A New Model for GRB Prompt Emission and a New E_{peak}-Luminosity Relation

(Guiriec et al. – 4 articles in preparation)

Sylvain Guiriec

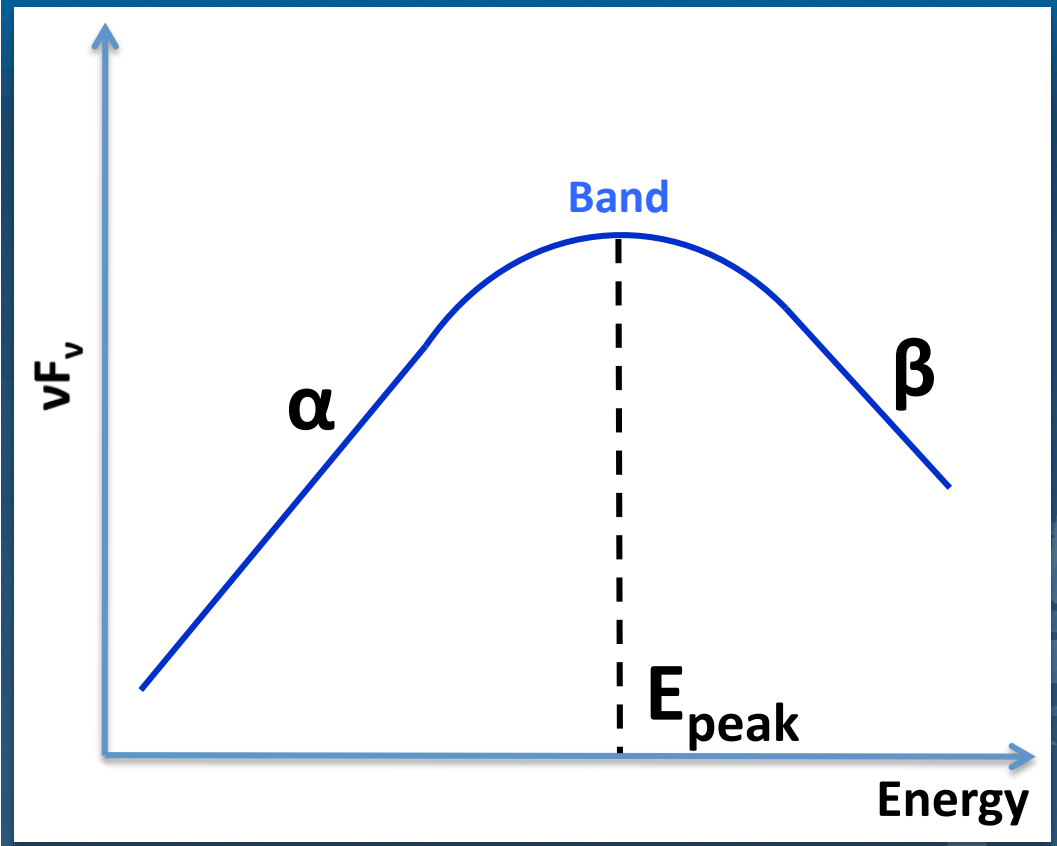
(NASA GSFC/UMD/CRESST)

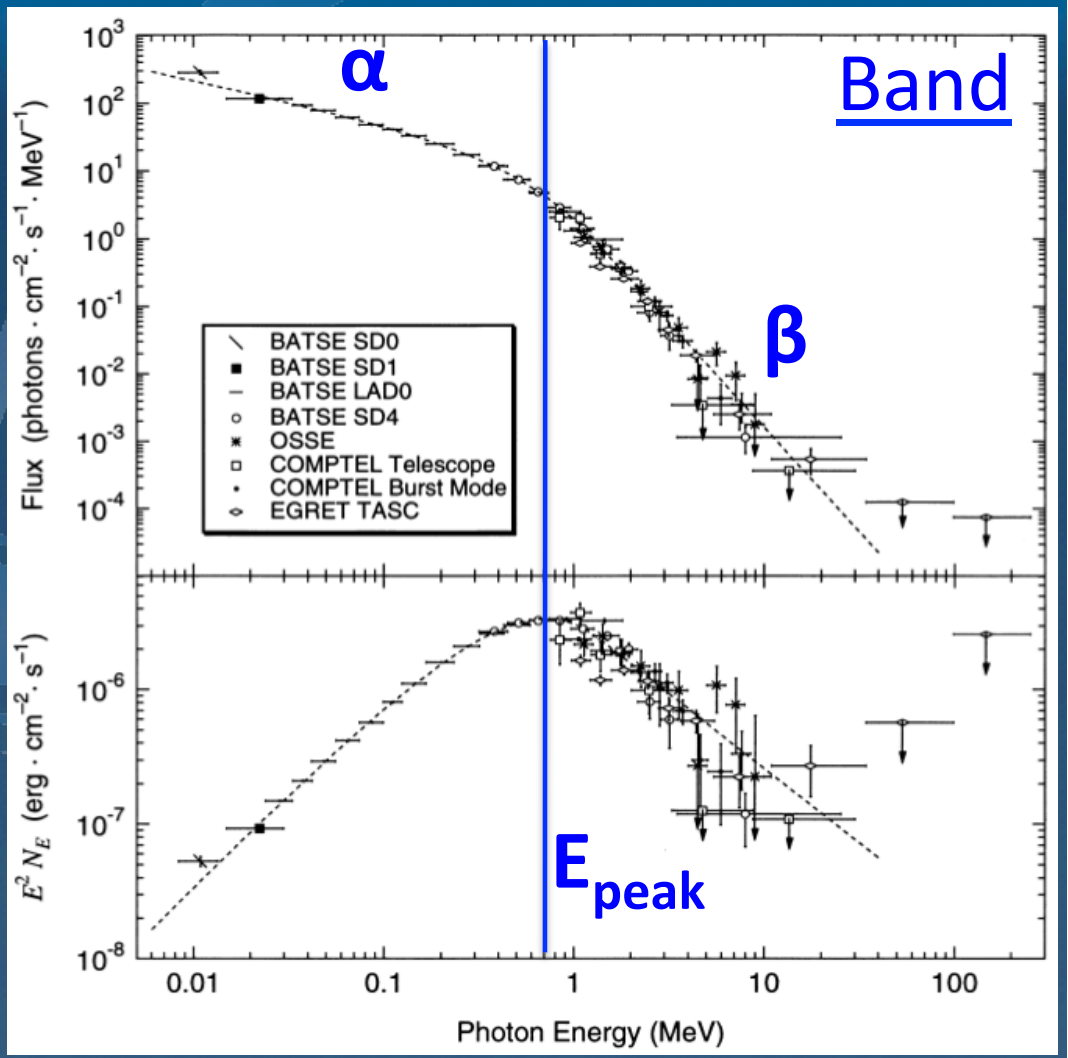
on behalf of

C. Kouveliotou, F. Daigne, B. Zhang, R. Hascoet, R. Mochkovitch, M. Gonzalez, R. Reyes, F. Ryde, R. Nemmen, J. Racusin, J. McEnery, N. Gehrels,

5th Fermi Symposium - Nagoya, Japan – October 23rd, 2014

The Band Function

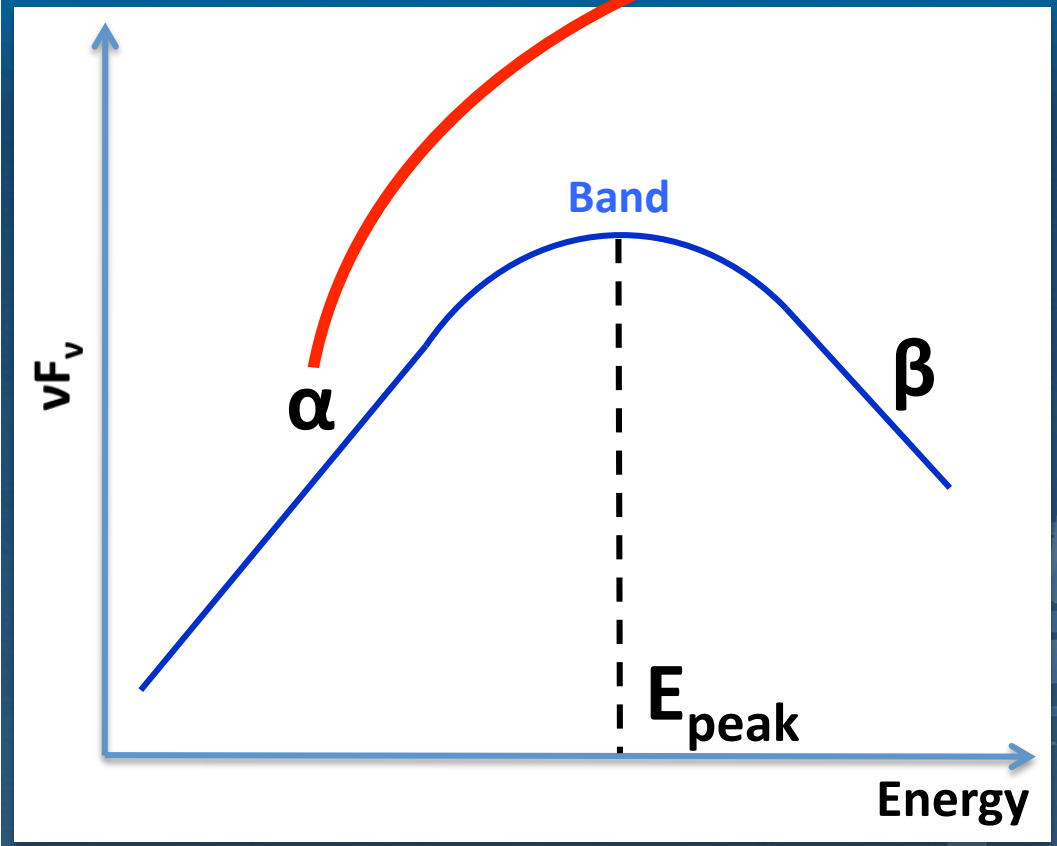


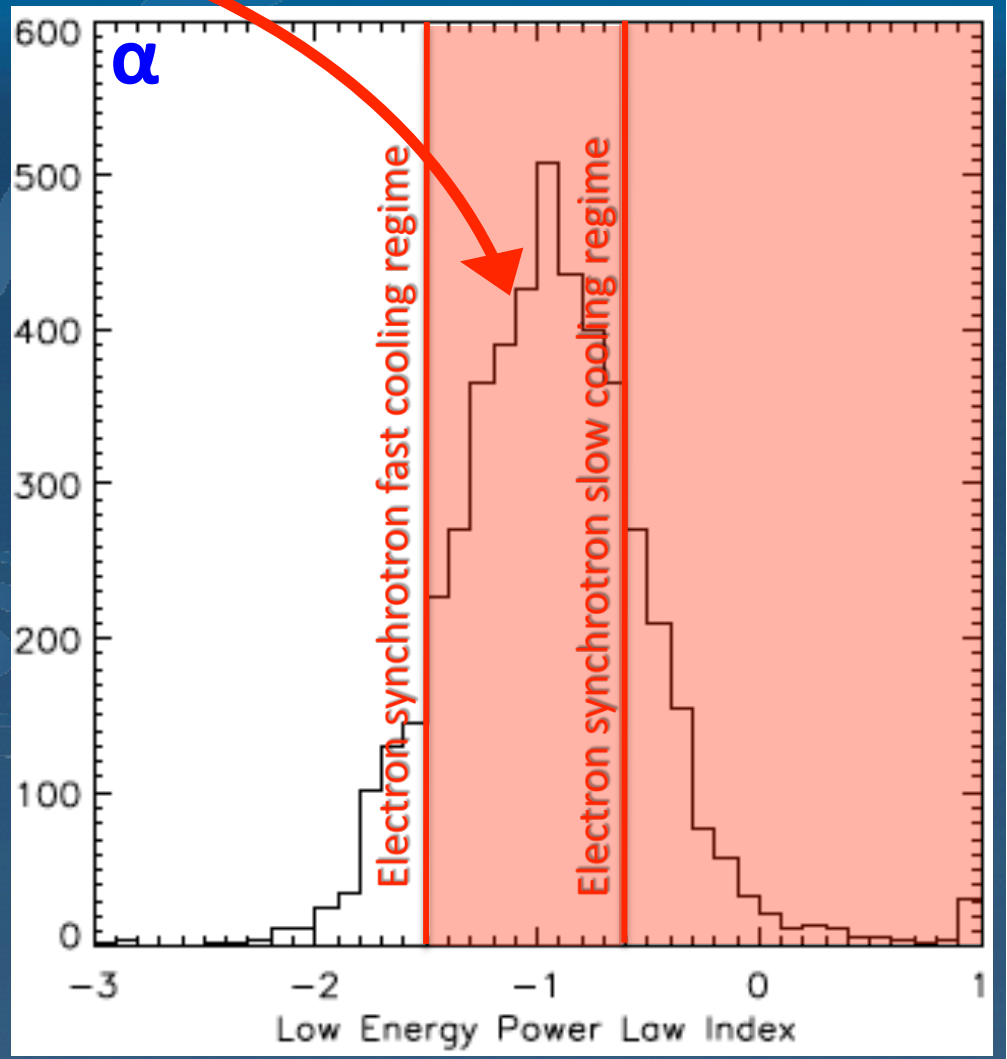


(Briggs et al. 1999)
(Greiner et al. 1995)

- Band function usually associated to synchrotron emission from e^- accelerated within the jet.

Line of Death



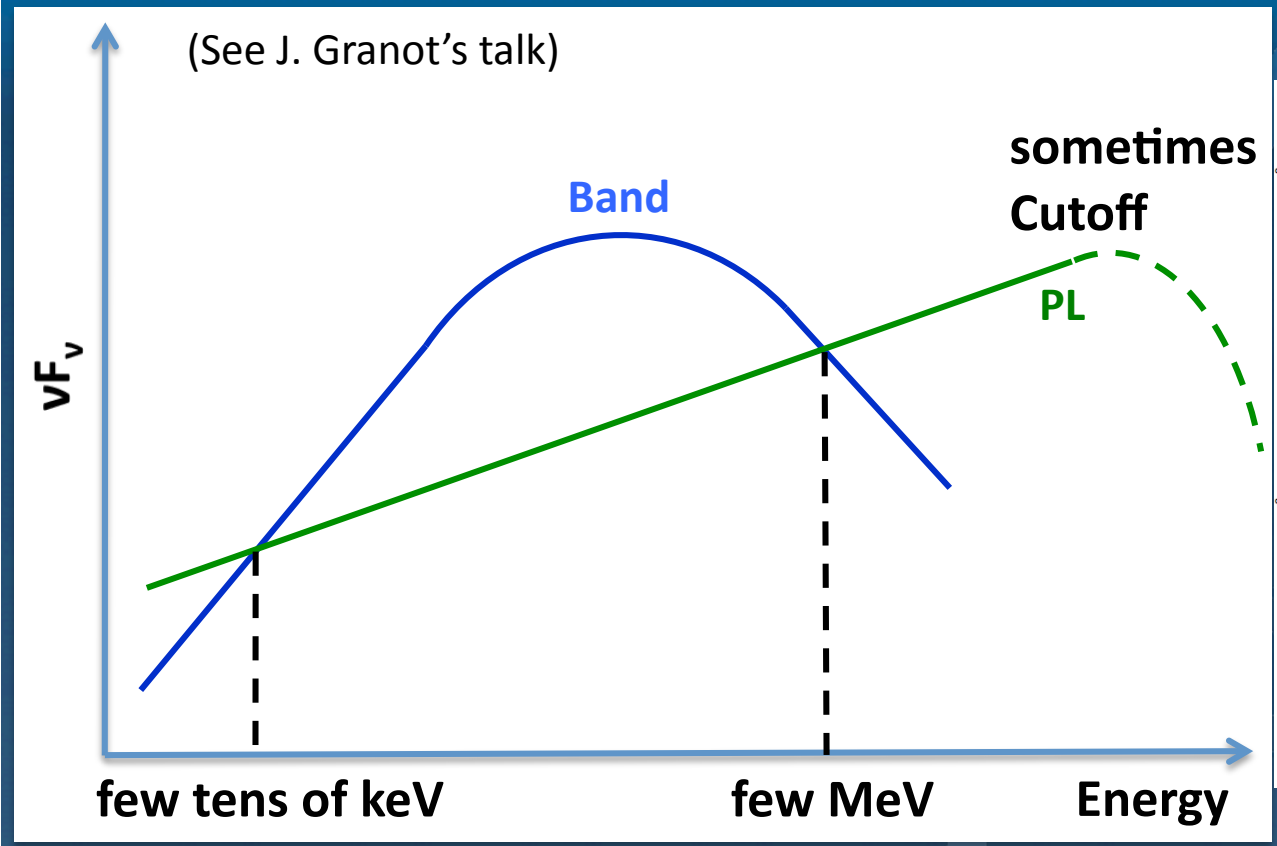


(Preece et al. 2000)

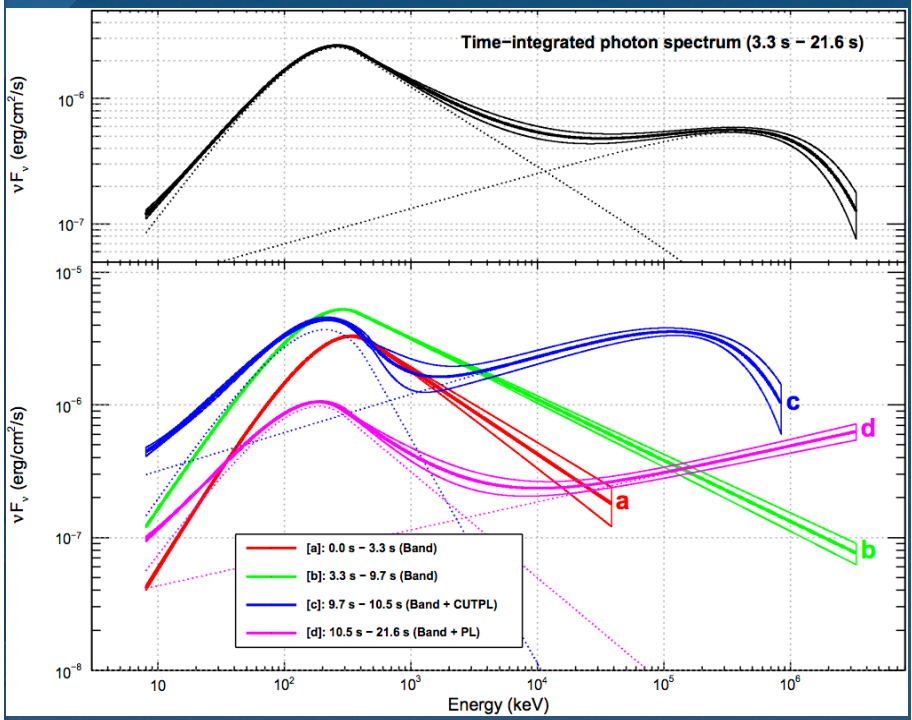
- Band function usually associated to synchrotron emission from e^- accelerated within the jet.
- However, values of α are often incompatible with synchrotron emission predictions.

(See M. Burgess' talk "synchrotron or not to Synchrotron")

Band + Power Law



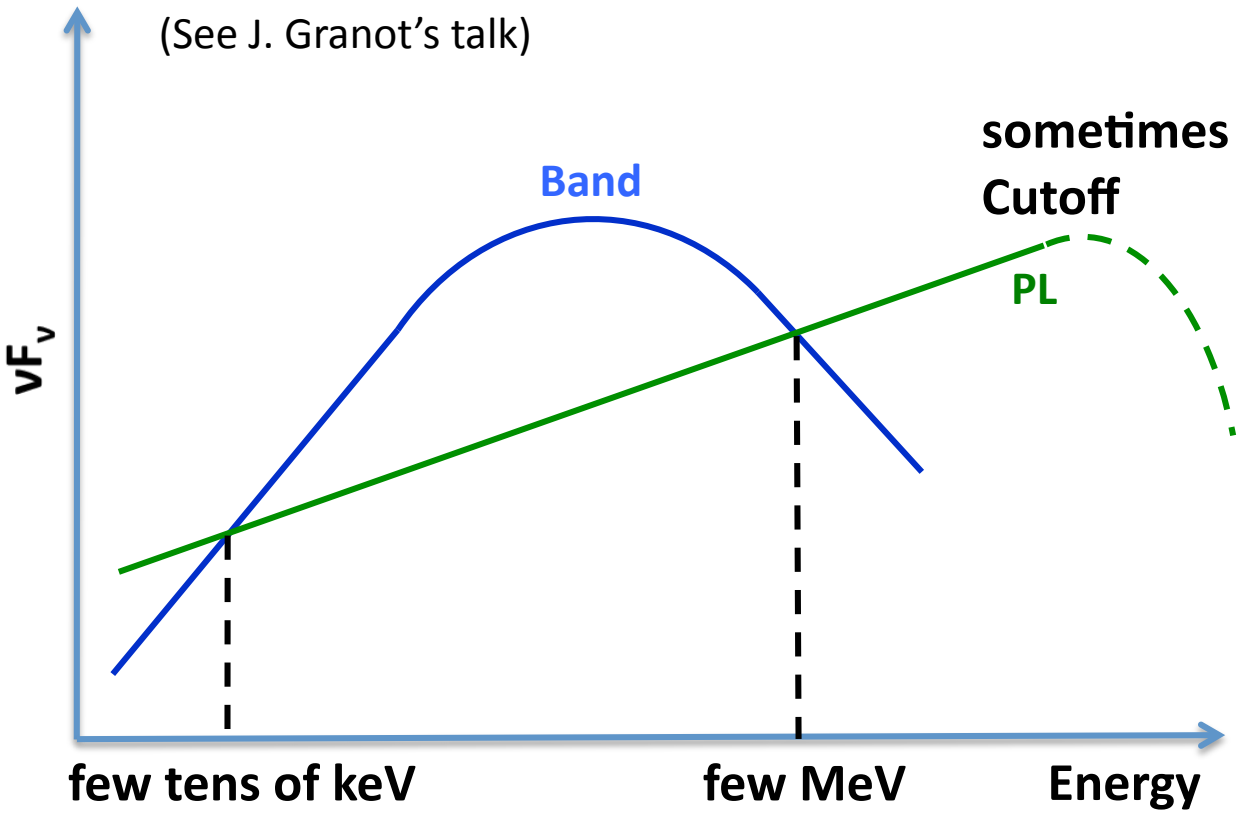
GRB 090926A



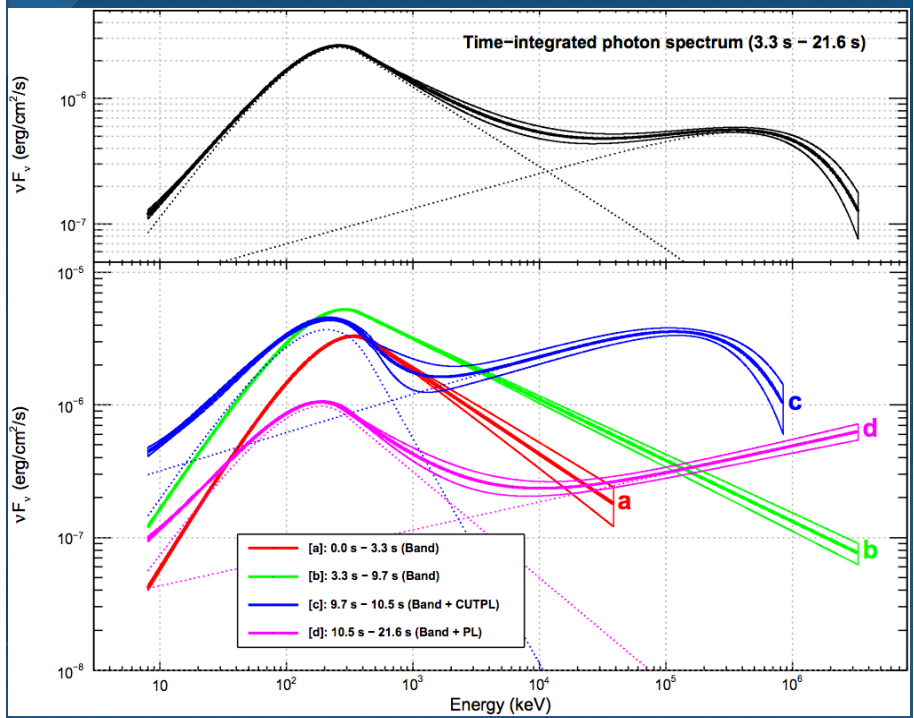
(Ackermann et al. 2011)

Band + Power Law

(See J. Granot's talk)

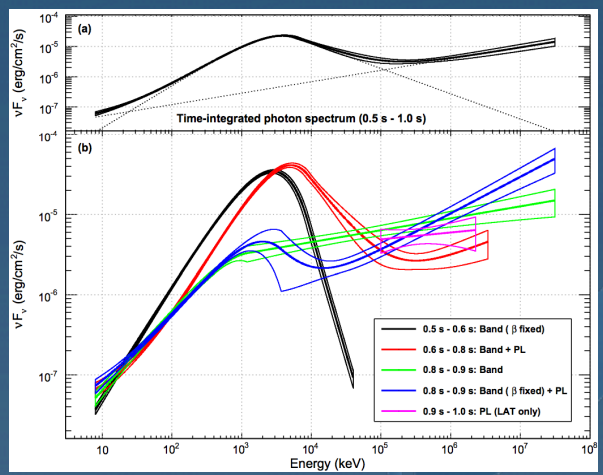


GRB 090926A



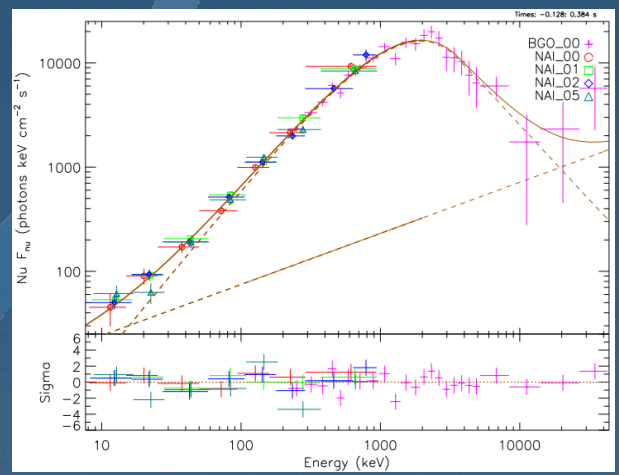
(Ackermann et al. 2011)

GRB 090510

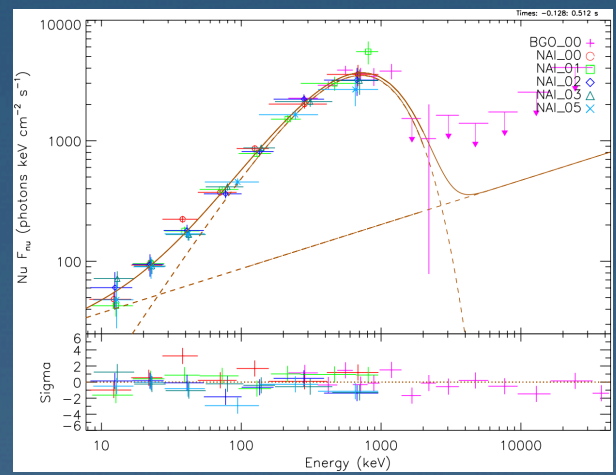


(Ackermann et al. 2010)

GRB 090227B

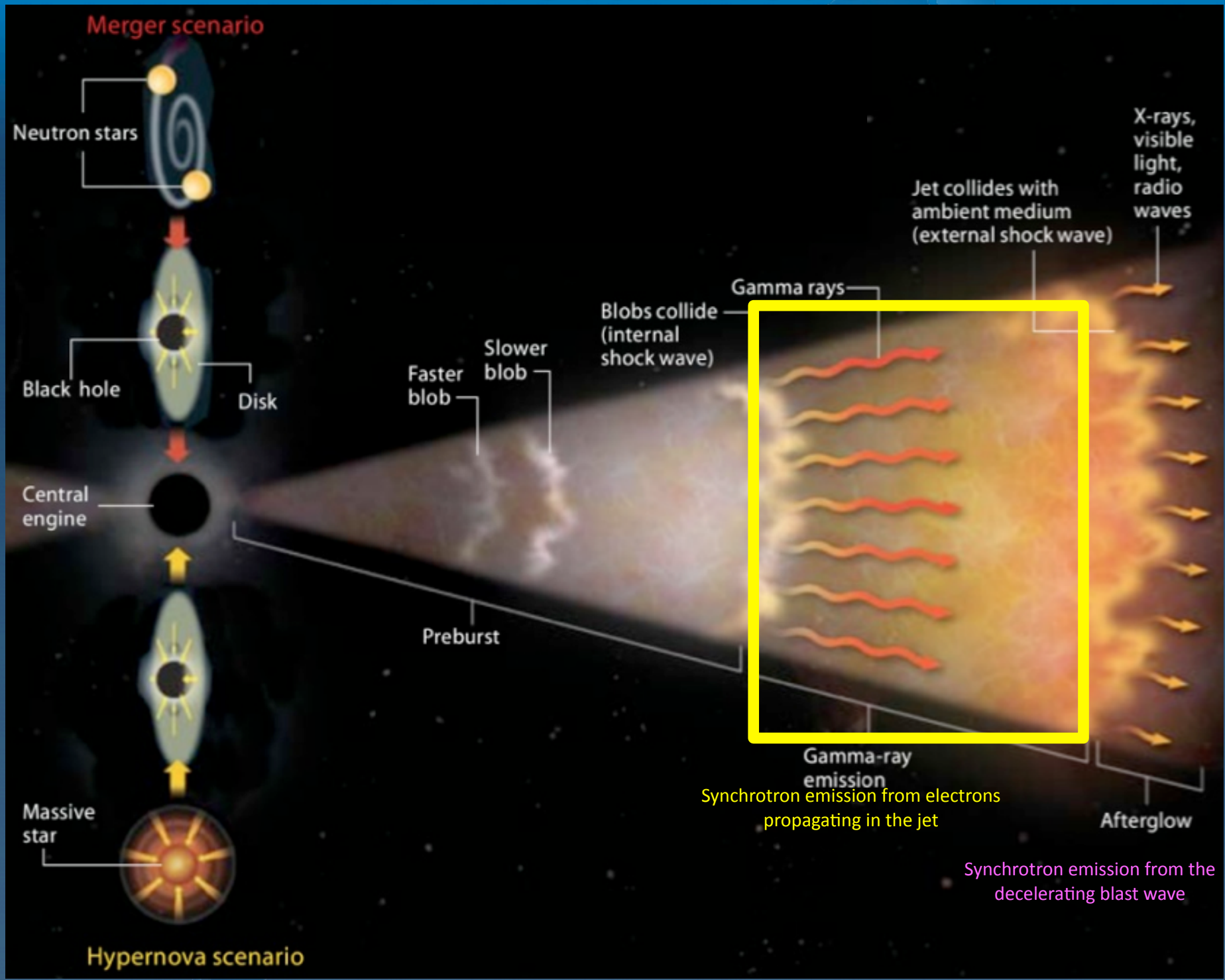


GRB 090228



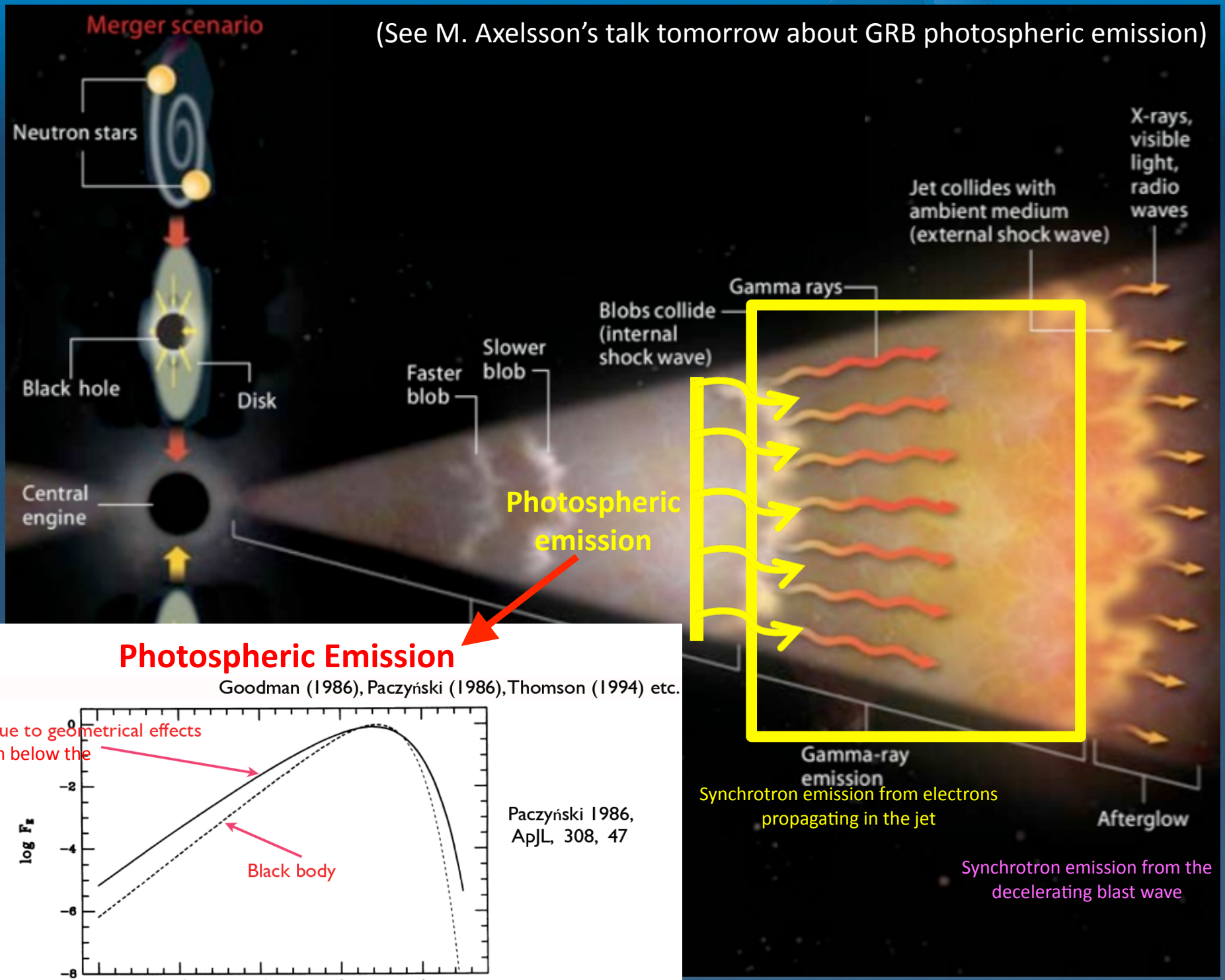
(Guiriec et al. 2010)

The Fireball Model



The Fireball Model

(See M. Axelsson's talk tomorrow about GRB photospheric emission)



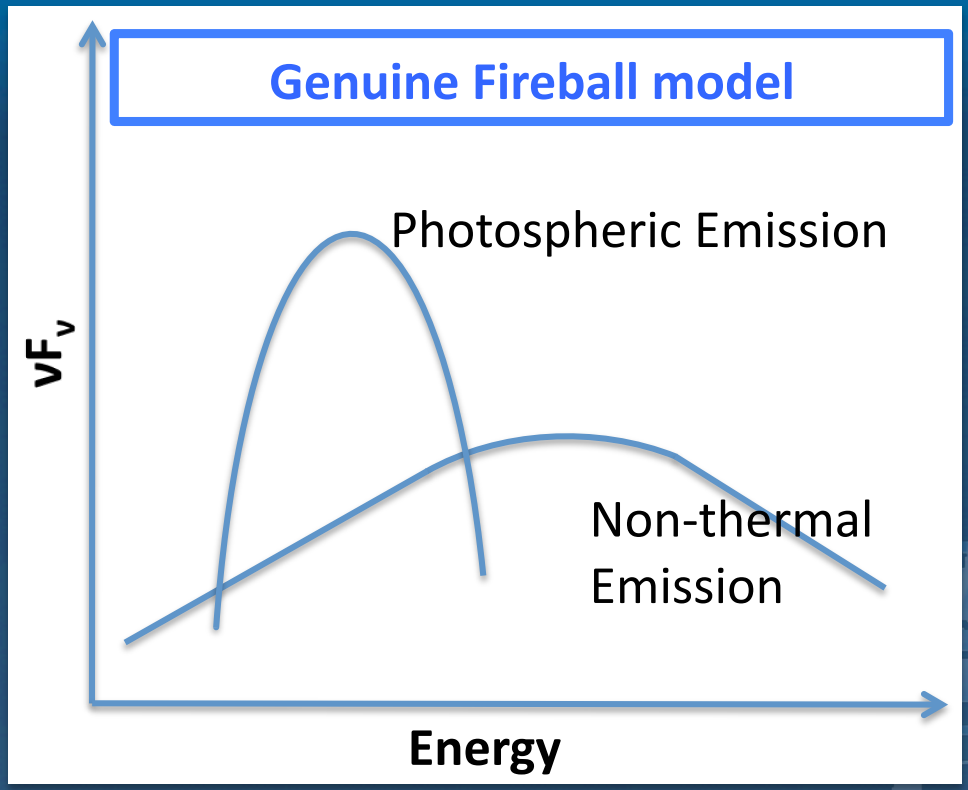
Photospheric Emission

Goodman (1986), Paczyński (1986), Thomson (1994) etc.

Broadening due to geometrical effects or dissipation below the photosphere

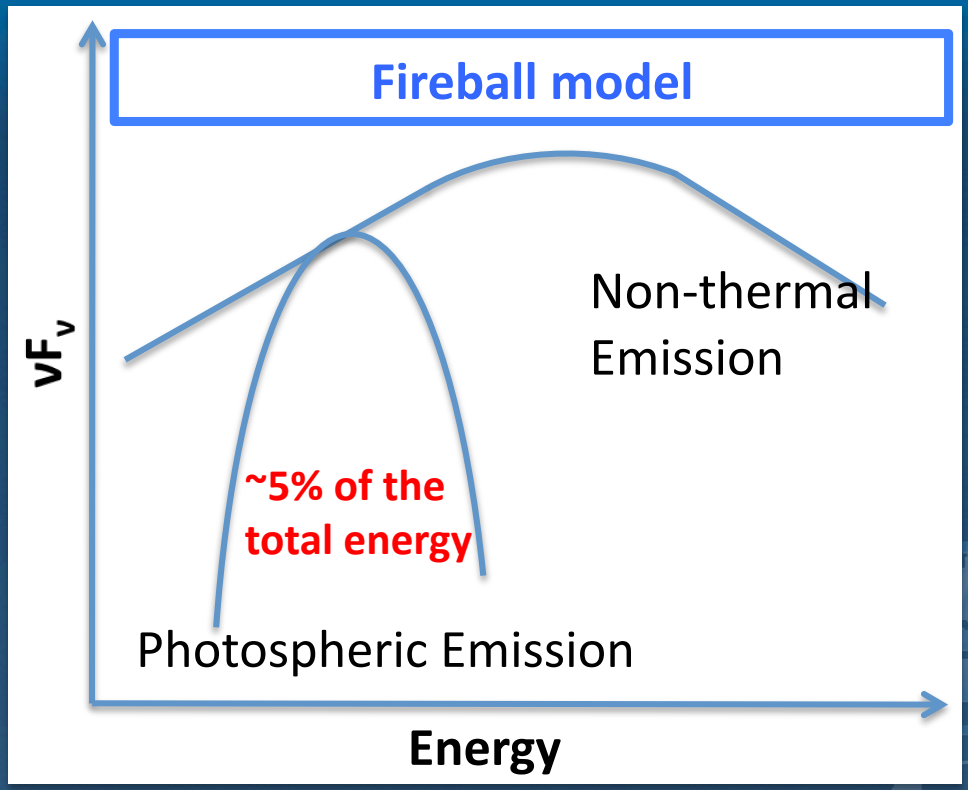
Paczyński 1986, ApJL, 308, 47

Photospheric Emission



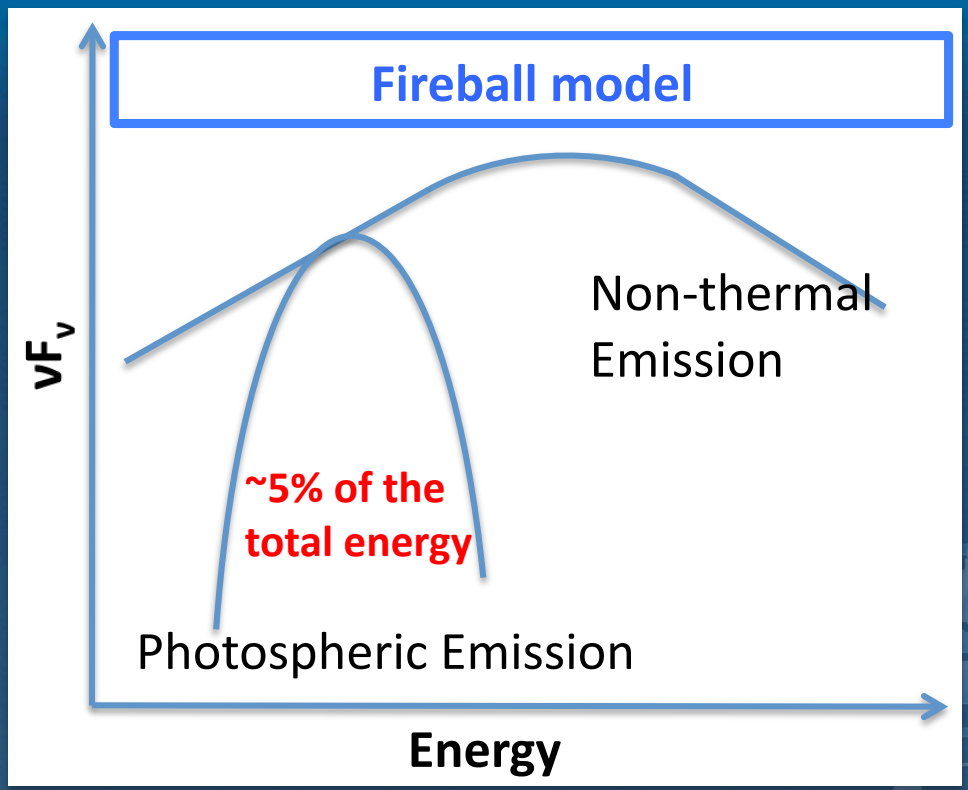
- The genuine fireball model predict a strong photospheric emission overpowering the non-thermal one.

Photospheric Emission

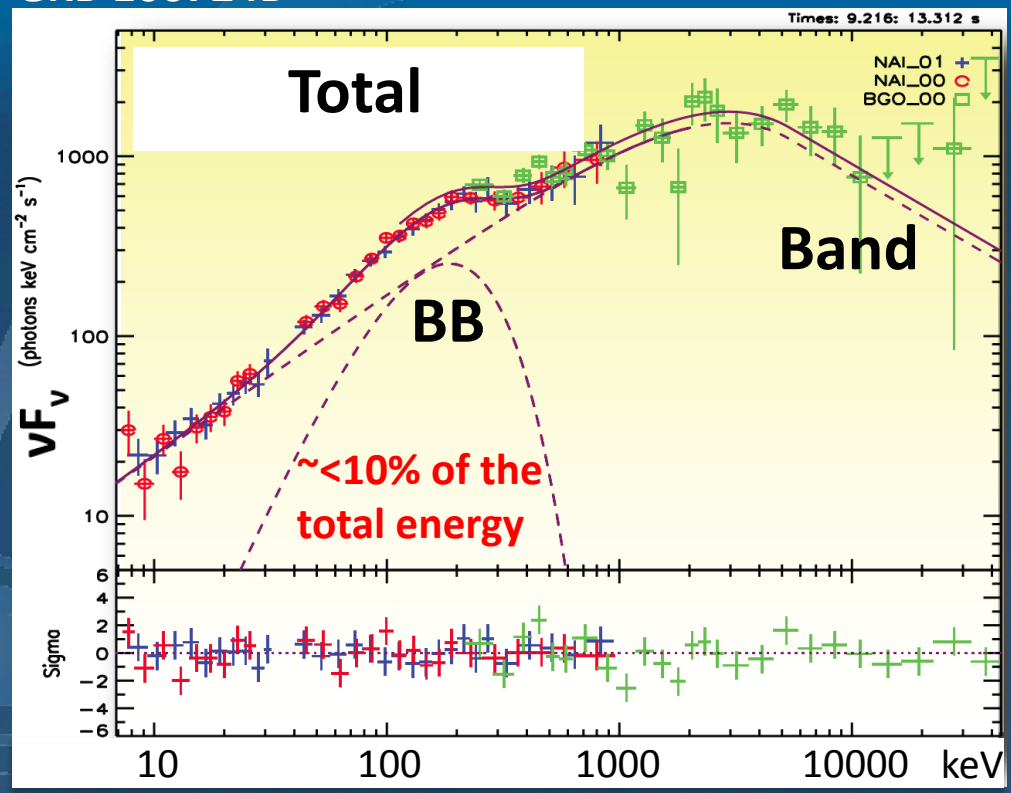


(Daigne et al. 2002)
(Nakar et al. 2005)

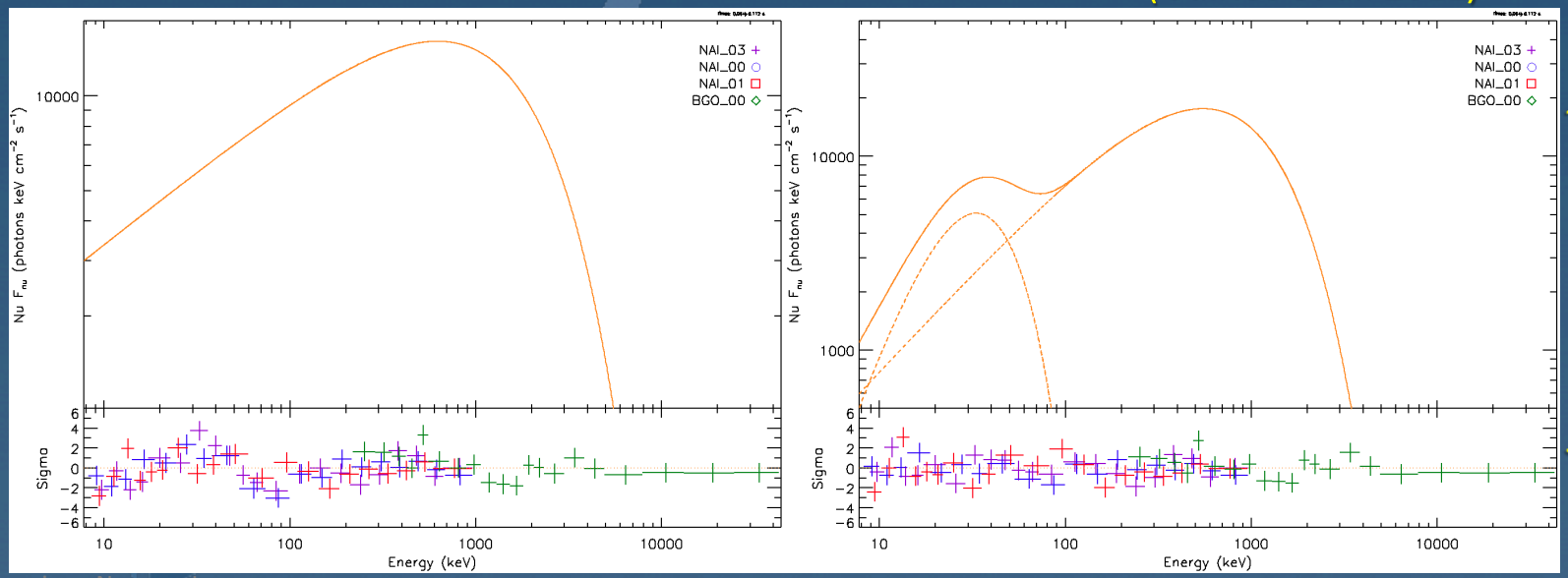
Photospheric Emission



GRB 100724B

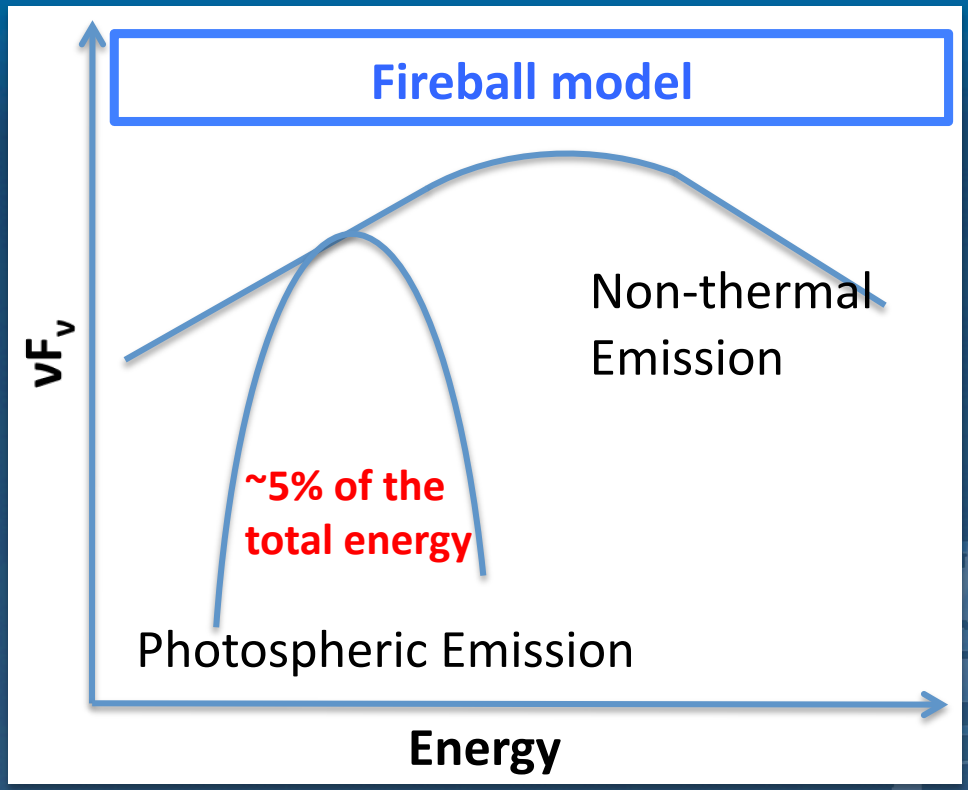


(Guiriec et al. 2011)

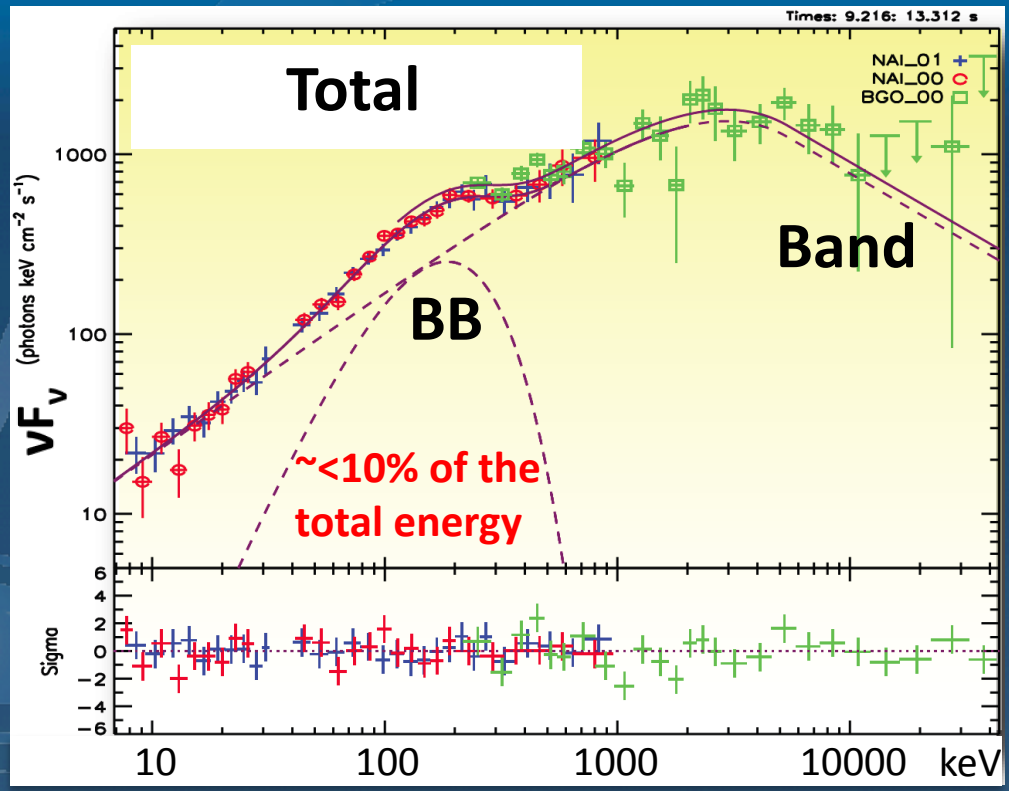


(Guiriec et al. 2013)

Photospheric Emission



GRB 100724B

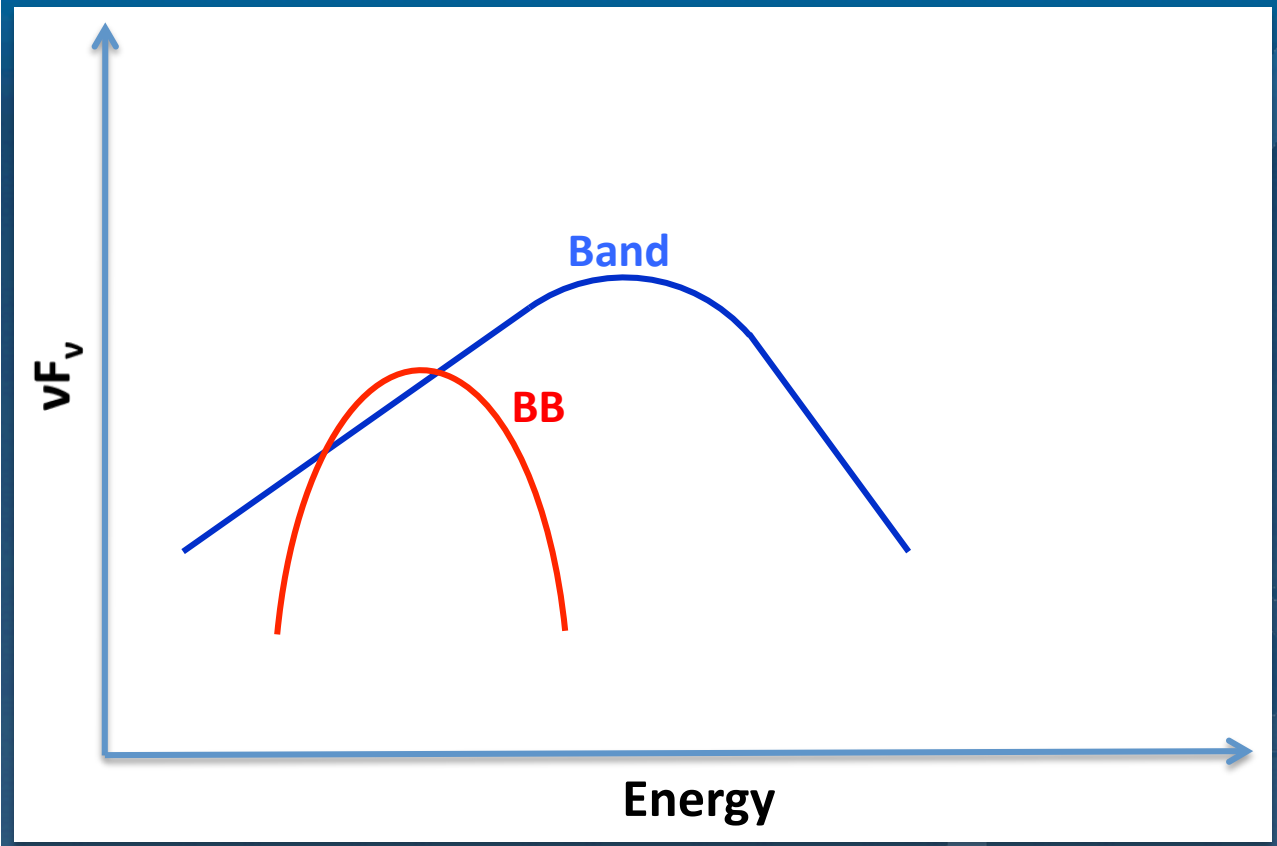


(Guiriec et al. 2011)

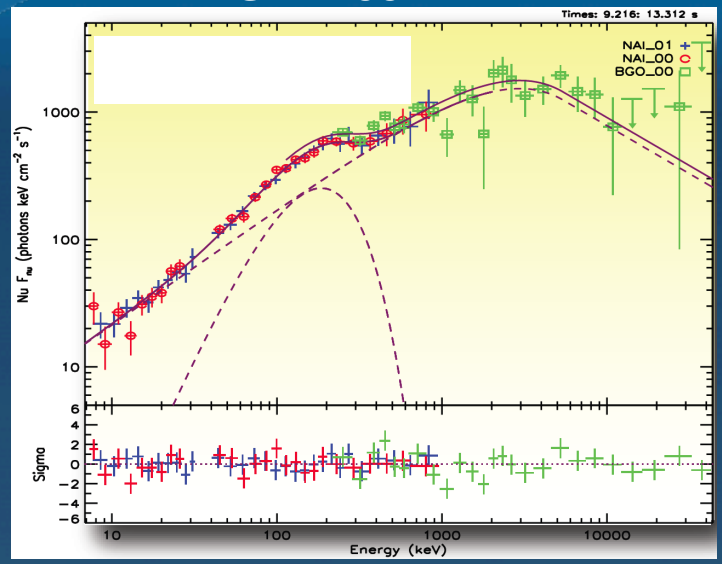
- The genuine fireball model predict a strong photospheric emission overpowering the non-thermal one.
- Only a subdominant thermal-like emission component compared to the non-thermal one is observed (1st time reported in Guiriec et al. 2011)

→ The outflow must be highly magnetized close to the source and magnetization must be low at large radii in order make possible internal shock mechanisms.

Black Body + Band

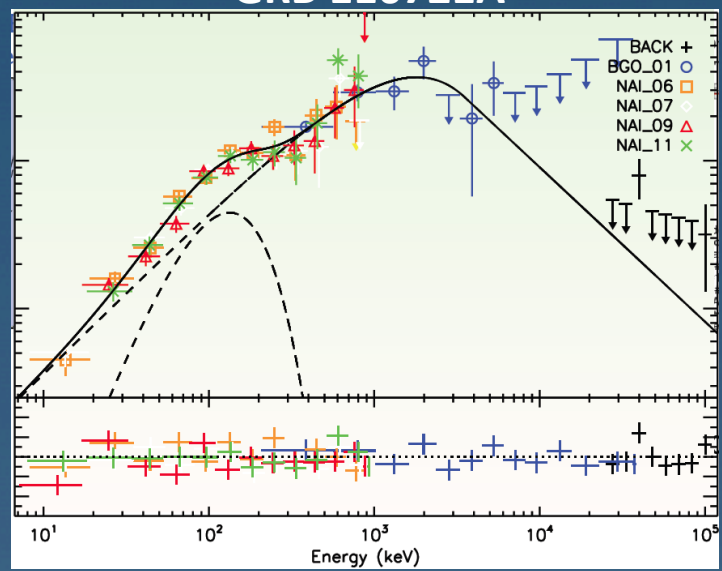


GRB 100724B



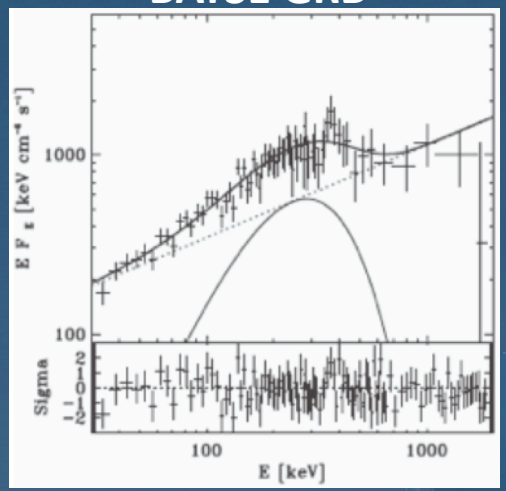
(Guiriec et al. 2011)

GRB 110721A



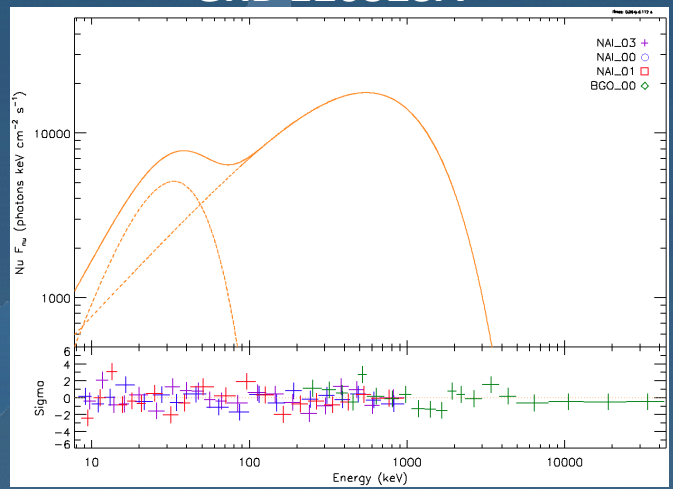
(Axelsson et al. 2012)

BATSE GRB



(Ryde et al. 2005)

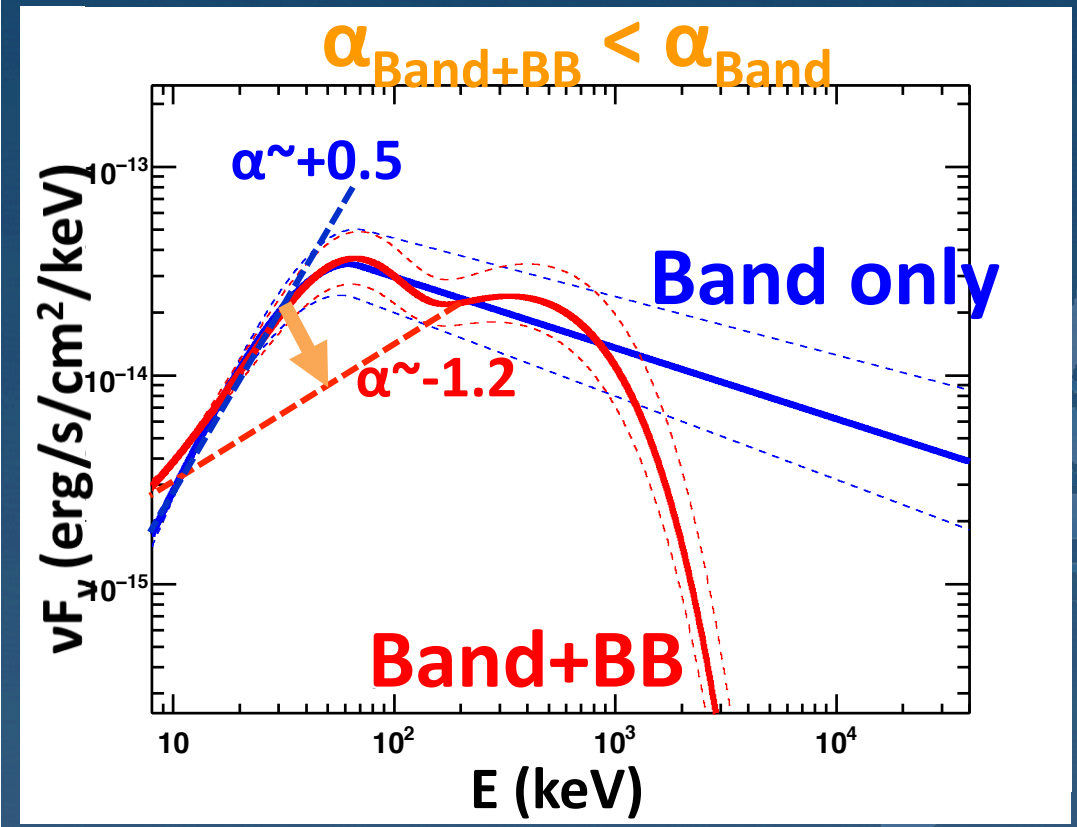
GRB 120323A

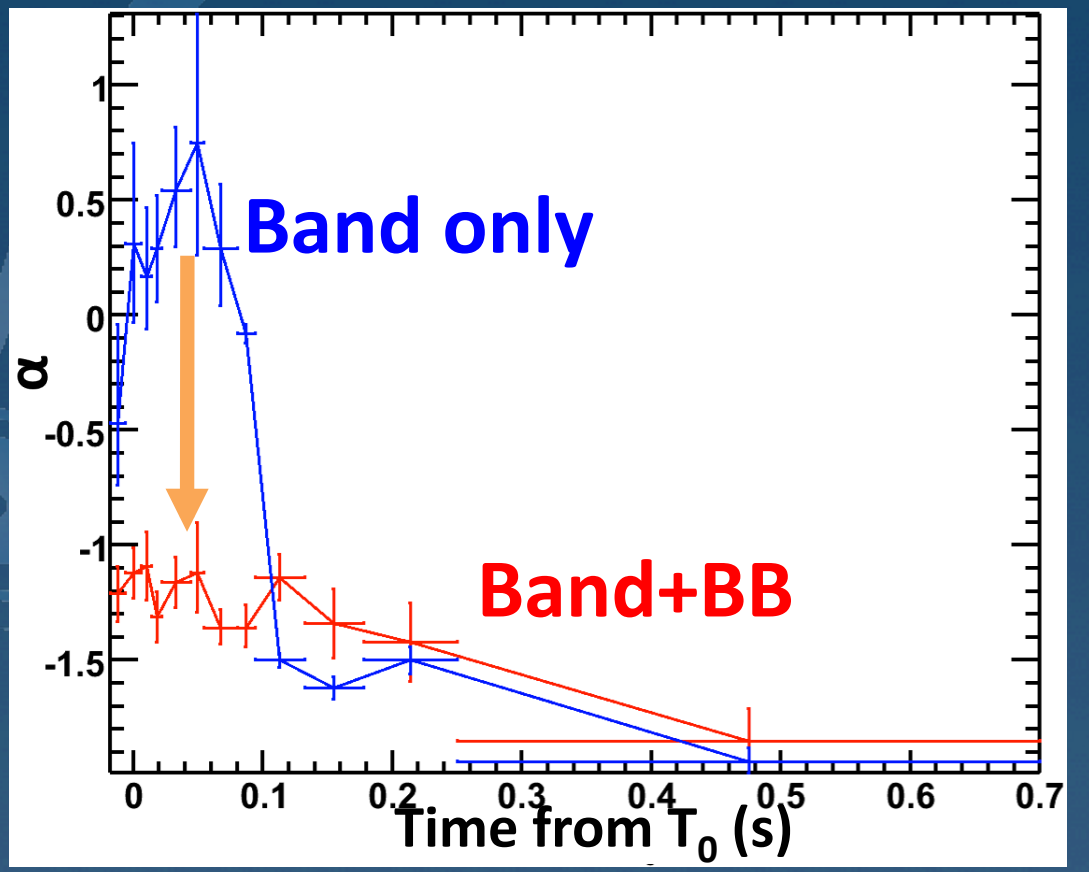


(Guiriec et al. 2013)

Black Body + Band

GRB 120323A

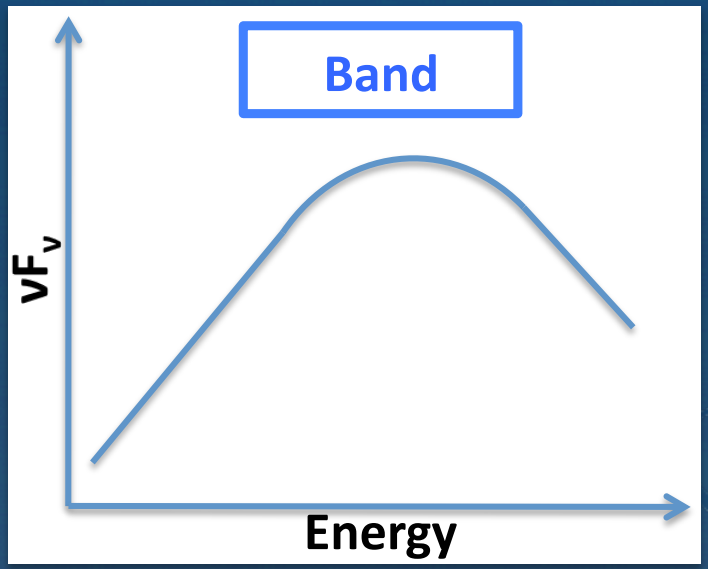


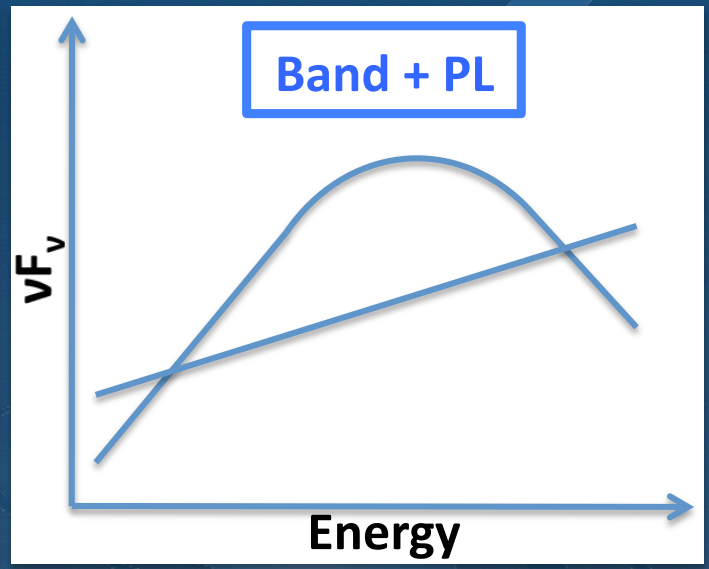


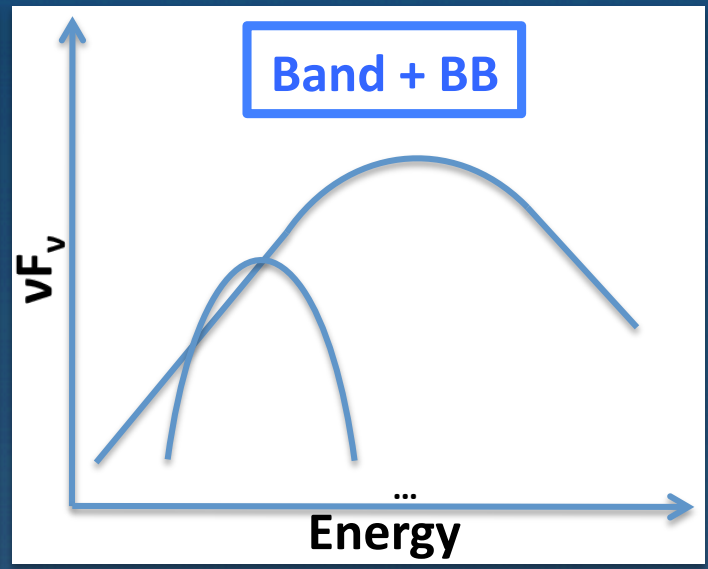
(Guiriec et al. 2013)

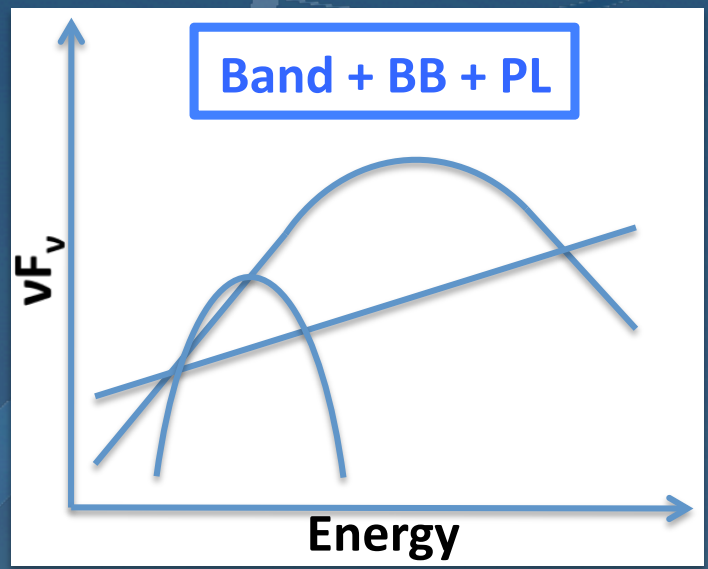
With BB, the Band function is more compatible with synchrotron emission scenarios !

Spectral Shapes





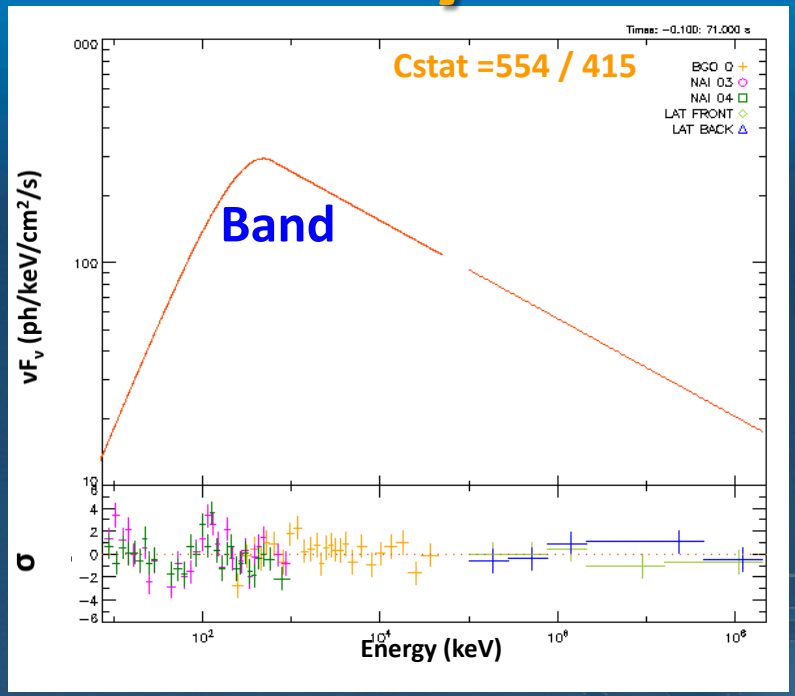




?

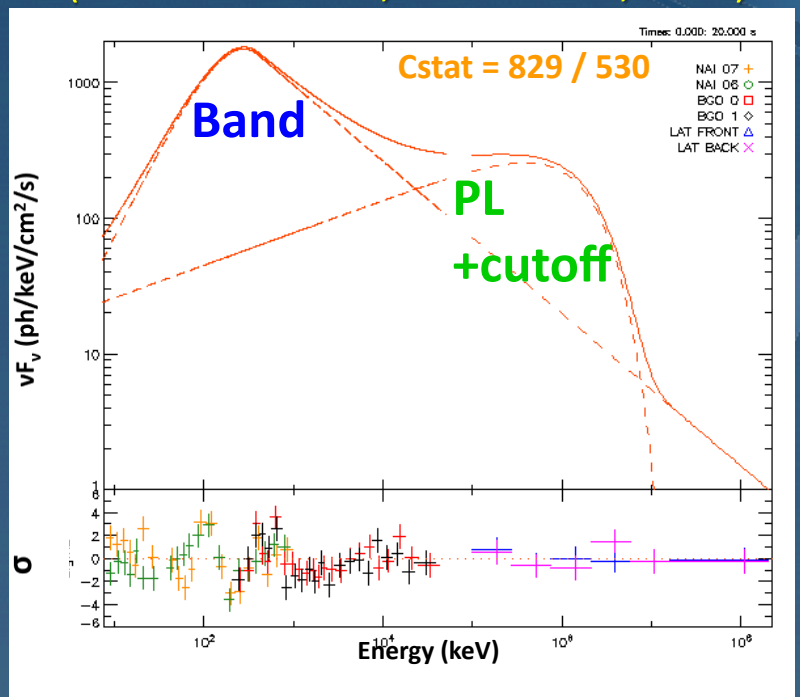
Black Body + Band + PL with/without cutoff

GRB 080916C



(Abdo et al. 2009, Science 323, 1688)

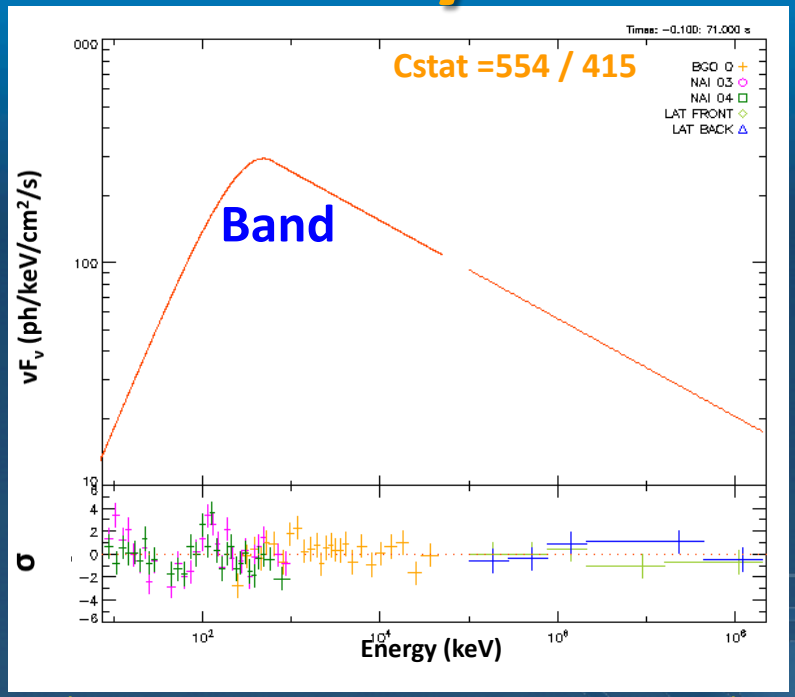
GRB 090926A



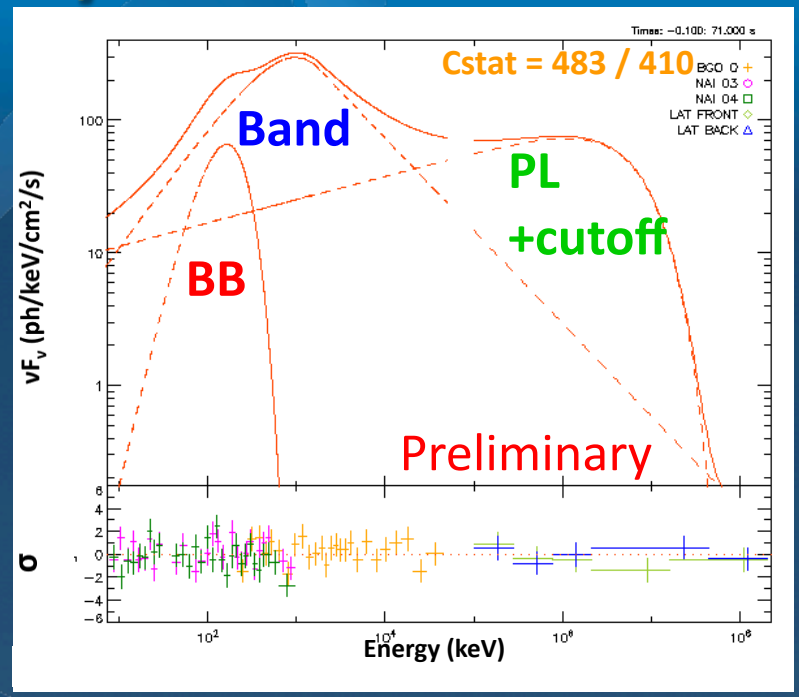
(Ackermann et al. 2011, ApJ 725, 225)

Black Body + Band + PL with/without cutoff

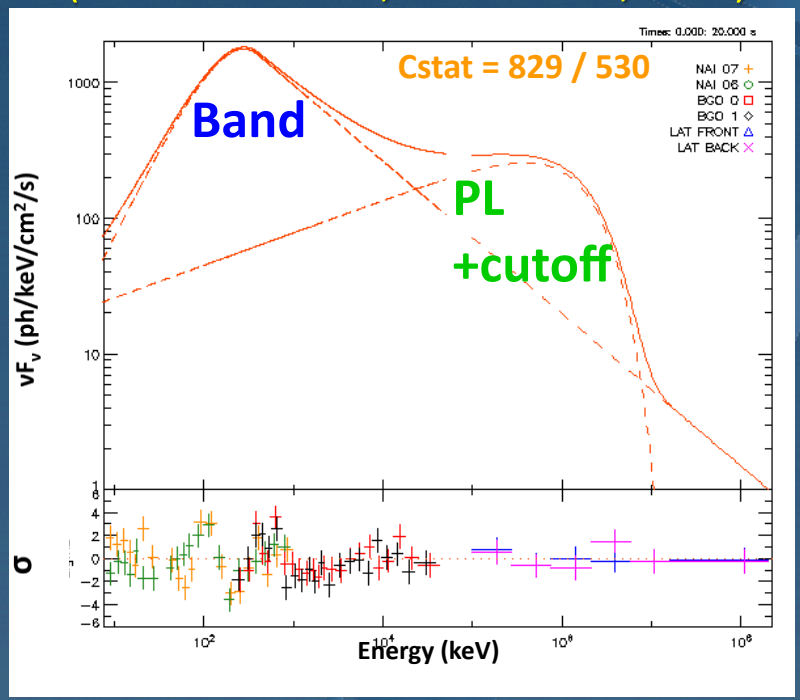
GRB 080916C



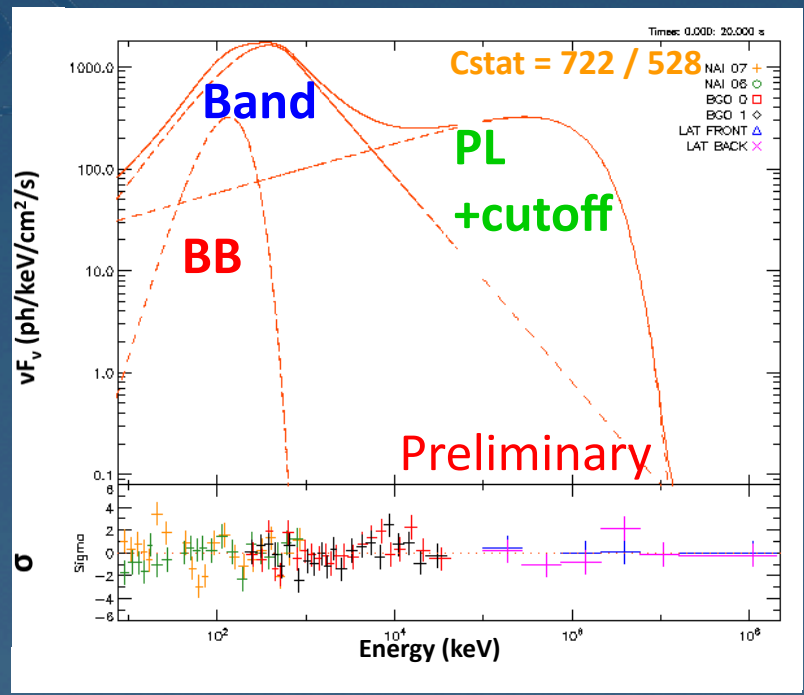
(Abdo et al. 2009, Science 323, 1688)



GRB 090926A

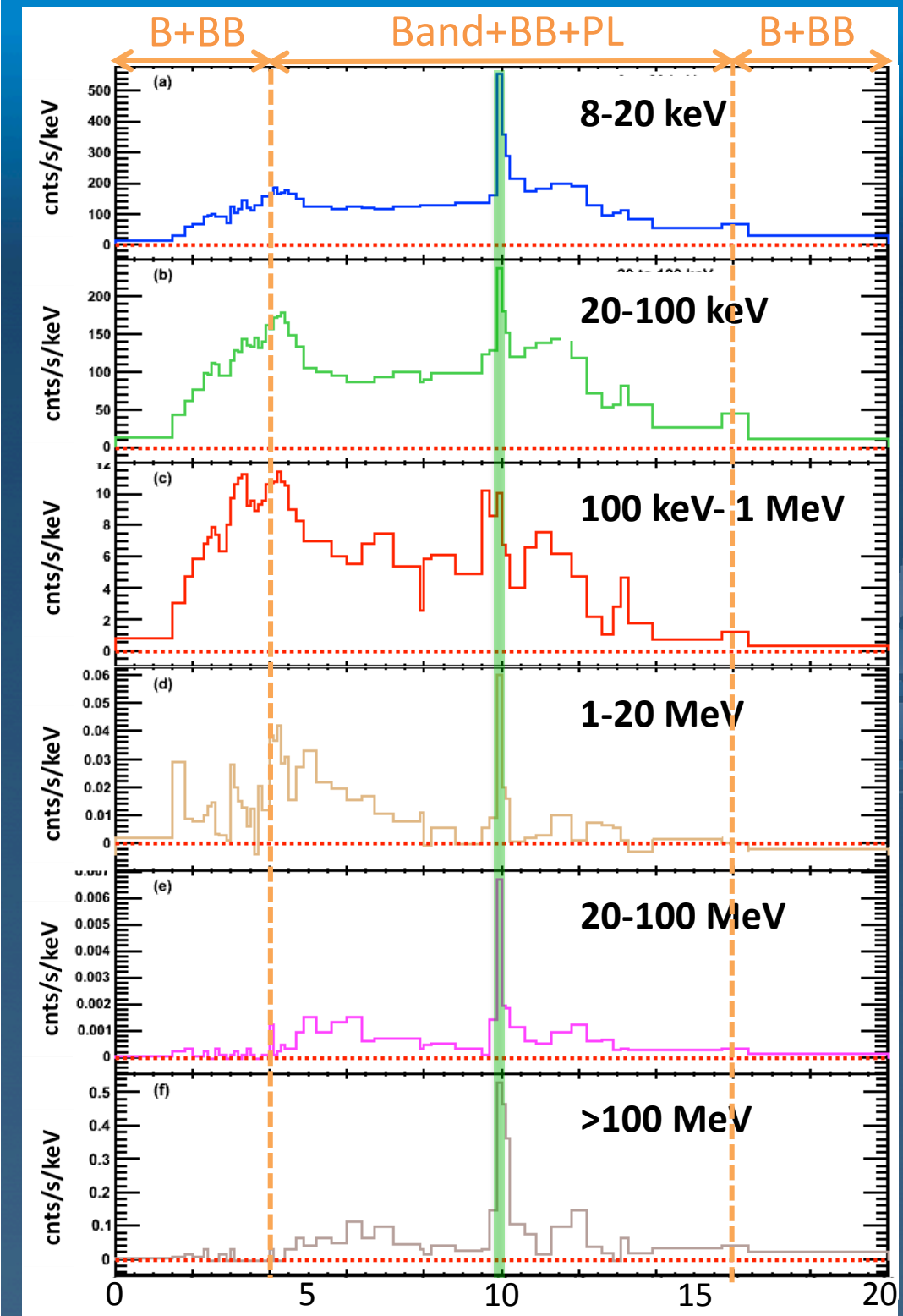


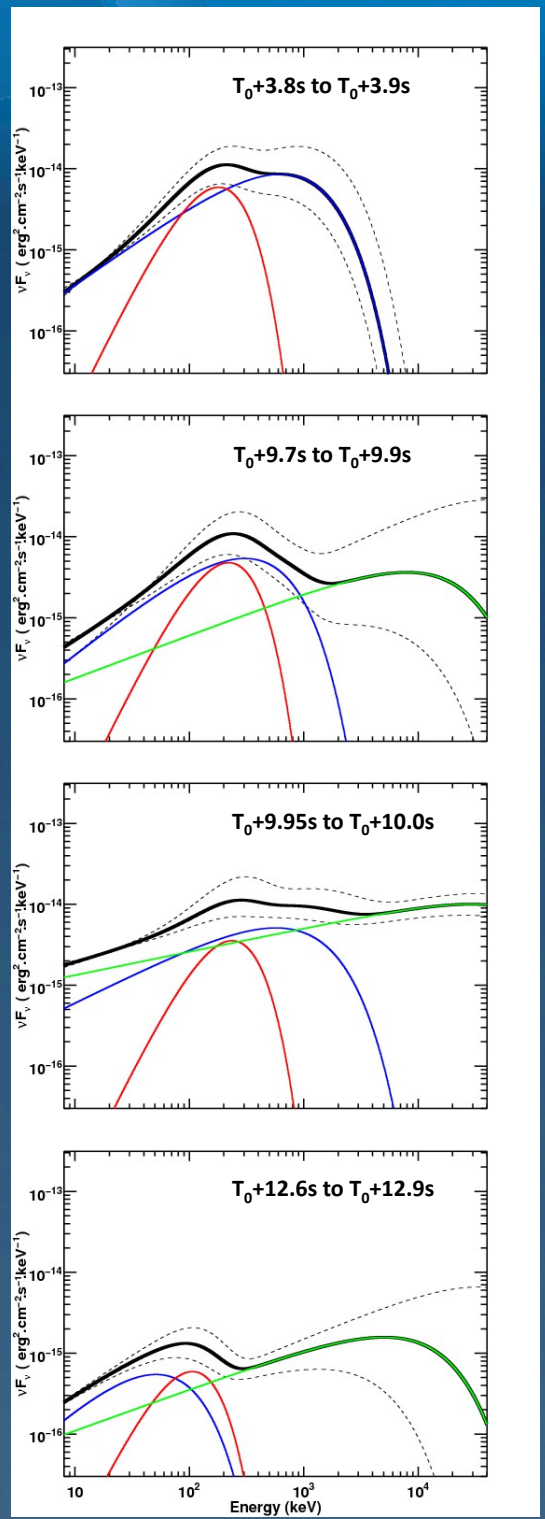
(Ackermann et al. 2011, ApJ 725, 225)

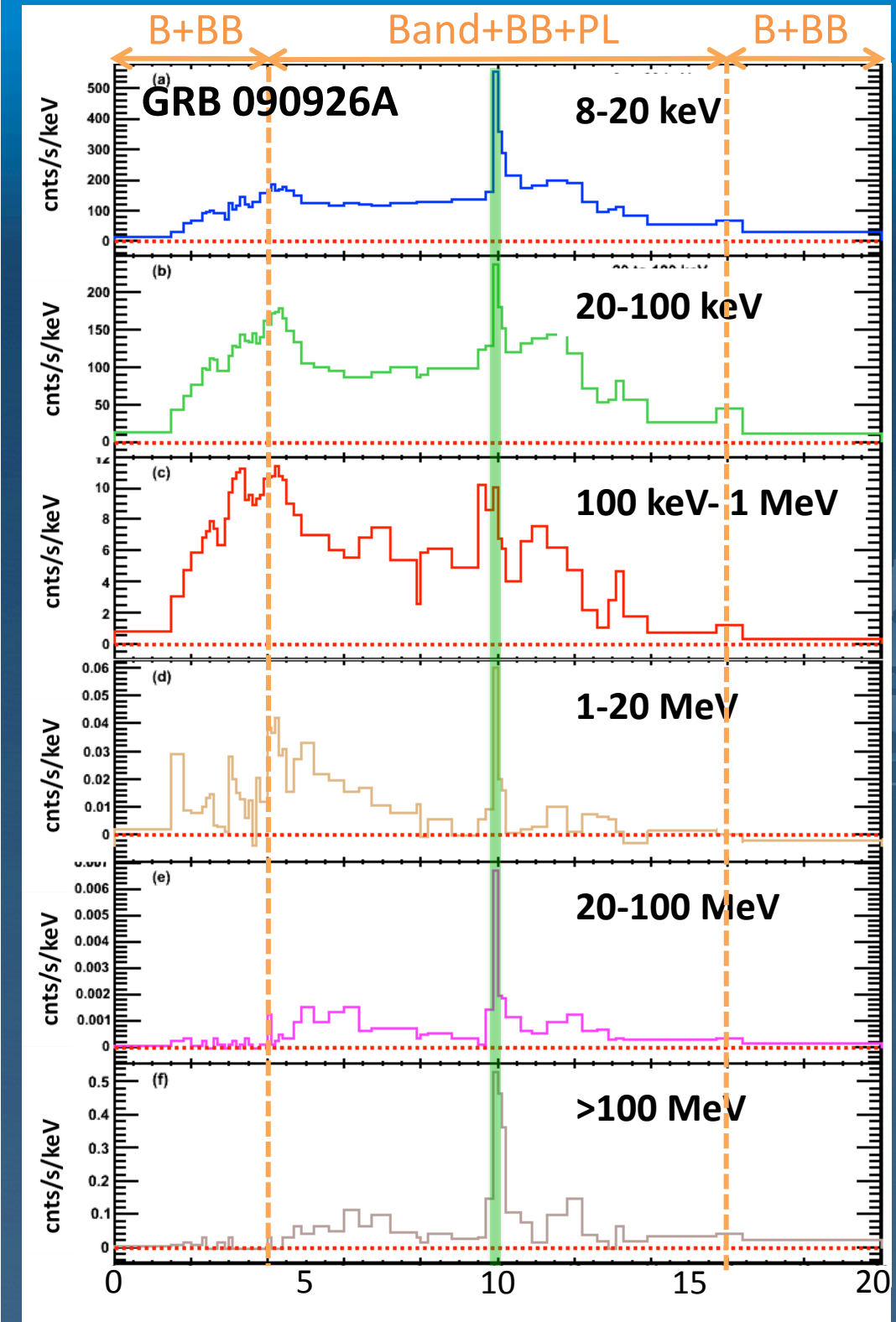


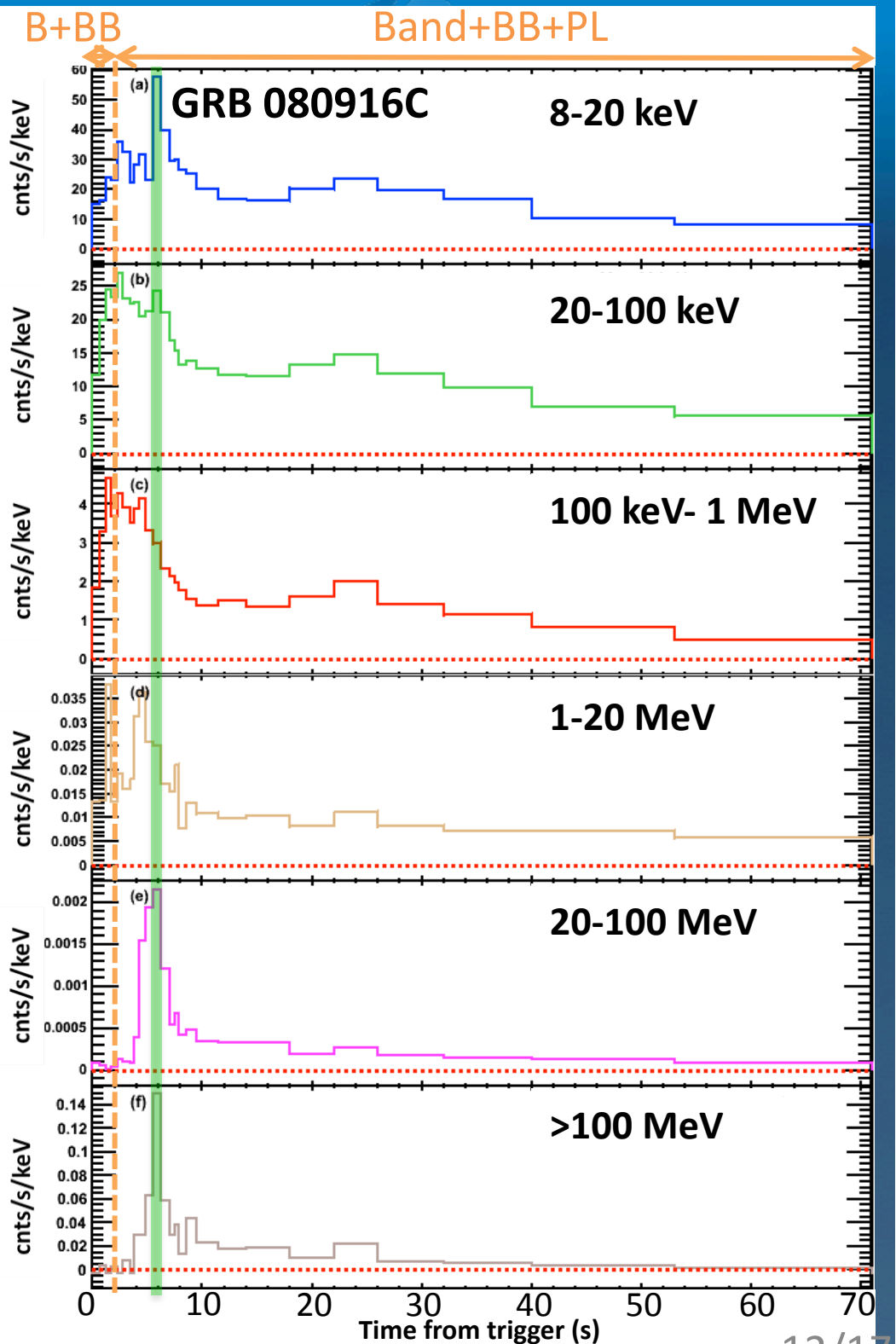
(Guiriec et al., in preparation)

GRB 090926A

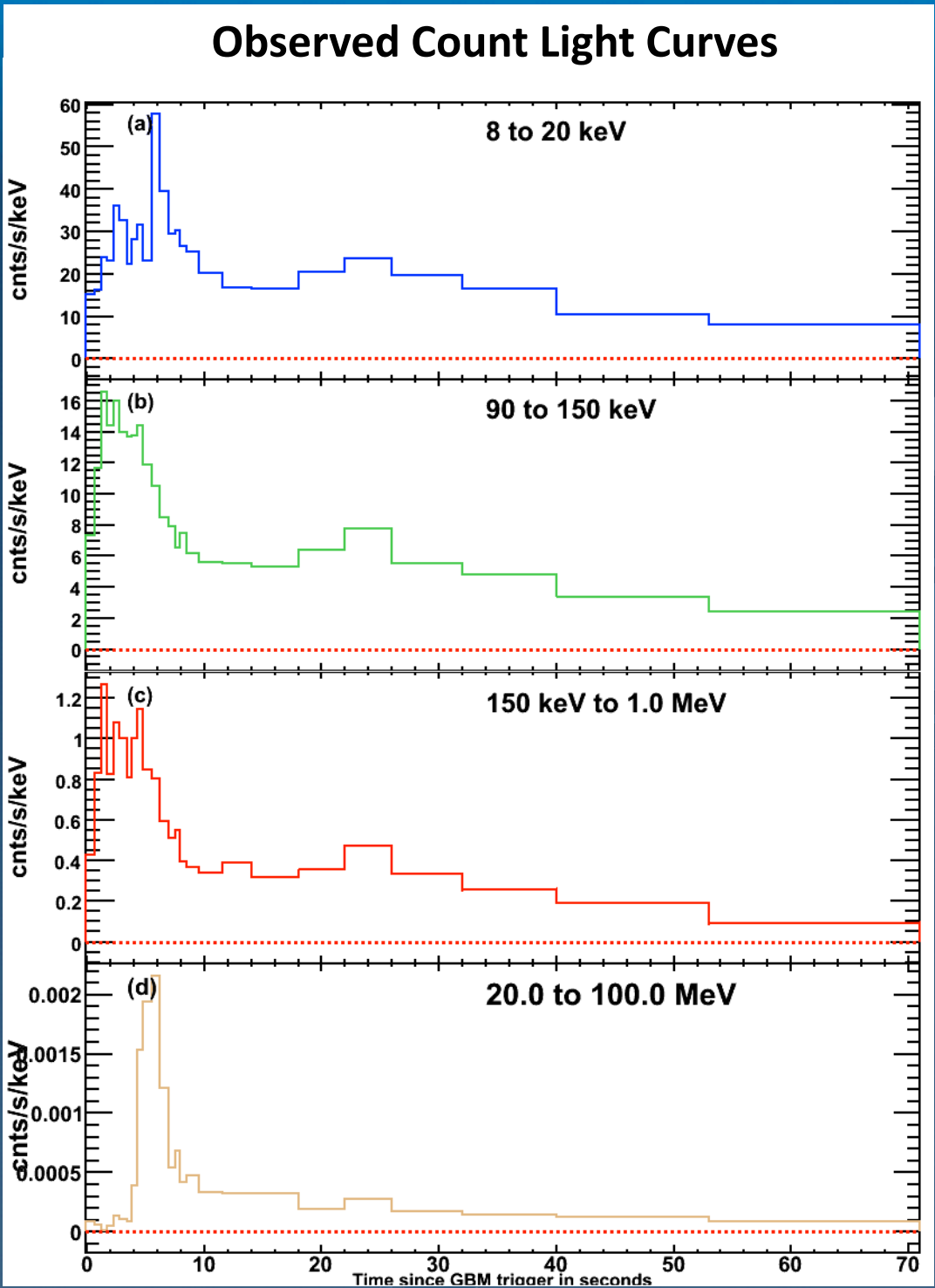

B+BB
Band+BB+PL
B+BB
(a)
8-20 keV
(b)
20-100 keV
(c)
100 keV- 1 MeV
(d)
1-20 MeV
(e)
20-100 MeV
(f)
>100 MeV
cnts/s/keV
0
5
10
15
20


T0+3.8s to T0+3.9s
T0+9.7s to T0+9.9s
T0+9.95s to T0+10.0s
T0+12.6s to T0+12.9s
νF_ν (erg².cm⁻².s⁻¹.keV⁻¹)
Energy (keV)


B+BB
Band+BB+PL
B+BB
GRB 090926A
8-20 keV
20-100 keV
100 keV- 1 MeV
1-20 MeV
20-100 MeV
>100 MeV
cnts/s/keV

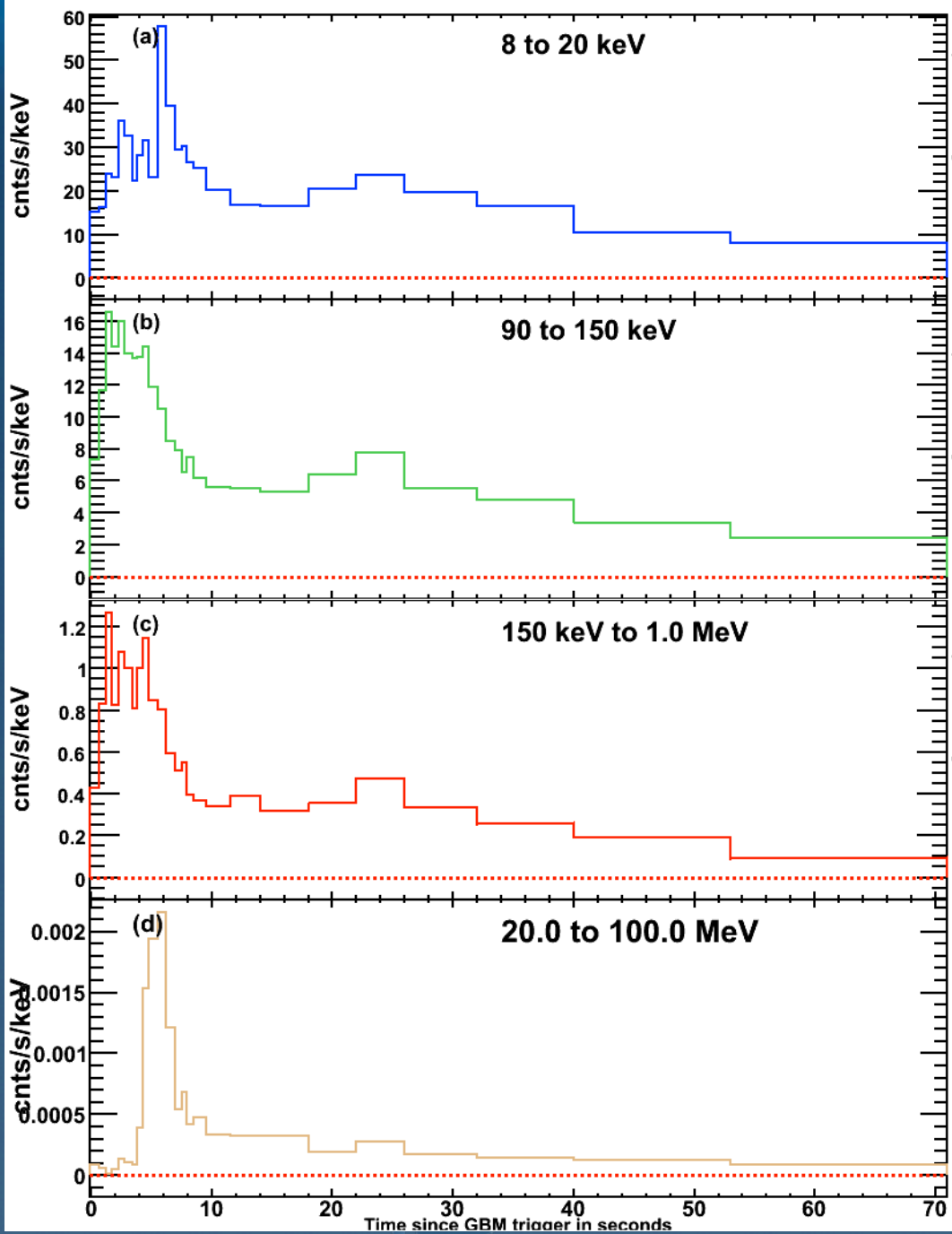

B+BB
Band+BB+PL
GRB 080916C
8-20 keV
20-100 keV
100 keV- 1 MeV
1-20 MeV
20-100 MeV
>100 MeV
cnts/s/keV
Time from trigger (s)

GRB 080916C

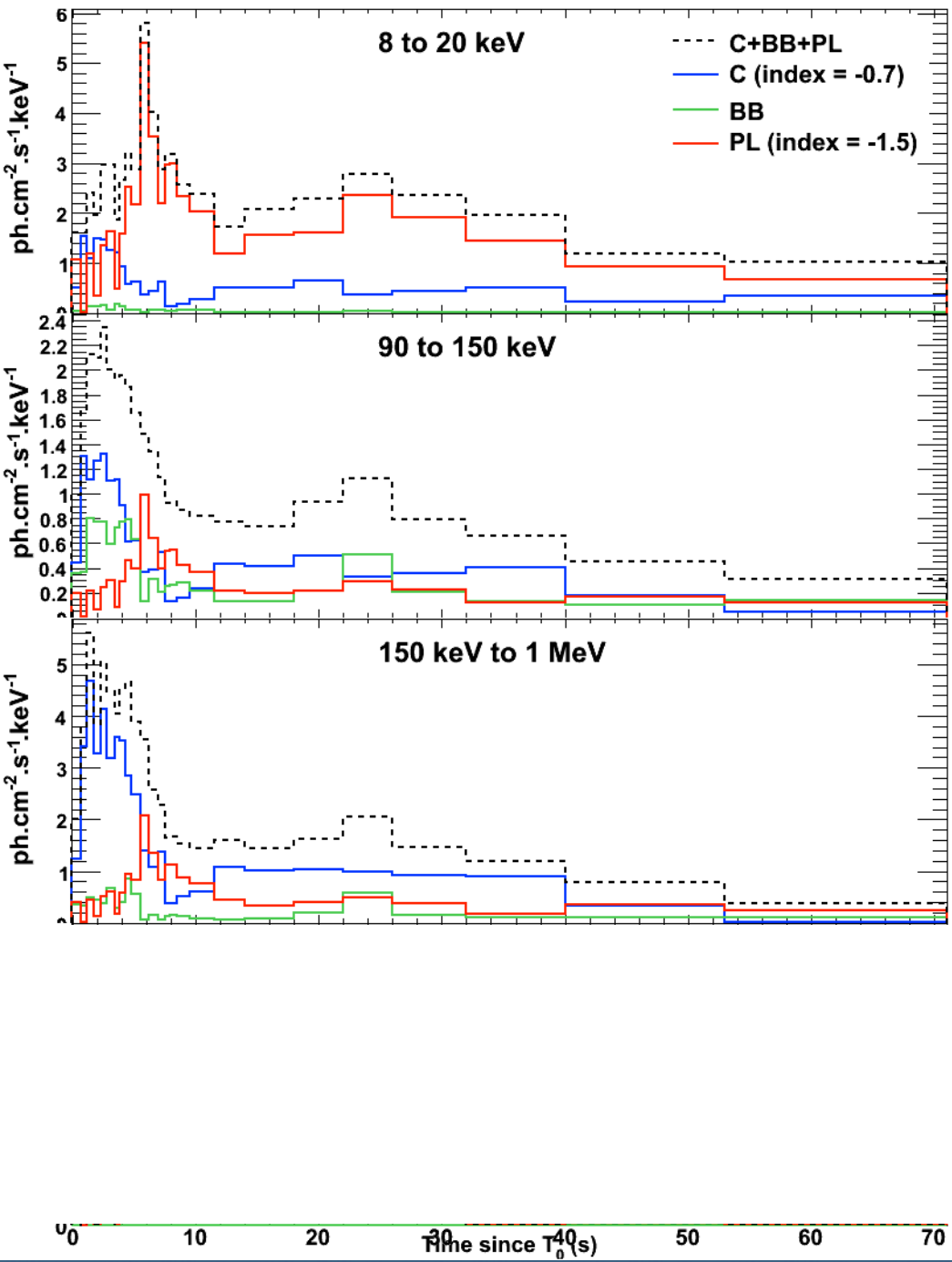

Observed Count Light Curves
(a)
8 to 20 keV
(b)
90 to 150 keV
(c)
150 keV to 1.0 MeV
(d)
20.0 to 100.0 MeV
cnts/s/keV
Time since GBM trigger in seconds

GRB 080916C

Observed Count Light Curves

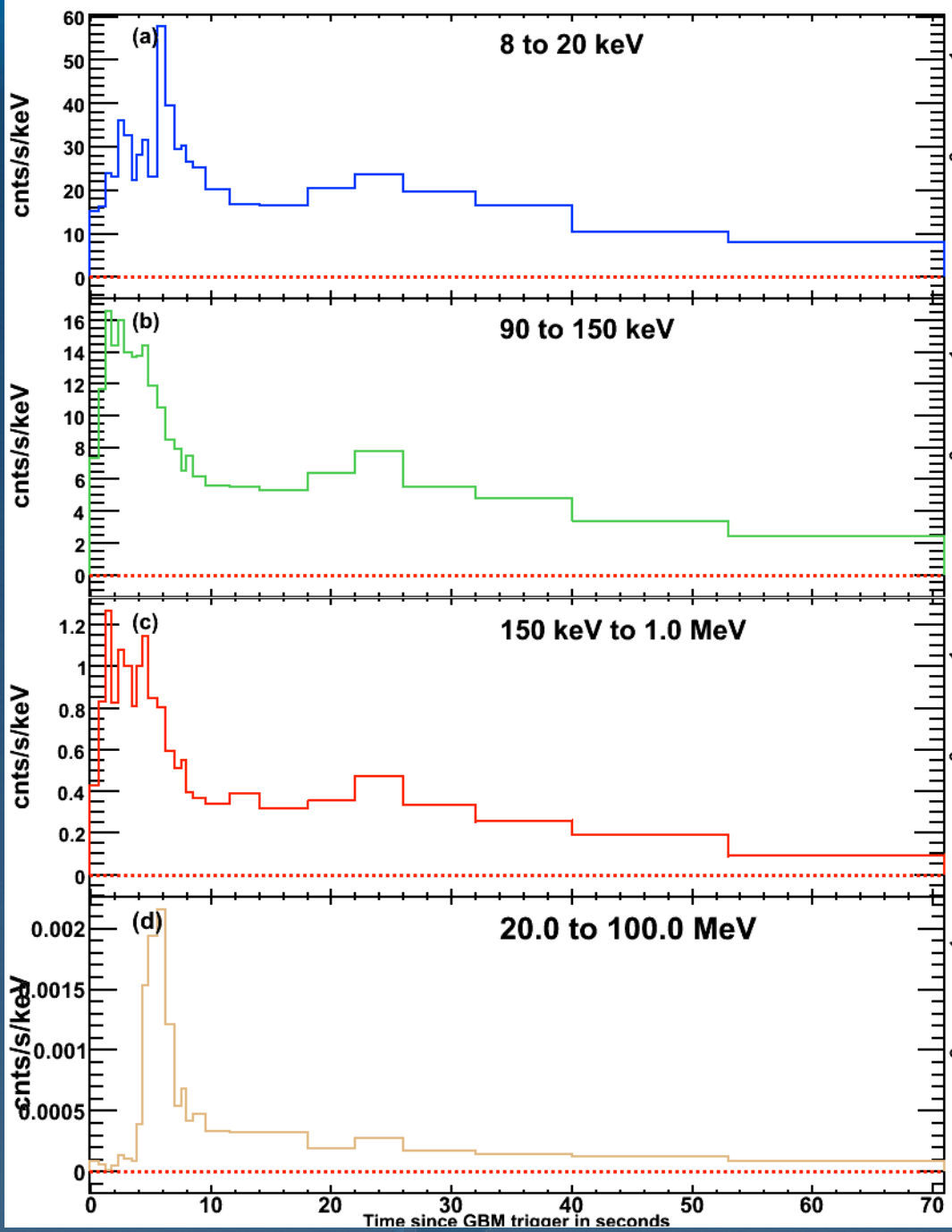


Reconstructed Photon Light Curves

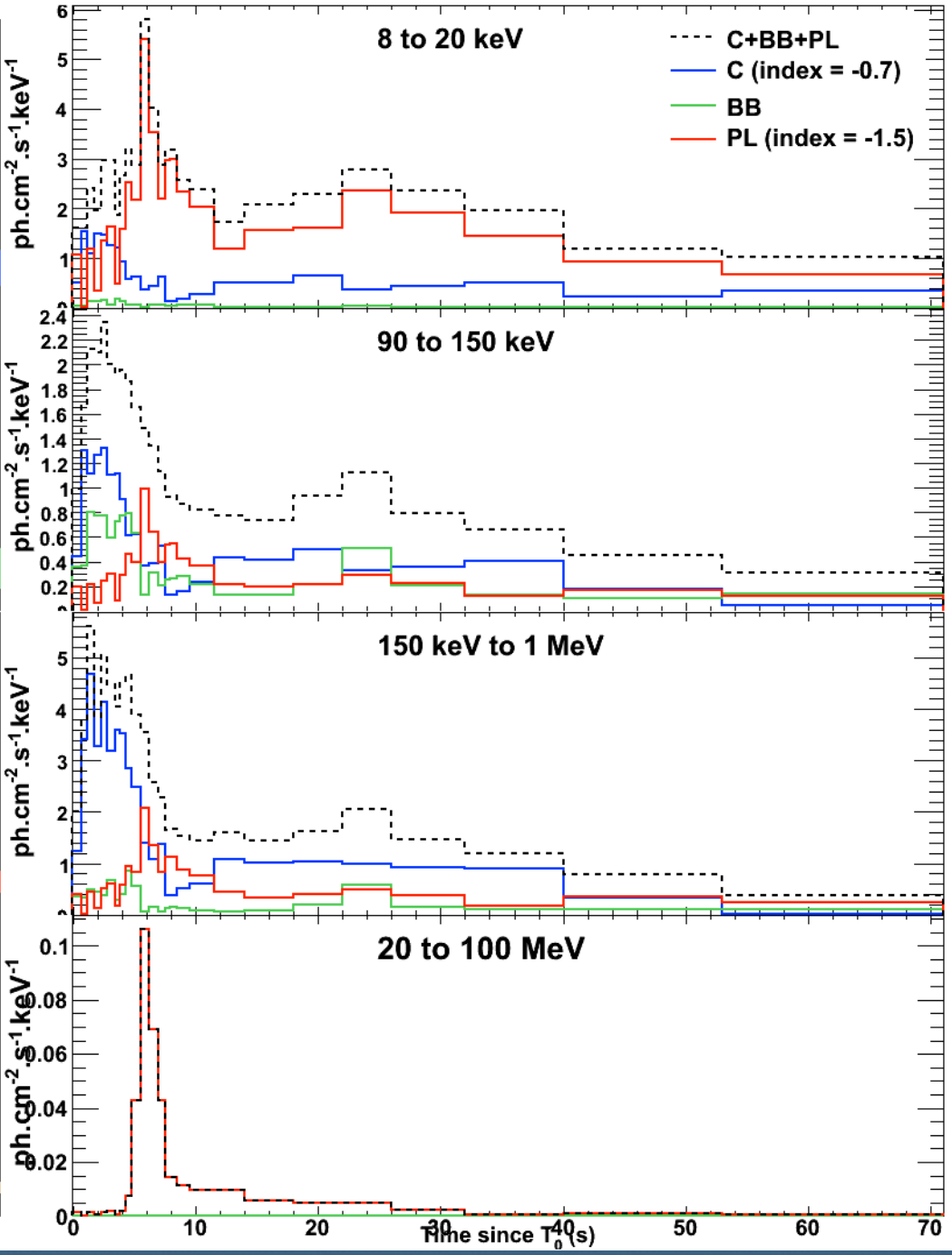


GRB 080916C

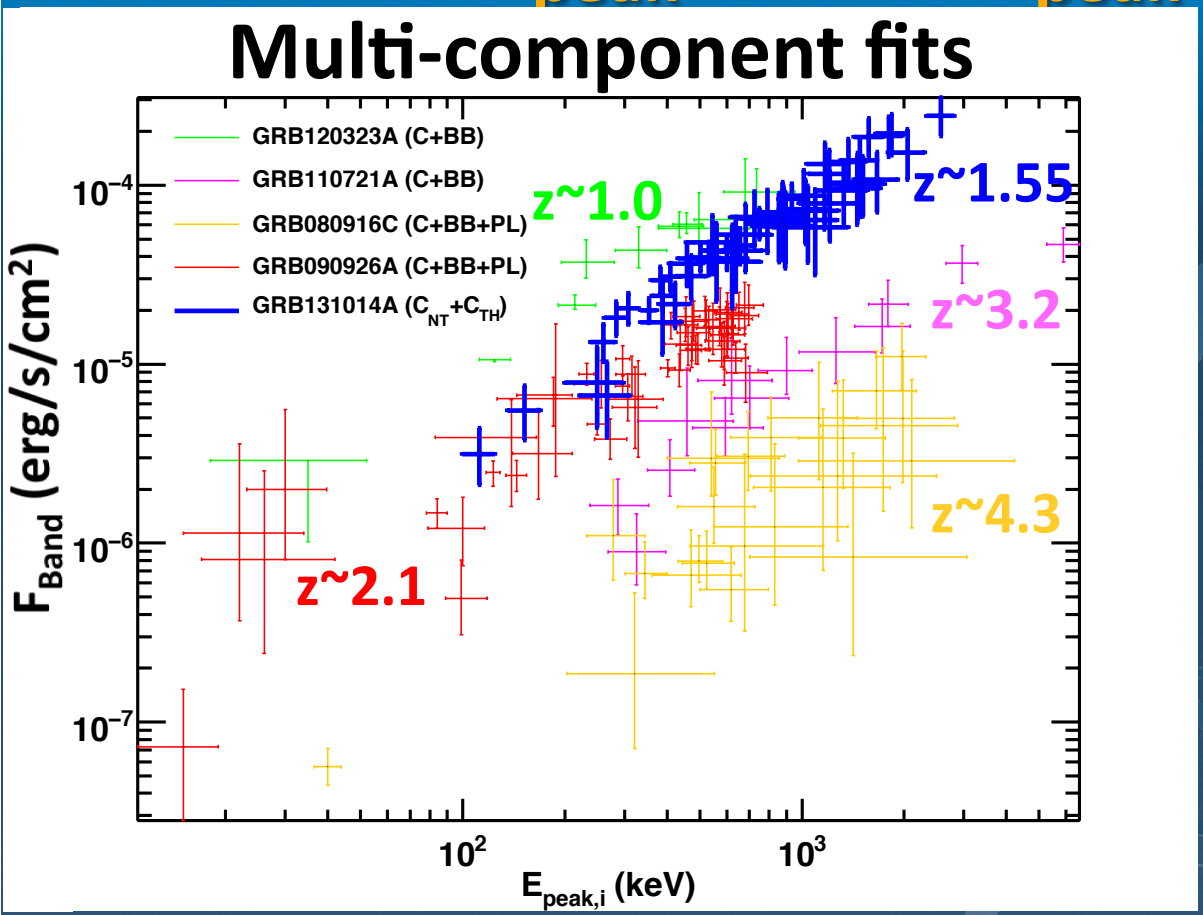
Observed Count Light Curves



Reconstructed Photon Light Curves



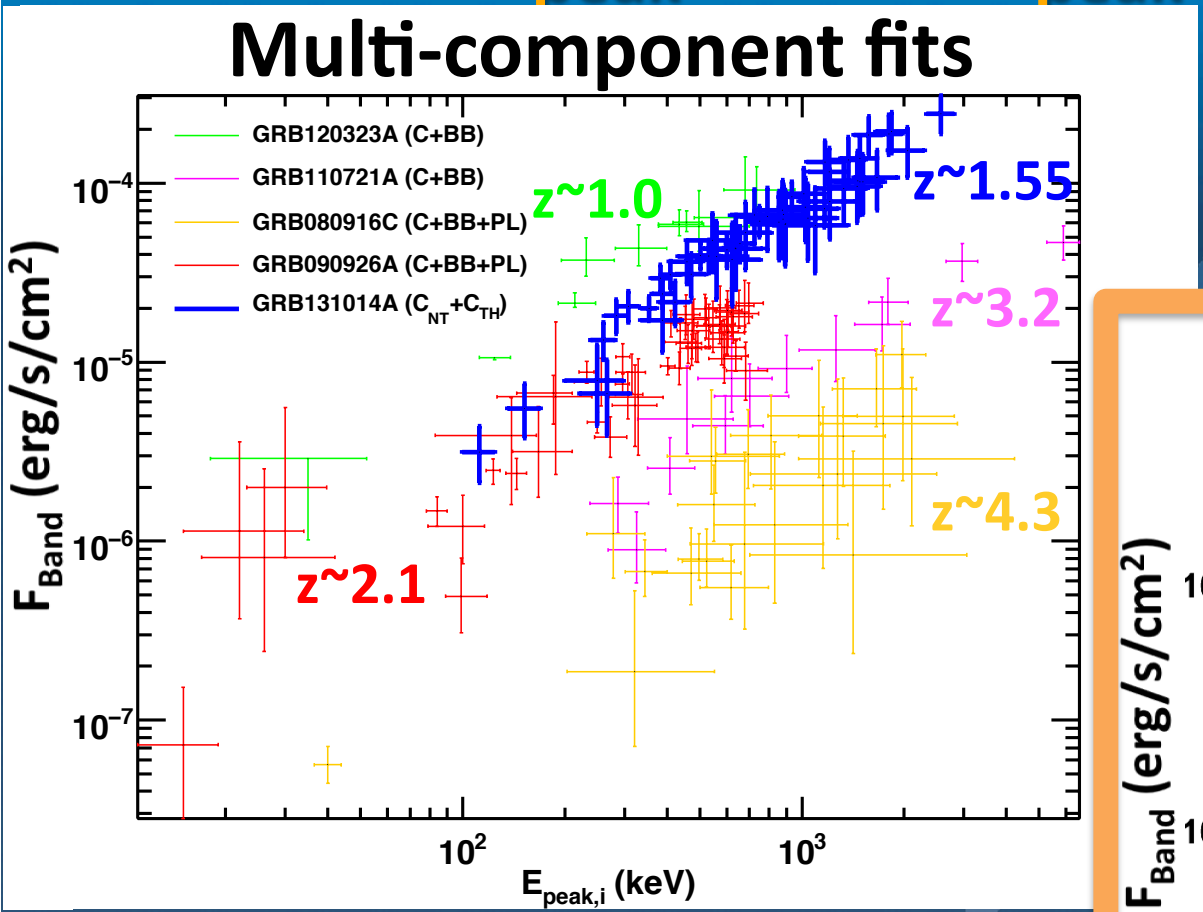
E_{peak}-F and E_{peak}-L Relations



(Guiriec et al., in Preparation)

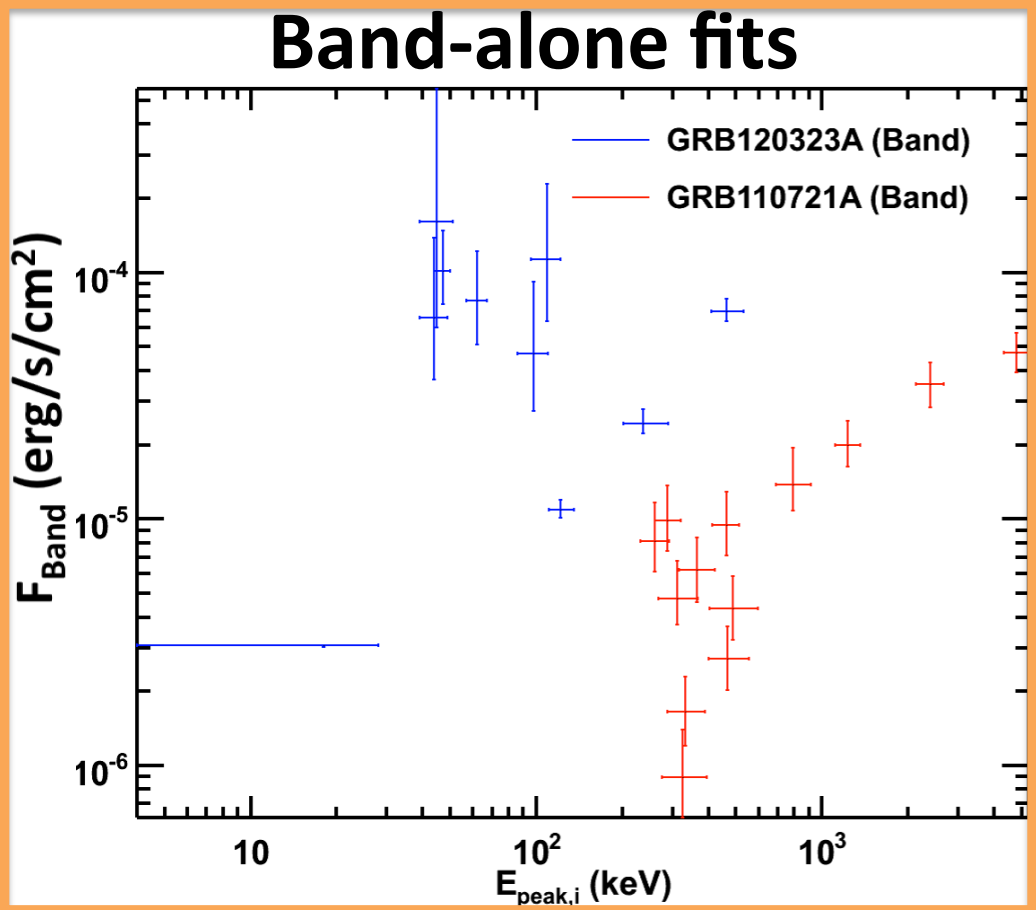
E_{peak}-F and E_{peak}-L Relations

Multi-component fits

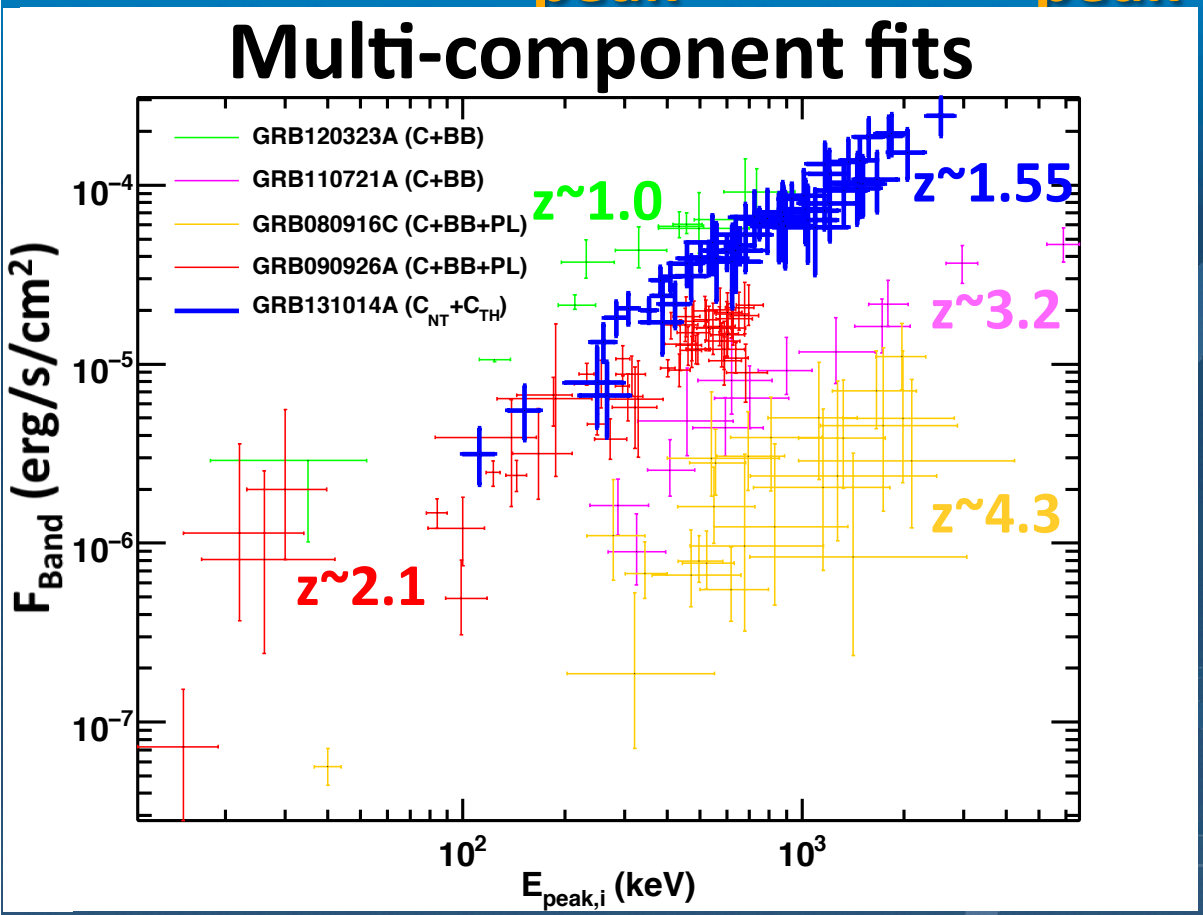


(Guiriec et al., in Preparation)

Band-alone fits



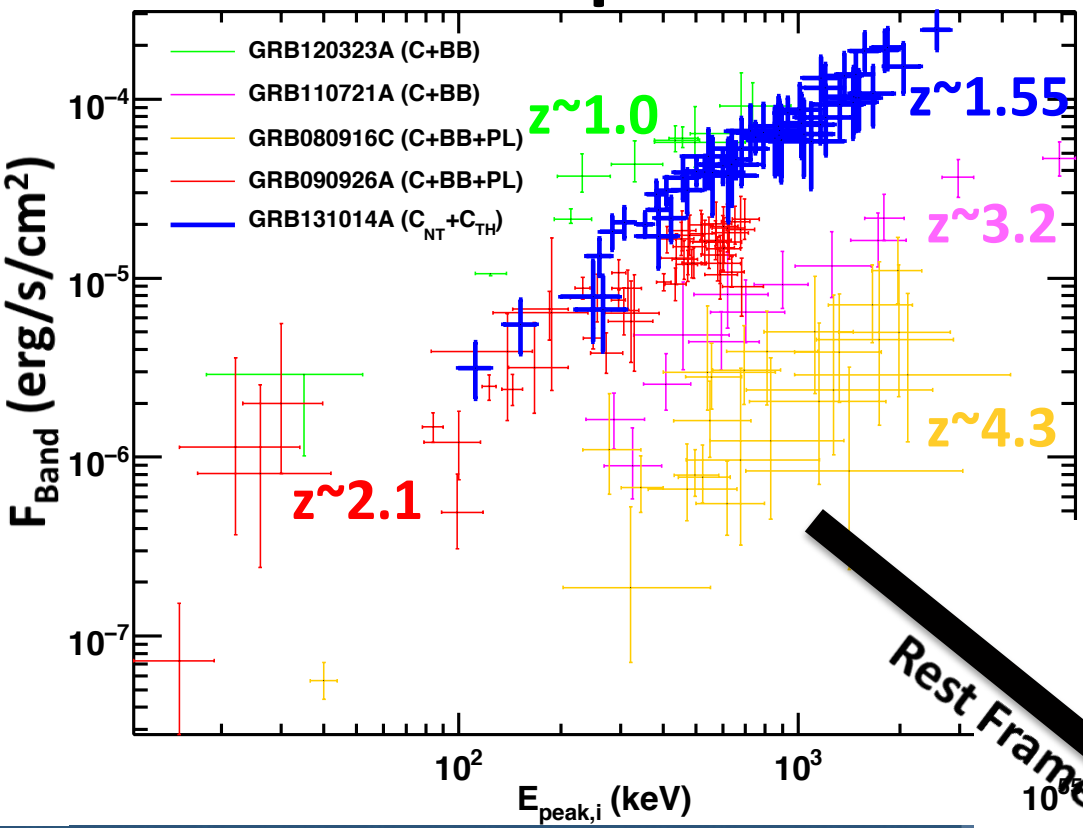
E_{peak}-F and E_{peak}-L Relations



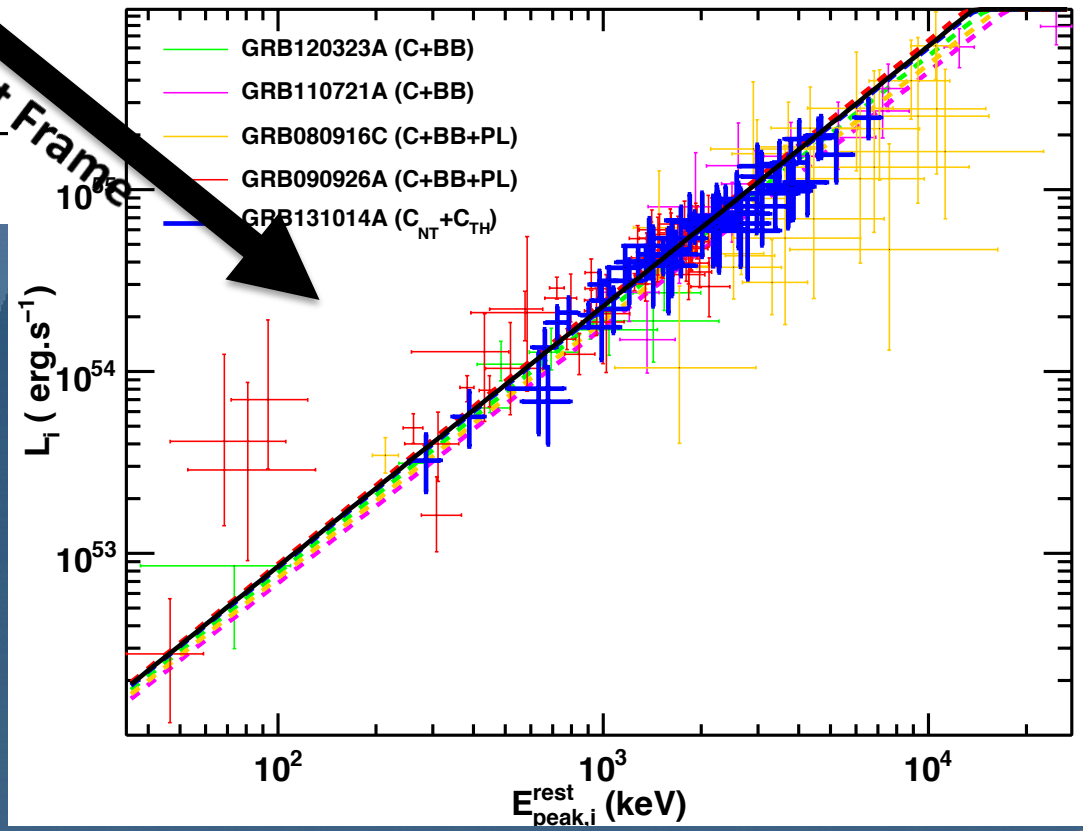
(Guiriec et al., in Preparation)

E_{peak}-F and E_{peak}-L Relations

Multi-component fits



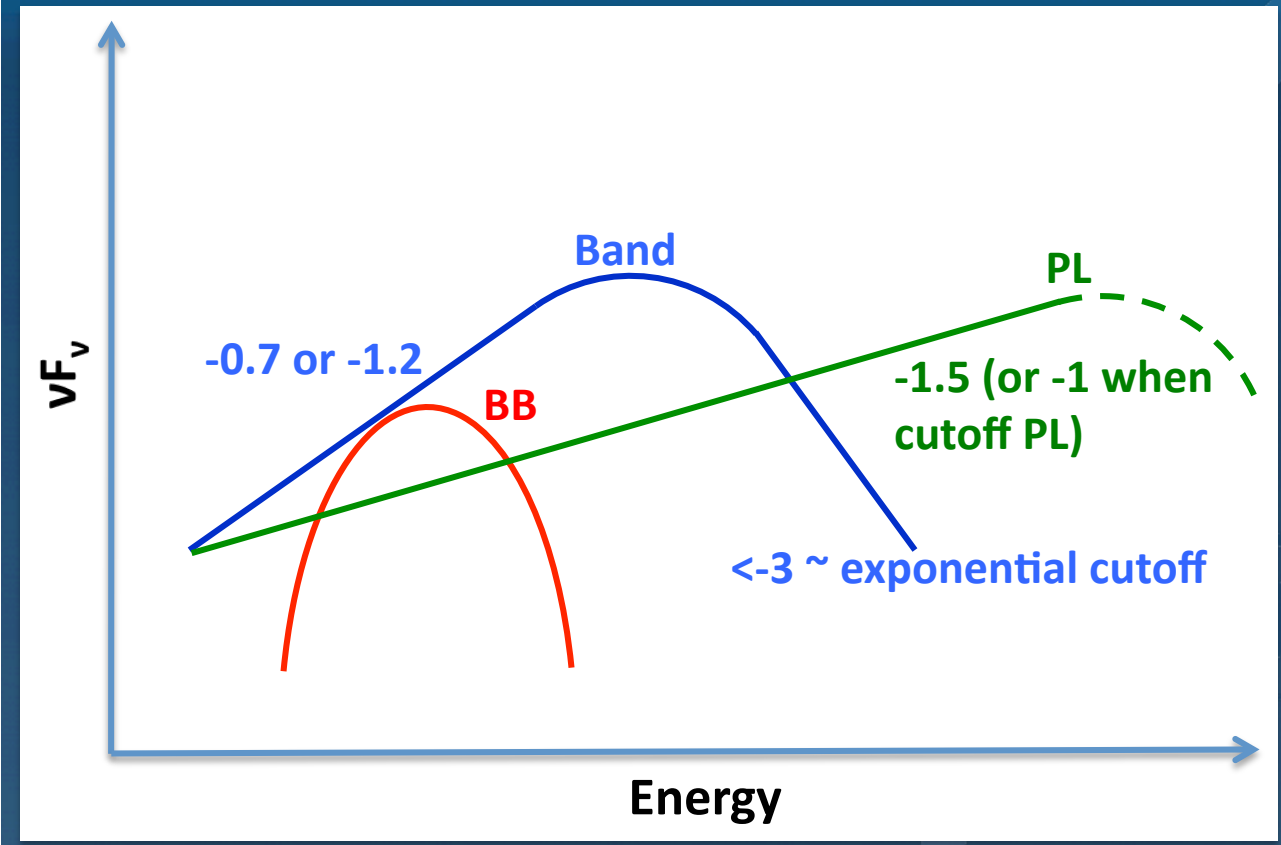
Rest Frame

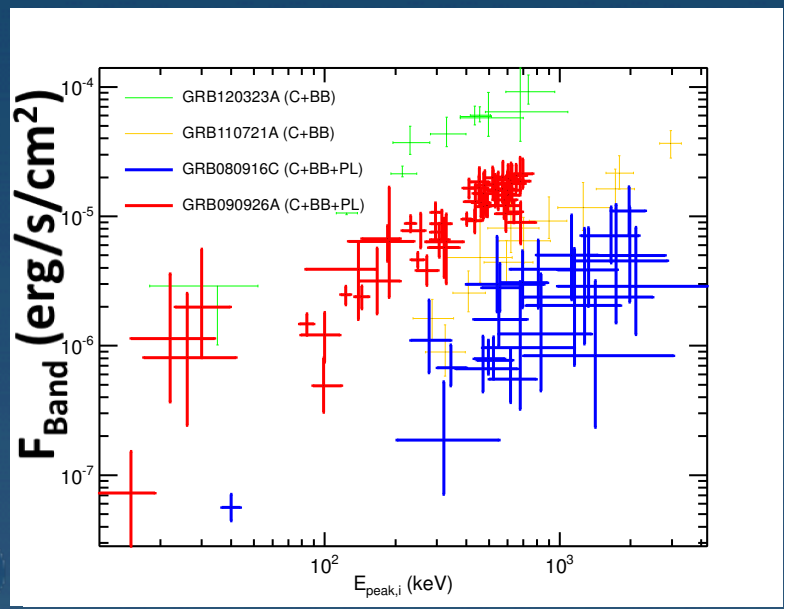


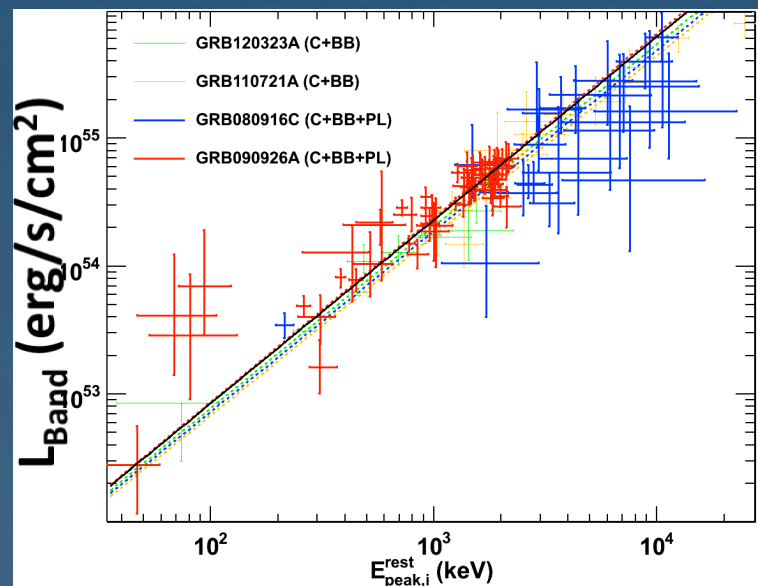
(Guiriec et al., in Preparation)

$$L_i^{Band} = (1.59 \pm 0.84)10^{50} \ (E^{rest}_{peak,i})^{1.33\pm0.07} \text{erg s}^{-1}$$

Conclusion


Band
PL
-0.7 or -1.2
BB
-1.5 (or -1 when cutoff PL)
<-3 ~ exponential cutoff
νF_ν
Energy


GRB120323A (C+BB)
GRB110721A (C+BB)
GRB080916C (C+BB+PL)
GRB090926A (C+BB+PL)
F_{Band} (erg/s/cm^2)
$E_{peak,i}$ (keV)


GRB120323A (C+BB)
GRB110721A (C+BB)
GRB080916C (C+BB+PL)
GRB090926A (C+BB+PL)
L_{Band} (erg/s/cm^2)
$E^{rest}_{peak,i}$ (keV)

Conclusion

• Empirical Band function alone not always well represent the physics behind prompt emission spectra AND it may even prevent to understand it.

• Combination of a thermal-like component with a Band function makes the Band function shape more compatible with synchrotron scenarios.

• An additional non-thermal power law extending from few keV up to hundred MeV is sometimes present in the spectra => challenging for interpretation.

• Band and BB components most intense at early time, the additional power law flux peaks at later time and lasts much longer.

• Band+BB+PL = 5 free parameters + 1 constraint (Ep-F) while Band = 4 free parameters => ~same number of degrees of freedom !!!

• Band+BB+PL model also consistent with data of other instruments.

• New Ep-F and Ep-L relations.

Backup Slides