

Data reduction of the echelle spectra using IRAF

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The background is a dark blue space-themed illustration. It features a satellite with solar panels and a dish antenna in the upper left, a spiral galaxy, a shooting star with a long tail, and several small stars and planets scattered throughout. A large, light-colored, irregular shape in the center contains the text.

IRAF

Image **R**eduction and **A**nalysis Facility

Is distributed by the National Optical
Astronomy Observatories, which is operated by
the Association of the Universities for Research
in Astronomy, inc. (AURA) under cooperative
agreement with the National Science
Foundation

IRAF - first steps

<https://iraf.net>

help task

Plot spectrum

splot spec.fit

Plot set of spectra

specplot @spec.list

specplot e*.fit,01.fit,02.fit...

Check header

imhead spec.fit/@spec.list l+ | page

Select some field from header

hselect spec.fit/@spec.list \$!,obj-name,exptime yes

Check stats of spectrum

imstat spec.fit/@spec.list

See image with ds9

!ds9 &

display spec.fit Nframe (nframe=1,...,12)

EDIT:

1) login.cl line ~34

set stdimage = imt4096

set imextn = "oif:imh fxf:fit,fits ..."

2) include data of Ondrejov observatory in the database, edit file **obsdb.dat** (path:

~miniconda3/envs/iraf38/iraf/noao/lib/obsdb.dat)

```
fix32 (on merak)
This is the EXPORT version of IRAF V2.16 supporting PC systems.

Welcome to IRAF. To list the available commands, type ? or ??. To get
detailed information about a command, type `help <command>'. To run a
command or load a package, type its name. Type `bye' to exit a
package, or `logout' to get out of the CL. Type `news' to find out
what is new in the version of the system you are using.

Visit http://iraf.net if you have questions or to report problems.

The following commands or packages are currently defined:

(Updated on 2013-12-13)

adccdrom.  deitab.   images.   mtools.   softtools.  upsqiid.
cfh12k.   esowfi.  kepler.  nfextern.  sqiid.     utilities.
cirred.   finder.  language. noao.     stecf.     vo.
ctio.     fitsutil. lists.   obsolete.  stsdas.   xdimsum.
cutoutpkg. gemini.  mem0.    plot.     system.    xray.
dataio.   gmisc.  msbdb.   proto.    tables.
dbms.     guiapps. mscred.  rvsao.   ucscrllis.

ec1>
```

observatory = "ondrejov"

name = "Ondrejov observatory"

longitude = 345:12:59

latitude = 49:54:38

altitude = 528

timezone = -1

OESRED.CL

task oesred=path/oesred.cl



- SEMI automatic

- always check your data!

imstat
ds9
splot

- Divided in two parts: Calibration and Science.

- Parameters were tested and works exclusively for OES.

- for now, recommend stepbystep

epar oesred (or any task- edit parameter)

Quit :q

Go! :g

```
fix32 (on merak)
I R A F
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202102040008.fit Spectrum target to reduce(.fit)
(output = hd54482) Output filename
(idtarget= HD 54482) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0008) Observation id number

# CALIBRATION PARAMETERS

(orgfile= no) do you want organize files?
(zeroom= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrimc= no) Use trim flat & comp?
(zeroeor= no) Apply zero level correction to flat & comp?
(compcom= no) Combine comparison lamp images?
(flatcom= no) Combine flat field images?
(flatapa= no) Extract flat apertures?
(compapa= no) Extract comparison apertures?
(idatab= no) Use database folder for identification?
(idfolde= idcomp) folder name with identification database
(idencom= no) Identify features in spectrum for dispersion sol

# OBJECT PARAMETERS

(trimob = no) Trim object?
(iftrimo= no) Use trim object?
(zeroeor= no) Apply zero level correction to object?
(crays = no) Remove cosmic rays?
(ifcrays= no) Use object with cosmic rays extraction?
(objecta= no) Extract object apertures?
(flatcor= no) Apply flat correction to object?
(helioco= no) calculate JD + heliocentric correction?
(idref = no) refer database identification to images?
(norm = no) normalize spectra?
(ncombin= no) combine normalized spectra?
(mode = ql)

ESC-? for HELP
```

1) Initial parameters!

Check type of "image":

flat: flat fields

zero: bias

comp: ThAr comparison spectra

Object: science

imhead e*.fit (short way)

- print list filename and object type

hselect e*.fit \$!,object yes

- check header!

imhead e202109060001.fit l+ / page

- for example, we wanna start with alp Lyr.

- take note about the filename and the target name in the header!

```
fix32 (on merak)
SGH-OIC =                2 / OES Iodine cell
TM-DIFF =               -1 / T1630950141 - P1630950142
OBJECT = 'zero'         / Title of observation
IMAGETYP= 'zero'       / Type of observation, eg. FLAT
OBSERVER= 'Geier Rezba' / Observers
SYSVER = 'PES0 exported.exp'
READSPD = '100kHz'
FILENAME= 'e202109060001.fit'
CAMFOCUS=              3080. / Camera focus position
SPECTEMP=              21.8 / 17912
SPECFILT=              0 / Spectral filter
SLITHEIG=             1.07 / Slit height in mm
TM_START =             63741 / 17:42:21, 1630950141
UT = '17:42:21'       / UTC of start of observation
EPOCH =              2000. / Same as EQUINOX - for back compat
EQUINOX =             2000. / Equinox of RA and DEC
DATE-OBS= '2021-09-06' / UTC date start of observation
TM_END =             63742 / 17:42:22, 1630950142
EXPTIME =              1 / Length of observation excluding pauses
DARKTIME=              1 / Length of observation including pauses
CCDTEMP =             -110 / Detector temperature
STDIN-line 63-file 1 of 1
```

```
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarget= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number
```

```
e202109060013.fit comp
e202109060014.fit comp
e202109060015.fit comp
e202109060016.fit "alp Lyr"
e202109060017.fit "alp Lyr"
e202109060018.fit "HD 10780"
e202109060019.fit "BD+44 2417"
e202109060020.fit "HD 153911"
e202109060021.fit "KIC 11134982"
e202109060022.fit "HD 209027"
e202109060023.fit "HD 194905"
e202109060024.fit comp
e202109060025.fit comp
e202109060026.fit comp
```

ALWAYS keep raw data as backup!!

Image Reduction and Analysis Facility

```
PACKAGE = clpackage
```

```
TASK = oesred
```

```
input      =      e202109060016.fit  Spectrum target to reduce(.fit)
(output    =                alpLyr) Output filename
(idtarget=                alp Lyr) Target name on header
(napertu=                49) Number of apertures to be found
(id        =                0016) Observation id number
```

input: The complete fit file name of our target, science

output: Filename of the final reduced spectrum > “output-id.fit”

Idtarget: **EXACT** name of the target which is in the header!!

naperture: Number of apertures, important if we wanna use the wavelenght calibration database.

id: recommended the last four numbers of the fit file

2) sort files!

- complete first set of parameters, in the part of calibration set:

orgfile = yes

:go

After this step files are organized, you can check each folder and files.

Example:

imstat @flat.dat

#	IMAGE	NPIX	MEAN	STDDEV	MIN	MAX
	<i>e202109060006.fit</i>	<i>4194304</i>	<i>931.1</i>	<i>2621.</i>	<i>0.</i>	<i>25203.</i>
	<i>e202109060007.fit</i>	<i>4194304</i>	<i>949.1</i>	<i>2679.</i>	<i>0.</i>	<i>25797.</i>
	<i>e202109060008.fit</i>	<i>4194304</i>	<i>944.7</i>	<i>2664.</i>	<i>0.</i>	<i>25560.</i>
	<i>e202109060009.fit</i>	<i>4194304</i>	<i>941.4</i>	<i>2654.</i>	<i>0.</i>	<i>25521.</i>
	<i>e202109060010.fit</i>	<i>4194304</i>	<i>940.2</i>	<i>2649.</i>	<i>0.</i>	<i>25405.</i>

- visual inspection:

!ds9 &

display e202109060006.fit 1

**Before each run be
sure we are in the
main folder!**

pwd

```
fix32 (on merak)
IRAF
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input =  e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarget= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number

# CALIBRATION PARAMETERS

(orgfile= yes) do you want organize files?
(zero= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrim= no) Use trim flat & comp?
(zero= no) Apply zero level correction to flat & comp?
(comp= no) Combine comparison lamp images?
(flat= no) Combine flat field images?

More
ESC-? for HELP

s on...asu.cas.cz 20210906
alpLyr comp flat other zero all.spec
```


3) Combine zeros!

- before, is possible edit the list **zero.dat**

- change the previous task to "no"

orgfile = no

zerocom = yes

:go

- new file: **Zero.fit**

```
104 ##### ZEROCOMBINE
105 if (access("zero/Zero.fit")){
106     zerocomb=no
107 }
108 if (zerocomb==yes){
109     cd "zero/"
110     unlearn zerocombine
111     zerocombine.reject="minmax"
112     zerocombine.rdnoise= "READNOIS"
113     zerocombine.gain = "GAIN"
114     zerocombine (input="@zero.dat",output="Zero.fit")
115     cd "../"
116 }
```



















```
IRAF
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarget= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number

# CALIBRATION PARAMETERS

(orgfile= no) do you want organize files?
(zerocom= yes) Combine zero level images?
(trimcal= no) Trim flat and comp?
```

ezas on...asu.cas.cz 20210906 zero

						
e202109060001.fit	e202109060002.fit	e202109060003.fit	e202109060004.fit	e202109060005.fit	e202109060034.fit	e202109060035.fit
						
e202109060036.fit	e202109060037.fit	e202109060038.fit	e202109060039.fit	e202109060040.fit	e202109060041.fit	e202109060042.fit
						
e202109060043.fit	logfile	zero.dat	Zero.fit			

4) trim flat and comp (optional)

- completely optional, but sometimes the first and last pixel of each aperture is saturated and can be annoying during normalization.

- lines 120 in oesred.cl

zerocom = no

trimcal = yes

iftrimc = yes

:go

- new files, prefix T

Te*.fit

The screenshot shows the IRAF (Image Reduction and Analysis Facility) interface. At the top, it displays 'I R A F' and 'Image Reduction and Analysis Facility'. Below this, the 'PACKAGE' is set to 'clpackage' and the 'TASK' is 'oesred'. The 'input' is 'e202109060016.fit', which is identified as a 'Spectrum target to reduce(.fit)'. Other parameters include '(output = alpLyr) Output filename', '(idtarget= alp Lyr) Target name on header', '(napertu= 49) Number of apertures to be found', and '(id = 0016) Observation id number'. A section titled '# CALIBRATION PARAMETERS' lists several options: '(orgfile= no) do you want organize files?', '(zerocom= no) Combine zero level images?', '(trimcal= yes) Trim flat and comp?', '(iftrimc= yes) Use trim flat & comp?', '(zerocor= no) Apply zero level correction to flat & comp?', '(compcom= no) Combine comparison lamp images?', '(flatcom= no) Combine flat field images?', '(flatapa= no) Extract flat apertures?', and '(compapa= no) Extract comparison apertures?'. A 'More' button is visible below these options. The terminal prompt is 'ecl>'. Below the terminal window, a file browser shows a directory with files: 'e20210906 0006.fit', 'e20210906 0007.fit', 'e20210906 0008.fit', 'e20210906 0009.fit', 'e20210906 0010.fit', 'flat.dat', and 'logfile'. A second row of files is also visible, prefixed with 'Te': 'Te20210906 0006.fit', 'Te20210906 0007.fit', 'Te20210906 0008.fit', 'Te20210906 0009.fit', and 'Te20210906 0010.fit'. Each file icon shows a small thumbnail of a 3x3 grid of numbers (0100, 0101, 1001, 0110).

4) trim flat and comp (optional)

If we apply trim and you wanna use the trimmed images, you need to set iftrimc=yes during the whole reduction!

```
125 if (trimcal==yes){
126     unlearn ccdproc
127     ccdproc.trimsec = "[2:2035,*]"
128 #   ccdproc.trimsec = "[5:2025,800:1500]"
129     ccdproc.trim = yes
130     ccdproc.fixpix = no
131     ccdproc.overscan = no
132     ccdproc.darkcor= no
133     ccdproc.zerocor=no
134     ccdproc.flatcor=no
135     #
136     cd "flat/"
137     ccdproc.ccdtype = "flat"
138     ccdproc (images="@flat.dat",output="T@flat.dat")
139     cd "../"
140     #
141     cd "comp/"
142     ccdproc.ccdtype = "comp"
143     ccdproc (images="@comp.dat",output="T@comp.dat")
144     cd "../"
145
146 }
147
```

5) Bias correction -> flat and comp

trimcal = no

iftrimc = yes

zerocor = yes

:go

- new files, prefix **Z**

ZTe*.fit


















```
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarge= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number

# CALIBRATION PARAMETERS

(orgfile= no) do you want organize files?
(zerocom= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrimc= yes) Use trim flat & comp?
(zerocor= yes) Apply zero level correction to flat & comp?
(compcom= no) Combine comparison lamp images?
(flatcom= no) Combine flat field images?
(flatapa= no) Extract flat apertures?
(compapa= no) Extract comparison apertures?
More
ecl>
```

bezas on...asu.cas.cz 20210906 flat

 e20210906 0006.fit	 e20210906 0007.fit	 e20210906 0008.fit	 e20210906 0009.fit	 e20210906 0010.fit	 flat.dat	 logfile
 Te20210906 0006.fit	 Te20210906 0007.fit	 Te20210906 0008.fit	 Te20210906 0009.fit	 Te20210906 0010.fit	 ZTe2021090 60006.fit	 ZTe2021090 60007.fit
 ZTe2021090 60008.fit	 ZTe2021090 60009.fit	 ZTe2021090 60010.fit				

5) Bias correction flat and comp

```
149 if (zerocorcal==yes){
150     unlearn ccdproc
151     ccdproc.ccdtype="zero"
152     ccdproc.fixpix = no
153     ccdproc.overscan = no
154     ccdproc.darkcor= no
155     ccdproc.zerocor=no
156     ccdproc.flatcor=no
157     #
158     cd "flat/"
159     ccdproc.ccdtype="flat"
160     ccdproc.zerocor=yes
161     ccdproc.zero="../zero/Zero.fit"
162     if (iftrimc==yes){
163         ccdproc (images="T@flat.dat",output="ZT@flat.dat")
164     } else {
165         ccdproc (images="@flat.dat",output="Z@flat.dat")
166     }
167     cd "../"
168     #
169     cd "comp/"
170     ccdproc.ccdtype="comp"
171     ccdproc.zerocor=yes
172     ccdproc.zero="../zero/Zero.fit"
173     if (iftrimc==yes){
174         ccdproc (images="T@comp.dat",output="ZT@comp.dat")
175     } else {
176         ccdproc (images="@comp.dat",output="Z@comp.dat")
177     }
178     cd "../"
179 }
```

6) Combine comp (ThAr)

iftrimc = yes (keep “yes”)

zerocor = no

compcom = yes

:go

- new file

ZTcomp.fit

```
IRAF
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarget= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number

# CALIBRATION PARAMETERS

(orgfile= no) do you want organize files?
(zerocom= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrimc= yes) Use trim flat & comp?
(zerocor= no) Apply zero level correction to flat & comp?
(compcom= yes) Combine comparison lamp images?
(flatcom= no) Combine flat field images?
(flatapa= no) Extract flat apertures?
(compapa= no) Extract comparison apertures?
More
ESC-? for HELP
```

ezas on...asu.cas.cz 20210906

alpLyr comp flat other zero all.spec ZTcomp.fit

7) Combine flat field

iftrimc = yes
compcom = no
flatcom = yes
:go

- new file

ZTflat.fit

```

I R A F
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred

input = e202109060016.fit Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarge= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id = 0016) Observation id number

# CALIBRATION PARAMETERS

(orgfile= no) do you want organize files?
(zerocom= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrimc= yes) Use trim flat & comp?
(zerocor= no) Apply zero level correction to flat & comp?
(compcom= no) Combine comparison lamp images?
(flatcom= yes) Combine flat field images?
(flatapa= no) Extract flat apertures?
(compapa= no) Extract comparison apertures?
More
ESC-? for HELP
ezas on...asu.cas.cz 20210906
alpLyr comp flat other zero all.spec ZTcomp.fit
ZTflat.fit
```

6) and 7) Combine comp/flat field

```
182 ##### COMBINE - comp/lamp
183 if (compcomb==yes){
184     cd "comp/"
185     unlearn imcombine
186     imcombine.reject = "none"
187     imcombine.lsigma = 3
188     imcombine.hsigma = 3
189     imcombine.rdnoise= "READNOIS"
190     imcombine.gain    = "GAIN"
191     imcombine.scale = "exposure"
192     imcombine.expname="EXPTIME"
193     # imcombine (input="@comp.dat",output = "comp.fits")
194         if (iftrimc==yes){
195             imcombine (input="ZT@comp.dat",output = "../ZTcomp.fit")
196         } else {
197             imcombine (input="Z@comp.dat",output = "../Zcomp.fit")
198         }
199     cd "../"
200 }
```


8) Model apertures - Flat

iftrimc = yes

flatcom = no

flatapa = yes

:go

Find apertures for Ztflat? (yes):

Number of apertures to be found automatically (49):

Resize apertures for ZTflat? (yes):

Edit apertures for Ztflat? (yes):

- accept everything with “enter” or typing “yes”. Default answer in parenthesis.

- in order to do everything a bit easy/fast. We will use a database for wavelength calibration, for that we need to choose 49 apertures.

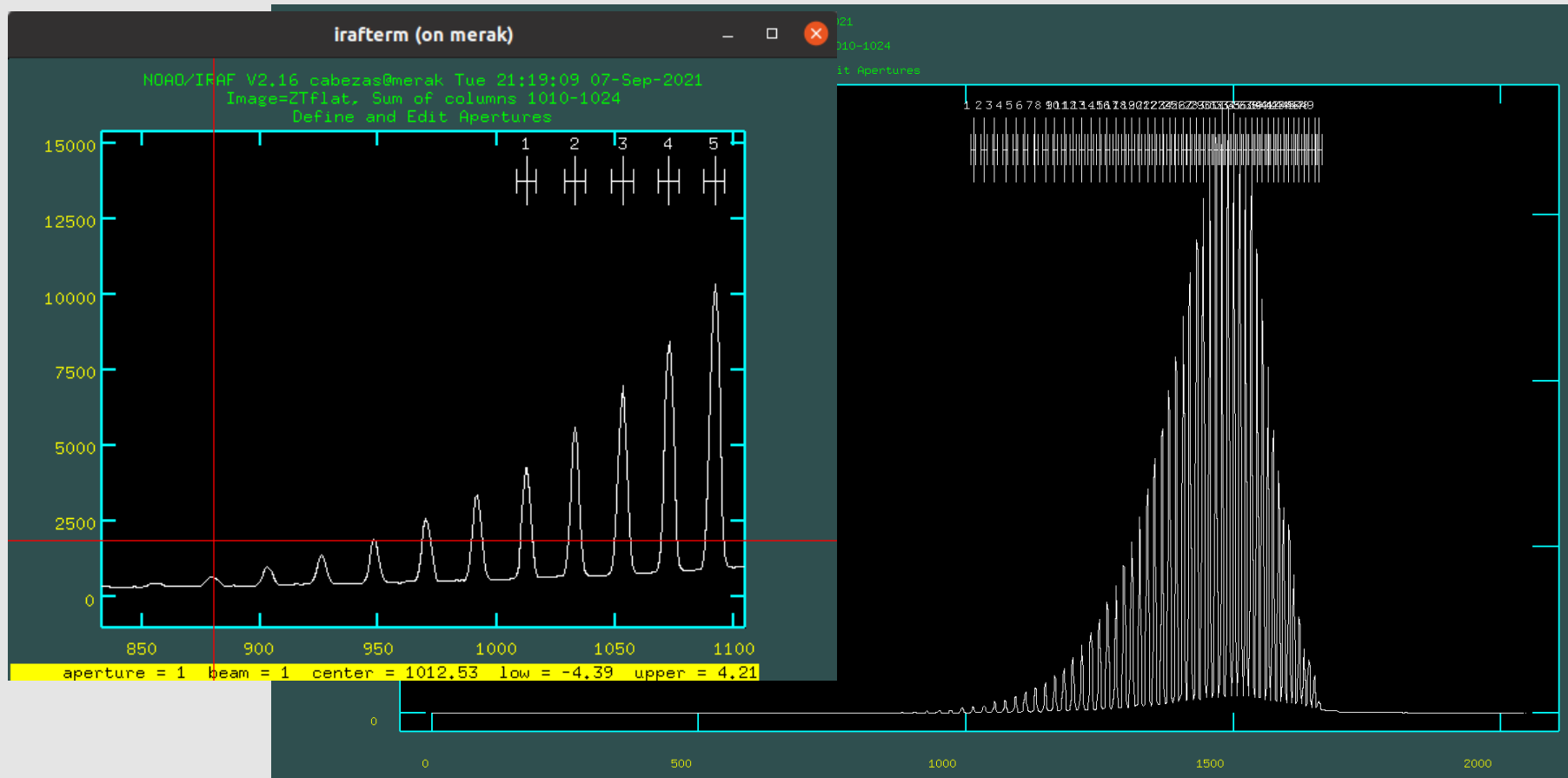
Background fitting is not necessary because overlapping.

```
TASK = oesred
input   = e202109060016.fit  Spectrum target to reduce(.fit)
(output = alpLyr) Output filename
(idtarge= alp Lyr) Target name on header
(napertu= 49) Number of apertures to be found
(id      = 0016) Observation id number

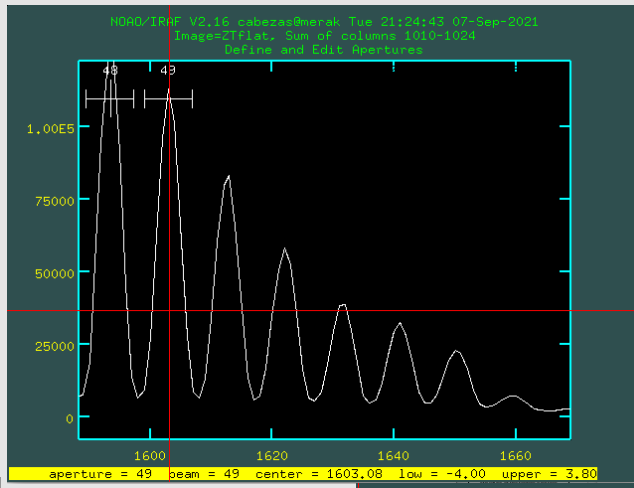
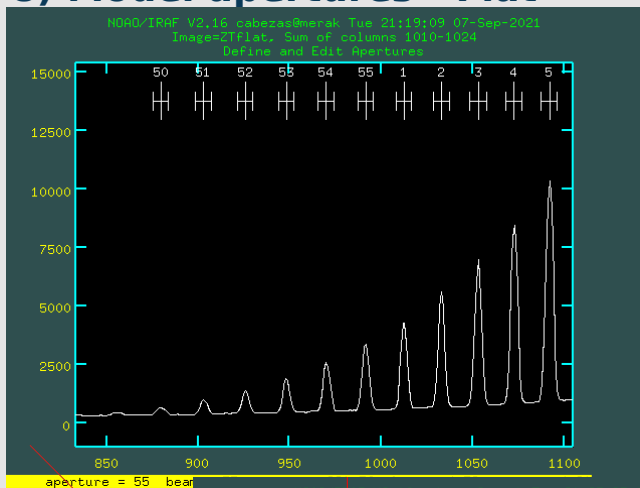
# CALIBRATION PARAMETERS
(orgfile= no) do you want organize files?
(zerocom= no) Combine zero level images?
(trimcal= no) Trim flat and comp?
(iftrimc= yes) Use trim flat & comp?
(zerocor= no) Apply zero level correction to flat & comp?
(compcom= no) Combine comparison lamp images?
(flatcom= no) Combine flat field images?
(flatapa= yes) Extract flat apertures?
(compapa= no) Extract comparison apertures?
More
Find apertures for ZTflat? (yes):
Number of apertures to be found automatically (49):
Resize apertures for ZTflat? (yes):
Edit apertures for ZTflat? (yes):
```

8) Model apertures - Flat

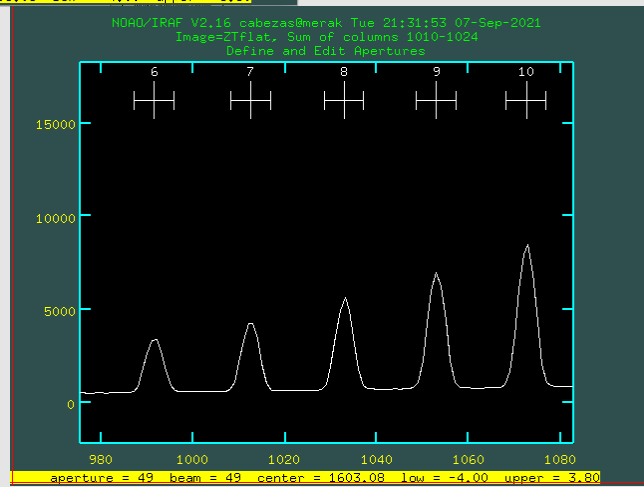
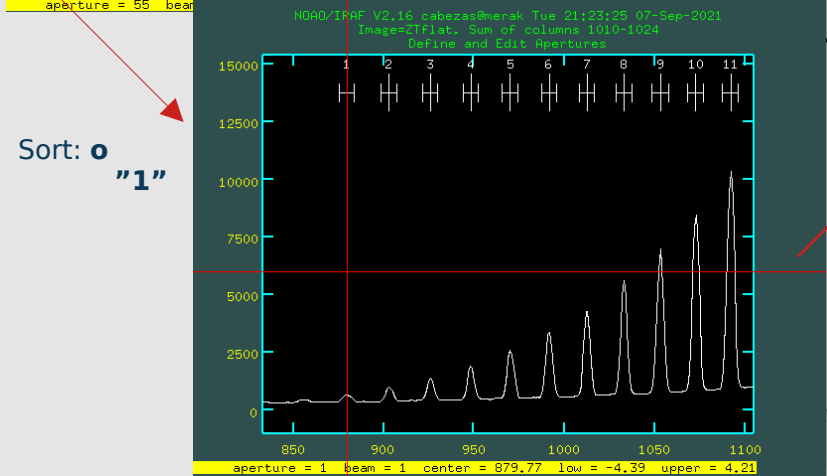
- first aperture near the pixel 890
mark: **m**



8) Model apertures - Flat



- delete last aperture: **d**



8) Model apertures - Flat

Fit curve to aperture N of Ztflat interactively (yes): YES

Write apertures for ZTflat to database (yes):

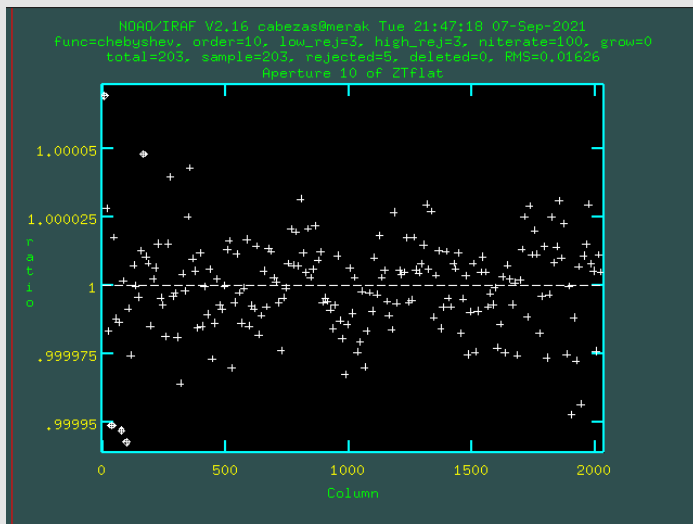
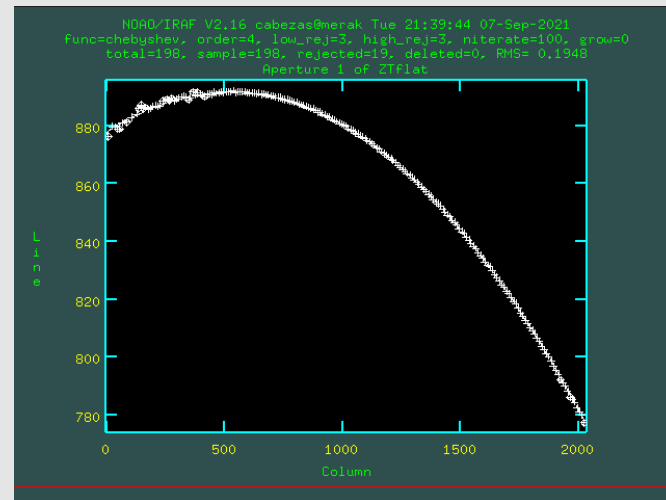
Extract aperture for ZTflat? (yes):

Review extracted spectra from ZTflat? (yes):

Review extracted spectrum for aperture 1 from ZTflat? (yes)

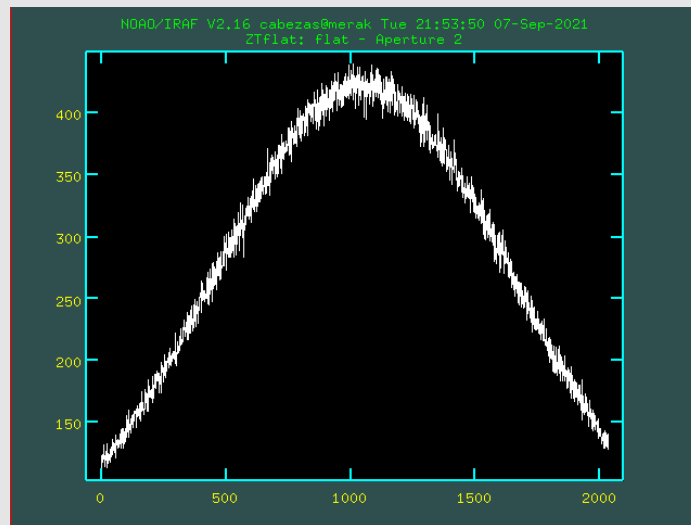
YES

- new file: **AZTflat.fit**



Polinomial fitting of
the echelle orders

- change order :o **N**
- relative residuals **k**
- residuals (px) **j**
- aperture **h**



9) Model apertures - Comparison lamp

- Template: AZTflat.fit

iftrimc = yes

flatapa = no

compapa = yes

:go

Edit apertures for Ztflat? (yes):

Can be “no” but always is better to check it!

q

Write apertures for Ztcomp to database (yes):

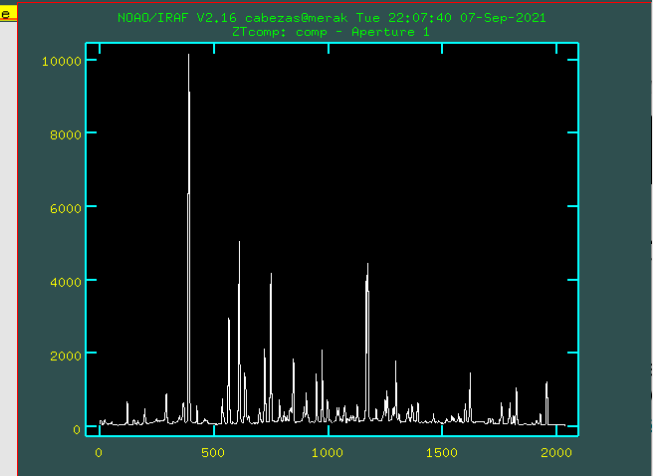
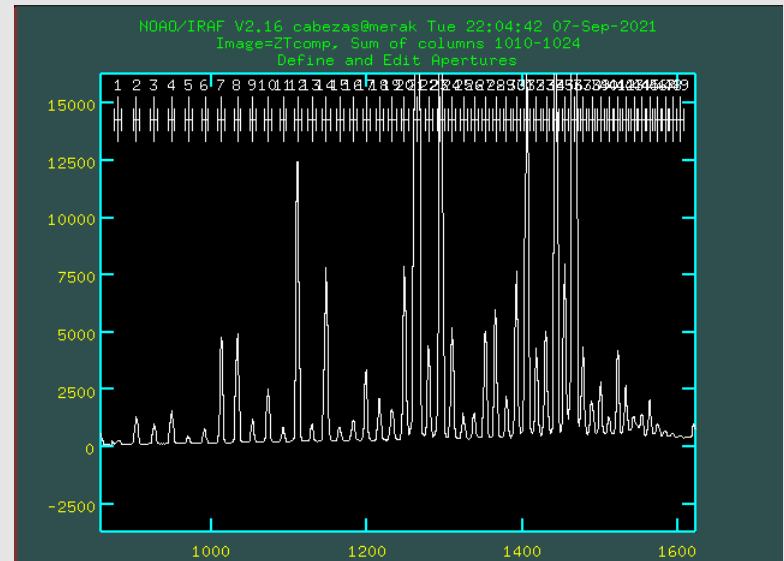
Extract aperture spectra for Ztcomp? (yes):

Review extracted spectra from Ztcomp? (yes):

Review extracted spectrum for aperture 1 from ZTcomp? (yes) YES

- if you are using database, check if the first aperture corresponds to the first aperture in the atlas. (inside folder **idcomp**)

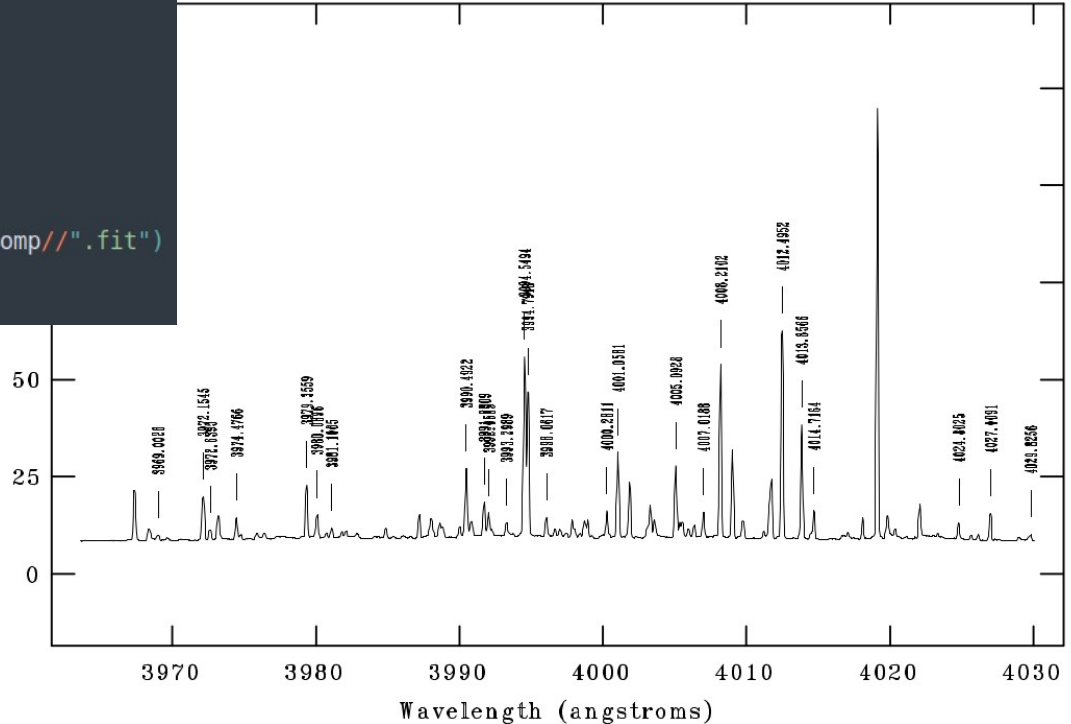
- new file: **AZTcomp.fit**



9) Model apertures - Comparison lamp

```
272 #####APERTURES - COMP
273 if (compapall==yes){
274     apall.referen=inflat
275     apall.format = "echelle"
276     apall.find=no
277     apall.recente=no
278     apall.resize=no
279     apall.trace=no
280     apall.fittrace=no
281     apall.extras=no
282     apall.ylevel = 0.04
283     apall.extract=yes
284     apall (input=incomp, output="A//incomp//".fit")
285 }
286
```

```
0/IRAF V2.16 mauricio@mauricio Wed 12:32:54 30-Dec-2020
identify iazcomp.0001 - Ap 1
comp
```



10) Wavelength calibration

- using database, folder “idcomp” must be in the main path

iftrimc = yes

compapa = no

iddatab = yes

idfolder = idcomp

idencom = yes

:go

- database can be shifted few pixels, in order to fix we need to “shift” the points of our database.

s

- always fit!

f (delete point d), **q**, **q**

- rms ~ 0.005 acceptable

- Write feature data to the database (yes)?

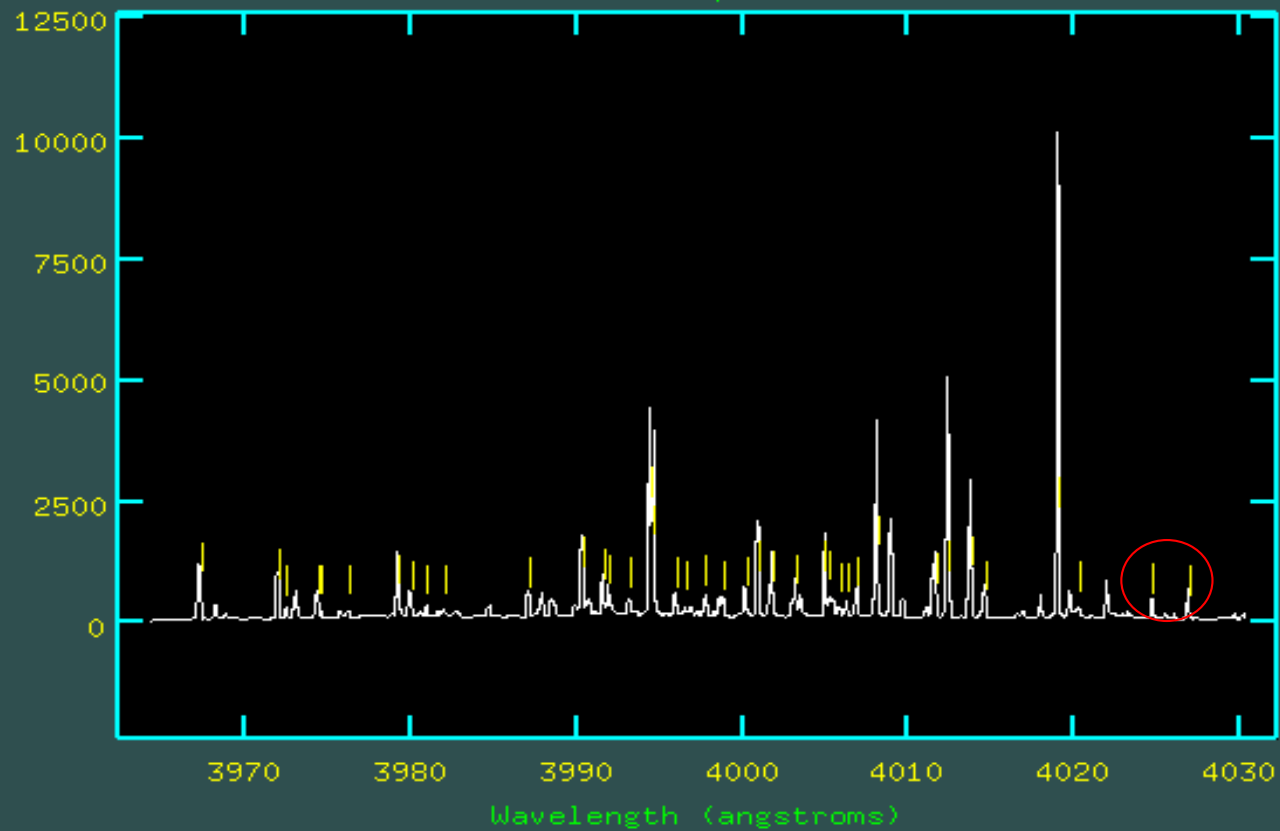
```

                                     I R A F
                                Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred
More
(iddatab=          yes) Use database folder for identification?
(idfolde=          idcomp) folder name with identification database
(idencom=          no) Identify features in spectrum for dispersion sol

                                # OBJECT PARAMETERS

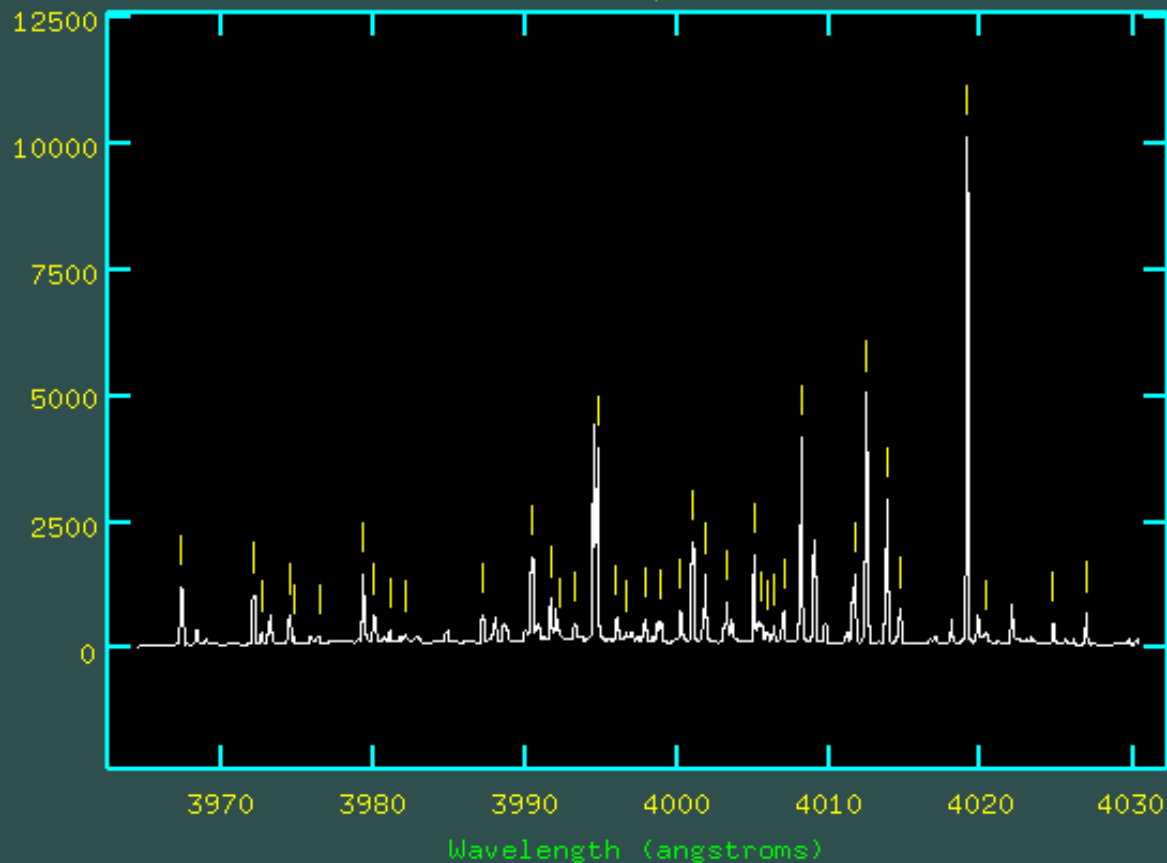
(trimob =          no) Trim object?
(iftrimo=          no) Use trim object?
(zerocor=          no) Apply zero level correction to object?
(crays =          no) Remove cosmic rays?
(ifcrays=          no) Use object with cosmic rays extraction?
(objecta=          no) Extract object apertures?
(flatcor=          no) Apply flat correction to object?
(helioco=          no) calculate JD + heliocentric correction?
(idref =          no) refer database identification to images?
(norm =          no) normalize spectra?
(ncombin=          no) combine normalized spectra?
More
ESC-? for HELP
```

NOAO/IRAF V2.16 cabezas@merak Tue 22:21:55 07-Sep-2021
identify lazcomp.0001 - Ap 1
comp



No match!
Press "s"

NOAO/IRAF V2.16 cabezas@merak Tue 22:24:31 07-Sep-2021
identify lazcomp.0001 - Ap 1
comp



Recentered=39/39, pixel shift=3.33, user shift=-0.11, z=-2.7E-5, rms=0.057

11) Trim Object

iftrimc = yes
iddatab = no
idfolder = idcomp
idencom = no

trimob = yes
iftrimo = yes
:go

New file: **Te202109060016.fit**

```

I R A F
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred
More
(iddatab=          no) Use database folder for identification?
(idfolde=         idcomp) folder name with identification database
(idencom=         no) Identify features in spectrum for dispersion sol

# OBJECT PARAMETERS

(trimob =         yes) Trim object?
(iftrimo=        yes) Use trim object?
(zeroacor=       no) Apply zero level correction to object?
(crays =         no) Remove cosmic rays?
(ifcrays=        no) Use object with cosmic rays extraction?
(objecta=        no) Extract object apertures?
(flatcor=        no) Apply flat correction to object?
(helioco=        no) calculate JD + heliocentric correction?
(idref =         no) refer database identification to images?
(norm =          no) normalize spectra?
(ncombin=        no) combine normalized spectra?
More
ecl> 
```

as on...asu.cas.cz 20210906 alpLyr

e20210906 0016.fit logfile Te20210906 0016.fit

12) Bias correction object

iftrimc = yes

trimob = no

iftrimo = yes

zerocor = yes

:go

New file: **ZTe202109060016.fit**





```

I R A F
Image Reduction and Analysis Facility
PACKAGE = clpackage
TASK = oesred
more
(idatab=          no) Use database folder for identification?
(idfolde=        idcomp) folder name with identification database
(idencom=        no) Identify features in spectrum for dispersion sol

# OBJECT PARAMETERS

(trimob =        no) Trim object?
(iftrimo=        yes) Use trim object?
(zerocor=        yes) Apply zero level correction to object?
(crays =         no) Remove cosmic rays?
(ifcrays=        no) Use object with cosmic rays extraction?
(objecta=        no) Extract object apertures?
(flatcor=        no) Apply flat correction to object?
(helioco=        no) calculate JD + heliocentric correction?
(idref =         no) refer database identification to images?
(norm =          no) normalize spectra?
(ncombin=        no) combine normalized spectra?
more
ecl> 
```

son...asu.cas.cz 20210906 alpLyr

 e20210906 0016.fit	 logfile	 Te20210906 0016.fit	 ZTe2021090 60016.fit
--	---	---	--

13) Cosmic Rays - LACOS (2001PASP..113.1420V)

iftrimc = yes
iftrimo = yes
zerocor = no
crays = yes
ifcrays = yes
:go

New file: **CrZTe202109060016.fit**

Some issues with parameters

Best setup?

Different for each target/night/exposure

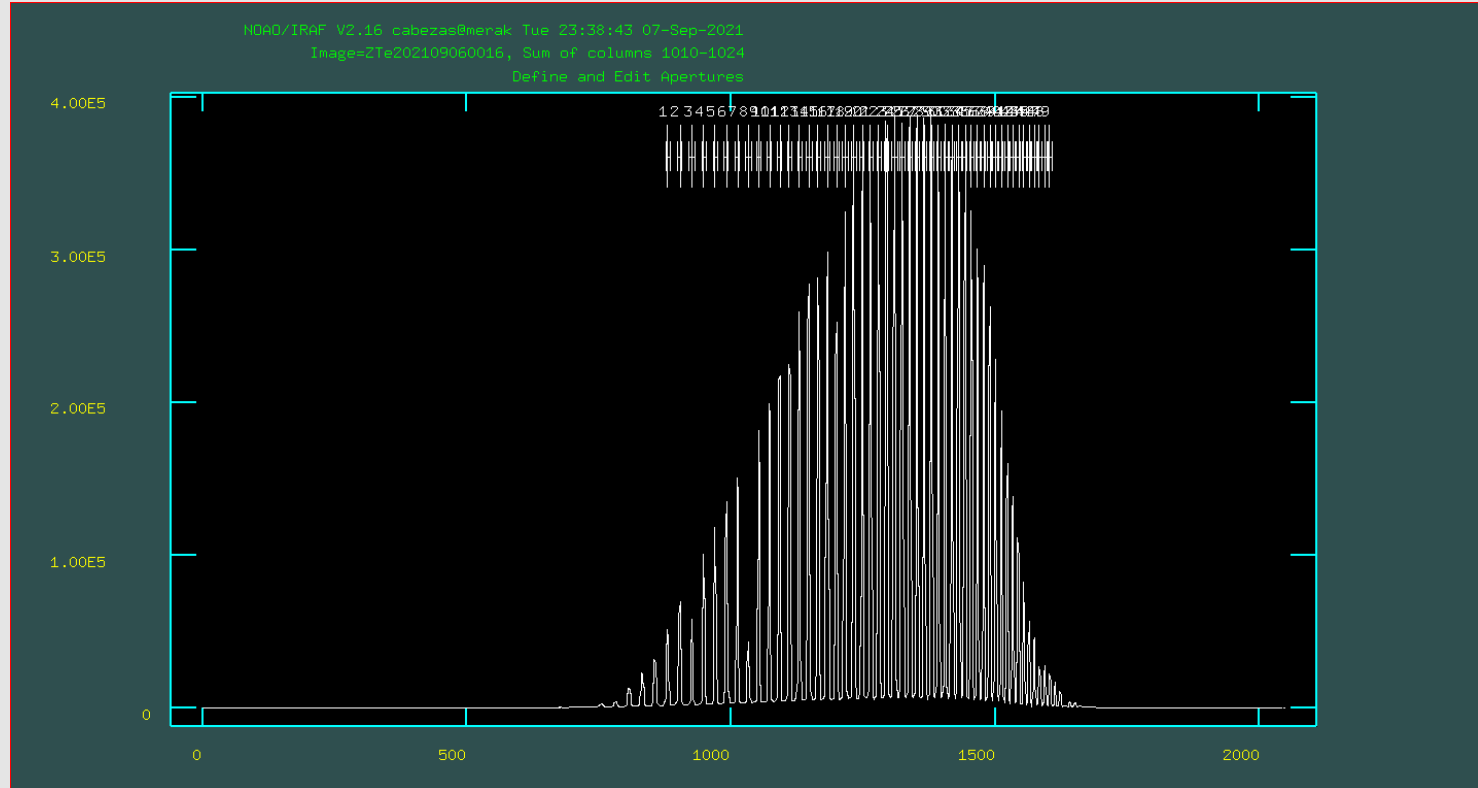
<http://www.astro.yale.edu/dokkum/lacosmic/>

```
400 #####COSMIC RAYS - COMP
401 if (crays==yes){
402     stsdas
403     #####
404     #read gain
405     cd (oname)
406     hselect (images="Z"//inobject,fields="GAIN", exp=yes) | scan (gainh)
407     hselect (images="Z"//inobject,fields="READNOIS", exp=yes) | scan (readnh)
408     #print (gainh)
409     inputCR="Z"//inobject
410     outputCR="CrZ"//inobject
411     outmaskCR="MCrZ"//inobject
412     gainCR = gainh # 2 #3
413     readnCR = readnh #2
414     xorderCR = 3
415     yorderCR = 3
416     sigclipCR = 4.5
417     sigfracCR = 0.3
418     objlimCR = 4
419     niterCR = 5
420     verboseCR = no
421     "#"
```

14) Model apertures - Object

iftrimc = yes
iftrimo = yes
crays = no
ifcrays = no
objecta = yes
:go

- Template: AZTflat.fit



14) Model apertures - Object

Edit apertures for ZTe202109060016? (yes):

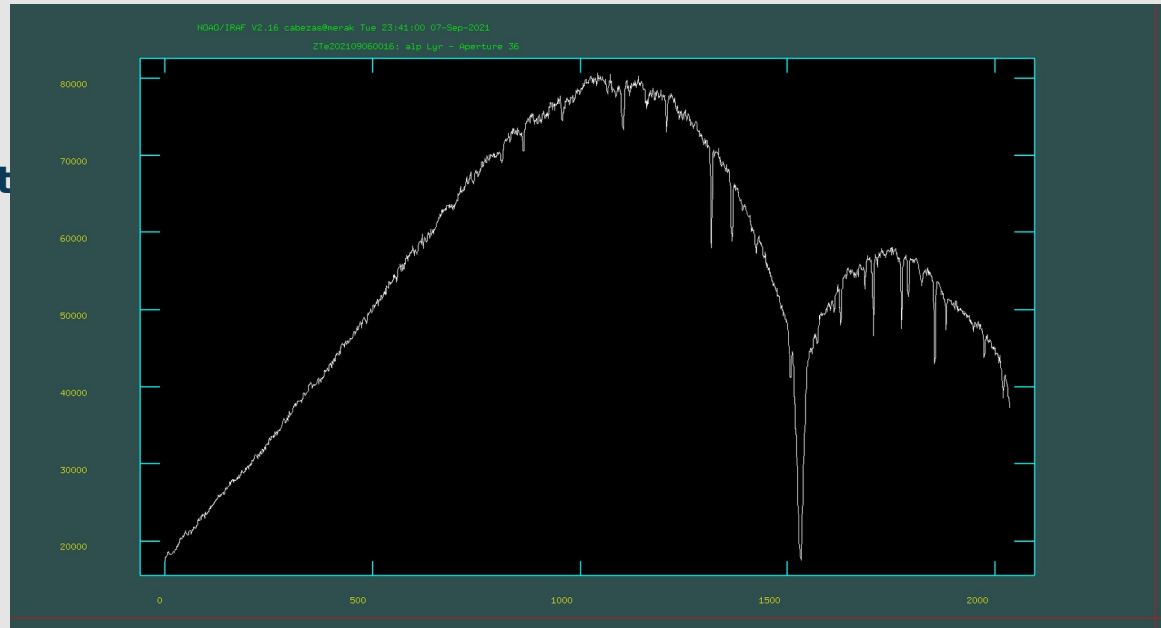
Can be “no” but always is better to check it!

q

***Review extracted spectrum for aperture 1 from
ZTe202109060016? (yes) YES***

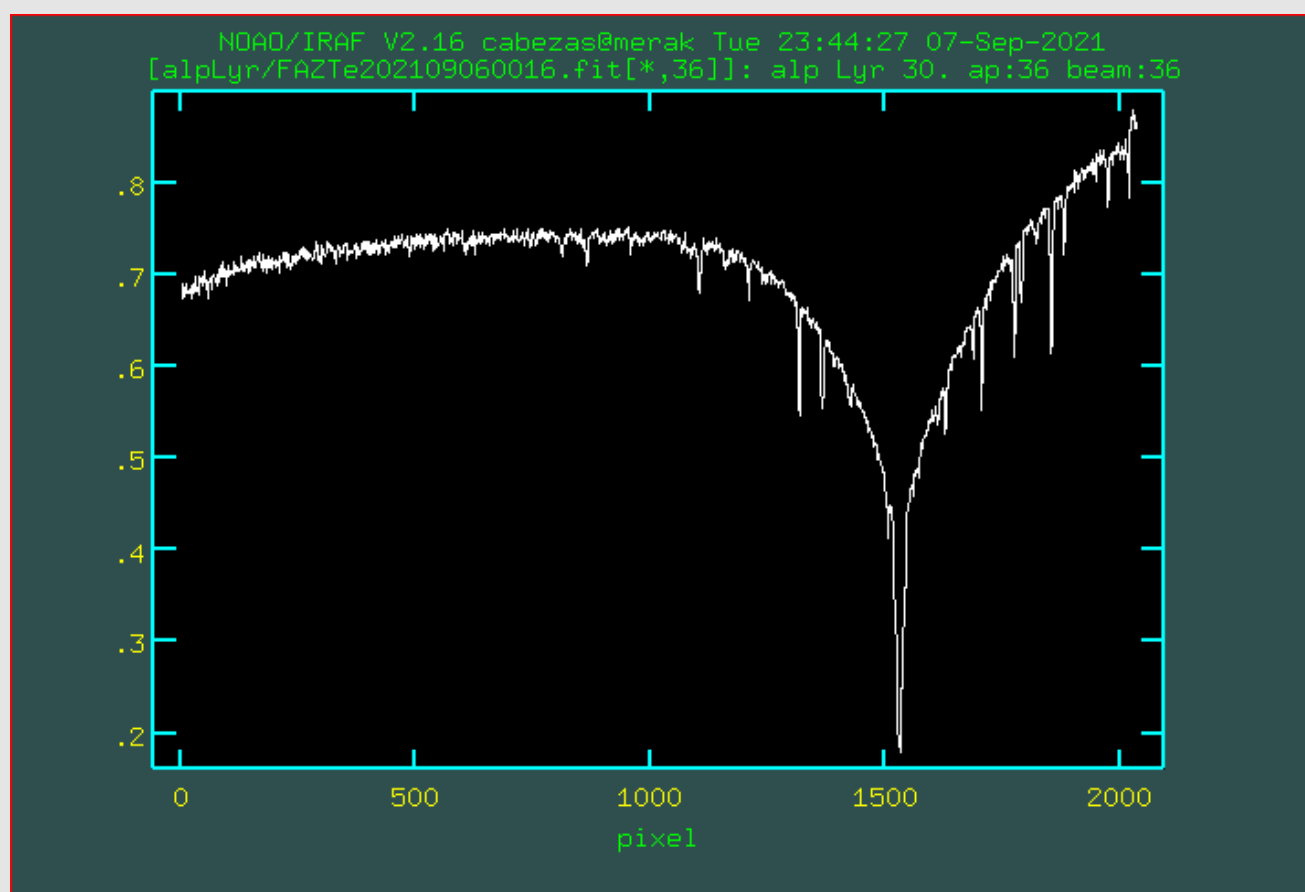
- still each spectrum in pixels

new file: ***AZTe202109060016.fit***



15) Flat correction

```
iftrimc = yes  
iftrimo = yes  
ifcrays = no  
objecta = no  
flatcor = yes  
:go
```



new file: ***FAZTe202109060016.fit***

16) JD + heliocentric correction

```
iftrimc = yes
iftrimo = yes
ifcrays = no
flatcor = no
helioco = yes
:go
```

```
(crays = no) Remove cosmic rays?
(ifcrays= no) Use object with cosmic rays extraction?
(objecta= no) Extract object apertures?
(flatcor= no) Apply flat correction to object?
(helioco= yes) calculate JD + heliocentric correction?
(idref = no) refer database identification to images?
(norm = no) normalize spectra?
(ncombin= no) combine normalized spectra?
```

More

```
18:9:0ZTe202109060016.fit
```

```
#           Image           jd           hjd           ljd
# SETJD: Observatory parameters for Ondrejov observatory
#           timezone = -1
Warning: Image header parameter not found (UTMIDDLE)
# RVCORRECT: Observatory parameters for Ondrejov observatory
#           latitude = 49:54:38
#           longitude = 345:12:59
#           altitude = 528
##YR MO DY   UT           RA           DEC           VOBS
##   HJD           VOBS   VHELIO           VLSR   VDIURNAL   VLUNAR   VANNUAL   VSOLAR
2021  9  6 18:09:00 18:36:56 38:47:01           0.0
2459464.25768 0.00 -12.05 7.57 0.026 -0.005 -12.072 19.625
FAZTe202109060016.fit
```

imhead FAZTe202109060016.fit l+

```
CD2_2 =
HJD = 2459464.25767855
VHELIO = -12.0510150041803
VLSR = 7.57409507948893
VSUN = ' 20. 18. 30. 1900.'
ec1>
```


17) Ref spectrum

iftrimc = yes

iftrimo = yes

ifcrays = no

helioco = no

idref = yes

:go

```
(ncombin=          no) combine normalized spectra?
More
[ap.0001] refspec1='iazcomp.0001'
ap.0001.fit: REFSPEC1 = 'iazcomp.0001 1.'
wap.0001.fit: ap = 1, w1 = 3964.476, w2 = 4030.398, dw = 0.032426, nw = 2034
[ap.0002] refspec1='iazcomp.0002'
ap.0002.fit: REFSPEC1 = 'iazcomp.0002 1.'
wap.0002.fit: ap = 2, w1 = 4009.502, w2 = 4076.196, dw = 0.032806, nw = 2034
[ap.0003] refspec1='iazcomp.0003'
ap.0003.fit: REFSPEC1 = 'iazcomp.0003 1.'
wap.0003.fit: ap = 3, w1 = 4055.563, w2 = 4123.023, dw = 0.033183, nw = 2034
[ap.0004] refspec1='iazcomp.0004'
ap.0004.fit: REFSPEC1 = 'iazcomp.0004 1.'
wap.0004.fit: ap = 4, w1 = 4102.691, w2 = 4170.963, dw = 0.033582, nw = 2034
[ap.0005] refspec1='iazcomp.0005'
ap.0005.fit: REFSPEC1 = 'iazcomp.0005 1.'
wap.0005.fit: ap = 5, w1 = 4150.934, w2 = 4220.016, dw = 0.03398, nw = 2034
[ap.0006] refspec1='iazcomp.0006'
ap.0006.fit: REFSPEC1 = 'iazcomp.0006 1.'
wap.0006.fit: ap = 6, w1 = 4200.32, w2 = 4270.232, dw = 0.034389, nw = 2034
[ap.0007] refspec1='iazcomp.0007'
ap.0007.fit: REFSPEC1 = 'iazcomp.0007 1.'
wap.0007.fit: ap = 7, w1 = 4250.877, w2 = 4321.653, dw = 0.034813, nw = 2034
[ap.0008] refspec1='iazcomp.0008'
```

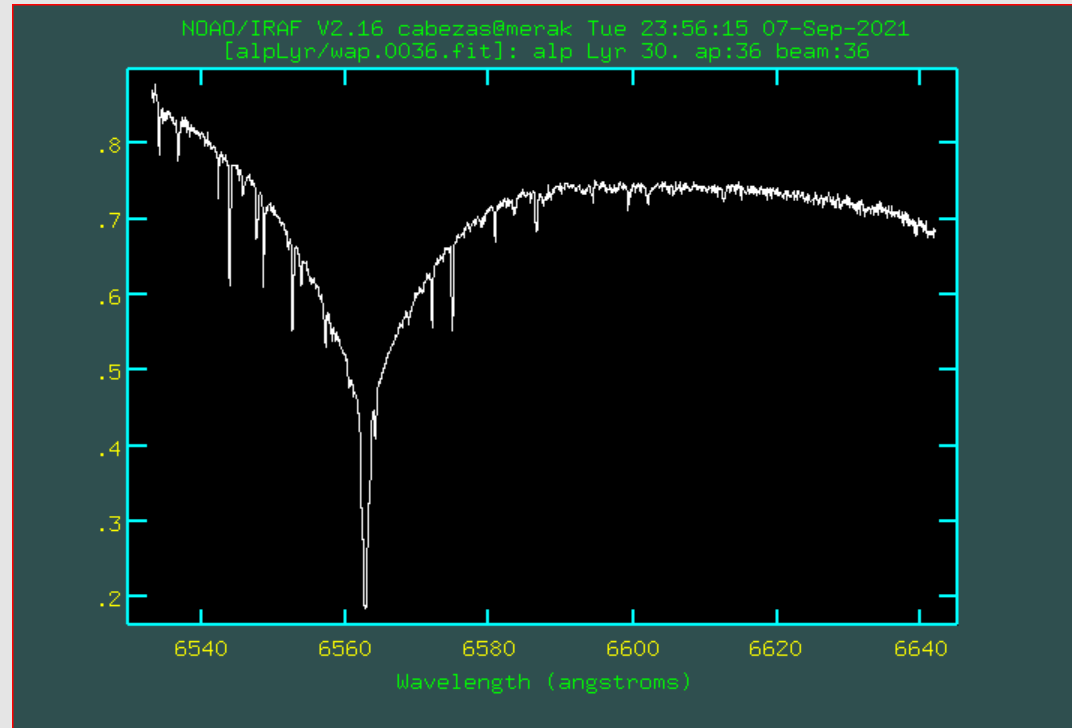
17) Ref spectrum

Read database of wavelength calibration and apply!

New files:

ap.00XX.fit - 1D spectra in pixels

wap.00XX.fit - 1D spectra in Angstrom



18) Normalization

iftrimc = yes

iftrimo = yes

ifcrays = no

idref = no

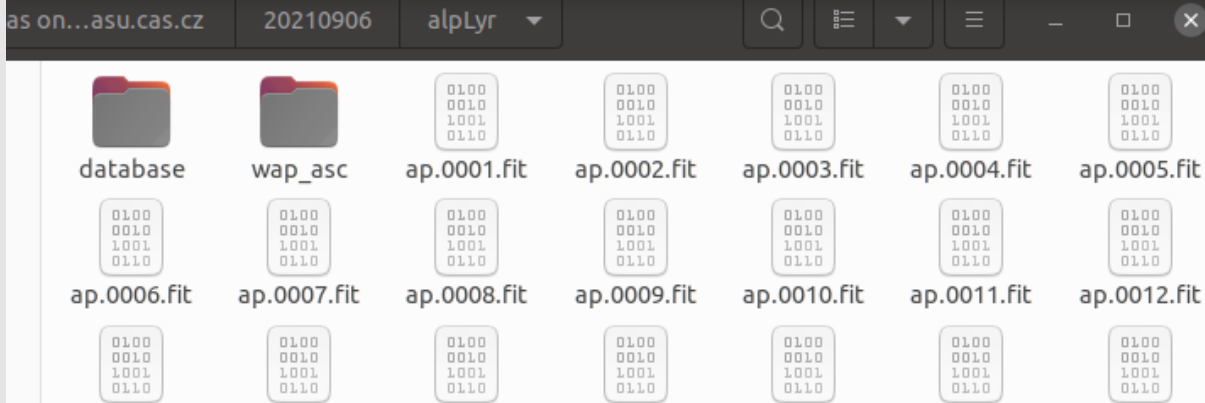
norm = yes

:go

Fit [1,1] of wap.0001.fit w/ graph?

(yes/no/skip/YES/NO/SKIP) (yes):

```
# OBJECT PARAMETERS
(trimob =          no) Trim object?
(iftrimo=         yes) Use trim object?
(zerocor=        no) Apply zero level correction to object?
(crays =         no) Remove cosmic rays?
(ifcrays=        no) Use object with cosmic rays extraction?
(objecta=        no) Extract object apertures?
(flatcor=        no) Apply flat correction to object?
(helioco=        no) calculate JD + heliocentric correction?
(idref =         no) refer database identification to images?
(norm =          yes) normalize spectra?
(ncombin=        no) combine normalized spectra?
More
wap.0001.fit ap.0001.fit nap.0001.fit
Fit [1,1] of wap.0001.fit w/ graph? (yes|no|skip|YES|NO|SKIP) (yes):
```

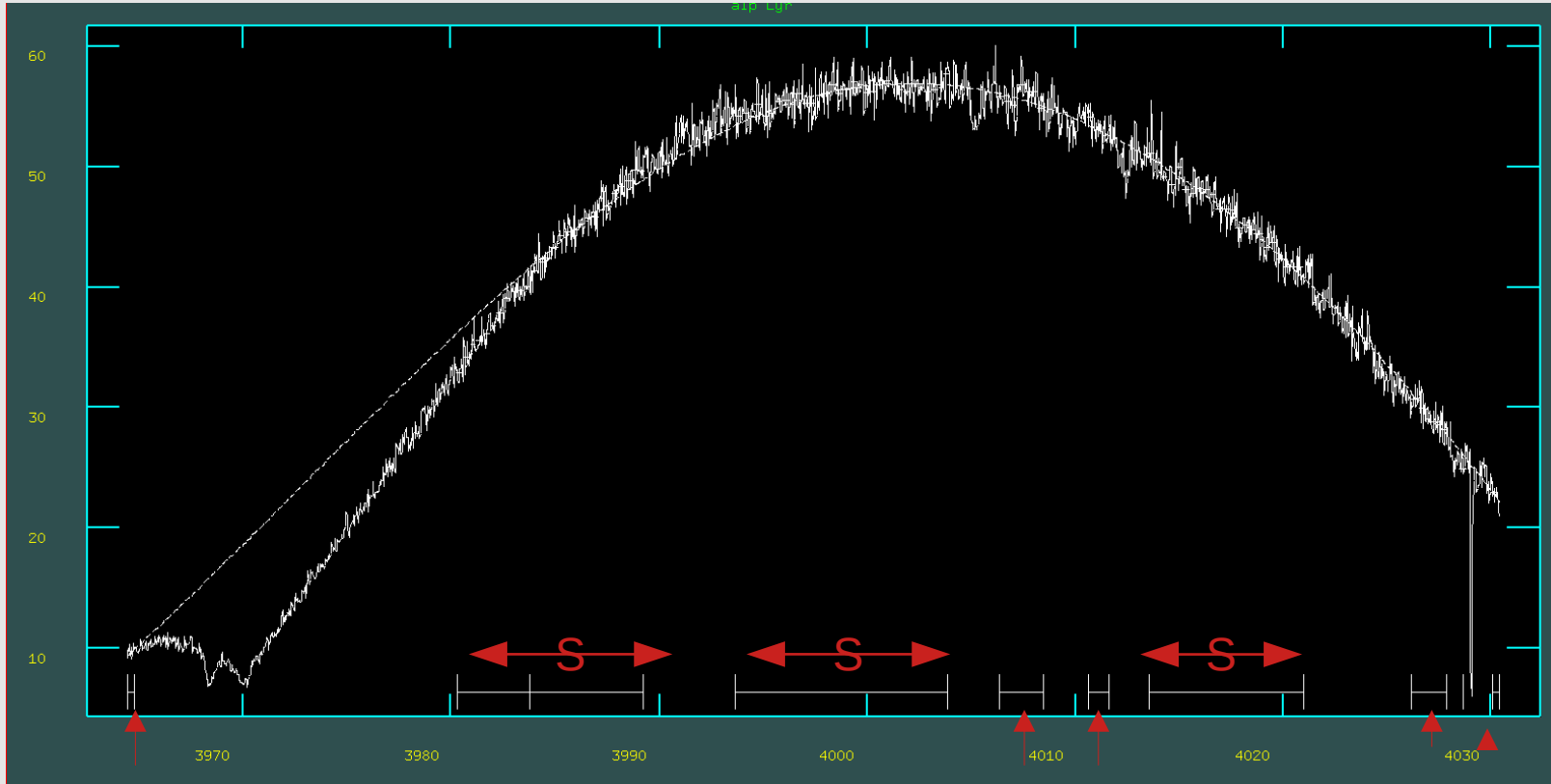


18) Normalization

- change order :o N
- residuals j
- high rejection :hi N

- low rejection :lo N
- function :f legendre/spline3/chebyshev
- select region s..s
- delete region z
- delete all regions t

- zoom/window w, e..e
- resize w,a
- move right w,r
- move left w,l
- move up w,u
- move down w,d



18) Normalization

```
840 #norm=no
841 ##### normalization
842 if (norm==yes){
843     cd (oname)
844     unlearn continuum
845     unlearn scombine
846     continuum.type="fit"
847     continuum.function=cfunction
848     continuum.order=corder
849     continuum.naverage=10
850     continuum.markrej=no
851     continuum.niterat=2000
852     continuum.high_re=2
853     continuum.low_re=1.5
854     continuum.grow=0
855     for (i=1; i <=napp; i+=1) {
856         printf ("wap.00%02d.fit\n",i) | scan(wap)
857         printf ("fap.00%02d.fit\n",i) | scan(fap)
858         printf ("napp.00%02d.fit\n",i) | scan(napp)
859         print (wap, fap, napp)
860     }
861     continuum (input=wap, output=fap)
862     cd "../"
863 }
```

21) merging

iftrimc = yes

iftrimo = yes

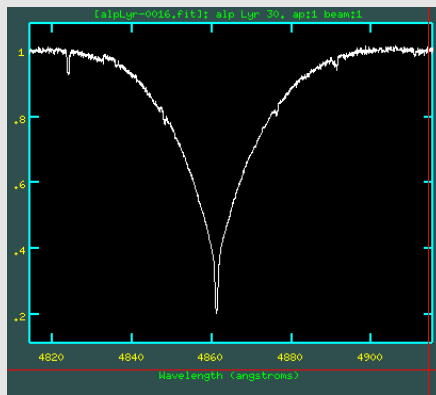
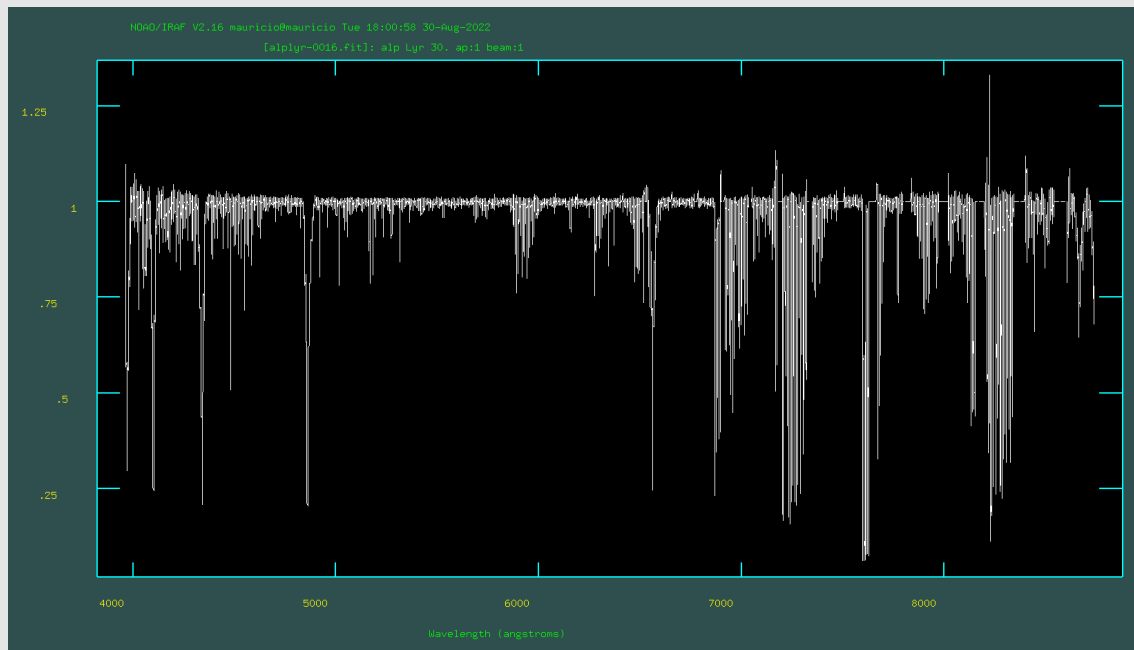
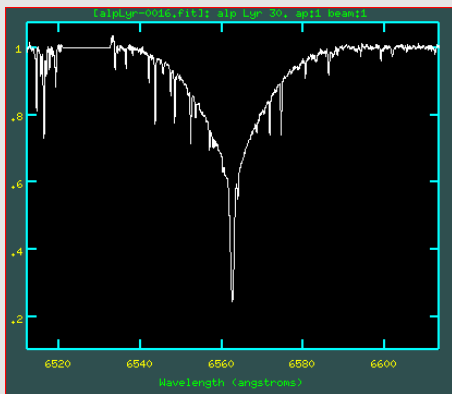
ifcrays = no

norm = no

ncombine = yes

:go

new file: **alpLyr-0016.fit**



SPLIT

split alpLyr-0016.fit

Fit: gaussian: **k..k**(or **g**)

lorentzian: **k..l**

voigt: **k..v**

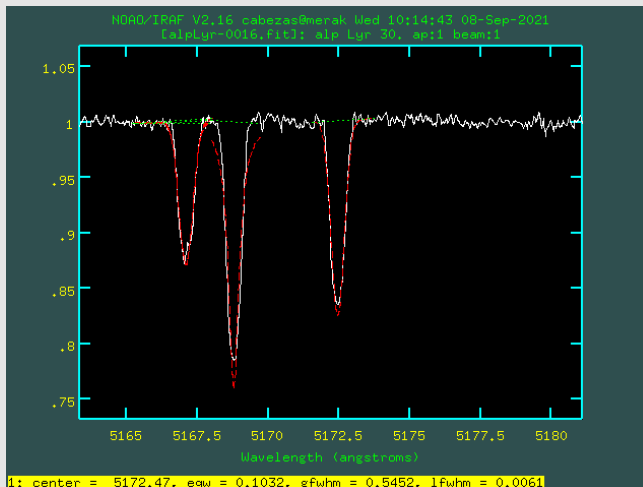
centroid **e..e**

snr: **m..m**

Change unit (angstrom to km/s)

:u km/s 6562.8 an

:u an



SPEC PLOT

specplot spec1.fit,spec2.fits

Change step: **step 1** (or any number)

See wavelength: **u**

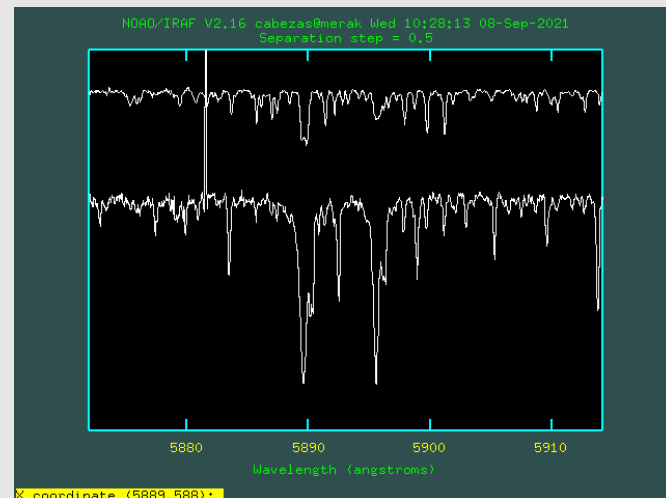
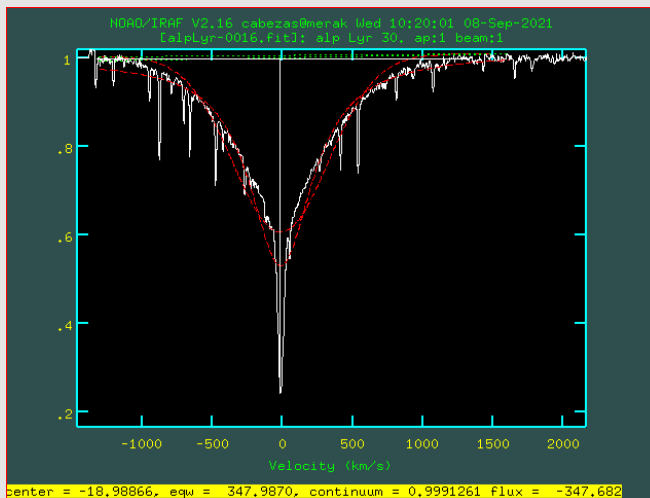
snr: **m..m**

Change unit (angstrom to km/s)

:u km/s 6562.8 an

:u an

Replot: **r**



General Remarks

Thank
you!!

- The optimal reduction process always will be different for each instrument.
- IRAF “sometimes” is a bit tricky, but really useful.
- Quick check/inspection of spectra!!
- Versatil program because many parameters (sometimes too much).
- Pre-defined task.
- “opensource” you can write your own task/package.
- Xgterm – nice interactive tool.
- Slow with computation, python/idl/fortran would be good option.