1. INTRODUCTION

Gamma-ray bursts (GRBs) are the most luminous explosions in the universe. They feature extremely relativistic outflows with bulk Lorentz factors $\sim 10^{3}$–$10^{5}$ and isotropic energies of $10^{48}$–$10^{55}$ erg. Though their cosmological origin as well as the relativistic movement has been firmly established, the radiation mechanism and the outflow composition are still uncertain (Piran 1999; Zhang & Mészáros 2004). It is widely believed that the high-energy emission of GRBs can shed light on these two fundamental issues (see Fan & Piran 2008 for a review). For example, a distinct GeV–TeV spectrum excess can be taken as an indication evidence of a baryonic outflow and a radiation process in addition to synchrotron (e.g., inverse Compton scattering) will be needed, while the absence of such a component in most spectra may favor the magnetic outflow model. Recently, the Fermi collaboration has released their observation data of GRBs 080916C and 090510 (Abdo et al. 2009a, 2009b). In this work, we examine the origins of these prompt and afterglow GeV emission. The work is structured as follows. In Section 2, we discuss the origin of the prompt GeV emission and the corresponding constraint on the physical composition. In Section 3, we employ the standard external forward shock model to interpret the X-ray and optical afterglow data. In Section 4, we investigate the origin of the afterglow GeV emission. Our results are summarized in Section 5 with some discussion.

2. PROMPT GeV EMISSION OF GRBs 080916C AND 090510

GRB 080916C was a long burst with a duration $T_{90} \sim 66$ s (Abdo et al. 2009a) and was at a redshift $z \sim 4.35 \pm 0.15$ (Greiner et al. 2009b). A few hundred high-energy photons have been detected by the Large Area Telescope (LAT) onboard the Fermi satellite and three of them are above 10 GeV. The joint analysis of the LAT and Gamma-ray Bursts Monitor (GBM) data suggests a featureless Band spectrum in the energy range 8 keV–10 GeV (Abdo et al. 2009a). A straightforward interpretation of the spectrum is that the synchrotron radiation of internal shock electrons. Such an interpretation, if correct, demands a very large bulk Lorentz factor $\Gamma_{i} \sim 10^{3}$ of the emitting/shocked region (Abdo et al. 2009a; Greiner et al. 2009b). In the internal shock scenario, the fast shells should move faster and the corresponding bulk Lorentz factor should be $\Gamma_{i} \sim 5\Gamma_{r}$, otherwise the internal shock efficiency will be too low to match the observations (e.g., Piran 1999). The photosphere radius of the fast shells is $R_{ph} \sim 5 \times 10^{9}$ cm $L_{54}^{-1/3}R_{10}^{-1}$ (Paczynski 1990), where $L$ is the total luminosity of the burst. On the other hand, for a baryonic shell we have $\Gamma_{i} \lesssim R_{ph}/R_{0} \sim 5 \times 10^{1}L_{54}^{-1/3}R_{10}^{-1}$ (Piran 1999), where $R_{0} > 10^{9}$ cm is the size of the central engine. So the shell becomes transparent at the late stage of its acceleration. As a result, the thermal radiation of these shells will be too strong to be effectively outshone by the internal shock non-thermal emission, in disagreement with the data (Fan 2009; see Zhang & Pe’er 2009 for the other approach). Hence we would not discuss the standard/unmagnetized internal shock model for this burst.

An interesting possibility is that the prompt emission has a very soft MeV–GeV spectrum and the GeV photons are due to the synchrotron radiation of the external forward shock (Kumar & Barniol Duran 2009). Here we outline a few potential challenges of such a model. (1) In the forward shock model, the variability of the radiation is determined by the angular timescale $T_{ang}$, which is $\sim t$ as long as the edge of the emitting region is invisible (Piran 1999). So the light curve should be smooth. The variability shown in the LAT data then disfavors the external forward shock model. (2) For the initial outflow expanding into the wind medium (see Section 3 for the medium identification), strong reverse shock may form. The bulk Lorentz factor of the shocked medium will be almost a constant (Chevalier & Li 2000). A strong reverse shock exists till $t \sim T_{90}/2$. In such a phase, we have the magnetic field strength $B \propto t^{-1}$, the maximum specific flux $F_{\nu, max} \propto t^{0.5}$, the typical synchrotron frequency $\nu_{m} \propto t^{-1}$, and the cooling frequency $\nu_{c} \propto t$. Hence the synchrotron radiation flux in the LAT band can be estimated as $F_{\nu} = F_{\nu, max}^{V_{m}/V_{p}-1/2}V_{c}^{1/2}t^{(2-p)/2}$ for $h\nu_{c} <$...
100 MeV, inconsistent with the observation, where \( p \) is the power-law distribution index of the accelerated electrons at the shock front (see Xue et al. 2009, for extensive discussion). Since the reverse shock emission has not been detected in most GRBs and it is not clear whether the model suffers some disadvantages, we do not take the current temporal inconsistency as a conclusive argument. (3) To reproduce the prompt spectrum, the forward shock emission at \( t \sim 10 \) s should have \( h_{\nu m} \sim 300 \) keV. At such early time, the synchrotron self-Compton radiation is in extreme Klein–Nishina regime and the Compton parameter \( Y \sim 0 \). With proper parameters, \( V_{c} \) can be comparable to \( v_{\infty} \). So the sub-MeV spectrum can be \( F_{\nu} \propto v^{-\Gamma_{3}} \), steep enough to be consistent with the data. However, if \( v_{\infty} \sim 10^{30} (t/10^{-3})^{-2/3} \) Hz, the XRT light curve will be \( F_{\nu} \propto t^{0} \) for \( t < 10^{-3} \) s and the optical light curve will be \( F_{\nu opt} \propto t^{0} \) for \( t < 10^{5} \) s. These behaviors are very unusual and have not been detected in other GRB afterglows so far. The lack of observation of early afterglow of GRB 080916C, however, hampers us to test the model.

If the prompt high-energy emission of GRB 080916C was from the soft gamma-ray emitting region, a plausible origin of the GeV photons is the synchrotron radiation of electrons accelerated in magnetic energy dissipation of a Poynting-flux dominated outflow (Zhang & Pe'er 2009). A disadvantage of such a scenario is the difficulty of reproducing the hard low-energy spectrum (Fan 2009).

GRB 090510 was a short burst at a redshift \( z \sim 0.903 \) (Abdo et al. 2009b). The high-energy emission is much more intense than that of GRB 080916C and shows some variability, which disfavors the external forward shock model. In the time interval 0.5–0.6 s, the sub-MeV spectrum is very hard but the high-energy spectrum is very soft (Abdo et al. 2009b), possibly dominated by the photosphere emission of the baryonic shell.8 In the time interval 0.5–0.8 s, the high-energy spectrum gets harder and harder but the “thermal”-like MeV component is still evident. GeV emission is naturally produced in the IC scattering of the “photosphere” photons by the shocked electrons. The photosphere radius is \( \sim 6 \times 10^{11} \) cm \( L_{54} T_{4}^{13/4} \), where \( T_{4} \) is the bulk Lorentz factor of the shell. The internal shocks take place at a rather larger radius \( R_{\gamma} \sim T_{4}^{3/4} c \delta t/(1+z) \sim 1.5 \times 10^{15} \) cm \( T_{4}^{3/4} \delta t/(0.1 \) s), where \( \delta t \) is the detected variability timescale of the prompt emission. In the comoving frame of the emitting region, the seed/photosphere photons are moving along the radial direction and are highly anisotropic. In such a case, the strongest radiation is from an angle \( \sim 1/T_{4} \) relative to the line of sight (Fan & Piran 2006b). The arrival of the GeV photons will be delayed by a time \( \sim \delta t \) and the GeV radiation duration will be extended, in agreement with the observation. Below we show how to reproduce the high-energy spectrum \( F_{\nu} \propto v^{-0.54} \) in time interval 0.8–0.9 s. If the cooling of the electrons is dominated by the prompt soft gamma-rays with a luminosity \( L_{\gamma} \), the cooling Lorentz factor can be estimated by \( \gamma_{c, ic} \sim 5 L_{\gamma}^{1/4} R_{0}^{1/2} \) (Fan & Piran 2008). Here we do not take \( L_{\gamma} \sim 10^{52} \) erg s\(^{-1}\), the luminosity of the simultaneous soft gamma-ray emission, since in the photosphere-internal shock model the arrival of the upscattered photons is delayed, as already mentioned. The corresponding IC radiation frequency \( \nu_{c, ic} \sim \gamma_{c, ic}^{2} e_{\nu m} \sim 5 \times 10^{25} MeV(E_{\nu}/1 MeV)L_{\gamma}^{-1/2}R_{0}^{-3/2} \), where \( E_{\nu} \) is the typical energy of the seed photons. On the other hand, \( \gamma_{m, i} \approx 0.1 (m_{i}/m_{e}) (\Gamma_{sh} - 1)/3 \approx 100 (\epsilon_{i, i}/0.5) (\Gamma_{sh} - 1)/0.3 \) for \( p \sim 2.5 \), where \( \Gamma_{sh} \) is the parameter denoting the strength of the shocks. The corresponding IC radiation frequency is \( \nu_{m, ic} \sim \gamma_{m, i}^{2} e_{\nu m} \sim 10 \) GeV \( (\epsilon_{m, i}/100)^{-3/2}(E_{\nu}/1 MeV) \). The spectrum in the energy range \( \sim 10 \) MeV–10 GeV is \( F_{\nu} \propto v^{-1/2} \), consistent with the data. We note that in the time interval 0.9–2 s the soft gamma-ray emission is very weak while the GeV emission is still strong. These delayed GeV photons may be produced by the IC scattering of the soft gamma-rays by the electrons accelerated by the reverse shock or by the shocks generated in the collision of the late time \( t > 0.5 \) s outflow with the precursor outflow.

3. THE AFTERGLOW OF GRBs 080916C AND 090510

GRB 080916C. Swift XRT started to observe this source at about 17 hr after the Fermi trigger. In our data analysis, the X-ray light curve can be fitted by a single power law \( F_{\nu} \propto t^{-1.30 \pm 0.07} \) for \( 6.1 \times 10^{4} < t < 1.3 \times 10^{5} \) s and the XRT spectrum is \( F_{\nu} \propto v^{-0.50 \pm 0.16} \). The earliest optical/infrared observation started at \( t \sim 0.26 \) hr after the burst. The optical/NIR light curve can be well described by \( F_{\nu} \propto t^{-1.40 \pm 0.05} \). The optical to X-ray spectrum is consistent with a single power law \( F_{\nu} \propto v^{-0.63} \) (Greiner et al. 2009b). These facts suggest that the optical to X-ray afterglow emission is within the same regime. In the standard external shock model (e.g., Zhang & Mészáros 2004), the slow cooling spectrum takes the form \( F_{\nu} \propto v^{-(p+1)/2} \) and the decline should be either \( t^{3(1-p)/4} \) (ISM) or \( t^{1-3p}/4 \) (wind medium). One can see that the X-ray and optical afterglow data are in agreement with the wind medium model for \( p \sim 2.2 \) (see also Zou et al. 2009).

Assuming a GRB efficiency \( \epsilon \sim 0.2 \), the isotropic-equivalent kinetic energy of the outflow is \( E_{k} \sim 4 \times 10^{53} \) erg. In the wind case, the equations that govern the forward shock emission are (e.g., Yost et al. 2003)

\[
\nu_{m} \sim 3 \times 10^{14} Hz \epsilon_{e, -1}^{2} E_{B}^{1/2} C_{p}^{2} E_{55.6}^{1/2}(1+z)^{1/2} t^{-3/16}, \tag{1}
\]

\[
\nu_{c} \sim 1.7 \times 10^{13} Hz \epsilon_{e, -1}^{2} E_{55.6}^{3/2} A_{48}^{-1/2} (1+z)^{1/2} t^{-3/16} t_{48}^{1/4} (1+Y)^{-2}, \tag{2}
\]

\[
F_{\nu, max} \sim 100 \text{mJy}^{1/2} E_{B}^{1/16} A_{48}^{-1/2} t_{48}^{-1/2} (1+z)^{3/16} D_{L, 29.1}^{-2}. \tag{3}
\]

where \( C_{p} \equiv 13(p-2)/[3(p-1)] \) for \( p > 2.05 \), \( A_{48} = (M/10^{-5} M_{\odot} \text{ yr}^{-1})[v_{w}/(10^{8} \text{ cm s}^{-1})]^{-1} \) is the wind parameter, \( v_{w} \) is the speed of the wind, \( M \) is the mass-loss rate (Chevalier & Li 2000), and \( Y = [-1 + \sqrt{1+4/3(\epsilon_{e}/\epsilon_{B})}] / 2, \eta \sim \min[1, (v_{m}/v_{c})(p-2)/2] \), and \( \eta_{KS} \) is the factor reflecting the importance of the Klein–Nishina correction (see Appendix A of Fan & Piran 2006b for the expression).

Since \( v_{m} \) decreases with time while \( v_{c} \) increases with time, the current afterglow data suggest that \( \nu_{m} < (t < 10^{5} \) s \() \approx \nu_{opt}/\nu_{IR} \) and \( \nu_{c}(t = 6 \times 10^{5} \) s \() \sim v_{w} \approx 10^{18} \) Hz, i.e.,

\[
\epsilon_{e, -1}^{2} E_{B}^{1/2} \leq 5, \epsilon_{e, -1}^{3/2} A_{48}^{-2} (1+Y)^{-2} \geq 7 \times 10^{5}. \tag{4}
\]

At \( t < 10^{5} \) s, the \( K_{s} \)-band flux is \( \sim 3 \times 10^{-5} \) Jy (Greiner et al. 2009b), which gives us another constraint

\[
\epsilon_{e, -1}^{1/2} E_{B}^{1/2} \approx 7 \times 10^{-5}. \tag{5}
\]
$A_{k} \geq 10^{-5} \epsilon_{\text{iso}}^{2} / t_{\text{is}}^{1} - \epsilon_{B} \geq 10^{-4} \epsilon_{\text{iso}}^{2} / t_{\text{is}}^{1}$. Though the shock parameters cannot be uniquely determined, we see that the “reasonable” parameters ($\epsilon_{e}, \epsilon_{B}, A_{k}$) ~ (0.1, 2.5 × 10^{-3}, 0.01) can reproduce the data.

**GRB 090510.** In our data analysis, before and after the break at $t_{b} \sim 676(1+z)\text{s}$, the X-ray declines are $t^{-0.72 \pm 0.08}$ and $t^{-1.89 \pm 0.06}$, respectively. The X-ray spectrum can be reasonably fitted by $F_{e} \propto \nu^{-0.63 \pm 0.06}$. We reduced the UVOT data in a standard way with the aid of reduction threads at http://www.swift.ac.uk/UVOT.shtml. The combined V-band and white light curves show a rise since the beginning of UVOT observation to a peak around 1000 s after the BAT trigger, which is followed by an apparent decay leading to the optical flux lower than the threshold of UVOT quickly. Our results are generally in agreement with those of De Pasquale et al. (2009). Within the standard external shock model, the above data are roughly consistent with a slow cooling ejecta expanding into the ISM for $p \sim 2$, while the break can be interpreted as the jet effect (Piran 1999; Zhang & Mészáros 2004). The slowly rising optical emission may suggest that the observer’s frequency is below $v_{\text{m}}$. In the ISM case, the equations that govern the forward shock emission are (e.g., Sari et al. 1996; Yost et al. 2003)

$$v_{c} \approx 5.2 \times 10^{18} \text{Hz} \ E_{k,54}^{4/5} \ e_{B,-4}^{-1/2} (1 + z)^{-1/2} (1 + Y)^{-2},$$

then $v_{m} = 7.0 \times 10^{13} \text{Hz} \ E_{k,54}^{4/5} \ e_{B,-4}^{-1/2} (1 + z)^{-1/2} (1 + Y)^{-2},$ (5)

$$F_{r,\text{max}} = 2.7 \times 10^{-3} \text{Jy} (1 + z) D_{L,28.56}^{-2} (1 + z)^{-1/2} E_{k,54} n_{0}^{-1/2} \text{},$$

(6)

please note that $c_{P} (t = 1284 \text{s}) > v_{c}$, $v_{m} (t \sim 1000 \text{s}) \sim 5 \times 10^{14} \text{Hz}$, and $F_{r,\text{max}} \geq 1 \times 10^{-4} \text{Jy} (\text{De Pasquale et al. 2009})$ yield

$$E_{k,54}^{1/2} \ e_{B,-4}^{-3/2} (1 + Y)^{-2} \geq 0.2,$$

$$E_{k,54}^{1/2} \ e_{B,-4}^{-3/2} \geq 0.2.$$ (7)

The parameters ($E_{k,54}, \epsilon_{B,-4}, \epsilon_{e,-1}, n_{0}$) ~ (1, 1, 1, 7, 0.01) satisfy the above constraints (note that $Y \ll \sqrt{\epsilon_{e}} / \epsilon_{B}$ thanks to the Klein–Nishina correction). The jet break time $t_{b} = 1284 \text{s}$ suggest a half-opening angle $\theta_{j} = 6 \times 10^{-3} \ t_{5}^{-1} E_{k,54}^{1/3} \ e_{0,-7}^{1/3} \ t_{b,3}^{1/3}$.

So the true gamma-ray energy released is $E_{\nu,y} \propto \theta_{j}^{2} E_{\nu,y} / 2 = 2 \times 10^{48} \text{erg}$, where $E_{\nu,y} \sim 1.4 \times 10^{53} \text{erg}$ is the isotropic-equivalent gamma-ray energy.

**4. THE HIGH-ENERGY AFTERGLOW EMISSION**

4.1. **IC Scattering in the Forward Shock Region?**

If the high-energy afterglow is due to the IC radiation of the forward shock electrons, there is a simple method to estimate the number of seed photons, regardless of the origin of the seed photons (either the late prompt emission from the central engine or the synchrotron radiation of the forward shock electrons). Following Fan & Piran (2006b), the possibility of one seed photon being scattered (i.e., the optical depth) in the forward shock region can be estimated as

$$\tau_{\text{ISM}} \sim 4.2 \times 10^{-8} E_{k,54}^{1/4} n_{0}^{3/4} t_{3}^{1/4} [(1 + z)/2]^{-1/4},$$

(8)

respectively. With the parameters derived for GRBs 080916C and 090510, we have

$$\tau_{\text{wind}}(080916C) \sim \sim 10^{-9} A_{k,-2}^{3/2} E_{k,54}^{-1/2} [(1 + z)/2]^{-1/2},$$

$$\tau_{\text{ISM}}(090510) \sim \sim 7 \times 10^{-10} E_{k,54}^{1/4} n_{0}^{3/4} t_{3}^{1/4},$$

respectively.

If the detected high-energy afterglow photons are indeed the IC radiation of the forward shock electrons, the number flux of the seed photons will be

$$F_{\text{seed}} \sim \sim 10^{6} \text{MeV}/\tau.$$ (9)

For GRB 090916C, in the time interval ~100–1400 s (i.e., $\Delta t = 1300 \text{s}$), $F_{\text{seed}} \sim 7 \times 10^{-6} \text{ph cm}^{-2} \text{s}^{-1} (\text{Abdo et al. 2009a})$, so the number of total seed photons is

$$N_{\text{seed}} \sim 4 \pi D_{\text{L}}^{2} \Delta t F_{\text{seed}} \sim 6 \times 10^{64}.$$ (10)

If most seed photons are in the X-ray band, the total energy will be $\sim 10^{58} \text{erg}$, which is too large to be realistic. If the seed photons are mainly in optical/infrared band, the total energy will be $\sim 10^{55} \text{erg}$. Though bright infrared/optical flare can be produced in the afterglow phase by the prolonged activity of the central engine (for example, the infrared flare detected in GRB 080129; Greiner et al. 2009a; Gao 2009), it is clear that such events are very rare. So we think this kind of model is less likely.

**4.2. Synchrotron Radiation of Forward Shock Electrons?**

The spectrum of the synchrotron radiation of shocked electrons can extend to an energy ~30AT/(1+z) MeV (e.g., Cheng & Wei 1996), where $\Gamma$ is the bulk Lorentz factor of the emitting region and $A \sim 1, 2\pi r$, depending on the comoving acceleration timescale of the particles. But usually the IC scattering plays a more important role in producing high-energy afterglow emission. The situation changed in GRB 080319B, the naked-eye burst with abundant optical and X-ray afterglow data. With the well-constrained parameters, Zou et al. (2009, Figure 3 therein) have shown that the forward shock synchrotron radiation dominates over the synchrotron self-Compton radiation up to an energy ~10 GeV. The detection prospect for LAT is pretty good. Our estimated forward shock parameters of GRB 080916C are similar to those of GRB 080319B, a strong forward shock synchrotron GeV emission is naturally expected (see also Kumar & Barniol Duran 2009).

In the synchrotron radiation model, the random Lorentz factor of electrons emitting $\geq 100 \text{MeV}$ afterglow photons is so high that $\eta_{\text{ks}} \ll 1$ (e.g., Fan & Piran 2006a), one should take $Y \sim 0$ in calculating $v_{c}$, otherwise the radiation flux will be underestimated. For GRB 080916C, at $t \sim 400 \text{s}$, $v_{c} < 100 \text{MeV}$, the
flux \( F_{100\text{MeV}} = F_{\nu, \text{max}}(\nu/\nu_{\text{max}})^{-(p-1)/2}(100 \text{ MeV}/h\nu_{\gamma})^{-p/2} \sim 2.7 \times 10^{-5} \text{ Jy} \)
\( E_{\nu}^{-0.55} B_{-2.6}^{-1.2} t_{2.6}^{-1.15} D_{L,29.4}^{-2} \) and the corresponding energy flux is \( \sim 6.5 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1} \), matching the observation \( \sim 1.2 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1} \). For GRB 090510, at \( t \sim 5 \text{ s} \), \( h\nu_{\gamma} \sim 18 \text{ MeV} \), so the high-energy flux \( F_{100\text{MeV}} = F_{\nu, \text{max}}(\nu/\nu_{\text{max}})^{-(p-1)/2}(100 \text{ MeV}/h\nu_{\gamma})^{-p/2} \sim 2.0 \times 10^{-6} \text{ Jy} \ e_{\epsilon, -0.1} E_{\nu,54}^{-1} L_{\gamma,28.26}^{-2} \). The corresponding energy flux is \( \sim 5.0 \times 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \). The GeV photon flux recorded by AGILE is \( \sim 4 \times 10^{-5} \text{ ph cm}^{-2} \text{ s}^{-1} \) for \( t \sim 5 \text{ s} \) (see Figure 3 of Giuliani et al. 2009), suggesting an energy flux \( \sim 6.4 \times 10^{-7} \text{ erg cm}^{-2} \text{ s}^{-1} \). So the observation may be accounted for.

5. CONCLUSION AND DISCUSSION

In this work, we have interpreted the high-energy emission and the afterglow of GRB 080916C and 090510. For the prompt high-energy emission of GRB 080916C with a featureless Band spectrum, the standard/unmagnetized internal shock model is disfavored. The main reason is that in such a model the fast shells move with a very high bulk Lorentz factor \( (\sim 10^3) \) and the thermal radiation from their photospheres will be too strong to be hidden by the non-thermal emission of the internal shocks. As for the idea that the prompt GeV photons are the synchrotron radiation of the forward shock electrons, we predict very unusual X-ray (for \( t < 10^3 \text{ s} \)) and optical (for \( t < 1 \text{ day} \)) afterglow light curves. The lack of early afterglow observation, however, hampers us to test the model. If the prompt GeV photons and the soft gamma-rays are from the same region, a non-baryonic component seems needed (Zhang & Pe’er 2009; Fan 2009).

For GRB 090510, the prompt spectrum consists of two distinct components. The MeV emission may be from the photosphere, while the GeV emission is produced in the IC scattering of the photosphere photons by the shocked electrons. We suggest that the outflow of GRB 090510 is baryonic.

The circum-burst medium of GRBs 080916C and 090510 is wind-like and ISM, respectively. The standard external shock model can reproduce the afterglow data reasonably well. The common features are the low density of the medium they are expanding into and the very high isotropic-equivalent kinetic energy of the outflows. We have proposed a simple method to estimate the total number of seed photons supposing the GeV afterglow emission is due to the IC radiation of the forward shock electrons. Such a model is disfavored because the seed photons needed in the modeling are too many to be realistic. Though other possibilities, for example, the GeV afterglow photons are the synchrotron self-Compton radiation of the extended X-ray emission, cannot be ruled out, the high-energy afterglow detected in these two bursts may be just the synchrotron radiation of the forward shock electrons. Our analysis is then in support of the “prediction” of Zou et al. (2009) in GRB 080319B and the suggestion of Kumar & Barniol Duran (2009) for GRB 080916C. GRBs 080319B, 080916C, and 090510 are very unusual. They are extremely bright and may have a very large initial bulk Lorentz factor. Both facts are helpful to give rise to a strong GeV synchrotron radiation of the forward shock. The number density of the circum-burst medium is very low, which lowers the detection prospect of the IC radiation component for LAT. For normal GRBs, the detection prospect of the GeV synchrotron radiation of the forward shock will be much less promising.

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9 For the two long bursts \( E_{\gamma} \sim 10^{54} \text{ erg} \); while for the short burst GRB 090510 \( E_{\gamma} > 10^{55} \text{ erg} \). All are at least 1 order of magnitude brighter than the normal long and short GRBs.