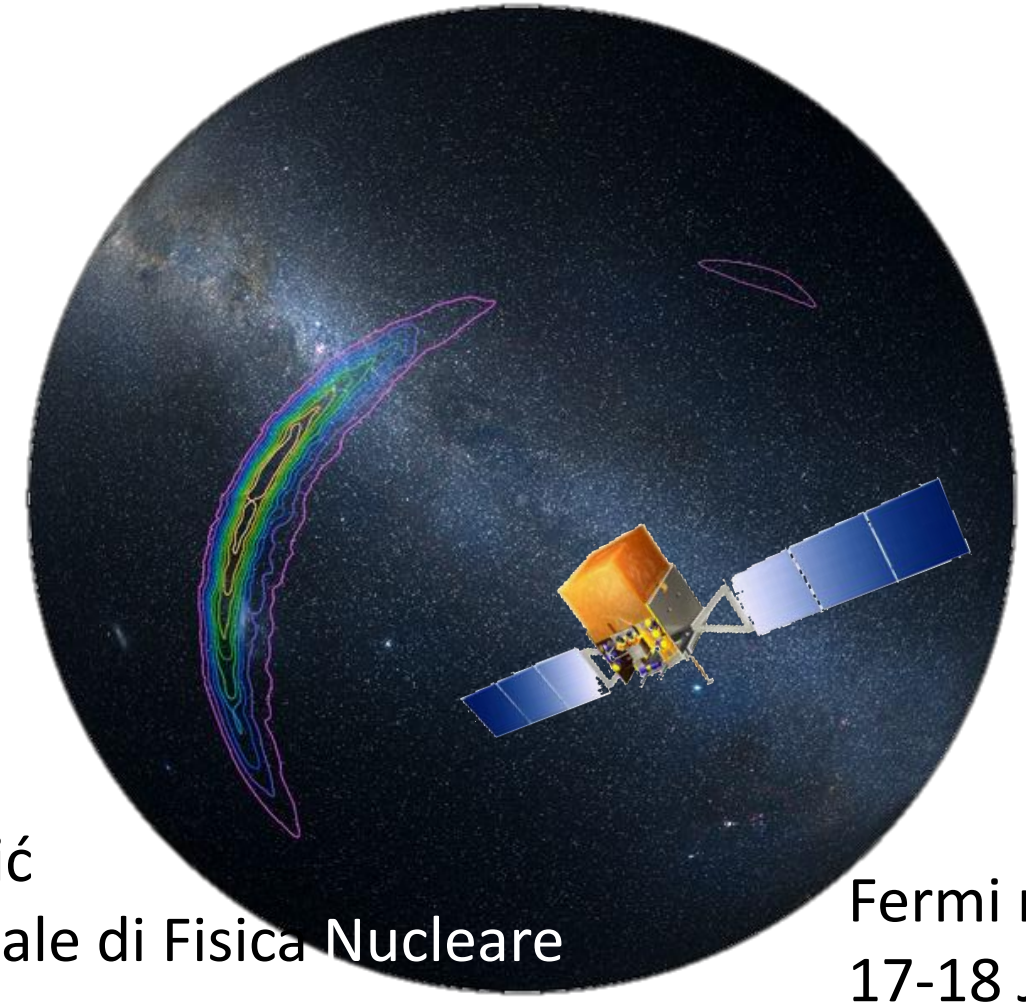
Determining the threshold for GRB LAT detection in gravitational wave localization area



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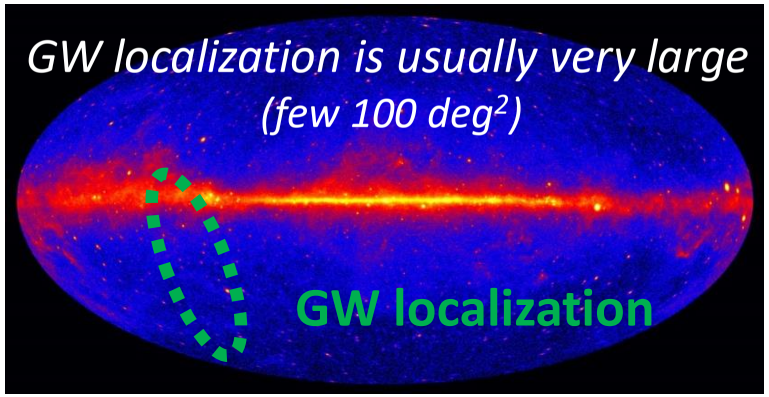
Introduction

Monte-Carlo simulations for fixed time window



- **1) Simulating the background (whole sky)**
- 10.000 times
- For 10.000 seconds starting little bit before GW trigger
- Background is composed of:
  - point & extended sources
  - diffuse galactic emission
  - isotropic background

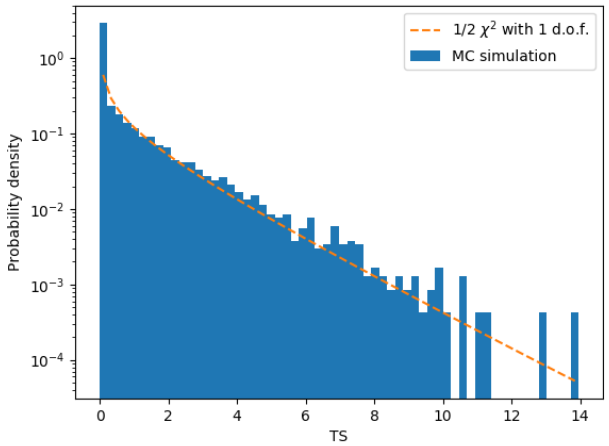
- **2) Performing LAT analysis**
- standard unbinned likelihood analysis
- at each point (HEALPix pixel) in GW loc. area (90% containment for example)
- for each of 10.000 backg. simulations
- (N_{pix} x 10.000 total analysis)
- with real Fermi pointing history during the time window

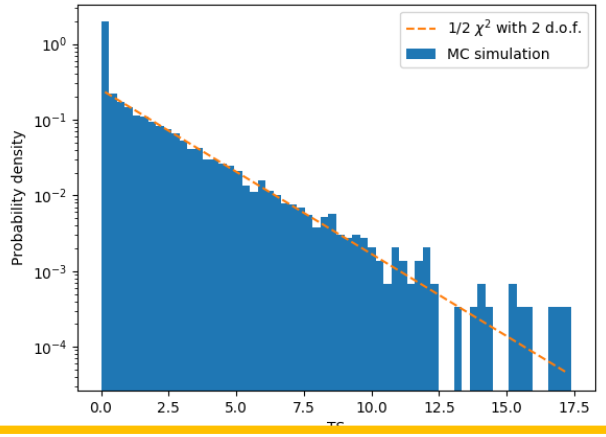
- **3) Calculating TS value**
- after each analysis as TS = -2 ln (L_0/L_1)
- L_1: max. likelihood (for model: background & GRB)
- L_0: max. likelihood (for model: just background)

Omodei, Vianello et al

Introduction

Behavior of TS values with simulated background for single position/pixel





Confluence: Family-wise error rate, Vianello, 2017

- Distribution of TS values should follow ½ χ^2 (surface = 0.5) with degree of freedom equal to number of additional free parameters when adding GRB to the model (negative TS values account for half the surface)
- Probability to obtain certain TS_0 value (or higher) in one analysis due to background fluctuation should be equal to surface of area under the ½ χ^2 function from TS_0 to infinity.

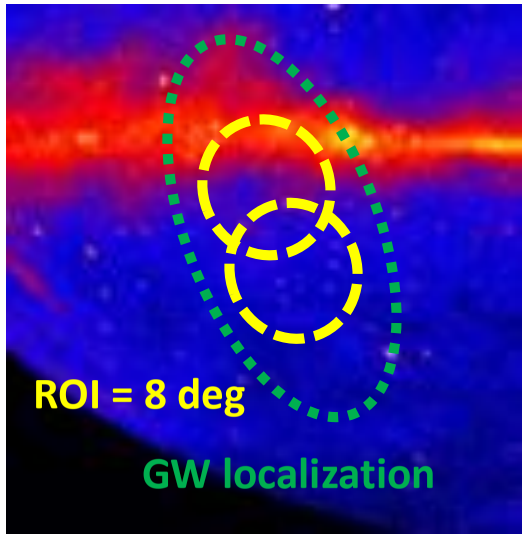
- Upper plot: GRB in the model has a fixed position with flux left to vary during fitting, so the 10k TSs follow pretty well ½ χ^2 with 1 d.o.f. (TS=25 ↔ 5σ)
- Lower plot: GRB in the model has position and flux left to vary during fitting, so the 10k TSs follow pretty well ½ χ^2 with 2 d.o.f. (TS=28.5 ↔ 5σ)

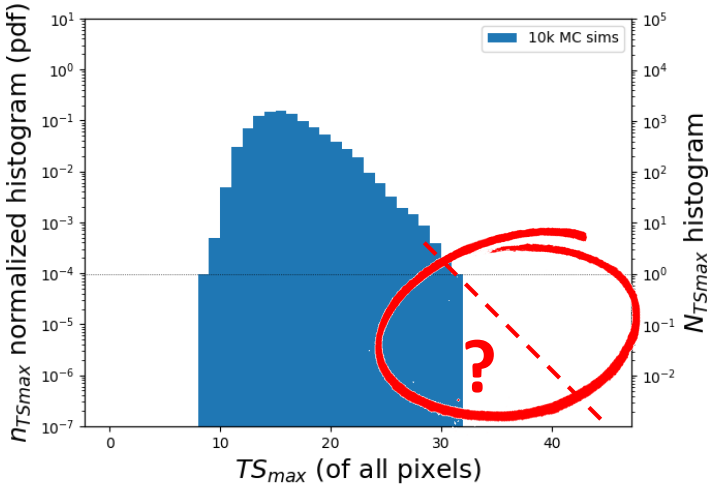
(in both plots first bin contains TS values which were negative and were then set to 0. They account for half the histogram surface leaving the rest to follow ½ χ^2)

The problem

Behavior of TS values with simulated background for many positions/pixels within GW localization area

- Corrections for multitrial (analysis at many pixels)
- Analysis at different pixels are not independent because regions of interest (ROIs) overlap
- So far, no analytical formula like for the case of single trial/pixel (½ χ^2)
- Ideally: performing >>10k simulations and analysis at each pixel, and select maximum TS (max. TS of all pixels for each simulation) and see how these max. TSs are distributed
- Not possible, too computationally intensive (even for SLAC computers).
- Trying with semi-analytical, semi-numerical (with 10k simulations) approach.



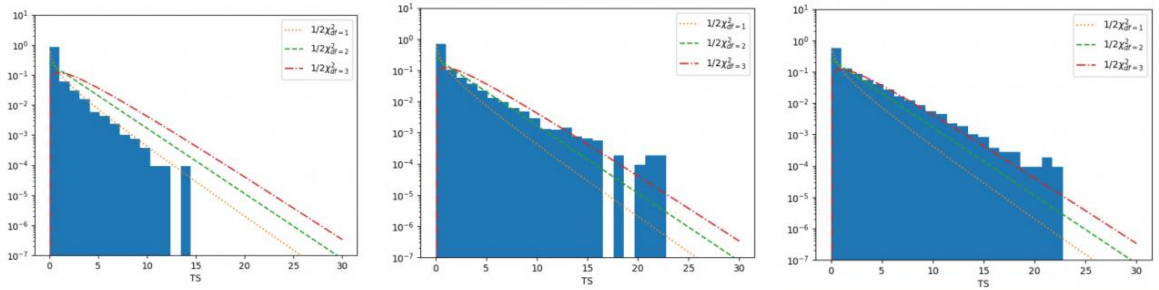


10k TS_{max} from 1271 pixels corresponding to 70% loc. of GW 150914

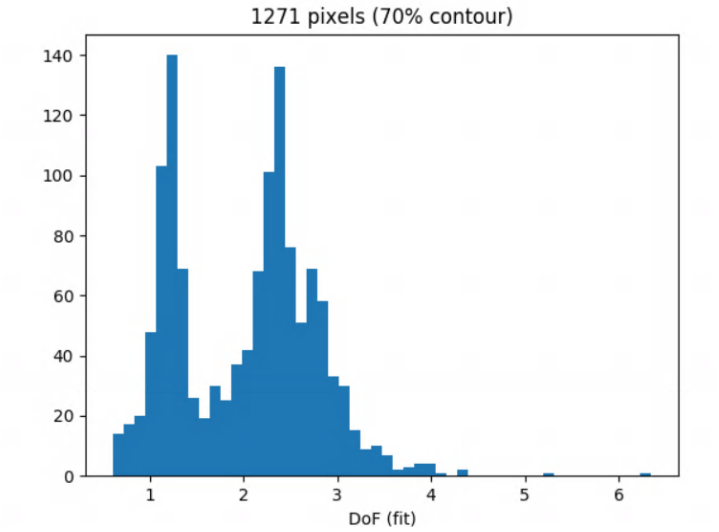
Also

Individual pixels don't exactly follow ½ χ^2 with single degree of freedom

(example for 70% localization of GW 150914)

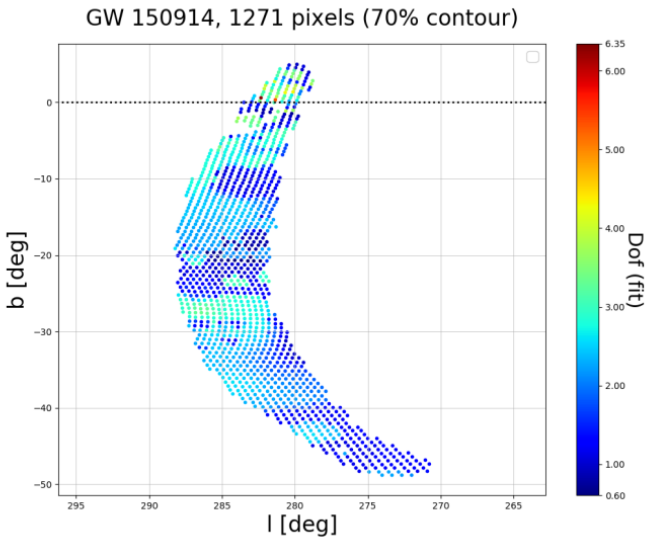


Example of three different pixels which follow more closely ½ χ^2 with dof = 1, 2 and 3 (left plot to right)



Degree of freedom obtained from fit for each 1271 pixel

Two peaks instead of one peak centered on single dof



Each dot is the center of pixel with color matching dof obtained from fit

Currently…

- Verifying that there were no issues with Monte-Carlo simulations and analysis;
- Examining effects of extended sources and allowing for GRB position to vary within pixel during fit on MC simulations-analysis;

Conclusions

- Useful to have a well-defined LAT threshold (for example: TS=? $\leftrightarrow$ 5σ) for the upcoming GW observatory runs;
- This type of determination of threshold could be used for other experiments where larger areas of the sky are searched for a source.