IMPACT OF PLANCK DATA ON DARK MATTER SEARCHES

Céline Boehm, IPPP

DM status

<15 years ago: DM = neutralino (or axion). Range: from 10 GeV to < TeV

10 years ago (INTEGRAL/SPI): DM can be light!

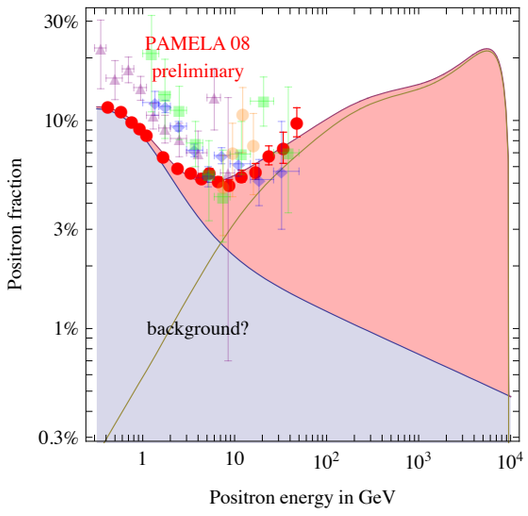
1 year before SPI

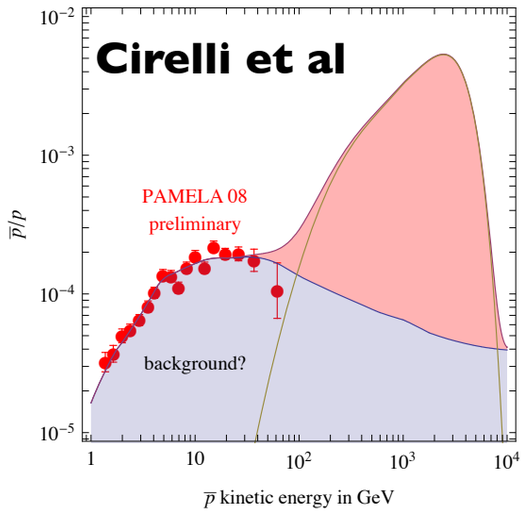
Are light annihilating Dark Matter particles possible?

C. Boehm[1], T. A. Enßlin[2], J. Silk[1]
[1] *Denys Wilkinson Laboratory, Astrophysics Department, OX1 3RH Oxford, England UK;*
[2] *Max-Planck-Institut für Astrophysik Karl-Schwarzschild-Str. 1, Postfach 13 17, 85741 Garching*
(Dated: 22 August 2002)

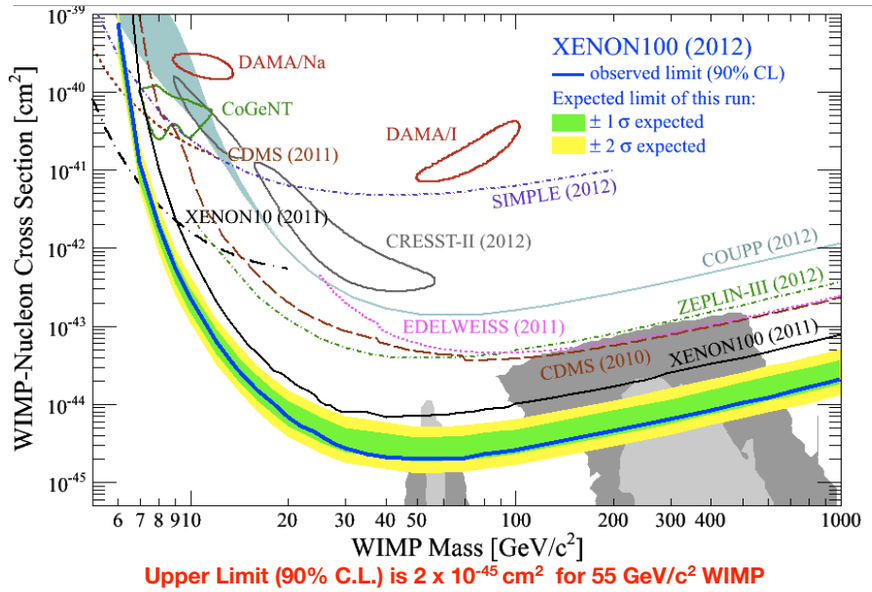
We investigate the status of light Dark Matter (DM) particles from their residual annihilation and discuss the range of the DM mass and total annihilation cross section compatible with gamma-rays experiment data. We find that particles as light as a few 10 MeV or up to ∼ 10 GeV could perhaps represent an interesting alternative to the standard picture of very massive WIMPs. astro-ph/0208458

5 years ago (PAMELA): DM can be very heavy (>TeV)!





XENON100: New Spin-Independent Results



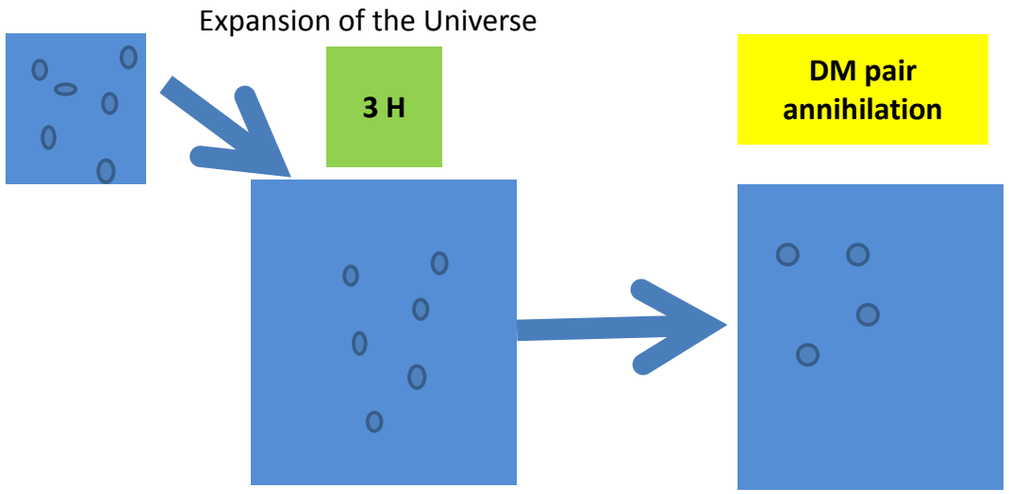
Upper Limit (90% C.L.) is 2 x 10^{-45} cm² for 55 GeV/c² WIMP

Wednesday, July 18, 2012

2-3 years ago (CoGeNT/CRESST/CDMS): DM can be very heavy (mdm >TeV)!

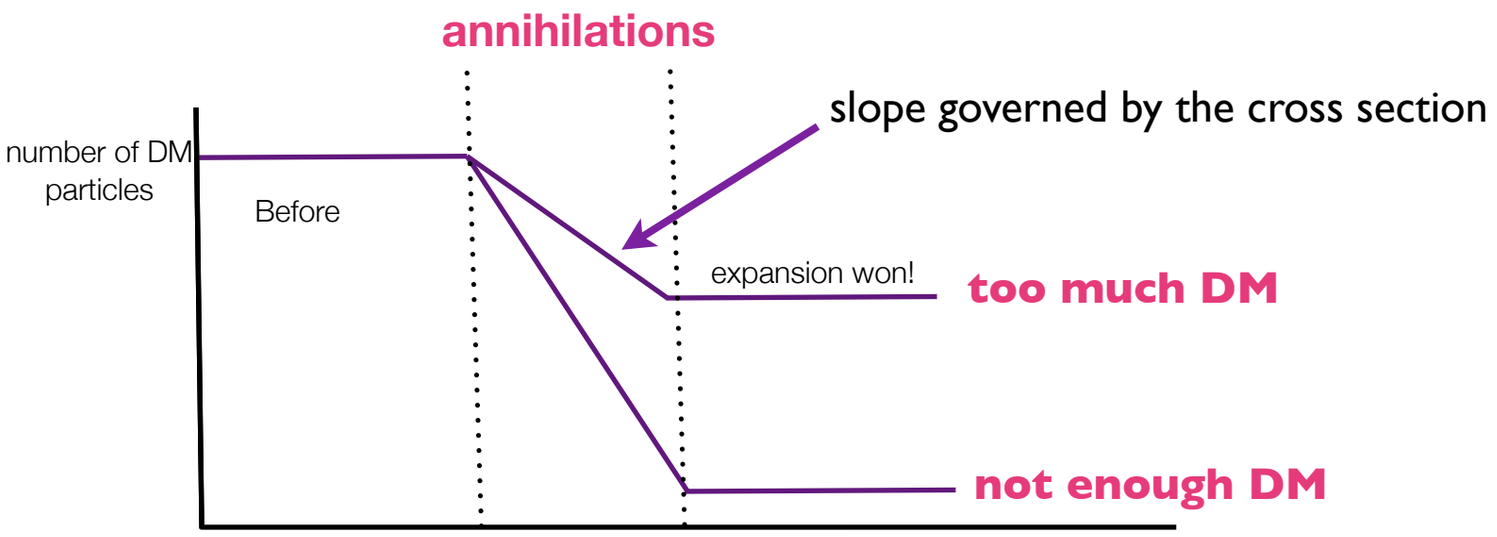
RELIC DENSITY
COSMOLOGICAL PARAMETERS

Evolution of the DM number density



Boltzmann equation requires **NO** Particle Physics input !

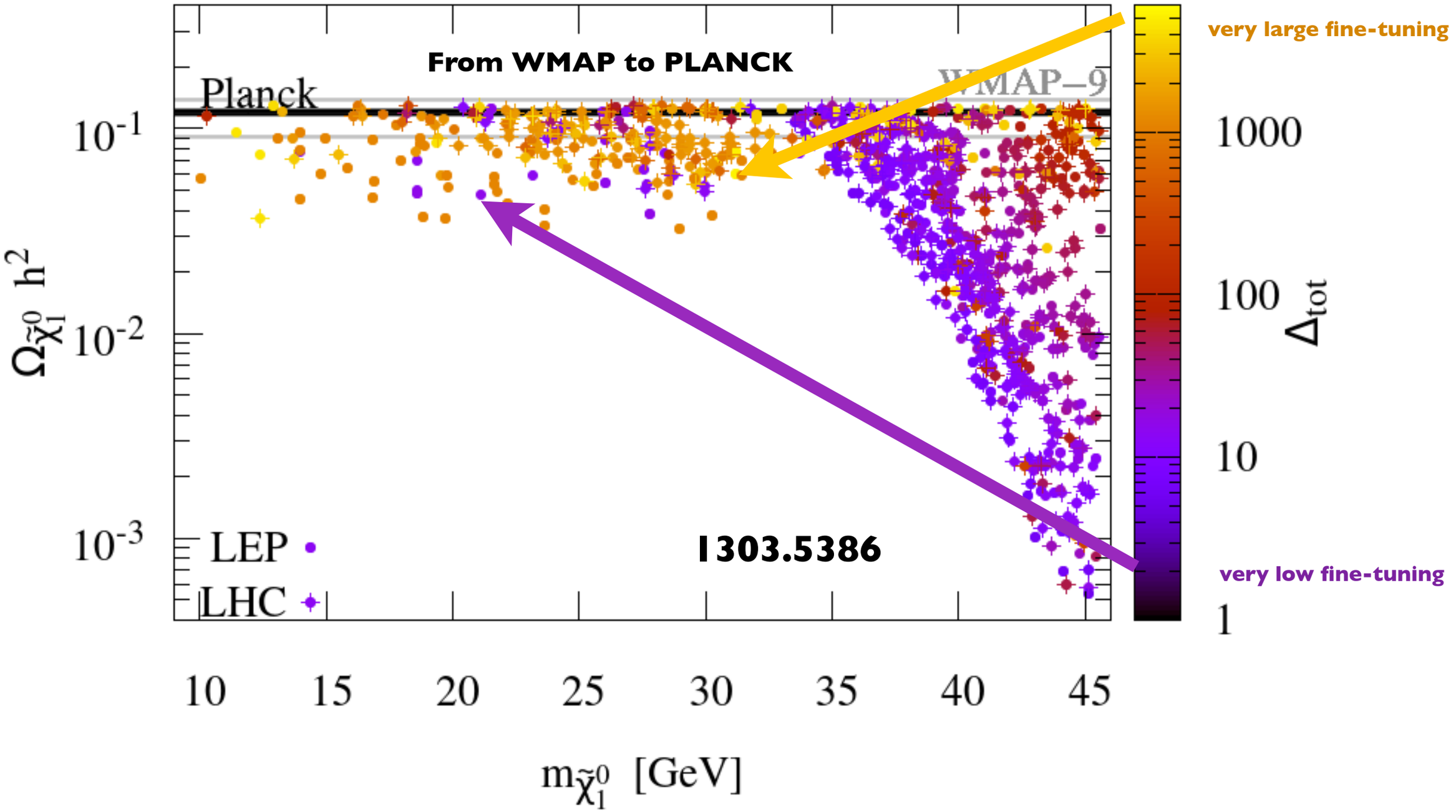
Importance of measuring Omega h^2



Only one value of the cross section works!

$$\langle \sigma v \rangle = \frac{3.\ 10^{-27} cm^3/s}{\Omega_{dm} h^2}$$

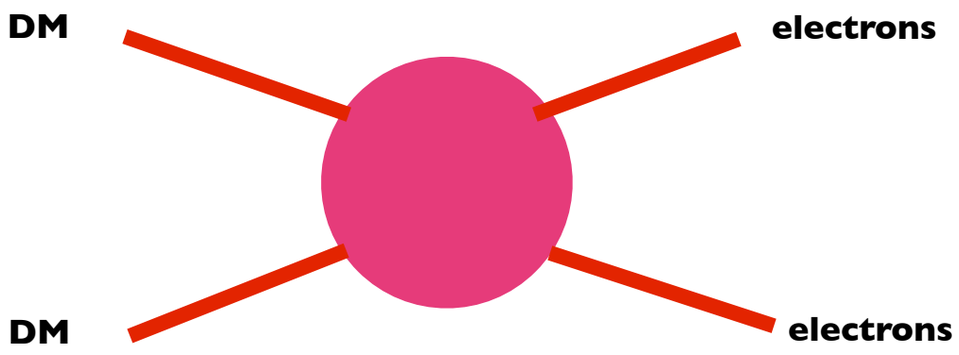
RELIC DENSITY
EXAMPLE OF THE NEUTRALINO



Reducing the error bars on the relic density (from WMAP to PLANCK), reduces the number of SUSY scenarios and **increases** the fine tuning

Generalisation to other DM models require new mediators

GENERAL DM:
RESIDUAL ANNIHILATIONS
&PLANCK REIONISATION



$$\frac{dE}{dt}(z) = \rho_c^2 c^2 \Omega_{DM}^2 (1+z)^6 p_{ann}, \;\; p_{ann} \equiv f(z)\frac{\langle \sigma v \rangle}{m_\chi}$$

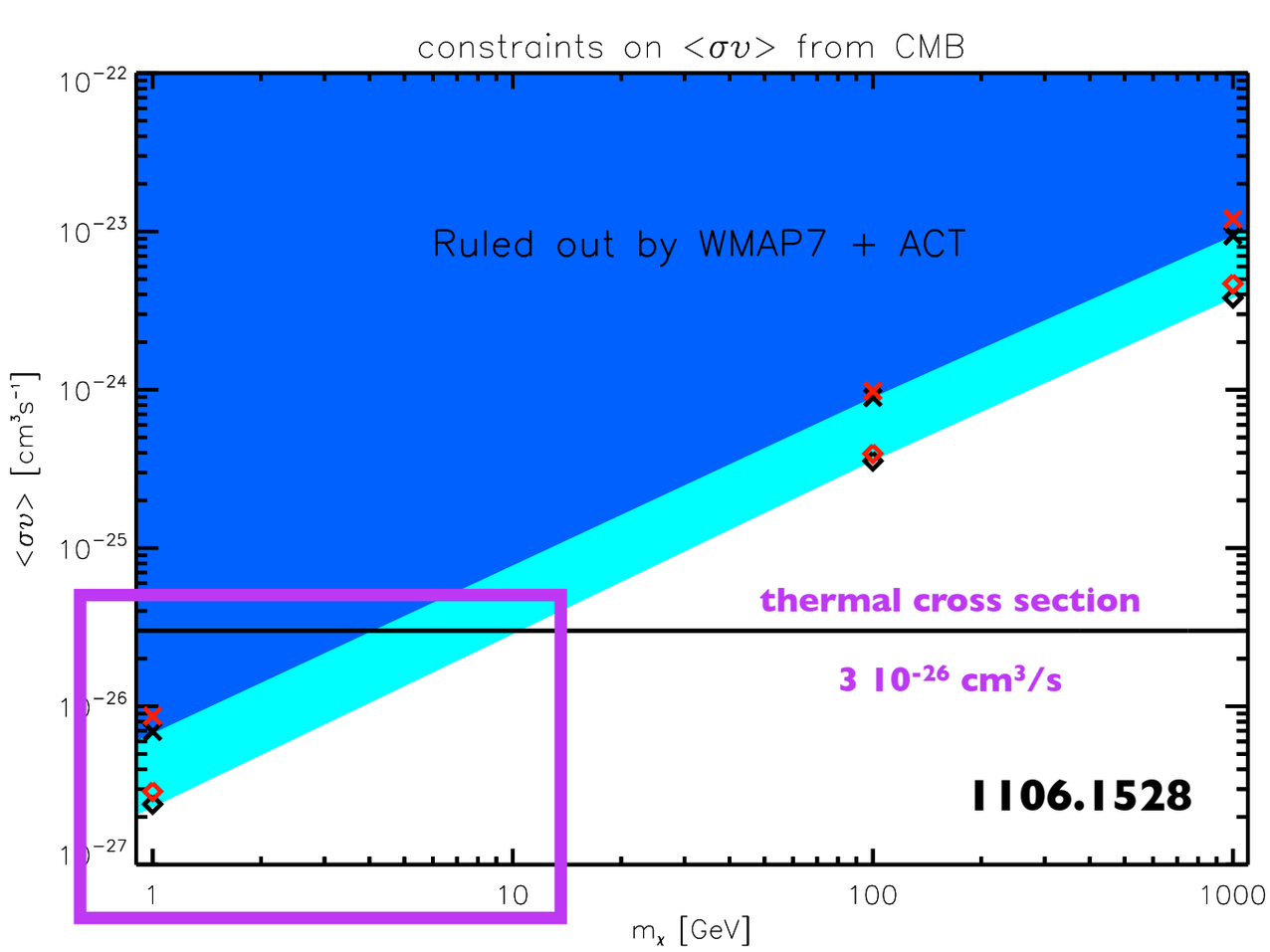
astro-ph/0503486 astro-ph/0603237 arXiv:0907.0719 arXiv:0905.0003

astro-ph/0503486

[DM annihations...] “change the residual ionization after recombination. This broadens the surface of last scattering, suppressing the temperature fluctuations and enhancing the polarization fluctuations.“

s-wave only!!!

PLANCK polarisation should do better soon (1 more year)



LOWER BOUND ON Thermal DM MASS

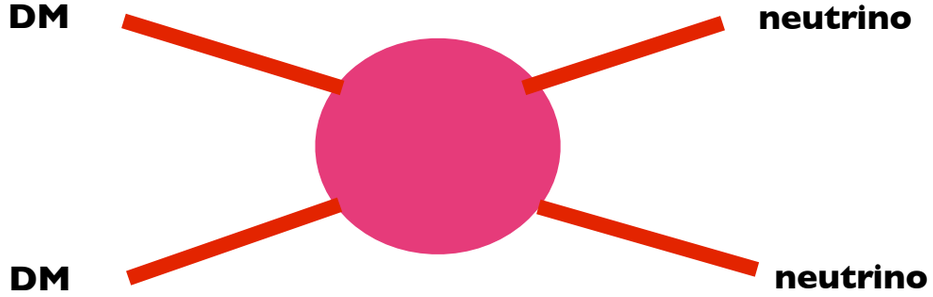
PLANCK & (Neff,Ho)

Céline Bœhm,[1,2] Matthew J. Dolan,[1] and Christopher McCabe[1] **1303.6270**

DM in equilibrium with electrons/photons/neutrinos

Kolb, M. S. Turner, and T. P. Walker, Phys.Rev. D34 (1986), 2197

P. D. Serpico and G. G. Raffelt, Phys.Rev. D70 (2004), 043526



Reheating of the photons due to e^--e^+ annihilations into photons

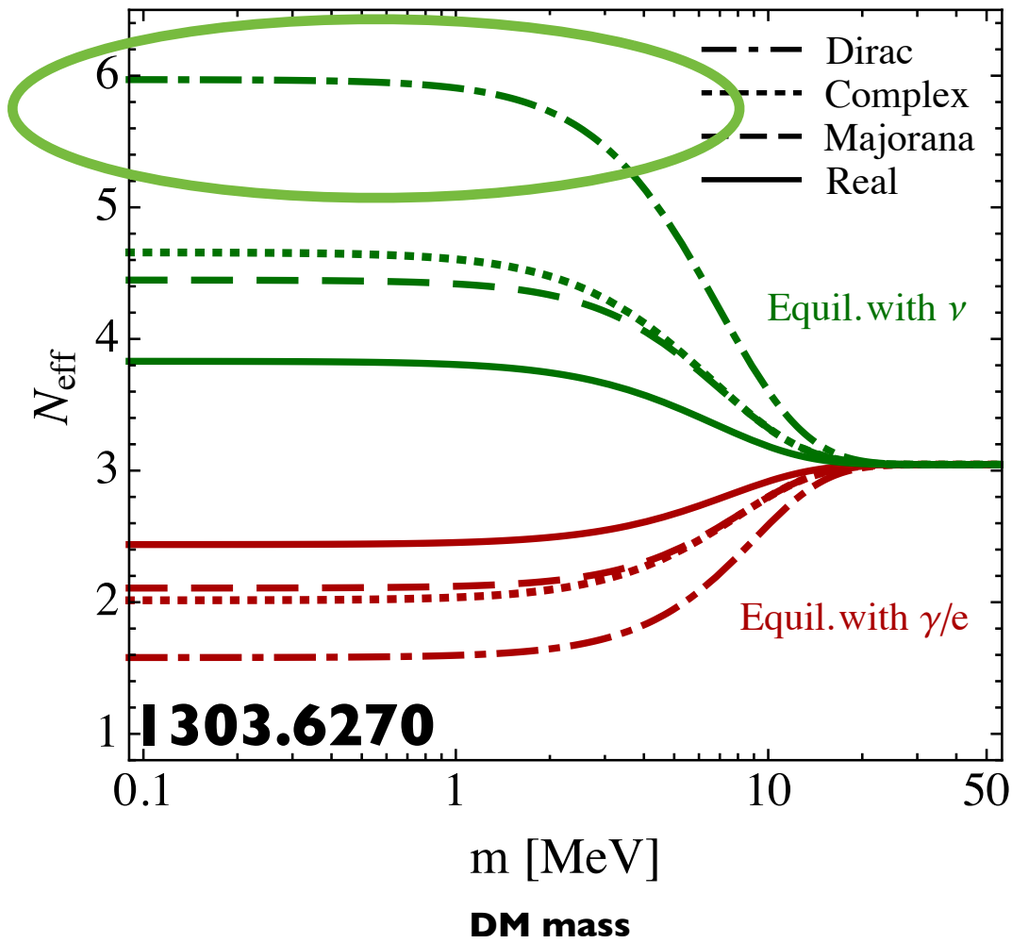
$$\rho \equiv \rho_\gamma \left[1 + \frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{\rm eff}\right]$$

if neutrinos, the reheating can be reinterpreted as an increase in the number of neutrino species

$$\frac{\rho_{\nu+n}}{\rho_\gamma} = \frac{7}{8}\left(\frac{T_\nu}{T_\gamma}\right)^4 \left[N_\nu + \sum_{i=1}^{n} \frac{g_i}{2} I\left(\frac{m_i}{T_\nu}\right)\right]$$

if new species injects neutrinos

$$\frac{T_\nu}{T_\gamma} = \left(\frac{g_{\star s:\nu}}{g_{\star s:\gamma}}\bigg|_{T_{\rm D}} \frac{g_{\star s:\gamma}}{g_{\star s:\nu}} \right)^{1/3}$$



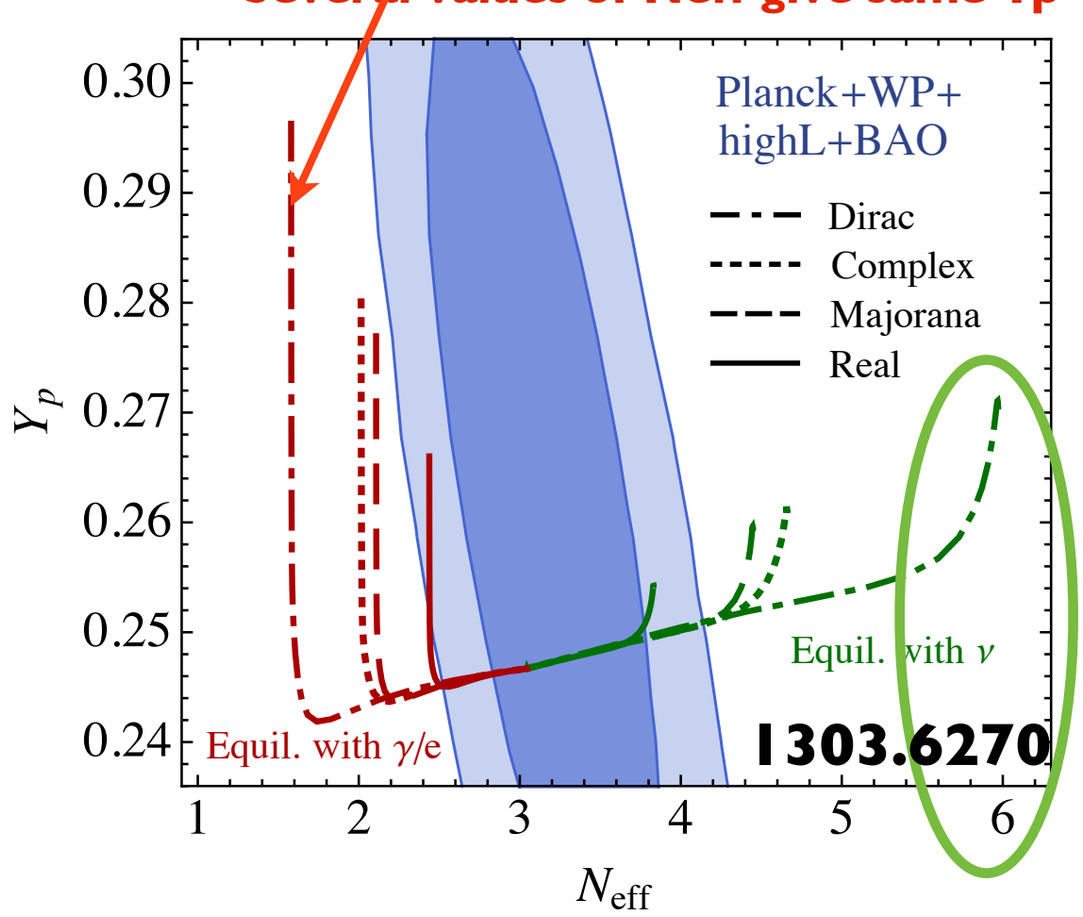
DM mass

$$g_{\star s:\nu} = \frac{14}{8}\left[N_\nu + \sum_{i=1}^{n} \frac{g_i}{2} F\left(\frac{m_i}{T_\nu}\right)\right]$$

DM in thermal equilibrium with neutrinos after BBN increases Neff

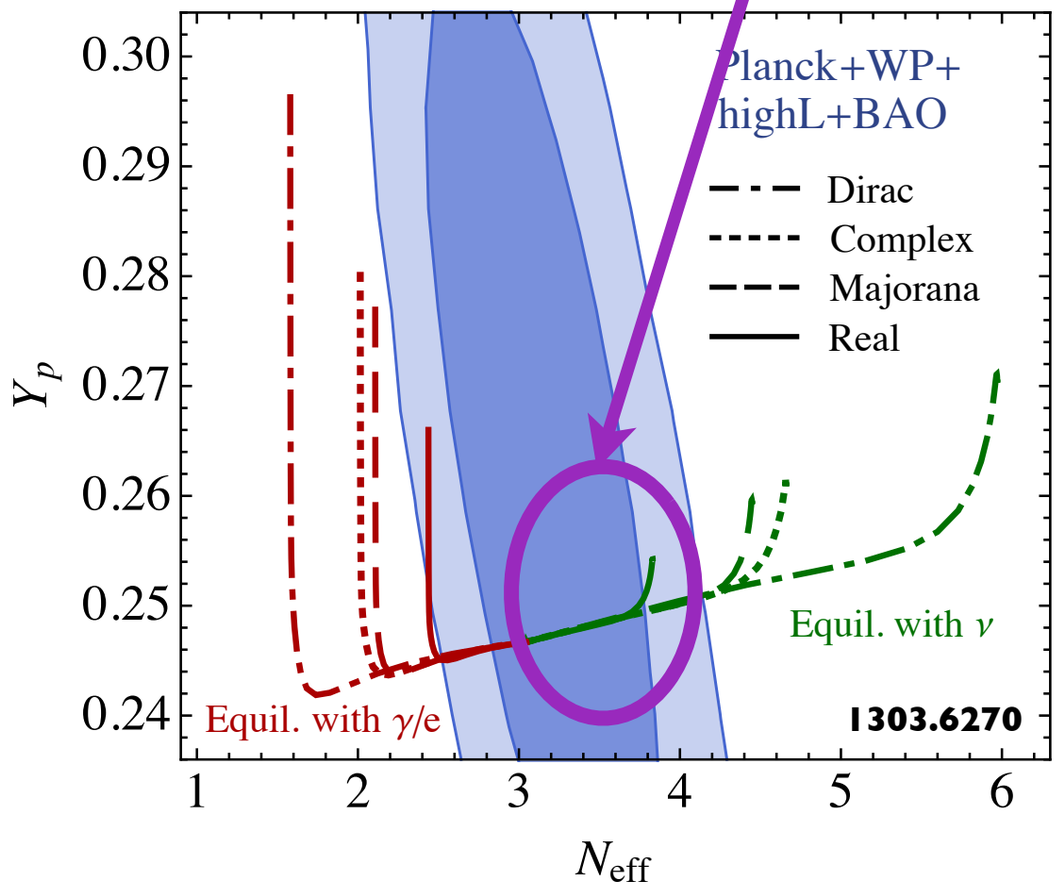
We can therefore set a lower bound on the DM mass

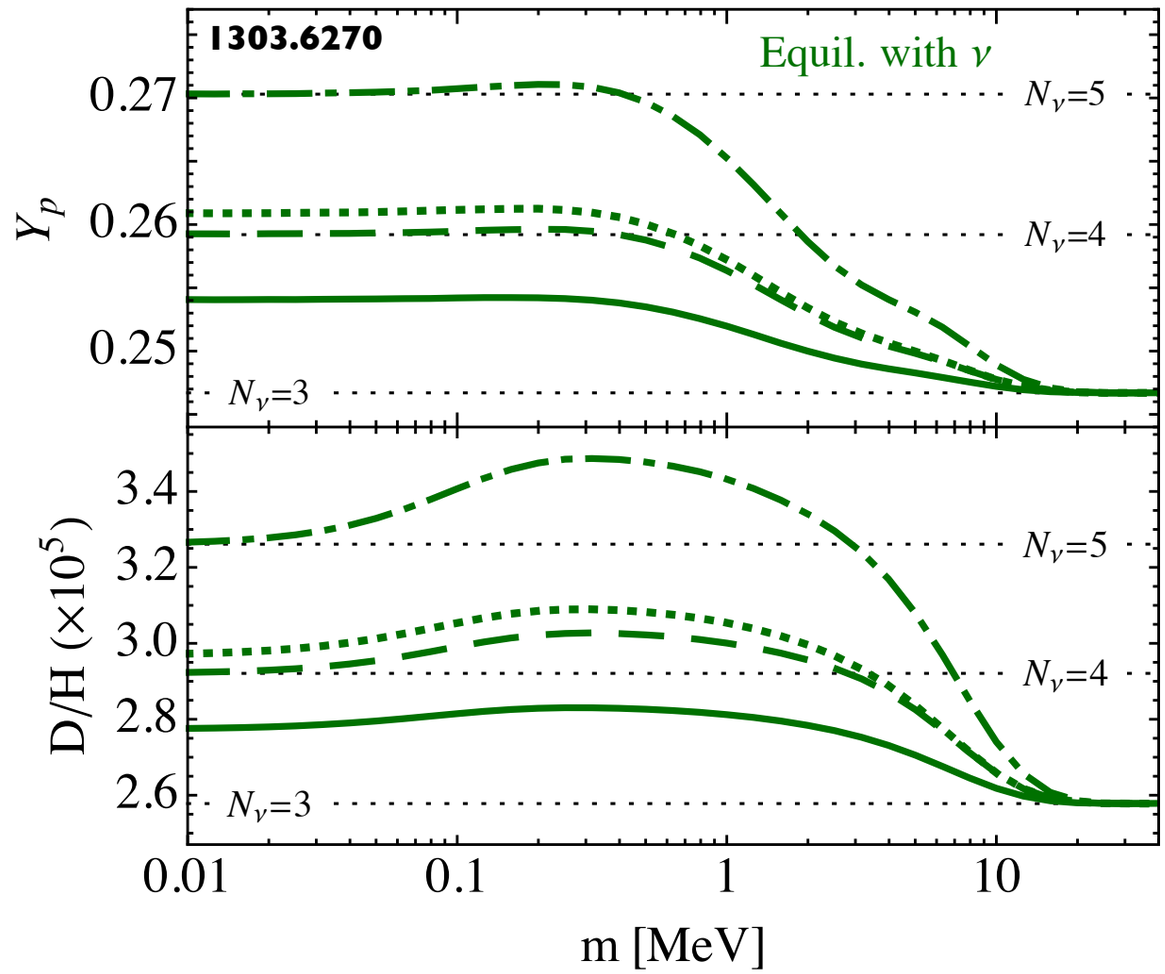
Saturation of Neff, increase of Yp
Several values of Neff give same Yp



DM masses ruled out by PLANCK

Real scalar	No constraint
Complex scalar	$m < 3.9$ MeV
Majorana fermion	$m < 3.5$ MeV
Dirac fermion	$m < 7.3$ MeV





Note that Neff < 4 in this scenario, despite reheating the neutrinos!

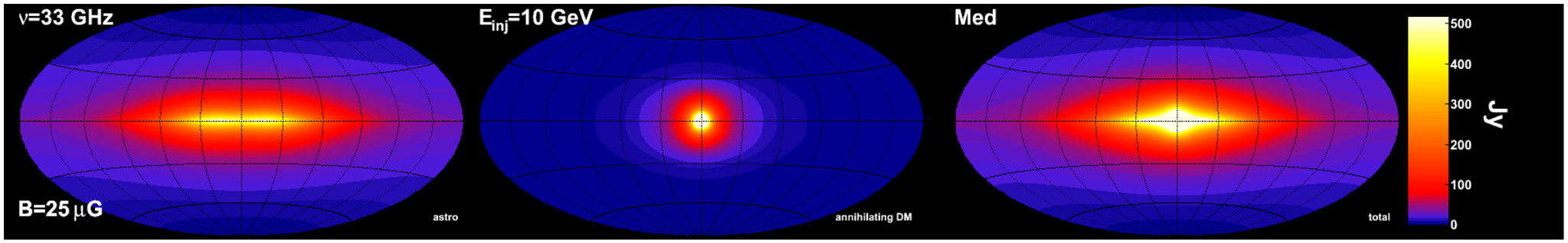
MORPHOLOGY OF ANNIHILATIONS

PLANCK FOREGROUND

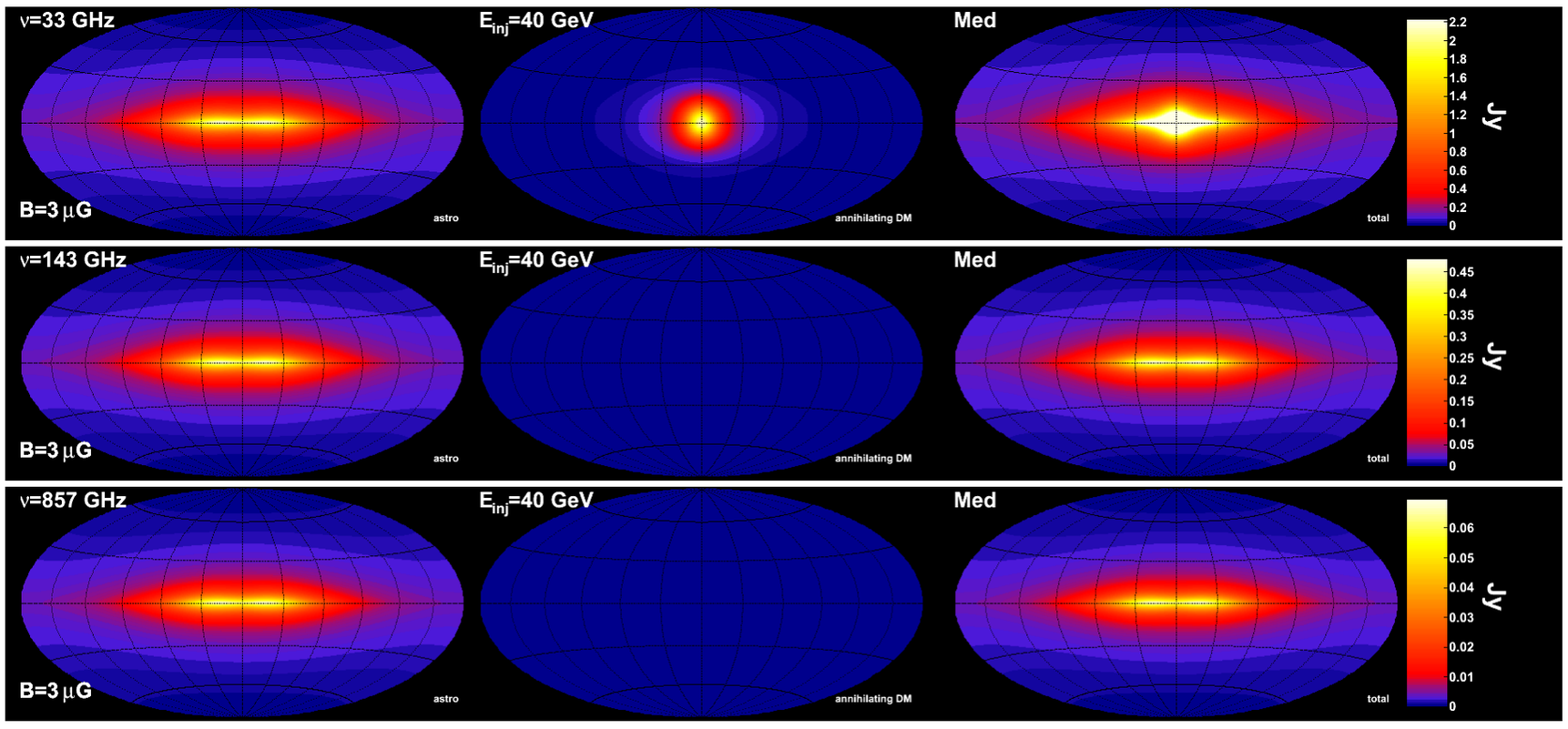
Timur Delahaye[1], Céline Bœhm[2,3] and Joseph Silk 1105.4689

10 GeV

Astro **DM** **DM+Astro**



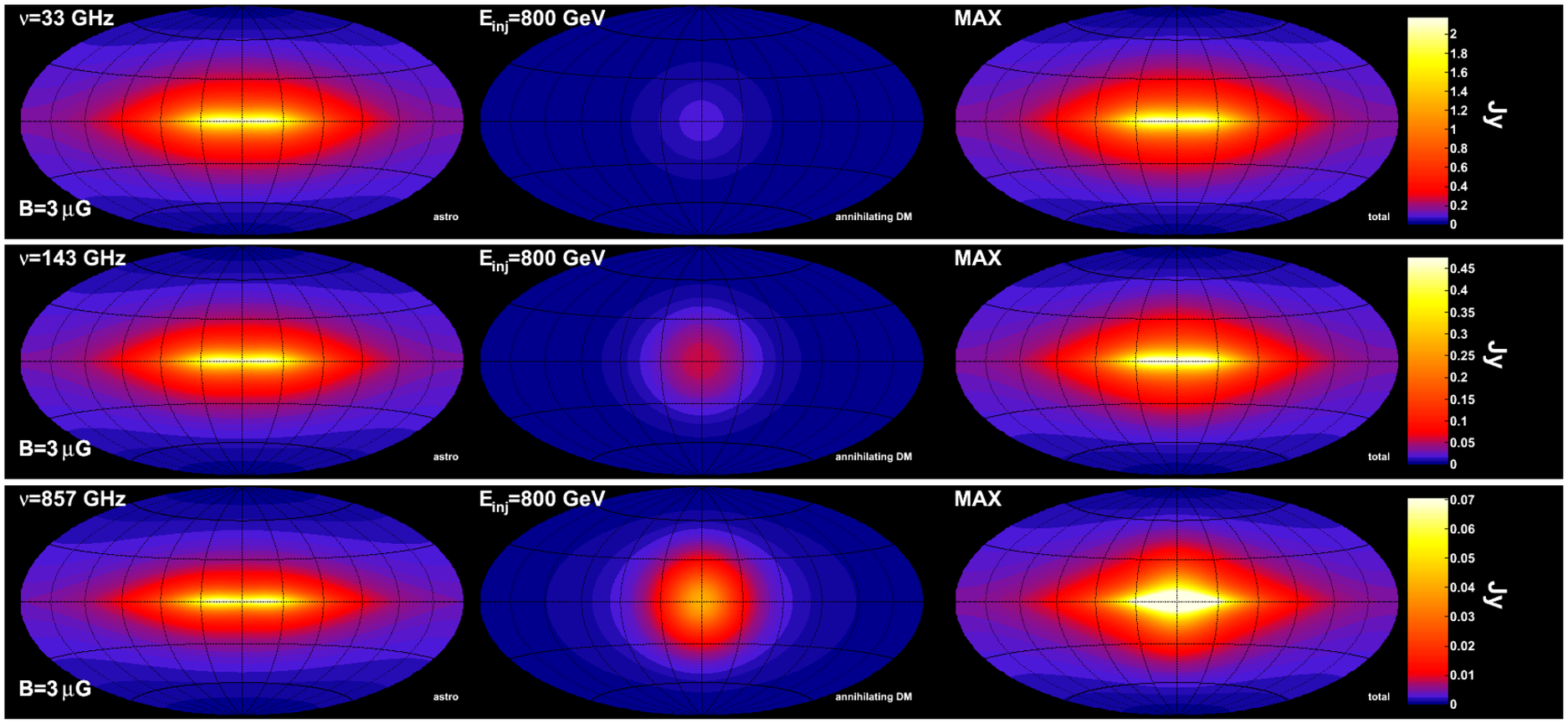
40 GeV



MORPHOLOGY:
Taking advantage of HFI

800 GeV

Astro **DM** **DM+Astro**



1105.4689

HFI can in principle discover very heavy particles by comparing with LFI (who should have no signal);
(background normalisation issue!)

CONCLUSION

Planck is a powerful tool to study DM !

* **relic density** = massive fine tuning for SUSY and others
* **reionisation** = confirm p-wave needed below 10 GeV
* **Neff** = thermal dm must be > MeV (unless real scalar)

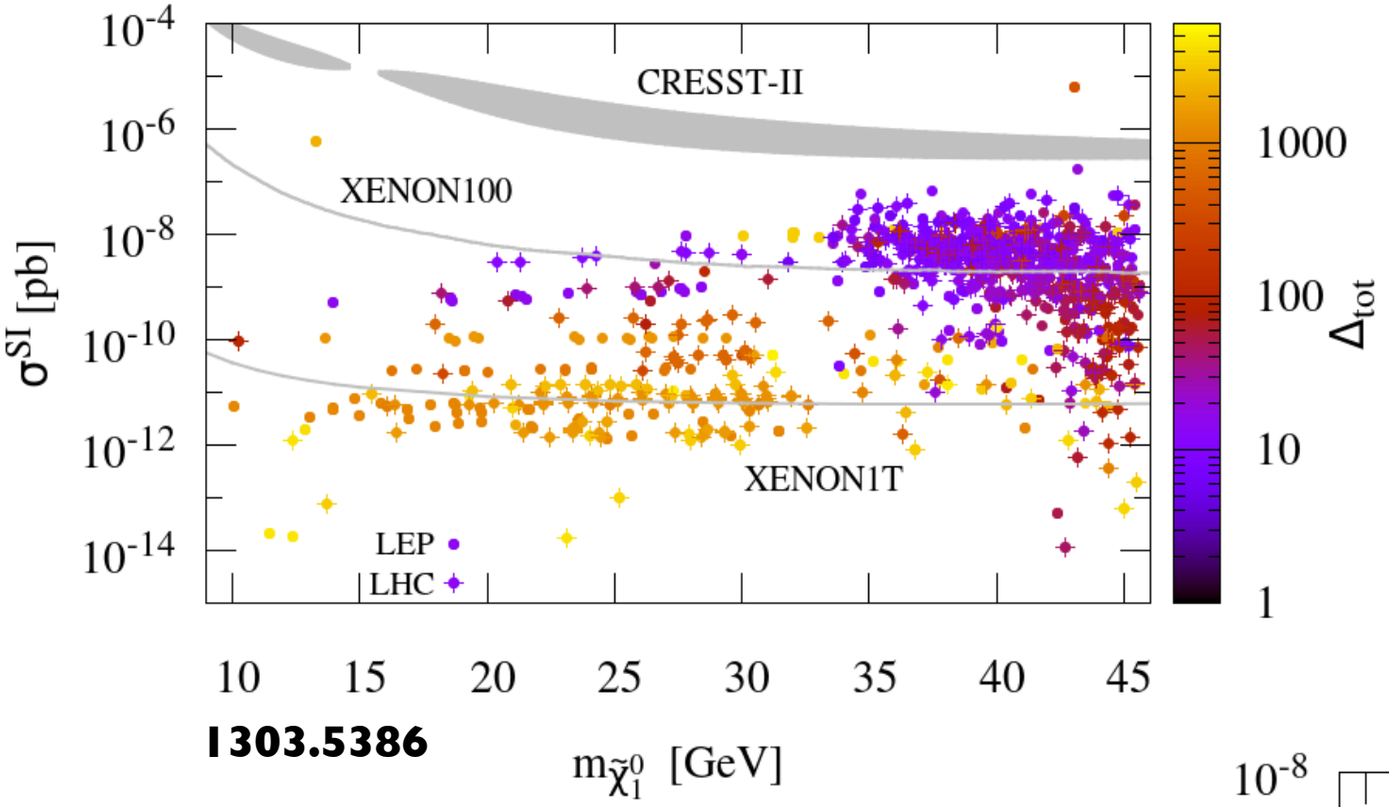
* **morphology of synchrotron emission**
* **and much more in fact!**

To progress further we need, e.g.:

* **the polarisation data**
* **a careful study of the foreground**

Céline Boehm, IPPP

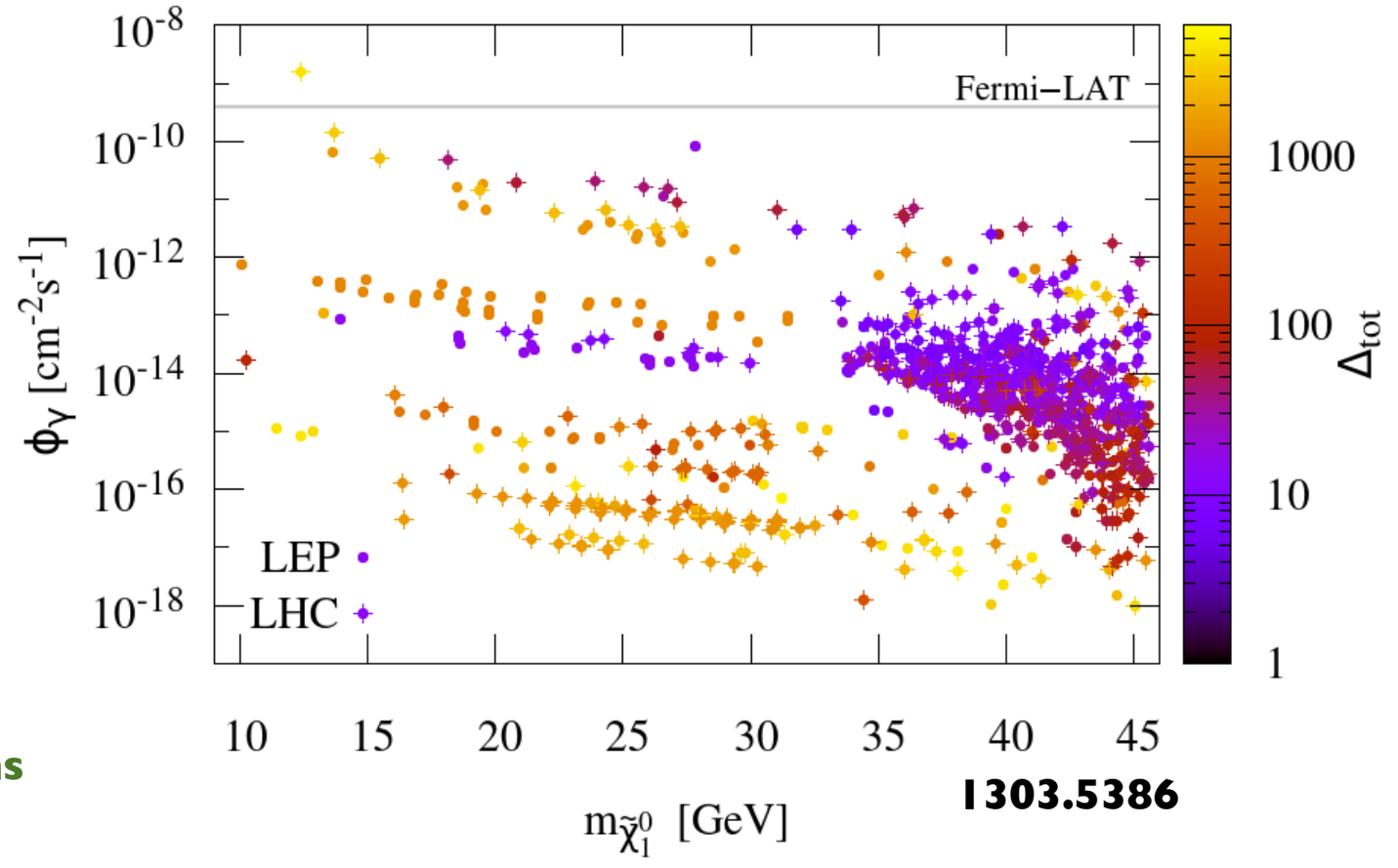
DM DIRECT/INDIRECT DETECTION



Fine-tuned configurations (as required by PLANCK) can be hard to found in Direct Detection experiments although XENON1T is on its way...

Again this forces one to consider light Z'/ H' if DM is relatively light.

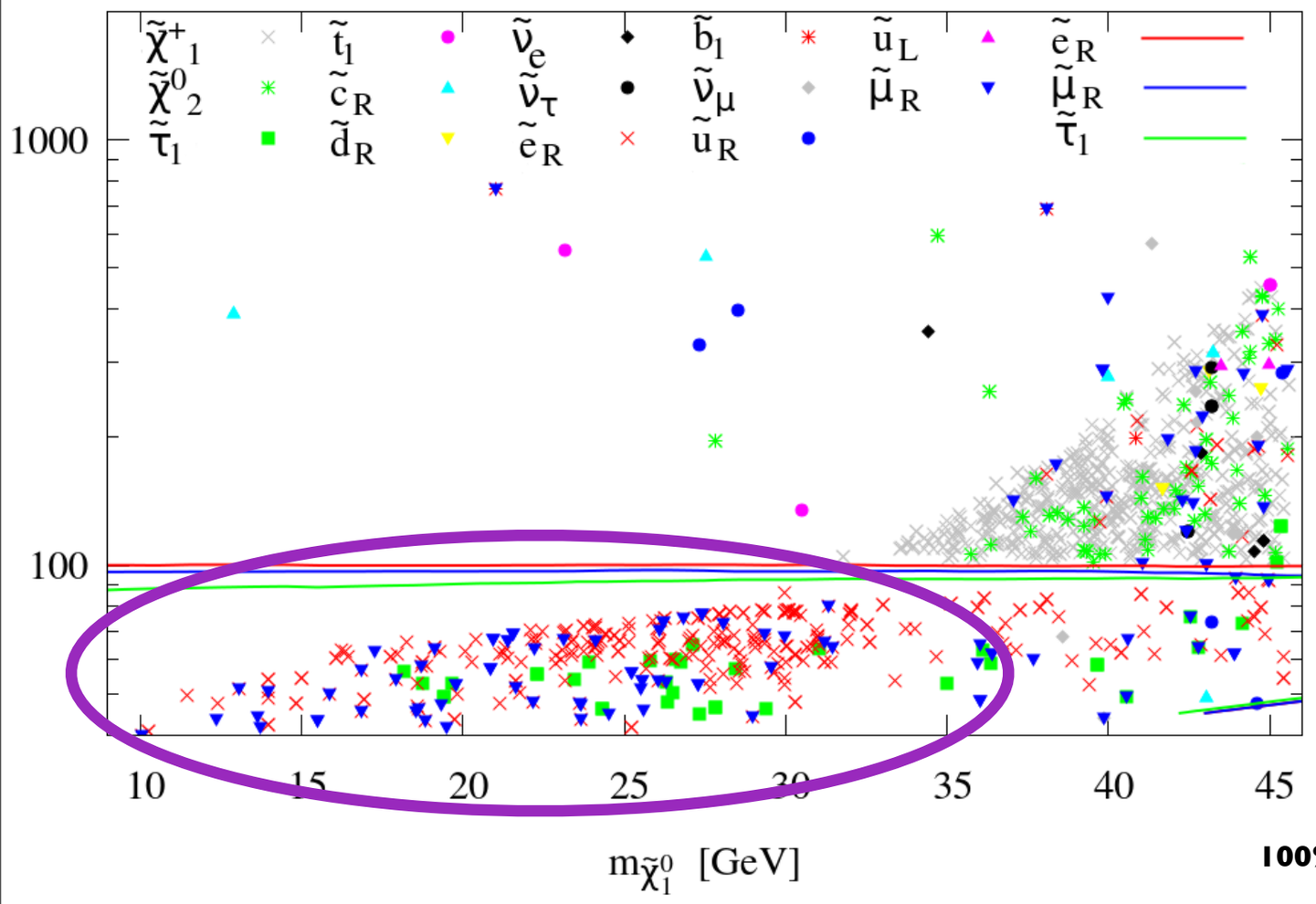
Indirect Detection will not do a better job...



unless astrophysical boost factors or Sommerfeld enhancement of the cross sections

CONSEQUENCES ON SUSY SPECTRUM

1303.5386

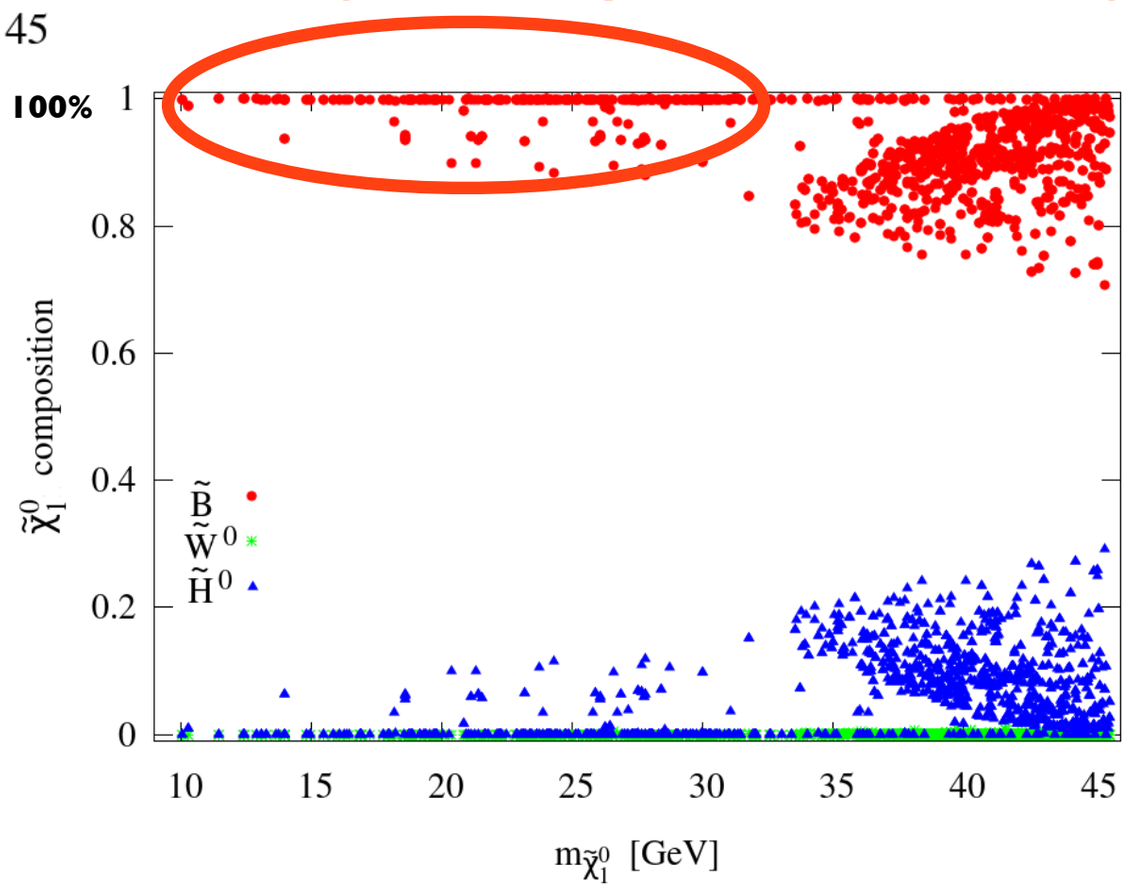


Light neutralinos require light charged mediators which can be excluded by LEP or LHC

This conclusion can be generalised to other types of DM models although there are exceptions, e.g. light Z' or light Higgs bosons.

m> 30 GeV is still safe; below is tough!

Bino-like (i.e. not coupled to SM Z/H boson)



Lessons from the relic density & reionisation arguments:

Thermal DM are in trouble but still fine though if:

*** one invokes new types of interactions**

*** one sticks to P-wave annihilations (velocity-dependent)...**

Thermal DM is on its way to be discovered

new Physics soon!

2 options

Whatever is going on here, this calls for a revolution (of ideas)

* non thermal DM?

* new RD mechanisms