Using External SExtractor (v2.8.6) Catalogs from *_crclean.fits Images to Align ACS/WFC Images With Drizzlepac/Tweakreg

Introduction

This example describes the alignment of four ACS/WFC images that contain a large number of extended sources, but relatively few point sources. Dithers of roughly 60 pixels between images were performed between the images, in order to obtain good sky coverage in the area of the gap betqween the two CCDs. **Where possible, it is very important to start with images taken in the same visit and in the same filter.**

Summary of Steps

1. Examine the data & observing program structure; note **same visit/filter**
2. Do initial single drizzle to produce *_crclean.fits files (cosmic rays removed)
3. Download and install SExtractor
4. Run SExtractor to produce catalogs for use in tweakreg alignment
5. Visually inspect and clean up SExtractor catalogs, iterating if needed
6. Prepare control file for inputting SExtractor catalogs into tweakreg
7. Run tweakreg, iteratively, if needed, inputting the SExtractor catalogs
8. Proceed with alignment of other same visit/same filter combinations if available, then use tweakback to align all images to a common reference frame across all visits and filters, concluding with final drizzle, per filter, of all co-aligned frames.

(1) Examine the data and observing program structure

The Data (from a single visit of HST Program 10092):

Image Name	POSTARG (x, in arcsec)	POSTARG (y, in arcsec)	PA_V3 Orientation (degrees)	RA of Aperture	Dec of Aperture	Exp Time (sec)
j8xi0xs0q_flc.fits	0.062	-3.052	280.00269	150.20317	2.6771942	507
j8xi0xs3q_flc.fits	0.310	0.024	280.00259	150.20232	2.6772377	507
j8xi0xs6q_flc.fits	-0.062	3.052	280.00259	150.20149	2.6774503	507
j8xi0xsaq_flc.fits	0.186	6.127	280.00259	150.20064	2.6774938	507

Table 1 (above): Data parameters and dither pattern in the field of view **(same visit & filter)**. The images have many extended sources (faint galaxies) but few stellar point sources for alignment, so the default DAOFIND-like imagefindpars task does not generally work as well as it does on stellar-sources. Thus, we try using SExtractor-generated catalogs generated from *_crclean.fits images as input to tweakreg for determining shifts, updating headers, and aligning the images.

Description of Data

These data are ACS/WFC exposures of a field of galaxies from a single visit (0X) of program 10092. Each of the four exposures were collected through the F814W filter and had an exposure time of 507 seconds. The images all shared the same nominal pointing (RA: 150.20233 Dec: 2.6773222) but were dithered, with large (many pixel) steps between each. The sizes of the steps can be seen in the POSTARG columns of the table in Table 1, above, keeping in mind that the plate scale of the WFC channel is 0.05" per pixel, implying dither steps of about 60 pixels (3.1"/0.05" /pixel) between consecutive images. These data were collected on 15 May, 2004. The RA and Dec of Aperture columns in Table 1 above show the pointing location listed in the header, after taking the POSTAGs into account.

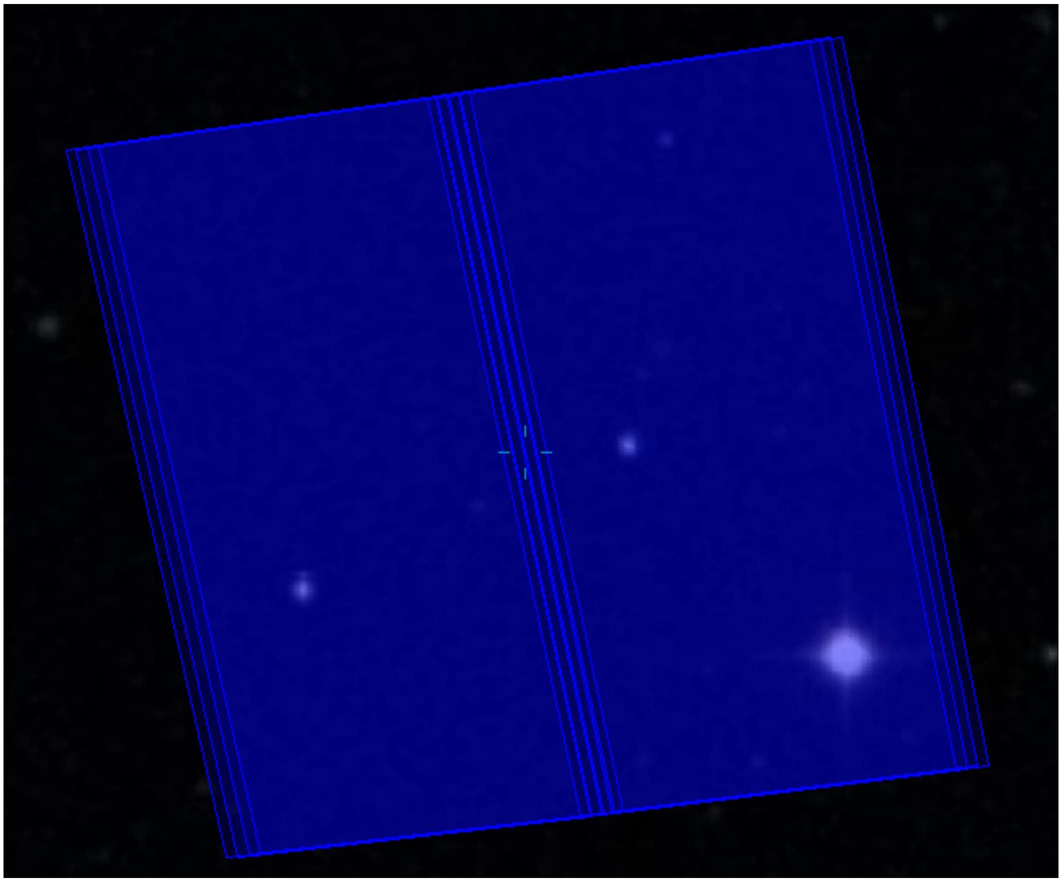

Figure 1 (above): Dither pattern in the field of view (same visit & filter). North is up, East is to the left.

(2) Initial single drizzle, making *_crclean.fits images

Second, run astrodrizzle through the single drizzle step using default WCS for alignment during preliminary cosmic ray rejection and production of *_crclean.fits. In PyRAF, if using line commands rather than the Teal GUI interface, this is the syntax:

- → import drizzlepac
- → from drizzlepac import astrodrizzle
- → unlearn astrodrizzle
- → astrodrizzle.AstroDrizzle('j8xi0x*flc.fits',driz_cr_corr=yes,driz_combine='no')

- This produces a CR-cleaned version of each input image called ***_crclean.fits.** It is the *_crclean.fits files on which you run SExtractor.
- **The quality of the initial CR-rejection depends on the quality of the original WCS alignment, and this is best for images taken within the same visit and same filter.**

Image full of cosmic rays before CR cleaning (above)

Image cleaned of cosmic rays except for strip along bottom of chip (below)

Figures 2a, 2b (above): Original and CR-cleaned images

(3) Download and Install SExtractor

Third, download and install SExtractor. **We recommend the latest version (currently v2.8.6) for this purpose since it handles multi-extension FITS files better than some earlier versions.** SExtractor may be downloaded from the web site referenced at the end of this example (or your institution may have a site-specific version for you to download), and you may follow instructions in the various guides or documentation referenced there, or with any site-specific version. Included with the download, in the /config subdirectory, are 4 files which you will need for running SExtractor – **default.sex**, **default.param**, **default.conv**, and **default.nnw**. In general, it is best to leave the originals in your defined SExtractor directory and just copy the 4 default.* files into your working directory for a given project, for editing as desired for the specific purposes of your work since SExtractor looks first in the working directory to see if there are any there. For this example, we used the default.nnw – a neural network file - and default.conv – a convolution kernel file - without any modifications, and only a few were made to default.sex, as listed below – mainly to do with parameters for object detection and measurement, and default.param, which is where we define the names and contents and format of our output catalogs, etc.

(4) Run SExtractor on the *_crclean.fits images

Fourth, experimenting as needed, run SExtractor at the unix prompt. In this case, we used PSF FWHM=0.08 for ACS/WFC, detect_minarea=3, & detect_thresh=7. These values are set in the SExtractor default.sex file. Note that Sextractor completely ignores the initial extension of a multi-extension FITS file, and therefore the group numbers [0] & [3] in the example below correspond to the 1st and 4th extensions of the *_crclean.fits files, which are the science data extensions [1] & [4] of ACS/WFC data. For example:

```
sex –catalog_name j8xi0xs0q_crclean_ext1.cat –checkimage_name
j8xi0xs0q_crclean_ext1_aperturecheck.fits j8xi0xs0q_crclean.fits'[0]'

sex –catalog_name j8xi0xs0q_crclean_ext4.cat –checkimage_name
j8xi0xs0q_crclean_ext4_aperturecheck.fits j8xi0xs0q_crclean.fits'[3]'
```

Repeat this for all of your *_crclean.fits images in this visit/filter combination.

(5) Visually inspect results, and clean up catalogs if needed

At this point, you may want to visually inspect your SExtractor results. To do this, you will need to display the images in ds9 with PyRAF line commands, and then overplot the catalog for various images with the tvmark task, both of which are also documented within PyRAF.

In this example, there were a number of spurious sources (cosmic rays) which were not removed in the earlier step since that area of the CCD chip (a strip along the bottom) did not overlap any other images to which comparison could be made for automatic identification and removal of the cosmic rays, so these were then edited from the catalog by hand before they were fed to the tweakreg task for alignment of the images. An alternate, more automated solution might have been to use a larger detect_minarea in SExtractor, however, this, too can have its drawbacks since that will result in fewer objects, and may also yield a poorer solution in some cases, as it did in this one. It can be very data-dependent, so experimentation is key. Yet another way to do this is to mask out the affected area before running SExtractor, but you may want to use replacement values which are near to some mean global sky value if the sky background is not strongly variable since this can otherwise also affect the global sky level which SExtractor uses in object detection and measurement. SExtractor can also be set up to use local sky values around each object, but other factors come into play then.

A final hint: to view the maps that SExtractor created as checkimages, you may need to insert the SIMPLE = T header keyword in the checkimages before you can display and view them.

(6) Prepare control file for inputting SExtractor catalogs to tweakreg

To feed the SExtractor catalogs to tweakreg, you must create a list file that relates the images to be updated to the catalog file for each chip of each image. In this example, we created a file called astdriz_catfile.list, shown below. (The name doesn't matter as long as it matches the file name for it in the 'catfile' parameter in tweakreg. In the automated version of tweakreg, it is called coords_catfile.lis.) On each line (and the order on the line is important), the file must contain:

1) the name of the *_flc.fits file, 2) the name of the SExtractor catalog file corresponding to data extension [1], and 3) the name of the SExtractor catalog file corresponding to data extension [4]. (The SExtractor catalog names are the ones from your SExtractor runs, and should be ones that make sense to you and reflect the fact that they represent ACS/WFC extensions [1] and [4] in that order on each line.)

In this case, our file called astdriz_catfile.list contains:

```
j8xi0xs0q_flc.fits  j8xi0xs0q_crclean_ext1.cat  j8xi0xs0q_crclean_ext4.cat
j8xi0xs3q_flc.fits  j8xi0xs3q_crclean_ext1.cat  j8xi0xs3q_crclean_ext4.cat
j8xi0xs6q_flc.fits  j8xi0xs6q_crclean_ext1.cat  j8xi0xs6q_crclean_ext4.cat
J8xi0xsaq_flc.fits  j8xi0xsaq_crclean_ext1.cat  j8xi0xsaq_crclean_ext4.cat
```

(7) Run tweakreg (iteratively) using input catalogs from SExtractor

Next, run tweakreg, telling tweakreg which columns in the SExtractor catalogs contained the x and y positions. (Those columns were determined earlier by the order in which you list them when editing your SExtractor default.param file. In this case, we used columns 5 and 6.) Run it first with updatehdr=no until you are satisfied (rms ~0.15, rms plots centered around 0) with a clear view that upper and lower bounds are not being artificially cut off by a sigma-clipping that is too aggressive in order to achieve an artificially lower rms.

Finally, run it once more with updatehdr=yes in order to propagate the WCS updates into the headers of the input files.

In the run below, we used default values of minobj=15, searchrad=1.0 (arcsec), nclip=3, sigma=3.0, fitgeometry=rscale, and x,y positions in units of pixels. Again, using line commands in PyRAF:

- → from drizzlepac import tweakreg
- → unlearn tweakreg
- → tweakreg.TweakReg('j8xi0x*flc.fits',catfile='astdriz_catfile.list',xcol=5,ycol=6)

Tweakreg will produce output that looks like the following plots in Figures 3a, 3b, and 3c.:

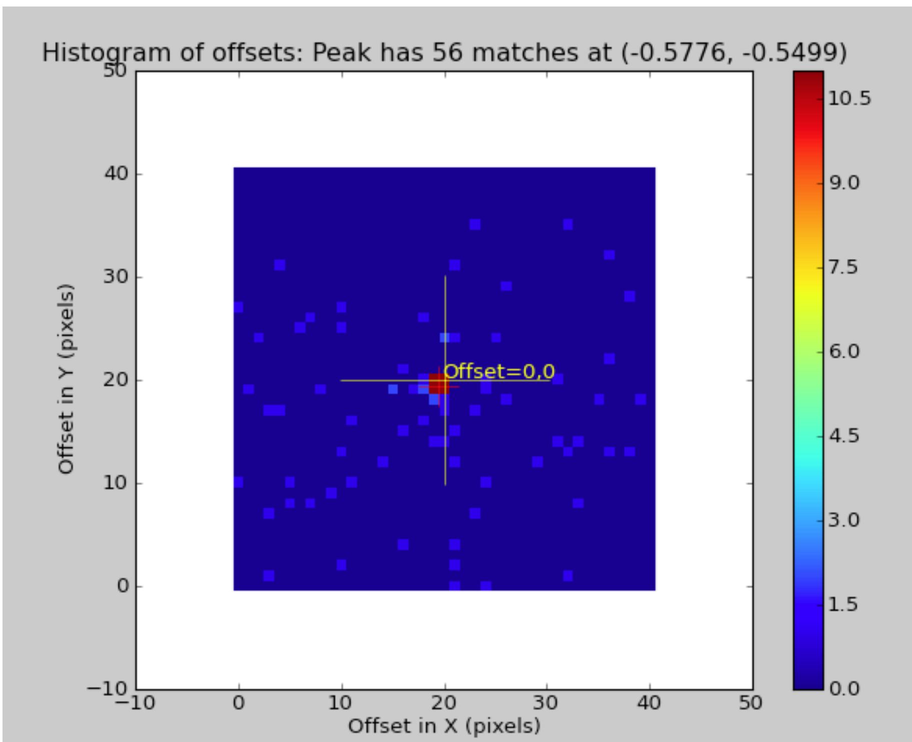

Figure 3a: Histogram showing offsets associated with peak number of source matches.

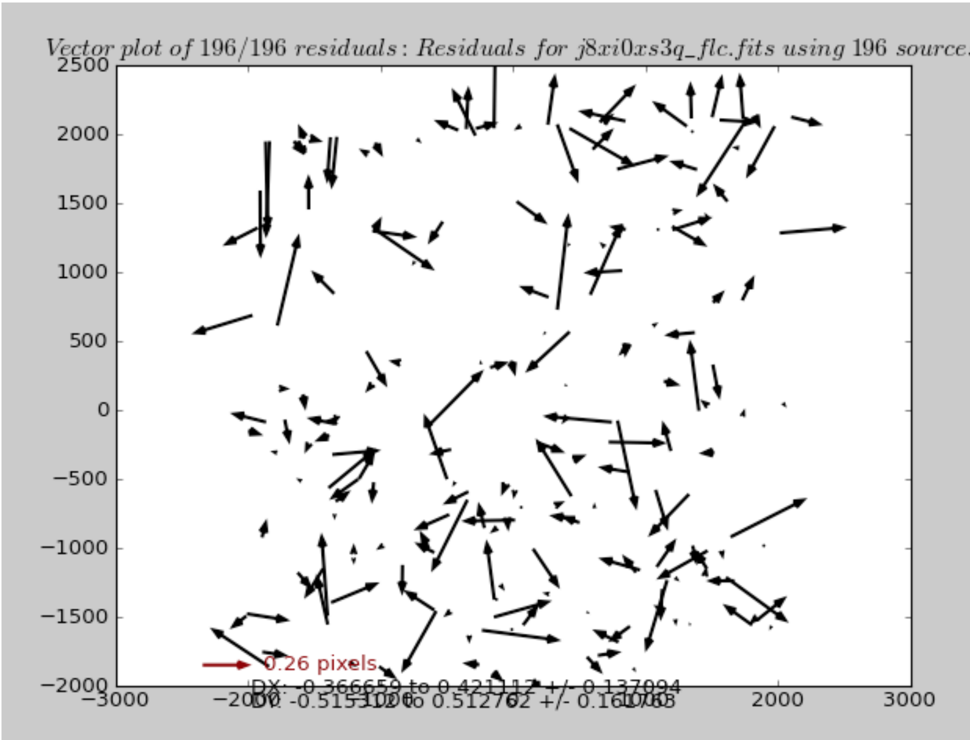

Figure 3b: Vector plot. Random values are preferable to strong trends.

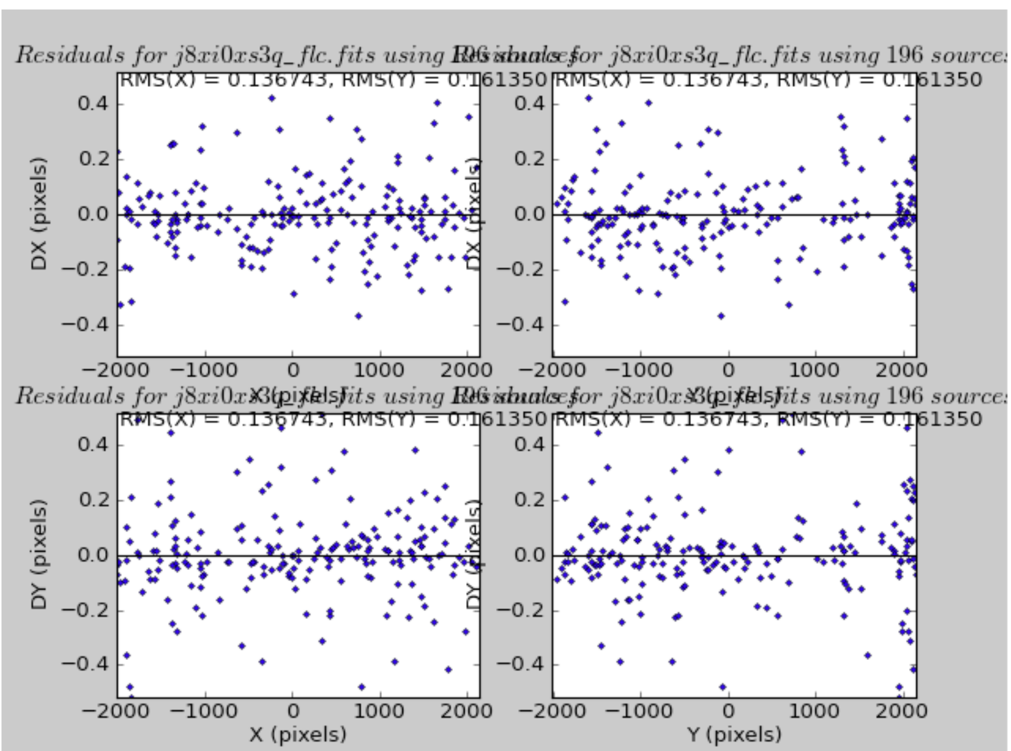

Figure 3c: RMS residuals. RMS values of ~0.14, 0.16 are good; plots well-centered at ~0.0.

(8) Proceed with further alignments of visit/filter groups (if available), then across visits and filters, concluding with all images from all visits and filters co-aligned and drizzled to a common reference frame

Once you are happy with the alignment solution for that **single visit and filter combination** and have re-run tweakreg with updatehdr=yes, then you can continue by using astrodrizzle to drizzle together all of the images for that given visit and filter combination which you have aligned. **Again, remember that the alignment process works best when starting with all images in the same visit taken in the same filter.**

Finally, if data from other visits and filters are available, repeat steps 4-7 for data from each filter within your visit. The **tweakback** task can then be used to align the data from all of the filters in the visit, and to align and combine images taken across multiple visits and filters, drizzling them all to a common reference frame, as shown in Sections 7.5.5 and 7.5.6 in the DrizzlePac Handbook.

(9) References

SExtractor:

SExtractor: http://www.astromatic.net/software/sextractor
Bertin, E., & Arnouts, S., 1996: SExtractor: Software for Source Extraction, Astronomy & Astrophysics Supplement 317, 393
Bertin, E., SExtractor v2.13 User's Manual, at https://www.astromatic.net/pubsvn/software/sextractor/trunk/doc/sextractor.pdf
Akhlaghi, M., 2012, Notes on SExtractor 2.8.6, at http://www.astr.tohoku.ac.jp/~akhlaghi/sextractor_notes.html
Holwerda, B., SExtractor for Dummies, at http://astroa.physics.metu.edu.tr/MANUALS/sextractor/Guide2source_extractor.pdf

DrizzlePac tasks and usage:

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Gonzaga et al., 2012, The DrizzlePac Handbook (Available on-line.)
http://documents.stsci.edu/hst/HST_overview/documents/DrizzlePac/DrizzlePac.cover.html