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The Effective Theory of Gravity and Dynamical Vacuum Energy

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Gravity and general relativity are considered as an Effective Field Theory (EFT) at low energies and macroscopic distance scales. The effective action of the conformal trace anomaly of light or massless quantum fields has significant effects on macroscopic scales, owing to its describing light cone singularities not captured by an expansion in local curvature invariants. A compact local form for the Wess-Zumino effective action of the conformal anomaly and stress tensor is given, involving the introduction of a new light scalar, which it is argued should be included in the low energy effective action for gravity. This scalar conformalon couples to the conformal part of the spacetime metric and allows the effective value of the vacuum energy, described as a condensate of a 4-form abelian gauge field, to change in space and time. The EFT of vacuum energy thereby replaces the fixed constant Lambda of the classical theory with a dynamical condensate whose natural ground state value in empty flat space is Lambda_eff = 0 identically. In addition to the conformal anomaly, the principal physical inputs to the EFT are a topological vacuum susceptibility characterizing the coupling of the 4-form condensate to the anomaly current, in analogy to the chiral susceptibility of QCD, and the extension of the fermion anomaly to a general Einstein-Cartan space including torsion. By allowing Lambda_eff to vary rapidly near a black hole horizon, the EFT of dynamical vacuum energy provides an effective Lagrangian framework for gravitational condenstate stars, as the final state of complete gravitational collapse consistent with quantum theory. The possible consequences of dynamical vacuum dark energy in cosmology, the cosmic coincidence problem, and the role of conformal invariance for other fine tuning issues in the Standard Model are discussed.

Author: MOTTOLA, Emil

Presenter: MOTTOLA, Emil