Enabling the Sharpest Baby Picture of Our Universe

Overview/Abstract:

The Cosmic Microwave Background (CMB) is the afterglow of the birth and early evolution of the infant Universe. This afterglow is in the form of microwave light; it is invisible to our eyes but surrounds us here on Earth. Powerful telescopes on Earth and in space have been collecting this light for decades with progressively higher sensitivity and resolution. This CMB light has revealed a wealth of information about the Universe we live in. For example, it has told us the age of the Universe, what it is made of, and the geometry of the spacetime in which all galaxies and planets live. However, the CMB still holds many untapped keys that can answer fundamental physics questions. For example, the CMB contains the signatures of any new unknown light particles that were in thermal contact and equilibrium with the known standard-model particles at any time in the early Universe, all the way back to the Big Bang. Measuring this signature can tell us if new particles exist that we have so far been unaware of. Definitively making this measurement *requires unprecedented CMB telescope sensitivity* that will not be achieved by any upcoming CMB telescopes.

Another example of the information that the CMB contains is that the light of the CMB gets bent by intervening dark matter structure as this light travels to us, an effect called gravitational lensing. This CMB lensing effect can allow us to make a map of all the dark matter in the Universe down to scales smaller than galaxies. Dark matter on these small scales is not necessarily lit up by stars or gas that could trace its distribution, so this gravitational light-bending effect offers the best, and possibly the only, pathway to mapping it. Once we know the distribution of dark matter on sub-galactic scales, this can inform us about the particle properties of dark matter. This is important because physicists and astronomers currently do not understand what dark matter is. To make this high-resolution map of all the dark matter in the Universe *requires a CMB telescope with unprecedented telescope resolution*, resolution at least six times higher than will be achieved by current and near-future CMB telescopes.

In order to access the information about new light particles and dark matter contained in the CMB, the PI has proposed a new ground-based CMB experiment, called CMB-HD [1–4]. *CMB-HD would be about three times more sensitive and have six-times higher resolution, over half the sky, than the upcoming Stage 4 CMB wide-area survey.*

The objective of this proposal is to theoretically assess how well CMB-HD could probe dark matter properties and the existence of light thermal particles, by quantifying and demonstrating the mitigation of some potential systematics effects. In particular, the PI will develop and demonstrate techniques to remove astrophysical foreground contamination caused by clusters of galaxies, which contain hot gas that interacts with the CMB light and distorts its signal. In this way, some risk associated with the feasibility of the science goals of this observatory can be retired, paving the way for further concept development funding by the NSF and DOE.