Expanding wave solutions of the Einstein equations that induce an anomalous acceleration into the Standard Model of Cosmology

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Abstract

We derive a system of three coupled equations that implicitly defines a continuous one-parameter family of expanding wave solutions of the Einstein equations, such that the Friedmann universe associated with the pure radiation phase of the Standard Model of Cosmology is embedded as a single point in this family. By approximating solutions near the center to leading order in the Hubble length, the family reduces to an explicit one-parameter family of expanding spacetimes, given in closed form, that represents a perturbation of the Standard Model. By introducing a comoving coordinate system, we calculate the correction to the Hubble constant as well as the exact leading order quadratic correction to the redshift vs. luminosity relation for an observer at the center. The correction to redshift vs. luminosity entails an adjustable free parameter that introduces an anomalous acceleration. We conclude (by continuity) that corrections to the redshift vs. luminosity relation observed after the radiation phase of the Big Bang can be accounted for, at the leading order quadratic level, by adjustment of this free parameter. The next order correction is then a prediction. Since nonlinearities alone could actuate dissipation and decay in the conservation laws associated with the highly nonlinear radiation phase and since noninteracting expanding waves represent possible time-asymptotic wave patterns that could result, we propose to further investigate the possibility that these corrections to the Standard Model might be the source of the anomalous acceleration of the galaxies, an explanation not requiring the cosmological constant or dark energy.

Footnotes

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↵* As far as we are aware the only other known way the PDEs for metrics in SSC with perfect fluid sources reduce to ordinary differential equations (ODEs), is the time independent case when they reduce to the Oppenheimer–Volkoff equations (2).

↵† B.T. originally proposed the idea that a secondary expansion wave reflected backwards from the cosmic shock wave constructed in ref. 7 might account for the anomalous acceleration of the galaxies discussed in footnote ‡ and in National Science Foundation proposal DMS-060-3754.

↵‡ Temple B, Numerical Refinement of a Finite Mass Shock-Wave Cosmology. Numerical Relativity: American Mathematical Society National Meeting, January 5–7, 2007, New Orleans. Notes available at: www.math.ucdavis.edu/~temple/talks/NumericalShockWaveCosTalk.pdf.

↵§ See also ref. 10, which appeared while this work was under review.

↲¶ We thank the referee for pointing out that the equations become autonomous under the change of variables $\xi = e^S$.

↲// This is of course a theoretical relation, as the pure radiation FRW spacetime is not transparent.

↲** In the Standard Model, the universe is approximated by uniform density on a scale of a billion light years or so, about a tenth of the radius of the visible universe (2). The stars, galaxies, and clusters of galaxies are then evidence of large oscillations on smaller scales.

↲†† The size of the center, consistent with the angular dependence that has been observed in the actual supernova and microwave data, has been estimated to be ≈15 megaparsecs, approximately the distance between clusters of galaxies, ≈1/200 the distance across the visible universe (cf. refs. 2, 8 and 14).

↲1 We have departed from our usual convention of listing authors alphabetically in order to recognize B.T.'s extraordinary contribution to this particular article.
