On the Theory of Gamma-ray and Fast Radio Bursts

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Abstract

Gamma-ray bursts are characterized by energy comparable to the rest mass of stars and duration comparable to the time of passage of light of several diameters of star. It means GRBs signal the flares occur when stars fall on supermassive neutron collapsars (SMNC) located at the centers of galaxies. Long, short, very short and weak GRBs are matched the fall of main sequence stars, white dwarfs, neutron stars (NS) and rogue planets, respectively. GRB is the result of heating of star caused by the action of three factors: transverse compression of angular convergence to SMNC, friction of light matter (LM), and volumetric compression of the entry into gravitationally distended space. GRB is a circular flare in the stellar corona. GRB lasts until the star will be hidden under the π-horizon, on which the angle of gravitational deflection of beams is 180°. Multiple peaks are caused by the fall of binary stars and stars with planets, as well as by consecutive bursts of stellar core and overlying layers. Early afterglow is due to the annihilation, and later (x-ray and radio) due to aurora and remanence of LM. FRB precedes very short GRB. Milliseconds before GRB, "magnetic lightning" arises, which is a reconnection of magnetic field lines from NS anterior pole to SMNC. Magnetic dipoles of LM nuclei are aligned along the magnetic lines of force. This is accompanied by radio emission generated strictly perpendicular magnetic tube connecting NS and SMNC. Gravitation bends the plane of FRB in the hyperboloid with the cone angle of 40°. Double FRB is due to gravitational lensing, emerging with a small angle between the axis of cone and the direction to us. In this case, the linear polarization of adjacent pulses will not coincide.

1. Introduction

Hypothesis that gamma-ray bursts signal the falls of stars on supermassive neutron collapars (SMNC) located at the centers of galaxies, would be perhaps the most simple conjecture, if it were not the generally accepted view coincide with the predictions of general theory of relativity, according to which any compact object with a sufficiently large mass can be none other than "black hole" (BH). For an external observer, the fall of any object in the BH should be completed by the sudden disappearance of the object from view because of increasing time dilation, as the object approaches the "event horizon" located on the Schwarzschild radius. The theory explains that gravitational time dilation (GTD) occurs in conjunction with the curvature of space, since space and time are considered as if concatenated into a unified "four-dimensional space-time" (4DST). But if we assume that the time stops at the event horizon, it should not be there in such a case a spatial dimension to experience some analogue of a stop? And if there is no such analogue, is not wise to doubt the reality of 4DST, GTD and BH? To show that GTD is a fallacy, consider an explanatory example with the speed of free fall from infinity (or escape velocity):

$$v = \sqrt{2 G M r^{-1}} \tag{1}$$

At the Schwarzschild radius the speed of free fall is obtained equal to the speed of light, and since according to STR no body can reach the speed of light, it is as though proves the existence of an event horizon. However, it should not slip away from us the fact that the speed of the fall is obtained equal to the speed of light by the non-relativistic formula! Recall that the speed of particles and bodies is determined not by their location, but by the kinetic energy they have in a given place. According to the inverse square law (ISL), the increment of the kinetic energy of the free fall of bodies and particles tends to infinity only in the center of the attracting body. This means that the calculated speed of free fall at the Schwarzschild radius must be smaller than the speed of light. The following formula for escape velocity satisfies both the ISL and STR:

$$v = c\sqrt{1-\left(\frac{GM}{c^2 r}+1\right)^{-2}} \tag{2}$$

According to this formula, the escape velocity at the Schwarzschild radius amounts to 0.745c. Thus, it turns out that the explanatory example with the speed of the fall is not so much supports as rather refutes the idea of GTD. However, the singularity refutes itself, because if time stops at the event horizon, then the matter concentrated in BH must completely lose the ability to reproduce its own essence, including the gravitational interaction. This does not occur, hence time does not stop. And nevertheless, what could serve as the equivalent of a non-existent GTD for the spatial dimension? The answer provides a new model of gravitation (NMG), according to which such an imaginary equivalent of non-existent GTD is really existing gravitational distension of space. And then the Lorentz factor of the body or particle freely falling from infinity will be exactly equal to the linear distension of space created by the attracting body:

$$\Theta = \frac{GM}{c^2 r}+1 \tag{3}$$

Parameter of Θ indicates that at this point in space, each of the three spatial dimensions gets distension of scale in Θ times. For the gravitational field the gradient of distension of space and the curvature of space can be regarded as identical notions. And then the action of gravitation can be explained by the fact that the gradient of distension of space causes the corresponding change in relativistic kinematics effects of moving bodies.

When describing the supermassive objects, basic value has the presence or absence of an upper limit on the mass of the neutron star (NS), in which the pressure of the degenerate neutron gas gives way the pressure of the overlying layers and NS undergoes unlimited gravitational collapse. In our model, the upper limit of the mass does not exist, but the density limit is introduced, which cannot be exceeded under any circumstances as well as the speed of light. As such a limit, we consider the density of matter in the cores of neutron stars, and accept it equal to 5×10^{17} kg/m^3. And if compaction of matter means consistent transition from gas to liquid and finally to a solid state of aggregation, then we will consider the neutron matter not as a gas, but as a solid substance with a polycrystalline structure. Polycrystalline neutron matter will be considered as completely impervious to all elementary particles including neutrinos.

In NMG the gravitational bending of light rays passing near the stellar disk is determined by the formula:

$$\varphi = \frac{8}{3}\frac{GM}{c^2 r} \tag{4}$$

Near SMNC the gravitational bending of light is so strong that the angle of φ can be many times greater than 360°. In this connection, it is expedient to introduce an intermediate radius where the angle of bending of light will be 180°. We denote the sphere delineated by this radius as π-horizon. The radiation that occurs below the π-horizon undergoes such a strong gravitational lensing, that is almost completely absorbed by the collapsar. Only those of photons that come up almost vertically, have a chance to go out of the π-horizon and leave SMNC, and the nearer to SMNC, the less the chance. But If gravitation deflects the light, then why magnetic field lines could not experience the gravitational deflection? Such gravitational deflection should really take place, but it will be caused not by the gravitational attraction but by the gravitational deformation of space. That is, if you imagine yourself the magnetic field line coincides with the ray of light, then its deflection will be only ¼ of the deflection of light.

As show astronomical observations, ordinary matter of galaxies accounts for only about 15% of their mass, and the rest is accounted for by dark matter. Based on the model of light matter (LM) [4], we will assume that around SMNC (or central collapsars, CC) there is always present halo of LM. According to the two-level mass model of the Milky Way [3], halo of LM within the bulge (first level) is characterized by the following dependence of the density of the radius:

$$\rho_{GM}(r) = k_{RD}\, \rho_A\, (r_L / r)^{2.5} \ , \tag{5}$$

where ρ_A is limiting density of LM, accepted in 1840 times less than the neutron density ($\rho_A = 2.72 \times 10^{14}$ kg/m^3), k_{RD} is rarefaction factor to density limit of LM (k_{RD} = 0.96), r_L is radius of CC (r_L = 355 km). The mass of matter around CC limited to a given radius r, will be:

$$M_{GM}(r) = M_{CC} + \int_{r_L}^{r} 4\pi r^2 \rho_{GM}(r)\, dr \ , \tag{6}$$

where M_{CC} is estimated mass of CC (9.38×10^{34} kg or $4.71 \times 10^4\ M_{\odot}$).

These parameters were chosen so that the calculated mass of the object Sagittarius A*, distributed inside the sphere with a radius of 1880 AU (apocenter of S0-2 star), is coincided with the current estimate of the mass of Sgr A* [8], [9], [10]. We assume the mass of Sgr A* is equal to $4.2 \times 10^6\ M_{\odot}$. We note that in our model, the mass of CC is only 1.1% of the total estimate mass of Sgr A *, and the rest is accounted for the halo of LM.

Since in NMG there is no "event horizon", then we have no need to discern the existence of an accretion disk at SMNC. Accretion of any object onto SMNC will be strictly radial, with negligible tangential component of falling velocity.

On this, our review of the preliminary results of NMG is completed and we proceed to the description of the main part of the study, namely, the theory of gamma-ray and fast radio bursts.

2. Gamma-ray bursts and factors of their occurrence

The energy of GRB comparable to the rest mass of stars and duration comparable to the time of passage of light of several diameters of star clearly indicate that GRBs occur at falling of stars on SMNCs. We note first that GRB does not arise from the collision with the surface of SMNC (this event is not observed due to a very strong attenuation of brightness due to the gravitational lensing), but by the heating of star or planet before entering the π-horizon. The following factors play a decisive role in the heating of star and the emergence of GRB:

- transverse compression arising from the angular convergence of star on a much smaller area of the final place of the fall on SMNC;

- friction of the electrons and atomic nuclei of falling star of LM in a very dense halo of SMNC;

- volumetric compression from the entry of star into the area of gravitationally distended space.

To determine in what extent these and other factors affect the observed properties of GRBs, we distribute 4 types of GRBs (long, short, very short and weak) on four typical representatives of different classes of stars. The distribution of stars and GRBs is shown in table 1.

Table 1. Distribution of typical representatives of different classes of stars and rogue planets and gamma-ray bursts

	Red Dwarf	White Dwarf	Neutron star	Rogue planet
Representative	Averaged	Averaged	Averaged	Callisto
Mass	$0.2\ M_\odot$	$0.64\ M_\odot$	$1.5\ M_\odot$	0.018 Earths
Radius	$0.25\ R_\odot$	8360 km	16 km	2410 km
Average density, kg/m^3	1.8×10^4	5.2×10^8	3.3×10^{17}	1834
Type of GRB corresponding to the fall of the object	Long	Short	Very short	Weak
Typical range of the duration of GRB, s	From 12 and more	From 0.1 to 1	From 0.01 to 0.1	From 0.4 to 25
Expected duration of corresponding GRB, s	30	0.3	0.07	2

Falling of star or planet on SMNC is regarded as random event caused by gravitational slingshot, after which the star or planet is accidentally directed to the galactic center. Such a star or planet can come from anywhere in the galaxy. For simplicity we assume that the fall onto SMNC always happens strictly vertical.

Time of passage by star of any section of vertical fall can be defined by the integral:

$$t = \int \frac{1}{v(r)}\, dr\ , \qquad (7)$$

As SMNC we take CC of our Galaxy. Taking into account the mass of distributed LM, the radius of π-horizon will be 173 times greater than the radius of CC, and will constitute 6.13×10^{7} m. Long GRB with duration of 30 seconds will start at a radius of 52 times greater than the radius of π-horizon. Minutes before the beginning of GRB the heating caused by transverse compression from angular convergence increases the temperature of star by tens and hundreds of times.

Now find out the value of the factor of friction of halo of LM. Considering the difference in size of atoms and atomic nuclei, as well as the difference in the masses of air molecules and LM nuclei, we will assume that LM density, equivalent by resistance of the medium, should be higher than the air density by 10^{12} times ($10^{5\times3}$ / 10^{3}). For comparison, in the Earth's atmosphere meteors begin to burn and become visible at an altitude of 100 – 120 km. In conditions of moderate solar and geomagnetic activity the density of the Earth's atmosphere at these altitudes is:

2.03×10^{-8} kg/m^3 at altitude 120 km,
5.37×10^{-7} kg/m^3 at altitude 100 km.

The corresponding equivalent values of LM density will be crossed by star for 43 and 7 seconds before entering the π-horizon. Hence we can conclude that the beginning of long GRB has the cause of the heating of star by combined action of two factors, the transverse compression and friction of halo of LM.

In cases when there is a fall of binary star, or star with a planetary system, the light curve of GRB will have several peaks. Outstripping fall of planet will correspond to a weak peak, followed by a few tens of seconds the main GRB. Such a preliminary weak peak can be interpreted as a precursor of GRB, but it should be rather considered as the beginning of GRB.

For WD and NS the friction of the halo as a factor of heating is not as important as that of main sequence stars (MSS) due to incommensurable higher density of degenerate matter of WD and NS. The heating from friction will experience only the outer shell of star. Therefore, before to burst out, WD and NS flies to the π-horizon much closer than MSSs and giants. Short and very short GRBs arise when the star is heated sharply from volumetric compression when entering into the gravitationally distended space. And the same factor causes final series of peaks at long GRBs.

By the beginning of short GRB the transverse compression from angular convergence is plumping WD hundreds of times. The longitudinal size of WD increases several times. For WD with a mass of 0.64 $M_\odot$, the beginning of short GRB corresponds to the achievement of radius 2.2 times greater than that of the π-horizon.

At NS the transverse compression of angular convergence reduces the cross-section of star and increases its length by dozens of times. For NS with the mass of 1.5 $M_\odot$ the beginning of very short GRB corresponds to the achievement of radius 1.3 times greater than that of the π-horizon.

At falling of rogue planets it is possible one or two peaks in the light curve of weak GRBs. The first peak is due to heating of the giant planet from the transverse compression and friction of the halo of LM. The second peak of giant planet and one single of dwarf planet will be conditioned by heating from volumetric compression, which happens at the radius of 3-8 times greater than that of the π-horizon.

3. Mechanism of gamma-ray bursts

The heating of falling star to a high temperature leads to the fact that in the depths of star are starting to go reactions generating neutrinos and antineutrinos, analogous to reactions of Urca process during supernovae explosion and in the cooling of NS. It would seem the neutrinos and antineutrinos, which does not tend to interact with matter, must take the energy from the depths of falling star completely unnoticed. But in this case, everything is exactly the opposite. Explanation is next. Firstly, any GRB occurs in dense halo of LM. Secondly, neutrinos and antineutrinos to counterbalance their disinclination to interact with ordinary matter, as well as with LM, under certain conditions readily interact with electrons and with each other[1], forming short lived

1 Generally accepted view is that neutrinos "oscillate", that is on the move change their "flavor". That and another is absent in our model. According to the new classification of elementary particles

Cooper neutrino pair (CNP). Among such CNP, the neutrino-antineutrino pairs annihilate immediately, and the same name pairs either decay, or will experience subsequent merger with the conversion into nuclei of neutrinium and antineutrinium. The nuclei of newly formed antineutrinium LM are mixed and come into synthesis with the same antineutrinium nuclei of halo, and neutrinium nuclei of anti-LM, facing native antineutrinium nuclei, are annihilated. Fusion of the LM nuclei is accompanied by X-rays with an energy from 2 keV and higher, and radiation from the annihilation of LM has a very wide range, from infrared to gamma. Annihilation of LM nuclei produces a shower of secondary neutrinos and antineutrinos, as well as secondary nuclei of antineutrinium LM (with an average mass number smaller than in the halo). We note that if GRB is happening in a galaxy composed of antimatter, the role of anti-LM will serve antineutrinium LM, and as a native LM will be neutrinium LM. Radiation from the circular flare in the stellar corona will be immeasurably more powerful than the radiation from the star's photosphere. Since not all the nuclei of anti-LM have time to interact immediately with the nuclei of native LM, the annihilation of LM will continue for some time after decline of star beyond the π-horizon, which explains the earlier afterglow.

But we have a question, why the number of neutrinos and antineutrinos in falling star increases not proportional to the heating, but abruptly? This can be explained by the hypothesis of stimulated generation of neutrino and antineutrino (SGNA). To SGNA arose, must be achieved and slightly surpassed the temperature threshold of pair production. As soon as the flux of neutrinos and antineutrinos reaches a critical level, SGNA begins and orders of magnitude more powerful stream of neutrinos and antineutrinos rapidly takes out the stored energy from the heating of star.

The temperature required for the start of SGNA is initially achieved in stellar core, and this point corresponds to the first peak of GRB (excluding the preliminary weak peak from planet satellite). Sequential heating of the overlying layers will be accompanied by successive surges of SGNA and corresponding peaks in the light curve of GRB. It will be the third factor in the emergence of multiple peaks.

Thus, the mechanism of GRB can be represented by the following sequence of events: 1) gravitational slingshot directs the star onto SMNC, 2) during the last few tens of seconds of falling, there is a rapid heating of the star, 3) heating of the star leads to one or more bursts of SGNA and annihilation of LM in the stellar corona, 4) GRB ends when the star goes beyond the π-horizon, 5) in the halo of LM continues afterglow.

4. Dependence of the duration of GRB on the parameters of star

For each type of GRB we can find a simple empirical dependence of the duration of GRB of the stellar mass.

Duration of long GRB can be expressed through the mass of MSS in the following formula:

$$t = 150 \frac{M_{MS}}{M_{\odot}} \qquad (8)$$

In the case of the fall of giant the factor will be 4 times greater:

[2] there is only one type of neutrino, having the shape of a cube.

$$t = 600\ \frac{M_{GS}}{M_{\odot}} \tag{9}$$

Duration of short GRB depends not only on the mass but also on the temperature of WD. The colder WD, the closer to the π-horizon GRB appears and the less it lasts:

$$t = 0.12\ \frac{M_{WD}}{M_{\odot}}\ \left(\log_{600}(T_{WD})\right)^4\ , \tag{10}$$

where T_{WD} is the surface temperature of WD, Kelvin.
For example, for GRB, with a duration of 0.3 s and for WD with a mass of 0,64 $M_{\odot}$, the surface temperature of WD should be 8050 K.

The dependence of the duration of very short GRB of the mass of NS has the following formula:

$$t = 0.11\left(\frac{M_{NS}}{M_{\odot}} - 0.7\right)^2 \tag{11}$$

For weak GRB dependence of the duration of the mass of the planet has the following formula:

$$t = 3.6\left(\frac{M_{RP}}{M_{T}}\right)^{\frac{1}{3}}\ , \tag{12}$$

where M_T is Earth's mass.

5. Fast radio bursts

The action of transverse compression from angular convergence is similar to the action of tidal forces. These forces slow down the rotation of falling NS at the expense of reducing the share of angular momentum of the vector perpendicular to the direction of falling. As NS heating, the crystal neutron matter becomes a liquid, and then gaseous. Factor of friction of LM leads to the fact that in the outer shell of NS is set the annular electric current with the direction of motion of electrons opposite to the rotation of NS. This annular electric current creates around NS extremely powerful magnetic field.

In just a few seconds before entering NS on the π-horizon the magnetic field lines with the greatest length extending from the front magnetic pole of NS are experiencing gravitational deflection and reconnect to SMNC. The shorter the distance between NS and π-horizon, the greater the area on the front pole of NS, from where the magnetic field lines reconnect to SMNC. When the magnetic fields of NS and SMNC are equalized, then arises "magnetic lightning", which is the instantaneous reconnection of magnetic field lines from the front magnetic pole of NS onto SMNC. The profile of reconnected magnetic lines is changed from S-shaped to rectilinear. Simultaneously abruptly decreases magnetic field strength in NS between its magnetic poles. At the same moment in the star begins outbreak of SGNA, giving rise to vsGRB. Flurry of neutrinos and antineutrinos makes instantly extinguished the annular electric current and the magnetic field of NS disappears. And the magnetic tube disappears, having lasted only a few milliseconds.

For NS with the mass of 1.5 $M_{\odot}$ the length of magnetic tube to the π-horizon is 1.8×10^{4} km, and its diameter is about 6 km. Mass of LM in the area of effect of the magnetic tube will be comparable to the mass of the Earth. LM is paramagnetic and its nuclei are oriented in the magnetic field so that their magnetic dipoles are aligned along the magnetic field lines. Strictly ordered straight orientation induces LM nuclei to condense into molecular aggregates. Condensation of LM nuclei into molecules is accompanied by radio emission. For cold LM frequency of radio emission is 100-150 kHz (like auroral kilometric radiation). In a dense halo of SMNC light matter has a very high temperature, so the radio emission from LM is shifted to higher frequencies (as well as from pulsars).

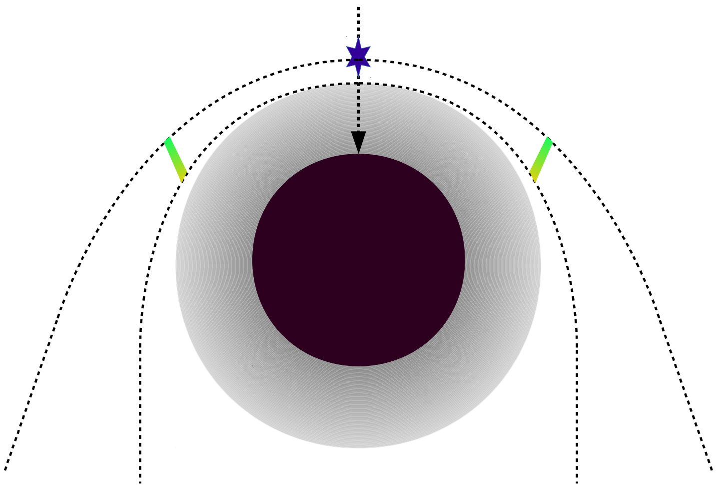

Figure 1. Fast radio burst and subsequent very short GRB. SMNC (black circle) is shown with zoom of gravitationally distended space. Grey shows the area under the π-horizon. FRB precedes vsGRB and propagates in a cone with an angle of 40°. Gradient color of FRB shows gravitational redshift. Blue 6-pointed star indicates location of vsGRB.

Photons of FRB are emitted strictly perpendicular to the magnetic field lines. Gravitation of SMNC bends the trajectory of photons causing them to move in a hyperbola. The angle of the cone of spread of FRB is 40°. This means that only 3% of the observed vsGRBs have the possibility to detect associated FRB. Such vsGRBs will be observed due to gravitational lensing of SMNC, and this means that for each FRB there is a theoretical possibility to detect concomitant vsGRB, unless the latter will not be obscured by clouds of gas and dust.

The recent discovery of a two-component FRB [35] is of particular interest from the standpoint of checking capabilities of our model to explain this event. But how to explain double peak, if subsequent GRB instantaneously extinguishes magnetic lightning? We can consider three scenarios, two of which are based on the division of NS into two parts, and the third assumes gravitational lensing. The first scenario assumes that NS has a relatively long period of proper rotation. In the last seconds of the fall the rotation of NS is slowing still more, contributing to greater elongation of falling NS. In the elongated NS there is a considerable gradient heating along the length. The surge of SGNA always starts from hotter the front end of NS. At the same time the dynamo of NS, fueled by annular electric current, compete with SGNA and converts the heat energy into magnetization of surrounding LM. If NS is stretched too much, then the surge of SGNA at the front end of NS will be not powerful enough to extinguish the electric current in the rear part of NS. Having exhausted the stored energy of heating of star, the primary surge of SGNA is quickly extinguished, and the dynamo of NS restores the magnetic tube for a short time. Repeated and more powerful surge of SGNA already fully extinguishes the dynamo of NS.

The second scenario assumes that NS is a pulsar with a relatively short period. The faster NS rotates the more elongated triaxial ellipsoid of NS. About two seconds before entering NS on the π-horizon the reconnection of magnetic field lines from the anterior pole of NS to SMNC leads to the appearance on the π-horizon the reciprocal fixed magnetic pole. The opposite magnetic pole of SMNC has no fixed localization on the π-horizon. In less than one second before FRB the magnetic attraction between the rear magnetic pole of NS and nonlocal magnetic pole on the π-horizon becomes strong enough to hold the rear part of NS from precession. At this moment NS divides into two parts. Each of the two parts of NS produces its own FRB and vsGRB.

The third scenario assumes a small angle between the axis of the cone of FRB and the direction to us. In this orientation, the original components of double burst originally were simultaneous, but opposite in direction. "Farther", but comes before the first pulse begins just below the π-horizon, and the deflection angle of the beam from the line will be a little more than 90°. "Nearest" pulse comes second, and begins just above the π-horizon, and its beam angle will be slightly less than 90°. Pulse with more curved trajectory comes to us a little earlier, because in the initial part of the way he runs through the region of more distended space than that of the second pulse. Calculations show that the interval of 2.44 ms, separating two components of FRB, corresponds to the deviation of the axis of the cone on the direction of FRB to us at 1.9°. The following features are here:

- the first (and farther) pulse has a slightly larger gravitational redshift than the second (for 2.44 ms interval the difference in redshift will be about 0.0115);

- linear polarization of the first and the second pulses will not coincide, since while the magnetic field equally rotates their polarization, the two pulses diverge in opposite directions.

According to the third scenario, the possibility of observing double FRB appears only in the case where the deviation of the line of sight from the axis of the cone of FRB does not exceed 2-3°. At a higher angle, farther pulse closes on the collapsar. If we assume that the cutoff of farther pulse occurs at angles of deviation of the line of sight by more than 2.5°, then the probability of detection of double FRB can be estimated as 1 per 60 normal FRB.

6. Afterglow of GRBs

Early afterglow of GRB apparently arises from the residual annihilation between the newly formed anti-LM and native LM of the halo. Later and longer afterglow is caused by the residual magnetic field in the halo of LM. In most cases, the magnetic field of falling star will have time to magnetize the halo of LM before GRB extinguish the dynamo of star. Later afterglow in radio is caused by the condensation of LM nuclei into molecular aggregates near the magnetic poles of the halo. Later afterglow in X-rays is the radiation from the aurora, which is caused by the synthesis of LM in the circumpolar regions. Its maximum should be in the range of 2-6 keV.

7. Conclusions

Assuming that GRBs signal the outbreaks of stars at the final stage of their falling on SMNC, we set ourselves a goal to construct a theory of GRBs. The goal was achieved, and we have been able to explain the mechanism of as GRBs and FRBs, as well as to predict that after each FRB within a few milliseconds should follow vsGRB. To test this prediction will need to simultaneously observe the same regions of the sky with radio telescopes and spacecraft GRB detectors. Another no less interesting opportunity to test our theory is to detect the phenomenon of SGNA. The experiment can be carried out under laboratory conditions on the basis of a power installation that allows to reach temperatures of tens millions kelvins. By approaching one or more bright enough sources of neutrinos and antineutrinos to the place of the maximum release of energy, it is possible to initiate SGNA. Neutrino beams should be directed towards the nearest neutrino detectors. No doubt, a powerful burst of neutrinos and antineutrinos will not go unnoticed.

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