
# Spectral Analysis of the 3 Brightest Short GRBs Observed with GBM

by

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**See also poster P3-233 by Erin Kara (Wed-Thurs)**

**(Guiriec et al. In preparation)**

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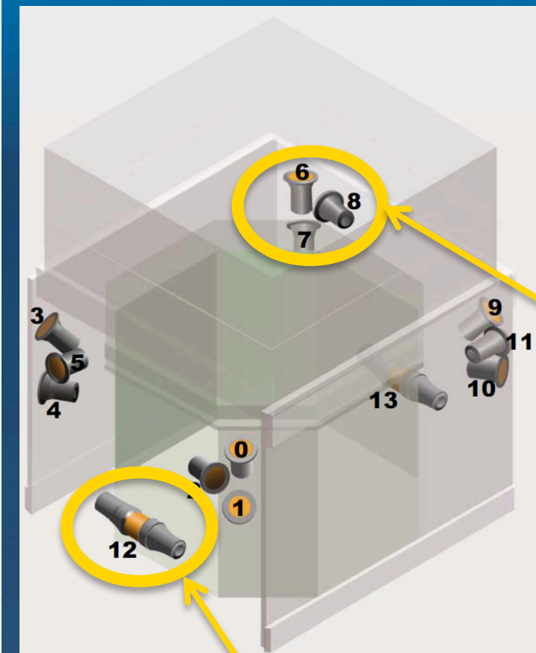
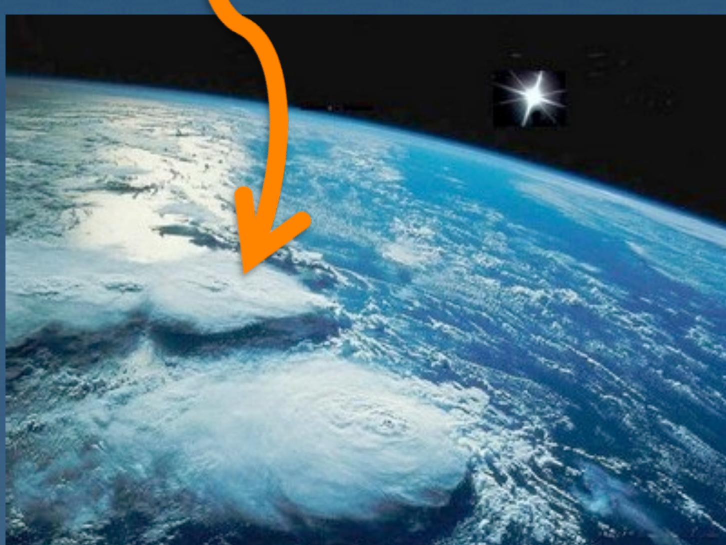
# Why is GBM unique for short and hard GRBs ?




12 Iodine Sodium detectors (NaI: 8 keV to 1 MeV)

2 Germanate Bismuth detectors (BGO: 200 keV to 40 MeV)



• GBM has an effective area 1/36 of its famous predecessor BATSE
=> GBM required bright events

BUT

• Even if smaller, GBM/BGO detectors are much thicker with higher z.
=> Much better photo-peak efficiency and effective area above 1 MeV :

BATSE maximal energy ~10 MeV.
GBM maximal energy ~40 MeV.

=> Spectroscopy of hard bursts possible with GBM.

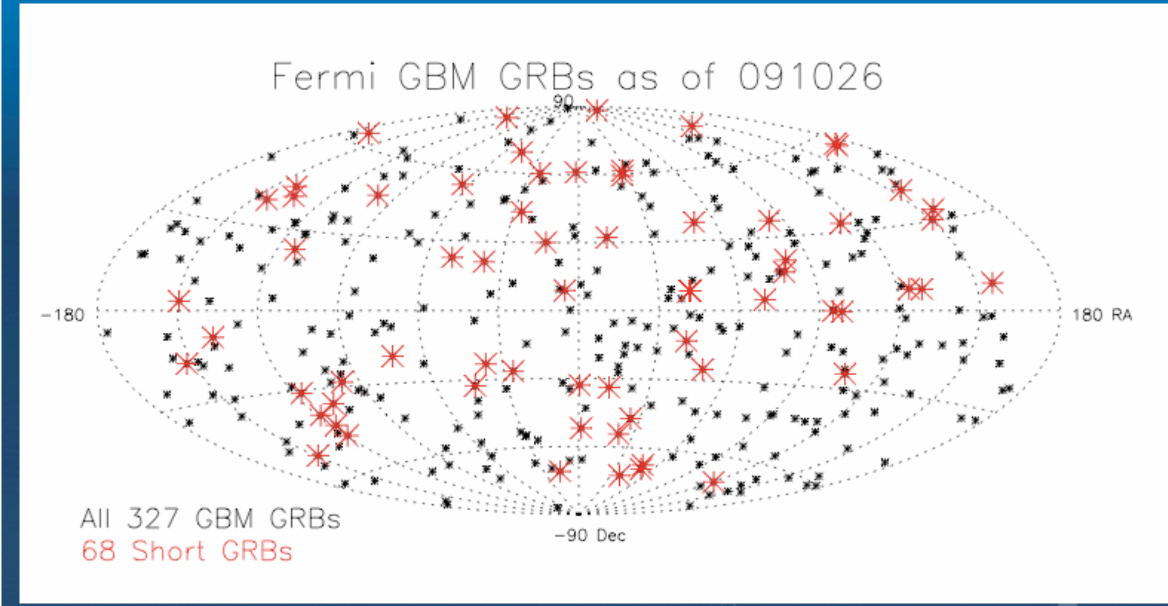
• GBM has :

✓ much more available on-board memory.
✓ a much higher telemetry downlink budget.
✓ a better data design for Time Tag Events (TTE).

=> Data available with a time resolution down to 2 μs, 128 spectral channels from 8 keV to 40 MeV and from -30 to 300 s.

=> Ideal for the study of short events like short GRBs, TGFs (see Michael Briggs talk and Jerry Fishman poster on TGFs) and SGRs (see Chryssa Kovеliotou and Ersin Gogus talks)

# GBM and short GRBs




- About 68 short GRBs detected with GBM since since July, 2008.
- Short GRBs correspond to ~20% of the total GRBs detected with GBM

## Sample criteria for this analysis

- $T_{50} < 1s$
- Fluence > $2e^{-6}$ erg/cm2 => bright enough for time-resolved spectroscopy with GBM

=> This selection results in 3 brightest and hardest short GRBs detected with GBM so far:

- GRB 090227B
- GRB 090228
- GRB 090510

In all the following, spectral analysis performed from 8 keV to 40 MeV.

# Time-integrated spectra of the 3 GRBs

- Various model tested :

Standard model before the Fermi Era

✓ Power-law with exponential decay (comptonized)
✓ Band function
✓ Comptonized+PL
✓ Band+PL

Additional component often present in Fermi's GRB spectra

- Fit performed with the analysis package Rmfit

- Choice of the best model : statistical improvement of the Castor Cstat value between models according to the additional degree of freedom

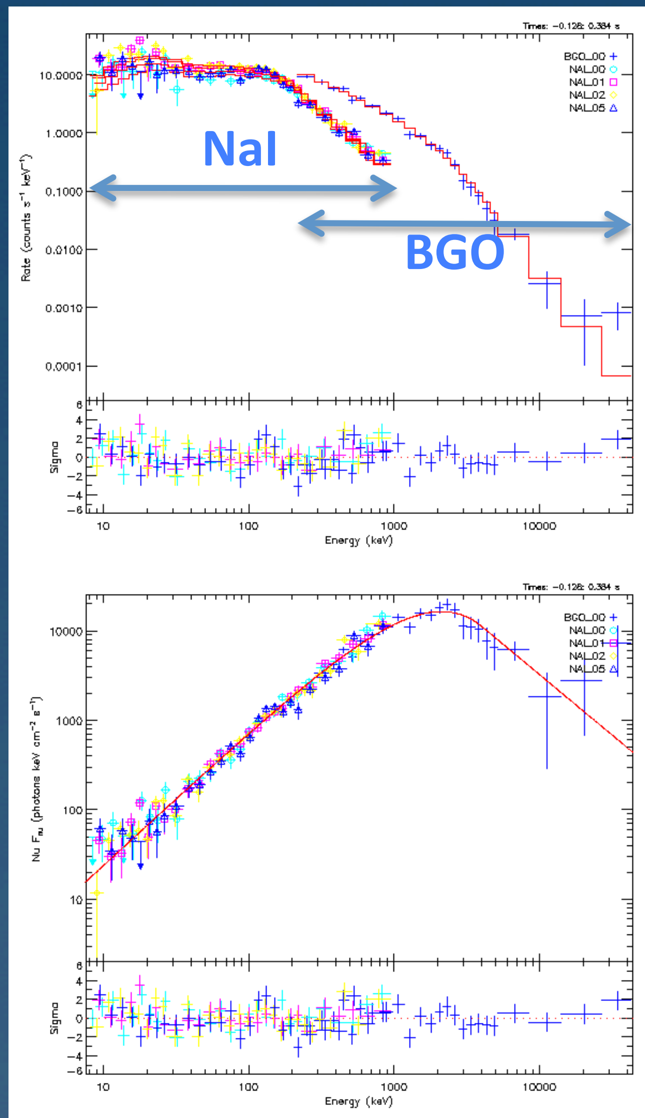
# Time-integrated spectra of the 3 GRBs

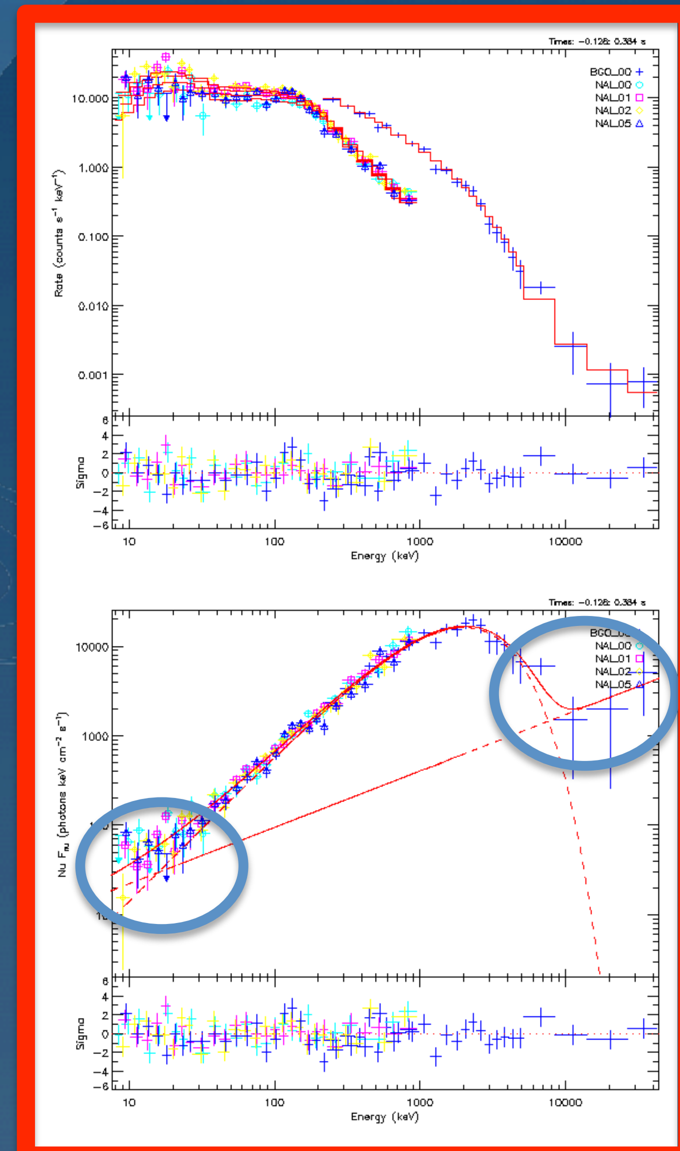
## Case of GRB 090227B

Band (Cstat: 699/607 dof)    <u>Comptonized + PL (Cstat: 689/606 dof)</u>

Count spectrum

$\upsilon F_\upsilon$ spectrum




The additional component dominates the standard Band function at both low and high Energy

| Name | Model | Parameters of the Band function | | | PL | Castor |
|---|---|---|---|---|---|---|
| | | $E_{peak}$ (keV) | α | β | index | Cstat / dof |
| GRB 090227B | Compt | $2227^{+90}_{-85}$ | $-0.52^{+0.02}_{-0.02}$ | | | 706/608 |
| | Band | $2116^{+97}_{-95}$ | $-0.50^{+0.02}_{-0.02}$ | $-3.35^{+0.27}_{-0.39}$ | | 699/607 |
| | Compt+PL | $1995^{+96}_{-91}$ | $-0.36^{+0.05}_{-0.05}$ | | $-1.37^{+0.06}_{-0.06}$ | 689/606 |
| | Band+PL | $1947^{+205}_{-98}$ | $-0.36^{+0.05}_{-0.13}$ | $-3.44^{+0.58}_{-0.80}$ | $-1.51^{+0.05}_{-0.04}$ | 686/605 |
| GRB 090228 | Compt | $862^{+52}_{-47}$ | $-0.59^{+0.03}_{-0.03}$ | | | 813/729 |
| | Band | $860^{+50}_{-49}$ | $-0.59^{+0.03}_{-0.03}$ | $-3.77^{+0.64}_{-0.64}$ | | 813/728 |
| | Compt+PL | $722^{+47}_{-42}$ | $-0.23^{+0.11}_{-0.10}$ | | $-1.63^{+0.09}_{-0.15}$ | 795/727 |
| | Band+PL | $723^{+45}_{-41}$ | $-0.24^{+0.10}_{-0.10}$ | $-4.74^{+1.14}_{-\infty}$ | $-1.64^{+0.03}_{-0.02}$ | 795/726 |
| GRB 090510 | Compt | $4797^{+255}_{-237}$ | $-0.77^{+0.02}_{-0.02}$ | | | 922/851 |
| | Band | $4383^{+290}_{-278}$ | $-0.75^{+0.02}_{-0.02}$ | $-2.80^{+0.20}_{-0.28}$ | | 911/850 |
| | Compt+PL | $3731^{+265}_{-246}$ | $-0.51^{+0.08}_{-0.07}$ | | $-1.35^{+0.04}_{-0.04}$ | 897/849 |
| | Band+PL | $3695^{+284}_{-265}$ | $-0.51^{+0.08}_{-0.08}$ | $-3.65^{+0.75}_{-\infty}$ | $-1.38^{+0.04}_{-0.03}$ | 897/848 |
| (GBM+LAT) | Band+PL | $3936^{+280}_{-260}$ | $-0.58^{+0.06}_{-0.05}$ | $-2.83^{+0.14}_{-0.20}$ | $-1.62^{+0.03}_{-0.03}$ | |

- Comp + PL is systematically prefered => Existence of an additional component in these 3 GRBs
- Value of the index of the additional PL similar in all these bursts
- Higher $E_{peak}$ values than for long GRBs (=> question during Ehud talk : short vs long GRBs with GBM)
- Steep β values (which confirm the comment from Guido to Nicola in the previous talk)
- GBM only results and GBM+LAT fits are consistent for GRB 090510

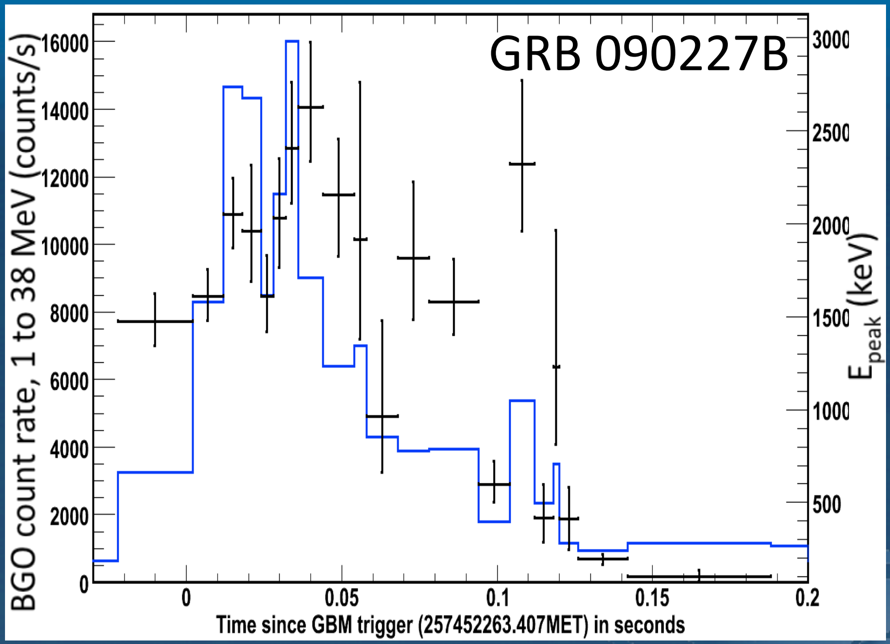
# Time-integrated spectra of the 3 GRBs

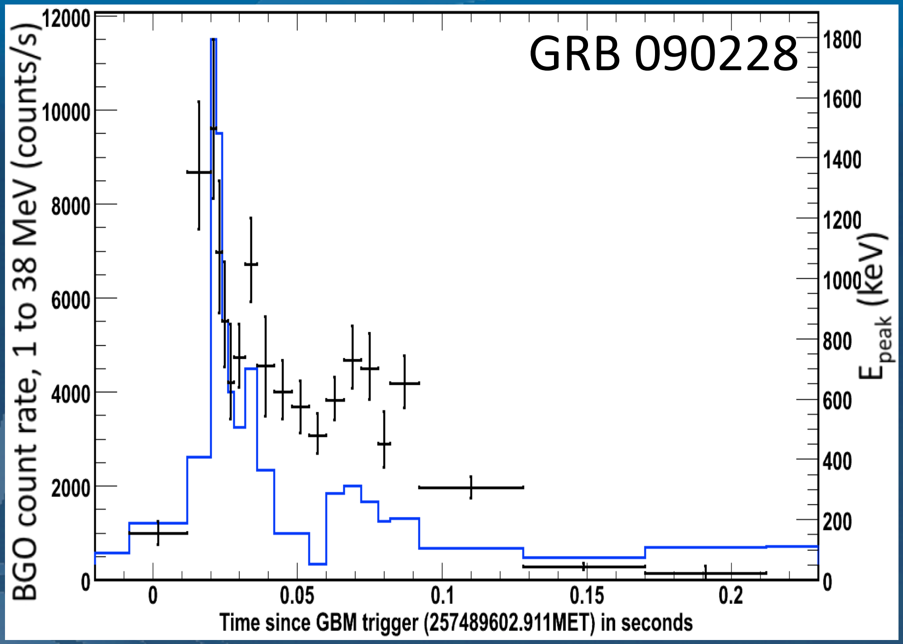
The existence of additional components in these 3 GRBs is

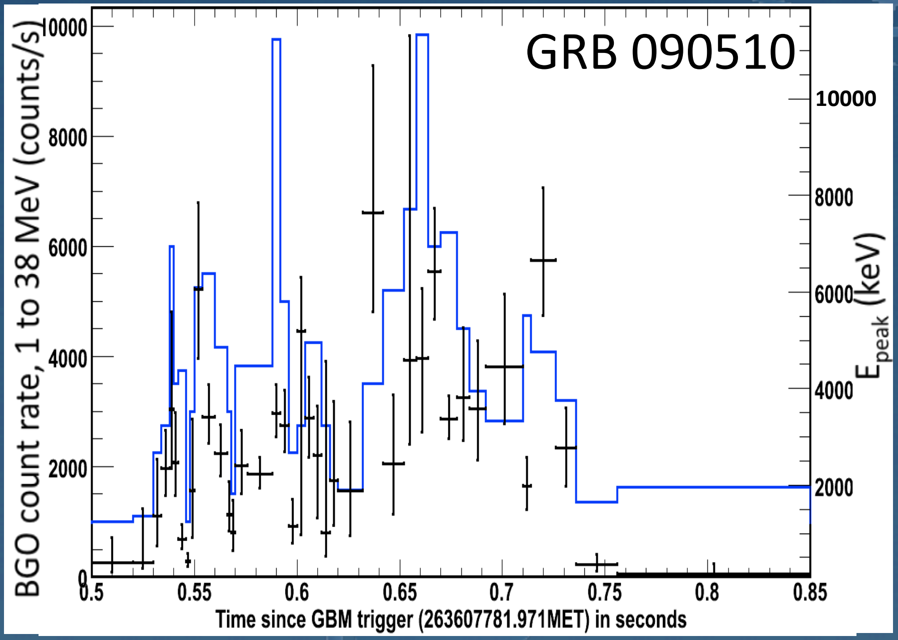
consistent with LAT data

See Poster Valerie Connaughton P3-171 (Wed-Thur)

# Fine Time-Resolved Spectroscopy

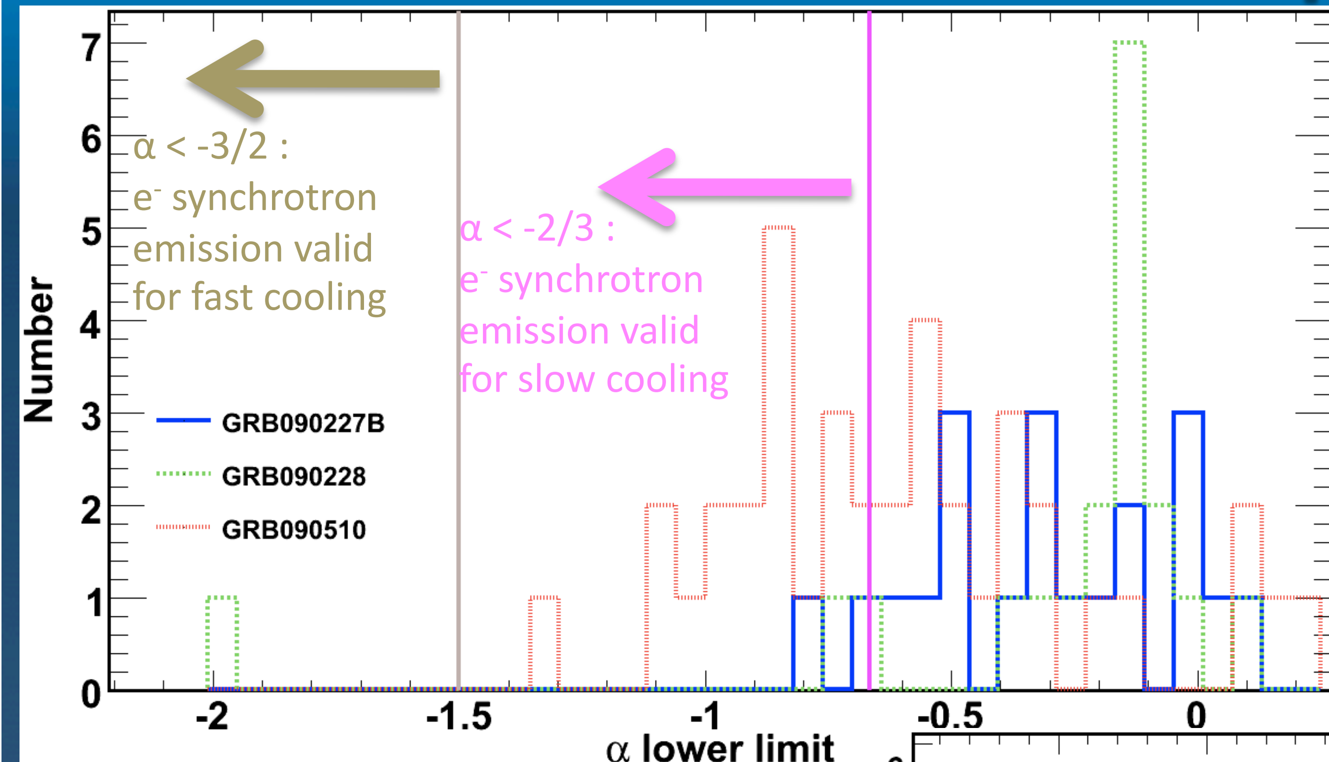


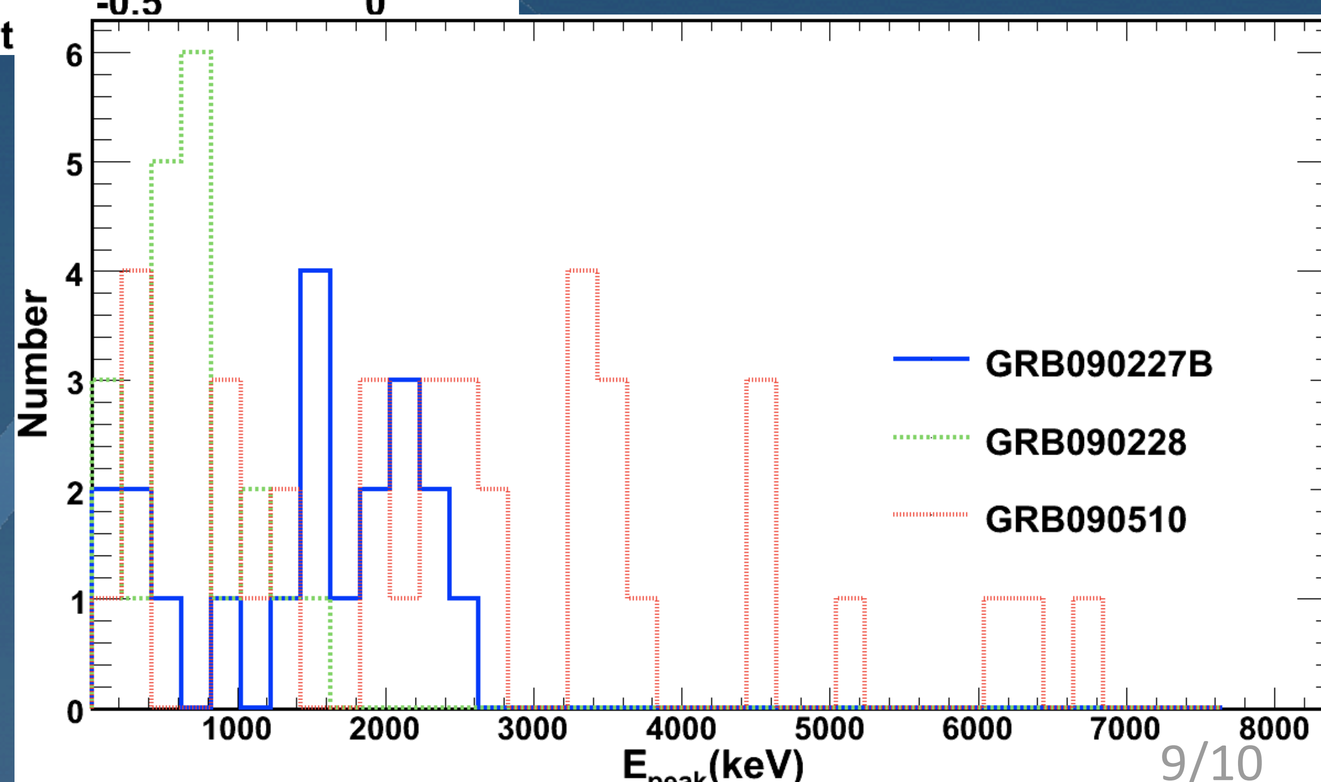




- Similar to what we observed in long GRBs but contracted in time and shifted to higher energy (Ford et al.).
- $E_{peak}$ tracks the light curves like for the long burst.
- The hardest part is not always at the beginning.
- The most intense peaks are not always the hardest.

# Fine Time-Resolved Spectroscopy




- α nearly systematically violates the synchrotron line of death of -2/3.




- $E_{peak}$ evolves over an incredible broad range of energy

# Conclusion

## Time-integrated spectra

- Time-integrated spectra are best fit with Band+Power law model

  => Additional component : electron SSC or hadronic emission
- The additional power law dominates the standard Band spectrum at low and high energy

  => low energy extension of the PL challenges all the models
- The hardest short GRBs have Epeak values well above those of the hardest long GRBs.

## Fine time-resolved spectroscopy

- Short GRBs have similar light curves than long GRBs but contracted in time and shifted towards higher energy, and appear to have steeper β.
- $E_{peak}$ tracks the light curves and spreads over a broad energy range

  => consistent with the electron synchrotron models in the internal shocks context (Acceleration and cooling of the electrons leading to a hardening with the peak rise then a softening of the burst during the pulse decay)
- α in the time resolved spectroscopy violates the synchrotron limits ( Frederic Daigne talk: possible answer with IC ?)

Poster P3-233 by Erin Kara (Wed-Thurs)
Poster P3-171 by Valerie Connaughton (Wed-Thurs)

# BACKUP

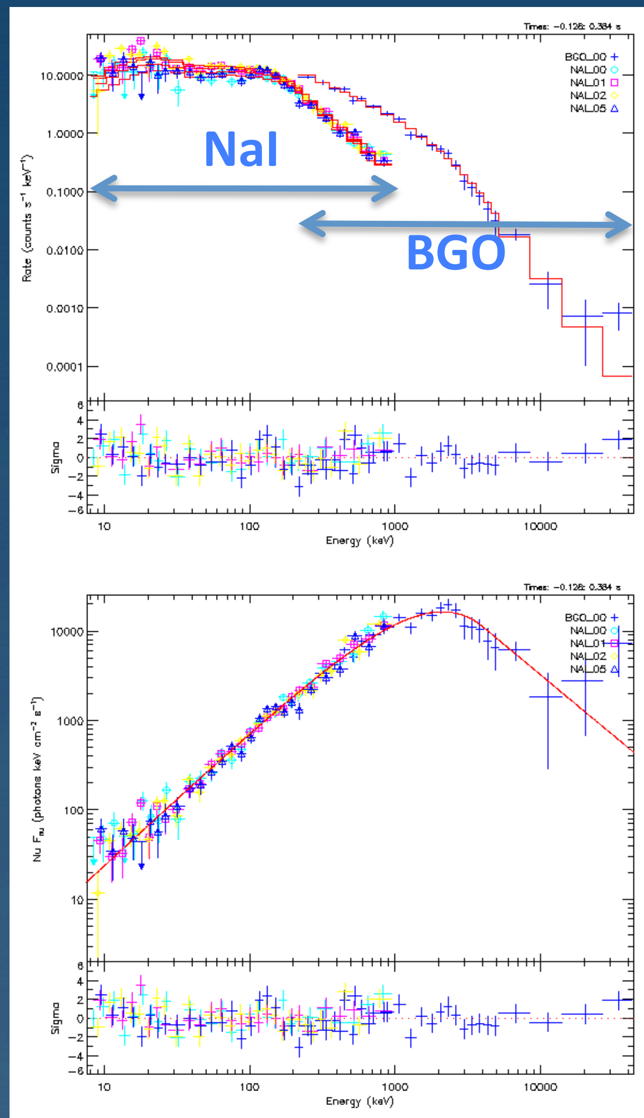
# Time-integrated spectra of the 3 GRBs

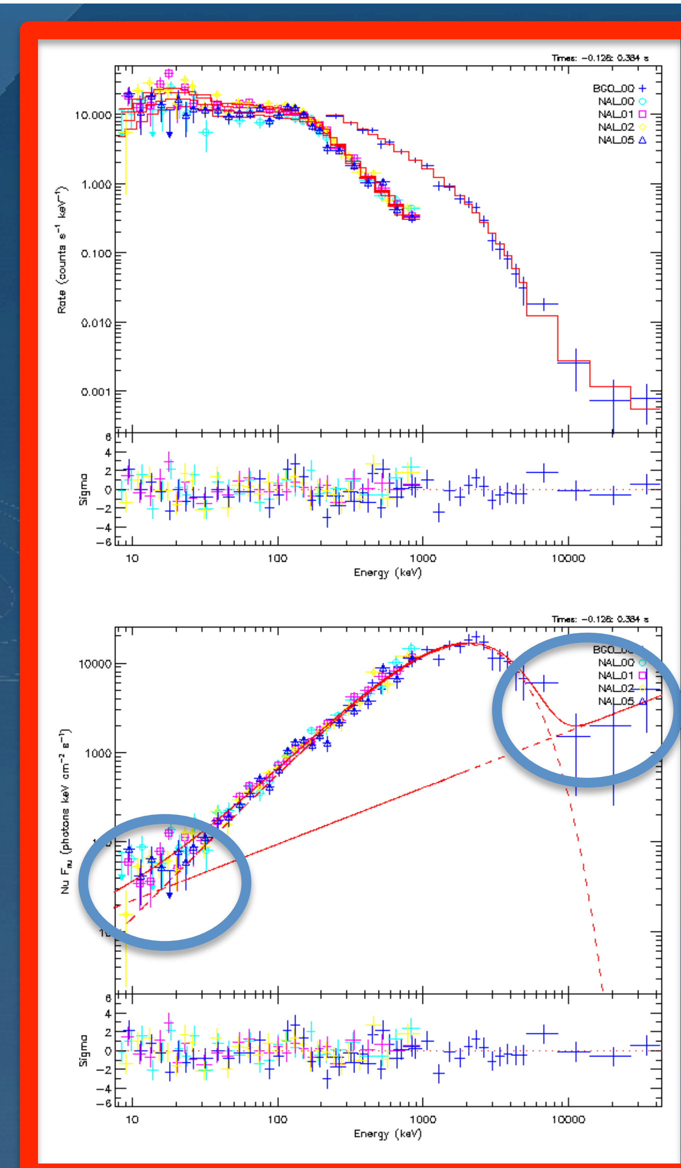
## Case of GRB 090227B

Band (Cstat: 699/607 dof) Comptonized + PL (Cstat: 689/606 dof)

Count spectrum

$\nu F_\nu$ spectrum




The additional component dominates the standard Band function at both low and high Energy

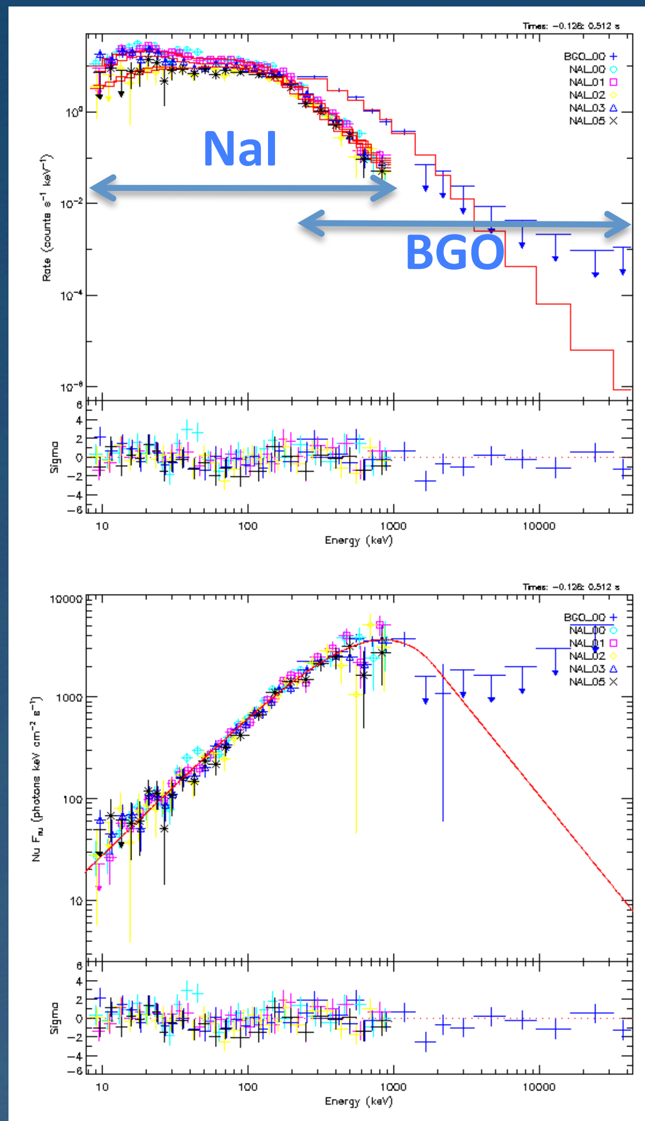
# Time-integrated spectra of the 3 GRBs

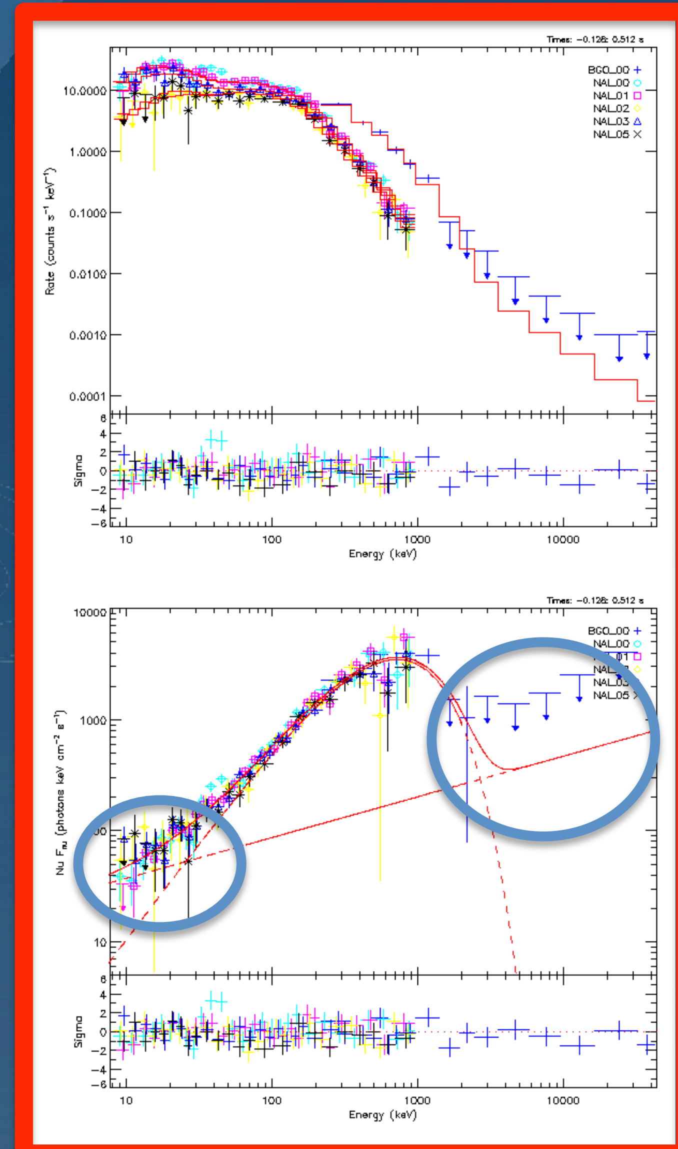
## Case of GRB 090228

Band (Cstat: 813/728 dof) | Comptonized + PL (Cstat: 795/727 dof)

Count spectrum

$\upsilon F_\upsilon$ spectrum




The additional component dominates the standard Band function at both low and high Energy

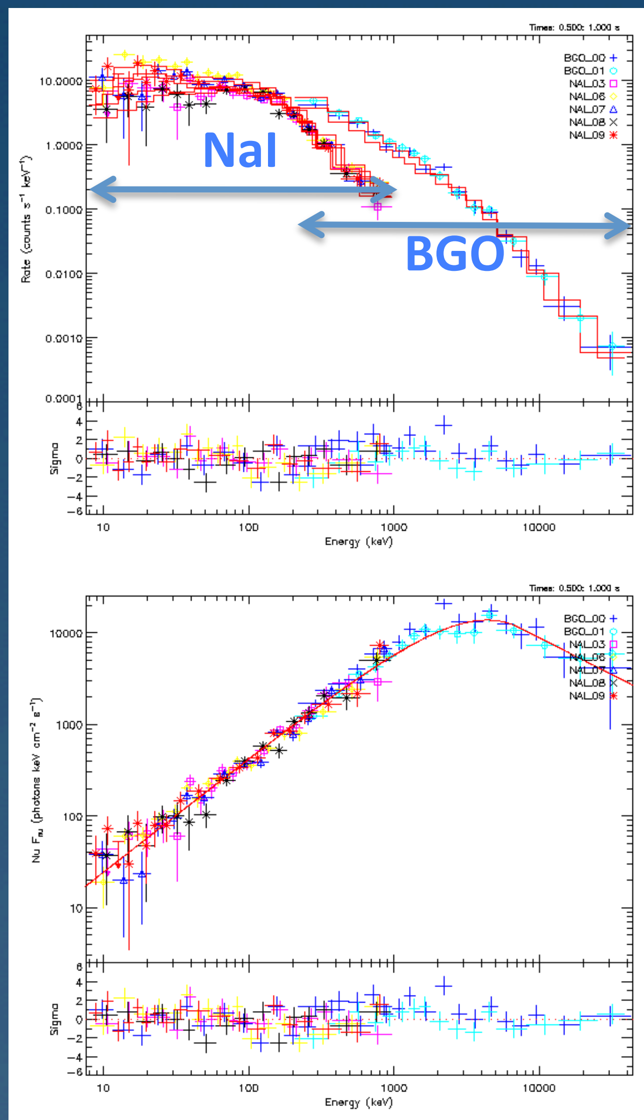
# Time-integrated spectra of the 3 GRBs

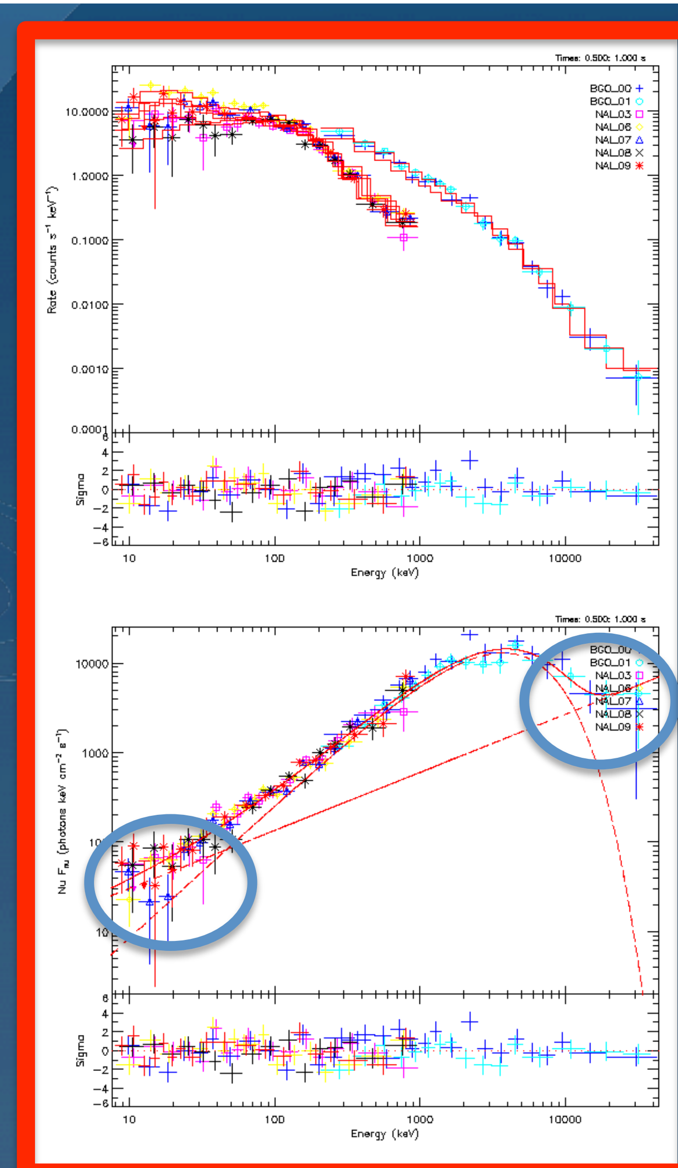
## Case of GRB 090510

Band (Cstat: 911/850 dof) <u>Comptonized + PL (Cstat: 897/849 dof)</u>

Count spectrum

$\nu F_\nu$ spectrum




The additional component dominates the standard Band function at both low and high Energy