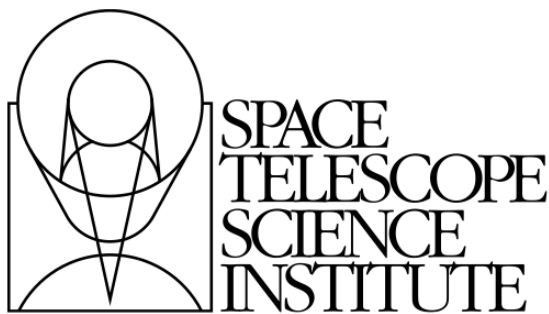


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# Basic PyRAF



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## Revision History

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This is an unofficial document for internal RIAB training purposes only

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# Chapter 1

## Introduction to PyRAF

### 1.1 What is PyRAF?

PyRAF is a command language for running IRAF tasks in a Python like environment. It works very similar to IRAF, but has been updated to allow such things as importing Python modules, starting in any directory, GUI parameter editing and help. Most importantly, it can be imported into Python allowing you to run IRAF commands from within a larger script. PyRAF is part of the `stsci_python` package and is a product of the Science Software Branch here at STScI. All of the STScI calibration pipelines can be run from PyRAF although they are now written in Python and more recent pipelines (e.g. *Calcos*) can be run as stand-alone programs.

#### 1.1.1 IRAF

IRAF stands for Image Reduction and Analysis Facility and is written and supported by the National Optical Astronomy Observatories (NOAO). It has many tools for both spectroscopic and image analysis. Scripting in IRAF can be done using an IRAF-specific language called “CL script”, however that will not be covered in this document. Most information covered in this document applies to both IRAF and PyRAF but is generally more user friendly in PyRAF.

## 1.2 Getting Started

Ensure you have activated the `conda` environment that you set up in the **Computer Setup** section. Create a `login.cl` file to configure IRAF by running `mkiraf` in your home directory. When asked to Initialize `uparm?`, answer `y`. When prompted to Enter terminal type, you should supply `xterm`.

If the command `mkiraf` is not available, use `conda install -c http://ssb.stsci.edu/conda-dev iraf pyraf`. Packaging for PyRAF and IRAF is currently transitioning to a new system, so check with your trainer if the installation does not work.

## 1.3 The Basics

### 1.3.1 Navigation

PyRAF contains many packages which have to be imported. You import a package by typing the name in the command line. For example, to use the **Calstis** function I need to have the **stis** package loaded which is in the **hst\_calib** package, which is in the **stdas** package, I type the following in a PyRAF window:

```
-> stdas
-> hst_calib
-> stis
```

To find out the packages available in your current package type `?`. For example:

```
-> stdas
-> hst_calib
-> ?
```

This will tell you all of the packages in **hst\_calib**. Functions with an `@` symbol are parameter tables, not functions.

### 1.3.2 Help

You get help information on any package or function by typing **help function**. This not only tells you about a function, it also tells you the packages that you have to call to get to it. For instance, if you want to use the command **splot**:

```
-> help splot
```

This will tell you that **splot** is in the **onedspec** in the **noao** package. This can also be entered in GUI form from the epar GUI.

### 1.3.3 epar

All functions have input parameters most of which can either be entered in the command line or can be set in the parameter editor using the epar GUI. If you type: *epar function* you will get a table of all of the parameters. There are 5 buttons at the top of the epar editor: Execute, Save, Unlearn, Cancel, and Help. Execute runs the function with the parameters given, Save exits the epar editor and saves the parameters but doesn't execute the function, Unlearn set all of the parameters to their default values, Cancel exits the epar editor without saving, and Help displays the help file for the function.

### 1.3.4 Using a List as Input

Many PyRAF functions cannot use wildcards but can take a file which is a list of files. A file which is a list is distinguished from an input file for processing by using an @ sign at the beginning of the file name. For example if you have 3 files, file1.fits, file2.fits, and file3.fits, you can first make a file which is a list of the file names:

```
> ls *.fits > filelist.txt
```

Then use this as the input to the **catfits** function:

```
-> catfits @filelist.txt
```

### 1.3.5 importing function

Because PyRAF is Python based, you can import any Python module. This is particularly useful when calibrating a group of datasets as many instrument pipelines (Cal\*) will not take wild cards as inputs. If you are mixing PyRAF and Python commands you often have to put an iraf. in front of the commands to let PyRAF know that your are executing a PyRAF command. In the following example I will import the **glob** module from python and use it to select all of the raw files in a directory. I will then calibrate each raw file (note I use iraf.calstis rather than just calstis).



```
> pyraf
-> import glob
-> flist = glob.glob('*raw.fits')
-> for ifile in flist:
    iraf.calstis(ifile)
```

### 1.3.6 Exercises

1. In PyRAF locate the package **apextract**. What tasks are in this package? What does the **aptrace** task do? Are there any parameter tasks?

# Chapter 2

## Useful IRAF Tasks

## 2.1 General

### 2.1.1 Institute Specific Packages

#### 2.1.1.1 `stdas`

The **stdas** package (Space Telescope Science Data Analysis Software Package) is a package put together by the institute. It includes all of the instrument specific calibration packages as well as other helpful tasks. You will most likely load it every time you use PyRAF and may want to consider adding it to your `login.cl` file.

#### 2.1.1.2 `hst_calib`

The **hst\_calib** package contains all of the HST science instrument calibration packages. These packages contain all of the tasks which are used to calibrate data from each instrument as well as tasks to model the combined response of the various detectors and optical elements. It also contains tasks to derive the instrument calibrations and construct the calibration reference files.

### 2.1.2 `catfits`

**catfits** gives you the details of a file. For each extension it tells you the type (table or image), name, dimension, and pixel type.

### 2.1.3 Header Information

There is a lot of information contained in the header of each file. These tasks will help you view and edit them. I will only describe these briefly as I encourage you to use python or IDL for these tasks. Note a version of **hedit** and **imheader** have been written in Python. Please see the help sections of these tasks for additional information on the parameters and examples of their use.

WARNING: **imheader** and **hselect** only work on the 0th extension of fits binary tables. **thselect** can be used instead of **hselect**.

### 2.1.3.1 imheader

**imhead** displays the header information for a given image. If the parameter LONGHEADER = no, the image name, dimensions, pixel type, and title are printed. If LONGHEADER = yes all header data for a given extension is printed. If no extension is specified, the 0th extension is used.

### 2.1.3.2 hselect

**hselect** displays a single header keyword.

### 2.1.3.3 hedit

**hedit** updates or adds a given header keyword.

## 2.1.4 Exercises

1. Use **catfits** to determine how many extensions the file /grp/hst/cdb/oref/t9a1003so\_tds.fits has.
2. Use **imhead** to determine the dimensions of the file /grp/hst/cdb/oref/v8918108o\_bia.fits.
3. Use **hselect** to find the value of the DETECTOR keyword in the file /grp/hst/cdb/oref/ub920085o\_tds.fits.
4. Copy the file /grp/hst/cdb/oref/ub920085o\_tds.fits to your computer. Modify the DATE keyword to be today's date

## 2.2 Images

### 2.2.1 display

This task is used to display images in DS9. You must make sure a DS9 window is open before you use the **display** task. **display** has many options which are detailed in the help section, in general you need to specify an extension and a DS9 frame for the image to be displayed in. When you use **display** to bring up an image in DS9 you cannot use the DS9 options for scale.

For this reason you may sometimes find it helpful to open a file directly in DS9 rather than using PyRAF.

#### EXAMPLE

<pre>&gt; ds9 &amp; &gt; pyraf -&gt; display /grp/hst/cdbs/oref/u211310do_bia.fits[1] 2 z1=-0.7425513 z2=15.1016</pre>	<pre>Open DS9 Open PyRAF Display the first extension of the file in the second DS9 frame. This is output from <b>display</b> which tells you about your contrast and scaling.</pre>
--	---

### 2.2.2 imexamine

**imexamine** allows you to display your image in a similar manner to **display**, however it has additional image analysis capabilities. By placing your cursor over the image and typing certain commands, various types of plots and text output can be created. A complete list of tools can be found in the help to the **imexamine** task. I most often use 'e' to create a contour plot, 'c' to create a column plot, 'l' to create a line plot, and 'r' to create a radial profile. Type 'q' when you are in the image window to exit **imexamine** and continue your work.

#### EXAMPLE

<pre>&gt; ds9 &amp; &gt; pyraf -&gt; imexamine /grp/hst/cdbs/oref/u211310do_bia.fits[1] 2</pre>	<pre>Open DS9 Open PyRAF Display the first extension of the file in the second DS9 frame.</pre>
---	---

You should now have a circular cursor on top of the DS9 window. Place the cursor over a part of the image and type e. You should see a new window pop up with a contour plot of the area where your cursor is on the image. Press q to exit **imexamine**.

### 2.2.3 imstatistics

**imstatistics** is a task which computes statistics of the pixel values of images. **imstatistics** can compute the number of pixels, mean, median (called midst), mode, standard deviation, skew, kurtosis, min and max pixel values. Upper and lower sigma clipping can also be performed for a set number of iterations.

#### EXAMPLE

```
->imstatistics /grp/hst/cdbs/oref/u211310do_bia.fits[1]
#  IMAGE                                NPIX  MEAN  STDDEV  MIN  MAX
   /grp/hst/cdbs/oref/u211310do_bia.fits[1] 1048576 1.487  3.747  -18.41 2224.
```

## 2.2.4 imcalc

**imcalc** is used to combine images arithmetically pixel by pixel (sum, multiply, divide, etc). A list of images is used in the input field, and then each image is referred to as im1, im2, im3, etc. in the calculation.

### EXAMPLE

Find the average of the first extensions of j8c0a1011\_drz.fits and j8c0c1011\_drz.fits in their over-lapping regions [1:4211, 1:4232] and call the output out.fits

```
-> imcalc j8c0a1011_drz.fits[1][1:4211,1:4232],j8c0c1011_drz.fits[1][1:4211,1:4232] out.fits "(im1+im2)/2."
Percent done: 10 20 30 40 50 60 70 80 90 100
```

## 2.2.5 Exercises

1. Download the following datasets from the MAST archive: j8c0a1011, j8c0c1011, j8c0d1011
2. Display the first extension of j8c0a1011\_drz.fits in the first frame of DS9
3. Use **imexamine** to make a radial plot of one of the stars in the first extension of j8c0c1011\_drz.fits
4. What are the maximum and minimum pixel values of the j8c0d1011\_drz.fits? What if you use an upper sigma boundary of 3 and a lower of 2 and repeat the clipping 5 times? How many pixels are eliminated using this sigma clipping?
5. Find the dimensions of each image. Create a weighted average of the 3 images, weighting by their exposure times.

## 2.3 Photometry

### 2.3.1 daofind

**daofind** is a commonly used tool to locate a bunch of point sources in an image. **daofind** searches images for local density maxima, which have a full-width half-maximum of datapars.fwhmpsf and a peak amplitude greater than findpars.threshold \* datapars.sigma above the

local background, and writes a list of detected objects in the file output. For this reason, the values that you use in these parameters will greatly affect the number of objects missed and the number of object with false detections. Each image is different and usually requires some parameter tweaking.

EXAMPLE:

Parameter	Assignment Value	Maximum Objects Value
datapars.sigma	3.6	2.0
datapars.fwhmpsf	2.0	2.0
datapars.gain	ccdgain	ccdgain
findpars.thresh	50	20
findpars.sharplo	0.2	0.2
findpars.sharphi	0.8	0.8
findpars.roundlo	-1.0	-1.0
findpars.roundhi	1.0	1.0

Set the above values in the parameter files using epar.

### 2.3.2 tvmark

**tvmark** will mark the locations given in a text file on an image displayed in DS9. You can specify the shape marked, the size of the marker, and the marker color. This is most often used to check which objects were chosen when one uses a program to manually find stars (such as daofind or star find).

EXAMPLE

```
-> display f435w_drz.fits[1] 1
-> tvmark 1 cood_file.txt mark = circle radii = 8 color = 205
```

### 2.3.3 phot

**phot** performs aperture photometry on a list of stars based on a series of parameter files. The parameter files used are photpars@, centerpars@, and fitskypars@. Datapars describes instrument dependent parameters, photpars describes the functions used for computing the photometry, centerpars describes the centering algorithm parameters, and fitskypars describes the sky fitting parameters.

EXAMPLE

```

->epar datapars
->epar findpars
->daofind f435w_drz.fits[1]
Input image(s) ('f435w_drz.fits[1]'):
FWHM of features in scale units (2.5) (CR or value):
New FWHM of features: 2.5 scale units 2.5 pixels
Standard deviation of background in counts (INDEF) (CR or value):
New standard deviation of background: INDEF counts
Detection threshold in sigma (6.) (CR or value):
New detection threshold: 6. sigma INDEF counts
Minimum good data value (INDEF) (CR or value):
New minimum good data value: INDEF counts
Maximum good data value (INDEF) (CR or value):
New maximum good data value: INDEF counts

```

Parameter	Value
datapars.exposure	EXPTIME
fitskypars.annulus	10.0
fitskypars.dannulus	5.0
fitskypars.salgoithm	mode
fitskypars.skyvalue	0.0
photpars.apertures	3.0, 10.0
centerpars.calgorithm	centroid
centerpars.cbox	10.
centerpars.maxshift	6
phot.interactive	no
phot.verbose	yes

Set the above values in the parameter files using epar.

```

->epar datapars
->epar fitskypars
->epar photpars
->epar centerpars
->epar phot

```

Run **phot**

```

->phot f435w_drz.fits[1] f435w_drz.fits1.coo.1

```

*(Note: If the phot task doesn't seem to be running, ensure the interactive parameter flag is set to no!)*



### 2.3.4 Exercises

1. Run `daofind` on `j8c0a1011_drz.fits`. Play with the parameters to try at least 3 runs. Choose your best run (most correctly marked stars and least incorrectly marked stars) for 2 and 3.
2. Mark the location of the stars found in 1 with green squares.
3. Perform aperture photometry on `j8c0a1011_drz.fits` using the same parameter values as were used in the example

## 2.4 Tables

### 2.4.1 `tdump`

**tdump** takes a table from PyRAF memory and writes it to an ASCII file. This can be especially helpful for global edits which are difficult using `tedit`.

EXAMPLE

```
-> tdump f435w_drz.fits1.mag.1 colum=c7,8,15,29,30,31,38,39,40 datafil=f435w.phota
```

### 2.4.2 `tmerge`

**tmerge** is used to merge two tables or to append one to the other.

EXAMPLE

```
-> tmerge f435w.phota,j8c0d101160_dao_ascii.tab phot_all.tab option="merge"
```

### 2.4.3 `tcalc`

Similar to **imcalc**, **tcalc** performs arithmetic operations on table columns.

EXAMPLE

```
-> tcalc phot_all.tab 435_apcor "mag3_435-mag10_435" colfmt=%6.5g
```

### 2.4.4 Exercises

1. Look in the help files for `tcalc` for all of the arithmetic options.

## 2.5 Spectroscopy

Note also that many IRAF spectral functions (including `scopy` and `scombine`) accept the optional parameters `w1` and `w2`, where `w1` refers to the minimum wavelength and `w2` the maximum wavelength. Thus, to copy the wavelength range from 1700 - 3200 Å, the command would be

→ `scopy input.fits output.fits w1=1700 w2=3200`

The **sarith** task also has many of the same functions as **imarith**, except that, by default, it will apply those functions in wavelength rather than pixel space.

Most of these tasks require a one-dimensional image rather than a fits binary table. Therefore you will need to use **tomultispec** to convert your table into an image before using **scombine**, **splot**, and **continuum**.

### 2.5.1 tomultispec

The **tomultispec** command, available in the **hst calib.ctools** package, is the canonical way to move from STIS 1-dimensional spectra (`sx1.fits` or `x1d.fits`, which are stored as FITS binary tables) to standard spectra stored as one-dimensional images (which may then be plotted using `splot` or an equivalent tool). Note that `tomultispec` produces `imh` rather than FITS files, and these can be converted back into FITS files (e.g. so that they can be sent or copied elsewhere more easily) through the use of the **imcopy** command. Be sure that the `imdir` in your `login.cl` file is set to "\$HDR"

EXAMPLE

→ `tomultispec obmzl1020_sx1.fits obmzl1020_sx1.imh`

### 2.5.2 scombine

**scombine** is a good tool for combining multiple spectra (in order to improve the final signal-to-noise ratio when several spectra were taken with the same settings). It allows any number of spectra to be combined by taking the average, the median, or the sum of the input spectra (using the `combine` parameter).

## EXAMPLE

To combine "obmzl1020\_sx1.imh" and "obmzl2020\_sx1.imh" into "out.fits", using the median of the input spectra, the command would be:

```
-> scombine obmzl1020_sx1.imh,obmzl2020_sx1.imh out.imh comb=median
```

### 2.5.3 continuum

**continuum** is a task intended for normalizing spectra (it has many other functions, but that is the most important one when working with spectra here). **continuum** allows fit regions to be selected with the "s" key (pressing the first time to establish the start of the fit region, and the second time for the end, and using "z" to delete a fit region. Note that the continuum should not be fit across the line of interest, as this might distort the line's shape or equivalent width. Other useful commands in continuum include ":func", allowing the fitting function to be set (e.g. to "chebyshev", "legendre", "spline3"), ":o N", setting the order of the fitting function to N, and "f" to see the new fit after changing the order and fitting function.

## EXAMPLE

```
-> continuum obmzl1020_sx1.imh obmzl1020_sub1.imh
Fit [1,1] of obmzl1020_sx1.imh w/ graph? (yes|no|skip|YES|NO|SKIP) ('yes'): yes
```

### 2.5.4 plot

plot is a tool that does many spectroscopy-related tasks. In addition to displaying spectra, it also allows you to fit spectral lines, determine signal-to-noise ratios, and even de-blend overlapping lines. plot has many other capabilities in addition to those described here, but these at least provide some information. Below are a very few of the extensive capabilities of plot. I encourage you to look at the help file to see what else is available.

**WINDOWING:** Press **w** to enter windowing mode. To autoscale the data between a range of values (basically zooming) move your cursor to one edge of the range you wish to use and press **a** then move your cursor to the other end of the range and press **a** again. Press **c** to clear all windowing and return to your original spectrum.

**SIGNAL-TO-NOISE:** Move your pointer to the leftmost part of the area you wish to check and press **m**, then move your pointer to the rightmost part of the area and press **m** again. In addition to SNR, you also get the average value and the rms.

**LINE FITTING:** Move your pointer to the leftmost edge of the line and press **k**. Then move your pointer to the rightmost edge of the line, and press **k** again for a simple fit, **g** for a Gaussian fit,

**l** for a Lorentzian fit, and **v** for a Voigt profile fit. This gives you the line center, flux, equivalent width, and fwhm.

**EQUIVALENT WIDTH:** Move your pointer to the leftmost point of the area and press **e**, then move the pointer to the rightmost point of the area and press **e** again. This yields the line center, equivalent widths, continuum, and flux. You can also use **k** for different profile fitting options and **h** for the most flexibility.

**DEBLENDING:** Move your pointer to the leftmost part of the line group and press **d**, then move your pointer to the rightmost part of the group and press **d** again. Now move your pointer to the centre of each line in the group, each time pressing **g** for a Gaussian fit, **l** for a Lorentzian fit, and **v** for a Voigt profile fit. Press **q** when all lines have been marked. Then press **s** to fit a single line, or **a** to fit all lines. Do the same for Gaussian, Lorentzian, and Voigt profile lines. Press **y** to fit and subtract the background, or **n** to leave it in place in the fit. You can now press **+** and **-** to move between fits, and **q** to exit the deblend fitting mode.

### 2.5.5 Exercises

1. Download the following datasets from the MAST archive: obmzl3030, obmzl4030
2. Combine the datasets obmzl3030\_sx1.fits and obmzl4030\_sx1.fits – *Remember, scombine requires a 1-D image rather than a FITS binary table.*
3. Take your combined spectrum from 1 and remove the continuum
4. Display the continuum subtracted combined spectrum in splot. Fit a line with a Gaussian and a Voigt profile. What changes in the reported values?