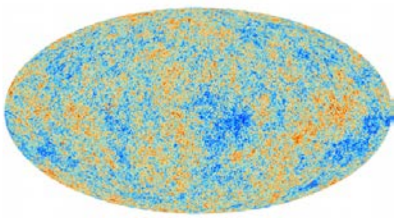
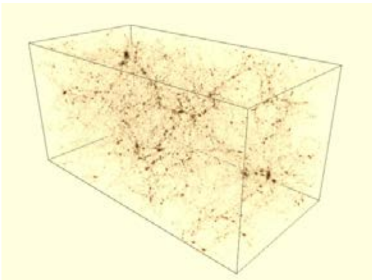
1.) Publishable Summary:

All observational evidence suggests that the universe began explosively from a hot, dense, singular initial state– the big bang. The energy for this `bang' came from a primordial field, the `inflaton', whose initial energy density stretched out the universe exponentially fast in its first 10^{-32} seconds. This initial burst of expansion, known as the `inflationary epoch' smoothed out the primordial proto-universe into an almost featureless, homogeneous space which ended in a burst that created all matter in the universe, commonly referred to as the big bang. Incredibly, we can still see the `echo' of this bang everywhere we look: This echo is in the form of relic microwave radiation, whose temperature is 2.7 ℃ above absolute zero. Recent maps of this microwave background, in particular by the European Space Agency satellite, PLANCK have served to confirm our current basic working model of cosmology, known as LCDM (Lambda-Cold Dark Matter) cosmology whose basis is commonly accepted to be inflationary cosmology. It is in the departures of this relic radiation from perfect uniformity that we see a topographical map of the earliest inhomogeneities in the early universe (below, left) that went on to form the clusters of galaxies that is the universe at its largest scales today (below, right).





By studying the statistical properties of the inhomogeneities in the cosmic microwave background (CMB), one can infer a great deal of information about the early universe. We know from the latest PLANCK results, that Inflation in its simplest phenomenological guise most likely took place, and that the universe is very nearly flat, with 68% of its energy density stored in a space filling fluid known as Dark Energy, 27% in the form of Cold Dark Matter and only 5% as visible matter and radiation. One is immediately confronted with many further questions:

- What caused inflation?
- How does inflation fit in with our current understanding of particle physics?
- Did inflation even happen as we think it did?
- Was there really an initial singularity, or did something precede it?
- Can we see evidence of theories beyond the standard model in the data?
- Any signs of extra dimensions? Exotic particles? Cosmic strings? Pre-inflationary phases?

FP7-PEOPLE-2011-IEF project 302817 ran from 09/2012-09/2014 and set out to ask these very basic questions. The basic objectives were to:

- Confront theory with observation.
- Possibly test theories of fundamental physics at energies a trillion times higher than what is possible at the Large Hadron Collider at CERN.
- Adapt and develop techniques from particle physics phenomenology known as `Effective Field Theory' and apply it to the study of the early universe cosmology.
- Test and constrain models of inflation within self-consistent particle physics realizations.
- Look for, and suggest better parameterizations of the data to help us understand what was really going on in the early universe, relevant for future observations.

The project has resulted in several key publications that have not only advanced the methodology of effective field theory on time dependent backgrounds, but have also uncovered novel ways in which one could discern the fundamental theory in which inflation is embedded through correlations across different observables in the CMB. In addition, with the recent activity surrounding the possible discovery of primordial gravitational waves in the CMB – the imprints of it of ripples in the fabric of spacetime itself— one is potentially granted a whole new window onto early universe physics. We proposed a novel signature of the statistical properties of this gravitational wave background that would be a smoking gun signature that something other than inflation took place, for which there are suggestive hints in the very preliminary data. The collaborations that have resulted from the work of this project continue to explore new and uncharted directions in the search for the fundamental theory that underlies inflationary cosmology, including a recent investigation in to the possibility that inflation can probe the quantum strengthening of the gravitational force at very high energies. Were this to be effected (by the presence of extra dimensions, for example) one could entertain the tantalizing possibility of probing inflationary physics in particle physics experiments.