BatAnalysis: A Comprehensive Python Pipeline for Swift BAT Data Analysis

Tyler Parsotan & the Swift-BAT Team

NASA GSFC

Outline

- Introduction to Swift & BAT
- BAT Survey and Event Data
- Prior Analyses
- The BatAnalysis Tool (BAT)
  - Verifying the Survey analysis with past results
  - Example uses of survey data

  - Verifying the Event data analysis with past results
  - Examples of analyzing different event datasets
- Summary and Future Work

The Neil Gehrels Swift Observatory

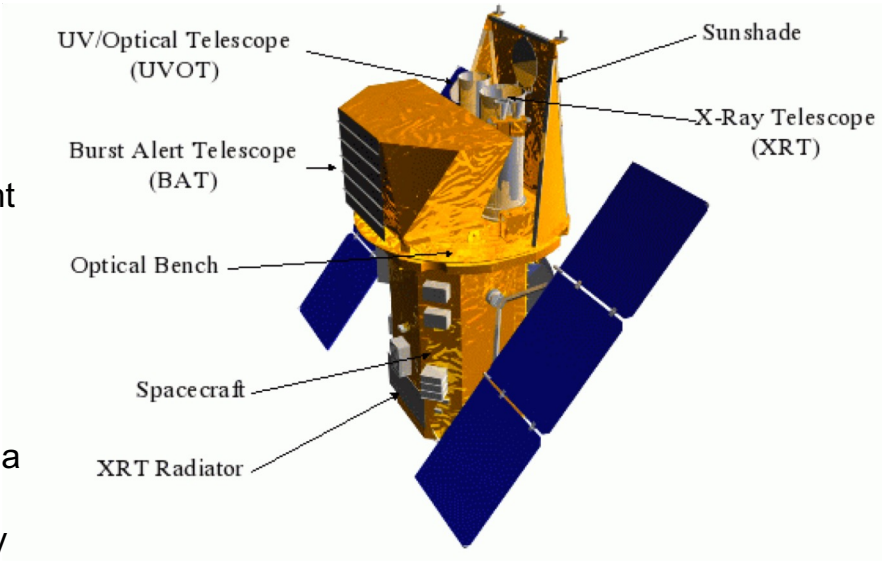
- Launched in 2004
- Different Modes of Operating:
  1. BAT Detects a Gamma Ray Burst (BAT) and collects event data
  2. Autonomous slewing to the GRB
  3. XRT and UVOT observe the field to detect afterglow counterparts

  OR

  1. There is a ToO/manypoint plan for XRT/UVOT to observe a source
  2. BAT is pointed towards that same source collecting survey data

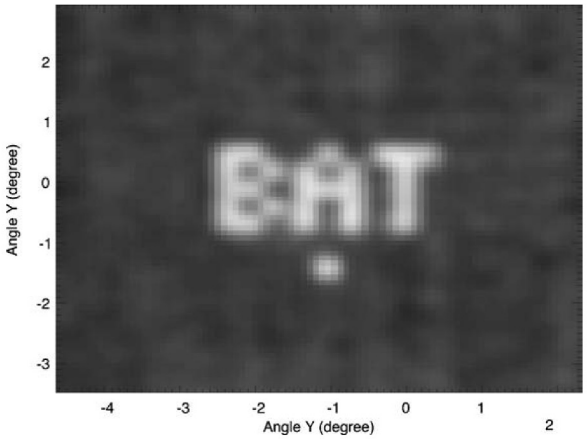
  OR

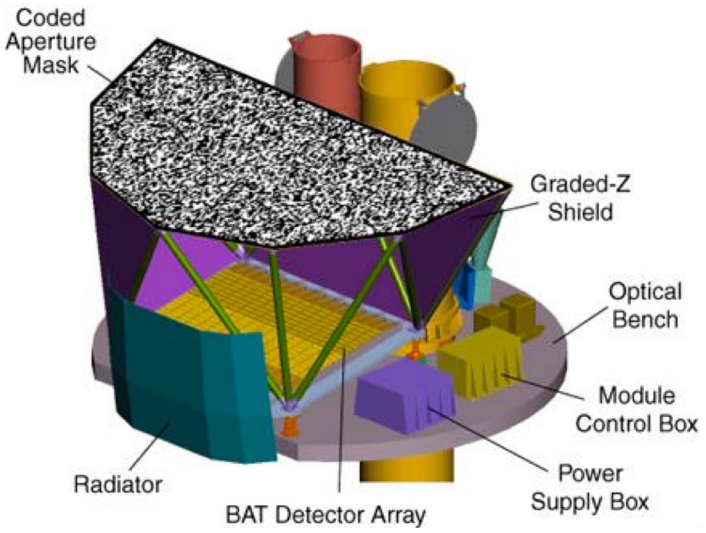
  1. BAT is surveying the sky normally, collecting survey data between slews



The Burst Alert Telescope (BAT)

- Uses the coded mask technique to image and localize transients
- The field of view is ~60 deg x 120 deg
- Localizes transients to within ~3 arcmins

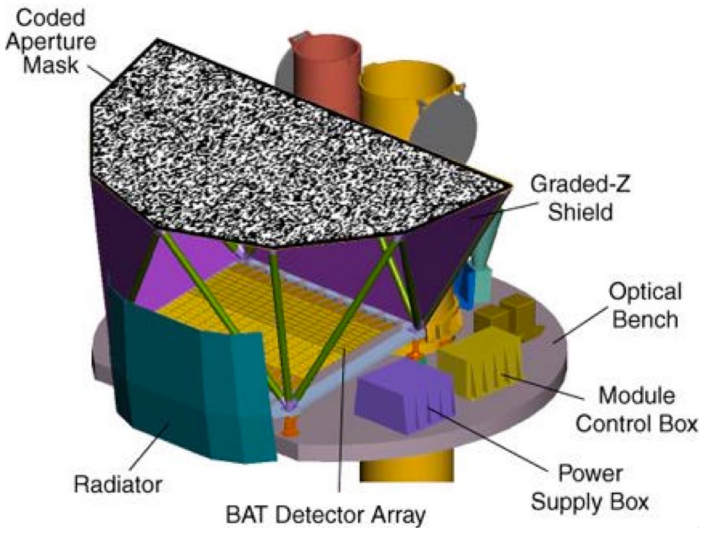




The Burst Alert Telescope (BAT)

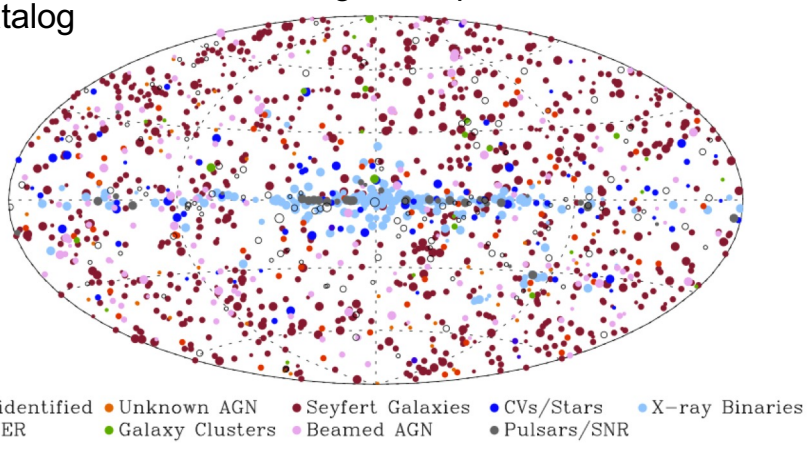
- Two primary datasets
  1. Time Tagged Event (TTE) data
  2. Survey Data

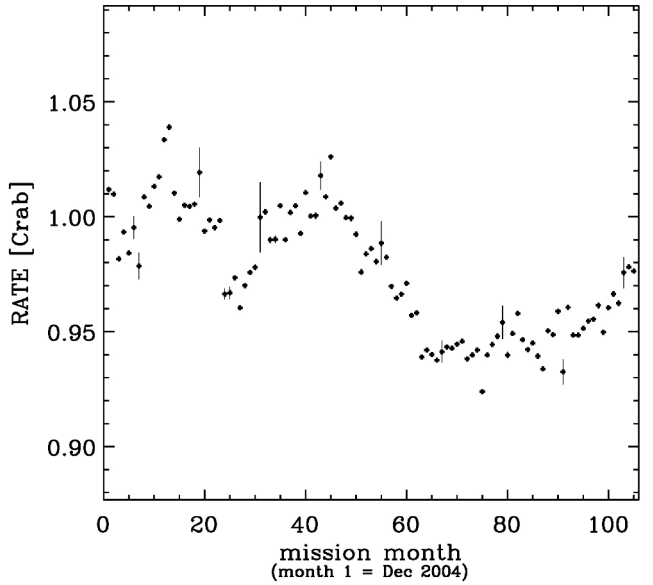
- TTE data
  - Produced by onboard and external triggers (see the GUANO pipeline) and subthreshold triggers
  - Highest quality data with each photon's energy and location on the detector plane
  - Intensive to store onboard and downlink
- Survey data
  - Compressed event data into 80 channel histograms collected over 300 sec or more

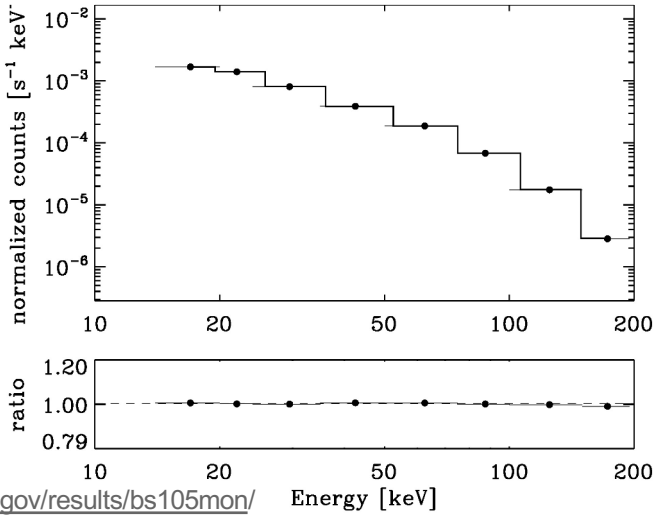


BAT Data Products

- BAT Survey lightcurves/spectra available from the 22,70,105, and 157 month catalogs
  - Analyze known sources to produce monthly mosaiced lightcurves and time-integrated spectra over the course of the catalog



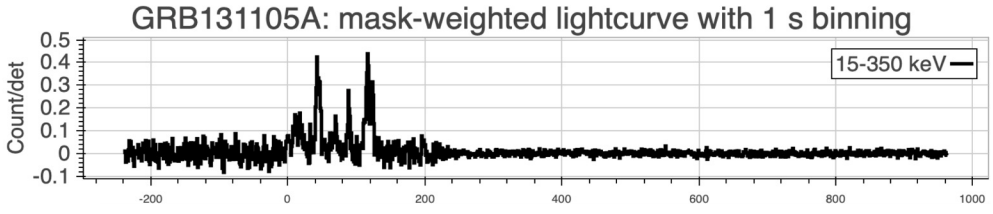




Tueller+ 2010, Baumgartner+ 2013, Oh+ 2018, Lien+ in Prep;
http://swift.gsfc.nasa.gov/results/bs22mon/ http://swift.gsfc.nasa.gov/results/bs70mon/ http://swift.gsfc.nasa.gov/results/bs105mon/

BAT Data Products

- BAT TTE lightcurves and spectra are produced for the 1st, 2nd, and 3rd GRB catalogs
  - The data products for the 3rd GRB catalog can be found at: https://swift.gsfc.nasa.gov/results/batgrbcat/



The *Swift*/BAT Gamma-Ray Burst Catalog

Contact

This website presents analysis results for the *Swift*/BAT Gamma-Ray Burst (GRBs), which includes:

1. Summary tables
2. A webpage of quick-look plots for each burst
3. Original data product for each burst, which contains these folders:
   - "Trigger-ID"/: original data for the burst. Note that there might be some manual corrections applied to the data when necessary, and thus these data might be different from those downloaded from HEASARC. These manual corrections are documented in the "comment.txt" file, which can also be found via the "Special notes of this burst" link under the burst webpage.
   - "Trigger-ID"-results/: results from batgrbproduct (e.g., light curves), and some additional products required for the quick-look page.
   - "Trigger-ID"-results-detection-mask/: This folder only exist for those bursts that require analysis using the "DETECTION" mask, to include the relevent results from batgrbproduct using "DETECTION" mask.
   - remake_spec/: this folder contains the spectra, response files, and spectral-fit results for T100, 1s-peak, 20ms-peak, and individual bayesian block time periods. This folder includes the following sub-directories:
     - "spec_T100/", "spec_1speak/", "spec_20ms_peak/": spectrum and response files for the T100, 1s-peak, and 20ms-peak time period, respectively. The *_avg.pha and *_avg.rsp are the final average spectrum and response files with the spacecraft slewing period taken care of. The log files and figures from spectral fitting (*.log and *.gif) are also included. The spectra and response files with numbers (e.g., *_1.pha and *_1.rsp) are those spectra/response files used for making the averaged spectrum/response file to correctly account for the reponse changes during spacecraft slews.
     - "spec_time_resolved/": This folders contain spectral analysis results for the time-resolved spectra. The file time_resolved_spec_info.txt lists an overall summary from the power-law fits of the time-resolved spectra. Each sub-folder with names like resolved_spec_"number"/ includes the spectrum (*_avg.pha), the response file (*_avg.rsp), and spectral-fit results (pow.log for power-law fit, and cutoff.log for the cutoff power-law fit) for each individual bayesian block period selecting by battblocks. The number always starts at 2 because the first bayesian block covers the period before the start of T100.

* Note: Because of the different definition in Xspec, the power-law index in all the *.log files in the data-product folders are presented with a sign different from those presented in the paper and the quick-look page. Xspec defines the power-law index "alpha" as E^-(alpha), while in the 3rd GRB catalog paper and the quick look page, it is defined as E^(alpha).

For detail analysis methods, please refer to the paper The Third Swift GRB Catalog. This website includes results from the paper, and will continue to be updated with analysis results of new bursts, once data become available on HEASARC (usually within about two weeks).

Sakamoto+ 2008, Sakamoto+ 2011, Lien+ 2016

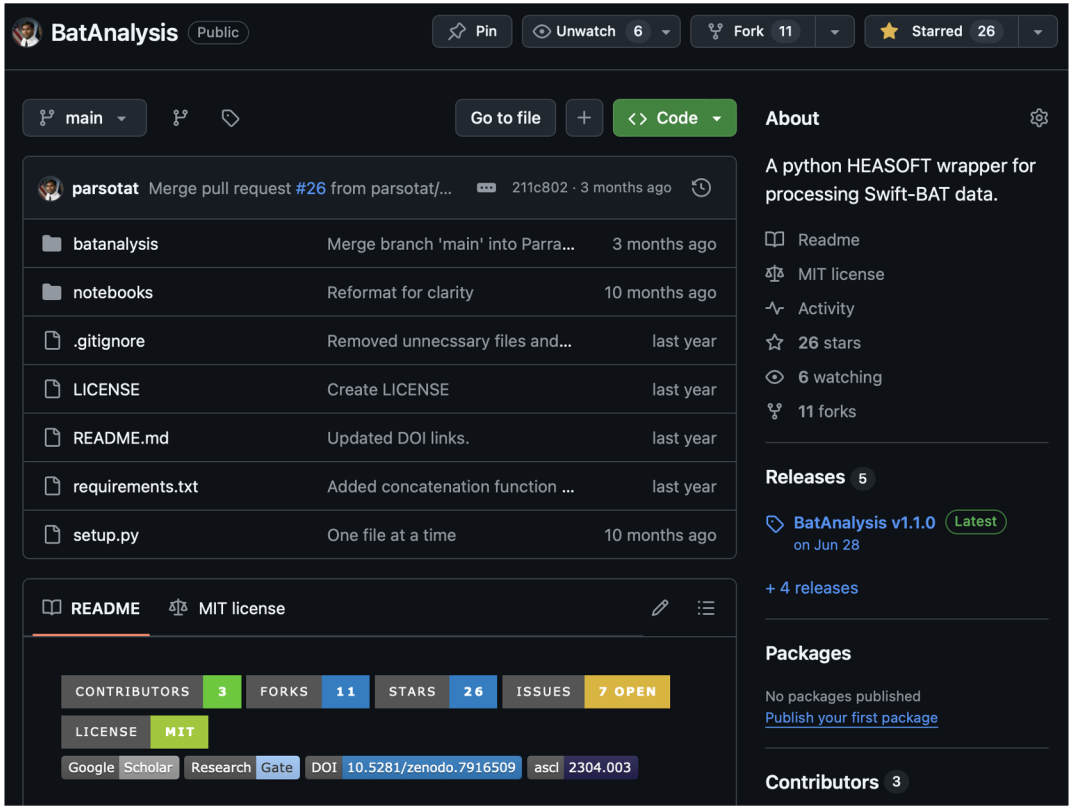
Barriers to Using BAT TTE & Survey Data

- How do we find if there is data available for a given time/coordinate?
- How do we create custom lightcurves/spectra for the time intervals that we are interested in?
- How do we use the BAT data in creative new ways and increase synergies with Fermi and various other observatories?

The BatAnalysis Package:

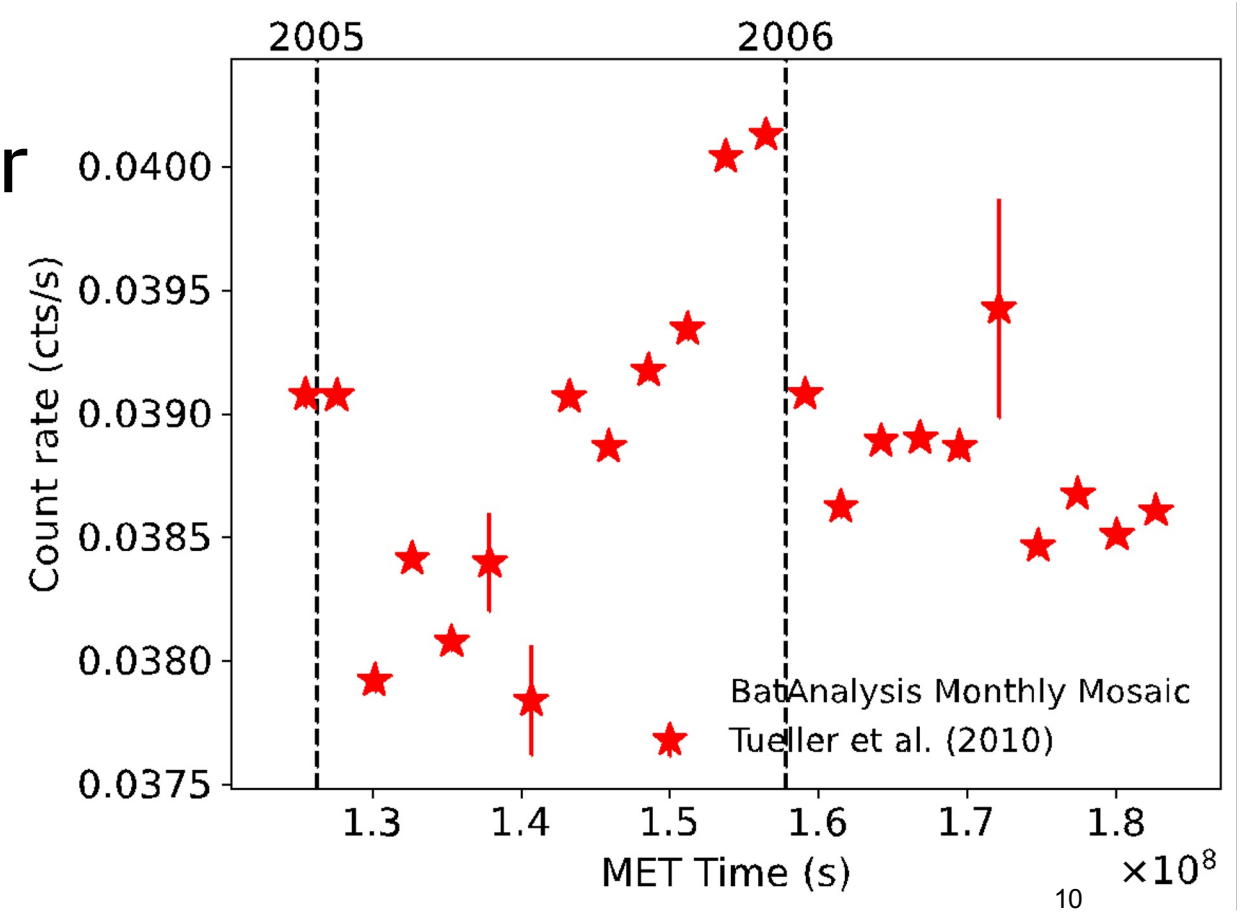
github.com/parsotat/BatAnalysis

- Allows for a modern pythonic interface to interacting with BAT data
- Allows for programmatic querying and downloading of data
- Allows for straightforward processing of survey and TTE data, permitting users to get to the spectra and lightcurves products quicker
- Allows for advanced data analysis techniques such as mosaicing
- Examples of downloading and processing BAT data are in the form of jupyter notebooks



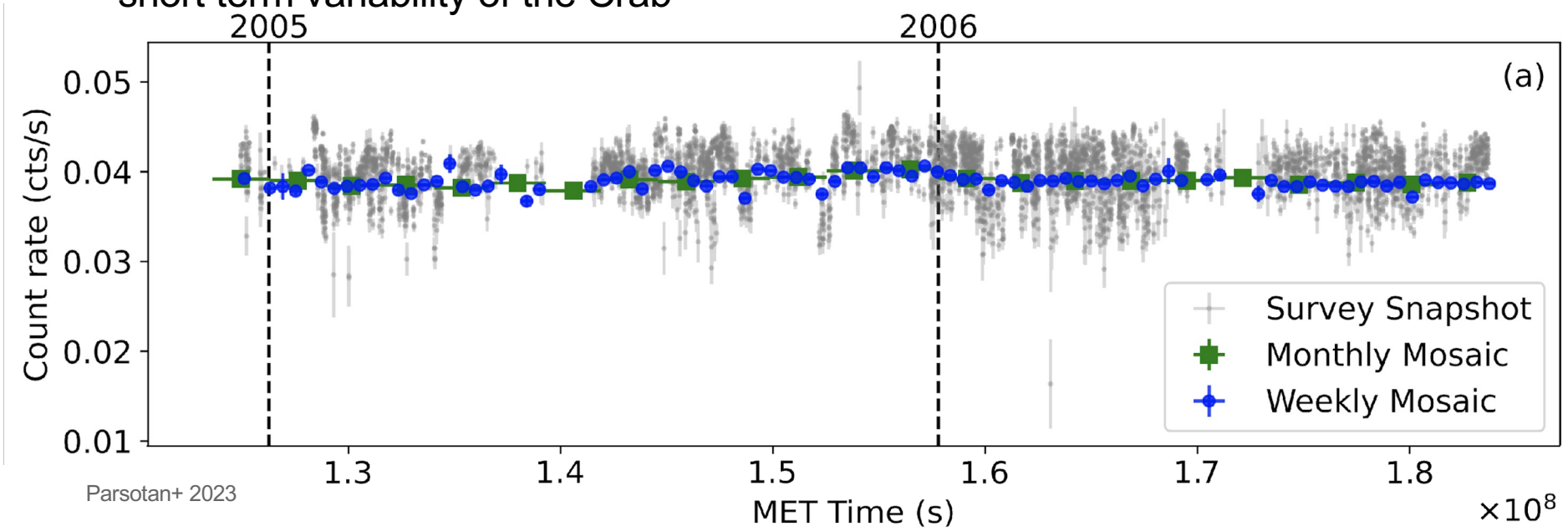
The BatAnalysis Package Reproduces Prior Survey Analyses

- The 22 month survey catalog results for the Crab is reproduced to within 2%



The BatAnalysis Package Allows for New Analysis Capabilities

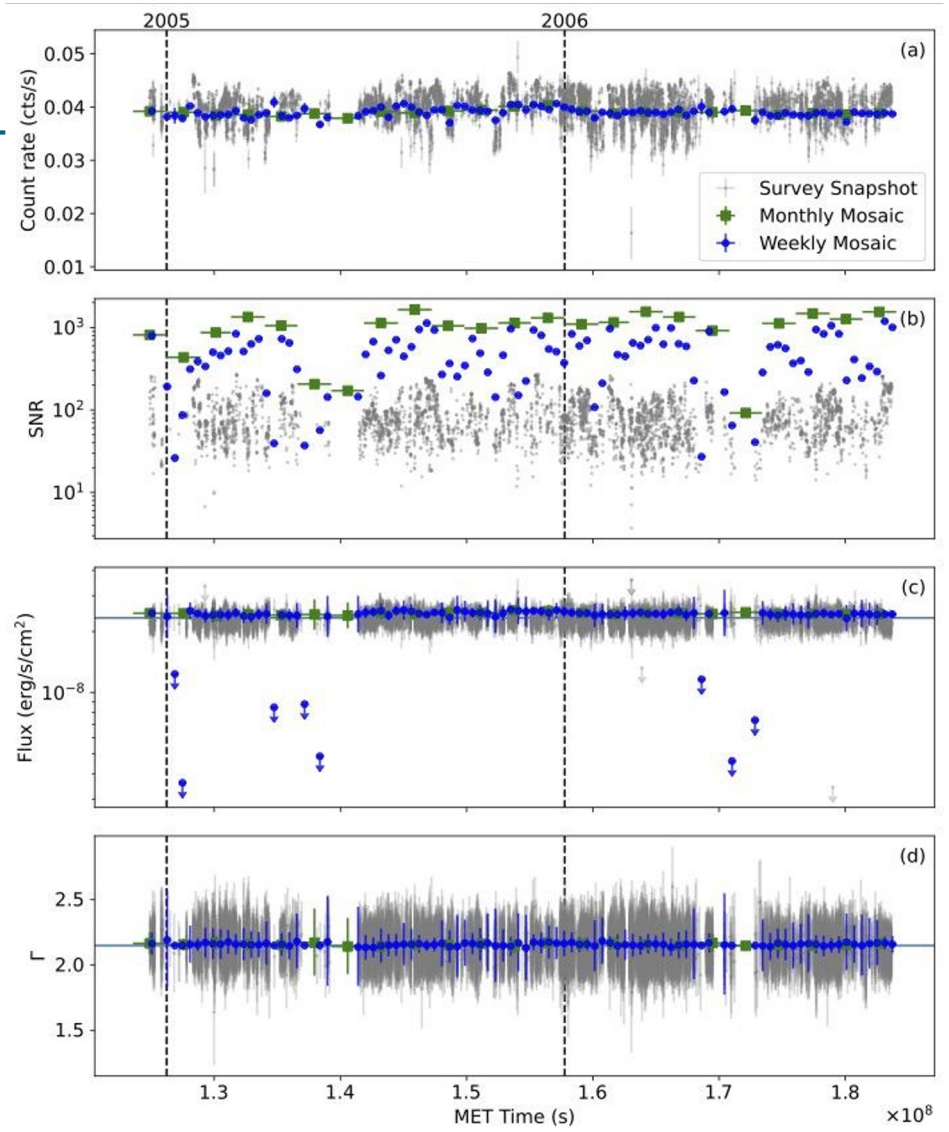
- We can also produce mosaic images on weekly timescales showing the short term variability of the Crab



Parsotan+ 2023

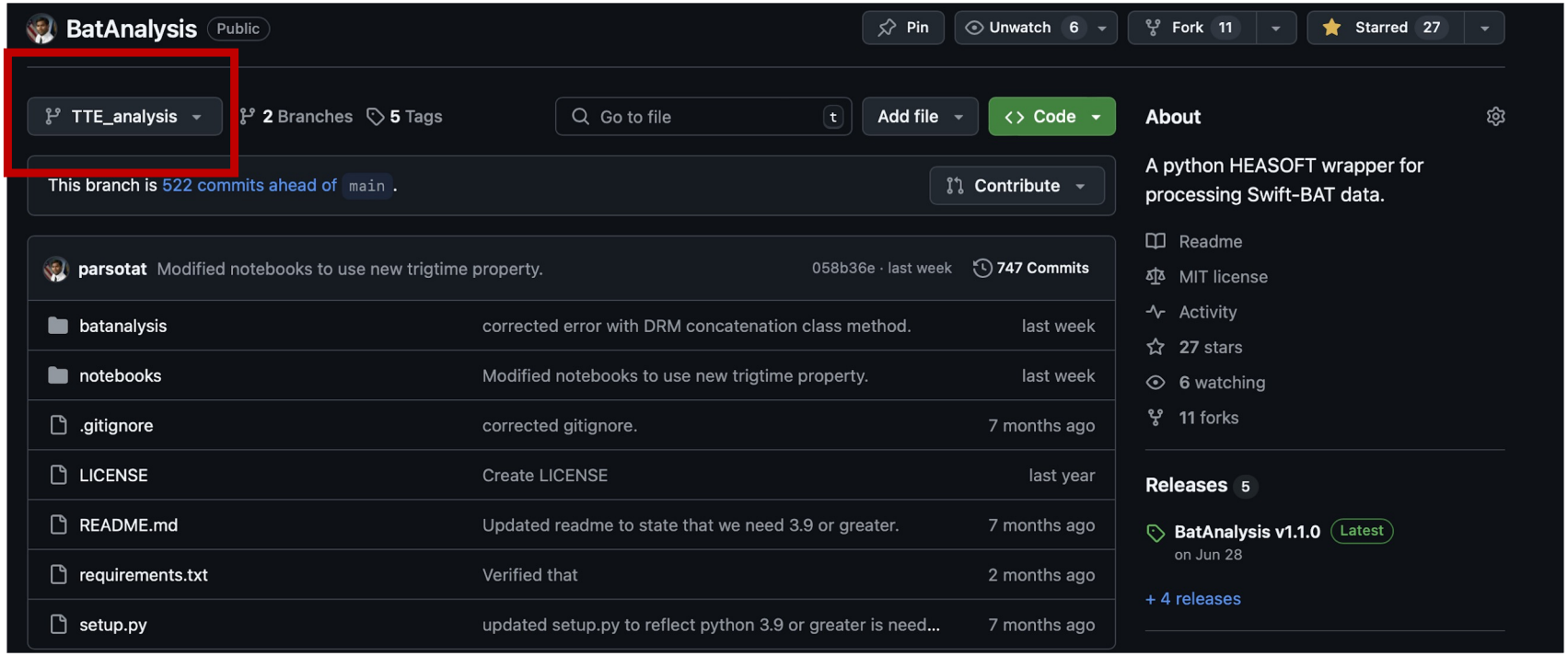
The BatAnalysis Package Allows for New Analysis Capabilities

- We can also produce mosaic images on weekly timescales showing the short term variability of the Crab

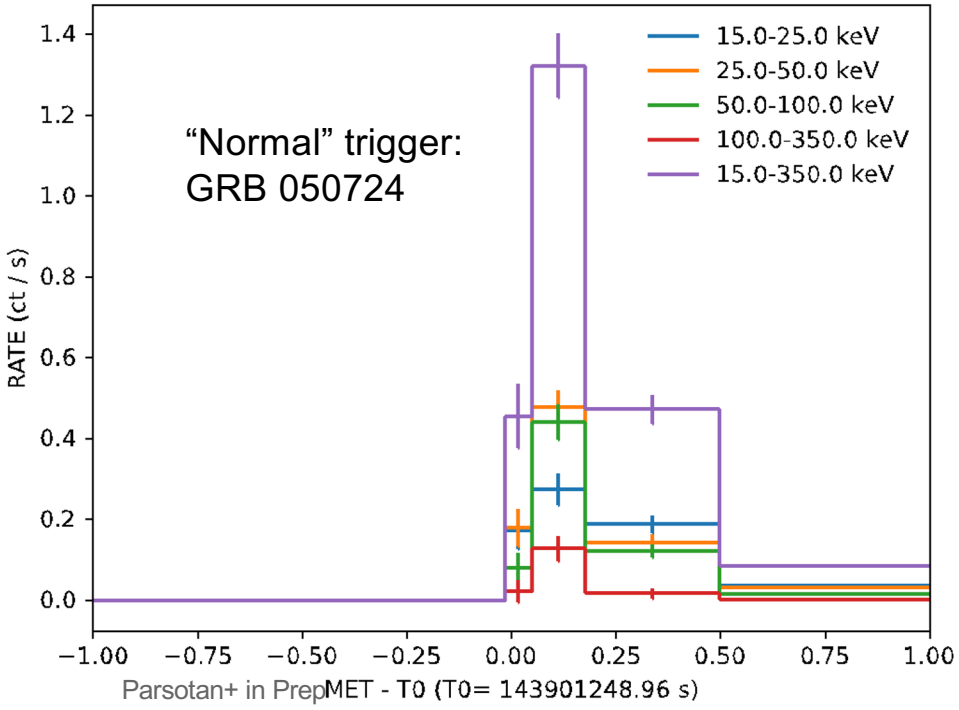


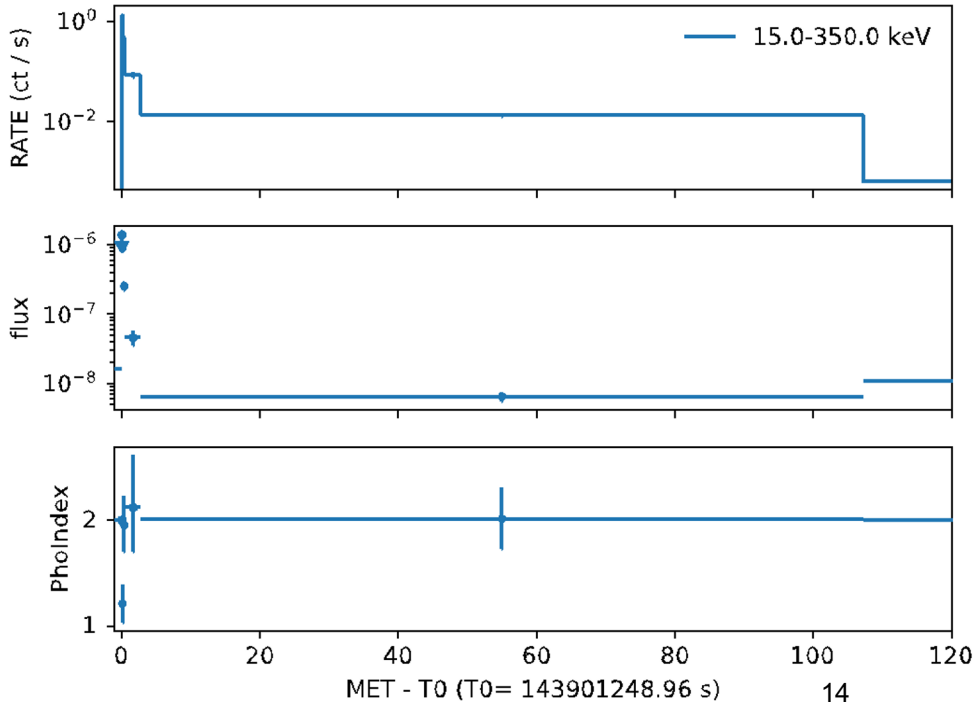
Parsotan+ 2023

The BatAnalysis Package Makes All TTE data accessible



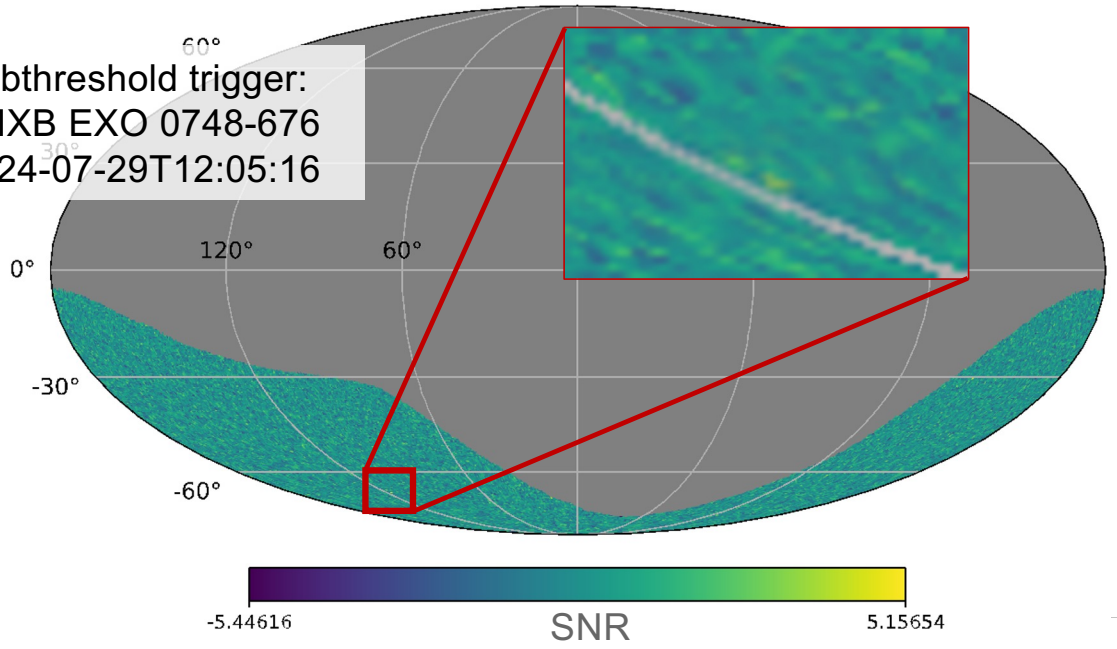
The BatAnalysis Package Makes All TTE data accessible

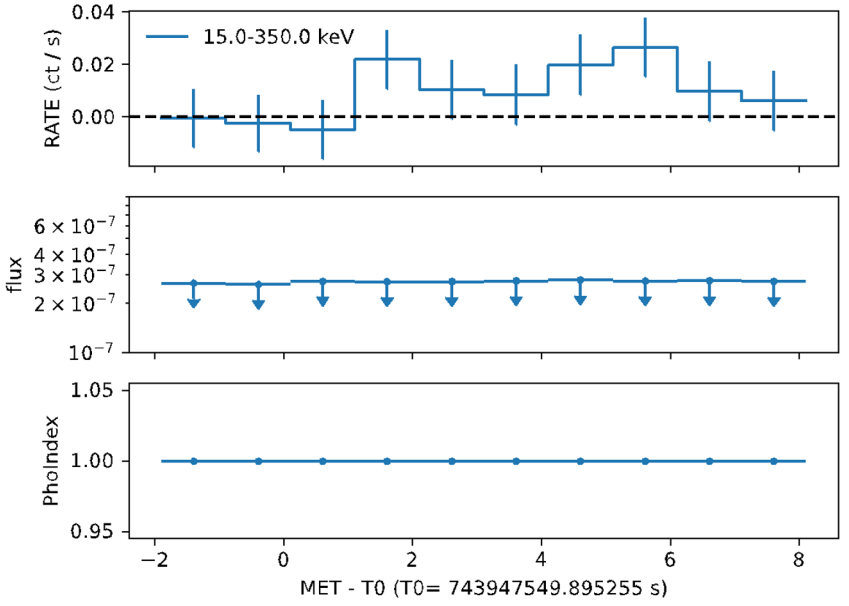




The BatAnalysis Package Makes All TTE data accessible

Subthreshold trigger:
LMXB EXO 0748-676
2024-07-29T12:05:16



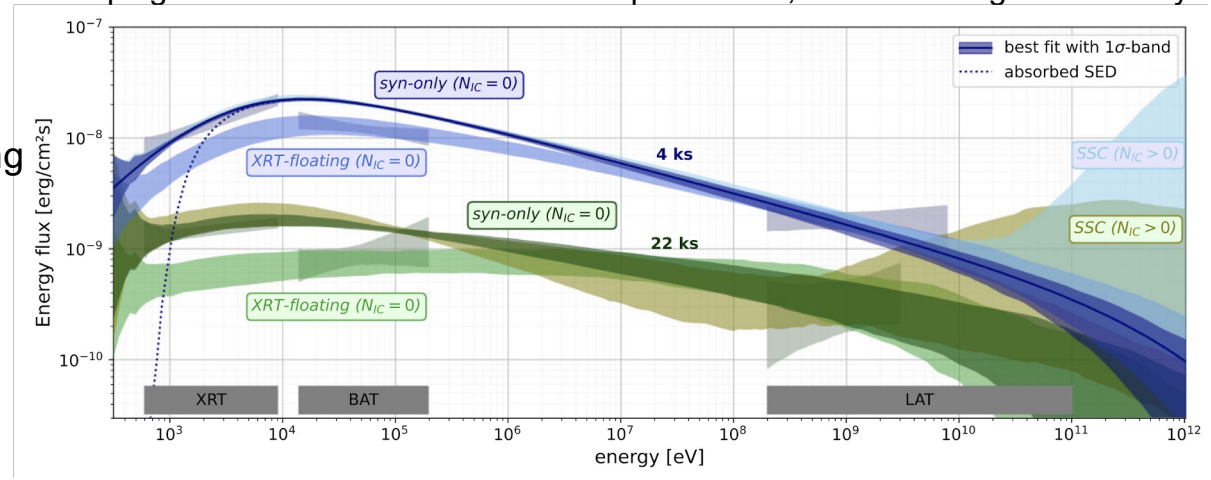


Palmer+ 2024 (ATel #16790), Parsotan+ in Prep

Summary & Future Work

- The BatAnalysis package unlocks the potential of BAT data for a number of different analyses
- Allows for users to query and download data *and* produce custom lightcurves, spectra, and sky images
- Future work will focus on
  - Creating python native implementations of BAT HEAsoft tools
  - Creating a 3ML plugin for the use of BAT data in comprehensive, multiwavelength data analyses

GRB 221009A
MWL Afterglow Fitting



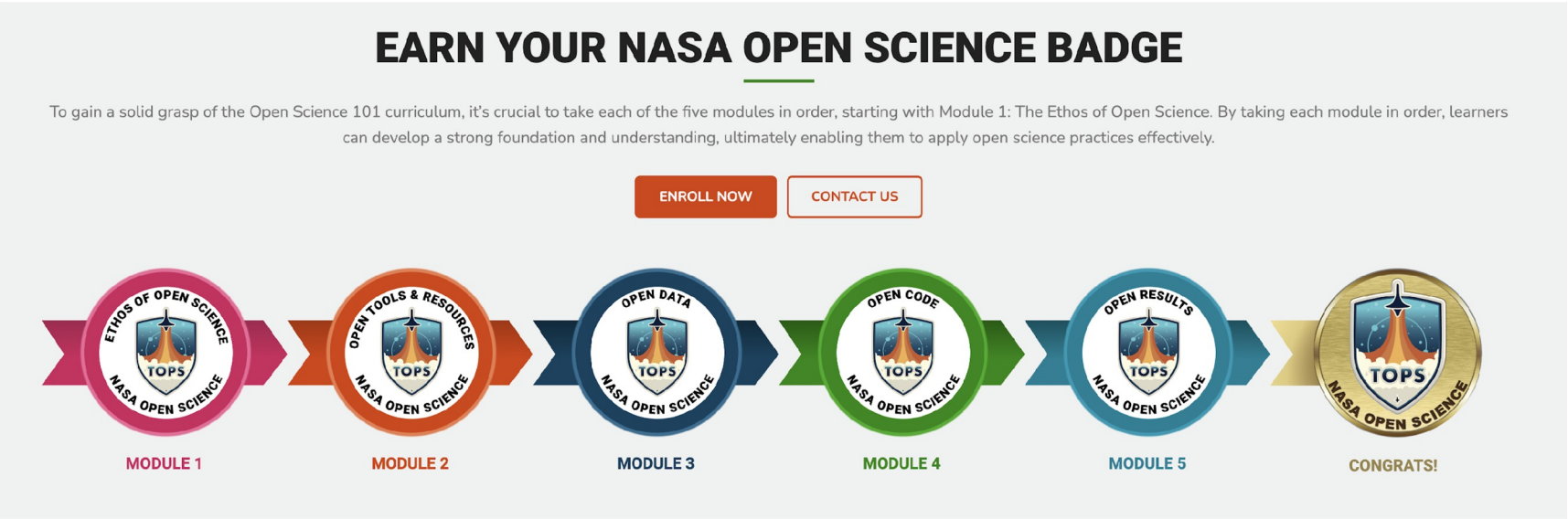
Klinger+ 2023

Summary & Future Work

- The BatAnalysis package unlocks the potential of BAT data for a number of different analyses
- Allows for users to query and download data *and* produce custom lightcurves, spectra, and sky images
- Future work will focus on
  - Creating python native implementations of BAT HEASoft tools
  - Creating a 3ML plugin for the use of BAT data in comprehensive, multiwavelength data analyses
- Please open a github issue if:
  - The documentation is not clear
  - There is a software issue
  - There is a feature missing that you would like to see
- If you would like to contribute to the project, consider creating a pull request

Transform to Open Science

- Self paced Training:
  - https://nasa.github.io/Transform-to-Open-Science/take-os101/
- Increases Accessibility, Reproducibility, Usability, Citations, etc.



Questions