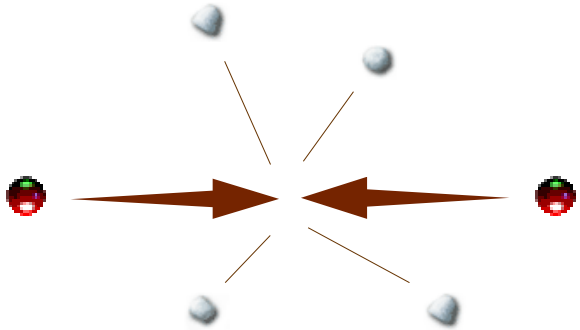
Structure formation and sterile neutrino dark matter

Collaboration:
Trujillo-Gomez, Papastergis
Merle, Totzauer

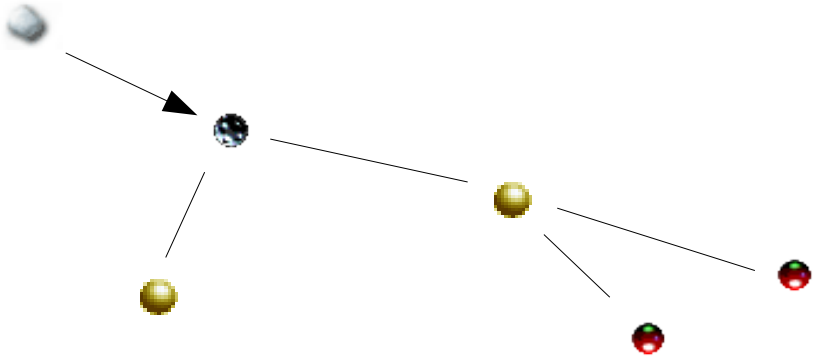
Aurel Schneider – ETH Zurich

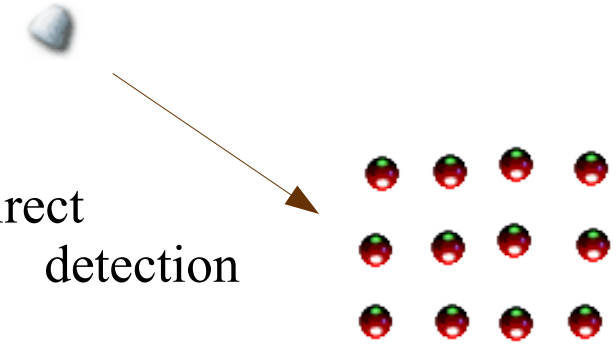
Dark matter: explore all possibilities



DM from Collider

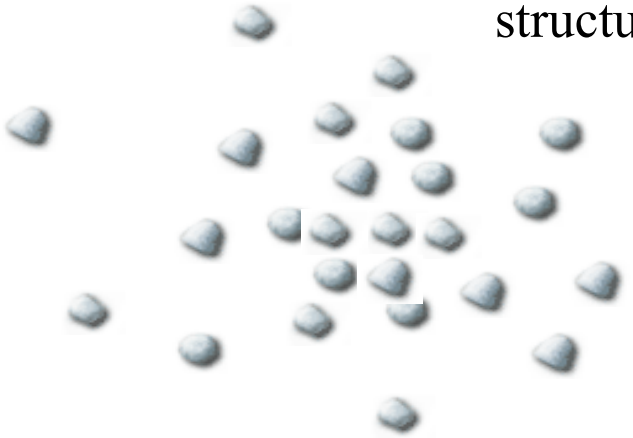
DM via
annihilation/decay products





Direct
detection

DM via
structure formation



DM via structure formation

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Boltzmann moments :

$$\dot{\delta} + \theta - 3\dot{\phi} = 0,$$
$$\dot{\theta} + H\theta - k^2 c_s^2 \delta - k^2 \psi = 0.$$

$$\Rightarrow \quad \ddot{\delta} + H\dot{\delta} = \left[4\pi G \rho_{\rm b} - k^2 c_s^2\right] \delta,$$

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Jeans criterion :

$$\lambda_{\rm J} = \frac{2\pi}{k_{\rm J}} = \sqrt{\frac{\pi c_s^2}{G\rho_{\rm b}}}$$

Sound speed :

$$c_s^2 \equiv {\rm func}(f_{\rm sn}) \sim T_{\rm sn}/m_{\rm sn}$$

DM via structure formation

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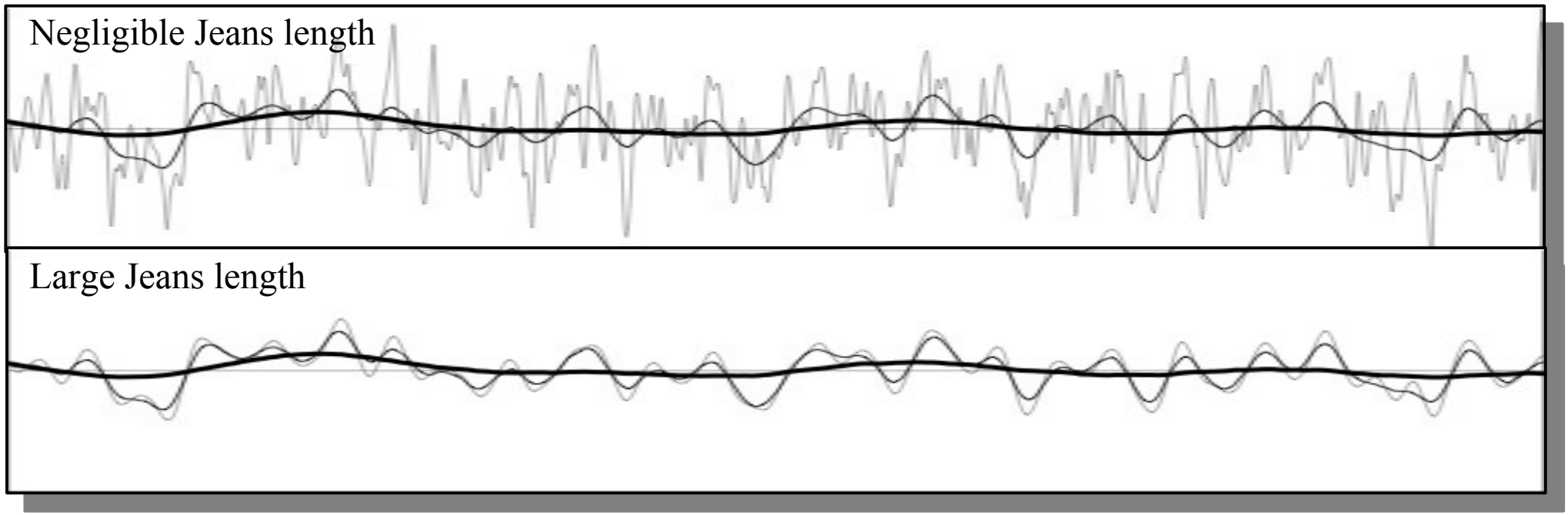

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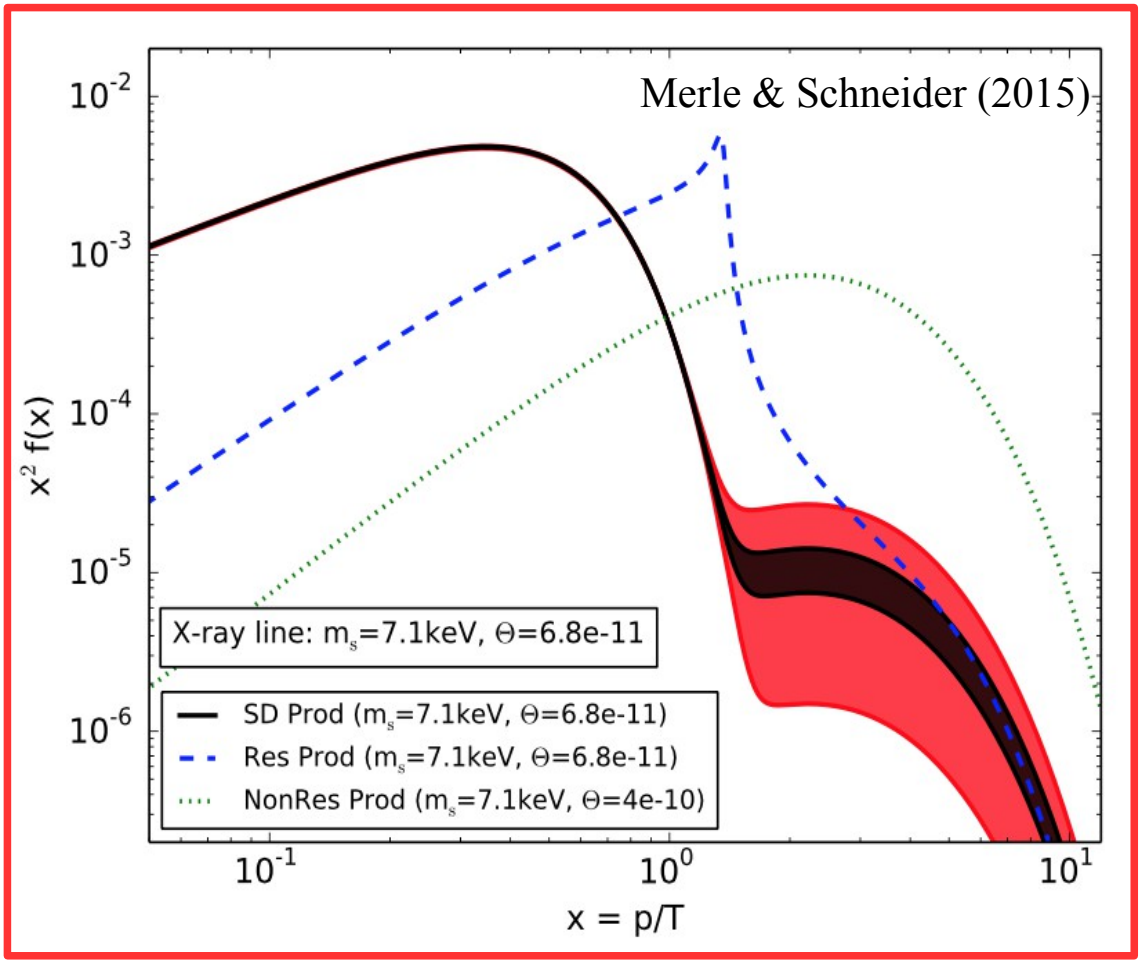
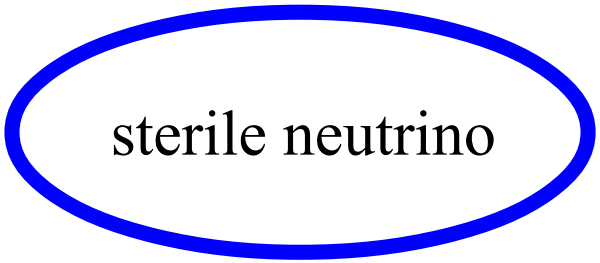


Sterile Neutrino Dark Matter: production



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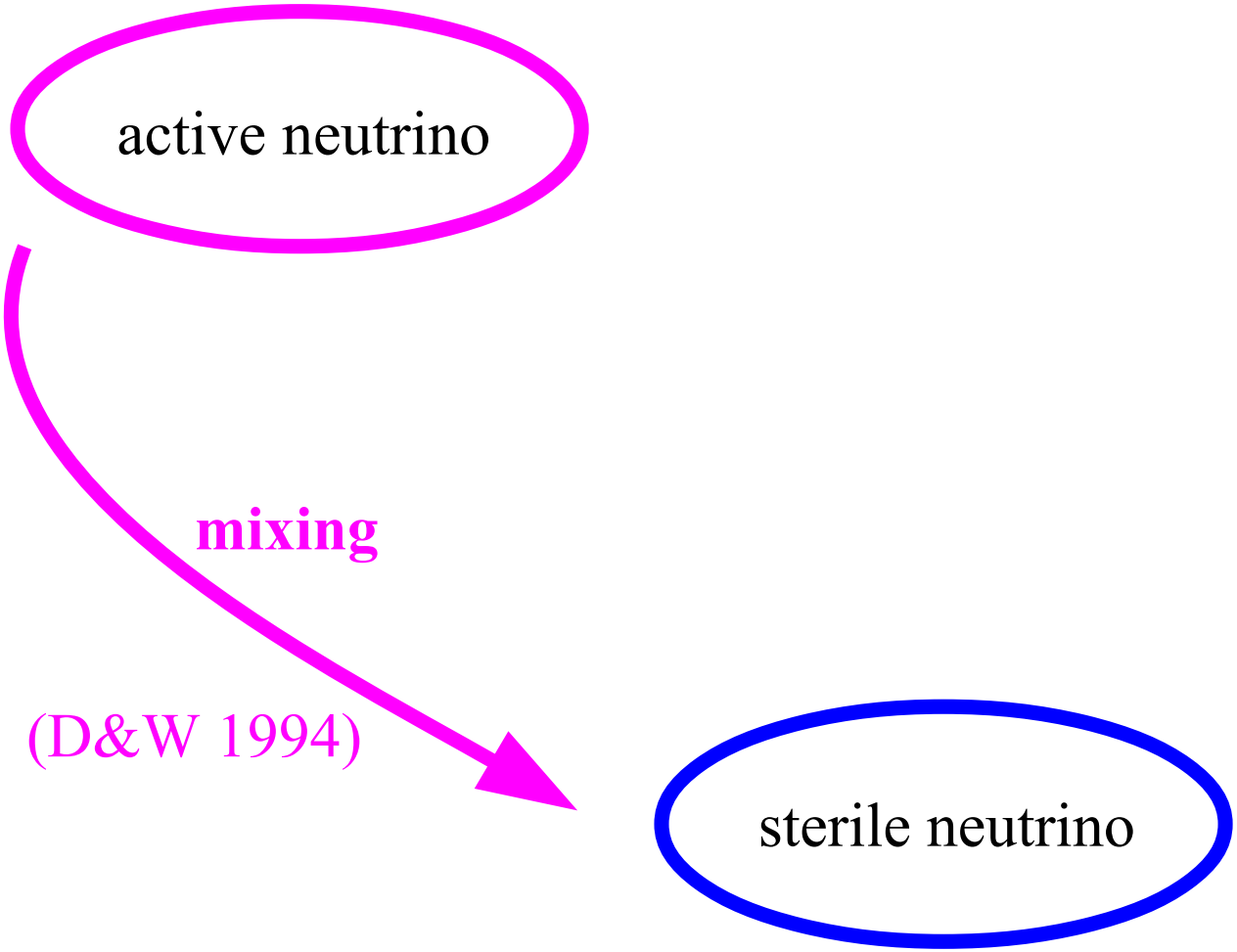

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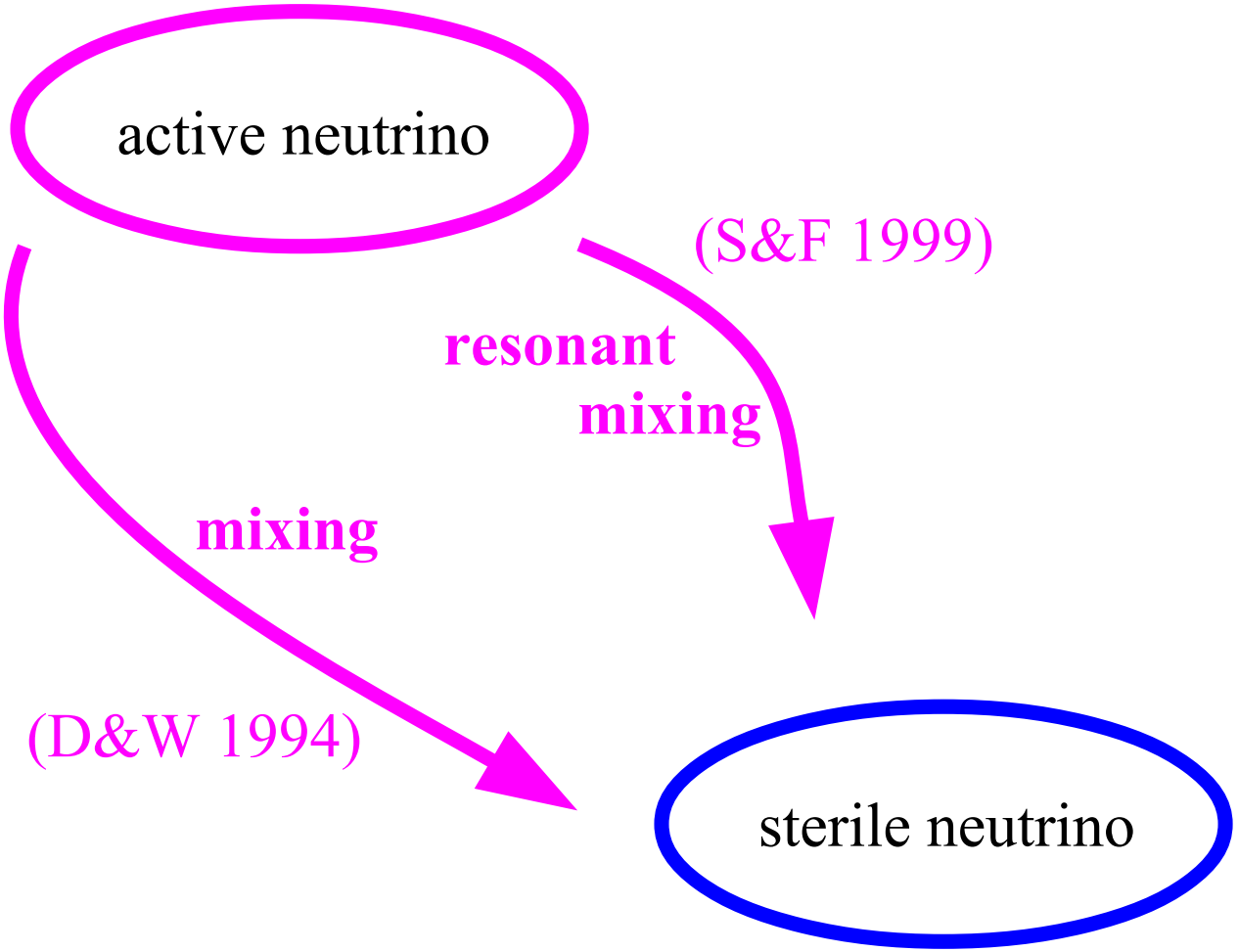

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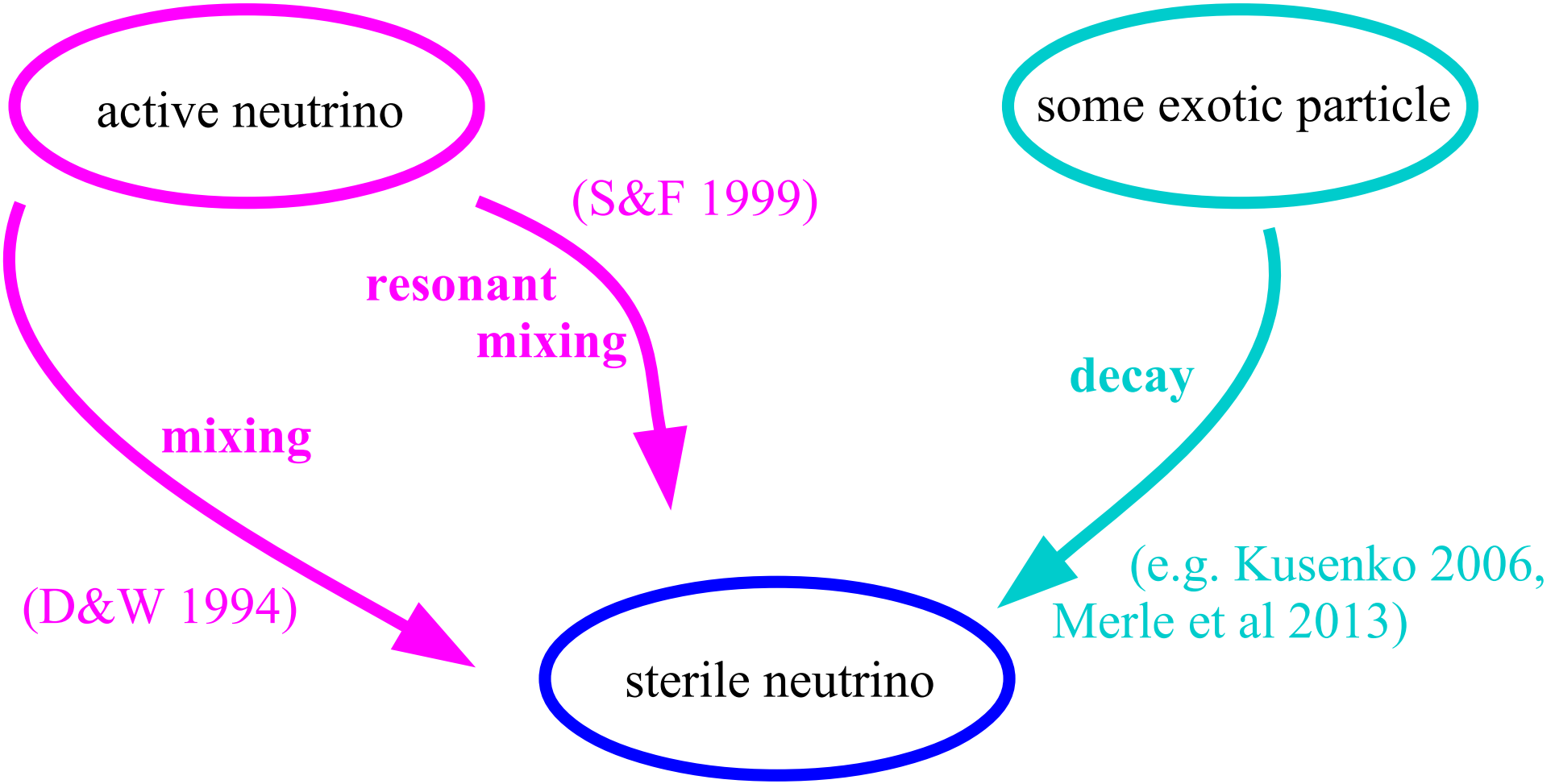


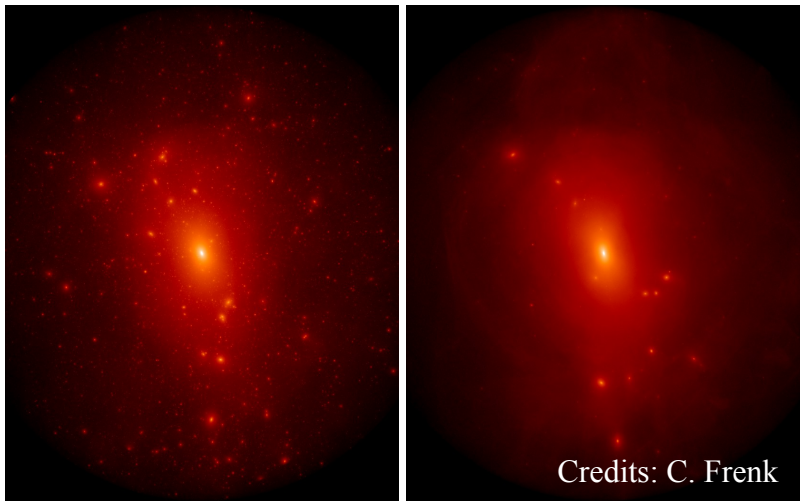
DM and structure formation: 2 options

Constraining sterile neutrino DM

Solving *problems* of structure formation

Constraining sterile neutrino DM

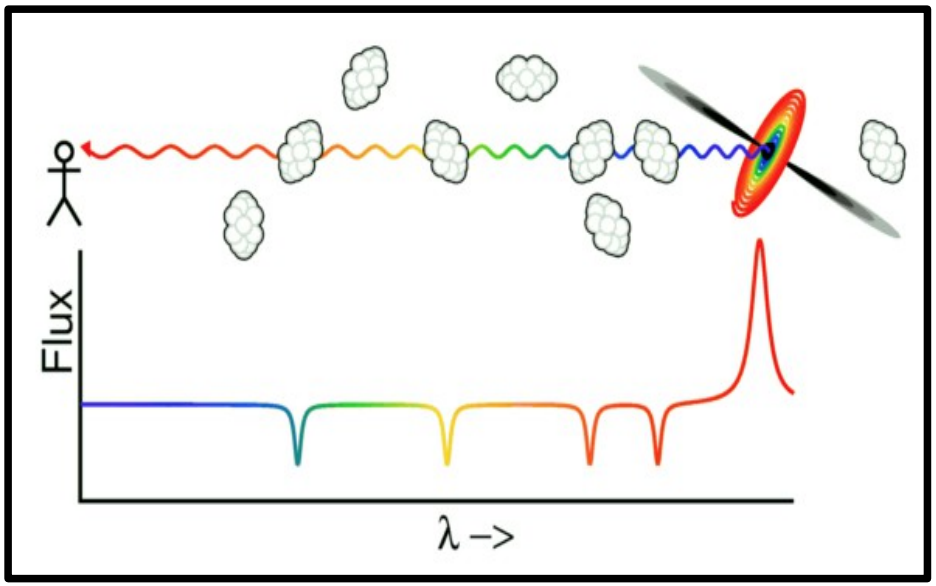
Milky-Way satellites:



Observed Number of satellites :

N_{sat} = 63
= classical dwarfs + 3.5 x SDSS dwarfs

Lyman-α forest:



Transformed into 1D power spectrum

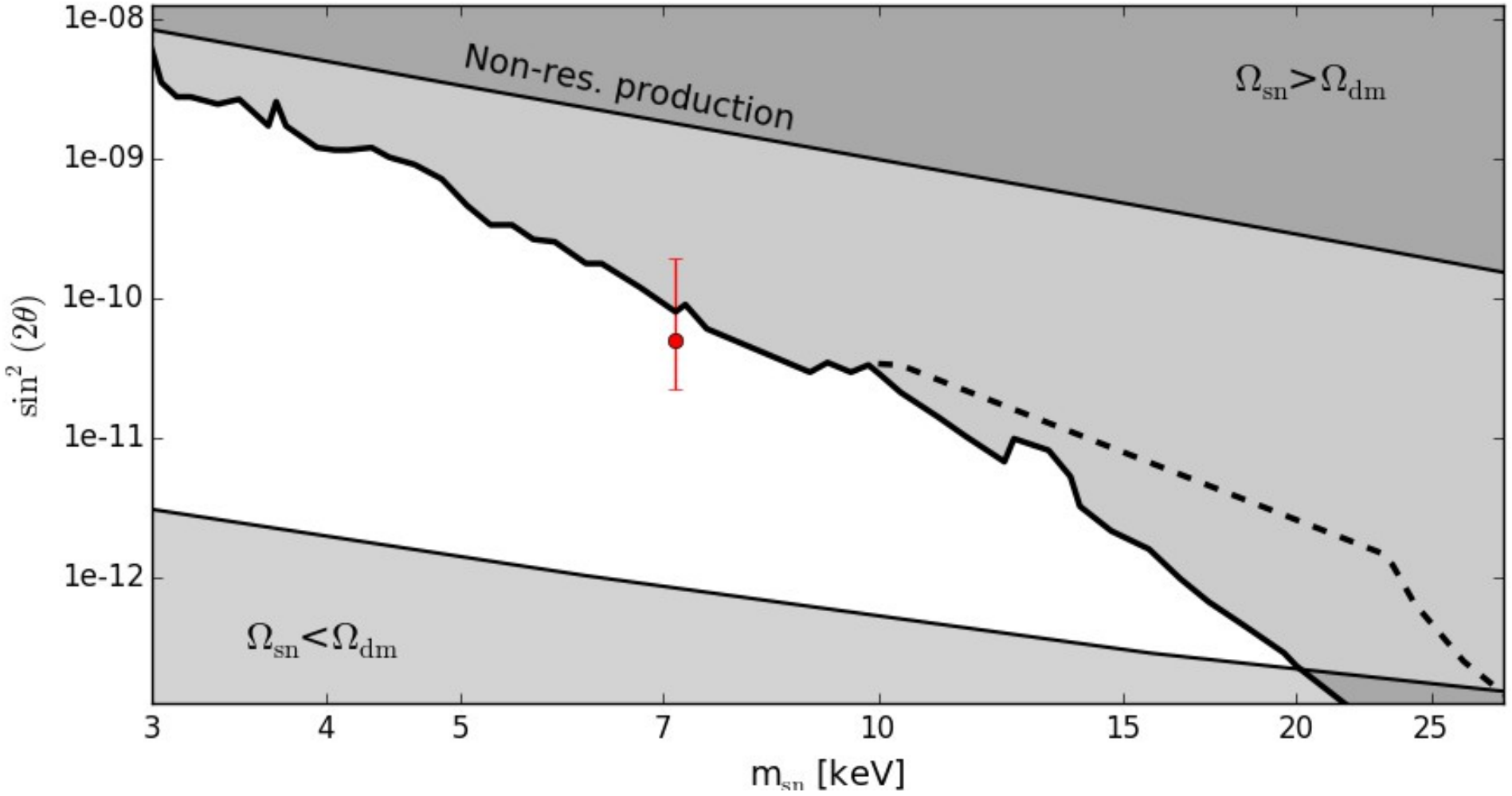
along line-of-sight

Sterile neutrino DM from resonant production

Sterile neutrino DM from resonant production

X-ray limits:

Schneider (2016)



Sterile neutrino DM from resonant production

Limits from Milky-Way satellite counts:

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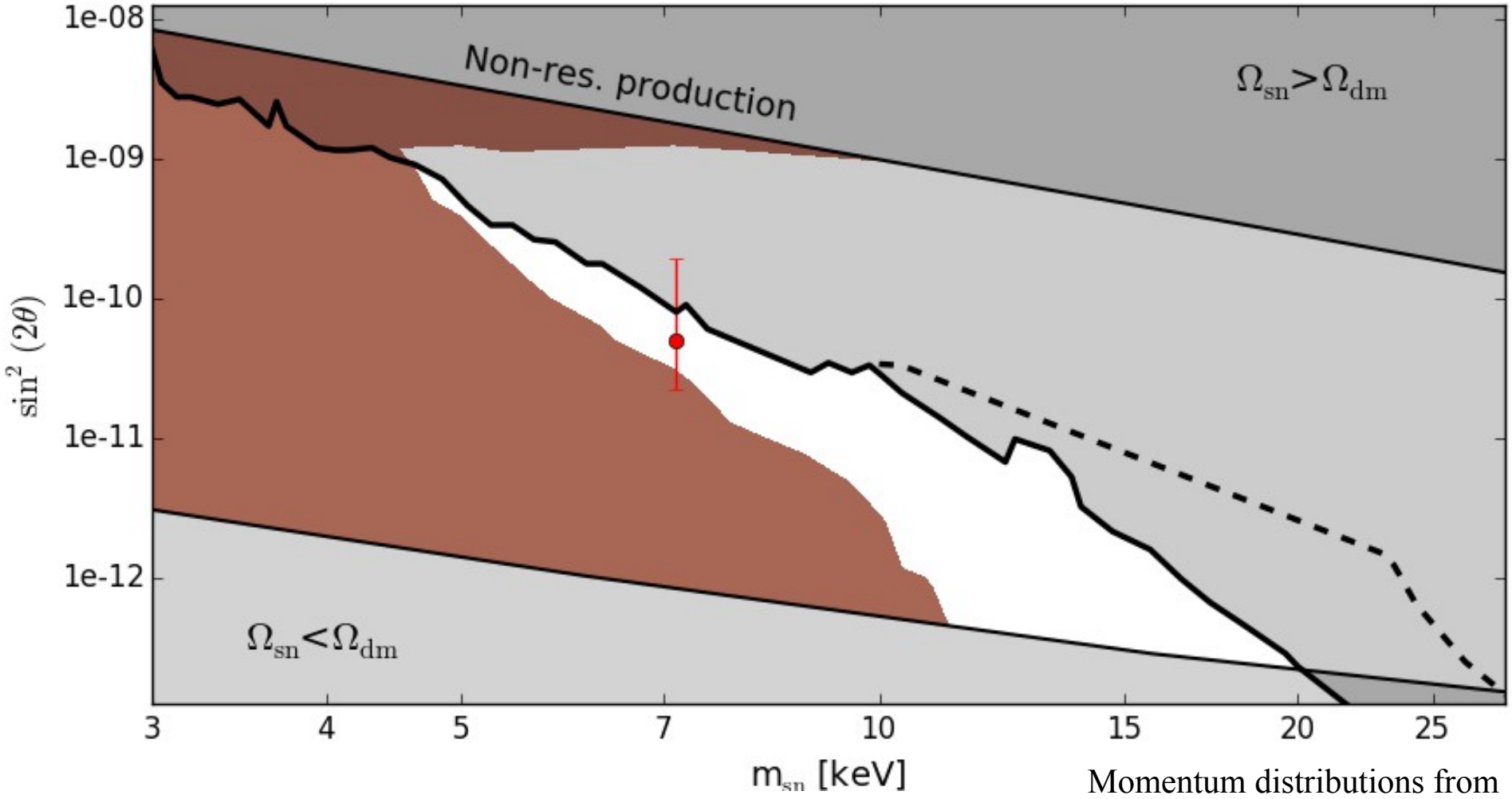

Momentum distributions from Venumadhav et al. (2016)

Sterile neutrino DM from resonant production

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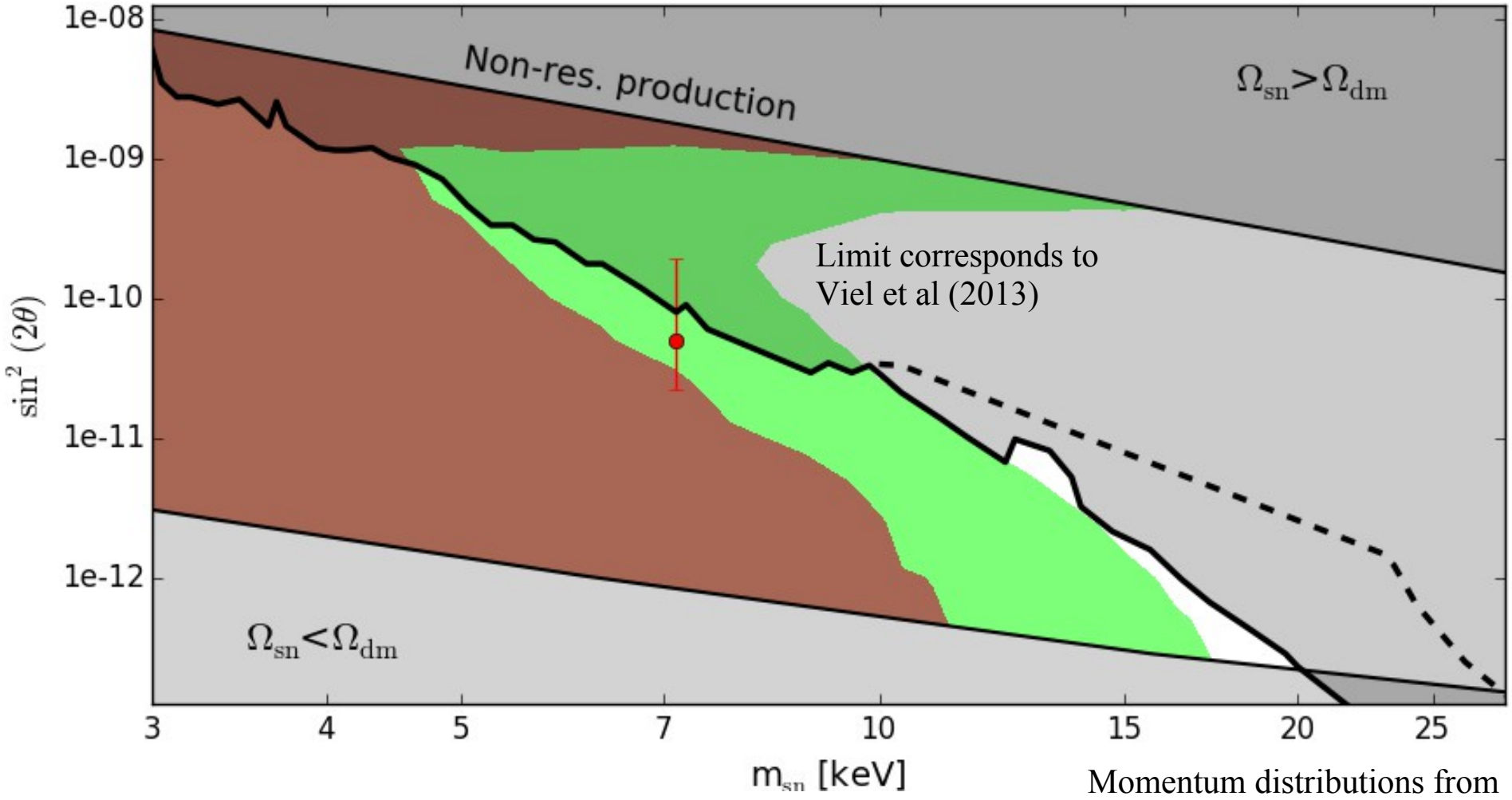

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Sterile neutrino DM from scalar decay production

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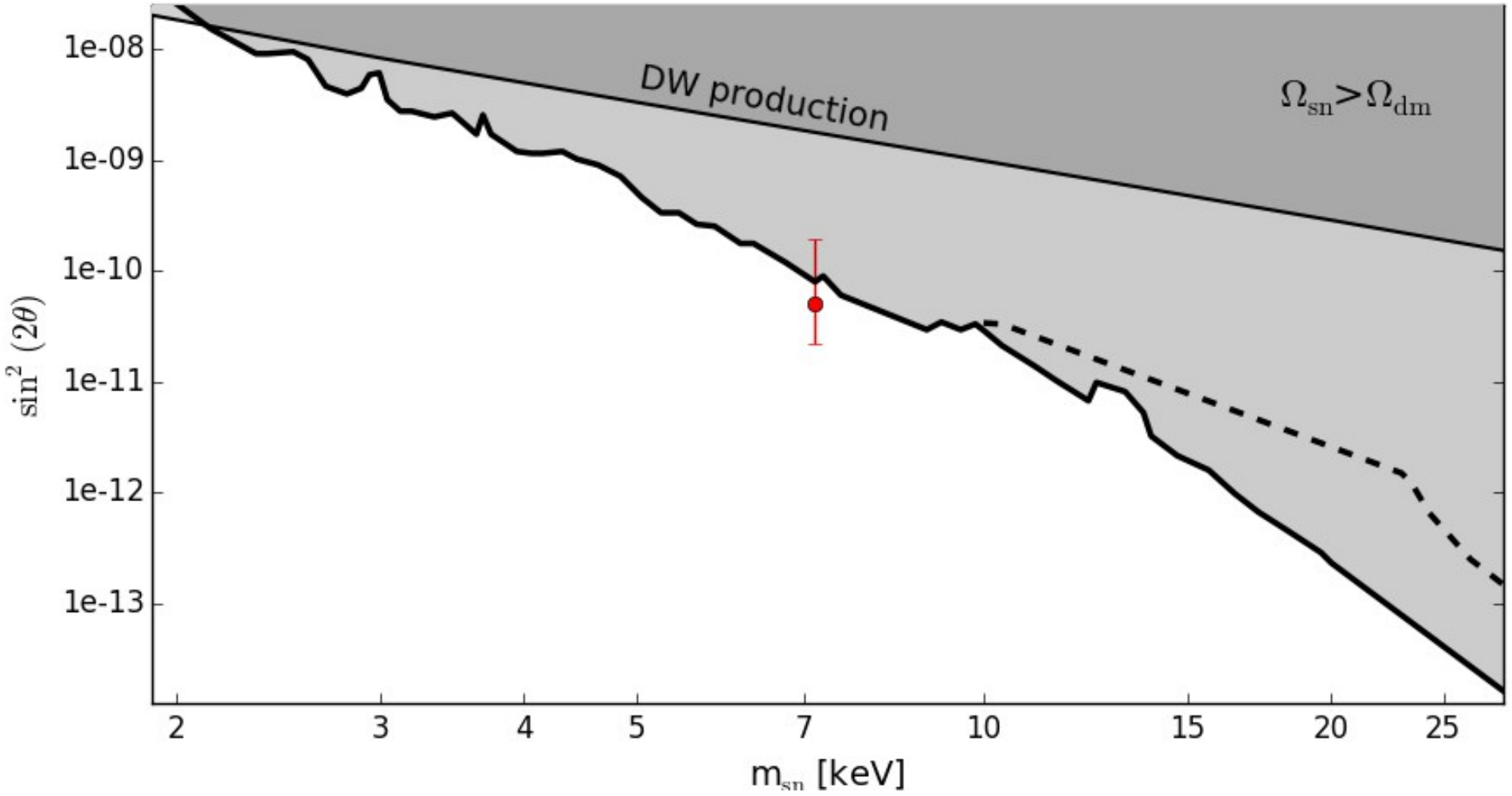
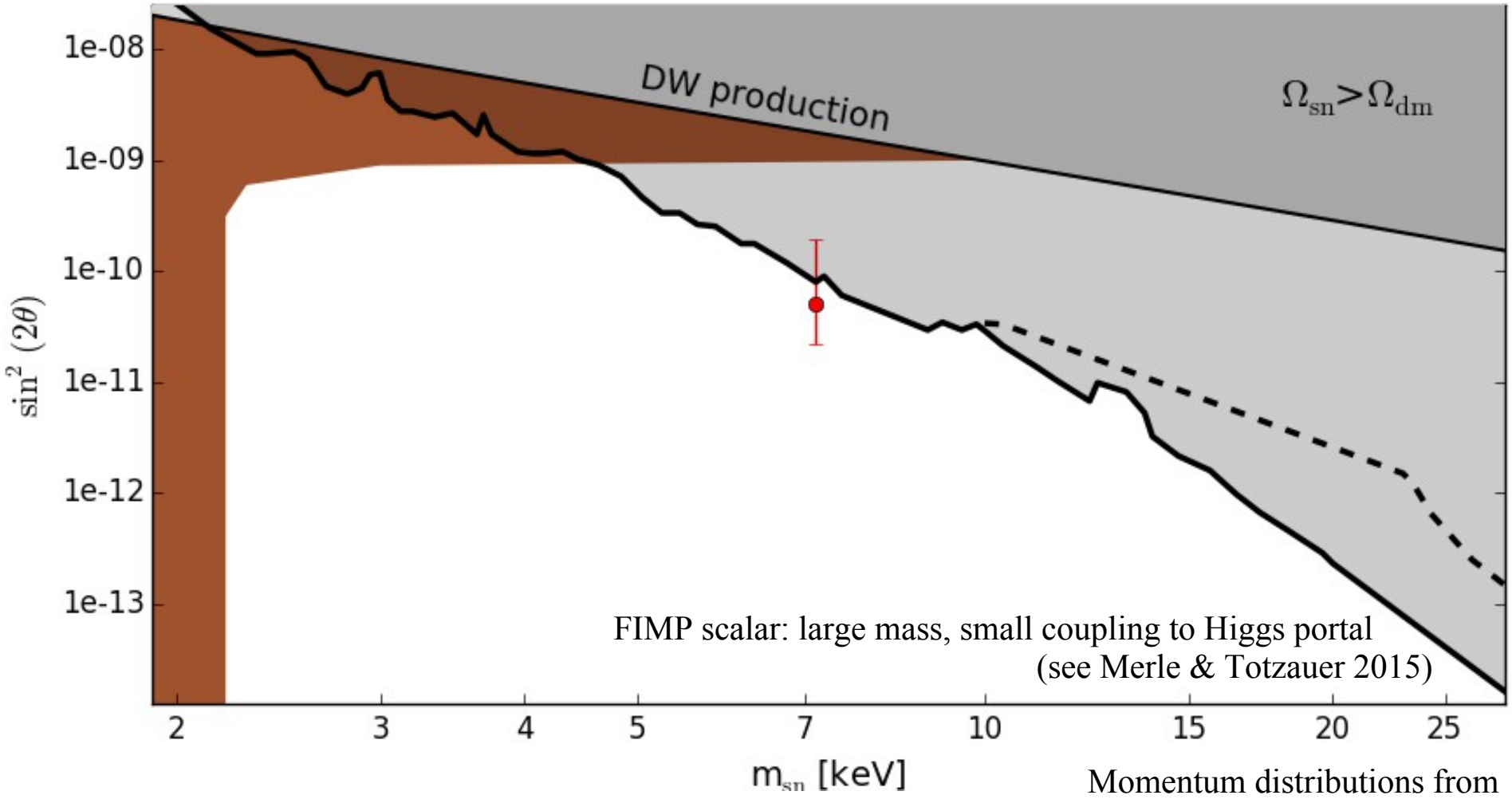


Sterile neutrino DM from scalar decay production

Limits from Milky-Way satellite counts (approximate):

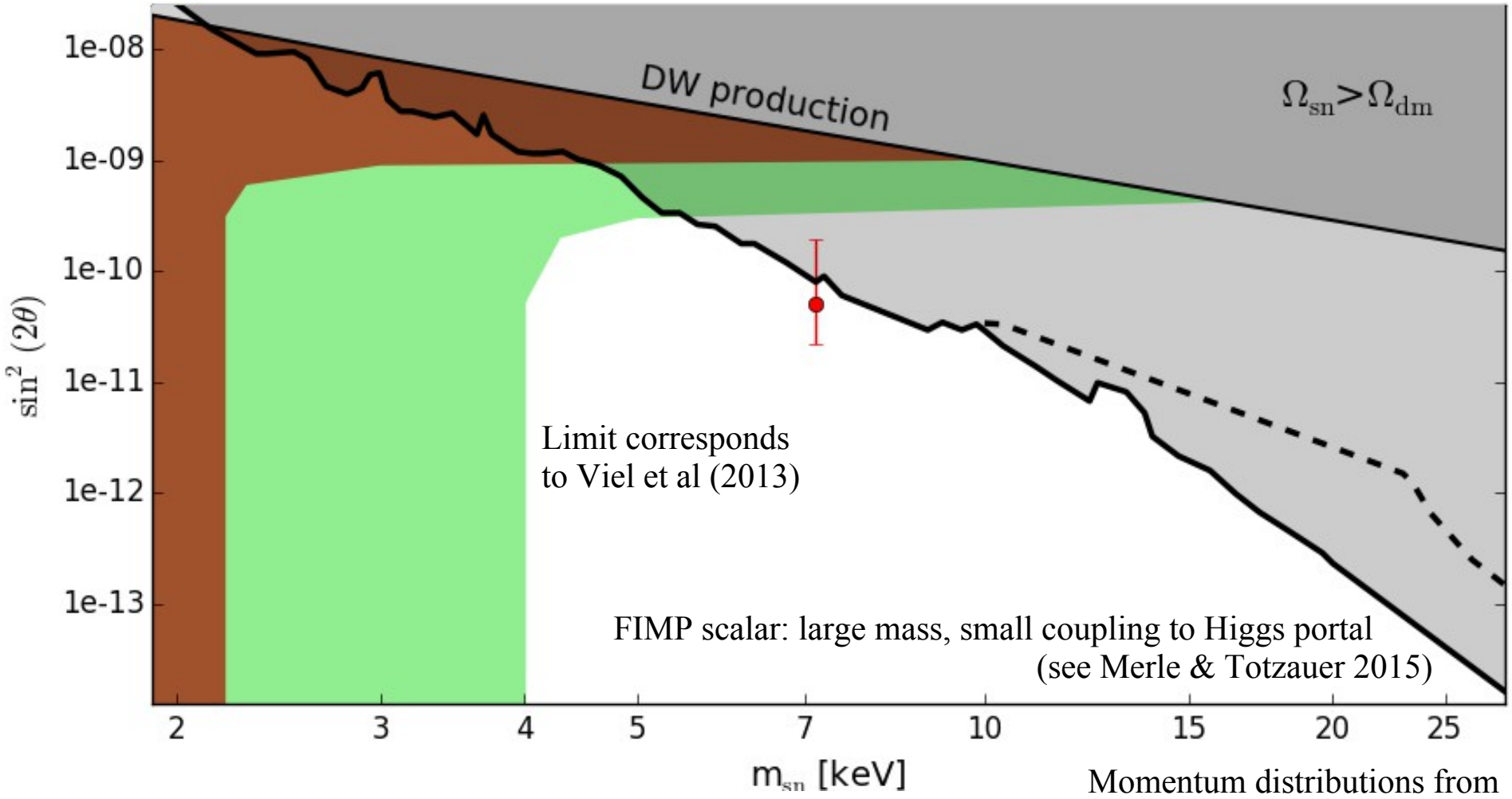


Momentum distributions from
Merle et al. (2016)

Sterile neutrino DM from scalar decay production

Limits from Lyman-α forest (approximate):

Merle et al (2016)



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Velocity Function: one for all and all for one !

Relatively clean probe

- Field galaxies
- Good statistics

Combination of …

- Over-abundance problem
- Cusp-core problem
- TBTF problem

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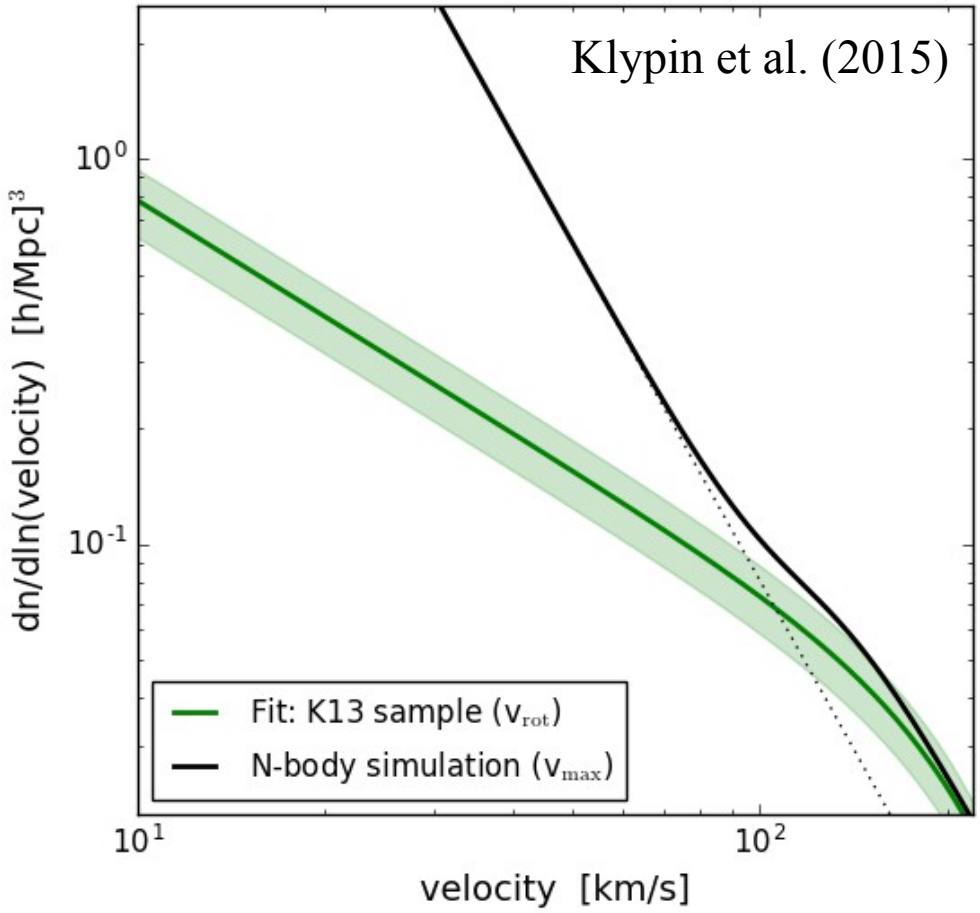

Velocity Function: connection with BTF

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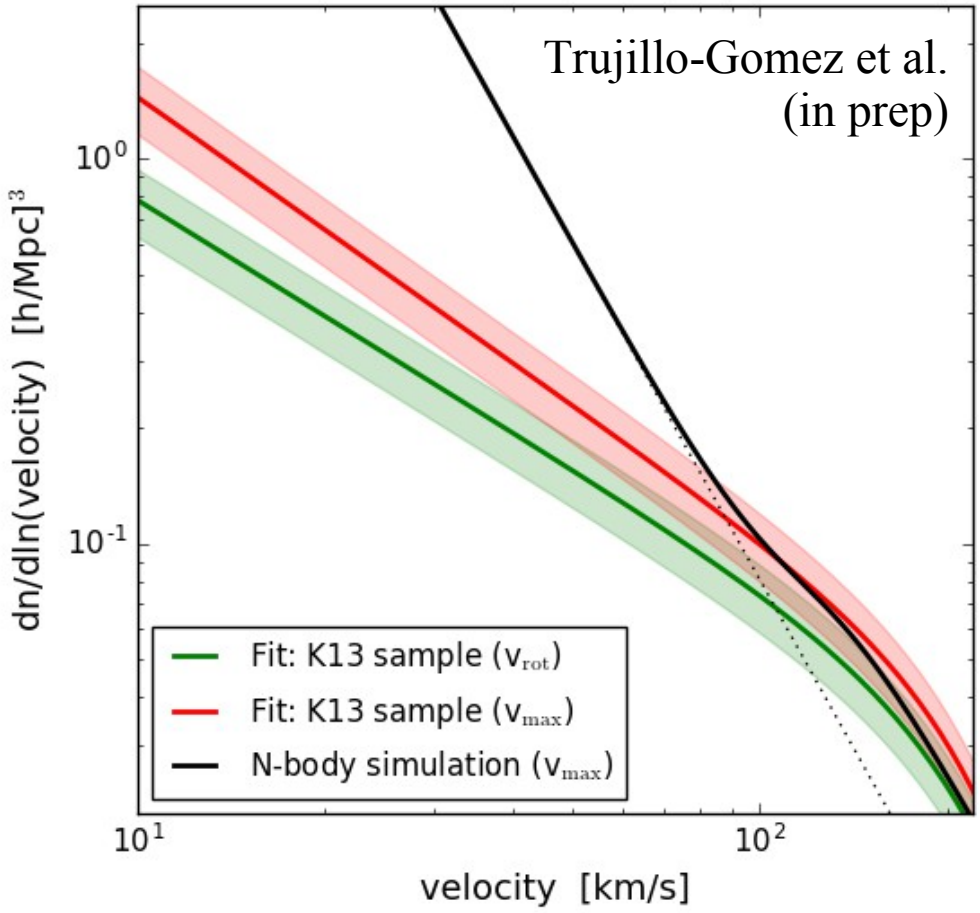
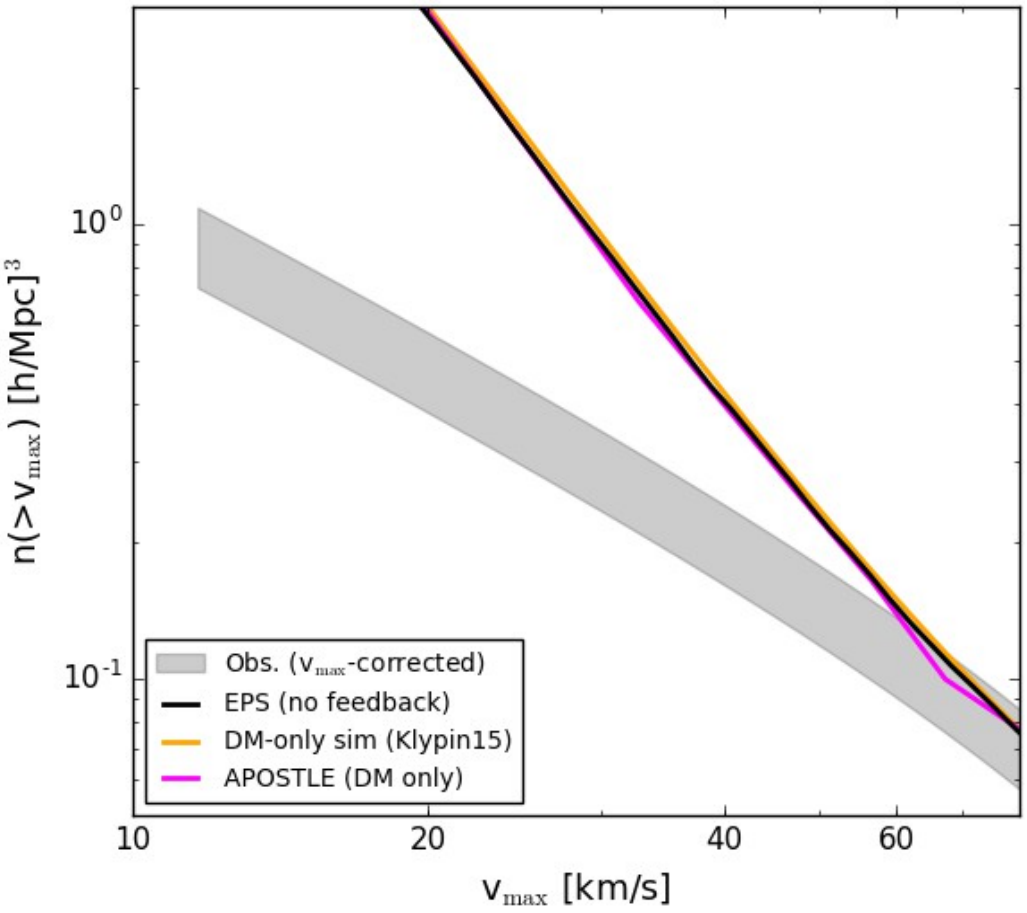


Velocity Function: DM-only

But wait – Theory is DM only !



Velocity Function: Max Baryon Depletion

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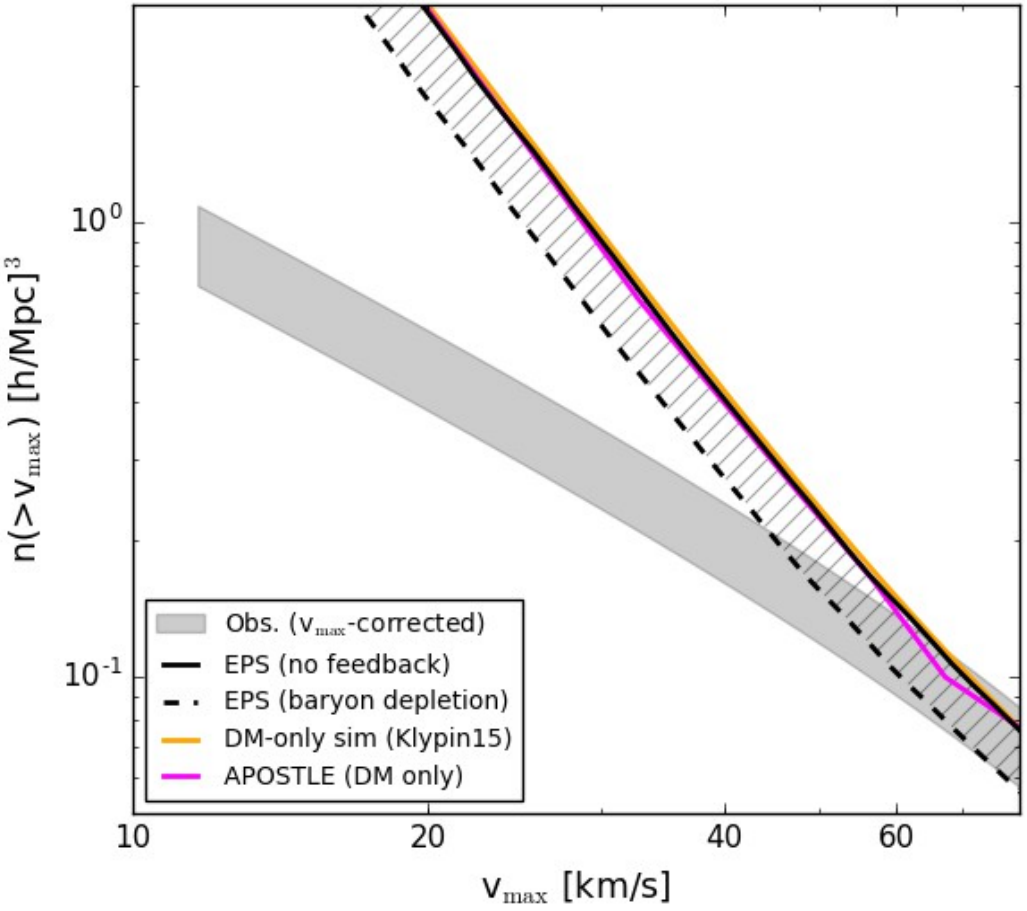
Need to include baryon feedback :

- baryon depletion



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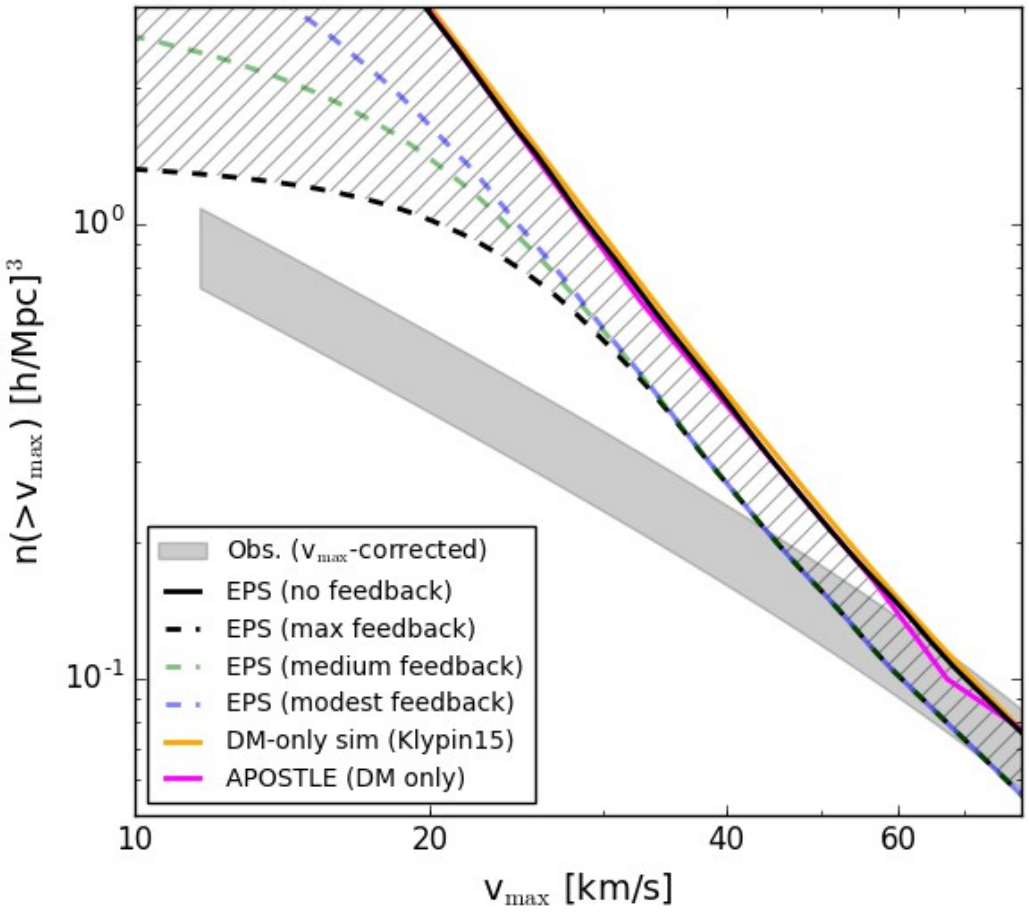

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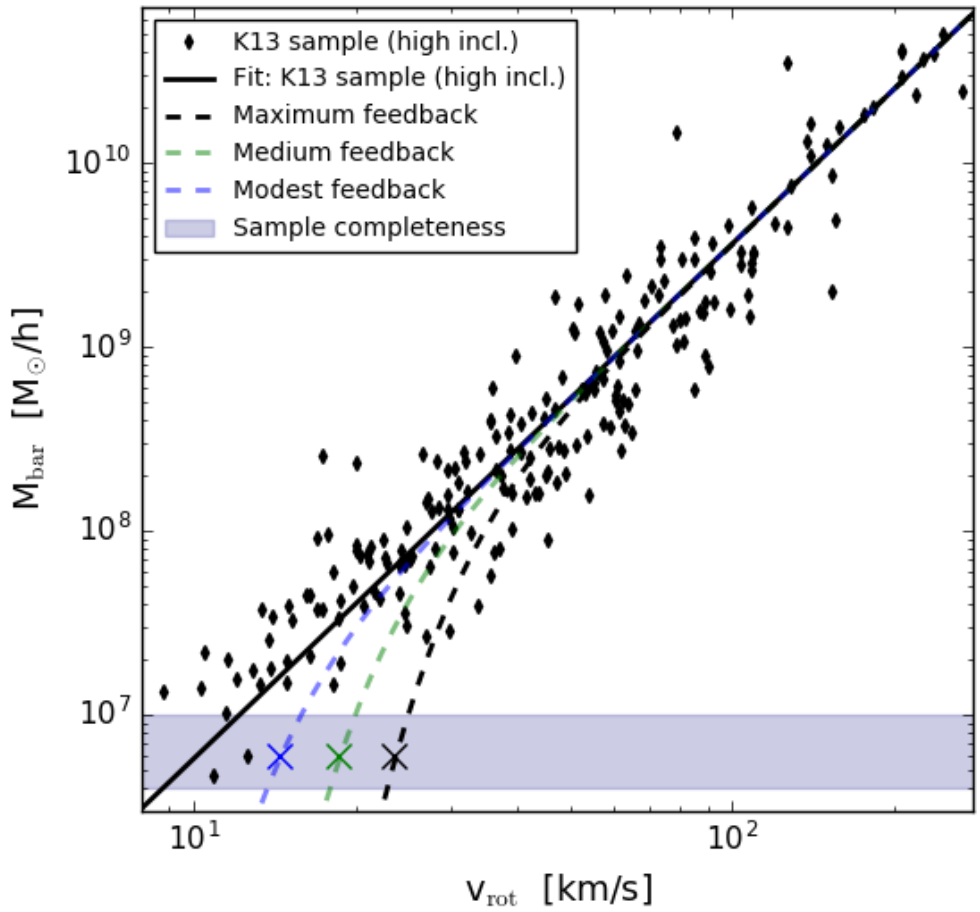
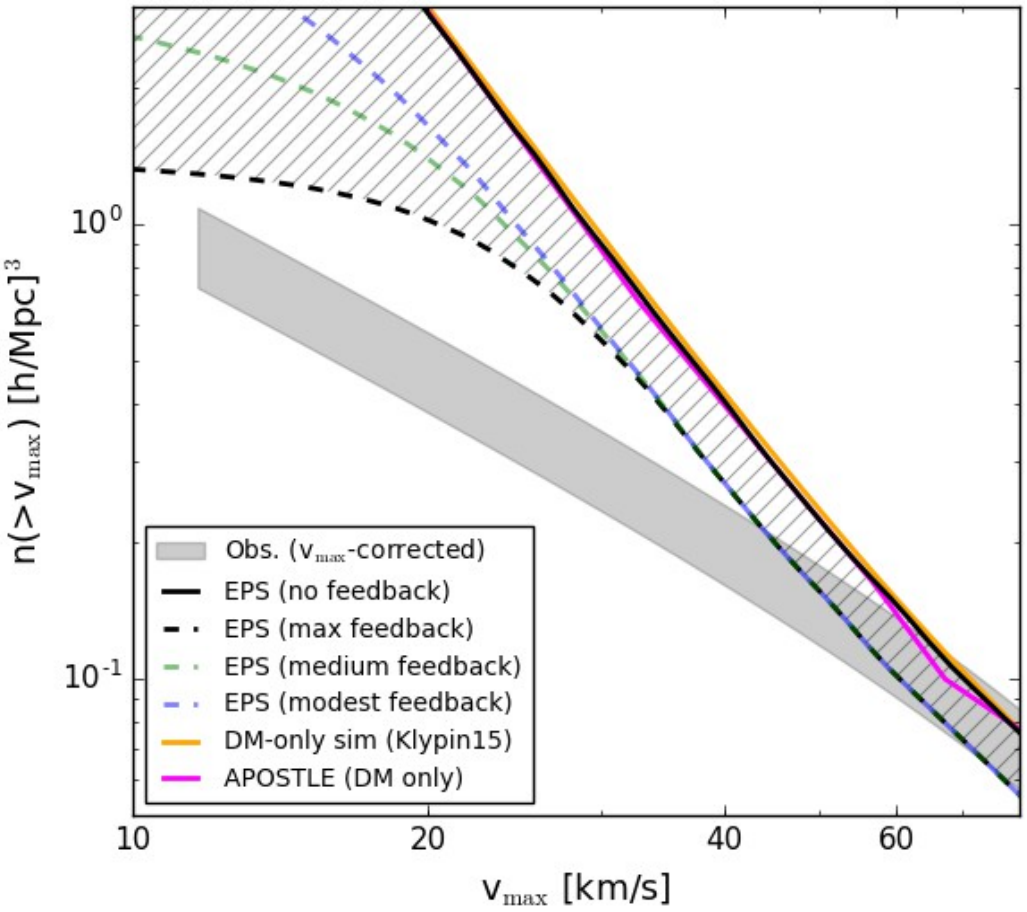
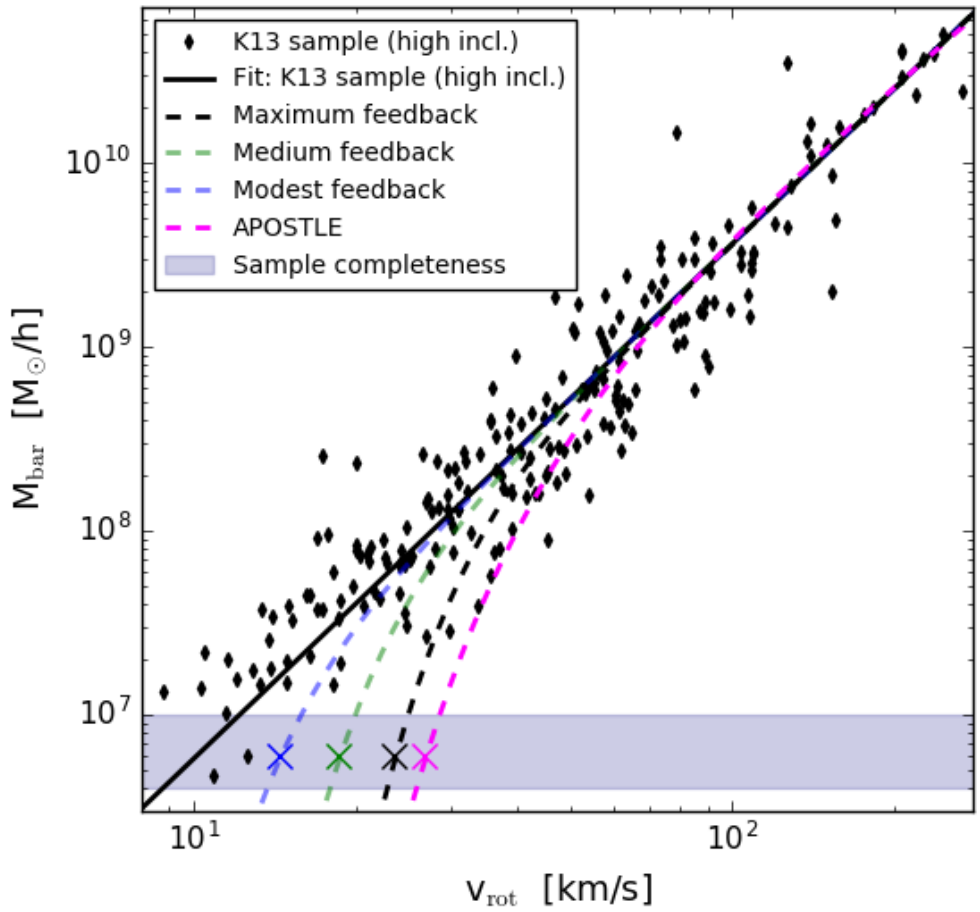
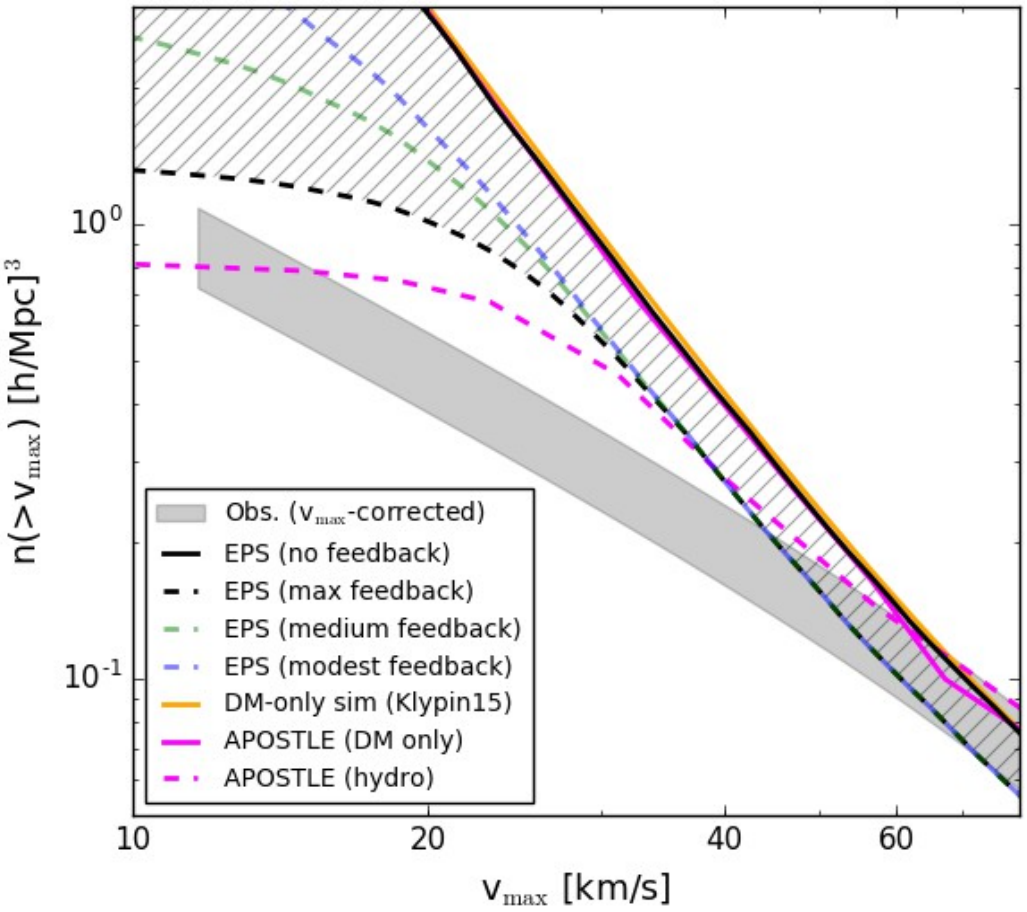




Velocity Function: Hydro Simulation





APOSTLE: Sawala et al 2015, Sales et al 2015

Velocity function

What about Sterile Neutrino Dark Matter ?

Warm Dark Matter

Strongly suppressed perturbations (at free-streaming scale)

Shallower halo profiles

Leads to …

… Lower halo abundance

… Modified vmax

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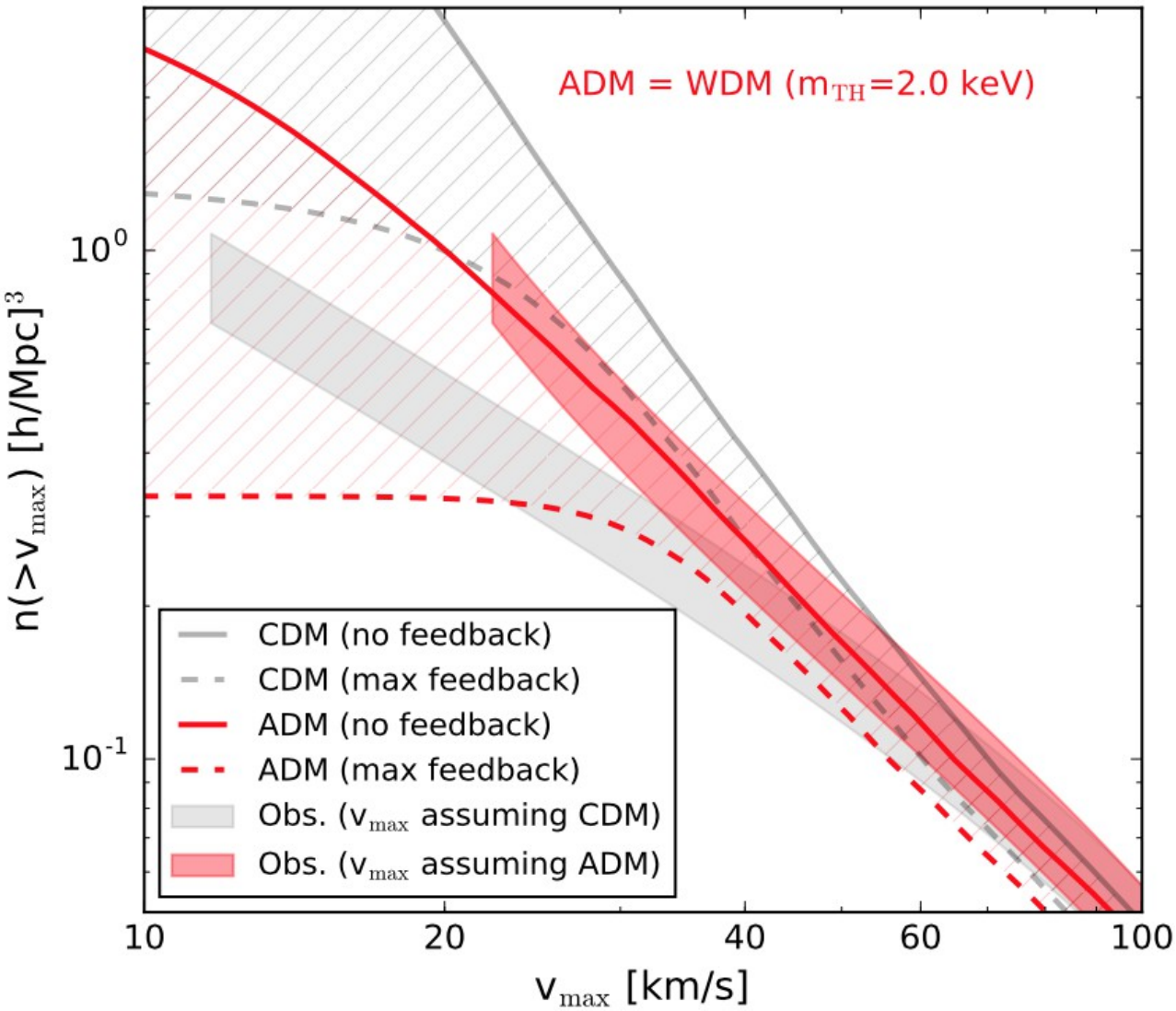

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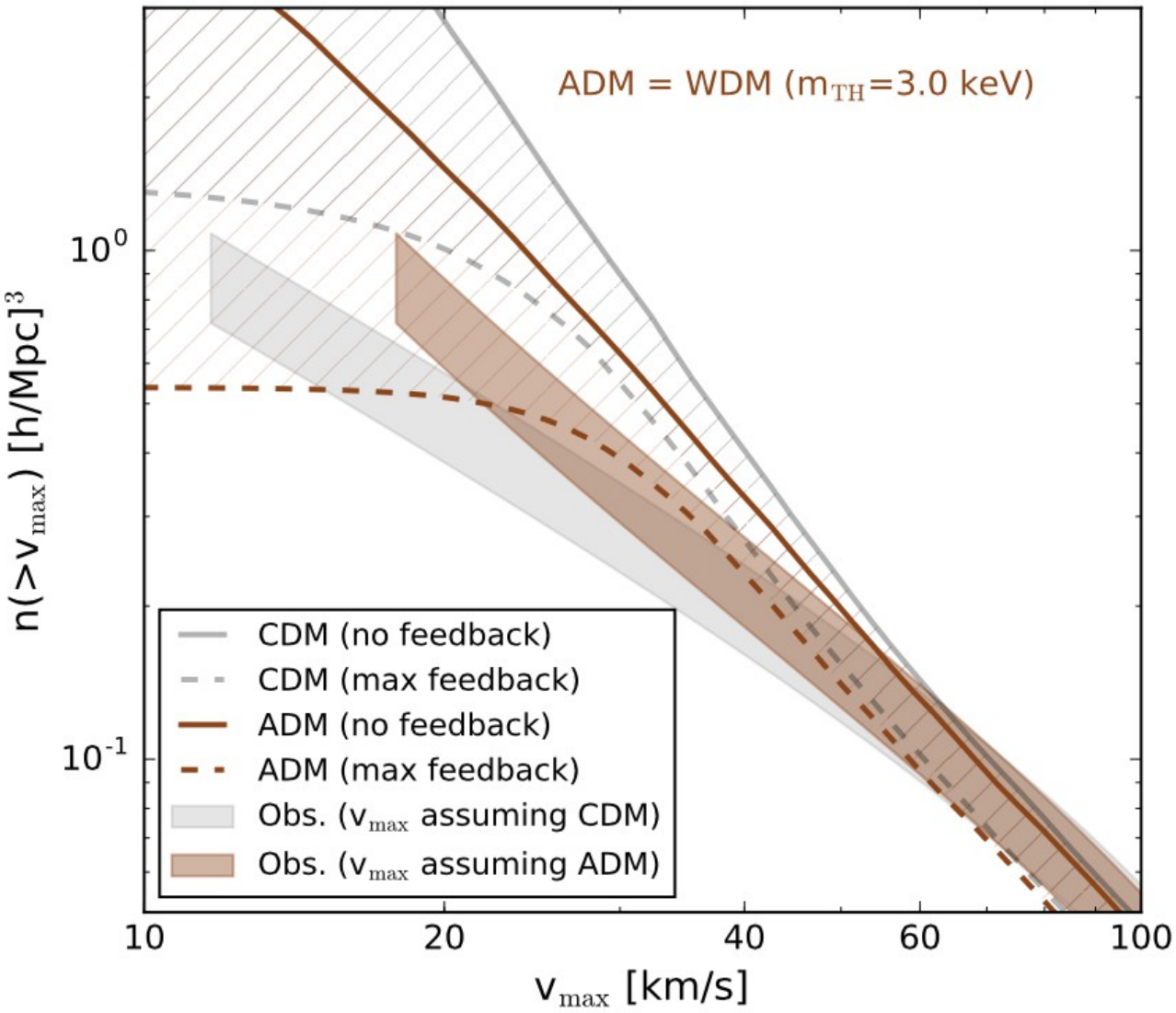

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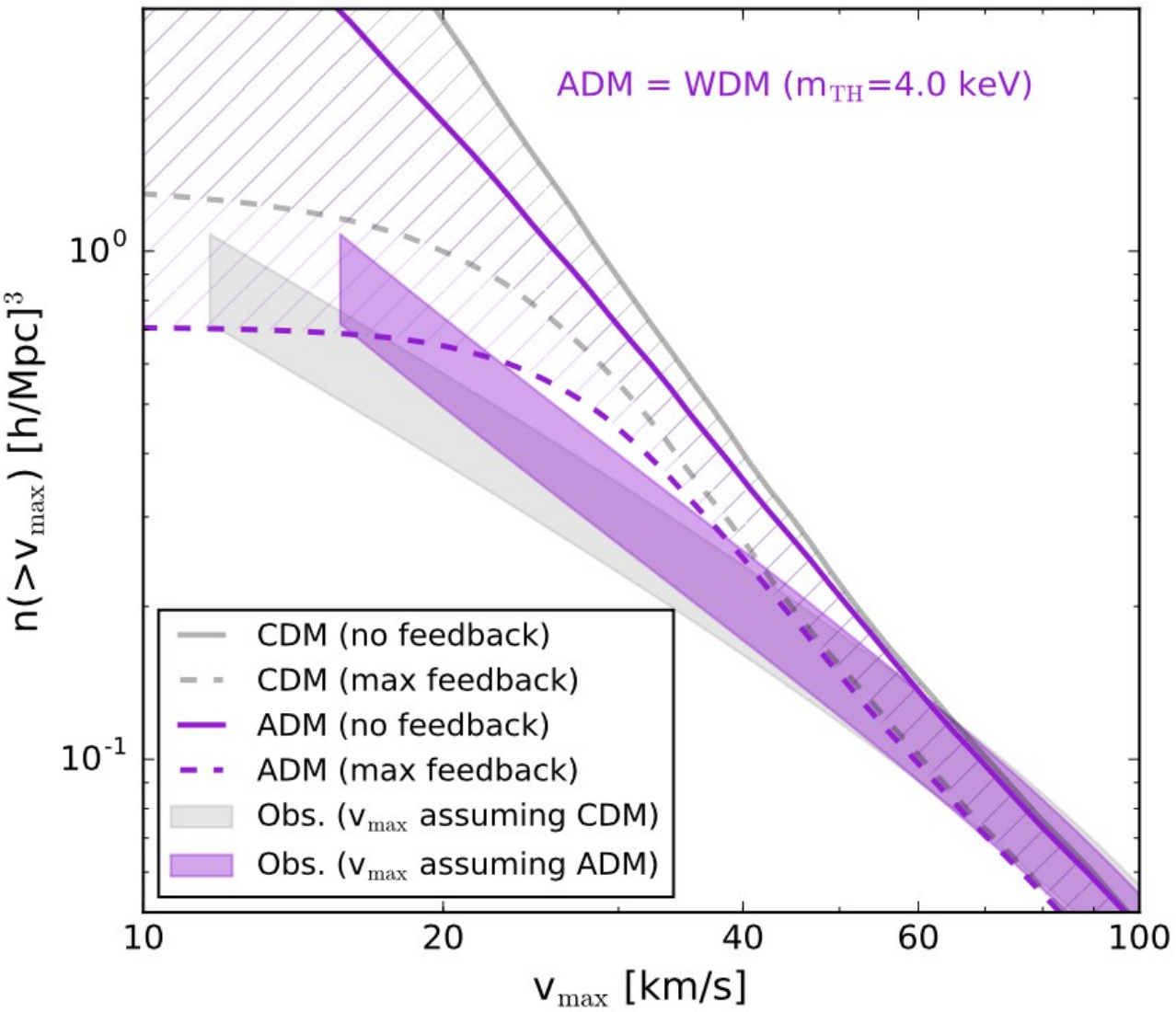
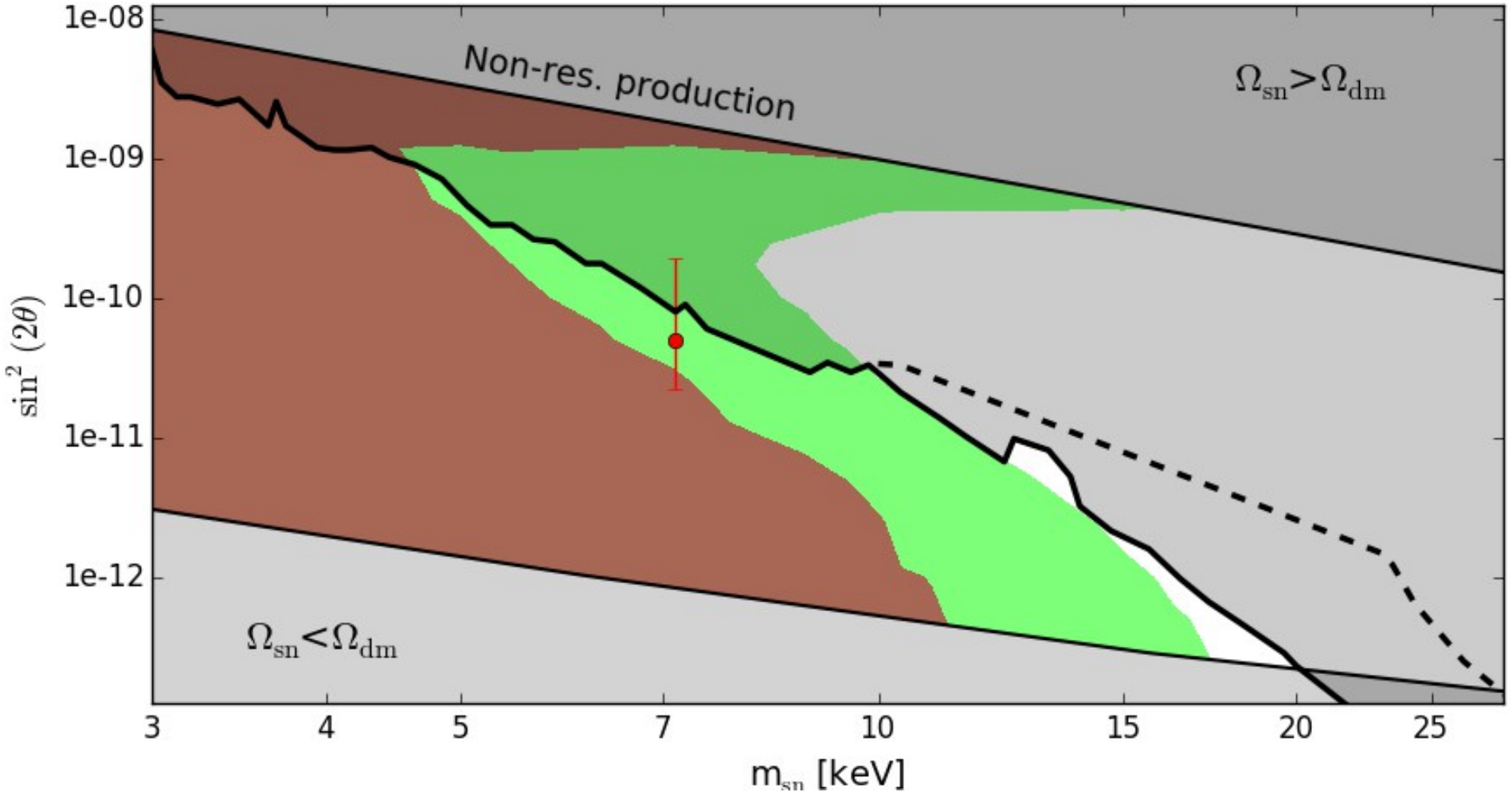


Velocity function and resonant production

Limits from Lyman-α forest :

Schneider et al (in prep)



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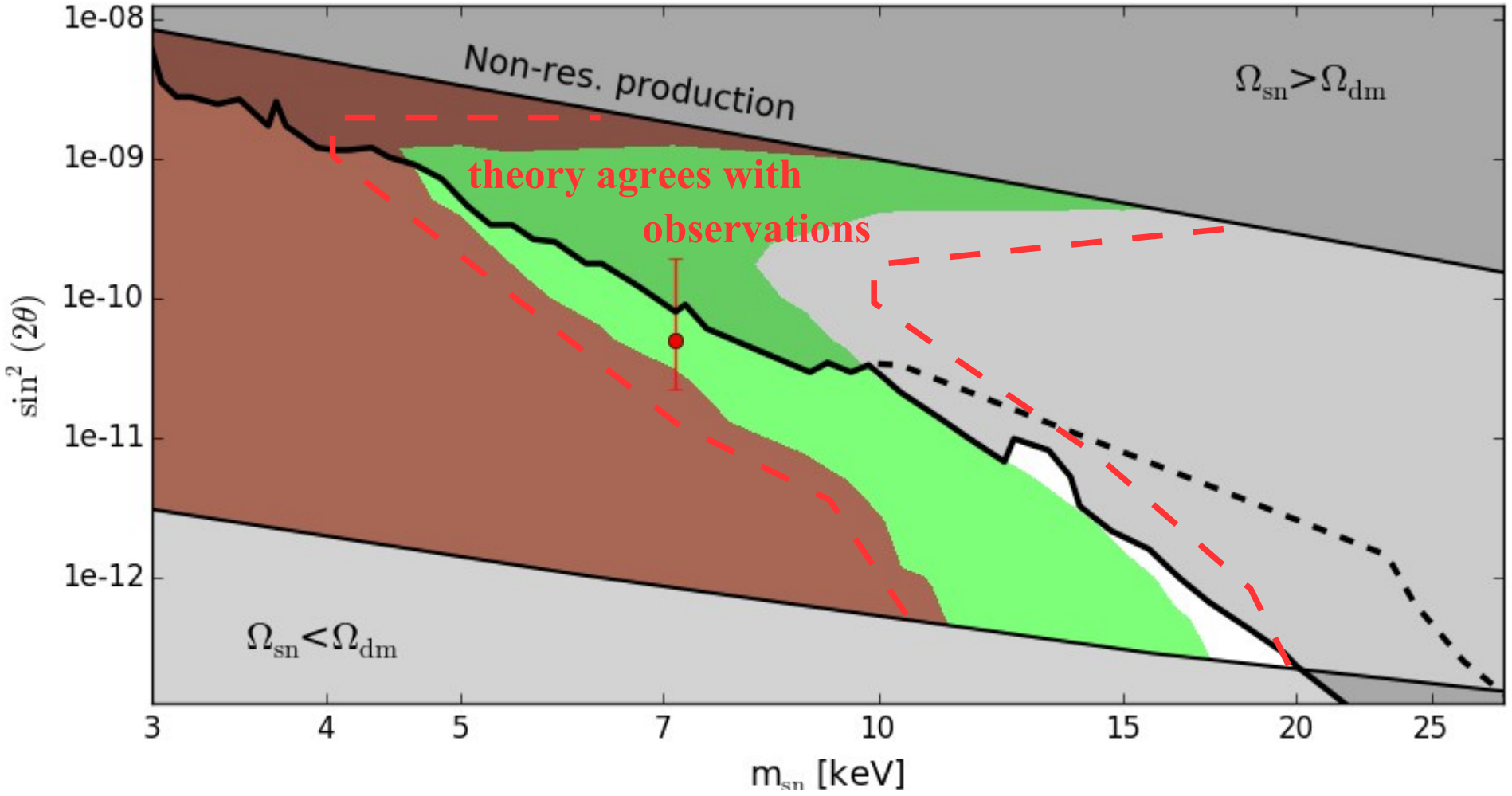

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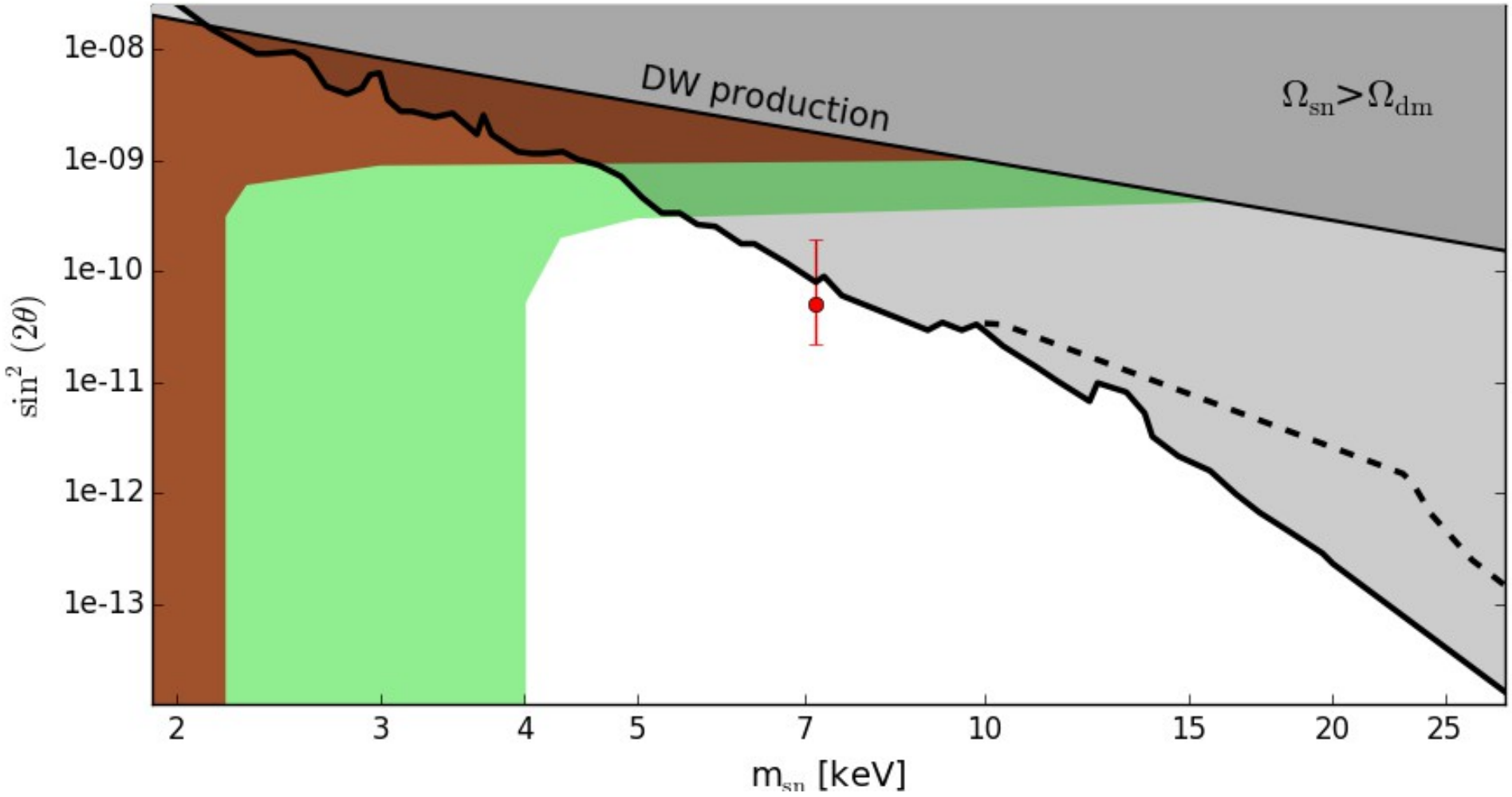

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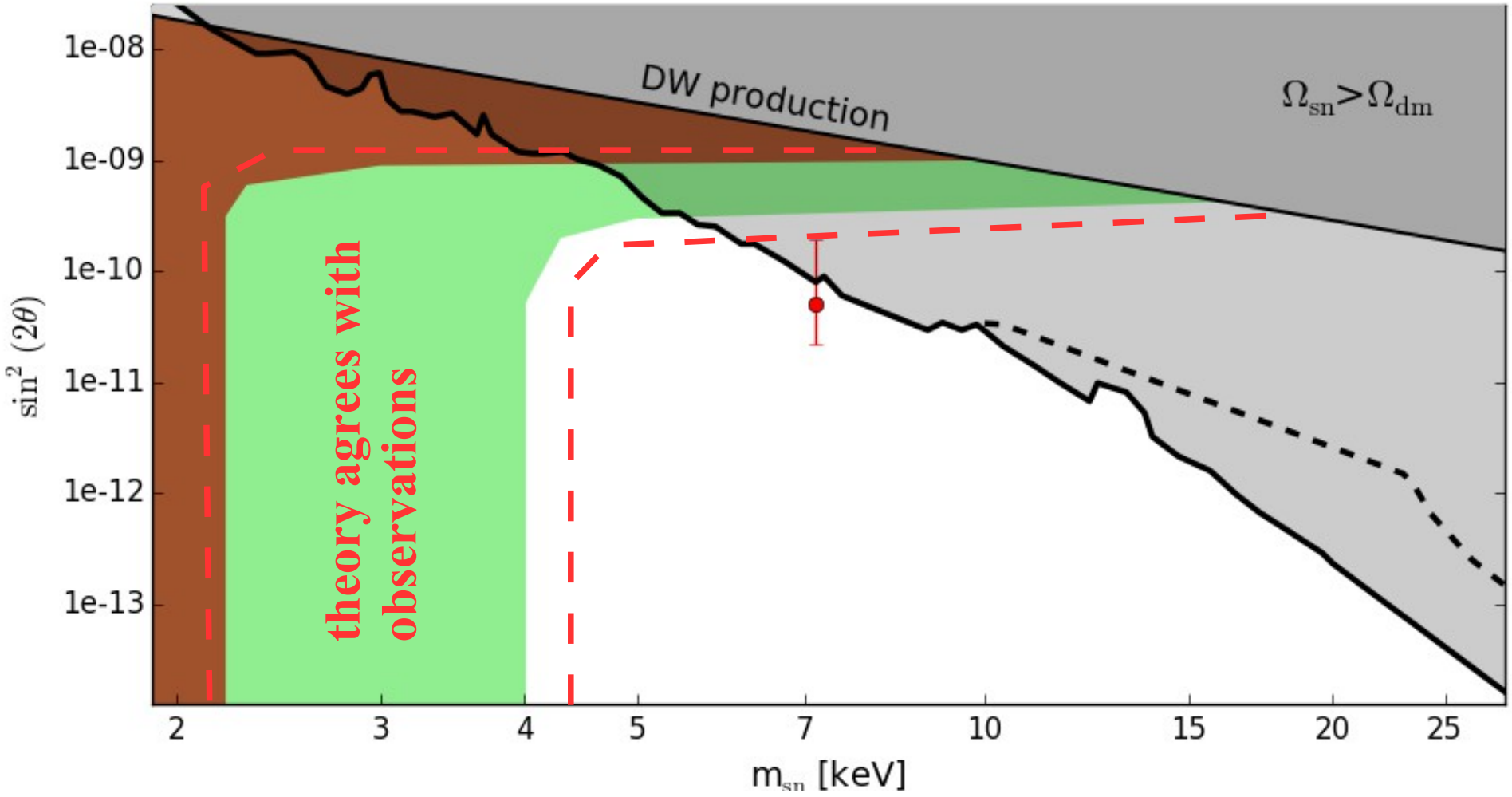

Conclusions :

Sterile neutrino DM: A better match observations from local galaxies

resonant production: in trouble!
scalar decay production: fine!

Aurel Schneider – ETH Zurich

Profile fitting