Erratum: Proto-neutron star structure within an extended lowest-order constrained variational method at finite temperature [Phys. Rev. C **92**, 035806 (2015)]

S. Goudarzi and H. R. Moshfegh

(Received 18 December 2017; published 25 April 2018)

DOI: [10.1103/PhysRevC.97.049904](https://doi.org/10.1103/PhysRevC.97.049904)

As reported in the Erratum [1], several errors were found in the program code for the nuclear matter calculation reported in the associated original paper [2]. The changes in the procedure of adding the three-body force (TBF) to the lowest-order constrained variational (LOCV) program code, affect the results of the thermodynamic properties of nuclear matter and subsequent applications of them to the description of the structure of the proto-neutron stars (PNS) reported in the original paper for which we present corrected results in the present Erratum. From these changes and modifications, our numerical results in Table I, Figs. 6 and 7 as well as Figs. 10–13 should be corrected.

Below we show the corrected table and figures together with corrections to the main text.

Associated with the modification in Figs. 10 and 11, the eighth sentence of the seventh paragraph in Sec. IV, “By comparing Figs. 8 and 9 with Figs. 10 and 11, one can conclude that at a fixed entropy and a fixed Y_e , using the TBF shifts the relative fraction of protons to larger values and correspondingly results in smaller values of x_{ν_e} .” should be replaced by the following sentence, “From Figs. 10 and 11 one can conclude that inclusion of the TBF affects both the value and the behavior of the relative population of the constituents

of the PNS core. As is seen in these figures, the relative population of protons tends to be saturated. The value of the baryon density in which x_p saturates seems not to be strongly dependent on the entropy and lepton fraction of the system.”

Associated with the modification in Fig. 13 and Table I, the two following changes should be made. First, the seventh sentence of the ninth paragraph in Sec. IV, “It can be concluded that for a fixed value of Y_e the maximum mass does not strongly depend on entropy, in contrast with the radius.” should read as “It can be concluded that for a fix value of Y_e both the maximum mass and the radius are not strongly dependent on entropy.”

Second, the tenth and 11th sentences of this paragraph “On the other hand, as the value of Y_e increases the relative population of protons increases according to the charge neutrality condition (as can be seen in Figs. 10 and 11) and the EOS of baryonic part becomes softer. Therefore, a system with larger value of Y_e provides a smaller maximum mass compared to one with smaller value of Y_e with the same entropy.” should also be replaced by “On the other hand, as the value of Y_e increases the relative population of protons increases according to the charge neutrality condition (as can be seen in Figs. 8–11), and the EOS of the baryonic part becomes softer. Therefore, a system with a larger value of Y_e should provide a smaller maximum mass compared to the one with a smaller value of Y_e with the same entropy. Moreover, for a fixed entropy, the more the lepton fraction, the less the temperature at which a given baryon density is reachable, according to Fig. 7. In order to make the statement more clear, let us consider, for example, the case of $S/A = 2$ and $\rho_B = 0.5 \text{ fm}^{-3}$. According to Fig. 7 this density is reached at $T = 34$ and 31 MeV for $Y_e = 0.3$ and 0.4 , respectively. On the other hand, the internal energy increases with temperature, which means that a system with lower temperatures (more lepton fraction) contains more internal energy. According to this point of view, a system with a larger value of Y_e should provide a larger maximum mass compared to one with a smaller value of Y_e with the same entropy. Both of the above facts affect the value of the maximum mass of the PNS. According to Figs. 8 and 9, since the proton fraction increases by density in the case of using only two-body forces, the first fact dominates. Whereas according to Figs. 10 and 11, the proton fraction tends to saturate and decrease with density if the TBF is included. Therefore, the second fact dominates in this case. As a consequence, a slight decrease in the value of the maximum mass by increasing the lepton fraction is observed in the case of using only two-body

TABLE I. Revised version of Table I in the original paper. The maximum mass and the corresponding radius of the PNS obtained within the LOCV method as well as other approaches for some values of entropy and lepton fraction.

Method	Y_e	S/A	$R \text{ (km)}$	$M/M_\odot$
LOCV(2BF)	0.3	1	8.5	1.63
LOCV(2BF)	0.3	1.5	8.6	1.63
LOCV(2BF)	0.3	2	8.8	1.62
LOCV(2BF)	0.4	1	8.5	1.61
LOCV(2BF)	0.4	1.5	8.6	1.60
LOCV(2BF)	0.4	2	8.9	1.59
LOCV(2BF + TBF)	0.3	1	11.7	2.38
LOCV(2BF + TBF)	0.3	1.5	11.6	2.35
LOCV(2BF + TBF)	0.3	2	11.5	2.32
LOCV(2BF + TBF)	0.4	1	11.9	2.41
BHF(2BF + TBF) [7]	0.4	1	10.2	1.95
LOCV(2BF + TBF)	0.4	1.5	11.8	2.39
LOCV(2BF + TBF)	0.4	2	11.7	2.32
BHF(2BF + TBF) [7]	0.4	2	10.7	1.95
Effective-field theory [18]	0.4	2	13.2	1.76

FIG. 6. Revised version of Fig. 6 in the original paper. (a) Free energy per baryon of the symmetric nuclear matter as a function of density for different values of temperature with and without the TBF. (b) The same as panel (a) but for the pure neutron matter.

FIG. 7. Revised version of Fig. 7 in the original paper. (a) The temperature of the PNS matter as a function of baryon density for different values of entropy per baryon obtained with and without the TBF for $Y_e = 0.3$. (b) The same as panel (a) but for $Y_e = 0.4$.

FIG. 10. Revised version of Fig. 10 in the original paper. Relative population of the constituents of the PNS core calculated by using the AV18 + TBF potential and for $Y_e = 0.3$ and $S/A = 1$. (b) The same as panel (a) but for $S/A = 2$.

FIG. 11. Revised version of Fig. 11 in the original paper. Relative population of the constituents of the PNS core calculated by using the AV18 + TBF potential and for $Y_e = 0.4$ and $S/A = 1$. (b) The same as panel (a) but for $S/A = 2$.

FIG. 12. Revised version of Fig. 12 in the original paper. (a) The EOS of the proto-neutron star with $Y_e = 0.3$ calculated with and without the TBF for some fixed values of the entropy per baryon. (b) The same as panel (a) but for $Y_e = 0.4$.

FIG. 13. Revised version of Fig. 13 in the original paper. (a) The mass-radius relation of the proto-neutron star with $Y_e = 0.3$ calculated with and without the TBF for some fixed values of the entropy per baryon. (b) The same as panel (a) but for $Y_e = 0.4$.

forces, and an opposite behavior is seen if the TBF is also included.”

Our conclusion remains unchanged except that the seventh sentence, “However, a slight decrease in the value of the maximum mass by increasing the entropy and electron fraction

is observed.” should read as “However, a slight decrease in the value of the maximum mass by increasing the entropy is observed. Moreover, as the lepton fraction increases the maximum mass decreases in the case of using only two-body forces. An opposite behavior is seen if the TBF is also included.”

-
- [1] S. Goudarzi and H. R. Moshfegh, preceding Erratum, *Phys. Rev. C* **96**, 049902(E) (2017).
[2] S. Goudarzi and H. R. Moshfegh, *Phys. Rev. C* **91**, 054320 (2015).

- [7] M. Baldo and L. S. Ferreira, *Phys. Rev. C* **59**, 682 (1999);
G. F. Burgio and H.-J. Schulze, *Astron. Astrophys.* **518**, A17 (2010).
[18] I. Bednarek and R. Manka, *Phys. Rev. C* **73**, 045804 (2006).