Probe of Inflation and Cosmic Origins (PICO) Science Objectives. Qi Wen[1], PICO Collaboration
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The next decade holds tremendous potential for exciting discoveries that the Probe of Inflation and Cosmic Origins (PICO) [1] will deliver. PICO is an imaging polarimeter that will scan the sky for 5 years in 21 frequency bands spread between 21 and 799 GHz. Its noise level is equivalent to 3300 Planck missions for the baseline required specifications, and our current best estimate is that it would perform as 6400 Planck missions.

With these capabilities, unmatched by any other existing or proposed platform, PICO could determine the energy scale of inflation and give a first, direct probe of quantum gravity. The mission will attempt to detect the signal that arises from gravitational waves sourced by inflation and parameterized by the tensor-to-scalar ratio, r, at a level of $r = 5 \times 10^{-4}$ (5σ). This level is 100 times lower than current upper limits, and more than 10 times lower than limits forecast by funded future experiments. If the signal is not detected, PICO will constrain broad classes of inflationary models, exclude at 5σ models for which the characteristic scale in the potential is the Planck scale, and distinguish between reheating scenarios at 3σ.

The mission will have a deep impact on particle physics by measuring the minimal expected sum of the neutrino masses, 58 meV, with 4σ confidence, rising to 7σ if the sum is near 0.1 eV. The data will either detect or strongly constrain deviations from the standard model of particle physics by counting the number of light particle species N_{eff} in the early universe. The data will enable a search for primordial magnetic fields with sufficient sensitivity to rule them out as the sole source for the largest observed galactic magnetic fields; will improve by a factor of ~300 constraints on polarization rotation arising from early universe fields that lead to cosmic birefringence, and will thus constrain string theory-motivated axions; and will constrain generic models of dark matter candidates.

PICO will elucidate the processes affecting the evolution of cosmic structures. It will measure the optical depth to reionization τ with an error $\sigma(\tau) = 0.002$ limited only by the small number of spatial modes available in the largest angular scale CMB polarization. The measurement will be used to constrain models of the formation of the first luminous sources, and is a key input to all astrophysical attempts to improve the determination of the sum of neutrino masses. The data will give a map of the projected gravitational potential due to all structures with a signal-to-noise ratio (SNR) 14 times higher than Planck, and a catalog of 150,000 clusters extending to their earliest formation redshift z. Each of these datasets will be used in combination with other data – from LSST and from future optical and infrared surveys – to independently constrain the evolution of the amplitude of linear fluctuations $\sigma_8(z)$, with sub-percent accuracy.

Cross-correlating PICO's map of the thermal Sunyaev–Zeldovich effect with LSST's gold sample of galaxies, a correlation that is forecast to have an SNR exceeding 1000, will give precise tracing of the evolution of thermal pressure with z. This will be used to place constraints on models of energetic feedback, which is the most uncertain ingredient in models of galaxy formation.

With the mission's Galactic dust polarization maps we will constrain dust properties, including compositions, temperatures, and emissivities, and we will make maps of the Galactic magnetic field. These detailed 1′ resolution maps will be used to quantify the relative roles of turbulence and magnetic fields in the dynamics of the Galaxy and in the observed low star-formation efficiency.

PICO will give full-sky maps of intensity and polarization at 21 frequency bands, each much more sensitive than Planck's nine frequency maps in intensity and seven in polarization. At 30, 155, and 385 GHz PICO's noise is 17, 40, and 100 times lower than Planck's at 30, 143, and 353 GHz, respectively. Five PICO bands will have polarization information at frequencies between 385 and 800 GHz that Planck did not have, and PICO's highest resolution is five times finer than Planck's. Only PICO will provide such full-sky legacy maps. These data will constrain the early phases of galaxy evolution by discovering 4500 strongly lensed dusty galaxies with z up to 5; investigate the early phases of cluster evolution by discovering 50,000 proto-clusters out to z~4.5; perform a census of cold dust in 30,000 low z galaxies; make cosmic infrared background maps of the anisotropies due to dusty star-forming galaxies; map magnetic fields in 70 nearby galaxies.

References:

[1] PICO website, https://sites.google.com/umn.edu/picomission/home, 2019.