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A Multiple-Scales Approach to the Averaging Problem in Cosmology

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The Universe is homogeneous and isotropic on large scales, so on those scales it is usually modelled as a Friedmann-Lemaître-Robertson-Walker (FLRW) space-time. The non-linearity of the Einstein field equations raises concern over averaging over small-scale deviations form homogeneity and isotropy, with possible implications on the applicability of the FLRW metric to the Universe, even on large scales. In this talk I will present a technique, based on the multiple-scales method of singular perturbation theory, to handle the small-scale inhomogeneities consistently. I will obtain a leading order effective Einstein equation for the large-scale space-time metric, which contains a back-reaction term. The derivation relies on a series of consistency conditions, that ensure that the growth of deviations from the large-scale space-time metric do not grow unboundedly; criteria for their satisfiability are discussed, and it is shown that they are indeed satisfied if matter is non-relativistic on small scales. I will also estimate the magnitude of the back-reaction term relative to the critical density of the Universe in the example of an NFW halo. In this example, the back-reaction term can be interpreted as a contribution of the energy-density of gravitational potential energy, averaged over the small-scale, to the total energy-momentum tensor.

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