Tenth International Fermi Symposium

9th-15th October 2022

The Moon Burst Energetics All-sky Monitor (MoonBEAM)

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The MoonBEAM Team

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MoonBEAM Overview

Science Goals:

- explore the behavior of matter and energy under extreme conditions by observing relativistic astrophysical explosions.

3-year gamma-ray mission:

- Provides time for observations of :
  - 1600 binary compact mergers
  - 5900 optically discovered core collapse supernovae
  - 140 magnetar giant flares
  - and enables 55 very high energy gamma-ray and 360 optical follow-up

Cislunar orbit:

- instantaneous all-sky gamma-ray field of view
- uninterrupted observations with >96% duty cycle
- background radiation stability

Astro2020 Decadal Survey:
Astronomical Transient Events

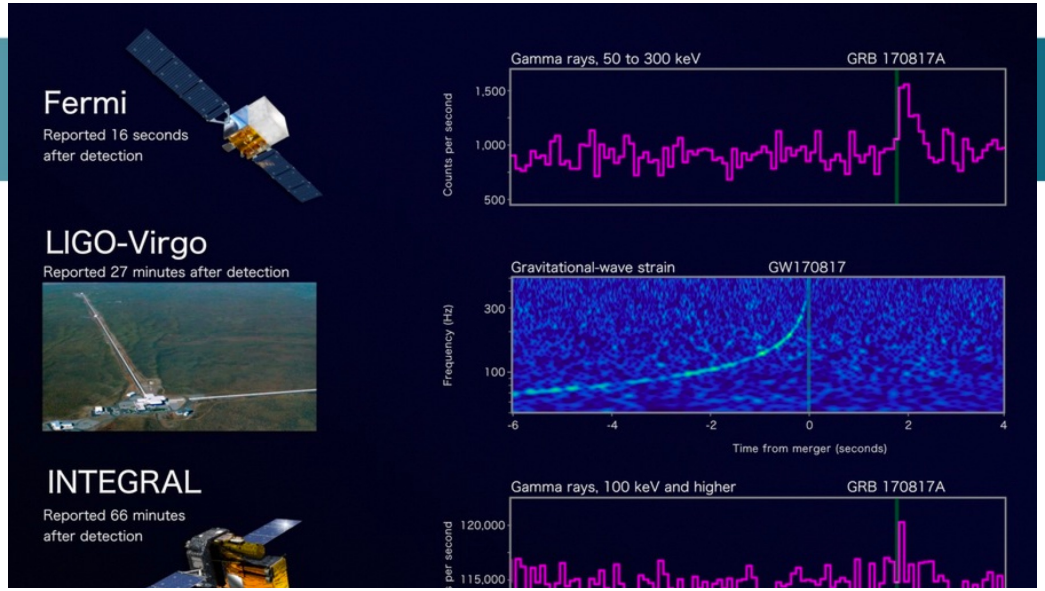
"Higher sensitivity all-sky monitoring of the high-energy sky, complemented by capabilities in the optical such as from Kepler and TESS, is a critical part of our vision for the next decade in transient and multi-messenger astronomy."

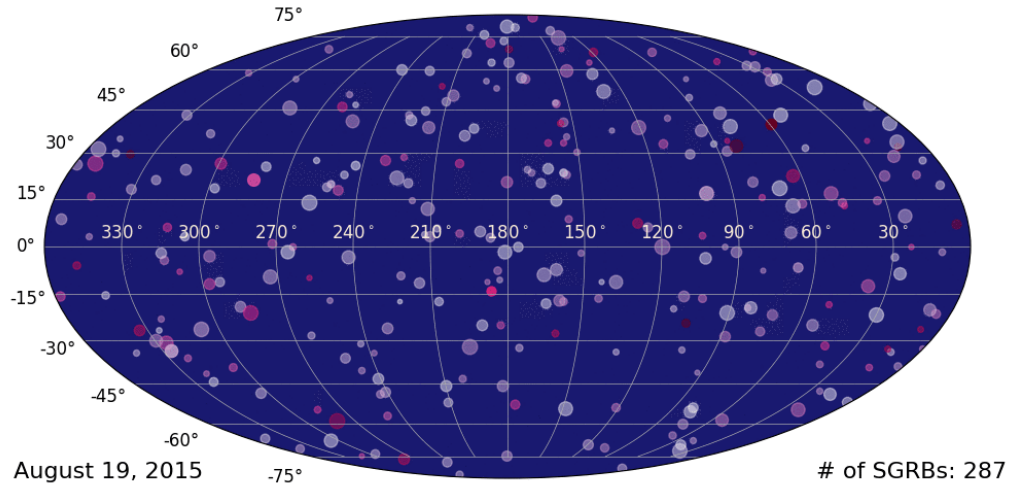
Science: GRBs

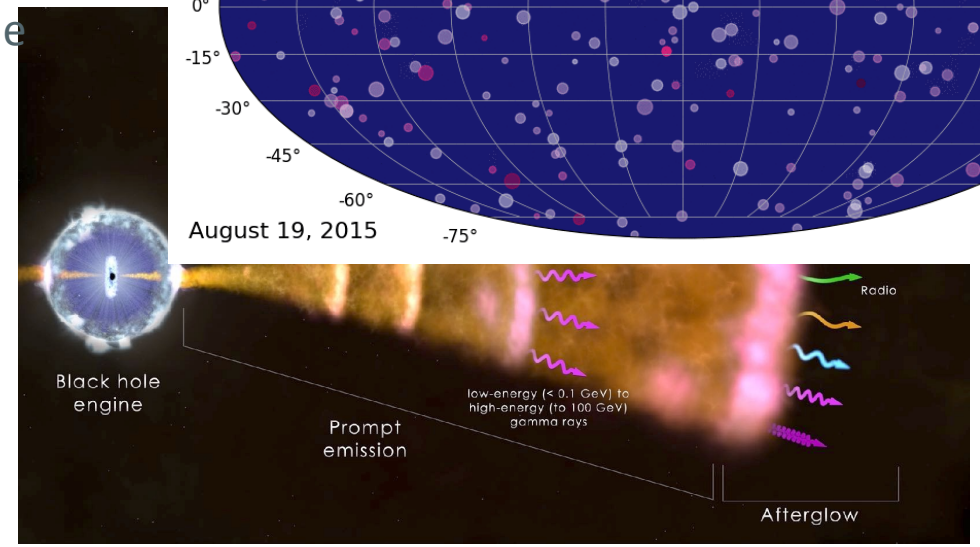
Gamma-ray Bursts (GRBs): most energetic explosions in the Universe.

- **Multiwavelegnth:** detected from radio to gamma rays.
- **Multimessenger:** can generate gravitational waves, neutrinos, and cosmic rays.
- **Transient nature:**
  - prompt emission in gamma rays, lasting <1s to >100 s.
  - afterglow starting within minutes and can last up to years.
  - detectable ~once per day, distributed all over the sky.

- **Era of Multi-Messenger Astrophysics**
  - **Open Questions:** merger and jet geometry,intrinsic properties etc.
  - Need a population of joint detections.
  - LVK O4 coming up in March!



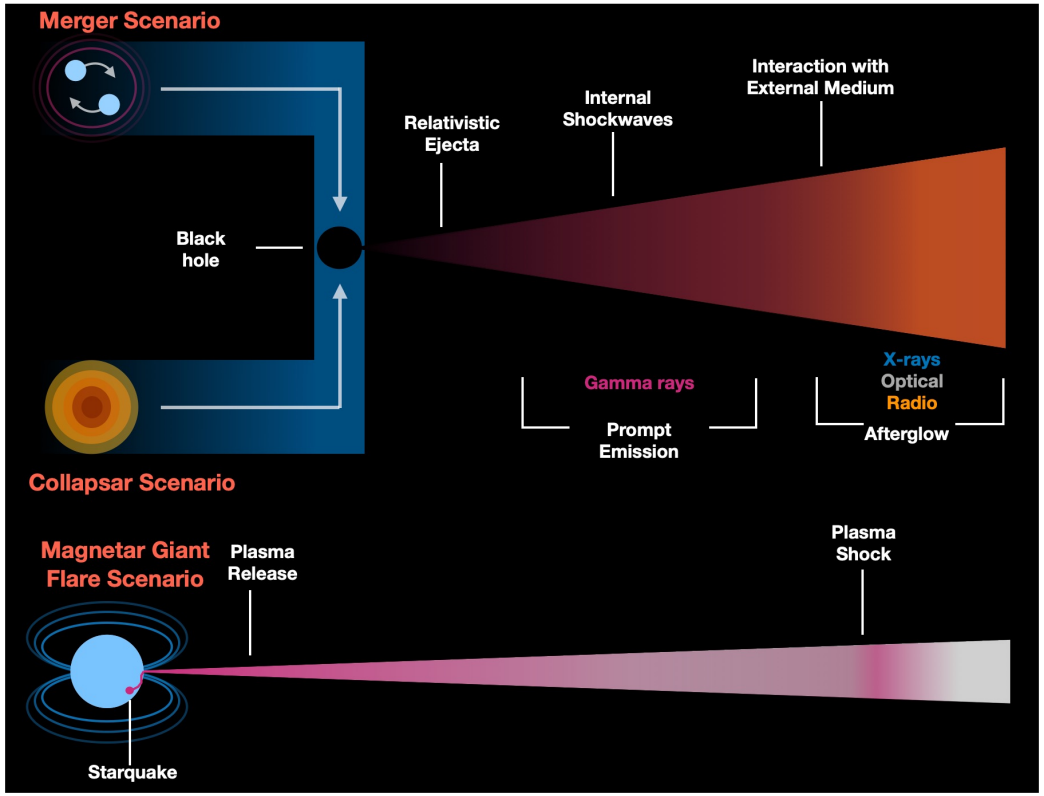


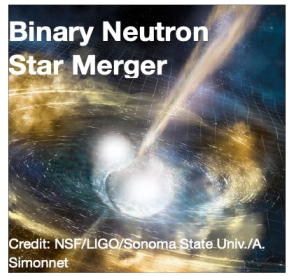


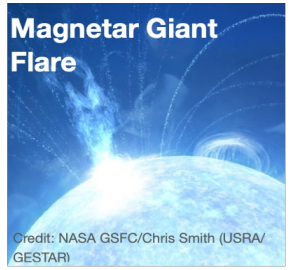
Mission Objectives

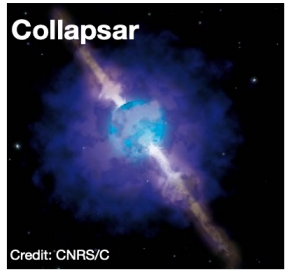
Mission Goal: Explore the behavior of matter and energy in its most extreme environments

- **Objective 1**: Characterize the progenitors of GRBs and their multi-messenger and multi-wavelength signals
- **Objective 2:** Identify conditions necessary to launch a transient astrophysical jet
- **Objective 3:** Determine the origins of the observed high-energy emission within the relativistic outflow

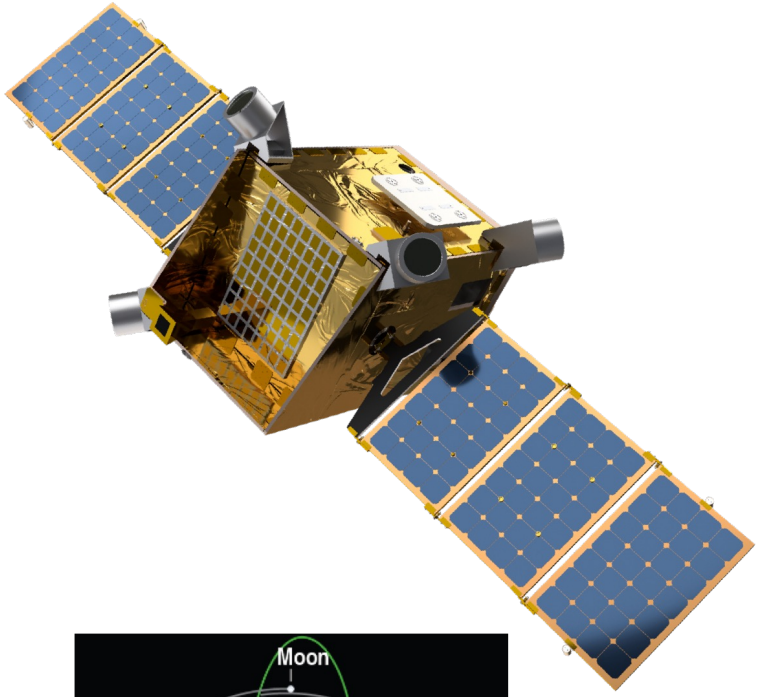


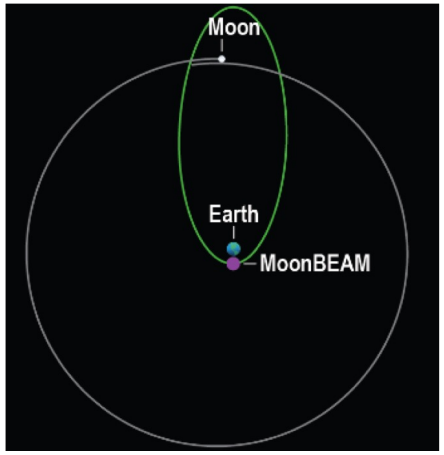






Spacecraft and Mission Design

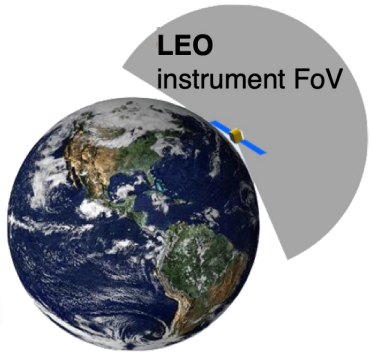


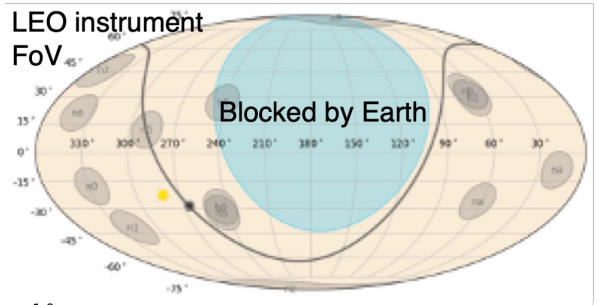


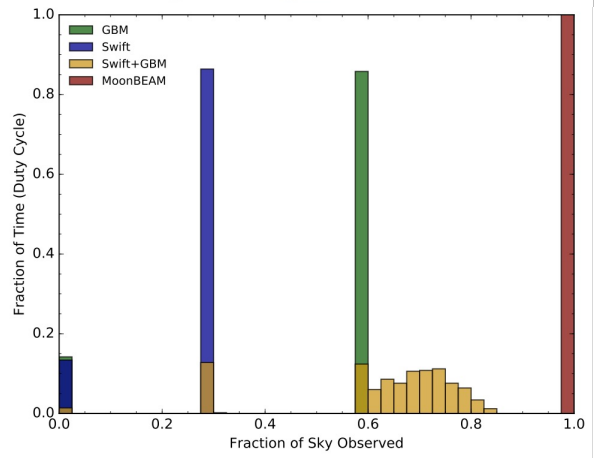
- Lockheed Martin SmallSat spacecraft bus:
  - reusing >90% of high-maturity Lunar Trailblazer design.
  - compatible with ESPA Grande mass and volume constraint.
  - high-heritage deep space propulsion approach to lunar resonant orbit from *any* Geosynchronous Transfer Orbit (GTO) rideshare launch.

- Orbital distance: up to 460,000 km from Earth (**1.5 light-seconds**).
- Orbital period: **13.7 days**.
- Mission lifetime: **3 years**.
- Communication:
  - **continuous burst alert coverage** with dedicated ground stations.
  - daily data downlink with the Near Space Network.

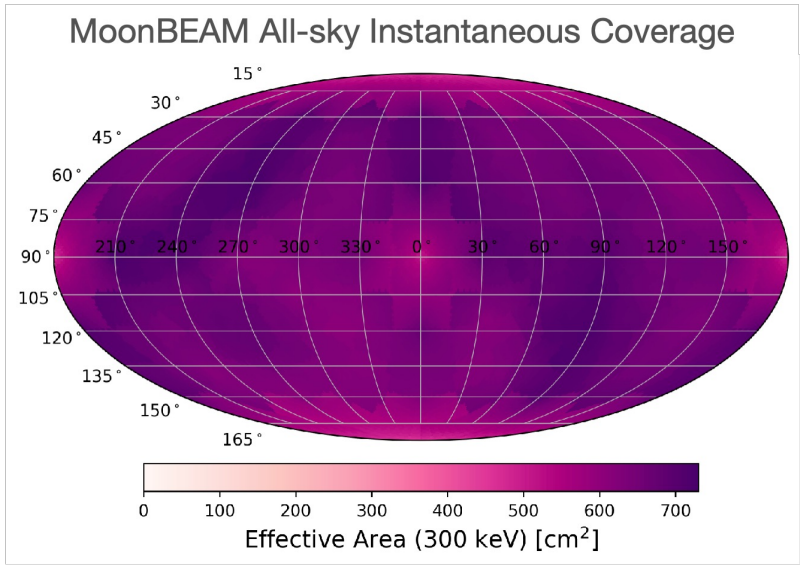
Mission Capability

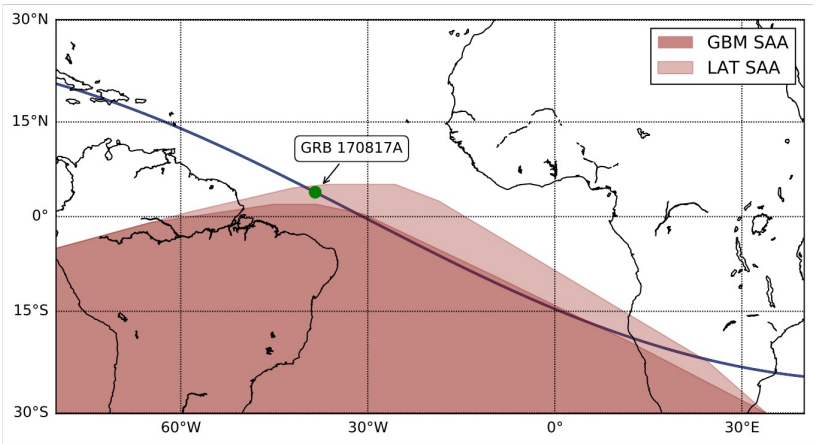






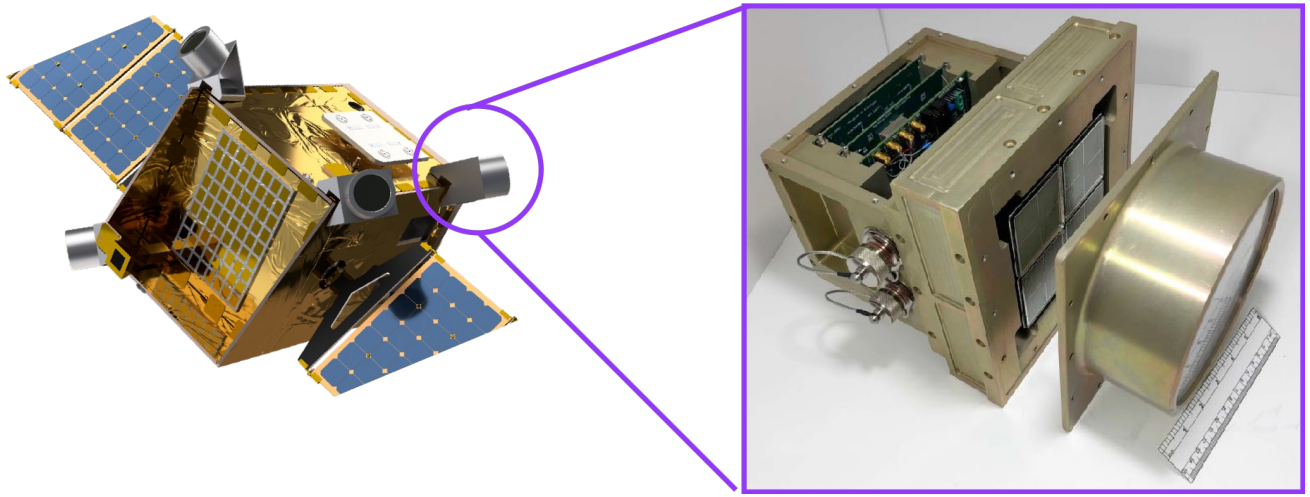
- **Orbital distance:** 22,000km to 460,000km from Earth (up to 1.5 light-seconds).
  - **instantaneous all-sky field of view:** Earth only occults ~2% of the sky at closest approach, <<1% on average**.=**
  - **high duty cycle** >96%, 13+ days uninterrupted livetime: no passage through the South Atlantic Anomaly (SAA)
  - **stable background** compared to LEO: no atmospheric scattering and SAA-related radiation.
  - **add to localization improvement**: timing triangulation technique with other gamma-ray missions.

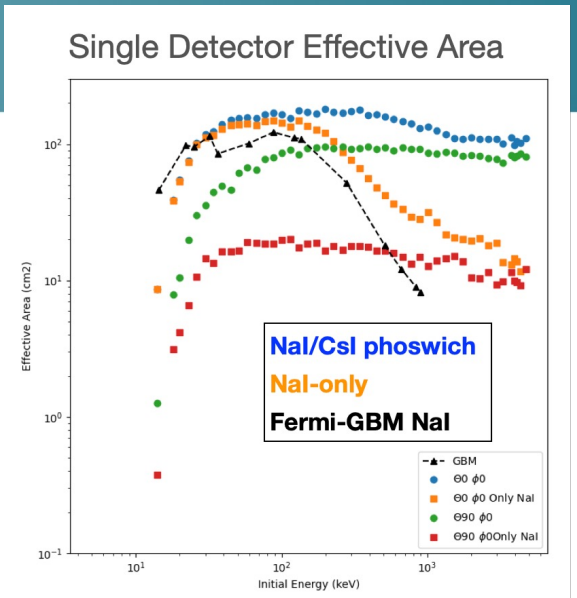


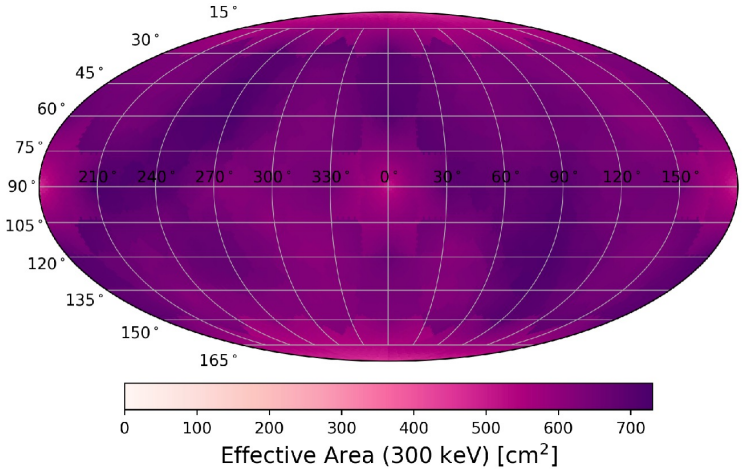


Fermi-GBM turned off for SAA 2 minutes after GRB 170817A / GW170817.

Instrument Design



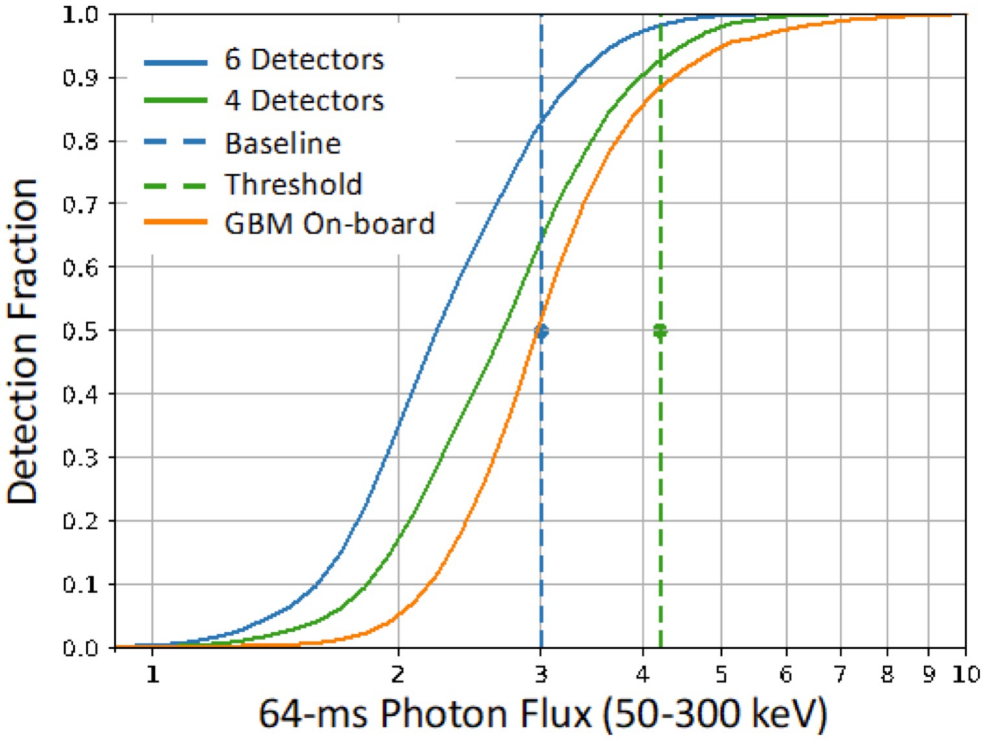




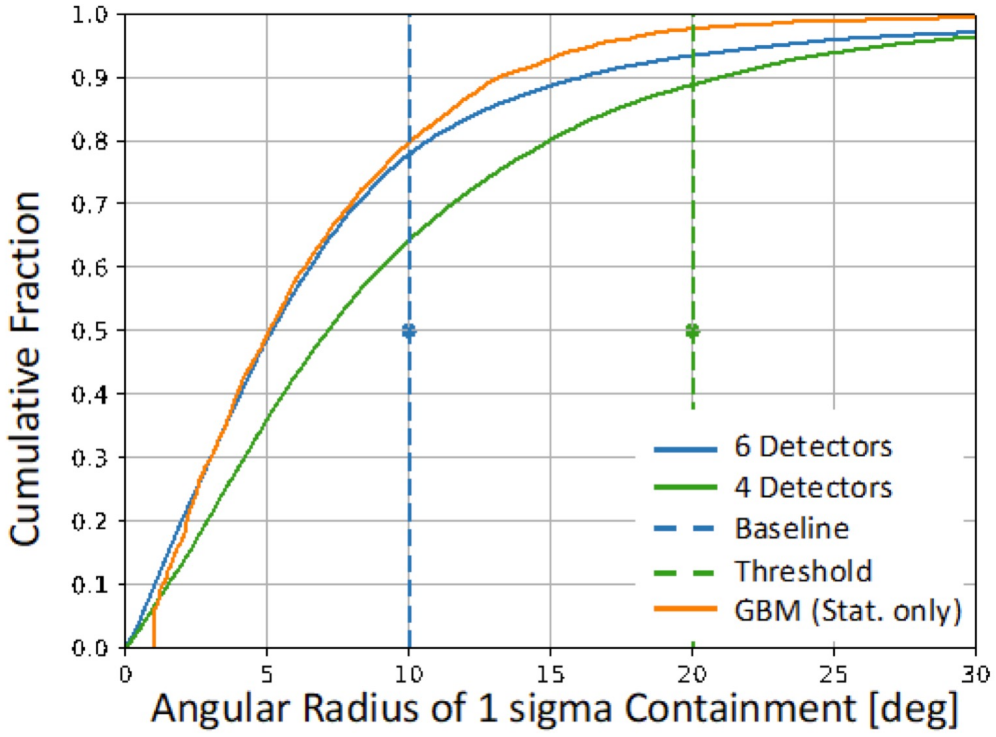
- 6 scintillating detectors positioned for instantaneous all-sky coverage: **no pointing needed.**
- each detector module consists of a NaI(Tl)/CsI(Na) phoswich and flat panel PMTs.
- **phoswich design:** simultaneous dual-mode observations:
- low background, direction dependency for localization
  - pulse discrimination identifies origin >96% for background rejection
- **Spectroscopy:** wide energy range and wide field-of-view
  - 10—5000 keV, prompt GRB peak energy range
  - 10% energy resolution at 662 keV

Instrument Capability

- **Short GRB sensitivity:** MoonBEAM benefits from lower background and increased detector size compared to *Fermi* GBM.



- **Localization:** Independent localization comparable to *Fermi* GBM. (Median IPN timing annulus width is 1.4 deg.)



The MoonBEAM Team

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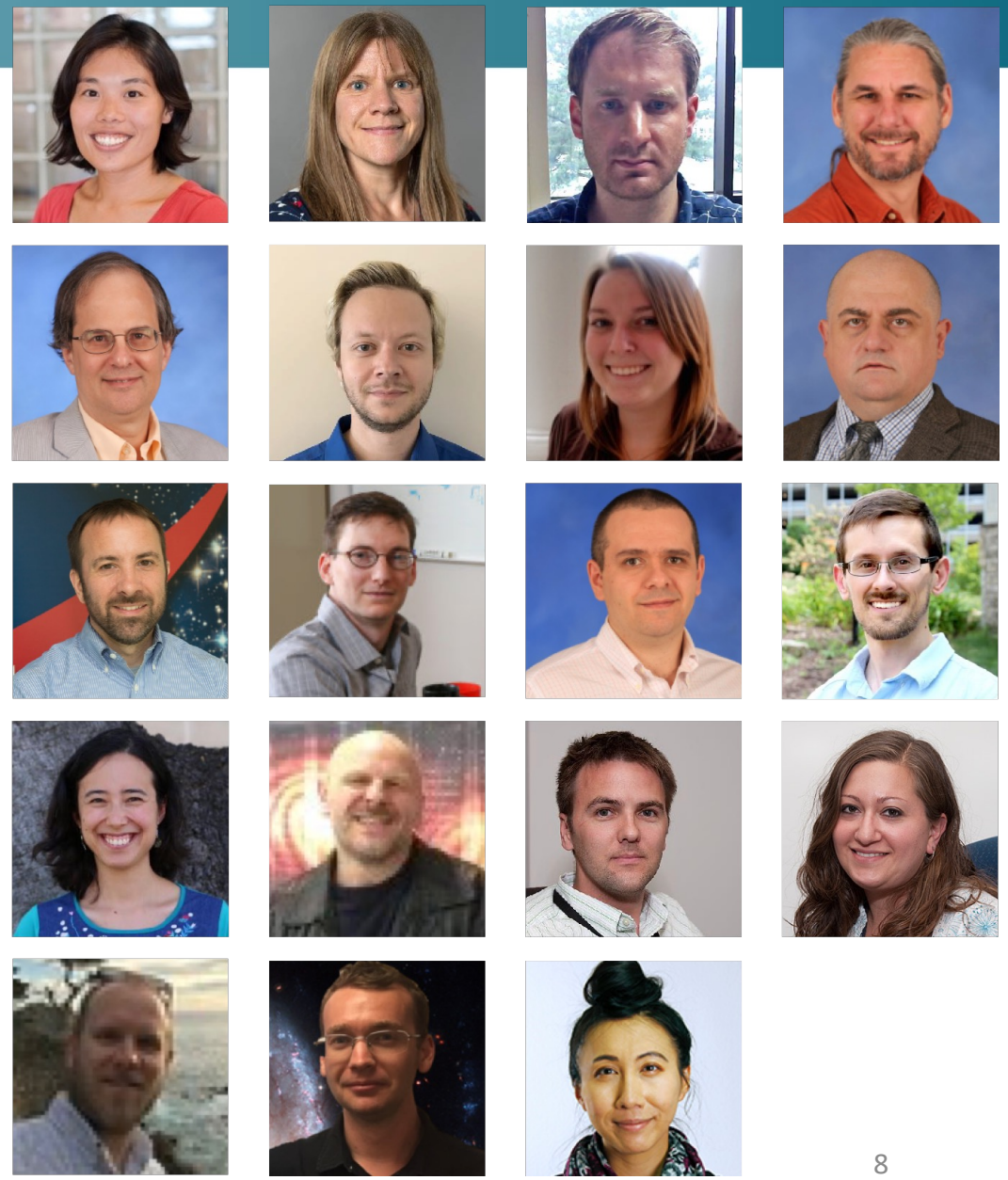
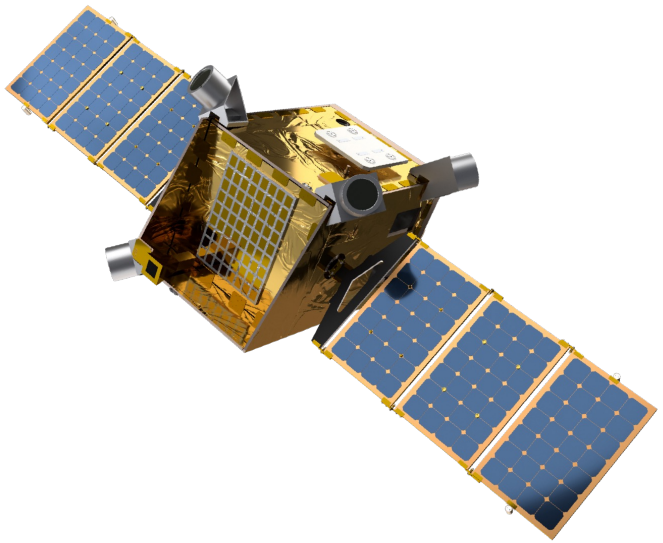


Summary



MoonBEAM provides essential gamma-ray observations of relativistic astrophysical transients with the following capabilities:

- instantaneous all-sky field of view from lunar resonant orbit.
- 13+ days of uninterrupted livetime.
- stable background for ultra long duration GRBs.
- sensitive to prompt GRB emission energy range, with broad coverage for spectroscopy.
- independent localization and longer baseline for additional localization improvement with other gamma-ray missions.
- rapid alerts to the astronomical community for contemporaneous and follow-up observations.

Potential future collaborations with MoonBEAM:

- LIGO Laboratory
- IceCube Neutrino Observatory
- InterPlanetary Network for Gamma-ray Bursts
- Cherenkov Telescope Array Consortium
- Southern Wide-field Gamma-ray Observatory

Received Funding through the NASA Mission of Opportunity for Phase A Study!!

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Thank you for your attention!

Speaker Name Last name*

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