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From Quarks to Cosmos

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Condensation of a magnetized gas of charged scalar bosons

Charged scalar bosons may naturally form in the interior of neutron stars due to the pairing of protons with antiparallel spins. Although the concentration of proton pairs is small with respect to that of neutrons or neutron pairs, they might still have a relevant role in the macrophysics of these compact objects, especially in connection to their response to the strong magnetic fields of neutron stars. In this work, we study the effects of a uniform and constant magnetic field on the Bose-Einstein Condensation (BEC) of a magnetized gas of charged scalar bosons. The condensation of relativistic magnetized charged bosons is discussed usually in the weak (WF) or strong (SF) field regimes separately. In the WF limit, the gas undergoes a usual transition to the BEC, and the critical temperature depends on the magnetic field. In the SF regime, all the particles are confined to the lowest Landau level, making the system effectively one-dimensional. Since one-dimensional Bose gases do not exhibit BEC, it has been debated whether or not a magnetized scalar gas condenses. Indeed, in the SF regime, a critical temperature cannot be defined, but it can be shown that there exists an interval of temperatures along which the bosons start to concentrate around the ground state, indicating the occurrence of a diffuse phase transition. Here we review these limits and develop a low-temperature analysis suitable for any field. It allows us to observe how the gas evolves from one regime to the other and to answer the question of whether magnetized charged scalar bosons condense or not. To do so, we will study the particle density and the specific heat of the gas as a function of the temperature and the magnetic field.

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