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Unimodular Hartle-Hawking wave packets and their probability interpretation

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We re-examine the Hartle-Hawking wave function from the point of view of a quantum theory which starts from the connection representation and allows for off-shell non-constancy of Λ (as in unimodular theory), with a concomitant dual relational time variable. By translating its structures to the metric representation we find a non-trivial inner product rendering wave packets of Hartle-Hawking waves normalizable and the time evolution unitary; however, the implied probability measure differs significantly from the naive $|\psi|^2$. In contrast with the (monochromatic) Hartle-Hawking wave function, these packets form travelling waves with a probability peak describing de Sitter space, except near the bounce, where the incident and reflected waves interfere, transiently recreating the usual standing wave. Away from the bounce the packets get sharper both in metric and connection space, an apparent contradiction with Heisenberg's principle allowed by the fact that the metric is not Hermitian, even though its eigenvalues are real. Near the bounce, the evanescent wave not only penetrates into the classically forbidden region but also extends into the $a^2 < 0$ Euclidean domain. We work out the propagators for this theory and relate them to the standard ones. The $a = 0$ point (aka the "nothing") is unremarkable, and in any case a wave function peaked therein is typically non-normalizable and/or implies a nonsensical probability for Λ (which the Universe would preserve forever). Within this theory it makes more sense to adopt a Gaussian state in an appropriate function of Λ, and use the probability associated with the evanescent wave present near the time of the bounce as a measure of the likelihood of creation of a pair of time-symmetric semiclassical Universes.

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