Gamma-ray Bursts and Gravitational Waves

Gamma-ray Burst (GRB)
- Merger of two compact objects or collapse of a massive star.
- Collimated relativistic outflow.
- Prompt keV-MeV emission, afterglow in other wavelengths.
- ~ once per day, isotropically distributed.

Gravitational Wave (GW)
- First observed by LIGO in 2015, merger of two blackholes.
- Merger of two neutron stars observed in 2017 — GW170817:
  - 1.7s after merger, GRB 170817A detected by Fermi-GBM and triggered extensive electromagnetic followup resulting in detection of a kilonova.
- First association between gravitational wave and short gamma-ray burst from a binary neutron star merger.

Increasing Sky Coverage and Localization Improvement

- Current Fermi-GBM is the most prolific GRB detector, it has a sky coverage of ~70% and location precision no better than a few degrees.
- Adding another instrument in a different orbit will increase the number of GRB detections and improve localization via arrival time difference.
- The Interplanetary Gamma-Ray Burst Timing Network demonstrated an average improvement by a factor of 180 relative to Fermi-GBM when combining with additional detection from another spacecraft in a different planetary orbit.
- Why near the Moon:
  - Low Earth Orbit is <0.1s, improvement to only top 5% brightest short GRBs.
  - Cislunar space can improve localization for 20+ short GRBs per year, more if searching below trigger threshold events in continuous data coincident with triggers from another instrument.
  - A reduction of >50% in area reduction is achievable for short GRBs with average brightness at a baseline angle of 45deg.
  - Outside of the Tracking and Data Relay Satellite (TDRS) network, data downlinks delay prevents rapid followup. In cisluunar space, fast communication is still possible with current technology and limitations.

MoonBEAM

- 12U CubeSAT designed with high TRL components, most are already flight tested.
- 2-year mission duration, 1-year minimum.
- Earth-Moon L3 halo orbit provides a baseline of 0.3-2.1s when paired with an Earth-orbit instrument.
- Science instrument consists of 5 detector modules positioned in 5 of the 6 sides of the instrument. Each module will contain a 12.7cm x 12.7cm NaI scintillation crystal coupled to an array of Silicon photomultipliers.

Joint scientific results
- Tightest constraints on speed of gravity.
- Constraints on neutron star equation of state.
- Open questions: merger and jet geometry, intrinsic properties, population characteristics.

Right: Tiling observations done by different instruments for the first GW detection sky contours [ApJL 826, L13, 2016].
Most instruments have small viewing and rapid followup is difficult when localization area is large.

Right: Localization area reduction relative to Fermi-GBM assuming 385,000 km baseline for short GRBs with different intensities.