HAWC: The facility far-IR camera for SOFIA

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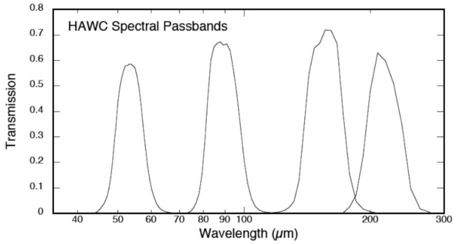
Introduction:

HAWC is the facility far infrared imager for SOFIA. It is designed to cover the peak emission from interstellar dust grains that emit most of their energy in the 40-300 micron spectral region that is inaccessible from the ground. It is currently configured with four spectral bands centered at 53, 88, 155, and 215 microns. In each band, the detector is re-imaged such that there are approximately two pixels per beam width (Airy FWHM). The instrument has been designed to accommodate progressive enhancements such as the addition of additional passbands, larger detector arrays, or polarimetry. The system has been thoroughly tested in the laboratory and will be ready to integrate with the observatory after fabrication of the external optics and instrument handling cart. In this poster, we describe the instrument's spectral and photometric specifications, its major subsystems, and some possible directions for future development.

Observing:

The initial detector for HAWC is a 32 × 12 pixel bolometer array. The instrument will be operated in standard chop and nod modes (with optional dithering) as well as using continuous scanning mode. The following image illustrates the HAWC passbands, the table below describes HAWC's observational capabilities:



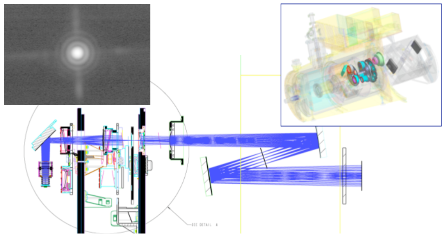
Quantity	Units	Band1	Band2	Band3	Band4
Central Wavelength	μm	53	89	155	216
Bandwidth	$\Delta\lambda/\lambda$	0.16	0.19	0.22	0.21
Pixel Size	arcsec	2.25	3.50	6.00	8.00
Image Diameter (Diffraction-limit FWHM)	arcsec	5.4	9	16	22
Pixels per Airy FWHM		2.4	2.6	2.6	2.7
Mean transmission (cold optics & detector QE)	%	15	21	29	25
Mean transmission (warm optics & vacuum window)	%	34	43	42	53
Mean transmission (atmosphere, 10μm pwv, 40° elevation)	%	73	74	65	81
Background Power, per pixel	pW	52	51	54	24
NEP (thermal background), per pixel	$fW\ Hz^{-1/2}$	63	50	42	24
NEFD (chopped, background limited, $A\Omega=\lambda^2$)	$Jy\ s^{1/2}\ beam^{-1}$	0.94	0.61	0.61	0.49
NEFD (chopped, background limited, $A\Omega=\lambda^2$)	$mJy\ pixel^{-1}$ (4σ, 900s)	57	35	34	26

Instrument Control / Software:

The HAWC subsystems are controlled by the Instrument Remote Control (IRC) package, developed at GSFC. The IRC archives the data and provides user interfaces for instrument control and quick-look data analysis. The data reduction pipeline runs on a dedicated computer and provides reduced data products via a webserver on the airplane ethernet. Both software packages are flexible to accommodate changes necessary with future upgrades.

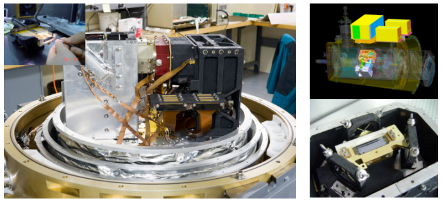
Instrument systems:

Optical system:

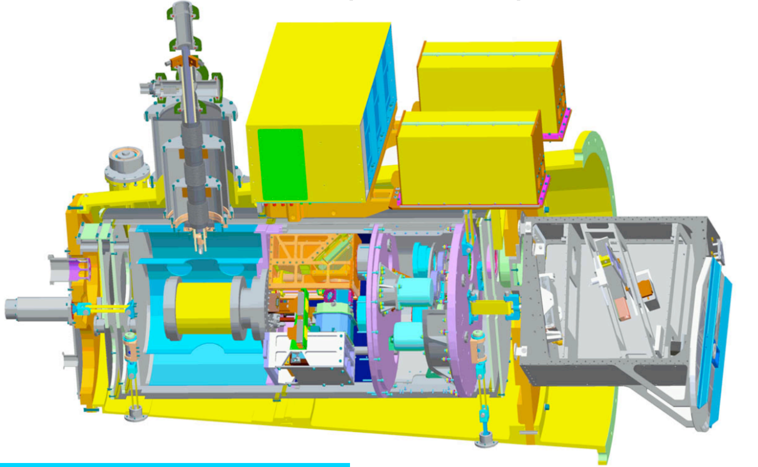


Light from the telescope is reflected from a flat steering mirror through the focal plane to a concave field mirror that re-images the telescope entrance pupil through a polyethylene pressure window to a cold Lyot stop just inside the He4-cooled optical bench. Masks and/or auxiliary filters are mounted on an eight-position carousel in the plane of the cold pupil. The light then passes through one of up to four sets of re-imaging lenses and bandpass filters mounted on a six-position filter carousel (two positions are available for additional bands and/or focal scales). From the lenses, the light reflects from a flat diagonal mirror to the detector array. The optics produce diffraction-limited images in each of the four bands.

Detector assembly:



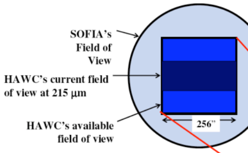
Current bolometer array mounted in cryostat. Large black box on right is JFET preamp assembly (operating temperature of JFETs ~120 K). Aluminum-colored structure on left is radiation baffle surrounding folding flat mirror and dark slide mechanism. Detector array is 12x32 array of silicon-thermometer "pop-up" detectors cooled by ADR to 200 mK. Approximately 90% of detectors are functional and meet operating requirements. Performance is limited by background noise. Analog signals from individual detector pixels are buffered by JFETs in the detector package, and fed to warm preamplifier boards in the data electronics subsystem. These signals are digitized by individual A/D converters, multiplexed into a single digital data stream, and fed by optical fiber to a computer in the floor-mounted experimenters' rack.

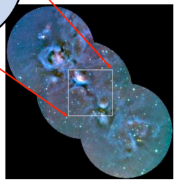


Cryostat and ADR:

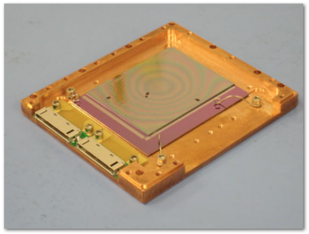
The HAWC cryostat has been designed to meet SOFIA emergency load requirements and provide the maximum possible stiffness (highest natural frequencies) consistent with the cryogenic hold time requirements. The ADR refrigerator subsystem uses a high-capacity magnet and salt pill that can provide detector cooling down to 200 mK while operating from a base temperature of 4 K (unpumped liquid helium). The radiation shields are vapor-cooled. The suspension system for the cryogenic optical bench is purely kinematic, using fixed Kevlar straps opposed by spring-loaded tensioning straps. The six degrees of freedom can be individually adjusted and load cells continuously monitor the tension in each. There are no welded joints in the primary load path of the cryostat vacuum shell. The system can be disassembled with minimal disturbance to the cryogenic reservoir or system wiring. The optomechanical subsystem containing the filter/lens carousel and pupil carousel can be removed without disturbing the detector subsystem. The system has proven to be robust and reliable during laboratory testing and multiple assembly/disassembly cycles.

Potential Enhancements:

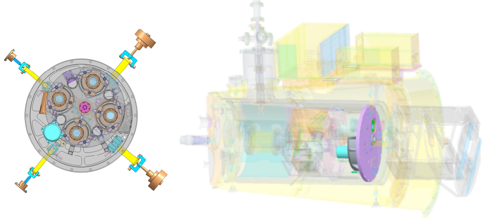




The 256"x256" FOV above can be accommodated with no changes to current external or internal optics. With modifications to HAWC's optical subsystem, it would be possible to fill the SOFIA focal plane with diffraction-limited pixels.



Kilopixel arrays of TES-based bolometers are currently under development at GSFC. The backshort-under-grid (BUG) architecture provides the flexibility to support various photon coupling strategies at wavelengths ranging from the far-infrared through millimeter. These arrays are 32 x 40 pixels each and are designed to mate to the two-dimensional NIST SQUID-based multiplexers originally developed for SCUBA-2. Such arrays would offer background-limited performance and can take advantage of SOFIA's large focal plane area. (See the poster by Jhabvala et al.).



JPL is constructing a polarimeter subsystem (using internal funds) that can be incorporated into HAWC as a single unit, replacing the outer bulkhead of the HAWC optomechanical structure and the current pupil carousel. It has four half-wave plate cassettes (one for each of the four HAWC spectral bands) that can be rotated by a high-efficiency cryogenic motor. It also has four open pupil apertures that preserve HAWC's ability to operate in its current non-polarimetric imaging mode. (See the posters by Dowell et al. and Vaillancourt et al.).

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