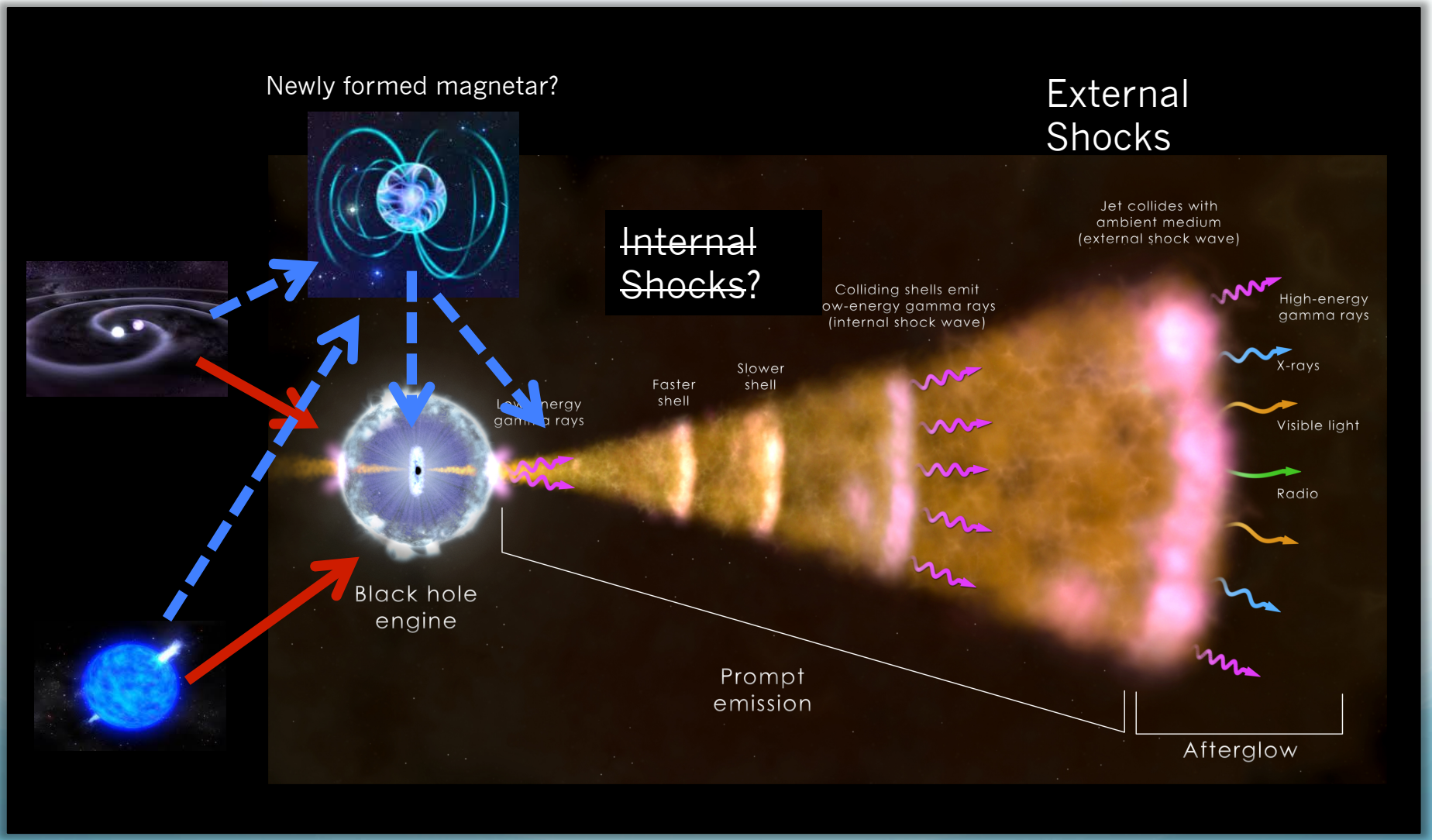
Future Prospects for MeV Gamma-ray Burst Observations

Judy Racusin (NASA/GSFC)

Future Space-Based Gamma-ray Observatories Workshop, GSFC, Feb 4-5, 2015

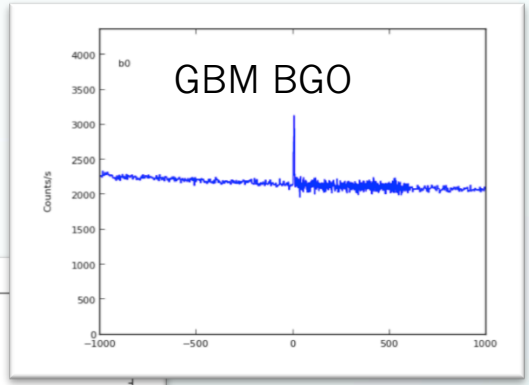
GRB Formation

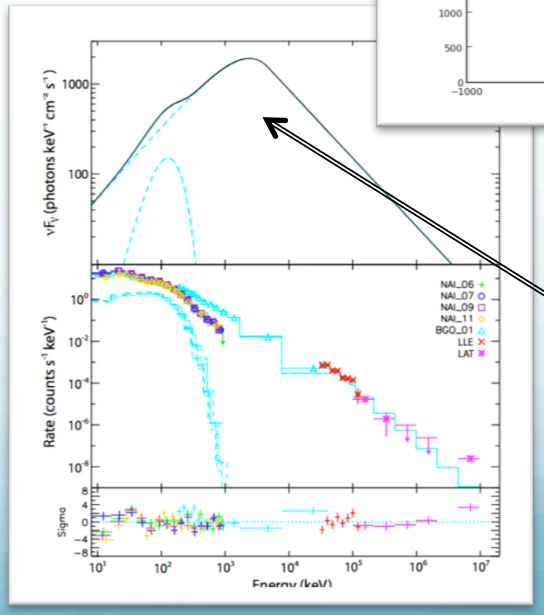


GRBs in the MeV Range

- GRBs are already detected regularly with scintillators (Fermi/GBM, Konus/WIND, Suzaku/WAM, CGRO/ BATSE) in the 10's of keV – MeV range
  - Background dominated – Only sensitive to bright transient objects
  - Huge fields of view – Poor localizations (~few deg)
  - Sensitivity peaks at ~few hundred keV – as do most GRB spectra
  - Few GRBs peak in > 1 MeV range (for which E_{peak} measurements have been possible)

GRB 110731A



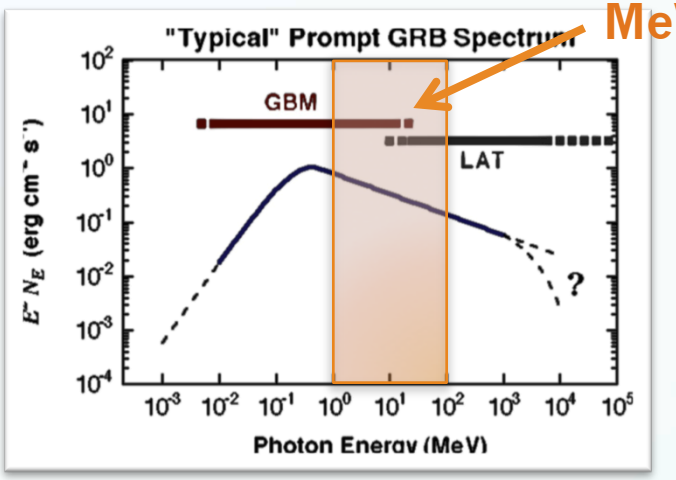


15 MeV
E_{peak}

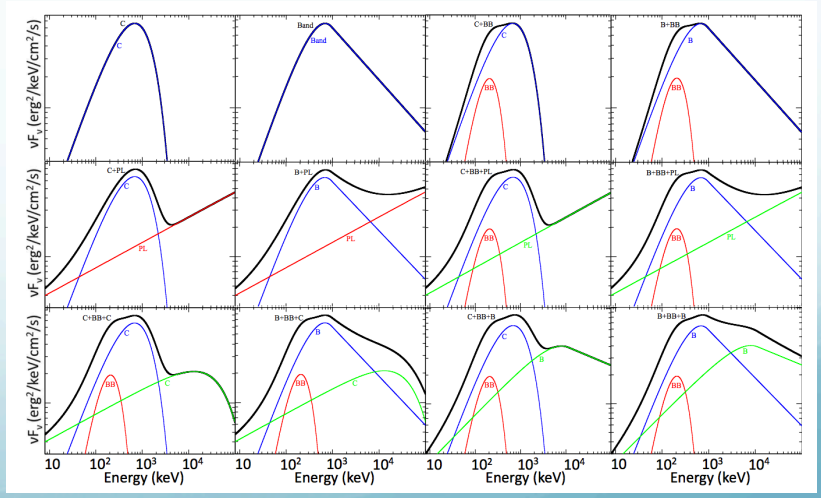
GRB 110721A:
Axelsson et al. 2012

What have we learned about GRBs from Fermi?

- Broad energy coverage (8 keV – >100 GeV) showed that:
  - Prompt emission spectra require additional components at both low and high energies to explain excesses
  - Afterglow appears to be a single spectral component from optical to GeV energies
- GeV GRBs tend to be highly energetic, have high bulk Lorentz factors (~1000)
- Some GRBs show cutoffs in MeV range – due to pair opacity?



Band et al. 2009

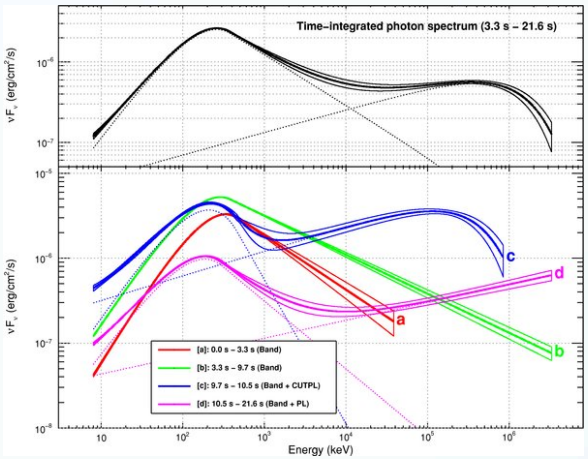


Guiriec et al. 2015

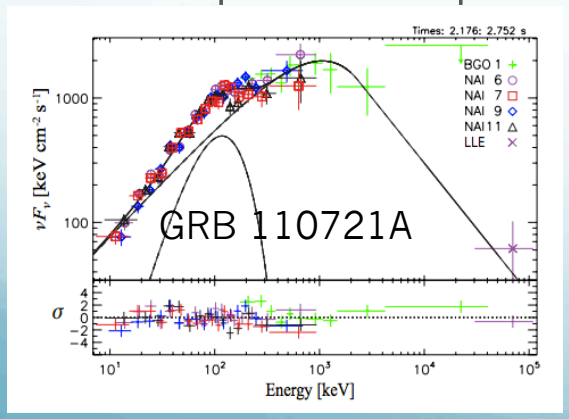
Prompt Emission Spectra

- Synchrotron shock model (particles accelerated in a relativistic shock)
  - Predicts Maxwellian distribution with low energy index < -2/3 ("Synchrotron Line of Death")
  - Band function is an empirical approximation
  - Low energy index frequently exceeds -2/3
- Extra power laws extending from low to high energies could be afterglow onset
- Sub-dominant blackbodies (natural consequence of photospheric emission)

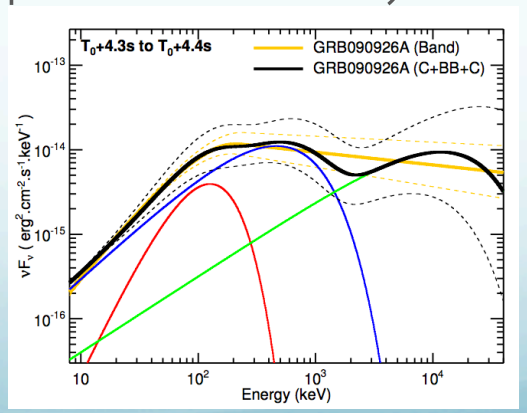
GRB 090926A



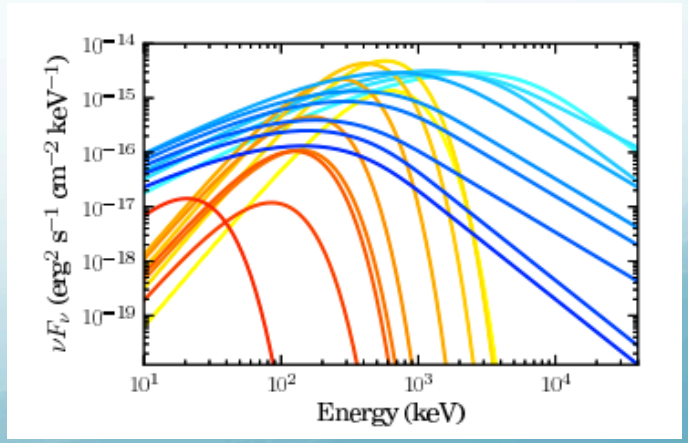
Ackermann et al. 2011



Axelsson et al. 2012, Iyyani et al. 2013



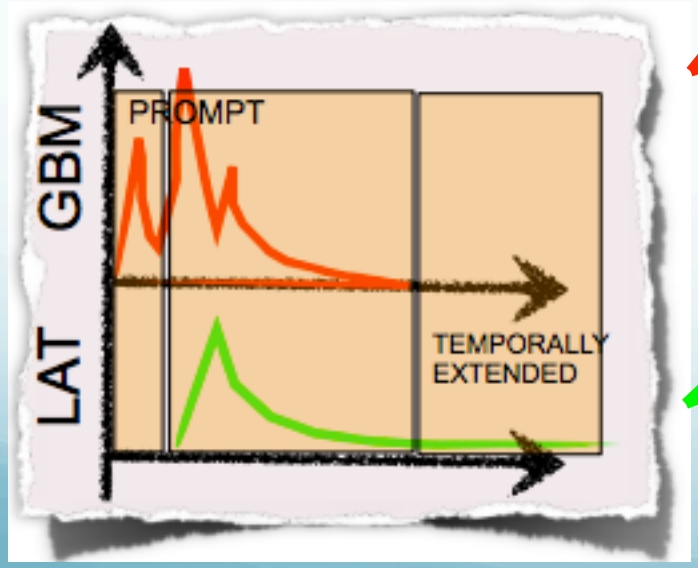
Guiriec et al. 2015



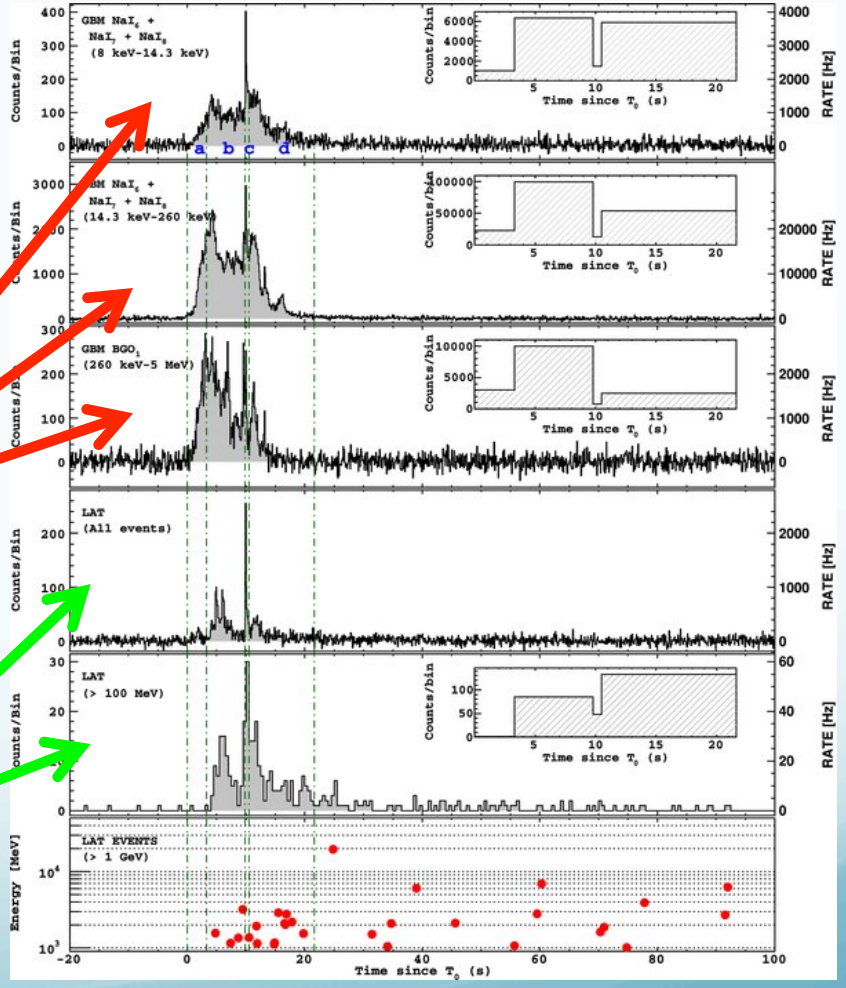
Burgess et al. 2014

Origin of GeV emission

- Few second delay compared to keV emission
- Lasts substantially longer than keV emission
- Probably some mixture of prompt and afterglow
- No strong evidence of additional Synchrotron Self-Compton or Inverse Compton components



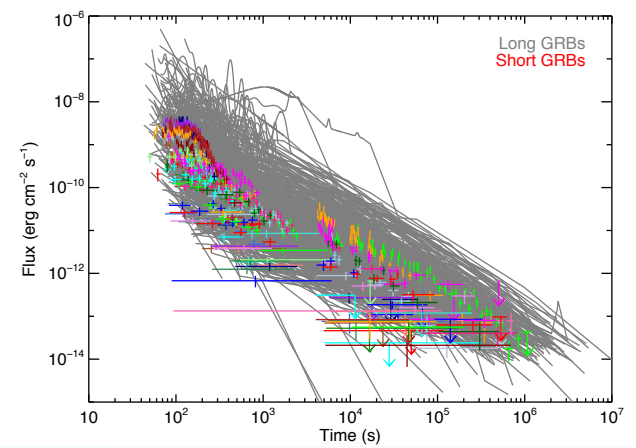
Credit: Nicola Omodei



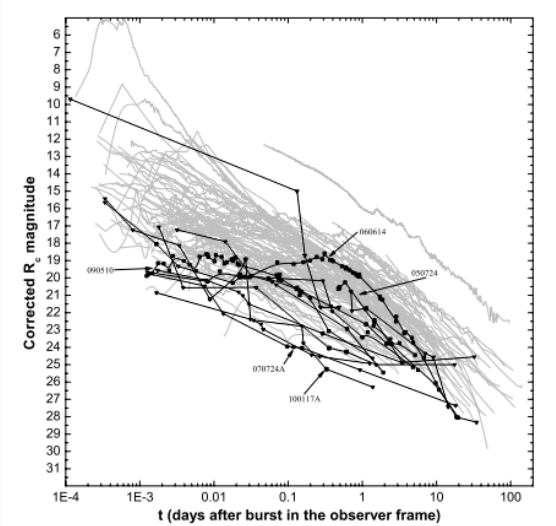
Ackermann et al. 2011, ApJ, 729, 114

GRB Afterglows

X-ray Afterglows

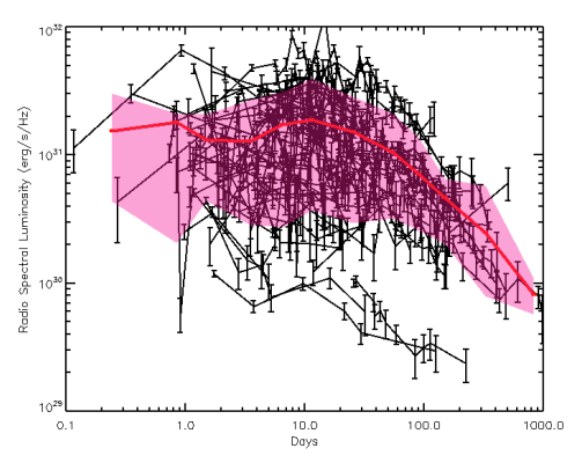


Optical Afterglows



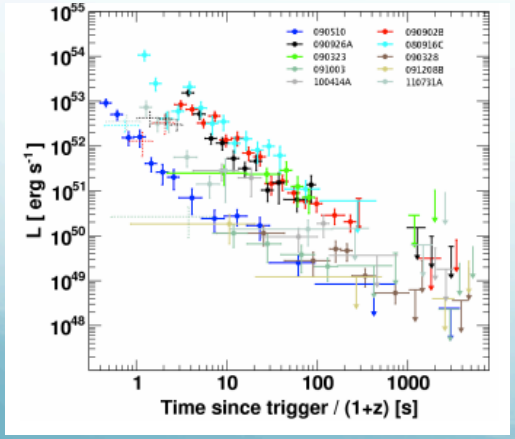
Kann et al. 2011

Radio Afterglows



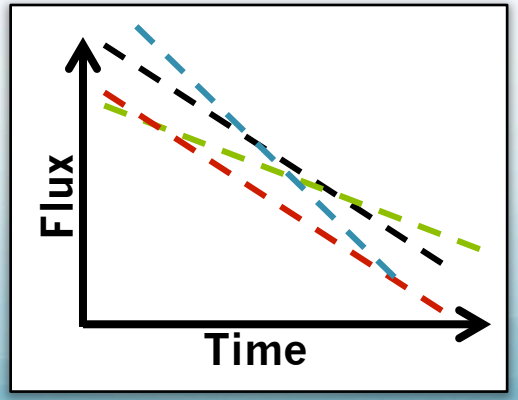
Chandra et al. 2011

>100 MeV γ-ray Afterglows



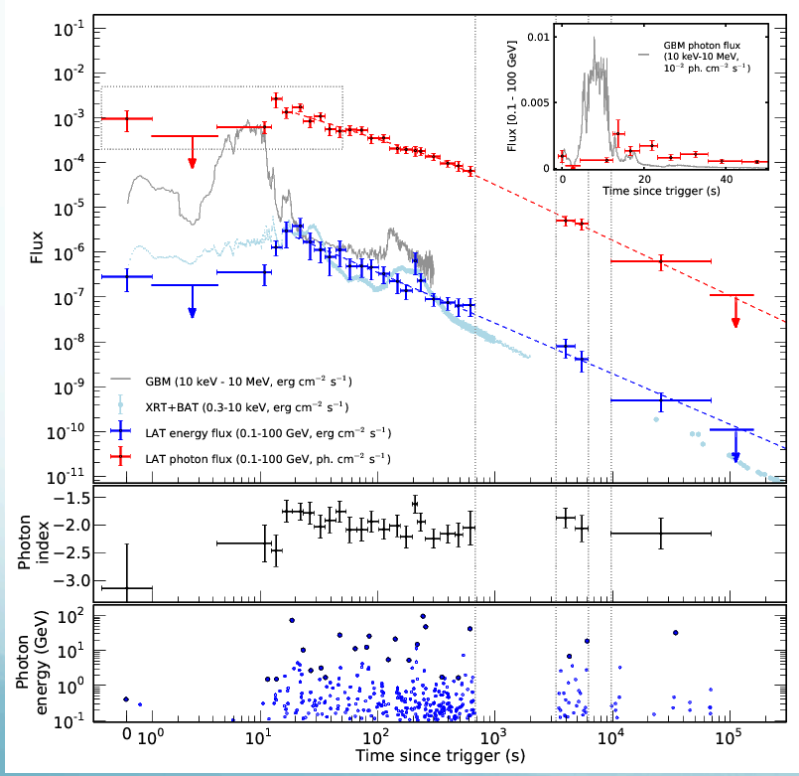
Ackermann et al. 2013

MeV Afterglows?

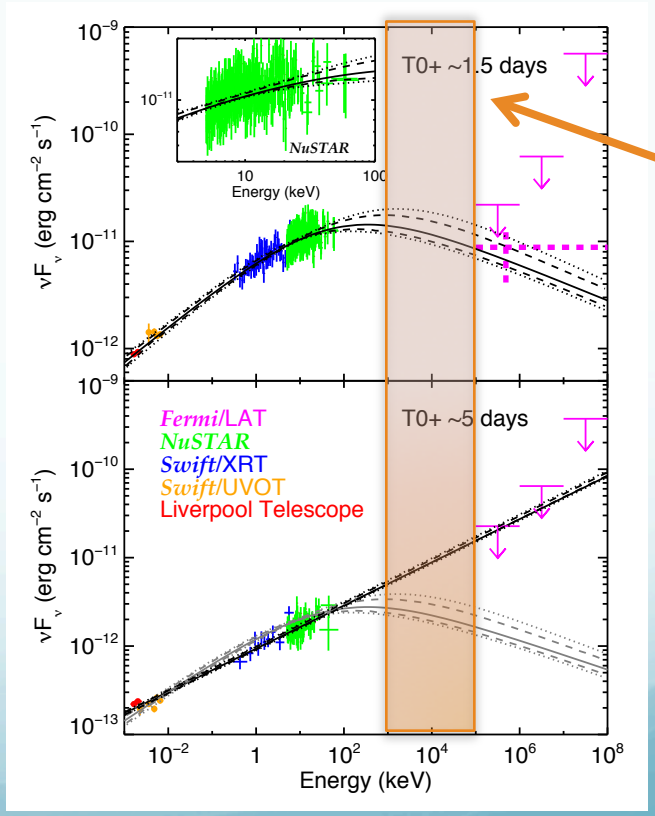


GRB 130427A Challenges Synchrotron Shock Physics?

- Single component from radio to GeV strongly suggests Synchrotron origin, and no secondary SCC or IC component
- High energy photons violate maximum Synchrotron energy

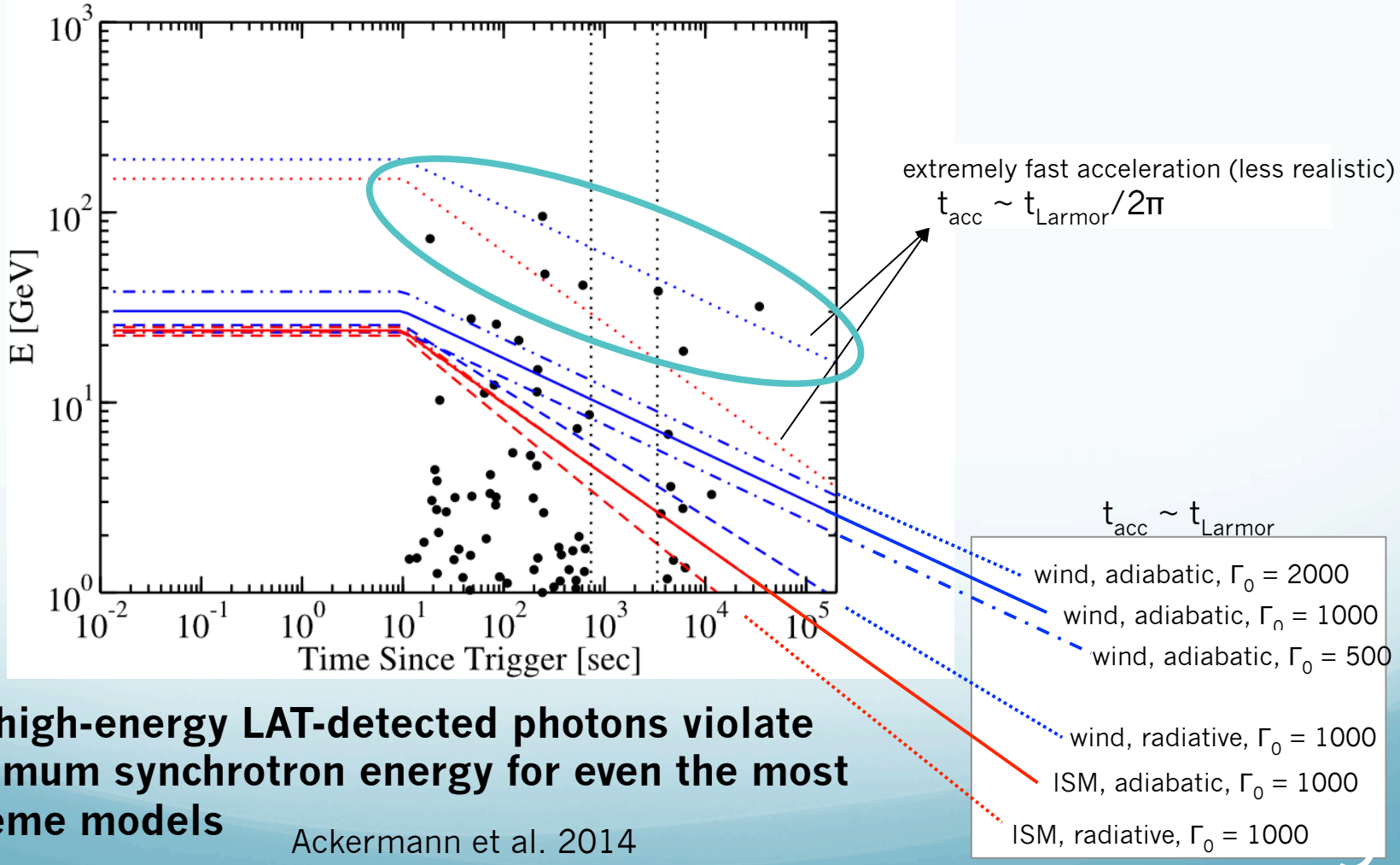


Ackermann et al. 2014



Kouvelioutou, Granot, Racusin et al. 2013

GRB 130427A Challenges Synchrotron Shock Physics?



The high-energy LAT-detected photons violate maximum synchrotron energy for even the most extreme models

Ackermann et al. 2014

Open Questions in GRBs

- What is the true shape of the the prompt emission spectum, and therefore also emission mechanism(s)?
  - How common are multiple components?
  - Temporal and spectral evolution of components?
  - This would benefit from simultaneous keV-10's of MeV sensitive spectral coverage
- Is the afterglow of synchrotron origin and a single component from radio to GeV?
  - Bridging gap between few MeV and GeV would help
- When is the transition between prompt emission and afterglow? What radius from the central engine does that occur? What are the implications for jet composition (magnetic vs baryonic)?

What's needed to do next generation GRB Science?

- Need a keV triggering instrument to get temporal and spectral context of higher energy observations
  - Huge field of view (all sky?)
  - Wide energy coverage (10's of keV to few MeV)
  - Accurate localization (<few deg)
  - Rapid triggering sent to ground
  - Trigger rapid repointing?
  - Also useful for continued GRB science including LIGO/Virgo counterparts
- MeV instrument
  - Onboard triggering and localization (to fraction of deg accuracy)
  - Automated repointing and following new bright GRB for ~hours
  - Good energy resolution and sensitivity to measure GRB spectra and light curves

A sensitive, large FoV, good energy resolution, MeV Instrument would:

- Provide a larger sample of gamma-ray prompt and afterglow observations (there are a lot more photons in MeV range with photon index=-2 spectrum) than Fermi-LAT
- Have an effective area optimized at 10's of MeV and would provide better statistics for spectral fitting in what has previously been a noisy MeV spectral regime
- Provide large sample of MeV afterglows that would address single component synchrotron issue
- Measure polarization to put constraints on magnetic versus baryonic dominated jets?
  - GRBs are bright, but don't last very long – unlikely to provide enough counts to make significant measurements