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

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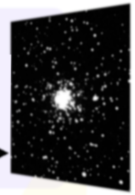
Introduction

Single slit spectrographs can only generate the spectra of one object at a time. By acting as a programmable slit mask, DMDs allows a spectrograph to generate spectra of many different objects in the same field of view, such as M56 pictured here →



Problem

How can we predict the location each object's spectra will be on the detector, and select objects so that their spectra don't overlap?

Solution Outline

1. Calculate output parameters
2. Relate mirror location with spectra location
3. Generate spectra with simulated data
4. Perform wavelength calibration

1 Input Parameters

Telescope

diameter D_T resolving power R

F-ratio $F/\#_T$ field of view FOV_X, FOV_Y

DMD

\# of mirrors N_{MX}, N_{MY}

mirror pitch p_M

plate scale S_M

Wavelength

minimum λ_{min}

central λ_c

maximum λ_{max}

Detector

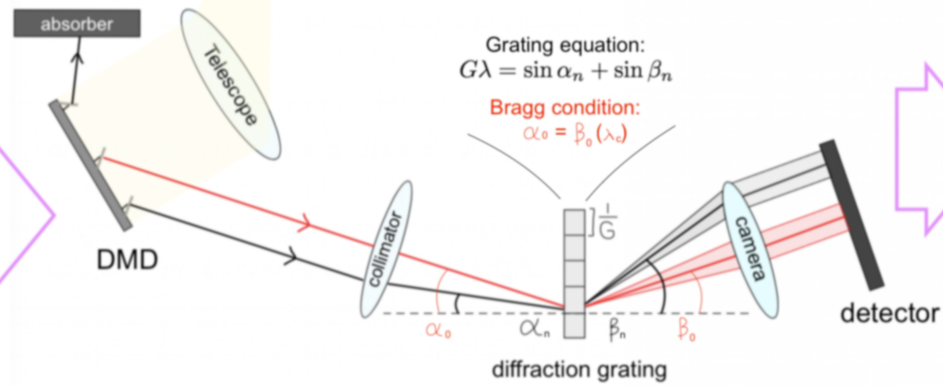
\# of pixels N_{DX}, N_{DY}

pixel pitch p_D

plate scale S_D

Diffraction grating

Groove density G



Calculated Output Parameters

pixels per mirror N_{p1} (S_D, S_M)

spectrograph magnification M_S(p_D, p_M, N_{p1})

spectral resolution $\Delta\lambda$ (R, λ_c)

Number of bandpasses BP (λ_{min}, λ_{max}, $\Delta\lambda$)

focal lengths f_T(F/#, D)

f_{cam} (λ_{min}, λ_{max}, G, BP, p_D)

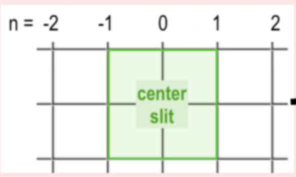
f_{col} (f_{cam}, M_S)

grating to camera distance d(p_D, p_M, N_{p1}, N_{MX}, f_{col}, λ_c)

Solving for outputs illustrates how each parameter is related to the others

2 Translating DMD slit choice to location of spectra on detector

slit n mirrors from DMD center



2x2 mirror per slit by Nyquit Sampling Theorem

central entrance angle

$$\alpha_0 = \arcsin\left(\frac{G\lambda_c}{2}\right)$$

From Bragg condition

entrance angle n

$$\alpha_n = \alpha_0 + \arctan\left(\frac{np_M}{f_{col}}\right)$$

From trigonometry

exit angle n

$$\beta_n(\lambda) = \arcsin(G\lambda - \sin(\alpha_n))$$

From grating equation

distance from detector center

$$X_n(\lambda) = d\tan(\beta_0(\lambda_c) - \beta_n(\lambda))$$

$$P_x(n,\lambda) = \frac{N_{DX}}{2} + \frac{X_n(\lambda)}{p_D}$$

Spectral pixel number

The pixel number corresponding to each wavelength and slit location can now be predicted

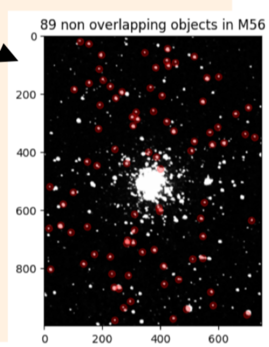
3 Simulating Predicted Spectra

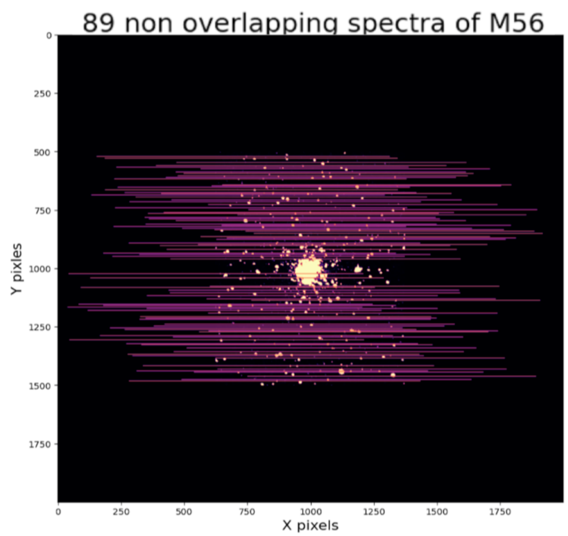
Exposure of M56 taken via iTelescope

Objects identified using algorithm taking threshold brightness and size into account

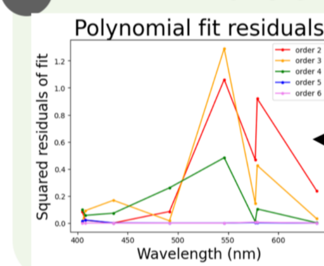
Overlap prevented by filtering for objects at least 2 slit widths apart in the spatial (y) dimension

Spectra generated using equation derived in part 2





4 Wavelength Calibration



Using a light source with known spectral features, a polynomial fit for spectra at each location on the detector can be performed

← This figure shows that higher order fits have lower residuals

(Without lab access to DMD-MOS, a single slit spectrograph was calibrated using an Hg lamp as practice)

Next Steps

Generate true simulated data to pass through simulated optics on Zemax, and perform calibration on real DMD-MOS

(limited by restricted access to lab)