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Experimental Quantum Cosmology: Probing Analogue Trans-Planckian Physics in Dipolar Bose-Einstein Condensates

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The talk will describe proposals for the quantum simulation of possible trans-Planckian effects on two fundamental phenomena in effective curved spacetime:
1. Scale Invariance of the Inflationary Power Spectrum. We consider an analogue de Sitter cosmos in an expanding quasi-two-dimensional Bose-Einstein condensate with dominant dipole-dipole interactions between the atoms or molecules in the ultracold gas. It is demonstrated that a hallmark signature of inflationary cosmology, the scale invariance of the power spectrum of inflaton field correlations, experiences strong modifications when, at the initial stage of expansion, the excitation spectrum displays a roton minimum. Dipolar quantum gases thus furnish a viable laboratory tool to experimentally investigate, with well-defined and controllable initial conditions, whether primordial oscillation spectra deviating from Lorentz invariance at trans-Planckian momenta violate standard predictions of inflationary cosmology.
2. Cosmological Particle Production aka Dynamical Casimir Effect. A rapid quench in the dipolar gas, performed on the speed of sound of excitations propagating on the condensate background, leads to the dynamical Casimir effect (and hence analogue cosmological particle production), which can be characterized by measuring the density-density correlation function. For both zero and finite initial temperatures, the continuous-variable bipartite quantum state of the created quasiparticle pairs with opposite momenta, resulting from the quench, displays an enhanced potential for the presence of entanglement (represented by nonseparable and steerable quasiparticle states), when compared to a gas with solely repulsive contact interactions. Steerable quasiparticle pairs contain momenta from close to the roton, and hence quantum correlations significantly increase in the presence of a deep roton minimum.

References

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