

PICTURE-C: A Balloon-borne Optical MKID Camera



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We present PICTURE-C, a NASA-funded mission to fly optical MKIDs on a balloon to observe circumstellar debris disks of three nearby systems in scattered optical light in 2019. UC Santa Barbara is developing the 10,000 pixel MKID array, cryostat, and readout electronics. The PtSi MKIDs will be optimized for 600nm with a 20% bandpass, and will be read out with five feedlines by ten ROACH2 and custom ADC/DAC boards. The balloon will launch from Fort Sumner NM and fly for ~24 hours, carrying the MKIDs for one night at an altitude of ~40 km. The Wallops Arc-Second Pointing system on the gondola will support a 0.6 meter primary mirror and the MKID cryostat, as well as deformable mirrors for wavefront correction and a Vector Vortex Coronagraph to suppress the on-axis starlight.

Introduction

- Young stars often have debris disks, which can scatter light in the optical and other wavelengths.
- Debris disks are "signposts" for planet formation.
- Scattered light may present significant limitations on the contrast ratio one can achieve, even with an ideal instrument. Characterizing scattered light from debris disks will be important for setting detection limits of exoplanets, especially exo-earths in the optical and near IR • Planetary Imaging Concept Testbed Using a Recoverable Experiment – Coronagraph (PICTURE-C) is a mission that will use adaptive optics, a coronagraph, and an optical MKID camera to observe and characterize the scattered light from nearby debris disks • We will observe 3 targets during 1 night in September 2019 from a balloon Alpha Aquilae (Altair) Tau Cet • Eps Eri Launch location: Fort Sumner, NM Flight Duration: ~24 hrs • Observing time: ~12 hrs, while sun is down • Umass Lowell is constructing the pointed section of the payload, including Optical surfaces • Wavefront controllers



• UCSB is constructing the MKID camera

Wavelength	600 nm	
Bandpass	20% (540nm to 660nm)	
Inner Working Angle	1.5 λ/D = 0.34"	
Contrast at IWA	10-7	
Resolution ($\lambda/\Delta\lambda$)	20]

MKIDs

- Microwave Kinetic Inductance Detectors provide:
 - µs photon timing resolution
 - Energy resolution
 - Image
- Array and resonator design will be adapted from DARKNESS instrument
 - 10,000 pixels
 - 5 feedlines
 - 2,000 pixels/feedline, ~2 MHz spacing to cover 4-8 GHz range.
 - Sputtered and annealed PtSi
 - 100 mK operating temperature \bullet
 - Microlens will focus light onto inductor to bring fill factor to ~90%
 - Platinum silicide
 - test chips have internal quality factors of $Q_i > 10^6$
 - $T_c \sim 940 \text{ mK}$

- FOV = $10 \lambda/D$
- Contrast < 10⁻⁷
- 32x32 actuator high order deformable mirror
- 76 actuator and tip/tilt/piston low order wavefront control
- Low order wavefront control will use speckle information to actively maintain a "dark hole" in the focal plane where unwanted starlight will be suppressed by ~2 orders of magnitude compared to the rest of the focal plane
- Vector vortex coronagraph will suppress on-axis starlight
- ~f/600 beam on MKID





- ~20 µs quasiparticle lifetime
- With low order wavefront control, one can remove quasistatic • speckles to achieve raw contrast ratios of $\sim 10^{-7}$
- With post-processing, it is possible to use MKID data to further improve the effective contrast ratio and detection limits



Balloon and Payload

- Short duration zero-pressure helium balloon
- Wallops Arc-Second Pointer (WASP) will keep pointed on target
- Observing altitude ~40 km

Outside pressure ~1 mbar

Ambient temperature -20°C

(enclosure not shown)



250 300 Speed of sound (m/s)

200 250 Temperature (K)

M2 + Hexapod



WASP interface

structure

NASA

MKID

(mounting bracket not

/shown)



Cryostat

- Custom liquid helium/nitrogen cryostat
 - Manufactured by Precision Cryogenic Systems
- Designed hold time ~50 hrs
- ADR insert, manufactured by High Precision Devices
- ~115 kg full
- NbTi flex cables from 4 K to 100 mK for low loss and low thermal loading
 - ~20 cm length on input and output of device
 - < 3 dB loss
- 5 HEMTs with ~40 dB of gain at 4 K by Low Noise Factory
- Option for integrating with Cryomech pulse tube cooler for reducing liquid helium consumption in the lab.

coupling capacitor Microwave feedline

Readout

- Pulse detection readout based on ARCONS and DARKNESS firmware
- 10 ROACH2 boards
- 10 custom ADC/DAC boards
- 10 custom IF boards
- ~1400 W power dissipation while running

Real Ulbricht + 2015

M1 + Mount Electronics



Avionic

Trim weights