Neutrinos and the Gravitational θ-Term

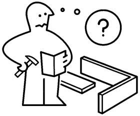
A Low-Energy Solution to the Neutrino Mass Problem

Lena Funcke

In collaboration with Gia Dvali

Invisibles18 Workshop, KIT

Question: Origin of Small Neutrino Masses?



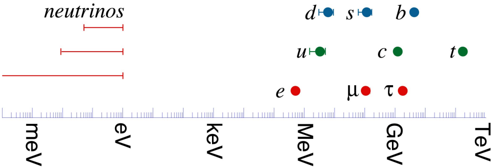


Image credits: IKEA and Murayama [http://hitoshi.berkeley.edu/].

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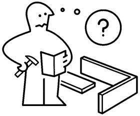

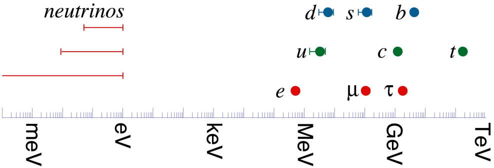

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Seesaw mechanisms,
large extra dimensions, ...

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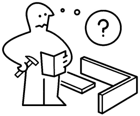

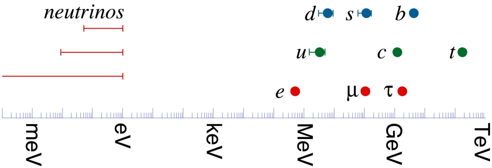

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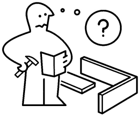

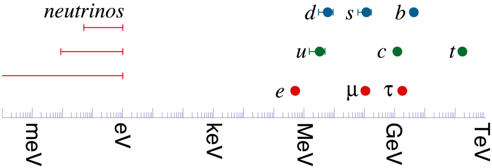

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Small neutrino masses from gravitational θ-term.

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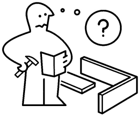

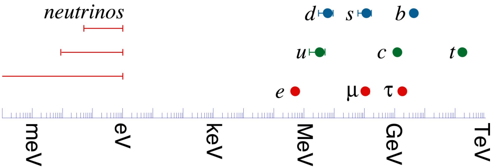

IR → Small neutrino masses from gravitational θ-term. → Neutrino condensate and effective masses at new infrared gravitational scale.

UV → Seesaw mechanisms, large extra dimensions, ... → Higgs condensate at EW scale, neutrino mass scale suppressed by BSM effects.

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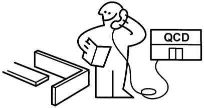

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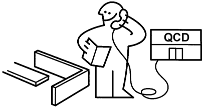

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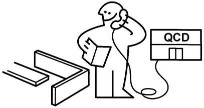

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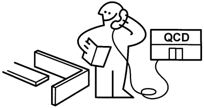

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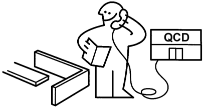

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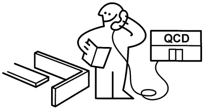

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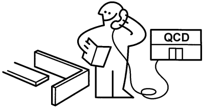

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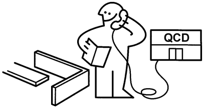

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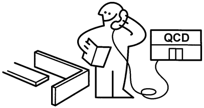

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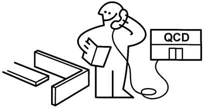

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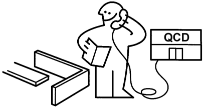

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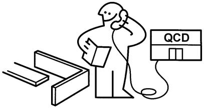

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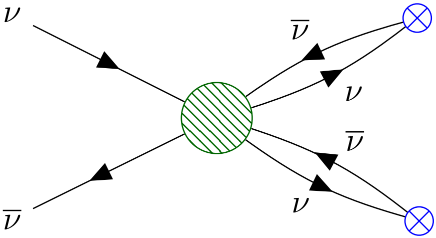
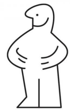
- Small effective neutrino mass generation through non-perturbative coupling to neutrino condensate.





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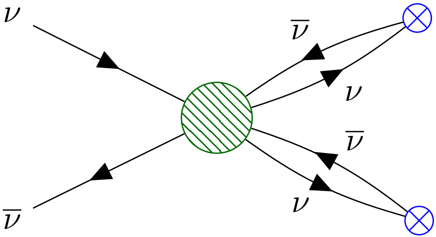

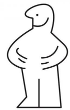

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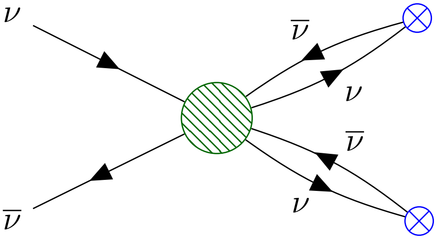

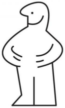

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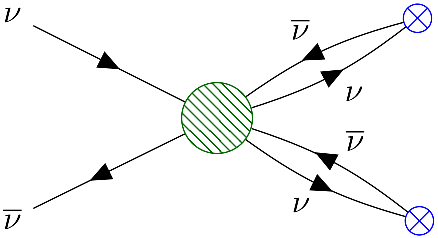

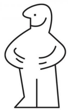

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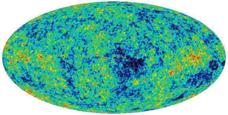

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Image credits: NASA / WMAP Science Team [http://map.gsfc.nasa.gov/]

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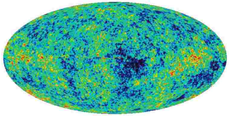
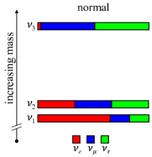


~ 4 meV

Lower bound from neutrino mass splitting [10].



[9] Archidiacono, Hannestad (2014). [10] Olive *et al.* (Particle Data Group) (2014).
Image credits: NASA / WMAP Science Team [http://map.gsfc.nasa.gov/] and Patterson (2005).

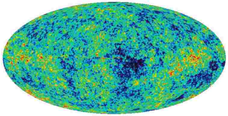
Constraints: Symmetry Breaking Scale Λ_G

Assumption: condensate $|\langle\bar{\nu}\nu\rangle|$ = scale Λ_G^3 = temperature $T_{\chi\mathrm{SB}}^3$.

$\Lambda_G \ll \Lambda_{\mathrm{QCD}}$

~ 256 meV

Upper bound from CMB constraints [9].



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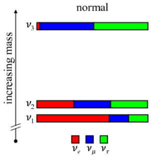

$\rightarrow$ Neutrino vacuum condensate $\langle\bar{\nu}\nu\rangle$ on dark energy scale.

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Invalidity of cosmological neutrino mass bound.

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Image credit: KATRIN [http://www.ikp.kit.edu/].

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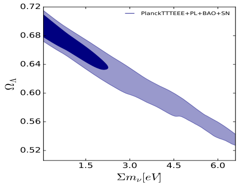

$\Omega_\Lambda(m_\nu)$ without annihilation

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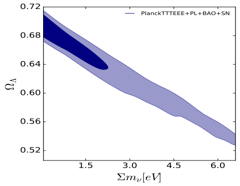

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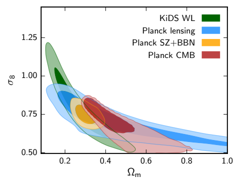
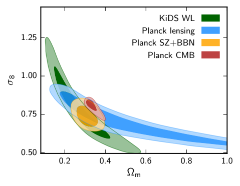


$\sigma_8(\Omega_m)$ for late m_ν



vs. $\sigma_8(\Omega_m)$ for ΛCDM

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Relic(s) and sterile neutrinos:

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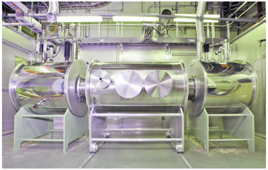

PTOLEMY

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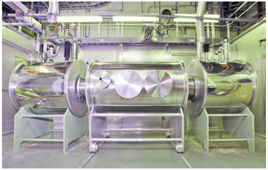

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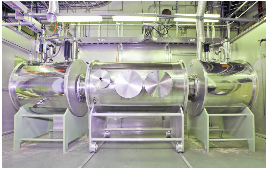

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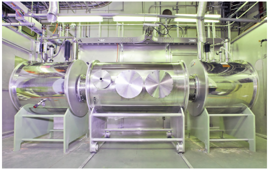

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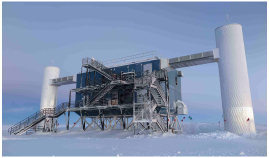

IceCube

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Image credits: Betts *et al.* (2013). Beiser, IceCube/NSF [http://gallery.icecube.wisc.edu/]

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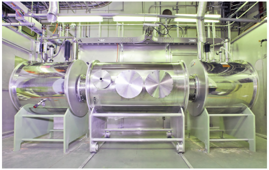

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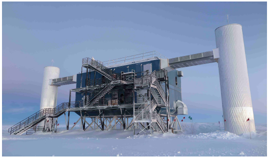

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Frontiers of gravity measurements:

- Different polarization intensities of gravitational waves [16].

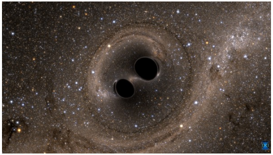

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Image credits: The SXS Project [https://www.ligo.caltech.edu/]

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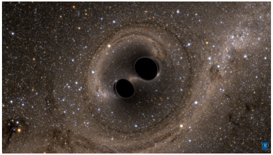

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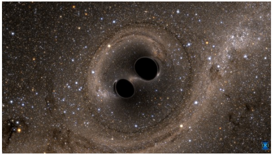

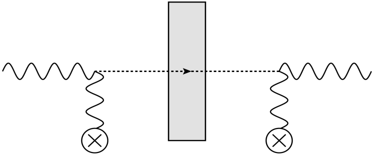

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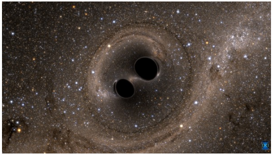

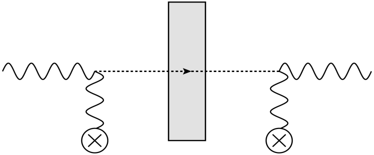

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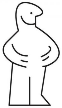

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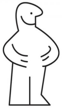

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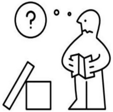

Do you have any questions?