The Boller & Chivens CCD Spectrograph (CCDS)

Contents:

Summary

The Boller & Chivens CCD Spectrograph (CCDS) is a conventional optical grating spectrograph operating in the 3,200-9,500Å region. It can be used on either the Hiltner 2.4m and McGraw-Hill 1.3m telescope as a facility instrument. It was acquired by The Ohio State University through a grant from the National Science Foundation in 1970 for stellar spectral classification programs and was used for roughly 28 years (1970-1998) on the Perkins 1.8m telescope on Anderson Mesa in Arizona. It was moved to MDM in 1999.

Five diffraction gratings are available, providing a range of spectral resolutions from 550 to 9,100. The slit-width is continuously adjustable between 0.5 and 13 arcsec. The current science detector is a Loral 1,200x800 CCD utilizing permanent backside charging and a dual-layer anti-reflection coating which provide high quantum efficiency over the extent of spectral range. The CCD read noise is typically 7 electrons and the gain is nominally set to 2.1e^{-}/ADU. Lamps located in the MIS box at each telescope are used for wavelength and flat-field calibration. With the lowest-dispersion grating in first order, the peak system quantum efficiency is about 19% at 5,200Å.

A thermo-cooled FLI CCD camera is used to image the polished entrance slit jaws of CCDS for target acquisition. See the [CCDS Acquisition Camera](#) section for more detail.

CCD Characteristics & Parameters

Grating (grooves/mm)	Blaze (order/angle/lambda)	Dispersion Å/pixel)	Coverage (Å)	Resolution (Å) 1” slit (87¨μ 2.4m)	Resolution (Å) 1” slit (47μ 1.3m)	~ColFoc @ 20ºC
150	1st / 2.15 / 4700	3.29	3650	8.2	4.4	850
158	1st / 3.63 / 7530	3.16	3650	8.1	4.1	
350	1st / 4.30 / 4026	1.33	1592	3.4	1.9	850
600/1	1st / 8.63 / 4700	0.79	953	1.9	1.0	910
600/2`	2nd / 22.03 / 5875	0.41	495	0.8	0.4	
1800	1st / 26.75 / 4700	0.275	330	0.825	0.3	

Table 1: Grating Information

Measured 2008Oct15 (Pogge, OSU)
Dimensions: 1200 x 800; 15μm square pixels
Manufacturer: Loral
Designation: OSU Loral C
Read Noise: 3.5 electrons
Gain: 1.5 electrons per ADU
Linearity: Linear to 65,000 ADU
Orientation: Shorter wavelengths are at smaller column numbers; East on the slit corresponds to smaller row numbers
Pixel Scale: 0.41 arcsec per unbinned pixel (2.4m); 0.75 arcsec per unbinned pixel (1.3m)
Unvignetted slit length: 5.2 arcmin (2.4m); ~10 arcmin (1.3m, not directly measured)
Dual-layer anti-reflection coating for broad wavelength sensitivity (400Å HfO_2 + 900Å MgF_2 coatings)
Thinned and packaged by the University of Arizona Imaging Technology Laboratory
Mounted and interfaced by the OSU Imaging Sciences Laboratory

Detector format, binning and overscan regions are user-selectable options.

Gratings and Spectral Information

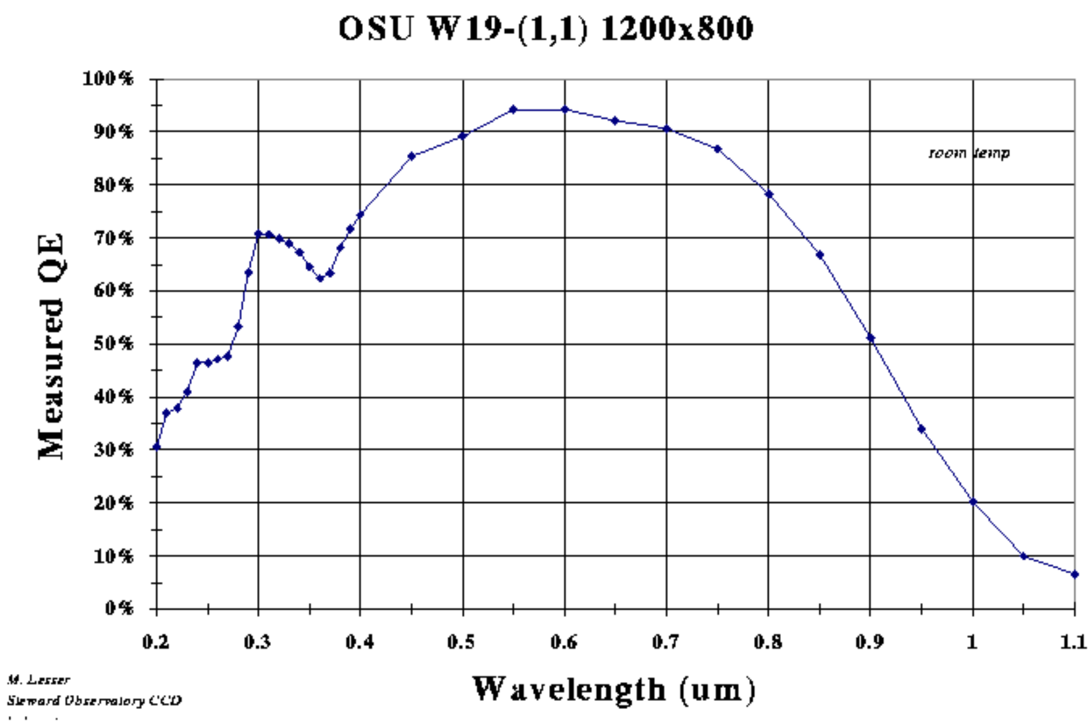

Figure 1: Quantum Efficiency Curve

Table 1 above summarizes the characteristics of the available gratings for use with CCDS. The indicated values for dispersion, spectral coverage and spectral resolution have been calculated, but appear to be accurate when compared with actual data obtained with the instrument. Also given are the approximate collimator focus measured at 20°C for as many gratings as we have information.

Notes: The 600/2 & 1800 line gratings are undersampled at the 2.4m; All gratings are undersampled at the 1.3m.

Figure 2 below shows the measured grating efficiencies as reported by the manufacturer as a function of wavelength. It should be noted that these curves were measured in a Littrow configuration and may not be applicable to CCDS. The 1800 g/mm grating has a strong polarization dependence on its measured efficiency curve that is not shown below and which is based on unpolarized light. They are provided here for relative comparison only. Quantitative performance estimates should use the information provided below based on the spectra of standard stars with the CCDS.

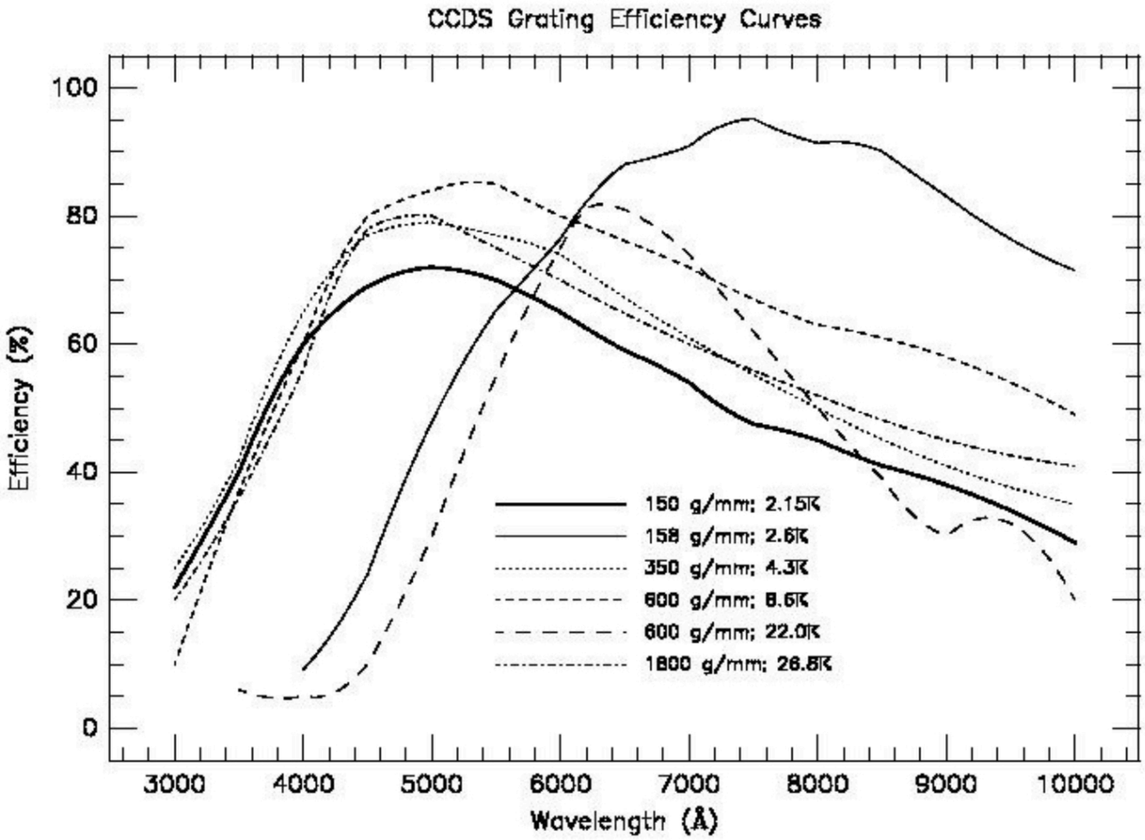

Figure 2: Grating Efficiencies

Performance & Throughput

Throughput:

The sensitivity function shown in Figure 3 below is the convolution of contributions from the Hiltner 2.4m telescope and its reflective surfaces, the spectrograph and its optics, and the detector. It was derived based on spectra of the standard stars BD+28 4211 and Hiltner 102 obtained under photometric conditions on 1999Aug21. To avoid light losses which would affect the measurement, the slit was widened to 13 arcsec. The 150 g/mm grating was employed and was centered at 4400Å (blue), 7970Å (red) and 5500Å (green) respectively. Exposure times were 100s in the blue, 240s in the red and 100s in the green. No order separating filters were used. The stellar spectra were extracted from the frames with sky subtraction and were corrected for the effects of atmospheric extinction, but were not flat-fielded.

Count Rates:

The counting rate of the CCDS for each grating has been measured at the 2.4m telescope. Table 2 presents the results.

	Count Rate (e^{-}/s/Å) for m(5556)=10.0mag at Unit Airmass	
Grating	Hiltner 2.4m	McGraw-Hill 1.3m[a]
150	730	214
350	592	174
600/1	650	220
600/2	840[b]	246[b]
1800	688[c]	202[c]

Table 2: Count Rates

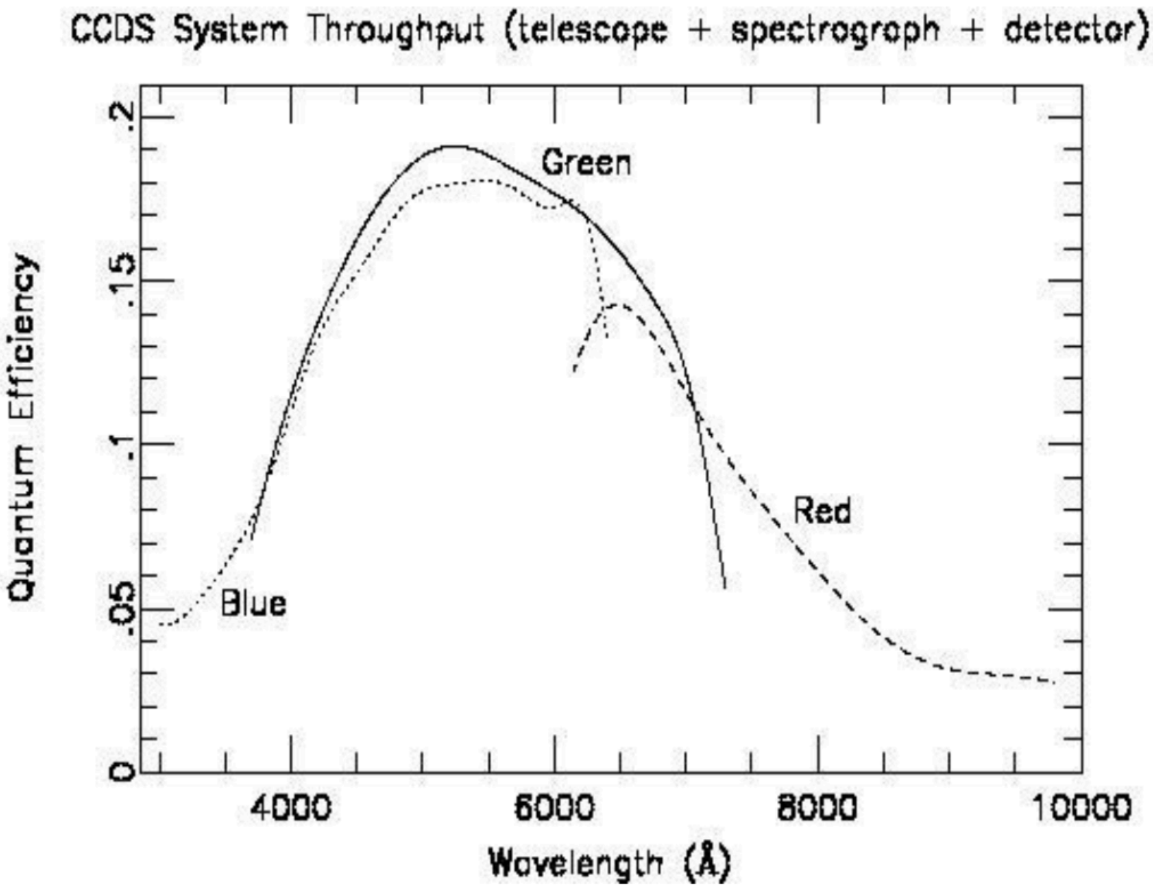

Figure 3: System Throughput as a Function of Wavelength

The count rates given for the 1.3m telescope are estimates and simply reflect he difference in aperture with respect to the 2.4m. Count rates are given in e^{-}/sec/Å in an extracted spectrum at 5556Å for a star of monochromatic magnitude m(5556) = 10.0 at unit airmass. Figure 4 below graphically displays the count rate s a function of wavelength for each CCDS grating normalized such that m(lambda) = 10.0 at unit airmass in order to illustrate the wavelength dependence.

Notes:

- a Count rate estimated from 2.4m count rate based on ratio of collecting areas.
- b Count rate at 6436Å. Designed for use at h-alpha.
- c Count rate at 5710Å

Slit Width Adjustment

The instrument utilizes a bi-parting slit, consisting of two 2.5”-long polished and aluminized jaws. The Jaws are continuously adjustable over a range from 10 to 1,100 microns. Both jaws move in the direction of the slit length for changes in slit width. The jaws remain parallel up to widths of at least 900

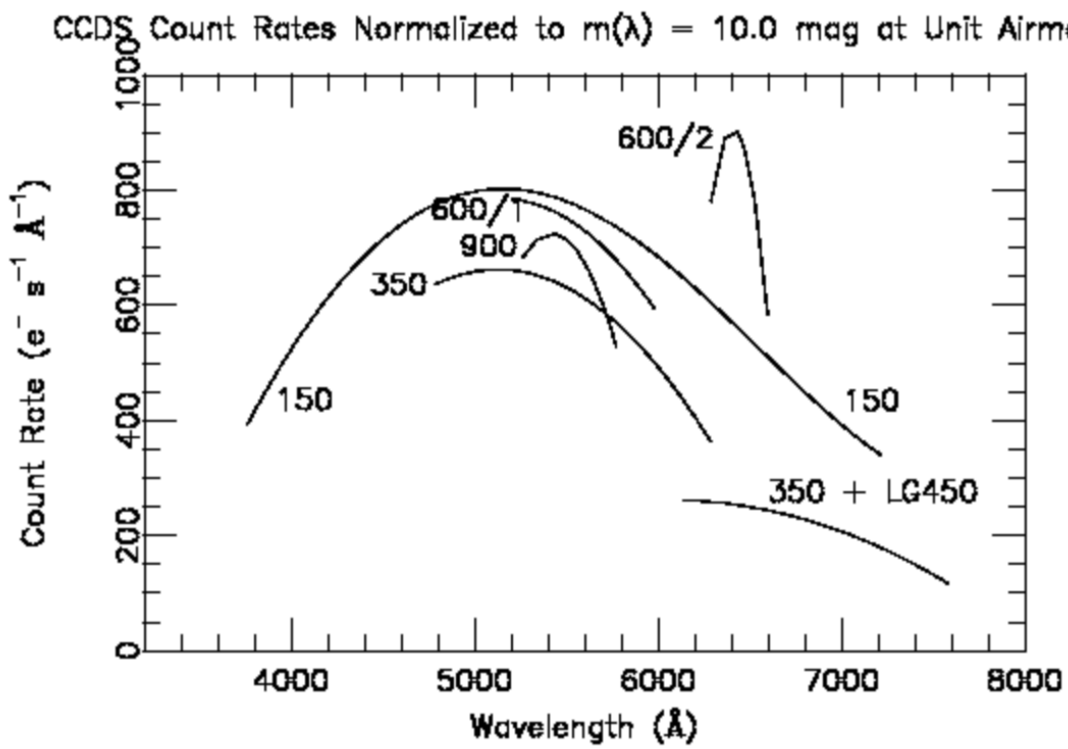

Figure 4: Count Rates
Note the 900 l/mm grating is no longer available

microns. Beyond that, some tapering of the slit may be evident.

The slit width is controlled by the **setslit <n>** command where <n> is the slit width in microns. Table 3 lists the physical slit widths in microns of popular settings for each telescope. The unvignetted slit length at the 2.4m telescope is 5.2 arcmin; at the 1.3m, it is roughly 10 arcmin (inferred).

Width (arcsec)	Width @ 2.4m (μ)	Width @ 1.3m (μ)
1.0	87	47
1.5	131	71
2.0	174	94
3.0	261	141
5.0	435	235
7.5	653	353
10.0	870	470
12.0	1044	564

Table 3: Slit Size Conversion

CCDS Filters

CCDS has two internal filter slides, both positioned through software. The above-slit filter slide (*prefilter*) carries four neutral density filters made of quartz which can be used to alter the intensity of the lamps in the MIS box. Each filter measures 0.35” x 1.5”, with a maximum thickness of 0.20”. They can be used for slit targets as well, but target acquisition using the slit-viewing camera will be difficult if not impossible. For normal operation, the prefilter slide is moved out of the optical path by using the following command:

prefilter 0

The below-slit filter slide is referred to as the *filter*. It carries five order-separating filters. All of these are long-wave passband filters. The number in the filter designation identifies the wavelength (nm) at which 50% maximum transmission occurs. The filter slide is moved out of the optical path with the following command:

filter 0

Position	Filter	Prefilter
0	Retracted	Retracted
1	LG350	ND 0.5
2	LG370	ND 1.0
3	LG400	ND 1.5
4	LG450	ND 2.0
5	LG505	

Table 4: CCDS Filters

It should be noted that insertion of an order-blocking filter moves the instrument focus approximately -50 units as measured on the collimator dial, as defined by the **setfocus** command. Table 4 below summarizes installed filters:

Transmission curves for the order-blocking filters can be found here.

FILTER=*HI* Condition:

The CCDS mechanism control computer (IE) can occasionally get into a state where it reports the filter and/or the prefilter ID as *HI*. This means the controller thinks either filter insert system has been pushed into the high limit position. Typically this is a bug, resolved as follows:

In Prospero, issue the following commands:

filter reset or *prefilt reset*

as required to clear the condition. These commands override the high limit safeties and drive the filter/prefilter mechanism back to the *zero* or *home* position.

Comparison Lamps & Spectral Templates

Emission-line lamps currently available for wavelength calibration include Hg-Ne, Ne, Ar and Xe. They are enabled through the MIS software and can be used individually or in any combination. Templates and line lists for the lamps are given below for display and download. Hardcopy plots are also available in the CCDS manual in the control rooms. The line lists can be combined in any combination. The format is IRAF compliant.

Hg lamp:

This lamp requires as much as 30s to warm up. After warm up, the HgNe spectrum will be replaced by a strong Hg-only spectrum. When using the Hg lamp, it is necessary to use an ND 1.0 filter to cut down on the intensity of the light. With the 150 g/mm grating, the exposure time is at most a few seconds. Observers should start with the ND 1.0 or 1.5 filter if they are unsure of the proper filtering for their chosen grating and slit width. The Hg line list includes 2nd order blue lines visible in the 1st order red. For low resolution applications in the 3200-7000Å region, the Hg and Ne lamps provide a good array of strong lines.

Hg plots: 3300 - 6900Å (enlarged), 6550 - 9900Å, Hg linelist

Ne Lamp:

The Ne lamp contains strong lines in the red, beginning at 5700Å. A filter should not be necessary. The Ne lamp should b used in conjunction with the Ar lamp to construct a dense comparison lamp spectrum spanning the red and blue spectral regions respectively. Care should be taken with balancing exposure times since the Ar lamp is considerably weaker. The Ne lamp is not useful below 5300Å.

Ne plots: 5300 - 6800Å (enlarged), 6500 - 9900Å (enlarged), Ne linelist

Ar Lamp:

The Ar lamp is relatively weak and does not require a filter. An exposure of 120s with the 600/1 grating centered at 4700Å gives an adequate spectrum for cross-correlation with a longer exposed template.

Ar plots: 3300 - 6900Å, 3300 - 5300Å, 5000 - 7000Å, 6550 - 9900Å (enlarged), Ar linelist

Xe Lamp:

The Xe lamp provides two clusters of bright lines: one at roughly 4500-5000Å, the other between 8000-10000Å. It is a useful lamp for use with blue spectra where you need to fill in the numerous gaps in calibration line coverage below about 5000Å.

Xe plots: 3300 - 7000 Å (enlarged), 4000 - 6000Å, 6550-9900Å (enlarged), Xe linelist

All Lamps:

You can download a complete set of PostScript versions of these plots and the ASCII format line lists ready for use in IRAF using the link below:

ccds_lamps.tgz (128k gzipped tar file)

Flatfields:

The MIS box lamp set includes an incandescent light bulb that produces a continuous (essentially thermal) spectrum. This source can be used to illuminate the slit and thus to obtain internal flatfields. The lamp is far too red to construct flatfields for CCDS in the blue parts of the spectrum.

CCDS Acquisition (Slit-Viewing Camera

An FLI camera, equivalent to what is used for guiding on both telescopes, has been incorporated into CCDS for slit-viewing/target acquisition. Control is provided through MaximDL Pro 5 software. To learn more about operating the camera, observers ca n refer to the documentation on guiding, found here.

Figure 5 shows the slit jaws as imaged by the camera. The field-of-view (FOV) imaged is roughly 2 arcmin on a side for the 2.4m (3.54 arcmin on the 1.3m().

Note in Figure 5 that the button to adjust *screen stretch* is highlighted. Clicking this button opens the associated control box, as seen in the bottom-left of the figure. Manually setting min/max values for screen stretch will maximize contrast on the night sky. Typically min/max values around 95/180 work well, although observers may want to play around in order to achieve optimal settings.
The FLI camera's cooler should be set to around -25ºC or cooler. A good rule of thumb is that the cooler's duty cycle should be around or less than 70%.

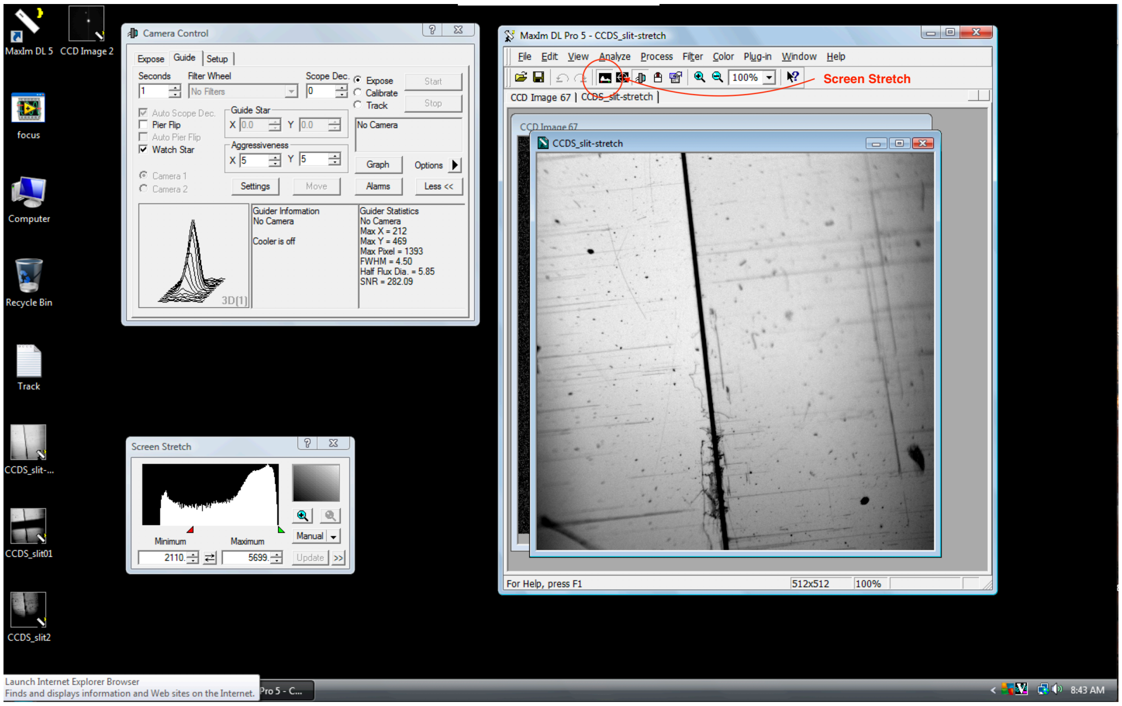

Figure 5: Slit as Imaged by the Acquisition Camera

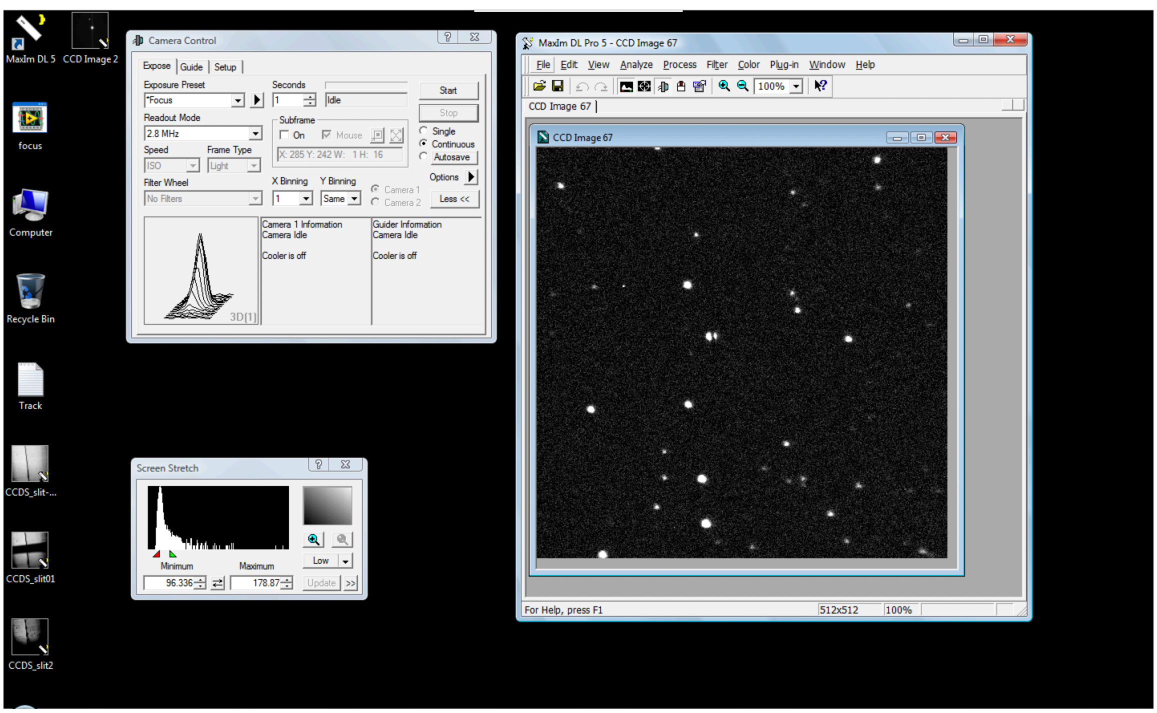

Figure 6: Star-Field as Imaged by the Acquisition Camera
Note the User-Set Screen-Stretch values

Figure 6 shows a star field, as imaged by the target acquisition camera. Note the min/max settings for screen stretch as compared to the full slit illuminated by the MIS flat lamp in Figure 5.

Operations Manuals

- CCDS-specific Prospero commands
- CCDS Prospero Quick Reference Card
- Multiple Instrument System (MIS)
- OSU Manual for CCDS Use

Additional Documentation & Information

- CCDS Data-Taking System Functional Block Diagram
- IRAF documentation
- qccds - a pyraf-based quick-look spectral extraction script (courtesy of Thorstensen)
- KPNO Low-to-Moderate Optical Spectroscopy Manual