SCALAR FIELD COMPLEXITY

Exploring complications in models containing multiple scalar fields

MULTIPLE VEVS — SYMMETRY BREAKING — CROSS SECTIONS

Future OBJECTIVE

Two-Step EWSB's impact on Dark Matter

Standard vs. Improved

Quantifying the difference in **Dark Matter Relic Density** between approaches:

Standard Approach — Freeze-out: Broken Phase

Improved Approach — Freeze-out: Symmetric + Broken Phase

Evidence for Dark Matter

Spiral Galaxies and Rotation Curves

Bullet Cluster Observations

Cosmic Microwave Background (CMB)

A Study on the Role of EWSB in Dark Matter Relic Density Calculations

TÉCNICO LISBOA

Electroweak Phase Transitions Impact on Dark Matter

Author: Catarina Cristina [ist1112098]

Supervisors: Prof. Rui Santos
Prof. João P. Silva

Project MEFT

January 26th, 2024

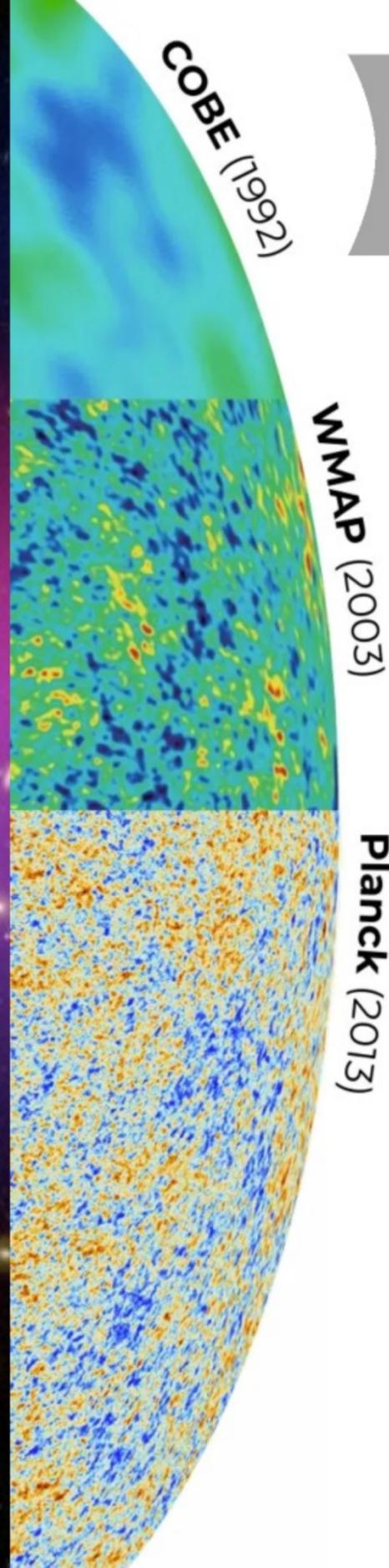# Electroweak Phase Transitions Impact on Dark Matter

Author: Catarina Cristina [ist1112098]

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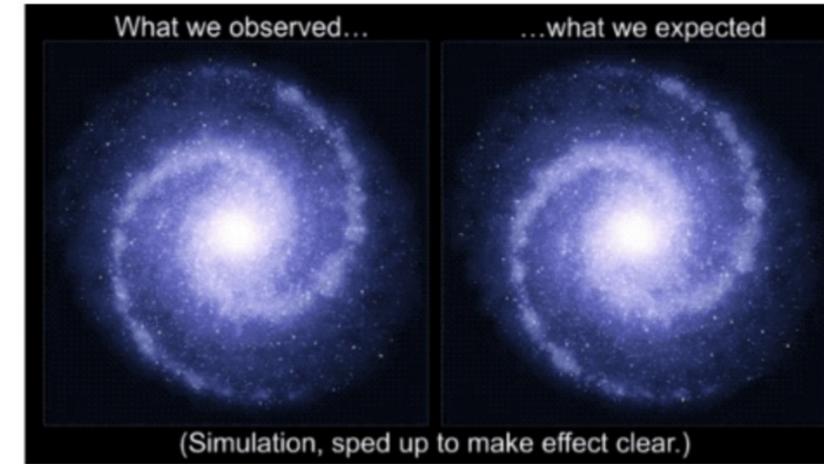   Prof. João P. Silva

Project MEFT

January 29th, 2026

TÉCNICO LISBOA

COBE (1992)

WMAP (2003)

Planck (2013)

Spiral Galaxies and Rotation Curves

Fig.1: Simulation of the rotation velocity that we observe compared to the one we expect based on luminous matter alone. Credit: NASA

What we observed...   ...what we expected

(Simulation, sped up to make effect clear.)

Bullet Cluster Observations

Fig.2: X-ray emission overlaid with weak gravitational-lensing contours (green). The white bar indicates a physical scale of 200 kpc. Credit: Cirelli et al., arXiv:2406.01705
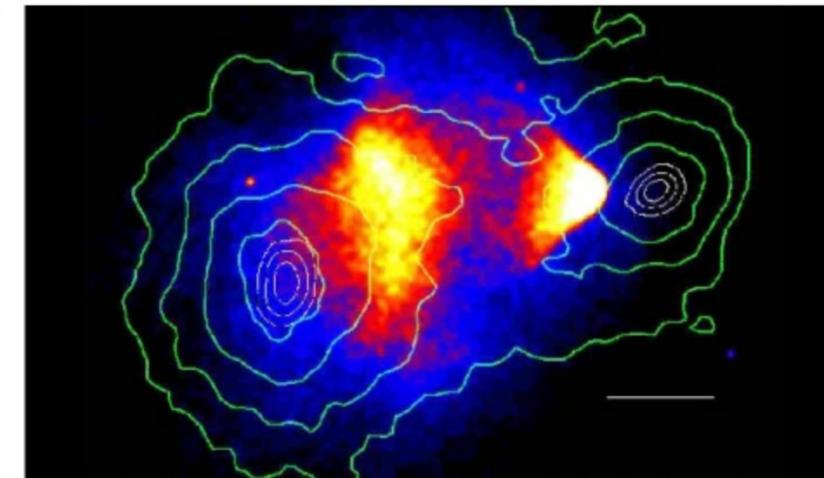
Cosmic Microwave Background (CMB)

Fig.3: Measurement of the cold dark matter density from the Lambda-CDM model and CMB angular power spectrum showing acoustic peaks. Credit: Planck 2018 results

$$\Omega_c h^2 = (0.1200 \pm 0.0012)$$

Ordinary Matter 16.00%

Matter Content

Dark Matter 84.00%

Fig.4: A schematic illustration of particle freeze-out. Source: Daniel D. Baumann, Lecture notes on Cosmology
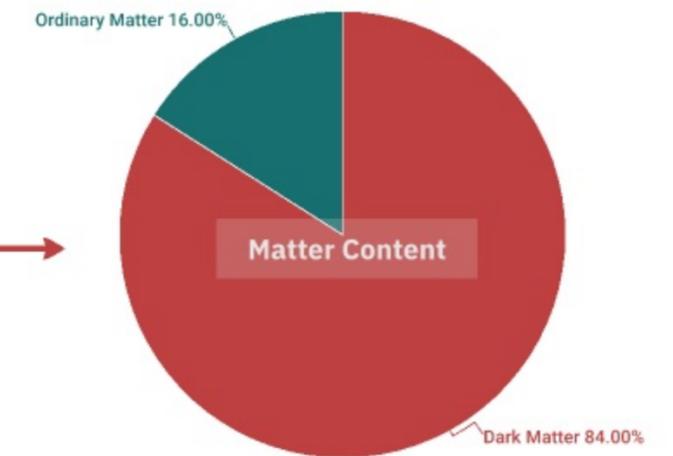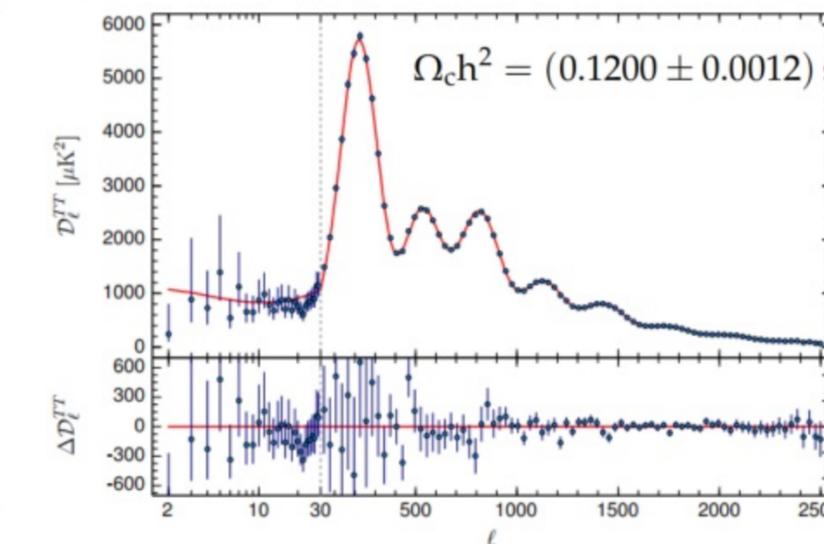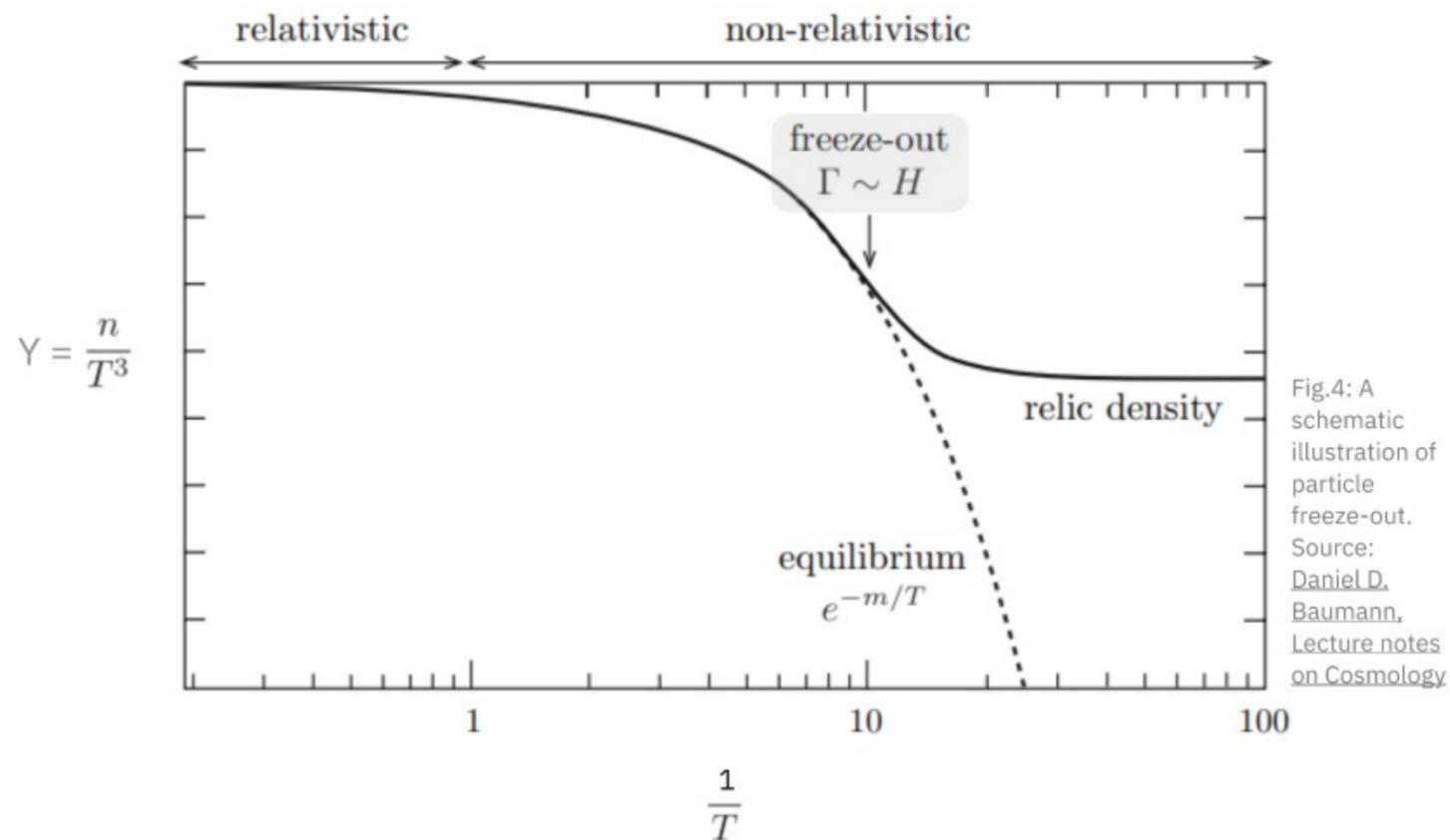
Boltzmann Equation (Y=n/s) for DM abundance calculation:

$$\frac{dY_{DM}}{dy} = Z(y)(\bar{Y}(y)^2 - Y_{DM}^2), \quad \text{with} \quad y \equiv \frac{1}{T}$$

(1)

Standard Approach
Freeze-out: Broken Phase

• Final states with massive particles may be inaccessible or suppressed in the symmetric phase.

• Yukawa couplings vanish before EWSB, excluding certain channels.

• Number of relativistic degrees of freedom changes across EWSB, affecting entropy density and Hubble expansion rate.

Improved Approach
Freeze-out: Symmetric + Broken Phase

$$\langle \sigma v \rangle (T) = \begin{cases} \langle \sigma v \rangle_{\text{sym}}, & T > T_{\text{EWSB}}, \\ \langle \sigma v \rangle_{\text{br}}, & T < T_{\text{EWSB}}. \end{cases}$$

(2)

3

Quantifying the difference in **Dark Matter Relic Density** between approaches:

$$\delta\Omega h^2 \equiv \frac{\Omega_c^{(I)}h^2 - \Omega_c^{(S)}h^2}{\Omega_c^{(S)}h^2} \qquad (3)$$

I : Improved   S : Standard
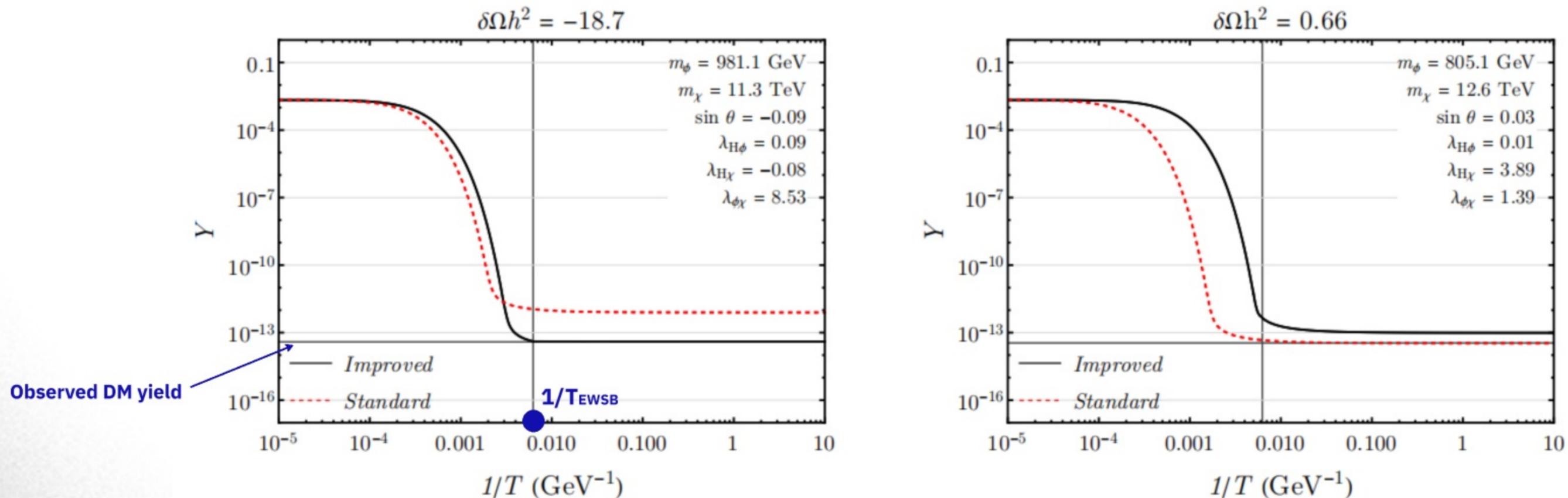
Taking two extreme benchmarks:

Fig.5: Left: A point allowed in the improved approach but discarded by the standard formalism. Right: A point allowed in the standard approach, but the improved approach forbids it. Credit: https://arxiv.org/abs/2505.07946.

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SCALAR FIELD COMPLEXITY

Exploring complications in models contaning multiple scalar fields...

MULTIPLE VEVS

Fields other than the one responsible for EWSB may also acquire vacuum expectation values during the thermal evolution of the Universe.

SYMMETRY BREAKING

Additional symmetries can be broken at different times, leading to varied outcomes in the model's behavior.

$\langle \sigma v \rangle$ **CROSS SECTIONS**

The number of independent thermally averaged cross sections is contingent on how many fields acquire vevs and the timing of these transitions.

Future **OBJECTIVE:** The study of at least one model exhibiting three distinct stages, with two symmetries being broken at different epochs in the early Universe.
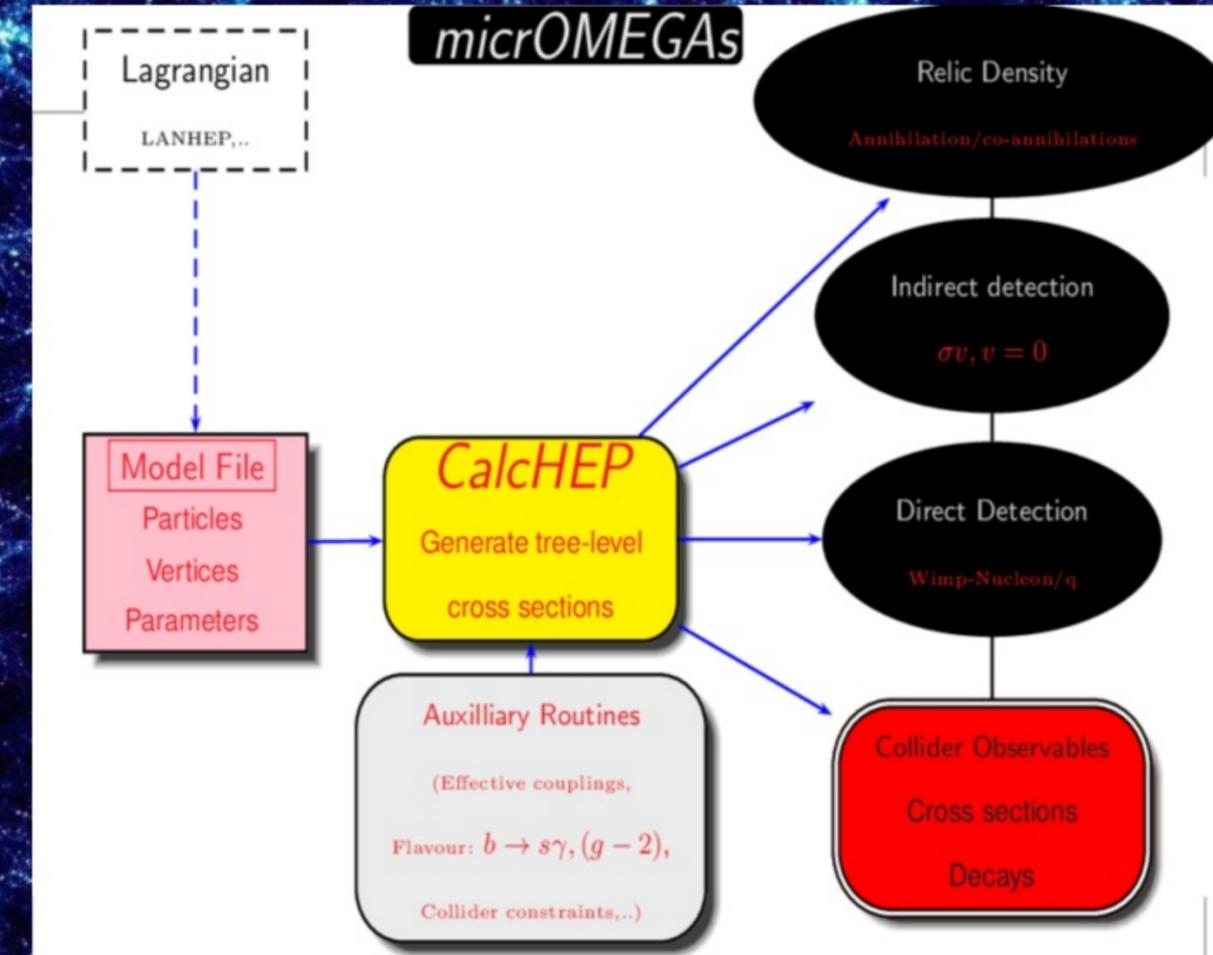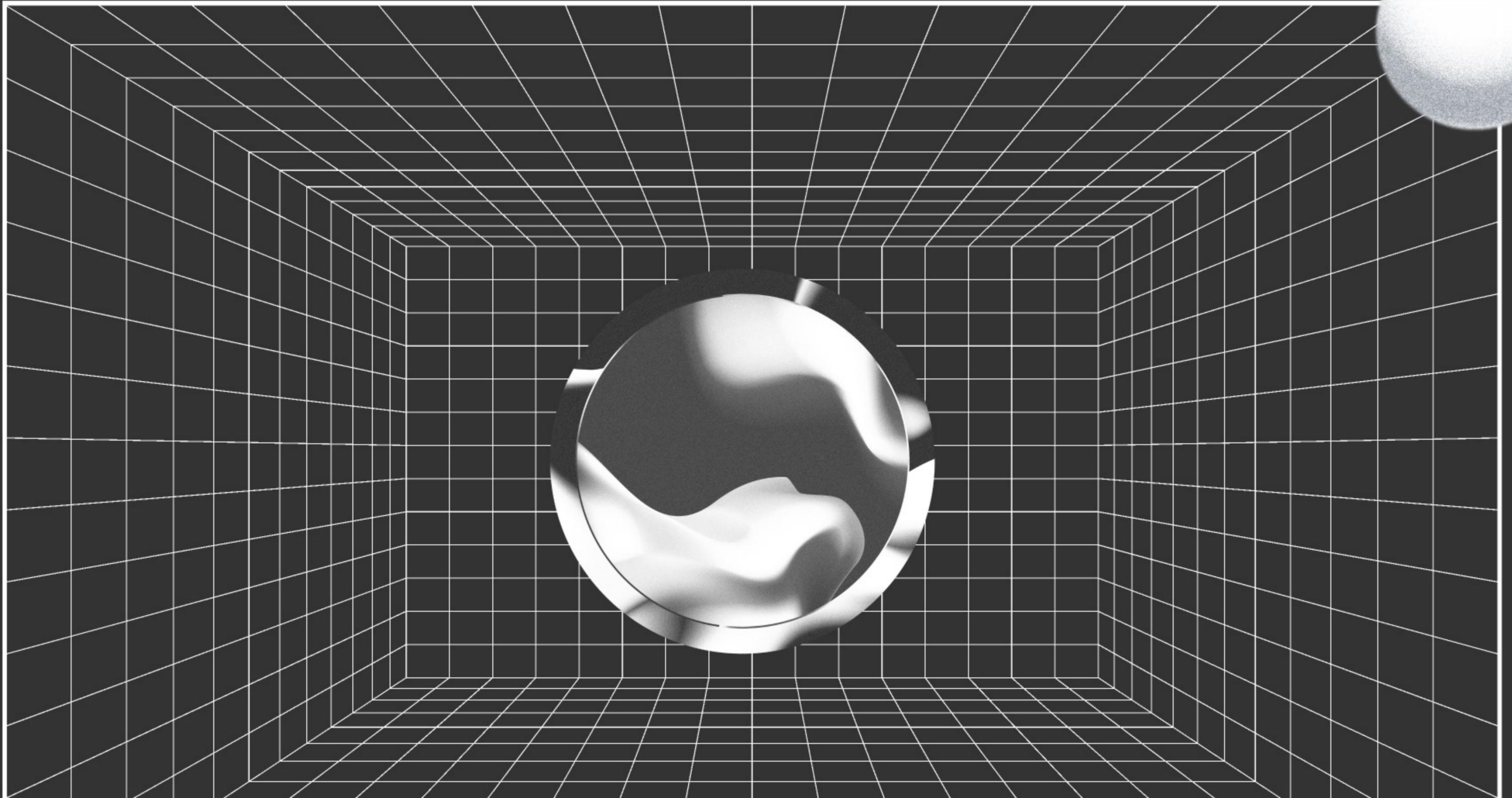
Fig.4: The MicrOMEGAs flow chart. Credit: arXiv:1402.0787v1

Two-Step EWSB's impact on Dark Matter

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Leve com você.
Revisite quando desejar.

Perdeu alguma parte? Deseja explorar mais?
Escaneie ou clique para abrir a apresentação. A
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