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Boson stars and their relatives in semiclassical gravity

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We construct boson star configurations in quantum field theory using the semiclassical gravity approximation. Restricting our attention to the static case, we show that the semiclassical Einstein-Klein- Gordon system for a single real quantum scalar field whose state describes the excitation of N identical particles, each one corresponding to a given energy level, can be reduced to the Einstein-Klein-Gordon system for N complex classical scalar fields. Particular consideration is given to the spherically symmetric static scenario, where energy levels are labeled by quantum numbers n, l, and m. When all particles are accommodated in the ground state n ¼ l ¼ m ¼ 0, one recovers the standard static boson star solutions, that can be excited if n ≠ 0. On the other hand, for the case where all particles have fixed radial and total angular momentum numbers n and l, with l ≠ 0, but are homogeneously distributed with respect to their magnetic number m, one obtains the l-boson stars, whereas when l ¼ m ¼ 0 and n takes multiple values, the multistate boson star solutions are obtained. Further generalizations of these configurations are presented, including the multi-l multistate boson stars, that constitute the most general solutions to the N-particle, static, spherically symmetric, semiclassical real Einstein-Klein-Gordon system, in which the total number of particles is definite. In spite of the fact that the same spacetime configurations also appear in multifield classical theories, in semiclassical gravity, they arise naturally as the quantum fluctuations associated with the state of a single field describing a many-body system. Our results could have potential impact on direct detection experiments in the context of ultralight scalar field/fuzzy dark matter candidates.

Primary authors: Dr DIEZ-TEJEDOR, Alberto (University of Guanajuato-México); Dr BERNAL, Argelia (University of Guanajuato-México); Dr NÚÑEZ, Darío (UNAM-México); BARRANCO, Juan (University of Guanajuato-México); Dr DEGOLLADO, Juan Carlos (ICF-UNAM, México); Dr ALCUBIERRE, Miguel (UNAM-México); Dr MEGEVAND, Miguel (Instituto de Física Enrique Gaviola, CONICET.); Dr SARBACH, Olivier (IFM-Universidad Michoacana de San Nicolas de Hidalgo, México)

Presenter: BARRANCO, Juan (University of Guanajuato-México)

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