Observations of the Sun in GeV Gamma Rays by CALET on the ISS

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Observations from Fermi-LAT

- Seckel, Stanev, Gaisser 1991 (ApJ 382:652)
 - CR electrons and protons interacting with Solar photosphere and corona



Image: Tang et al. 2018, PRD 98, 6, 063019

Black points: LAT at previous solar min. Blue region: LAT between solar mins. Red region: Solar min. cumulative flux Black line: Limit of all protons being reversed and converted to photons Green region: Expectation from SSG model, extended to higher energies

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- Abdo et al. 2011 (ApJ 734:116)
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 - Actual flux in excess of expectation (~7×)



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- Tang et al. 2018 (*PRD 98 063019*)
 Linden et al. 2018 (*PRL 121 131103*)
 - Events at E > 100 GeV, only at solar min.
 - Dip at 30–50 GeV?



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- Asaoka et al. 2018 (AP 100:29)
 - CALET calorimeter
 - LE-γ trigger at low latitudes



Sample flight data event identified in the CAL as a photon with E ~ 400 GeV. Disclaimer: not associated with the Sun!

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 - Solar exposure calculated at Sun position each day at 12:00



Total cumulative exposure for PASS 3.1 dataset (35 months)

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 - CALET calorimeter sensitive to photons of GeV energies
- Pass 3.1 dataset contains first three years of CALET operations
 - Solar exposure calculated at Sun position each day at 12:00
 - Expected single photon detection in each bin approaches Tang et al. 2018 flux



Event selection

- LE-γ trigger used for E < 10 GeV
 - CC Track trajectory
 - Moderate background
 - Moderate statistics
 - Ang. res. ~1 deg
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 - Moderate background
 - Moderate statistics
 - Ang. res. ~1 deg
 ➢ Window: R_☉ + 68% cont.
- HE trigger used for E > 10 GeV
 - EM Track trajectory
 - Low background
 - Low statistics
 - Ang. res. ~0.2 deg
 ➢ Window: R_☉ + 95% cont.



Galactic plane veto: |b| > 10 deg

Detection efficiency and BG fraction



- Consider event consistent with solar gamma-ray if angular separation from the sun position is less than $(R_{Sun} + \theta_{68})$ or $(R_{Sun} + \theta_{95})$
 - Scale number of events seen by previously derived efficiencies as a function of energy

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- Accumulate expected background from Fermi-LAT observations and daily exposure
 - Scale expected background numbers by previously derived fraction

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 - Scale expected background numbers by previously derived fraction
- Calculate flux

Preliminary fluxes

Galactic plane veto: |b| > 10 deg

- Results with LE-γ trigger consistent with Fermi-LAT measurements
- Three photons candidates associated with Sun position with energies E > 10 GeV
 - All three in 2017 & 2018
 - Consistent with Tang et. al continuum
 - Dip not detected but not confidently ruled out



Summary

- CALET detects the Sun in GeV gamma rays significantly over the background signal
- Pass 3.1 dataset contains three photon candidates associated with Sun position with E > 10 GeV
 - Flux measurement consistent with Tang et al. continuum
 - Dip at 30-50 GeV not detected in CAL analysis, but not confidently ruled out
- Analysis refinement in progress
 - Expanding HE photon geometry to increase exposure at E > 10 GeV
 - Robust background trials including false Sun studies
 - Increase angular window to include IC halo contribution
 - Observations throughout solar minimum & solar cycle 25

Backup

Sun-centered frame transformation



Sun-centered frame maps

