Theory of Gamma-Ray Bursts

Sylwester Kornowski

Abstract: Here, using the dynamics of the core of baryons described within the Scale-Symmetric Theory (SST), we explain the origin of the rest frame peak energy versus isotropic energy for Gamma-Ray Bursts (GRBs). We present also how isotropic energy depends on mass of captured star by the most massive neutron star.

1. Introduction

In papers [1], [2], [3], [4], we described partially phenomena characteristic for the Gamma-Ray Bursts – we took into account the theory of baryons and the theory of most massive neutron star (which we call also the neutron black hole (NBH)) both described within the Scale-Symmetric Theory (SST) respectively in [5] and [6].

Here, using the dynamics of the core of baryons described within the Scale-Symmetric Theory (SST), we explain the origin of the rest frame peak energy versus isotropic energy for the short-duration Gamma-Ray Bursts (SGRBs) and long-duration GRBs (LGRBs). We present also how isotropic energy depends on mass of captured star by NBH.

We use the formula for GRBs, which is derived in [4], that shows how the time duration of a burst, t_{Burst}, depends on mass of star, m_{Star}, captured by NBH with a mass of M_{NBH} = 24.81 [solar masses]

$$t_{Burst} = 716 (m_{Star} / M_{NBH})^4 \text{ [seconds]} . \quad (1)$$

The SGRBs lasts shorter than 2 seconds while LGRBs longer than 2 seconds. From (1) we can calculate that the threshold time is for mass of star equal to $m_{Star,threshold}$ = 5.7 [solar masses].

Some baryonic analog to stars captured by NBH looks as follows [4]

$$m_{Star} / M_{NBH} = m_{Particle} / n , \quad (2)$$

where $m_{Particle}$ is mass of particle that in the theory of GRBs represents m_{Star} while mass of the neutron, n = 939.565 MeV, represents mass of NBH.

SST [5] shows that theory of NBH and theory of the core of baryons are similar. It causes that we can solve many theoretical problems concerning GRBs. Due to quantum effects, there is created orbit/tunnel in spacetime near the equator of the core of baryons so the same concerns the NBH. It causes that initially the captured star is packed in thin torus/orbit/tunnel so it is the very dense nuclear plasma. According to SST, such plasma consists of the cores of baryons – it means that the orbits outside the core, besides the orbit tangent to the equator, are destroyed. This causes that there dominate the carriers of the weak interactions, i.e. the scalar

$Y = 424.12$ MeV in centre of the core of baryons and the scalar with a mass equal to mass of the neutral pion $\pi^o = 134.98$ MeV. From (2) and (1) follows that the two masses relate respectively to the LGRBs (it is easy to calculate that the averaged time duration is equal to ~30 seconds) and to the SGRBs (the averaged time duration is ~0.3 seconds) – such GRBs should be most numerous what is consistent with observational facts. In such a way, we proved that GRBs are directly associated with the neutron black hole and with very dense nuclear plasma which consists of the cores of baryons described within SST. We must radically change the theory of baryons.

Notice that from (1) and (2) we obtain that the ratio of the averaged time durations of LGRBs and SGRBs is

$$f = t_{LGRBs} / t_{SGRBs} = (Y / \pi^o)^4 \approx \pi^4 = 97.4 \text{ times}, \tag{3}$$

i.e. is about 100 as it should be.

2. The LGRBs

The isotropic energy, E_{iso}, emitted in GRBs should be directly proportional to the product of mass of captured star by NBH and some relative coupling constant, $\alpha_{Relative}$,

$$E_{iso} = m_{Star}\, \alpha_{Relative}, \tag{4}$$

where

$$\alpha_{Relative} = \alpha_i / \alpha_o \tag{5}$$

depends on the hedgehog mechanism which describes emission of the isotropic energy [2]. In SST, the four known interactions are described by the following formula for coupling constants, α_i,

$$\alpha_i = G_i\, M_i\, m_i / (\hbar\, c), \tag{6}$$

where G_i is the constant of interaction which depends on density of field (density of all the scalar condensates, which carry the weak interactions, is the same i.e. G_{Weak} = constant [5]), $M_i = M_{Carrier}$ is the mass of carriers of interactions, and $m_i = m_{Flow}$ is mass of exchanged particle (it can be a condensate) i.e. it is mass of a particle that flows between the carriers.

For the condensates, from (5) and (6) we have

$$\alpha_{Relative} = M_{Carrier}\, m_{Flow} / (M_{o,Carrier}\, m_{o,Flow}), \tag{7}$$

where $M_{o,Carrier}$ and $m_{o,Flow}$ are the maximum possible values.

The LGRBs are produced because of exchanges of the condensates Y i.e. $m_{Flow} = Y$. Such condensate is exchanged between two neutrons while maximum mass of condensate can be equal to mass of two colliding neutrons so $M_{o,Carrier} = m_{o,Flow} = 2n$. Condensates flow inside strings composed of neutrons with spins tangent to the strings. The real mass of carriers, $M_{Carrier}$, changes from $(e^+ + e^-)_{bare} = 1.0208$ MeV, where $(e^{+,-})_{bare} = 0.510407$ MeV [5] to $(n + n) = 1879.13$ MeV. From it we can calculate that $M_{Carrier} / M_{o,Carrier}$ is defined by following interval: $F \equiv (0.0005432, 1)$.

The above remarks lead to following formula

$$E_{iso,LGRBs} = m_{Star}\, E_{Sun}\, [Y / (2\, n)]\, F\,, \tag{8}$$

where m_{Star} is expressed in [solar masses] and $E_{Sun} = 1.79 \cdot 10^{54}$ erg is the energy of the Sun.

Masses of LGRBs are defined by the interval:

$$5.70 \text{ [solar masses]} \leq m_{Star} \leq 24.81 \text{ [solar masses]}$$

It leads to the lower and upper limits for isotropic energy of LGRBs

$$E_{iso,LGRBs} \text{ is defined by the interval } (1.25 \cdot 10^{51},\, 1.00 \cdot 10^{55}) \text{ erg}\,. \tag{9}$$

For $m_{Star} \geq M_{NBH} = 24.81$ [solar masses] there are created new NBHs so involved mass responsible for isotropic energy is

$$m = m_{Star} - k\, M_{NBH} > 0\,, \tag{10}$$

where k is the maximum possible natural number. It leads to conclusion that isotropic energy of stars with $m_{Star} \geq M_{NBH}$ are placed inside the derived here intervals for LGRBs and SGRBs.

3. Peak energy, E_{Peak}

For torus we have that its squared radius is directly proportional to surface. On the other hand, peak energy should be directly proportional to radius of the torus while isotropic energy should be directly proportional to surface. From it follows the relation

$$E_{Peak} = E_{o,Peak}\, (E_{iso} / E_{o,iso,maximum})^{1/2}\,. \tag{11}$$

The $E_{o,Peak}$ and $E_{o,iso}$, i.e. the maximum values, we can calculate from the boundary conditions. The maximum isotropic energy for LGRBs is $E_{o,iso,maximum,LGRBs} = 1.00 \cdot 10^{55}$ erg (see (9)). For such isotropic energy, the peak energy should be equal to the weak mass of the central condensate Y

$$E_{o,Peak} = \alpha_{W,proton}\, Y = 7.94 \text{ MeV}\,, \tag{12}$$

where $\alpha_{W,proton} = 0.0187229$ is the coupling constant for the nuclear weak interactions [5] – emphasize that in nuclear plasma dominate interactions via the scalar condensates i.e. dominate the nuclear weak interactions.

Such conditions lead to following relation

$$E_{Peak,LGRBs} = E_{o,Peak}\, (E_{iso,LGRBs} / 1.00 \cdot 10^{55} \text{ erg})^{1/2}\,. \tag{13}$$

The lower and upper values are:

$E_{Peak,LGRBs,lower} = 88.8$ keV,

$E_{Peak,LGRBs,upper} = 7.94$ MeV. (14)

4. The SGRBs

The SGRBs are produced because of exchanges of condensates with a mass equal to mass of the neutral pion $\pi^o = 134.98$ MeV i.e. $m_{Flow} = \pi^o$.

Most important is the fact that due to the nuclear weak interactions, the neutral pion, which is produced inside the core of baryons, can collapse to a scalar condensate and next decay to four energetic neutrinos: $E_{Neutrino} = \pi^o / 4 = 33.74$ MeV [5]. Then, a star can quickly/promptly emit energy because of the emitting energetic neutrinos which very weakly interact with matter.

The minimum star size is estimated to be about 0.083 [solar masses] [7]. On the other hand, SST shows that the progenitor of the Higgs boson (H = 125.0 GeV) has mass 3.097 MeV [5]. Using formula (2) we obtain that such a mass relates to 0.0818 [solar masses]. It shows that within SST we can calculate the lower limit for mass of stars!

Masses of SGRBs are defined by interval:

$$0.0818 \text{ [solar masses]} \le m_{Star} \le 5.70 \text{ [solar masses]}$$

The above remarks lead to following formula

$$E_{iso,SGRBs} = m_{Star}\, E_{Sun}\, [\pi^o / (2\, n)]\, F\,, \qquad (15)$$

It leads to the lower and upper limits for isotropic energy of SGRBs

$$E_{iso,SGRBs} \text{ is defined by the interval } (5.71 \cdot 10^{48},\ 7.33 \cdot 10^{53}) \text{ erg}\,. \qquad (16)$$

Such conditions lead to following relation

$$E_{Peak,SGRBs} = E_{o,Peak}\, (E_{iso,SGRBs} / 7.33 \cdot 10^{53} \text{ erg})^{1/2}\,, \qquad (17)$$

The lower and upper values are:

$E_{Peak,SGRBs,lower} = 22.2$ keV,

$E_{Peak,SGRBs,upper} = 7.94$ MeV. (18)

But only for $E_{iso,SGRBs}$ equal to about 10^{51} erg – 10^{52} erg, the SGRBs are placed near the curve defined by (15) and (17). It results from the fact that SGRBs choose special conditions to "smoothly" emit the excess energy. But emphasize that the ratio $\pi^o/(2n)$ cannot be changed.

Let us consider a few examples. In formula (15), we can choose m_{Star} and value from the interval F. In formula (17), we can choose value of $E_{o,Peak}$.

A)

The first relativistic mass of charged pion above the Schwarzschild surface for the nuclear strong interactions is $W_{d=2} = 181.704$ MeV [5]. From (2) it relates to mass of star equal to 4.80 [solar masses]. Assume that the F is defined by $F = \alpha_{Weak} Y/n = 0.00845$. It leads to (see formulae (15) and (17))

$E_{iso,SGRBs} = 5.22 \cdot 10^{51}$ erg,

$E_{Peak,SGRBs} = 671$ keV. (19)

B)
The same as in A) but the $E_{Peak,SGRBs}$ = 671 keV decreases Y/π^o = 3.14 times. We have

$E_{iso,SGRBs} = 5.22 \cdot 10^{51}$ erg,
$E_{Peak,SGRBs}$ = 214 keV. (20)

C)
The upper limit m_{Star} = 5.70 [solar masses] relates to $F = \mu^{+,-}/n = 0.11246$, where $\mu^{+,-}$ = 105.66 MeV is the mass of muon. For $E_{Peak,SGRBs} = \alpha_{Weak} Y$ we have

$E_{iso,SGRBs} = 8.24 \cdot 10^{52}$ erg,
$E_{Peak,SGRBs}$ = 7.94 MeV. (21)

D)
The lower limit m_{Star} = 0.0818 [solar masses] relates to $F = (n - p)/n = 0.0013765$, where p = 938.272 MeV is the mass of proton. For $E_{o,Peak,SGRBs} = \pi^o$ we have

$E_{iso,SGRBs} = 1.45 \cdot 10^{49}$ erg,
$E_{Peak,SGRBs}$ = 600 keV. (22)

Obtained here results are collected in Fig.1. We can compare them with observational data (see Fig.5 (left panel) in [8]).

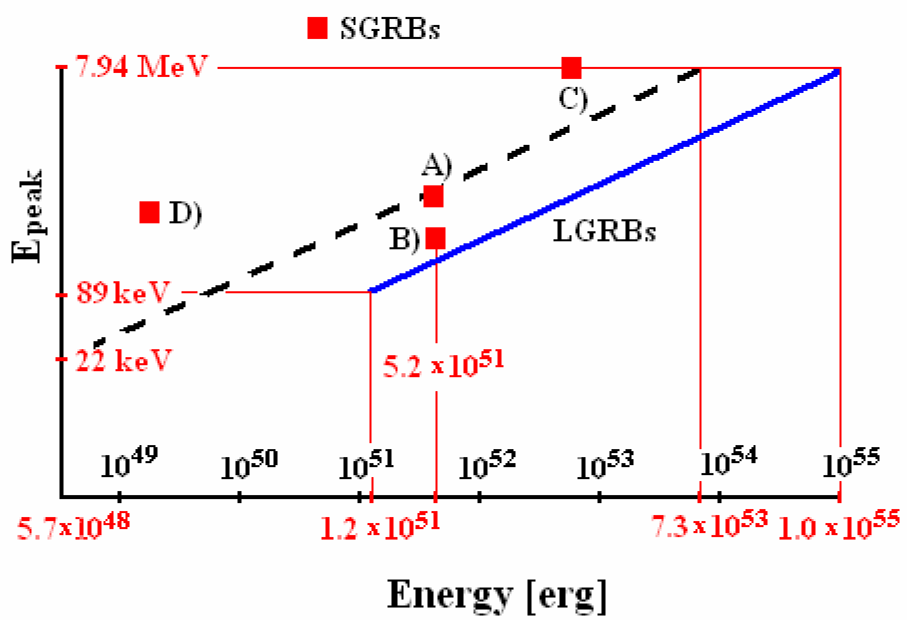

Fig.1 Rest frame peak energy versus isotropic energy.

5. Summary

Here, using the dynamics of the core of baryons described within the Scale-Symmetric Theory (SST), we explained the origin of the rest frame peak energy versus isotropic energy for GRBs. We described also the dependence of isotropic energy on mass of captured star by the most massive neutron star (NBH). The NBH can capture a neutron star as well.

The dependence of the rest-frame peak energy on the isotropic energy we can present using following relation

$$\log (E_{Peak}\ [\mathrm{keV}]) = a_i + b_i \log (E_{iso}\ [\mathrm{erg}] / 10^{52}) . \qquad (23)$$

Results obtained in this paper, on the basis of the SST structure of baryons and the theory of most massive neutron star, lead to:

* for the LGRBs is ($i = L$): $a_L = 2.40$ and $b_L = 0.50$ (the blue solid line in Fig.1), (24a)

* for the SGRBs is ($i = S$): $a_S = 2.97$ and $b_S = 0.50$ (the black dashed line in Fig.1) (24b).

Of course, the nuclear quantum processes widen the blue-solid and black-dashed lines – it should be a Gaussian-function-like widening. Notice also that in Paragraph **4**, we described the special cases A), B), C) and D) concerning the SGRBs.

Emphasize also that due to the lowest mass of star (0.0818 [solar masses] – see this paper) and the highest mass of neutron star (24.81 [solar masses] – see [6]) and the condition (10) in this paper, there should be the upper and lower limits for the lines/segments defined by (24a) and (24b). Moreover, when we take into account the masses of stars defined by the interval (0.0818, 24.81 [solar masses]), the mass of star equal to 5.70 [solar masses] separates the SGRBs from LGRBs.

Here we described the cases when a star is captured by the most massive neutron star but there can be realised the second scenario: a massive star with a mass higher than 24.81 [solar masses] collapses to the most massive neutron star (it looks as a supernova) and just next, the rest mass of the initial star is captured by the created neutron star (it looks as a GRB) – the GRBs that lay outside the lower limit defined by (24a) were created in such a way.

Because of the hedgehog-like mechanism, the isotropic energy is the real emitted energy. But when we wrongly assume that energy is emitted only via the jets then from the fact that along the jets are moving especially the electron-positron pairs produced by charged baryons and electrons, we obtain that typical mass is

$$M_{Typical} = \alpha_{W,proton}\ (e^+ + e^-)_{bare} = 0.01911\ \mathrm{MeV} . \qquad (25)$$

From (2) follows that then the typical emitted energy via jets, $E_{Typical,jets}$, relates to

$$E_{Typical,jets} = (M_{Typical} / n)\ M_{NBH} = 1 / 1982\ [\text{solar masses}] \approx$$

$$\approx 1 / 2000\ [\text{solar masses}] \approx 10^{51}\ \mathrm{erg} . \qquad (26)$$

Bigger neutron “black holes” are built of the NBHs.

Near the NBHs and groups of them are created orbits – such phenomenon is confirmed by the observations of the NASA’s planet-hunting Transiting Exoplanet Survey Satellite (TESS) [9]. It shows that when a “black hole” (i.e. the NBH or an association of the NBHs) tears apart a star then there appear the radial and orbital motions of the plasma from the destroyed star. But the orbital radii are quantized – I can see three different radii. Very important is the fact that at the end of destruction of the star there is created a plasma torus as it is in presented here theory of GRBs.

References

[1] Sylwester Kornowski (16 October 2019). “A Counterpart of the Isotropic Gamma-Ray Bursts in the Centres of Created Baryons”
http://vixra.org/abs/1910.0285
[2] Sylwester Kornowski (22 October 2019). “The Hedgehog-Like Mechanism as the Origin of the Prompt Emission of Gamma-Ray Bursts”
http://vixra.org/abs/1910.0439
[3] Sylwester Kornowski (24 October 2019). “The Time and Mass Versus Number of Bursts for Gamma-Ray Bursts”
http://vixra.org/abs/1910.0481
[4] Sylwester Kornowski (26 October 2019). “The Main Equation in Theory of Gamma-Ray Bursts”
http://vixra.org/abs/1910.0535
[5] Sylwester Kornowski (23 February 2018). “Foundations of the Scale-Symmetric Physics (Main Article No 1: Particle Physics)”
http://vixra.org/abs/1511.0188
[6] Sylwester Kornowski (14 February 2019). “Foundations of the Scale-Symmetric Physics (Main Article No 2: Cosmology)”
http://vixra.org/abs/1511.0223
[7] David Shiga (17 August 2006). “Mass cut-off between stars and brown dwarfs revealed” Science, Vol 313, p 936
http://space.newscientist.com/article/dn9771-mass-cutoff-between-stars-and-brown-dwarfs-revealed.html
[8] G. Ghirlanda (September 2015). “Are short Gamma Ray Bursts similar to long ones?” Journal of High Energy Astrophysics, Volume 7, September 2015, Pages 81-89
https://doi.org/10.1016/j.jheap.2015.04.002
[9] https://NASA (25 September 2019).
https://www.youtube.com/watch?v=85tdoDt1Qh0