IRAF Data Reduction Guide for the ARC Echelle Spectrograph[1]

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The ARC echelle spectrograph (ARCES) is a very high bandwidth, high resolution instrument which is capable of complete wavelength coverage from 3500 Å to 10,200 Å in 130 spectral orders. Due to the exceptional number of recorded orders and the relatively large size of detector pixels, the ARCES poses a data reduction challenge for standard data reduction packages. Aliasing is easily introduced by IRAF routines, which do not perform fractional pixel weighting. Scattered light subtraction and cosmic ray correction under these circumstances is also fraught with difficulty. In most cases, data reduction methods tailored to instruments with broader, more widely separated spectral orders work poorly on ARCES data.

The purpose of this guide is to detail a set of procedures which enable IRAF routines to extract maximum information from ARCES data. Most of the techniques described here will be familiar to experienced IRAF users, the intended readership of this guide. A detailed description of the IRAF 'echelle' package is beyond the scope of this document. Rather, this guide is intended to suggest specific techniques and parameter settings to avoid data degradation from IRAF 'echelle' algorithms that were tuned for use with NOAO spectrographs.

Due to the size of ARCES images, as well as the highly floating-point intensive nature of the calculations to be performed, computing requirements for ARCES data reduction are considerable. Plan to have several gigabytes of fast hard disk space available for images and intermediate data products. Scattered light correction and cosmic-ray correction are also RAM and cpu intensive; minimum requirements are Sun Ultra, Intel Pentium III Xeon, or faster processor configured with at least 128 Mb of RAM on a single-user system and 3 to 4 times as much disk swap space. As a reference, on a Sun Ultra 5/333 MHz system with 384 Mb of RAM and 1.3 Gb swap space, the scattered light correction for a factor-of-four magnified, bias-subtracted ARCES spectrum (67 Mb) takes approximately 5 minutes.

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Generic Echelle Data Reduction Procedures in IRAF
(**not all are recommended for ARCES**)

- Combine quartz flat field exposures using **noao.imred.ccdred.flatcombine**
- (Optional) Remove radiation events from object spectra using **noao.imred.echelle.cosmicrays**
- For each object spectrum and wavelength comparison frame subtract bias voltage, correct for dark current, remove preflash (if any), trim overscan, and apply 2-dimensional flat field correction using **noao.imred.ccdred.ccdproc**.
- (Optional) Subtract scattered light from object spectra using **noao.imred.echelle.apscatter**.
- Define approximate aperture locations and traces for a standard star using **noao.imred.echelle.apall**. Interactive tuning of fitting parameters is required.
- (If S/N allows) Use the aperture reference from the last step to extract spectra from all object spectra. Parameters in **apall** should be adjusted to allow aperture recentering and resizing, but tracing need not be performed again.
- Use object aperture traces and masks defined above as references to extract wavelength comparisons using **apall**. If S/N is too low to define aperture references from the object spectra, then use aperture positions and traces from the standard star.
- Define a dispersion function from an extracted wavelength comparison frame using **noao.imred.echelle.ecidentify**. The resulting calibrated file can then be used as a dispersion reference for all other wavelength comparison frames using **noao.imred.echelle.ecreidentify**.
- Assign wavelength reference images for each extracted object spectrum using **noao.imred.echelle.refspectra**.
- Linearize the dispersion function and convert to a wavelength grid for each object spectrum using **noao.imred.echelle.dispcor.**

IRAF Data Reduction for ARCES (expanded discussion)

- Construct a suitable flat field reference by combining quartz-tungsten-halogen (QTH) lamp exposures using **noao.imred.ccdred.flatcombine**. Due to the low color temperature of the QTH lamp, two sets of QTH exposures should be used: one taken with a blue filter and one taken without a filter. Unfiltered QTH are combined as a group, as are blue-filtered QTH exposures. The two composite images are then scaled by inverse exposure time and coadded using **noao.imred.echelle.imarith** to form a flat field reference.

- Construct a bad pixel mask for ARCES using **cl.proto.text2mask**, which converts a list of columns and lines into a mask for use in **noao.imred.ccdred.ccdproc**. The parameter listing for text2mask below contains a list of bad columns or charge traps in the ARCES 2048x2048 detector.

- For each object spectrum, wavelength comparison frame, and the flat field reference frame, subtract the bias voltage (estimated from overscan), apply a bad pixel mask, and trim the overscan region using **noao.imred.ccdred.ccdproc**. *Although 2-d flat fielding can yield superior results under proper conditions, this technique is not recommended as a matter of course for ARCES.* Neither of the ARCES slits is sufficiently long to ensure that flat field aperture masks will always be substantially wider than object spectra. In addition to making aperture tracing very difficult, 2-d flat fielding under these conditions will lead to amplification of high frequency noise and often worsens any aliasing introduced during aperture tracing. See Figure 1 for an illustration of these points. 1-d flat fielding with the extracted QTH reference frame is described below.

- (Optional) Remove radiation events using **noao.imred.echelle.cosmicrays.** This step can lead to data dropouts---regions in which real continuum data are discarded by the cosmic ray identification algorithm---unless the task parameters are tuned carefully. See the parameter listing below for more details. To avoid dropouts, the value of “fluxratio’—the ratio (in percent) of candidate events fluxes compared to neighboring pixels—must not be set too high. If more aggressive cosmic ray rejection is desired, the candidate cosmic ray events should be flagged manually and **cosmicrays** run interactively. A sample c**osmicrays** candidate identification window is depicted in Figure 2. Regions of high cosmic ray percentage are indicated.

- Use a standard star to define approximate aperture locations and traces, then extract desired orders from the standard star using n**oao.imred.echelle.apall**. Interactive identification of aperture positions and widths plus careful attention to **aptrace** fitting parameters is recommended, but the parameters listed below for **apall** help to automate the tracing process. Spectra extracted in this step will probably exhibit significant aliasing or low frequency undulations due to the narrowness of the apertures in pixels. The effects of aliasing can be seen even more clearly if the parameter ‘format’ in **apall** is set to ‘strip’ rather than ‘echelle’. Then the component rows for each extracted aperture can be inspected individually before the sum is formed. See Figure 3 for an illustration of this effect. Further refinements to the data reduction technique will be needed before the full potential of the recorded ARCES spectra is realized. In the meanwhile, these aperture traces are satisfactory as references for the Th/Ar lamp frames.

- (Optional) Use the aperture reference from the last step to find and extract apertures from all object spectra. Parameters in **apall** should be set to allow aperture recentering and resizing, but tracing need not be performed again.

- Use object aperture traces and masks defined in the previous step as references to extract *Th/Ar apertures only* using **apall**. If the highest precision in the wavelength scale is not needed, aperture traces from the standard star may be used as a reference.

- Define a two-dimensional dispersion function from the extracted Th/Ar exposure using **noao.imred.echelle.ecidentify**. Because ARCES spectra usually include more than 100 overlapping spectral orders, **ecidentify** can be time consuming and difficult to run. The parameter values listed below---particularly for fitting the dispersion solution---are intended as starting values. The most effective technique for using **ecidentify** on ARCES spectra is to look for an order with an easily recognized pattern of Th/Ar emission features, using the NOAO or a similar atlas. The reddest several orders are best skipped, since the atlases often do not cover this wavelength region and there are few suitable Th/Ar lines for use in pattern recognition. The Hα order (6500Å) can be recommended as a good starting position. Note that the orders displayed in **ecidentify** are flipped such that blue is to the right when displayed in pixel space. Use the window environment to flip the x axis for easier recognition of arc line patterns.

  Mark and assign wavelengths to 8 or 10 Th/Ar lines in the first order and then move to the next bluer order. Do the same for at least 5 adjacent orders. Skip several orders and then repeat this process for another 5 orders. When 10 or more non-contiguous apertures have had features marked and labeled, the initial dispersion solution can be calculated. Delete any obvious outliers from the fit, and then return to the identification screen. Save the feature data to disk (use the colon command **:write)** before proceeding with further identifications. Use the same technique as described above to bootstrap the dispersion solution across the spectrum, stopping to save feature data and to refit the dispersion function after every 10-20 orders. From this point forward, **ecidentify** will suggest possible line identifications for each feature that you mark, thus saving a great deal of drudgery if the dispersion fit is relatively good. Once a sufficient number of apertures have been included in this iterative process, the order of the fitting function will need to be increased to improve residuals to the dispersion function fit. Note that the rms fluctuations about a good, final fit should not be more than 0.01 Å for ARCES spectra (using Palmer and Engleman 1983 Los Alamos thorium wavelengths), and they can often be as low 0.003 Å. When the identification procedure is complete, the resulting dispersion solution can be used as a reference to help automate dispersion fitting for all future Th/Ar exposures using **noao.imred.echelle.ecreidentify**.

- Due to the narrowness of aperture masks, measures must be taken to avoid aliasing that is otherwise introduced by **apall** during aperture extraction. The simplest, least model dependent way of doing this in IRAF is to expand the vertical scale (i.e. perpendicular to the dispersion direction) by a factor of 4 or more using a simple linear interpolation and the IRAF task **images.imgeom.magnify**. This step should be performed for all object spectra as well as the reference flat field.

- Define reference aperture positions, widths, and traces for the resampled standard star and the reference flat using **apall**. Note that these positions and traces will not be the same as before, due to the change of image aspect ratio.

- (If S/N allows) Use the aperture reference from the last step to extract spectra from all resampled object spectra. Parameters in.**apall** should be set to allow aperture recentering and resizing, but tracing need not be performed again.

- At this point, we have trimmed, bias-subtracted, and properly extracted object spectra. However, scattered and inter-order light has not yet been removed. To remove this background, IRAF will make use of the aperture positions and widths defined in the previous step to define the inter-order data points. Fit the lower envelope of the inter-order light using **noao.imred.echelle.apscatter** and remove it from the data.

- Extract apertures from the background-subtracted, resampled spectra using.**apall** and the aperture references defined by the same spectra prior to background subtraction. Notice that the output images from **apall** are the same in size as those generated before image resampling. The output from this **apall** session may be compared with the output prior to image resampling to check whether aliasing has been reduced. The amount of noise reduction will depend on the seeing, the length of the exposures, the quality of the tracking, and on whether or not object trailing has been performed. The best results will be realized in cases of excellent seeing, short exposures, and no trailing.

- Assign a wavelength reference image to each extracted object spectrum using **noao.imred.echelle.refspectra**.

- Divide the extracted, background-subtracted object spectra by the extracted reference flat field using **noao.imred.echelle.imarith**.

- Linearize dispersion and attach wavelength scale to the extracted, scattered light corrected, 1-d flat fielded object spectra using **noao.imred.echelle.dispcor**.

- Spectra are now ready for continuum normalization using **noao.imred.echelle.continuum** or some other technique.

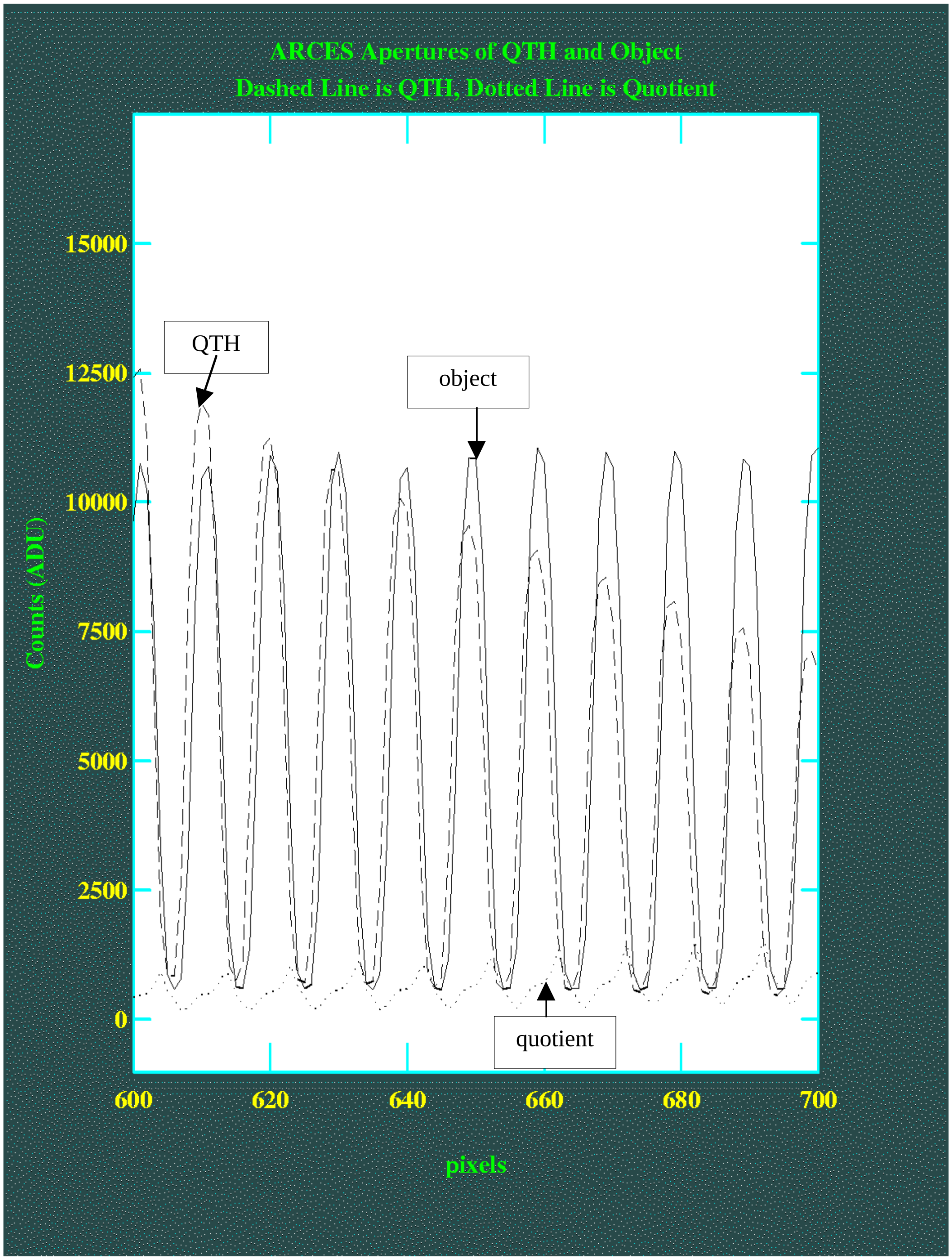

Figure 1: A comparison of QTH and object aperture cross-sections for the ARCES long slit. Note that the aperture masks are nearly identical for both types of data, but the maxima are displaced. Thus, the apparent maxima of the quotient spectrum are displaced relative to where they appear in the raw object spectra and the overall contrast between maximum and minimum flux is greatly reduced. For this reason, apertures extracted from the quotient spectrum will be incorrectly weighted and much noiser than the raw data. For this reason, 2-d flat fielding is not recommended with ARCES.

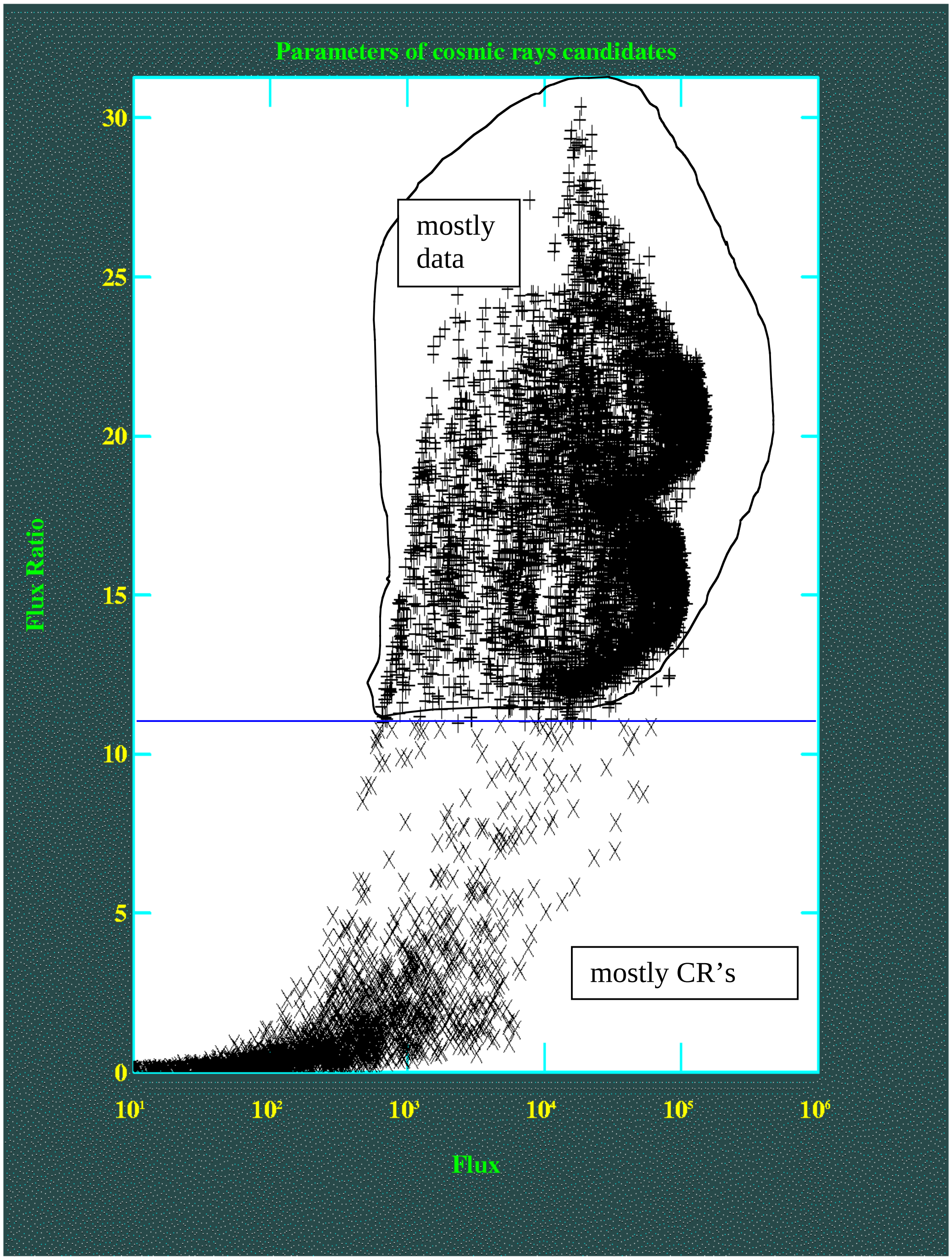

Figure 2: Candidate identification window in **noao.imred.ccdred.cosmicrays**. The 'X' points indicate events flagged as likely cosmic rays, and the '+' points show the events to be treated as data. The **cosmicrays** algorithm compares fluxes of candidate events to those of neighboring pixels ("Flux Ratio") to discriminate between the types of events. Additional candidates may be marked manually after inspection by surface plots. The real data in ARCES object spectra usually exhibit a similar shape in this parameter space.

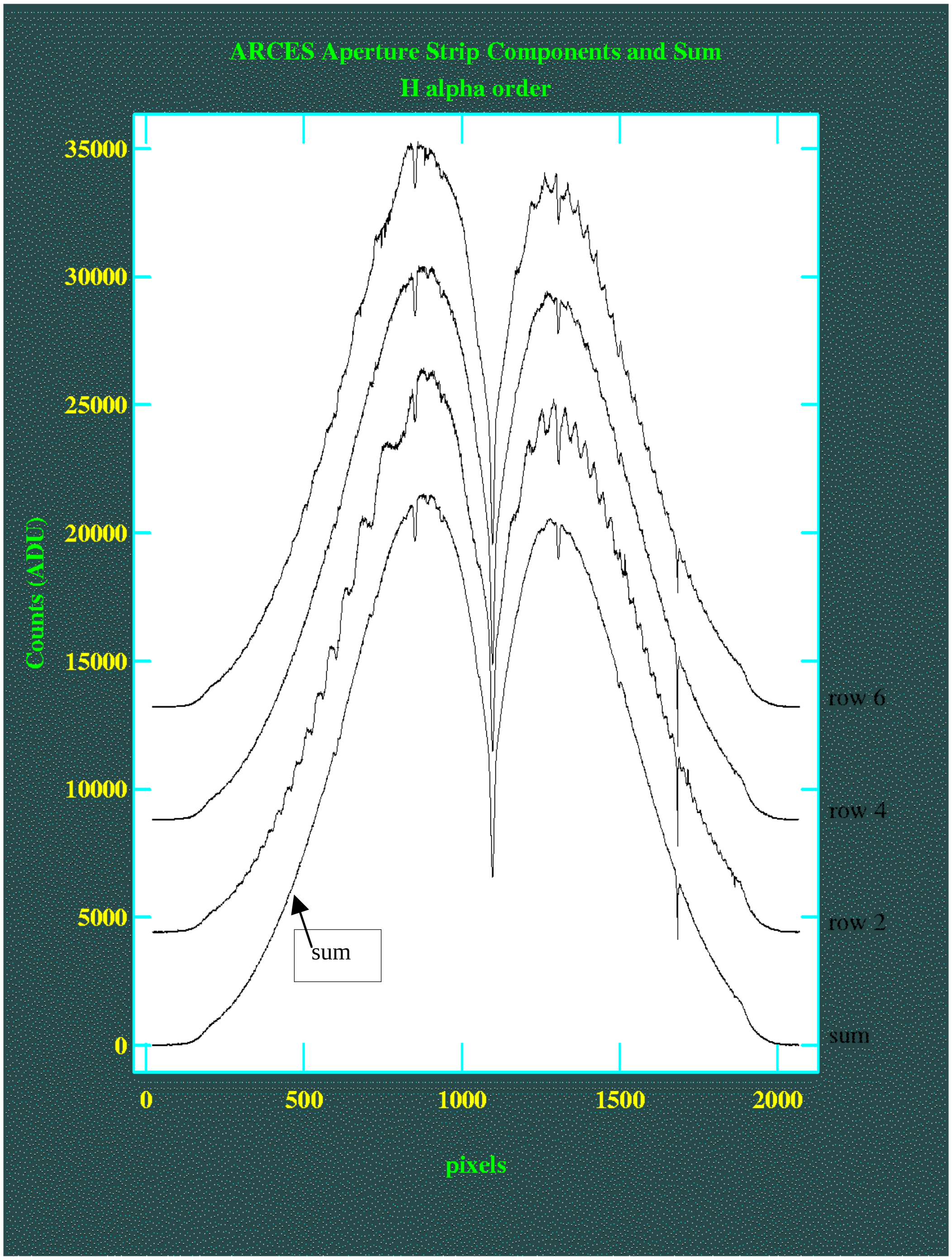

Figure 3: A comparison of an extracted order and the individual rows that constitute parts of the sum. The fringe-like pattern is caused by aliasing from the coarse pixel grid used to sample the data. Although not apparent at this scale, the summed spectrum also shows signs of aliasing. Removal of this digital noise requires both special observational techniques (e.g. trailing of object spectra along the slit) and data resampling to enable fractional pixel weighting in the aperture extraction.

ARCES Parameter Listings for IRAF

APALL:

PARAMETER		STANDARD	OBJECT	WAVE COMP	DEFAULT
input	**=**	**"jan23AlSex"**	**"hd183143noff"**	**"thar183143"**	
nfind	=				
(output	=	" ")	" ")	" ")	"")
(apertures	=	" ")	" ")	" ")	"")
(format	=	"echelle")	"echelle")	"echelle")	"echelle")
(references	**=**	**" ")**	**"jan23AlSex")**	**"hd183143noff")**	**"")**
(profiles	=	" ")	" ")	" ")	"")
(interactive	**=**	**yes)**	**no)**	**no)**	**yes)**
(find	**=**	**no)**	**no)**	**no)**	**yes)**
(recenter	**=**	**yes)**	**yes)**	**no)**	**yes)**
(resize	**=**	**yes)**	**yes)**	**no)**	**yes)**
(edit	**=**	**yes)**	**no)**	**no)**	**yes)**
(trace	**=**	**yes)**	**no)**	**no)**	**yes)**
(fittrace	**=**	**yes)**	**no)**	**no)**	**yes)**
(extract	=	yes)	yes)	yes)	yes)
(extras	**=**	**no)**	**no)**	**no)**	**yes)**
(review	=	yes)	yes)	yes)	yes)
(line	=	INDEF)	INDEF)	INDEF)	INDEF)
(nsum	=	10)	10)	10)	10)
(lower	=	-2.)	-2.)	-2.)	-5.)
(upper	=	2.)	2.)	2.)	5.)
(apidtable	=	"")	"")	"")	"")
(b_function	=	"chebyshev")	"chebyshev")	"chebyshev")	"chebyshev")
(b_order	=	1)	1)	1)	1)
(b_sample	=	"-6:-3,3:6")	"-6:-3,3:6")	"-6:-3,3:6")	"-10:-6,6:10")
(b_naverage	=	1)	1)	1)	-3)
(b_niterate	=	0)	0)	0)	0)
(b_low_reject	=	3.)	3.)	3.)	3.)
(b_high_rejec	=	3.)	3.)	3.)	3.)
(b_grow	=	0.)	0.)	0.)	0.)
(width	=	12.)	12.)	12.)	5.)
(radius	=	16.)	16.)	16.)	10.)
(threshold	=	0.)	0.)	0.)	0.)
(minsep	=	5.)	5.)	5.)	5.)
(maxsep	=	100.)	100.)	100.)	1000.)
(order	=	"increasing")	"increasing")	"increasing")	"increasing")
(aprecenter	=	"")	"")	"")	"")
(npeaks	=	INDEF)	INDEF)	INDEF)	INDEF)
(shift	=	no)	no)	no)	yes)
(llimit	=	INDEF)	INDEF)	INDEF)	INDEF)
(ulimit	=	INDEF)	INDEF)	INDEF)	INDEF)
(ylevel	=	0.05)	0.05)	0.05)	0.1)
(peak	=	yes)	yes)	yes)	yes)

(bkg	=	yes)	yes)	yes)	yes)
(r_grow	=	0.)	0.)	0.)	0.)
(avglimits	=	no)	no)	no)	no)
(t_nsum	=	3)	3)	3)	10)
(t_step	=	2)	2)	2)	10)
(t_nlost	=	3)	3)	3)	3)
(t_function	=	"legendre")	"legendre")	"legendre")	"legendre")
(t_order	=	5)	5)	5)	2)
(t_sample	=	"200:1850,*")	"200:1850,*")	"200:1850,*")	"*")
(t_naverage	=	3)	3)	3)	1)
(t_niterate	=	3)	3)	3)	0)
(t_low_reject	=	3.)	3.)	3.)	3.)
(t_high_rejec	=	3.)	3.)	3.)	3.)
(t_grow	=	0.)	0.)	0.)	0.)
(background	=	"none")	"none")	"none")	"none")
(skybox	=	1)	1)	1)	1)
(weights	=	"none")	"none")	"none")	"none")
(pfit	=	"fit1d")	"fit1d")	"fit1d")	"fit1d")
(clean	=	no)	no)	no)	no)
(saturation	=	INDEF)	INDEF)	INDEF)	INDEF)
(readnoise	=	"0")	"0")	"0")	"0.")
(gain	=	"1")	"1")	"1")	"1.")
(lsigma	=	4.)	4.)	4.)	4.)
(usigma	=	4.)	4.)	4.)	4.)
(nsubaps	=	1)	1)	1)	1)
(mode	=	"ql")	"ql")	"ql")	"ql")

APSCATTER and associated APSCAT1 and APSCAT2:

PARAMETER		ARCES	DEFAULT
input	=	"jan23AlSexrs"	
output	=	"jan23AlSexrs_scat"	
(apertures	=	"")	"")
(scatter	=	"	"")
(references	=	"	"")
(interactive	=	yes)	yes)
(find	=	no)	yes)
(recenter	=	no)	yes)
(resize	=	no)	yes)
(edit	=	no)	yes)
(trace	=	no)	yes)
(fittrace	=	no)	yes)
(subtract	=	yes)	yes)
(smooth	=	yes)	yes)
(fitscatter	=	yes)	yes)
(fitsmooth	=	yes)	yes)
(line	=	INDEF)	INDEF)
(nsum	=	-10)	10)
(buffer	=	0.40000000596046)	1.)
(apscat1	=	"")	"")
(apscat2	=	"")	"")
(mode	=	"ql")	"ql")

PARAMETER		ARCES	DEFAULT
(function	=	"spline3")	"spline3")
(order	=	25)	1)
(sample	=	"*")	"*")
(naverage	=	1)	1)
(low_reject	=	6.)	5.)
(high_reject	=	1.5)	2.)
(niterate	=	5)	5)
(grow	=	1.)	0.)
(mode	=	"ql")	"ql")

PARAMETER		ARCES	DEFAULT
(function	=	"spline3")	"spline3")
(order	=	5)	1)
(sample	=	"*")	"*")
(naverage	=	1)	1)
(low_reject	=	3.)	3.)
(high_reject	=	3.)	3.)
(niterate	=	2)	0)
(grow	=	0.)	0.)
(mode	=	"ql")	"ql")

CCDPROC:

PARAMETER		ARCES	DEFAULT
images	=	hd183143	""
(output	=	"")	"")
(ccdtype	=	"")	"object")
(max_cache	=	0)	0)
(noproc	=	no)	no)
(fixpix	=	yes)	yes)
(overscan	=	yes)	yes)
(trim	=	yes)	yes)
(zerocor	=	no)	yes)
(darkcor	=	no)	yes)
(flatcor	=	no)	yes)
(illumcor	=	no)	no)
(fringecor	=	no)	no)
(readcor	=	no)	no)
(scancor	=	no)	no)
(readaxis	=	"line")	"line")
(fixfile	=	"echmask.pl")	"")
(biassec	=	"[2100:2128,2:2027]")	"")
(trimsec	=	"[21:2068,1:2048]")	"")
(zero	=	"")	"")
(dark	=	"")	"")
(flat	=	"")	"")
(illum	=	"")	"")
(fringe	=	"")	"")
(minreplace	=	1.)	1.)
(scantype	=	"shortscan")	"shortscan")
(nscan	=	1)	1)
(interactive	=	no)	no)
(function	=	"legendre")	"legendre")
(order	=	3)	1)
(sample	=	"*")	"*")
(naverage	=	1)	1)
(niterate	=	3)	1)
(low_reject	=	3.)	3.)
(high_reject	=	3.)	3.)
(grow	=	0.)	0.)
(mode	=	"ql")	"ql")

COSMICRAYS:

PARAMETER		ARCES	DEFAULT
input	**=**	**"hd183143"**	
output	**=**	**"hd183143cr"**	
answer	**=**	**"yes"**	
(badpix	=	"")	"")
(ccdtype	=	"")	"")
(threshold	=	50.)	25.)
(fluxratio	=	10.95)	2.)
(npasses	=	20)	5)
(window	=	"5")	"5")
(interactive	=	yes)	yes)
(train	=	no)	no)
(objects	=	"")	"")
(savefile	=	"")	"")
(mode	=	"ql")	"ql")

DISPCOR:

PARAMETER		ARCES	DEFAULT
input	**=**	**"hd183143rs_scatff.ec"**	
output	**=**	**"hd183143rs_scatffdc.ec"**	
(linearize	=	yes)	yes)
(database	=	"database")	"database")
(table	=	"")	"")
(w1	=	INDEF)	INDEF)
(w2	=	INDEF)	INDEF)
(dw	=	INDEF)	INDEF)
(nw	=	INDEF)	INDEF)
(log	=	no)	no)
(flux	=	yes)	yes)
(samedisp	=	no)	no)
(global	=	no)	no)
(ignoreaps	=	no)	no)
(confirm	=	no)	no)
(listonly	=	no)	no)
(verbose	=	yes)	yes)
(logfile	=	"")	"")
(mode	=	"ql")	"ql")

ECIDENTIFY:

PARAMETERS		ARCES	DEFAULT
images	=	"refthar.ec"	""
(database	=	"database")	"database")
(coordlist	=	"linelists$thar.dat")	"linelists$thar.dat")
(units	=	"")	"")
(match	=	1.)	1.)
(maxfeatures	=	1500)	100)
(zwidth	=	10.)	10.)
(ftype	=	"emission")	"emission")
(fwidth	=	3.)	4.)
(cradius	=	5.)	5.)
(threshold	=	100.)	10.)
(minsep	=	2.)	2.)
(function	=	"chebyshev")	"chebyshev")
(xorder	=	3)	2)
(yorder	=	2)	2)
(niterate	=	0)	0)
(lowreject	=	3.)	3.)
(highreject	=	3.)	3.)
(autowrite	=	no)	no)
(graphics	=	"stdgraph")	"stdgraph")
(cursor	=	"")	"")
(mode	=	"ql")	"ql")

ECREIDENTIFY:

PARAMETER		ARCES	DEFAULT
images	=	"@tharlist"	""
reference	=	"refthar.ec"	""
(shift	=	INDEF)	0.)
(cradius	=	1.)	5.)
(threshold	=	100.)	10.)
(refit	=	yes)	yes)
(database	=	"database")	"database")
(logfiles	=	"STDOUT,logfile")	"STDOUT,logfile")
(mode	=	"ql")	"ql")

FLATCOMBINE:

PARAMETER		ARCES	DEFAULT
input	=	"@jan22_23bflat.lis"	""
(output	=	"jan22_23bflat")	"Flat")
(combine	=	"average")	"average")
(reject	=	"avsigclip")	"avsigclip")
(ccdtype	=	"")	"flat")
(process	=	no)	yes)
(subsets	=	no)	yes)
(delete	=	no)	no)
(clobber	=	no)	no)
(scale	=	"mode")	"mode")
(statsec	=	"")	"")
(nlow	=	1)	1)
(nhigh	=	1)	1)
(nkeep	=	1)	1)
(mclip	=	yes)	yes)
(lsigma	=	3.)	3.)
(hsigma	=	3.)	3.)
(rdnoise	=	"0.")	"0.")
(gain	=	"1.")	"1.")
(snoise	=	"0.")	"0.")
(pclip	=	-0.5)	-0.5)
(blank	=	1.)	1.)
(mode	=	"ql")	"ql")

MAGNIFY:

PARAMETER		ARCES	DEFAULT
input	**=**	**"hd183143"**	
output	**=**	**"hd183143rs"**	
xmag	=	1	
ymag	=	4	
(x1	=	INDEF)	INDEF)
(x2	=	INDEF)	INDEF)
(dx	=	INDEF)	INDEF)
(y1	=	INDEF)	INDEF)
(y2	=	INDEF)	INDEF)
(dy	=	INDEF)	INDEF)
(interpolatio	=	"linear")	"linear")
(boundary	=	"nearest")	"nearest")
(constant	=	0.)	0.)
(fluxconserve	=	yes)	yes)
(logfile	=	"STDOUT")	"STDOUT")
(mode	=	"ql")	"ql")

REFSPECTRA:

PARAMETER		ARCES	DEFAULT
input	**=**	**"thar.ec"**	**""**
answer	**=**	**"yes"**	**""**
(references	**=**	**"refthar.ec")**	**"*.imh")**
(apertures	=	"")	"")
(refaps	=	"")	"")
(ignoreaps	=	yes)	yes)
(select	=	"interp")	"interp")
(sort	=	"")	"jd")
(group	=	"")	"ljd")
(time	=	no)	no)
(timewrap	=	17.)	17.)
(override	=	yes)	no)
(confirm	=	yes)	yes)
(assign	=	yes)	yes)
(logfiles	=	"STDOUT,logfile")	"STDOUT,logfile")
(verbose	=	no)	no)
(mode	=	"ql")	"ql")

TEXT2MASK and contents of bad pixel file:

PARAMETER		ARCES	DEFAULT
text	=	"badcols"	""
mask	=	"echmask"	""
ncols	=	2128	
nlines	=	2068	
(linterp	=	1)	1)
(cinterp	=	2)	2)
(square	=	3)	3)
(pixel	=	4)	4)
(mode	=	"ql")	"ql")

badcols

```
 788  788 803 2000
1683 1683 664 2000
```

Definitions of terms used in the manual

Aliasing: low frequency noise resulting from an overly coarse grid used to digitize analog information. In spectroscopy, aliasing occurs when an aperture is sparsely sampled by detector pixels perpendicular to the dispersion direction, unless offsetting observing techniques or data reduction strategies are used.

Aperture: part of an echelle order recorded on the detector.

Aperture mask: the contours which parallel an aperture trace and enclose a critical fraction of the detected light in an aperture.

Aperture trace: a smooth path followed by the peak light in each cross-section of a given aperture.

Extraction: the process of converting a 2-dimensional spectrum to one or more 1-dimensional pieces. This process involves locating apertures, tracing them across the detector, defining aperture masks, and then coadding light in common wavelength bins.