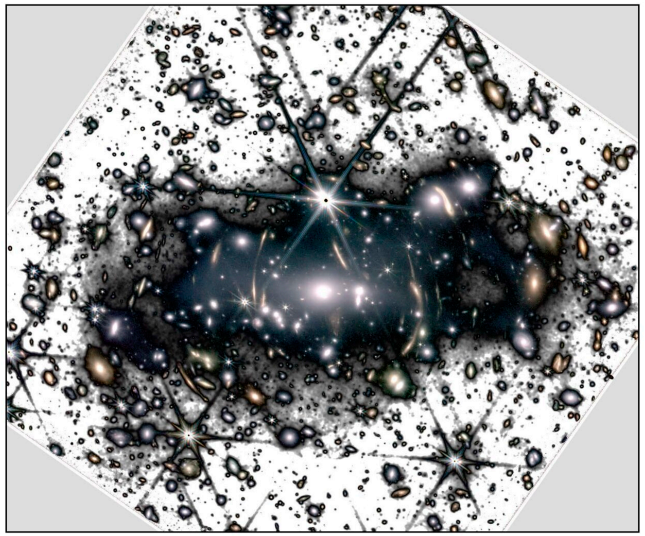
Universität Siegen

TP1 Theoretical Particle Physics

CPPS Center for Particle Physics Siegen



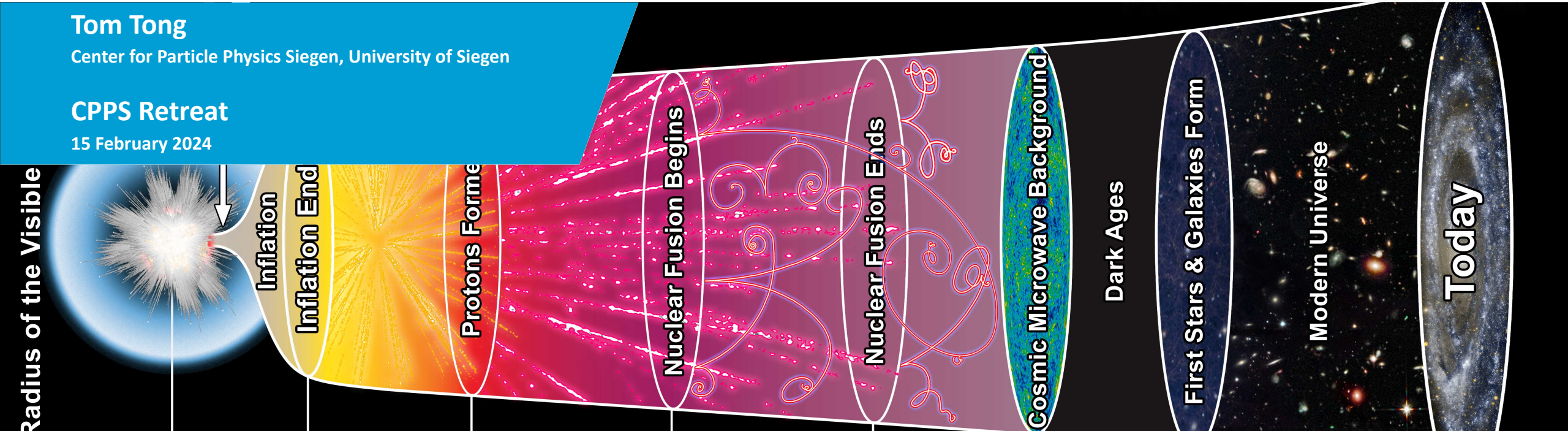
Super-Heavy Dark Matter

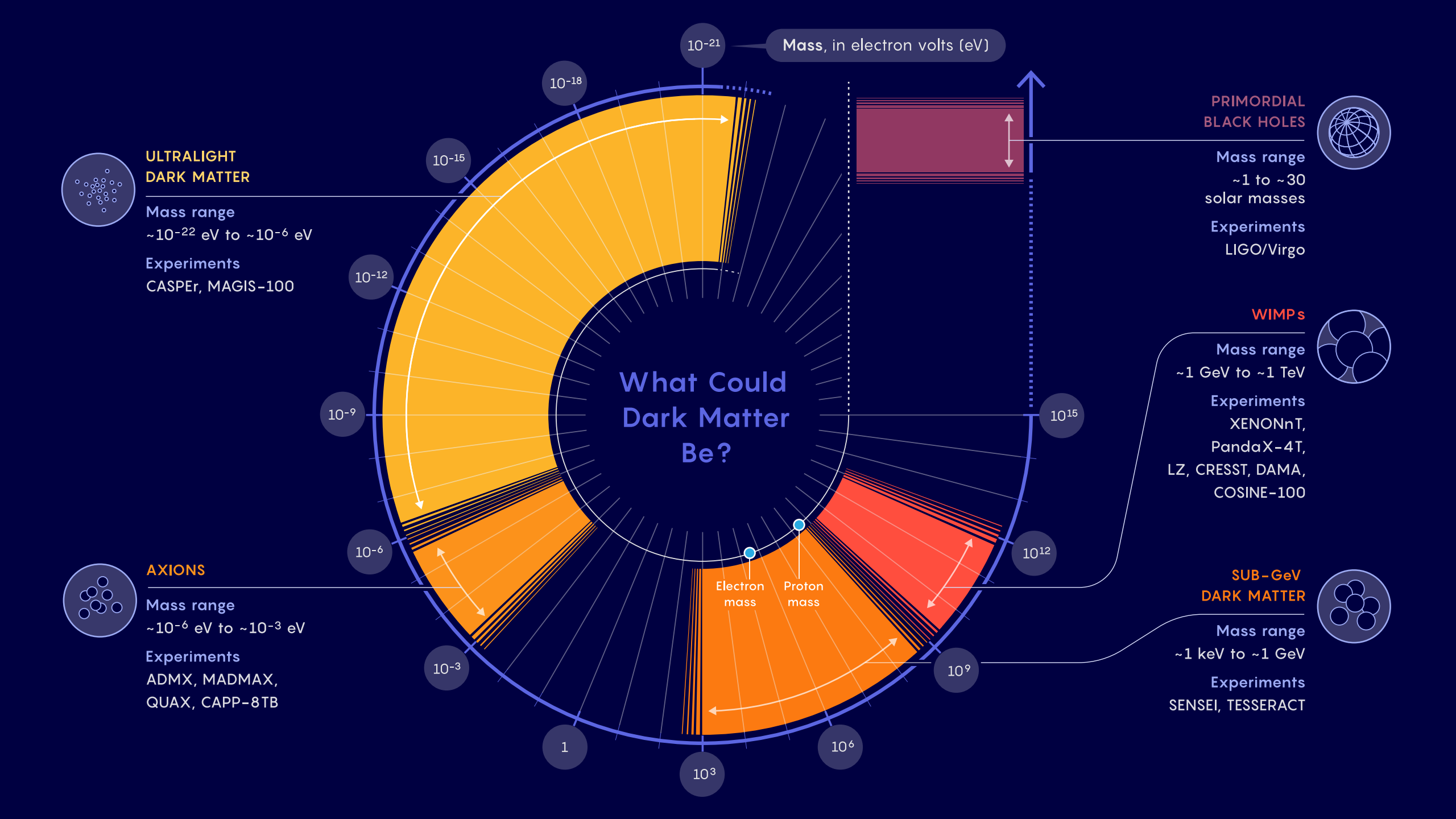
Tom Tong

Center for Particle Physics Siegen, University of Siegen

CPPS Retreat

15 February 2024




Mass, in electron volts (eV)
10-21
10-18
10-15
10-12
10-9
10-6
10-3
1
103
106
109
1012
1015
What Could Dark Matter Be?
Electron mass
Proton mass
ULTRALIGHT DARK MATTER
Mass range
~10-22 eV to ~10-6 eV
Experiments
CASPEr, MAGIS-100
AXIONS
Mass range
~10-6 eV to ~10-3 eV
Experiments
ADMX, MADMAX, QUAX, CAPP-8TB
PRIMORDIAL BLACK HOLES
Mass range
~1 to ~30 solar masses
Experiments
LIGO/Virgo
WIMPs
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SUB-GeV DARK MATTER
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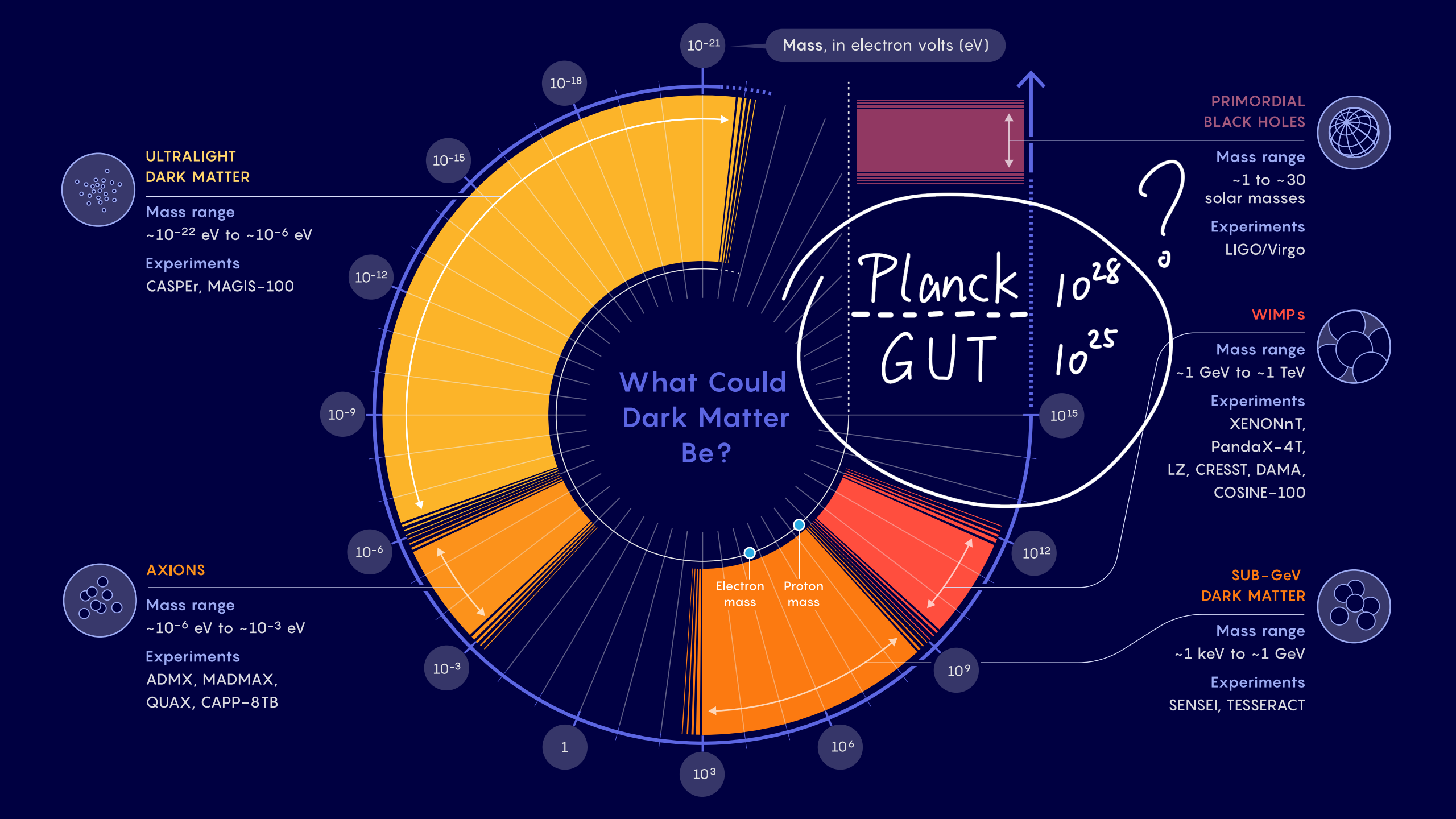
SENSEI, TESSERACT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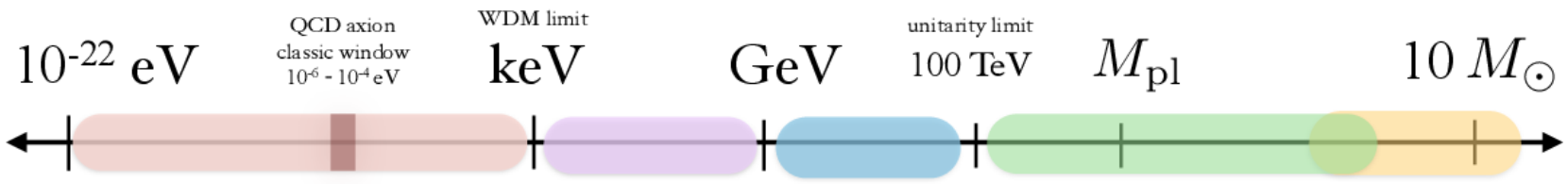
Mass scale of dark matter

(not to scale)



``Ultralight" DM

non-thermal
bosonic fields

``Light" DM

dark sectors
sterile ν
can be thermal

WIMP

Composite DM

(Q-balls, nuggets, etc)

Primordial
black holes

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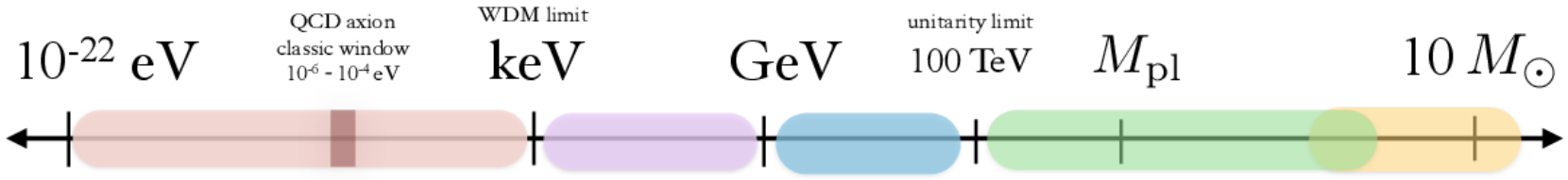

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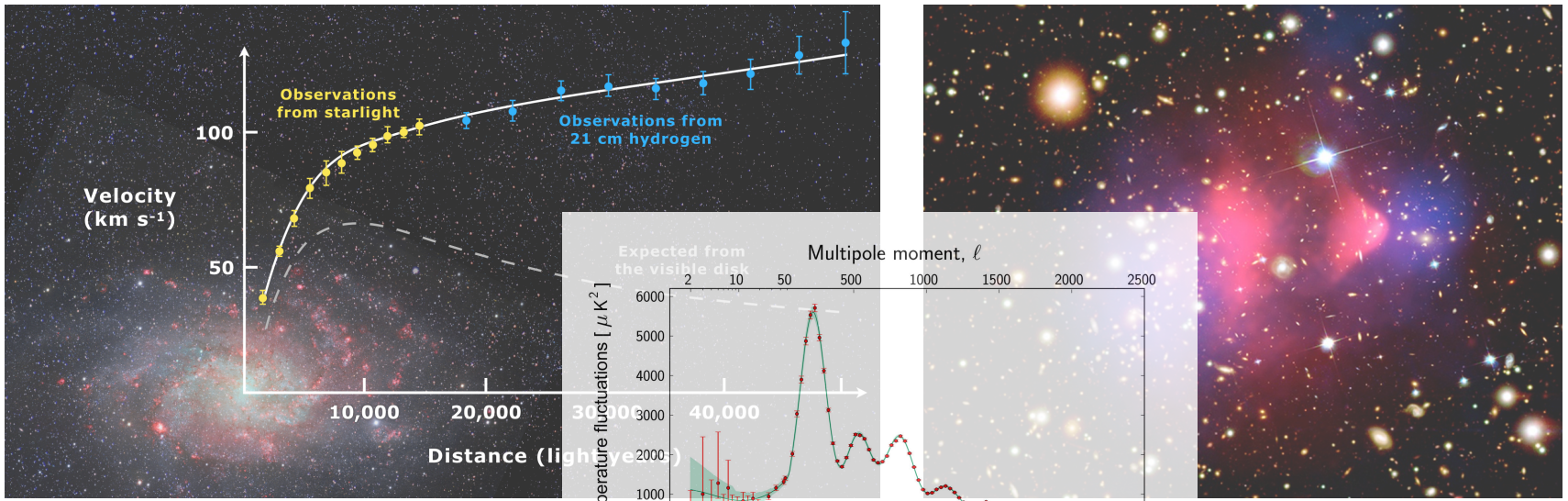

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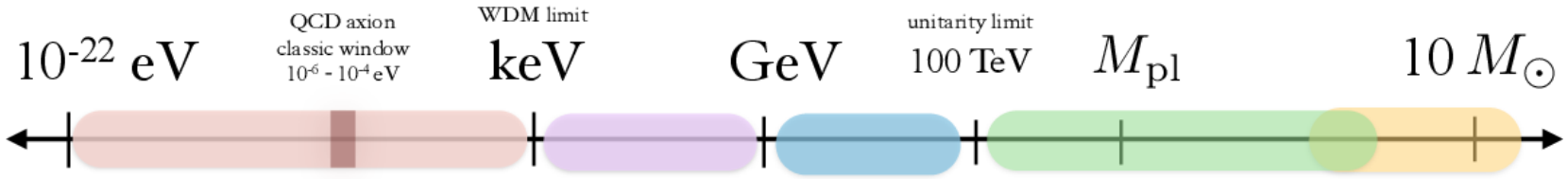

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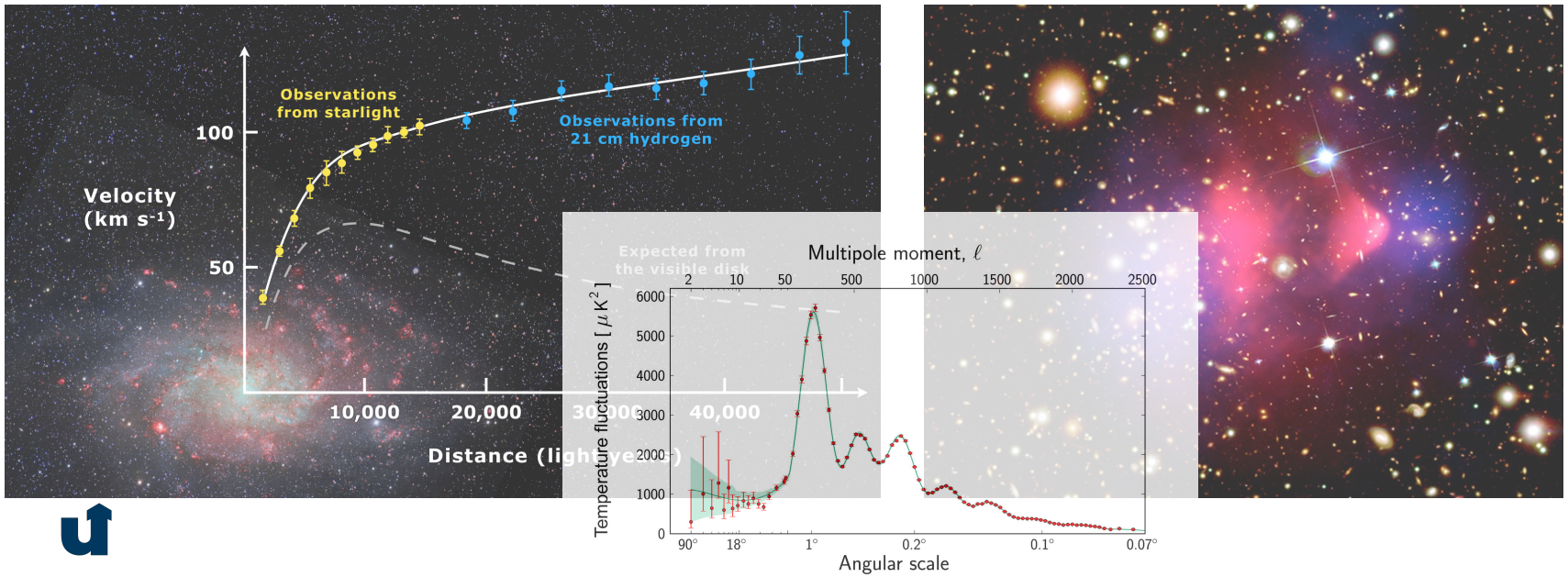

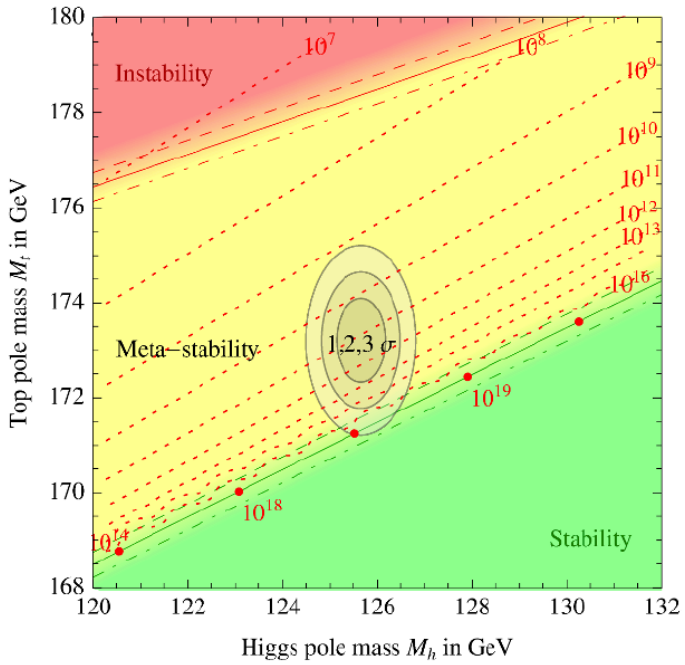

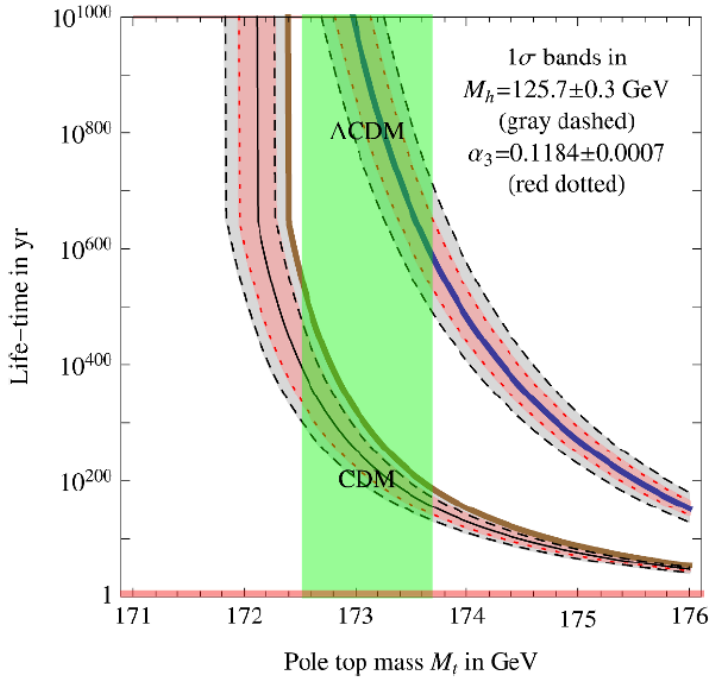

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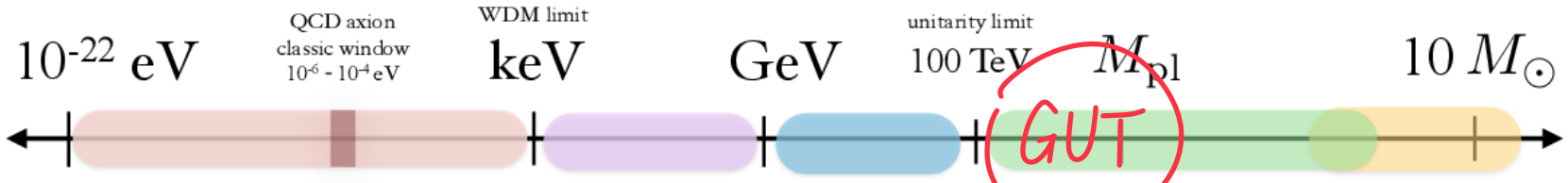

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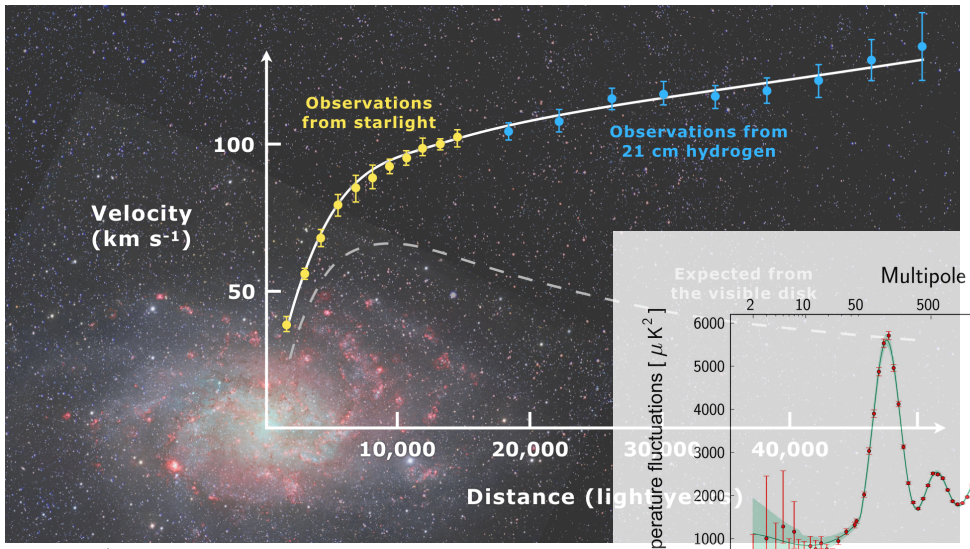

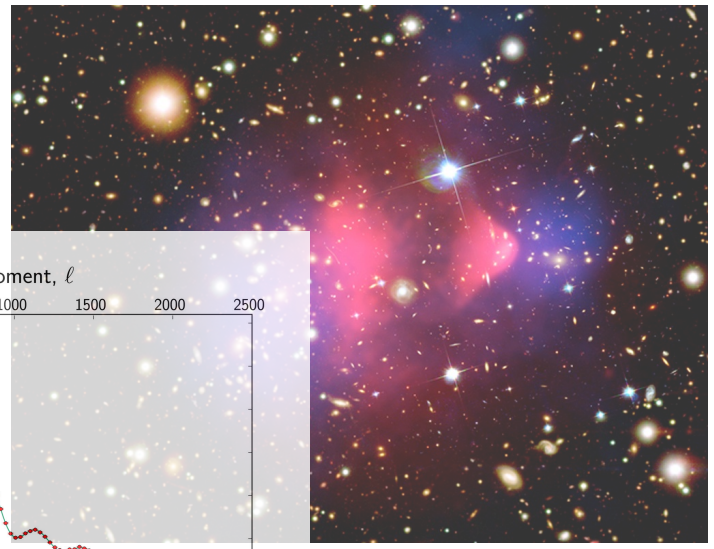

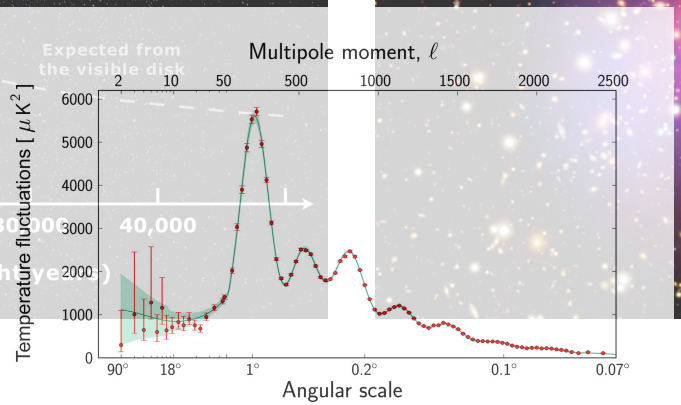

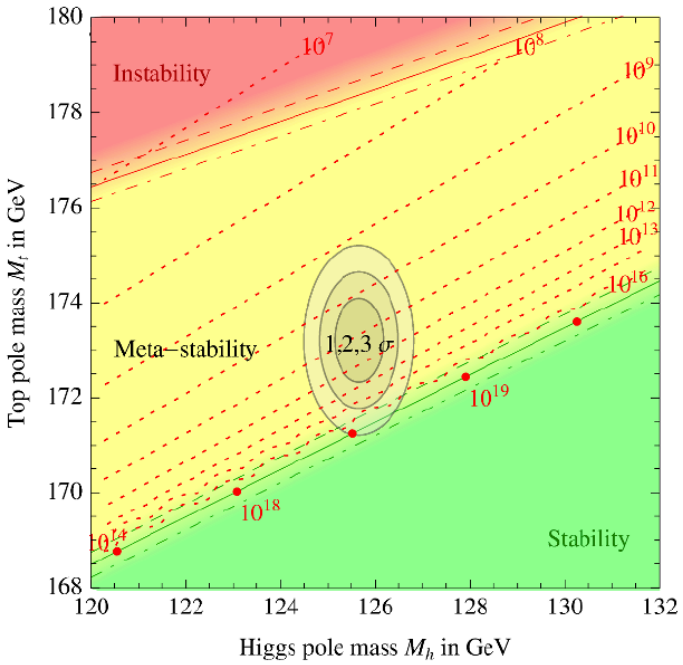

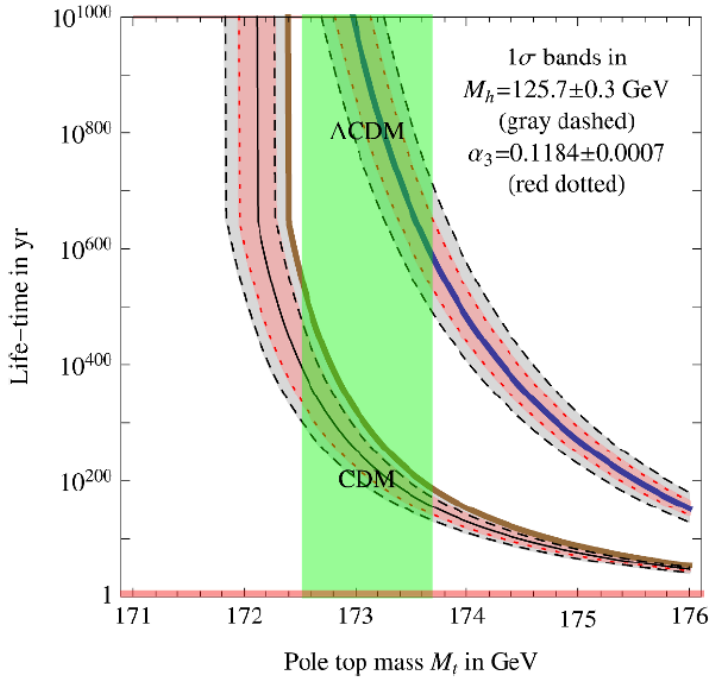

Quiz: If SHDM is near the GUT scale, how do we probe it?

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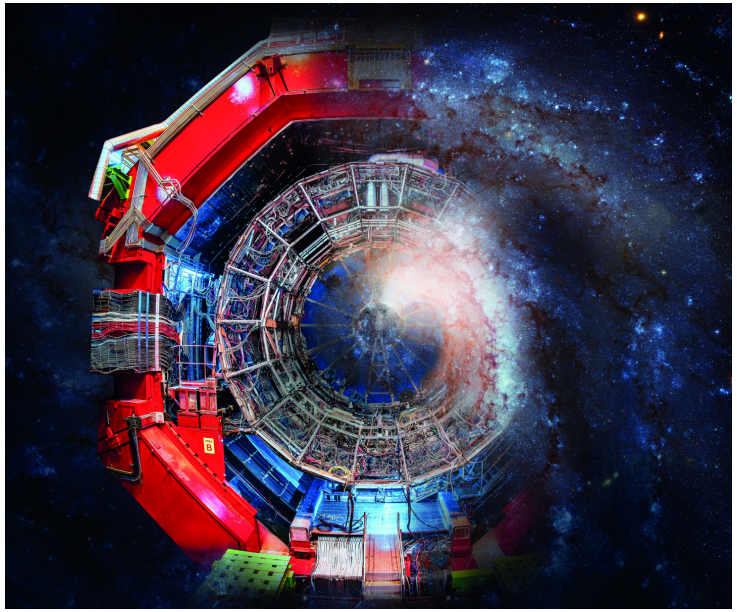

Galaxy-Size Collider!

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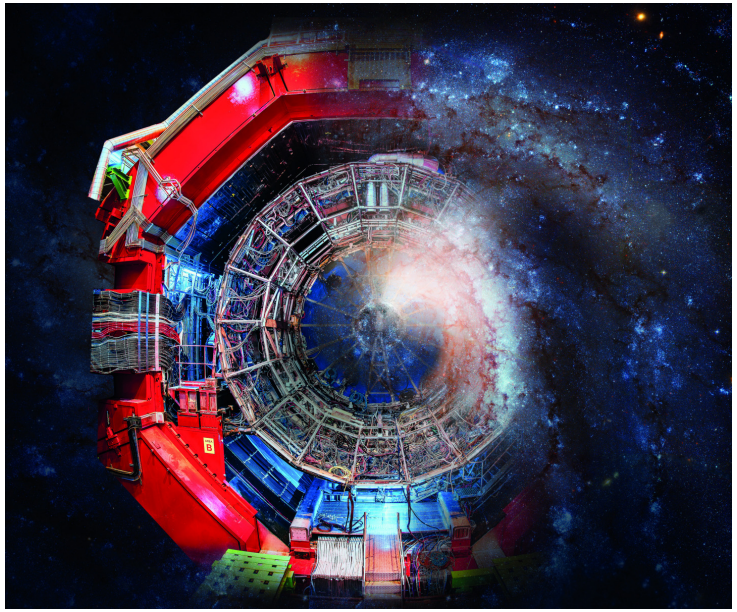

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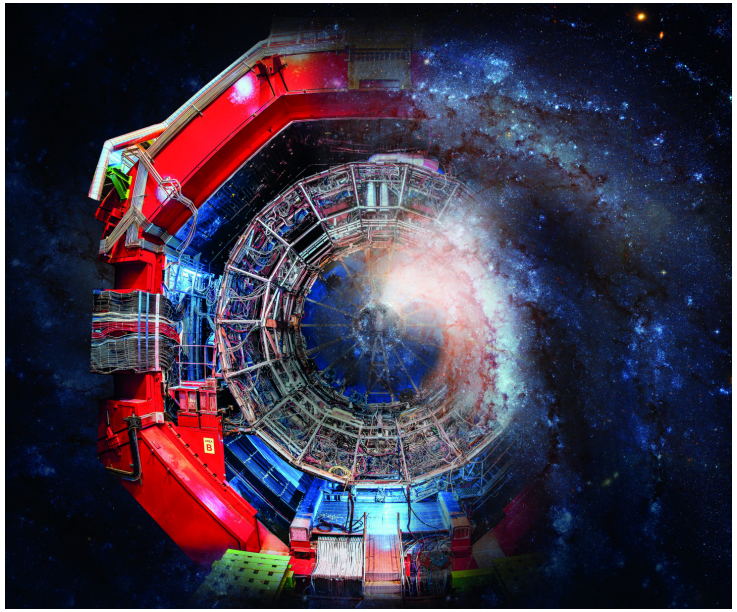

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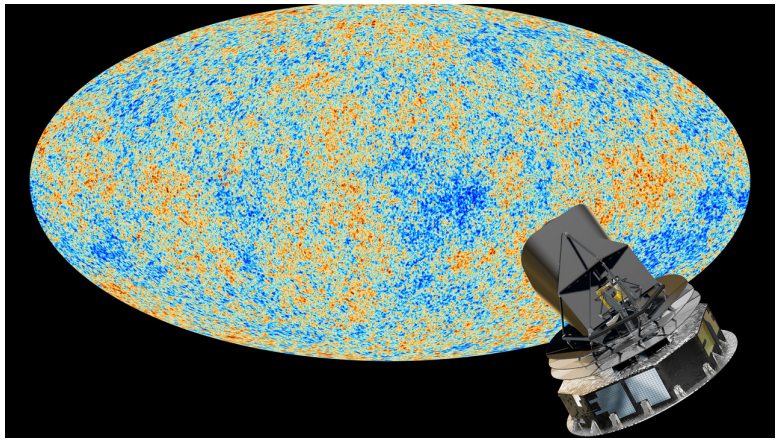

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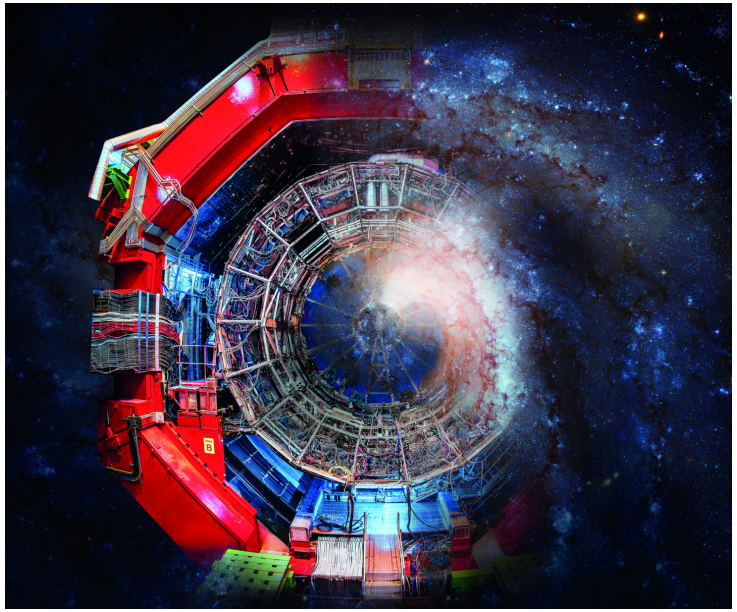

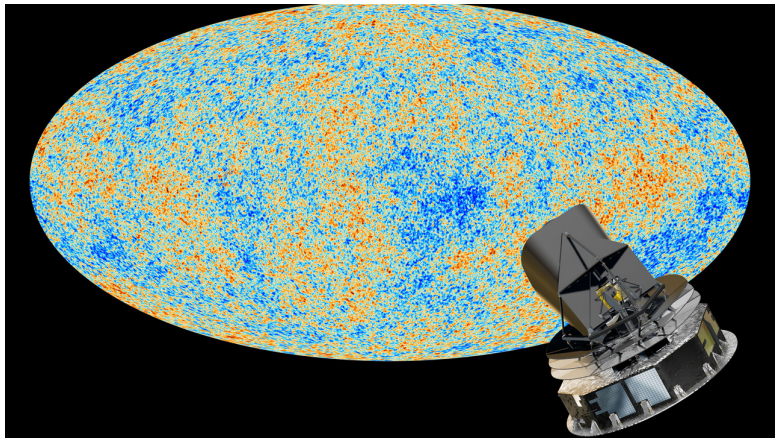

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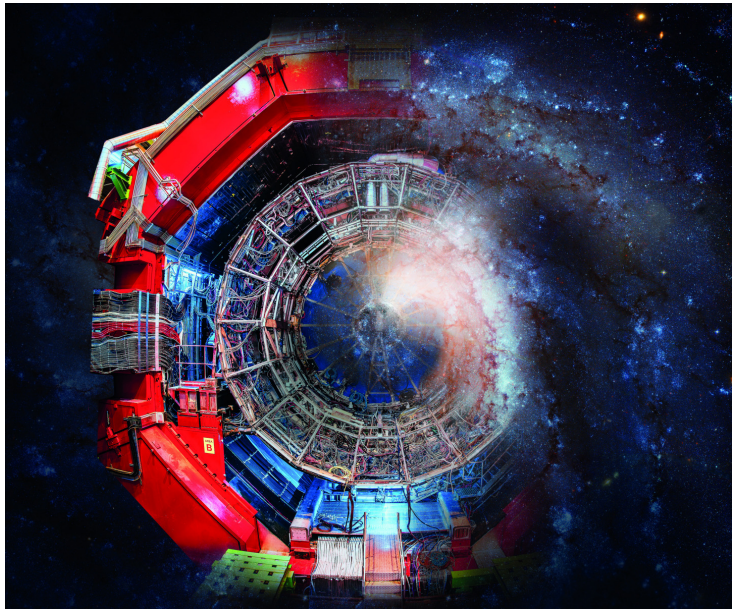

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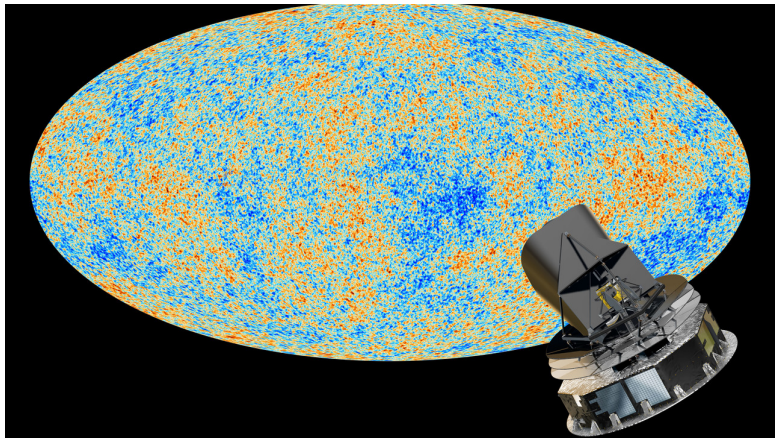

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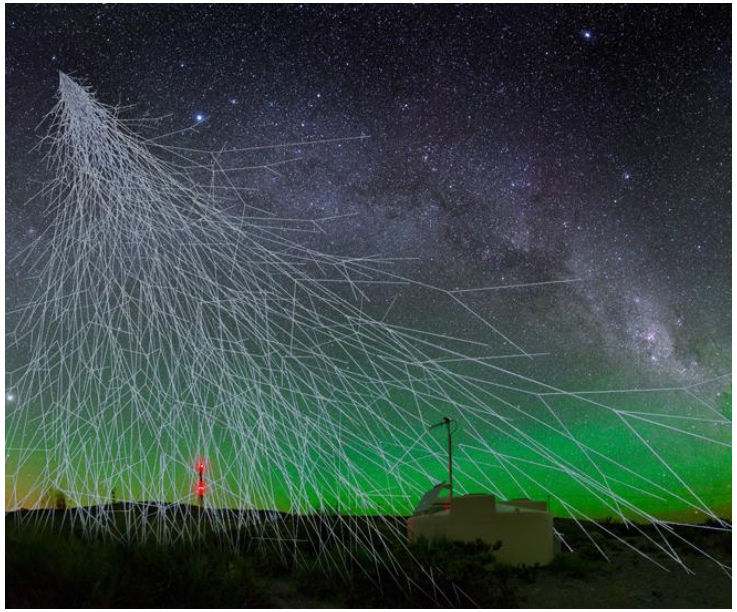

Ultra-High Energy Cosmic Rays

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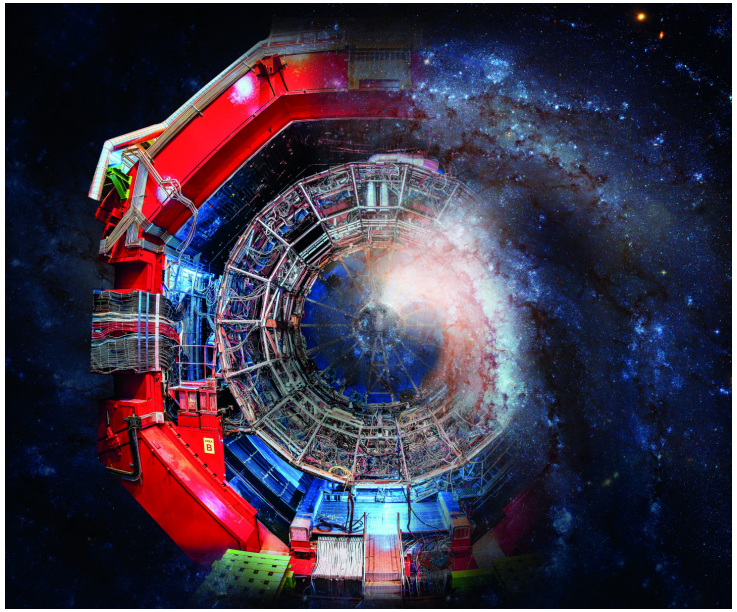

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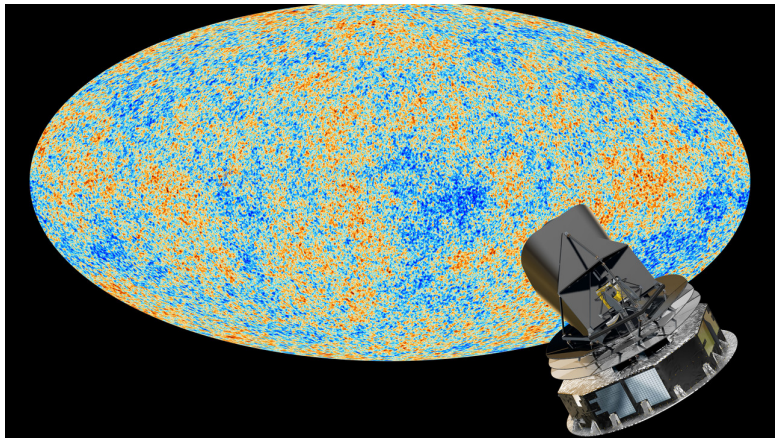

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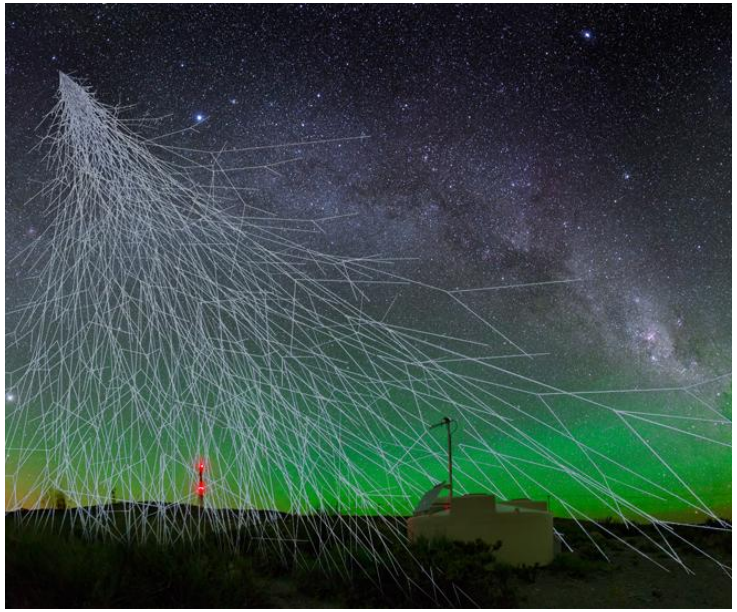
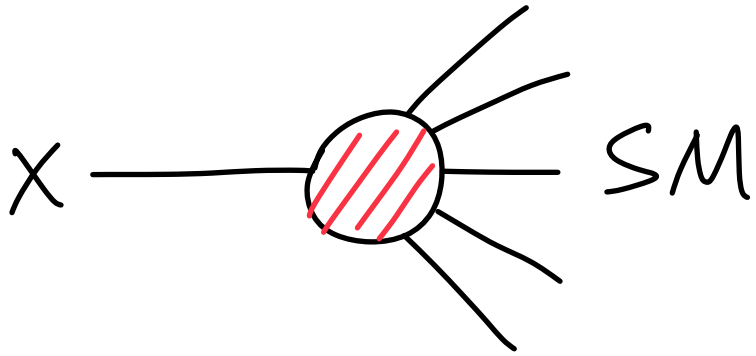


Ultra-High Energy Cosmic Rays

SHDM Decay Scenario: Pertubative, with a small coupling to the SM



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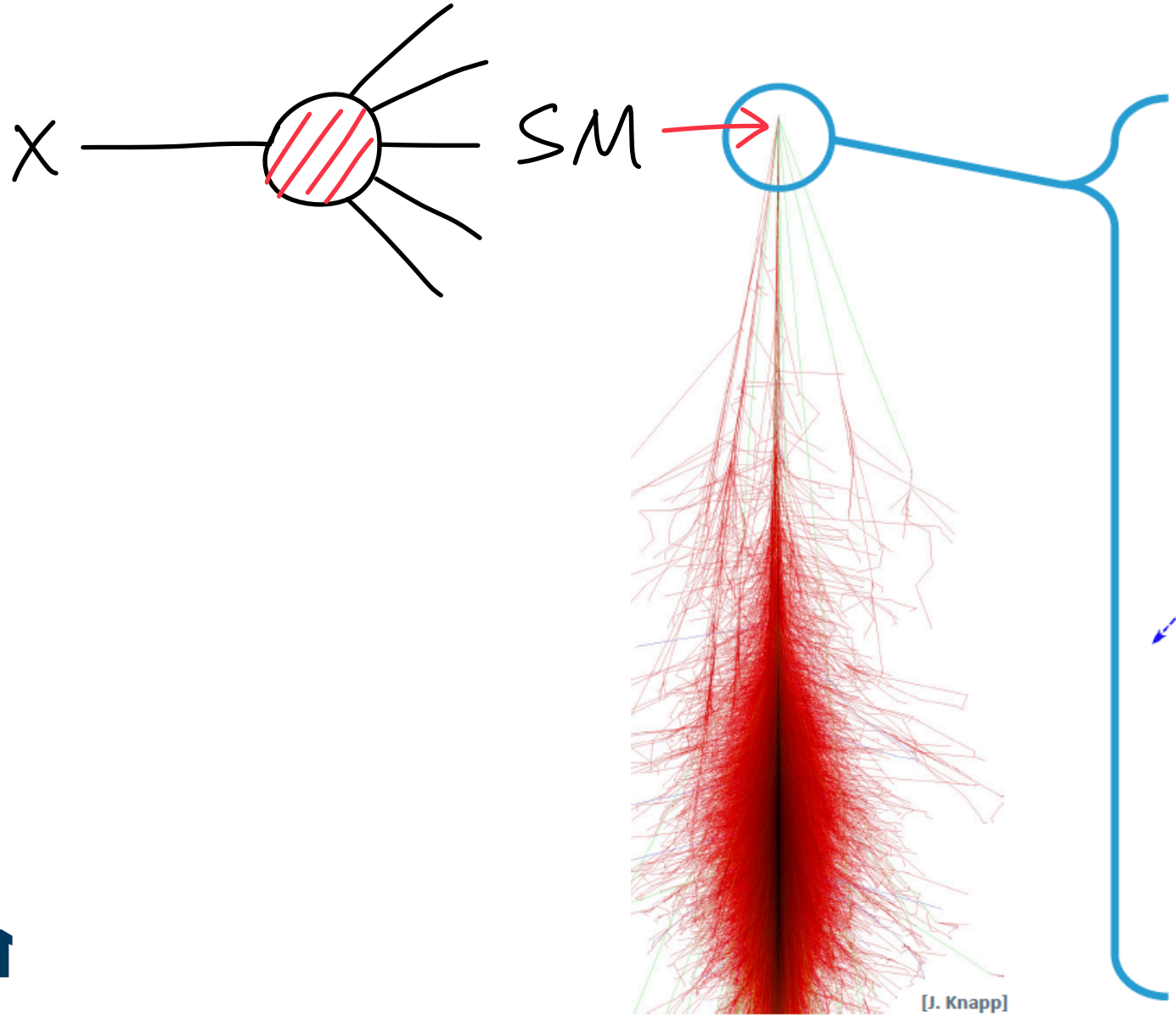

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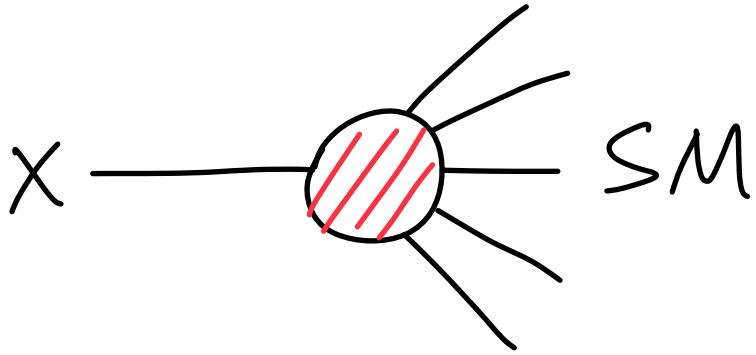

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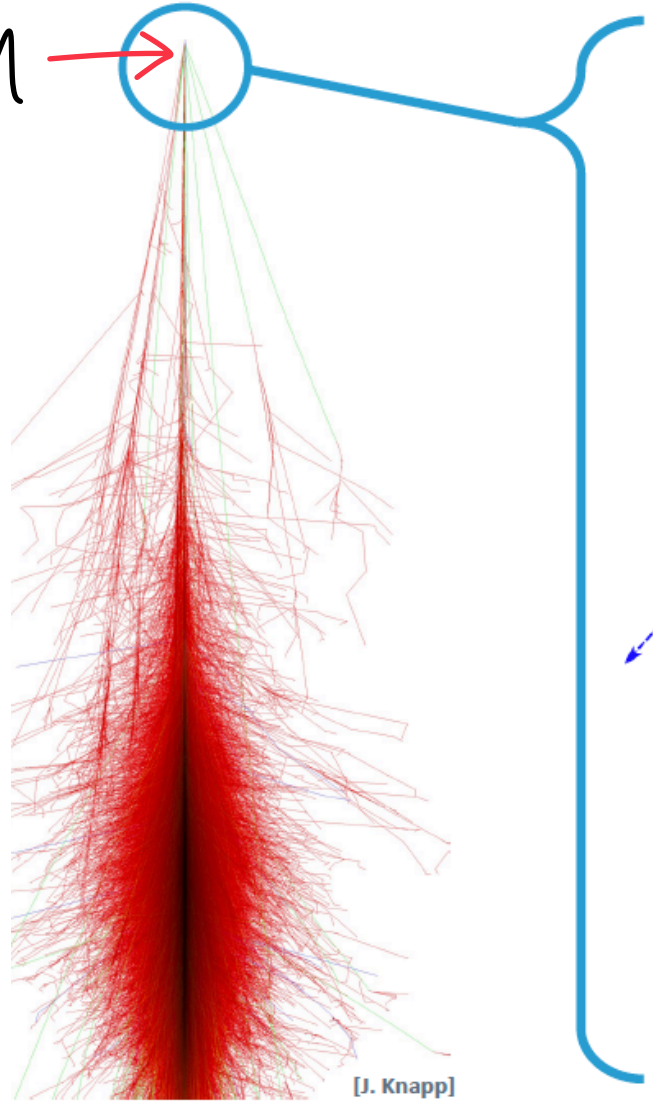
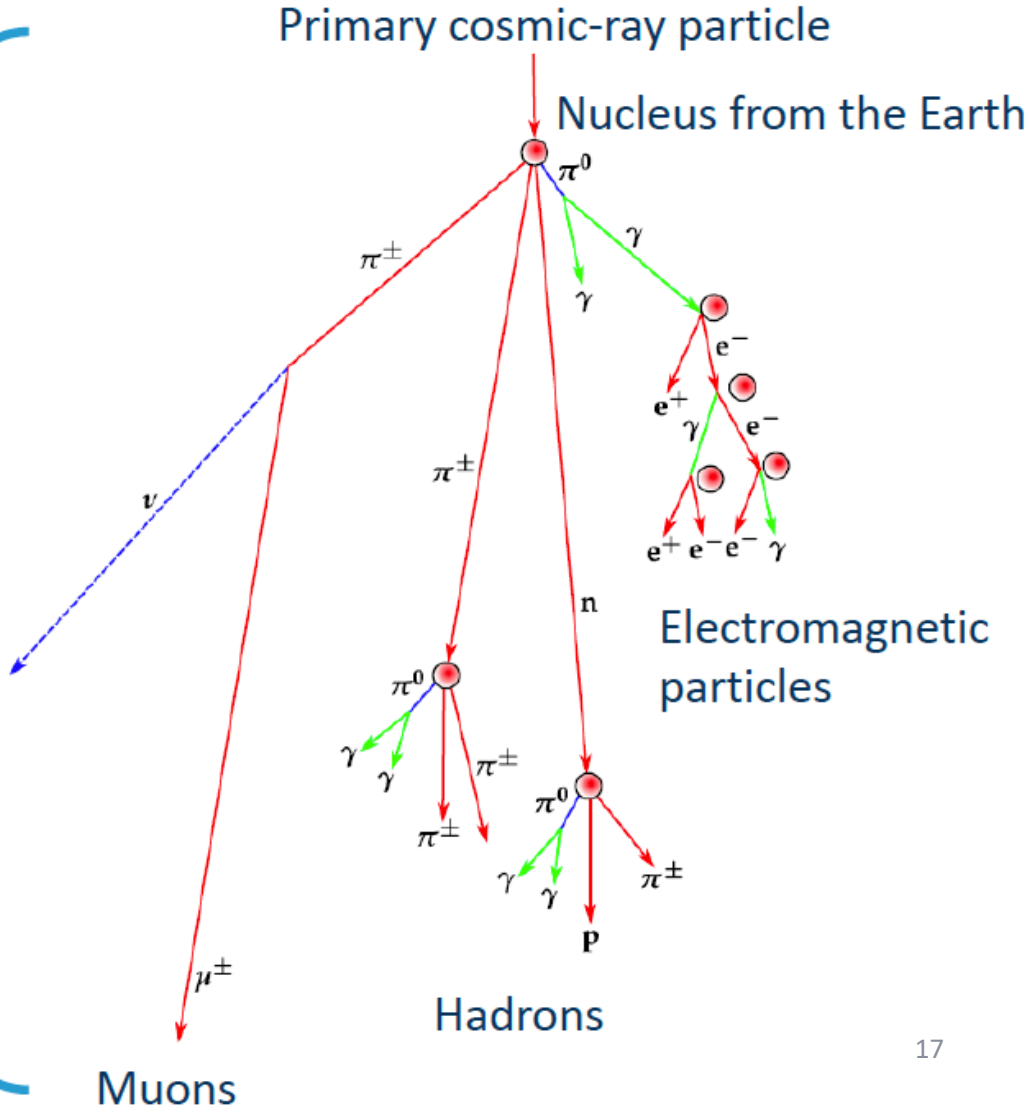
$\Lambda \sim GUT \sim 10^{16}\,GeV$





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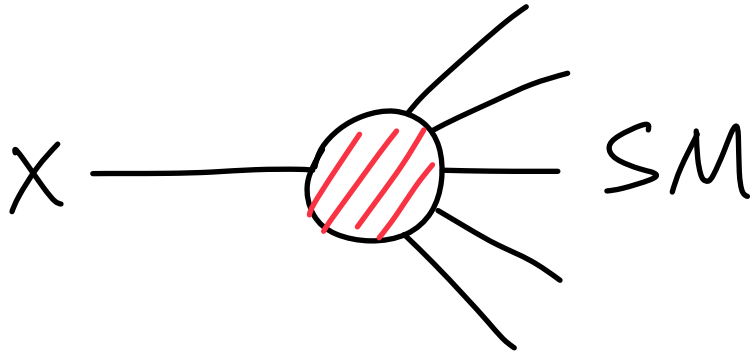

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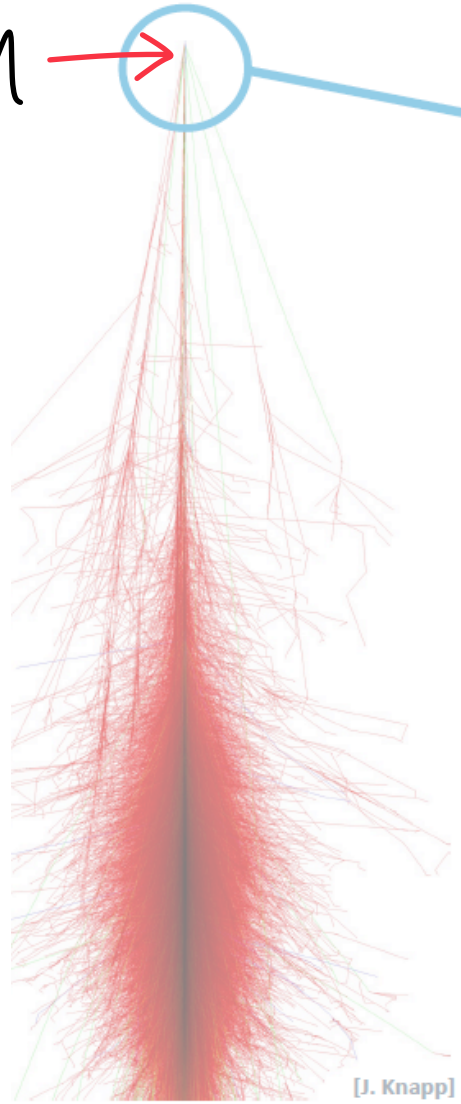

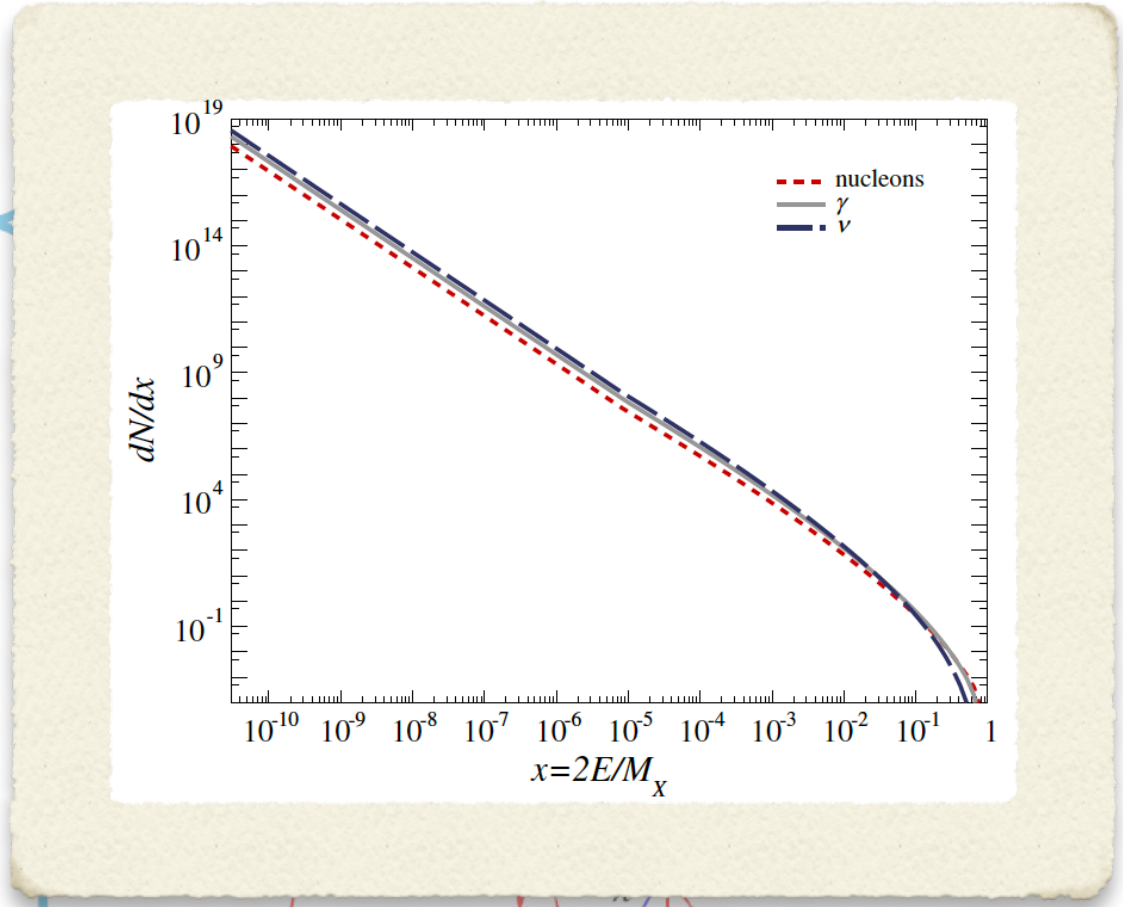

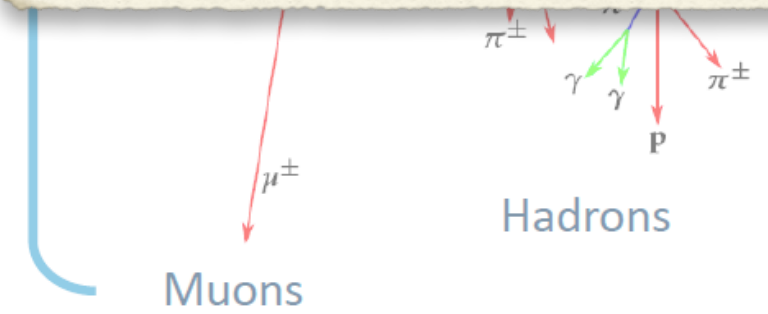

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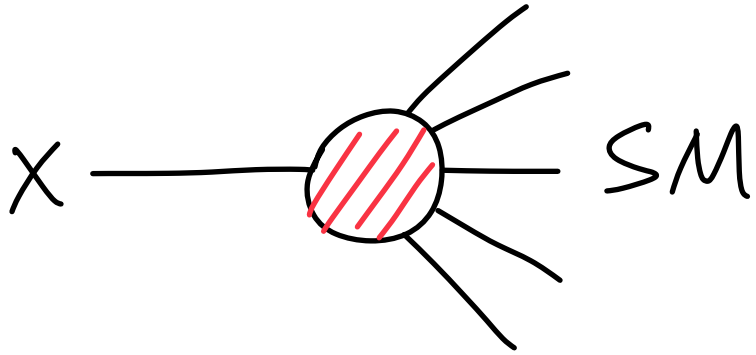

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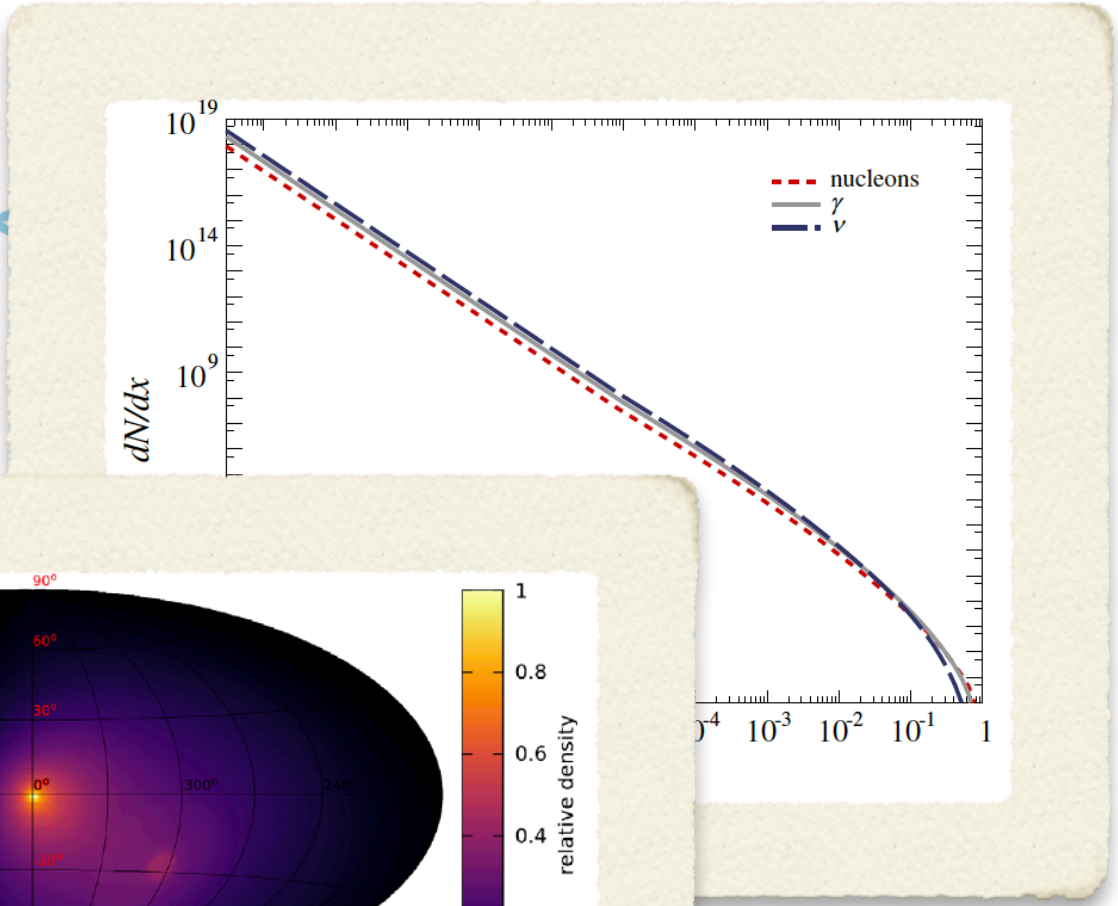

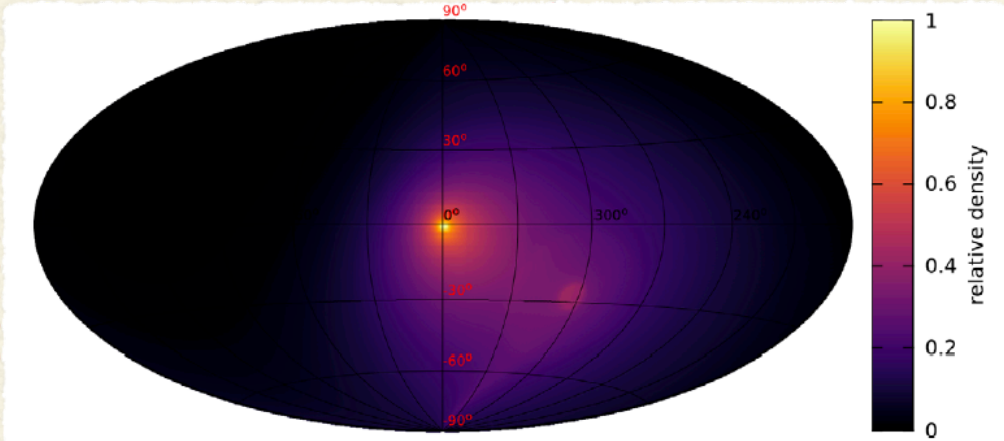

FIG. 2. Signal term of the directional density, $\delta\mu(\mathbf{n}, E = 32\ \text{EeV})$, as expected to be observed at the Pierre Auger Observatory in Galactic coordinates.

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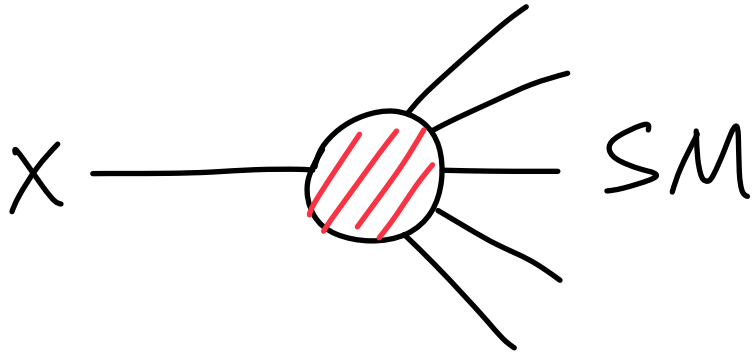

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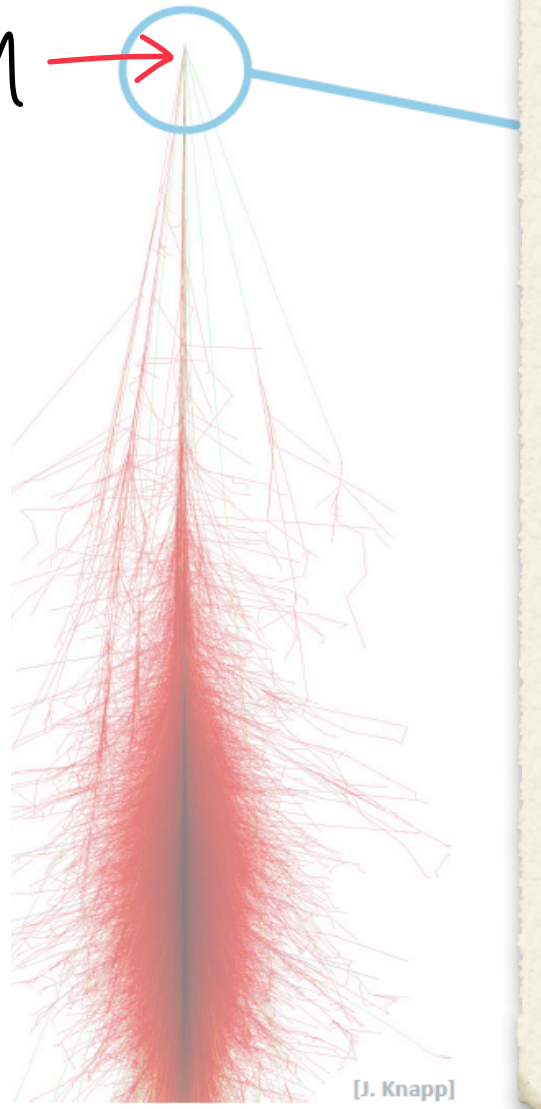

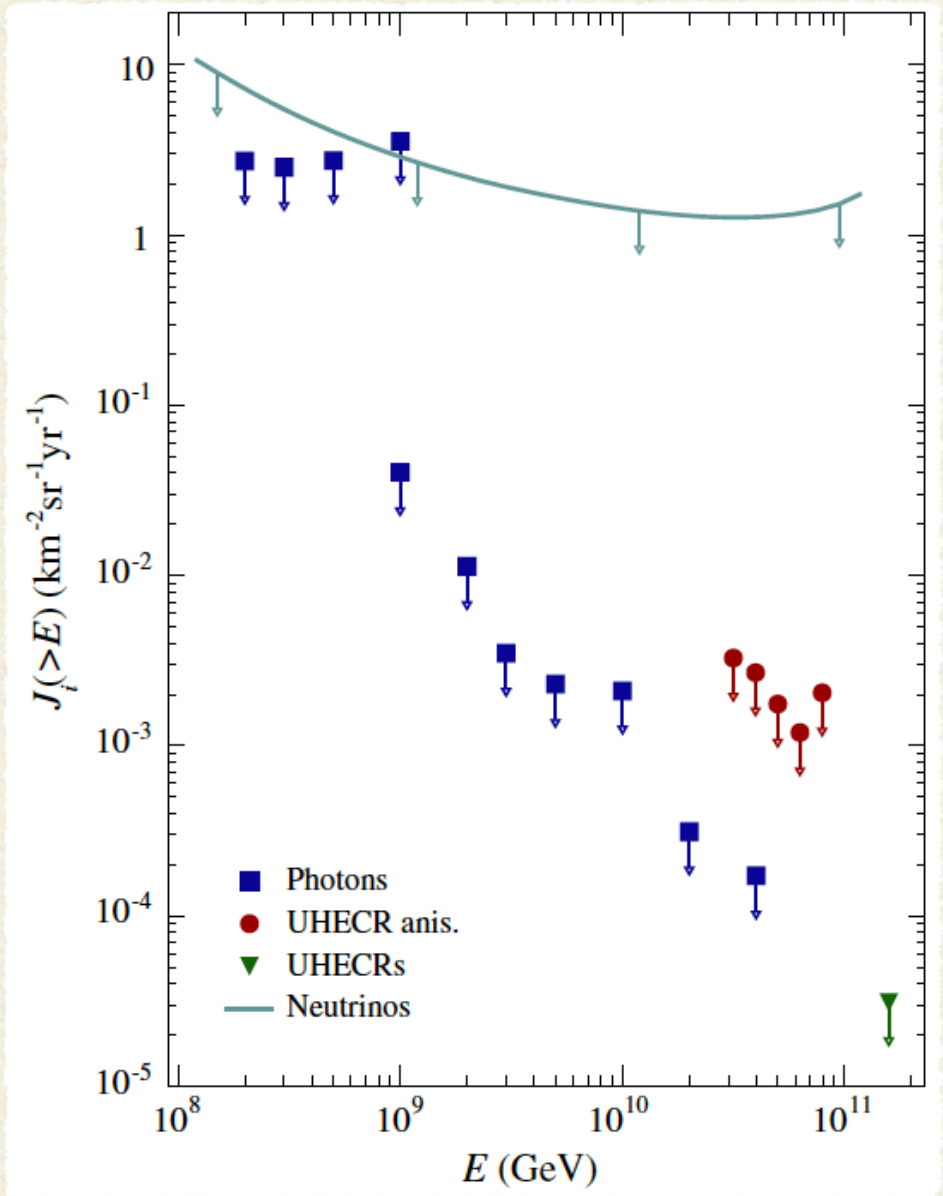

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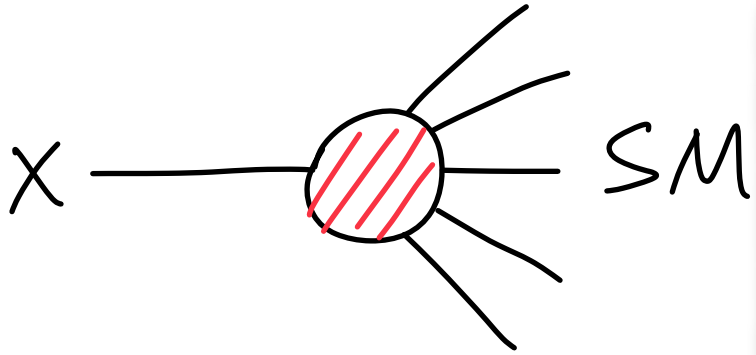

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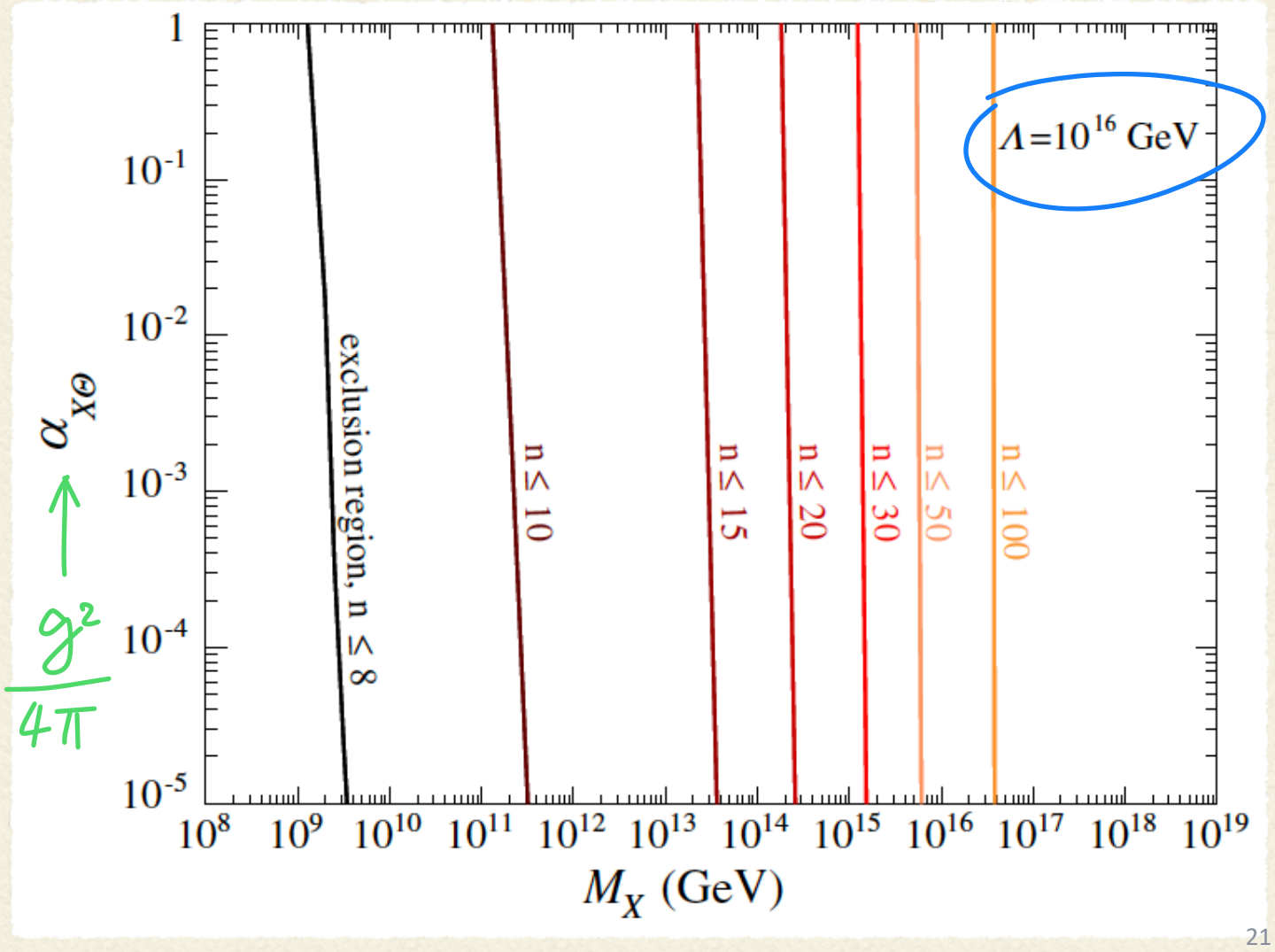

Quiz: A physicist's Dark Matter Nightmare

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No WIMPs! No SUSY!

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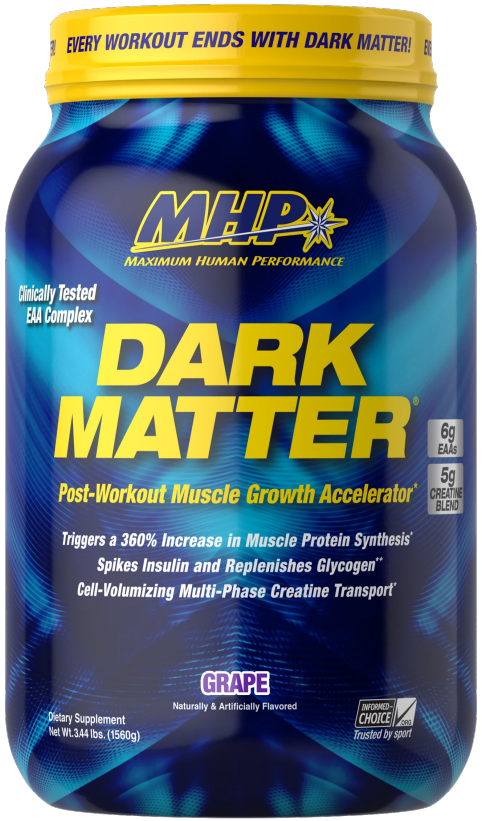

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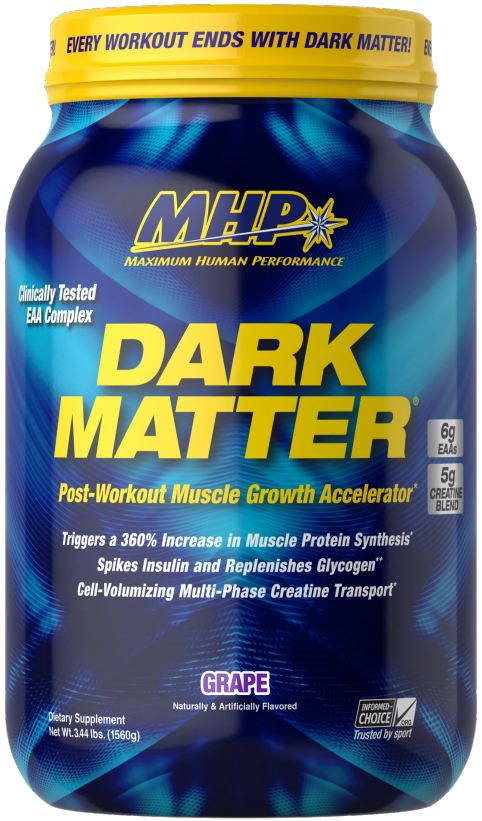

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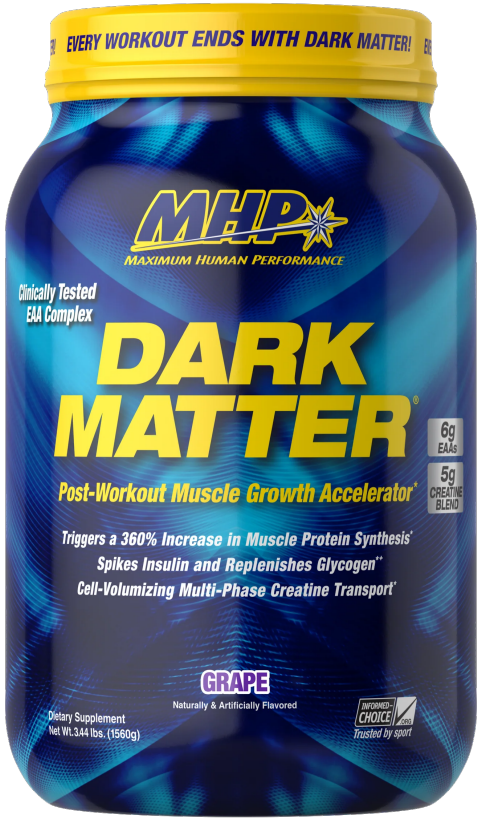

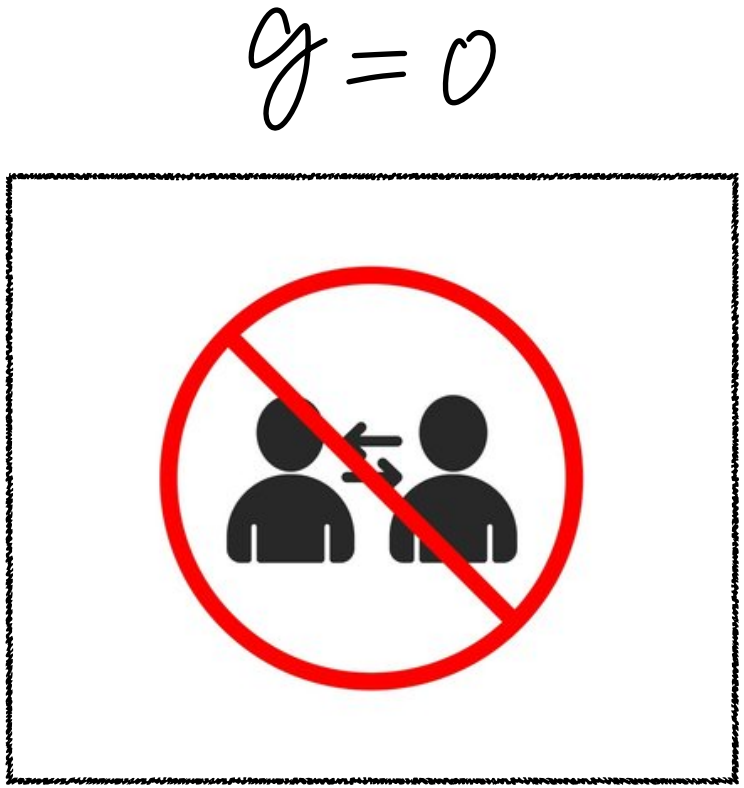

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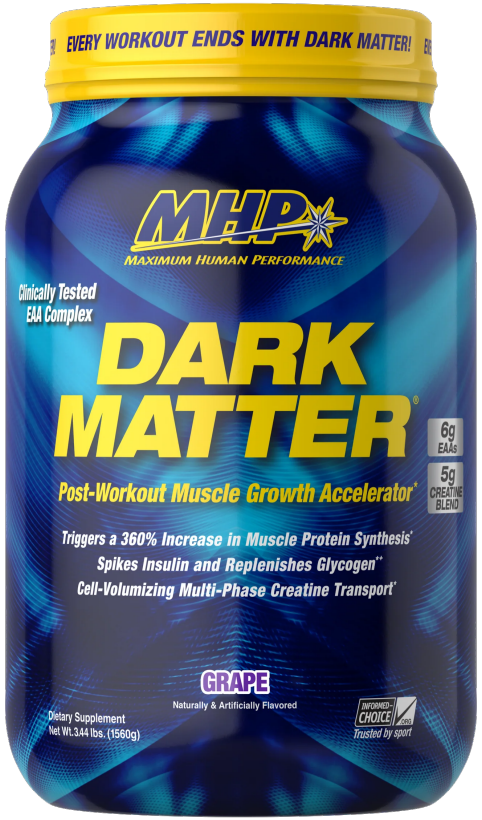

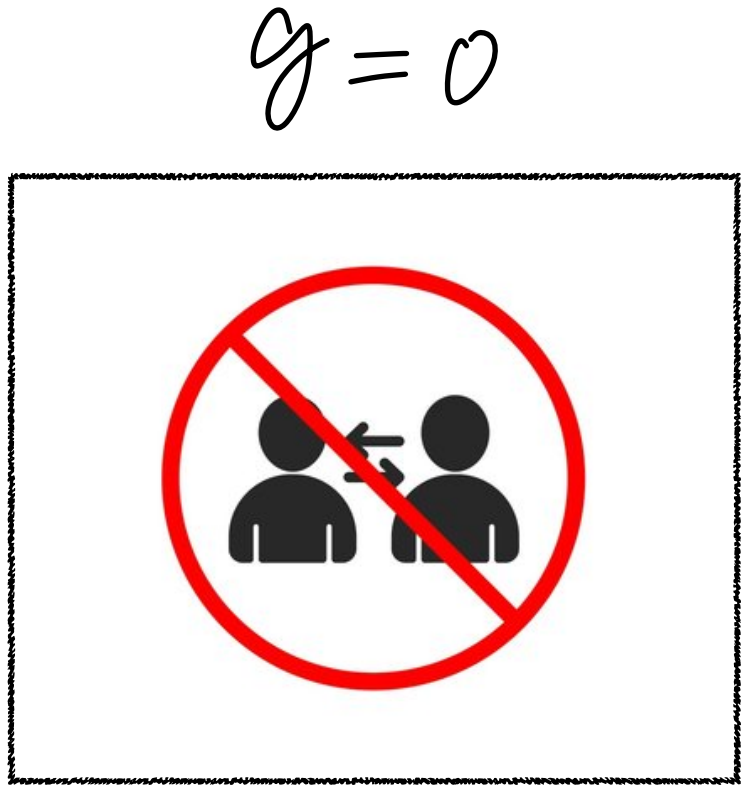

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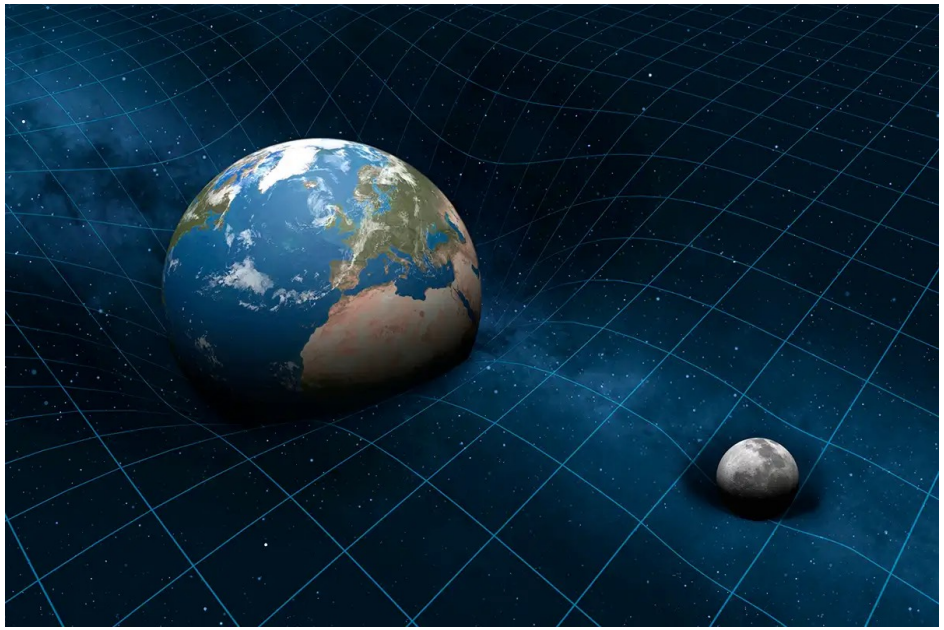
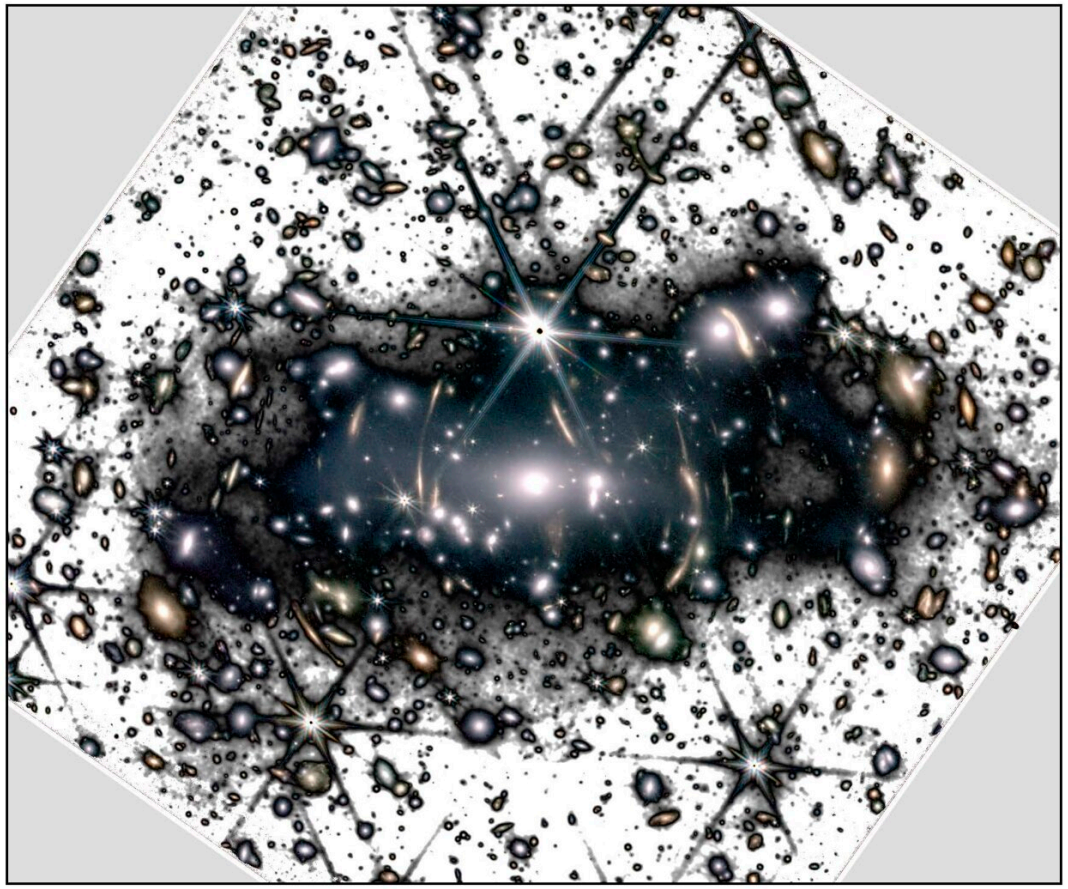
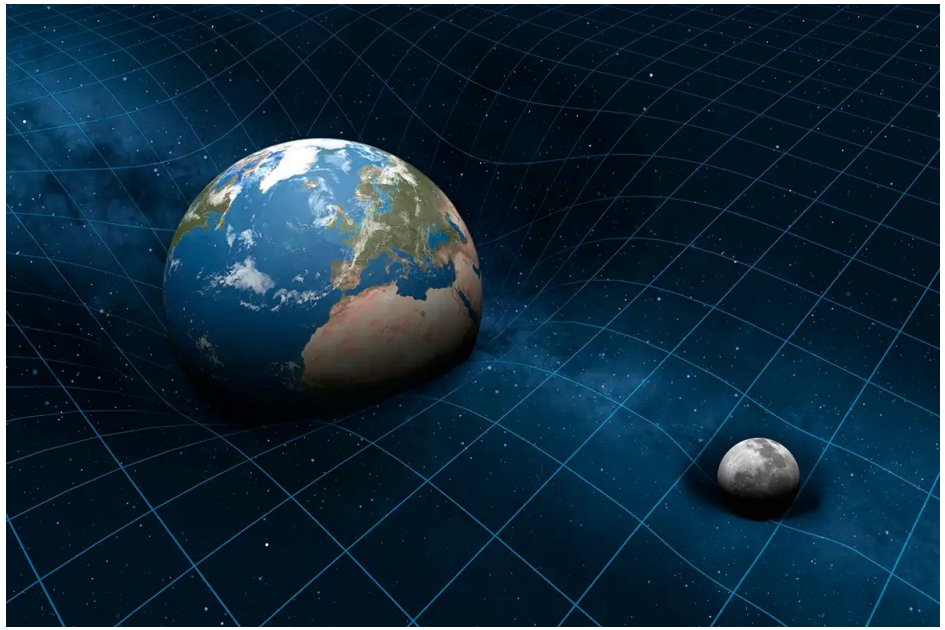
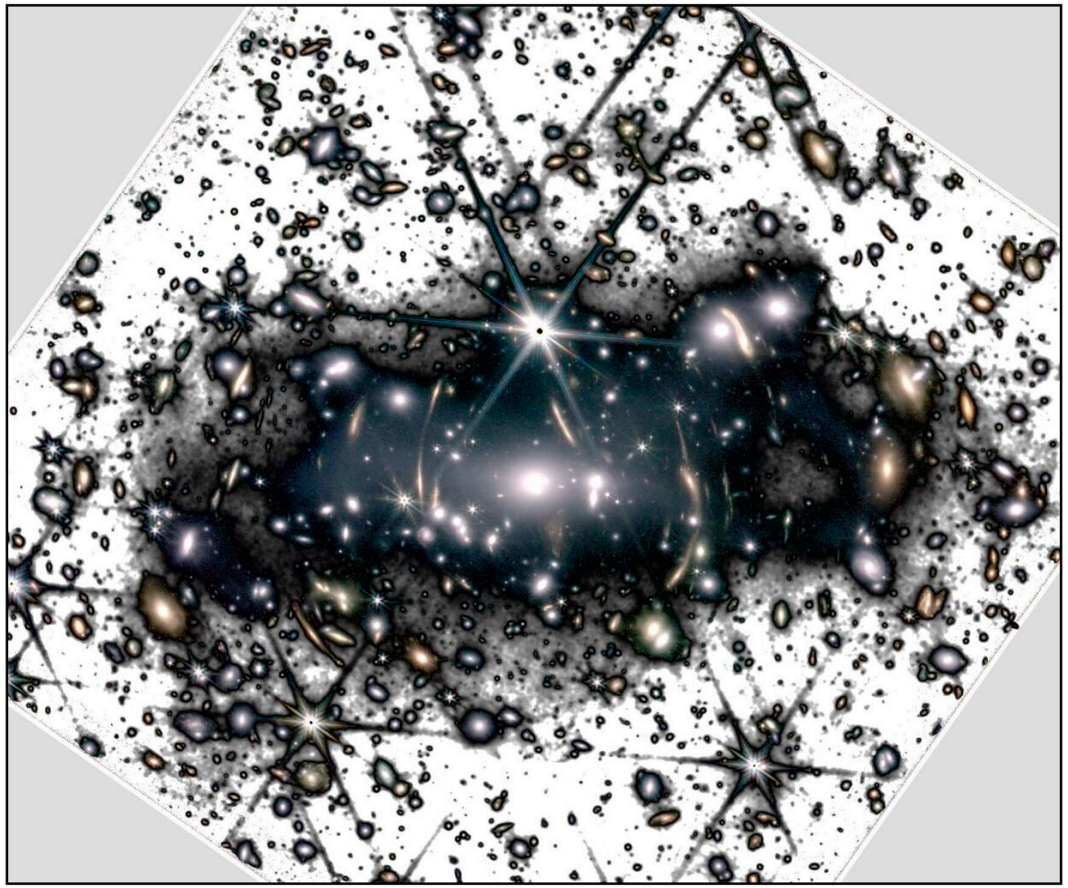


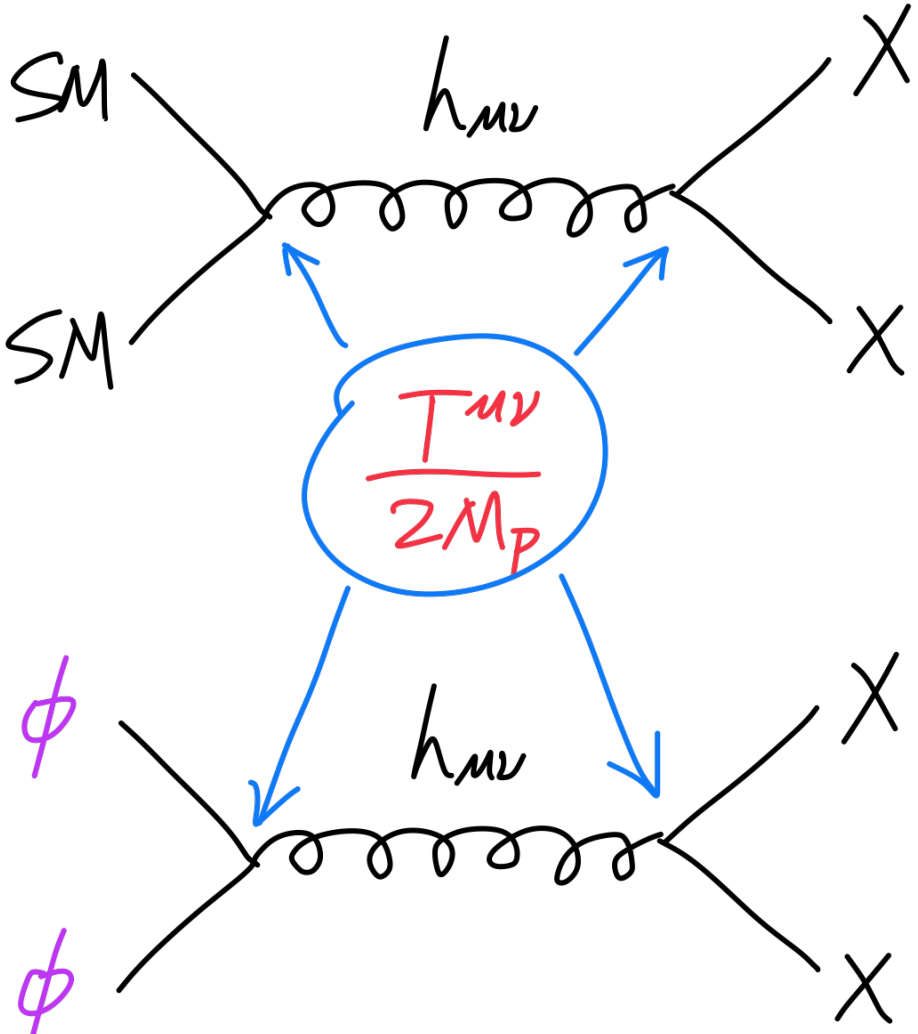
Gravity connects ALL





Purely gravitational SHDM can be produced around reheating





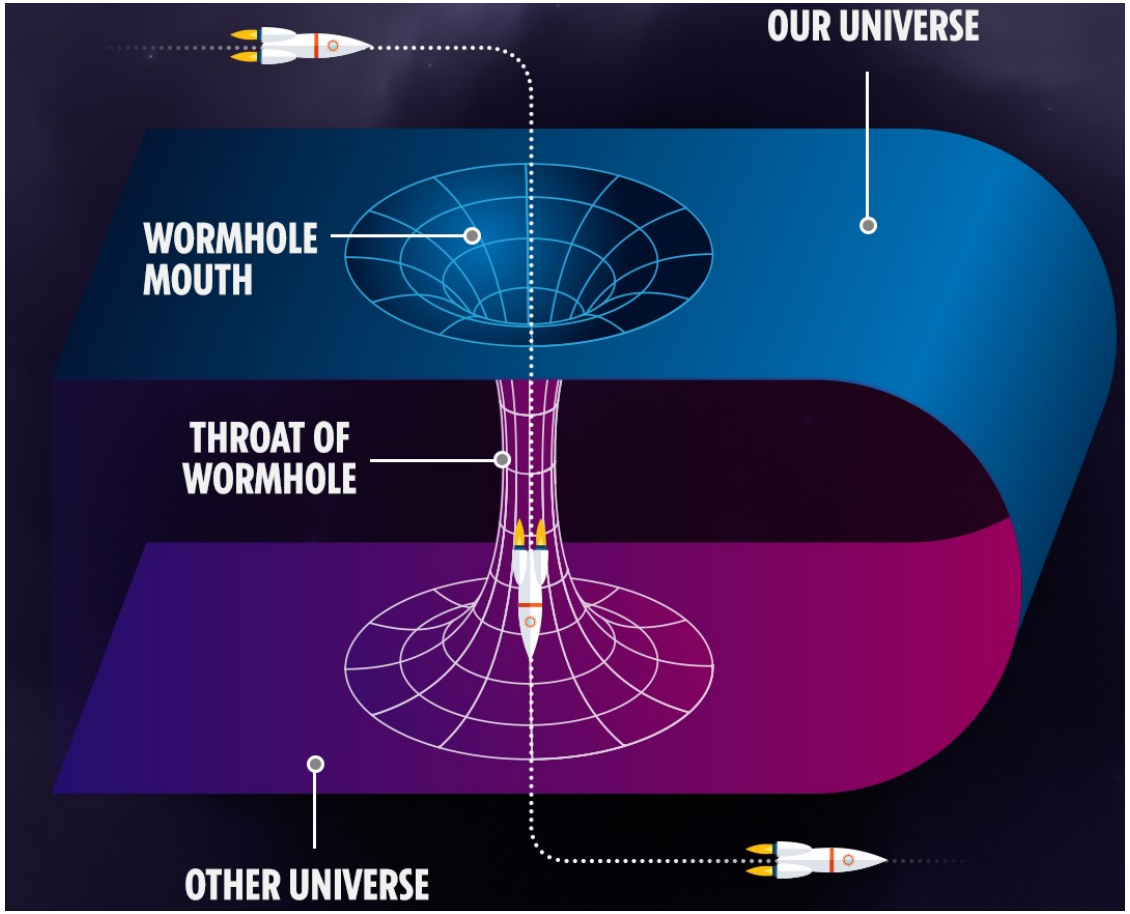
Inflaton → ϕ

Gravity eats ALL

Gravity eats ALL

- Assume the DM is stable
- Protected by a global symmetry
- The new quantum number is respected by all particle interactions
- Even such a DM particle can decay
- Through gravitational instanton
- Quantum gravity effects!

Gravity eats ALL



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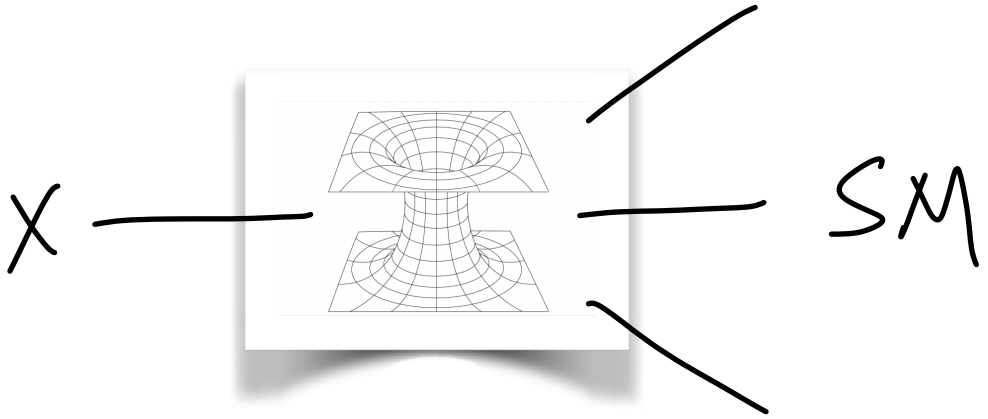
SHDM Decay Scenario: Non-pertubative



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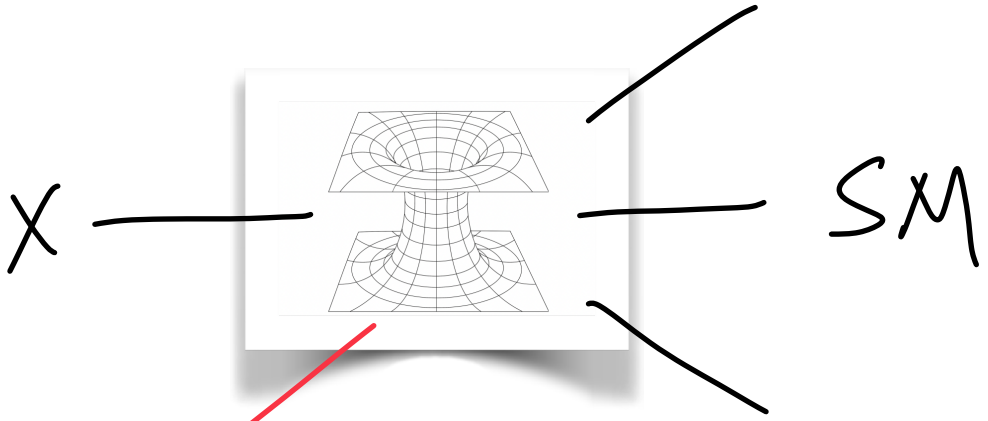

$$e^{-S}, \quad S \sim \left(\frac{R}{L_P}\right)^2$$

$$\tau_X \sim \frac{e^{2S}}{M_X} \sim \frac{e^{\frac{4\pi}{\alpha}}}{M_X}$$

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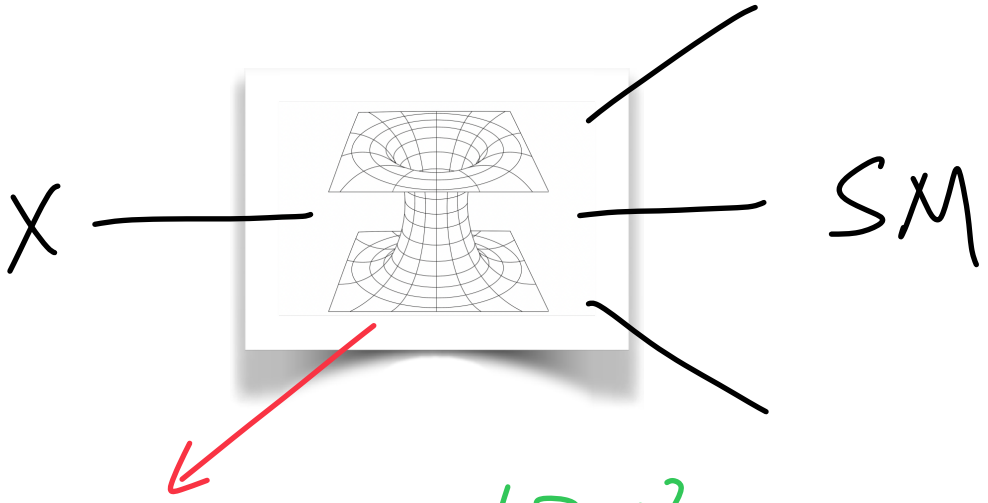

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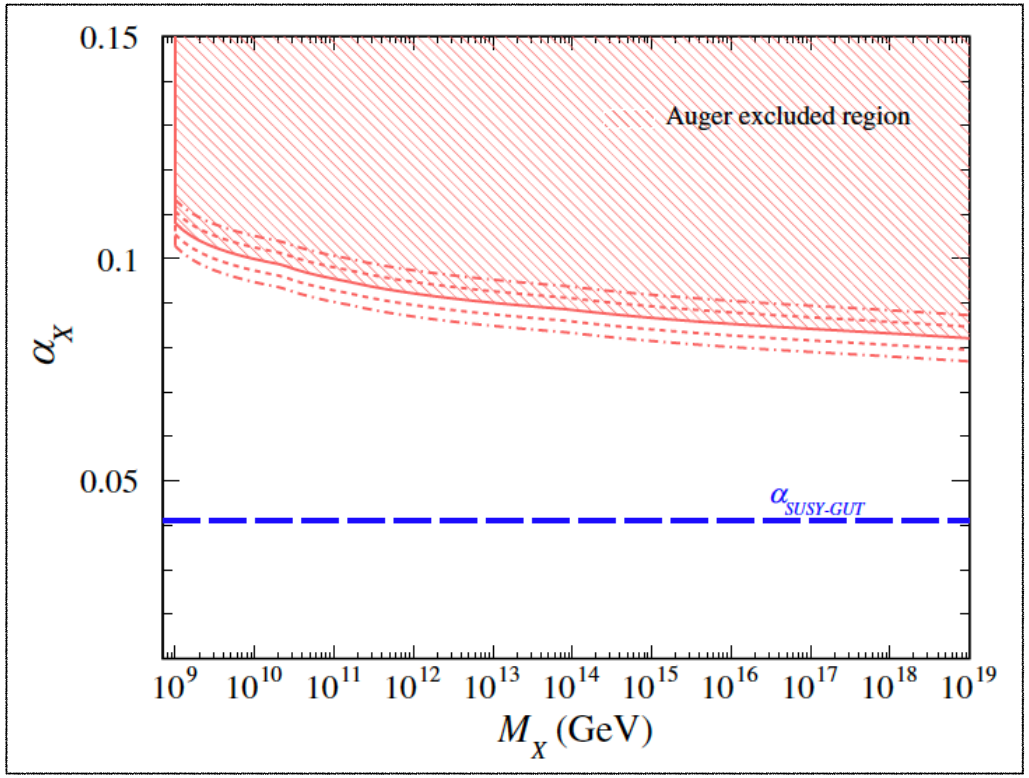

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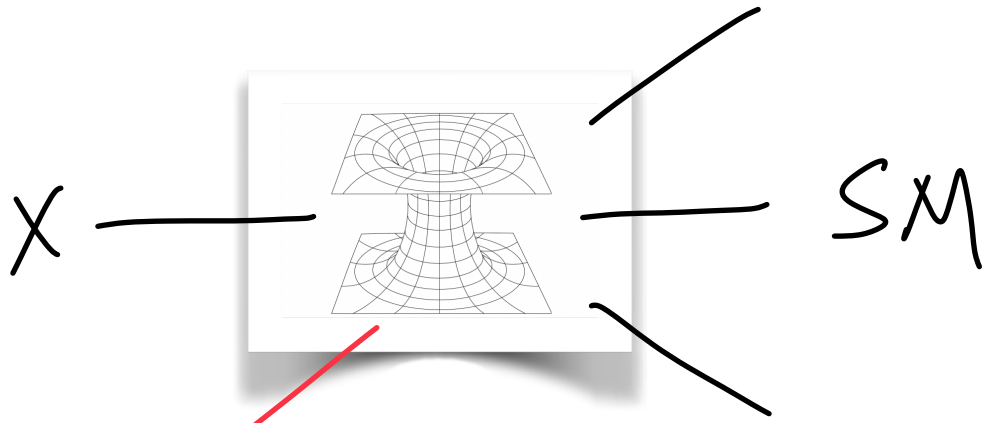

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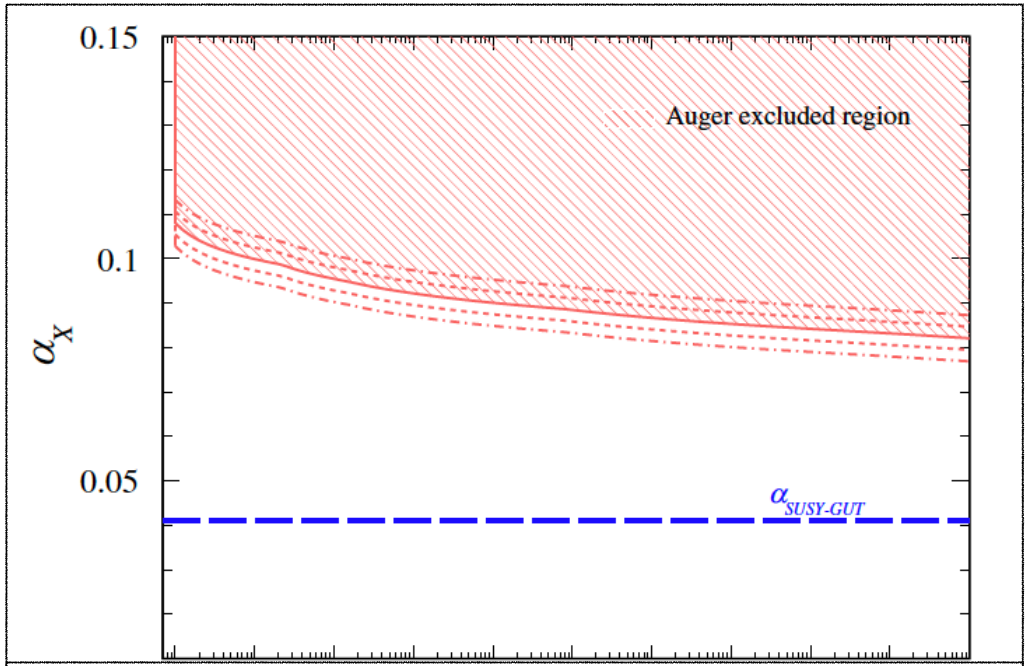

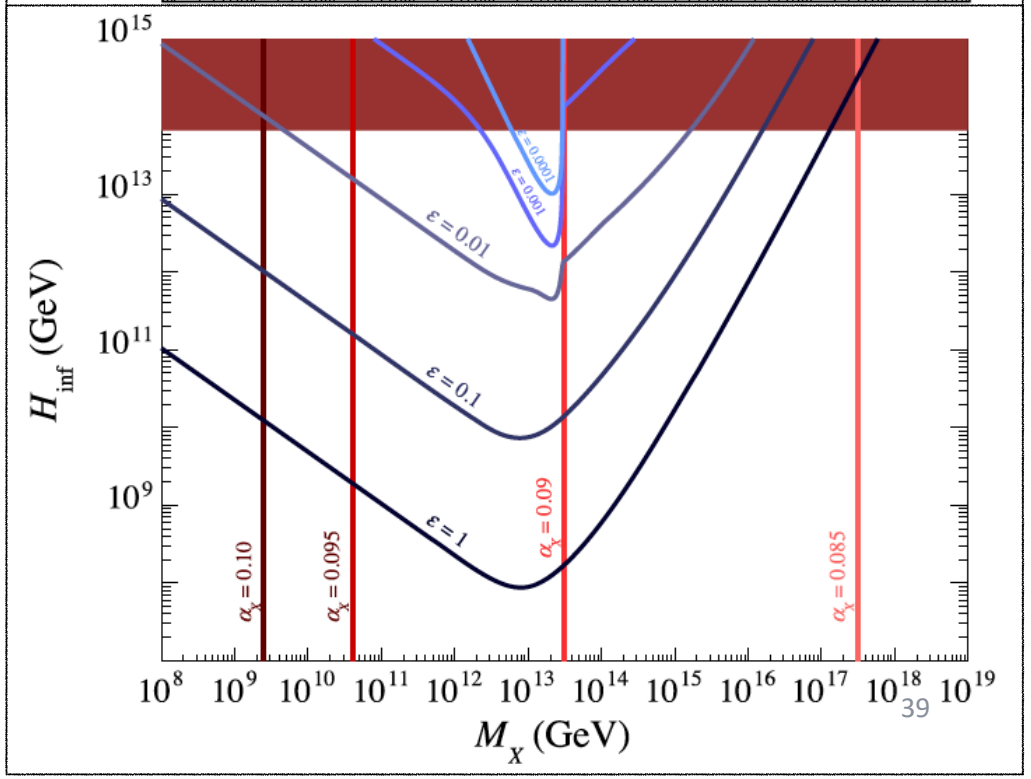

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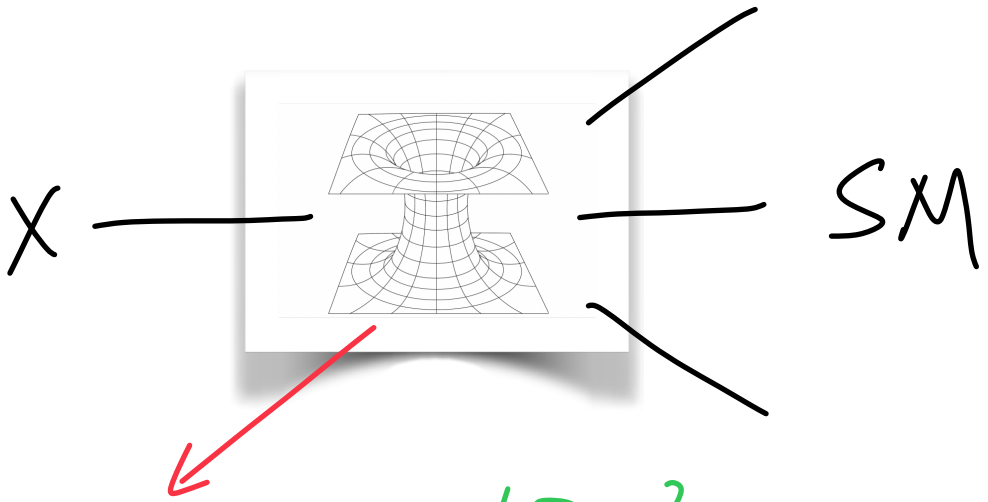
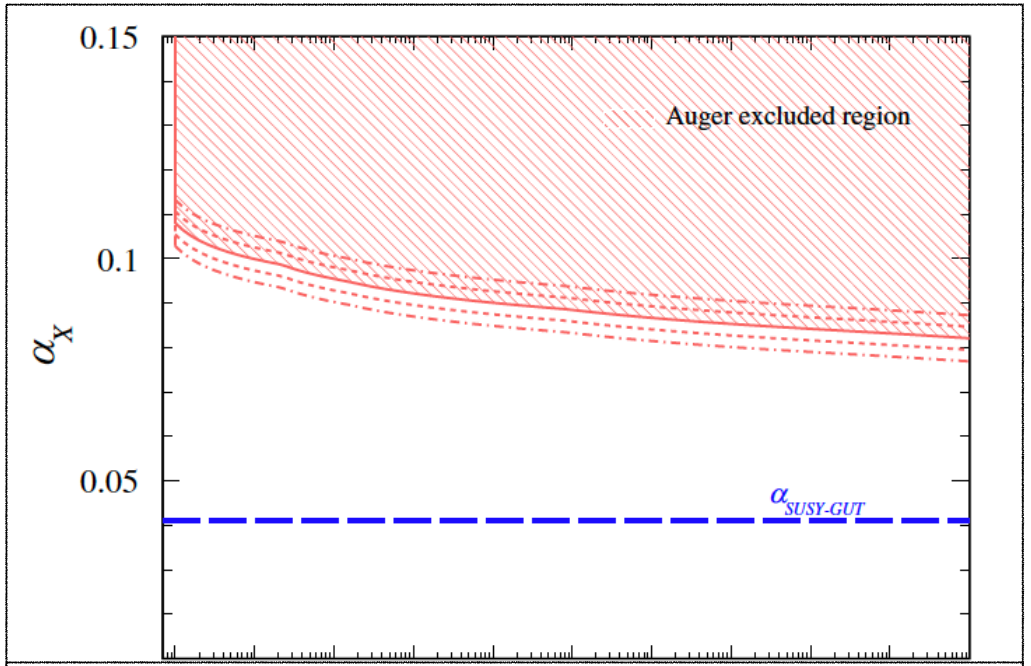
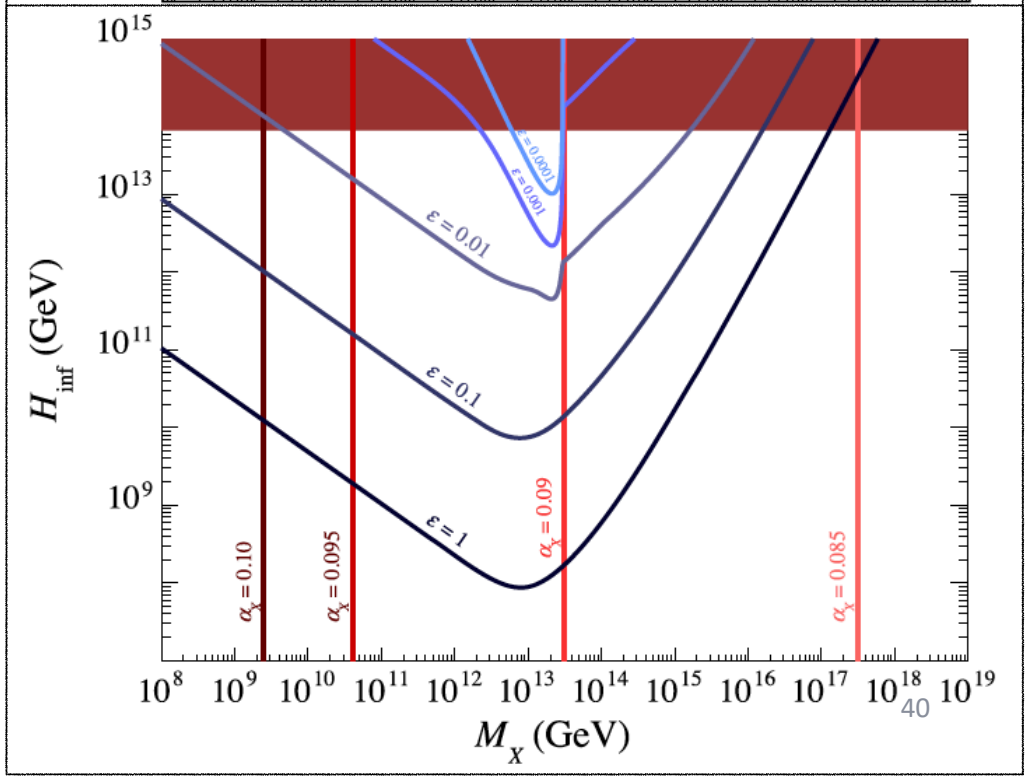


$$e^{-S}, \quad S \sim \left(\frac{R}{L_P}\right)^2 > 80$$

$$\tau_X \sim \frac{e^{2S}}{M_X} \sim \frac{e^{\frac{4\pi}{\alpha}}}{M_X} > 10^{22}\,y$$





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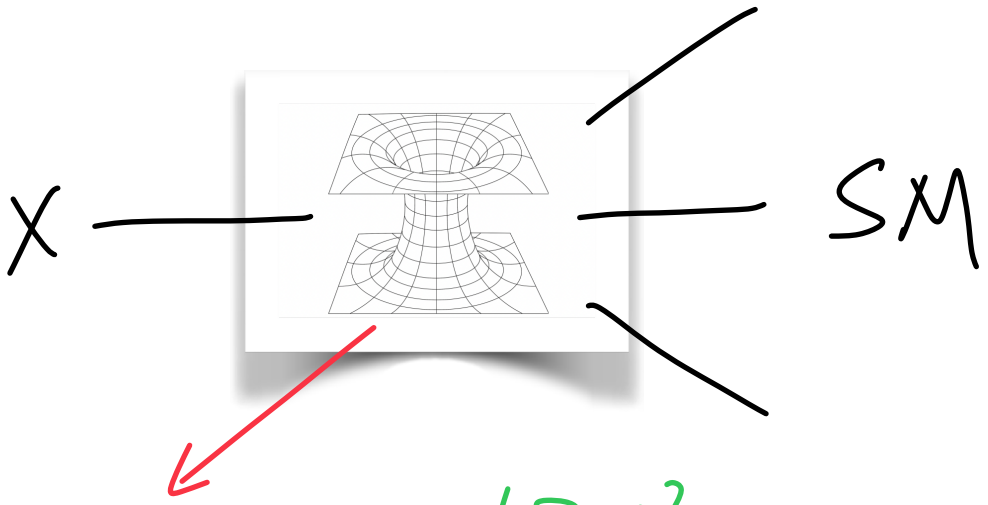

$$e^{-S}, \quad S \sim \left(\frac{R}{L_P}\right)^2 > 80 \approx \frac{8\pi^2}{g_s^2}$$

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