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# Quantum Primordial Standard Clocks

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In this paper, we point out and study a generic type of signals existing in the primordial universe models, which can be used to model-independently distinguish the inflation scenario from alternatives. These signals are generated by massive fields that function as standard clocks. The role of massive fields as standard clocks has been realized in previous works. Although the existence of such massive fields is generic, the previous realizations require sharp features to classically excite the oscillations of the massive clock fields. Here, we point out that the quantum fluctuations of massive fields can actually serve the same purpose as the standard clocks. We show that they are also able to directly record the defining property of the scenario type, namely, the scale factor of the primordial universe as a function of time a(t), but through shape-dependent oscillatory features in non-Gaussianities. Since quantum fluctuating massive fields exist in any realistic primordial universe models, these quantum primordial standard clock signals are present in any inflation models, and should exist quite generally in alternative-to-inflation scenarios as well. However, the amplitude of such signals is very model-dependent.

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