

SUPERFLUID STARS AS THE FINAL STAGE OF STAR EVOLUTION

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Abstract

Astrophysics traditionally deals with phenomena and objects in which quantum effects are not expected to be important or even significant – too large, too massive, too hot. Therefore, does it make sense to speak about “quantum astrophysics” as a separate discipline, and what would its key features and ideology be?

Motivated by the properties of laboratory superfluids and Bose-Einstein condensates, we consider a general relativistic model of superfluidic matter, based on logarithmically nonlinear scalar field theory. Such matter can ultimately develop in neutron star cores, or other supermassive objects, when gravity overcomes the neutron degeneracy pressure, and eventually turn them into superfluid stars. The latter are thus compact, dark objects whose stability against gravitational collapse is enhanced not only by the quantum uncertainty principle but also by drastically reduced adhesion due to superflow. Such objects are no longer bound by any mass limits of the Tolman-Oppenheimer-Volkoff type; their relativisticity and effective compactness are comparable to values expected for neutron stars and black holes. The spatial distribution of matter inside superfluid stars drops at a Gaussian-like rate, which, considering the low accuracy of astrophysical measurements, can be mistaken for the presence of a material surface or crust. However, no deterministic surface occurs there, nor does an event horizon or a spacetime singularity.

We therefore propose (logarithmic) superfluid stars to be stable dark compact objects and black hole mimickers. Their existence would be a strong argument towards accepting quantum astrophysics as a next step in understanding processes occurring in supermassive objects and high-energy phenomena in astronomy.