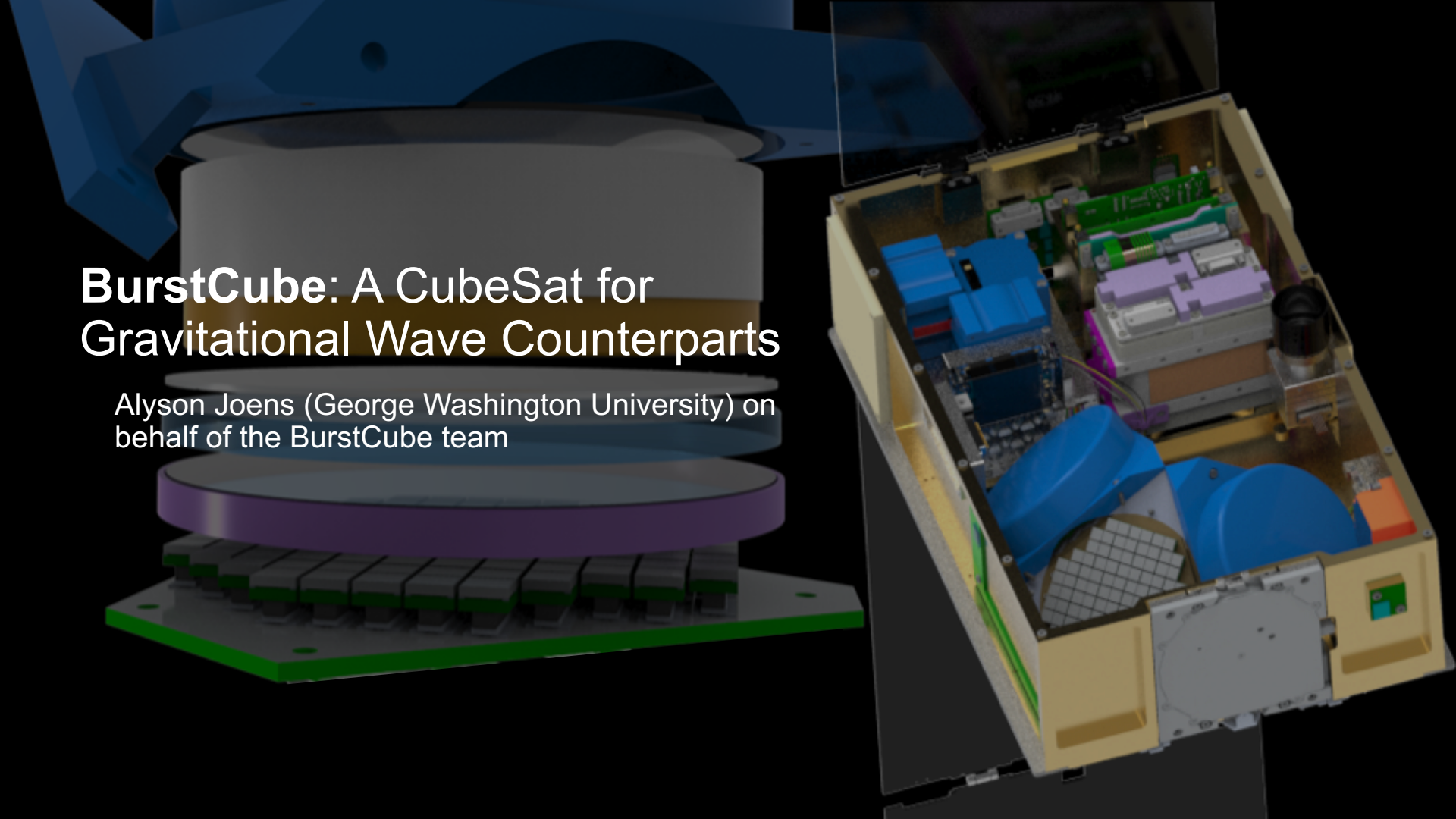
BurstCube: A CubeSat for Gravitational Wave Counterparts

Alyson Joens (George Washington University) on behalf of the BurstCube team



BurstCube Team

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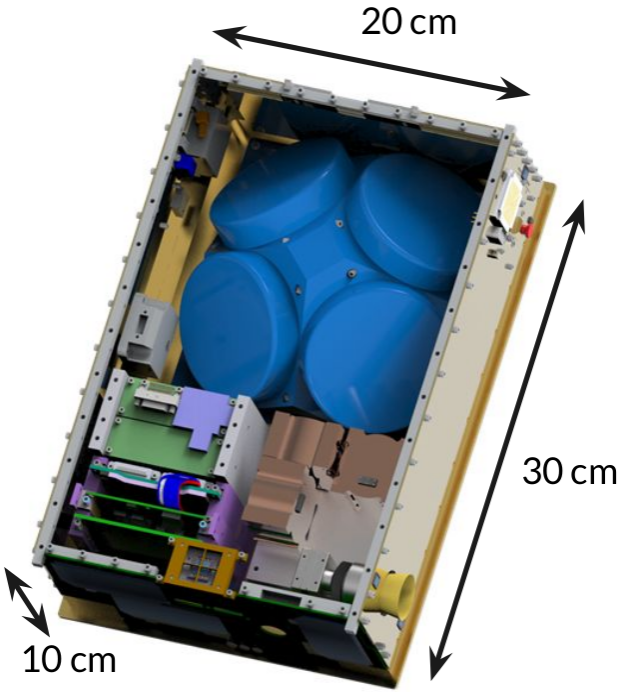
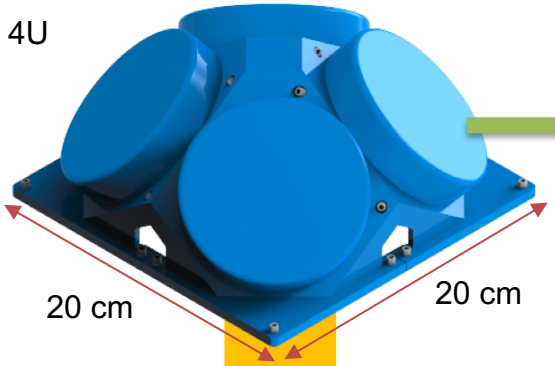
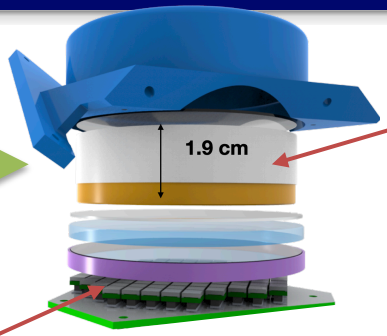
Overview

- 6U CubeSat with the **primary science goal to detect, localize, and characterize short gamma-ray bursts** (SGRBs)



BurstCube Instrument

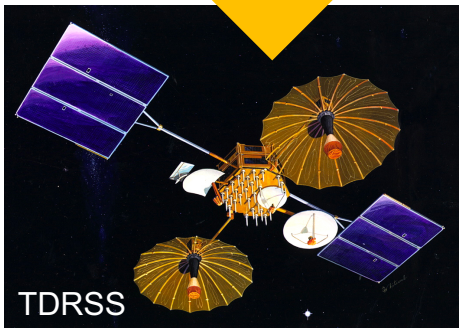




CsI(Tl) Scintillator Crystal

Silicon Photomultipliers (SiPMs)

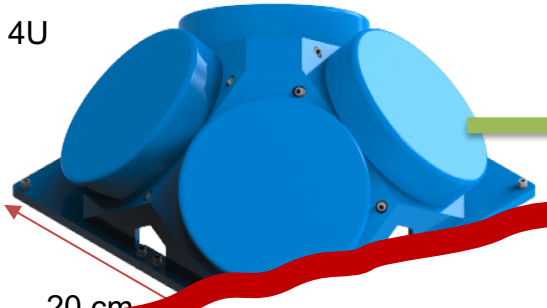
Energy range: ~50 keV- 1 MeV

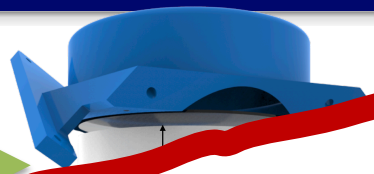


NEN

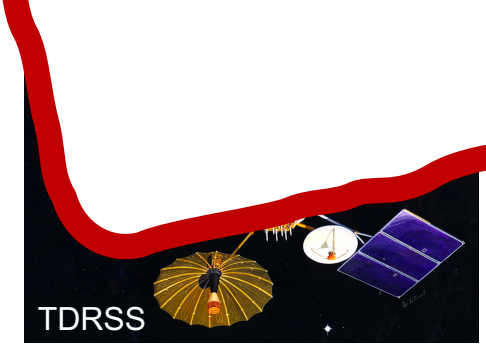
Science Data: Once Daily (NEN)
Alert Data: Instantaneous (TDRSS)

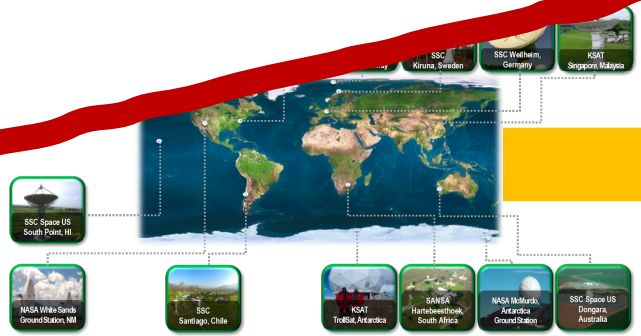
BurstCube Instrument





Coming 2022!





NEN

Science Data: Once Daily (NEN)
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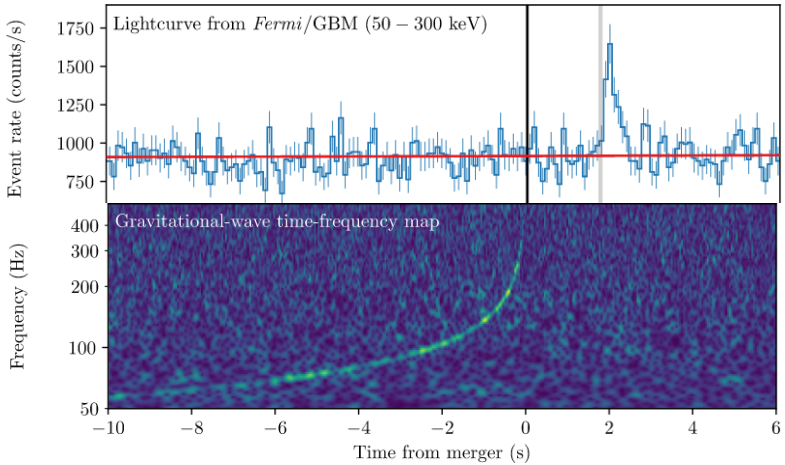
BurstCube Science - Why now?

- Joint detection of GRB 170817A and GW170817
  - Proved that binary neutron star (BNS) mergers are progenitors of SGRBs
  - Constraints on speed of gravity:
    - differs from speed of light by 1 part in 10^15
  - Constraints on neutron star EOS

- Questions remain:
  - Spectral properties observed in GRB 170817A a signature to these events?
  - What is the origin of gamma-ray emission?
  - What is the structure of relativistic jets?

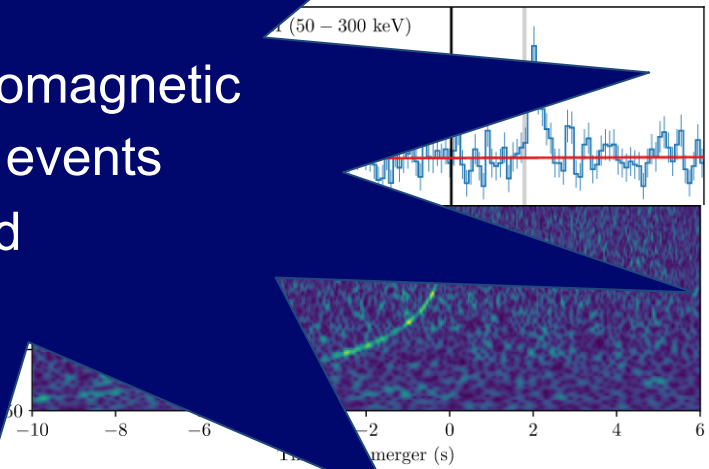


Abbott, et. al. 2017 arXiv:1710.05834

BurstCube Science - Why now?

- Joint detection of GRB … 17A and GW…
  - …d that binary ne… (BNS) … rogenitors of SGRBs
  - …
- …
  - …
  - What is the…
  - What is th… je…

BurstCube will provide electromagnetic context to gravitational wave events detected by **LIGO, Virgo**, and **KAGRA.**



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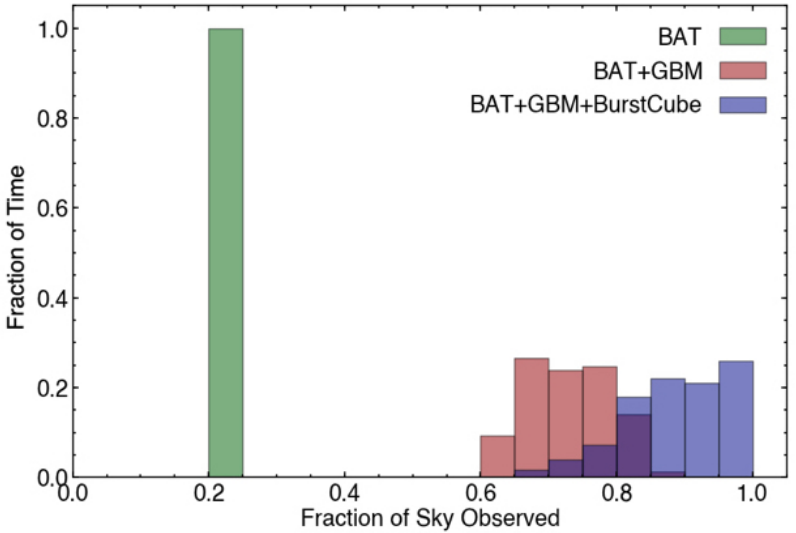
BurstCube Science - Why now II?

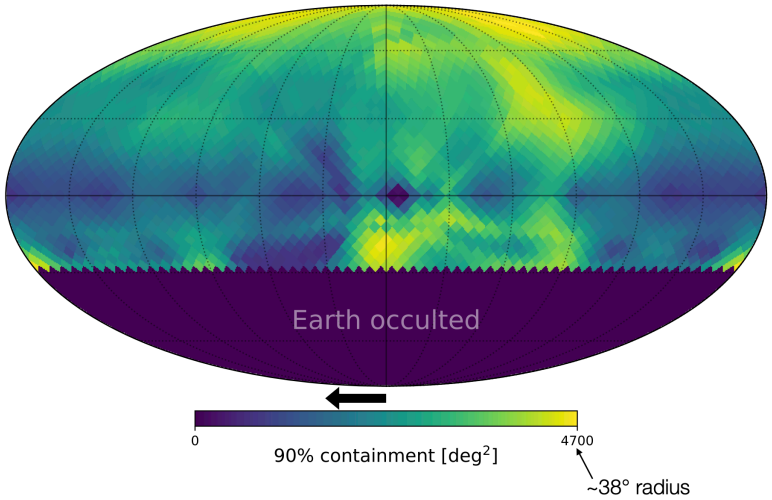
- Complement current, funded, and proposed missions
  - Current: Fermi, Swift, ect.
  - Future: Glowbug, StarBurst, LEAP ect.
  - Proposed (2025+): MoonBEAM, etc.
    - Increase sky coverage
    - Detect and localize bursts



See: Jeremy S. Perkins et al. http://dx.doi.org/10.1117/12.2562796

BurstCube Science-What else?

- Enable wide-field follow-up observers in afterglow detection and redshift measurement.
- Will lead to:
  - additional insight into cosmological parameter estimation,
  - constraint on the neutron star equation of state, and
  - an inventory of r-process elements in the Universe.



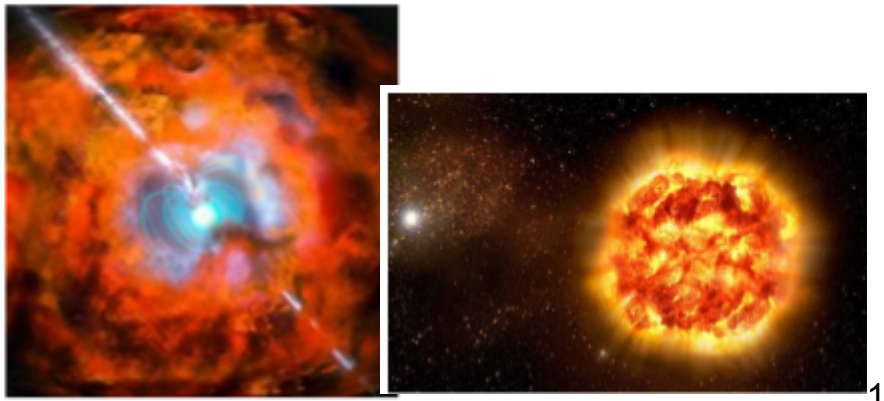
BurstCube Science- What else II?

- BurstCube will **detect** GRBs from the **entire unocculted sky**
  - Broadband spectra
  - Rough localizations for follow-up
  - Accurately timed light curves
- BurstCube will also **detect solar flares, magnetar flares,** and other **transients.**
- Combined with Fermi and Swift, BurstCube will provide all-sky coverage for a **small fraction of the cost** of an Explorer mission

Mission Performance

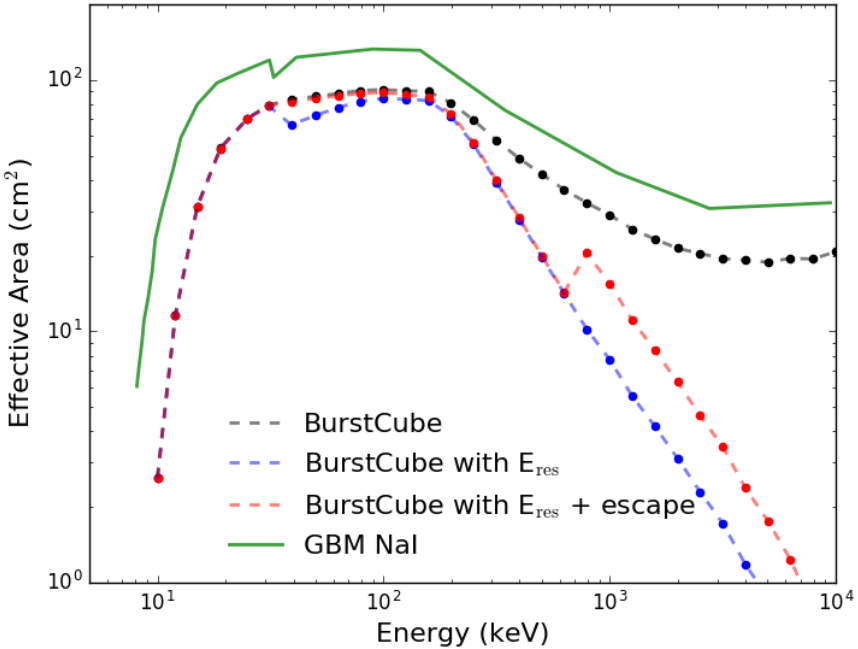
Energy range: ~50 keV - 1 MeV
Energy resolution: 10% at 662 keV
Field of View: ~50% of the sky (instantaneous)
Localization goal: ~30 degrees (90% of bursts)

BurstCube:
SGRBs: ~20 per year
LGRBs: >100 per year
GBM:
SGRBs: ~40 per year
LGRBs: ~200 long per year



Mission Performance-Effective Area

Effective area is 70% that of the larger GBM NaI detectors at 100 keV and 15 degree incidence



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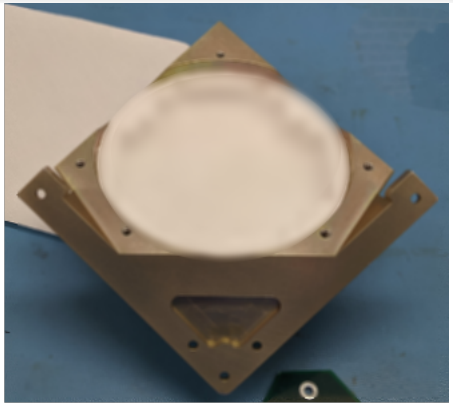
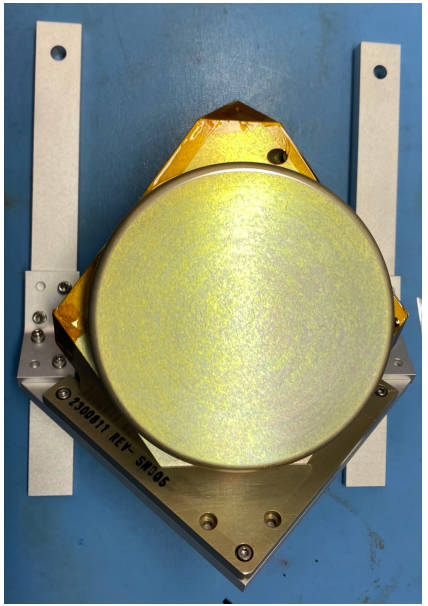
Current Status

- Detectors being assembled
- Front end electronics undergoing final testing
- Initial detector testing initiated
  - Crystal Uniformity testing
- Functional tests of S/C components completed
- bc-tools being developed
  - Detector agnostic library for counting gamma-ray instruments
  - Open source: **https://gitlab.com/burstcube/bc-tools**



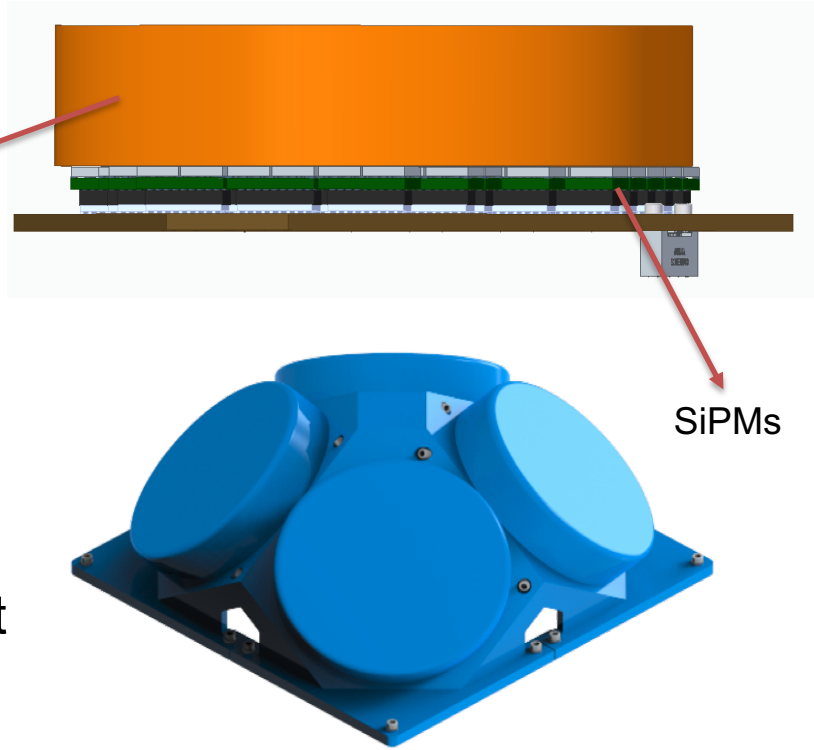
Detector crystal assembly



Detector in GSE

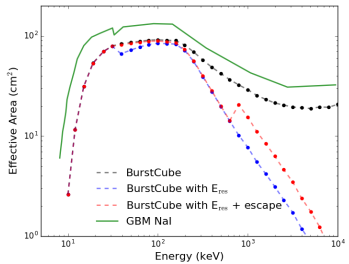
Upcoming Activities

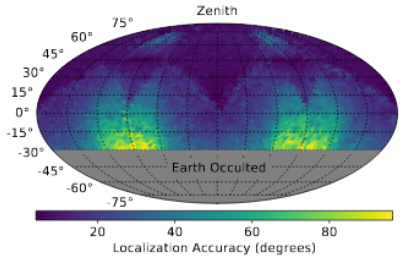
- Characterization of analog boards and SiPMs
  - Noise
  - Low energy response
  - Dynamic range
  - Gain and breakdown voltage
- Calibrations
- Integrate detectors into final instrument configuration



Instrument Calibration

- Localization and energy spectrum of a GRB are derived from the instrument energy dependent angular response
  - Ground calibrations prior to launch are critical





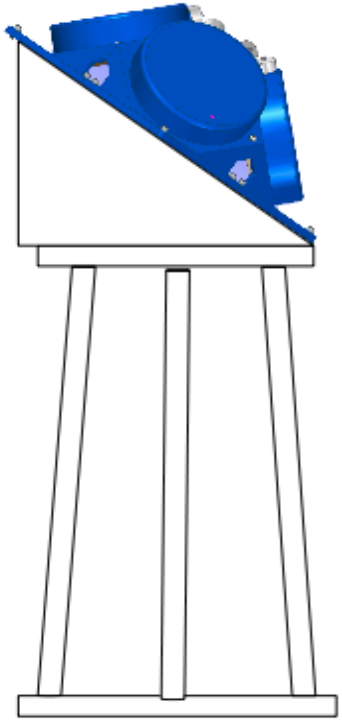
Simulations
Predict

Physical tests
Validate

Detector response matrix
Create

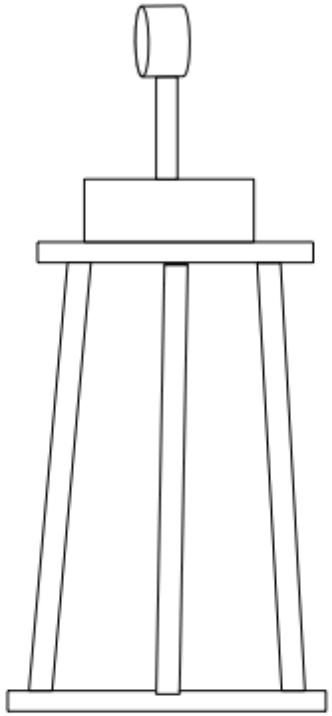
Instrument Calibration

BurstCube Instrument



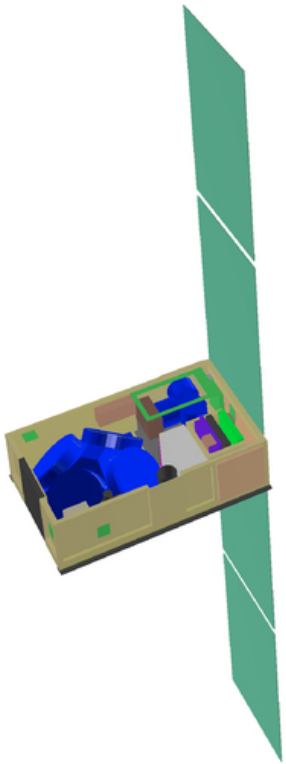
- Calibration measurements will utilize various calibrated radioactive sources in the energy range of BurstCube.
- Calibration Campaigns:
  - Flight Spare
  - Instrument
  - Spacecraft
- Instrument properties:
  - Channel-energy relationship
  - Effective area
  - Energy resolution

Source Holder



Conclusion

- BurstCube: a 6U CubeSat that will detect and localize GRBs
  - focus on counterparts of gravitational wave (GW) sources
- Four CsI(Tl) scintillators coupled with arrays of compact low-power SiPMs
- Complements existing and future facilities
- Detector assembly and testing has begun
- Reach launch readiness 2022



THANK YOU!