Review of PICO Proposal – Nov 17, 2018

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My report focuses on just a few topics that I know well, together with high-level comments that may improve the effectiveness of the presentation. Although the quantity and quality of science from PICO is impressive, it appeared somewhat overwhelming at times. With so many listed applications to astrophysics and particle physics, the key scientific justifications may get lost to a general audience. For that reason, I suggest that you devote a portion of the introduction (or *Executive Summary)* to highlight a small number of top-priority goals of the Probe Mission. In some NASA circles, it is common to provide a single statement of what the mission will do. This gives readers the key science that must be done in case of a de-scope.

From my brief reading of the proposal science section, the most compelling arguments for the PICO mission involved the following: (1) foreground modeling of dust, facilitated by the 21 frequency channels; (2) full-sky polarization maps (> 350 GHz); (3) particle physics (neutrino masses, $N_{eff,}$ inflationary B-modes); (4) reionization physics (CMB optical depth and EE power spectrum); (5) general astrophysics (cluster S-Z, Compton y-maps, magnetic fields, dust physics; molecular cloud maps; lensed dusty galaxies, etc). Tables 1 and 2 lay out these goals in detail, but I think a more succinct overview would help reviewers understand which of this science is in the ``must-do category'' and which is ancillary.

Here are four specific comments on issues that struck me in reading the proposal:

(1) It is likely that some of the best signal will come from select parts of the sky (``cleanest'' of dust emission). At the high sensitivity of PICO, how will these be chosen? Remember the experience of the BICEP observations.

(2) Various models imply different values of the tensor-to-scalar ratio (r). It has never been clear what lower-limit would discriminate among and rule out the variety of inflation models. At what point is the experiment "enough"? Can the proposed delensing analysis actually reach the quoted "floor level" ($r > 0.001$ or even 4×10^{-4}) suggested as a goal?

(3) The proposal makes a good point about co-variance (amplitude A_s and optical depth tau) which enter the EE signal as the product, $A_s \exp(-\tau)$. Thus, getting the error level down to $\sigma(\tau) = 0.007$ is critical. What about covariance with other parameters such as neutrino mass-sum? Noise sources for modes ($l < 40$)? I especially liked the possibility of all-sky Compton y-maps (helpful for baryon census compared to galaxies) and measuring $d(\tau)/dz$. But the discussion on page 12 was vague. Please explain the gradient method better.

(4) To make progress beyond WMAP and Planck in the dust modeling, one must improve on the simple emissivity model (modified blackbody with beta = 1.6). Explain clearly how grain composition (graphite, silicate, PAH) and size distributions will be modeled. Can this really be done with only polarization diagnostics?