Excluded volume approximation for supernova matter

A. V. Yudin*

Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia

Starting from a simple modification of the ordinary Fermi-gas description [1], we develop a general approach to the excluded volume approximation (EVA). The approach is valid for any degree of particle degeneracy and permits the inclusion of other interactions (in addition to EVA). We introduce the effective excluded volume function, whose form can be chosen in different ways to obtain various models. For example, it is easy to obtain the EVA described in [2] which was used in the studies of heavy ion reactions [3, 4] and in the description of extreme states of matter in astrophysics [5].

By implementing our general approach to the case of the Boltzmann limit, we can reproduce such results of well-elaborated theory of hard-sphere particles as, for example, the behavior of many-component different-size mixtures ([6] and references therein).

By adding to the EVA the long-ranged Yukawa-like attractive potential, we have obtained a quasi van der Waals equation of state and used it to explore thermodynamic properties and chemical composition of matter in collapsed supernova cores. The ability of the above approach to describe a phase transition to uniform nuclear matter is also considered.

References

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*E-mail: yudin@itep.ru