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Detecting the Cosmic Microwave Background at the Frontier of Cosmology and in the Classroom

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The 3K blackbody Cosmic Microwave Background (CMB), while exceedingly faint, is the most abundant light in the Universe, permeating all of space as a relic of the hot, dense, primordial fireball. Its detection in 1965 established the Big Bang as the standard model of cosmology and earned its co-discoverers Penzias and Wilson a Nobel Prize. Over the past two decades, advances in detector technology driven by CMB research have produced telescopes with ever-increasing numbers of photon background-limited microwave detectors, capable of mapping fine structure of the CMB to micro-Kelvin precision. These have had enormous impact, determining the geometry of the universe, quantifying the dark matter and dark energy that dominate it, and detecting the faint polarization arising from the primordial seeds of structure. The current frontier is defined by new arrays of thousands of superconducting, polarized detectors producing maps approaching nano-Kelvin precision. In this decade, these measurements will answer questions about the physics driving the earliest moments of the Big Bang and will survey the large-scale structure of the universe, determining neutrino masses and constraining the nature of dark energy. The advanced detector technology fueling this frontier provides superb device-physics training for graduate students and postdocs working on current-generation CMB telescopes. At the same time, careful experimental techniques developed for CMB observations can now be combined with inexpensive high-quality satellite TV detectors to allow even undergraduates to detect the CMB, reproducing Penzias and Wilson's famous discovery. I describe one such undergraduate class at Harvard, which builds CMB telescopes from scratch in a few weeks with a modest budget, teaching students about microwave techniques and detectors and allowing them to find their own evidence for the Big Bang.