Using Fermi for CTA population forecasts

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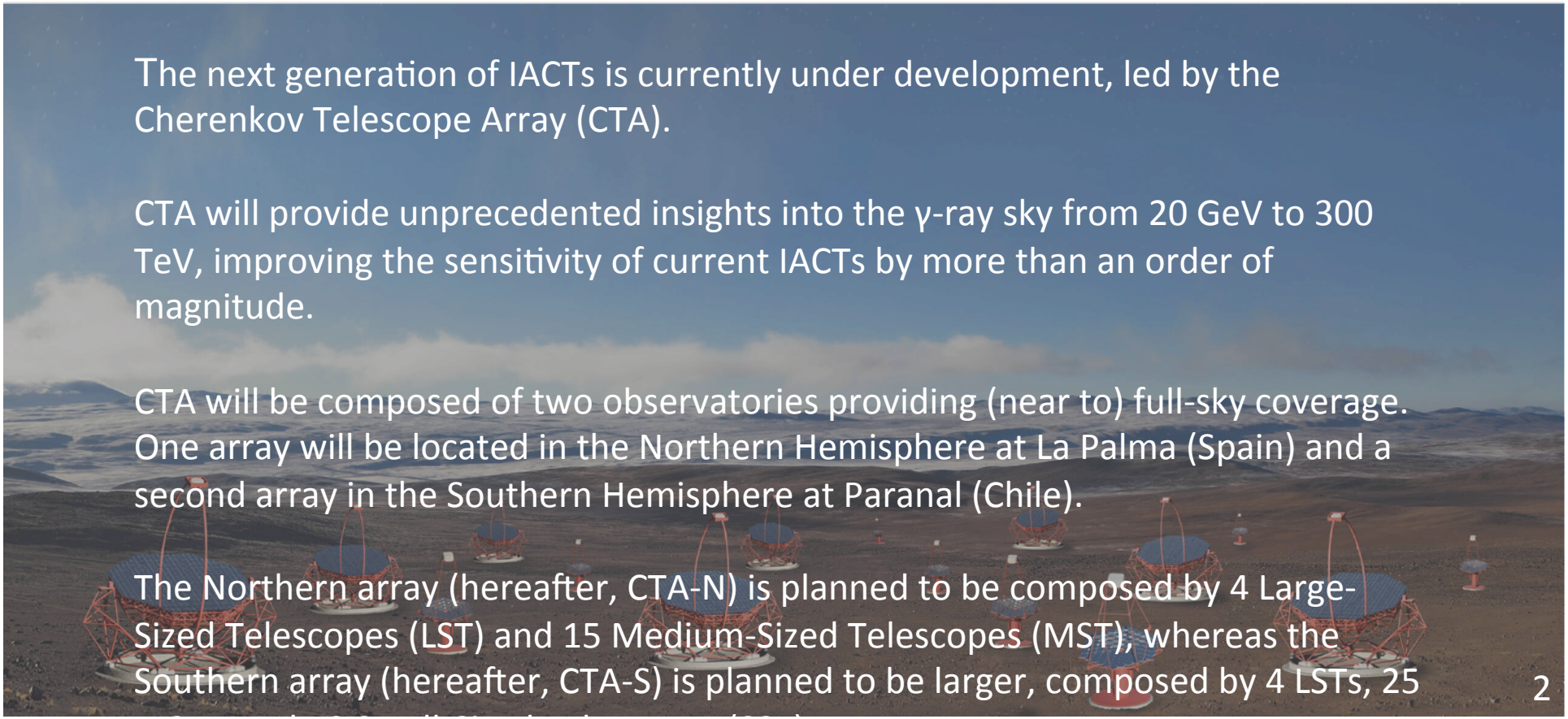
The Cherenkov Telescope Array



The next generation of IACTs is currently under development, led by the Cherenkov Telescope Array (CTA).

CTA will provide unprecedented insights into the γ-ray sky from 20 GeV to 300 TeV, improving the sensitivity of current IACTs by more than an order of magnitude.

CTA will be composed of two observatories providing (near to) full-sky coverage. One array will be located in the Northern Hemisphere at La Palma (Spain) and a second array in the Southern Hemisphere at Paranal (Chile).

The Northern array (hereafter, CTA-N) is planned to be composed by 4 Large-Sized Telescopes (LST) and 15 Medium-Sized Telescopes (MST), whereas the Southern array (hereafter, CTA-S) is planned to be larger, composed by 4 LSTs, 25

Why bother?

1. I'm mad(as you've probably guessed by now).

2. I didn't get a job(see reason 1) and someone has to…..but the real reason……

3. The large collection area of IACTs makes up for the limited payload of space telescopes, allowing us to explore shorter variability time scales with an improved sensitivity for moderate observation times .

4. It's rather fun using LAT source catalogues to make population predictions for a ground based instrument.

Using the 3FHL catalogue

The *Fermi*-LAT collaboration released a new catalog of 1,556 sources detected in the 10 GeV – 2 TeV range by the Large Area Telescope (LAT) in the first 7 years of its operation (the 3FHL catalog).

This catalog is currently the most appropriate description of the sky that will be energetically accessible to CTA.

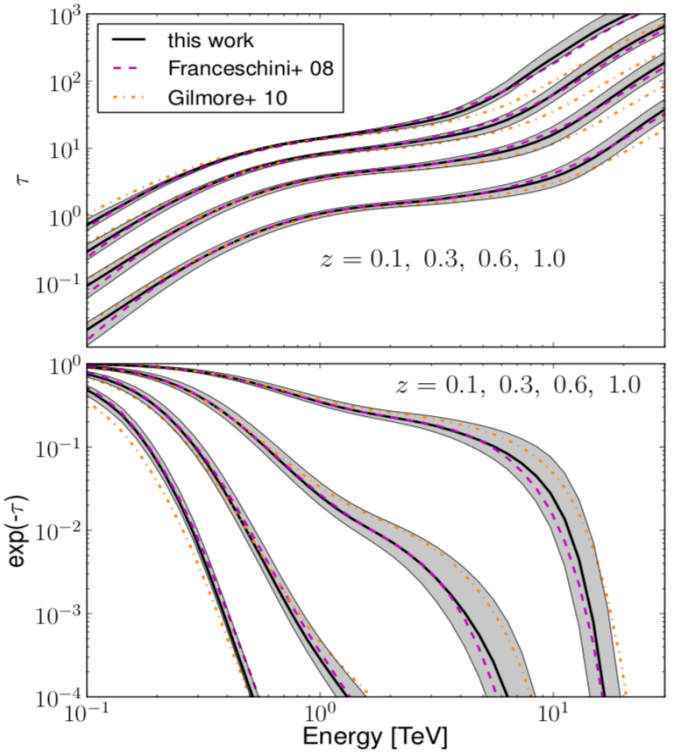
Most of these sources 1,231 (79% of the total catalog) are associated with sources of extragalactic nature, and 526 (43% of the extragalactic sources) have a known redshift. Note that only 72 of the 3FHL extragalactic sources have been already detected by ground-based telescopes.

Knowing the redshifts is quite important…..because of …….

Extragalactic Background Light

The Extragalactic Background Light (EBL) is all the accumulated radiation from star formation processes in the Universe.
Very high energy photons coming from cosmological distances interact with and get attenuated EBL photons by the process of pair production.

Can find intrinsic spectrum from observed spectrum.
Here's the optical depth and flux attenuation versus observed photon energy for sources at different redshifts for the Dominguez model we use.



Ctools

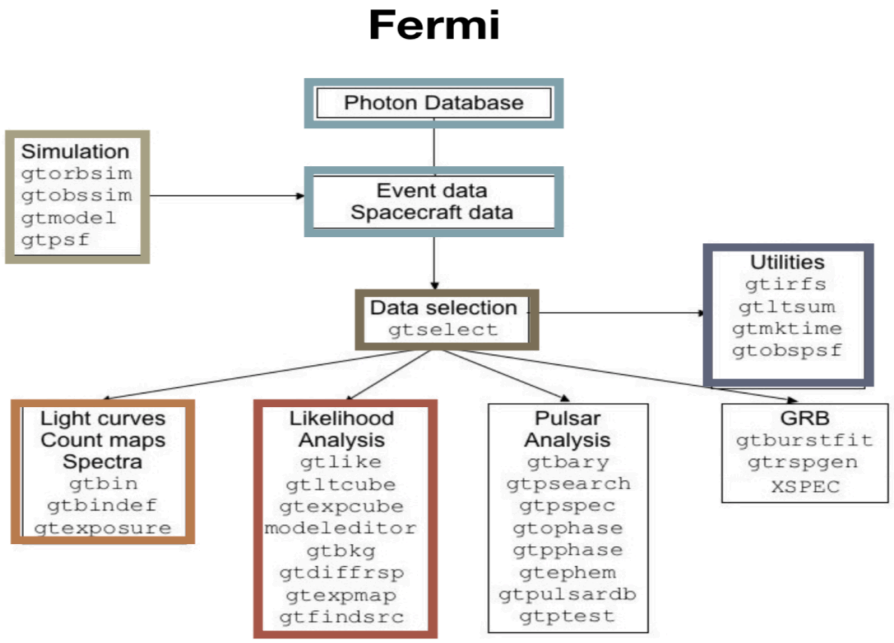
The ctools are a software package developed for the scientific analysis of Cherenkov Telescope Array (CTA) data.

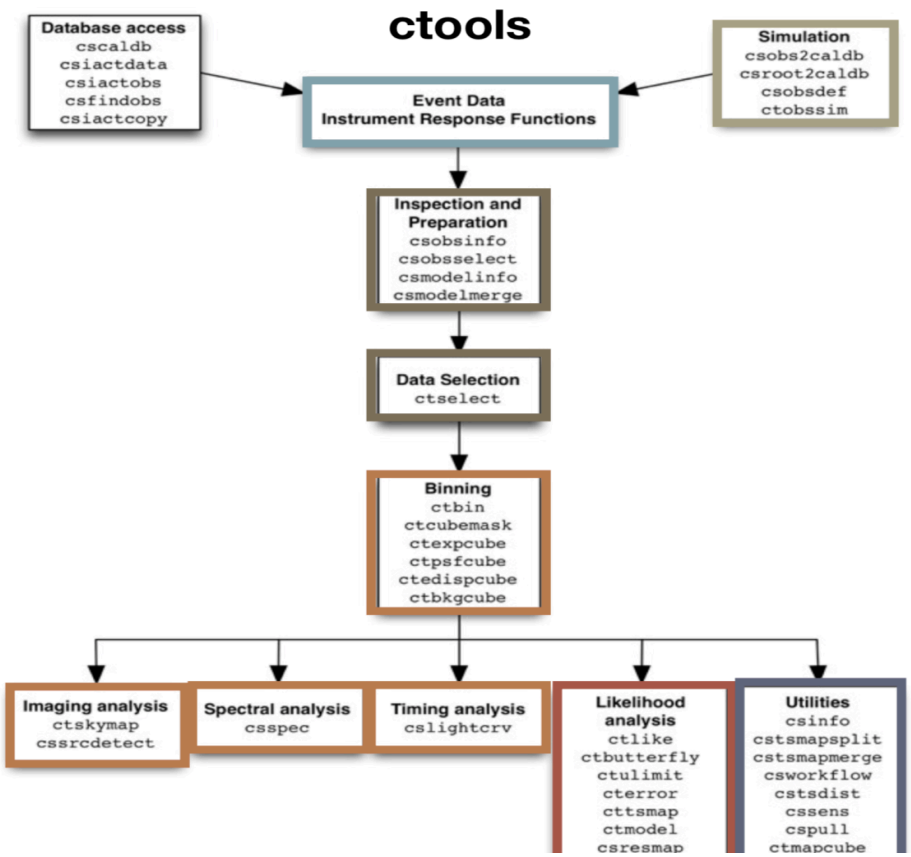
They are based on GammaLib, a C++ library interfaced to Python that provides a framework for instrument independent analysis of gamma ray data.

A general data analysis using Ctools involves producing images, spectra and light curves.

It shares all functionalities and interface capabilities as Fermitools ……such as…….

Fermi tools vs Ctools





Pre-analysis and detection conditions

To handle the unknown spectrum above ~60 – 100 GeV we must extrapolate.

For this we use different functions like power law(most optimistic), power law with exponential cut off and log parabola.

For each of these we use the Dominguez model for flux attenuation.

Resulting data stored in .dat file. Also create xml file from 3FHL catalogue.

Conditions for detection: A source is detectable if $S > 5\sigma$ (off-to-on source exposure ratio of 5), excess > 10 and 5 times larger than 1% of the background.

Analysis inputs

input_datafile.xml

input_datafile.xml 〉 No Selection

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```

spectra_3FHL_J1216.0-0242.dat

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52725.30 2.899e-15
60707.70 2.269e-15
69898.60 1.769e-15
80480.90 1.371e-15
92665.30 1.056e-15
106694.00 8.034e-16
122847.00 6.015e-16
141446.00 4.411e-16
162860.00 3.144e-16
187517.00 2.172e-16
215906.00 1.437e-16
248593.00 9.141e-17
286229.00 5.501e-17
329562.00 3.164e-17
379457.00 1.724e-17
436905.00 8.953e-18
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spectra_3FHL_J1218.0-0028.dat

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```

Left: Xml file created from 3FHL catalogue describing the source and background models.
Right: data file containing the simulated energy in MeV and photon flux in photons cm^{-2} s^{-1} MeV^{-1}.

Analysis Chain

CTA events are simulated based on certain dummy instrument properties(IRFs) plus source and background model. IRF used is from prod2 database.

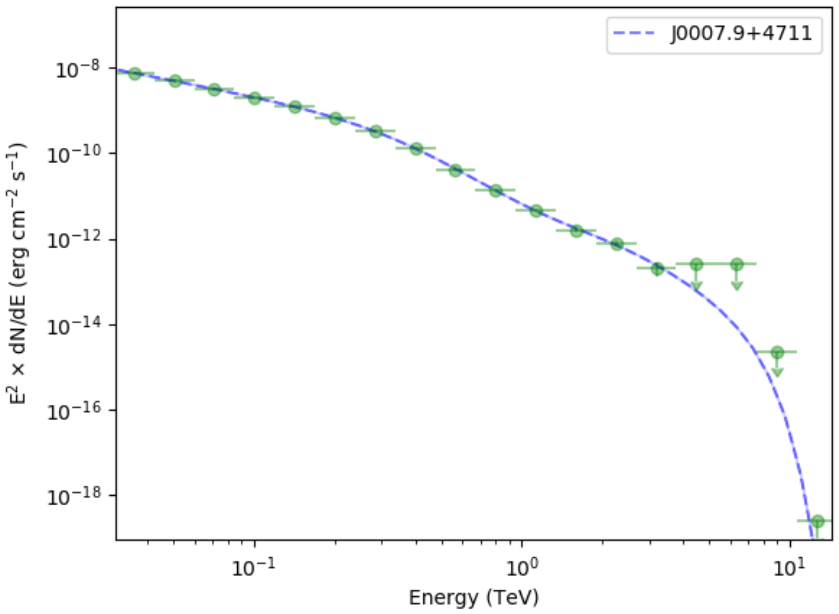
Mars bar question: How to decide which one among CTA N/CTA S to use for a particular source?(Hint: Think where and what)

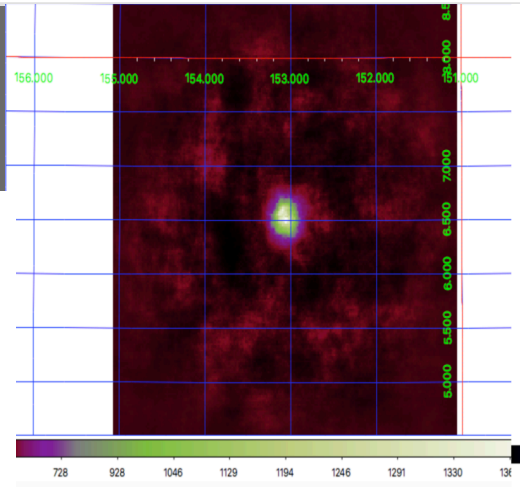
We then restrict the region of interest to 3 degrees around object as well as extract a 5/20hour slice in the required energy range.

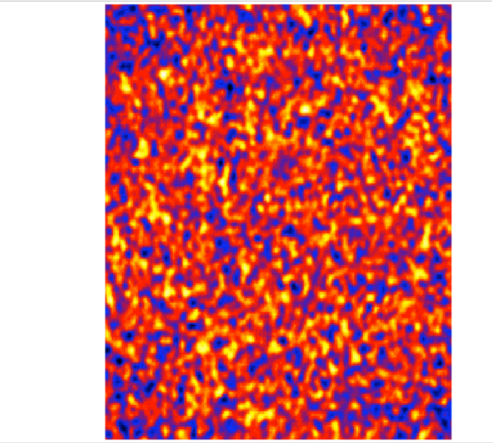
Fit using ctlike which produces a xml output file which contains the fit results as well as the statistical uncertainties for each fitted parameter.

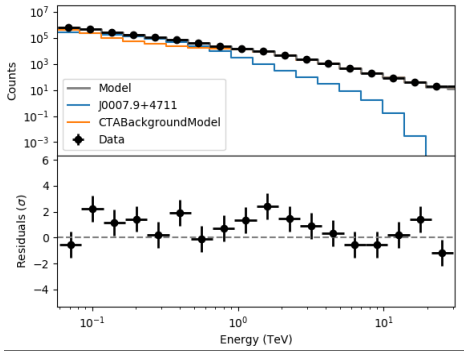
Ctbutterfly gives all spectral models statistically compatible with the data and can generate a butterfly diagram.

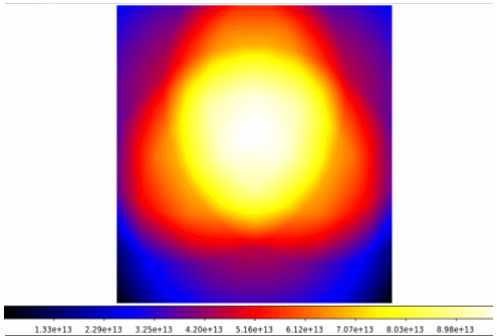
What pops out



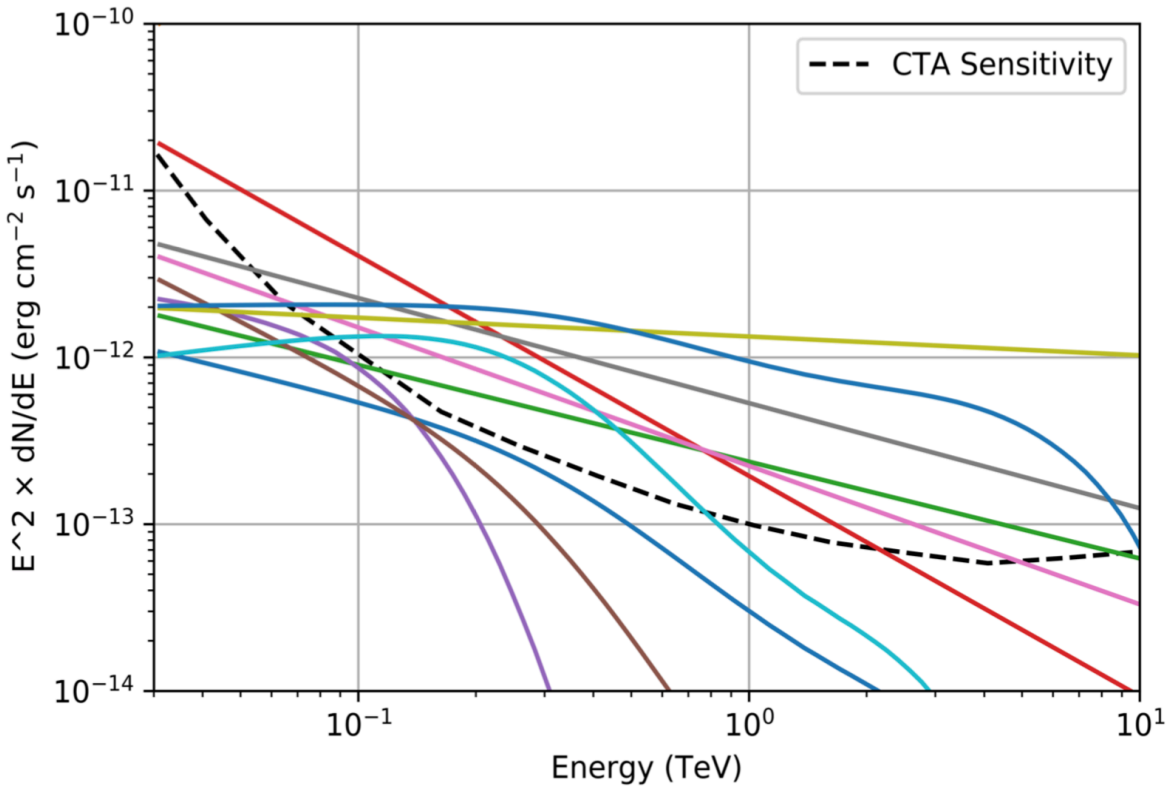








Preliminary Results



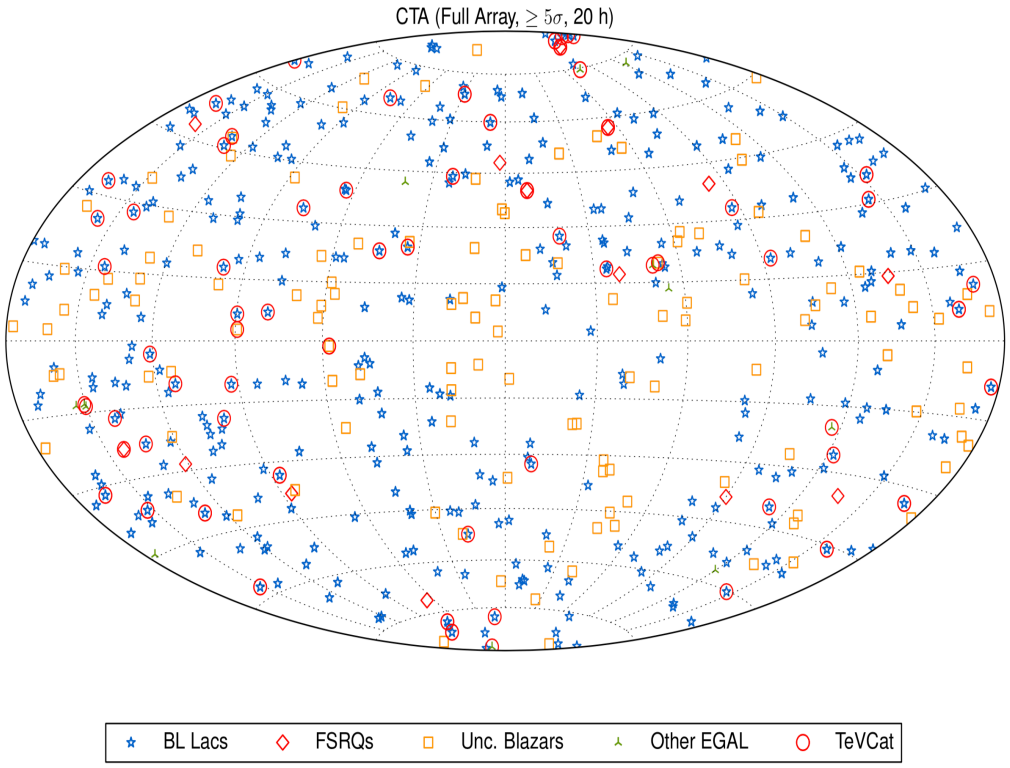
Extrapolated spectra from the 3FHL catalog attenuated by the Dominguez model. Black dashed line marks the CTA performance sensitivity for the Southern array and 50hr observations.

More Results

Left :Number of 3FHL extragalactic sources detectable by CTA under different extrapolation schemes and two different observation times. From each sub-sample of detectable sources, the number of these objects already detected by the current generation of IACTs is shown in parenthesis.

	CTA-N (5h)	CTA-N (20h)	CTA-S (5h)	CTA-S (20h)	CTA-N/S (5h)	CTA-N/S (20h)
PL	261 (50)	383 (54)	272 (37)	381 (40)	395 (63)	566 (69)
PLE	190 (47)	339 (52)	190 (37)	336 (39)	304 (62)	498 (66)
BPL	142 (45)	302 (53)	142 (45)	322 (39)	238 (57)	470 (68)
LP	67 (37)	139 (47)	75 (27)	161 (37)	111 (50)	230 (62)

Right : Skymaps of the predicted extragalactic sources detectable by the CTA Observatory (either CTA-N or CTA-S), under the PLE extrapolation scheme, at $S \geq 5\sigma$ in 20 h . Different symbols and colours are used for different source populations.



Conclusions

These results show the CTA potential to expand our understanding of the extragalactic populations of γ -ray emitters and their evolution over redshift.

CTA will not only dramatically increase the amount of detectable blazars in their average state, it will also enable their spectral study over more than five decades in energy by combining its observations with *Fermi*-LAT data.

We have also shown the CTA potential in discovering new source populations of hard spectra and low fluxes.

Information provided by the *Fermi*-LAT will be key to optimising follow-up observations strategies for CTA.

Acknowledgements

All of you for being such a fine audience. I always say that but this time I mean it(I always say that too) .

My supervisors(Paula and Anthony) and my fellow members of the gamma ray group back at Durham.

The organizers of the summer school for doing such a brilliant job.

The CTA population task force led by Tarek Hassan.

Have a lovely day, safe trip home, wonderful summer and if you can't have a pie…..have a pasty……matey!!!!