Photospheric Emission in Fermi GBM Gamma Ray Bursts

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on behalf of the GBM collaboration

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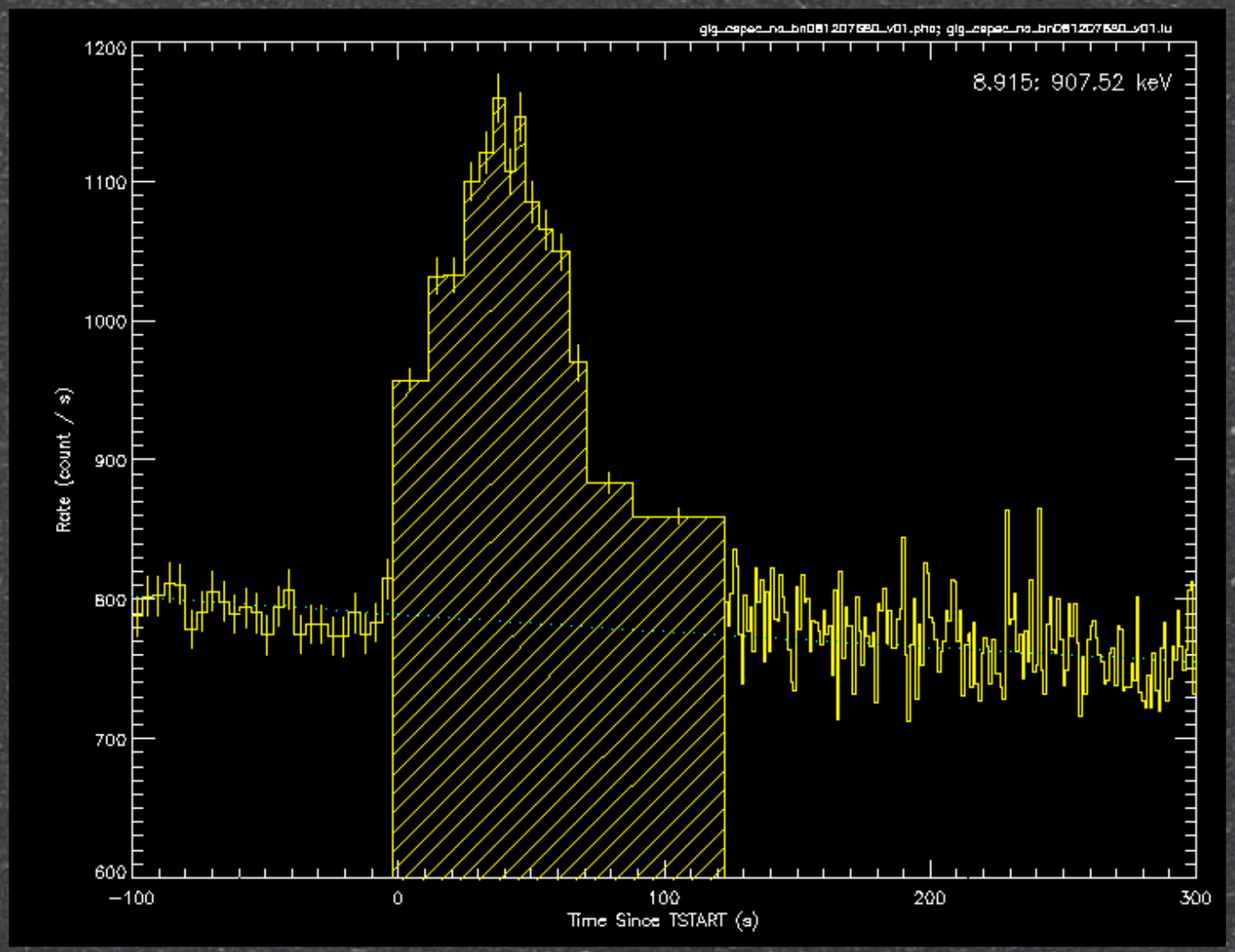
Fermi GBM bright burst sample

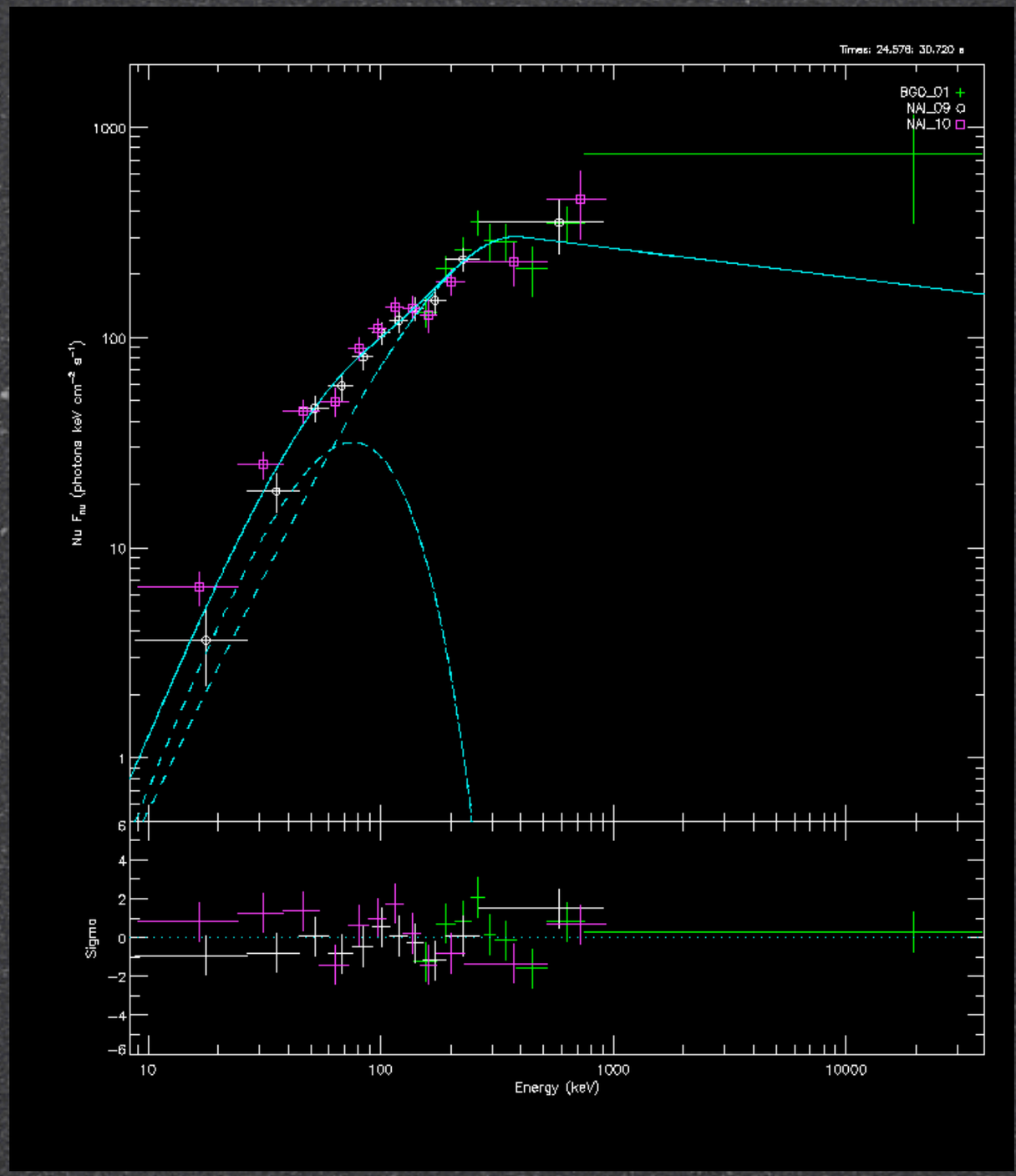
- Elisabetta's bright high energy GRB sample (Sep 08-Sep 11)
- significant counts in 1 BGO detector (>150 keV), Band parameter β well constrained in total spectrum
- time-resolved spectra (S/N per bin >15-20)
- Band parameters: α, β, E_{peak}, normalisation
- Band+BB parameters: α, β, E_{peak}, kT, normalisation (2 extra DoF)

- Bursts classified depending on location of BB peak
  - "shoulder" kT is low, visible as bump in spectrum
  - "curvature" kT is higher, boosts Epeak in spectrum
- several bursts classified as mixed, several separate pulses which evolve
- ignore bursts with very low Ep/few bins

Examples: GRB 081207

- Band+BB in some bursts shifts Epeak to higher values and softens α somewhat
  - e.g. 081207: 1 single pulse with several time-resolved bins

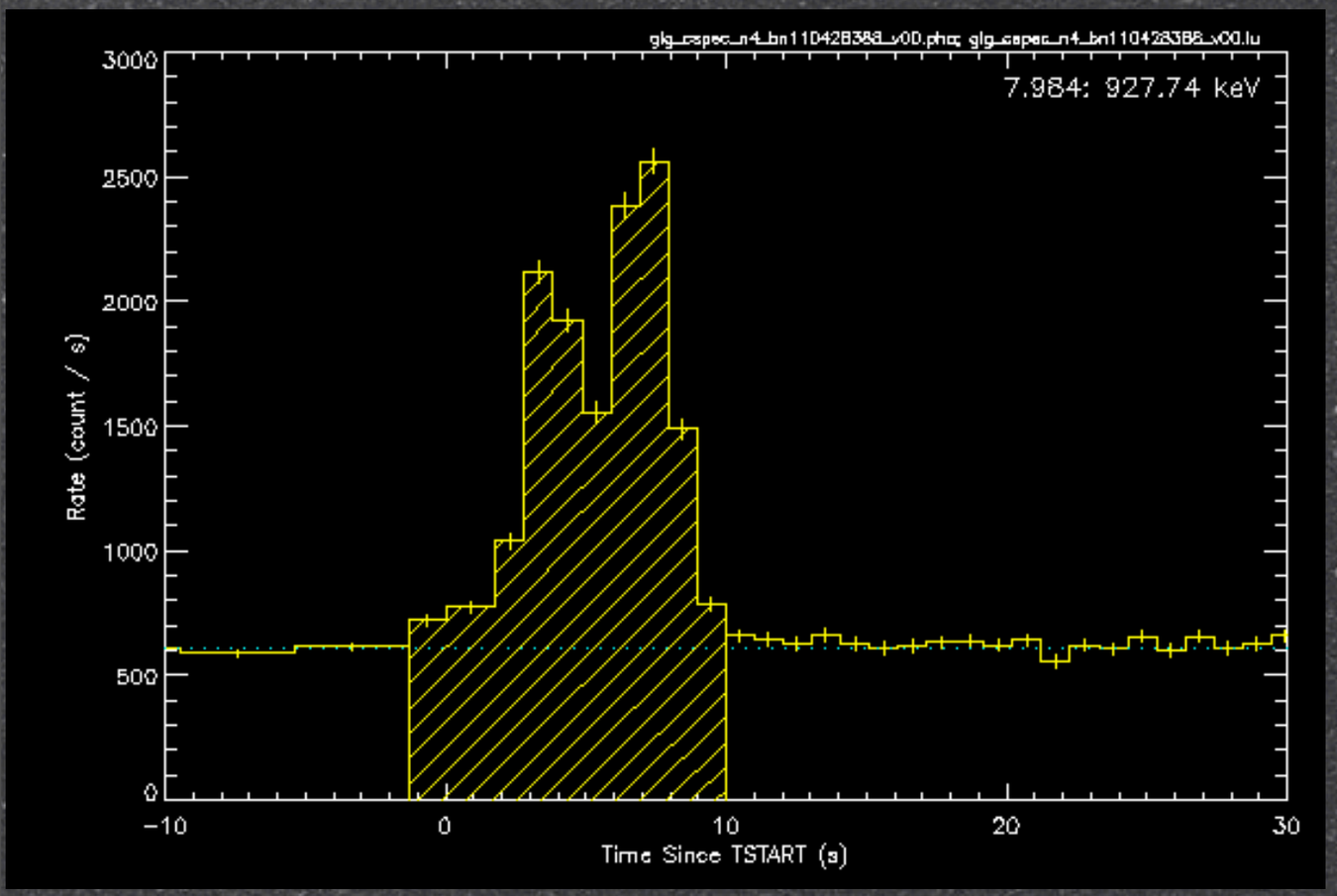


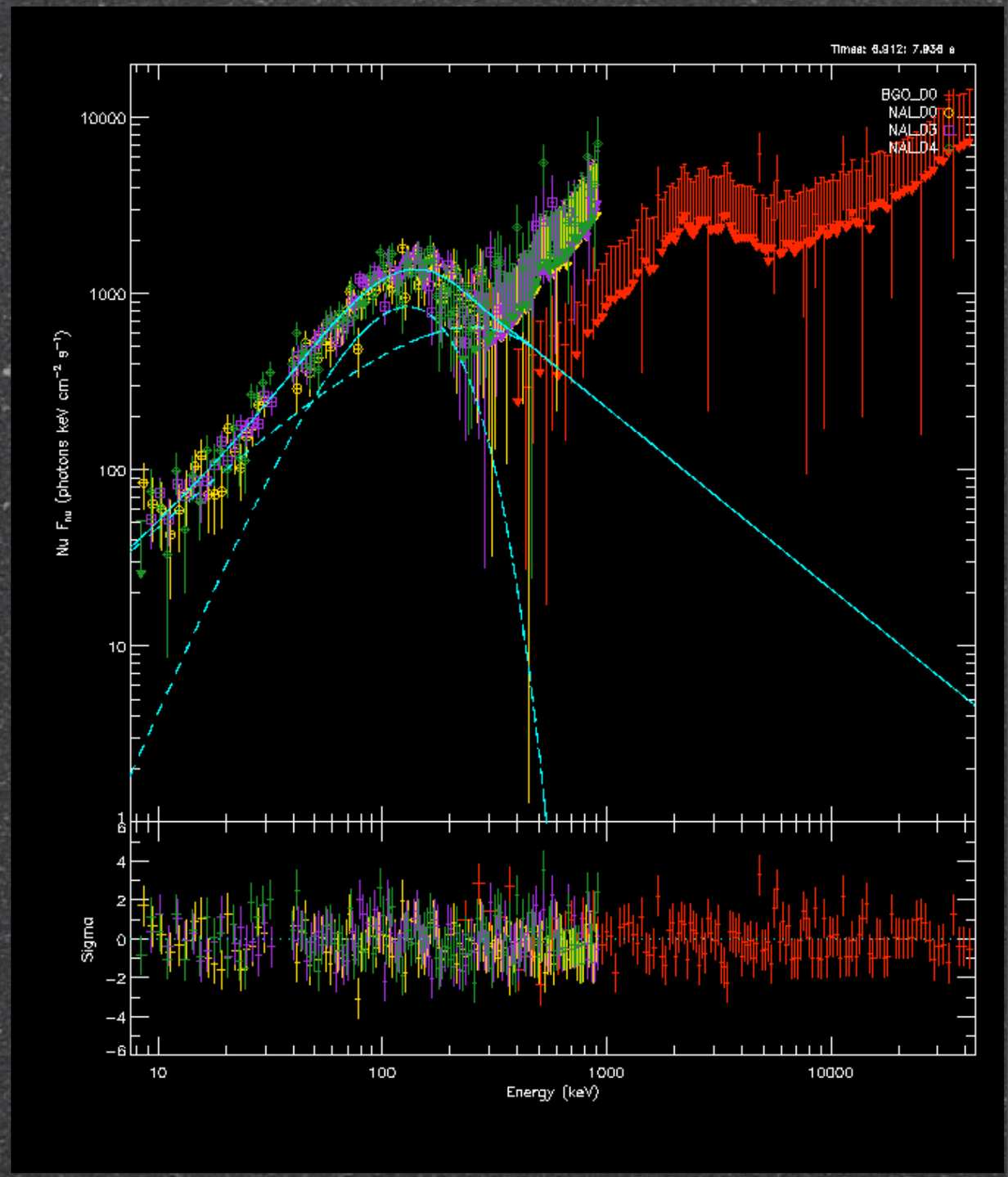


therefore classified as “shoulder”

GRB 110428

- In other bursts, little difference between Band/Band+BB fits, or BB boosts peak of spectrum
  - e.g. 110428: >1 pulse, BB has less noticeable effect on Band parameters





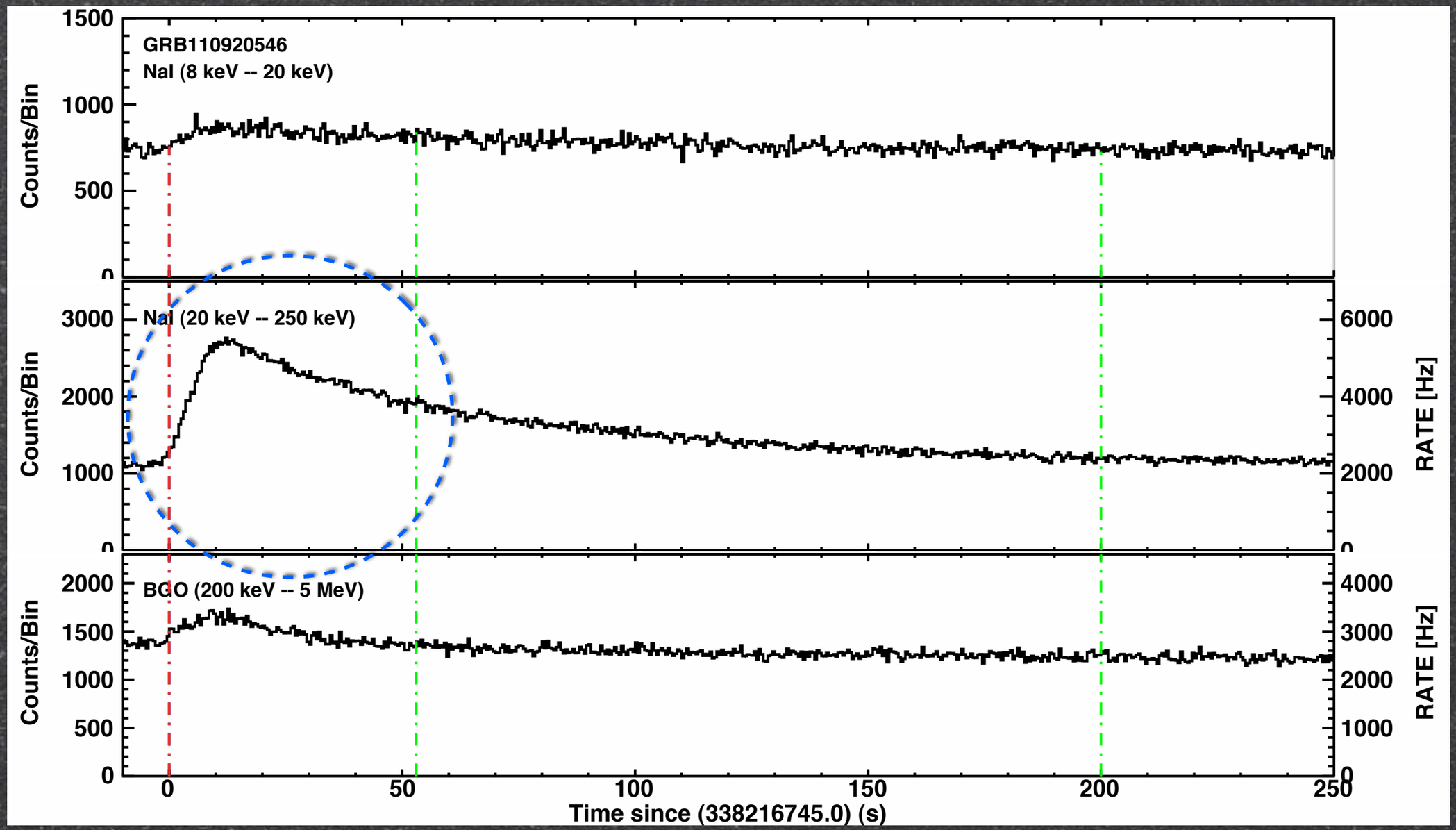
classified as “curvature”

- The difference in these two types of class may be due to the level of subphotospheric dissipation present
- The “curvature” bursts may have broadened spectra due to strong dissipation
- This can occur if:
  - dissipation processes take place below the photosphere which modifies an expected Planck spectrum (e.g. collisional dissipation)
  - or the energy given to the electrons is comparable to or greater than the energy of the thermal photons

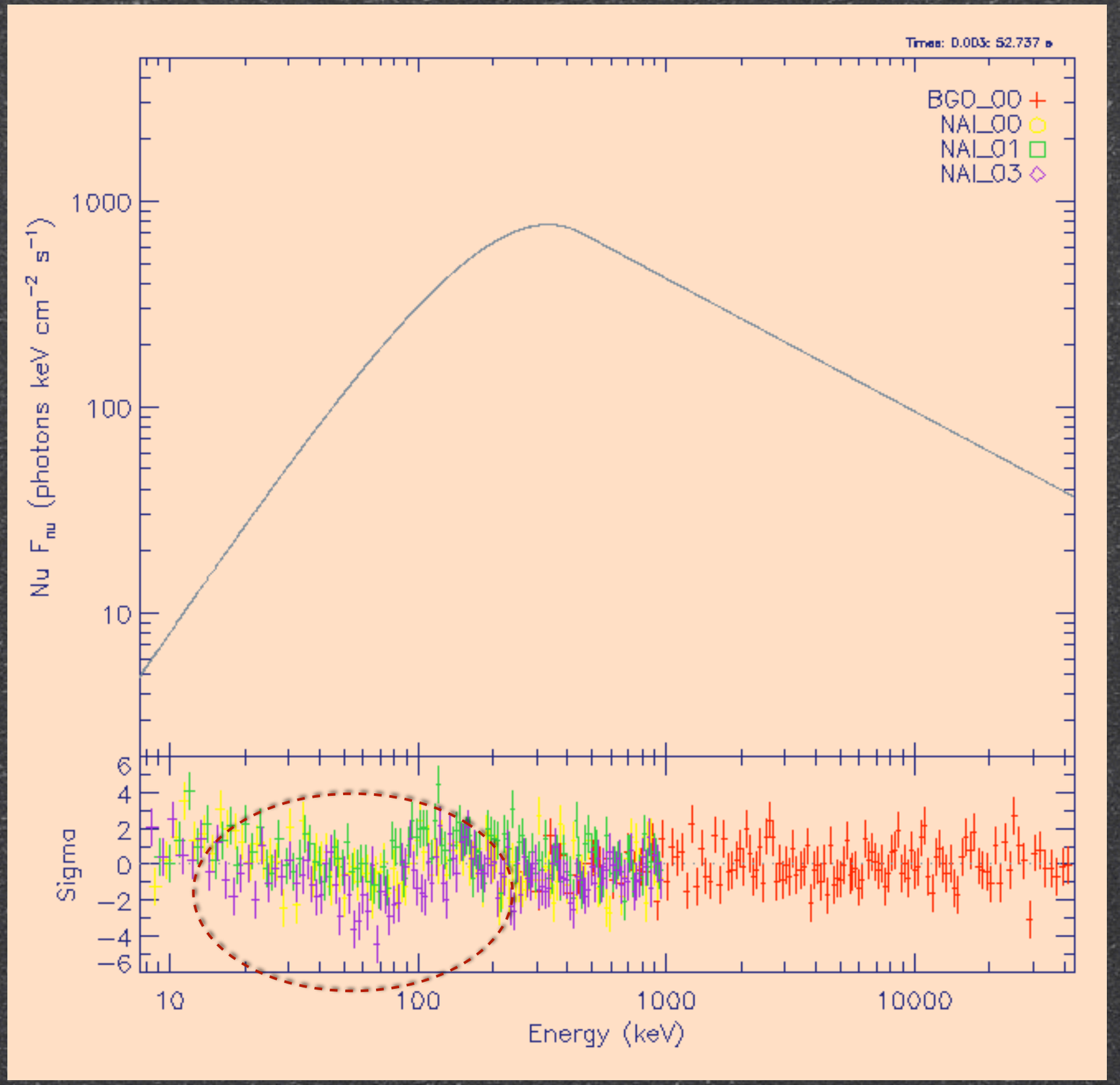
GRB 110920: a special case

- Unknown redshift
- no LAT data available
- No GCNs available
- FRED (Fast Rise Exponential Decay) type lightcurve
- T90 = 170 +/- 17 s

McGlynn et al., 2012, in prep

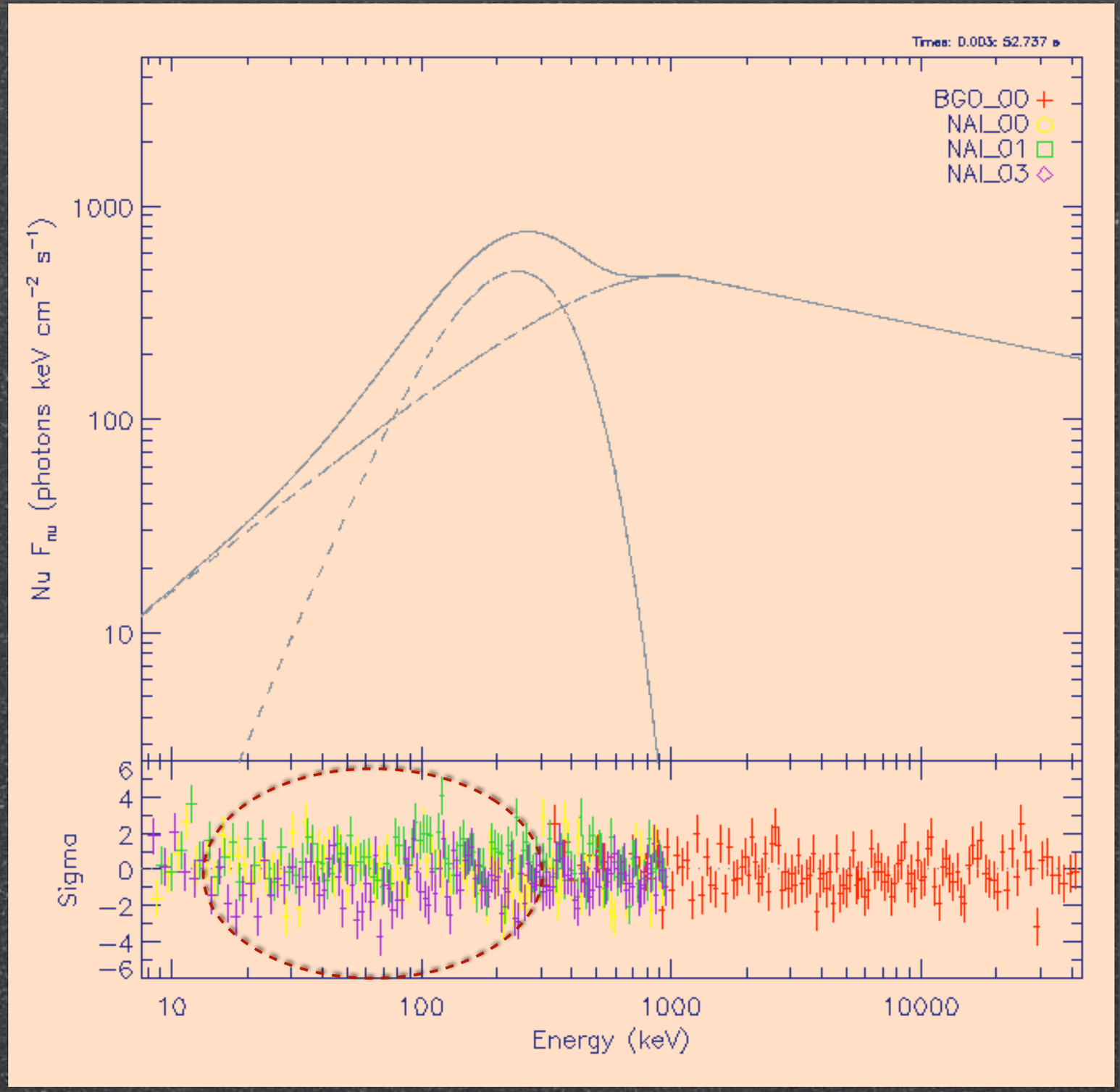


Band fit for T= 0 -> T = 53s



- α = -0.20 +/- 0.02
- β = -2.65 +/- 0.08
- E_{peak} = 334 +/- 5 keV
- C-stat = 3206.5 (485 degrees of freedom)

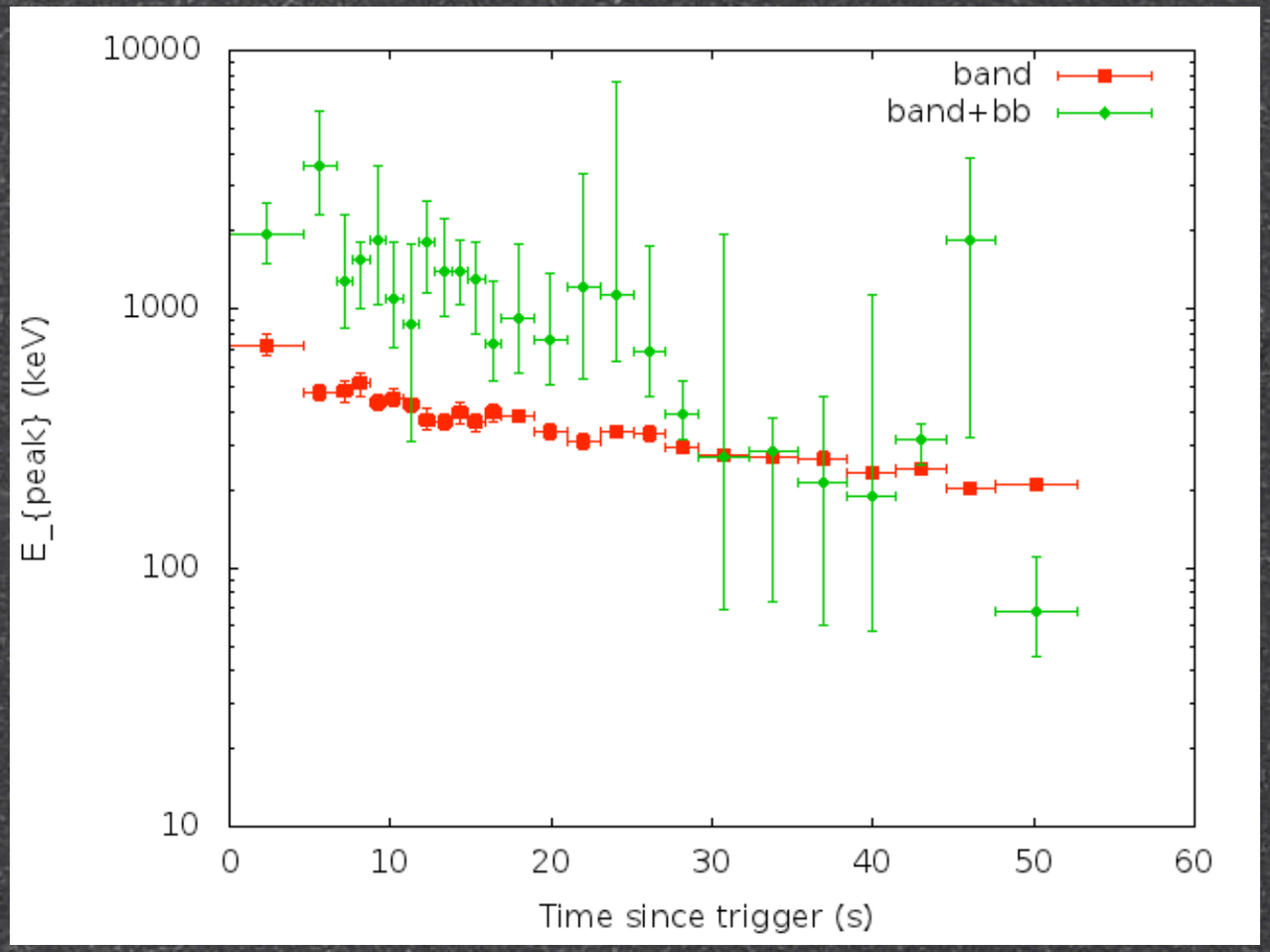
Band+BB fit for T= 0 -> T = 53s

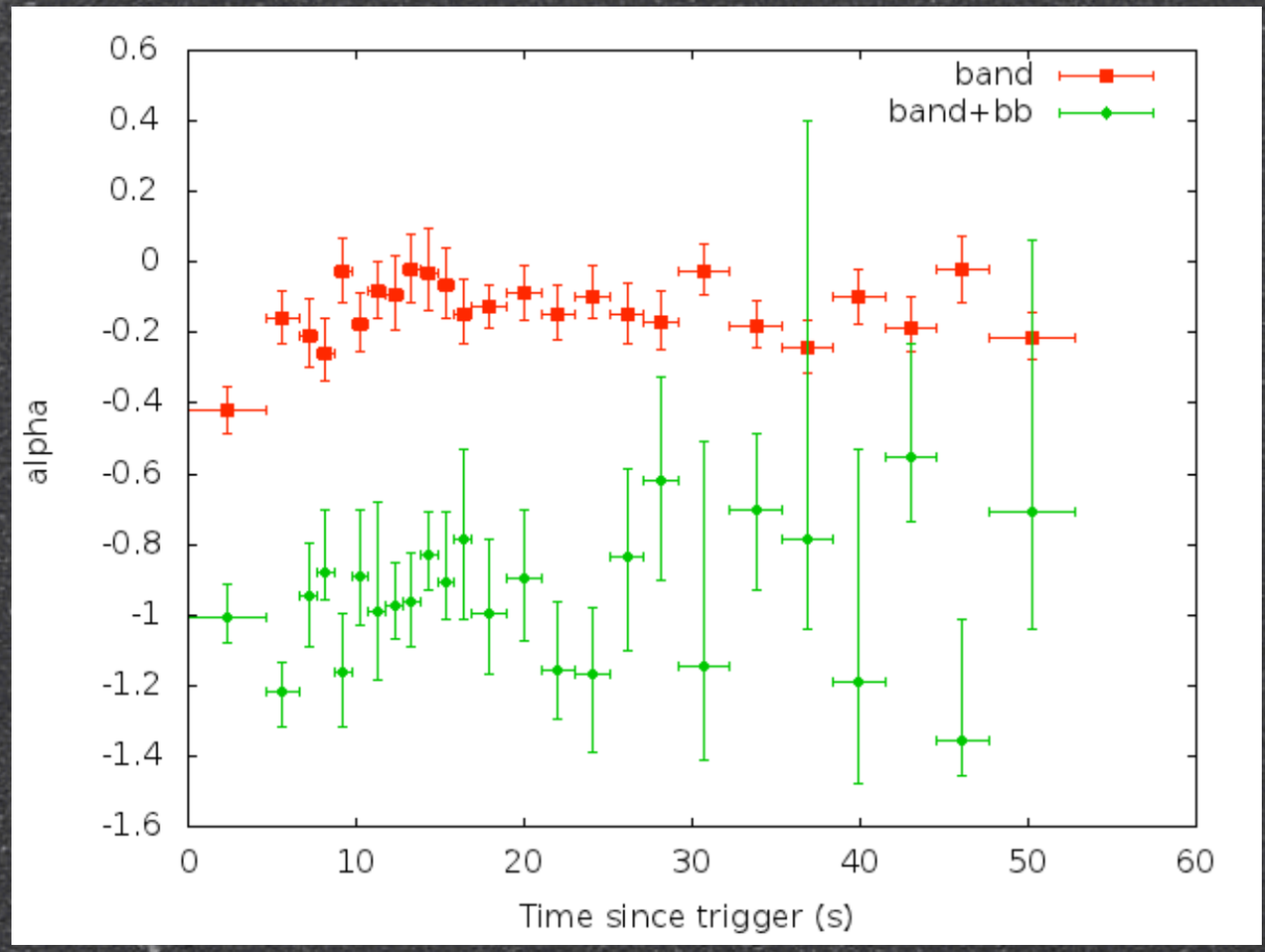


- α = -1.05 +/- 0.04
- β = -2.24 +/- 0.10
- E_{peak} = 978 +/- 150 keV
- kT = 61.3 +/- 0.7 keV
- C-stat = 2848.3 (483 degrees of freedom)

Difference between models:
Δ C-stat = 358 for 2 DoF

Variation in Band parameters

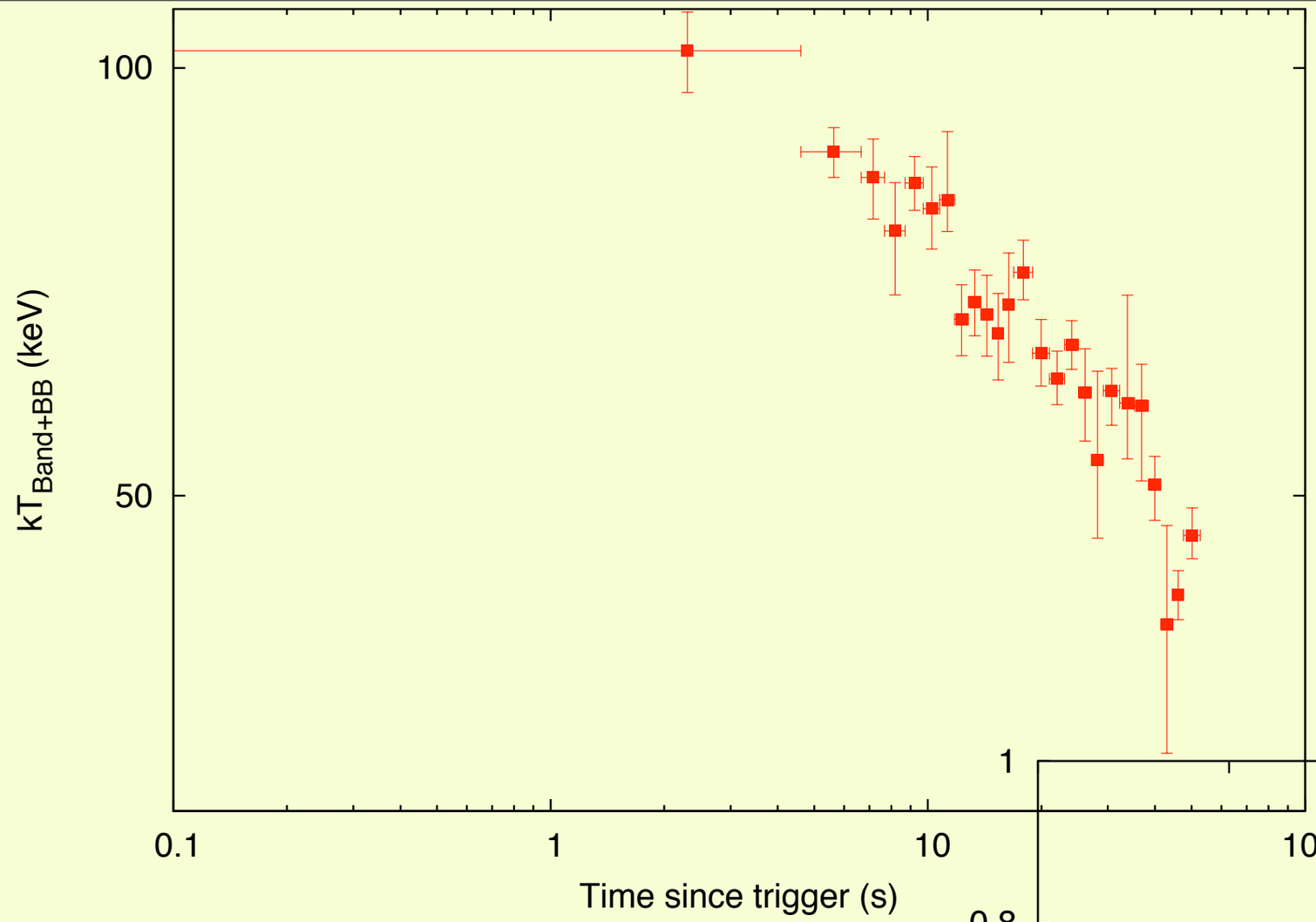




25 time resolved bins (T0+0.003 -> T0+52.737s)

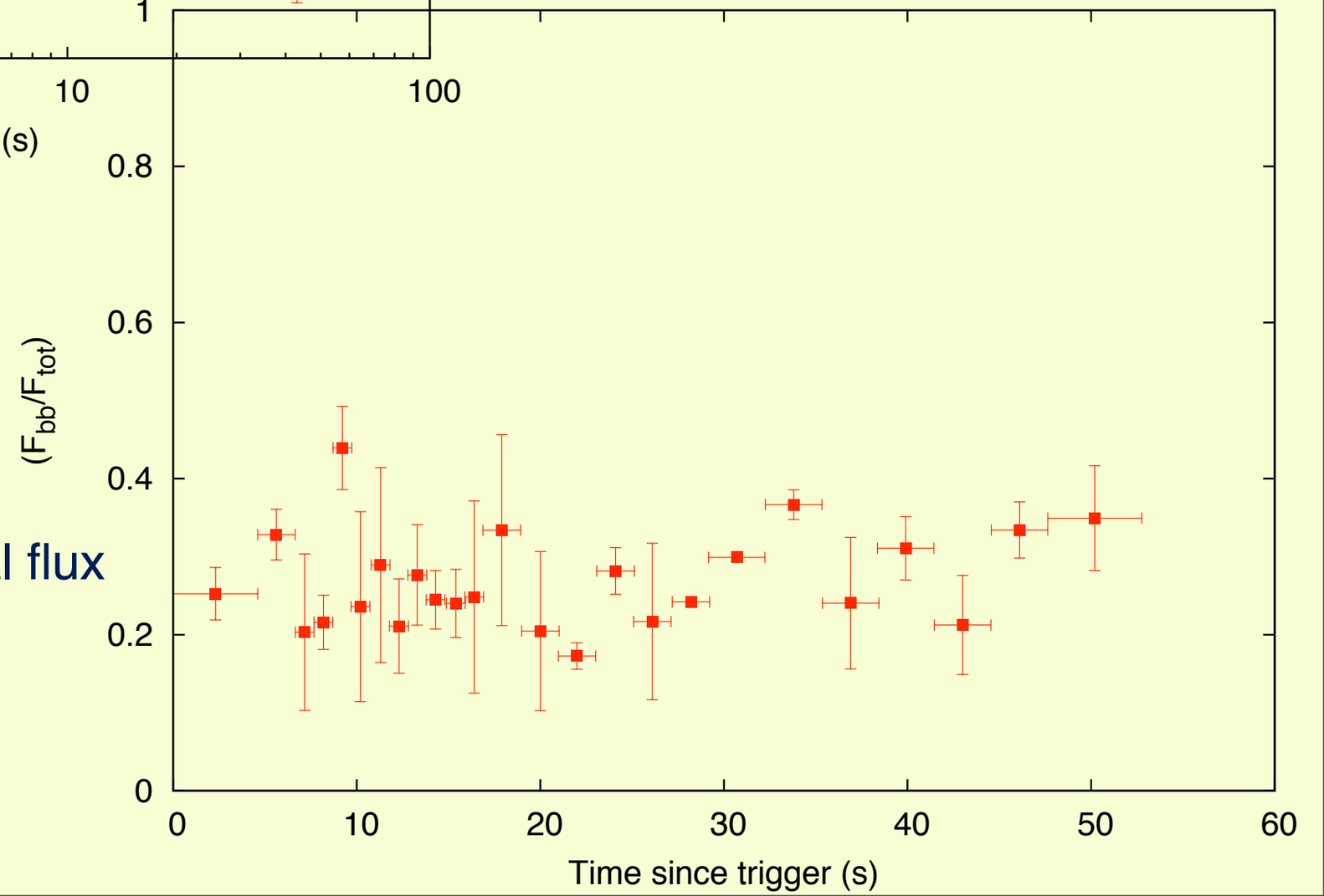
ΔC-stat is >10 for 19/25 bins
ΔC-stat is >20 for 9/25 bins

Epeak shifted to higher energies
α becomes shallower



kT evolves from ~100 keV to ~40 keV

BB flux is between ~20-40% of total flux (10keV-10MeV)



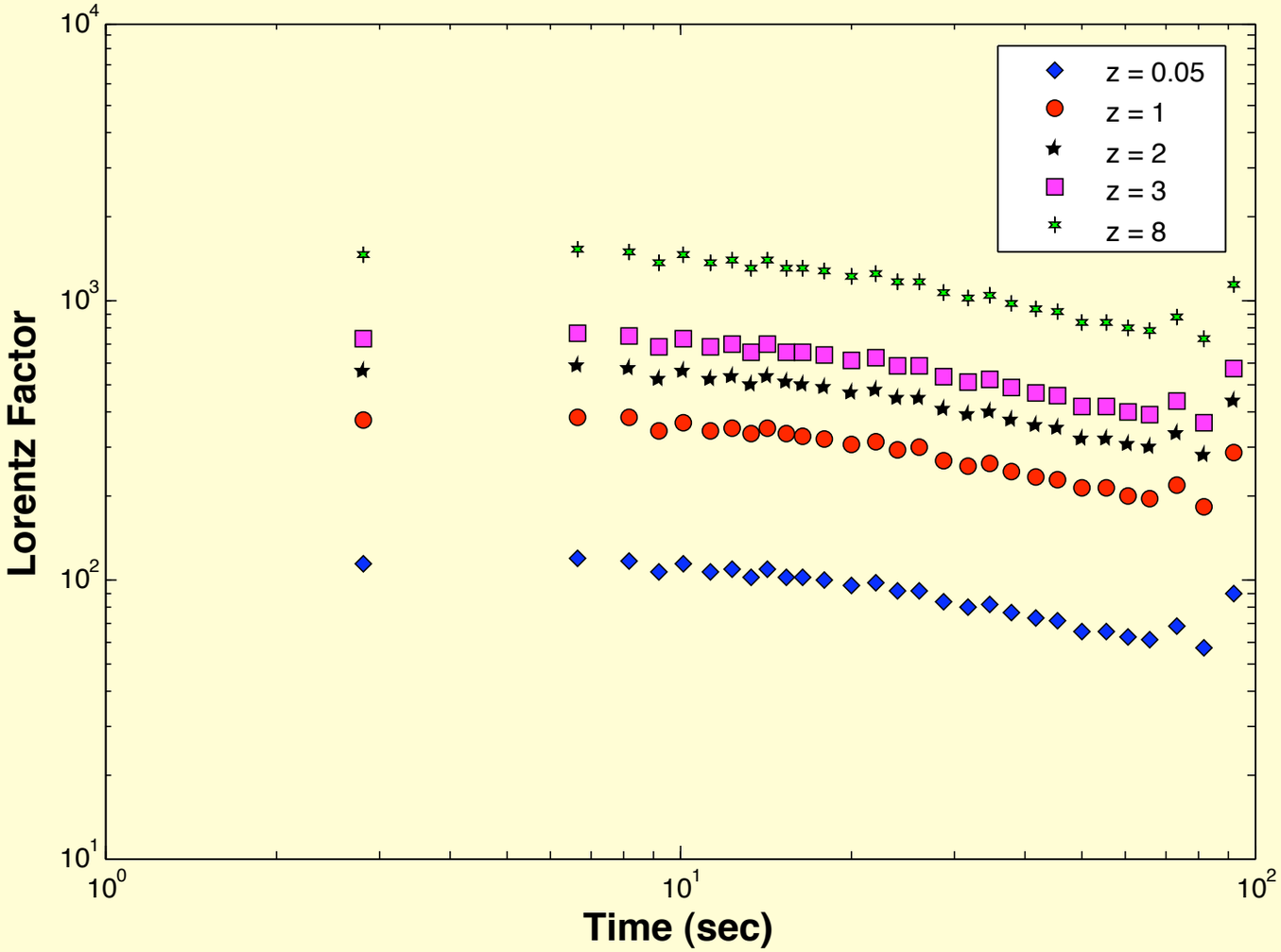
Flow dynamics

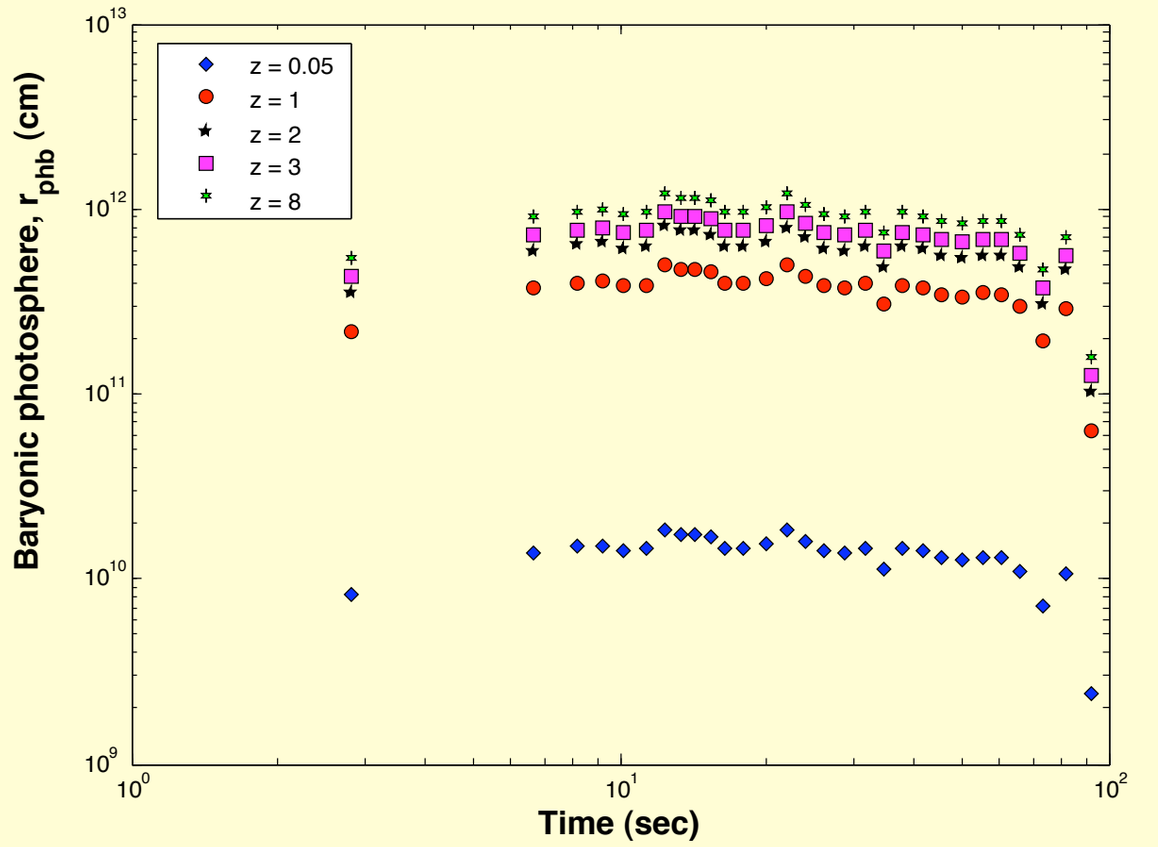
Observed parameters: F_{bb}, T_{ob}, ***R*** (normalisation of BB component) and Y_0 (ratio of total fireball E to gamma ray E)

Physical parameters: η, r_{ph} (if $r_{ph} > r_s$ saturation radius), r_0

Average values assuming z = 2:
$\eta = 442\ Y_0^{1/4}$ (decreases with time in 110920 from ~600 to ~300)
$r_{ph} = 6 \times 10^{11}\ Y_0^{1/4}$ cm
$r_0 = 2 \times 10^{8}\ Y_0^{-3/2}$ cm
$r_s = 8.6 \times 10^{10}\ Y_0^{-5/4}$ cm

[Y_0 close to unity]





Summary

- large sample of GBM bursts with possible photospheric emission
  - shoulder - low kT compared to E_{peak}
  - curvature - peak of BB is close to rollover of spectrum
  - is the difference in the spectra due to subphotospheric dissipation?
  - more analysis to be done

- 110920 is the most prominent new case where a photospheric component is observed
  - Band+BB is preferred to Band overall & in time-resolved spectra
  - BB flux is ~20-40% of total flux
  - bulk Lorentz factor (assuming z = 2) is ~300-500 (determined from observed thermal parameters)
  - photospheric radius is ~6 x 10^{11} cm, consistent with previous measurements (e.g. 100724b)