The Origin of Gamma-Ray Bursts

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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 bolometric isotropic energy for Gamma-Ray Bursts (GRBs).

1. Introduction

AstroMeV is an international consortium of laboratories which want to prepare a new space mission to observe the cosmos at photon energies between 0.1 and 100 MeV. In their documents, the energies about 0.3 MeV and about 400 MeV appear as the peaks in best-fit model for the time-integrated photon spectrum (3.3 s – 21.6 s) [1]. On the other hand, within the dynamics of the core of baryons described within the Scale-Symmetric Theory (SST), there appears a counterpart of the isotropic Gamma-Ray Bursts (GRBs), i.e. there in the centre of created baryons is produced a condensate/scalar with a mass of \( Y = 424.122588 \text{ MeV} \approx 400 \text{ MeV} \) – there is emitted a photon with an energy of \( \Delta E = 0.272302 \text{ MeV} \approx 0.3 \text{ MeV} \) [2]. Comparison of the results leads to conclusion that the GRB spectra follow from the dynamics of the core of baryons.

Here, applying the SST, we described the origin of the collimation emitted energy, \( E_{\gamma,\text{collimated}} \), bolometric isotropic equivalent energy, \( E_{\gamma,\text{isotropic}} \), and the source frame peak energy, \( E_{\text{peak}} \), for the GRBs.

2. The dynamics

The Chandrasekhar limit is about 1.38 solar masses [3] or about 1.395 solar masses [4]. Energy of such mass is

\[
E_{\gamma,\text{isotropic, supernova-Ia}} \approx 2.5 \cdot 10^{54} \text{ erg} .
\]  

(1)

SST shows that there are the neutron “black holes” (NBHs) – the spin speeds of photons on the equators of NBHs are equal to the speed of light in “vacuum”. Mass of the NBHs is 24.81 times higher than the mass of the Sun [3].

More massive “black holes” are the associations of the NBHs but due to the four-object symmetry, their numbers in the “black holes” are quantized [5]

\[
N = 4^d, \text{ where } d = 0, 1, 2, 4, 8, 16, 32 \text{ for single components, } \\
N^* = 2 \cdot 4^d \text{ for binary-system components.}
\]

(2)
The relations (2) concern also other objects produced inside the core of baryons, for example, the bare electrons and positrons \((e^+ - e^- \text{_{bare}} = 0.510407 \text{ MeV})\) in groups of the electron-positron pairs or the tori/electric-charges in groups of them (mass of the tori/electric-charges is \(X^{+/-} = 318.29554 \text{ MeV}\)).

Most important is the mechanism of creation of the uncharged scalar condensates (i.e. the spin-zero objects) from the Einstein-spacetime components i.e. from the neutrino-antineutrino pairs \([6]\).

The core of baryons consists of the spin-1/2 torus/electric-charge \(X^{+/-}\) (which is also responsible for the nuclear strong interactions) and of the spin-0 uncharged-scalar condensate, \(Y\), in centre of the torus \([6]\). Due to collapse of groups of fermions or photons/gluons, near the condensate \(Y\) can be created the other spin-0 uncharged-scalar condensates – there are possible the vice versa processes.

To conserve spin and charge of the core of baryons, resultant spin and charge of the groups of fermions or photons/gluons must be equal to zero! The fermion-antifermion pairs have unitary spin and distance between them is \(2\pi R/3\), where \(R\) is the equatorial radius of the torus/charge \([6]\). It leads to conclusion that in the simplest case there collapses quadrupole of fermions (more precisely: two fermion-antifermion pairs with opposite spins) or two photons with opposite spins. Emphasize that the condensates can decay into quadrupoles of fermions or into two photons/gluons but due to the relations (2), number of final particles can be higher.

### 3. Calculations

In collisions of nucleons are produced the \(X^+X^-\) pairs. Assume that the Chandrasekhar limit corresponds to two pairs \(2(X^+ + X^-)\) which create two bare electron–positron pairs i.e. \(2(e^+ + e^-)_{\text{bare}}\) – it means that the \(E_X = 2(X^+ + X^-) \approx 1273 \text{ MeV}\) represents the bolometric isotropic equivalent energy for the Type Ia supernova \(E_{\gamma,\text{isotropic, supernova-Ia}} \approx 2.5 \cdot 10^{54} \text{ erg}\) while \(E_e = 2(e^+ + e^-)_{\text{bare}} \approx 2.042 \text{ MeV}\) represents the source frame peak energy \(E_{\text{peak,1}} \approx 2.0 \text{ MeV}\) for the collimation emitted energy \(E_{\gamma,\text{collimated}}\)

\[
E_{\text{peak,1}} = E_e \approx 2.0 \text{ MeV}.
\]  

The collimation emitted energy, \(E_{\gamma,\text{collimated,4e(bare)}}\), for the source frame peak energy equal to \(E_{\text{peak}} \approx 2.0 \text{ MeV}\) is

\[
E_{\gamma,\text{collimated,4e(bare)}} = E_{\gamma,\text{isotropic, supernova-Ia}} \frac{E_e}{E_X} \approx 4.0 \cdot 10^{51} \text{ erg}.
\]  

But there is the second value of the source frame peak energy for the bolometric isotropic equivalent energy \(E_{\gamma,\text{isotropic}}\) when it is equal to the collimation emitted energy equal to \(E_{\gamma,\text{collimated,4e(bare)}} \approx 4.0 \cdot 10^{51} \text{ erg}\). In paper \([2]\), we described a mechanism in which a transition of a particle from radius to circle (from \(r\) to \(2\pi r\)) decreases mass of the particle \(2\pi\) times. For such transition of the bare electron we obtain

\[
E_{\text{peak,0}} = \frac{e^{+/-}_{\text{bare}}}{(2\pi)} \approx 81 \text{ keV}.
\]
Such frame peak energy interacts with the bare electron-positron pair – it is the reason that with the value $4.0 \cdot 10^{51}$ erg (collimated and isotropic) are associated two frame peak energies. The frame peak energy 81 keV refers to following collimation emitted energy

$$E_{\gamma, \text{collimated,81-keV}} = E_{\gamma, \text{collimated},4e(bare)} \alpha_{\text{w,proton}} \approx 0.75 \cdot 10^{50} \text{ erg}$$  \hspace{1cm} (6)

where $\alpha_{\text{w,proton}} = 0.0187229$ is the coupling constant for the nuclear weak interactions [6].

Emphasize that the segments in Fig.1 relate to the nuclear weak interactions: the left one relates to a mean mass of $Y \approx 424$ MeV while the two right segments relate to the mean mass of condensate equivalent to the mass of neutral pion $\pi^0 \approx 135$ MeV. To the Einstein-spacetime condensates, we can apply the theory of stars so lifetime is inversely proportional to four powers of involved mass [6]. This lead to conclusion that the long-duration GRBs (LGRBs) last at the average

$$f = t_{\text{LGRBs}} / t_{\text{SGRBs}} = (Y / \pi^0)^4 \approx \pi^4 = 97.4 \text{ times}$$  \hspace{1cm} (7)

longer than the short-duration GRBs (SGRBs). It is consistent with observational data [7]: LGRBs last with an average time of about 30 seconds while SGRBs with an average duration of about 0.3 seconds i.e. the SGRBs last about 100 times shorter.

There is the third solution for the bolometric energy for the source frame peak energy equal to $E_{\text{peak,1}} = 2.0$ MeV. It is because instead $X^{+,-} = 318.29554$ MeV there can be $H^{+,-} + Y$, where $H^{+,-} = 727.44$ MeV is the mass of the charged core of baryons while $Y = 424.122588$ MeV is the central condensate/scalar in centre of the core. Such a change increases the bolometric isotropic equivalent energy

$$E_{\gamma, \text{isotropic,max.}} = E_{\gamma, \text{isotropic, supernova-Ia}} (H^{+,-} + Y) / X^{+,-} \approx 9.0 \cdot 10^{54} \text{ erg}.$$  \hspace{1cm} (8)
It relates to the bolometric isotropic equivalent energy emitted in the highest-energy gamma-ray emission of GRB 080916C: $8.8 \cdot 10^{54}$ erg [8].

Here we show that almost all GRBs should group near three curves (see Fig. 1). Only a few GRBs are outside the region defined by two intervals:

$$81 \text{ keV} < E_{\text{peak}} < 2.0 \text{ MeV}$$

but due to relation (2), there also can be, for example, $4.2 = 8 \text{ MeV}$.

$$0.75 \cdot 10^{50} \text{ erg} < E_{\gamma} < 9.0 \cdot 10^{54} \text{ erg}$$

but a few GRBs can be outside this interval.

We can compare obtained here theoretical results with observational facts [9]. We can see that both data are consistent.

Summary

Here we showed that theoretical results that follow from the theory of the core of baryons described within SST are consistent with observational data. This leads to conclusion that theory of GRBs is tightly related to the Scale-Symmetric Theory.

References

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