Probing Dark Matter (and other things) with small-scale cosmology

In collaboration with:

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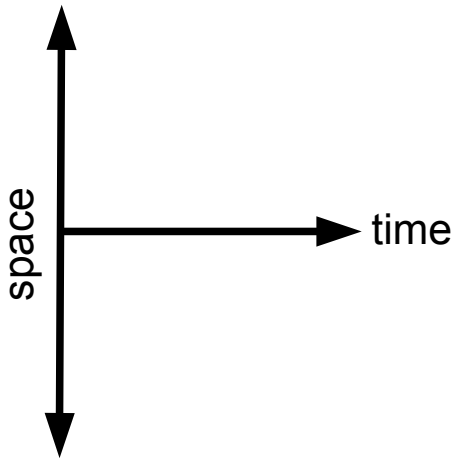
Oslo 2017

Cosmology in a nutshell



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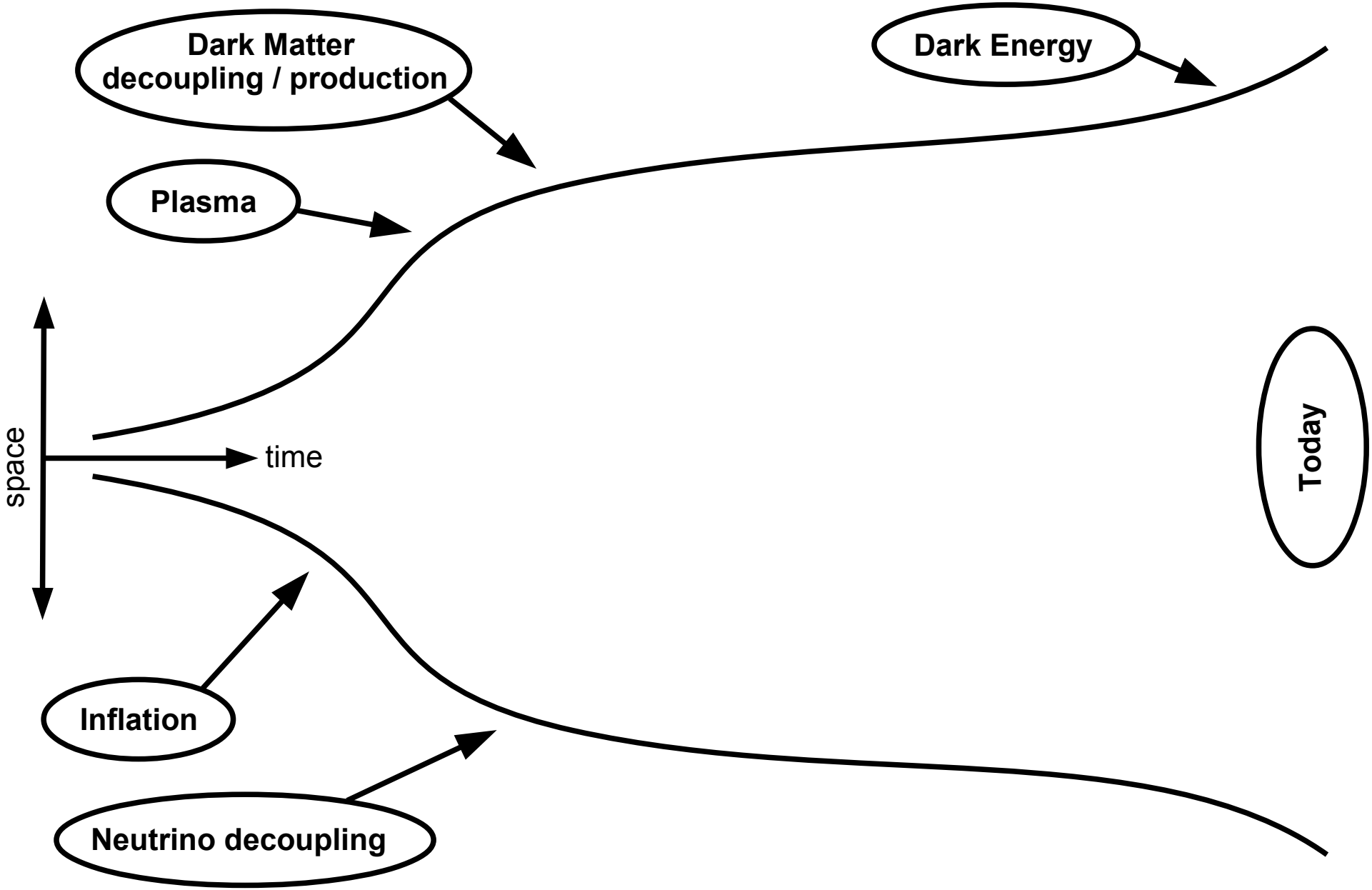

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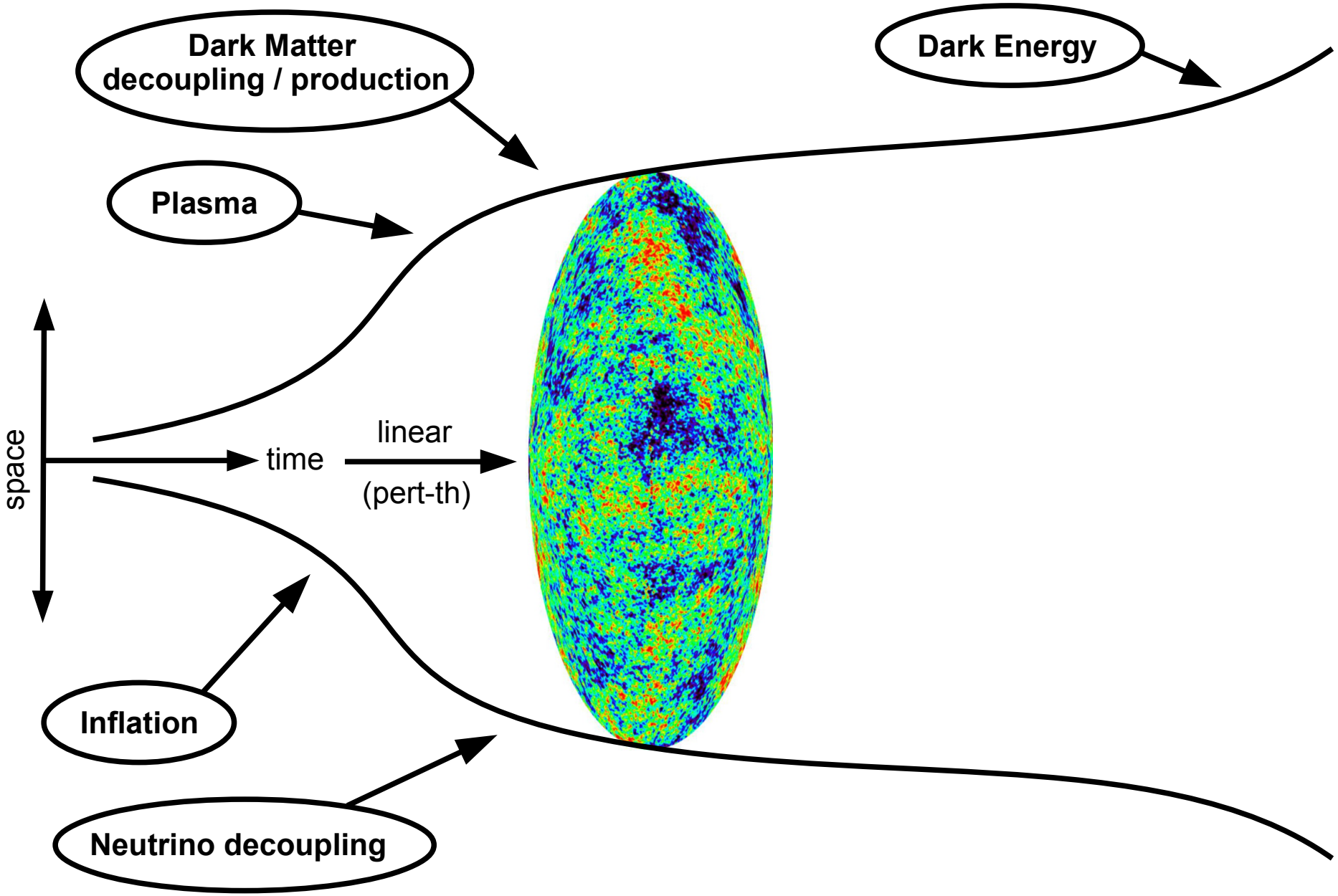

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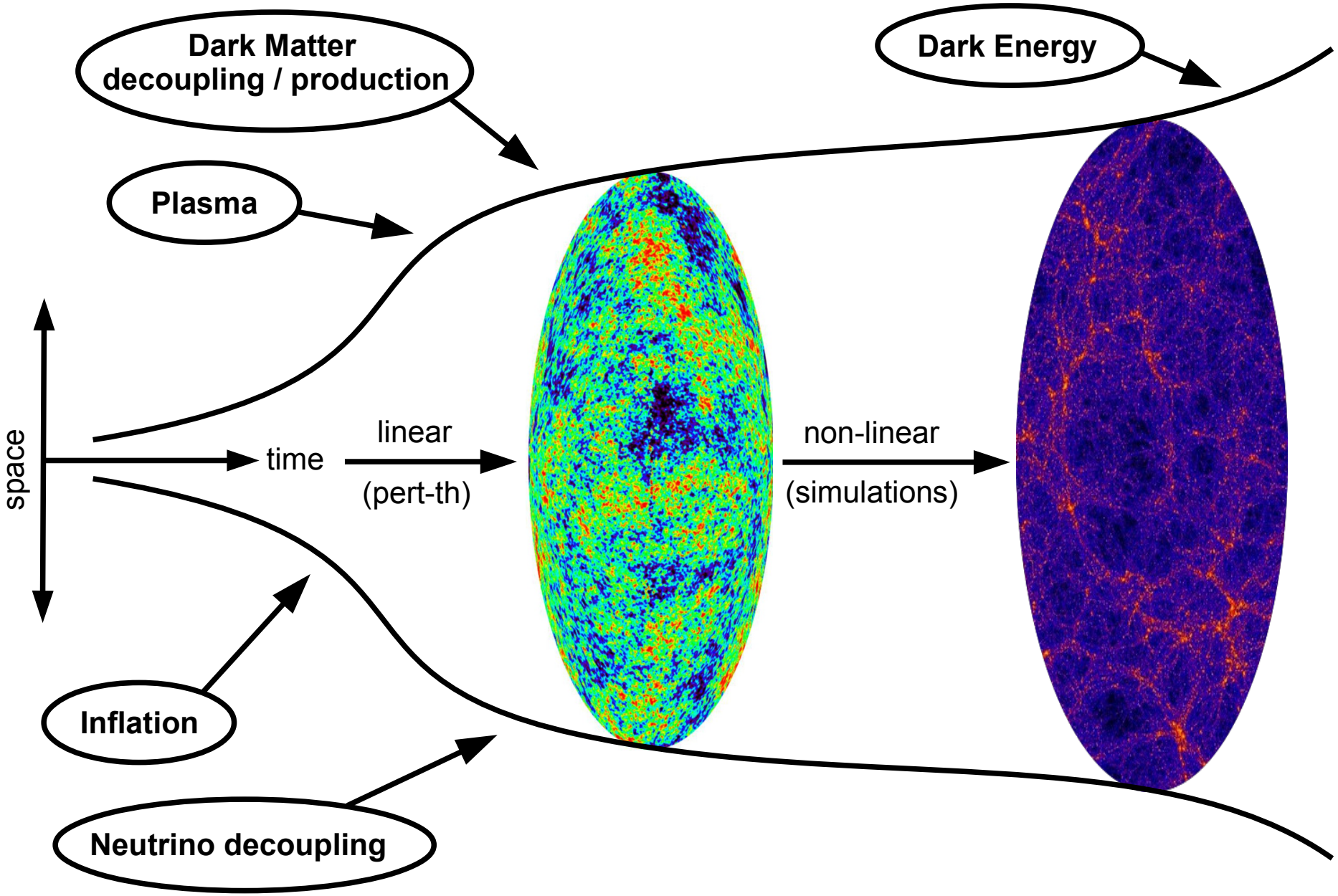

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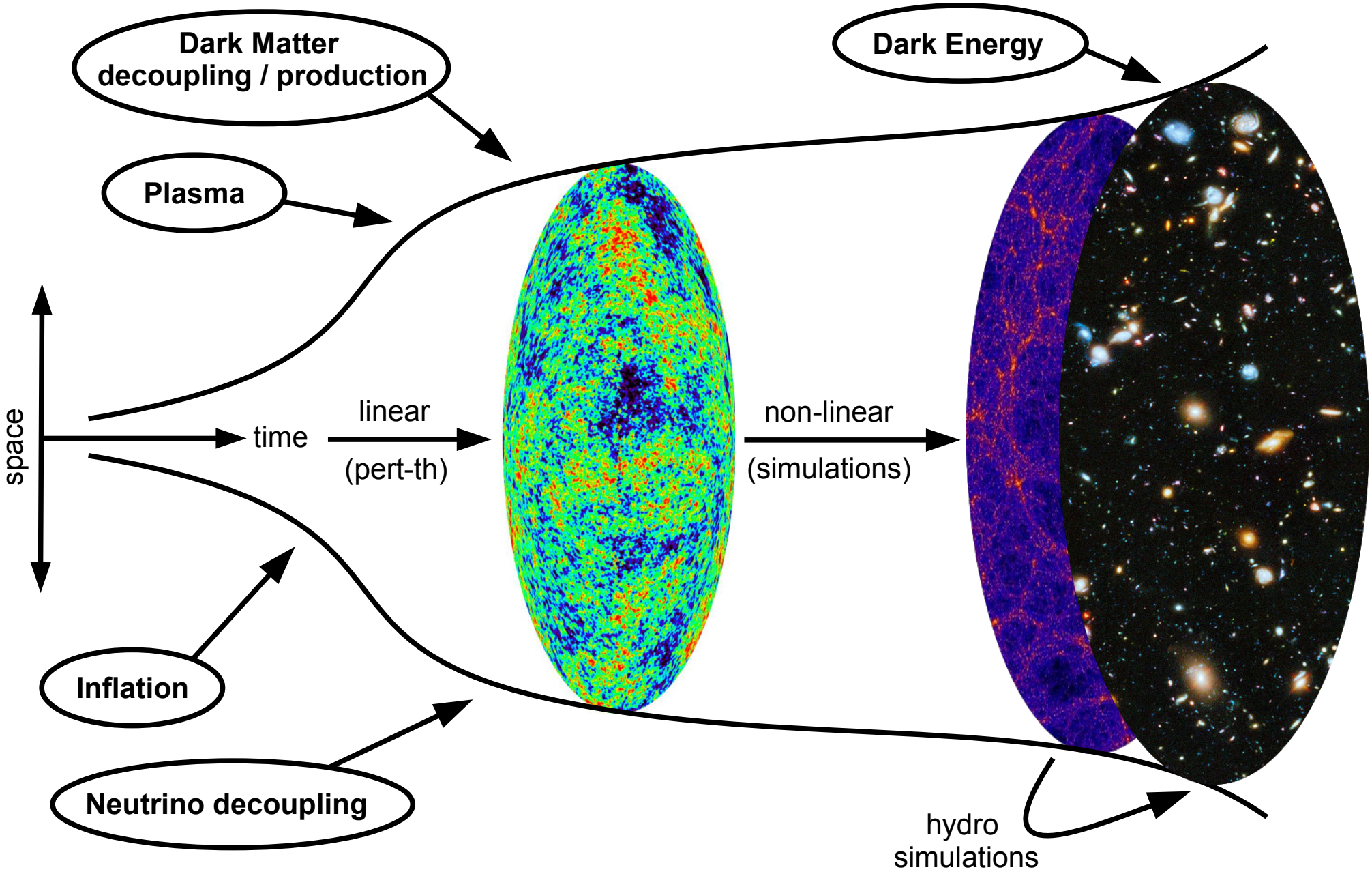

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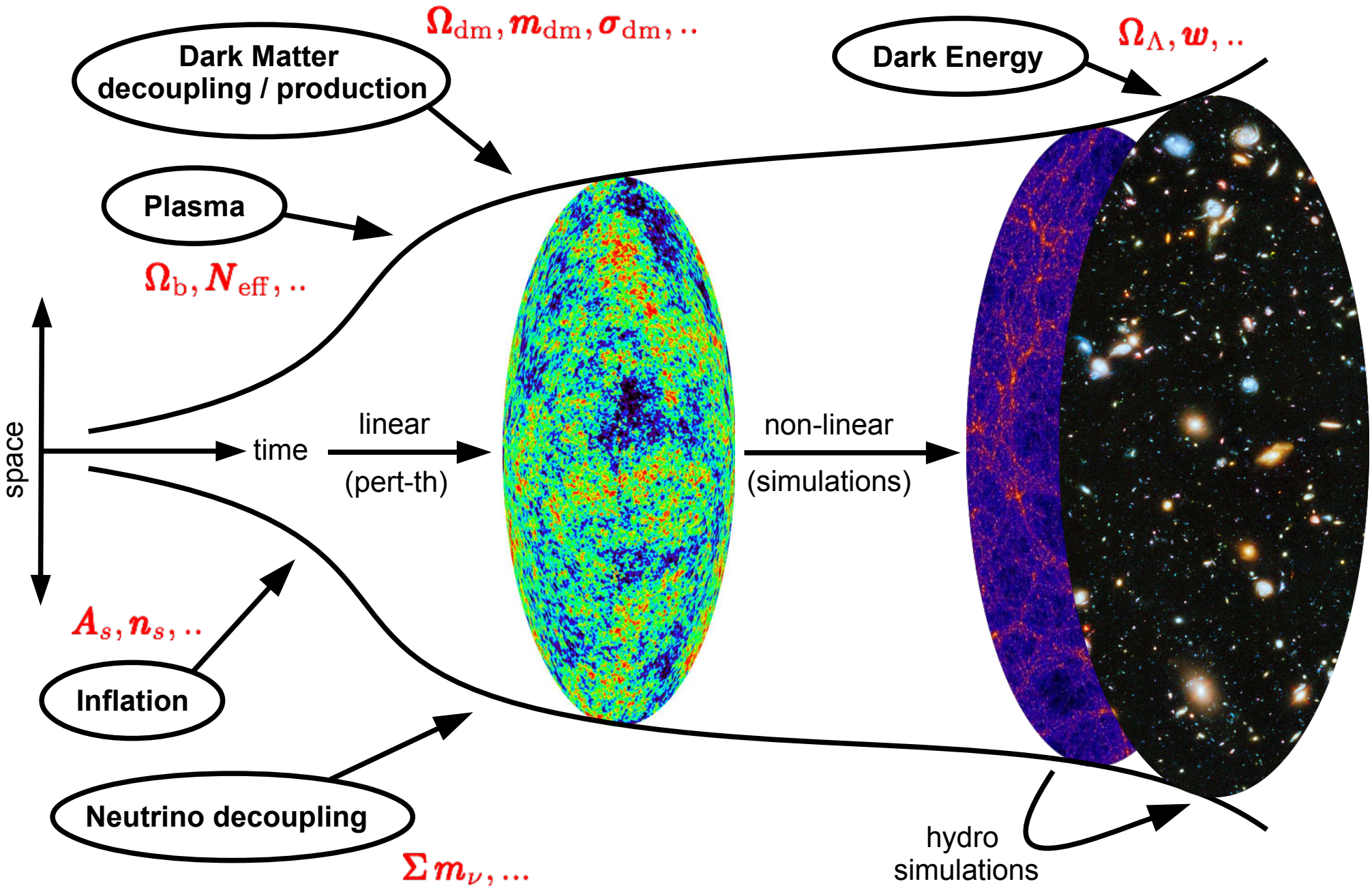
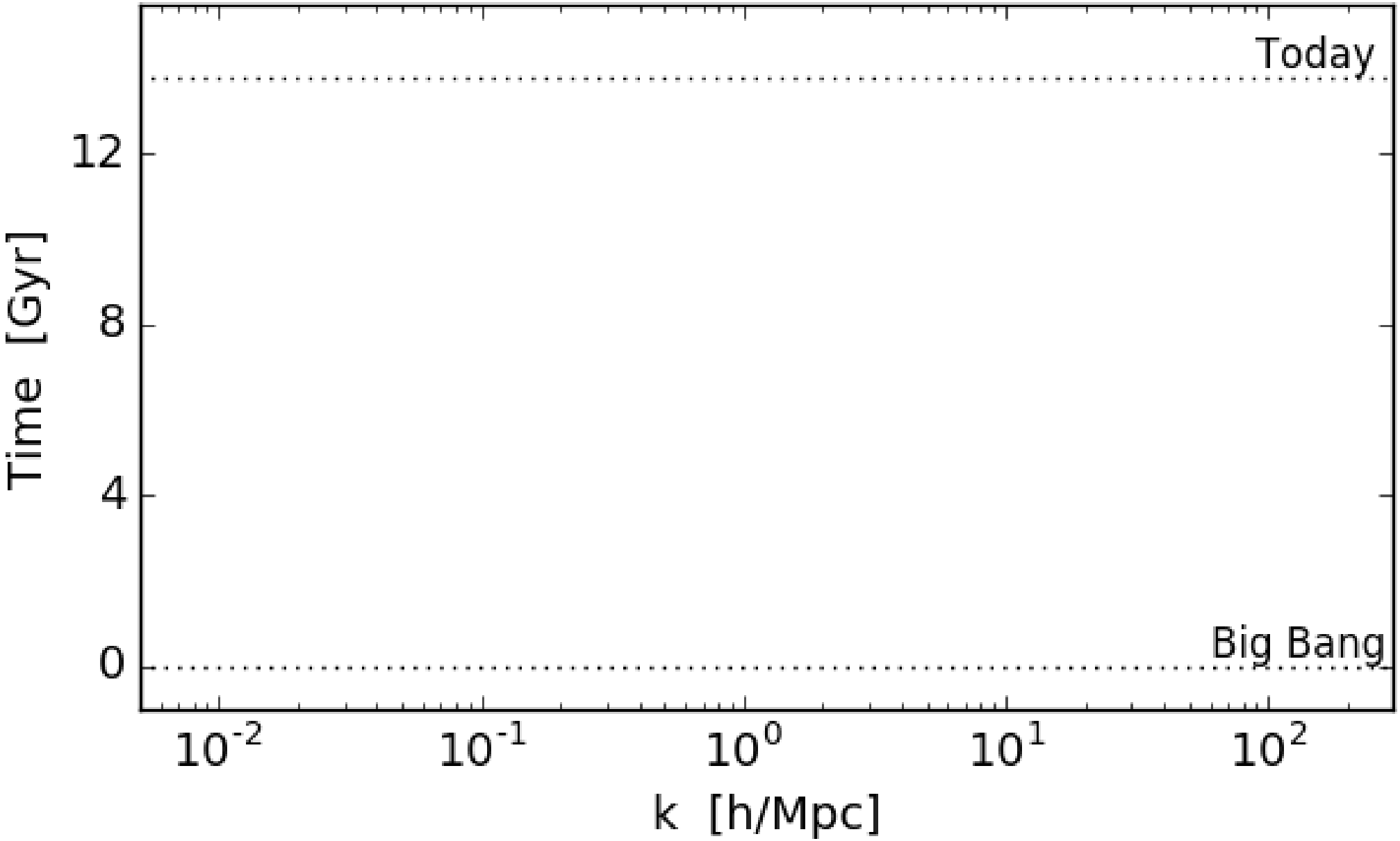


Observations and the scales they probe



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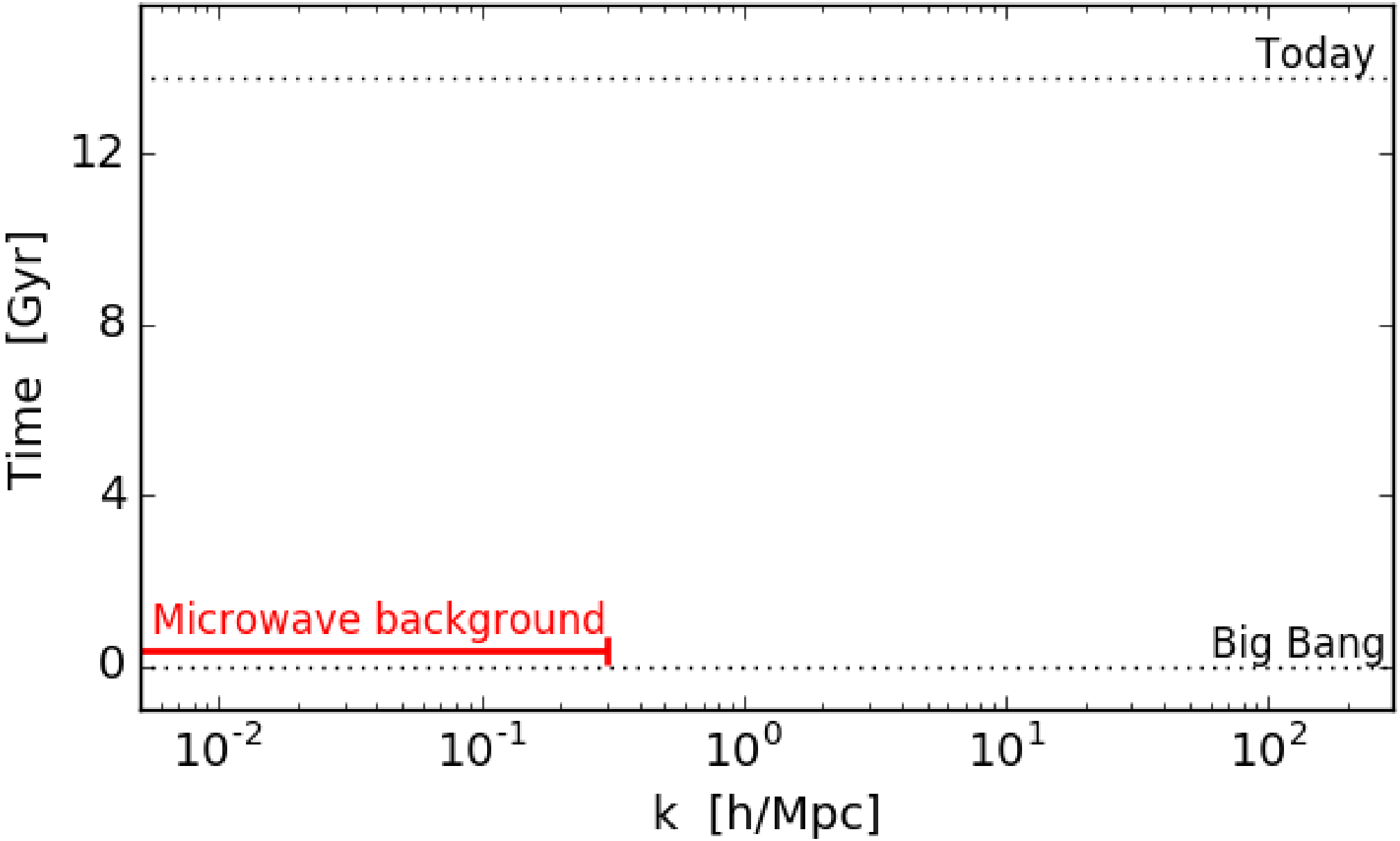

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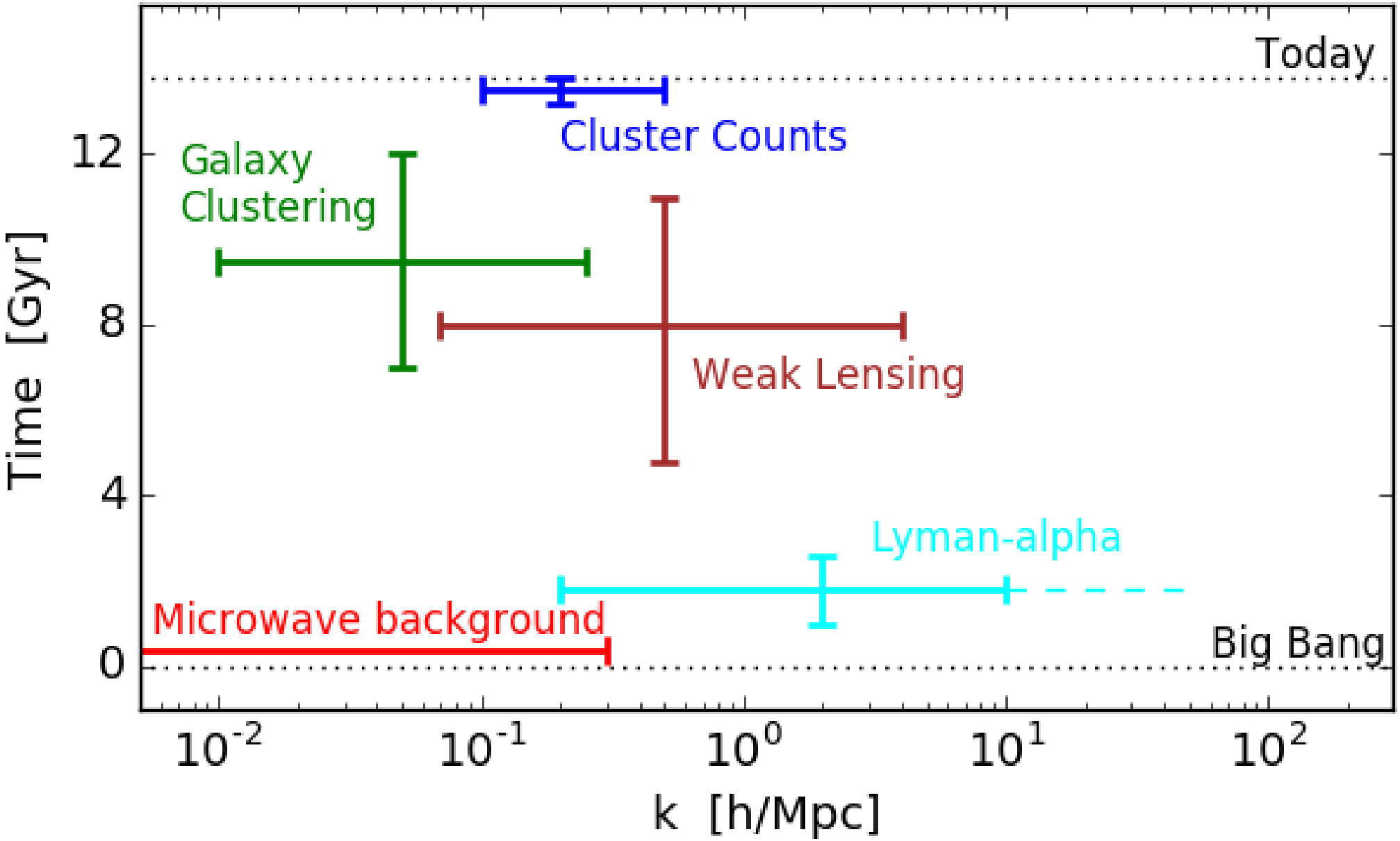

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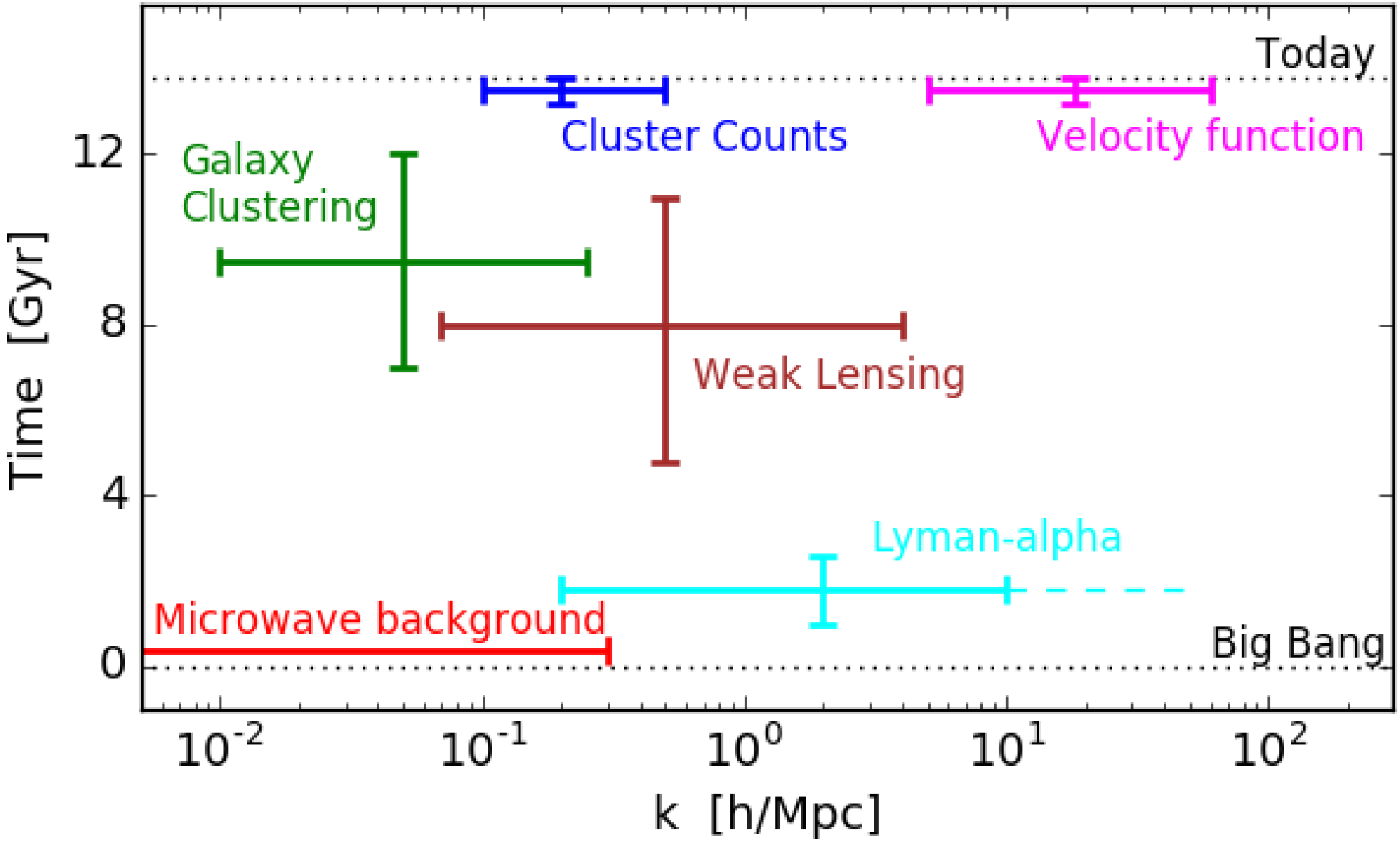
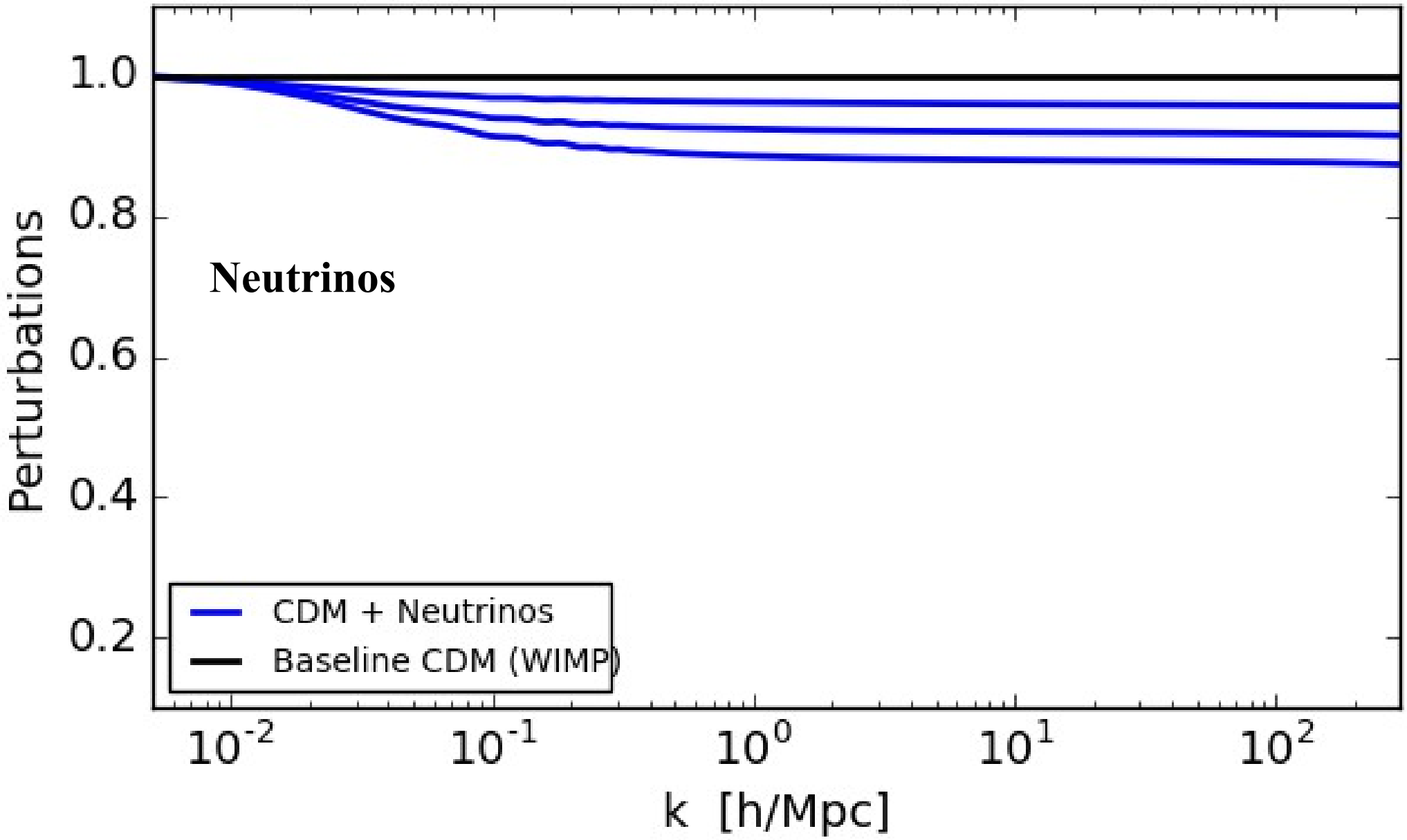


Perturbations for different cosmological scenarios



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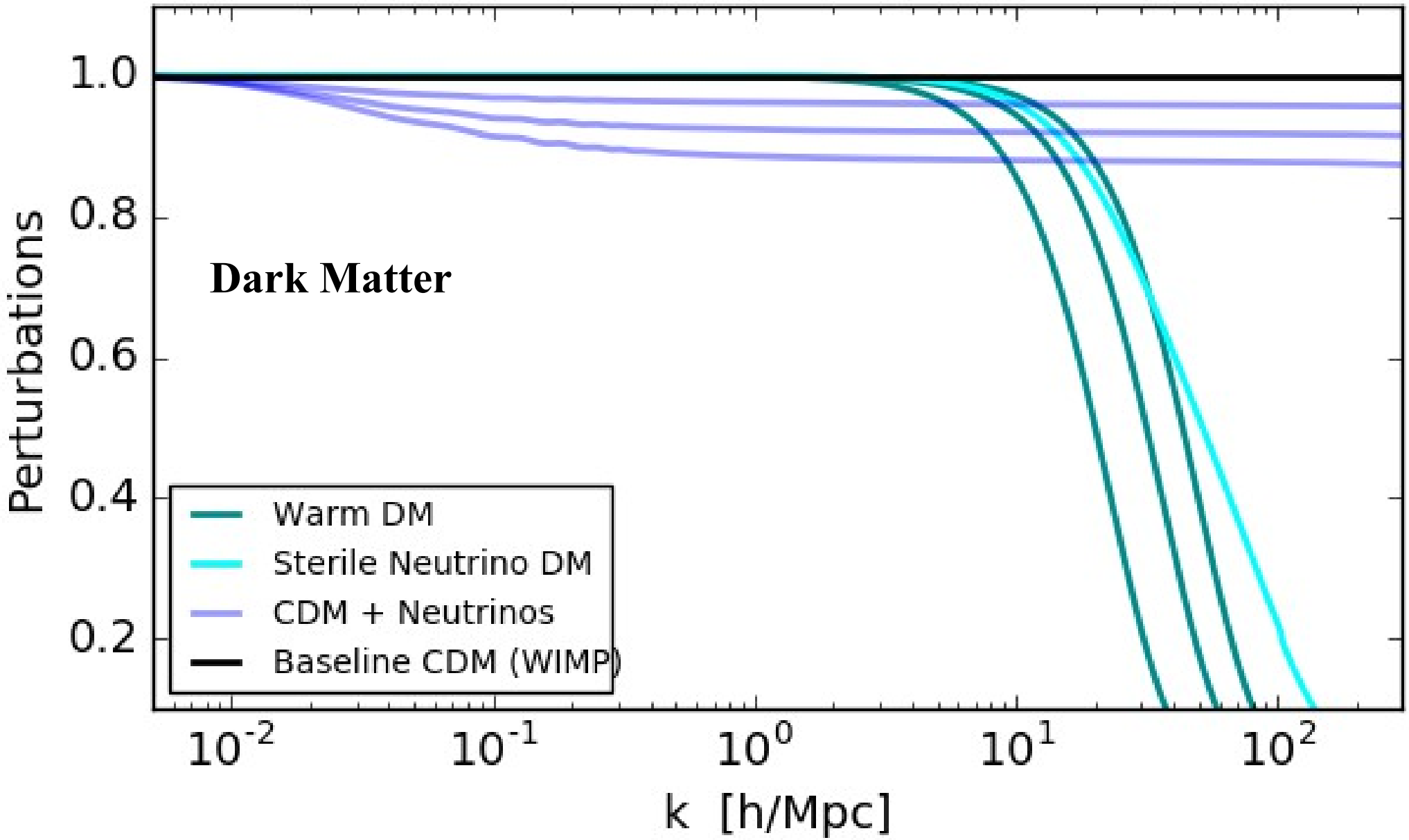

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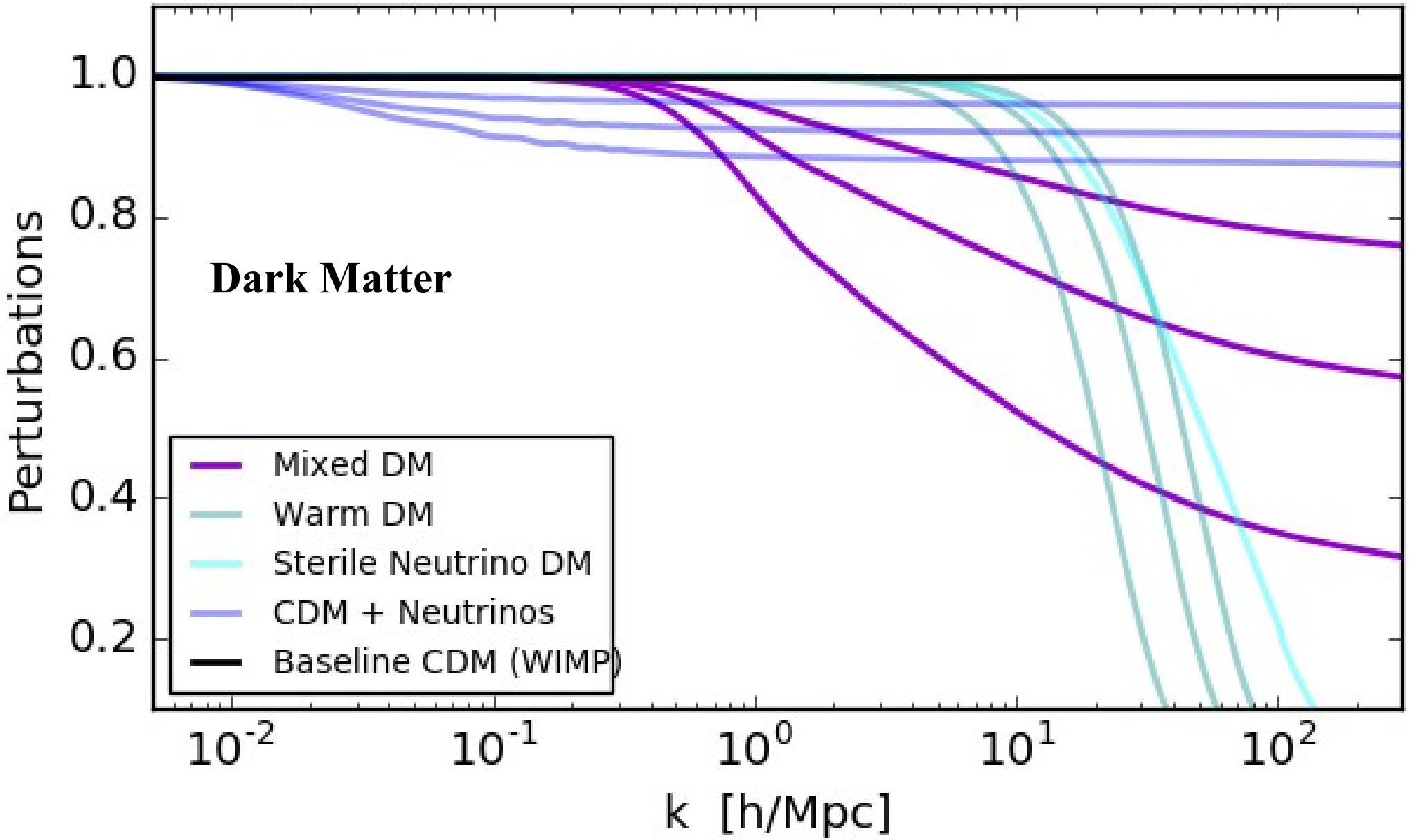

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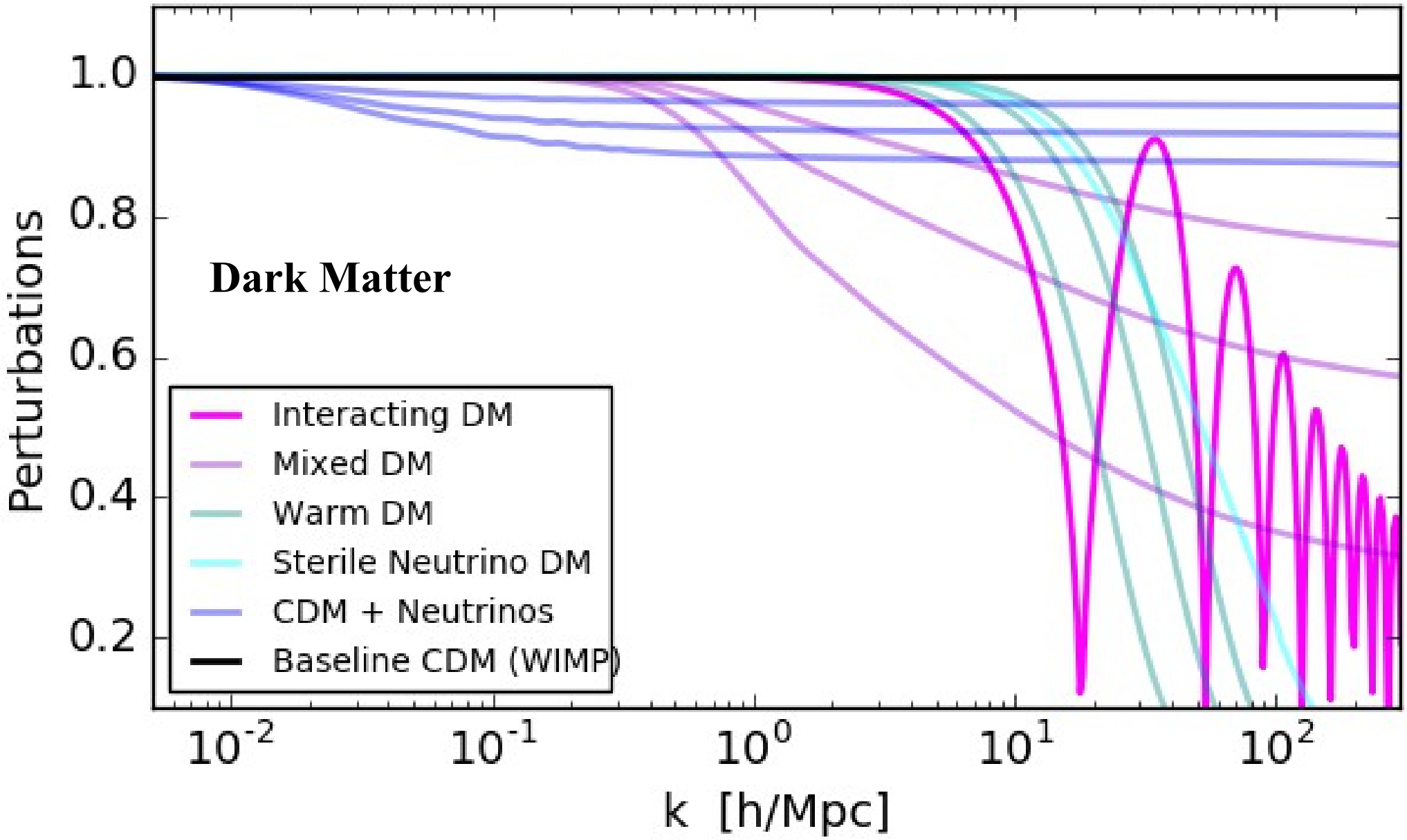

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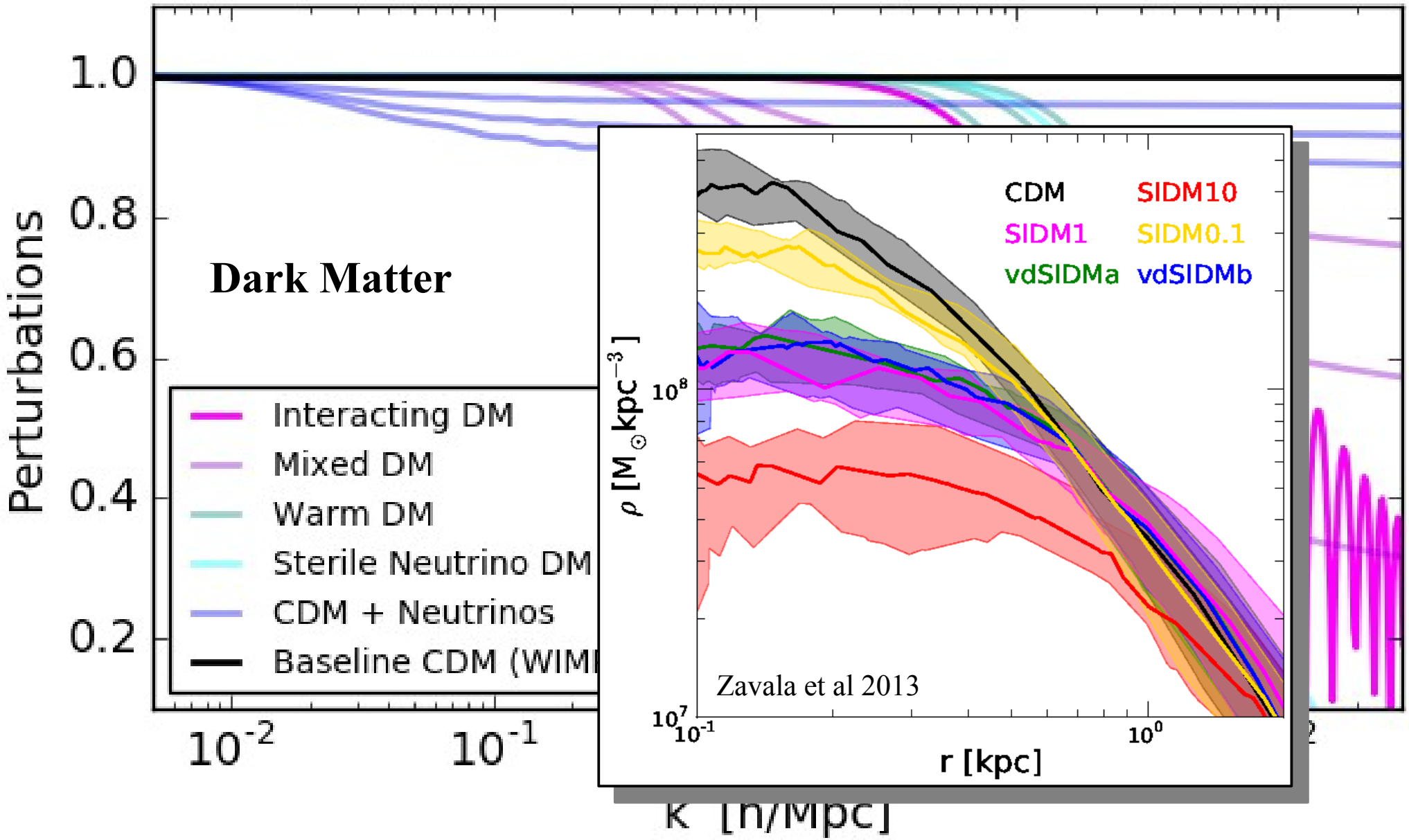

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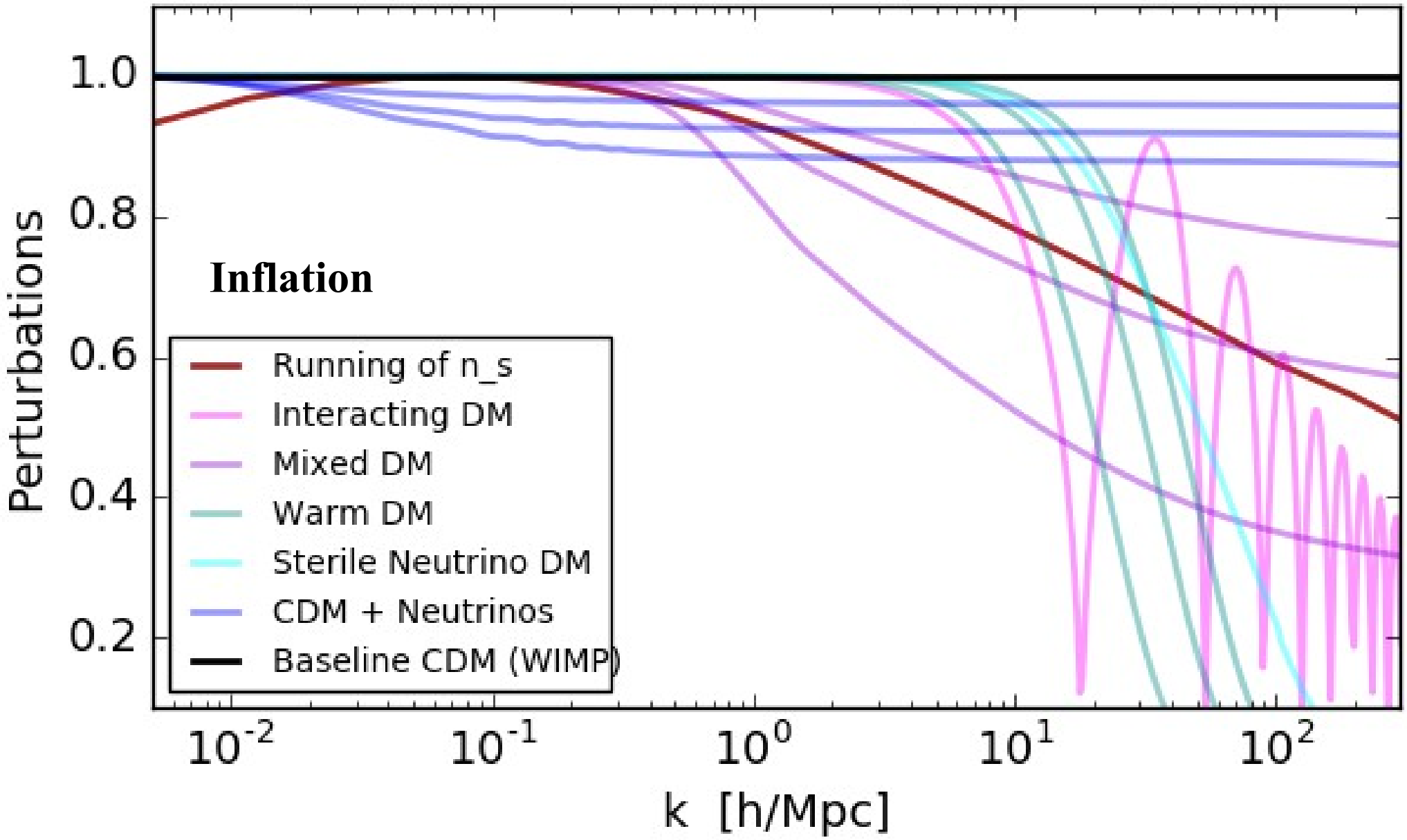

OVERVIEW

I. Velocity function – a new probe for cosmology ?

Small scales – large uncertainties – large effects !

II. Constraining dark matter – Lyman-alpha et al.

Very tight limits – but are they right ?

III. Lensing surveys: modeling baryonic effects

Do we understand the systematics ? What is in there for dark matter ?

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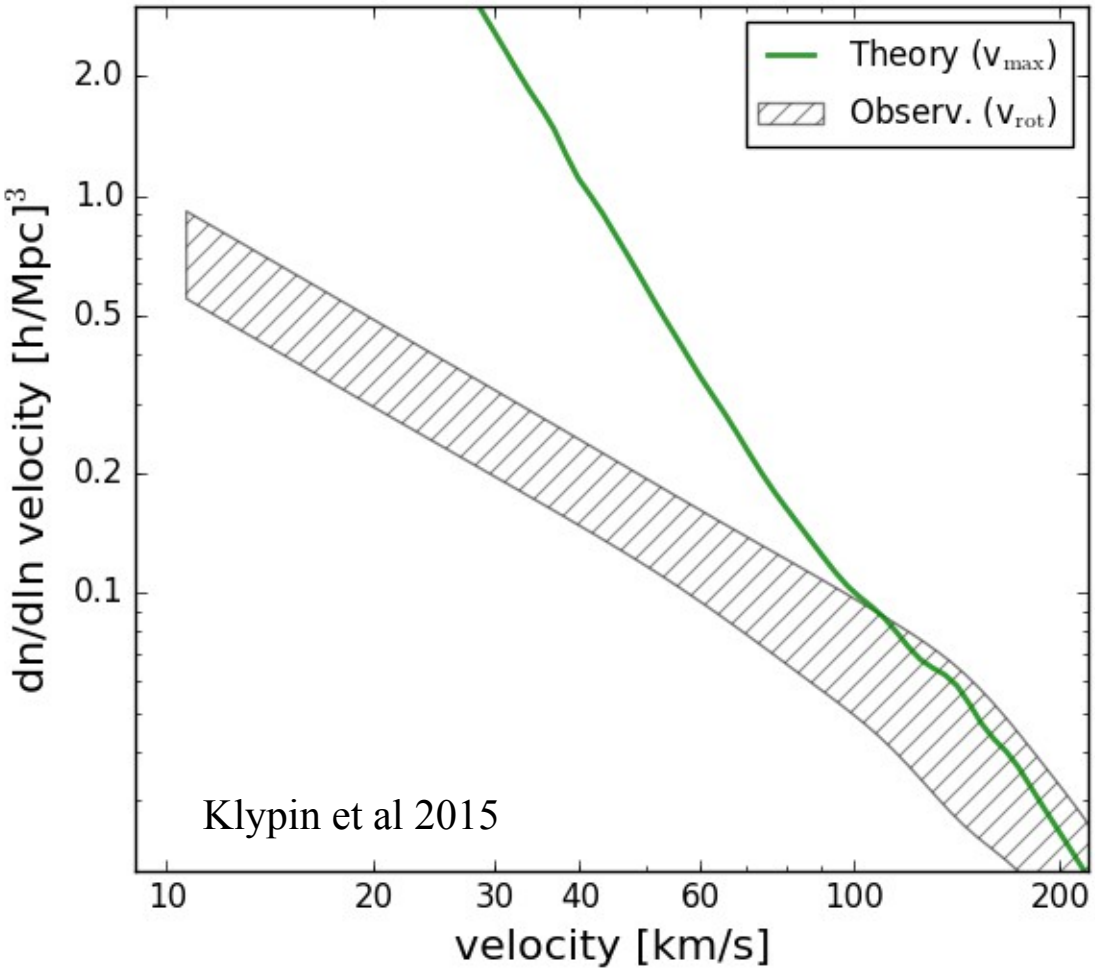
I. Velocity function – Is there a tension ?

Large discrepancy between theory and observations … but is this a fair comparison ?



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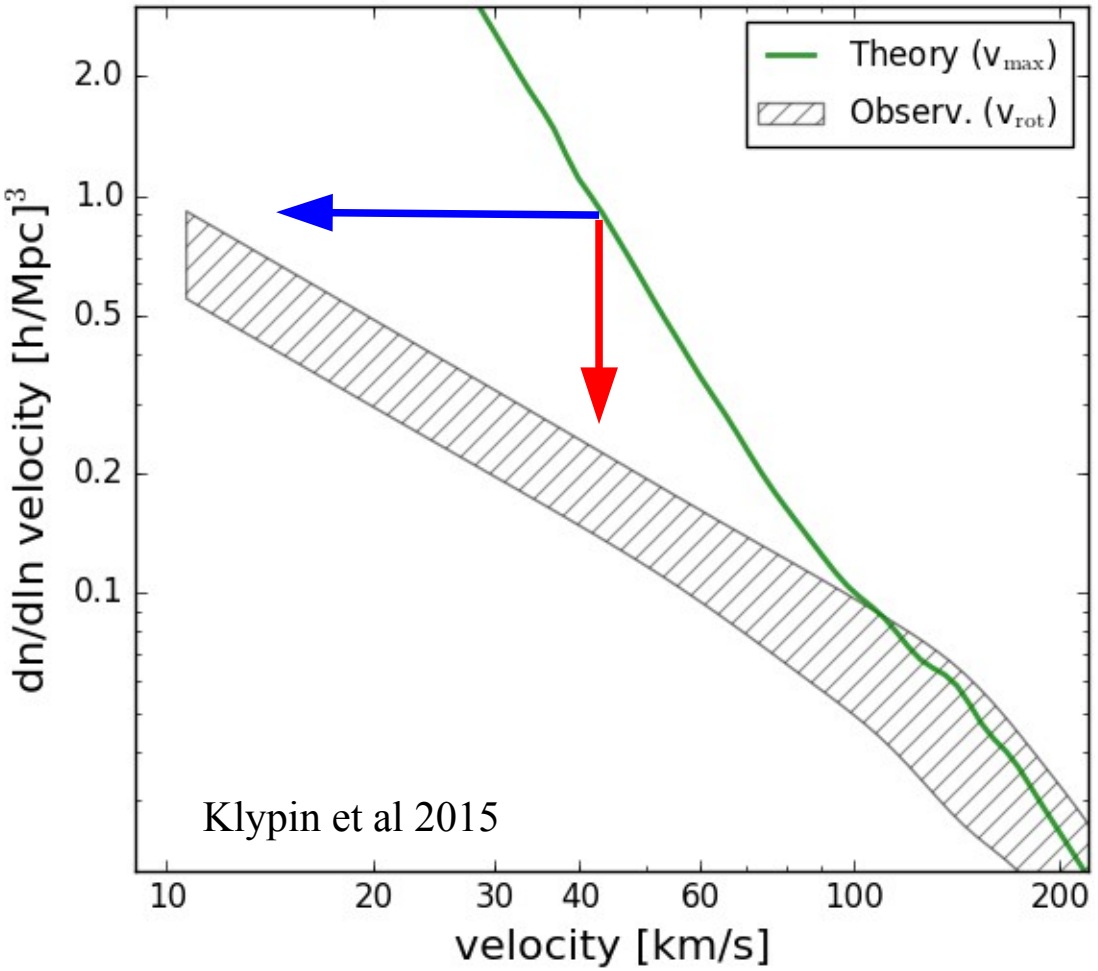
Tension between theory and observations disappears if

Small haloes do not contain galaxies

Large haloes contain small galaxies (vmax >> vrot)



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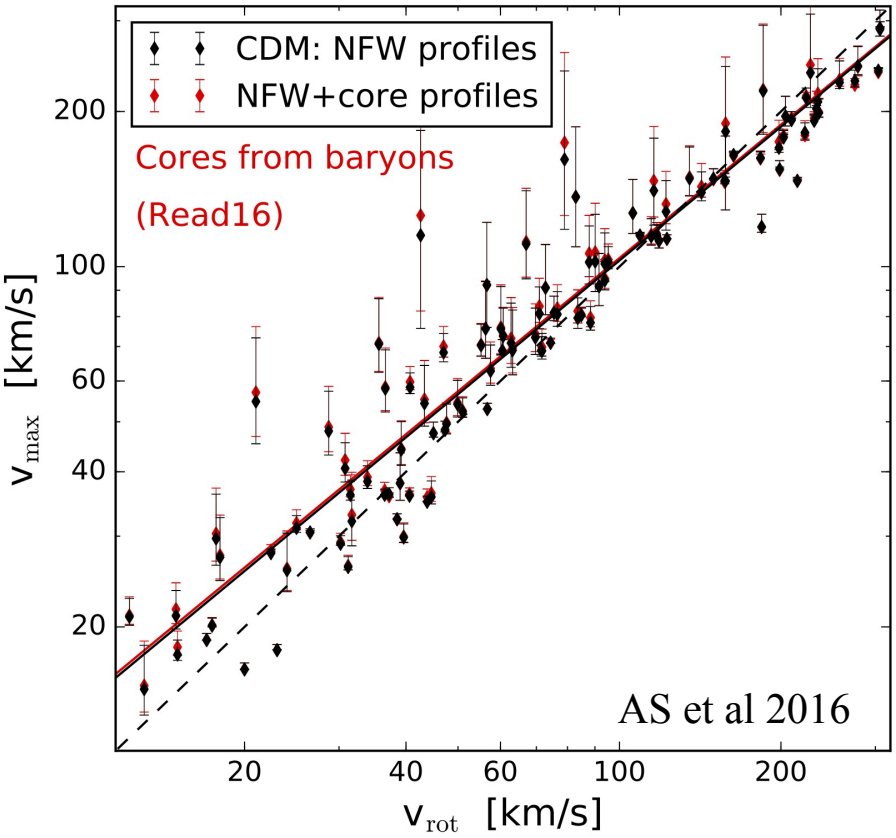
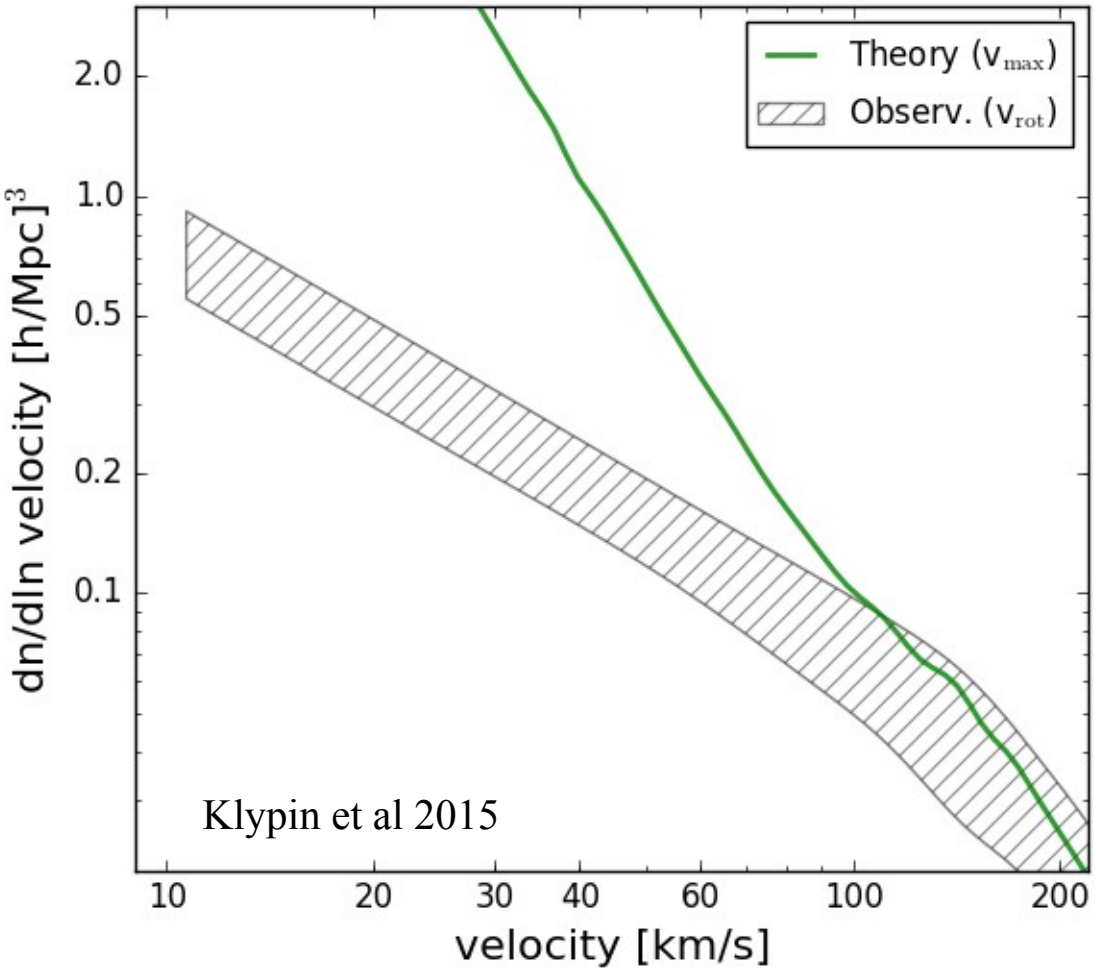
Find vrot-vmax connection using dwarfs with kinematic information.





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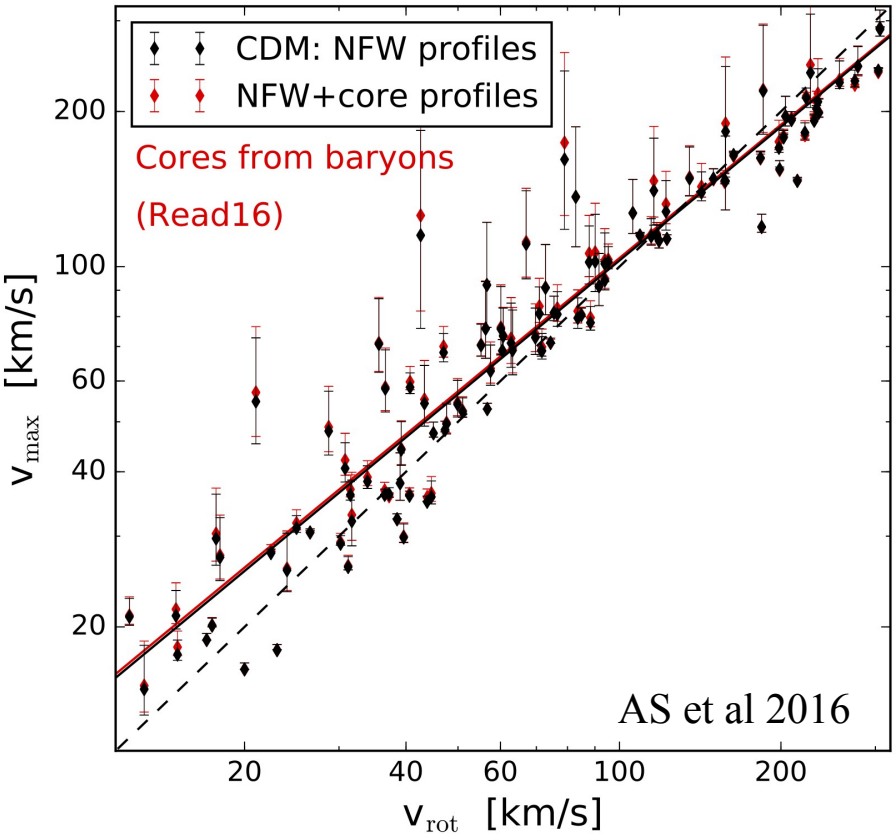

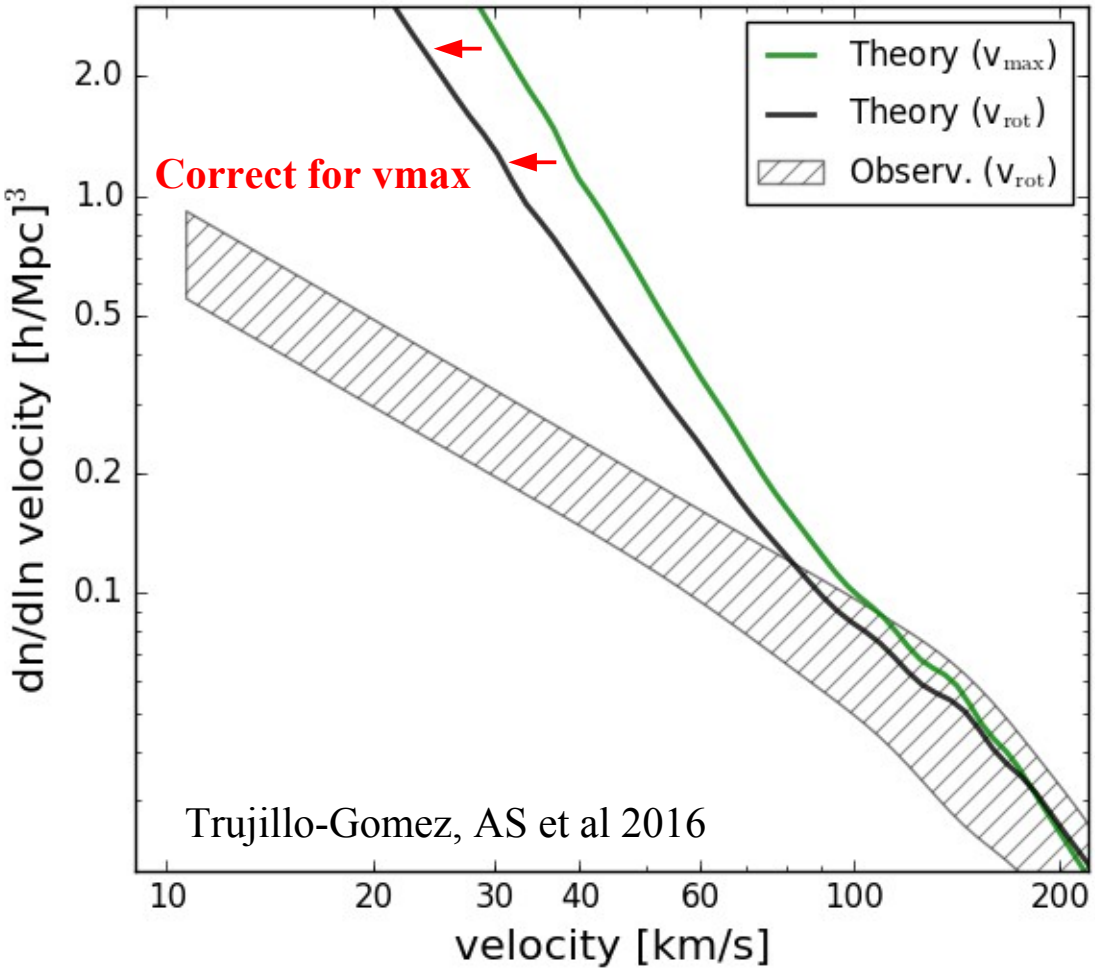

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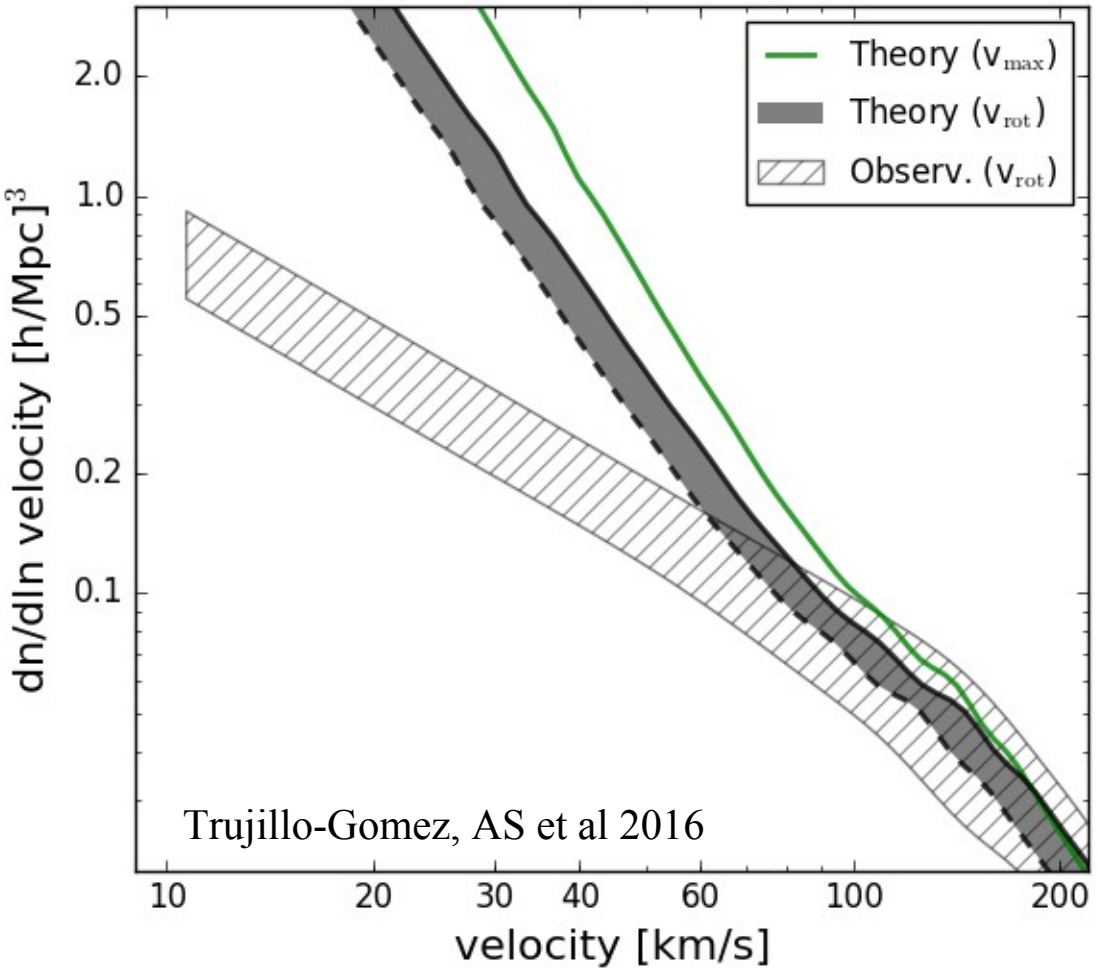
Include baryon effects:

- Maximum baryon depletion



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Include baryon effects:

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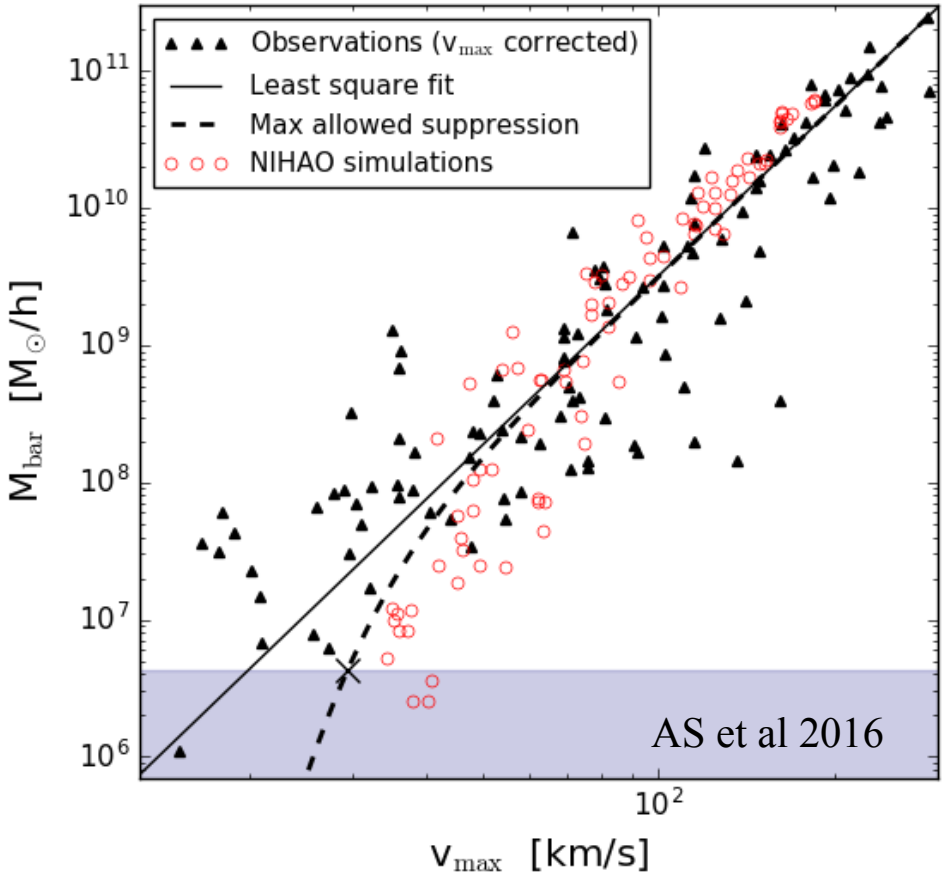

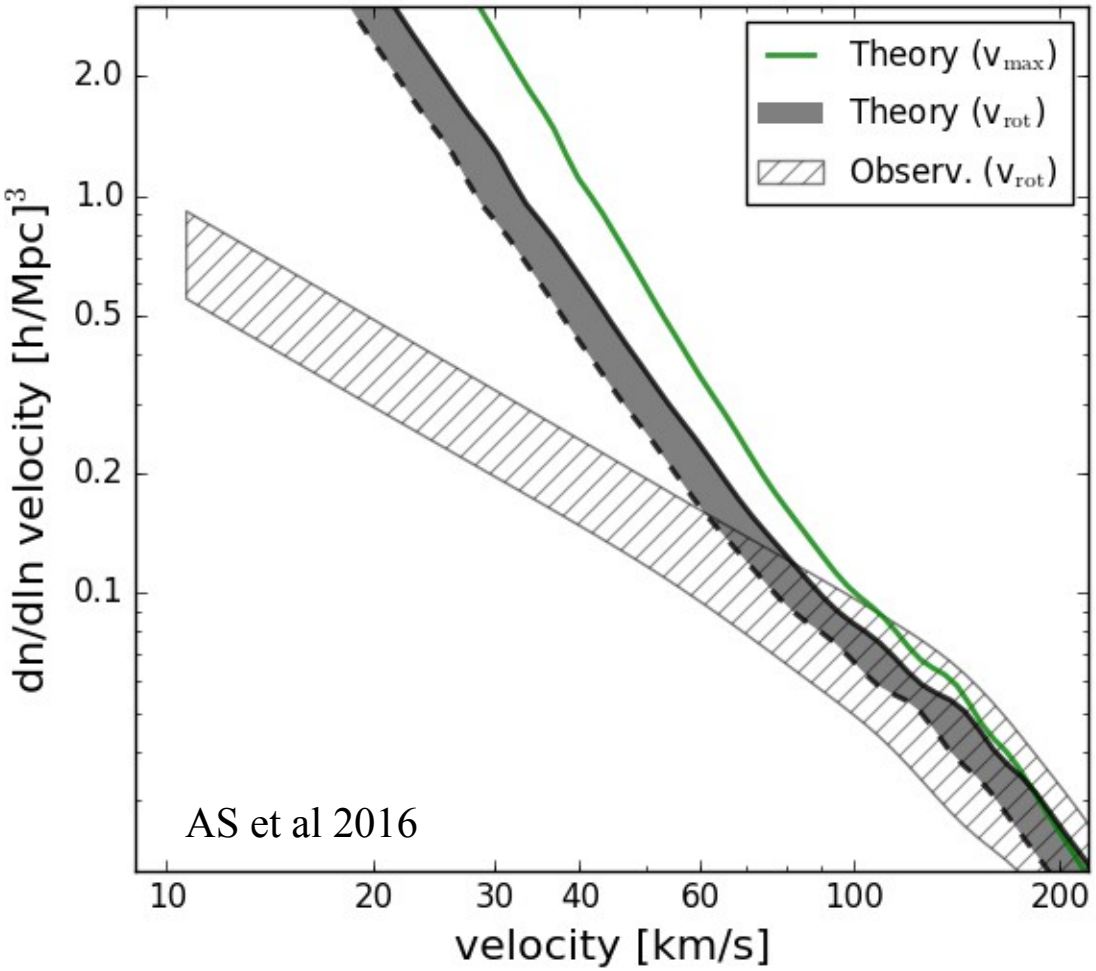

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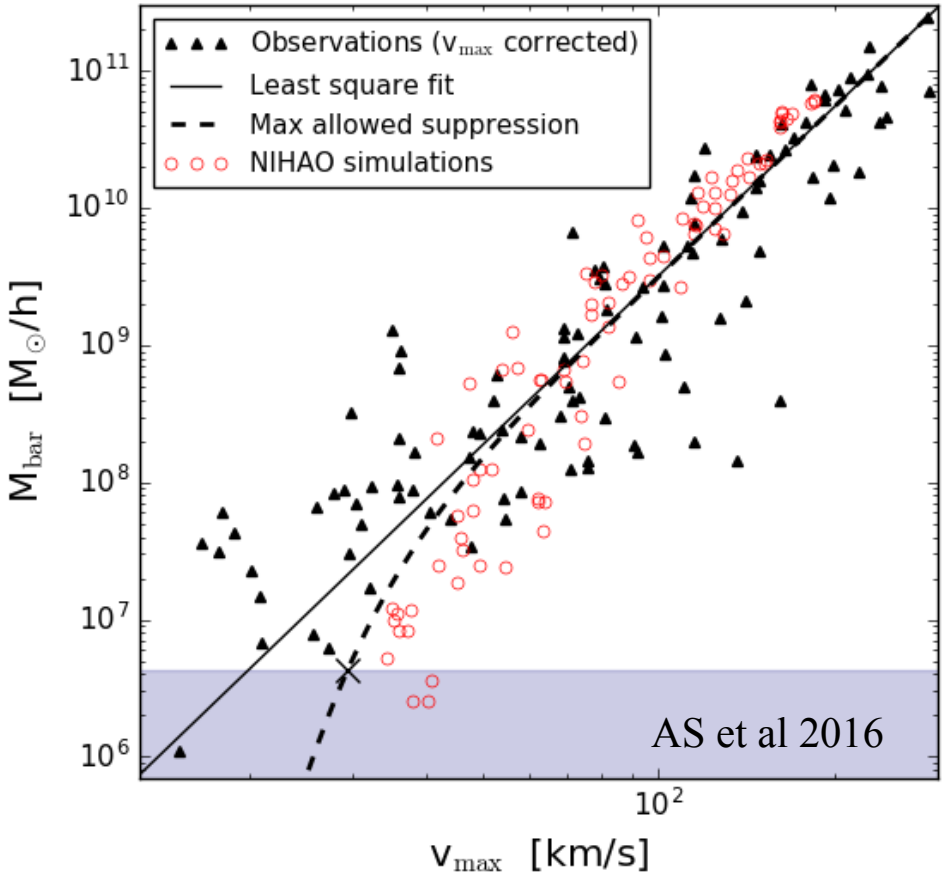
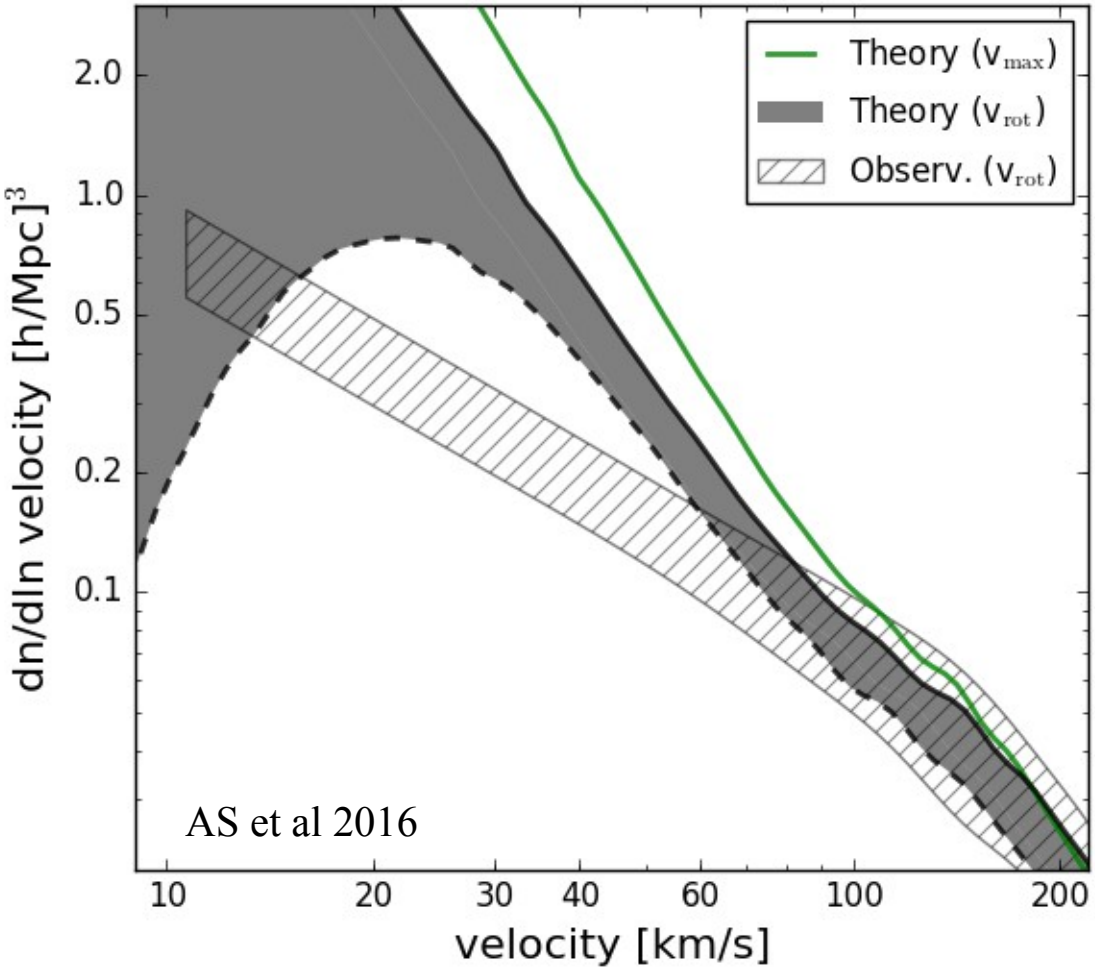




I. Velocity function – Solution with hydro sims ?

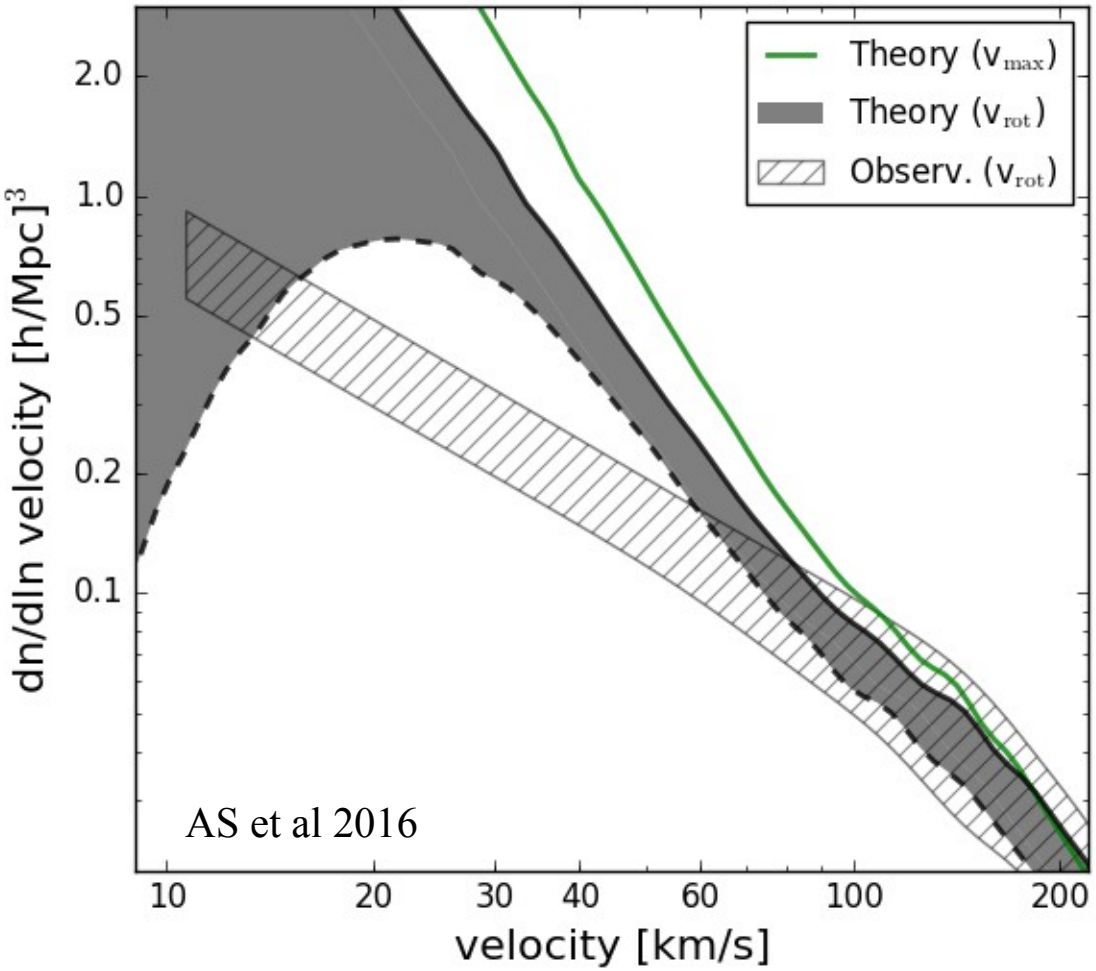
Recent results from the hydro community:

Maccio et al 2016 (NIHAO)

→ completely solves discrepancy

Brooks et al 2017

→ strongly reduces discrepancy



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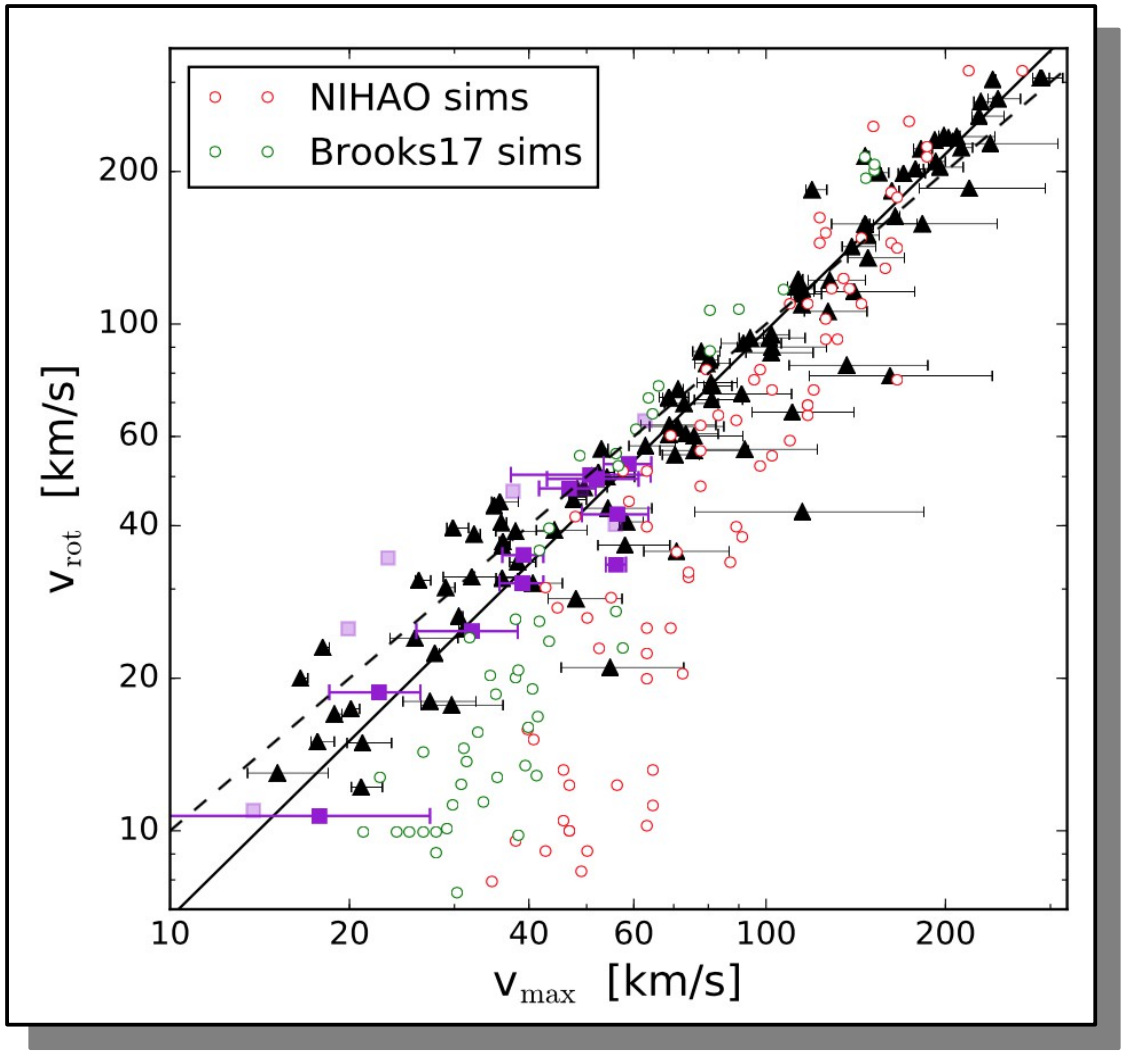

I. Velocity function – Influence of dark matter

Small galaxies in the local volume:

A powerful probe for **dark matter**

and cosmology !

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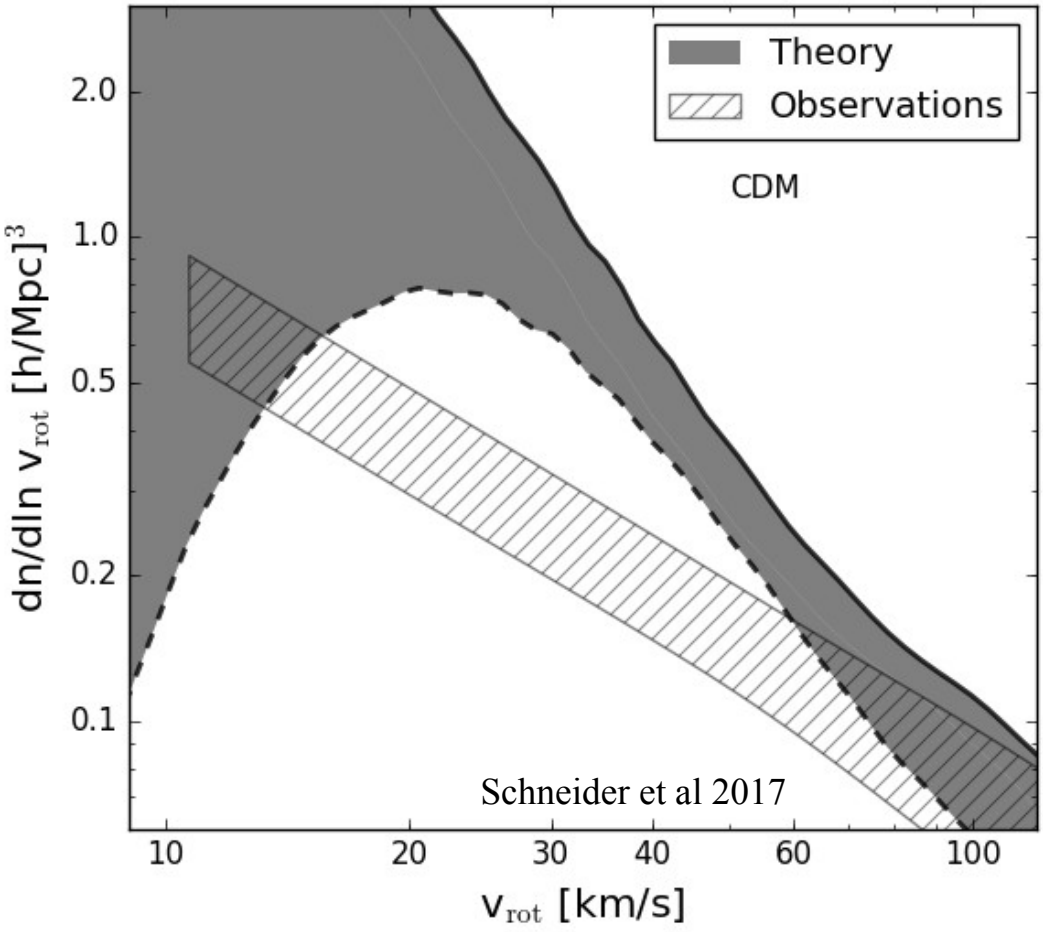

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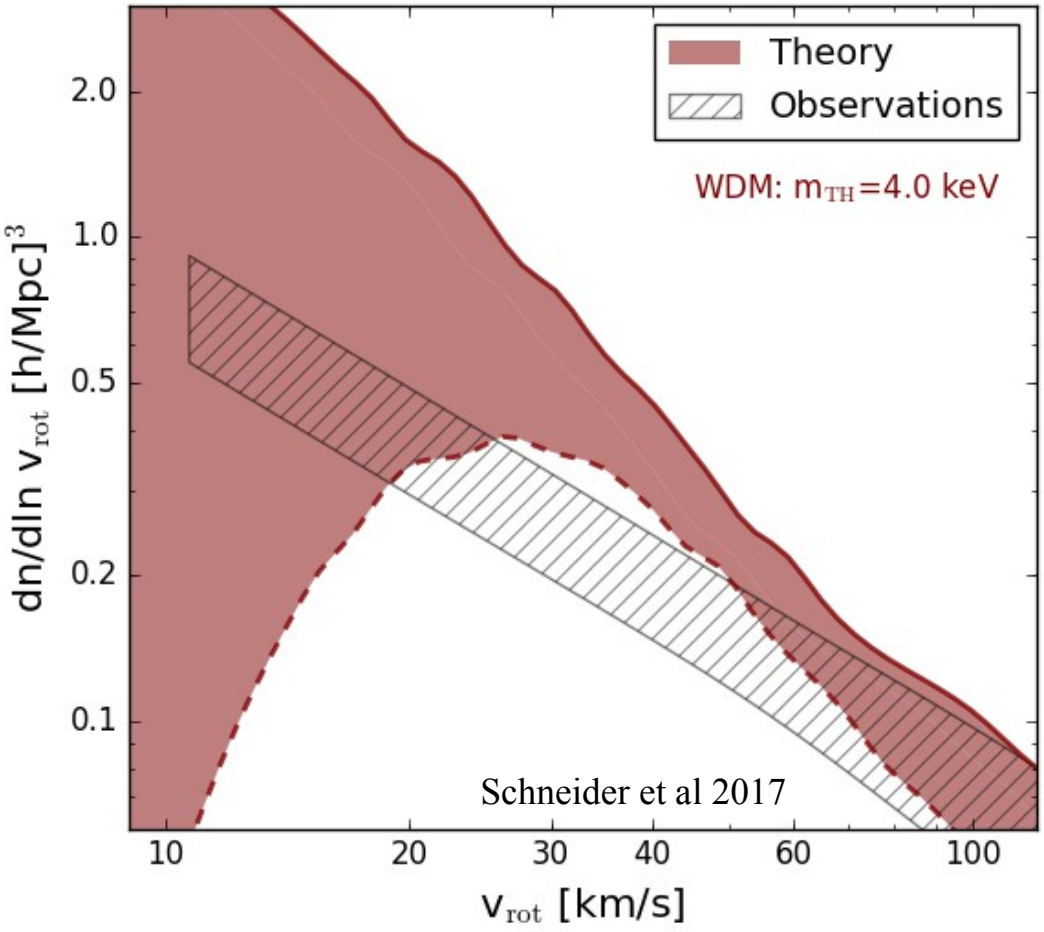

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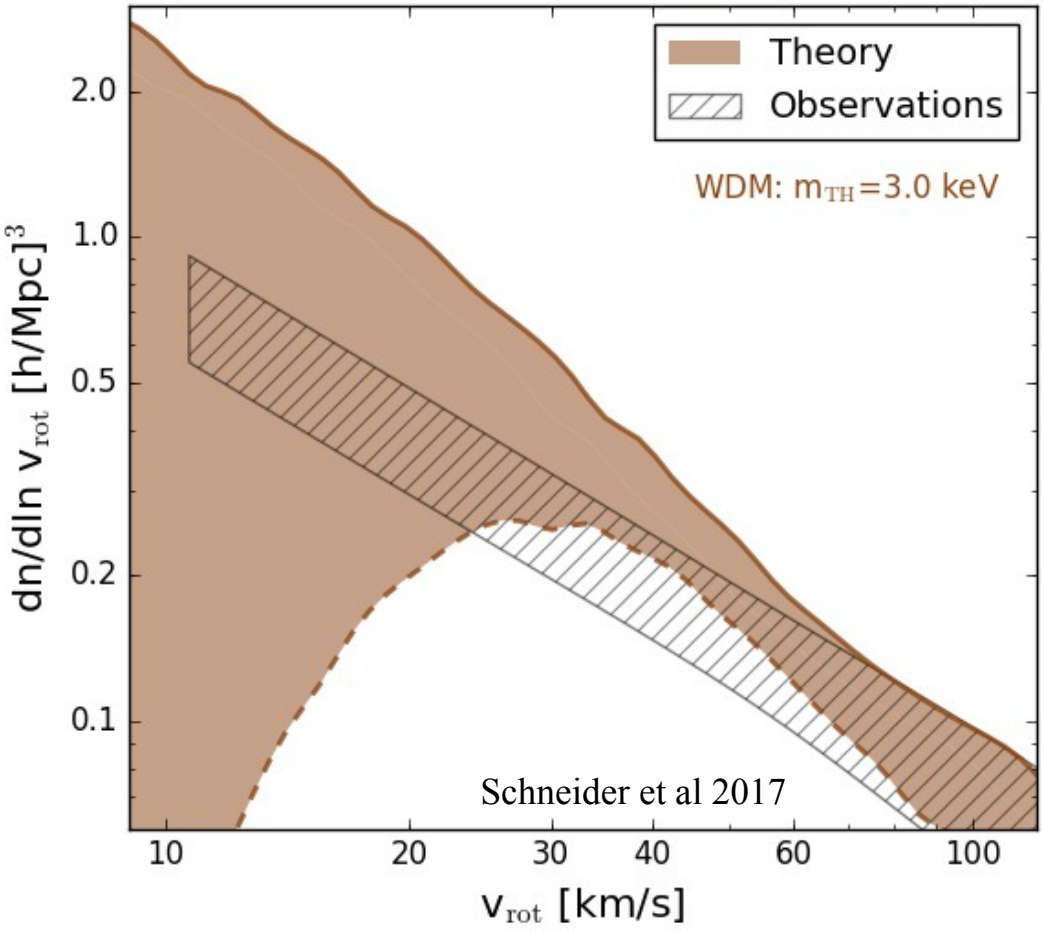

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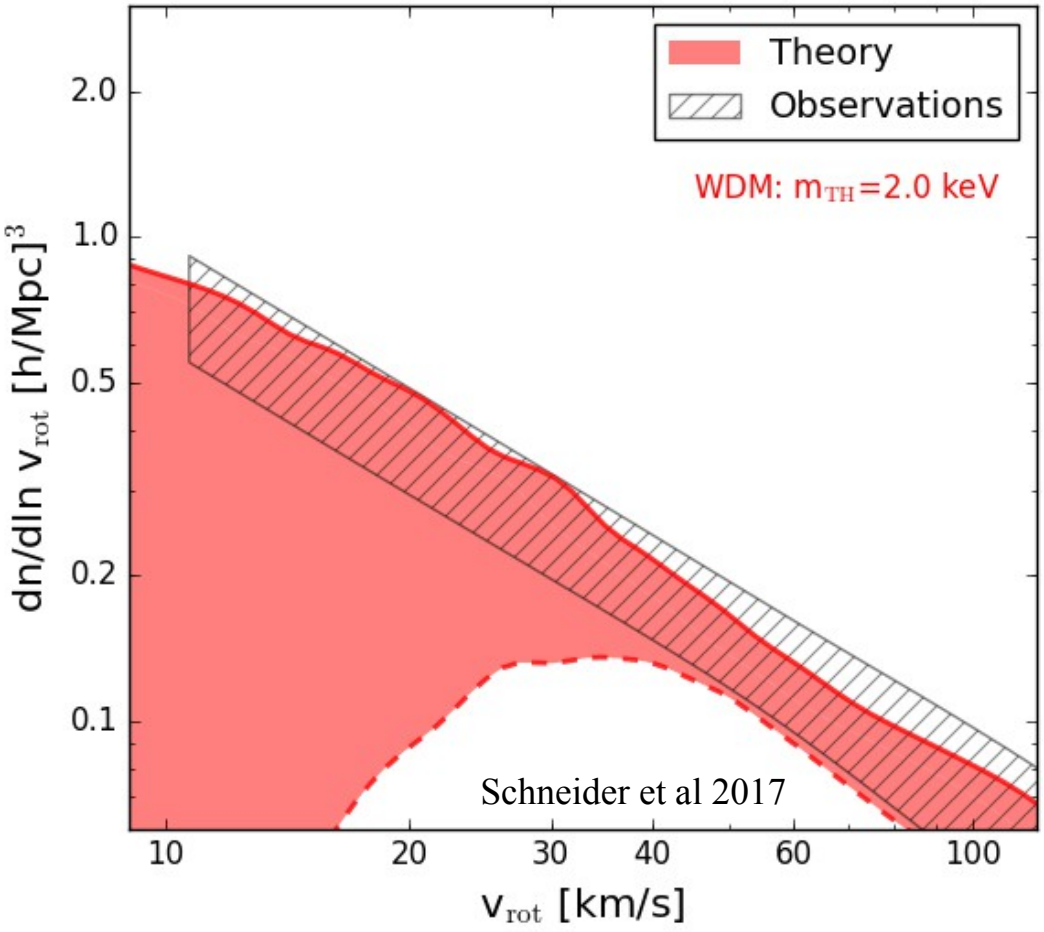

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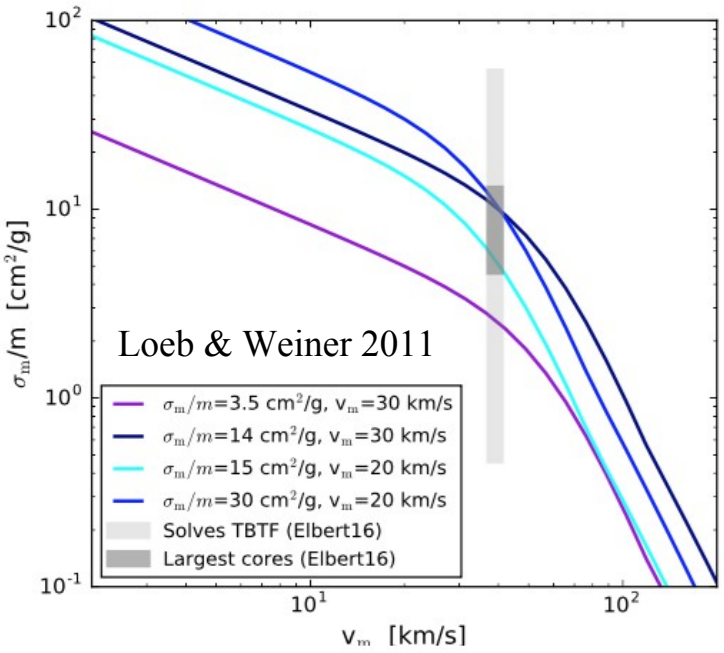

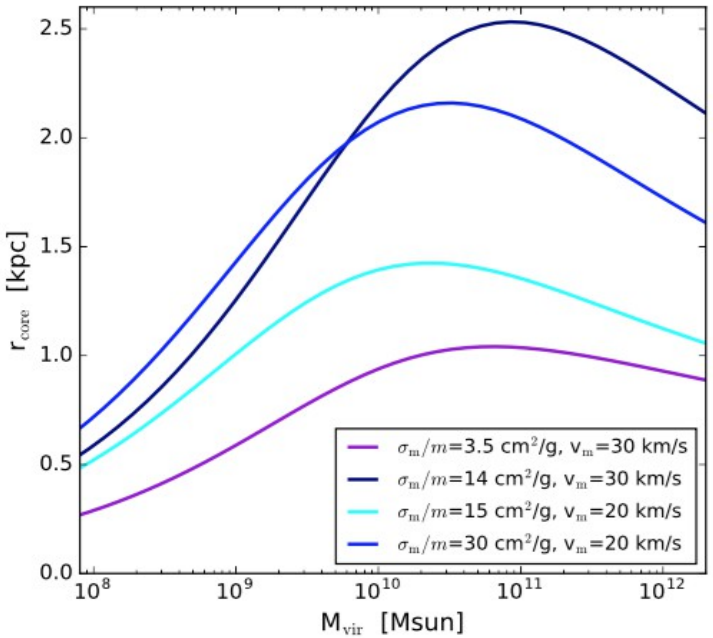

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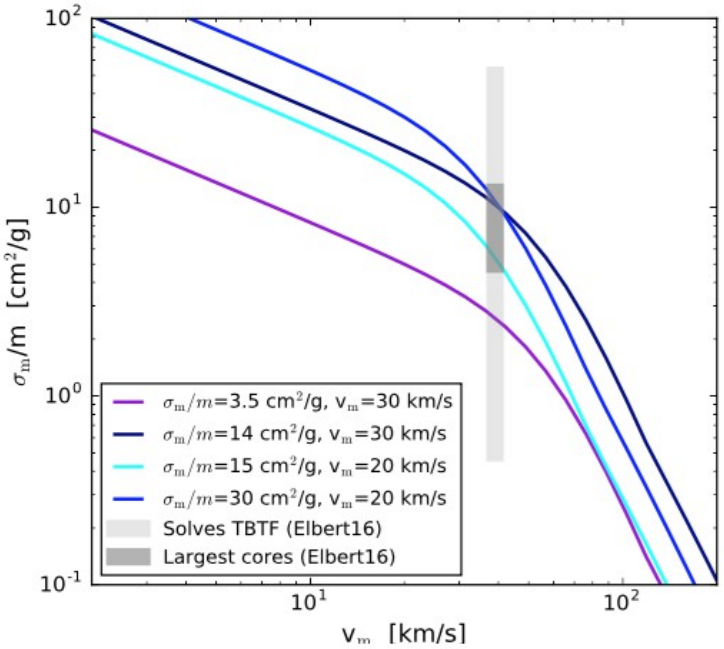

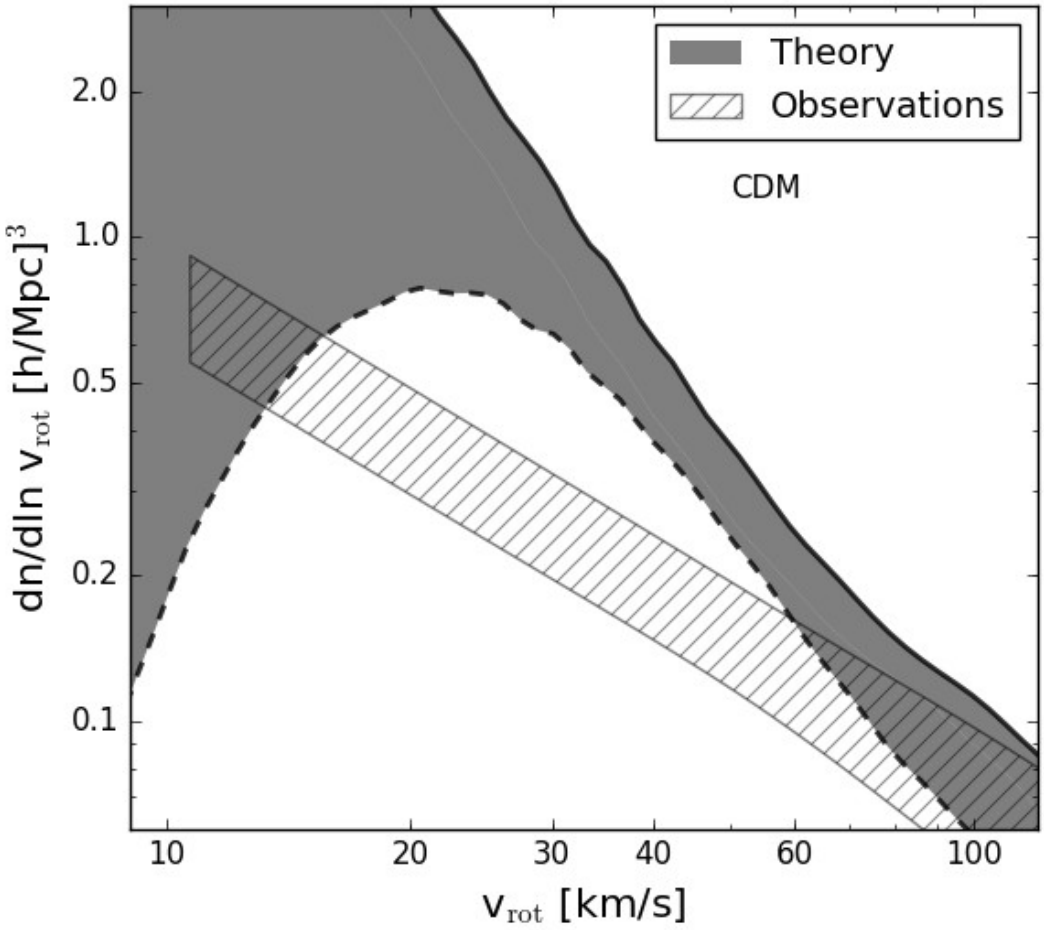

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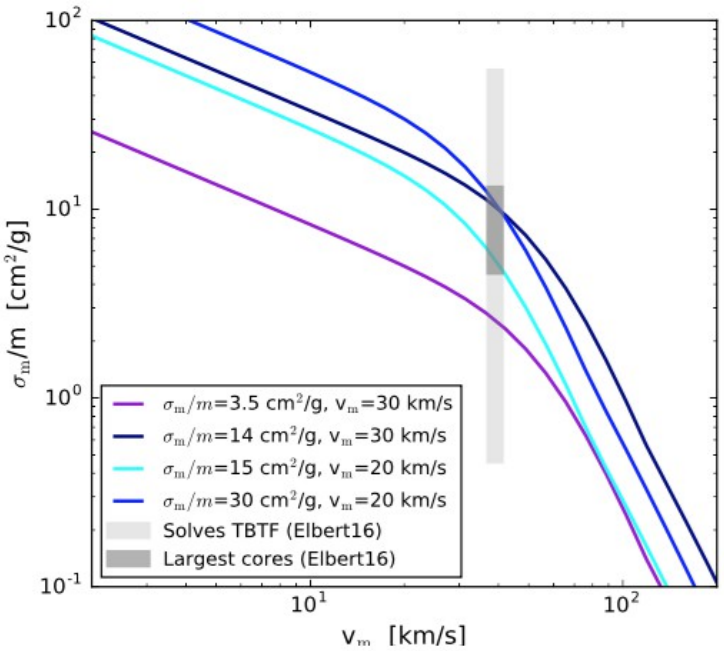

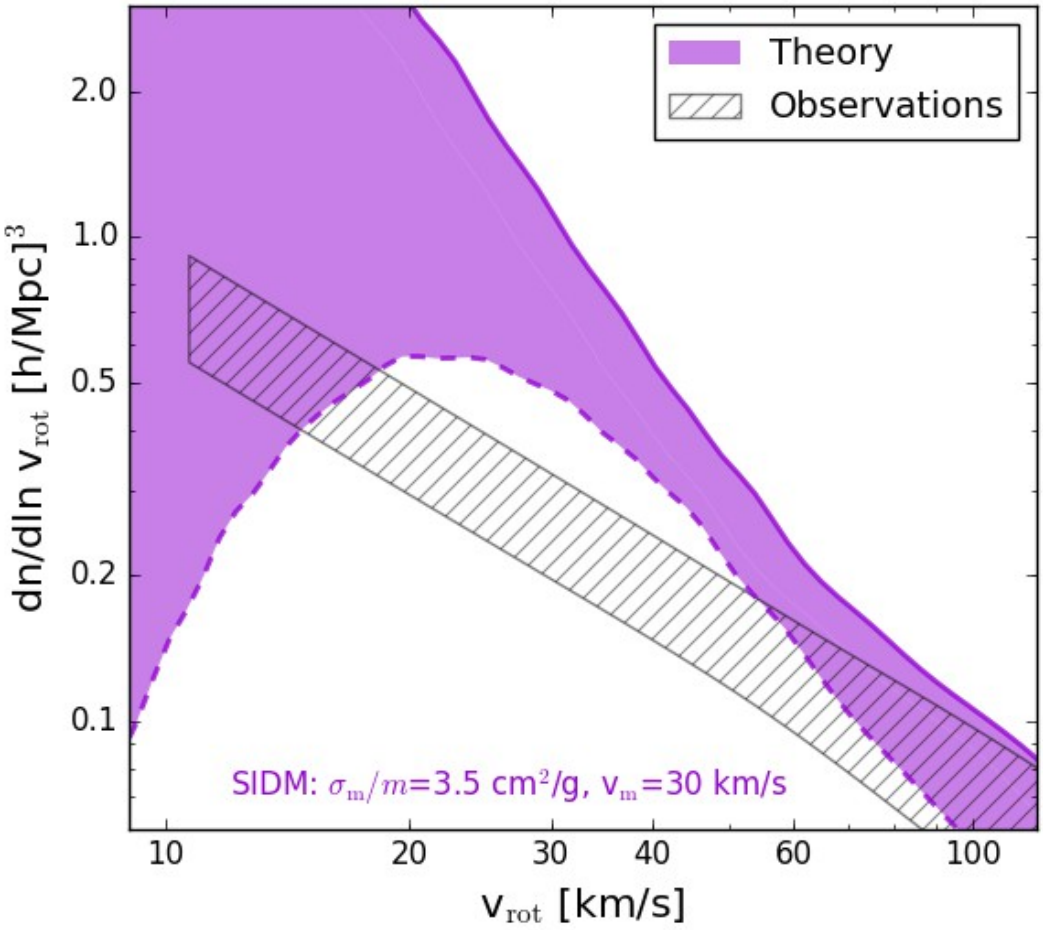

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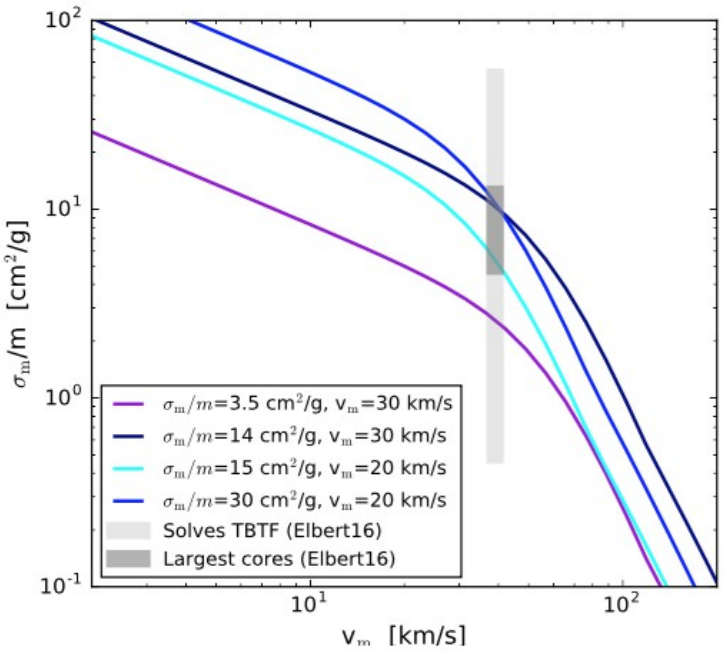

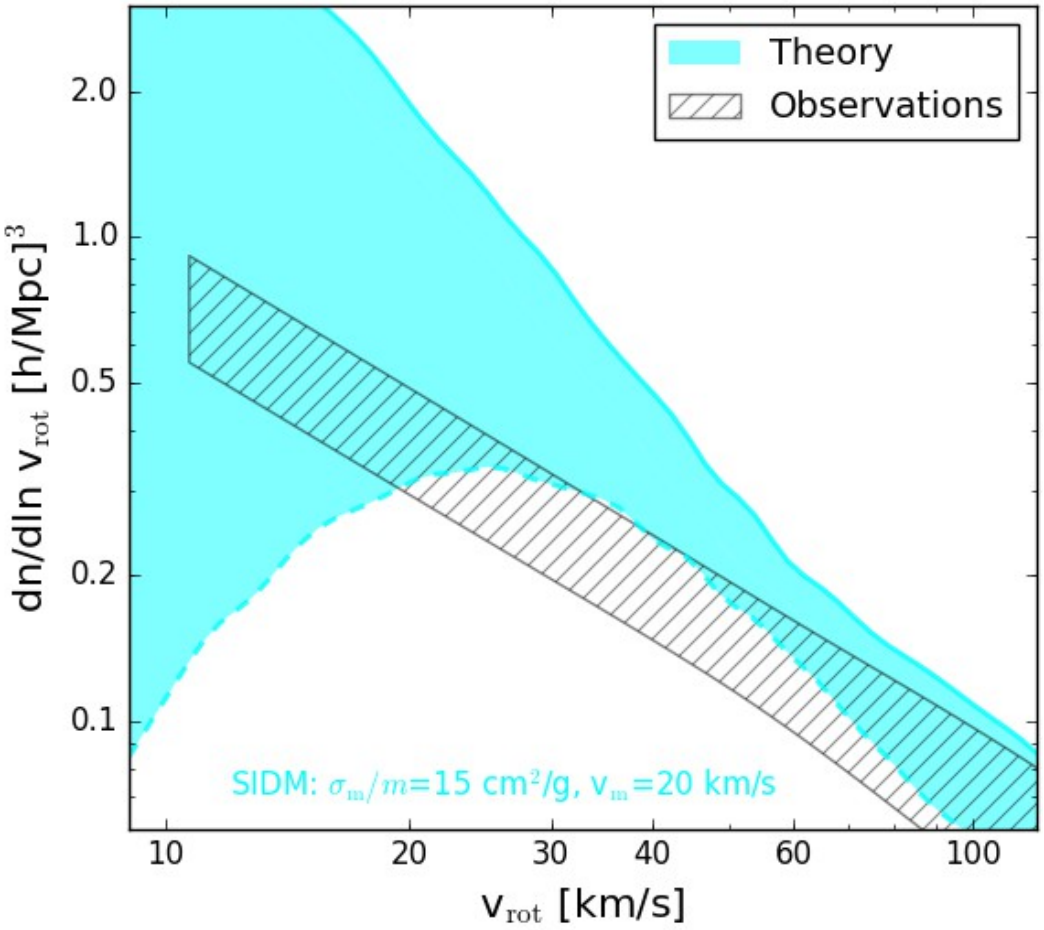

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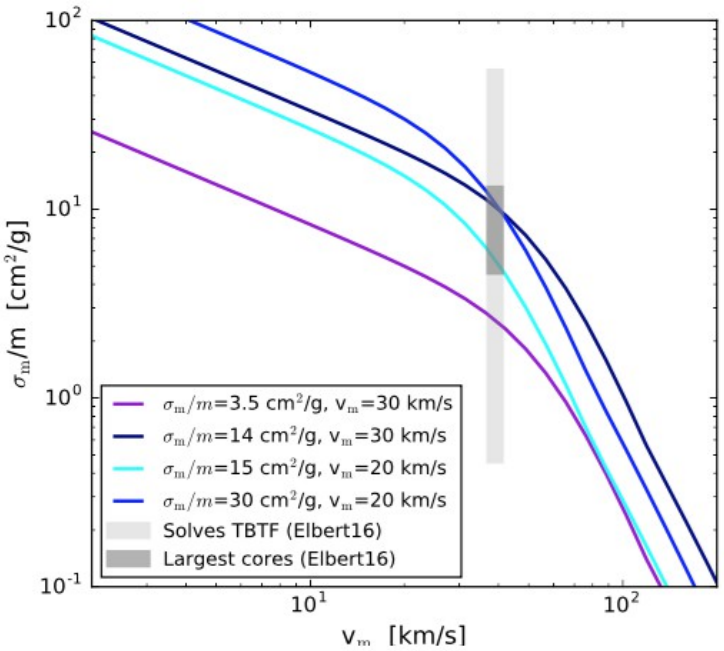

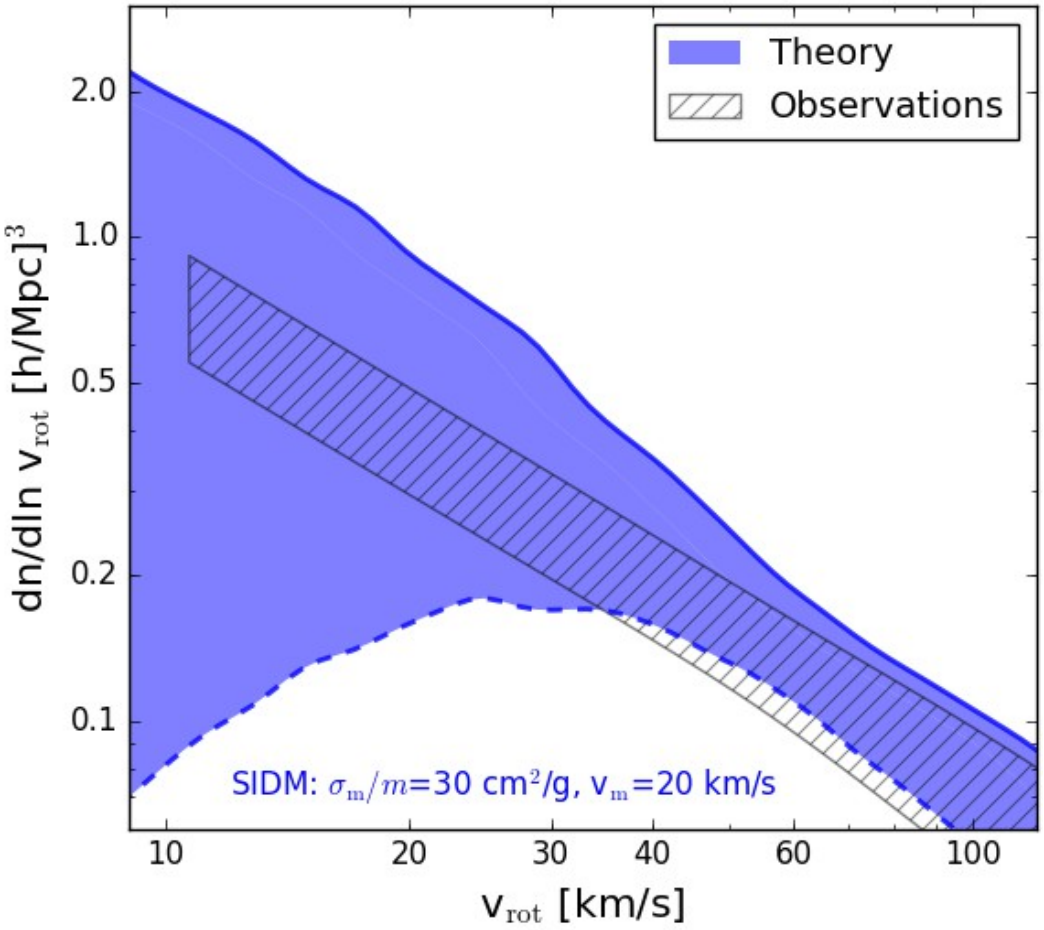

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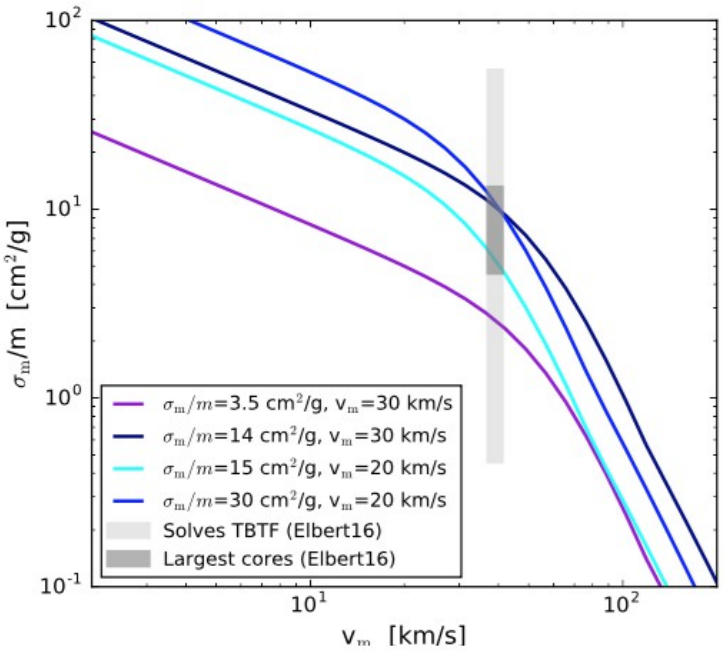

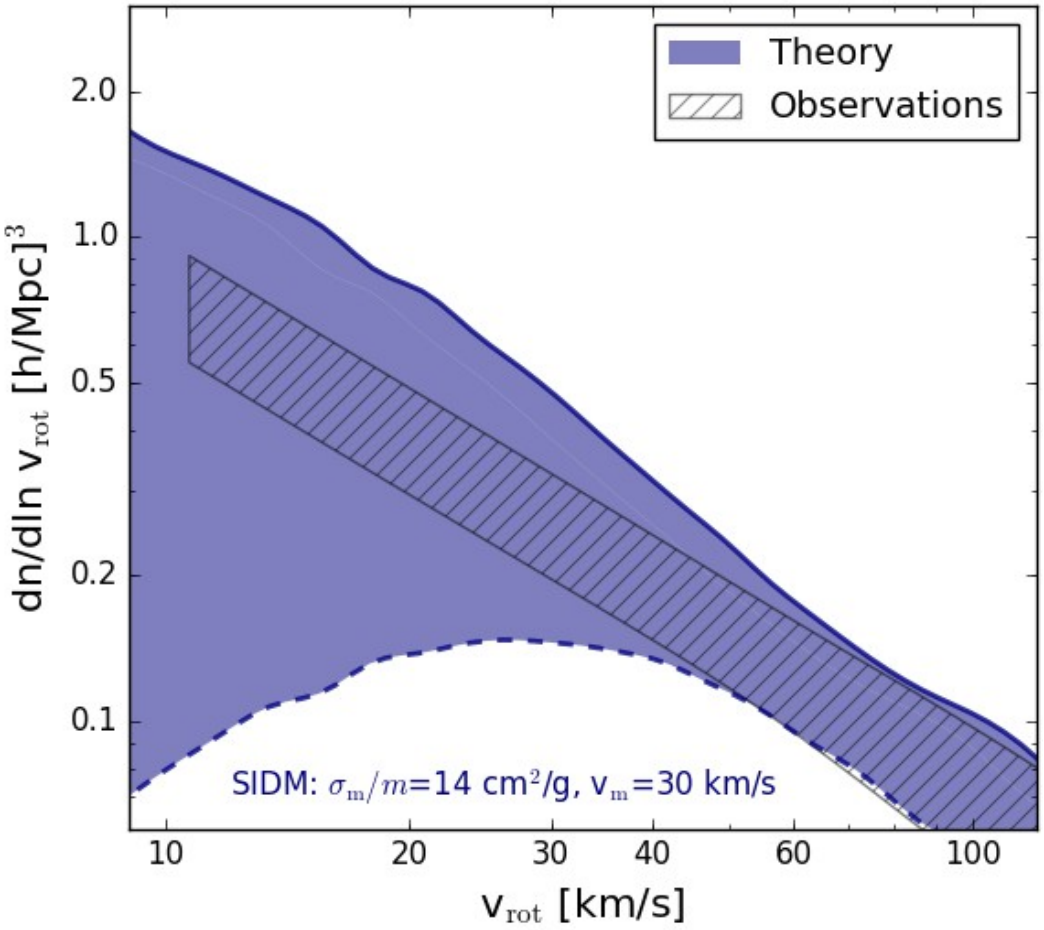

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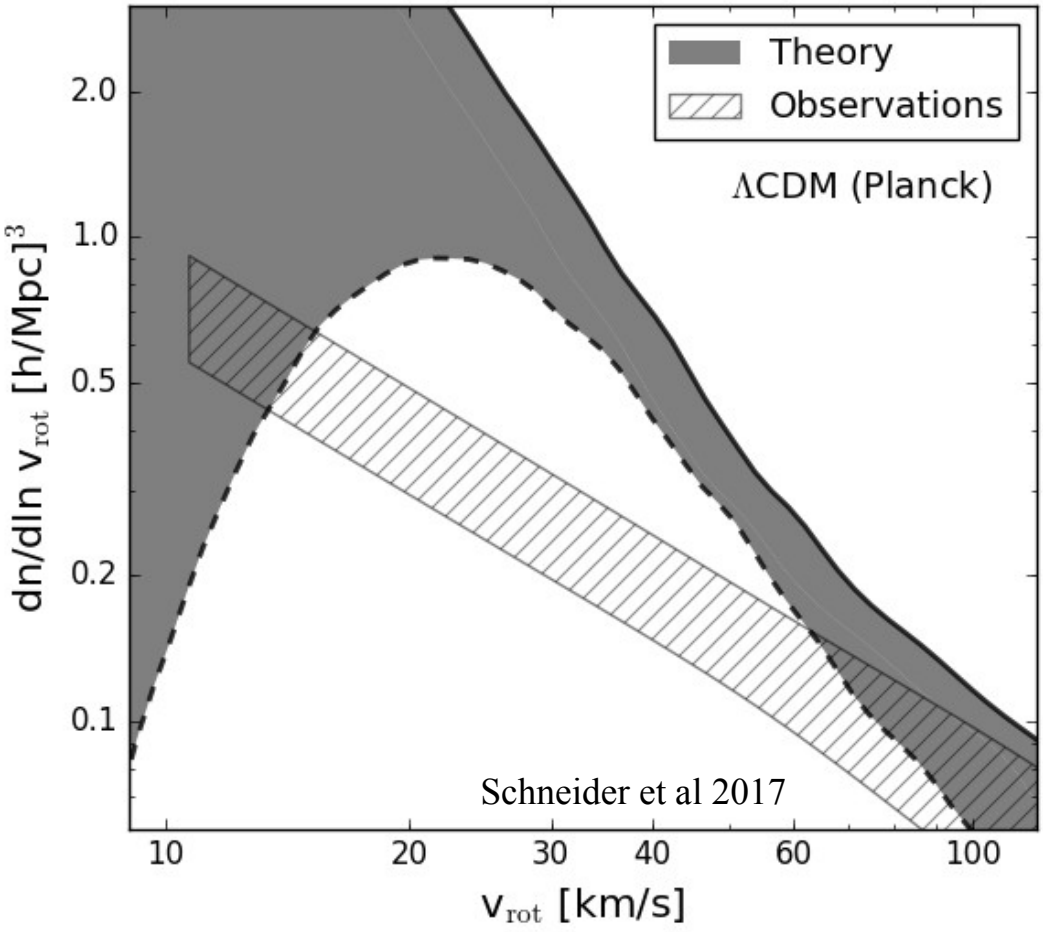

… going from Planck to
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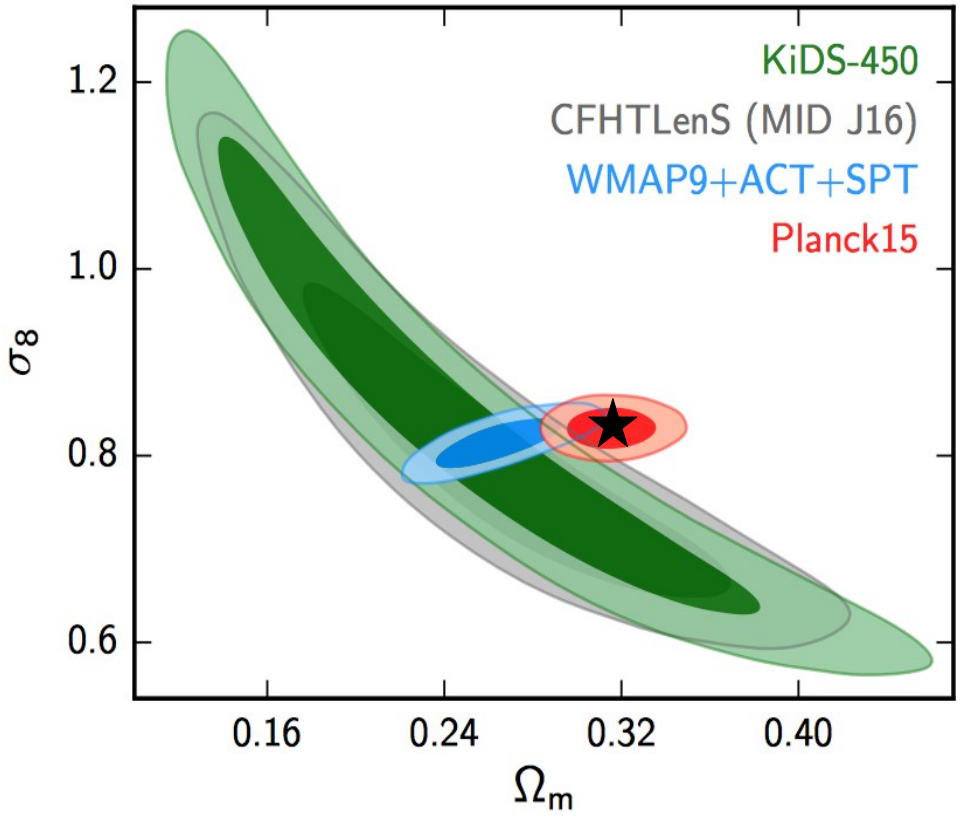

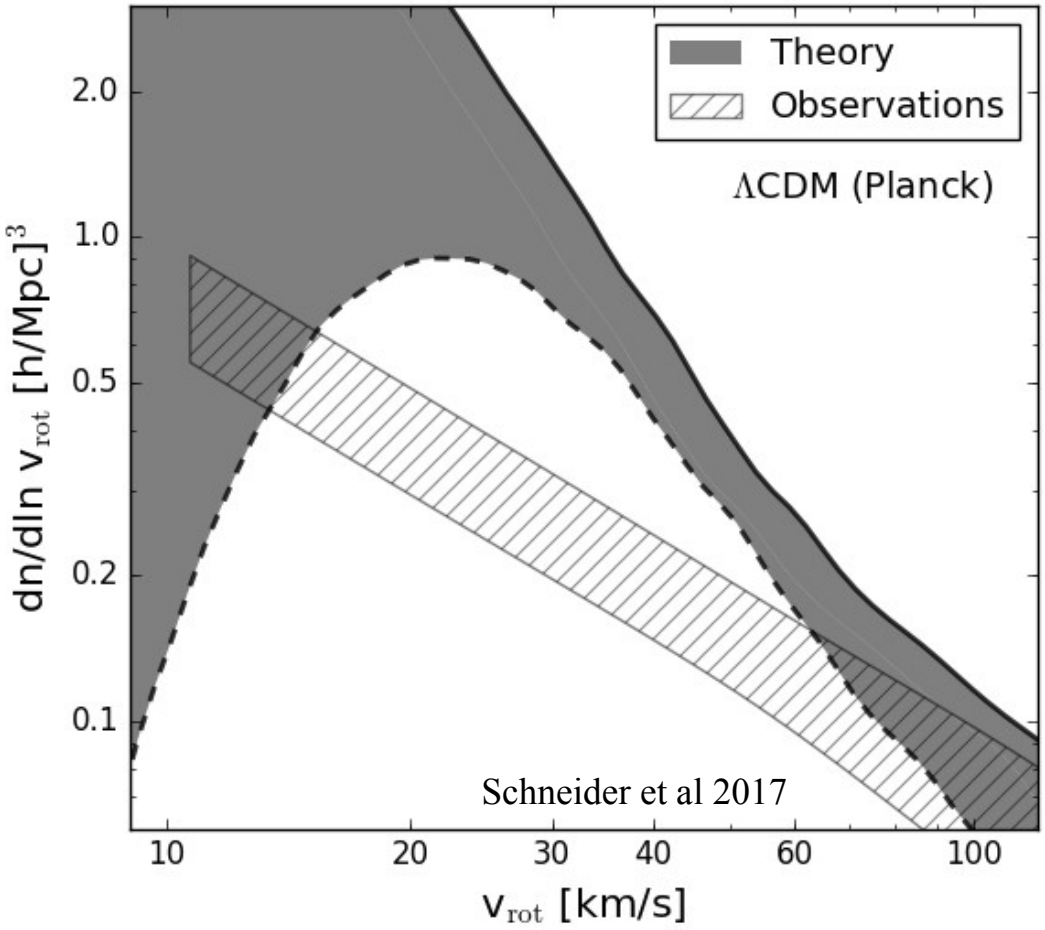

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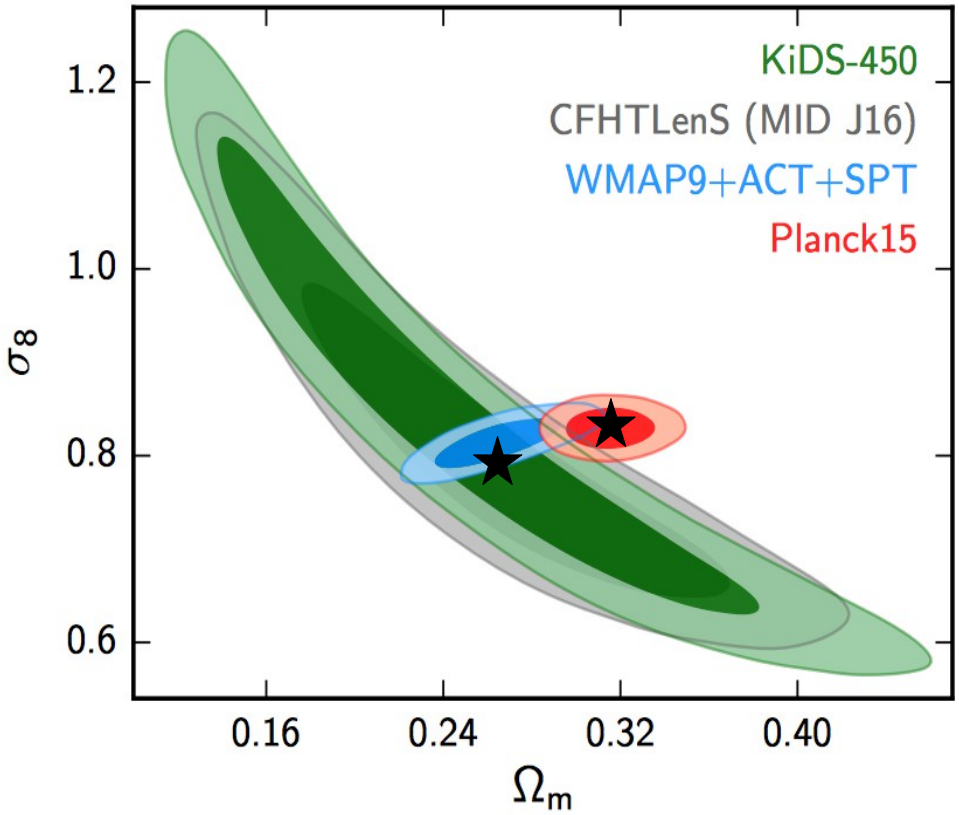

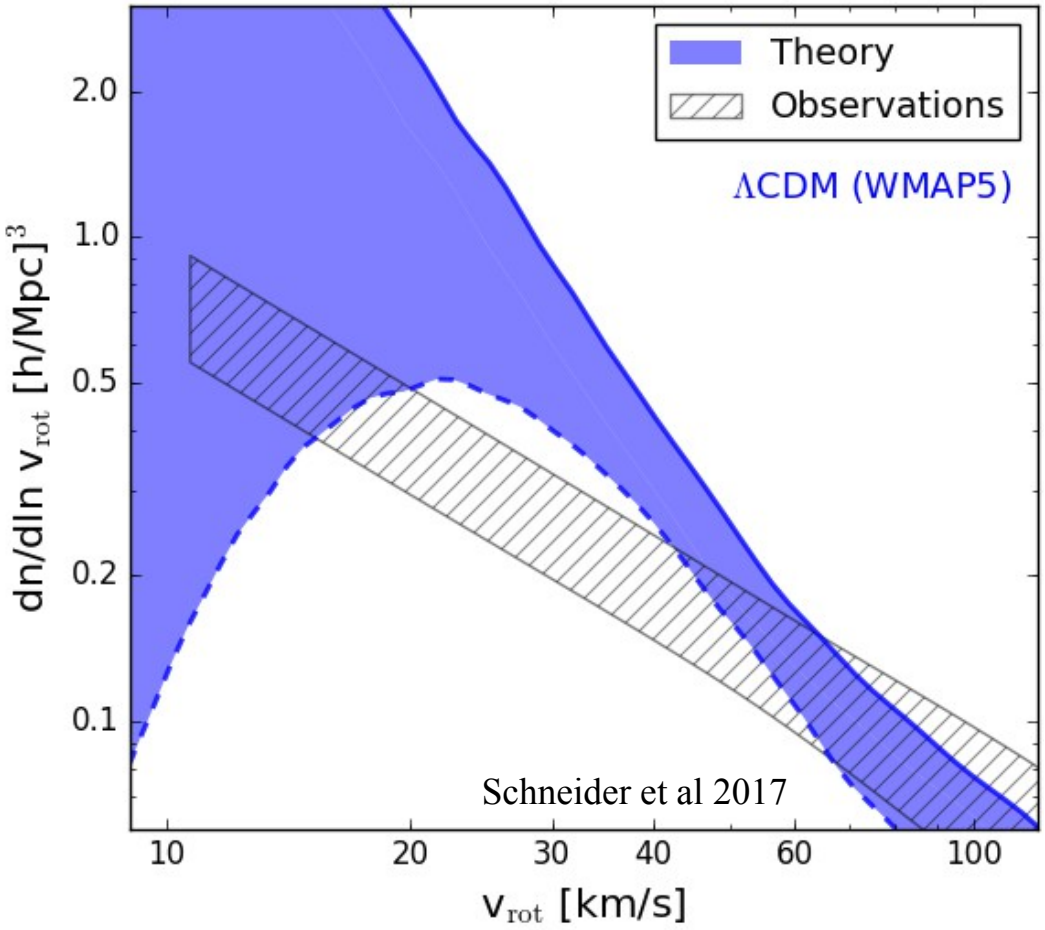

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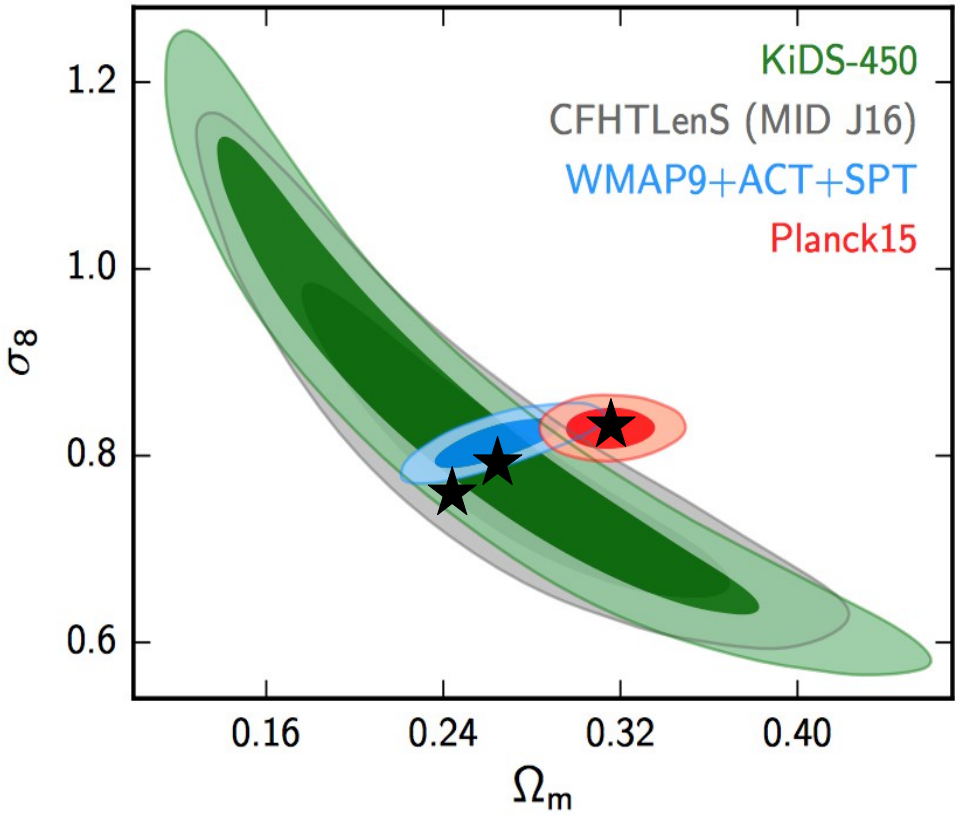

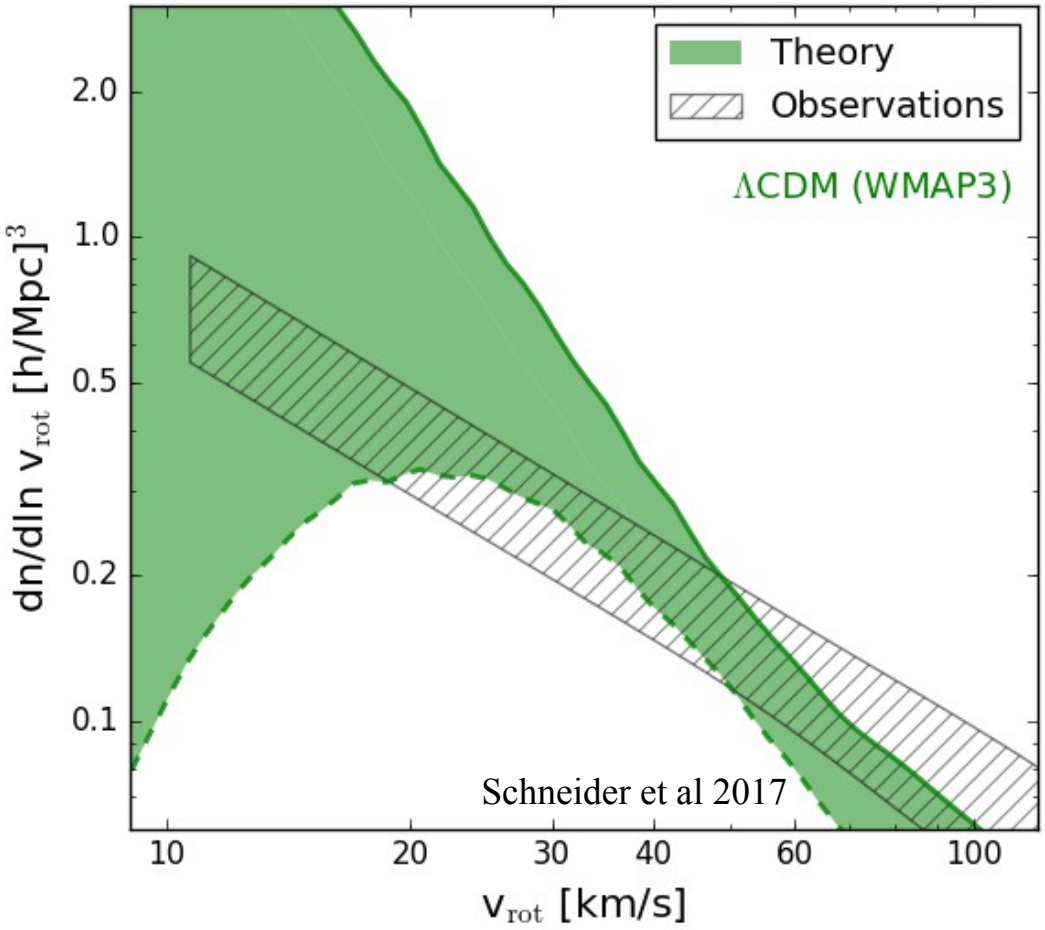

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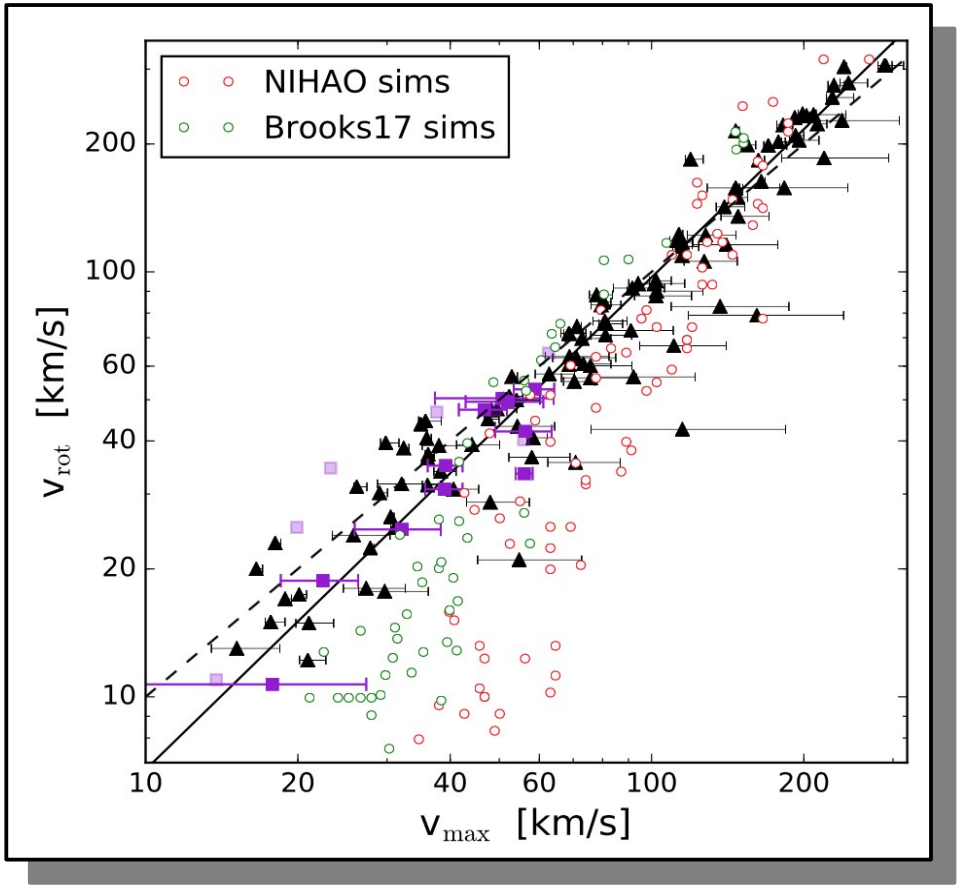
I. Velocity function – The future is bright !

Better and more data is required …

… and lot more is coming !



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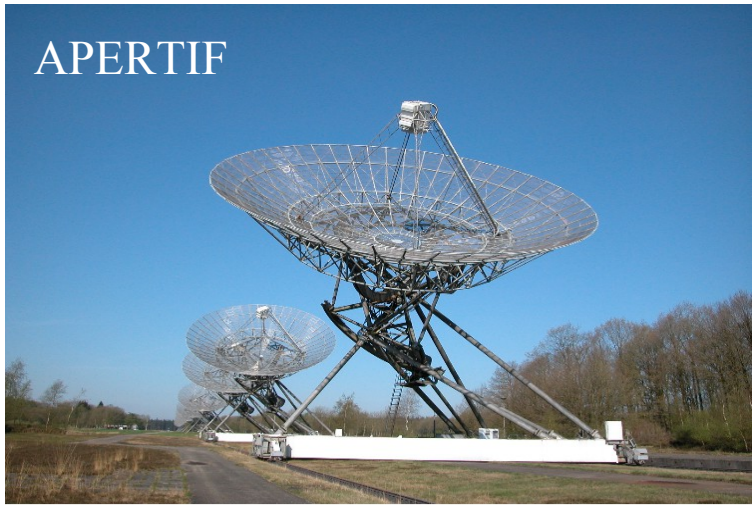

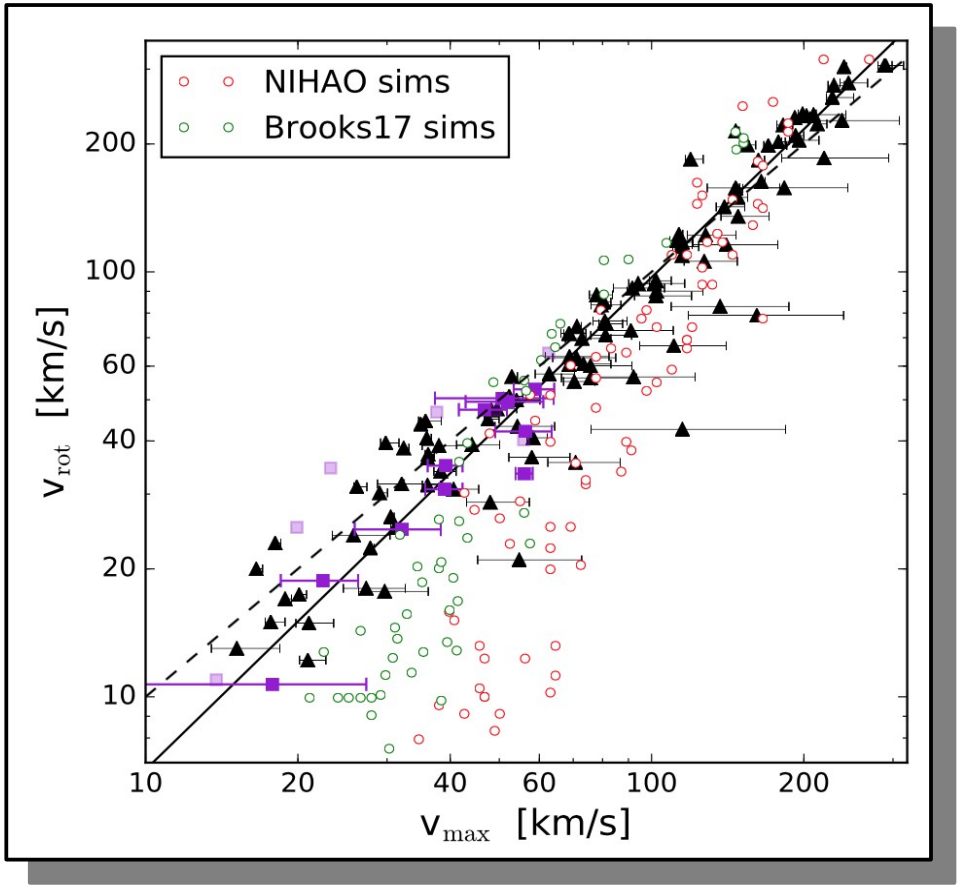

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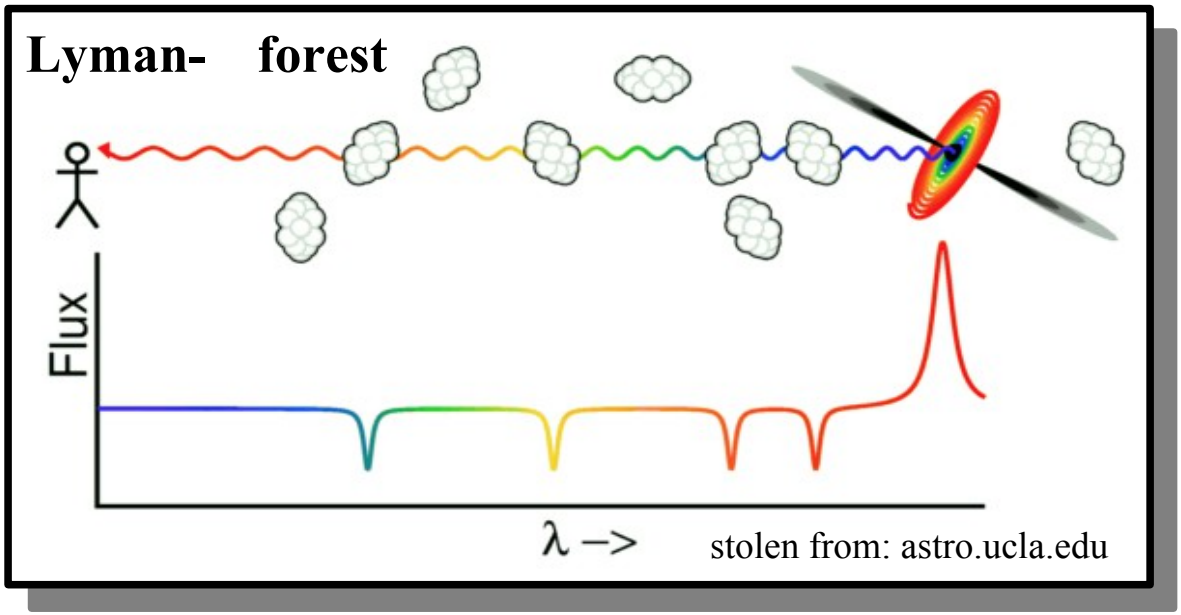

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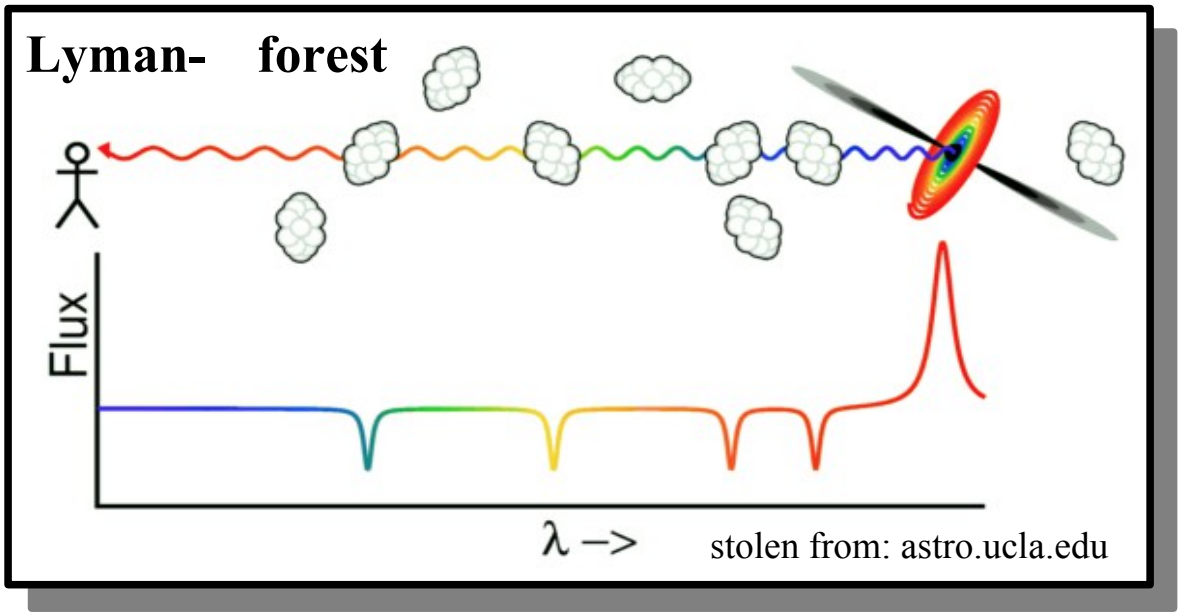

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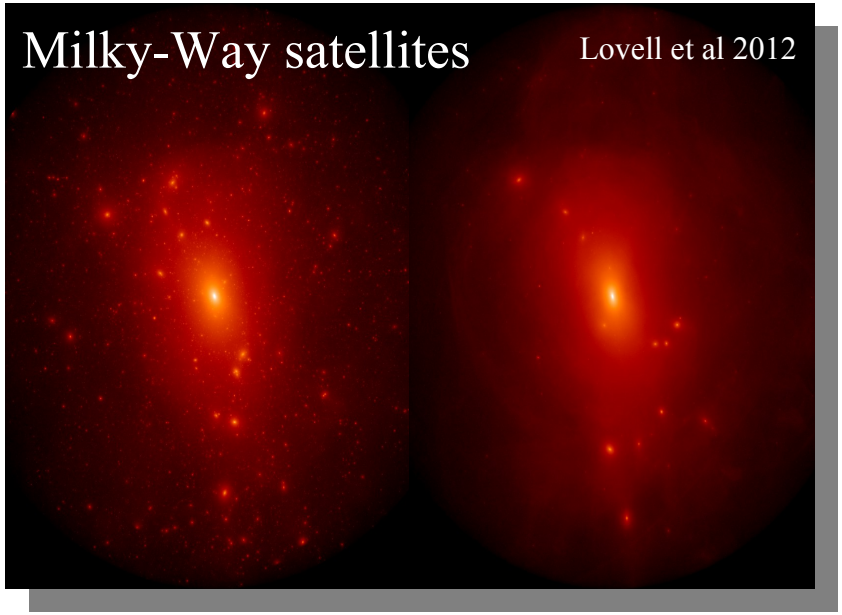

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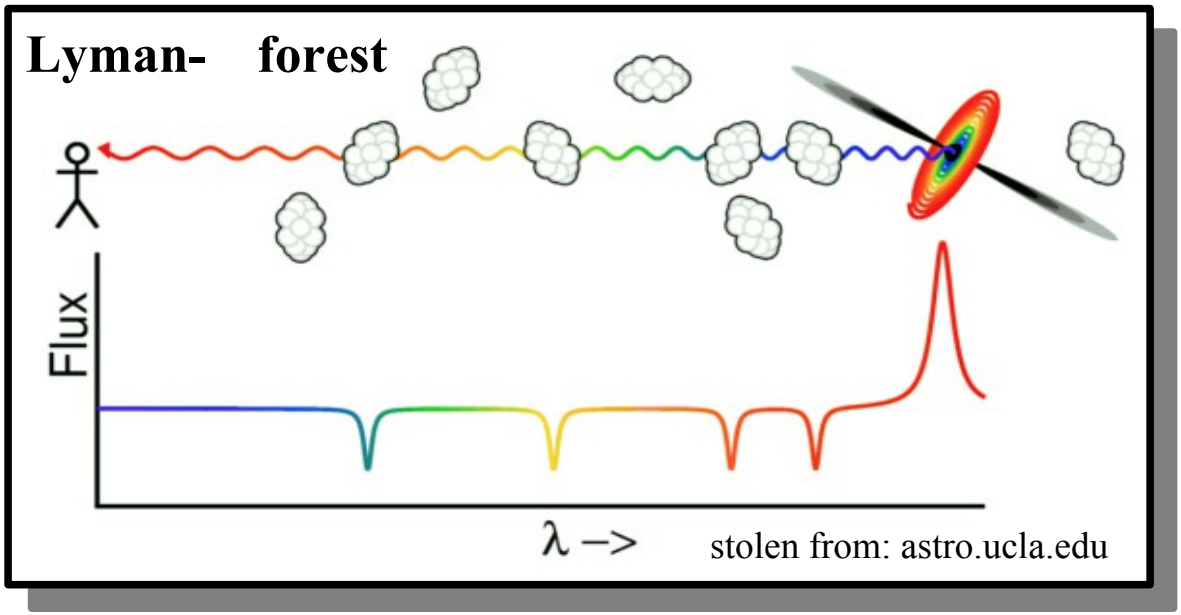

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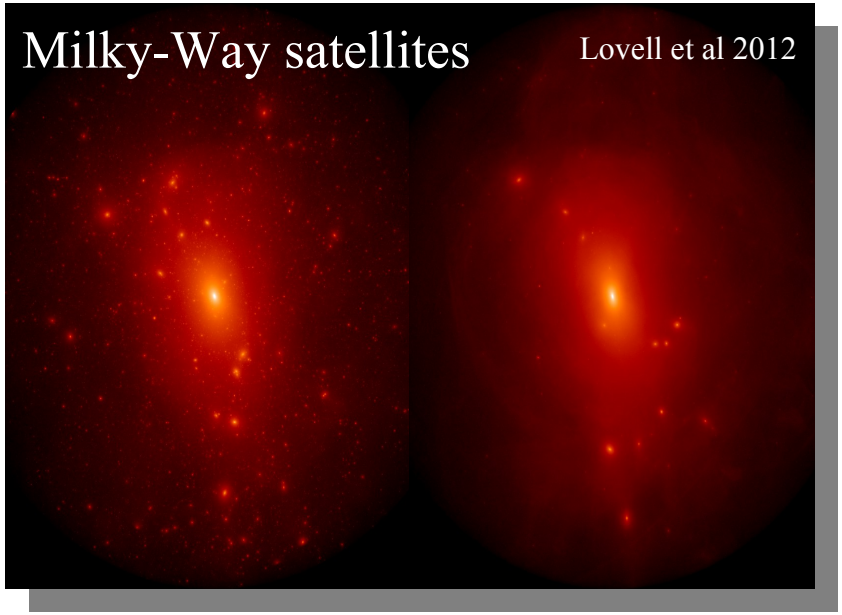

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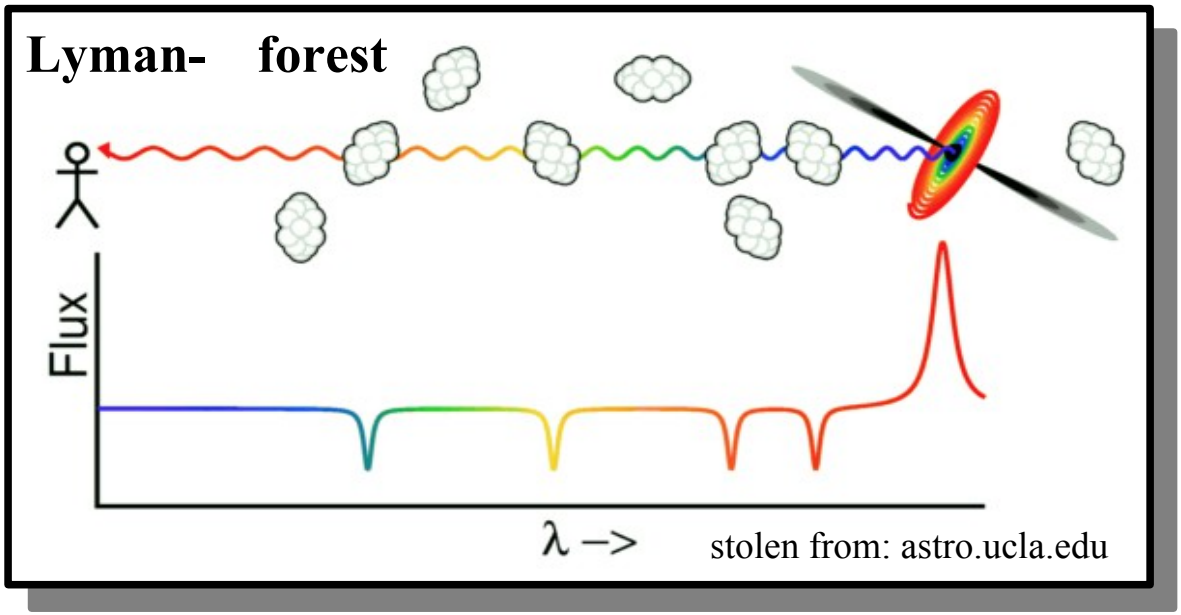

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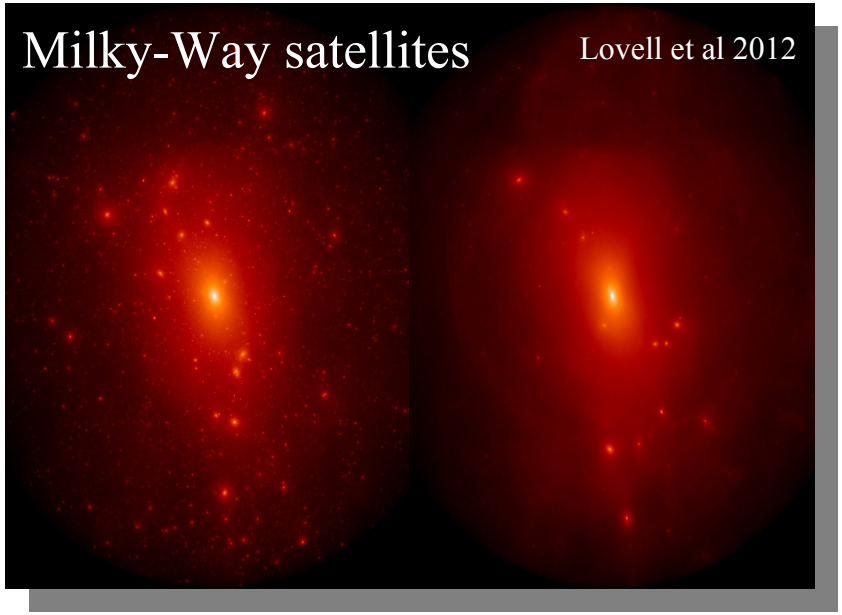

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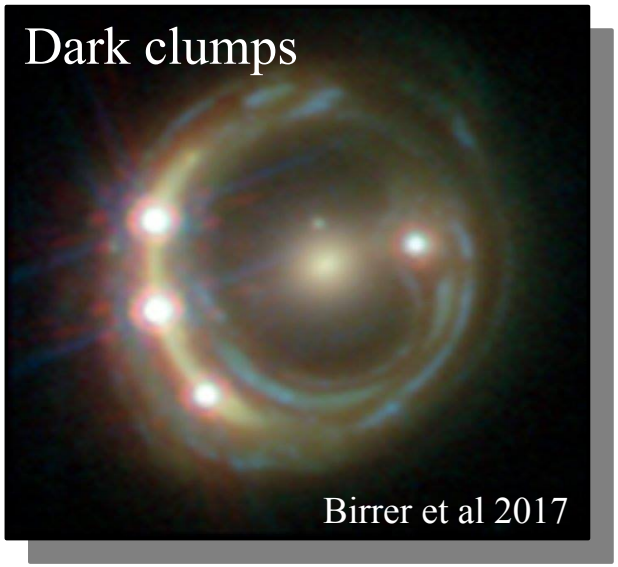

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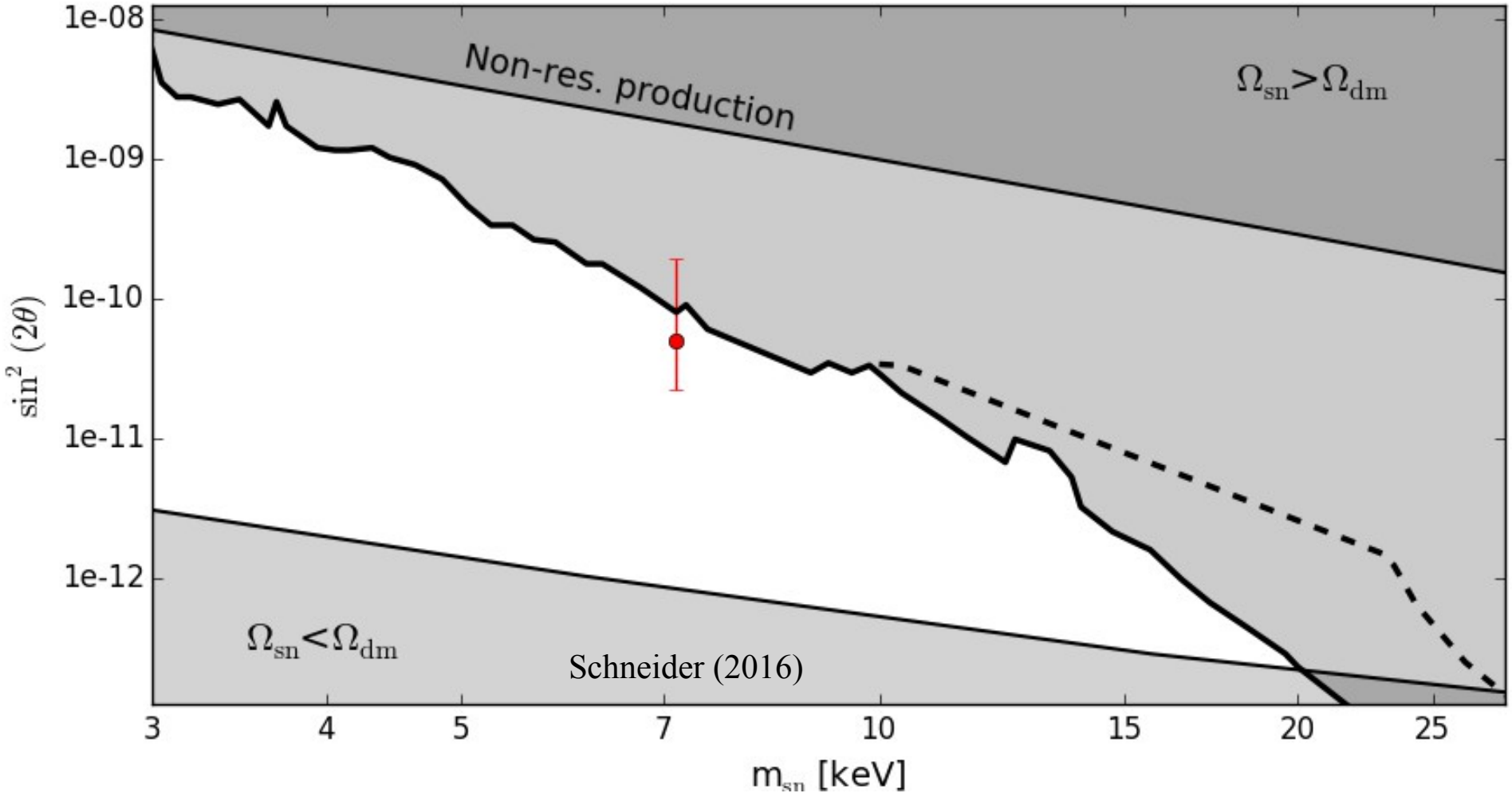

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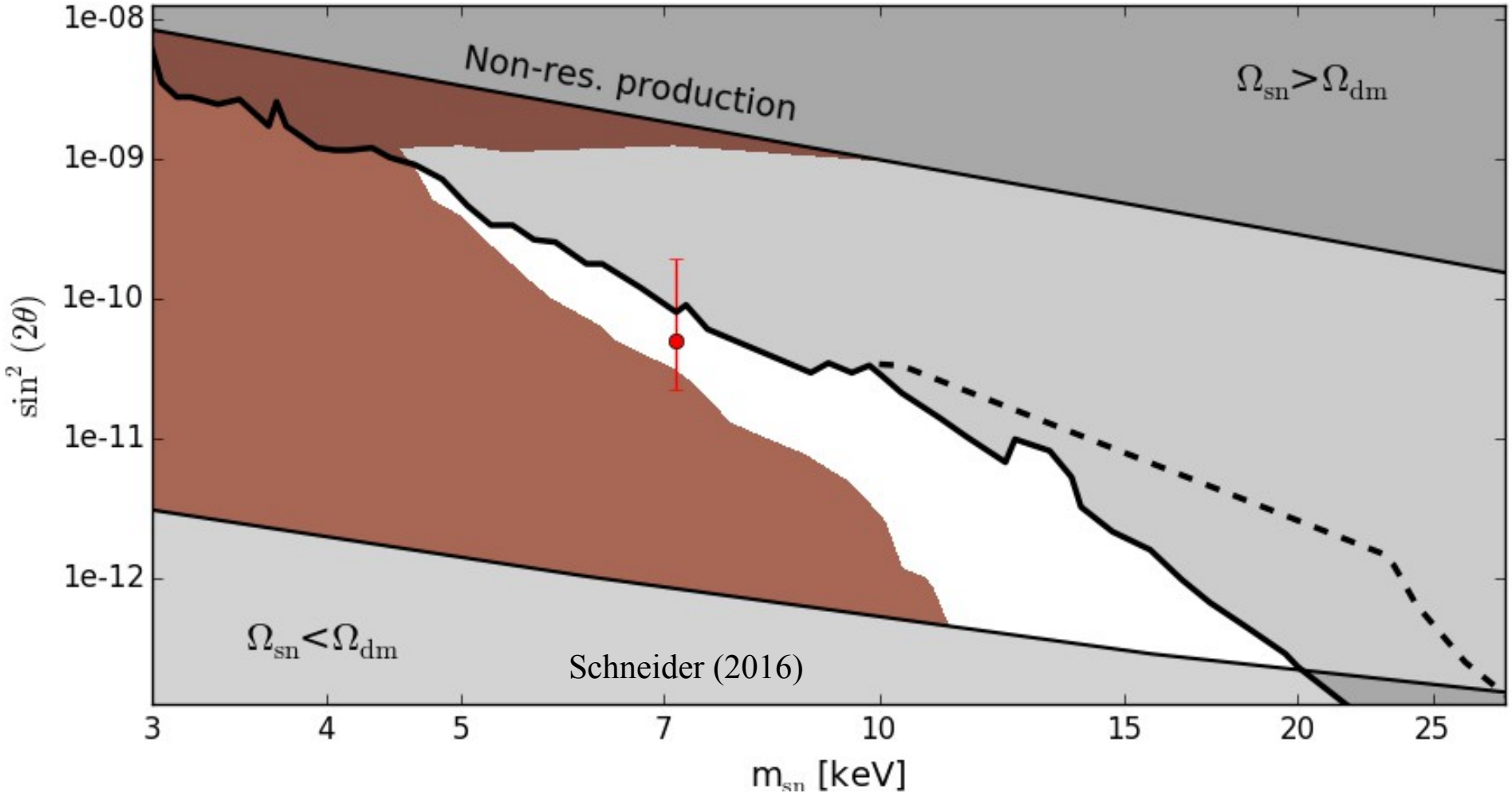

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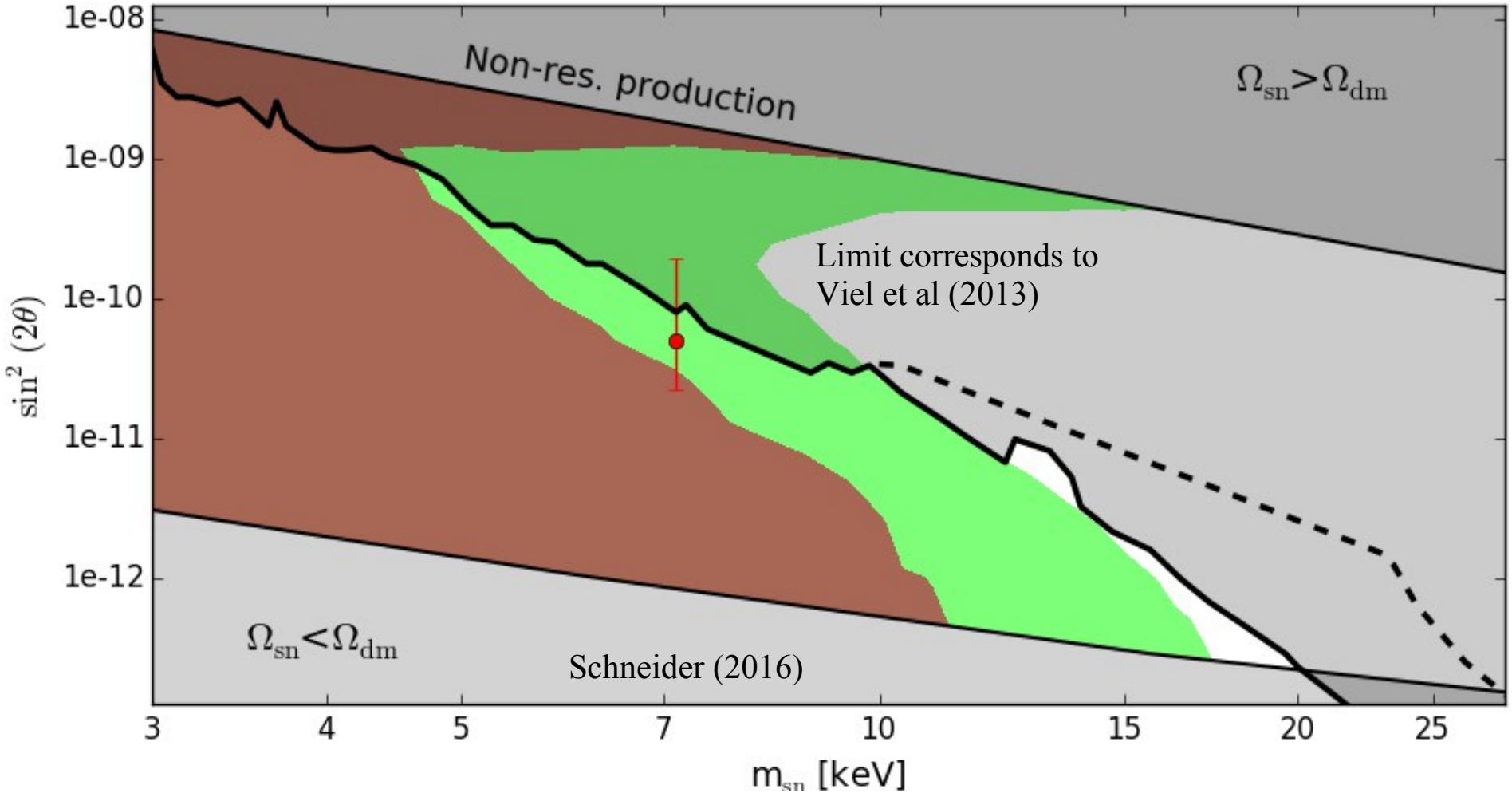

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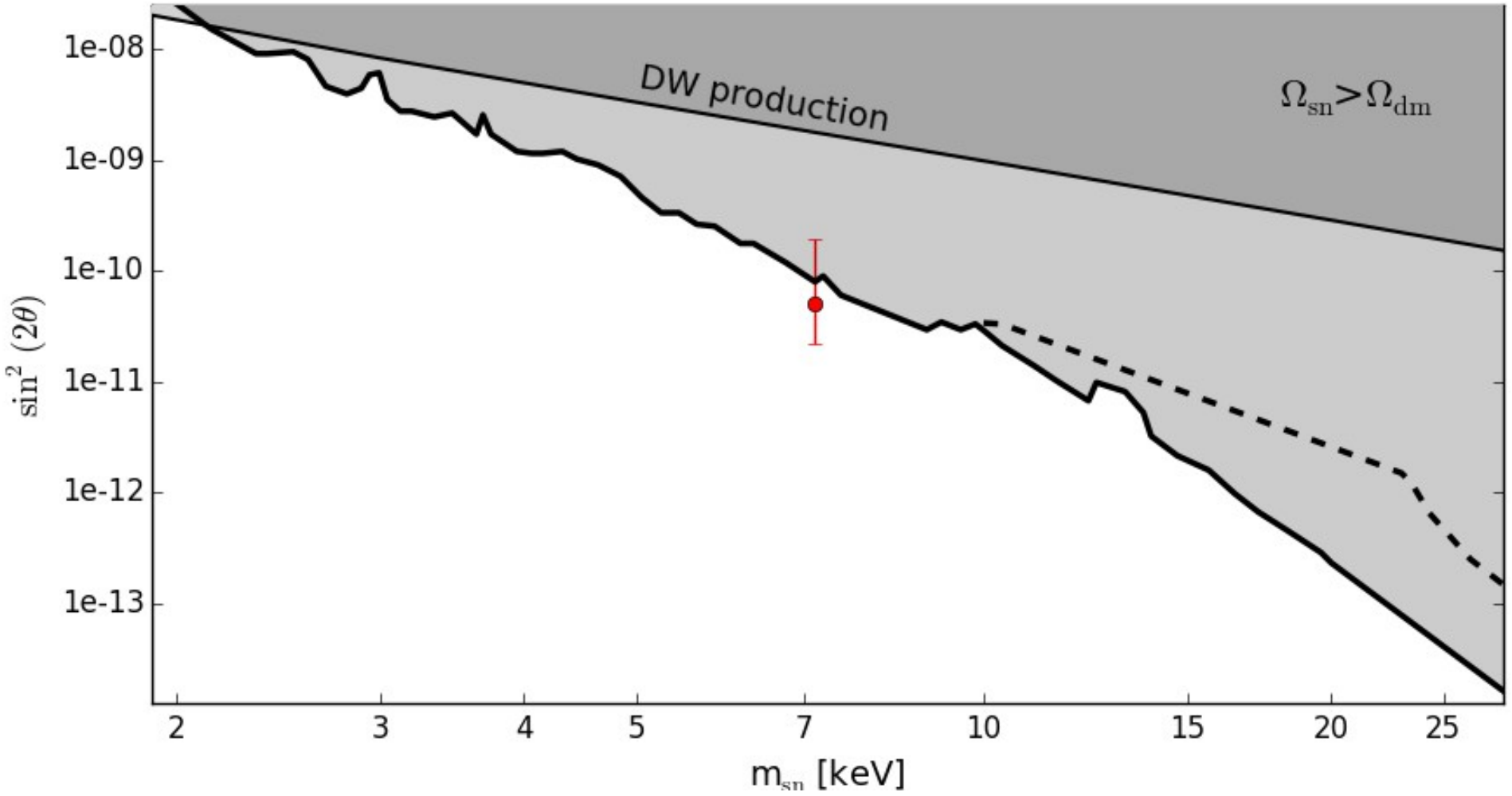

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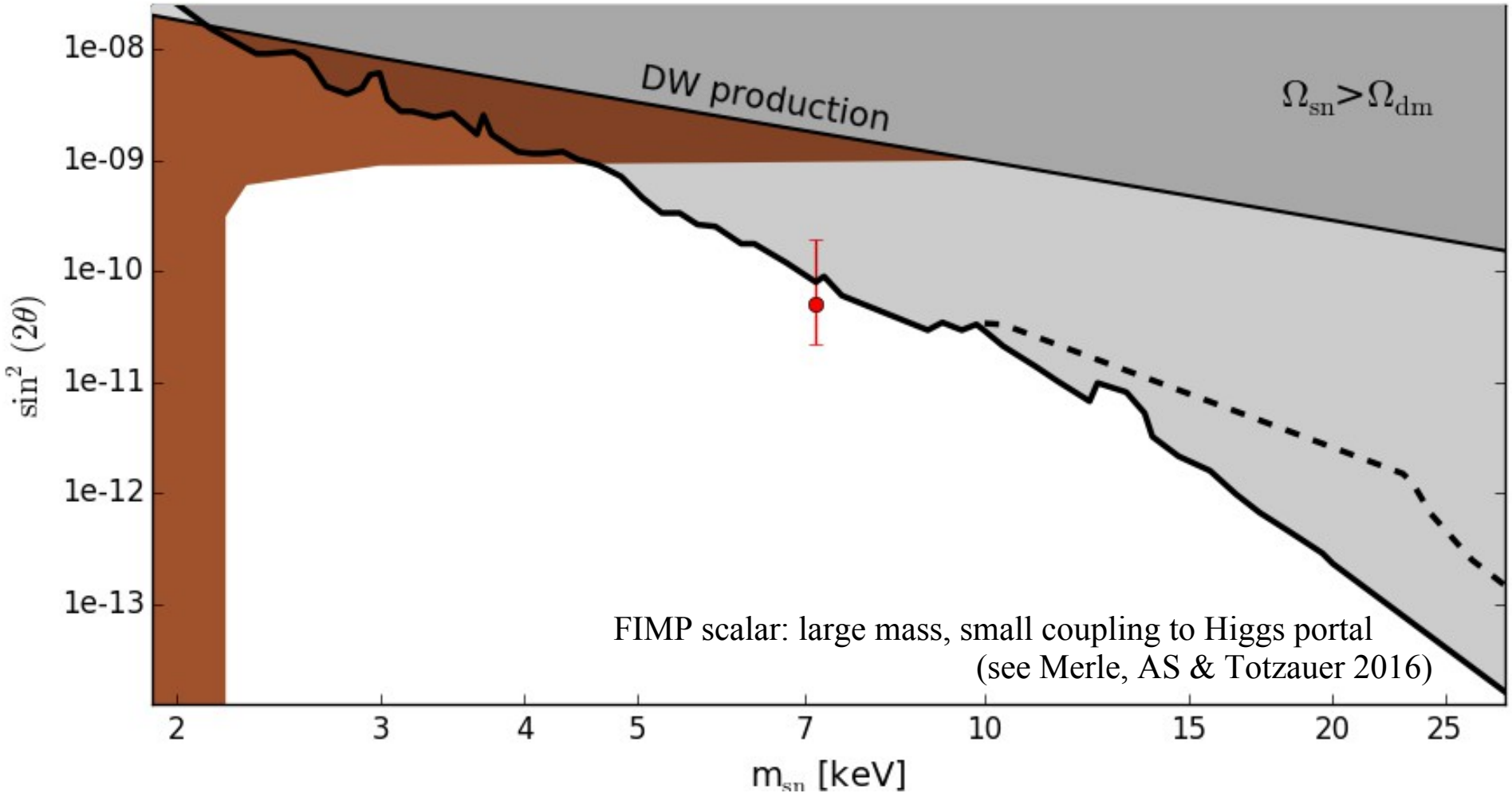

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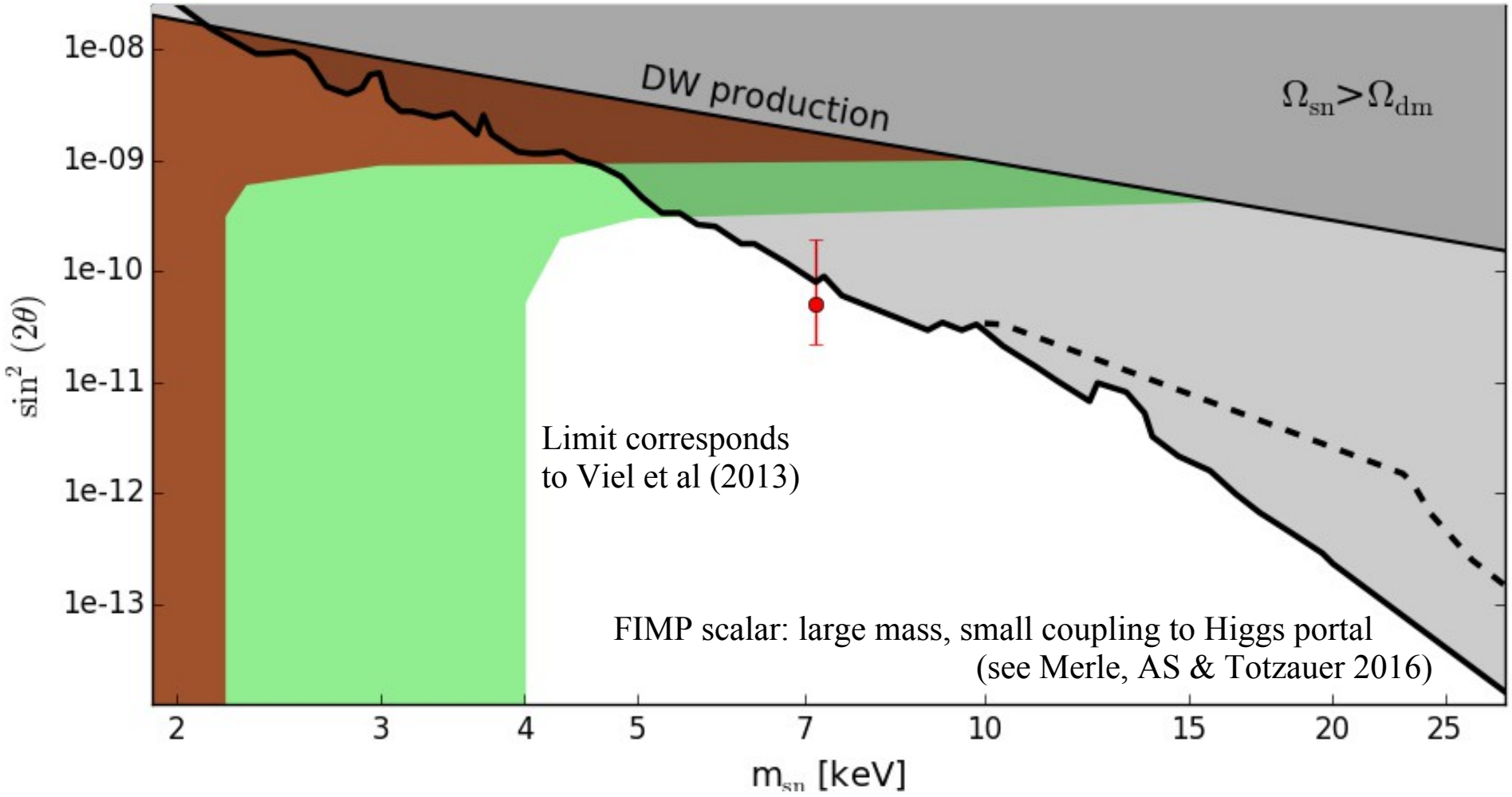

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Lyman-alpha – a word of warning:

Hydrogen density:

$$n_{\rm HI} \propto (1+\delta_b)^2 T^{-0.7} J^{-1}$$

Temp-density relation:

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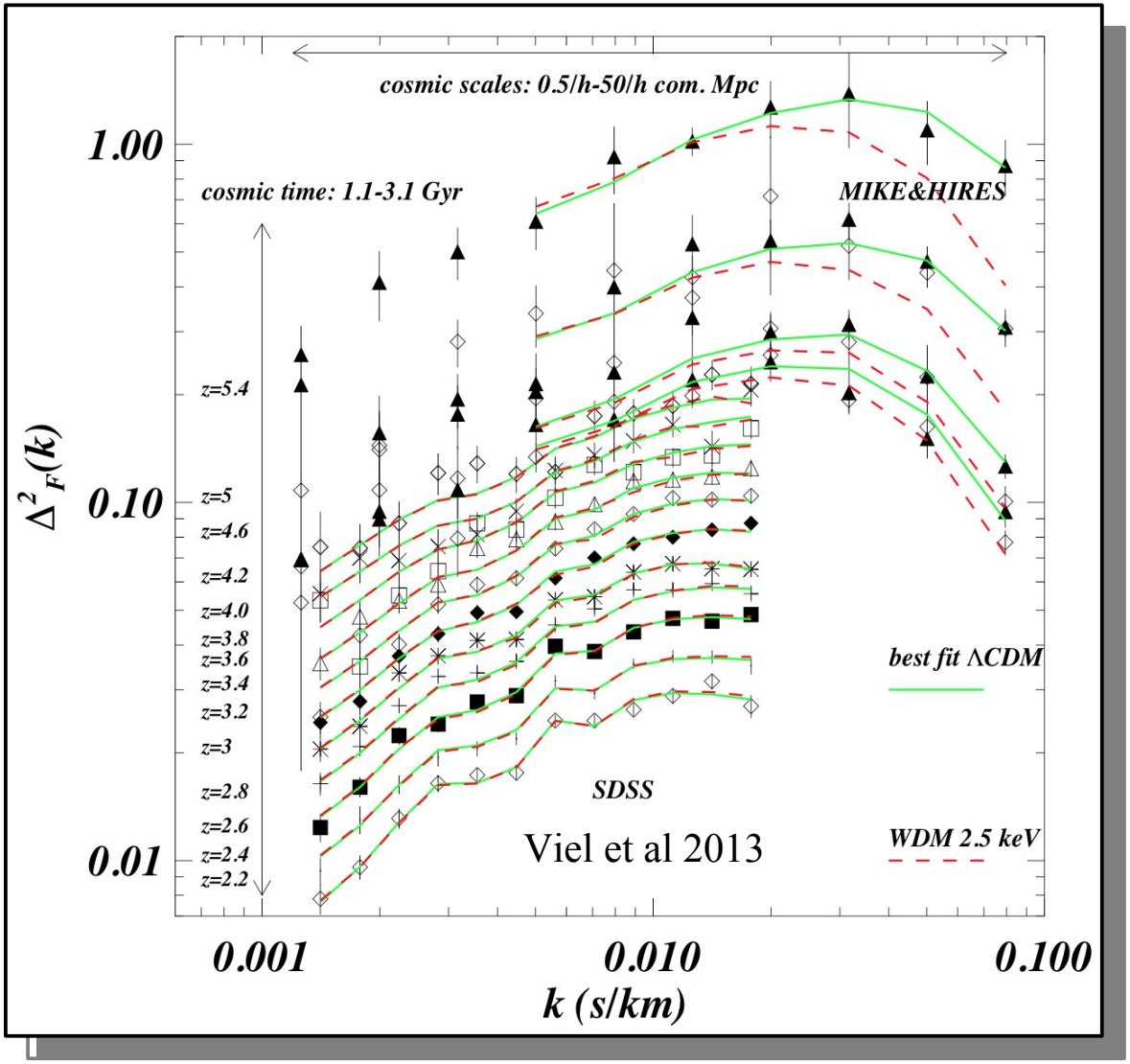
Are spatial variation negligible ?

Is T(z) a power law ?

(see Hui et al 2016)



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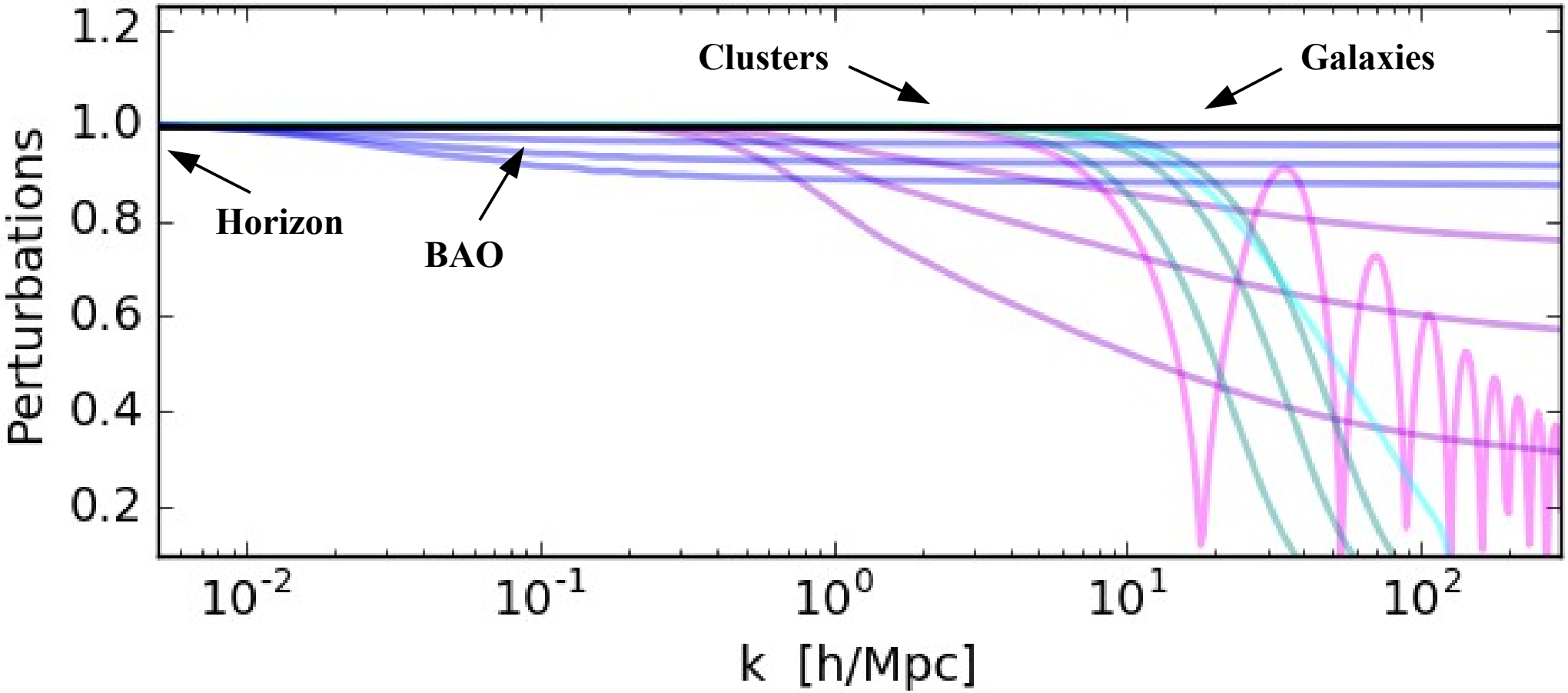

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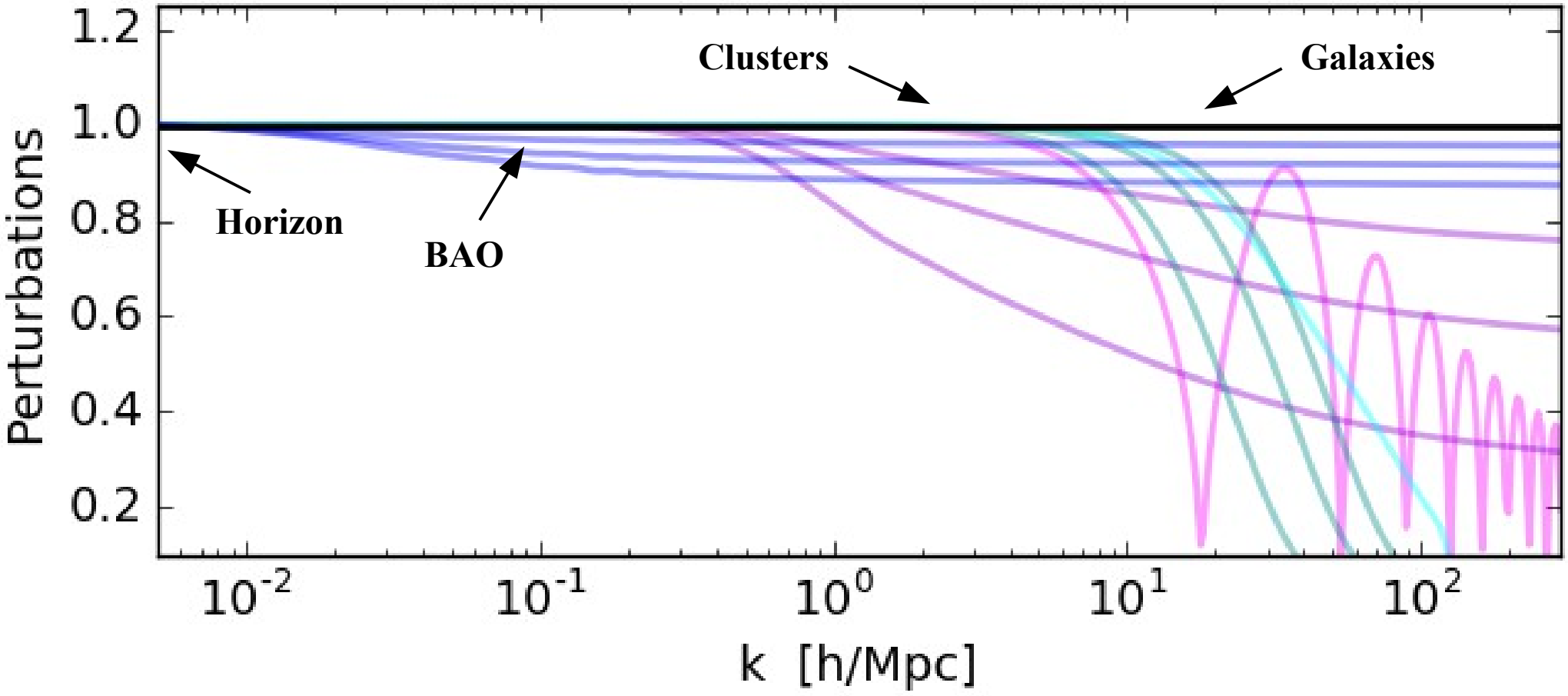
Higher order PT ⟵



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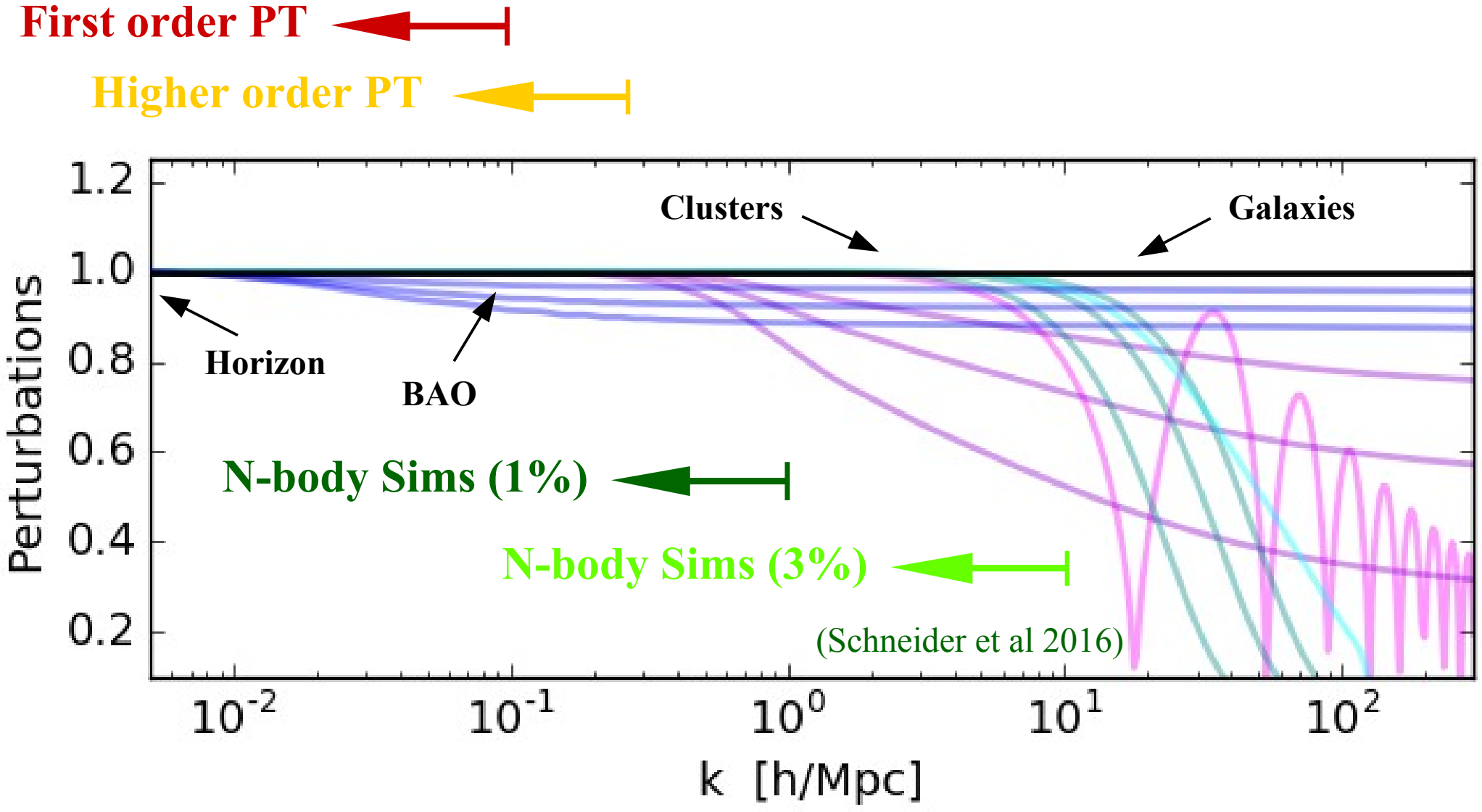

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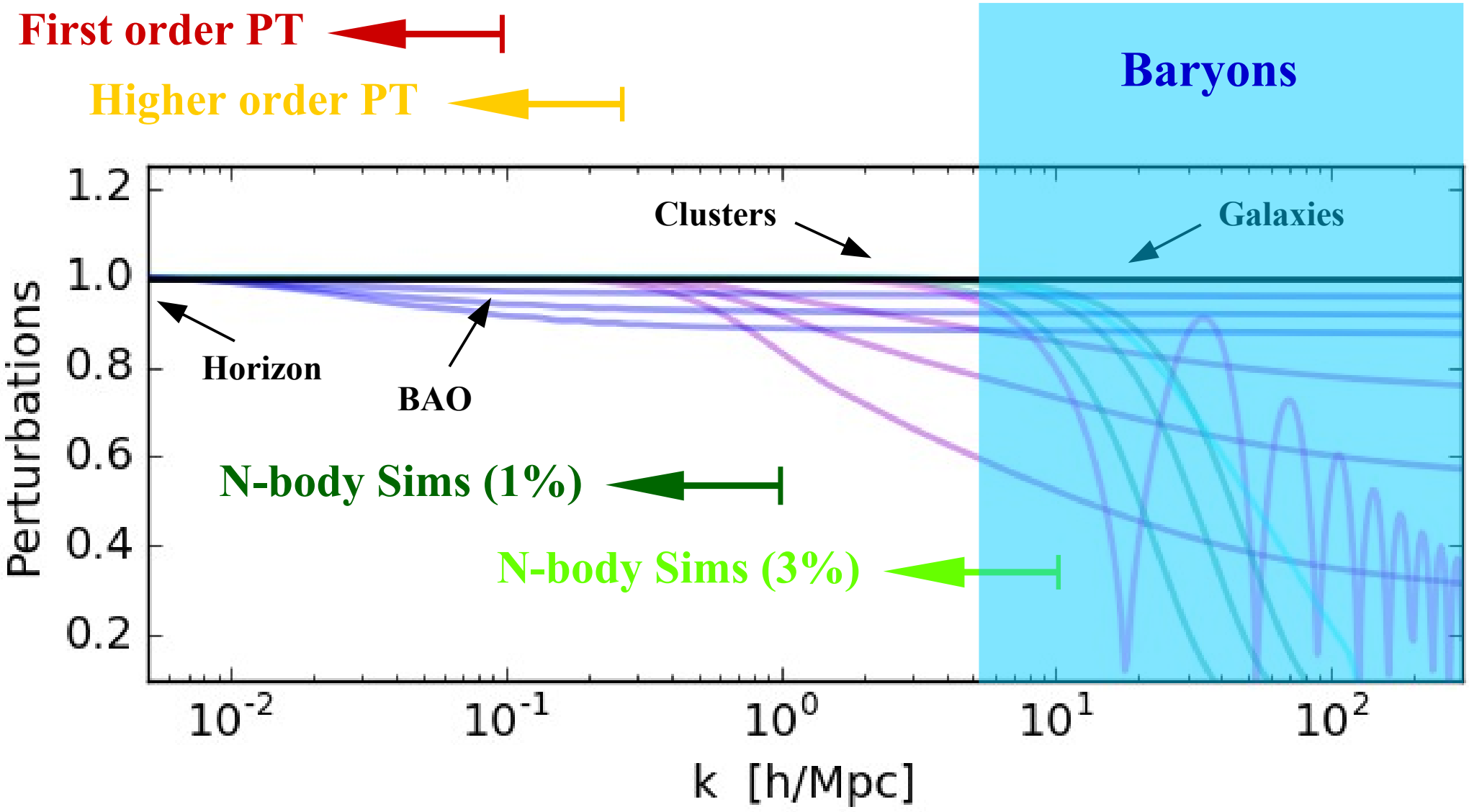

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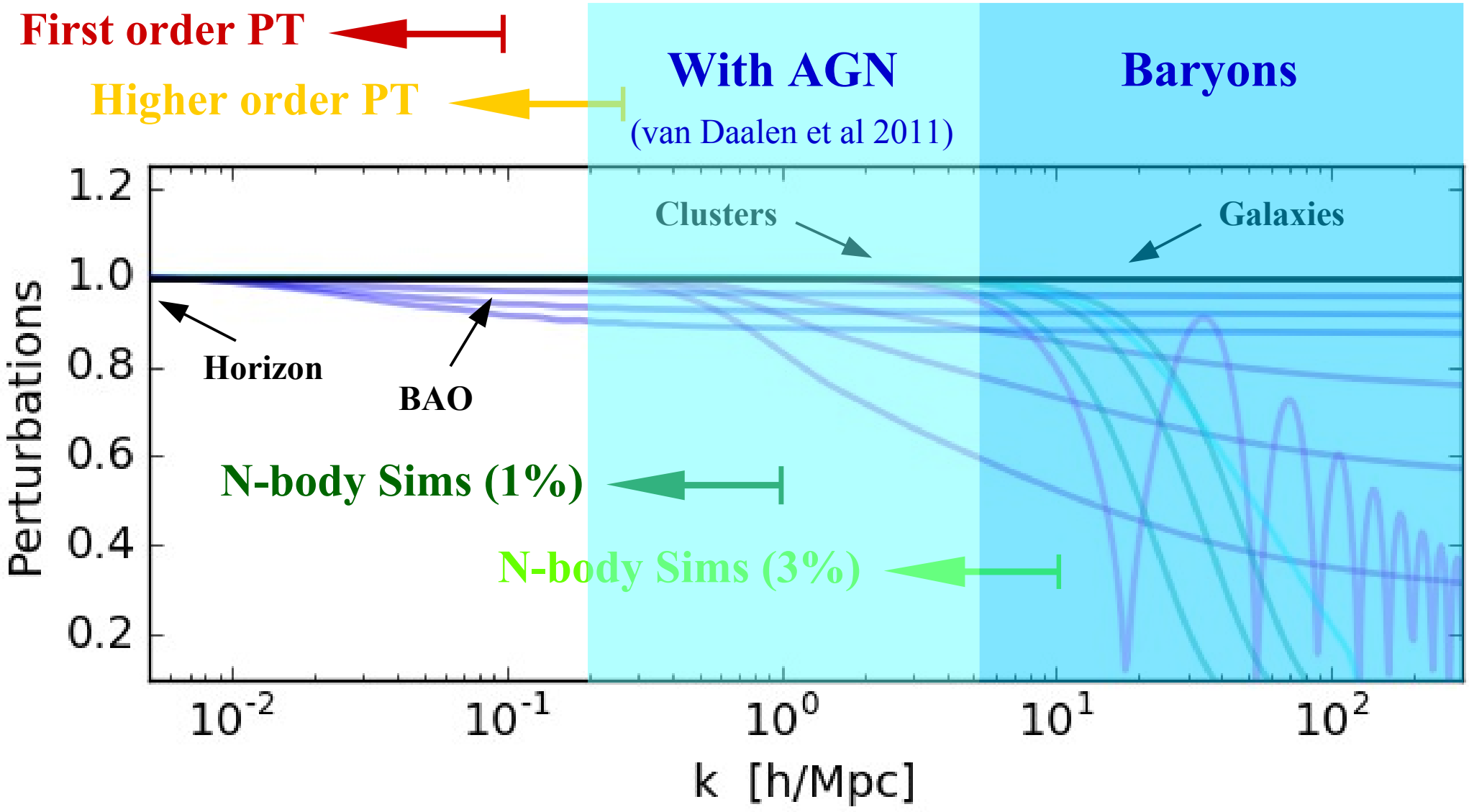

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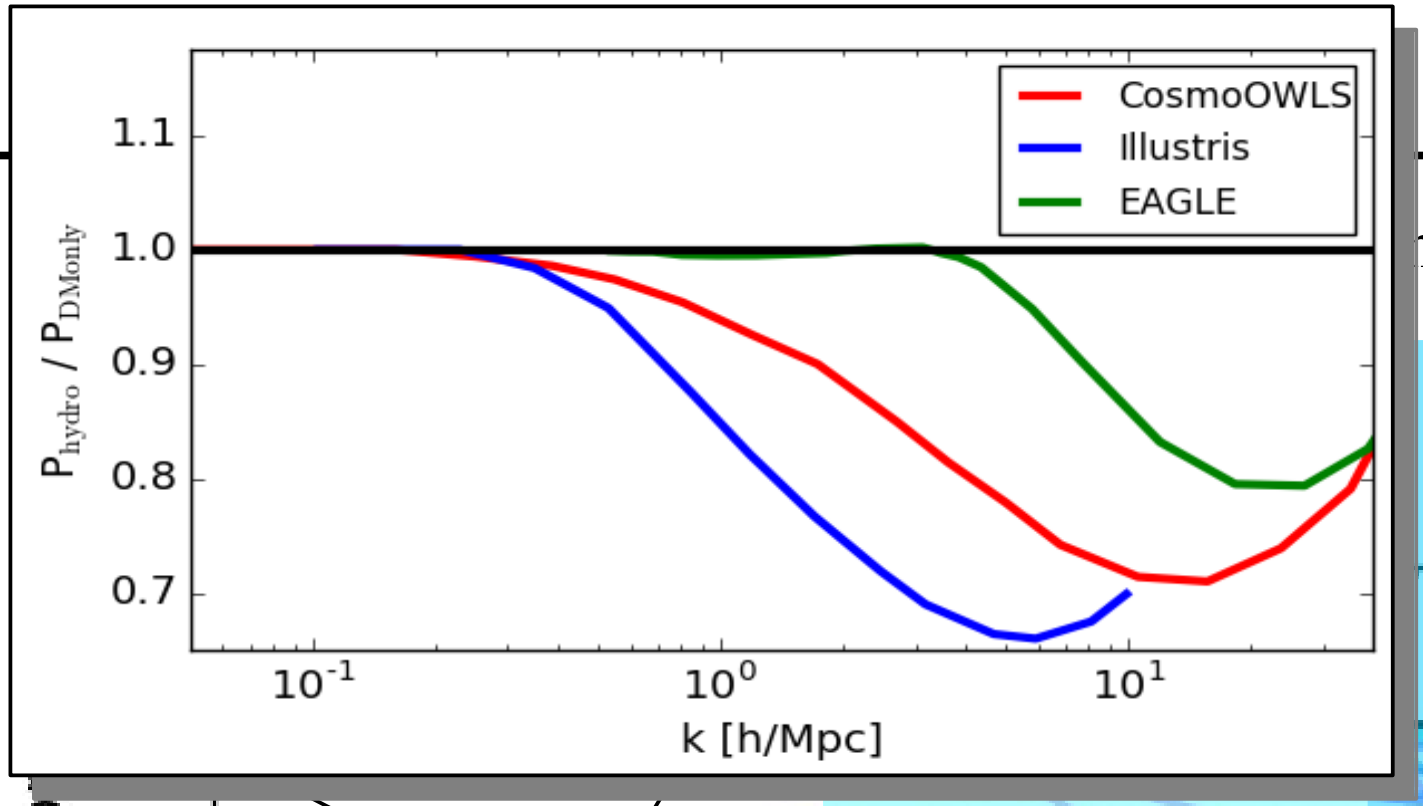

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Full hydro sims: based on semi-analytical subgrid models !

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→ Possible alternative: high-level parametrisation

(change halo profiles – measure cosmological statistics)

How it works:

Initial halo profiles:

$$\rho_{\rm dmo}(r) = \rho_{\rm nfw}(r) + \bar{\rho}_{\rm bg}$$

background

truncated NFW

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Corrected halo profiles:

$$\rho_{\rm bcm}(r) = f_{\rm rdm} y_{\rm rdm}(r) + f_{\rm bgas}(M) y_{\rm bgas}(r) + f_{\rm egas}(M) y_{\rm egas}(r) + f_{\rm cgal}(M) y_{\rm cgal}(r) + \bar{\rho}_{\rm bg}$$

adiabatically relaxed DM

bound gas

ejected gas

central galaxy

background

How it v

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$\rho_{\rm dmo}(r) =$

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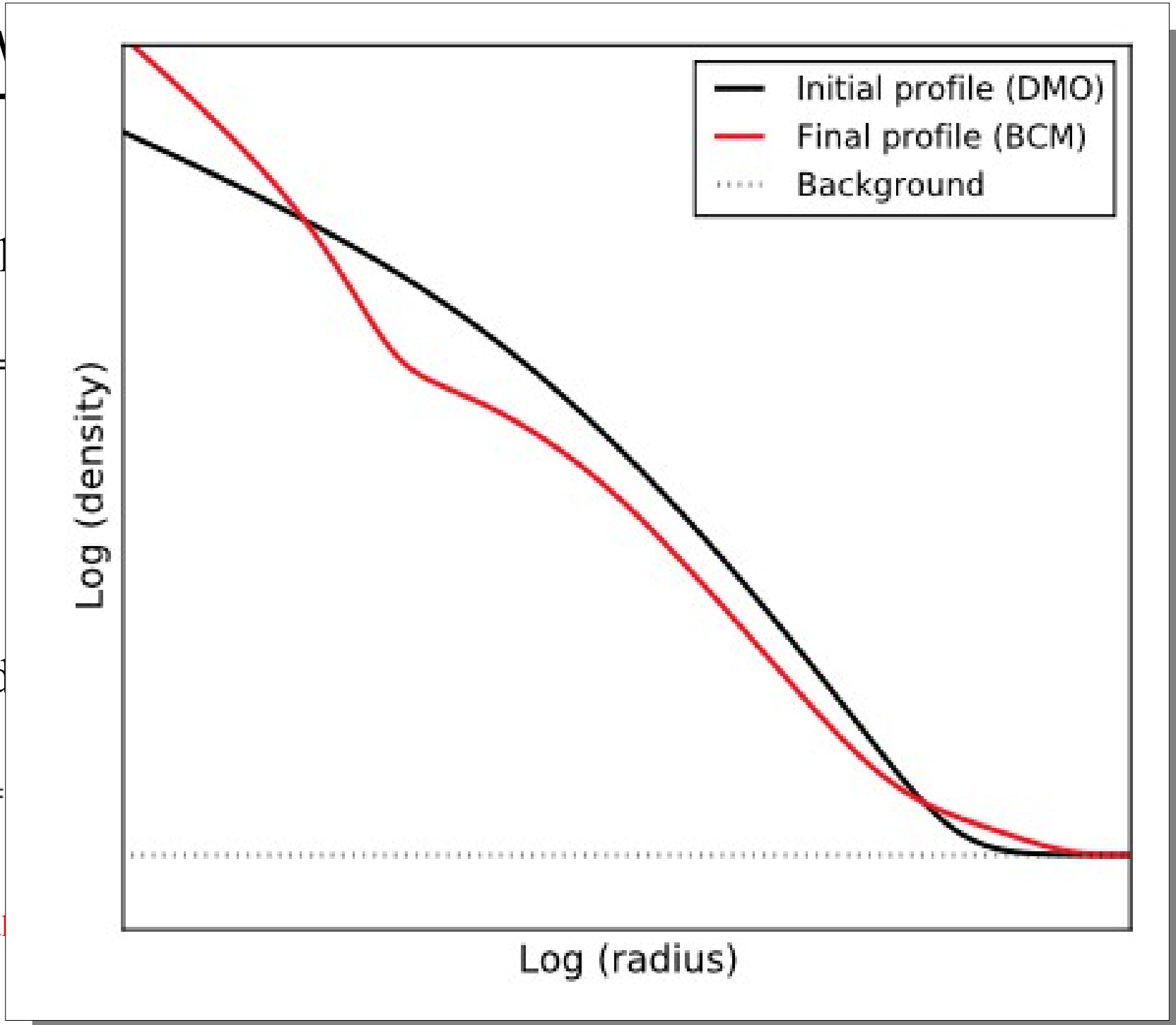
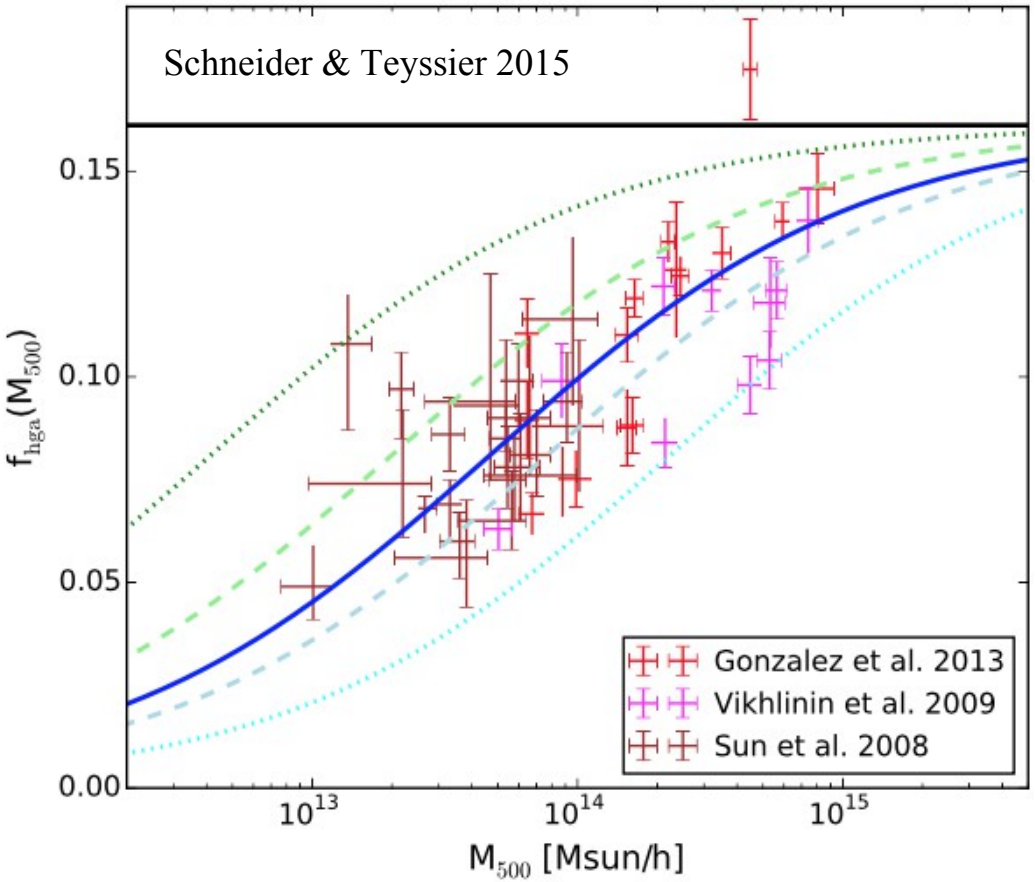
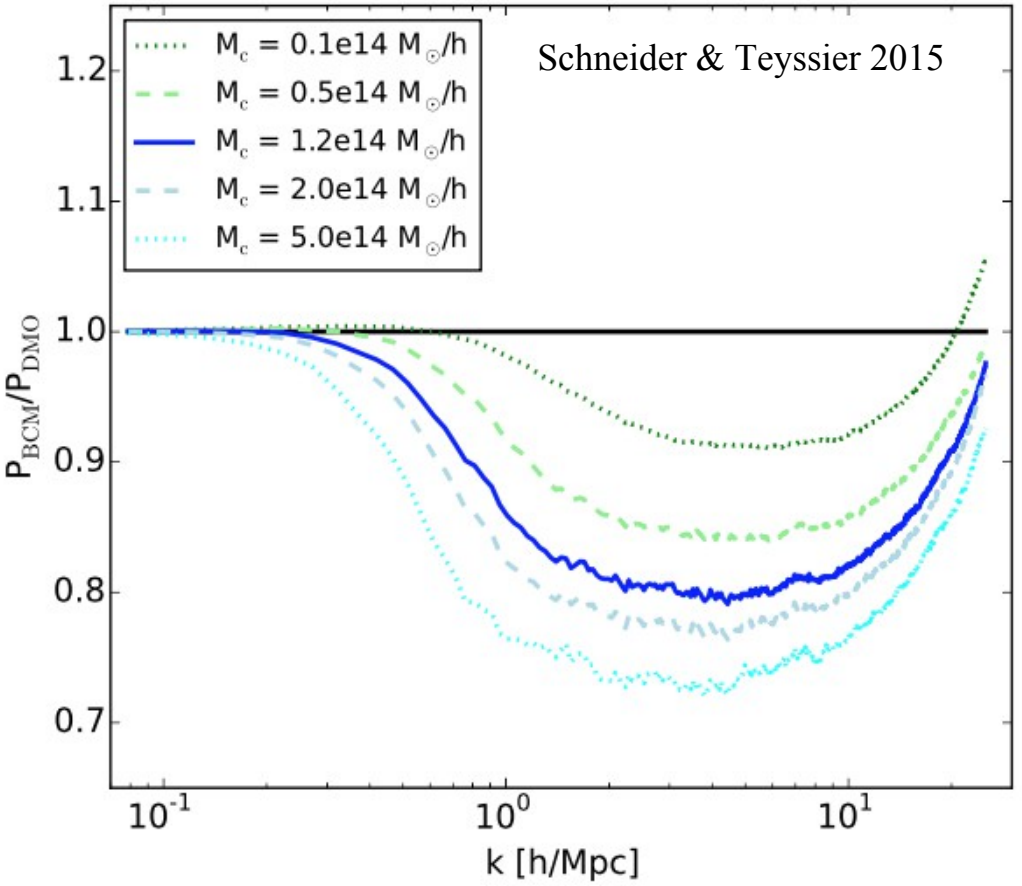


Power suppression with two parameters

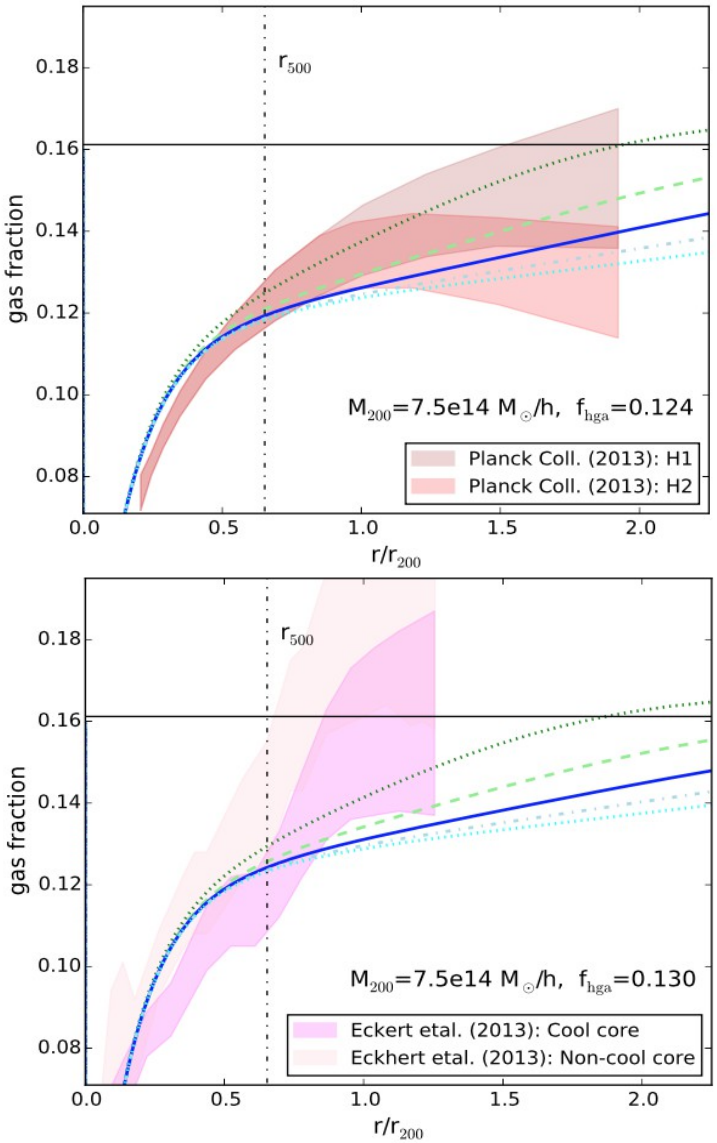
Only two main parameters: ejected gas fraction and …

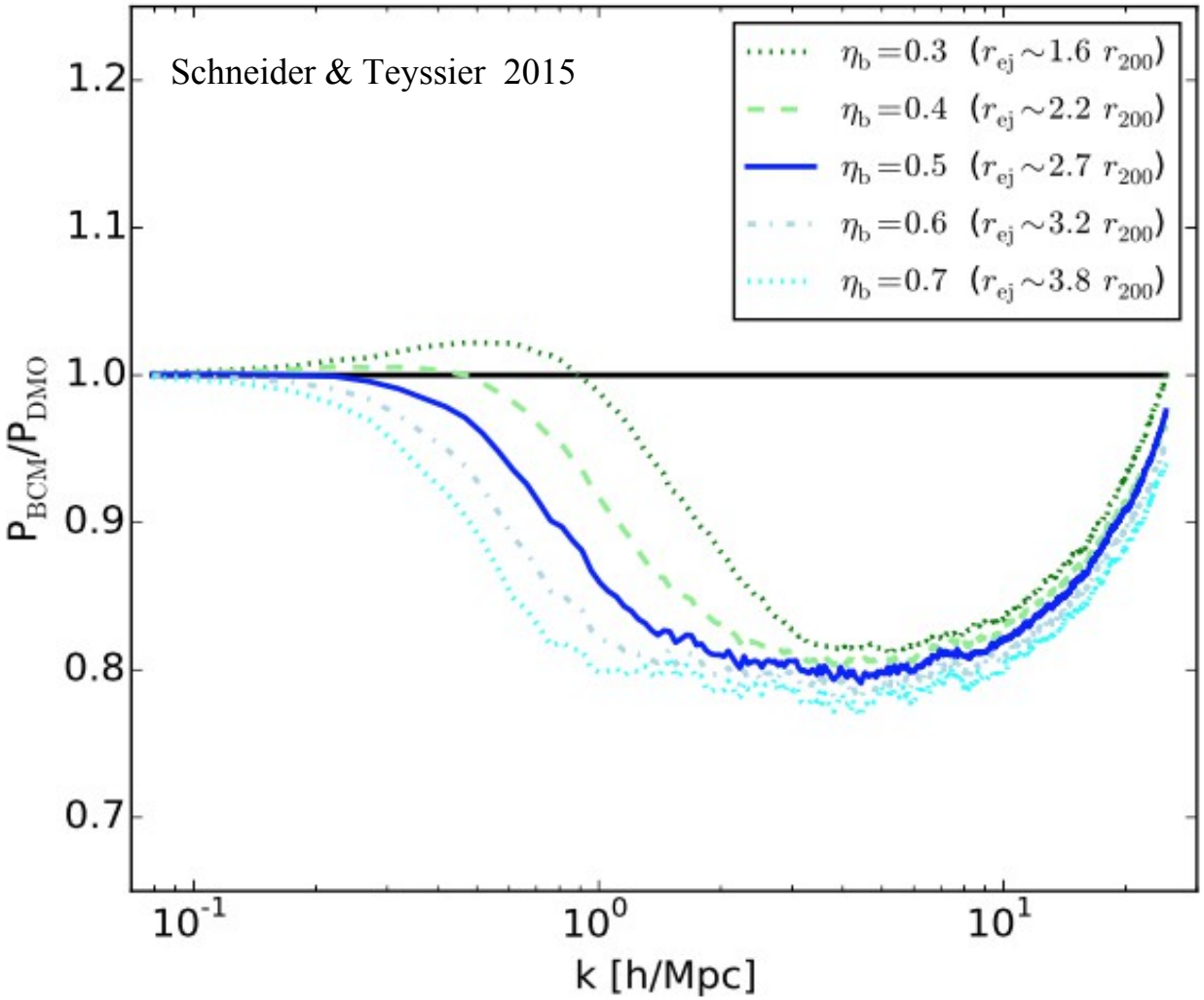




Power suppression with two parameters

Only two main parameters: … ejected gas radius

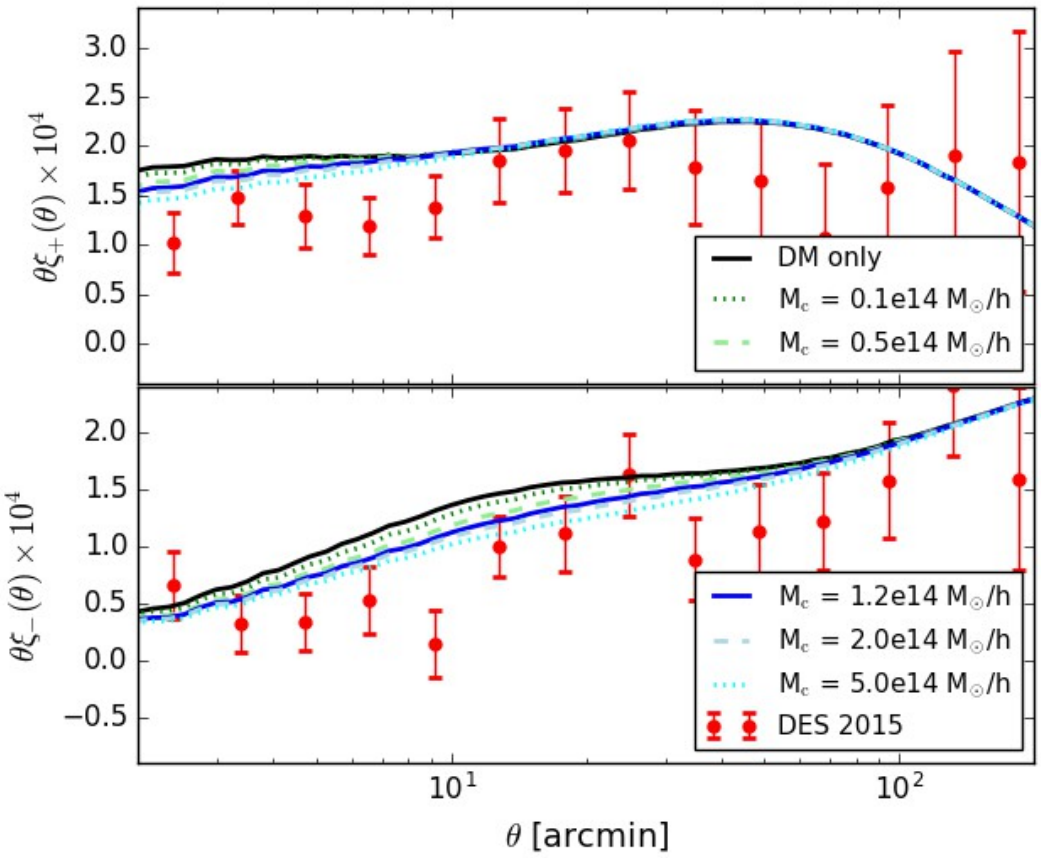




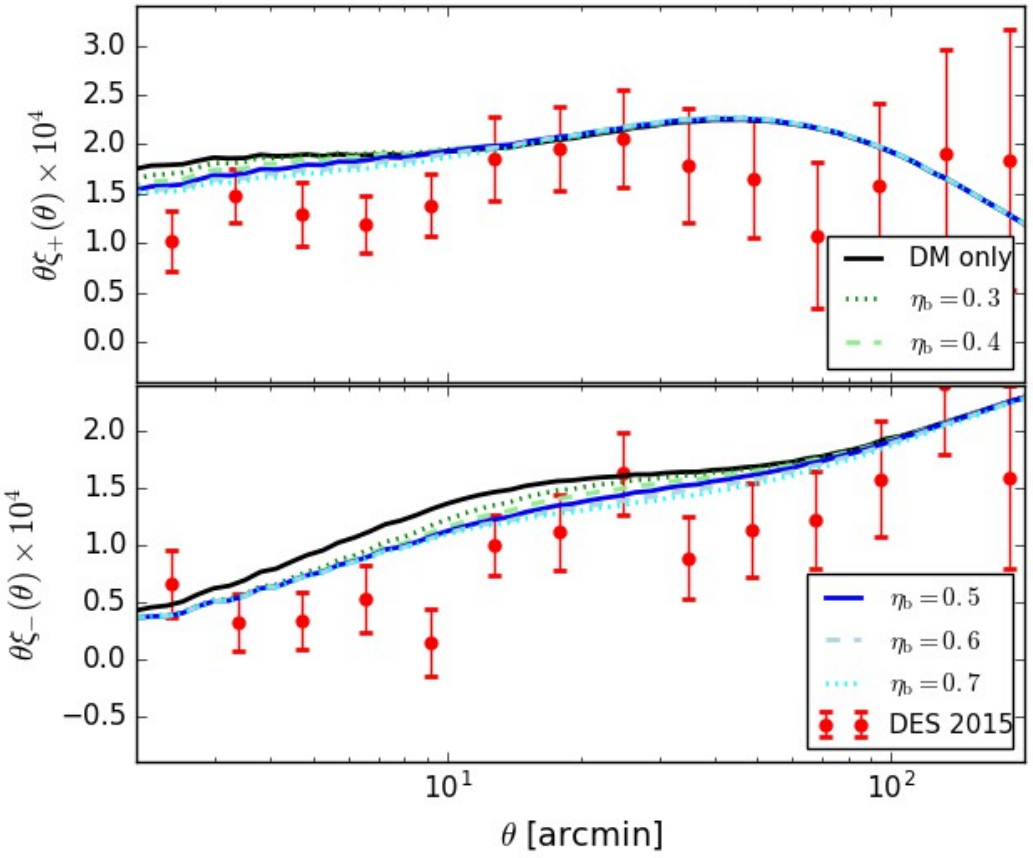
THE FUTURE – where to go from here ?

Example: lensing shear correlation:

First param: ejected gas fraction



Second param: ejected gas radius



Large scale structure: the future is bright !

A lot of data in the next decade (DES, eBOSS, Euclid, LSST, etc) !

What is in there for DM ?

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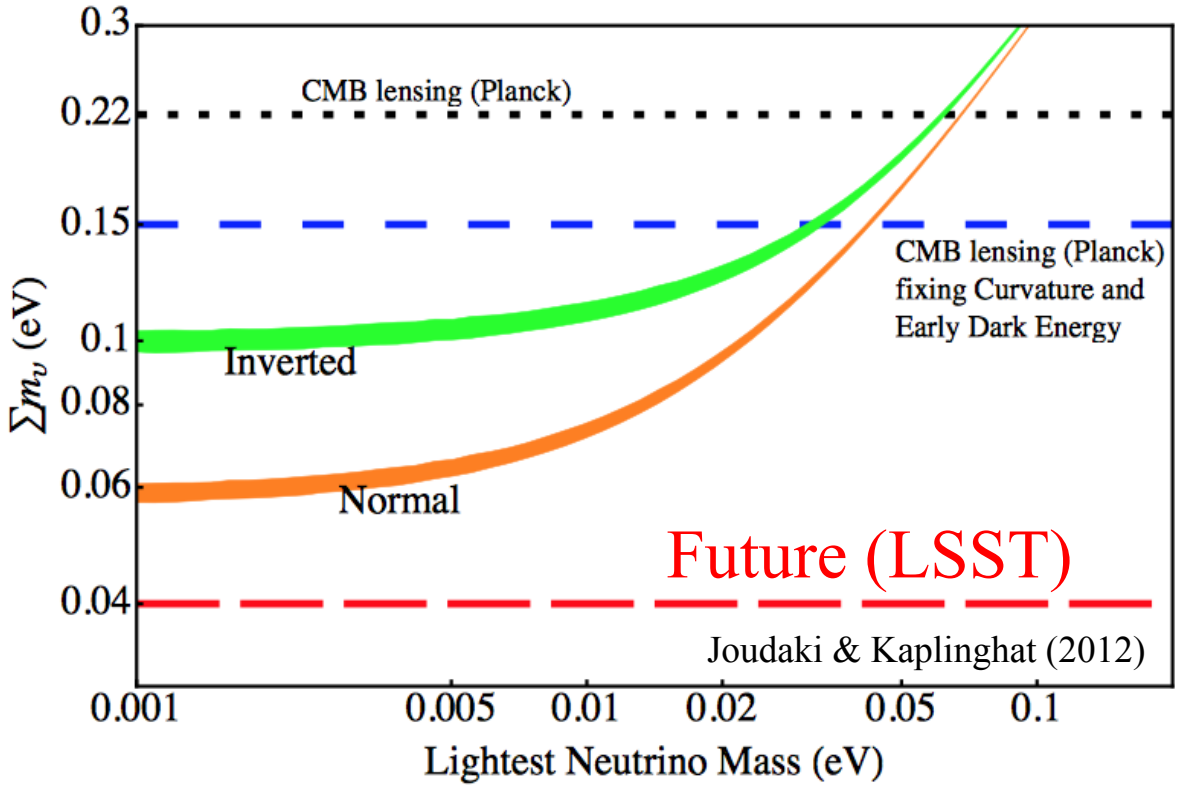
Neutrino masses and hierarchy – the guaranteed success !



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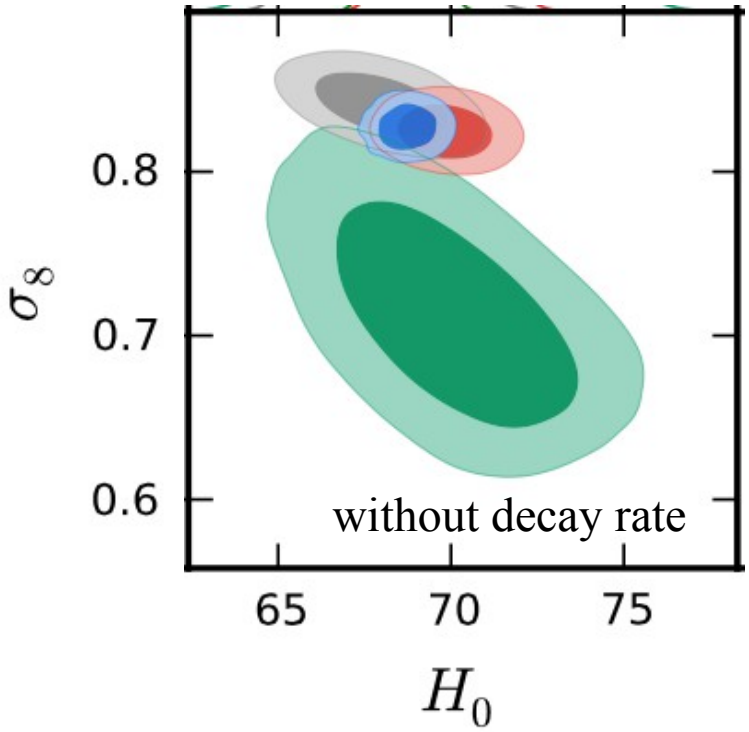
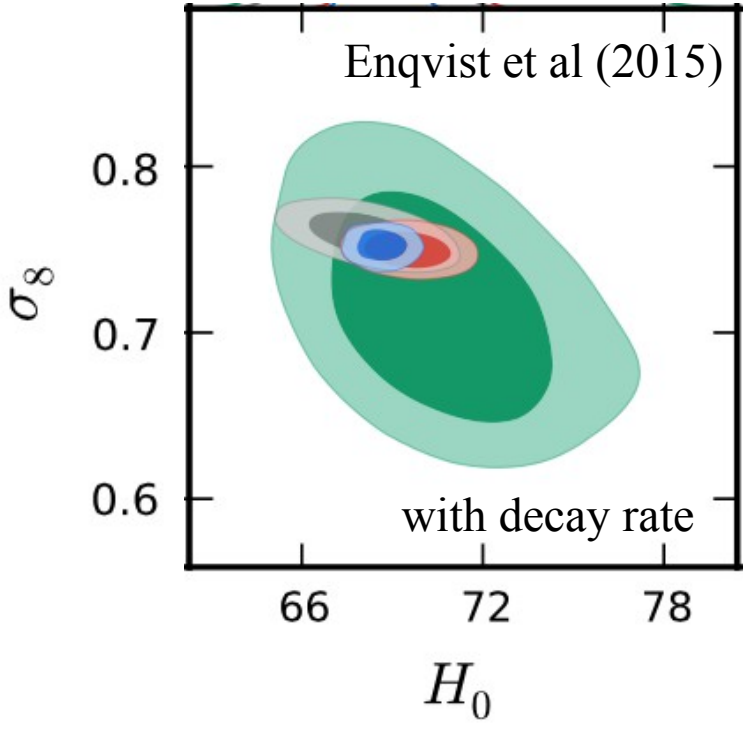
Decaying DM – is there a hint ?





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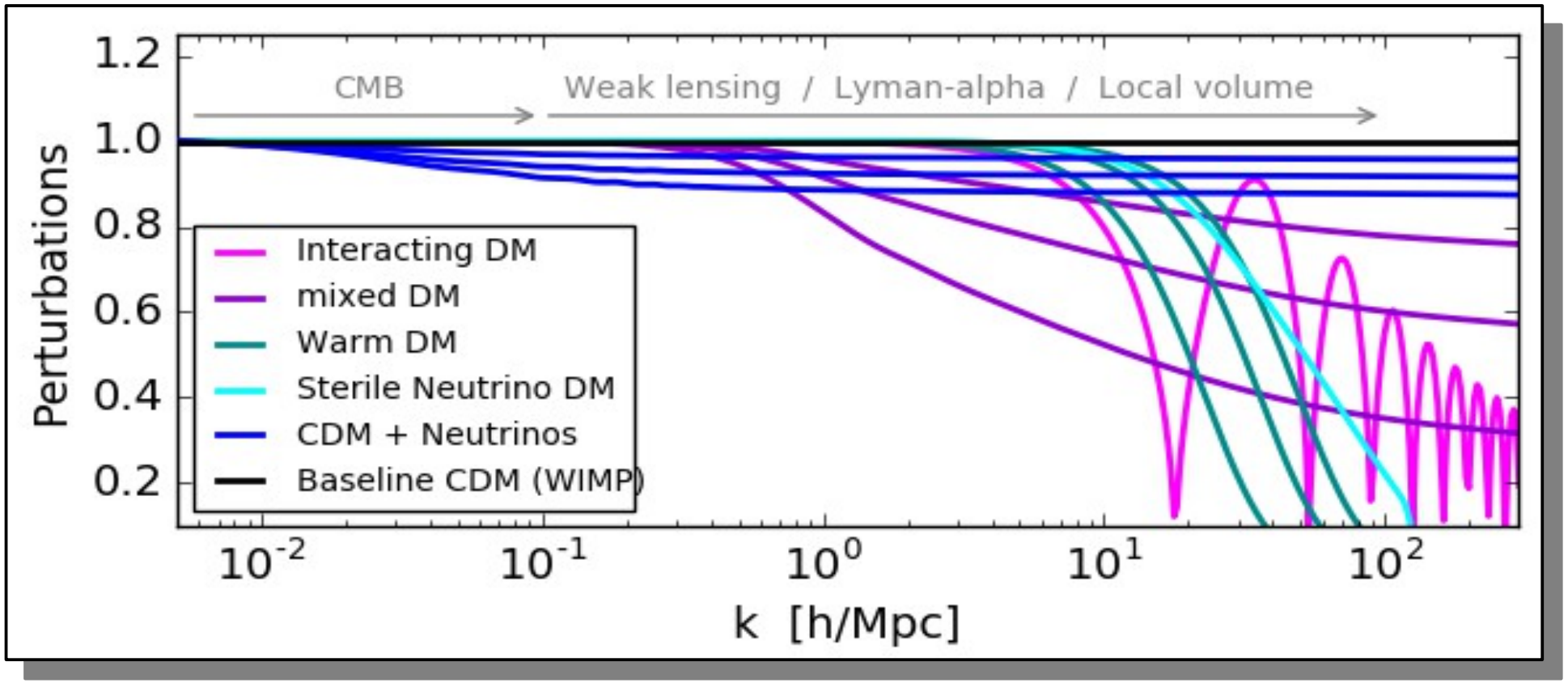
More complex DM sector? – constraining the power spectrum



Conclusions :

The galactic velocity function – a potential new probe for dark matter and cosmology

Lyman-alpha forest:
an unrivalled measure of small-scale clustering
– or are there unknown systematics ?

Future surveys have
the potential to
discover new physics
(and if not we still have the neutrinos)

Aurel Schneider – ETH Zurich

Profile fitting