A_4 based neutrino masses with Majoron decaying dark matter

Mariam Tórtola, IFIC (Valencia)

Based on Esteves et al, Phys. Rev. D82 (2010) 073008

Outline

- A_4 flavor symmetric model with spontaneous breaking of L.
- Implications for neutrino phenomenology.
- Majoron -> candidate for decaying dark matter:
  - $J \longrightarrow \nu\nu$
  - $J \longrightarrow \gamma\gamma$

A_4 flavor-symmetric model

	L_1	L_2	L_3	l_{Ri}	ν_{iR}	Φ_i	Δ	σ	S_i
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spontaneous breaking of L -> Majoron

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$$m_D = v \, \mathrm{diag}(h_1, h_2, h_3) \, U$$

$$U = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & \omega^2 & \omega \\ 1 & 1 & 1 \\ 1 & \omega & \omega^2 \end{pmatrix} \qquad \omega = e^{2\pi i/3}$$

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→ consistent minimization of scalar potential with non-zero vevs.

$M_\Delta \ll M_R \sim u_\sigma$

Experimental constraints for the light neutrino mass matrix

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$$\mathcal{M}_\nu = U M_\nu^{diag} U^\dagger$$

$$M_\nu^{diag} = \mathrm{diag}(m_1, m_2, m_3)$$

$$U = \begin{pmatrix} c_{13}c_{12} & s_{12}c_{13} & s_{13} \\ -s_{12}c_{23} - s_{23}s_{13}c_{12} & c_{23}c_{12} - s_{23}s_{13}s_{12} & s_{23}c_{13} \\ s_{23}s_{12} - s_{13}c_{23}c_{12} & -s_{23}c_{12} - s_{13}s_{12}c_{23} & c_{23}c_{13} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha} & 0 \\ 0 & 0 & e^{i(\beta+\delta)} \end{pmatrix}$$

parameter	best fit $\pm 1\sigma$	2σ	3σ
Δm^2_{21} $[10^{-5}\mathrm{eV}^2]$	$7.59^{+0.20}_{-0.18}$	7.24–7.99	7.09–8.19
Δm^2_{31} $[10^{-3}\mathrm{eV}^2]$	2.45 ± 0.09 $-(2.34^{+0.10}_{-0.09})$	$2.28 - 2.64$ $-(2.17 - 2.54)$	$2.18 - 2.73$ $-(2.08 - 2.64)$
$\sin^2\theta_{12}$	$0.312^{+0.017}_{-0.015}$	0.28–0.35	0.27–0.36
$\sin^2\theta_{23}$	0.51 ± 0.06 0.52 ± 0.06	0.41–0.61 0.42–0.61	0.39–0.64
$\sin^2\theta_{13}$	$0.010^{+0.009}_{-0.006}$ $0.013^{+0.009}_{-0.007}$	≤ 0.027 ≤ 0.031	≤ 0.035 ≤ 0.039

Schwetz, M.T., Valle 2011

Predictions for neutrino phenomenology (I)

- texture B1:
  - correlation between atmospheric mixing angle and the lightest neutrino mass -> lower bound on m_1 (m_3) for NH (IH).
  - amplitude $0\nu\beta\beta$

$$|m_{ee}| = \left|c_{13}^2 c_{12}^2 m_1 + c_{13}^2 s_{12}^2 m_2 e^{2i\alpha} + s_{13}^2 m_3 e^{2i\beta}\right|$$

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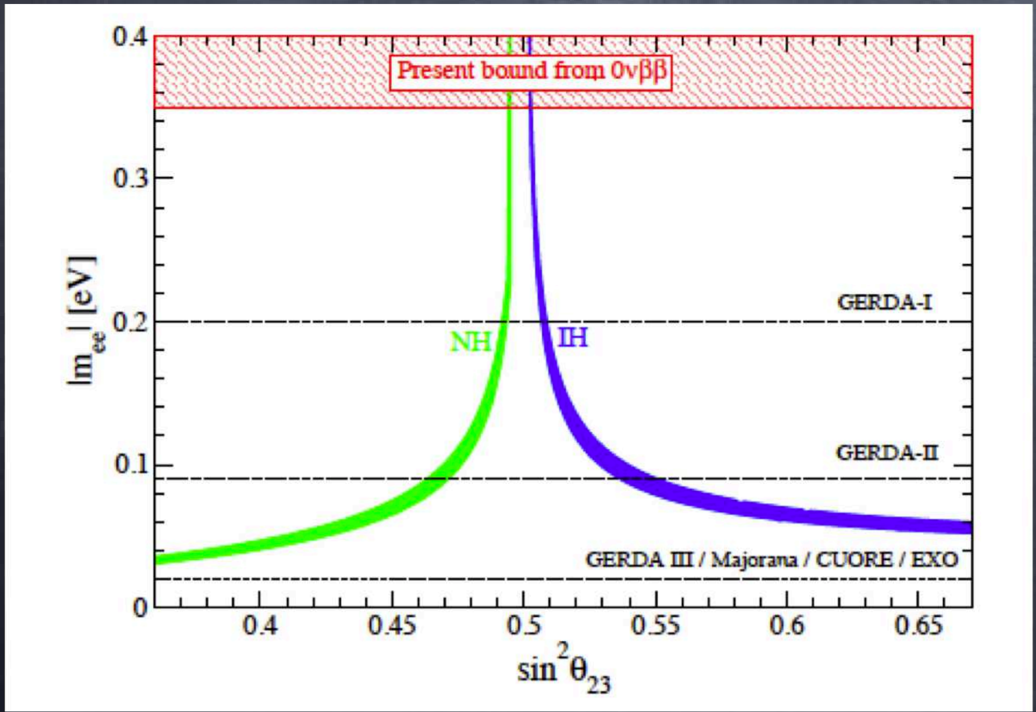

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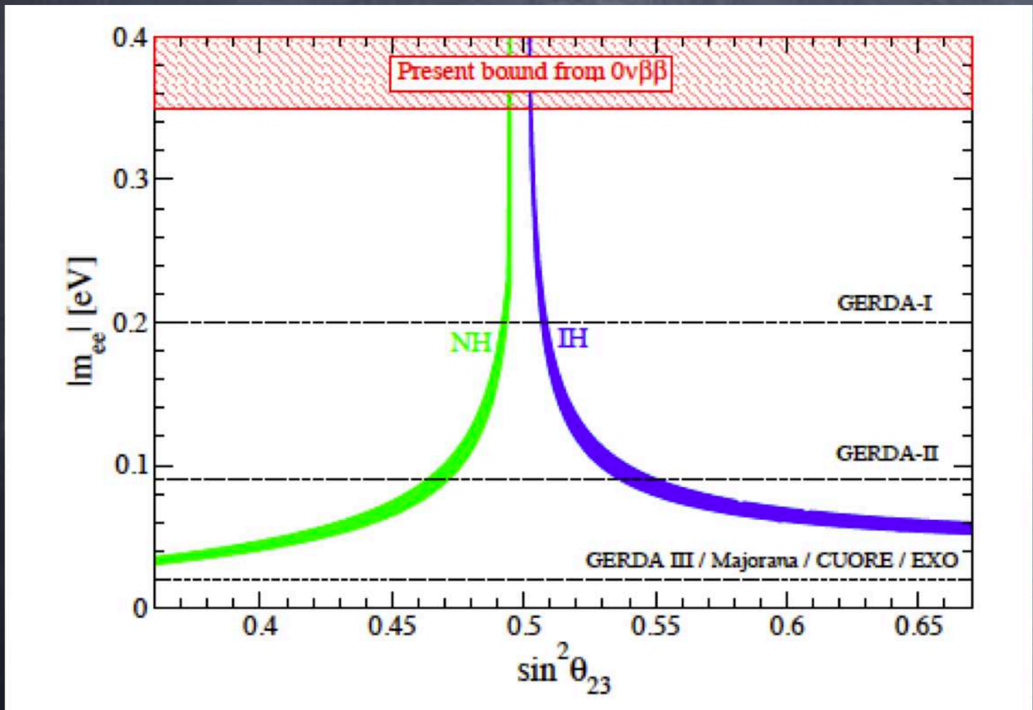

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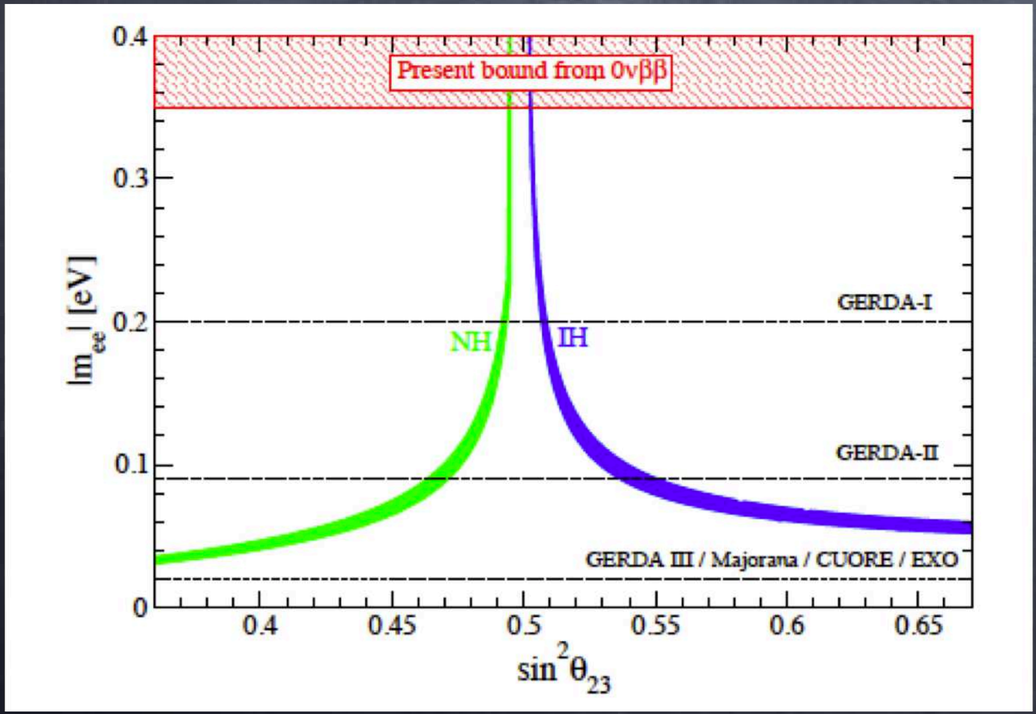

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→ lower bound in the reach of future generation of experiments

Predictions for neutrino phenomenology (II)

- correlations between CP violating parameters δ and invariant J:

$$J = s_{12}s_{23}s_{13}c_{12}c_{23}c_{13}^2 \sin\delta$$

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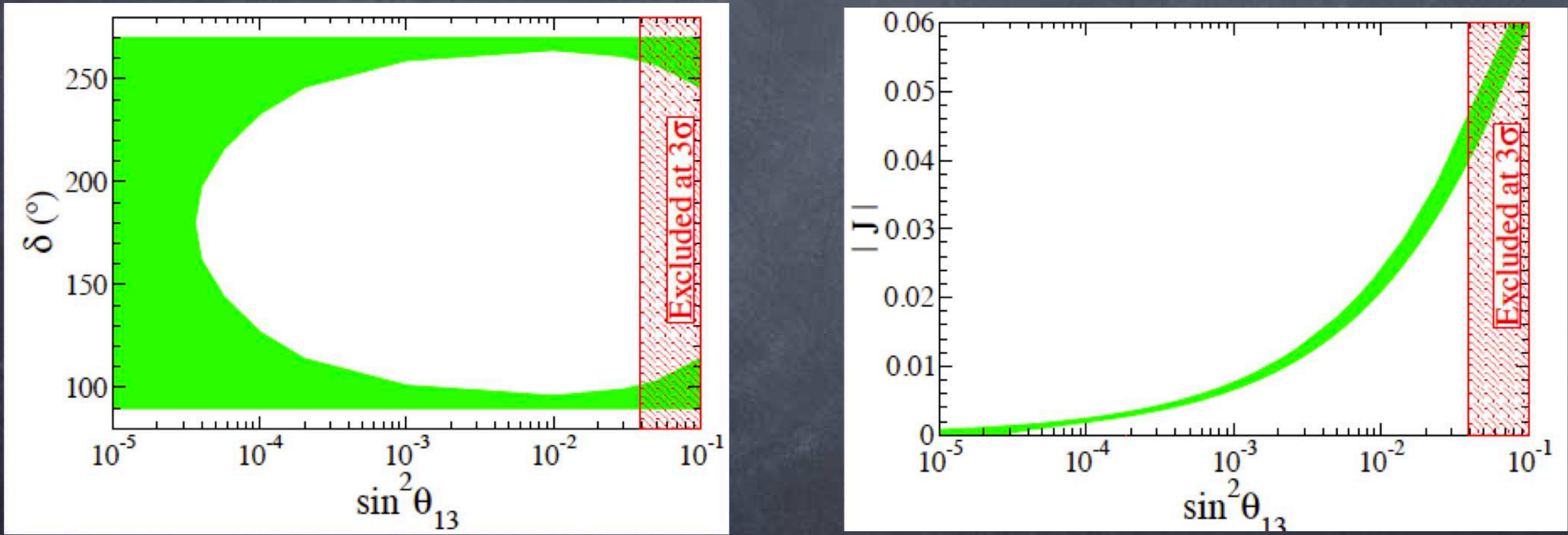

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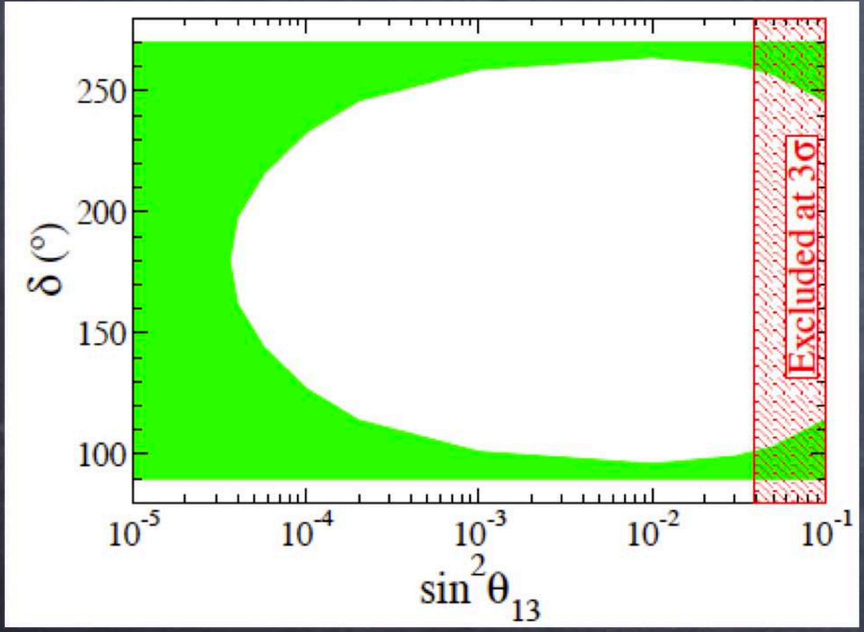

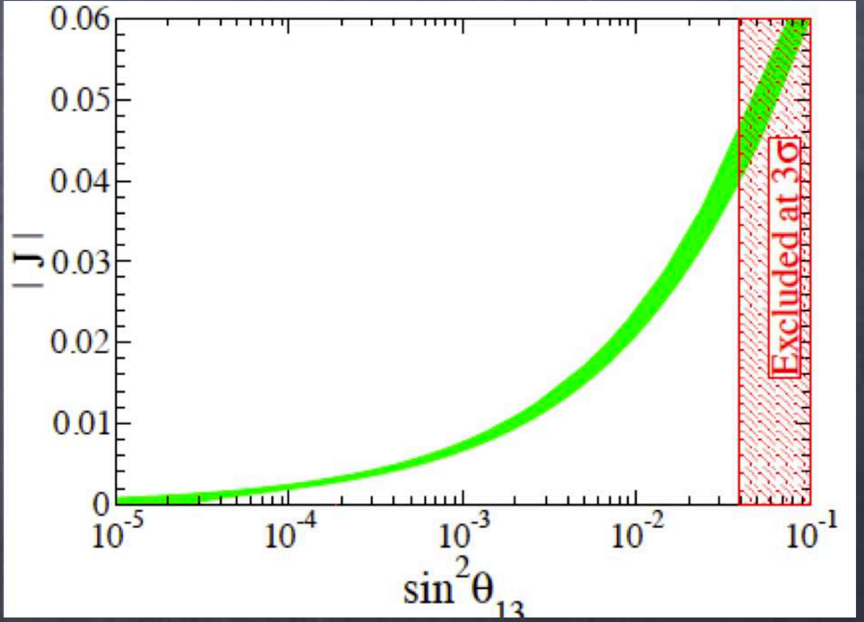

➡ maximal violation of CP for large θ_{13} values, where CP violation is likely to be probed in neutrino oscillations

Majoron as a candidate for dark matter

- the spontaneous breaking of lepton number implies the existence of a Goldstone boson, the Majoron (J).

- due to non-perturbative gravitational effects that explicitly break global symmetries, the Majoron may acquire a mass in the keV range.

- despite the fact that the Majoron will decay, it could be a good candidate for dark matter since its couplings to matter is very small.

- the Majoron couplings to neutrinos and photons can be constrained by cosmological and astrophysical observations.

Cosmological constraints on the Majoron

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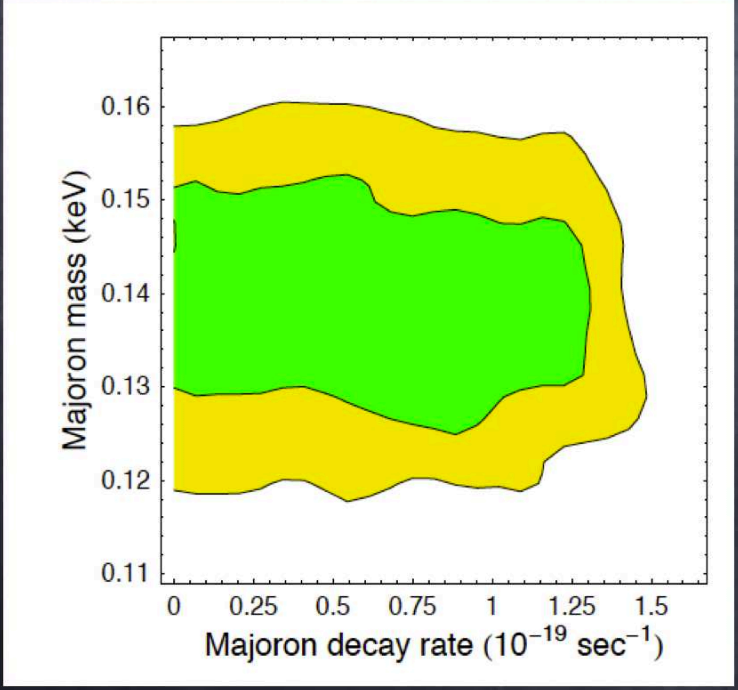

$\Gamma_{J\nu\nu} < 1.3 \times 10^{-19}\ \mathrm{s}^{-1}$ $\rightarrow$ $\tau_J > 250\mathrm{Gyr} \sim 20 t_0$

$0.12\ \mathrm{keV} < \beta\, m_J < 0.17\ \mathrm{keV}$

Lattanzi and Valle, 2007

CMB constraints applied to our A_4 model

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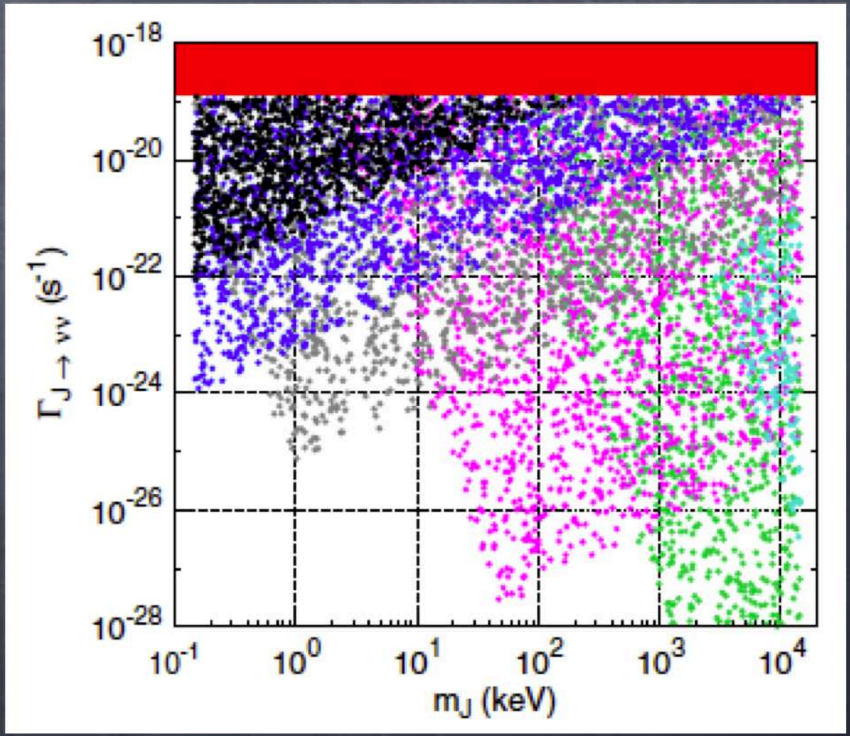

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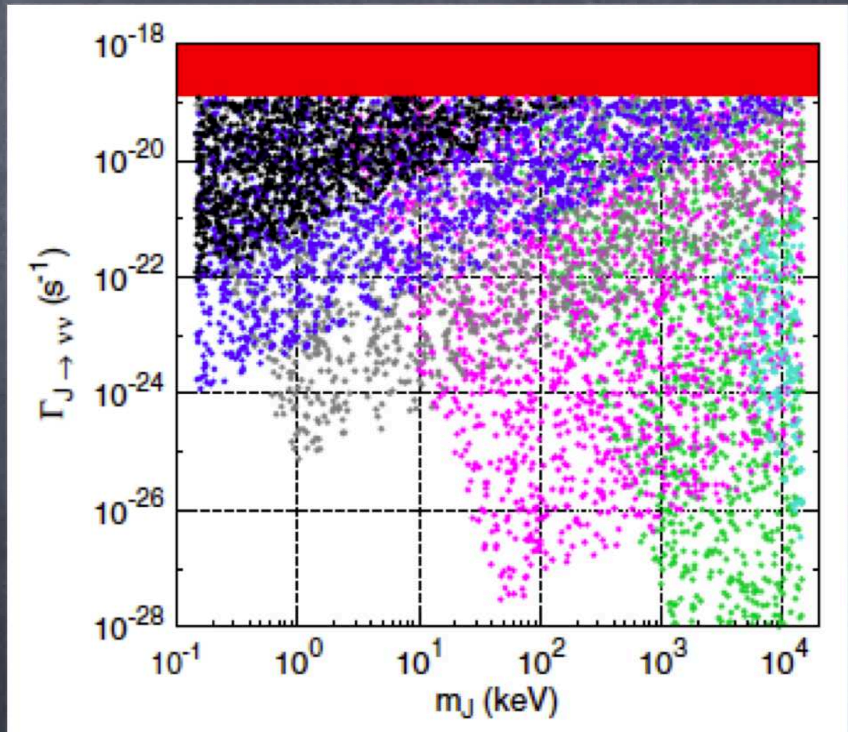

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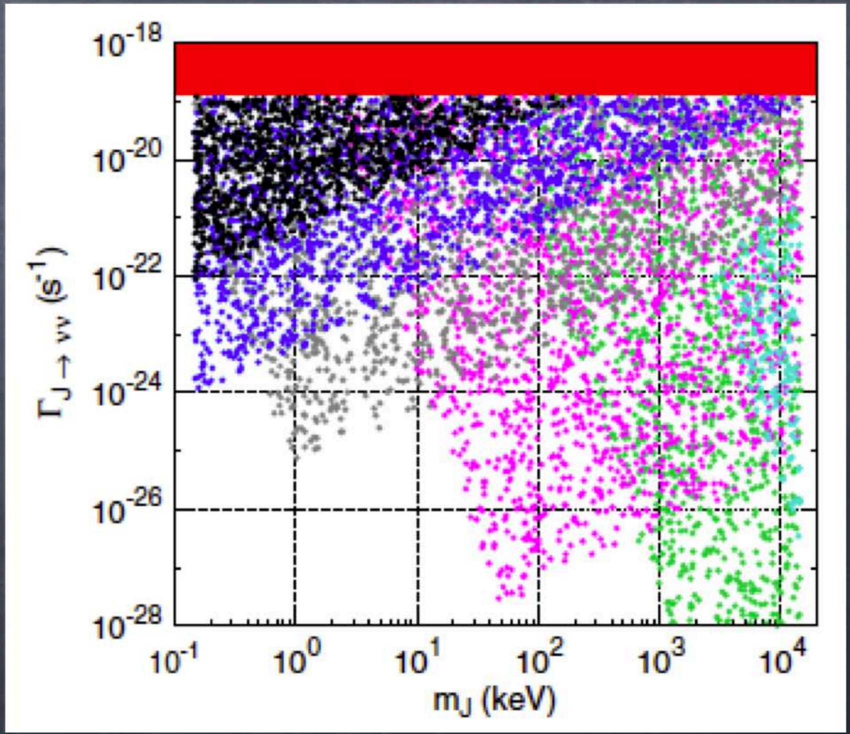

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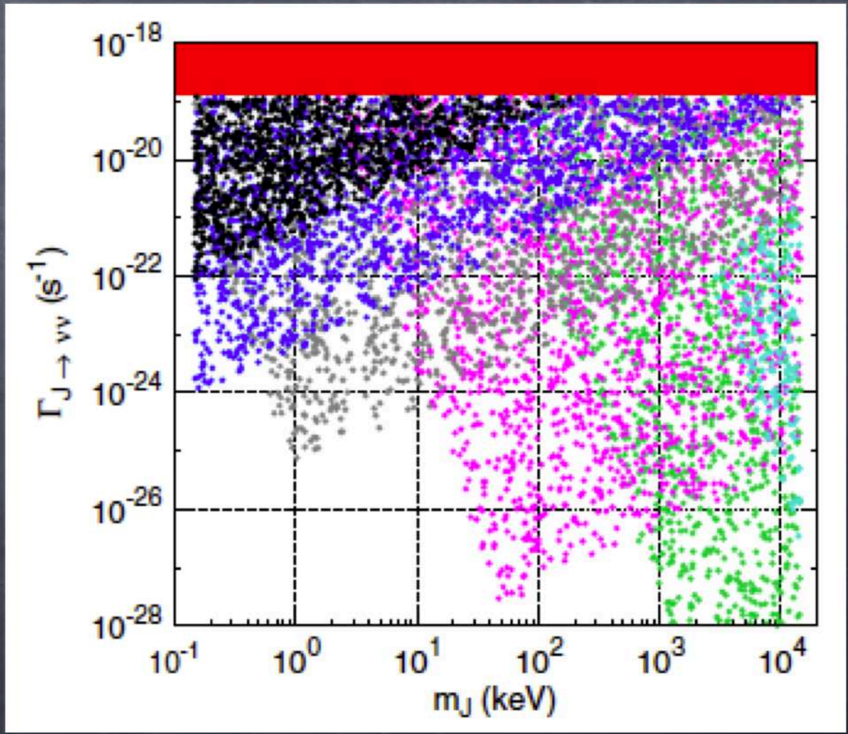

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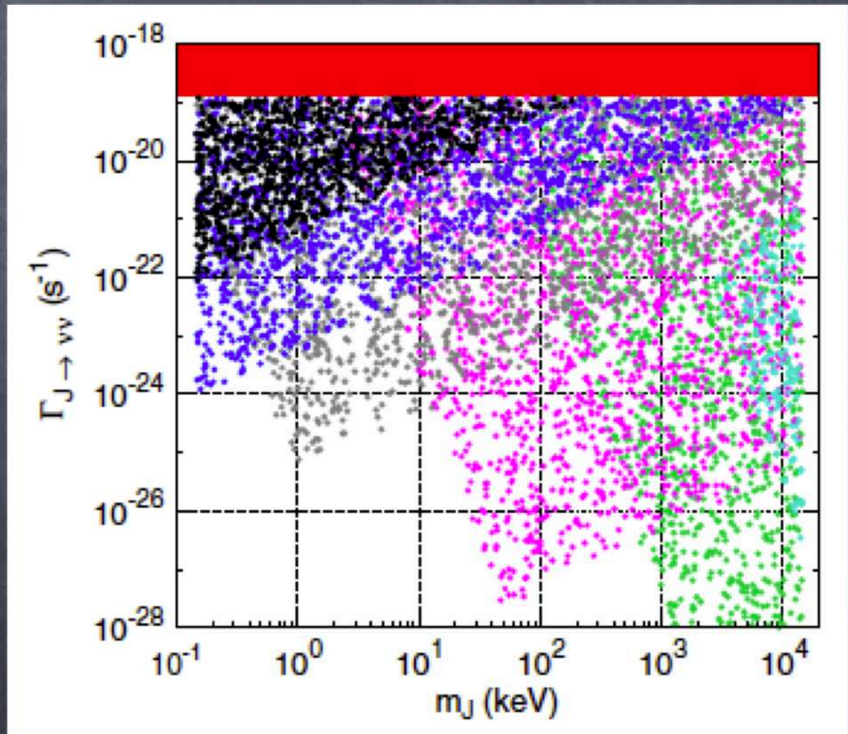

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Majoron decay into photons

- effective Majoron-photon interaction term: $\mathcal{L} = g_{J\gamma\gamma}\varepsilon^{\mu\nu\alpha\beta}F_{\mu\nu}F_{\alpha\beta}$
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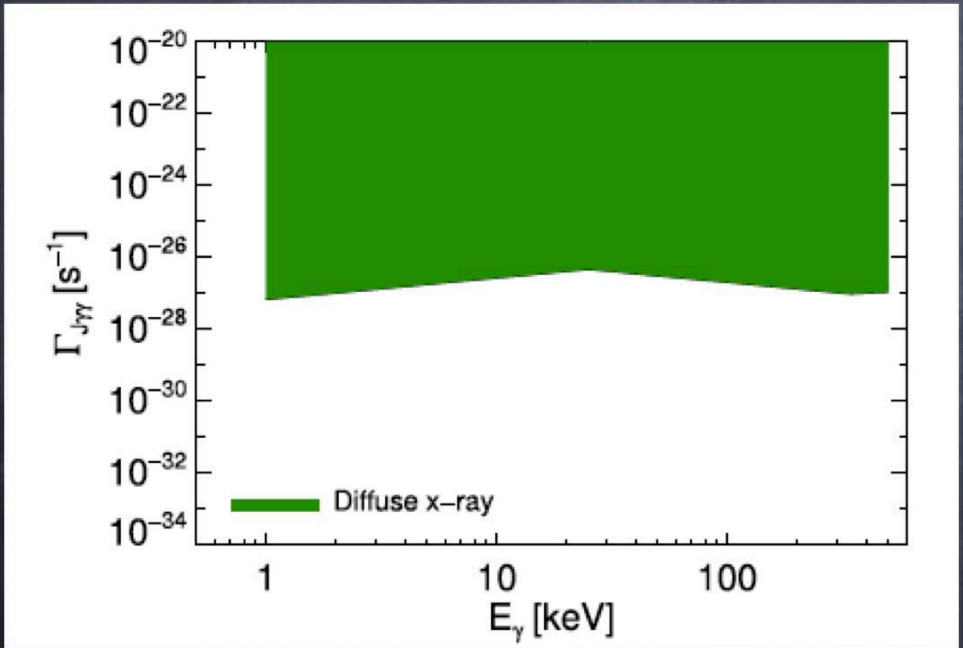
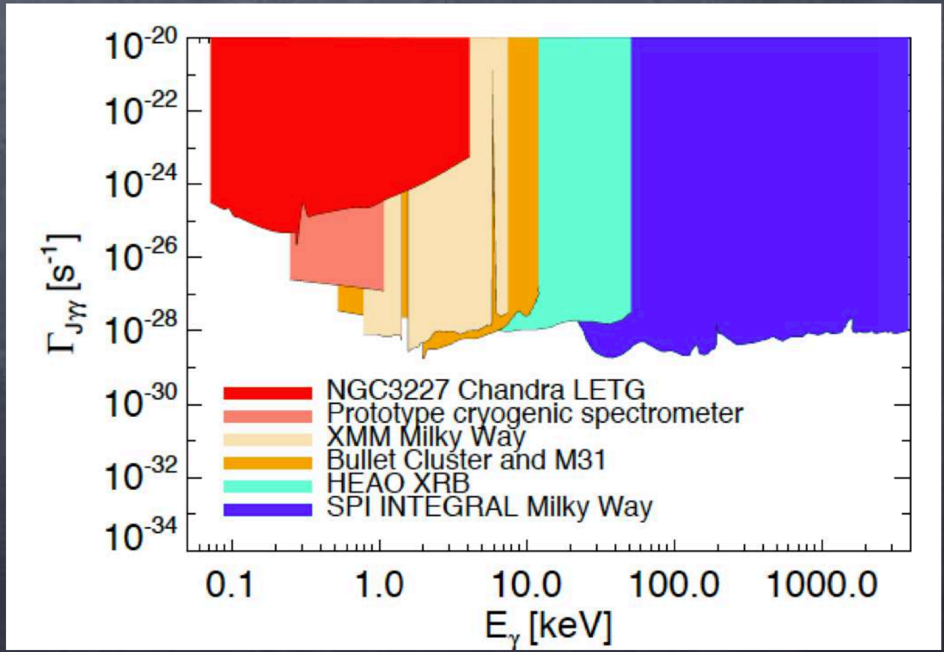
- constraints on the decay rate: Bazzocchi et al, 2008





X-ray constraints applied to our A4 model

Majoron decay width to photons:

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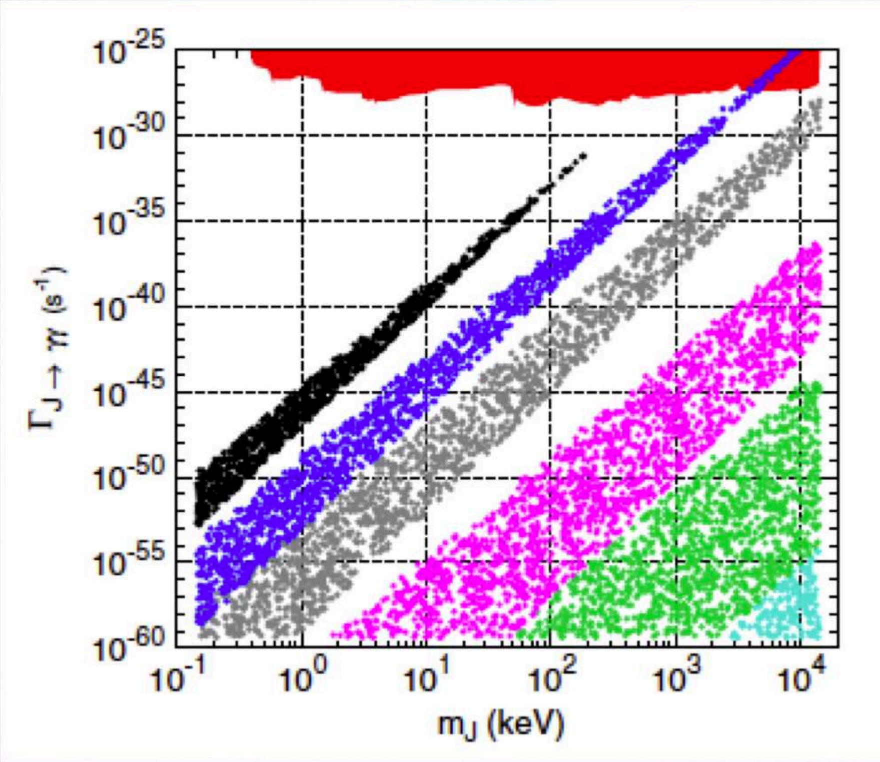

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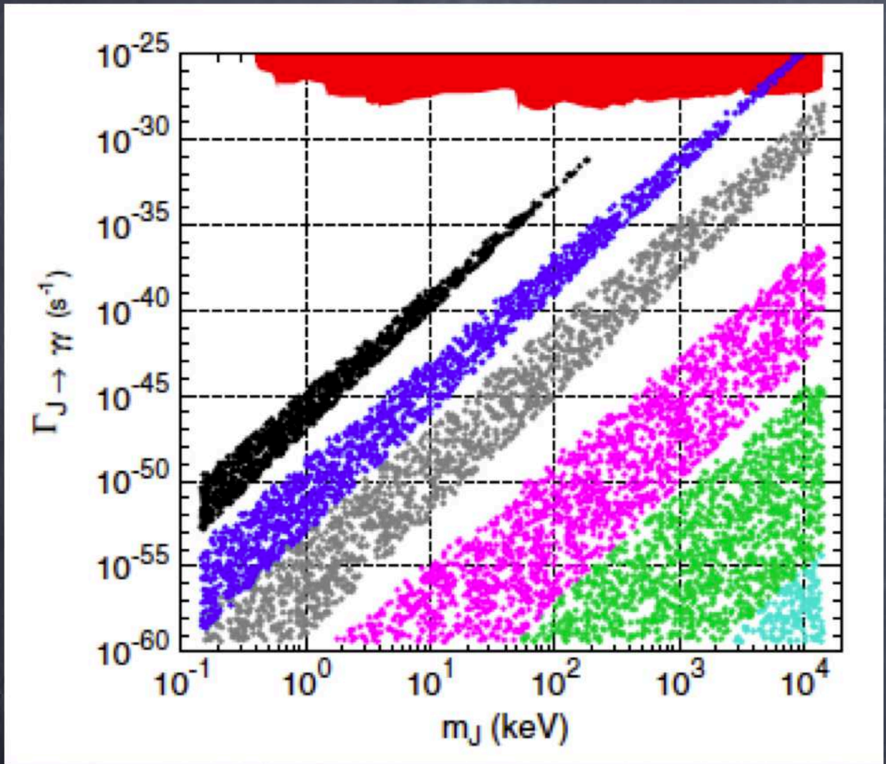

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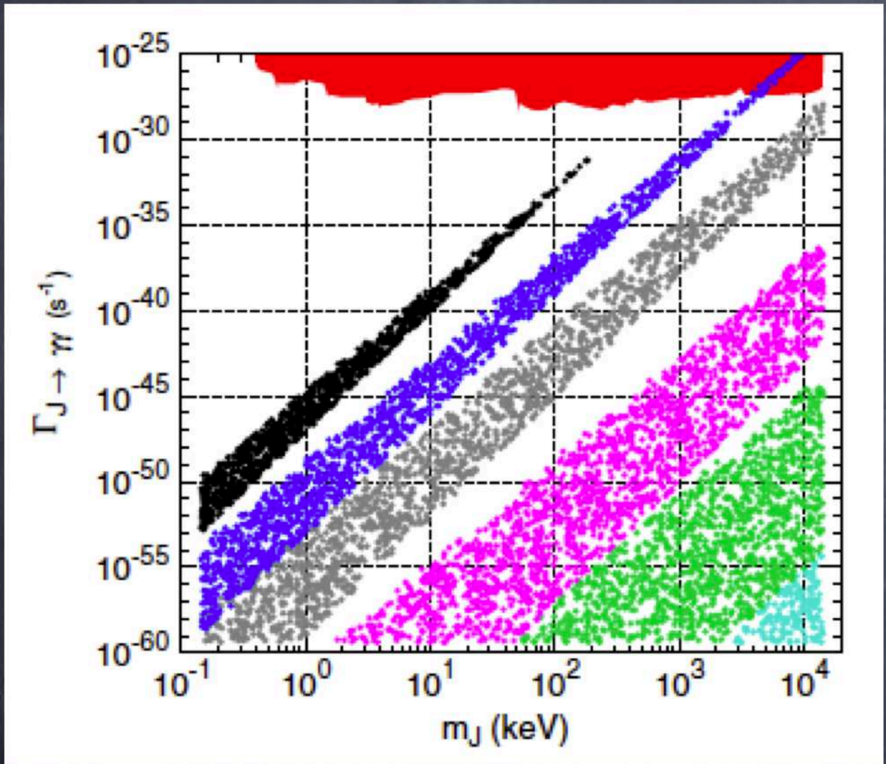

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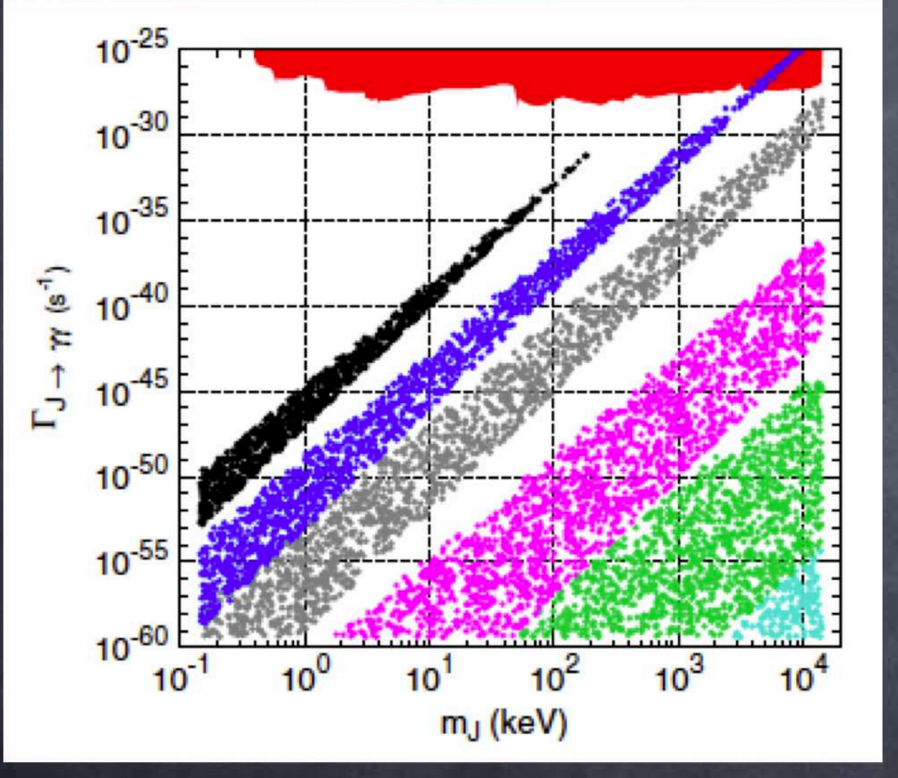

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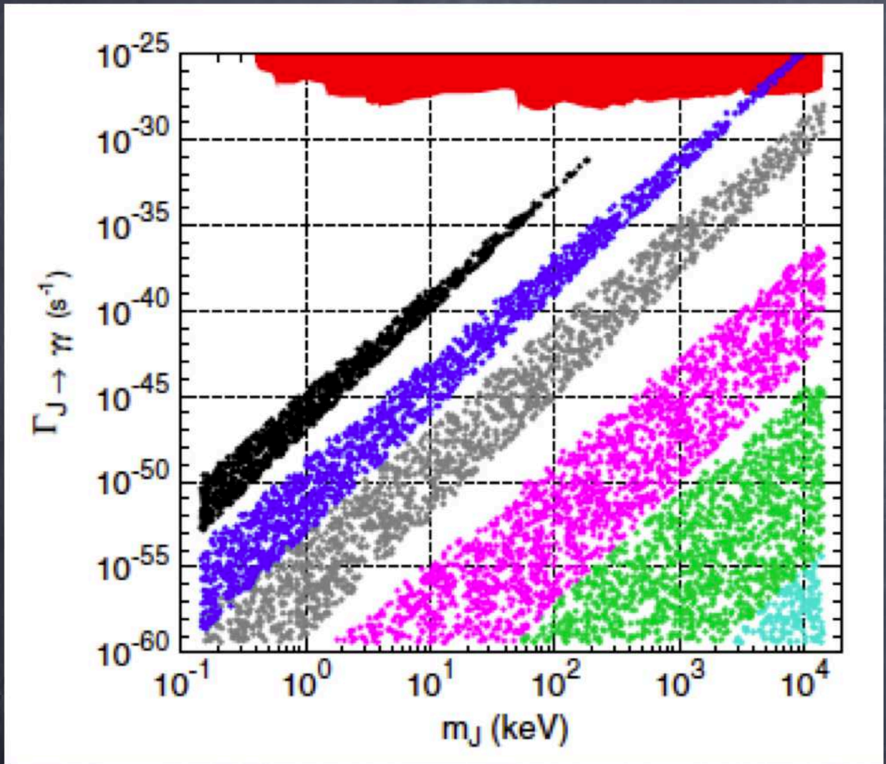

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- signal is close to the present sensitivity of X-ray searches.
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- vev-seesaw relation:

$$u_\Delta u_\sigma \sim v^2$$

$\rightarrow$ u_Δ cannot be arbitrarily large since u_σ is bounded from below by CMB data.

Summary

- We have proposed a seesaw model with a discrete A_4 flavor symmetry and spontaneous breaking of L to explain neutrino masses and mixings as well as the dark matter of the Universe.
- A predictive pattern of neutrino masses emerges from the interplay of type I and type II seesaw contributions, with a lower bound on the amplitude of neutrinoless double beta decay and nearly maximal CP violation.
- Assuming that the associated Majoron gets a mass, we showed how it can constitute a candidate for decaying dark matter, consistent with CMB observations.
- The possibility of probing the existence of this decaying Majoron in future X-ray observatories has been discussed