# Universidade de São Paulo
# Instituto de Física de São Carlos

# XII Semana Integrada do Instituto de Física de São Carlos

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# PG29

# Bose-Einstein condensates and the thin-shell limit in anisotropic bubble traps.

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The Bose-Einstein condensate (BEC) have been a hot topic since Eric A. Cornell and C. E. Wieman (1) were able to experimentally achieve them in 1995 with confined alkaline gases of 87Rb atoms. Since then, with the fairly recent growing use of cold atoms to design BEC, many different theoretical models and experimental setups have appeared in the literature. In particular, the bubble trap shaped potential has been of great interest in the last 20 years, due to its fairly easy experimental manipulation. Inspired by the recent scientific developments in this field (2), in this work we study the anisotropic bubble trap physics in the thin-shell limit relating the physical parameters of the system with the geometry of the manifold in question, in which we believe to be a very original approach. Firstly, the mathematical background in which our theory is placed is defined and explained, considering the Gaussian Normal Coordinate System (GNCS). This system is well known and allows for a better description of the physics involved, granting a fairly simple understanding of the calculations. Then our main ideas are exposed, where the general potential in which our work is valid is defined with the aid of a parameter $\Lambda$ which is used to reach the thin-shell limit as it goes to infinity. It turns out that the usual naive approach for taking the thin-shell limit leads to infinite answers when anisotropic shells are considered. Therefore, in order for us to have a consistent theory, it was necessary to consider regularized infinitesimal anisotropies. The radial oscillation frequency is calculated considering such potential, and a rigorous definition of the thin-shell limit is obtained considering the geometrical distortion of the bubble trap, in order to provide a more sophisticated mathematical description. We chose to work with one experimental potential as a particular example. Next, some physical quantities such as the general potential $V$, the particle interaction gINT, and the main system Hamiltonian H are manipulated considering expansions in $\Lambda$. Non degenerate time-independent perturbation theory is applied to find the energies in question and an effective Hamiltonian is defined. Finally, this Hamiltonian is solved and analyzed in the final chapter regarding perturbative solutions in $\epsilon$ for both the ground-state wavefunction and oscillation frequencies of the system with the aid of the Bogoliubov theory.(3)

**Palavras-chave:** Bose-Einstein condensates. Thin-shell limit. Bubble trap.

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