How Gravity Can Shape the Low-Energy Frontier of Particle Physics

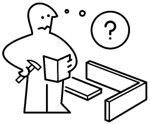
Lena Funcke

PERIMETER INSTITUTE

In collaboration with Gia Dvali, Georg Raffelt, Tanmay Vachaspati, and others
(1602.03191, 1608.08969, 1811.01991, 1905.01264, 2102.13618, and ongoing work)

Leona Woods Colloquium, BNL, 25 March 2021

Question: Origin of Small Neutrino Masses?



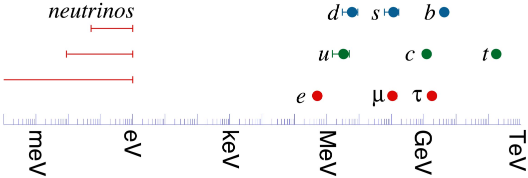


Image credits: IKEA and Murayama (2018).

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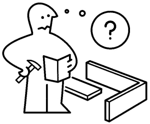

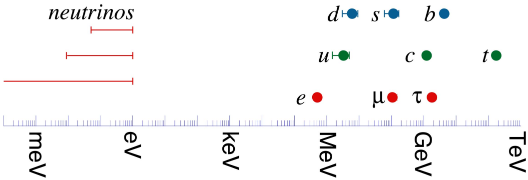

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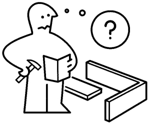

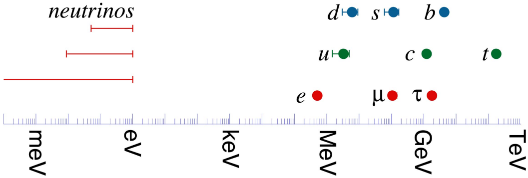

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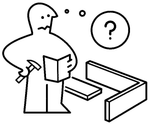

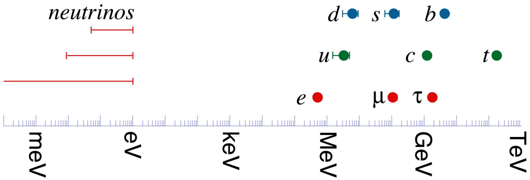

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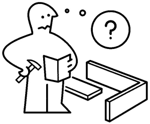

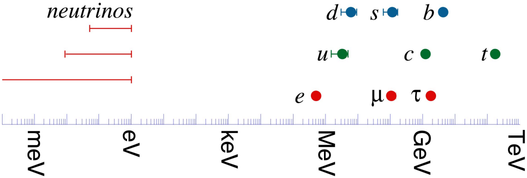

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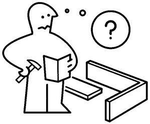

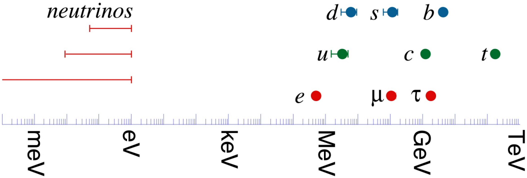

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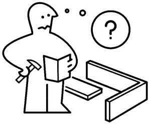

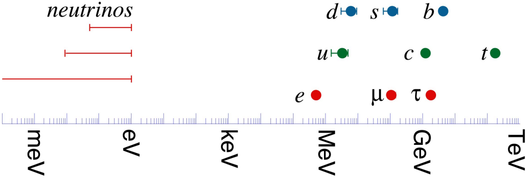

High-Energy Models

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

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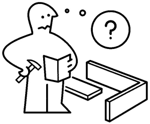

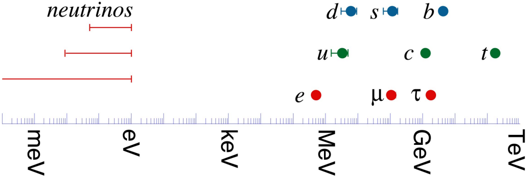

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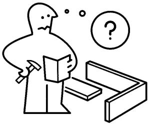

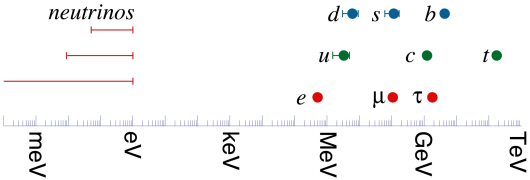

Low-Energy Model

Small neutrino masses from gravitational θ-term.

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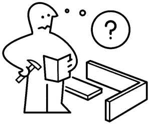

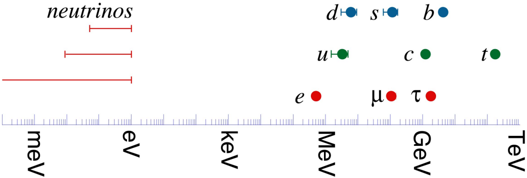

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Neutrino condensate and effective masses at new infrared gravitational scale.

High-Energy Models

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

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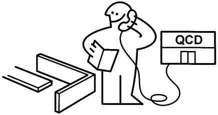
Analogy: Non-Perturbative QCD Vacuum



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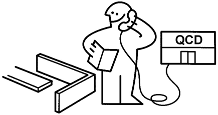

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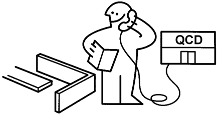

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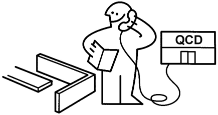

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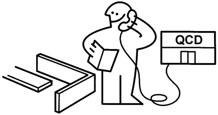

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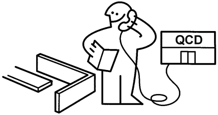

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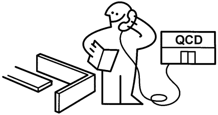

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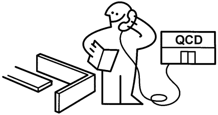

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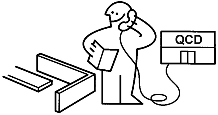

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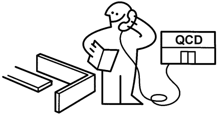

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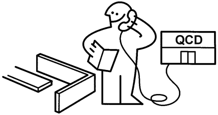

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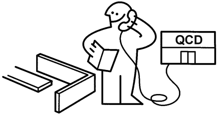

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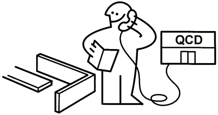

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Non-perturbative topological effects in pure gravity.

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Physical θ-term in pure gravity: $\langle R\tilde{R}, R\tilde{R}\rangle_{p\to 0} \neq 0$.

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Non-perturbative topological effects in pure gravity. → New low-energy scale Λ_G.

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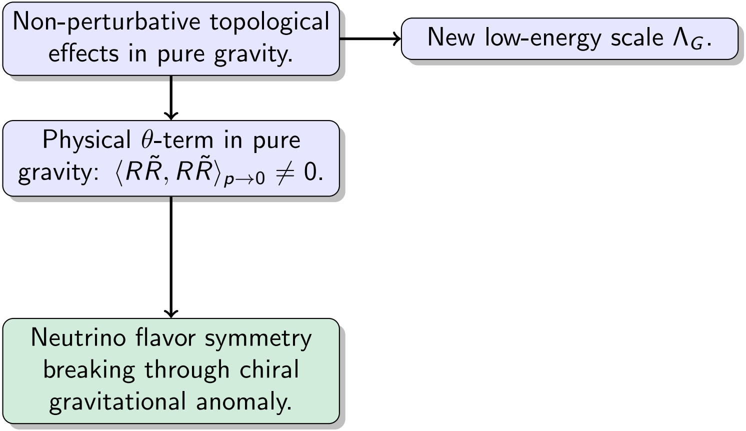

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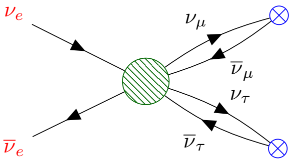

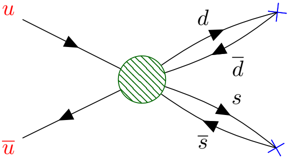

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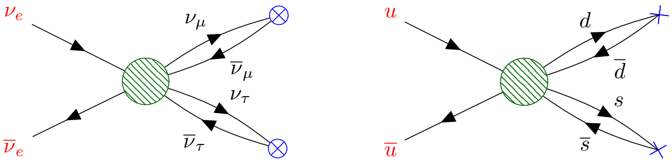

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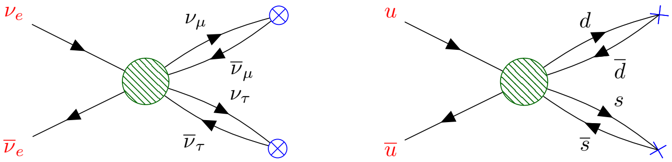

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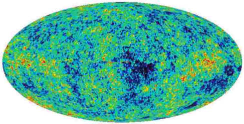
Upper bound from SM and cosmology [9].



[9] Archidiacono, Hannestad (2014).

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

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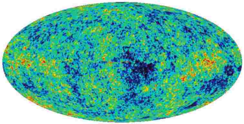
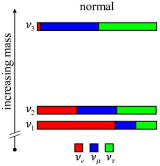


$\sim 4\ \mathrm{meV}$ — Lower bound from Δm_ν and gravity [10].



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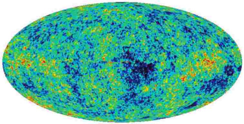

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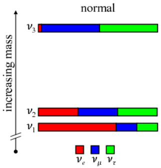

$\rightarrow$ Neutrino vacuum condensate $\langle\bar{\nu}\nu\rangle$ on dark energy scale

[9] Archidiacono, Hannestad (2014). [10] Tanabashi *et al.* (Particle Data Group) (2018).
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Image credit: KATRIN [http://www.ikp.kit.edu/].

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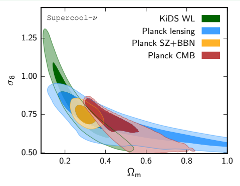
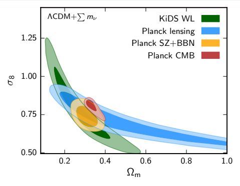


$\sigma_8(\Omega_m)$ for late m_ν



vs. $\sigma_8(\Omega_m)$ for ΛCDM

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Image credit: KATRIN [http://www.ikp.kit.edu/]. Plots: Lorenz, LF, Calabrese, Hannestad (2018).

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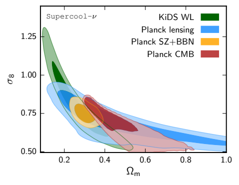

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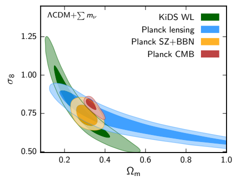

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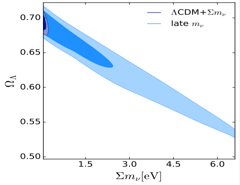

$\Omega_\Lambda(m_\nu)$ for both models

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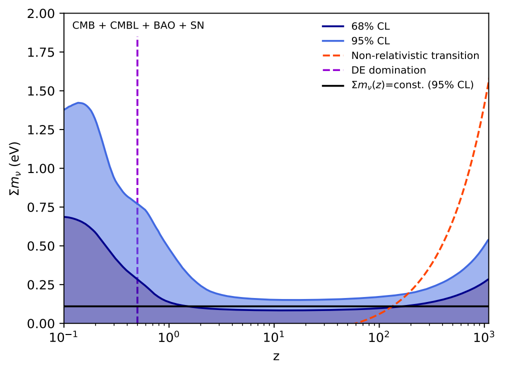

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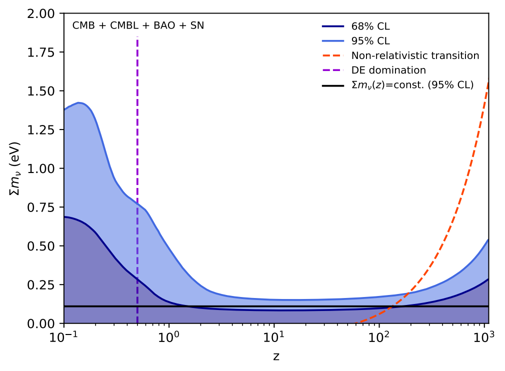

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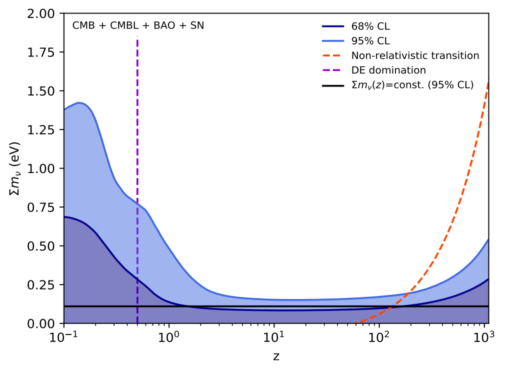
  $\Rightarrow$ Parameter degeneracy and/or new physics?



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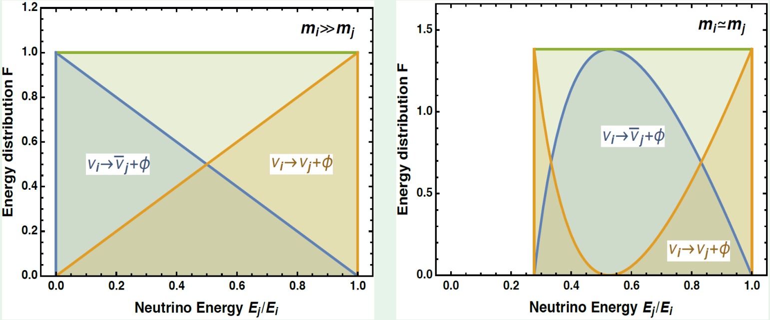

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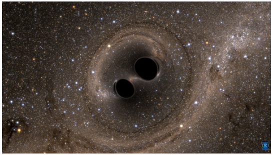

[16] Jackiw, Pi (2003).
Image credits: The SXS Project [https://www.ligo.caltech.edu/]

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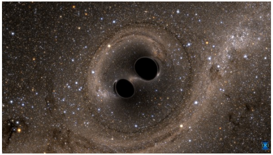

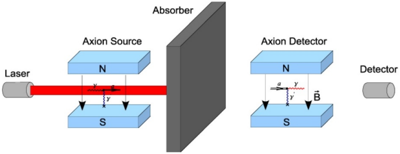

New particle detection:

- Searching for new ϕ bosons in axion-like experiments [17].
- ...

[16] Jackiw, Pi (2003). [17] Dvali, LF (2016b), "Domestic Axion" solution to strong CP problem.
Image credits: The SXS Project [https://www.ligo.caltech.edu/] and Kim, Carosi (2008).

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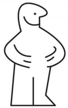

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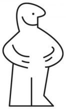

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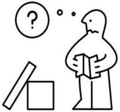

Do you have any questions?