### Project Summary

We have recently been shown that the remarkable temperature maps of the microwave background space made by Planck and WMAP 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. We model this structure as a potential map interior to the last scattering surface, valid from the time of inflation to the present. Our map-making methodology seems to be robust, having been tested on both real and simulated data, so long as the initial fluctuation spectrum truly has the general form – power law, Gaussian and adiabatic – that has been inferred elsewhere from the observations.

Having established this proof of concept, we now aim to extend our general approach, improving the map’s resolution, making links to a variety of other datasets, and exploring a number of novel cosmological tests. The goal of mapping the actual universe that we inhabit provides a strong complement to the methodology practiced in much of contemporary cosmology, where the objective is to infer the statistical properties of an *ensemble* of universes, either imagined or realized in a multiverse that extends far beyond our current 40 billion light year radius horizon, and thereby infer fundamental physical principles that are relevant under conditions that cannot be realized in the laboratory. For example, the modes we reconstruct can be traced back to the time of inflation, where their phases as well as their amplitudes can be used in novel investigations of this epoch. Our complementary approach can also provide important new priors for investigations, of, for example, the kinematics of the universe’s expansion.

Increasing our map resolution 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 exercise of combining two dimensional CMB data with local three dimensional data to infer the linear perturbations which evolve according to prescriptive physical laws could exhibit inconsistency, in either the assumed evolution, or of the assumed statistical character of the initial conditions. Either of these inconsistencies, if detected, would be of considerable interest, and we will investigate ways to probe for such anomalies. For example, an auxiliary investigation in which the nesting of equipotentials inferred on the surface of last scattering is represented as a tree provides an explicit test of Gaussianity, as well as a route to infer the topology of the three dimensional equipotential surfaces interior to this surface.

Mapping the universe on the largest scales has broad popular appeal as well as scientific utility. Even at low resolution, the images of previously undetected cosmic structure are likely to be of great interest, and we are exploring a variety of public presentation techniques including movies, modern graphics and three dimensional printing. The research to date has been prosecuted in the open at

<http://github.com/rogerblandford/Music>, where contributions are invited from all-comers.