GRAPPA
GRavitation AstroParticle Physics Amsterdam

Fast Forecasting for Counting Experiments

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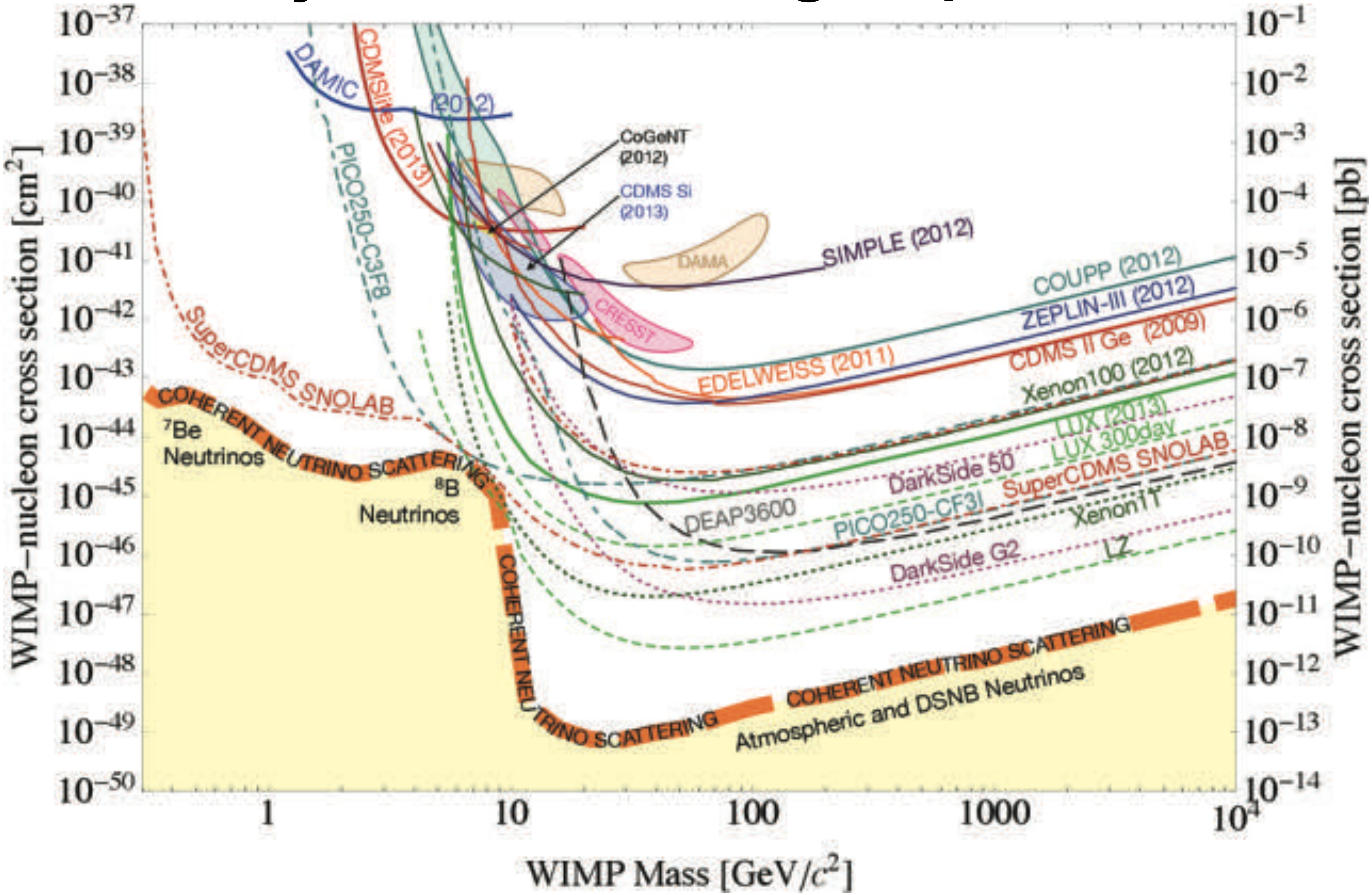
https://github.com/cweniger/swordfish

What questions am I trying to answer?

- I don't have a strong theoretical prior
- In this case, what is the best way to maximize a discovery?
- If we find something, what is the best set of experiments to build?
- Both questions come down to maximizing the the information gain from multiple experiment for a large variety of models

Why is forecasting important



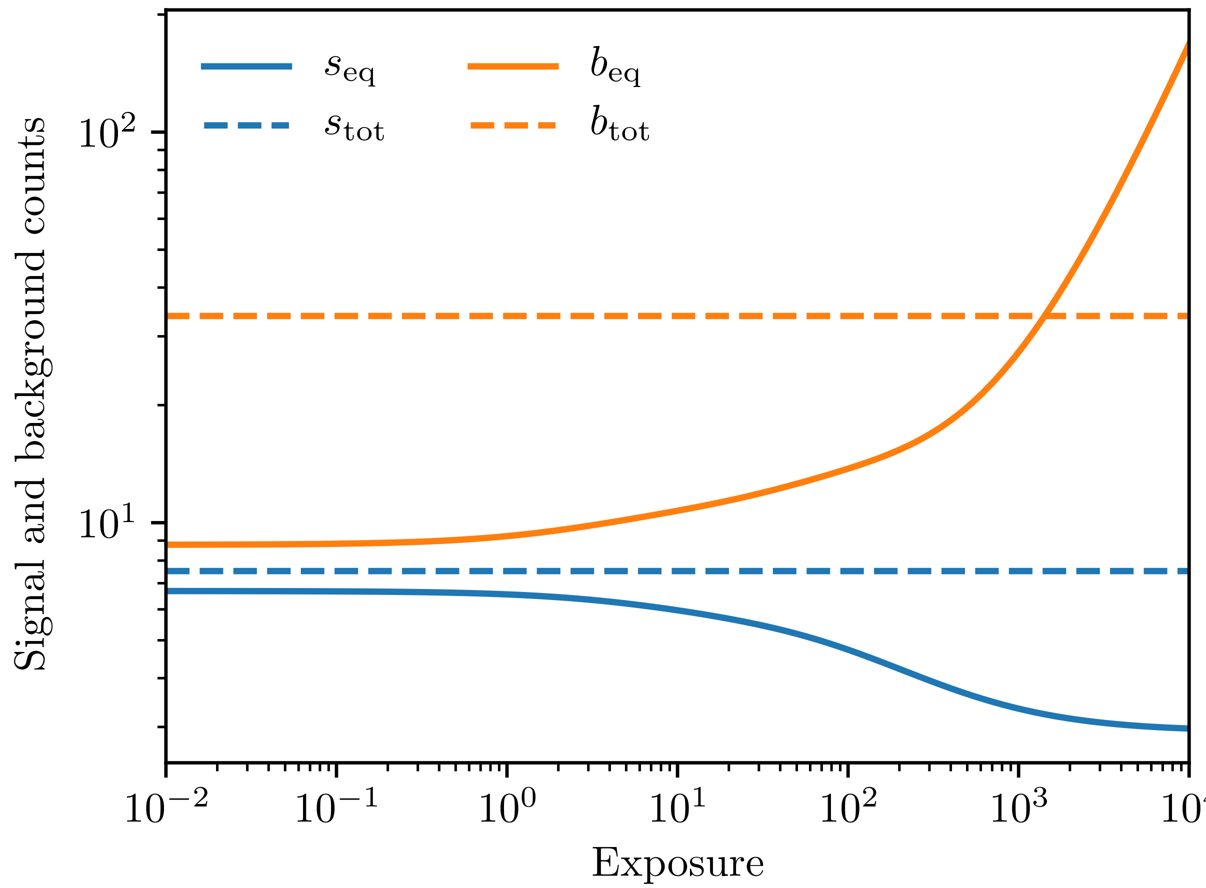
Equivalent Counts

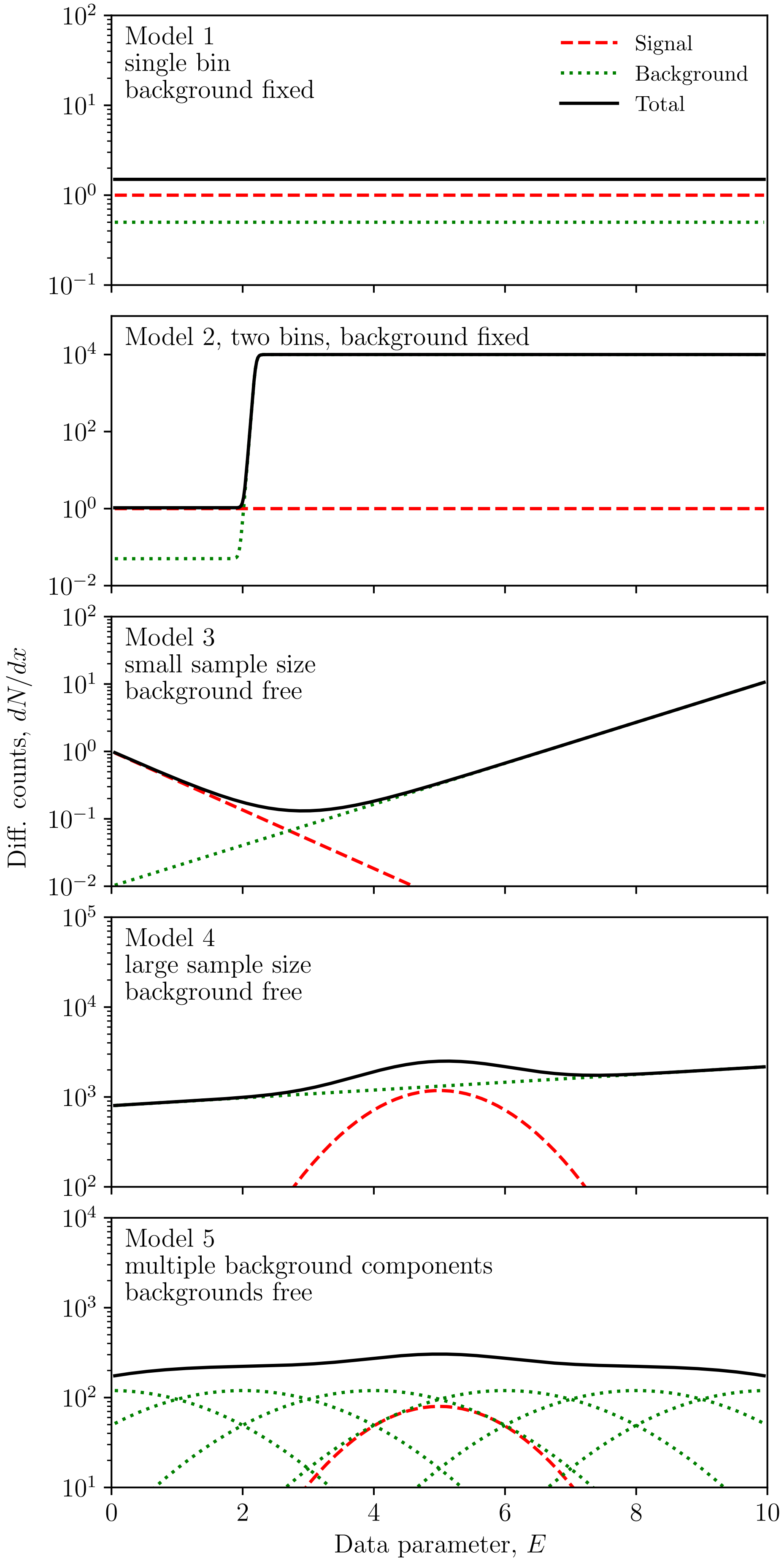
Logic:

- **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**

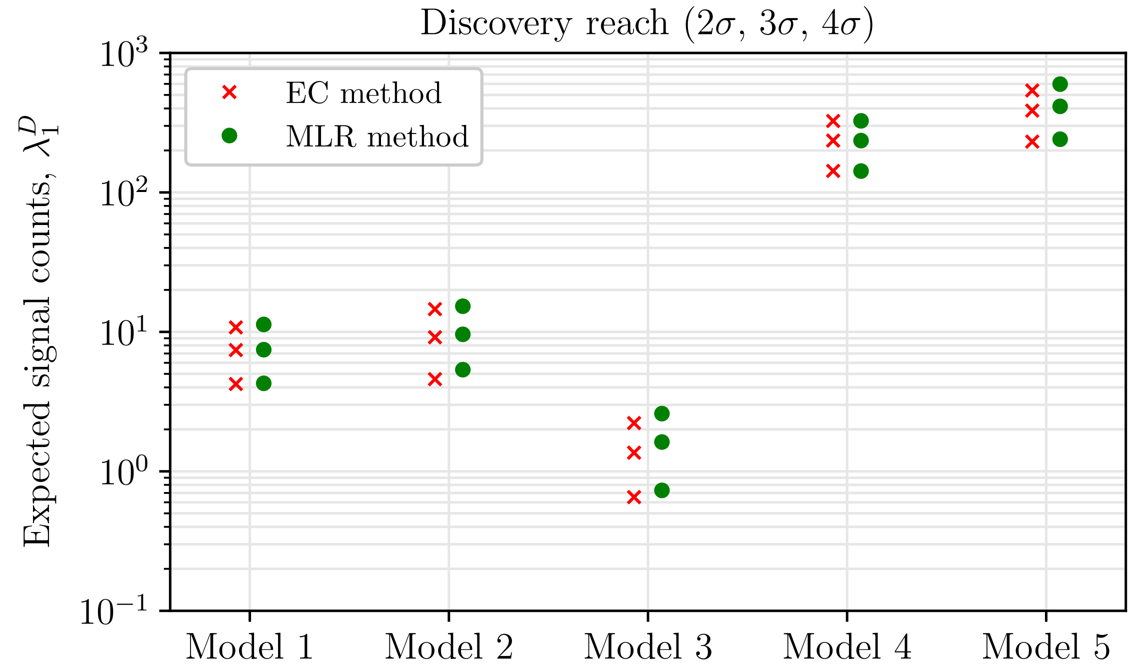
$$s_{\rm eq}(\theta) \equiv \frac{\theta^2}{\sigma^2(\theta) - \sigma^2(\theta_0)}$$

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

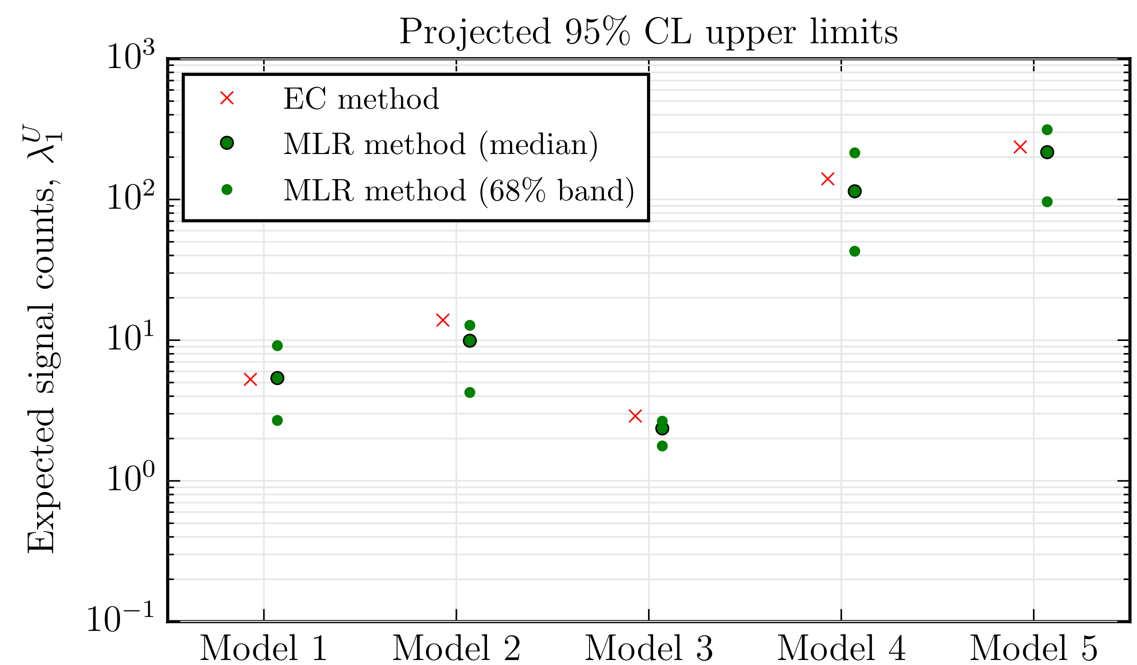




$$-2\ln\frac{P(s_{\rm eq}+b_{\rm eq}|b_{\rm eq})}{P(s_{\rm eq}+b_{\rm eq}|s_{\rm eq}+b_{\rm eq})}=Z^2$$



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



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

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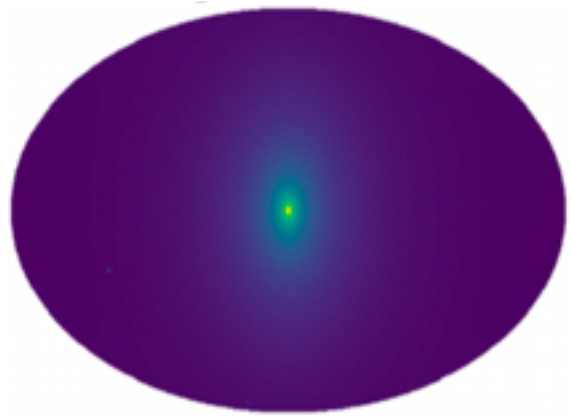
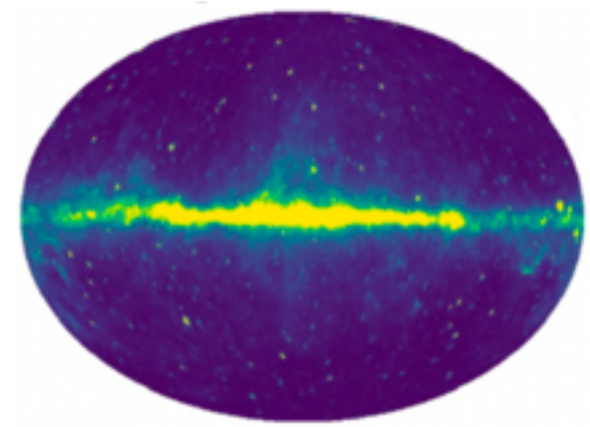
Dark Matter Halo

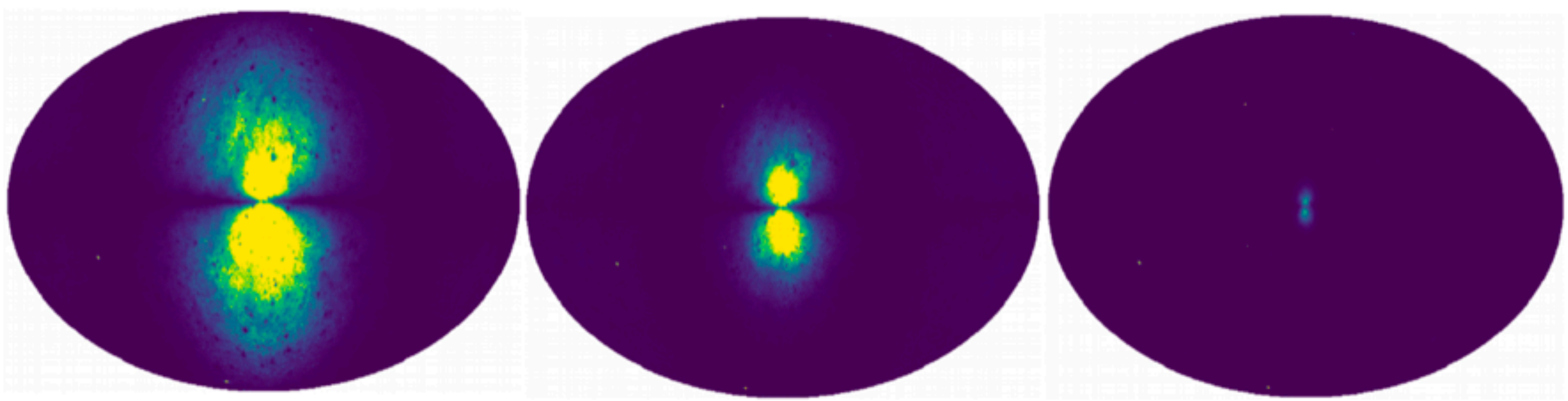




Background - assumed 10% error with a 10 degree correlation length

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

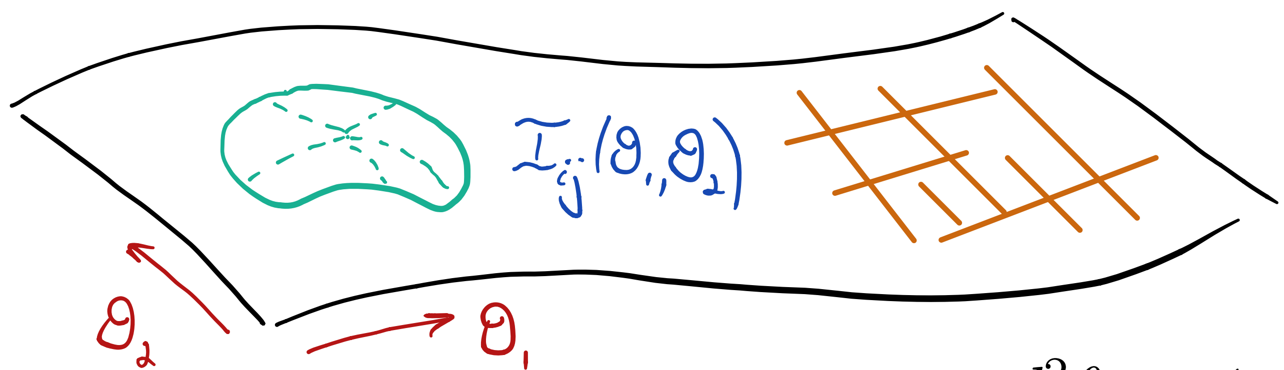
Increasing Exposure



= High Information

= Low Information

Visualisation



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

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

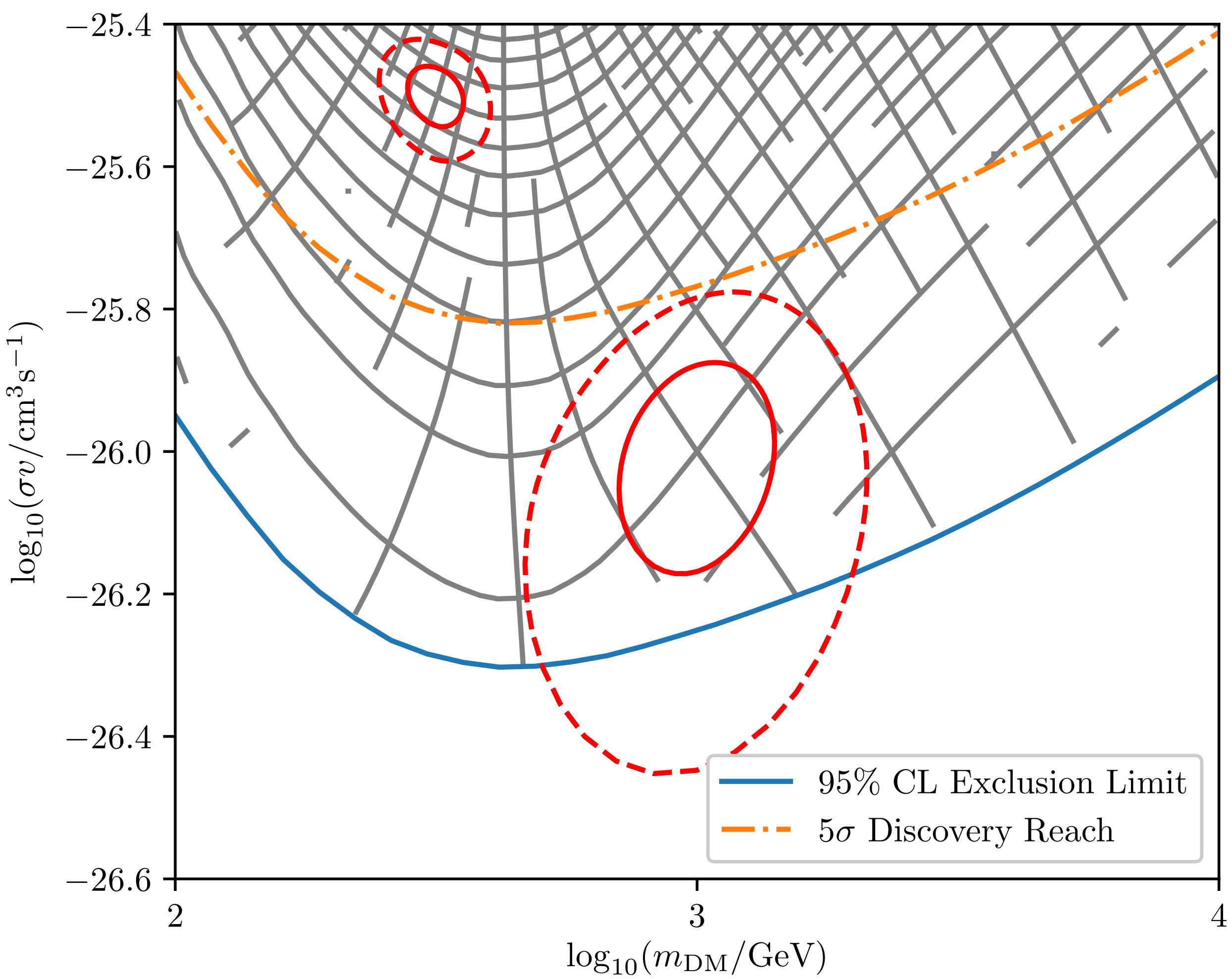
Equal Geodesic Confidence Contours

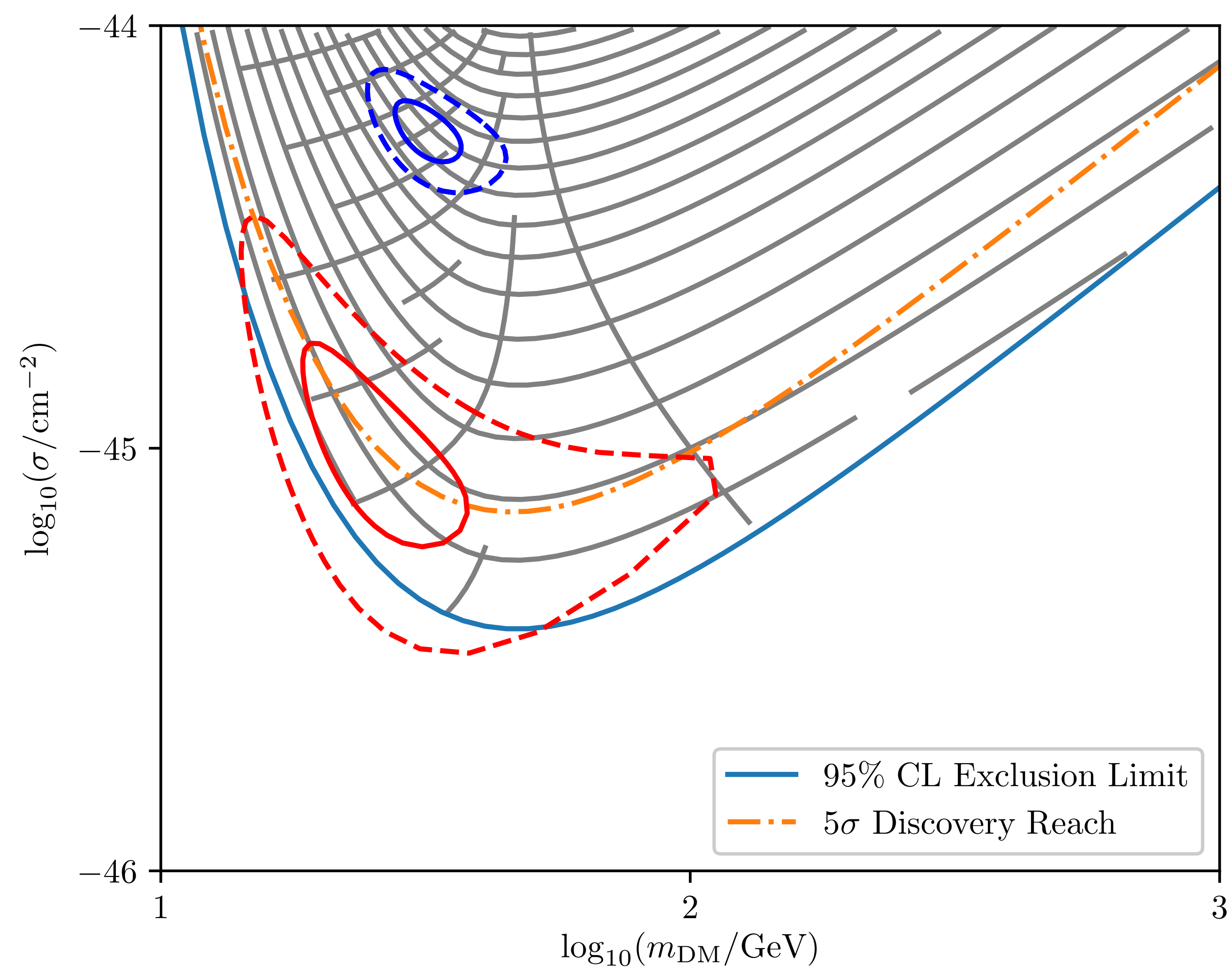
- **Trace geodesics in different directions and connect the curves**
- **Matches very accurately with traditional confidence contours**

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

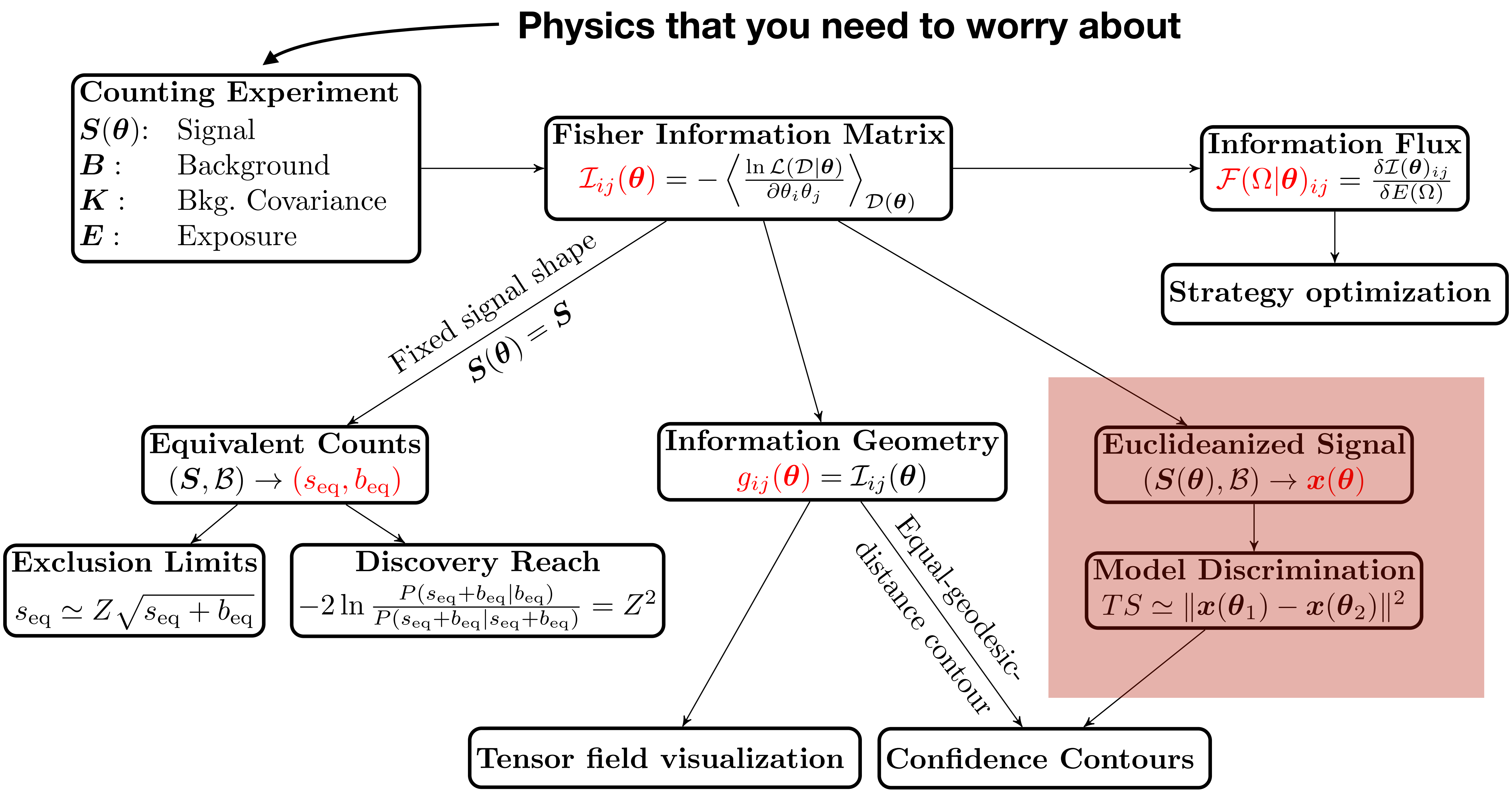




Replicated analysis from Silverwood et al.

Simplified 1-D Xenon1T projection

Swordfish



= C. Weniger's talk (later today)

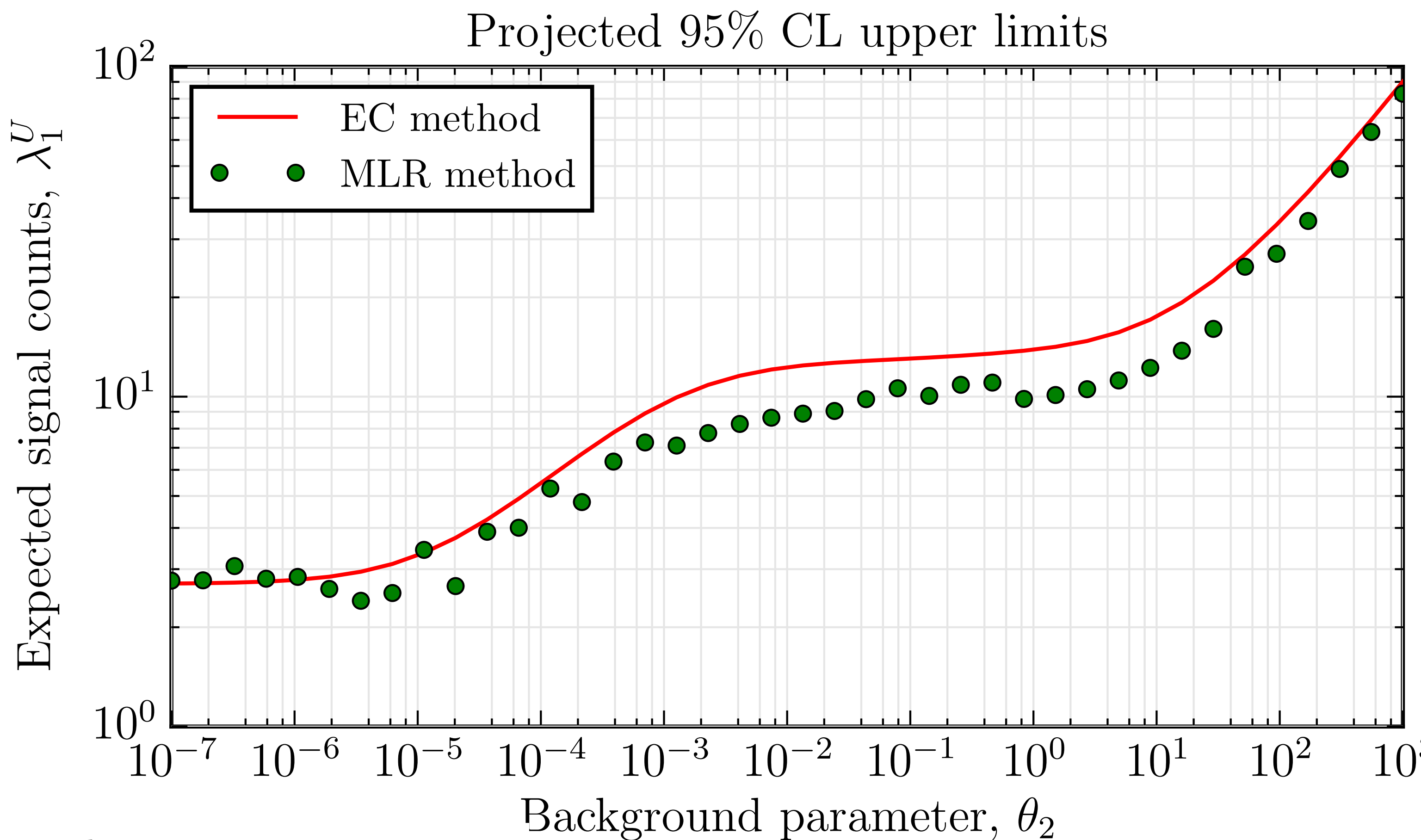
Questions? - for you

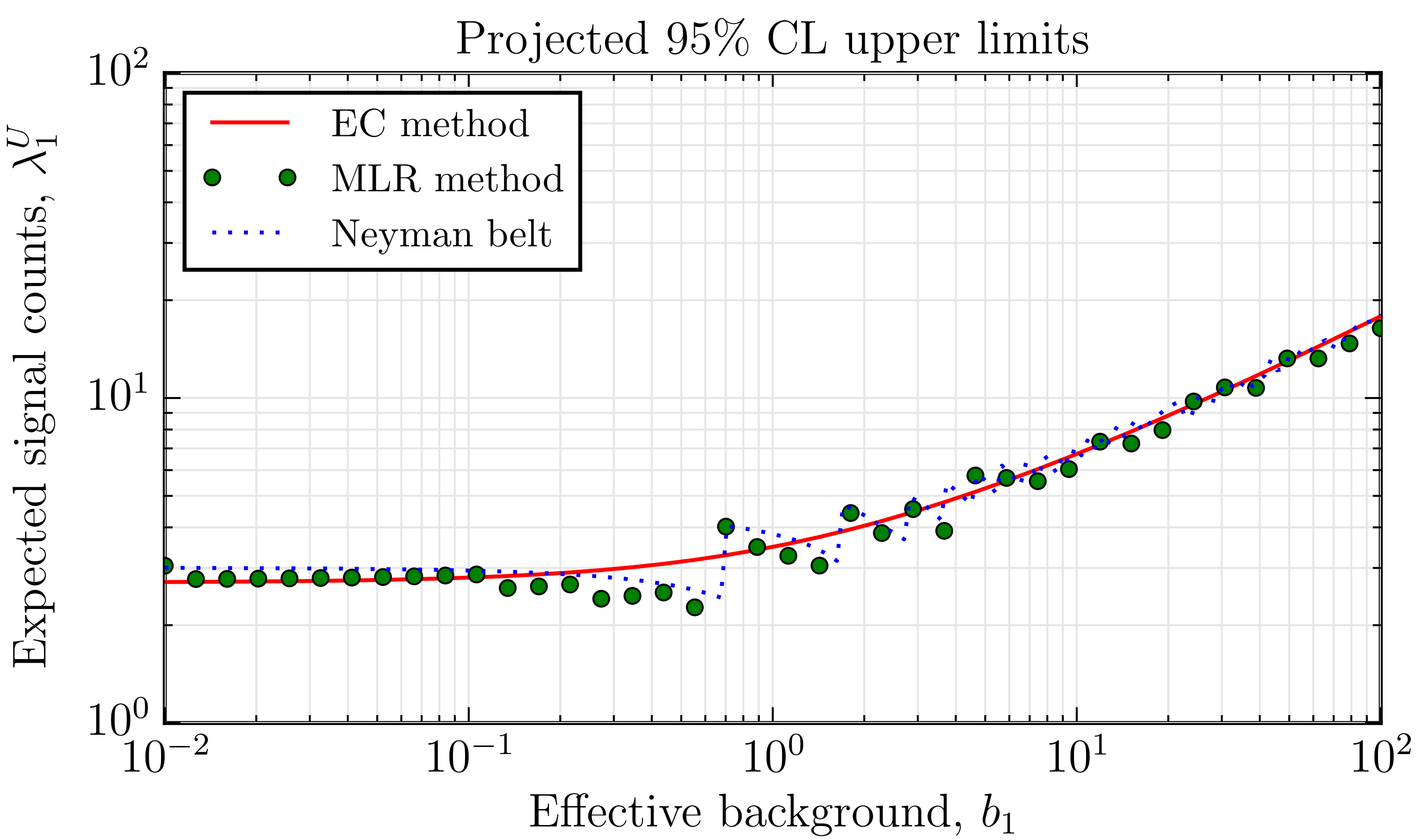
- In what other ways can we develop the tool such that it's useful?
- Any other quantities we can compute from the fisher matrix which would be useful for forecasting

Questions? - for us

- Are there other nice ways to visualize the parameter space?
- Is there any additional information we can derive from the likelihood surface... manifold learning, clustering?

Backup


Projected 95% CL upper limits
EC method
MLR method
Expected signal counts, λ_1^U
Background parameter, θ_2
10^0
10^1
10^2
10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^0 10^1 10^2 10^3


Projected 95% CL upper limits
EC method
MLR method
Neyman belt
Expected signal counts, λ_1^U
Effective background, b_1
10^0
10^1
10^2
10^{-2} 10^{-1} 10^0 10^1 10^2