To Synchrotron or Not to Synchrotron

The First Pulse of GRB 130427A

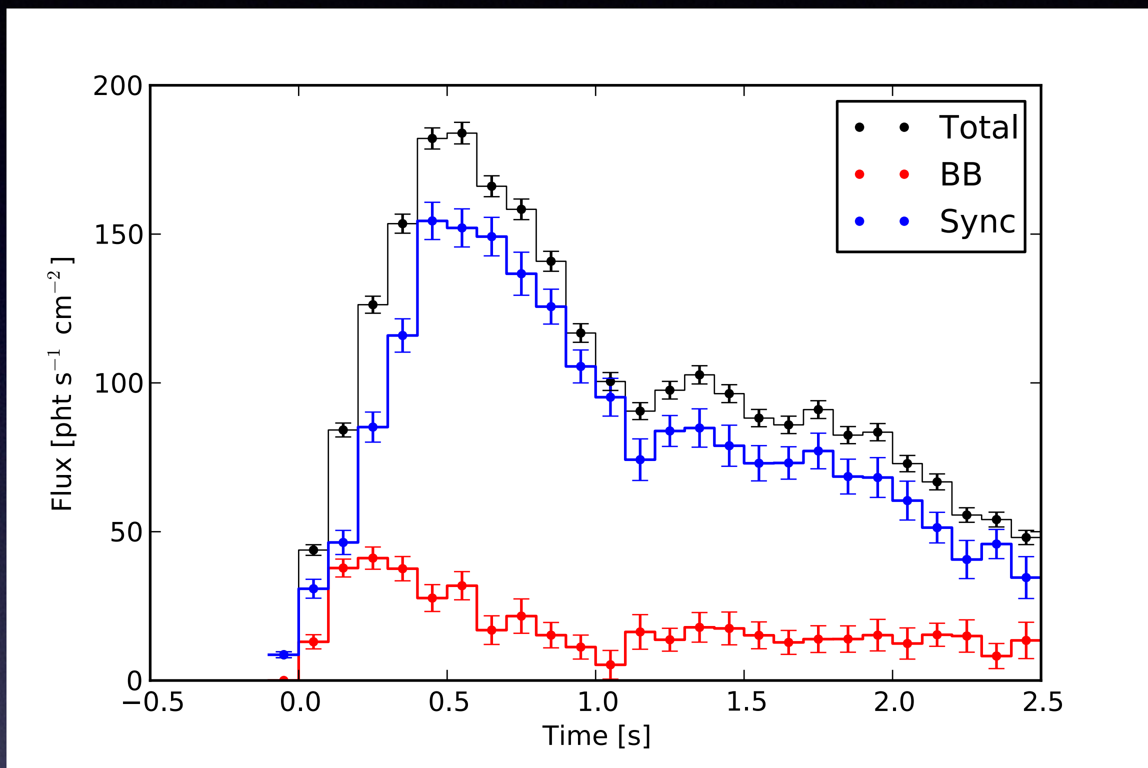
J. Michael Burgess, Rob Preece, Charles Dermer, Nicola Omodei, and Andreas von Kienlin

on behalf of the Fermi GBM team

Oskar Klein centre

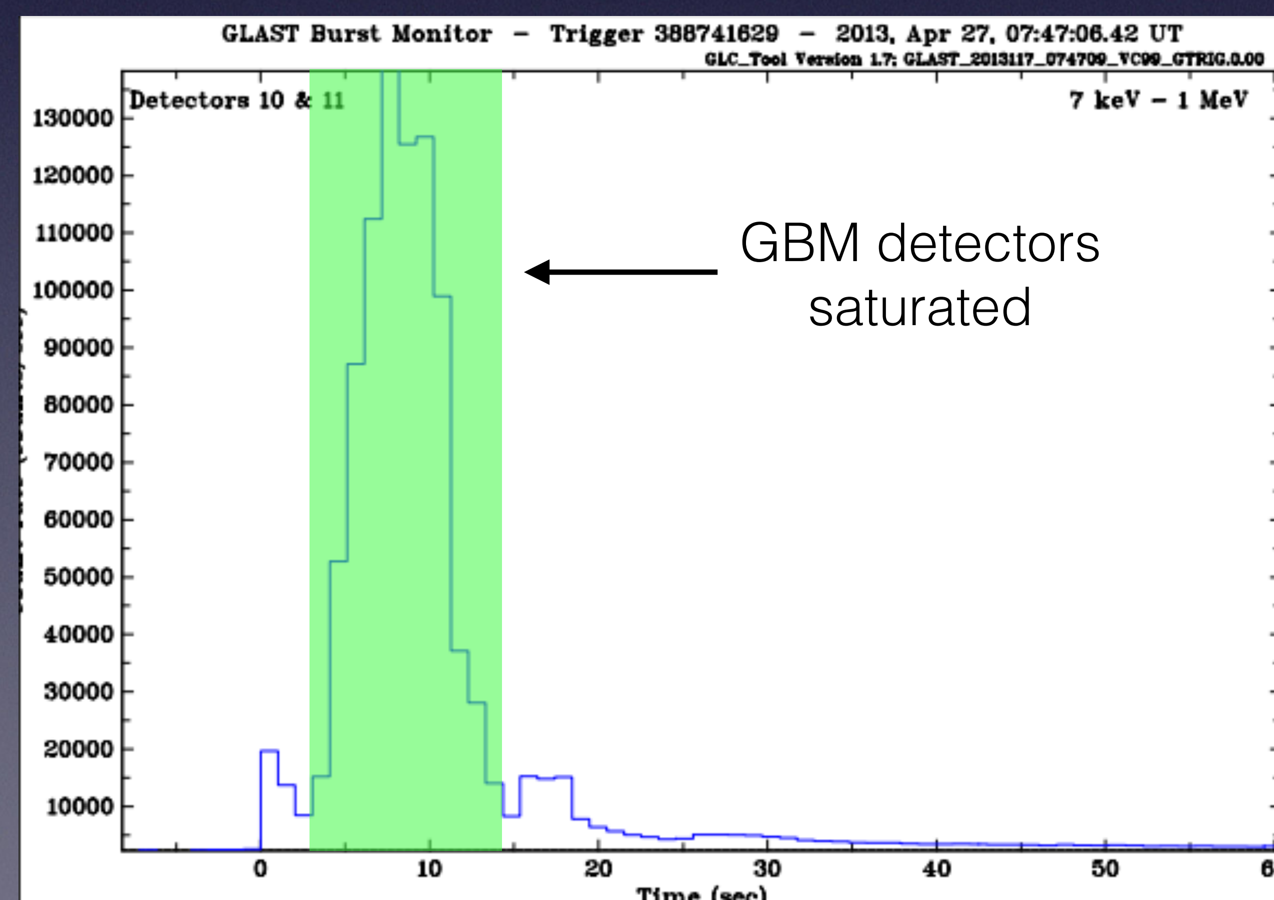
KTH VETENSKAP OCH KONST

GRB 130427A



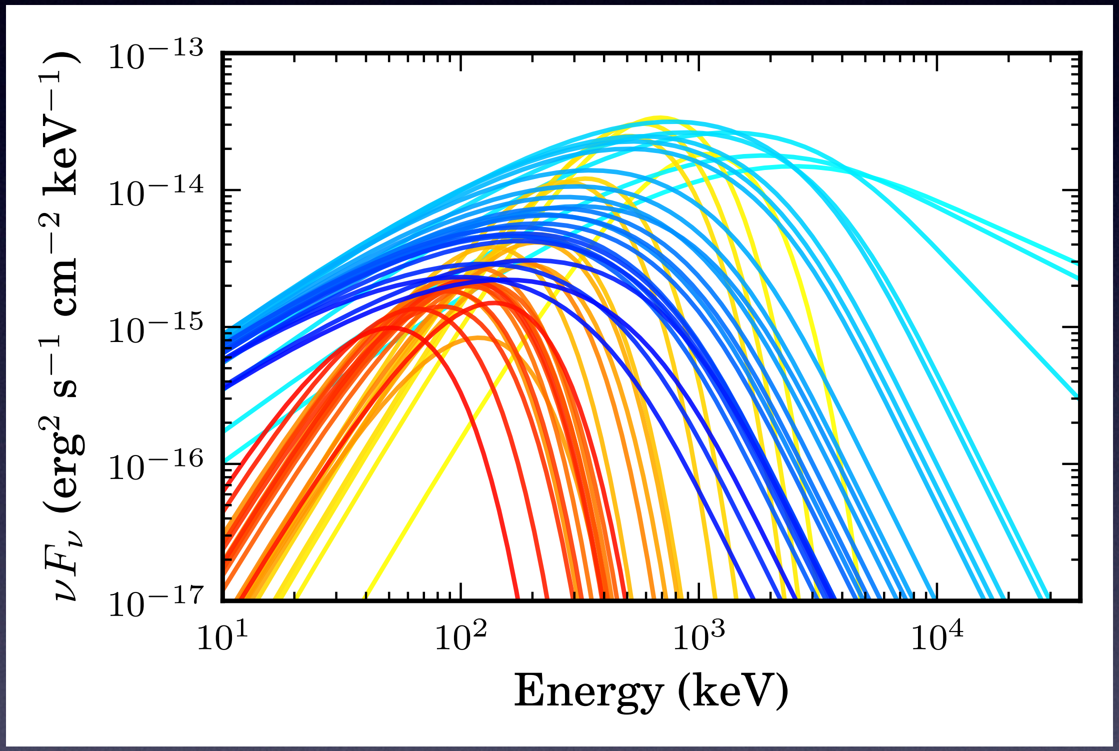
Context:

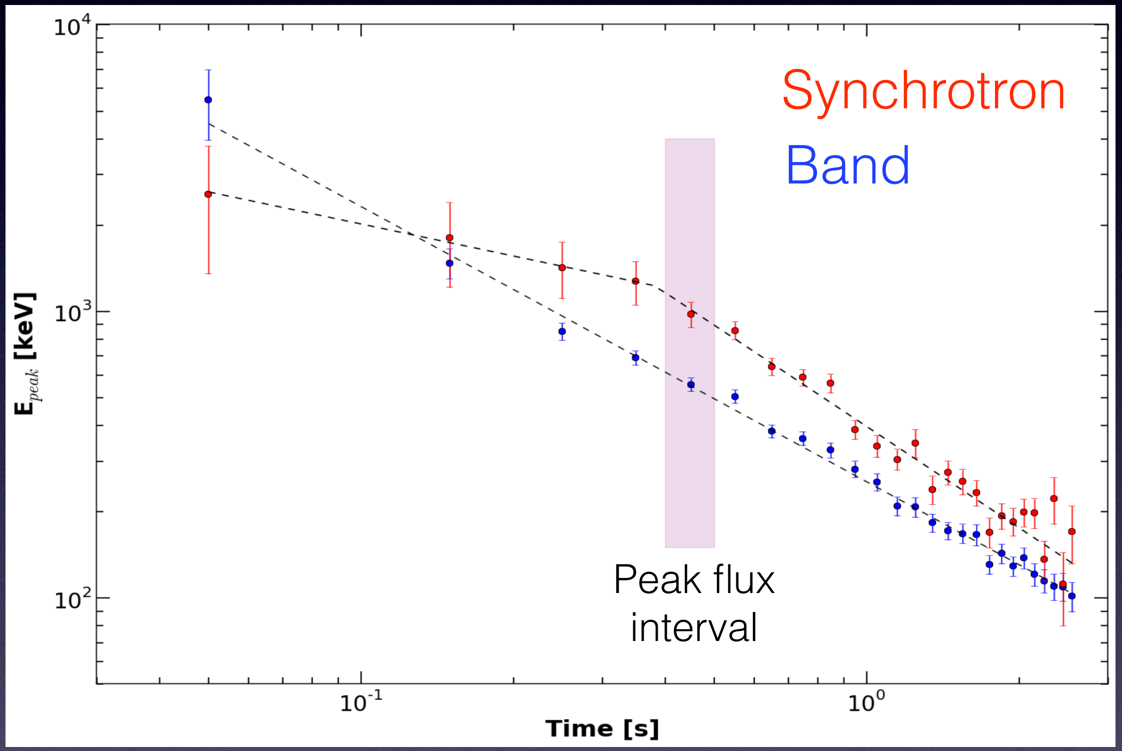
Fluence: $(2.4\pm0.1)\times10^{-3}$ erg cm^{-2}
Duration: ~35 s
Most fluent GRB ever detected



First Pulse: ~2.5 s
Brighter than most GRBs!

Time-Resolved Spectral Analysis





Two-component spectrum:
Synchrotron + blackbody

Band function is able to fit the spectrum, but does not call for a significant blackbody.

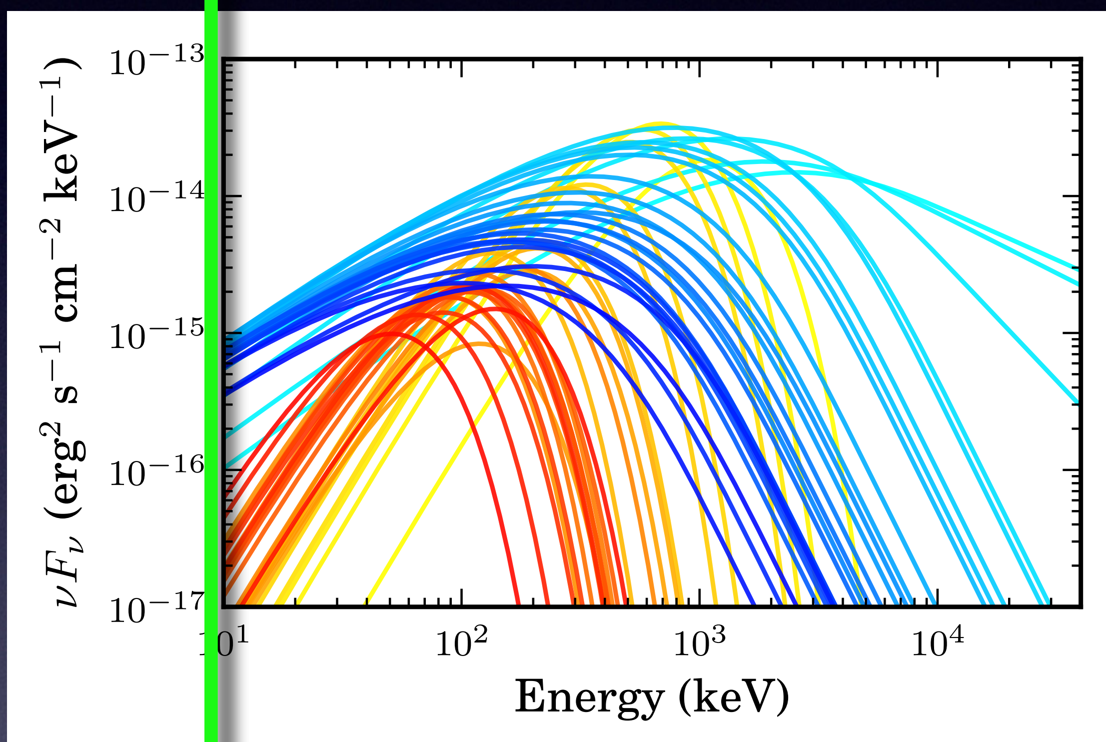
Classic hard-to-soft evolution of E_p.

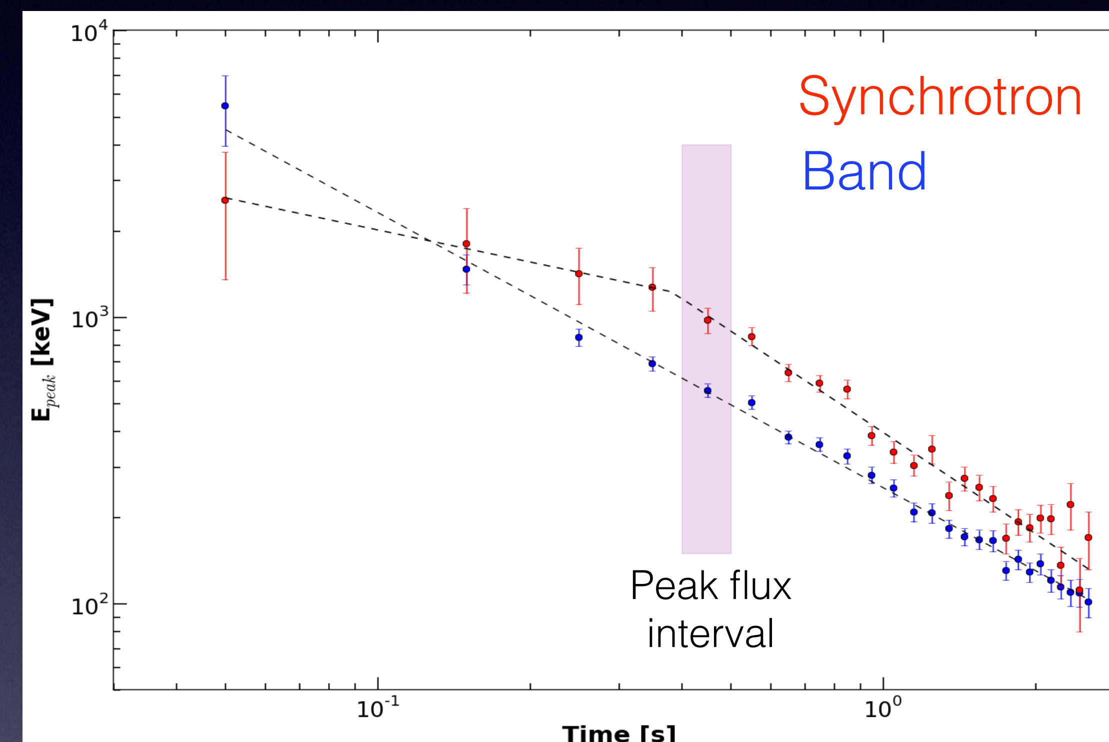
Synchrotron E_p follows a broken power law in time.

Preece & Burgess et al (2014)

Time-Resolved Spectral Analysis

Slow cooling!





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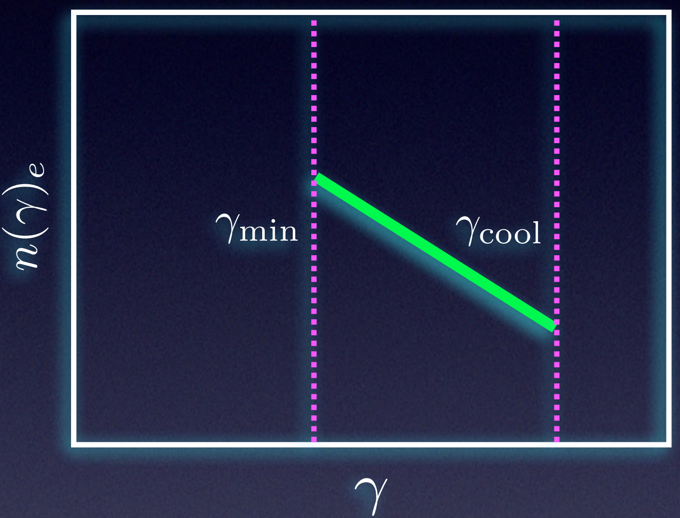
Slow cooling
synchrotron??

Slow cooling

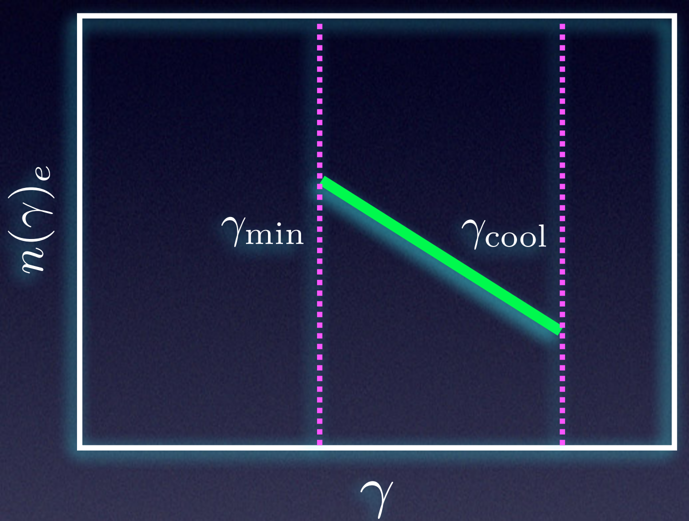
$$\gamma_{\rm min} \ll \gamma_{\rm cool}$$



$$\alpha \simeq -2/3$$

Slow cooling

$$\gamma_{\rm min} \ll \gamma_{\rm cool}$$

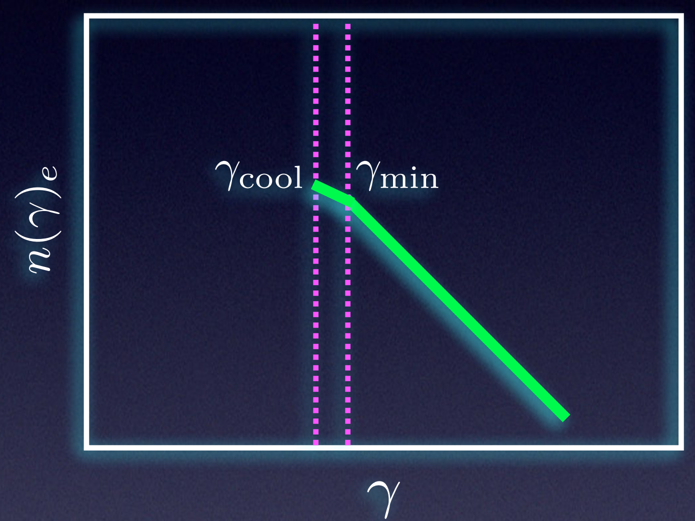


$$\alpha \simeq -2/3$$

Marginally fast cooling

$$\gamma_{\rm min} \simeq \gamma_{\rm cool}$$

see Beniamini & Piran (2013)



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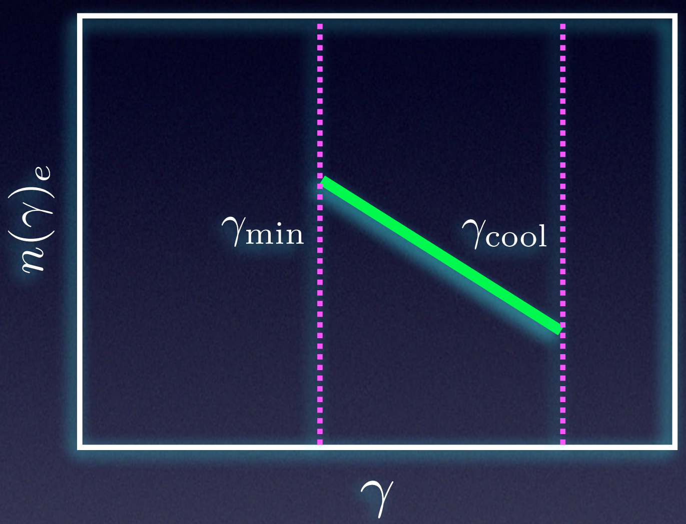

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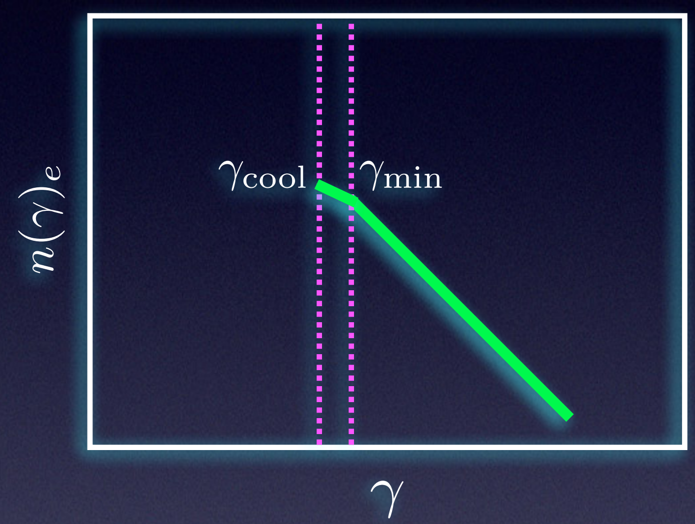

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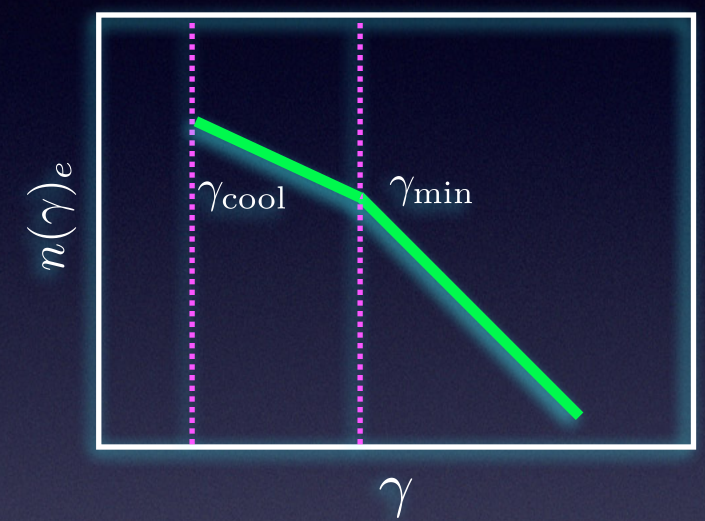
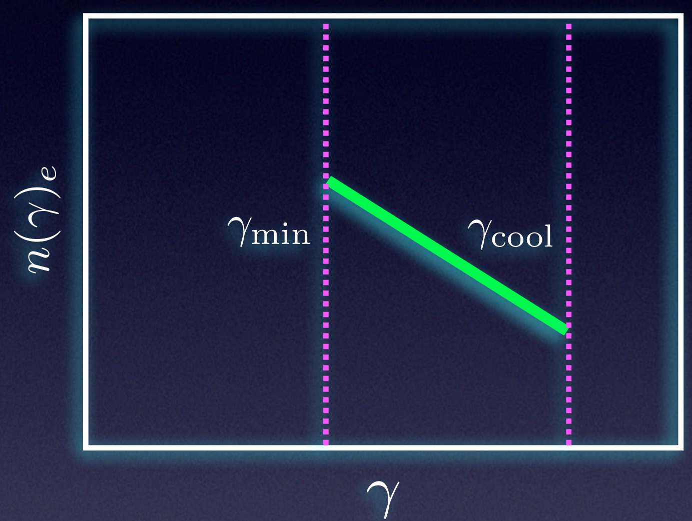


$$\alpha \simeq -3/2$$

Slow cooling

$$\gamma_{\rm min} \ll \gamma_{\rm cool}$$



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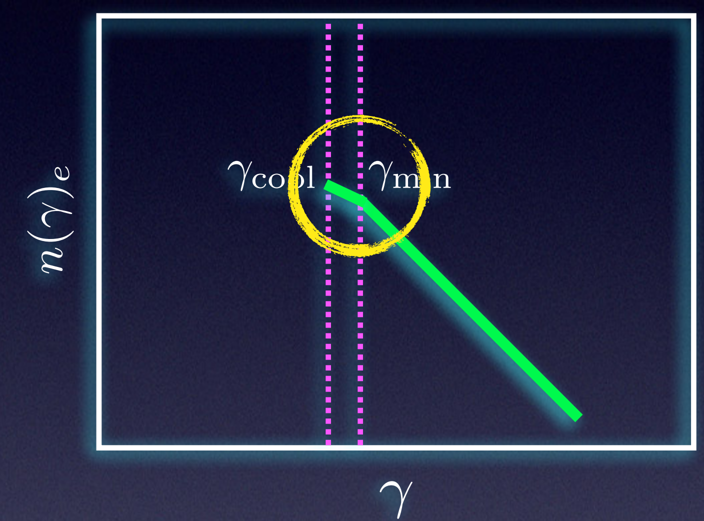

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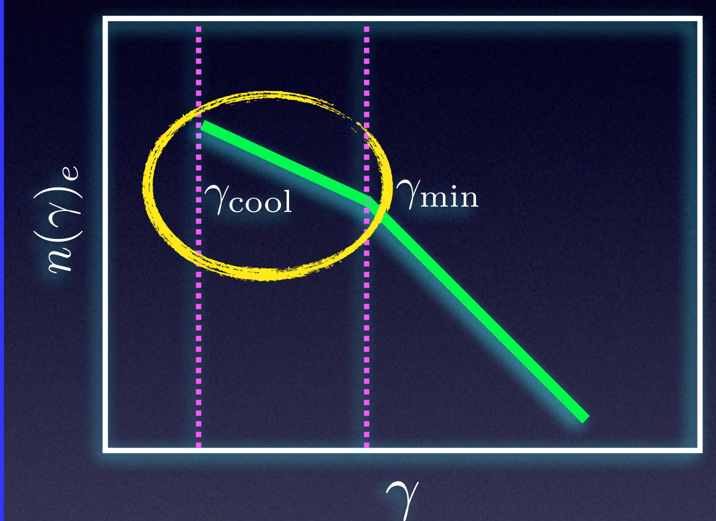


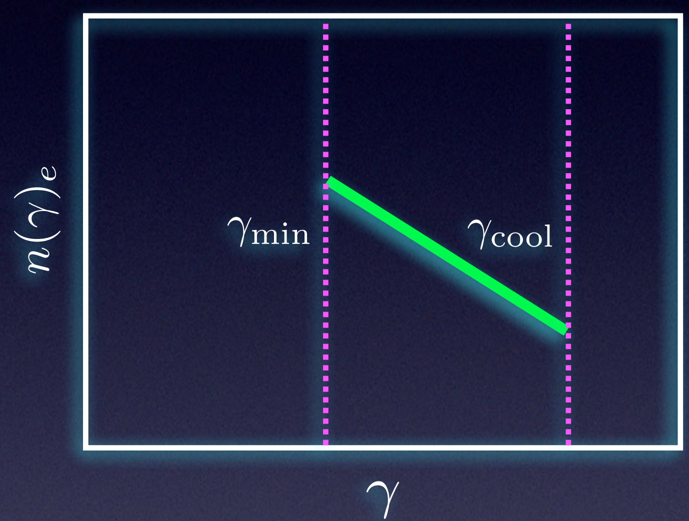
$$\alpha \simeq -3/2$$

Slow cooling and marginally fast cooling are indistinguishable via their photon spectra…

However, the one must explain either scenario in a self-consistent manner

Slow cooling

$$\gamma_{\mathrm{min}} \ll \gamma_{\mathrm{cool}}$$

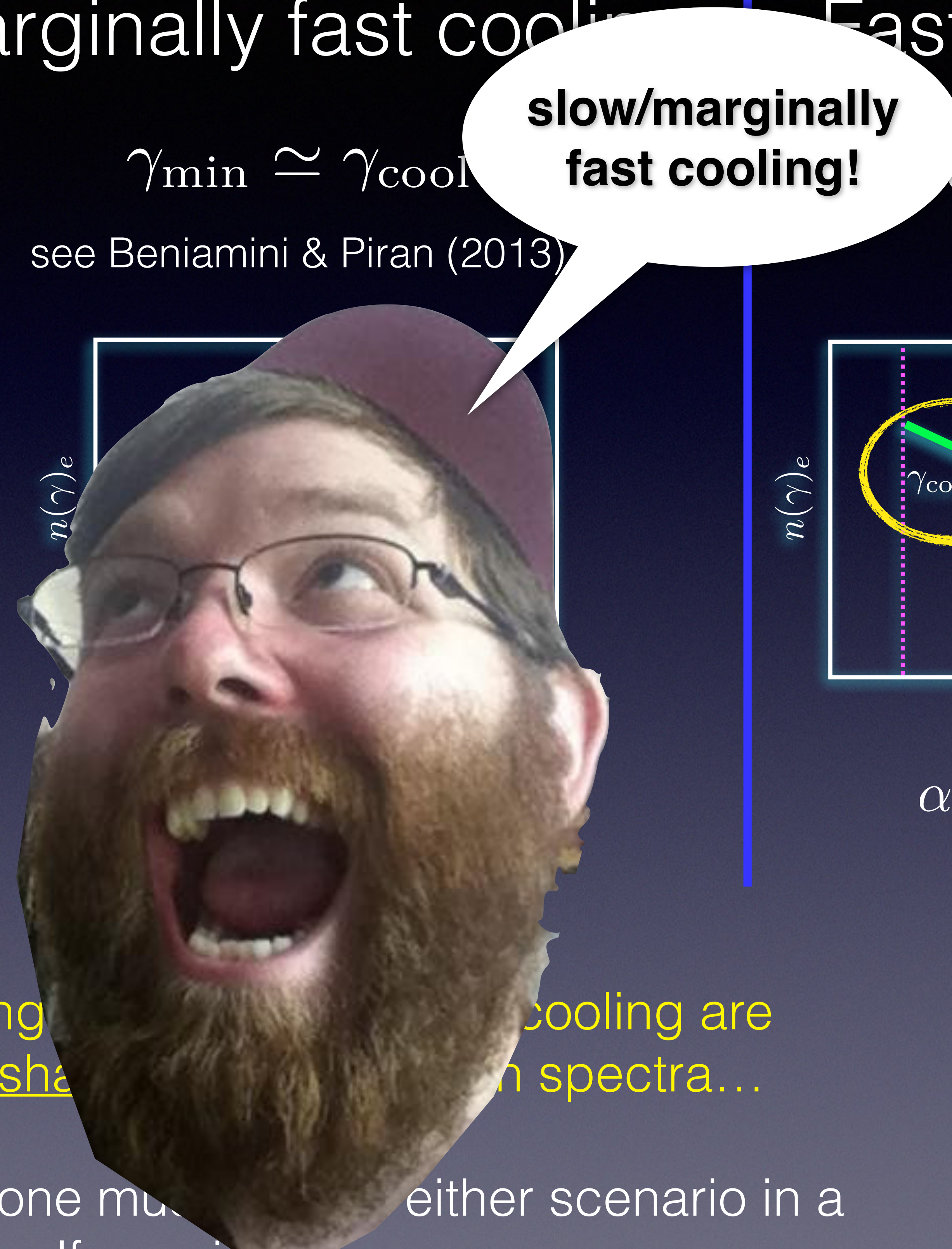


$$\alpha \simeq -2/3$$

Marginally fast cooli

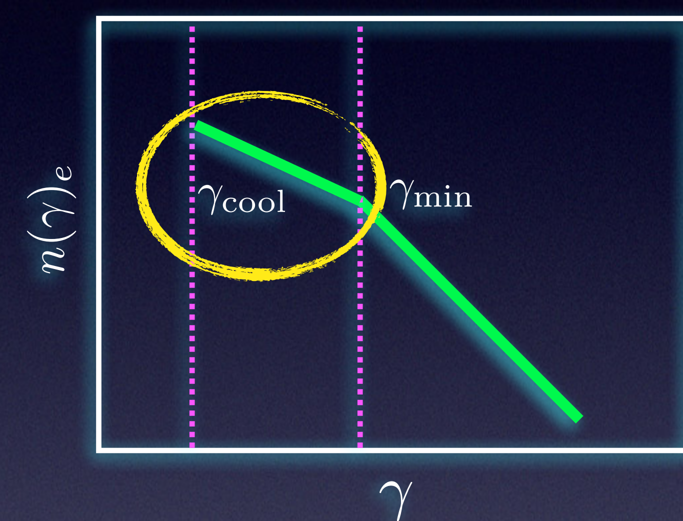
$$\gamma_{\mathrm{min}} \simeq \gamma_{\mathrm{cool}}$$

see Beniamini & Piran (2013)



ast cooling

$$\ldots\mathrm{ol} \ll \gamma_{\mathrm{min}}$$



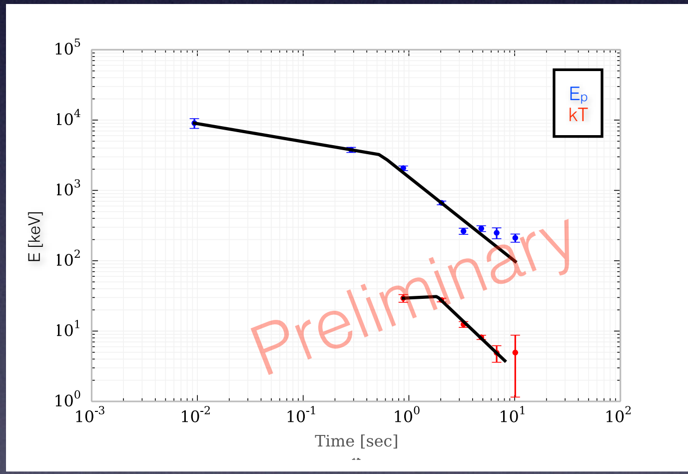
$$\alpha \simeq -3/2$$

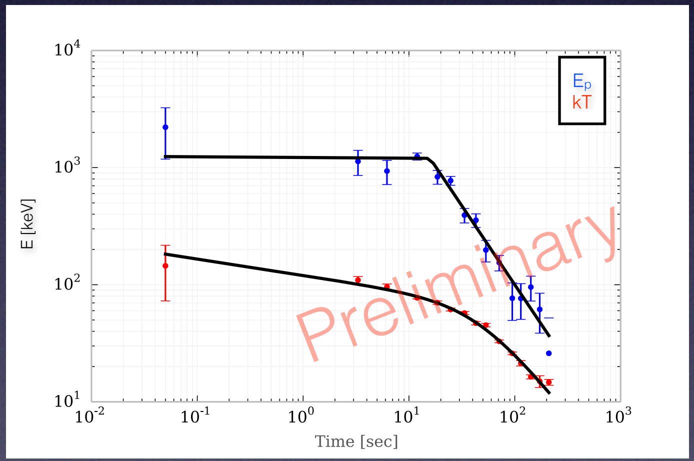
Slow cooling … cooling are
<u>indistinguisha</u> … n spectra…

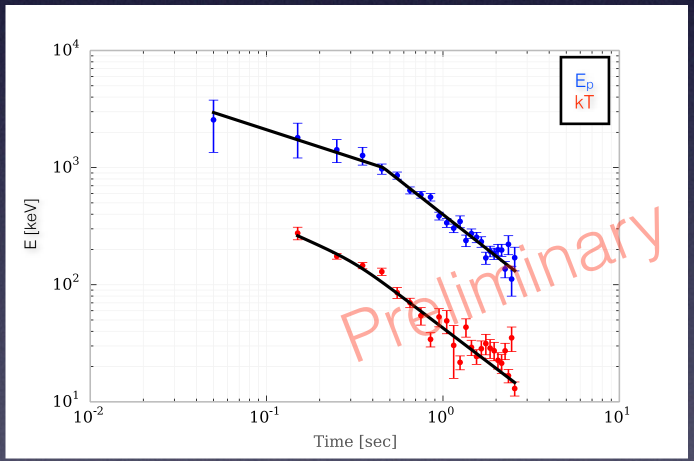
However, the one mu … either scenario in a
self-consis… manner

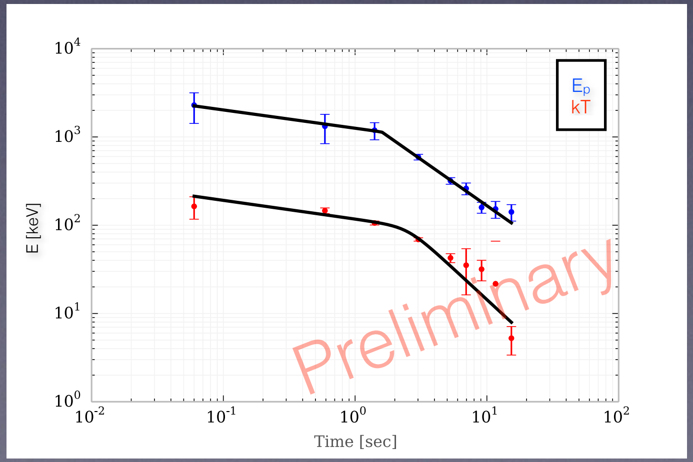
Time-Resolved Spectral Analysis

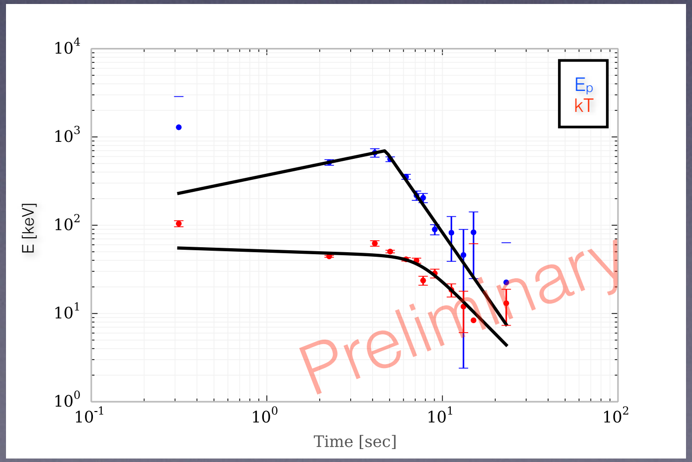
GRB	$\mathrm{Peak}_{\mathrm{syn}}$	$\mathrm{Peak}_{\mathrm{bb}}$	E_{p} brk [s]	kT brk [s]	kT indx_1	kT indx_2	E_{p} indx_1	E_{p} indx_2
081224A	1.40	0.59	1.59	2.51	-0.21	-1.38	-0.21	-1.05
090719A	5.04	5.04	4.74	7.36	-0.07	-2.02	0.41	-2.87
110920A	11.65	5.9	15.53	45.30	-0.14	-1.13	-0.01	-1.35
110721A	0.28	2.03	0.54	1.85	0.07	-1.43	-0.26	-1.19
130427A	0.45	0.15	0.36	0.22	-0.67	-1.15	-0.49	-1.18











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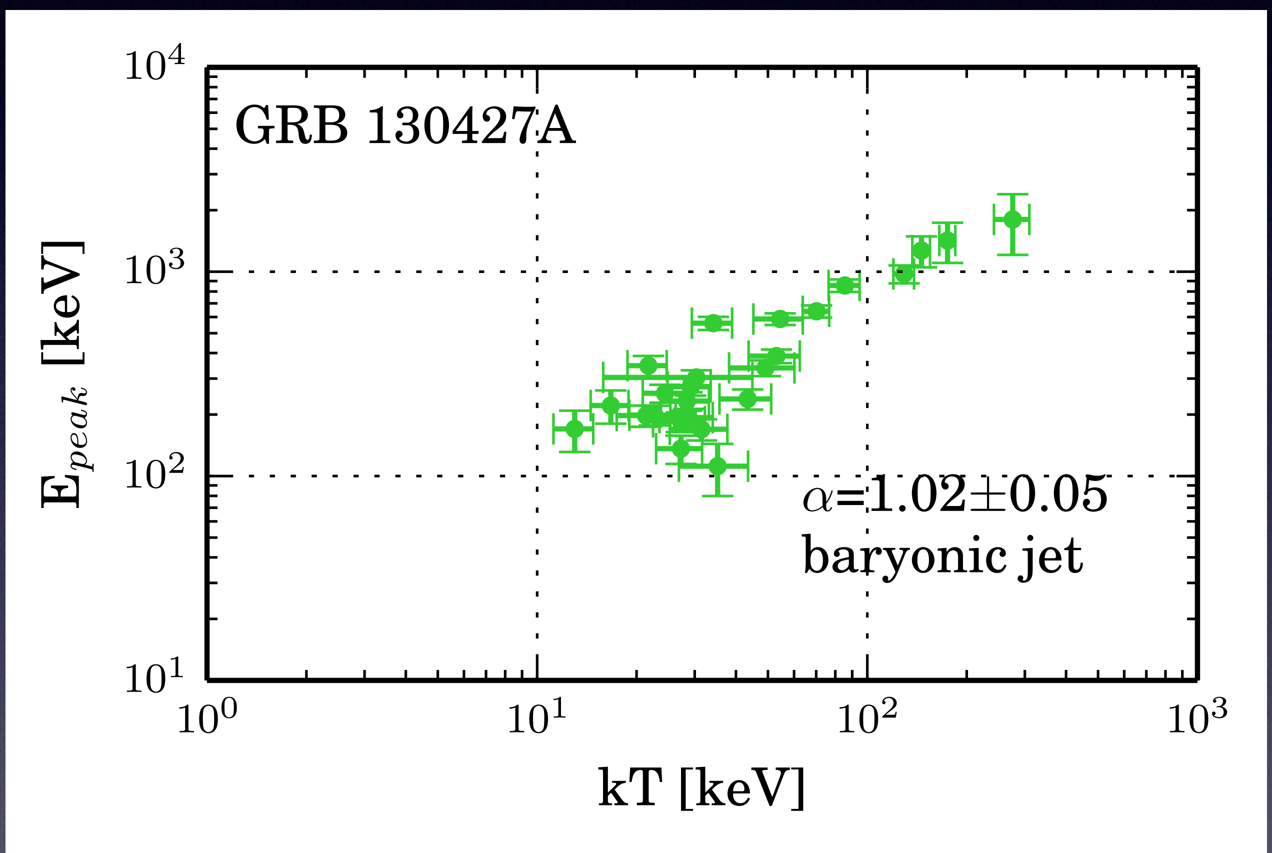
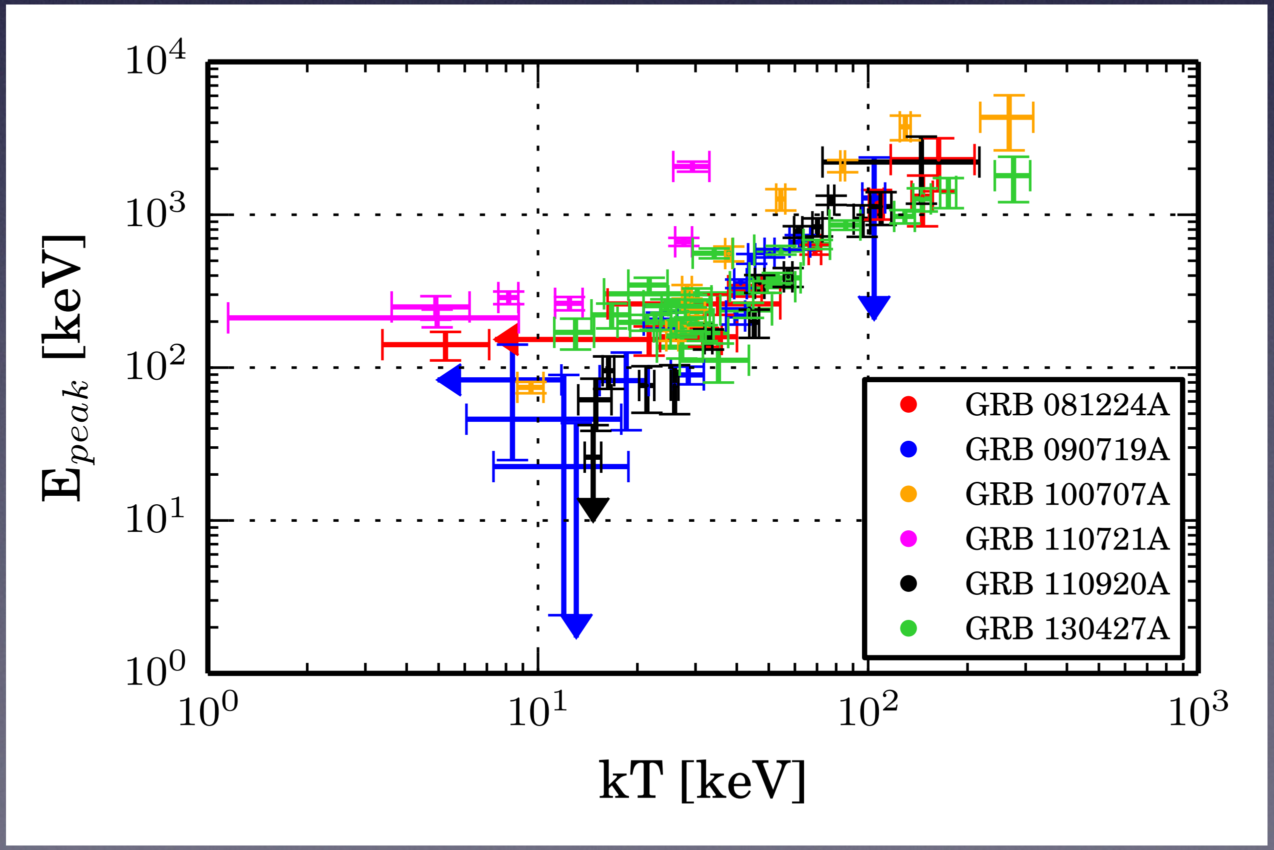


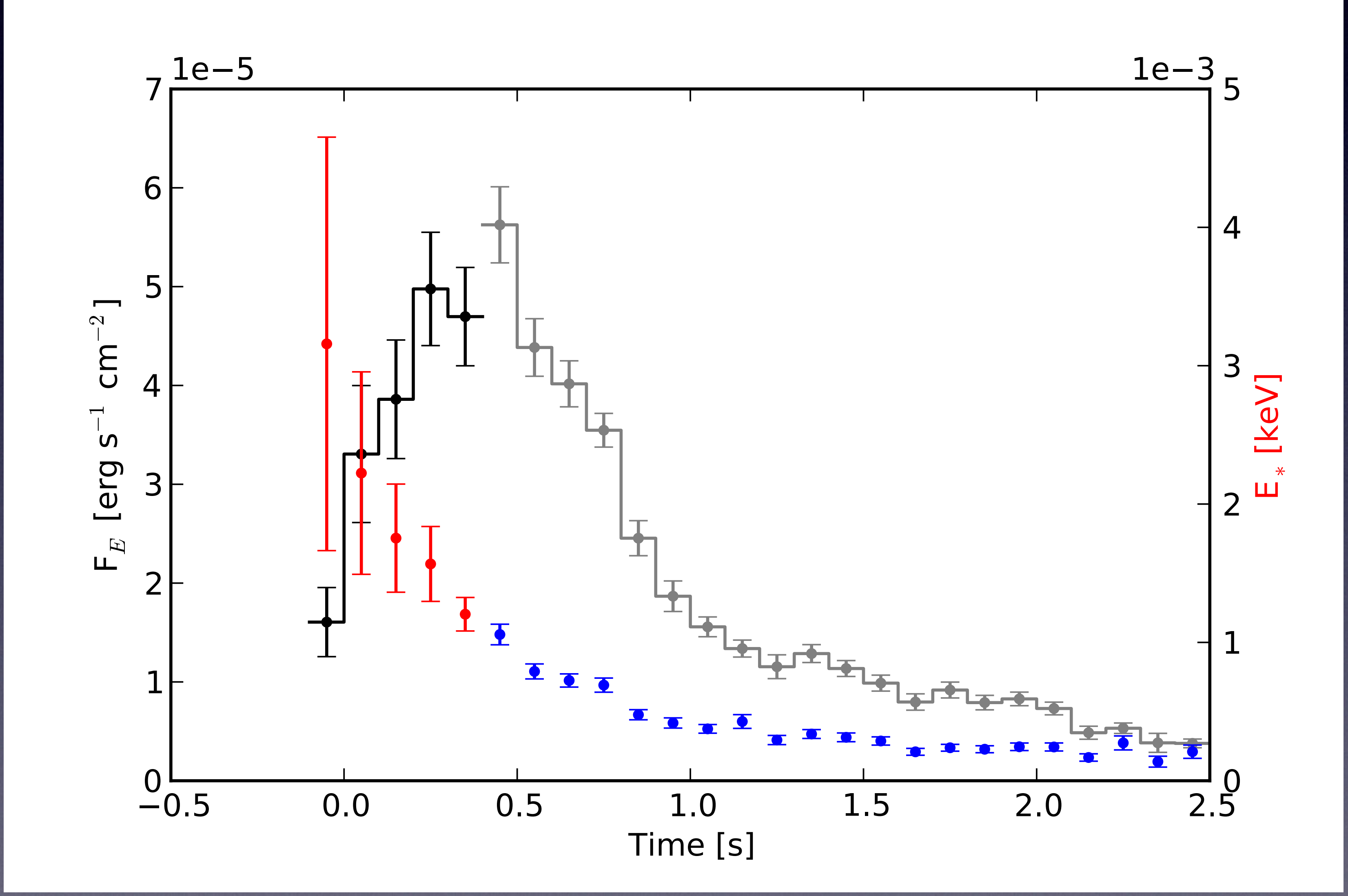
Burgess et al. 2014b

Blackbody kT and synchrotron E_p are correlated. Consistent with a larger sample of GRBs (see talk by Peter Veres)

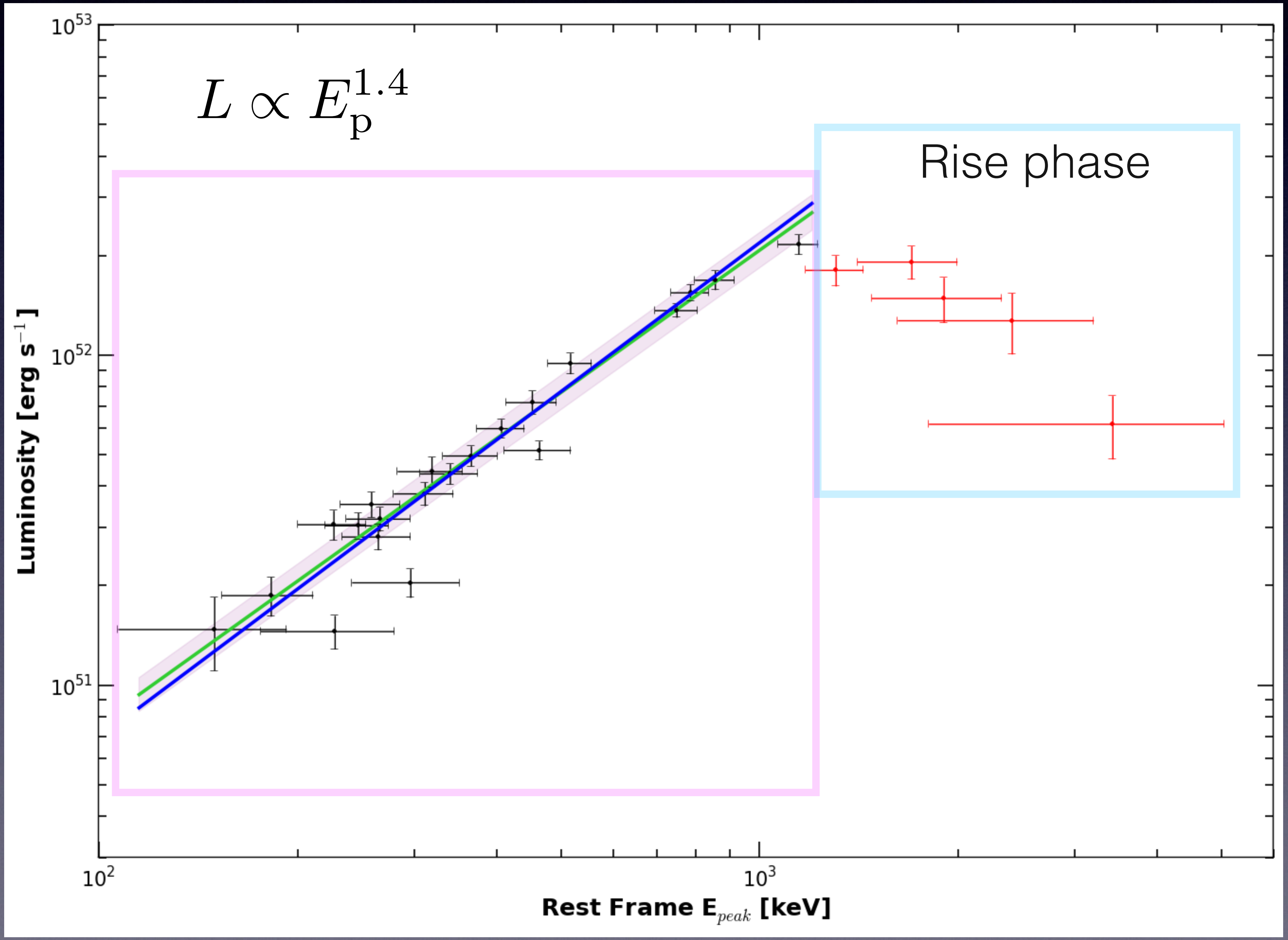


Lots of common behavior in resolved, single pulses!

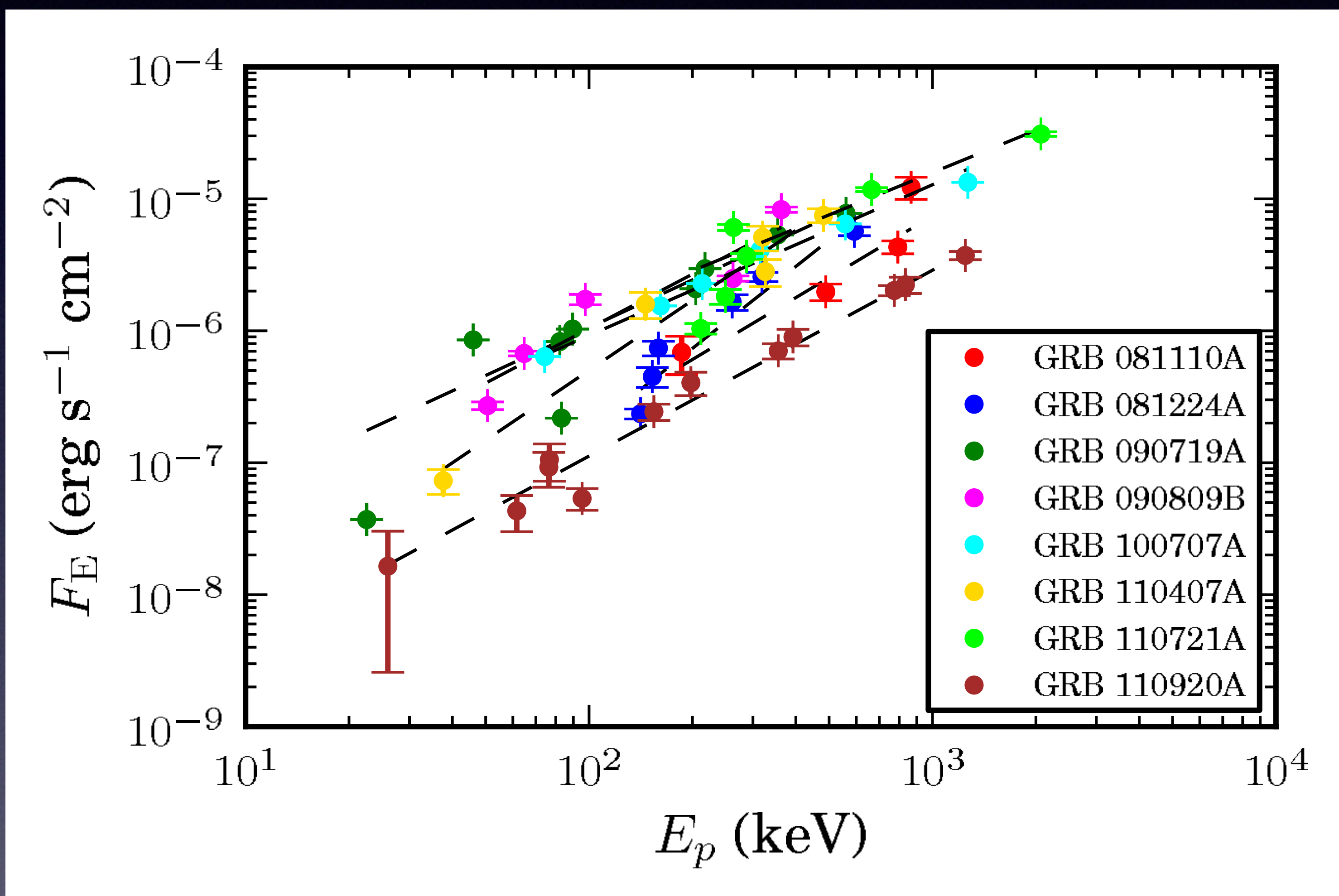
L-E_p Correlation



L-E_p Correlation



L-E_p Correlation



Burgess et al 2014a

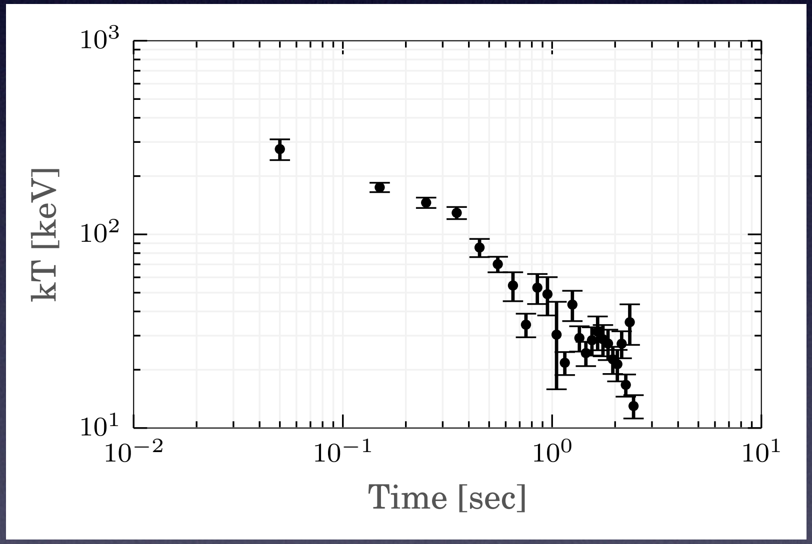
$$E_\mathrm{p} \propto \Gamma B \gamma_\mathrm{min}^2$$
$$L \propto \Gamma^2 B^2 \gamma_\mathrm{min}^2$$

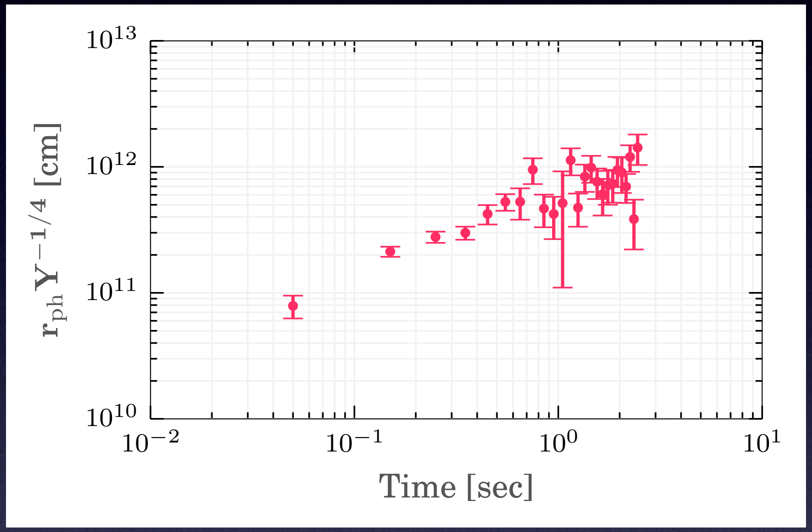
$$BR^2 \propto constant \;\Rightarrow\; B \propto R^{-2}$$
$$\gamma_\mathrm{min} \propto R^{-1}$$

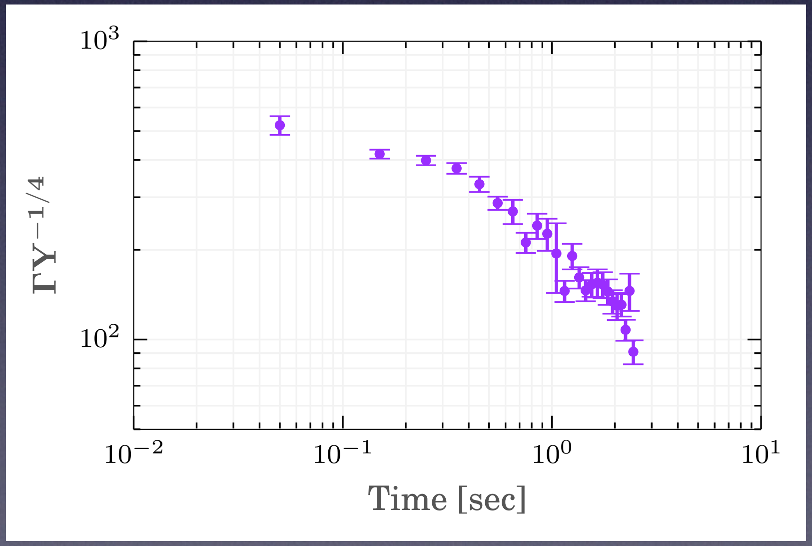
$$E_\mathrm{p} \propto \Gamma R^{-4}$$
$$L \propto \Gamma^2 R^{-6}$$

$$\boxed{L_\mathrm{synch} \propto E_p^{3/2}}$$

Outflow Parameters





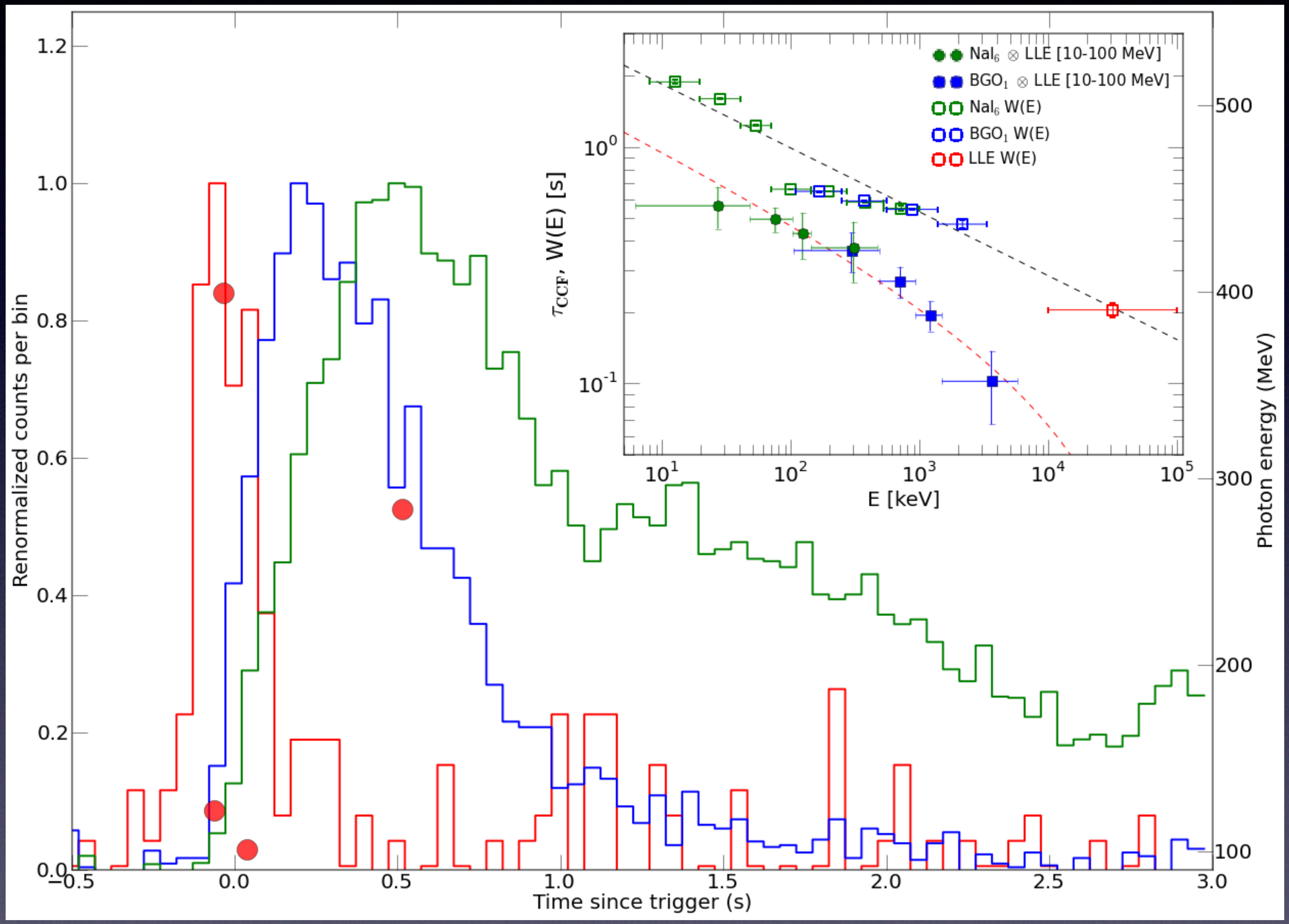


via Pe'er et al (2007)

Using the blackbody kT and flux, outflow parameters are calculated.

A *decreasing* bulk Lorentz factor with time!

Pulse Width Evolution

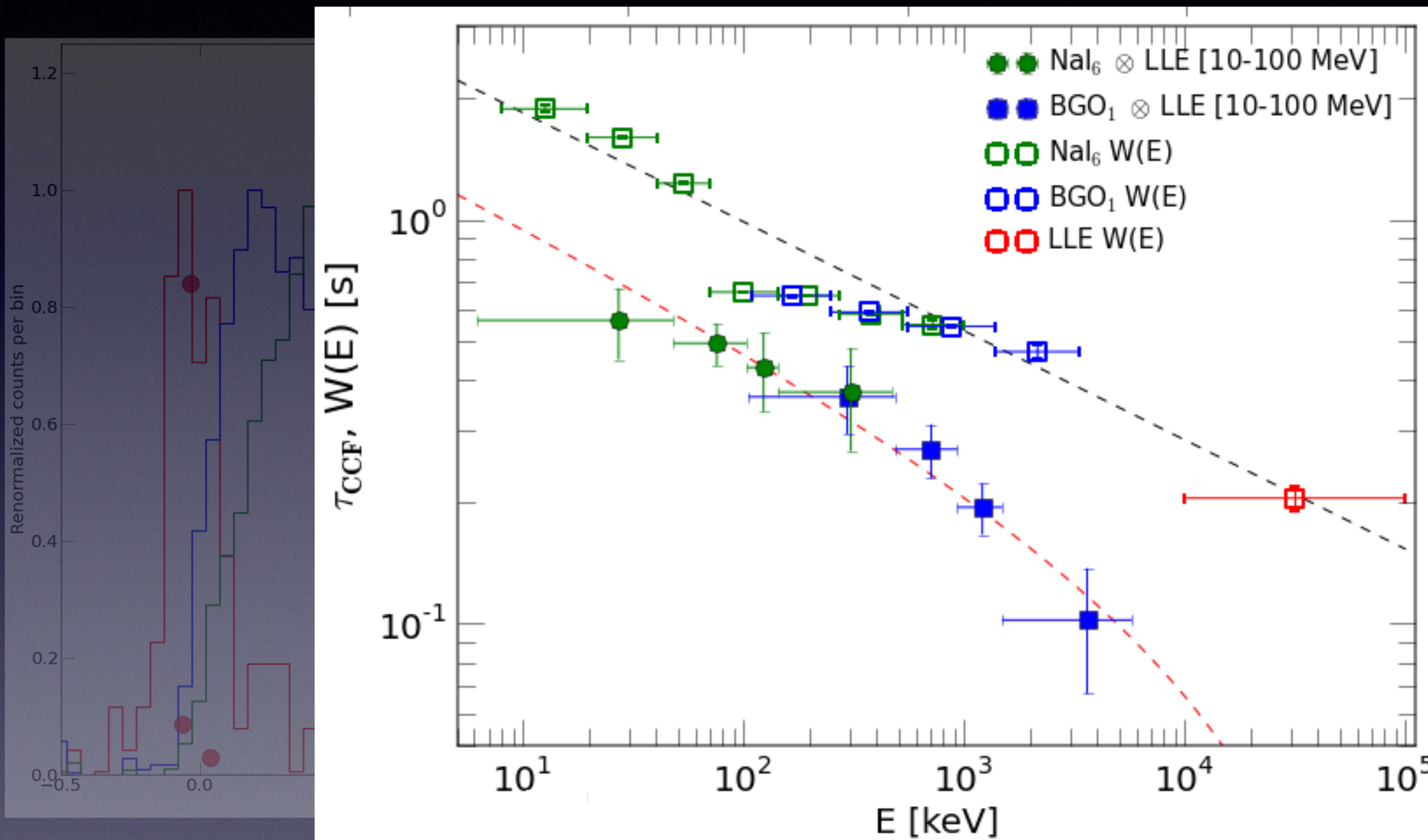


Cross correlation of LAT LLE and GBM detectors

Pulse width and lag analysis consistent with predictions of Daigne & Machkovitch (1998)

Indicative of synchrotron from internal shocks.

Pulse Width Evolution



Cross correlation of LAT LLE and GBM detectors

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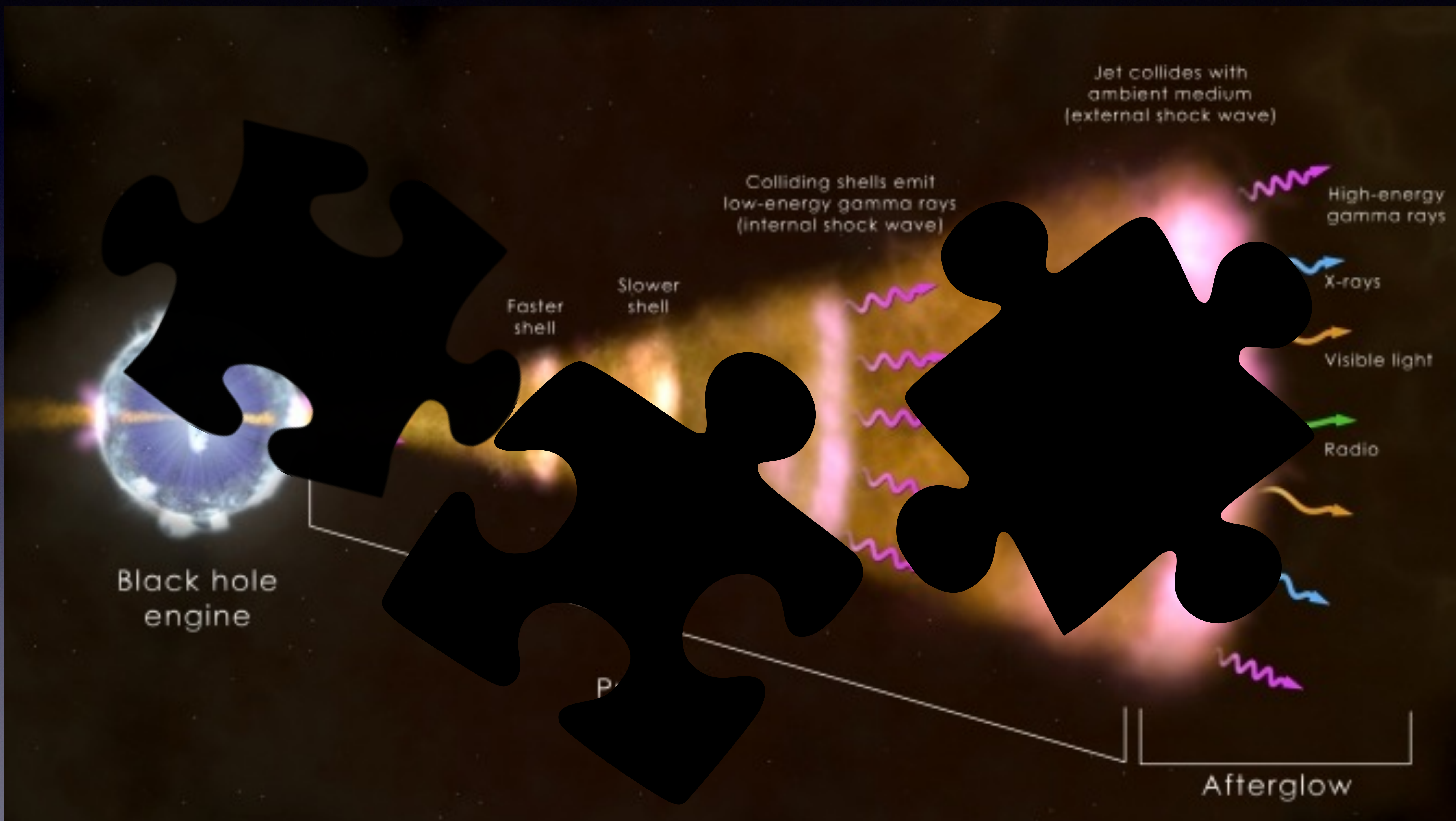
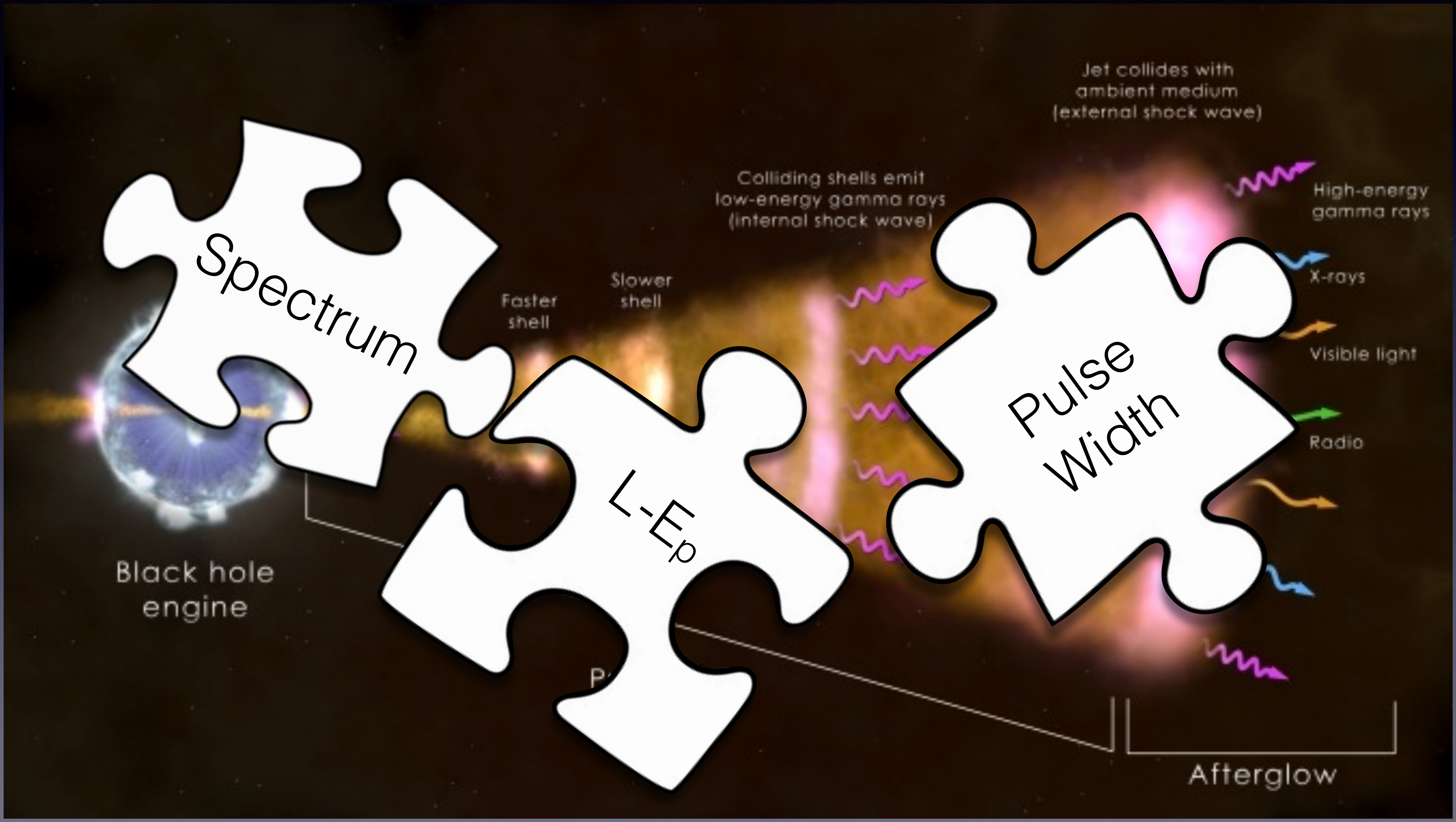
synchrotron from
ks.

Puzzles…


Jet collides with
ambient medium
(external shock wave)
Colliding shells emit
low-energy gamma rays
(internal shock wave)
Faster
shell
Slower
shell
High-energy
gamma rays
X-rays
Visible light
Radio
Black hole
engine
Afterglow

Puzzles…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Slower
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Black hole
engine
Afterglow
Spectrum
L-E_p
Pulse
Width

Puzzles…

Summary:

- Two-component spectrum:
  - Consistent with synchrotron+blackbody
  - Best solution?
- Spectral evolution could imply flux-freezing
- Pulse width evolution matches well with simulations of Daigne & Mochkovitch (1998)
- Explaining spectrum, pulse width, and L-Ep curve simultaneously is very difficult!

Puzzles…

However:

- These simple synchrotron models seem to work for some pulses (Burgess et al. 2014), now we can test sub-photospheric dissipation models (see poster of Björn [9.01])
- Recent findings indicate that synchrotron +blackbody cannot explain over the half the detected GRBs (see my poster [9.03] and talk by Magnus Axelsson)
- Band (or Band+blackbody) fits to spectra should be interpreted with *caution*!