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# Hyperstars – Main Origin of Short Gamma-Ray Bursts?

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**Abstract** Short-duration hard-spectrum gamma ray bursts (SHBs) such as 050509B, 050709, 050724 and 050813 could have been the narrowly beamed initial spike of hyperflares of soft gamma ray repeaters (SGRs) in galaxies at cosmological distances. Such bursts are expected if SGRs are young hyperstars, i.e., neutron stars where a considerable fraction of their neutrons have converted to hyperons and/or strange quark matter.

**Key words:** stars – stars: neutron – GRB

## 1 INTRODUCTION

Gamma-ray bursts (GRBs) divide into two distinct classes; long-duration ($T > 2$ s) bursts (long GRBs) and short-duration ($T < 2$ s) bursts with a harder spectrum (SHBs). There is mounting evidence from observations of optical afterglows (AGs) of relatively nearby long duration GRBs that they are produced by highly relativistic jets ejected in supernova (SN) explosions of massive stars, as long advocated by the cannonball model of GRBs (Dar & De Rújula 2004 and references therein). The origin of SHBs, however, is still unknown.

The leading scenarios for the origin of short GRBs, include, (a) merger of neutron-star (ns) or black hole (bh) binaries[1] (Goodman et al. 1987; Eichler et al. 1989; Mochkovitch et al. 1993), (b) gravitational collapse of accreting white dwarf (Dar & De Rújula 2003; Dar & De Rújula 2004), (c) gravitational collapse of neutron stars to strange-quark stars (Dar 1999) or hyperstars (Dar & De Rújula 2000) and (d) giant flares from soft gamma ray repeaters (SGRs) in external galaxies (Dar 2005; Hurley et al. 2005).

As of today, only SGRs are a proven source of short GRBs. SGRs are widely believed to be magnetars: slowly rotating neutron stars with ultra-strong surface magnetic field, $B \sim 10^{15}$ Gauss, misaligned with respect to their rotation axis, which spin down rapidly by magnetic dipole radiation and are powered by their large magnetic field energy. In the magnetar model of SGRs (Duncan & Thompson 1995), crustal instabilities lead occasionally to dissipation of their magnetic energy through large scale magnetic reconnection on their surface, which produce their X-ray and $\gamma$-ray flares. However, the energy release in such events cannot exceed the total magnetic field energy, $E_{\rm M} \sim B^2\, R^3/12$, where $B$ is their surface magnetic field which is constrained by their spin-down rate, and $R$ is the radius of the neutron star (ns). As of today, about 10 magnetar candidates are known and their $B$ field, as estimated from their spin down rate, is listed in Table 1. Even if the total field energy of such magnetars was released in a single short duration quasi-isotropic flare, the GRB energy could not have exceeded $5 \times 10^{46}$ erg.

Recently, the SWIFT and HETE satellites (e.g. Gehrels et al. 2004) provided the first rapid and accurate X-ray localization of four short GRBs, 050509b, 050509, 050724 and 050813, Their fluences were quite typical of short GRBs with durations $\leq 250$ ms, observed before by BATSE on board CGRO (Paciesas et al. 1999). Follow-up optical observations have detected a giant, non-star-forming elliptical galaxy at redshift $z = 0.225$ in the XRT error circle of GRB 050509b (Bloom et al. 2005), a bright star-forming galaxy at

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[1] Merger of neutron-star or black hole binaries was first suggested as possible origins of long GRBs, but, their localization in star-formation regions and their association with core collapse supernovae left this scenario viable only for short GRBs.

**Table 1** Magnetic Field Energy of SGRs and AXPs

| Identity | $P$ (s) | $\dot{P}^a$ ($10^{-11}$) | $\tau_c^b$ (kyr) | $B^c$ ($10^{14}$ G) | $E_B^d$ ($10^{46}$ erg) | SNR? |
|---|---|---|---|---|---|---|
| SGRs | | | | | | |
| SGR 0525−66 | 8 | 6.6 | 1.9 | 7.4 | 4.5 | N49 |
| SGR 1627−41 | 6.4? | ? | ? | ? | ? | no |
| SGR 1806−20 | 7.5 | 2.8 | 4.2 | 4.6 | 1.8 | no |
| SGR 1900+14 | 5.2 | 6.1 | 1.3 | 5.7 | 2.6 | no |
| AXPs | | | | | | |
| CXOU J011−7211? | 8.0 | ? | ? | ? | ? | no |
| 4U 0142+62 | 8.7 | 0.20 | 69 | 1.3 | 0.14 | no |
| 1E 1048.1−5937 | 6.4 | 3.3 | 3.0 | 4.7 | 1.8 | no |
| RX 1708−4009 | 11.0 | 1.9 | 9.2 | 4.6 | 1.8 | no |
| XTE J1810−197? | 5.5 | 1.5 | 7.6 | 2.5 | 0.52 | no |
| 1E 1841−0450 | 11.8 | 4.2 | 4.6 | 7.0 | 4.1 | Kes 73 |
| AX 1844−0258? | 7.0 | ? | ? | ? | ? | G29.6+0.1 |
| 1E 2259+586 | 7.0 | 0.048 | 220 | 0.6 | 0.03 | CTB 109 |

[a] Long-term average value.
[b] Characteristic age estimated from $P/2\dot{P}$.
[c] Surface dipolar magnetic field estimated from $3.2 \times 10^{19}(P\dot{P})^{1/2}$ G.
[d] Magnetic field energy estimated from $B^2 R^3/12$ erg.
Unknown or uncertain entry denoted by "?".

redshift $z = 0.16$ in the error circle of GRB 050709 (Price et al. 2005) and a bright elliptical galaxy in the XRT error circle of GRB 050724 at $z = 0.257$ (Berger et al. 2005), respectively, with a small chance probability. The observed brightness and energy fluence, and the measured redshifts of the SHBs imply that their intrinsic brightness is smaller than that of typical long GRBs by two to three orders of magnitude. Moreover, their inferred total emitted radiation, assuming isotropic emission, is smaller by four to five orders of magnitude. So it is quite possible that SHBs are seen at relatively small redshifts because most of them are intrinsically faint and cannot be seen from large cosmological distances. However, their equivalent isotropic energies are larger than either the equivalent isotropic gamma ray energy $\sim 4 \times 10^{46}$ erg, released by the giant flare from SGR 1860–20 on December 27, 2004 (Hurley et al. 2005) or the entire magnetic field energy of any known magnetar candidate, by more than 3 orders of magnitude (see Table 1). Because magnetars are not expected to produce highly collimated hyper-flares, this has been considered (e.g Gehrels et al. 2005) as conclusive evidence against the SGR origin of short GRBs at $z > 0.01$.

The non detection of a supernova in deep optical images of the host galaxy of GRB 050509b taken with large telescopes, such as Gemini (Bersier et al. 2005) and VLT (Hjorth et al. 2005) up to 3 weeks after burst, were used to argue (Hjorth et al. 2005) that "the absence of an SN rules out models [2] predicting a normal SNIa associated with short GRBs".

The association of GRB 050509b and GRB 050724 with non-star forming elliptical galaxies was advanced, e.g., by Gehrels et al. (2005), by Hjorth et al. (2005) and by Berger et al. (2005) as supporting evidence for the assumption that short GRBs are produced by ns-ns or ns-bh mergers. The observation that SHBs, such as GRB 050709, take place also in star-forming spiral galaxies does not contradict the n-n merger hypothesis as such mergers take place both in old elliptical galaxies and in star-forming spiral galaxies.

However, here I argue that hyperflares of SGRs may be observed from cosmological distances and can be the main source of the observed short GRBs. The giant flares/bursts from SGR 0526–66 on March 5, 1979, SGR 1900+14 on August 27, 1998 and SGR 1806–20 on December 27, 2004 consisted of an initial short ($< 0.5$ s) spike and a much longer ($> 200$ s) pulsating tail. While the spikes had quite different intensities and thermal bremsstrahlung spectra (e.g., Mazets er al. 2005; Palmer et al. 2005) the pulsating tails had similar durations, fluences and black body spectra (e.g., Mazets et al. 1999; Hurley et al. 2005). It suggests that, perhaps, the above three bursts/giant flares were similar bursts where the initial spike was

[2] Short GRBs may have more than a single origin. Evidence from a single GRB may rule out certain sources for that particular GRB, but, it cannot "rule out" any source for other GRBs.

generated by the beamed emission of a relativistic jet (e.g., by inverse Compton scattering of ambient light) and the differences were mainly because of different viewing angles of the jet, while the similar pulsating tail was a black body surface emission with an enhanced temperature near the polar caps. The detected radio afterglows from the giant flares of SGR 1900+14 (Frail et al. 1999) and SGR 1806–20 (Cameron et al. 2005; Gaensler et al. 2005) provide additional evidence that relativistic jets are ejected in giant flares of SGRs (Yamazaki et al. 2005). In this talk I argue that SGRs are not magnetars, but are hyperstars (Dar & Re Rújula 2000), i.e. ns's where a significant fraction of their neutrons are converting to hyperons or strange quark matter, releasing gravitational binding energy which accumulates and causes eruptions with ejection of collimated bipolar jets along their magnetic axis. These jetted ejections presumably produce the initial short and bright spike of giant flares, which appear as short GRBs from cosmological distances. Like in ordinary pulsars, the ejection mechanism of the collimated jets is not clear.

## 2 HYPERSTARS

Ordinary nuclear matter is made entirely of neutrons and protons which contain only valence $u$ and $d$ quarks. Baryons that contain $s$ ("strange") quarks, such as $\Sigma$ and $\Lambda$ , were first discovered in the late 40's and early 50's of the last century and were named 'hyperons'. It was speculated long ago that strange matter made of $u$, $d$ and $s$ quarks can be the true ground state of hadronic matter (Bodmer 1971; Witten 1984) and that the interior of neutron-like star consists of such deconfined quarks and not of neutrons. It was also suggested that there may be no ns's and all neutron-like stars are strange quark stars (Alcock et al. 1986) containing approximately equal numbers of deconfined $u$, $d$ and $s$ quarks. Even if strange quark matter is not the true ground state of hadronic matter, hyper matter bound by a strong gravitational potential can still be the ground state of nuclear matter in hyperstars – ns's where a significant fraction of their neutrons have converted to hyperons. Both in ns's and in hyperstars, neutrons and hyperons do not decay because the quantum states of their Fermionic decay products are already occupied in the star (Pauli blocking). Indeed, simple arguments strongly suggest that slowly-rotating, cold ns's have a critical mass beyond which they collapse to hyperstars which continue to be hyperactive and release gravitational binding energy by gradual contraction, first due to the conversion $n\,n\,\rightarrow\,p\,\Sigma^-$ and later also due to $n\,n\,\rightarrow\,n\,\Lambda$ and $n\,n\,\rightarrow\,n\,\Sigma^0$ conversions:

For instance, ignoring first general-relativistic corrections, the radius and central density $\rho_{\rm c}$ of a self-gravitating degenerate Fermi gas of neutrons of total baryonic mass M and zero angular momentum obtained from a (postulated) polytropic (Emden-Lane) solution of the hydrostatic equation are,

$$R \approx 15.1 \left(\frac{M}{M_\odot}\right)^{-1/3} \,{\rm km}, \tag{1}$$

$$\rho_{\rm c} \approx 6\,\bar\rho \approx 0.83\times 10^{15} \left(\frac{M}{M_\odot}\right)^{2} \,{\rm g\ cm^{-3}}. \tag{2}$$

In this simplest of models, low mass ns should indeed be made of neutrons and a small fraction of protons and electrons to assure stability against their $\beta$ decay,

$$n_{\rm p} \approx \left[\frac{h\,c}{m_{\rm n}\,c^2}\right]^3 \frac{3\,n_{\rm n}^2}{64\,\pi}\,. \tag{3}$$

But as $M$ is increased past $\sim\,1\,M_\odot$, $\rho_{\rm c}$ increases until the central Fermi energy $\epsilon_{\rm f}(n)\,=\,(h^2/8\,m_{\rm n})$ $(3\,\rho_{\rm c}/\pi\,m_n)^{2/3}$ exceeds $(m_{\Sigma^-}+m_p-2\,m_n)\,c^2+\epsilon_{\rm f}(p)$. At this point, it is favourable for the strangeness changing weak process $n\,n\,\rightarrow\,p\,\Sigma^-$ (or $u\,d\,\rightarrow\,s\,u$) to start transforming neutron pairs at the top of the Fermi sea into (initially pressureless) $\Sigma^-$ p pairs at the bottom of the sea. This reduces the pressure, causes contraction and increases $\rho_{\rm c}$, which initiates a run-away strangeness changing reactions which stop only when the balance of chemical potentials of the various species, mainly $n\,,p\,,\Lambda\,,\Sigma$ and $e^-$ guarantees $\beta$ stability.

Although this argument is based on Newtonian gravity, it is valid also in general relativity because general relativity produces a stronger effective gravity at short distances, i.e. gravity becomes singular at zero distance in Newtonian gravity, while in general relativity, it becomes 'infinite' already at the Schwartzchild radius, $R_{\rm s} = 2\,G\,M/c^2$ . Consequently, it yields larger central densities and enforces the transition to a hyper star.

In general relativity, slowly rotating ns's satisfy the Tolman- Oppenheimer-Volkoff (TOV) equations (Tolman 1939; Oppenheimer & Volkoff 1939) for hydrostatic equilibrium,

$$\frac{dP}{dr} = -\frac{G}{r}\frac{[\epsilon + P]\,[M + 4\,\pi\,r^3\,P]}{[r - 2\,G\,M]}\,, \tag{4}$$

$$\frac{dM}{dr} = 4\,\pi\,r^2\,\epsilon\,, \tag{5}$$

where $P$ and $\epsilon$ are, respectively, the pressure and total energy density in the star ($c = 1$), $G$ is the gravitational constant and $M(r)$ is the gravitational mass inside radius $r$ . The TOV equations set a limit $R > (9/4)\,G\,M/c^2 = 1.125\,R_{\rm s}$ for maximal compact stars, which is much smaller than the radius of a canonical ns. The actual radius of a compact star is determined by the solutions of the TOV equations, which are rather sensitive to the equation of state $\epsilon(\rho,\,P)$ of baryonic matter at sub-nuclear, nuclear and super nuclear densities and pressures which are below the densities where quantum chromodynamics (QCD) becomes asymptotically free. They cannot be calculated yet from first principles. Thus, the precise properties of strange quark stars and hyperstars cannot yet be predicted reliably enough for establishing their existence from astronomical observations. Rather than adopting a specific model, we will assume that SGRs are hyperstars with a gravitational mass similar to that of canonical ns's, $M \approx 1.4\,M_\odot\,, t$ and with a radius significantly smaller than that of ns's, and that their energy source is gravitational contraction induced by the transition from neutron matter to hyper matter.

Is there supportive evidence that the slowly rotating SGRs and anomalous X-ray pulsars (AXPs) are objects much more compact than ordinary ns's? The best supportive evidence that the slowly rotating SGRs and AXPs are hyperstars with a radius significantly smaller than that of ordinary radio pulsars, may come from the black body component of their persistent emission (Dar and De Rújula 2000) and/or from the redshift of $e^+e^-$ annihilation line if emitted near their surface. The application of the Stefan-Boltzman law to their black body emission yields, $F_{\rm X} = \sigma_{\rm B}\,R_\infty^2\,T_\infty^4\,/d^2$ where $\sigma_B$ is the Stefan-Boltzman constant, and $T_\infty$ and $R_\infty$ are, respectively, the stellar effective surface temperature and radius as inferred from measurements of the spectral flux density $F_{\rm X}$ at a large distance $d$ from the star. The true stellar radius $R$ and the effective radius $R_\infty$ are related through, $R = R_\infty/(1+z)$ where $(1+z) = [1 - 2\,G\,M/R\,c^2]^{-1}$ is the gravitational redshift factor. Unfortunately, the values of $R_\infty$ which may be extracted from black body fits to accurate spectral energy flux measurements of SGRs and AXPs in the soft X-ray region (e.g. by XMM) are proportional to their uncertain distances and are also sensitive to the extinction along the line of sight.

## 3 SHBS FROM HYPERSTARS

### 3.1 Bright SHBs from the Birth of SGRs/Hyperstars

The total energy release in the transition of an ns to a hyper star is $\sim 50\%$ of the gravitational energy release, because $\sim$ half of the gravitational energy release is used to increase the pressure and energy of the Fermi gas. The total energy release for, e.g. an Emden-Lane polytrop is approximately

$$\Delta E \sim \left(\frac{2\,G\,M^2}{7\,R_{\rm hs}}\right)\frac{R_{\rm ns} - R_{\rm hs}}{R_{\rm ns}} \approx 5\times 10^{52}\,{\rm erg}\,, \tag{6}$$

where the transition from an ns with a canonical $M_{\rm ns} = 1.4\,M_\odot$ to a cold hyper star changes its radius from $R_{\rm ns} \sim 10\,{\rm km}$ to $R_{\rm hs} \sim 7\,{\rm km}$, the typical radius of a hyper star. Most of this internal release of energy can be radiated away in a very short burst of neutrinos and antineutrinos. The dynamical time scale of the collapse is very short, $\tau \sim 1/\sqrt{G\,\bar\rho} \leq$ ms, yielding a relatively high efficiency of neutrino annihilation to $e^+e^-$ pairs outside the bare hyperstar which can produce a relativistic $e^+, e^-, \gamma$ fireball and a GRB with an isotropic energy of $\sim 10^{50} - 10^{51}$ erg (Goodman et al. 1987). Such bursts can be seen from Gpc distances. However, the estimated birth-rate of SGRs $R \approx \Sigma_i 1/\tau_i$ from their spin down ages $\tau_i$ (see Table 1) is $\sim 1/750\,{\rm yr}^{-1}$ in our Galaxy and $\sim 2\times 10^6$ yr$^{-1}$ within a luminosity distance of $\sim 2\,$Gpc assuming that their birth rate is proportional to the star formation rate ($\sim (1+z)^4$, for $z < 1$, e.g. Perez-Gonzalez et al. 2005 and references therein). Hence, if the birth of SGRs produces GRBs, they must be highly collimated, i.e., produced by highly relativistic bipolar jets, presumably along their magnetic axis, like in core collapse SN explosions. But, SGRs are young pulsars (see Table 1). As such, they may be born inside supernova remnants (SNR) of core collapse or accretion induced collapse supernovae. Thus, in the cannonball model of GRBs (Dar & De Rújula 2004), inverse Compton scattering of light emitted or scattered by the SNR by electrons in the jet may produce an SHB which is dimmer than ordinary long GRBs and is not associated with an SN akin to SN 1998bw.

### 3.2 Repeated SHBs from SGRs/Hyperstars

The left over internal thermal energy from the birth of a hyperstar can be radiated over a long time, comparable to the cooling time of a newly born ns. Loss of angular momentum by relativistic particle emission along open magnetic lines (Dar and De Rújula 2000) and cooling reduce the centrifugal and thermal support. The resulting contraction converts more neutrons to hyperons in internal layers. The heat released by the gradual phase transition from neutron matter to hyper matter may be radiated continuously or in bursts/flares. A large energy release in the star from a phase transition in a stellar layer (neutronization near the crust or hyperonization in more internal layers) may result in bipolar relativistic jets along the magnetic axis and thermal emission from the surface, which generate a hyper flare.

A large phase transition may take place over a short time comparable to the dynamical time scale of the star (<ms), but the duration of the burst depends both on the duration of the jetted ejection and on the environment of the hyper star. No doubt, the bursting activity of hyperstars is a very complex phenomenon whose theoretical study will require many more years. At present, only rough estimates of the total energy and the spectral, temporal and angular properties of the initial burst and the following bursting activity can be made. They will be described in detail elsewhere (Dado, Dar and De Rújula, in preparation).

Roughly, the cooling and continuous contraction of a hyperstar can power a total luminosity:

$$L \simeq \left(\frac{2\,G\,M^2}{7\,R}\right)\frac{\dot{R}}{R}\,. \tag{7}$$

For the canonical $M = 1.4\,M_\odot$ and $R = 10\,\mathrm{km}$ a contraction rate of $\dot{R} \sim 2\,\mu\mathrm{m\,yr^{-1}}$ (a tiny $\dot{R}/R \sim 2\times 10^{-9}\,\mathrm{yr^{-1}}$ is sufficient to provide the inferred total luminosity, $L_\mathrm{X} \leq 10^{36}$ erg s$^{-1}$, of SGRs and anomalous X-ray pulsars (AXPs). But for the explicit numerical coefficient, Eq. (7) should, on dimensional grounds, be approximately correct in general.

If ${E_\gamma}'$ is the total energy radiated isotropically in the rest frame of a jet moving at an angle $\theta$ relative to the line of sight with a bulk motion Lorentz factor $\gamma = 1/\sqrt{1-\beta^2}$ (Doppler factor, $\delta = 1/\gamma\,(1-\beta\,\cos\theta)$), then Doppler boosting and relativistic beaming yield a fluence,

$$F_\gamma \approx \delta^3\,\frac{(1+z)\,E'_\gamma}{4\,\pi\,D_\mathrm{L}^2}\,, \tag{8}$$

where $z$ is the redshift and $D_\mathrm{L}$ is the luminosity distance of the SGR. The inferred 'equivalent GRB isotropic $\gamma$-ray energy' of a GRB pulse, is

$$E_\gamma^\mathrm{iso} = \frac{4\,\pi\,D_\mathrm{L}^2\,F_\gamma}{1+z} \approx \delta^3\,E'_\gamma\,. \tag{9}$$

For small viewing angles, $\theta^2 \ll 1$, and large Lorentz factors, $\gamma^2 \gg 1$,

$$\delta \approx \frac{2\gamma}{1+\gamma^2\,\theta^2}\,. \tag{10}$$

For $\gamma \gg 1$, it is by far more likely that a beamed GRB from a Galactic SGR is observed with a viewing angle $\theta \gg 1/\gamma$ than with a viewing angle $\theta \leq 1/\gamma$. For $\theta \gg 1/\gamma$, Eqs. (9), (10) yield $E_\gamma^\mathrm{iso} \propto \delta^3 \propto \theta^{-6}$. Thus, if the initial short spike of SGR 1806–20 on December 27, 2004 with $E_\gamma^\mathrm{iso} \approx 5\times 10^{46}$ erg was produced by a relativistic jet, which was viewed from an angle $\theta \gg 1/\gamma$, it could have been seen at a redshift $z = 0.25$, as a short GRB with an isotropic energy $\sim 4\times 10^{50}$ erg, similar to that of the short GRBs 050509b, 050709 and 050724, if its viewing angle was smaller by a factor $\sim 3$. Note that this is independent of the value of $\gamma$ provided that $\theta \gg 1/\gamma$.

## 4 THE BRIGHTNESS DISTRIBUTION OF SHORT GRBS

Long duration GRBs seem to be produced by highly relativistic jets ejected from mass accretion on a proto-neutron star or a black hole in core collapse SN explosions (see, e.g. Dar and De Rújula 2004). They are detected up to very large redshifts. Short duration GRBs, if produced by SGRs are much dimmer and are detected from smaller distances where the geometry of the Universe is nearly Euclidean. In a steady state Euclidean universe, the number $n(>P)$ of GRBs with peak photon fluxes exceeding $P$ behaves like $P^{-3/2}$, independent of beaming, for $P \geq P_{\rm min}$, where $P_{\rm min}$ is the detection threshold. Cosmic evolution modifies this behaviour for large values of $z$ (low values of $P$). If short GRBs are relatively much nearer they should deviate less from a $P^{-3/2}$ behaviour. Figure 1 presents plots of $n(>P)$ for the long ($T_{90} > 2$ s) and short duration ($T_{90}$ <1 s) GRBs (circles) in the 4-th BATSE catalog (Paciesas et al. 1999). A small number (11) of GRBs with 1s< $T_{90}$ <2s, which can belong to the tail of either one of the two distributions, were not included in the plots. The lines are best fitted power-laws. The best fitted power-law indices are, $-1.45 \pm 0.11$ with $\chi^2/{\rm dof} = 0.33$ and $-1.42 \pm 0.28$ with $\chi^2/{\rm dof} = 0.14$, respectively, compatible with the expectation. However, the deviation from the $n(>P) \sim P^{-3/2}$ law seen in Fig. 1 is much larger for long duration GRBs than for short duration GRBs, consistent with our expectation. It suggests that the distances of short GRBs in the BATSE 4-th catalog extend up to a much shorter distance than that of long GRBs.

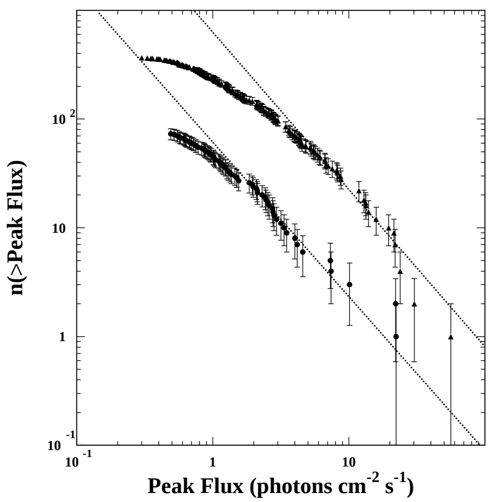


**Fig. 1** The number of long duration ($T_{90} > 2$ s) GRBs (triangles) and short duration ($T_{90} < 1$ s) GRBs (circles) in the 4-th BATSE catalog (Paciesas et al. 1999) with peak photon flux above the indicated value. The lines are the best fitted power-law to the distribution of GRBs with peak flux $> 5\,{\rm cm}^{-2}\,{\rm s}^{-1}$ and $> 2\,{\rm cm}^{-2}\,{\rm s}^{-1}$, respectively. The best fitted power-law indices are, $-1.45 \pm 0.11$ with $\chi^2/{\rm dof} = 0.33$ and $-1.42 \pm 0.27$ with $\chi^2/{\rm dof} = 0.14$, respectively.

## 5 CONCLUSIONS

- Short GRBs from cosmological distances may be produced mainly by hyperflares from SGRs, if the initial spike of their hyperflares is highly beamed. Such hyperflares may be the result of phase transitions from neutron matter to hyperon or strange-quark matter in hyperstars.
- The so called 'peak energy' of short GRBs ($E_{\rm p} = E$ at max$\{E_\gamma^2\, dn_\gamma/dE\}$), in the BATSE sample (Paciesas et al. 1999) is slightly higher than that of long GRBs. However, in the rest frames of their progenitors, they may be quite similar. In the CB model of GRBs (e.g., Dar and De Rújula 2004), this suggests similar Lorentz factors $\gamma$ (and consequently similar beaming effects) in short and Long GRBs. Then, their different luminosities/equivalent isotropic $\gamma$-ray energies may result from a smaller baryon

number of the jet ejected in a hyperflare and/or a smaller density of the ambient light ('glory') near SGRs, than those in long GRBs which are produced in SN explosions.

- The shorter duration of the pulses of short GRBs relative to long GRBs (McBreen et al. 2003) may result from a smaller scale-height of the ambient light (glory) around SGRs.
- Although anomalous pulsars (SGRs and AXPs) are very young pulsars ($\tau < 10^4$ yr), and the typical kick velocity of pulsars ($\sim 400\,\mathrm{km\,s^{-1}}$) is much smaller than the typical velocity of the spherical ejecta in SN explosions, only a fraction of them are found within/near young SNRs (see Table 1). This indicate that SGRs may be born not only in core collapse SN explosions but also in, e.g. accretion induced collapse of white dwarfs. This may explain why short GRBs are produced both in elliptical galaxies with old stellar populations and in star-forming spiral galaxies with young stellar populations.
- Finally, the rate of hyperflares from Galactic SGRs ($\sim 10^{-1}\,\mathrm{yr}^{-1}$) is much larger than the estimated rate of ns-ns and ns-bh mergers in the Galaxy ($\sim 1.8 \times 10^{-4}\,\mathrm{yr}^{-1}$; Kalogera et al. 2004). In the CB model, it makes SGRs a much more likely source of short GRBs than ns-ns or ns-bh merger.

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## References


Alcock, C., Farhi, E. & Olinto, A. 1986, ApJ, 310, 261
Berger, E. et al. 2005, astro-ph/0508115
Bersier, D., Fruchter, A., Rhoads, J., et al. 2005, GCN Circ. 3521
Bloom, J. S., et al. 2005, astro-ph/0505480
Bodmer, A. R. 1971, Phys. Rev. D. 4, 1601
Cameron, P. B., Chandra, P., Ray, A., et al. 2005, Nature, 434, 1112
Dar, A. 1999, A&AS, 138, 505
Dar, A. 2005, GCN Circ. 2942
Dar, A. & De R´ujula, A. 2000, *Results and Perspectives in Particle Physics* (ed. M. Greco) Vol. XVII, 13 (astro-ph/0002014)
Dar, A. & De R´ujula, A. 2003, GCN Circ. 2174
Dar, A. & De R´ujula, A. 2004, Physics Reports, 405, 203
Duncan, R. & Thompson, C. 1995, MNRAS, 275, 255
Eichler, D., Livio, M., Piran, T. & Schramm, D. N. 1989, Nature, 340, 126
Frail, D. A., Kulkarni, S. R. & Bloom, J. S. 1999, Nature, 398, 127
Gaensler, B. M, Kouveliotou, C., Gelfand, J. D., et al. 2005, Nature, 434, 1104
Gehrels, N., Chincarini, G., Giommi, P., et al. 2004, ApJ, 611, 1005
Gehrels, N., et al. 2005, Nature, submitted (astro-ph/0505630)
Germany, L. M., et al. 2004, A&A 415, 863
Glendening, N. K. 2000, *Compact Stars* (Springer-Verlag, N.Y. 2000)
Goodman, J., Dar, A., & Nussinov, S. 1987, ApJ, 314, L7
Hjorth, J., et al. 2005, astro-ph/0506123
Hurley, K., et al. 2005, Nature, 434, 1098
Kalogera, V., et al. 2004, ApJ. 601, L179
Lattimer, J. M. & Prakash M. 2004, 304, 536
Mazets, E. P., Cline, T. L., Aptekar, R. L., et al. 1999, Ast. L., 25, 635
Mazets, E. P., Cline, T. L., Aptekar, R. L., et al. 2005, astro-ph/0502541
McBreen, S., et al. 2003, AIP, 662, 280
Mochkovitch, R., Hernanz, M., Isern, J. & Martin, X. 1993, Nature, 361
Schlegel, D. J., Finkbeiner, D. P. & Davis, M. 1998, ApJ, 500, 525
Oppenheimer, J. R. & Volkoff, G. M. 1939, Phys. Rev. 55, 374
Paciesas, W. S., et al. 1999, ApJS, 122, 465
Palmer, D. M., Barthelmy, S., Gehrels, N., et al. 2005, Nature, 434, 1107
Perez-Gonzalez, P. G., Rieke, G. H., Egami, E., et al. 2005, astro-ph/0505101
Price, P. A., et al. 2005, GCN Circ. 3605
Tolman, R. C. 1939, Phys. Rev. 55, 364
Witten, E. 1984, Phys. Rev. D. 30, 272
Woods, P. M. & Thompson, C. 2004, astro-ph/0406133
Yamazaki, R., Ioka, K., Takahara, F., Shibazaki, N. 2005, PASJ, 57, L11, 2005