Dark Matter Indirect Detection with Neutrino Lines

Camilo Garcia Cely, ULB

DaνCo
Dark Matter, νs and their Connections

Aug 29th, 2017

In collaboration with Chaimae El Aisati, Thomas Hambye, Julian Heeck and Laurent Vanderheyden.
Based on arXiv:1706.06600 and JCAP 1703 (2017) no.03, 054

Indirect dark matter detection:

Dark matter annihilates or decays into some particles and these in turn produce a flux of γ, $e^{\pm}$, p, $\overline{p}$, and (anti-)neutrinos. Subsequently, these propagate from the point where they are produced until they reach the earth.

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This talk: DM $\to \nu\nu$ or DM DM $\to \nu\nu$.

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What sort of models naturally lead to neutrino lines?

- multi-TeV DM Dark Matter: Thomas Hambye's Talk.
- Majoron DM below a few TeV. CGC, Heeck (2017)

Majoron Dark Matter

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  Above a few TeV, three-body and four-body final states dominate the decay. Dudas, Mambrini and Olive (2015).

Let us see this more in detail

- Consider $\sigma = \frac{f+\sigma^0+iJ}{\sqrt{2}}$ with two units of lepton number:

$$\mathcal{L} = \underbrace{-\overline{L}yN_RH}_{\text{Dirac Mass Term}} - \underbrace{\tfrac{1}{2}\overline{N}_R^c\lambda N_R\sigma}_{\text{Majorana Mass Term}} + \text{h.c.}$$

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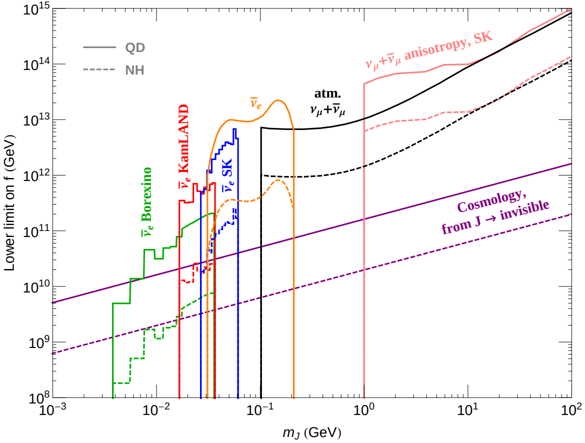
- Sub-GeV Majorons can be produced via Freeze-in

Frigerio, Hambye, Masso (2011) , Heeck, Teresi (2017). See Daniele Teresi's talk.

Neutrinos from Majoron DM

$$\Gamma(J \to \nu\nu) \simeq \frac{m_J}{16\pi f^2}\sum_{j=1}^{3} m_j^2 \simeq \frac{1}{3\times 10^{19}\,\mathrm{s}}\left(\frac{m_J}{1\,\mathrm{MeV}}\right)\left(\frac{10^9\,\mathrm{GeV}}{f}\right)^2\left(\frac{\sum_j m_j^2}{10^{-3}\,\mathrm{eV}^2}\right).$$



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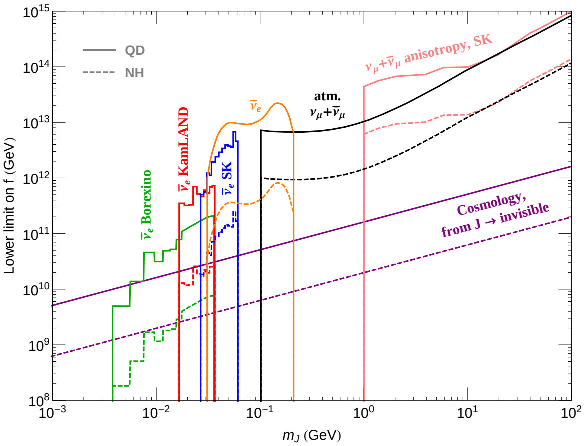

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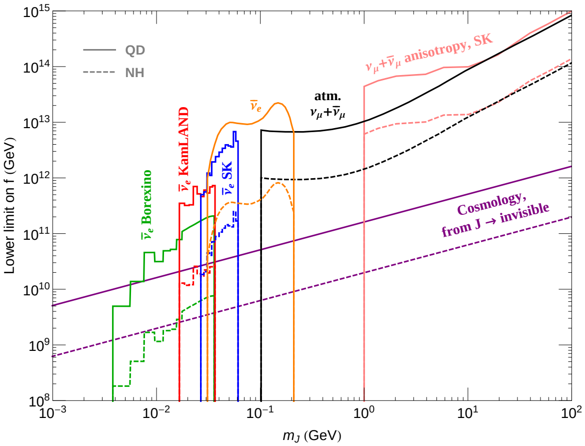

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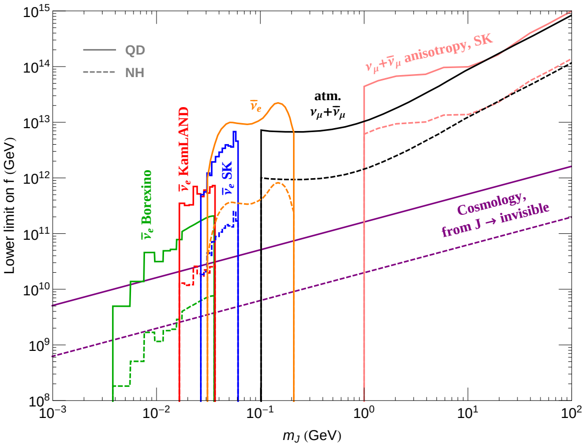

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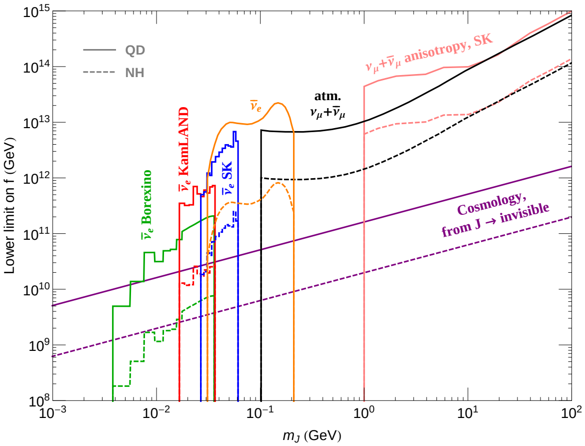

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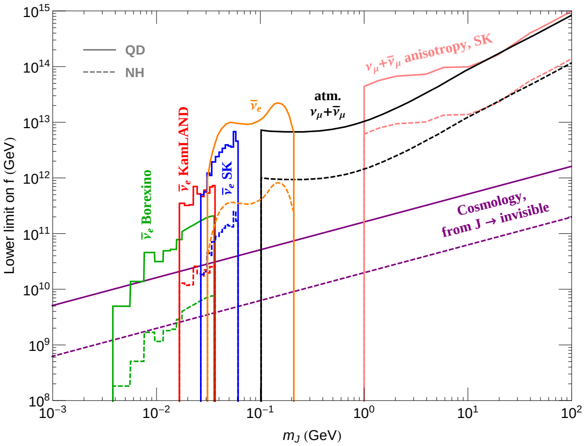

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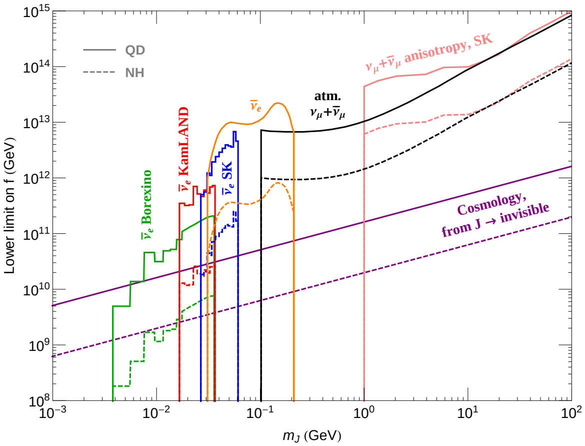

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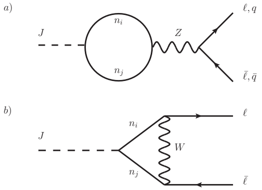
Decay into charged fermion pairs



$$\mathcal{L}_J = iJ\bar{f}_1(g^S_{Jf_1f_2} + g^P_{Jf_1f_2}\gamma_5)f_2$$

$$g^P_{Jqq'} \simeq \frac{m_q}{8\pi^2 v}\delta_{qq'}T^q_3\,\mathrm{tr}K\,, \quad g^S_{Jqq'} = 0\,,$$

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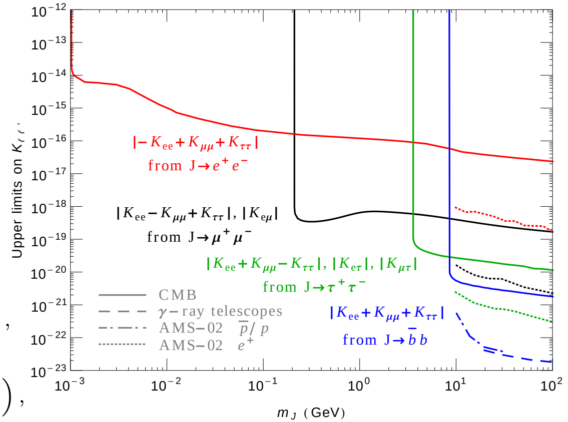

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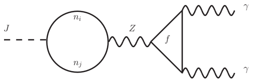
Decay into photons (much more difficult)



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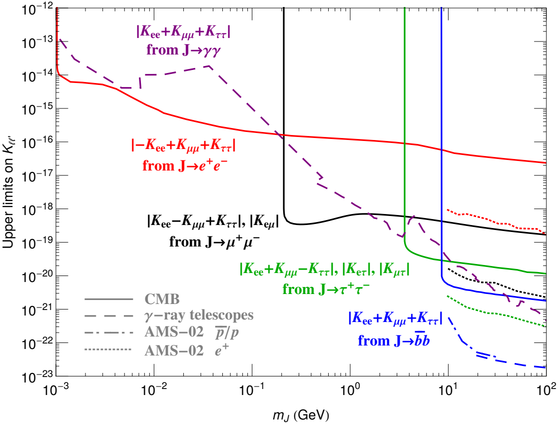

CGC, Heeck (2017)

Neutrinos also carry flavor...

Astrophysical neutrinos (produced as flavor eigenstates)

$$\rho^S = \overbrace{\begin{pmatrix} \alpha_e^S & 0 & 0 \\ 0 & \alpha_\mu^S & 0 \\ 0 & 0 & \alpha_\tau^S \end{pmatrix}}^{\text{flavor-eigenstate basis}}, \qquad H \simeq E\,\mathbb{1} + \overbrace{\begin{pmatrix} \frac{m_1^2}{2E} & 0 & 0 \\ 0 & \frac{m_2^2}{2E} & 0 \\ 0 & 0 & \frac{m_3^2}{2E} \end{pmatrix}}^{\text{mass-eigenstate basis}}$$

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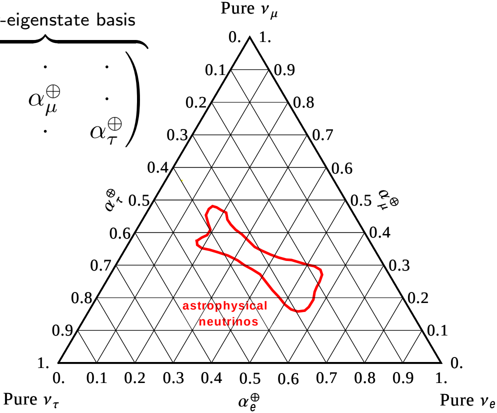

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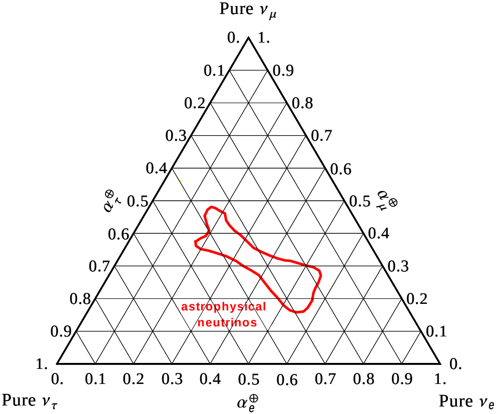

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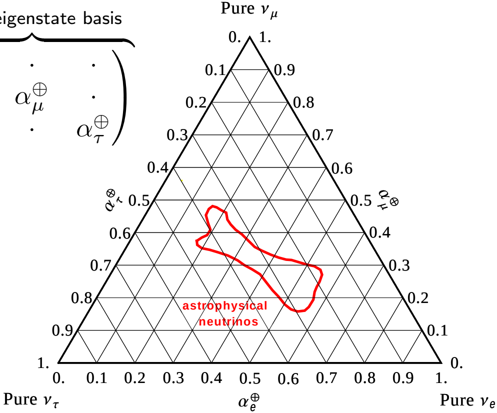

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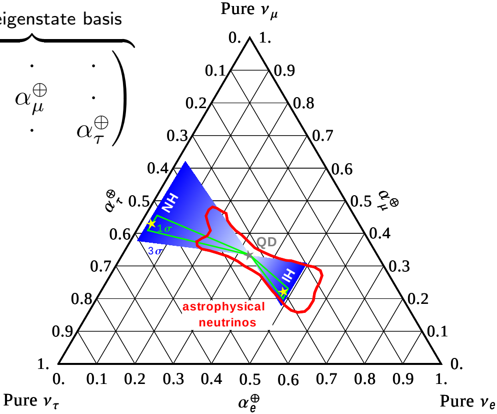

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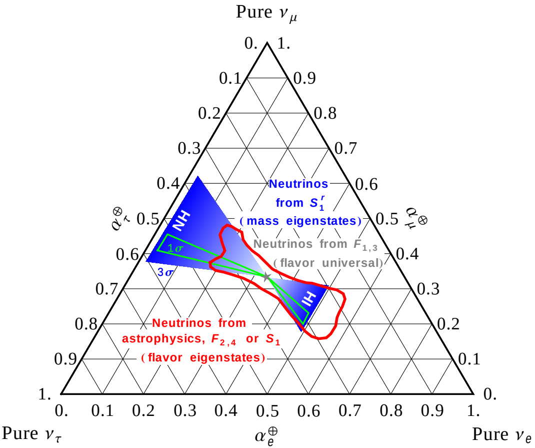
The same is true for DM annihilations

- Process DM DM $\to \nu\nu$
- Process DM DM $\to \nu\overline{\nu}$ with a t-channel induced by a Yukawa interaction
- Process DM DM $\to \nu\overline{\nu}$ with a Z' in the s-channel



El Asaiti, CGC, Hambye, Vanderheyden (2017)

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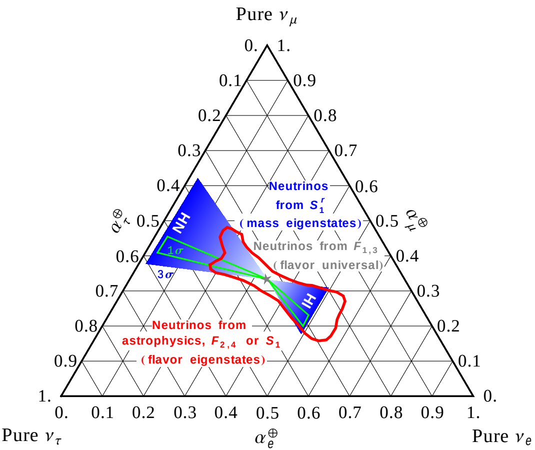

More on this in Thomas Hambye's talk!

El Asaiti, CGC, Hambye, Vanderheyden (2017)

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