

# Formal Existence of Friedmann-Static Pure Radiation Shock Waves

Christopher E. ALEXANDER \*

A two parameter family of general relativistic shock wave solutions to the perfect fluid Einstein field equations are constructed. The solutions are obtained by matching a self-similar perturbation of a Friedmann-Lemaître-Robertson-Walker spacetime [1] to a self-similar static spacetime across a spherical shock surface. These shock wave solutions model a general relativistic explosion within a static isothermal sphere and extend the one parameter family of general relativistic shock waves constructed by Smoller and Temple [2] by fully resolving the expansion waves created behind the shocks. Such an extension partially resolves a long standing problem posed by Cahill and Taub [3] by determining a subset of the self-similar spacetimes that may be matched to a self-similar static spacetime to form a general relativistic shock wave. The original problem is posed for a pure radiation equation of state, however the shock waves that are constructed resolve the problem for general barotropic equations of state either side of the shock. These shock waves are stable in the Lax sense and a formal existence proof is provided in the pure radiation case, as self-similar perturbations of FLRW spacetimes are not known explicitly. These spacetimes are of particular interest as they have an accelerated expansion similar to the accelerated expansion found in the Standard Model of Cosmology, but solve the Einstein field equations in the absence of a cosmological constant. It is conjectured by Temple that a vast primordial shock wave, with a perturbed FLRW interior, could provide the mechanism for the accelerated expansion observed today without the need for dark energy.

## Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1809311

## References

- [1] J. Smoller, B. Temple. General Relativistic Self-Similar Waves that Induce an Anomalous Acceleration into the Standard Model of Cosmology. *Mem. Am. Math. Soc.*, 208(1025), 2012.
- [2] J. Smoller, B. Temple. Astrophysical Shock Wave Solutions of the Einstein Equations. *Phys. Rev. D*, 51(6), 1995.
- [3] M. Cahill, A. Taub. Spherically Symmetric Similarity Solutions of the Einstein Field Equations for a Perfect Fluid. *Commun. Math. Phys.*, 21, 1971.

---

\*Department of Mathematics, University of California - Davis. Email: cealexander@ucdavis.edu