# Signs of magnetic acceleration and multi-zone emission in GRB080825C

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On behalf of the Fermi-LAT collaboration

# The LAT and GBM on Fermi

**The GBM detects ~250 GRBs/year**

**~18% short**

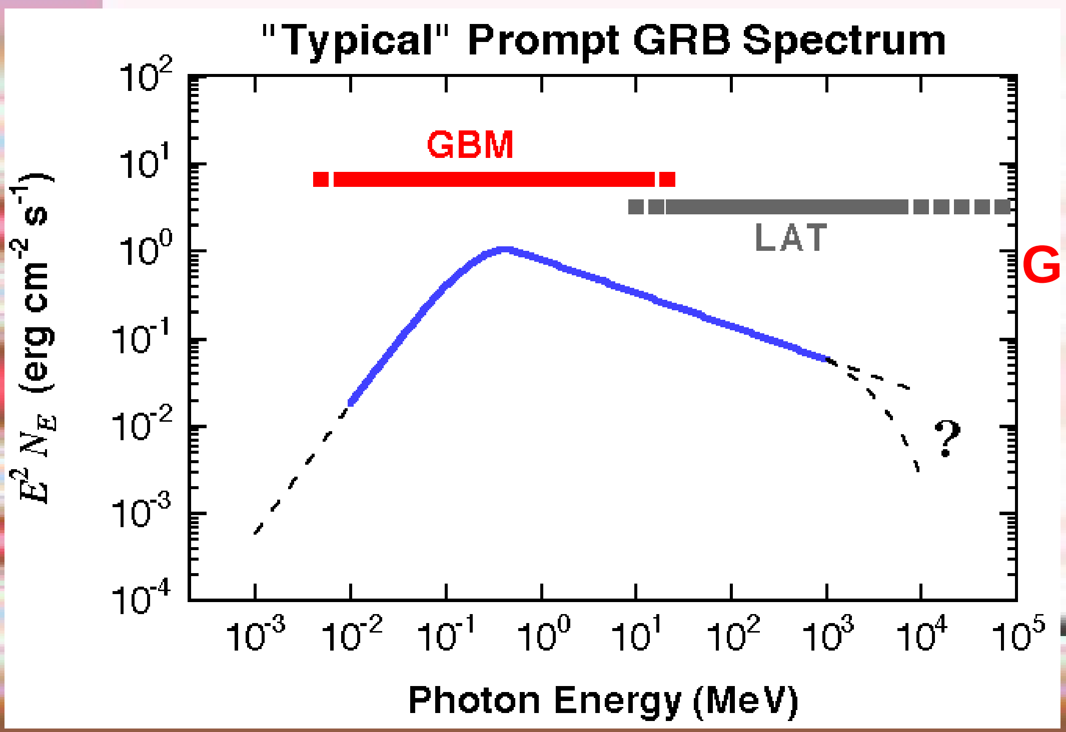
**~50% in the LAT FoV**

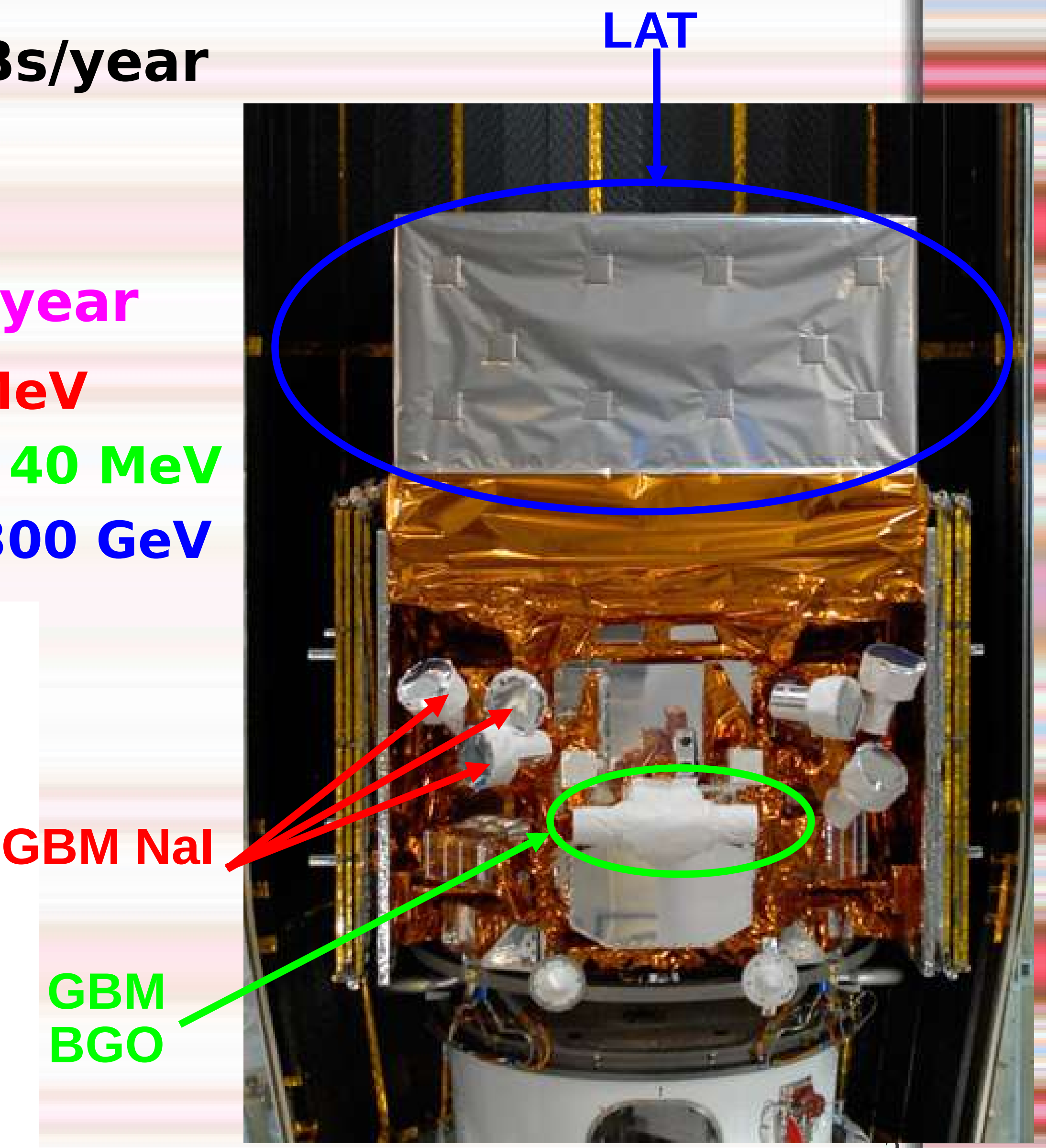
**The LAT detects ~10 GRBs/year**

**NaI: 8 keV - 1 MeV**

**BGO: 200 keV - 40 MeV**

**LAT: 30 MeV – 300 GeV**



# The Idea

- The LAT GRB catalog (Ackermann et al. 2013) shows that the most fluent GRBs deviate from a Band only spectral modelling.
- Do all bursts deviate from the Band function?
- Are we limited by the statistic to detect this deviation in the less fluent bursts?
- Can we investigate deviations with lower significance of the extra-components?

| | Flue[illegible] 10 [illegible] - 10 GeV ($10^{-7}$ erg/cm$^2$) | [illegible] | $\theta$ deg |
|---|---|---|---|
| [illegible]0724B | $4665^{-76}_{+78}$ | Band with exponential cutoff | 4[illegible] |
| 090902B | $4058^{-24}_{+25}$ | Comptonized + Power law | 50.8 |
| 090926A | $2225^{-48}_{+50}$ | Band + Power law with exponential cutoff | 48.1 |
| 080916C | $1795^{-39}_{+41}$ | Band + Power law | 48.8 |
| 090323 | $1528^{-44}_{+44}$ | Band | 57.2 |
| 100728A | $1293^{-27}_{+28}$ | Comptonized | 59.9 |
| 100414A | $1098^{-27}_{+35}$ | Comptonized + Power law | 69.0 |
| 090626 | $927^{-16}_{+17}$ | Logarithmic parabola | 18.3 |
| 1[illegible]721A | $876^{-28}_{+28}$ | Logarithmic parabola | [illegible].3 |
| 090328 | $817^{-33}_{+34}$ | B[illegible] | 64.6 |
| 100116A | $638^{-25}_{+26}$ | Band | 26.6 |
| 110709A | $518^{-21}$[illegible] | Band | 53.4 |
| 080825C | [illegible]$17^{-20}_{+21}$ | Band | 60.3 |
| [illegible] | [illegible]$^{-15}_{+16}$ | [illegible] | [illegible] |
| 091003 | $461^{-14}_{+15}$ | Band | 21.3 |
| 110[illegible]20A | $422^{-22}_{+23}$ | Band | [illegible].6 |
| 110328B | $417^{-37}_{+47}$ | Comptonized | 31.7 |
| 110731A | $379^{-21}_{+20}$ | Band + Power law | 3.4 |
| 090510 | $360^{-16}_{+18}$ | Band + Power law | 13.6 |
| 091031 | $288^{-10}_{+10}$ | Band | 23.9 |
| 110428A | $255^{-9}_{+10}$ | Band | 34.6 |
| 090720B | $185^{-11}_{+13}$ | Band | 56.1 |
| 100225A | $101^{-7}_{+7}$ | Band | 55.5 |
| 091208B | $93^{-11}_{+13}$ | Band | 55.6 |
| 100620A | $84^{-9}_{+9}$ | Band | 24.3 |
| 081006 | $56^{-9}_{+10}$ | Band | 11 |
| 110529A | $49^{-6}_{+6}$ | Band | 3[illegible] |
| 100[illegible]25A | $46^{-4}_{+4}$ | Band | 7.1 |
| 090531B | $38^{-5}_{+5}$ | Comptonized | 21.9 |
| 081024B | $30^{-5}_{+6}$ | Band | 18.7 |

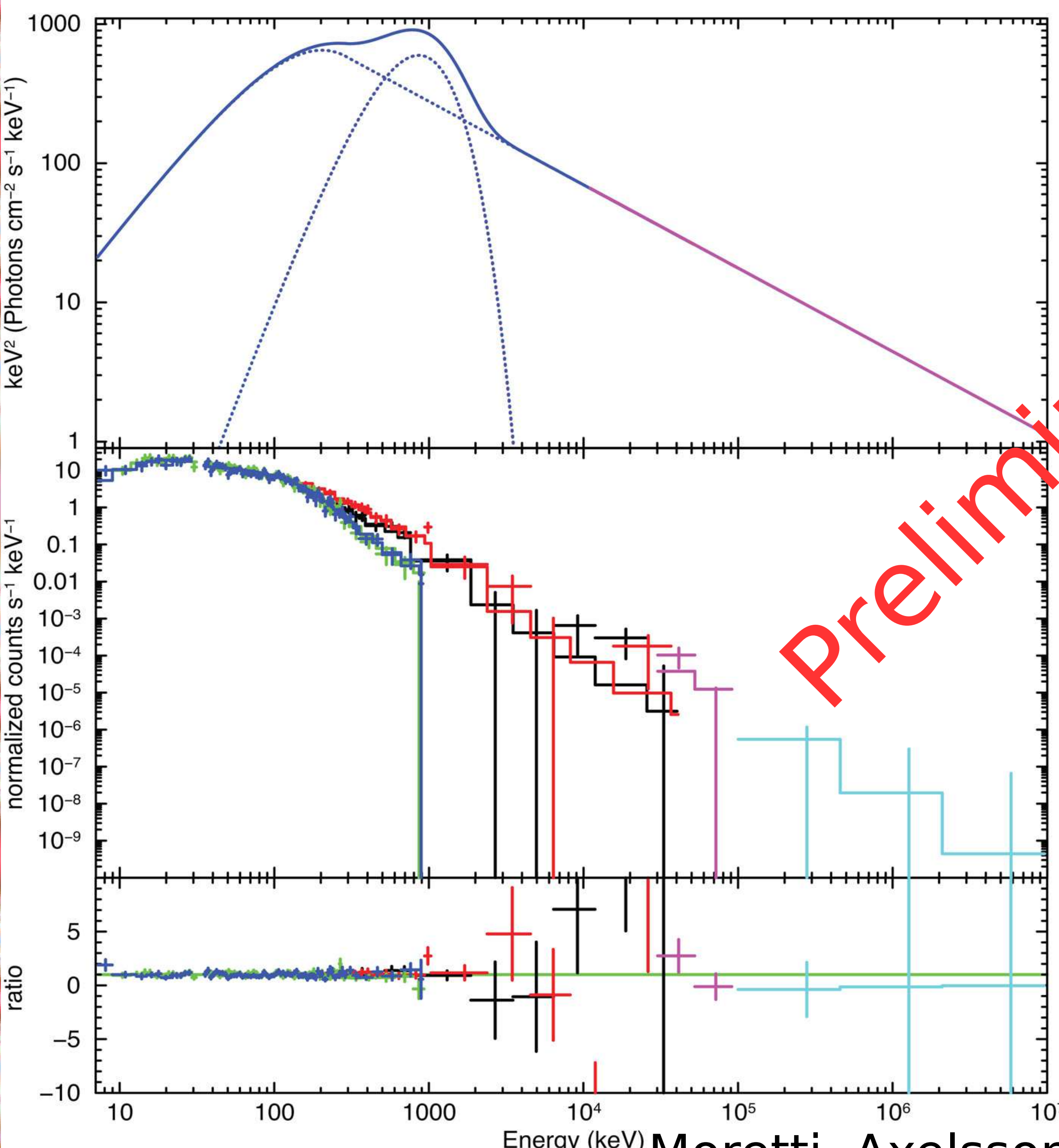
NOTE.—We exclude from this table all GRBs outside the nominal LAT FOV (with $\theta > 70°$) and GRB 101014A, which was detected too close to the Earth limb.

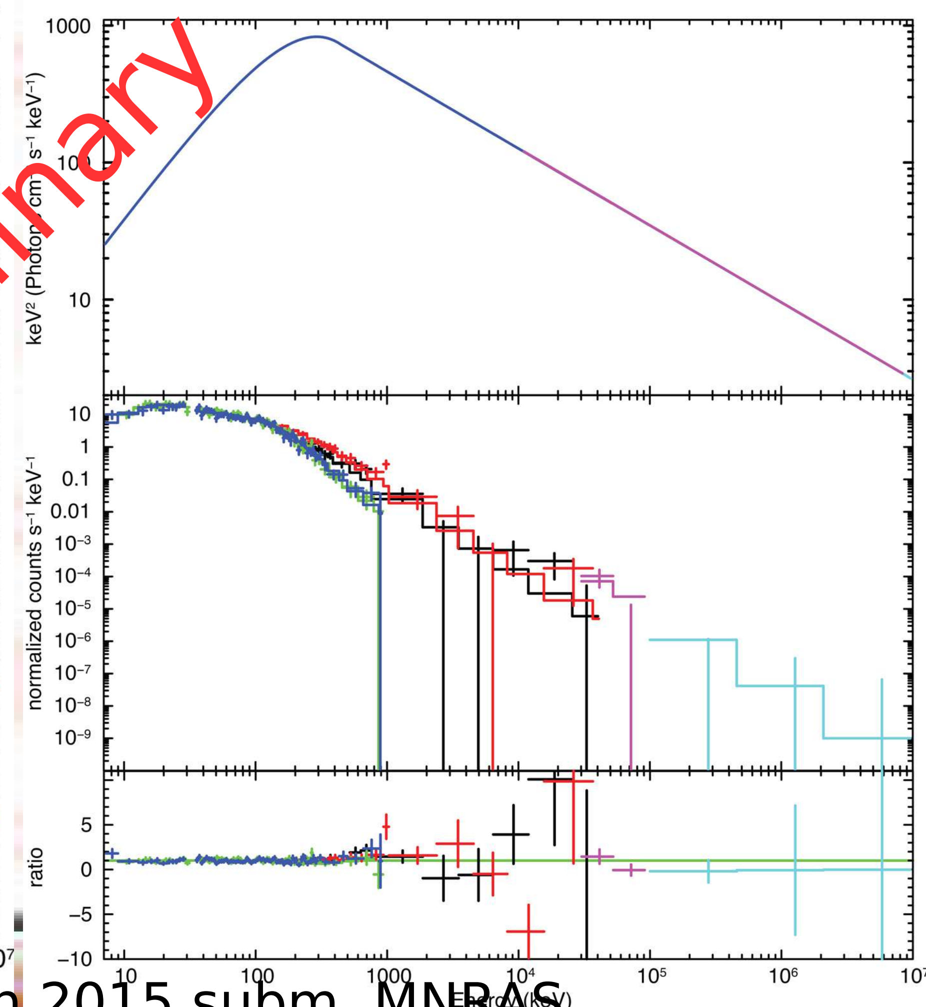
# The Implementation & Analysis

- GRB 080825C is a moderately weak burst that did not show any deviation >4σ from the Band function in Abdo et al. 2009.
- We add the LLE (LAT Low Energy) events to model the gaping region between GBM and LAT from 30 to 100 MeV.
- Data used: NaI 9 & 10 and BGO 0 & 1 (same as in Abdo et al. 2009); LLE (P7), P7REP_transient (new datasets).
- We use the same time bins as in Abdo et al. 2009.
- We lower the significance threshold, and investigate extra components above 3σ.

# Bin I

An extra component is found with 3.5σ significance in the first and fourth time bins.




Preliminary

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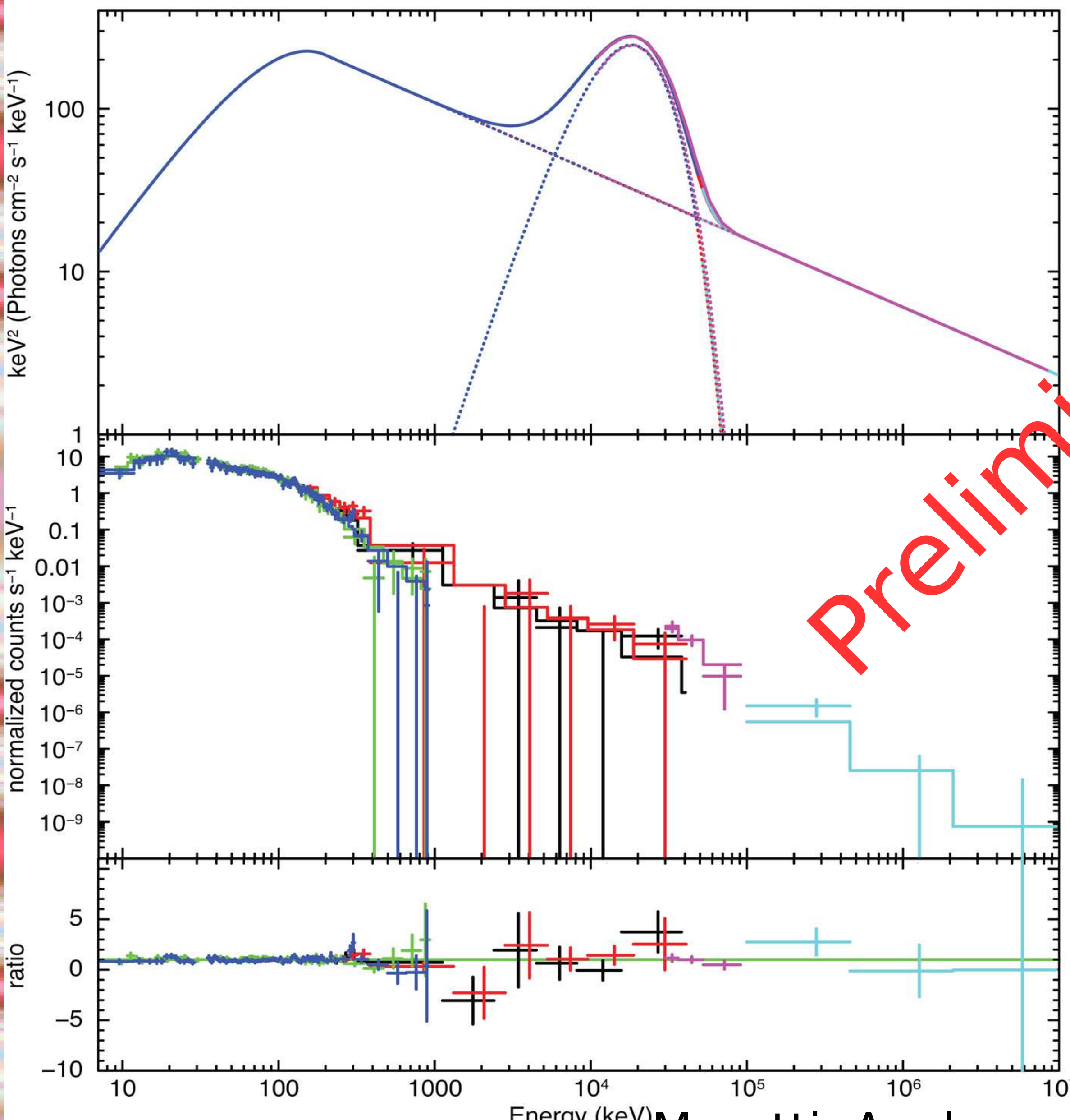
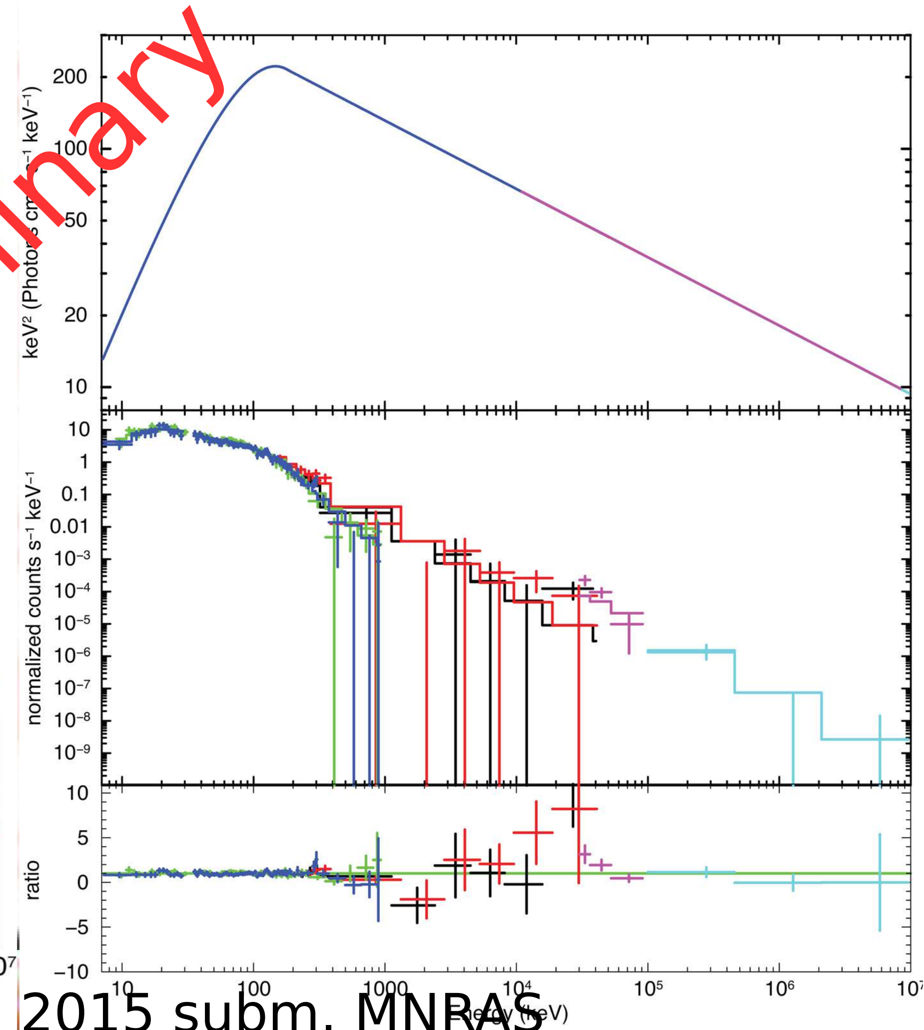
# Bin IV

An extra component is found with 3.5σ significance in the first and fourth time bins.

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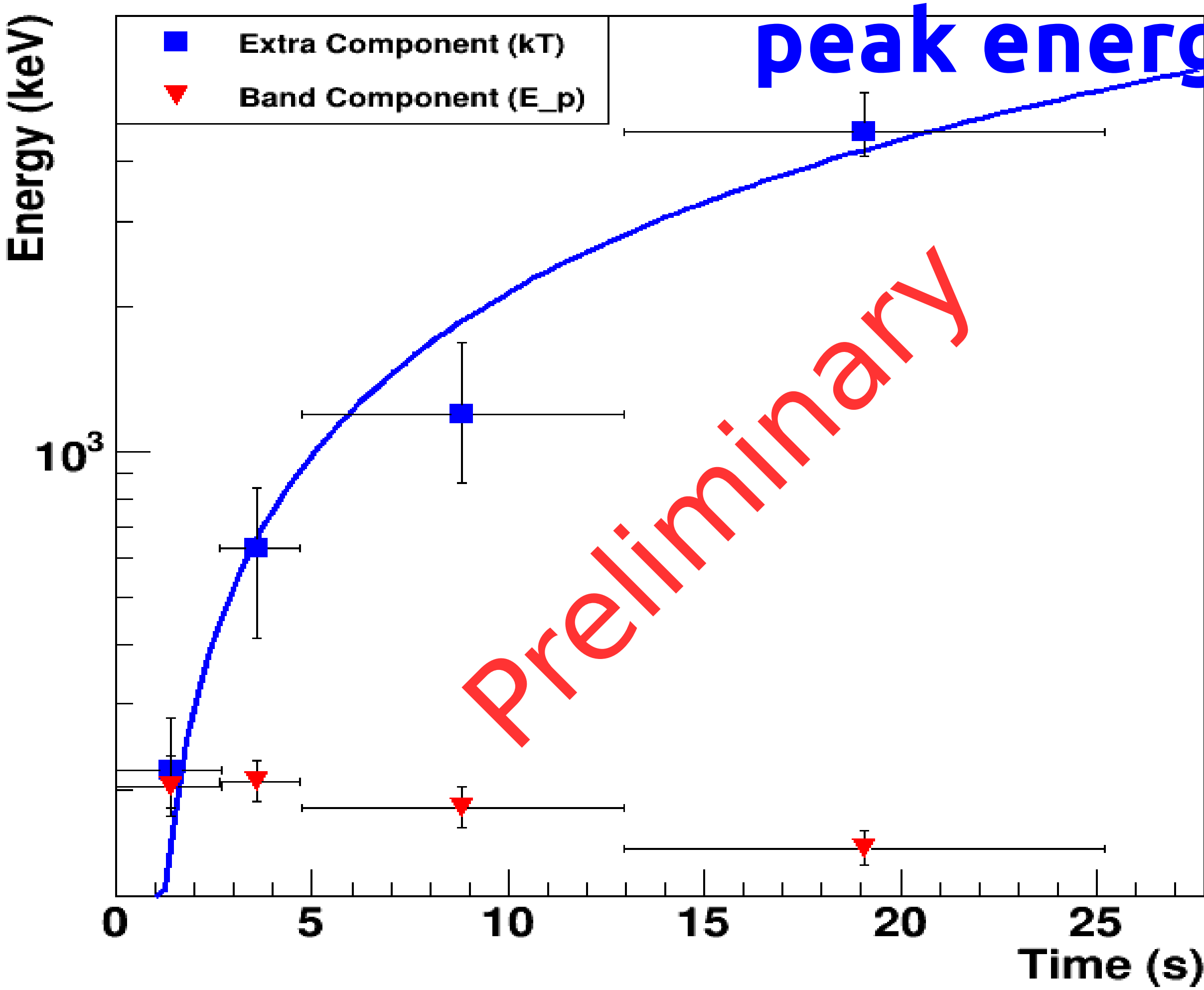
# Results

- An extra component is found with 3.5σ significance in the first and fourth time bins.
- It is not significant in the time bins between, but the recovered parameters follow the same relation throughout the burst.
- The simplest model consistent throughout the burst is Band+BB.
- The first peak can not be modelled with a BB as it is wider.
- The second peak is likely wider than a BB peak, but if modelled with a Band function the parameters can not be fully constrained.

# Time evolution of the Band and BB peak energies




- The energy of the Band peak has a typical hard-to-soft evolution.
- The energy of the second peak (BB) increases linearly with time and reaches almost 16 MeV (similar to 110721).

| Time | $\alpha$ | $\beta$ | $E_p^a$ | $N^b_{Band}$ | $kT^a$ | $N^b_{BB}$ | $N^b_{PL}$ |
|---|---|---|---|---|---|---|---|
| $0.0 - 2.69$ | $-0.56^{+0.08}_{-0.07}$ | $-2.6^{+0.1}_{-0.2}$ | $203^{+31}_{-28}$ | $0.10^{+0.01}_{-0.01}$ | $219^{+62}_{-36}$ | $15^{+3}_{-3}$ | - |
| $2.69 - 4.74$ | $-0.46^{+0.06}_{-0.07}$ | $-2.43^{+0.06}_{-0.07}$ | $208^{+22}_{-19}$ | $0.14^{+0.01}_{-0.01}$ | $632^{+208}_{-221}$ | $11^{+8}_{-7}$ | - |
| $4.74 - 12.93$ | $-0.74^{+0.05}_{-0.05}$ | $-2.46^{+0.07}_{-0.08}$ | $183^{+19}_{-17}$ | $0.046^{+0.004}_{-0.003}$ | $1191^{+497}_{-332}$ | $7^{+4}_{-4}$ | - |
| $12.93 - 25.22$ | $-0.64^{+0.05}_{-0.05}$ | $-2.42^{+0.06}_{-0.06}$ | $151^{+13}_{-13}$ | $0.050^{+0.004}_{-0.004}$ | $4613^{+920}_{-508}$ | $6.0^{+2.0}_{-1.5}$ | - |
| $25.22 - 35.46$ | $-1.94^{+0.03}_{-0.04}$ | - | - | - | - | - | $8.3^{+1.0}_{-1.4}$ |

[a] keV
[b] $ph\ cm^{-2}\ s^{-1}\ keV^{-1}$

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# Interpretation (1)

Assuming that at least one component is related with the photosphere, there are two scenarios:

**(1) One zone emission at the photospheric radius:**

- ✗ Double-peaked spectra can be produced by subphotospheric emission, but the evolution of the second peak does not match predictions (Keren & Levinson 2014).
- ✔ If there is no subphotospheric dissipation, the temperature of the BB component is too high for photospheric emission. Possibly inverse Compton component from thermal/MeV photons scattering on accelerated electrons? (Pe’er et al. 2006, Vurm et al. 2014).

➔ Not a likely scenario!

# Interpretation (2)

**2) Multi-zone emission:**

✔ The Band is the photospheric emission:

- thermal acceleration;
- the BB component could be from synchrotron (internal shocks) or inverse Compton (Beloborodov et al. 2014; unlikely given the peak energy and the temporal behaviour).

✔ The BB is the photospheric emission:

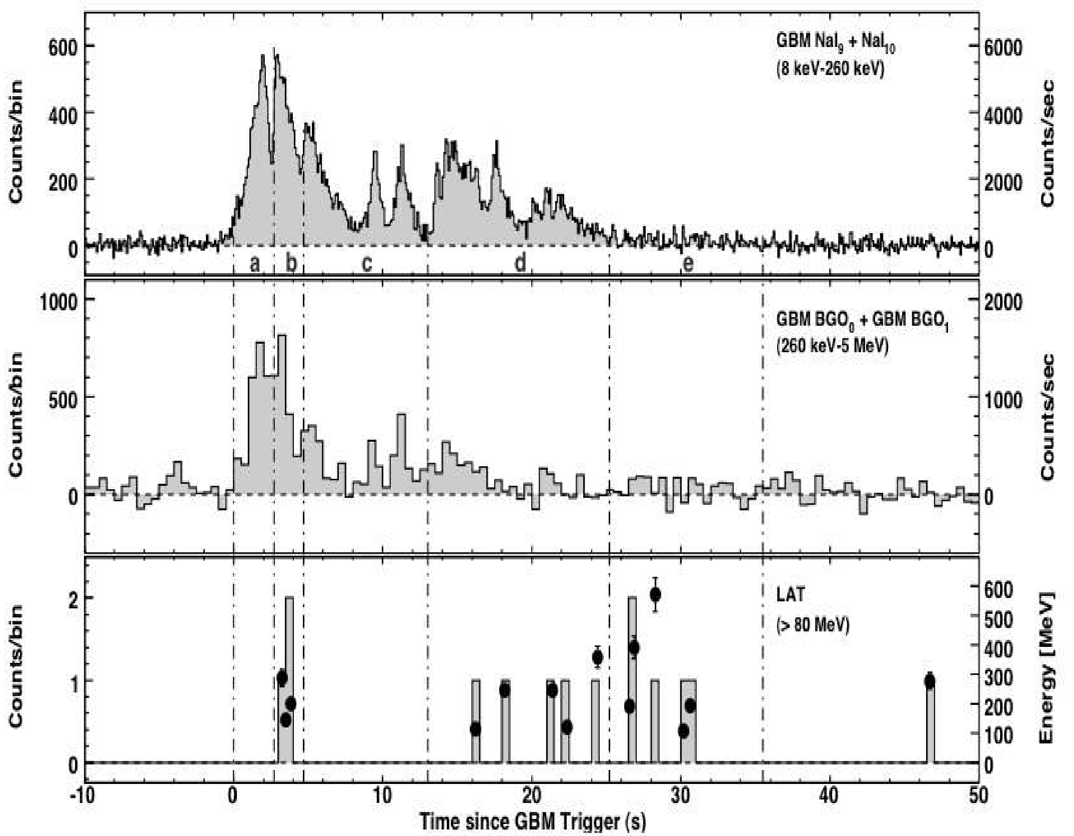
- acceleration from magnetic reconnection (kT too high for thermal acceleration; Bégué & Pe'er 2015);
- the Band component could be synchrotron emission from electrons accelerated via reconnection (as the ICMART scenario of Gao & Zhang 2015).

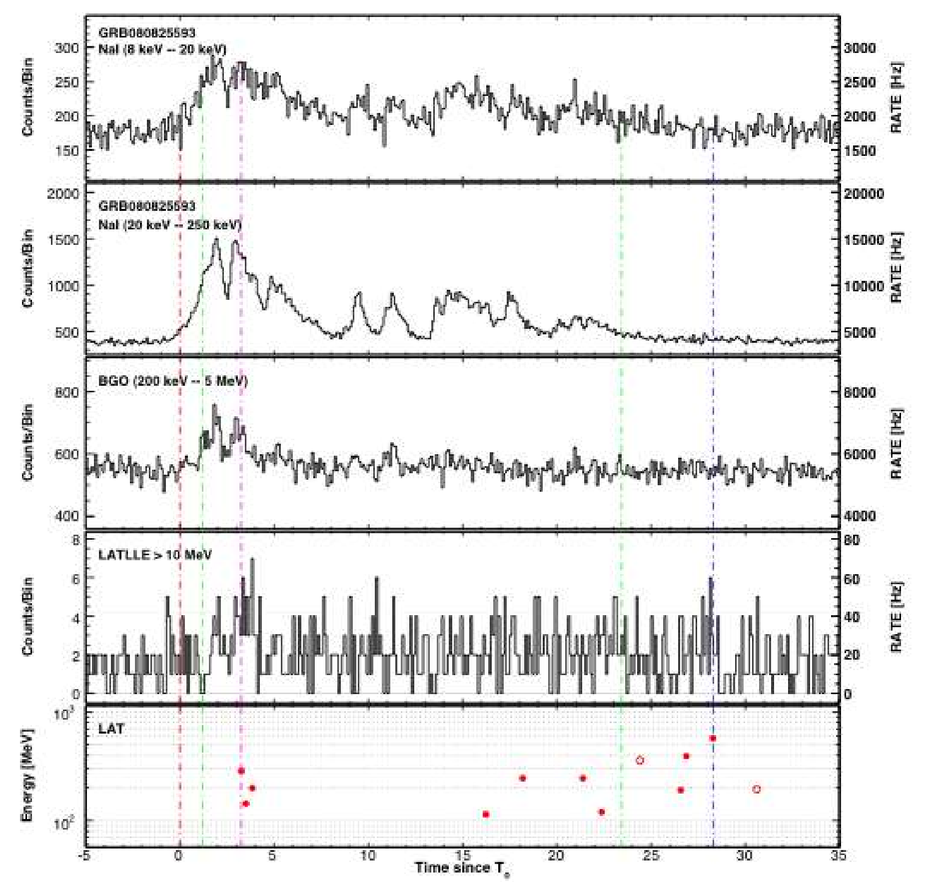
➔ Most likely scenario if BB is photospheric!

# Conclusions

- Evidence for a second peak at energies above the previously reported Band component, present at the level of 3.5σ.
- The peak energy of the extra/component increases throughout the emission episode, from a few hundred keV to several MeV.
- The results point to a 2 zone emission model disfavouring a single radius origin of the emission.
- The high energy of the second peak points to magnetic dissipation in the photospheric emission scenario.

# Thank you


GBM $NaI_9$ + $NaI_{10}$
(8 keV-260 keV)
GBM $BGO_0$ + GBM $BGO_1$
(260 keV-5 MeV)
LAT
(> 80 MeV)
Counts/bin
Counts/sec
Energy [MeV]
a
b
c
d
e
Time since GBM Trigger (s)


GRB080825593
NaI (8 keV -- 20 keV)
GRB080825593
NaI (20 keV -- 250 keV)
BGO (200 keV -- 5 MeV)
LATLLE > 10 MeV
LAT
Counts/Bin
RATE [Hz]
Energy [MeV]
Time since $T_0$

# Tests

- We checked we had the same results with and without LAT>100 MeV data.
- We tested different spectral models but the simplest and consistent throughout the whole burst is Band+BB.
- We checked the width of the second peak by fitting the IV time bin with 2 Band functions. The peak is wider than a BB peak, but the second Band could not be fully constrained (alpha had to be fixed).
- We check the effect of a systematic error on the effective area, but it resulted in a marginal change of the significance of the extra-component.
- Effects on the GBM energy dispersion and calibration are likely below the statistical errors (from communications with GBM team).