Low-Energy Gamma-Ray Observations above 1 GeV with CALET on the International Space Station

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CALET[(1)] electromagnetic calorimeter (CAL)
- Charge Detector (CHD)
  - Plastic scintillating paddles
- Imaging Calorimeter (IMC)
  - Plastic scintillating fibers
  - Tungsten sheets
- Total Absorption Calorimeter (TASC)
  - Lead Tungstate logs

30 radiation lengths at normal incidence
Energy deposit resolution ~3% [(2)]

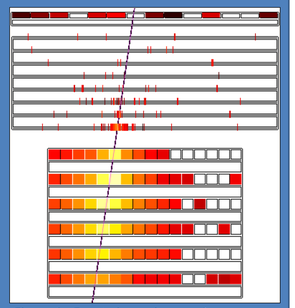

Figure 1. Event viewer image of a gamma-ray candidate in the CALET calorimeter.

Gamma Rays in CAL: LE-gamma mode[(3)]
- Effective area[(4)] ~400 cm^2
- Field-of-view ~60°
- Angular resolution < 2°
- Energy threshold ~ 1 GeV
- Active at low geomagnetic latitudes

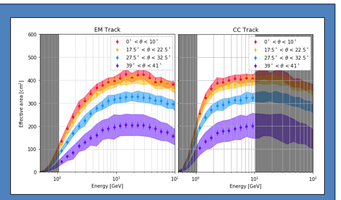

Figure 2. Effective area for HE (left) and LE (right) selections based on Epics simulations.

Multiple tracks for reconstruction:
- EM Track: focus on E > 10 GeV
- CC Track: improves E ~ 1—10 GeV

Contamination from ISS structures:
(CRs interact → secondary photons)
- Rotating and fixed structures
  (solar panels, radiators)
  Removed by JAXA model
- Transient structures
  (robotic arms, deployable payloads)
  Removed by manually defined cuts

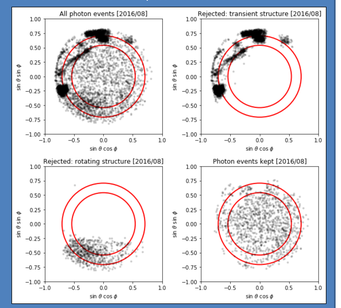

Figure 3. One month of gamma-ray candidates with various obstructions. Clockwise from upper left: all candidates; candidates removed by manually defined cuts; candidates removed as coming from rotating structures; events kept after FOV cuts. Red circles: 45° and 60° from zenith.

Observation overview:
- Pass 4.1 calibration
- Over five years of stable data collection to date (2015/11 – 2020/10)
- Maximum exposure with LE-gamma trigger at 5 GeV: 1.6 × 10^9 cm^{2}s

Bright galactic sources:
- Crab, Geminga, Vela

Extragalactic sources:
- Steady AGN emission (Mrk 501, PG1553+113)
- Variable AGN emission (CTA 102, PKS 2155-304)

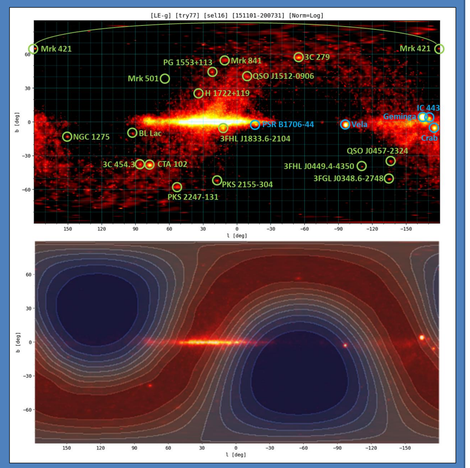

Figure 4. Skymap based on LE-gamma trigger mode over five years of observations. Top: counts map with logarithmic scaling. Sources detected by CAL are circled. Blue: galactic sources, green: extragalactic sources. Bottom: exposure contours overlaid on counts map. Red region is >90% of maximum exposure, contours represent steps of 10%.

Fluxes from bright galactic sources
- Events selected if within 1 std. dev. of PSF for LE-gamma trigger (~1°), within 2 std. dev. Of PSF for HE trigger (~0.5°); numbers scaled based on PSF containment fraction
- Exposures calculated vs. sky position and energy, including obstruction cuts
- Results consistent with published Fermi LAT fits[(5,6,7)]

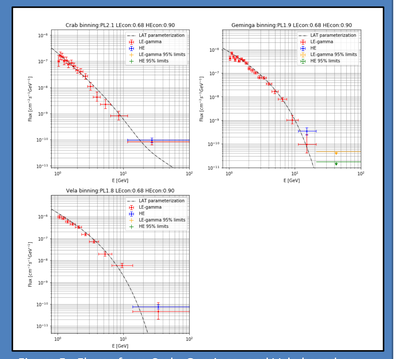

Figure 5. Fluxes from Crab, Geminga, and Vela based on five years of CALET observations. Fits published by Fermi LAT Collaboration shown by dashed lines.

Very bright flare from AGN CTA 102
- Quiescent signal near sensitivity limit for CALET observations
- In late 2016/early 2017, flux increased, even at high energy
- After 2017, emission only seen in the 1—2 GeV region

Other flares under investigation
- 3FHL J1833.6-2104
- 3C 279
- NGC 1275

Evaluating spectral changes in flaring states for these systems

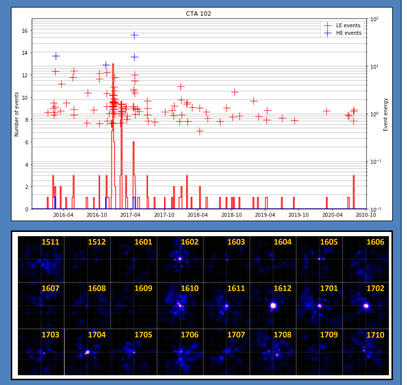

Figure 6. Time evolution of signal from the AGN CTA 102. Top: count rate in 5-day time bins with candidate energies overlaid. Bottom: monthly frames from 2015/11 through 2017/10, covering the full period where very bright flares were observed.

Emission expected at GeV energies from Sun
- Quiescent emission- not flares
- Emission from cosmic-ray proton interactions near Solar photosphere[(8)]
- Emission from cosmic-ray electrons inverse Compton scattering Solar photons[(9)]

Previous observations
- Confirmation by EGRET[(10)], Fermi[(11)]
- Studies with Fermi LAT in 2018 show dip in spectrum[(12)], Solar cycle dependence[(13)]

CALET observations
- Current simple analysis shows no features
- Improved 3-component modeling underway

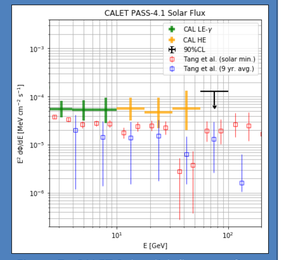

Figure 7. CALET Solar disk flux over five years based on preliminary analysis. Red points and blue points show the Tang et al. measurements from Fermi LAT in the Solar minimum and off-Solar minimum periods, respectively. Error bars for the CALET points are statistical only, and event selection does not account for contamination from the inverse Compton halo emission.

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