Observational Challenges on the ISS: A Case Study with CALET (and potential impacts for TIGERISS)

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Abstract: The International Space Station (ISS) provides an orbital platform for astrophysical missions with lower resource requirements than free-flying satellites. The many uses of the ISS, however, can produce unique challenges to the accurate analysis of the data acquired by these instruments. In this work, we present effects observed by the Calorimetric Electron Telescope (CALET), an astroparticle physics mission installed on the Japanese Experiment Module Exposed Facility of the ISS. The CALET calorimeter is sensitive to cosmic-ray electrons and gamma rays from ~1 GeV up to above 10 TeV, and to cosmic-ray hadrons up to ~PeV total energies. The CALET Gamma-ray Burst Monitor (CGBM) is sensitive to X-rays and low-energy gamma rays from 7 keV to 20 MeV. Furthermore, ultra-heavy galactic cosmic-ray (UHGCRs) abundances are measured by CALET using a much more open geometry than is possible for events which shower in the instrument. In this work, we discuss ISS-related issues that affect the observations by CALET. Here we detail the ways these effects are accounted for in the production of scientific results. Finally, the possible impact on future missions such as TIGERISS (Trans-Iron Galactic Element Recorder for the International Space Station; planned for deployment to the ISS in 2026) and mitigation strategies are discussed.

CALET – Calorimetric Electron Telescope

Measures:

- Cosmic-ray electrons 1 GeV–20 TeV
- Cosmic-ray hadrons 10 GeV–~1 PeV
- Gamma rays 1 GeV–10 TeV
- X-rays/γ-rays 7 keV–20 MeV (CGBM)

Calorimeter subdetectors:

- Charge Detector (CHD)
- Imaging Calorimeter (IMC)
- Total Absorption Calorimeter (TASC)

CALET Gamma-ray Burst Monitor:

- Hard X-ray Monitor (HXM)
- Soft Gamma-ray Monitor (SGM)

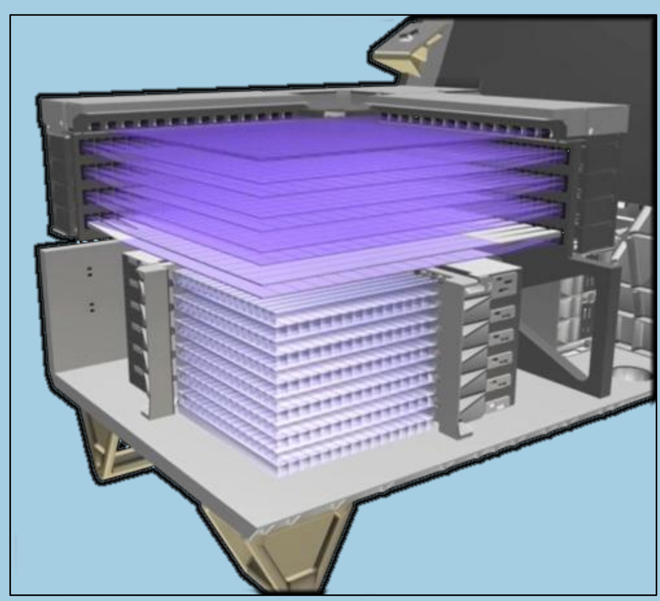


Figure 1. The CALET Calorimeter

Figure 2. The CGBM detectors

Soyuz Low-energy Background

Step-function background seen in CGBM since early operations

- Found to correlate with Soyuz arrival and departures
- Gamma-ray altimeter provides intense radiation background

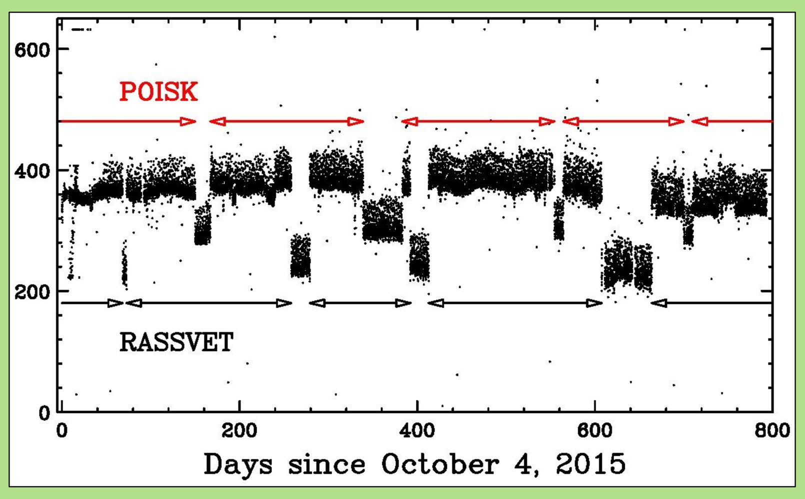
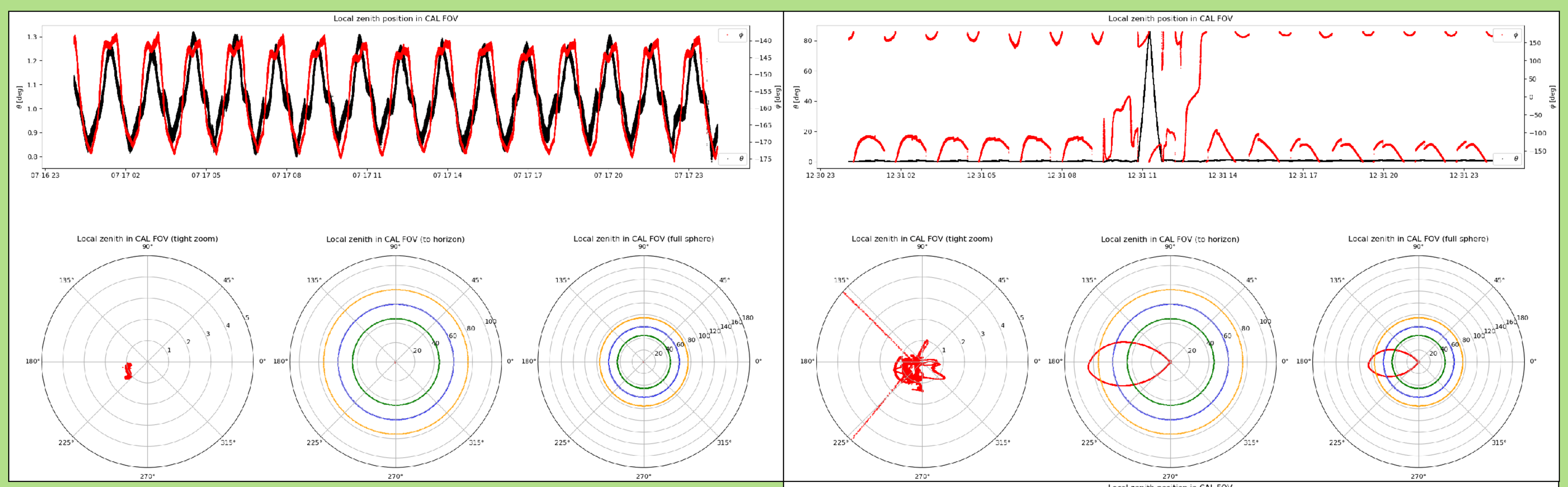


Figure 3. CGBM SGM rates showing different background levels depending on which Soyuz docking ports are occupied (RASSVET is closer to the JEM-EF than Poisk).

Maneuvers for Docking and Other Motions



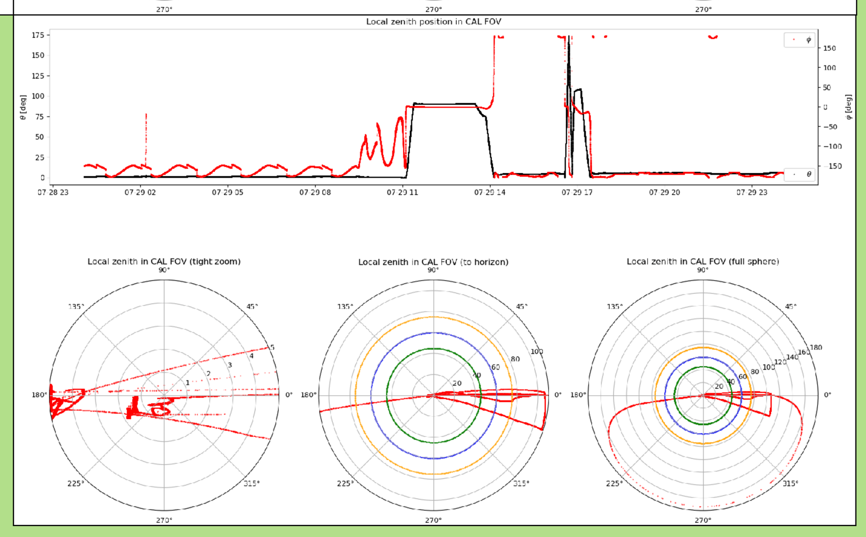


Figure 6. Motion of the local zenith position in CALET's field-of-view (FOV) for three days exhibiting different activity. Time-series plots show polar (black) and azimuthal (red) angles throughout a day. Circular plots show three zoom levels of the track of the local zenith in the CALET FOV. Days shown are (upper left) 2021/07/17, (upper right) 2019/12/31, and (lower right) 2021/07/29.

CALET standard observations mean that the instrument should be nearly zenith pointing. Usually this is the case (Fig. 6 upper left). However,

- Regular docking procedures for material and personnel require the station to rotate to accept the docking vehicle. Fig. 6 upper right panel shows the smooth maneuver for such a procedure.
- Orbital boosting can cause small changes in the station orientation
- Rarely, larger disturbances can be seen. Fig. 6 lower right panel shows one such day, where a misfire by a docked vehicle caused the station orientation to change radically for around 12 hours.

These rotations do not affect most CALET analyses, but must be considered when geomagnetic modeling is used over long periods.

Field-of-view Obstructions

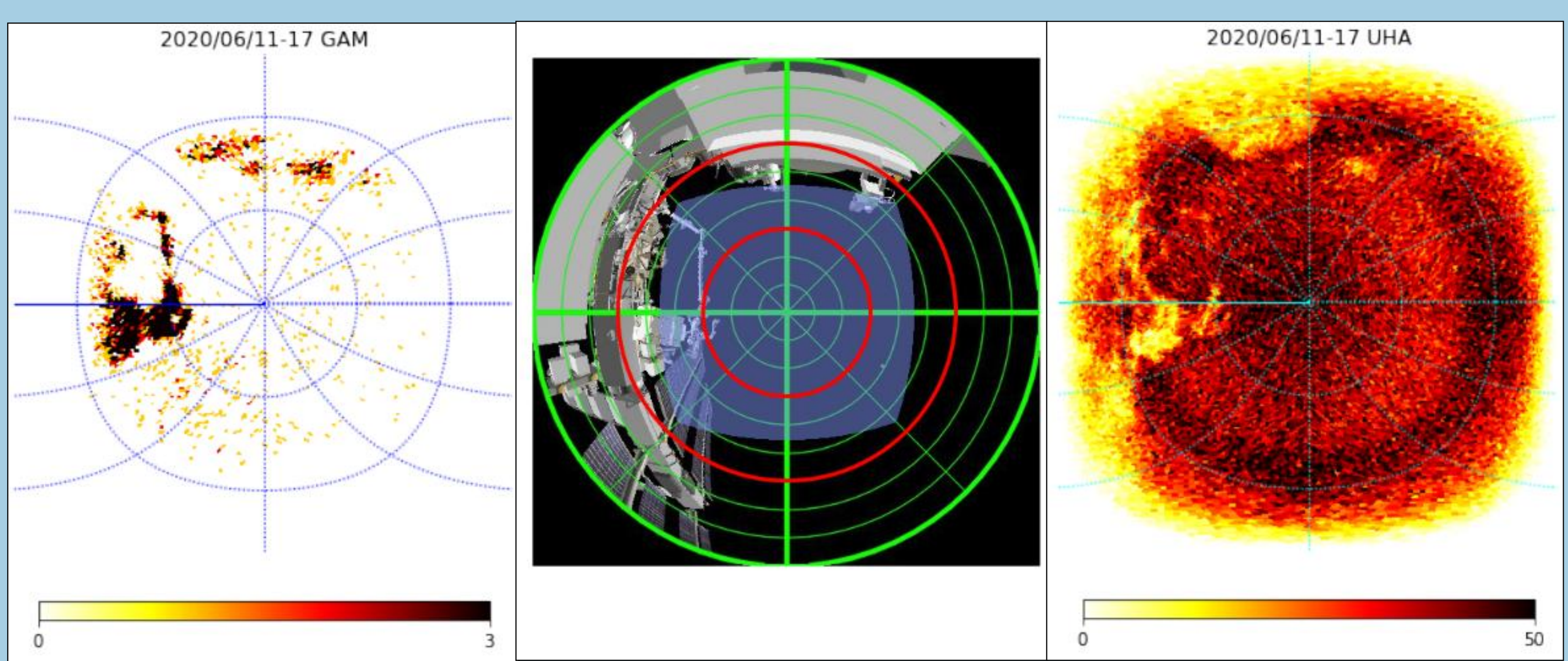


Figure 4. CALET field-of-view during a planned robotic arm active period. From left: (1) bright gamma-ray background; (2) planned arm position; (3) shadow in UHGCRs.

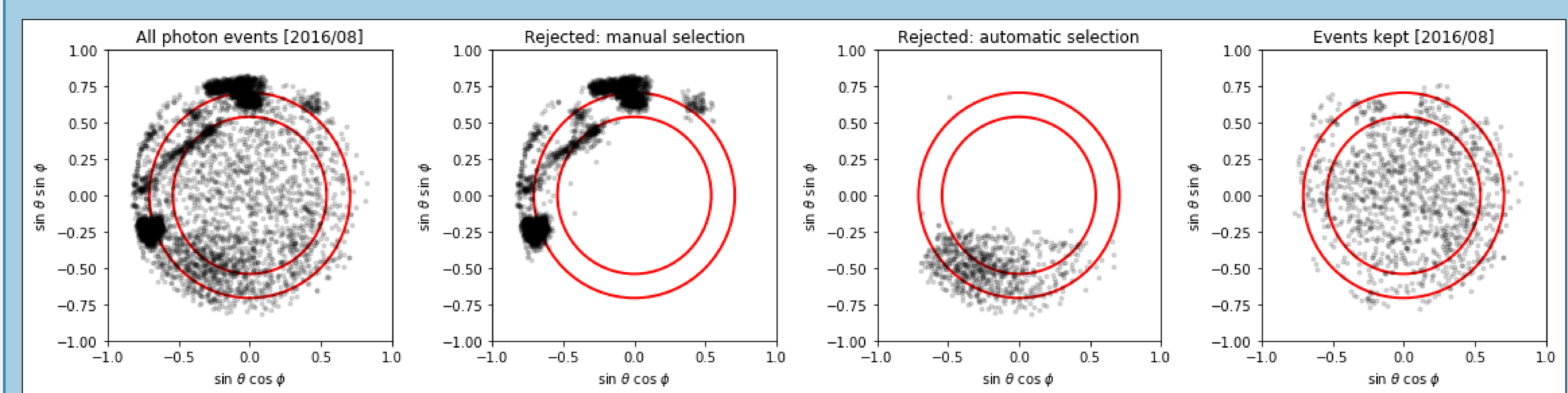


Figure 5. One month of intetegrated low-energy photon events in the CALET field-of-view. From left, the frames show (1) all events; (2) events removed by manual inspection; (3) events removed via modeling of rotating structures; and (4) events remaining after the cuts are applied.

Obstructions appear in the CALET field-of-view and are seen via:

- Low-energy photons (<~5 GeV) produced from cosmic-ray impacts (as seen in Figures 4 and 5)
- Ultra-heavy Gal. cosmic rays (UHGCRs) are shadowed (Fig 4)
- Optical glare from Solar reflection can impact star camera operation

Regularly appearing objects such as Solar panels and radiators are removed via ray-tracing code provided by JAXA

Irregularly appearing objects such as robotic arms and slow-moving objects are removed via manual inspection of field-of-view maps. Cut maps are registered in the calibration DB.

TIGERISS

The Trans-Iron Galactic Element Recorder for the ISS (TIGERISS) is an upcoming mission selected in the 2021 Astrophysics Pioneers call

TIGERISS will measure cosmic-ray elemental abundances up to $~_{82}$Pb

Some members of the TIGERISS team have experience in observing from the ISS as part of CALET

These effects are being planned for in the formulation of TIGERISS:

- A field-of-view camera will be used to monitor obstructions
- Station orientation will be monitored in geomagnetic modeling to account for tilt
- Thresholds will be too high for significant impact from Soyuz

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