# Towards a new agnostic top-down approach for studying dark matter signals over the entire sky

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## Introduction

Indirect dark matter (DM) searches have, to date, provided no compelling evidence of a standard WIMP decay or annihilation signal. Typically it has been accepted that either the galactic centre or dwarf spheroidal's will provide the strongest constraints on DM. This statement is in principle not true for all models of DM. Given the situation it is essential to have a systematic framework to predict signals for a variety of DM models allowing one to select the best targets for observation. Here are the first steps towards a unified framework for indirect DM searches.

= Building Blocks = Main Result = Useful Properties = Simple Example = Python Packages

## Method and Results

$$\mathcal{L}(\boldsymbol{\theta}|\mathcal{D}) = e^{-\mu_{\rm tot}(\boldsymbol{\theta})} \prod_{i=1}^{n_{\rm ev}} \Phi_{\rm tot}(\Omega_i|\boldsymbol{\theta})$$

Begin with the most general expression possible, the unbinned likelihood defined above. This allows us to use all the photons with no loss of information. The exponential term exits because of the passion nature of having infinitely thin bins i.e. unbinned. $n_{ev}$ is the total number of observed photons in the given angular and energy range

$$\mathcal{I}_{\theta\theta} \approx -\left\langle \frac{\partial^2}{\partial \boldsymbol{\theta}^2} \ln \mathcal{L}(\boldsymbol{\theta}|\mathcal{D}) \right\rangle$$

The Fisher information is defined as the expectation value of the observed information. This means that it measures the amount of information contained within a random sample X about model parameters theta

$$\Phi_{\rm tot}(\Omega|\boldsymbol{\theta}) = \sum_{k=1}^{n_{comp}} \theta_k \Phi_k(\Omega)$$

*Assumption:* Total map of the sky can be decomposed into a linear combination of multiple maps, comprised of the different populations of sources

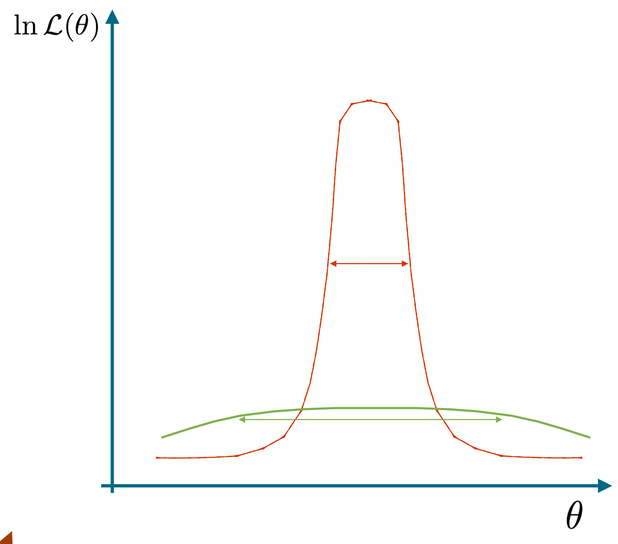
This is a relatively conservative assumption since the sky maps are merely made up of photon counts. In the unbinned limit this amounts only the position and energy of a photon

$$\propto \rightarrow = T_{\rm obs} A_{\rm eff}$$

- The proportionality simply becomes the total observation time multiplied by the effective area for the most simple case
- Fisher information describes the best analysis possible
- Signal squared dependence means peaked signals are easier to detect

$$\mathcal{I} \propto \int_{\rm ROI} d\Omega \frac{\Phi_S^2(\Omega)}{\Phi_B(\Omega)}$$

Here we have the differential Fisher information. Within the proportionality, it is easy to take into account instrumental effects. Most importantly it is an easy to compute quantity for all types of signals




### Additive

$$\mathcal{I}_{\rm Tot} = \mathcal{I}_{\rm dSphs} + \mathcal{I}_{\rm MW} + \dots$$

### Sigma Limits

$$\mathcal{I} < 25 \equiv \text{5-sigma Detection}$$

### Easy to include distance information

$$\int d\Omega \rightarrow \int d\Omega dE$$

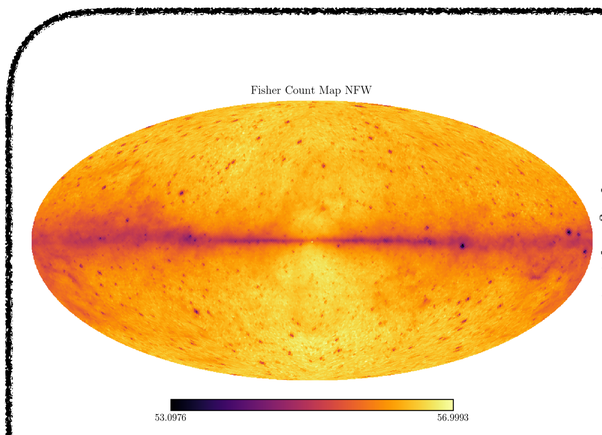
$$\Phi_{\rm Tot} = \begin{pmatrix} \Phi_{\rm DM} \\ \Phi_{\rm MSP} \\ \Phi_{\rm BG} \\ \vdots \end{pmatrix} \quad \mathcal{I}_{kl} = \int_{\rm ROI} \frac{\Phi_k \Phi_l}{\Phi_{\rm B}}$$

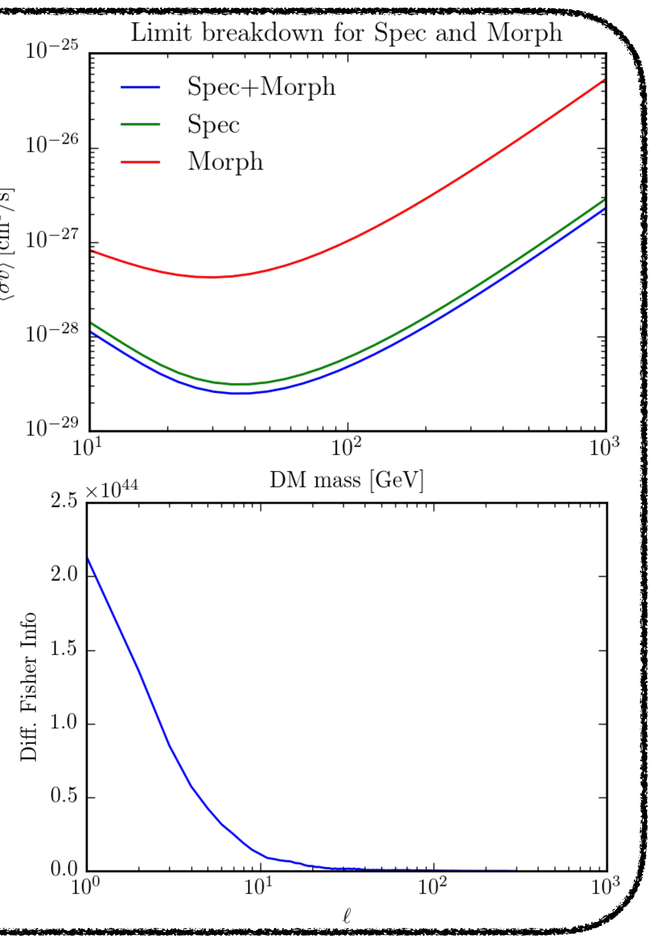
Allows for multiple component analysis as well as cross correlation analysis

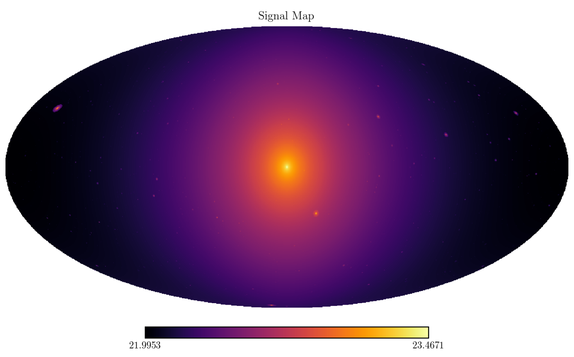
$$\mathcal{I}_{\rm Red} > \mathcal{I}_{\rm Green}$$
$$\mathcal{I}_{\rm Red} = \frac{1}{\sigma^2_{\rm Red}}, \quad \mathcal{I}_{\rm Green} = \frac{1}{\sigma^2_{\rm Green}}$$

Using the Cramer Rao inequality, we can define a relationship to the variance of the different matrix elements on the Fisher information

## Future Work







### VADER

- **V**irtual **A**tlas for **D**ark matter **E**ngendered **R**adiation
- Creates probabilistic catalogs of Dark matter halos
- Based on galaxy & cluster catalogs, local group observations
- Subhalo + Halo MC
- Easily takes in many different particle physics models as well as user input signal shapes
- Easy modelling of backgrounds
- Very high resolution thanks to hierarchical healpix format
- Ability to store arbitrary halo information such as B-field, allowing for signal predictions from radio to gamma rays
- Easy to use python interface to halo catalog information

### YODA

- **Y**ield **O**ptimisation for the **D**ark matter **A**narchist
- Tools to make Fisher matrix analysis clean and easy!
- Easy to use plotting routines

New Python Packages in the making

Stay tuned!

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