Probing dark matter with AGN jets

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The idea

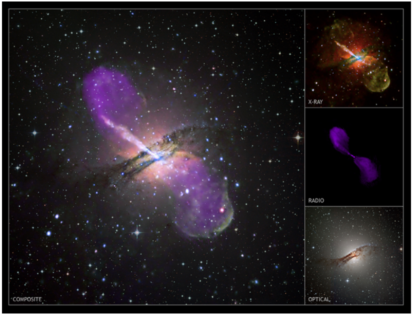
- Original idea by Bloom & Wells (98).
- Active Galactic Nuclei live in the densest regions of the largest dark matter halos and are sources of powerful and collimated jets containing ultra relativistic electrons and protons.
- Study the scattering of those high energy particles off of the dark matter present in the AGN halo with photons in the final state.
- If dark matter is heavy, the photons will be isotropically distributed, and if they have a distinct spectral feature we can hope to detect a signal.
- Fermi has potential for such a detection.

AGN candidates

Requisites for the AGN (if we hope to detect a signal)

- Close by
- Jets perpendicular to the line of sight

Centaurus A and **M87** seem to be the best candidates.



Photon flux

We are interested in the flux of photons

$$\frac{d\Phi_\gamma}{dE_\gamma} = \int dE_{e[p]} \underbrace{\left(\frac{1}{M} \frac{d^2\sigma_{e[p]+\chi\to\gamma+\dots}}{d\Omega dE_\gamma} \right)_{\cos\theta_0}}_{1} \underbrace{\left(\frac{1}{d^2_{\mathrm{AGN}}} \frac{d\Phi^{\mathrm{AGN}}_{e[p]}}{dE_{e[p]}} \right)}_{2} \underbrace{\delta_{\mathrm{DM}}}_{3} .$$

Three factors in the integrand

1. Differential cross section (depends on the DM particle model);
2. Electron (proton) energy distribution in the jet;
3. $\delta_{\mathrm{DM}} = \int_{r_{min}}^{r_0} \rho_{\mathrm{DM}}(r) dr$, which involves the DM profile.

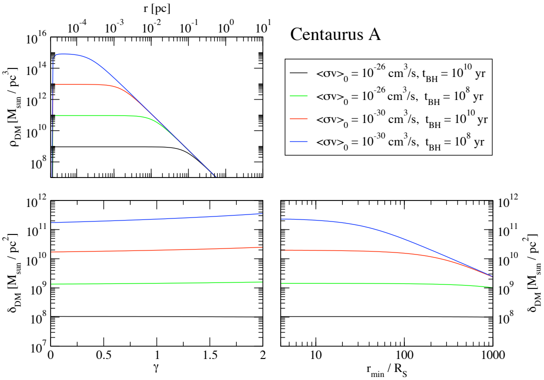
Dark matter profile

We use an adiabatically contracted profile [Gondolo & Silk 99]

$$\rho_{\rm DM}(r) = \frac{\rho'(r)\rho_{\rm core}}{\rho'(r) + \rho_{\rm core}}$$

where

$$\rho_{\rm core} \simeq M_\chi/(\langle\sigma v\rangle_0 t_{BH})$$



Electron energy distribution

Blob geometry: the electrons move isotropically in the blob frame with a power law energy distribution, and the blob itself moves with respect to the central black hole with a moderate bulk Lorentz factor.
Broken power law in the blob frame

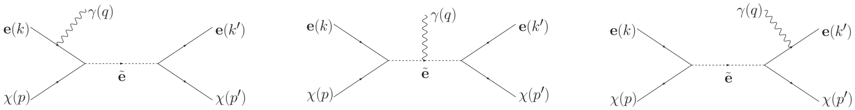
$$\frac{d\Phi_e^{\rm AGN}}{d\gamma'}(\gamma') = \frac{1}{2} k_e \gamma'^{-s_1} \left[1 + \left(\frac{\gamma'}{\gamma'_{\rm br}}\right)^{s_2 - s_1}\right]^{-1} \quad \text{for} \quad \gamma'_{\rm min} \le \gamma' \le \gamma'_{\rm max},$$

where the normalization k_e is obtained from the kinetic power of the jet, L_e.

Values for CenA:
$s_1 = 1.8$, $s_2 = 3.5$, $\gamma'_{\rm min} = 8 \times 10^2$, $\gamma'_{\rm br} = 4 \times 10^5$, $\gamma'_{\rm max} = 10^8$, $L_e = 3 \times 10^{43}$ erg/s.

Differential cross section

Assume MSSM → neutralino is the dark matter particle candidate



Two enhancements for the cross section

1. Resonance when the exchanged selectron goes on shell;
2. Log enhancement when the photon is collinear with the final electron.

Differential cross section

$$\left(\frac{d^2\sigma}{dE_\gamma d\Omega}\right)_{\cos\theta_0} = \frac{1}{(2\pi)^5}\frac{1}{32E'_N}2e^2(a_L^4 + a_R^4)\overbrace{\frac{1}{(s-M_{\tilde{e}}^2)^2 + s\Gamma^2}}^{\text{resonance at } s=M_{\tilde{e}}^2}$$

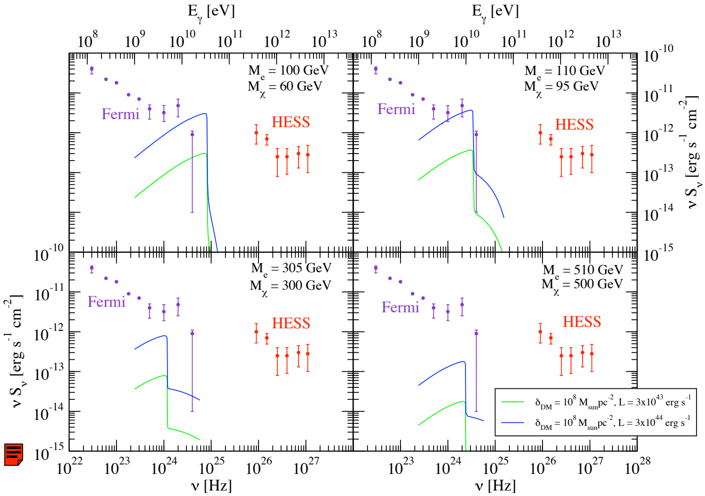
$$\left[E_\gamma\left(M_\chi + E(1-\cos\theta_0)\right) - |\Pi_{s'}|^2\left(s' - M_{\tilde{e}}^2 + \frac{\sqrt{s'}\Gamma^2}{\sqrt{s}+\sqrt{s'}}\right)\right.$$

$$\left. 4EM_\chi\left(EM_\chi - E_\gamma\left(M_\chi + E(1-\cos\theta_0)\right)\right)\right]$$

$$\underbrace{\pi\ln\left(\frac{4E'^2}{m_e^2}\right)}_{\text{log enhancement}}$$

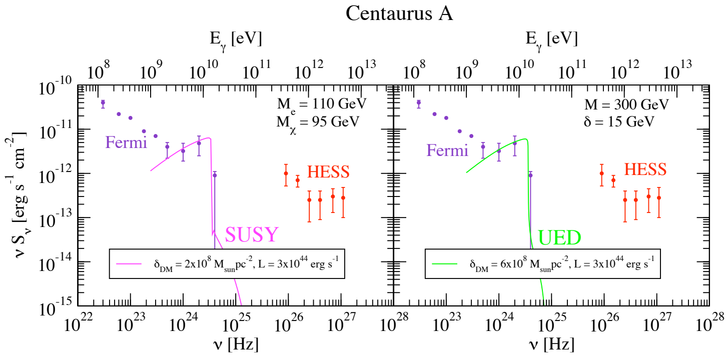
Results

Centaurus A, SUSY scenario



Results

With a reasonable choice of the parameters we get a curve that fits quite nicely the data collected by Fermi



Conclusions

- Given the very characteristic spectral feature shown in the plots, the detection of this effect is possible in principle.
- It is crucial to collect more data in the ”gap”: higher energy for Fermi, lower energy for atmospheric cherenkov telescopes.
- In 1998 Bloom and Wells concluded that there was no hope to detect such a signal. After twelve years we have a different conclusion: there is hope!
- There are still large astrophysical uncertainties associated with jet geometry and composition, particle spectrum and dark matter distribution.
- This method can be used as a cross check if discovery of dark matter is claimed by other experiments.
- Preprint of the paper to appear soon, stay tuned.