Balloon flight of the Advanced Scintillator Compton Telescope (ASCOT)

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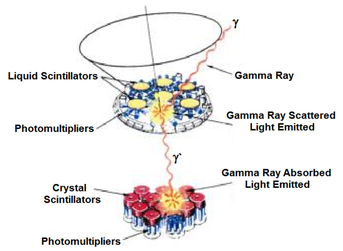
ASCOT is a new medium-energy gamma-ray Compton telescope addressing the existing need for a mission in the medium-energy gamma-ray energy range of 0.4 - 20 MeV. It is a prototype built on the legacy of COMPTEL instrument onboard CGRO. ASCOT uses commercially available high-performance scintillators, such as Cerium Bromide ($CeBr_3$) and p-terphenyl in conjunction with Silicon Photomultipliers (SiPM) which as readout devices to improve the instrument response. It also uses the Time-of-Flight background rejection, an important tool for effective imaging in this energy range. The instrument was developed with the goal of imaging the Crab Nebula at MeV energies during a high-altitude balloon flight. The balloon payload was launched by NASA from Palestine (TX) on 5th July 2018 and ASCOT observed the Crab for ~ 5 hours from an altitude of 120,000 ft. We present here the development of the instrument and a preliminary look at the flight data. Based on simulations we expect a ~4.5 sigma detection of the Crab in the 0.2 - 2 MeV band. The results from ASCOT will be pivotal in demonstrating an improvement in the energy, timing, and position resolution using this advanced technology.

ASCOT Balloon Payload

Legacy of COMPTEL

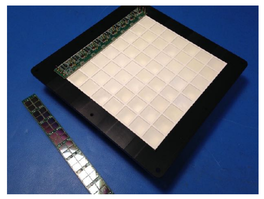
- The COMPTEL instrument on CGRO was a double-scatter instrument (D1 - liquid scintillator D2 - NaI(Tl)) capable of imaging gamma rays in the range of 0.75-30 MeV.
- It relied on pulse shape discrimination (PSD) and Time-of-Flight (ToF) techniques to identify and reject various background components.
- The ToF proved to be a crucial aspect of COMPTEL data analysis. We believe that ToF techniques utilizing the latest technologies offer a significant advantage for future Compton telescopes. ASCOT was designed and developed keeping this in mind.



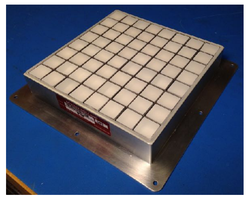
Advanced Scintillator Materials

P-terphenyl (Proteus, Inc.) & $CeBr_3$ (Scionix/BNC)

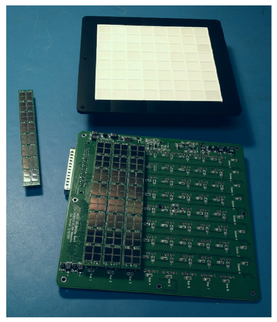
- Each scintillator elements is 15 mm × 15 mm × 25 mm
- An 8 × 8 array of these elements forms a module



D1 module consisting of p-terphenyl crystals in black Delrin frame separated by Gigahertz Optik reflective slats.



D2 module consisting of $CeBr_3$ crystals in vacuum-rated hermetic package.



SiPM array board partially populated with SiPM strips.

Silicon Photomultipliers (SiPMs)

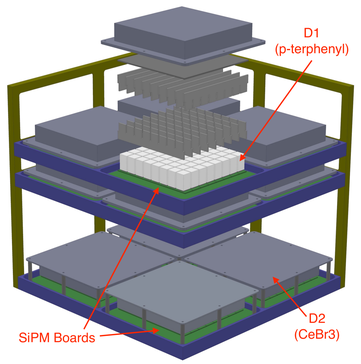
SensL MicroFC-60035-SMT SiPM

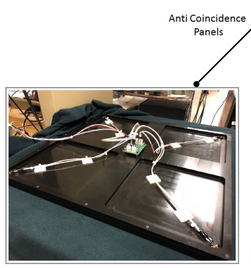
- Each scintillator element is read out by a 2 × 2 sub-array of SiPMs mounted on custom "strip" boards, fabricated by IMS Corp. in Manchester, NH.
- These strips boards are mounted on an array board which provides front-end readout electronics and bias voltage (~29 V) with passive temperature-based gain correction.

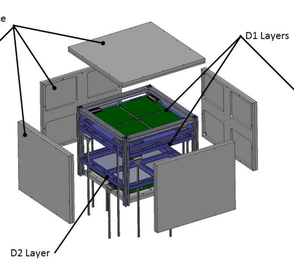
ASCOT Instrument

Detector Modules, Anti-Coincidence Panels, and Tagged Calibration Source

- The telescope comprises two D1 layers (p-terphenyl) and one D2 layer ($CeBr_3$) separated by 13 cm. Smaller separation increases both the effective area and the FoV.
- Each detector layer consists of a four detector modules.
- The layers are surrounded by six anti-coincidence panels, each containing a plastic scintillator sheet read out by SiPMs at the four corners.
- A tagged calibration source made of plastic scintillator infused with ^{60}Co with SiPM readout is located at the center of the D2 layer.







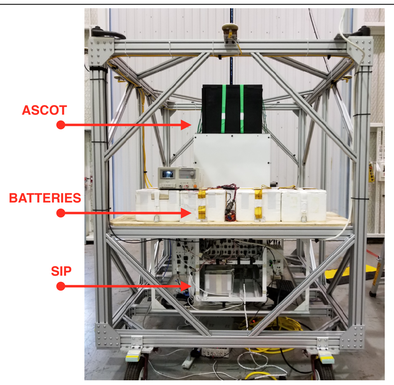
Assembled ASCOT instrument

Launch & Flight

Balloon Payload

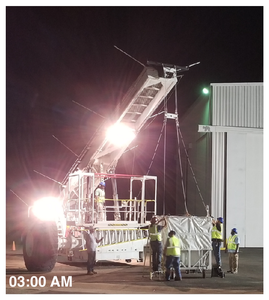
Instrument, Gondola, GPS Compass, and CSBF Equipment

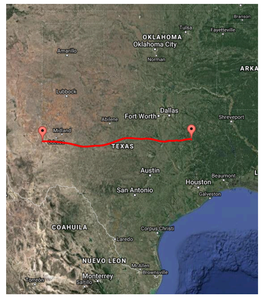
- The gondola frame is made of 8020 extruded aluminum T-slot elements. The instrument sits at the center pointed at the zenith
- Batteries are mounted along with GMoDem, a piggyback instrument by University College Dublin.
- The CSBF Mini-SIP package is mounted below ASCOT. Attitude knowledge is provided by the ADU5 GPS compass (no attitude control was required).

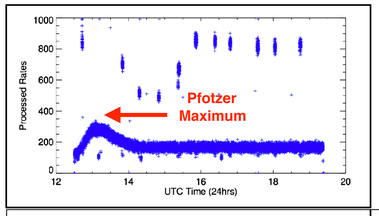


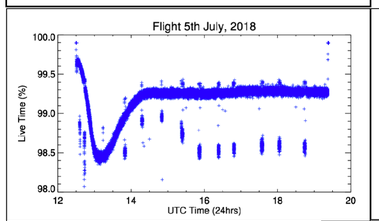
Balloon Launch

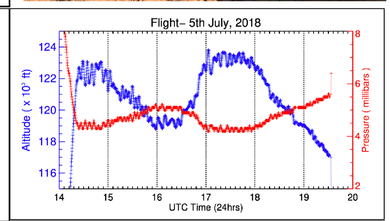
- The payload was assembled at NASA's Columbia Scientific Balloon Facility (CSBF) in Palestine, Texas. It weighed ~1350 lbs
- It was launched on July 5th, 2018 at 12:10 PM (UTC)
- ASCOT took 2 hours to reach the float altitude of ~120,000 ft
- Stayed at float for ~ 5 hours, the flight was terminated at 19:20 PM (UTC)
- The payload landed safely and was recovered close to the city of Wink in West Texas, around 450 miles west of Palestine.
- ASCOT operated stably throughout the flight with a live time > 99% at float. As seen from the Tagged events, the gain was almost constant in both D1 & D2 layers.

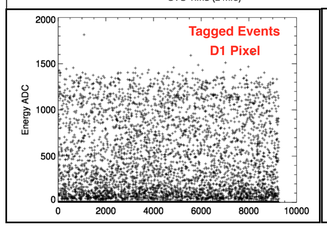


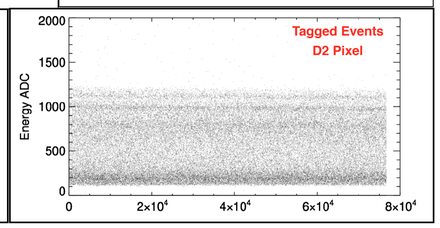












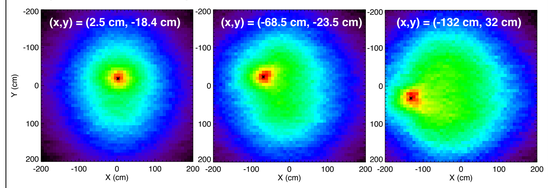
Data Analysis

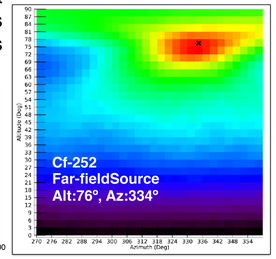
Calibration

- The instrument was energy-calibrated in the laboratory using various radioactive sources. Am-241 (60 keV), the two Compton Edges for Na-22 were used for D1 layer. Ba-133 (356 keV), Na-22 photo peaks (511 keV, 1275 keV), Cs-137 (662 keV), Co-60 photo peaks (1173 keV, 1332 keV), 2223 keV from neutron capture, were used to calibrate D2 layer.

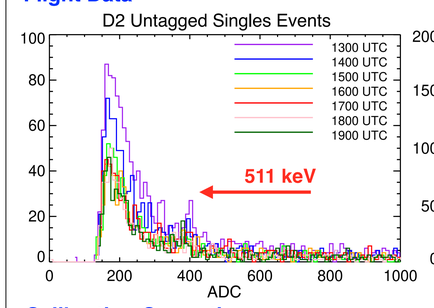
Near-Field Source & Far Field Source Images

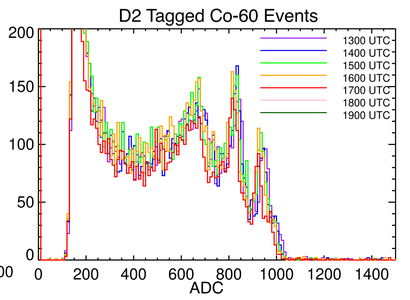
- Co-60 was placed at three different locations in x, y, z directions with respect to the instrument. The source was approximated as a near-field source in all the three cases and the corresponding images were obtained using the data which accurately showcase the source locations.
- Cf-252 source was placed far enough from the instrument to be considered a far-field source, and the image was generated using the data from the experiment. The cross depicts the actual position of the source.





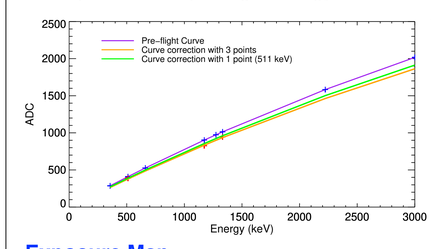
Flight Data

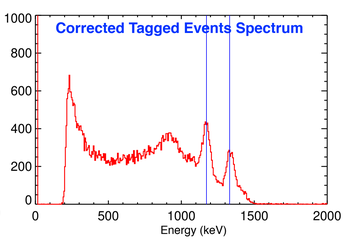




Calibration Correction

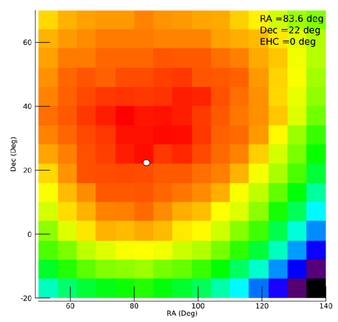
- The three points (511 keV, 1.1 MeV, 1.3 MeV) obtained from the flight data are compared to the pre-flight Energy-Channel curve to correct for any changes in gain.





Exposure Map

- Azimuth pointing correction from ADU5 was applied to the calibrated flight data and a simple back projection image from all the events was generated (shown alongside).
- No background rejection applied yet.
- The white point indicates the Crab position.



Future Work

- ToF correction & PSD to be applied to reject background.
- Events recorded in multiple columns that have not been included in the analysis so far to be analyzed to improve Signal to Noise Ratio.
- Maximum Likelihood Estimation to be explored.

For more info, please contact ts1043@wildcats.unh.edu

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