IMPP: A far-infrared IMaging Polarimeter and Photometer for SOFIA

D. Clemens, J. Jackson, T. Bania, & L. Deutsch
(Institute for Astrophysical Research, Boston University)

Abstract:

We have designed the SOFIA far-infrared IMaging Photometer and Polarimeter (IMPP) to perform simultaneous dual-wavelength (60 & 80μm) moderate-field (45x90") imaging and dual-polarization (70μm) polarimetric imaging. The broad photometric (20μm) and polarimetric (40μm) bandpasses and 2.8" sub-diffraction-limit pixels permit background-limited faint object detection and mapping. The dual-wavelength capability enables acquiring flux and spectral index maps simultaneously, using a single telescope pointing and integration. The dual-polarization capability provides the highest precision magnetic field maps possible with current technology. IMPP is intended to be a general purpose instrument capable of addressing a wide range of astrophysical studies involving young protostellar environments, normal and starburst galaxies, and solar systems as well as providing follow-up, high resolution imaging of ISO, 2MASS, and SIRTF targets. Design and construction of IMPP will meet current and future needs for state-of-the-art airborne far-infrared imaging science, demonstrate instrumentation and operations concepts for future space missions (such as a magnetic field mapping mission), educate young instrumentalists, and provide opportunities for transferring interest and enthusiasm for science to many K-12 teachers.

Science, Operations Requirements -> IMPP Properties

Magnetic field mapping	high-precision, far-infrared imaging polarimeter
Rapid mapping, surveys	high pixel count, large FOV (2 arrays of 16x32 pixels)
High angular resolution	diffraction-limited design, oversampling of PSF to support superresolution (2.8" PFOV; 7" diffraction limit)
High sensitivity	background limited design (telescope + atmosphere dominate)
Rapid mode selection, operation	internal motorized half-wave plate, beamsplitter, filter wheels
Capability upgrades/future science themes	accommodations for simultaneous narrow-band line imaging modes; longer wavelength detectors; higher pixel counts
Robust, low-cost operations	most optical components at 77K, detectors at 2K
Meet SOFIA SI envelope limits	compact instrument in conventional cryostat

IMPP Science Themes:

- Magnetic fields in star-forming cloud cores
- Young embedded clusters - YSO/protostellar properties
- PDR/HII region structures

IMPP Features:

- SOFIA instrument concept
- Unique niche - magnetic field mapping
- High-precision, low-loss imaging polarimeter
- Also, simultaneous dual-band imager
- Accommodation for simultaneous narrow-band line & continuum imaging
- SIRTF-derived detector array technology - unstressed Ge:Ga arrays, two 16x32 devices
- Background-limited in all bands and modes

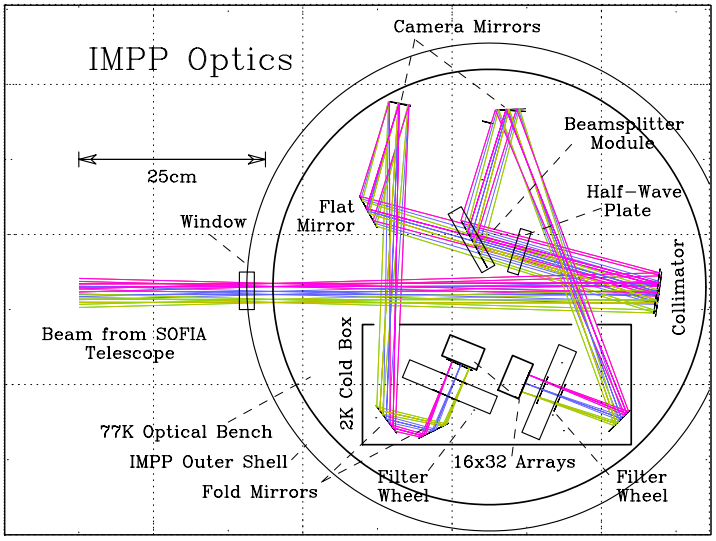


Figure 1: Two-dimensional (bottom view) ZEMAX ray tracing of IMPP optics. The SOFIA beam enters from the left, passes through the cryostat window, and is reflected by the collimator mirror. The collimated beam is modulated by the rotating half-wave plate before being split by either plane of polarization (wire grid beamsplitter) or wavelength (dichroic) to for the transmitted and reflected beams. These two beams are reimaged, passing through two filter wheels, onto twin 16x32 pixel Ge:Ga (unstressed) detector arrays. Most of the optics operate at 77K; the 2K cold box contains the final camera mirrors, filter wheels, and array detectors.

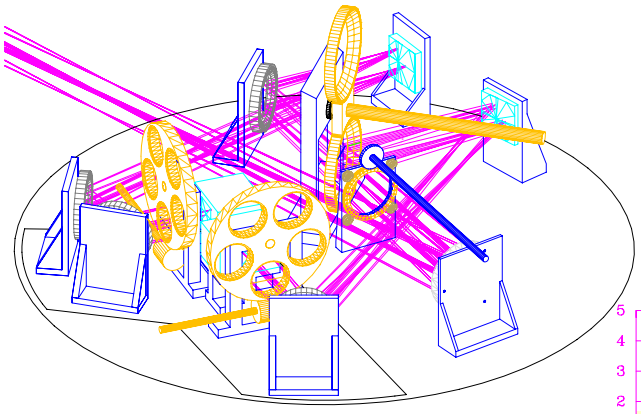


Figure 2: Oblique, three-dimensional AUTOCAD layout of the IMPP optics system. The SOFIA beam enters from the upper left. The two-position beamsplitter module is the tall unit in the figure center. The twin five-position filter wheels reside just in front of the detector array modules. The enclosure for the 2K region has been omitted in this rendering, though its footprint is outlined. The four shafts shown (beamsplitter, half-wave plate, two filter wheels) attach to cryomotors operating within the 77K volume.

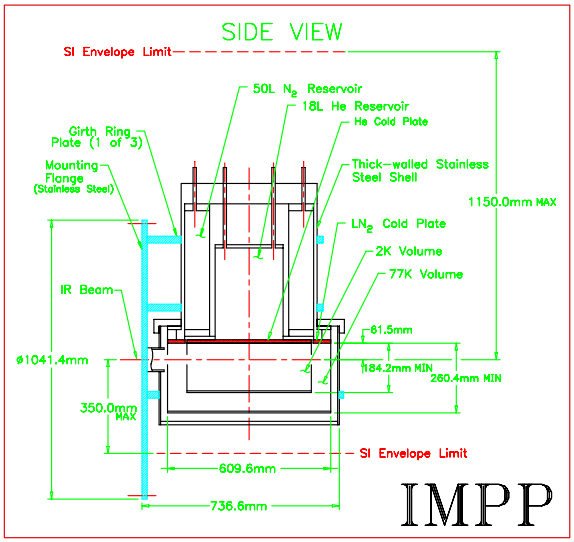
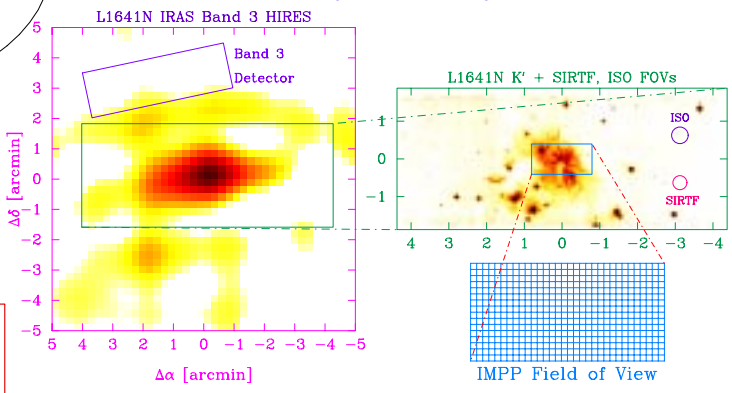


Figure 3: AUTOCAD side view diagram of IMPP cryostat, mount, and support structure compared to the SI instrument flange and SI envelope limits. IMPP features a conventional LN_2 and LHe cryostat, using pumping of the He reservoir to achieve the 2K detector operating temperature. Not shown are the vertical channel stiffeners between girth rings and the side-mounted electronics units.

Figure 5: Different views of the L1641N young star cluster. (Left panel) IRAS 60μm emission, as computed using the HIRES procedure. Inset shows the sky projection of the IRAS Band 3 detector size. (Right panel) Near-infrared image of the indicated field at K' (Hodapp 1994). Insets show the ISO and SIRTF beamsizes at 60μm. (Bottom Right) IMPP field of view and pixel sampling of the same region. IMPP will recover IRAS Band 3 information at an angular resolution similar to that of the ground-based K' image.



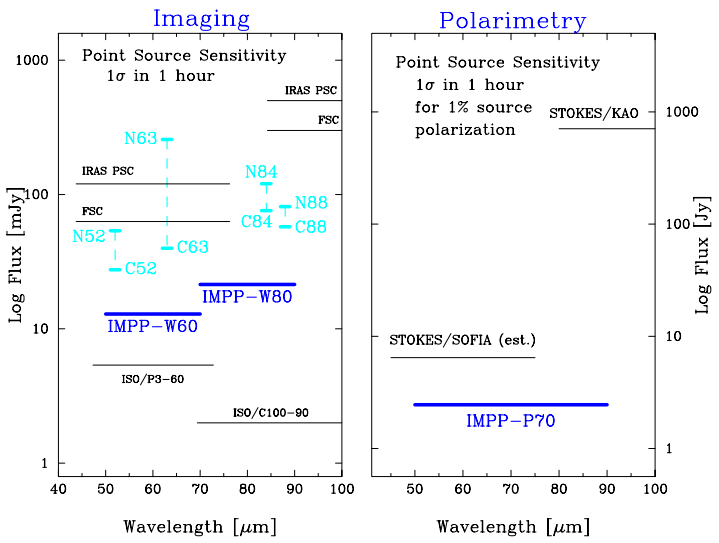


Figure 4: Sensitivity estimates for IMPP compared to *IRAS* and *ISO* imaging limits (left panel) and STOKES polarimetric limits (right panel).

IMPP Filters, Array Operations, and Sensitivities

Filter			Wheel &	Detector Arrays				NEP	NESB		NEFD
Name	Center	Width	Position	Full Well	Read	QE	Read	(e-15)	[GJy/sr]		(ZA=20)
	[microns]			[e]	Noise [e]	[%]	Rate [Hz]	[W/rt Hz]	ZA=20	ZA=60	[e-16 W/m2]
P70	70	40	FW1,2-1	8.00E+07	4472	0.1	365	32	1.5	1.9	184
W60	60	20	FW1-1	8.00E+07	4472	0.1	500	22	1.3	1.5	89
W80	80	20	FW2-1	8.00E+07	4472	0.1	225	11	1.6	2.1	86
N52	51.89	0.2	FW1-2	1.00E+06	500	0.15	300	2	6.2	6.8	5.1
C52	52.35	0.7	FW1-3	1.00E+06	500	0.15	1000	3.8	3.2	3.3	9
N63	63.18	0.06	FW1-4	1.00E+06	500	0.15	100	0.6	24.7	37.8	4.8
C63	62.4	0.8	FW1-5	1.00E+06	500	0.15	800	2.6	3.8	4.3	10.4
N84	84.42	0.2	FW2-2	1.00E+06	500	0.15	75	0.6	8.6	10.4	4.4
C84	83.98	0.55	FW2-3	1.00E+06	500	0.15	220	1	5.4	6.6	7.5
N88	88.51	0.4	FW2-4	1.00E+06	500	0.15	110	0.8	5.5	6.1	5.3
C88	87.9	0.7	FW2-5	1.00E+06	500	0.15	200	1	4	4	6.8