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 for the SS, where I also included the angular dependence of the density, following [CCH+10].

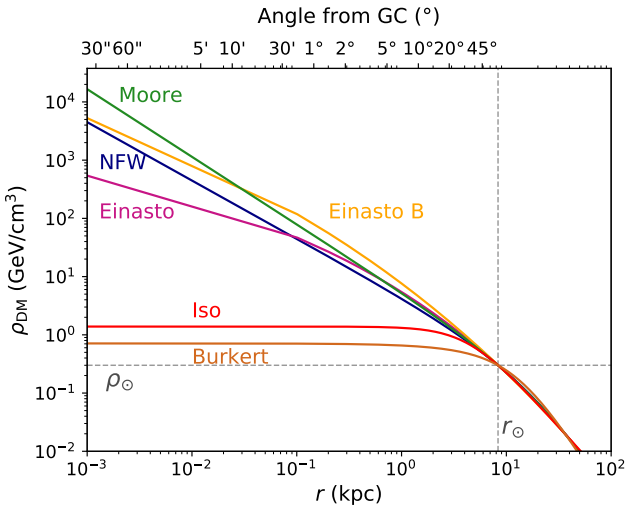

Figure 1: DM profiles and the predicted DM densities ($\rho_{\rm DM}$) for the Milky Way.

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? [CCH+10] discusses this under his Figure 1. Do simulations include baryonic feedback? Does feedback change the profile far from the GC?

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 effect of the detecting instrument aperture $\Delta\Omega$ on the total differential flux by introducing the mean J-factor:

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

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 calculation of $\bar{J}$, as defined on (8).

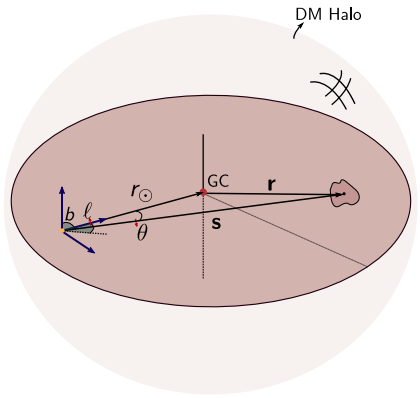

Figure 2: Schematic of the Milky Way disk and its DM halo.

In Figures 3 and 4, the calculated J-factors for annihilating and decaying DM are depicted assuming the common density profiles for DM in the MW. These computations can be checked in .

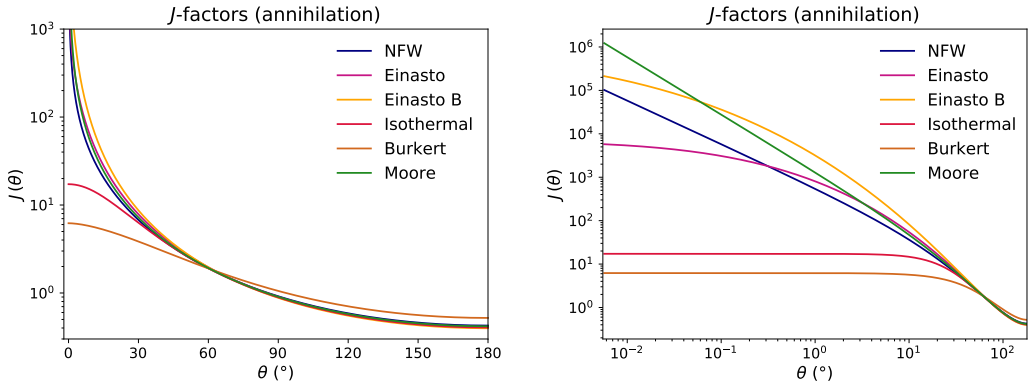

Figure 3: Annihilating DM J-factors for the common dark matter density profiles.

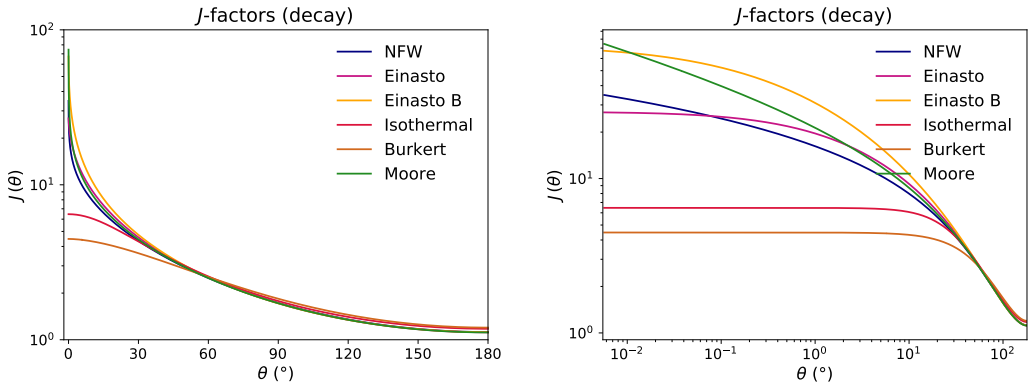

Figure 4: Decaying DM J-factors for the common dark matter density profiles.

A Notation

B Spherical Astronomy

Based on [RC82].

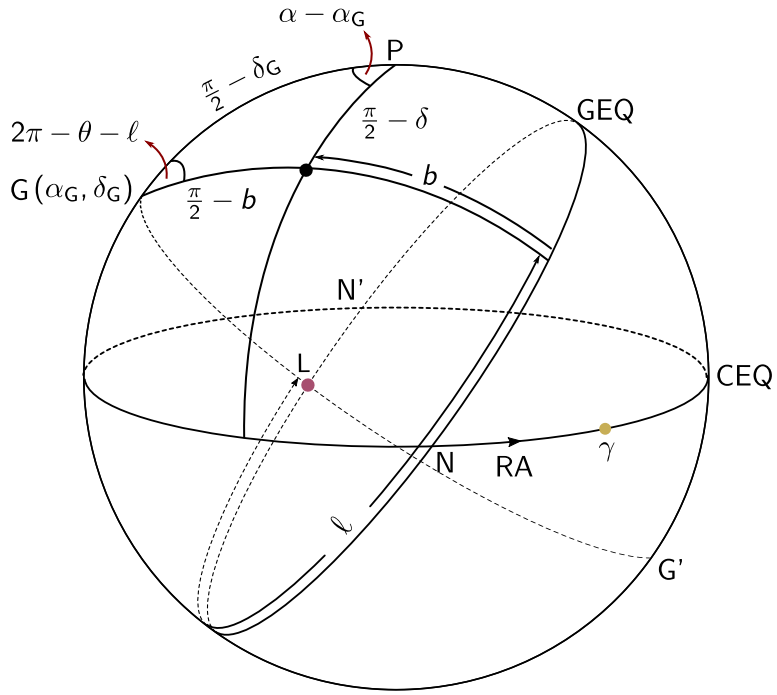

Figure 5: Celestial sphere geometry for the relation between the equatorial and galactic coordinate systems.

References

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Glossary

DM Dark Matter

MW Milky Way

NFW Navarro-Frenk-White Density Profile

RC Rotation Curves

SS Solar System