Future γ-ray Observatories in the Era of Advanced LIGO/Virgo

What's in the works, and how a concept becomes a mission ...

Judy Racusin (NASA/GSFC) &
Valerie Connaughton (UAH)

Why do we need space-based missions for joint γ-ray/GW science?

- short GRBs are likely related to NS-NS mergers
- γ-ray triggers are a good way to find them
- all (wide) sky coverage
- follow-up with low background rate of transients (e.g. soft X-ray)
- broadband observations to understand spectrum and energetics

Why we need to plan now?

- *Swift* and *Fermi* will not be operating forever ☹
  - both compete in NASA Senior Review every 2 years
  - both up for review in 2016 (to determine funding for 2017-2018)
- It takes years to go from proposal to operations
- Most successful mission concepts are proposed multiple times before selection
- Opportunities in relevant funding class arise rarely (~inversely proportional to $)
- Years of design, construction, testing, and reviews are necessary to get to launch

What new capabilities/ characteristics would be ideal for joint γ-ray/GW science?

Discovery	Follow-up
• all sky field of view • broad energy coverage • sub-degree localization (or better) • many sources • rapid notification	• rapid responsiveness • arcsec-arcmin localizations • wide field of view (degrees) • Automated pipelines to search for afterglow

NASA astrophysics mission types

- **“Suborbital” program** (rockets, balloons, cubesats) - smaller payoad, shorter lead time to launch
- **Explorer program** (small:SMEX and medium:MIDEX) - propose to an opportunity (every 1-2 years) on any topic i.e., not a predefined scientific topic. Peer review determines acceptance.
- **Probe-class mission**: medium-size, science in NASA roadmap
- **Flagship mission**: in roadmap - decadal survey of field - and main focus of NASA (currently JWST, next WFIRST)
- Nothing for us at high energies in current decadal review (from 2010) - limited to Explorers and suborbitals
- Need to get the community behind probe-class concept!

How does one propose a mission?

- Plan for relevant AO (Announcement of Opportunity) is coming (ESA M-class downselect - 2015, NASA MidEX - 2016)
- Start 1+ year before that
- Plan
  - Evaluate technologies and any needed technology development
    - potentially write technology development proposals
  - Find spare parts, reuse designs, already space qualified components (if possible)
    - necessary for lower cost missions
    - need high TRL (Technology Readiness Level) components
  - Plan science strategically - why now?
  - Find team with right science/technical expertise
  - Available launch vehicles (sets mass & volume limits)
- Write Proposal (science, design, launch, operations plan)
  - with margins for cost, schedule, power, mass, volume, etc.
- Win Proposal (+further down select?)
- Design, Build, Integrate, Tests, Reviews
- Launch (and don’t blow up or fail on orbit)

Upcoming Space-Based GRB Missions

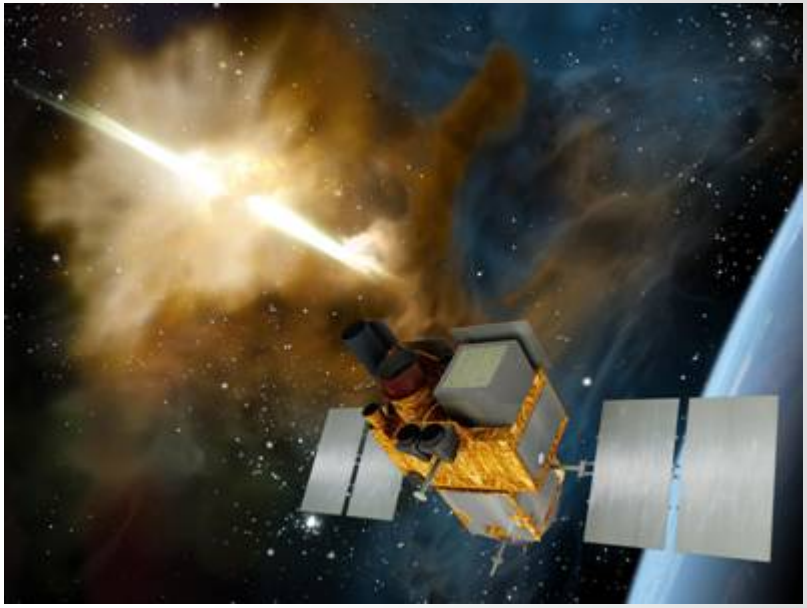
- SVOM (French/Chinese) - launch ~2021
- UFFO (Korean, Russian, Spanish) - pathfinder launching in 2015?

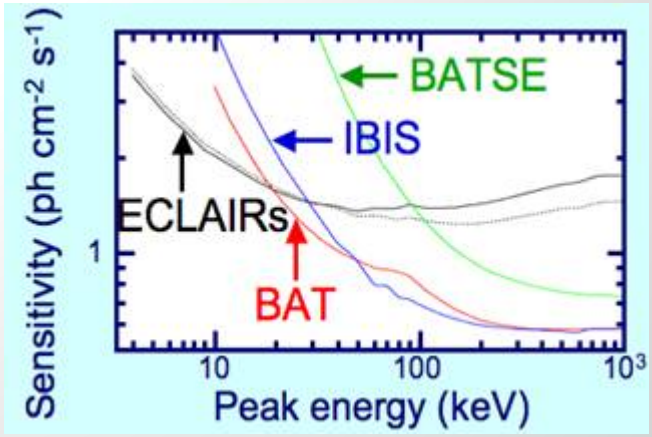
Upcoming Ground-Based Observatories that (may) Detect GRBs

- CTA (VHE, 2021?, small FoV)
- HAWC (VHE, now!, all sky)
- ZTF, LSST, etc. (optical, 2020?, 100's of deg^2)

SVOM (France, China)

- Approved and being built now
  - rapid GRB notifications requires ground VHF network
- **ECLAIRS**
  - 2D coded mask
  - 4-250 keV
  - 80° x 80° FoV
  - 10’ localizations
- **Gamma-ray Monitor**
  - 50 keV - 5 MeV
  - spectro-photometers
- **X-ray Imager**
  - microchannel Lobster optic
  - 0.3-7 keV
  - 1.1° FoV
  - 20” localizations
- **Visible Telescope**
  - 21’ x 21’ FoV





Proposed Mission Concepts

- ISS-Lobster (Explorer MoO, PI: Jordan Camp - NASA/GSFC, UMD, MIT, Leicester)
- XTiDE (Explorer SMEX, PI: Dave Burrows, Penn State, SAO, SwRI, Leicester)
- BurstCube (APRA, CubeSat, PI: Jeremy Perkins, NASA/GSFC, UAH, UMD)
- Einstein Probe (China)
- LOFT (ESA)
- THESEUS (ESA)
- others?

ISS-Lobster (NASA)
PI: Jordan Camp

Launch 2020 – 2+ year mission onboard ISS

Wide Field Imager (WFI)

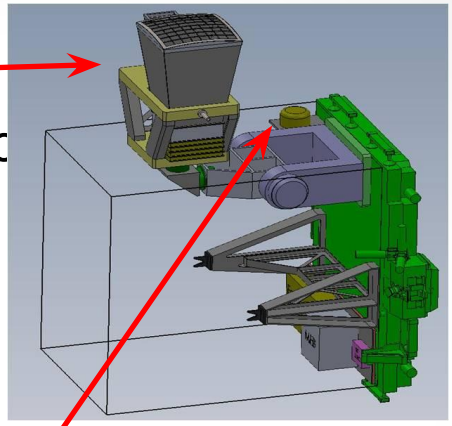
- Curved Microchannel plate optic

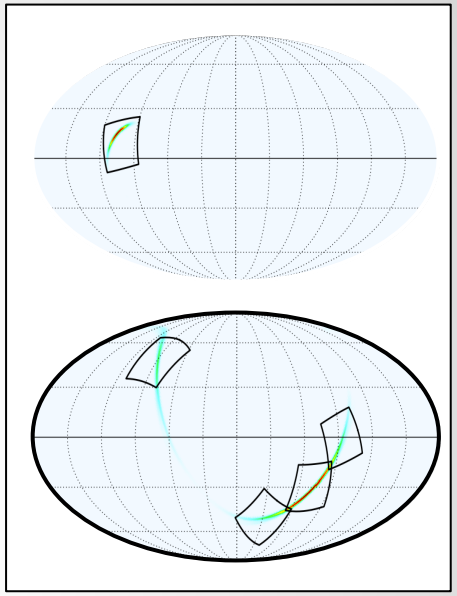
3x3 CCD array

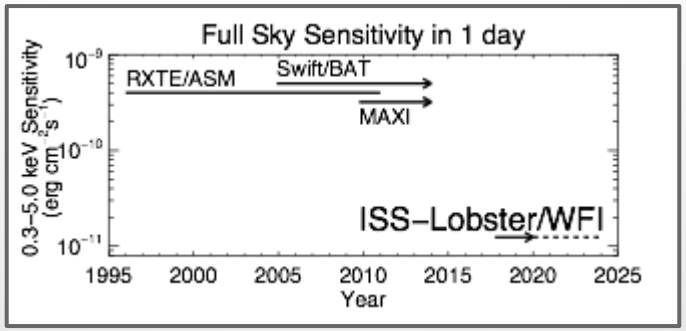
- 30 x 30 deg FoV
- 0.3-5 keV
- 1 arcmin localizations
- Rapid autonomous repointing

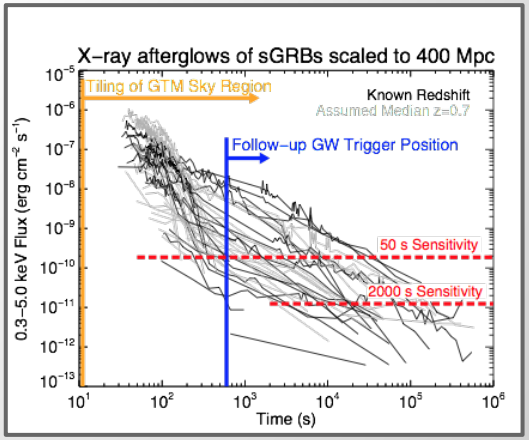
Gamma-ray Transient Monitor (GTM)

- Single NaI detector (GBM-like)
- 10 – 1000 keV
- 2π ster FoV (if unocculted by Earth or ISS)





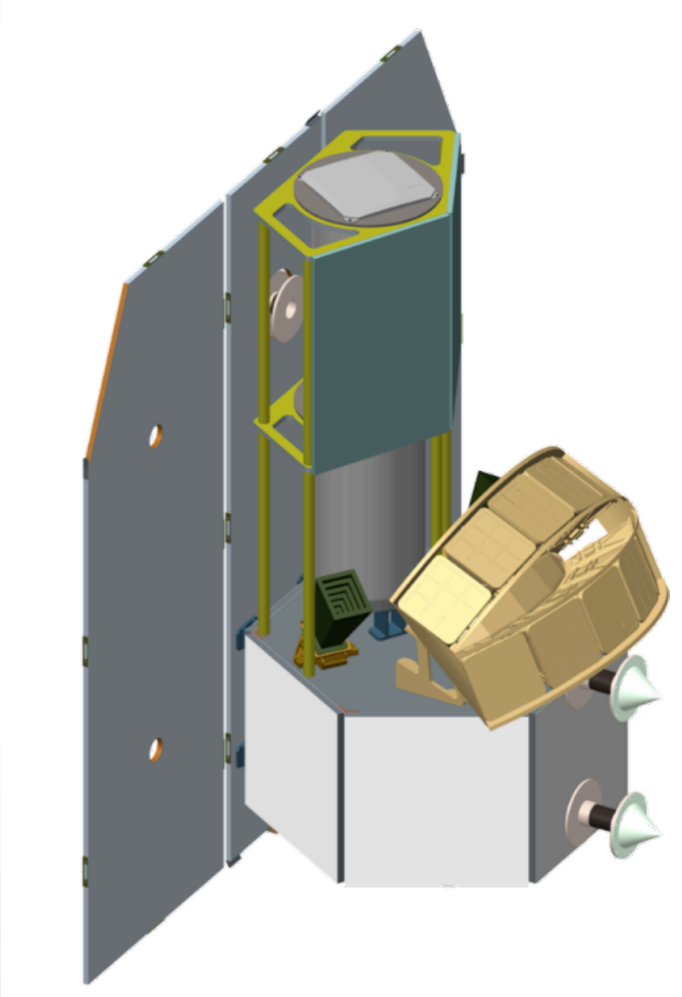




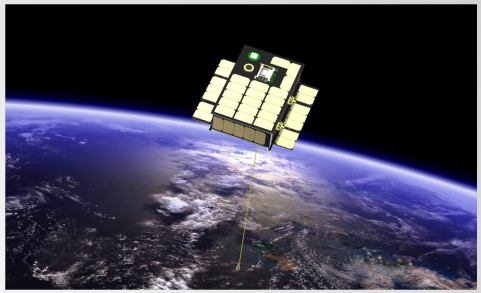
Submitted to 2014 Explorer MOO AO

XTiDE (X-ray Time Domain Explorer)
PI: Dave Burrows (PSU)

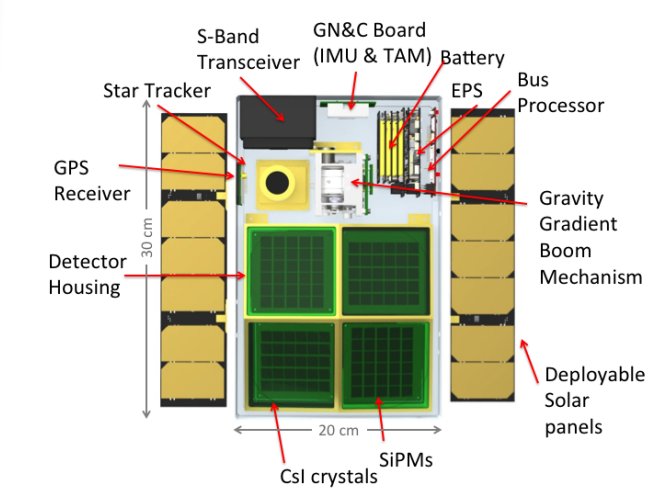
- **XLT (X-ray Lobster Telescope)**
  - Lobster optic (curved microchannel)
  - 0.5-10 keV
  - 2.5° radius FoV
- **XCAT (X-ray Coded Aperture Telescope)**
  - coded mask
  - 0.5-20 keV
  - 4 ster FoV
- Will explore GRBs, TDEs, SN shock breakout, extreme flares, and more

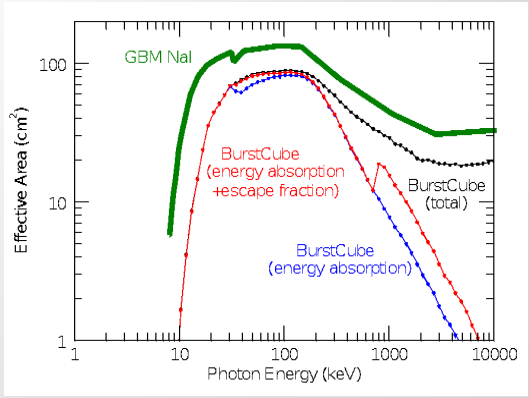


BurstCube (NASA)
PI: Jeremy Perkins



- Launch in 2019 – 1+ year mission
- LEO orbit
- CubeSat (6U = 20x30x10 cm)
- 4 detectors (CsI scintillator crystals + 12x12 SiPM arrays) – 10-1000 keV
- Similar operation to GBM, but optimized for short GRBs, simpler more compact design
- Localizations ~13+ deg radius
- Latency = 1-12 hours (depends on Near Earth Network for comm)
- adds ~15% sky exposure to *Swift*+ *Fermi* alone
- Eventual goal to have set of ~10 to cover full sky

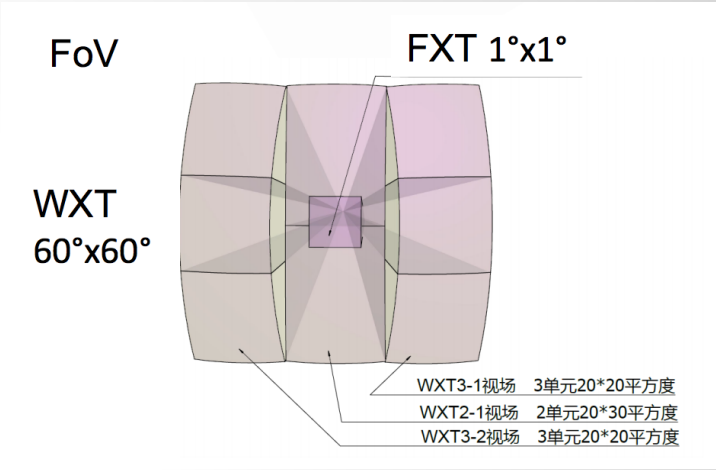


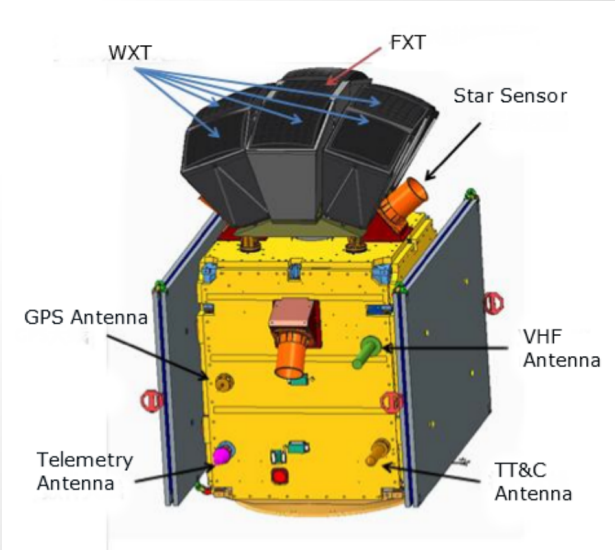


To be submitted to 2015 APRA (due next week)

Einstein Telescope (China)

- Selection in 2015, Launch in ~2020/2021
- micro-satellite, VHF comm
- **Wide-field X-ray telescope (WXT)**
  - Micro-pore lobster-eye focusing optics
  - Gas detectors (based line)
  - FoV 60°x60° (~1.1 sr), FWHM ~ 4’
  - 0.5-4keV
- **Follow-up X-ray telescope (FXT)**
  - Micro-pore K-B/Wolter-I optics Si (CCD) or gas detector
  - Focal length: 1400mm
  - FoV 1°, FWHM~4’
  - Bandpass: 0.5-4keV

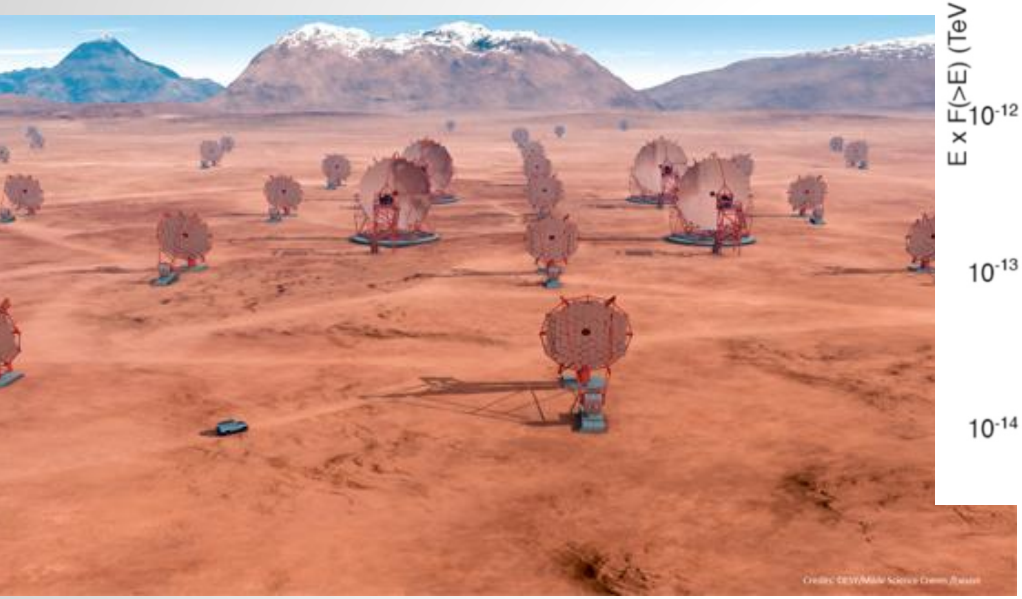


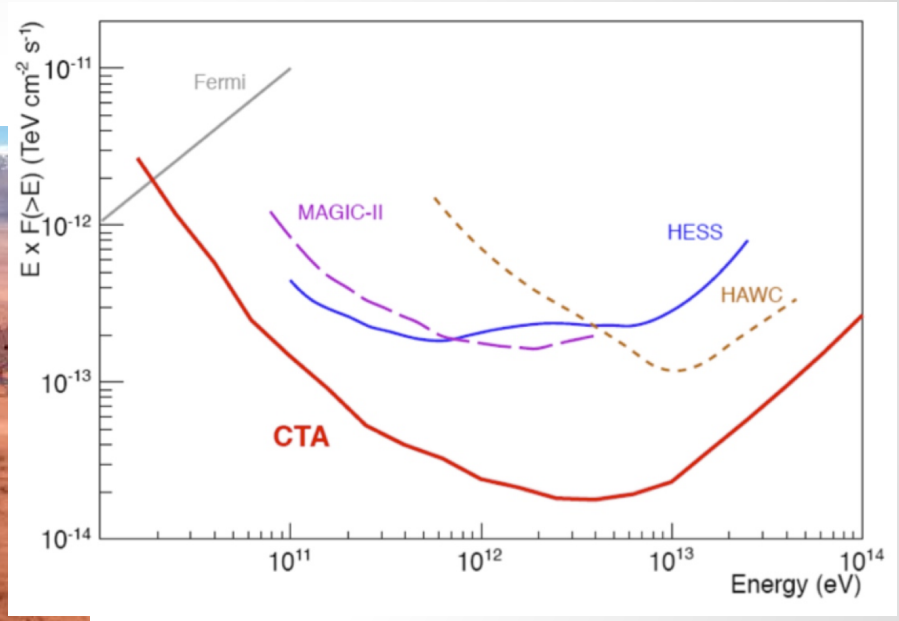


Borrowed from talk by Weimen Yuan @ 10 Years of Swift Conference, Rome, Dec 2014

Cherenkov Telescope Array

For long GRBs:





5 attempts per year with Swift = 0.6 - 1.6 prompt detections

10 attempts with GBM = 0.4 - 1.6 prompt detections

High Altitude Water Cherenkov (HAWC)

Assuming fluence > 100 Mev is 100% fluence 10 keV - 1 MeV
HAWC will see 1.4 short GRBs per year
0.25 long GRBs per year

CTA and GWs?

Going after the afterlow of short GRBs at HE: CTA is sensitive to all of them!
Duty cycle is problematic