Notes on Dark Matter and Data Analysis

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Abstract

These are my personal notes on dark matter (DM) physics and data analysis developed to substantiate my undergraduate monograph on the *Fermi GeV excess*. Particularly, I will be using these to write my research assignments and to perform my own incursions on the above mentioned topics.

1 Dark Matter profiles

- NFW [NFW95]: based on N-body simulations.

$$\rho_{\rm NFW}(r) = \rho_s \frac{r_s}{r}\left(1+\frac{r}{r_s}\right)^{-2} \tag{1}$$

- Einasto [TWPS09]: based on N-body simulations.

$$\rho_{\rm Ein}(r) = \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\} \tag{2}$$

- Isothermal [BBS91]: reproduces the naive r^{-2} dependence of the DM density.

$$\rho_{\rm Iso}(r) = \frac{\rho_s}{1+(r/r_s)^2} \tag{3}$$

- Burkert [SB00]: based on the observation of galactic RCs.

$$\rho_{\rm Bur}(r) = \frac{\rho_s}{(1+r/r_s)(1+(r/r_s)^2)} \tag{4}$$

- Moore [DMS04]: fit on N-body simulations of a NFW like density profile.

$$\rho_{\rm Moo}(r) = \rho_s \left(\frac{r_s}{r}\right)^{1.16}\left(1+\frac{r}{r_s}\right)^{-1.84} \tag{5}$$

These profiles are depicted in Figure 1, where I also included the angular dependence of the density as seen from the SS, following [CCH+10].

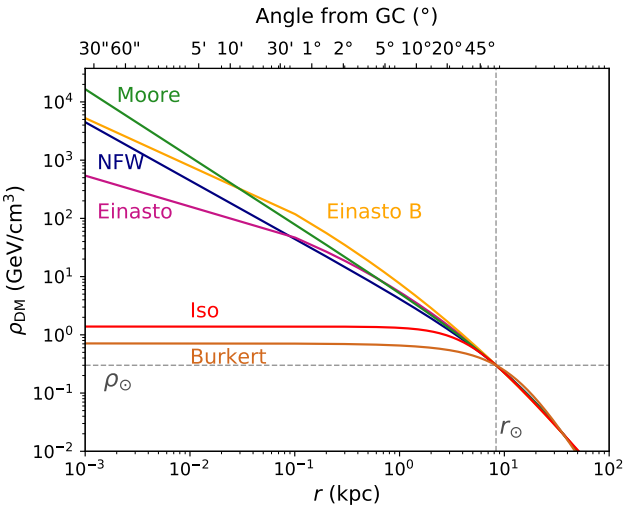

Figure 1: DM profiles and the predicted DM densities ($\rho_{\rm DM}$).

1.1 Discussion and Questions

- Spherical symmetry

  All these profiles contain only radial dependence, *i.e.* they are assumed to have spherical symmetry. [JS02] discusses, using simulated halos, that the profile is better described by triaxial ellipsoids. [LMJ09] uses the tidal stream from SagDEG disruption to determine the shape of the MW halo.

- Galactic Center

  Do these profiles provide a good description of the GC dark matter distribution? Simulations do include baryonic feedback?

2 Dark Matter J-factors

Dark matter J-factors describe the astrophysical component of the observed differential photon flux, in the sense that it integrates the particle physics processes occurring along the line of sight ($\rm los$) of the observer. For annihilating DM, they are defined as:

$$J_{\rm a} = \int_{\rm los} \frac{ds}{r_\odot} \left(\frac{\rho(r(s,\theta))}{\rho_\odot} \right)^2 \tag{6}$$

Whilst for decaying DM:

$$J_{\rm d} = \int_{\rm los} \frac{ds}{r_\odot} \left(\frac{\rho(r(s,\theta))}{\rho_\odot} \right) \tag{7}$$

We can also define the mean J-factor:

$$\bar{J} = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} J d\Omega \tag{8}$$

that is used to calculate the flux observed at the detecting instrument aperture $\Delta\Omega$.

These quantities can only be useful when connected to the physical description of the DM interactions, that we'll deal with later.

The geometry and the parameters involved in these integrals are represented in Figure 2, where I also included the galactic polar coordinates (ℓ, b), that are useful in the calculus of $\bar{J}$, Equation (8).

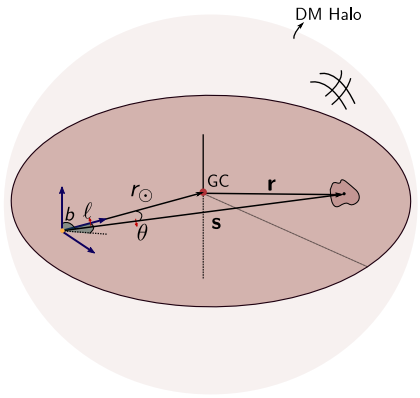

Figure 2: Schematic of the Milky Way disk and its DM halo.

In Figures 3 and 4, we depict the calculated J-factors for annihilating and decaying DM with the common density profiles. These computations can be checked in .

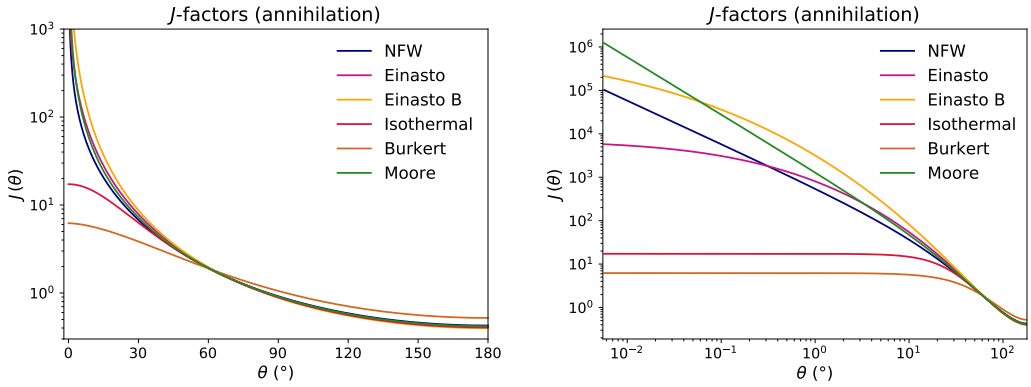

Figure 3: Annihilating DM J-factors for the common dark matter density profiles.

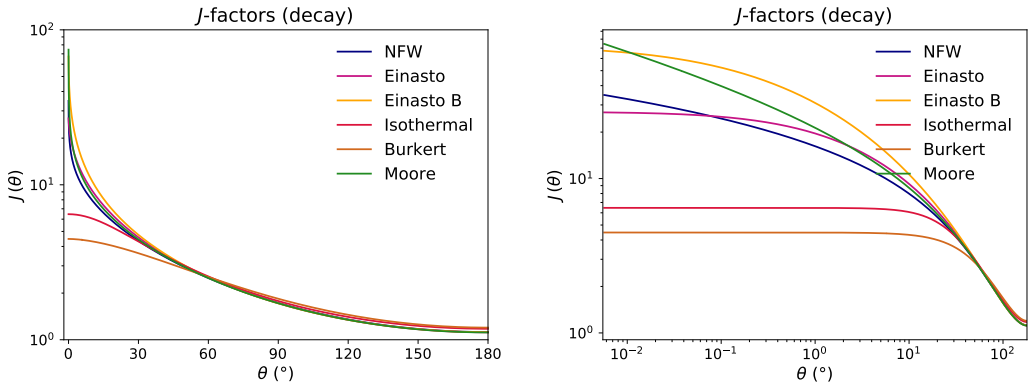

Figure 4: Decaying DM J-factors for the common dark matter density profiles.

A Notation

Mainly based on [Mou01].

References

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[SB00] Paolo Salucci and Andreas Burkert, *Dark matter scaling relations*, 2000.

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Glossary

DM Dark Matter

MW Milky Way

NFW Navarro-Frenk-White Density Profile

RC Rotation Curves

SS Solar System