Constraining emission mechanisms in GRBs using spectral width

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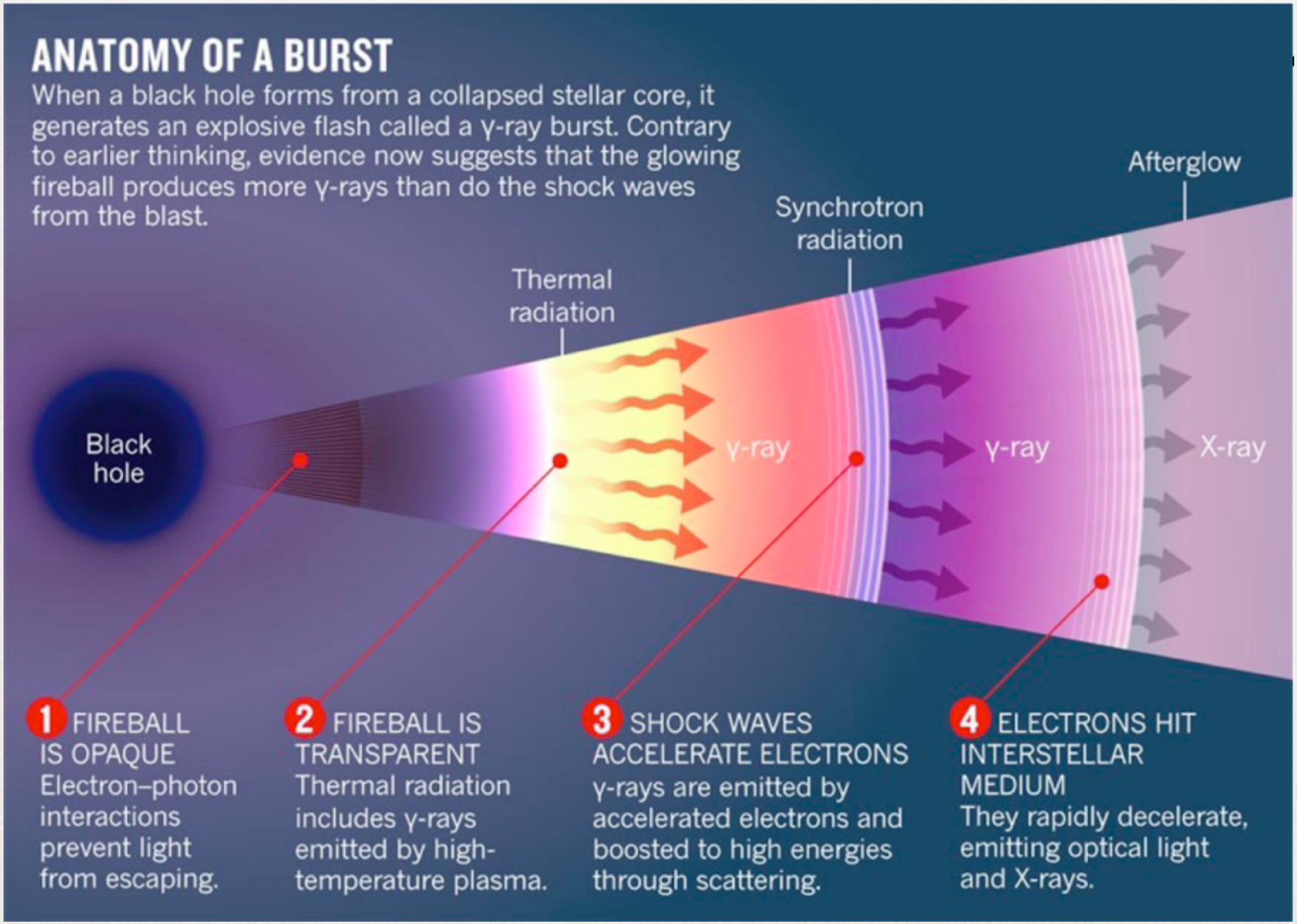
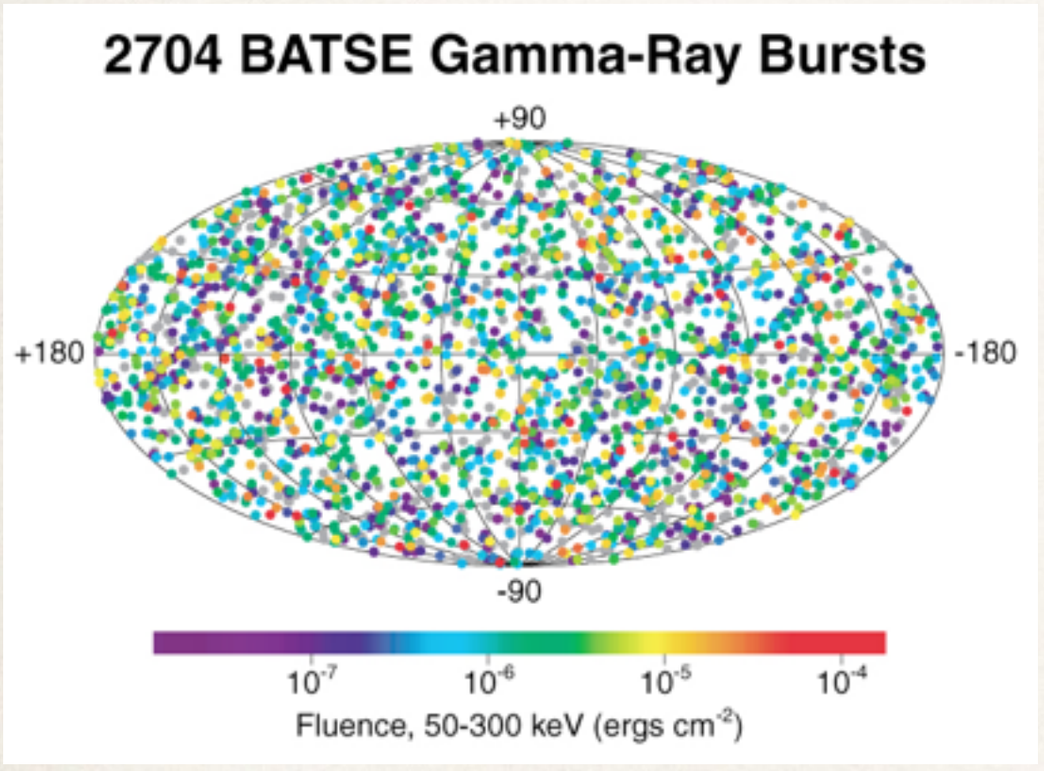
Origin of prompt emission?

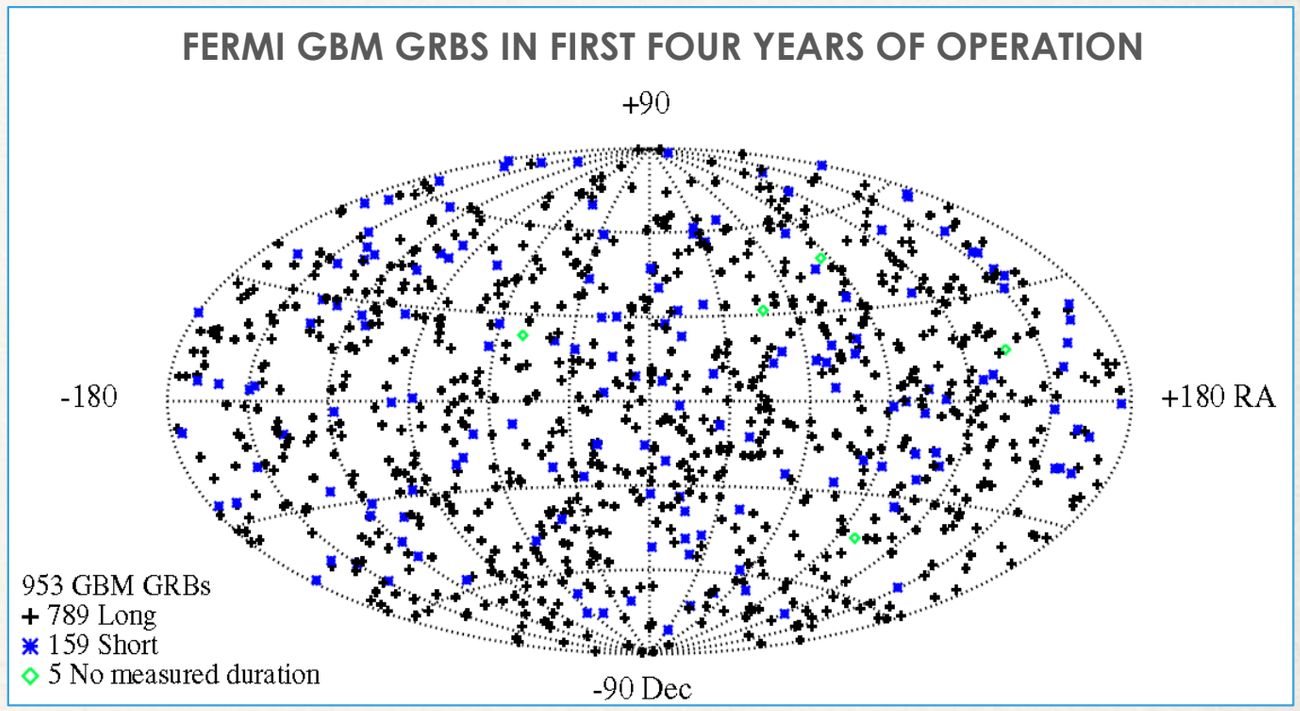


Large samples

Lightcurves of individual GRBs vary a lot

Spectra remarkably similar - similar emission processes?

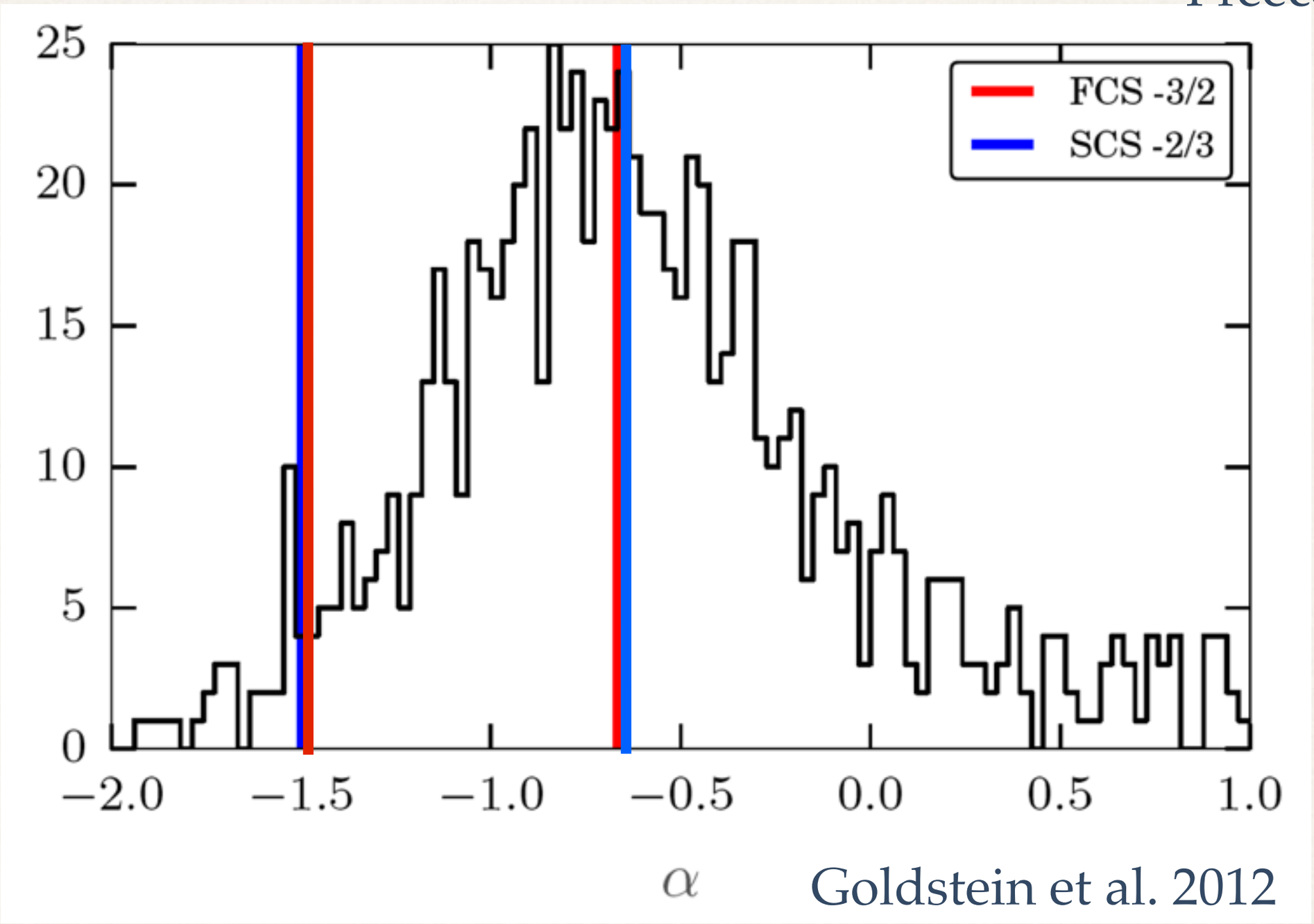




With large samples we can probe general properties

Line of death of synchrotron emission

Preece et al. 98



Goldstein et al. 2012

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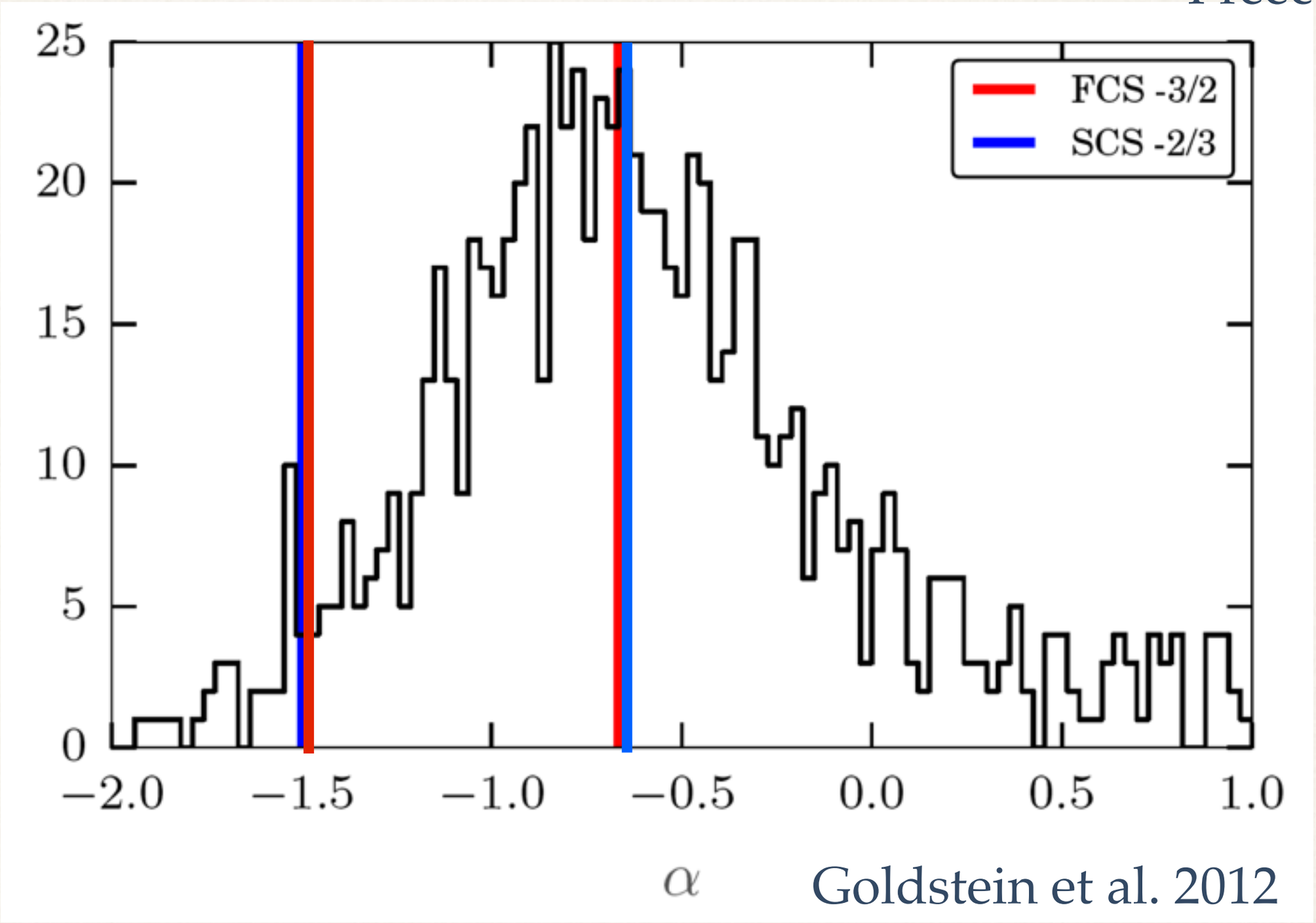

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Synchrotron emission is not well represented by the Band function

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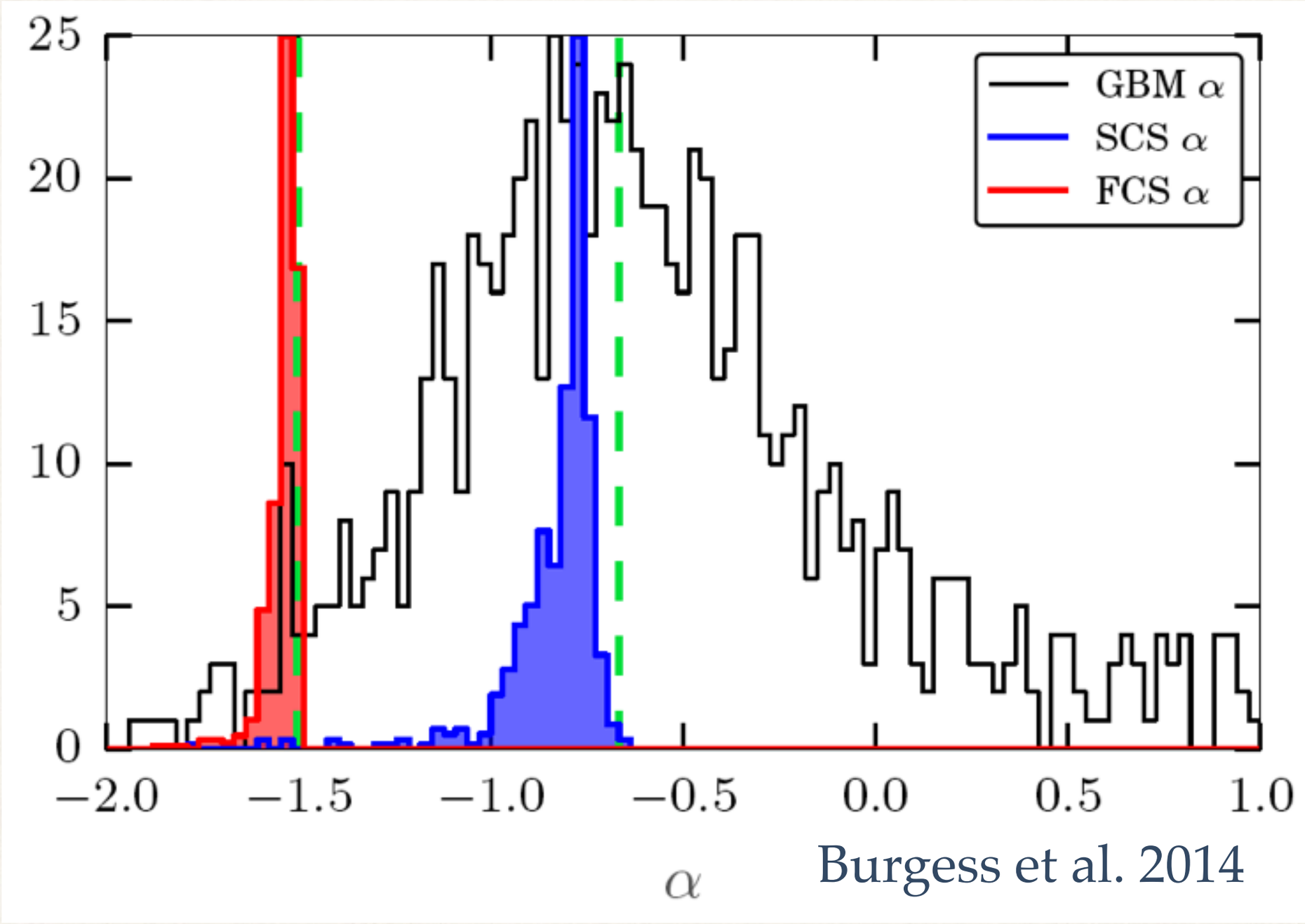

Burgess et al. 2014

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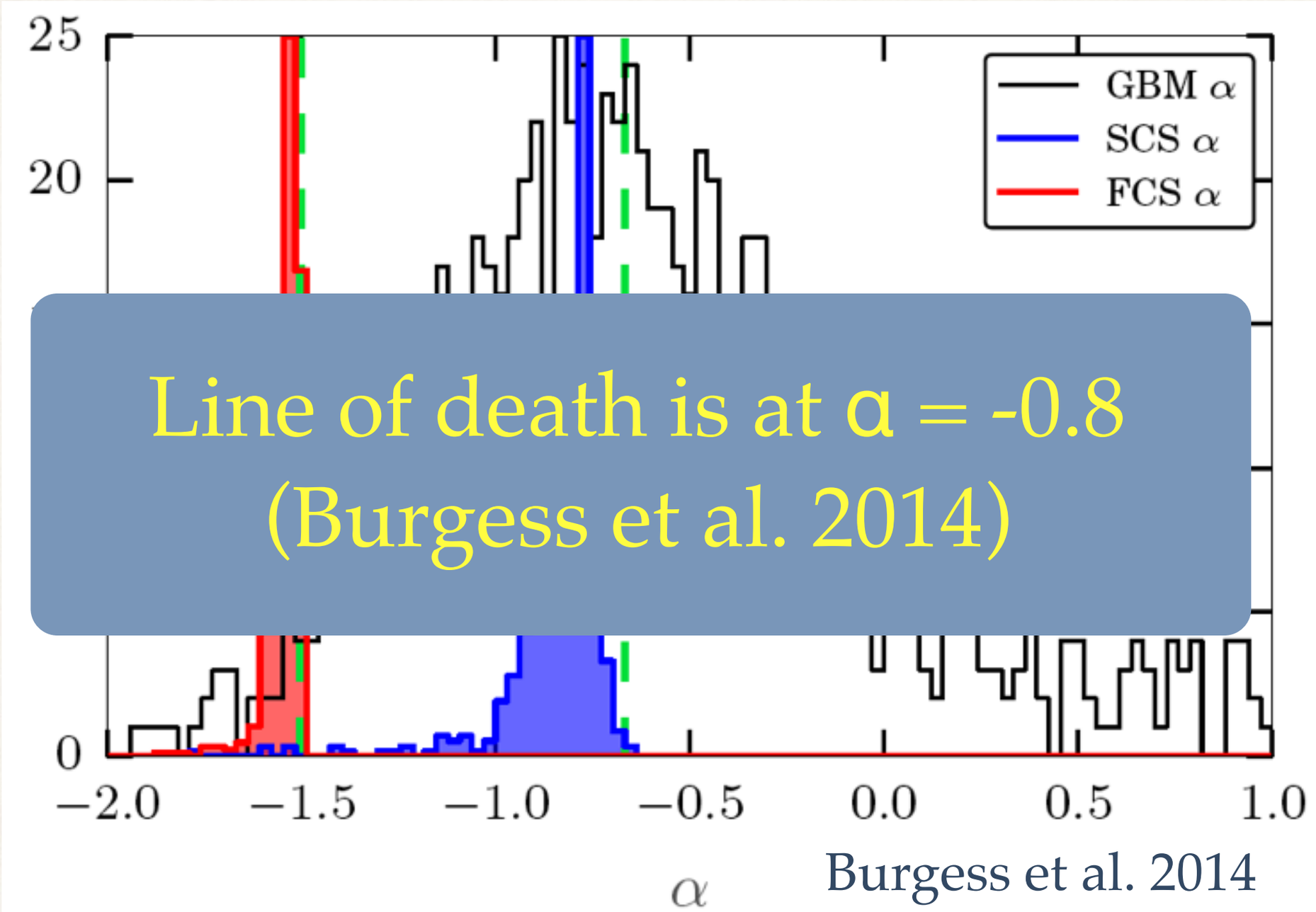


Line of death is at α = -0.8 (Burgess et al. 2014)

Burgess et al. 2014

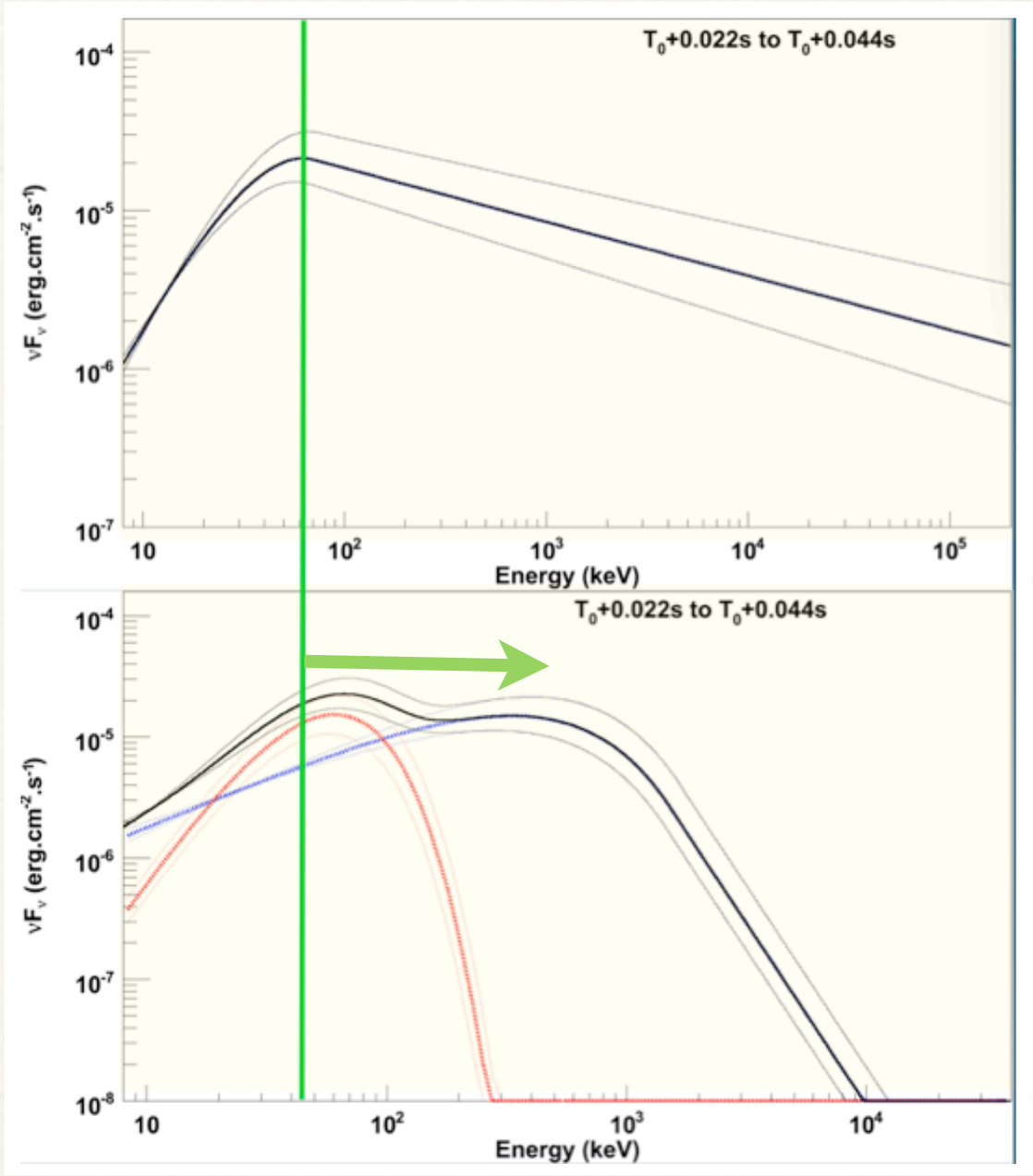
Synchrotron emission is not well represented by the Band function

Line of death of synchrotron emission

Adding an extra component can change the interpretation - alpha becomes compatible with synchrotron.

Extra component is blackbody: likely photospheric emission

Might solve the problem for some GRBs, but dependent on spectral model used…



Guriec et al. (2013)

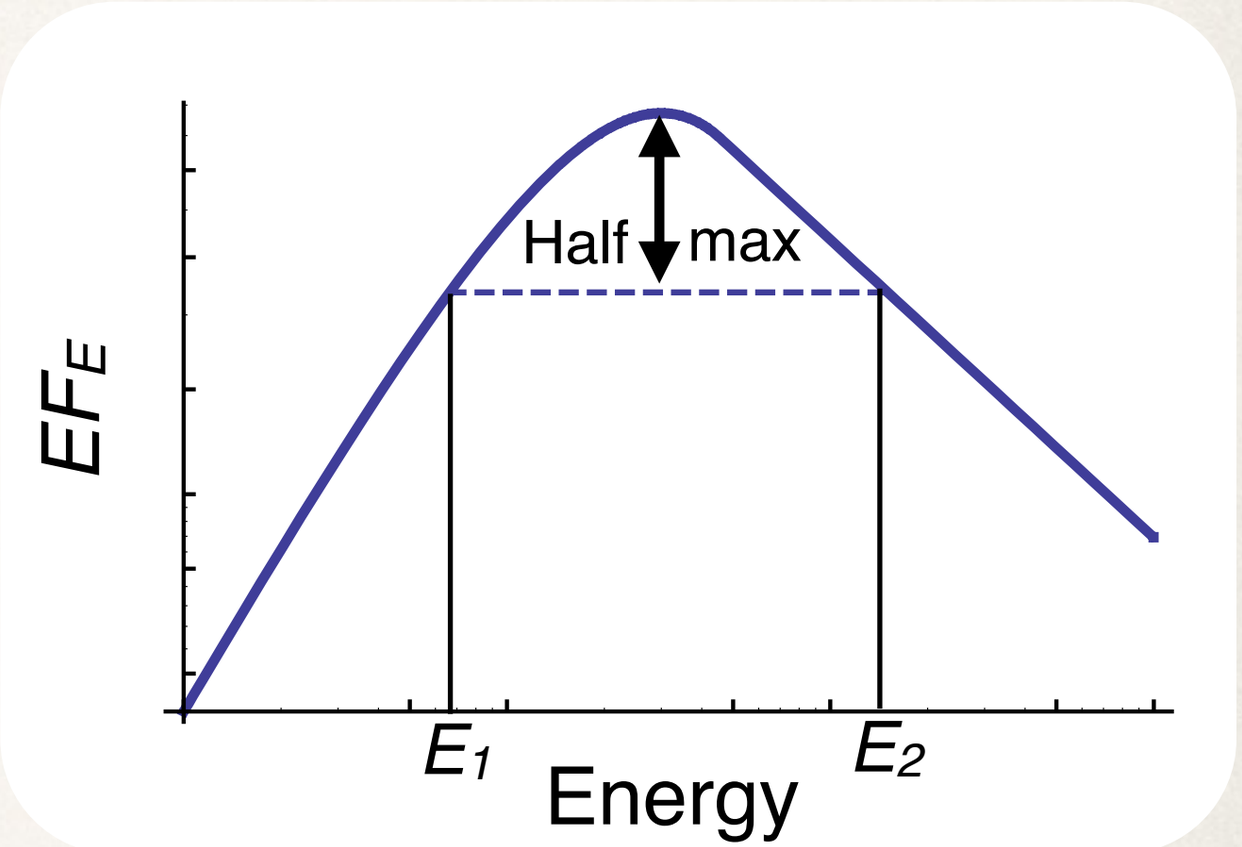
Spectral width?

- The Band function does not provide a physical interpretation - but does give a good "geometrical" description.

- The *W* parameter does not depend on any spectral model - all models giving a good fit will give similar *W*.

- *W* does not depend on E_{peak} - important since E_{peak} evolves

- Spectral evolution during integration time will act to increase *W*, so the measured one is an upper limit (finite bin size)



$$W = \log\left(\frac{E_2}{E_1}\right)$$

The study

- Analysed Band-function fits to GRBs in BATSE (1970) and Fermi/GBM (943) spectral catalogs.

- Use peak flux spectra for GBM: 64ms for short GRBs and 1.024s for long. In BATSE, all spectra were 2.048s.

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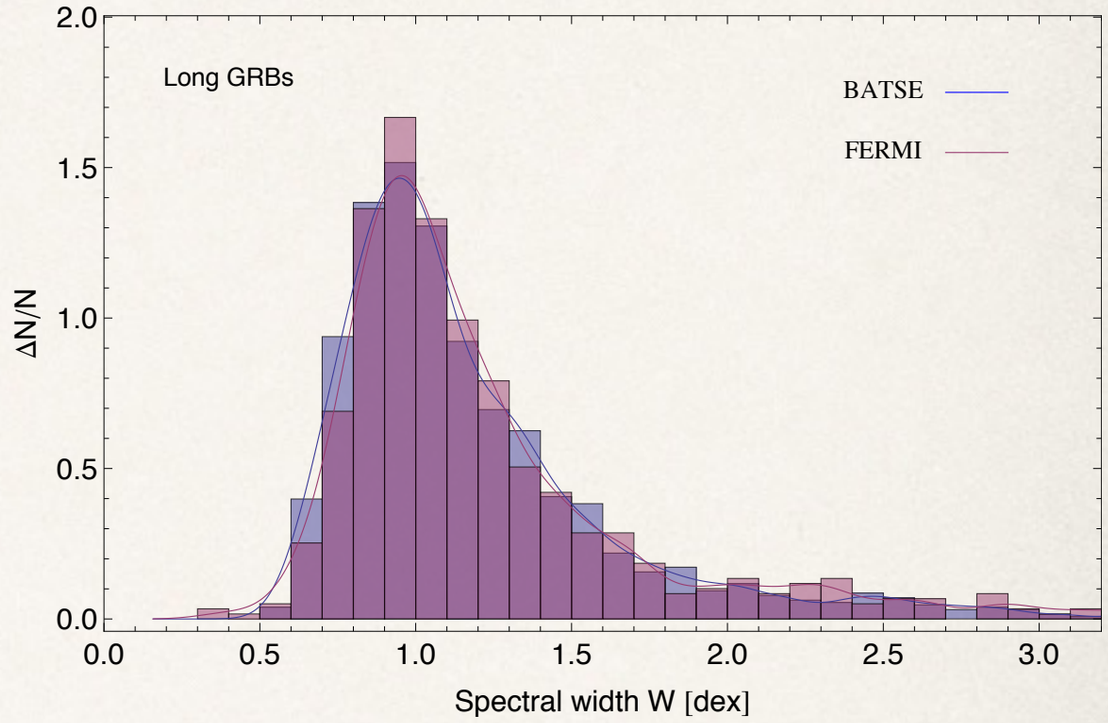


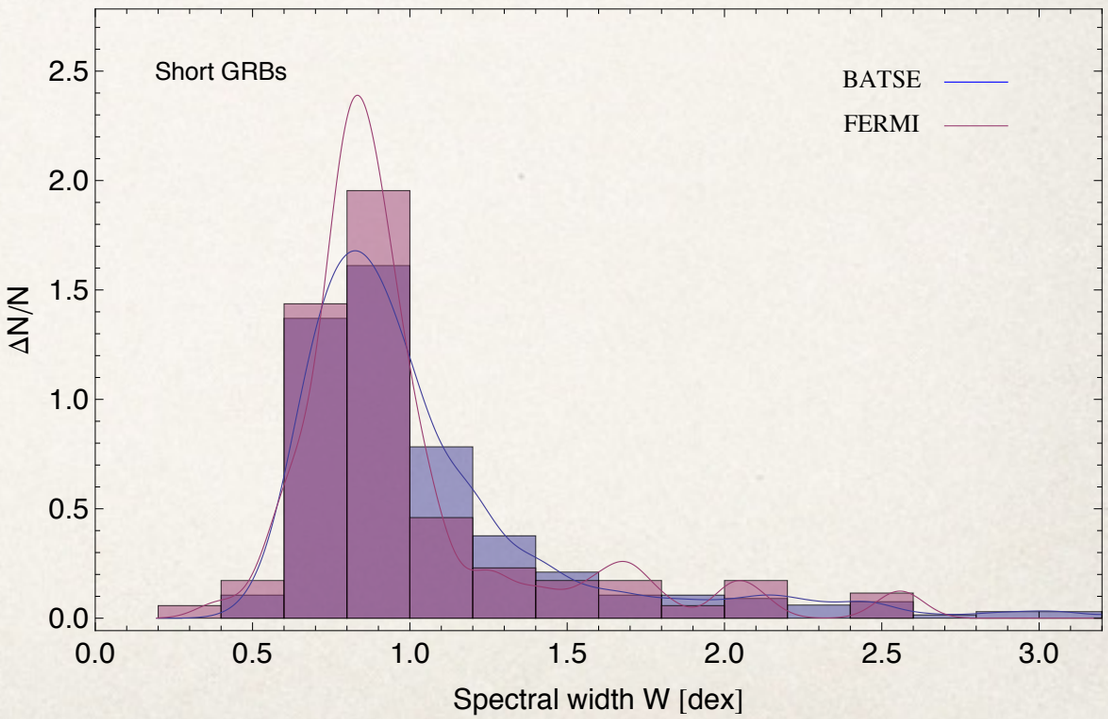
Results

- GBM and BATSE results consistent

- Mean uncertainty is ~0.15

- Narrow distribution!

- No correlation with T_{90} or E_{peak}



Comparing long and short GRBs

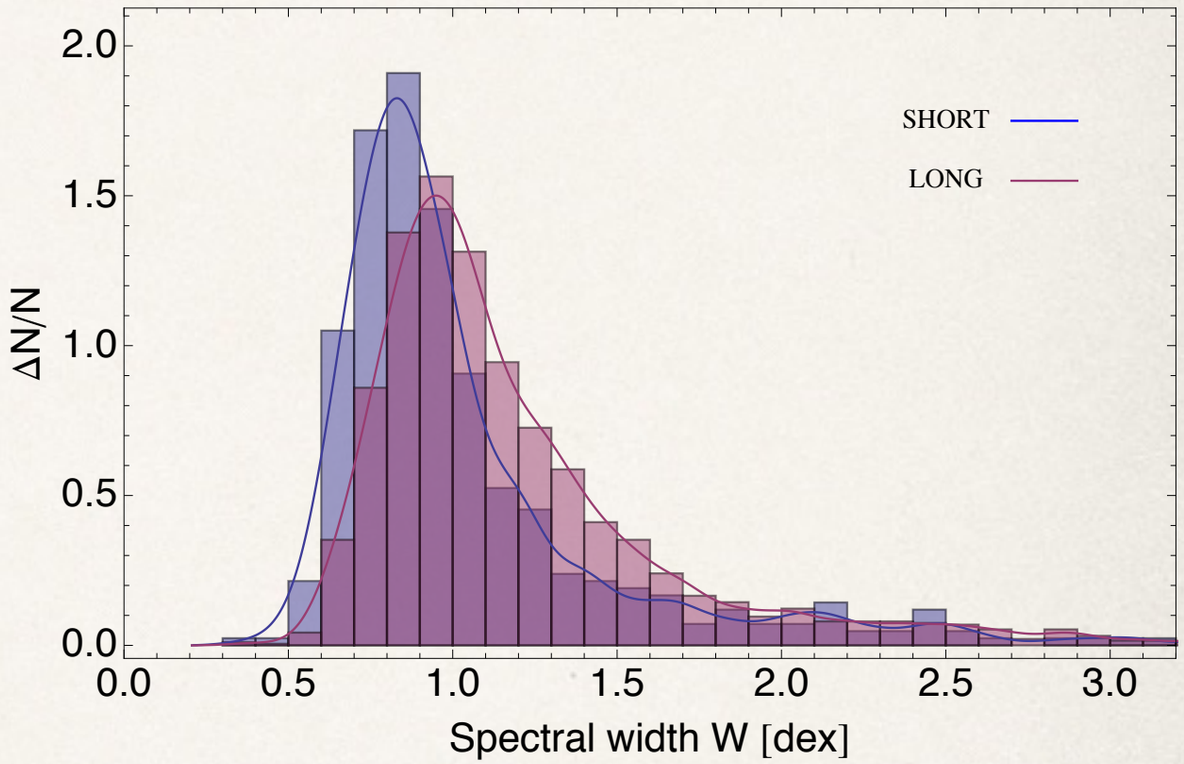
- Two groups of GRBs based on duration (split at T_{90} = 2s).

- Short GRBs have generally harder spectra and higher E_{peak}.

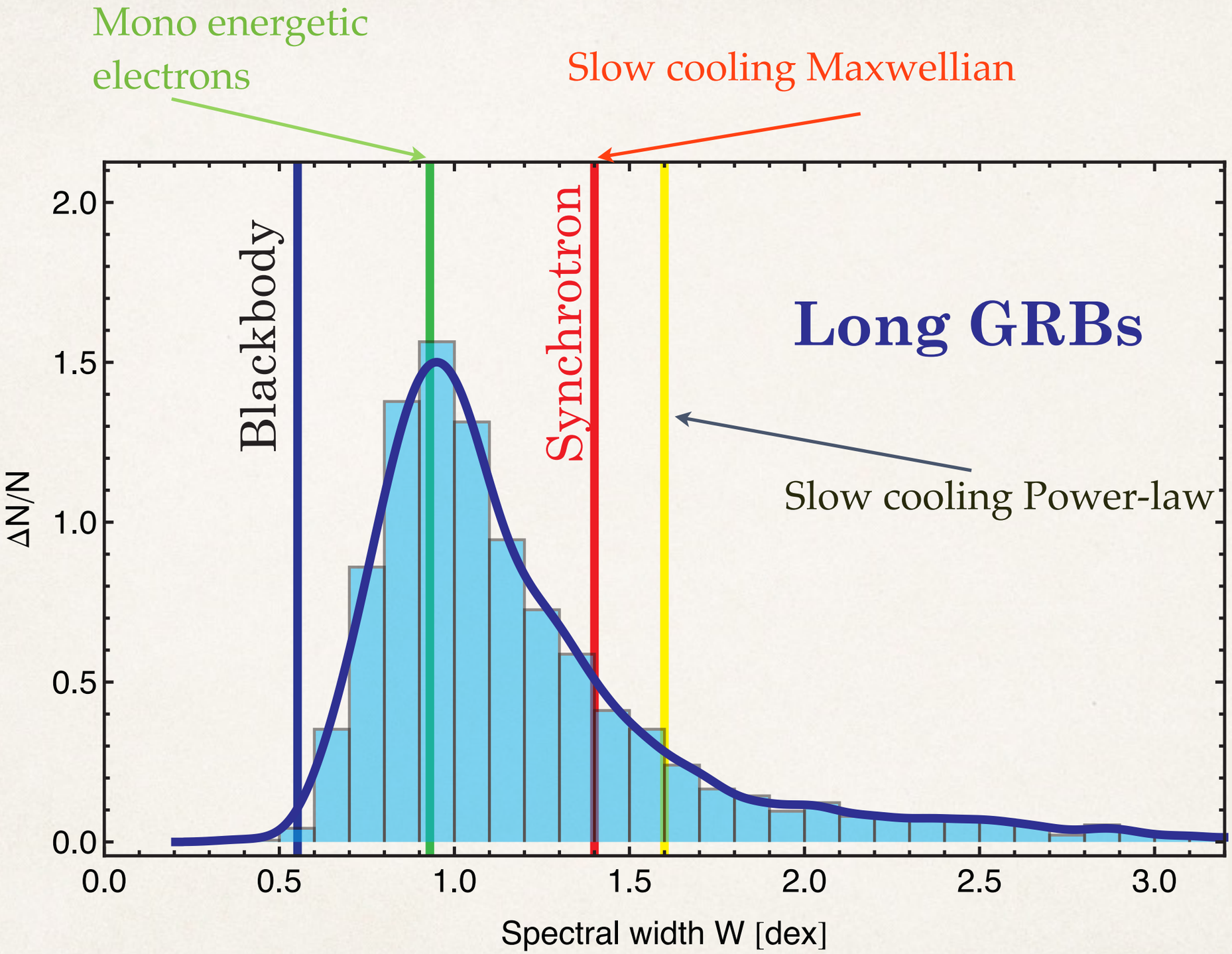
- We find that there is a significant difference between *W* for long and short GRBs - short GRBs have smaller *W*!

- Chance probability < 10^{-6}.

- Spectral evolution would broaden short GRB spectra more, why are they more narrow? Connected to the different progenitor scenarios?



Comparing with emission processes



Axelsson & Borgonovo (2015)

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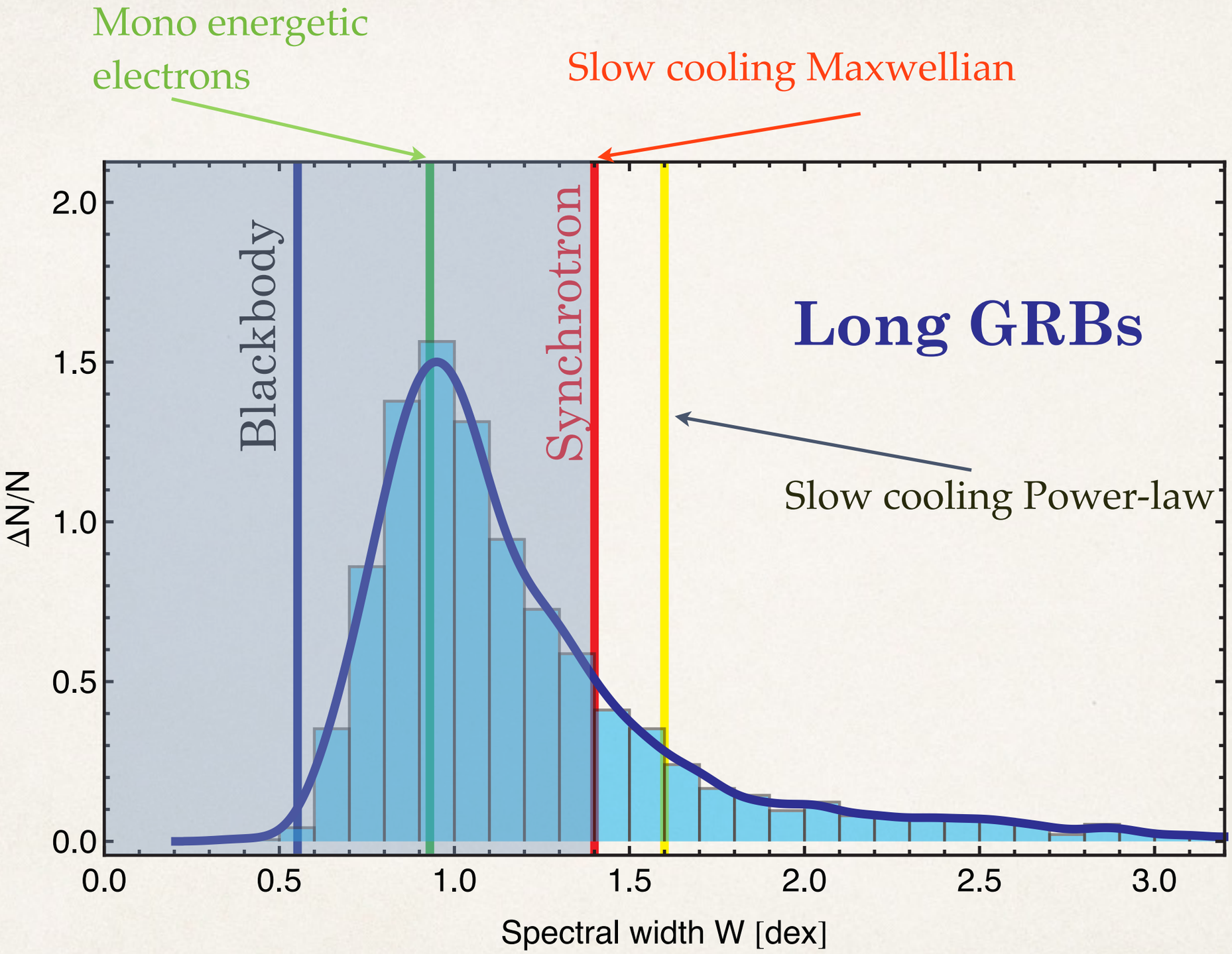

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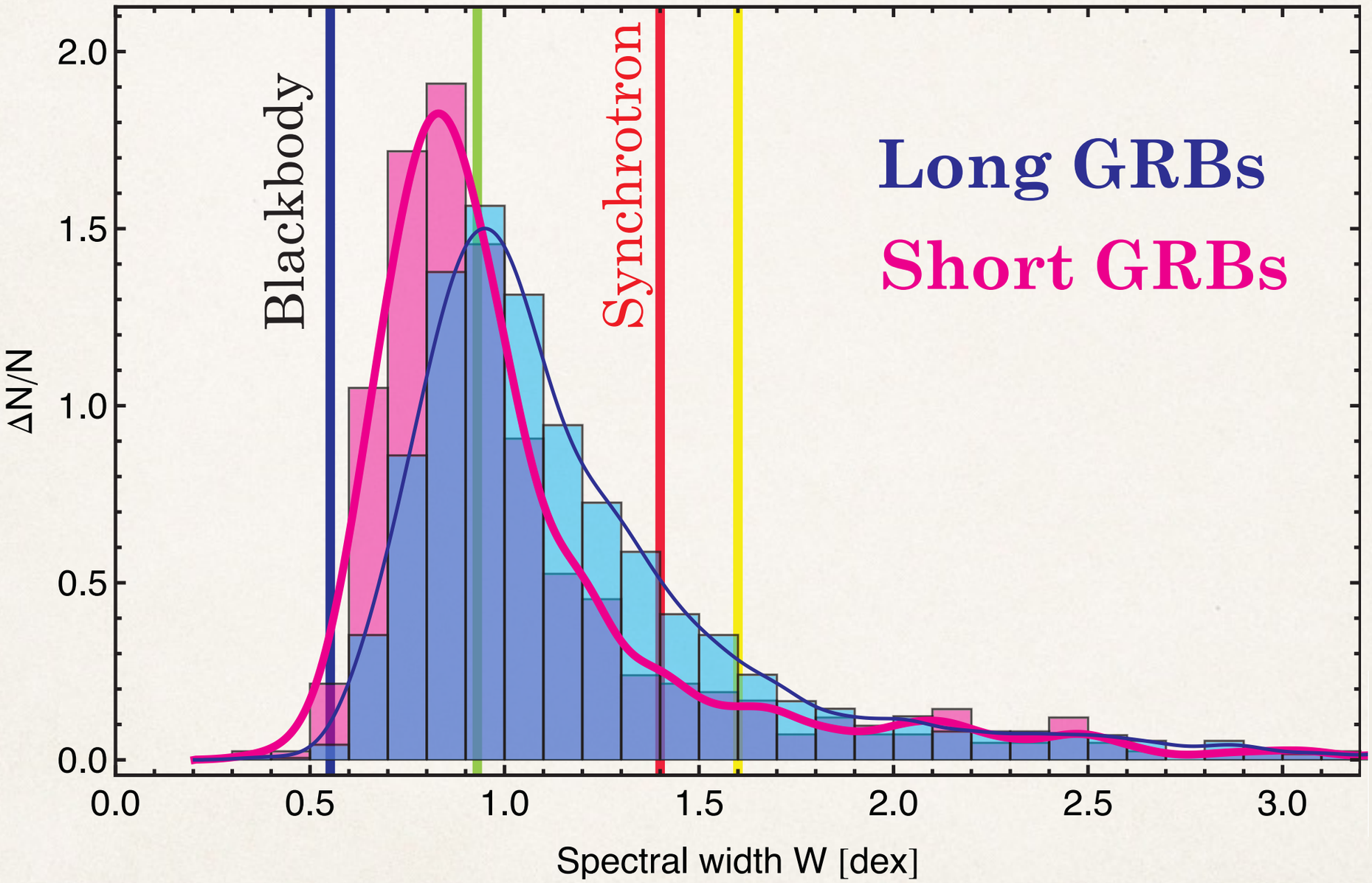

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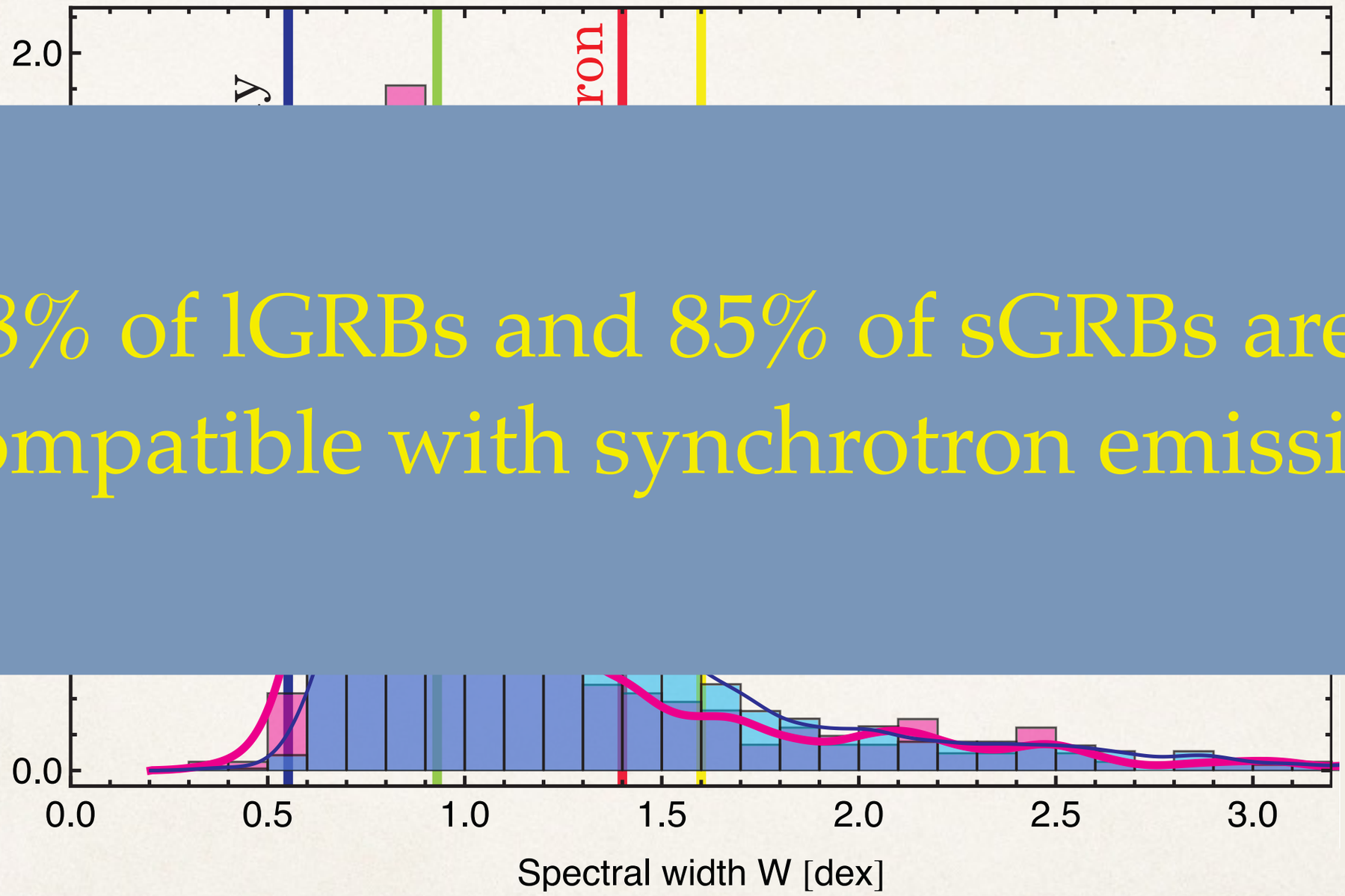


78% of lGRBs and 85% of sGRBs are incompatible with synchrotron emission

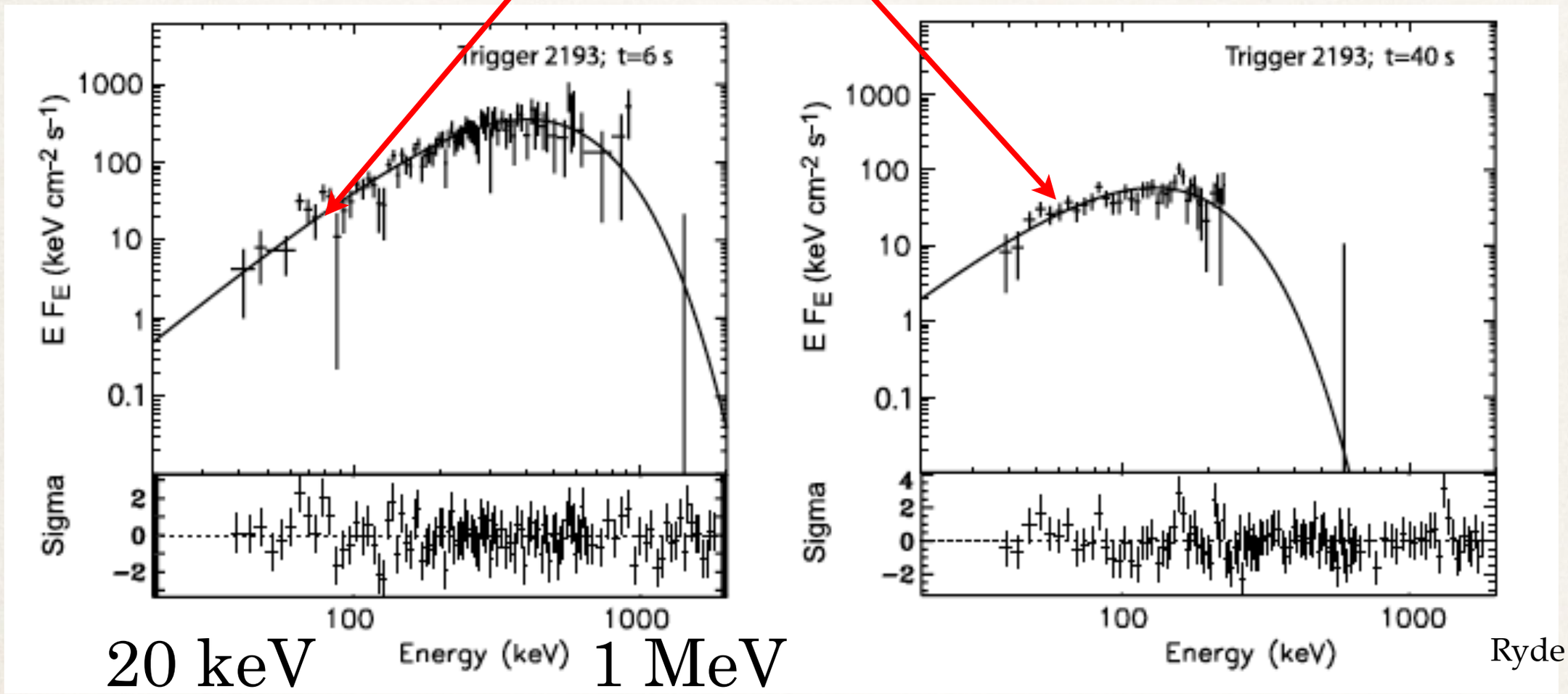
Axelsson & Borgonovo (2015)

Single Planck function bursts

Compton Gamma-Ray Observatory

GRB930214

Rayleigh Jeans



20 keV 1 MeV

Ryde 2004

- **Ryde (2004):** Blackbody through out the pulse
- **Ghirlanda et al. (2003):** Blackbody in initial phase of burst

Single Planck function bursts

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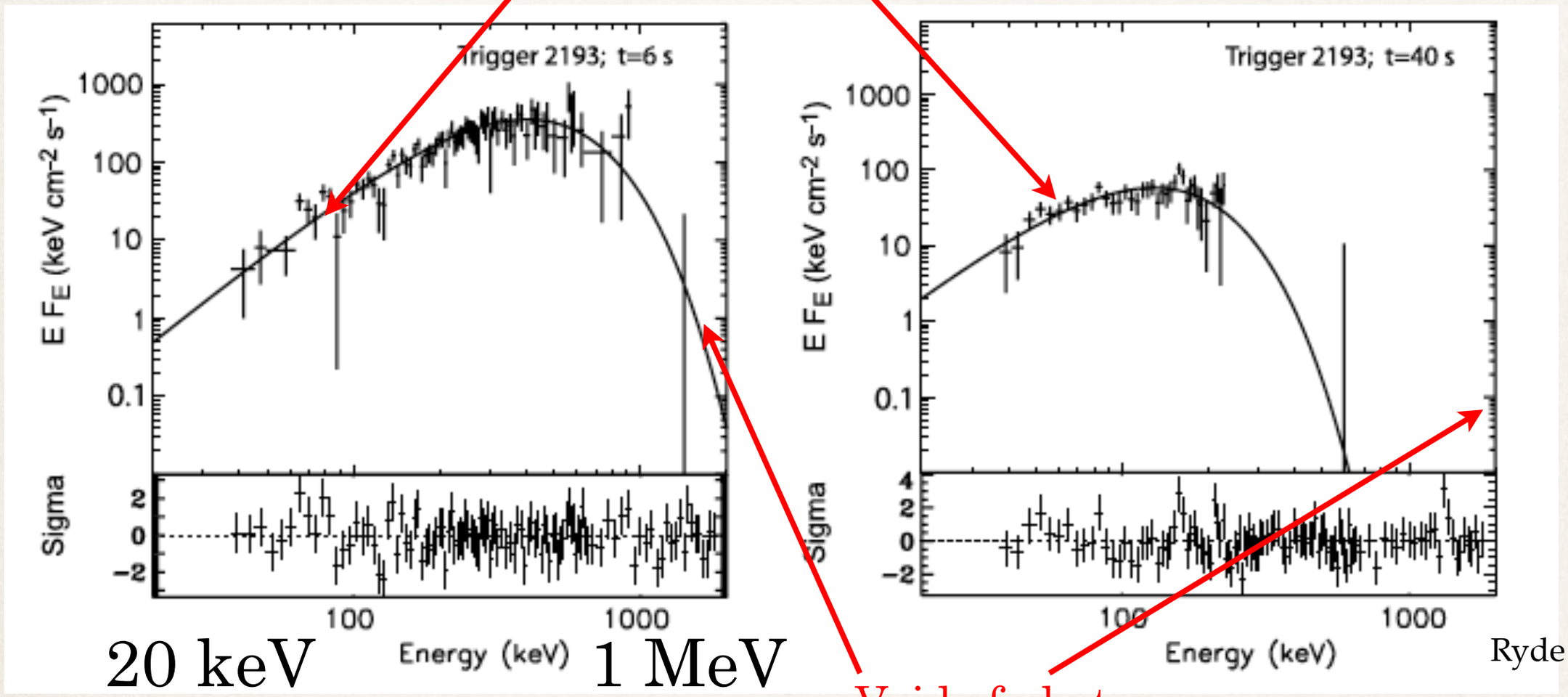

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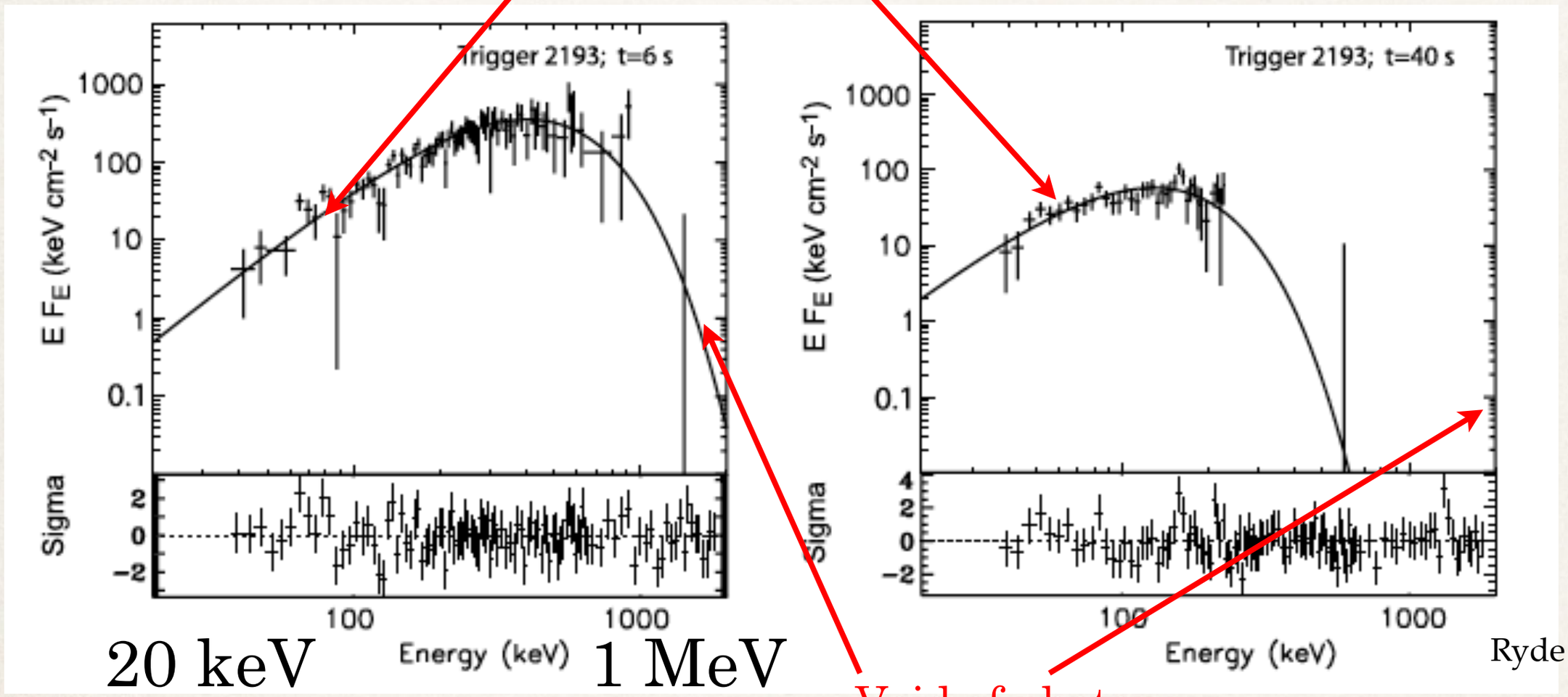

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CGRO BATSE: 6 observed bursts out of 2200

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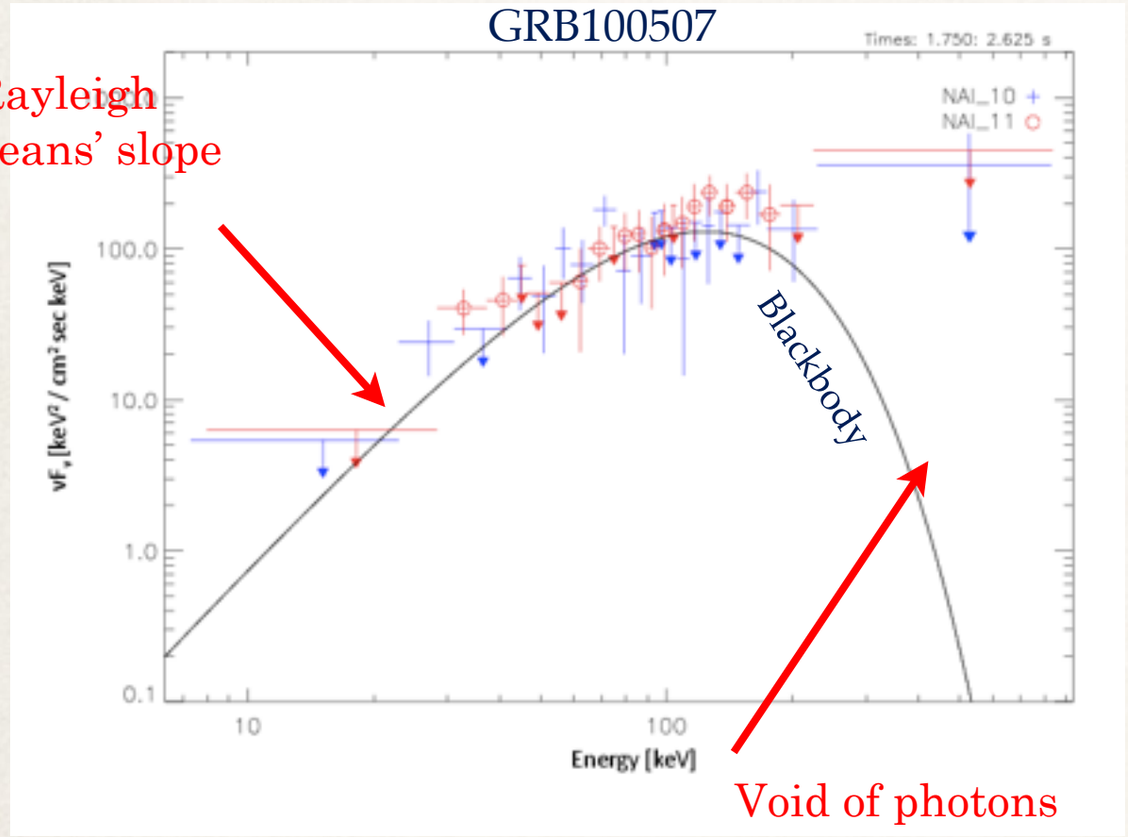
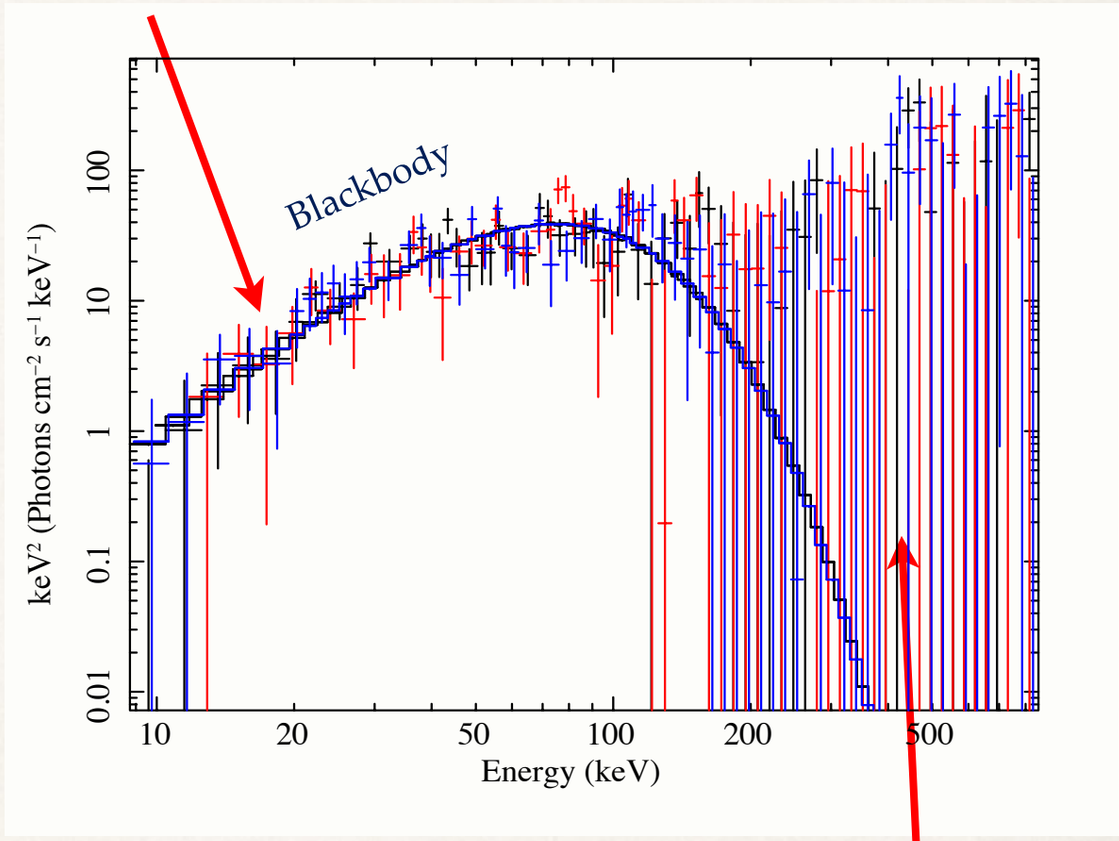
Single Planck function bursts

Fermi Gamma Ray Space Telescope



Ghirlanda et al. 2013



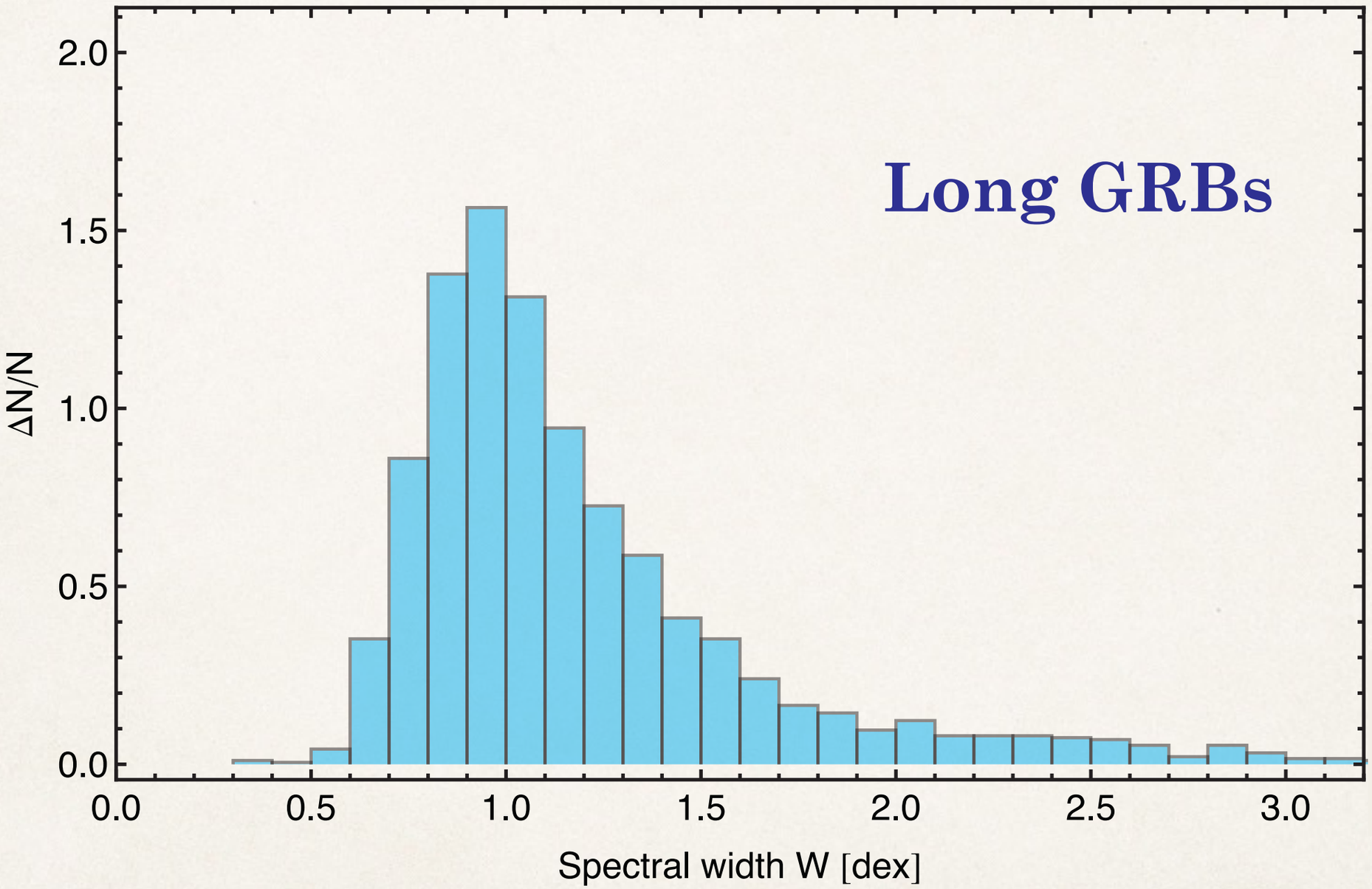
Larsson et al. 2014

Fermi: 2 pure BB (out of 1400)

(J. Larsson's talk)

Width of GRB spectra

Peak flux spectra of 1970 CGRO/BATSE and 943 Fermi/GBM



Axelsson & Borgonovo (2015)

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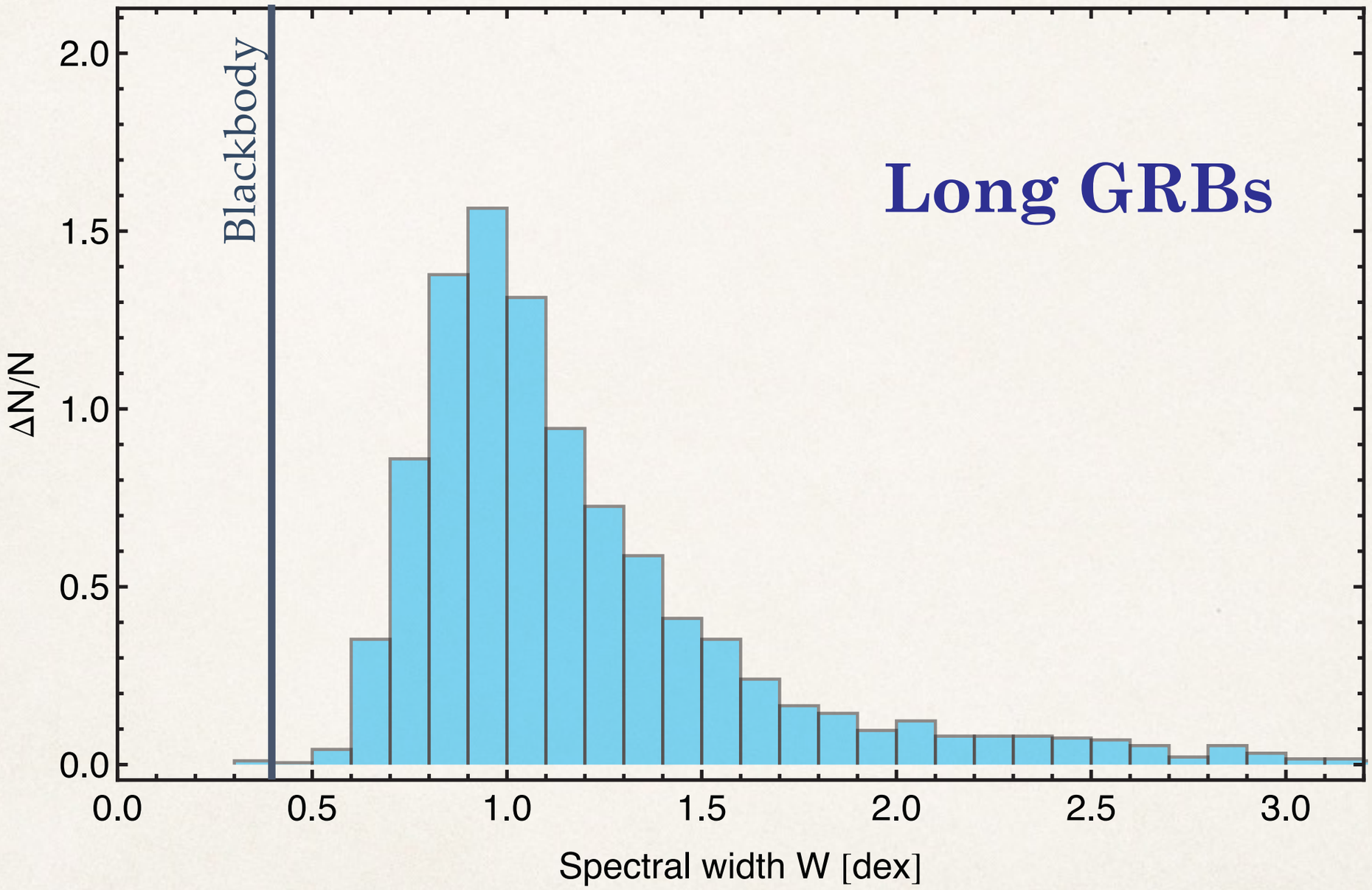

Axelsson & Borgonovo (2015)

How can we explain the data?

Problem:

- 0.3% are pure blackbodies during the whole burst

- 78% are more narrow than the synchrotron function

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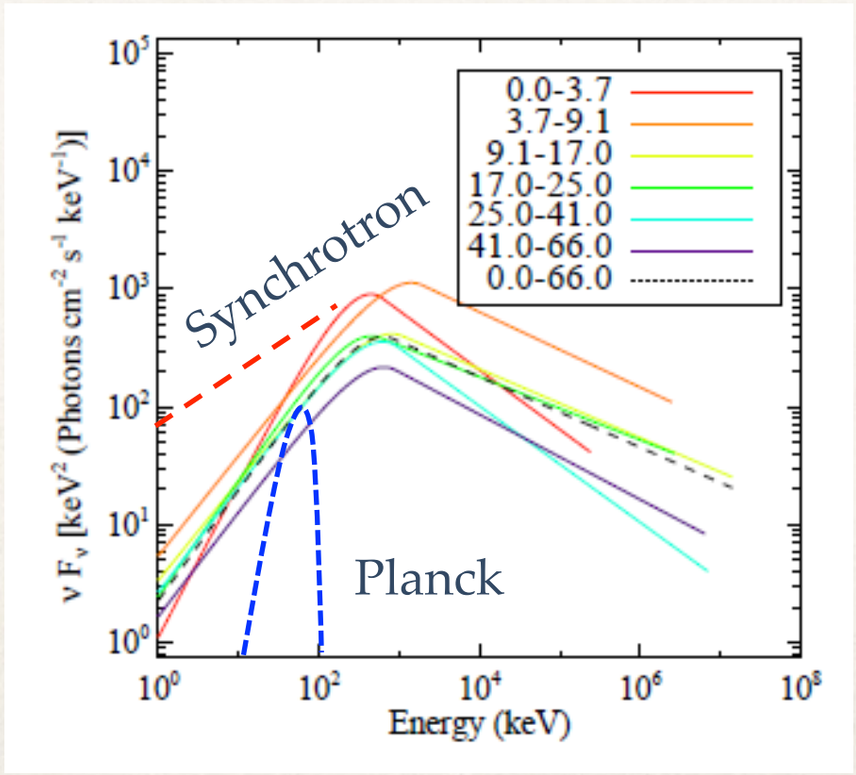
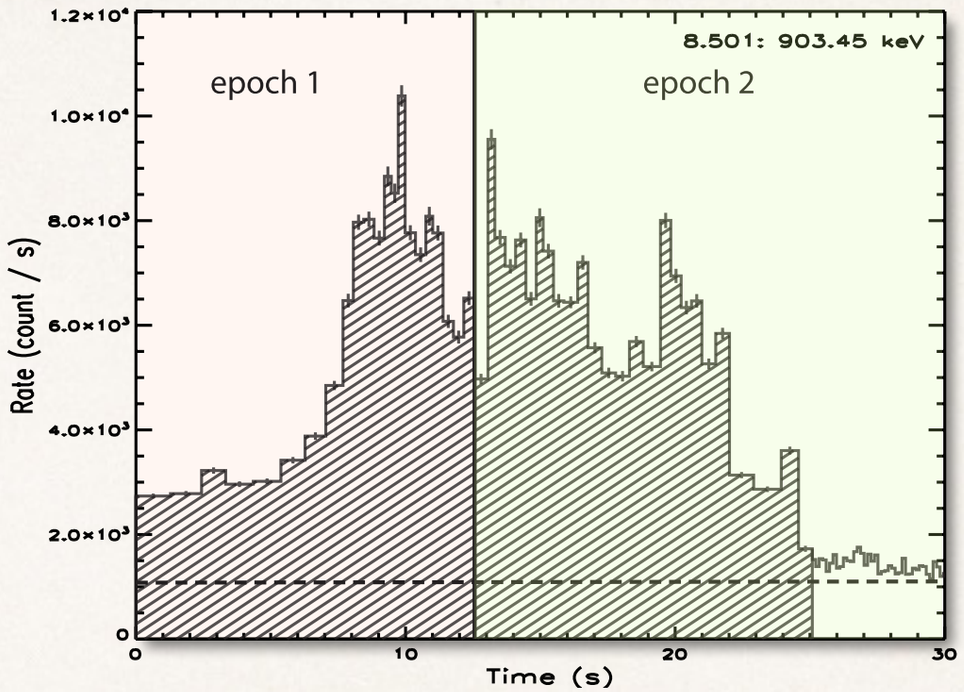
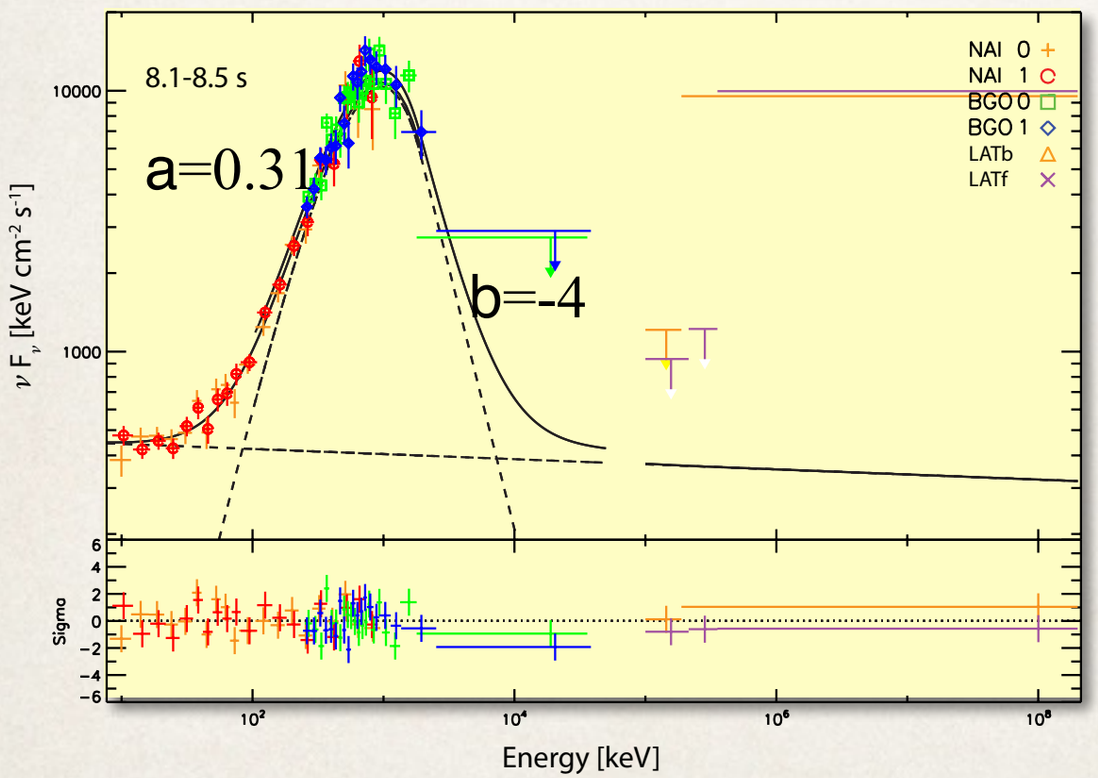
Many ways to broaden a spectrum, but not easy to make it more narrow!



Changing “BB-like” components



GRB 090902B



Ryde et al. 2011

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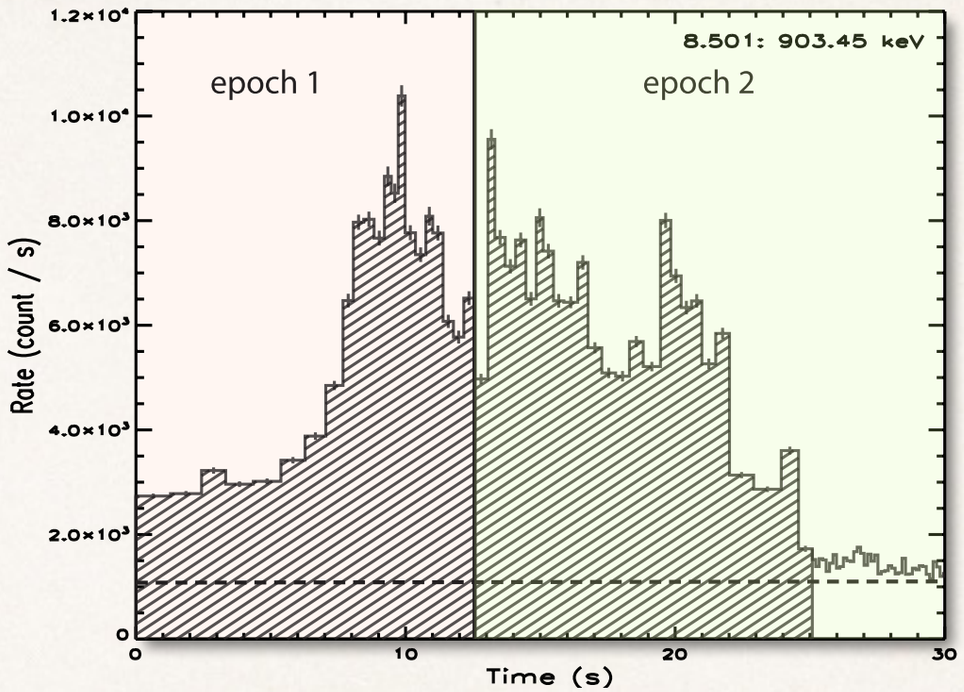

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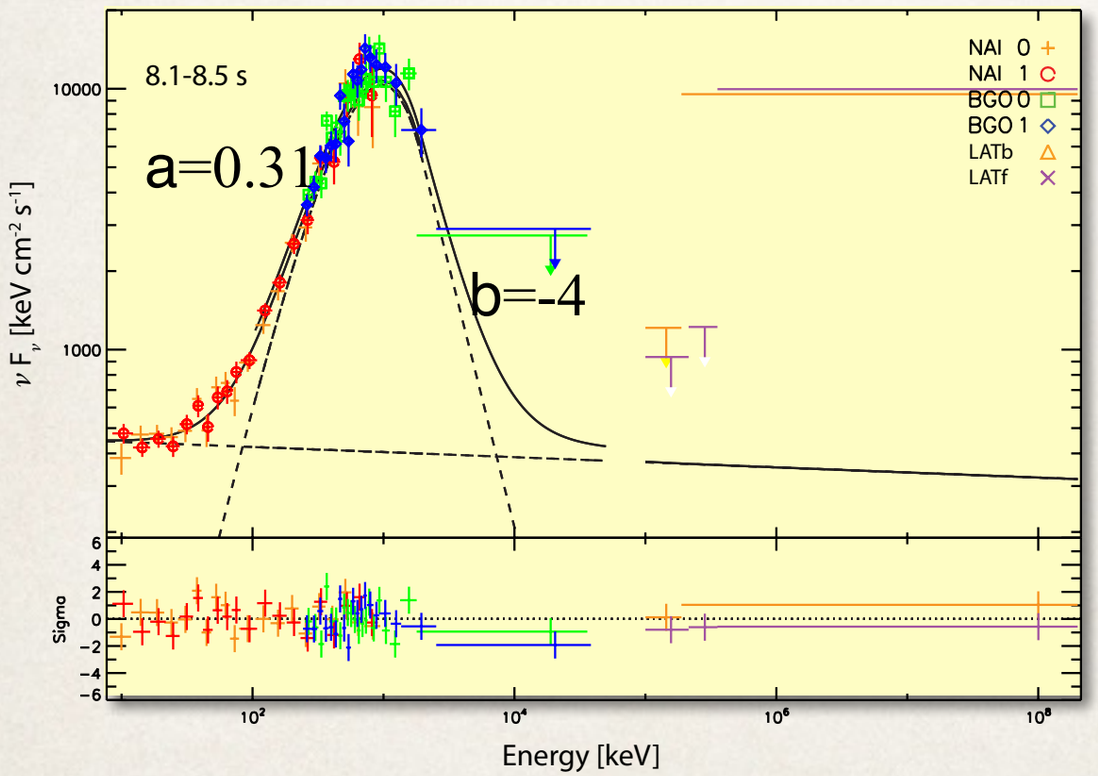
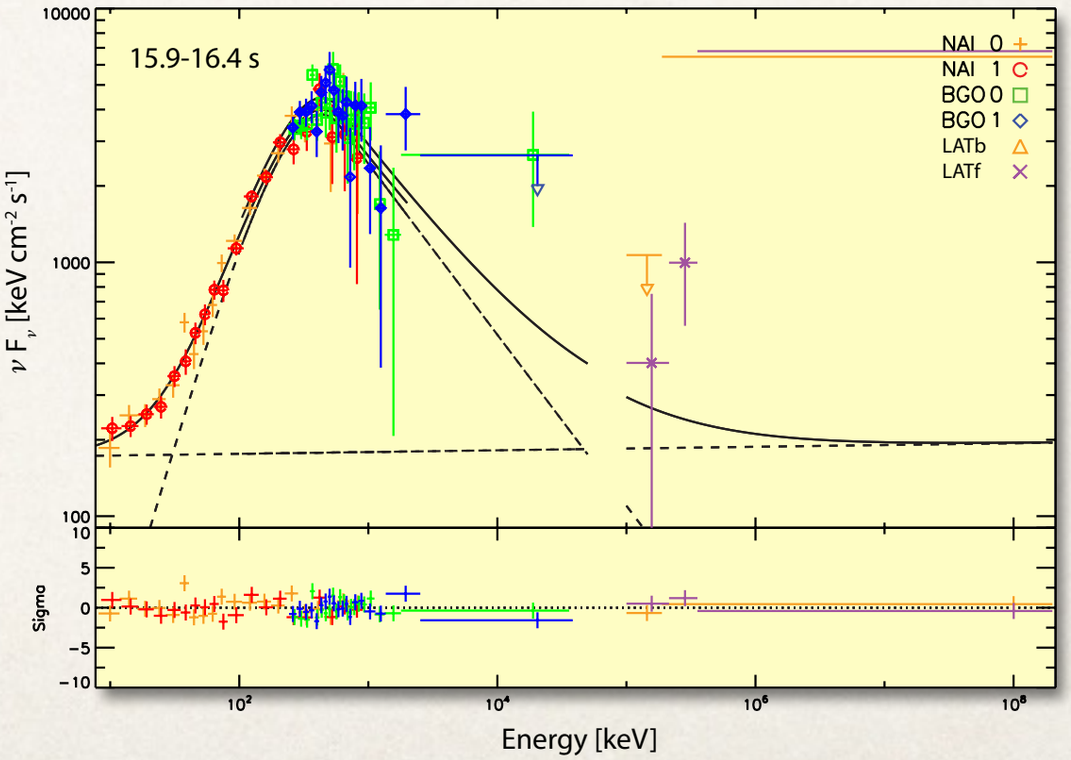
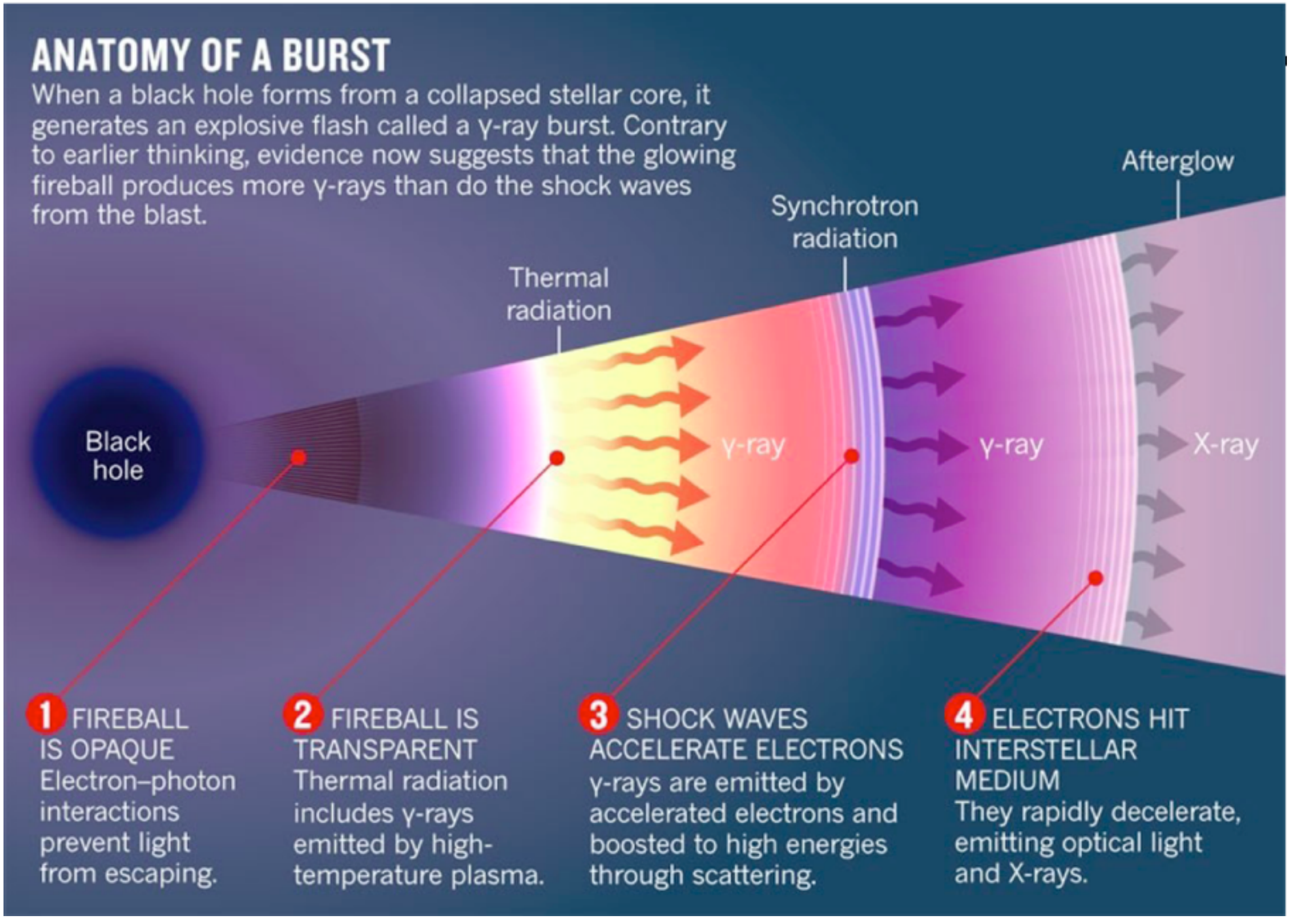




Ryde et al. 2011

A closer look at photospheric emission



Broadening the Planck spectrum?

Heating mechanism below the photosphere modifies the spectrum

Internal shocks

(Pe'er, Meszaros, Rees 06, Ryde+10, Toma+10, Ioka10)

Magnetic reconnection

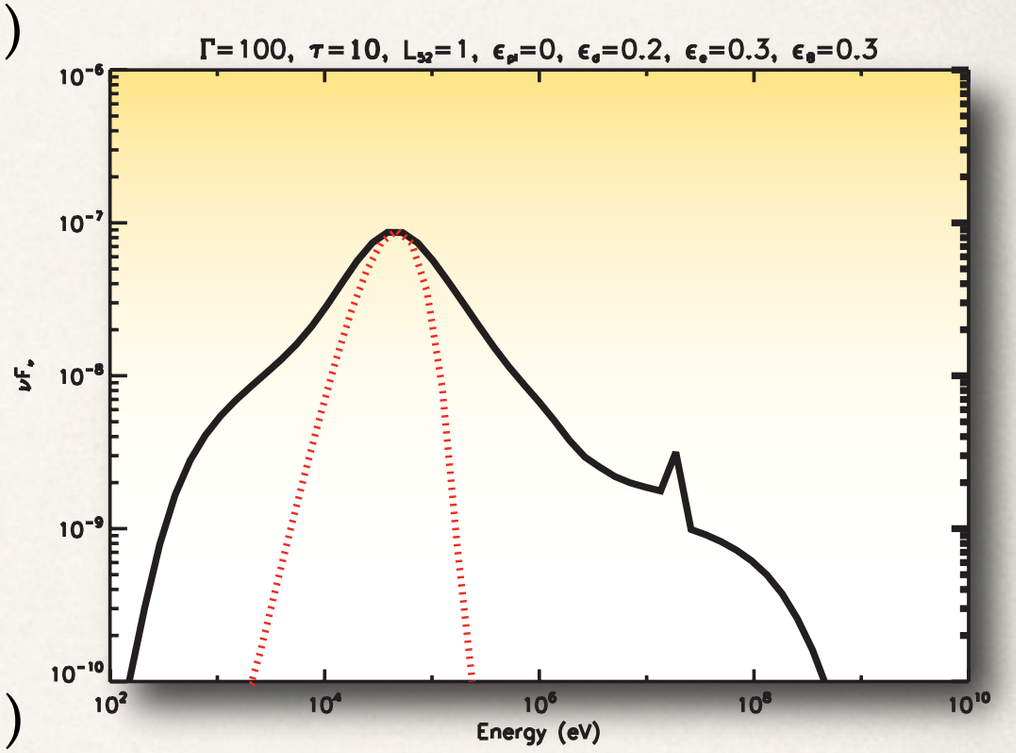
(Giannios 06, 08)

Weak/oblique shocks

(Lazzati, Morsonoi & Begelman 11; Ryde & Peer 11)

Collisional dissipation

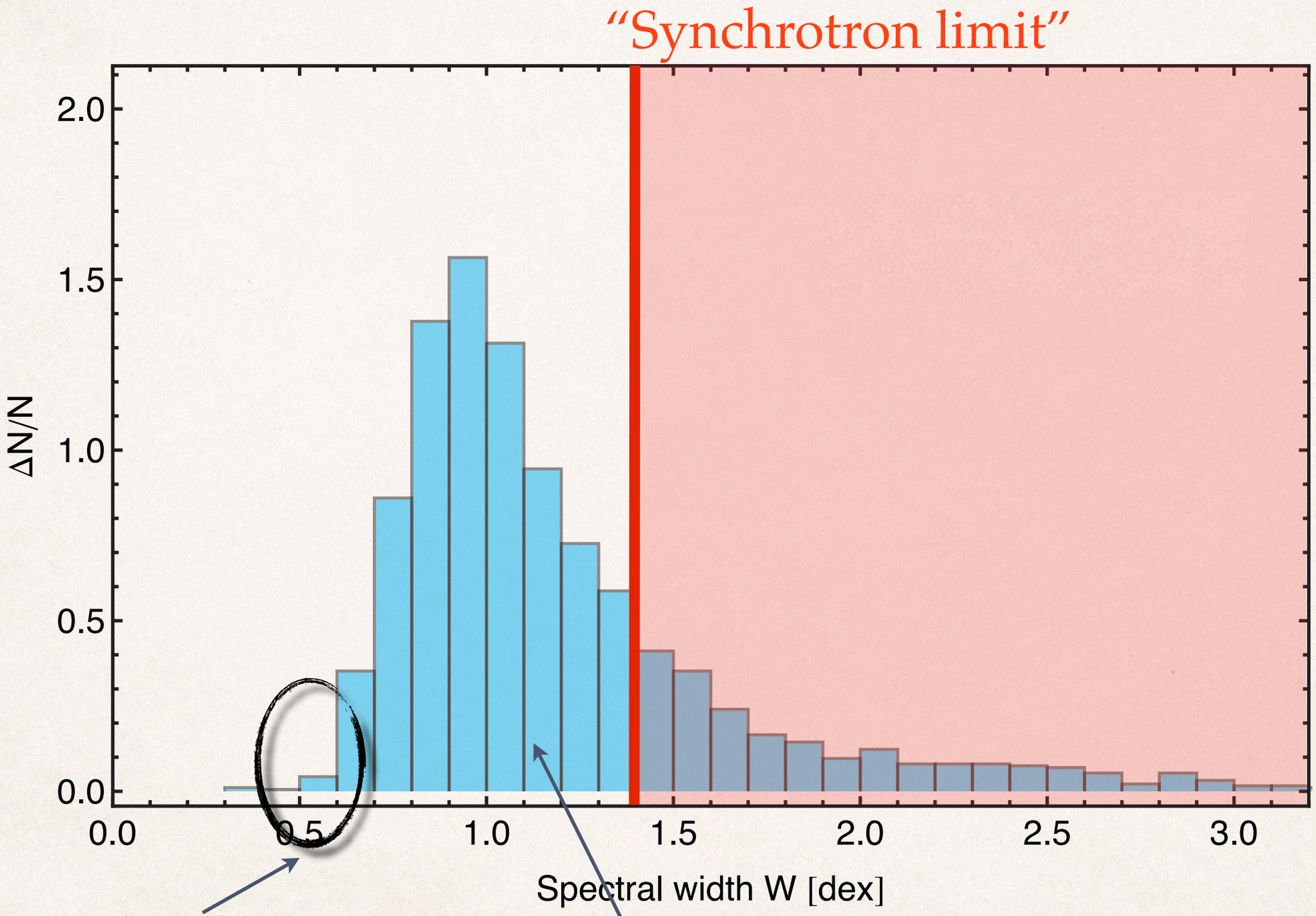
(Beloborodov 10; Vurm, Beloborodov & Poutanen 11)



Emission from the photosphere is NOT seen as Planck !

(B. Ahlgren's talk)

Width of GRB spectra



Planck spectra

Subphotospheric dissipation?

Conclusions

- The spectral width *W* only depends on finding a good fit to the data, and is therefore a robust measurement parameter.
- There is a significant difference in *W* between long and short GRBs: a new independent measure to separate the classes.
- Severe difficulties for synchrotron to explain the majority of observed GRB spectra. Assuming a distribution of electrons gives spectra that are too wide.
- Models of photospheric emission need to include mechanisms to significantly broaden the spectrum. Can this really explain the majority of GRBs?