Pis'ma v ZhETF, vol.62, iss.2, pp.86 - 90

ABOUT POSSIBILE GENERATION OF COSMIC RAYS AND GAMMA-BURSTS IN PLASMA PINCHES

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Submitted 18 May 1995

The hypothesis is considered that the cosmic gamma-bursts are generated by bremsstrahlung of the electrons accelerated in discharges of "lightning" type arising in "peripheral plasma shells" of stars. Such shells could be formed between stars as a result of the long-duration accumulation of the plasma "wind" (similar to "solar wind") in those places, where it meets with the wind from neighbouring stars. The possibility of it, that in the same discharges the ions are generated and accelerated as cosmic rays, is also considered.

1. Introduction. Approximately once in 24 hours the devices on satellits register the short-time powerful bursts of the cosmic gamma-radiation, however, the distances to their sources and their nature remain to be unknown. By a number of features in their energy spectra it was previously considered that they arose on the old neutron stars which were not directly observed. However, at present the supervisions on satellites ("Granat" – Russia and "GRO" – USA) do not confirm the presence of such features [1-3], and so some authors consider other possibilities of gamma-burst generation (GB), not connected with neutron stars.

So, in our papers [4,5] it is assumed that GB arise in the discharges of "cosmic lightning" type within interstar plasma clouds. This hypothesis is criticized in [6], where it is supposed that the discharges occur in the Sun-system limits at distances of the order 100 a.u. Note also [7], there the possibility of GB birth is considered as a result of comet collisions.

Previously in a number of papers (see, for example, [8-10]) we considered the possibility of acceleration for galactic cosmic rays (GCR) in electrical discharges of hypothetical "cosmic lightnings" with currents. On their cylindrical channel, due to an instability, the narrow necks should emerge from which the plasmoids of quasi-neutral plasma should be extruded along the axis. In this situation the velocities of electrons and ions should be equal, so the energy of protons should be $m_p/m_e \sim 2000$ times greater, than the energy of electrons.

In a given study the question under discussion – is whether the observable GB are the direct manifestation of such "cosmic lightnings", and whether GCR (as a proton component) and GB (as an electron component giving the bremsstrahlung) emerge in them simultaneously.

2. The power of galactic cosmic rays and gamma-bursts. As known, the GCR energy density is equal 1 eV·cm^{-3}, and at the volume of Galaxy 10^{68} cm^3, their total energy is equal $\sim 10^{56}$ erg. However, approximately during 100 mln. years they diffusionally leave the Galaxy, so for their sustainment the capacity $W_{GCR} = 2 \cdot 10^{40}$ erg/s is necessary. At the "pinch-mechanism"

the power 2000-times smaller would belong to electrons, $W_e = 10^{37}$ *erg/s,*
from all the GCR-sources, number of which in Galaxy we tried to compare with the number of gamma-burst sources.

Approximately one GB, $\sim 1 \div 10$ s long, is registered with the flows of energy from the minimum 10^{-6} to the maximal 10^{-3} erg·cm^{-2}·s^{-1} during 24 hours. However, the distances, R, to them are unknown. It is natural to assume that the weak GB-s correspond to large distances R_{max}, and the powerful, to short distances R_{min}, and then we have the ratio $R_{max}/R_{min} = \sqrt{1000} = 31.6$. At the average GB duration equal 3 s we have an evaluation of the total energy of one GB:

$$E_1[\text{erg}] = 4 \cdot 10^{-2} R^2_{min,\text{cm}} = 4 \cdot 10^{-5} R^2_{max,\text{cm}}. \qquad (1)$$

Then we assume, that GB are related not with the neutron stars but with usual stars. Since 1 GB is observed for 24 hours, the relationship (1) corresponds, on average, to the "stationar" capacity $W = 5 \cdot 10^{-10} R^2_{max,\text{cm}}$ erg/s in the sphere with the radius R_{max} and with the volume $V = (4/3)\pi R^3_{max}$. In the neighbouhood of the Sun the density of the star matter is equal $\rho = 0.05\ M_\odot$ ps^{-3} (1 ps $= 3 \cdot 10^{18}$ cm), so the number of stars in the mentioned sphere is equal $N = \rho V/M_\odot = 7.4 \cdot 10^{-57} R^3_{max,\text{cm}}$.

Hence, we have the "stationar" capacity of GB per star $W_{1star} \approx 0.7 \cdot 10^{47} R^{-1}_{max,\text{cm}}$ erg/s. And since the Galaxy has 10^{11} stars, we must to ascribe to them the total capacity of GB $W_\gamma = 0.7 \cdot 10^{58} R^{-1}_{max,\text{cm}}$ erg/s. And if we assume that $W_\gamma = W_e$, then we shall find $R_{max} \approx 220$ ps, and this length appears to be shorter than the width of the galactic disk.

Then the energy of one typical GB would be equal $E_1 \approx 2 \cdot 10^{37}$ *erg.*

It is remarkable that the same evaluation of energy per one GB was taken previously from the hypothesis about neutron stars, as GB-sources too. In our representation, for close GB we find $R_{min} \approx 7$ ps that approximately corresponds to the average distance between stars. The number of stars in a sphere with the radius R_{max} is equal to $N \approx 2$ mln. that provides the observable isotropy in the distribution of GB-sources in their directions.

The received evaluations look like rather reasonable and permit to assume that GCR and GB are being generated simultaneously in the "cosmic lightnings" which occur from time to time in the clouds of magnetized cosmic plasma the properties of which are discussed below.

3. The assumed characteristics of plasma clouds. In an interstellar space there are large molecular clouds, where new stars can often emerge. However, we are interested in the smaller plasma clouds which are not directly observed. It is possible to assume that they arise in those places, where the plasma "star winds" emitted by adjacent stars collide. In the neibourhood of the Sun we have:

star number density $n = L^{-3} = 0.05$ ps^{-3},

the average distance between them $L = 2.7$ ps $= 8 \cdot 10^{18}$ cm,

and their relative velocities $v = 20$ km/s.

If L is assumed to be the radius of a plasma shell, the cross-section of shell collisions will be equal $\sigma = \pi L^2$, the number of collisions of one shell with another during a unit of time is equal $\nu = n\sigma v = \pi v/L \approx 8 \cdot 10^{-13}$ s$^{-1} \approx 7 \cdot 10^{-8}$ for 24 hours. Multiplying this value by $N = 2 \cdot 10^6$, number of stars in a sphere of the radius R_{max}, we receive 0.14 [GB/24h], that is rather close to the observable frequency "one GB per day". This proximity, which we can improve by a small change of multipliers, by our opinion, is a rather remarkable fact also.

The duration of GB (~ 3 s) indicates that the length of breaking the neck of a pinch should be of the order of $\lambda \sim 10^{11}$ cm. It corresponds to the diameter of the Sun, and, as noted in [6], for the hypothesis under consideration the most important question is: how the energy E_1, giving one GB, can be concentrated in the area with such dimensions?

4. Can "star wind" generate gamma-bursts ? In [6] it is assumed that GB occur at the distances of the order of $R_{min} \sim 100$ a.u.$= 1.5 \cdot 10^{15}$ cm, and then $E_1 \sim 10^{29}$ erg. But when $R_{min} = 7$ ps $= 2 \cdot 10^{19}$ cm, then $E_1 = 1.6 \cdot 10^{37}$ erg.

Evidently, for explanation of the latter value we must assume that the total pinch length, l, with "roots of lightning" feeding it, can considerably exceed the length of the most narrow part, neck, gradually pinched by forces of magnetic pressure. Most probably, the currents are closed, and the plasma clouds often have toroidal configurations. It would be of interest to note that similar structures (but with huge dimensions ~ 50 ps!) are observed close to the center of our Galaxy. However, we are interested in smaller structures of "solar wind".

In the neibourhood of Earth the solar wind has the velocity $v = 400$ km/s, density of particles (basically protons - "p") $n = 50$ cm^{-3}, and bears inself the "frozen" magnetic field. If these caracteristics are the same on whole sphere surrounding the Sun, the total expense of the mass carried by the wind will be $dM/dt = 4\pi R^2 m_p n v = 10^{13}$ g/s$=$ 10 mln. tons/s. At the average distance between the stars $L = 2.7$ ps and at their relative velocity $v = 20$ km/s the "time of slipping" two neibouring stars is equal $T = L/v = 4 \cdot 10^{12}$ s $=$ 130 thousand years. During this period the solar wind carries away the total mass $\delta M = 3.6 \cdot 10^{25}$ g (for comparison the mass of the Earth is equal $6 \cdot 10^{27}$ g). In contrast to it, at the velocity of the wind $v = 400$ km/s the time of its passage to the distance $L/2 = 1.3$ ps$= 4 \cdot 10^{18}$ cm would be equal $t_{L/2} = 10^{11}$ s≈ 3000 years.

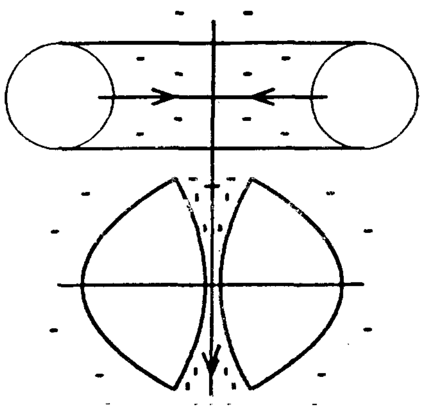
If we surround mentally the Sun by the cube with 6 borders, on one border we shall have the mass $\delta M/6 = 6 \cdot 10^{24}$ g, moving with the velocity 400 km/s, and, hence, having the total kinetic energy $K \approx 5 \cdot 10^{39}$ erg. This energy, in principle, is sufficient for generation of 300 GB with the energy $1.6 \cdot 10^{37}$ erg each.

If these very approximate evaluations increase 20 times only, the energy $E \sim$ $\sim 10^{41}$ erg in each discharge could supply not only the electron component of GB, but the sustainment of the proton component of GCR too. Below we discuss the possible ways of discharge formation.

5. **The preliminary contraction of a pinch and its rapid break.** It is possible to assume that at the collision of plasma winds from adjacent stars the kinetic energy of the winds is converted, at their stoppage, into the potential energy of a magnetic field. As known, the average magnetic field of the Galaxy (it is in a dynamic balance with GCR) is equal $< B >= 10^{-5} \div 10^{-4}$ Gs, and we assume, as the first way, that the magnetic field induced by the stopped (and accumulated for a long time) plasma star wind, has approximately such a value, and it is not chaotic, but forms, at the beginning, separate closed toroids with the minimal radius r_{min} and with the maximal radius r_{max}. At the maximal radius the internal field $B_\varphi \sim r^{-1}$ is assumed to be equal to the external field $< B >$, so the condition of equality between the pressure outside and inside the toroid is fulfilled here.

Therefore the toroid is not expanded itself here, but it can expand towards the z-axis due to the ploughing and extension of a plasma from the centre up and down along the z-axis, as it is conditionally represented in Figure. At the initial average internal field $B_\varphi \sim 10^{-4}$ Gs, and at the accepted by us energy of one GB ($E = 1.6 \cdot 10^{37}$ erg), the volume of a toroid should be equal $V = 4 \cdot 10^{46}$ cm^3. Then, its initial dimensions should be of the order of $r_{max} \sim 10^{15} - 10^{16}$ cm $\sim 10^{-2} - 10^{-3}$ ps. Approxymately such a length, $l \sim 10^{15}$ cm, should also be for the central pinch under formation. However, for explanation of the GB duration (~ 3 s), we must assume that the length of its most narrow part – neck (see Figure) – is smaller. Before the final break the length of the neck can be $\lambda \sim 10^{12}$ cm at its diameter of the order of $D \sim 10^{11}$ cm. So the initial radius of the central pinch decreases 4 orders of magnitude, and, respectively, the magnetic field on its boundary increases similarly, reaching before break the value of the order of $B_{max} \sim 1$ Gs at the current $J \sim 5 \cdot 10^{11}$ A. During the process of ploughing, the density of plasma increases 8 orders of magnitude in the central pinch. If, for instance, at the beginning it was equal $n \sim 10$ cm^{-3}, then to the instant of the current break we have $n \sim 10^9 - 10^{10}$ cm^{-3} in the area with the volume of the order of $V = (\pi/4)\lambda D^2 \sim 10^{34}$ cm^3. We note that the possibility of such GB generation, at the annihilation of a closed magnetic field loop, was mentioned previously qualitatively in the review [11], applicably to the magnetosphere of a neutron star. The similar way of pinch formation was proposed also in [12], applicably to the solar flares.

The situation, caused by collision of two plasma winds carryng the oppositely-directed "frozen" magnetic fields, could be the second possible approach. In this situation the so called "neutral current layer" (flat pinch) arises in the plane of collision.



Evolution of magnetic torus and formation of a pinch with neck

For a rather long time it can be in equilibrium, but exceeding some critical parameters, it loses the stability and, due to reconnection of magnetic force lines, breaks into some cylindrycal pinches. Such a picture was observed in the experiments [13] with flat pinches. However, applicably to cosmic GB for such configurations of currents, it is difficult to evaluate the possible length of pinches, in contrast to the above-discussed approach with the magnetic toroid.

In conclusion the authors express their gratitude to Dr. I.L.Rosenthal for his useful critical remarks on this work.

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