

NEUTROSTRICTION IN NEUTRON STARS

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Abstract

It is demonstrated that not only gravity, but also neutrostriction forces due to optical potential created by coherent elastic neutron-neutron scattering can hold a neutron star together. The effect of these forces on mass, radius and structure of the neutron star is estimated.

1 Introduction

Interaction of neutrons with matter at low energies is characterized by optical potential

$$V_o(\mathbf{r}) = \frac{\hbar^2}{2m} 4\pi n(\mathbf{r})b, \quad (1)$$

where m is neutron mass, $n(\mathbf{r})$ is atomic density at a point \mathbf{r} , and b is coherent s-wave neutron-nucleus scattering amplitude (usually the amplitude is defined with opposite sign, but it is not convenient. See, for example [1, 2]). It is important that though the amplitude b is the result of short range strong interactions, the potential V_o is the long range one.

Neutron-nucleus scattering amplitude b is of the order of several fm, the density of matter in the earth conditions is of the order 10^{23} cm^{-3} , so the optical potential of matter is of the order 10^{-7} eV . If b is positive the potential is also positive, i.e. repulsive. If b is negative the potential is also negative, i.e. attractive.

Interaction of neutrons with neutron matter is also described by eq. (1), and since the amplitude b is negative, the potential (1) of the neutron matter is attractive. The attractive force $F_o = -\nabla V_o(\mathbf{r})$ is called here neutrostriction.

Neutron-neutron s-wave scattering can take place only in singlet state, and the singlet amplitude b_s at low energies is $b_s \approx -18 \text{ fm}$ [3]. The coherent amplitude obtained by averaging over all possible spin states of two neutrons is 4 times lower, therefore $b = -4.5 \text{ fm}$. For such values of b at star densities larger than $10^{36} \text{ neutrons/cm}^3$ the potential V_o is larger than 1 MeV.

Let's compare the total gravitational and optical energies for a star of radius R , mass M and uniform density

$$n = \frac{M}{(4\pi/3)R^3m}. \quad (2)$$

The total gravitational energy is

$$U_g = \frac{3}{5}G\frac{M^2}{R}, \quad (3)$$

where G is gravitational constant, while the optical energy is

$$U_{opt} = \frac{\hbar^2}{2m} 4\pi n b N = 3 \frac{\hbar^2}{2m^3} b M^2 / R^3, \quad (4)$$

where N is the total number of neutrons in the star. For amplitude $|b| = 4.5$ fm we have $U_{opt} > U_g$, when [4]

$$R < R_0 = \sqrt{\frac{5\hbar^2|b|}{2m^3G}} = \frac{\hbar}{mc} \sqrt{\frac{5mc^2|b|}{2Gm^2}} \approx 20 \text{ km}, \quad (5)$$

which is independent of the star mass M . Using the parameter R_0 one can rewrite (4) as

$$U_{opt} = \frac{3}{5} G R_0^2 \frac{M^2}{R^3}. \quad (6)$$

However, the s-wave amplitude b_s is a constant only at low energies. In neutron stars, where energies are rather high, energy dependence of b must be taken into account. This dependence is well described by the theory of effective radius

$$\frac{1}{b_s(E)} = \frac{1}{b_s(0)} \left(1 - \frac{1}{2} k^2 a b_s(0) \right), \quad (7)$$

where a is the effective radius of neutron nucleus interaction, $a = 1.2$ fm, $b_s(0) = -18$ fm, and $k^2 = 2mE/\hbar^2$. One can now deduce energy dependence of b :

$$b(E) \equiv \frac{b_s(E)}{4} = \frac{b(0)}{1 + Qx^2}. \quad (8)$$

where $x = k/k_c$, $k_c = mc/\hbar = 4.8 \cdot 10^{13} \text{ cm}^{-1}$, and $Q = a|b_s(0)|k_c^2/2 \approx 250$. In the degenerate neutron gas the most important is the energy at the Fermi level: $E = E_F = \hbar^2 k_F^2 / 2m$, where k_F is the neutron wave number at the Fermi level. It is related to neutron density by equation $n = k_F^3 / 3\pi^2$. Thus $b(E) = b(E_F)$ can be represented as a function of n :

$$b(E) \equiv b(n) = \frac{b(0)}{1 + Qx^2} = \frac{b(0)}{1 + Q(n/n_c)^{2/3}}, \quad (9)$$

where a unit of density $n_c = k_c^3 / 3\pi^2 \approx 3.7 \cdot 10^{39} \text{ cm}^{-3}$ is introduced.

In the next section the contribution of the optical potential to neutron star parameters R , M and density distribution $n(r)$ is estimated. The neutron star is considered as a nonrotating spherical object composed of a degenerate neutron gas at zero temperature. Calculations were performed with the help of the Tolman-Oppenheimer-Volkov (TOV) equation [5], generalized by inclusion of neutrostriction forces. We do not take into account the short range nuclear forces because they come into play only at nuclear densities $n_N \approx 10^{38} \text{ cm}^{-3}$, while optical potential is the most important at $n \ll n_N$.

In the third section the optical potential is compared with commonly used short range nuclear interactions, and in conclusion some effects are discussed, which can take place in neutron stars, if energy dependence $b(E)$ contains a resonance.

2 Neutron star without short range nuclear interactions

The Tolman-Oppenheimer-Volkov (TOV) equations in nonrelativistic Newtonian form are

$$\frac{dp(r)}{dr} = -G \frac{\varepsilon(r)\mathcal{M}(r)}{c^2 r^2}, \quad (10)$$

$$\frac{d\mathcal{M}(r)}{dr} = \frac{4\pi r^2 \varepsilon(r)}{c^2}, \quad (11)$$

where $\varepsilon(r)$ is energy density of particles.

The first equation (10) represents a condition for a balance between pressure and gravitational compression acting on a mass element $dM = 4\pi r^2 dr mn(r)$ (m is the neutron mass and $n(r)$ is the particles density) within a thin spherical shell of thickness dr shown in fig. 1. The force $F_p = 4\pi r^2 [p(r) - p(r + dr)]$, which repels the mass element dM from the star center, is balanced by gravitational force $F_g = GdM\mathcal{M}/r^2$, which pulls the mass element toward the star's center. Here $\mathcal{M} = 4\pi \int_0^r r'^2 dr' mn(r')$ is the mass of the part of the star with the radius r , and in equations (10-11) the mass density $mn(r)$ is replaced by energy density $\varepsilon(r)/c^2$.

The pressure $p(r)$ is related to energy density $\varepsilon(r)$ by thermodynamic relationship

$$p = -\frac{\partial U}{\partial V} = n \frac{d\varepsilon}{dn} - \varepsilon. \quad (12)$$

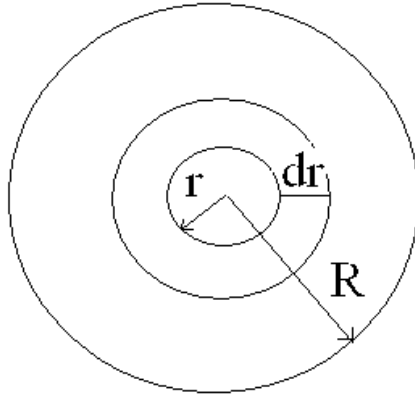


Figure 1: To derivation of the TOV equation.

In the case of free particles the energy density is given by their Fermi distribution

$$\begin{aligned} \varepsilon = \varepsilon_F(r) &= \frac{8\pi\hbar c}{(2\pi)^3} \int_0^{k_F(r)} \sqrt{k^2 + k_c^2} k^2 dk \\ &= mc^2 n_c \int_0^x 3\sqrt{u^2 + 1} u^2 du = \varepsilon_c f_F(x), \end{aligned} \quad (13)$$

$x = k_F/k_c = \sqrt[3]{n/n_c}$, $n_c = k_c^3/3\pi^2$, $\varepsilon_c = mc^2 n_c = 5.6 \cdot 10^{36}$ erg/cm³, and

$$\begin{aligned} f_F(x) &= 3 \int_0^x \sqrt{1 + u^2} u^2 du = \\ \frac{3}{8} \left[(2x^2 + 1)x\sqrt{1 + x^2} - \ln(x + \sqrt{1 + x^2}) \right] &= x^3 \begin{cases} 1 & \text{for } x \rightarrow 0 \\ 3x/4 & \text{for } x \rightarrow \infty \end{cases}. \end{aligned} \quad (14)$$

Substitution of (13) into (12) gives for the pressure

$$p = p_F = n \frac{d\varepsilon_F}{dn} - \varepsilon_F = \varepsilon_c \varphi_F(x), \quad (15)$$

where

$$\begin{aligned}\varphi_F(x) &= \frac{x}{3} \frac{df_F}{dx} - f_F \\ &= \frac{1}{8} \left[(2x^2 - 3)x\sqrt{1+x^2} + 3 \ln(x + \sqrt{1+x^2}) \right] \\ &= x^4 \begin{cases} x/5 & \text{for } x \rightarrow 0 \\ 1/4 & \text{for } x \rightarrow \infty \end{cases}.\end{aligned}\quad (16)$$

It is useful to note that

$$\varphi'_F(x) \equiv \frac{d\varphi_F(x)}{dx} = \frac{x^4}{\sqrt{1+x^2}}.\quad (17)$$

The optical potential changes the energy density to

$$\varepsilon = \varepsilon_F + nV_o(r) = \varepsilon_c f(x),\quad (18)$$

where

$$f(x) = f_F(x) - f_o(x)\quad (19)$$

$$f_o(x) = \beta \frac{x^6}{1+Qx^2},\quad (20)$$

and $\beta = 2|b(0)|k_c/3\pi \approx 4.6$. Substitution of (18) into Eq. (12) gives

$$\begin{aligned}p &= p_F + p_o = p_F + n^2 \frac{d}{dn} V_o(n) \\ &= \varepsilon_c \varphi_F(x) + nV_o \left(1 + \frac{n}{b(n)} \frac{db(n)}{dn} \right) = \varepsilon_c \varphi(x),\end{aligned}\quad (21)$$

where

$$\varphi(x) = \varphi_F(x) - \varphi_o(x),\quad (22)$$

and

$$\varphi_o(x) = x^6 \beta \frac{1+Qx^2/3}{(1+Qx^2)^2}.\quad (23)$$

We see that the optical potential gives a negative contribution to pressure, which can be called “neutrostriction”.

Let’s introduce a unit of space radius r_0 , and a unit of mass

$$\mathcal{M}_0 = \frac{4\pi}{3} r_0^3 \varepsilon_c / c^2,\quad (24)$$

which will be determined soon, then one can use dimensionless variables $z = r/r_0$, and $\mu(z) = \mathcal{M}/\mathcal{M}_0$.

After substitution of (21) and (18) into (10) and (11), one obtains

$$\frac{dx}{dz} \frac{d}{dx} \phi(x) = -\frac{G}{r_0 c^2} \mathcal{M}_0 f(x) \frac{\mu(z)}{z^2}, \quad (25)$$

$$\frac{d\mathcal{M}}{dz} = \mathcal{M}_0 \frac{d\mu}{dz} = 4\pi r_0^3 \frac{\varepsilon_c}{c^2} z^2 f(x). \quad (26)$$

Now one can define unit radius r_0 by requiring that

$$\frac{G\mathcal{M}_0}{r_0 c^2} \equiv \frac{4\pi G \varepsilon_c r_0^2}{3c^4} \equiv \frac{4\pi}{3} n_c r_0^2 \frac{Gm}{c^2} = 1. \quad (27)$$

Therefore

$$r_0 = \sqrt{\frac{3c^2}{4\pi G m n_c}} = \frac{3}{2} \frac{\hbar}{mc} \sqrt{\frac{\pi \hbar c}{G m^2}} = 7.3 \text{ km}. \quad (28)$$

Substitution of (28) into (24) gives

$$\mathcal{M}_0 = \frac{4\pi}{3} r_0^3 n_c m = 10 \cdot 10^{33} \text{ g} = 5M_\odot. \quad (29)$$

Finally Eq-s (25), (26) can be rewritten as:

$$z^2 x \frac{dx}{dz} = -\frac{f(x)}{x^3 g(x)} \sqrt{1+x^2} \mu(z), \quad (30)$$

$$\frac{d\mu(z)}{dz} = 3z^2 f(x), \quad (31)$$

where

$$g(x) = 1 - 6x\beta \sqrt{1+x^2} \frac{1 + (7/9)Qx^2 + (2/9)Q^2x^4}{(1+Qx^2)^3}. \quad (32)$$

Integration of two equations for given $x(0)$ and $\mu(0) = 0$ at the star's center can be easily performed with the help of any existing software program (mathcad, for instance). The results are presented in table 1.

The first column of the table shows $x(0)$. We made calculations for five points in the interval $0.1 \leq x(0) \leq 0.5$, i.e. for densities $n(0) = x(0)^3 n_c$ in the interval $3.7 \cdot 10^{36} \leq n(0) \leq 4.6 \cdot 10^{38} \text{ cm}^{-3}$, because for larger densities the effect of optical potential is negligible, and at smaller densities the neutron star should contain electron-nuclei plasma.

The table is divided into two parts, the left one contains the results calculated without optical potential, and the right part — with optical potential included. Every part is subdivided again into two subparts. The left one is calculated with TOV equations in nonrelativistic Newtonian form, while the right part is calculated with the Eq. (33), containing general relativity corrections [5] in the right hand side:

$$\frac{dp}{dr} = -G \frac{\varepsilon(r)\mathcal{M}(r)}{c^2 r^2} \left[1 + \frac{p(r)}{\varepsilon(r)} \right] \left[1 + \frac{4\pi r^3 p(r)}{\mathcal{M}(r)c^2} \right] \left[1 - \frac{2G\mathcal{M}(r)}{c^2 r} \right]^{-1}. \quad (33)$$

In dimensionless variables this equation is representable in the form

$$\frac{dx}{dz} \frac{d}{dx} \varphi(x) = -f(x) \frac{\mu(z)}{z^2} \left[1 + \frac{\varphi(x)}{f(x)} \right] \left[1 + \frac{3z^3 \varphi(x)}{\mu(z)} \right] \left[1 - \frac{2\mu(z)}{z} \right]^{-1}, \quad (34)$$

and for integration it is more convenient to rewrite it as

$$z[z - 2\mu(z)]x \frac{dx}{dz} = -\sqrt{1 + x^2} \frac{f(x) + \varphi(x)}{x^3 g(x)} [\mu(z) + 3z^3 \varphi(x)]. \quad (35)$$

In every subpart the table contains two columns. The first one gives dimensionless radius of the star $z_0 = R/r_0$, at which $n(z_0) = 0$, and the second column presents dimensionless mass of the star $\mu(z_0) = \mathcal{M}(R)/\mathcal{M}_0$. Dependence of $n(r)$ on r is monotonic and qualitatively the same as shown in paper [5], so we do not reproduce it here.

From the Table 1 it follows that neutrostriction force gives corrections to the star's mass and radius, which surpass relativistic ones.

3 Neutron star with short range nuclear forces

At high densities the short range nuclear interactions come into play. According to (69) of [5] the energy density of symmetrical

x(0)	without V_o				with V_o			
	nonrelativistic		relativistic		nonrelativistic		relativistic	
	z_0	$\mu(z_0)$	z_0	$\mu(z_0)$	z_0	$\mu(z_0)$	z_0	$\mu(z_0)$
0.1	4.7	0.017	4.76	0.017	3.44	0.008	3.44	0.008
0.2	3.35	0.048	3.32	0.045	2.75	0.034	2.71	0.033
0.3	2.7	0.085	2.6	0.075	2.37	0.068	2.26	0.061
0.4	2.34	0.124	2.2	0.101	2.1	0.105	2.01	0.088
0.5	2.05	0.162	1.9	0.121	1.9	0.142	1.745	0.108

Table 1: Parameter $x(0)$ in the first column gives density at the star's center $n = n_c x(0)^3$, the parameter z_0 gives radius of the star, $R = r_0 z_0$, and the parameter $\mu(z_0)$ gives mass of the star, $M = \mathcal{M}_0 \mu(z_0)$. Calculations were made using Eq-s (30) and (31) in nonrelativistic approximation and using Eq-s (35), (31) with relativistic corrections. When the optical potential is included, the parameter β is equal to 4.6, and when it is excluded, the parameter β is put to zero.

nuclear matter with equal number of neutrons and protons can be represented as

$$\varepsilon_{sym} = mc^2 n_c (x^3 + 0.3x^5 - 1.5x^6 + 17x^{9.336}). \quad (36)$$

The neutron star considered here is not a symmetrical nuclear matter, because it does not contain protons, and for asymmetrical nuclear matter energy density according to (86) – (88) of [5] is

$$\varepsilon_{nonsym} = \varepsilon_{sym} + \Delta\varepsilon, \quad (37)$$

where $\Delta\varepsilon$ can be represented as

$$\Delta\varepsilon = \varepsilon_c (0.07x^5 + 0.55x^6). \quad (38)$$

Therefore the total nuclear energy density for neutron matter is

$$\varepsilon_{nonsym} = \varepsilon_{sym} + \Delta\varepsilon = \varepsilon_c (x^3 + 0.37x^5 - 0.95x^6 + 17x^{9.336}). \quad (39)$$

Now we want to compare the attractive part of nuclear energy density, $\varepsilon_- = -0.95\varepsilon_c x^6$ with optical energy density $\varepsilon_o = \beta\varepsilon_c x^6 / (1 + Qx^2)$.

The ratio of optical energy density to the attractive part of nuclear energy density is

$$\frac{\varepsilon_{opt}}{\varepsilon_-} \approx \frac{\beta}{1 + Qx^2}, \quad (40)$$

and we see that optical energy is larger than the nuclear one at $Qx^2 < (\beta - 1)/0.95$, or $x < 0.12$, which is equivalent to $n < 0.0018n_c = 7 \cdot 10^{-36} \text{ cm}^{-3}$.

4 Discussion

The neutrostriction forces are to be taken into account in calculation of neutron star. They play important role at low densities and small masses $\mathcal{M} < M_\odot$. More over they present many interesting problems worth of research for their own.

1. It seems that neutron-neutron interaction in the degenerated neutron gas is eliminated because of the Pauli exclusion principle. However the Pauli exclusion principle, as was correctly pointed out in [6], eliminates scattering process and imaginary part of the scattering amplitude, but it does not affect its real part. Therefore because of the Pauli exclusion principle the optical potential in neutron stars becomes lossless.
2. The decrease of $b(n)$ with density is a source of pulsations, and it is interesting to investigate how well possible pulsation match parameters of the observed pulsars.
3. The pulsations are especially well understandable, if scattering contains a resonance, as is shown in fig. 2. At some energy the scattering amplitude changes the sign, so for smaller density the optical potential is attractive, and for larger one it becomes repulsive. At the point E , where $b(E) = 0$, pulsations arise naturally.
4. In the case of resonance we have a mechanism for star explosion. Indeed, if at contraction the density (and therefore Fermi energy) overcomes the resonant point, the strong repulsive optical energy abruptly changes to strong attractive one, and a huge energy is released.

Neutrostriction in neutron stars

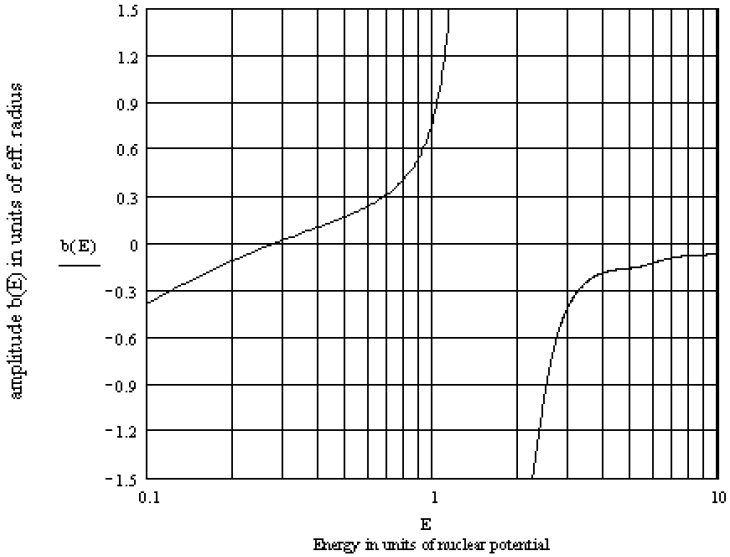


Figure 2: Schematic energy dependence of scattering length in presence of resonance.

5. Protons were not considered in this evaluation, however inclusion of protons will not change the arguments about optical potential, because the coherent neutron-proton scattering amplitude is nearly the same as the neutron-neutron one. At the same time, with protons one must also take into account neutron-proton resonances, which do certainly exist. Their presence can also provide a source of pulsations and explosions.
6. We considered only s-scattering amplitude. However, when the energy (or density) increases, one must also include p-, d- and higher harmonics. The question arises: how will they affect the results.
7. This paper discussed only neutron stars, but the notion of the optical potential is considerably more widely applicable. It can be used in other stars, in Bose-Einstein condensates, superfluidity and superconductivity, because everywhere we must take

into account the coherent atom-atom and atom-electron scattering amplitude.

Acknowledgment

The author is grateful to Yu. Petrov, V.L. Lyuboshits and Prof. R.R. Silbar for interesting discussion, to B.V. Vasil'ev and S.B. Borzakov for their useful remarks, to E. Shabalin for his support, to Steve Lamoreaux for collaboration, to I. Carron and I. Petruski for their help.

5 History of submissions and rejections

I submitted the paper first to PRL, and did not fight against their rejection. I did not save the referee report, however his comment was like the following one: "I am not a specialist in neutron star physics, but I do not believe that such simple things are not known to them, so I recommend to reject the paper."

On 04.05.2005 after having read [5] I submitted the paper to Amer. J. Phys. I had 3 referees and fought hard.

On 03.08 The 1-st referee conclusion was: "Because the author wishes to introduce a new idea and several new conclusions, the paper (after extensive rewriting into better English and, of course, and with less didacticism) might be appropriate for another journal."

I corrected didacticism and English (with all my best), and pointed out that the idea about neutrostriction is published in my book [2], however on 19.08 the referee conclusion was the same:

"Although Dr. Ignatovich is highly respected for his accomplishments, this paper is still misdirected..."

I insisted for further refereeing and on 26.09 received two reports
REVIEW #1:

"I agree with the reviewer that this paper constitutes an argument for "new" physics. The assertion of this paper is that "neutrostriction" results in an additional term in the standard Tolman-Oppenheimer-Volkov equation. I can't find anybody other than the author who uses the term neutrostriction, and it seems a pretty big claim that the astrophysical community has been missing this potential for so many years. The author is well-published in the field of

neutron scattering, and may be correct that the astrophysical community needs to take account of coherent neutron scattering effects, but AJP isn't the place to be putting forward such claims."

REVIEW #2:

"My main objection continues to be the misplacement of this submission. The very first line of the paper's abstract states, "It is demonstrated that...". This is the announcement of a new result by the author (even if he has already made the announcement before in any number of conferences and published conference papers).

Following the AJP guidelines which state, in part, "Manuscripts announcing new theoretical or experimental results ... are not acceptable and should be submitted to an archival research journal for evaluation by specialists," I must again recommend that the AJP not publish this paper."

I appeal directly to Jan Tobochnik, the Chief Editor of AJP, however in vain. The last report was on 20.10:

"I completely agree with the previous referee regarding unsuitability of this paper for American Journal of Physics. What is presented here looks like a new result and it needs to be reviewed by a technical expert for an archival journal such as Physical Review C. I recommend that the article is rejected without prejudice, i.e. the subject matter is more suitable for a technical journal in the field in nuclear physics. I did not find the article particularly pedagogical."

So on 26.10 I submitted the paper to Phys. Rev. C

5.1 Referee report on 10.11.2005 and my replies in italic

Dear Dr. Ignatovich,

The above manuscript has been reviewed by one of our referees. Comments from the report are enclosed.

These comments suggest that the present manuscript is not suitable for publication in the Physical Review.

Yours sincerely,

Jonathan T. Lenaghan Assistant Editor Physical Review C

Report of the Referee – CKJ1005/Ignatovich

Everything in this paper is just wrong and it should never be published. Bad language set aside,

I edited it once again and will be grateful for any suggestion.

the physics presented here is a collection of bits and pieces from here and there, with the attempt to invent a name, neutrostriction, for a force deriving from well-known many-body physics, that only the author seems to use. The paper carefully avoids referring to the literature in many occasions. A search on google.com for neutrostriction shows that this is a term used only by this author.

The discussion of section 4 sets the standard. It suffices to read point 1, page 10. Here the author states

'in some textbooks it is claimed that the neutron-neutron interaction in the degenerated neutron gas is absent because of pauli exclusion principle'

There is a careful omission to any reference for obvious reasons.

I included reference to Bohr and Mottelson, and changed the paragraph.

There are, to my knowledge, no textbooks which claim such things. It is the pressure set up by a gas of identical particles (here neutrons) interacting via, at least, the neutron-neutron interaction. This interaction leads, due to the Pauli principle to a repulsive EoS which counteracts gravity. Read carefully Shapiro and Teukolsky, The physics of compact objects, chapter 8 and 9. This is basic quantum mechanical wisdom.

The author continues 'it means that scattering cross section, which enters imaginary part of the scattering amplitude is suppressed, however, the real part is no changed, so pauli exclusion principle helps to create lossless optical potential'

The real part of the optical potential is related, via a dispersion relation to the imaginary part. Any quenching of the imaginary part leads to changes in the real part. The statement above is simply wrong.

The referee speaks about relation between imaginary and real parts of complex analytical functions. I speak about a complex number, which can have arbitrary real and imaginary parts. The potential contains scattering amplitude with imaginary part defined by the optical theorem. In some respect the real part also changes with the change of imaginary one, but this change can be neglected.

The optical potential is an outcome of the many-body physics (see standard texts such as the many-body book of Fetter and Walecka),

in this case the interactions among neutrons in an idealized star of neutrons only. Viz, it is derived from many-body physics.

No. Many-body theories do not include multiple wave scattering, which transforms short-range interaction into a long-range one.

The author, both in the abstract and the introduction, portrays the optical potential as something independent from the many-body physics and even invents a name for it, neurostriction.

There is no new mechanism or physics at play here, the optical potential is entirely linked with the many-body physics, which in turn sets up a repulsive EoS (due to the Pauli principle) which counteracts gravity.

No! Pauli exclusion principle and repulsive forces are included in my consideration, however, there is also an attractive long range interaction, which is overlooked by many-body theories.

The rest of the discussion in this paper is more or less at the same level and I refrain from further comments.

Dear editors, consider, please, my objections against main referee points, and accept, please, my paper for publication.

5.2 Referee report on 30.01.2006 and my replies in italic

The same formal rejection letter but from
Christopher Wesselborg Associate Editor Physical Review C

Second Report of the Referee – CKJ1005/Ignatovich

I thank the author for his reply. I still disagree with the author, especially his answers to remarks 3 and 4 below.

3. “The optical potential is an outcome of the many-body physics (see standard texts such as the many-body book of Fetter and Walecka), in this case the interactions among neutrons in an idealized star of neutrons only. Viz, it is derived from many-body physics.”

No. Many-body theories do not include multiple wave scattering, which transforms short-range interaction into a long-range one.

– I disagree strongly with this statement; if performed correctly, including particularly particle-hole correlations one generates long-range correlations. Many-body theory such as Green’s function Monte Carlo, coupled cluster theory or the summation of parquet diagrams, should include these correlations.

The optical potential can in turn be derived from many-body theories, see, e.g., Fetter and Walecka, Quantum theory of many-particle systems, chapter 40, pages 352-357.

Can be derived or is derived? Pages 352-357 do not help. Do you know, that though neutron-nucleus potential $V(z)$ is negative, the optical potential of the medium composed of nuclei has positive, i.e. repulsive optical potential? In particular, all the terms on pages 352-357 are proportional to negative value $V(z)$ and cannot become positive.

4. "There is no new mechanism or physics at play here, the optical potential is entirely linked with the many-body physics, which in turn sets up a repulsive EoS (due to the Pauli principle) which counteracts gravity."

No! Pauli exclusion principle and repulsive forces are included in my consideration, however, there is also an attractive long range interaction, which is overlooked by many-body theories.

– See my reply to the remark 3. I don't see why this shouldn't arise from a many-body description as offered by, for example, Green's function Monte Carlo or the other methods mentioned above. I cannot see any new physical mechanism at play.

See my reply above at remark 3, which proves that many-body theory does not describe multiple wave scattering phenomenon, which accounts for neutrostriction.

I would like to uphold most of my previous criticism. The disagreements voiced in the previous report remain and I would advise the author to ask for a new referee if he feels incorrectly judged by me.

Dear editor I don't agree with judgement of the referee, I ask you to reconsider your decision and to publish my paper, which is absolutely correct and discovers new phenomena.

5.3 Referee report on 10.02.2006 and my replies in italic

Dear editors, according to rules of Physical Review I have right to appeal. I replied to all referees, and pointed out what do they not understand. No referee could raise an objection against my arguments, they only don't believe that it is possible to say a new word after their 50 years research. It is wrong. I insist that my paper is absolutely

correct and discovers new phenomena. Consider, please, this letter as my appeal.

The above manuscript has been reviewed by one of our referees. Comments from the report are enclosed.

We regret that in view of these comments we cannot accept the paper for publication in the Physical Review.

In accordance with our standard practice, this concludes our review of your manuscript. No further revisions of the manuscript can be considered.

Yours sincerely,

Benjamin F. Gibson Editor Physical Review C

Email: prc@ridge.aps.org Fax: 631-591-4141 <http://prc.aps.org/>

Report of the Second Referee – CKJ1005/Ignatovich

I agree with the previous referee in all respects, so I have nothing to add that would be of interest to the editors.

But perhaps if I restate a piece of the referee's comments in my own words it will be helpful to the author in understanding our point: At its most primitive level, say the state of the art of half a century ago, the calculation of the nuclear interaction energy would have been the Hartree term, which is no more or less than the expectation value of the N-N potential in the Fermi gas, leaving out the exchange terms (which are always a lot smaller). An optical potential, or an index of refraction derived from the Born forward scattering amplitude, generates exactly the same term.

The Born terms in strong interactions are unable to give a correct value and even sign for a scattering amplitude. This scattering amplitude gives you not a nuclear optical potential, but optical potential of the full medium of nuclei.

And the same is true in principal if we use data to directly make the estimate of the nuclear interaction energy, instead of using data to find the potential as an intermediate step.

Thus whatever physics is there in the author's optical potential is contained in the work of the people who have calculated the equations of state used for neutron stars. These workers have used the present state-of-the-art nuclear potentials, fit to vastly more data than the author invoked, and applied in many-body calculations that have

grown more sophisticated over the years. We certainly hope, or even trust, that there is much, much more correct physics in these equation of state results in the literature than in the kinds of estimates one could make 50 years ago.

I present a good physical idea which shall enrich equation of state and sophisticated state-of-the-art nuclear potentials.

Correspondence about the appellation

Letter on 03.03.06 from Dr. Christopher Wesselborg

Dear Dr. Ignatovich:

Thank you for your prompt response. I suggest that you send us your appeal letter with your response to the referees' criticisms, part of which seems to be already contained in your recent email.

As to your specific inquiry, I was referring solely to your previous, rather general (i.e., unspecific) request for an appeal. Note that the editors rejected your manuscript based on the reports from the two referees and your responses.

For your information, we had also sent the previous correspondence to the second referee, including your resubmission letters, when we asked a second referee for an additional opinion.

Again, we will begin with the appeal as soon as we have your complete appeal letter.

Sincerely,
Christopher Wesselborg
Associate Editor
Physical Review C

My reply on 06.03

Dear Dr. Christopher Wesselborg, I need your advice, how to make The Complete appeal letter? I feel that everything depends whether it will be correct or not. Thank you for your information that the second referee had my replies to the first one. I wonder why he did not take them into account.

How to make the complete appeal letter? Should I analyze arguments of both referees? Should I add more arguments in defense of

my position? There is a single point of our disagreement: They insist that everything is contained in many-body theory. The first referee even pointed out the pages of the many-body book, and the second referee told that everything is contained in Born forward scattering amplitude. My point is: that the values on the pages, the first referee pointed out, and the Born scattering amplitude of the second referee are proportional to the two-body interaction potential. Therefore they have the same sign as the interaction itself. The multiple wave theory contains not the Born scattering amplitude. The scattering amplitude is the result of more rigorous solution of scattering problem for a given two-body potential. This amplitude can be of opposite sign than the potential. The optical potential of medium is a secondary construction, which uses multiple-wave scattering formalism, absent in many-body theory.

The second referee does not accept my paper also because my idea is very simple comparing to sophisticated theories used by present day astrophysicists. I remind you that some referees in other journals rejected the paper, because they did not believe that such simple things are not known to astrophysicists. You see, they are really not known!

Dear Dr. Christopher Wesselborg, may I ask you, are the above arguments appropriate for the Complete appeal letter? Should I write the similar letter via internet resubmission? What is the form of such a Complete appeal letter? Really yours, really need your help, Vladimir Ignatovich.

Reply on 08.03

Dear Dr. Ignatovich,

Thank you for your message of March 6. I appreciate that you want to write the most complete appeal letter possible. You should analyze and carefully consider the arguments of the referees. In particular, you should try to address in your letter each point made by both referees. Please avoid polemical language and argue your case dispassionately. If you have more arguments in defense of your position then you should make them. Note, however, the appeals process is based on the rejected version of the manuscript and the further revisions are not considered.

You should submit your appeal letter via the internet submission server if possible. If I can be of any more help, please let me know.

Yours sincerely,
Jonathan T. Lenaghan
Assistant Editor
Physical Review C

Appellation 16.03

The main objection of two referees, formulated in my own words, is the following: “the optical potential, which leads to refraction index, can be found in many-body theory. This sophisticated theory does not see the effects discussed in your paper, therefore your ideas are wrong.”

My defence was: “the many-body theory does not contain multiple wave scattering phenomenon, because in other case it would found the potential I discuss in my paper.”

Now I must admit that I was not right. Thanks to the first referee, who pointed out to me the book by Fetter and Walecka [FW], I could improve my education. Now I can tell that many-body theory contains everything I discuss in my paper, nevertheless the effect was overlooked by astrophysicists and I can explain why.

First I want to point out the place in FW, where this potential is shown. It is formula (11.65) for chemical potential μ , obtained by V.M.Galitskii:

$$\mu = \frac{\hbar^2 k_F^2}{2m} \left[1 + \frac{4}{3\pi} k_F a + \frac{4}{15\pi^2} (11 - 2 \ln 2) (k_F a)^2 \right], \quad (11.65)$$

where a is scattering length, and k_F is Fermi wave-number: $k_F^3/3\pi^2 = n$ is particle density.

This formula was obtained for dilute Fermi-gas, when $k_F a \ll 1$, which case is just what I discuss in my paper. If we neglect last term $\propto (k_F a)^2$, we can rewrite (11.65) in the form

$$\mu = \frac{\hbar^2}{2m} k_F^2 + \frac{\hbar^2}{2m} 4\pi n a, \quad (I)$$

and the second term is just optical potential which I introduced in (1) (in my notation scattering length a is b).

However formula (11.65) was found for scattering from a repulsive core, when the actual (not perturbative) scattering length a is positive. So the optical potential $\propto 4\pi na$ is also repulsive.

Attractive, negative, potentials are not considered by many-body theory because, according to problem 1.2 of the chapter 1, a system with a potential $V(\mathbf{r}) < 0$, and $\int |V(\mathbf{r})| d^3r < \infty$, will always collapse. The collapse follows from expression (I), because for negative a and high density n chemical potential becomes $\mu \approx Cn^{2/3} - an$, where C is a constant, which goes to $-\infty$ when $n \rightarrow \infty$.

It is correct for constant a , but it is not correct, if we take into account energy dependence of a . My formulas (7) and (8) introduce dependence $a/(1+k_F^2|a|r_0)$, where r_0 is effective radius of interaction, so we have no collapse. More over, if neutron-neutron interaction contains a repulsive core, the scattering length can become positive at high density.

I can summarize as follows: The sophisticated mathematics contains everything, but without physical idea it is difficult to predict something. On the other hand, a physical idea helps to predict with few relevant mathematics, however, and it is especially important, the correct idea is always supported by sophisticated mathematics. My paper contains idea, it helps to predict some phenomena and it is supported by many-body theory. I think it is an important contribution both: to physics of neutron stars and to many-body theory.

Reply to the appellation 12.04

Dear Dr. Ignatovich,

This is in reference to your appeal on the above mentioned paper. We enclose the report of our Editorial Board member Richard Furnstahl which sustains the decision to reject.

Under the revised Editorial Policies of the Physical Review (copy enclosed), this completes the scientific review of your paper.

Yours sincerely,

Benjamin F. Gibson Editor Physical Review C

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Report of the Editorial Board Member – CKJ1005/Ignatovich

I concur with the comments of the first and second referee. The physics discussed in this manuscript is not new and is presented in a misleading way (e.g., the comparison of gravitational and "optical" energies using the scattering length only throughout the volume of the neutron star).

Based on the reports of the referees and my own assessment, I recommend that this manuscript should not be published in Physical Review C.

Richard Furnstahl

Member, Physical Review C Editorial Board

Please see the following forms:

<http://forms.aps.org/author/polprocc.pdf>

PRC EDITORIAL POLICIES AND PRACTICES

My reply 13.04

Dear Editor!

No argument is an argument for Dr. Furnstahl, who "concur with the comments of the first and second referee" without an argument. He writes that "The physics discussed in this manuscript is not new". Then how does he concur with the statement of the first referee: "Everything in this paper is just wrong"? He writes that my not new physics "is presented in a misleading way (e.g., the comparison of gravitational and "optical" energies using the scattering length only throughout the volume of the neutron star)." I cannot understand neither this sentence, nor what is misleading in such a comparison? May I ask you: do you understand? May I ask you to explain it to me?

Now, when everything is in vain, may I ask you to send all my files to Editor-in-Chief Dr. Blume? I know that his reply will be negative and formal. I can even formulate his reply, but will not do that. Let his secretary to use a template to support the decision of the editorial board and to blame me for insulting manners. His reply will not help, but I need it as a last stone for a monument to American Physical Society.

Vladimir Ignatovich

From Phys.Rev. 17.05

Dear Dr. Ignatovich,

Thank you for your message. We will soon initiate the appeal of your manuscript to the Editor-in-Chief. We are writing to ask you to draft an appropriate cover letter. Your current letter may be interpreted as polemical. Your appeal letter should clearly demonstrate why your manuscript warrants publication in view of the arguments presented by the referees, Editors and the Editorial Board member.

Upon receiving your cover letter, we will initiate your appeal to the Editor-in-Chief. Thank you for your attention to this matter.

Yours sincerely,

Jonathan T. Lenaghan Assistant Editor

My reply on 18.05

Dear Dr. Lenaghan, I was really surprised to get your friendly letter after so long silence. May I ask you to teach me, how to compose such a letter. I prepared it, but I am not sure it has an appropriate form. I has a terrible experience that no appeal is successful after rejection by editorial board. Nevertheless, I am ready to try and try again. May I ask you to help me? Read, please, my reply, and give me to know, please, what is it better to change. Yours sincerely Vladinir.

To Dr. Blume.

Dear, Dr. Blume, I appeal to you as the Editor-in-Chief of the American Physical Society, against rejection of my paper titled: "Neutrostriction in neutron stars" by editorial board of Phys. Rev. C.

In this paper I had shown that neutron-neutron scattering forms strong attractive optical potential inside neutron stars, which compresses the star together additionally to gravity. This attraction decreases with increase of density, but leads to many interesting physical effects and influences such parameters of neutron stars, as radius, mass and distribution of density. Effect of this optical potential can surpass effects of general relativity.

My paper was considered by two anonymous referees and by a Memeber of Physical Review C Editorial Board Richard Furnstahl. So formally my paper met a fair hearing. However the reports of all these referees show that they did not consider my paper responsibly. May I ask you to look, please, at their arguments and my responses.

The first report of the first referee started with the words: "Everything in this paper is just wrong and it should never be published."

He pointed out several "errors" and claimed that "There is no new mechanism or physics at play here, the optical potential is entirely linked with the many-body physics, which in turn sets up a repulsive EoS (due to the Pauli principle) which counteracts gravity." The last sentence clearly shows presumption of the first referee. I calmly replied. Included some references, which the first referee supposed to be omitted intentionally, and explained to the referee all his misunderstandings with respect to "errors". His second report was softer, however he insisted on his presumption. Our difference was: Referee claimed that many body contains everything, and it does not show my effects, while I insisted that many body theory is incomplete, because it does not show my effects.

The second referee also rejected my paper on the same presumption. His report started with the words: "I agree with the previous referee in all respects, so I have nothing to add that would be of interest to the editors." He tried to teach me that the state of the art of calculations became more sophisticated than my approach which is alike to the old-fashioned Hartree approach to the many body theory. He wrote that optical potential and an index of refraction can be found from the Born forward scattering amplitude. The truth of this reply is not complete. The scattering amplitude can be derived from precise equations and it can differ in sign from the Born amplitude. Such a difference is crucial for determination of the sign of the optical potential.

I used my right to appeal, and during preparation of my appeal letter, I studied more carefully the many-body theory and found that in principle it really contains the attractive optical potential, but it was overlooked by scientists, and I even understood why. I pointed out it in my appeal letter. I found also that the error in many body theory is related to the widely accepted practice of discretisation. We all introduce finite dimension L , when we describe scattering. It seems very natural, but I found the first case where this practice leads to an error. I pointed it out.

In reply to my appeal letter, the member of Editorial board Dr. Richard Furstahl did not discuss the point I mentioned. His report starts with the words: "I concur with the comments of the first and second referee. The physics discussed in this manuscript is not new and is presented in a misleading way." These words are

not understandable. If it is not new physics, why the neutrostriction forces are not discussed by astrophysical community? If it is not new physics, why the first referee, with whose report Dr. Furnstahl concurs, claimed that it is wrong physics?

Dear Dr. Blume, I would be very grateful to you if you find a time or ask some other experts to explain me what did Dr Furnstahl meant. I still continue to think that my paper is a very important contribution to the neutron star physics and to many-body theory.

Yours sincerely, Vladimir Ignatovich.

From Phys.Rev. on 06.06

Dear Dr. Ignatovich,

Thank you for your improved cover letter. I will be forwarding your file to the Editor-in-Chief very shortly. If I can be of any more assistance, please feel free to let me know.

Yours sincerely,

Jonathan T. Lenaghan Assistant Editor

Letter from Martin Blume, dated 09.06

Dear Dr. Ignatovich,

I have reviewed the file concerning this manuscript which was submitted to Phys. Rev. C. The scientific review of your paper is the responsibility of the editor of Phys. Rev. C, and resulted in the decision to reject your paper. The Editor-In-Chief must assure that the procedures of our journals have been followed responsibly and fairly in arriving at this decision.

Contrary to your assumption, every appeal case that is submitted to me receives a thorough review. I note that the referee and editorial board member were unanimous in their opinion that your paper was not appropriate for Phys. Rev. C. Let me add that we take pride in our appeal process. Many other journals have no such policy; for those journals an editorial rejection is final and authors have no right to appeal.

On considering all aspects of this file I have concluded that our procedures have in fact been appropriately followed and that your paper received a fair review. Accordingly, I must uphold the decision of the Editors.

Yours sincerely, Martin Blume.

My reply to it on 27 June

Dear Dr. Blume,

Thank you for your reply and for taking time to review my case. I continue to be strongly convinced, that my paper contains important work, which can and should be allowed to appear in Phys. Rev. C. I still believe that the referees unfortunately were not well qualified to review my manuscript, because from their comments I deduce that they did not understand my work.

I have a concern about the appeal process, namely: were there any precedents when the opinion of editorial board member was opposite to unanimous opinion of two referees? Were there any precedents when your decision was opposite to that of the editorial board? If not, the appeal process seems to fail, as the unanimous opinion of two referees predefines the appeal outcome.

To overcome this possible flaw, I propose to send my file to an independent person, who would agree to judge the validity of arguments of both sides.

I would like to suggest a person, who is to my opinion qualified to listen and understand the arguments. Furthermore, it will be even better if you could also choose one, and then compare the judgments of these two people to help you to come up with the final decision. I understand that it will require some of your time, but it will be well rewarded by the benefit to science.

I will highly appreciate your attention and effort to resolve my case.

Sincerely, Vladimir Ignatovich

P.S. Please contact me via e-mail ignatovi@nf.jinr.ru

Afterword

Dr. Martin Blume the Editor-in-chief of the American Physical Society did not reply to me.

Why do I insist on publication after so many negative reports? It is because I see that there were no arguments against it. I want to review them briefly:

“I do not believe that such simple things are not known to astrophysicist.” It is not a serious argument at all.

“Everything in this paper is just wrong and it should never be published.” and after that no error is pointed out except

“A search on google.com for neurostriction shows that this is a term used only by this author.“ What would this man tell about the word “quark”?

“There is no new mechanism or physics at play here, the optical potential is entirely linked with the many-body physics, which in turn sets up a repulsive EoS (due to the Pauli principle) which counteracts gravity.” I have shown this mechanism. The referee did not show where I am wrong. He never knew about it. So he resists it. Look further: “I cannot see any new physical mechanism at play.” It is not a serious objection.

“I agree with the previous referee in all respects, so I have nothing to add that would be of interest to the editors.” So, there are also no errors pinpointed in my paper. The referee agrees that equation of state gives only repulsive interaction.

“I concur with the comments of the first and second referee. The physics discussed in this manuscript is not new and is presented in a misleading way (e.g., the comparison of gravitational and “optical” energies using the scattering length only throughout the volume of the neutron star).” What can I reply? Old physics gives only repulsion. I introduce attraction, and it is not a new physics.

So, all the referee are unanimous in these *no arguments*, and this unanimity was sufficient for Dr. Blume to reject my manuscript.

I am so much grateful to editorial board of “Concepts of Physics” for their decision to publish my paper notwithstanding the negative attitude of APS. I would like to have an open discussion with physical society, and will be grateful to those, who will point out any error, because it will improve my knowledge. I admit that something can be corrected, but I am sure that the whole field opened by introduction of optical potential is enormous. By the way, the fact that optical potential goes to zero at high densities well concurs with asymptotical freedom in quark physics¹.

¹I am grateful to S.S.Shimanskii for this remark

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Comment on NEUTROSTRICTION IN NEUTRON STARS

Sebastian Kubis

The Niewodniczański Institute of Nuclear Physics, PAN
Radzikowskiego 152, 31-342 Kraków, Poland

After the corrections made by author I am still doubtful about publication of this work and leave the definite decision to the Editor.

1. The saturation point properties

As I mentioned in previous report the saturation point properties are the basic parameters of matter around density $n_0 = 0.16 \text{ fm}^{-3}$ [1]. The optical potential describes interactions between neutron and matter at very low (terrestrial) densities. Then author try to extrapolate this form of interaction many orders of magnitude up to nuclear densities $\sim n_0$. But then the assumed form of optical potential $V_{opt} = \frac{\hbar^2}{2m} 4\pi n b(n)$ should recover proper values of nuclear matter parameters like binding energy or matter compressibility. Meanwhile, the nuclear mater at n_0 , described by the optical potential is not even bounded (there is no minimum at n_0 for energy per particle: $E = \varepsilon/n = \varepsilon_F/n + V_{opt}$). It means that nuclei should not exist at all.

I cannot understand the author claiming that *it may happen that the strong interactions are nothing but optical potential*

whereas the optical potential itself cannot reproduce the fundamental properties of nuclear matter.

2. Predictive power of presented work

The results presented for neutrons star leads to conclusion that optical potential in the assumed form cannot be applied to realistic description of neutron stars. First, it lead to a very low maximal mass for neutron star. It would be good to present masses for higher central density to see what is the maximum, nevertheless, the results in Table 1 suggest the maximal mass is fairly below $1M_{\odot}$. It is well known fact that free neutron gas leads to maximal mass around $0.7M_{\odot}$. As the optical potential represents attractive force it, perhaps, gives the maximal mass even lower. The greatest mass measured with high accuracy (10^{-3}) is $1.445M_{\odot}$, recent observation, with less precision, indicate the mass being even as large as $2.1M_{\odot}$ [3].

The optical potential, in principle, could be relevant in the case of very densities, let say $< 0.1n_0$, but then we enter into the region of densities corresponding to the neutron star crust. In this region the matter cannot be described as a degenerated neutron liquid interacting through a simple form of optical potential. It is a Coulomb lattice of nuclei immersed in the degenerated electron sea. Pressure comes mainly from these electrons not from the neutrons [2]. For these nuclei one must include isovector channel of interactions (because of the beta equilibrium between protons, neutrons and electrons) and superfluidity of neutrons (because of neutron drip above $\rho \sim 10^{11}g/cm^3$). Above facts are not a model speculations but have quite good observational support in the following phenomena, like pulsar glitching (neutron superfluidity) or elastic properties of crust ($\sim 10Hz$ oscillations in Soft Gamma Repeaters). If one want to estimate the role played by the optical potential must take into account the whole complexity of star crust. Using only the optical potential seems to be too far going simplification.

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Reply to referee's comments

The essence of the comment is: everything was perfect without the optical potential therefore it is not needed. I don't agree with such a position.

1 The saturation point properties

“Meanwhile, the nuclear matter at n_0 , described by the optical potential is not even bounded...”

Sorry, with increase of the density n the term ε_F/n grows proportionally to $n^{2/3}$ while optical potential with account of density dependence of $b(n)$ grows proportionally to $n^{1/3}$. Therefore minimum exists. Moreover, if $b(n)$ has a resonant behavior (the dependence $b(n)$ is not yet known well), then it may happen that $b(n_0) = 0$, so no corrections are needed for “the basic parameter” n_0 .

In any case all the parameters, including compressibility can be found with the help of equations presented in Appendices of [1] with account of optical potential and with variation of density dependence $b(n)$.

I do not discuss the claim “that the strong interactions are nothing but optical potential” because it is a hypothesis, which needs yet further elaboration.

2 Predictive power of presented work

First, I considered low mass neutron stars. The maximal mass exists for higher density, where optical potential is negligible.

“If one wants to estimate the role played by the optical potential he must take into account the whole complexity of star crust.” I am not a specialist in the full neutron star physics, however, the phenomenon neutronstriction exists, and astrophysicists must prove that it does not exist to ignore my paper.

Vladimir K. Ignatovich

References

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