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Running vacuum approach to renormalizing the vacuum energy in cosmological spacetime and the cosmological constant problem

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In the last few years the idea that the vacuum energy density (VED) is a running' quantity with the cosmological evolution has become phenomenologically advantageous, as it helps in alleviating the current cosmological tensions afflicting the ΛCDM. The theoretical studies backing up this approach go under the name of "running vacuum model" (RVM). Using this framework, based on quantum field theory (QFT) in curved spacetime, one can show that the properly renormalized VED in FLRW spacetime is free from fine-tuning troubles since the vacuum dynamics proves to be a power series of the Hubble rate H and of its time derivatives. The calculation is performed using an off-shell version of the adiabatic renormalization procedure, which leads to a smooth cosmic evolution of the VED with H, ρ_vac(H). As a result the "cosmological constant" Λ appears here as the nearly sustained value of 8πG(H)ρ_vac(H) around (any) given epoch H, where G(H) is the gravitational coupling at the corresponding epoch, which runs very mildly (logarithmically) with H. The VED evolution between points H and H_0 of the cosmic expansion history reads δρ_vac(H)~\nu_eff m_Plˆ2(Hˆ2−H_0ˆ2) (where |\nu_eff|≪1) and m_Pl is the Planck mass. The effective coefficient \nu_eff receives contributions from all the quantized matter fields and can be explicitly computed in QFT. Remarkably, there are also higher powers of H which can trigger inflation in the early universe within a new inflationary paradigm calledRVM-inflation', which does not make use of (ad hoc) inflaton fields. Finally, the equation of state (EoS) of the running vacuum also receives quantum corrections from bosons and fermion fields, shifting its value from -1. The striking consequence is that the EoS of the quantum vacuum may nowadays appear as quintessence, which is consistent with the recent DESI results.

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