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REVIEW

on the Ph.D. thesis entitled

INVESTIGATION OF HOT ROTATING WHITE DWARFS IN GENERAL RELATIVITY

By

BAKYTZHAN ZHAMI

In this thesis the candidate studies the equilibrium configurations of white dwarfs taking into account the effects of general relativity, finite temperature, nuclear composition and rotation which make a substantial contribution to the structure of white dwarf stars.

First, the equation of state (EoS) is specified in order to theoretically describe the structure and physical properties of white dwarf (WD) matter. As a particular example, the candidate investigates three EoS in the thesis: the Chandrasekhar EoS, the Salpeter EoS and the Feynman-Metropolis-Teller EoS. The EoS is necessary to close and solve the system of differential equations of stellar structure.

Second, the candidate studies *axially* symmetric exterior solutions of the Einstein equations that can be used to describe the gravitational field of *rotating* white dwarfs. More specifically, the relations between the Kerr and Hartle-Thorne solutions, then the Kerr and Fock solutions were clearly established. Then, the exterior Sedrakyan-Chubaryan approximate solution is derived in an analytical form, which makes it practical in the astrophysical context. In the limiting case of vanishing angular momentum, the solution reduces to the well-known Schwarzschild solution in vacuum. It has been demonstrated that the Sedrakyan-Chubaryan solution is *equivalent* to the exterior Hartle-Thorne solution. This result is new.

Third, the candidate shows that the effects of general relativity are crucial close to the Chandrasekhar mass limit and important to analyze the stability of white dwarfs. In addition, analytical expressions (fits)with high precision have been obtained for the classical and relativistic mass-radius relations. Furthermore, the cold and hot white dwarfs were explored in the framework of general relativity using the Chandrasekhar EoS. Basic parameters of white dwarfs such as the central density, pressure, mass, radius, the temperature of an isothermal core and the logarithm of surface gravity have been calculated. It has been shown that it is necessary to take into account the effects of finite temperatures in white dwarfs with low masses. Similarly, the core temperatures have been estimated for white dwarf-companions of the millisecond pulsars PSR J1738+0333, PSR J1012+5307 and PSR J1911-5958A.

Fourth, the candidate studies static cold white dwarfs by means of the Salpeter EoS within general relativity. The main parameters of white dwarfs are calculated solving the Tolman-Oppenheimer-Volkoff (TOV) equation, employing the Salpeter EoS. Moreover, the white dwarf characteristics from the Sloan Digital Sky Survey (SDSS)Data Releases (DR) 4, 10 and 12 are analyzed. The histogram and the Gaussian distribution of mass and radius are constructed for these catalogues. The maximum, minimum and average values of the logarithm of the surface gravity, effective temperature, mass and radius are calculated. The theoretical mass-radius relations are compared with the observational data. The candidate shows that the consideration of the nuclear composition, neutronization threshold, the Thomas-Fermi corrections and Coulomb interactions is critical to describe some white dwarfs in the catalogues of the SDSS DR 10 and 12.

Fifth, the equilibrium configurations of uniformly rotating white dwarfs are investigated using the Chandrasekhar and Salpeter equations of state in the framework of Newtonian gravity. All the relevant equations up to the second order in the angular velocity were derived. Moreover, the total mass, the moment of inertia, the quadrupole moment, the polar and equatorial radii, the eccentricity and the gravitational binding energy of the rotating body have been explicitly found. It was illustrated that the so-called*I-Love-Q* relations are also valid for *cold* white dwarfs regardless of the EoS. It was also shown that the moment of inertia, quadrupole moment and eccentricity (*I-Q-e*) relations are valid as well.

Finally, cold and hot, static and rotating white dwarfs were investigated within the framework of general relativity, employing the well-known EoS. The major parameters of WDs were calculated. It was shown that the effects of finite temperatures become crucial for low-mass white dwarfs, whereas the corrections of general relativity were essential for massive white dwarfs. To construct a rotating configuration the Hartle approach was used. It was demonstrated that rotation is relevant in all mass range. It turned out that the accounting for temperature, general relativity and rotation is significant in the calculation of the radii of white dwarfs.

Bakytzhan Zhami, as a Ph.D. student of the Faculty of Physics and Technology at Al-Farabi Kazakh National University, has spent his scientific probation period at the International Center for Relativistic Astrophysics Network (ICRANet), Pescara, Italy in 2016 and 2017. During his research visit he has worked on the topic of the Ph.D. thesis and has performed some calculations related to the equilibrium structure of static and rotating white dwarfs both in Newtonian gravity and general relativity. Also, Bakytzhan Zhami interacted and collaborated with other scientists, postdocs and Ph.D. students during his visit to ICRANet.

Overall, the candidate has completed a piece of research that demonstrates a significant and original contribution to the knowledge in his field of study. The thesis of Bakytzhan Zhami contains enough new and interesting results to be considered as a completed Ph.D. thesis which fulfills all the requirements for obtaining Ph.D. degree in the field of study(the specialty 6D060400 – Physics), therefore the Ph.D. thesis is recommended for the defense.

Excellent work

Prof. Remo Ruffini
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