

VERITAS DATA ANALYSES: PROGRESS WITH GAMMALIB & CTTOOLS

NATHAN KELLEY-HOSKINS

PYGAMMA15, HEIDELBERG, GERMANY

16 NOVEMBER 2015

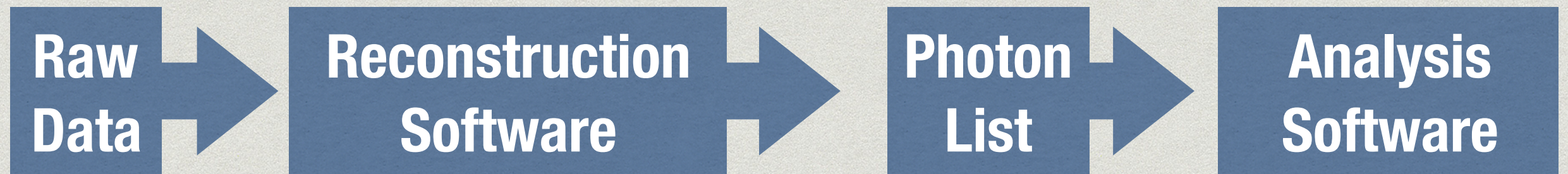
VERITAS

- * Gamma-Ray Observatory, Arizona
- * 85 GeV - 30 TeV
- * Images Particle Showers in the Atmosphere



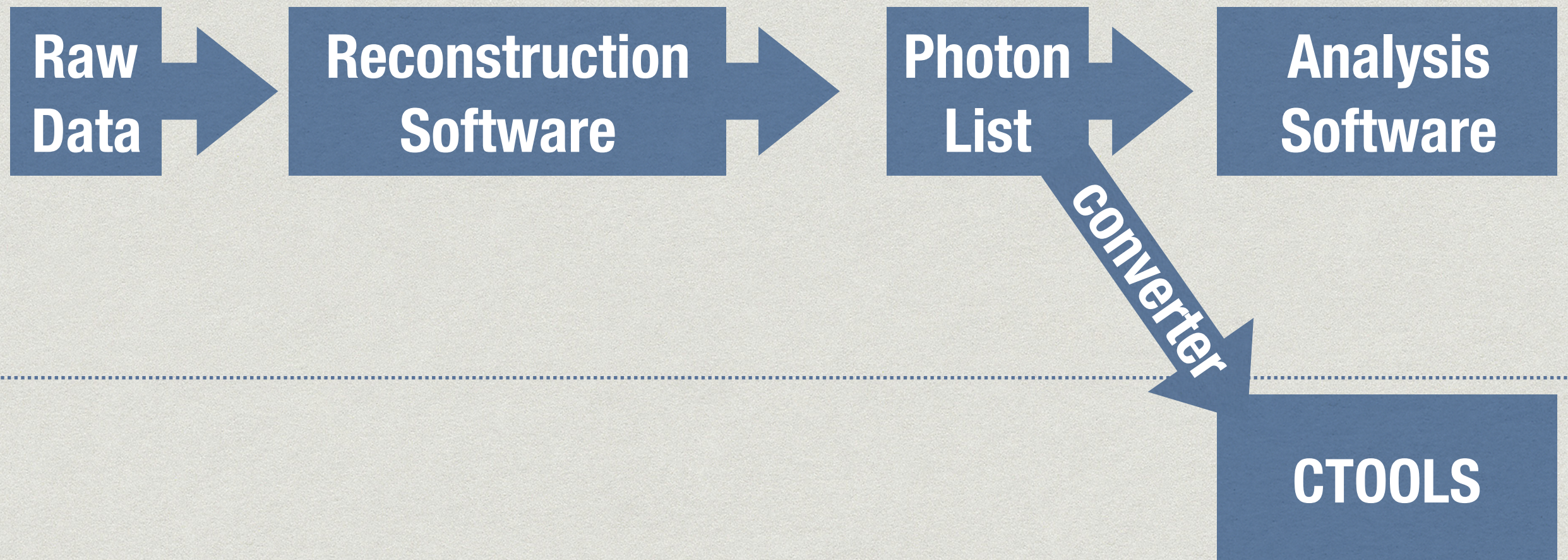
VERITAS Software

VERITAS-Developed Software



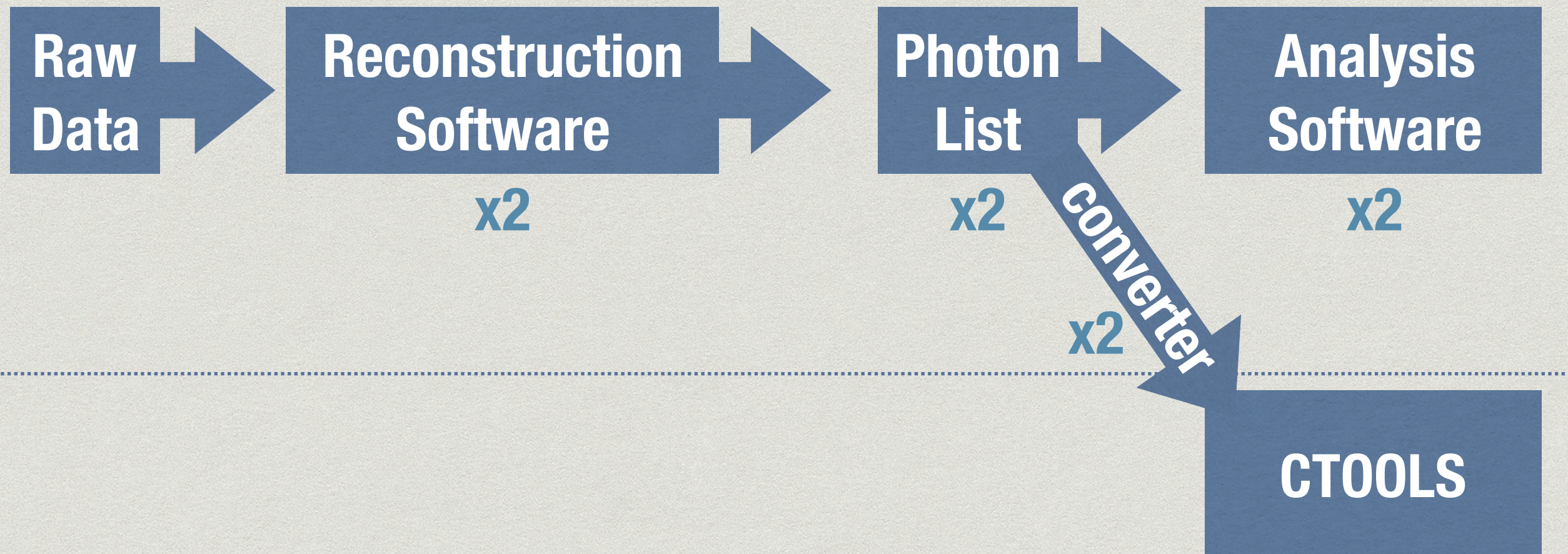
VERITAS Software

VERITAS-Developed Software



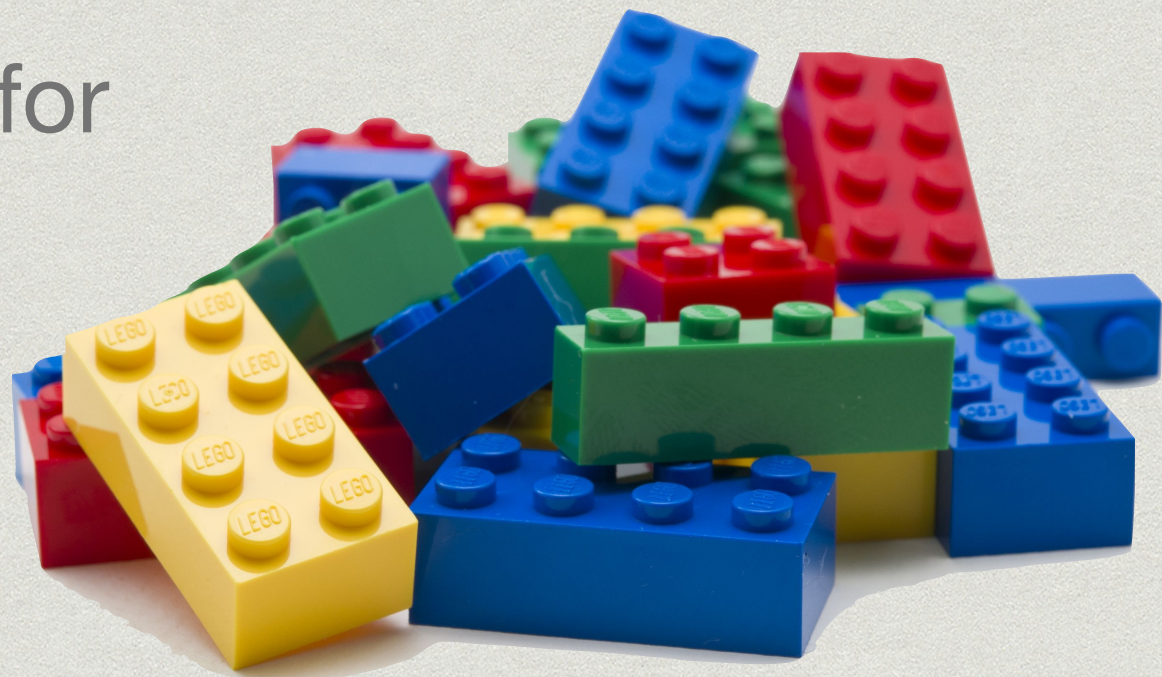
VERITAS Software

VERITAS-Developed Software



GAMMALIB/CTOOLS

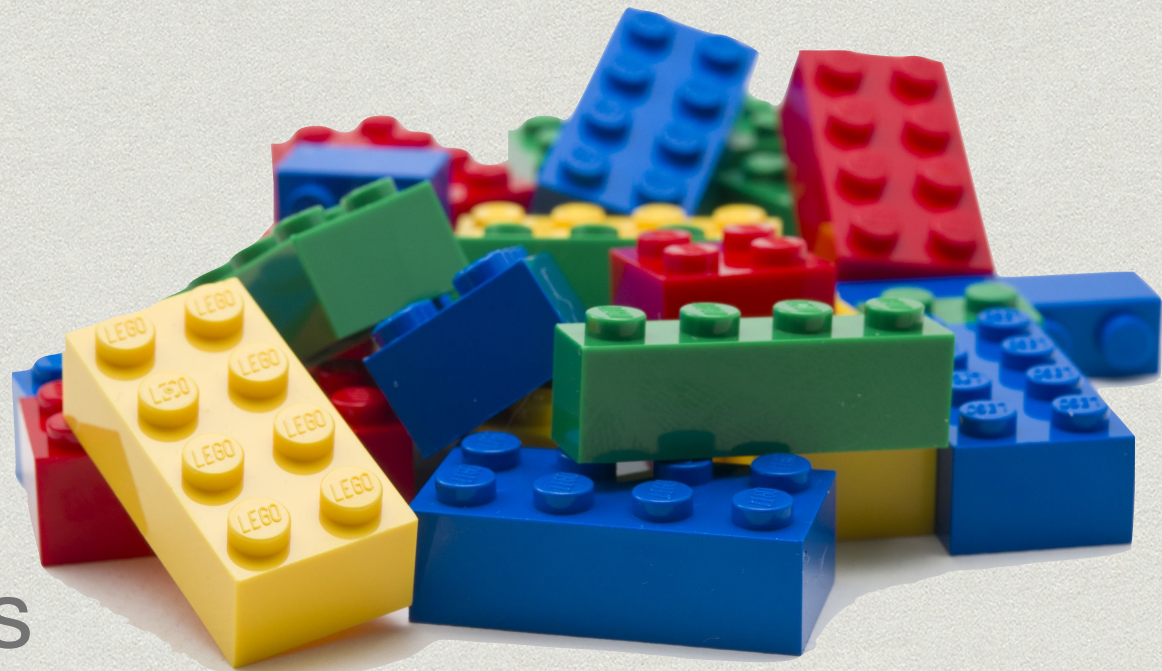
- * Astrophysics (X+Gamma) Analysis Package
- * Python and C++
- * Built on gammalib
- * A primary candidate for high-level CTA science analysis



<http://cta.irap.omp.eu/ctools>

GAMMALIB

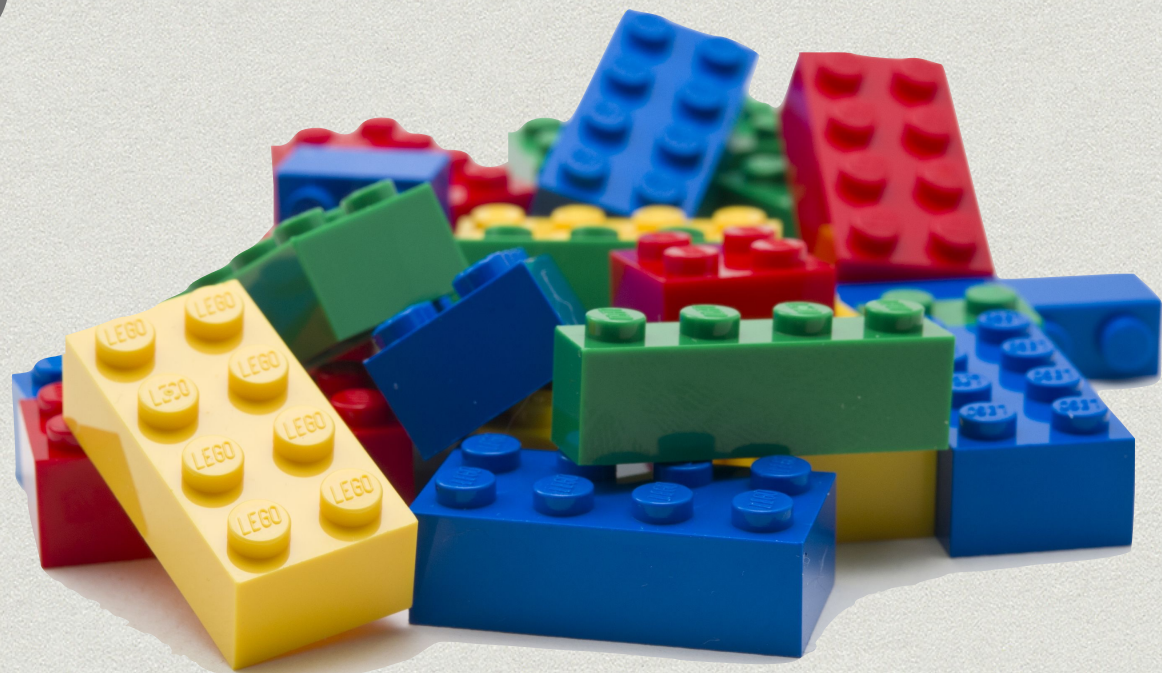
- * Formatted FITS files are loaded into an observation **bucket**:
- * Event Lists
- * PSFs
- * Effective Areas
- * Backgrounds
- * Time/Energy Spans



<http://cta.irap.omp.eu/ctools>

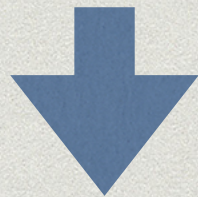
CTOOLS

- * Lego-like programs that operate on a **bucket** of observations
- * slice data by energy/time/sky position
- * likelihood engine(s)
- * skymaps
- * spectra
- * light curves

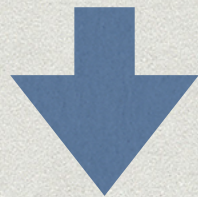


<http://cta.irap.omp.eu/ctools>

1. Convert Data to FITS



2. Fill the bucket



3. Science that bucket!

ctlike
likelihood tests

ctlightcurve
light curves

ctbutterfly
spectra plot

cttsmap
sky maps

ctulimit
flux upper limit

List of Ctools So Far...



Simulate Data

ctobsdef, ctobssim

Slice Data

ctselect

Bin Data

ctbin, ct cubemask, ctexpcube,
ctpsfcube, ctbkgcube

Analyses:

Timing

cslightcurv

Imaging

ctskymap

Spectral

csspec

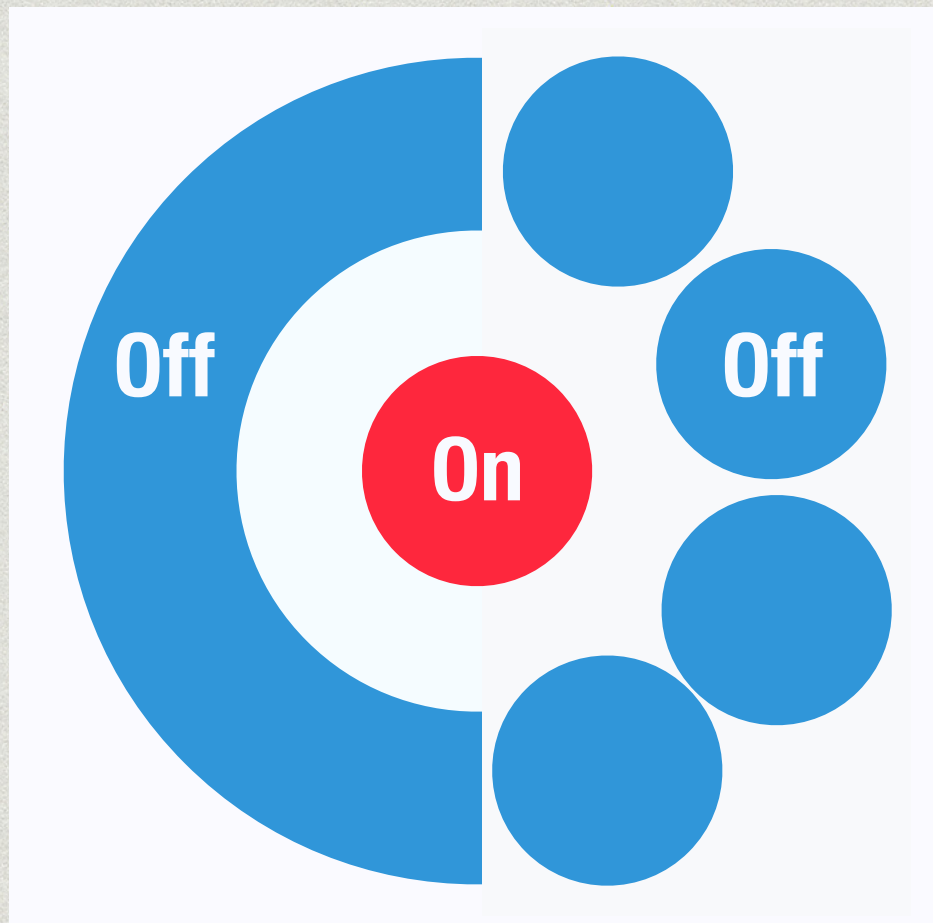
Likelihood

ctlake, ctbutterfly,
ctulimit, cterror,
cttsmap, ctmodel,
csresmap



Classical Analysis

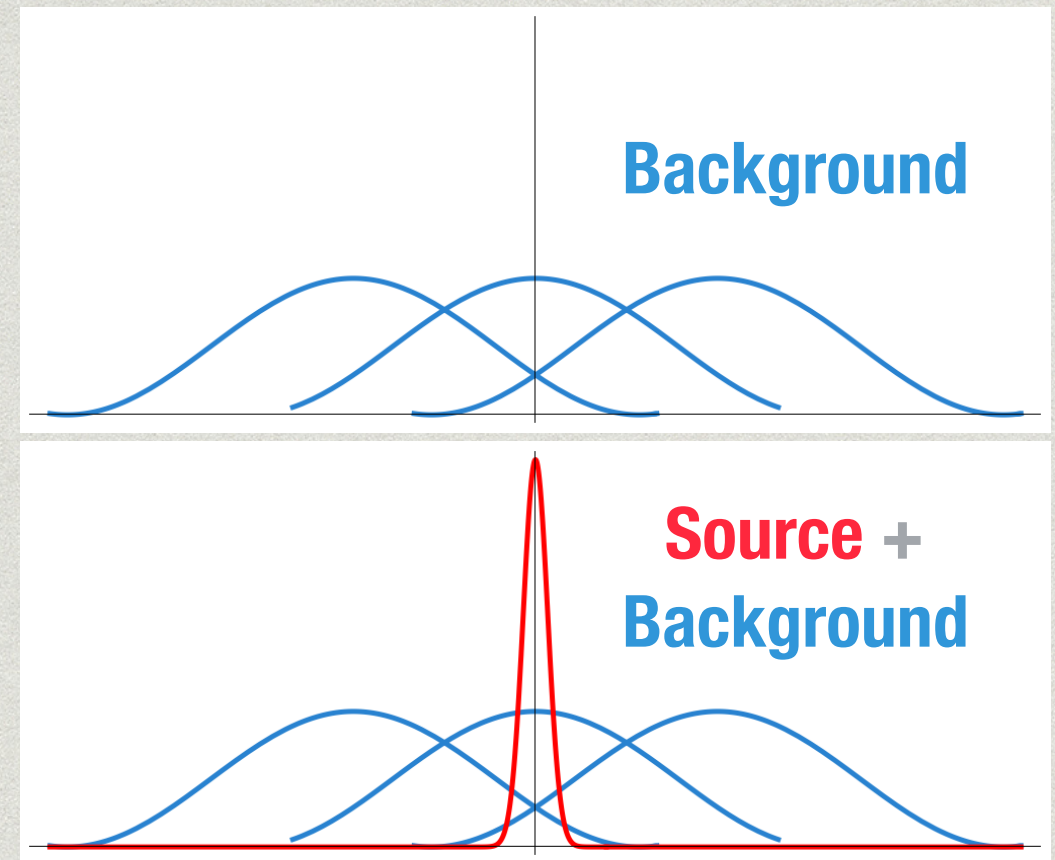
- * Pick **On** region
- * Pick **Off** region



$$significance = \sqrt{-2 * \ln(\lambda(N_{on}, N_{off}, \alpha))}$$

CTOOLS Likelihood

- * Construct two model groups (hypotheses)



- * Likelihood for each hypothesis

$$significance \cong \sqrt{-2 * \ln \left(\frac{L_{background}}{L_{source+background}} \right)}$$

VERITAS Data Conversion

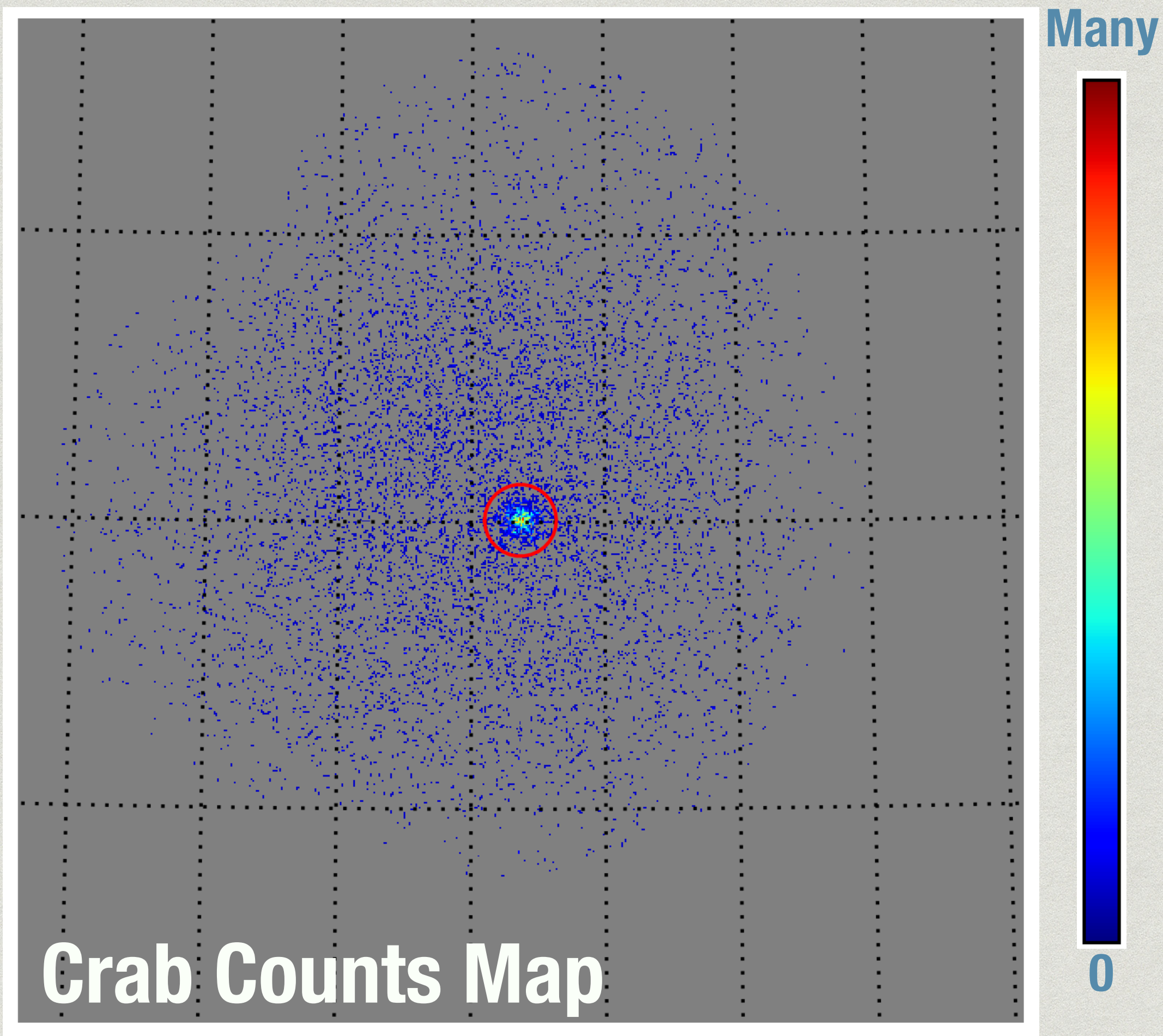
- * VERITAS raw data saved in 30min data files
- * For CTOOLS: Pack N-minute data to one fits file
 - * IRFs included in fits file
 - * special loading of **bucket**
 - * very simple organisation
 - * *tiny* file size (30min data < 1MB, with IRFs)

Conversion Progress

- * VERITAS Data Converter almost complete
 - * Gamma-Ray Photon Lists done
 - * IRF's nearly done, being verified:
 - GCTAPsfKing (energy/offset)
 - GCTAAeff2D (energy/offset)
 - GCTABackground3D
(energy/detx/dety, in Az/Elev coordinates)
- * Compare non-ctools analysis of 39 sources to ctools results

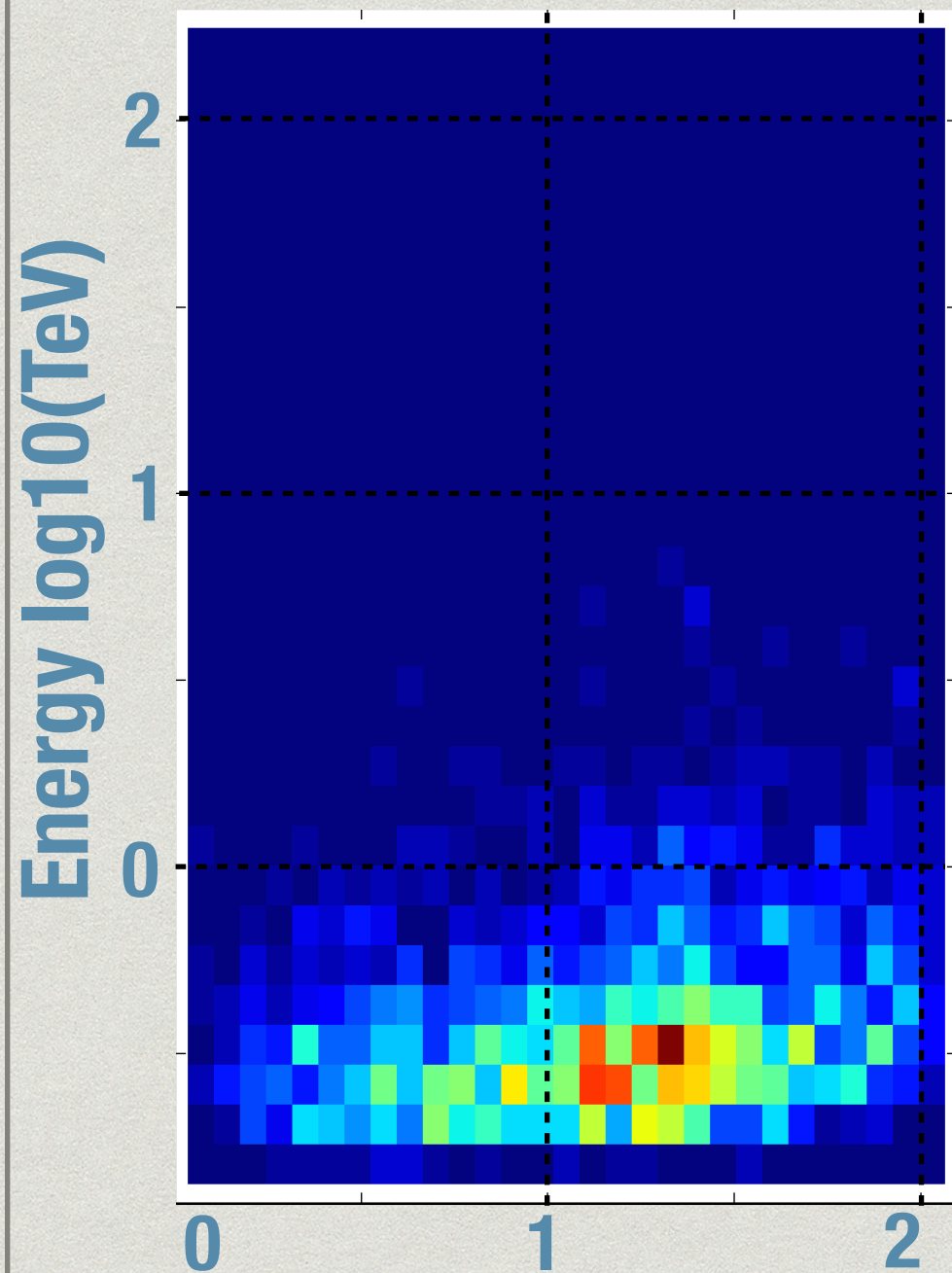
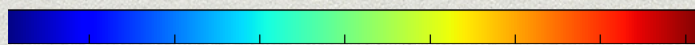
VERIPY

- * Auxiliary python module for VERITAS
VERITAS members only (sorry)
- * Load fits files to CTOOLS **bucket** with special function
- * host for private VERITAS functionality
- * *Not* a layer between VERITAS and CTOOLS



IRFs

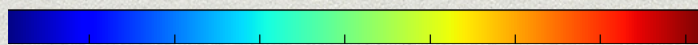
Photons



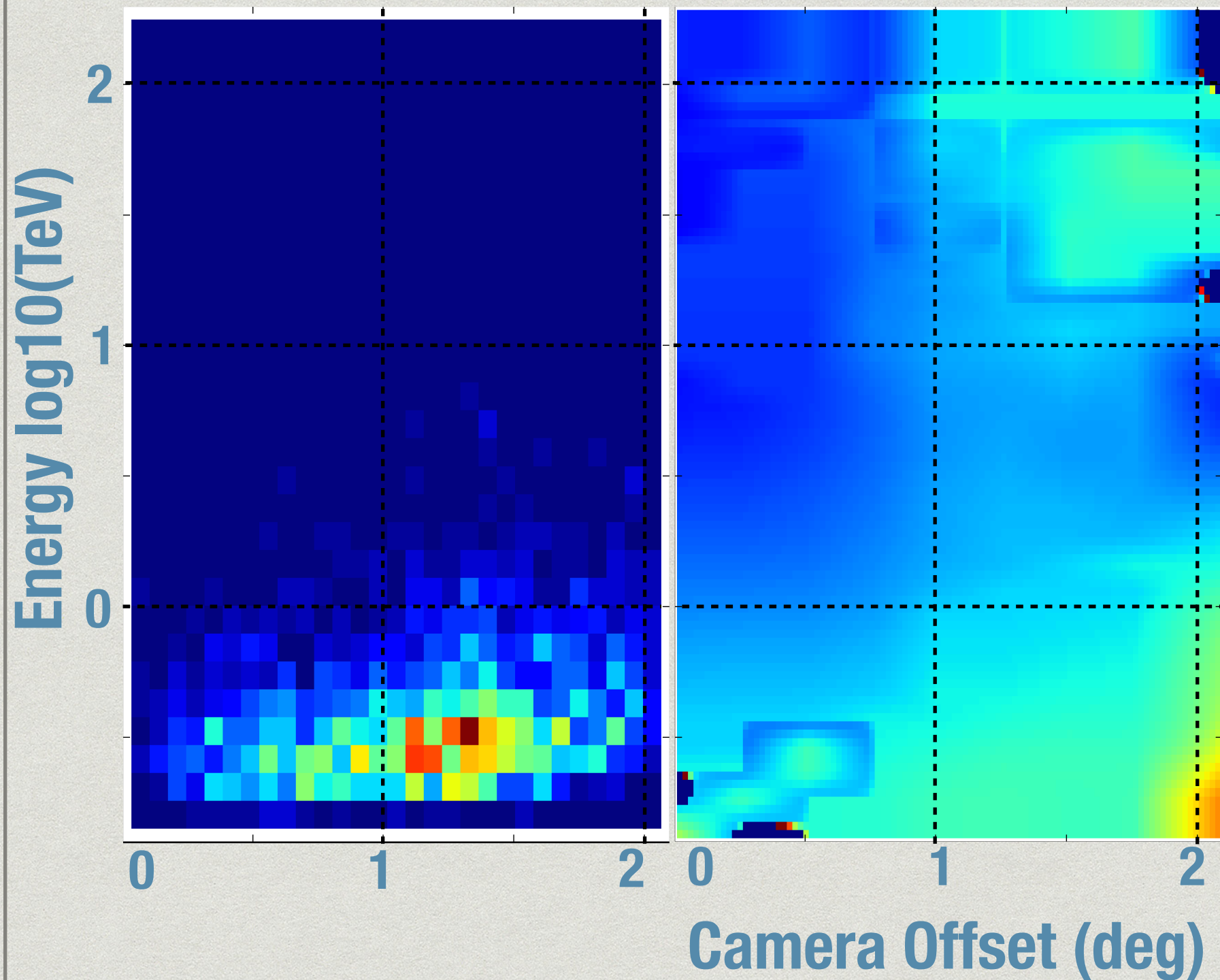
Camera Offset (deg)

IRFs

Photons



PSF Containment
Radius



IRFs

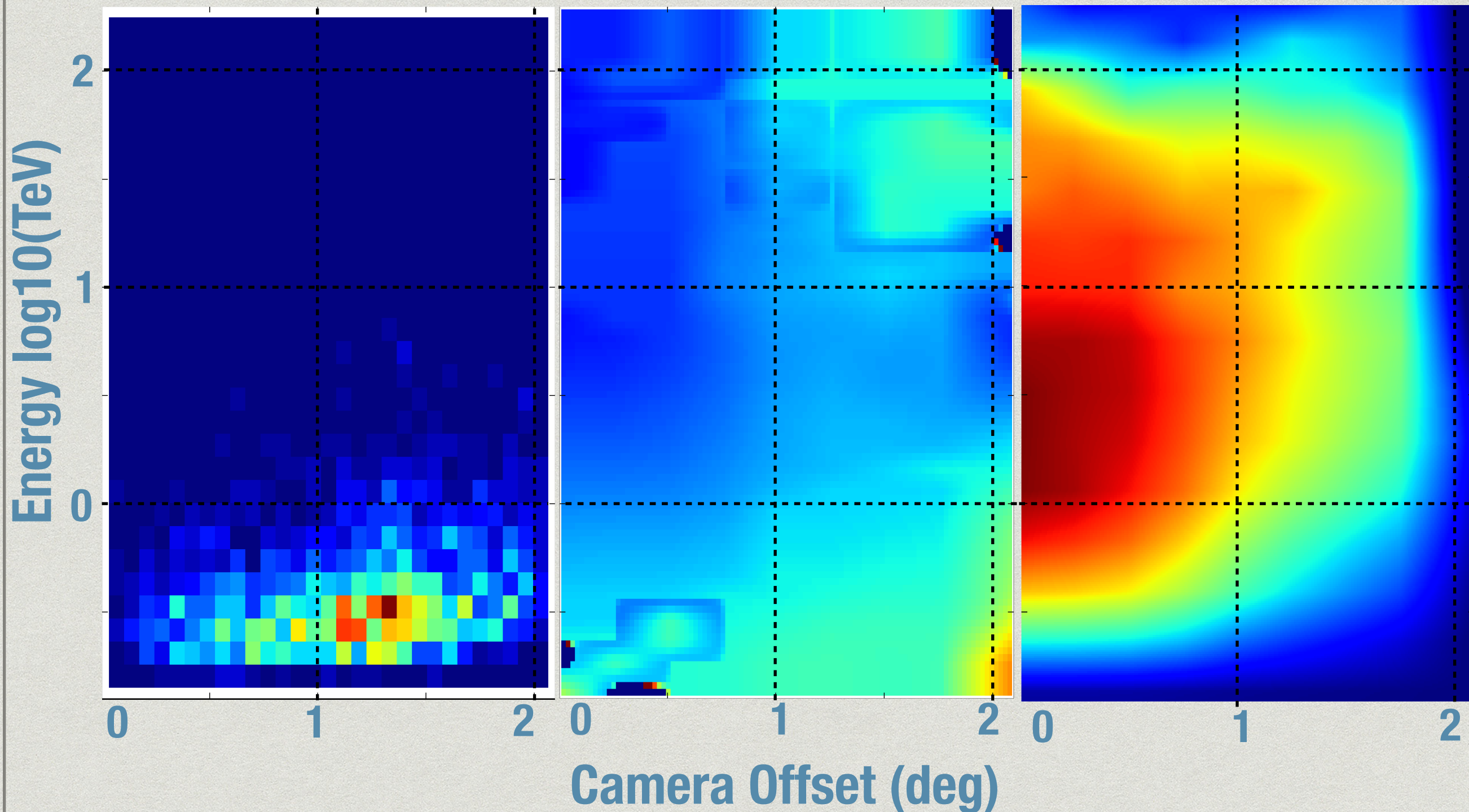
Photons



PSF Containment
Radius

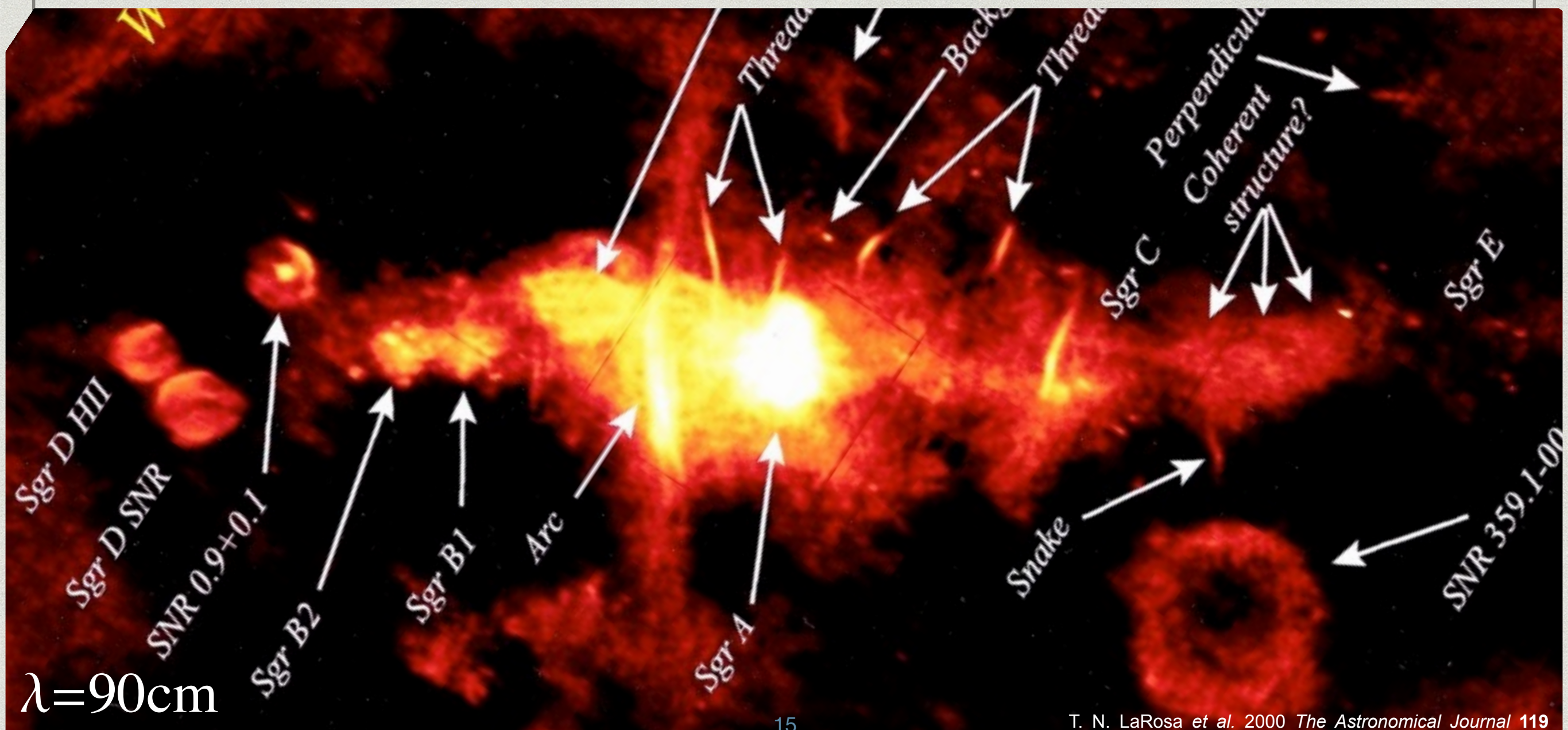


Effective Area



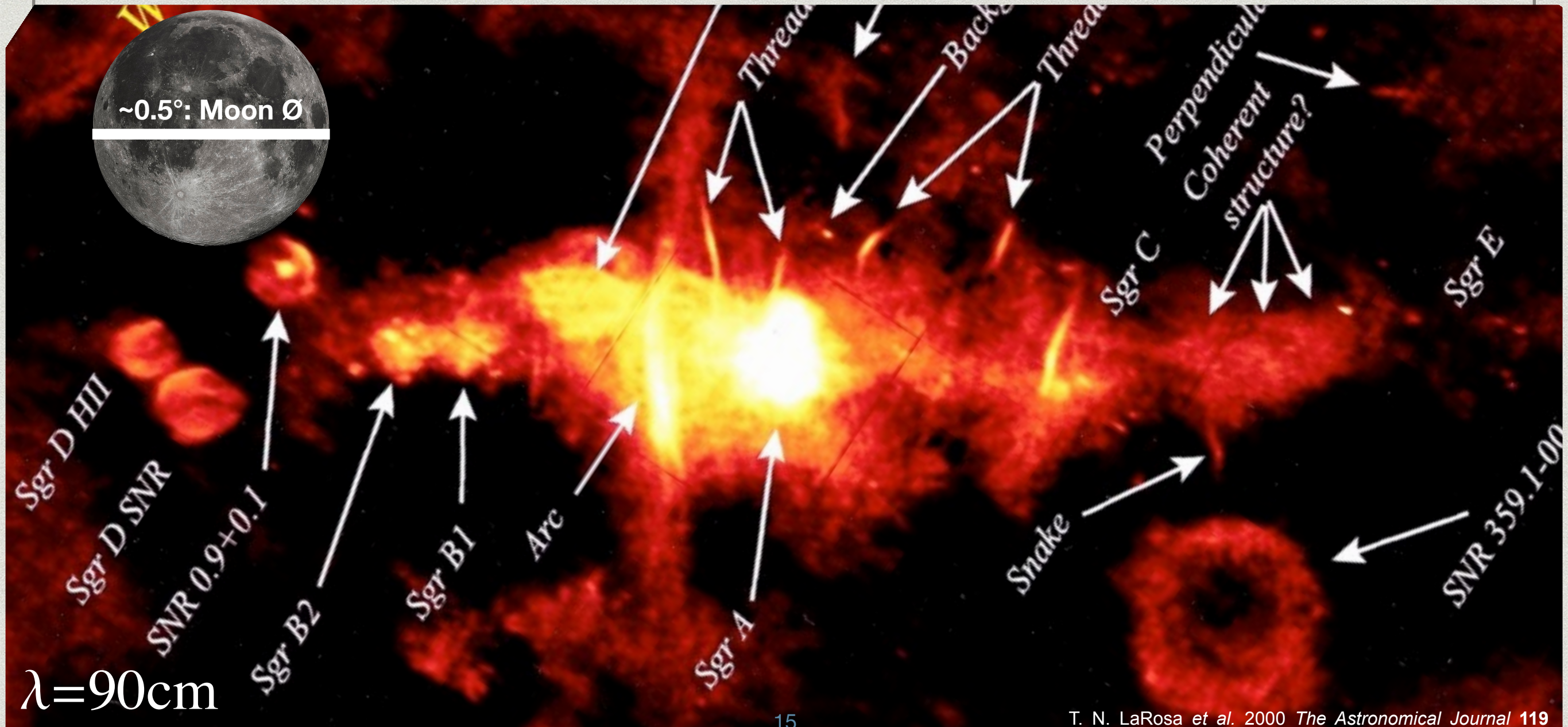
VERITAS+CTOOLS Projects

- ✱ Galactic Center Dark Matter Halo Search



VERITAS+CTOOLS Projects

- Galactic Center Dark Matter Halo Search

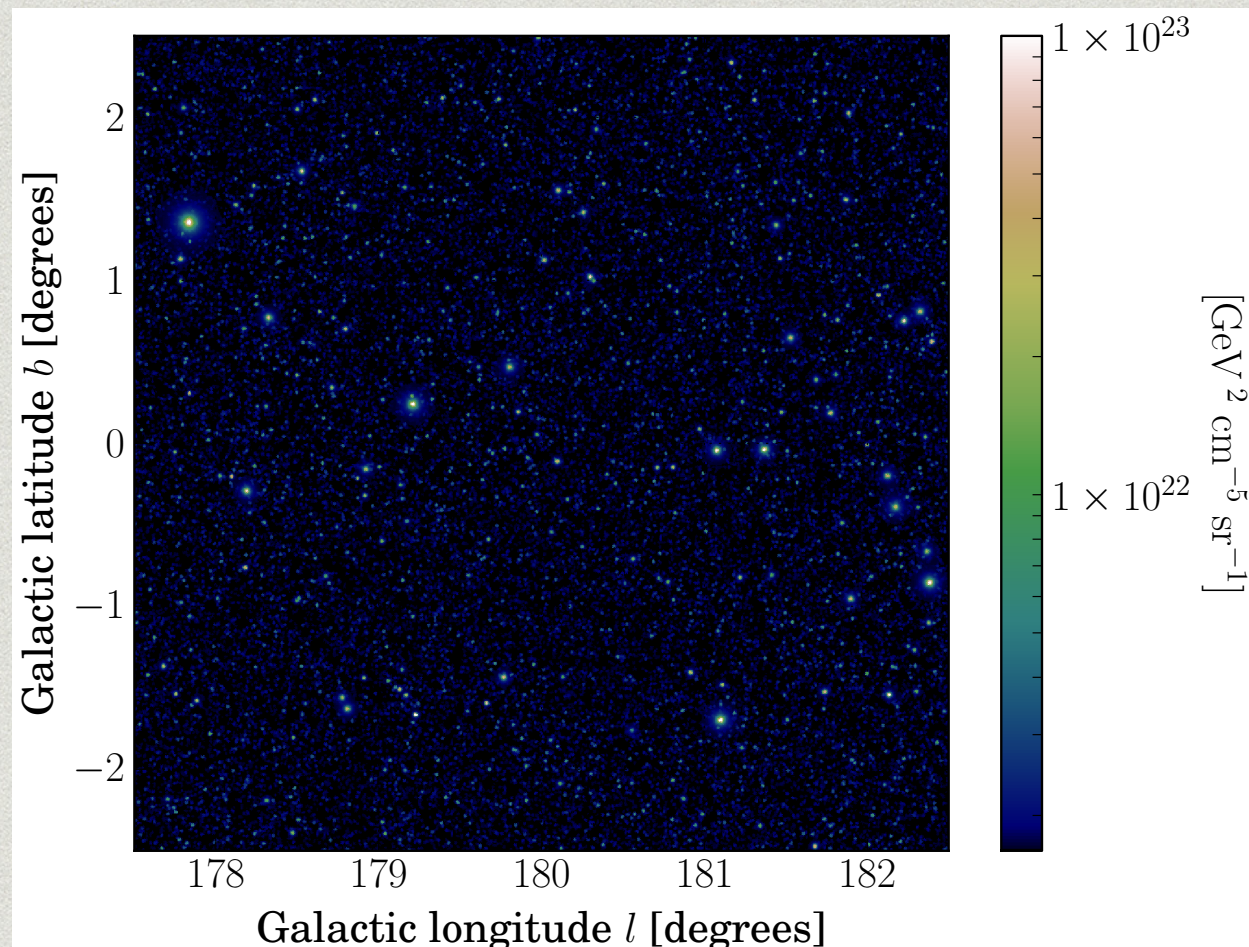


VERITAS+CTOOLS Projects

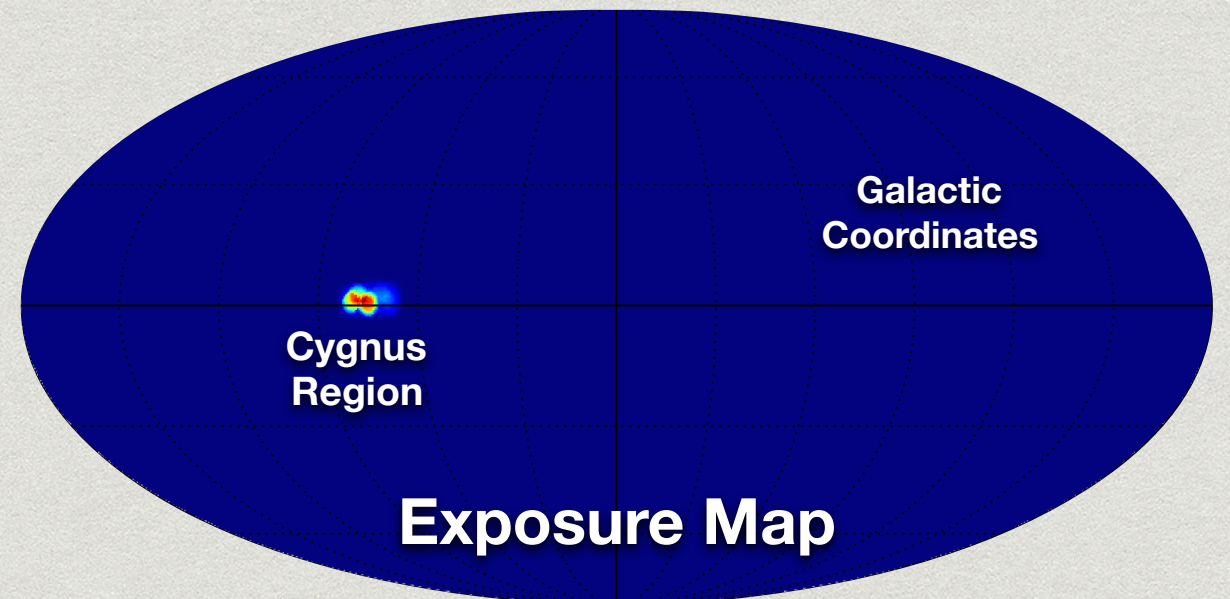
- ✱ Galactic Center Dark Matter Halo Search



VERITAS+CTOOLS Projects



Dark Matter Clump Searches
Moritz Huetten



Cygnus Region
Extended Emission Search
Maria Krause

2nd CTOOLS Converter

- * Worked on by Hugh Dickinson
(hughd@iastate.edu)
- * VTOOLS: branch/fork of CTOOLS for VERITAS
- * Event Lists and IRFs complete
(with extra IRF dimension for NSB Noise)
- * Currently working on multi-observation and multi-instrument likelihood tools

Conclusions

- * Veripy development continues
- * Conversion of VERITAS data/IRFs to CTOOLS nearly complete
- * Next Steps:
 - * Comparison analysis for 39 VERITAS sources
 - * Galactic Center Dark Matter Halo Search