Neutron Anomalous Magnetic Moment in Dense Magnetized Systems

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Abstract

In this work, we calculate the neutron anomalous magnetic moment supposing that this value can depend on the density and magnetic field of system. We employ the lowest order constraint variation (LOCV) method and AV_{18} nuclear potential to calculate the medium dependency of the neutron anomalous magnetic moment. It is confirmed that the neutron anomalous magnetic moment increases by increasing the density, while it decreases as the magnetic field grows. The energy and equation of state for the system have also been investigated.

Keywords: neutron; anomalous magnetic moment; magnetic field

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I. INTRODUCTION

High-density neutron matter and nuclear matter with strong magnetic field can be found in the interior of neutron stars. Therefore, investigation of the nucleonic matter with high density and strong magnetic fields are of great interest in nuclear astrophysics. In such conditions for the density and magnetic field, the magnitude of the nucleon anomalous magnetic moments (AMM) can be different from the free nucleon and its value can change when the physical conditions of the medium vary. We note that having various magnitudes of the nucleon AMMs may lead to significant consequences for the thermodynamic properties of the neutron and nuclear matter. Accordingly, study of the dependency of nucleon AMMs on the physical parameters of the medium, (e.g. density, magnetic field, etc.) seems necessary.

Many works have been focused on the dependence of the nucleon AMMs on the conditions of the medium\textsuperscript{[1–11]}. Chiral symmetry constraints on scale changes of the nucleon in a nuclear medium have been investigated within the framework of a chiral non-linear meson theory\textsuperscript{[1]}. It has been shown that the isoscalar AMM of nucleon increases with increase in the density. In the framework of the cloudy bag model and by introducing the effective masses of mesons and nucleons, the bound nucleon AMMs have been calculated\textsuperscript{[2]}. It has been confirmed that the nucleon AMMs are enhanced compared to the free ones. Using a self-consistent quark model for nuclear matter, the variations of the masses of the non-strange vector mesons, the hyperons, and the nucleons in the dense nuclear matter have been investigated\textsuperscript{[3]}. In this reference, the authors have shown that the AMM of the proton in symmetric nuclear matter increases with density. They have also confirmed that in the bag model, the attractive scalar potential leads to the decreasing of quark mass, and the lower component of the wave function is enhanced, leading to the increase of the AMM of the proton and the other hadrons. Using the ideas of color neutrality, the influence of the nuclear medium upon the internal structure of a composite nucleon has been studied\textsuperscript{[4]}. It has been concluded that the medium effect is an increase in the value of the AMM. By calculating the electric and magnetic form factors for the proton, bound in specific shell-model orbits, it has been found that the AMM of the bound proton is increased by the medium modifications\textsuperscript{[5]}. They have also pointed out that this medium correction is solely due to the change of the internal quark structure. Chiral quark-soliton model has been employed to calculate the electromagnetic form factors of a bound proton\textsuperscript{[6]}. The results show the enhancement of
the AMM. Applying Nambu-Jona-Lasinio model to investigate the medium modifications of the nucleon electromagnetic form factors, it has been shown that the medium effects tend to decrease the intrinsic AMM of the proton but when combined with the enhancement of the nuclear magneton, the spin g-factor is enhanced \cite{7}. AMMs of hyperons in dense nuclear matter have been calculated using relativistic quark models in which hyperons have been treated as MIT bags and the interactions have been considered to be mediated by the exchange of scalar and vector mesons \cite{8}. The results confirm that the magnitudes of the AMMs increase with density for most octet baryons. Using a quantum hadrodynamical model, the medium effects caused by density-dependent AMMs of baryons on neutron stars under strong magnetic fields have been studied \cite{9}. It has been found that the AMMs of nucleons can be enhanced to be larger than those of hyperons. Strongly magnetized symmetric nuclear matter is investigated within the context of effective baryon-meson exchange models \cite{10}. It has been found that by increasing the dipole moment strength, the system becomes more tightly bound. The influence of the AMM on the equation of state of charged fermions in the presence of a magnetic field has been considered \cite{11}. In this work, the AMM has been found from the one-loop fermion self-energy. It has been concluded that in the strong magnetic field region the AMM depends on the Landau level. Their results show that the AMM of charged fermions have no significant effects on the equation of state.

In addition to predict the dependency of AMM on the medium, it is important to find the way that the physical parameters affect the nucleon AMMs. Many authors have explored the effects of medium on the intrinsic properties of nucleons and how the modifications of the AMM occur. From an analysis of the structure functions for inelastic electron scattering, it has been found that the charge radius and the AMM of nucleons increase in $^{12}$C, due to the effect of the nuclear medium on the quark wave functions \cite{12}. It has been concluded that from the increases in the nucleon radius, one also expects an increase of the AMM, since for massless quarks in the nucleon, the AMM is proportional to the size of the quark wave function. It has been also found that the AMM and radius are the best quantities from which to deduce the size of the quark wave functions in nuclei. Besides, it has been indicated that the proton and neutron charge radii increase with density \cite{1}. In a chiral nonlinear quark-meson theory, it has been shown that in the presence of an external baryon medium, the proton radius increases \cite{13}. It has been argued that the increase in the AMM tends to cancel the effect of the increased radius \cite{4}. Besides, it has been concluded that at
low values of the square of the momentum transfer, the electric form factor is suppressed and displays an increased charge radius, while the magnetic radius and the AMM are increased. Moreover, it has been shown that the electromagnetic rms radii and the AMM of the bound proton are increased by the medium modifications [5]. They have found that the intrinsic AMM is enhanced in matter because of the change in the quark structure of the nucleon. Using MIT bag model, it has been found that in the presence of ultra-strong magnetic fields, a nucleon either flattens or collapses in the direction transverse to the external magnetic field in the classical or quantum mechanical picture respectively [14]. According to Ref. [8], there is a big difference between the bag properties obtained from the quark-meson coupling (QMC) and modified quark-meson coupling (MQMC) models. In the QMC model, the bag radius decreases as the density increases, but in the MQMC model, the bag radius increases with density [15]. It has been concluded that since the AMM depends on the bag radius, the prediction of the AMM in the MQMC model will differ from that obtained from the QMC model. In addition, the authors of Ref. [9] believe that the medium effects due to density-dependent AMMs are larger in higher magnetic fields.

In our previous study, we have calculated the magnetic properties of neutron matter in the presence of strong magnetic fields using the lowest order constraint variation (LOCV) method assuming that the neutron AMM is not affected by the medium [16]. In the present work, we are interested in the medium dependency of the neutron magnetic moment as well as the properties of magnetized neutron matter with the medium dependent AMM using the LOCV method applying $AV_{18}$ nuclear potential.

II. LOCV FORMALISM FOR MAGNETIZED NEUTRON MATTER WITH THE MEDIUM DEPENDENT ANOMALOUS MAGNETIC MOMENT

We start with a pure homogeneous system of spin polarized neutrons with the spin-up (+) and spin-down (−) states. The number densities of spin-up and spin-down neutrons are shown by $\rho^{(+)}$ and $\rho^{(-)}$, respectively. The spin polarization parameter $\delta = \frac{\rho^{(+)} - \rho^{(-)}}{\rho}$, is introduced where $\rho = \rho^{(+)} + \rho^{(-)}$ is the total density of system. We take the uniform magnetic field along the $z$ direction, $B = B\hat{k}$, which leads the spin up and down particles corresponding to parallel and antiparallel spins with respect to the magnetic field. In this work, LOCV method is applied to calculate the energy of the system as follows.
We consider a trial many-body wave function of the form
\[ \psi = F\phi, \]  
where \( \phi \) is the uncorrelated ground-state wave function of \( N \) independent neutrons, and \( F \) is a proper \( N \)-body correlation function. Jastrow approximation [17] is employed in which \( F \) can be replaced by
\[ F = S \prod_{i>j} f(ij), \]
where \( S \) is a symmetrizing operator. We consider a cluster expansion of the energy functional up to the two-body term,
\[ E([f]) = \frac{1}{N} \frac{\langle \psi | H | \psi \rangle}{\langle \psi | \psi \rangle} = E_1 + E_2. \]
The one-body term, \( E_1 \), for magnetized neutron matter is given by
\[ E_1 = \sum_{i=+,-} \frac{3 \hbar^2 k_F^{(i)}^2}{5} \frac{\rho^{(i)}}{\rho} - \mu_{dep} B \delta, \]
where \( k_F^{(i)} = (6\pi^2 \rho^{(i)})^{\frac{1}{3}} \) is the Fermi momentum of a neutron with spin projection \( i \) and \( \mu_{dep} \) is the value of neutron AMM that can depend on the density and magnetic field of the system. We define the parameter \( r_\mu = \mu_{dep}/\mu_n \) in which \( \mu_n = -1.9130427(5) \) is the AMM of the free neutron. The dimensionless parameter \( r_\mu \) quantifies the medium dependent neutron AMM. The value \( r_\mu = 1 \) corresponds to the AMM of the free neutron. The two-body energy, \( E_2 \), is as follows,
\[ E_2 = \frac{1}{2N} \sum_{ij} \langle ij | \nu(12) | ij - ji \rangle, \]
where \( \nu(12) = -\frac{\hbar^2}{2m} [f(12), [\nabla_{12}^2, f(12)]] + f(12)V(12)f(12). \)
In the above equation, \( f(12) \) and \( V(12) \) are the two-body correlation function and nuclear potential, respectively. In order to calculate the energy of neutron matter, we employ the \( AV_{18} \) two-body nuclear potential [18],
\[ V(12) = \sum_{p=1}^{18} V^{(p)}(r_{12})O_{12}^{(p)} \]
where $O_{12}^{(2)}$ shows the operators in $AV_{18}$ potential [18]. In our formalism, we consider the two-body correlation function, $f(12)$, as follows [19],

$$f(12) = \sum_{k=1}^{3} f^{(k)}(r_{12}) P_{12}^{(k)},$$

where

$$P_{12}^{(k=1-3)} = \left( \frac{1}{4} - \frac{1}{4} O_{12}^{(2)} \right), \left( \frac{1}{2} + \frac{1}{6} O_{12}^{(2)} + \frac{1}{6} O_{12}^{(5)} \right),$$

$$\left( \frac{1}{4} + \frac{1}{12} O_{12}^{(2)} - \frac{1}{6} O_{12}^{(5)} \right).$$

The operators $O_{12}^{(2)}$ and $O_{12}^{(5)}$ are given in [18]. Using the mentioned two-body correlation function and potential, after doing some algebra, the two-body energy is obtained as follows,

$$E_2 = \frac{2}{\pi^4 \rho} \left( \frac{\hbar^2}{2m} \right) \sum_{JLSz} \left( \frac{2J+1}{2(2S+1)} \right) \left[ 1 - (-1)^{L+S+1} \right]$$

$$\times \left| \left\langle \frac{1}{2} \sigma \uparrow \frac{1}{2} \sigma \downarrow \left| SS_z \right\rangle \right| ^2 \right| \int_{0}^{\infty} dr \left\{ \left[ f^{(1)} \right] ^2 \alpha \alpha \left( r, \rho^{(i)} \right) \right. \right.$$  

$$+ \frac{2m}{\hbar^2} \left\{ \{ V_c - 3V_\sigma + V_\tau - 3V_\sigma + 2(V_T - 3V_{\sigma T}) \right.$$  

$$- 2V_{\tau z} \} a_\alpha^{(2)}(r, \rho^{(i)}) + [V_{12} - 3V_{12\sigma} + V_{12\tau} - 3V_{12\sigma T}]$$

$$\times c_\alpha^{(1)}(r, \rho^{(i)}))c_\alpha^{(1)}(r, \rho^{(i)}) + \sum_{k=2,3} \left[ f^{(k)} \right] ^2 \alpha \alpha \left( r, \rho^{(i)} \right) \right.$$  

$$+ \frac{2m}{\hbar^2} \left\{ \{ V_c + V_\sigma + V_\tau + V_\sigma + (-6k + 14)(V_T \right.$$  

$$+ V_c) - (k - 1)(V_{s_\tau} + V_{s_z}) + 2(V_T + V_{\sigma T})$$

$$+ (-6k + 14)V_{s_\tau - V_{s_\tau}} \} a_\alpha^{(k)}(r, \rho^{(i)}) + [V_{12} + V_{12\tau}$$

$$+ V_{12\sigma} + V_{12\sigma T}]c_\alpha^{(k)}(r, \rho^{(i)}) + [V_{s_\tau} + V_{s_\tau}]$$

$$\times d_\alpha^{(k)}(r, \rho^{(i)}))f^{(k)} \alpha \alpha \left( r, \rho^{(i)} \right) + \frac{2m}{\hbar^2} \{ V_{s_\tau} + V_{s_\tau} - 2(V_{12} + V_{12\sigma}$$

$$+ V_{12\sigma} + V_{12\tau} - 3(V_{s_\tau} + V_{s_\tau}) \} b_\alpha^{(2)}(r, \rho^{(i)})f^{(3)} \alpha \alpha$$

$$+ \frac{1}{r^2} \left[f^{(2)} \alpha \alpha - f^{(3)} \alpha \alpha \right] b_\alpha^{(2)}(r, \rho^{(i)}) \right\},$$

with the definition for $\alpha = \{J, L, S, S_z\}$. The coefficient $a_\alpha^{(1)}$, etc., are as follows,

$$a_\alpha^{(1)}(x, \rho) = x^2 I_{L,S_z}(x, \rho),$$

$$a_\alpha^{(2)}(x, \rho) = x^2 [\beta I_{J-1,S_z}(x, \rho) + \gamma I_{J+1,S_z}(x, \rho)],$$

$$a_\alpha^{(3)}(x, \rho) = x^2 [\delta I_{J,S_z}(x, \rho) + \epsilon I_{J+1,S_z}(x, \rho)].$$
\[ a_\alpha^{(3)}(x, \rho) = x^2[\gamma I_{J-1,S_z}(x, \rho) + \beta I_{J+1,S_z}(x, \rho)], \quad (12) \]

\[ b_\alpha^{(2)}(x, \rho) = x^2[\beta_{23} I_{J-1,S_z}(x, \rho) - \beta_{23} I_{J+1,S_z}(x, \rho)], \quad (13) \]

\[ c_\alpha^{(1)}(x, \rho) = x^2\nu_1 I_{L,S_z}(x, \rho), \quad (14) \]

\[ c_\alpha^{(2)}(x, \rho) = x^2[\eta_2 I_{J-1,S_z}(x, \rho) + \nu_2 I_{J+1,S_z}(x, \rho)], \quad (15) \]

\[ c_\alpha^{(3)}(x, \rho) = x^2[\eta_3 I_{J-1,S_z}(x, \rho) + \nu_3 I_{J+1,S_z}(x, \rho)], \quad (16) \]

\[ d_\alpha^{(2)}(x, \rho) = x^2[\xi_2 I_{J-1,S_z}(x, \rho) + \lambda_2 I_{J+1,S_z}(x, \rho)], \quad (17) \]

\[ d_\alpha^{(3)}(x, \rho) = x^2[\xi_3 I_{J-1,S_z}(x, \rho) + \lambda_3 I_{J+1,S_z}(x, \rho)], \quad (18) \]

with

\[ \beta = \frac{J + 1}{2J + 1}, \gamma = \frac{J}{2J + 1}, \beta_{23} = \frac{2J(J + 1)}{2J + 1}, \quad (19) \]

\[ \nu_1 = L(L + 1), \nu_2 = \frac{J^2(J + 1)}{2J + 1}, \quad (20) \]

\[ \nu_3 = \frac{J^3 + 2J^2 + 3J + 2}{2J + 1}, \quad (21) \]

\[ \eta_2 = \frac{J(J^2 + 2J + 1)}{2J + 1}, \eta_3 = \frac{J(J^2 + J + 2)}{2J + 1}, \quad (22) \]

\[ \xi_2 = \frac{J^3 + 2J^2 + 2J + 1}{2J + 1}, \xi_3 = \frac{J(J^2 + J + 4)}{2J + 1}, \quad (23) \]

\[ \lambda_2 = \frac{J(J^2 + J + 1)}{2J + 1}, \lambda_3 = \frac{J^3 + 2J^2 + 5J + 4}{2J + 1}. \quad (24) \]

In the above equations, the terms \( a_\alpha^{(i)} \), \( b_\alpha \), \( c_\alpha^{(i)} \), and \( d_\alpha^{(i)} \) have dimension \( L^{-2} \), and \( x \) has dimension \( L \). In addition, \( I(x, \rho) \) with dimension \( L^{-6} \) is given by

\[ I_{J,S_z}(x, \rho) = \int_0^\infty dq \, q^2 P_{S_z}(q) J^2(xq). \quad (25) \]
In the last equation, the parameter $q$ has dimension $L^{-1}$, $J_j(xq)$ is the spherical Bessel function and $P_{S_z}(q)$ is defined as

$$
P_{S_z}(q) = \frac{2}{3} \pi [(k_{Fz}^\sigma)^3 + (k_{Fz}^{\sigma z})^3 - \frac{3}{2}(k_{Fz}^\sigma)^2 + (k_{Fz}^{\sigma z})^2] q - \frac{3}{16}((k_{Fz}^\sigma)^2 - (k_{Fz}^{\sigma z})^2)^2 q^{-1} + q^3
$$

(26)

for $\frac{1}{2}|k_{Fz}^\sigma - k_{Fz}^{\sigma z}| < q < \frac{1}{2}|k_{Fz}^\sigma + k_{Fz}^{\sigma z}|$,

$$
P_{S_z}(q) = \frac{4}{3} \pi \min((k_{Fz}^\sigma)^3, (k_{Fz}^{\sigma z})^3)
$$

(27)

for $q < \frac{1}{2}|k_{Fz}^\sigma - k_{Fz}^{\sigma z}|$, and

$$
P_{S_z}(q) = 0
$$

(28)

for $q > \frac{1}{2}|k_{Fz}^\sigma + k_{Fz}^{\sigma z}|$, where $\sigma_z$ or $\sigma_\tau = +1, -1$ for spin up and down, respectively. In the next step, the two-body energy is minimized with respect to the variations in the function $f^{(i)}_\alpha$ subject to the normalization constraint $[20]$, 

$$
\frac{1}{N} \sum_{ij} (ij) \left[ h_{S_z}^2 - f^{2(12)} | ij \right]_a = 0,
$$

(29)

where in the case of magnetized neutron matter, the function $h_{S_z}(r)$ is defined as follows,

$$
h_{S_z}(r) = \begin{cases} 
1 - 9 \left( \frac{f^{(j)}(S_z)}{k_{Fz}^\sigma} \right)^2 ; & S_z = \pm 1 \\
1 ; & S_z = 0.
\end{cases}
$$

(30)

The minimization of the two-body cluster energy leads to a set of Euler-Lagrange differential equations with the forms,

$$
g_\alpha^{(1)''} - \left\{ \frac{a_j''}{a_j^\alpha} + \frac{m}{\hbar^2} [V_c - 3V_\sigma + V_\tau - 3V_{\sigma \tau} + 2(V_T - 3V_\sigma T) - 2V_\tau z + \lambda] + \frac{m}{\hbar^2}(V_{12} - 3V_{12\sigma} + V_{12\tau} - 3V_{12\sigma \tau}) \frac{a_j^{(1)2}}{a_j^\alpha} \right\} g_\alpha^{(1)} = 0,
$$

(31)

$$
g_\alpha^{(2)''} - \left\{ \frac{a_j''}{a_j^\alpha} + \frac{m}{\hbar^2} [V_c + V_\sigma + 2V_\tau - V_\sigma T - V_{12} + \lambda] + \frac{m}{\hbar^2}(V_{12} + V_{12\sigma} + V_{12\tau} - 3V_{12\sigma \tau}) \frac{a_j^{(2)2}}{a_j^\alpha} \right\} g_\alpha^{(2)} = 0.
$$

(32)
FIG. 1: Energy per particle versus the spin polarization parameter at different values of dimensionless AMM, $r_\mu$, at $B = 10^{18}$ G.

\[ g_\alpha^{(3)''} = \left\{ \frac{\alpha^{(3)''}}{\alpha_\alpha} + \frac{m}{\hbar^2} [V_c + V_\sigma - 4V_l - 2V_{ls} + V_\tau + V_{\sigma\tau} - 4V_{l\tau} + 2(V_T + V_{\sigma T} - 4V_{Tl}) - 2V_{\tau z} + \lambda] \\
+ \frac{m}{\hbar^2} [V_{t2} + V_{t2\sigma} + V_{t2\tau} + V_{t2\sigma\tau}] \frac{c_{(3)}^2}{a_\alpha} + \frac{m}{\hbar^2} [V_{ls2} + V_{ls2\tau}] \frac{d_{(3)}^2}{a_\alpha} \\
+ \frac{b^2_\alpha}{r^2 a_\alpha^{(2)r}} \right\} g_\alpha^{(3)} + \left\{ \frac{1}{r^2} - \frac{m}{2\hbar^2} [V_{ls} - 2V_{t2} - 2V_{t2\sigma} - 3V_{ls2} + V_{ls\tau} - 2V_{t2\tau} - 2V_{t2\sigma\tau} - 3V_{ls2\tau}] \right\} \frac{b^2_\alpha}{a_\alpha^{(3)}} g_\alpha^{(2)} = 0, \quad (33) \]

where

\[ g_\alpha^{(i)}(r) = f_\alpha^{(i)}(r)a_\alpha^{(i)}(r). \quad (34) \]

In the above equations, the primes denote differentiation with respect to $r$ and the Lagrange multiplier $\lambda$ is associated with the normalization constraint, Eq. (29). Solving these differential equations leads to the results for the correlation functions, the two-body energy, and the total energy per particle of the system.

### III. RESULTS AND DISCUSSION

Figs. 1 and 2 show the energy per particle versus the spin polarization parameter at different values of dimensionless AMM, $r_\mu$. It can be seen that at each AMM, the energy reaches a minimum at a value of the spin polarization parameter. The values of dimensionless
FIG. 2: Energy per particle versus the spin polarization parameter at different values of dimensionless AMM, \( r_\mu \), at \( \rho = 0.5 \, fm^{-3} \).

AMM are acceptable that lead to an equilibrium point with spin polarization parameter higher than \(-1\), i.e. \( \delta > -1 \). We can found From Figs. 1 and 2 that the energy at the equilibrium state decreases with the increase in the dimensionless AMM. This indicates that at high densities and magnetic fields, the neutron AMM at which the system is stable differs from the known neutron AMM, \( \mu_n \), in agreement with the result of Ref. \[2, 4–6\]. In addition, it is clear that the neutron matter with the medium dependent AMM is more spin polarized compared to the case with \( r_\mu = 1 \). It is possible to find the equilibrium state of the system by varying the AMM. Comparing Fig. 1 a and b shows that at higher densities, the value of the dimensionless AMM corresponding to the equilibrium state is larger than lower densities. In addition, we can see from Fig. 2 a and b that at higher magnetic fields, the equilibrium value of the dimensionless AMM is smaller than the lower magnetic fields. The effects of density and magnetic field on the equilibrium value of the AMM will be considered in the following.

We have shown the density and magnetic field dependence of the equilibrium value of the AMM in Figs. 3 and 4 respectively. It is clear from Fig. 3 that at each magnetic field, the value of the dimensionless AMM increases as the density grows. This result is in agreement with the results reported in Refs. \[1, 3, 8\]. The enhancement of the neutron AMM can be due to the increase in the neutron radius at higher densities \[1, 12\] and the change in the quark structure of neutron \[5\]. We understand from Fig. 3 that in our model, the coupling
FIG. 3: The equilibrium value of the dimensionless AMM versus the density at different magnetic fields.

FIG. 4: The equilibrium value of the dimensionless AMM versus the magnetic field at different densities.

of neutrons to the magnetic field is more significant at higher densities. It is obvious from Fig. 3 that the increase of the dimensionless AMM due to the density is more significant at lower magnetic fields.

Fig. 4 confirms that at each density, the dimensionless AMM decreases when the magnetic
field grows. The decrease of the AMM with the increase in the magnetic field has been also reported in a previous work [11]. This result is expected considering the quark wave functions of the neutrons. From the quantum mechanical point of view, strong magnetic fields result in collapse of neutrons, and therefore the decrease in the neutron radius [14]. Moreover, the AMM is proportional to the size of the quark wave function [12]. Consequently, strong magnetic fields lead to the decrease in the AMM. We see from Fig. 4 that the coupling of neutrons to the magnetic field is weaker at higher magnetic fields. Furthermore, the effects of the density on the AMM is less significant at higher magnetic fields.

Fig. 5 shows the energy of magnetized neutron matter at the equilibrium value of the AMM versus the density for different values of the magnetic field. We can see that for each value of the magnetic field, the neutron matter is bound and has a minimum at a specific value of the density. This bounding of the neutron matter is the result of the strong magnetic field which affects the value of the neutron AMM. We found that the neutron matter with the medium dependent AMM is more bound when the magnetic field increases. We have given the equation of state of magnetized neutron matter in Fig. 6. Our results confirm that for the system with the medium dependent AMM, the equation of state is softer compared to the constant one. It is clear from Fig. 6 that the equation of state is
not significantly affected by the AMM in agreement with the results of a recent work \cite{11}. The soft equation of state in the present case can have astrophysical consequences related to the neutron stars. However, the influence of the other factors such as the amount of charged particles, macroscopic magnetic field distributions, and the parameterizations of the many-body forces in magnetized neutron stars \cite{21} should also be considered.

IV. SUMMARY AND CONCLUSIONS

Applying the lowest order constraint variational method and AV$_{18}$ nuclear potential, we investigated the properties of magnetized dense neutron matter with the medium dependent AMM. It was clarified that the neutron magnetic moment increases with the increase in the density. In addition, we showed that the neutron magnetic moment decreases as the magnetic field grows. For our system, the energy of neutron matter has a minimum value at a specific density. The bounding of neutron matter is due to the density and magnetic field dependence of the neutron AMM. We found that the neutron matter is more bound when the magnetic field increases. Moreover, the equation of state of magnetized neutron matter with the medium dependent AMM was found to be softer compared to the case with constant AMM.
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