

ASTR 4880/PHYS 5880 — Fall 2008 – Lab 2

Due: October 22, 2008

1 Introduction

In Lab 1, we determined the gain and read noise of CCD3. In part 1 of this lab, we will apply this result to determine the value of or an upper limit to the dark charge generation rate of this CCD, in electrons $\text{pixel}^{-1} \text{ hour}^{-1}$.

In part 2, we will study the position in the array of pixels of selected features in the Th-Ar spectrum, as a function of time during the course of a night of observing. Position shifts of the CCD are an important source of error in the measurement of wavelengths of lines in the spectra of stars.

2 Dark Charge

In `/mnt/vo101/ndm/iraf/course/F2008/20080929Dark` you'll find four bias frames, four 60-s dark exposures, and four 1-hour (3600-s) dark exposures. They are as follows. Create a folder for

Table 1: Bias and Dark Exposures

Bias	60 s	3600 s
200809290002.fits	200809290007.fits	200809290012.fits
200809290003.fits	200809290008.fits	200809290013.fits
200809290004.fits	200809290009.fits	200809290014.fits
200809290005.fits	200809290010.fits	200809290015.fits

them in your *iraf* directory, and copy them to it.

Verify the exposure times by printing out the relevant keyword with the command:

```
hedit *.fits param25 .
```

The header keyword PARAM25 gives the exposure time in milliseconds. Insert the exposure time explicitly into the header of each image with the command:

```
hedit [any file].fits EXPTIME [value in seconds] add+ update+
```

Construct the median of each set of four images that have the same exposure time, using an appropriate cosmic ray rejection method. Then, subtract the median bias from the other two median images. Use *imstat* to determine the mean of each difference image. Plot and inspect one or more rows of the difference image.

Is the mean of the difference image greater than zero? If so, the cause is thermal dark charge generation. Using your gain value from Lab 1, estimate the dark charge generation rate per second and per hour. If not, provide an estimate of the upper limit to the dark charge generation rate. That is, estimate how large the rate would have to be to produce a detectable signal.

3 CCD Shifts

Attached to this lab is a corrected version of the observing log for the night of 20071022, in which the observer's incorrect listing of file numbers (Don't do this!) has been fixed. The complete set of Th-Ar exposures from that night has now been added to the *astro1* directory `/mnt/vol101/ndm/iraf/course/F2008`. Copy these files to your *iraf* directory, and create a list of these file names, as follows:

```
200710220016.fits
200710220018.fits
200710220020.fits
200710220022.fits
200710220024.fits
200710220026.fits
200710220028.fits
200710220030.fits
200710220033.fits
200710220035.fits
200710220037.fits
200710220039.fits
200710220041.fits
200710220043.fits
200710220045.fits
200710220047.fits
200710220049.fits
```

Table 2 lists the x and y coordinates (as displayed in *ds9*) of 11 features in the Th-Ar spectrum, together with the initials of the student who is assigned to measure the coordinates of that feature. Except for the instructor (NDM), each student is to measure two features. The instructor will then collate and analyze the results for the whole image. Using *splot* with

Table 2: Features to Measure for 20071022

Feature	x	y	Student
1	125	1860	JWD
2	144	967	AMG
3	239	492	ALH
4	660	1833	BMM
5	729	994	MPN
6	748	71	JWD
7	1158	1920	AMG
8	1135	1103	ALH
9	926	238	BMM
10	1116	466	MPN
11	493	1422	NDM

`dispaxis = 2`, plot the row in the first image corresponding to the y coordinate of one of your

assigned features. Zoom the window in closely on the feature. Set `nsum = 10` to sum 10 rows together, set `:wreset no` and then move up and down in the y direction with (and) until the peak counts are maximized. Measure the position of the feature with `e`. Proceed to the next image with `q` and the process of measuring all the images should be quick.

When you finish with a final `q` there will be a file entitled by default, `splot.log` in your current working directory. Open it with a text editor and copy the values for the feature center into math software or a spreadsheet. Calculate the mean and standard deviation of the values for each feature, and graph them as a function of the universal time from the observing log. Don't forget to convert the hours and minutes into hours and decimals.

Now (just to see how much better life has become with CCD3), let's repeat the exercise with a night of data from the older camera, CCD1. The Th-Ar images from that night will be found in the `astro1` directory `/mnt/vol01/ndm/iraf/course/F2008/20061030`. The log sheet for that night is attached to this writeup. Examine the header of a typical image with `imhead [filename] l0+ | page` and you'll see that it has much more information, including `dispaxis = 2` already set. With that camera, the data acquisition software set many header parameters automatically, and others were set by the observer.

Here, each student is assigned to measure one feature as given in Table 3.

Table 3: Features to Measure for 20061030

Feature	x	y	Student
1	530	513	NDM
2	81	822	JWD
3	150	304	AMG
4	438	874	ALH
5	626	226	BMM
6	710	856	MPN

In order to compare your results from the two cameras, you'll need to convert the pixel dimensions to microns: $22.5\mu\text{m}$ for CCD1 and $30\mu\text{m}$ for CCD3.

When a wavelength calibration is applied to a stellar spectrum, the results from the two bracketing Th-Ar exposures are interpolated linearly in time. In view of that fact, what do you think are the likely errors (in microns in y) of spectral line positions derived from the two cameras. Refer to the graphs you constructed for this lab.

4 Your Report

Everything in this section of the instructions for Lab 1 also applies to this lab.

Echelle settings		UT Date: 22 Oct 2007	Observer: GBT/NDM	LDS Settings			
X-Disp Tilt: 208.0	λ_c : H α	Exposure: 2007022.*	Temp. (°C): 22	RH (%): 43	Grating: 6	λ_c : H α	Tilt: 4°
Echelle Tilt: 22.25	Slit: 275	Sky Conditions: clear/clear, mediocre seeing			Slit: 255	Temp.: -87.5°C	Focus: 5.81

Exp #	Start Time (UT)	Dur (s)	HA Start	E/L	Object	Sp. Type	V Mag	ADU's (/pix)	Comments
1-5	23:31	0		E	bias			510	
6-10	23:48	240		E	blue flat			5622	
11-15	0:11	0.5		E	red flat			4054	
16	0:13	300		E	Th-Ar				far right strip of image in CCDOPS is all gray*
17	0:22	900	+1:43	E	zeta Aql	A0Vn	3.0	706	#18 0:39 Th-Ar
19	0:53	240	+0:37	E	alpha Cyg	A2Ia	1.3	732	#20 0:58 Th-Ar
21	1:10	3000	+1:27	E	28 Cyg	B2.5Ve	4.9	572	#22 2:01 Th-Ar
23	2:17	2700	+1:05	E	9 Cep	B2Ib	4.7	619	#24 3:04 Th-Ar
25	3:23	1800	-0:04	E	rho Cas	G2IaOe	4.4	695	#26 3:55 Th-Ar
27	4:10	3600	+0:37	E	LQ And	B4Vne	6.5	531	#28 5:11 Th-Ar
29	5:22	300	+1:08	E	alpha Cas	K0IIIa	2.2	611	Did I mess up the focus? ... #30 5:29 Th-Ar
31	5:36	300	+1:22	E	"	"	"	583	Focus OUT, do again ... Should have gone IN, I guess ...
32	5:43	300	+1:29	E	"	"	"	738	Better! #33 5:49 Th-Ar
34	5:58	2700	+1:41	E	omicron Cas	B5III	4.5	640	#35 6:44 Th-Ar
36	6:54	900	+2:25	E	gamma Cas	B0IVpe	2.5	856	#37 7:10 Th-Ar
38	7:20	1800	+0:18	E	HR 1035	B9Ia	4.3	686	#39 7:51 Th-Ar ... *To solve this problem, make box larger
40	8:01	2700	+0:58	E	HR 1040	A0Iab	4.6	712	#41 8:47 Th-Ar
42	9:02	300	-0:07	E	epsilon Ori	B0Ia	1.7	623	Should have gone 600s ... #43 9:08 Th-Ar
44	9:14	300	+0:05	E	"	"	"	640	#45 9:19 Th-Ar
46	9:29	3600	-0:34	E	AX Mon	B2:IIIpshe	6.7	537	#47 10:30 Th-Ar

Echelle settings		UT Date: 30 Oct 2006	Observer: NDM, SJR/NDM		LDS Settings		
X-Disp Tilt: 235.0	λ_c : H α	Exposure: 20061030.0*	Temp. (°C): 18	RH (%): 48	Grating: 6	λ_c : H α	Tilt: 4°
Echelle Tilt: 21.95	Slit: 275	Sky Conditions: clear			Slit: 255	Temp.: -93.5°C	Focus: 5.81

Exp #	Start Time (UT)	Dur (s)	HA Start	E/L	Object	Sp. Type	V Mag	ADU's (/pix)	Comments
01-05	22:46	0	zenith	E	bias			77	Rebooted Noah to make change to EST
06-10	23:11	1	zenith	E	flat			2617	
11	23:42	300	+0:01	E	Th-Ar			107	
12	23:53	300	+0:10	E	alpha Cyg	A2Ia	1.25	446	#13 Th-Ar 0:02
14	0:23	1200	+2:31	E	beta Lyr	B7Vpe	3.45	227	#15 Th-Ar 0:46
16	1:05	600	+1:18	E	eta Cep	K0IV	3.41	208	#17 Th-Ar 1:18
18	1:44	1800	+0:56	E	nu Cep	A2Ia	4.29	227	#19 Th-Ar 2:17
20	2:38	3600	-0:21	E	LQ And	B4Vne	6.5	113	SJR left ... #21 Th-Ar 3:41
22	3:54	180	+0:13	E	alpha Cas	K0IIIa	2.2	198	#23 4:00 Th-Ar
24	4:11	900	+0:13	E	gamma Cas	B0IVpe	2.4	629	#25 4:28 Th-Ar
26	4:40	1800	+1:06	E	kappa Cas	B0.7Ia	4.2	192	#27 5:13 Th-Ar
28	5:26	1800	+0:41	E	phi Per	B2Vpe	4.1	237	#29 5:58 Th-Ar
30	6:10	2700	-0:27	E	psi Per	B5Ve	4.3	281	#31 6:58 Th-Ar
32	7:11	3600	+0:22	E	28 Tau	B8IVe var	5.1	151	#33 8:14 Th-Ar
34	8:28	1800	+1:19	E	48 Per	B3Ve	4.0	218	#35 9:01 Th-Ar
36	9:18	300	+0:41	E	epsilon Ori	B0Ia	1.7	202	#37 9:25 Th-Ar
38	9:37	2700	+0:58	E	omega Ori	B3IIIe	4.6	170	#39 10:25 Th-Ar
40	10:37	900	+0:10	E	beta CMi	B8Ve	2.9	217	#41 10:55 Th-Ar ... Close, no time for another star
42-46	11:03	0		E	Bias			81	
47-51	11:15	1		E	Flat			2670	