Distinguishing standard reionization from dark matter models

with Dominik J. Schwarz
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Aravind Natarajan
Carnegie Mellon University
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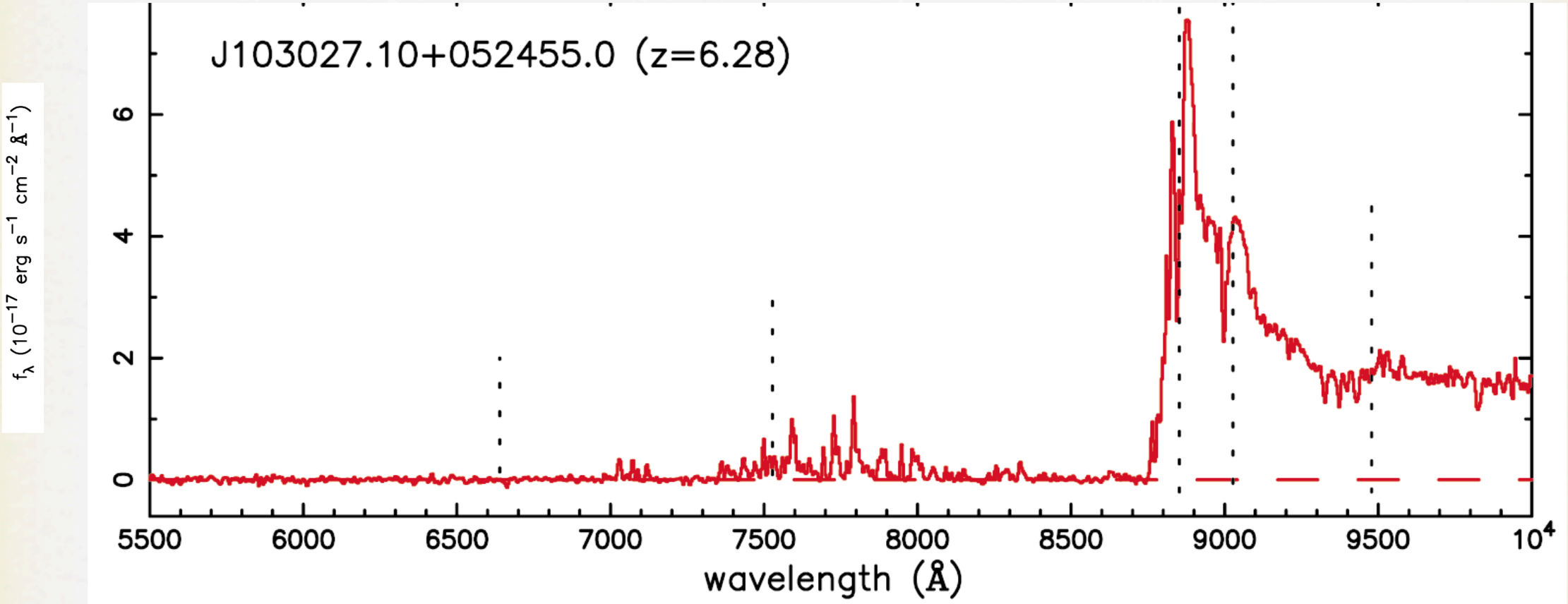
Reionization



R.H. Becker et al. 2001 (Sloan Digital Sky Survey)

Outline

- If the DM is a WIMP, some particles annihilate, releasing energy.
- Some of this energy heats and ionizes Hydrogen atoms.
- Free electrons scatter CMB photons, changing the polarization power, and the observed optical depth.

Particle annihilation:

Probability of annihilation = $\langle \sigma_a v \rangle \, n_\chi \, \delta t$

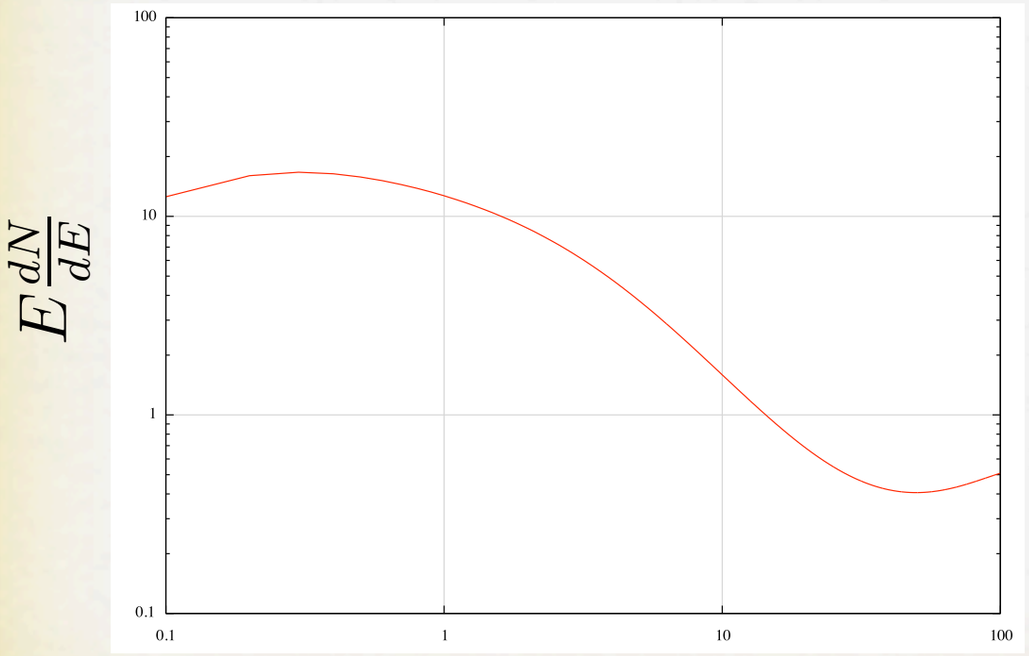
Number of particles pairs = $\frac{1}{2} \, n_\chi \, \delta V$

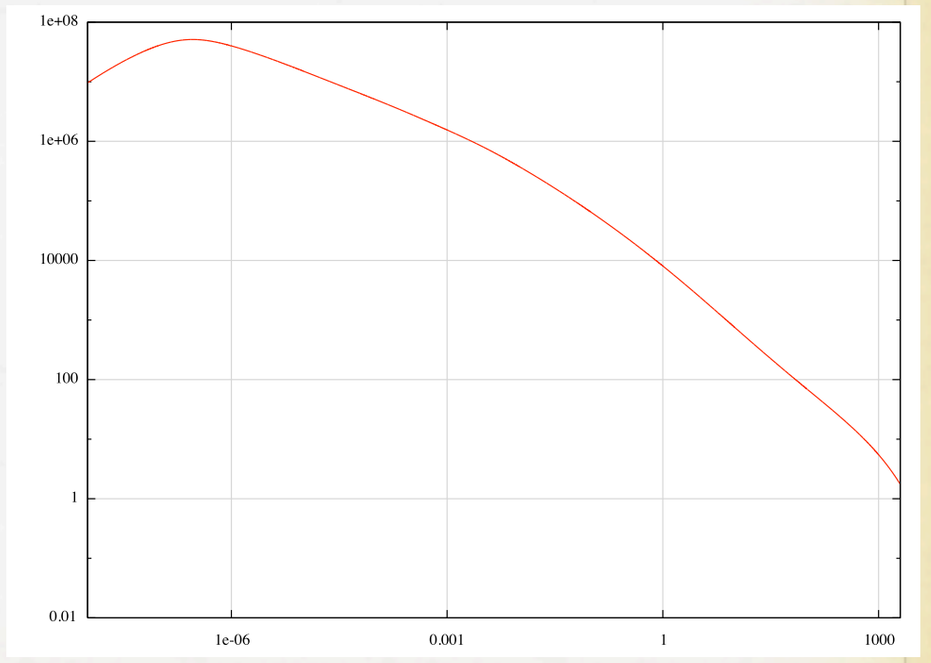
Energy released per annihilation = $2 \, m_\chi \, c^2$

$$\frac{dN_{\rm ann}}{dt dV} \sim \frac{\langle \sigma_{\rm a} v \rangle}{m_\chi} \, \rho_\chi^2$$

charged particles
photons
neutrinos

Scattering by CMB photons.





Scattering cross section:

- Photoionization.
- Compton scattering.
- Pair production (with atoms)

Natarajan and Schwarz (2008, 2009)
Cirelli and Panci (2009)
Belikov and Hooper (2009)
Cirelli, Iocco, and Panci (2009)
Hutsi, Hektor, and Raidal (2009)
Yuan, Yue, Bi, Chen, and Zhang (2009)
Natarajan and Schwarz (2010)

- $\gamma\gamma \longrightarrow \gamma\gamma$
- $\gamma\gamma \longrightarrow e^+e^-$

$$-\frac{dx_{\rm ion}}{dz} = I(z) - R(z)$$

Optical depth for CMB photons

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

WMAP 1 year $\tau = 0.17 \pm 0.04$

WMAP 3 year $\tau = 0.09 \pm 0.03$

WMAP 5 year $\tau = 0.087 \pm 0.017$

$\tau = 0.084 \pm 0.016$ with BAO+SN

WMAP 7 year $\tau = 0.088 \pm 0.015$

$\tau = 0.087 \pm 0.015$ gradual reionization.

WMAP 7 year results from low-l polarization alone

Cosmic variance limited for $2 \leq l \leq 6$

Residual electrons:

60 < z < 1000

Sudden and complete recombination at z=1000.

m_χ (GeV)	10	50	100	500
τ ($\tau_{\rm R} = 0$)	0.070	0.033	0.024	0.011

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Gradual recombination using RECFAST code.

m_χ (GeV)	10	50	100	500
τ ($\tau_{\rm R} = 0$)	0.070	0.033	0.024	0.011
$\tau - \tau_{\rm R}$	0.028	0.007	0.004	0.001

Residual electron dominate for $z > 800$

DM particles ionize the Universe $60 < z < 800$

DM halos ionize the Universe $25 < z < 60$

Baryonic objects are important for $z < 25$

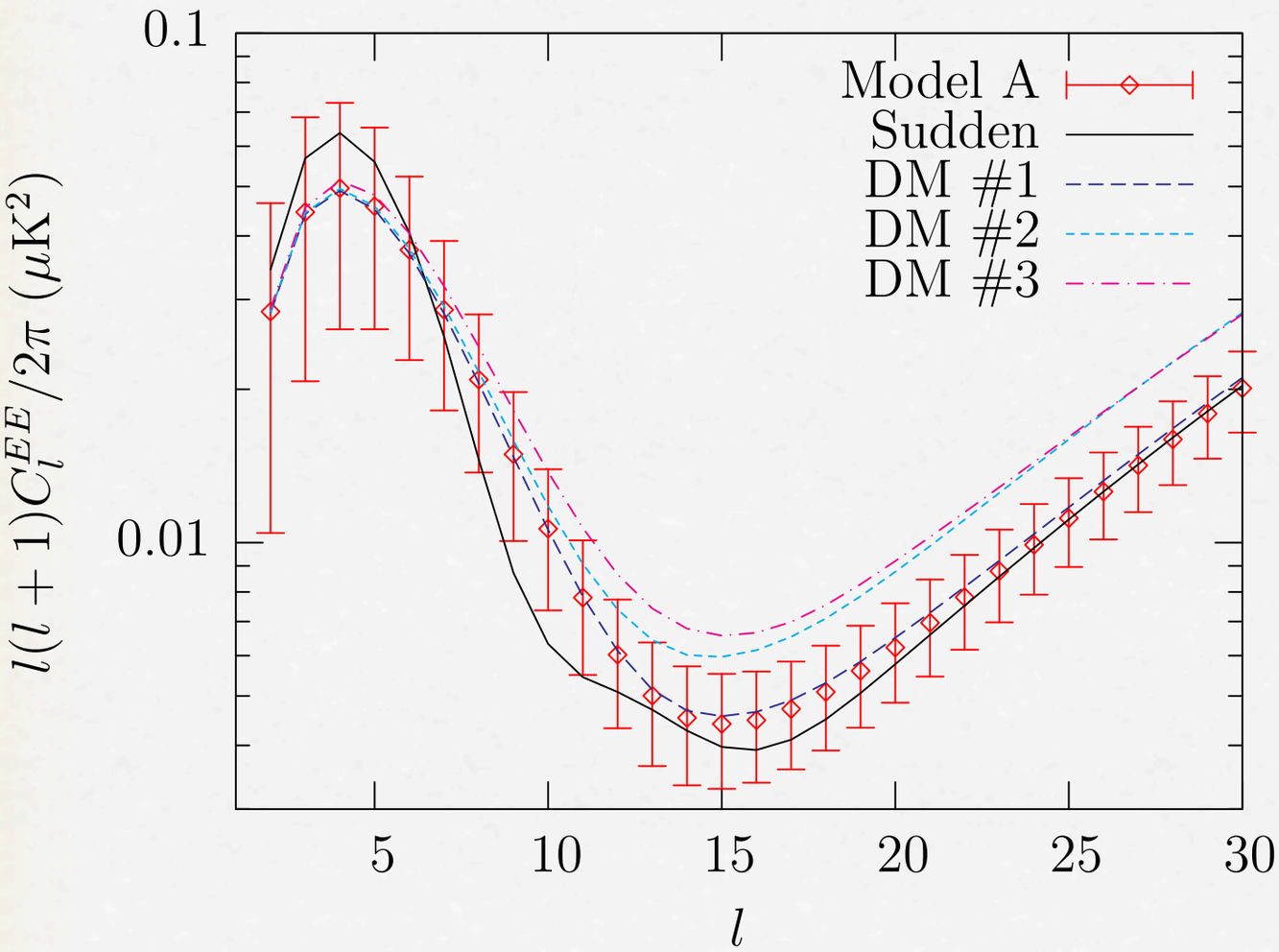
Optical depth up to $z=25 = 0.087$

Optical depth for $z > 25 =$???

DM Model #1: $m_\chi = 100$ GeV, $c = 15$

DM Model #2: $m_\chi = 10$ GeV, $c = 5$ $\quad \langle \sigma_{\rm a} v \rangle = 3 \times 10^{-26}$ cm^3/s

DM Model #3: $m_\chi = 10$ GeV, $c = 15$



See also:

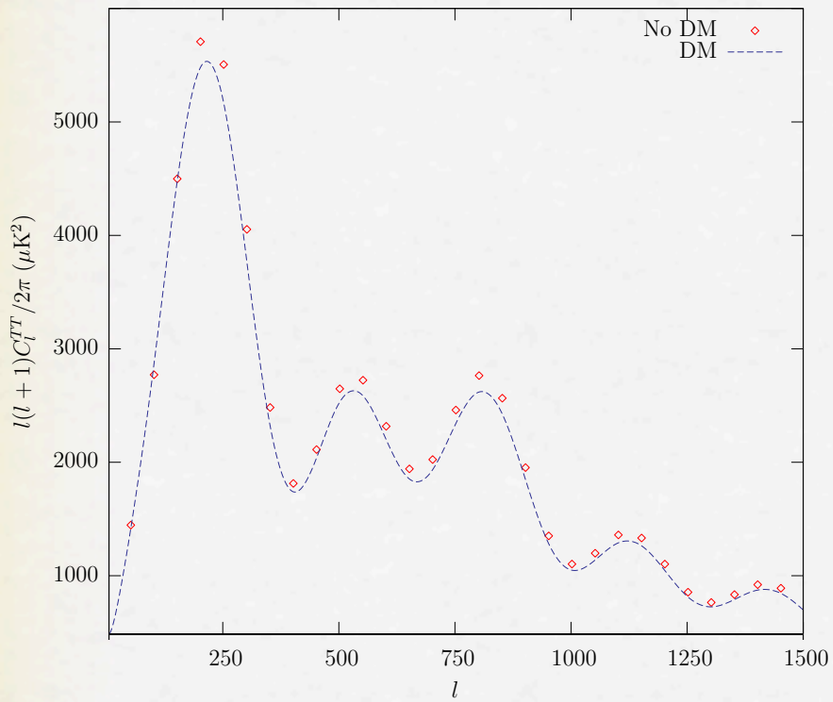
Iocco (2009)

Kanzaki, Kawasaki, Nakayama (2009)

Naselsky and Kim (2010)

Error bars drawn for the 2-step baryonic reionization model.

What about TT ?



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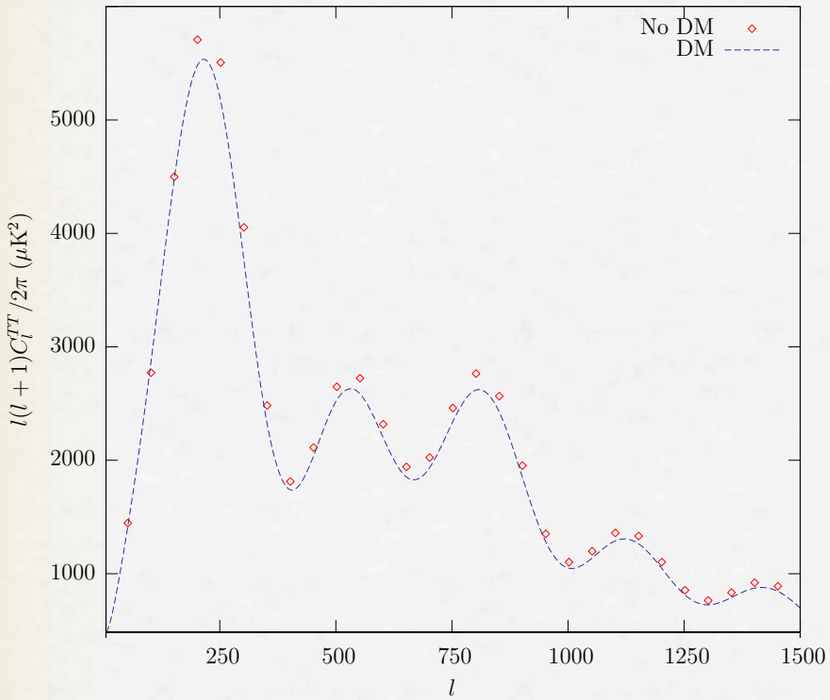
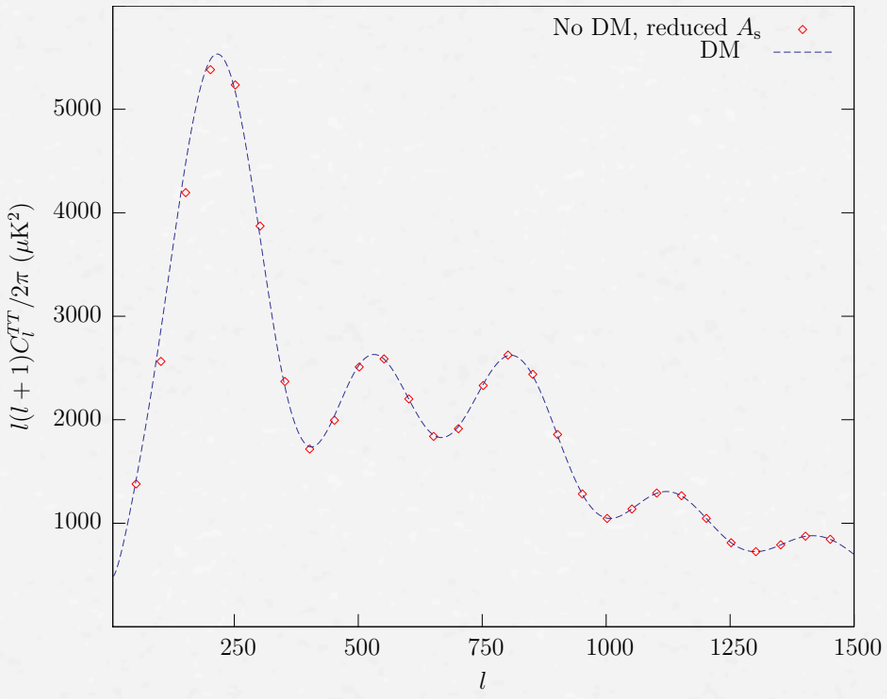


A_s reduced by 5%



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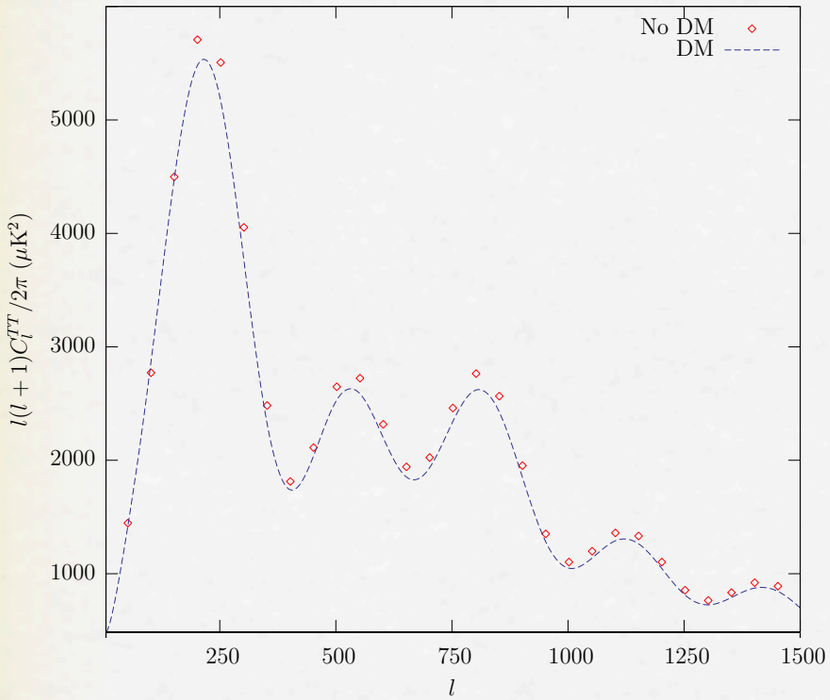

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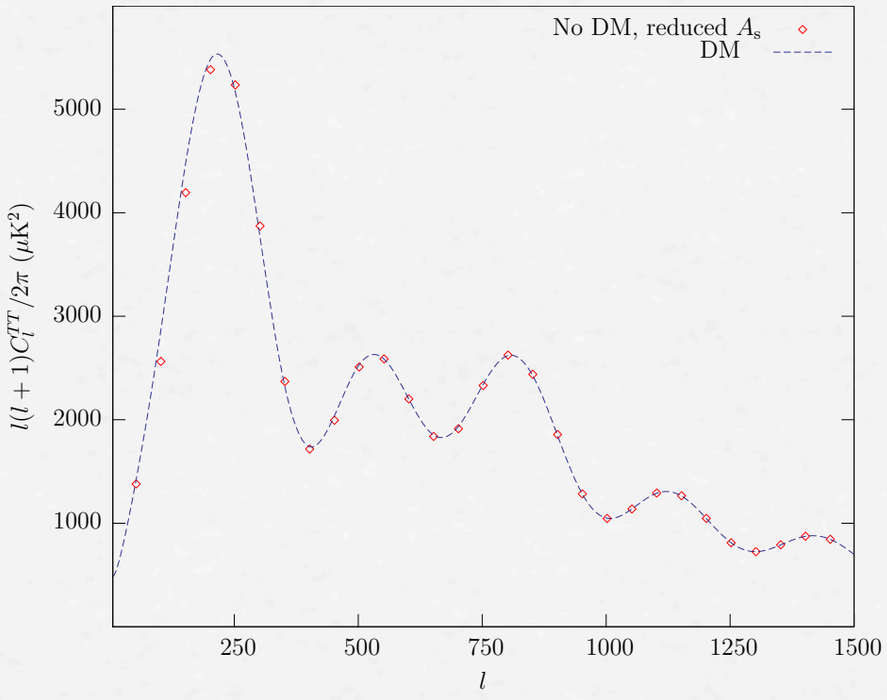

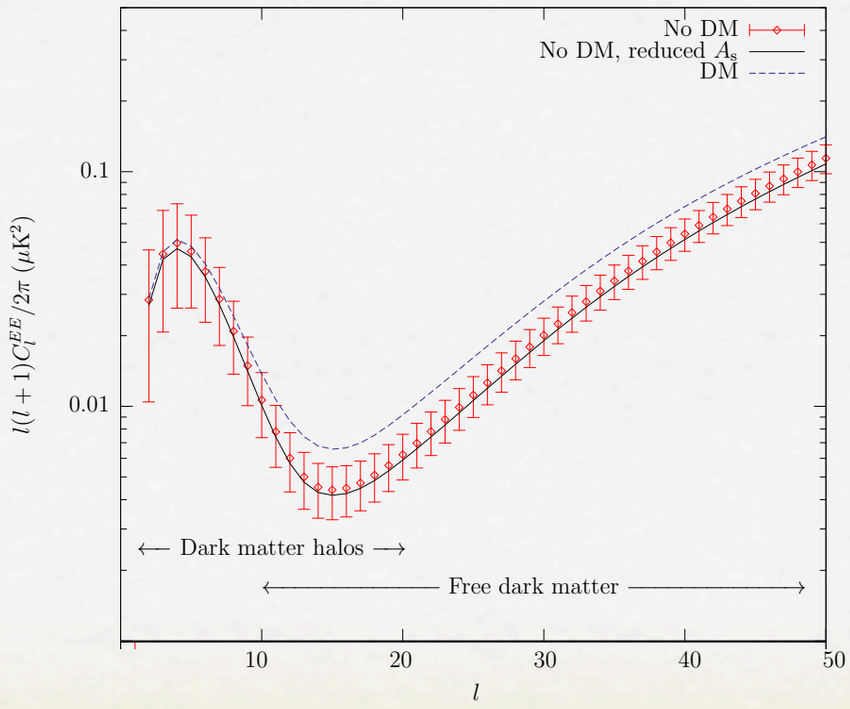

Conclusions

- WIMP DM can alter the CMB power spectra and the optical depth.
- WMAP does not observe the optical depth to last scattering and cannot distinguish DM from a 2-step baryonic model.
- Planck will do better with EE data up to l=20.
- Future surveys will place better constraints on WIMP DM.