

The two-body decaying dark matter model in cosmology

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Elsa M. Teixeira
Adele Poudou
Vivian Poulin

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arXiv:2505.20193



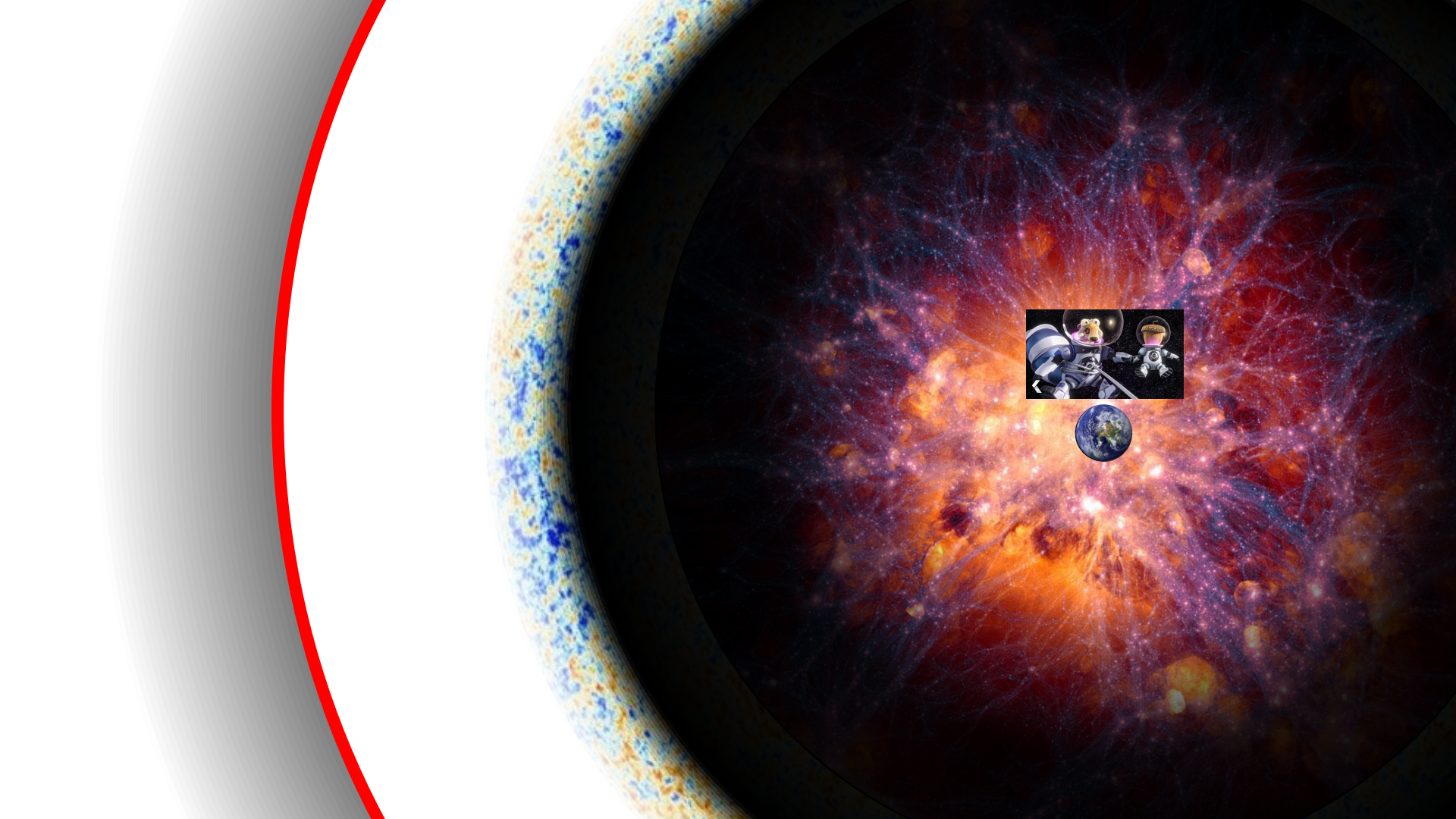
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MONTPELLIER



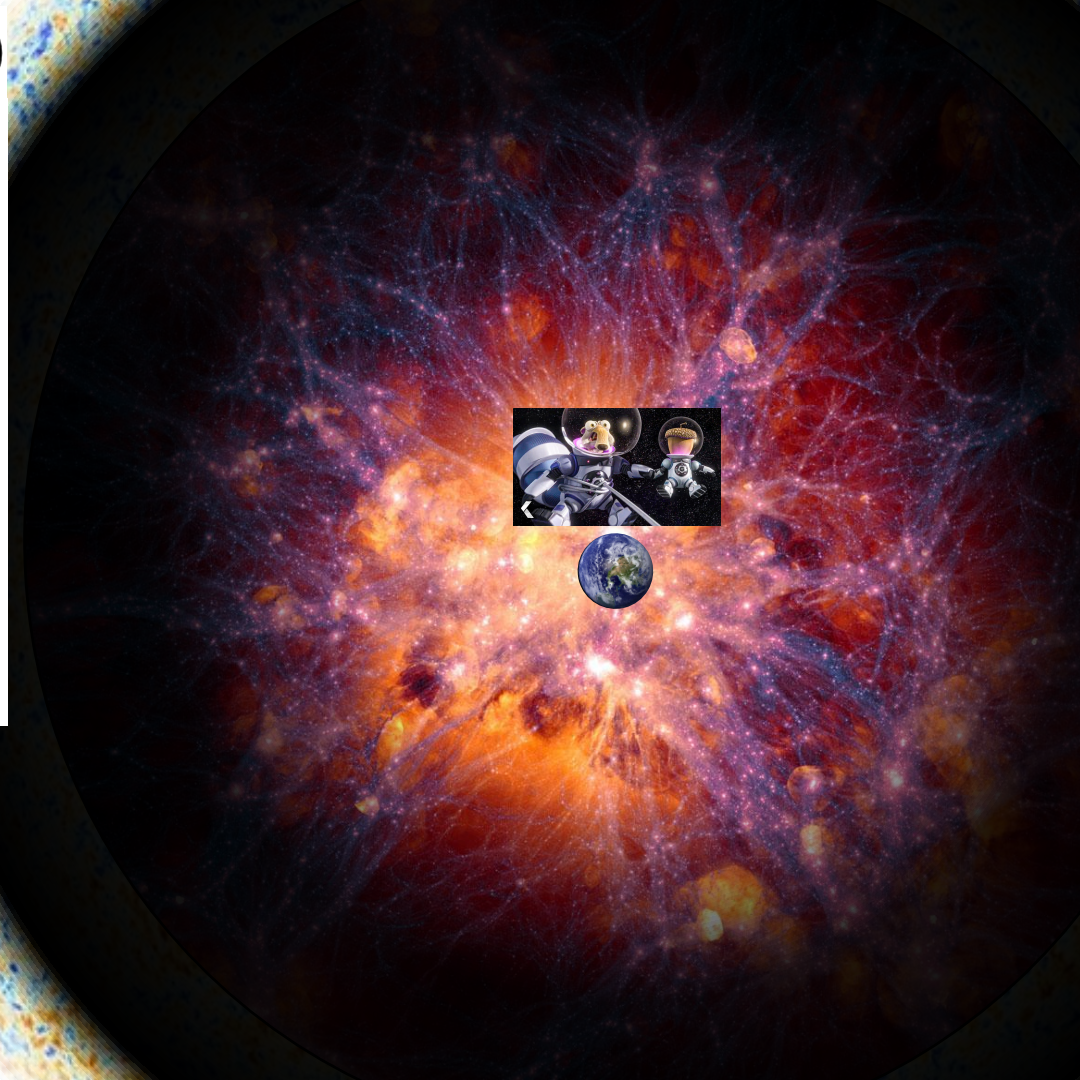
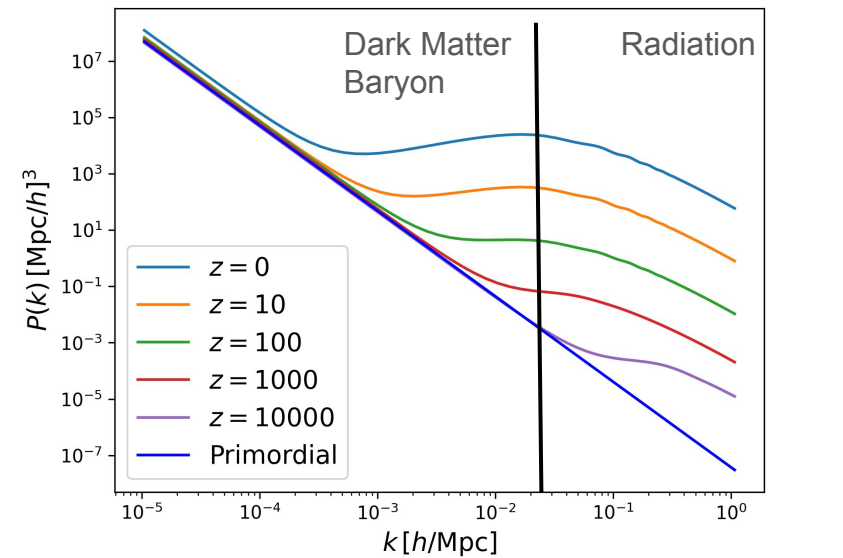
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AGREEMENT NO. 101076865)



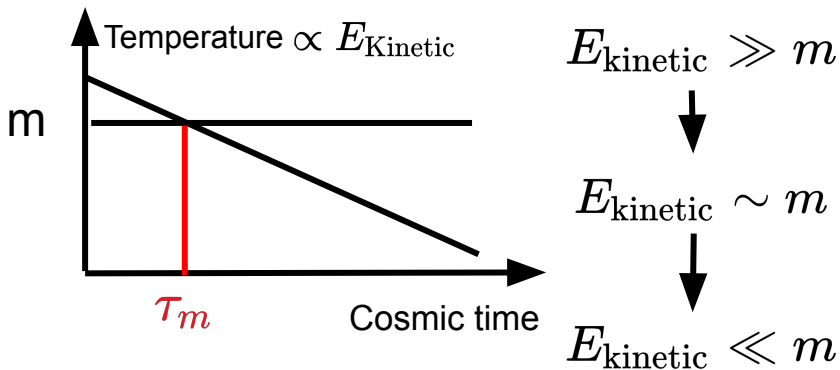
$$\langle \delta(\mathbf{k}_1) \delta(\mathbf{k}_2) \rangle = (2\pi)^3 \delta(\mathbf{k}_1 + \mathbf{k}_2) P(k_1)$$



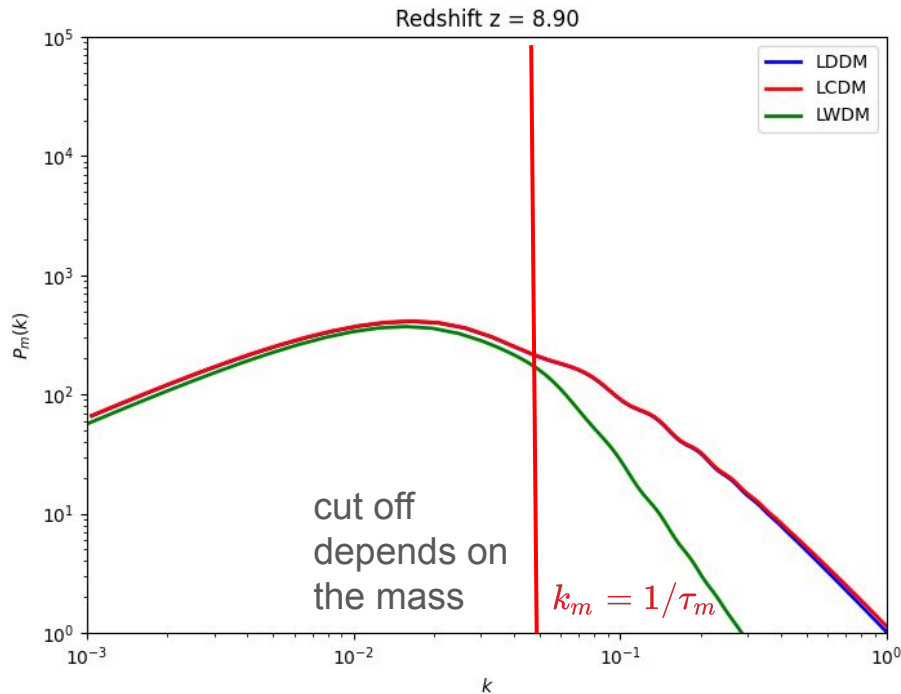
Decaying Dark Matter

- What?

- cold: $E_{\text{kinetic}} \ll m$
- hot: $E_{\text{kinetic}} \gg m$
- warm:

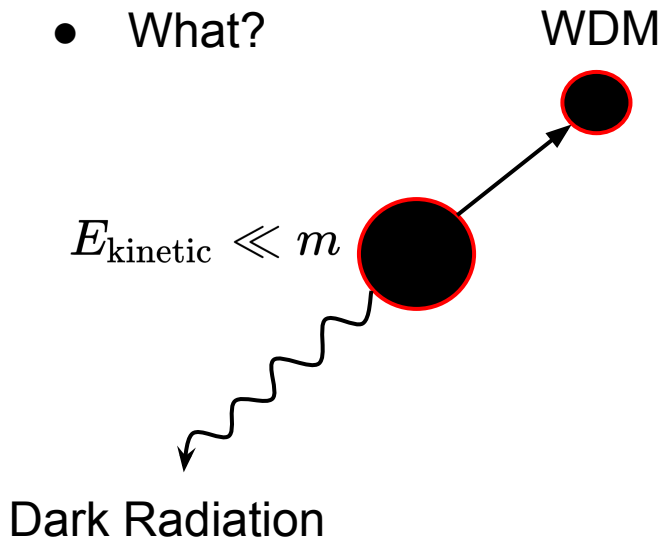


Like Neutrinos!



Decaying Dark Matter

- What?

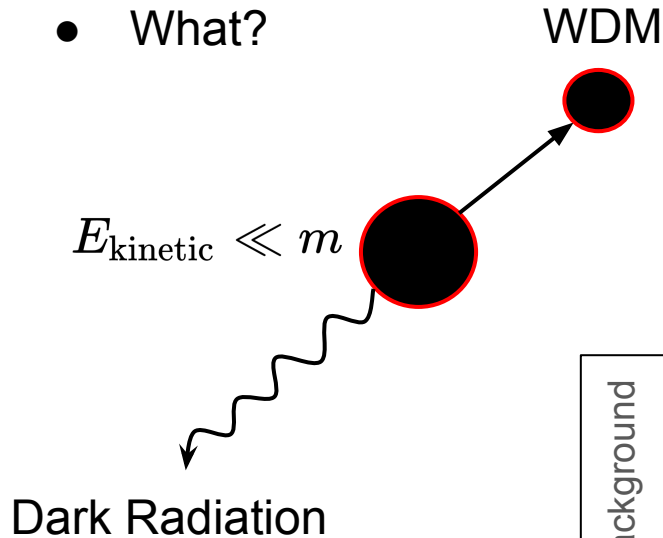


In particle physics:

- T. Hambye: *On the stability of particle dark matter* (1012.4587)
- M. Drewes et al. : *A White Paper on keV Sterile Neutrino Dark Matter* (1602.04816)
- V. Berezhinsky et al. : *Cosmological signatures of supersymmetry with spontaneously broken R parity*
- L. Covi: *Axinos as Cold Dark Matter* (9905212)
- H.-B. Kim and J. E. Kim: *Late decaying axino as CDM and its lifetime bound* (0108101)
- C.-H. Chou and K.-W. Ng: *Decaying Superheavy Dark Matter and Subgalactic Structure of the Universe* (0306437)
- And many others...

Decaying Dark Matter

- What?



Phenomenology of DDM in Cosmology

- Mei-Yu Wang and Andrew R. Zentner (1201.2426)
- Guillermo F. Abellan, Riccardo Murgia and Vivian Poulin (2102.12498)
- G. F. Abellan, R. Murgia, V. Poulin, and J. Lavalle (2008.09615)

Background

$$\dot{\bar{\rho}}_{\text{dcdm}} = -3\mathcal{H}\bar{\rho}_{\text{dcdm}} - a\Gamma\bar{\rho}_{\text{dcdm}},$$

$$\dot{\bar{\rho}}_{\text{dr}} = -4\mathcal{H}\bar{\rho}_{\text{dr}} + \varepsilon a\Gamma\bar{\rho}_{\text{dcdm}},$$

$$\dot{\bar{\rho}}_{\text{wdm}} = -3(1+w)\mathcal{H}\bar{\rho}_{\text{wdm}} + (1-\varepsilon)a\Gamma\bar{\rho}_{\text{dcdm}}.$$

Linear
perturbation

$$\dot{\delta}_{\text{dcdm}} = -\frac{\dot{h}}{2}.$$

And dark radiation...

$$\dot{\delta}_{\text{wdm}} = -3\mathcal{H}(c_s^2 - w)\delta_{\text{wdm}} - (1+w)\left(\theta_{\text{wdm}} + \frac{\dot{h}}{2}\right)$$

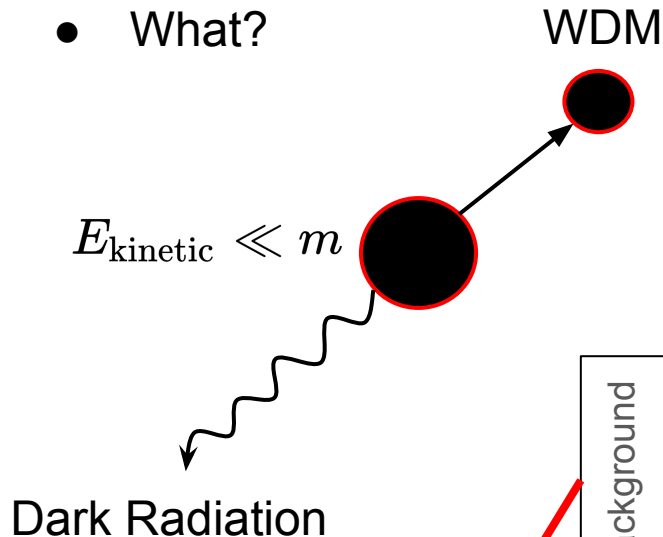
$$+ (1-\varepsilon)a\Gamma\frac{\bar{\rho}_{\text{dcdm}}}{\bar{\rho}_{\text{wdm}}}(\delta_{\text{dcdm}} - \delta_{\text{wdm}}),$$

$$\dot{\theta}_{\text{wdm}} = -\mathcal{H}(1-3c_g^2)\theta_{\text{wdm}} + \frac{c_s^2}{1+w}k^2\delta_{\text{wdm}} - k^2\sigma_{\text{wdm}}$$

$$- (1-\varepsilon)a\Gamma\frac{1+c_g^2}{1+w}\frac{\bar{\rho}_{\text{dcdm}}}{\bar{\rho}_{\text{wdm}}}\theta_{\text{wdm}}.$$

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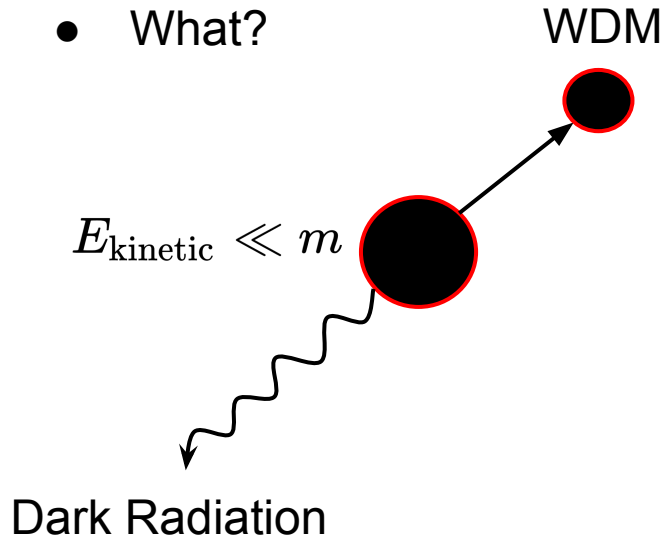
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Einstein-Boltzmann
solver: `class_decays`

https://github.com/PoulinV/class_decays

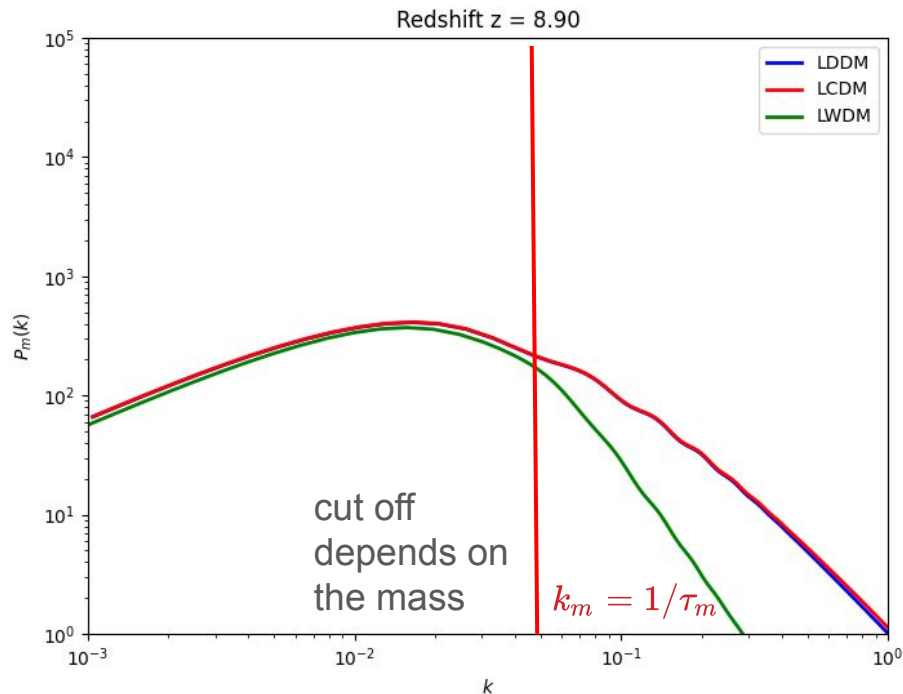
Decaying Dark Matter

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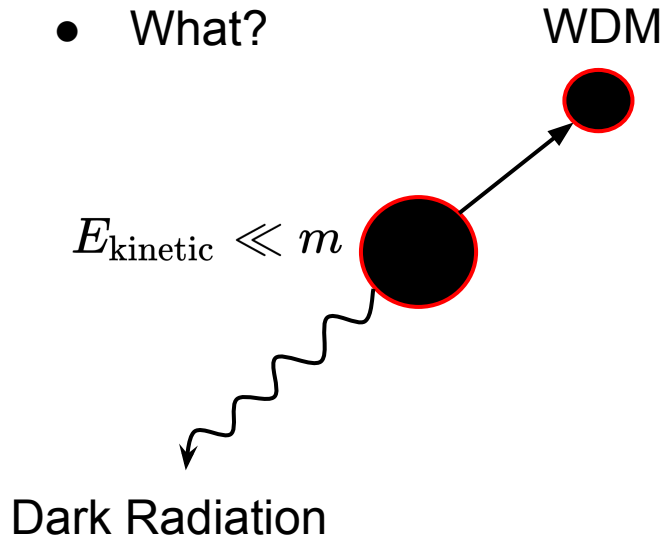
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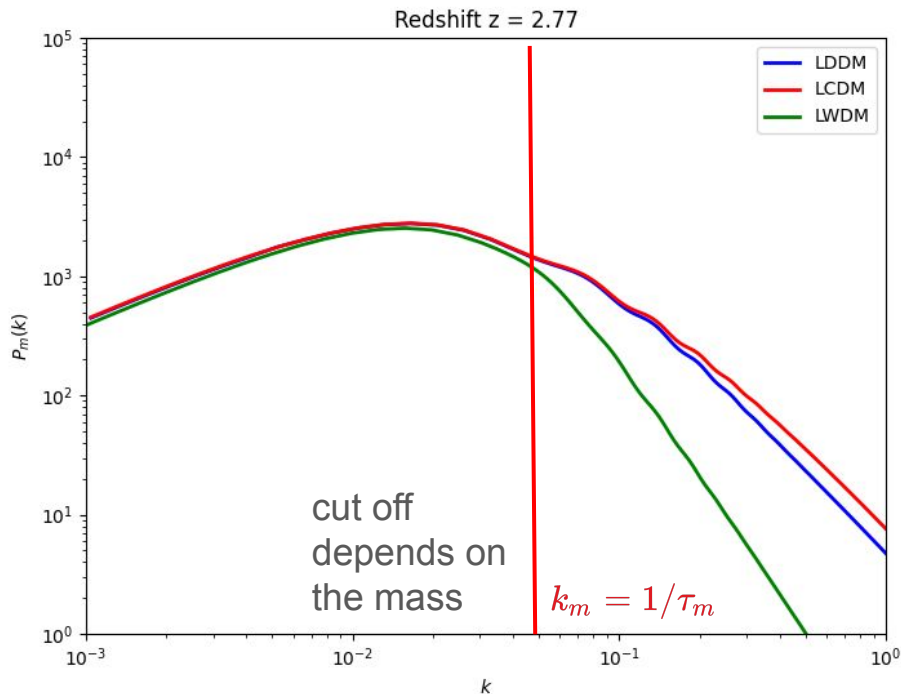
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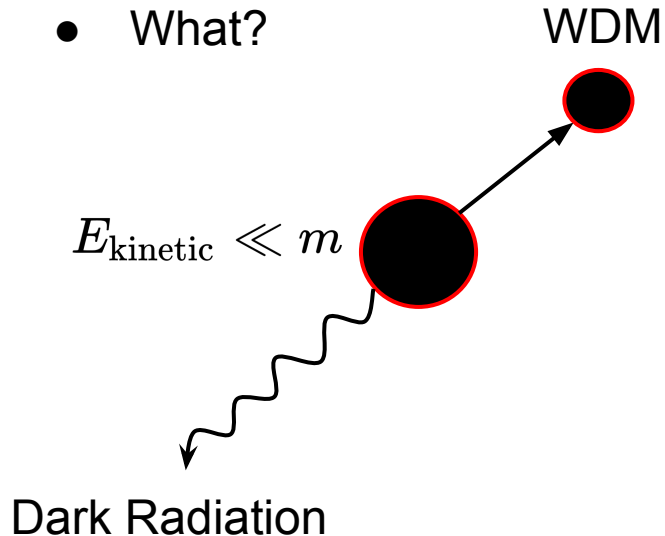
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Phenomenology of DDM in Cosmology



Decaying Dark Matter

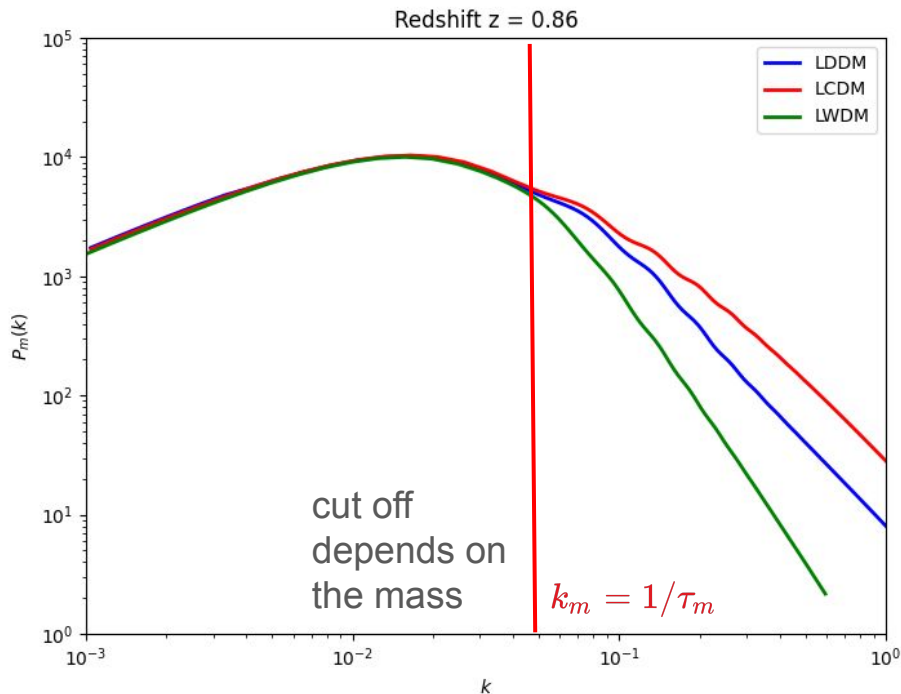
- What?



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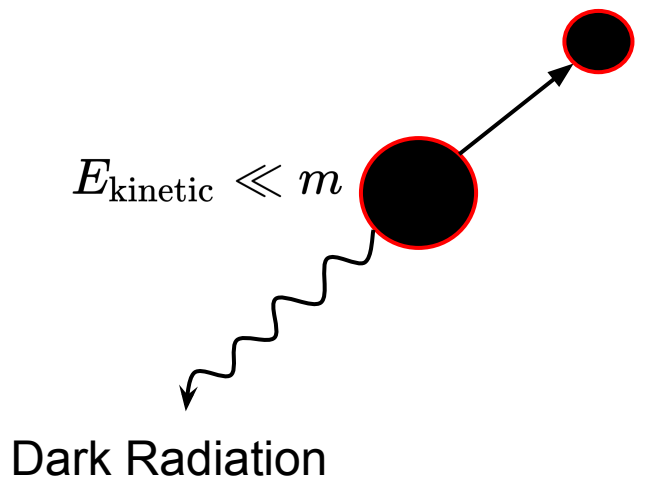
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Phenomenology of DDM in Cosmology



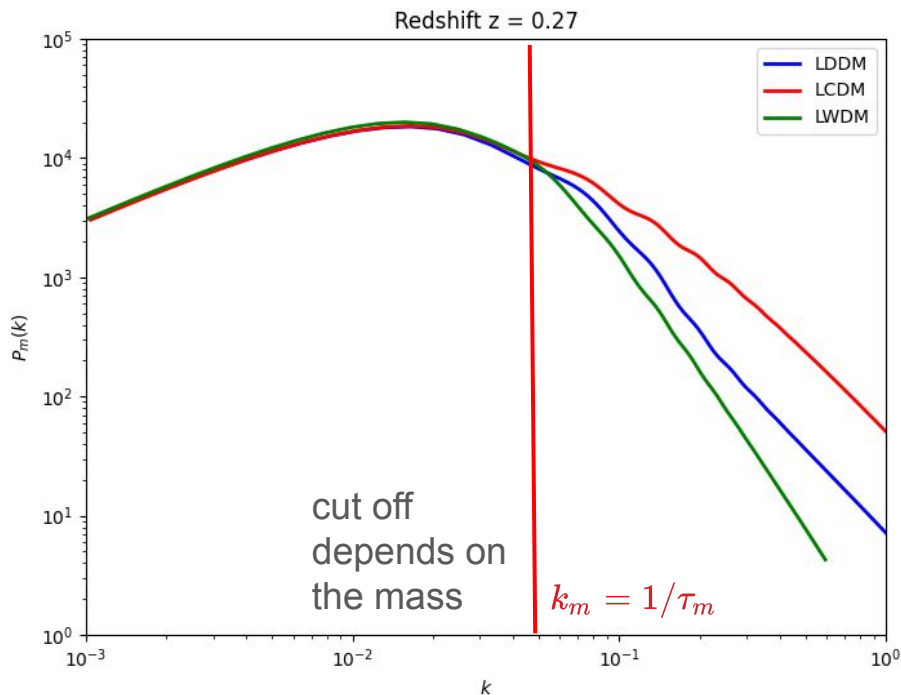
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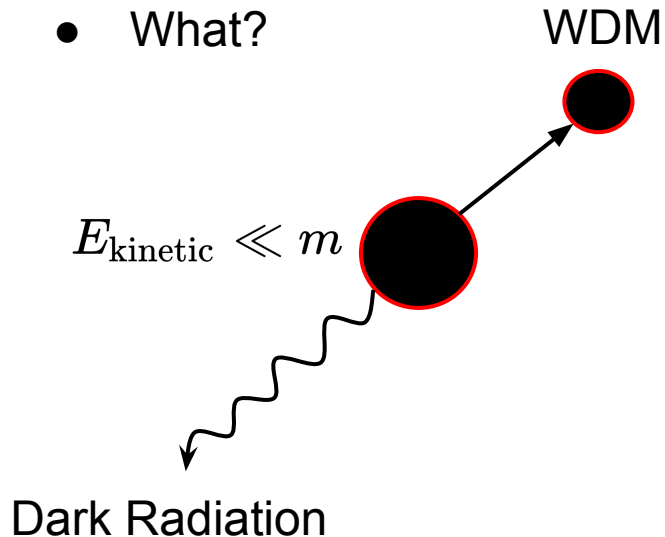
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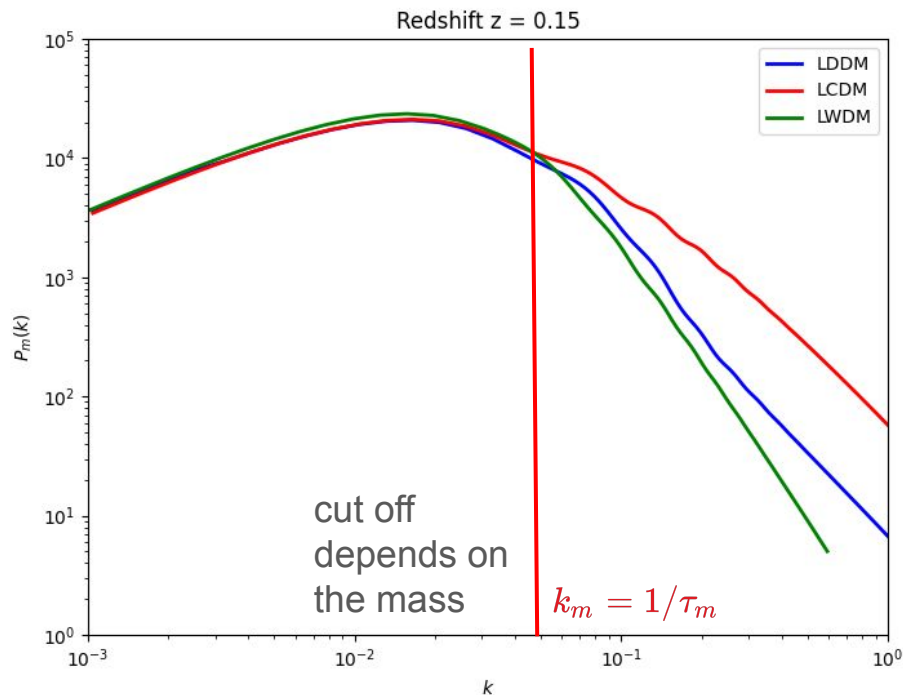
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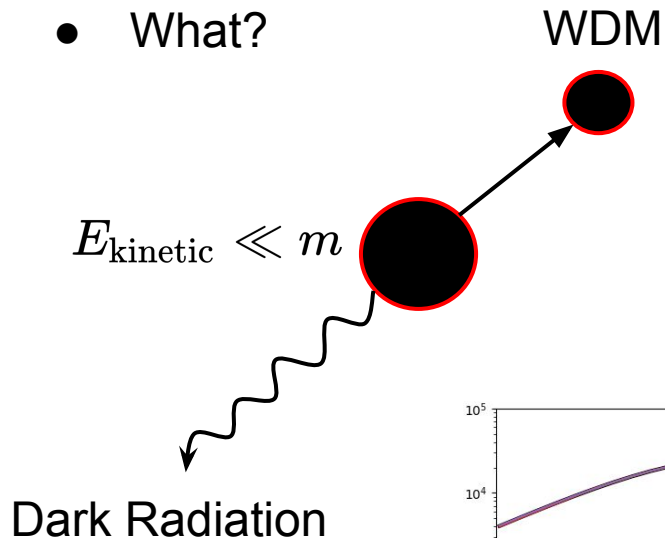
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Phenomenology of DDM in Cosmology



Decaying Dark Matter

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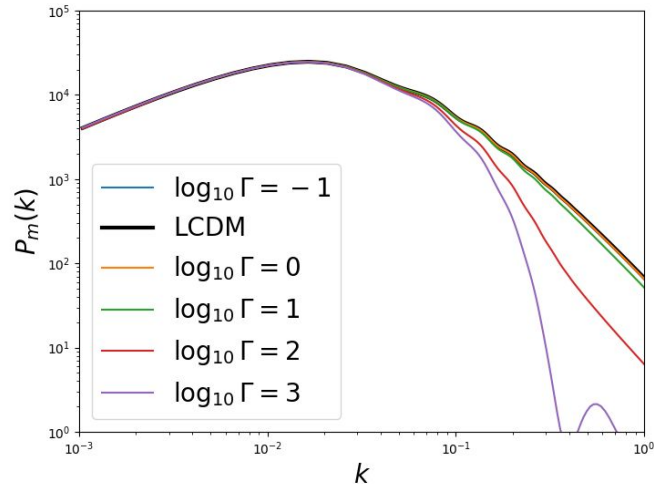


Two parameters:

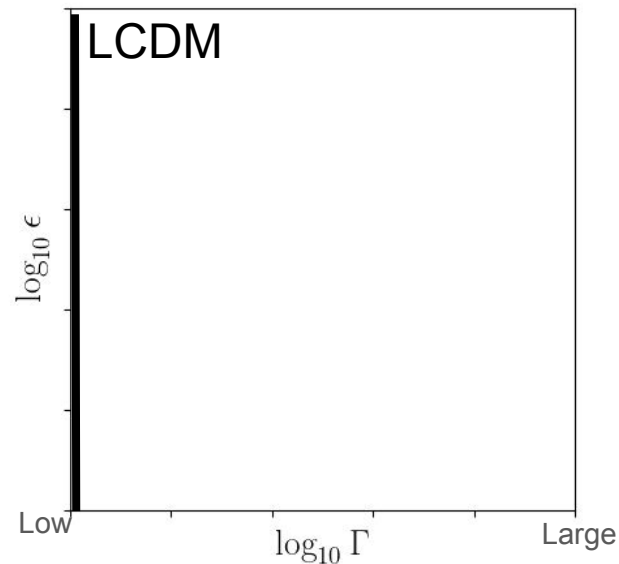
- Life time
- kick

$$\Gamma^{-1}$$

$$\varepsilon = \frac{1}{2} \left(1 - \frac{m_{\text{wdm}}}{m_{\text{cdm}}} \right)$$

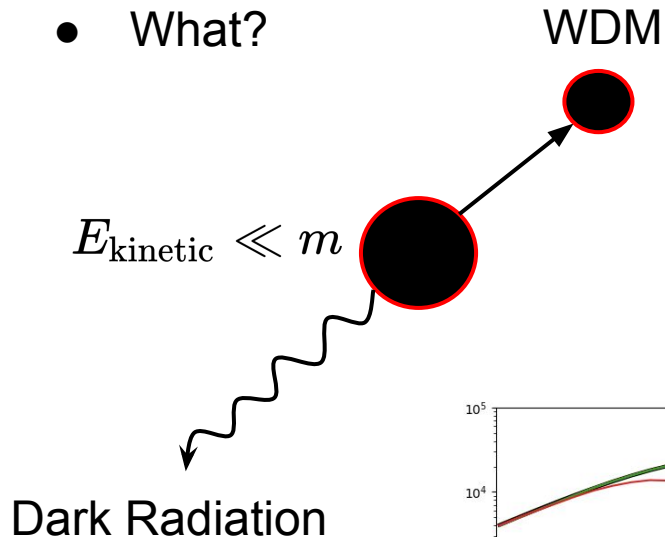


Large



Decaying Dark Matter

- What?

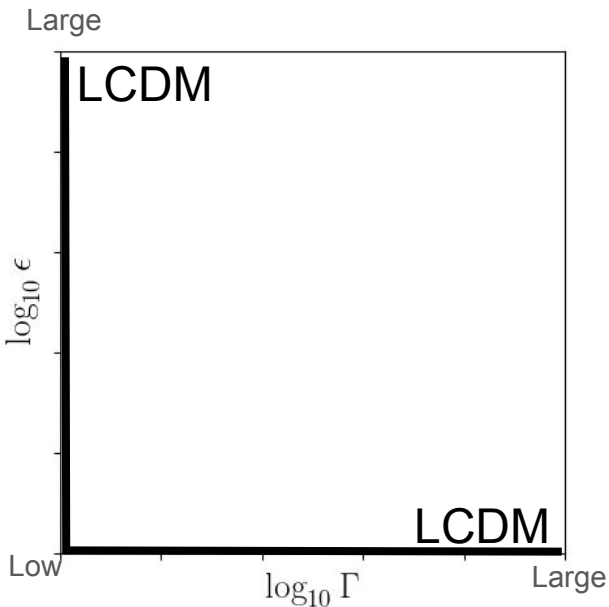
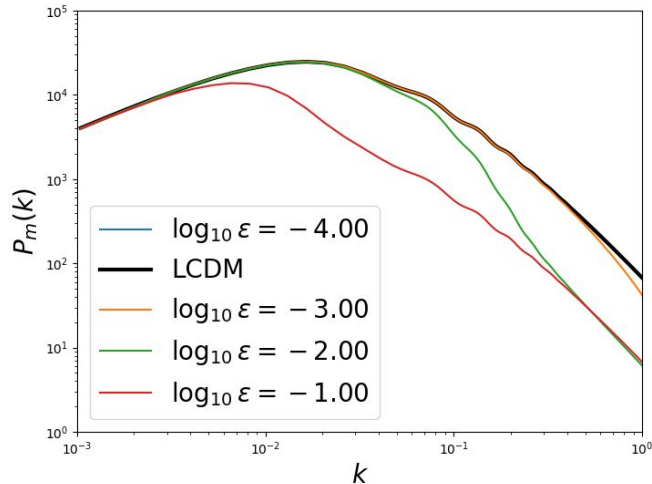


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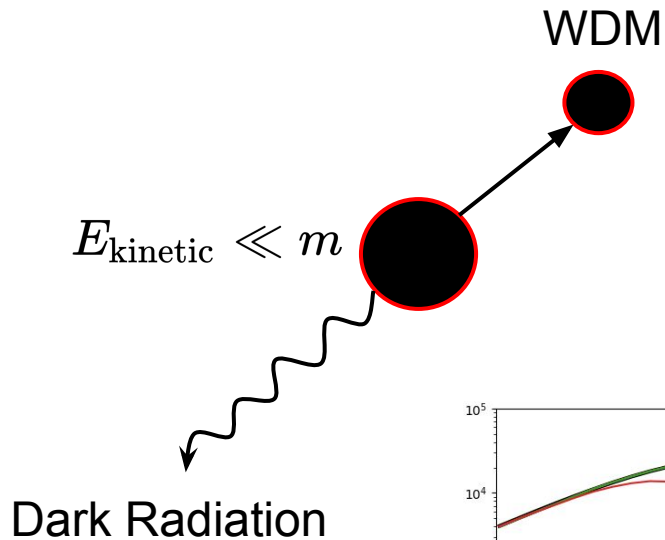
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Decaying Dark Matter

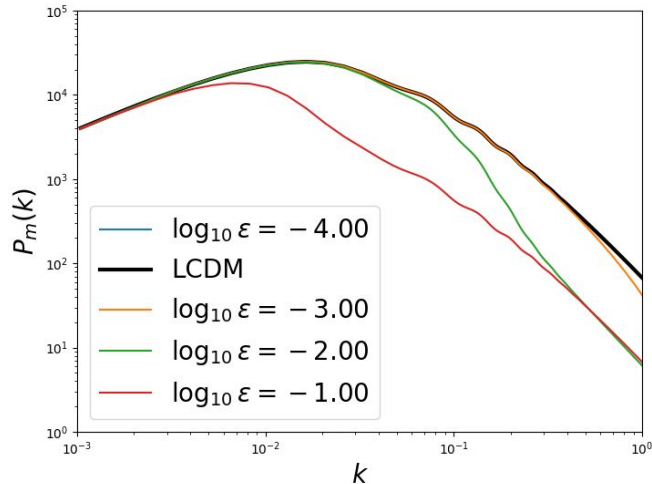


Two parameters:

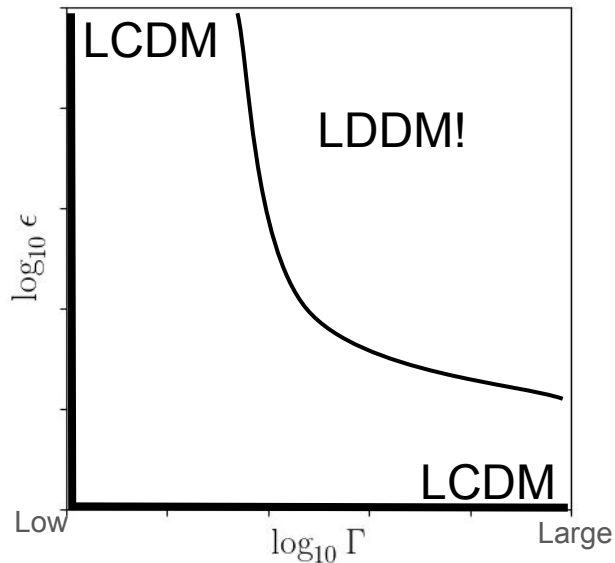
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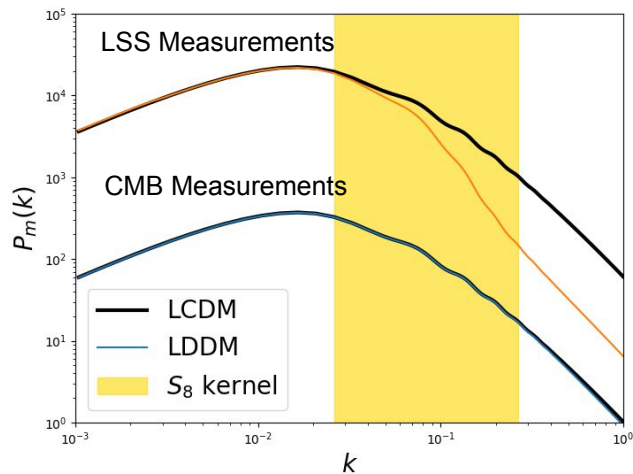


Sigma-8 tension

- Why?

$$\sigma_R^2 = \int dk \frac{k^2 P_m(k)}{2\pi^2} W^2(kR)$$

$$R = 8h^{-1} \text{Mpc} \sim \text{Galaxy clustering scale}$$



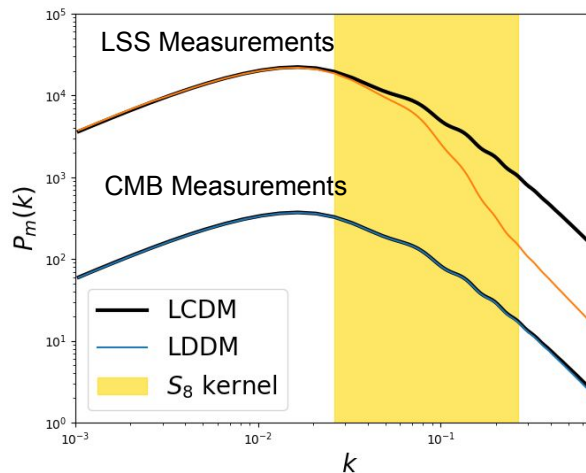
Sigma-8 tension

Abdalla et al (2203.06142)

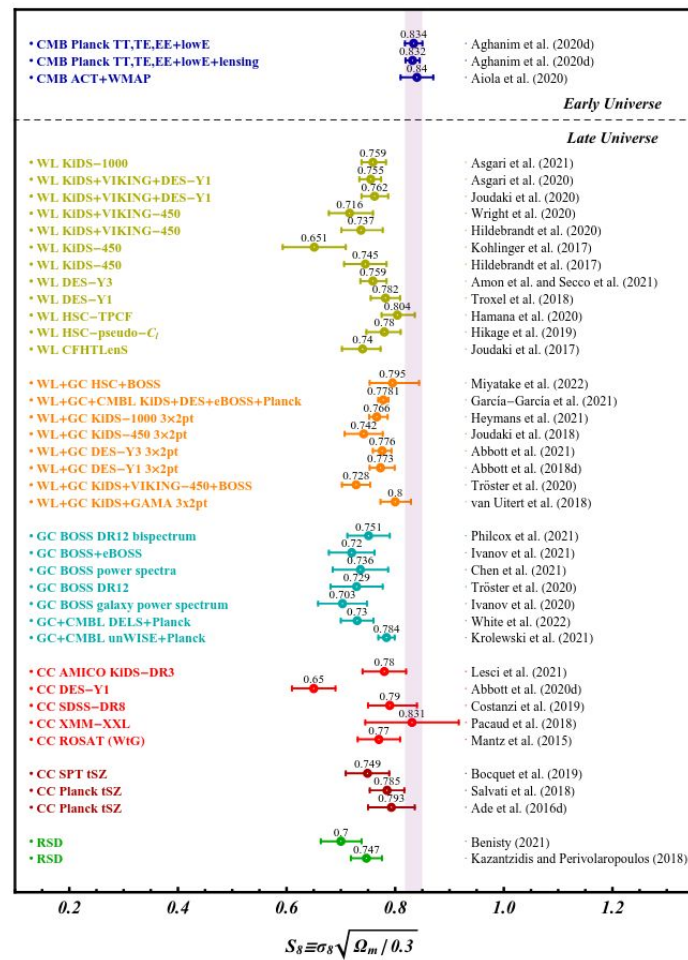
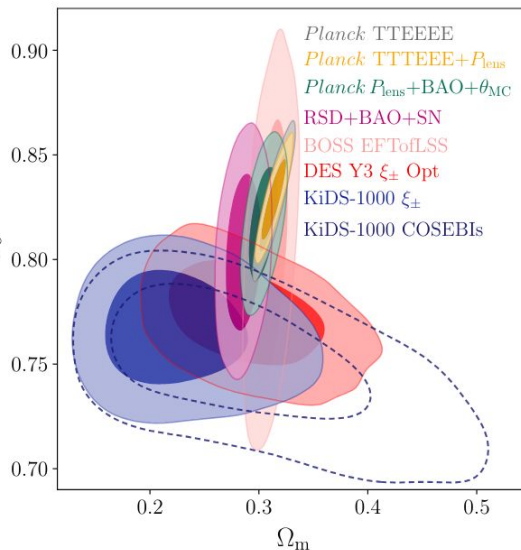
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Amon and Efstathiou (2206.11794)



Sigma-8 tension

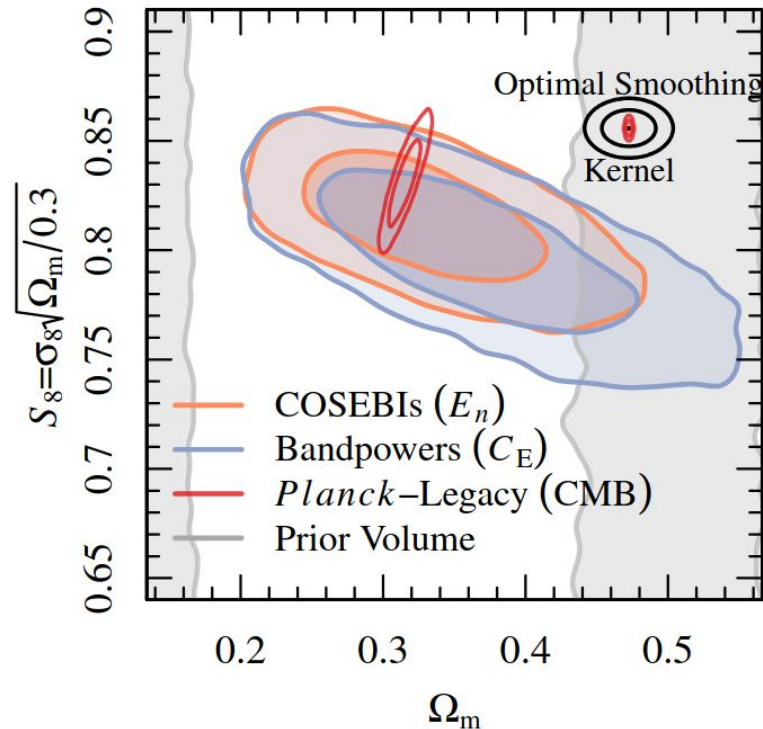
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The KiDS Collaboration: 2503.19441



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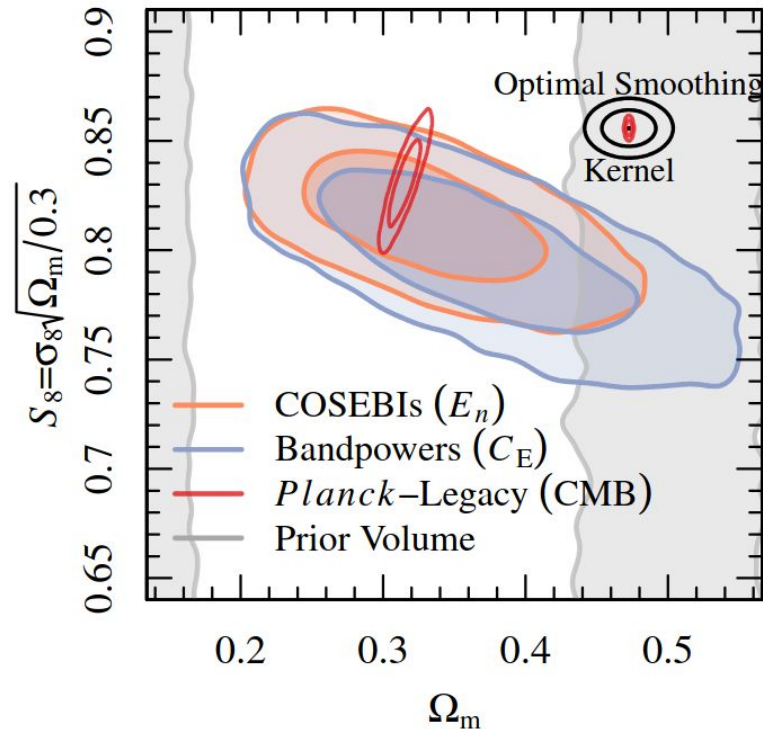
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We can still test nature of DM!



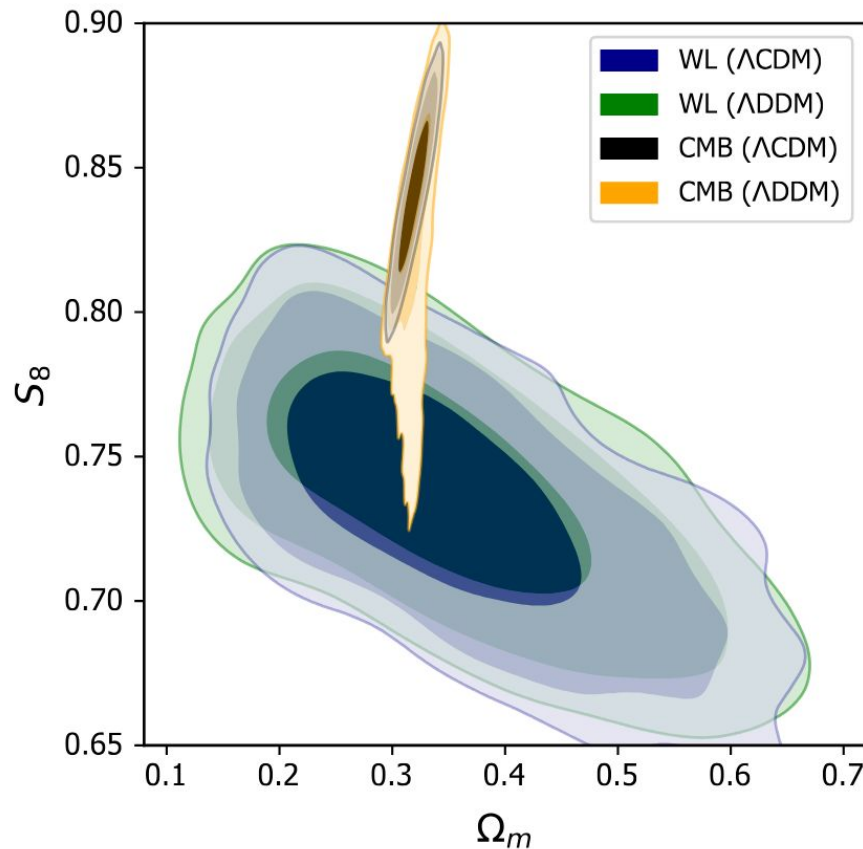
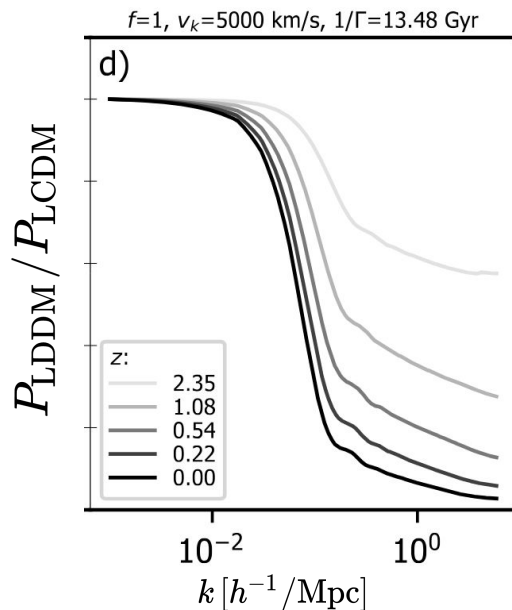
The KiDS Collaboration: 2503.19441



Decaying Dark Matter Bayesian analysis

For LSS we need nonlinearity

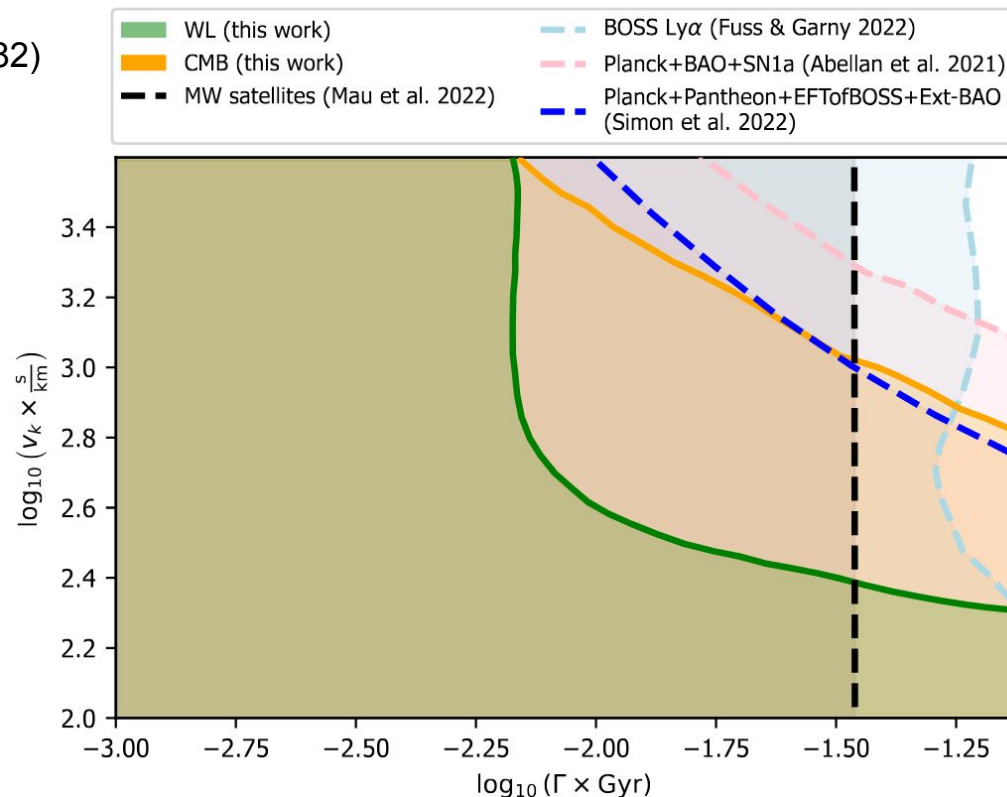
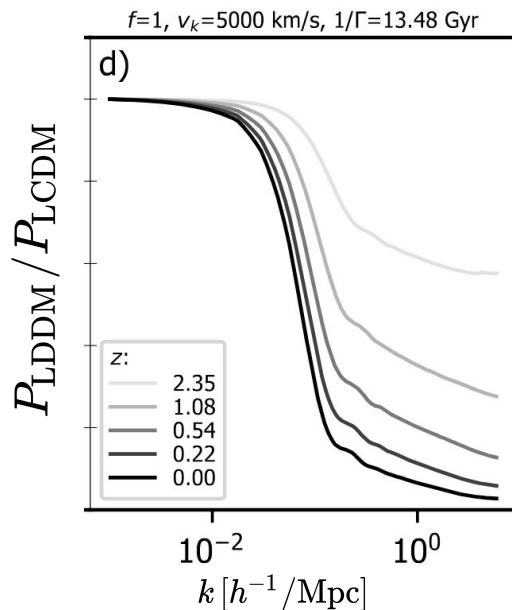
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 - DDM simulation with PKDGRAV3
 - Neural Network fit of $P(k)$



Decaying Dark Matter Bayesian analysis

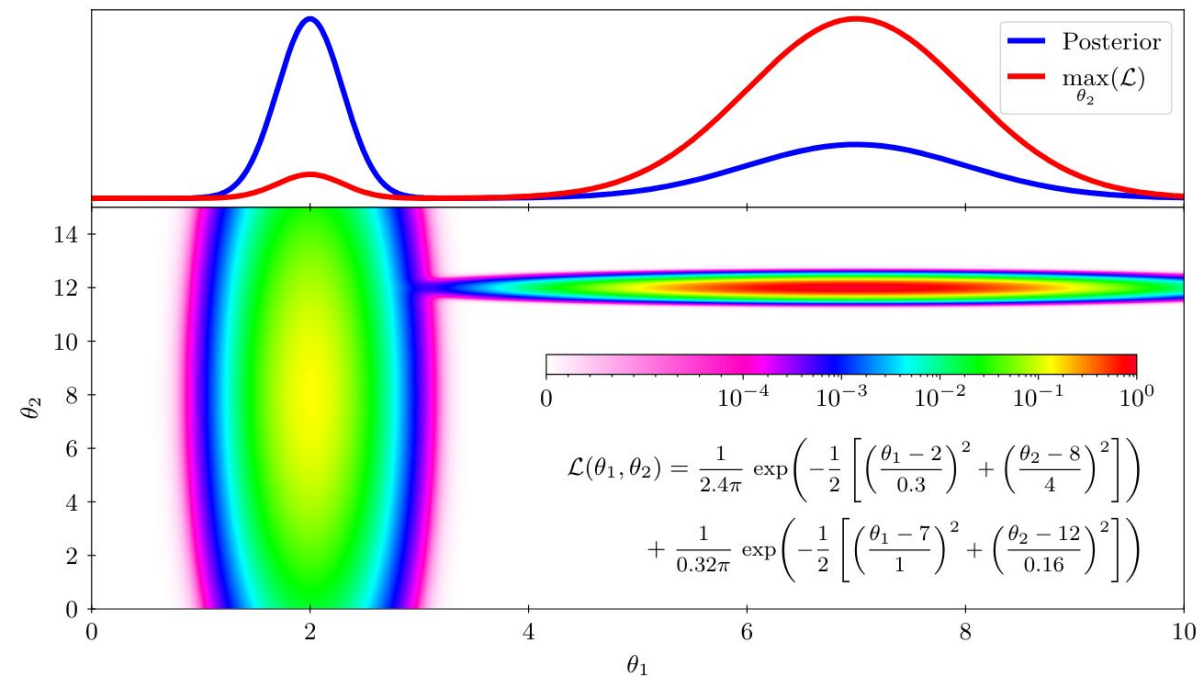
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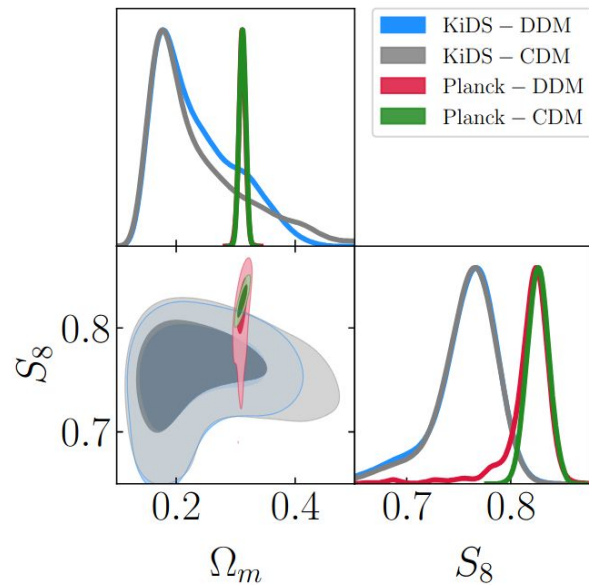


Bayesian vs Frequentist

A.Nygaard et al 2308.06379

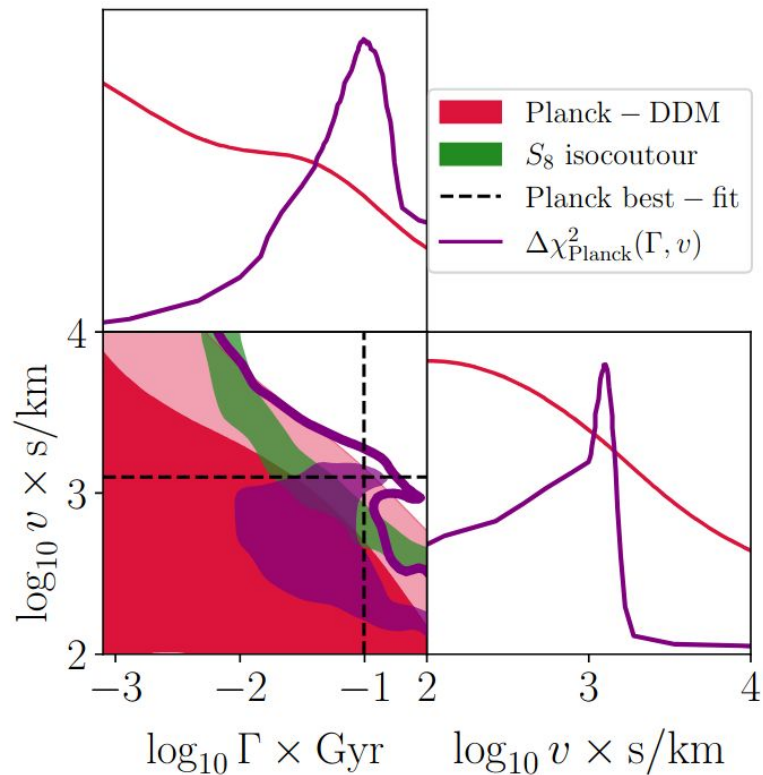
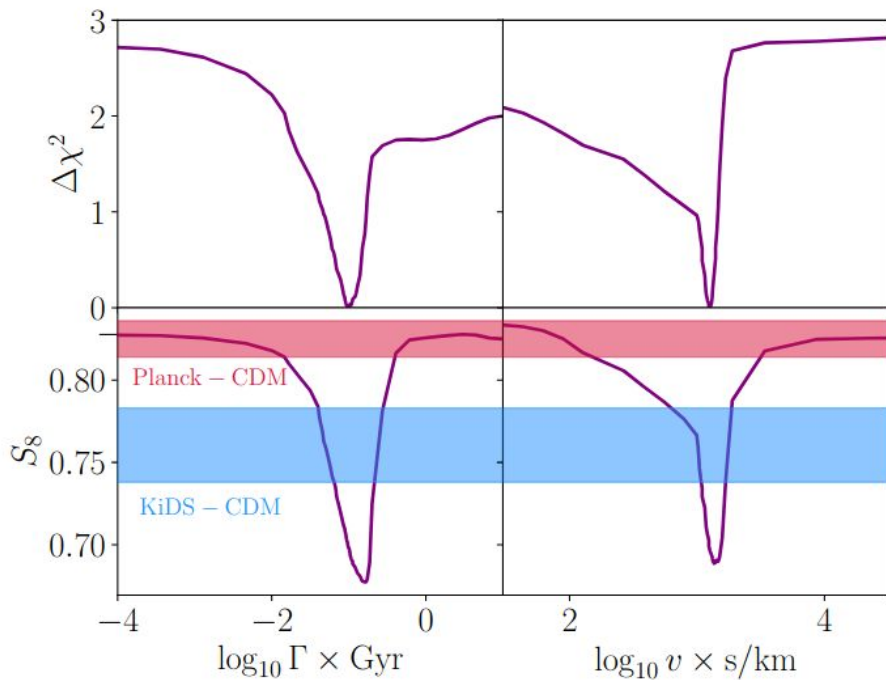


Our work:



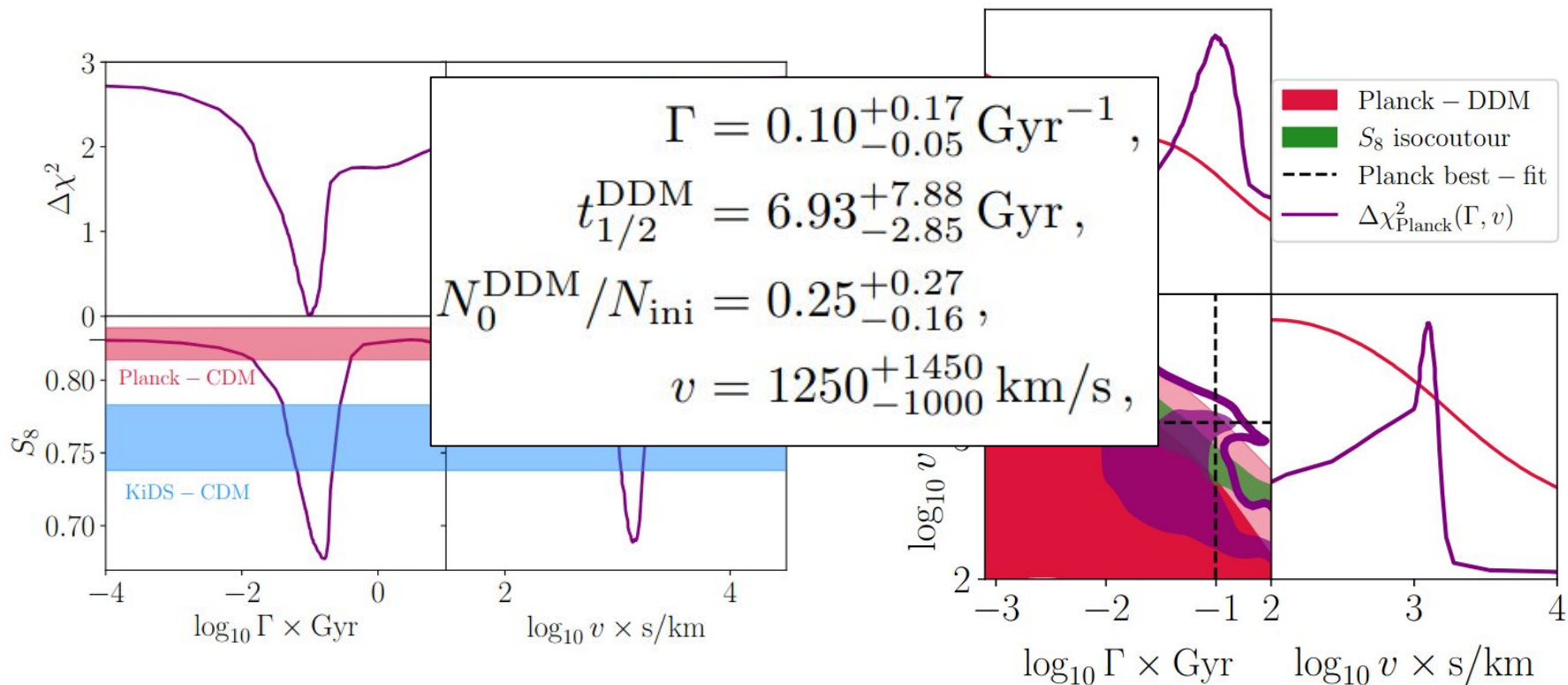
Our work:

- Planck: There is something here!



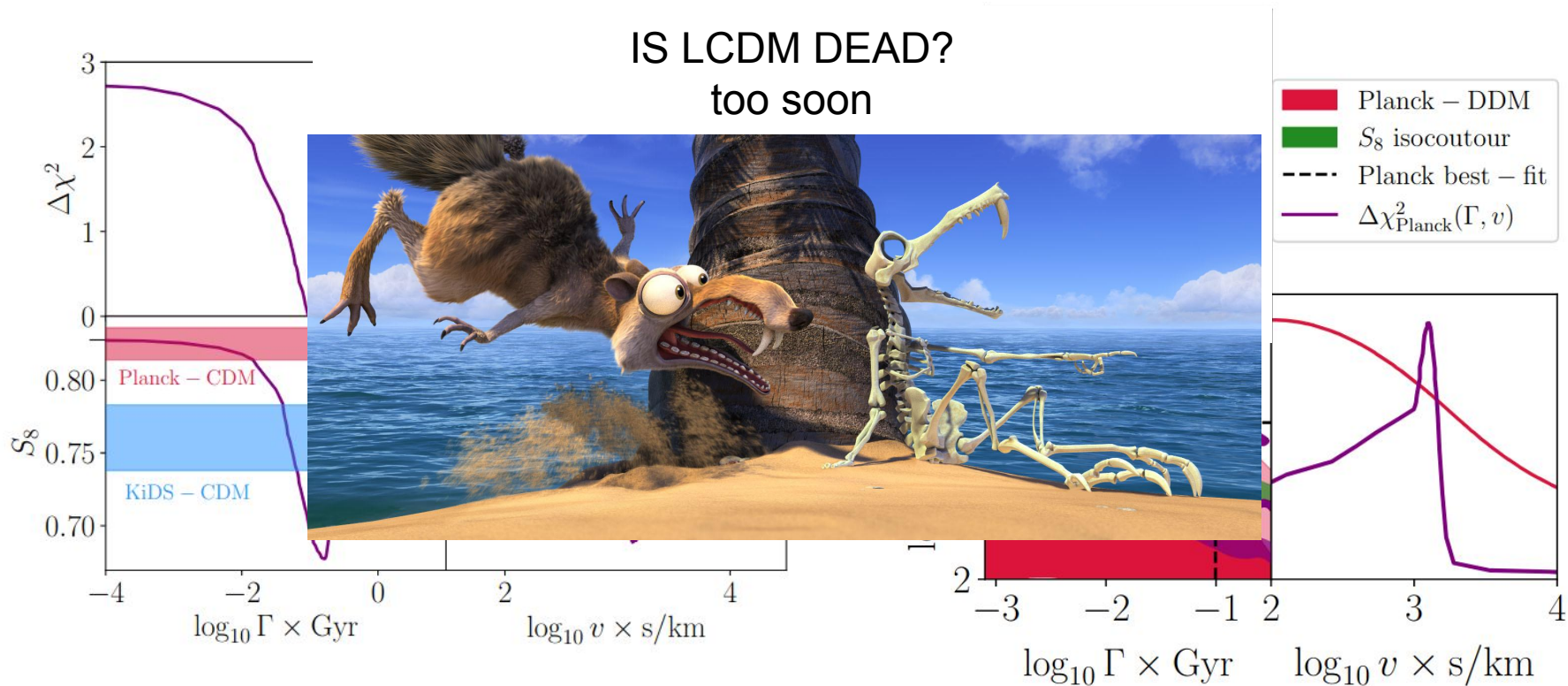
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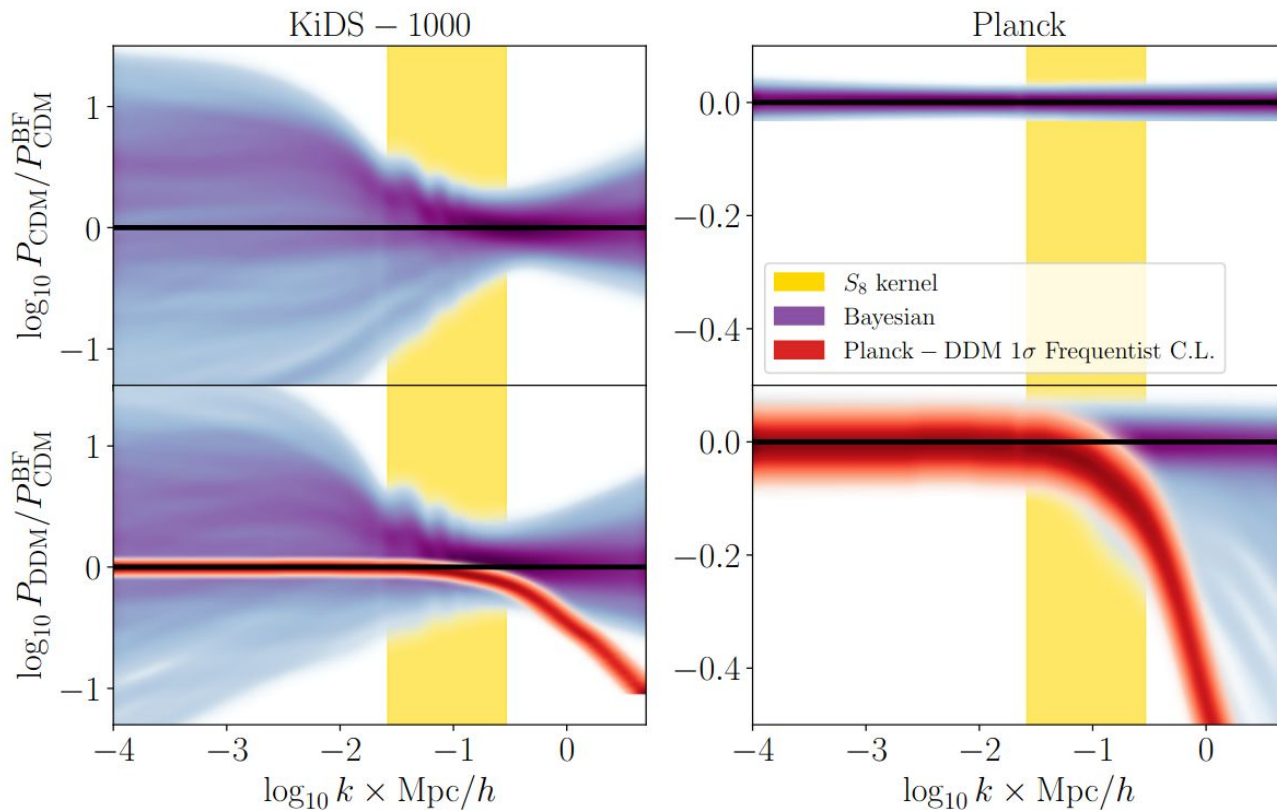
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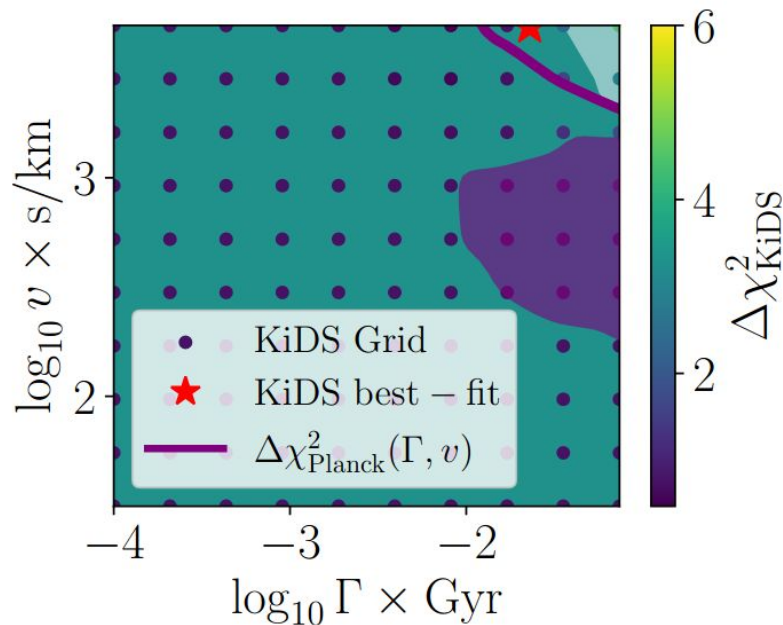
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Our work:

- Planck: There is something here!
- What KiDS really measures: not just S8!
- KiDS: Frequentist not under control

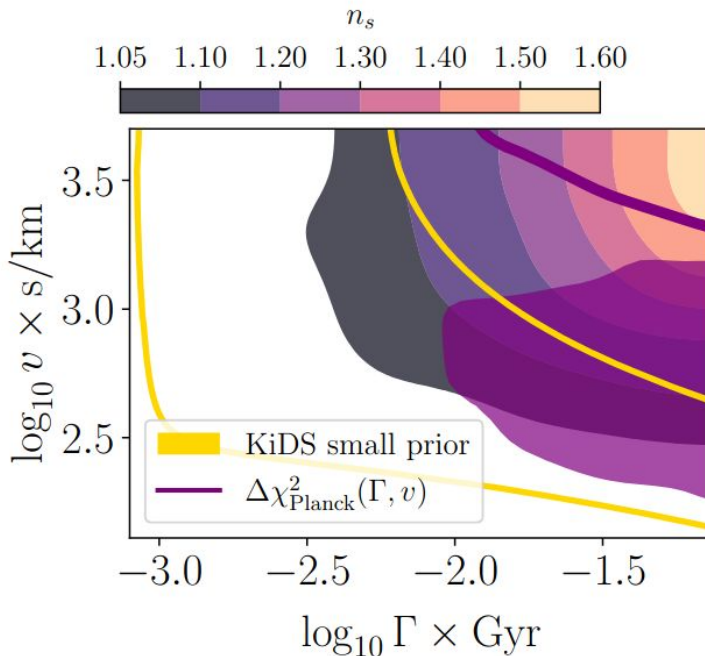
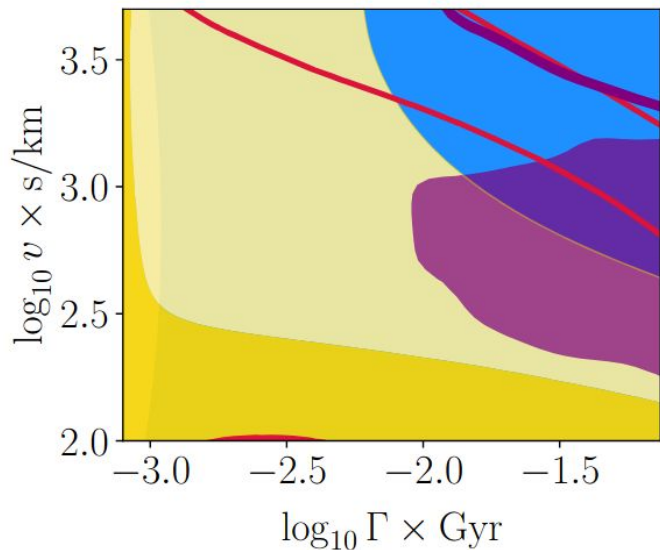
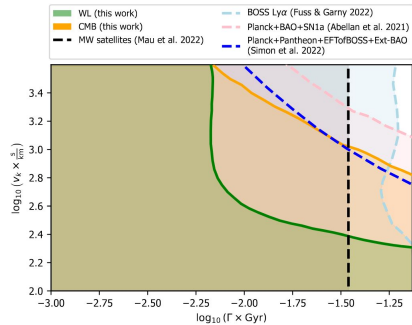


Systematics not under control...

The redshift dependence of the intrinsic alignment parameter reaches the edges of the prior range

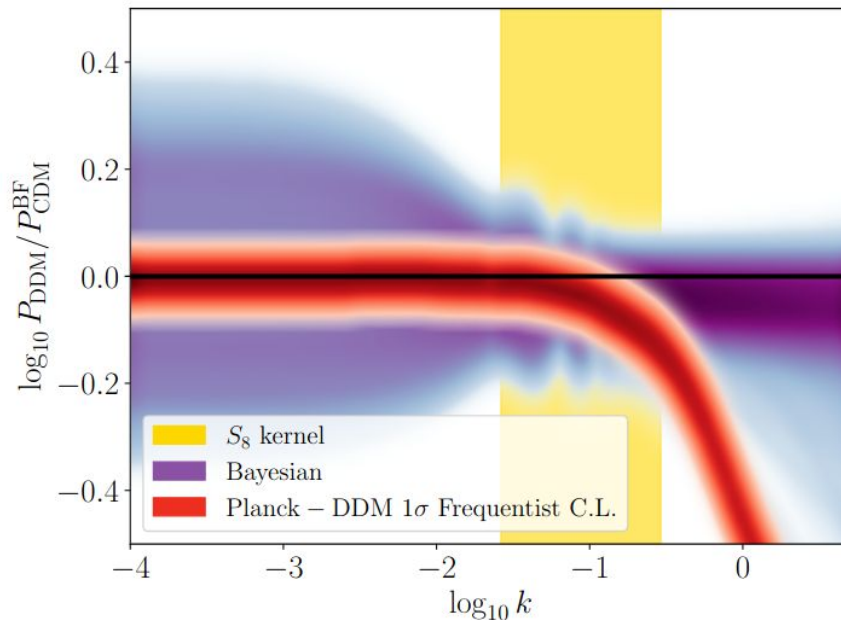
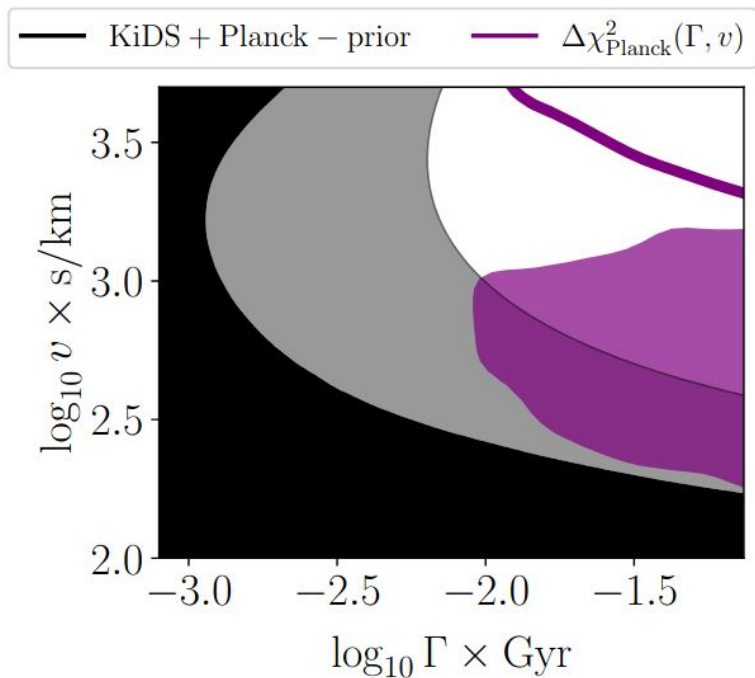
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- KiDS: a prior issue...



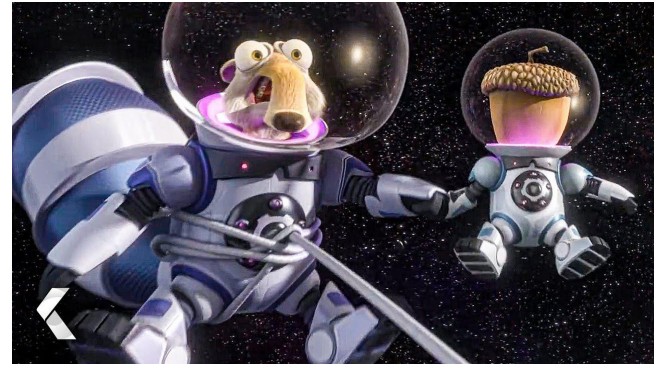
Our work:

- Planck: There is something here!
- What KiDS really measures: not just S8!
- KiDS: a prior issue...
- KiDS and Planck



Conclusion

- Decaying Dark Matter is great
- So was this conference
- See you around!



THANK YOU!



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Ongoing work:

Halo Mass Function

