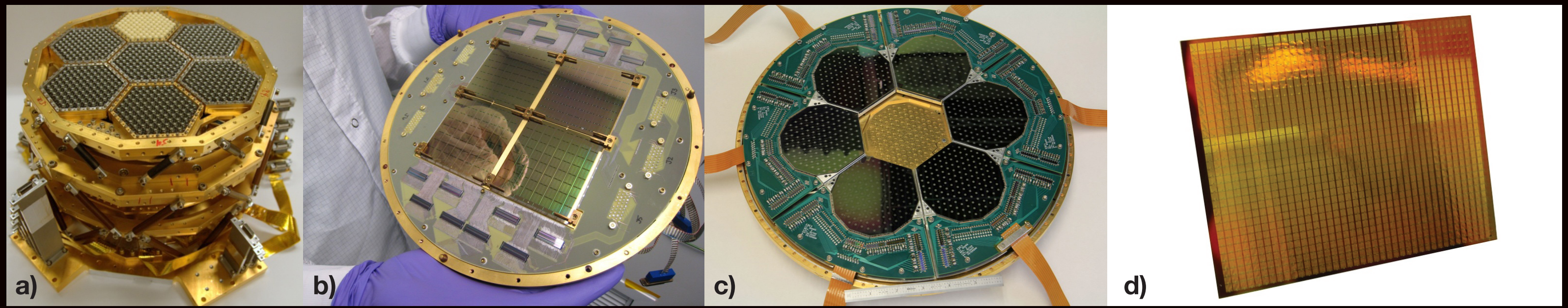


New technology incorporated in large-format multicolor focal plane detector arrays enables the Inflation Probe. Collaborations throughout the U.S. are advancing detector and readouts, and operating these new technologies on pioneering CMB polarization experiments. Elements of these technologies are widely applicable to NASA astrophysical far-infrared and X-ray missions.

a) Lens-coupled transition-edge sensor (TES) array developed for the ground-based POLARization of the Background Radiation (POLARBEAR) experiment
b) Antenna-coupled TES array developed for the ground-based Keck Polarimeter Array and the Spider balloon payload
c) Absorber-coupled TES with feedhorn arrays developed for the EBEX (E and B Experiment) balloon payload
d) Absorber-coupled bolometer array developed for balloon-borne Primordial Inflation Polarization Explorer (PIPER)
e) Silicon stacked feedhorns developed for the Atacama Cosmology Telescope's polarization-sensitive TES bolometer array

Advanced multiplexing leads to another leap in array formats, enabling new capabilities for future NASA infrared and X-ray missions and benefitting the Inflation Probe.

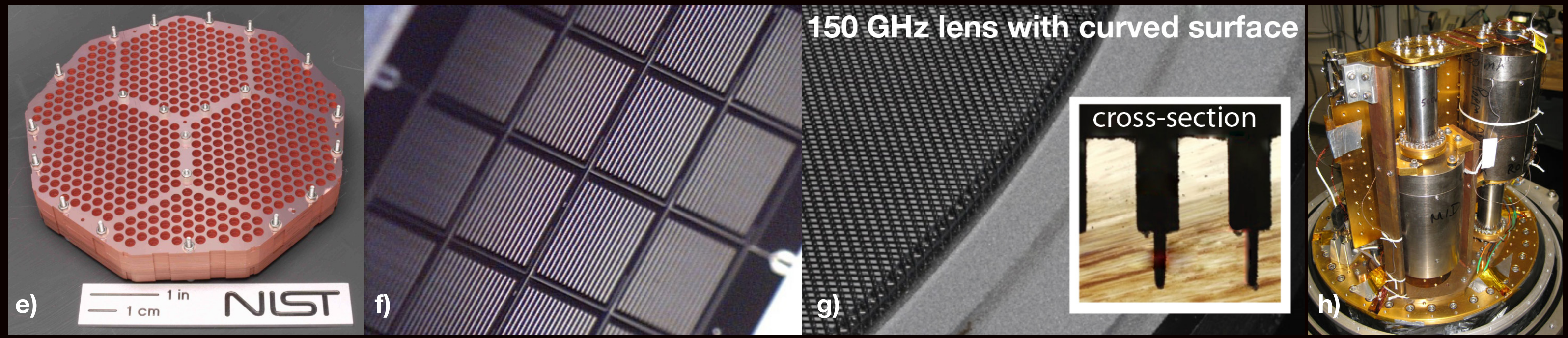
f) Microwave Kinetic Inductance Detectors (MKID), shown here, and TES bolometers with Superconducting Quantum Interface Device (SQUID) amplifiers increase the multiplexing factor by using a comb of radiofreqency signals on a single readout.

Novel designs and anti-reflection coatings will advance high-throughput wide-bandwidth optics.

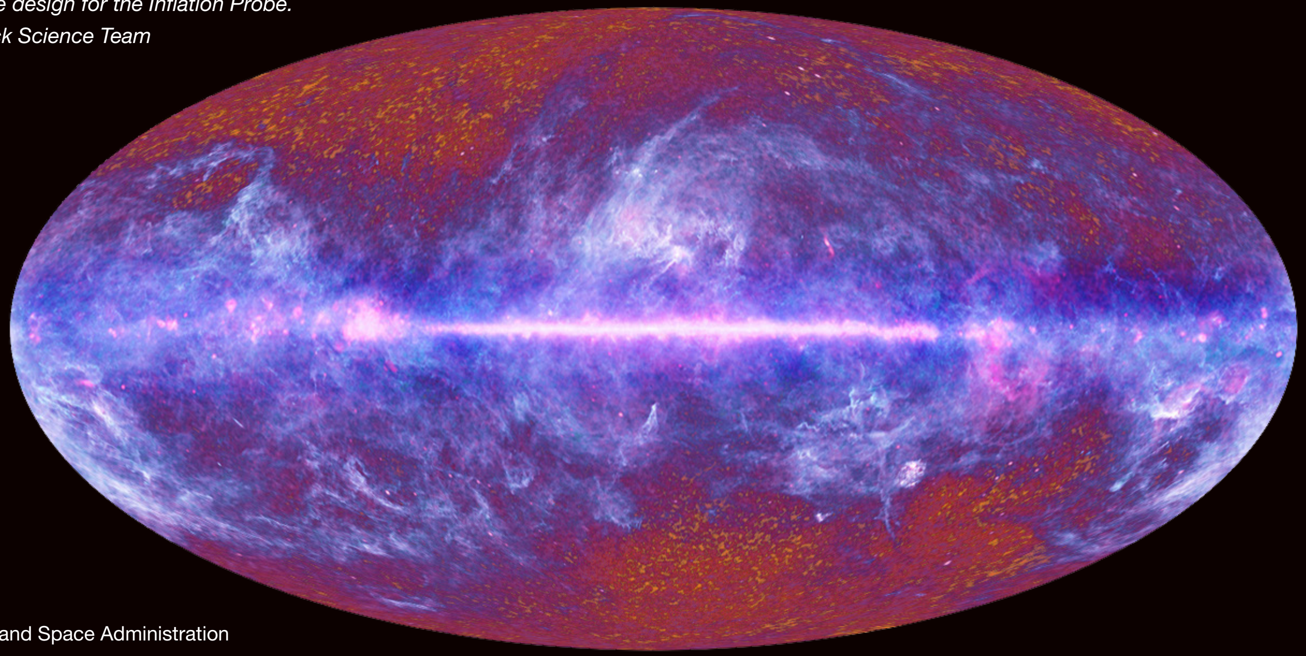
g) Machined grooves in a silicon lens are used to make a broadband anti-reflection coating.

Continuous cooling in stages from ambient to 100 mK will leverage space-qualified technologies for improved performance.

h) 100 mK cooling system developed for PIPER



The Planck CMB polarization data will set the scientific stage and guide the design for the Inflation Probe. Image credit: Planck Science Team



National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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NASA's Physics of the Cosmos Program

Inflation Probe: Revealing the Birth of the Universe

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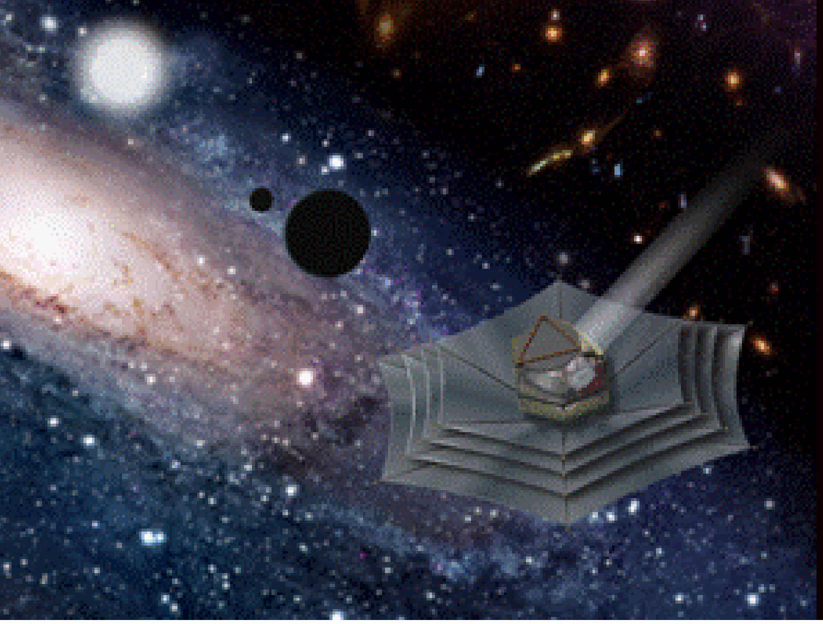
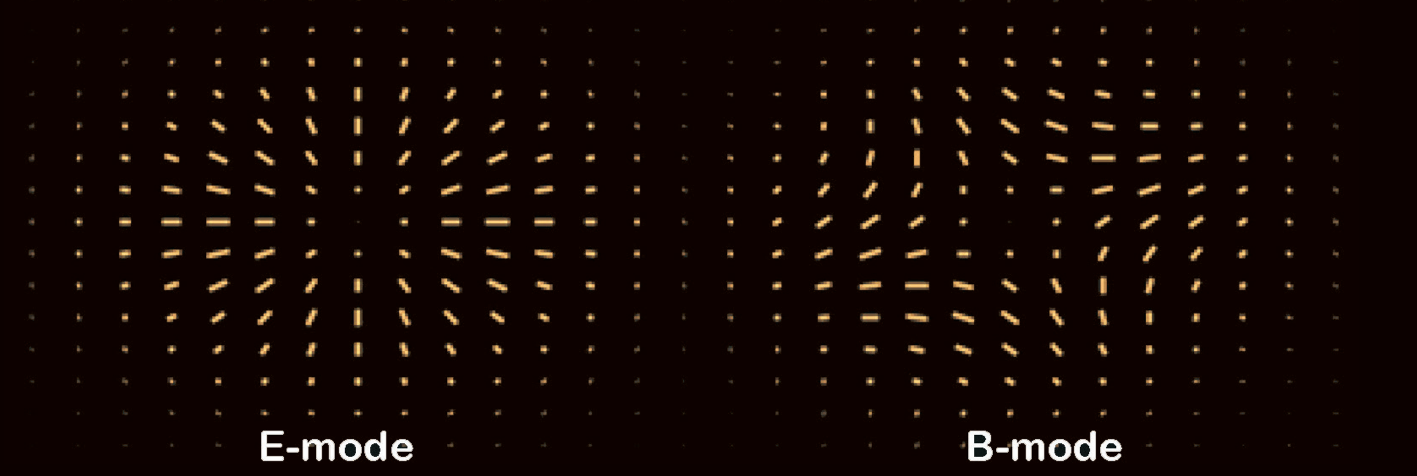


The Inflation Probe will pursue the polarization signature associated with the inflationary gravitational-wave signal. ***A detection of primordial gravitational waves will establish inflation as the source of cosmological perturbations and connect inflationary models to fundamental physics.***



Light from the cosmic microwave background (CMB) is partially polarized. Density fluctuations in the early Universe only give a polarization signature that does not have a preferred handedness (E-modes). Gravity waves from inflation will also produce polarization having a handedness (B-modes). ***Thus measurements of the polarization of the CMB provide a direct probe of the physics at the earliest observable instants of our Universe.***

Modern cosmology has sharpened questions posed for millennia about the origin of our cosmic habitat. The age-old questions have been transformed into two pressing issues primed for attack in the coming decade: How did the Universe begin? What physical laws govern the Universe at the highest energies and earliest times?

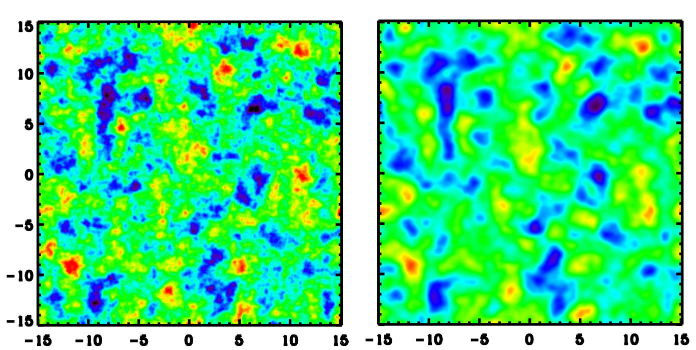
Since its discovery close to 50 years ago, the cosmic microwave background (CMB) has become a pillar of Big Bang cosmology. An integral element of this cosmology is the existence of a period of inflationary expansion that took place a small fraction of a second after the beginning of time and at energy scales that may far exceed those achievable with terrestrial particle accelerators. Quantum fluctuations during this period are the origin for all matter distribution in the Universe today. Inflation directly bears on the current frontiers of fundamental physics: the union of general relativity and quantum mechanics, string theory, and the highest accessible energies.

Revealing the birth of the Universe

Many models of inflation predict that an appreciable gravitational-wave signal has permeated the Universe. The gravitational-wave amplitude is directly tied to the energy scale during inflation. Therefore detection of this signal can be translated into clues about the new physics responsible for the origin of structure in the Universe. ***The Inflation Probe is an unparalleled probe of physics at the highest energy scales, and during the epoch of cosmic inflation.*** A detection of inflationary gravitational waves would

- Rule out alternatives to inflation,
- Pinpoint the energy scale at which inflation took place,
- Provide clues about the symmetries underlying new physics at energy scales a trillion times larger than those presently achievable in terrestrial accelerators.

The *Astro2010 Decadal Survey* described the search for inflationary gravity waves as “the most exciting quest of all.”



With its unmatched sensitivity, the Inflation Probe will image the gravitational-wave signature of the entire sky. Left: a 30 x 30 square degree simulation of the gravitational-wave (B-mode) signal. Right: Reconstructed Inflation Probe map. Color scale +/- 400 nK

Reionization

The young Universe was dominated by atomic hydrogen, but is now completely ionized. When and how did this transition occur? Are the earliest galaxies, observed now with the Hubble Space Telescope and soon with the James Webb Space Telescope, responsible for ionizing the Universe? Recent data indicate a reionization transition at redshift z~10, but there is a large uncertainty on this value and on the exact reionization history. Ground and suborbital experiments will be unable to greatly improve upon this result due to the limited sky coverage area and the intervening foregrounds. With its full sky coverage, the Inflation Probe will provide a CMB cosmic-variance limited measurement of the reionization process, thus leading to a factor of > 5 improvement over the state of the art in the determination of the integrated optical depth. ***The Inflation Probe will provide the crucial insight into whether or not the observed galactic emission is consistent with our present understanding of the epoch of reionization.***

E-mode polarization

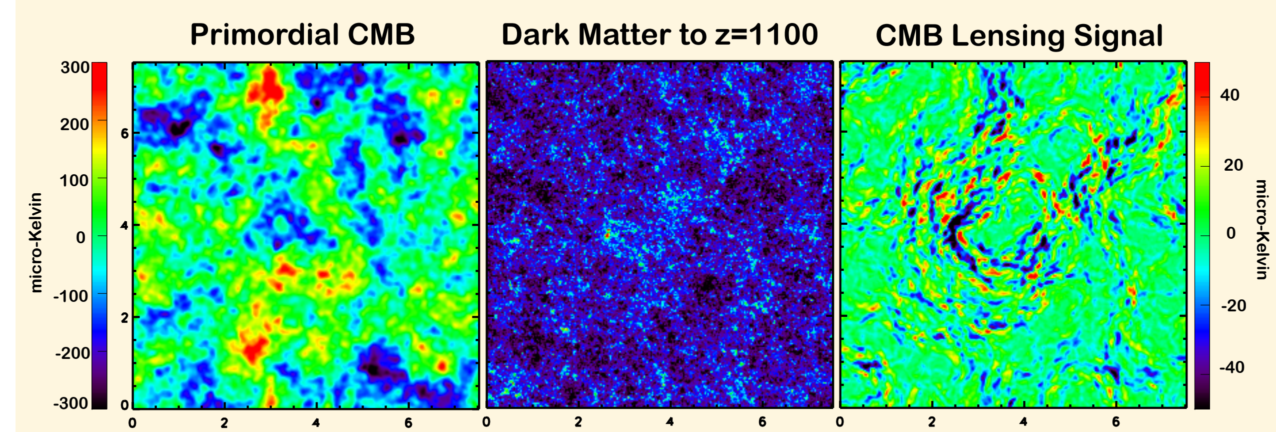
The Inflation Probe will extract all of the information encoded in the CMB and the E-mode polarization out to the limit of the beam resolution. Inflation predicts that the primordial energy density fluctuations have almost no preferred spatial scale. Any deviation from perfect scale-invariance is a powerful discriminator between different inflationary mechanisms. ***With its high sensitivity, the Inflation Probe will measure deviations from scale-invariance to an accuracy of 10^{-3} and will provide strong discrimination between inflationary models.***

Current data indicate that the Universe is spatially flat. However, string-theory landscape models predict fluctuations in the spatial curvature at the level of 10^{-4} to 10^{-5}. The Inflation Probe’s high-precision polarization data will constrain departures from a spatially flat Universe at a level of one part in 10^5. ***The Inflation probe is a test-bed for string-theory landscape models***.

Cosmic shear

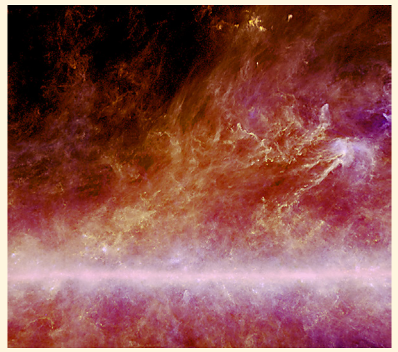
As CMB photons travel through the Universe toward our telescopes, their paths are distorted due to the gravitational interactions with intervening mass. This gravitational lensing distortion converts some of the E-mode to B-mode polarization. The B-mode signal from lensing is most prominent at angular scales of few tens of arcminutes and provides a unique probe of the integrated mass distribution, or projected gravitational potential, along the line of sight. With a full sky map of the projected gravitational potential, the Inflation Probe will determine or constrain the sum of the neutrino masses to < 0.05 eV. This level is competitive with the best limits anticipated from terrestrial particle physics experiments and is motivated by atmospheric neutrino oscillation data. ***The Inflation Probe will make a definitive cosmological measurement of the sum of the neutrino masses.***

These CMB measurements are a legacy product that will be used for all future measures of large-scale structures such as surveys based on weak lensing and baryonic acoustic oscillations. Because CMB lensing depends on the integrated potential out to the last scattering surface, it is more sensitive to an early dark energy component in the Universe than are traditional galaxy surveys. ***CMB lensing studies with Inflation Probe will provide the best constraint on the presence of dark energy at redshifts > 3.***



Gravitational lensing modification to the CMB temperature fluctuations. The primordial CMB (left) is gravitationally lensed by the integrated dark matter mass distribution out to z=1100 (middle). The resulting lensing effect (right), which can be probed with higher fidelity by the polarization signal, is a sensitive probe of massive neutrinos and dark energy.

Mapping galactic magnetic fields



Large-scale magnetic fields are believed to be important in galactic dynamics and in the formation of stars. However, relatively little is understood as to the nature of these fields and the details of their interaction with other galactic constituents. The superb sensitivity, high resolution, and frequency coverage of the Inflation Probe will provide polarization maps that are of great interest to astronomers studying the role of magnetic fields on galactic scales. In its highest frequency bands, the Inflation Probe is primarily sensitive to the polarization of dust grains in the interstellar media of galaxies. The polarized emission from these dust grains reveals the geometry of the magnetic fields. ***The broad spectral coverage of the Inflation Probe polarization maps will answer fundamental questions about how magnetic fields regulate star formation and galactic dynamics, both in our own Milky Way and in other galaxies in our local neighborhood.***