The Mini Astrophysical MeV Background Observatory (MAMBO) CubeSat Mission

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The MAMBO Team

- The MAMBO CubeSat mission is a collaboration between the **Intelligence and Space Research Division** and **Center for Theoretical Astrophysics** at Los Alamos National Laboratory:

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MAMBO Overview

The **Mini Astrophysical MeV Background Observatory (MAMBO)** is an innovative gamma-ray astrophysics investigation that will answer three decades-old questions about the mysterious Cosmic Diffuse Gamma-ray (CDG) background:

- ***What is the detailed spectral shape of the CDG from 0.3 – 10 MeV?***
- ***Is the MeV CDG truly isotropic across the sky?***
- ***What is the contribution of nuclear processes over the history of the Universe to the MeV CDG?***

The MAMBO mission represents a new way of doing MeV astronomy which will solidify Los Alamos' leadership in space-based gamma-ray sensing, and demonstrate a flexible new paradigm for rapid, inexpensive science missions.

Scientific Motivation: The MeV CDG

- The origin of the CDG background in the MeV band remains a mystery over 40 years after the first measurements by Apollo 15 & 16 (Trombka et al. 1977)
- It seems certain that blazars (particle acceleration; e.g. Ajello at al. 2009) and Type Ia SNe (nuclear processes; e.g. Ruiz-Lapuente et al. 2016) must contribute
- Other proposed sources include Seyferts, star-forming galaxies, kilonovae, and dark matter interactions
- Existing data indicate multiple sources due to changes in spectral slope; ***however***, these data have issues
- COMPTEL (Weidenspointner et al. 2000) suffered from large systematic errors due to background, and SMM (Watanabe et al. 2000) was constrained to observe the Sun

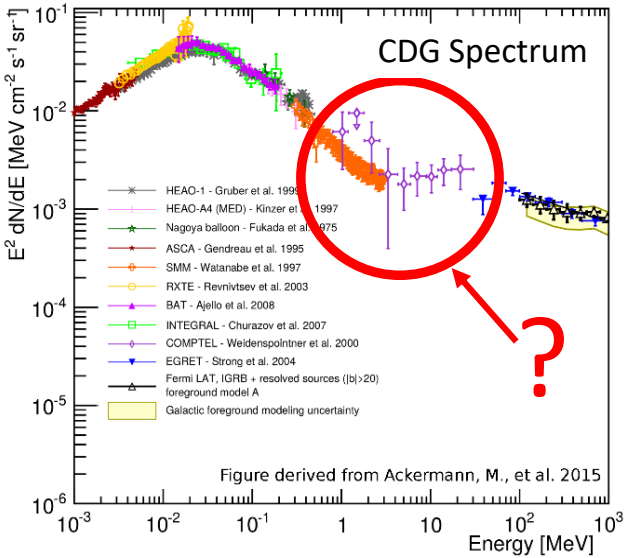
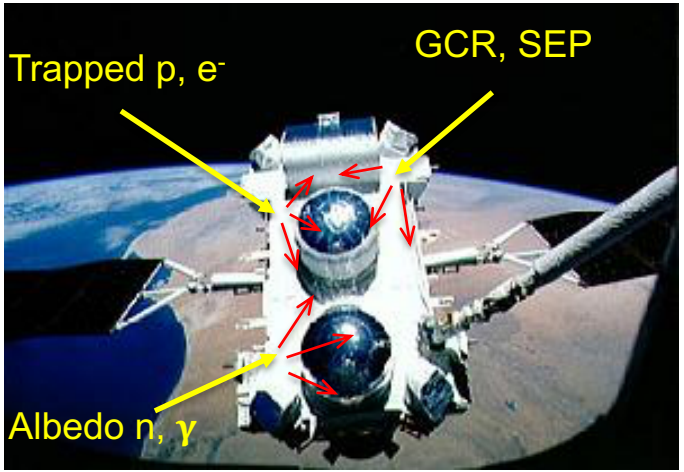


Fig. adapted from Ackermann et al. (2015)

What is required is a full-sky map of the MeV CDG spectrum and anisotropy collected with a low-background instrument

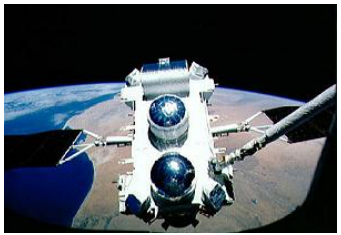
Low-Background MeV Observations

- **The Problem:** The sensitivity of space-based gamma-ray instruments is severely limited by *locally generated instrumental backgrounds*
- Energetic particles in space interact in spacecraft materials to produce both **prompt** and **delayed** (activation) background signals in the MeV band
- Intensity in a given detector scales as the integral over the mass distribution of $1/d^2 \Rightarrow$ background scales roughly as ~$(\text{mass})^{1/3}$
- As a result, previous measurements of the MeV CDG suffer from large systematic errors due to subtraction of instrumental backgrounds

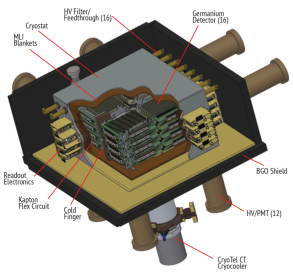


A New Approach: Low-Mass Spacecraft

- **Traditional approach:** Large, complex instruments to maximize efficiency to faint astrophysical MeV sources
- Leads to 1000+ kg spacecraft and large instrumental background



CGRO: 17,000 kg



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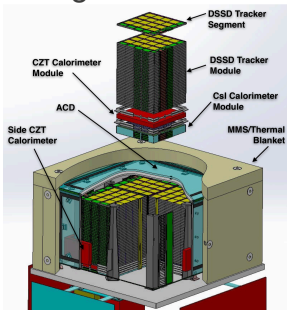
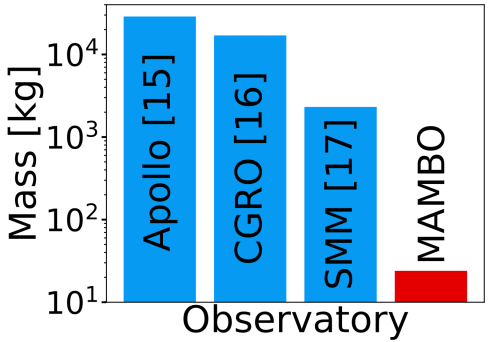


AMEGO

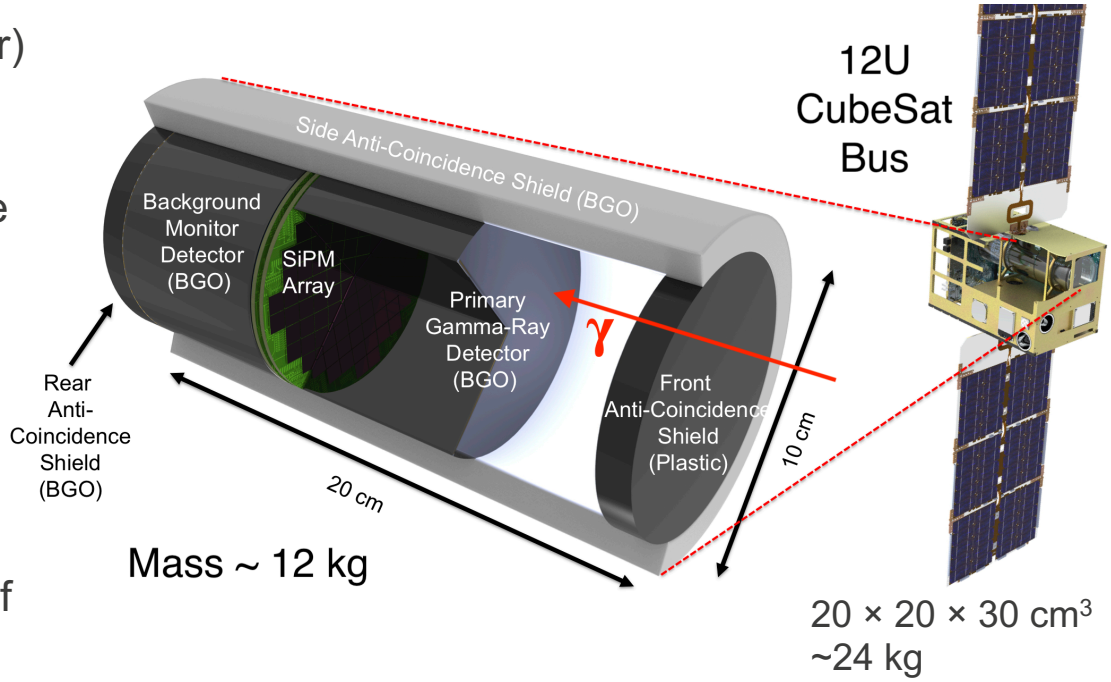
⇒

- **Our Approach:** To significantly reduce background, *mass must be dramatically reduced*
- The CDG is relatively bright, so *only a small detector needed*
- MAMBO utilizes a 12U CubeSat bus = 24 kg total
- Will experience an *order of magnitude less instrumental background* than COMPTEL on CGRO



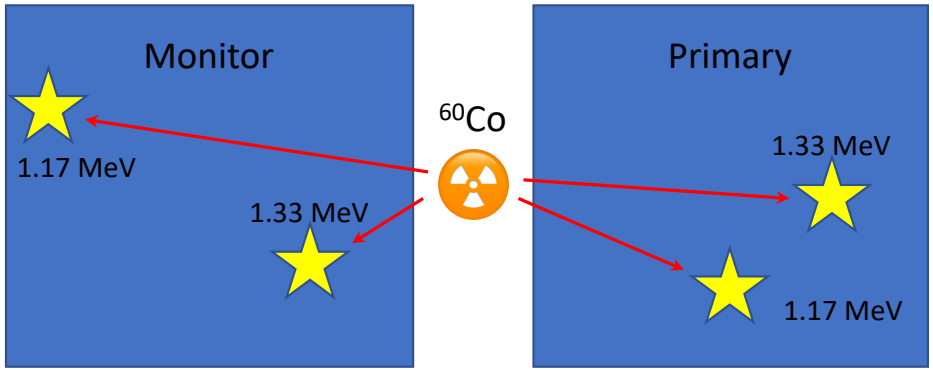
The MAMBO Instrument

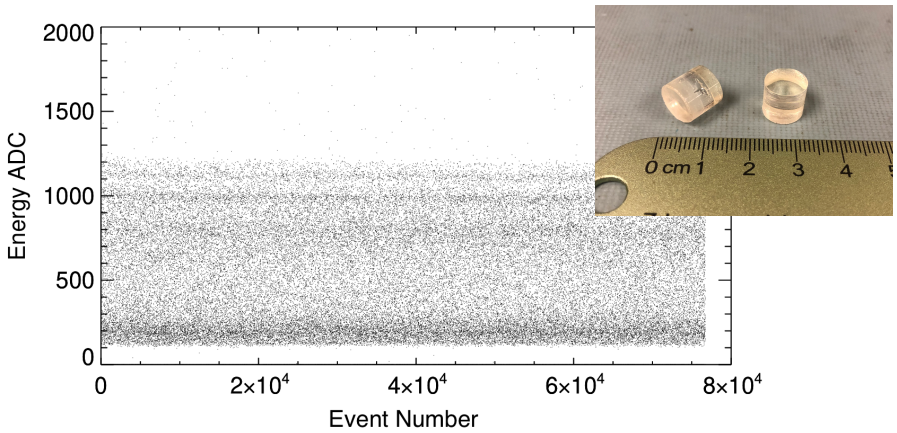
- MAMBO achieves high efficiency and exceptional background rejection using an innovative shielding configuration
- The Primary Detector (BGO scintillator) is exposed to the CDG
- The Background Monitor (identical BGO) is shielded from the CDG by the Primary, but exposed to the identical instrumental background
- Gains are kept the same using a **tagged ^{60}Co source**
- *Instrumental background is thus **directly measured and subtracted***
- Close spacing is enabled by the use of **silicon photomultipliers (SiPMs)**



MAMBO Instrument On-Board Calibration

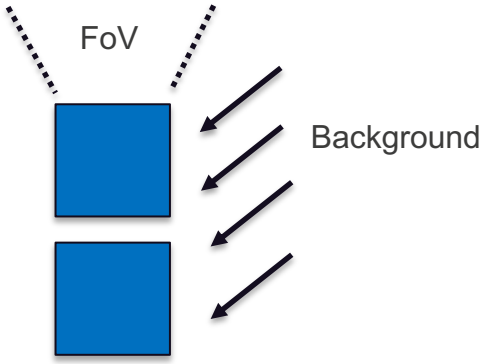
- It is critical that the Primary Detector and Background Monitor have the same gain
- A tagged ^{60}Co source (10s of nCi) between the two will provide calibration events
- FPGA-based algorithm will monitor and adjust – cadence TBD, depends on thermal variation in orbit
- Technique successfully used on SMM (Forrest et al. 1980)
- SiPM readout of tagged source demonstrated on ASCOT balloon (Bloser et al. 2019)



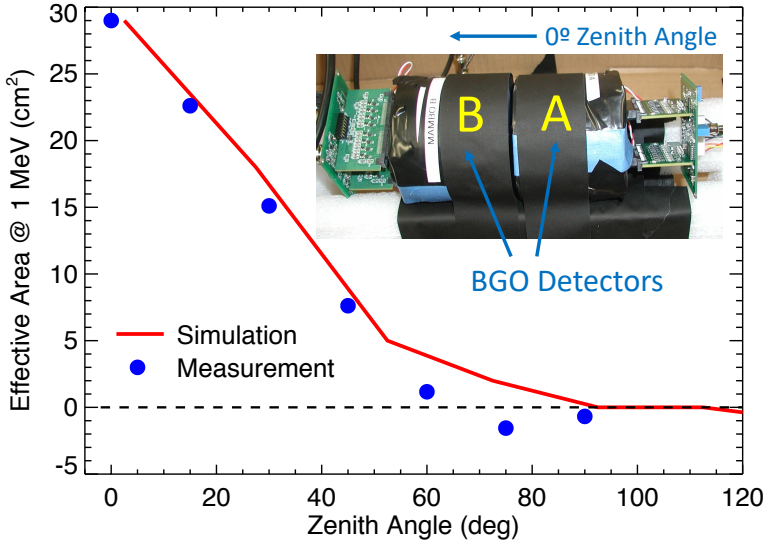


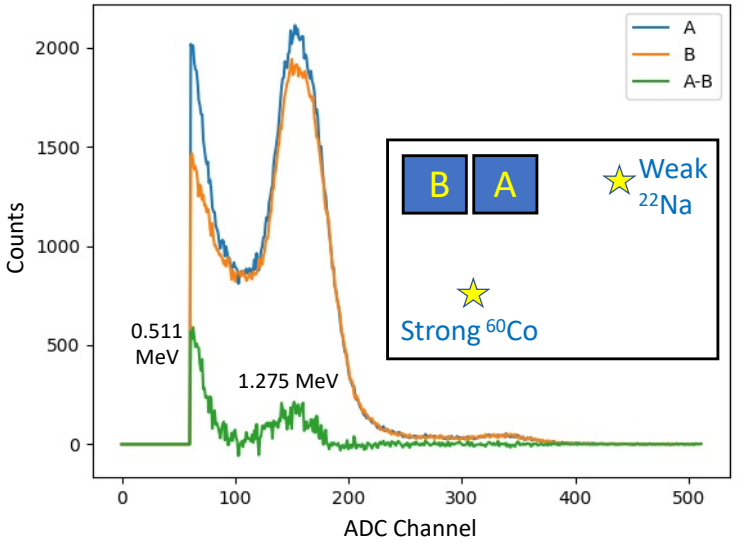
Tagged calibrations events during ASCOT balloon flight

MAMBO Detection Concept Demonstration



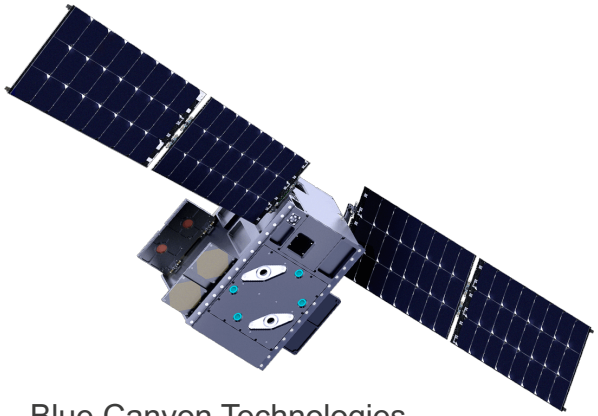
- Background subtraction approach demonstrated in lab
- Radiation incident from sides common to both Detectors, subtracted away – radiation from outside FoV strongly suppressed
- Response vs. incident angle agrees with simulations
- Field of view ~1 steradian
- **A_{eff} ~30 cm^2 on-axis at 1 MeV: roughly same as COMPTEL**



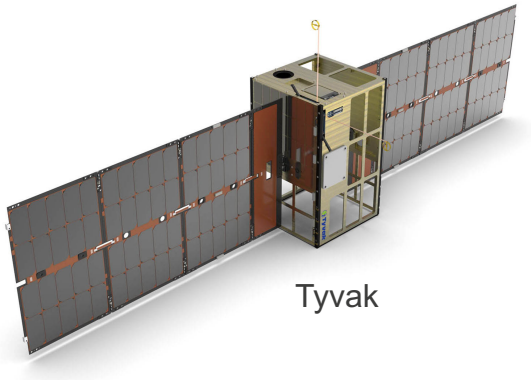


MAMBO Mission Concept

- MAMBO is well-matched to at least two standard commercial 12U CubeSat busses
- Ideal science orbit: circular LEO, ~400-500 km, 0º inclination
- For practical reasons (comms, schedule) will accept up to ISS-like orbit (~52º inclination)
- Estimate data rate of $\lesssim$ 500 MB per day
- Pointing accuracy/knowledge of ~1º
- Background noise generated by trapped radiation belts, especially activation in SAA
- Point at high-Galactic-latitude regions for $\gtrsim 10^6$ seconds each; extrapolate time-variable backgrounds to zero
- Minimum of 6 months; desire 2+ years

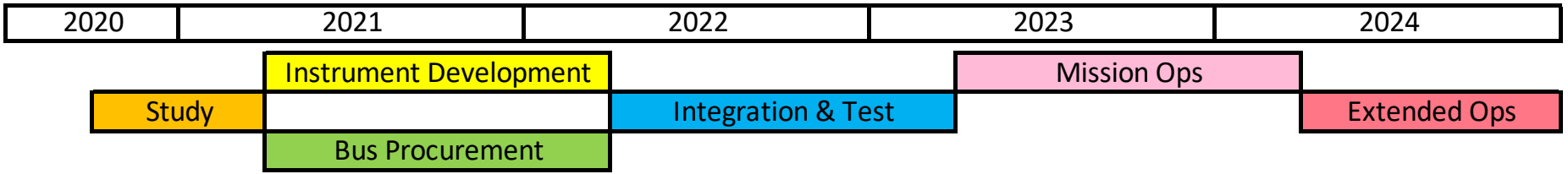


Blue Canyon Technologies



Tyvak

Expected MAMBO Project Timeline



- Six-month Feasibility Study currently underway
- Feasibility Review in March 2021
- One-year instrument development & bus procurement
- One-year integration & test
- One-year baseline mission
- Desire one-year-plus extended mission (propose to NASA for additional funding)

Seeking MAMBO Postdoc!

The Space Science and Applications (ISR-1) Group at Los Alamos National Laboratory is seeking applicants for postdoc positions working on development of satellite-based X-ray, gamma-ray, neutron, and charged particle detectors for civilian and defense-related programs…

…including MAMBO!

Go to **lanl.jobs** and search for "**IRC81782**"

Conclusions

- The MAMBO CubeSat mission will address an important, decades-old question in gamma-ray astrophysics using an innovative approach
- The low-mass 12U CubeSat platform will provide a uniquely “quiet” environment for MeV observations
- The compact, shielded scintillator spectrometer, enabled by SiPMs, will deliver low-background measurements of the MeV CDG over the entire sky
- MAMBO joins a new wave of rapid, inexpensive space science missions enabled by CubeSats

Thank you for your attention!