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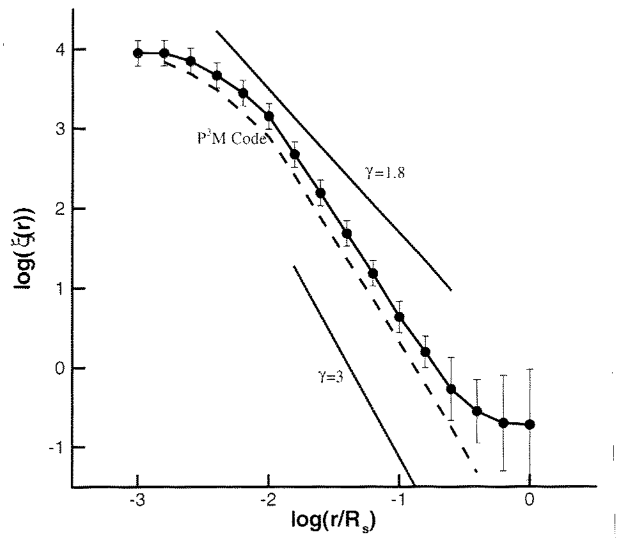

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ON SMALL MASS HYBRID STARS WITH QUARK CORE

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The models of layer neutron stars with strange quark core were constructed, based on wide range of realistic equations of state of superdense matter. The parameters of minimal mass layer stars were obtained to be sensitive enough to the selected models for both the neutron and strange quark matter. In particular, within the region of small masses for some models of neutron matter the appearance of additional local maximum on star mass-central pressure curve was revealed. This fact makes possible the existence of stable superdense stars of small masses ($M/M_\odot \sim 0.08$), having quark core with radius of $\sim 1km$, where only 6% of the whole star mass is concentrated. Their radius can reach the values of order of 1000km, that makes them resembling to white dwarfs.
In the considered model an accretion of matter can result in two consecutive transitions to the neutron star with a quark core with an energy release resembling supernovae explosions.

1. Introduction

The possibility of formation of strange quark matter in nuclear plasma results in the fact that the equation of state of superdense matter acquires van-der-vaalsian character [1,2]. Thereto energy per baryon ε, as a function of baryon density n, depending on values of parameters, unsufficiently exactly determined in the theory of strong interactions, can have both negative and positive minimum ε_{min}. This circumstance, in its turn, results in two alternative opportunities.

If a case with $\varepsilon_{min} < 0$ is realized, a self-connected state of strange quark matter is possible and, as a consequence, self-confined configurations wholly consisting of such matter - so-called " strange stars ", - can exist [3] . If the variant with $\varepsilon_{min} > 0$ is realized, then at density higher than the threshold for the formation of strange quark matter, the first order phase transition with density jump takes place. Thus, according to Gibbs conditions, thermodynamical equilibrium between quark matter and nucleon component is possible, i.e. simultaneous coexistence of two phases takes place. The models corresponding to such equation of state, will have a core consisting of strange quark matter and a crust with structure of usual neutron stars, with the jump of density on the phases separation boundary .

In this connection it is necessary to note the calculations of models with the "mixed phase", containing quark formations of different configurations and supposing continuous change of pressure and density in the region of quark phase forming [4]. The results of these authors have shown, that the formation of the mixed phase of quark and nuclear substances can be more or less preferable, than usual first order phase transition from nucleon state to quark one, depending on values of local surface and Coulomb energies, connected with the formation of quark and nuclear structures of the mixed phase.

Below we examine a case supposing such surface tension, which results in first order phase transition with an opportunity of coexistence of two phases.

With the purpose of study of functional dependence of stellar configurations structural and integral parameters on the form of superdense matter equation of state we have considered a wide set of realistic equations of state ensuring the coexistence of neutron and strange quark matter. In the region of small masses it was revealed, that some of these equations of state result in the occurrence of an additional local maximum on star mass - central pressure dependence, that causes an opportunity of existence of new family of stable equilibrium configurations with very interesting distinctive features.

In the given work we present the results received for one of such equations of state, concentrating attention on small masses region.

2. Equation of state and the results of calculations

Constructing the equation of state of neutron star substance, the different equations of state for different intervals of density are usually used providing continuity at transition from one interval to another.

In the present paper the equations of state FMT,

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BPS and BBP (for so-called Aen-structure - matter consists of nuclei, degenerated neutrons and electrons) were used for density values below normal nuclear [5].

At supernuclear densities tabulated in [6] relativistic equation of state of neutron matter was used, taking into account two-particle correlations and calculated on the basis of meson-exchange potential of Bonn [7].

The specified equations of state covering in totality the density interval of $7.86 g/cm^3 < \rho < 4.81 \cdot 10^{14}$ g/cm^3, describe a matter of neutron star having nucleon structure.

For the description of quark component the MIT "bag" model was used [8], according to which strange quark matter consists of u, d, s- quarks and electrons, being in equilibrium with respect to weak interactions. In the examined equation of state with density jump the quark phase is characterized by the following phenomenological parameters of bag model: "bag" constant $B = 55 MeV/fm^3$, strange quark mass $m_s = 175 MeV$ and coupling constant $\alpha_c = 0.5$.

Gibbs conditions

$P^{(NM)} = P^{(QM)} = P_O$,

$\mu_b^{(NM)} = \mu_b^{(QM)}$

allow to find the pressure P_O, baryon number densities n_N and n_Q, and mass densities ρ_N and ρ_Q, describing the coexistence of two phases (the indices (NM) and (QM), N and Q specify that quantities belong to nucleon and quark phases correspondingly). Here P is a pressure and μ_b – baryon chemical potential .

The numerical calculations within the framework of this model have resulted in the following values for the characteristics of first order phase transition: $P_O = 0.76 MeV/fm^3$, $n_N = 0.12 fm^{-3}$, $n_Q = 0.26 fm^{-3}$, $\rho_N c^2 = 113.8 MeV/fm^3$, $\rho_Q c^2 = 250.5 MeV/fm^3$.

Integral parameters of spherically-symmetrical static superdense star were determined for the given equation of state: coordinate radius of the star R, total gravitational mass M, total rest mass M_O, total proper mass M_P and relativistic moment of inertia I, depending on the central pressure P_c.

If in the maximal mass region (configuration f with $M = 1.86 M_\odot$, $R = 10.8 km$) these dependences have usual character, in small masses region, where again there is a loss of stability - the condition $dM/dP_c > 0$ is violated (configuration a with $M = 0.0798 M_\odot, R = 254.7 km$), - the curve has a number of features, which are absent in case of other equations of state. Right away after the configuration a there is sharp fracture (configuration b with $M = 0.080 M_\odot$, $R = 205 km$) on the curve caused by the birth of quarks. The section (ab) corresponds to stable neutron stars without quark core. The configurations with small quark cores are unstable - section (bc) of the curve (configuration c is characterized by $M = 0.079 M_\odot, R = 380 km$), where $dM/dP_c < 0$. This corresponds to the results of [9], where for

$\lambda = \rho_Q/(\rho_N + P_O/c^2) > 3/2$

the configurations with small mass core of a new phase were found to be unstable. In the considered case $\lambda = 2.19$, i.e. meets the mentioned condition.

Usually for $\lambda > 3/2$ the sharp fracture abc appears not in the small masses region, but on the ascending branch of $M(P_c)$ curve, and after the configuration c up to the configuration with maximal mass f the curve has monotone ascending character. In the considered case right away after that fracture, again in small masses region the local maximum is formed - configuration d with $M = 0.082 M_\odot$ and $R = 1251 km$. At this configuration both the radius and the moment of inertia dependences on the central pressure have distinguished maximum.

For all specified critical configurations the packing coefficient is positive and, except for the configuration f, has the same order, as that for white dwarfs (configuration e is characterized by $M = 0.072 M_\odot$, $R = 133.2 km$).

As follows from calculations, for configuration d the values of radial coordinate $R_{nd} = 13.24 km$ and accumulated mass $M_{nd} = 0.07 M_\odot$ correspond to the threshold density for the formation of Aen-plasma.

The stars of the same mass corresponding to branches (cd) and (ef), differ considerably from each other by radius. While the stars of branch (ef) have radii of $\sim 10 km$, the stars of branch (cd) have sufficiently large radii of order of $1000 km$, that is characteristic for white dwarfs.

It is necessary to note, that in case of realization of the considered equation of state matter accretion on the neutron star will result in two consecutive catastrophic transitions to a neutron star with quark core, therefore two consecutive processes of energy release will take place. A star with a quark core belonging to the branch (cd) at first is formed; further accretion will result in configurations with radius about $1000 km$, and, at last, as a result of the second catastrophic reorganization a star of branch (ef), having the radius about $100 km$, is formed.

The research has confirmed a regularity of result and has shown, that the variation of the equation of state within the interval $9 \cdot 10^{13} g/cm^3 < \rho < 1.8 \cdot 10^{14} g/cm^3$ can result in some cases even in strengthening of the found out feature of $M(P_c)$ curve.

3. Conclusion

The first order phase transition in superdense nuclear matter from nucleon component to strange quark state with the transition parameter $\lambda > 3/2$ usually results in the appearance of small sharp fracture on the stable branch of star mass- central pressure curve. In the considered above model, where the loss of stability in the region of small masses occurs at higher density than in other models ($\rho_c = 2 \cdot 10^{14} g/cm^3$) and is close to the threshold for the birth of quarks ($\rho_c = 4.5 \cdot 10^{14} g/cm^3$), a new local maximum arises, that makes possible the existence of superdense stars of small masses with the radius, exceeding one thousand kilometer, and having quark core with radius of $\sim 1km$, in which only 6 % of the whole star mass is concentrated. Such stars by their size are similar to white dwarfs, but the main part of their mass is concentrated in Aen-plasma.

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References

[1] E. Witten, *Phys. Rev.*, **D30**, 272 (1984).

[2] E. Farhi, R.L. Jaffe, *Phys. Rev.*, **D30**, 2379 (1984).

[3] C. Alcock, E. Farhi, A. Olinto, *Astrophys. J.*, **310**, 261 (1986); P.Haensel, J.L.Zdunik, R.Schaeffer, *Astron. and Astrophys.*, **160**, 121 (1986).

[4] N.K. Glendenning, *Phys. Rev.*, **D46**, 1274 (1992); H.Heiselberg, C.J.Pethick, E.F.Staubo, *Phys. Rev. Lett.*, **70**, 1355 (1993); C.P.Lorenz, D.G.Ravenhall, C.J.Pethick, *Phys. Rev. Lett.*, **70**, 379 (1993).

[5] G.S. Bisnovatyi-Kogan, "Physical problems of the theory of stellar evolution", Nauka, Moscow, 1989 (in Russian).

[6] F. Weber, N.K. Glendenning, M.K. Weigel, *Astrophys. J.*, **373**, 579 (1991).

[7] R. Machleidt, K. Holinde, Ch. Elster, *Phys. Rept.*, **149**, 1 (1987).

[8] A. Chodos, R.L. Jaffe, K. Johnson et al., *Phys. Rev.*, **D9**, 3471 (1974).

[9] B. Kaempfer, *Phys. Lett.*, **101B**, 366 (1981).

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