

Sterile neutrinos in the cosmos

Maria Archidiacono
University of Milan

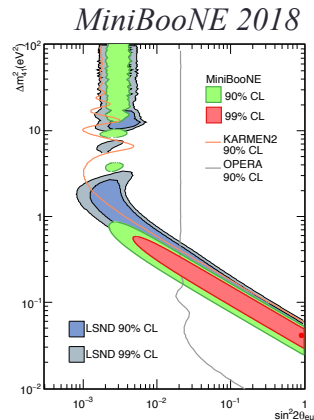
The logo for SnowMass2021, featuring the text "SnowMass2021" in a stylized, cursive font. "Snow" is in light blue, "Mass" is in white, and "2021" is in white. The text is set against a dark grey rectangular background.

NF02 Mini-Workshop, September 25th, 2020

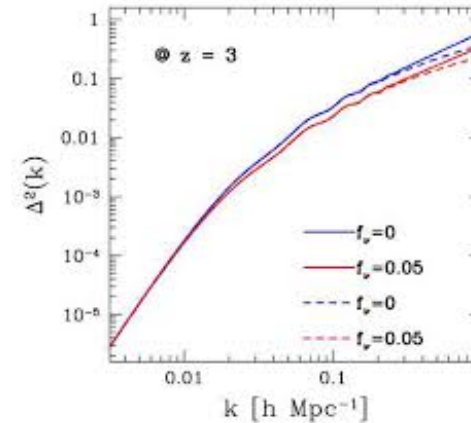
Which sterile neutrinos?

- eV sterile neutrinos

Motivation:

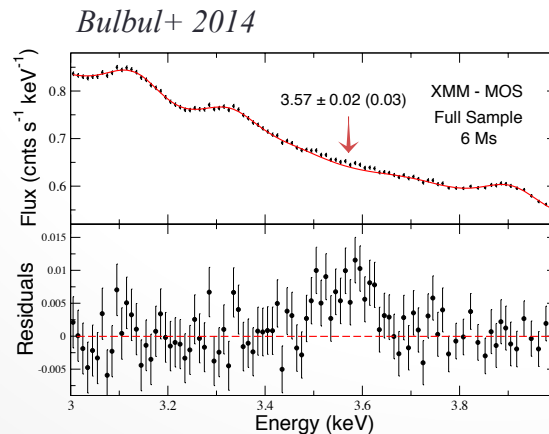


Cosmology: Hot Dark Matter

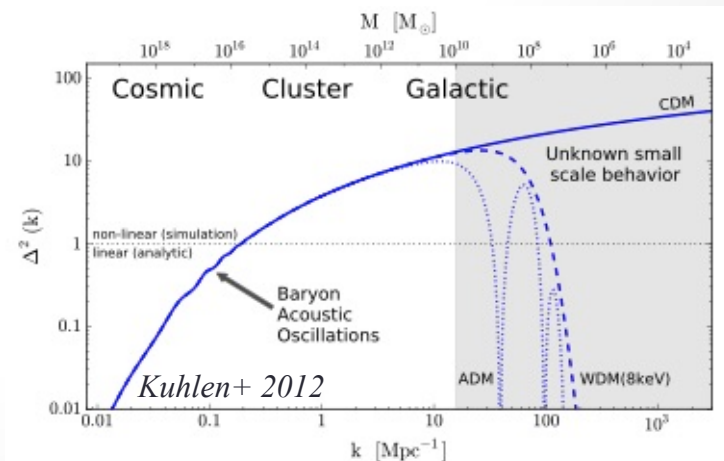


- keV sterile neutrinos

Motivation:

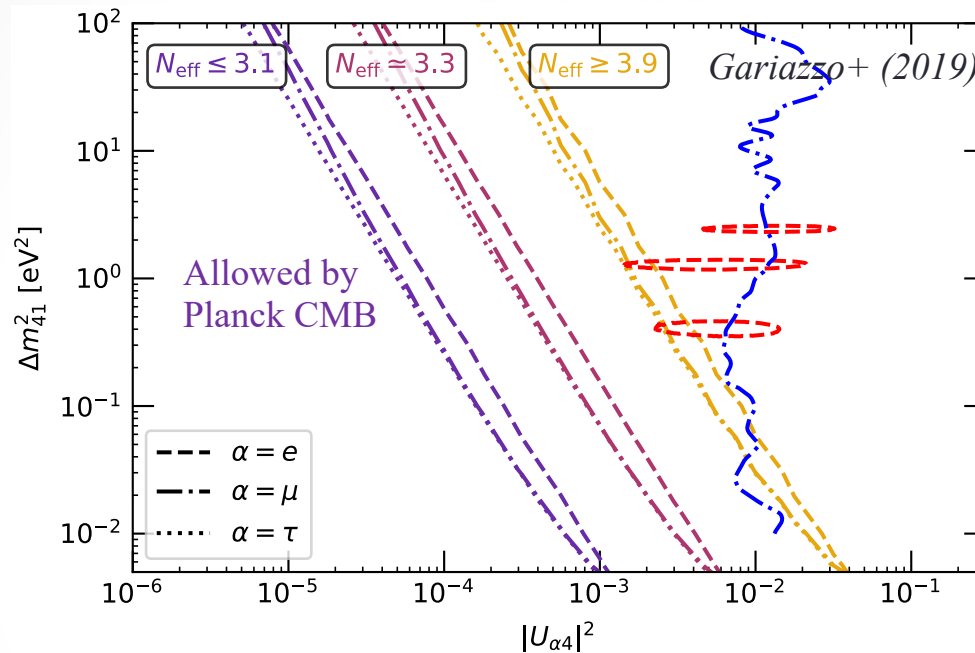


Cosmology: Warm Dark Matter



eV sterile neutrinos

Status



$$\rho_{\text{rad}} = \rho_{\gamma} \left[1 + \frac{7}{8} \left(\frac{4}{11} \right)^{4/3} N_{\text{eff}} \right]$$

$$N_{\text{eff}} = 3.045 + \Delta N_{\text{eff}}$$

Planck 2018 TTTEEE + lowE

$$N_{\text{eff}} = 2.92^{+0.36}_{-0.37} \text{ (95\%cl)}$$

Light sterile neutrino problem

Oscillation
experiments

Theoretical
efforts
BSM physics

Cosmological
observations

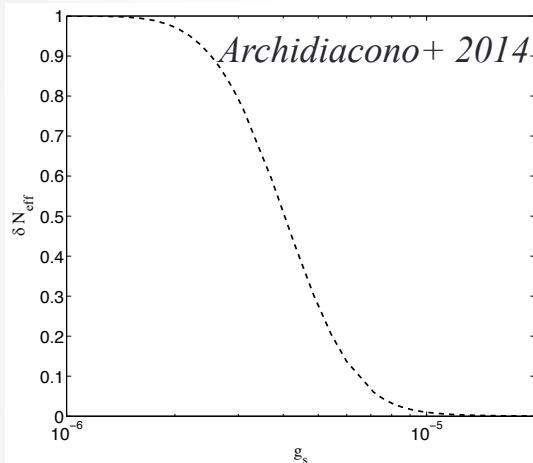
(LOI: NuSte: Global Light Sterile
Neutrino fits; Gariazzo+)

Theoretical efforts

BSM physics

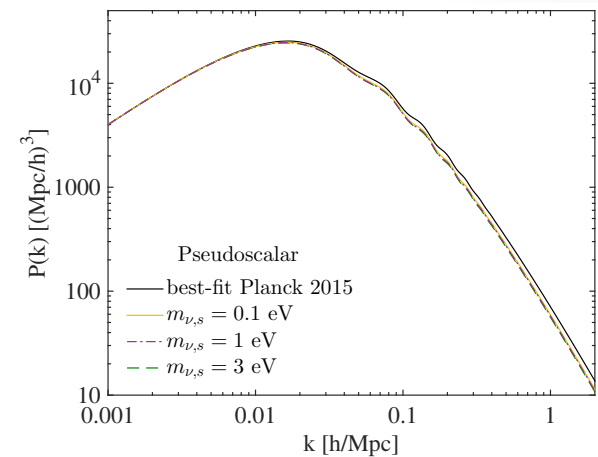
LOI: *Sterile Neutrinos with Non-Standard Interactions; Archidiacono, Hannestad+*

Early Universe



$$\nu_s \nu_s^{-1} \rightarrow \phi$$

Late Universe

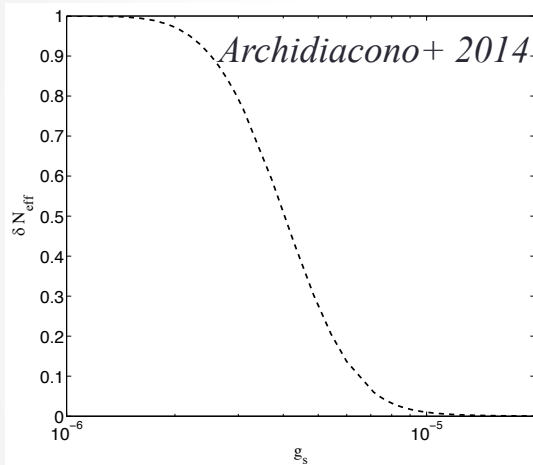


Theoretical efforts

BSM physics

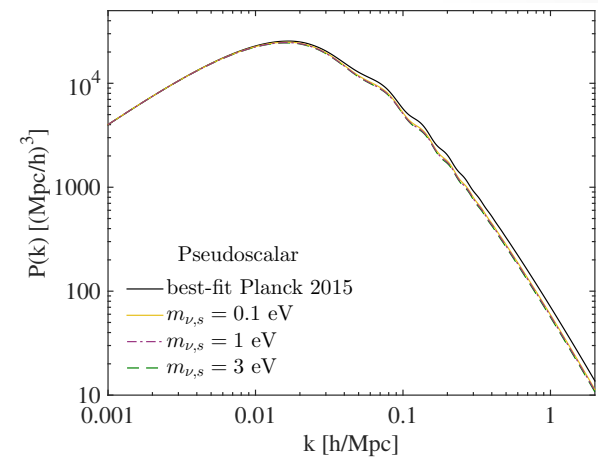
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Early Universe



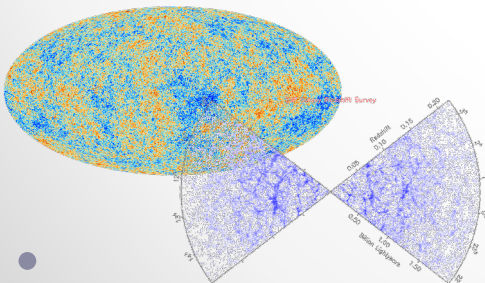
$$\nu_s \nu_s^{-1} \rightarrow \phi$$

Late Universe



Future directions

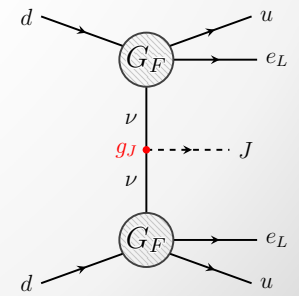
Cosmology



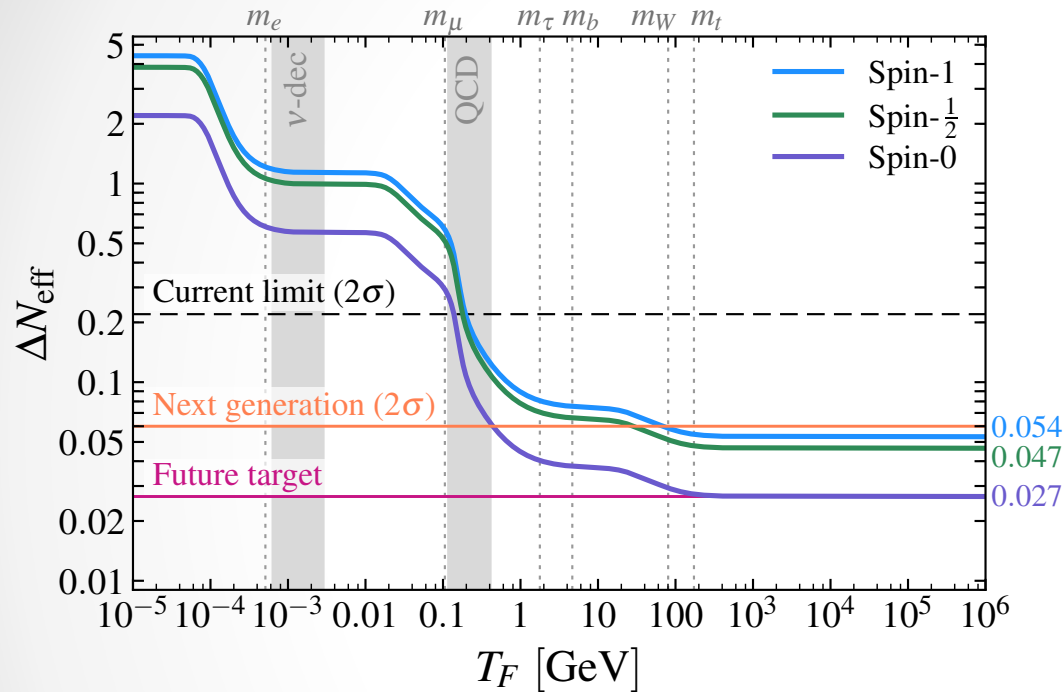
Astrophysics



Particle Physics



Cosmological observations



$$\rho_{rad} = \rho_{\gamma} \left[1 + \frac{7}{8} \left(\frac{4}{11} \right)^{4/3} N_{\text{eff}} \right]$$

$$N_{\text{eff}} = 3.045 + \Delta N_{\text{eff}}$$

$$\Delta N_{\text{eff}} = 0.027 g_{*,\phi} \left(\frac{g_{*,\text{SM}}}{g_*(T_{\text{F},\phi})} \right)^{4/3}$$

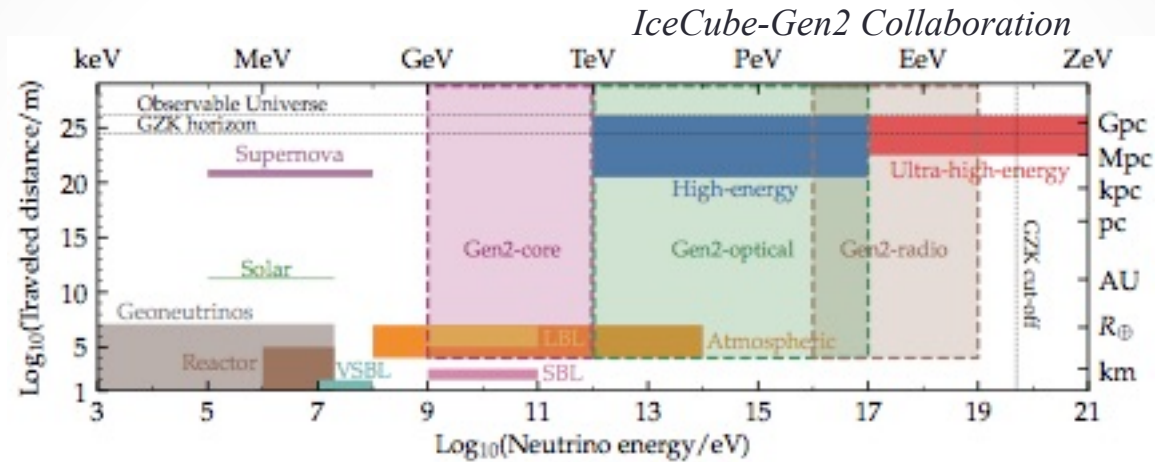
$$g_{*,\text{SM}} = 106.75$$

Figure from **LOI**: *Insights for Fundamental Physics and Cosmology with Light Relics*; Meyers+

LOI: *CMB-HD: An Ultra-Deep, High-Resolution Millimeter-Wave Survey Over Half the Sky*; Sehgal+, $\sigma(N_{\text{eff}}) = 0.014$

See also **LOI**: *Cosmological Neutrinos*; Grohs+

Astrophysical observations



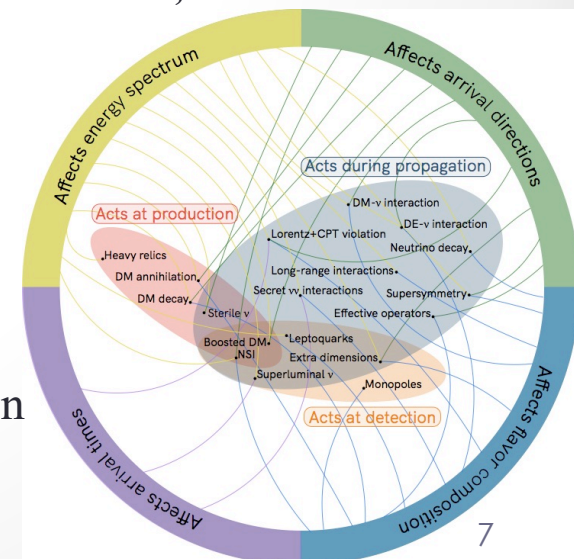
LOI: *IceCube Neutrino Observatory; Grant, Halzen+, IceCube Collaboration*

LOI: *IceCube-Gen2: The Window to the Extreme Universe; Karle, Kowalski+, IceCube-Gen2 Collaboration*

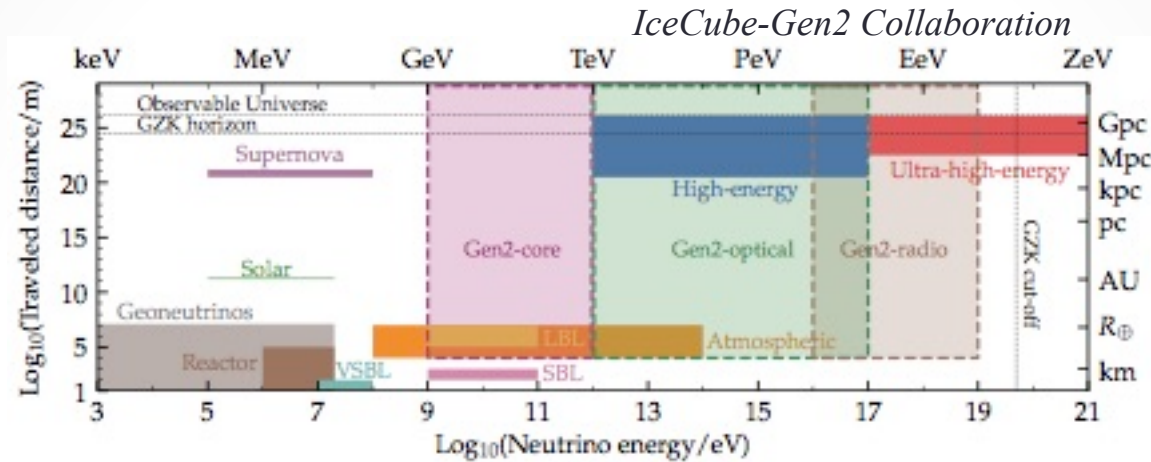
LOI: *Cosmic Neutrino Probes of Fundamental Physics; Bustamante+*

- Sterile neutrinos (energy spectrum)
- NSI (energy spectrum)
- DM – ν interactions (arrival direction)

Flavour composition



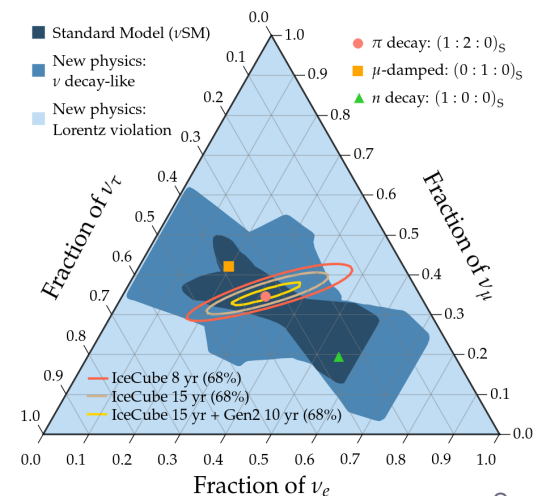
Astrophysical observations



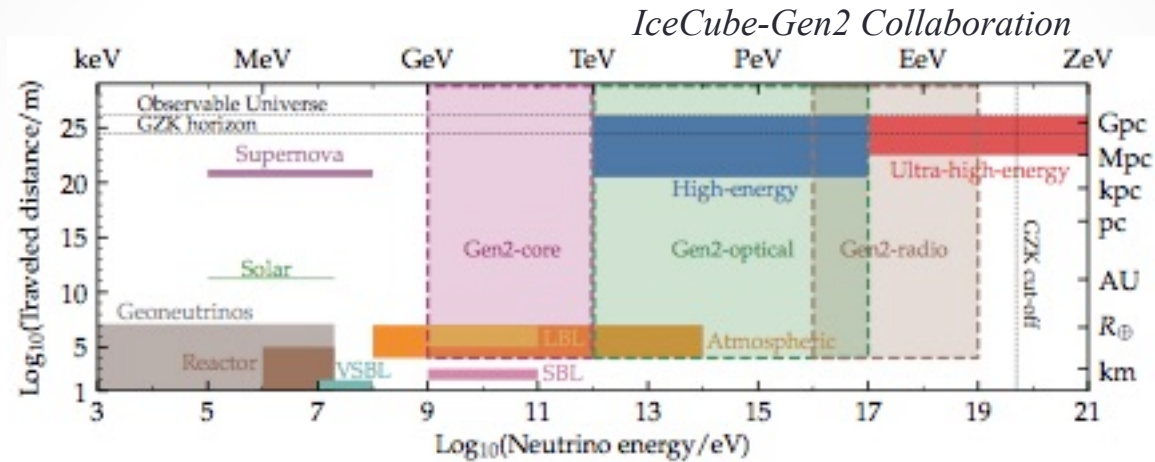
LOI: *IceCube Neutrino Observatory; Grant, Halzen+, IceCube Collaboration*

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LOI: *New physics with astrophysical neutrino flavour; Arguelles+, IceCube-Gen2 Collaboration*



Astrophysical observations



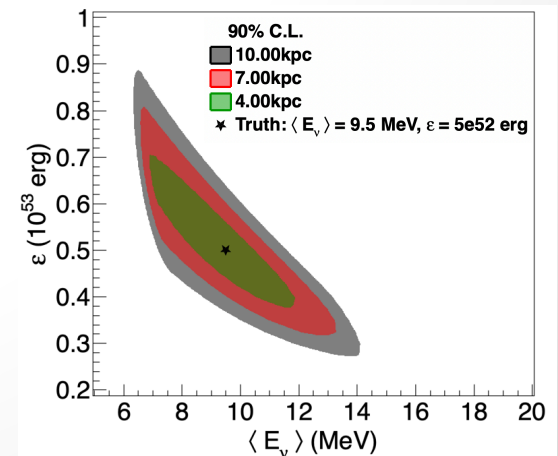
LOI: *IceCube Neutrino Observatory; Grant, Halzen+, IceCube Collaboration*

LOI: *IceCube-Gen2: The Window to the Extreme Universe; Karle, Kowalski+, IceCube-Gen2 Collaboration*

LOI: *Supernova Burst and Other Low-Energy Neutrino Physics in DUNE; Patterson, Worcester+, DUNE Collaboration*

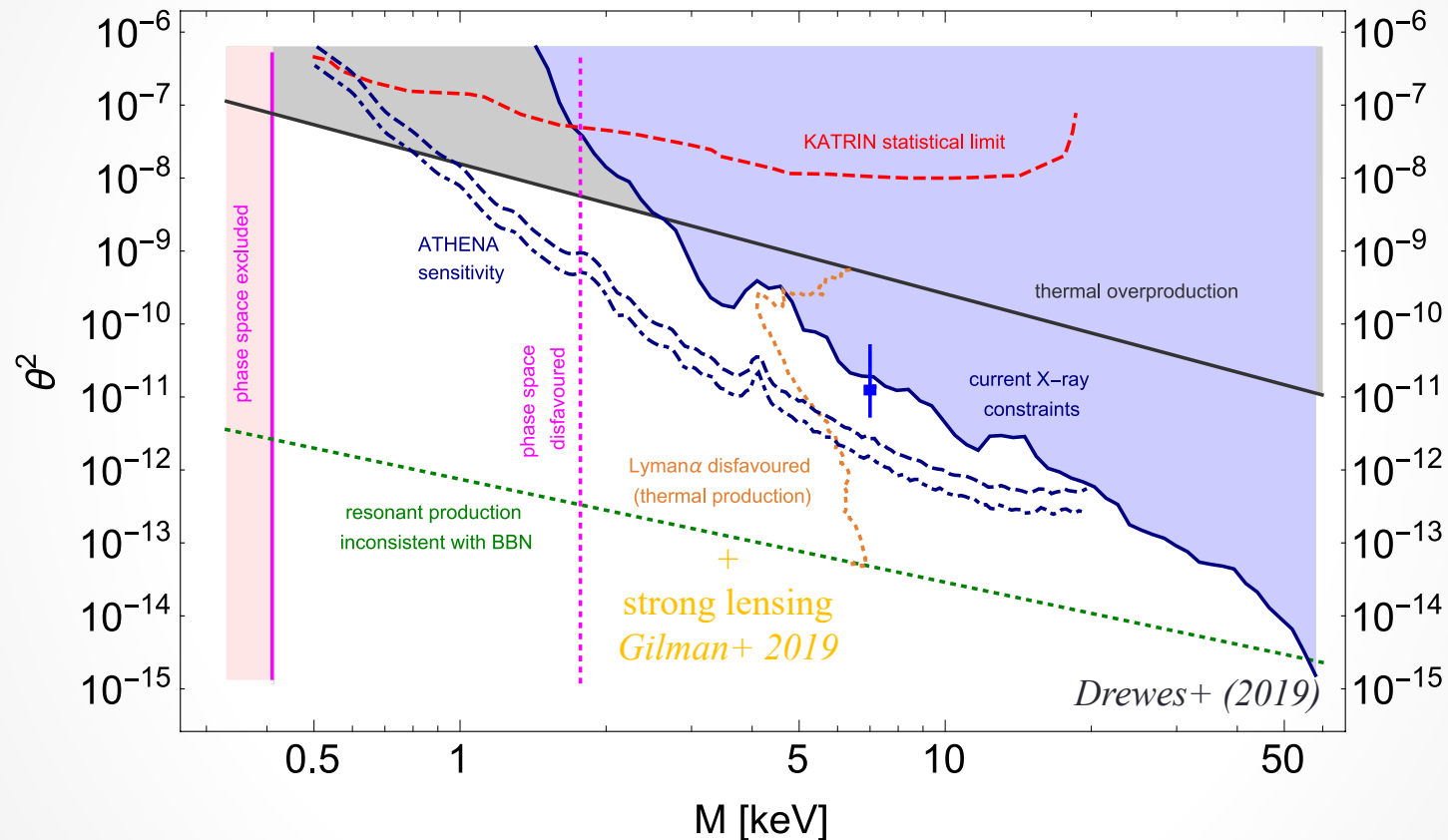
Theoretical uncertainties and computational effort:

LOI: *Deciphering explosion physics from the supernova neutrino signal; Friedland+*



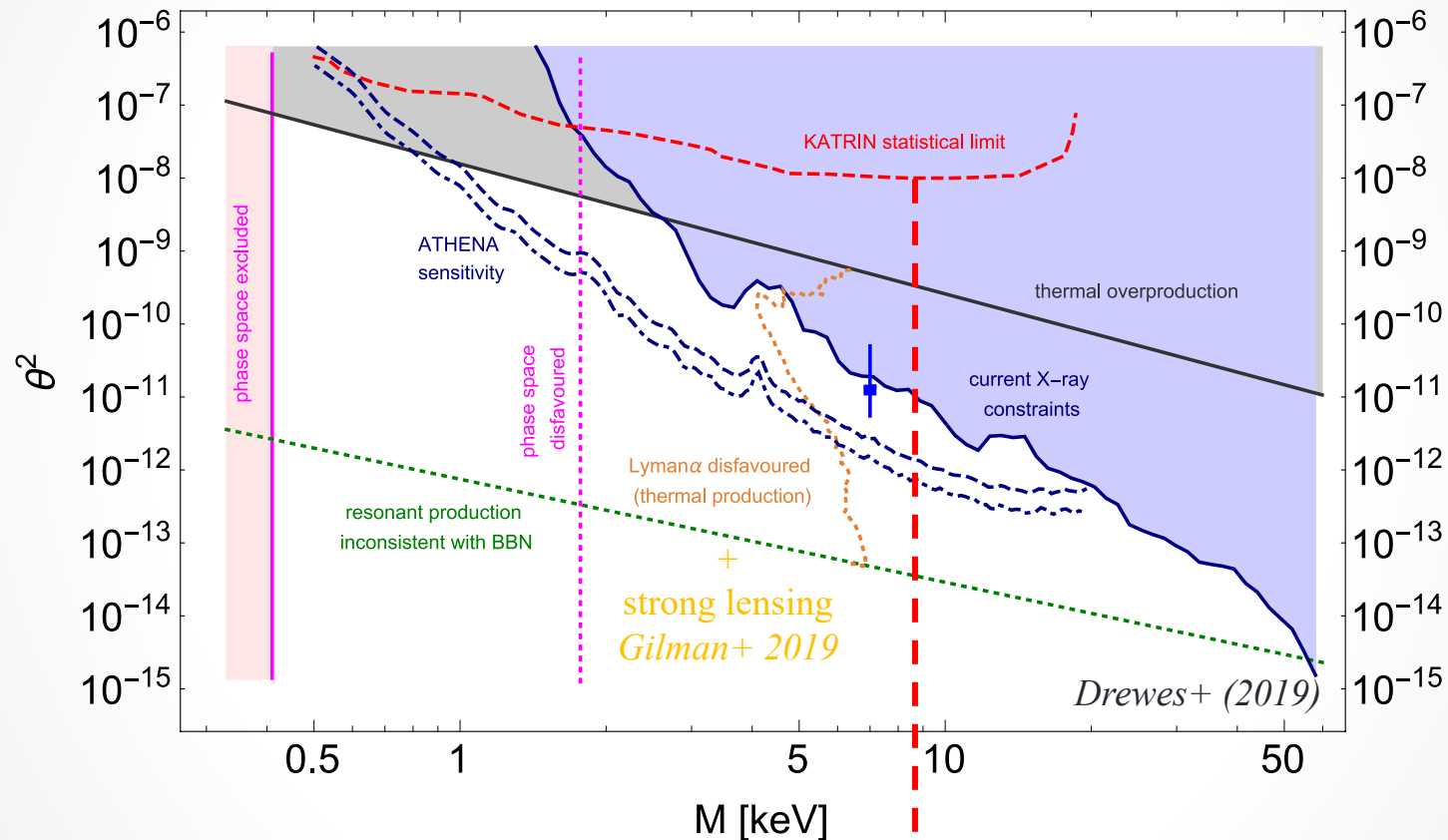
keV sterile neutrinos

Status



keV sterile neutrinos

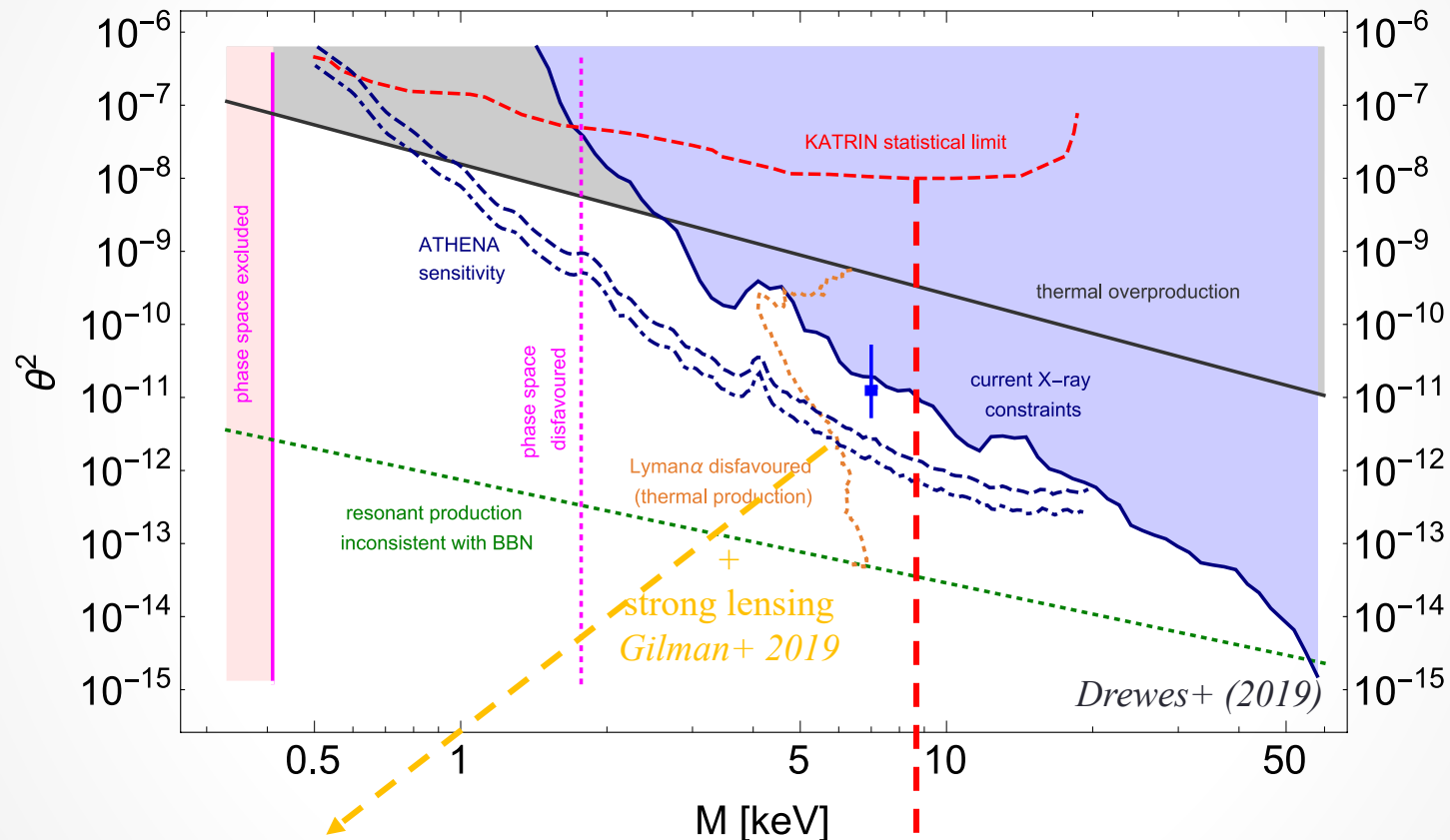
Future prospects



LOI: Prospects for keV Sterile Neutrino Searches with KATRIN
Mertens+

keV sterile neutrinos

Future prospects



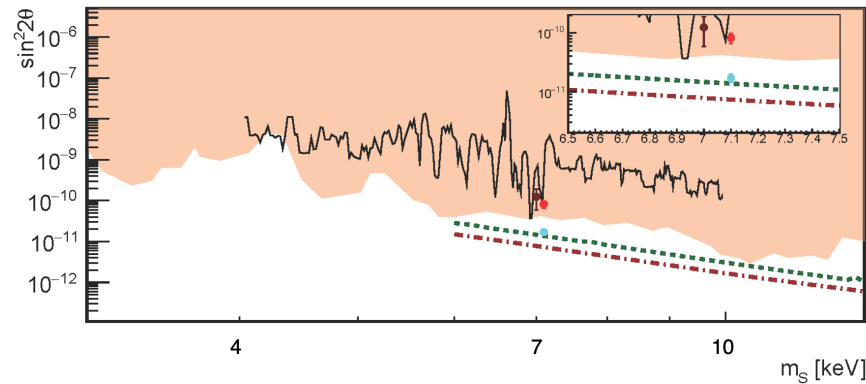
LOI: CMB-HD: An Ultra-Deep, High-Resolution Millimeter-Wave Survey Over Half the Sky; Sehgal+,

LOI: Prospects for keV Sterile Neutrino Searches with KATRIN
Mertens+

keV sterile neutrinos

Future prospects

LOI: *Dark Matter Searches with the Micro-X X-ray Sounding Rocket*
Figueroa-Feliciano, Hubbard+



- significantly less expensive than satellite missions, and the instrument can be recovered after flight and reflown
- Micro-X has the sensitivity to discern between dark matter and atomic origin of the 3.5 keV line

Conclusions

