DECal: A Spectrophotometric Calibration System For DECam

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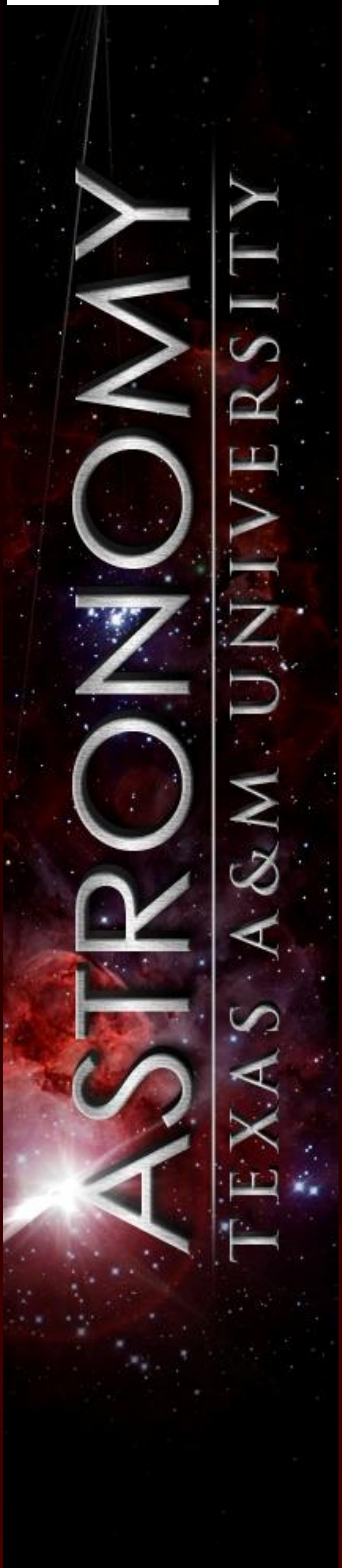
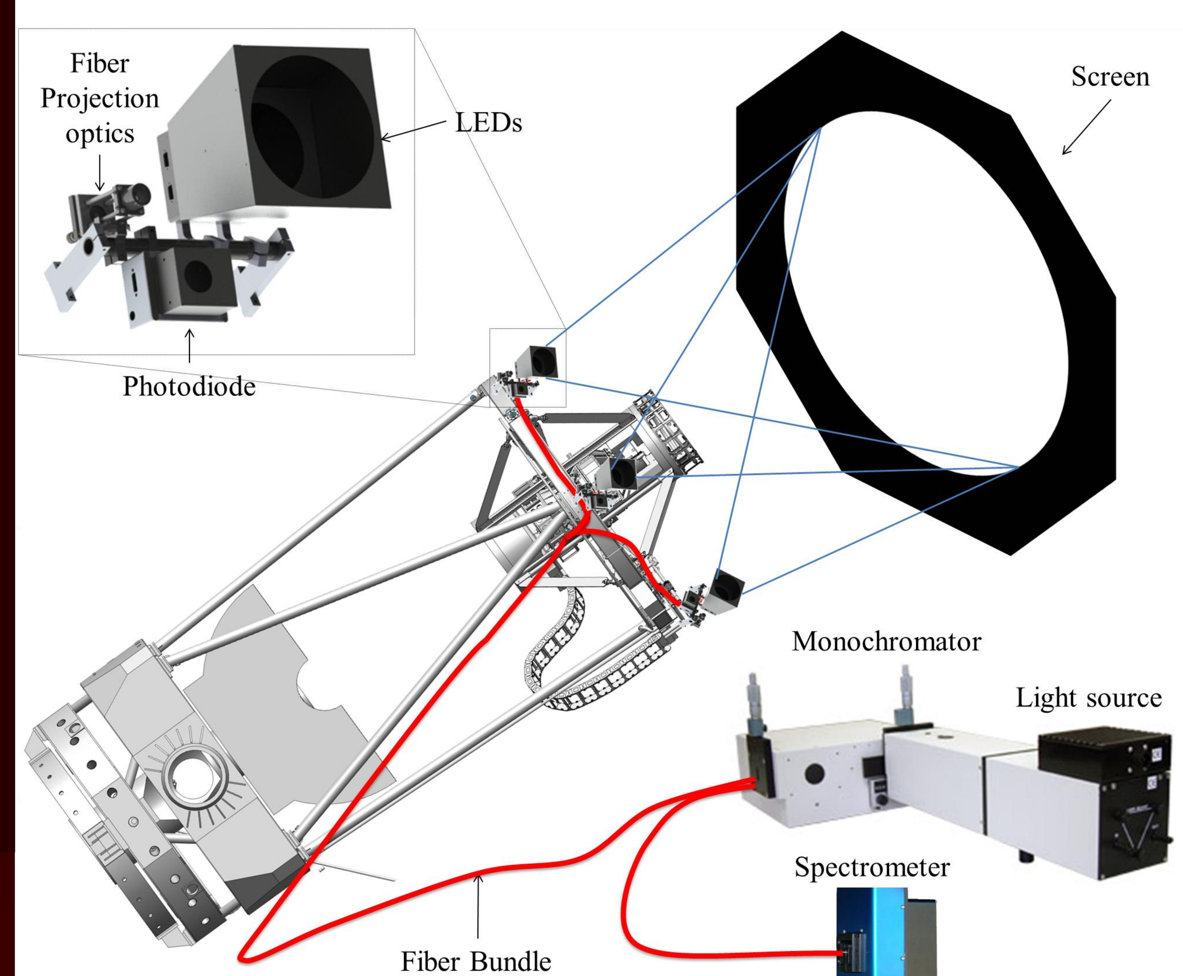


Introduction

The discovery that the universe is *accelerating*, not slowing down from the mass it contains, is the surprise that sets the initial research program of 21st Century cosmology. The Dark Energy Survey is a next generation sky survey aimed directly at understanding this mystery. The survey will rely on DECam, an extremely red sensitive 520 Megapixel camera that has a 1 meter diameter, 2.2 degree field of view prime focus corrector, and a data acquisition system fast enough to take images in 17 seconds. DECam is in the process of being installed at the prime focus of the Blanco 4-meter telescope at CTIO, a southern hemisphere NOAO telescope.

We have built a spectrophotometric calibration system for this camera that will measure the total instrument throughput versus wavelength. The system will be installed permanently at the telescope. The goal is to monitor the throughput of the telescope at regular intervals (~every 1 month) during the 5-year survey to monitor the instrumental performance. The data from our calibration will also provide accurate knowledge of the filter transmission functions that can be used to calculate more accurately photometric redshifts, supernovae k-correction transformations and other valuable precision photometric results.

We have successfully deployed a prototype of our system at the Swope and DuPont telescopes located at Las Campanas Observatory in Chile. We measured the throughput of the u, B, V, g, r, i,Y, J, H and K filters used during the Carnegie Supernova Project. This was the first time such a calibration was performed in the Infra-red. We also present the final design of the permanent DECam system we will implement at the CTIO Blanco telescope this summer.



Experimental Setup

The experimental setup consists of a broadband light source from which we select a narrow bandwidth (2-5 nm FWHM) using a monochromator. The monochromator output is coupled into a fiber bundle and brought to the top of the telescope and then projected onto the flat field screen using beam projection optics that ensure uniform illumination of the screen. 4 NIST traceable calibrated photodiodes measure the power on the screen. A sample of the illumination beam is fed to a spectrometer that monitors the wavelength with an accuracy of ~0.1nm.

Abstract

We present preliminary results for a spectrophotometric calibration system that is being implemented as part of the DES DECam project at the Blanco 4 meter at CTIO. Our calibration system uses a 2nm wide tunable source to measure the instrumental response function of the telescope from 300nm up to 1100nm. This calibration will be performed regularly to monitor any change in the transmission function. The system consists of a monochromator based tunable light source that provides illumination on a dome flat that is monitored by calibrated photodiodes and allow us to measure the throughput as a function of wavelength. Our system has an output power of 2 mW, equivalent to a flux of approximately 800 photons/s/pixel on DECam. Preliminary results of the measure of the throughput of the telescope will be presented.

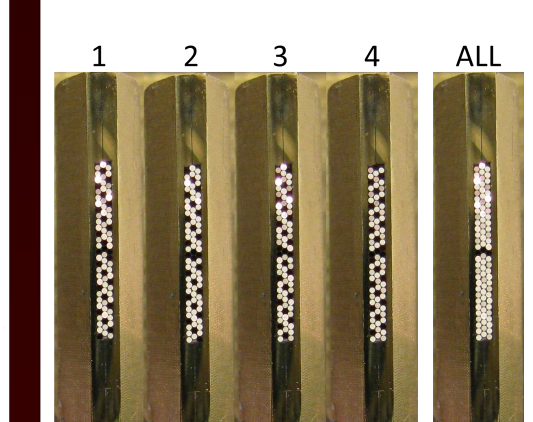
Monochromator and Light Source

We use a fully automated F/4 Czerny-Turner monochromator with a high reciprocal dispersion of 2.3 nm/mm. This allows us to open the slits to 1mm and still keep a relatively narrow bandwidth of 2nm FWHM with a 1200g/mm grating. We use 3 gratings, 5 order sorting filters and two light sources to maximize the throughput over the whole wavelength range of 300 to 1100nm. All of these are remotely controlled by a Labview based calibration program.

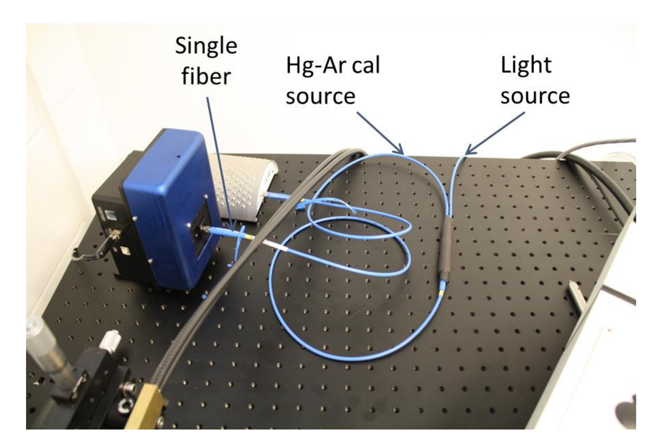
Fiber Bundle

We use a custom 75mm long fiber bundle made with special broad-spectrum fiber. This fiber has excellent transmission both in the UV and the IR. This contrasts with most fibers where good transmission is only available in the infrared (low OH^- content) or in the UV (high OH^- content) but never at both end of the spectrum simultaneously.

The bundle consists of 87 fibers with 300 micron cores arranged in a 3 vertical lines by 29 rows at the input end (monochromator). The bundle is separated in 5 branches, 4 of which go to the top of the telescope to illuminate the screen. The 5th branch is fed into a spectrometer to monitor the central wavelength and FWHM of the illuminating beam in real time.



Fiber bundle: slit end



Y fiber coupler

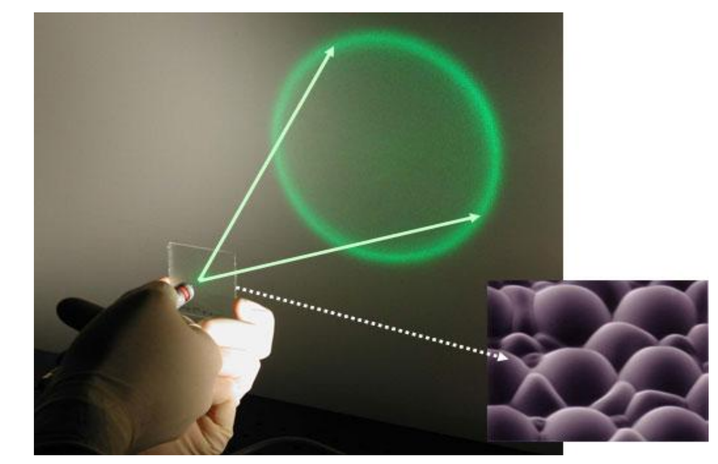
Wavelength Monitoring

One of the fibers in the bundle is bifurcated toward a spectrometer to measure in real time the spectral content of the illumination source. The spectrometer measures both the central wavelength and the FWHM of the source. A spectrum is saved for every exposure and subsequently reduced to get the FWHM and central wavelength to 0.1nm. The spectrometer is calibrated every night with a Mercury calibration lamp. We use an echelle spectrograph from Optomechanic Research (SE-100) that covers the whole wavelength range in a single scan while keeping a high resolution of 3500.

The calibration lamp and the 5th branch from the fiber bundle are connected to the spectrograph using a mode mixer and a "Y" fiber coupler.

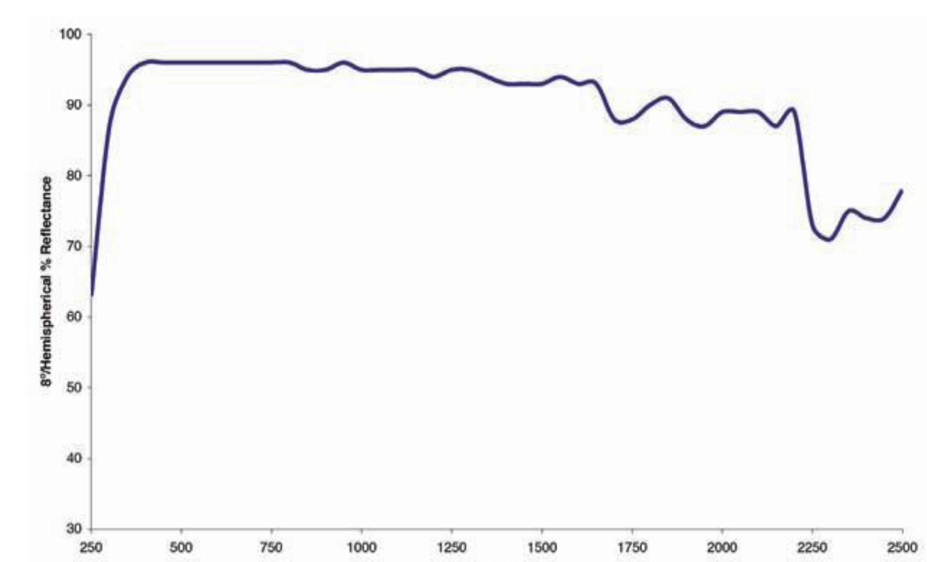
Diffuser

To ensure a uniform illumination of the focal plane area, we use an Engineered Diffuser from RPC Photonics to project the light from the fibers on the screen (see example at left). Our diffuser is a 30° angle cone diffuser that projects the light in a top hat shape with a diverging angle of 30 degrees.



Flat Field Screen

A new flat field screen was installed at CTIO in November 2011. It is made of a lightweight aluminum honeycomb panel coated with a highly reflective and almost perfectly Lambertian coating called Duraflect from Labsphere. It is a coating that was developed for use in integrating spheres. The spectral reflectivity of the Duraflect coating is excellent with reflectivity over 95% from 350 to 1200nm and over 85% from 300 to 2200nm. This is shown in the figure below.



Photodiode Monitoring

Reference photodiodes measure the amount of light reflected off the screen. They are positioned on the top ring, facing the screen. They have a baffle that limits their field of view to the screen only so they don't receive any light reflected from the dome. We use 10mm Ø silicon photodiodes that are sensitive from 300nm to 1150nm to measure the light. We expect to measure signals on the order of 1 nW on the photodiode. These signals will be amplified by a low noise trans-impedance amplifier with a selectable gain from 10^9 up to 10^{12}. The amplifier has a cut-off frequency around 20 Hz to reduce noise levels. The amplified signal is read by an analog to digital converter acquiring signal at 10kHz. The signal will be averaged over the duration of an exposure by the camera for the analysis. The photodiodes were calibrated in our labs using a reference photodiode calibrated directly at NIST.

Conclusion

We have built a monochromator based light source that will perform an accurate spectrophotometric calibration on the system on the CTIO Blanco 4 meter telescope as part of a permanent calibration system. The calibration system if fully automated by the DECam control software for a convenient user friendly operation. Installation should be complete within the next year. The spectrophotometric calibration products will be used in the DECam data reduction pipeline to help the DES survey reach their ambitious photometric accuracy goals.

Texas A&M University Department of Physics and Astronomy is an institutional member of:

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HETDEX Hobby-Eberly Telescope Dark Energy Experiment — Illuminating the Darkness
LSST Large Synoptic Survey Telescope
DARK ENERGY SURVEY

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