Rethinking the Origin of Neutrino Masses

The Role of Gravity

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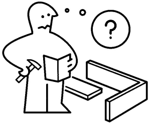
PERIMETER INSTITUTE

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

Fermilab Theory Seminar, 3 December 2020

Question: Origin of Small Neutrino Masses?



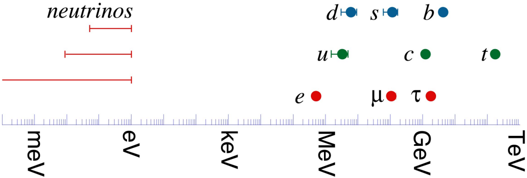


Image credits: IKEA and Murayama (2018).

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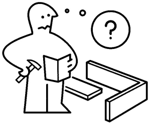

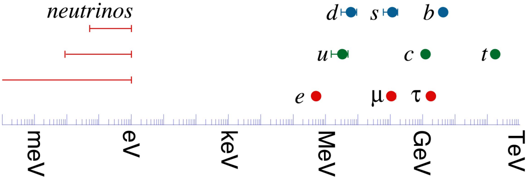

High-Energy Models

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

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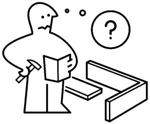

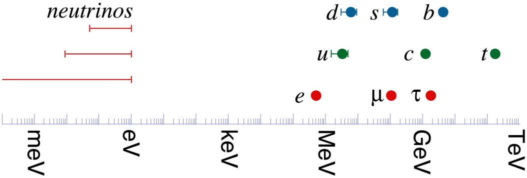

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Neutrino masses from Higgs condensate, suppressed by new high-energy physics.

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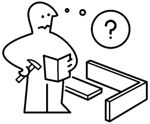

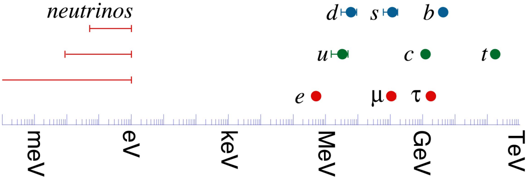

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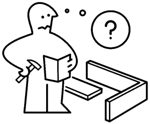

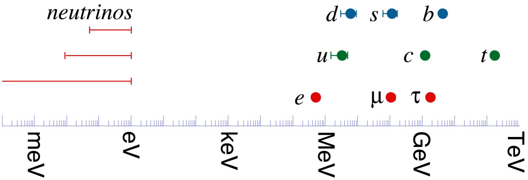

Low-Energy Model

Small neutrino masses from gravitational θ-term.

↓

Neutrino condensate and effective masses at new infrared gravitational scale.

High-Energy Models

“Seesaw” mechanisms, large extra dimensions, ...

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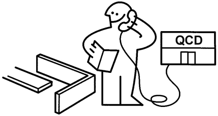
Analogy: Non-Perturbative QCD Vacuum



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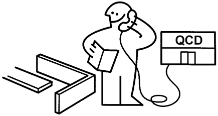

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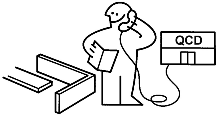

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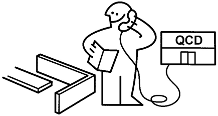

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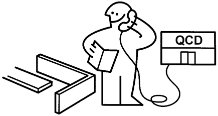

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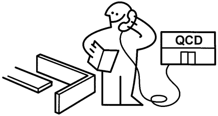

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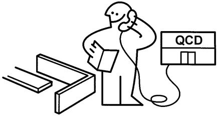

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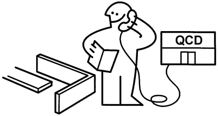

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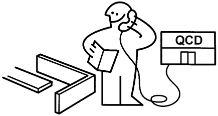

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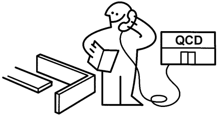

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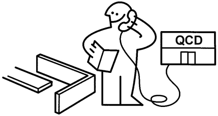

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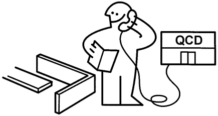

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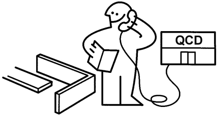

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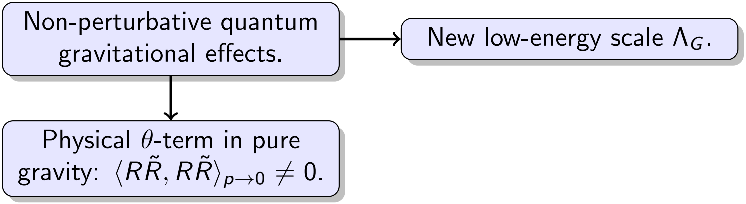

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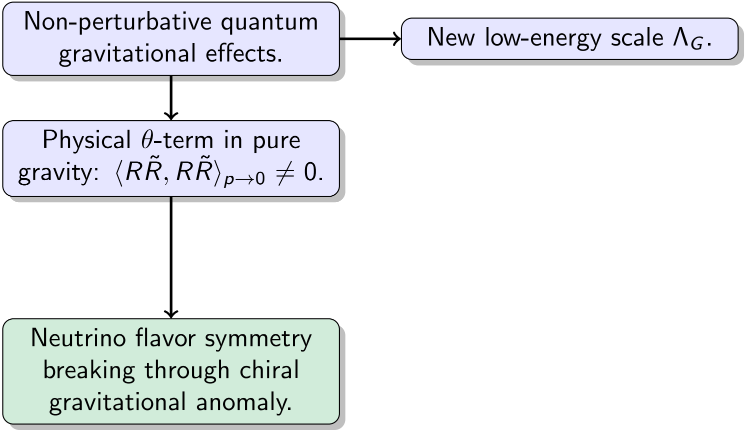

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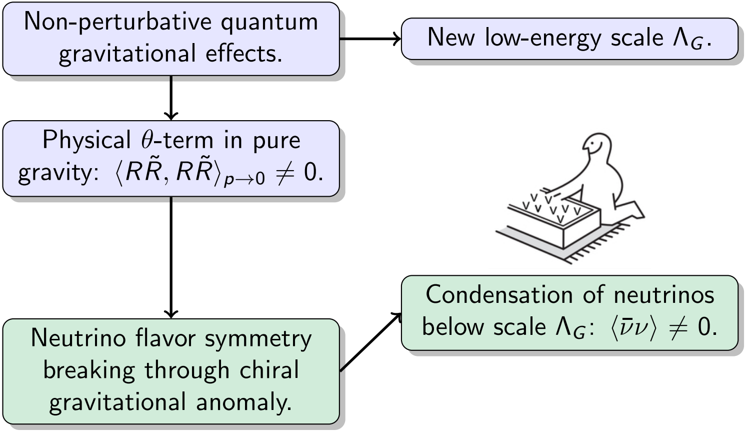


The Model: Neutrino Condensation

Non-perturbative quantum gravitational effects.

→ New low-energy scale Λ_G.

↓

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

↓

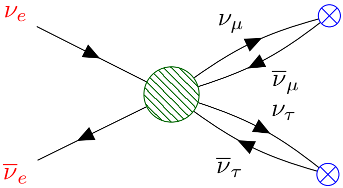
Neutrino flavor symmetry breaking through chiral gravitational anomaly.

→ Condensation of neutrinos below scale Λ_G: $\langle \bar{\nu}\nu \rangle \neq 0$.

→ Emergence of η_ν and 14 massless Goldstones ϕ_k.

The Model: Neutrino Mass Generation

- Small effective neutrino mass generation through non-perturbative coupling to neutrino condensate.



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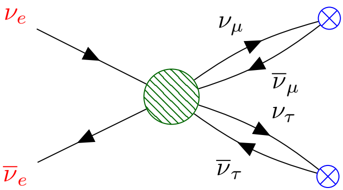

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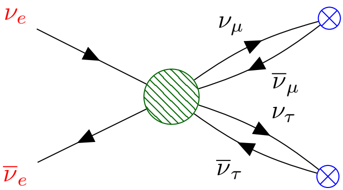

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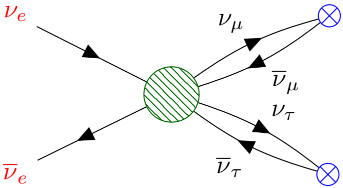

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- Mechanism works for Dirac and Majorana masses.

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Constraints: Symmetry Breaking Scale Λ_G

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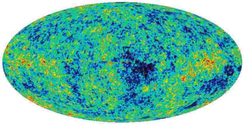
Λ_G

$\sim 0.3\ \mathrm{eV}$

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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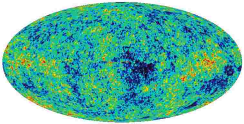

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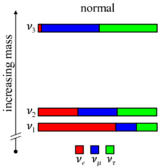

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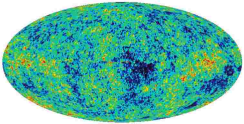

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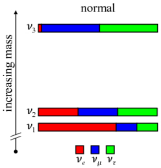

$\rightarrow$ Neutrino vacuum condensate $\langle\bar{\nu}\nu\rangle$ on dark energy scale

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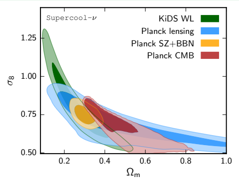
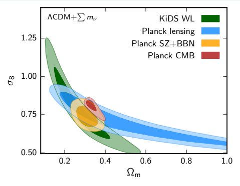


$\sigma_8(\Omega_m)$ for late m_ν



vs. $\sigma_8(\Omega_m)$ for ΛCDM

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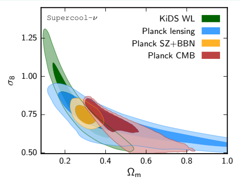

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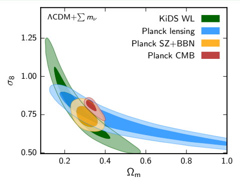

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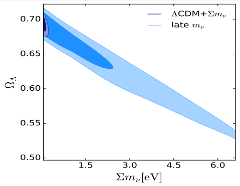

$\Omega_\Lambda(m_\nu)$ for both models

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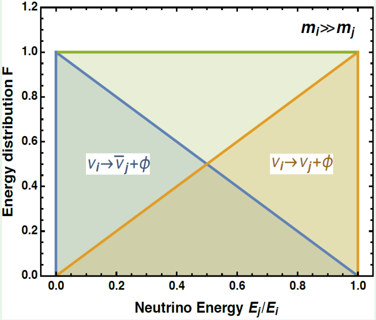

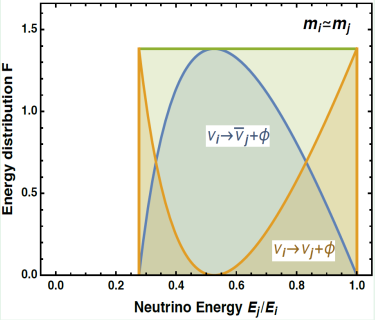

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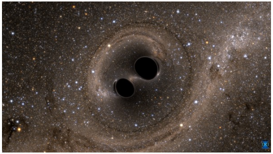

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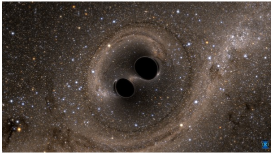

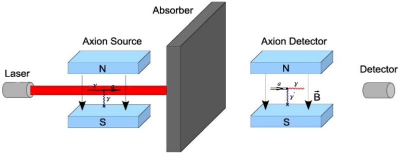

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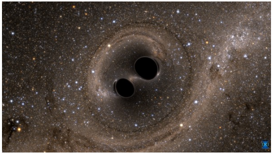

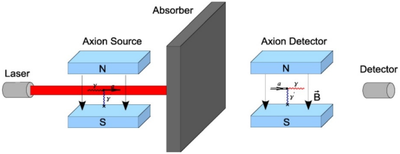

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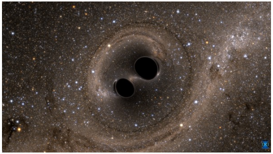

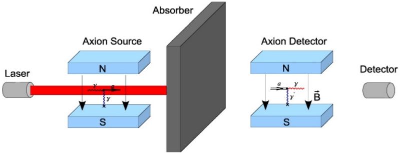

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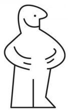

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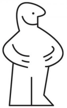

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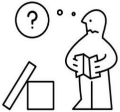

Do you have any questions?