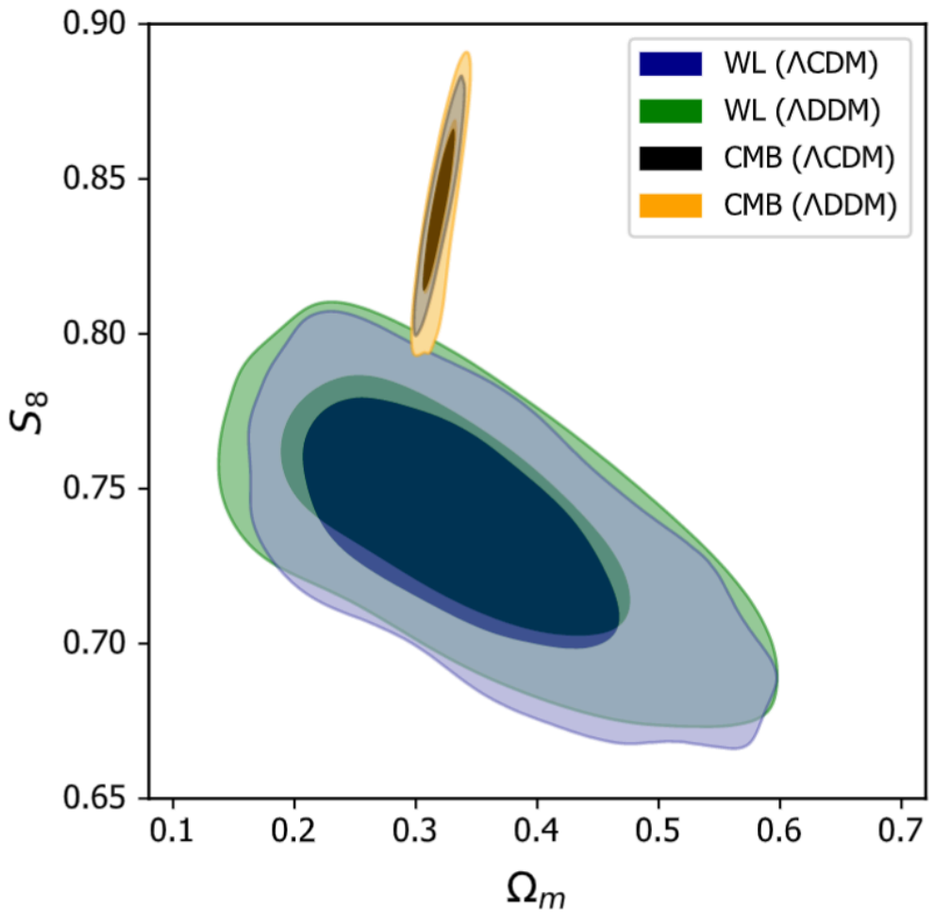
Effects on nonlinear matter $P(k)$ from N-body simulations



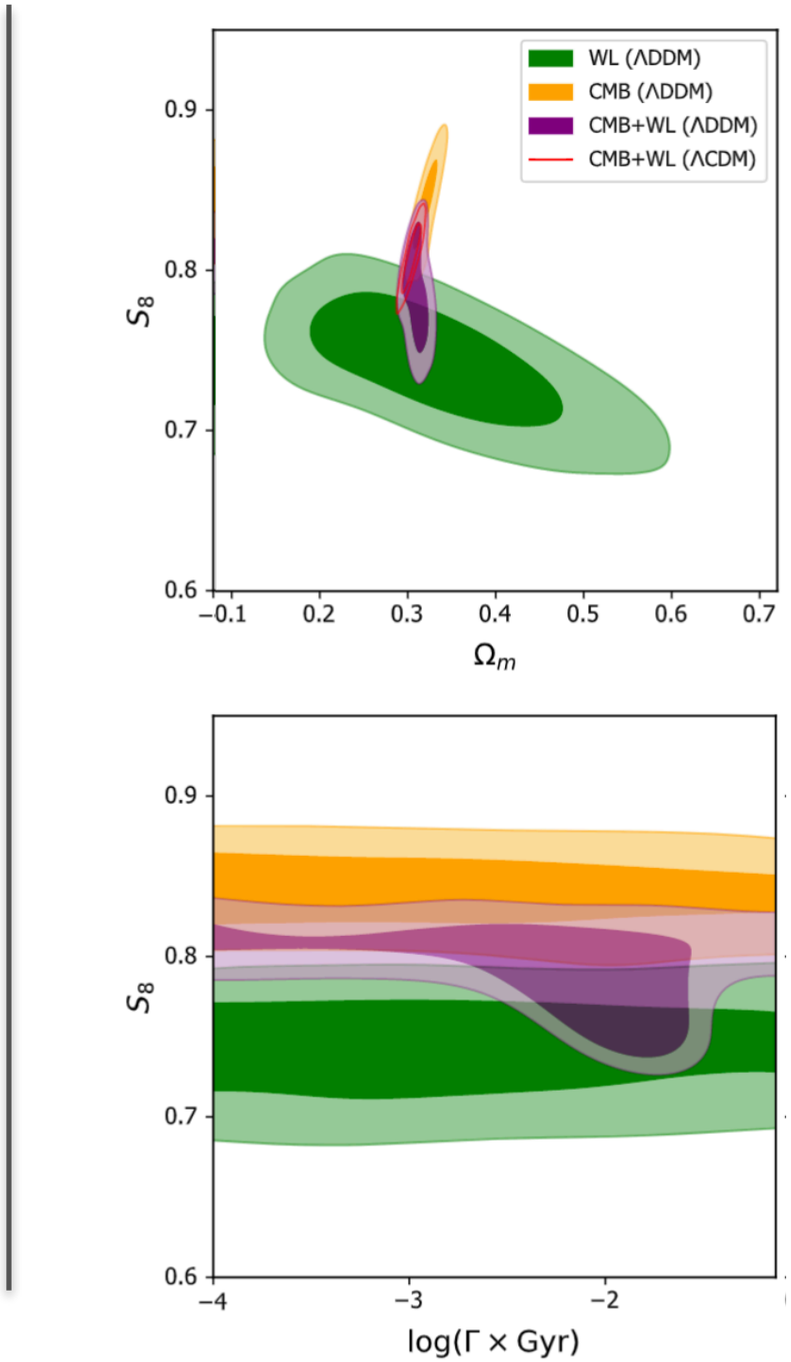
Downturn scale modified

Two-body decays of dark matter

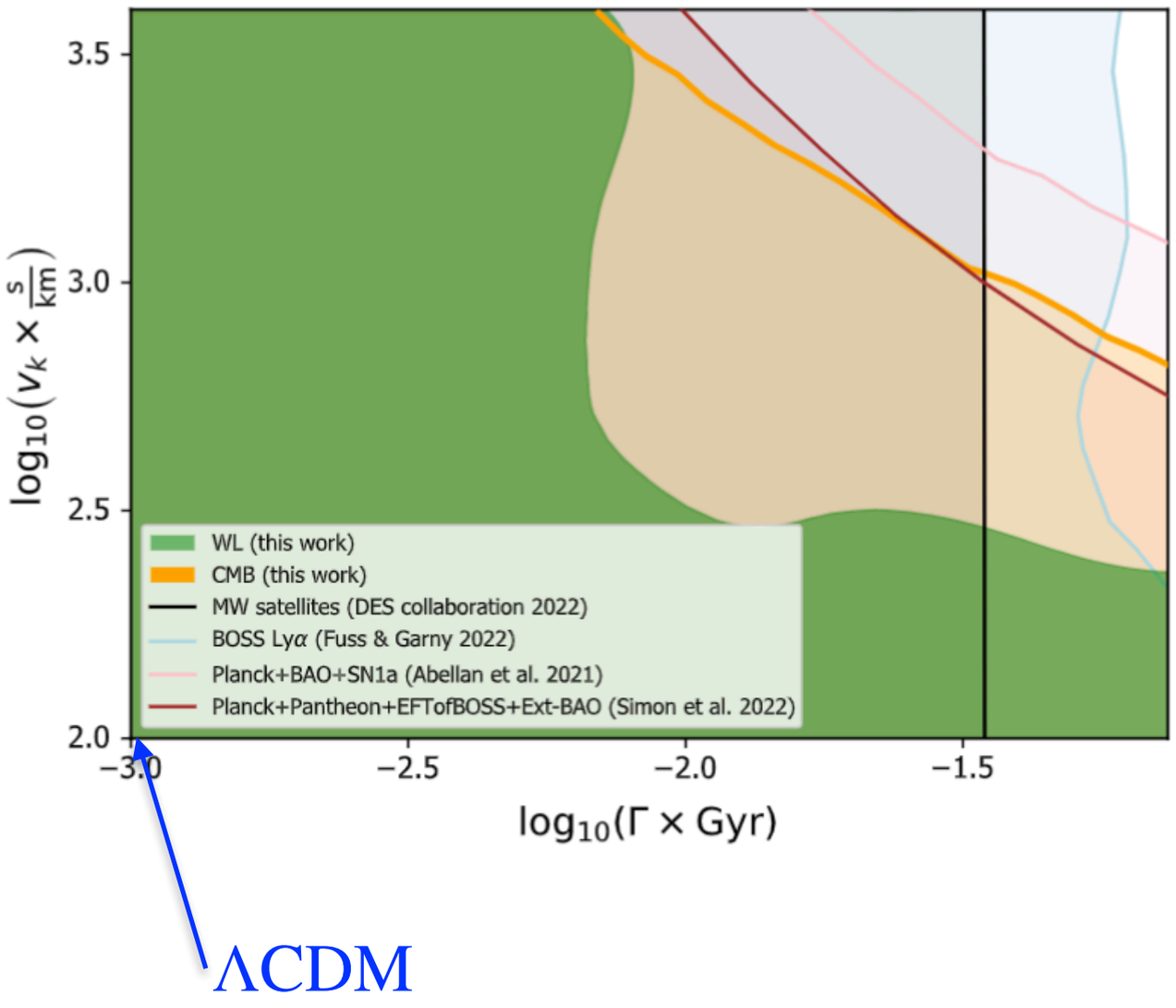
- ΛCDM cosmology preferred
- Negligible modification of (low) S_8 value



When combined with *Planck 2018 TTTEEE*



Two-body decays of dark matter

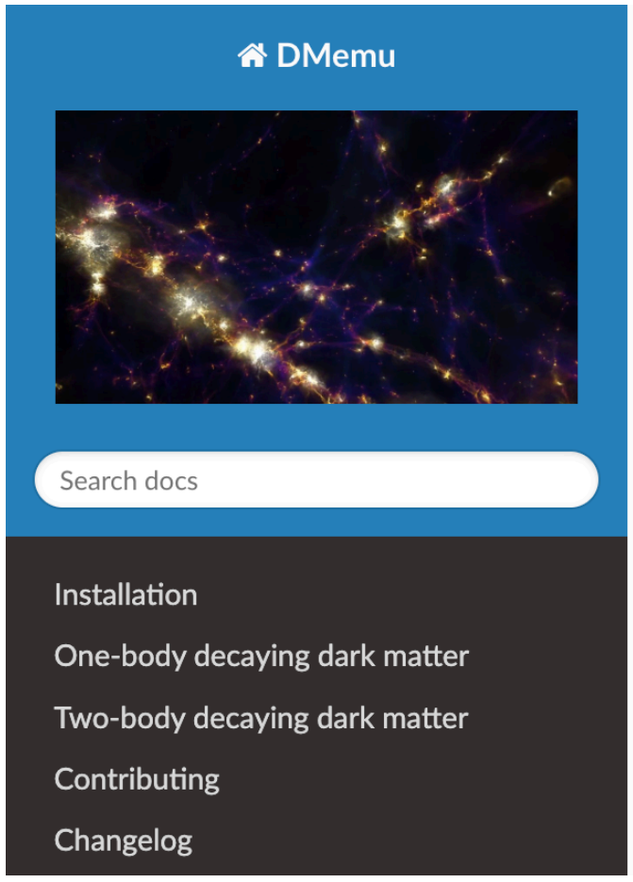


Takeaway:

- Emulator of nonlinear effects built
- Two-body decays can be strongly constrained by weak lensing from *KiDS*
- Constraints in **agreement with** $\Lambda\mathrm{CDM}$
- Strongest constraints up-to-date for decay rate Γ and velocity kick magnitude v_k
- Two-body decays **cannot naturally explain** S_8 **tension**

One & two-body decays of dark matter

- DMemu - a package for fast emulation of late-time dark matter decays effects of matter $P(k)$
- For different dark matter models and S_8 tension, see also Hervas Peters et al. 2023 (in prep.)



www.dmemu.readthedocs.io

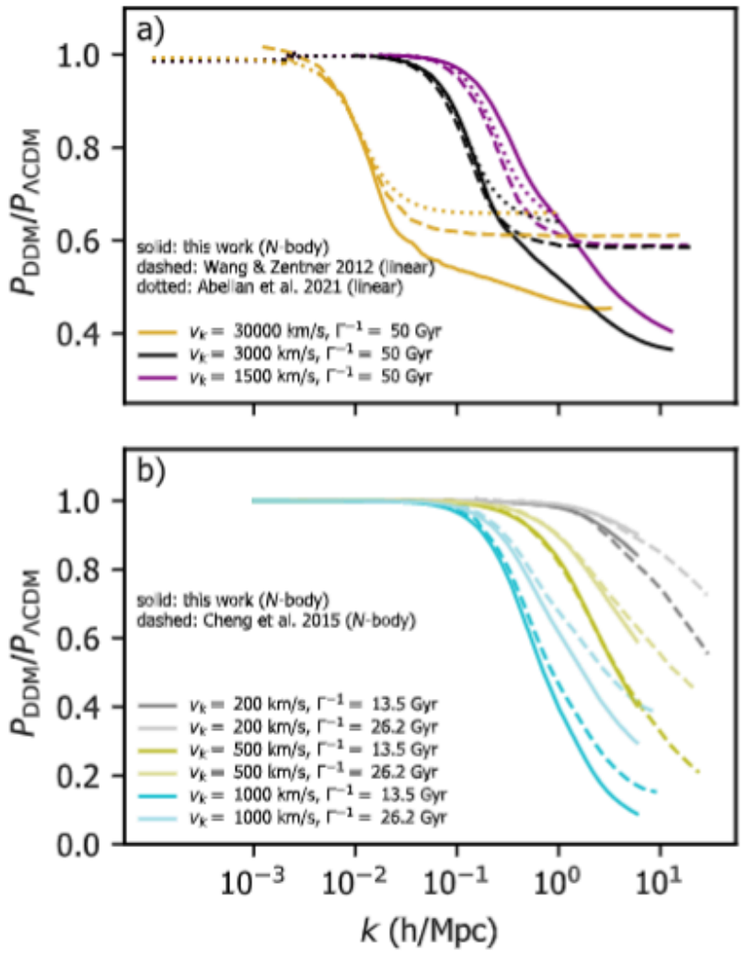
Thank you…

…and enjoy the conference dinner!

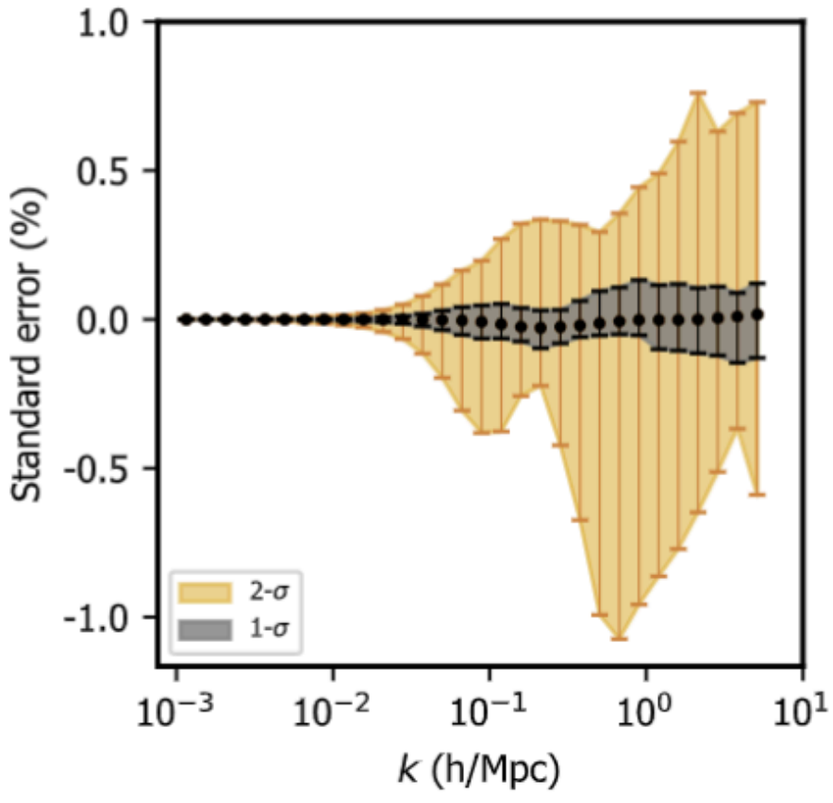
DALL-E: “cosmology barbecue party”

Two-body decays -

N-body simulations of warm DM decays compared to past N-body implementation and to predictions of Boltzmann code



Warm DM emulator's performance



Two-body late-time decays of dark matter: effects on observables