The FourStar Infrared Camera

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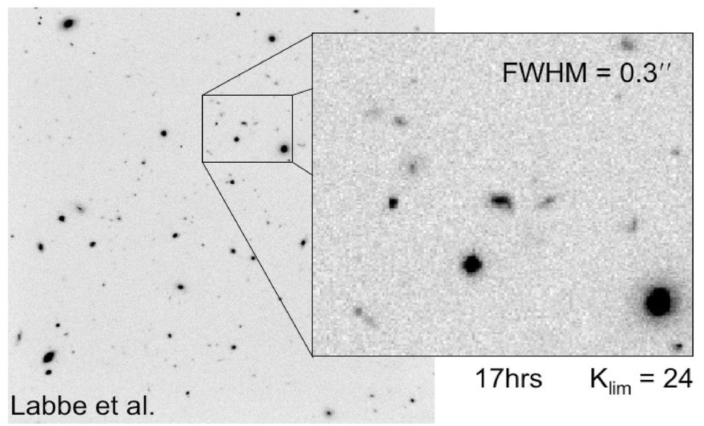
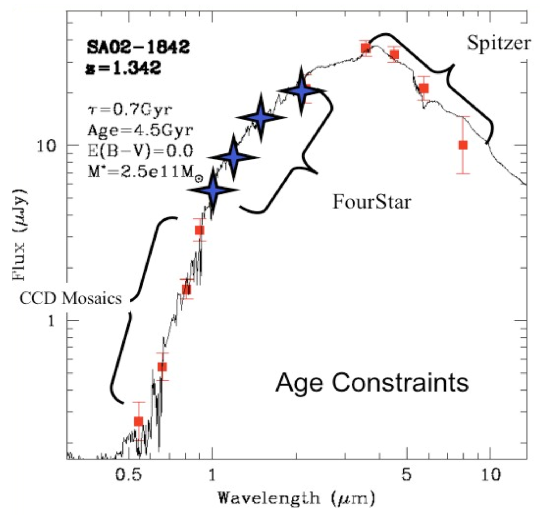
IDG INSTRUMENT DEVELOPMENT GROUP

1. Science with FourStar



An example of the image quality and sensitivity offered by the Magellan Telescopes. This 17 hour Ks-band image of the Hubble Ultra-Deep Field with PANIC reaches a limiting depth of Ks = 24 mag. The resolution of the images rivals that of NICMOS on HST. The 25 times larger field of view of FourStar will make deep surveys over moderate areas practical and will enable studies of massive red galaxies in the $1 < z < 3$ range with high precision and statistical accuracy. The image is from Labbé (2007). The PANIC camera is described by Martini et al. (2005).



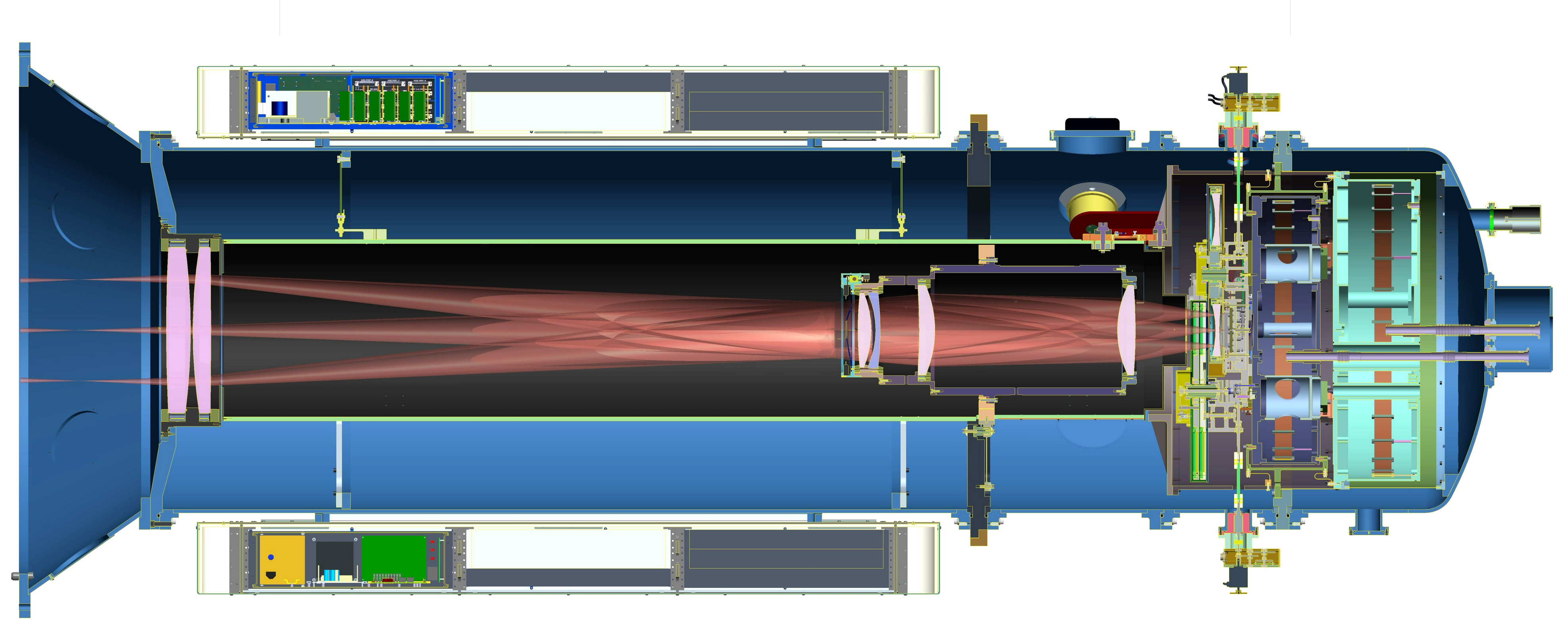
Sample spectral energy distribution and color images of massive red galaxies at intermediate redshift. The near-IR bands sample the rest-frame visible region of the spectrum and thus provide critical leverage in constraining the age and stellar content of massive galaxies as well as providing the primary selection bands. Above we have marked the regions of the spectrum that are sampled by CCD mosaics and those that can only be efficiently observed from space (e.g. Spitzer or JWST) as well as the near-IR bands that will be sampled with FourStar. The near-IR images are critical to identifying and determining the redshifts of over-dense regions of red galaxies.

FourStar will be primarily a survey instrument. Its combination of sensitivity, image quality and field of view are ideally suited to addressing key problems in the study of distant galaxies, star formation and stellar astrophysics.

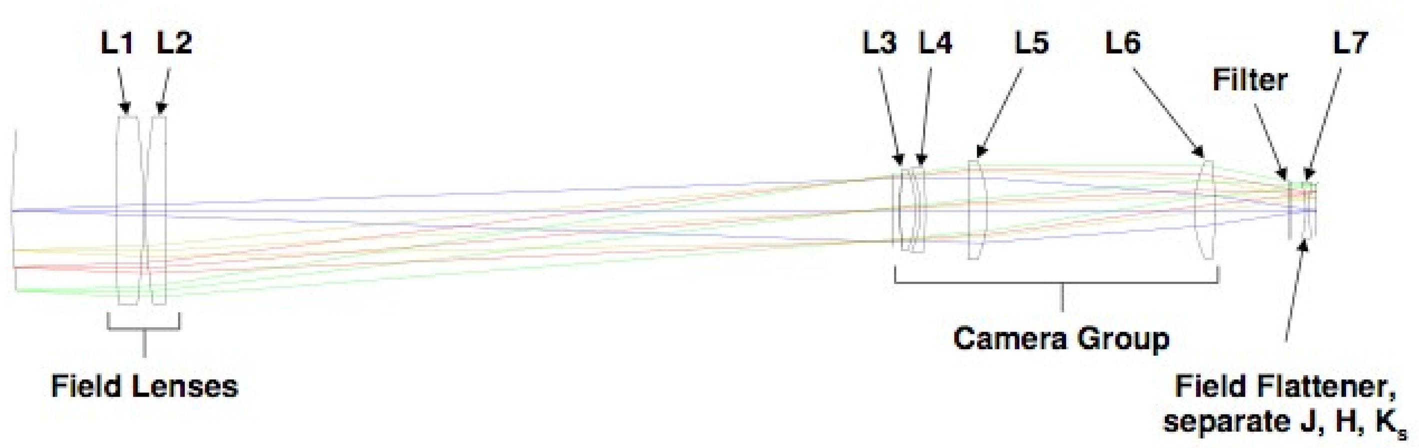
The highest priority scientific programs for FourStar within Carnegie Observatories center on studies of the distant universe. Near-IR imaging surveys allow one to select galaxies on the basis of their stellar mass and to trace the evolution of rest-frame visible light to early epochs. We plan to carry out a number of surveys designed to study the assembly of stellar mass in galaxies in the key $1 < z < 3$ epoch. These surveys will be of intermediate area and depth and will build on extant data at other wavelengths. The near-IR photometry aids determinations of stellar mass and star formation histories in massive galaxies, particularly passively evolving systems, as illustrated in Figure 4. At higher redshifts, ultra-deep surveys will allow us to trace the evolution of the most massive galaxies in the $3 < z < 4$ era when the first massive stellar systems appeared. FourStar will complement the spectroscopic capabilities of IMACS and LDSS3 at Las Campanas and allow powerful surveys over a wide range of redshifts.

Abstract

The FourStar infrared camera is a 1.0-2.5 μm (JHK_s) near infrared camera for the Magellan Baade 6.5 m Telescope at Las Campanas Observatory (Chile). It is being built by Carnegie Observatories for use by the Magellan Consortium and is scheduled for completion in June 2009. The instrument uses four Rockwell HAWAII-2RG 2048x2048 imaging arrays in a close-packed arrangement for a 4096x4096 pixel imaging area. The field size is 10.9‘x10.9' with a 0.16 arcsec/pixel scale. The survey power, in terms of A-Ω (telescope aperture times field), will be the largest of any southern hemisphere imager. FourStar will be mounted at a Magellan telescope Nasmyth focus. Fed by the *f*/11 telescope beam, cryogenically cooled optics reduce this to *f*/3.6 providing the desired field and pixel sampling. The optics comprise a seven element, three group system with one aspheric surface. Two filter wheels accommodate ten filters. The readout electronics are provided by Teledyne-supplied Application Specific Integrated Circuits (ASICs) cooled to LN2 temperatures. The imaging arrays present themselves as USB 2.0 devices to our data system. A network of eleven computers implement control and reduce data reduction functions. An online data pipeline will produce fully reduced and calibrated images at the telescope. The outstanding seeing at Las Campanas site, coupled with the high sensitivity and large field of view of FourStar will enable a range of survey and targeted science programs. These include surveys of massive red galaxies at $z > 2$, surveys of galaxy clusters at $z > 1$, near-IR follow-up of Spitzer legacy fields, and surveys of T and L brown dwarfs using both intermediate-band methane and broad-band filters. FourStar funding has been provided by the National Science Foundation and the Carnegie Institution of Washington.



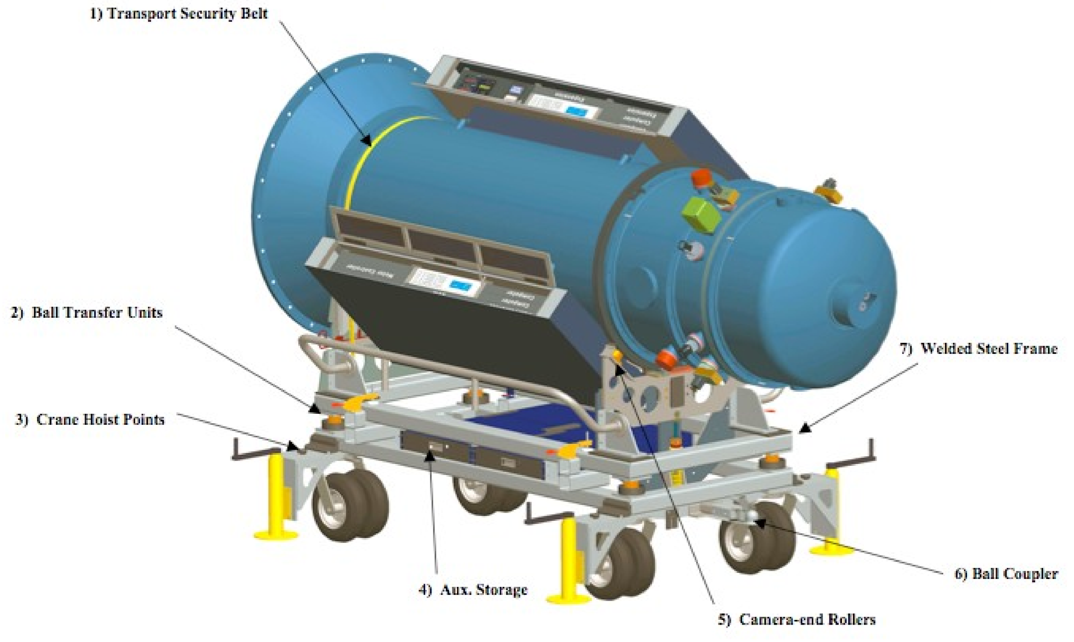
2. Optical Design



The FourStar optical design is similar to that of the PANIC infrared camera. The instrument has seven elements in three groups. The two-element vacuum vessel entrance window (L1 & L2) is also a Fabry lens that images the telescope entrance pupil onto a cold stop inside the instrument, just in front of lens L3. The choice of a doublet for L1/L2 reduces icing on L1. Four lenses (L3-L6) and a field flattener (L7) bring the beam to focus at *f*/3.6. One aspheric surface, on L3, leads to a substantial gain in field area, a factor of 1.64. The "camera module" optics, L3-L6, are cooled to 200K, a temperature that is low enough to ensure negligible background contribution from the instrument itself. The focal plane area (mechanisms, filters, field flattener lenses, and detectors) is cooled to 77K. Two filter wheels can accommodate up to 10 filters. The final plate scale delivered by the *f*/3.6 beam is 0.16 arcsec/pixel accommodating a total field of 10.9' X 10.9'.

3. Mechanical Design

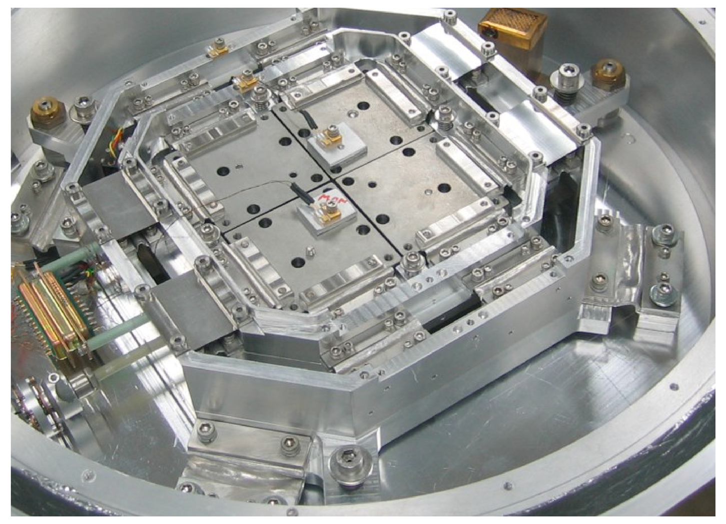
The instrument will reside at one of the two *f*/11 Nasmyth ports of the Baade 6.5m telescope. FourStar will be 10 feet long and weigh 2500 lbs. Most of its weight will be supported by the Nasmyth platform and the attachment to the instrument mounting ring/guider is used only to locate the instrument in space. The above figure shows a cutaway view of the instrument. The main structural function of the vacuum vessels, apart from providing the internal thermal environment, is to transfer the weight of the instrument through the camera module load ring onto two roller bearings and onto a handling cart.



4. Instrument Handling Carts

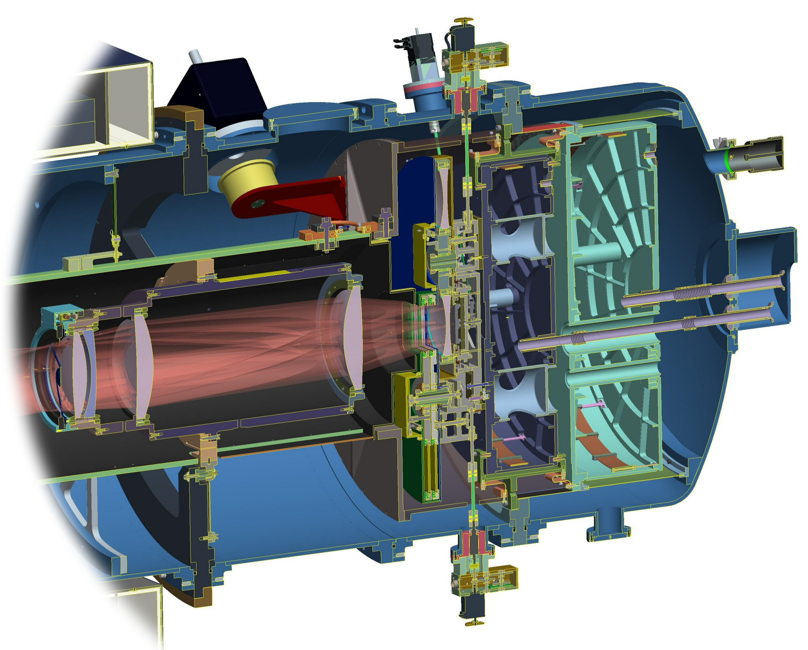
The instrument handling carts for FourStar carry most of the weight of the instrument and must allow for the instrument to rotate; hence the carts are an important part of the instrument. Below we show photos of the two instrument handling carts.

5. Cold Mechanisms and Detectors



The FourStar detectors are four HAWAII-2RG 2048x2048 arrays manufactured by Teledyne Scientific and Imaging (formerly Rockwell Scientific) mounted in a 2x2 format. The arrays will be read out by the new application-specific integrated circuit (the "SIDECAR" ASIC) devices designed by Teledyne.

The above picture shows the detector module on which the detectors will be mounted. The design of the detector module allows us to align the plane of the detectors parallel to each other and orthogonal to the optical axis. Each detector is kinematically mounted on its own Molybdenum block, and the assembly of blocks is kinematically mounted on the cold work surface of the detector dewar.



The above figure shows a cutaway of the FourStar cold mechanisms. The internal mechanisms hold and locate the detectors (with the ability to focus them cold), hold and move the field flattener and filter wheels, and open and close a stop at the cold pupil.

Key FourStar Parameters

Property	Value	Notes
Focal Plane Format	4096x4096	Four Hawaii-2RG arrays
Pixel Scale	0.159 arcsec	18 micron pixels
Field of View	10.8x10.8 arcmin	
Sensitivity	K_s = 21.5	Point source in 1 hour

6. Electronics and Data System

The data acquisition system consists of four Windows PCs that read out the four arrays, and seven Macintosh computers that process the data and control the instrument. Five of these Macintoshes are devoted to real-time data processing, so that the observer will leave the mountain with fully reduced data.

7. Instrument Status

We are in the process of assembling the mechanical hardware in the lab and will align the optics, test the mechanisms, and integrate the detectors at OCIW. The instrument will be shipped to Las Campanas in early 2009, where it will be installed on the telescope soon thereafter.