BEYOND THE STANDARD MODEL

LEC3A: PIONS!

LEC3B: AXIONS!

LEC3C: WIMPS!

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UC Riverside Particle Theory

31 JULY 2019

PHYSICS & ASTRONOMY

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References

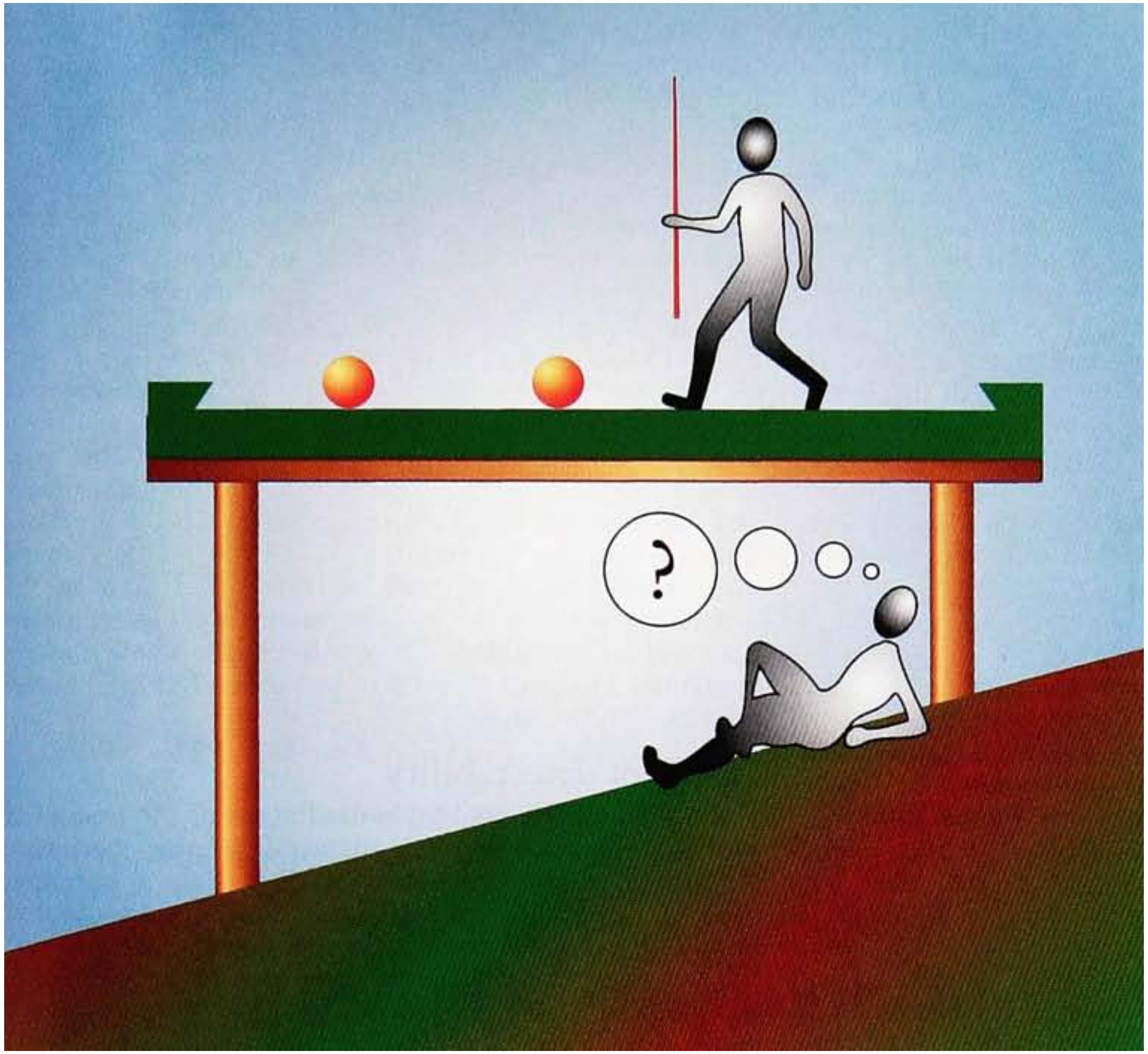
Just a Taste: Lectures on Flavor Physics
Grossman & F.T. arXiv: 1711.03624

Javier Redondo's lectures on axions
e.g. ("3 hours with axions")

Cahn, "The eighteen arbitrary parameters of the standard model in your everyday life"
RMP **68** 951 (1996)

Axion Analogy

The Pool-Table Analogy with Axion Physics (Sikivie)



Physics Today 49, 12, 22 (1996); doi: 10.1063/1.881573

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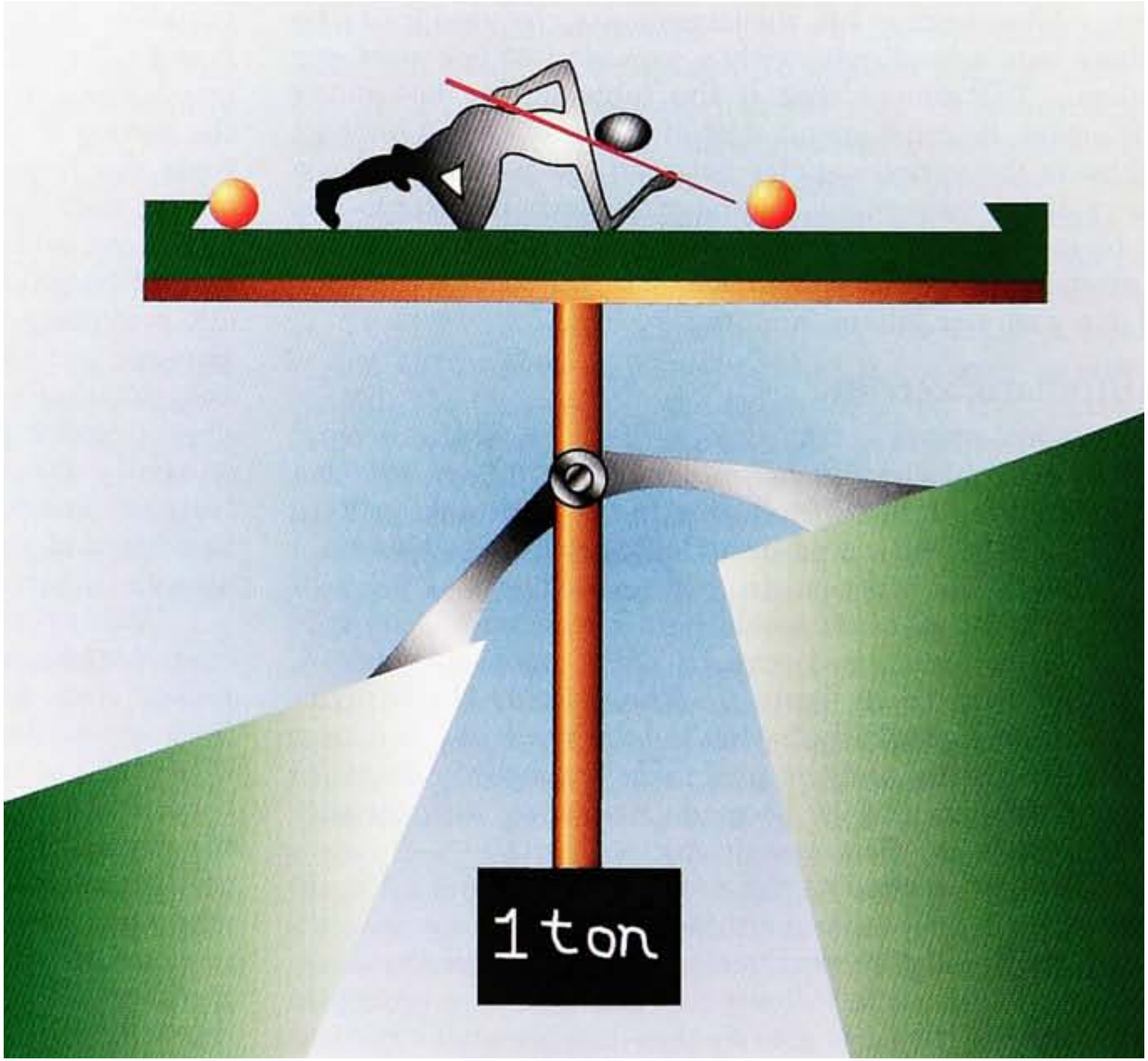

$$1/f_a$$

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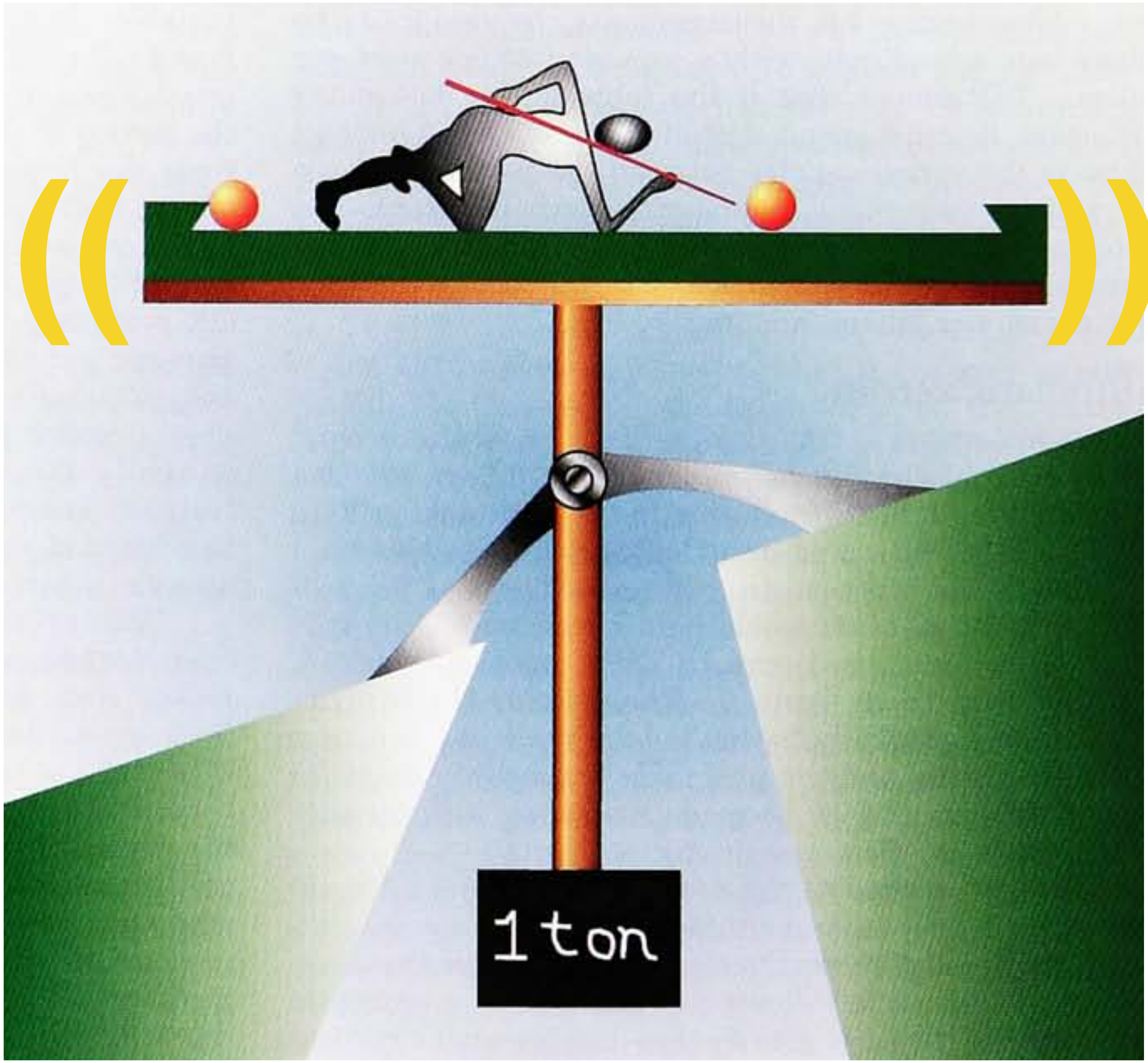

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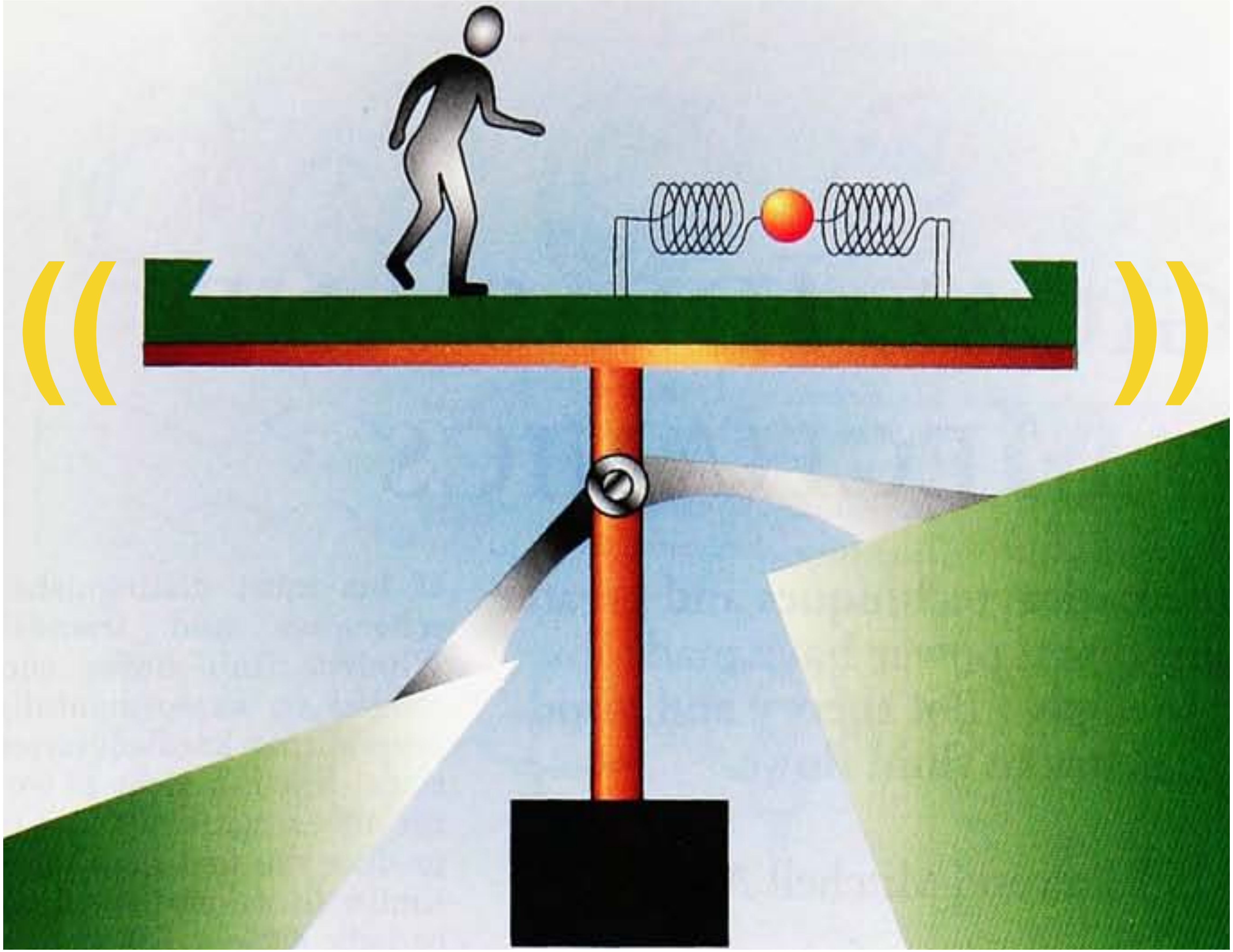

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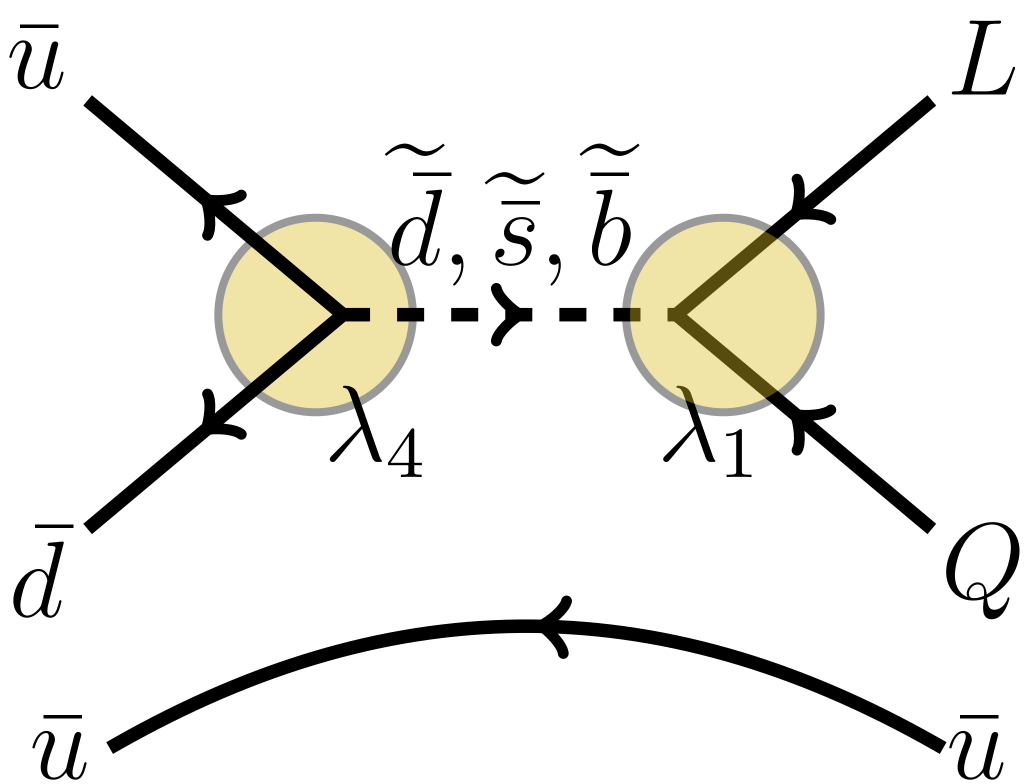
WIMPs

Preventing Proton Decay: R-parity



$$P_R = (-)^{3(B-L)+2s}$$

P_R[ordinary matter] = +

P_R[superpartner] = –

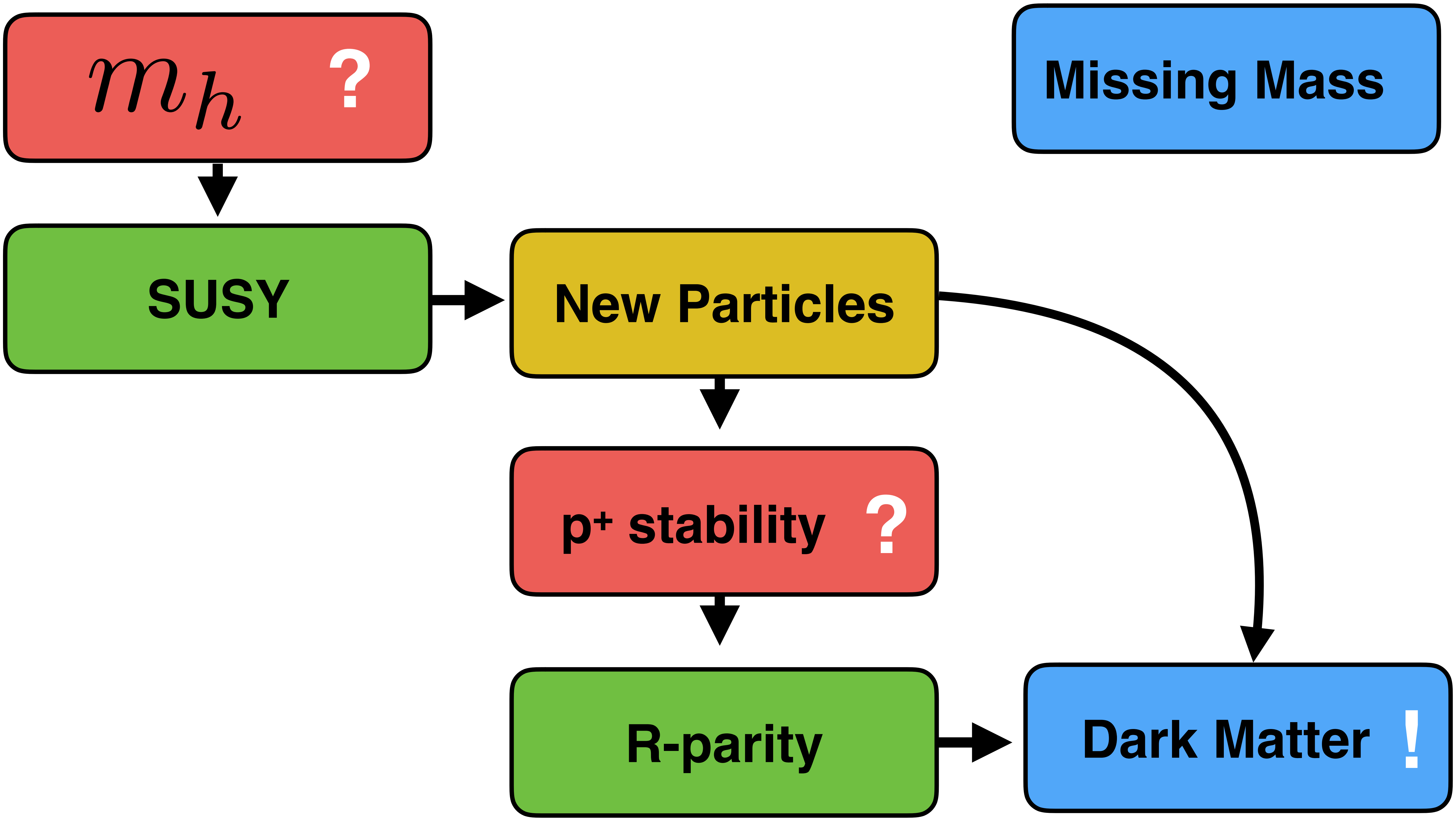
Added bonus:
lightest superpartner is stable.

Known Unknowns

m_h ?

Missing Mass

The story so far: SUSY



Weakly-Interacting Massive Particle

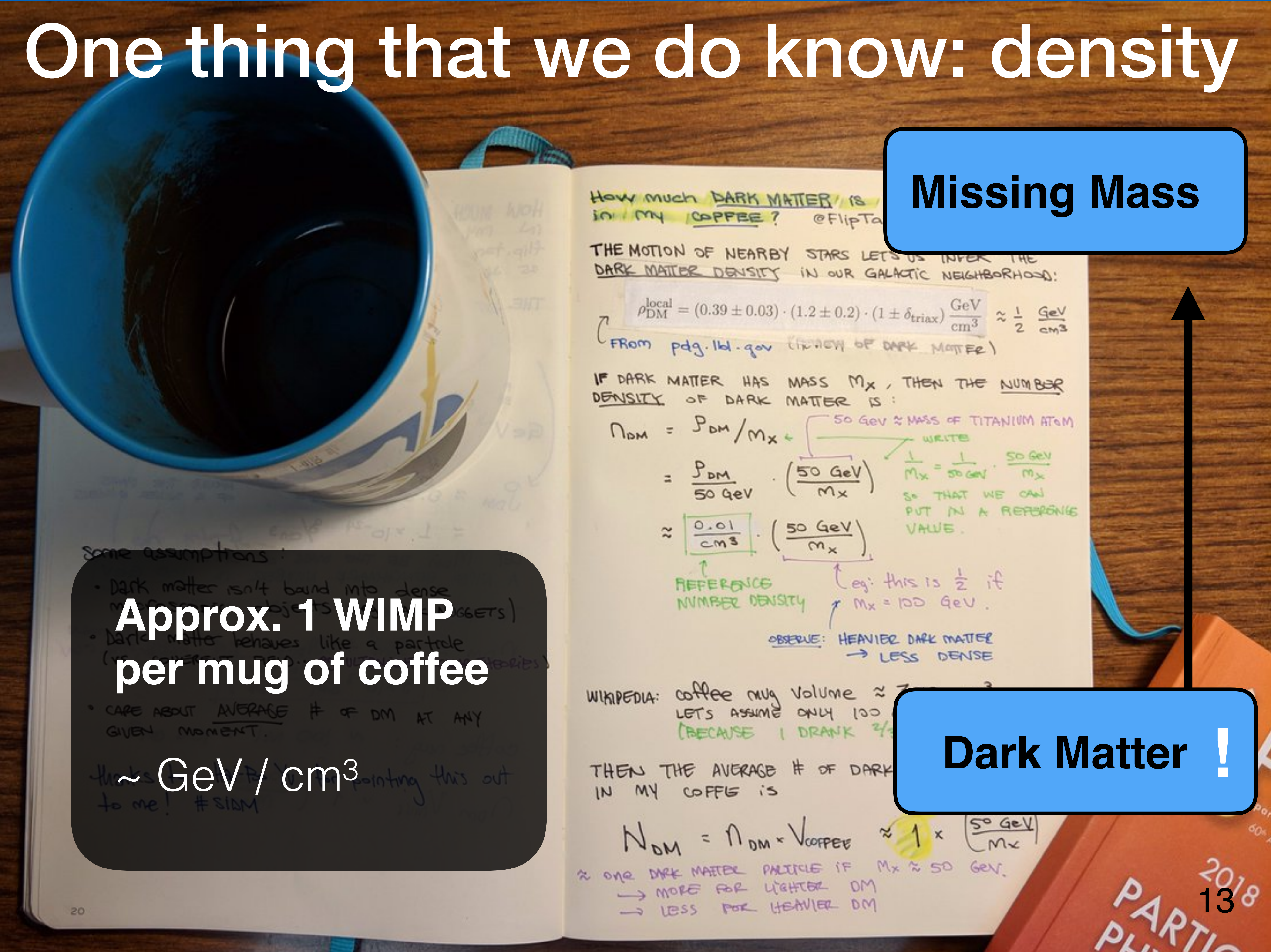
m_h ?

Missing Mass

Weak scale mass ~100 GeV
Weak scale interaction strength G_F
No additional parameters (roughly)

Dark Matter !

One thing that we do know: density



Missing Mass

Dark Matter !

Approx. 1 WIMP per mug of coffee

~ GeV / cm^3

Weakly-Interacting Massive Particle

m_h ?

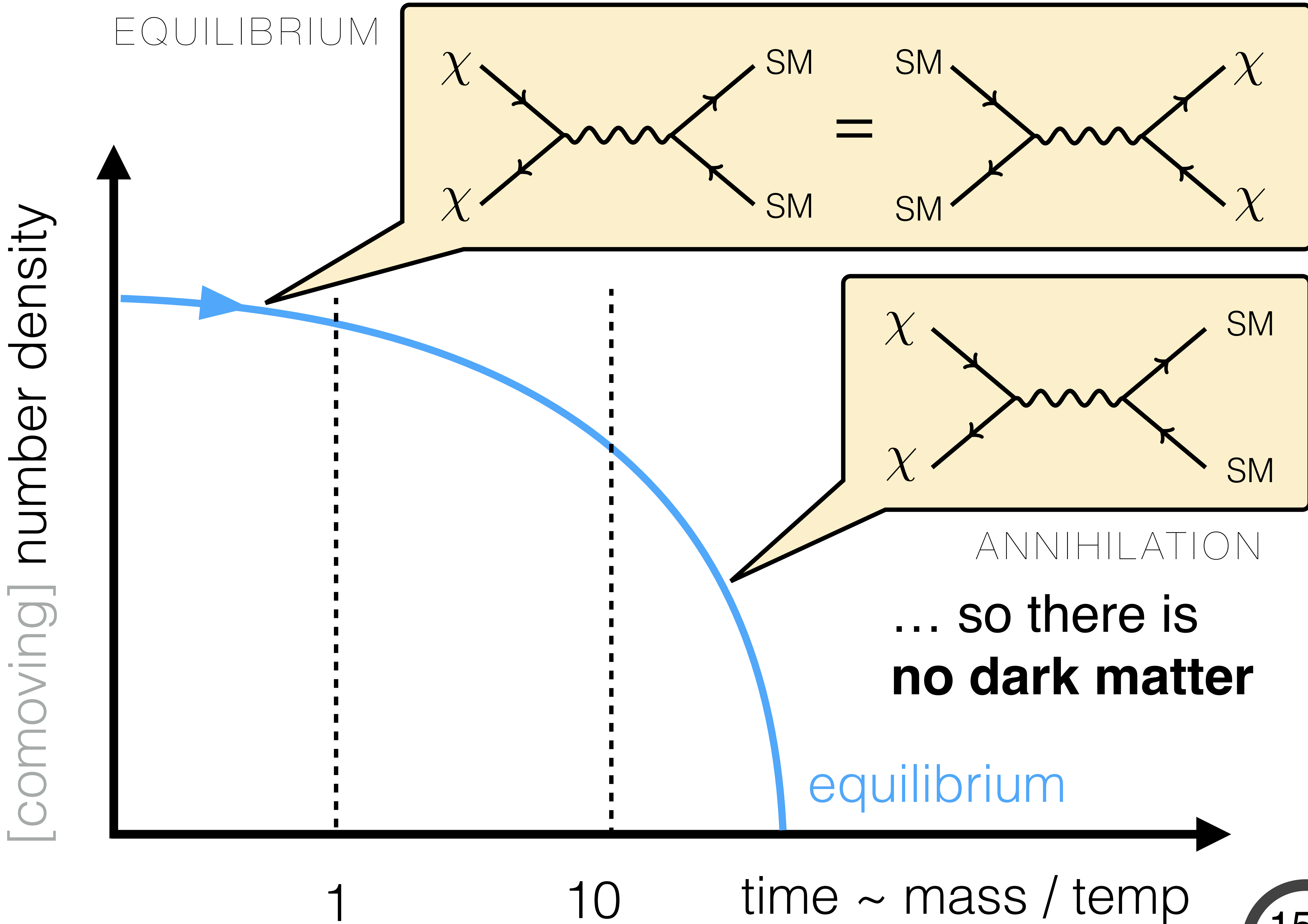
Missing Mass

Weak scale mass ~100 GeV
Weak scale interaction strength G_F
No additional parameters (roughly)

How much dark matter do we predict?

Dark Matter !

How much dark matter is there?

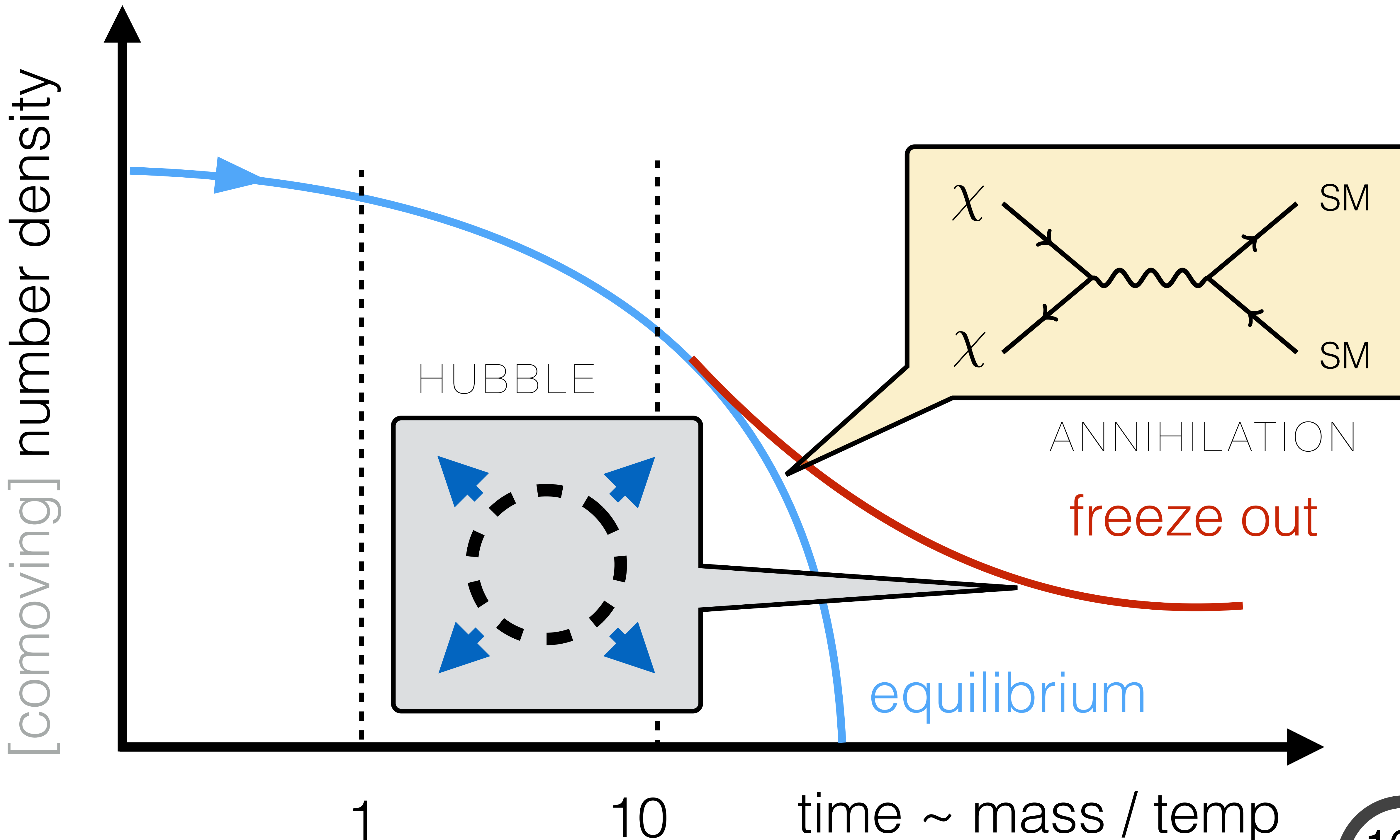


… so there is
no dark matter

How much dark matter is there?

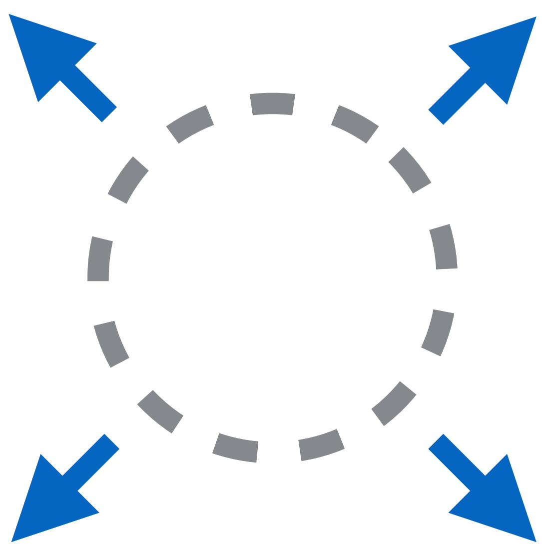
WIMP prediction: relic abundance of dark matter

[neutralino & cousins]



The "WIMP Miracle"

automatically get the correct abundance (almost)

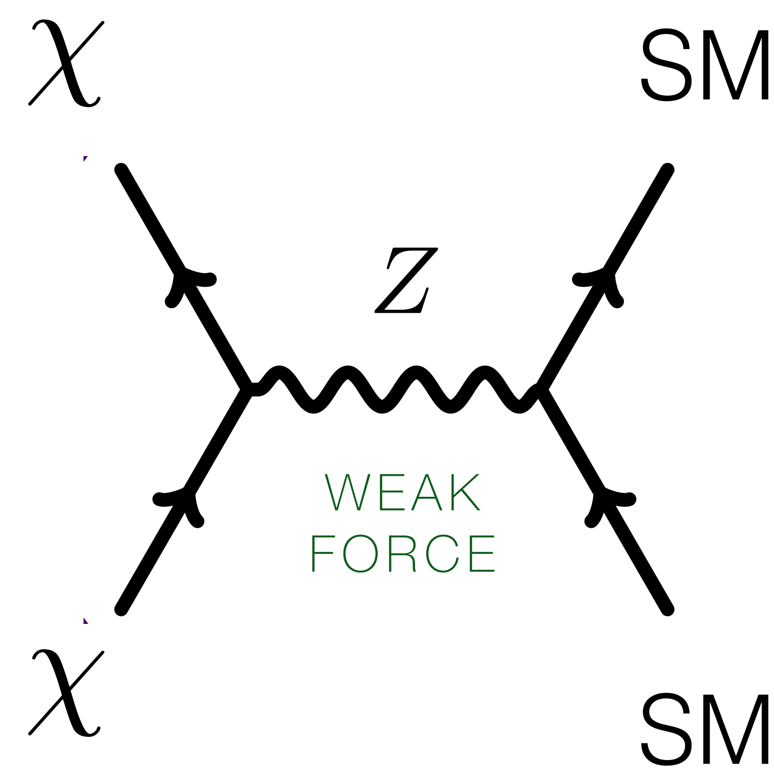


PRESENT ABUNDANCE

$$\boxed{\Omega_\chi h^2 \sim \frac{0.1\ \text{pb}}{\langle \sigma_{\text{ann}} v \rangle}}$$

"WEAK SCALE" **ANNIHILATION** RATE

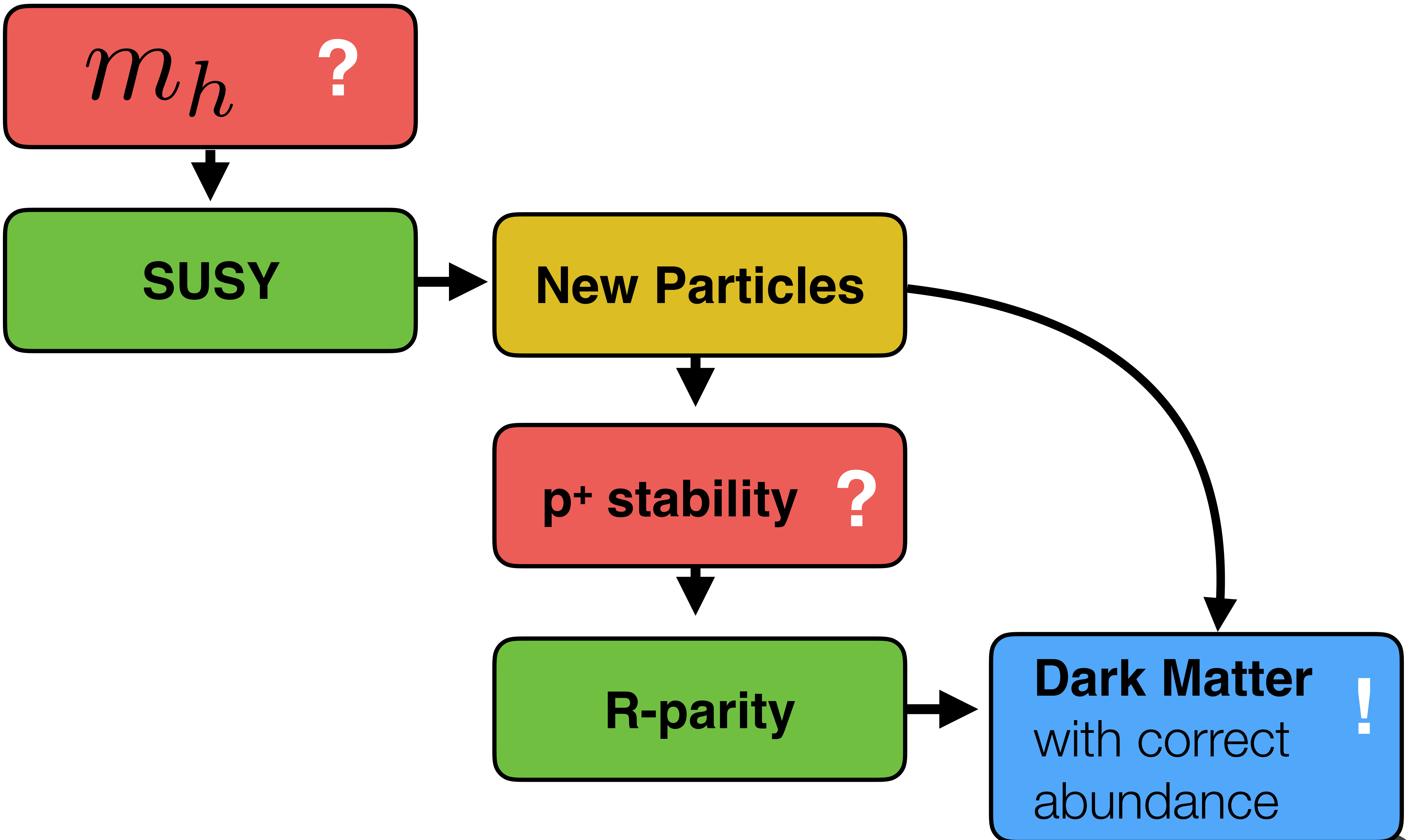
"WEAK SCALE" MASS



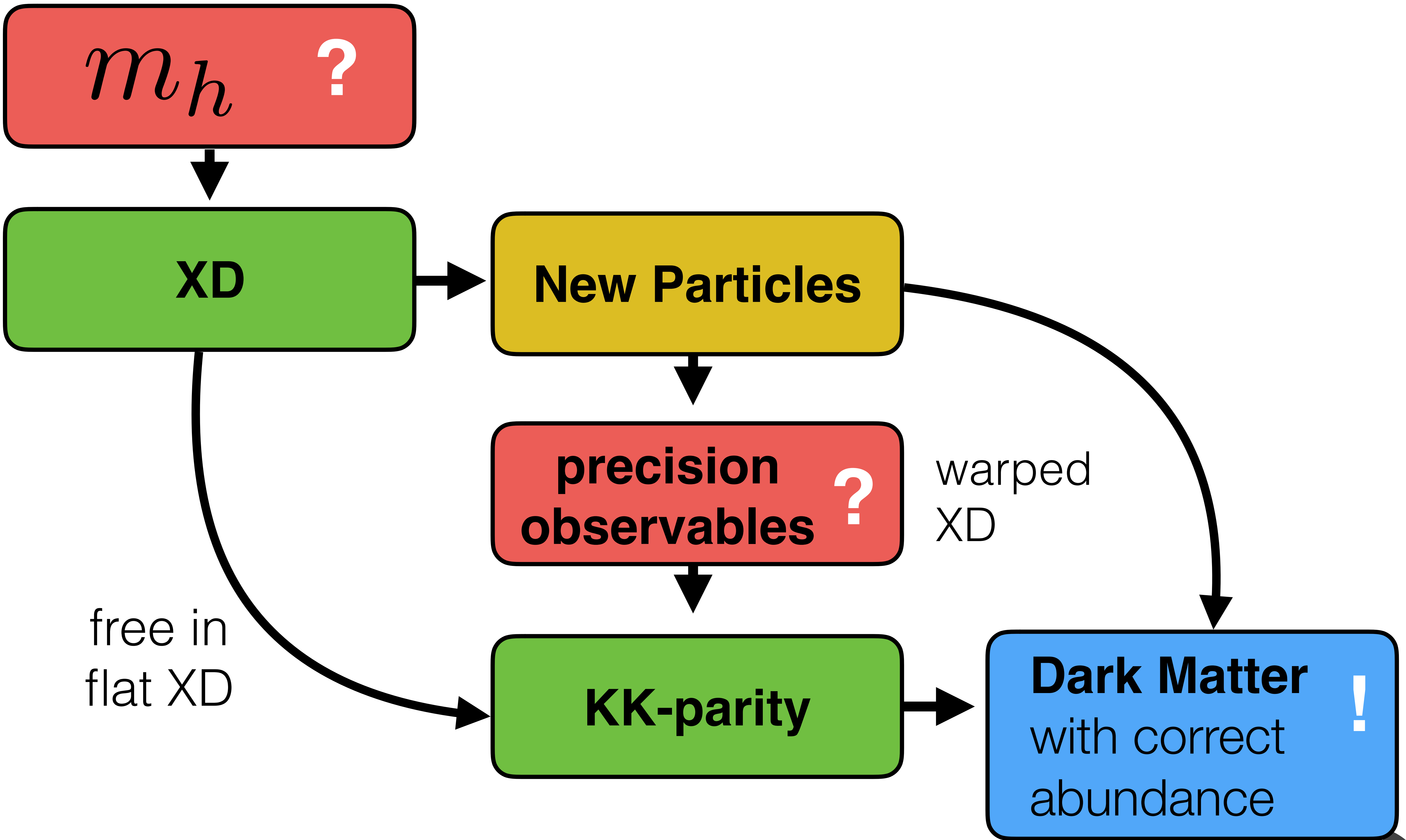
expansion of universe

annihilation

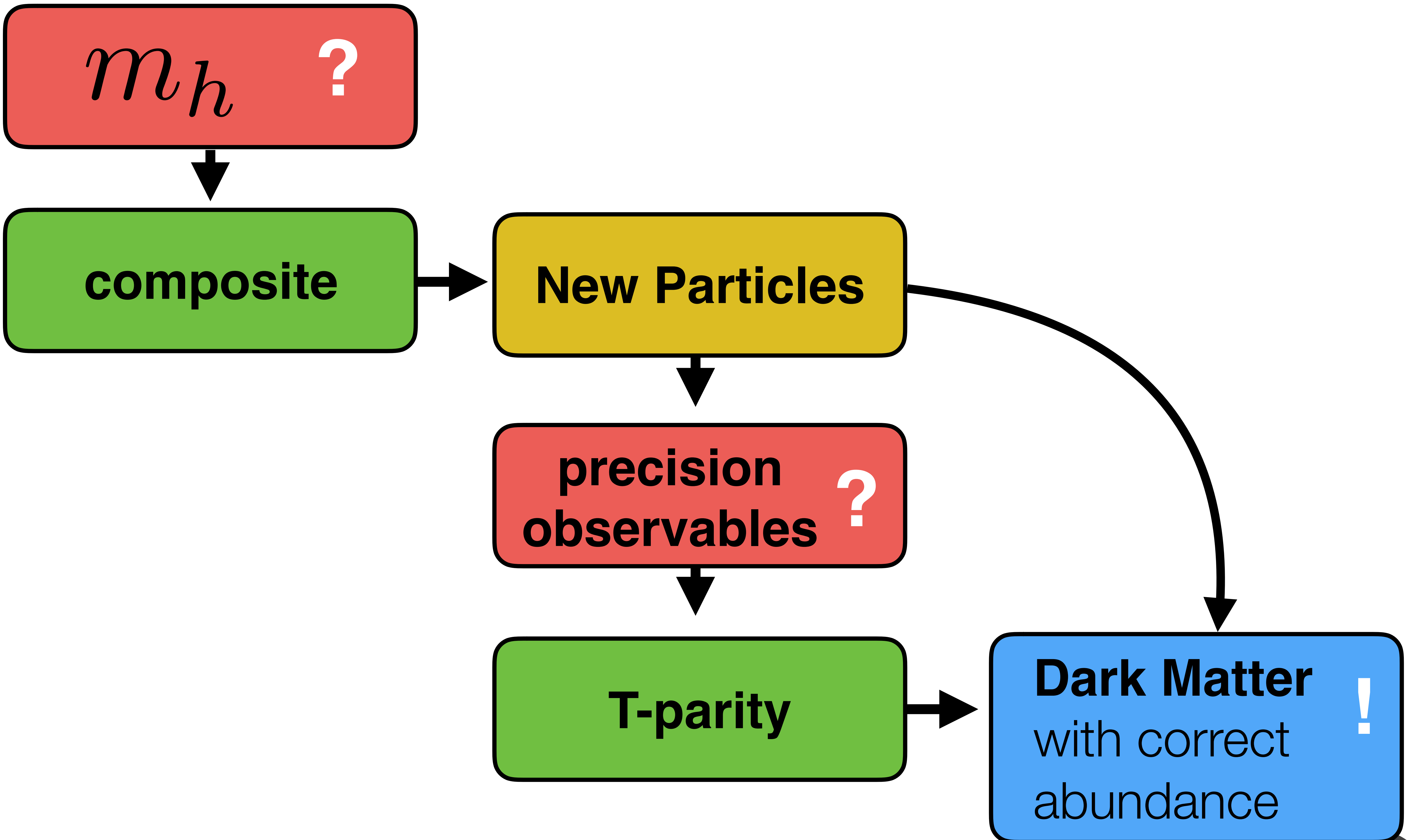
The story so far: SUSY



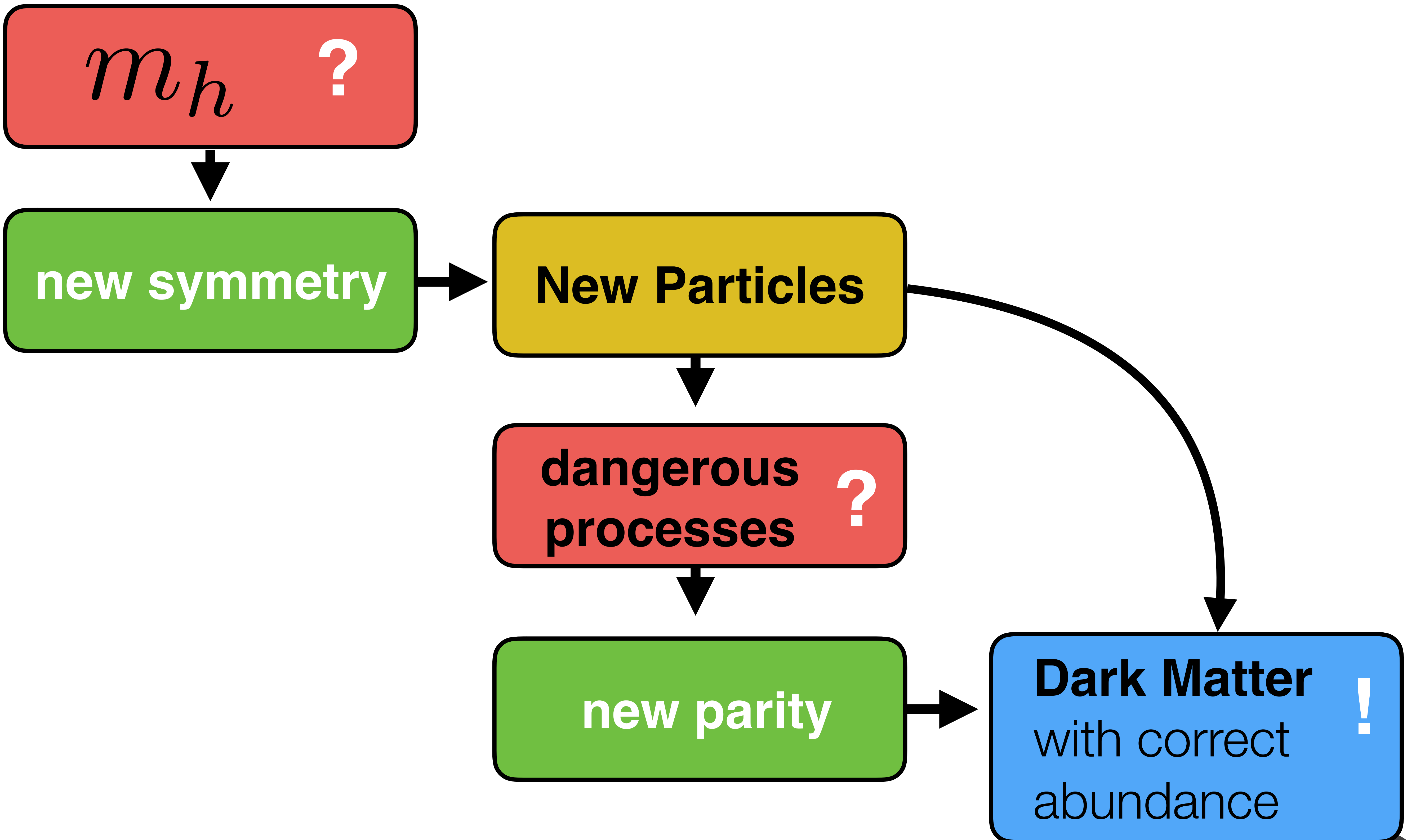
extra dimensions



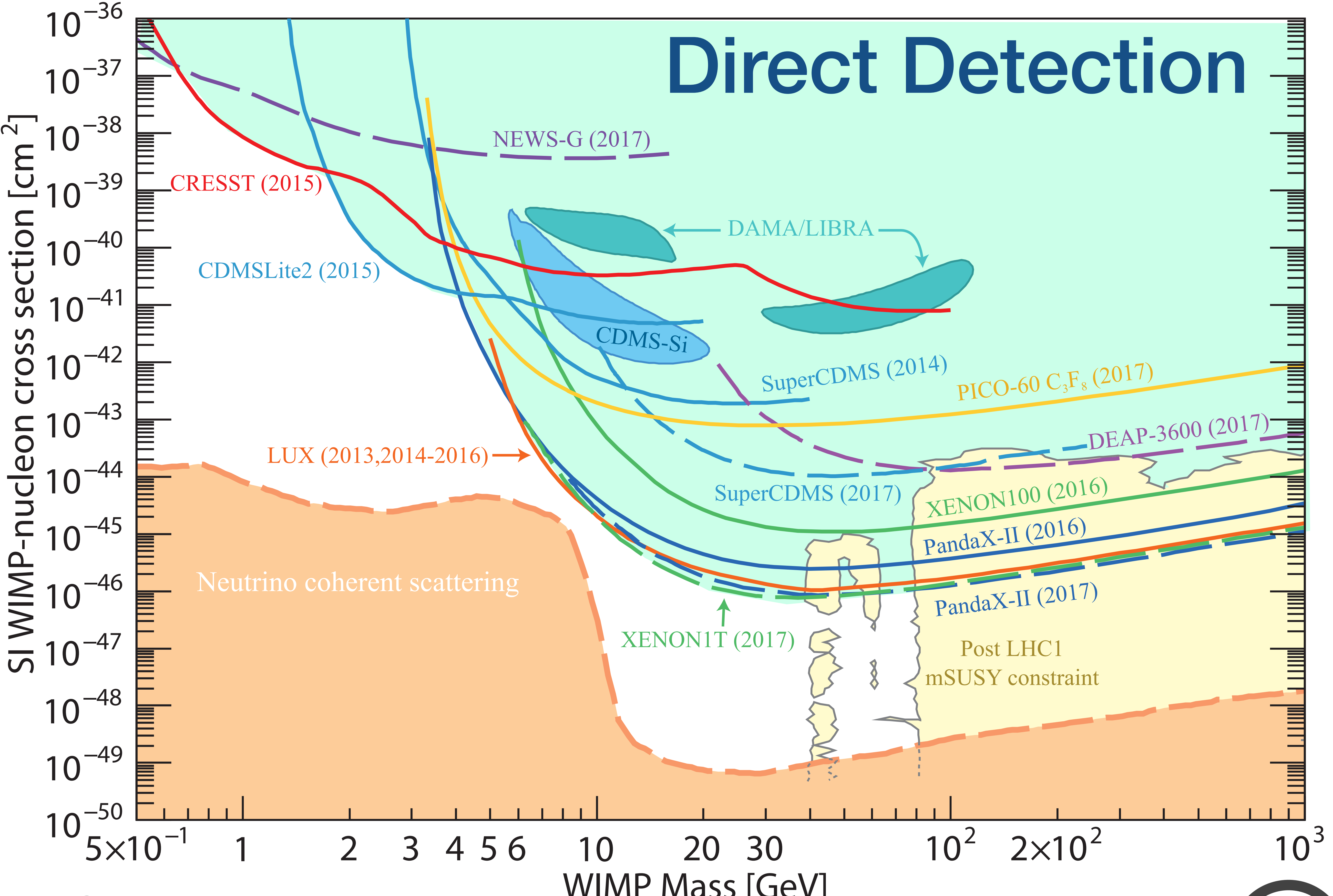
compositeness



WIMP story


m_h ?
new symmetry
New Particles
dangerous processes ?
new parity
Dark Matter with correct abundance !

Direct Detection



PDG Dark Matter Review 2018