Fast Forecasting for Counting Experiments

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1704.05458

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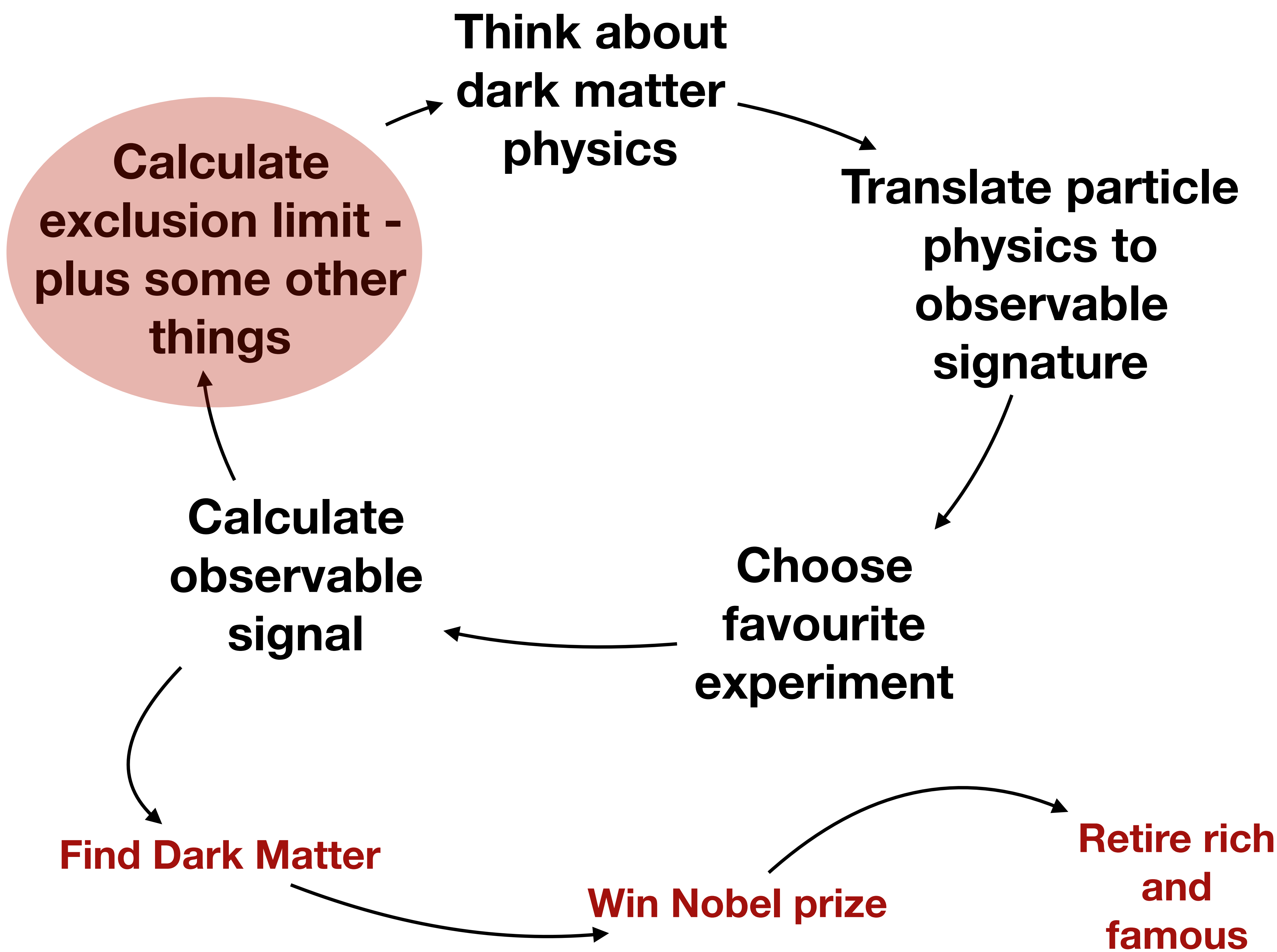
https://github.com/cweniger/swordfish

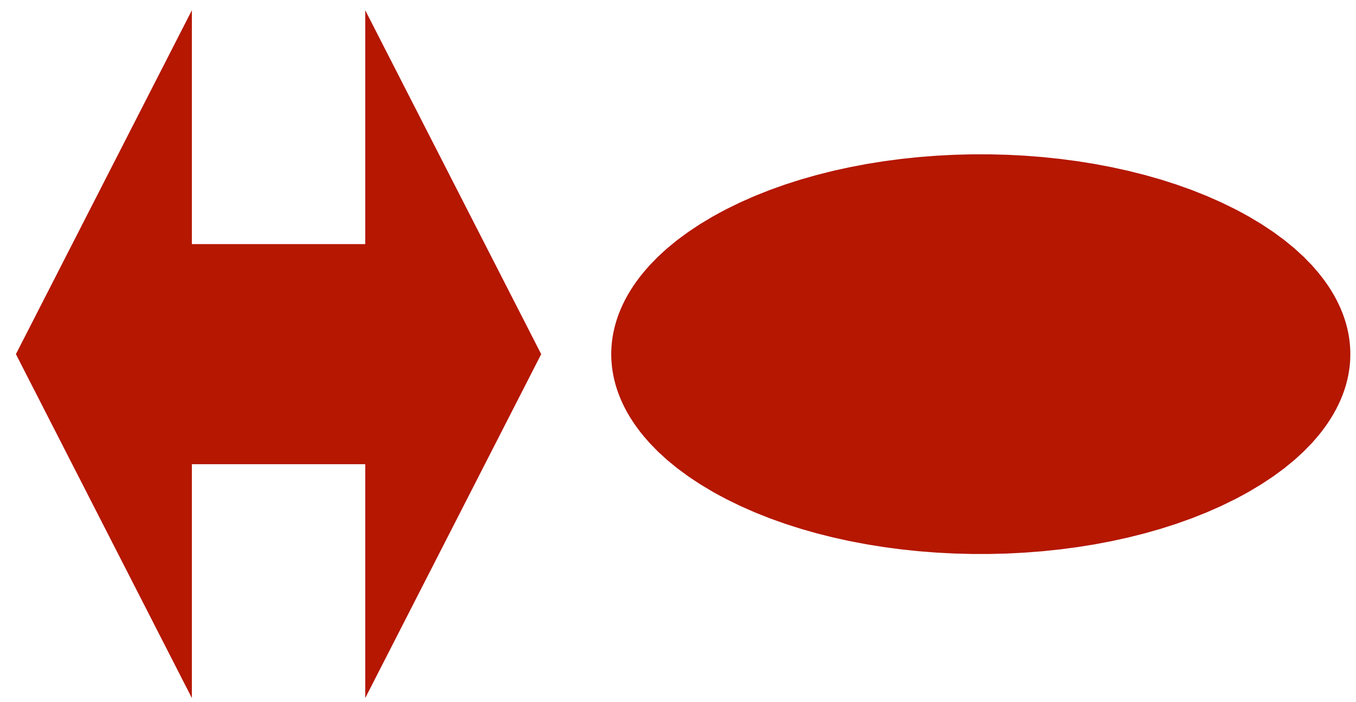
Typical Dark Matter Researcher Workflow



Overview

Equivalent counts

1. **What are equivalent counts**
2. **Accounting for systematics**



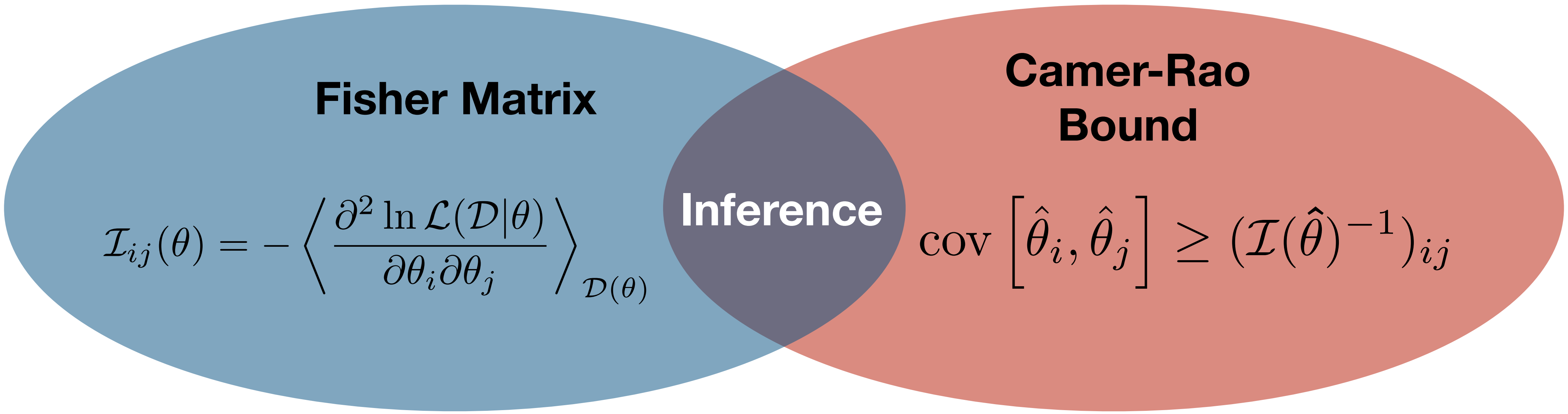
Information flux

1. **Definition**
2. **Experimental design**

Parameter space Visualization

1. **Equal geodesic distance contours**
2. **Streamline plotting**

Fisher Information Matrix



- The **Fisher Information** is a description of the **curvature of the likelihood**
- Curvature of the likelihood surface gives us a description of the variance
- The **Cramér-Rao** bound is based on the Fisher information matrix, which quantifies how 'sharply peaked' the likelihood function describing the observational data is around its **maximum** value
- Bound is '**asymptotically efficient**' when the bound is saturated in the large sample limit

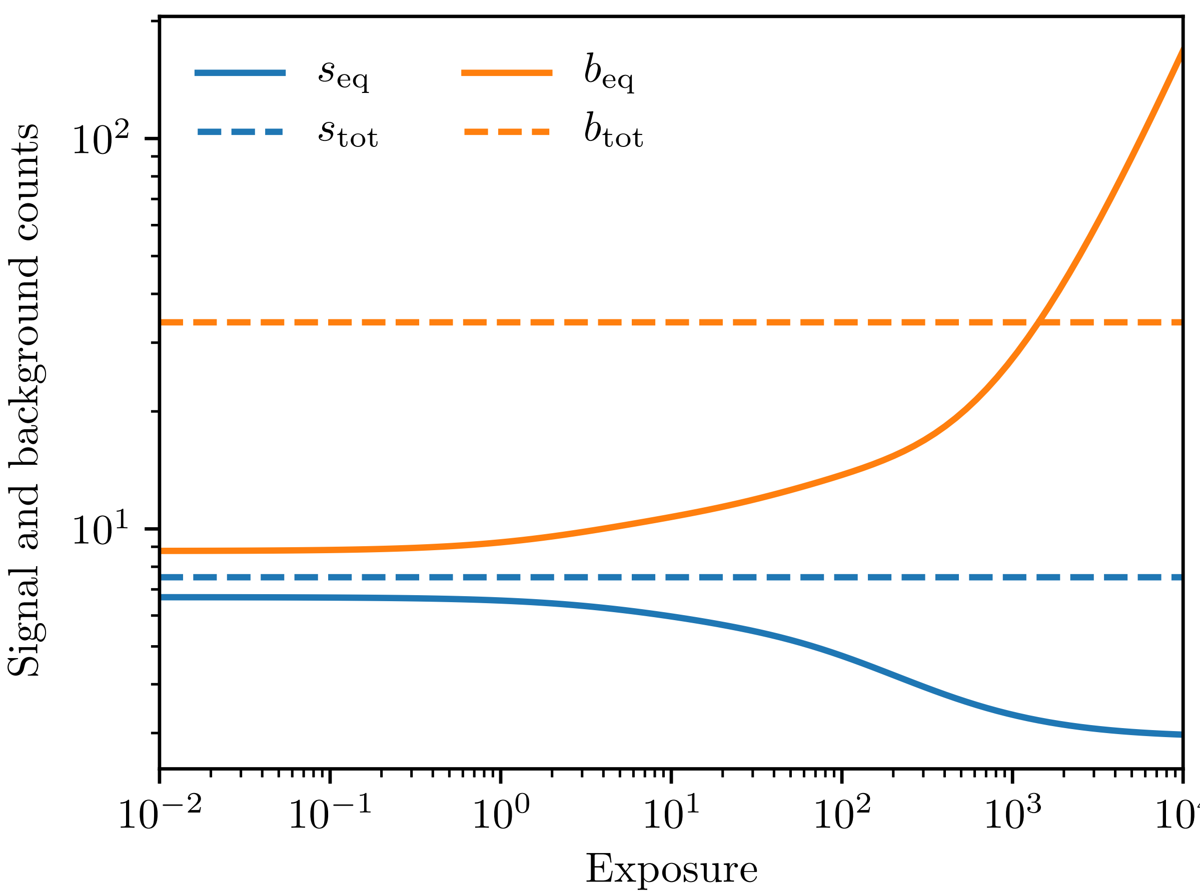
Equivalent Counts

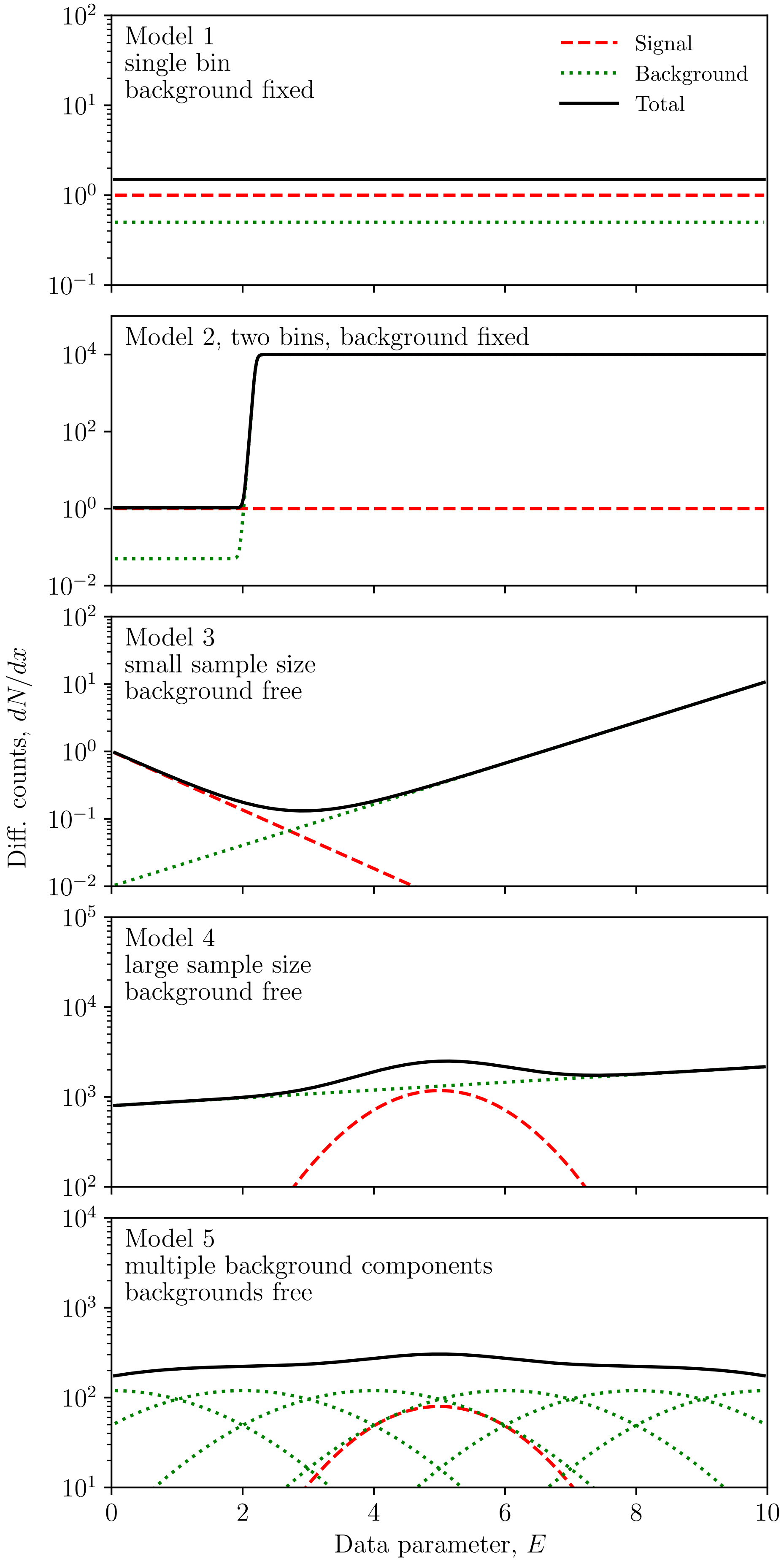
Logic:

- **Signal to Noise of events in a single bin example tells us about the significance of the signal**
- **Extend same technique to multi-bin case**
- **Not all signal events statistically contribute if they are drowned out by large backgrounds**
- **Convenient to define significant signal and background events using the FIM**

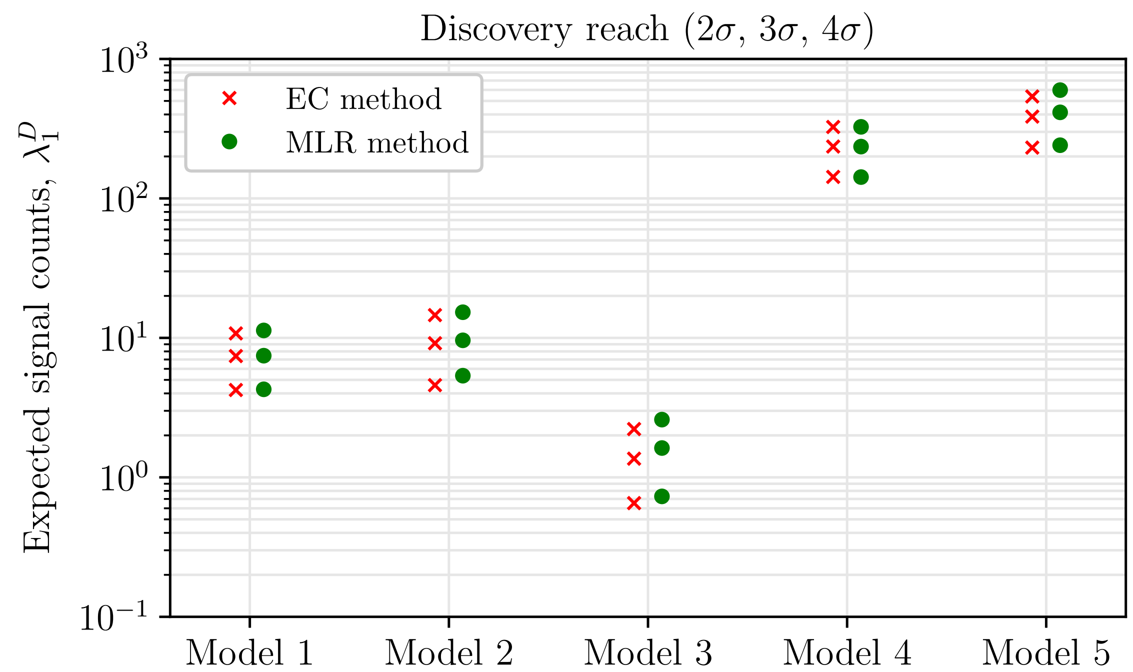
$$s_{\mathrm{eq}}(\theta) \equiv \frac{\theta^2}{\sigma^2(\theta) - \sigma^2(\theta_0)}$$

$$b_{\mathrm{eq}}(\theta) \equiv \frac{\theta^2 \sigma^2(\theta_0)}{[\sigma^2(\theta) - \sigma^2(\theta_0)]^2}$$

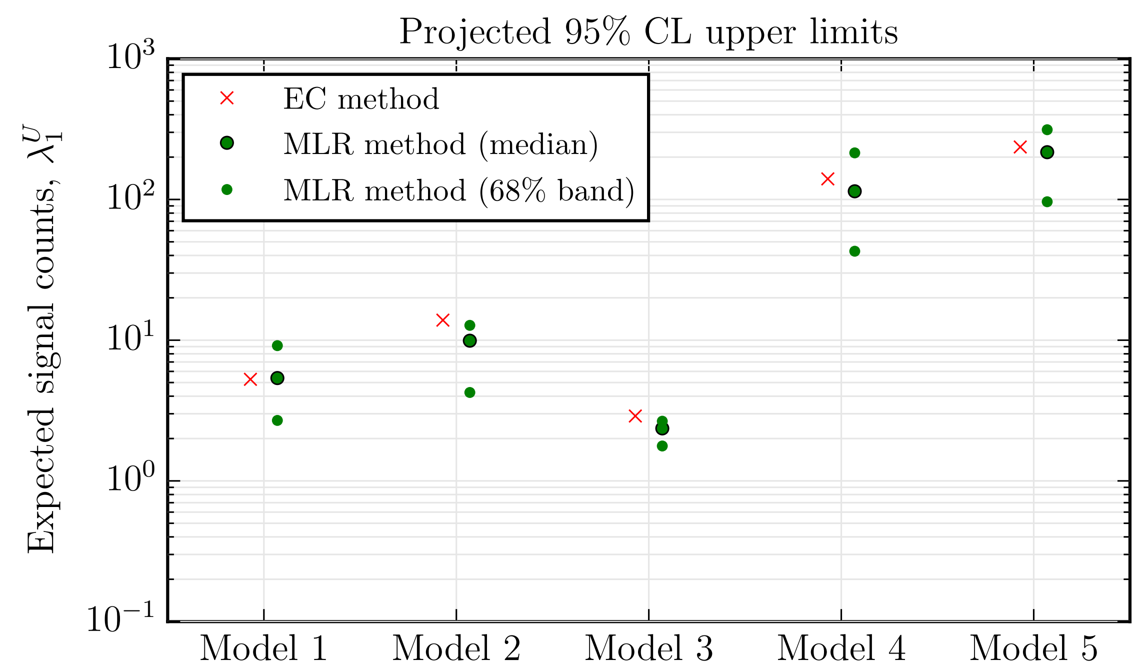




$$-2\ln\frac{P(s_{\rm eq}+b_{\rm eq}|b_{\rm eq})}{P(s_{\rm eq}+b_{\rm eq}|s_{\rm eq}+b_{\rm eq})}=Z^2$$



$$s_{\rm eq}=Z\sqrt{s_{\rm eq}+b_{\rm eq}}$$



- **Maximum deviations from coverage corrected Monte Carlos up to 40%**

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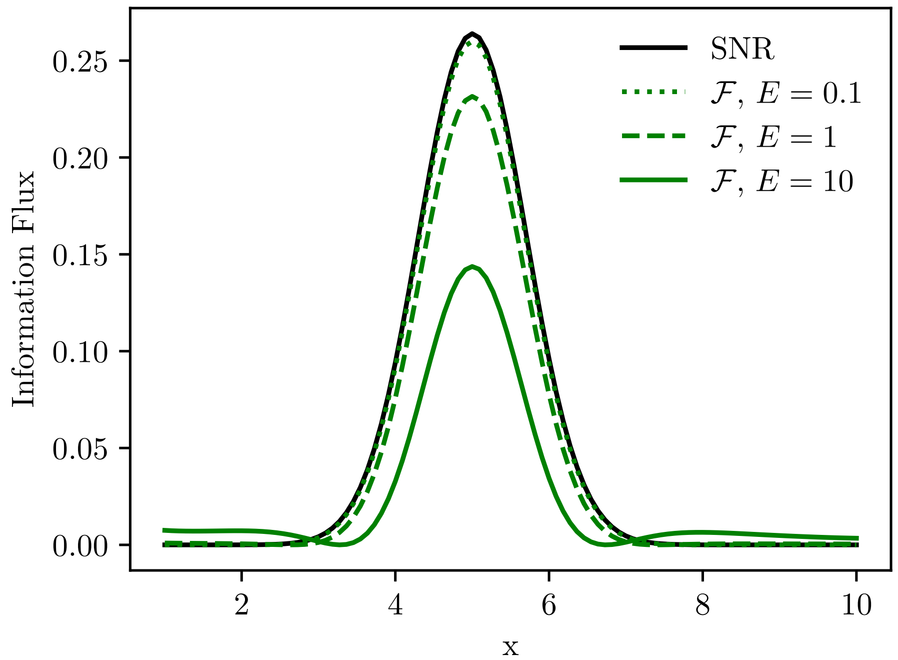
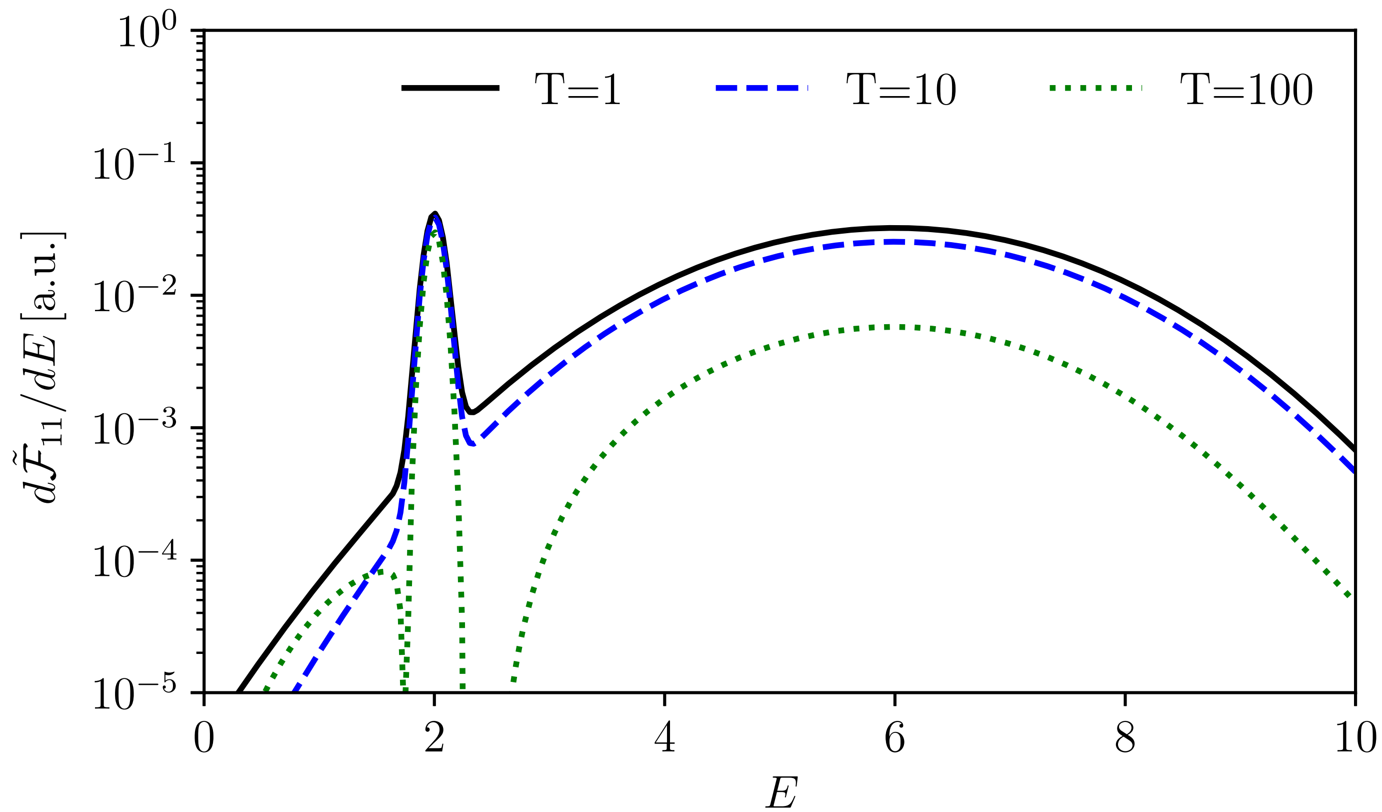
Information Flux

- It is possible to include an additional term to the likelihood that describes **background correlated systematics**. In addition we can look how the information is distributed over a binned variable, we call this object the **Effective *Fisher information flux***

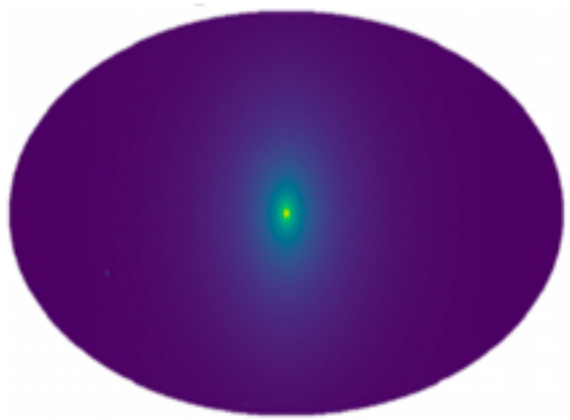


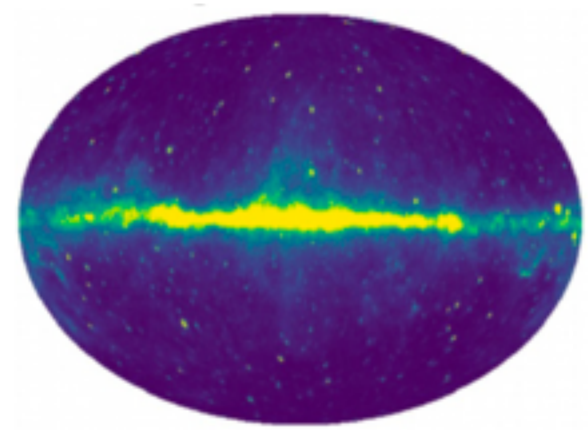
$$\mathcal{F}_i \equiv \frac{\partial(1/\sigma^2)}{\partial E_i}$$

- The diagonal part of the Fisher information flux corresponds to the **square of the SNR** of component i, and the non-diagonal parts provide information about the degeneracy of the components pairs (i, j)



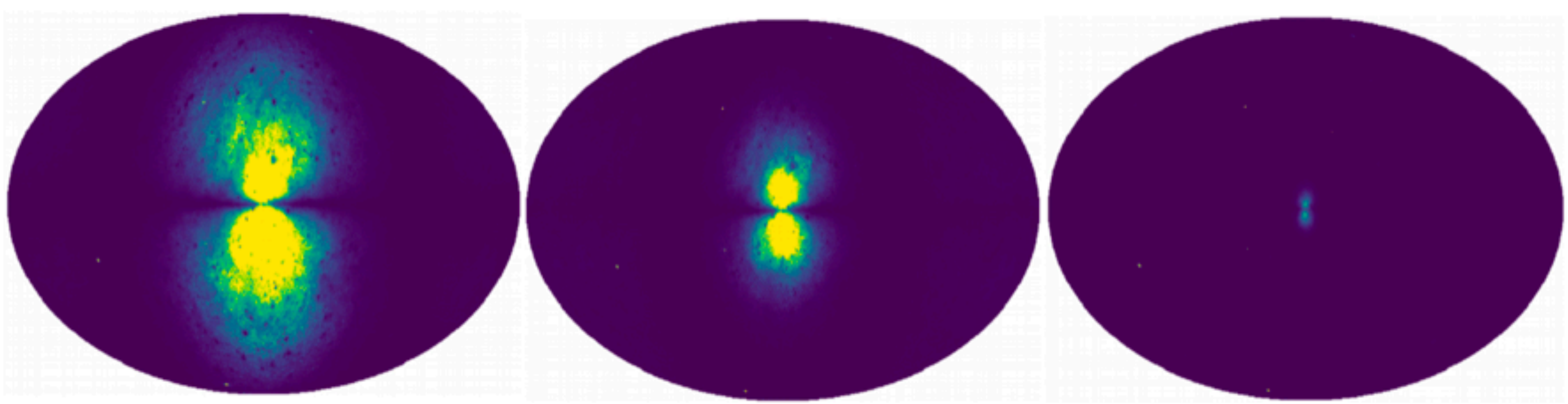
Dark Matter Halo





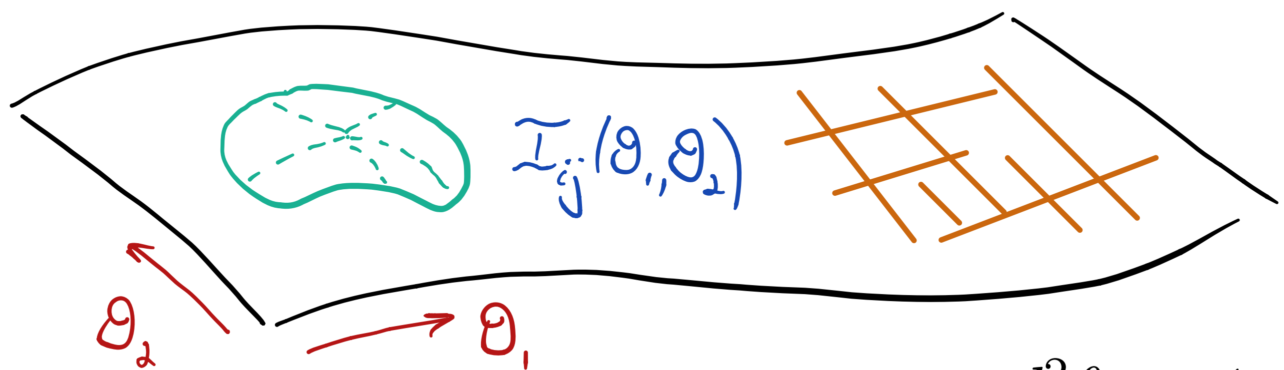
Background - assumed 10% error with a 10 degree correlation length

Increasing Exposure



= **High Information** = **Low Information**

Visualisation



Treat the Fisher Information Matrix as a local metric on the space of parameters

$$\frac{d^2\theta_i}{ds^2} + \frac{1}{2}\mathcal{I}_{ij}^{-1}\left(\frac{\partial \mathcal{I}_{lj}}{\partial \theta_k} + \frac{\partial \mathcal{I}_{kj}}{\partial \theta_l} - \frac{\partial \mathcal{I}_{kl}}{\partial \theta_j}\right)\frac{d\theta_k}{ds}\frac{d\theta_l}{ds} = 0$$

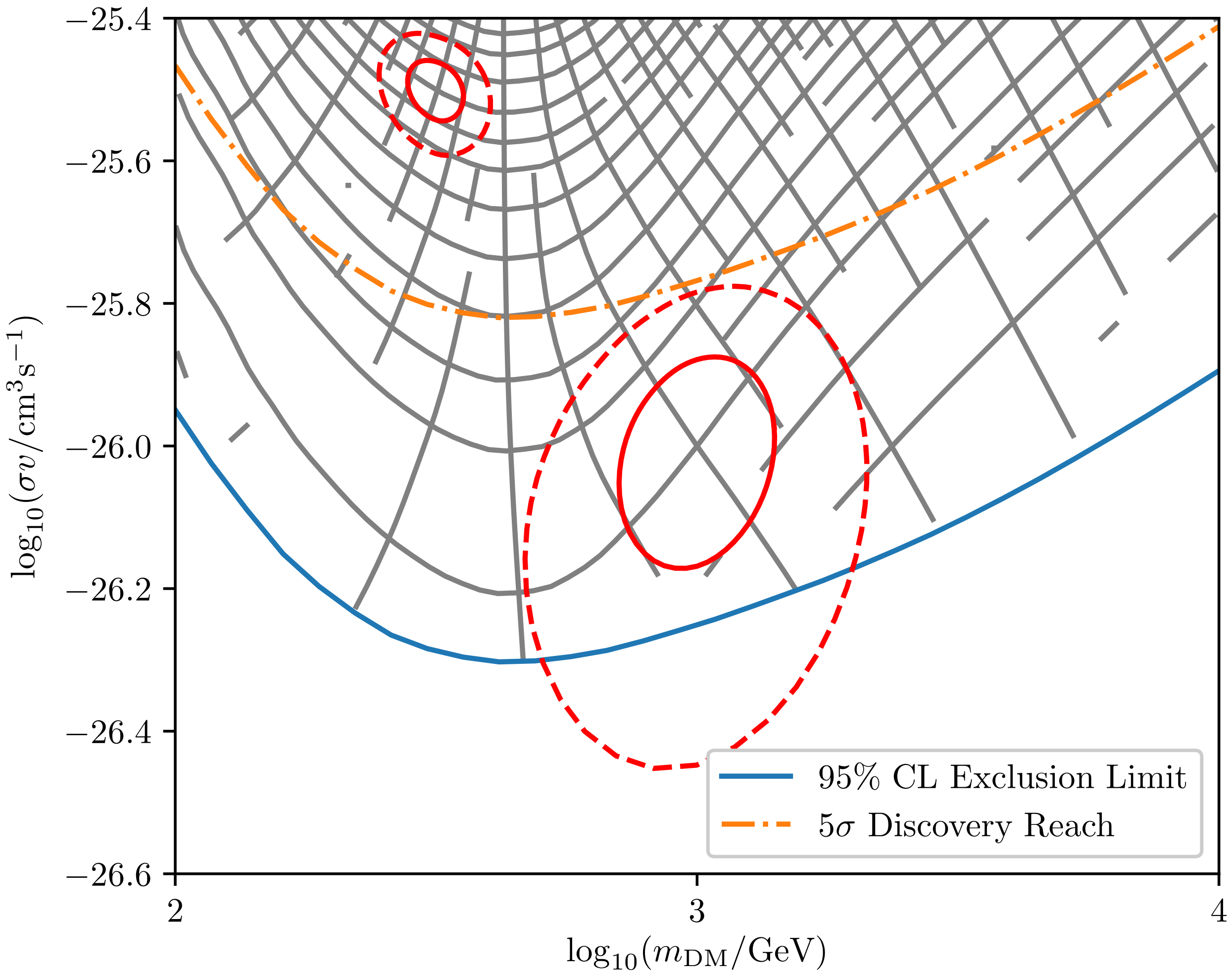
Equal Geodesic Confidence Contours

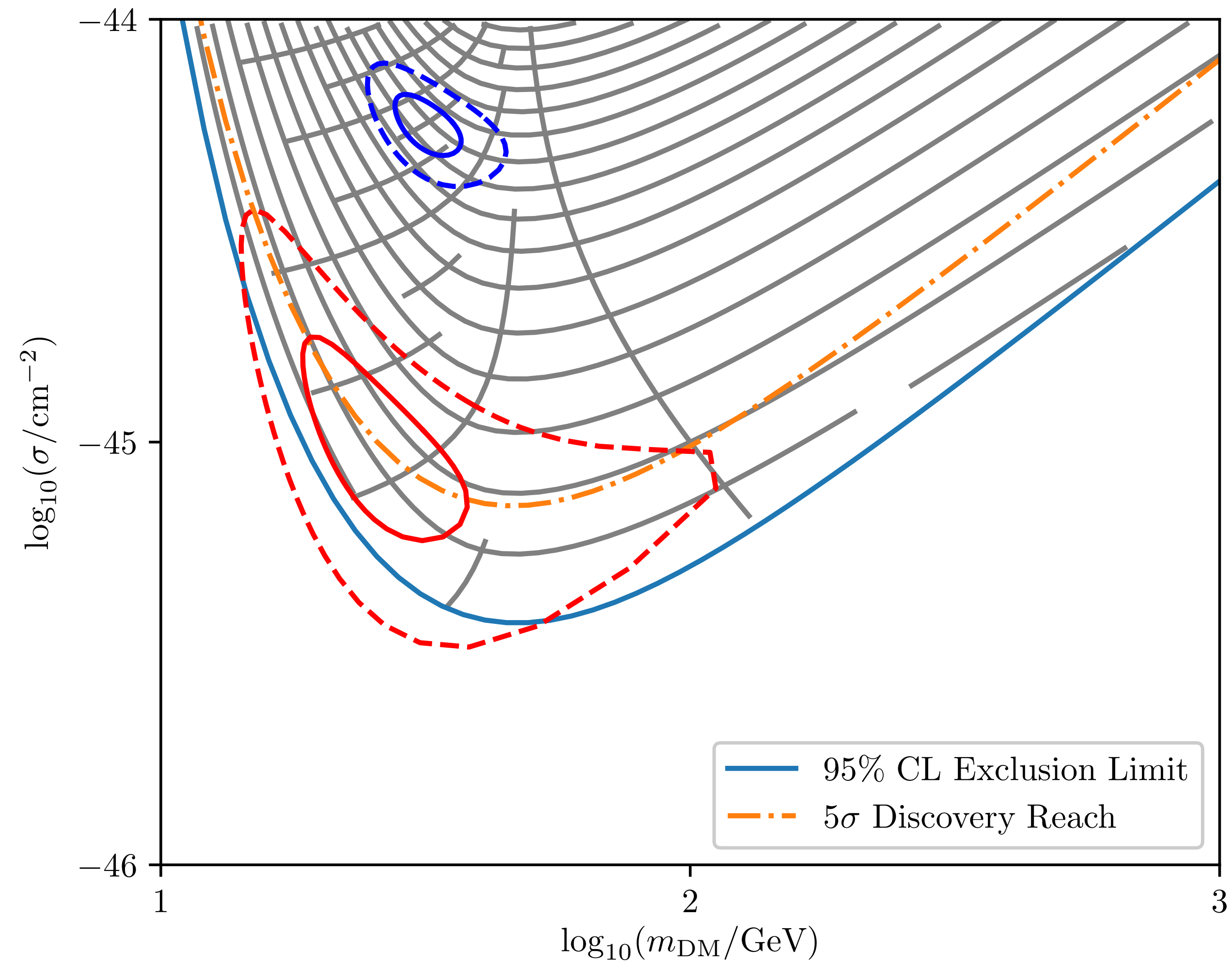
- **Trace geodesics in different directions and connect the curves**
- **Matches very accurately with traditional confidence contours**

Streamline Density

- **The distance between two parallel streamlines corresponds approximately to 1σ in the direction perpendicular to the streamlines.**
- **The latter condition is realized by adding or removing lines as necessary.**

CTA and Xenon1T

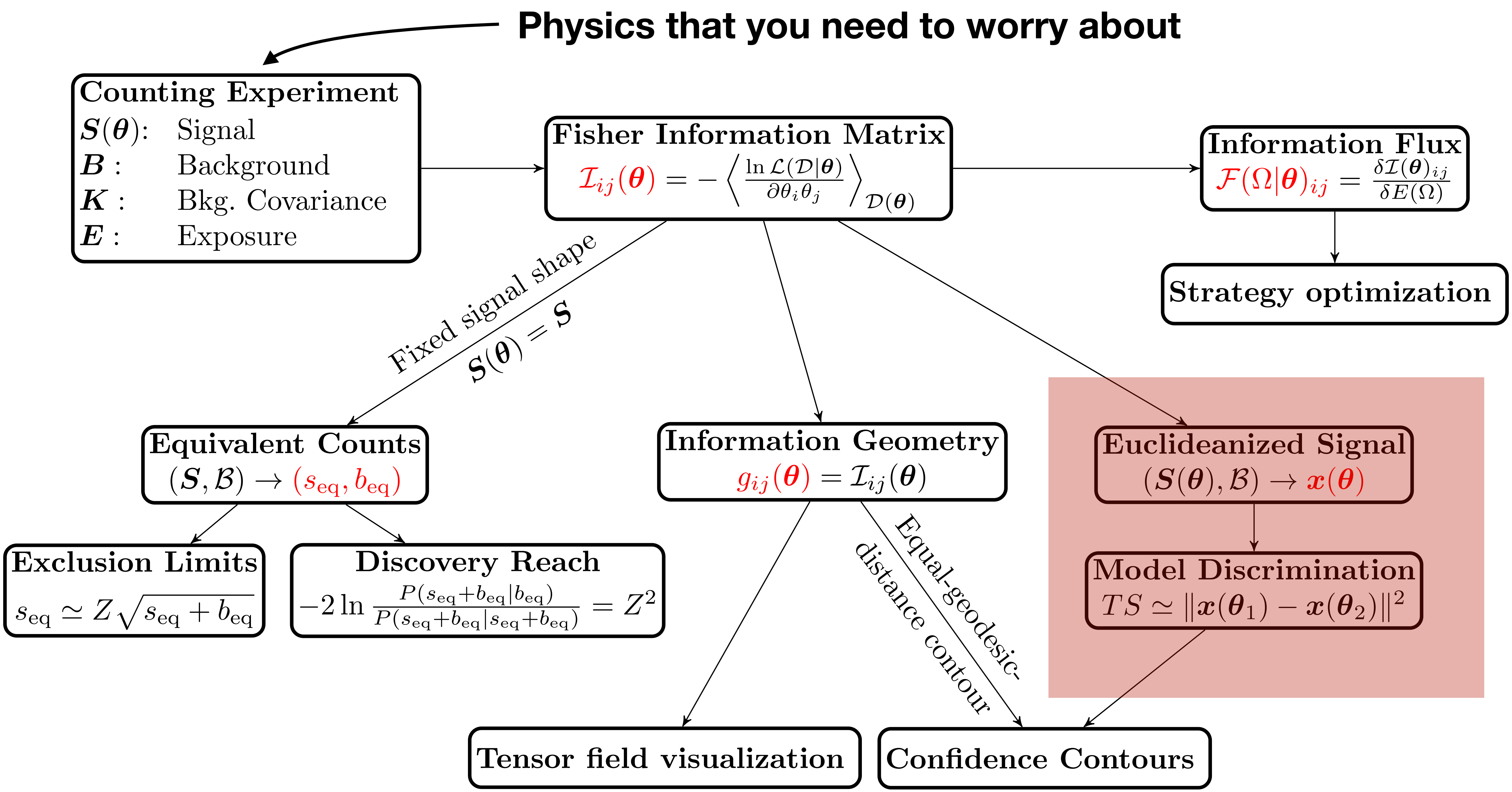




Replicated analysis from **Silverwood et al.**

Simplified 1-D Xenon1T projection

Swordfish



= C. Weniger's talk (yesterday)

Thanks!

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