Astrocal: a mobile spectrophotometric calibration system

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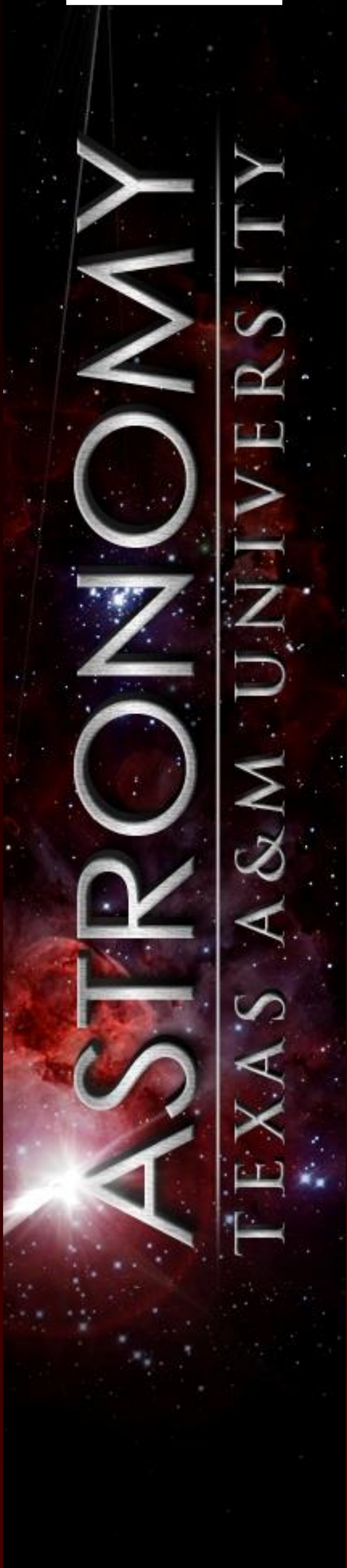

Abstract

Astrocal is a mobile version of DECal[1]. DECal is a spectrophotometric calibration system used to determine the relative throughput of a telescope. This measurement is important because large surveys, like the Dark Energy Survey, rely on precise measurements. The throughput calculations produced by DECal are used to correct photometry produced for these surveys. However, for multiple telescopes to participate in a given imaging survey, they must all be placed on a standard accuracy scale. Because DECal was permanently installed on the Víctor M. Blanco Telescope 4M telescope in Chile, a new system had to be develop that could be adapted to a wide variety of telescopes. The challenges encountered and potential solutions are the focus of this work.

Introduction

Astrocal is a spectrophotometric calibration system used on 0.4 meter to 4 meter telescopes in the 300nm to 1100nm range.
Astrocal is intended to be used on all telescopes for a follow up on the data Large Synoptic Sky Survey Telescope (LSST) will be gathering. If multiple telescope are used for this they must be calibrated to a common photometry scale, so they can be compared to the data produced by a single telescope.
Astrocal works fundamentally the same as DECal. Like DECal, Astrocal consists of seven major components: a light source; monochromater; spectrometer; fiber bundle; projectors; photodiodes; and a lambertian screen, Figure 1.

The light source provides light to the monochromater. The monochromater mechanically selects a specific wavelength of light. The light is carried by the fiber optic cable, and evenly projected through engineered diffusers onto a lambertian screen. Photodiodes mounted around the top of the telescope see the light being bounced off the lambertian screen. The amount of light seen by the photodiodes is compared to the amount of light seen by the CCD in the telescope. The relative throughput of the telescope can be determined from this.

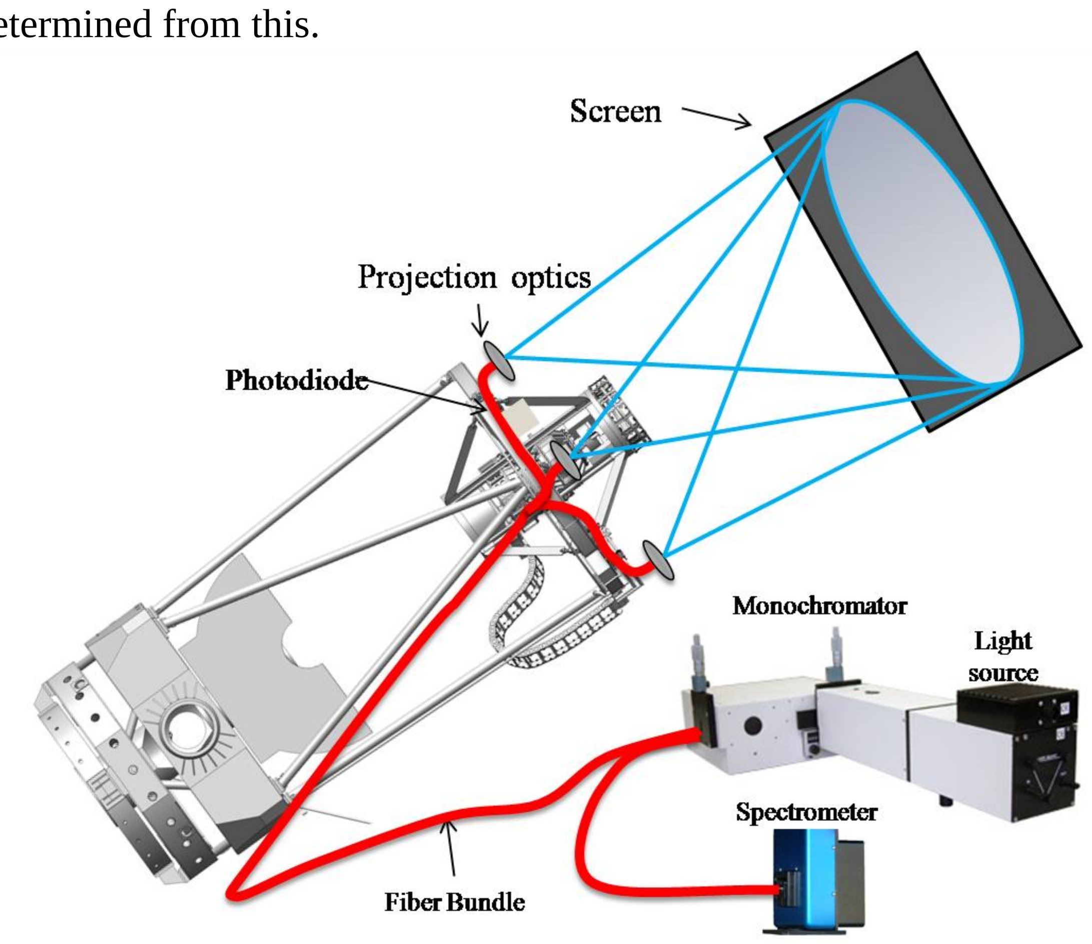

Figure 1: Astrocal and DECal set up[1]

Research

The biggest challenge with making DECal mobile, stems from the wide variety of telescopes it would be calibrating. To get an idea of what Astrocal would face in the real world, a list of 22 telescopes to research was made. These telescopes were chosen because they are candidates for calibration once Astrocal is complete. Research on these telescopes focused on aspects of their design that would influence Astrocal's mounting system, and projection pattern. These criteria include: Primary mirror diameter; secondary mirror diameter; f/#; dome clearance; and if the telescope is made out of a material that a magnetic mount could attach to, like steel.
In addition to the research on telescopes, research was conducted on improving the individual components of DECal. The most important of these was the light source. DECal's light source used two separate lamps, this was done because neither could cover the 300nm to 1100nm range. The 75 watt was used from 300nm to 700nm, and the quartz was used from 700nm to 1100nm. The new light source, an EQ-99X[2], can cover the whole range and it is brighter than the previous light sources. This increase in brightness is important because it allows us to take shorter exposer times, due to the photodiodes and the telescope seeing more light in a given timeframe. This will shorten the overall length of time needed to preform a calibration.

Dome Clearance

One of the design parameters for Astrocal is the distance between the top of a telescope to the dome wall Figures 4 and 5. This is important because the engineered diffusers need distance to spread to their target diameter. If there was just one projector the target diameter would be the diameter of the lambertian screen. The labertian screen is the same diameter as the primary mirror. The dome clearance was determined by looking at pictures of the telescopes and comparing the diameter of the telescope to the distance between the front of the telescope and the dome. This method, while relatively inaccurate, allowed us to find outliers.

Projectors

In order to evenly project light onto the lambertian screen diffusers have to be used. Diffusers take light and project it in a cone at a set angle, Figure 2. Diffusers come in angles ranging from half a degree to 120 degrees. It was determined that diffusers with different angles could be used to alter the necessary dome clearance for a given telescope.

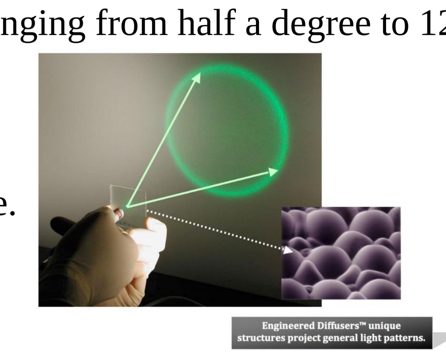

Figure 2: Projection cone[3]

The number of projectors used can also alter the clearance needed. More projectors require less clearance because they don't need to spread out to as large of a diameter. Figure 3 shows the pattern and size for a four projector pattern.

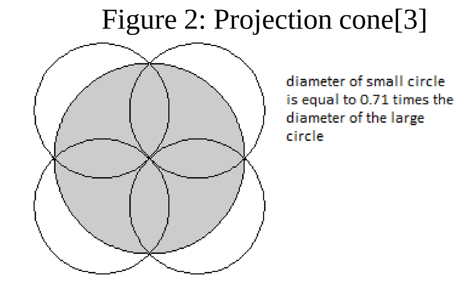

Figure 3: Projection pattern for four projectors[4]

To determine what angle of diffuser should be used with a given telescope and number of projectors, the telescopes were plotted on a primary mirror diameter vs dome clearance graph. Lines that mark the minimum distance needed for a diffuser to reach its target diameter were also plotted, Figures 4 and 5. If a telescope falls over a line it has more than the necessary dome clearance. If it falls under a line it has less than the necessary clearance. Any telescope that falls under the widest angle diffuser will need to mount its lambertian screen externally to get the appropriate clearance.

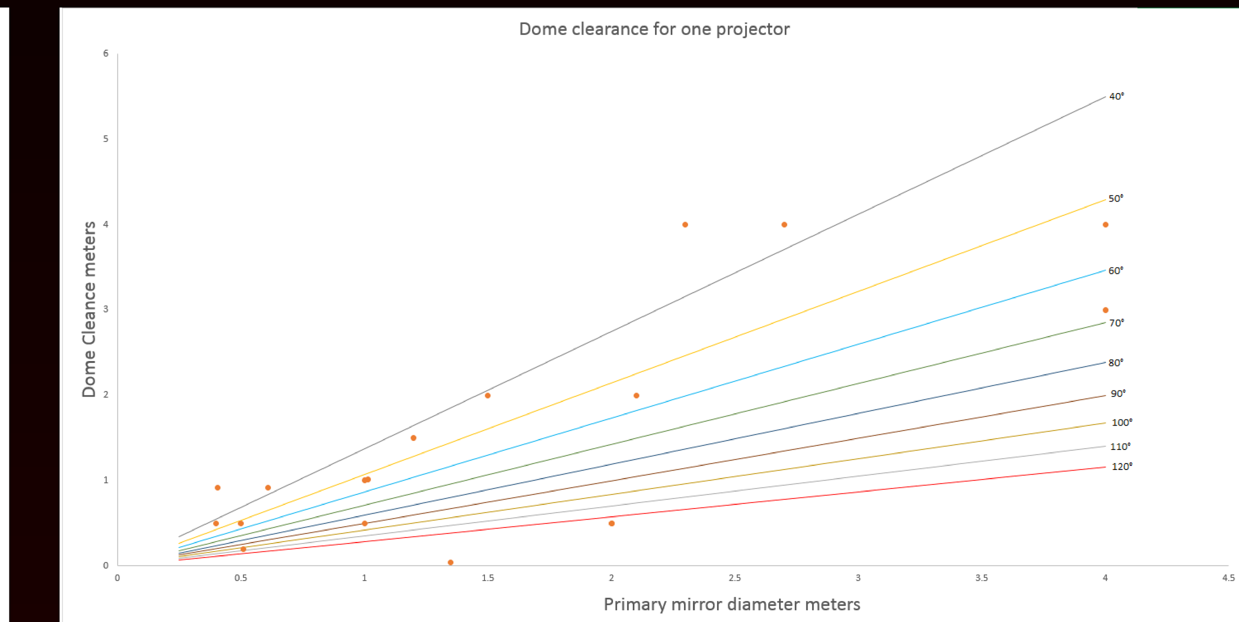

Figure 4: Dome clearance and diffuser angles for one projector

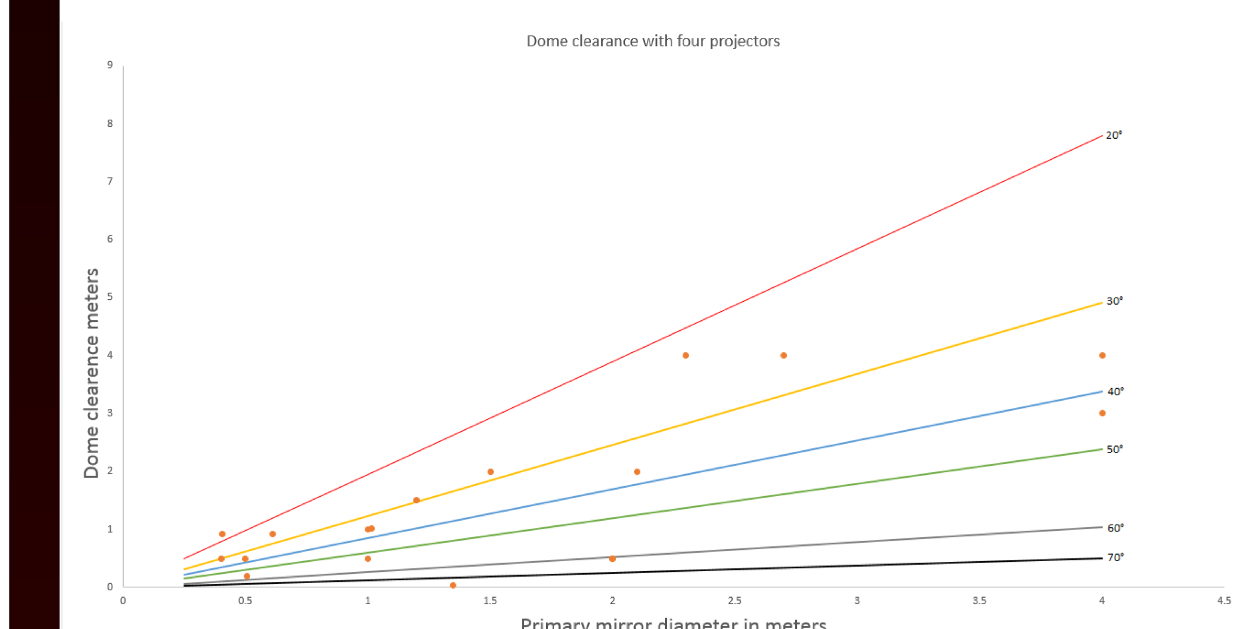

Figure 5: Dome clearance and diffuser angles for four projectors

Fiber optic

The fiber optic cable used in Astrocal is a 75 meter fiber bundle consisting of 35 300 micron cores. This number of cores was chosen based on the height of the exit slit of the monochromater, and 35 cores is less than half of the 87 used in DECal. This provides significant cost savings. These cores would be arranged in a single row. The fiber bundle would separate at 65 meters into four fibers with eight cores each. The remaining three cores would branch off at the ferrule and be 75 meters long like the other branches. This branch would connect with the spectrometer.

Conclusion

This poster covers the initial research done on Astrocal. Over the next three years we will continue to design, build, and deploy Astrocal, a mobile spectrophotometric calibration system. Astrocal will help reduce systematic errors when comparing imaging data from other telescopes to LSST, by calibrating other telescopes to a standard photometry scale. Future work will focus on purchasing and machining components, and building software to automate Astrocal.

References

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GMT

HETDEX Illuminating the Darkness Hobby-Eberly Telescope Dark Energy Experiment

LSST Large Synoptic Survey Telescope

DARK ENERGY SURVEY

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