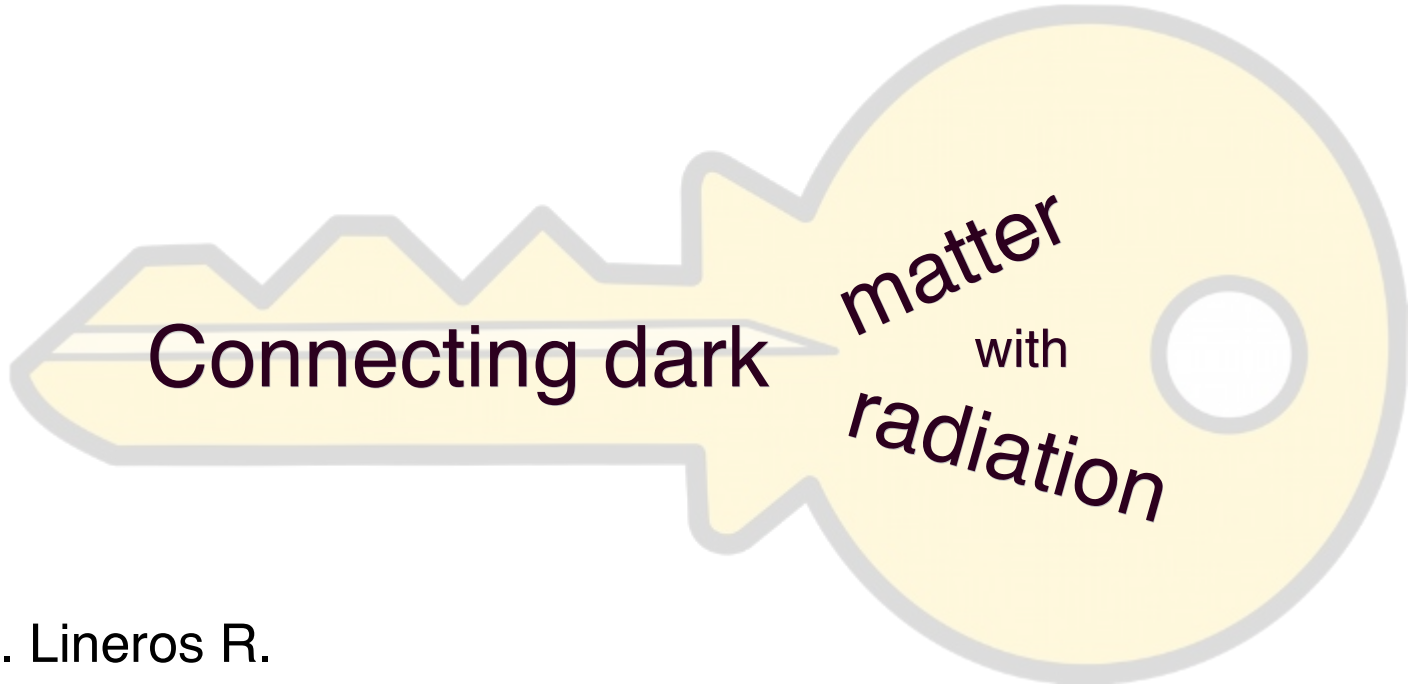

Roberto A. Lineros R.
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In collaboration with U. França, J. Palacio and S. Pastor

Based on Phys. Rev. D 87, 123521 (2013), 1303.1776 and work in progress

Dark Matter Hunters

Digital resources for hunting the dark sector

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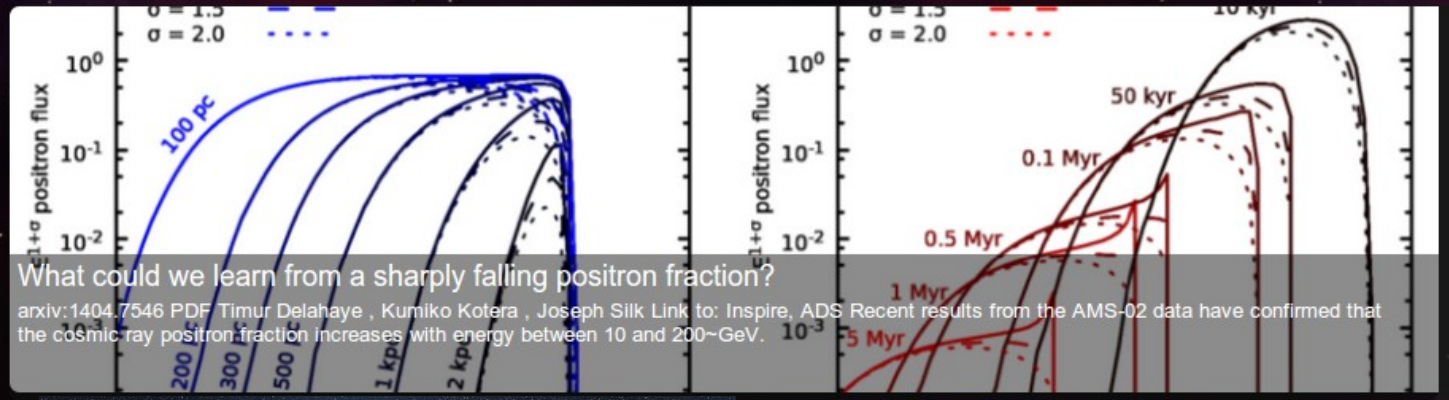
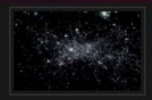
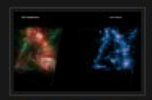


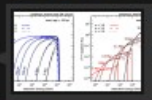
What could we learn from a sharply falling positron fraction?

arxiv:1404.7546 PDF Timur Delahaye , Kumiko Kotera , Joseph Silk Link to: Inspire, ADS Recent results from the AMS-02 data have confirmed that the cosmic ray positron fraction increases with energy between 10 and 200~GeV.


[video] Fly through of the GAMA Galaxy Catalogue


[video] A virtual Universe


Jupiter as a Giant Cosmic Ray Detector


What could we learn from a sharply falling positron fraction?

neutrino masses due to ba
V lensing surveys

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/pages/Dark-Matter-Hunters/130320483778241

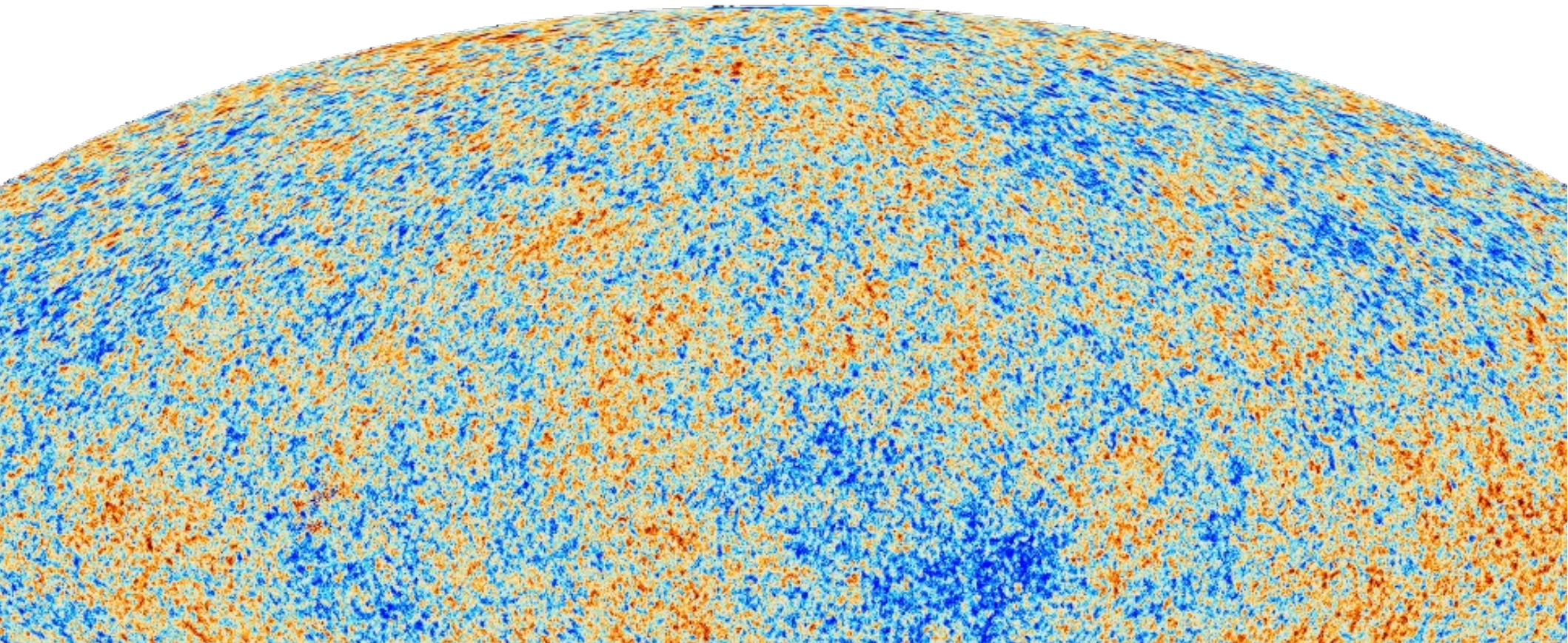
Probing interactions within the dark matter sector via extra radiation contributions

Roberto A. Lineros R.
IFIC-CSIC/U. Valencia and MULTIDARK fellow

In collaboration with U. França, J. Palacio and S. Pastor
Based on Phys. Rev. D 87, 123521 (2013), 1303.1776 and work in progress

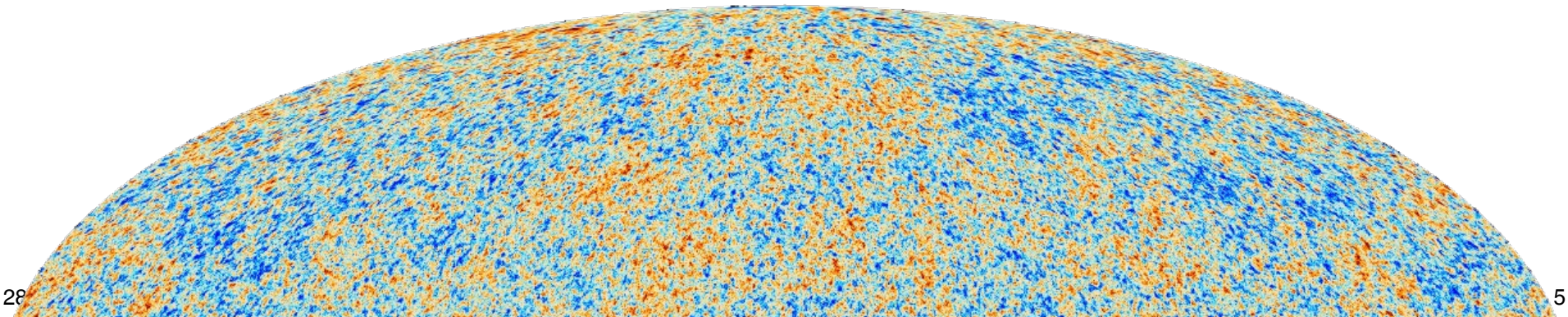
Motivation

Can we estimate how large is the dark (matter) sector?

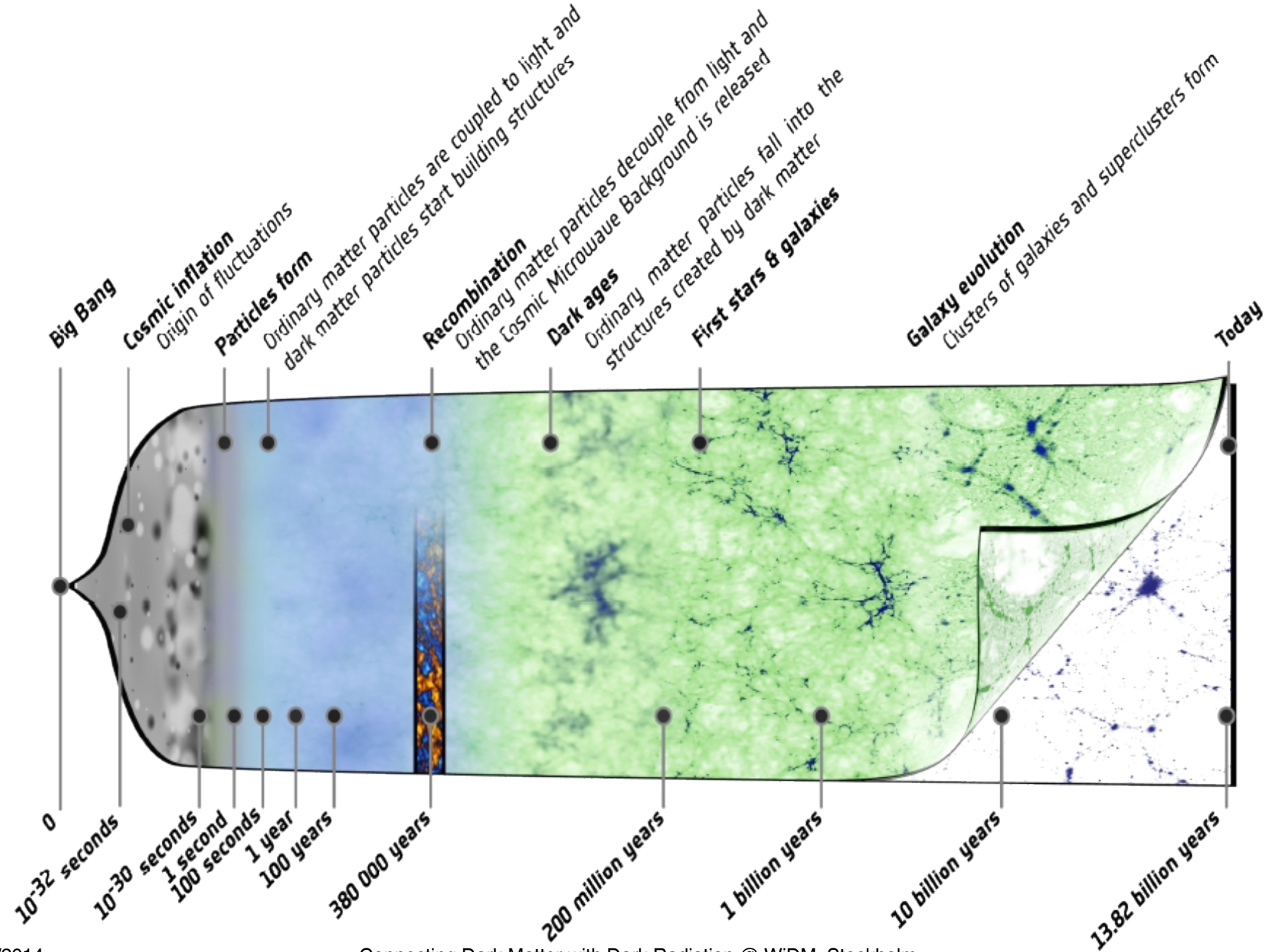


Outline

- Introduction
- Relativistic species in the Early Universe
- WIMP dark matter
- A connexion between WIMP and Neff
- Conclusions

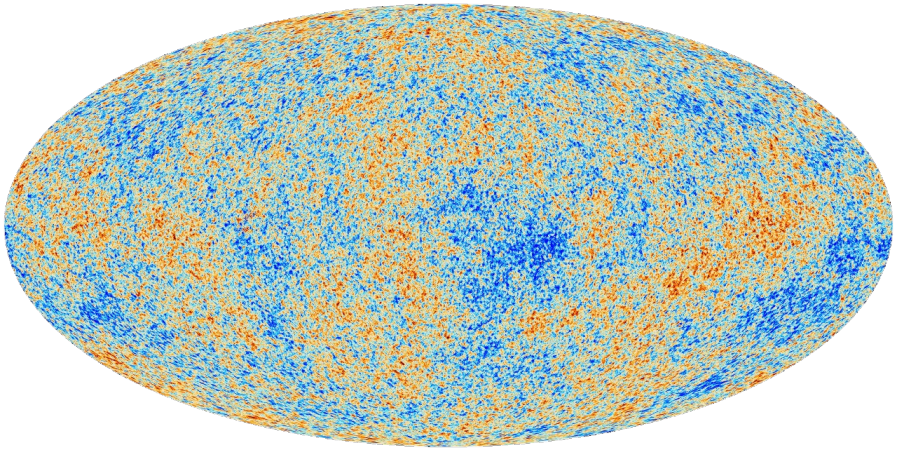


The history of the Universe



Relativistic species in the Early Universe

$$H^2 = \frac{8\pi G}{3}\,\rho_r$$



$$\rho_r = \rho_\gamma \left[1 + \frac{7}{8}\left(\frac{11}{4}\right)^{4/3} \times N_{\rm eff}\right]$$

$$N_{\rm eff} = N_{\rm eff}^{\rm std} + \Delta N_{\rm eff}$$

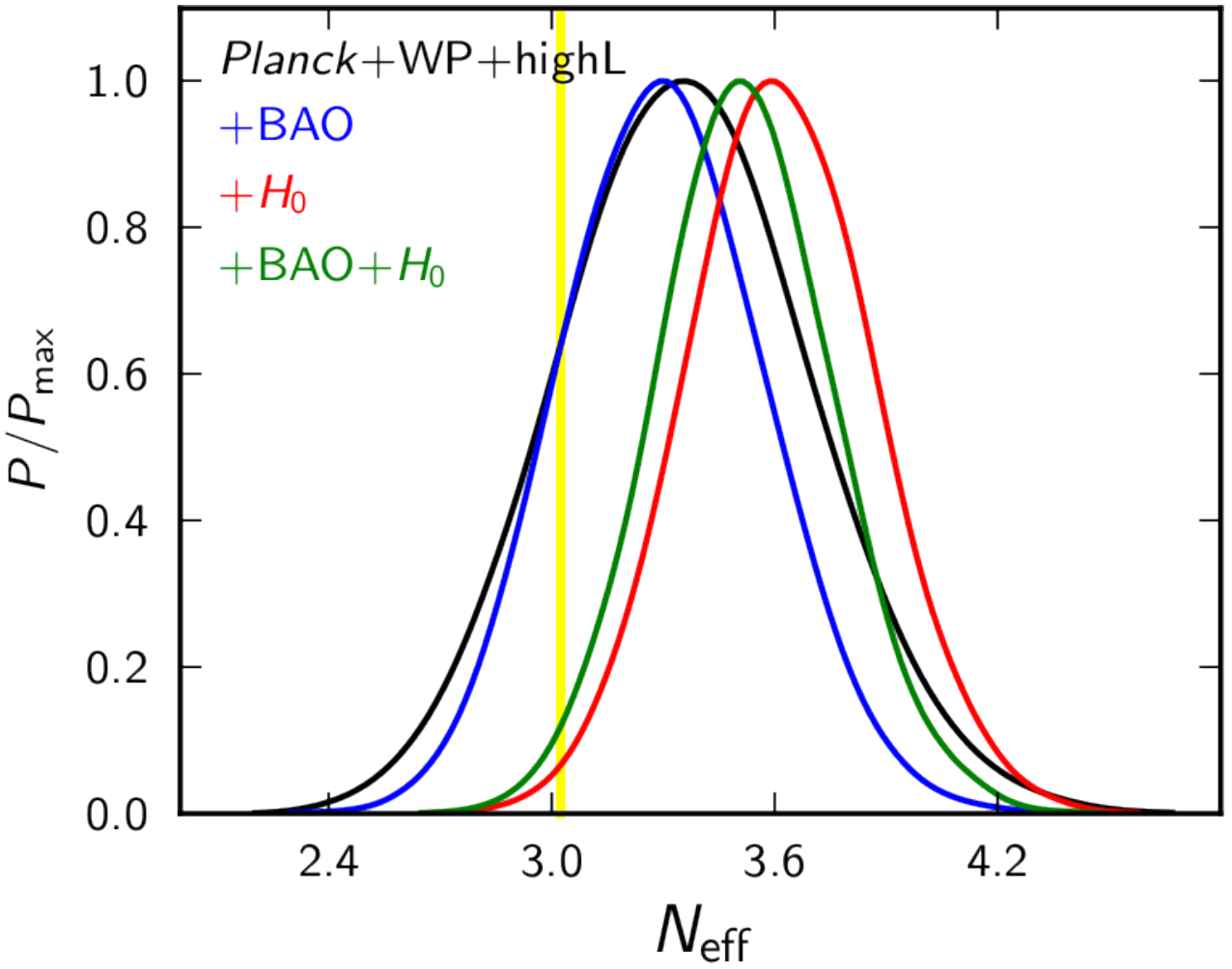
SM neutrino contribution

$$N_{\rm eff}^{\rm std} = 3.046$$

Candidates for Dark Radiation

- Sterile neutrinos
- Lepton asymmetries
- Neutrino reheating

Relativistic species in the Early Universe



Planck 2013 results
Arxiv: 1303.5076

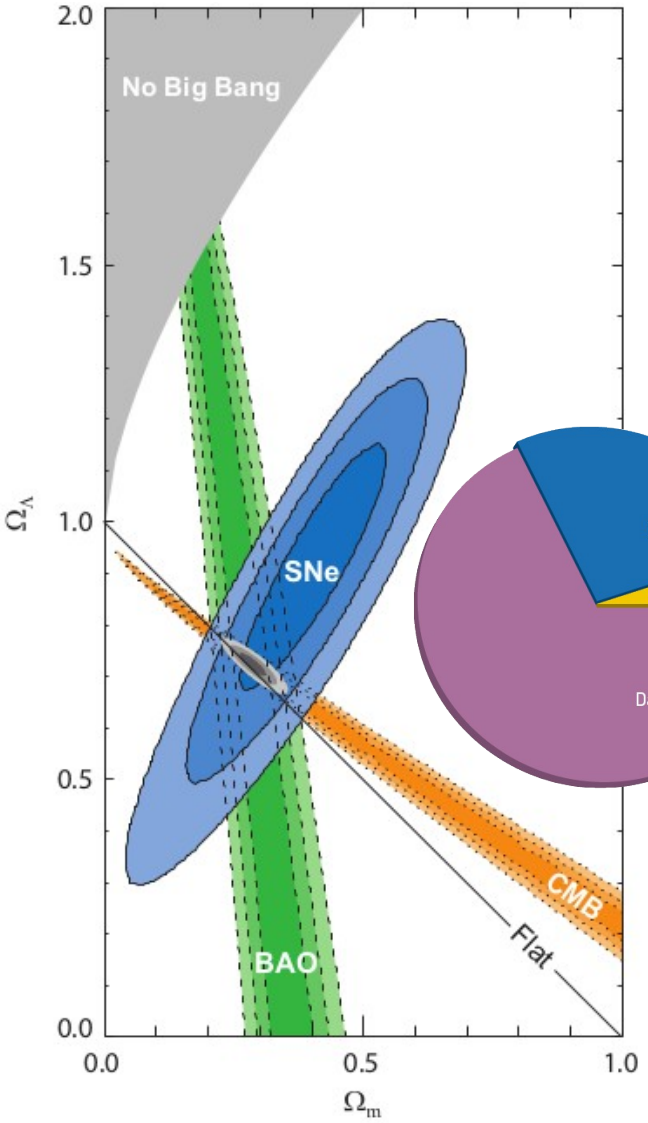
SM neutrino contribution

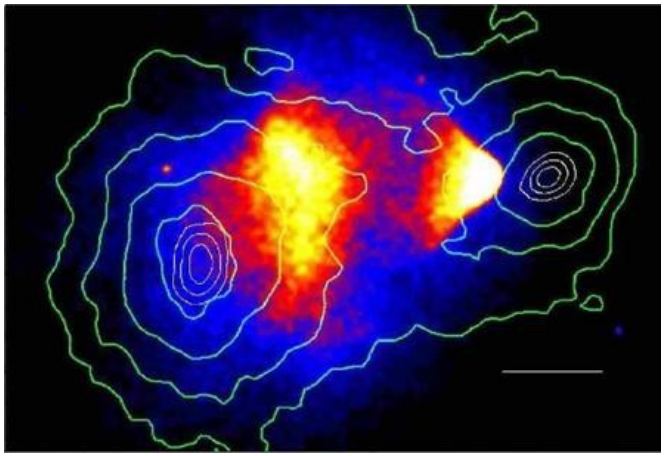
$$N_{\rm eff}^{\rm std} = 3.046$$

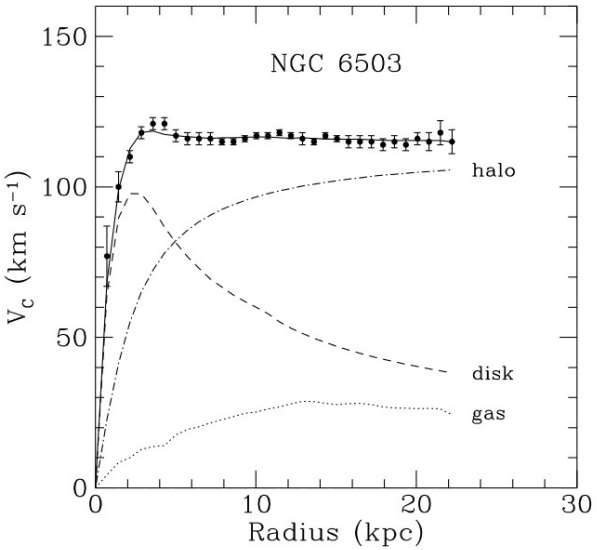
$$N_{\rm eff} = 3.30^{+0.54}_{-0.51} \quad (95\%\,{\rm C.L.;\,CMB + BAO})$$

$$N_{\rm eff} = 3.62^{+0.50}_{-0.48} \quad (95\%\,{\rm C.L.;\,CMB}{+}H_0)$$

Dark Matter





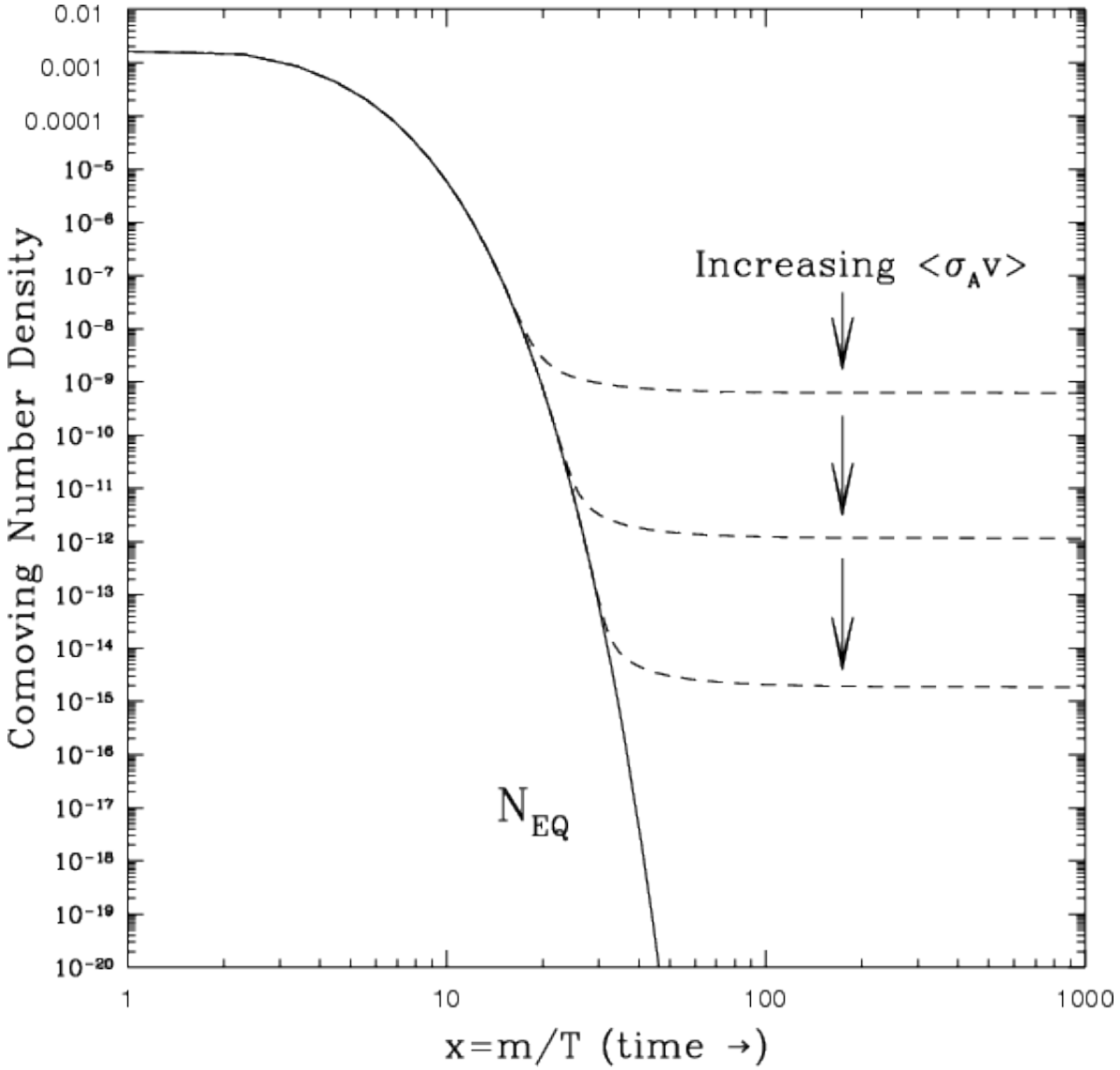


$$\Omega_{\rm DM} h^2 = 0.1196 \pm 0.0031$$

Observations supporting the **Dark Matter hypothesis**

- Dynamics of clusters and galaxies
- Structure formation
- CMB anisotropies
- Baryon Acoustic Oscillation

WIMP dark matter



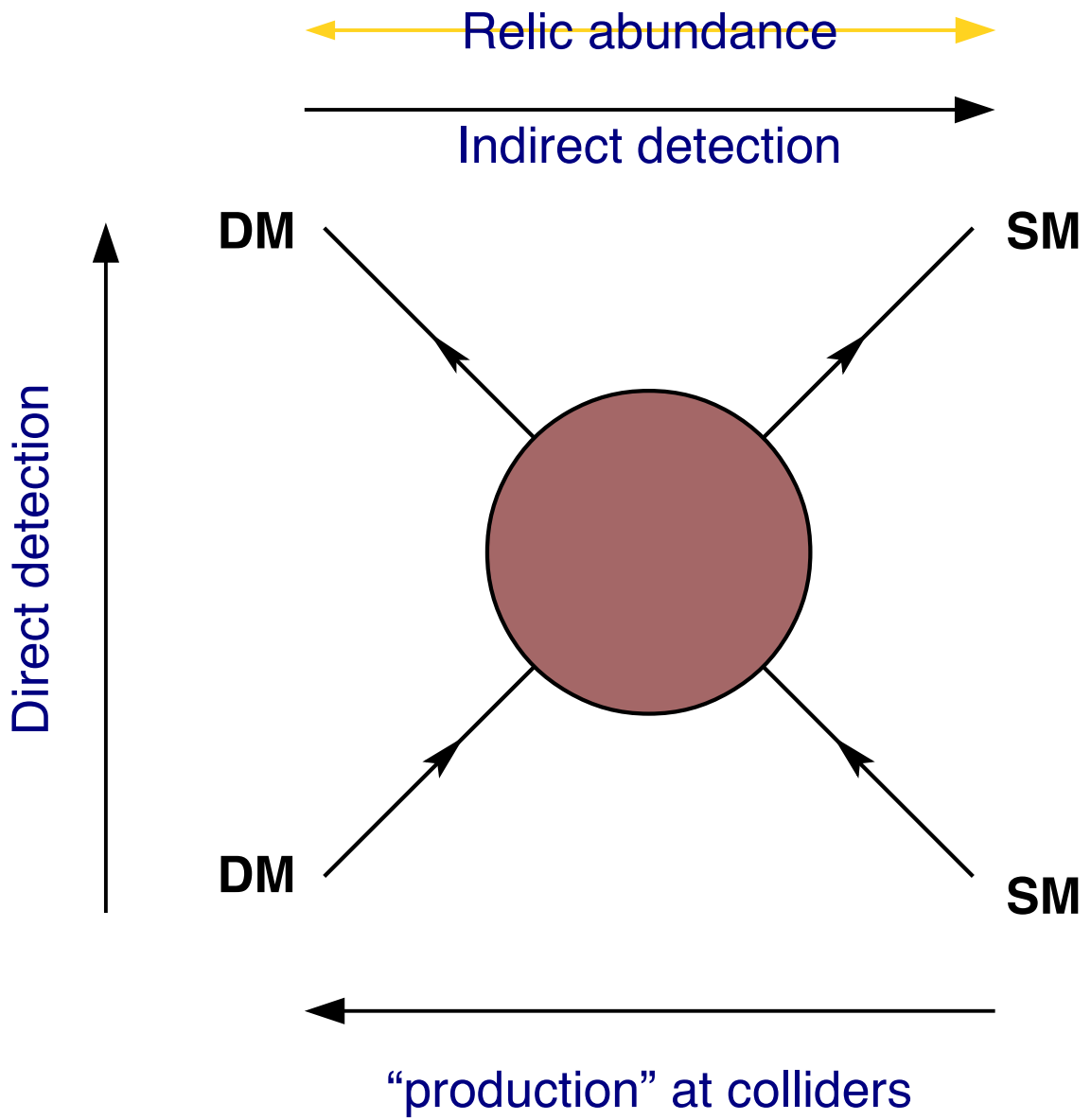
- Big Bang thermal relic
- Correct relic abundance

  for $\langle\sigma v\rangle \sim 1$ pb · c
- Mass in GeV-TeV range
- Many searches strategies

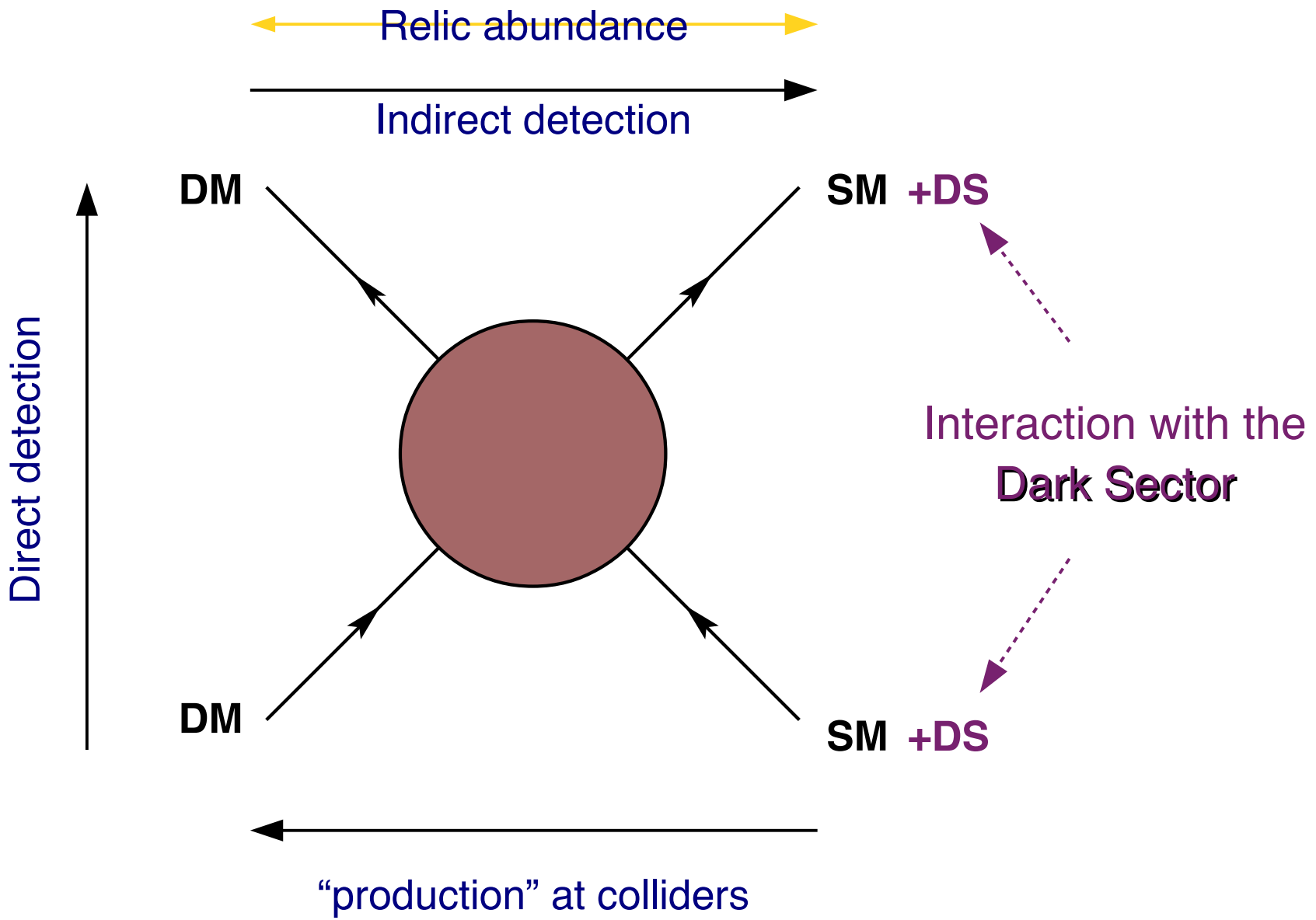
$$T_{\rm DM}^{\rm f.o.} \approx \frac{1}{20} M_{\rm DM}$$

$$\Omega_{\rm CDM} h^2 \simeq 0.1 \frac{3 \times 10^{-26}\ {\rm cm}^3 {\rm s}^{-1}}{\langle \sigma v \rangle_{\rm f.o.}}$$

WIMP dark matter

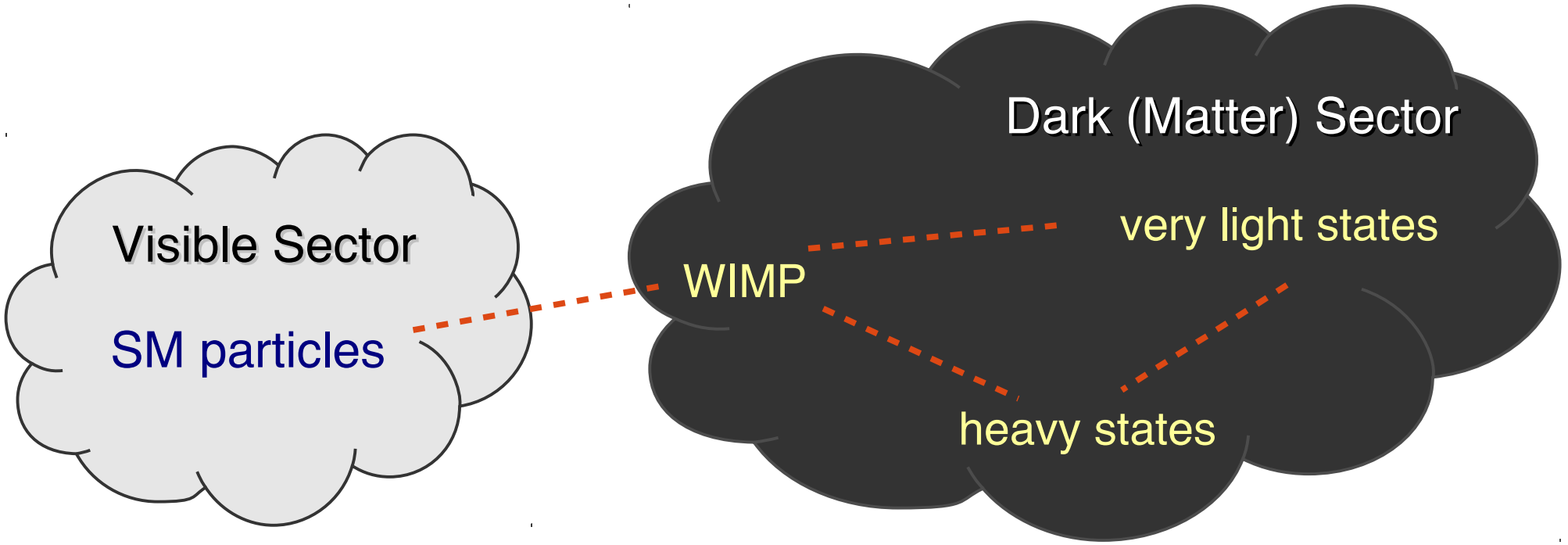


WIMP dark matter



WIMPs and Dark Radiation

Nothing forbids that WIMPs can have interactions with the Dark Sector



Both sectors are in thermal equilibrium only if WIMPs do

$$\langle \sigma v \rangle = \langle \sigma v \rangle_{\rm SM} + \langle \sigma v \rangle_{\rm DS}$$

WIMPs and Dark Radiation

Indeed, temperatures for WIMP freeze-out and the DS decoupling are related:

$$\frac{T_{\rm D}}{T_{\rm DM}^{\rm f.o.}} \simeq \frac{18 + \log\left(\dfrac{\langle\sigma v\rangle}{3\times10^{-27}\,{\rm cm^3 s^{-1}}}\,\dfrac{M_{\rm DM}}{\rm GeV}\right)}{18 + \log\left(\dfrac{\langle\sigma v\rangle_{\rm DS}}{3\times10^{-27}\,{\rm cm^3 s^{-1}}}\,\dfrac{M_{\rm DM}}{\rm GeV}\right)}$$

allowing us to explore the contribution of relativistic dof from the Dark Sector in the Early Universe:

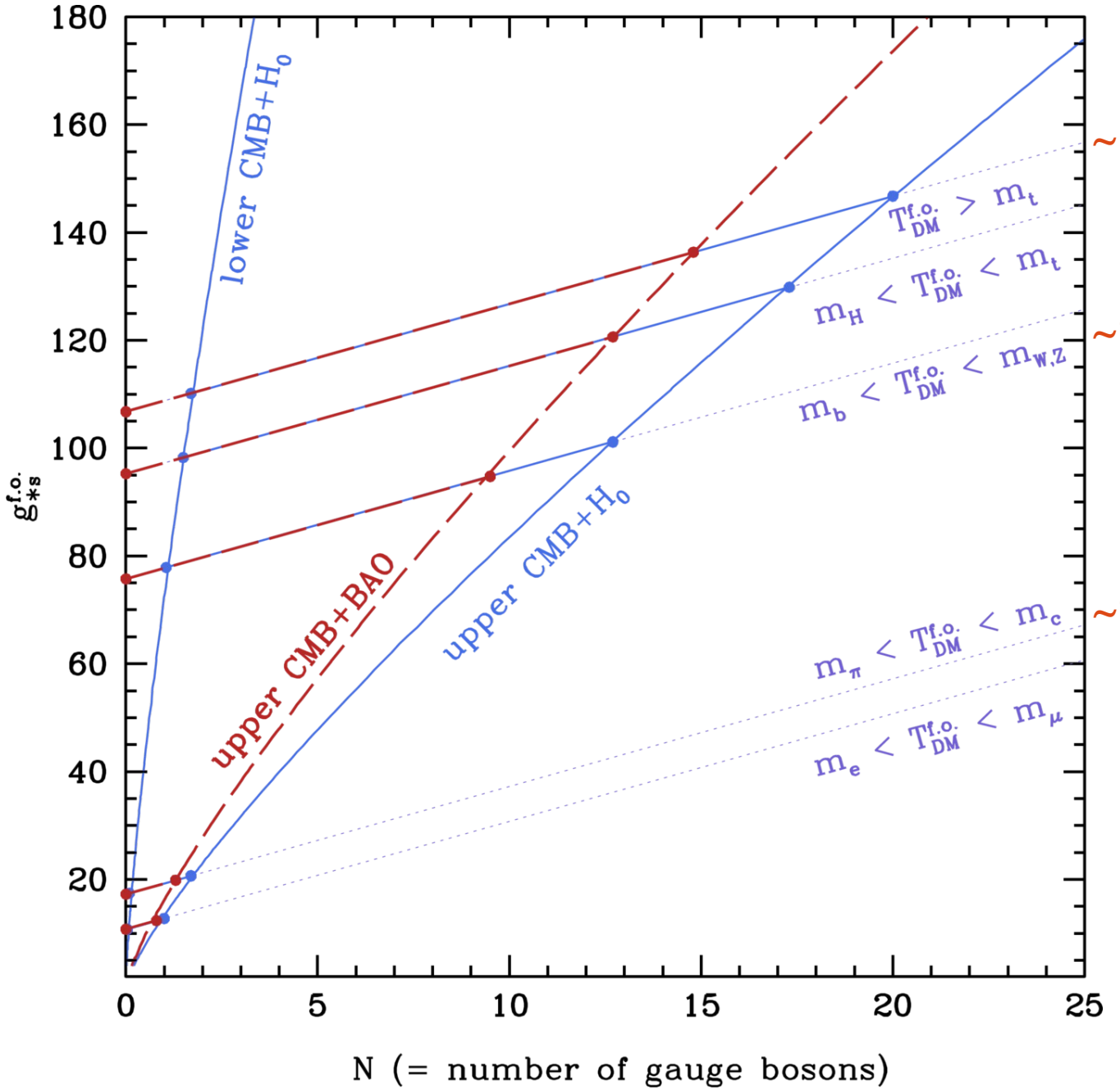
$$\Delta N_{\rm eff} \approx 4.402\,N\left(\frac{3.91}{g_{*s}^{\rm f.o.} - 2N}\right)^{4/3}$$

N dark gauge bosons

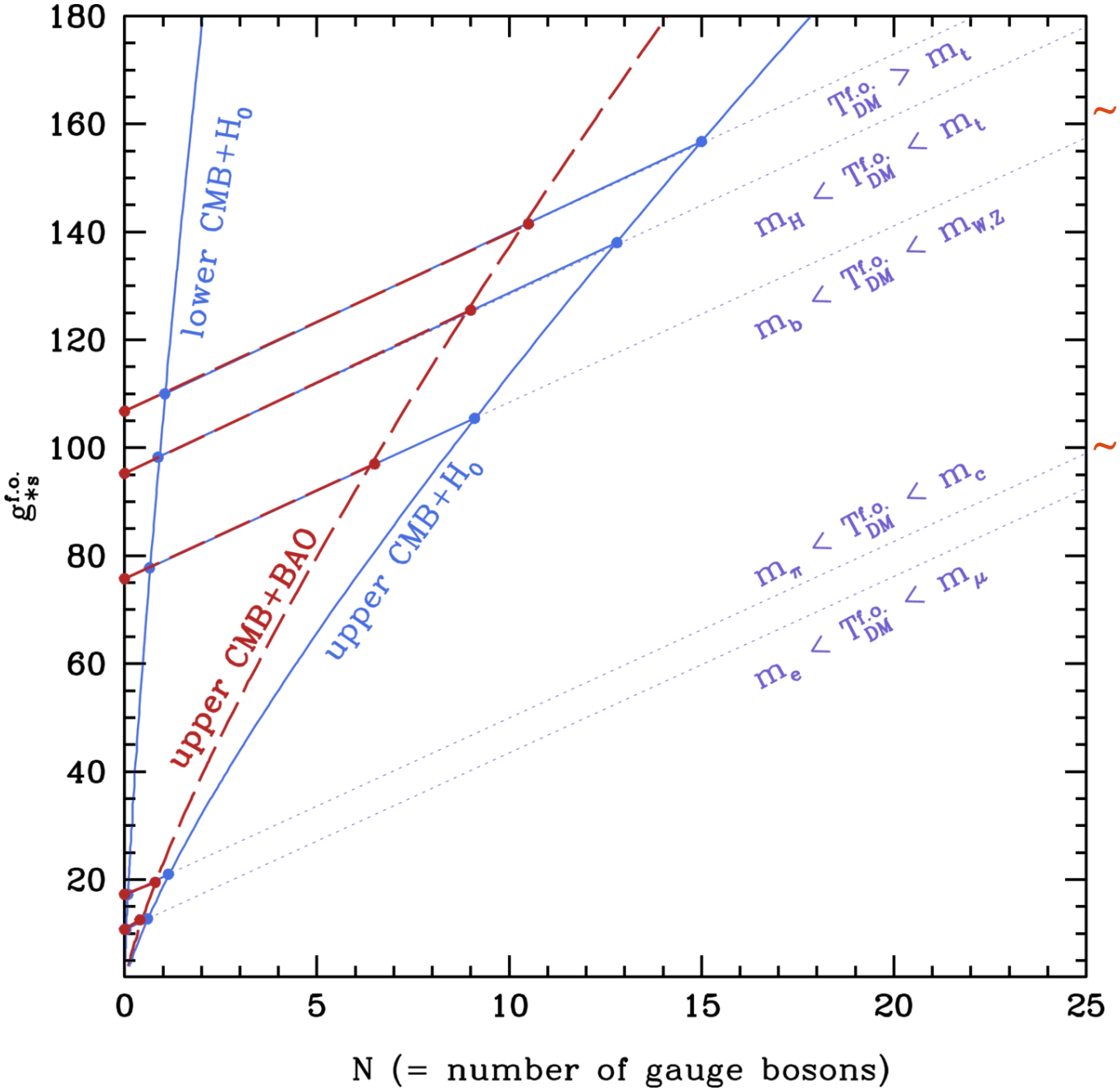
$$\Delta N_{\rm eff} \approx 7.369\,N\left(\frac{3.91}{g_{*s}^{\rm f.o.} - 3.91\,N}\right)^{4/3}$$

+3 dark fermions

N dark gauge bosons



+3 dark fermions



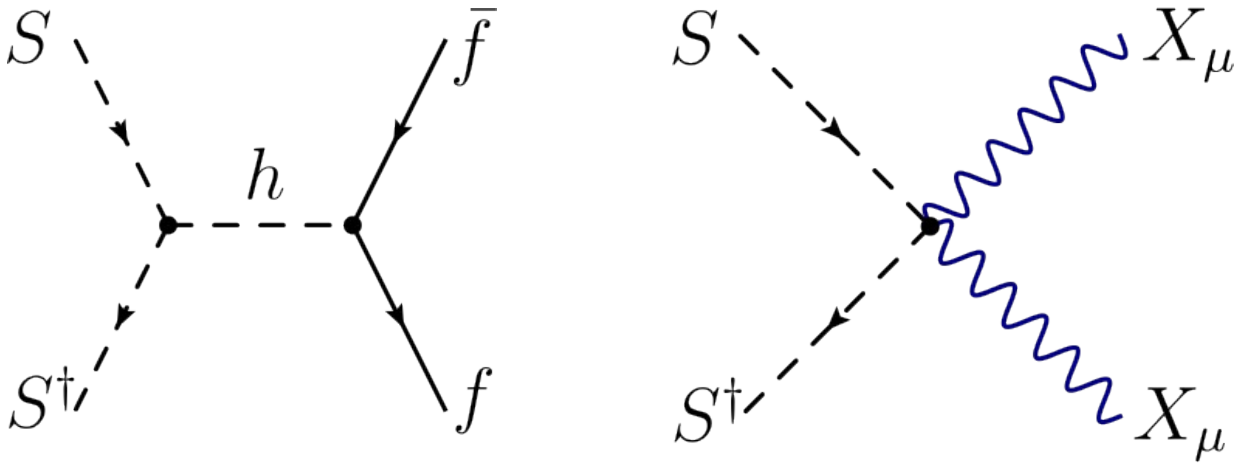
A prototype particle model

A possible realization of the idea is:

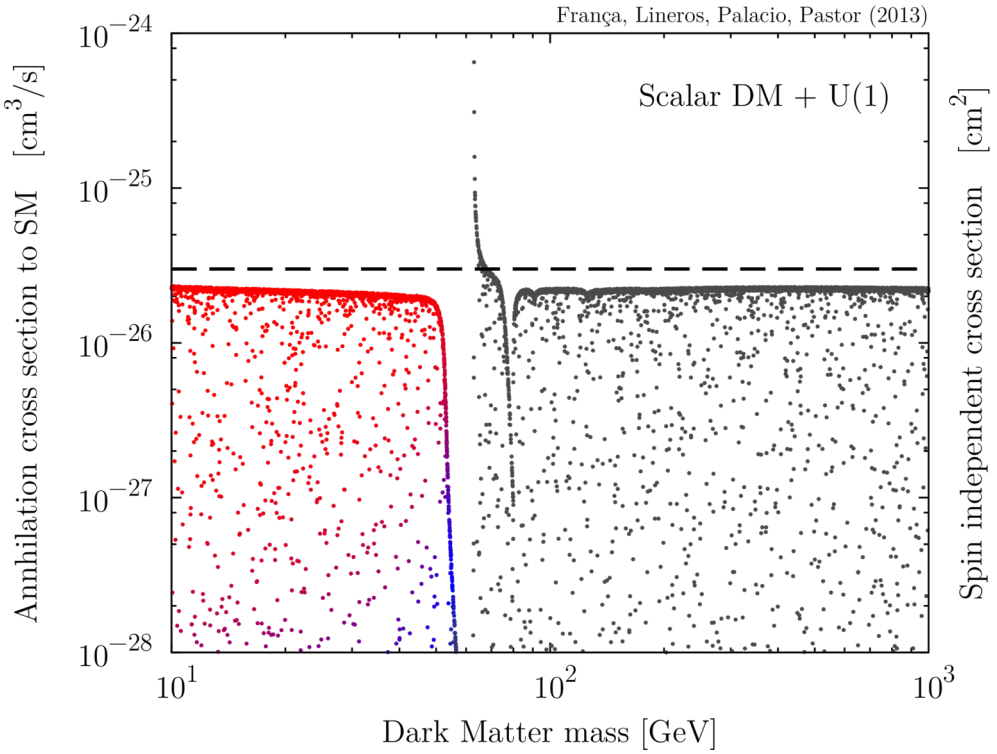
$$\mathcal{L}_{\rm SM} \supset -\frac{1}{4}\hat{X}^{\mu\nu a}\hat{X}^{a}_{\mu\nu} + (D^{\mu}S)^{\dagger}D_{\mu}S - m^{2}_{\rm DM}S^{\dagger}S - V_{\rm scalar}$$

$$V_{\rm scalar} = a_2(H^{\dagger}H - \frac{v^2}{2})S^{\dagger}S + a_4(S^{\dagger}S)^2$$

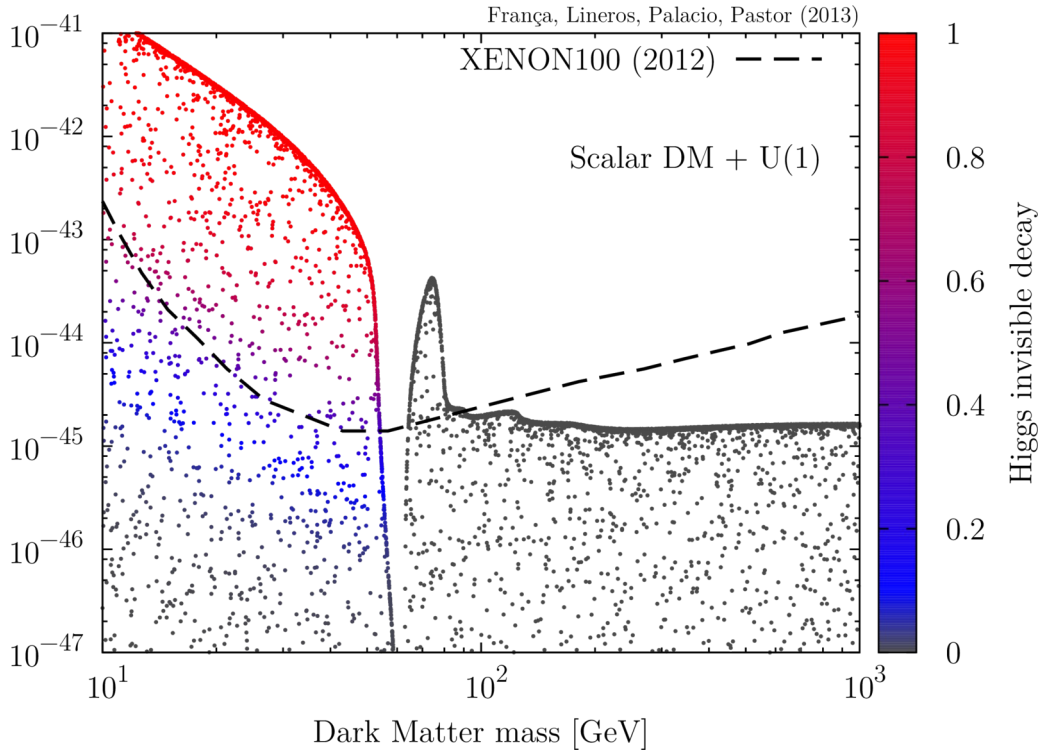
Scalar DM with a SU(N) symmetry



Scalar DM + U(1)

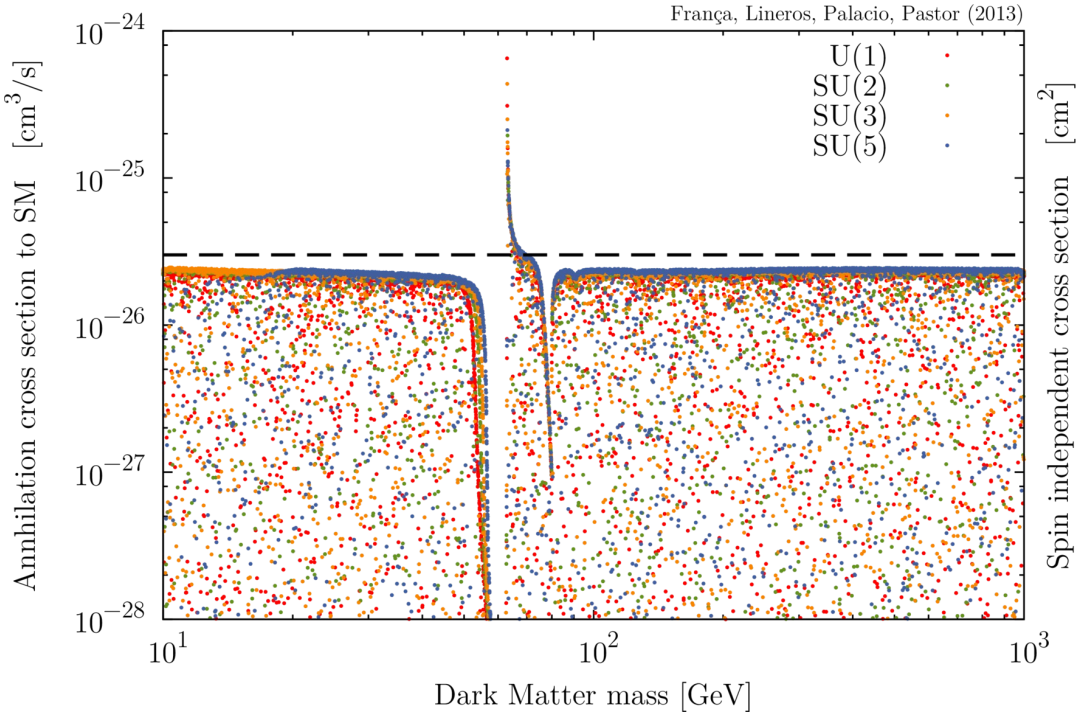


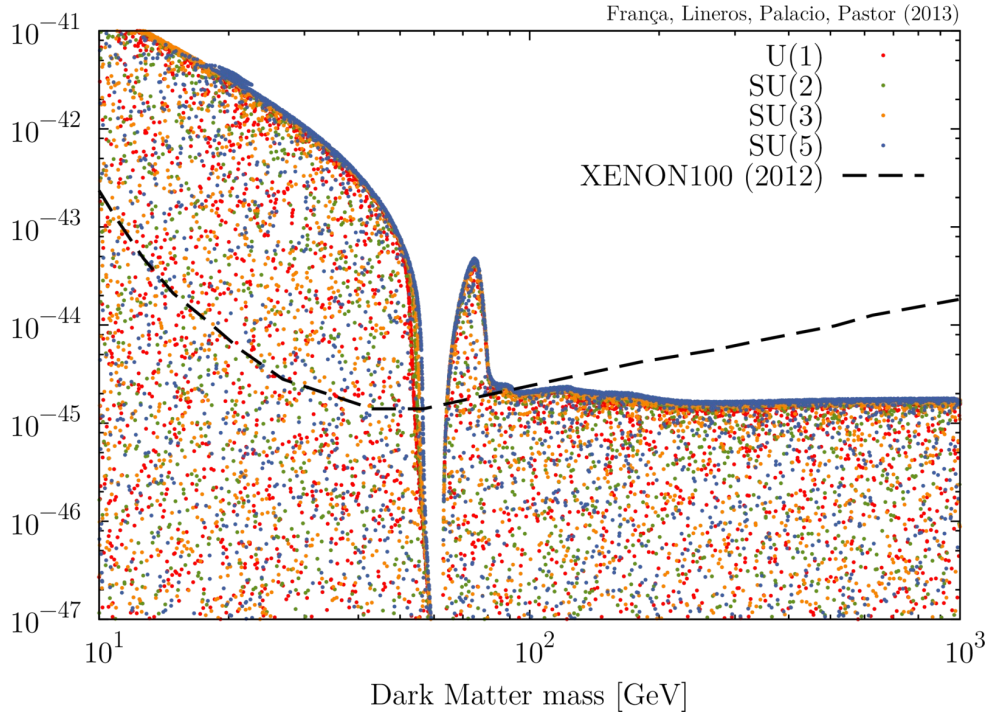
Indirect detection cross section



Direct detection cross section

Scalar DM + SU(N)

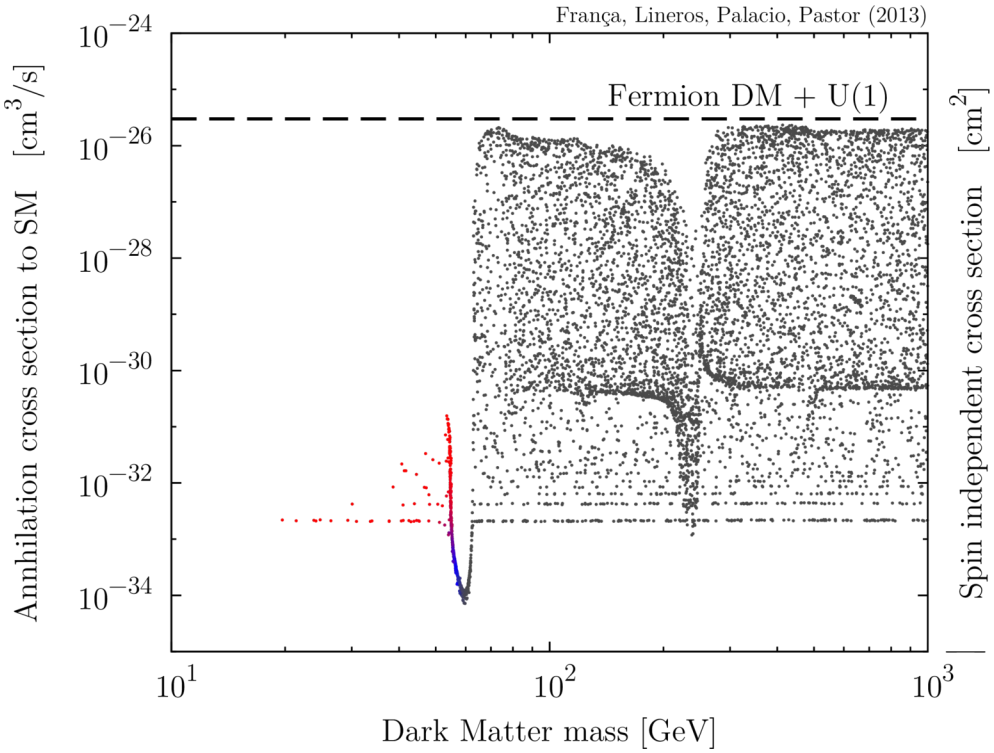


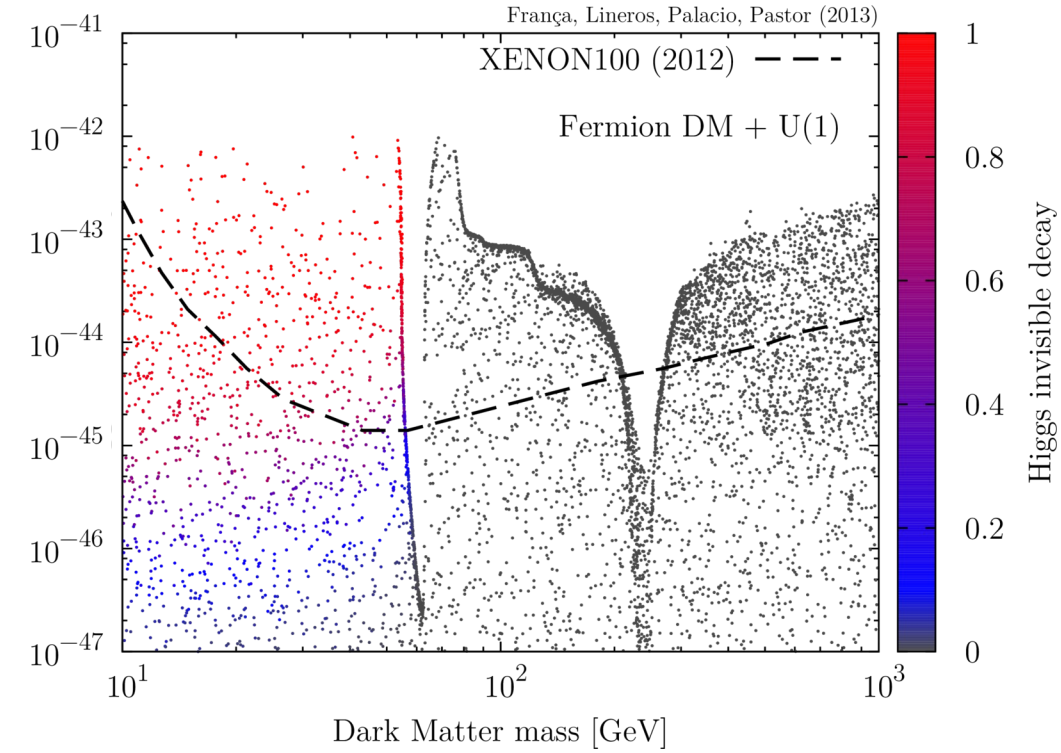


Indirect detection cross section

Direct detection cross section

Fermion DM + U(1)





It also works for fermion DM (+ scalar singlet) + SU(N)

Indirect detection cross section

Direct detection cross section

Conclusions

- The interactions only present in the Dark Sector can be observed

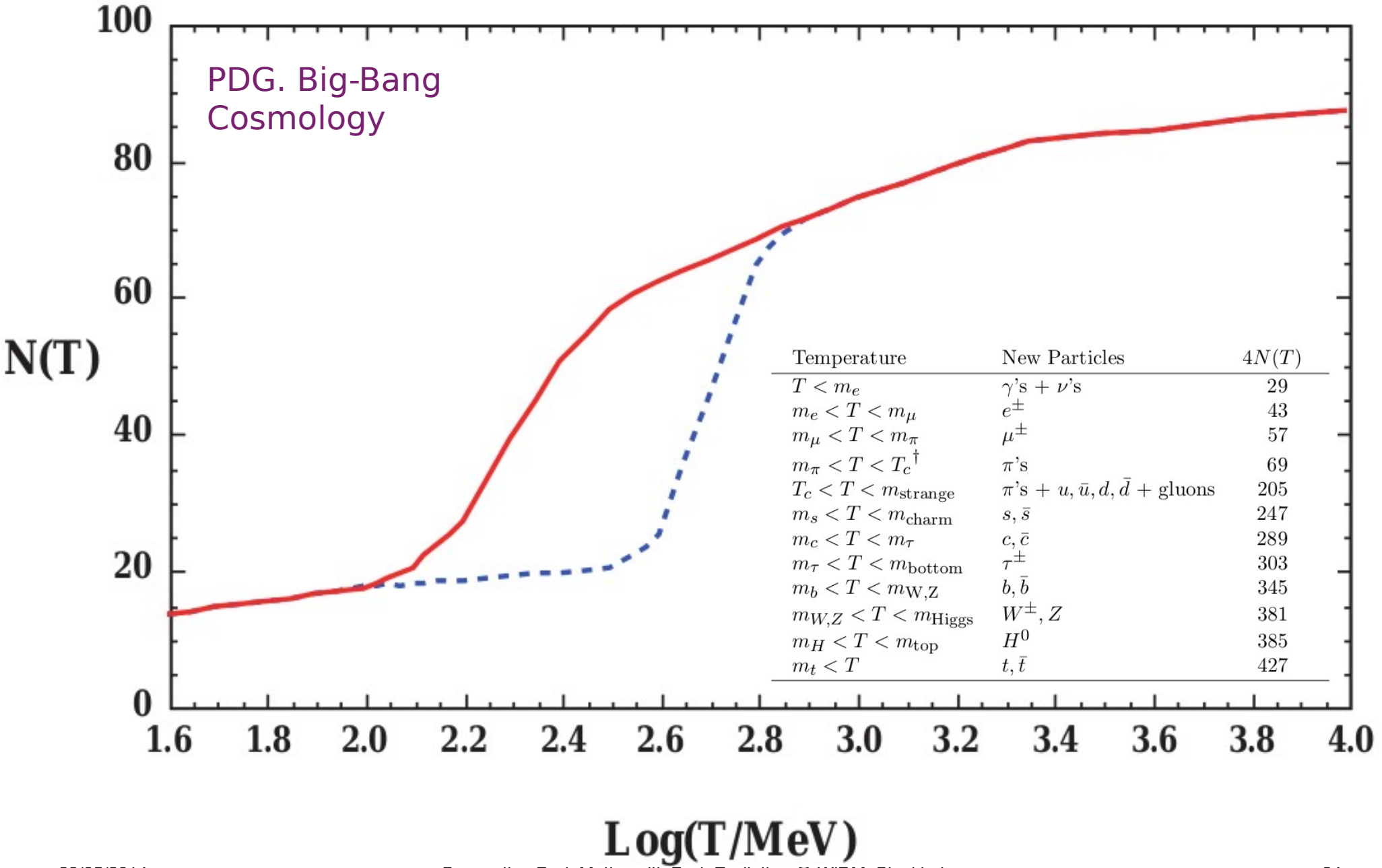
- The latest results on Neff allow a maximum of 20 dark gauge bosons for TeV WIMPs and 13 for ~100 GeV WIMPs

- WIMP annihilations in DS reduce the signal on indirect and direct searches allowing to surpass current exclusion zone

Thanks for you attention

Backup slides

Relativistic dof of the SM



Temperature	New Particles	$4N(T)$
$T < m_e$	γ's + ν's	29
$m_e < T < m_\mu$	$e^\pm$	43
$m_\mu < T < m_\pi$	$\mu^\pm$	57
$m_\pi < T < T_c$ [†]	π's	69
$T_c < T < m_{\rm strange}$	π's + $u, \bar{u}, d, \bar{d}$ + gluons	205
$m_s < T < m_{\rm charm}$	$s, \bar{s}$	247
$m_c < T < m_\tau$	$c, \bar{c}$	289
$m_\tau < T < m_{\rm bottom}$	$\tau^\pm$	303
$m_b < T < m_{\rm W,Z}$	$b, \bar{b}$	345
$m_{W,Z} < T < m_{\rm Higgs}$	$W^\pm, Z$	381
$m_H < T < m_{\rm top}$	H^0	385
$m_t < T$	$t, \bar{t}$	427