The Future is Flavourful

Discussion 2:
Astroparticle physics and cosmology

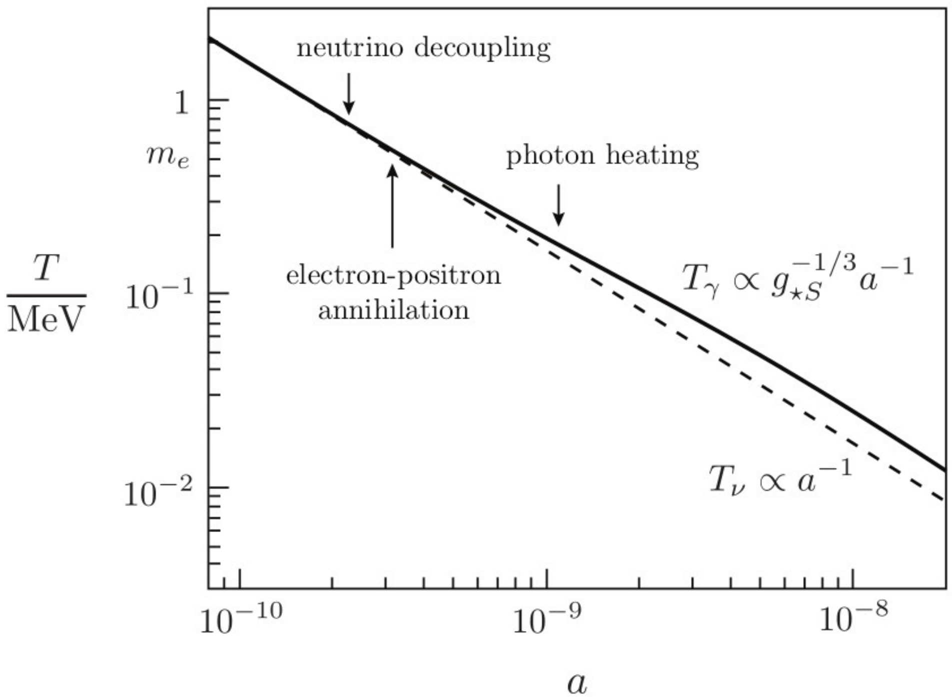
Astroparticle physics and cosmology

- Neutrino & cosmology.
- Neutrino to photon temperature ratio (11/4)^1/3 and Neff.

$$\frac{\rho_\nu}{\rho_\gamma} = \frac{7}{8} N_{\text{eff}} \left(\frac{4}{11}\right)^{4/3}$$

Shouvik's talk.

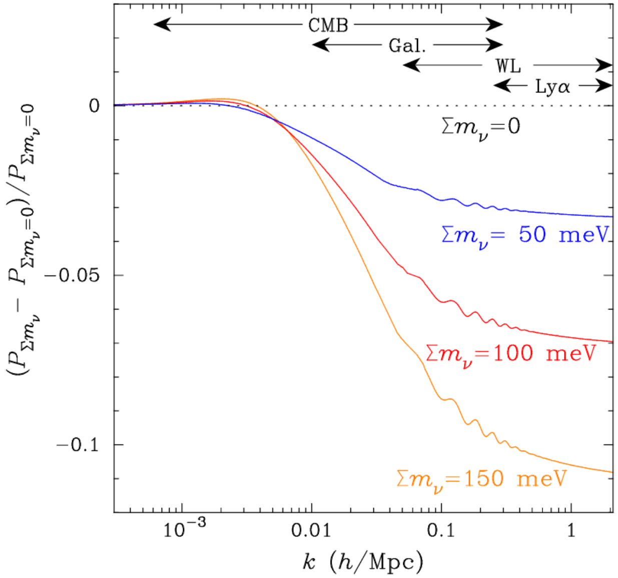
PDG review: neutrinos in cosmology



D.Baumann's lecture

Astroparticle physics and cosmology

- Neutrino mass and matter power spectrum:



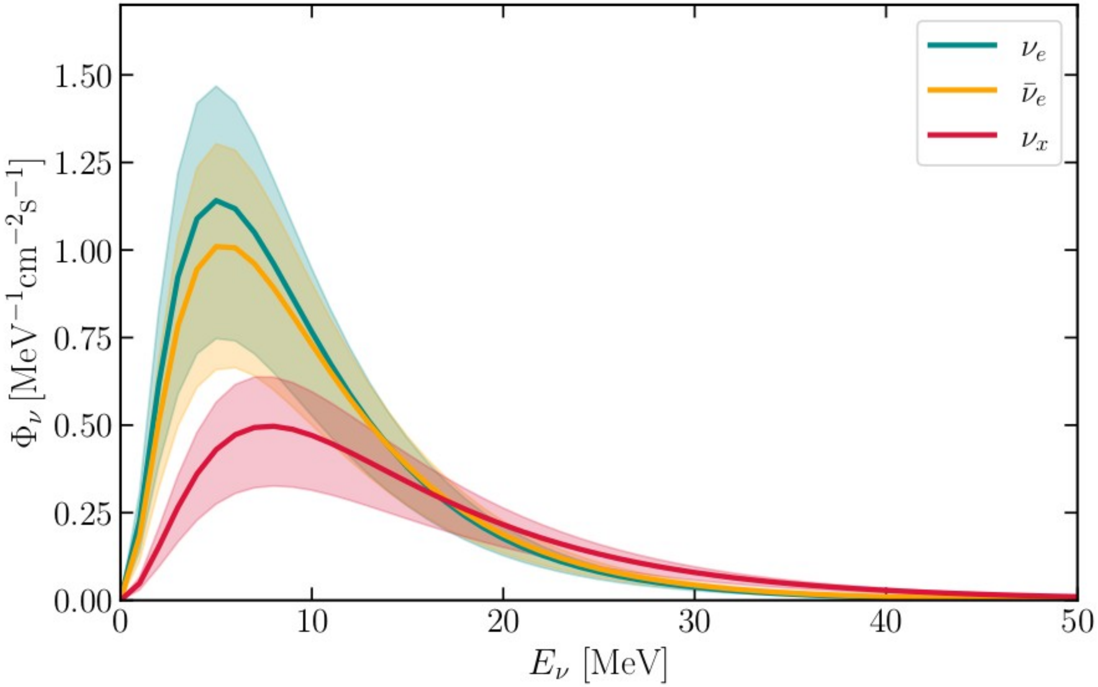
PDG review: neutrinos in cosmology, 1309.5383.

- Non-relativistic neutrino cluster at scale larger than free steaming scale, suppressing structure formation at small scale.

Bond et al., Phys.Rev.Lett. 45 (1980) 1980-1984.

Astroparticle physics and cosmology

- Diffuse supernova neutrino background (DSNB).



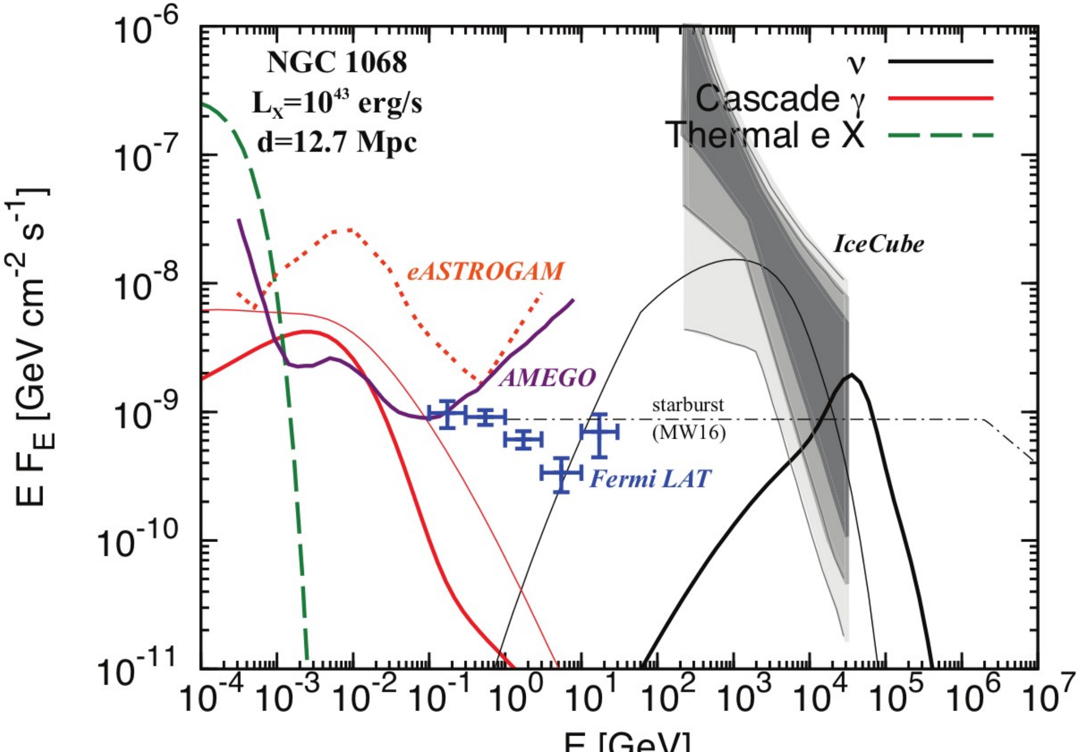
$$F_\nu(E) = \frac{E_\nu^{\rm tot}}{6}\,\frac{120}{7\pi^4}\,\frac{E_\nu^2}{T_\nu^4}\,\frac{1}{e^{E_\nu/T_\nu}+1}$$

$$\Phi_\nu(E) = \int_0^{z_{\rm max}} \frac{dz}{H(z)} R_{\rm CCSN}(z) F_\nu(E)$$

J.F.Beacom: 1004.3311,
A.Das, M.Sen: 2104.00027

Astroparticle physics and cosmology

- AGN: high energy neutrino source, and DM pike profile.

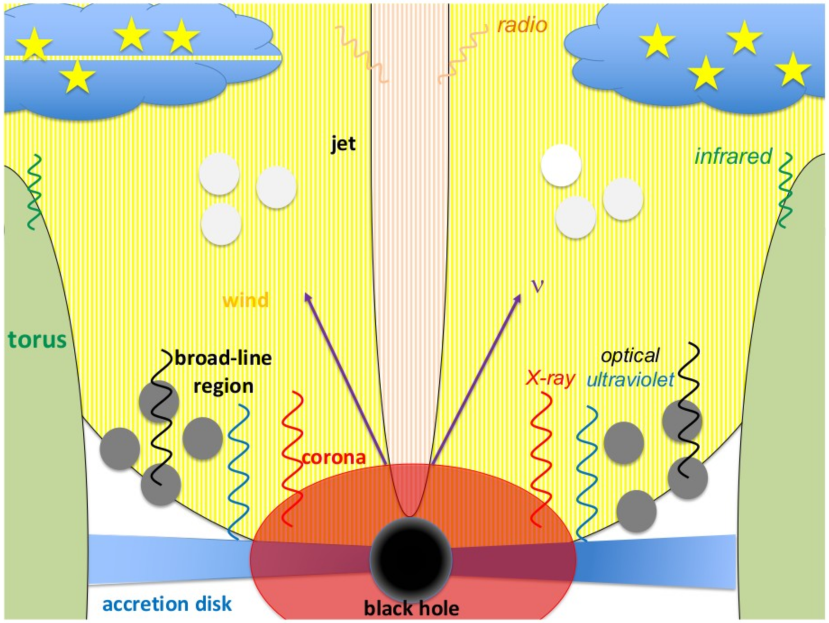


K.Murase, S.S.Kimura, P.Meszaros:1904.04226,
C.Blanco, D.Hooper, T.Linden, E.Pinetti: 2307.03259,
J.M.Cline, M.Puel: 2301.08756

A model for neutrino, gamma-ray from NGC 1068

- Proton acceleration and diffusion from the corona near supermassive black hole. C.Blanco, D.Hooper, T.Linden, E.Pinetti: 2307.03259, K.Murase : 2211.04460

$$\left(\frac{\mathrm{d}N_p}{\mathrm{d}E_p}\right)_{\mathrm{inj}} \propto \left[1 - \exp\left(-\frac{E_p}{m_p c^2}\right)\right] \left(\frac{E_p}{1\,\mathrm{GeV}}\right)^{-\Gamma_p} \exp\left(-\frac{E_p}{E_p^{\mathrm{max}}}\right),$$



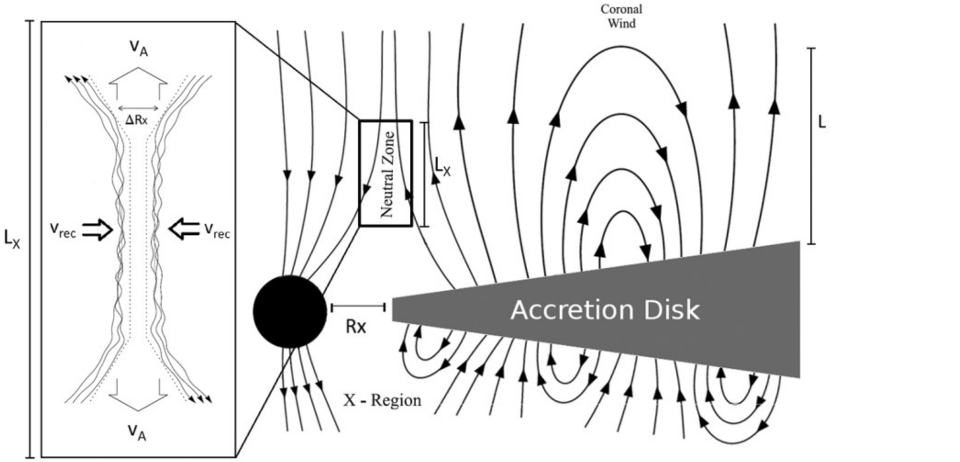
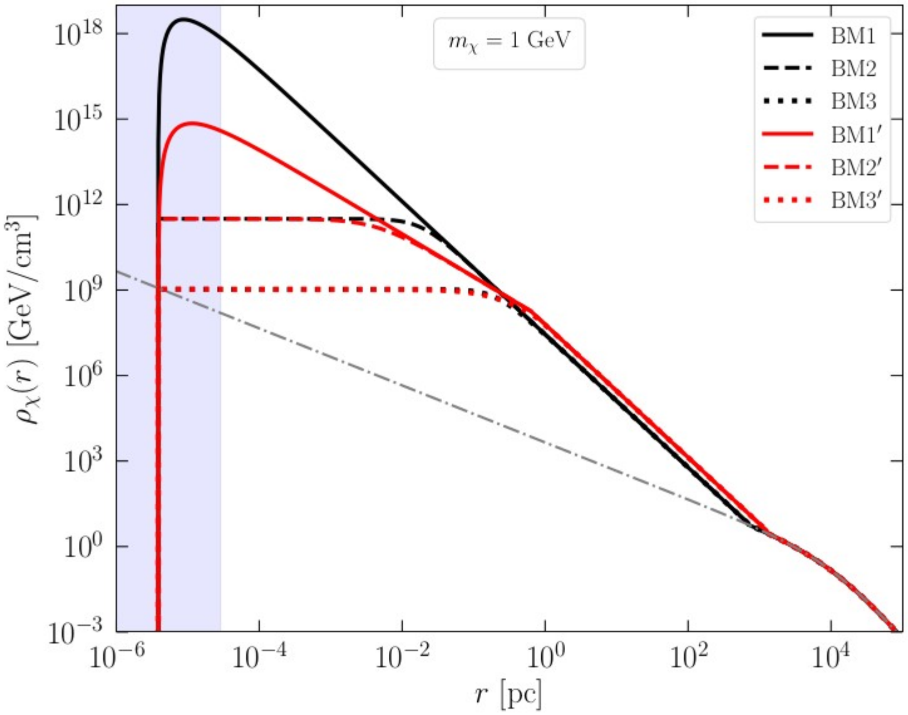


Figure 1. Scheme of magnetic reconnection between the lines arising from the accretion disc and the lines anchored into the BH horizon. Reconnection is made fast by the presence of embedded turbulence in the reconnection (neutral) zone (see text for more details). Particle acceleration may occur in the magnetic reconnection zone by a first-order *Fermi* process (adapted from GL05).

DM spike around Supermassive BH

- The adiabatic growth of BHs form a spike of DM particles with radius.



J.M.Cline, M.Puel: 2301.08756,
G.Herrera,K.Murase: 2307.09460

Astroparticle physics and cosmology

- Scalar DM-neutrino interactions

$$\mathcal{L}_{int} = \frac{1}{2}\sum_{i,j} y_{ij}\bar{\nu}_i\nu_j\phi$$

C.Doring, S.Vogl: 2304.08533

- Adding new Fermion

M.M.Reynoso, O.A.Sampayo: 1605.09671

$$\mathcal{L}_{\nu_\alpha\varphi} = g_\alpha\bar{\nu}_\alpha\varphi P_R F + \text{h.c.},$$

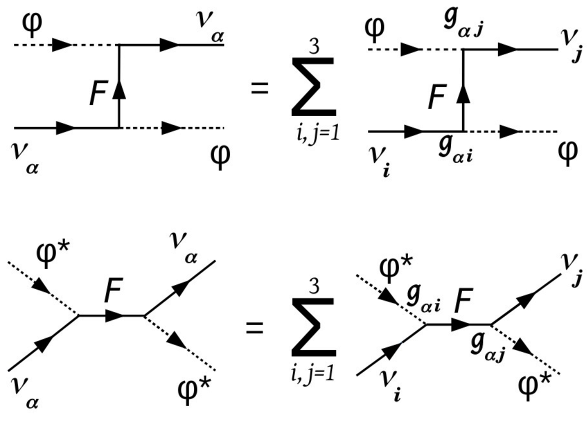
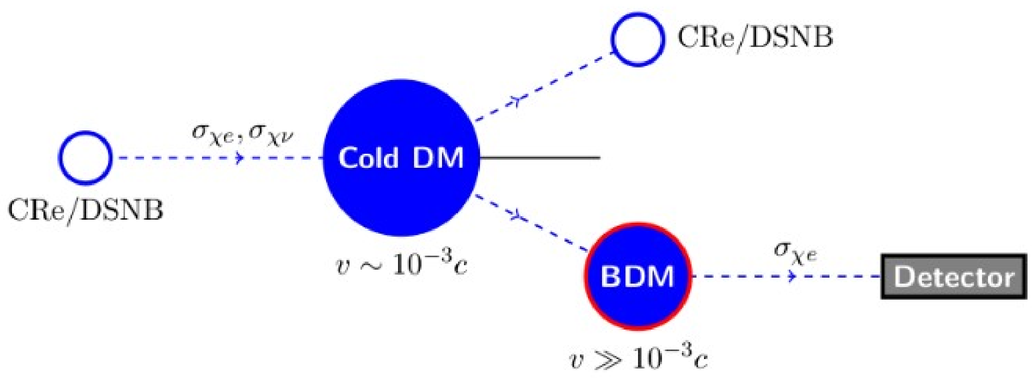
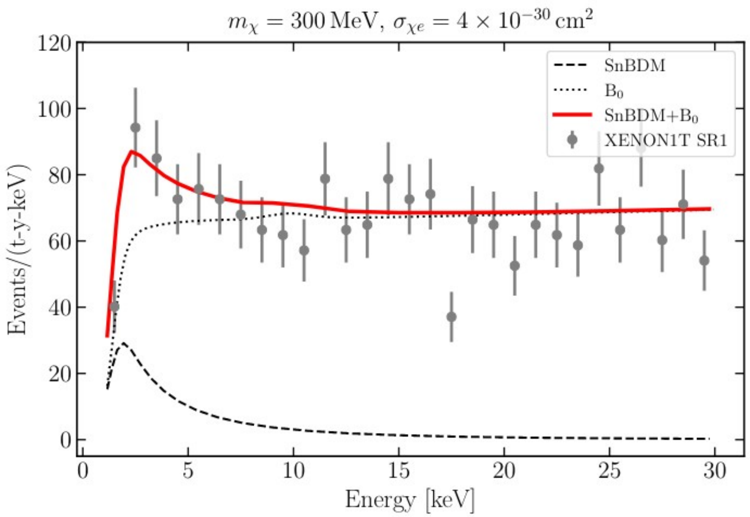


Figure 1: Diagrams for the $\nu_i\varphi \rightarrow \nu_j\varphi$ interactions.

Phenomenology and Constraints

- Boosted sub-GeV DM by cosmic-electron, DSNB, stellar neutrino etc.
- Boosted DM carries energy above detector threshold can be detected.





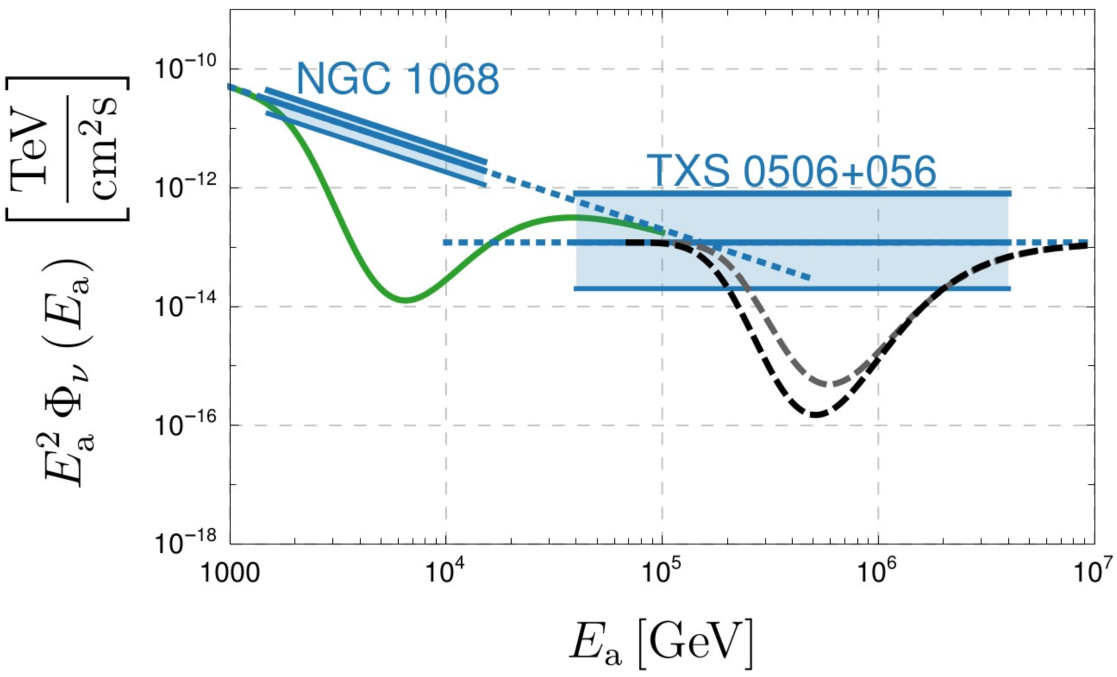
Herry T. Wong's Talk

D.Ghosh et. al 2110.00025

A.Das, M.Sen 2104.00027, 2206.06864

Phenomenology and Constraints

- Neutrino flux attenuation: IceCube (NGC 1068, TXS 0506+056), SN1987A, DSNB



2304.08533, 2301.08756

Phenomenology and Constraints

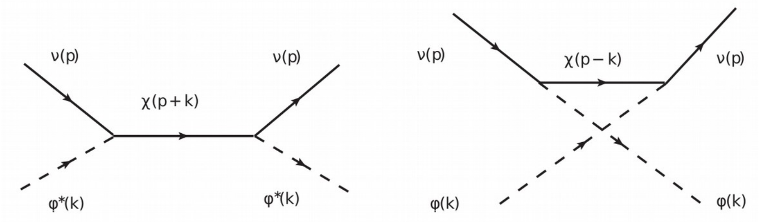
- Wave-like DM-neutrino interaction:

$$\mathcal{L} \supset \sum_{\alpha=e,\mu,\tau} \sum_{k} g_{\alpha k} \bar{\chi}_{kR} \nu_{\alpha L} \phi^* + m_{\chi k} \bar{\chi}_{kR} \chi_{kL} + \text{h.c}$$

M.Sen, A.Y.Smirnov: 2306.15718

- Ultralight/Fuzzy DM behaves as background field, contributing to the effective potential and effective neutrino mass (refractive mass differs from VEV-induced mass).

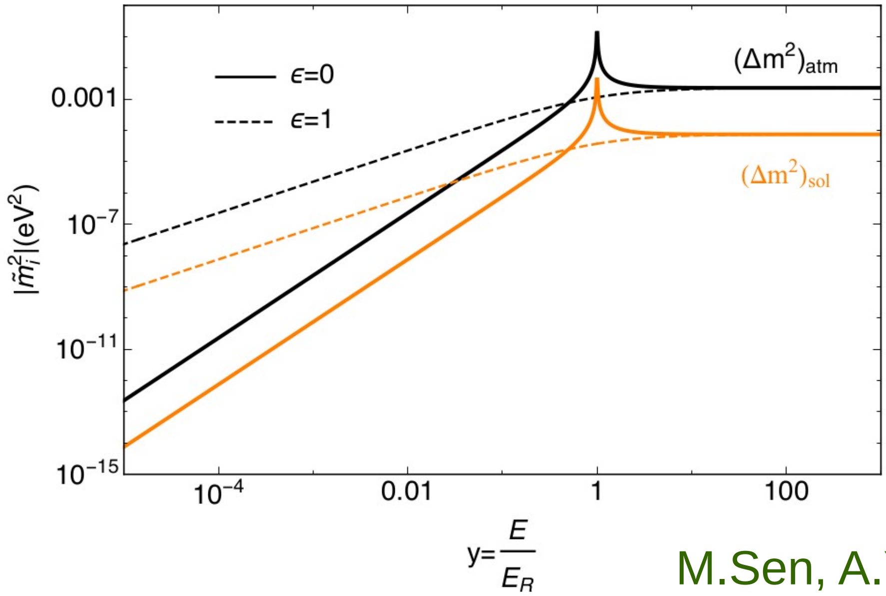
$$V_{\alpha\beta} = \sum_k g_{\alpha k} g^*_{\beta k} \left[\frac{\bar{n}_\phi (2Em_\phi - m^2_{\chi k})}{(2Em_\phi - m^2_{\chi k})^2 + (m_\chi \Gamma_{\chi k})^2} + \frac{n_\phi}{2Em_\phi + m^2_{\chi k}} \right]$$



Phenomenology and Constraints

- To satisfy neutrino-oscillation observations that neutrino masses are energy independent, the resonance energy should be smaller than lowest energy of detected neutrinos:

$$E_R \leq 0.1\,\text{MeV} \qquad E_R = m_\chi^2/(2m_\phi)$$



M.Sen, A.Y.Smirnov: 2306.15718

Phenomenology and Constraints

- The mediator χ mix with ν and can be produced from $\nu - \chi$ oscillation in the early Universe via Dodelson-Widrow mechanism.
- Mediator contribute to extra radiation at time of BBN:

$$\Delta N_{\rm eff} = \frac{\rho_\chi}{\rho_\nu}\,, \qquad \Delta N_{\rm eff}^{\rm BBN} < 0.5$$

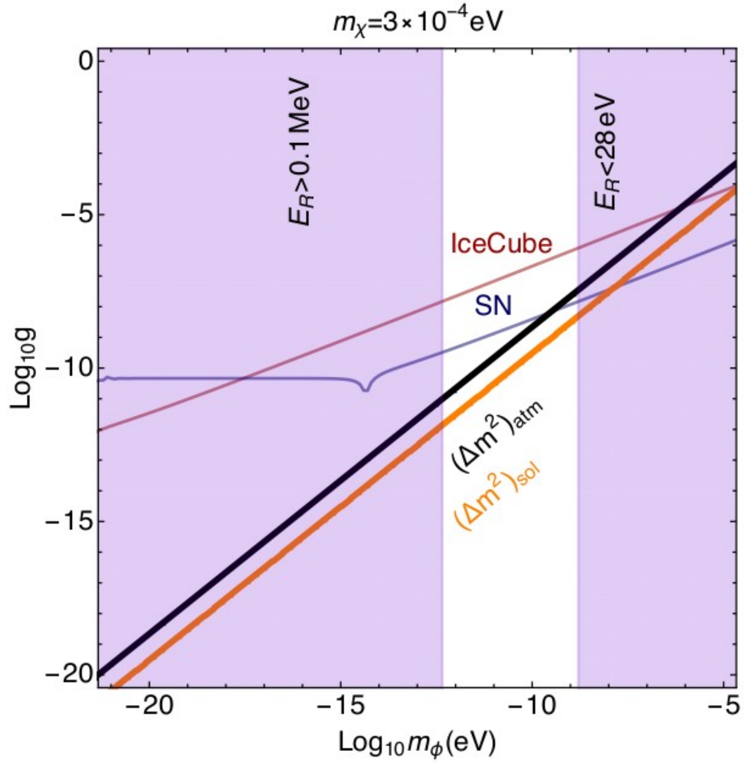
- Since DM density evolves as (1+z)^3, neutrino mass grows in the early Universe. CMB and BAO requires $\sum m_\nu < 0.12\,{\rm eV}$:

$$E_R > 28\,{\rm eV}$$

M.Sen, A.Y.Smirnov: 2306.15718

Phenomenology and Constraints

- Summarize above constraints.



M.Sen, A.Y.Smirnov: 2306.15718

Questions:

- DM-neutrino reduces free streaming → Hubble tension?
- DM-Neutrino constraints from cosmology/astrophysics?
- Wave interference and observation ultra-faint dwarf galaxy.

N.Dalal, A.Kravtsov: 2203.05750

- Degree of freedom and phase transition in early Universe?
- Can we improve BBN predictions?

- Sterile neutrino.