Barely Even a WIMPer

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Introduction

For decades, astrophysicists and particle physicists alike have been searching for an explanation of the elusive *dark matter*. Our best cosmological models predict that more than 25% of the universes energy density lies within dark matter [3], corroborated by a multitude of observed gravitational effects that necessitates that dark matter, whatever it may be, vastly dominates over baryonic matter. Over time, a number of hypotheses have been made as to the source of dark matter; namely Massive Compact Halo Objects (MACHOs), Weakly Interacting Massive Particles (WIMPs), and Axion dark matter.

Dark Matter by WIMPs

As MACHOs have been effectively ruled out as dark matter candidates (at least within the Milky Way), WIMPs emerge as the most widely held mechanism by which we explain dark matter observations [4]. The behaviour of a WIMP, as the name implies, is limited to weak force interactions. In fact, there is *observational* evidence that dark matter is electromagnetically neutral in the form of the *Bullet Cluster* (Figure 1, right), and interacts gravitationally through any gravitational lensing example (left in figure) or via galaxy rotation curves.

Figure 1. Observational Evidence for Dark Matter. *Left:* SDSS J1226+2149 (JWST), *right:* Bullet Cluster (Magellan + HST + Chandra)

One held notion is that WIMPs pair annihilate to form quark-antiquark pairs (or alternatively τ lepton-antilepton pairs), where γ rays could be produced depending on the interaction cross section [1]. Feasibly, space-based telescopes could observe these energetic photons in regions of high dark matter density in an astronomical context. These regions notably include the galactic center (where dark matter profiles peak) and DM-dominated dwarf spheroidal galaxies (dSphs).

References

[1] A. Albert et al. “Searching for Dark Matter Annihilation in Recently Discovered Milky Way Satellites with Fermi-LAT”. In: *The Astrophysical Journal* 834.2 (Jan. 2017), p. 110. DOI: `10.3847/1538-4357/834/2/110`. URL: `https://doi.org/10.3847%5C%2F1538-4357%5C%2F834%5C%2F2%5C%2F110`.

[2] Lisa Goodenough and Dan Hooper. *Possible Evidence For Dark Matter Annihilation In The Inner Milky Way From The Fermi Gamma Ray Space Telescope*. 2009. arXiv: `0910.2998 [hep-ph]`.

[3] Farinaldo S. Queiroz. *WIMP Theory Review*. 2017. arXiv: `1711.02463 [hep-ph]`.

[4] Leszek Roszkowski, Enrico Maria Sessolo, and Sebastian Trojanowski. “WIMP dark matter candidates and searches—current status and future prospects”. In: *Reports on Progress in Physics* 81.6 (May 2018), p. 066201. DOI: `10.1088/1361-6633/aab913`. URL: `https://doi.org/10.1088%5C%2F1361-6633%5C%2Faab913`.

Direct Detection

Figure 2 shows the fitting of a 28GeV WIMP pair annihilation event to the observed diffuse γ radiation in the Milky Way galactic center. This diffuse radiation is statistically significant from an isotropic background of γ rays, implying a definite source within 3^o of the dynamical galactic center.

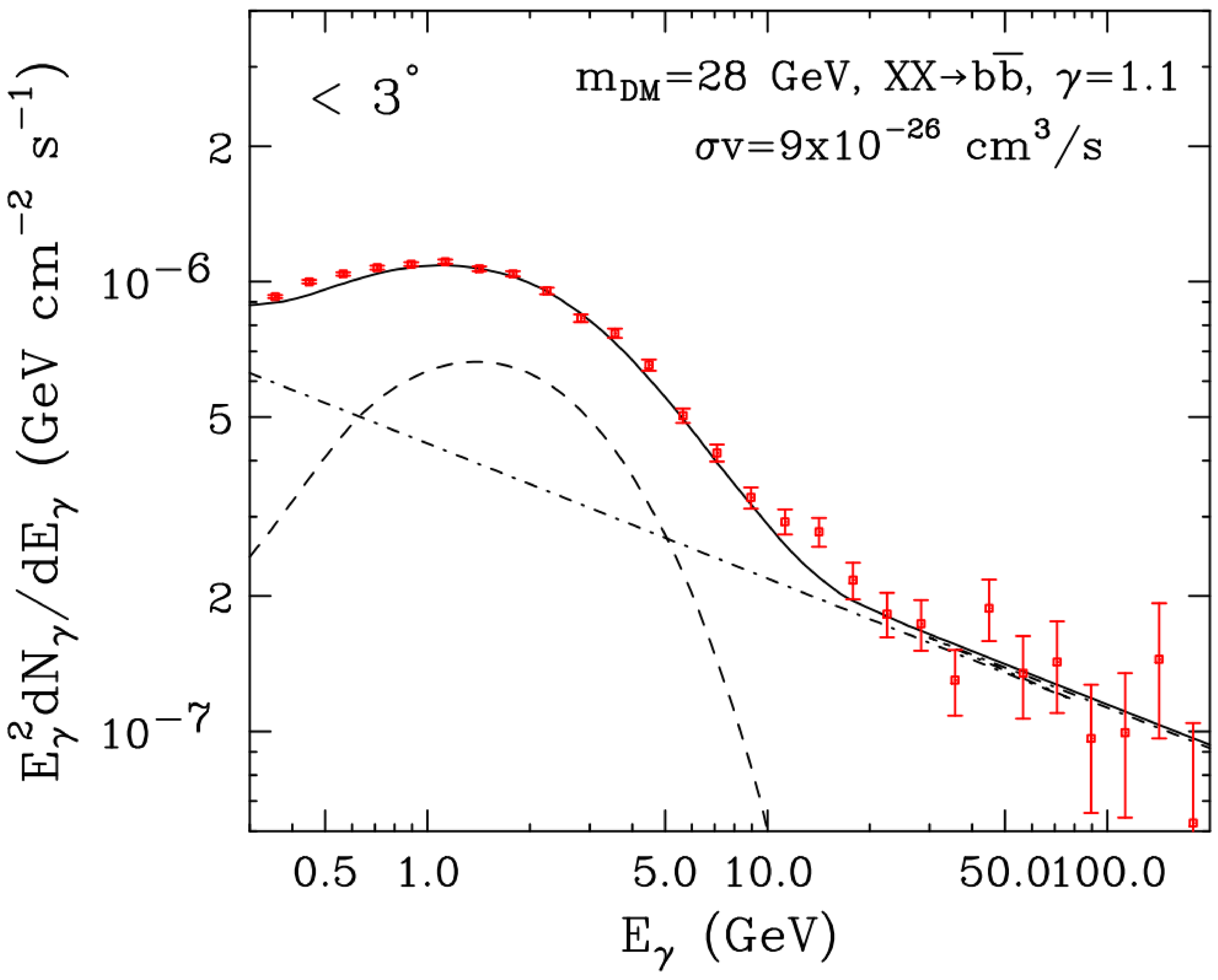

Figure 2. Gamma Ray Spectrum around the Galactic Dynamical Center [2]

Further, the energy and cross section of the work in Goodenough et al aligns within the constraints imposed by an analysis (of independent methods) from Albert et al (Figure 3). In this analysis, a population DM-dominated dSphs were analysed in search of γ emission above the approximately isotropic background. Here they found four statistically significant systems (with low errorbars) that exhibited larger-than-background radiation; the constraints of this paper constitute current-best velocity averaged cross sections in the $\sim$ 100GeV mass regime.

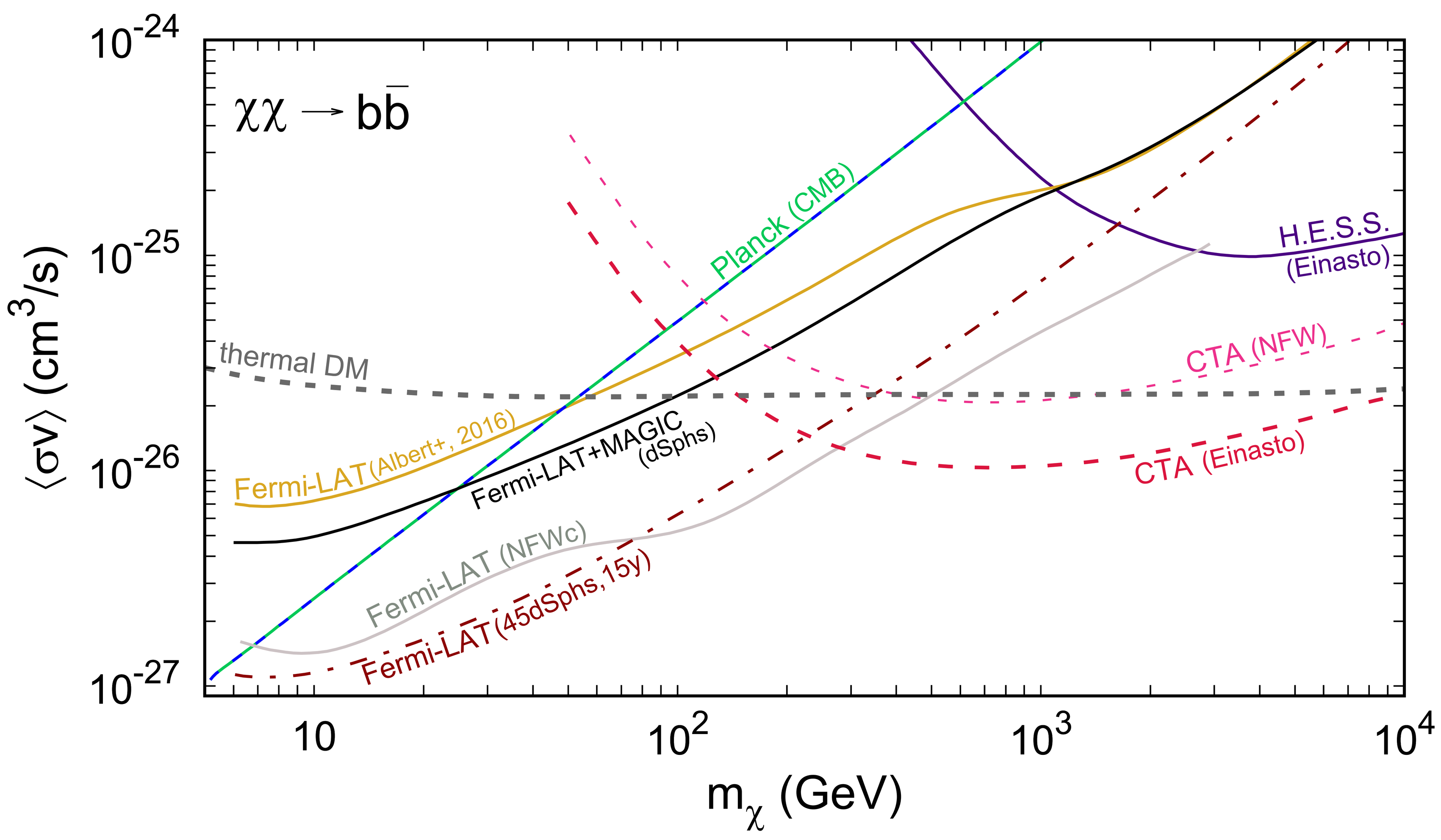

Figure 3. Mass-Cross Section Constraints on Dark Matter from γ Ray Direct Detection [4]

Roszkowski et al notes that γ rays make for an ideal direct-detection source (as opposed to charged cosmic rays) due to them being photons and thus are unaffected by the magnetic fields inherent within the galaxy. This allows observation to the exact regions in which $\chi\chi$ annihilation could be taking place.

Conclusions

Although a contentious topic, pair annihilation of cold-dark matter candidate WIMPs provide an attractive solution to the detection conundrum of dark matter. Since [2] was published, counter papers citing millisecond pulsars have attempted to provide an astrophysical explanation for the Galactic Center Excess of γ radiation. With that said, the literature is yet to postulate on the statistically significant γ radiation originating from the dSphs observed in [1], which leaves WIMP pair annihilation a plausible mechanism for direct detection of dark matter particles.