

Analysis of WIMP, FIMP and SIMP dark matter production mechanisms in the early universe.

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1) Study possible dark matter production mechanisms in the early universe.

WIMPs

Weakly Interacting Massive Particles

FIMPs

Feebly Interacting Massive Particles

SIMPs

Strongly Interacting Massive Particles

Weakly Interacting Massive Particles

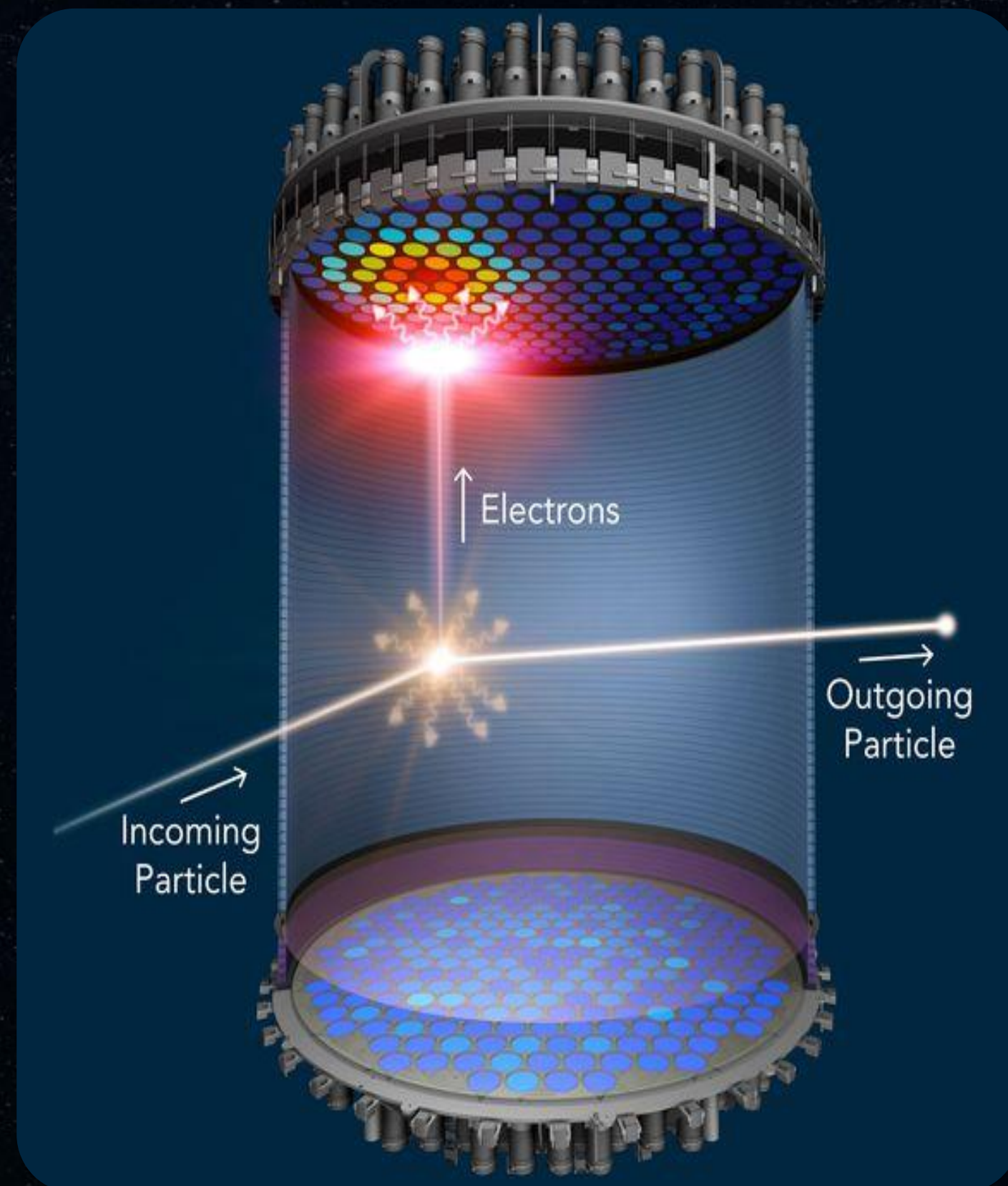


Fig 3: Very basic diagram of the LUX-ZEPLIN detector.
LUX-ZEPLIN (LZ) COLLABORATION / SLAC NATIONAL ACCELERATOR LABORATORY

WIMP's Boltzmann Equation

$$\frac{dn_{\psi}}{dt} + 3Hn_{\psi} = - \langle \sigma_{\psi\bar{\psi} \rightarrow X\bar{X}} |v| \rangle [n_{\psi}^2 - (n_{\psi}^{EQ})^2],$$

Characteristics

- Uses $2 \rightarrow 2$ annihilation mechanism.
- Uses the Freeze-out method.
- No WIMP has ever been detected.
- Neutralino which are the most common candidate for WIMPs are still theoretical.

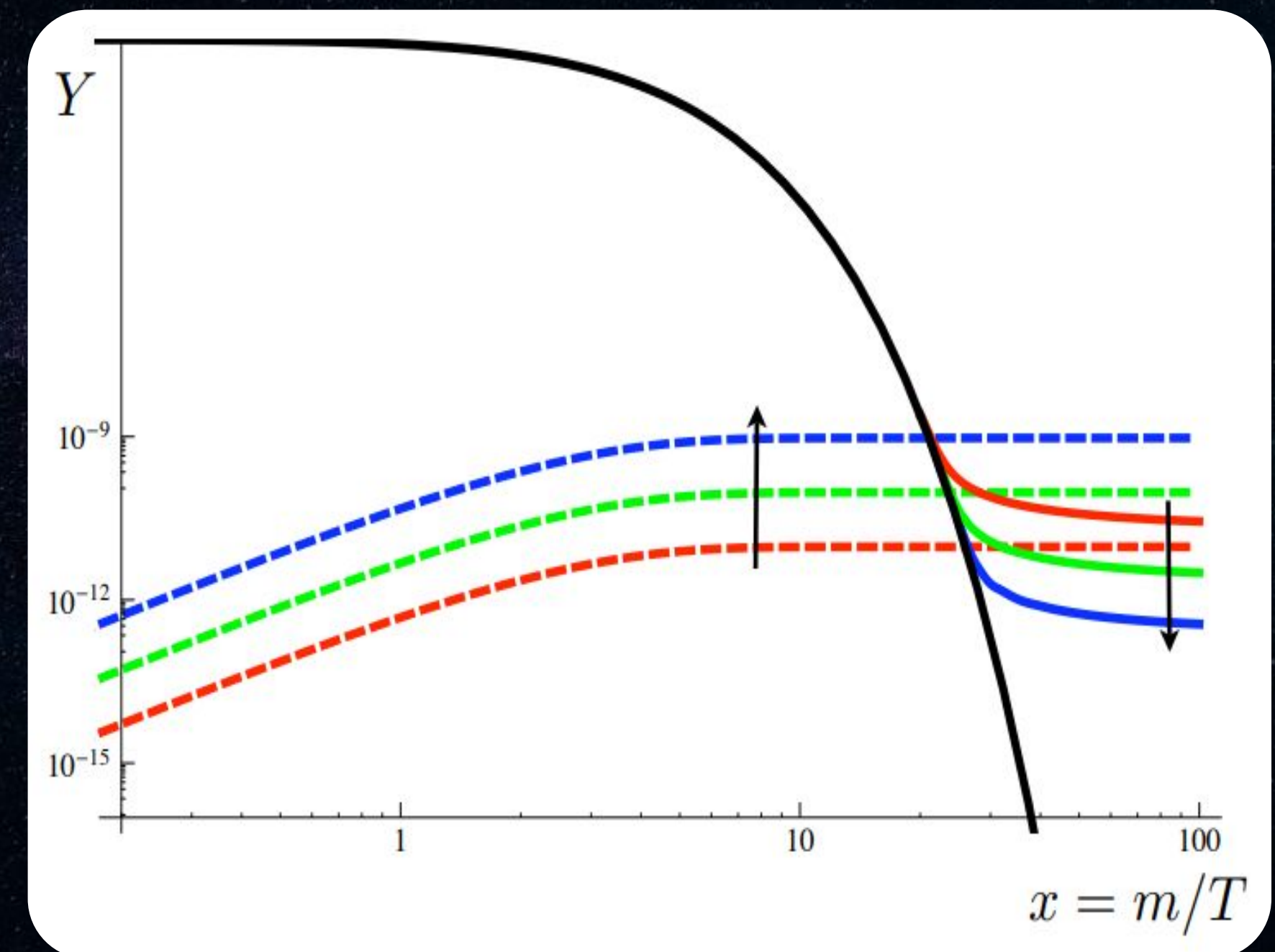
Feebly Interacting Massive Particles

Characteristics

- Also called Freeze in Massive Particles.
- Have weaker baryonic interaction than WIMPs.
- Uses $2 \rightarrow 2$ annihilation mechanism.
- Uses the Freeze-in method.
- Would be harder to have direct detection.

FIMP's Boltzmann Equation

$$\frac{dn_\psi}{dt} + 3Hn_\psi = \langle \sigma_{\psi\bar{\psi} \rightarrow X\bar{X}} |v| \rangle (n_\psi^{EQ})^2.$$

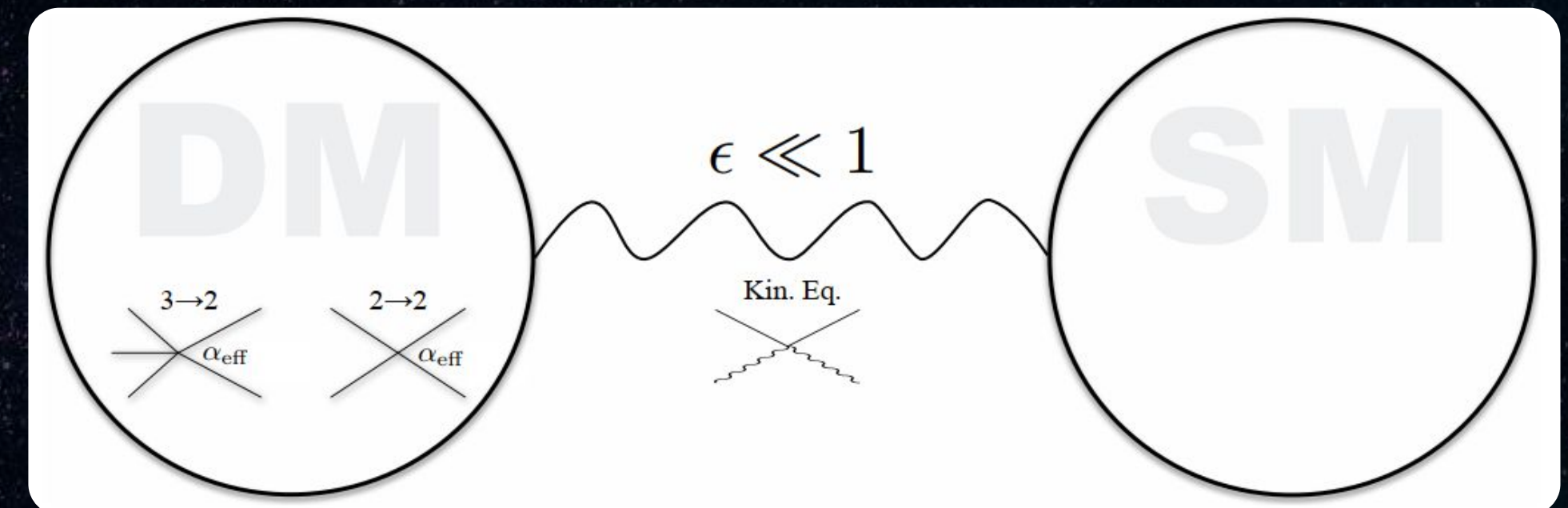


Dark matter production as a function of $X = m/T$, where the solid colored lines are due to the Freeze-out method, the dashed lines are due to the Freeze-in method, the black line is the production if thermal equilibrium is preserved and the arrows indicate the increase in coupling forces.
arXiv:0911.1120

Strongly Interacting Massive Particles

Characteristics

- Interacts strongly with itself.
- interacts weakly with baryonic matter
- Uses $3 \rightarrow 2$ or even $4 \rightarrow 2$ annihilation mechanism.
- Uses the Freeze-out method.
- DM sector and SM sector are in thermal equilibrium.



A schematic description of the SIMP paradigm. The dark sector consists of DM which annihilates via a $3 \rightarrow 2$ process. Small couplings to the visible sector allow for thermalization of the two sectors, thereby allowing heat to flow from the dark sector to the visible one. [arXiv:1402.5143](https://arxiv.org/abs/1402.5143)

SIMP's Boltzmann Equation

$$\frac{dn_\psi}{dt} + 3Hn_\psi = -[n_\psi^3 - n_\psi^2 n_\psi^{EQ}] \langle \sigma v^2 \rangle_{3 \rightarrow 2} - [n_\psi^2 - (n_\psi^{EQ})^2] \langle \sigma v \rangle_{ann}.$$

Thank you!





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