Dark matter annihilation at cosmological redshifts: possible relic signal from WIMP annihilation[1]

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The extragalactic gamma-ray background spectrum

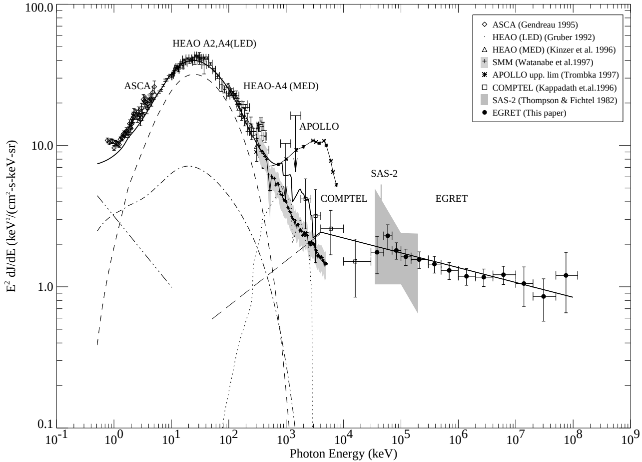


Figure: The extragalactic gamma-ray background spectrum taken from Sreekumar et al., 1998. It reportedly has a peculiarity in the energy range 0.5 - 20 MeV (Inoue, Totani, & Y. Ueda (2008); Ahn & Komatsu (2005a,b); Rasera et al. (2006); Strigari et al. (2005)).

The dark matter annihilation in the early Universe

Principle suppositions

- The metric has usual shape $ds^2 = c^2dt^2 - a^2(t)dl^2$ and our Universe has zero three-dimensional curvature.
- The dark matter is a mixture of equal quantities of particles and antiparticles, generated in the early Universe.
- Of all the particles that can be generated by the dark matter annihilation we consider only photons, as they are both uncharged and easily detectable.
- The dark matter is homogeneous

Temporary suppositions

- One act of annihilation produces one photon of fixed energy β.
- The Universe is transparent for the photons.

The case of transparent Universe

If the produced photons have some distribution $f(\beta)\,d\beta$, we should convolute $Q(\varepsilon,\beta)$

$$\tilde{Q}(\varepsilon) = \int Q(\varepsilon,\beta) f(\beta)\,d\beta$$

The number of photons that come to the local observer from unit solid angle per unit time per unit of area per unit energy interval is:

$$Q = \frac{\langle\sigma \upsilon\rangle\, n_0^2 c}{8\pi H_0 \sqrt{\Omega_m}}\,\frac{\beta\sqrt{\beta}}{\varepsilon^2\sqrt{\varepsilon}}$$

Here ε is the present-day photon energy.

The universe opacity must be taken into account!

WIMP dark matter

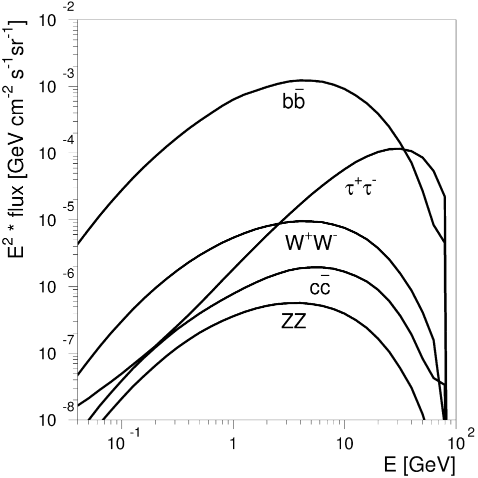


Figure: The spectra of photons generated by various WIMP annihilation channels, taken from de Boer et al., 2005 (the normalization is arbitrary, the WIMP mass is 100 GeV)

WIMP dark matter

Annihilation cross-section

WIMPs were in thermal equilibrium with other particles in the early Universe:

$$\langle \sigma \upsilon \rangle \simeq \frac{2 \cdot 10^{-27}\,(\mathrm{cm}^3/\mathrm{s})}{\Omega_{DM} h^2}$$

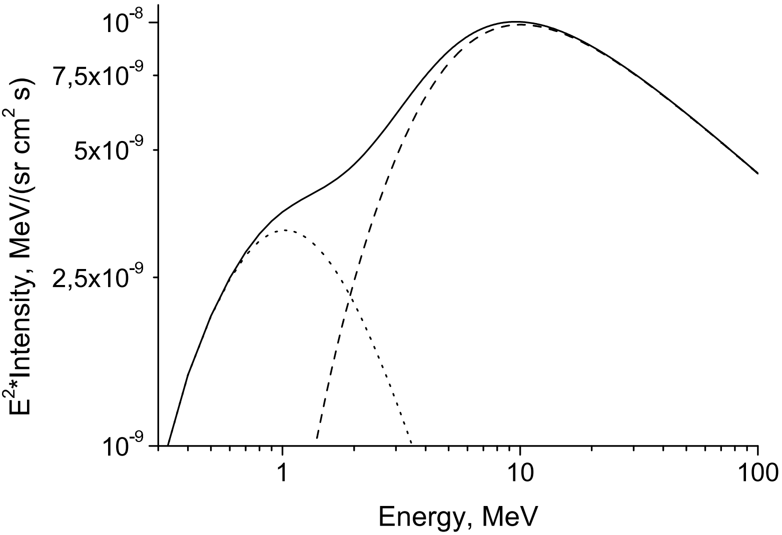
Absorption cross-section

The main channel of interaction with the baryonic matter is pair production on atoms and ionized matter $(\gamma A \to A e^+ e^-)$. The Universe becomes transparent for the photons at $z \simeq 300$.

$$\aleph = 1.63 \cdot 10^{-26}\,\mathrm{cm}^2; \qquad \wp = \frac{\aleph c n_0^b}{H_0 \sqrt{\Omega_m}}$$

$$Q = \frac{\langle \sigma \upsilon \rangle \, n_0^2 c}{8\pi H_0 \sqrt{\Omega_m}} \, \frac{\beta\sqrt{\beta}}{\varepsilon^2 \sqrt{\varepsilon}} \, \exp\left(-\frac{2}{3} \wp \frac{\beta\sqrt{\beta}}{\varepsilon \sqrt{\varepsilon}} \right)$$

Predicted spectrum of the relic gamma-ray background



The boost factor

The energy range of the experimental and predicted features correspond closely, but the relic gamma emission predicted is approximately five orders fainter than the observed feature. We need a boost factor $C \equiv \frac{<\rho^2>}{<\rho>^2}$.

The spectrum of primordial fluctuations

It is usually supposed to be power-law $|\delta^2(\mathbf{k})| \sim k^n$ and to have a cut-off at $10^{-6} - 10^{-12} M_\odot$

- For $n = 1$ (the Harrison-Zeldovich spectrum) the first clumps collapse at $z \simeq 80$.
- For $n = 2$ small clumps appear much earlier ($z \simeq 2500$) and have much higher density.

The boost factor evolution with z for $n = 2$, calculated according to Ahn & Komatsu, 2005