PRECISE DARK MATTER RELIC ABUNDANCE IN DECOUPLED SECTORS

based on

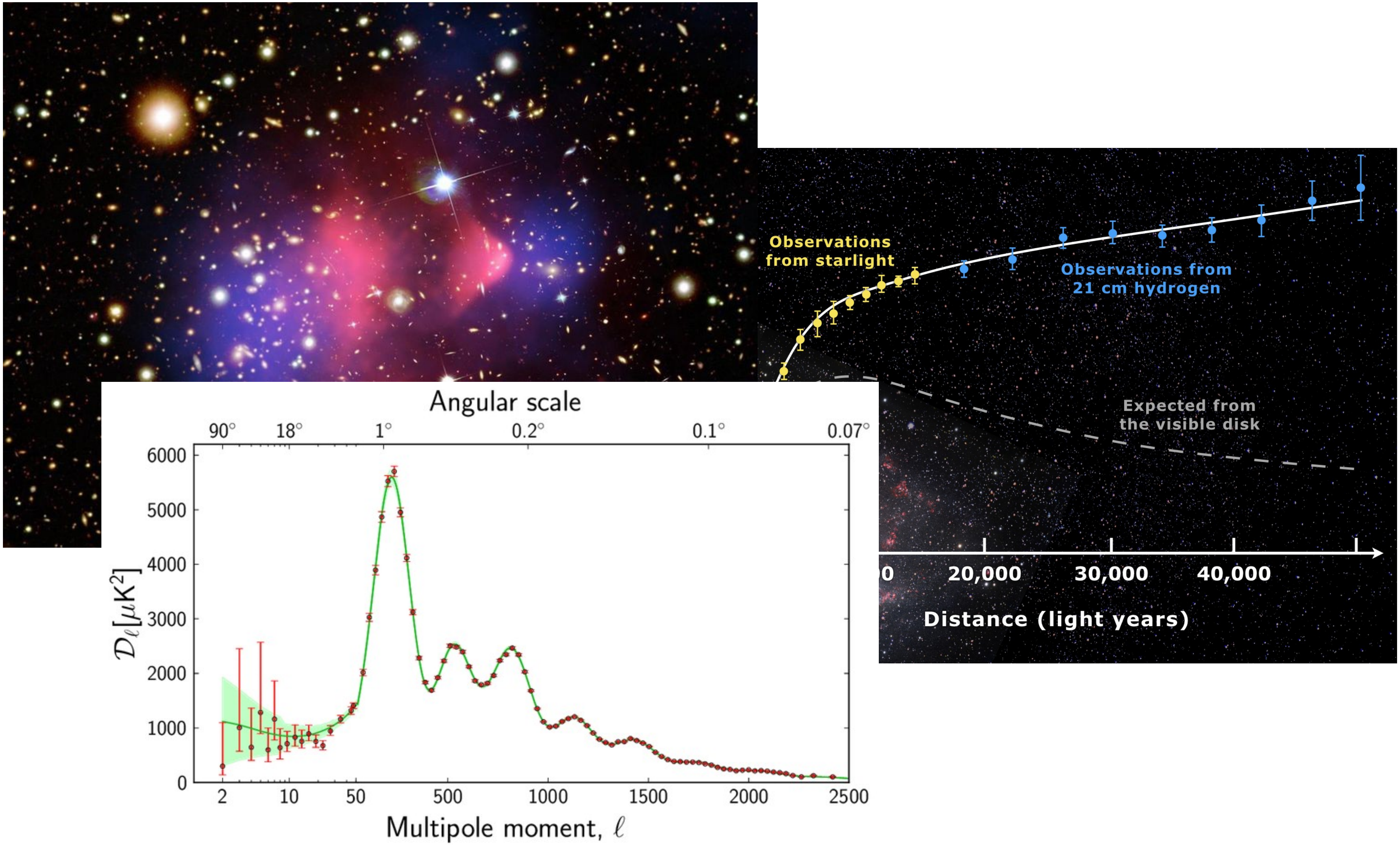
[2007.03696]

by

Torsten Bringmann, Paul Frederik Depta,
Marco Hufnagel, Kai Schmidt-Hoberg

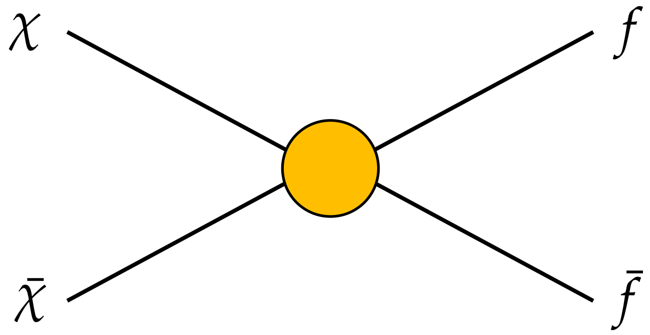
Wednesday, December 16, 2020

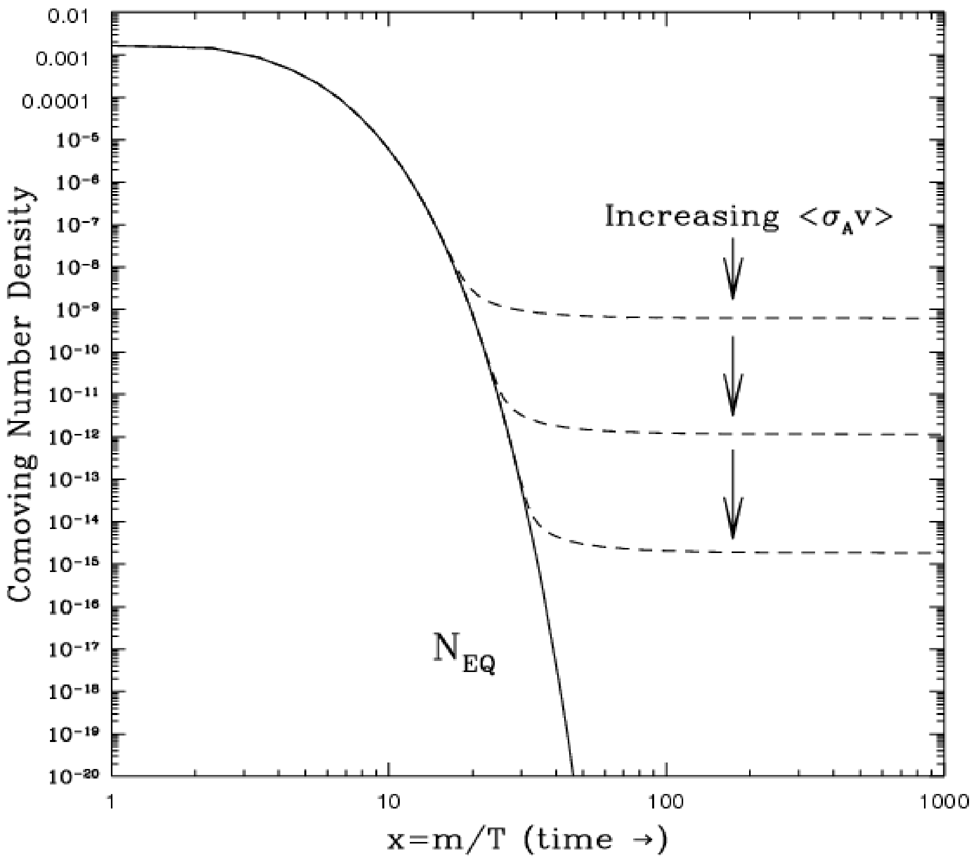
Dark Matter


Observations from starlight
Observations from 21 cm hydrogen
Expected from the visible disk
0
20,000
30,000
40,000
Distance (light years)
Angular scale
90°
18°
1°
0.2°
0.1°
0.07°
6000
5000
4000
3000
2000
1000
0
$\mathcal{D}_\ell [\mu K^2]$
2
10
50
500
1000
1500
2000
2500
Multipole moment, ℓ

Standard Freeze-out

Boltzmann equation $\chi\bar{\chi} \leftrightarrow f\bar{f}$





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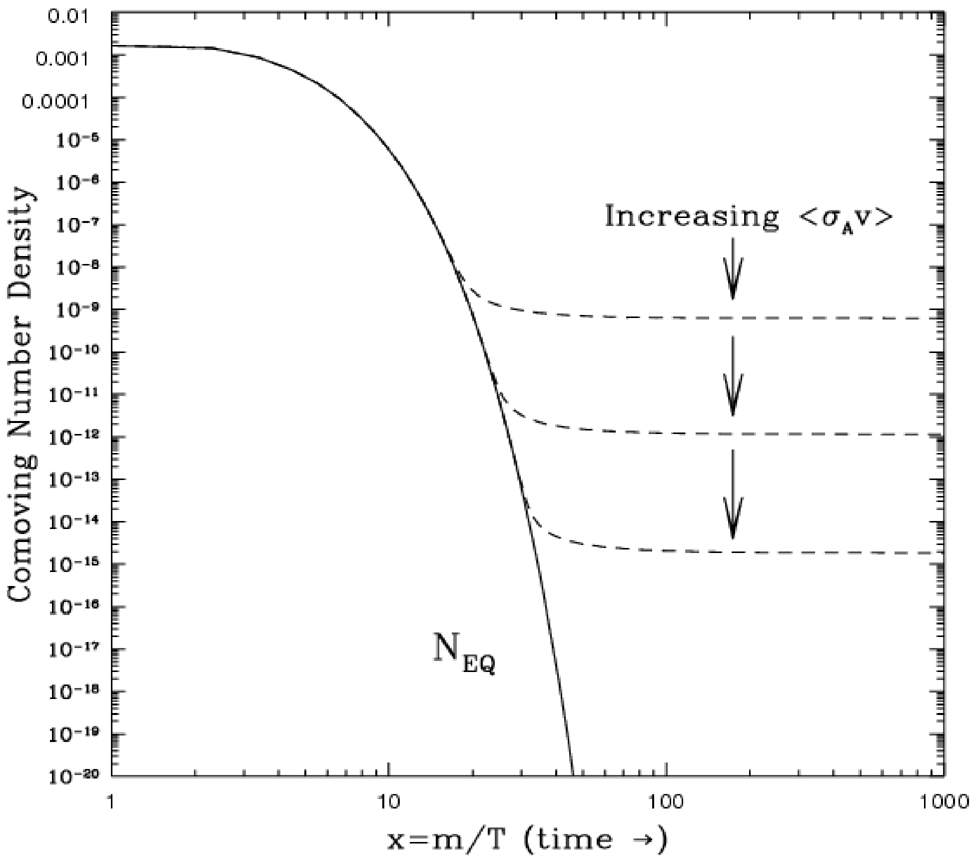
$$\frac{\mathrm{d}n_i}{\mathrm{d}t} + \underbrace{\boxed{3Hn_i}}_{\text{dilution term}} = \underbrace{\boxed{\mathfrak{C}/N_\chi}}_{\text{collision operator}}$$



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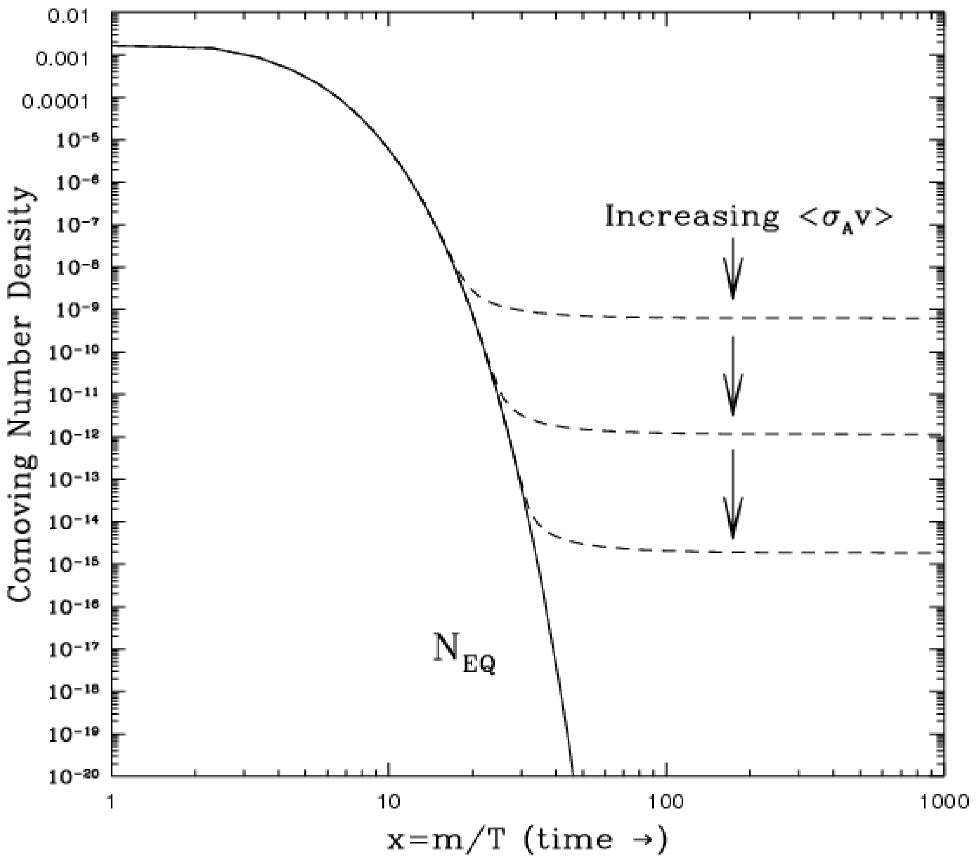
$$\frac{\mathrm{d}n_i}{\mathrm{d}t} + 3Hn_i = \langle\sigma v\rangle \left(n_{\chi,\mathrm{eq}} n_{\bar{\chi},\mathrm{eq}} - n_\chi n_{\bar{\chi}}\right)$$



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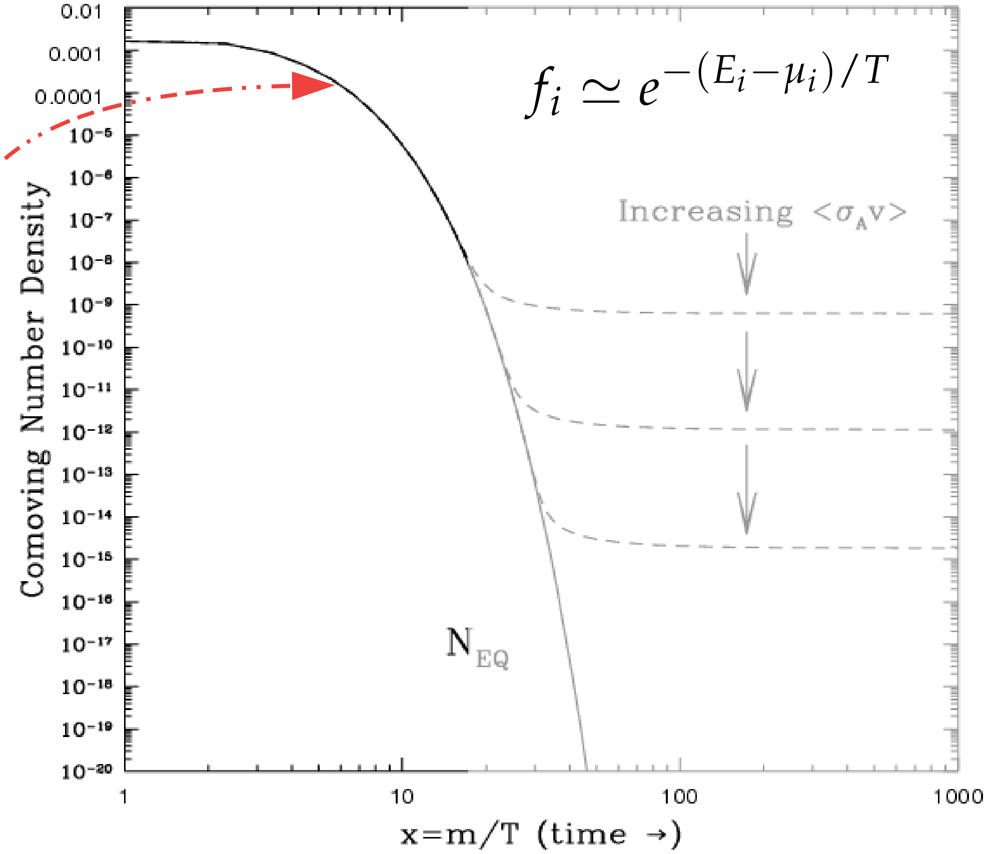
chemical equilibrium

$$0 \simeq \mu_f + \mu_{\bar{f}} = \mu_\chi + \mu_{\bar{\chi}} \to \mu_{i,\mathrm{eq}} = 0$$

$$\langle\sigma v\rangle n_\chi \gg H$$



$$f_i \simeq e^{-(E_i - \mu_i)/T}$$

Standard Freeze-out

$$\langle \sigma v \rangle n_\chi \ll H$$

Boltzmann equation $\chi\bar{\chi} \leftrightarrow f\bar{f}$

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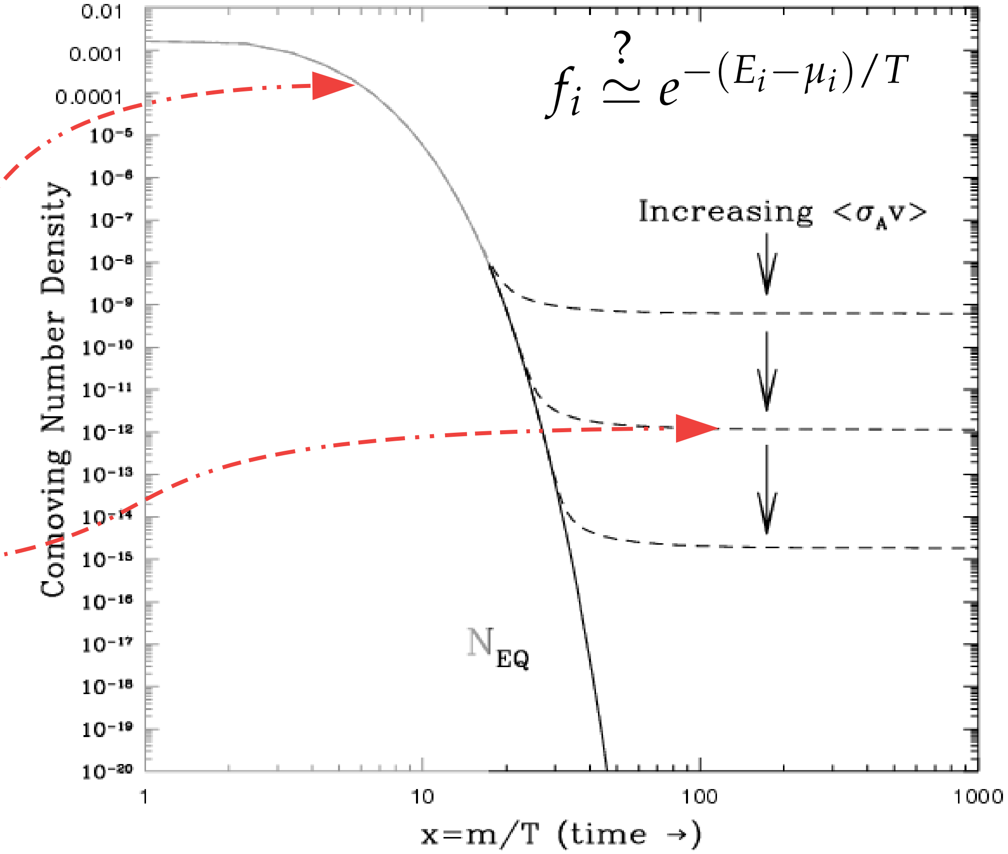

$$f_i \overset{?}{\simeq} e^{-(E_i - \mu_i)/T}$$

Standard Freeze-out

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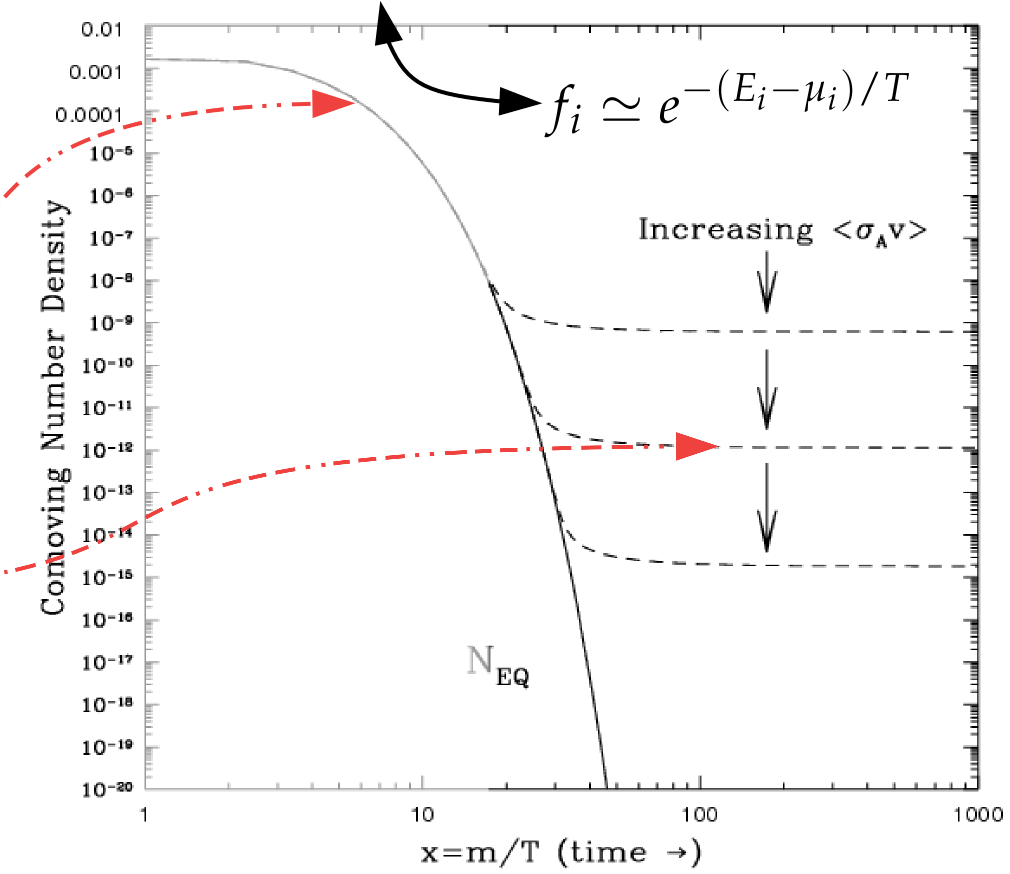

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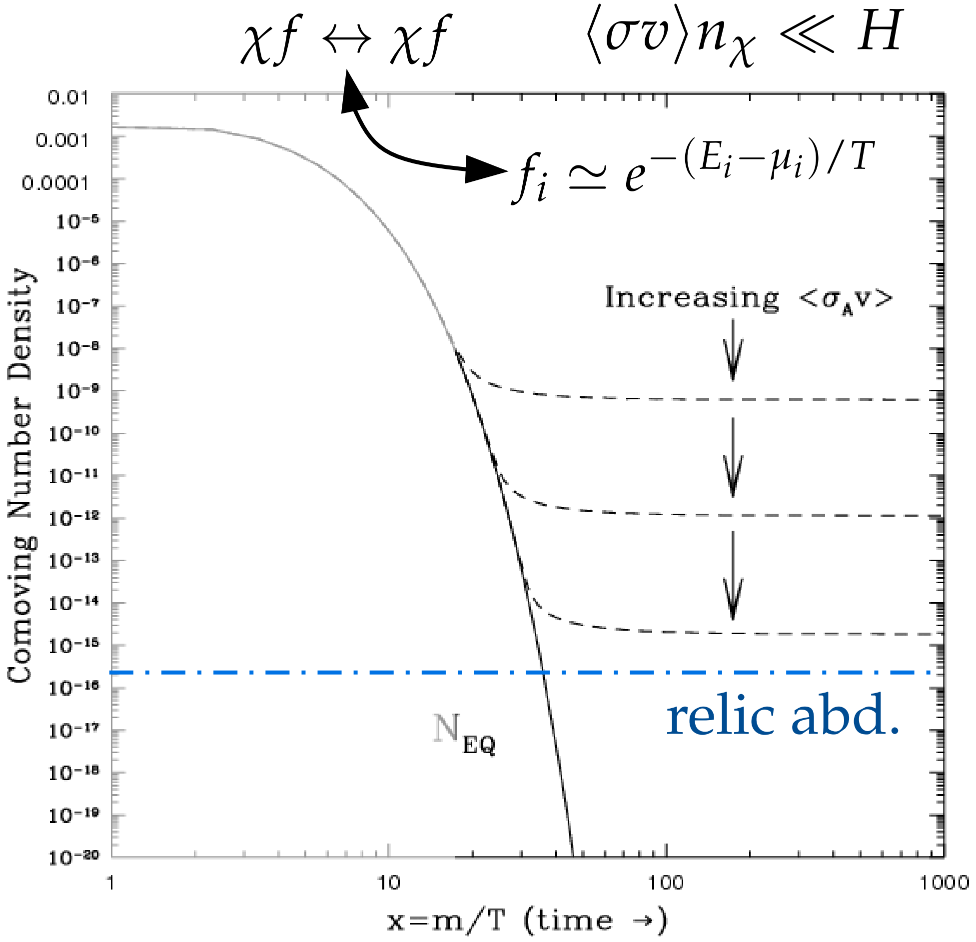

$\chi f \leftrightarrow \chi f$

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relic abd.

Standard Freeze-out

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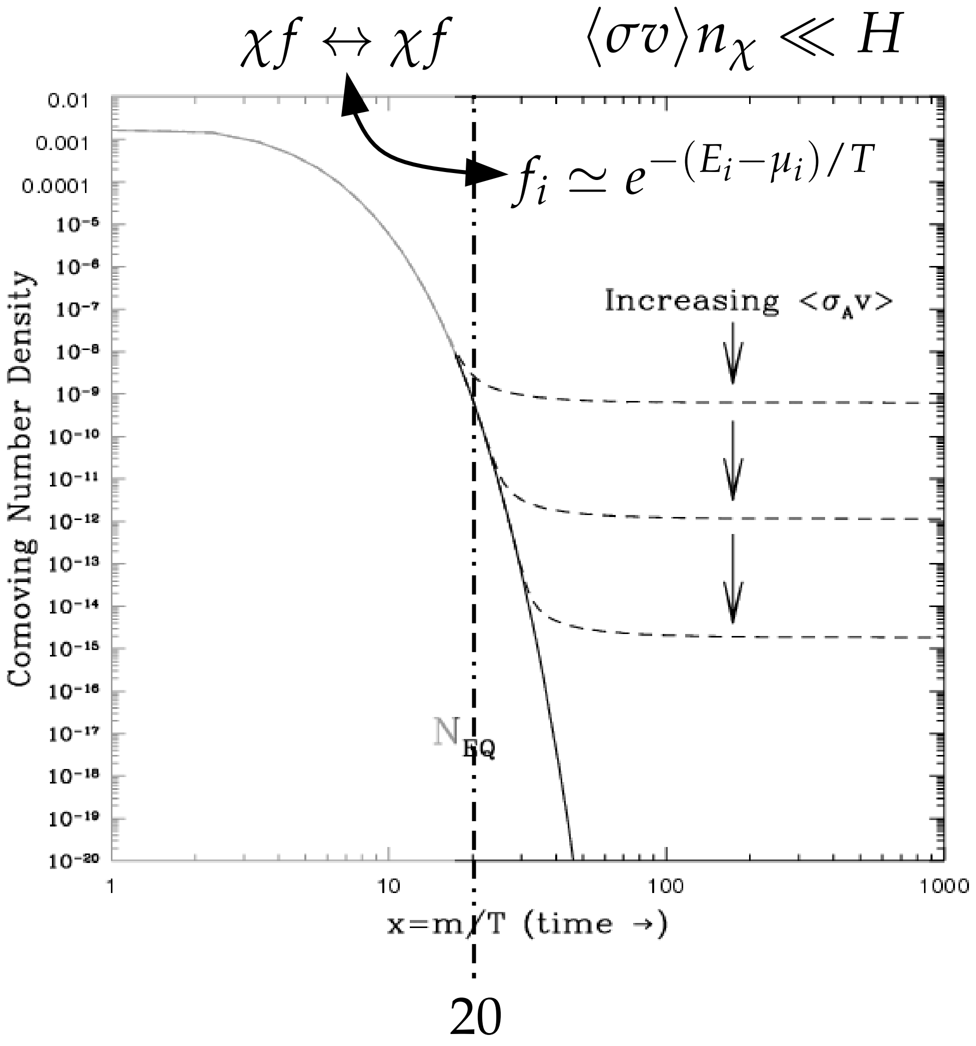

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20

Standard Freeze-out

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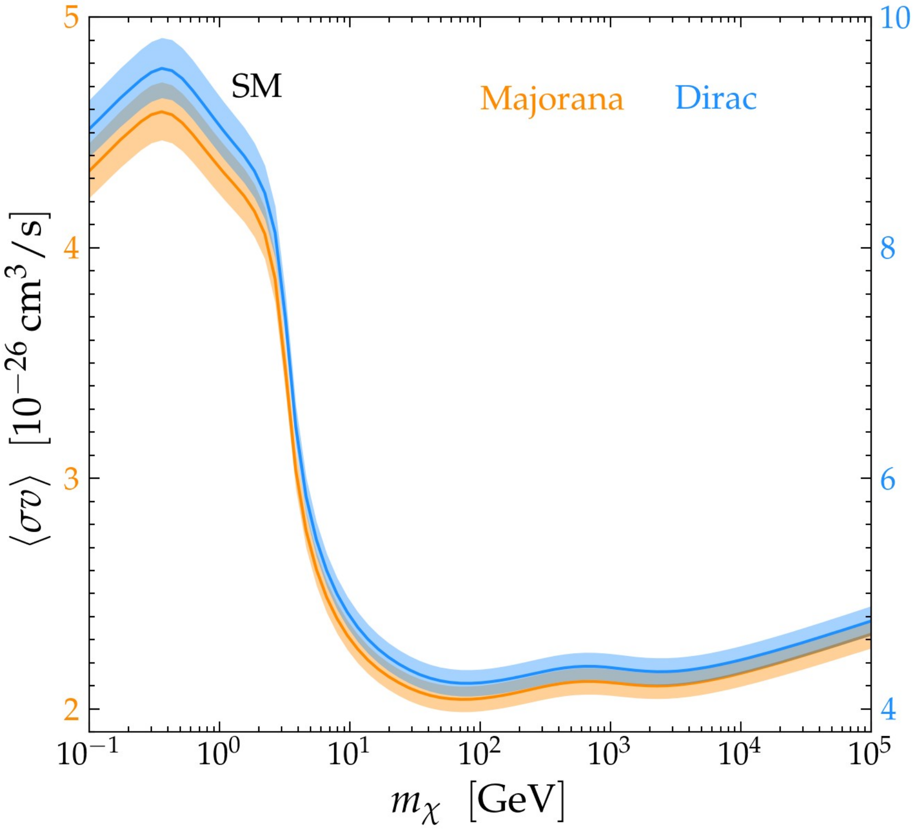

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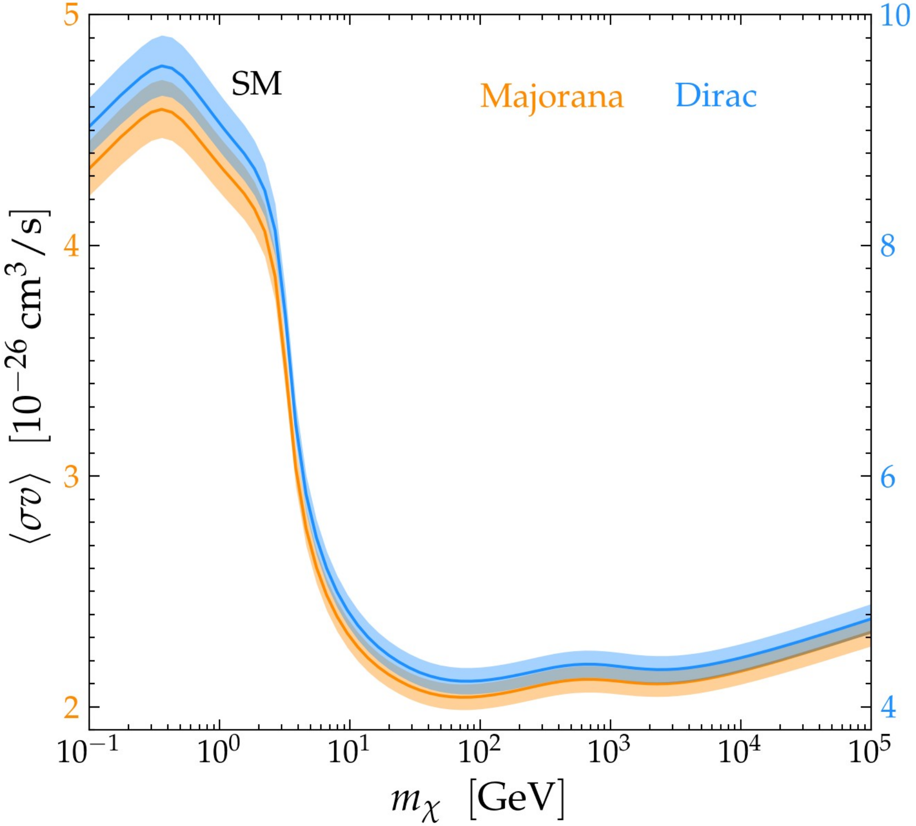

Assumptions

- $f_i \simeq e^{-(E_i-\mu_i)/T} = e^{\mu_i/T} f_{i,\mathrm{eq}}$

  $\rightarrow$ kinetic equilibrium | non-relativistic during freeze-out | $\mu_i/m_i \ll 1$

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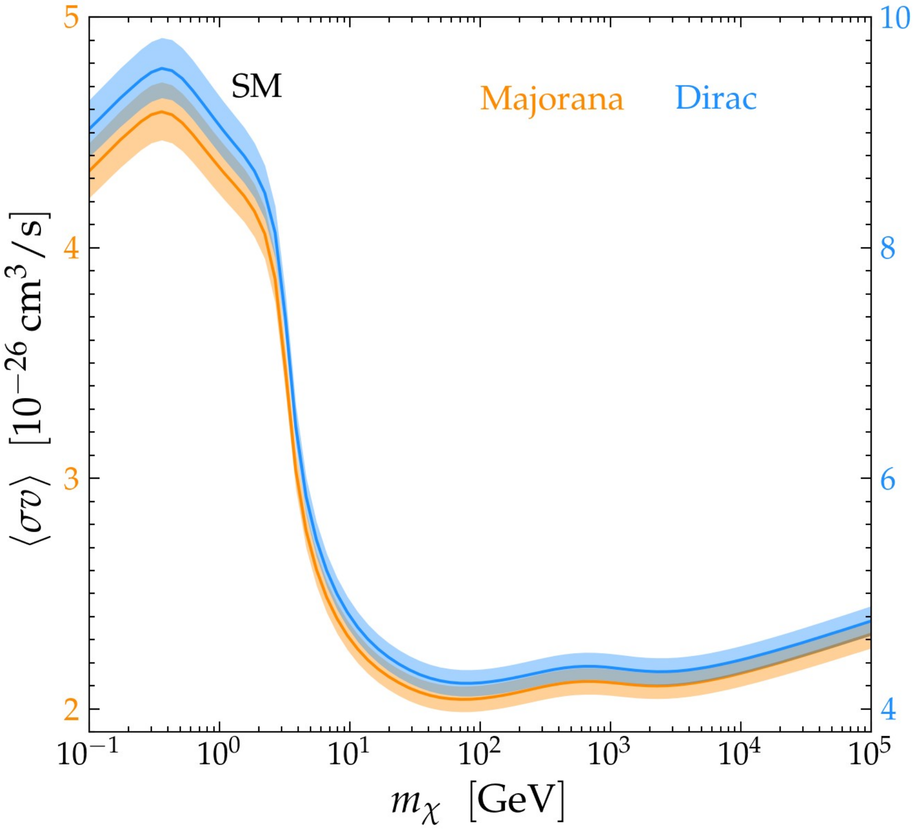

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Relativistic and quantum effects are small

Hidden Freeze-out

Boltzmann equation $\chi\bar{\chi} \leftrightarrow SS$

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?

Possible scenarios

$m_S = 0$	$\Gamma_{\chi\bar{\chi}\leftrightarrow\chi\bar{\chi}S} \gg \Gamma_{\chi\bar{\chi}\leftrightarrow SS}$	$\mu_S = 0$
$m_S \neq 0$	$\Gamma_{N\bar{N}\leftrightarrow SS} \gg \Gamma_{\chi\bar{\chi}\leftrightarrow SS}$	$\mu_S = 0$
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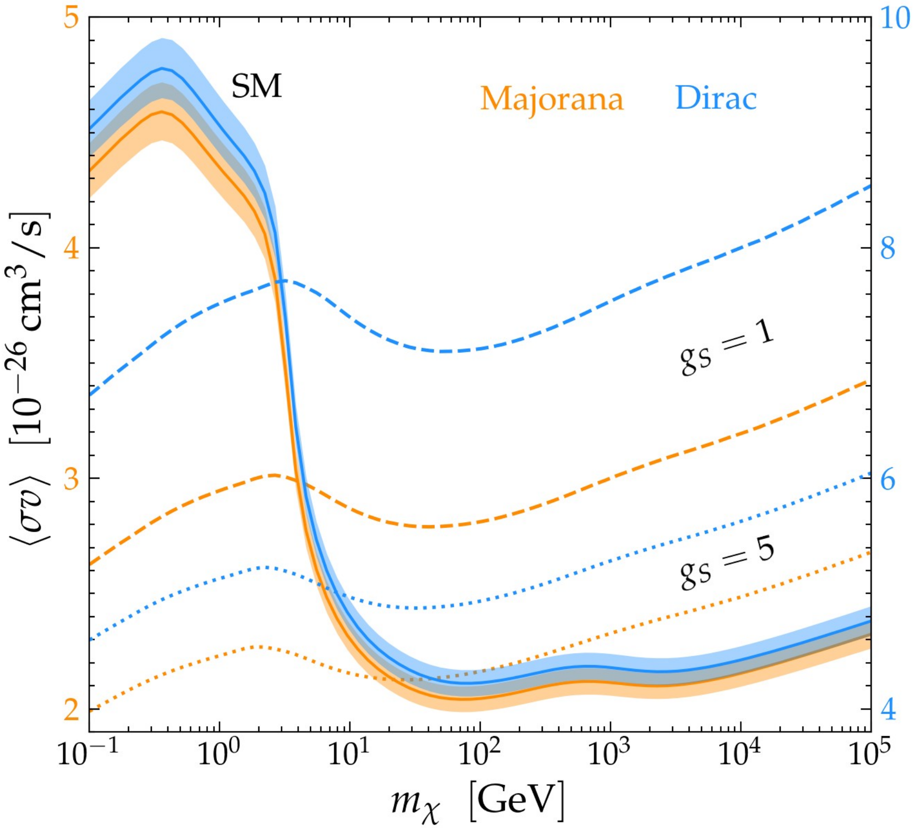

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DarkSUSY

Hidden Freeze-out

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For $m_S \sim m_\chi$, $\mu_S \sim m_S$

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$$\frac{\mathrm{d}n_i}{\mathrm{d}t} + 3Hn_i = \mathfrak{C}/N_\chi$$

$$\frac{\mathrm{d}n_S}{\mathrm{d}t} + 3Hn_S = -\mathfrak{C}$$

$\rightarrow$ Solve for both μ_S and μ_χ
with full spin-statistics

$$f = \frac{1}{e^{(E-\mu)/T_\chi} \pm 1}$$

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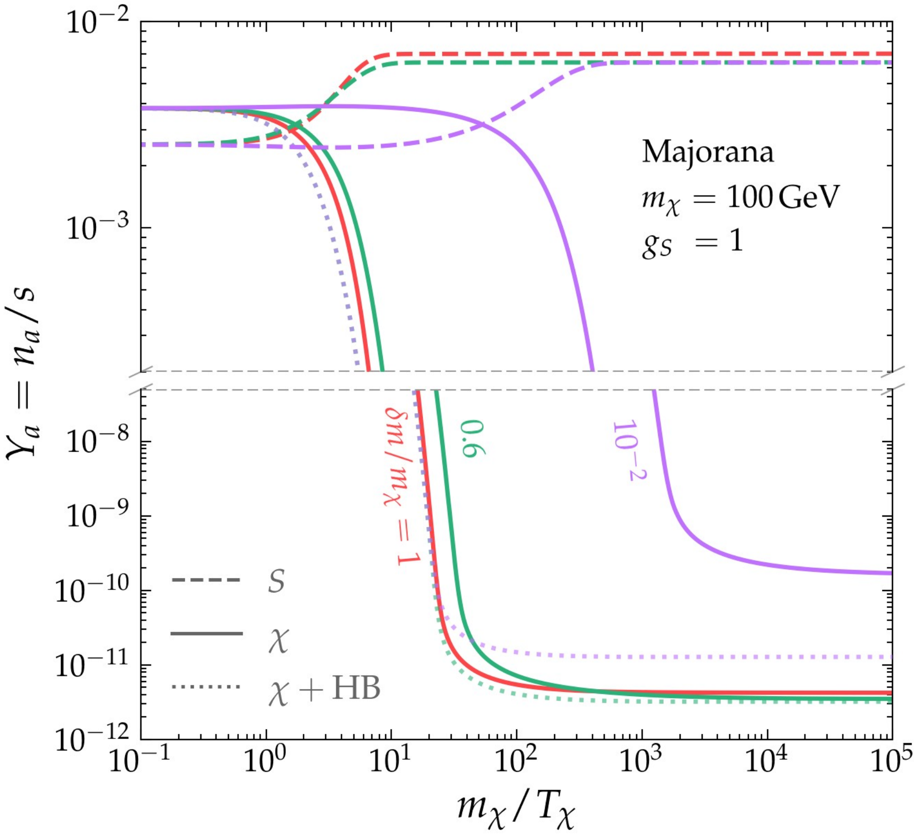

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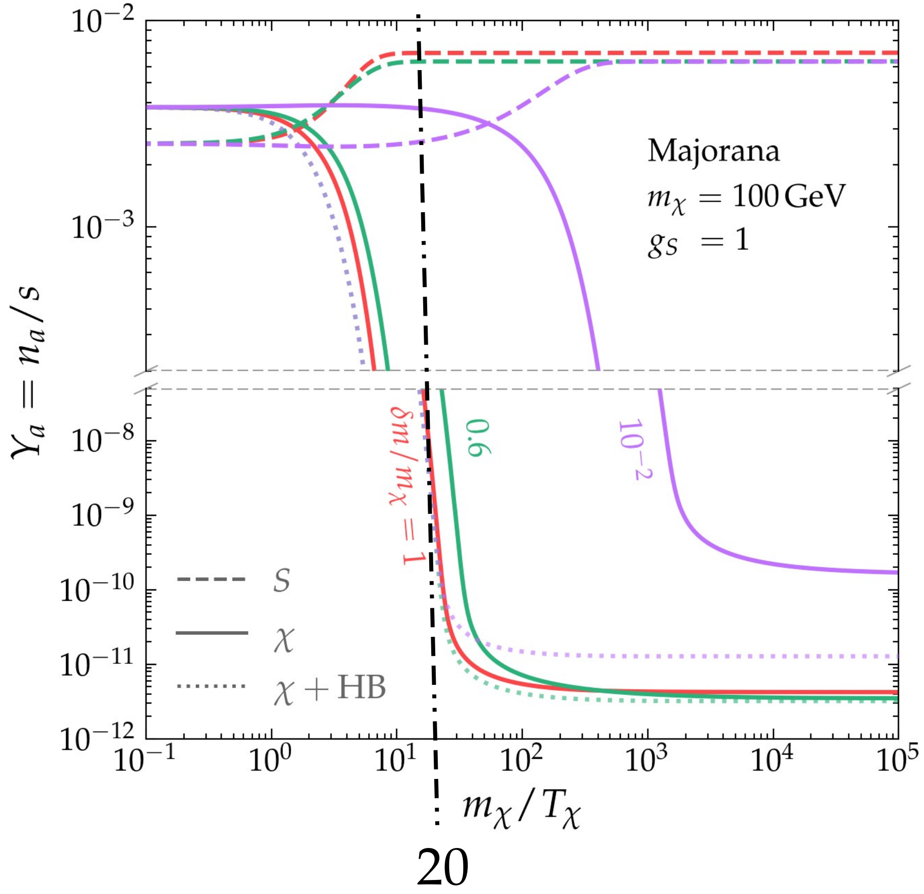

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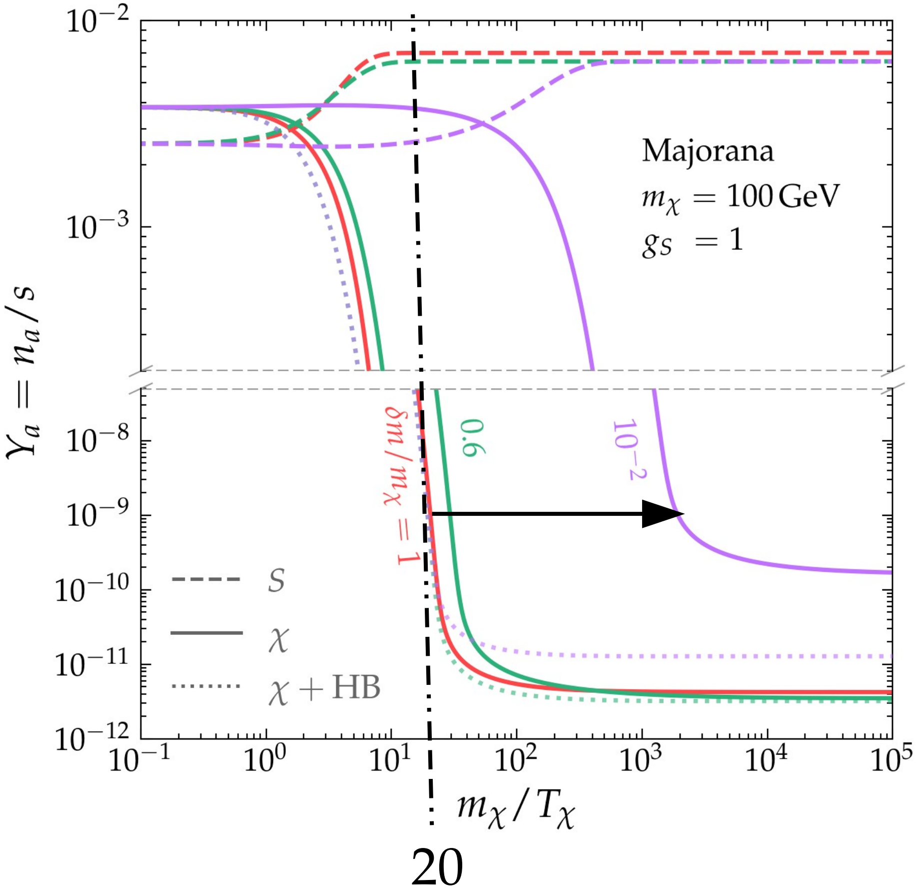

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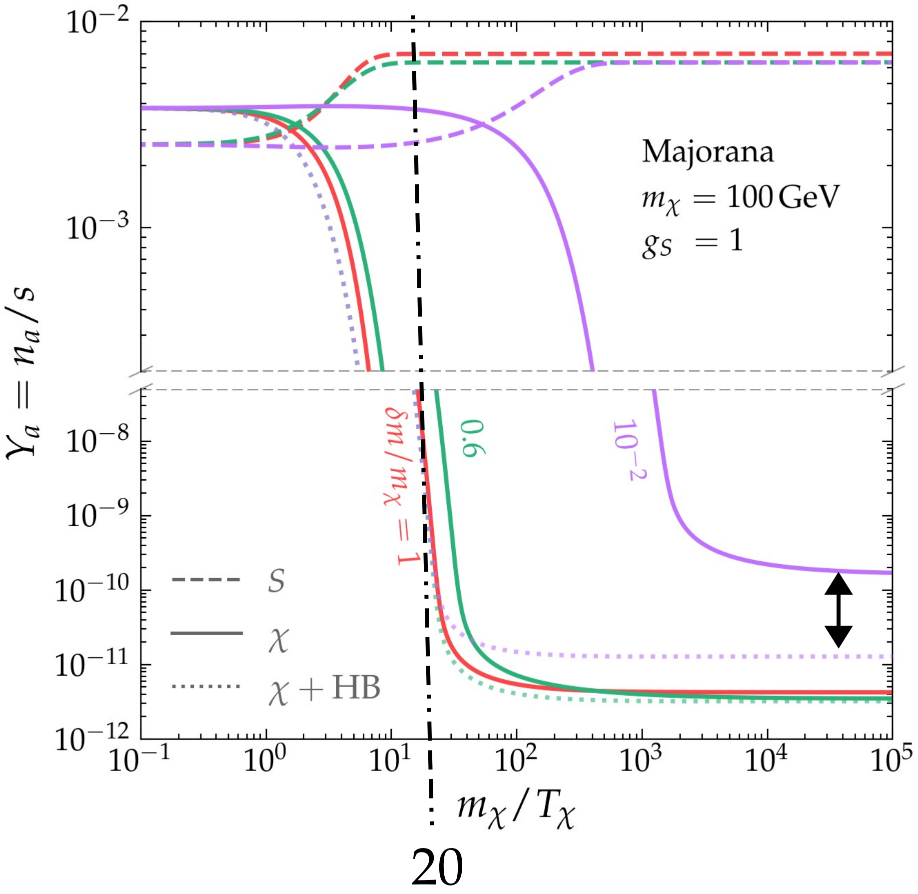

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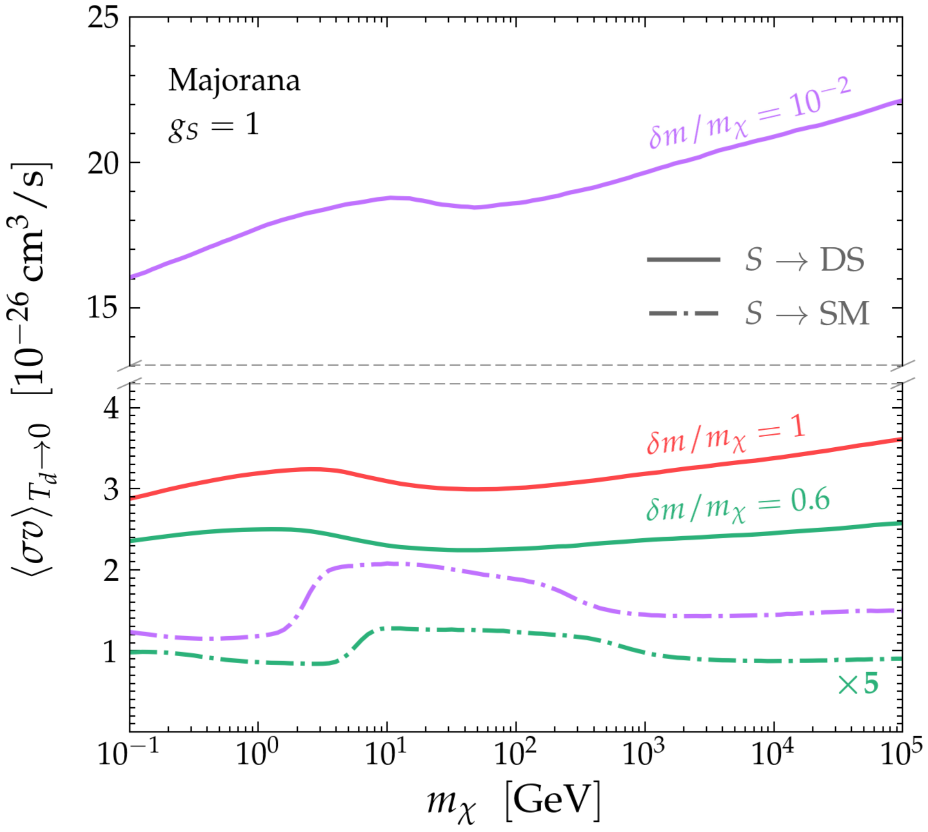

Conclusions

- We presented a formalism that can be used to make precision calculations for DM freeze-out in secluded dark sectors
- For dark-sector particles that are degenerate in mass, the standard treatment breaks down and correction can be rather large


рахмат
ngiyabonga
danke
謝謝
teşekkür ederim
Баярлалаа
mersi
kia ora
barka
welalin
spas
tack
mahalo
спасибо
faafetai lava
vinaka
спасибі
blagodaram
dank je
misaotra
matondo
paldies
grazzi
tapadh leat
kiitos
dankie
nanni
nandri
dhanyavad
mauruuru
thank you
gracias
хвала
asante
manana
bedankt
bayarlalaa
gràçie
hvala
köszönöm
dankon
aćiū
akun
obrigada
tenki
murakoze
enkosi
djiere dieuf
tau
mochchakkeram
mamnun
дякую
chokrane
dziękuję
chnorakaloutioun
gratias ago
gràcies
sulpáy
taiku
go raibh maith agat
sobodi
děkuji
sukriya
kop khun krap
obrigado
mèsi
didi madloba
sagolun
najis tuke
ありがとう
tanemirt
grazie
arigatô
takk
dakujem
trugarez
terima kasih
rahmet
kam sah hamnida
rahmat
ευχαριστώ
diolch
dhanyavadagalu
shukriya
mercê
мерси
merci
তোমাকে ধন্যবাদ
감사합니다
xièxie