SILESIAN UNIVERSITY
INSTITUTE OF PHYSICS
IN OPAVA

Univerzita Komenského v Bratislavě
Fakulta matematiky, fyziky a informatiky

Habilitation Thesis
Many – body aspects of neutron star physics

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Referee report: prof. RNDr. Zdeněk Stuchlík, CSc.

The Habilitation Thesis is devoted to some very important aspects of neutron star physics, namely to physical processes influencing the equation of state (EoS) governing the structure of their cores (central parts). Of course, it is demonstrated that in the cores there could exist not only neutrons (and admixture of protons), but also hyperons, quarks, or they could be fully constituted by stable quark matter (strange stars). The author relates very detailed studies of particle microphysics to astrophysical phenomena, demonstrating the fact that neutron stars (generally compact objects) could serve efficiently as particle and nuclear physics laboratory. Astrophysically, the author is concentrated on pulsars, mainly in the isolated form. However, a lot of important information could be also deduced from the Binary systems of neutron stars, especially in the case of colliding neutron stars resulting in kilonova explosions during the merging process leading to a black hole and an orbiting ultra-dense torus.

The thesis is separated into five parts. In the first part (Introduction), the author presents a short overview on the particle physics, starting with quantum chromodynamics, presenting main theoretical ideas and main experimental laboratories that are relevant for the physics of neutron (compact) star interior. The second part (Compact star as nuclear physics laboratory) is devoted to introducing some astrophysical characteristic of neutron stars that could be relevant for testing the predictions of particle physics. The three remaining parts are devoted to description of contributions of the author to the developments of neutron star physics.

The third part (EoS of dense nuclear matter) represents the area central of the Habilitation Thesis and the main author contributions to the field. The mass-radius relation is connected to EoS, and

then constraints on the EoS relevant for neutron (compact) stars are represented. Relativistic mean-field model used for EoS is discussed in detail, along with possible role of hyperons (hybrid stars) and role of quark matter.

The fourth part (Stability of the neutron star rotation) is concentrated on the so-called r – modes and their relevance for stability of young rapidly rotating pulsars, the influence of viscosity is also discussed.

In the fifth part (Neutron star cooling) the cooling processes are discussed, the thermal evolution of the neutron star is described, and neutrino production reactions are presented. Reaction rates in media are introduced, the role of antineutrinos is tested by strangeness modes.
Special attention is devoted to the excitation and de-excitation of superfluid neutron matter being in both in/out equilibrium states. Finally, spin excitonic and diffusive modes are discussed in superfluid Fermi liquids.

The Habilitation Thesis is very well written, giving a reasonable overview of the area of scientific interests of the author, and a very good review of his most relevant results related to properties of neutron star interior, being extended by the relevant published papers. The author has a number of relevant papers published in highly impacted journals that obtained a highly relevant citation response. According to WoS he has 70 papers that were cited more than 2 500 times, and the H – index = 23. Such a record surely corresponds to the position of Associate Professor.

I have a minor comment to the Habilitation thesis. The author is discussing the stability of the neutron star rotation (Chapter). However, there is no mention on the rotating neutron stars, as related to their spacetime (both in the interior and exterior of the neutron star), and any comment on the possibility to infer some conclusions related to the EoS of the neutron star matter from observations of astrophysical phenomena, namely those related to high – frequency quasiperiodic oscillations of X-ray radiation observed in accretion disks orbiting neutron stars in Binary systems containing a low – mass secondary star.

For this reason, it could be useful to make some comments on the rotating neutron stars during the defense. The appropriate way is to give basic information on the so called Hartle – Thorne metric describing slowly rotating black holes, considering their mass, spin, and quadrupole moment, as this metric can be relevant for all the observed neutron stars, as their rotation frequency is allowing application of the Hartle – Thorne metric. The author should make some comments on the influence of the spacetime rotation, at least of its spin (angular momentum), on the phenomena considered in his thesis. It should be stressed that omission of the rotating neutron star spacetime not relevant for very good impression as related to the Habilitation Thesis.

I conclude that the candidate clearly demonstrates competence and readiness necessary to accept duties of the Associate Professor (docent) affiliation. I am strongly recommending the submitted Habilitation Thesis and awarding Dr. Eugeni Kolomeitsev the title Associate Professor.

In Opava 19. 8. 2022

Prof. RNDr. Zdeněk Stuchlík, CSc.
director

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