Chapter 2

IRAF Manual

2.1 General Information

1. IRAF is the acronym for *Image Reduction and Analysis Facility*. The reduction process was based on the "User's Guide to Reducing Slit Spectra with IRAF" by P. Massey, F. Valdes and J. Barnes.[1] IRAF is an old but very valuable image reduction program. It is segmented into packages and tasks. To have access to a specific task it is necessary to change into the package including the wanted task. Type `help taskname` into the IRAF terminal and the package including the task will be displayed as well as an elaborated help page.

   To start IRAF, type (into the LINUX terminal from the directory where IRAF is located):

   - cd iraf

   - iraf . -9

2. You have to edit parameters. Every task has it's own parameter set which can be modified and thus adapted to the data. Type `epar taskname` to edit the parameters. To save changes type `:wq` in the "edit parameter" menu. If you want to leave the menu without saving, type `:q`. (`:w` writes the changes into the "uparm" directory ("user parameter" directory)). To reset the parameters of a specific task type `unlearn taskname`.

3. After having executed specific tasks on the images, IRAF will ask under which name to save the changes. Please stick to the following convention:

   a) Starting image: obj001.fit

   b) After dark subtraction → obj001m.fits

   c) After task `dispcor` → dobj001m.ms.fits

   d) After dividing by the flat field →fdobj001m.ms.fits

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[1] `http://iraf.noao.edu/docs/spectra.html`, accessed on September 6., 2011.

e) After task `continuum` → kfdobj001m.ms.fits

WATCH OUT: No periods "." in the image names e.g. do not name an image obj001.m.fits, name it obj001m.fits because IRAF can't read periods. IRAF will name an image after having extracted it `obj001m.ms.fits`. In this case `.ms` stands for "multispec" format and thus for a format change, not for a name change.

2.2 Image reduction in respect of darks and flats

Darks have to be subtracted before the spectrum will be extracted. Unfortunately it happens that cosmic rays or echoes of the calibration lamp appear in dark exposures. For this reason you should take at least three dark frames and combine them with the task *imcombine* to get a masterdark. *Imcombine* does not belong to a specific package and can be used no matter what package is invoked. To get rid of cosmic rays, set the parameter `reject` on `crreject` (type `epar imcombine` and read through the parameters to find `reject`). The input images for *imcombine* must either be written in a wildcard or in a list:

    ls *.fit > listname.dat

If a list is used then the input (in `epar imcombine`) must be `@listname.dat`. The division by the flat field exposures will be done after the wavelength calibration - see Section 2.5.

2.3 Extraction of spectrum

The raw images you get out are two-dimensional images which show just the image of CCD chip. Figures 2.1 and 2.2 show two examples of stellar spectra taken with the DADOS spectrograph after dark subtraction. Figure 2.1 shows a spectrum of Regulus ($V = 0.03$ mag with an exposure time of 120 s) with a signal-to-noise ratio of more than 50. Figure 2.2 shows a spectrum of AO Cassiopeiae ($V = 6.102$ mag; exposure time: 600 s) with a worse signal-to-noise ratio but still more than 35. The signal-to-noise ratio was determined in the continuum spectrum. The detailed method how to determine the signal-to-noise ratio is described in Section 2.9.

The spectrum of Regulus is thinner, which is due to better focusing. To obtain usable data the signal-to-noise ratio should not be worse than 35. See Table 2.1 for more details on exposure times and associated signal-to-noise ratios.

To extract the spectrum use the package *apextract* with the task *apall* (noao → twodspec → apextract → apall). Check if the dispersion axis lies along lines or along columns. To do so go to `epar apextract`.

- `epar apextract`

- `dispaxi = 1 or 2`

Now check in what range of the CCD the spectrum lies, because IRAF will search for it automatically on the CCD in this given area. It is assumed the spectrum lies along
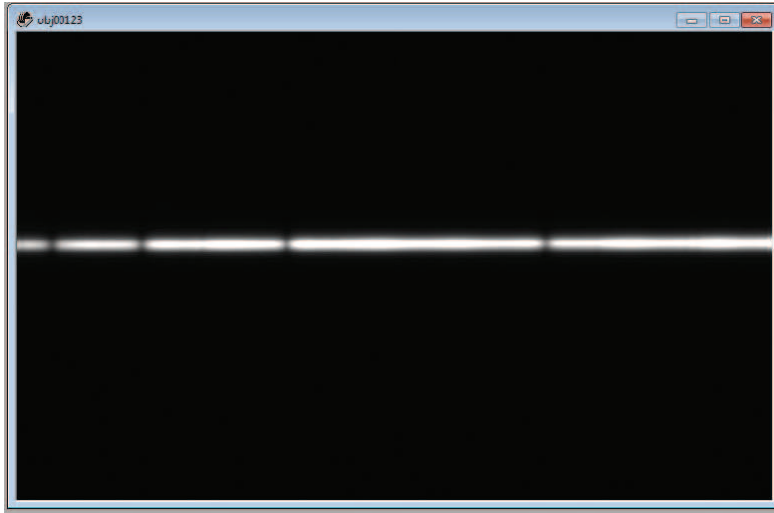
Figure 2.1: Example of a spectrum of Regulus with good signal-to-noise ratio. This spectrum was taken with the 900-line grating and an exposure time of 120 s. The brightness (in the visual part of the spectrum) of Regulus is $V = 0.03$ mag (from `http://simbad.u-strasbg.fr/simbad/`, accessed on August 29., 2011). With help of the slit viewer, the star is centered on the middle (smallest) slit. The contrast was adjusted in a way that only the image of the star (spectrum) is seen and the rest of the image appears black.

lines, use the task *implot* to find out where it lies. *Implot* starts with the command `implot imagename`. Another window ("irafterm") opens. To prevent an IRAF crash do not close the irafterm window with "`x`". Always leave it by typing "`q`" in the activated window. It happens that the image just shows background noise (see Fig. 2.3). The reason for that is that the default setting of *implot* plots the middle line, thus line 255 (the CCD has approximately 500 lines and 700 columns). The spectrum crosses column 1 and column 700 at different lines. `:l 197` or `:c 300` are examples to plot line 197 or column 300. With *implot* it can thus be found out where on the CCD the spectrum lies. Figure 2.4 shows a plot of column 10. The commands ":c 10" etc are typed into the irafterm window where the plot is displayed, not in the IRAF terminal. If it happens that it is not possible to say where the spectrum lies and to distinguish between signal and noise, then the signal-to-noise ratio is not good enough and you should get exposures with a better signal-to-noise ratio (longer exposure times). Type capital "`C`" to see at which line the spectrum starts and where it ends. Two numbers are displayed on the bottom left of the irafterm window, the left number is the pixel number, the right one is the pixel value at that point. Determine where the peak starts and where it ends and note the values. IRAF needs this information later on to have a starting point to search for the spectrum and a reference for at what point lies the maximum from where on the spectrum extends up and down. It is possible to stick to "nice numbers" e.g. 45 instead of 43. EXAMPLE: At column 10 the spectrum goes from line 187-262 and at column 690
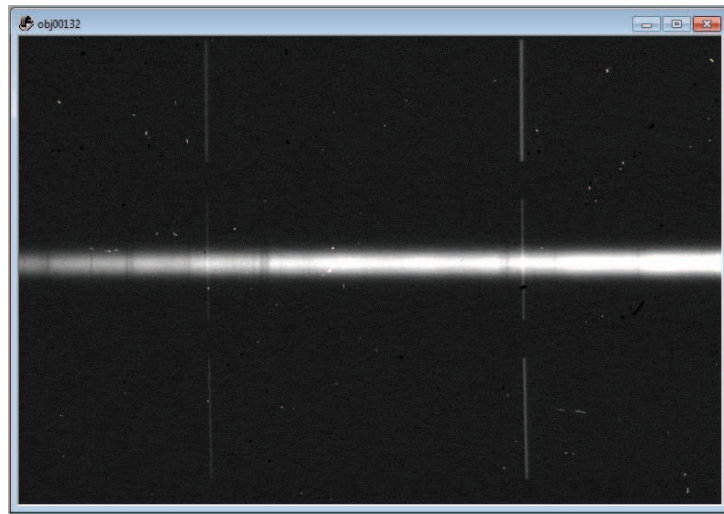
Figure 2.2: Example of a star with worse signal-to-noise ratio than the one of Fig. 2.1, overlaid by the echo image of the calibration lamp. This spectrum of AO Cassiopeiae used an exposure time of 600s and was also taken with the 900-line grating. The brightness (in the visual part of the spectrum) of AO Cassiopeiae is $V = 6.102$ mag (from `http://simbad.u-strasbg.fr/simbad/`, accessed on August 29., 2011). With help of the slit viewer, the star was centered on the middle (smallest) slit. The contrast was adjusted in a way that only the image of the star (spectrum) is seen and the rest of the image appears black.

from line 190-262. The middle is at approximately 255 and the spectrum extends not further than 35 pixels up and down from the middle line. To be sure that the spectrum lies inside this range of 35 pixels, it is advisable to set the range to ±40pixels. The same procedure is done to find out where the background begins (a pixel value further away than 40 pixels from the middle 255). This area lies between the red and green marks in Fig. 2.4. The area in between the red marks represents the spectrum.

Now start with the task *apall*. *Apall* has to be edited to put in the just gained information of the location of the spectrum. Thus type `epar apall` into the IRAF terminal and set the parameters to the following values. It is important that you compare and set the parameters in your IRAF session to the parameters given here.
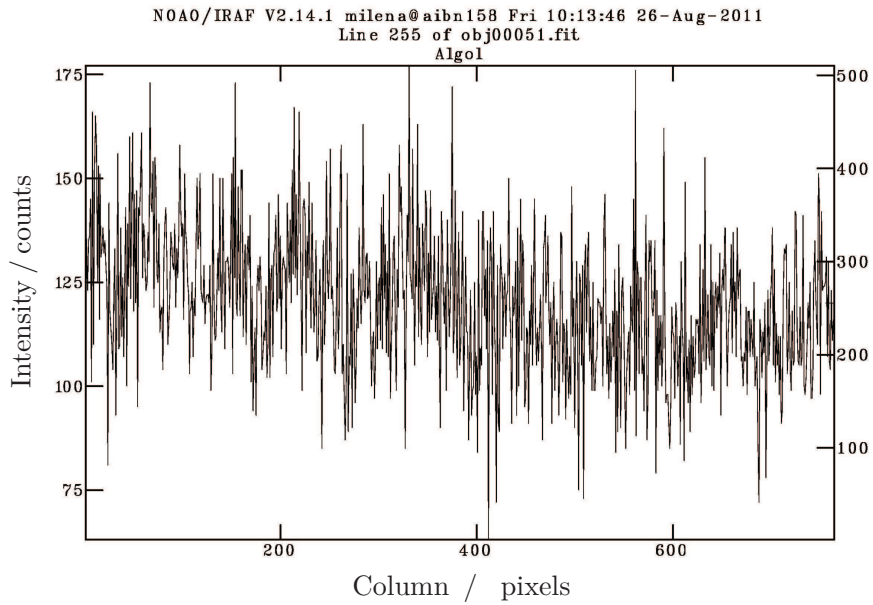
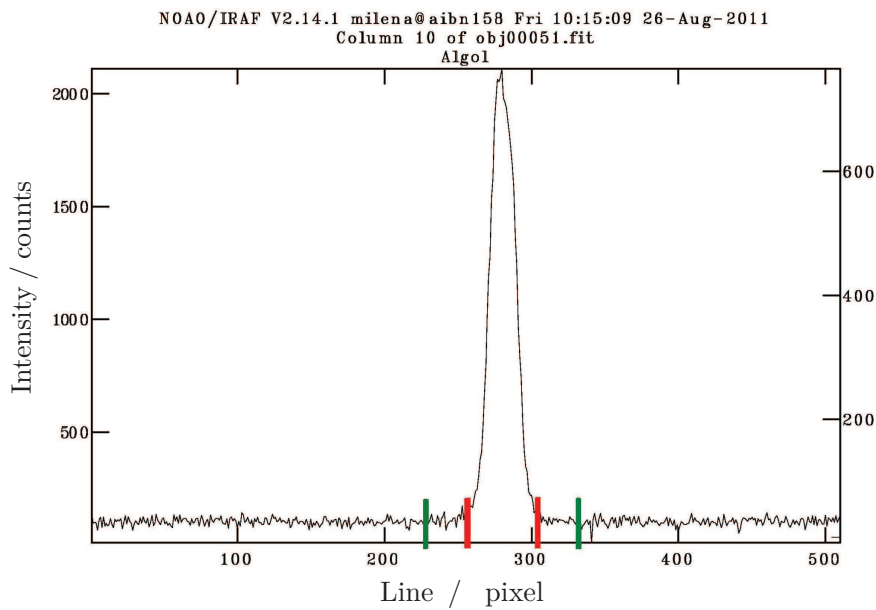Figure 2.3: Implot of line 255. The image just shows background noise.

Figure 2.4: Implot of column 10. The background lies in between the two marks on each side of the spectrum. The area in between the inner marks includes the spectrum.

Parameter	Value	Remark
apertur		
format	multispec	
referen		
profile		
interac	yes	
find	yes	
recente	yes	
resize	no	
edit	yes	
trace	yes	
fittrac	yes	
extract	yes	
extras	yes	
review	yes	
line	INDEF	IRAF searches the area of the CCD that was determined with *implot* and uses the intensity to decide whether or not it is spectrum or background. Leave this parameter on INDEF.
nsum	100	

Default Aperture Parameters		
Parameter	Value	Remark
lower	⋯	Here type in the value, determined with *implot*, how far from the middle the spectrum goes down (in our case -40).
upper	⋯	Here type in the value, determined with *implot*, how far from the middle the spectrum goes up (in our case +40).
apidtab		

Default Background Parameters		
Parameter	**Value**	**Remark**
b_funct	chebyshev	
b_order	1	
b_sampl	⋯	Here type in the values determined with *implot* to deduct the background from the spectrum. Leave enough space between the point where the spectrum ends and where the background begins, to be sure that there is no intensity from spectrum in the background area. EXAMPLE: If the spectrum ends at ±40, start the background at ±55 and take 10 to 20 lines into account. Type in `-70:-55,55:70`.
b_naver	100	
b_niter	0	
b_low_	3.	
b_high	3.	
b_grow	0.	

Aperture Centering Parameters		
Parameter	**Value**	**Remark**
width	...	Type in the maximum width of the spectrum determined with *implot*. For the given example that would be 80.
Radius	10.	
thresho	0	

Automatic Finding and Ordering Parameters		
Parameter	**Value**	**Remark**
nfind	1	
minsep	5.	
maxsep	1000.	
order	increasing	

Recentering Parameters		
Parameter	**Value**	**Remark**
aprecen		
npeaks	INDEF	
shift	yes	

Resizing Parameters		
Parameter	**Value**	**Remark**
llimit	INDEF	
ulimit	INDEF	
ylevel	0.1	
peak	yes	
bkg	yes	
r_grow	0	
avglimi	no	

Tracing Parameters		
Parameter	**Value**	**Remark**
t_nsum	10	
t_step	10	
t_nlost	3	
t_funct	legendre	
t_order	2	
t_sampl	*	
t_naver	1	
t_niter	0	
t_low_r	3.	
t_high_	3.	
t_grow	0.	

Extraction Parameters		
Parameter	**Value**	**Remark**
backgro	fit	
Skybox	1	
weights	none	
pfit	fit1d	
clean	no	
Saturation	65536.	
readnoise	17.8	
gain	1.5	
lsigma	4.	
usigma	4.	
nsubaps	1	
mode	ql	

All changes have to be saved into the user parameter directory (with "`:wq`"). Start *apall* by typing `apall` into the IRAF terminal.

`List of input images - imagename`
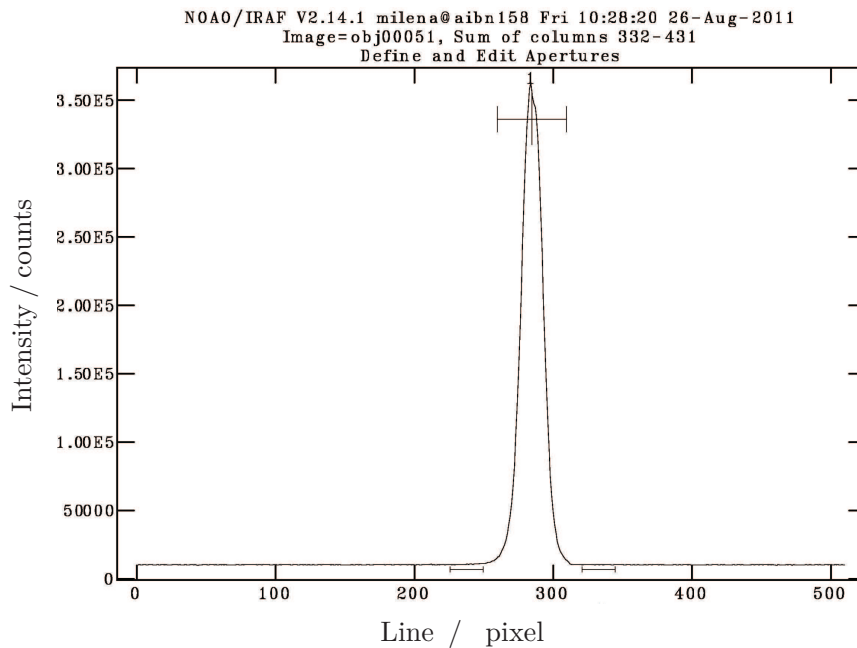`Find apertures for imagename - yes`

Figure 2.5: Aperture Editor.

```
Number of apertures to be found automatically - 1
Edit apertures for imagename?  - yes
```

Now you are in the aperture editor where it is possible to reset the parameters typed into *apall* in case you notice that the chosen apertures were badly chosen. You can see the apertures in the new irafterm window. They look like errorbars (see Fig. 2.5). Press "?" (in the irafterm window) to get a list with all cursor commands. "l" sets the lower aperture limit to cursor position, "u" sets the higher aperture limit to cursor position. "d" deletes apertures. By pressing "b" the background editor will open where badly chosen background apertures can be deleted with "z" and reset with "s". "q" brings you back to the aperture editor and if you type again "q" you will leave the aperture editor to come to the trace editor. For more information read the script "Reducing Slit Spectra with IRAF". In the trace editor the following questions have to be answered:

```
Trace apertures for imagename?  - yes
Fit traced positions for imagename interactively?  - yes
Fit curve to imagename interactively?  - yes
```

Now you can see the fit to the "trace", e.g. the run of the spectrum on the CCD. The fitting order can be increased in case the fit deviates too far from the data points (for order 3 type :order 3 in the irafterm window). The cursor commands in this fitting routine are different from the aperture or background editor. Just type ":" and the name of the parameter to be changed e.g. :order. Data points can be deleted with "d". Press "f" for a new fit. If the fit to the trace satisfies the demand, press "q".
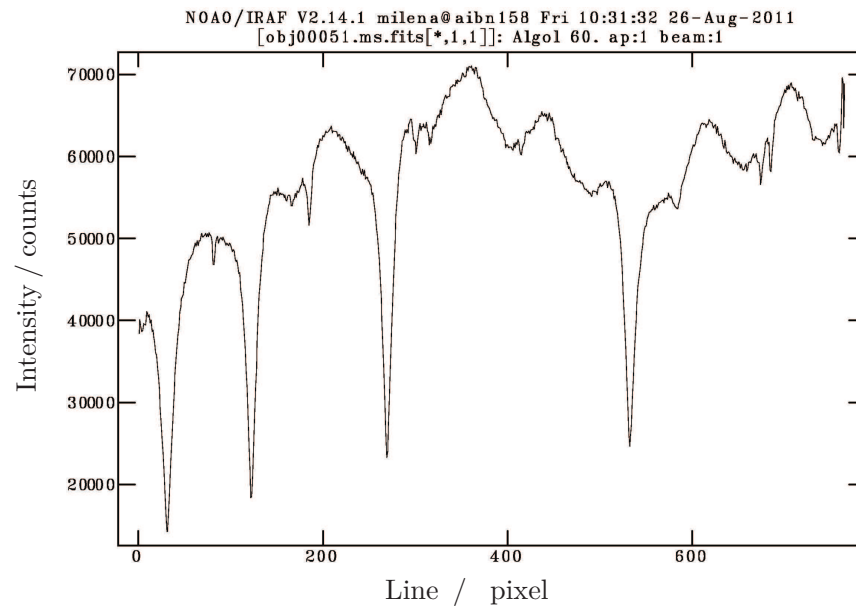
Figure 2.6: An extracted spectrum of Algol. Note the spectroscopic fringes, this spectrum is not yet flat field corrected. See Section 2.5 to learn how to remove the fringes.

```
Write apertures for imagename to database?  - yes
```
"Database" is a "directory" which is created automatically by IRAF and where data is saved such as the apertures of the extraction parameters etc. In case it is necessary this information can be deleted.
```
Extract aperture spectra for imagename?  - yes
Review extracted spectra from imagename?  - yes
Clobber existing output image imagename.ms ?  - yes oder no...
Review extracted spectrum for aperture 1 from imagename?  - yes
```
Figure 2.6 shows the extracted spectrum. IRAF names the images of the extracted spectra `imagename.ms.fits`. .ms stands for the multispec format. At the extracted spectra can be looked with the task *splot* (noao → onedspec → splot). Sometimes it occurs that although a dark subtraction was made that there is still a hot pixel in the spectrum (see Fig. 2.7). The "spectral line" caused by the hot pixel can be deleted (in the irafterm window when the image is viewed with *splot*) with the cursor command "`j`". "`j`" fudges a point to y-cursor value. Use cursor command "`i`" to save the changed image.

2.4 Wavelength calibration

After the spectrum is extracted a wavelength calibration is needed, which is done by mapping pixels to wavelengths. The spectrum of the calibration lamp has to be extracted
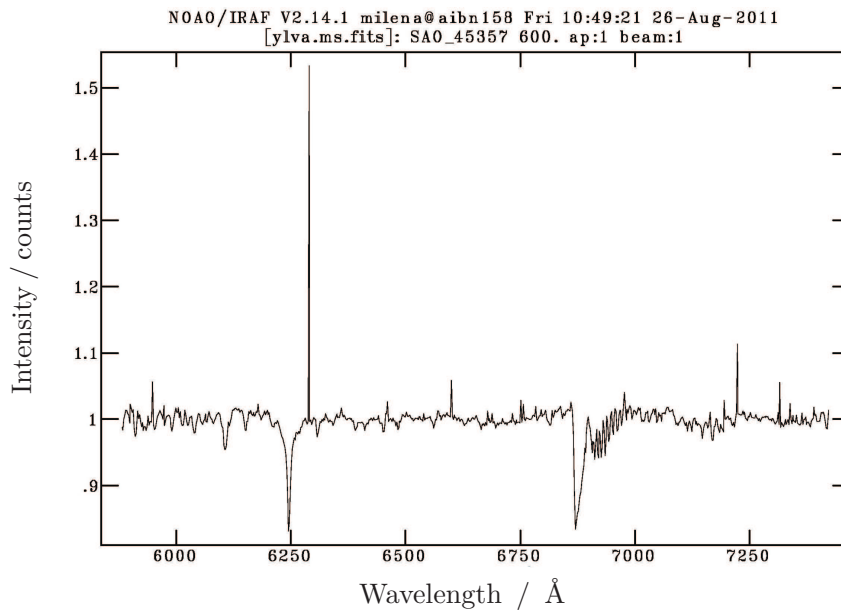
Figure 2.7: Spectrum of 44 Boötis with a hot pixel at ca 6290 Å.

the same way as the one of the object frame. IRAF wrote the extraction parameters of the object frames in the headers of these frames. With the following command IRAF reads these extraction parameters and uses them for the extraction of the calibration image belonging to the respective object frame:

`apall laser00001 out=claser00001 ref=obj00001m recen- trace- back- intera-`

In this case the original image is called `obj00001.fit` and the corresponding calibration frame `laser00001.fit`.

```
Searching aperture database ...
Date, Time:  DATABASE - 1 apertures read for obj00001 from database
Date, Time:  DATABASE - 1 apertures for laser00001 written to database
Extracting apertures ...
Date, Time:  EXTRACT - Aperture 1 from laser00001 → claser00001
```

Image frame and calibration frame have to be in the same folder! Make copies of your images! Calibration frames that were extracted are called with a "c" in front: laser001.fit → claser001.fits. The extracted calibration frame is one dimensional. Look at it with by typing `display claser00004.fits` (Fig. 2.8). The spectral lines in the calibration frame have to be identified. Use *identify* (noao → onedspec → identify).

```
identify
Images containing features to be identified:  claser00001.fits
```

Again the irafterm window will open and shows the spectral lines of the calibration lamp. On the basis of the spectra given to you by the tutor you should be able to identify the spectral lines. With the cursor go over an identified line and press `"m"`. If IRAF does not
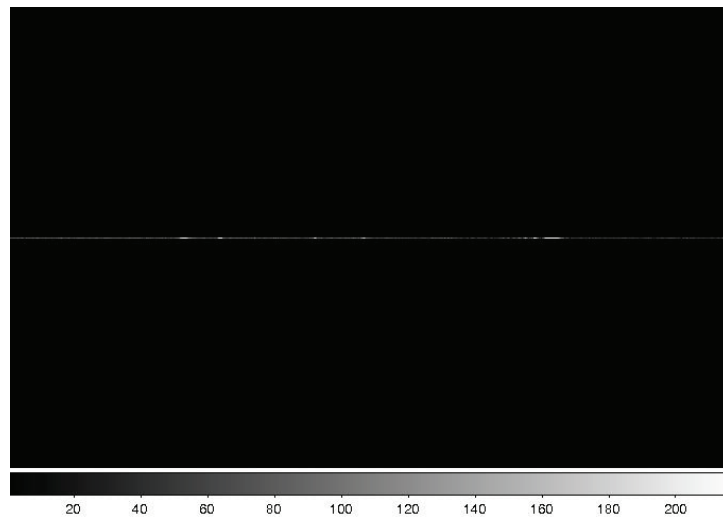
Figure 2.8: Extracted, one dimensional calibration spectrum.

recognize the line, check the parameter `fwidth` in `epar identify`. Set this parameter to 4. If two lines are identified press "`l`" so IRAF identifies all other lines. If you made a mistake the identified values of the lines can be deleted with "`d`". IMPORTANT: After having identified all lines you have to press "`f`" to start the fit for the mapping between pixels and wavelength.

```
Write feature data to the database?  - yes
```

The identified calibration spectrum now has to be connected to the object frame. To do so write its name into the object frames header so IRAF will use it for the dispersion correction.

```
hedit obj00001m.ms.fits REFSPEC1 "claser00001.fits" add+ ver- show+
add obj00001, REFSPEC1 = claser00001
obj00001.ms.fits updatet
```

Finally the dispersion correction has to be done. Type `dispcor` into the iraf terminal.

```
List of input spectra:  (obj00001):  - obj00001.ms.fits
List of output spectra (dobj00001):  - dobj00001.ms.fits
```

Dispersion corrected images are called with a "d" in front.

```
obj00001.ms.fits:  REFSPEC1 = 'cneon00004.fits 1.'
dobj00001.ms.fits:  ap = 1, w1=5732 w2 = 7222, dw = 1,95, nw = 765
```

Use *splot* to see the result (Fig. 2.9).

```
splot dobj00001m.ms.fits
```

Press "`?`" to get all cursor commands of *splot* displayed. Leave the plot with "`q`". Images can be stacked with *scombine*.

```
NOAO/IRAF V2.14.1 milena@aibn158 Fri 10:53:13 26-Aug-2011
[dobj00051.ms.fits[*,1,1]]: Algol 60. ap:1 beam:1
```
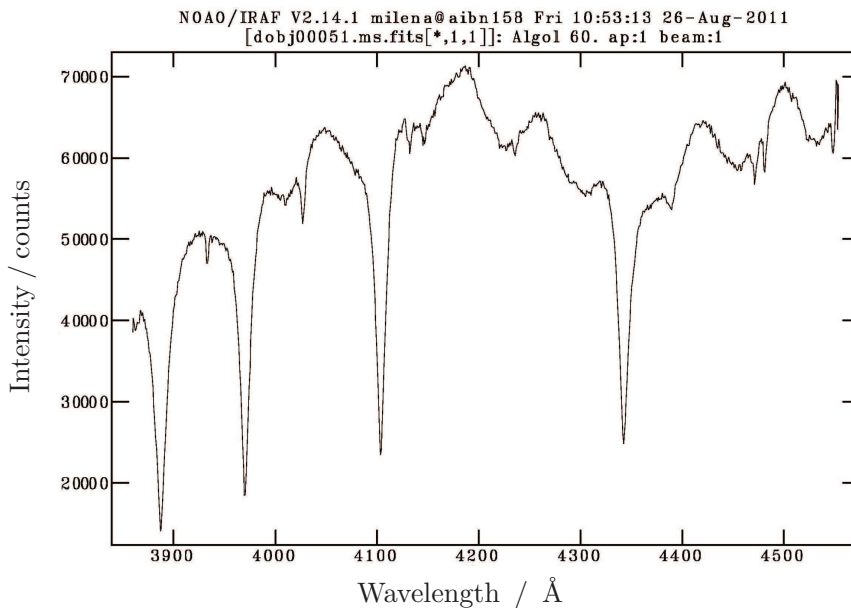
Figure 2.9: Spectrum of Algol with wavelength scale. This spectrum is not divided by a flat field. The spectroscopic fringes are still visible.

2.5 Flats

Like other spectrographs the spectra taken with the DADOS spectrograph show spectroscopic fringes. These are presumably due to intereference effects on the glass plate protecting the CCD chip.[2] Figure 2.10 shows a flat field image and Fig. 2.11 the corresponding extracted spectrum. In both images the periodic change of the amplitude can be seen. To remove these fringes from the object frames it is necessary to divide the object frame by a flat field image, but this can not be done pixel by pixel as in photometry. The problem is that the pattern is not related to spacial coordinates (e.g. pixels), but to wavelength. It is necessary to extract and wavelength calibrate the flat field exposure and then divide the object frame by it according to their wavelengths (use the `sarith` task in IRAF). It is not necessary to take an image frame and flat field frame in the same night as long as the wavelength calibration is well done.

The flats have to be extracted and dispersion corrected exactly the same way as the object frames. When using *apall* it has to be paid attention that the spectrum of the flat is much broader than the one of a star because the whole slit is illuminated and so the apertures must be adapted. To divide a dispersion corrected object frame by a dispersion corrected flat field, use the task *sarith*. If it does not work set the parameter `ignorea` at `epar sarith` to `yes`. Furthermore the wavelength range in `epar sarith`

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[2]See `http://www.astrosurf.com/aras/fringing/schlatter/ripple.htm`, accessed on August 29., 2011.

Figure 2.10: A two dimensional not yet reduced flat field image. Taken with the 900-line grating and an exposure time of 600 s. The three slits can be seen. The illumination of the slits is different because of the different slit sizes. The periodic change of the amplitude is also visible with a period that is the same for all three slits. The period changes with the thickness of the glass plate that protects the CCD chip (`http://www.astrosurf.com/aras/fringing/schlatter/ripple.htm`, accessed on August 29., 2011).

has to be set to the biggest range still included in both frames. Figure 2.12 shows a spectrum of 44 Boötis that is not yet divided by a flat field in contrast to Fig. 2.13 which shows the same spectrum but this time divided by a flat field.

2.6 Continuum Normalization

To normalize the spectra to the continuum, use the task *continuum*. Start the task, type in input and output image name whereupon the output image name should be indicated with a `"k"` in front of the name. So finally a dark subtracted, extracted, flattened and wavelength calibrated spectrum should be called `kdobj00255m.ms.fits`. If two spectra are supposed to be compared, pay attention to use the same fit function for the continuum fit. A "good" function is "spline3" with order 10.
The continuum fit for Wolf-Rayet stars is a little more tricky. If "spline3" with order 10 is used then IRAF identifies the big emission lines as continuum and erases them. Use a linear fit for Wolf-Rayet stars (function chebychev, order 1). Compare your spectrum to one from the literature (e.g. Fig. 2.14) to see what is continuum and what is signal. With the cursor command `"s"` ranges can be selected where the continuum lies and IRAF will fit the linear function to the height of this continuum. Function and order can be changed in `epar continuum`.

NOAO/IRAF V2.14.1 milena@aibn158 Wed 17:08:41 03-Aug-2011
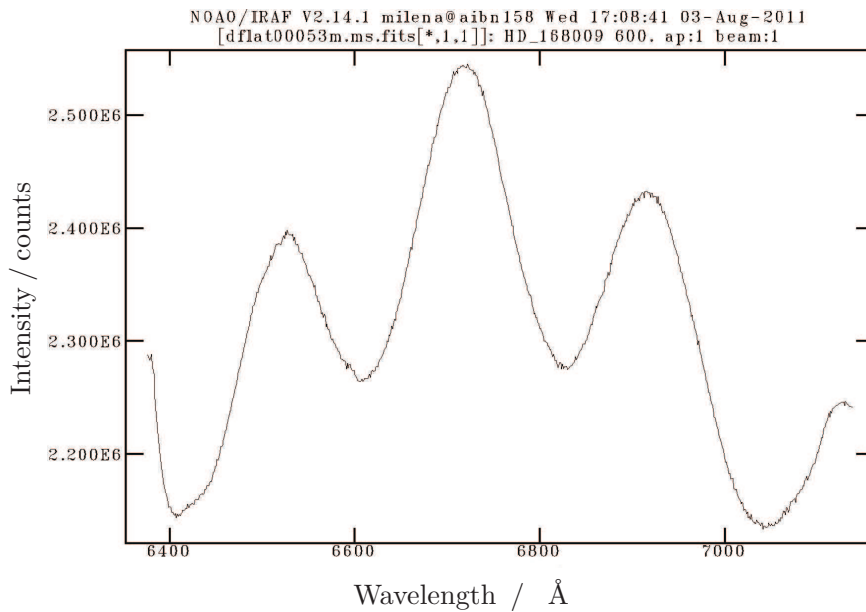[dflat00053m.ms.fits[*,1,1]]: HD_168009 600. ap:1 beam:1

Figure 2.11: Here is shown the flat field from Fig. 2.10 but already extracted and wavelength calibrated. The periodic change of the amplitude is still visible.

2.7 In short

- Generate a masterdark (`imcombine`)

- Subtract dark (`imarith`)

- Extract spectrum (`apall`)

- Extract spectrum of calibration lamp
  (`apall laser00004 out=claser00004 ref=obj00001m recen- trace- back- intera-`)

- Identify spectrum of calibration lamp (`identify`)

- Update header (`hedit obj00001m.ms.fits REFSPEC1 "claser00004.fits" add+ ver- show+`)

- Accomplish dispersion correction (`dispcor`)

- Divide by flat field (`sarith`)

- Normalize to the continuum (`continuum`)
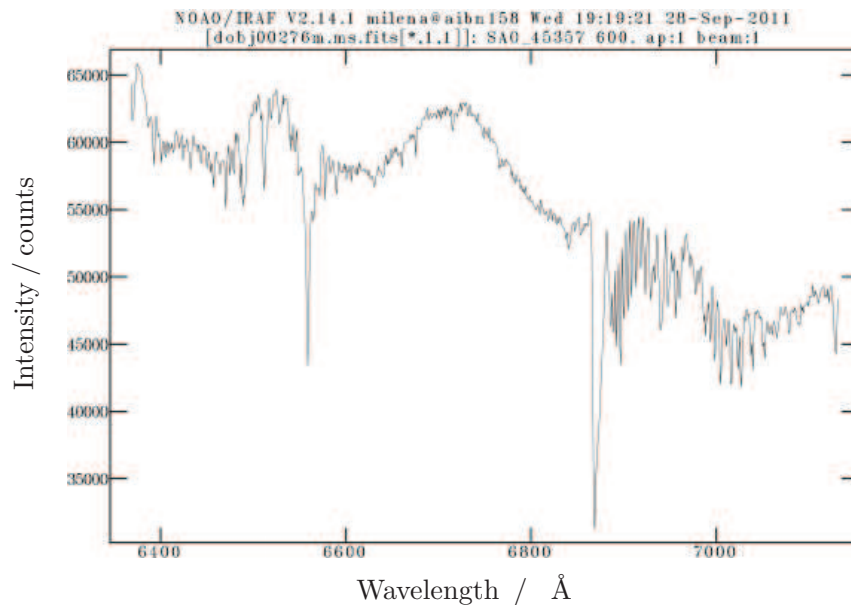
Figure 2.12: Spectrum of 44 Boötis that is not yet divided by a flat field.

2.8 Analysis of spectral lines

We are interested in the widths of the spectral lines. These can be determined with the *splot* task. Start *splot* and activate the irafterm window. Press "?" for a list of cursor commands. It is possible to fit a Gaussian, Lorentzian or Voigt profile to the lines, depending if you press "k" and "g", "k" and "l" or "k" and "v". By fitting some lines just for fun you will notice that the displayed full-width-half-maximum depends on the start and ending points of the fit (the "k" and "g", "l", "v" position). To be able to compare the full-width-half-maxima of two images (e.g. maximum and minimum position of a binary system) it is important to do the fit between the same positions in the different images! Y-values have to lie in the continuum and x-values have to go, for example, 100 Å to the left and 100 Å to the right from the line. The choice of the x-coordinates is optional but needs to be consistent within the different images.
IRAF writes the fit parameters in the `logfile.cl`.

The images with the fitted spectral lines including the fit can be exported as .eps files. To get the .eps file type the following into the irafterm window (not IRAF terminal) which has to be activated.
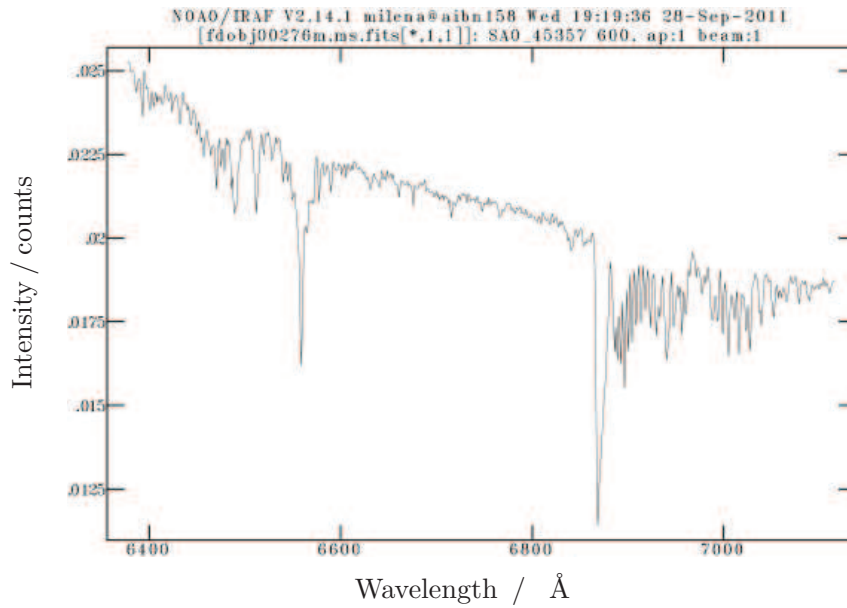
- `:.snap eps`

- `:.gflush`

Figure 2.13: Here is shown the same spectrum of 44 Boötis as in Fig. 2.12 but this time divided by a flat field.

2.9 Signal-to-noise ratio

To determine the signal-to-noise ratio, the task *imexam* is used. Open the desired spectrum with `display imagename` in the SAO DS9 window, then start *imexam* in the IRAF terminal. Reactivate the DS9 window and press "?", IRAF now displays the possible cursor commands. "m" is for `statistics`. Under `epar imexam` the number of pixels (number of rows and columns) which are used for the statistics can be adjusted. Set it to 1 line and 20 columns (number of pixel = 20). Go back to the DS9 window and check the spectrum for ranges where there are no spectral lines. Put the cursor centered over the spectrum and press "m". The values are displayed in the IRAF terminal.
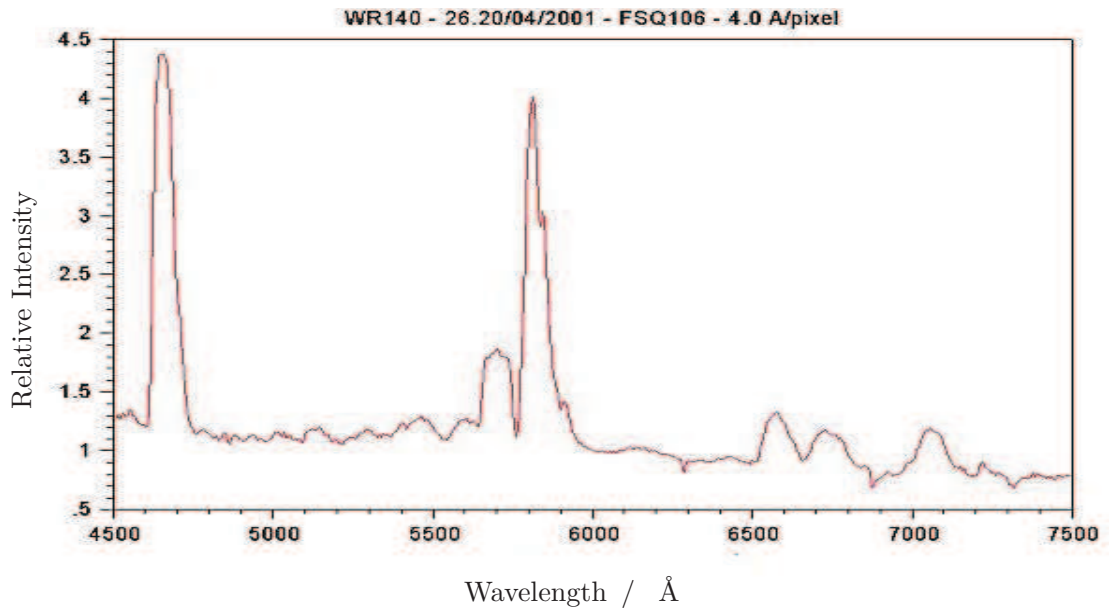
Figure 2.14: Spectrum of WR 140 from `http://www.astrosurf.com/~buil/us/peculiar2/wolf.htm`, accessed on August 29., 2011.

star name	magnitude of star	$T_{\mathrm{exp}}/$ s	S/N ratio
Vega	0.03	5	20
		15	22
		30	39
		60	37
		120	43
Regulus	1.36	10	13
		30	29
		60	32
SAO 61391	3.92	5	7
		10	7
		30	9
		60	16
		120	17
		300	39
AO Cassiopeiae	6.102	1200	28

Table 2.1: Signal-to-noise ratios determined with the IRAF task *imexam*. The individual signal-to-noise ratio was determined in a narrow region in the continuum of the stellar spectrum in the original, two dimensional image before extraction of the spectrum. Note, that the signal-to-noise ratio depends also on the focus of telescope and spectrograph and on the weather (seeing). For example, it is shown here that after an exposure time of twenty minutes, the signal-to-noise ratio of AO Cassiopeia is still lower than 35. AO Cassiopeia rose late in that night and dawn already started. Nevertheless it is possible to obtain useful data of AO Cassiopeia with exposure times of 600 s. The magnitudes of the stars were taken from `http://simbad.u-strasbg.fr/simbad/`, accessed on August 29., 2011. It is shown how long the exposure time T_{exp} needs to be to obtain a desired signal-to-noise ratio depending on the magnitude of the star.

Chapter 3

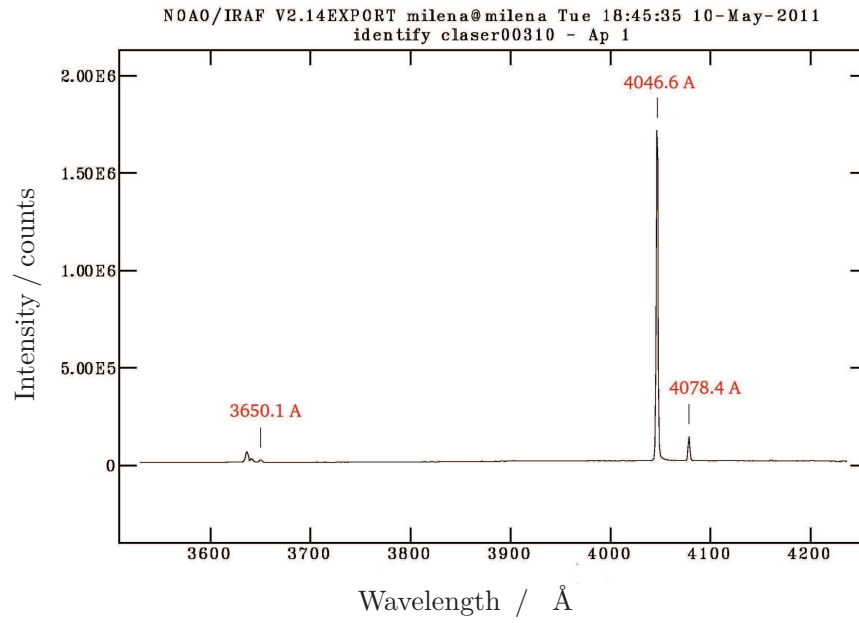**Spectra of Calibration Lamp**

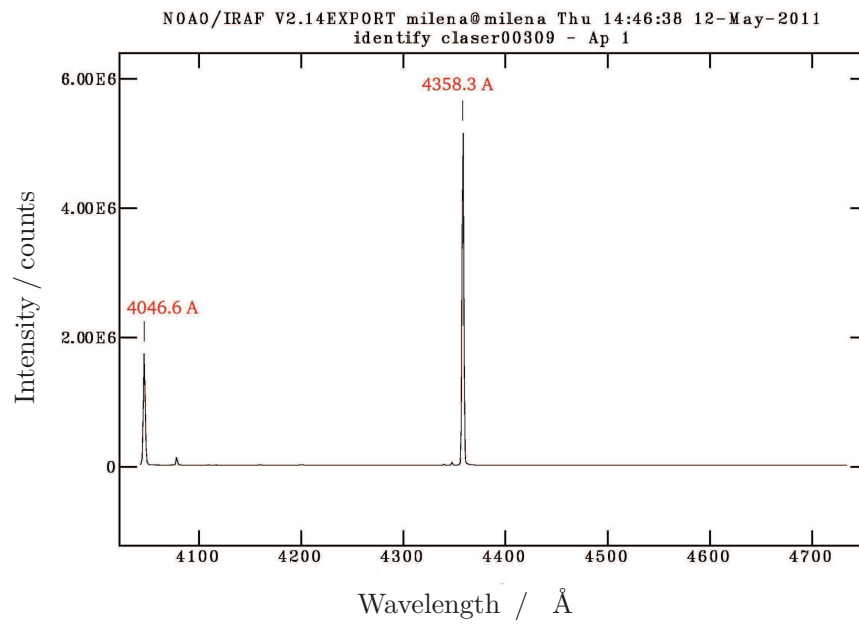Figure 3.1: Spectrum of calibration lamp for line identification.

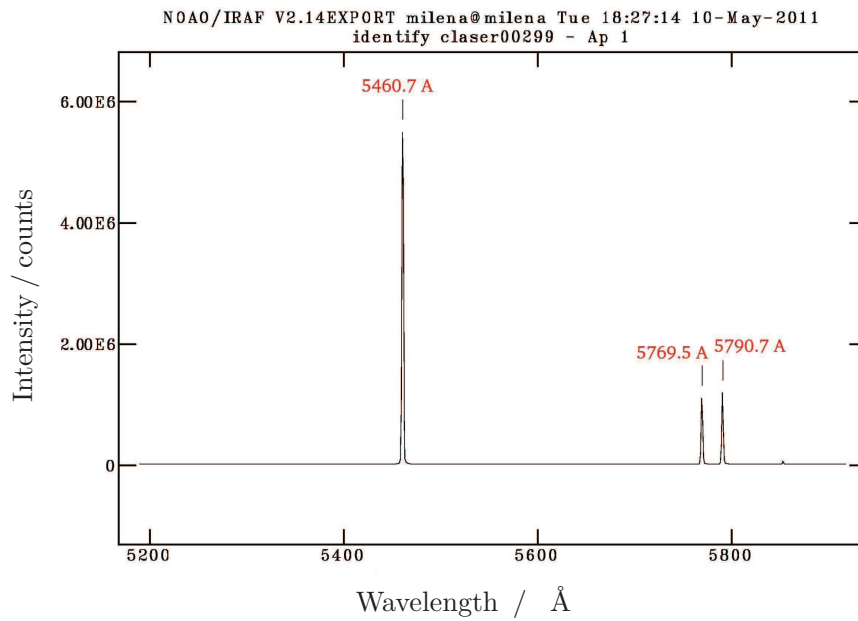Figure 3.2: Spectrum of calibration lamp for line identification.

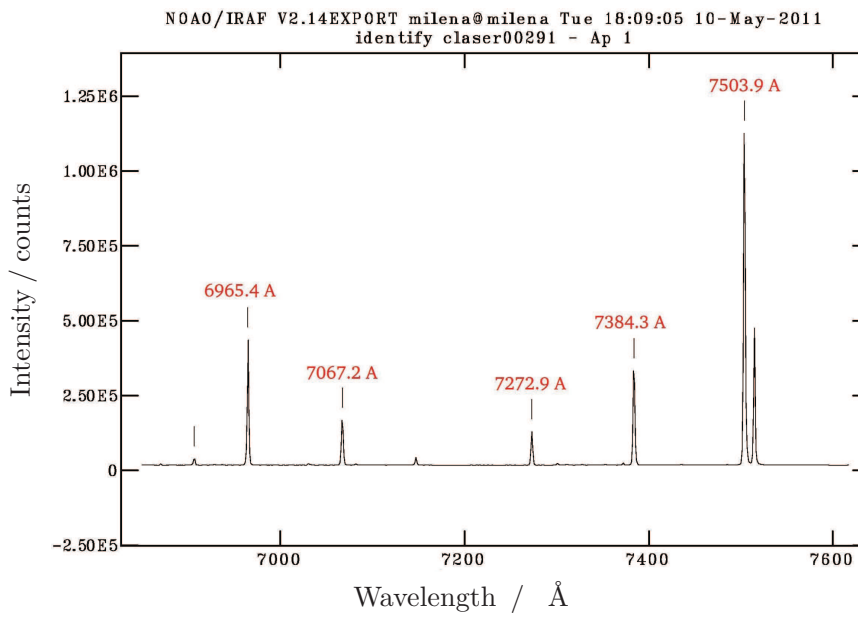Figure 3.3: Spectrum of calibration lamp for line identification.

Figure 3.4: Spectrum of calibration lamp for line identification.
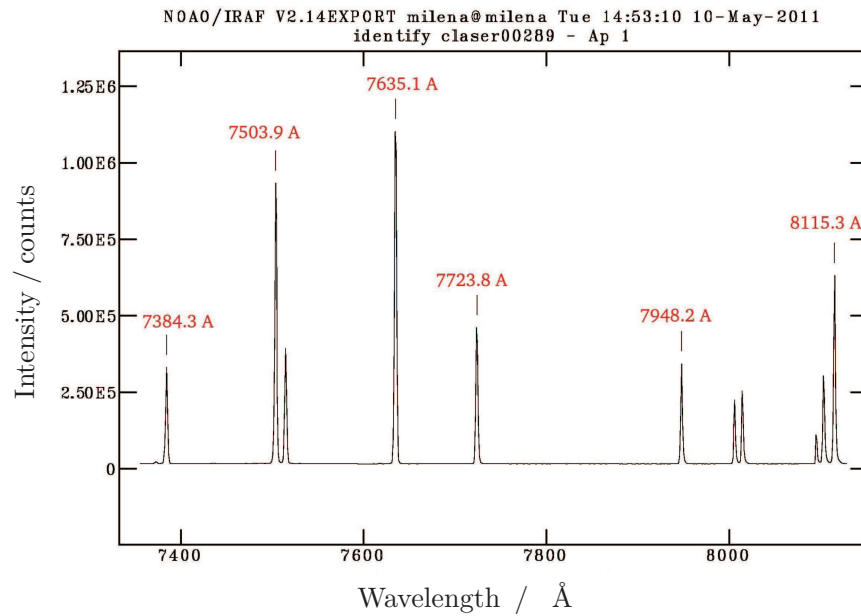
Figure 3.5: Spectrum of calibration lamp for line identification.
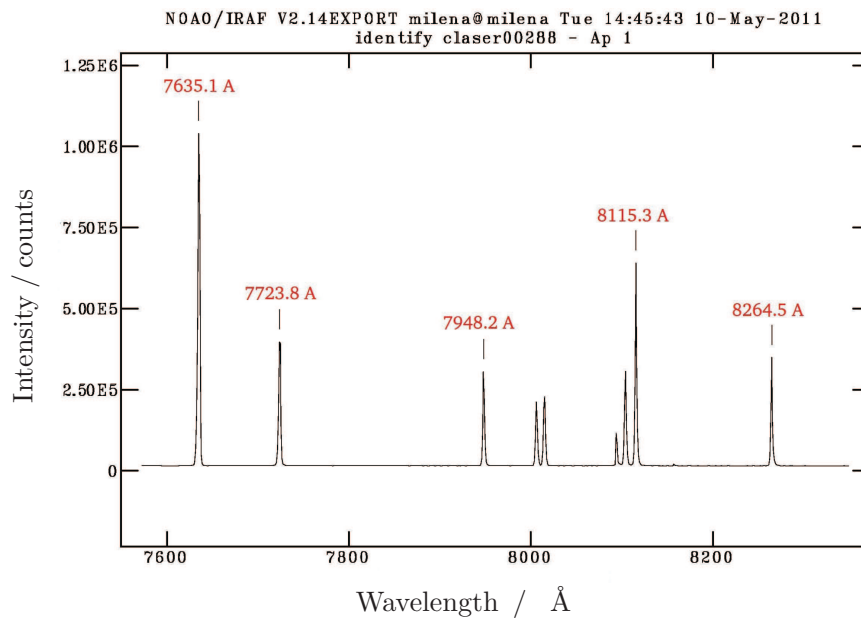
Figure 3.6: Spectrum of calibration lamp for line identification.

Chapter 4

Parameters of the SBIG ST 402 ME

CCD	
CCD	Kodak KAF-0402ME
Pixel Array	765 x 510 pixels
CCD Size	6.9 x 4.3 mm
Total Pixels	390,000
Pixel Size	9 x 9 microns
Full Well Capacity	~100,000 e-
Dark Current	1e⁻/pixel/sec at 0° C
Antiblooming	Optional

Readout Specifications	
Shutter	Electromechanical
Exposure	0.09 to 3600 seconds, 10ms resolution
Correlated Double Sampling	Yes
A/D Converter	16 bits
A/D Gain	1.5e- unbinned 2.0e- binned 2x2, 3x3 (1.0e- and 1.4e- for ABG CCD)
Read Noise	13.8e⁻ RMS Typical
Binning Modes	1 x 1, 2 x 2, 3 x 3
Pixel Digitization Rate	Up to 800.000 pixels per second with USB 2.0
Full Frame Download	<1 second

System Specifications	
Cooling - Enhanced	Single Stage Thermoelectric, Active Fan, -30 C from Ambient Typical
Cooling - Standard	Single Stage Thermoelectric, Active Fan, -20 C from Ambient Typical
Temperature Regulation	±0.1°C
Power	12VDC Power supply included
Computer Interface	USB 2.0 (USB 1.1 compatible)
Computer Compatibility	Windows 98/2000/Me/XP Mac OS-X

Physical Dimensions	
Optical Head	5 x 4 x 2.5 inches (including fan)
CPU	All electronics integrated into Optical Head, No CPU
Mounting	T-Thread, 1.25" nosepieces included
Weight	Approx. 20 oz. (0.6kg)
Backfocus (C-mount compatible)	0.69 inches

Figure 4.1: Parameters of SBIG ST 402 ME given by the manufacturer. From `http://www.sbig.com/ST-402ME-C1.html` accessed on September 13., 2011.

Chapter 5

Explanation of "Spectroscopic binary catalog"

Eighth Catalogue of the Orbital Elements of Spectroscopic Binary Systems

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Figure 5.1: The spectroscopic binary catalog gives a detailed list of many binary star systems. To calculate the times when to observe the desired binary system, the epoch and the period are needed. For more accuracy it is advisable to look for more accurate values on the internet. The calculated mass can be compared to the mass given in the catalog. The listed orbital velocities must be added for the total orbital velocity. In some works about radial velocity curves, the amplitude of the curve is labeled with K, that's why in the catalog the orbital velocities are marked as K_1 and K_2.

Chapter 5 Explanation of "Spectroscopic binary catalog"

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Bibliography

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