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Quantum stress-energy at timelike boundaries: testing a new beyond-ΛCDM parameter with cosmological data

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We analyze the basic cosmological effects of a population of timelike boundaries –a form of nontrivial spacetime topology –containing a boundary layer of quantum stress energy. This accumulation of vacuum fluctuations of quantum fields can be consistently negative and UV sensitive, providing an additional source of cosmic energy density strong enough to compete with matter and dark energy. For boundary conditions enabling a solution with fixed comoving boundary size, this effect contributes a qualitatively new term to the Friedmann equation determining the expansion history, scaling like $-1/a$ for scale factor a. It naturally dominates at relatively late times ($a \approx 1/2$), while leaving intact well-measured early universe physics such as big bang nucleosynthesis and recombination. For a wide window of parameters, the boundaries can be larger than the Planck length throughout their history, back through the start of inflation at any viable scale. We analyze CMB and BAO data sets (Planck, ACT, and DESI) allowing for this component, finding a slight preference ($\sim 2\sigma$) and a relaxation of current tensions in the data (including the neutrino mass) in a physical manner. This novel parameter fits into a larger space of physical parameters beyond-ΛCDM that may serve this role, including negative spatial curvature, which may also be motivated by topological considerations and chaotic dynamics. Finally, we comment on additional phenomenological prospects for testing for this form of topology in the universe.

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