Multi-Wavelength Far-Infrared Polarimetry with SOFIA

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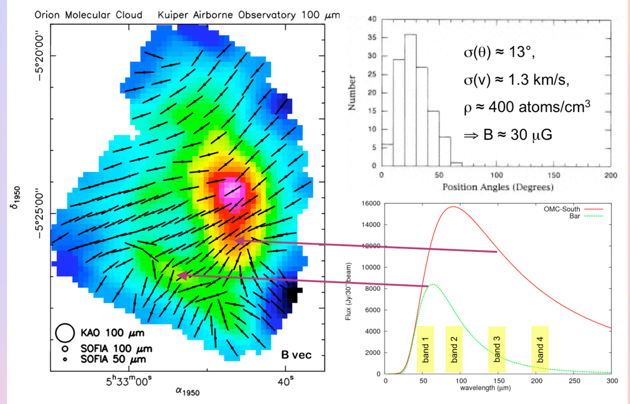
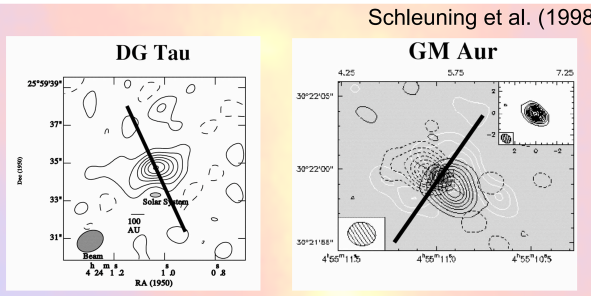
Questions for SOFIA Far-IR Polarimetry

For some time, far-infrared polarimetry has been recognized as a scientific niche for SOFIA (Clemens et al. 1996; Novak et al. 1999; Vaillancourt et al. 2007). Polarimetry provides critical information about magnetic fields in the interstellar medium, thereby complementing measurements of mass, pressure, chemical composition, and gas dynamics from SOFIA and other facilities. Particular questions which can be addressed by SOFIA and instrument requirements are briefly summarized here; see poster by J. Vaillancourt for more details.

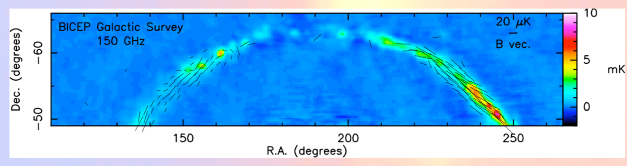
- *What is the strength of magnetic fields in molecular clouds, as inferred through the Chandrasekhar-Fermi (1953) method?*
  ➔ extensive, accurate, high-angular-resolution polarization maps
- *What is the configuration of the magnetic field in the Galactic Center?*
  ➔ rapid, advanced polarization mapping; observations on Wien and Rayleigh-Jeans side of the spectrum
- *What are the large grain populations in molecular clouds, and which are aligned?*
  ➔ good sensitivity to extended emission, multiple passbands
  ➔ synergy with mid-IR polarimetry (e.g., Packham et al. 2008)
- *What is the configuration of the magnetic field in a statistical sample of YSOs?*
  ➔ good sensitivity; observations on Wien and Rayleigh-Jeans side of the spectrum
- *Is the far-IR polarization from other galaxies detectable, at a level appropriate for further study from space?*
  ➔ good sensitivity

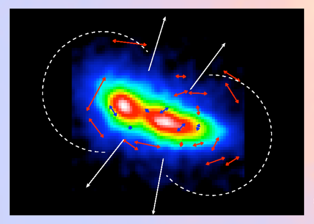


Schleuning et al. (1998)



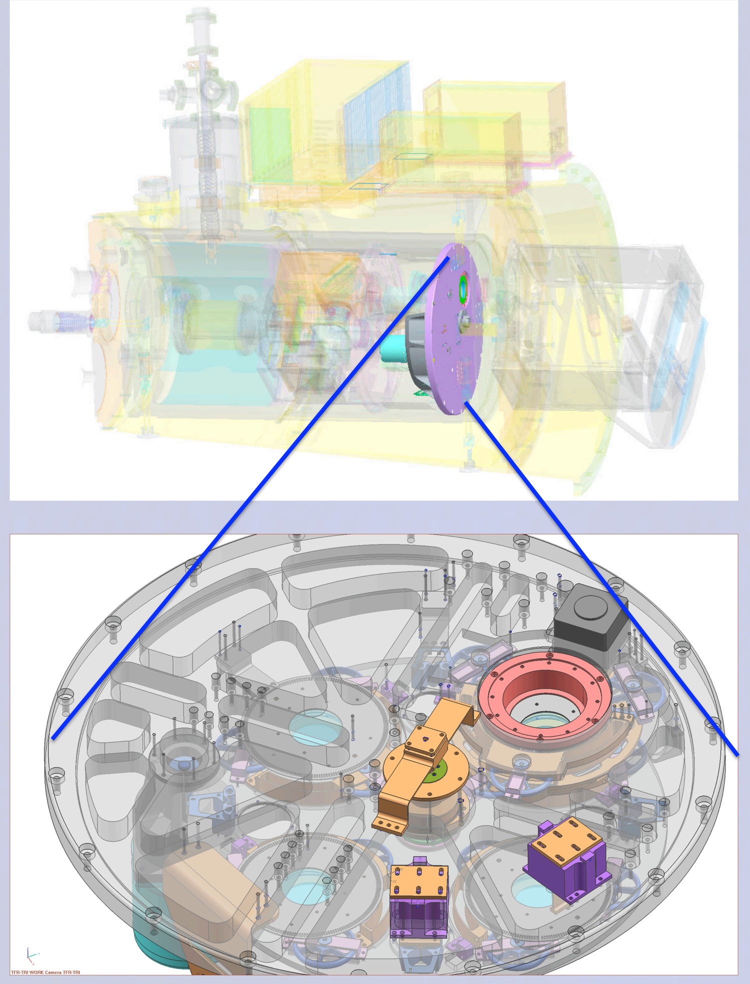
Tamura et al. (1999)

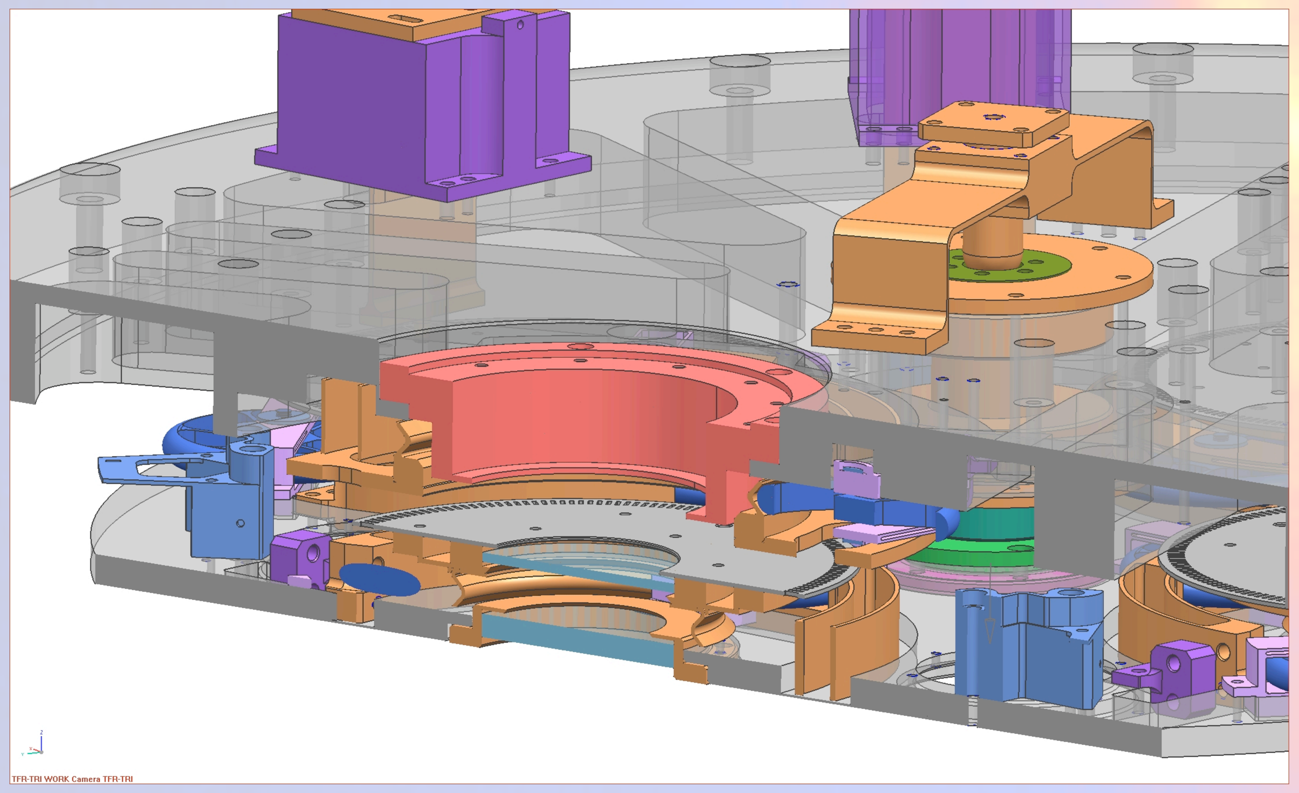

Bierman et al. (2010)


Greaves et al. (2000)

HAWCPol: A First Far-IR Polarimeter for SOFIA

At JPL, we are actively building HAWCPol, a multi-band polarimeter for the first-generation far-IR camera HAWC (Harper et al. 2004). It will be ready for integration with HAWC in Summer 2011 and will support all of the original camera modes in addition to adding new science capability.

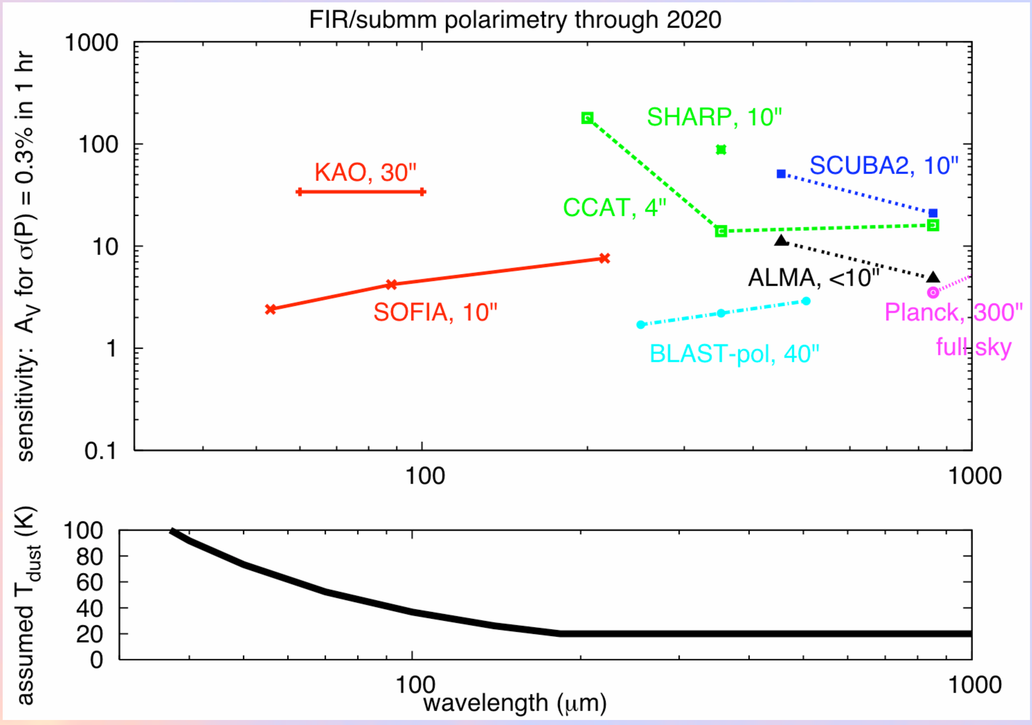




HAWCPol detects polarization with a slowly rotating quartz half-wave plate and fixed wire grid polarizer, both located in the pupil wheel. Components of HAWCPol have been demonstrated in the lab at cryogenic temperature, and we are currently assembling the full system over Summer 2010. The basic observing mode for HAWCPol is rapid (~10 Hz) chopping of the SOFIA secondary mirror, slow polarization modulation (~1 Hz), and occasional nodding of the telescope (~0.03 Hz).

HAWCPol Capability

- *HAWCPol detects polarization 30× faster than the KAO polarimeter, for a given target surface brightness, and has 3× as many beams.*
- *HAWCPol fills a gap in angular scale between Planck (>300") and SMA/ALMA (<10") polarimetry.*
- *HAWCPol has competitive polarization sensitivity far into the future.*
- *Only HAWCPol cleanly separates emission from cold and warm dust grains.*

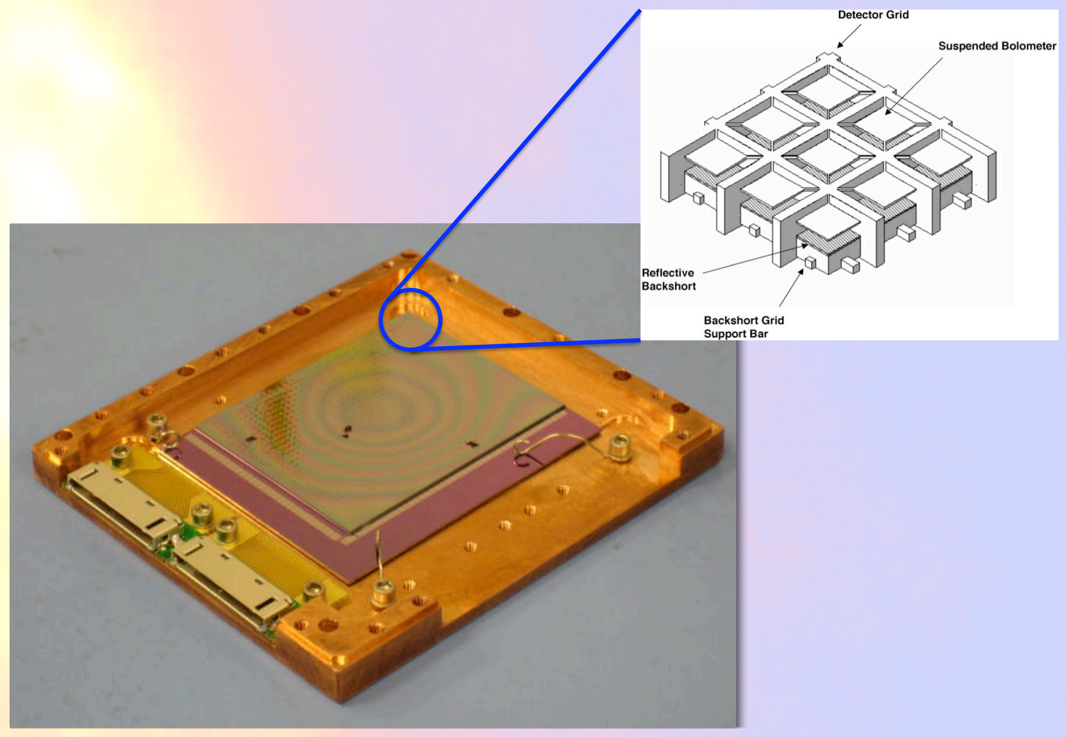


HAWCPol Specifications

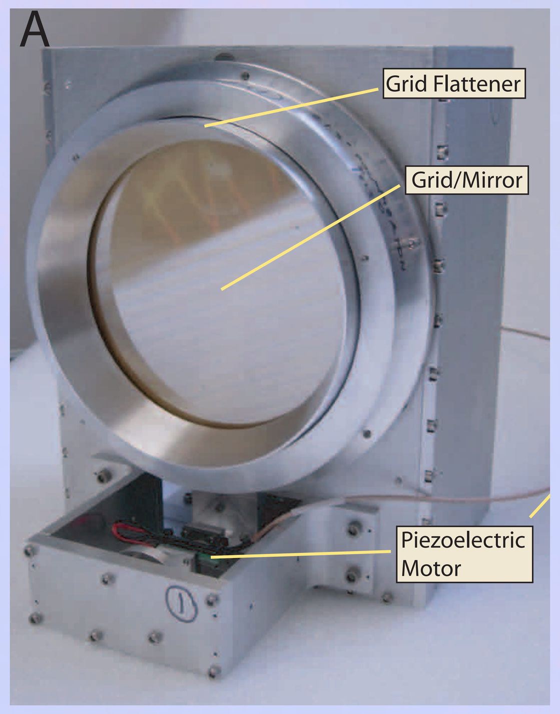
observation bands	53, 89, 155, 216 μm
angular resolution	5 – 22 arcsec
field of view	0.5×1.2 – 1.6×4.3 arcmin²
polarization modulation technique	quartz half-wave plate, 15 rpm
minimum flux density to achieve σ(P) = 0.2% in 5 hour integration	9, 6, 6, 5 Jy
minimum column density to achieve σ(P) = 0.2% in 5 hour integration	A_V = 1, 2, 5, 4
systematic error goal	δP < 0.2%; δθ < 2°

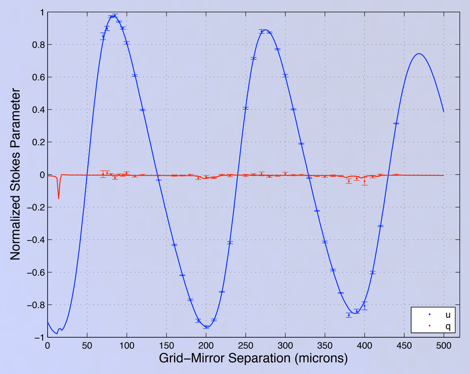
Enabling Technology for Future Far-IR Polarimetry

Some of the more challenging projects for SOFIA polarimetry – mapping of interstellar features with size approaching a degree, and detection of cirrus – will require the largest possible detector arrays along with advanced mapping techniques. While HAWCPol uses cold quartz waveplates effectively, alternate polarization modulation techniques such as the Variable Polarization Modulator (VPM) permit operation over a wider range of wavelengths and at room temperature.



Kilopixel arrays of TES-based bolometers are currently under development at GSFC. (See poster by C. Allen Jhabvala.). The backshort-under-grid (BUG) architecture provides the flexibility to support various photon coupling strategies at wavelengths ranging from the far-infrared through millimeter (Allen et al. 2006; Benford et al. 2010). These arrays are 32 x 40 pixels each and are designed to mate to the NIST SQUID-based multiplexers originally developed for SCUBA-2. Such arrays would have high quantum efficiency and take advantage of SOFIA's large focal plane area.





Left: The VPM consists of a polarizing grid in front of and parallel to a movable mirror. By varying the grid-mirror separation, the phase that is introduced between two orthogonal linear polarizations can be changed resulting in a modulation of the polarization state of the incoming radiation (Chuss et al. 2006).
Right: Preliminary results are shown for a single VPM. The VPM modulates a single linear Stokes parameter as the grid-mirror separation is varied.

Contact / References

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