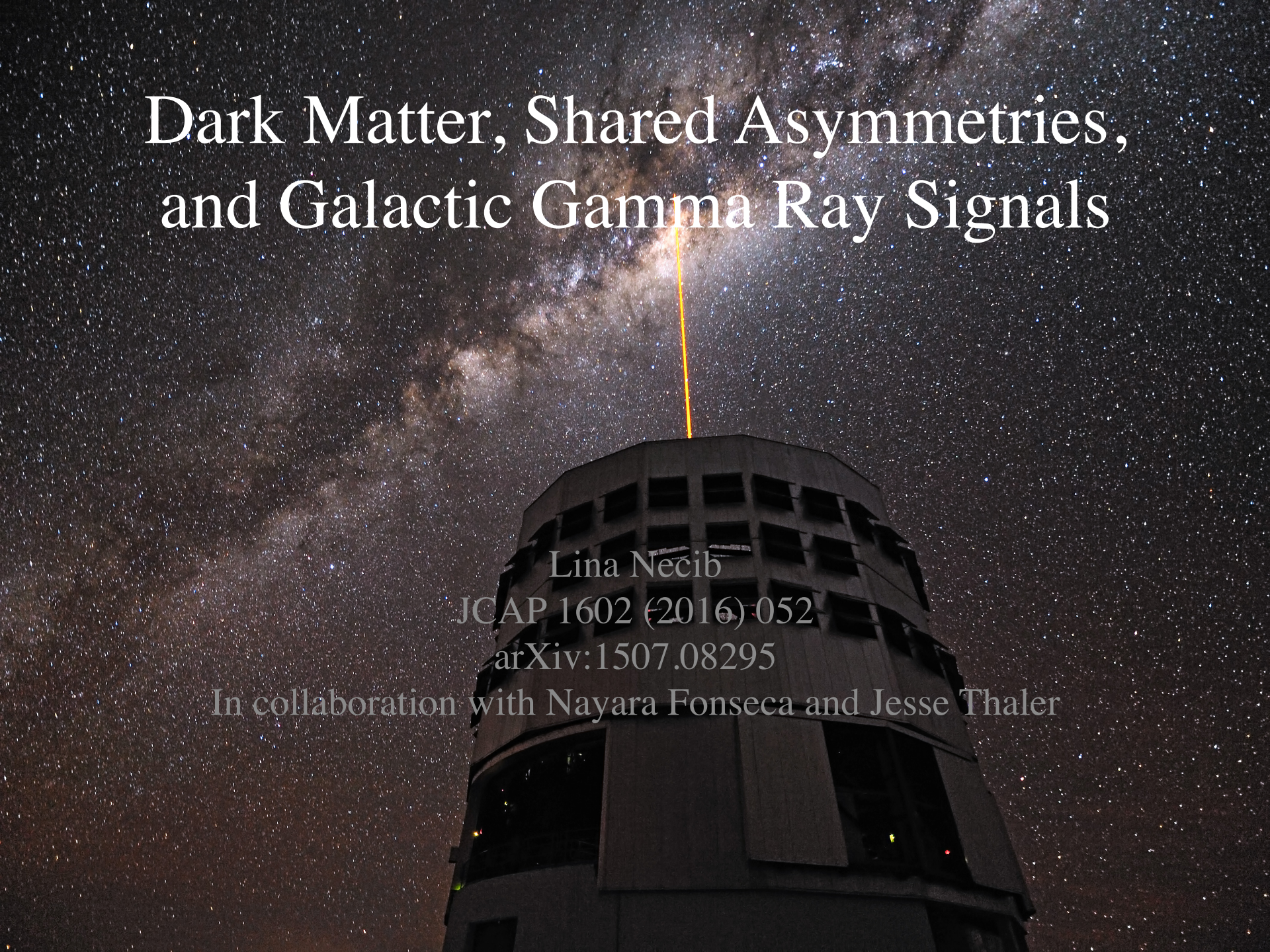
Dark Matter, Shared Asymmetries, and Galactic Gamma Ray Signals

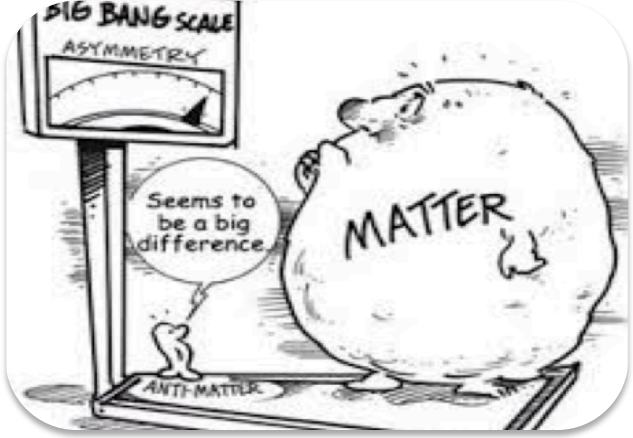


Lina Necib

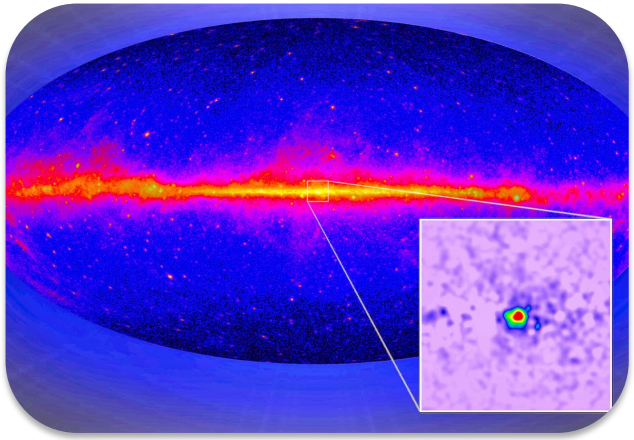
JCAP 1602 (2016) 052
arXiv:1507.08295

In collaboration with Nayara Fonseca and Jesse Thaler

Nature of Dark Matter



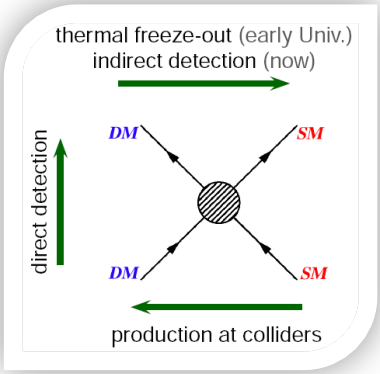
Matter-Anti Matter Asymmetry

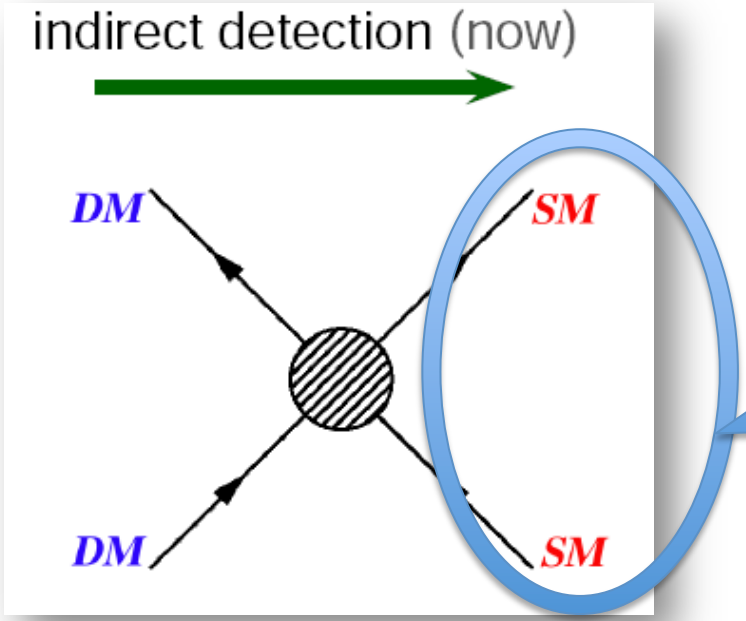


Galactic Center Excess

www.symmetrymagazine.org
www.research.vt.edu

Problem we are trying to solve?





Indirect signatures without residual anti-DM component

Why?

Asymmetry of the visible sector!

Similarity between the abundance of baryons and dark matter (only a factor of 5.)

Dominant DM component

Dark particle

2 fermion/boson particles

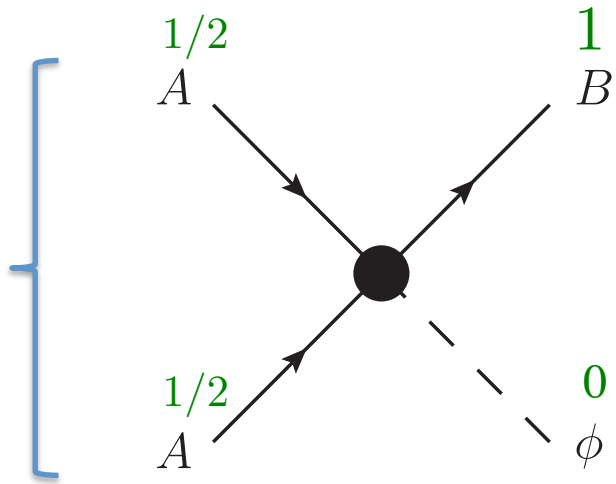
A

B

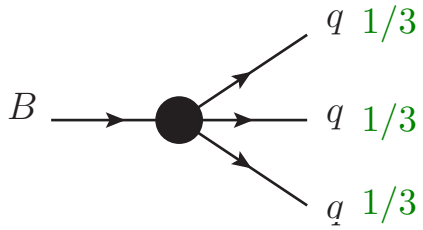
ϕ/γ'

Production

No anti-particles



Indirect Detection



m_A $\mathcal{O}(10\ \text{GeV})$

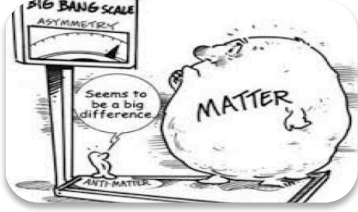
m_B $\mathcal{O}(10\ \text{GeV})$

m_ϕ $\mathcal{O}(100\ \text{MeV})$

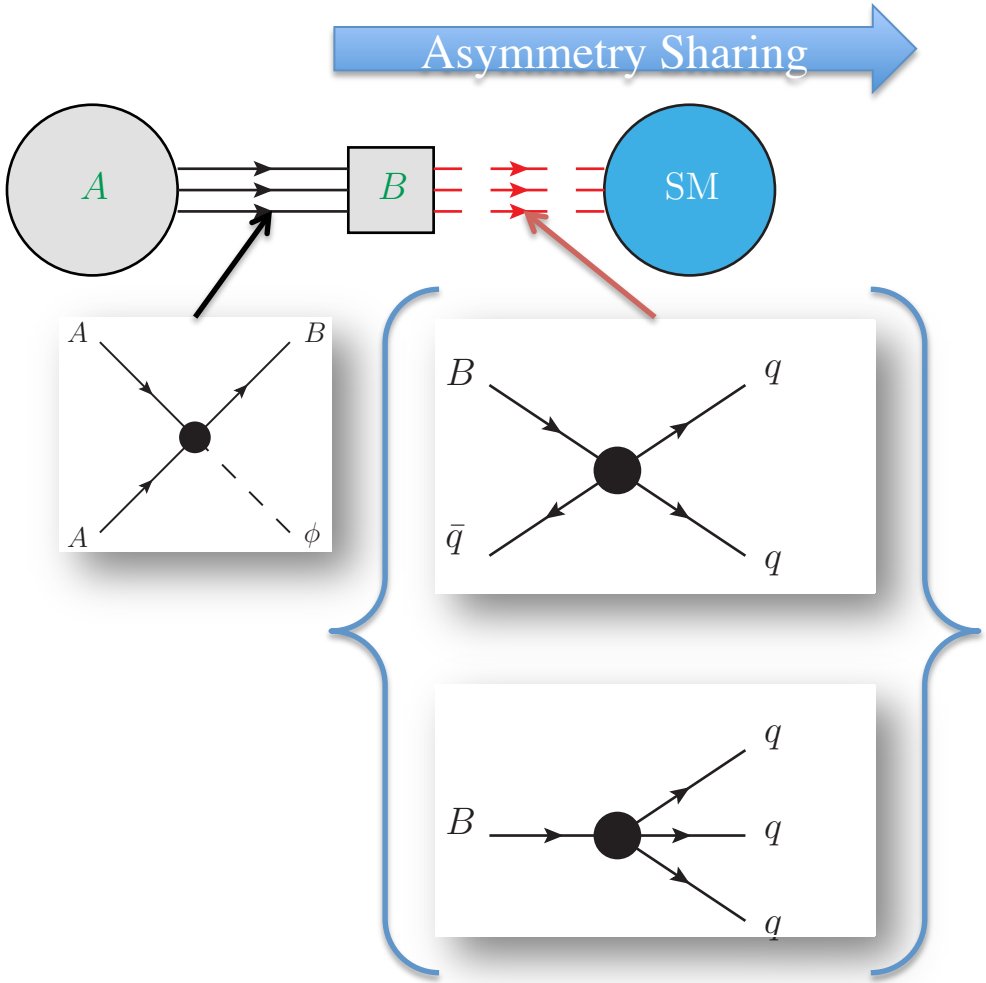
D'Eramo, Thaler (2010)

Semi-Annihilation!

And there was light!
(And other things)

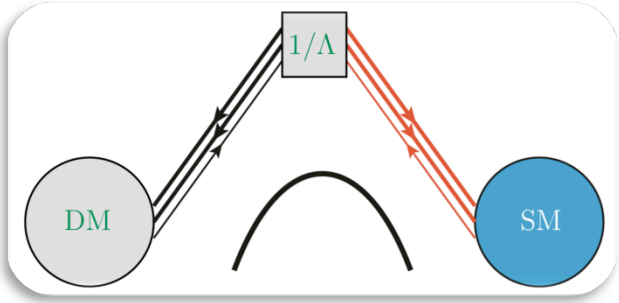


Initial Asymmetry

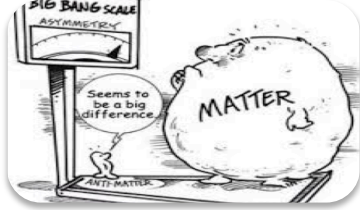


Occur at different scales!

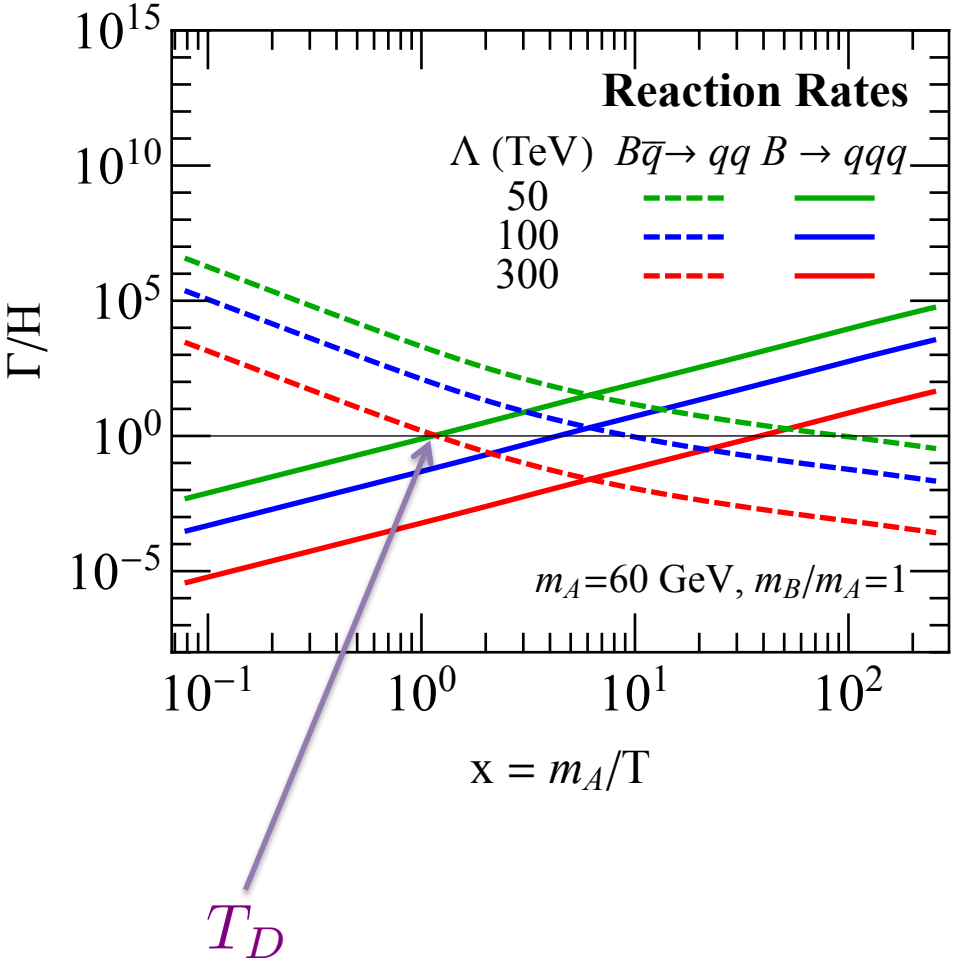
Other models:

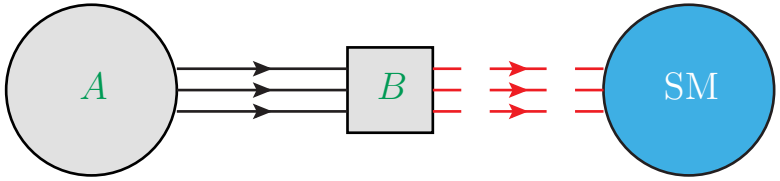


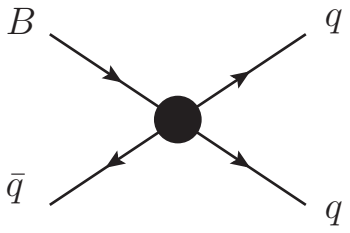
For Review:
Zurek 1308.0338
Petraki, Volkas 1305.4939



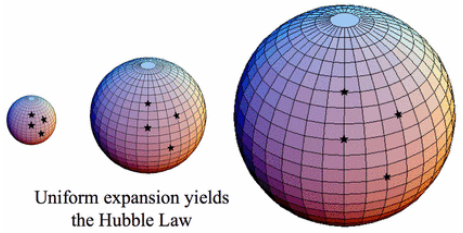
Asymmetry Progression



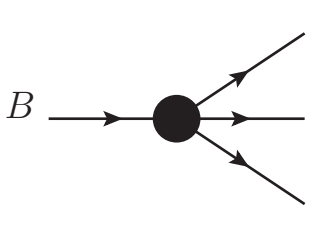




$$\frac{T^2}{\Lambda^4} \times T^3$$

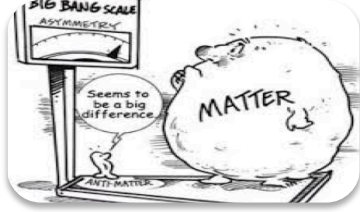


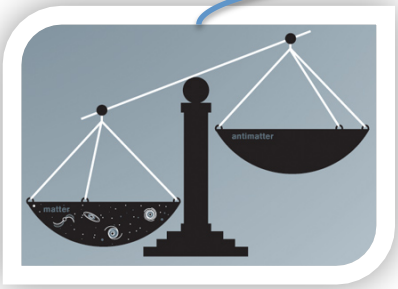
$$H \propto T^2$$

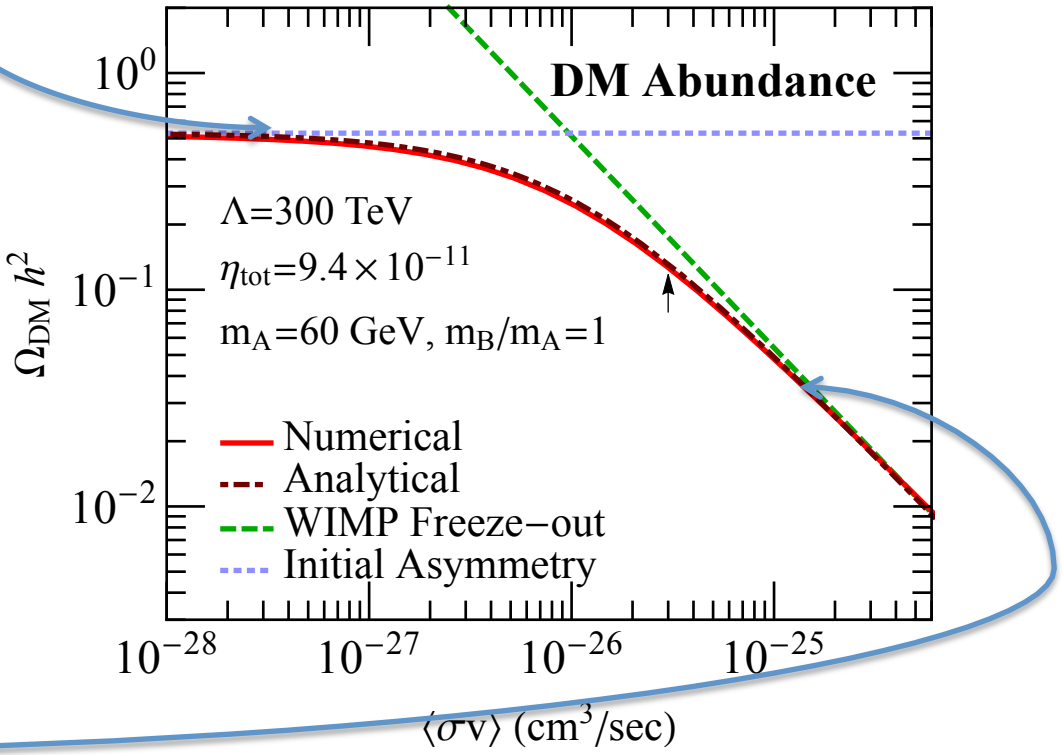


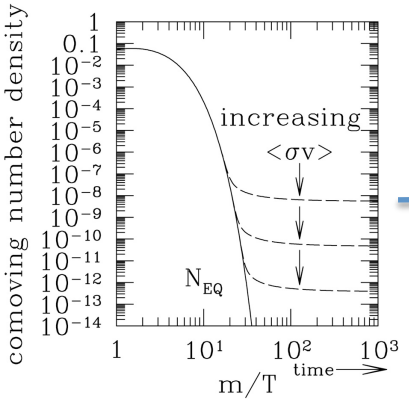
$$\Gamma_B \propto \frac{m_B^5}{\Lambda^4}$$

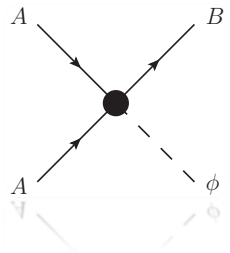

DARK MATTER
VISIBLE MATTER
Wimp
Axion

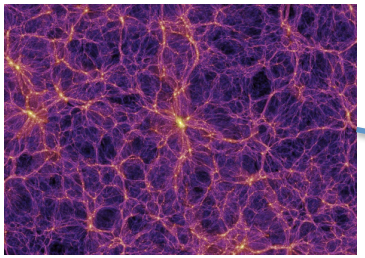

BIG BANG SCALE
ASYMMETRY
Seems to be a big difference
MATTER
ANTI-MATTER


antimatter
matter

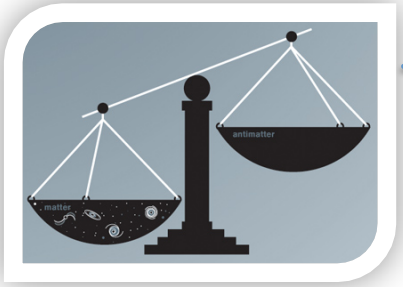

DM Abundance
10^0
10^{-1}
10^{-2}
$\Omega_{DM}\,h^2$
Λ=300 TeV
$\eta_{tot}=9.4\times10^{-11}$
m_A=60 GeV, m_B/m_A=1
Numerical
Analytical
WIMP Freeze−out
Initial Asymmetry
10^{-28}
10^{-27}
10^{-26}
10^{-25}
$\langle\sigma v\rangle$ (cm^3/sec)


comoving number density
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
increasing
<σv>
N_{EQ}
1
10^1
10^2
10^3
m/T
time

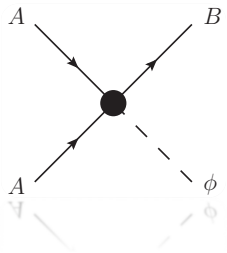

A
B
A
ϕ

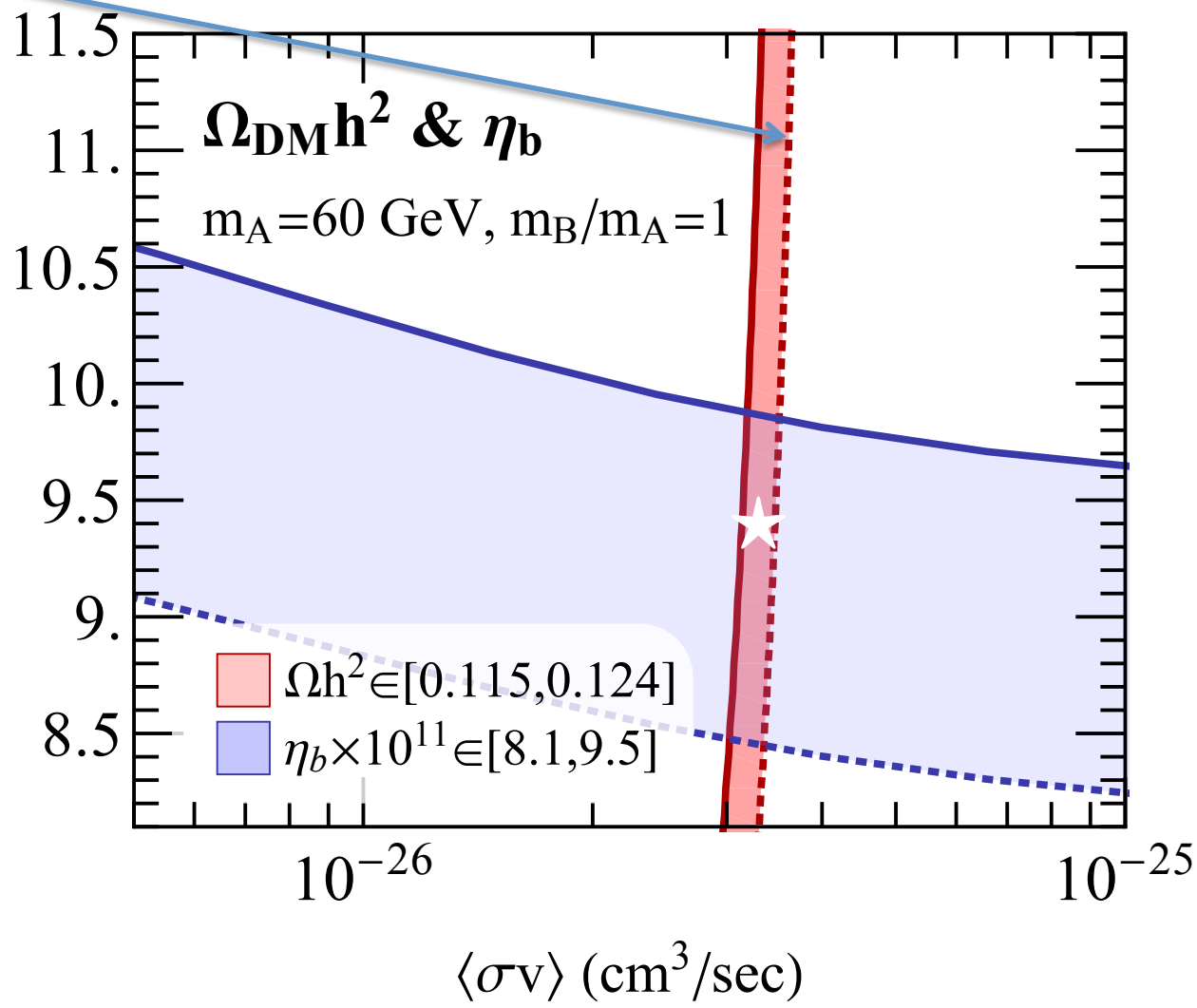


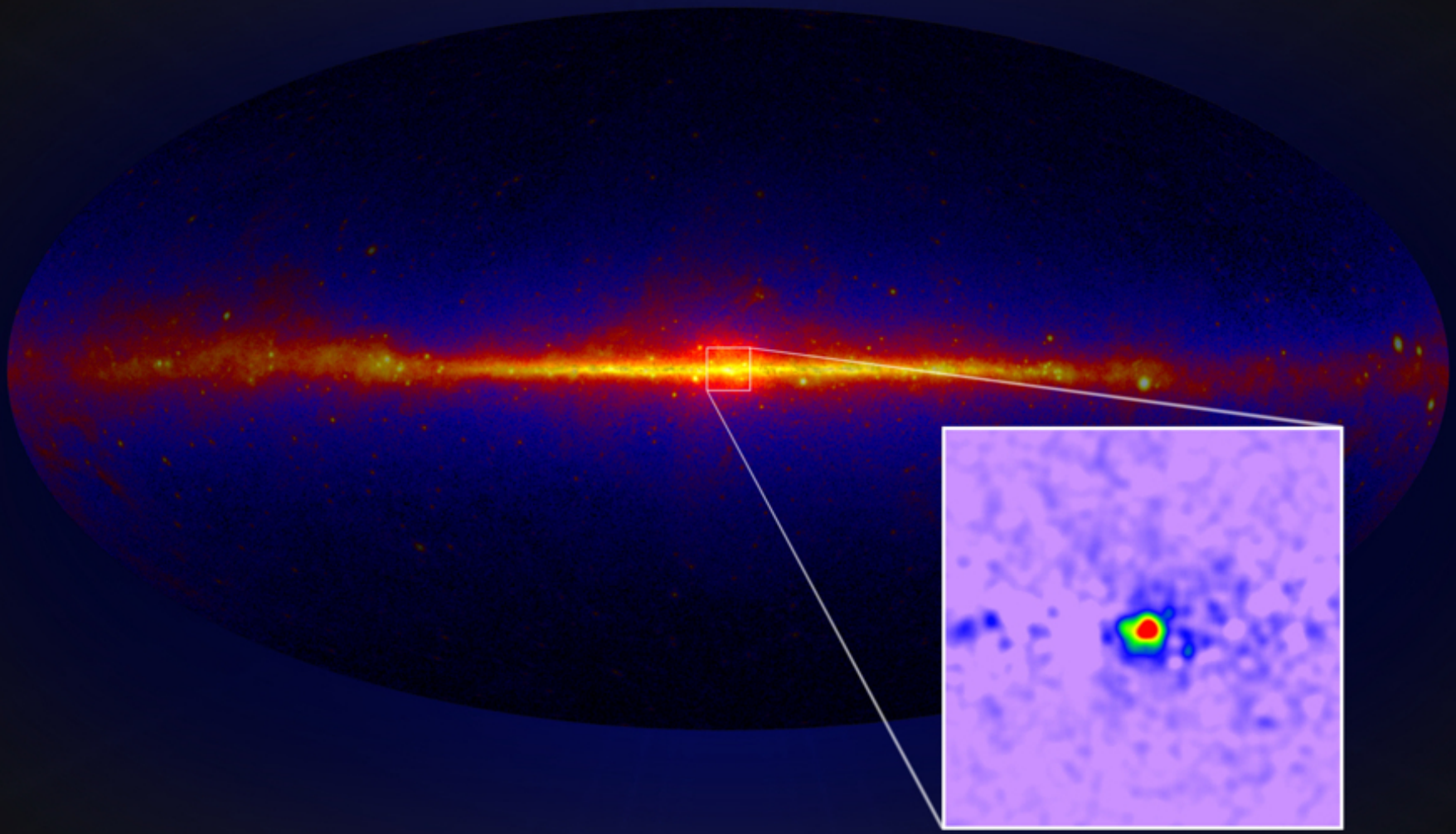
DM abundance



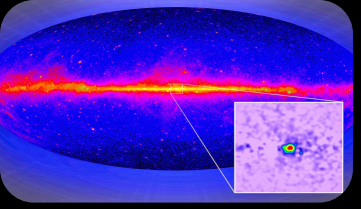
Baryon Asymmetry

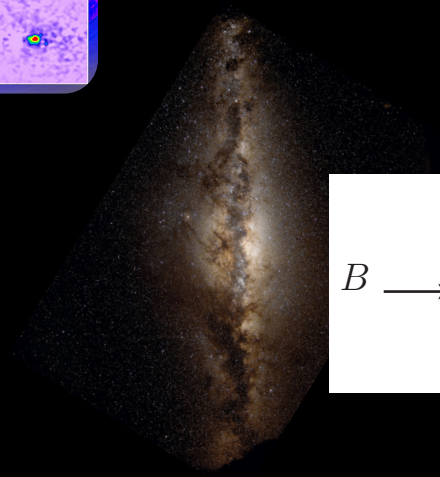


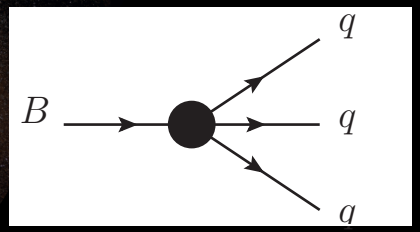


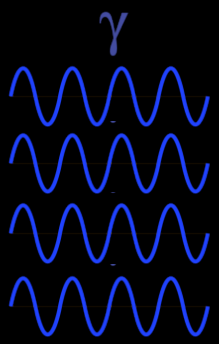


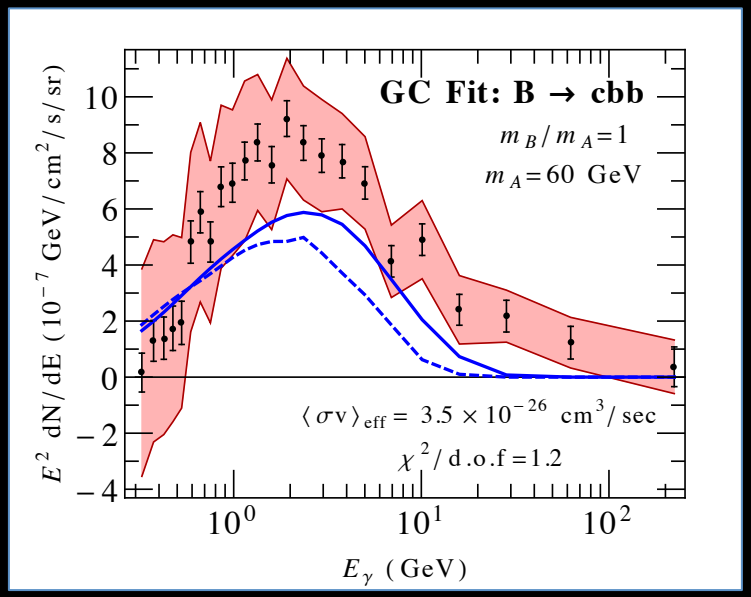
NASA Goddard; A. Mellinger; T. Linden

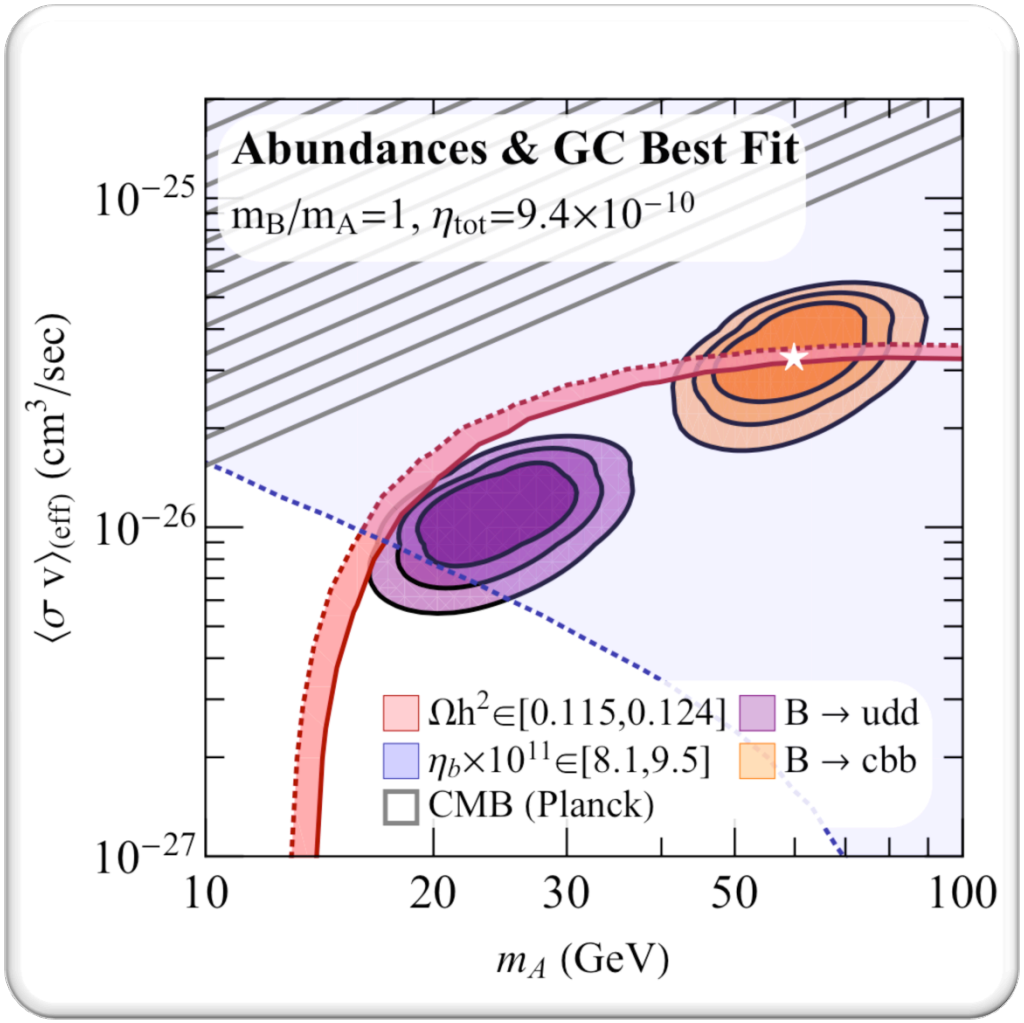




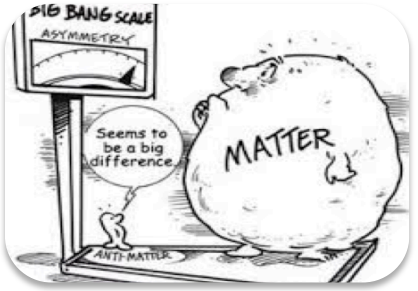

B
q
q
q


γ

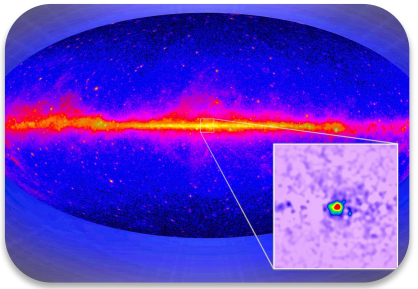

GC Fit: B → cbb
$m_B / m_A = 1$
$m_A = 60$ GeV
$\langle \sigma v \rangle_{\rm eff} = 3.5 \times 10^{-26}$ cm^3/sec
χ^2/d.o.f = 1.2
E^2 dN/dE (10^{-7} GeV/cm^2/s/sr)
E_γ (GeV)
10
8
6
4
2
0
−2
−4
10^0
10^1
10^2



Asymmetric Dark Matter with viable indirect detection signals



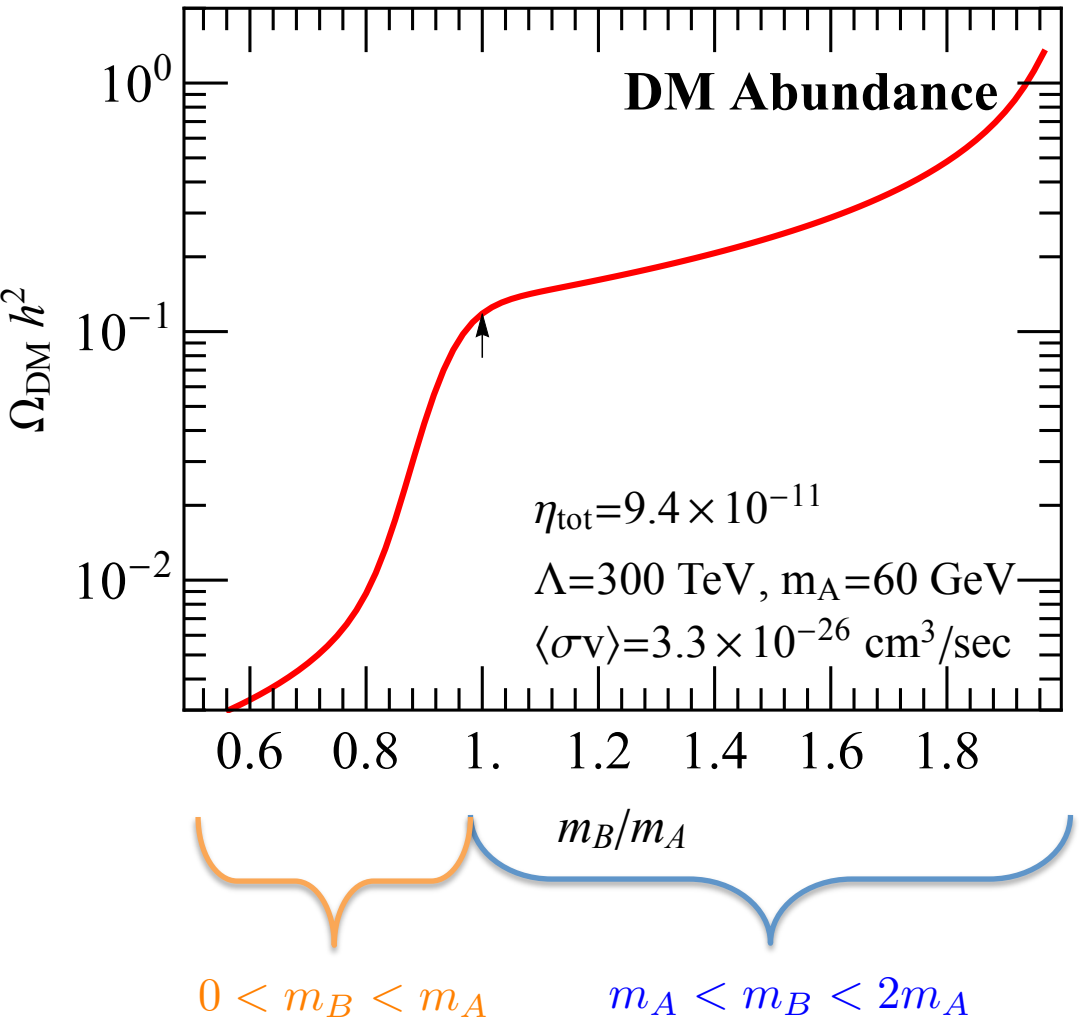
Coherent story relating Dark Matter and baryon asymmetries

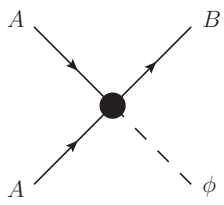


Semi-annihilation spectrum naturally reproduces Galactic center excess

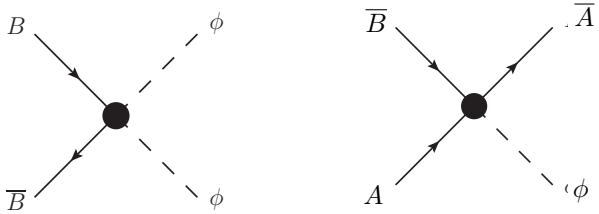
BONUS SLIDES

$x = m_A/T$

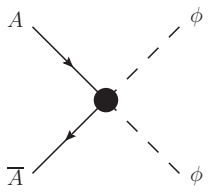




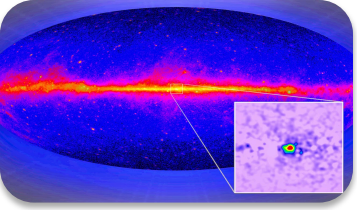
$$Y^{\rm eq} \propto \exp\left(-\frac{2m_A - m_B}{m_A}x\right)$$



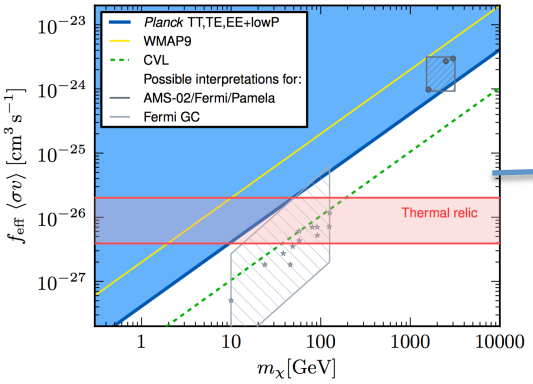
$$Y^{\rm eq} \propto \exp\left(-\frac{m_B}{m_A}x\right)$$



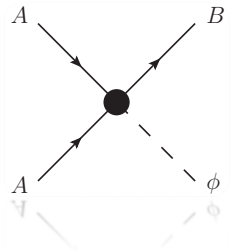
$$Y^{\rm eq} \propto \exp\left(-x\right)$$

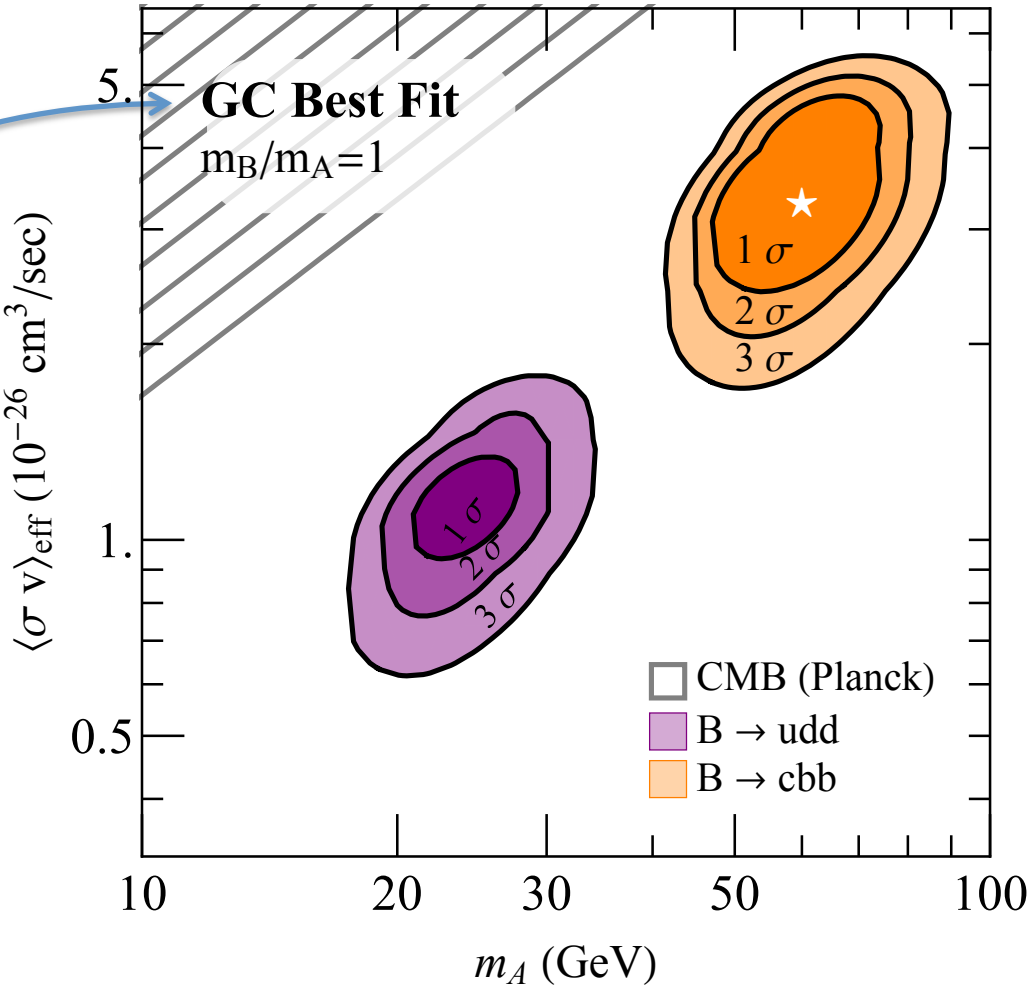


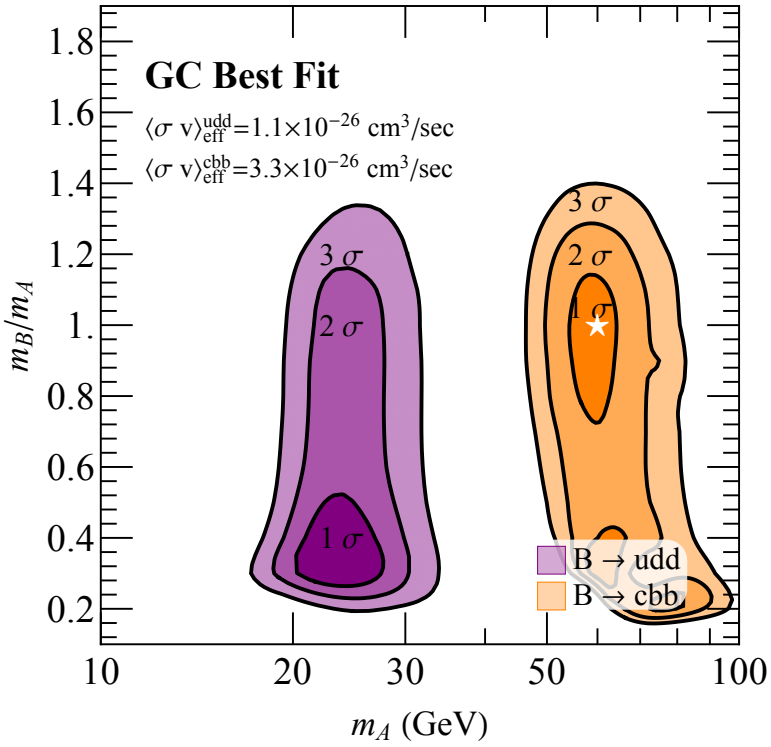
CMB limits



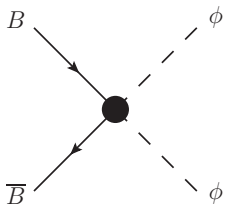
$$\langle\sigma v\rangle_{\rm eff} = \langle\sigma v\rangle \left(\frac{\Omega_A}{\Omega_{\rm DM}}\right)^2$$

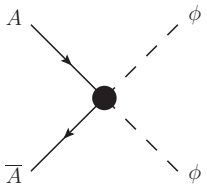


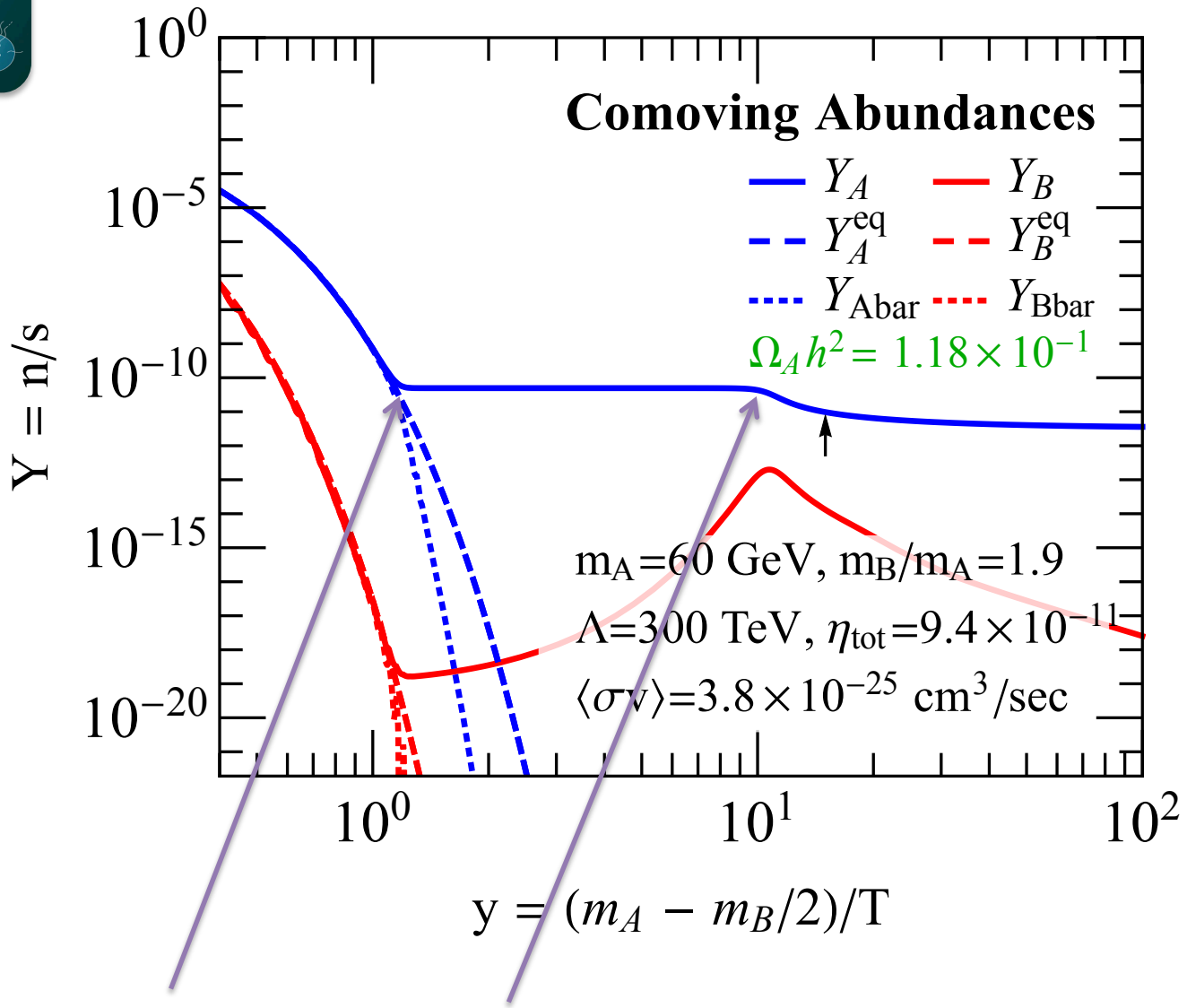



GC Best Fit
$\langle\sigma\ v\rangle_{eff}^{udd}=1.1\times10^{-26}$ cm^3/sec
$\langle\sigma\ v\rangle_{eff}^{cbb}=3.3\times10^{-26}$ cm^3/sec
3 σ
2 σ
1 σ
3 σ
2 σ
1 σ
B → udd
B → cbb
m_B/m_A
m_A (GeV)
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
10
20
30
50
100


DARK MATTER
VISIBLE MATTER
Wimp
Axion
Wimp


B
ϕ
$\overline{B}$
ϕ

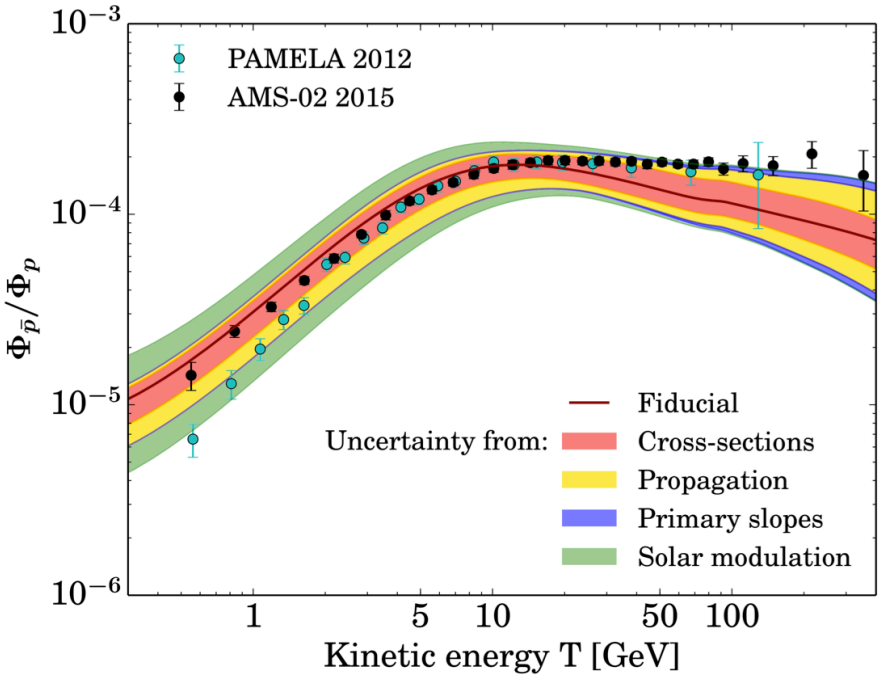

A
ϕ
$\overline{A}$
ϕ


Comoving Abundances
Y_A
Y_B
Y_A^{eq}
Y_B^{eq}
Y_{Abar}
Y_{Bbar}
$\Omega_A h^2 = 1.18 \times 10^{-1}$
m_A=60 GeV, m_B/m_A=1.9
Λ=300 TeV, $\eta_{tot} = 9.4 \times 10^{-11}$
$\langle \sigma v \rangle = 3.8 \times 10^{-25}$ cm^3/sec
Y = n/s
10^0
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^0
10^1
10^2
y = $(m_A - m_B/2)$/T

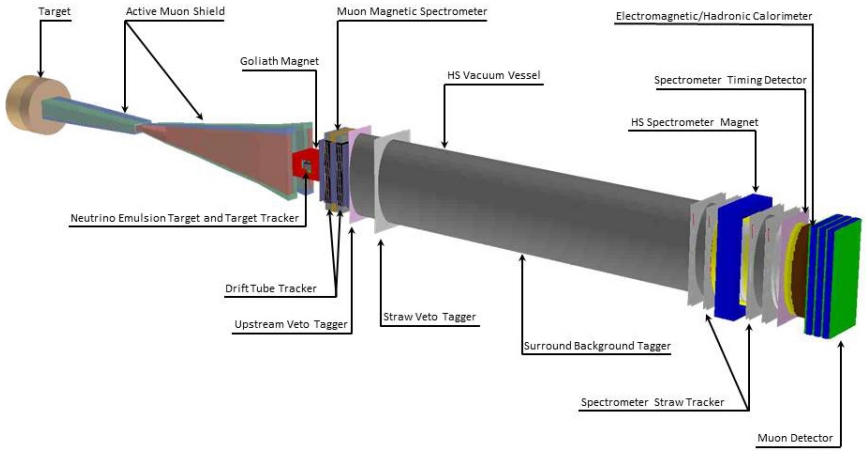
$T_D > T_I > T_F$

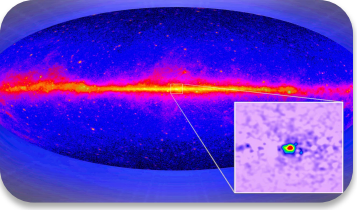
Ignoring the GC excess benchmarks, what else can we think about?

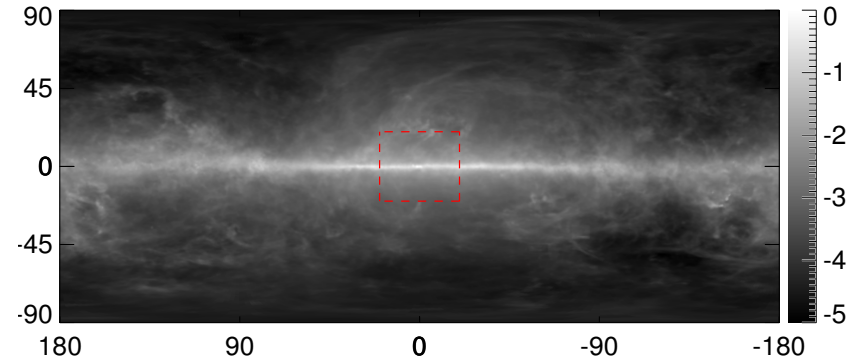
Anti protons



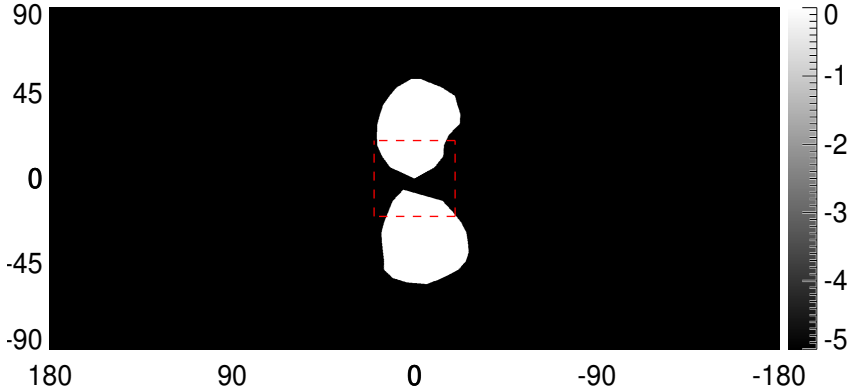
Fixed target experiments



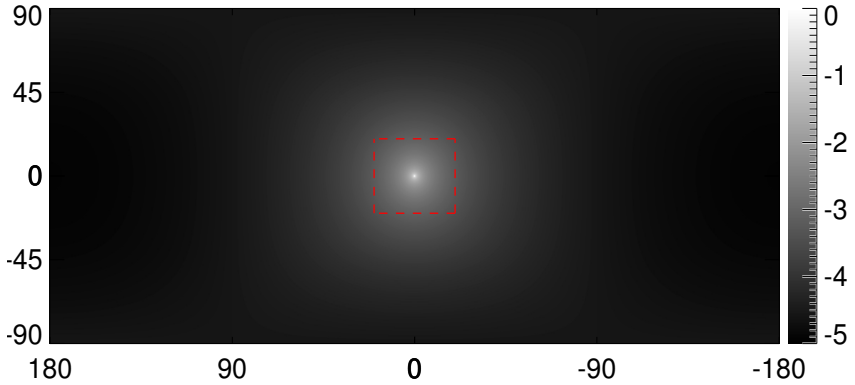




Diffuse

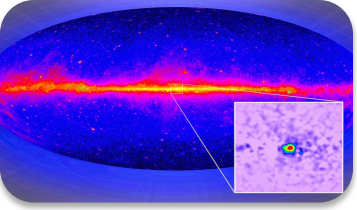


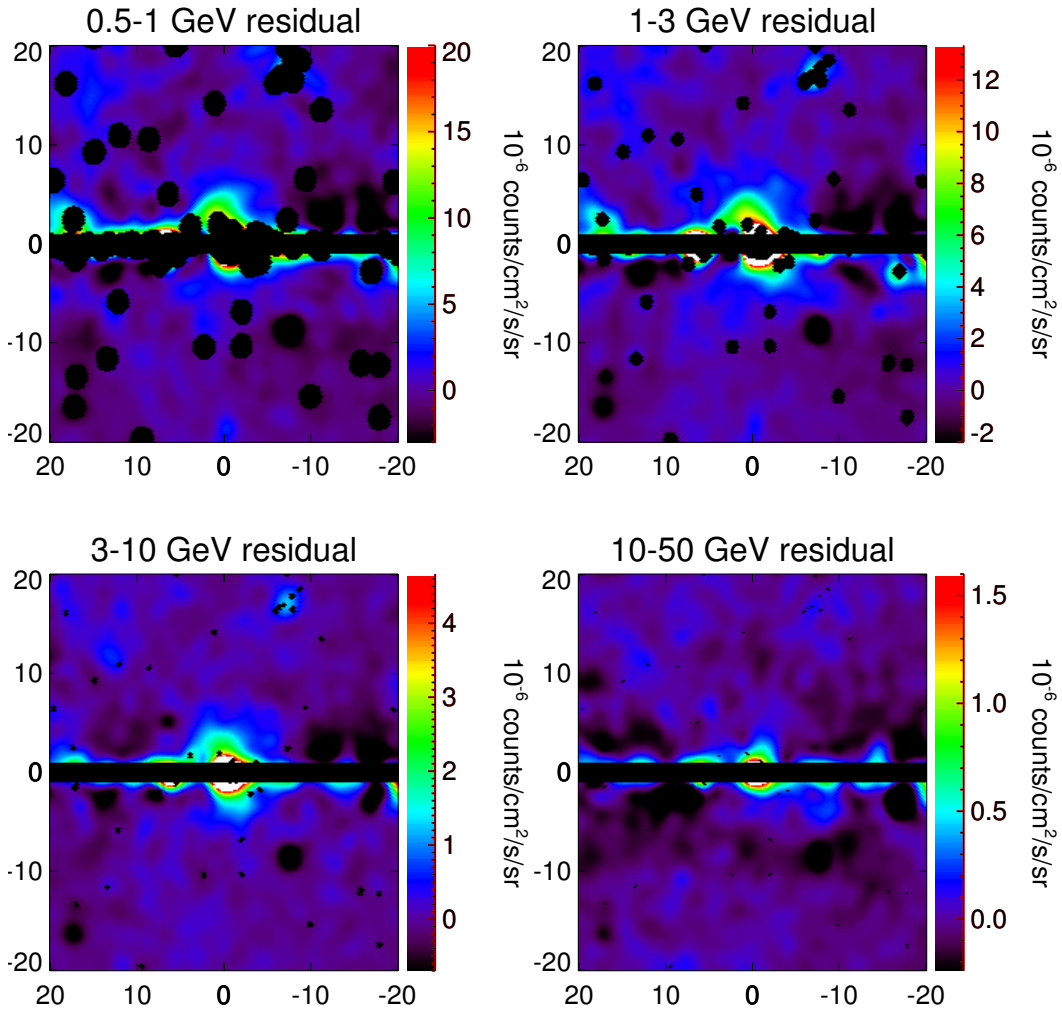
Bubbles



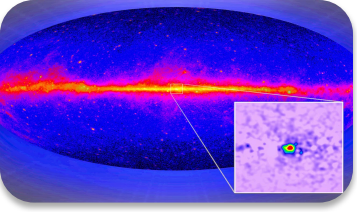
NFW DM

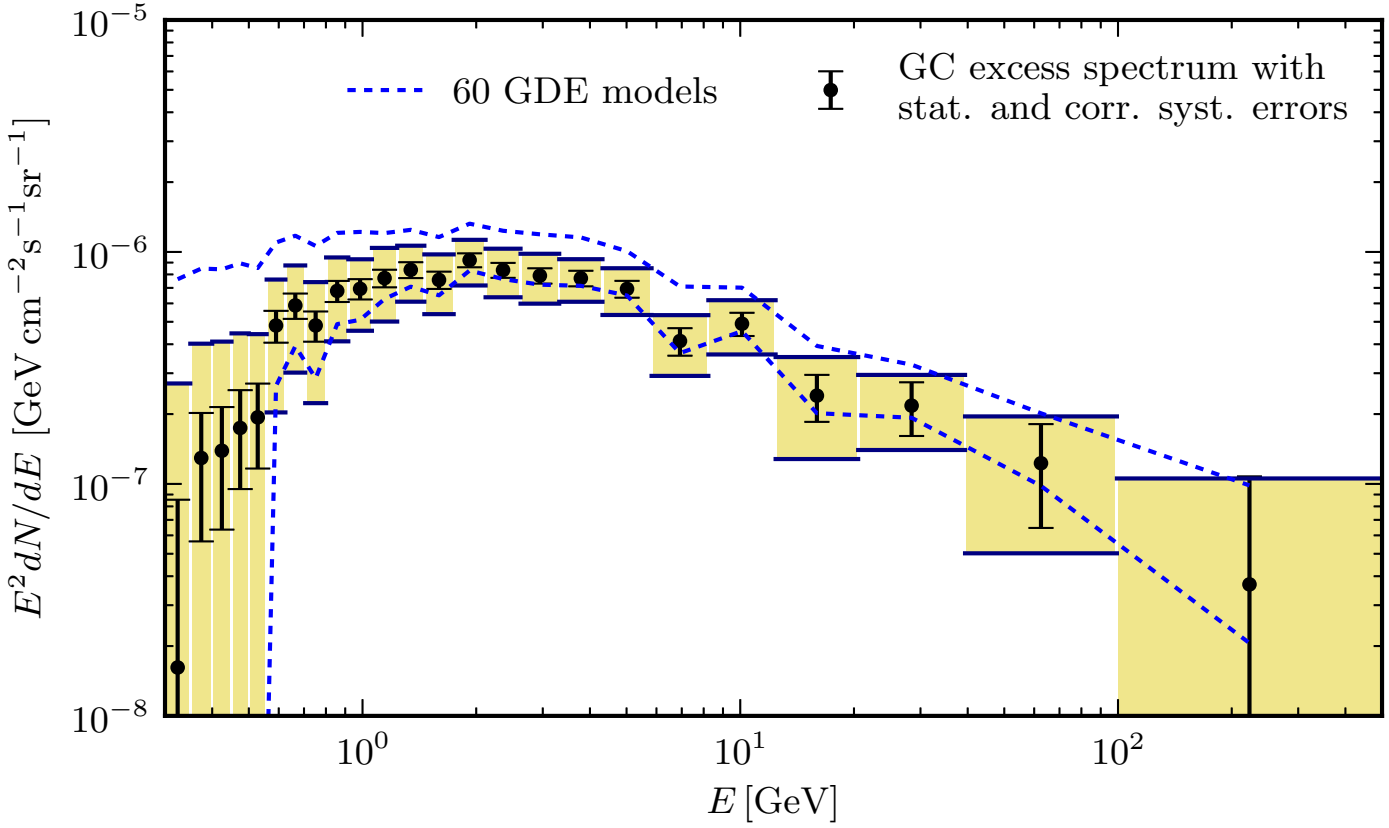
Daylan et al. (2014)



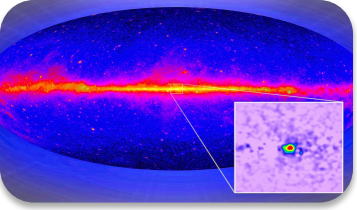


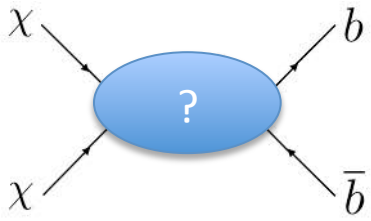
Daylan et al. (2014)

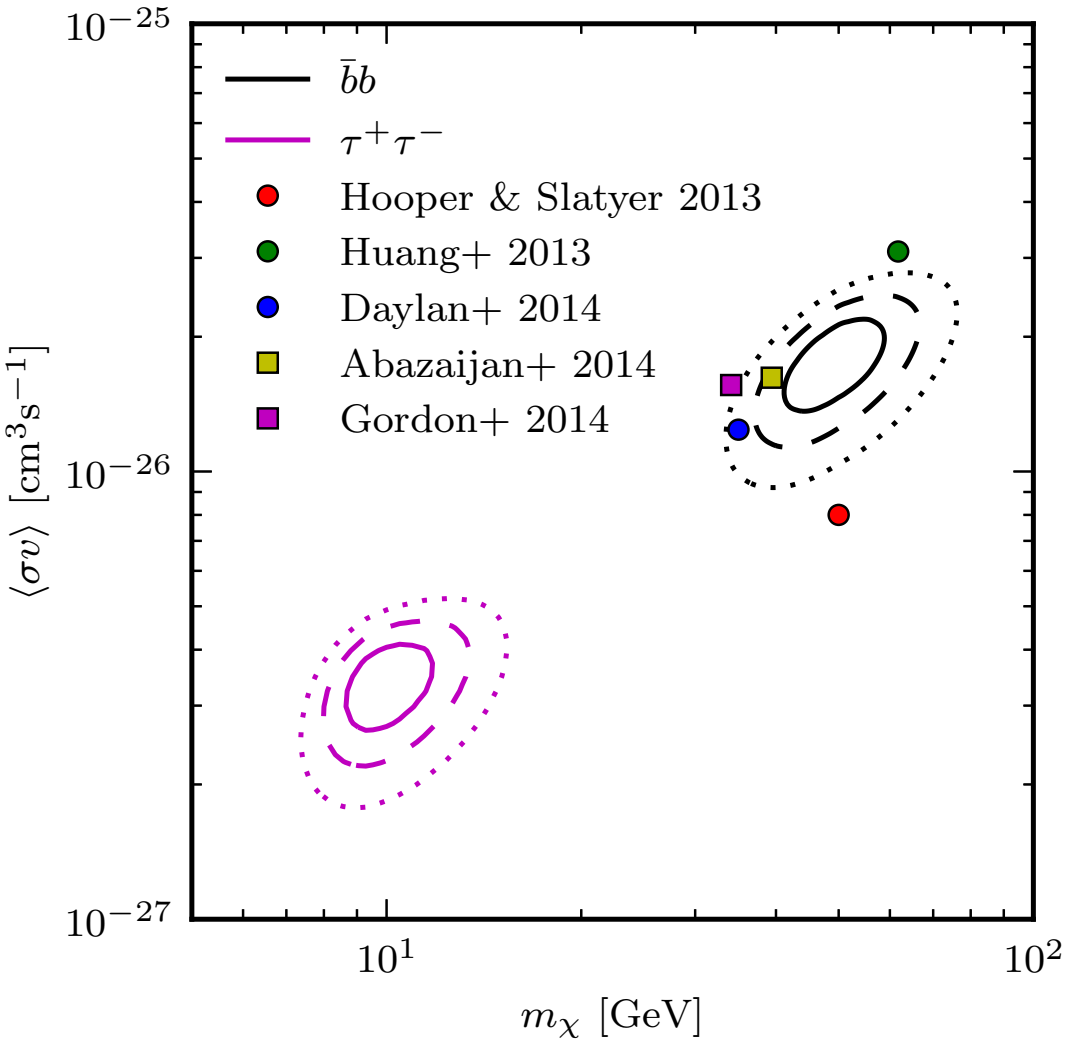




Calore, Cholis, Weniger (2014)







Calore, Cholis, Weniger (2014)

1) Right Dark matter abundance.
2) Right baryon asymmetry.
3) Fits the GC excess