SOFTWARE DEVELOPMENT OF TCAL: A MOBILE SPECTROPHOTOMETRIC CALIBRATION SYSTEM

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ABSTRACT

TCal is a mobile spectrophotometric calibration unit that will be used to characterise imaging systems at observatories around the world. We developed software in LabVIEW to automate our scans which measure transmission as a function of wavelength, and place all calibrated systems on a common photometric baseline. Our calibration system uses a ~1 nm wide tunable source to measure the instrumental response function of the telescope optics and detector from 300 nm up to 1100 nm[1]. The system consists of a monochromator based tunable light source that illuminates a flat field screen. This screen is monitored by calibrated photodiodes allowing us to measure the telescope throughput as a function of wavelength. This system will be taken to various 1-8m telescopes that expect to devote time to wide field/synoptic survey follow-up.

INTRODUCTION

Current and future generations of wide field/synoptic surveys with high precision photometry will rely heavily on follow-up efforts from other telescopes to enhance the surveys' scientific yield. Each telescope in astronomy has a unique set of optical equipment produced by a variety of different manufacturers, it is vital that they are calibrated using the same system in order to obtain the level of precision required to reduce systematic errors when combining data. TCal has been designed specifically for this purpose and was tested for the first time on the 250mm telescope mounted on the 30-inch telescope at the McDonald Observatory, TX.

EXPERIMENTAL SETUP

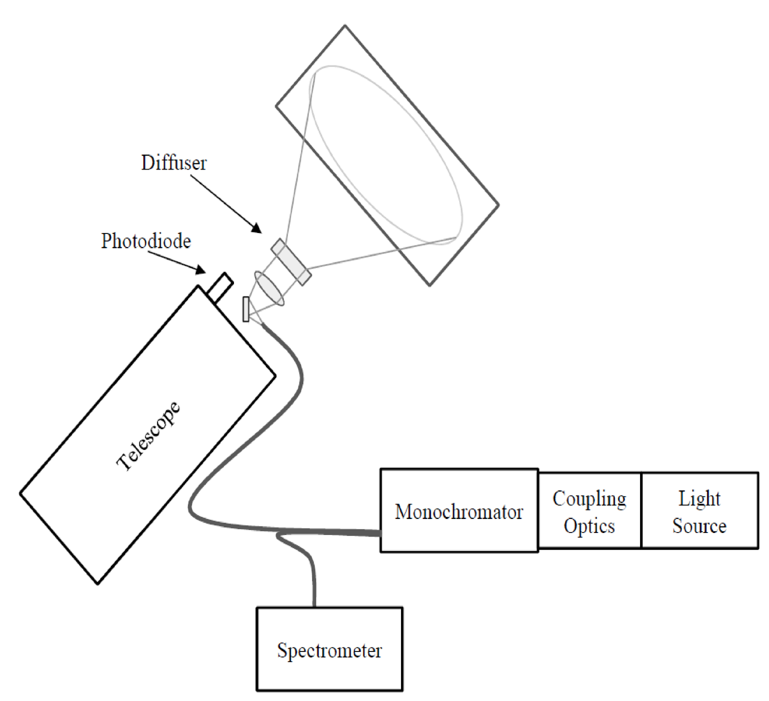

Figure 1. Schematic diagram of TCal

TCal operates as follows: A broadband light source is fed into a monochromator which selects a narrow bandwidth (~1nm FWHM). This light is fed into a fibre bundle which leads to a spectrometer as well as a signal diffuser on top of the telescope. A schematic diagram of the system is shown in Figure 1[2].

The spectrometer allows us to measure and verify the central wavelength and bandwidth of the signal in real time. The diffuser projects the light onto a flat field screen which the telescope can then take flat images of whilst we simultaneously take readings using the photodiode. The ratio of these two measurements gives the relative instrumental transmission at a given wavelength.

Software Development

Each of the components for TCal came with their own individual software to operate them, however it was necessary to combine them so that both the controls and measurements displayed on one GUI. This was done using LabVIEW. We developed a program to take data for the spectrometer and photodiode concurrently. This data was then written to a file for further analysis.

The code was structured as a state machine with two while loops in parallel. A state machine will read a series of inputs and switch to a different state based on these. The inputs were the controls for the monochromator which adjusts the wavelength, this was then fed into the other loop to adjust the data charts.

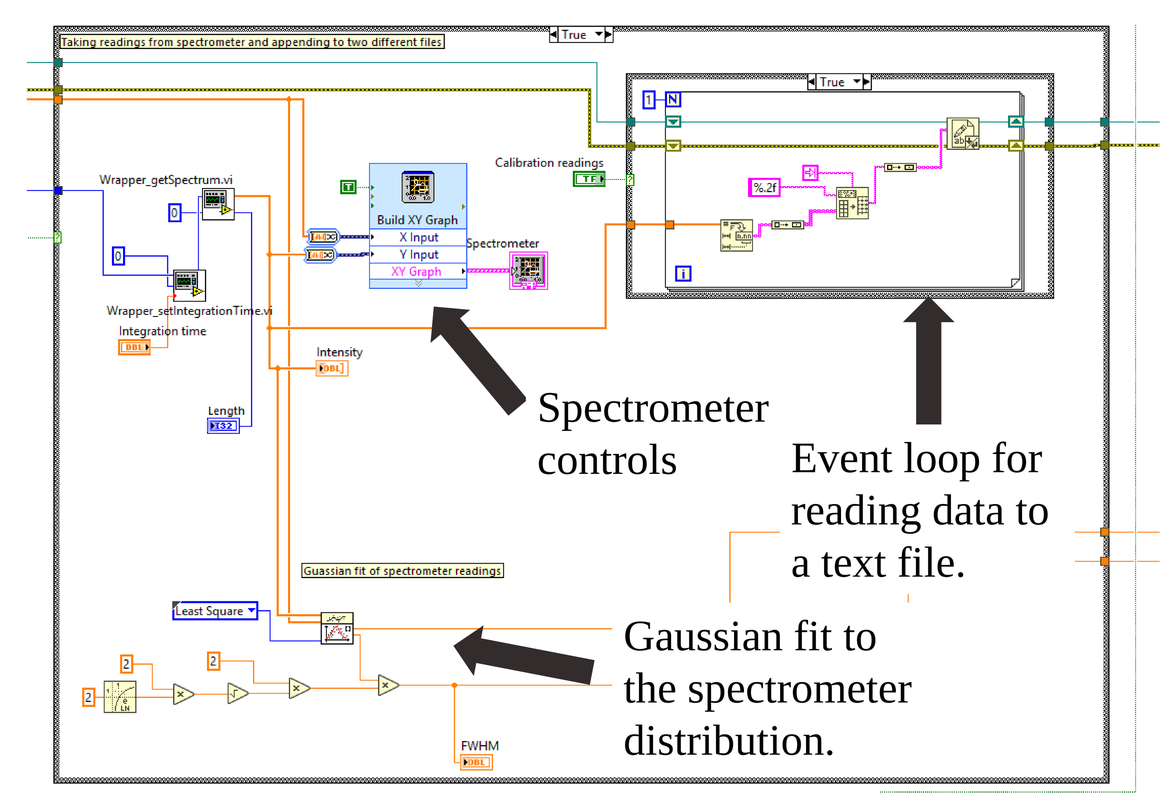

Figure 3. Event loop in the code to display and extract data from the spectrometer.

The second loop displayed and output signal readings for the spectrometer and photodiode. A flat sequence frame was used to ensure that certain events happened in a specific order i.e. first opening a data file in the correct path before any readings were taken. Both loops were linked so that the data flow could be managed and both sections stopped simultaneously.

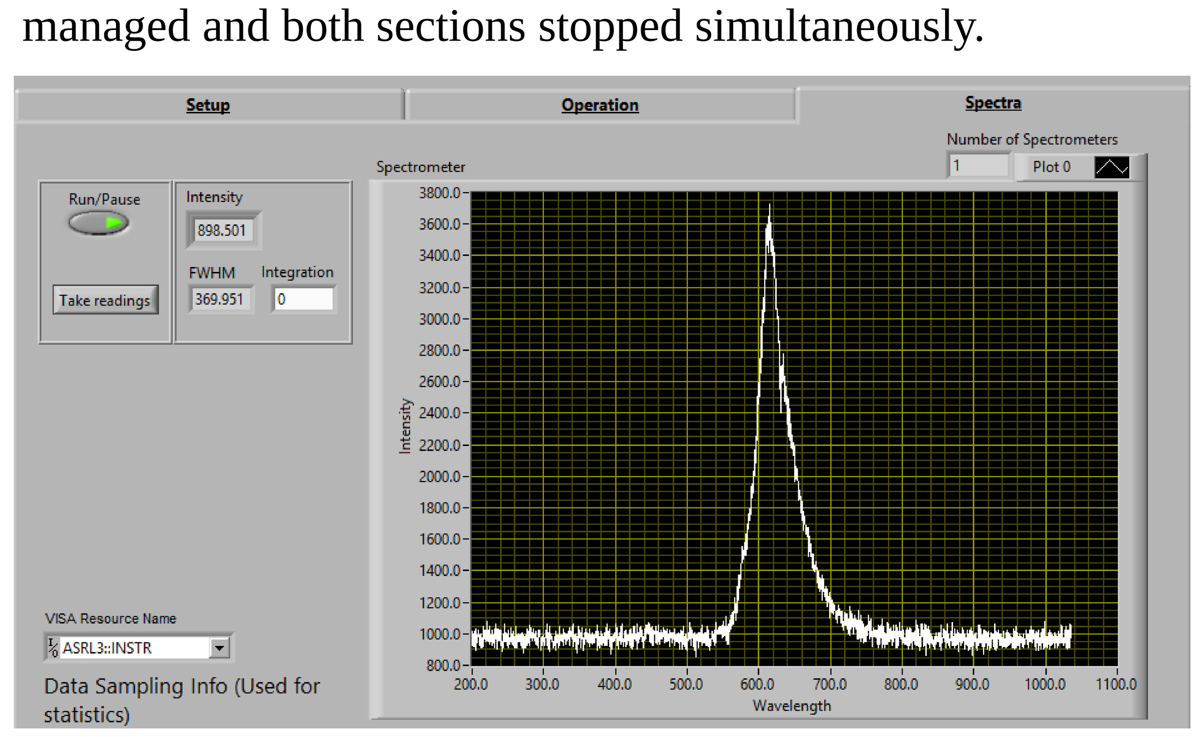

Figure 4. Display of the spectrometer during testing prior to the McDonald observatory run. Shows a plot of intensity against wavelength. The light source is a flashlight, but when using the monochromator the peak is much sharper and contains less noise.

FIRST TEST RUN

The first test run of TCal was on the 250mm telescope on the 30-inch telescope at the McDonald observatory on the 19th July 2018. The instrument was mounted on the telescope as shown in Figure 5. The observing run lasted for 3 days and we obtained measurements for both the V band and B band filter wavelength ranges. We soon hope to test more bands and to repeat V and B.

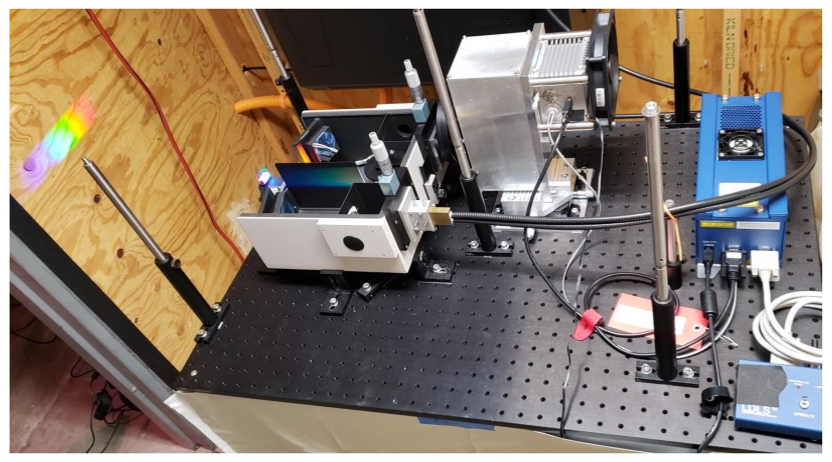

Figure 5. Image of the TCal light source and monochromator sending specific wavelengths of light down the optical fibres to the photodiode and spectrometer.

The relative transmission of the system had an accuracy of ±2% and we hope to reduce this to ±1% in the future. Improvements will be made to fully automate the scanning process.

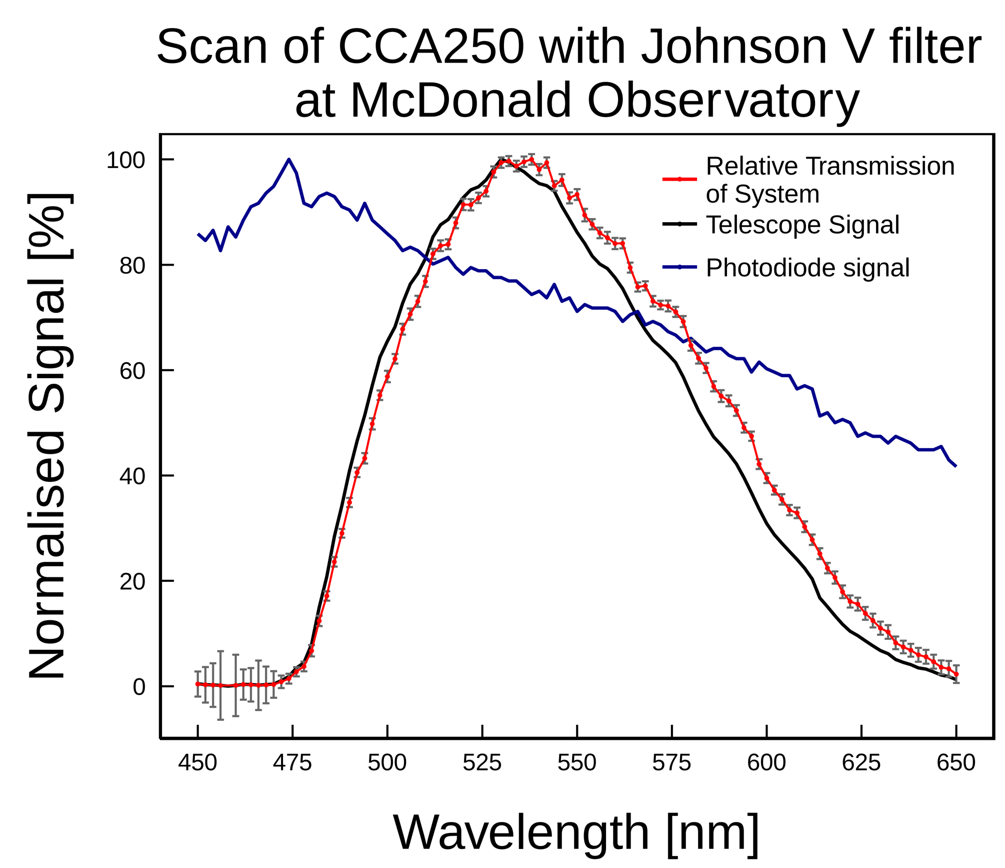

Figure 6. Plot of the normalised signal against wavelength for the telescope signal, relative transmission of the system and the photodiode signal. This was conducted for the V-band filter range. The relative transmission was calculated by dividing the telescope signal by the photodiode signal.

CONCLUSION

TCal had a successful first run and we are now developing a finalised design which will be tested on a series of 1-8m telescopes in the next few years. We expect to see significant scientific benefits from having their transmission function precisely characterized. This effort will serve to enhance the scientific return of follow-up efforts, which will benefit the entire astronomical community in the next decade and beyond.

REFERENCES

[1] Ferguson P., et al., "Development of TCal", SPIE 2018

[2] Marshall, J., et al., "TCal Brief", pg 1., June 2018

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