Digital Micromirror Device Multi Object Spectrograph (DMD-MOS) Calibration Research Summary

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Introduction

Spectroscopy is a foundational pillar of astronomy. By passing their light through a slit and diffraction grating, astronomers can extract the unique wavelength spectra of distant space objects that hold the key to their compositions, trajectories and much more. Traditional spectrographs use a single slit, requiring spectra of each object to be collected one at a time; However, this is an inefficient way to study large groups of objects, such as a globular cluster. This project introduces a relatively novel technology called a digital micromirror device (DMD). By using an array of rotatable mirrors to selectively reflect light towards or away from the grating, a DMD acts as a programmable slit mask that can be customized for unique sets of multiple objects in a field of view. The main goal of this project was to derive the relationship between the location of a slit on the DMD and the location of its corresponding spectrum on the detector, in order to prevent overlap between spectra of multiple objects on the detector. Figure 1 shows the trajectory of light from a globular cluster through the DMD-MOS, as it travels from telescope to detector.

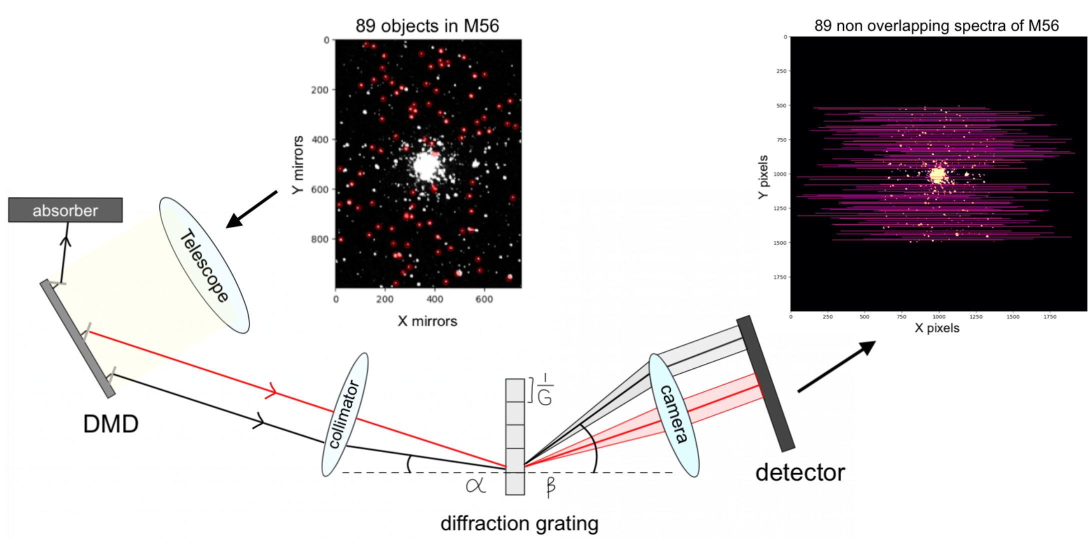

Figure 1: Schematic illustrating the trajectory of light through DMD-MOS. Coordinates of light selectively reflected into the instrument by the DMD are focussed onto the diffraction grating by the collimator. Diffracted light is then focussed by the camera onto the detector, forming a set of spectra

Methods

The first step in the calibration process was to calculate a variety of output parameters using the input parameters provided. These input parameters included basic information about the instrument, such as the size of the telescope, dimensions of the DMD and detector, groove density of the grating, and wavelength range of interest. Using these values, a series of calculations building off each other allowed me to derive useful outputs such as the focal lengths of each lens, spectral resolution, and approximate size of each spectrum on the detector. With a deeper understanding of relationships between each variable, my next step was to find the relationship between slit location on the DMD and spectra location on the detector. As shown in figure 1, light from each mirror of the DMD will enter the diffraction grating at a particular entrance angle α, which corresponds to a particular set of exit angles β for each wavelength, before finally arriving on a particular set of pixels on the detector as a spectrum. By mathematically defining each of these steps throughout the light's journey, I was able to derive the precise pixel coordinates spanned by a spectrum as a function of which mirrors on the DMD were being used as slits.

Results and Next Steps

To test the results of my calculations, I used a remotely accessed telescope to take an image of the globular cluster M56. Each coordinate on the field of view was matched to a micromirror coordinate on the DMD, so that this image could be used as simulated data. Using a program written in Python, I started by identifying all objects within the field of view within a certain brightness and size threshold. Next, I filtered for objects whose spectra would not overlap based on my prior calculations, which left me a set of 89 objects (figure 1, top left). Finally, by applying the function for spectra pixel location, I was able to generate predicted spectra location for all 89 objects (figure 1, top right). As can be seen in figure 1, I was able to successfully plan a set of slit locations on the DMD so that resulting spectra do not overlap. This result also demonstrates the efficiency of using a DMD-MOS to study spectra of large sets of objects simultaneously, where a traditional spectrograph would have needed to be reoriented 89 separate times. With more time and lab access, next steps for this project would involve collecting test data and performing calibration on the actual DMD-MOS, in order to physically verify my findings.