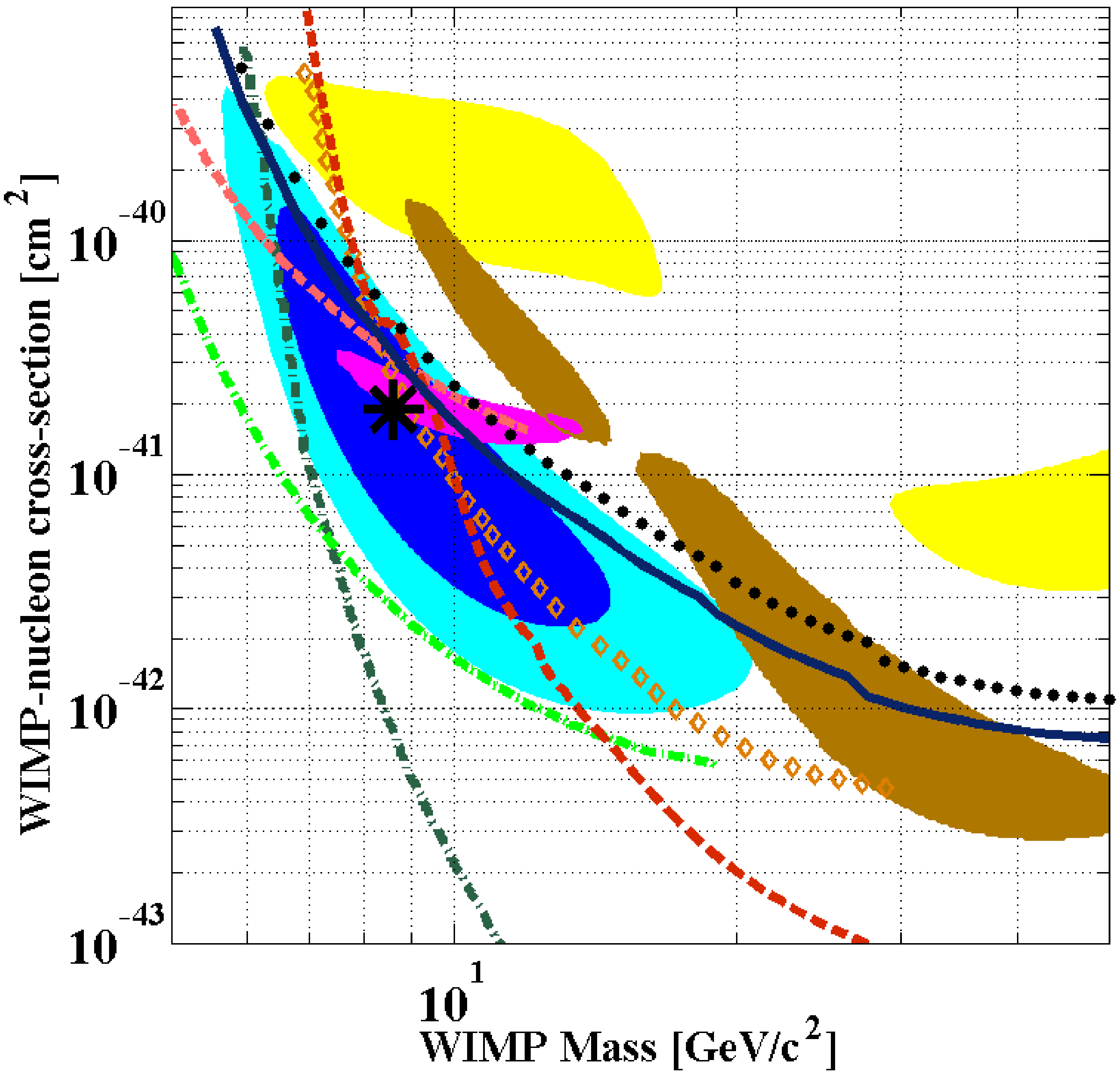
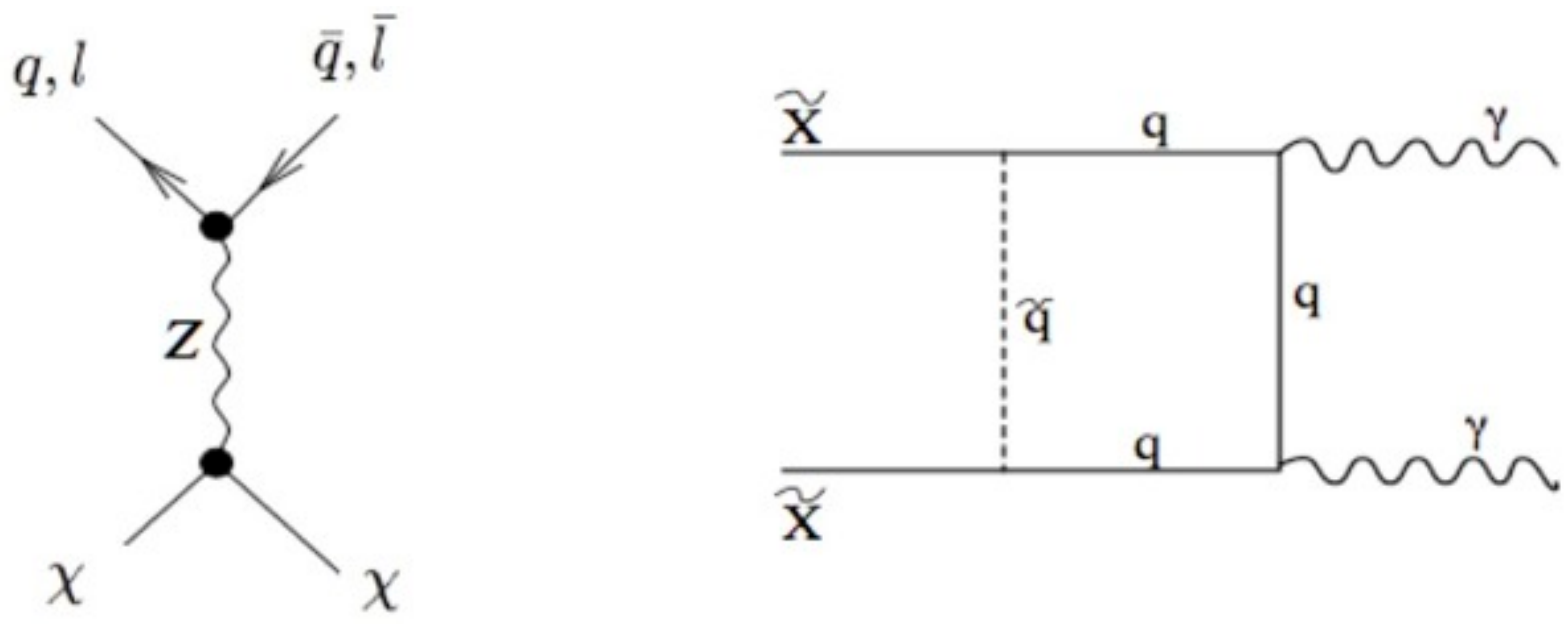
CMB Bounds on Light Dark Matter

Aravind Natarajan (Carnegie Mellon University)
PHENO 2013, U. Pittsburgh
May 7 2013

Exciting results from experiments



Low mass DM can be tested with the CMB



- CMB is well understood (linear physics)
  and very well measured by WMAP + Planck + ACT/SPT.

- DM annihilation is most important at high redshifts z > 100
  Thus halos are not very important.
  No astrophysical backgrounds to worry about.

DM annihilation to standard model particles

$$\chi\chi \longrightarrow b\bar{b} \searrow e^{\pm},\ p\bar{p},\ d\bar{d},\ \gamma\gamma,\ \nu\bar{\nu}$$

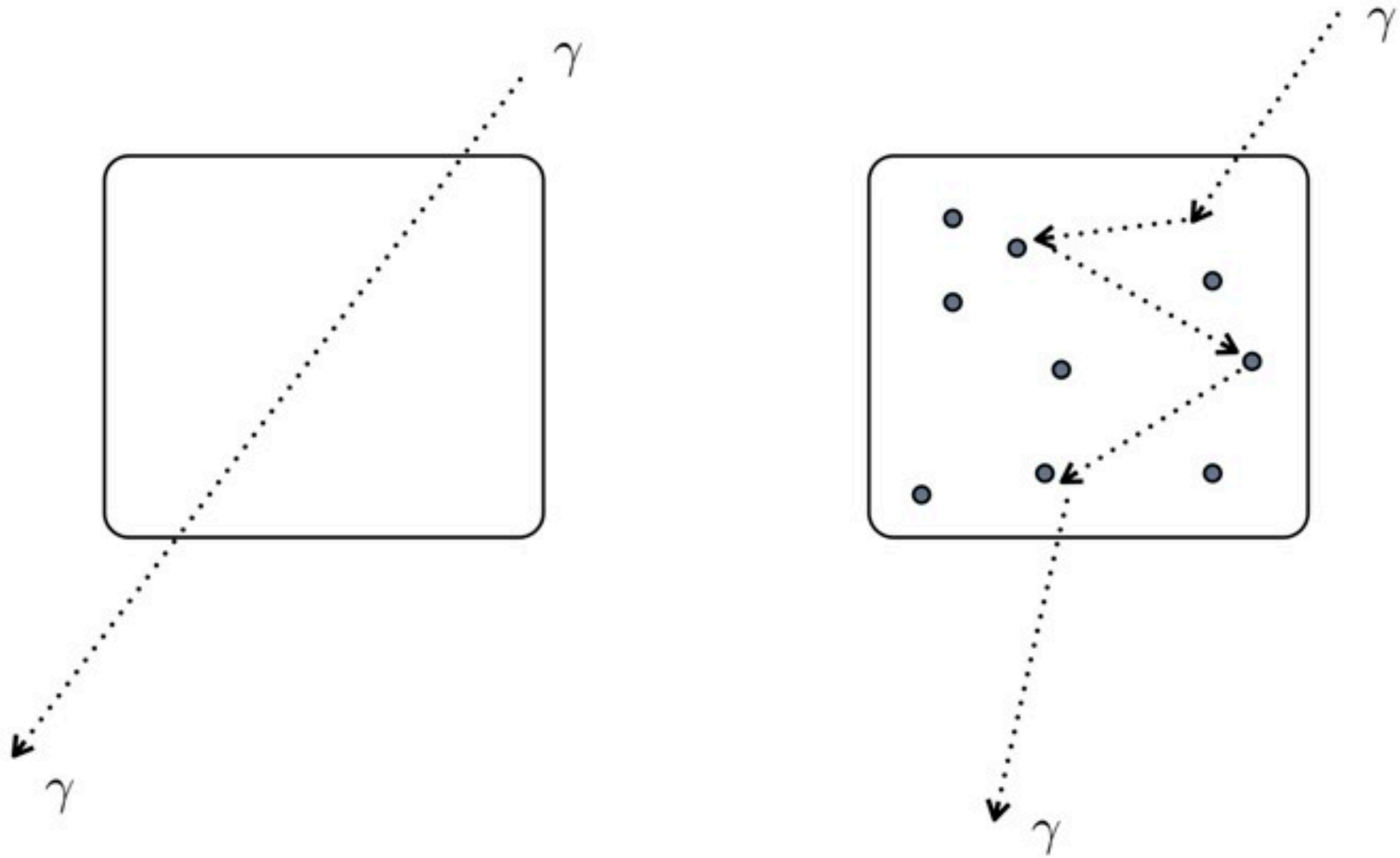
- $e^{\pm}$: inverse Compton scatter with the CMB very quickly
  --> Boost CMB to higher energies.
  Medium energy photons photoionize the gas.

- $p^{\pm}$ inverse Compton scatter slowly.

- γ Delbruck scatter with the CMB.
  Ionize and Compton scatter with neutral atoms.

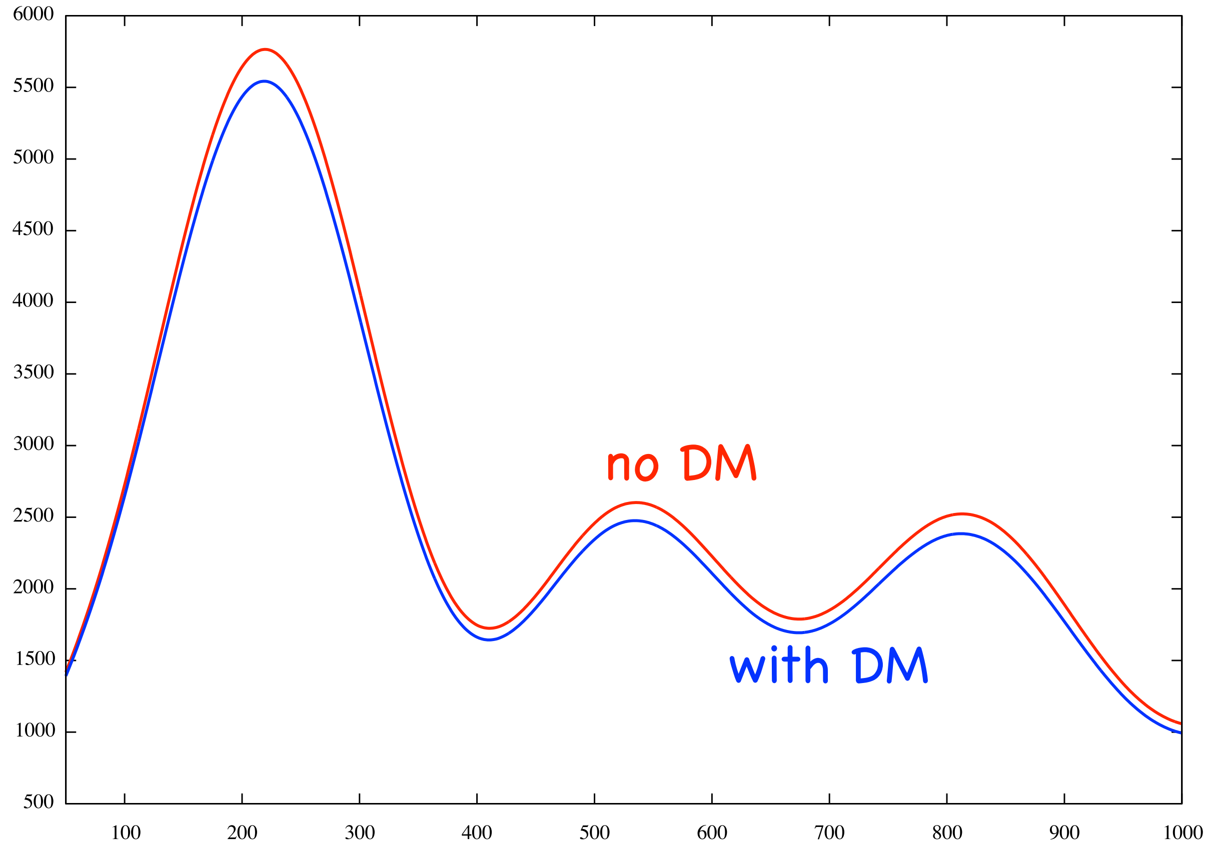
A.N. & Schwarz 2009, 2010; Cirelli & Panci 2009; Belikov & Hooper 2009;
Slatyer, Padmanabhan, & Finkbeiner 2009; Furlanetto & Stoever 2010

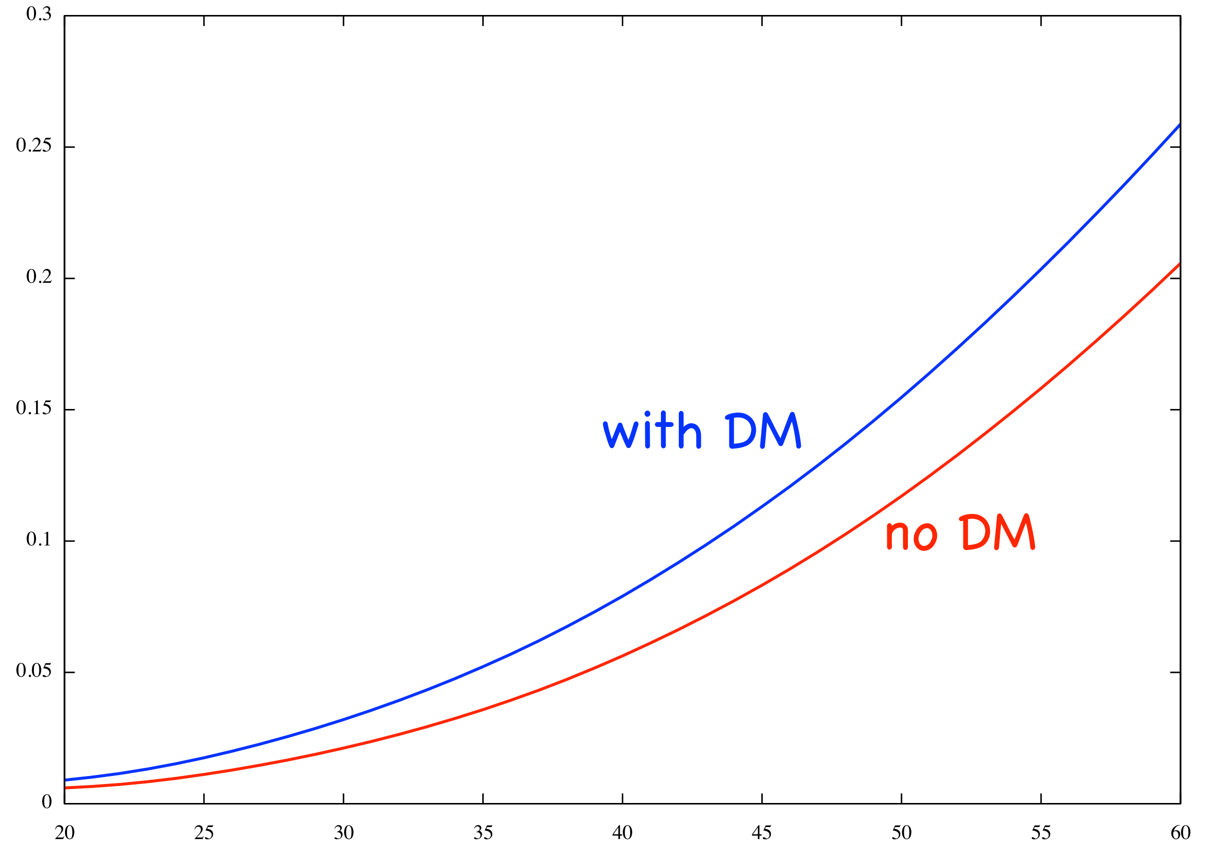
DM annihilation to standard model particles



$$\tau = \int dt\, c\, n_{\rm e}(z)\, \sigma_{\rm T}$$

TT damped on small scales
EE boosted on large scales



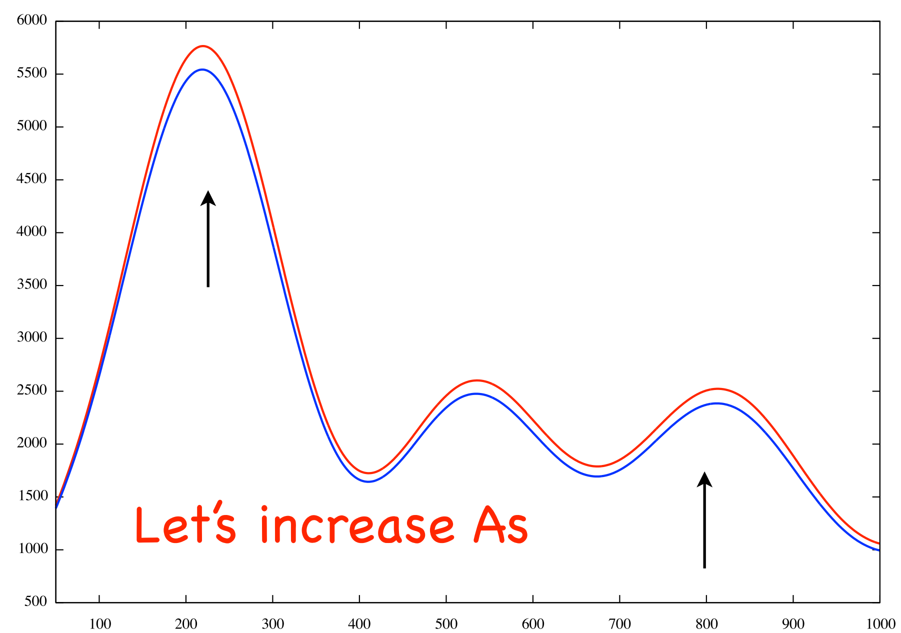


A.N. 2012, A.N. et al. in preparation.

Damping of the TT spectrum is scale dependent due to causality

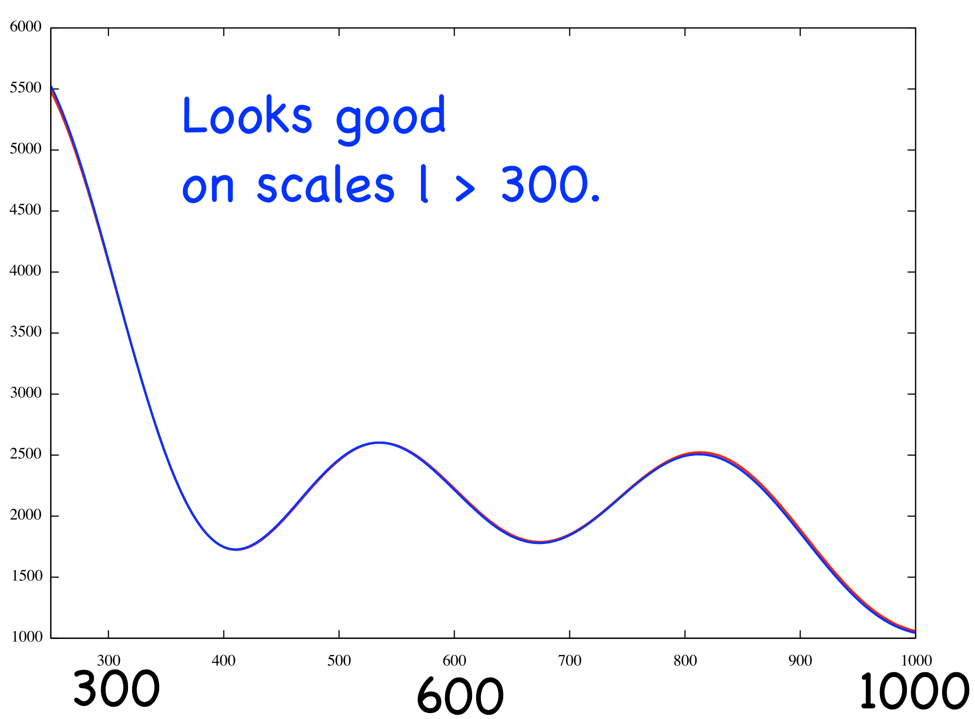
$$C_l \propto A_\mathrm{s}\,(k/k_\mathrm{pivot})^{n_\mathrm{s}}\,e^{-\tau}$$

Let's keep n_s fixed, but increase As

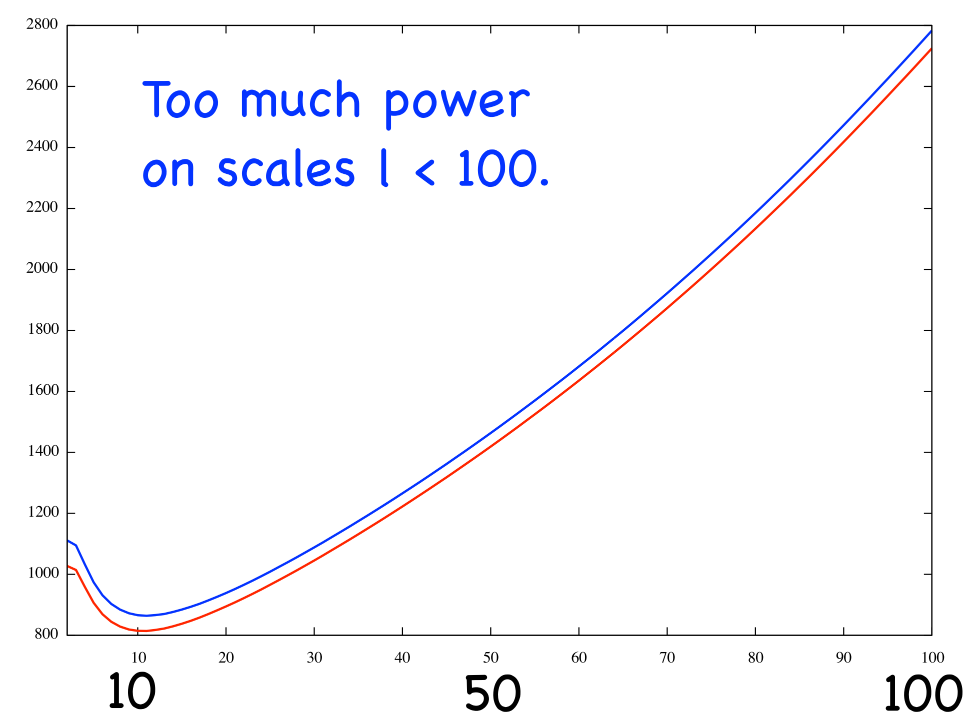


Red: no DM

Blue: with DM



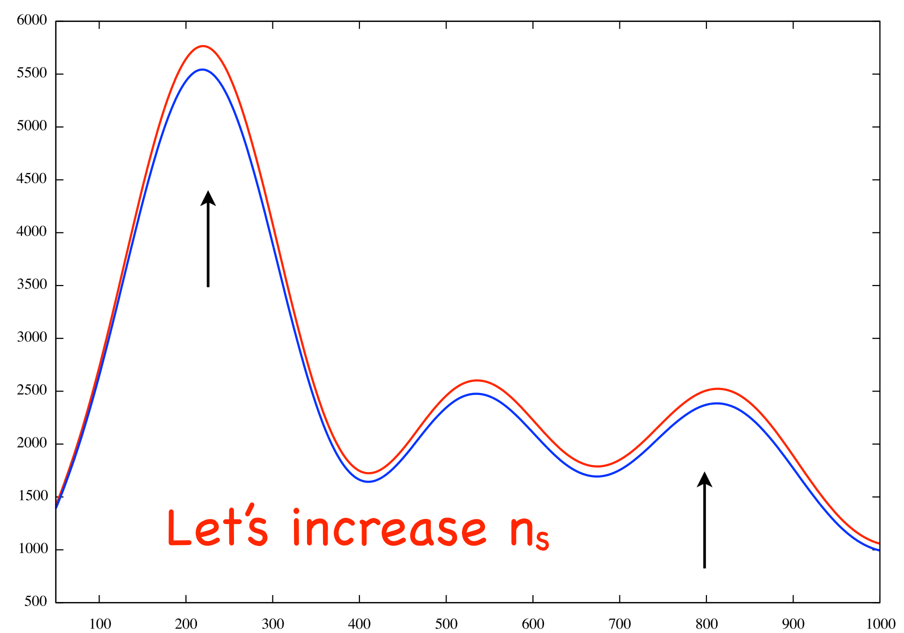
BUT



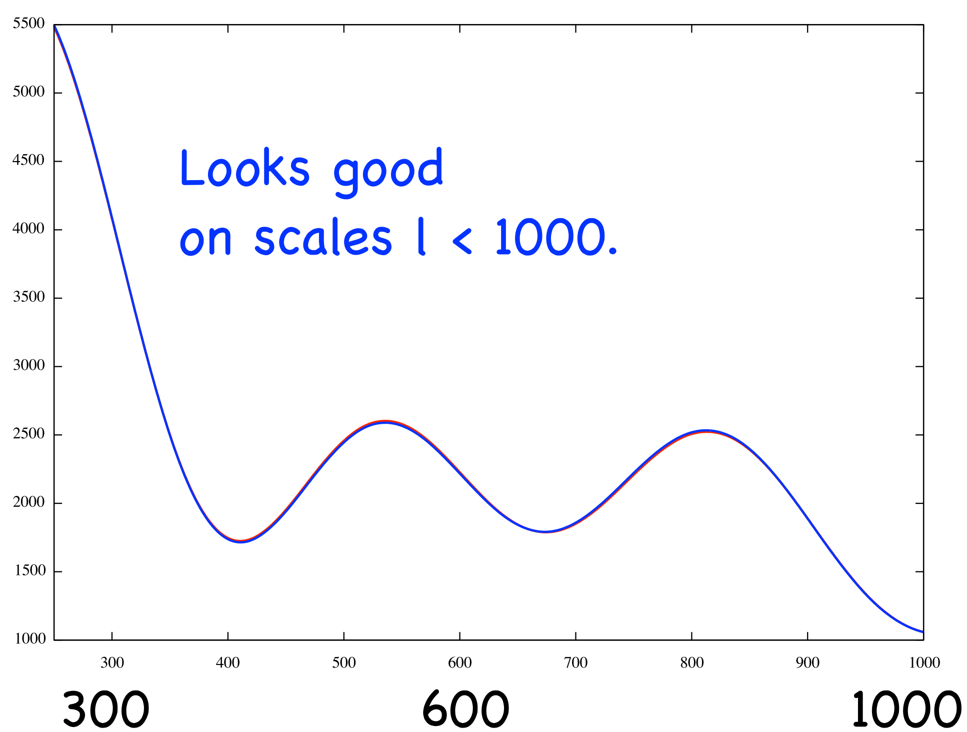
Damping of the TT spectrum is scale dependent due to causality

$$C_l \propto A_\mathrm{s} \left(k/k_\mathrm{pivot}\right)^{n_\mathrm{s}} e^{-\tau}$$

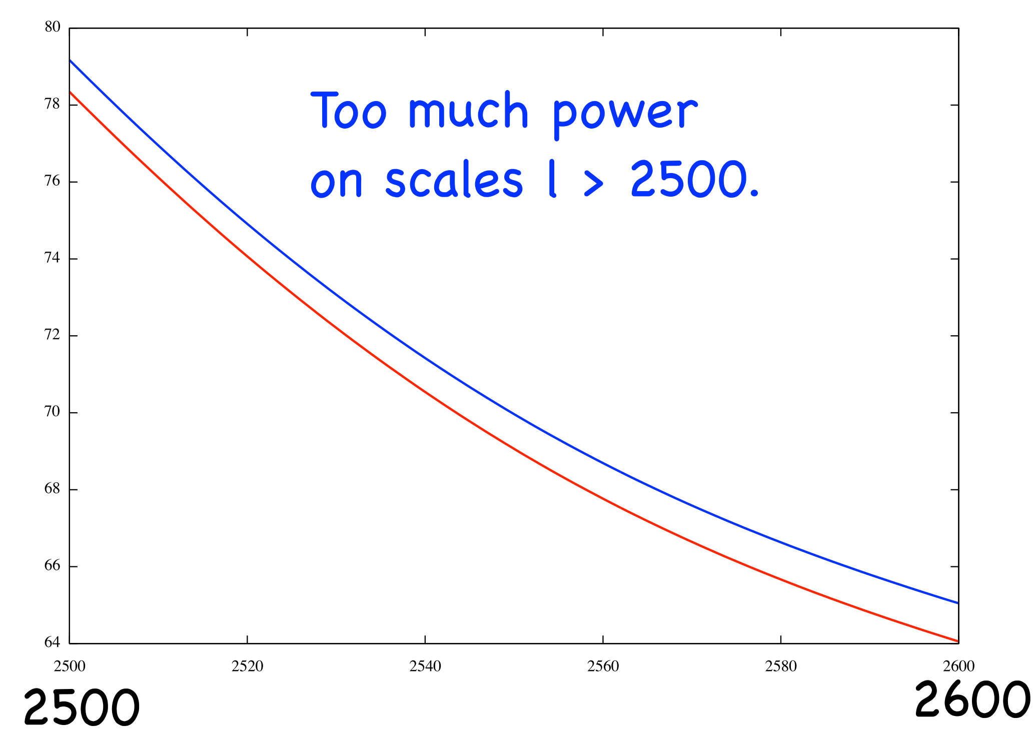
Let's keep As fixed,
but increase n_s



Red: no DM
Blue: with DM



BUT



CMB Data & Variables

Cosmological: $h, \tau, n_{\rm s}, A_{\rm s}, \Omega_{\rm b}h^2, \Omega_{\rm c}h^2$

Particle: m_χ

Nuisance: A_tSZ, A_kSZ, A_PS(100), A_PS(143),
A_PS(217), A_CIB(143), A_CIB(217) [PLANCK]

+ A_SZ, A_CIB_cl, A_CIB_ps [SPT]

Data:

PLANCK (for TT)
+ WMAP (for TT, EE and TE)
+ SPT (high ell TT)
+ ACT (high ell TT)

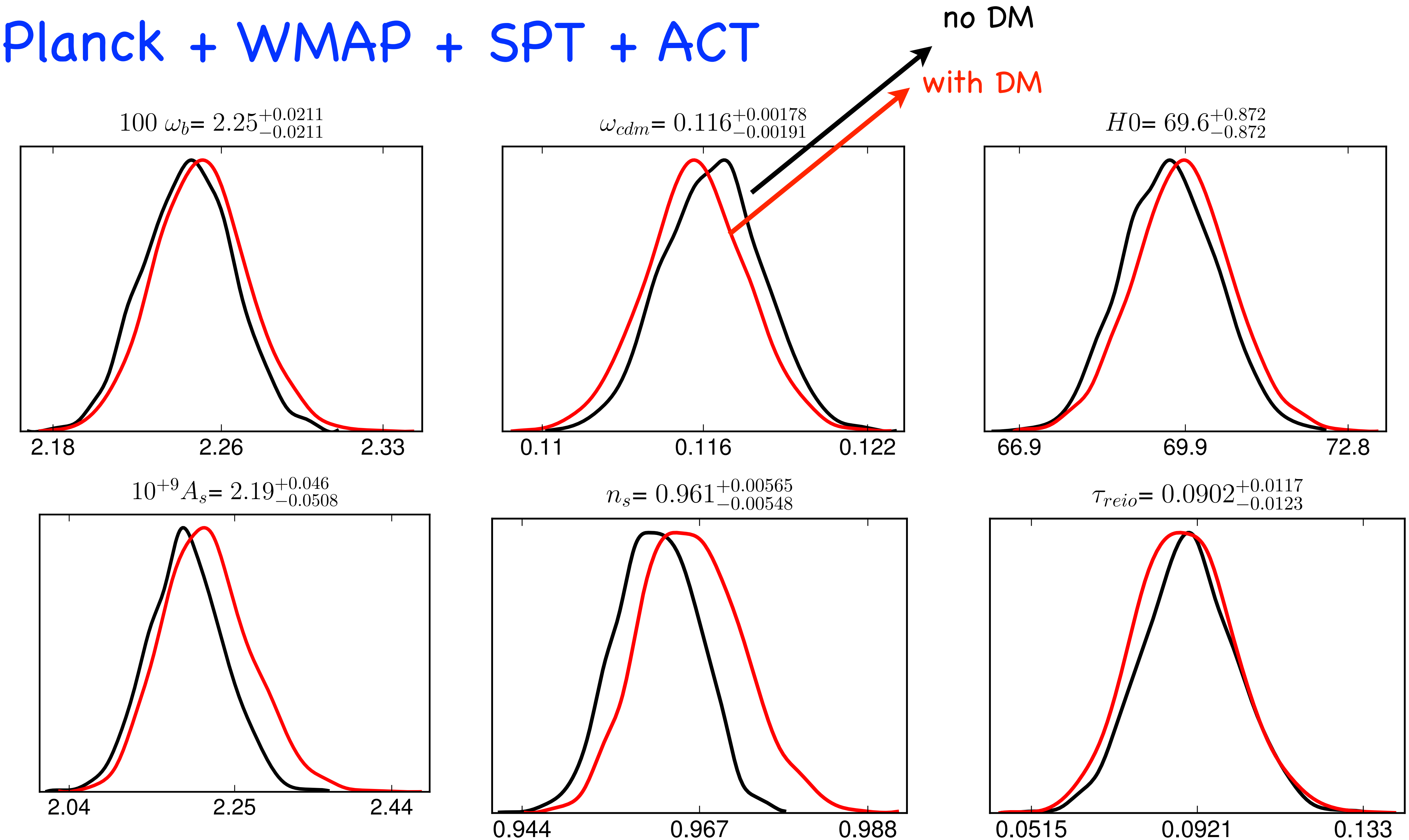
Bounds on the WIMP mass:

$$\xi = \frac{1\ \mathrm{pb}}{m_\chi} \frac{f_{\mathrm{abs}}}{1.0}$$

Planck + WMAP + SPT + ACT	m > 19.7 GeV
Planck + WMAP + SPT	m > 23.0 GeV
Planck + WMAP + ACT	m > 17.4 GeV

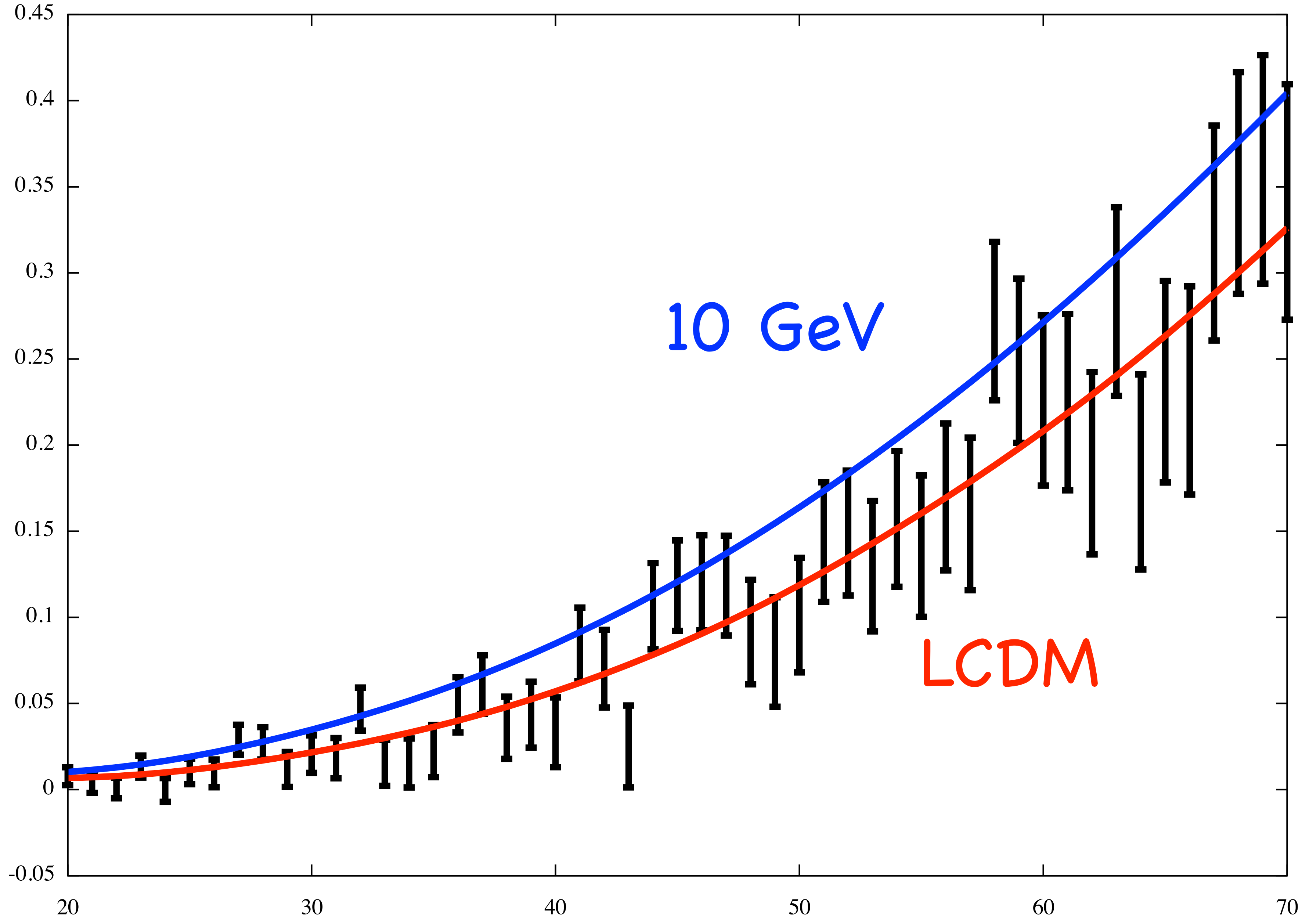
Preliminary results.

Planck + WMAP + SPT + ACT



	without DM	with DM
100 x ombh2:	2.25 \pm 0.021	2.25 \pm 0.022
omch2:	0.116 \pm 0.0018	0.116 \pm 0.0019
H0:	69.6 \pm 0.87	69.8 \pm 0.89
10^9 As:	2.19 \pm 0.048	2.21 \pm 0.056
ns:	0.961 \pm 0.006	0.966 \pm 0.007
\tau:	0.090 \pm 0.01	0.089 \pm 0.01

With simulated Planck Polarization data:



82 uK sqrt(s); 30 months, 7 arcminutes.

m > 65 GeV at 95% CL !

Conclusions

- WIMPs are well motivated dark matter candidates.
  Low mass WIMPS are favored by direct detection expts.

- Low mass WIMPs annihilate at early times z > 100.
  The energy released is absorbed by gas
  --> The gas is ionized and heated.

- The CMB is a very clean probe of low mass WIMP dark matter.
  Current limits from Planck + WMAP + SPT + ACT
  disfavor WIMP mass < 20 GeV if f_{abs} = 1.0 and c/s = 1 pb.c

- Polarization data from Planck can constrain WIMP masses as large as 65 GeV for f_abs = 1.0 and c/s = 1 pb.c !