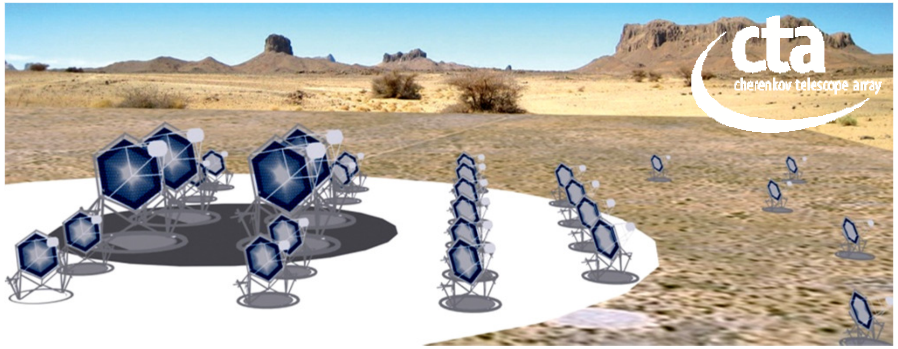
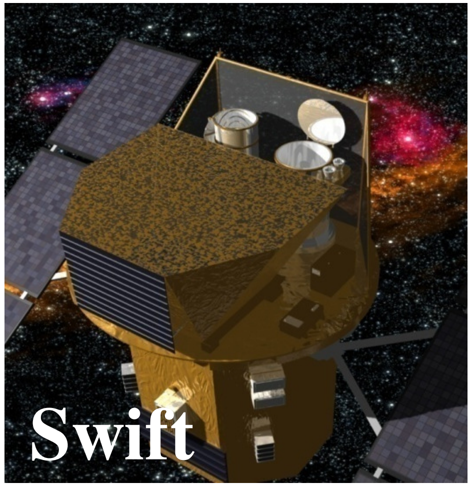
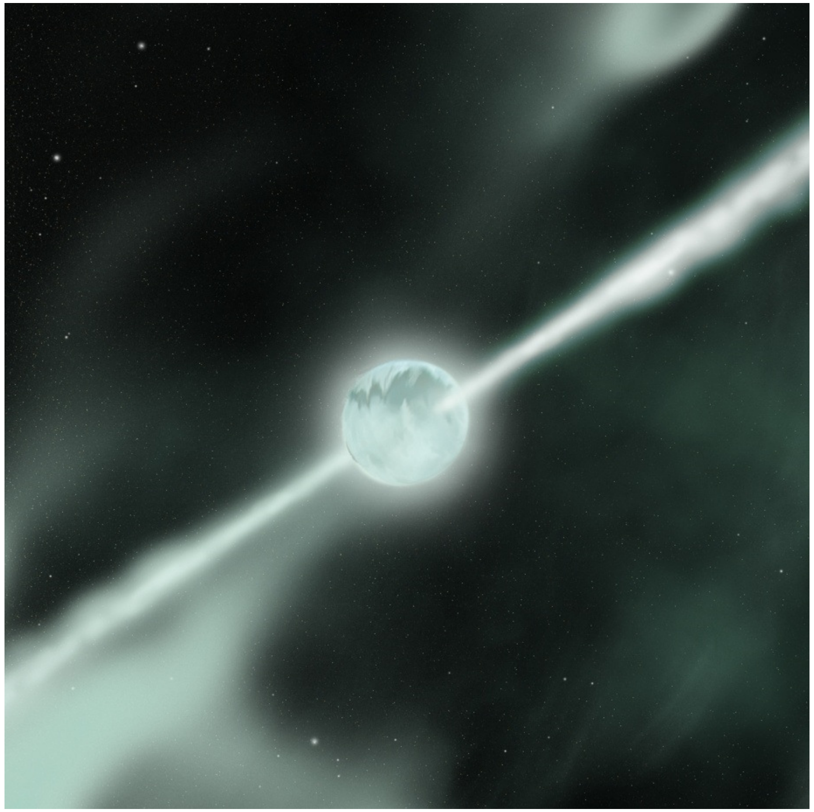
Gamma-Ray Bursts with CTA



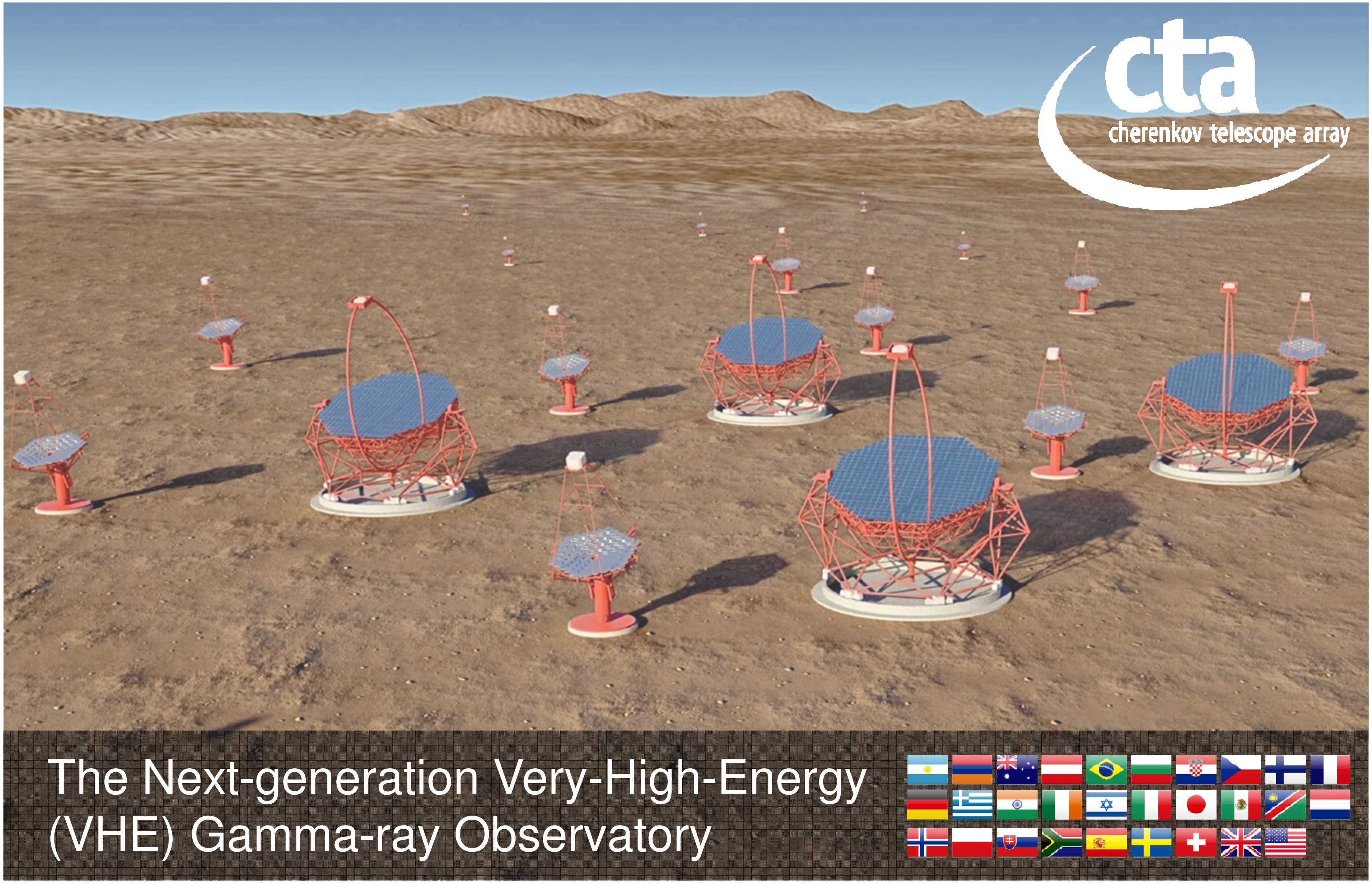




Paul O'Brien

with thanks to Valerie Connaughton, Susumu Inoue, Yoni Granot, Yoshi Inoue, Jim Hinton, Judy Racusin, Akira Okumura and the CTA GRB working group.

Cherenkov Telescope Array (CTA)
20 GeV – 300 TeV



Why Study GRBs at VHE?

(see Inoue, Granot, O'Brien et al. (2013) for details)

University *of* Leicester

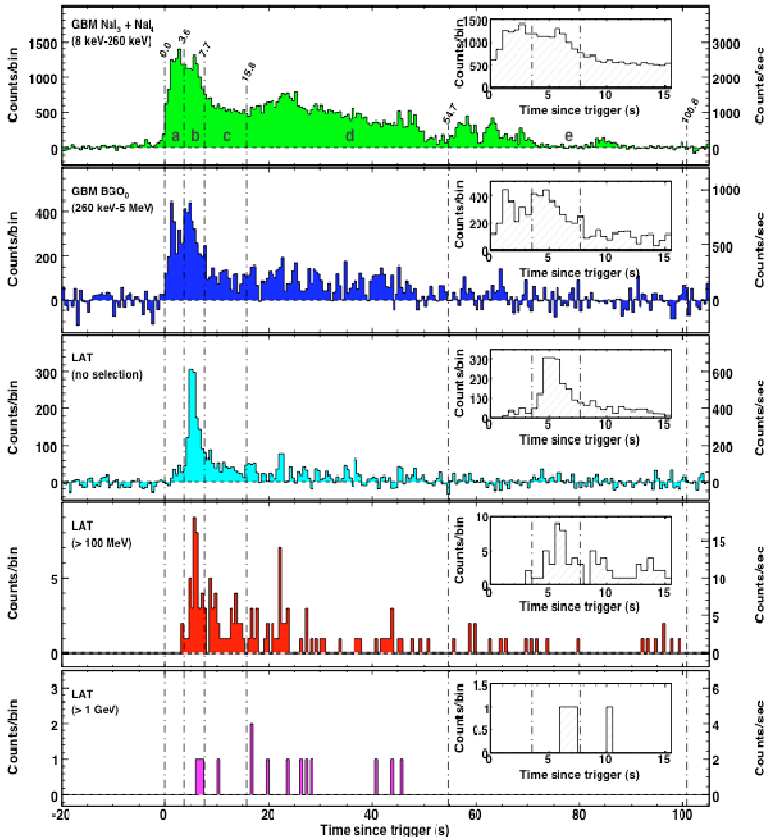
Probe GRBs:

- Better understand acceleration mechanisms in jets: energetics, bulk Γ, emission radius, hence constrain accretion, progenitors, environment…
- Use VHE (and neutrinos) to distinguish between:
  - Hadronic process (protons/ions radiate or produce pions which decay to give pair cascades and emission by secondary particles)
  - Leptonic process (mainly synchrotron, IC and SSC emission)

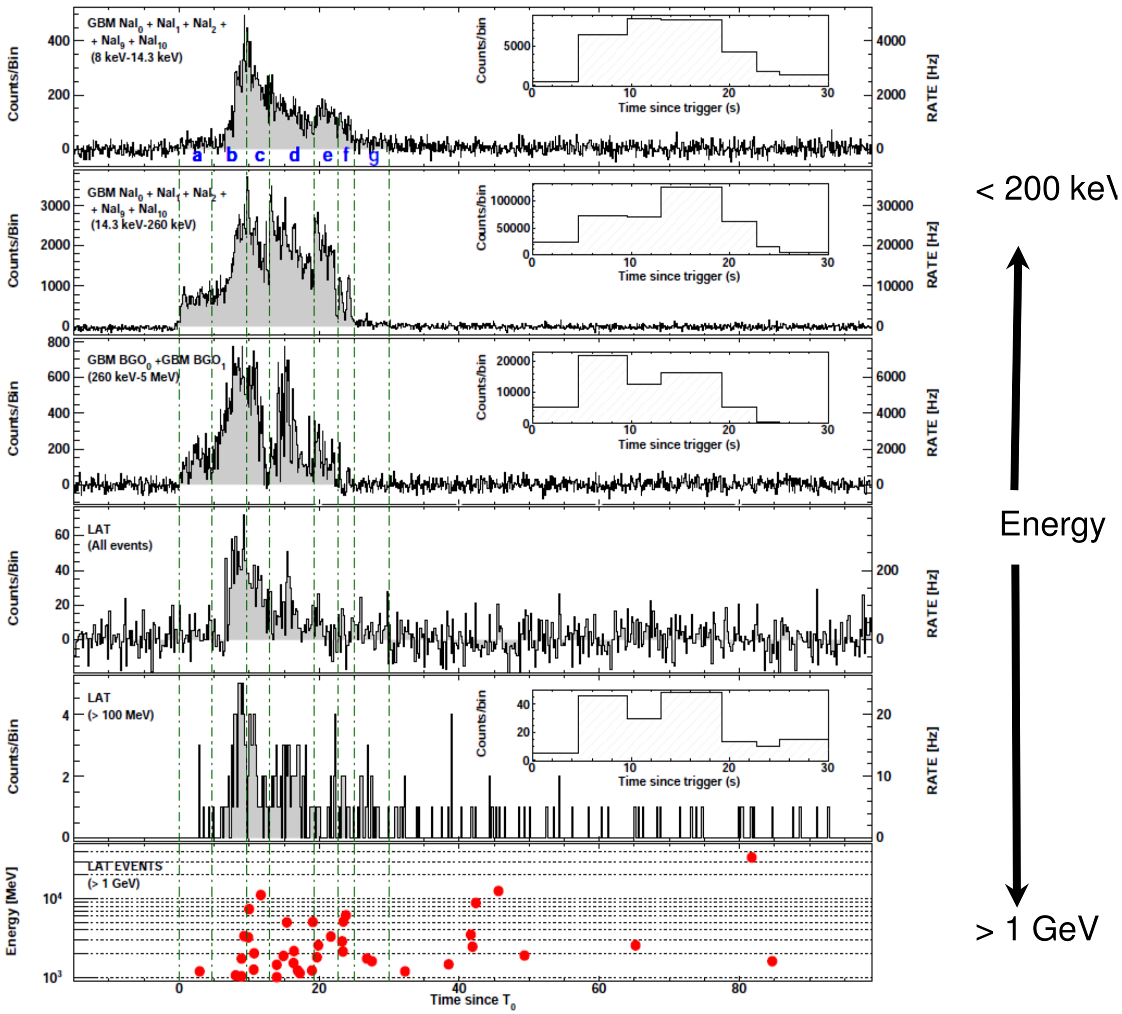
Use GRBs as probes:

- Constrain Lorentz invariance
- Probe extragalactic IR background via attenuation of VHE (pair production)

Prompt HE emission correlated with LE > GeV is less well-correlated.



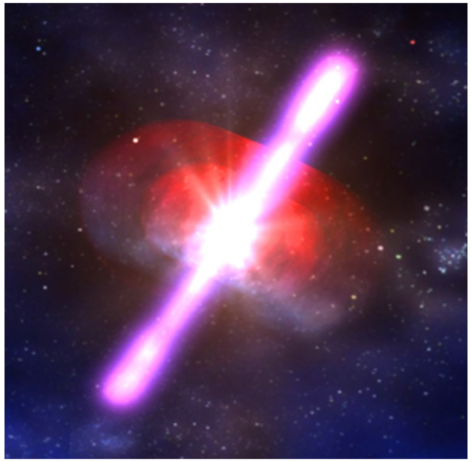
GRB 080916C Abdo+ 2009



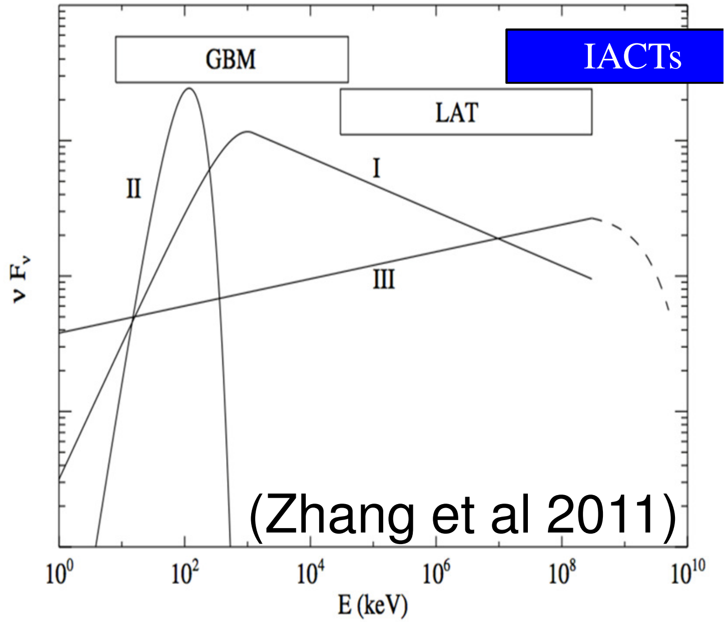
GRB 090902B Abdo+ 2009 arXiv:0909.2479

HE LAT Gamma-ray Bursts

University of Leicester

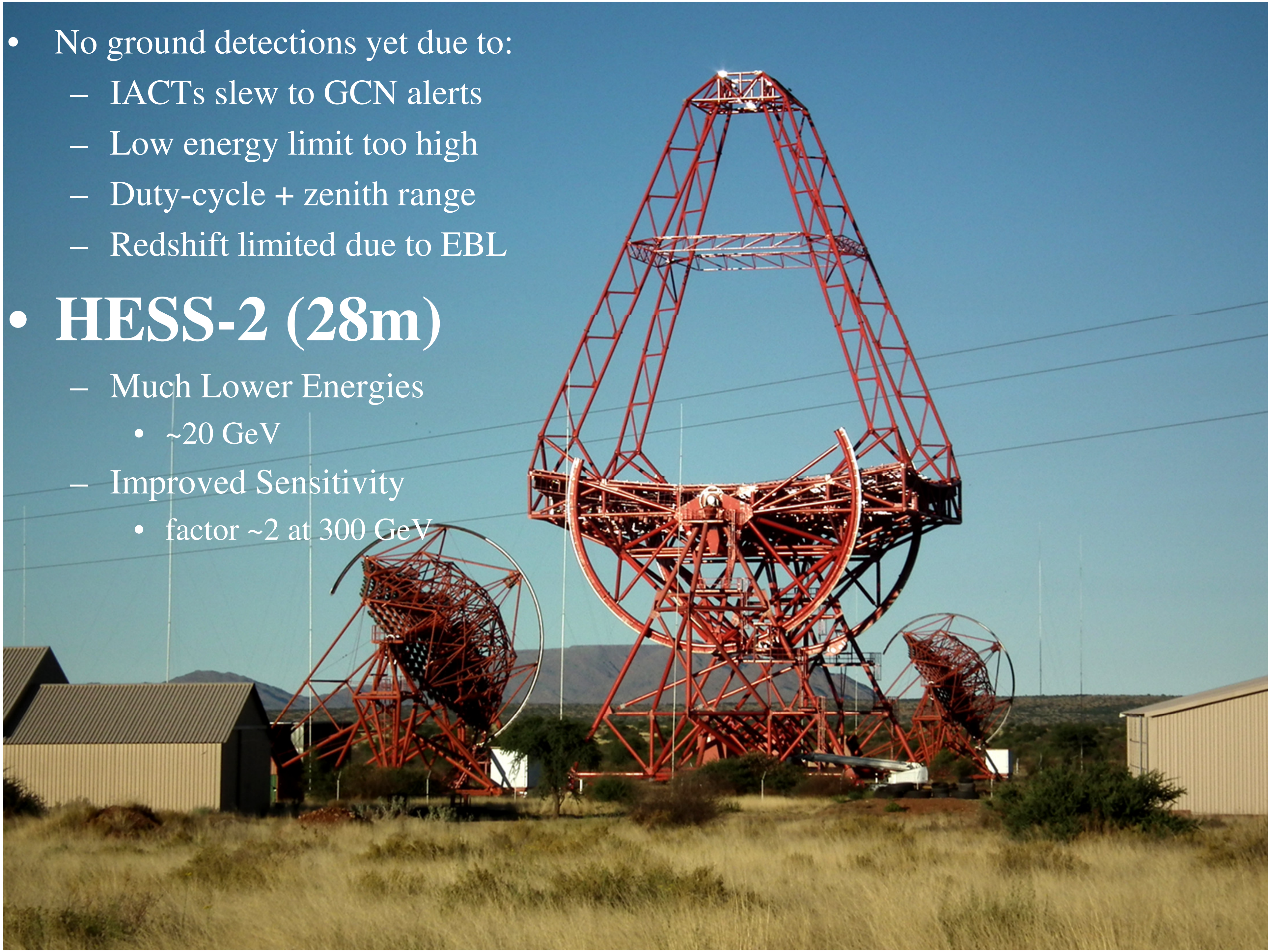


- Many Fermi detections >10 GeV
- Highest energy photons ~100 GeV in rest frame of host galaxy (at typical z of ~2)
- Multiple emission components



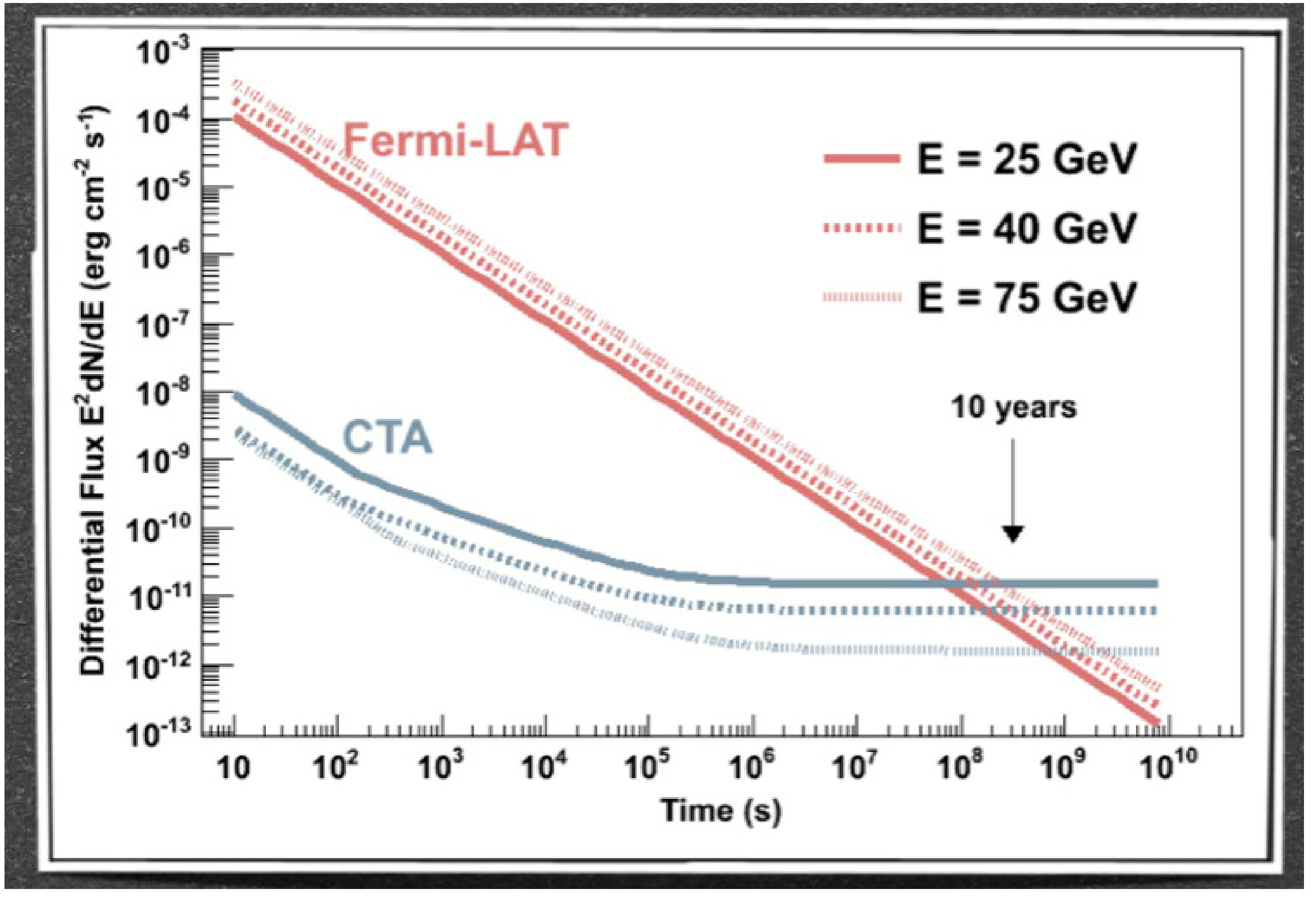
- I - "Band Function" – broken power law; peak at ~1 MeV (synchrotron?)
- II – psuedo-thermal ~100 keV bump
- III - hard power-law peaking beyond 100 GeV (SSC?, hadronic (delayed?)
- IV Could it all be afterglow related (Ghisellini et al. 2010)?

- No ground detections yet due to:
  - IACTs slew to GCN alerts
  - Low energy limit too high
  - Duty-cycle + zenith range
  - Redshift limited due to EBL
- **HESS-2 (28m)**
  - Much Lower Energies
    - ~20 GeV
  - Improved Sensitivity
    - factor ~2 at 300 GeV



For fast transient events, CTA better than Fermi; but FoV and Duty Cycle low

University of Leicester



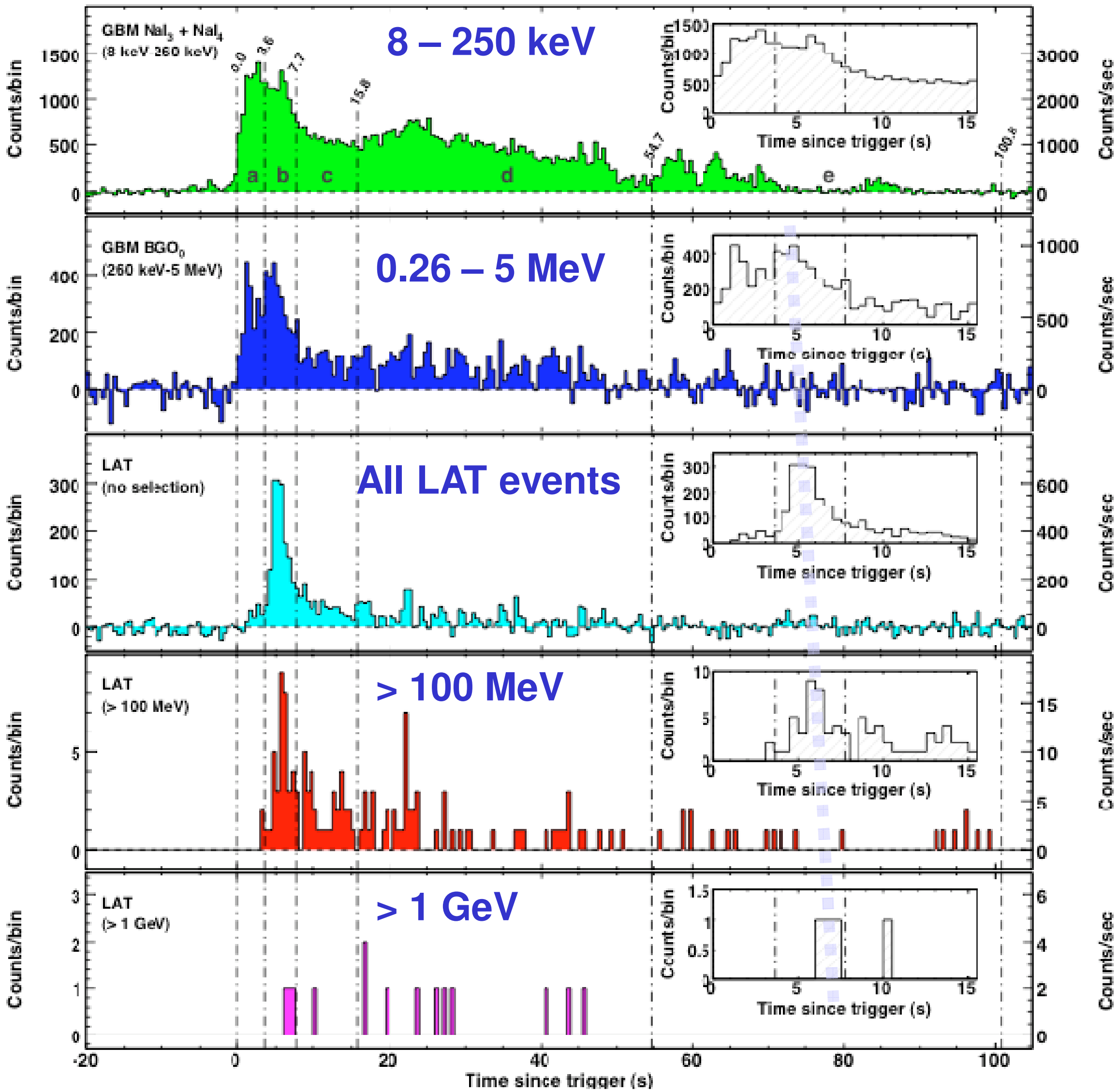
Funk & Hinton (2013)

Abdo et al., (2009)

GRB 080916C

University of Leicester

- z=4.35 GRB
- Start of HE emission delayed relative but detected for longer.
- Simple spectrum (Band function) but evolves.
- No spectral cutoff or extra components (SSC or thermal)
- Derive bulk Γ~4-900) (assuming low-energy seed ,expand region to prevent pair production)

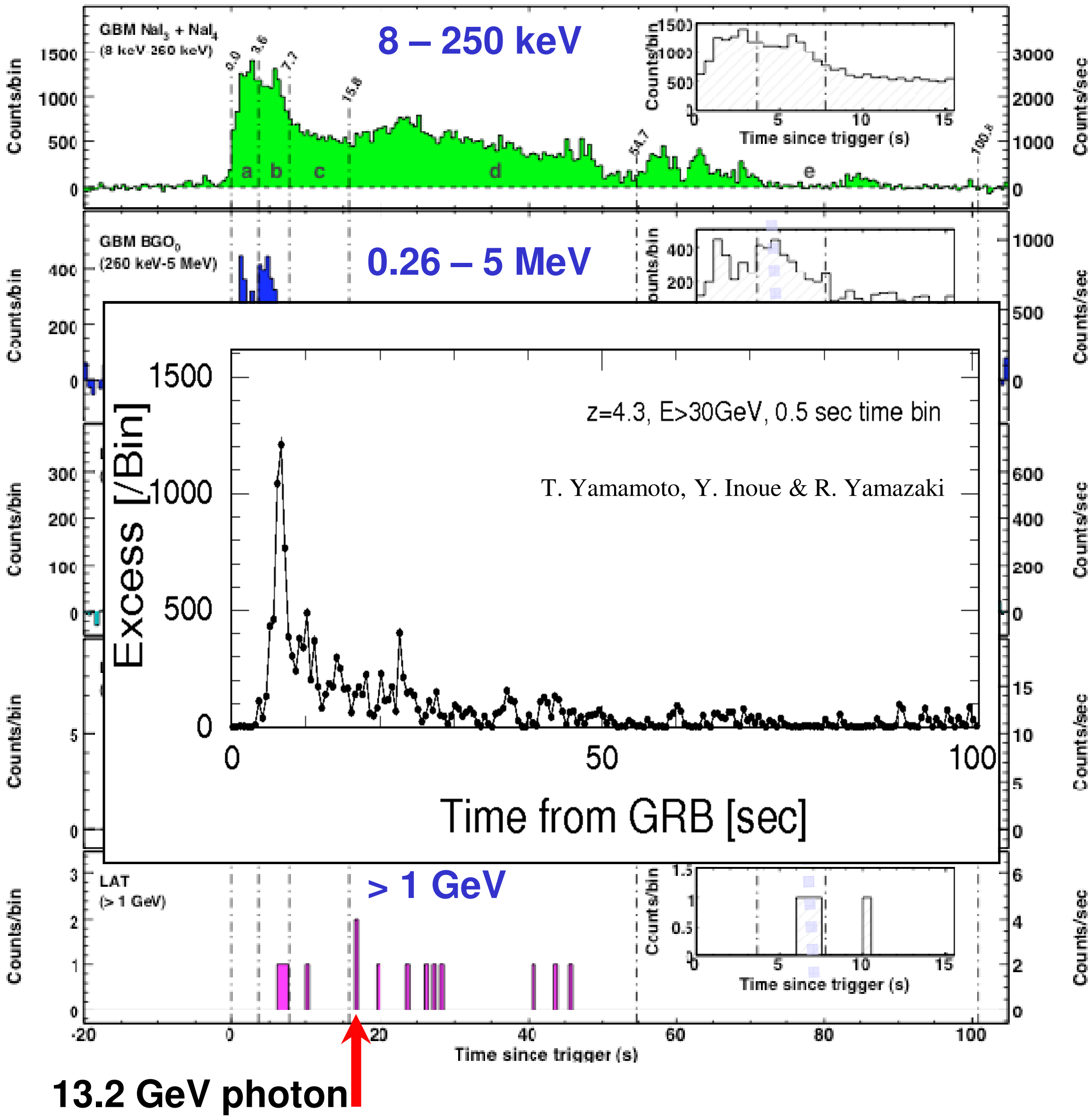


Abdo et al., (2009)

GRB 080916C

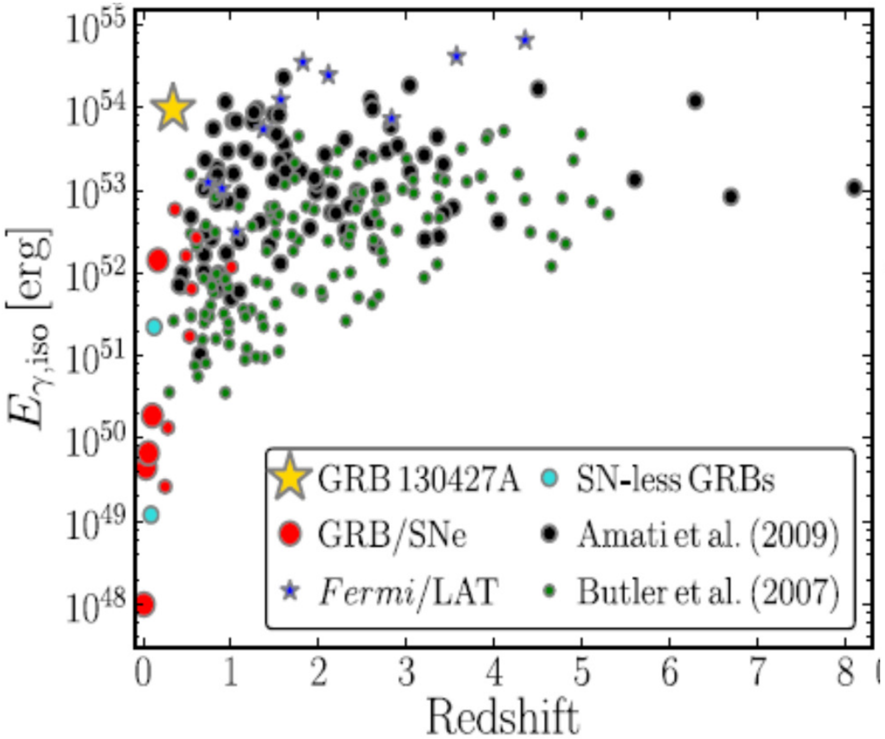
University of Leicester

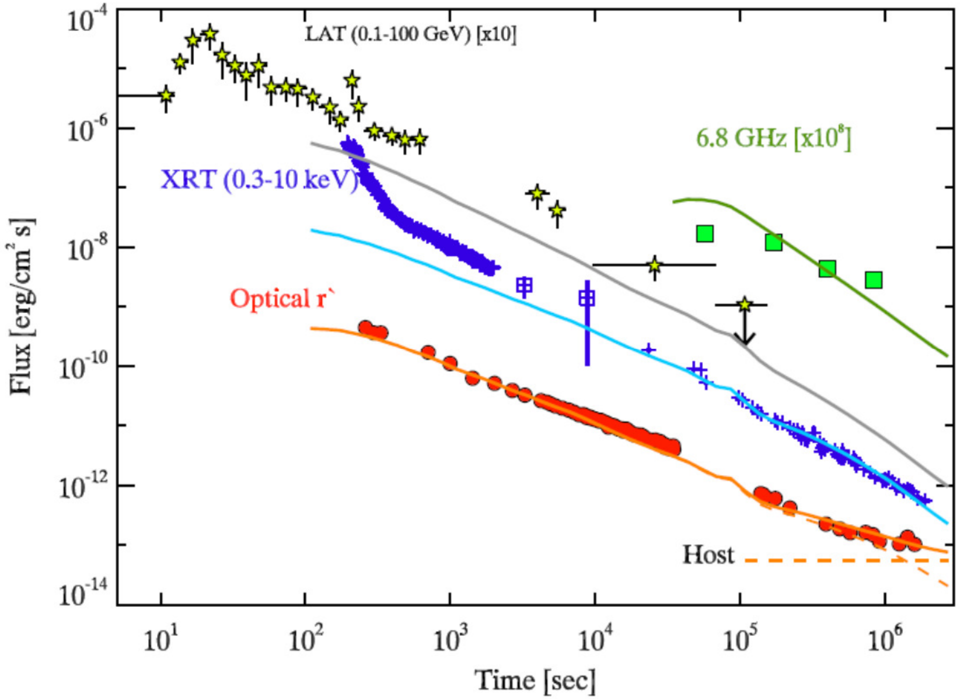
- z=4.35 GRB
- Start of HE emission delayed relative but detected for longer.
- Simple spectrum (Band function) but evolves.
- No spectral cutoff or extra components (SSC or thermal)
- Derive bulk Γ~4-900) (assuming low-energy seed ,expand region to prevent pair production)



GRB 130427A: the brightest Fermi GBM and LAT GRB

University of Leicester





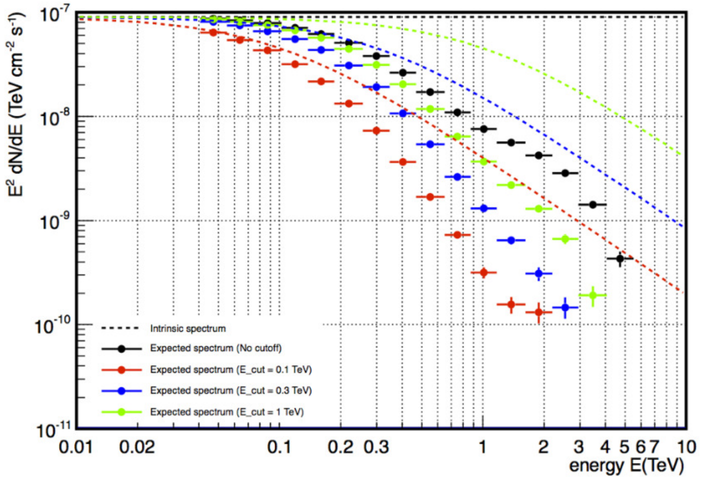
A highly energetic GRB + and a highly energetic SNe (Xu et al. 2013) – you can have both from the same object

Ackermann et al. (2014); Maselli et al. (2014)…

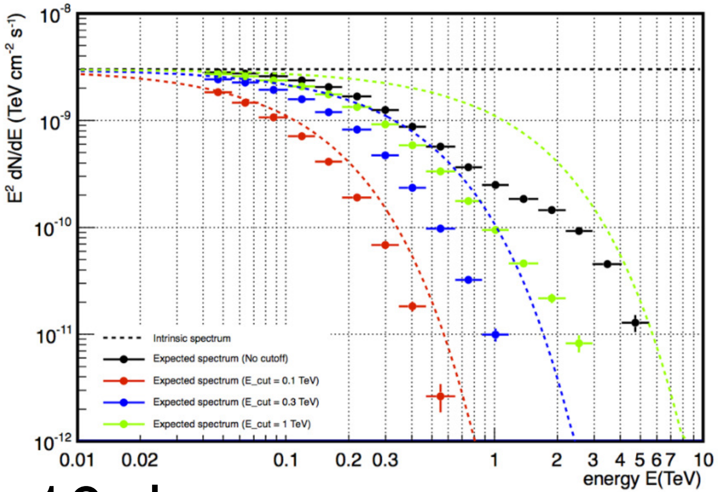
GRB 130427A and CTA

PL cutoff (steepening) due to $\gamma\gamma$ at early times (cutoff E = none, 0.1 TeV, 0.3 TeV, 1 TeV)
PL cutoff (exponential) in afterglow phase (cutoff E = none, 0.1 TeV, 0.3 TeV, 1 TeV)
EBL attenuation (z = 0.35) from Inoue et al. (2013)
CTA Configuration E at 2000m [Spectra from Tam et al. (2013); model from Granot (2008)]

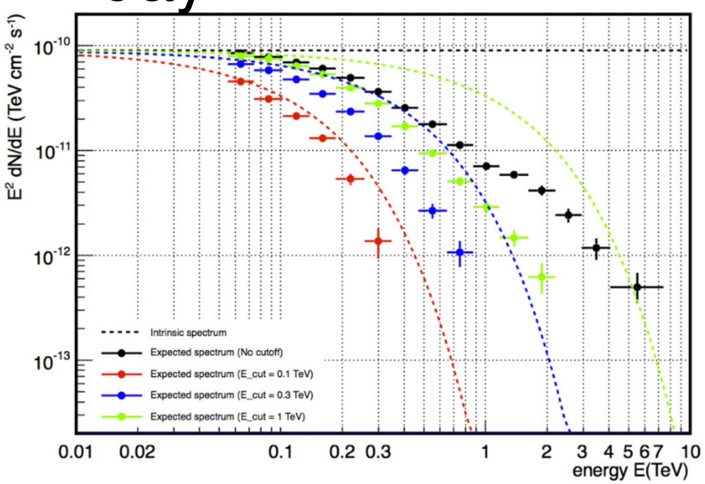
100 s



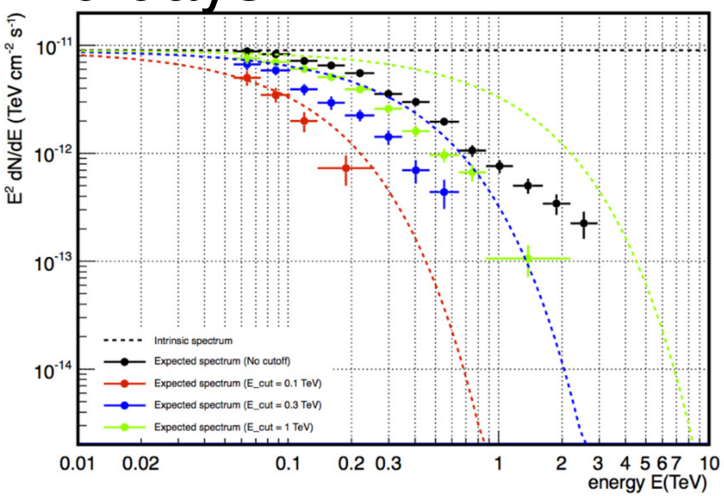
1 hr



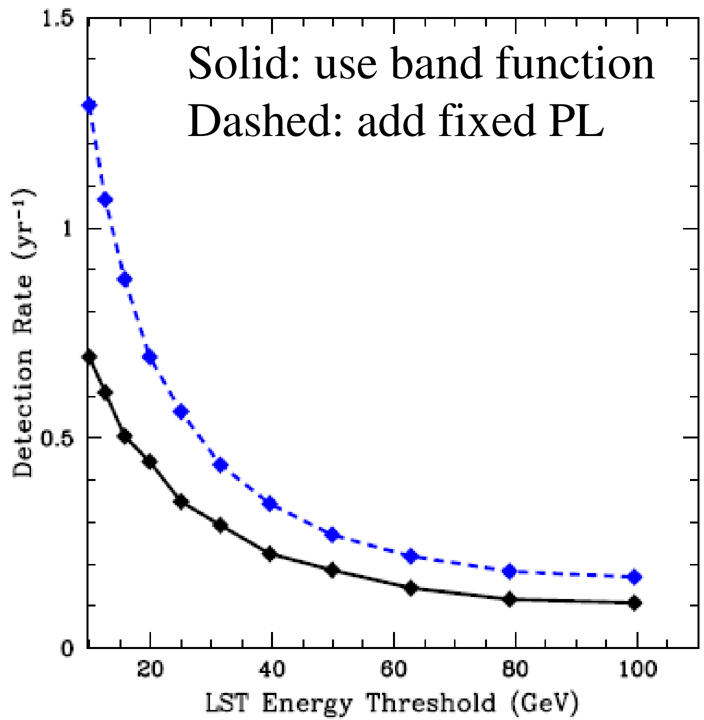
1 day

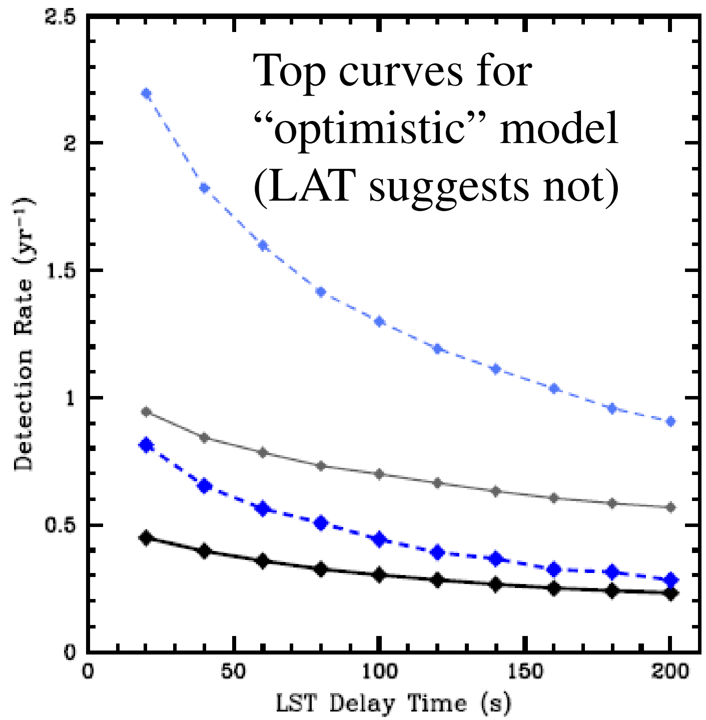


10 days



Predicted detection rates for Swift alerts
(adding GBM gives extra assuming a search pattern)





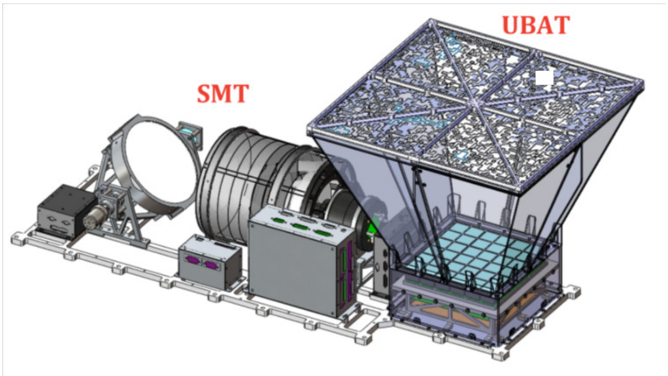
Swift BAT location: 50% within 18sec, 75% within 50sec, 90% within 175sec

With Fermi/GBM and a N+S CTA array and we could get ~few prompt and ~6 afterglow detections per year (see special issue paper, Inoue et al. 2013).

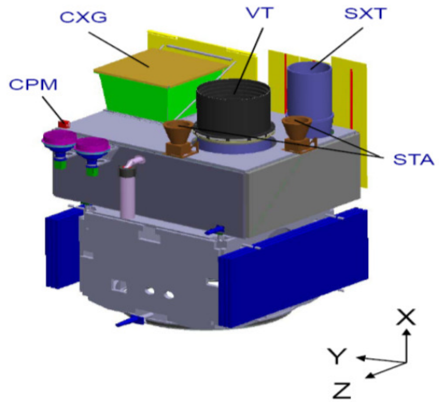
Could also use CTA in "survey mode" (~1000 sq. degs) to find GRBs in FoV

The near future (+ Swift, Fermi…)

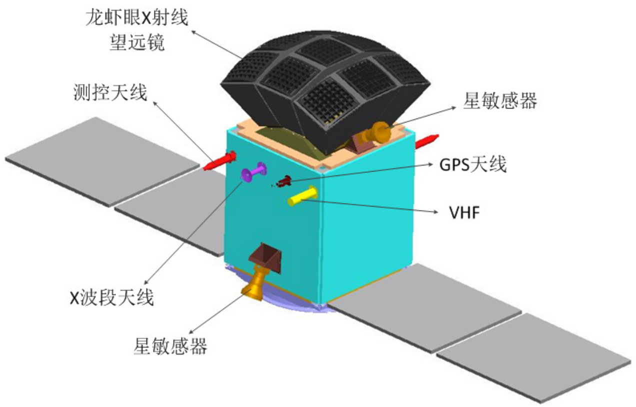
University of Leicester



"UFFO Pathfinder", launch 2014(?), 10cm optical (200-600nm) and UBAT GRB finder (5-200keV), ~40 GRBs/yr.



"SVOM", France, China, Leicester launch ~2021, 4-300 keV , 0.3-7 keV, 30 keV – 5MeV, optical, ~ 80 GRBs/yr



"Einstein Probe", a China 'advanced study' concept, possible launch ~2020, 0.5-7 keV use micro-channel plate optics for wide-field X-ray monitoring survey

(+other concepts for ESA & NASA missions)

Conclusions

- Detection of VHE emission from GRB prompt or afterglow emission with CTA would strongly constrain emission models, distinguish intrinsic vs. EBL effects and probe fundamental physics.
- Expect only a few detections per year, so very important to point at every available GRB. Few detections but each one will be photon rich.
- Must slew CTA as fast as possible (<few tens of seconds).
- We need current + new GRB missions…lobby your local space agency!