Relaxing the cosmological neutrino mass bound with late neutrino mass generation

Christiane S. Lorenz (ETH) and Lena Funcke (Perimeter Institute)

In collaboration with Erminia Calabrese, Gia Dvali and Steen Hannestad

Based on arXiv:1602.03191 and arXiv:1811.01991

Cosmology from Home Conference, September 2020

Neutrino mass bounds from cosmology

Impact of Σm_ν on the matter power spectrum:

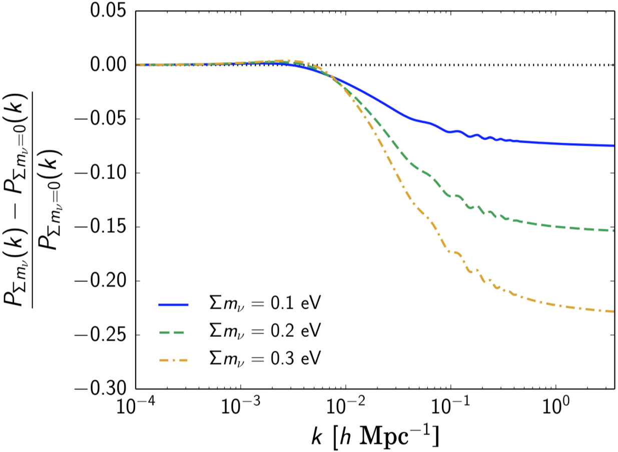

Image credit: Allison et al. (2015)

Good reviews on neutrino cosmology: Lesgourgues and Pastor (2006).; Lesgourgues et al. (2013); Lattanzi and Gerbino (2017).

Neutrino mass parameter space

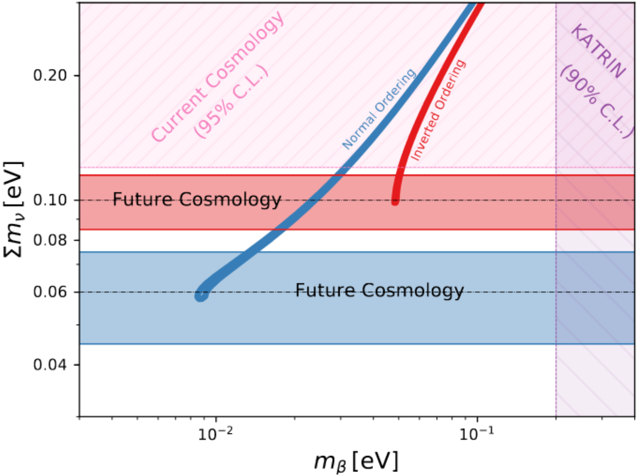

Image credit: Abazajian et al. (CMB Stage 4 Collaboration) (2019).

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In that case, how could cosmology and particle physics be reconciled?

Σm_ν for different cosmological models

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$\Sigma m_\nu < 4.8$ eV	**ΛCDM+$m_\nu(z)$ from supercooled phase transition in relic neutrino sector** (Planck 2015 CMB + BAO + SN)	[4]

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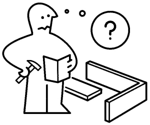

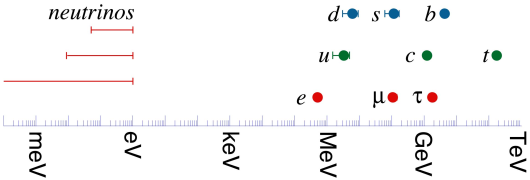

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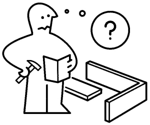

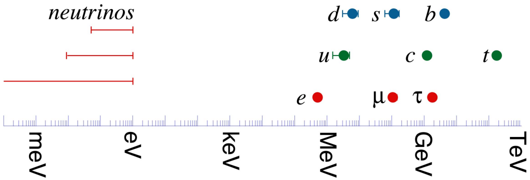

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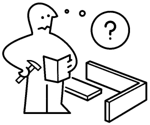

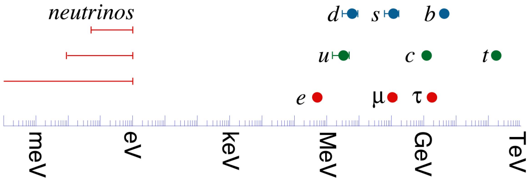

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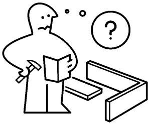

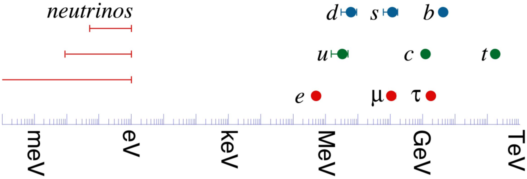

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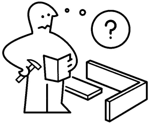

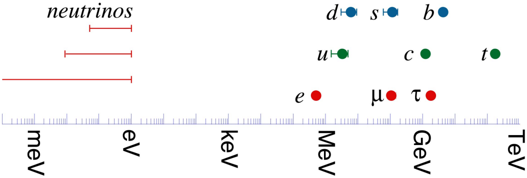

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- ... are among the main motivations for physics beyond the SM!

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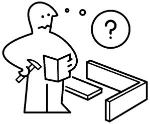

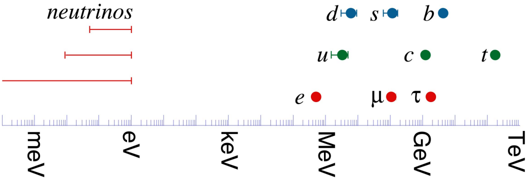

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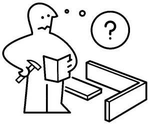

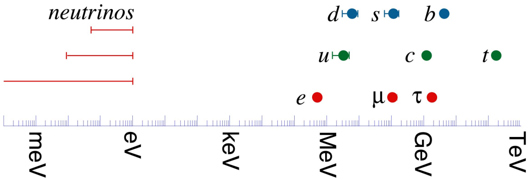

Early-Universe Models

"Seesaw" mechanisms,
large extra dimensions, ...

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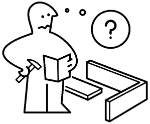

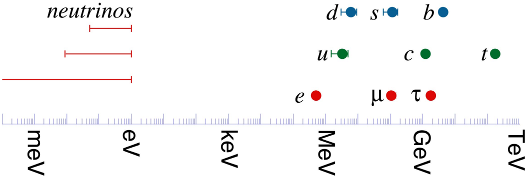

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Neutrino masses from Higgs condensate, suppressed by new high-energy physics.

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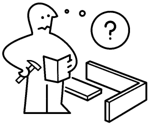

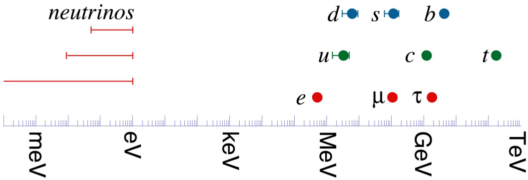

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Small neutrino masses from gravitational θ-term [5].

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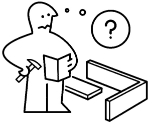

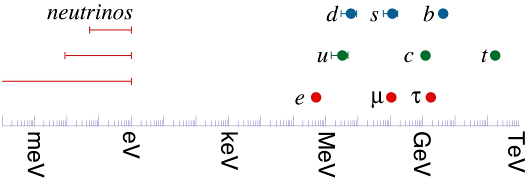

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Neutrino condensate and effective masses at new low-energy gravitational scale.

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The Model: Neutrino Condensation

Analogy: quark condensation and effective mass generation in QCD

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Assumption: gravitational θ-term $\mathcal{L}_G \supset \theta_G R\tilde{R}$ [6]

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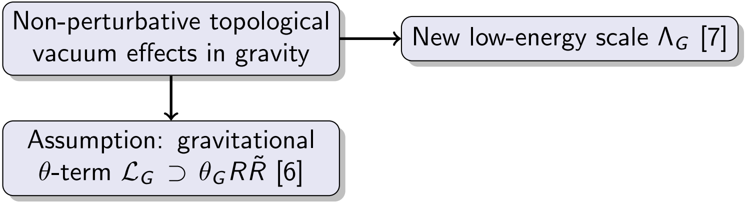

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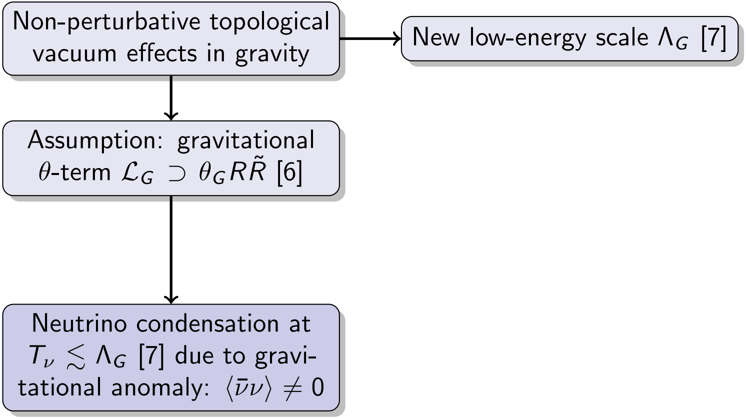

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→ Emergence of 1 massive [7] and 14 massless [5] bosons

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Upper bound from SM and free-streaming [5,8]

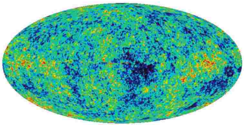

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Image credits: NASA / WMAP Science Team [http://map.gsfc.nasa.gov/]

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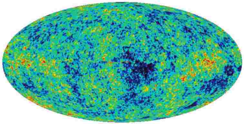

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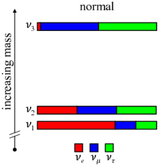
Lower bound from Δm_ν and gravity [5,9]



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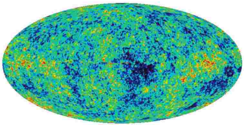

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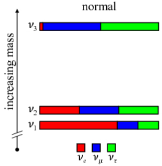

$\Rightarrow$ Neutrino vacuum condensate $\langle\bar{\nu}\nu\rangle$ on dark energy scale

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Late neutrino masses from a supercooled phase transition

Post-recombination phase transition

- Relic neutrinos massless until late phase transition at $T_\nu \lesssim \Lambda_G$ [5]
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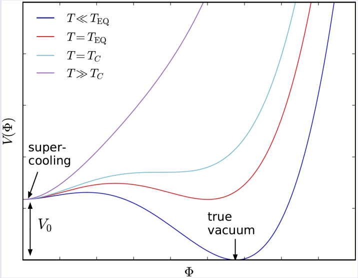

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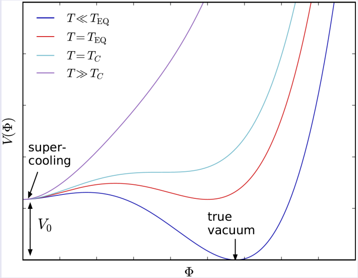

- Cosmological analysis of a simplified version of this model [12]

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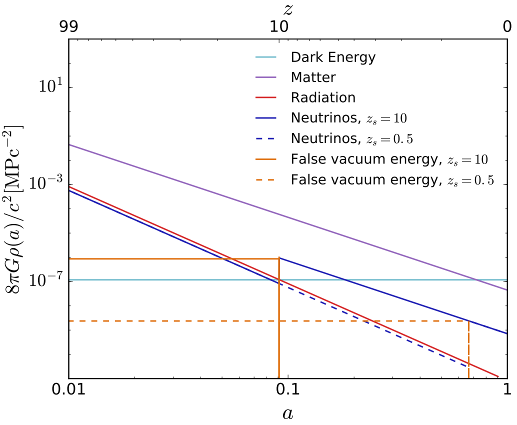
Late neutrino masses from a supercooled phase transition

Energy densities of cosmological components in this scenario:



CSL, LF et al. (2018).

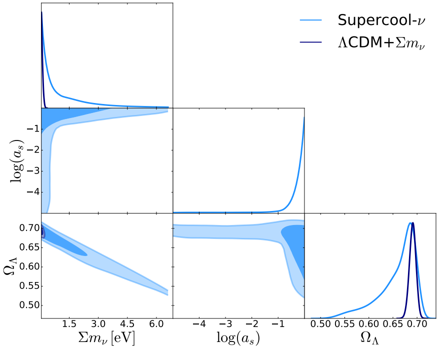
Relaxing the cosmological neutrino mass bound

Constraints from Planck 2015 + BAO + SN:

$$\Sigma m_\nu < 4.8 \text{ eV} \qquad (95\ \%\ \text{C.L.})$$

$$\Omega_\Lambda = 0.66^{+0.02}_{-0.04} \qquad (68\ \%\ \text{C.L.})$$

$$\log(a_s) \leq -3.6 \qquad (95\ \%\ \text{C.L.})$$



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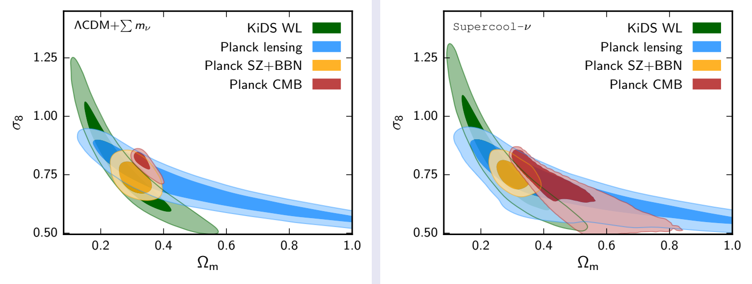
Impact on cosmological tensions

Cosmological tensions are unaffected:

- Ω_m-σ_8 countours are broadened, but do not overlap more
- Hubble parameter tension is unaffected



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Cosmological implications:

- Cosmological neutrino mass bound weakened
- Strong degeneracy with the dark energy sector

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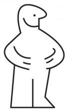

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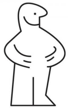

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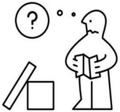

Do you have any questions?