What can diffuse extragalactic gamma-ray background tell us about DM? Inverse Compton Photons.

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A.Belikov, D. Hooper, Phys.Rev.D **80**, *035007 (2009)*
A.Belikov, D. Hooper, Phys.Rev.D **81**, *043505 (2009)*

Outline

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1. Motivation

2. Aspects of the model
   - Annihilation spectrum
   - Inverse Compton Spectum
   - Halo parameters.

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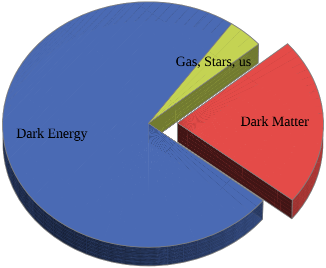
3. Results
4. Summary

The composition of Universe today.

Evidence for Dark Matter.

- Dark Energy: 74%
- Dark Matter: 22%
- Baryonic Matter: 4%
- Neutrinos: 0.003-0.02%
- Radiation: 0.01%

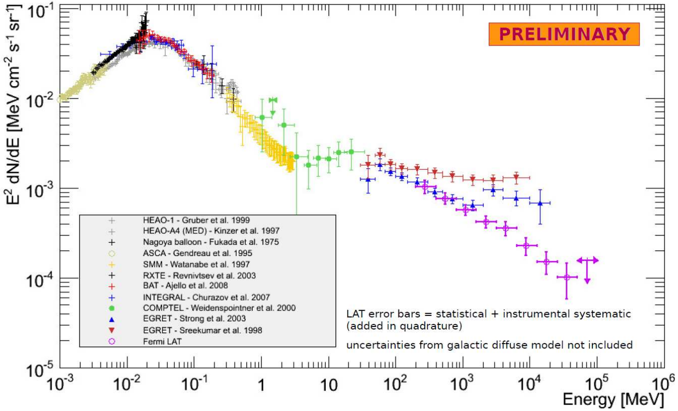


1. Galaxy rotation curves, velocity dispersion of galaxies
2. Gravitational lensing by galaxy clusters
3. Structure formation (CMB anisotropies and N-body simulations)
4. Big Bang nucleosynthesis

The scope.

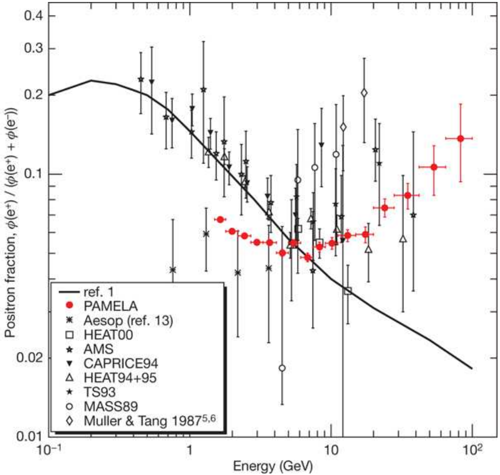
- MSSM: Neutralino.
- Indirect detection: searching for products of annihilation.
  - Photons: COMPTEL, EGRET, Fermi.
  - Electrons: PAMELA, ATIC.
- Extragalactic Dark Matter in Halos. Diffuse signal.

EGRET,COMPTEL and Fermi



Ackerman, TeVPA 2009

PAMELA



Adriani *et al.*, *Nature*, **458**, 607, (2009)

Components of the model

1. Halo mass function
2. The dimensionless enhancement factor $\Delta^2(z, M)$ of the square of density for a halo of a given mass
3. The annihilation spectrum: electrons and prompt photons
4. Inverse Compton photons production by high-energy electrons
5. Optical depth

$$\frac{d\phi}{dEdtd\Omega dA} = \frac{\langle\sigma v\rangle}{8\pi}\frac{c}{H_0}\frac{\rho_X^2}{m_X^2}\int dz\, dM \frac{(1+z)^3}{h(z)}\frac{dn}{dM}(z, M)\times$$

$$\times\Delta^2(z, M)\frac{dN_\gamma}{dE}(z, E)\, e^{-\tau(z,E)}$$

Monochromatic line: forbidden at tree level, but distinct.

$$\chi + \bar{\chi} \to \gamma + \gamma$$

Continuum spectrum: photon is a by-product of annihilation to ...

- Gauge bosons: $\chi + \bar{\chi} \to W^+ + W^- \to \gamma + ...$
- leptons: $\chi + \bar{\chi} \to \tau^+ + \tau^- \to \gamma + ...$
- quarks: $\chi + \bar{\chi} \to b + \bar{b} \to \gamma + ...$

Monochromatic line: suppressed.

$\chi + \bar{\chi} \to e^+ + e^-$

The amplitude of s-wave annihilation to fermions is suppressed by the square of mass of the final-state fermion.

Continuum spectrum: photon is a by-product of annihilation to ...

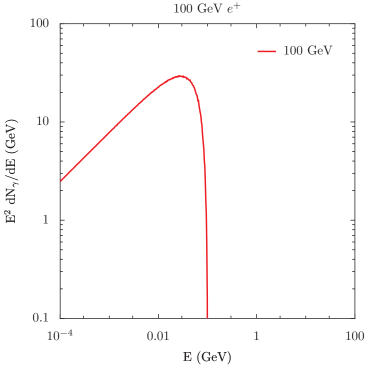
- Gauge bosons: $\chi + \bar{\chi} \to W^+ + W^- \to e^+ + e^- ...$
- leptons: $\chi + \bar{\chi} \to \tau^+ + \tau^- \to e^+ + e^- + ...$
- quarks: $\chi + \bar{\chi} \to b + \bar{b} \to e^+ + e^- + ...$

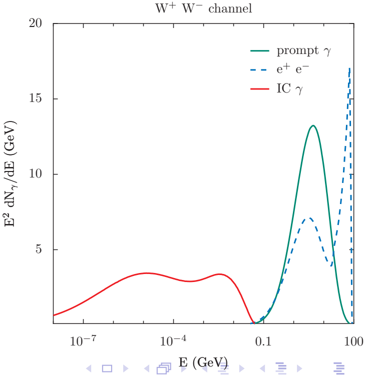
Inverse Compton scattering off abundant CMB photons

$$\frac{dN}{d\epsilon\, dt} = 3\sigma_T\, c\, n_e (2\epsilon \ln\epsilon + \epsilon + 1 - \epsilon^2) N(\nu_0) d\nu_0, \text{ where } \epsilon = \frac{\nu}{4\gamma^2\nu_0}$$

$$h\bar{\nu} \sim \frac{4}{3}\left(\frac{E_e}{m_e}\right)^2 E_{CMB} = 3.4\times10^{-2}(1+z)\left(\frac{E_e}{100GeV}\right)^2 \text{ GeV}$$

$$\frac{dN}{dE_\gamma} \sim E_\gamma^{-3/2},\ \tau_H \gg \tau_{IC}$$





Halo mass function.

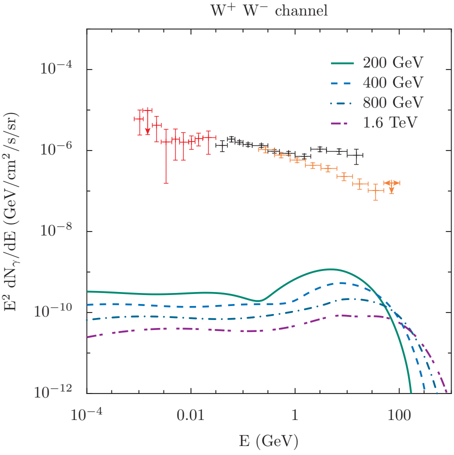
1. Power spectrum: $\sigma_8 = 0.812$, $n_s = 0.96$.
2. Linear overdensity: $\delta_{sc} = 1.686$.
3. Sheth-Tormen multiplicity function: $\nu f(\nu) = A\left(1 + \frac{1}{\nu'^{2q}}\right)\sqrt{\frac{\nu'^2}{2\pi}}\exp\left(-\nu'^2/2\right)$ with $\nu' = \sqrt{a}\nu$, $a = 0.75$ and $q = 0.3$.

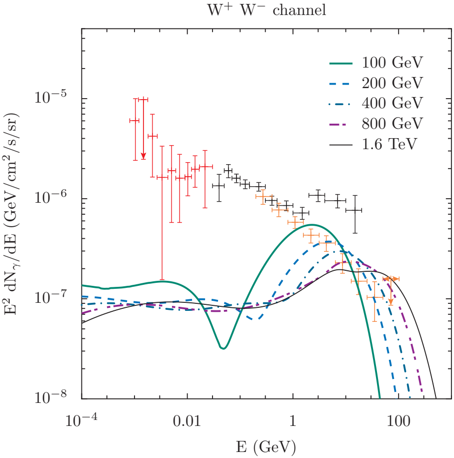
At z $= 0$ approximately 70% of mass is in halos heavier than 10^{-6} solar masses.

$\Delta^2(z, M)$ parameters

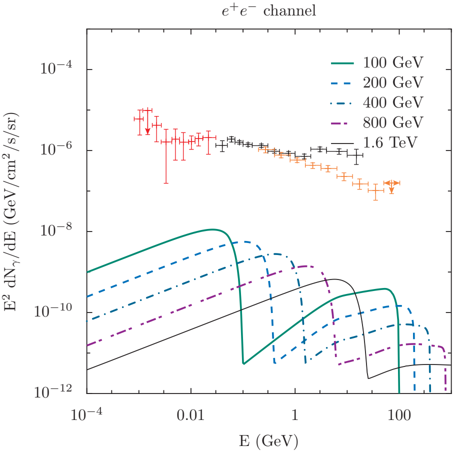
1. NFW density profile: $\rho(r) = \frac{\rho_0}{r/a(1+(r/a)^2}$.
2. $\{a, \rho_0\} \to \{c, M\}$, $c(M) \sim R_{vir}/a$.
3. c is distributed log-normally with the mean $c_0(M)$, where $c_0(M)$ is given by Bullock scheme: $\sigma(FM) = \delta(z')$, $c(M, z) = c_0\frac{1+z'(M)}{1+z}$
4. The concentration is cut off at 10^5 solar masses.

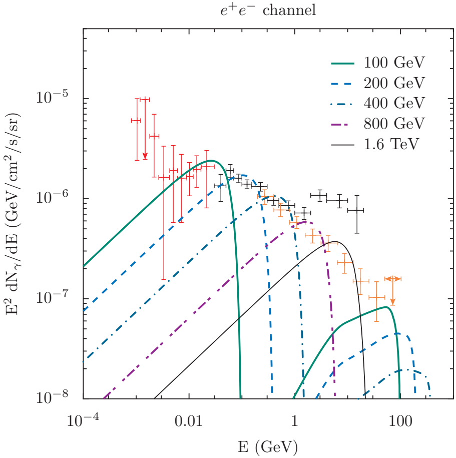
W^+ W^- channel: conservative case



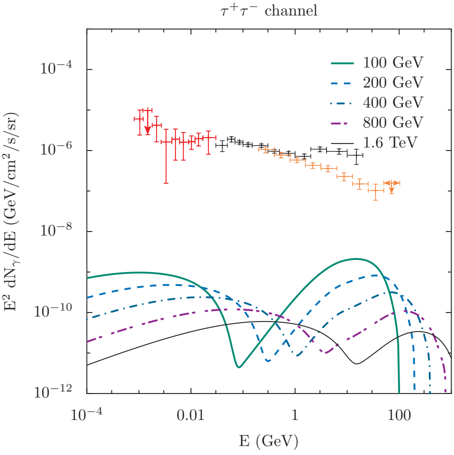


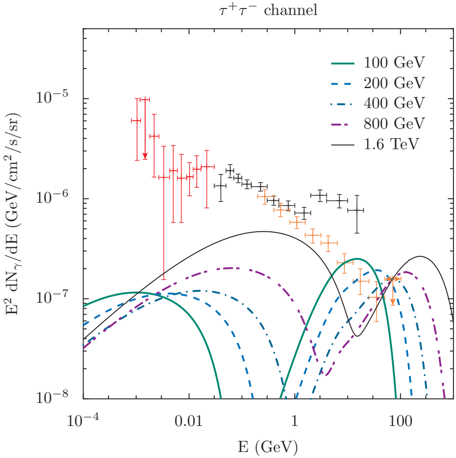
$e^+ e^-$ channel: extreme case



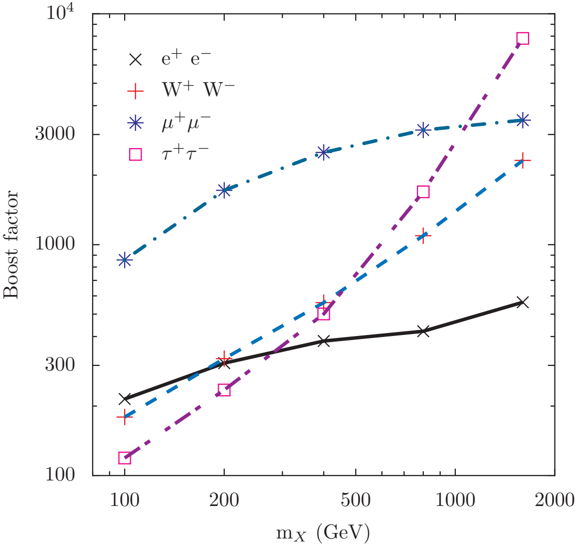


$\tau^+ \tau^-$ channel





Required Boost Factor



Summary

- Inverse Compton photon spectrum is widened by a factor of 2 and shifted down in energies compared to electron spectrum.
- Consideration of inverse Compton scattered photons coming from Dark Matter annihilating primarily in leptophilic channels weakens DM constraints by a factor of two: required boost factor is about a hudnred for 100 GeV neutralino annihilating to $\tau^+ \tau^-$.
- Gauge boson annihilation channels such as $W^+ W^-$, require BF from 200 to 2,500 for NFW for M_χ from 100 GeV to 1.6 TeV.
- The consideration of Fermi data moved the gauge boson channel constraint closer to $\tau^+ \tau^-$ channel constraint (prompt vs IC).
- Apart from observational consequences, IC photons might have played a role in reionization history.