Studying Star Formation with HAWC
(High-resolution Airborne Wideband Camera)
A Facility Far-IR Camera for SOFIA

Al Harper (UC) PI

Sean Casey (USRA)  Joel Kastner (RIT)
Jackie Davidson (USRA)  Bob Loewenstein (UC)
Rhodri Evans (UC)  Harvey Moseley (GSFC)
Ian Gatley (RIT)  Rick Shafer (GSFC)

UC: University of Chicago
GSFC: Goddard Space Flight Center
RIT: Rochester Institute of Technology
USRA: Universities Space Research Association
HAWC Goals

- Until the end of the decade SOFIA will be the largest far-infrared telescope available, so it will have the best angular resolution.

- HAWC is a first-generation facility instrument for SOFIA. It is a far infrared camera designed to cover to 40-300µm spectral region at the highest possible angular resolution.

- HAWC's goal is to provide a sensitive, versatile, and reliable far-infrared imaging capability for the astronomical community during SOFIA's first years of operation.
HAWC - Principal Characteristics

- Spectral range: 40 and 300µm - wavelengths which are inaccessible from the ground
- 4 wavebands centered at 58, 90, 155 and 215µm
- 12x32 array of “pop-up” bolometers
- 2 detectors per Airy disk at each wavelength
- FOV: 27”x72” @ 58µm, 42”x112” @ 90µm, 72” x192” @ 155µm, 96”x256” @ 215µm
## Optical and Photometric Specifications

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Wavelength</td>
<td>µm</td>
<td>58</td>
<td>90</td>
<td>155</td>
<td>215</td>
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<tr>
<td>Bandwidth</td>
<td>Δλ/λ</td>
<td>0.23</td>
<td>0.10</td>
<td>0.20</td>
<td>0.23</td>
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<tr>
<td>Pixel size</td>
<td>arcsec</td>
<td>2.25</td>
<td>3.50</td>
<td>6.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Image diameter (FWHM)</td>
<td>arcsec</td>
<td>6</td>
<td>9</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>Detector array field size</td>
<td>arcsec</td>
<td>27x72</td>
<td>42x112</td>
<td>72x192</td>
<td>96x256</td>
</tr>
<tr>
<td>Detector array areal filling factor</td>
<td>%</td>
<td>&gt;95</td>
<td>&gt;95</td>
<td>&gt;95</td>
<td>&gt;95</td>
</tr>
<tr>
<td>Mean transmission (cold optics)</td>
<td>%</td>
<td>0.14</td>
<td>0.18</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean transmission (warm optics plus vacuum window)</td>
<td>%</td>
<td>0.51</td>
<td>0.63</td>
<td>0.69</td>
<td>0.7</td>
</tr>
<tr>
<td>Mean transmission (atmosphere, 10µm H₂O, 40° elevation)</td>
<td>%</td>
<td>0.67</td>
<td>0.73</td>
<td>0.63</td>
<td>0.82</td>
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<tr>
<td>Background power per pixel</td>
<td>nW</td>
<td>0.061</td>
<td>0.023</td>
<td>0.039</td>
<td>0.022</td>
</tr>
<tr>
<td>NEP (thermal background limit, 1 pixel)</td>
<td>fW/Hz^{1/2}</td>
<td>0.66</td>
<td>0.34</td>
<td>0.35</td>
<td>0.23</td>
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<tr>
<td>Frequency range (for background-limited performance)</td>
<td>Hz</td>
<td>5-100</td>
<td>5-100</td>
<td>5-100</td>
<td>5-100</td>
</tr>
<tr>
<td>NEFD (1σ, background limit, AΩ=λ²)</td>
<td>Jy/Hz^{1/2}</td>
<td>1.3</td>
<td>1.3</td>
<td>1.0</td>
<td>0.7</td>
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<tr>
<td>NEFD (1σ, background limit, AΩ=λ²)</td>
<td>mJy(1 hr)</td>
<td>15.0</td>
<td>15.0</td>
<td>12.0</td>
<td>7.8</td>
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Key Science Areas

• Formation of stars and stellar systems within our Galaxy
• Star formation in external galaxies
• The nature and evolution of protoplanetary and remnant disks around nearby stars
• The structure and energetics of interstellar clouds
• The return of gas and dust to the interstellar medium from evolved stars
• Conditions in regions surrounding active galactic nuclei
Issues

• Most of the energy in the extragalactic background appears at infrared and submillimeter wavelengths
• Combined with light at shorter wavelengths, the observed radiation density is higher than expected from the production of known heavy elements by stellar nucleosynthesis
• Most heavy elements were/are produced in massive stars
• Massive stars form in groups (clusters, associations, starbursts)
• A high fraction of known luminous far infrared galaxies are disturbed or merging systems
• The fractions of the extragalactic background caused by star formation and emission from AGNs are unknown
• The details of star formation and emission from AGNs are poorly understood
• The metallicity of interstellar gas and the composition and amount of dust in the universe are critical to the physics of star formation and the production of far infrared radiation

• **High angular resolution at far infrared wavelengths will play a major role in resolving these issues**
• **Studies of sources in the Milky Way, nearby galaxies, and distant galaxies will be needed**
The Extragalactic Background
Observing Opportunities

- Star-forming clouds in the Milky Way
  - Fragmentation and collapse of dense clouds to form clusters of stars
  - Interactions of stars and clusters with their natal clouds
- Nearby galaxies
  - Roles of metallicity and environment
  - Example: Magellanic Clouds
- Disturbed galaxies and AGNs
  - Special properties of star formation in merging systems
  - Fueling of starbursts and AGNs
  - Examples: NGC 4038/39 (the Antennae), NGC 1068, NGC 4151, the Galactic Center
- High-redshift galaxies
  - SOFIA has lower limits than SIRTF for observing very distant galaxies because of source confusion
- Reflection nebulae and evolved stars
  - Nature and origins of dust
**Flux-limited Sensitivities**

- **1-Sigma, 1-Hour Sensitivities**
  - Arp 220 (z=0.018)
  - IRAS (60µm)
  - ISO 175 µm
  - SOFIA
  - SIRTF "Arp 220 (x10)" (z=3)
  - SCUBA+
  - SRTF

**Confusion-limited Sensitivities**

- **5-Sigma Detectability**
  - Arp220 (z=0.018)
  - ISO (175 µm)
  - SCUBA+
  - SRTF
  - "Arp 220 (x10)" (z=3)
Confusion-Limited Images of Distant Galaxies
(Based on simulations by Andrew Blain 1999)

70 microns, SIRTF, 8' x 8' FOV

160 microns, SIRTF, 8' x 8' FOV

Total MIPS Observing Time = 11 mins

200 microns, SOFIA, 8' x 8' FOV

850 microns, SCUBA+, 8' x 8' FOV

Total HAWC Observing Time = 105 hrs

Total SCUBA+ Observing Time = 400 hrs