

**2016 ASTROPHYSICS PROBES MISSION CONCEPT STUDIES PROGRAM  
(NNH16ZDA001N-APROBES)  
PANEL EVALUATION**

**Proposal No.:** 16-APROBES16-0004

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**Proposal Title:** Inflation Probe Mission Concept Study

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**Brief Summary of Research Objectives:**

This proposal seeks funding to study an Astrophysics Probe concept to measure two properties of the CMB: the first is the polarization over the full sky, both E-mode and B-mode; the second is the CMB spectrum. To achieve these goals, two instruments, an imager and a spectrometer, would be studied.

The primary science goal is to detect the B-mode polarization signal expected from gravitational waves produced during cosmic inflation, if that signal, characterized by  $r$ , exceeds  $\approx 10^{-3}$ . This target is nearly two orders of magnitude fainter than the current upper limit on  $r$ . If detected, the measurement would directly probe physics at energy scales far beyond that attainable by any other foreseeable method. The mission also seeks to place important constraints on dark matter properties, the number of light relic species, neutrino mass, and the reionization history of the universe. Indeed, new research in the past decade has shown that detecting the cosmological signature of a minimum non-zero neutrino mass at  $3\sigma$  is within reach of upcoming CMB experiments, but *only if* we also have a cosmic variance-limited measurement of the large-scale E-mode polarization signal. A space mission is likely required in order to produce the latter.

The primary challenges for the mission are confusion from foreground sources, and the need to control stray sources of polarized emission. The mission is intended to produce the definitive all-sky map at all scales larger than a few arc minutes, but the team will evaluate the mission requirements in the context of ongoing sub-orbital programs, paying special attention to developments with the proposed CMB-S4 suite of experiments. Once optimized mission requirements are defined, the team will undergo a detailed design exercise with Team X at JPL.

**OVERALL ADJECTIVAL RATING: Very Good**

## **DETAILED FINDINGS**

### **Major Strengths:**

- The scientific merit of the stated goals is strong. A detection or characterization of a primordial B-mode polarization signal is of enormous interest. Next-generation measurements of the CMB spectrum may provide a unique window to search for the effects of light relics, the detection of which would be stunning. The determination of the summed neutrino mass would be a highly interesting result.
- The team consists of highly-experienced members of the CMB community, representing all the major areas of expertise required to carry out a successful mission concept study, including experimentalists, analysts, and theorists.
- The team covers a range of CMB experience from space missions, balloon-based instruments, and ground-based projects; the team's breadth of expertise allows for the optimization of a mission to best complement contemporaneous sub-orbital efforts. The proposed workshop to assess the synergy of a CMB Probe with the various sub-orbital efforts is an important aspect of the proposed study.

### **Major Weaknesses:**

- The proposed science case is based on a combined imager and spectrometer mission, but the proposal does not present convincing evidence that this combined mission could be achieved within the required cost cap, though the proposal shows that a mission based on either one of these instruments could. The proposal does not clearly delineate which science goals rely on which instrument, does not expressly discuss descope options, does not describe the process for selecting such options, and does not discuss what impacts a descope would have on the scientific objectives.

**Minor Strengths:**

- The field has advanced since the last decade, especially in our knowledge of the polarized foreground emission, and in the detection of non-primordial B-mode polarization. The community has also gained experience in working with polarization-focused measurement technologies and has learned a great deal about systematic error control. Many of the proposal team members have been directly involved in producing those advancements. Integrating this knowledge into a new Probe concept is very timely and valuable.
- The proposed foreground models are sophisticated, and well informed by recent measurements from *Planck* and related experiments. These models will be an important aspect of the proposed study.
- This proposal is relevant to the ROSES APROBES solicitation.
- The labor and procurements proposed here are reasonable to accomplish the goals of this proposal.

**Minor Weaknesses:**

- The large size of the team could prove to be unwieldy, and some of the working groups have dependencies which will require significant coordination.
- The proposal does not make clear whether the trade studies by the working groups will be completed in time to maximize the usefulness of the workshop.
- The science goals of this proposal are at risk of being substantially achieved through a combination of sub-orbital observations at high  $l$ , a mission like LiteBIRD to characterize low  $l$  polarization, and PIXIE to investigate the CMB spectrum.
- The proposal did not specifically address potential systematic issues with the spectrometer.

**COMMENTS OR SUGGESTIONS FOR THE PROPOSER (Optional):**

None.