Data Challenge II

Logo by Stefano Ciprini
The DC2 Sky

• DC2 sky in galactic coordinates

Plot by Seth Digel
DC2 Goals, requirements and purpose

- 55 days of LAT data provide a deeper view of the high energy gamma-ray sky than has previously been achieved.
  - Results from previous gamma-ray missions provide, at best, an incomplete guide to the DC2 sky.
  - Part of the challenge of DC2 will be to figure out what was included in the sky model.
  - DC2 data has a fairly realistic level of detail which will support a wide variety of both science and instrument performance studies.
  - Exercise the science tools – but don’t feel restricted to them
  - Improve the documentation and analysis software from user feedback.
Produce LAT point source catalog

- Requirement: Spectral index and flux (with associated uncertainties), location with 68% and 95% confidence ranges, flux in discrete energy bands.
- Goal: Variability index, flux history, peak flux, measure of whether a source is extended.

The catalog analysis and results proved to be an extremely important part of DC2. It provided a starting point for a large fraction of the more detailed source analysis and was a reference for people doing population/source detection type studies.

There was a somewhat higher rate of false detections than would have been expected (~10%), this needs to be understood.
Develop and test source detection algorithms

- Requirement: That these algorithms are tested and compared with one another in a systematic way using the DC2 data.
  - Many source detection methods developed – Stephens, Tosti, Burnett, Casandjian, Ballet, Romeo/Cillis
  - Compared with one another by Seth Digel
Source Identification

• This was not identified as either a requirement or a goal, but there was some significant work in this area by Lonjou and Pittori.

• ASDC catalog webpage was a big hit with DC2 users, very convenient way for people to browse high-level DC2 results.
– Requirement: Determine the gamma-ray lightcurves for at least 6 pulsars which have an exact ephemeris.

– Requirement: Determine timing properties of pulsars and produce gamma-ray lightcurves for at least one pulsar with an approximate ephemeris.

– Goal: Determine lightcurves for more of the fainter pulsars in the DC2 data.

– Results for all the pulsars in the ephemerides were produced by Smith et al, Max Razzano and Andrea Caliandro.
Pulsars

- Goal: blind periodicity searches on candidate DC2 pulsars
- Goal: Pulsar population studies: the ratio of radio-loud to radio-quiet pulsars.

Marcus Ziegler – lightcurves of pulsars without radio data.

**Epoch MET = 220838550**

<table>
<thead>
<tr>
<th>Light Curve MRF0054 100 bins</th>
<th>Light Curve MRF0058 100 bins</th>
<th>Light Curve MRF0155 100 bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries 8489 Mean 0.2602 RMS 0.2999</td>
<td>Entries 9076 Mean 0.5194 RMS 0.2597</td>
<td>Entries 11229 Mean 0.5260 RMS 0.2876</td>
</tr>
</tbody>
</table>

\[ F_0 = 5.885928323969 \]
\[ F_1 = -1.306230 \times 10^{-12} \]
\[ F_2 = 1.0 \times 10^{-21} \]

\[ F_0 = 3.91691474178 \]
\[ F_1 = -1.936137 \times 10^{-13} \]
\[ F_2 = 6.0 \times 10^{-22} \]

\[ F_0 = 3.766282209980 \]
\[ F_1 = -3.677283 \times 10^{-13} \]
\[ F_2 = -3.3 \times 10^{-21} \]

\[ F_0 = 5.885928323969 \]
\[ F_1 = -1.306230 \times 10^{-12} \]
\[ F_2 = 1.0 \times 10^{-21} \]
Extended sources

- Goal: To identify extended sources in the DC2 data (there are some...)
- Goal: Perform spatially resolved spectroscopy.

After deconvolution

3EG J1714-3857

HESS RX-J1713 profile

Vela Jr

Hiro Tajima

Omar Tibolla
Variable sources

- **Requirement**: Produce lightcurves for at least 20 bright sources (from the data release plan, these are the sources we will release high level data from in year 1)
- **Goal**: look at lightcurves for many more sources

By Benoit Lott
Variable Sources

3C 279 Light Curve

flux (1 day bin)

3C 279 flux light curve (bin 8h)

flux (8h bin)

Gino Tosti – Taking lightcurves to the next level…
Variable sources

- **Goal:** To find and study variable sources that might not be blazars (i.e. the AGN folk do not get to have all the fun)

- An example of this was a study of the solar flare by Jim Chiang.
Spectral Studies

- **Goal:** Study spectra of pulsars to determine the shape of spectral cutoffs
- **Goal:** EBL attenuation studies (redshift dependent cutoffs)
- **Goal:** Search for spectral signatures of dark matter

---

PSR0904-5008 with $E_B = 25$ GeV

**Omar Tibolla**
Spectral Studies

- **Goal:** Study spectra of pulsars to determine the shape of spectral cutoffs
- **Goal:** EBL attenuation studies (redshift dependent cutoffs)
- **Goal:** Search for spectral signatures of dark matter

![Graphs and plots showing spectral studies results]

Luis Reyes

Jennifer Carson

Julie McEnery
Riccardo Rando found a source that appeared to consist of two components, a pulsed hard component and a soft, steady component.

Power-law point source + background model is a very poor fit to the data.

Phase vs energy plot shows that the pulsed emission dominates above 1 GeV.

Refit with a composite source consisting of a power-law and a log normal component.
Sara Cutini and Dario Gasparini presented spectral studies of a sample of blazars using xspec.
Gamma-ray bursts

- Requirement: Temporal studies/comparison of at least one GRB
- Much more to be discovered here that we had originally intended. Several people (Nukri Komin, Nicola Omodei etc) noticed systematic (and unintentional offsets between the GBM and LAT bursts)
Gamma-ray bursts

- Requirement: Perform joint spectral fits of at least one burst using both LAT and GBM data. (gtbin, rspgen, xspec)

GRB08015885 – Nukri Komin

This was one of the “rejected” fits due to the strange spectrum. The cause is likely to be because this GRB was simulated with an additional “hard” extended component lasting for 400s.
requirement: produce preliminary GRB catalog, this should include GBM + LAT properties (goal: include LAT upper limits for GRB with no LAT detection).

Nukri Komin – fit all GRB with more than 4 LAT photons, also compared xspec with likelihood fits

low and high energy spectral index...
Gamma-ray bursts

- Requirement: Produce preliminary GRB catalog, this should include GBM + LAT properties (goal: include LAT upper limits for GRB with no LAT detection).

David Band presented likelihood fits of the LAT GRB.
Gamma-Ray Bursts

- Goal: Search for LAT only GRB
- Searches by Nukri Komin, David Band and Jerry Bonnell
- There were several “lat-only” GRB to find. All the lat only GRB discoveries posted on the confluence page were “real” transient events.
Gamma-Ray Bursts

- **Goal:** Search for additional high energy components and/or afterglows

Spectral analysis: spectral index=
(FT1Viewer*): $1.53 \pm 0.07$ (52%)
(Xspec): $1.64 \pm 0.09$ (75%)

**Omodei:** GRB08010514 – Delayed emission beginning ~400s after the GRB trigger.
Gamma-Ray Bursts

- Goal: Compare the LAT and GRB locations and quoted statistical uncertainties to study the systematic GBM localisation uncertainty.
- Localisations by David Band, GBM systematic uncertainty analysis by Michael Briggs.
Other sources

- Requirement: Identify at least one source that is not a pulsar, AGN or GRB (there are some that can be identified from the gamma-ray data)
- Moon (Tosti, Rando)
- Sun (Tosti, Chiang)
The Moon

• Several people “found” the moon, generally as an irritant that got in the way of the analysis that they set out to do
  – Spurious sources – Tosti, Ballet
  – Modulating the lightcurve of sources along the moons path – Rando

• It is clear that the moon is something that we are going to have to learn how to deal with.
Diffuse sources

- Goal: Study flux, spectra and spatial distribution of the galactic diffuse and compare with the diffuse model provided for source analysis.
- Studied by Jean Marc Casanjian, Andy Strong and Larry Wai
**Diffuse sources**

- **Goal:** Study flux and spectral properties of the extragalactic background. This will include a study of the effect of residual background, contribution from galactic diffuse and resolving the point sources.

- Riccardo Rando performed an analysis of the extragalactic diffuse spectrum. He produced a mapcube fits file which described the residual background which was subsequently used by several people in source analyses.
Quicklook and transient release tasks

- **Requirement:** define a format of the summary data that could be released for these objects (i.e. what variables etc) and pull the analysis results into this format.
- **Goal:** Search for and produce time resolved summary data for any source that exceeds $2 \times 10^{-6}$ photons/cm$^2$/sec
  - The catalog group produced time resolved results (on week timescales) on the 20 sources (and many more).
  - Benoit Lott produced ascii tables of time resolved spectral fits (on day timescales).
General Studies

- Localisation – Smith, Burnett, Band
- Stability/accuracy of the likelihood analysis (see next slide)
- Alignment calibration
- Identify warts (data not perfect)
  - Pulsar adventures
  - LAT/GBM time offsets
- Studies of background level with orbit position
- Study effect of different event cuts (driven by a specific science topic: diffuse – low background, GRB – high Aeff etc)
  - (see later slides)

- Don’t limit yourself to these suggestions, there are many other analysis possibilities.
### Likelihood accuracy/stability

- Several people examined the effect of residual background (Reyes, Carson, Cutini/Gasparini)
- Rita Sambruna presented a systematic study of the behaviour of the likelihood analysis in the presence of neighbouring sources and then took a closer look at the 3C279 region.

<table>
<thead>
<tr>
<th>DRMNGB</th>
<th>MINUIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-60%</td>
</tr>
<tr>
<td>2</td>
<td>10-120%</td>
</tr>
<tr>
<td>3</td>
<td>0-110%</td>
</tr>
<tr>
<td>4</td>
<td>20-100%</td>
</tr>
<tr>
<td>5</td>
<td>20-50%</td>
</tr>
<tr>
<td>6</td>
<td>30-80%</td>
</tr>
</tbody>
</table>

The wrong model overestimates the flux
Several people discussed the details of the impacts of choices made at the higher analysis levels – photon selection region etc. A systematic study was performed by Andrea Caliandro to investigate and optimise analysis selections for pulsar studies.

Nicola Omodei presented an analysis of GRB detection sensitivity for looser sets of event selection cuts.

There are many more things that could be done in this area!
Summary

- Coordination and interaction across the collaboration
  - Results of some analyses were used to refine studies in other areas
    - Catalog
    - Riccardo’s mapcube
  - Verifies that we are able to communicate results and ideas with one another and also that we have developed our standard data formats and software interfaces sufficiently that people can case their results in a shareable way.
- The range and details of the analyses performed on the DC2 data exceeded our expectations.