IRAF 一维光谱处理入门

（内容来自多方，在此不详细注明出处）

IRAF 入门

之一维光谱

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第一章：IRAF 基本操作

1.1 Fits 文件

老版本的 IRAF 需要进行文件格式转换，新版本的 IRAF 可以直接对 fits 或 fit 进行操作，无需转换成 imh 格式。

1.2 批处理

使用 list 进行批处理，可以节省大量时间。

ecl> ls *.fits > l1

将本地所有的 fits 文件名添加到 l1 文件中，对列表进行操作时只需在列表名前增加@符号，如删除 l1 中的文件

ecl> del @l1 ***现在版本的IRAF不再区别imdel和del*

1.3 图像拷贝

使用 imcopy 命令可以方便地进行图像拷贝以及裁剪等操作。

ecl> imcopy raw.fits new.fits ***将raw.fits复制到new.fits*

ecl> imcopy raw.fits[600:1200,700:3600] new2.fits ***将raw.fits x轴（600：1200）y轴（700：3600）区域内的数据复制到new2.fits,对YFOSC长缝光谱而言，这一区域经常被用到*

在处理 YFOSC 数据时，由于 fits 文件有两层，而只有第一层有数据，因此在进行操作时需要指明是对第一层进行。比如显示一幅 YFOSC 数据：

ecl> display YFub090021.fits[1] 1 ***[1]即指明是第一层*

而在一些处理中，IRAF 不能很好的识别[1]符号，因此可以用 imcopy 将原始的具有两层结果的 fits 文件，转话为单层 fits 文件。

ecl> imcopy YFub090021.fits[1]　object.fits

利用批处理，一次转换全部数据

ecl> ls *.fits > l1

在本地建立 l2 文件，将 l1 中的内容拷贝进 l2，利用查找替换，将 l1 中的 fits 替换成 fits[1]. 如果要保留原始数据，用查找替换修改 l2 中的文件名。

ecl> imcopy @l1 @l2

如需进行裁剪，在 l1 中添加裁剪区域即可，fits[1][600：1200，700：3600].

下面也将介绍利用 ccdproc 命令的 trim 进行图像裁剪，本文没有考虑两者的差别。

1.4 程序包

IRAF 中有大量的程序包可供使用，为了使用程序包中的函数，需要先登陆到该程序所在的程序包中，比如要使用 ccdproc 命令，需要知道这个函数属于哪个程序包。

ecl> help ccdproc

出来帮助信息，第一行就给出了该函数所在的程序包。

CCDPROC (Dec93)　　noao.imred.ccdred　　CCDPROC (Dec93)

ecl> noao　　*****输入最上层程序包名—noao，进入后出现一系列第二层程序包***

artdata.　　digiphot.　　nobsolete.　　onedspec.

astcat.　　focas.　　nproto.　　rv.

astrometry.　　imred.　　observatory　　surfphot.

astutil.　　mtlocal.　　obsutil.　　twodspec.

noao> imred　　*****输入第二层程序包名—imred，出现第三层程序包***

argus.　　crutil.　　echelle.　　iids.　　kpnocoude.　　specred.

bias.　　ctioslit.　　generic.　　irred.　　kpnoslit.　　vtel.

ccdred.　　dtoi.　　hydra.　　irs.　　quadred.

im>　　ccdred　　*****进入到imred程序包，　出现下列函数***

badpiximage　　*ccdmask*　　*flatcombine*　　*mkskyflat*

ccdgroups　　*ccdproc*　　*mkfringecor*　　*setinstrument*

ccdhedit　　*ccdtest*　　*mkillumcor*　　*zerocombine*

ccdinstrument　　*combine*　　*mkillumflat*

ccdlist　　*darkcombine*　　*mkskycor*

ccd> ccdproc　　*****现在可以调用ccdproc函数了***

对于一些常用函数、子程序包或者自行编写的脚步，可以通过修改 login.cl 文件，在登陆 IRAF 时即刻加载。详细内容见本系列关于脚本部分的介绍文档，此次不再赘述。

第二章：图像处理

2.1 数据特点

在进行 CCD 光谱图像的预处理时，基本原理与测光内容相同，只是由于光谱观测的曝光时间较长，因此有更多地宇宙线进入 CCD，影响观测。比起测光观测，需要更加细致的剔除宇宙线。另外，光谱观测时经常使用灯光平场，这种平场在色散方向以及空间方向上都存在一定的不均匀性，需要进行归一化。

所谓的一维光谱是针对 Echell 光谱而言，即只有色散方向是一维，而不像 Echell 光谱，多级光谱分布在不同的空间位置上。因此，使用长缝所拍摄的面源光谱，也一并称作一维光谱。

2.2 数据检查

数据检查主要包括两部分内容。

首先是数据的完备性检查。待处理的数据包含有本底、平场、待测目标等几类数据，有些时候还需要标准星的观察数据。对于光谱观测而言，还需要定标灯谱，灯光平场等数据。

其次是数据质量检查。对拍摄的目标用 *display* 依次显示所有获取图像，*(**在脚本部分的介绍中，将提供一个自动显示图像的脚本)*，目视检测图像质量，尤其是辅助图像，如本底、平场等。去掉那些有明显问题的图像，比如平场中有星。接下来，用 imstat 命令统计辅助图像的平均值和标准差。统计范围一般选取图像中心的避开坏列的一块小区域。

例如:

ecl>imstat bias01.fits[600:1200,700:3600] ****统计[600:1200,700:3600]范围内的统计结果***

去掉那些平均值和标准差值差别很大的图像。

2.3 文件改名

在处理数据前，根据文件内容修改文件名是一个比较好的习惯。可以通过 log 文件来进行分类，也可以使用 imhead 命令，来查看文件类型。将文件按照 bias、flat、object、stdstars、lamb 等类型，分别设置新的名字。可以采用批处理的方法，在此不再赘述。

2.4 裁剪图像

有时候，由于光学设计以及 CCD 本身的原因，CCD 的边缘部分不可用。这时候需要对除 bias 以外的数据进行裁剪。裁剪的方法可以参考 1.3，也可以使用 ccdproc 命令。

注意，ccdproc 命令不允许 fits 头文件中有 CCDSEC、DATASEC 两个参数，如果待处理的文件中还有上述参数，需要先用 hedit 命令删除

PACKAGE = imutil

TASK = hedit

images = *.fits images to be edited

fields = CCDSEC DATASEC fields to be edited ***空格号隔开*

value = value expression

(add = no) add rather than edit fields

(addonly= no) add only if field does not exist

(delete = yes) delete rather than edit fields

(verify = no) verify each edit operation

(show = yes) print record of each edit operation

(update = yes) enable updating of the image header

(mode = ql)

:g

登陆到 noao/imred/ccdred 中：

ccd> epa ccdp ***epa 命令是editparameter的缩写，用来编辑命令中的各项参数*

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Image Reduction and Analysis Facility

PACKAGE = ccdred

TASK = ccdproc

images = *imagename* List of CCD images to correct***亦可使用list进行批处理，@l1*

(output =) List of output CCD images***若设置为空，则覆盖原文件*

(ccdtype=) CCD image type to correct

(max_cac= 0) Maximum image caching memory (in Mbytes)

(noproc = no) List processing steps only?

(fixpix = no) Fix bad CCD lines and columns?

(oversca= no) Apply overscan strip correction?

(trim = *yes*) Trim the image?***裁剪图像*

(zerocor= no) Apply zero level correction?

(darkcor= no) Apply dark count correction?

(flatcor= no) Apply flat field correction?

(illumco= no) Apply illumination correction?

(fringec= no) Apply fringe correction?

(readcor= no) Convert zero level image to readout correction?

(scancor= no) Convert flat field image to scan correction?

(readaxi= line) Read out axis (column|line)

(fixfile=) File describing the bad lines and columns

(biassec=) Overscan strip image section

(trimsec= [600:1200,700:3600]) Trim data section***裁剪尺寸*

(zero =) Zero level calibration image

(dark =) Dark count calibration image

(flat =) Flat field images

(illum =) Illumination correction images

(fringe =) Fringe correction images

(minrepl= 1.) Minimum flat field value

(scantyp= shortscan) Scan type (shortscan|longscan)

(nscan = 1) Number of short scan lines

(interac= no) Fit overscan interactively?

(functio= chebyshev) Fitting function

(order = 1) Number of polynomial terms or spline pieces

(sample = *) Sample points to fit

(naverag= 1) Number of sample points to combine

(niterat= 1) Number of rejection iterations

(low_rej= 3.) Low sigma rejection factor

(high_re= 3.) High sigma rejection factor

(grow = 0.) Rejection growing radius

(mode = ql)

:g ***:g运行, :q保存并退出,:e编辑子函数的参数*

2.5 BIAS

2.5.1 合并 BIAS

利用 noao\imred\ccdred 中 *zerocombine*

cc> epa zeroc ***IRAF 中的所有命令均可使用简写，只要该简写在该程序包中以及默认加载的包中是唯一的***

I R A F

Image Reduction and Analysis Facility

PACKAGE = ccdred

TASK = zerocombine

input = bias*.fits List of zero level images to combine **本人习惯将所有bias文件改成biasxx.fits

(output = zero) Output zero level name

(combine= average) Type of combine operation

(reject = minmax) Type of rejection

(ccdtype=) CCD image type to combine

(process= no) Process images before combining?

(delete = no) Delete input images after combining?

(clobber= no) Clobber existing output image?

(scale = none) Image scaling

(statsec=) Image section for computing statistics

(nlow = 0) minmax: Number of low pixels to reject

(nhigh = 1) minmax: Number of high pixels to reject

(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)

(mclip = yes) Use median in sigma clipping algorithms?

(lsigma = 3.) Lower sigma clipping factor

(hsigma = 3.) Upper sigma clipping factor

(rdnoise= ***6.5***) ccdclip: CCD readout noise (electrons) ****YFOSC一号CCD***

(gain = ***0.4***) ccdclip: CCD gain (electrons/DN) ***YFOSC一号CCD***

(snoise = 0.) ccdclip: Sensitivity noise (fraction)

(pclip = -0.5) pclip: Percentile clipping parameter

(blank = 0.) Value if there are no pixels

(mode = ql)

:g

生成文件 zero.fits

2.5.2 减去 bias

利用 ccproc 命令，减去平场、目标等图像中的 bias

cc> epa ccdp

I R A F

Image Reduction and Analysis Facility

PACKAGE = ccdred

TASK = ccdproc

images = imagename List of CCD images to correct

(output =) List of output CCD images

(ccdtype=) CCD image type to correct

(max_cac= 0) Maximum image caching memory (in Mbytes)

(noproc = no) List processing steps only?

(fixpix = no) Fix bad CCD lines and columns?

(oversca= no) Apply overscan strip correction?

(trim = no) Trim the image?

(zerocor= yes) Apply zero level correction?***减本底***

(darkcor= no) Apply dark count correction?

(flatcor= no) Apply flat field correction?

(illumco= no) Apply illumination correction?

(fringec= no) Apply fringe correction?

(readcor= no) Convert zero level image to readout correction?

(scancor= no) Convert flat field image to scan correction?

(readaxi= line) Read out axis (column|line)

(fixfile=) File describing the bad lines and columns

(biassec=) Overscan strip image section

(trimsec=) Trim data section

(zero = ***Zero.fits***) Zero level calibration image

(dark =) Dark count calibration image

(flat =) Flat field images

(illum =) Illumination correction images

(fringe =) Fringe correction images

(minrepl= 1.) Minimum flat field value

(scantyp= shortscan) Scan type (shortscan|longscan)

(nscan = 1) Number of short scan lines

(interac= no) Fit overscan interactively?

(functio= chebyshev) Fitting function

(order = 1) Number of polynomial terms or spline pieces

(sample = *) Sample points to fit

(naverag= 1) Number of sample points to combine

(niterat= 1) Number of rejection iterations

(low_rej= 3.) Low sigma rejection factor

(high_re= 3.) High sigma rejection factor

(grow = 0.) Rejection growing radius

(mode = ql)

:g

2.6 平场

2.6.1 原始平场合并

cc>epa flatcombine

I R A F

Image Reduction and Analysis Facility

PACKAGE = ccdred

TASK = flatcombine

input = flat*.fits List of flat field images to combine

(output = Flat.fits) Output flat field root name

(combine= average) Type of combine operation

(reject = avsigclip) Type of rejection

(ccdtype=) CCD image type to combine

(process= no) Process images before combining?

(subsets= yes) Combine images by subset parameter?

(delete = no) Delete input images after combining?

(clobber= no) Clobber existing output image?

(scale = mode) Image scaling

(statsec=) Image section for computing statistics

(nlow = 1) minmax: Number of low pixels to reject

(nhigh = 1) minmax: Number of high pixels to reject

(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)

(mclip = yes) Use median in sigma clipping algorithms?

(lsigma = 3.) Lower sigma clipping factor

(hsigma = 3.) Upper sigma clipping factor

(rdnoise= 6.5) ccdclip: CCD readout noise (electrons)

(gain = 0.4) ccdclip: CCD gain (electrons/DN)

(snoise = 0.) ccdclip: Sensitivity noise (fraction)

(pclip = -0.5) pclip: Percentile clipping parameter

(blank = 1.) Value if there are no pixels

(mode = ql)

:g

合并后的平场 Flat.fits

2.6.2 色散方向上的平场归一化

注意：由于平场灯是黑体辐射，经过色散系统后在色散方向上能量呈黑体谱分布，用 response 命令是来去除这种照明上的不均匀性。

noao\twodspec\longslit\response

lo> epa response

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = response

calibrat= Flat Longslit calibration images ***上一步合并的平场*

normaliz= Flat Normalization spectrum images

response= reFlat Response function images ***归一化后输出的平场*

(interac= yes) Fit normalization spectrum interactively?

(thresho= INDEF) Response threshold

(sample = *) Sample of points to use in fit

(naverag= 1) Number of points in sample averaging

(functio= spline3) Fitting function ** *有多种拟合函数可供选择：legendre，chebyshev，spline1以及spline3，常用三次样条函数spline3*

(order = 7) Order of fitting function **拟合的阶数，在交互模式下根据拟合情况而定，一般是高阶拟合

(low_rej= 0.) Low rejection in sigma of fit

(high_re= 0.) High rejection in sigma of fit

(niterat= 1) Number of rejection iterations

(grow = 0.) Rejection growing radius

(graphic= stdgraph) Graphics output device

(cursor =) Graphics cursor input

(mode = ql)

:g

在弹出的交互式窗口 irafterm 中，键入:f 可再次选择拟合函数的种类，如

:f spline3

键入:o 可选择拟合阶数，如

:o 10

按 q 退出，此时会发现文件夹中生成了归一化平场 reFlat.fits

2.6.3 空间方向上的平场归一化

由于采用灯光照明时，出射光在空间上具有不均匀性（如 YFOSC 的光纤，其出射光能的分布大致服从高斯分布），为了消除这一影响，需要使用 ***illumination*** 命令。

noao\twodspec\longslit\illumination

TASK = illumination

images = reFlat.fits Longslit calibration images

illumina= *ilFlat.fits* Illumination function images

(interac= yes) Interactive illumination fitting?

(bins =) Dispersion bins

(nbins = 5) Number of dispersion bins when bins = ""

(sample = *) Sample of points to use in fit

(naverag= 1) Number of points in sample averaging

(functio= spline3) Fitting function

(order = 1) Order of fitting function **使用低阶拟合

(low_rej= 0.) Low rejection in sigma of fit

(high_re= 0.) High rejection in sigma of fit
(niterat= 1) Number of rejection iterations
(grow = 0.) Rejection growing radius
(interpo= poly3) Interpolation type
(graphic= stdgraph) Graphics output device
(cursor =) Graphics cursor input
(mode = ql)

2.6.4 两个方向的平场归一化

利用 imarith 命令，用 response 得到的平场除以 illumination 命令得到的平场，生成完美的平场。

ecl> imarith reFlat / ilFalt perFlat ***生成完美的平场perFlat.fits*

2.6.5 对图像除归一化平场

lo> epa ccdp
I R A F
Image Reduction and Analysis Facility
PACKAGE = ccdred
TASK = ccdproc
images = Object*.fits List of CCD images to correct
(output =) List of output CCD images
(ccdtype=) CCD image type to correct
(max_cac= 0) Maximum image caching memory (in Mbytes)
(noproc = no) List processing steps only?
(fixpix = no) Fix bad CCD lines and columns?
(oversca= no) Apply overscan strip correction?
(trim = no) Trim the image?
(zerocor= no) Apply zero level correction?
(darkcor= no) Apply dark count correction?
(flatcor= *yes*) Apply flat field correction?
(illumco= no) Apply illumination correction?
(fringec= no) Apply fringe correction?
(readcor= no) Convert zero level image to readout correction?
(scancor= no) Convert flat field image to scan correction?

(readaxi= line) Read out axis (column|line)

(fixfile=) File describing the bad lines and columns

(biassec=) Overscan strip image section

(trimsec=) Trim data section

(zero = zero) Zero level calibration image

(dark =) Dark count calibration image

(flat = ***perFlat***) Flat field images

(illum =) Illumination correction images

(fringe =) Fringe correction images

(minrepl= 1.) Minimum flat field value

(scantyp= shortscan) Scan type (shortscan|longscan)

(nscan = 1) Number of short scan lines

(interac= no) Fit overscan interactively?

(functio= chebyshev) Fitting function

(order = 1) Number of polynomial terms or spline pieces

(sample = *) Sample points to fit

(naverag= 1) Number of sample points to combine

(niterat= 1) Number of rejection iterations

(low_rej= 3.) Low sigma rejection factor

(high_re= 3.) High sigma rejection factor

(grow = 0.) Rejection growing radius

(mode = ql)

:g

2.7 剔除宇宙线

有多种方法剔除宇宙线，在宇宙线不多的情况下，可以在抽取完光谱之后，利用 splot 命令手动剔除。下面介绍叠加多幅图像剔除宇宙线的办法。

2.7.1 谱对齐

拍摄一个暗弱目标的光谱，往往会曝光较长的时间。在曝光期间，宇宙射线会不可避免的在 CCD 上产生噪声。比方两个小时的曝光时间，如果只拍摄一张两个小时的图像，那么宇宙线在 CCD 上会有两个小时的累加；但如果分别拍摄两张一个小时的照片，由于宇宙线在 CCD 上得分布是随机的，因此通过把两张图像合并就可以去掉大部分的宇宙线。而由于没有比较，一张两小时曝光的照片

则无法通过这种方法去除宇宙线。因此，合并两张图像是必要的。而合并的第一步就是确保两张图像已经严格对齐；

打开两张图像：

lo> displ w0126012.fits 1

lo> displ w0126014.fits 2

在 ds9 中可以通过 Frame 中得 prev 和 next 对比查看两张图像；

lo> imexam

打开两张图像：

ec> displ w0424013.fits 1

ec> displ w0424014.fits 2

在 ds9 中可以通过 Frame 中得 prev 和 next 对比查看两张图像；

ec> imexam

将鼠标分别停在两张图像相同的坐标处，分别按 z，在 xgterm 窗口中比较两张图像上像素点随坐标的变化趋势，如图 15-1；结合对图像的观察，确定图像是否对齐；若没有，需要移动几个像素等；

比较后发现，对这组数据，不需要移动图像；若需要移动，则可使用命令 imshift；

xshift, yshift 分别为移动的大小；

输出 x 坐标＝输入 x 坐标＋xshift

输出 y 坐标＝输入 y 坐标＋yshift

cc>immatch

im> epa imshift

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Image Reduction and Analysis Facility

PACKAGE = immatch

TASK = imshift

input = w0126014.fits Input images to be fit

output = w0126014.fits Output images

xshift = Fractional pixel shift in x

yshift = Fractional pixel shift in y

(shifts_=) Text file containing shifts for each image

(interp_= linear) Interpolant (nearest,linear,poly3,poly5,spline3,sinc,drizzle)

(boundar= nearest) Boundary (constant,nearest,reflect,wrap)

(constan= 0.) Constant for boundary extension

(mode = ql)

:g

2.7.2 图像合并，产生一幅假图像：

im> epa imcombine

I R A F

Image Reduction and Analysis Facility

PACKAGE = immatch

TASK = imcombine

input = w0126012,w0126014 List of images to combine**输入两幅要合并的图像

output = w3com List of output images

(headers=) List of header files (optional)

(bpmasks=) List of bad pixel masks (optional)

(rejmask=) List of rejection masks (optional)

(nrejmas=) List of number rejected masks (optional)

(expmask=) List of exposure masks (optional)

(sigmas =) List of sigma images (optional)

(logfile= STDOUT) Log file

(combine= average) Type of combine operation

(reject = minmax) Type of rejection

(project= no) Project highest dimension of input images?

(outtype= real) Output image pixel datatype

(outlimi= none) Output limits (x1 x2 y1 y2 ...)

(offsets= none) Input image offsets

(masktyp=) Mask type

(maskval= 0.) Mask value

(blank = 0.) Value if there are no pixels

(scale = exposure) Image scaling

(zero = none) Image zero point offset

(weight = none) Image weights

(statsec=) Image section for computing statistics

(expname= exposure) Image header exposure time keyword

(lthresh= INDEF) Lower threshold

(hthresh= INDEF) Upper threshold

(nlow = 0) minmax: Number of low pixels to reject

(nhigh = 1) minmax: Number of high pixels to reject

(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)

(mclip = yes) Use median in sigma clipping algorithms?

(lsigma = 3.) Lower sigma clipping factor

(hsigma = 10.) Upper sigma clipping factor

(rdnoise= 2.64) ccdclip: CCD readout noise (electrons)

(gain = 2.25) ccdclip: CCD gain (electrons/DN)

(snoise = 0.) ccdclip: Sensitivity noise (fraction)

(sigscal= 0.1) Tolerance for sigma clipping scaling corrections

(pclip = -0.5) pclip: Percentile clipping parameter

(grow = 0.) Radius (pixels) for neighbor rejection

(mode = ql)

:g

2.7.3 修改第三幅图像的文件头：

键入：

im> hedit w3com.fits ncombine 0

im> hedit w3com.fits exposure 0

2.7.4 合并三幅图像以去除宇宙线：

im> epa imco

I R A F

Image Reduction and Analysis Facility

PACKAGE = immatch

TASK = imcombine

input = w0126012,w0126014,w3com List of images to combine

output = w3caver List of output images

(headers=) List of header files (optional)

(bpmasks=) List of bad pixel masks (optional)

(rejmask=) List of rejection masks (optional)

(nrejmas=) List of number rejected masks (optional)

(expmask=) List of exposure masks (optional)
(sigmas =) List of sigma images (optional)
(logfile= STDOUT) Log file
(combine= average) Type of combine operation
(reject = avsigclip) Type of rejection
(project= no) Project highest dimension of input images?
(outtype= real) Output image pixel datatype
(outlimi= none) Output limits (x1 x2 y1 y2 ...)
(offsets= none) Input image offsets
(masktyp=) Mask type
(maskval= 0.) Mask value
(blank = 0.) Value if there are no pixels
(scale = exposure) Image scaling
(zero = none) Image zero point offset
(weight = exposure) Image weights
(statsec=) Image section for computing statistics
(expname= exposure) Image header exposure time keyword
(lthresh= INDEF) Lower threshold
(hthresh= INDEF) Upper threshold
(nlow = 0) minmax: Number of low pixels to reject
(nhigh = 1) minmax: Number of high pixels to reject
(nkeep = 1) Minimum to keep (pos) or maximum to reject (neg)
(mclip = yes) Use median in sigma clipping algorithms?
(lsigma = 3.) Lower sigma clipping factor
(hsigma = 10.) Upper sigma clipping factor
(rdnoise= 2.64) ccdclip: CCD readout noise (electrons)
(gain = 2.25) ccdclip: CCD gain (electrons/DN)
(snoise = 0.) ccdclip: Sensitivity noise (fraction)
(sigscal= 0.1) Tolerance for sigma clipping scaling corrections
(pclip = -0.5) pclip: Percentile clipping parameter
(grow = 0.) Radius (pixels) for neighbor rejection
(mode = ql)

:g

2.7.5 对合并的图像手动去除宇宙线：

去除宇宙线是一个反复的过程，可以先粗略的去除，用 ds9 检查结果后再反复去除，以达到最佳效果；

im> crutil

cr> epa cosmicrays

I R A F

Image Reduction and Analysis Facility

PACKAGE = crutil

TASK = cosmicrays

input = w3caver List of images in which to detect cosmic rays

***再次去除时，要将此改为前一次去除后的输出图像，如w3caver.c*

output = w3caver.c List of cosmic ray replaced output images (optional)

(crmasks=) List of bad pixel masks (optional)

(thresho= 25.) Detection threshold above mean

(fluxrat= 2.) Flux ratio threshold (in percent)

***可先设置一个值，剔除一次宇宙线后可以再设置；*

(npasses= 5) Number of detection passes

(window = 5) Size of detection window

(interac= yes) Examine parameters interactively?

(train = no) Use training objects?

(objects=) Cursor list of training objects

(savefil=) File to save train objects

(plotfil=) Plot file

(graphic= stdgraph) Interactive graphics output device

(cursor =) Graphics cursor input

answer = yes Review parameters for a particular image?

(mode = ql)

:g

在交互式窗口中，鼠标放到某个小十字上，按 s 为查看该点的二维强度分布，d 为剔除，典型的宇宙线呈较平坦的面上突出的一个或较少得几个像素，如尖状；大多数情况需要反复剔除。

2.7.6 利用 splot 命令手动剔除宇宙线

在完成上述处理以及谱线抽取后，需要用splot命令显示抽取后的谱线，检查是否有宇宙线打在了目标上，如果有，需要进行手动剔除。

noao/onedspec

one> splot　aobject.fits ***完成光谱抽取后的图像，见第三章*

：hist yes ***直方图显示*

按 j 删除宇宙线（宇宙线在直方图显示时，往往只占1~2像素，突然增强）

按 i 生成新的图像

第三章： 一维光谱处理

3.1 目标的光谱抽取

noao/twodspec/ape/appall

cr> epa apall

I R A F

Image Reduction and Analysis Facility

PACKAGE = apextract

TASK = apall

input = object.fits List of input images ***经过图像处理的目标文件，习惯改成目标名字，方便识别，此处用object代表*

(output = aobject) List of output spectra

(apertur=) Apertures

(format = multispec) Extracted spectra format

(referen=) List of aperture reference images

(profile=) List of aperture profile images

(interac= yes) Run task interactively?

(find = yes) Find apertures?

(recente= yes) Recenter apertures?

(resize = yes) Resize apertures?

(edit = yes) Edit apertures?

(trace = yes) Trace apertures?

(fittrac= yes) Fit the traced points interactively?

(extract= yes) Extract spectra?

(extras = yes) Extract sky, sigma, etc.?

(review = yes) Review extractions?

(line = INDEF) Dispersion line

(nsum = 10) Number of dispersion lines to sum or median

DEFAULT APERTURE PARAMETERS

(lower = -5.) Lower aperture limit relative to center***设置目标孔径，可以在交互模式下更改*

(upper = 5.) Upper aperture limit relative to center

(apidtab=) Aperture ID table (optional)

DEFAULT BACKGROUND PARAMETERS

(b_funct= chebyshev) Background function

(b_order= 1) Background function order

(b_sampl= -10:-6,6:10) Background sample regions**设置背景孔径

(b_naver= -3) Background average or median

(b_niter= 0) Background rejection iterations

(b_low_r= 3.) Background lower rejection sigma

(b_high_= 3.) Background upper rejection sigma

(b_grow = 0.) Background rejection growing radius

APERTURE CENTERING PARAMETERS

(width = 5.) Profile centering width

(radius = 10.) Profile centering radius

(thresho= 0.) Detection threshold for profile centering

AUTOMATIC FINDING AND ORDERING PARAMETERS

nfind = 1 Number of apertures to be found automatically **对一个目标只需要一个孔径

(minsep = 5.) Minimum separation between spectra

(maxsep = 1000.) Maximum separation between spectra

(order = increasing) Order of apertures

RECENTERING PARAMETERS

(aprecen=) Apertures for recentering calculation

(npeaks = INDEF) Select brightest peaks

(shift = yes) Use average shift instead of recentering?

RESIZING PARAMETERS

(llimit = INDEF) Lower aperture limit relative to center

(ulimit = INDEF) Upper aperture limit relative to center

(ylevel = 0.1) Fraction of peak or intensity for automatic width

(peak = yes) Is ylevel a fraction of the peak?

(bkg = yes) Subtract background in automatic width?

(r_grow = 0.) Grow limits by this factor

(avglimi= no) Average limits over all apertures?

TRACING PARAMETERS

(t_nsum = 10) Number of dispersion lines to sum

(t_step = 10) Tracing step

(t_nlost= 3) Number of consecutive times profile is lost before quitting

(t_funct= spline3) Trace fitting function

(t_order= 3) Trace fitting function order

(t_sampl= *) Trace sample regions

(t_naver= 1) Trace average or median

(t_niter= 0) Trace rejection iterations

(t_low_r= 3.) Trace lower rejection sigma

(t_high_= 3.) Trace upper rejection sigma

(t_grow = 0.) Trace rejection growing radius

EXTRACTION PARAMETERS

(backgro= ***fit)*** Background to subtract *****在提取定标灯谱线时，此处为none***

(skybox = 1) Box car smoothing length for sky

(weights= variance) Extraction weights (none|variance)

(pfit = fit2d) Profile fitting type (fit1d|fit2d)

(clean = no) Detect and replace bad pixels?

(saturat= INDEF) Saturation level

(readnoi= 2.64) Read out noise sigma (photons)

(gain = 2.25) Photon gain (photons/data number)

(lsigma = 4.) Lower rejection threshold

(usigma = 4.) Upper rejection threshold

(nsubaps= 1) Number of subapertures per aperture

(mode = ql)

:g

在交互式窗口中的操作如下：

在峰的左侧按 l，右侧按 u，以设置孔径。要使得峰尽量被包括进孔径当中，但尽量不要使背景被划入孔径；见图 3.1.1.

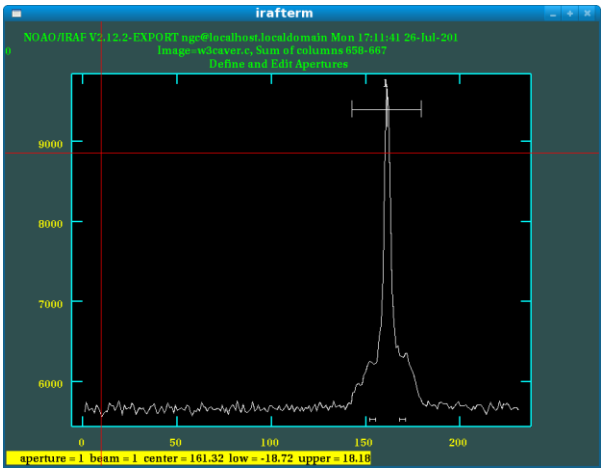

图 3. 1. 1

**：注意观察横坐标，此时横坐标为 y 方向，也就是最大 200 多大小的刻度。由于是一维光谱，所以只应该又一个峰；如果是高色散光谱，那么拍摄的原图有几个水平亮条纹，就对应几个级次，也应该有几个峰，应该选择数量相当的孔径。如果横坐标为 x 方向，说明色散轴的方向不对，需重新设置：

可用命令：

ap> epa apex

I R A F

Image Reduction and Analysis Facility

PACKAGE = twodspec

TASK = apextract

(dispaxi= 1) Dispersion axis (1=along lines, 2=along columns) ***dispaxi改为1*

(databas= database) Database

(verbose= no) Verbose output?

(logfile=) Text log file

(plotfil=) Plot file

(version= APEXTRACT V3.0: August 1990)

(mode = ql)

($nargs = 0)

:g

即可；

设置完 l 和 u 后，有效孔径选取完毕；

之后键入 b，来标定天光孔径，按 t 删除默认的天光孔径；随后我们要手动的在 x 轴方向，对应原图的 y 方向选取背景的亮度；

具体做法是：在峰的左右两侧分别输入两次 s，即鼠标放在峰背景左侧的某处，按 s；

再移动鼠标到峰左侧另一处，再按 s，即圈定了一侧的天光孔径范围；

鼠标移到峰的右侧执行相同的操作，即可选定天光孔径；

需要按的键大致是:b-t-s-s-s-s-f-q。

3)在交互式窗口中，若需要确认，则按回车(yes)；

确认完成后，按 q 退出，查看拟合图；

此处的拟合参数在之前得 apall 当中已经设置过，但为了更好的拟合孔径，需要在交互式窗口中剔除坏点，并重新选择拟合方式和阶数；

具体做法是：在拟合图中，鼠标放到坏点上按 d 剔除，再键入

:f spline3　回车(yes)　***一般采取三次样条函数拟合；*

以及

:o 5　　***5为拟合阶数；*

可以选择别的阶数，但不应过低或过高，阶数过低难真实拟合曲线大致的轮廓；阶数过高则会拟合出一些精细的轮廓，每个点的影响都会加大，测量的结果会失真。

如图 3.1.2

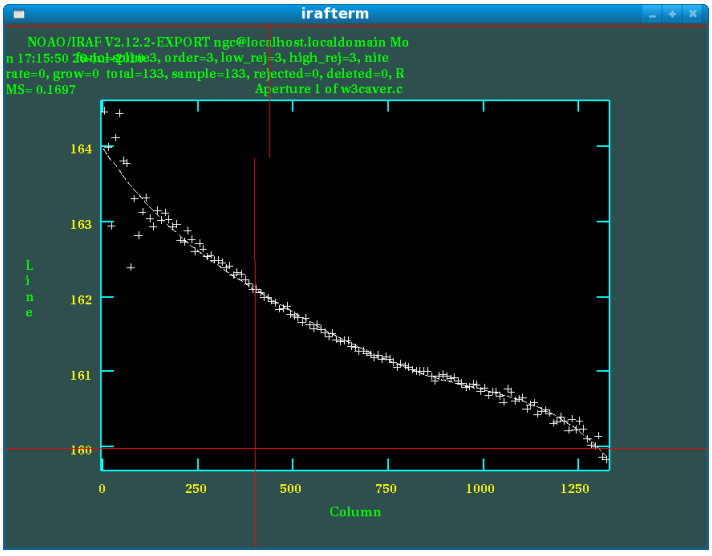

图 3.1.2

4）如果确认孔径选取好了，拟合效果也不错，按 q 退出，对交互式窗口中弹出的问题全部回车(yes)，最后按 q 退出；

可以发现新生成了文件 aobject.fits；这就是抽取得到的目标的光谱，注意观

察横轴和纵轴坐标：此时得到的是未定标的谱。如图 3.1.3,之后要对它进行波长定标和流量定标:

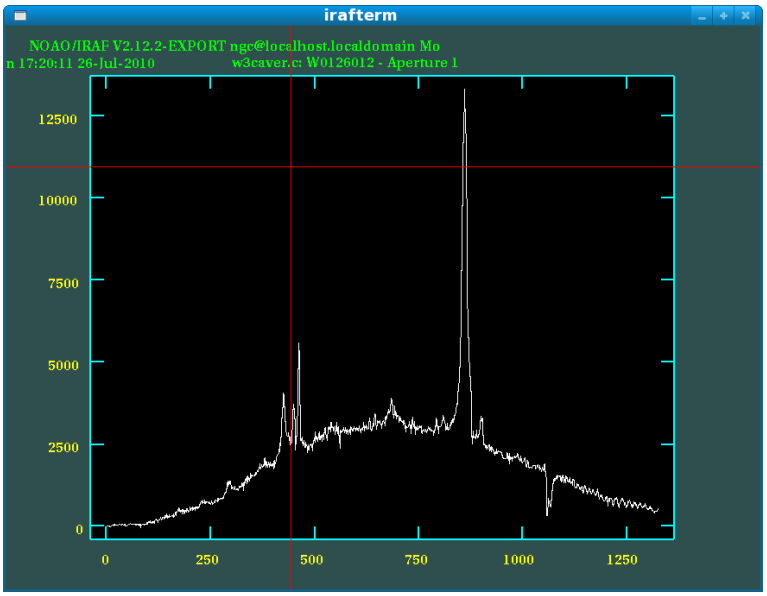

图 3. 1. 3

3.2 定标灯灯谱抽取

ap> epa apall

I R A F

Image Reduction and Analysis Facility

PACKAGE = apextract

TASK = apall

input = Neon.fits List of input images ***经过bias、flat处理后的Neon灯灯谱

(output = aNeon) List of output spectra***根据自身习惯命名，方便以后处理

(apertur=) Apertures

(format = onedspec) Extracted spectra format

(referen= *object.fits*) List of aperture reference images***以前面的目标为参考

(profile=) List of aperture profile images

(interac= no) Run task interactively?

(find = no) Find apertures?

(recente= no) Recenter apertures?

(resize = no) Resize apertures?

(edit = no) Edit apertures?
(trace = no) Trace apertures?
(fittrac= no) Fit the traced points interactively?
(extract= yes) Extract spectra?
(extras = no) Extract sky, sigma, etc.?
(review = yes) Review extractions?
(line = INDEF) Dispersion line
(nsum = 10) Number of dispersion lines to sum or median

DEFAULT APERTURE PARAMETERS

(lower = -5.) Lower aperture limit relative to center
(upper = 5.) Upper aperture limit relative to center
(apidtab=) Aperture ID table (optional)

DEFAULT BACKGROUND PARAMETERS

(b_funct= chebyshev) Background function
(b_order= 1) Background function order
(b_sampl= -10:-6,6:10) Background sample regions
(b_naver= -3) Background average or median
(b_niter= 0) Background rejection iterations
(b_low_r= 3.) Background lower rejection sigma
(b_high_= 3.) Background upper rejection sigma
(b_grow = 0.) Background rejection growing radius

APERTURE CENTERING PARAMETERS

(width = 5.) Profile centering width
(radius = 10.) Profile centering radius
(thresho= 0.) Detection threshold for profile centering

AUTOMATIC FINDING AND ORDERING PARAMETERS

nfind = 1 Number of apertures to be found automatically
(minsep = 5.) Minimum separation between spectra
(maxsep = 1000.) Maximum separation between spectra
(order = increasing) Order of apertures

RECENTERING PARAMETERS

(aprecen=) Apertures for recentering calculation
(npeaks = INDEF) Select brightest peaks
(shift = yes) Use average shift instead of recentering?

RESIZING PARAMETERS

(llimit = INDEF) Lower aperture limit relative to center

(ulimit = INDEF) Upper aperture limit relative to center

(ylevel = 0.1) Fraction of peak or intensity for automatic width

(peak = yes) Is ylevel a fraction of the peak?

(bkg = yes) Subtract background in automatic width?

(r_grow = 0.) Grow limits by this factor

(avglimi= no) Average limits over all apertures?

TRACING PARAMETERS

(t_nsum = 10) Number of dispersion lines to sum

(t_step = 10) Tracing step

(t_nlost= 3) Number of consecutive times profile is lost before quitting

(t_funct= spline3) Trace fitting function

(t_order= 3) Trace fitting function order

(t_sampl= *) Trace sample regions

(t_naver= 1) Trace average or median

(t_niter= 0) Trace rejection iterations

(t_low_r= 3.) Trace lower rejection sigma

(t_high_= 3.) Trace upper rejection sigma

(t_grow = 0.) Trace rejection growing radius

EXTRACTION PARAMETERS

(backgro= none) Background to subtract***此处选择none而不是fit，因此对定标灯谱而言，背景和目标是相同的

(skybox = 1) Box car smoothing length for sky

(weights= none) Extraction weights (none|variance)

(pfit = fit1d) Profile fitting type (fit1d|fit2d)

(clean = no) Detect and replace bad pixels?

(saturat= INDEF) Saturation level

(readnoi= 2.64) Read out noise sigma (photons)

(gain = 2.25) Photon gain (photons/data number)

(lsigma = 4.) Lower rejection threshold

(usigma = 4.) Upper rejection threshold

(nsubaps= 1) Number of subapertures per aperture

(mode = ql)

:g

之后会发现生成了文件 aNeon.fits

可以用 splot 命令查看灯谱，

ap> splot aNeon.fits

如图 3.2.1(YFOSC:Neon+G8+Slit1.2)

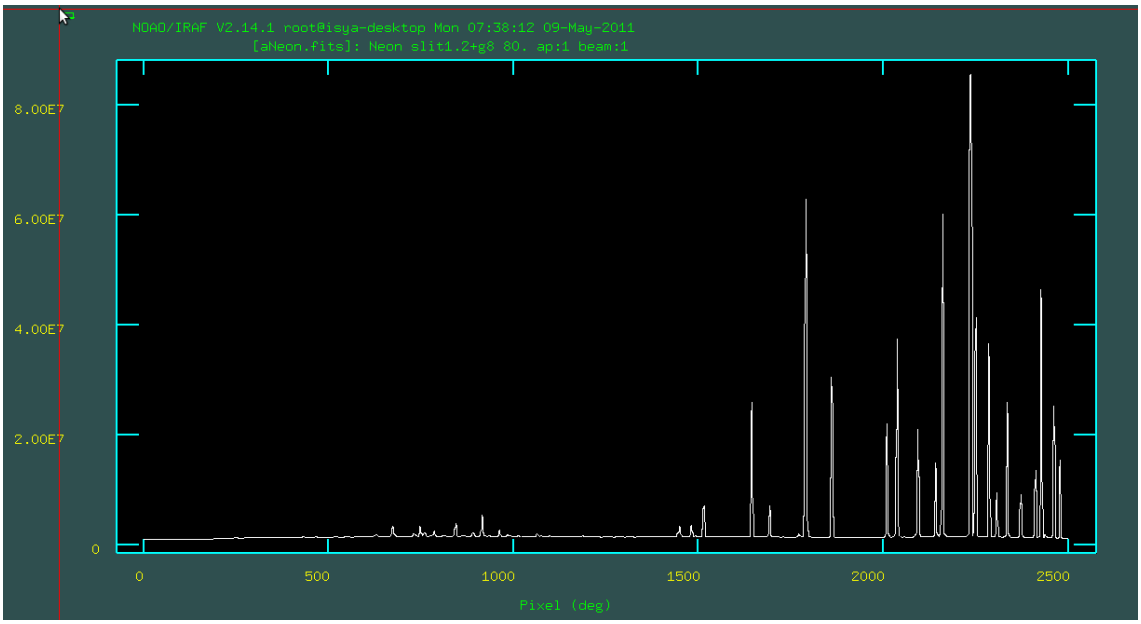

图 3.2.1

3.3 波长定标

3.3.1 波长证认

noao\onedspec\identify

one> epa identify

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = identify

images = aNeon Images containing features to be identified **抽出的灯谱

(section= middle line) Section to apply to two dimensional images

(databas= database) Database in which to record feature data

(coordli= linelists$henear.dat) User coordinate list **选择相对应的波长文件，此

处为氦氖氩灯谱文件

(units =) Coordinate units

(nsum = 10) Number of lines/columns/bands to sum in 2D images

(match = -3.) Coordinate list matching limit

(maxfeat= 50) Maximum number of features for automatic identification

(zwidth = 100.) Zoom graph width in user units

(ftype = emission) Feature type ***有时候会用到吸收线，absorption*

(fwidth = 4.) Feature width in pixels

(cradius= 5.) Centering radius in pixels

(thresho= 0.) Feature threshold for centering

(minsep = 2.) Minimum pixel separation

(functio= spline3) Coordinate function

(order = 1) Order of coordinate function

(sample = *) Coordinate sample regions

(niterat= 0) Rejection iterations

(low_rej= 3.) Lower rejection sigma

(high_re= 3.) Upper rejection sigma

(grow = 0.) Rejection growing radius

(autowri= no) Automatically write to database

(graphic= stdgraph) Graphics output device

(cursor =) Graphics cursor input

crval = Approximate coordinate (at reference pixel)

cdelt = Approximate dispersion

(aidpars=) Automatic identification algorithm parameters

(mode = ql)

:g

在交互窗口按 m，输入已知谱线波长的整数部分再回车，输入几个又把握的值之后，再按 l 标谱，这时所有的谱线上面都会有一个黄色的小竖线，证明这些谱线已经标好，按 f 查看拟合情况。*对于 **Prism**，由于棱角分光时，色散能力随波长而变化，因此，在进行波长标定时，需要在红端、蓝端各选几条线。*也就是说对于非线性的色散，需要在不同区间进行波长定标。

对于方差过大的点，鼠标放在上面按 d 剔除，最终的拟合结果最好要有接近 30 个点，且方差小于 0.5.

3.3.3 对目标源和标准星分别加定标文件头

对目标源：

one> epa refspectra

I R A F

Image Reduction and Analysis Facility

PACKAGE = specred

TASK = refspectra

input = aobject List of input spectra

(referen= aNeon) List of reference spectra

(apertur=) Input aperture selection list

(refaps =) Reference aperture selection list

(ignorea= yes) Ignore input and reference apertures?

(select = interp) Selection method for reference spectra

(sort =) Sort key

(group =) Group key

(time = no) Is sort key a time?

(timewra= 17.) Time wrap point for time sorting

(overrid= no) Override previous assignments?

(confirm= yes) Confirm reference spectrum assignments?

(assign = yes) Assign the reference spectra to the input spectrum?

(logfile= STDOUT,logfile) List of logfiles

(verbose= no) Verbose log output?

answer = yes Accept assignment?

(mode = ql)

:g

也可以使用 hedit 命令添加 DCLOG1 = 'REFSPEC1 = aNeon'

对标准星的操作与目标星完全一样，在此，我们也对定标灯的头文件进行修改，即，用 aNeon 作为 aNeon 的参考。下一步对 aNeon 进行色散轴改正。

3.3.4 对目标源和标准星分别进行色散轴改正

对 aNeon，利用 dispcor 命令

one> epa dispcor

I R A F

Image Reduction and Analysis Facility

PACKAGE = onedspec

TASK = dispcor

input = aNeon List of input spectra

output = wNeon List of output spectra

(lineari= yes) Linearize (interpolate) spectra?

(databas= database) Dispersion solution database

(table =) Wavelength table for apertures

(w1 = INDEF) Starting wavelength

(w2 = INDEF) Ending wavelength

(dw = INDEF) Wavelength interval per pixel

(nw = INDEF) Number of output pixels

(log = no) Logarithmic wavelength scale?

(flux = yes) Conserve flux?

(samedis= no) Same dispersion in all apertures?

(global = no) Apply global defaults?

(ignorea= no) Ignore apertures?

(confirm= no) Confirm dispersion coordinates?

(listonl= no) List the dispersion coordinates only?

(verbose= yes) Print linear dispersion assignments?

(logfile=) Log file

(mode = ql)

:g

得到文件 wNeon；

ecl> splot wNeon ***x轴此时显示的是波长***

如图 3.4.1 所示：

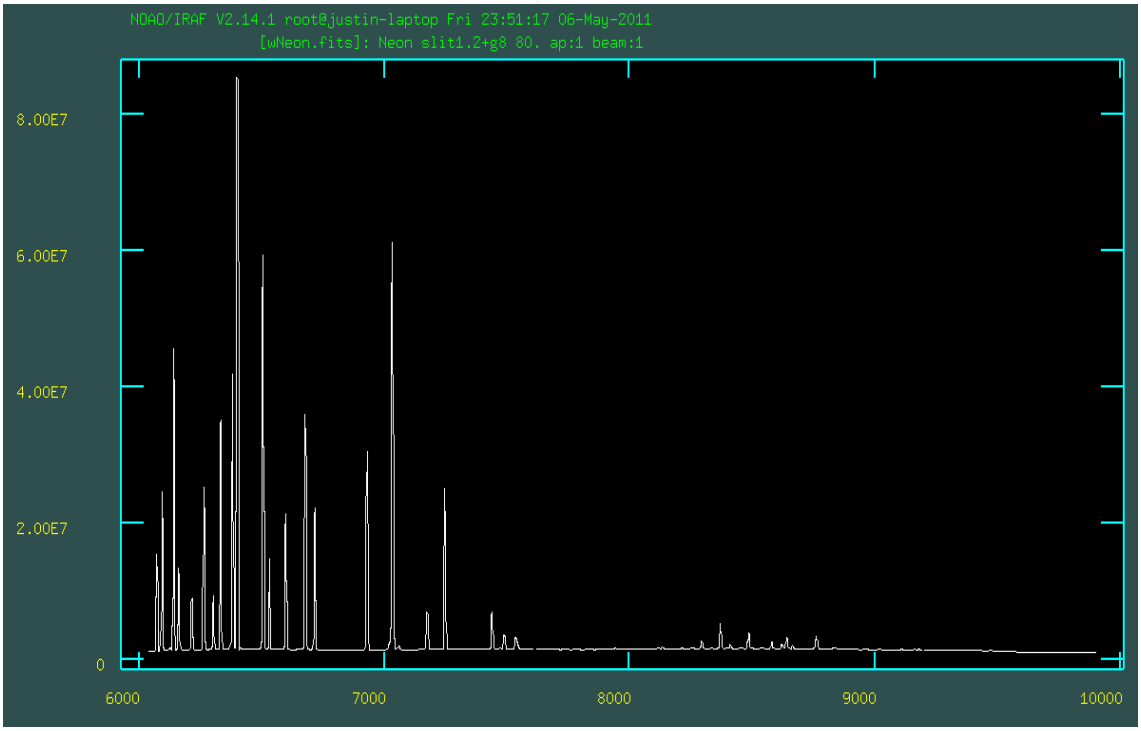

图 3.4.1

3.4 流量定标

3.4.1 对标准星加文件头，生成定标函数

two> longslit

lo> epa standard

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = standard

input = ***dwstandcaver*** Input image file root name *****波长定标后的标准星图像***

output = ***std*** Output flux file (used by SENSFUNC)

(samesta= yes) Same star in all apertures?

(beam_sw= no) Beam switch spectra?

(apertur=) Aperture selection list

(bandwid= 30.) Bandpass widths

(bandsep= 20.) Bandpass separation

(fnuzero= 3.6800000000000E-20) Absolute flux zero point

(extinct= ***workstation/LJextinct.dat***) Extinction file *****丽江观测站的大气消光文件***

LJextinct.dat，地址为该文件所在目录，本人习惯有一个专门的数据处理区

(caldir =)_.caldir) Directory containing calibration data

(observa=)_.observatory) Observatory for data

(interac= yes) Graphic interaction to define new bandpasses

(graphic= stdgraph) Graphics output device

(cursor =) Graphics cursor input

star_nam= *Hiltner600* Star name in calibration list ***标准星的星名*

answer = yes (no|yes|NO|YES|NO!|YES!)

(mode = ql)

:g

如果 fits 头文件中没有 airmass，则会出现如下错误：

dwstandcaver.c.ms: ERROR: parameter `airmass' not found

standard (mode=h)

在另一个关于脚本的文档中，将提到如何大批量为 fits 文件计算并添加 airmass 等信息，此处暂时用手动的方式添加，同时也需要对目标星添加 airmass 信息。

lo> epa hedit

I R A F

Image Reduction and Analysis Facility

PACKAGE = imutil

TASK = hedit

images = dwstandcaver.fits images to be edited

fields = airmass fields to be edited

value = 1.16 value expression

(add = yes) add rather than edit fields

(addonly= yes) add only if field does not exist

(delete = no) delete rather than edit fields

(verify = no) verify each edit operation

(show = yes) print record of each edit operation

(update = yes) enable updating of the image header

(mode = ql)

:g

这样就可以正常运行 standard 了；

新生成文件 std；

3.4.2 生成定标函数：

lo> epa sensfunc

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = sensfunc

standard= std Input standard star data file (from STANDARD)

sensitiv= sens Output root sensitivity function imagename

(apertur=) Aperture selection list

(ignorea= yes) Ignore apertures and make one sensitivity function?

(logfile= logfile) Output log for statistics information

(extinct=)_.extinction) Extinction file

(newexti=***workstation/LJextinct.dat***) Output revised extinction file ***** 依旧为之前的 LJextinct.dat所在目录***

(observa= bao) Observatory of data

(functio= spline3) Fitting function

(order = 6) Order of fit

(interac= yes) Determine sensitivity function interactively?

(graphs = sr) Graphs per frame

(marks = plus cross box) Data mark types (marks deleted added)

(colors = 2 1 3 4) Colors (lines marks deleted added)

(cursor =) Graphics cursor input

(device = stdgraph) Graphics output device

answer = yes (no|yes|NO|YES)

(mode = ql)

:g

在交互界面按回车后，用 d-p 消除坏点，f 为重新拟合。如图 3.4.1；

得到满意的拟合曲线后按 q 退出；产生文件 sens.0001.fits，如图 3.4.2；

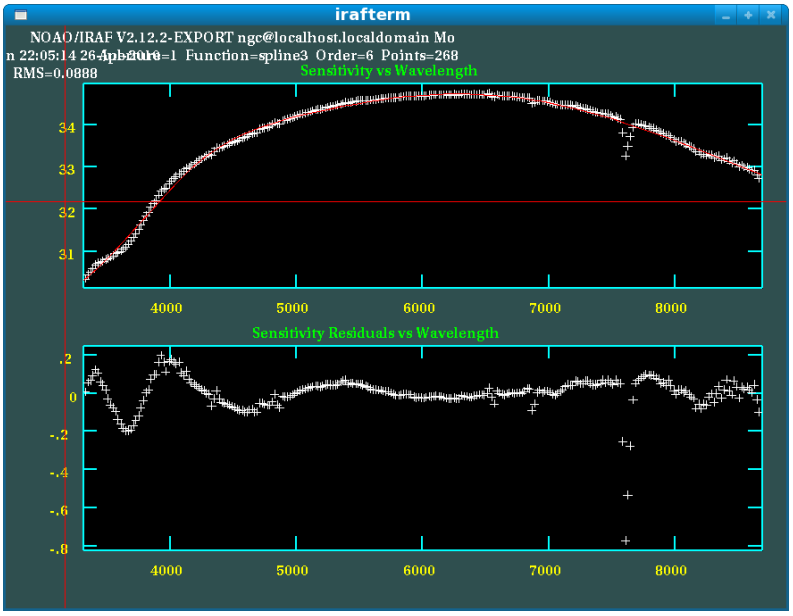

图 3. 4. 2

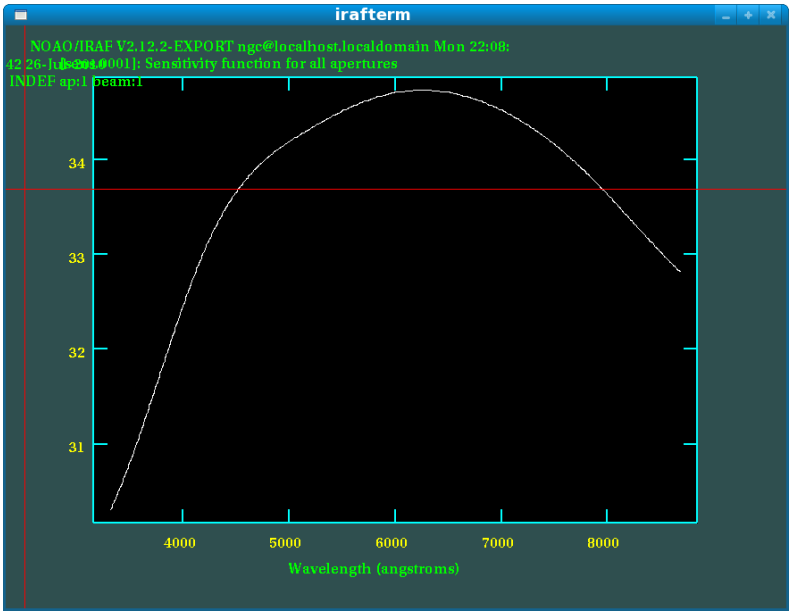

图 3. 4. 3

3.4.3 流量定标：

lo> epa calibrate

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = calibrate

input = wobject Input spectra to calibrate **输入经过波长定标后的目标源

output = cwobject Output calibrated spectra

(extinct= yes) Apply extinction correction?

(flux = yes) Apply flux calibration?

(extinct= workstation/LJoextinct.dat) Extinction file

(observa= bao) Observatory of observation

(ignorea= yes) Ignore aperture numbers in flux calibration?

(sensiti= sens.0001) Image root name for sensitivity spectra ***新生成的sens.0001文件*

(fnu = no) Create spectra having units of FNU?

(mode = ql)

:g

运行后，当xgterm中显示：

cwobject:object

extinction correction applied

flux calibration applied

至此，抽谱以及定标全部完成；

3.4.4 将结果转成一维文件

lo>epa scopy

I R A F

Image Reduction and Analysis Facility

PACKAGE = longslit

TASK = scopy

input = cwobject List of input spectra ***定标全部完成后的输出文件*

output = markobject.fits List of output spectra

(w1 = INDEF) Starting wavelength

(w2 = INDEF) Ending wavelength

(apertur=) List of input apertures or columns/lines

(bands = 1) List of input bands or lines/bands

(beams =) List of beams or echelle orders

(apmodul= 0) Input aperture modulus (0=none)

(format = onedspec) Output spectra format

(renumbe= no) Renumber output apertures?

(offset = 0) Output aperture number offset

(clobber= no) Modify existing output images?

(merge = no) Merge with existing output images?

(rebin = yes) Rebin to exact wavelength region?

(verbose= no) Print operations?

(mode = ql)

:g

生成文件 mark618-1.fits

用 splot 查看：

lo> splot mark618-1.fits.0001.fits

即为最终结果，如图 3.4.3：

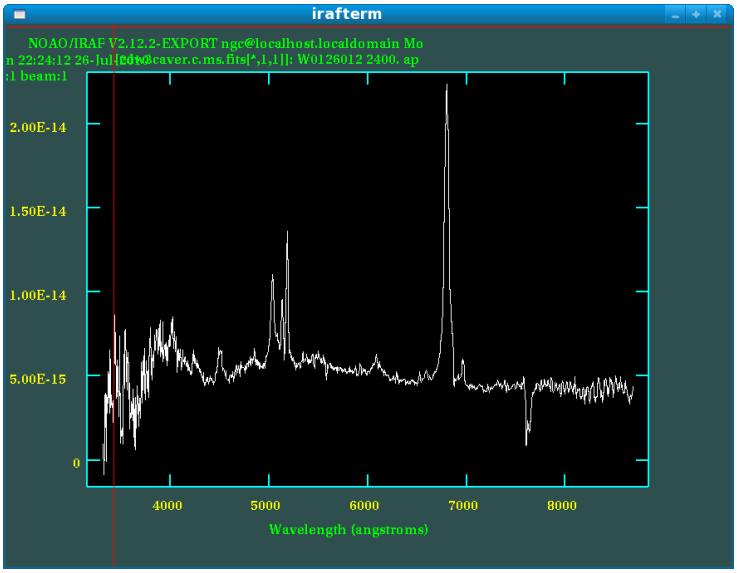

图 3.4.3

3.5 连续谱归一化

这一步并不是必须的，很多时候对光谱分析而言，连续谱的信息很重要，但是对于谱线位置等相对测量而言，去除背景的影响，能更好的标定波长，这时候需要对定标后的图像进行连续谱的归一化，用到 noao\onedspec\continuum 命令。

PACKAGE = onedspec

TASK = continuum

input = wobject Input images

output = conobject Output images

(lines = *) Image lines to be fit

(bands = 1) Image bands to be fit

(type = ***ratio***) Type of output

(replace= no) Replace rejected points by fit?

(wavesca= yes) Scale the X axis with wavelength?

(logscal= no) Take the log (base 10) of both axes?

(overrid= no) Override previously fit lines?

(listonl= no) List fit but don't modify any images?

(logfile= logfile) List of log files

(interac= yes) Set fitting parameters interactively?

(sample = *) Sample points to use in fit

(naverag= 1) Number of points in sample averaging

(functio= spline3) Fitting function

(order = 1) Order of fitting function

(low_rej= 2.) Low rejection in sigma of fit

(high_re= 0.) High rejection in sigma of fit

(niterat= 10) Number of rejection iterations

(grow = 1.) Rejection growing radius in pixels

(markrej= yes) Mark rejected points?

(graphic= stdgraph) Graphics output device

(cursor =) Graphics cursor input

ask = yes

(mode = ql)

生成归一化的 conobject.fits

用 splot 命令显示，以 YFOSC 拍摄的 Hiltner600 为例