Generic cold dark matter annihilation spectrum

- Including prompt gamma rays, inverse Compton, and synchrotron radiation -

Till Steinbring

Lehrstuhl für Astronomie, Universität Würzburg

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Dark matter and the standard model of cosmology

Multiple evidences für CDM:

- Rotation curve of spiral galaxies, Gravitational lensing, Microwave background (CMB)

Most recent example:

- Dark matter mass required to explain gravitational redshift observed in clusters of galaxies

  Radoslaw Wojtak, Steen H. Hansen, Jens Hjorth: Gravitational redshift of galaxies in clusters as predicted by general relativity (September 2011, arXiv:1109.6571v1 [astro-ph.CO])

WIMP miracle: Freeze-out of massive, weakly interacting particles with observed relic density

Candidates for dark matter

Particle physics

New particles beyond the standard model

- Beyond the scale of electroweak interaction

$$\mathcal{O}((G_F\sqrt{2})^{-\frac{1}{2}}) \approx 250\mathrm{GeV}$$

Possible extension of the SM: Supersymmetry

Stable WIMPs in R-parity conserving Supersymmetry

LSP as dark matter candidate

- Lightest stable particle (electrical neutral) e.g.:

  Neutralino χ_0

- Decay in light SM-particles via $\chi\chi$-annihilation

  ($\rightarrow$ high muliplicity)

Dark matter annihilation

- Assumed decay-chanel:

  $\chi\chi \rightarrow ... \rightarrow \pi^0 + \pi^{\pm} + ...$

  $\pi^0 \rightarrow \gamma\gamma$: *prompt* γ *rays*

  $\pi^{\pm} \rightarrow ... e^{\pm} + \nu$: *IC scattering, Synchrotron radiation*

CDM annihilation

The generic spectrum

$$\left(\frac{d\Phi}{dE}\right)_{tot} = \left(\frac{d\Phi}{dE}\right)_{\gamma} + \left(\frac{d\Phi}{dE}\right)_{IC} + \left(\frac{d\Phi}{dE}\right)_{Syn}$$

- $\left(\frac{d\Phi}{dE}\right)_{\gamma}$ prompt gamma rays from $\pi^0 \rightarrow \gamma\gamma$
- $\left(\frac{d\Phi}{dE}\right)_{IC}$ secondary gamma rays due to inverse Compton scattering off **CMB** photons and **star light** photons
- $\left(\frac{d\Phi}{dE}\right)_{Syn}$ synchrotron radiation in interstellar magnetic fields

Calculations done for the local universe $(z = 0)$

Prompt gamma peak

$$\left(\frac{d\Phi}{dE}\right)_\gamma = \frac{1}{8\pi}\frac{dN_\gamma}{dE}\frac{\langle\sigma_a v\rangle}{m_\chi^2}J$$

Line of sight integration:

$$J = \int_0^{\theta_{max}} d\theta \sin(\theta) \int_{s_{min}}^{s_{max}} ds \left(\rho_{NFW}\left[\sqrt{s^2 + D^2 - 2Ds\cos(\theta)}\right]\right)^2$$

NFW DM density profile

$$\rho_{NFW}(r) = \frac{\rho_0}{\left(\frac{r}{r_s}\right)\left(1 + \frac{r}{r_s}\right)^2}$$

Navarro, J.F.; Frenk, C.S.; White, S.D.M.: The structure of cold dark matter halos; Astroph. Journal 462 (1996), S. 563, http://dx.doi.org/10.1086/177173.

Generic gamma ray spectrum

$$\frac{dN_\gamma}{dE} = \frac{0.42}{m_\chi} \frac{\exp(-\frac{8E}{m_\chi})}{\left(\frac{E}{m_\chi}\right)^{1.5} + 0.00014}$$

Method: averaging simulations runs with DARKSUSY for 10^6 different cosmologically interesting dark matter candidates.

Bergström, L.; Edsjö, J.; Ullio, P.: Spectral gamma-ray signatures of cosmological dark matter annihilations; PRL 87 (2001), Nr. 25, S. 251301, http://dx.doi.org/10.1103/PhysRevLett.87.251301.

Inverse Compton peak

$$\left(\frac{d\Phi}{dE}\right)_{IC} = \frac{1}{E}\frac{\langle\sigma_a v\rangle}{2m_\chi^2} J \times \int_{m_e}^{m_\chi} dE' \frac{P(E,E')}{b(E')} \int_{E'}^{m_\chi} d\epsilon \frac{dN_e}{d\epsilon}$$

- Assumption of thermal photon fields with $T_{CMB} = 2.7$ K and $T_{SL} = 5000$ K

Synchrotron peak

$$\left(\frac{d\Phi}{dE}\right)_{Syn} = \frac{\sqrt{3}q^3 B}{\pi m_e c^2} J \times \int_{E'}^{m_\chi} d\epsilon \frac{dN_e}{d\epsilon} F(x)$$

- $F(x) = x\int_x^\infty d\zeta K_{5/3}(\zeta)$, $K_{5/3}(\zeta)$, modified Bessel-function
- $B_{ISM} \approx 3 - 5\mu\mathrm{G}$ (disorderd)

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Fig.: Spectral energy distribution for the generic cold dark matter annihilation spectrum including synchrotron radiation (brown), IC gamma rays off CMB photons (purple), IC gamma rays off star light photons (green) and prompt gamma rays (blue).

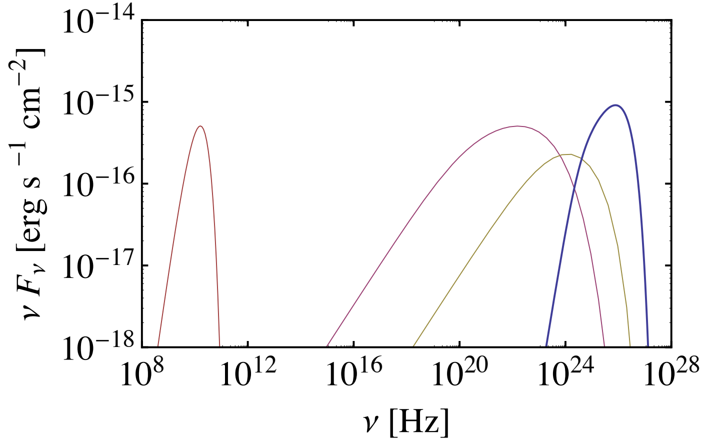


Fig.: Peak distance as a function of m_χ

Summa, A. Dunkelmaterie Annihilation und Inverser Comptoneffekt, Diplomarbeit (2010), Universität Würzburg

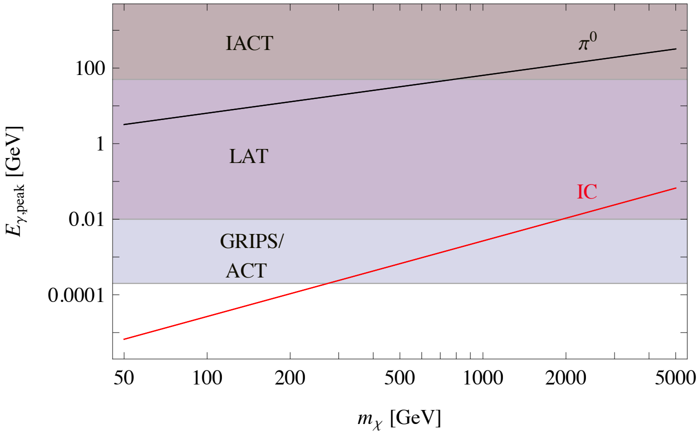
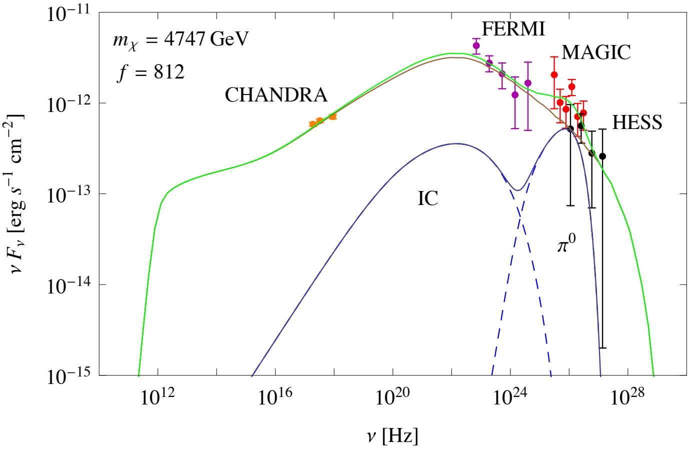


Fig.: Spectral energy distribution of M87 using a SSC model and with inclusion of the DMA (IC off CMB photons) model.

Saxena, S.; Elsässer, D.; Rüger, M.; Summa, A.; Mannheim, K.: Searching for dark matter annihilation in M87, ICRC 2011



Thank you for your attention