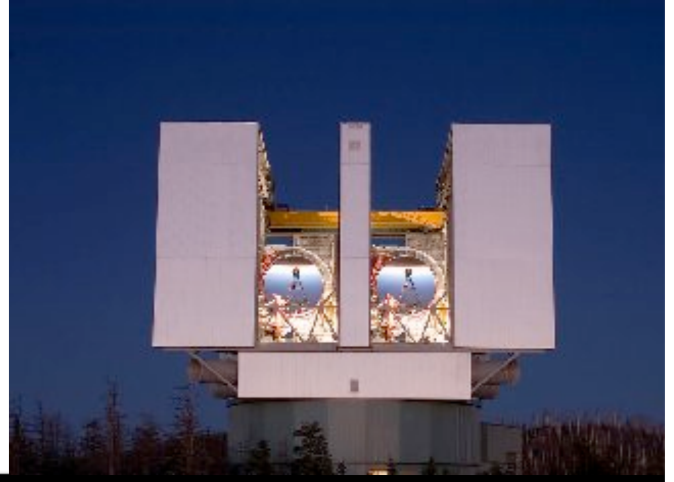
IWI: The Infrared Widefield Imager

An instrument concept for the Large Binocular Telescope: An 8.4m mirror, a 21' field of view, and imaging from z to H band (0.8 to 1.6 microns).



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Overview:

Near infrared observations are a frontier in studying galaxies at large redshifts, stars in dust-reddened regions of our Galaxy and nearby galaxies, cool substellar objects, and Kuiper belt objects in the solar system. Near-infrared (NIR) cameras with high sensitivity and wide areal coverage will allow unprecedented statistical samples of these faint, red objects to be studied.

The Infrared Widefield Imager (IWI) on the Large Binocular Telescope (LBT) is a proposed instrument to address this situation. IWI will combine a 21' field of view with the light grasp of an 8.4m primary mirror, and with simultaneous deep optical imaging provided by the blue channel of the Large Binocular Camera (which is currently being commissioned along with the telescope). IWI will achieve this at a fraction of the cost of building a comparable camera from scratch, by combining the optical train and control systems of the existing Large Binocular Camera (LBC) red channel with engineering HgCdTe arrays provided by the JWST NIRCAM project. IWI will achieve a fifteen-fold increase in survey efficiency relative to any existing NIR camera on any large (> 4m) telescope worldwide.

Philosophy:

IWI is to work as an integral component of the Large Binocular Camera system. In essence, it is to be a "plug and play" IR dewar that can be mounted in place of the red channel optical dewar.

IWI Components:

•Optics: Prime focus optics from LBC Red channel. The last lens (L6) serves also as the dewar window, and we will "duplicate" the LBC-Red cryostat's L6 window/lens with slight modifications for NIR use.

•Cryostat: LN_2 dewar, with at least 1 day hold time. Baseline plan is a commercial dewar from IR Labs in Tucson.

•Detectors: Science arrays will be four JWST NIRCAM project engineering arrays, which the NIRCAM team at University of Arizona can provide after lab testing of the arrays for the JWST project is complete.

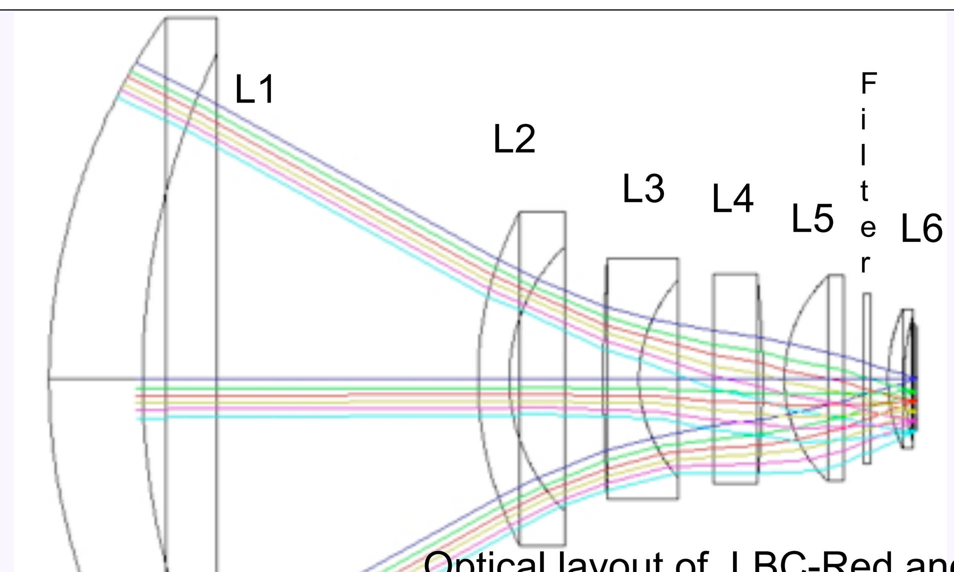
•Technical chips (for guiding, wavefront control) will be patterned on the LBC-Red channel technical chips, which are E2V corp. 2048x512 optical CCDs.

•Array controllers: "Leach heritage" controllers, based on the controllers used by the NIRCAM team for their test unit focal plane array (which is populated with the exact chips that will later go into IWI).

•Filters: Bandpass filters in the existing filter wheel, and a cold blocking filter directly in front of the IR detectors.

•Computers, interface to Telescope, interface to blue channel: IWI will use LBC-Red systems as much as possible.

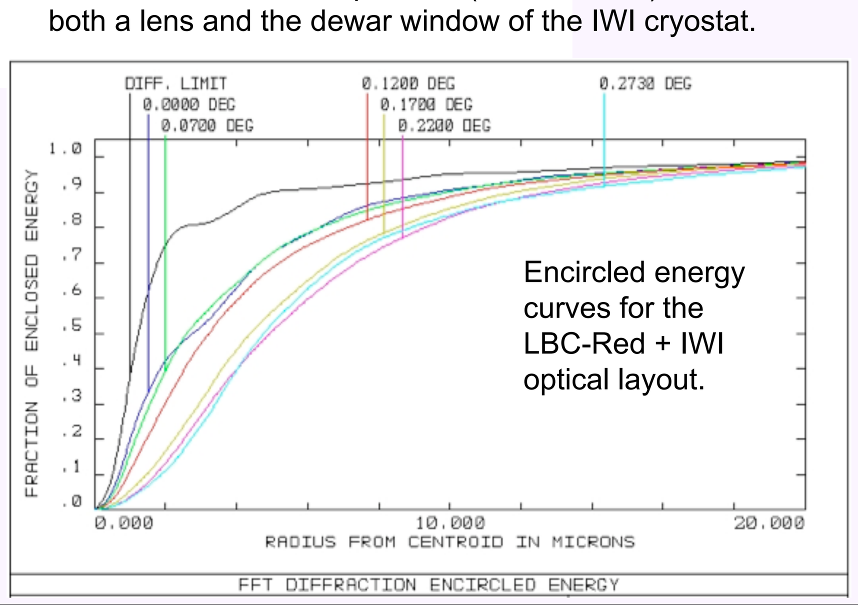
Optics



Optical layout of LBC-Red and IWI.

Lenses L1 through L5, and the filter wheel, are existing LBC Red Channel components (the "red hub"). L6 is both a lens and the dewar window of the IWI cryostat.

The LBC red channel optics form good images over the full IWI field and wavelength range. Beyond 1.7 microns, the transmission of the optics drops rapidly, and the thermal background rises. There is no space for a collimated beam and cold stop at the LBT prime focus. IWI therefore does not attempt K band coverage.



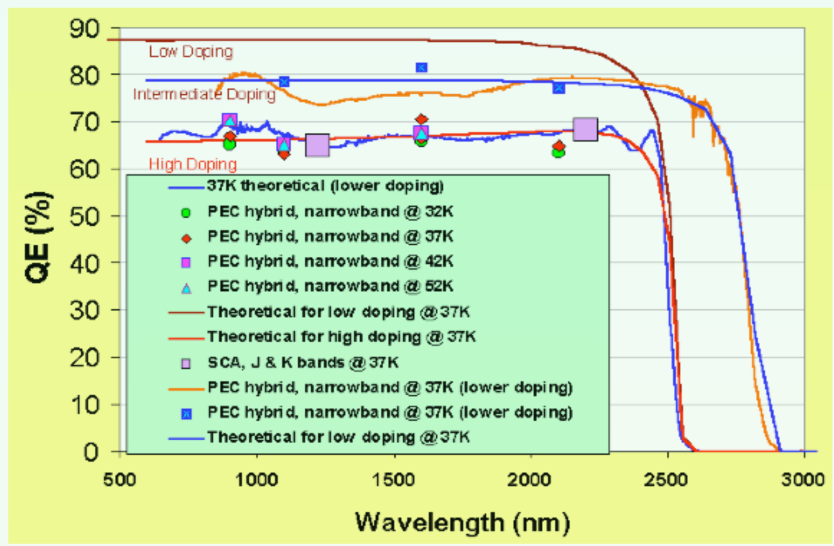
Encircled energy curves for the LBC-Red + IWI optical layout.

IWI Vital Statistics:

4096 x 4096 pixels (four 2048^2 arrays). 18 μm (0.30") per pixel.
Full field 21' by 21' (including a 50" chip gap).
Prime focus; f/1.14 input beam; f/1.4 beam at detector.
Planned filters: z', Y, J, H_s possibly I, but not K.
QE > 80%. Array operating temp. ~ 80K.
Readout time: 5.3 seconds. Full well: 360,000 e^-
Maximum integration 30s in H_s band, longer in others, before sky fills well.
1 hour sensitivity estimates: J_{AB} = 25.0 and H_{AB} = 24.4 (3σ).

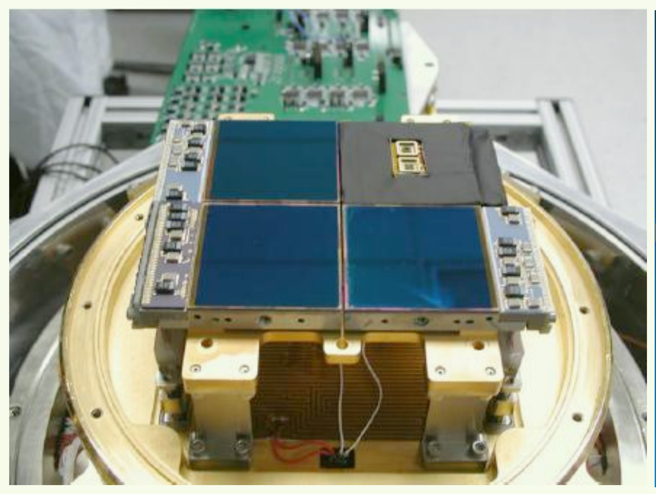
Detectors, Mount, and Controllers:

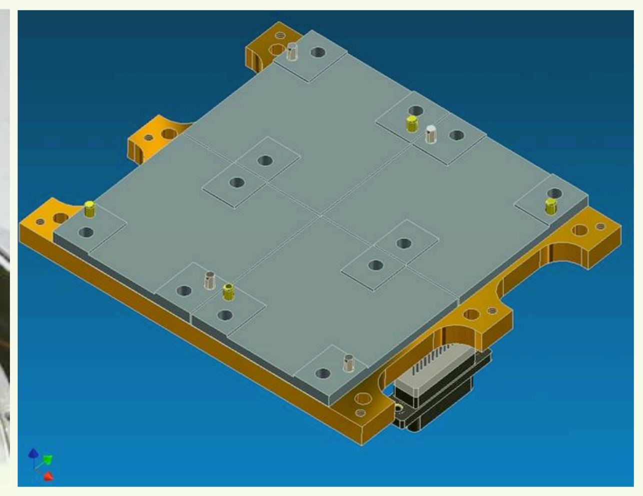
IWI will use four JWST NIRCAM short wavelength channel arrays. These combine very high quantum efficiency (QE) with low read noise and dark current. The wavelength response extends from optical to 2.5 micron. This introduces a requirement for good blocking of incident light outside the desired near-infrared bandpasses. The arrays have been delivered to University of Arizona, where they will first be used in a Test Focal Plane Array (presently under construction) for the JWST NIRCAM project. After completion of these tests, the arrays will be available for IWI.



QE predictions and measurement for short wavelength cut-off HgCdTe. The NIRCAM arrays we will use for IWI correspond to the top (low doping) theoretical curve. The remaining curves and data points demonstrate the accuracy of the theoretical curves for other Teledyne arrays.

IWI will use a new mount and new array controllers, based on experience gained in the test FPA construction. The mount will incorporate provisions for small adjustments to chip position, since focal plane flatness is a critical parameter in our f/1.4 beam. The controllers will be "Leach heritage" controllers. The near-IR arrays will be cooled near 77K by a thermal strap connecting the detector mount to the cold plate of the dewar. This is warmer than the JWST operating temperature, but the resulting dark current increase is trivial compared to the broad-band sky count rate.
The optical "technical chips" for guiding and wavefront sensing will be adjacent to the science arrays. They will need to be confocal but thermally isolated from the IR chips. Having technical chips identical to those in LBC Red ensures that IWI interacts naturally with the rest of the LBC system and can use existing LBC interfaces to the telescope.





Left: JWST prototype arrays in a test dewar at Teledyne. Right: Mosaic plate for mounting four detector arrays.

Comparison of survey efficiency of Infra-red cameras

Instrument	Aperture	Field	Pixel	Butted	Etendue	N/S?	Status
IWI	8.4	21'	0.30"	Y	100	N	Proposed: 2008
VISTA	3.7	46'	0.34"	N	93/31	S	Commissioning
NEWFIRM/KPNO	4.0	28'	0.40"	Y	40	N	Commissioning
WFCAM/UKIRT	3.8	27'	0.40"	N	34	S	Operating
WIRCam/CFHT	3.6	21'	0.30"	Y	18	N	Operating
FourStar/Magellan	6.5	11'	0.16"	Y	16	S	2008
EMIR/GTC	10.4	6'	0.20"	Y	13	N	in construction
HAWK-I/VLT	8.2	7.5'	0.106"	Y	13	S	2008
MOSFIRE/Keck	10	6.1'	0.18"	Y	12	N	2009
Omega2000/Calar Alto	3.5	15'	0.45"	Y	9	N	Operating
MMIRS/MMT	6.5	7'	0.20"	Y	7	N	2008
Flamingos-2/Gemini	8.0	6' diam	0.18"	Y	6	S	2008
MOIRCS/Subaru	8.2	4'x7'	0.12"	Y	6	N	Operating
Lucifer/LBT	8.4	4'	0.25"	Y	3.6	N	2008
ISAAC/VLT	8.2	2.5'	0.15"	Y	1.4	S	Operating
HST/WFC3-IR	2.4	2.2'	0.13"	Y	36	—	End of 2008

Etendue is inversely proportional to survey time for a very wide-field survey; it is scaled so that IWI is 100. VISTA and UKIRT/ WFCAM have large gaps between chips. The quoted field of view is their instantaneous sky coverage. Their quoted etendue is for a large survey. For a survey smaller than the field of 1.63 and 0.8 □°, respectively, their effective survey speed is lower, because they still need multiple pointings. For HST, the survey speed assumes that the sky background is 400 times fainter and that one is studying extended sources.

Filters:

Optical light is needed for the technical arrays, but cannot be allowed to reach the science detectors. Similarly, K band light must be prevented from reaching the science arrays, to avoid a large background from warm surfaces in the camera, telescope, and surroundings.

We therefore plan a cryogenic blocking filter, permanently mounted between L6 and the IR arrays, with a bandpass from about 0.8 to 1.7 microns. This filter needs to reject thermal radiation from 1.7 to 2.5 over a wide range of incidence angles. We are exploring the best technical solution for this filter.

The science bandpass filters will reside in the existing LBC-Red filter wheel. They do not need to be cooled, since thermal radiation is modest even at the longest IWI wavelength (1.7 microns). However, in addition to their IR bandpass, the filters will need to pass significant optical light at < 0.8 microns, to feed the technical chips. Such a design is possible by foregoing out-of-band blocking in the optical window.

Software:

We plan two software efforts. One is operational, and will incorporate IWI operations into existing Large Binocular Camera software systems. This will cover both the user interface and the interface to the telescope.

The second is for data reduction and analysis. Our goal is a working data reduction pipeline that will return science-ready products to observers with reasonably standard broad band imaging programs. This will enhance the scientific output of IWI greatly.

IWI Science Sampler:

IWI will be a general purpose instrument with a wide range of potential applications. Our funding proposals have given particular attention to …

•Searches for z>7 galaxies, quasars, and GRB afterglows;

•Improved photometric redshifts for large samples at 1<z<3;

•Mapping the outer reaches of nearby, resolved galaxies in order to study their merger histories;

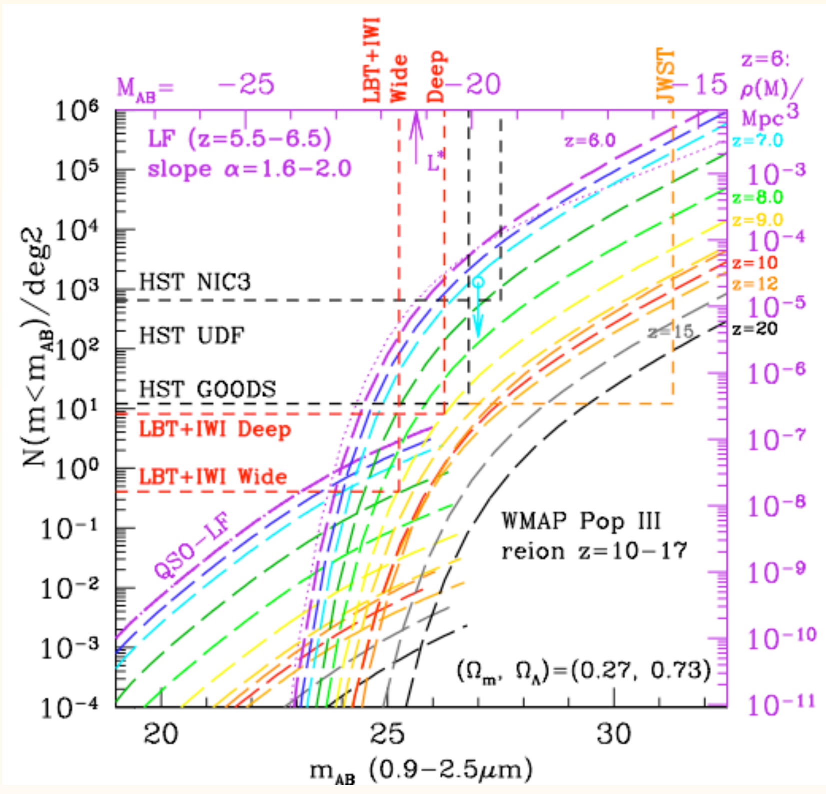
•Extending our knowledge of the initial mass function to still lower levels by searching for brown dwarfs cooler fainter than any yet found;

•Measuring near-IR colors of Kuiper belt objects to constrain their surface composition and hence formation histories.

We expect a creative user base will identify many other applications.

We plan an IWI First Look survey, consisting of 8 hours/filter in one pointing (0.12 □°), reaching J_{AB} = 26.1 and H_{AB} = 25.5 (3 σ), and 1 hour/filter over another 2 □°, to J_{AB} = 25.0 and H_{AB} = 24.4 (3 σ). In total, this would require 9 clear nights, which we will obtain from a combination of commissioning time and Arizona TAC awarded time. We will make the reduced images from this survey public.

Some LBT time will be available to the broader community as part of the NSF's Telescope System Instrumentation Program (TSIP).



The area and depth of the proposed IWI deep and wide surveys compared to the luminosity functions of galaxies and AGN based on z~6 data and extrapolated beyond under the no-evolution assumption. From top to bottom, the curves correspond to z=6.0, 6.5, 7.0, 7.5, 8.0, 9.0, etc. The IWI survey regions correspond to a dozen nights of telescope time; a larger survey would certainly be possible in the life of the instrument.
Figure based on fig. 4 of Windhorst, Hathi, Cohen, and Jansen, astro-ph/0703171.