The Main Equation in Theory of Gamma-Ray Bursts

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Abstract: Here, using the Scale-Symmetric Theory (SST), we derived the main equation in theory of Gamma-Ray Bursts (GRBs) and used it to describe the GRB 080916C. Such theory is closely related to the theory of neutron "black holes" (NBHs) which is similar to the theory of baryons.

1. Introduction

In paper [1], we explained the origin of the energies about 0.3 MeV and about 400 MeV which appear as the peaks in best-fit model for the time-integrated photon spectrum (3.3 s – 21.6 s) for Gamma-Ray Bursts (GRBs) [2].

In paper [3], we described the origin of the curves for the rest frame peak energy versus the bolometric energy, and we showed that the long-duration GRBs (LGRBs) last at the average ~100 times longer than the short-duration GRBs (SGRBs). It is consistent with observational data [4].

In paper [5], we showed that the hedgehog mechanism realized in the neutron matter is responsible for the prompt emission of GRBs.

In paper [6], we described the graphs of the time and mass versus number of bursts for the GRBs. There appeared as an initial parameter the characteristic time duration of bursts equal to 720 seconds.

Here, using the Scale-Symmetric Theory (SST) [7], [8], we derived the main equation in theory of GRBs which concerns both the theory of neutron "black holes" (NBHs) and the theory of baryons.

2. The main equation in theory of GRBs

SST shows that the gravitational interactions around the NBHs and the nuclear strong interactions around the core of baryons are similar. In both areas acts the Titius-Bode law i.e. there are orbits which radii defines following formula

$$R_i = A_i + d\, B_i \,, \qquad (1)$$

where $F = A_i / B_i \approx 1.3898$ for both objects, $d = 0, 1, 2, 4$ (for baryons and NBHs), $8, 16, 32, 64, 128$ (for NBHs) [7], [9].

The equatorial radius of NBH is $A_{i(NBH)} = 3.664 \cdot 10^4$ m [8].

A star is captured by NBH in its orbit/tunnel $R_{i(NBH)} = A_{i(NBH)} + B_{i(NBH)}$. Then, the star radially passes to the equator of NBH and is blurred inside the orbit/tunnel which size in the baryons we calculated within the theory of baryons [7]. The volume of the $A_{i(NBH)}$ orbit/tunnel is not important but very important is the fact that each star is blurred inside the same volume, i.e. $V_{A(i)} = \text{constant}$. Next, due to the hedgehog mechanism appearing in the blurred plasma and in the initial NBH, matter is emitted in all directions as the gamma rays to reduce the mass of NBH to its initial value – it follows from the fact that mass of the NBHs is quantized: $M_{NBH} = 24.81$ solar masses.

From the Stefan-Boltzmann law we have

$$j^* \sim T^4 , \quad (2)$$

where j^* is the total energy radiated per unit surface area of a black body across all wavelengths per unit time (the radiant emittance), and T is the black body's thermodynamic absolute temperature. The radiant emittance is the radiant flux emitted by a surface per unit area. In our theory, the area of the $A_{i(NBH)}$ orbit/tunnel is constant so the assumption that radiant flux is constant leads to

$$j^* \sim E_{Emitted} \sim t_{Burst} , \quad (3)$$

where $E_{Emitted}$ is the total/isotropic emitted energy during a t_{Burst}–second burst.

From the ideal gas law we have

$$p \, V_{A(i)} / T = \text{const.} , \quad (4)$$

where p, $V_{A(i)}$ and T are the pressure, volume which is constant (it is the volume of the $A_{i(NBH)}$ orbit/tunnel) and absolute temperature. On the other hand, for the dynamic pressure we have

$$p \sim \rho \, c^2 , \quad (5)$$

where $\rho = m / V_{A(i)}$ is the density of the plasma in the orbit/tunnel (m is the mass of captured star) and $c = \text{constant}$ is the speed of light in "vacuum".

From (4) and (5) we have

$$T \sim m . \quad (6)$$

From (2), (3) and (6) we have

$$t_{Burst} \sim m^4 . \quad (7)$$

During the creation of new NBH there is the radial transition of the weak mass of the NBH and of new NBH from distance $A_{i(NBH)}$ to distance $(A_{i(NBH)} + B_{i(NBH)})$ (there is some baryonic analog to such process because six of the seven hyperons decay due to the weak interactions [7]).

The weak mass is

$$M_{Weak} = \alpha_{W(proton)} \, M_{NBH} , \quad (8)$$

where $\alpha_{W(proton)} = 0.0187229$ [7]. We used some analog to formula (8) to calculate lifetime of the neutral pion (see formula (142) in [7]). Emphasize that the speed of light in "vacuum" c is characteristic for the nuclear strong interactions ($t_o = B_i / c$) so for the weak interactions, which is weaker, the speed of transition is slowed down. From (7) and (8) we obtain the time duration of burst for star with a mass equal to M_{NBH}

$$t_{Burst,NBH} = (B_{i(NBH)} / c) (M_{NBH} / M_{Weak})^4 =$$

$$= (B_{i(NBH)} / c) / \alpha_{W(proton)}^4 = 716 \text{ s} \approx 720 \text{ s} . \qquad (9)$$

In [6], we used the time 720 seconds as the initial parameter. We can see that here we derived this value within SST.

From (7) and (9) we have

$$t_{Burst} = 716 (m / M_{NBH})^4 \text{ [seconds]} , \qquad (10)$$

where m [solar masses] is mass of captured star by NBH and $M_{NBH} = 24.81$ [solar masses].

Equation (10) is the main equation in the theory of Gamma-Ray Bursts.

Some baryonic analog to stars captured by NBH looks as follows

$$m / M_{NBH} = m_{Particle} / M_{Neutron} . \qquad (11)$$

More data concerning formulae (10) and (11) we can find in [6].

3. The GRB 080916C

Consider a star or binary system of stars with total mass which relates to mass of the hyperon $\Lambda = 1115.3$ MeV [7]. From formulae (10) and (11) we obtain that some stellar analog to the hyperon Λ has mass equal to $M_\Lambda = 24.81 \cdot 1115.3/939.54 = 29.45$ solar masses i.e. such star is more massive than NBH. From (10) we obtain that the burst should lasts

$$t_{Burst,GRB080916C} = 716 (M_\Lambda / M_{NBH})^4 = 1422 \text{ s} = 23.7 \text{ min.} \qquad (12)$$

In the final stage there should appear new NBH while the mass equal to $29.45 - 24.81 = 4.64$ [solar masses] should be emitted as the gamma rays. Since total energy of the Sun is about $1.8 \cdot 10^{54}$ erg so emitted isotropic energy should be about $4.64 \cdot 1.8 \cdot 10^{54} = 8.4 \cdot 10^{54}$ erg.

We can compare these results with data obtained by the Fermi LAT and Fermi GBM Collaborations [10]. They obtained respectively ~1400 s and $\sim 8.8 \cdot 10^{54}$ erg.

4. Summary

Here, using the Scale-Symmetric Theory (SST), we derived the main equation in the theory of Gamma-Ray Bursts, we described properties of the GRB 080916C, and showed that initial star captured by NBH had mass which relates to mass of hyperon Λ (see formula (11)).

References

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