

# Gamma Ray Burst and Soft Gamma Repeaters. Spinning and Precessing $\gamma$ Jets

D. Fargion <sup>1</sup>

<sup>1</sup> *Physics Department, Rome University 1, and INFN, Rome1, P.za Aldo Moro 2 Rome, ITALY*

## Abstract

Gamma Ray Bursts as recent GRB990123 and GRB990510 are observed to occur in cosmic volumes with a corresponding output reaching, for isotropic explosions, energies as large as two solar masses annihilation. These energies are underestimated because of the neglected role of comparable ejected neutrinos bursts. These extreme power cannot be explained with any standard spherically symmetric Fireball model. A too heavy black hole or Star would be unable to coexist with the shortest millisecond time structure of Gamma ray Burst. Beaming of the gamma radiation may overcome the energy puzzle. However any mild explosive beam ( $\Omega > 10^{-2}$ ) should not solve the jet containment at those disruptive energies. Only extreme beaming ( $\Omega < 10^{-8}$ ), by a slow decaying, but long-lived precessing jet, it may coexist with characteristic Supernova energies, apparent GRBs output, statistics as well as their connection with older and nearer SGRs relics.

## 1 Introduction

After a decade, at present (GRB990123 over energetic event) none spent a regret word on the decline and possible final rejection of the popular isotropic burst fireball model. GRBs connections with jets is growing from supernova connections, energy crisis and polarization evidences. On the other hand SGRs have still a popular magnetar (isotropic mini-fireball) model well alive. It is therefore time to remind that recent strong SGR events on 1998 (SGR1900+14), (SGR1642-21), as well as the old 5th March 79 SGR, shared the same hard spectra of classical GRBs. It is in particular very instructive to notice the GRB-SGR similar spectra morphology and temporal evolution within BATSE trigger 7172 GRB981022 and 7171 GRB981022. Nature would be extremely perverse to mimic two very similar events (either for time structures and energy spectra) at same detector and at the same day by two totally different processes. A magnetar mini-fireball (for SGRs) versus the GRB burst, at the present more related to jets. We argue here that, apart of the energetics, both of them are blazing of powerful jets (NS or BH) by spinning and precessing source in either binary or in accreting disk systems (Fargion 1998). The GRBs optical transient after-gloves are the Supernova like explosive birth of the jet. Their optical flash, days after the burst, is related to the maximal optical explosion intensity and it is enhanced only by a partial beaming ( $\Omega \simeq 10^{-2}$ ). The rarest extreme peak OT during GRB990123 (at a million time a Supernova luminosity) is the beamed ( $\Omega \leq 10^{-5}$ ) Inverse Compton optical tail responsible of the same extreme gamma (MeV) extreme beamed ( $\Omega \leq 10^{-8}$ ) signal. The huge energy bath (for a fireball model) on GRB990123 imply the coexistence of an energetic neutrino burst comparable to the photon one. Indeed, in analogy to the early three minutes of the hot universe, if entropy conservation holds, the energy density factor to be added to the photon  $\gamma$  GRB990123 budget is at least ( $\simeq (21/8) \times (4/11)^{4/3}$ ). In this case the final gamma energy enjoy of the electron pairs annihilation, as in the thermal equilibrium in the first second of the universe. If the GRB had not time to keep the entropy conservation (the most probable case) than the energy needed for the neutrino burst was at least a factor  $[21/8]$  larger than the gamma one. The consequent energy-mass needed for the two cases (including both  $\nu$  and  $\gamma$  burst) are respectively 3.5 and 7.2 solar masses. No known isotropic fireball model may release at ideal total energy conversion such a huge energy burst. One must also remind that maximal black hole energy conversion takes place for rotational case at a level below a factor 0.4. Therefore the original masses for isotropic fireball must require at least a 8, 7 solar mass black hole, with obvious contradictions with millisecond gamma burst fine structures. Beaming may solve the puzzle. Extreme  $\nu$  and  $\gamma$  beaming by a rapid spinning and precessing jet, (a neutron star or a black hole), may explain the apparent extreme energy. Also the over supernova optical transient peak intensities are beamed within a

thin jet. We therefore predict here that future detailed (within fraction of second detection) observations of this contemporaneous (seconds delay) optical transient events must be modulated in a fine structured way, nearly comparable to the gamma ray burst signal. Moreover the GRB980425-SN1998bw (Galama et al. 1998) association put already since a year in severe strain any “candle” fireball. Indeed isotropic standard candle (luminosity  $l_\gamma$ ) fireballs are unable to explain the following key questions related to that GRB-SN association:

1. Why nearest “local” GRB980425 in ESO 184-G82 galaxy at redshift  $z_2 = 0.0083$  and the most far away “cosmic” ones as GRB971214 (Kulkarni et al.1998) at redshift  $z_2 = 3.42$  exhibit a huge average and peak intrinsic luminosity ratio?

$$\frac{\langle L_{1\gamma} \rangle}{\langle L_{2\gamma} \rangle} \cong \frac{\langle l_{1\gamma} \rangle}{\langle l_{2\gamma} \rangle} \frac{z_1^2}{z_2^2} \cong 2 \cdot 10^5 ; \left. \frac{L_{1\gamma}}{L_{2\gamma}} \right|_{peak} \simeq 10^7. \quad (1)$$

Fluence ratios  $E_1/E_2$  are also extreme ( $\geq 4 \cdot 10^5$ ).

2. Why GRB980425 nearest event spectrum is softer than cosmic GRB971214 while Hubble expansion would imply the opposite by a redshift factor  $(1 + z_1) \sim 4.43$ ?
3. Why, GRB980425 time structure is slower and smoother than cosmic one, as above contrary to Hubble law?
4. Why we observed so many (even just the rare April one over 14 Beppo Sax optical transient event) nearby GRBs? Their probability to occur, with respect to a cosmic redshift  $z_1 \sim 3.42$  must be suppressed by a severe volume factor

$$\frac{P_1}{P_2} \cong \frac{z_1^3}{z_2^3} \simeq 7 \cdot 10^7. \quad (2)$$

The above questions remain unanswered by fireball candle model. A family of new GRB fireballs are ad hoc and fine-tuned solutions. We believed since 1993 (Fargion 1994) that spectral and time evolution of GRB are made up blazing beam gamma jet GJ. The GJ is born by ICS of ultrarelativistic (1 GeV-tens GeV) electrons (pairs) on source IR, or diffused companion IR, BBR photons (Fargion, Salis 1998). The beamed electron jet pairs will produce a coaxial gamma jet. The simplest solution to solve the GRBs energetic crisis (as GRB990123 whose isotropic budget requires an energy above two solar masses) finds solution in a geometrical enhancement by the jet thin beam. A jet angle related by a relativistic kinematics would imply  $\theta \sim \frac{1}{\gamma_e}$ , where  $\gamma_e$  is found to reach  $\gamma_e \simeq 10^3 \div 10^4$  (Fargion 1994,1998). However an impulsive unique GRB jet burst (Blackman, et al., 1996), (Wang & Wheeler 1998) increases the apparent luminosity by  $\frac{4\pi}{\theta^2} \sim 10^7 \div 10^9$  but face a severe probability puzzle due to the rarity to observe a SN burst jet pointing in line toward us. Therefore we considered GRBs and SGRs as multiprecessing and spinning thin,  $\theta \simeq 10^{-4}$ , Gamma Jets. Its short Kilo-Hertz spinning is the source of the millisecond gamma burst fine structure, while the slower precessing periods due to the neutron star inertial momentum asymmetry and to the binary companion, make the GRB beam modulation nearly caotic. In particular we considered (Fargion 1998) an unique scenario where primordial GRB jet power decayed in hundred and thousand years becoming the lower power, but nearby galactic and still observable SGRs. The ICS for monochromatic electrons on BBR leads to a coaxial gamma jet spectrum (Fargion & Salis 1995,1996,1998):  $\frac{dN_1}{dt_1 d\epsilon_1 d\Omega_1}$  is

$$\epsilon_1 \ln \left[ \frac{1 - \exp\left(\frac{-\epsilon_1(1-\beta \cos \theta_1)}{k_B T(1-\beta)}\right)}{1 - \exp\left(\frac{-\epsilon_1(1-\beta \cos \theta_1)}{k_B T(1+\beta)}\right)} \right] \left[ 1 + \left( \frac{\cos \theta_1 - \beta}{1 - \beta \cos \theta_1} \right)^2 \right] \quad (3)$$

scaled by a proportional factor  $A_1$  related to the electron jet intensity. The adimensional photon number rate (Fargion & Salis 1996) as a function of the observational angle  $\theta_1$  responsible for peak luminosity (eq. 1) becomes

$$\frac{\left(\frac{dN_1}{dt_1 d\theta_1}\right)_{\theta_1(t)}}{\left(\frac{dN_1}{dt_1 d\theta_1}\right)_{\theta_1=0}} \simeq \frac{1 + \gamma^4 \theta_1^4(t)}{[1 + \gamma^2 \theta_1^2(t)]^4} \theta_1 \approx \frac{1}{(\theta_1)^3} . \quad (4)$$

The total fluence at minimal impact angle  $\theta_{1m}$  responsible for the average luminosity (eq. 1) is

$$\frac{dN_1}{dt_1}(\theta_{1m}) \simeq \int_{\theta_{1m}}^{\infty} \frac{1 + \gamma^4 \theta_1^4}{[1 + \gamma^2 \theta_1^2]^4} \theta_1 d\theta_1 \simeq \frac{1}{(\theta_{1m})^2} . \quad (5)$$

These spectra fit GRBs observed ones (Fargion & Salis 1995). Assuming a beam jet intensity  $I_1$  comparable with maximal SN luminosity,  $I_1 \simeq 10^{45} \text{ erg s}^{-1}$ , and replacing this value in adimensional  $A_1$  in equation 3 we find a maximal apparent GRB power for beaming angles  $10^{-3} \div 3 \times 10^{-5}$ ,  $P \simeq 4\pi I_1 \theta^{-2} \simeq 10^{52} \div 10^{55} \text{ erg s}^{-1}$  within observed ones. We also assume a power law jet time decay as follows

$$I_{jet} = I_1 \left(\frac{t}{t_0}\right)^{-\alpha} \simeq 10^{45} \left(\frac{t}{3 \cdot 10^4 \text{ s}}\right)^{-1} \text{ erg s}^{-1} \quad (6)$$

where ( $\alpha \simeq 1$ ) able to reach, at 1000 years time scales, the present known galactic microjet (as SS433) intensities powers:  $I_{jet} \simeq 10^{38} \text{ erg s}^{-1}$ . We used the model to evaluate if April SN-GRB precessing jet might hit us once again. The possibility was near unity and indeed the GRB980425 repeated.

## 2 The GRB980425-GRB980712 repeater

Therefore the key answers to the puzzles (1-4) are easily found in the precessing gamma jet model: the GRB980425 has been observed off-axis by a cone angle wider than  $\frac{1}{\gamma}$  thin jet by a factor  $a_2 \sim 500$  (Fargion 1998) and therefore one observed only the ‘‘softer’’ cone jet tail whose intensity is strongly reduced, its spectrum is softer and whose time structure is slower (larger impact parameter angle). A simple statistics favoured a repeater hit. Indeed GRB980430 trigger 6715 was within  $4\sigma$  and in particular GRB980712 trigger 6917 was within  $1.6\sigma$  angle away from the April event direction. An additional event 15 hours later, trigger 6918, repeated making the combined probability to occur quite rare ( $\leq 10^{-3}$ ). Because the July event has been sharper in times ( $\sim 4 \text{ s}$ ) than the April one ( $\sim 20 \text{ s}$ ), the July impact angle had a smaller factor  $a_3 \simeq 100$ . This value is well compatible with the expected peak-average luminosity flux evolution in eq.(6,4):  $\frac{L_{04\gamma}}{L_{07\gamma}} \simeq \frac{I_2 \theta_2^{-3}}{I_3 \theta_3^{-3}} \simeq \left(\frac{t_3}{t_2}\right)^{-\alpha} \left(\frac{a_2}{a_3}\right)^3 \leq 3.5$  where  $t_3 \sim 78 \text{ day}$  while  $t_2 \sim 2 \cdot 10^5 \text{ s}$ . The predicted fluence is also comparable with the observed ones  $\frac{N_{04}}{N_{07}} \simeq \frac{\langle L_{04\gamma} \rangle}{\langle L_{07\gamma} \rangle} \frac{\Delta\tau_{04}}{\Delta\tau_{07}} \simeq \left(\frac{t_3}{t_2}\right)^{-\alpha} \left(\frac{a_2}{a_3}\right)^2 \frac{\Delta\tau_{04}}{\Delta\tau_{07}} \geq 3$ .

## 3 The SGRs hard spectra and their GRB link

Last SGR1900+14 (May-August 1998) events and SGR1627-41 (June-October 1998) events did exhibit at peak intensities hard spectra comparable with classical GRBs. We imagine their nature as the late stages of jets fueled by a disk or a companion (WD,NS) star. Their binary angular velocity  $\omega_b$  reflects the beam evolution  $\theta_1(t) = \sqrt{\theta_{1m}^2 + (\omega_b t)^2}$  or more generally a multiprecessing angle  $\theta_1(t)$  (Fargion & Salis 1996) wich keeps memory of the pulsar jet spin ( $\omega_{psr}$ ), precession by the binary  $\omega_b$  and additional nutation due to inertial momentum anisotropies or beam-accretion disk torques ( $\omega_N$ ). On average, from eq.(5) the gamma and afterglow decays as  $t^{-2}$ ; the complicated spinning and precessing jet blazing is responsible for the wide morphology of GRBs and SGRs as well as their internal periodicity. In conclusion the puzzles for GRB980425-GRB971214 find a simple solution within a precessing jet: the different geometrical observational angle may compensate the April 1998 low peak gamma luminosity ( $10^{-7}$ ) by a larger impact angle which compensates, at the same time, the statistical rarity ( $\sim 10^{-7}$ ) to find in a near volume a GRBs, its puzzling softer nature as well as its

longer (larger impact parameter view) timescales. Finally the April GRB repetitivity on GRB980712 verified the model. Such precessing jets may also explain (Fargion & Salis 1995) the external twin rings around SN1987A. They may propel and inflate plerions as the observed ones near SRG1647-21 and SRG1806-20. In conclusion optical nebula NGC6543 (“Cat Eye”) and its thin jets fingers as well as the inexplicable double cones sections in Egg nebula CRL2688 are the spectacular lateral view of such spinning and precessing jets. Their blazing in-axis toward us would appear as SGRs . At their maximal power during their SN birth, their blazing would appear as a GRBs marked by their coeval optical afterglow.

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