### Project Summary

It has recently been shown that the remarkable temperature maps of the microwave background space made by Planck and other telescopes can be used to infer the four dimensional structure of the universe on the largest linear scale; specifically and conservatively on scales of ~ 4 Gpc. This is expressed primarily as a potential map interior to the last scattering surface valid from the time of inflation to the present. The map seems to be robust when tested on real and simulated data, so long as the initial fluctuation spectrum truly has the general form – power law, Gaussian and adiabatic – inferred from the observations. At this stage the goal is to improve the map’s resolution and this will require a much more careful approach to the microwave background data than has been followed so far. This will, in turn, be aided by the inclusion of existing, auxiliary datasets including especially deep and wide (spectroscopic and color) redshift surveys such as those associated with the WISE satellite, the Hubble – COSMOS survey, the DES survey and the SDSS/BigBOSS survey. Combining these large public datasets for this purpose will require investigating an additional set of issues that could compromise the accuracy of the map. The practical limits of this project are not yet known but it is proposed to determine them using existing data. Much larger datasets will become available over the next decade and it is proposed to test our methodology by using existing data to predict some of what should be measured The promise of future data for this general approach is considerable.

The goal of mapping the actual universe that we inhabit provides a strong complement to the methodology practiced in much contemporary cosmology where the objective is to infer the statistical properties of an ensemble of universe, either imagined or realized in a multiverse that extends far beyond our current horizon, with its roughly forty billion light year radius, and thereby infer fundamental physical principles that are relevant under conditions that cannot be realized in the laboratory. Although this research can be seen as a return to traditional astronomy, it can also provide important new priors for statistical investigations and ongoing measurements such as those describing the kinematics of the universe’s expansion. In addition, the modes can be traced back to the time of inflation and as they have phases as well as amplitudes can be used in novel investigations of this epoch.

At its simplest, this is an exercise to combine two dimensional CMB data with local three dimensional data to infer the linear perturbations which evolve according to prescriptive physical laws. There are several ways in which this exercise could exhibit inconsistency, either as a failure of the assume evolution or of the assumed statistical character of the initial conditions. Either of these outcomes would be of considerable. An auxiliary investigation in which the nesting of equipotentials inferred on the surface of last scattering is represented as a tree will also be carried out to provide an explicit test of Gaussianity and to infer the topology of the three dimensional equipotential surfaces interior to this surface.

It is believed that mapping the universe on the largest scale has broad popular appeal as well as scientific utility. Even at low resolution, the images of previously undetected cosmic structure is widely perceived as a big step and much thought has gone into its public presentation using movies, modern graphics and three dimensional printing. The research to date has been prosecute in the open at

<http://github.com/rogerblandford/Music>,

where contributions are invited from all-comers. Combining large, heterogeneous data sets optimally is raising new issues in inference, of the kind that are showing up increasingly in modern, data-driven science, which while lying beyond the scope of this proposal, we expect to address eventually.