AN EXTERNAL SHOCK ORIGIN OF GRB 141028A

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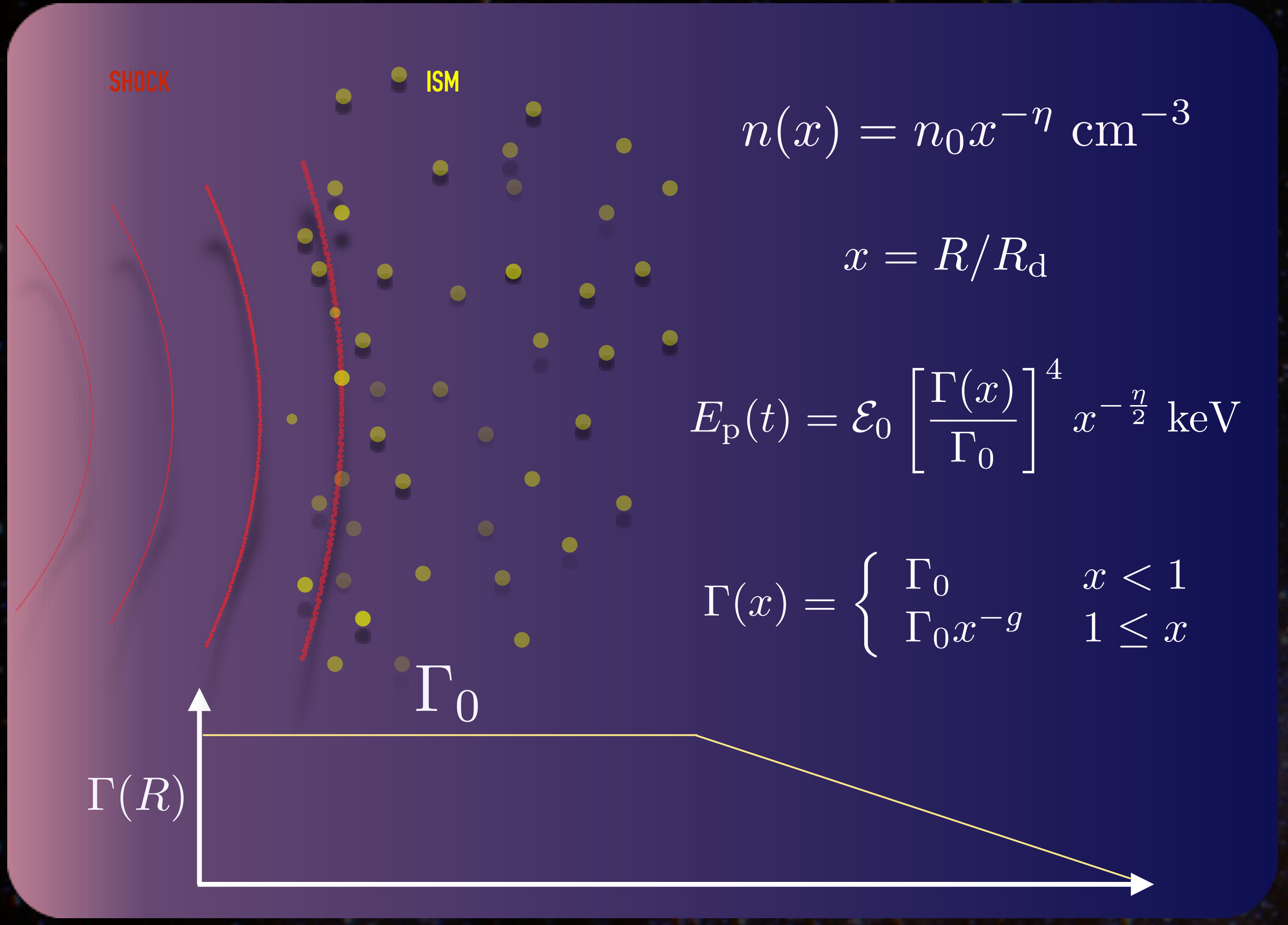
The external shock model predicts a simple evolution for the physical observables of GRB prompt emission. In particular, the evolution of the peak energy can be parameterized into a form that is strongly dependent on the blast wave properties.

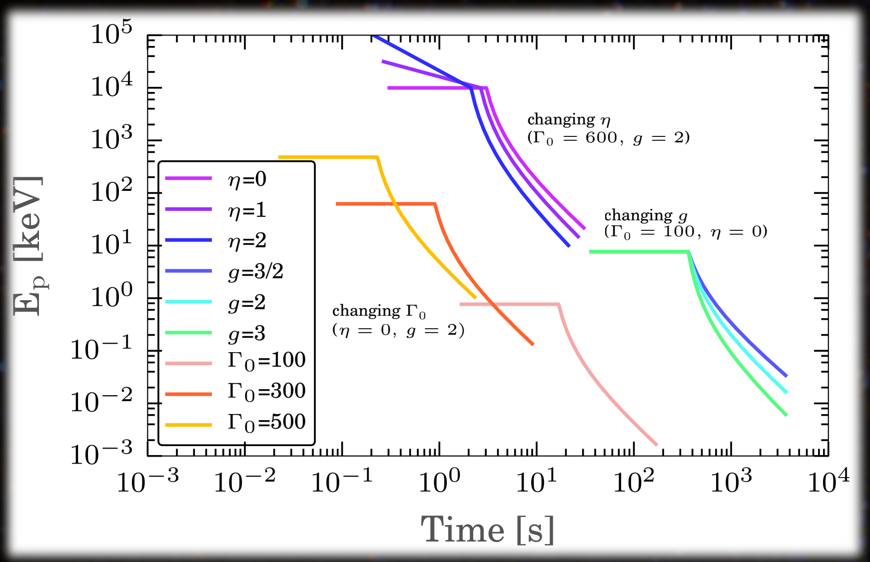


$$n(x) = n_0 x^{-\eta} \ \mathrm{cm}^{-3}$$

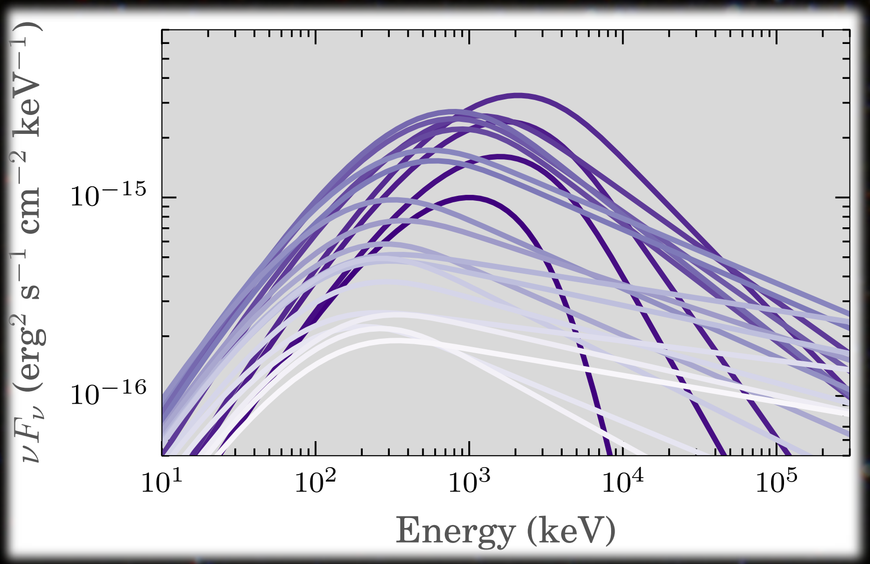
$$x = R/R_\mathrm{d}$$

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

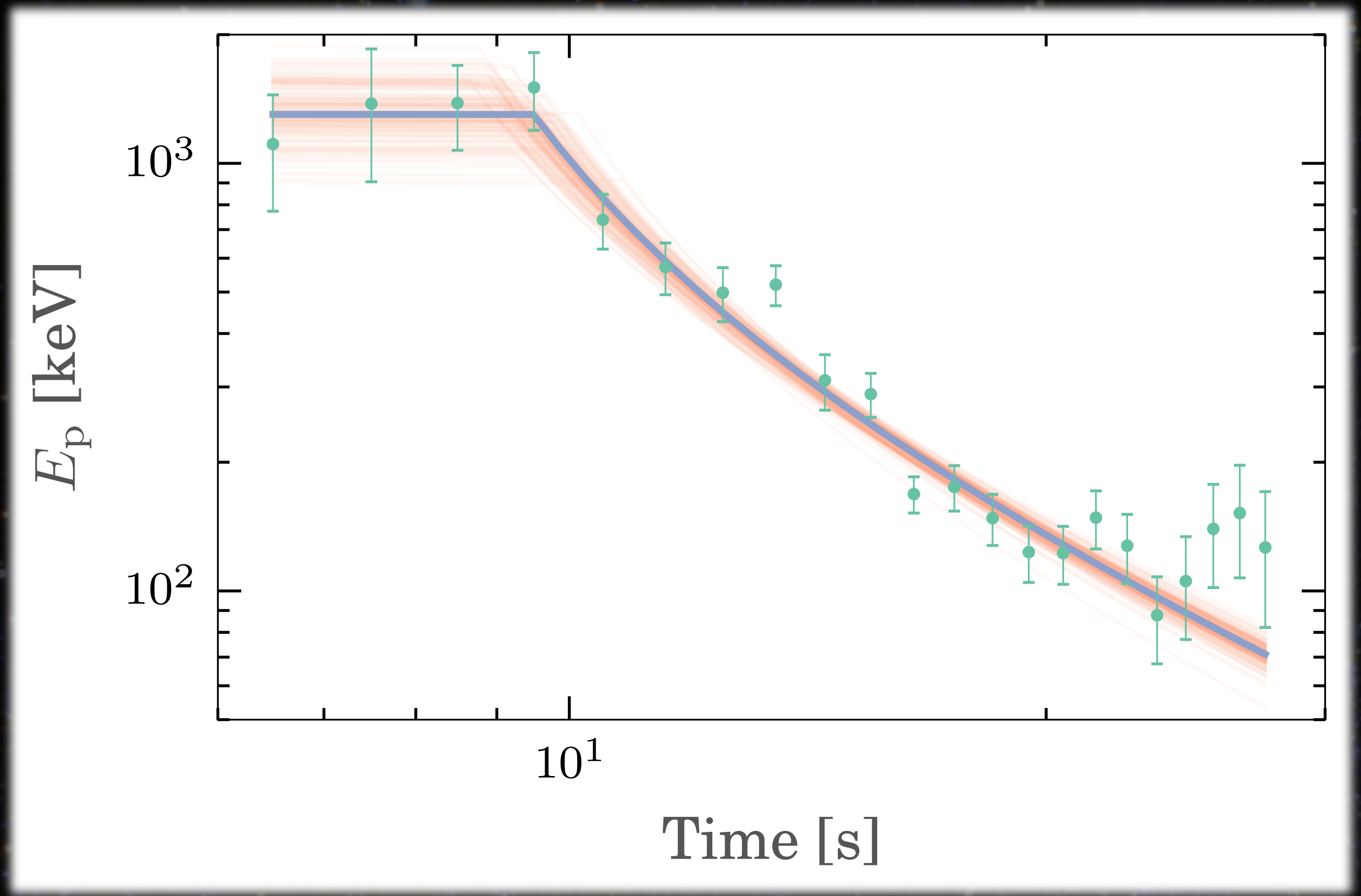
$$\Gamma(x) = \begin{cases} \Gamma_0 & x < 1 \\ \Gamma_0 x^{-g} & 1 \le x \end{cases}$$



We can turn the dependence of Ep with time into a function and fit for its evolution allowing a nearly unique determination of the blast wave properties: the radiative regime, the initial bulk Lorentz factor and ISM density profile.



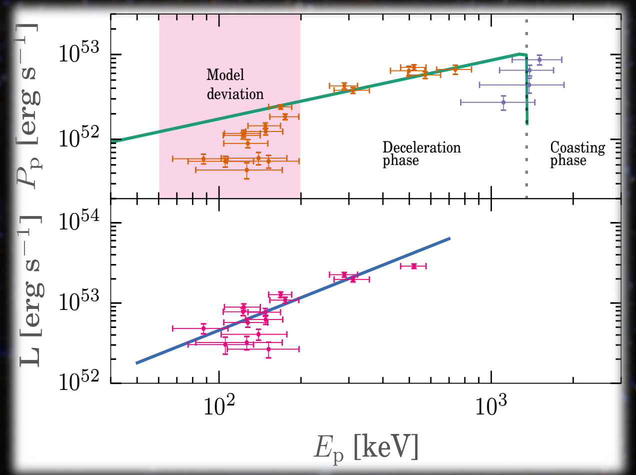
We then can fit the prompt emission of the single pulsed GRB 141028A with a synchrotron photon model to derive its evolving peak energy.



The fitted Ep evolution gives good agreement with the data. A unique determination of the the ISM density is impossible without outside observations. Nevertheless, we determine a uniform density profile for the ISM, and a weakly radiative regime for the blast wave.

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	$632.16^{+7.7}_{-4.5}$	$0.03^{+0.05}_{-0.02}$	$0.17^{+0.05}_{-0.06}$	$1.26^{+0.09}_{-0.11}$	$3.4 \cdot 10^{16}$

We can then use the evolution and match it with other predictions of the external shock model. The correlation between Ep and luminosity can be used as a second check on the emission mechanism.



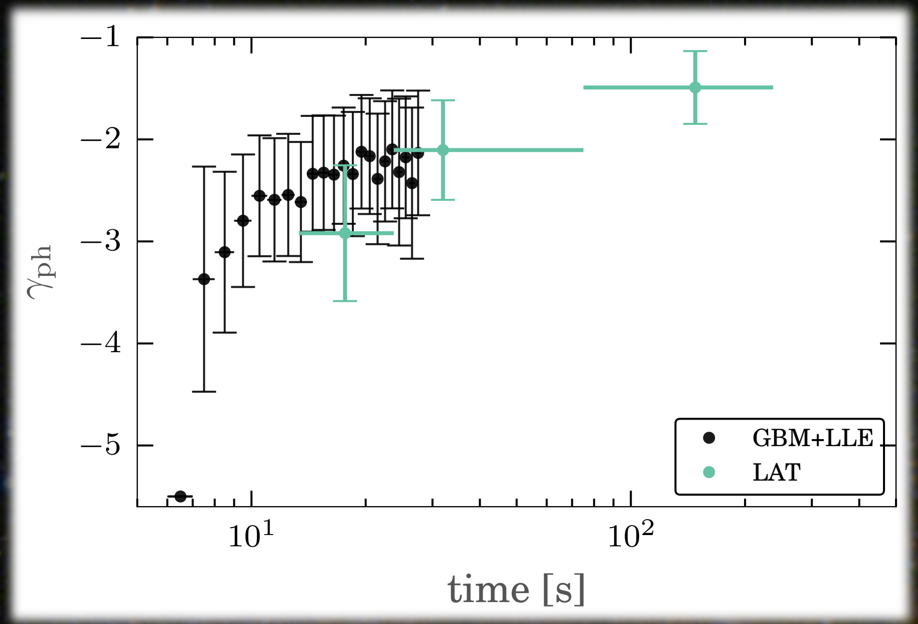
$$\gamma_\mathrm{min} \propto \begin{cases} \Gamma^4 \propto t^{-4g/(2g+1)} & \text{slow cooling} \\ (x\Gamma)^{-1} \propto t^{-2g/(2g+1)} & \text{fast cooling} \end{cases} .$$

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

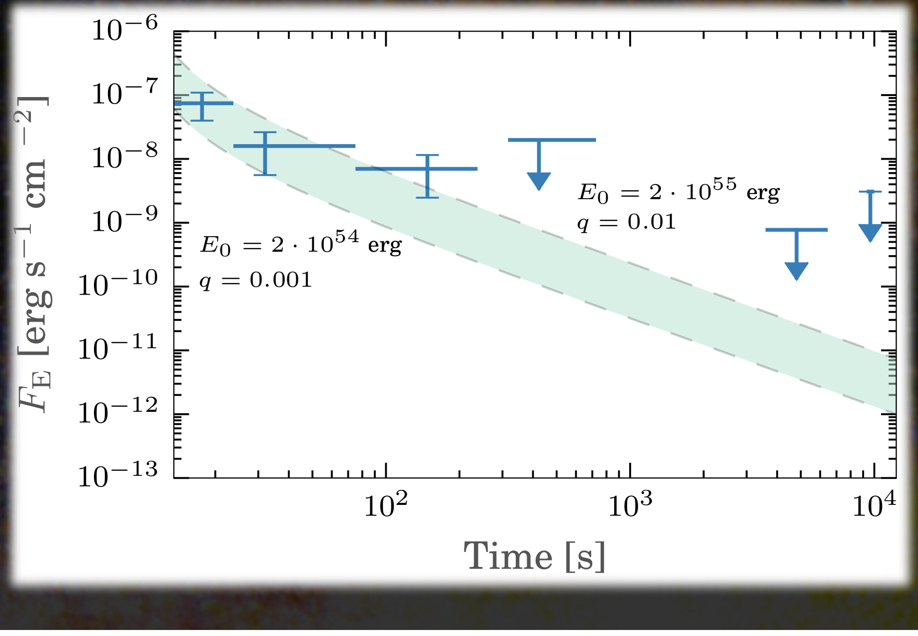
The slope of the relation matches with what is expected from slow cooling synchrotron. This is in agreement with the model used to fit the spectra, but independently measured.

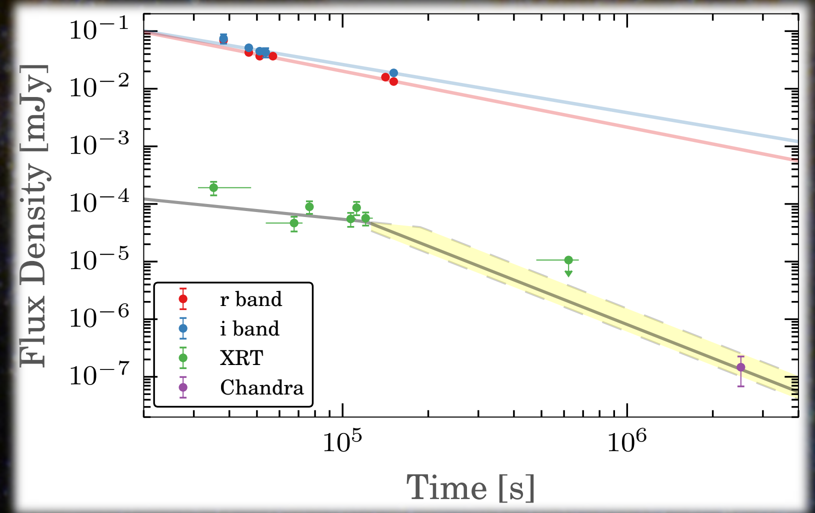
The prompt emission characteristics give strong evidence for a weakly radiative external shock that emits synchrotron radiation that cools very slowly. We can look to observations at other wavelengths from consistency of the model.

The measured photon index in GBM and the LAT grows with time indicating a possible evolution in the acceleration process. It is possible that this could be signature of a secondary emission process at high energy.



However, the computed flux in the LAT at late time matches well with a synchrotron only origin if we assume the fitted parameters from the prompt emission propagated into the expectations of the external shock model. Moreover, the computed SSC contribution is on the order of a few percent.





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

$$\nu_\mathrm{c} = 3.7 \cdot 10^{14} E_{53}^{-1/2} n^{-1} (Y+1)^{-2} \epsilon_{\mathrm{B},-2}^{-3/2} T_\mathrm{d}^{-1/2}$$

Finally, we examine the optical and x-ray late time emission. Two things are observed, a jet break at late time thanks to a Chandra observation, and the spectra index between optical and x-ray. The jet break enables a determination of the beam corrected isotropic energy and the lack of a break in the optical/x-ray spectrum enables an upper limit on the fraction of magnetic energy in the outflow which is consistent with the prompt mission thus pointing to a slowly cooling electron distribution.

The general picture for GRB 141028A is an external shock and is consistent across all wavelengths. Thus, it is important to investigate further the population of such bursts in the data as the analysis lends itself to understanding both the macro and microphysics of GRBs

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ABSTRACT

The prompt emission of the long, smooth, and single-pulsed gamma-ray burst, GRB 141028A, is analyzed under the guise of an external shock model. First, we fit the γ-ray spectrum with a two-component photon model, namely, synchrotron+blackbody, and then fit the recovered evolution of the synchrotron νF_{ν} peak to an analytic model derived considering the emission of a relativistic blast wave expanding into an external medium. The prediction of the model for the νF_{ν} peak evolution matches well with the observations. We observe the blast wave transitioning into the deceleration phase. Furthermore, we assume the expansion of the blast wave to be nearly adiabatic, motivated by the low magnetic field deduced from the observations. This allows us to recover within an order of magnitude the flux density at the νF_{ν} peak, which is remarkable considering the simplicity of the analytic model. Under this scenario we argue that the distinction between prompt and afterglow emission is superfluous as both early-time emission and late-time emission emanate from the same source. While the external shock model is clearly not a universal solution, this analysis opens the possibility that at least some fraction of GRBs can be explained with an external shock origin of their prompt phase.

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