# Nuclear matter equation of state from a quark-model nucleon-nucleon interaction


K. Fukukawa [1], M. Baldo [2], G. F. Burgio [2], and H.-J. Schulze[2]

[1] *Academic support center, Kogakuin University, Hachioji, Tokyo 192-0015, Japan*

[2] *INFN Sezione di Catania, Dip. di Fisica, Università di Catania, Via Santa Sofia 64, I-95123 Catania, Italy*


Studying the nuclear matter equation of state (EOS) is one of the major issues in nuclear physics. For discussing the nuclear matter EOS, microscopic calculations should provide a solid basic. Various nucleon-nucleon (NN) interactions from meson-exchange models and from the chiral effective field theory have been developed and they give very fruitful results in nuclear physics. However, it is difficult to have the simultaneous reproduction of the existing phenomenological data for the binding energy of three- or four-nucleon systems and nuclear matter. Various kinds of three-nucleon forces have been proposed, but this ambition is only partially accomplished.

In this report, we study the nuclear matter EOS from a quark-model NN interaction named fss2, which describes well few-nucleon systems [1]. We employ the Bethe-Brueckner-Goldstone approach up to three-hole line (THL) level around the saturation density in Ref. [2] and extend our study to high densities in Ref. [3].

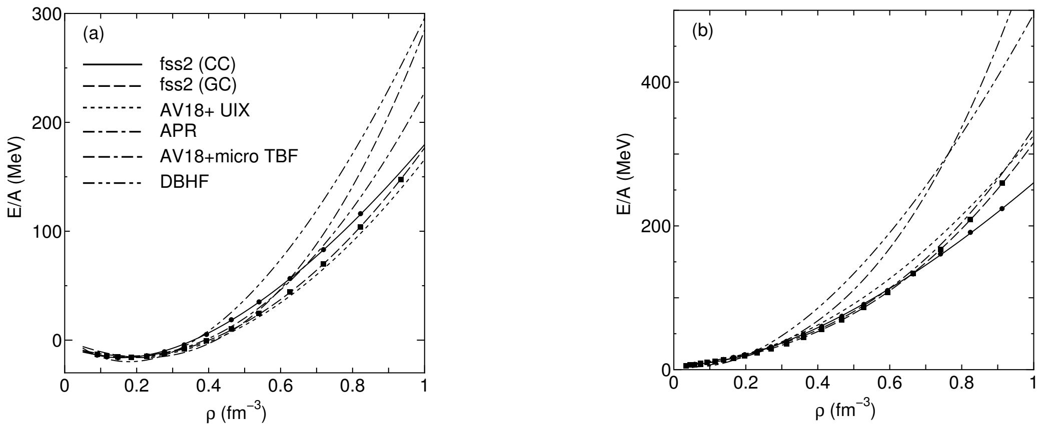


Figure 1: EOS of (a) symmetric nuclear matter and (b) pure neutron matter. The calculations in the continuous and gap choice are denoted by (CC) and (GC), respectively, and compared with other theoretical calculations from Ref. [4] for AV18+UIX, Ref. [5] for APR, Ref. [6] for AV18+micro TBF, and Ref. [7] for DBHF.

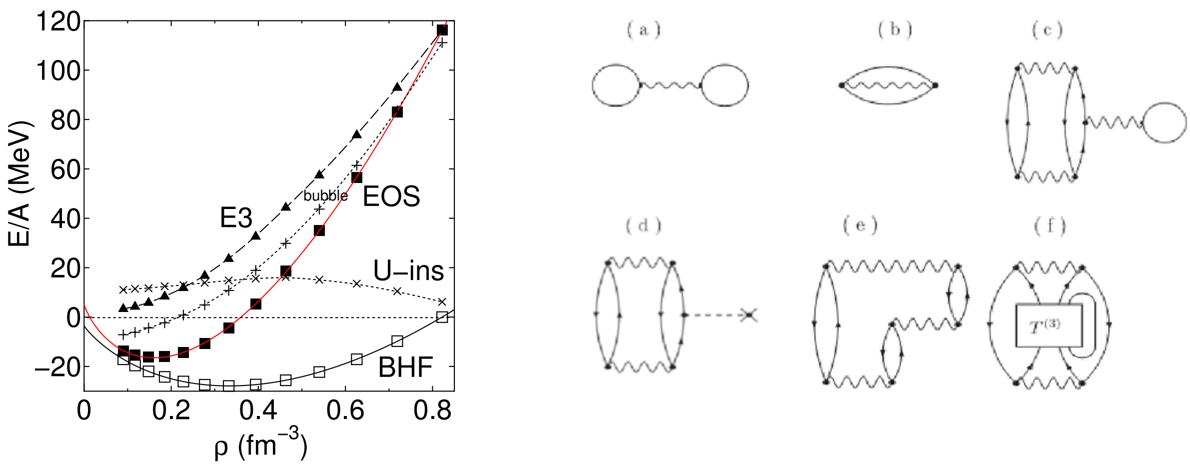


Figure 2: The binding energy as a function of nucleon density for symmetric nuclear matter in the continuous choice (left panel) and the diagrams considered in our calculations (right panel) are shown. The contribution from the Brueckner-Hartree-Fock (BHF) calculation [open squares, Diags. (a) and (b) ], the bubble diagram [‘ + ’ symbols, Diag. (c)], the corresponding U-insertion diagram [crosses, Diag. (d)], the total contribution from the THL diagrams [black triangles, Diags. (c) - (f)], and the resultant EOS [black squares, Diags. (a)-(f)], are plotted separately. The contributions from the other diagrams are not shown, because they are small.

Our calculated EOS is displayed in Fig. 1. We find that the fss2 EOS is quite soft at high densities, and that all EOS agree well in symmetric matter up to nucleonic density $\rho \sim 0.5\ \mathrm{fm}^{-3}$. The fss2 EOS in the continuous and the gap choice agree well with each other up to $\rho \sim 0.7\ \mathrm{fm}^{-3}$, so that the final EOS turns out to be independent of the choice of the single-particle potential.

The breakdown of the binding energy is shown in Fig. 2. THL give large contributions at high densities in the fss2 case, and this is at variance with the results found in the case of the Argonne $v_{14}$ or $v_{18}$ $NN$ potentials, where the THL are small [8]. We found that the THL contribution is important to predict the correct saturation point compatible with phenomenological data.

Then we solve the Tolmann-Oppenheimer-Volkoff equations under the conditions of the charge neutrality and $\beta$ stability. In Fig. 3, we show the mass-radius relation (left panel) and the mass-central density relation (right panel) for the cases discussed in Fig. 1. The fss2 EOS gives slightly different maximum masses for the gap choice and continuous choice approximations, in line with their different stiffness at high density. However, the range of the maximum mass predicted by fss2 turns out to be compatible with the largest mass observed up to now, which is $(2.01 \pm 0.04) M_{\odot}$ [9].

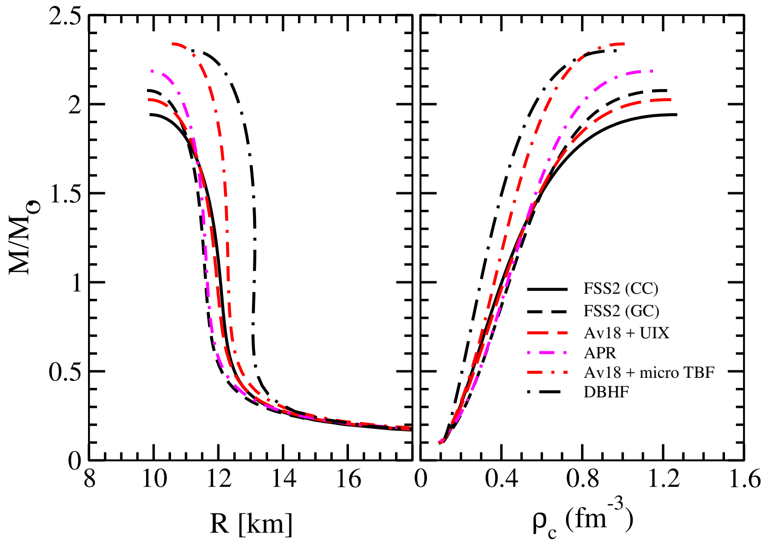


Figure 3: Neutron star mass as a function of radius (left panel) and central baryon density (right panel) for several EOS.

## References


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