1. Overview

- Proposed balloon-borne mm-wave polarimeter to study the CMB, the CBG, and Galactic dust emission, with first flight planned for 2017.
- Launching from ESANGE facility in Karas, Sweden, observation program consists of at least two 5-day Northern hemisphere flights (one at 150GHz, the other at 260 and 340 GHz).
- Camera housed in robust gondule designed for rapid deployment and recovery, enabling quick turnaround and multiple flights.
- Each flight will deploy one of 2 focal plane configurations, each with 2137 single-polarization, horn-coupled, aluminum-lamped-element kinetic inductance detectors (LEKIDs).
- Fully enclosed optical system cooled to 1K to minimize detector loading and maximize detector sensitivity.
- Best sensitivity (lowest NET) of any CMB polarimeter to date, yielding sensitivity to detect or place 5σ upper limit on cosmological B-modes to r = 0.02 after two flights.

2. Observation Strategy, Calibration, and Beam Mapping

- Retractable polarized grid at aperture stop enables accurate measurement of polarization angles and absolute calibration accomplished via comparison with WMAP and Planck maps.
- Calibration and beam for r = 0.1 and r = 0.01.
- Contamination assuming 5% without foreground separation.
- Filled Circles 99% confidence.
- Optical system fully enclosed within LN2 (77K, valved to atmospheric pressure) & LHe (1.5K, open to ambient pressure) cryostat, and cooled to 18K.
- Detector array cooled to 100mK using ADR, and fed by F/2.4 crossed LEKID array with 500mm aperture, yielding 15cm FWHM beam at 150GHz.
- One-meter long snout at cryostat top house radiation shield cooled to 77K to terminate side lobes, while shorter –1.5K snout intercepts horn beams to –70dB, minimizing loading on detectors.

3. Science

- Open Circles: Sensitivity assuming 5-day 150 GHz flight in addition to single foreground flight, including degradation due to component separation. Provides measurement of r < 0.02 at 99% confidence.
- Filled Circles: Sensitivity of 150GHz flight alone without foreground separation.
- Gray Band: Spectrum of Galactic foreground contamination assuming 99% B-dichroic polarization fraction for ~113 deg. CMB field.
- Dashed Line: Inflationary B-mode power spectrum for r = 0.1 and r = 0.01.
- Dotted Line: Anticipated CMB B-mode limiting signal.
- Single 150GHz flight will constrain r < 0.05 assuming dichroic polarization fraction of 10%.

4. Cryogenics and Optics

- Left: 2560mm aperture GBAD (crosshairs indicate operating point).
- Right: MAST camera, 500mm x 500mm field of view.
- Top: Simulated beam patterns over focal plane.
- Bottom: Simulated beam patterns over focal plane contact.
- Optical system fully enclosed within LN2 (77K, valved to atmospheric pressure) & LHe (1.5K, open to ambient pressure) cryostat, cooled to 18K.
- Detector array cooled to 100mK using ADR, and fed by F/2.4 crossed-Dracene-beam with 500mm aperture.
- One-meter long snout at cryostat top house radiation shield cooled to 77K to terminate side lobes, while shorter –1.5K snout intercepts horn beams to –70dB, minimizing loading on detectors.

5. Lumped-Element Kinetic Inductance Detectors (LEKIDs)

- Recent experiments have demonstrated that LEKIDs provide competitive NEP with time constant, while significantly reducing cost, complexity, and development risk.
- Left: 2nd generation 400 GHz low-noise, broadband, crossed-LEKID array for MAVIC 100mm camera.
- Right: MAST camera, 500mm x 500mm field of view, using a detector array with 150GHz band indicated. Inset shows prototype low-leakage signal mesh HWP to quickly modulate infrared signal.
- Comparator: detector layout across one module of focal plane.
- Right: 7 modules stacked in focal plane.

6. Polarimetry and Electronics

- Fast response-time of LEKIDs allows for continuously rotating metal-mesh HWP to quickly modulate linearly polarized sky signal, resulting in extremely low levels of systematic errors.
- 350um, obtained on 2013-01-04.
- Aluminum LEKID pixel consisting of microwave Josephson junction and superconducting quantum interference device (SQUID) band shown in gray.
- Contributions to detector NEP are generated-oscillation (g-r) noise, two-level system (TLS) noise, and amplifier (amp) noise. Total NEP includes contribution from photon noise.

7. Systematic Error Mitigation

- Fast response-time of LEKIDs allows for continuously rotating metal-mesh HWP to quickly modulate linearly polarized sky signal, resulting in extremely low levels of systematic errors.
- End-to-end simulation of pointing reconstruction using measured sensor noise and accuracy predicts that B-mode induced by pointing errors contributes to significantly less than 10% of anticipated cosmological B-mode signal, assuming r = 0.01.

8. Key SKIP Performance Characteristics and Strategies

- Adopted successful practices include a crossed-Dracene optics design, completely cooled optics, a double-window mechanism, metal-mesh IR-blocking filters, redundant star cameras, and low-noise gyroes.
- SKIP will be the first to employ the following design strategies: LEKIDs in a CMB experiment, 500mm long focal plane, 500mm window mechanism, metal mesh, low-power dissipation mode for driving HWP on superconducting magnetic bearing, and novel calibration strategies.