Double-dipping for dark matter with gamma-rays

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Abstract
Gamma-ray probes have historically been a gold-standard in indirect dark matter detection due to their smaller set of complicating factors and generally lower backgrounds. However, they are most optimally sensitive to the traditional supersymmetric WIMP annihilation channels while leptophilic channels (particularly for larger masses) are much harder to probe effectively in this manner. However, these channels do produce strong neutrino emission, detection of which has been previously complicated by lack of neutrino telescope sensitivity. In this work we display a method for inferring neutrino fluxes from gamma-ray data and using this to achieve superior constraints on the leptophilic channels of WIMP annihilation. This allows us to ‘double-dip’ re-using the same gamma-ray data sets to get a wider range of robust and stringent WIMP annihilation constraints. We demonstrate this approach with data from HESS and Fermi-LAT and use it to probe dark matter models suggested to explain recently reported cosmic-ray excesses.

Existing gamma-ray limits on WIMP annihilation

We place limits on the cross-section ($\sigma V$), which is pretty much the annihilation rate of WIMPs. Some limits are shown in Fig. (1), from [1, 2], are derived from HESS observations of the galactic centre with 112 hours and 254 hours of data respectively. These are compared to limits from dwarf galaxy observations by Fermi-LAT [3]. The goal is to be able to push models below the thermal relic line (black dashed in all figures) implying that model cannot constitute all cosmological dark matter as it annihilates too slowly. It is clear that this is difficult to achieve, especially for larger WIMP masses!

A double-dip

• For putatively hadronic gamma-ray emissions
• Following [4, 5] we can use gamma-ray fluxes to estimate neutrino fluxes from a given source
• These will be best at limiting large mass, leptonic channels for WIMPs

The same data can be used twice to get a better set of results!

A practical example using data from the HESS galactic plane survey within 0.1 to 1 degree from the galactic centre. This data is from [6], with 13% of the emission estimated to be from diffuse gamma-rays with a power-law index $-2.3$. This is compared to predictions for an NFW dark matter halo with scale length 30 kpc, normalised to our local DM density $0.1\text{ GeV cm}^{-3}$. At 8.5 kpc from the galactic centre (we use CLUMPY).

Figure 1: Comparison of cross-section limits between Fermi-LAT gamma-ray data from dwarf galaxies [3] and galactic centre limits from HESS [1, 2].

Figure 2: Seinfeld et al 1993

Figure 3: WIMP cross-section constraints from galactic centre neutrino flux estimation using HESS data [6].

Figure 4: WIMP cross-section constraints from galactic centre neutrino flux estimation using Fermi-LAT excess data [8].

Conclusions
Double-dipping gets us some interesting results:
• Powerful limits for leptonic models
• Mainly effective above 20 GeV WIMP masses
• Strong complementarity between Fermi and HESS
• If gamma-rays are partly leptonic in origin: limits get better

Open questions:
• Is the Seinfeld joke any good?
• Correct neutrino physics for hadronic processes?

References

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