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GRBs, SGRs by UHE leptons showering, blazing and re-brightening by precessing Gamma Jets in-off axis

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Abstract A list of questions regarding Gamma Ray Bursts (GRBs) and Soft Gamma Repeaters (SGRs) remain unanswered within the Fireball and Magnetar scenarios. We argue that a persistent, thin (less than few μsr) precessing and spinning gamma jet, with the same power (not just energy) of the progenitor supernova (SN) may explain these issues. The jets may have precessing time scales of a few hours but their lifetime, while decaying, could be as long as thousands of years. The orientation of the beam respect to the line of sight plays a key role in this scenario: the farthest GRB events correspond to a wider volume and mostly very narrow and on-axis beam, while for the nearest detectable ones has a the beam mostly off-axis. Relic neutron stars, anomalous X-ray Pulsars (AXRPs), with their spinning and precessing jets are the candidate blazing sources of earlier GRBs (born at Supernova peak activity) and late SGRs respectively. A side view of such a precessing jet may correspond to SS 433 and micro-quasars jet traces. The 'delayed' gamma jets (even weeks or months after the SN) blazing the observer might appear without the earliest SN bright optical transient (OT), contrary to those events where the SN and the GRB occur nearly at the same time; the OT is the result of a wider beamed Jet polluted by the SN lights and baryon halos. Delayed jets are observable in the local universe as X-Ray Flahes (XRFs) or short GRBs and at closer distances as SGRs and anomalous X-ray Pulsars AXRPs.

Key words: Gamma-Ray Bursts – pulsars – X-rays

1 INTRODUCTION: GRB-SGR OPEN QUESTIONS

Why GRBs are so spread in their total apparent (isotropic) energy, (above 6 orders of magnitude) and in their peak energy (quantities following the so-called Amati correlation; Amati et al. 2006, see also Fargion 1999)? Why these relation is even more dramatic in their power luminosity (Yonetoku et al. 2004)?

Does the Amati correlation imply the existence of more and more new GRB families spread in different output? Beaming, of course may explain it (but not just within Fireball-cone scenario by only three order of magnitude cone beaming). Why are the harder and more variable GRBs (Lazzati et al. 2006, Fargion 1999) found mainly at higher redshifts contrary to expected Hubble law? Why does the output power of GRB vary in a range (see also Fargion 1999) of 8–9 orders of magnitudes with the most powerful events residing at the cosmic edges (Yonetoku et al. 2004)? Why has it been possible to find in the local universe (40–150 Mpc) at least two nearby events (GRB 980425 at $z = 0.008$ and recent GRB 060218 at $z = 0.03$)[a]? Most GRBs should be located at $z \geq 1$ (Fargion 1999). Why are these two GRBs so much under-luminous (Fargion 1999)? Why are they so slow? Why do their afterglows show so many bumps and re-brightening

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[a] The very recent discovers of a second nearest GRB 060218 and of an extremely short GRBs, but with a longevous life X-ray afterglow, GRB 050724,because its long multi-rebrightening is testing the persistent jet activity and geometrical blazing views; they have been discovered just after the Vulcano presentation in May 2005, but they are introduced here to update the article.

as the well-known third nearest event, GRB 030329? Why they (as GRB 060218) hold so long? Why do not many GRB curves show a simple one-shoot monotonic decay (an obvious consequence of a single explosive event), rather they often show sudden re-brightening or bumpy afterglows at different time scales and wave-lengths (Stanek et al. 2006; Fargion 2003; see e.g. GRB 050502B, Falcone et al. 2005, 2006);why invoking always ad hoc shock waves at very different halo interactions places? Why have there been a few GRBs and SGRs whose spectra and time structure are almost identical if their origin is so different (beamed explosion for GRB versus isotropic magnetar) (Fargion 1999, Woods et al. 1999)? How can a jetted fireball (with an opening angle of $5^{\circ} - 10^{\circ}$) release a power (not just energy) nearly 6 orders of magnitude (spread among themselves) while being more power-full (by $5 - 10$ order of magnitude) than the corresponding isotropic SN powers? How can re-brightening take place in the X-ray and optical afterglows (Fargion 2003)? How can some ($\sim 6\%$) of the GRBs (or a few SGRs) survive the 'tiny' (but still extremely powerful, if isotropic) explosion of its $precursor$ without any consequences, and, later on explode, catastrophically, minutes later? In such a scenario, how could the very recent GRB 060124 (at redshift $z = 2.3$) be preceded by a 10 minutes precursor, and then being able to produce multiple bursts hundreds of times brighter? Why do not huge SGRs, such as SGR 1806–20, show evidence of the loss of angular velocity, while their hypothetical magnetic energy reservoir has been largely exhausted? Why do SGR 1806 radio afterglows show a mysterious two-bump radio curve implying additional energy injection many days later? In this connection why are the GRB 021004 light curves (from X to radio) calling for an early and late energy injection? Why has the SGR 1806 polarization curve been changing angle radically in short ($\sim$ days) timescale? Why is the short GRB 050724 able to bump and re-bright a day after the main burst Campana et al. 2006? Once these major questions are addressed and (in our opinion) mostly solved by our precessing gamma jet model, a final question still remains, calling for a radical assumption on the thin precessing gamma jet: how can an ultra-relativistic electron beam (in any kind of Jet models either explosive or alive) survive the SN background lights and dense matter layers and escape in the outer space while remaining collimated?

Such questions are ignored in most Fireball models that try to fit the very different GRB afterglow light curves with polynomial curves and-or with unrealistic ad-hoc shell mass redistribution around the GRB event. Their solution forces us more and more to the precessing Gamma Jet model feed by the PeV-TeV lepton showering discussed below. As we will show, the thin gamma precessing jet is indeed made by a chain of primary processes (PeV muon pair bundles decaying into electrons and then radiating via synchrotron radiation), requiring an inner ultra-relativistic jet inside the source.

In our scenario the gamma jet is originated by ultra-relativistic electron pairs showering via Synchrotron (or Inverse Compton) radiation outside of the dense SN core (or the strong neutron star magnetic field). We propose that the escape of the electron pairs from the inner core occurs thanks to a more penetrating carrier, the relativistic PeV muon pairs, themselves secondaries of inner UHE hadron jets. Such leptons are almost 'transparent' when they propagate through the SN shells of matter and its radiative background, thus they are able to decay far away in to electron pairs (and later on) in gamma and neutrinos jets. One of us Fargion, 2006 had foreseen that such a nearby off-axis GRBs would be accompanied by a chain of OT and radio bumps and possible re-brightening, as in earlier GRB 030329-SN 2003, as it has been indeed observed in last light curve in SN 060218.

2 BLAZING PRECESSING JETS IN GRBS AND SGRS

The huge GRBs luminosity (up to 10^{54} erg s^{-1}) may be due to a high collimated, on-axis blazing jet powered by a Supernova output; the gamma jet is made by relativistic synchrotron radiation (or ICS) and the inner the jet the harder and the denser is its output. The harder the photon energy, the thinner is the jet opening angle $\Delta\theta \simeq \gamma^{-1}$, $\Delta\Omega \simeq \gamma^{-2}$, $\gamma \simeq 10^{4}$. The thin solid angle explains the rare SN-GRB connection and for instance the apparent GRB 990123 extraordinary power (billions of times the typical SN luminosity). This also explainss the rarer, because nearer, GRB-SN events such as GRB 980425 or GRB 060218, whose jets were off-axis $300 \cdot \gamma^{-1}$, i.e. a few degrees, (increasing its probability detection by roughly a hundred thousand times), but whose GRB luminosity was exactly for the same reasons extremely low. This beaming selection in larger volumes explains the puzzling evidence (the Amati correlation) of harder and apparently powerful GRBs at larger and larger distances. The statistical selection favors (in wider volumes and for a wider sample of SN-GRB-jet) the harder and more on-axis events. A huge unobserved population of far off-axis SN-GRBs are below the detection thresholds. This Amati correlation remains

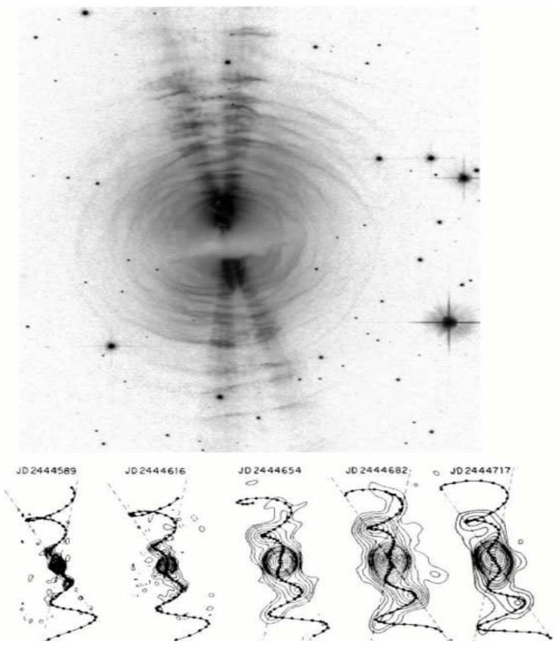

Fig. 1 *Up:* The Egg Nebula, whose shape might be explained as the conical section of a twin precessing jet interacting with the surrounding cloud of ejected gas. *Down:* The similar observed structure of the outflows from the microquasar SS 433. A kinematic model of the time evolution of two oppositely directed precessing jets is overlaid on the radio contours (from Blundell & Bowler 2005).

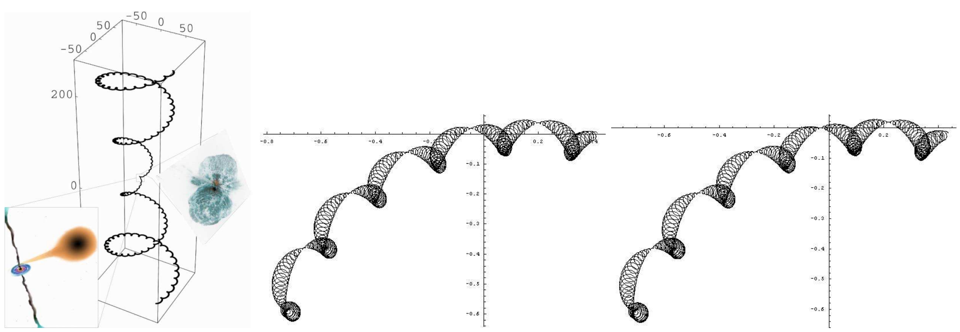

Fig. 2 A possible 3D structure view of the precessing jet obtained with, for instance, a non linear precessing, while spinning, gamma jet; at its center the "explosive" SN-like event for a GRB or a steady binary system for a SGRs where an accretion disc around a compact object powers a collimated precessing jet. In the left panel of the figure we show an Herbig Haro - like object such as HH49, whose spiral jets are describing, at a lower energy scale, the ones in micro-quasars such as SS 433. The Lorentz factor used in the electron pairs jet may reach $\gamma_e = 10^9$, corresponding to a $\sim$ PeV electron pair energy; its solid angle nevertheless maybe still asymmetric (small in one side but not in the other, because magnetic Larmor bending) leading to a solid angle $\frac{\Delta\Omega}{\Omega} \simeq 10^{-8} - 10^{-10}$: two different 2D trajectory geometry of the precessing jet while it blazes the observer along the line of sight: at the center, by a fine tuned beaming to the observer, while on the right side the slight off-axis flashes of the same jet; a more powerful but more off-axis event (a few degree away) would mimic the GRB 980425 and GRB 060218 soft, long and smooth X-ray bump.

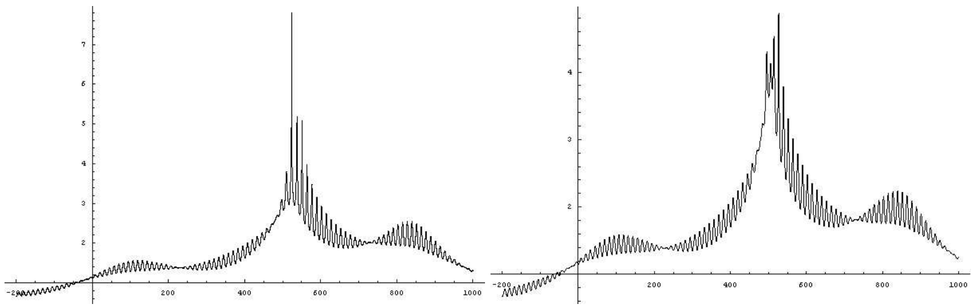

Fig. 3 A close up of the two corresponding light curve profile. Left panel: the multiple oscillatory signals may mimic the oscillatory bumps in SGR γ and the huge amplification of giant flare, while the multi-precessing tracks of the jet may lead to re-brightening and multi-bumps in the light profile of the GRB X afterglows as GRB 060218. The scale time of the GRB are ruled by the solid angle of the jet, its impact angle toward the off-axis observer, the precessing angular velocities. Right panel: note that a much off-axis beaming induce a different SGR smoother and softer profile and a much limited GRB amplification.

unexplained for any isotropic Fireball model and it is in contrast with the cosmic trend required by the Hubble-Friedmann law: the further the distances, the larger the redshifts and the softer the expected GRB event. Naturally the farthest events at large redshifts may compensate duration with time doppler shift. In our opinion to make GRB-SN in nearly energy equipartition the jet must be very collimated $\frac{\Omega}{\Delta\Omega} \simeq 10^8 - 10^{10}$ (Fargion & Salis 1995; Fargion 1999; Fargion & Grossi 2005). In order to fit the statistics between GRB-SN rates, the jet must have a decaying activity ($\dot{L} \simeq (\frac{t}{t_o})^{-\alpha}$, $\alpha \simeq 1$), it must survive not just for the observed GRB duration, but for a much longer timescale, possibly thousands of time longer, $t_o \simeq 10^4$ s. The late stages of the GRBs would appear as SGRs. Indeed similar criticism (against one shot magnetar model) arises for the surprising giant flare from SGR 1806–20 that occurred on 2004 December 27: if it has been radiated isotropically (as assumed by the magnetar model), most of (if not all) the magnetic energy stored in the neutron star NS should have been consumed at once. This should have been reflected into sudden angular velocity loss never observed. On the contrary a thin collimated precessing jet $\dot{E}_{\mathrm{SGR-jet}} \simeq 10^{36} - 10^{38} \mathrm{erg\,s^{-1}}$, blazing on-axis, may be the source of such an apparently (the inverse of the solid beam angle $\frac{\Omega}{\Delta\Omega} \simeq 10^8 - 10^9$) huge bursts $\dot{E}_{\mathrm{SGR-Flare}} \simeq 10^{38} \cdot \frac{\Omega}{\Delta\Omega} \simeq 10^{47} \mathrm{erg\,s^{-1}}$ with a moderate steady jet output power (X-Pulsar, SS 433). This explains the absence of any variation in the SGR 1806–20 period and its time derivative, contrary to any obvious correlation with the dipole energy loss law.

In our model, the temporal evolution of the angle between the jet direction and the rotational axis of the NS can be expressed as $\theta_1(t) = \sqrt{\theta_x^2 + \theta_y^2}$, where

$\theta_x(t) = \sin(\omega_{\mathrm{b}} t + \phi_{\mathrm{b}}) + \theta_{\mathrm{psr}} \cdot \sin(\omega_{\mathrm{psr}} t + \phi_{\mathrm{psr}}) \cdot |(\sin(\omega_{\mathrm{N}} t + \phi_{\mathrm{N}}))| + \theta_{\mathrm{s}} \cdot \sin(\omega_{\mathrm{s}} t + \phi_{\mathrm{s}}) + \theta_{\mathrm{N}} \cdot \sin(\omega_{\mathrm{N}} t + \phi_{\mathrm{N}}) + \theta_x(0)$ and

$\theta_y(t) = \theta_{\mathrm{a}} \cdot \sin \omega_0 t + \cos(\omega_{\mathrm{b}} t + \phi_{\mathrm{b}}) + \theta_{\mathrm{psr}} \cdot \cos(\omega_{\mathrm{psr}} t + \phi_{\mathrm{psr}}) \cdot |(\sin(\omega_{\mathrm{N}} t + \phi_{\mathrm{N}}))| + \theta_{\mathrm{s}} \cdot \cos(\omega_{\mathrm{s}} t + \phi_{\mathrm{s}}) + \theta_{\mathrm{N}} \cdot \cos(\omega_{\mathrm{N}} t + \phi_{\mathrm{N}})) + \theta_y(0)$

(where γ is the Lorentz factor of the relativistic particles of the jet, see Table 1 and Figure 1 and Figure 2. See also Fargion 1999 and Fargion 2003).

The simplest way to produce the γ emission would be by IC of GeVs electron pairs onto thermal infra-red photons. Also electromagnetic showering of PeV electron pairs by synchrotron emission in galactic fields, ($e^{\pm}$ from muon decay) may be the progenitor of the γ blazing jet. However, the main difficulty for a jet of GeV electrons is that their propagation through the SN radiation field is highly suppressed (Fig. 4, left panel). UHE muons ($E_\mu \gtrsim$ PeV) instead are characterized by a longer interaction length either with the circum-stellar matter and the radiation field, thus they have the advantage

Table 1 Parameters Adopted for the Jet Model Represented in Fig. 2

$\gamma = 10^9$	$\theta_a = 0.2$	$\omega_a = 1.6 \times 10^{-8}$ rad s^{-1}
$\theta_b = 1$	$\theta_{\rm psr}$=1.5 $\times 10^7/\gamma$	θ_N=5 $\times$ $10^7/\gamma$
ω_b=4.9 $\times 10^{-4}$ rad s^{-1}	$\omega_{\rm psr}$=0.83 rad s^{-1}	ω_N=1.38 $\times 10^{-2}$ rad s^{-1}
$\phi_b = 2\pi - 0.44$	$\phi_{\rm psr}$=$\pi + \pi/4$	ϕ_N=3.5 $\pi/2 + \pi/3$
$\phi_s \sim \phi_{\rm psr}$	θ_s=1.5 $\times 10^6/\gamma$	$\omega_s = 25$ rad s^{-1}

to avoid the opacity of the star and escape the dense GRB-SN isotropic radiation field (Fargion,Grossi 2005). Here we propose also the emission of SGRs is due to a primary hadronic jet producing ultra relativistic $e^{\pm}$ (1–10 PeV) from hundreds PeV pions, $\pi \rightarrow \mu \rightarrow e$, (as well as EeV neutron decay in flight): primary protons can be accelerated by the large magnetic field of the NS up to EeV energy. The protons could emit directly soft gamma rays via synchrotron radiation with the galactic magnetic field ($E_\gamma^{\rm p} \simeq 10(E_{\rm p}/E{\rm eV})^2(B/2.5\times10^{-6}\,{\rm G})$ keV), but the efficiency is poor because of the too long timescale of proton synchrotron interactions. By interacting with the local galactic magnetic field relativistic pair electrons lose energy via synchrotron radiation, $E_\gamma^{\rm sync} \simeq 4.2\times10^6\left(\frac{E_{\rm e}}{5\times10^{15}\,{\rm eV}}\right)^2\left(\frac{B}{2.5\times10^{-6}\,{\rm G}}\right)\,{\rm eV},$ with a characteristic timescale $t^{\rm sync} \simeq 1.3\times10^{10}\left(\frac{E_{\rm e}}{5\times10^{15}{\rm eV}}\right)^{-1}\left(\frac{B}{2.5\times10^{-6}\,{\rm G}}\right)^{-2}$ s.

This mechanism would produce a few hundreds keV radiation as it is observed in the intense γ-ray flare from SGR 1806–20. The Larmor radius is about two orders of magnitude smaller than the synchrotron interaction length and this may imply that the aperture of the jet is spread by the magnetic field, $\frac{R_{\rm L}}{c} \simeq 4.1\times10^8\left(\frac{E_{\rm e}}{5\times10^{15}{\rm eV}}\right)\left(\frac{B}{2.5\times10^{-6}\,{\rm G}}\right)^{-1}$ s. In particular a thin ($\Delta\Omega \simeq 10^{-9} - 10^{-10}$ sr) precessing jet from a pulsar may naturally explain the negligible variation of the spin frequency $\nu = 1/P$ after the giant flare ($\Delta\nu < 10^{-5}$ Hz). Indeed it seems quite unlucky that a huge ($E_{\rm Flare} \simeq 5\times10^{46}$ erg) explosive event (as the needed mini-fireball by a magnetar model; Duncan et al. 1992) is not leaving any trace in the rotational energy of the SGR 1806–20, $E_{\rm rot} = \frac{1}{2}I_{\rm NS}\omega^2 \simeq 3.6\times10^{44}\frac{P}{7.5{\rm s}}^{-2}\left(\frac{I_{\rm NS}}{10^{45}g\,{\rm cm}^2}\right)$ erg. The consequent fraction of energy lost after the flare must be severely bounded : $\frac{\Delta(E_{\rm Rot})}{E_{\rm Flare}} \leq 10^{-6}$. Finally a signal of secondary muons at PeV energies, induced by high energy neutrinos from the SGR, might be detected in Amanda and also (because of its better orientation) in Baikal. To conclude, we imagine that if the precessing jet model gives a correct interpretation of the properties of SGRs, SGR 1806–20 will (and indeed it has been) active all during 2005. Moreover, following our prediction, the recent GRB 060218 event showed long and short scale quasi-periodic re-brightening, reflecting (as in GRB 030329) the inner multi-precessing jet. Part of this multi-bump signature has been and is still being discovered in the new GRB events (GNC 4819, 06/02/23)[b].

3 CONCLUSIONS: THE PRECESSING JET ANSWERS

The thin precessing Jet while being extremely collimated (solid angle $\frac{\Omega}{\Delta\Omega} \simeq 10^8 - 10^{10}$ (Fargion & Salis 1995; Fargion 1999; Fargion & Grossi 2005) may blaze at different angles within a wide energy range (inverse of $\frac{\Omega}{\Delta\Omega} \simeq 10^8 - 10^{10}$). The emission at different wavelengths is more intense and harder in the inner part of the jet. The Jet cone solid angle embrace wider areas while it precesses, leading to a blazing variability mostly dominated by a tiny angle bending. The jet inner structure is made by concentric gamma radiation cones produced by higher energy electron pairs with harder spectra. The outer shells are characterized by a lower energy radiation. The jet transverse section maybe imagined as made by concentric multi-cones, the harder and the more intense in the center reflecting the higher energy boosted electron pairs. The concentric shape of this ideal jet is deformed while turning and rotating in angular precession, due to the different "inertia" of the electron Jet components: the inner hard core remains on-axis while the softer external cones, and their section rings, are coming later as a tail, in some analogy to the well known Doppler ring structure. The output power may exceed $\simeq 10^8$, explaining the extreme low observed output in GRB 980425, an off-axis event, the long late off-axis gamma tail by GRB 060218, respect to the on-axis

[b] A few very recent discovers on peculiar GRBs and SGRs, after the Vulcano presentation in May 2005, have been introduced here to update and complete the article.

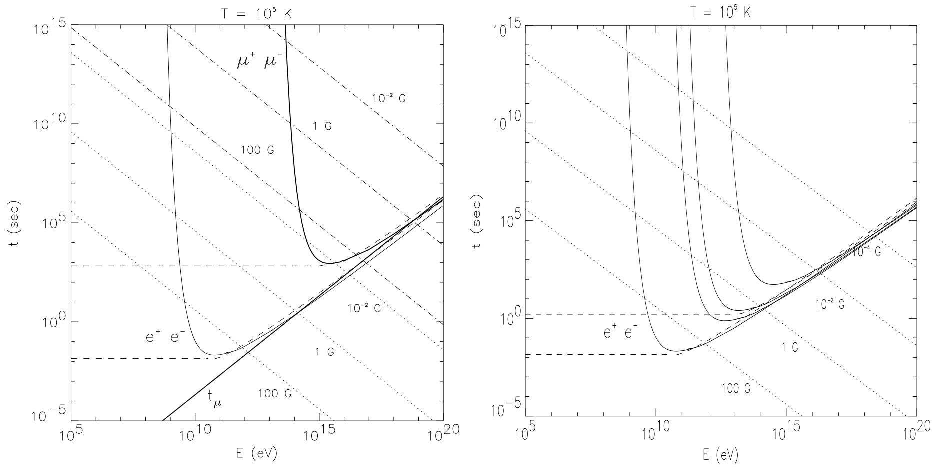

Fig. 4 Left:The electron and muon interaction lengths. The *dashed-dotted* and *dotted* lines correspond to the synchrotron energy loss distance (for muons and electrons respectively) for different values of the magnetic field: 100 G, 1 G and 10^{-2} G. The *straight solid* line labelled t_μ indicates the muon lifetime; the *dashed* lines indicate the IC interaction lengths for muons and electrons. Finally the two *solid* curves labelled $\mu^+\mu^-$ and e^+e^- correspond to the attenuation length of high energy photons producing lepton pairs (either $\mu^\pm$ or $e^\pm$) through the interaction with the SN radiation field. We have assumed that the thermal photons emitted by the star in a pre-SN phase have a black body distribution with a temperature $T \simeq 10^5$ K. Assuming a radius $R \sim 10\, R_\odot$, we are considering a luminosity of $L_{\rm SN} \simeq 2.5 \times 10^{41}$ erg s^{-1}. Around $10^{15} - 10^{16}$ eV muons decay before losing energy via IC scattering with the stellar background or via synchrotron radiation. Right: The Supernova opacity (interaction length) for PeV electrons at different times. PeV muon jets may overcome it and decay later in γ showering electrons (see for details Fargion, Grossi 2005);

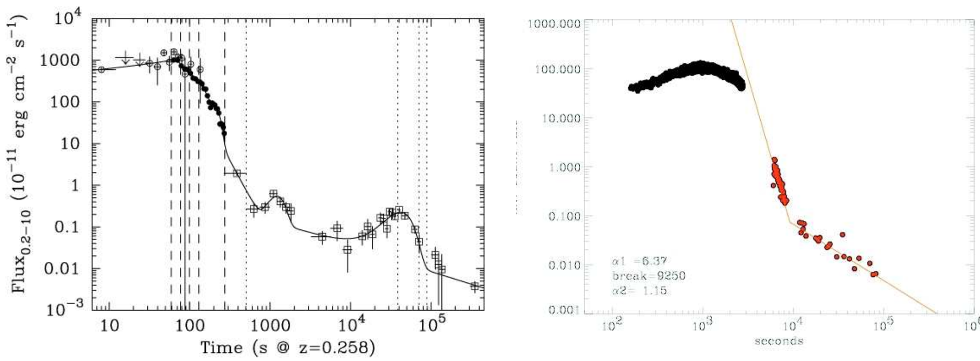

Fig. 5 Left: The short GRB 050724 and its long life X-ray afterglow whose curve (Campana et al. 2006) and whose multi-rebrightening is testing the persistent jet activity and geometrical blazing views. Right: the very recent optical afterglows of GRB 060218 whose smooth longest X-ray flare and whose recent dramatic optical bumps are reflecting the underneath precessing jet activity (Moretti 2006; GNC 4819, 06/02/23).

and more distant GRB 990123 (as well as GRB 050904). The time duration of GRB 060218 compensate the low power and its integrated energy sit in the Amati line; this paradox is not probably taking place in an average power (not energy) relation Yonetoku et al. 2004. In this scenario the Amati relation is not a physical law, but just a biassed statistical rule that selects the most distant events at large redshift, (a larger and larger GRB sample), possibly better and better on-axis, appearing (most probably) the brightest and (because of the inner jet core) the harder ones. Our detectors may capture signals in local Universe only from more and more off-axis sources as GRB 060218, GRB 980425, GRB 030329, or just in our galaxy as SGRs. The last GRB 060218 following the Amati correlation is very off-axis and would not be easily observed if located at larger redshifts; there is naturally an undetected huge rate (nearly a few each second) of under-luminous (five or six orders of magnitude less energetic) off-axis late blazing GRB in the Universe mixed up with under threshold lower power extragalactic SGRs. GLAST may show some of them. Short GRB (as GRB 050709) are just the latest (not too far) stage between GRB toward SGR. XRF are off-axis events not at far cosmic edges. SGR 1806–20 is an active jet whose beaming is rarely on-axis to us. Its precessing jet cone is sometimes blazing the Earth making the source "on" respect to times when the precessing cone point elsewhere. We foresee that in our galaxy there are hundreds or even a thousands of such precessing jets cone : only few already emerged as AXRPs and SGRs; most of them have a jet cone never pointing to us , like SS 433 and other microquasars (as Eta Carina jets feeding nebular twin lobe). Therefore a-periodic blazing are able to explain precursors and GRB or, viceversa a GRB and late X-afterglow re-brightening. Very recent GRB at cosmic edges are showing more bumps and variability as well as the very nearby GRB 060218. Let us try to search for jet traces in SGR 1806–20 and in extragalactic nearby GRB 060218: GRBs are not the most powerful explosions, but, as for BL Lacs AGNs, among the most collimated ones.

References

Amati L., astro-ph/0601553, submitted to MNRAS
Campana, S., et al., astro-ph/0603475, A&A accepted
Lazzati D. et al., astro-ph/0602216
Duncan, R., & Thompson, C., 1992, ApJ, 392, L9
Falcone A. et al., astro-ph/0512615 , astro-ph/0602135
Fargion, D., Salis, A., 1995b, Astrophysics & Space Science, 231, 191
Fargion,D., 1999, AA&SS, 138, 507; astro-ph/9903433, astro-ph/9808005
Fargion, D., 2003, Chin. J. Astron. Astrophys. (ChJAA), 3(S), 472
Fargion, D., Grossi, M., astro-ph/0504638
Fargion D., GCN 4819, 06/02/23
GNC 4819, 06/02/23.
Medina-Tanco, G. A., Watson, A. A, 2001, *Proceedings of ICRC (Hamburg)*, 531
Moretti, A., 2006, $www.merate.mi.astro.it/\ moretti/lc_0 60218.gif$
Stanek, R., et al., astro-ph/0602495
Woods, P. M., et al. 1999, ApJ, 527, L47; astro/ph 9909276
Yonetoku, D., Murakami, T., Nakamura, T., 2004, ApJ, 609, 935