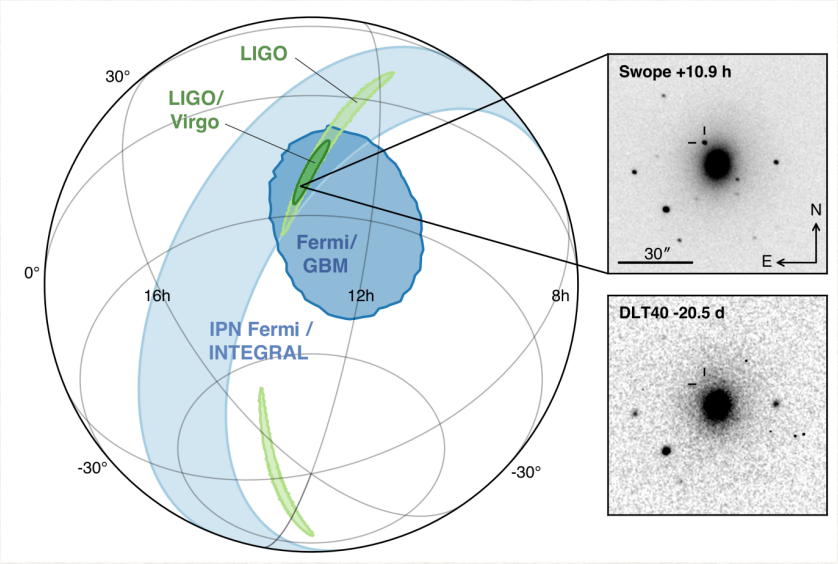
GAMMA-RAY-BURST LOCALIZING INSTRUMENT GALI

EHUD BEHAR

WELL KNOWN MOTIVATION

ENHANCED BY NEUTRON STAR BINARY MERGER GW/GRB 170817

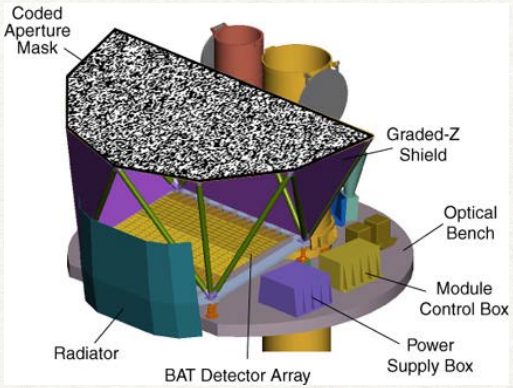
- LIGO/VIRGO => ~30 deg^2
- Fermi/GBM => ~1000 deg^2
- ~11 hrs of scanning galaxies with optical telescopes from the ground => kilonova in NGC 4993, only 41 Mpc away
- Not so lucky in O3
- This method of scanning galaxies will become increasingly prohibitive as LIGO increases its range to 160-190 Mpc for NS mergers
- Can we do better?

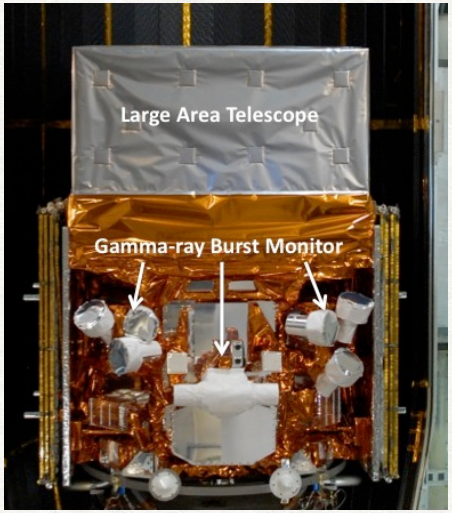


GRB LOCALIZATION

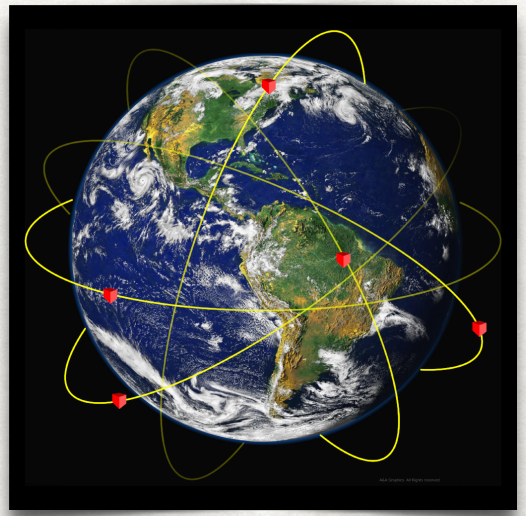
METHODS

- Coded Mask
  Swift/BAT 17′ FWHM
  (4′ centroid), FoV 1.4 sr
  SVOM/ECLAIR





- Projection on thin disks
  Fermi/GBM >3°, FoV 10 sr
  14 large detectors (115 kg),
  also BATSE, BurstCube, SVOM/GRM

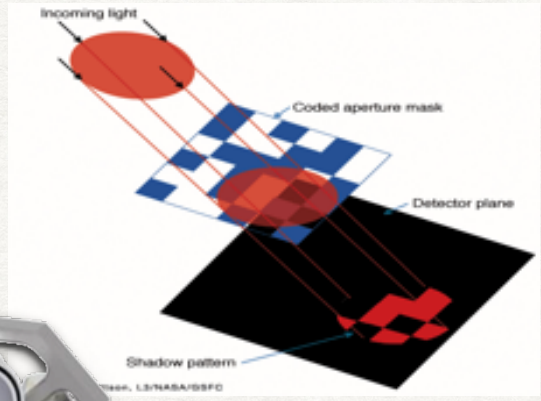


- Differential Time of Arrival between satellites
  IPN, and soon HERMES / CAMELOT ~1°,
  and increasing with #satellites

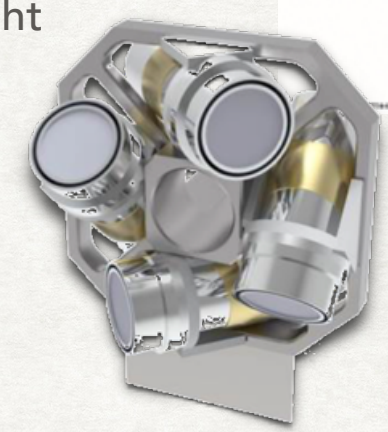
GRB LOCALIZATION METHODS

PRINCIPLES, PROS & CONS

- Coded Mask
  based on unique masking signal per direction
  - Excellent localization
  - Inherent tradeoff between FoV and resolution, lost photons on mask => heavy weight



- Thin-Disk scintillators
  based on simple geometric projections
  - Excellent FoV, & high count rates
  - Poor localization

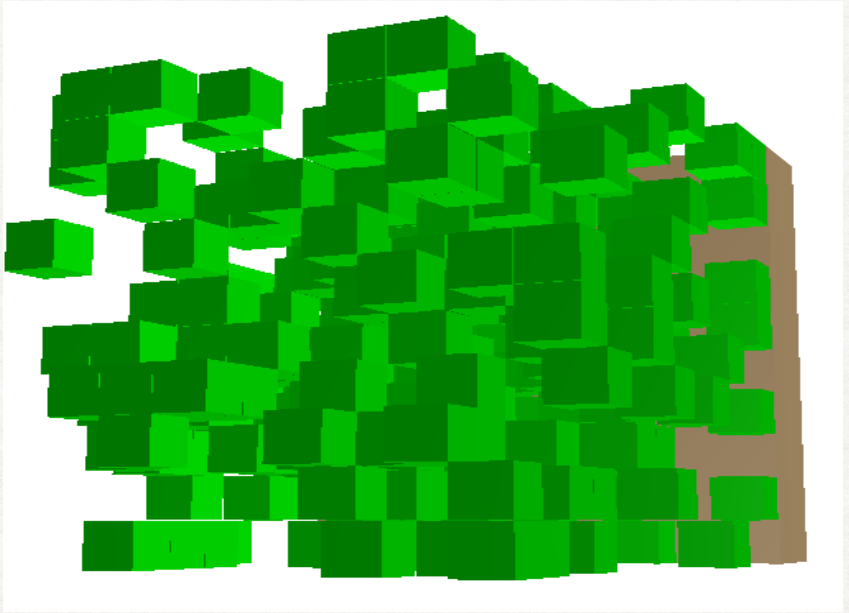


- Differential Time of Arrival
  based on correlating GRB light curves between remote detectors
  - Potentially unlimited localization accuracy
  - Accuracy limited by cross-correlation signal
  - Involve many simultaneously operating satellites

GALI - OUR CONCEPT

DETECTING 3D CODED MASK

- Compact array of many small scintillators
- Localization comes from mutual shading /masking
- Enabled by SiPM technology
- No photons lost
- Retain large FoV & sensitivity
- Totally scalable sizes



IMMEDIATE CONCERNS

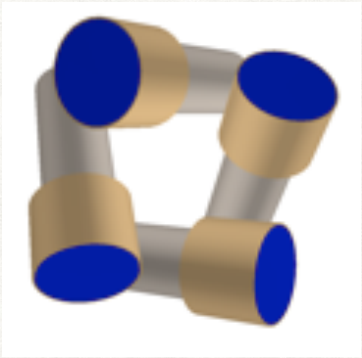
AND WHY IT WORKS NONETHELESS

- Low count rate on each detector
- Background dominated detectors
- Lose directional information with symmetric shape - cubes
- On the other hand,
- Directionality obtained statistically, from unique photon-count pattern for each burst direction, with high total statistics
- Majority hidden scintillators see almost no background.
  For lines of sight (through holes) each source photon matters
- Compactness crucial so flat disks less advantageous

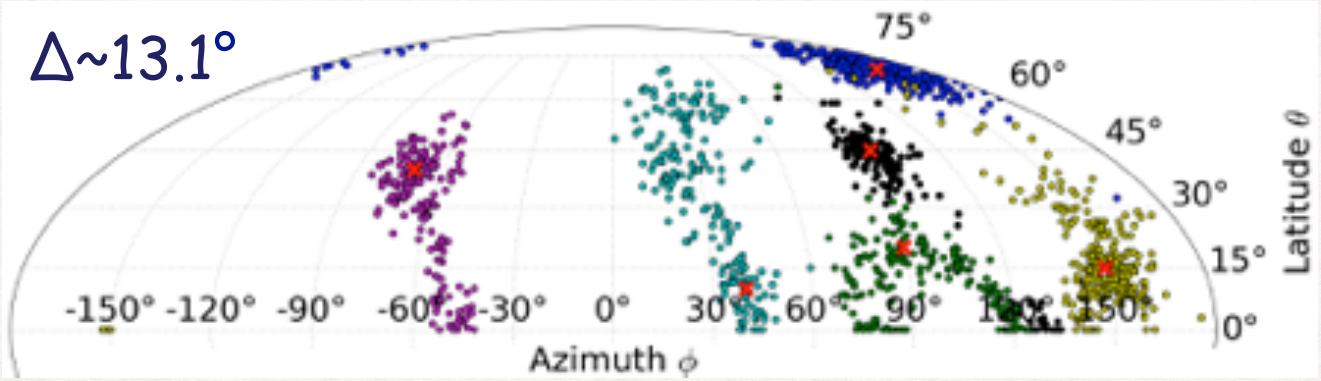
SIMULATIONS*

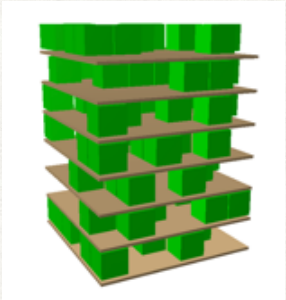
1s GRBs of $F_{10\text{-}1000keV}$ = 10 ph/s/cm^2 (w/bg)

Roi Rahin

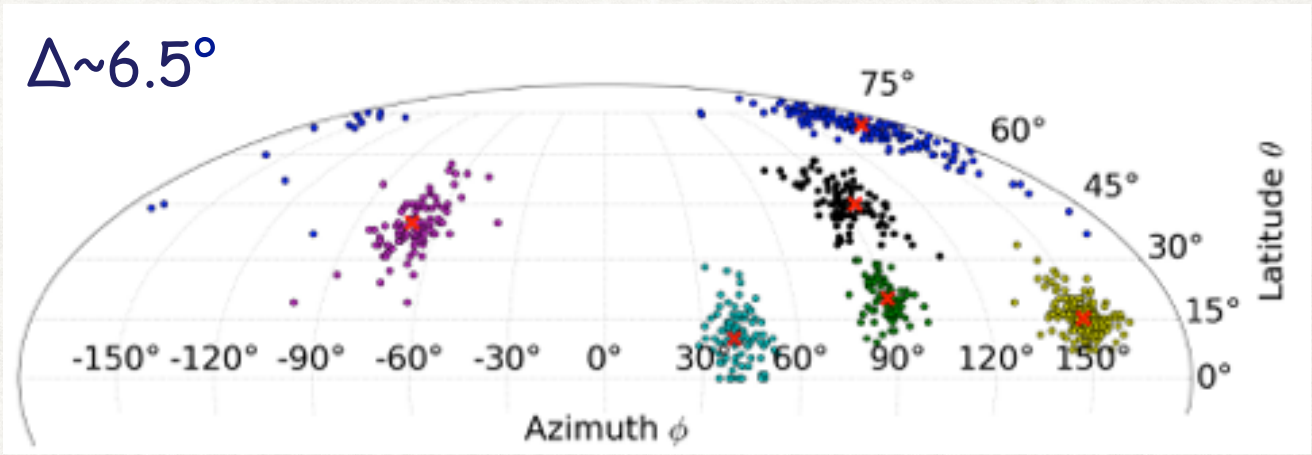


Four 2.5"x1" scintillators





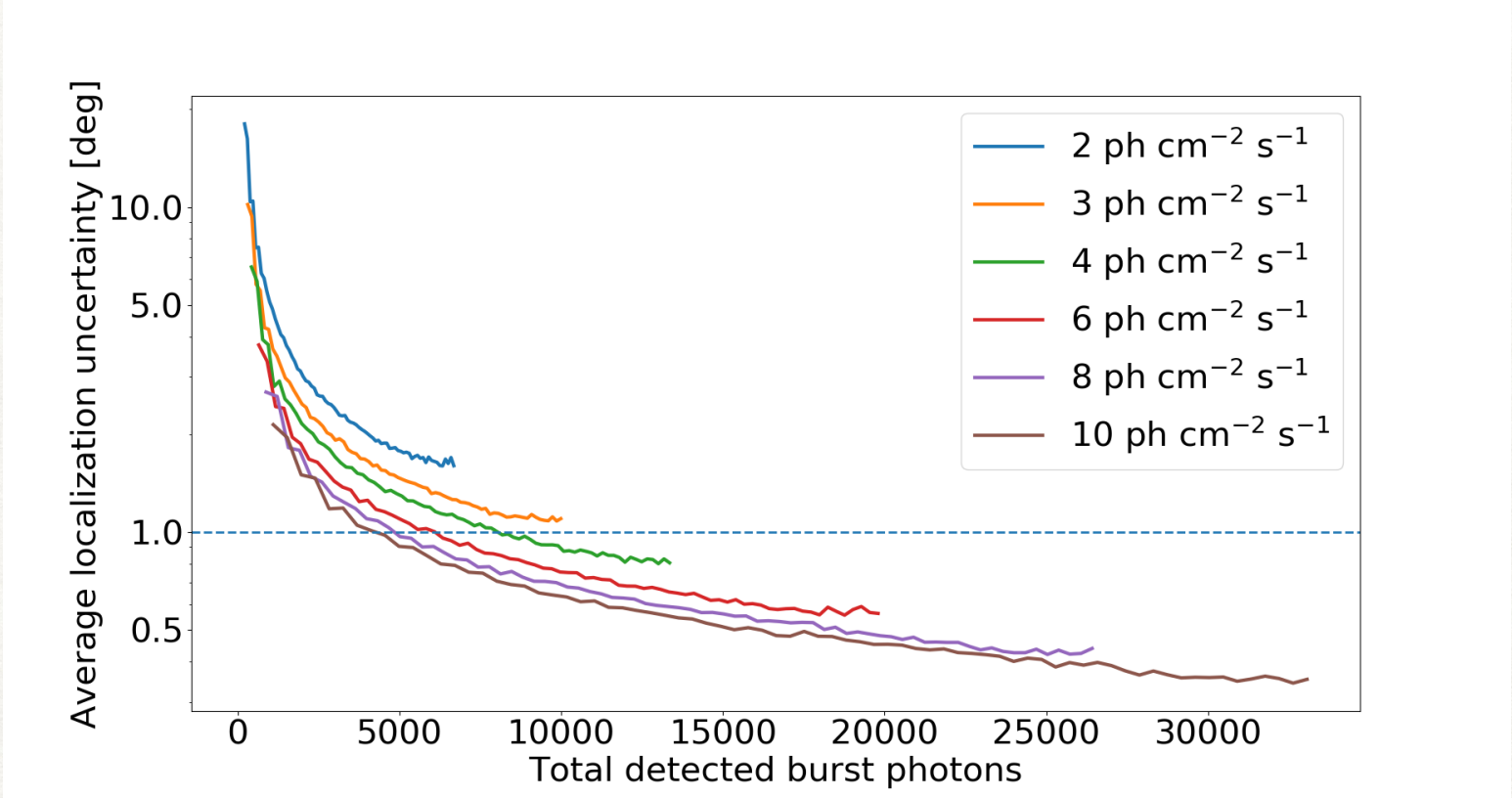
(much smaller) 90 ~1x1x1 cm^3 scintillators



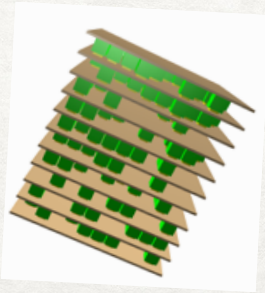
*MegaLib/geant4 by A. Zoglauer+

OF COURSE IT DEPENDS ON GRB FLUENCE

AND FLUX (10-1000 keV)



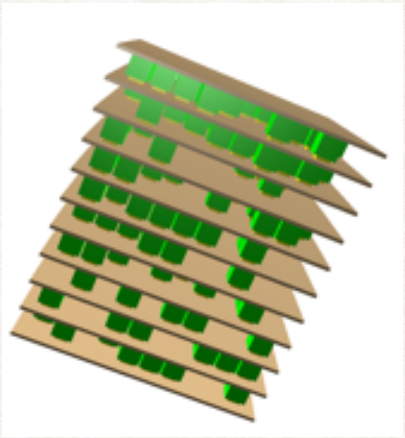
few 1000 counts => few degrees accuracy



IMPROVING WITH #SCINTILLATORS

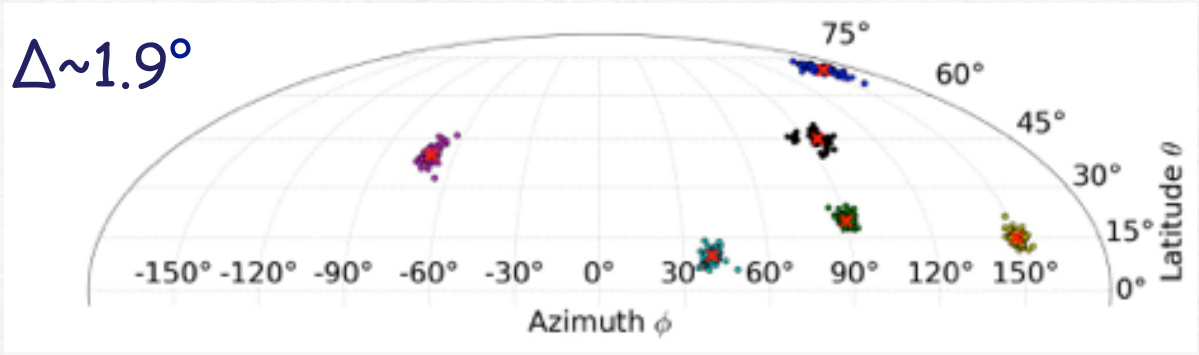
MORE SIMULATIONS

(1U)

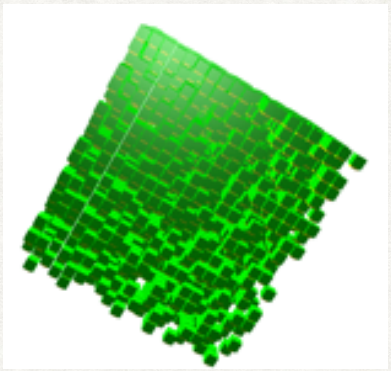


350 1cm^3 scintillators

Δ~1.9°

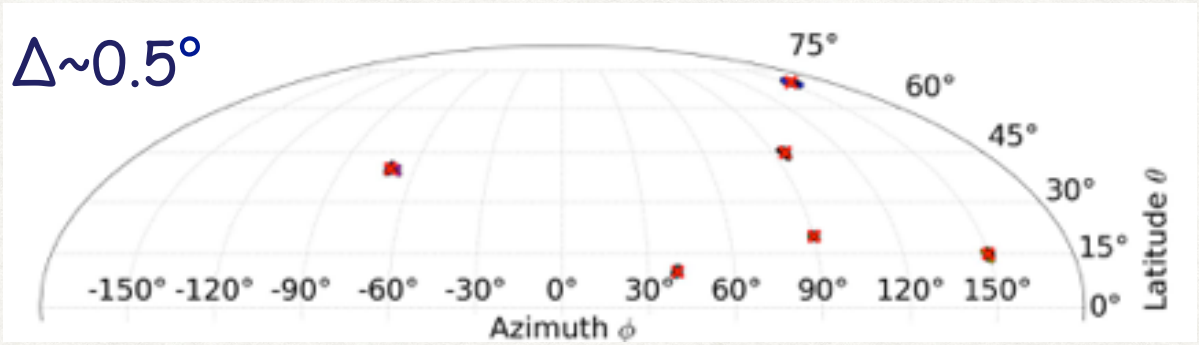


(8U)



2800 1cm^3 scintillators

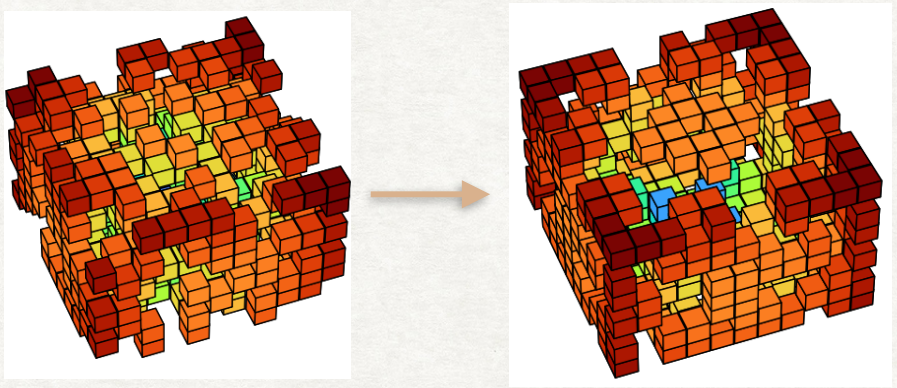
Δ~0.5°



HOW TO ORGANIZE THE DETECTORS?

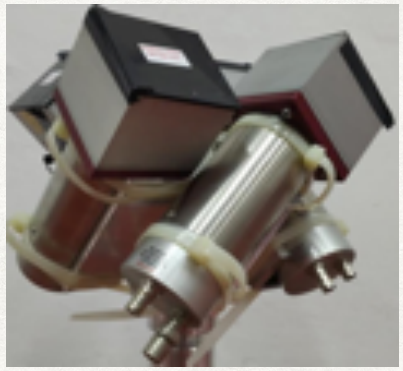
GOOD QUESTION

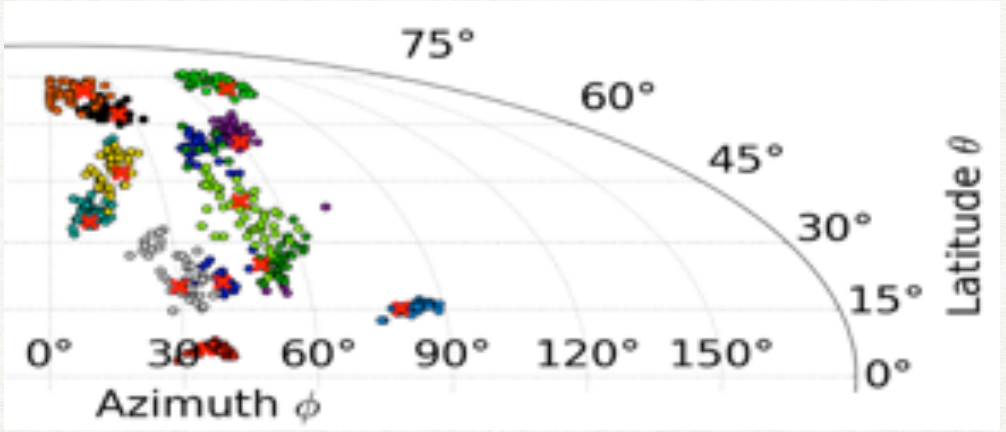
- To zeroth order, no idea
- Involves two questions:
  - Filling factor
  - Configuration
- Simulations show
  - ~30%, no cross through
  - Random does it
  - Some optimization is possible, but often counter productive
  - Support structure and boards can change the picture

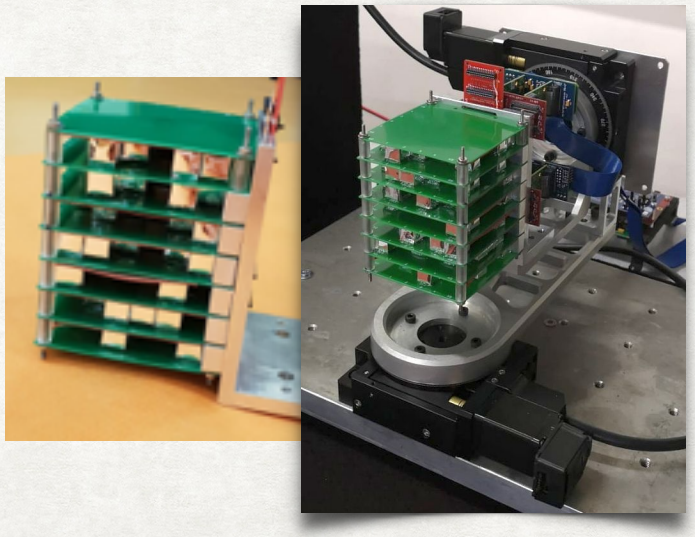


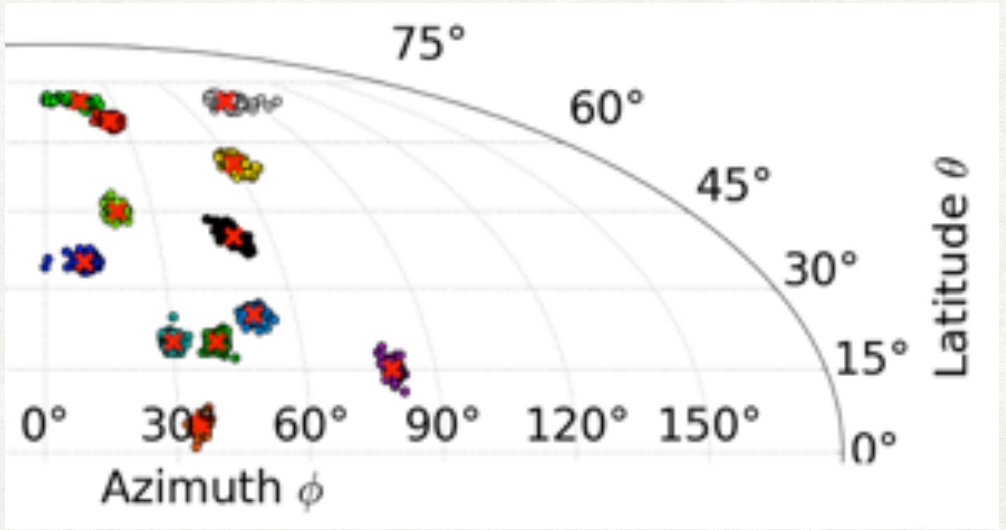
PROTOTYPE EXPERIMENTS

WITH 25 ph/cm^2 IN THE ^{241}Am 60 keV LINE



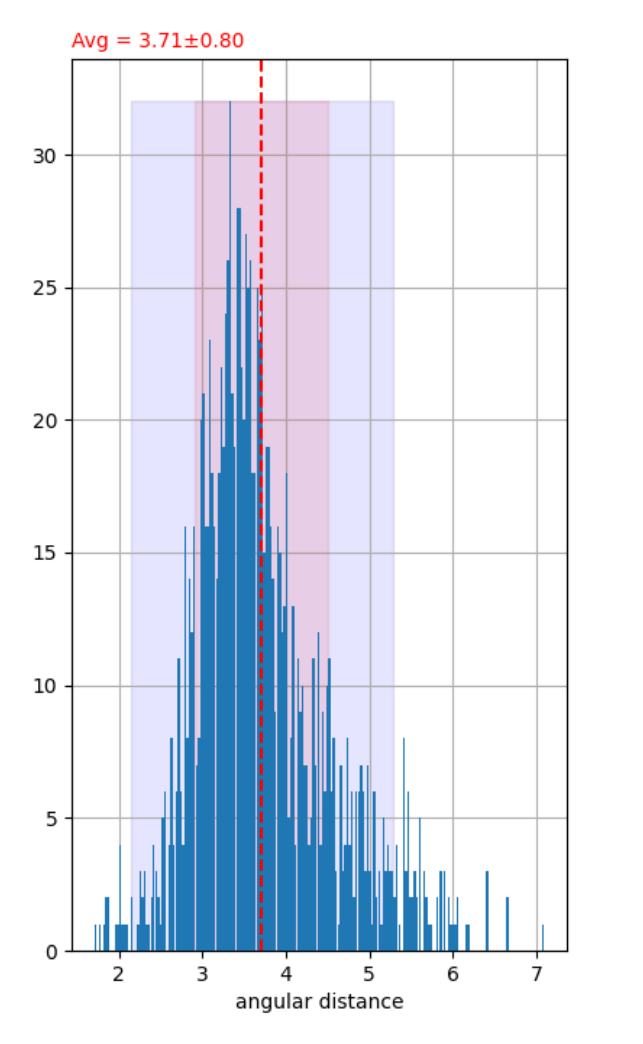


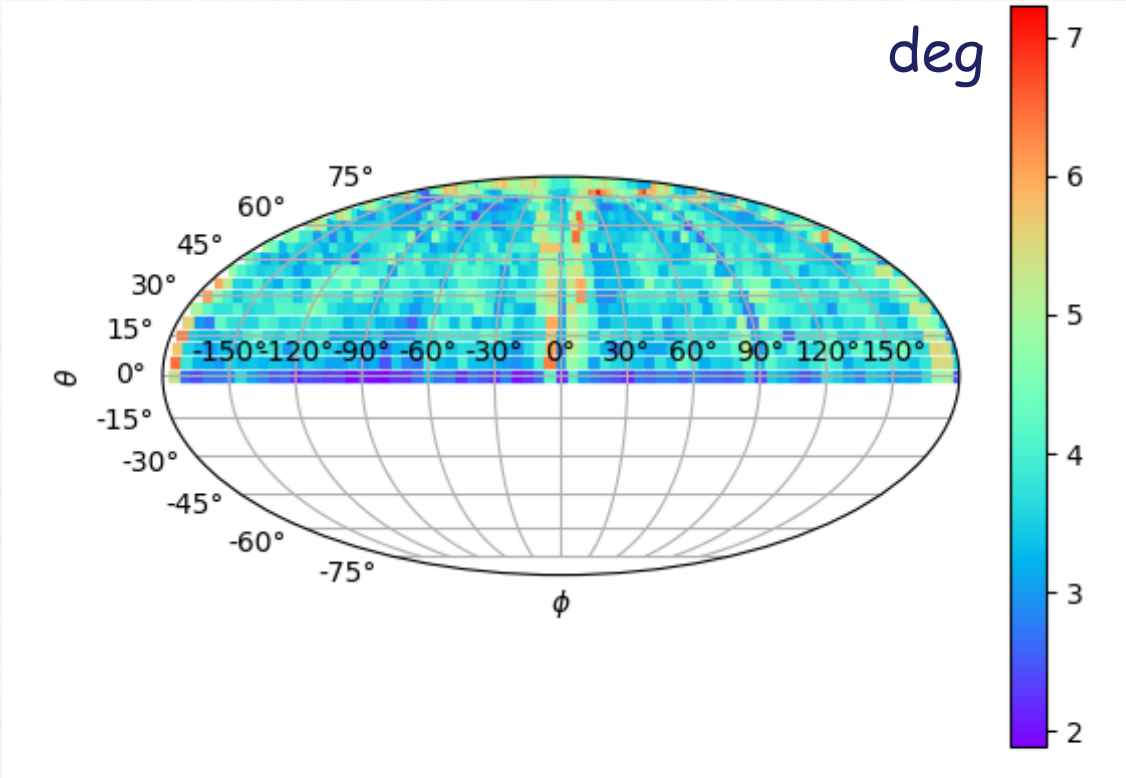




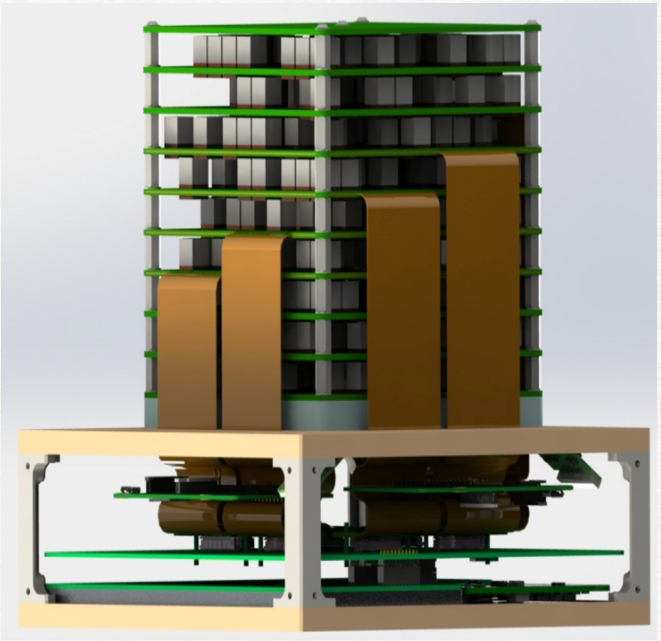
OMNI DETECTION, NO PREFERRED DIRECTION

(STILL IN THE LAB)

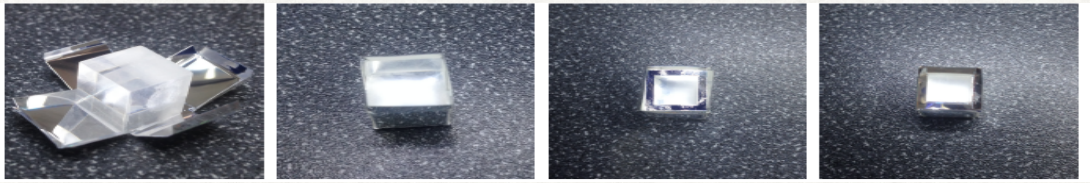


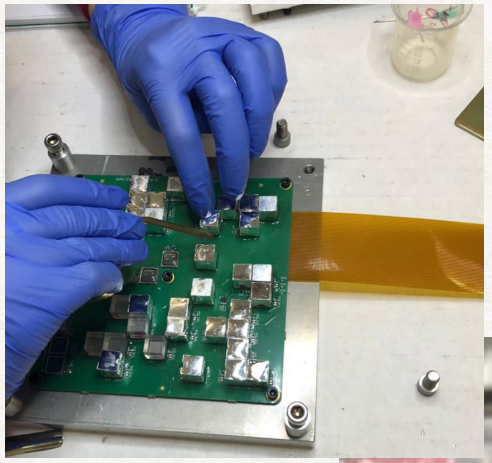


BUILDING GALI TO FLY



wrap

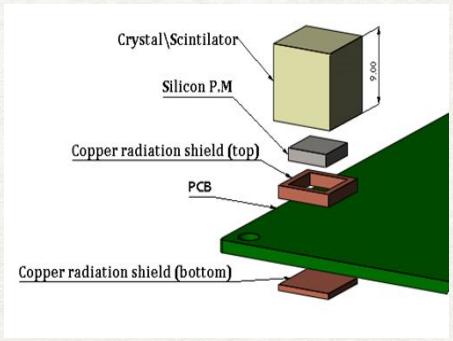




glue

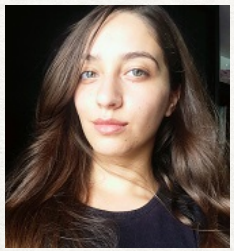
print on polimide boards

protect SiPM



FULL MODULE

W/ 362 SCINTILLATORS



Julia Salh

GALI, BRIEFLY

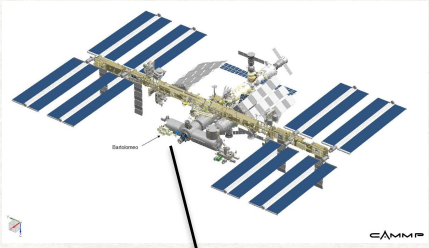
SOME OBVIOUS ADVANTAGES

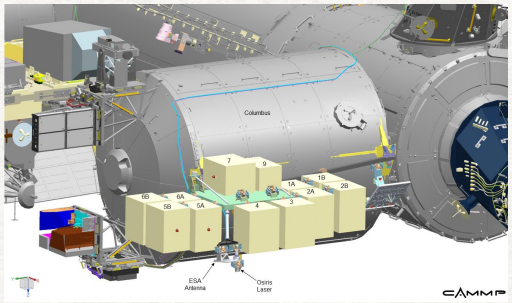
- Excellent localization on a single instrument/satellite
  - owing to mutual shading between scintillators
- No photons lost to mask/structure
  - detectors are the mask too
- Can be incorporated into a constellation
- Scalable, from cubesats to larger satellites
  - Provides better performance per mass/volume

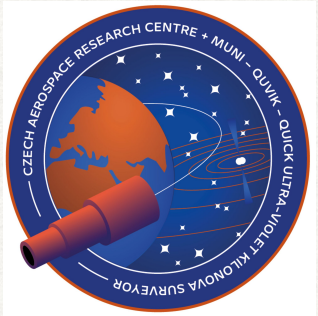
REMAINING CHALLENGES

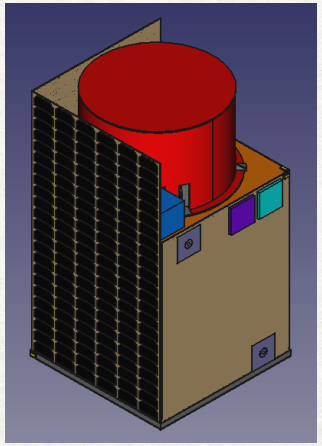
QUITE A FEW

- How to optimally distribute scintillators?
  - Choosing from random configurations
- Inflight calibration of 100s of scintillators
  - Internal (cosmic) activation?
- Multi-channel readout
  - Using medical-device (PET) ASICs
- Manual assembly
- SiPM radiation hardness
- Mechanical robustness
  - Tests ongoing
- Launch, funding:
  - considering ISS (Airbus),
    QUVIK (Czech 2027), and other options









GALI TEAM

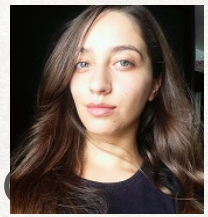
SCIENTISTS AND ENGINEERS

- PIs: Ehud Behar, Shlom

- Postdoc: leri

- PhD students: bi, Roi Rahin

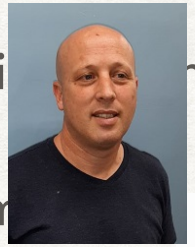
- PhD students: alh, Sharon Mitrani



- MSc/Project students: Zaberchik, Solomon Margolin, Omer Reic

- Sys. Eng. Avner Kaidar

- Elec. Eng. Alex Vdovi k Aglarian,

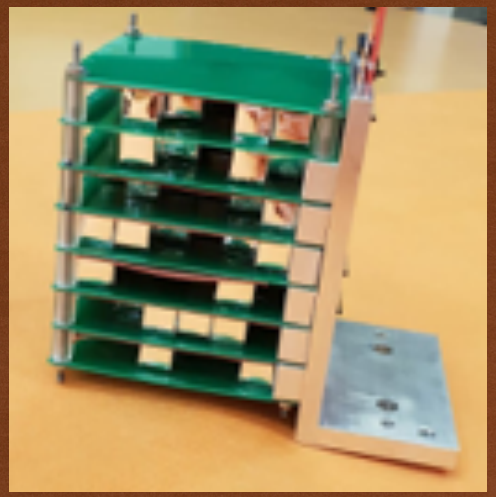


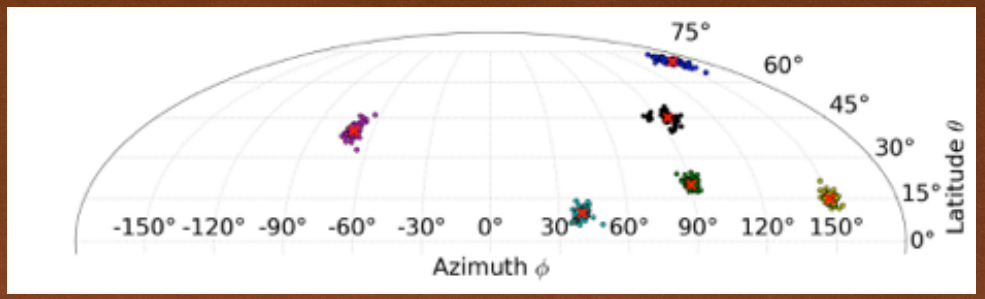
- Mech. Eng. Amir Fi m

- Zvi Tarem

- Thermal analysis: Yoel Arcos

- Advisory: Alon Max Gehlman, Eran





THANK YOU FOR YOUR ATTENTION