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PHYSICS

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Physics of Neutron Stars. (Short review)

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1.In the thirties,after the discovery of neutron by Chadwick(1932), in the works of Baade and Zwicki (1934) Oppenheimer and Volkoff(1939) the conception about neutron stars was formed: about the superdense celestial bodies, composed of degenerate ideal neutron gas. However, it was soon established that neutron is a nonstable particle, and it meant that the existence of celestial bodies, composed of neutrons only, is not possible. Thus, certainly, more valid models of superdense stars could be constructed, composed of mixtures of neutrons, protons and electrons degenerate gases; but this was not done. Later, for two decades the conception of neutron stars was ignored

The idea of superdense stars, composed of degenerate matter was again revived in the beginning of the sixties, in a completely new understanding and on a scientifically based level in the joint works of Hambartsumian and Sahakian. Those works were based on the achievements of physics of elementary particles made in the previous years.

In the white dwarfs especially in the stars of large density neutron stars) the temperature is visibly lower than the degeneration temperature of the matter components, that's why in those celestial bodies the matter is in condition of strong degeneration. When we approach to the center of star, the chemical composition of the plasma undergoes essential changes. Depending on the density, visible changes appear even at the densities lower than nuclear in so-called "Ae"-envelope of the neutron star, but in over nuclear region changes in the plasma are striking. In neutron stars at usual nuclear density ($\rho_0 = 2.85.10^{14}$ g/cm^3) the matter consists of neutrons, protons and negative pions with about the same concentrations, approximately and negative pions with about the same concentrations, approximately with 1% of electrons, which are necessary for guarantee of this state stability

With the increase of the plasma density, hyperons appear gradually as well as some other particles as stable components. In the degenerated hadron matter the stability of these particles, which are not stable in the usual conditions, is provided by the Pauli's principle. For this reason the decays of π^- and τ^- mesons will be forbidden, if the boundary energy of electrons will be higher than definite values, therefore in the corresponding medium they become stable particles. So in a more common case, when there is a sufficiently high density in the degenerate matter as stable particles there will be represent all kinds of baryons, leptons and mesons with negative charge. Such plasma will be called hadronic.

The chemical composition and particles concentration in the equilibrium hadronic plasma, as well the threshold of stabilization of particles in determined by following system of equations:

$$\mu^0_\iota=\mu_V,\ \mu^-_\iota=\mu_V+\mu_e,\ \mu^+_\iota+\mu_e=\mu_V,\ \mu_\pi=\mu_e,$$
$$\sum n^+_\iota+\sum n^-_\iota+\sum n^0_\iota=n,\ \sum n^+_\iota-\sum n^-_\iota=n_e+n_\pi \qquad (1)$$

Here μ_ι,n_ι are is chemical potential and number density of i-th particle, signs -,0 and + indicate the electric charge of baryons, and n is the density of the total number of baryons. The first four equations refer to the conditions of thermodynamic equilibrium between the components of the plasma, the fifth and sixth express the law of baryons number conservation and the condition of local electroneutrality of the plasma. Though in all physical processes the total number of leptons is kept, in superdense celestial bodies it isn't kept, as neutrino is not held in them. If neutrino had a rest mass we would have to take into account the three laws of conservation of the number of leptons of three different kinds as well. In all the equations with the participation of the baryons, the electrical and baryonic charges from the left and the right are similar, which is a direct consequence of conservation these charges in elementary actions. These relations between the chemical potentials express the conditions of equilibrium between the components of the plasma that is why they correspond to the minimum of the system energy. In conditions of degenerated hadron matter, after a new particle appeared, a degenerated gas from these partiales is formed right away.

The chemical potential of the baryon is equal to:

$$\mu_\kappa = \varepsilon_\kappa + V_\kappa (p_\kappa), \qquad (2)$$

where ε_κ is the boundary Fermi energy, V_κ is the energy of interaction of this baryon with the media, it depends on the boundary impulse. Here we speak about the potential energy of nuclear interactions.

In a hadron plasma no number of neutrons prevails the number of other baryons. On the whole the concentrations all kinds of baryons the same order, but the concentration of electrons is less than 1%. So, the name "neutron star" is not proper for celestial bodies consisting of hadron matter, nevertheless, we consider that this historically significant title should be preserved in our later works.

In the fundamental work ([4]) of Hambartzumian and Sahakian a condition of hadronic plasma in approximation of a ideal gas was investigated, i.e. in (1) it was assumed $|V_k << 1|$. Actually this approximation is not so bad. Thresholds of stabilization and concentration of particles in a plasma were calculated, the basic possibility of formation if negative pions condensate was justified. In a result the energy density and the pressure of hadronic matter was calculated. In the most common case the state equation of hadronic matter in approximation of ideal gas may be written in the following form

$$\rho c^2 = K_n \sum \delta_k (sht_k - t_k),$$
$$P = \frac{1}{3} K_n \sum \delta_k \left(sht_k - 8 \cdot sh\frac{t_k}{2} + 3t_k \right). \qquad (3)$$

Here ρc^2 is the energy density. P-pressure in a plasma

$$\delta_k = \left(\frac{m_k}{m_n}\right)^4,\quad K_n = \frac{m_n^4 c^5}{32\pi^2 \hbar^3},\quad t_k = 4 arcsh \frac{(3\pi^2)^{1/3} \hbar n_k^{1/3}}{m_k c},$$

n_k is a density of a k-kind particles. The summation is carried on all kinds of baryons and leptons with negative charge (electron and μ^- meson), which are present in a plasma at given density. In the energy density it is necessary to take into account contribution of pion condensate $n_\pi m_\pi c^2$ also, if it is present. Indeed in the variant of an ideal gas, availability or absence of pion condensate is determined by number of kinds positively and negatively charged baryons. In variant of the same number of kinds positive and negative baryons in hadronic matter pions are not present. The parameters t_k are functions from density of common number of baryons n. It seems, that in approximation of an ideal gas of baryons, we have an analytical state equation of a degenerate matter, but it not so. A situation here considerably more difficult. The point is that before to write equation (3) it is necessary to find out which particles can be in a plasma, to define their thresholds of stabilization and to calculate the concentration of particles depending on baryons density n.

In the second work of Hambartzumian and Sahakian ([5]) the models of neutron stars for variant of a baryons ideal gas were calculated. The masses of configurations were, as in the case purely neutron configurations about mass of Sun, and radiuses of the order of 10km. We shall note that already in these first works ([5,6]) the most characteristic features the stellar configurations from the degenerate matter were established. We have in view the character of curve dependence of mass on density, internal structure and anomal defect of mass. To these questions we yet shall return.

2. The models of the real baryons gas and consequent stellar configurations were investigated by Sahakian and Vartanian ([7,8]). In these works the contribution of nuclear interaction took account by introduction the conception of effective mass for baryons and relevant corrections in the state equation were made. The corrections in the threshold of stabilization and in concentration of particles were made. In the state equation of ideal gas to expression of density the item $\rho_V(n)$ was add, and to expression of pressure- the item $P_V(n)$, which took account the contribution of the nuclear interactions. The calculated masses of stellar configurations in this case were twice more than the masses of configurations of ideal baryons gas and the radius were the order of 10 km again. For the first time in work ([8]) was represented the dependence of mass degenerate stellar configurations on the central density, including the branch of white dwarfs

The further stage in the development of theory of superdense stars was the work of Sahakian and Chubarian ([10]). In it was initiated to investigate envelopes of neutron stars and white dwarfs. The theory of white dwarfs has been existed long ago ([11,12]). In this question some definitions, depending on the new development of degeneracy matter theory, were necessary carry out. In the white dwarfs and envelopes of the neutron stars the matter consist of an atomic nuclei and degeneracy gas of electrons. Such plasma has been called "Ae-plasma" or "Ae-phase" of matter. It had been shown, that in the "Ae" plasma parameters of nucleous A and Z depend on the boundary energy of electrons (mass density). It was shown, that the average value of relation A/Z grows with the growth of density. The circumstance depend on the effect of neutronization. This effect show down rapid growth of electrons boundary energy, with growth of density, i.e. depend on condition of plasma energy minimum at the given density. Following approximation for relation A/Z was found:

$$\frac{A}{Z} = 2 + 1.255 \cdot 10^{-2} x + 1.376 \cdot 10^{-6} x^3 + 1.755 \cdot 10^{-5} \quad (4)$$

where $x = p_e/m_e c$, and $p_e = (3\pi^2)^{1/3} \hbar n_e^{1/3}$ is boundary impulse of electrons. In our works ([7,10]) the existence so called neA and npeA phases, replacing Ae phase at high densities had been asserted. The later had been shown, that indeed such states in the degeneracy plasma don't exist. It appeared, that Ae phase replacing by phase of continuous nuclear matter and at this transition of plasma mass density experience the jump, changing in

500 times because of high densities (small distance between nuclei) owing to tunnel effect the light nuclei don't stable of the heavy nucleis formation. Hence, minimum value of mass number A_m is a function of mass density, it growth with density growth.

In the Ae plasma the energy density is determined by atomic nucleons, and pressure by electron gas. For state equation we have

$$\rho \approx \frac{32}{3}\left(\frac{m_e}{m_n}\right)^3 \frac{\overline{A}}{Z} x^3, \quad x = p_e / m_e c,$$

$$P = \frac{4}{3}\left(\frac{m_e}{m_n}\right)^4 \left[x\left(2x^2 - 3\right)\sqrt{1 + x^2} + 3\ln\left(x + \sqrt{1 + x^2}\right)\right] \tag{5}$$

Using this state equation the parameters of "Ae" envelopes of neutron stars and the models of white dwarfs have been calculated. The masses of "Ae" envelopes were of the order $10^{-6} \div 10^{-5}$ from the star mass, thickness the order several hundred meters. The curve of white dwarfs mass on the dependence of density in the center has the maximum $M_{max} \approx 1.27 M_\odot$ at the central density $\rho_0 \approx 2.1 \bullet 10^9$ g/cm^3, which is much less than Chandrasekhar's maximum. The maximum on the curve $M(\rho_0)$depends on the relation A/Z grows with the growth of density, and the diminution of the curve on the right limited by relativistic effects of gravitation theory.

3.The last important stage in the question of development of the theory of neutron stars was the systematic account of the π-mesons role in the thermodynamic of the degeneracy stellar matter in the works of Sahakian and Grigorian ([13-19]).

The analysis of date about masses of atomic nuclei has been shown that in the isobars of nucleons A>200 with the least atomic number exist several π-mesons in the average. The state of Ae plasma with the account of a possible role of π-mesons was investigated. Here the conditions for existence negative pions in nucleouses more favorable than in the nucleouses of usual matter, as in the Ae plasma at densities are higher than certain value $\mu_\pi = \mu_e > m_e c^2$.

Because of large densities in the Ae plasma the times of relaxation of the establishment of a condition with the least energy (absolute equilibrium) are small in the comparison with cosmogonics. That's why it is meaningful to consider Ae plasma, in which the energy on one nucleon, i.e. with the most probable value of mass number A at the given density. The parameters A and Z and nucleon binding energy b(A,Z) of the most stable nucleous are determined by the boundary energy of electrons, and therefore depend on the mass density. The base state of Ae plasma was determined by the following system of equations

$$\mu_p + \mu_e = \mu_n, \; \mu_\pi = \mu_e$$

$$N_n \mu_n + N_p \mu_p + N_\pi \mu_\pi = A\mu_n - Z\mu_e = Mc^2, \tag{6}$$

$$Zn / A = n_e$$

where N_n, N_p, N_π are number of neutrons, protons and negative pions in the nucleous, $N_n + N_p = A$, n_e is the density of electrons number, n is the density of the nuclons, M is the mass of the most probably nuclei, μ_k is the chemical potential of particles. Though the nucleouses are systems with the small number of degrees of freedom, nevertheless the use of concept of chemical potential for being in nucleouses nuclons is justified by that circumstance, that in the special conditions of Ae plasma they also accept the effective participation in an establishment of thermodynamic equilibrium, in the main though the processes of direct and return β decay. The mass of atomic nuclei is determined by the following specified formula of Weizseker ([19])

$$Mc^2 = N_n m_n c^2 + N_p m_p c^2 - c_0 A + c_1 A^{2/3} + c_2 (N_p - N_\pi)^2 / A^{1/3} +$$
$$+ c_3 (N_n - N_p + N_\pi)^2 / A + c_4 (N_n - N_p + N_\pi)^4 / A^3 + c'_3 N_\pi^2 / A + c_\pi N_\pi \quad (7)$$

where

c_0=15.75; c_1=17.8; c_2=0.71; c_3=23.7
c_4=-3.5; c'_3=17.65; c_π=11.96Mev

The first four numbers $c_0 \div c_3$ represent known coefficients in the usual Weizseker's formula, the other parameters were determined ([14]), by adjustments of binding energy for 200 nucleouses with mass numbers $220 \le A \le 257$ on a way of the least squares. The number of pions N_π was determined by formula ([14])

$$N_\pi = (1+\alpha)\frac{c_3}{c_3 + c_3'}(A - 2Z) - (1+\beta)\frac{c_\pi}{2(c_3 + c_3')}, \quad (8)$$

where $\alpha=-\beta=0.0088$. The formula for pions number was determined from relation

$$\mu_p + \mu_\pi = \mu_n$$

This relation gives us result (8) with $\alpha=\beta=0$. However, the parameters α and β were introduced for accounting a possible deflections from a case, when $\alpha=\beta=0$ (inaccuracy of thermodynamic approach). Chemical potential of electrons is equal

$$\mu_e = \varepsilon_e = \left(m_e^2 c^4 + a^2 n_e^{2/3}\right)^{1/4}, a = \left(3\pi^2\right)^{1/3} \hbar \quad (9)$$

ε_e is a boundary energy of electrons. The chemical potentials of the other particles were determined by a usual way:

$$\mu_n = m_n c^2 - c_0 + \frac{2}{3} c_1 A^{-1/3} - \frac{1}{3} c_2 y^2 A^{2/3} + c_3\left[1 - (2y - y_\pi)^2\right] +$$
$$+ c_4\left[1 + 3(2y + y_\pi)^2\right](1 - 2y - y_\pi)^3 - c_3' y_\pi^2,$$
$$\mu_p = m_p c^2 - c_0 + \frac{2}{3} c_1 A^{-1/3} - c_2\left(2 - \frac{y}{3}\right) y A^{2/3} - c_3(3 - 2y - y_\pi)(1 - 2y - y_\pi) -$$
$$- c_4\left[7 - 3(2y + y_\pi)\right](1 - 2y - y_\pi)^3 - c_3' y_\pi^2,$$
$$\mu_\pi = -2c_2 y A^{2/3} + c_\pi + 2c_3' y_\pi^2 + 2c_3(1 - 2y - y_\pi) + 4c_4(1 - 2y - y_\pi)^3, \quad (10)$$

where $y = Z/A$, $y_\pi = N_\pi / A_0$.

Substituting (7),(9) and (10) in the system of the equations (6), we obtain

$$2c_3(1 - 2y - y_\pi) + 4c_4(1 - 2y - y_\pi)^3 - 2c_3' y_\pi^2 - c_\pi + \Delta m \cdot c^2 = 0,$$
$$y_\pi = \frac{1}{4c_3'}\left(\varepsilon_e + 2c_3 y A^{2/3} - 2c_\pi + \Delta m \cdot c^2\right), \quad y = \left(\frac{c_1}{2c_2 A}\right)^{1/2}, \quad (11)$$

where $\Delta m = m_n - m_p$. The parameters of the basic state Ae-plasma are determined by this system of the equations. To a question on the state equation we shall return below. The basic results depending on the pressure are given in table 1. It is seen from table that in the Ae plasma beginning with $\rho=3.4 \cdot 10^{10}$ g/cm^3 the negative pions are in the nucleouses with $A \ge 80$. But the more important thing that with promotion of density their concentration monotonously grows, reaching the limiting value $y_\pi=0.22$ at the end of this phase of the degeneracy matter. The end of Ae phase is determined by conditions of monotonous growth and continuity of chemical potential of neutrons at transition in a phase of continuous nuclear matter and characterized following dates:

$$\rho=6\cdot10^{11}\ \text{g/cm}^3,\ \mu'_n=\mu_n-m_nc^2=-0{,}63\text{Mev}\ \varepsilon_e=24{,}8\text{Mev},$$

$$A=353,\ y=0{,}595,\ y_p=0{,}405,\ y_\pi=0{,}22 \tag{12}$$

Table 1

The parameters of ground state of Ae-plasma

P ergcm^{-3}	ρ ergcm^{-3}	$x_e=$ $=P_e/m_ec$	A	Z/A	N_π/A	$m_nc^2-\mu$ Mev	μ_E Mev	$(m_n-\rho/n)c^2$
$9.868\cdot10^{22}$	$2.611\cdot10^{6}$	1.065	62	0.450		9.010	0.746	9.049
$9.712\cdot10^{24}$	$6.296\cdot10^{7}$	3.066	63	0.445		8.607	1.648	8.766
$6.570\cdot10^{25}$	$2.573\cdot10^{8}$	4.883	65	0.440		8.209	2.547	8.473
$5.977\cdot10^{26}$	$1.355\cdot10^{9}$	8.428	68	0.430		7.430	4.337	7.887
$2.412\cdot10^{27}$	$3.931\cdot10^{9}$	11.926	71	0.420		6.674	6.115	7.310
$6.704\cdot10^{27}$	$8.657\cdot10^{6}$	15.389	75	0.410		5.942	7.880	6.745
$1.502\cdot10^{28}$	$1.624\cdot10^{10}$	18.819	78	0.400		5.233	9.630	6.192
$2.919\cdot10^{28}$	$2.742\cdot10^{10}$	22.216	82	0.390		4.550	11.36	5.653
$3.830\cdot10^{28}$	$3.410\cdot10^{10}$	23.776	85	0.385	0.001	4.239	12.160	5.407
$4.074\cdot10^{28}$	$3.598\cdot10^{10}$	24.147	86	0.382	0.004	4.167	12.350	5.344
$8.350\cdot10^{28}$	$6.787\cdot10^{10}$	28.888	104	0.347	0.043	3.284	14.771	4.564
$1.468\cdot10^{29}$	$1.146\cdot10^{11}$	33.259	127	0.314	0.080	2.546	17.003	3.879
$2.310\cdot10^{29}$	$1.790\cdot10^{11}$	37.252	157	0.283	0.115	1.937	19.143	3.281
$3.345\cdot10^{29}$	$2.639\cdot10^{11}$	40.862	195	0.253	0.147	1.442	20.887	2.763
$4.531\cdot10^{29}$	$3.721\cdot10^{11}$	44.082	246	0.226	0.177	1.049	22.532	2.318
$5.810\cdot10^{29}$	$5.066\cdot10^{11}$	46.909	314	0.200	0.205	0.741	23.967	1.938
$6.409\cdot10^{29}$	$5.780\cdot10^{11}$	48.074	353	0.188	0.217	0.626	24.571	1.783
$6.409\cdot10^{29}$	$2.846\cdot10^{11}$	100.37	∞	0.0035	0.406	0.626	51.269	0.628

The phase transition in a state of continuous nuclear matter with $\rho=\rho_0=2{,}85\cdot10^{14}$g/cm^3, μ'_n=-0,63Mev is made. The mass density experiences the jump about in 500times in this transition.

Dates, given in the table 1, show, that the process of neutralization of matter proceeds up to $\rho=3\cdot10^{10}$ g/cm^3 (μ_e=12 Mev). Then,the process of nucleuses filling by mesons is begin, which is possible to call by effect of pionization. From this threshold the process of nucleuses neutralization stops: at futher promotion of density, the concentration of neutrons and protons is fixed on values $y_n=N_n/A=0{,}6$; $y=N_p/A=y+y_\pi$ =0,4.

At the end of a Ae-phase there are π-mesons in the atomic nucleus,the number of which is 22% of nucleons number. They will obviously stay and in that case, when the atomic nucleuses merging, will form continuos nuclear matter. Certainly, the electrons should be in such plasma. The nuclear matter on the own thermodynamic properties is most likely similar to liquid that it is well known on an example of atomic nucleuses. Therefore, in the theory of nuclear matter the account of nuclear interactions of particles is important. But how to take into account these interactions? It is rather difficult problem. The nature, however, has presented us a unique possibility for round of this difficulty. We mean the fact of presence of atomic nucleuses and experimental dates about their bound energy, which with satisfactory accuracy are described by the half-empirical formula of Weitzeker. Just in the works ([13-19]) this possibility was successfully used. An essential deficiency on this way is the fact, that is does not allow to investigate properties of a plasma, depending on density of mass. However, incompressible character of nuclear matter in a wide range of hydrostatic pressure largely neutralized this deficiency, and as a result is possible to solve a number of the important questions of the theory of hadronic plasma, in particular, the questions of the state equation.

Using the specified Weitzeker formula (7) for a case of continuos nuclear matter for whole energy of plasma was assumed

$$E = N_n m_n c^2 + N_p m_p c^2 - c_0 N + c_3(N_n + N_\pi - N_p)^2/N + c_4(N_n + N_\pi - N_p)^4/N^3 + + c_\pi N_\pi + c_3 N_\pi/N + (3a/4)V^{-1/3} N_e^{4/3}, \quad (13)$$

where V is volume of some part of plasma, N_n, N_p, N_π, N_e are numbers of neutrons, protons, pions and electrons in this volume, $N=N_p+N_n$ is the number of nuclons, the last item represents the energy of relativistic gas of electrons $a=(3\pi^2)^{1/3}\hbar c$. In this formula were missed surface and coulomb parts.

Calculating the partial derivatives of expression (13) by the number of particles N_k, we obtain corresponding chemical potentials μ_k. State equilibrium is determined by system of equations

$$\mu_p + \mu_e = \mu_n,\ \mu_\pi = \mu_e,\ n_n + n_p = n_0,\ n_e + n_\pi = n_p \quad (14)$$

where $n_k = N_k/V$ is density of particles. Substituting in these relations the expressions of chemical potentials and solving the obtained equations, we shall get

$$y_n=0.591,\ y_p=0.409,\ y_\pi=0.4,\ y_e=0.0035,$$
$$(15)$$
$$\mu_n=938.94,\ \mu_p=887.67,\ \mu_\pi=\mu_e=51.29\text{Mev}$$

As we see, $\mu_n - m_n c^2 = -0.63$Mev, $\mu_p - m_n c^2 = 50.63$Mev and average binding energy of nucleon $b_0=(\rho_0/n_0 - m_n)c^2 \approx \mu_n - m_n c^2 = -0.63$Mev. From brought dates it is visible, that continuous nuclear matter is in a liquid state. Thus,is not correct as representation that at density near to nuclear, plasma is in a gas state, an the fact, that it consist from neutrons mainly.

Brought in(12) dates about the top threshold of Ae plasma were found from a condition of a continuity of chemical potential of neutrons at phase transition $Ae \rightarrow np\pi^- e$. In the phase transition in the interior of neutron stars, the pressure doesn't experience the jump and equal

$$P_0=6.4 \cdot 10^{29}\text{erg/cm}^3 \quad (16)$$

It means that neutron star consist of two basic parts: from hadronic nuclei and Ae-envelopes.On surface of division these regions of star the density experience jump about in 500 times. There are the essential changes in the nuclear matter, when it condensation. This take place when hydrostatic pressure $P \geq 5 \cdot 10^{33}$erg/cm^3. In accordance with increase of density at its certain values there are different hyperons, resonance and leptons in plasma. The chemical composition and the concentration of particles in equilibrium hadronic plasma are defined by the equations system (1).

At densities on one order higher than nuclear, we deal with plasma from all kind baryons and π^- mesons. There is a small impurity of electron gas, playing a role of stabilization of the this whole picture of hadronic plasma.

At rather high densities, when hadronic "bags" closely adjoin with each other, plasma consisting from quarks will be formed. But quarks give to know about self already at usual nuclear density during an exchange nucleons by mesons, i.e. the formations from pair quark-antiquark $[q\bar{q}]$. When density in plasma becomes so large, that hadronic bags are density adjoin, to speak about matter consisting from baryons, it is not meaningful, and obviously, the medium consisting from quarks and lepton will be formed. Figuratively speaking, will be formed hadron of macroscopic sizes. To speak about exact value of density, above which we deal with quark phase of degeneracy matter is impossible, so already at densities on one order above nuclear inflination of quarks through a barrier between hadronic bags, occurs so often, that in a scale of densities there is no sudden boundary of division between hadronic and quark phases of matter. Apparently the decay of hadrons occur when distance between their centres reaches value $r_0 \approx 0.5 l_0$, where $l_0 = 0.5$fm is radius, so called, hard core of nucleon, established in experiments by study of elastic scattering of nuclons. Now this peculiarity can be estimated as manifestation of a Pauli principle for quarks. According this presentation the radius of baryon should be about $r_e \approx r_c$ and therefore the threshould of formation of quark plasma approximately equal

$$n \approx \frac{3}{4\pi r_e^3} \approx 1.53 \cdot 10^{40} cm^{-3}, \quad \rho \approx 5 \cdot 10^{16} g/cm^3 \qquad (17)$$

From indeterminancy relation follows,that at such density the baryons still nonrelativistic: $cp \approx 400 Mev < mc^2$.

In the quark phase the thresholds of birth and particles concentration are defined by the following system of equations

$$\mu_d = \mu_s = \mu_b,\ \mu_u = \mu_c = \mu_t,\ \mu_n + \mu_e = \mu_d,\ \mu_\tau = \mu_\mu = \mu_e,$$
$$2(n_u + n_c + n_\tau) - (n_d + n_s + n_b) = 3(n_e + n_\mu + n_\tau), \qquad (18)$$
$$n_u + n_d + n_s + n_b + n_c + n_t = 3n$$

Here indexes u, d, s, c, b, t are denote tipes (flavors) of quarks, and indexes e, μ, τ concern to leptons, n is the density of equivalent number of baryons Chemical potentials of particles as former is defined by expression (2):$\mu_k = \varepsilon_k + V_k$. For boundary impulses we have

$$p_k = \begin{cases} (3\pi^2)^{1/3} \hbar n_k^{1/3}, \ for\ \ letpons \\ \pi^{2/3} \hbar n_k,\ for\ quarcks \end{cases} \qquad (19)$$

The difference in the formulas of boundary impulses of leptons and quarks is caused by the presence at the last additional quantum number called colour. Thus,if to consider, that the quark masses are known, the problem of definition of a state of quark plasma is reduced to knowledge of particles interaction energy V_k. For leptons $V_k = 0$. Apparently,it is possible to consider, that the interactions energy of quarks with medium approximately the same for all flavors and in calculations all V_k is possible to omit.

In the region of densities $\rho \geq 10^{23}$g/cm^3, when all particles in plasma becomes ultrarelativistic an asymptotic freedom of quarks becomes important, and the equations (18) are simplified. The solution of this system is

$$n_d \approx n_s \approx n_b,\ n_u \approx n_c \approx n_t,\ n_d^{1/3} - n_u^{1/3} = (3n_e)^{1/3},$$
$$2n_u - n_d \approx 3n_e,\ n_u + n_d \approx n,\ n_\tau \approx n_\mu \approx n_e$$

The solution of this system is

$$n_u \approx n_c \approx n_\tau \approx 0.335n,\ \ n_d \approx n_s \approx n_b \approx 0{,}665n,\ \ n_e \approx n_\mu \approx n_\tau \approx 1.883 \cdot 10^{-3} \qquad (20)$$

Thus in ultrarelativistic quark plasma, the concentrations of all kinds quarks about the same, and concentration of leptons on three order less that concentration of nucleons.

4. The most important question for theory of neutron star is finding of the state equation of degenerated stellar matter.It is one of equations defining a distribution of mass and integral parameters of star. Straight more or less precise definition of pressure depending on mass density, by the calculation of particles concentrations practically is impossible. In the work ([19]) this problem was solved by phenomenologically method, using some undebatable facts.

In the basis of inference of state equation were supposed the following well known relations of thermodynamics

$$\frac{dP}{d\mu}=n,\ \rho c^2=n\mu-P,\ \frac{c^2}{v_S^2}=c^2\frac{d\rho}{dP}=-\mu n^2\frac{d^2\mu}{dp^2}, \tag{21}$$

are true for all phase of degeneracy stellar matter. Here n is baryon's density, ρc^2 is density of whole energy, P is pressure, μ-chemical potential of neutrons, or in the case of quark plasma is the electroneutral combination of three particles with barionic charge equal one, v_S is sound velocity. Since on the division boundary of Ae-phase and nuclear matter the density experience the jump, it is convenient the state equation to seek in form ρ(P).

In the Ae phase the pressure determined by electrons and energy density in main by atomic nucleuses. The energy of electronic gas is equal

$$E_e=4VK_e\left[x(2x^2+1)\sqrt{x^2+1}-\ln(x+\sqrt{x^2+1})\right],$$

where V is volume of the system, $x=p_e/m_ec$, $K_e=m_e^4c^5/32\pi^2\hbar^3$. Hence, for pressure we obtain

$$P=\frac{4}{3}K_e\left[x(2x^2-3)\sqrt{x^2+1}-3\ln(x+\sqrt{x^2+1})\right]. \tag{22}$$

Energy density is equal

$$\rho c^2=\frac{n}{A}Mc^2+\frac{E_e}{V}. \tag{23}$$

The mass M and mass number A of nuclei are functions of mass density, so the state equation yet did not find. It is convenient to define it of system (22), but for this is required the knowledge of dependence μ, from x. This dependence in ([19]) was approximated by the formula

$$\frac{\mu-m_nc^2}{m_ec^2}=-18.34+(0.451-4.4\cdot10^{-4}x-3.2\cdot10^{-5}x^2)\times \tag{24}$$
$$\times\sqrt{x^2+1}+4.4\cdot10^{-4}\ln(x+\sqrt{x^2+1})$$

Thus, the expressions (22), (24) and $\rho c^2=n\mu-P$ together definition the state equation ρ(P) of Ae-plasma in the parametric form. For don't accurate calculations, neglecting in (23) by item E_e/V, taking $M/A=m_p$ and accounting the condition of electroneutrality $nZ/A=n_0$, we obtain

$$\rho c^2\approx nm_pc^2=\frac{1}{32\pi^2}m_pc^2\left(\frac{m_ec}{\hbar}\right)^3\frac{A}{Z}x^3. \tag{25}$$

In the nonrelativistic and ultrarelativistic cases from (22) we obtain

$$P\approx\begin{cases}\frac{32}{15}K_ex^5, & x<<1\\ \frac{8}{3}K_ex^4, & x>>1.\end{cases} \tag{26}$$

Excepting from (25) and (26) parameter x, we get

$$P\approx\begin{cases}B_1\rho^{5/3}, at & \rho<2\cdot10^6 g/cm^3\\ B_2\rho^{4/3}, at & \rho>>2\cdot10^6 g/cm^3.\end{cases} \tag{27}$$

The correct derivation of state equation for hadronic plasma spreading the region of densities $3\cdot10^{14}\le\rho\le7\cdot10^{16}g/cm^3$ does not simple problem. For this it is of particles in a plasma their concentrations, partial pressures, partial energy densities

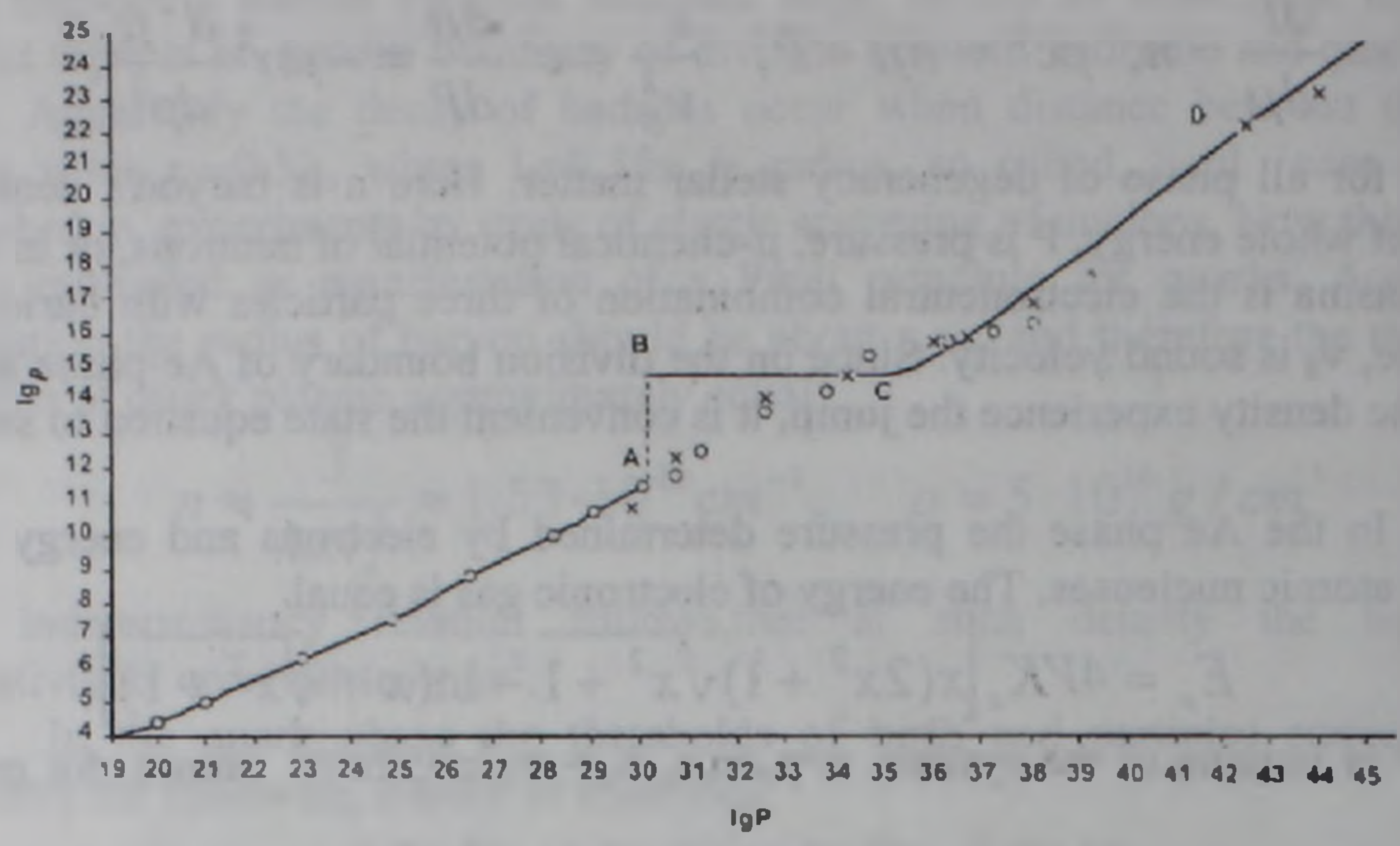

Fig. 1. The diagram of the state equation of degnerate plasma. Pressure P is measured in ergcm^{-3}, and mass density in gcm^{-3}. The initial part of the curve ρ(P) up to point A correspongs to Ae-plasma and the dashed line AB-to the density jump at the transition to the nucleas matter phase (the almost horizontal segment BC), Cdis the hadronic plasma, the quarck matter is beyond point D. The cucles correspond to the equation PBBP, but cross-to state equation SV.

necessary the exact knowledge of chemical potential of plasma, the interactions energy depending on the density of baryons n. This is practically does not solving problem. Therefore in ([19]) the question of state equation was solved round about way, using number physical considerations. But for this purpose first of all it is necessary to consider the quark phase, state equation of that is defined comparatively simple. Relatively simple situation in the quark phase with accounting asymptotic behavior (20) allowed us to find approximation

$$\mu = kP^{1/4}(1 + P^{-\alpha}), \tag{28}$$

between chemical potential and pressure, where α=0.0081, β=300erg$^{\alpha}$cm$^{-3\alpha}$. Now, using (22), we can calculate density of baryons n, density of whole energy and sound velocity.

Further the state equation of hadronic plasma was found by the conclusion of its parameters with phases of nuclear matter and quark plasma. The state equation of hadronic matter, covering the region of pressures $6{,}4\cdot10^{29} < P < 2\cdot10^{37}$ erg/cm^3, it is possible to obtain with sufficient accuracy, demanding that phase quantities μ, P, n, ρ, v_S changed by a continuous and monotonous manner. Here important is the fact, that at any phase transition chemical potential and pressure should not experience jump, and inside each of phase they should change by monotonous manner. For chemical potential the following approximations ([19]), ([21]) was found.

$$\mu = \begin{cases} a_1 + a_2(1 + P/L)^{\nu}, & at \;\; P_0 \le P \le P_1 \\ a_3(1 + P/D)^{\sigma}, & at \;\; P_1 \le P \le P_2 \end{cases} \tag{29}$$

where a_1, a_2, a_3, L, ν, D, σ are constants. They was determined from boundary conditions for μ, n, v_S at $P=P_0=6.41\cdot10^{29}$erg/cm^3 (pressure at the end of Ae plasma), from the requirement of a continuity of this quantities at $P=P_1=5\cdot10^{37}$erg/cm^3 (end of phase of

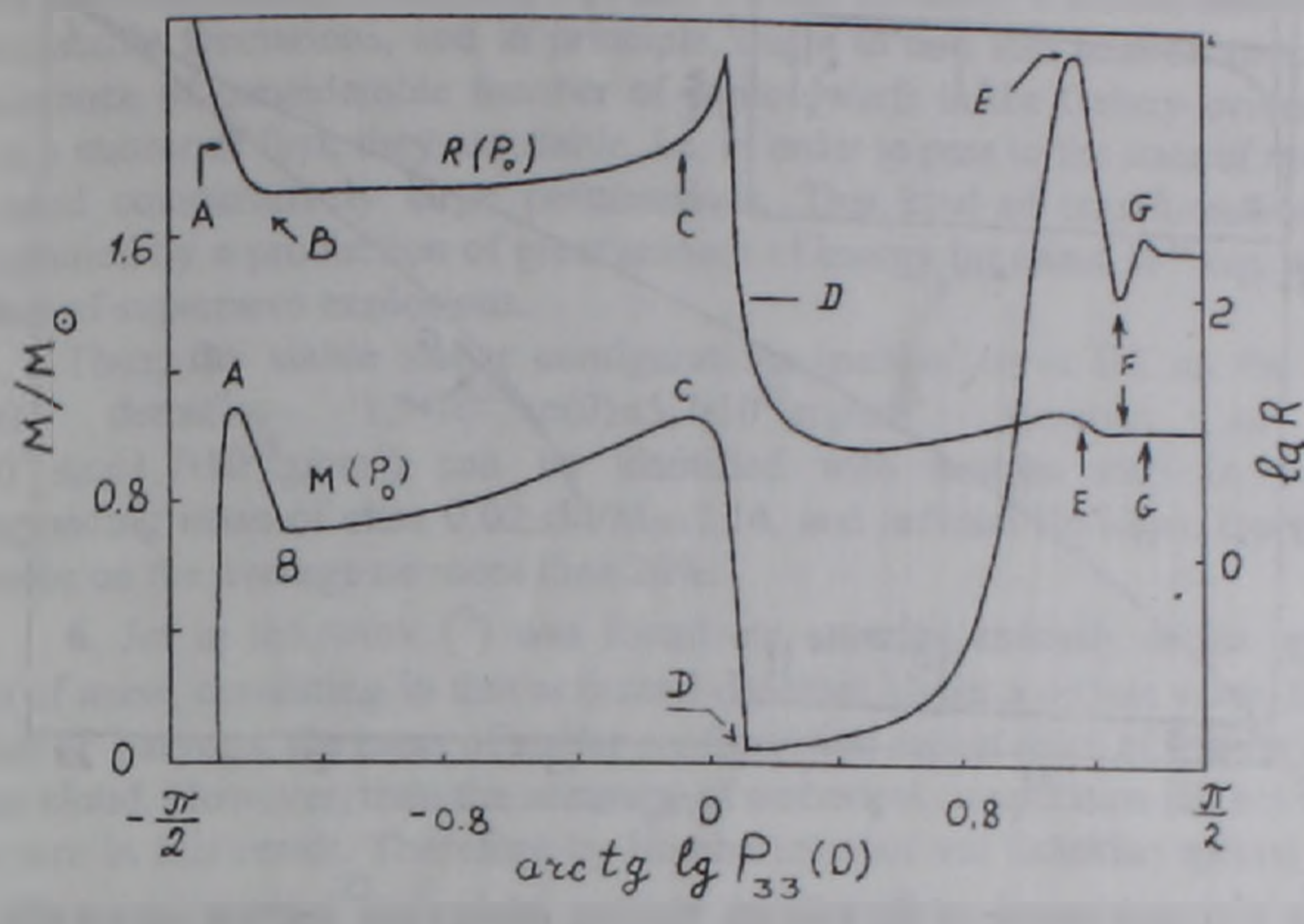

Fig.2. The dependece of the radius R measured in km and the mass of configurations measured in selar on the central pressure P(0). The same letter in this and next figure represent points corresponding to one same configurations.

incompressible nuclear matter) and continuity μ in a point $P=P_2=1.9\cdot 10^{37}erg/cm^3$, using the relations (21)

$$a_1=937.61,\ a_2=1.312,\ a_3=939.3,\ \nu=0.9384,$$
$$L=3.352\cdot 10^{32},\ D=6.659\cdot 10^{34},\ \sigma=0.232$$

In (29) the pressure is measured in GSS system, and μ-in Mev. So the state equation $\rho(P)$ is found in the whole region of pressure of degenerate Wae stellar matter, it was named the state equation GS (Grigorian-Sahakian). The diagram of this state equation is brought on fig 1.

5. The parameters of stellar configurations from degeneracy matter are determined by following system of equations

$$\frac{du}{dr} = 4\pi\rho r^2, \tag{30}$$

$$\frac{dp}{dr} = -\frac{G(\rho c^2 + p)}{c^2 r(r - \frac{2Gu}{c^2})}(u + \frac{4\pi}{c^2}pr^3) \tag{31}$$

$$\frac{dJ}{dr} = \frac{8\pi}{3}\rho r^4 \frac{1 + P/\rho c^2}{1 - 2Gu/c^2 r}(1 - \frac{2GJ}{c^2 r^3})(1 - \frac{GJ}{2c^2 r^3}), \tag{32}$$

Where r is distance from center of configuration, u(r)- accumulated mass, J(r)- accumulated moment of inertia. To these equations it is necessary to add state equation, then system will be complete, the boundary conditions are those

$$P(0),\ u(0)=0,\ J(0)=0,$$
$$p(R)=0,\ u(R)=M,\ J(R)=J, \tag{33}$$

where M is mass and J-moment of inertia of a star. The equations (30),(32) where integrated in work ([19]). On fig 2. the curves $M(P_0)$ and $R(P_0)$ are brought. Part of curve

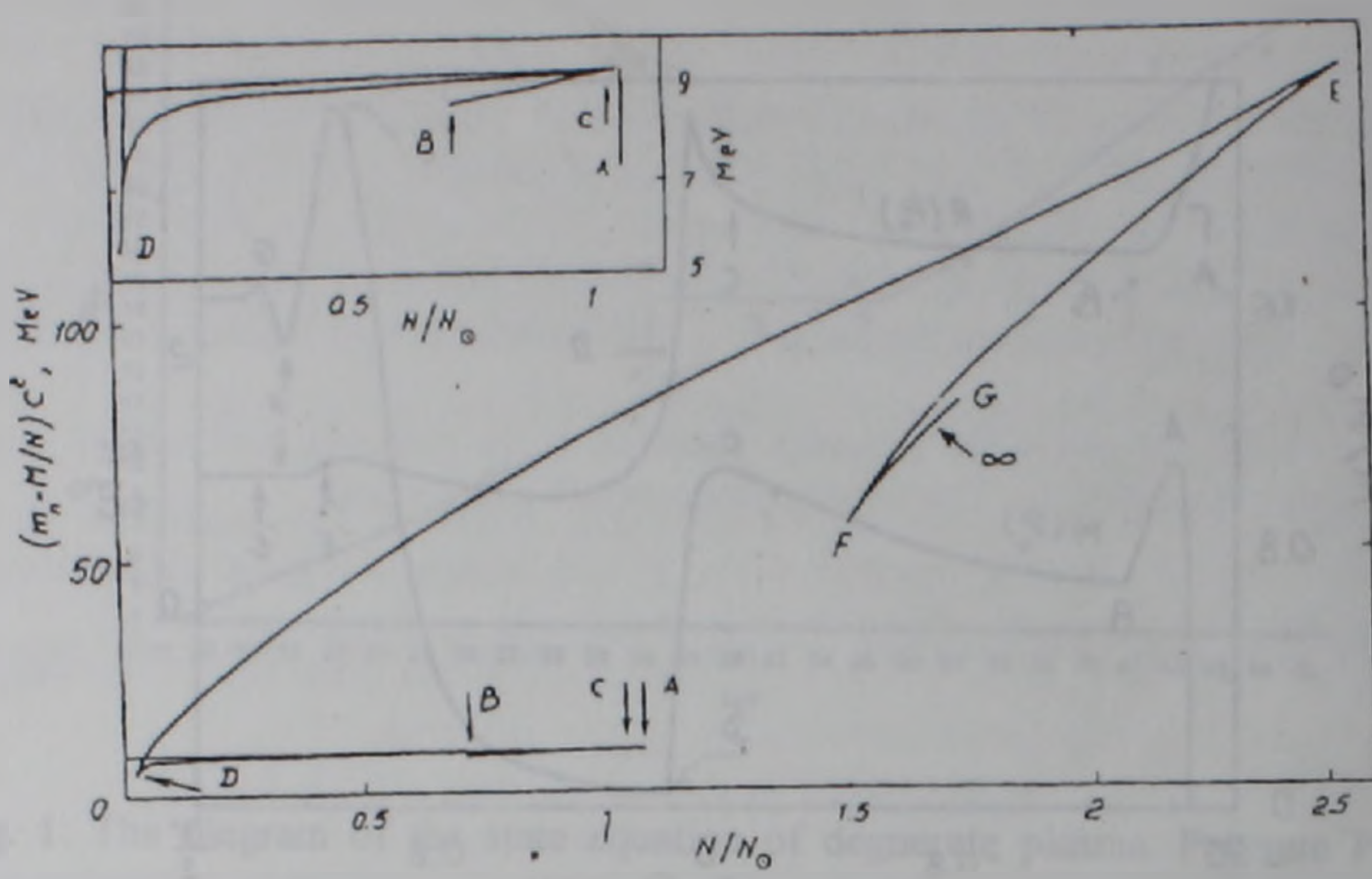

Fig 3. The dependence of the average binding energy per one baryon on the total number of baryons N; $N_{\Theta} = \frac{M_{\Theta}}{m_n}$ is the number of nuclear in the Sun, m_n is the neutron mass. In the left hand in upper corner is plotted in the large-scale DCBA part of the curve. The curve point designated by the symbol ∞ corresponds to configuration with an infinitely great central pressure. At the given number of baryons configurations with the greatest binding energy are stable.

$M(P_0)$ to the left of the point B represents the configurations of white dwarfs. The ordinate of curve in the point A has a maximum: $P(0)\approx 10^{27}$erg/cm^3, $M=1.08M_{\Theta}$, that noticeably is less than Chandrasechar's maximum. Part ABCD corresponds to unstable configurations. Their existence is not excluded in depts more massive celestial bodies. The stable are only the configurations appropriate the part DE. They represent models of neutron stars and are characterized by central pressures $1.3{\cdot}10^{29}\leq P(0)\leq 3,7{\cdot}10^{35}$ erg/cm^3,masses $0.2\leq M/M_{\Theta}\leq 2.15$ and radiuses $100\geq R\geq 10$km. Beyond the point E the ordinate of the curve oscillating with the attenuating amplitude goes down, to the value $M=1,5M_{\Theta}$ in the limit $P(0)=\infty$. All the configurations corresponding to this part of he curve are unstable. The others important parameters of the degeneracy stellar configurations are baryons number N and the average binding energy of nucleon $b=(m_n-M/N)c^2$. The baryons number in a star was calculated by formula

$$N = \int_0^R n(r)\sqrt{-g_{11}}\, r^2 dr \,,$$

where

$$g_{11} = -\left(1 - \frac{2Gu}{c^2 r}\right)^{-1}$$

is a radial component of metric tensor.Fig 3 shows the dependence of the average binding energy of nucleon b(N) from baryons number. From the curve b(N) it is seen, that at same number of baryons N, binding energy b(N) (i.e. mass) can two and, even in some parts (to right of point E) three and more values. Obviously, at the same number of baryons stable is that configuration of which the binding energy b(N) large, i.e. mass is less. In particular, at the same number of baryons average binding energy nucleons in neutron stars essentially more than in white dwarfs. Actually, it means, that white dwarfs are metastable formations, and in principle, ought to turn into neutron stars. However, the existence of considerable number of white dwarfs in the Galaxy evidently shows, that, as a matter of fact, they are stable, i.e. in order to pass to the state of neutron stars, they need comparatively large pertubartions. This kind of transformation will be accompanied by a production of great amount of energy for about 10^{51} erg, which enters the class of supernova explosions.

Thus, the stable stellar configurations (part of curve DE on the fig.2) with central densities $1{,}3\cdot10^{35}\leq p(0)\leq 5{,}7\cdot10^{35}$ erg/cm^3 (interval of densities $3{,}1\cdot10^{14}\leq\rho\leq1{,}7\cdot10^{15}$ g/cm^3) can be identified with neutron stars in pulsars. The corresponding mass of stars $0{,}02\leq M/M_0\leq2{,}14$, and radiuses $R\approx10$km. Deviations from this value on the average no more than 20%.

6. Jet in the work ([6]) was found out amazing anomaly in the gravitational defect of mass, consisting in that at central densities higher a certain value, for the same number of baryons, the mass of stellar configuration appear more of appropriate mass of diffuse cloud. However, then the accuracy of numerical computation did not rather large, to be sure in this result. Therefore by Hambartzumian and Sahakian special research of this effect was spent ([22]), and to exclude the distortions brought certainly by nuclear interactions and complications in chemical structure, the configurations, consisting of

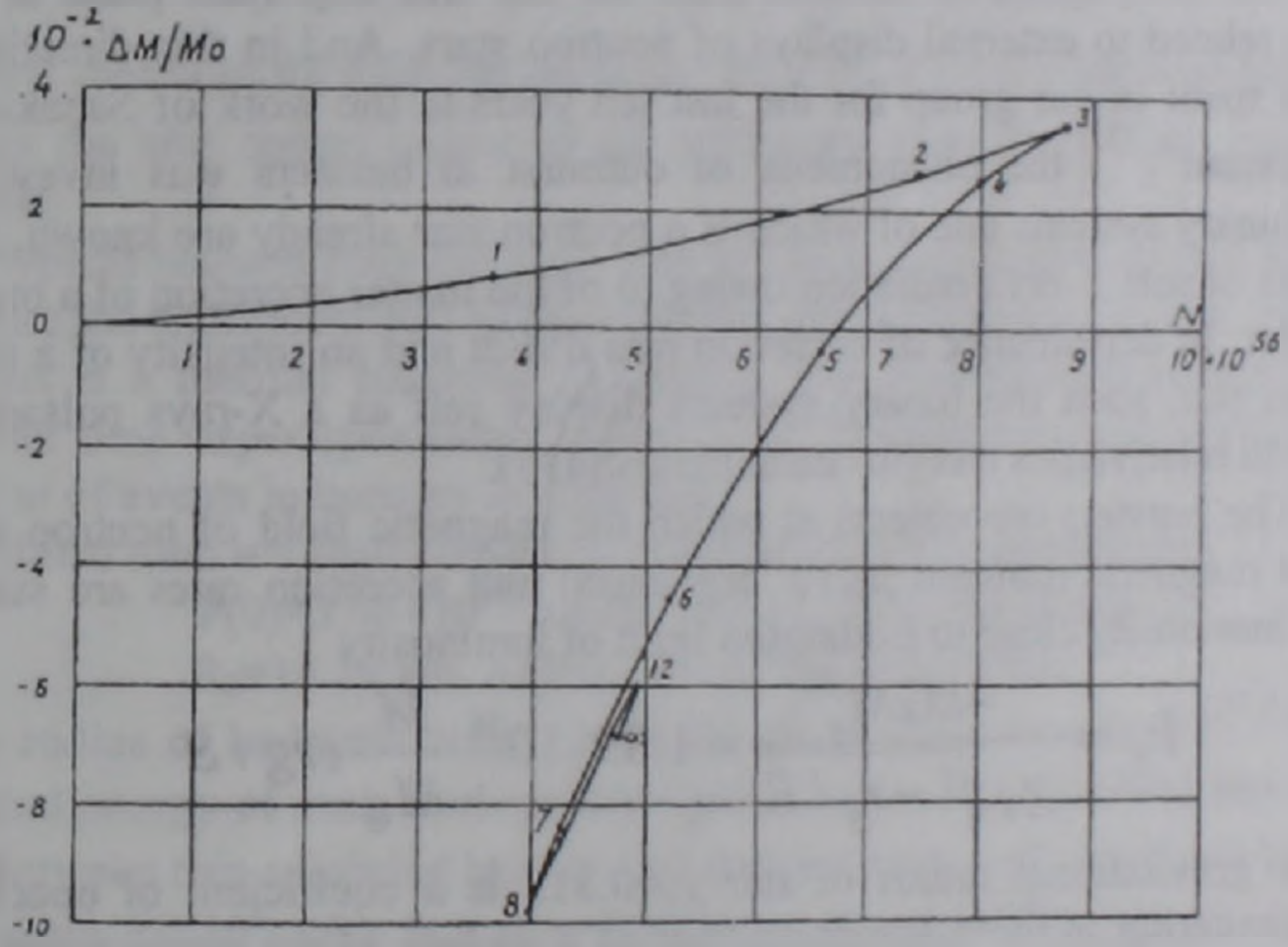

Fig 4. The dependence of packing fraction $\Delta M/M_\odot$ on the total number of neutrons N, $\Delta M = M_0 - M$, $M_0 = m_n N$ The figures on the curve indicate values of parameter $t_n(0) = 4 arcsh P_F / m_n c$ for corresponding configurations

ideal gas of neutrons, were considered.

The dependence of packing fraction of neutrons is

$$\frac{\Delta M}{M_0}=\frac{M_0-M}{M_0} \tag{34}$$

depending on the total number of neutrons in the configurations was calculated. Here

$$M_0 = Nm_n\ , \quad M = 4\pi \int \rho r^2 dr,$$

The result is represented on fig. 4.

For usual stars ΔM>0 always. In the linear sequence $M(\rho_0)$of neutron configurations the curve of pacing fraction at first has a normal behaviour with the growth of central density monotonously grows and at value $n(0)=3.10^{39}cm^{-3}$ reaches a maximum,then the curve sharply changing own direction, goes down. At $n(0)\geq 1.12 \cdot 10^{40} cm^{-3}$ the packing fraction becomes negative, in the point with $n(0)=2 \cdot 10^{41} cm^{-3}$ has a deep minimum,approximately equal -0.1, then it oscillating with a small and strongly damping amplitude, and continuing to remain negative, at $\rho(0)\rightarrow\infty$ it goes to limit -0.69. In the models of configurations from real gas of baryons ΔM>0 always.But never the less here absolute gravitational defect of mass has abnormal behavior too. Indeed at central pressures, exceeding $P(0)\approx 4 \cdot 10^{35} erg/cm^3$ the growth of nucleon gravitational binding energy is replaced by its appreciable ccc.

The circumstances analysis of the above mentioned peculiarities of mass gravitational defect of degeneraces stellar configurations brings us to conclusion that its abnormal behaviour is caused by two reasons, by strong growth of particles boundary energy in the appropriate configurations, and by catastrophic violation of additivity of internal energy in the inside the most dense baryonic configurations caused by strong curvative of space metric. The cosmogonical aspects of abnormal gravitational mass defect until do not investigated.

7.In the physics of neutron stars the not less important place is occupied the questions related to external displays of neutron stars. And in this direction the certain work was spent in our group for the last ten years.In the work of Sahakian, Alodjantz and Sargissian ([23]) the phenomena of outburst in bursters was investigated. Many compact binary systems one of which is a neutron star already are known. Such systems are sources of soft X-rays radiation owing to of the matter accretion of a ordinary star on neutron star. In dependence of accretion rate dM/dt and an intensity of a magnetic field of neutron star, such the binary systems display self as a X-rays pulsars, bursters or objects with relativistics jets (for examples SS433).

The bursters are objects at which the magnetic field of neutron star relatively weak (the magnetic moment $\mu\leq 10^{28}$erg/gauss) and accretion rates are such, that them radiation luminosity close to Eddington limit of luminosity

$$L_E = \frac{4\pi G M_c}{\chi_e \sqrt{1 - r_g / R}} = 1.89 \cdot 10^{38} \frac{M}{M_\odot} erg / S \qquad (35)$$

Here r_g is gravitational radius of star χ_e=0.312 is a coefficient of opacity, cosed by Tomson scattering in the assumption, that of a surface of the neutron star, the mass of hydrogen part is x=0.64. At quasistationar regime the accretion rate of appropriate luminosity (35) is equal

$$\dot{M}_E = \frac{4\pi G M}{c\chi(1 - \sqrt{1 - r_g / R_0})} = 1.21 \cdot 10^{18} \frac{M}{M_\odot} g / S \qquad (36)$$

At the constant rate of accretion $\dot{M} < \dot{M}_E$: the neutron star is in a stationary state and in dependence on that, what the magnetic field it keep self or as X-ray pulsar (at a strong magnetic field $H(R)\approx 10^{12}$gauss) or as compact nonpulsating source of X-radiation (when a magnetic field relative weak). The bursters are objects with the accretion rate close to

(36), $\left|\dot{M} - \dot{M}_E\right| << \dot{M}$. In this case in the neutron star qunsistationary thermal state is established, in which calm long periods ($\tau \sim 10^4 \div 10^5$S) of slow heating are interrupted by short outbursts, accompanying by ejection of certain quantity of matter and radiation energy, when the luminosity reached of Eddington limit, hardly only small part of its thermal energy, which necessary in order to the luminosity of a star was lowered hardly below of Eddington limit, therefore its shown in ([23]), that just these small fluctuation in the thermal reserve of neutron star bring in the phenomena outbursts in the bursters. Indeed, at accretion process, as soon as the luminosity, reaching the value L_E hardly exceeds it, a radiating force (a radiation pressure) on the star surface preponderate over gravitational, inevitably bring to flow of matter from a star and on the contrary. when during the outburst, the luminosity little bit lowered below L_E preponderate over the gravitation force and at once renews the process of accretion. At a outburst the star loses a energy, as in comparison with the calm period the luminosity on the order is higher, therefore for this short interval of time $\dot{T}(r,\tau) < 0$, however extenuation of temperature is rather insignificant. In an interval of time between outburstrs the star is in an accretion regime, on its surface huge energy is allocated, but the main part of this energy is radiated from a surface, and only the small part it is transferred in interior on heating of hadronic nuclei. The star slowly fills up that small energy, which has lost during the outburst therefore for calm period of its life $\dot{T}(r,\tau) < 0$. But with time $\dot{T}$ is decreasing, so as the star comes nearer to the stationary state, then there comes the following outburst.

At the typical neutron stars the main part of mass is concentrated in a hadronic nucleous, therefore the significant part of their thermal energy is reserved here. Thus, the hadronic nucleous is a thermal container of neutron star. The thermal energy of this container with the time experiepce rather insignificant fluctuations $|\Delta Q|/Q<<1$, than the regulnr motion of events in bursters in provided.

For an illustration we shall consider a configuration with parameters

$$P(0)=3.96 \cdot 10^{34}\ \text{erg/cm}^3,\ R=11.73\ \text{km},\ M=1.08M_\odot,$$
$$R_0=11.19\ \text{km},\ \Delta M=3.24 \cdot 10^{-5}M_\odot,\ r_g=3.21\ \text{km}, \quad (37)$$

where R_0 is the radius of hadronic core, ΔM is the mass of Ae-envelope ([19,21]). In a burster the thermal energy of such neutron star approximately is equal $Q=3.96 \cdot 10^{44}$erg ([21,23]). At time between two adjoining bursters the thermal energy of star grows by value $\Delta Q=2 \cdot 10^{38}\tau_1$, where $\tau_1 \approx 10^4 \div 10^5$s is a time between two bursts.This energy about on three order is more than that energy ($E \sim 10^{39}$erg) which is sheart out in one burst. While all energy ΔQ, accumulated during the time T_1, should be spent in burst time, in order to supply regular action of burster's mechanism. The fact is that the energy ΔQ in main is spent on accomplishment of work at mass eruption during the burst, The mass m_B ejecting during the burst is defined by relation

$$\frac{\gamma G M_m}{R} \approx \Delta Q,$$

where γ is Lorentz factor for ejected mass. For a star with parameters (37), the mass m_B is the order 10^{22}-10^{23} g. We shall at last note, that in bursters the temperature of neutron stars along radius with the accomt of the relativistic factor practically is do not change and equal $\sqrt{g_{00}}T(r) \approx 2 \cdot 10^7$.

8. At the beginning of 90-s, developing the pioneer works of Sturrok ([24]), Ruderman and Sutherland ([25]), by Sahakian was developed a new variant of radioradiation of pulsars([26-28]). In the work ([26]) the problem of radioradiation of pulsar was considered for aligned rotator, but in ([27,28]) for real case, when the magnetic axis of star does not coincide with a rotation axis (inclined rotator).

The electrical field in the neutron star, in its magnetosphere (region of closed field lines) and in the radiating channel (region of open field lines) is determined. For radioradiation of pulsar an electrical field in the radiating channel is important

$$E_B \approx -\frac{\Omega B_s R^5}{cr^4}\cos\alpha \tag{39}$$

where B_S is magnetic induction near to a pole, Ω is angular velocity of rotation, R-radius of the star, α-the angle of inclination of the vector of magnetic moment of star relatively rotation axis, r-distance from center of a star. It is shown, that over a magnetic cap of a star the special region, named the magnetic funnel will be formed, where there are the vigorous processes of multiplication of high energy quants and electron-positron pairs. The altitude of the magnetic funnel over a magnetic cap $h \approx 8 \cdot 10^6 \Omega^{0.2} \mu_{30}^{1/3} R_6^{1/3}$ cm, and it radius $r(\Omega r/c)^{0.5}$ slowly depends of inclination angle α, and μ is magnetic moment of star. It is shown, that radioradiation of pulsar is formed in magnetic funnel. Here during the active radiating processes two main flaws of high ultrarelativistic energy particles are formed: going upward a flow of electrons, and falling on magnetic cap of a star flow of positions. This main flows are accompanied by separate narrow strips of positrons and electrons streams rather small energy, being sufficient powerful coherent sources of radioradiation. These stripes of secondary particles streams are formed at once after the annihilation of quants of (curvative) radiation (emitting) by particles of main streams.

Estimation of pulsar radioluminosity is made

$$L \approx 7.4 \cdot 10^{23} \Omega^{3.52} \mu_{30}^{8/3} \psi(\alpha) \tag{39}$$

where $\psi(\alpha)$ is known function, at $\alpha < 50^0$, $\psi(\alpha) \approx 1$. Equating the theoretical L_0 and the observable radioluminosity L_0, we are obtained

$$\mu = 10^{30} p^{1.32} R_6^{0.4} (2{,}1 \cdot 10^{27} L_0 / \psi)^{3/8} \tag{40}$$

for a magnetic moment of pulsar, p is period of pulsar. The magnetic moments of slow pulsars calculated by this formula expressed appreciably larger, than magnetic moments of fast pulsars. It means, that in average the mass of slow pulsars there are more of fast pulsars masses.

Magnetic funnel works with interruption, periodically experiencing discharge, hence the process of formation of pulsar radioradiation works with interruption. Duration of process of radioradiation on formation and interruption between these processes are order

$$\frac{h}{c} \approx 2.7 \cdot 10^{-4} \Omega^{0.2} \mu_{30}^{1/3} s \tag{41}$$

i.e. radioimpulse of pulsar has microstructure. Hence the radiation of microstructure profiles of observed radioimpulses of pulsars will allow to obtain the additional valuable information about magnetic moments of neutron stars.

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Նեյտրոնային աստղերի ֆիզիկա

Աշխատանքը հանդիսանում է նեյտրոնային աստղերի ֆիզիկայի բնագավառում վերջին 30 տարում Երեւանի պետական համալսարանում կատարված աշխատանքների համառոտ ակնարկ: Մասնավորապես քննարկվում են հարցեր կապված 10^6 գ/սմ^3 եւ ավելի խտության դեպքում նյութի վիճակի, նյութի նեյտրոնացման եւ պիոնացման էֆեկտների հետ: Գտնված է այլասերված պլազմայի վիճակի հավասարումը, որոշվել են այլասերված աստղային կոնֆիգուրացիաների ինտեգրալ բնութագրիչները, նկատվել է գերխիտ աստղերում զանգվածի անոմալ դեֆեկտ, որը պայմանավորված է տարածության խիստ կորացման հետեւանքով ներքին էներգիայի ադիտիվության խախտման հետ: Դիտարկվել են նաեւ նեյտրոնային աստղերի արտաքին դրսեւորումներին առնչվող հետեւյալ հարցերը՝ բռնկումները բարստերներում եւ պուլսարների /բաբախիչների/ ռադիոճառագայթումը:

Академик НАН Армении Г.С.Саакян, Академик НАН Армении Э.В.Чубарян

ФИЗИКА НЕЙТРОННЫХ ЗВЕЗД

В работе приводится краткий обзор результатов, полученных в Ереванском университете по физике нейтронных звезд за прошедшие 30 лет. В частности обсуждаются вопросы, связанные с состоянием вещества при плотностях от 10^6 г/см^3 до сколь угодно больших, эффекты нейтронизации и пионизации вещества. Найдено уравнение состояния вырожденной плазмы, получены интегральные параметры вырожденных звездных конфигураций, обнаружен аномальный дефект массы в сверхплотных звездах, обусловленный нарушением аддитивности внутренней энергии, вызванной сильным искривлением пространства. Наконец, рассматриваются вопросы, относящиеся к внешним проявлениям нейтронных звезд: вспышки в барстерах, радиоизлучение пульсаров.

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