Short scientific report of the project "Bayesian analysis based on M-R data of new class of hybrid EoS"

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Motivation, purpose and workplan

The study of the internal composition of neutron stars is an active field of research which relies on astrophysical observations that allow to refine theoretical models. In this respect, the recent observations of massive neutron stars have imposed important constraints on the stiffness of the equation of state (EoS), and therefore on the density ranges covered by the density profiles of such high-mass compact star interiors. During the visit in collaboration with Prof. David Blaschke and Mark Kaltenborn at Univ. Wroclaw I worked on the following topics of my workplan:

1) development the new multi-parameter hybrid EoS
2) updating and running the BA routine for this new class of EoS
3) preparing the results for publication
4) giving seminar at the ITP (University of Wroclaw).

Results

During of my short term scientific mission at the Institute of Theoretical Physics (UW) we have worked on the extention of our previous Bayesian analysis (BA) studies[1] to a new class of hybrid EoS including a hadron-to-quark matter transition that is suitable for assessing systematically all possible pattern of hybrid star sequences in the mass-radius diagram [3], fulfilling the $2M_{sun}$ constraint and including the high-mass twin phenomenon [5].

This class of EoS is based on relativistic density functional theory applied for both, hadronic and quark matter to be joined by a Gibbs (Maxwell) construction of the phase transition. Hadronic EoS models are developed with the conventional excluded-volume mechanism generalized by introducing more general functional dependencies of the available volume fraction on the density [2]. This mechanism allows to vary the stiffening and softening of the nuclear matter. The quark matter was modeled by a two flavor Nambu-Jona-Lasinio (NJL) model with 8-quark interactions in the scalar and the vector channel [4]. The constructed hybrid EoS models allow possibility of the high-mass twin phenomenon.

The BA routine has been updated to make pissoble the analysis of this new hybrid EoS class in focus of the possible high-mass twin phenomenon with and without fictitious radius measurements of such twin. The fictitious radius measurements were proposed for the well-known two solar mass pulsars J1614-2230 [6] and J0348+0432 [7].

Bayesian analysis results show that most probable models have a large excluded volume parameter (p) and do not depend on the vector coupling strength (η_4), but taking into account ficticious measurements entails a narrow peak in the parameter space and the most probable models are located in the regoin $p > 40$ and $\eta_4 = 4 \sim 5$.

There is a strong peak of probabilities in the parameter space, even if fictitious radius measurements have quite large uncertainties with $\sigma = 1.5$ km, where the "measurements" have alarge overlap of 3σ regions. It means that even quite uncertain measurements of radii for massive pulsars could have a strong selective power for EoS models if they will possess high mass twins.

The BA routine was updated for parallel calculations with Message Passing Interface (MPI) technology [8], it allowed to the make analysis of the new class of hybrid EoS models within a few hours using the HybriLIT cluster [9].

The results were presented at the seminar of the group for THeory of Elementary Particles of the Institute of Theoretical Physics and will be published in the Journal Acta Physica Polonica B.

It is planned to continue the close collaboration with the ITP of UW for the further development of the Bayesian analysis tool for investigation of the hybrid EoS models based on the astrophysical M-R data.

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