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# 1 Scientific, Technical, and Management Section

0.5 page. Executive Summary

## 1.1 Science Objectives

5 pages for all science goals including the (temporary) two sections below.

### 1.1.1 The Inflationary Gravity Wave Background

The verbiage below is taken from another proposal. Here we need to explain what are the science objectives of the CMBProbe, how the science objectives relate to the current state of knowledge, and to NASA's goals

The paradigm of inflation [1–5] makes several predictions that are consistent with all current astrophysical measurements [6–9]. A robust prediction of inflation is the existence of a stochastic background of gravitational radiation with an amplitude depending on the mechanism driving the accelerated expansion [10–14]. In most scenarios, this ‘inflationary gravity wave background’ (IGB) is predicted to have a spatial power spectrum whose amplitude is proportional to the energy scale of inflation  $V^{1/4}$  via  $V^{1/4} = 3.7 \times 10^{16} r^{1/4}$  GeV, where  $V$  is the inflaton potential and  $r$  is the ratio of the temperature quadrupoles produced by gravity waves and by density perturbations. There are theoretical reasons  $V^{1/4}$  may be close to the Grand Unification scale of  $10^{16}$  GeV, suggesting detectable  $r$  values between  $\sim 0.001$  and  $\sim 0.1$ . In addition to determining the energy scale of inflation, measurements of the IGB probe the scalar field potential at or above the Planck scale, which is particularly relevant for inflation models motivated by string theory [15]. Measurements of the IGB thus probe fundamental physics at the highest possible energy scales.

The most promising way to search for the IGB is through its signature on the CMB polarization [16, 17]. Primordial energy density perturbations produce only a curl-free, or ‘E-mode’, pattern of polarization. Gravity waves also produce a curl, or ‘B-mode’, pattern of polarization that density perturbations cannot produce [18, 19]. The amplitude of the B mode is related to the energy scale of inflation by  $V^{1/4} = 2 \times 10^{16} (B_{peak}/0.1 \mu\text{K})^{1/2}$  GeV, where  $B_{peak}$  is the amplitude of the power spectrum of the B mode in  $\mu\text{K}$  at  $\ell = 80$ ; see Fig. ???. In its recent report New Worlds New Horizons (NWNH), the decadal survey committee strongly endorsed sub-orbital searches for the B-mode signal from inflation saying that “The convincing detection of B-mode polarization in the CMB produced in the epoch of reionization would represent a watershed discovery.” [20]

B-mode signatures near the expected IGB peak at  $\ell = 80$  have recently been detected by BICEP2 [21]. However, the combination of Planck data with those from the BICEP2 and Keck Array collaborations have demonstrated that the B-mode signal measured is entirely consistent with contributions from polarized emission of Galactic dust and the signal from the gravitational lensing of CMB photons by the large scale structure of the Universe (see Section ??) [?, 22, 23]. These data give an upper limit of  $r < 0.09$  at 95% confidence level. Most importantly, the constraint is largely limited by Planck’s noisy measurement of the dust properties in the 353 GHz band; a noiseless dust map could shrink the constraint by a factor of two [22]. Further progress — detections or improved limits — requires instruments with higher sensitivity at *both* the dust and CMB frequency bands so that this Galactic foreground can be properly identified and removed.

### 1.1.2 Other Science Goals (Spectrum, Lensing, Neutrinos, ...)

Here we write about other science goals. This structure – inflation and ‘other’ – is temporary. ‘Other’ can be on the same footing as inflation.

## **1.2 The Challenges: Foregrounds, systematics**

3 pages. Discuss the challenge of Foregrounds and Systematics.

## **1.3 Current and Forthcoming Efforts and the CMB Probe**

2.5 pages. S3 experiments, forthcoming S4, Baselines CMB Probe options and their complementarity with S4.

## **1.4 State of Technologies**

2 pages. Discuss the technologies, their TRL, and what will be studied

## **1.5 Mission Study, and Management Plan**

1.5 pages; Describe what we want to do, who is doing what, what we are funding

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## **2 Curriculum Vitae**

### 3 Summary of Work Effort

Summary of Personnel and Work Efforts, (Page 1 of 2)					
Personnel	Budgeted Effort/Year (months)				
	Year 1	Year 2	Year 3	Year 4	Year 5
University of Minnesota					
Hanany, PI	1/1	1/1	1/1	1/1	1/1
Cal Tech					
Jamie Bock, Co-I	0.25	0.25	0.25	0.25	0.25
Princeton					
Lyman Page, Co-I	1/1	1/1	1/1	1/1	1/1
Goddard Space Flight Center					
Al Kogut, Co-I	0.75	0.75	0.75	0.75	0.75
<sup>1</sup> PDR = Post-Doctoral Researcher;					
<sup>2</sup> GSRA = Graduate Student Research Assistant;					

Table 1: Personnel, time in months on the project funded by NASA/time in months on the project not funded by NASA, and their role. When only one time value appears it is time funded by NASA. **Continued on next page.**



Summary of Personnel and Work Efforts, (Page 2 of 2)					
Personnel	Effort/Year (Months)				
	Year 1	Year 2	Year 3	Year 4	Year 5
<a href="#">Johns Hopkins</a>					
Chuck Bennett, Co-I	0.5	0.5	0.5	0.5	0.5
<a href="#">NIST</a>					
Hubmayr, Co-I	0/0.25	0/0.25	0/0.25	0	0
<a href="#">Lawrence Berkeley National Lab</a>					
Borrill, Collaborator	0	0	0	0	0

## **4 Current and Pending Support**

## **5 Letters of Support**

## **6 Budget Details - Narrative**

### **6.1 Team, and Work Effort**

#### **6.1.1 Funded Team Members**

#### **6.1.2 Non-Funded Team Members**

### **6.2 Costing Principles**

- **Summer Salaries:**
  - **Workshop:**

### **6.3 University of Minnesota Budget**

#### **6.3.1 Direct Labor**

#### **6.3.2 Supplies**

#### **6.3.3 Travel**

#### **6.3.4 Other Direct Costs**

**Publications and Teleconferencing**  
**Other Subcontracts**

#### **6.3.5 Facilities and Administrative Costs**

## **7 Budget Sheets**