J. MICHAEL BURGESS

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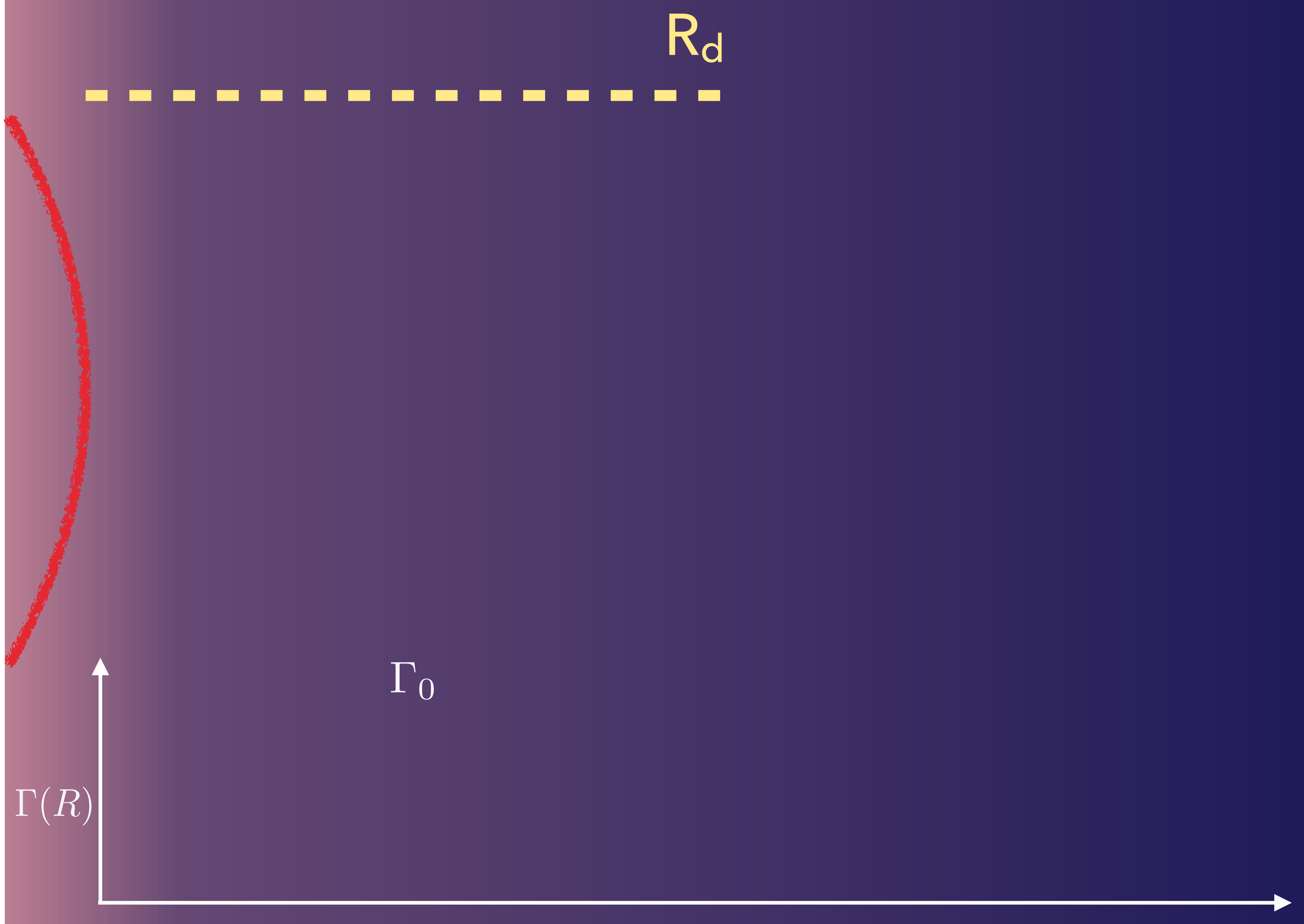
AN EXTERNAL SHOCK ORIGIN OF GRB 141028A

$$n(x) = n_0 x^{-\eta} \text{ cm}^{-3}$$

$$x = R/R_\mathrm{d}$$

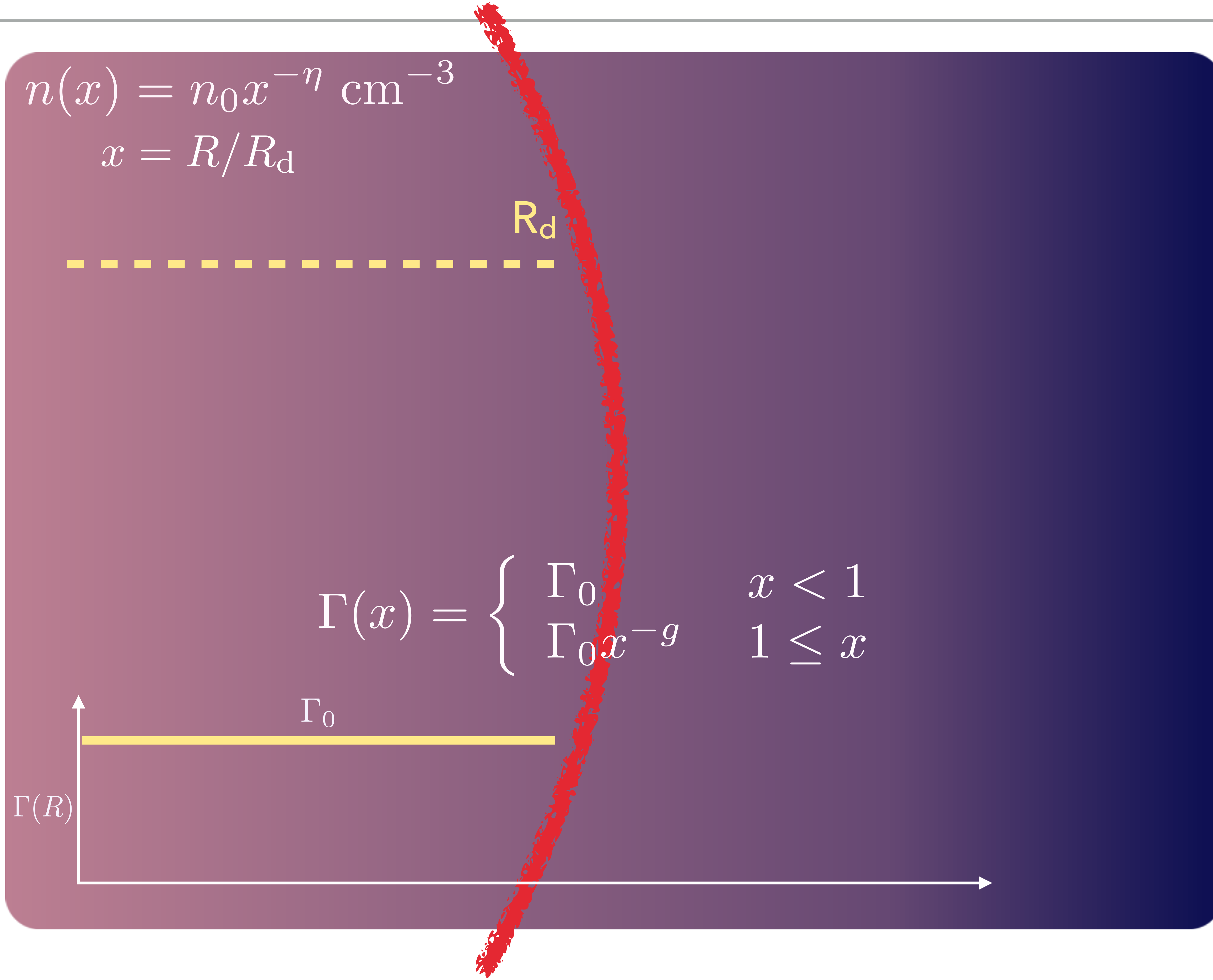


THE EXTERNAL SHOCK MODEL

$$n(x) = n_0 x^{-\eta}\ \mathrm{cm}^{-3}$$

$$x = R/R_\mathrm{d}$$

$$\Gamma(x) = \begin{cases} \Gamma_0 & x < 1 \\ \Gamma_0 x^{-g} & 1 \leq x \end{cases}$$



THE EXTERNAL SHOCK MODEL

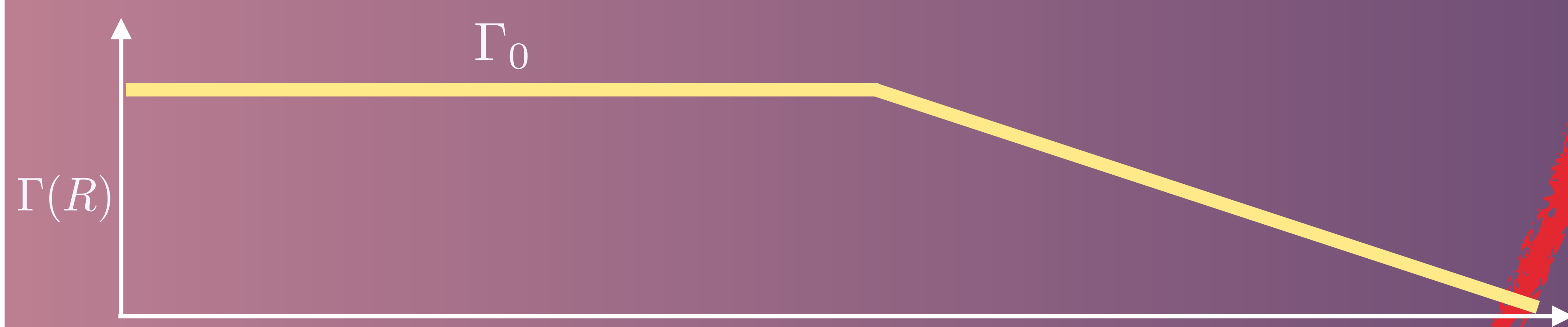
$$n(x) = n_0 x^{-\eta}\ \mathrm{cm}^{-3}$$

$$x = R/R_\mathrm{d}$$

$\mathrm{R_d}$

$$E_\mathrm{p}(t) = \mathcal{E}_0 \left[\frac{\Gamma(x)}{\Gamma_0}\right]^4 x^{-\frac{\eta}{2}}\ \mathrm{keV}$$

$$\Gamma(x) = \begin{cases} \Gamma_0 & x < 1 \\ \Gamma_0 x^{-g} & 1 \leq x \end{cases}$$

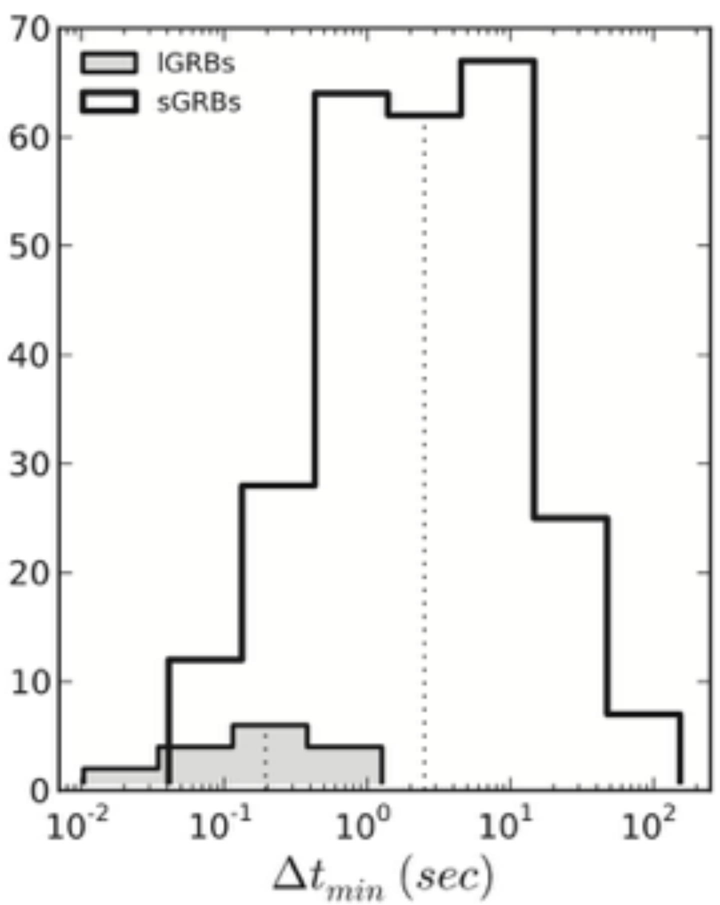


EXTERNAL SHOCKS ARE DEAD! SYNCHROTRON MUST BE FAST-COOLED!

The post 90's GRB community

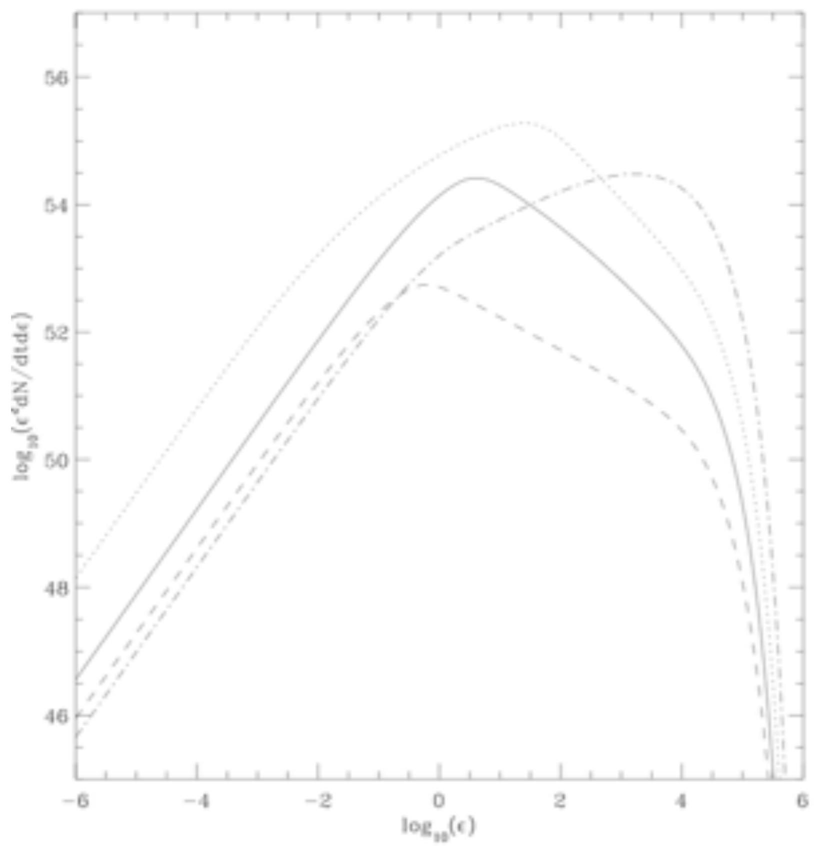
VARIABILITY AND SLOW-COOLED SYNCHROTRON

Golkhou & Butler (2014)



Very few GRBs have millisecond variability

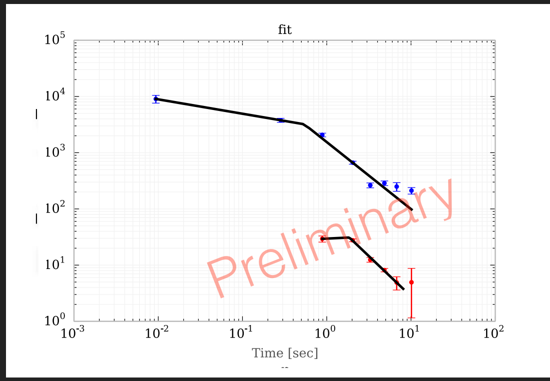
Chiang & Dermer (1999)

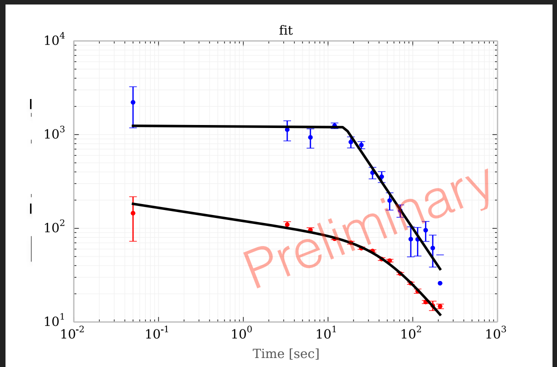


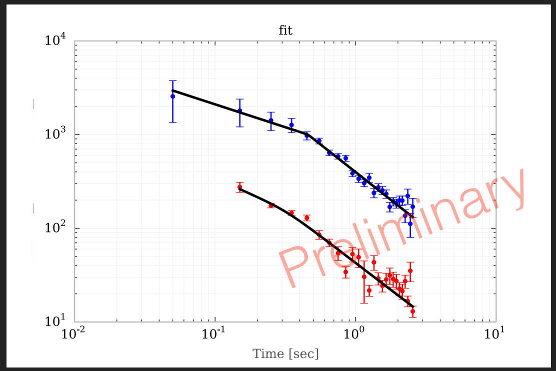
Slow-cooled is ok for long time scales and low magnetic field

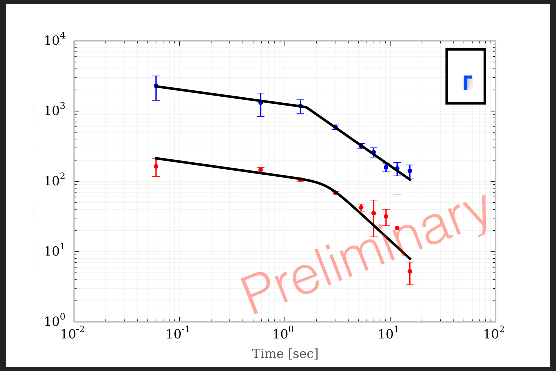
MOTIVATION

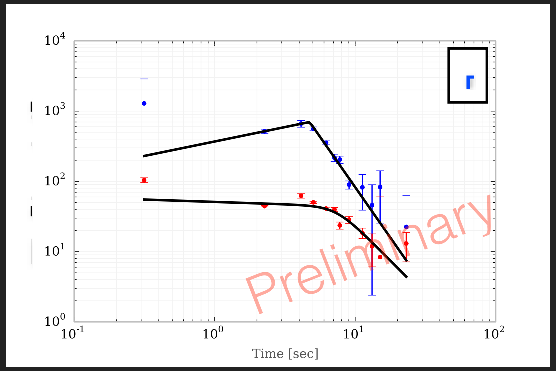
- Spectra fit by synchrotron from a power-law distribution of electrons
- Common, broken power-law evolution of Ep in single pulsed GRBs





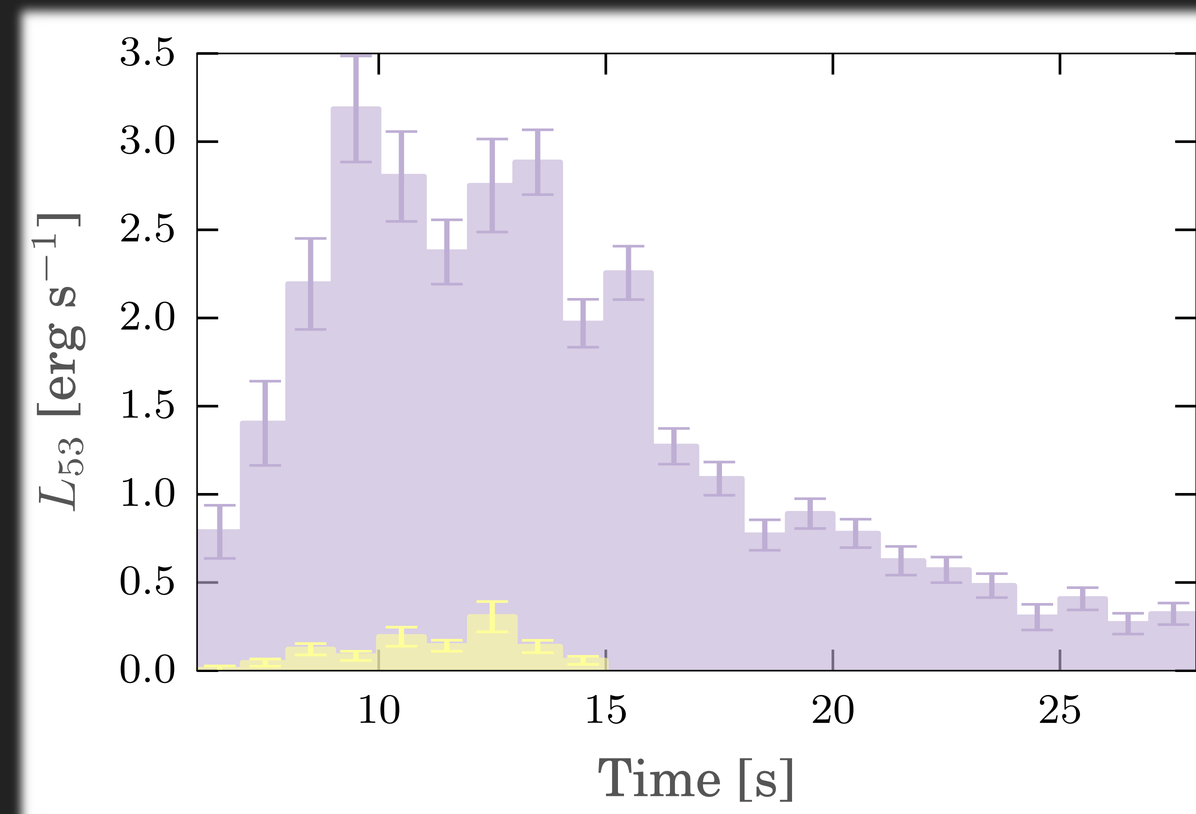






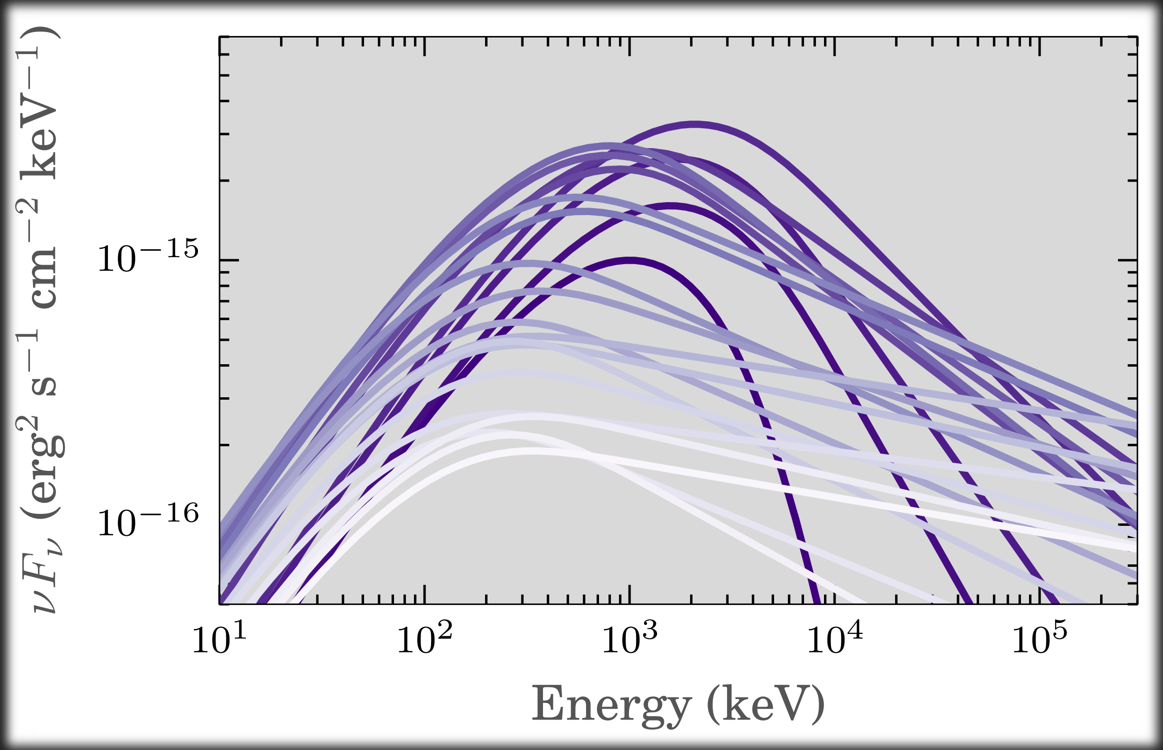
GRB 141028A

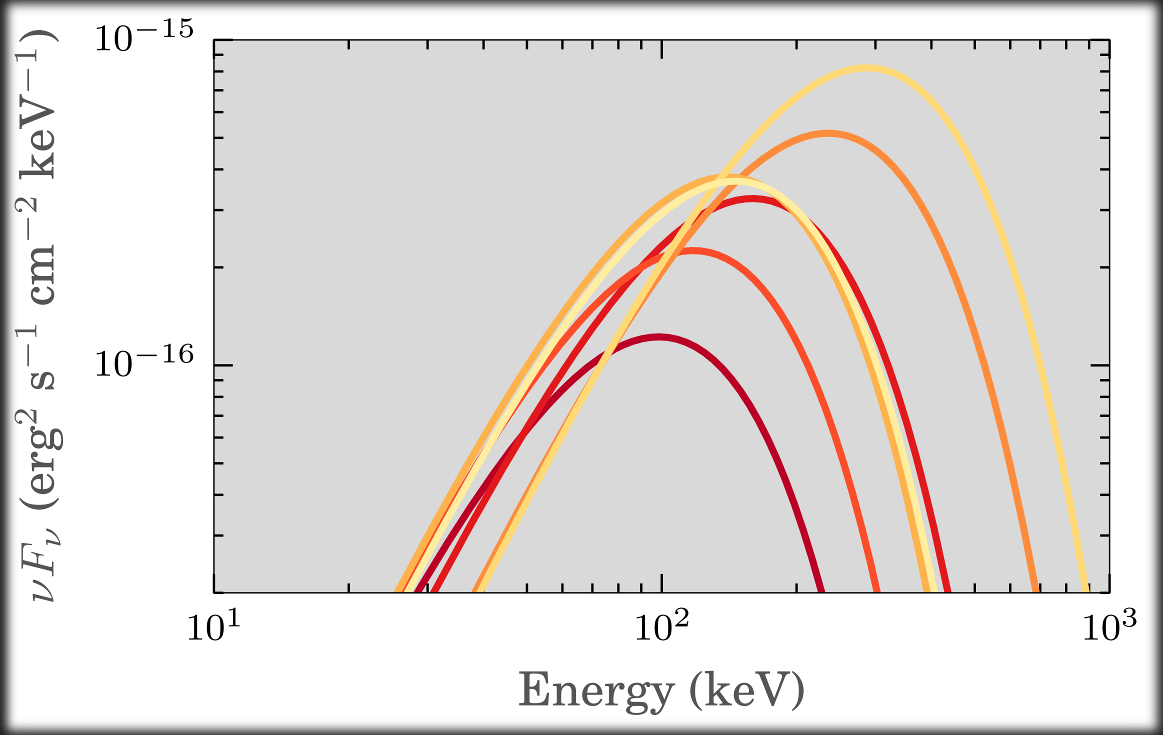
- A single-pulsed GRB
- Variability tested via low-pass filter method. Reveals a significant component on the order of the pulse duration and an insignificant component of about 3 sec
- Detected in both optical, x-rays, gamma-rays, and GeV
- Early time emission analyzed with GBM+LLE from 10 keV to 300 MeV
- LAT emission analyzed in the post prompt phase from 100 MeV - 10 GeV
- Late-time emission analyzed in optical and x-rays



SPECTRAL ANALYSIS

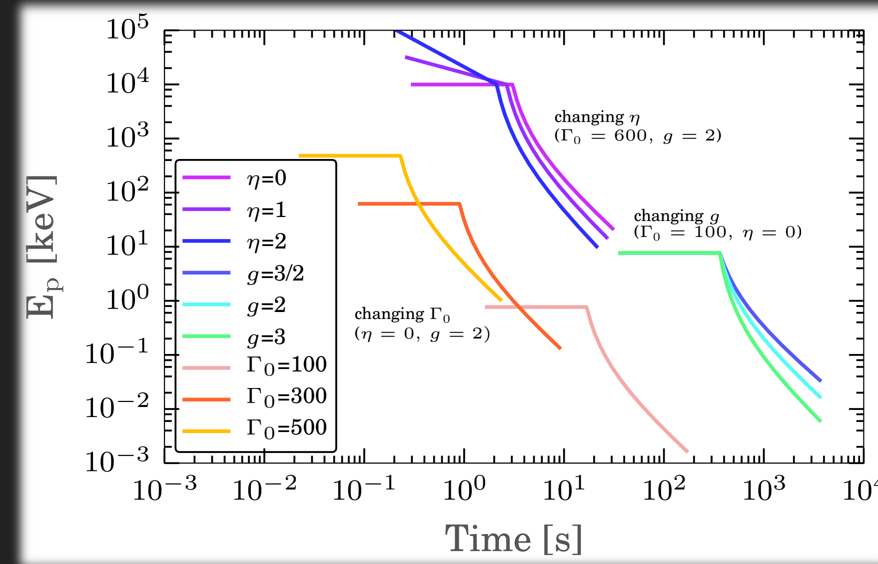
- Spectra fit with slow-cooled synchrotron + blackbody photon model
- Blackbody is only significant for the first 10 sec of the emission.
- We calculate the isotropic energy from the spectral fits to be ~10^{54} erg.

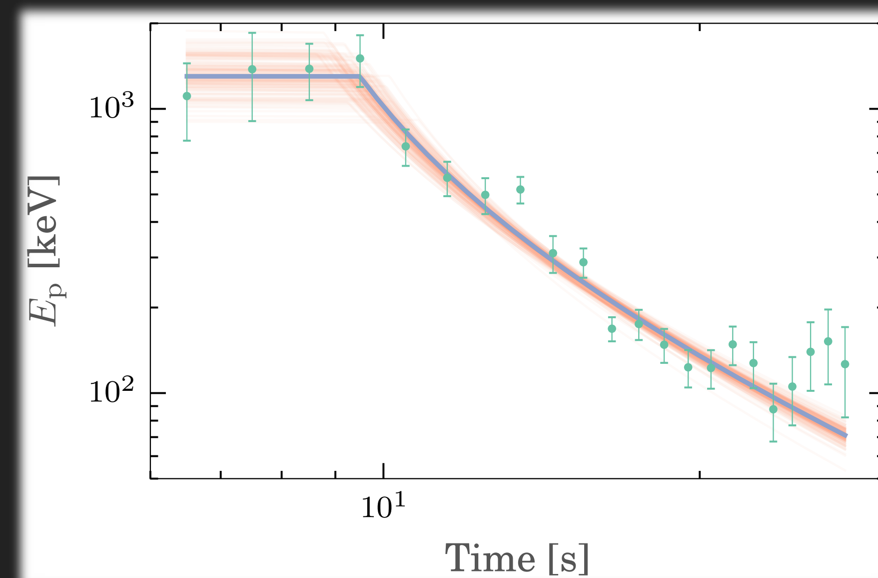




E_p EVOLUTION

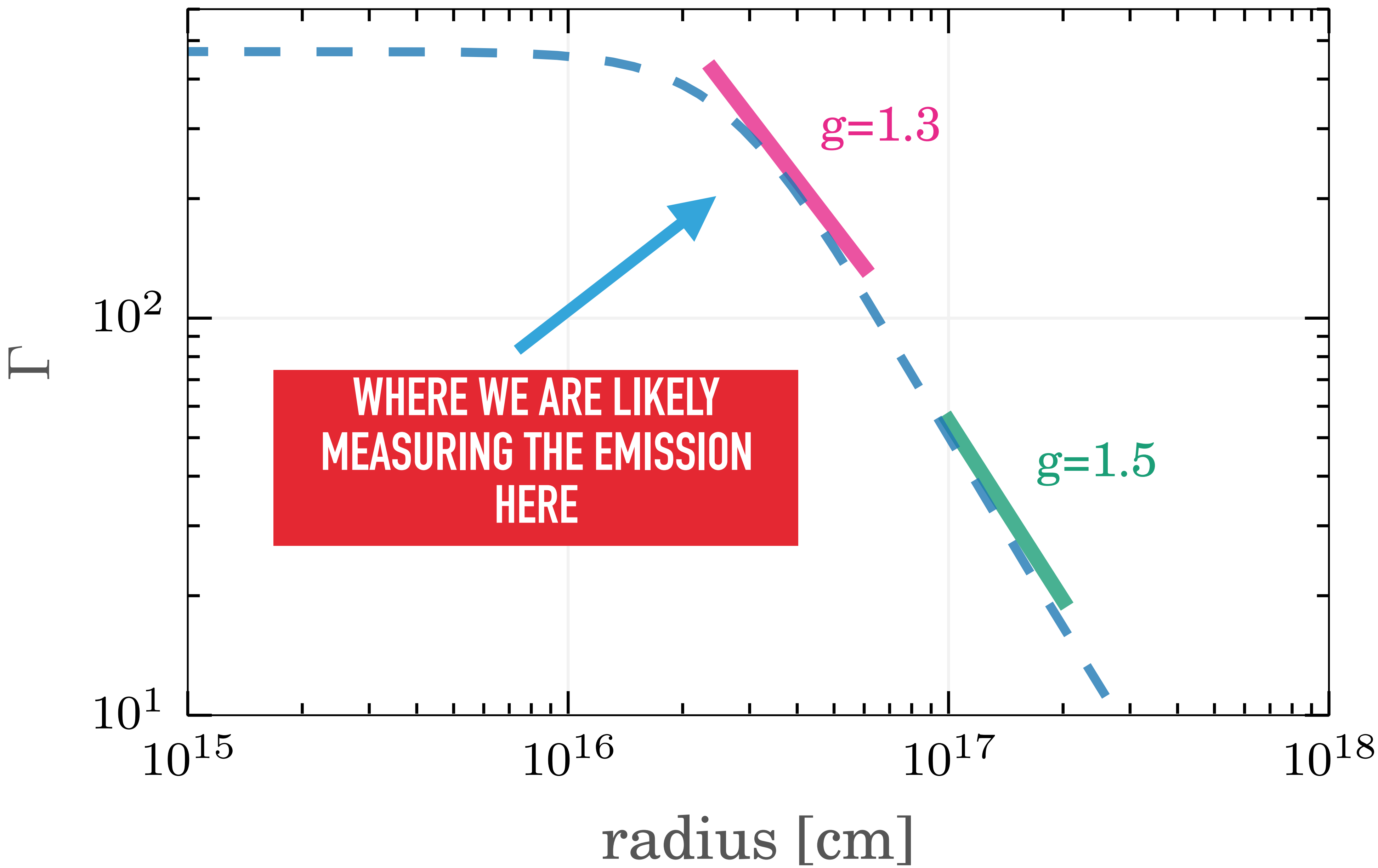
- The evolution of E_p is well fit by the prediction of the external shock model.
- We recover the value of the initial bulk Lorentz factor, the circumburst medium radial profile, and the radiative regime of the blast-wave.
- The density of Lorentz factor are degenerate so we fix the density at several values and repeat the fit to obtain a range of parameters.
- We find the blast-wave is still transitioning to asymptotic limits of the evolution but conclude that it is evolving adiabatically.





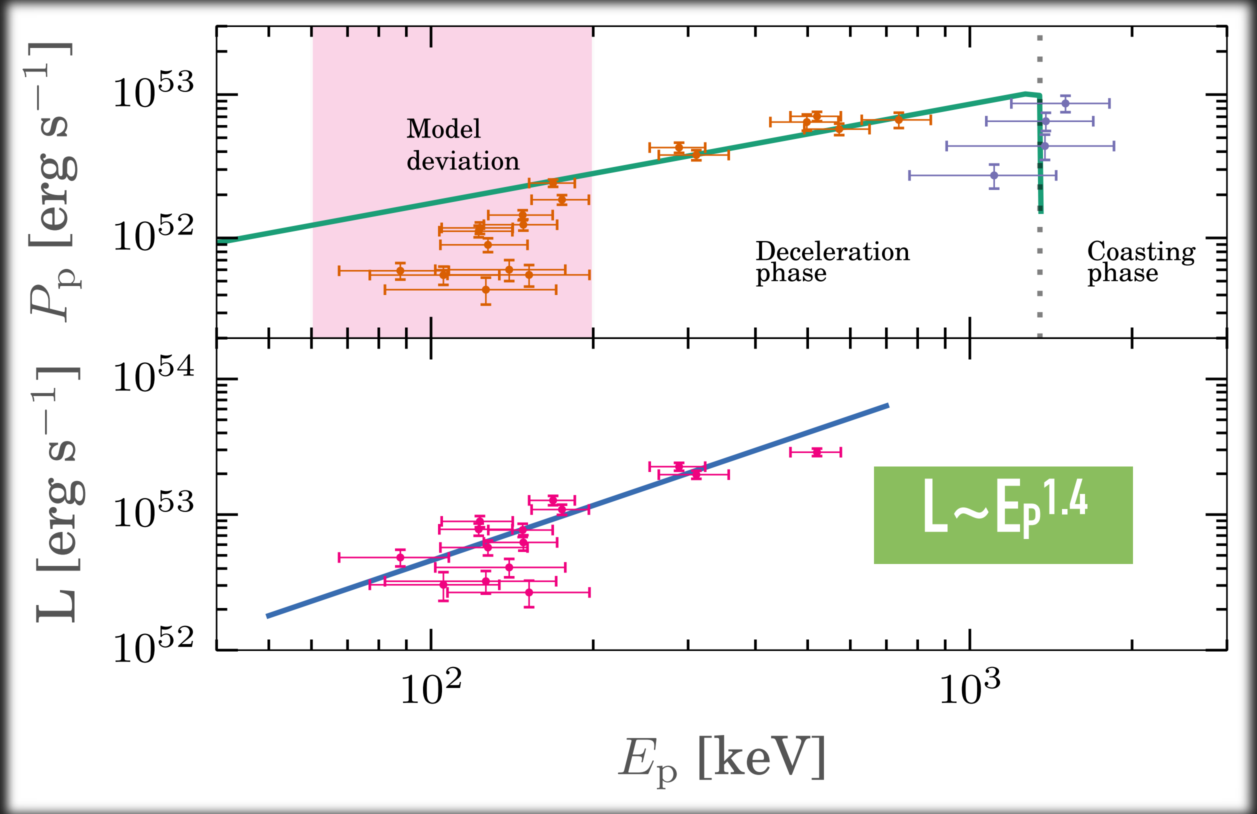
n_0 [cm^{-3}]	Γ_0	η	q_{-3}	g	r_d [cm]
1	$1125.9^{+16.6}_{-14.3}$	$0.00^{+0.08}_{-0.00}$	$0.17^{+0.01}_{-0.13}$	$1.25^{+0.1}_{-0.1}$	$1.1 \cdot 10^{17}$
10	$844.0^{+12.3}_{-10.9}$	$0.00^{+0.08}_{-0.00}$	$0.17^{+0.02}_{-0.14}$	$1.26^{+0.1}_{-0.11}$	$6.0 \cdot 10^{16}$
100	$632.16^{+7.7}_{-4.5}$	$0.03^{+0.05}_{-0.02}$	$0.17^{+0.05}_{-0.06}$	$1.26^{+0.09}_{-0.11}$	$3.4 \cdot 10^{16}$

TRANSITION PHASE



MODEL PREDICTIONS

- Using the recovered fit parameters, we predict the flux of the νF_ν peak flux and compare it to the data. Good agreement is found.
- We compute the luminosity-E_p plane and fit the power law and find it is consistent with predictions from an external shock emitting slow-cooled synchrotron radiation.



$$\gamma_{\min} \propto \begin{cases} \Gamma^4 \propto t^{-4g/(2g+1)} & \text{slow cooling} \\ (x\Gamma)^{-1} \propto t^{-2g/(2g+1)} & \text{fast cooling} \end{cases} .$$

$$L \propto \begin{cases} E_\mathrm{p}^{\frac{3}{2}} & \text{slow cooling} \\ E_\mathrm{p}^{1+g} & \text{fast cooling} \end{cases}$$

See Dermer (2004)

MAGNETIC FIELD STRENGTH

- Using the recovered parameters we, can estimate the magnetic field strength via E_p.
- The low value justifies the use of slow-cooled synchrotron.
- This can now be compared to the independent measurements of the late time optical and x-ray data.

$$E_{\mathrm{p}} \simeq \frac{\sqrt{32\pi\epsilon_{\mathrm{B}} m_{\mathrm{p}} c^2 n \Gamma^2}}{B_{\mathrm{crit}}} \Gamma \gamma_{\mathrm{min}}^2$$

$$\gamma_{\mathrm{min}} = \kappa \Gamma \frac{m_{\mathrm{p}}}{m_{\mathrm{e}}}$$

$$E_{\mathrm{p}} \sim 1.3\mathrm{MeV}$$

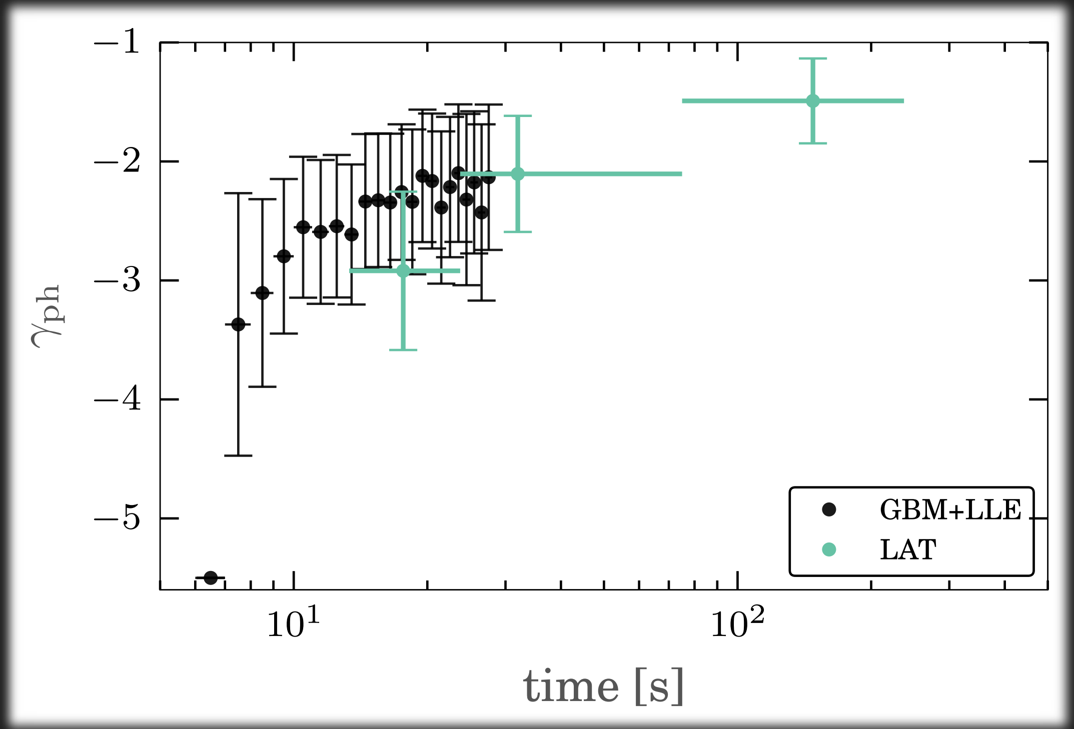
$$\epsilon_{\mathrm{B}} \sim 10^{-9}$$

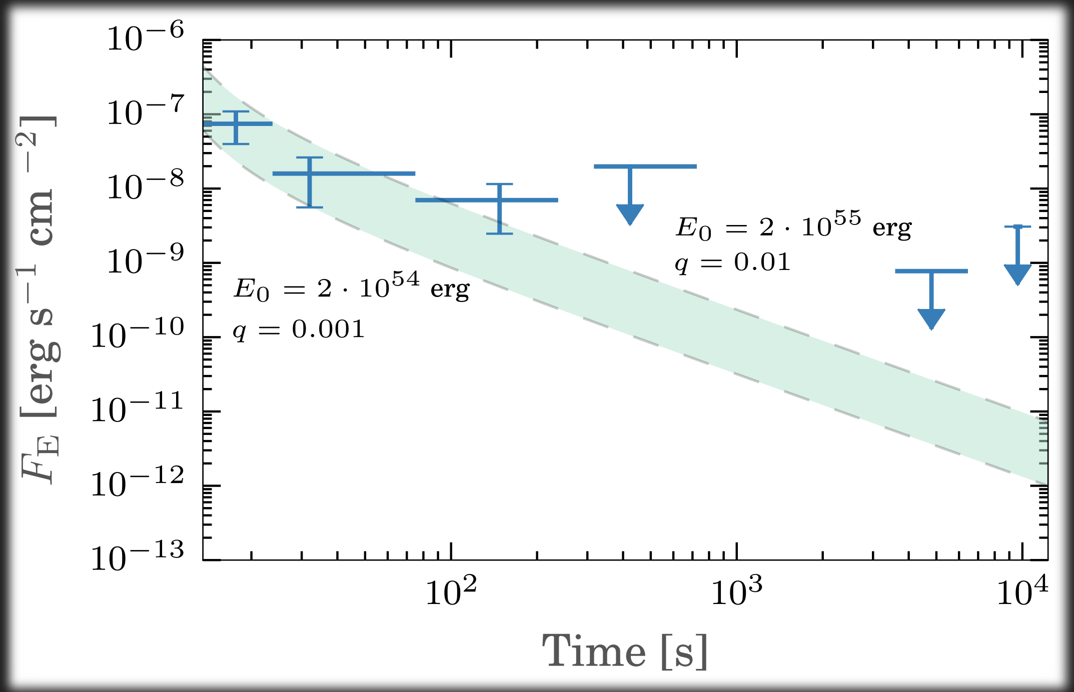
See also Beniamini+ (2015)

HIGH ENERGY EMISSION

- The “late time” LAT emission overlaps with the GBM observations.
- Fractional SSC emission content in the LAT (~10^{-4})
- Estimates from low-energy analysis match with high energy

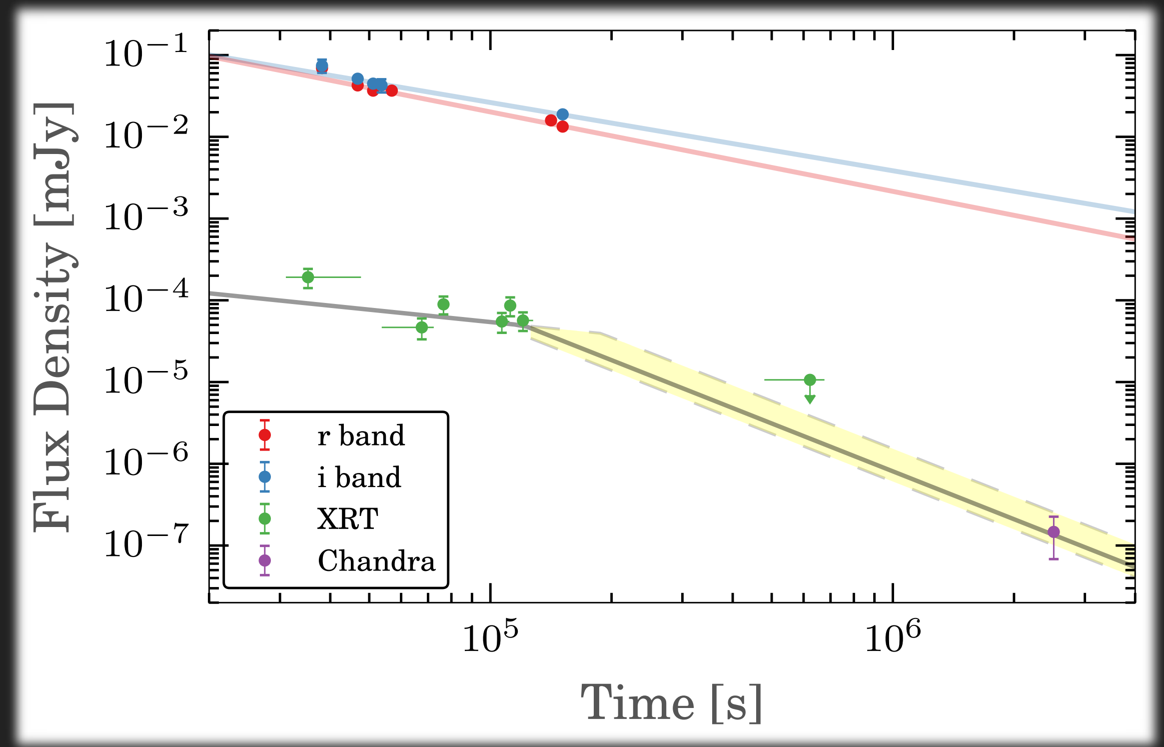
THE LAT EMISSION IS A CONTINUATION OF THE SYNCHROTRON EMISSION





OPTICAL AND X-RAY

- Using Swift XRT and GROND data, we fit a joint SED and find a single power law across the wavelengths consisted with the cooling index being above the XRT bandpass.
- From there, we can estimate the magnetic field strength upper-limit from the late time emission and find it is consistent with the estimates from the prompt.
- A jet break is also estimated lowering the observed isotropic energy.



$$\nu_c = 3.7 \cdot 10^{14} E_{53}^{-1/2} n^{-1} (Y+1)^{-2} \epsilon_{B,-2}^{-3/2} T_d^{-1/2}$$

n_0	Γ_0	ϵ_B via ν_c	ϵ_B via E_p	ξ
1	1125.9	$< 1.2 \cdot 10^{-3}$	$\sim 2.9 \cdot 10^{-9}$	0.8
10	884.0	$< 2.7 \cdot 10^{-4}$	$\sim 2.9 \cdot 10^{-9}$	0.8
100	632.2	$< 5.7 \cdot 10^{-5}$	$\sim 2.9 \cdot 10^{-9}$	0.8

WHAT DO WE KNOW NOW?

- At least two emission mechanisms:
  - Thermal (GRB 090902B Ryde+ (2009); Larsson+ (2015) ; Bjorn's talk)
  - Synchrotron (Zhang+ (2015), Burgess+ (2012-2014))
- Dynamic evolution predicted uniquely for one model: external shock; weakly predicted by internal shocks (Daigne+ (1998-2015))
- Slow-cooling is possible under the right conditions (Chiang+ (1999))
- Variability not a problem (Golkhou & Butler (2014))

WHERE DO WE GO?

- GRB 141028A is not inconsistent with having dynamics that originate from external shocks and emission from shock accelerated electrons slowly cooling via synchrotron radiation.
- We posit this as evidence for the external shock model still being viable and raise the question of why it seems that at least two emission/dynamic mechanisms observationally appear to be responsible for GRB emission.

THEORIST:
PREDICT EVOLUTION + SPECTRA

OBSERVERS:
USE PHYSICAL MODELS ON DATA

THANK YOU!