# SNDICE: a Direct Illumination Calibration Experiment at CFHT


LPNHE - IN2P3 - CNRS
Universités Paris VI et Paris VII
4 place Jussieu
Tour 43 - Rez de chaussée
75252 Paris Cedex 05

C. Juramy, E. Barrelet, K. Schahmaneche, P. Bailly, W. Bertoli, C. Evrard, P. Ghislain, A. Guimard, J-F. Huppert, D. Imbault, D. Laporte, H. Lebbolo, P. Repain, R. Sefri, A. Vallereau, D. Vincent, P. Antilogus, P. Astier, J. Guy, R. Pain, N. Regnault
Laboratoire de Physique Nucléaire et de Hautes Énergies, CNRS
R. Attapatu, T. Benedict, G. Barrick, J.-C. Cuillandre, S. Gajadhar, K. Ho, D. Salmon
Canada France Hawaii Telescope Corporation

June 2008

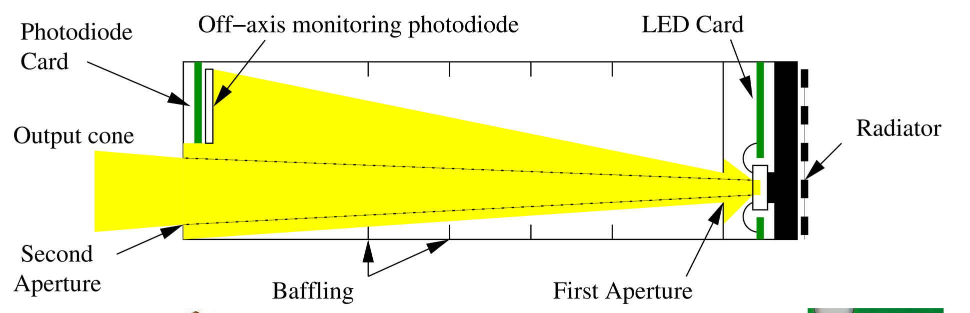
Canada France Hawaii Telescope

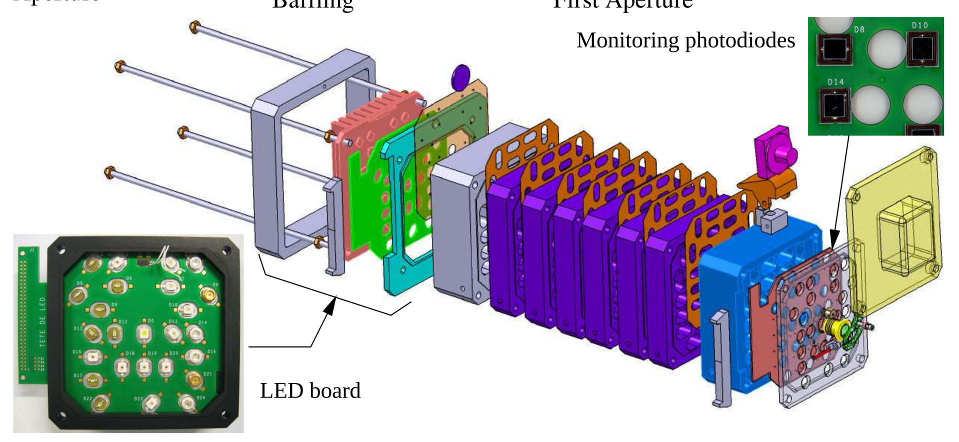

The latest figures for systematic uncertainties in the SuperNova Legacy Survey (SNLS) show that a photometric accuracy better than 1 % is required to improve on the measurements of the cosmological parameters with supernovae. The SuperNova Direct Illumination Calibration Experiment (SNDICE) aims at providing this accuracy by the absolute calibration of the instrumental transmission of the MegaCam camera at CFHT. This includes monitoring of the electronic and optical variations in the instrument.


## SNDICE development

### LED source

The source includes 24 calibrated channels and one 'artificial planet' channel for alignment. Each calibration channel is monitored by a photodiode. The calibrated beams have a 2° angular size. To make an 'artificial planet', the light from a 'white' LED is sent through a 60 $\mu$m pinhole and focused into a parallel beam by a lens ($f$ 25 cm).



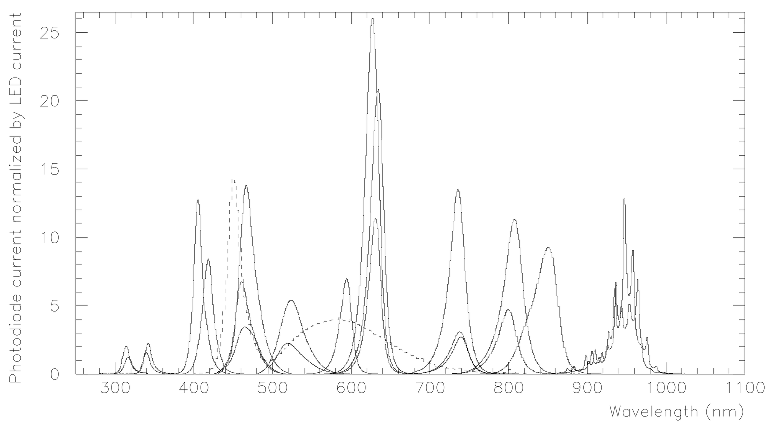




### Ultra-Low Current photodiodes

The absolute calibration necessitates a redundant check of the light flux: in addition to the monitoring photodiodes, calibrated photodiodes should be placed as close to the camera as possible. We designed the Cooled Large Area Photodiode (CLAP) modules to be inserted in MegaCam primary focus. The module houses a large photodiode with integrated Peltier cooler, and a Low Current Amplifier ASIC designed and tested at LPNHE.

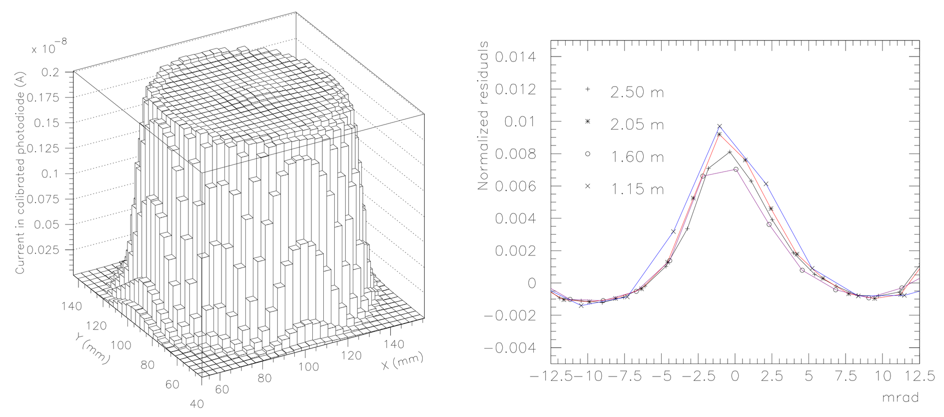
## SNDICE calibration

### Spectral calibration



Spectra of the 24 LEDs selected for the calibrated LED source, and of the 'white' LED used for the artificial planet (dashed line).

### 3D Mapping of the light field

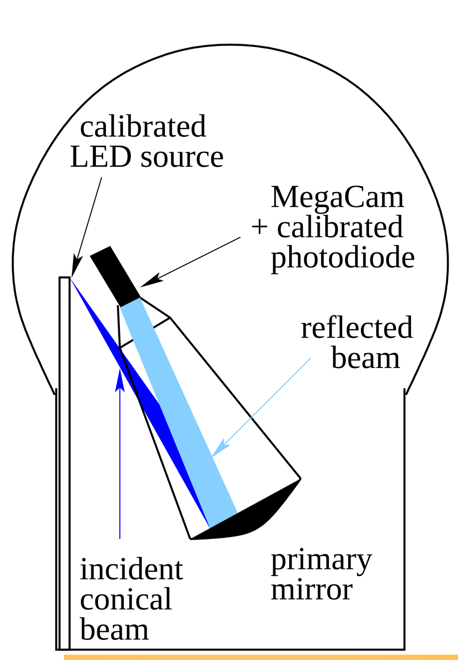


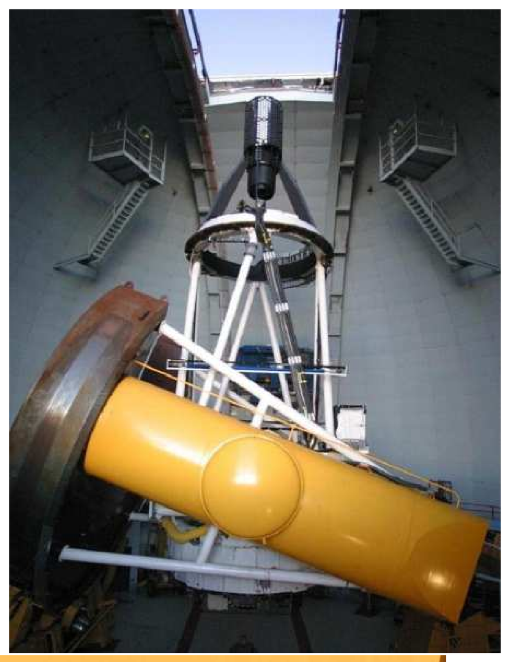
Doing the 3D mapping of the field means not only mapping the whole beam emitted by each LED, but also showing that this mapping is independent of the distance. From the 2D map at a given distance (left plot), we fit the 'flat field' cylindrical region with a plane. We subtract the fit to the maps at different distances, taking into account the distance ratio. The residuals (right plot) are identical within less 0.1 % in the 'flat field' region, showing the reliability of the beam model. This shows also how closely we verify the distance-flux relation, on which we base the absolute calibration.

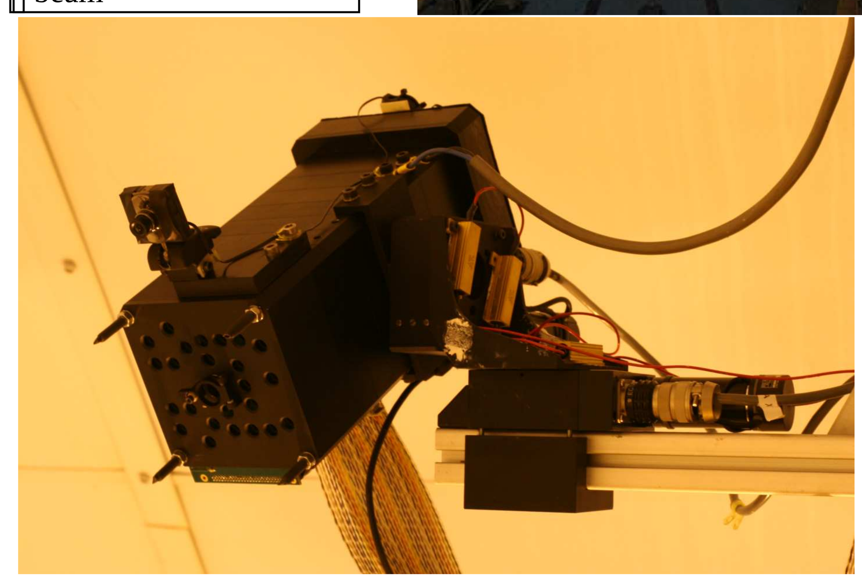
## Installation at CFHT

### Hardware setup

For SNDICE direct illumination setup, the LED source was installed on one of the platform inside the CFHT dome (near the slit on picture), so that it illuminates directly the primary mirror below. Angular motorization of the source is used to position optical axis of the source parallel to optical axis of the telescope.





### Software integration

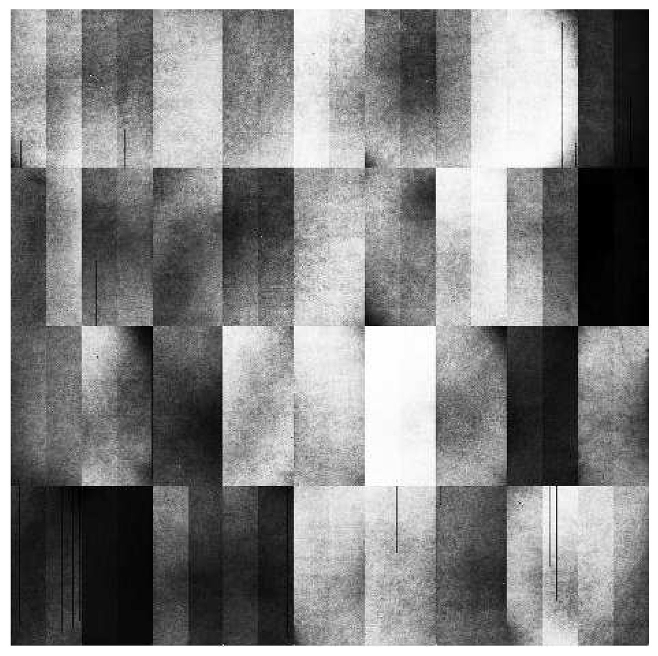
The LED source and the CLAP are controlled by independent 'PC 104' computers, acting as servers. SNDICE commands are integrated in the CFHT software architecture.

## First results with MegaCam

### Alignment procedure

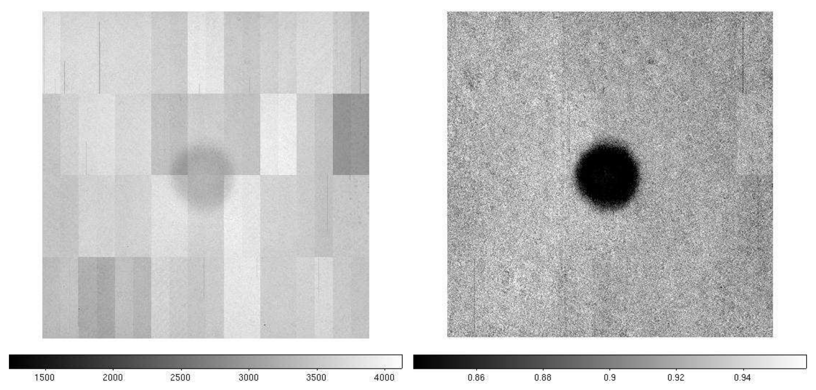
To explore the whole aperture of the telescope, and illuminate different parts of the mirror with the beam, the telescope is pointed towards SNDICE with an elevation angle varying by up to 8°. The optical axes of the source and the telescope are kept parallel, by positioning the artificial planet at the center of the MegaCam mosaic. An automatized procedure has been developped to do this with a $\pm 10''$ accuracy.

### Gain control and CCD efficiency



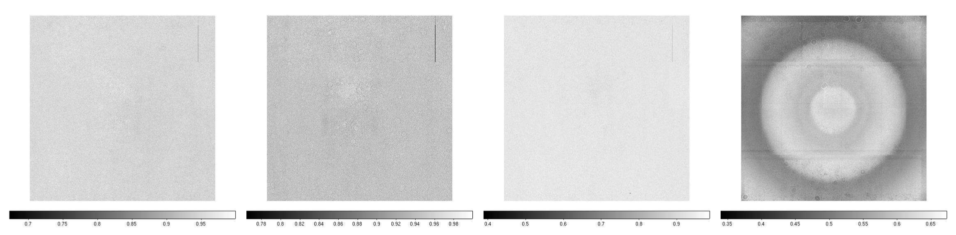
Illumination with a 850 nm LED, without filters (plotted for maximum contrast). The difference in responses at the level of the half-CCDs are due to the different gains of the readout amplifiers. The inhomogeneities of CCD efficiencies are also detected.

### Filter transmission



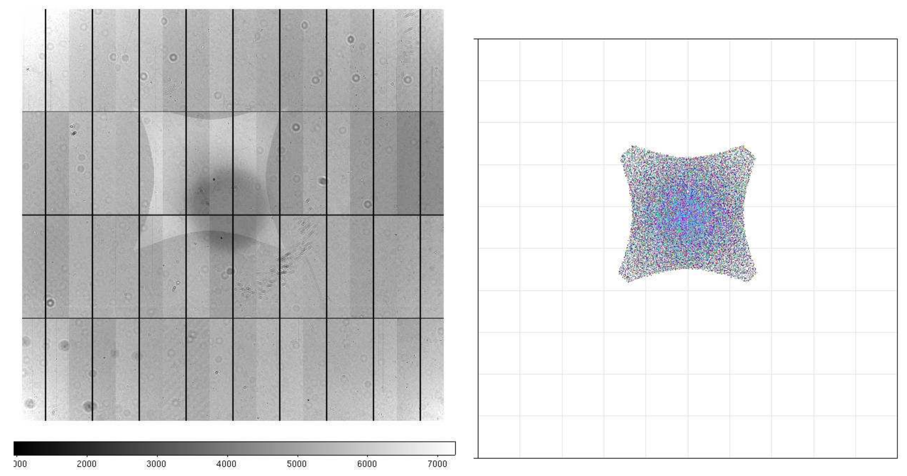
A 480 nm LED illuminating the mosaic with the filter g' in front of the CCDs (left). By making the ratio of that image with one taken without any filter, we obtain the g' filter transmission (right), showing an inefficiency of 10 % in the center.

### Filter edge



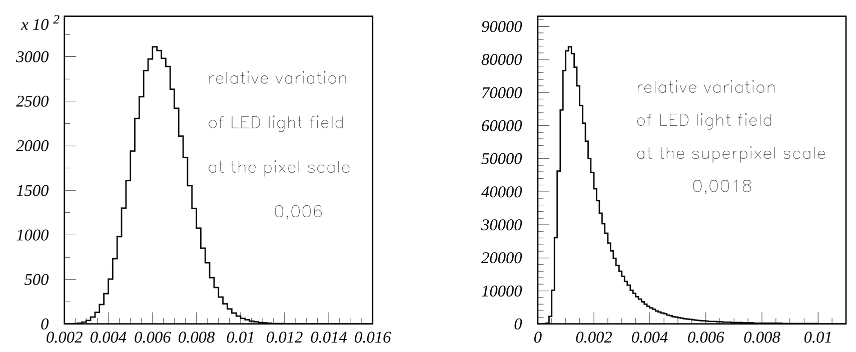
i' filter observed with LEDs at 735 nm, 750 nm, 810 nm and 850 nm, which is at the edge of the filter bandpass.

### Double Fresnel reflexions



Internal reflexions between the g' filter and the surface of one lens of the Wide Field Corrector: MegaCam image (left) and ray-tracing simulation (right), reproducing the same 'pincushion' pattern. The ratio of surfaces explains why small reflexion coefficients yield a large effect (10 %).

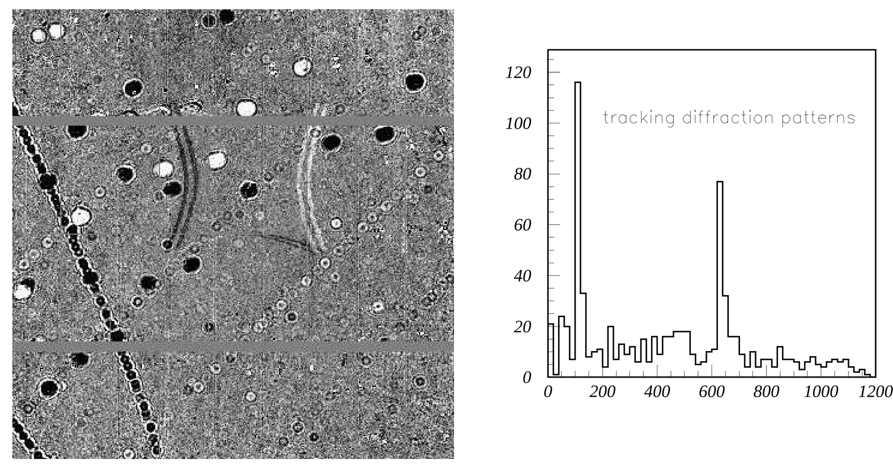
### Short-term stability




Stability of the LED illumination at each pixel/superpixel, evaluated on 16 successive shots in identical conditions.

### Optical monitoring

On a single calibration shot, optical faults along the path of light show up as diffraction patterns (as seen above and below). Using several shots taken at different positions allow us to eliminate these patterns, as seen on the previous images. However, we can also use these patterns to extract information about the optical quality of the instrument.




Tracking of diffraction pattern (left) when the illuminated spot is moved on the mirror. Four images have been stacked with alternate signs for visualization. The distances by which all features have moved are compiled in the plot on the left. The two prominent peaks mean that most of the optical faults are located in two optical planes, one being the mirror and one the front surface of the Wide Field Corrector.


### Acknowledgments

SNDICE has received funding support from CNRS/IN2P3, University Paris 6 and Paris 7. The SNDICE team would like to thank the CFHT staff, who made it possible to install and run SNDICE in a very short time.