Are there other universes? Historically, this has been a question for metaphysics. In the past decade, however, cosmologists have discovered compelling evidence – albeit circumstantial - that our entire Universe initially sprang from a volume smaller than the nucleus of an atom, in an explosive expansion known as Inflation. This incredible idea, first proposed by Alan Guth in 1980, has gained currency as it has passed one observational test after another. If inflation is correct, then it is likely that our Universe is just one of a multitude of universes born in this manner.

Much of the evidence in favor of inflation has come from the Cosmic Microwave Background (CMB) - the afterglow of the primeval fireball that filled the early Universe and is now visible as a faint, almost perfectly uniform glow of microwave radiation that fills the sky. The CMB is a pristine relic of the early Universe. The contents, structure and geometry of the Universe are encoded in faint but intricate patterns in the intensity and polarization of the radiation, formed long before the first stars and galaxies, when the Universe was approximately 380,000 years old and less than 1/1000 of its present size. In 1998, the first resolved images of the patterns in intensity were captured by BOOMERanG, a balloon-borne telescope, as it flew high above the Antarctic. These images revealed that the Universe has a Euclidean geometry, and that the early Universe was seeded with small fluctuations in density (the embryonic stages of galaxies and larger structures in the modern universe) that had roughly constant amplitude, independent of their size. These basic facts, along with the remarkable (10 ppm) isotropy of the CMB on large angular scales had all been predicted by the theory of inflation.

The detailed physics of inflation remains speculative. It is thought to have occurred in a tiny fraction of a second at energies far higher, and times far earlier, than the epoch probed by images of the CMB. There is thus no hope of ever seeing inflation in the conventional sense; the CMB represents the opaque surface beyond which we can never see. To “see” inflation requires using something altogether different from electromagnetic radiation.

Einstein’s General Theory of Relativity predicts that a violent spacetime disturbance such as inflation would have generated strong gravitational waves. These ripples in spacetime, traveling at the speed of light, would persist to this day as a Cosmic Gravitational-wave Background (CGB) – a gravitational analog to the CMB, equivalent to the echo of creation. It is this gravitational radiation that could, in principle, provide us with a clear view of the earliest moment in the history of the Universe, and an important clue to what physics was responsible for inflation.

Detecting the CGB due to inflation will be challenging. In fact, there has, to date, been no direct detection of gravitational radiation of any type – the existence of such radiation as only been inferred indirectly. Like the CMB, most of the energy in the CGB has been red-shifted to low frequencies. It will thus be difficult to detect the CGB directly, using gravitational-wave detectors like LIGO that have been designed to detect relatively higher frequency radiation from comparatively closer sources.

Fortunately, there is hope of detecting the CGB, and thus of probing inflation directly, by detecting the faint signature that the CGB would imprint in the polarization of the CMB. The signature is extremely faint, likely no more than a few parts per billion of the total intensity of the CMB. But recent advances in microwave technology specifically designed for CMB observations have brought the possibility within reach.

Today, thanks to a Keck Foundation grant to Andrew Lange at the California Institute of Technology, a suite of 3 mm-wave polarimeters- The Keck Array - is being developed to search for the imprint of the CGB in the CMB. The technique that the Keck Array will use has been pioneered by the BICEP polarimeter – a prototype polarimeter sited at the South Pole that was made possible in part by a generous gift from John Robinson. The Keck Array will be sited just a few hundred meters from the BICEP polarimeter. Three monochromatic polarimeters will use a powerful new detector system developed at JPL to probe 100 time deeper than the BICEP prototype.

The South Pole site is uniquely well-suited to the search. The very cleanest region of sky is visible 24/7, year round, at a convenient elevation of ~ 60 degrees from the horizon. The atmosphere is extremely dry and stable, especially during the 6 month long “night”. Last, but not least, the NSF’s Office of Polar Programs provides excellent logistical support both during the hectic 14-week long window of summer operations and during the long austral night.

The Keck Array represents a partnership among national funding agencies and private foundations, as well as among scientists. Astrophysicists and engineers from institutions in the US, Canada, and the UK—including Case Western Reserve, the University of Chicago, Stanford, the National Institute of Standards and Technology (NIST), the University of Toronto, and Cardiff University— will collaborate with Caltech / JPL on this project.

Additional funding has come from many sources: the Gordon and Betty Moore Foundation supported development of the detectors, the National Science Foundation will fund operation of the instruments at the South Pole, and funding has come from the James and Nelly Kilroy Foundation and the Balzan Foundation (research support linked to the prestigious Balzan Prize, awarded to Lange for his contributions to cosmology). Collaborators from other institutions also secured support. All of the Keck Funds will be used at Caltech.

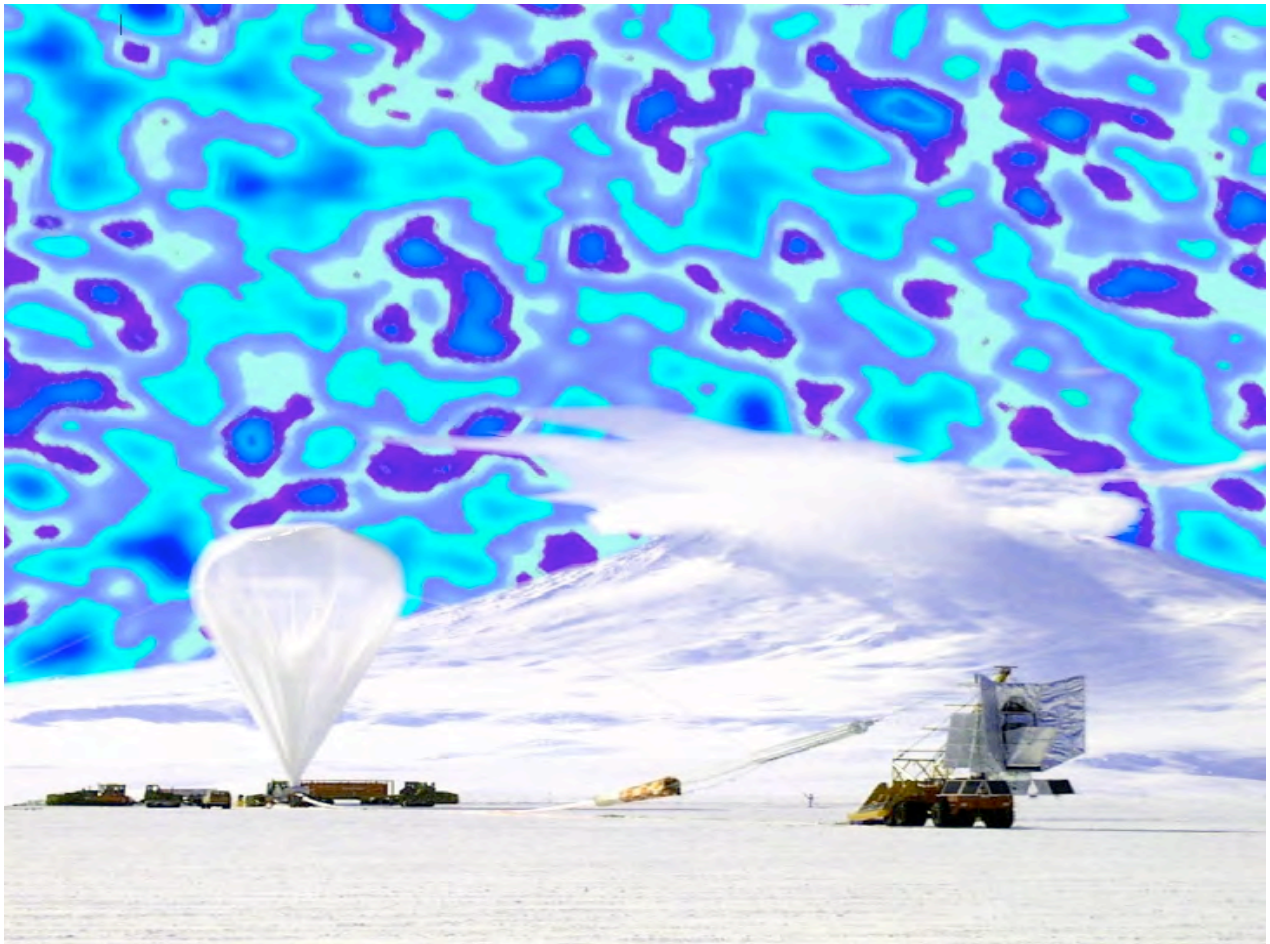

Fig 1: The intensity variations in the CMB, first resolved by the BOOMERanG experiment in 1998, during a flight over Antarctica.

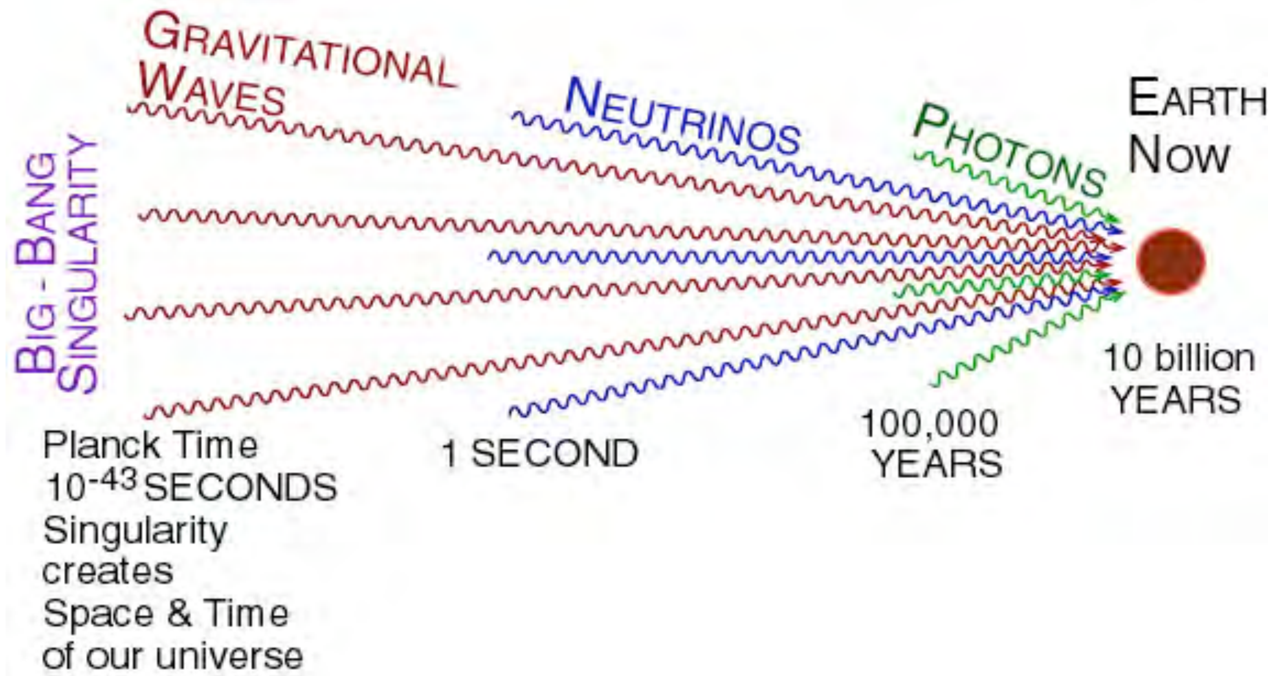

Fig 2. Gravitational radiation provides a means of seeing beyond the opaque wall of plasma at ~ 380,000 years after the Big Bang.

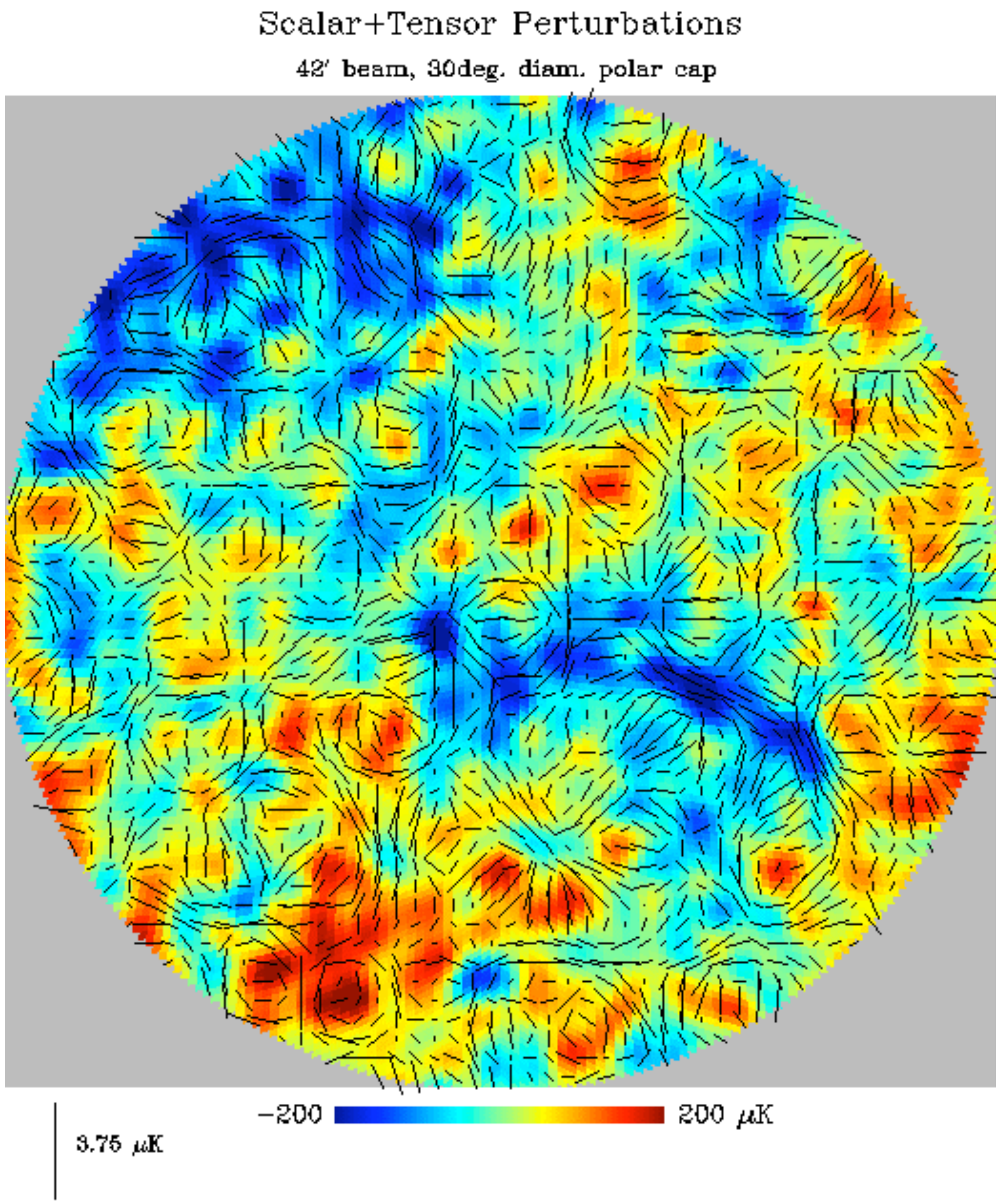

Fig 3. A simulation of the polarization of the CMB in the presence of a CGB.

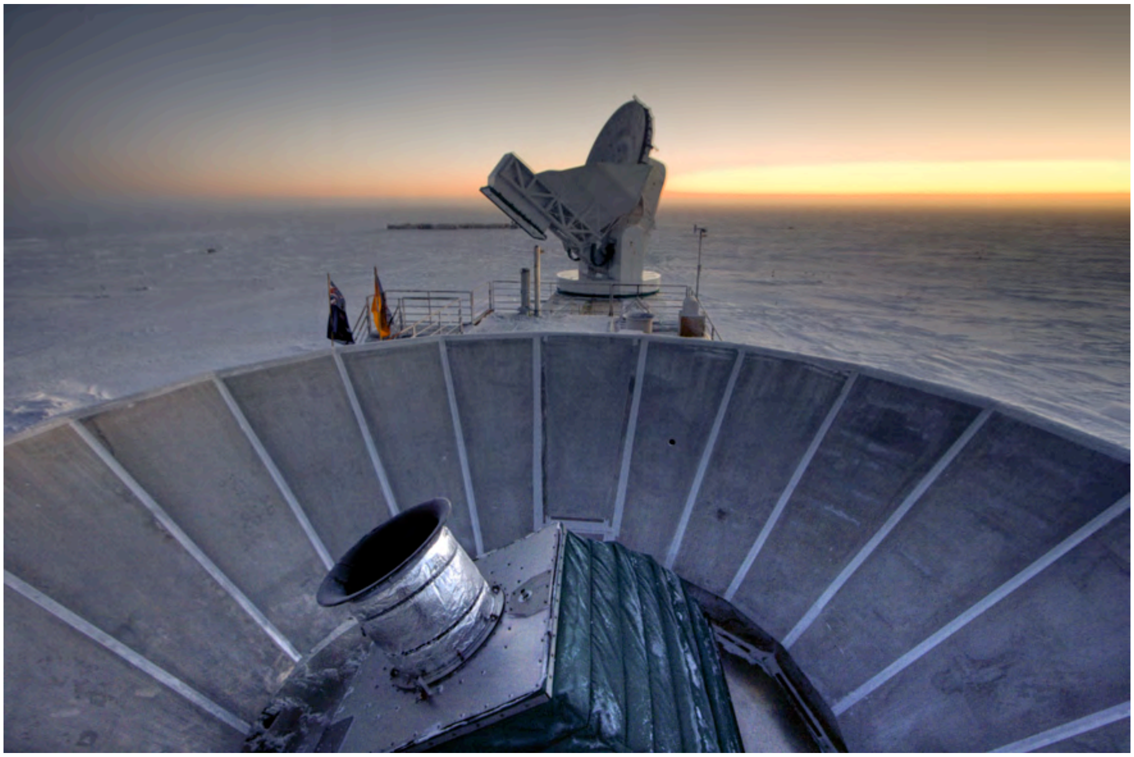

Fig 4. The BICEP prototype polarimeter (foreground) deployed at South Pole station.

Fig 5. A C-130 cargo plane taking off from South Pole station. Visible behind the runway are the 10 m South Pole telescope (large white dish) the BICEP prototype polarimeter (grey inverted cone on top of blue building) and the mount that will house the Keck Array (wooden inverted cone on far right).

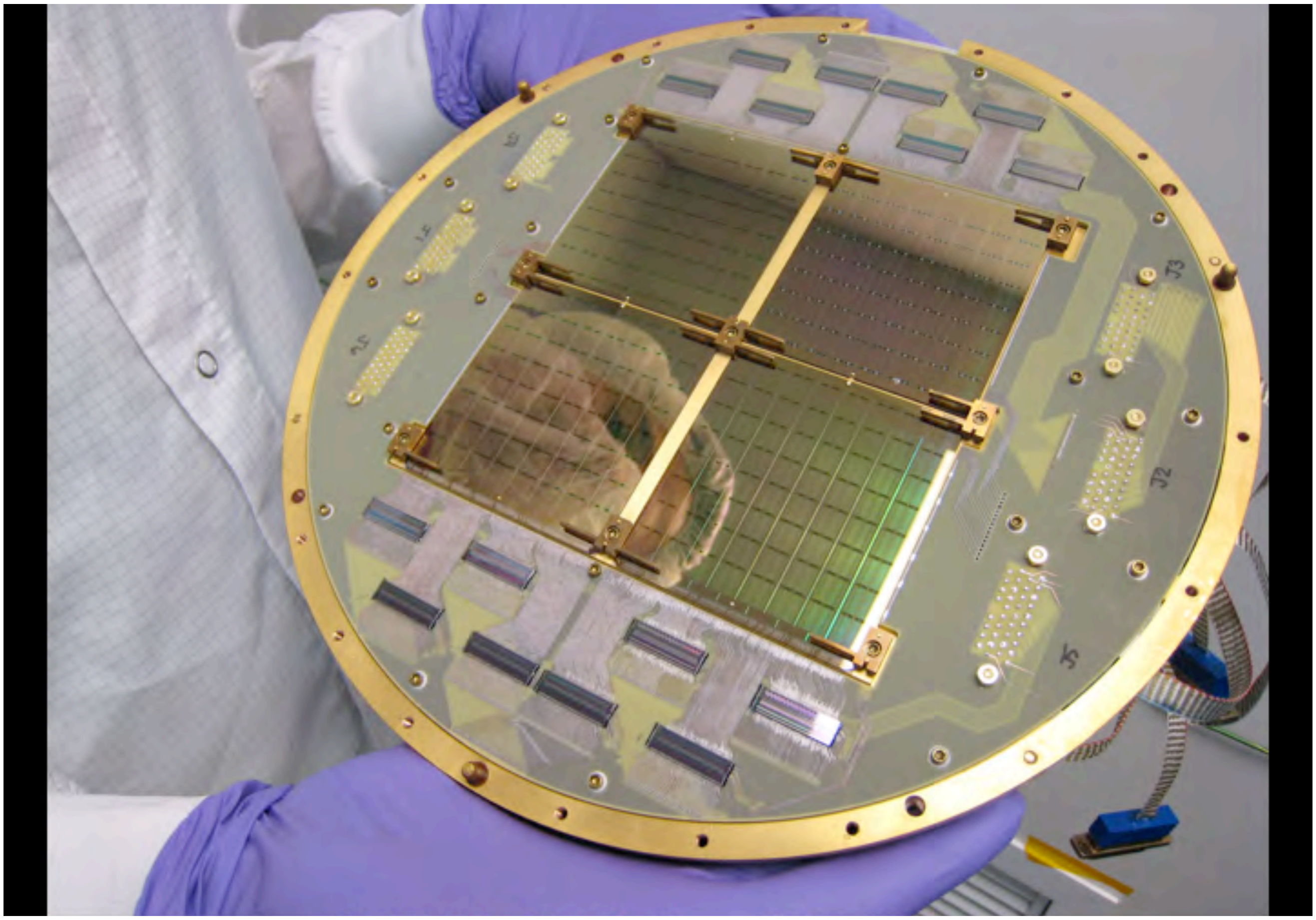

Fig 6. The advanced, polarization-sensitive mm-wave focal plane developed at JPL that will be at the heart of each of the Keck Array polarimeters.