Particle Production from Geometric Transition in Expanding Universe

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It has been known for long that an expanding universe produces cosmic particles [1]. In the in-out formalism, particle production in time-dependent backgrounds is a consequence of the difference between the in-vacuum and out-vacuum, which results in a complex $S$-matrix whose magnitude is less than one. Kim and Page showed that the instanton action in the complex time determines the magnitude of the $S$-matrix for a charged particle in time-dependent electric fields [2] and in dS$_2$ or AdS$_2$ with a uniform electric field [3] and in global coordinates of dS spaces [4].

In this presentation, we further argue that the geometric transition in the complex time [5] of the Hamilton evolution operator for time-dependent backgrounds such as expanding universes and/or electric fields is the origin of particle production [6].