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EXPLORE project: ”Dark Stars”

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In this project, we explore the properties of astronomical objects which can be formed by dark matter and the properties of neutron stars in the presence of a dark matter component. First, we will get ourselves acquainted with the properties of interacting bosons and interacting fermions and the properties of compact objects consisting of these dark matter particles. For this purpose, a specialized introductory lecture will be given based on the textbook ‘Schaffner-Bielich: Compact Star Physics’. Then, we will specifically address the following three topics: i) We will study the properties of dark matter particles with a dark charge corresponding to a dark photon. Also, interactions will be taken into account where we use input from the study of self-interacting dark matter from the other projects. The equation of state will be calculated and used as input to solve the Tolman-Oppenheimer-Volkoff equations. The mass-radius relation of dark compact objects with a dark charge will then be computed numerically. Possible constraints from astrophysical observations on the possible existence of those dark charge compact objects will be investigated also in connection with gravitational wave signals. ii) We will look at the modification of the properties of neutron stars, if there is some amount of dark matter present in the core. Here, we will use a model of self-interacting dark matter, which we assume to be dark bosons. The equation of state of neutron stars will be added to the one for dark bosons. The TOV equations will be solved numerically and the change of the mass-radius relation of neutron stars with a dark boson component derived. Constraints on the properties and the amount of dark bosons present in neutron stars will be delineated also in connection with gravitational wave signals. iii) We will derive analytic or semi-analytic expressions for the solution of the TOV equations by assuming a core of an incompressible fluid (of dark matter) surrounded by ordinary matter. The case for a compact object consisting of an incompressible fluid alone is known by the Schwarzschild solution. The limit on its compactness is known as the Buchdahl limit which can be calculated analytically. The solution for the case of an incompressible fluid surrounded by some additional matter is not known yet. For the equation of state of ordinary matter surrounding the incompressible core we adopt a relativistic polytrope and look for possible scaling solutions.

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