Title: Particle Physics Lecture

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Collection: Particle Physics

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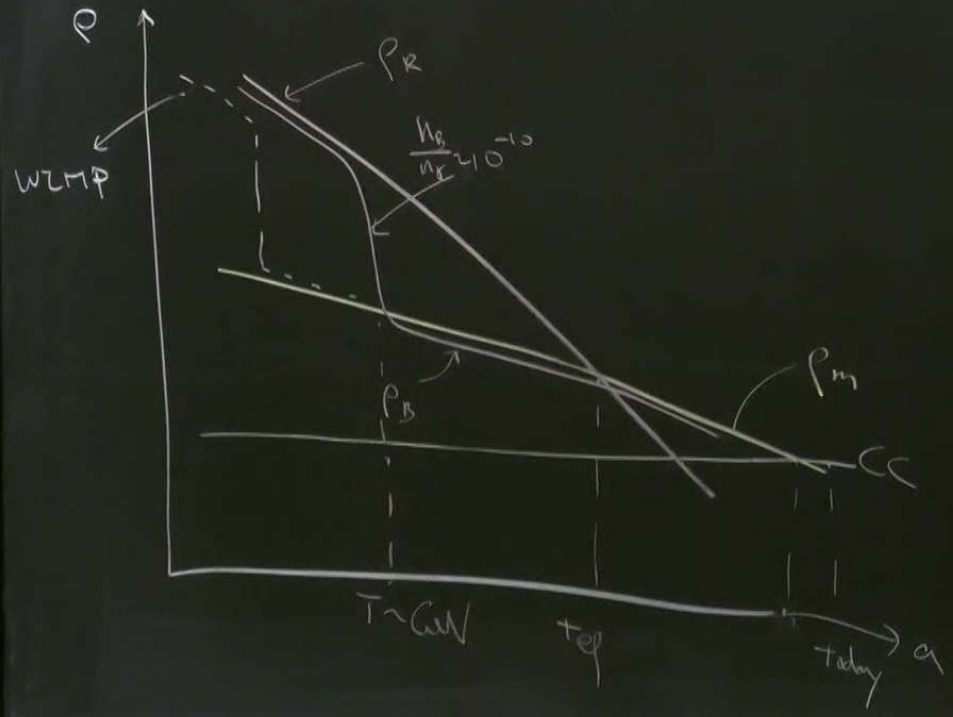
URL: https://pirsa.org/24030022

Lecture 8: WIMP



WIMP: SUSY lecture.

"χ" Higgsino

1. LSP: Lighted Supersymmetric Particle.

$\Gamma = \alpha_2 \cdot M_\chi$?

$n_S / T_{age} \sim 10^{-60}$

R-parity – Conserved Quam Number

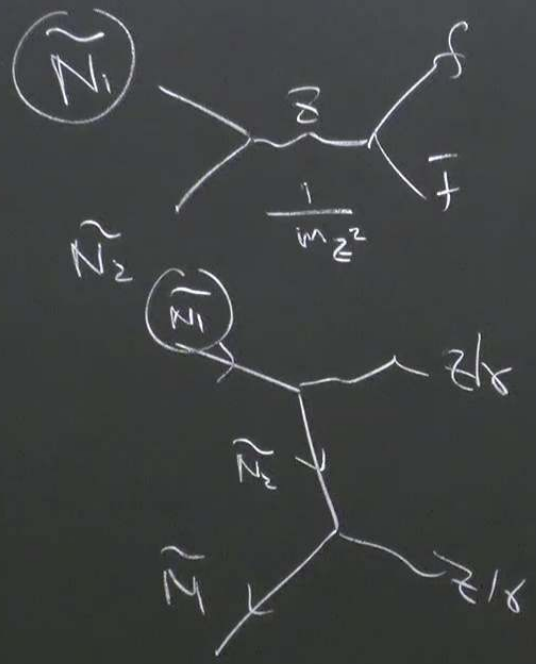
$\Gamma_{Decay} = 0$

ture.

symmetric Particle.

Quam Number

Annihilation:

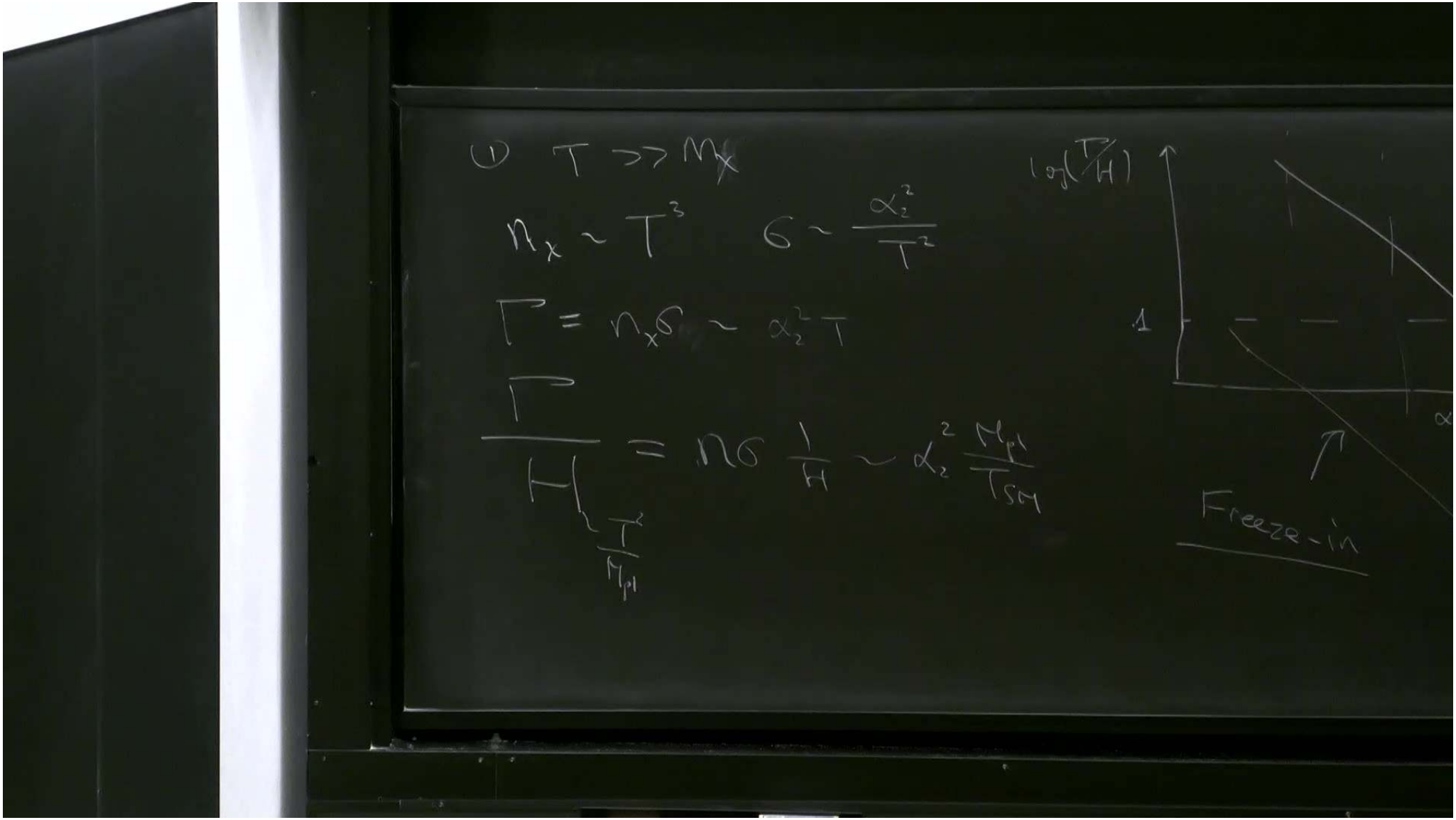


$$\text{If } M_{\tilde{N}_i} > M_Z$$

$$\sigma \sim \frac{\alpha_2^2}{m_\chi^2}$$

$$m_{\tilde{N}} < M_Z$$

$$\sigma \sim \frac{\alpha_2^2}{m_Z^4} m_\chi^2$$


① $T \gg M_X$
$n_X \sim T^3$ $\sigma \sim \frac{\alpha_2^2}{T^2}$
$\Gamma = n_X \sigma \sim \alpha_2^2 T$
$\frac{\Gamma}{H_{T=M_{Pl}}} = n\sigma \frac{1}{H} \sim \alpha_2^2 \frac{M_{Pl}}{T_{SM}}$
$\log(\frac{\Gamma}{H})$
1
Freeze-in

① $T \gg M_X$

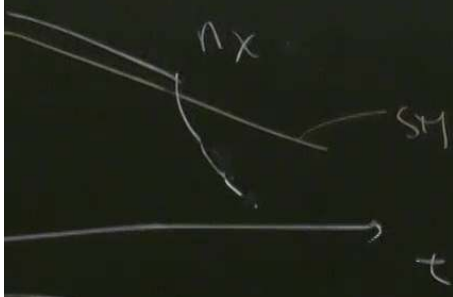
$n_X \sim T^3 \qquad \sigma \sim \frac{\alpha_2^2}{T^2}$

$\Gamma = n_X \sigma \sim \alpha_2^2 T$

$\frac{\Gamma}{H} = n\sigma \frac{1}{H} \sim \alpha_2^2 \frac{M_{Pl}}{T_{SM}}$

$H_{\frac{T^2}{M_{Pl}}}$

$T \sim m_X > m_Z$



$$\frac{\Gamma}{H} = \frac{n_X \cdot \alpha_2^2 M_{Pl}}{m_X^2 T^2} = \frac{n_X \alpha_2^2 M_{Pl}}{m_X^2 T_X^2} \sim 1$$

At this point:

$$n_X\Big|_{\Gamma/H=1} = \frac{m_X^2 \cdot T_X^2}{\alpha_2^2 M_{Pl}}$$

{ What about today?

T_X vs m_X?

What about today?

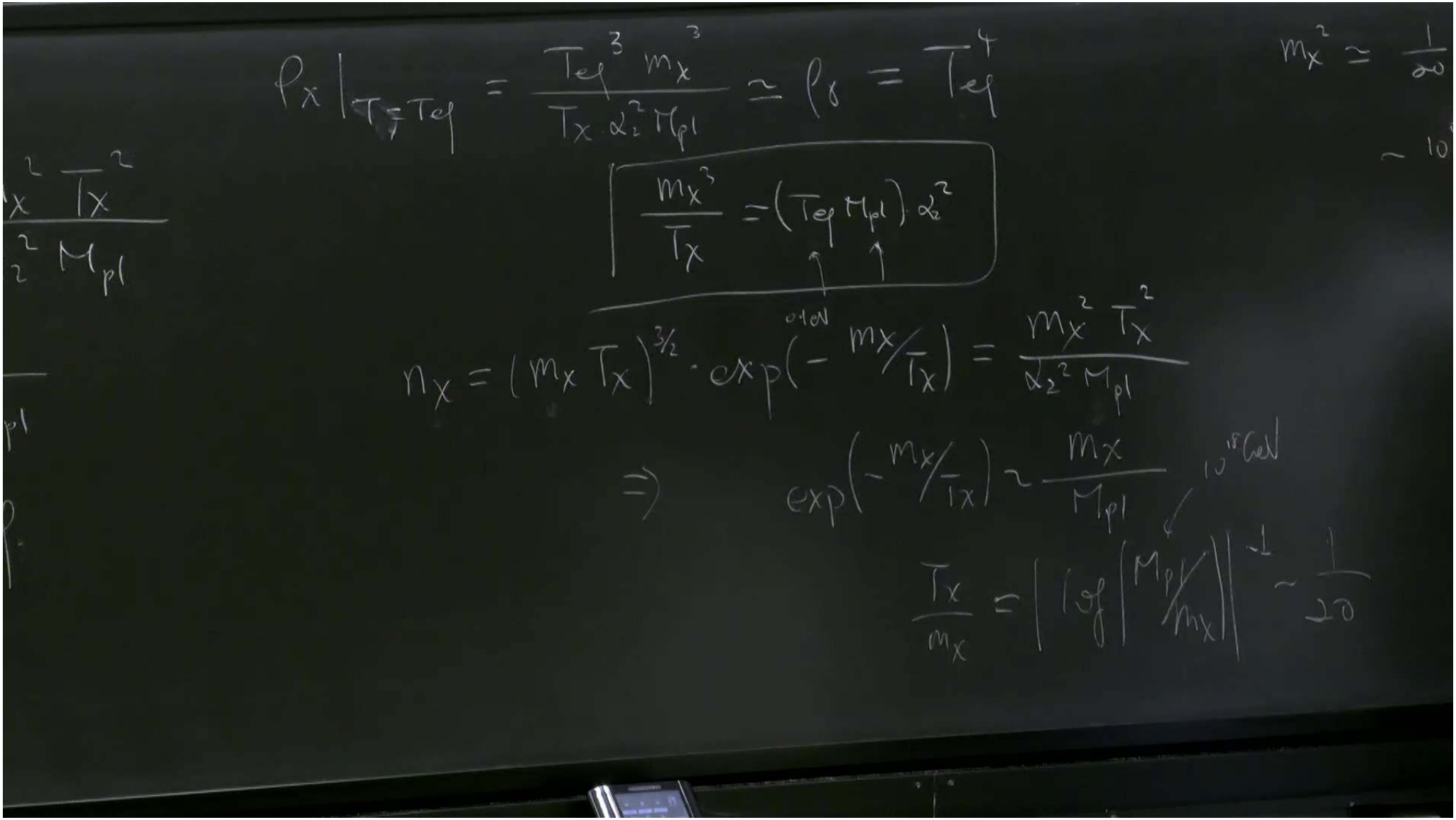
From T_X the X redshift like matter

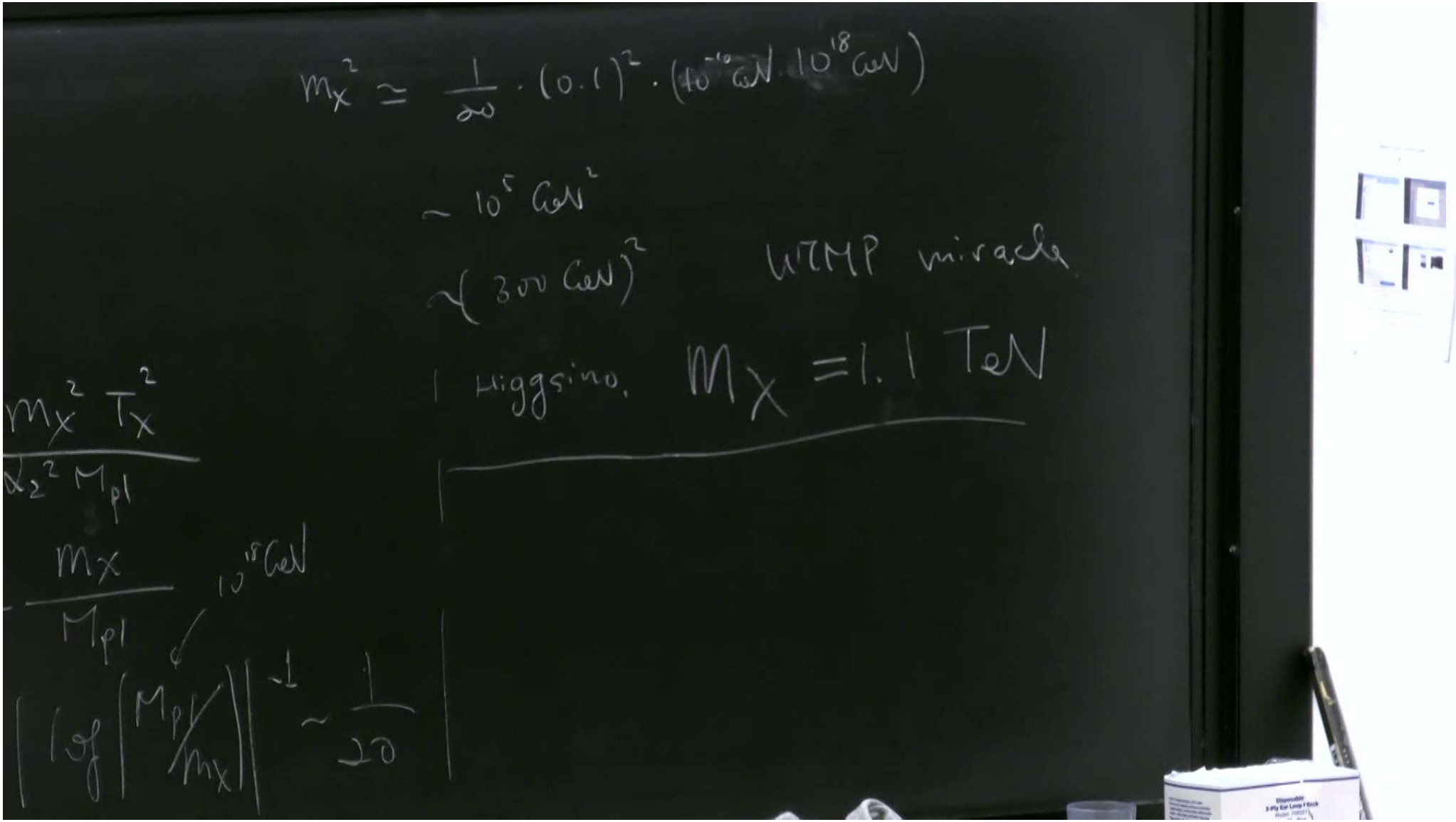
$$\begin{cases} \dfrac{n_X(T)}{n_X(T_X)} = \left(\dfrac{T}{T_X}\right)^3 \\ \dfrac{n_X}{n_\gamma} = \text{Constant} \end{cases}$$

$$\rho_X = m_X \left(\frac{T}{T_X}\right)^3 \frac{m_X^2 \overline{T_X}^2}{\alpha_2^2 M_{pl}}$$

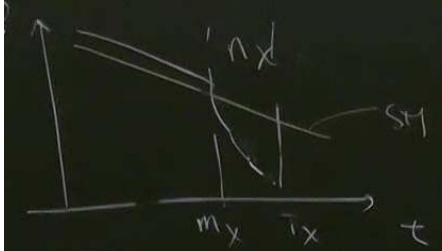
$$= \frac{T^3 m_X^3}{T_X \alpha_2^2 M_{pl}}$$

$$\frac{\rho_X}{\rho_\gamma} = 1 \quad @ \quad T = T_{eq}$$


$\rho_x|_{T=T_{eq}} = \frac{T_{eq}^3 m_x^3}{T_x \alpha_2^2 M_{pl}} \simeq \rho_\gamma = T_{eq}^4$
$m_x^2 \simeq \frac{1}{20}$
~ 10
$\frac{m_x^3}{T_x} = (T_{eq} M_{pl}) \alpha_2^2$
$n_x = (m_x T_x)^{3/2} \cdot \exp(-m_x/T_x) = \frac{m_x^2 T_x^2}{\alpha_2^2 M_{pl}}$
0.1eV
$\Rightarrow \exp(-m_x/T_x) \sim \frac{m_x}{M_{pl}}$
10^{18}GeV
$\frac{T_x}{m_x} = \left| \log \left| \frac{M_{pl}}{m_x} \right| \right|^{-1} \sim \frac{1}{20}$


$m_X^2 \simeq \frac{1}{20} \cdot (0.1)^2 \cdot (10^{-10}\,\text{GeV} \cdot 10^{18}\,\text{GeV})$
$\sim 10^5\,\text{GeV}^2$
$\sim (300\,\text{GeV})^2$
WIMP miracle
1 Higgsino.
$m_X = 1.1\,\text{TeV}$
$\frac{m_X^2 T_X^2}{\alpha_2^2 M_{pl}}$
$\frac{m_X}{M_{pl}}$
$10^{18}\,\text{GeV}$
$\left|\log\left|\frac{M_{pl}}{m_X}\right|\right|^{-1} \sim \frac{1}{20}$

$T \sim m_\chi > m_Z$



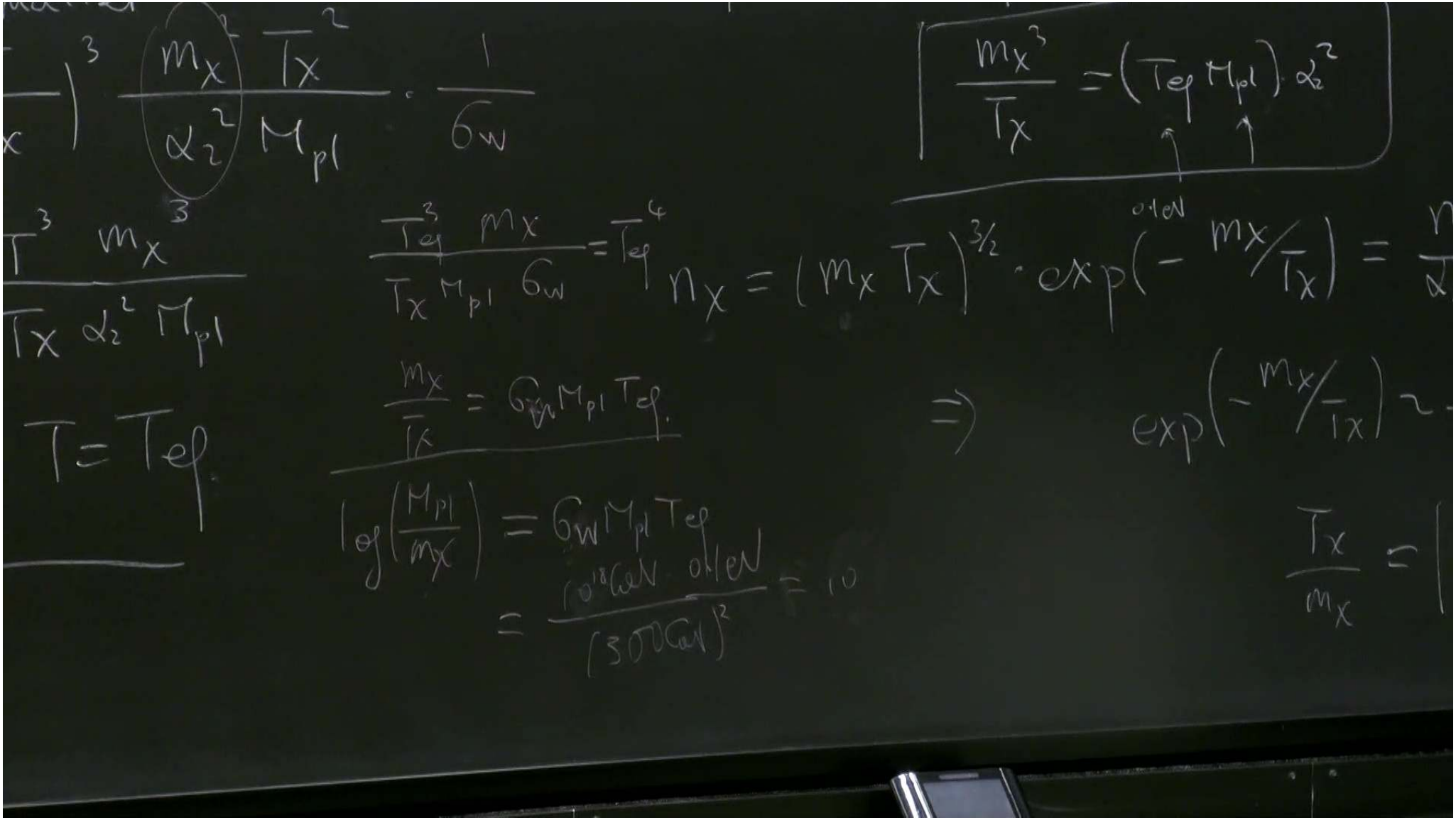
$$\frac{\Gamma}{H} = \frac{G_w \cdot n_\chi \cdot \alpha_2^2 M_{pl}}{m_\chi^2 \, T^2} = \frac{n_\chi \alpha_2^2 M_{pl}}{m_\chi^2 T_\chi^2} \sim 1$$

At this point:

$$n_\chi \Big|_{\Gamma/H=1} = \frac{m_\chi^2 \cdot T_\chi^2}{\alpha_2^2 M_{pl}} \qquad \left(\frac{T_\chi^2}{G_w \cdot M_{pl}} \right)$$

What about today?

T_χ vs m_χ?


$\frac{m_x^3}{T_x} = (T_{eq} M_{pl}) \cdot \alpha_2^2$
$n_x = (m_x T_x)^{3/2} \cdot \exp\left(-\frac{m_x}{T_x}\right)$
$T = T_{eq}$
$\log\left(\frac{M_{pl}}{m_x}\right) = G_N M_{pl} T_{eq}$
$\frac{T_x}{m_x} =$

Freeze-in

Became $\exp-(E/T)$ and

2 SM states. $E > m_X$ to produce

a X through freeze-in

Exponentially small $T_{SM} < m_X$

at $T = m_X$

$\sigma \sim \frac{\alpha^2}{m_X^2}$ $\quad n \sim T^3 \sim m_X^3$

$$\frac{\Gamma}{H} = \frac{\alpha^2 m_X}{m_X^2/M_{Pl}} \sim \frac{\alpha^2 M_{Pl}}{m_X} < 1$$

$$\alpha^2 < \frac{m_X}{M_{Pl}} = \left(\frac{m_X}{\text{GeV}}\right) \cdot 10^{-18}$$

$$\alpha < 10^{-9} \left(\frac{m_X}{\text{GeV}}\right)^{1/2}$$