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Superfluid Stars and the Dawn of Quantum Astrophysics

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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?

We consider a general relativistic model of a self-interacting complex scalar field with logarithmic nonlinearity motivated by studies of laboratory superfluids and Bose-Einstein condensates. Spherically-symmetric gravitational equilibria are shown in this model, which do not have event horizons but which are regular, singularity-free and asymptotically flat. They can be thus interpreted as compact stars whose stability against gravitational collapse is enhanced not only by the Heisenberg uncertainty principle but also by the property of superfluidity itself, their "darkness" comes naturally as a result of suppressed dissipative excitations. Such objects do not obey any absolute upper mass limit of a Tolman-Oppenheimer-Volkoff type, while their relativisticity and effective compactness values are comparable to those of black holes. Their spatial density distribution drops abruptly (at the Gaussian-like rate), which can be mistaken in realistic astronomical observations for the presence of an exact material surface.

We therefore present logarithmic superfluid stars as dark compact objects and black hole mimickers. Their existence would be a serious argument towards accepting quantum astrophysics as a next step in understanding phenomena occurring in supermassive objects and high-energy phenomena observed in astronomy.

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