
jhat Documentation

Release 0.0.1

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INSTALLATION

jhat works on Python 3+ and requires the following Python packages (these should install automatically when you install jhat):

- `numpy`
- `matplotlib`
- `astropy`
- `jwst`
- `scipy`
- `photutils`
- `pysiaf`
- `astroquery`
- `pandas`
- `stsci skypac`

1.1 Install using pip

Using pip:

```
pip install jhat
```

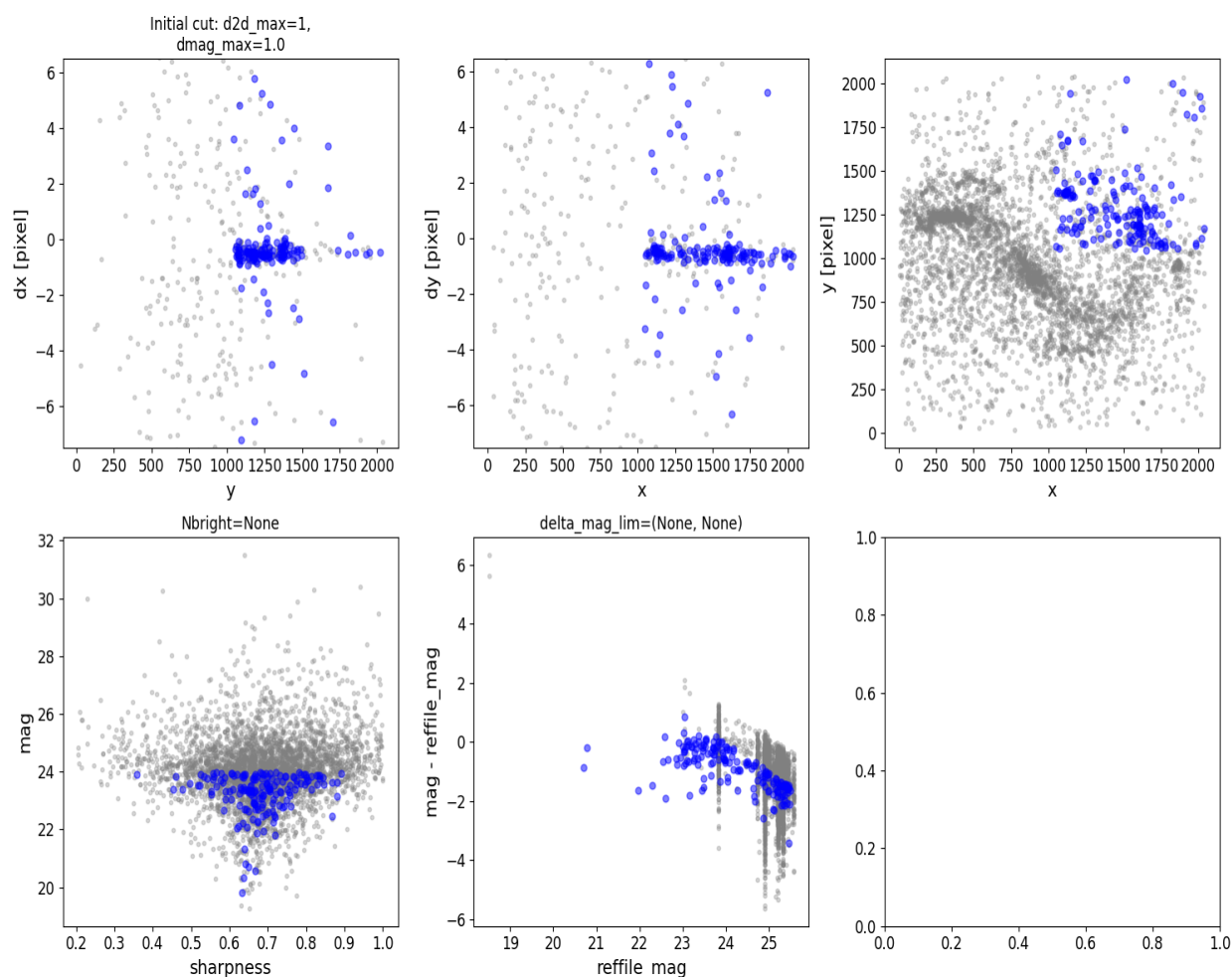
1.2 Install Development Version

Using git:

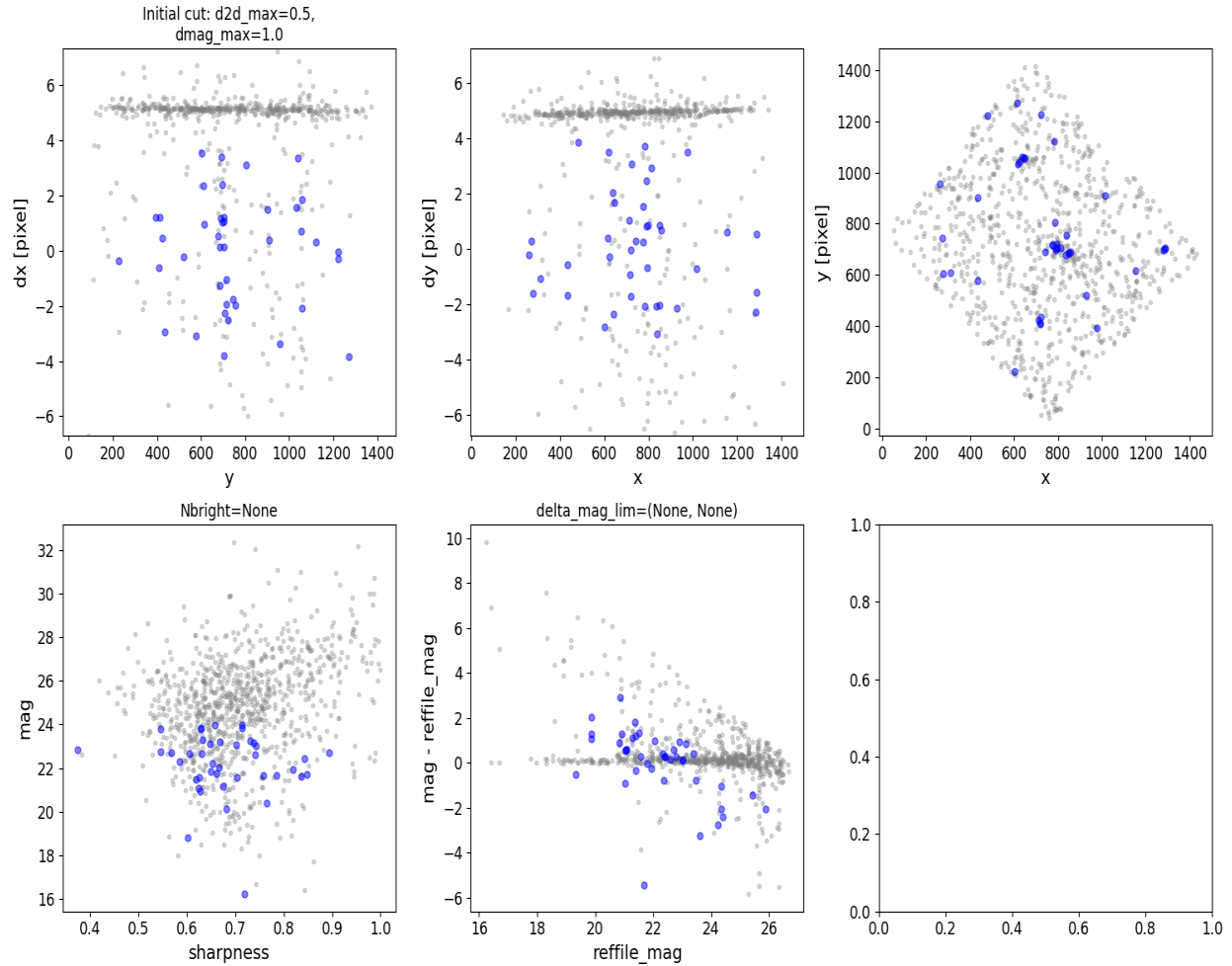
```
git clone https://github.com/arminrest/jhat.git
cd jhat
python setup.py install
```


INTERPRETING PLOTS

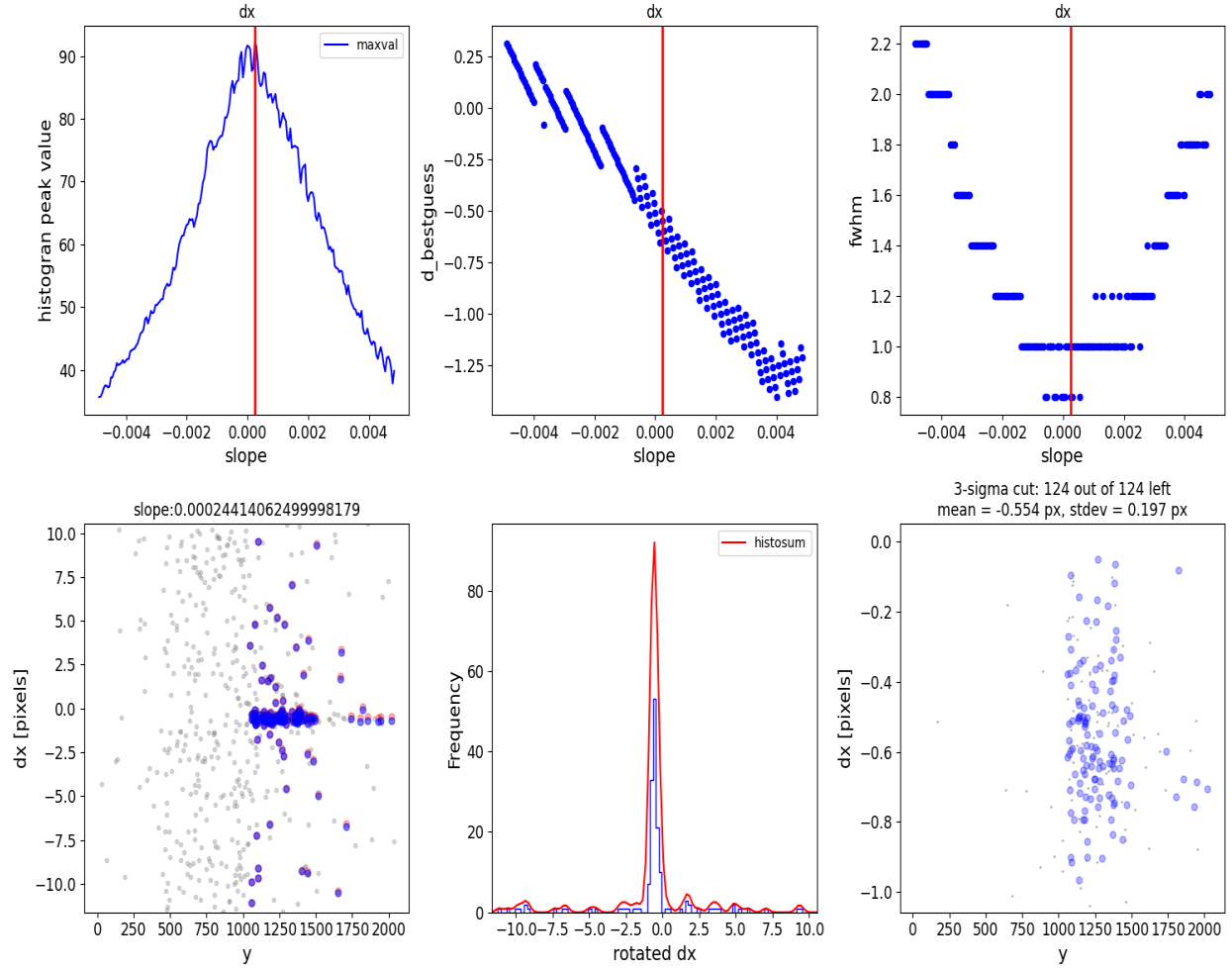
This is the initial plot to check if things are going the right direction. Here each point is a source detected in the image. Blue points have passed the initial cuts, gray points fail cuts and are not used. If there is a locus in both dx and dy , then the code will be able to find the correct alignment parameters. The second row just shows the same sources as a function of some photometric parameters.

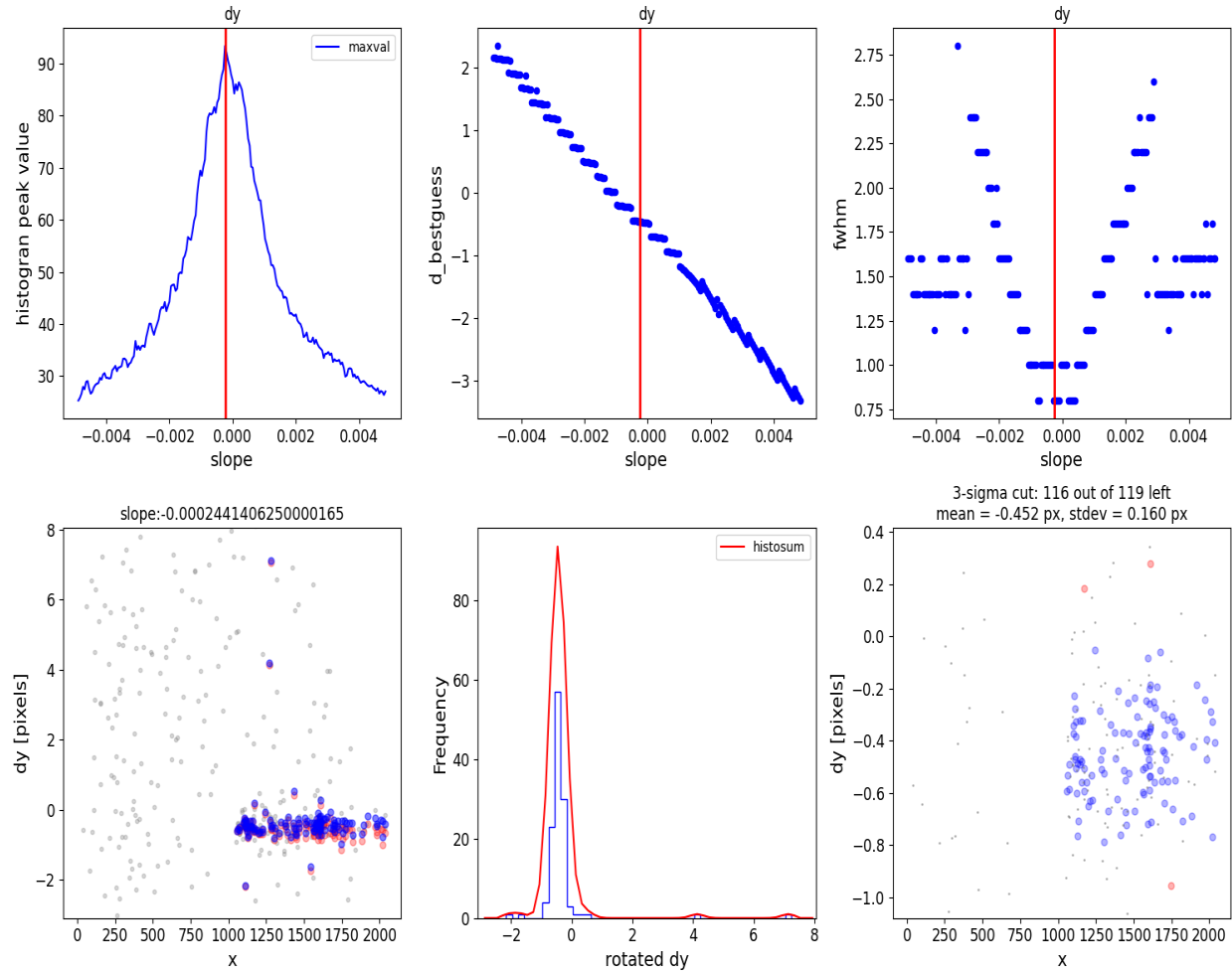


This is an example of the same set of plots for a case where the alignment has failed. No locus is apparent in dx or dy . If there is no relation to be seen in this initial plot, then cuts and params need to be changed/loosened (see [Useful Parameters](#)), in this case $d2d_max$ should be increased.

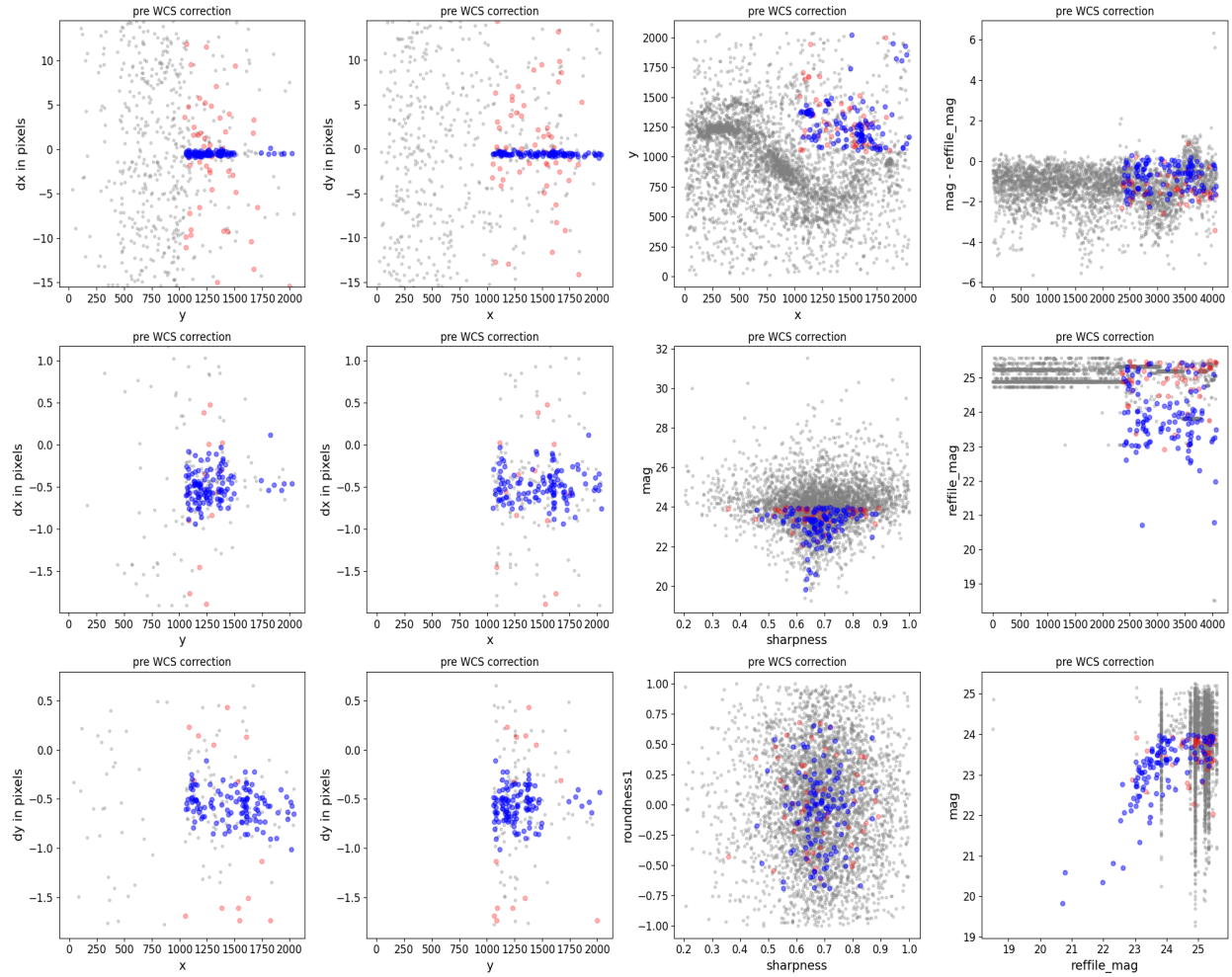


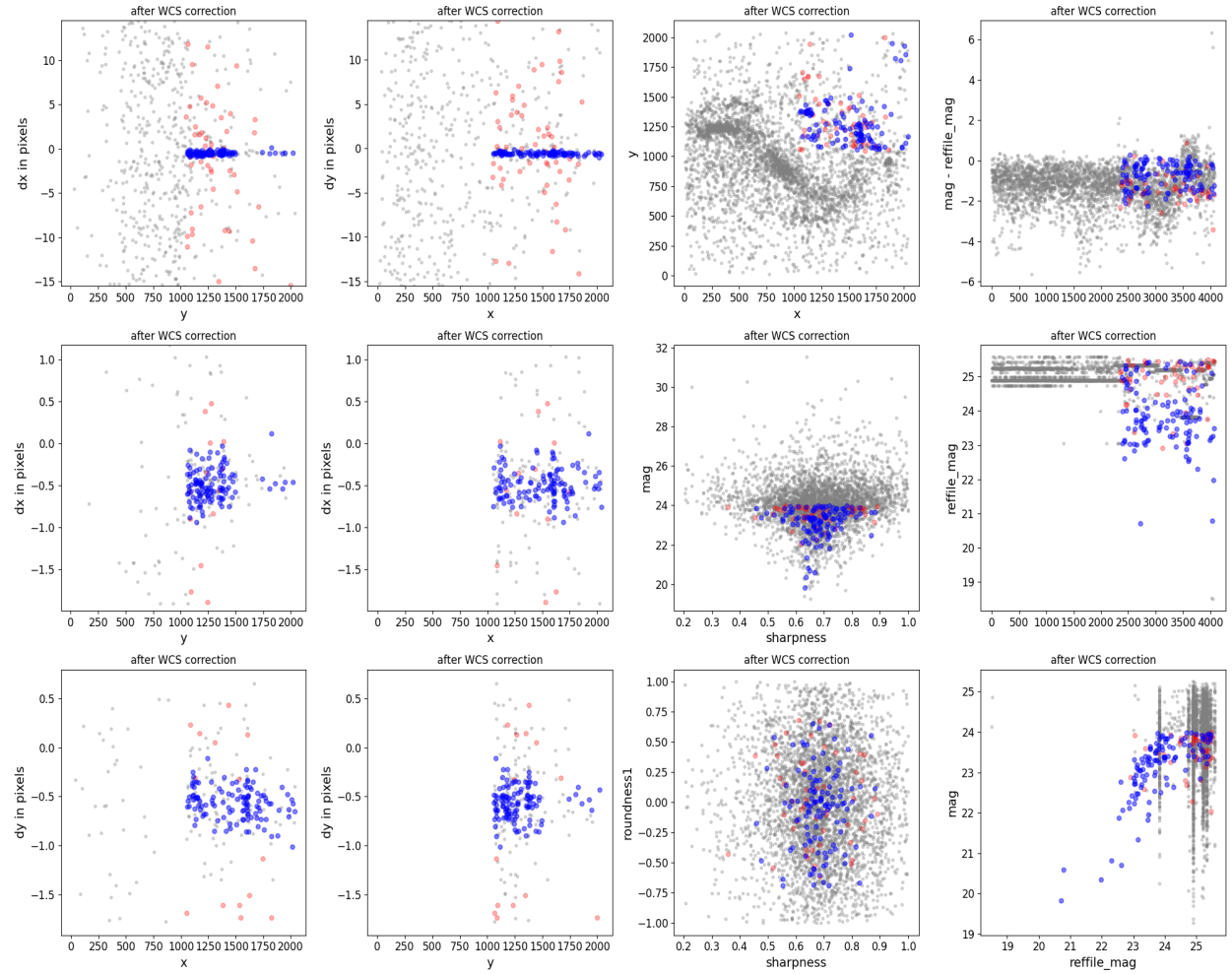
The second important set of plots comes from the selection of good matches between reference catalog and target image source catalog. First the best rotation and offset is chosen for dx , which is successful if there is a clear peak in the upper left panel (histogram peak value versus slope). In the second row, blue dots are sources that are kept after rotation, and red are the original unrotated dx residuals (lower left panel). Then a 3sigma cut is done on the sources in the dx parameter space, and red indicates the cut values in the far right center row. Finally, the the same is done for dy , but ONLY with sources that already passed the dx cut.





Finally, we can check what the alignment did by observing the pre and post wcs-correction plots.





USEFUL PARAMETERS

Here we describe the most useful parameters and what changing them does inside of the code.

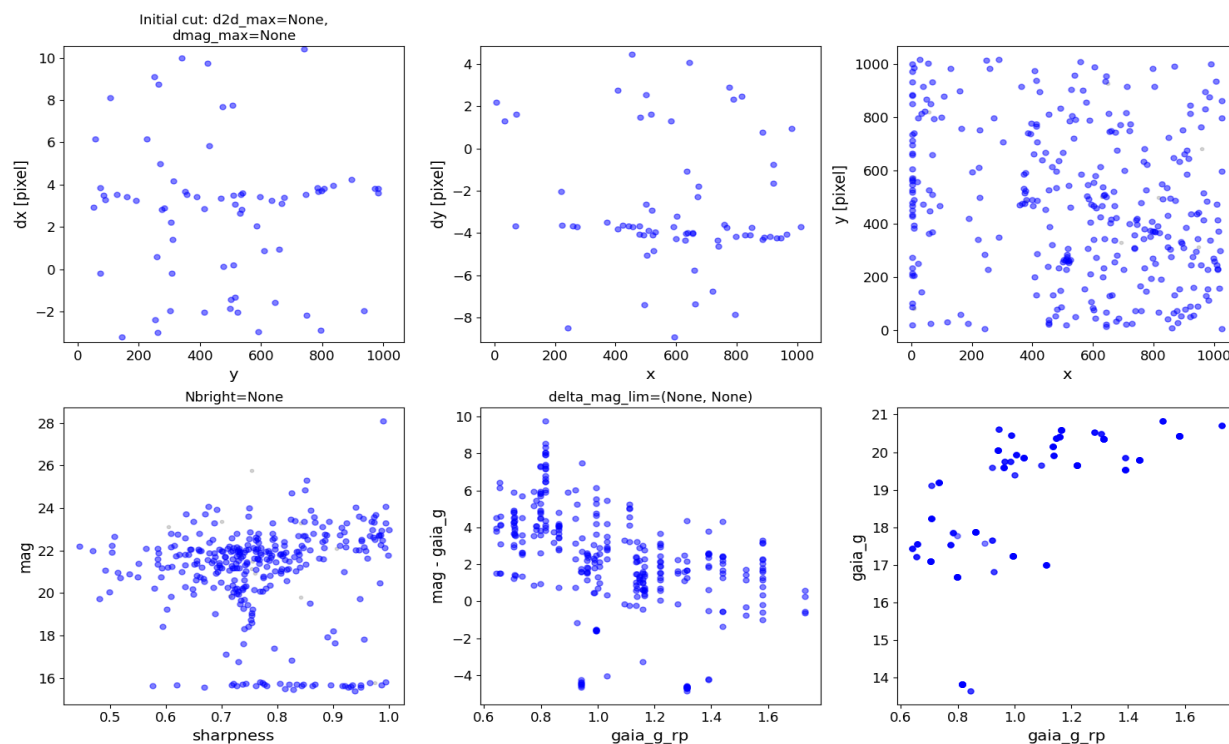
- `d2d_max`
- `sharpness_lim`
- `roundness1_lim`
- `delta_mag_lim`
- `objmag_lim`
- `refmag_lim`
- `slope_min`
- `Nbright4match`
- `Nbright`
- `xshift/yshift`
- `rough_cut_px_min/max`
- `d_rotated_Nsigma`

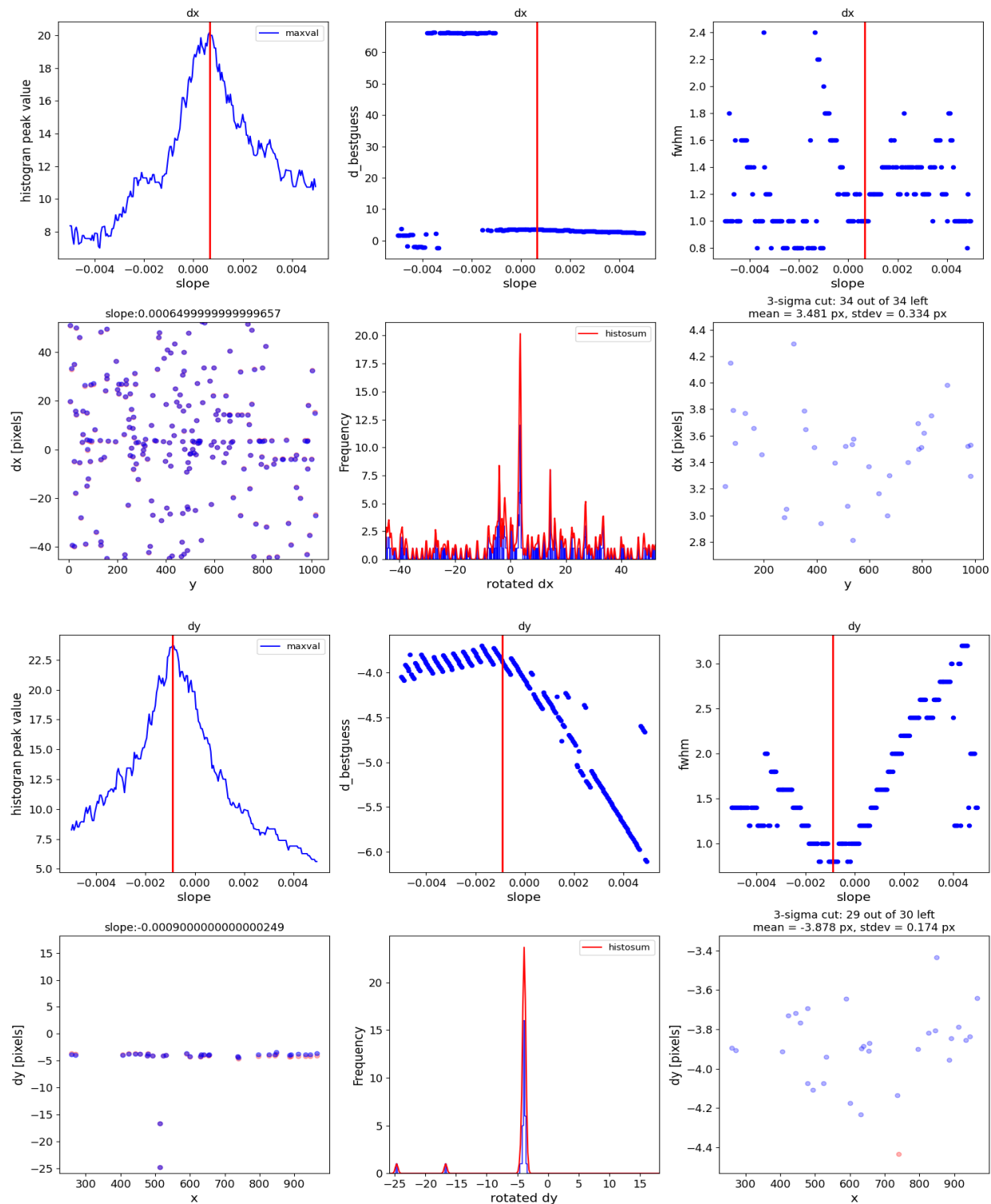
COMMAND LINE COMMANDS

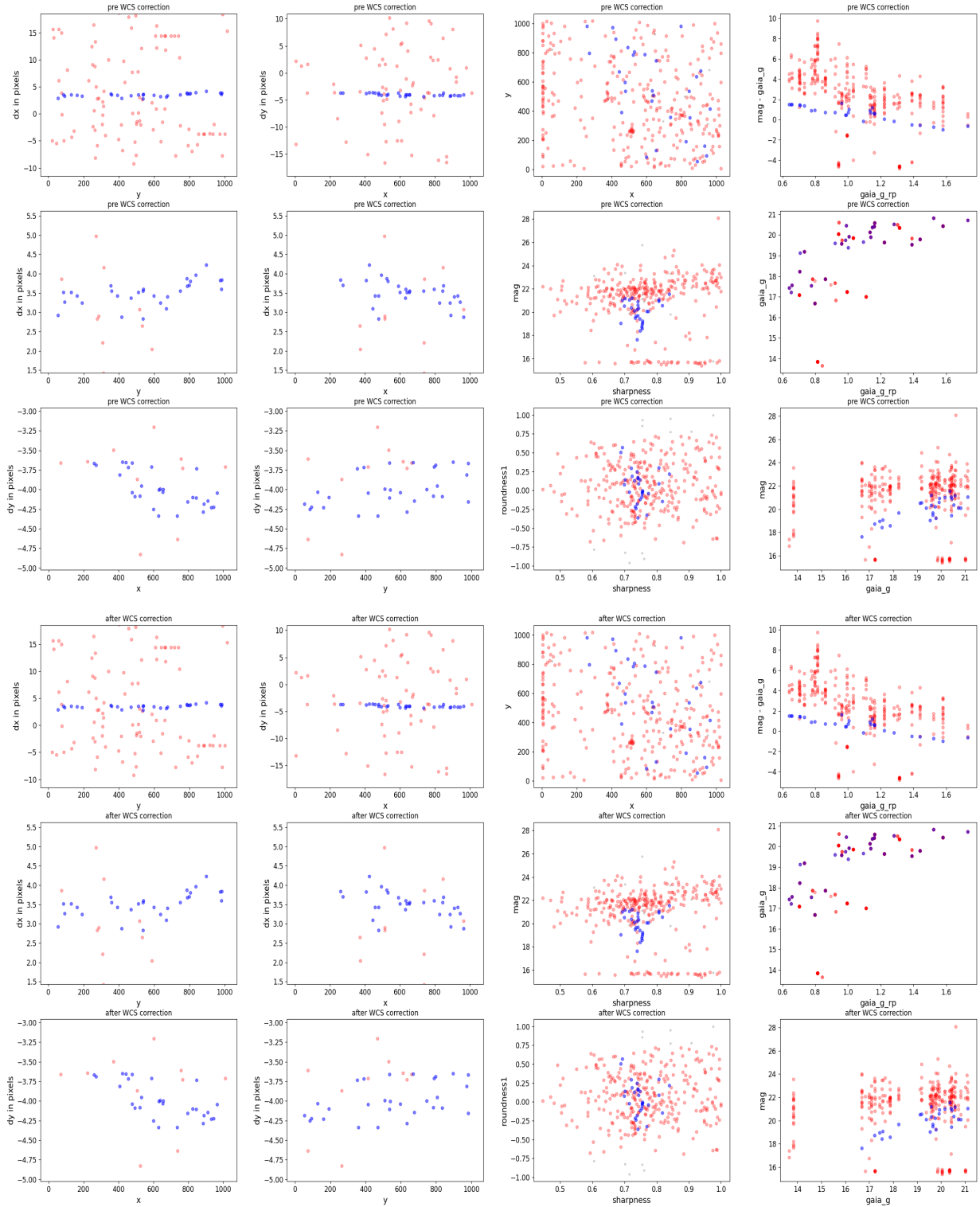
Here we have a directory called “miri_example” that has some MIRI cals. JHAT can also be run from the command line in the following way:

```
run_st_wcs_align.py miri_example/jw0266001001_02101_00001_mirimage_cal.fits --  
    ↳ outrootdir '.'  
    ↳ --outsubdir aligned --overwr -v --refcat gaia --saveplots -tt -pp --histocut_  
    ↳ order dxdy
```

Which produces the following plots:



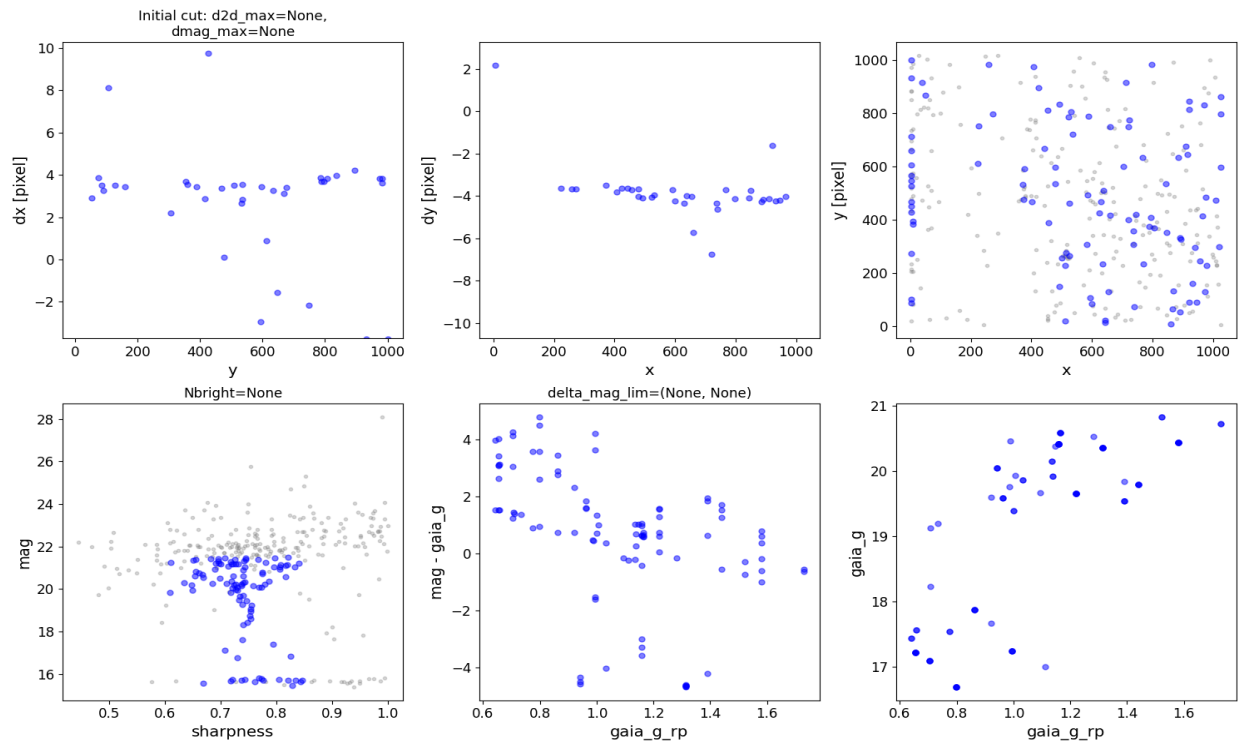


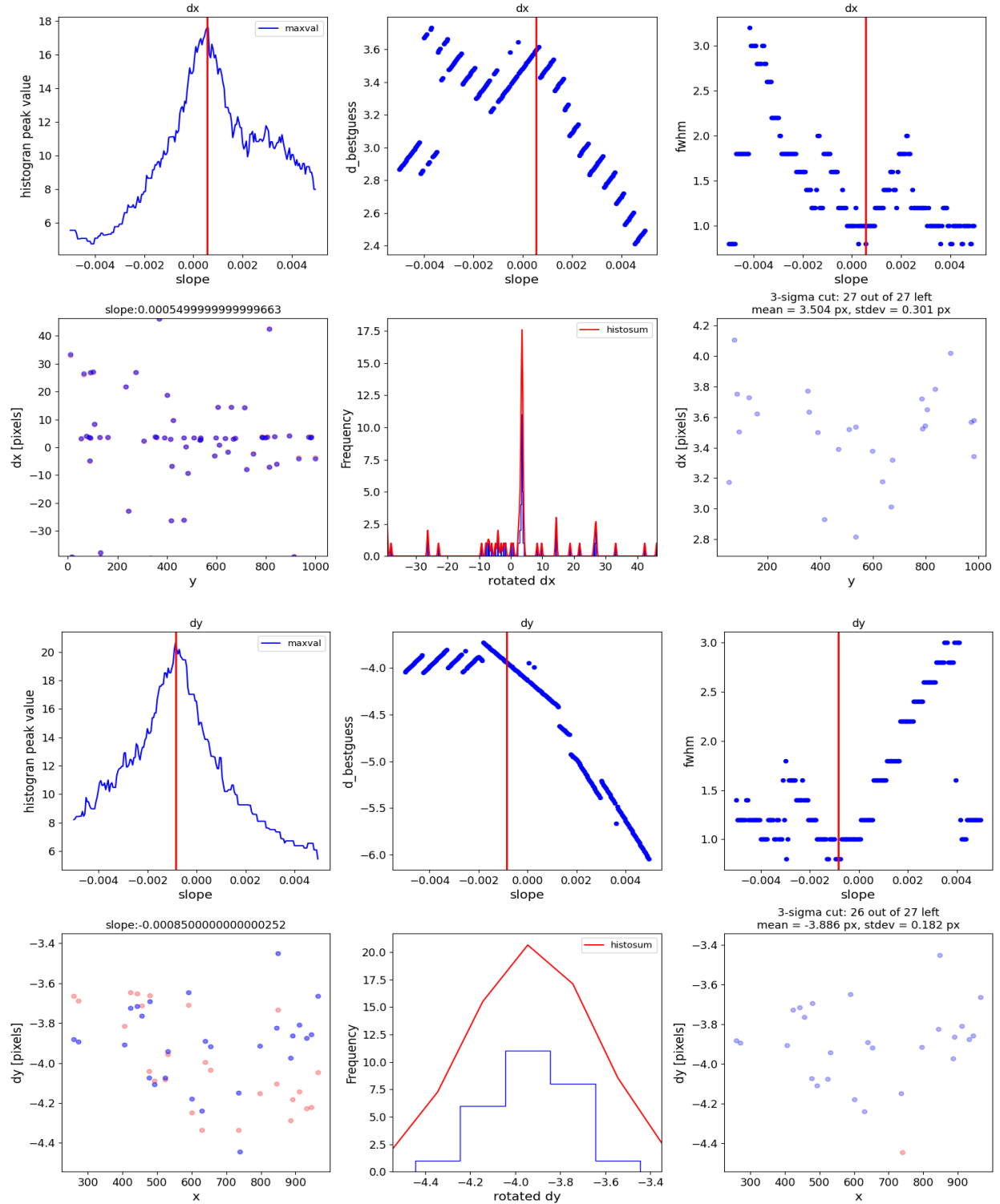


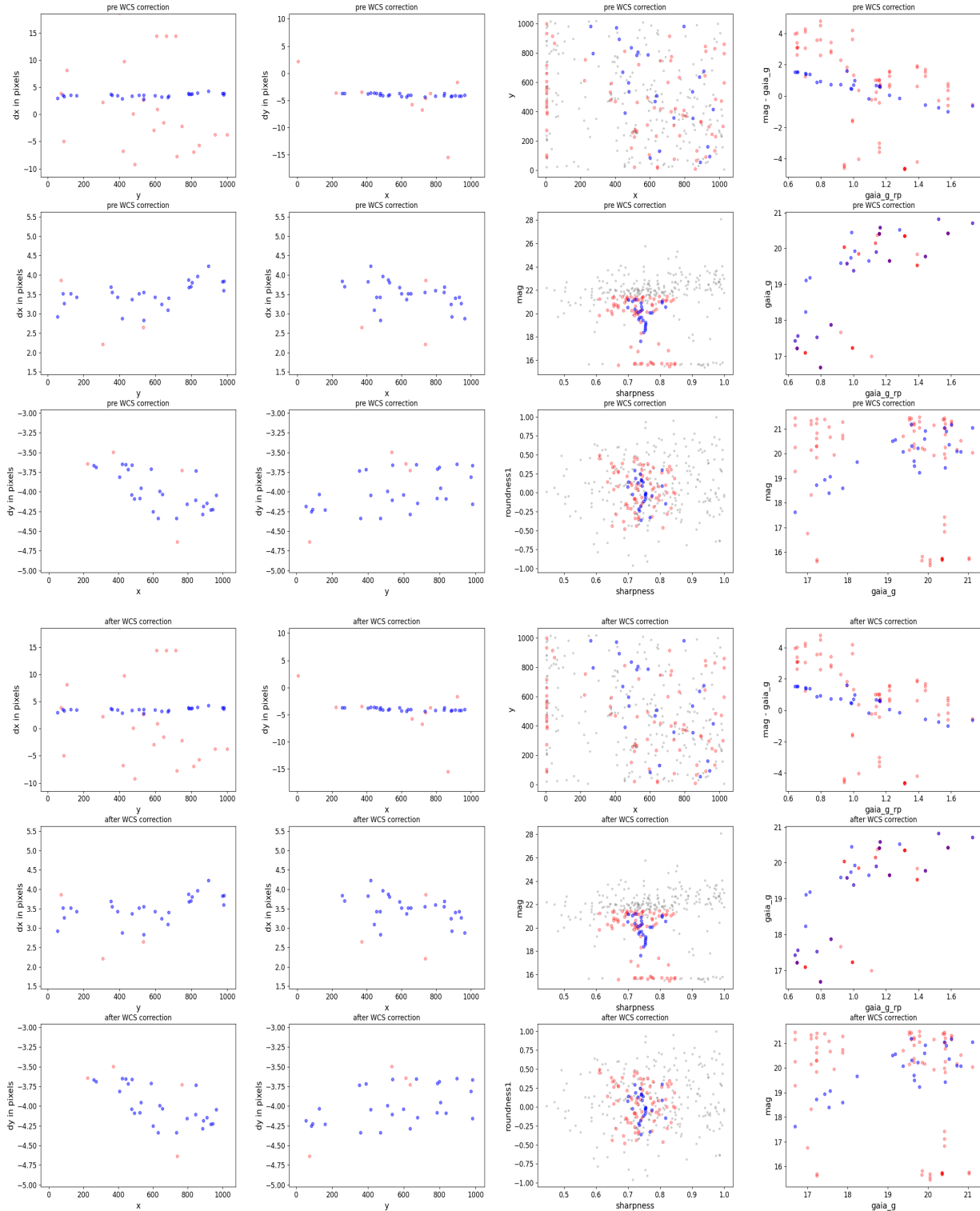
4.1 Improving Alignment

Sometimes, in particular if there are not enough sources or the images are particularly poorly aligned, JHAT has a difficult time finding a good alignment (or it can be improved). Here are a few methods for improving the results. First we add cuts on sharpness, roundness, and brightness:

```
run_st_wcs_align.py miri_example/jw02666001001_02101_00001_mirimage_cal.fits --
  ↳ outrootdir '.'
    --outsubdir aligned --overwr -v --refcat gaia --saveplots -tt -pp --histocut_
  ↳ order dxdy
    --roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --sharpness_lim 0.6 0.85 --refmag_
  ↳ lim 16 25
```







Next we increase the allowed distance between matches between the reference and target catalogs (`d2d_max`), and limit the difference between measured magnitudes between the catalogs.

```
run_st_wcs_align.py miri_example/jw02666001001_02101_00001_mirimage_cal.fits --
    outrootdir '.'
```

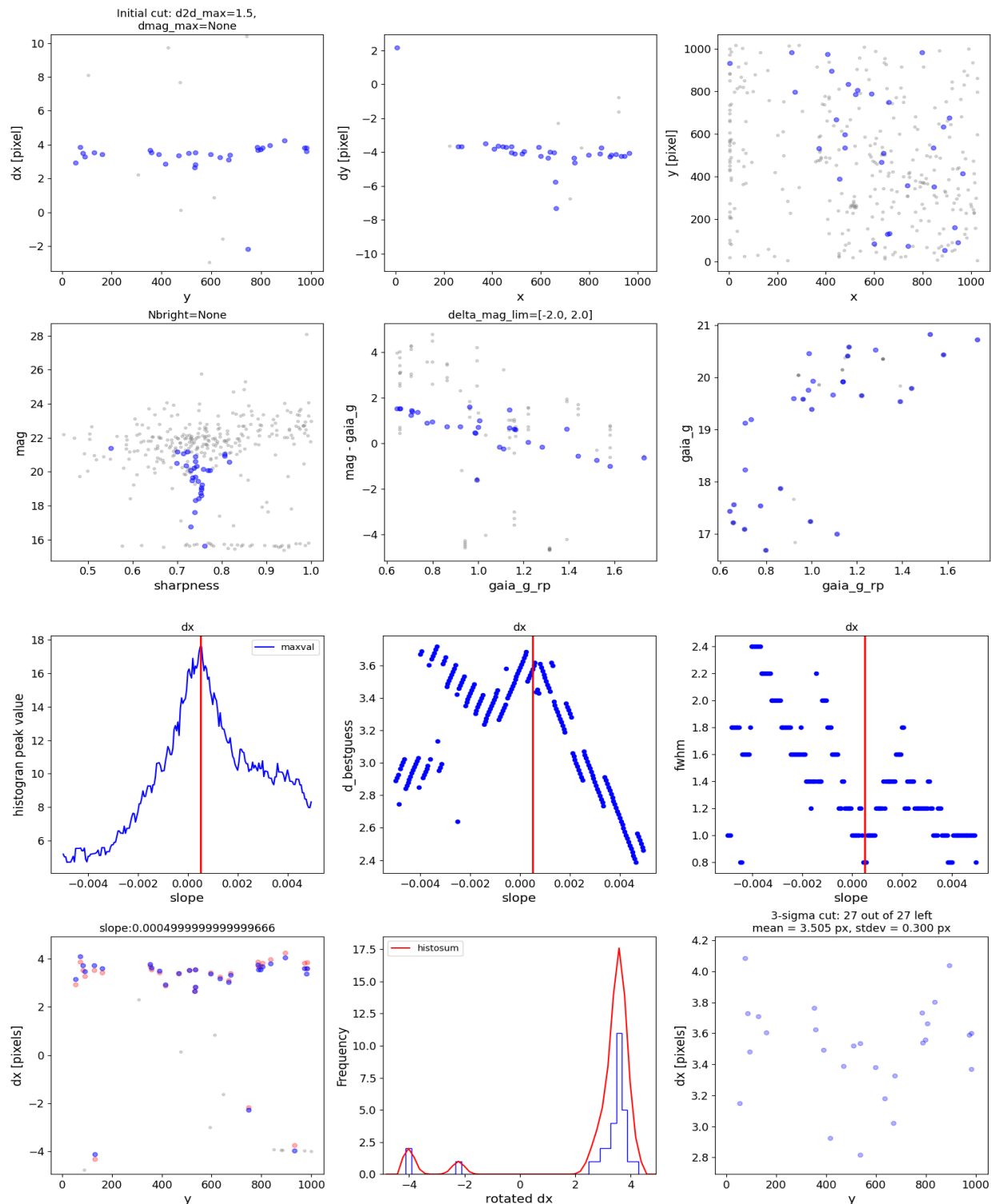
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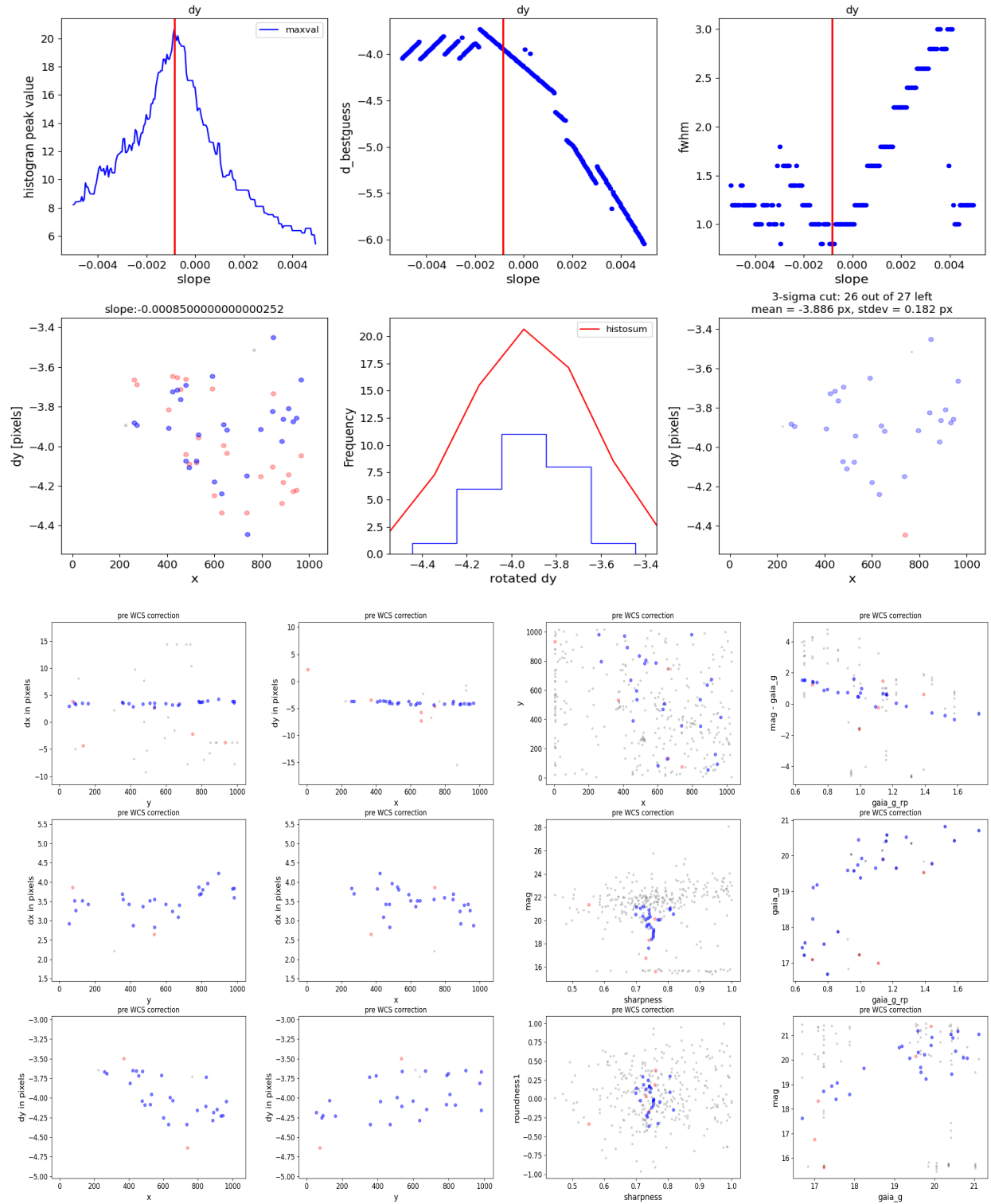
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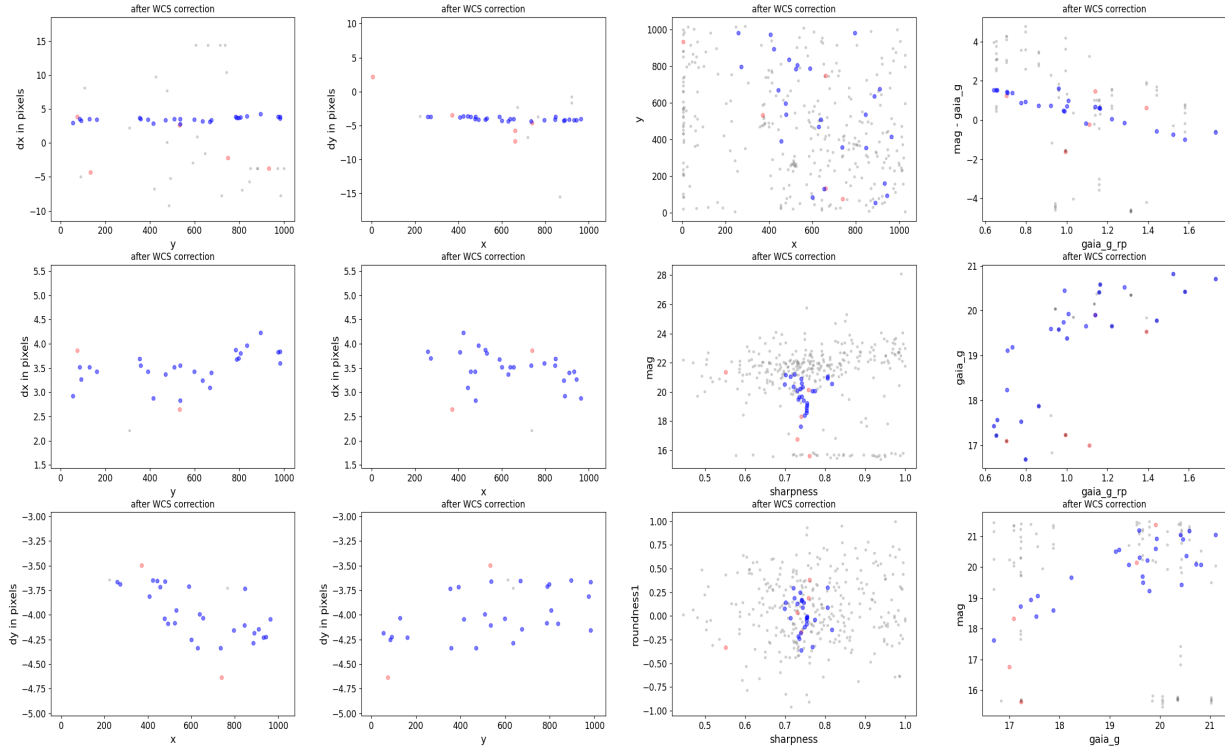
```

--outsubdir aligned --overwr -v --refcat gaia --saveplots -tt -pp --histocut_
↪order dxdy
--roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --refmag_lim 16 25 --delta_mag_
↪lim -2 2 --d2d_max 1.5

```

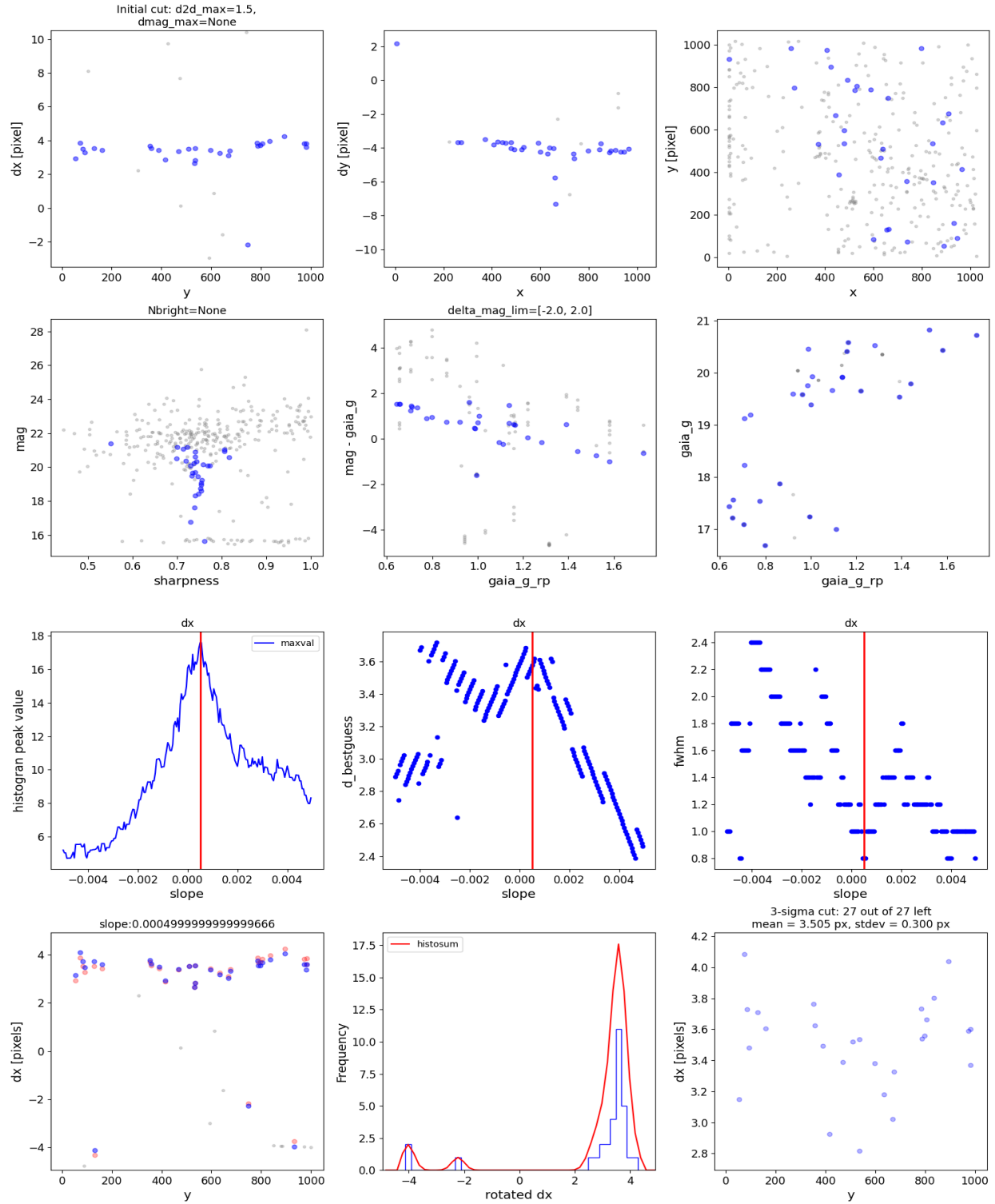


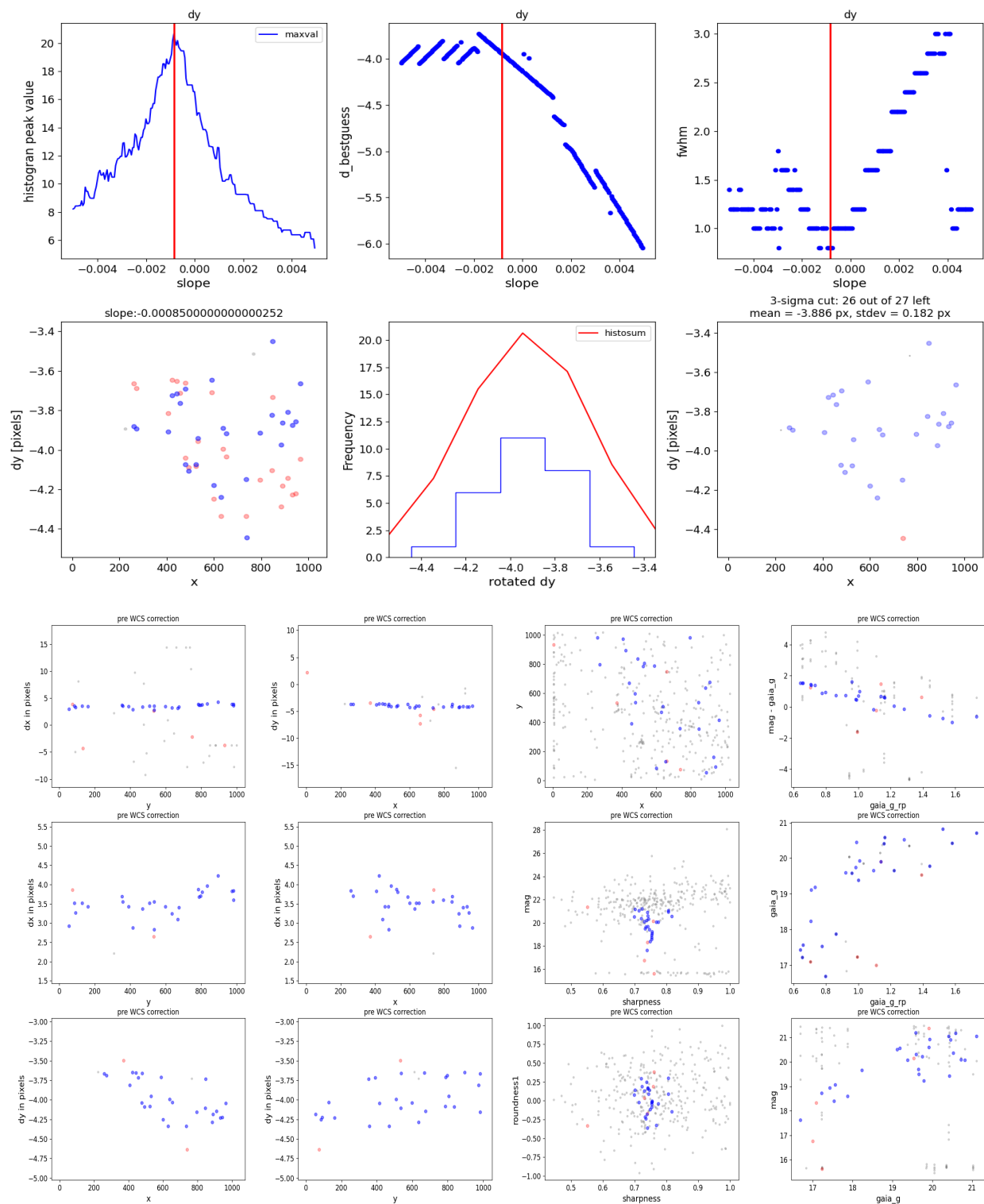


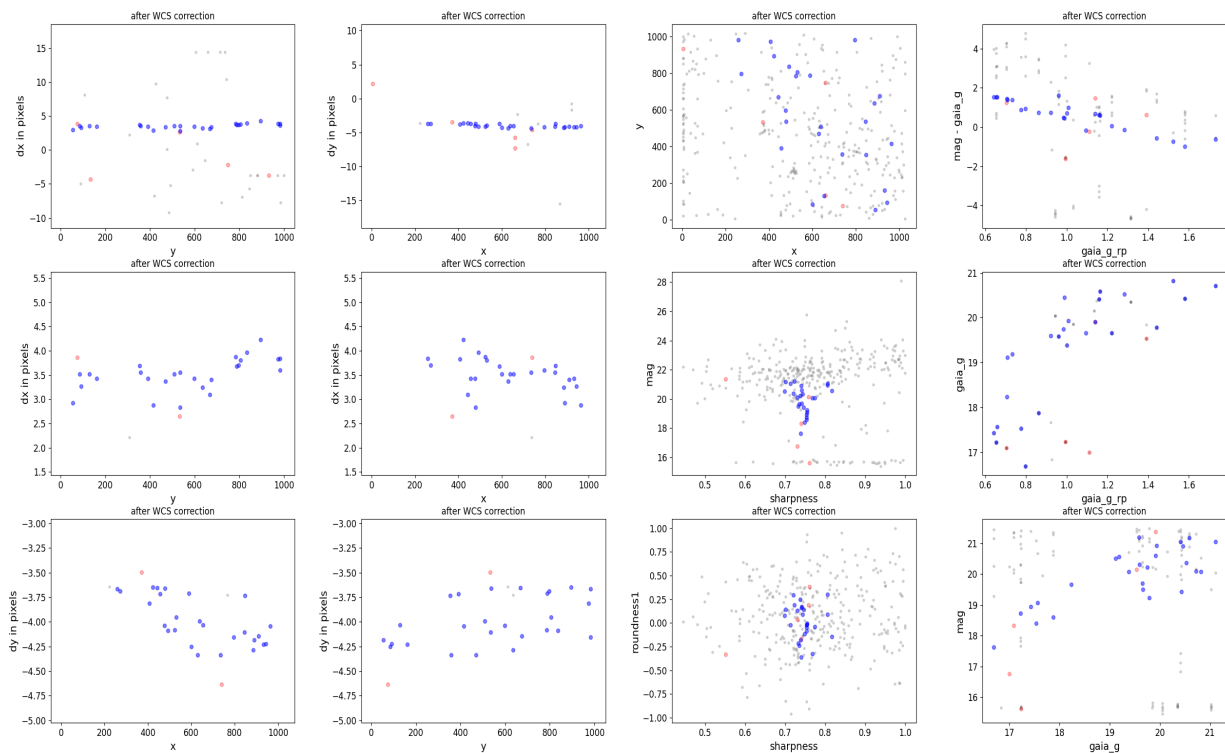


Finally, we might use the previous results to guess the rough needed offset, and apply it directly before the matching begins:

```
run_st_wcs_align.py miri_example/jw0266001001_02101_00001_mirimage_cal.fits --
  ↳ outrootdir '.'
      --outsubdir aligned --overwr -v --refcat gaia --saveplots -tt -pp --histocut_
  ↳ order dxdy
      --roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --refmag_lim 16 25 --delta_mag_
  ↳ lim -2 2
      --d2d_max 1.5 --xshift 3 --yshift -4
```







LEVEL 3 FROM ALIGNED CALS

We run F560W with the best options determined from the *Improving Alignment* example:

```
run_st_wcs_align_batch.py --input_dir '.' --input_files 'miri_example/*_cal.fits' --
↳ outrootdir aligned
    --outsubdir F560W_level2_gaia --overwr -v --refcat gaia --saveplots -tt -pp --
↳ histocut_order dxdy
    --roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --refmag_lim 16 25 --delta_mag_
↳ lim -2 2
    --d2d_max 1.5 --xshift 3 --yshift -4 --filter F560W
```

Now we run the notebook that runs level3 and creates the mosaic and the corresponding catalog ([On GitHub here](#)). That notebook produces a catalog (F560W_snr3_npix10_cat.ecsv), which we choose as our secondary astrometric catalog.

Now we run the rest of the filters. However, we remove `--delta_mag_lim`, since this cut depends on the filter!!! Note that we define the necessary column names from the catalog, which are different from the defaults.

```
run_st_wcs_align_batch.py --input_dir '.' --input_files 'miri_example/*_cal.fits' --
↳ outrootdir miri_example
    --outsubdir ALL_level2_catF560W --overwr -v --refcat F560W_snr3_npix10_cat.ecsv_
↳ --saveplots -tt -pp
    --histocut_order dxdy --roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --refmag_
↳ lim 16 25 --d2d_max 1.5
    --xshift 3 --yshift -4 --iterate_with_xyshifts --refcat_racol sky_centroid.ra
    --refcat_deccol sky_centroid.dec --refcat_magcol aper50_abmag --refcat_
↳ magerrcol aper50_abmag_err
    --filters F560W F1000W F1280W F1130W F1500W F1800W
```

We find that F1500W F1800W mostly work, but don't have many stars. Therefore we run it with `--d_rotated_Nsigma 0.0`: Too few stars to do a 3-sigma cut.

```
run_st_wcs_align_batch.py --input_dir '.' --input_files 'miri_example/*_cal.fits' --
↳ outrootdir miri_example
    --outsubdir ALLRED_level2_catF560W --overwr -vvv --refcat F560W_snr3_npix10_cat.
↳ ecsv --saveplots -tt -pp
    --histocut_order dxdy --roundness1_lim -0.5 0.5 --objmag_lim 14 21.5 --refmag_
↳ lim 16 25 --d2d_max 1.5 --xshift 3
    --yshift -4 --iterate_with_xyshifts --refcat_racol sky_centroid.ra --refcat_
↳ deccol sky_centroid.dec --refcat_magcol
    aper50_abmag --refcat_magerrcol aper50_abmag_err --filters F1500W F1800W_
↳ F2100W --d_rotated_Nsigma 0.0
```


EXAMPLES

6.1 JWST MIRI

Aligning JWST/MIRI images with JHAT.

An example MIRI Dataset is downloaded, and then a series of alignment methods are used. For more information on the key parameters used for alignment see *Useful Parameters*.

```
import sys,os,glob
from astropy.io import fits
from astropy.table import Table
from astropy.nddata import extract_array
from astropy.coordinates import SkyCoord
from astropy import wcs
from astropy.wcs.utils import skycoord_to_pixel
from astropy import units as u
import numpy as np
import matplotlib.pyplot as plt
from astroquery.mast import Observations
from astropy.visualization import (simple_norm,LinearStretch)

import jhat
from jhat import jwst_photclass,st_wcs_align
```

6.1.1 Relative Alignment

Download some Data

For this example we download 2 MIRI cal images from MAST. They're the same field and different filters. Note that the code will also work for level 3 images.

```
obs_table1 = Observations.query_criteria(obs_id='jw02107-o038-t019-miri-f770w')
data_products_by_obs = Observations.get_product_list(obs_table1)
data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==2]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
↳ 'productSubGroupDescription']=='CAL'][0]
Observations.download_products(data_products_by_obs,extension='fits')

obs_table2 = Observations.query_criteria(obs_id='jw02107-c1018-t019-miri-f1130w')
data_products_by_obs = Observations.get_product_list(obs_table2)
```

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```

data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==2]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
    ↳ 'productSubGroupDescription']=='CAL'][0]
Observations.download_products(data_products_by_obs,extension='fits')

```

```

Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:JWST/product/
↳ jw02107038001_02101_00001_mirimage_cal.fits to ./mastDownload/JWST/jw02107038001_02101_
↳ 00001_mirimage/jw02107038001_02101_00001_mirimage_cal.fits ... [Done]
Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:JWST/product/
↳ jw02107038001_02105_00001_mirimage_cal.fits to ./mastDownload/JWST/jw02107038001_02105_
↳ 00001_mirimage/jw02107038001_02105_00001_mirimage_cal.fits ... [Done]

```

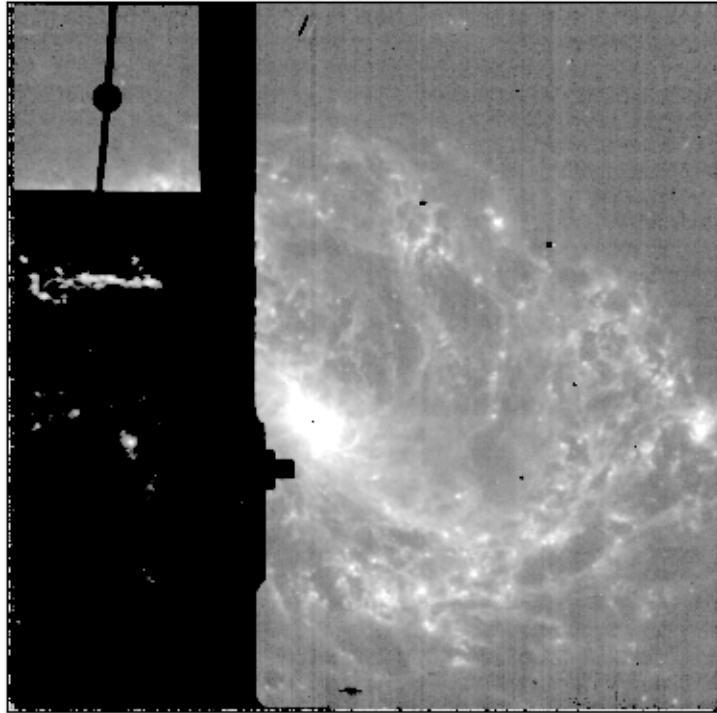
Examine the Reference Image

```

files = glob.glob('mastDownload/JWST/*miri*/*cal.fits')
ref_image = files[0]
print(ref_image)
ref_fits = fits.open(ref_image)
ref_data = fits.open(ref_image)['SCI',1].data
norm1 = simple_norm(ref_data,stretch='log',min_cut=5,max_cut=25)

plt.imshow(ref_data, origin='lower',
            norm=norm1,cmap='gray')
plt.gca().tick_params(labelcolor='none',axis='both',color='none')
plt.show()

```



```
mastDownload/JWST/jw02107038001_02101_00001_mirimage/jw02107038001_02101_00001_mirimage_
↳ cal.fits
```

Zoom in to see the offset

Here add an artificial offset to the wcs, and then we see the same star in both images at the same ra/dec location, demonstrating a large offset between the images.

```
star_location = SkyCoord('23:09:44.0809', '-43:26:05.613', unit=(u.hourangle, u.deg))
align_image = files[1]
align_fits = fits.open(align_image)
align_fits['SCI', 1].header['CRPIX1'] += 2
align_fits['SCI', 1].header['CRPIX2'] += 2
align_fits.writeto(align_image, overwrite=True)

align_data = fits.open(align_image)['SCI', 1].data
ref_y, ref_x = skycoord_to_pixel(star_location, wcs.WCS(ref_fits['SCI', 1], ref_fits))
align_y, align_x = skycoord_to_pixel(star_location, wcs.WCS(align_fits['SCI', 1], align_
↳ fits))

ref_cutout = extract_array(ref_data, (11, 11), (ref_x, ref_y))
align_cutout = extract_array(align_data, (11, 11), (align_x, align_y))
norm1 = simple_norm(ref_cutout, stretch='log', min_cut=-1, max_cut=200)
norm2 = simple_norm(align_cutout, stretch='log', min_cut=-1, max_cut=200)
```

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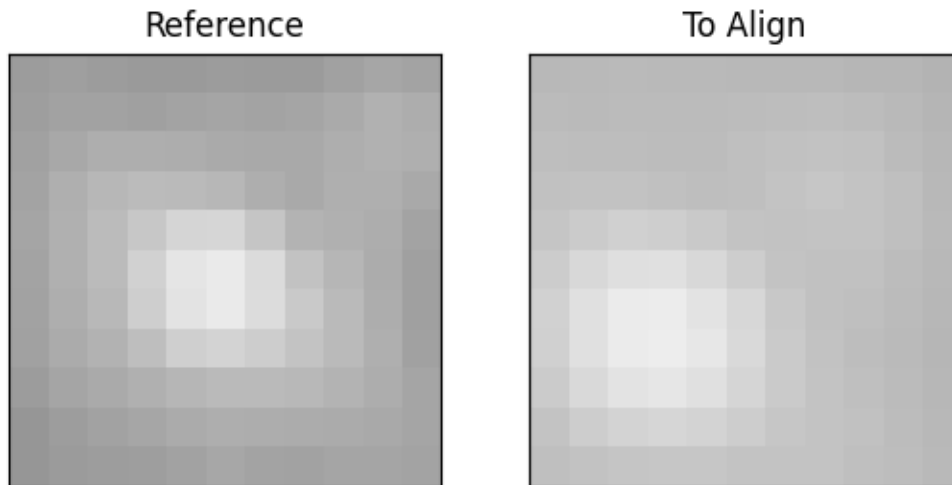
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```

fig, axes = plt.subplots(1, 2)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(align_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[0].tick_params(labelcolor='none', axis='both', color='none')
axes[1].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```



```

/Users/jpierrez/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
→py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
→06T17:29:42.548' from MJD-BEG.
Set DATE-AVG to '2022-07-06T17:29:53.648' from MJD-AVG.
Set DATE-END to '2022-07-06T17:30:04.748' from MJD-END'.
    warnings.warn(
/Users/jpierrez/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
→py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.176807 from
→OBSGEO-[XYZ].
Set OBSGEO-B to  -38.353152 from OBSGEO-[XYZ].

```

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```

Set OBSGEO-H to 1740801417.596 from OBSGEO-[XYZ]'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
↳06T17:47:53.158' from MJD-BEG.
Set DATE-AVG to '2022-07-06T17:48:32.008' from MJD-AVG.
Set DATE-END to '2022-07-06T17:49:10.859' from MJD-END'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.174733 from
↳OBSGEO-[XYZ].
Set OBSGEO-B to  -38.353284 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740817774.322 from OBSGEO-[XYZ]'.
    warnings.warn(

```

Create a Photometric Catalog for Relative Alignment

We choose one of the images to be the reference image, and then create a catalog that we will use to align the other image.

```

jwst_phot = jwst_photclass()
jwst_phot.run_phot(imagename=ref_image, photfilename='auto', overwrite=True)
ref_catname = ref_image.replace('.fits', '.phot.txt') # the default
refcat = Table.read(ref_catname, format='ascii')
print(refcat)

```

```

0 mastDownload/JWST/jw02107038001_02101_00001_mirimage/jw02107038001_02101_00001_
↳mirimage_cal.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
↳06T17:29:42.548' from MJD-BEG.
Set DATE-AVG to '2022-07-06T17:29:53.648' from MJD-AVG.
Set DATE-END to '2022-07-06T17:30:04.748' from MJD-END'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.176807 from
↳OBSGEO-[XYZ].
Set OBSGEO-B to  -38.353152 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740801417.596 from OBSGEO-[XYZ]'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/units/
↳function/logarithmic.py:47: RuntimeWarning: invalid value encountered in log10
    return dex.to(self._function_unit, np.log10(x))
/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:897: RuntimeWarning: invalid value

```

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```

↪ encountered in log10
phot['magerrr'] = 2.5 * np.log10(1.0 + (fluxerr/flux))
aper_sum_4.1px annulus_median_4.1px aper_bkg_4.1px ... x_idl y_idl
-----
297.650667 -99.99 -5238.189153 ... 37.152004 -55.873059
378.648855 5.548146 290.651448 ... 30.043803 -54.923731
115.583682 -99.99 -5238.189153 ... -76.001952 -54.071845
294.794123 0.126702 6.63754 ... -76.013673 -51.700329
234.943054 0.218582 11.450907 ... -76.018672 -50.556787
467.419303 6.36806 333.604394 ... -3.833359 -48.74132
342.922546 0.173903 9.110269 ... -76.032743 -47.064001
371.015027 0.207516 10.871191 ... -76.037395 -45.257877
173.426586 0.099091 5.191109 ... -76.03994 -44.794514
838.584206 7.751832 406.096233 ... -9.072841 -43.561009
...
133.430719 0.1092 5.720696 ... -75.754248 30.346453
245.152683 0.405534 21.244786 ... -75.721452 34.663273
233.690538 0.556301 29.143019 ... -75.716036 35.792661
445.263408 0.72363 37.908921 ... -75.646588 46.09179
176.538 0.783822 41.062174 ... -75.634492 47.785745
617.329614 4.899353 256.663045 ... 36.555135 50.32043
622.234759 4.964599 260.081101 ... 36.55006 51.069329
330.330828 0.707696 37.074164 ... -75.607653 52.275188
378.108748 0.679931 35.619658 ... -75.600128 53.678531
547.845954 -99.99 -5238.189153 ... -75.589207 55.779377
459.438067 -99.99 -5238.189153 ... 36.520526 55.674128
Length = 211 rows

```

Align the second image

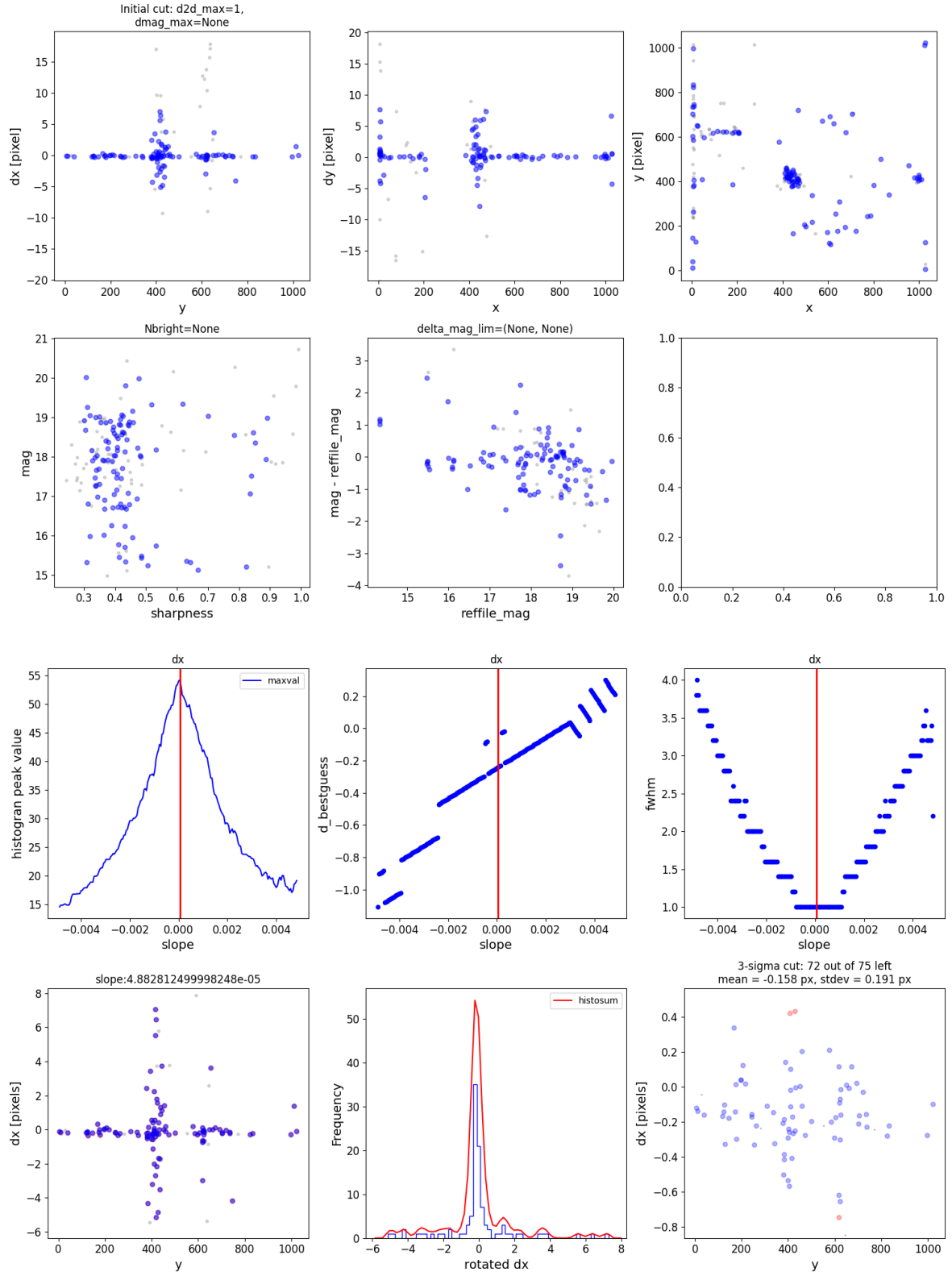
The plots outputted here show the various steps used by jhat to determine the true matching sources in the image, and the subsequent correction needed for optimal alignment.

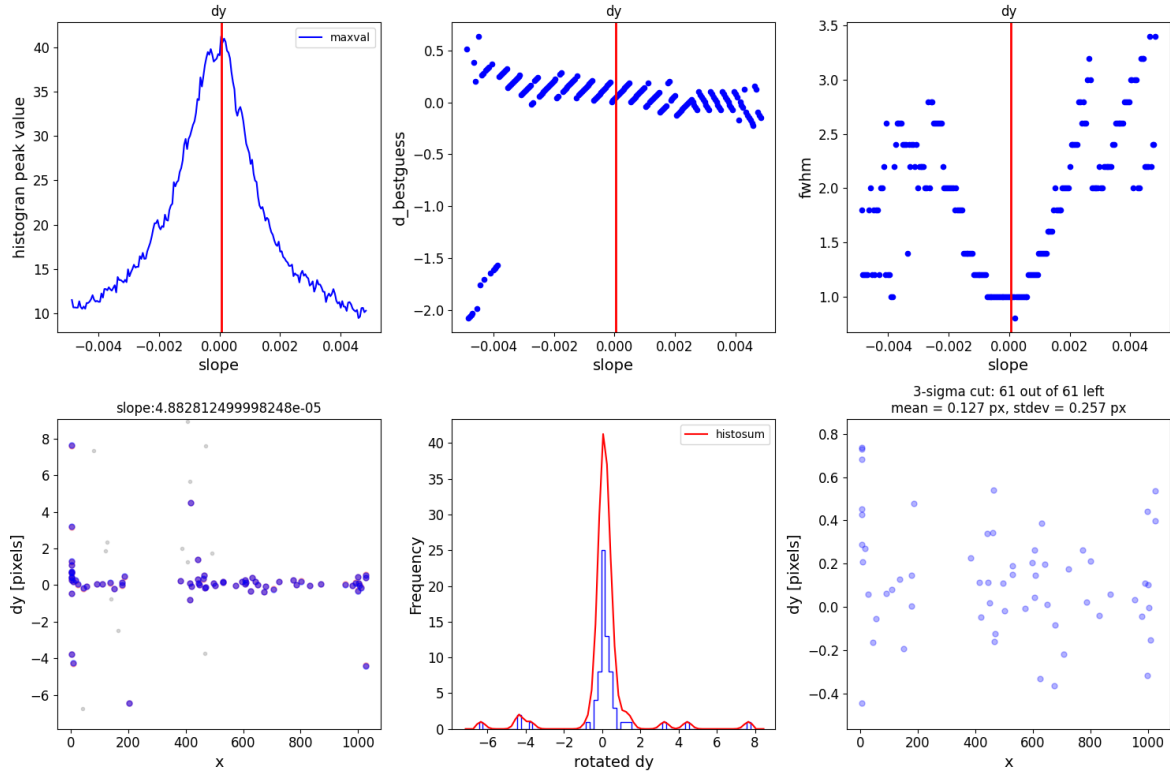
```

wcs_align = st_wcs_align()

wcs_align.run_all(align_image,
                  telescope='jwst',
                  outsubdir='mastDownload',
                  refcat_racol='ra',
                  refcat_deccol='dec',
                  refcat_magcol='mag',
                  refcat_magerrcol='dmag',
                  overwrite=True,
                  d2d_max=1,
                  showplots=2,
                  refcatname=ref_catname,
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,
                  objmag_lim =(14,24))

```





```
0 ./mastDownload/jw02107038001_02105_00001_mirimage.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
06T17:47:53.158' from MJD-BEG.
Set DATE-AVG to '2022-07-06T17:48:32.008' from MJD-AVG.
Set DATE-END to '2022-07-06T17:49:10.859' from MJD-END'.
warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.174733 from
OBSGEO-[XYZ].
Set OBSGEO-B to -38.353284 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740817774.322 from OBSGEO-[XYZ]'.
warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/units/
function/logarithmic.py:47: RuntimeWarning: invalid value encountered in log10
return dex.to(self._function_unit, np.log10(x))
/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:897: RuntimeWarning: invalid value
encountered in log10
phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/flux))
```

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```

*** Note: close plot to continue!
      slope intercept    maxval  index  d_bestguess  fwhm  multimax
0.000049    -0.025 54.211365    28    -0.241148  1.0    False
Keeping 75 out of 75, skipping 0 because of null values in columns d_rot_tmp
median: -0.161845
75.000000 percentile cut: max residual for cut: 0.212953
median: -0.162629
i:00 mean:-0.162629(0.014451) stdev:0.107171(0.010127) X2norm:0.99 Nchanged:0 Ngood:56
↪Nclip:19

mean: -0.144962
i:01 mean:-0.144962(0.017233) stdev:0.136786(0.012090) X2norm:1.00 Nchanged:8 Ngood:64
↪Nclip:11

mean: -0.145593
i:02 mean:-0.145593(0.019481) stdev:0.159460(0.013674) X2norm:1.00 Nchanged:4 Ngood:68
↪Nclip:7

mean: -0.158406
i:03 mean:-0.158406(0.020980) stdev:0.174271(0.014729) X2norm:1.00 Nchanged:2 Ngood:70
↪Nclip:5

mean: -0.158419
i:04 mean:-0.158419(0.022668) stdev:0.191002(0.015917) X2norm:1.00 Nchanged:2 Ngood:72
↪Nclip:3

mean: -0.158419
i:05 mean:-0.158419(0.022668) stdev:0.191002(0.015917) X2norm:1.00 Nchanged:0 Ngood:72
↪Nclip:3
      slope intercept    maxval  index  d_bestguess  fwhm  multimax
0.000049    -0.025195 41.262524    36     0.051438  1.0    False
Keeping 61 out of 61, skipping 0 because of null values in columns d_rot_tmp
median: 0.109562
75.000000 percentile cut: max residual for cut: 0.288823
median: 0.102123
i:00 mean:0.102123(0.021089) stdev:0.139885(0.014745) X2norm:0.99 Nchanged:0 Ngood:45
↪Nclip:16

mean: 0.114686
i:01 mean:0.114686(0.024837) stdev:0.177373(0.017393) X2norm:1.00 Nchanged:7 Ngood:52
↪Nclip:9

mean: 0.105753
i:02 mean:0.105753(0.028650) stdev:0.214397(0.020080) X2norm:1.00 Nchanged:5 Ngood:57
↪Nclip:4

mean: 0.126734
i:03 mean:0.126734(0.033214) stdev:0.257275(0.023293) X2norm:1.00 Nchanged:4 Ngood:61
↪Nclip:0

mean: 0.126734
i:04 mean:0.126734(0.033214) stdev:0.257275(0.023293) X2norm:1.00 Nchanged:0 Ngood:61

```

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```

↪Nclip:0
*** Note: close plots to continue!
/Users/jpierel/CodeBase/tweakreg_hack/tweakreg_hack/tweakreg_step_hack.py:540:
↪AstropyDeprecationWarning: The JWSTgWCS class is deprecated and may be removed in a
↪future version.
    Use JWSTWCSCorrector instead.
    im = JWSTgWCS(
replacing SIP ./mastDownload/jw02107038001_02105_00001_mirimage_jhat.fits
./mastDownload/jw02107038001_02105_00001_mirimage_jhat.fits
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↪py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.174733 from
↪OBSGEO-[XYZ].
Set OBSGEO-B to -38.353284 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740817774.322 from OBSGEO-[XYZ]'.
    warnings.warn(
*** Note: close plots to continue!

0

```

Check the Output

The reference image has not changed, but let's read in the newly aligned image and compare with the original. subsequent correction needed for optimal alignment.

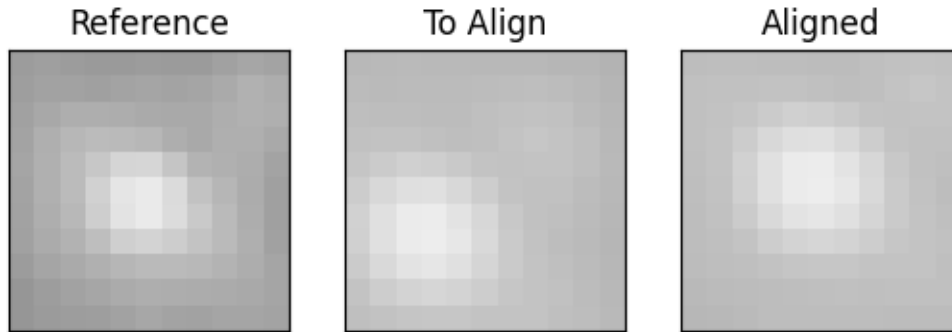
```

aligned_image = os.path.join('mastDownload', os.path.basename(aligned_image).replace('cal.
↪fits', 'jhat.fits'))
aligned_fits = fits.open(aligned_image)
aligned_data = fits.open(aligned_image)['SCI', 1].data
aligned_y, aligned_x = skycoord_to_pixel(star_location, wcs.WCS(aligned_fits['SCI', 1],
↪aligned_fits))
aligned_cutout = extract_array(aligned_data, (11, 11), (aligned_x, aligned_y))

norm3 = simple_norm(aligned_cutout, stretch='log', min_cut=-1, max_cut=200)
fig, axes = plt.subplots(1, 3)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[2].imshow(aligned_cutout, origin='lower',
               norm=norm3, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[2].set_title('Aligned')
for i in range(3):
    axes[i].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```



```
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
→py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.174733 from
→OBSGEO-[XYZ]'.
Set OBSGEO-B to -38.353284 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740817774.322 from OBSGEO-[XYZ]'.
warnings.warn(
```

Total running time of the script: (0 minutes 32.073 seconds)

6.2 JWST NIRCAM

Aligning JWST/NIRCAM images with JHAT.

An example NIRCcam Dataset is downloaded, and then a series of alignment methods are used. For more information on the key parameters used for alignment see [Useful Parameters](#).

```
import sys,os,glob
from astropy.io import fits
from astropy.table import Table
from astropy.nddata import extract_array
from astropy.coordinates import SkyCoord
from astropy import wcs
```

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```

from astropy.wcs.utils import skycoord_to_pixel
from astropy import units as u
import numpy as np
import matplotlib.pyplot as plt
from astroquery.mast import Observations
from astropy.visualization import (simple_norm, LinearStretch)

import jhat
from jhat import jwst_photclass, st_wcs_align

```

6.2.1 Relative Alignment

Download some Data

For this example we download 2 JWST NIRCcam images from MAST. They're the same field but different filters. Note that the code will also work for level 3 data images.

```

obs_table1 = Observations.query_criteria(obs_id='jw02107-o041-t019_nircam_clear-f200w')
data_products_by_obs = Observations.get_product_list(obs_table1)
data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==2]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
    ↳ 'productSubGroupDescription']=='CAL'][0]
Observations.download_products(data_products_by_obs, extension='fits')

obs_table2 = Observations.query_criteria(obs_id='jw02107-o041-t019_nircam_clear-f360m')
data_products_by_obs = Observations.get_product_list(obs_table2)
data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==2]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
    ↳ 'productSubGroupDescription']=='CAL'][0]
Observations.download_products(data_products_by_obs, extension='fits')

```

```

Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:JWST/product/
↳ jw02107041001_02101_00001_nrcb1_cal.fits to ./mastDownload/JWST/jw02107041001_02101_
↳ 00001_nrcb1/jw02107041001_02101_00001_nrcb1_cal.fits ... [Done]
Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:JWST/product/
↳ jw02107041001_02101_00001_nrcblong_cal.fits to ./mastDownload/JWST/jw02107041001_02101_
↳ 00001_nrcblong/jw02107041001_02101_00001_nrcblong_cal.fits ... [Done]

```

Examine the Reference Image

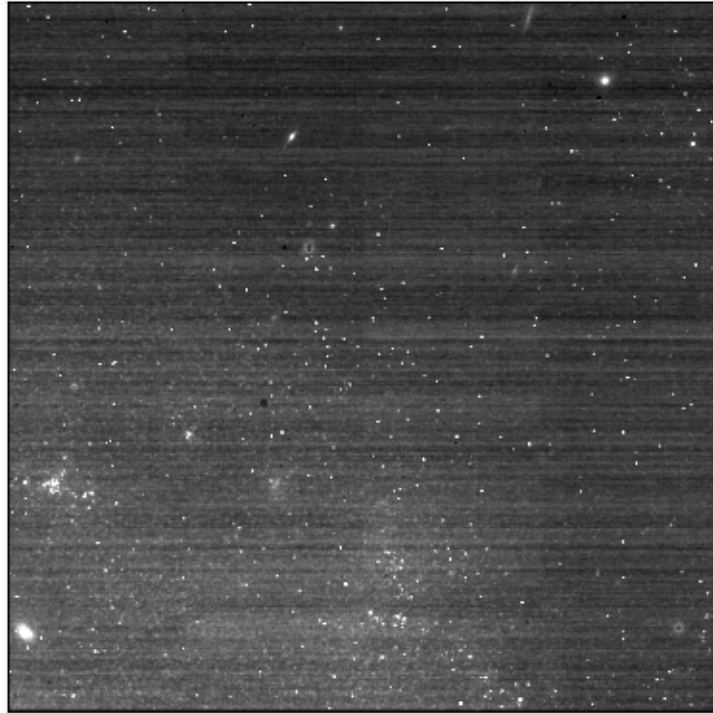
```

ref_image = glob.glob('mastDownload/JWST/*nrcb1*/cal.fits')[0]

ref_fits = fits.open(ref_image)
ref_data = fits.open(ref_image)['SCI', 1].data
norm1 = simple_norm(ref_data, stretch='linear', min_cut=-.5, max_cut=3)

plt.imshow(ref_data, origin='lower',
            norm=norm1, cmap='gray')
plt.gca().tick_params(labelcolor='none', axis='both', color='none')
plt.show()

```

Zoom in to see the offset

Here add an artificial offset to the wcs, and then we see the same star in both images at the same ra/dec location, demonstrating a large offset between the images.

```
star_location = SkyCoord('23:09:41.0532', '-43:26:41.128', unit=(u.hourangle, u.deg))
align_image = glob.glob('mastDownload/JWST/*long*/cal.fits')[0]
align_fits = fits.open(align_image)
align_fits['SCI', 1].header['CRPIX1'] += 1
align_fits['SCI', 1].header['CRPIX2'] += 1
align_fits.writeto(align_image, overwrite=True)

align_data = fits.open(align_image)['SCI', 1].data
ref_y, ref_x = skycoord_to_pixel(star_location, wcs.WCS(ref_fits['SCI', 1], ref_fits))
align_y, align_x = skycoord_to_pixel(star_location, wcs.WCS(align_fits['SCI', 1], align_
    fits))

ref_cutout = extract_array(ref_data, (11, 11), (ref_x, ref_y))
align_cutout = extract_array(align_data, (11, 11), (align_x, align_y))
norm1 = simple_norm(ref_cutout, stretch='linear', min_cut=-.5, max_cut=3)
norm2 = simple_norm(align_cutout, stretch='linear', min_cut=-.5, max_cut=3)
fig, axes = plt.subplots(1, 2)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
```

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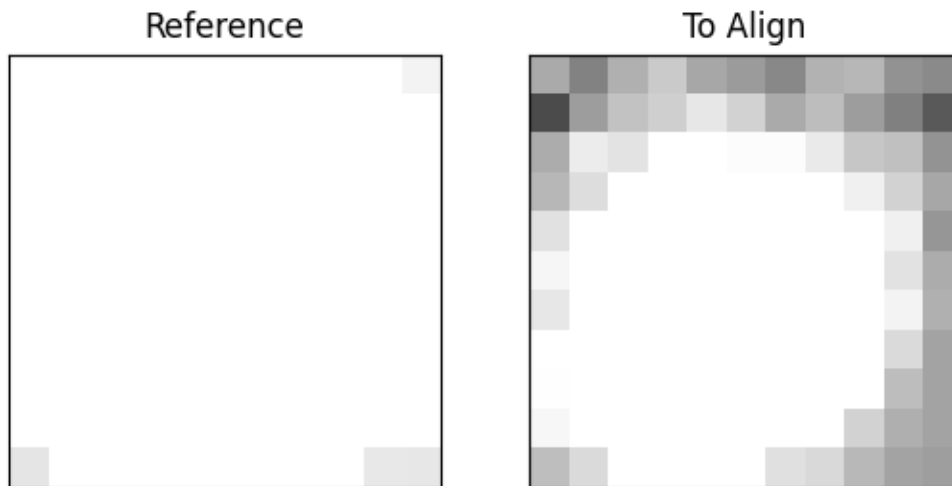
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```

axes[1].imshow(align_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[0].tick_params(labelcolor='none', axis='both', color='none')
axes[1].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```



```

/Users/jpierrez/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
06T19:16:42.721' from MJD-BEG.
Set DATE-AVG to '2022-07-06T19:17:14.932' from MJD-AVG.
Set DATE-END to '2022-07-06T19:17:47.142' from MJD-END'.
  warnings.warn(
/Users/jpierrez/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from
OBSGEO-[XYZ]'.
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
  warnings.warn(
/Users/jpierrez/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.

```

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```

↳py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
↳06T19:16:42.721' from MJD-BEG.
Set DATE-AVG to '2022-07-06T19:17:14.932' from MJD-AVG.
Set DATE-END to '2022-07-06T19:17:47.142' from MJD-END'.
    warnings.warn(
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.164999 from_
↳OBSGEO-[XYZ].
Set OBSGEO-B to  -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(

```

Create a Photometric Catalog for Relative Alignment

We choose one of the images to be the reference image, and then create a catalog that we will use to align the other image.

```

jwst_phot = jwst_photclass()
jwst_phot.run_phot(imagename=ref_image, photfilename='auto', overwrite=True, ee_radius=80)
ref_catname = ref_image.replace('.fits', '.phot.txt') # the default
refcat = Table.read(ref_catname, format='ascii')
print(refcat)

```

```

0 mastDownload/JWST/jw02107041001_02101_00001_nrcb1/jw02107041001_02101_00001_nrcb1_cal.
↳phot.txt
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
↳06T19:16:42.721' from MJD-BEG.
Set DATE-AVG to '2022-07-06T19:17:14.932' from MJD-AVG.
Set DATE-END to '2022-07-06T19:17:47.142' from MJD-END'.
    warnings.warn(
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.164999 from_
↳OBSGEO-[XYZ].
Set OBSGEO-B to  -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/units/
↳function/logarithmic.py:47: RuntimeWarning: invalid value encountered in log10
    return dex.to(self._function_unit, np.log10(x))
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:897: RuntimeWarning: invalid value_
↳encountered in log10
    phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/flux))
aper_sum_5.7px annulus_median_5.7px aper_bkg_5.7px ...    x_id1        y_id1

```

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105.310801	0.910453	92.21433	...	-11.710449	-31.373861
121.56116	0.960956	97.329433	...	1.390701	-31.374766
60.232352	0.498815	50.521961	...	18.604013	-31.26976
126.737312	1.019729	103.282174	...	-31.055244	-31.32962
113.529229	0.802048	81.234601	...	-18.547597	-31.34987
105.370409	0.767367	77.721958	...	-13.204667	-31.345555
89.411974	0.648643	65.697099	...	11.290307	-31.300338
110.788413	0.861123	87.217932	...	-0.18106	-31.287703
124.473601	0.862357	87.342937	...	6.266814	-31.255725
108.728849	0.849587	86.04952	...	10.634677	-31.259596
...
33.278942	0.200456	20.302942	...	-18.177622	29.366304
23.6942	0.04802	4.863676	...	-17.540134	29.519926
18.277825	0.013074	1.324192	...	-9.43527	29.52744
0.06818	-99.99	-10127.382506	...	-2.732965	29.758751
14.784146	-99.99	-10127.382506	...	20.030247	29.877627
47.576291	0.323802	32.795919	...	8.796703	31.023101
36.125728	0.251559	25.478925	...	26.612871	31.127561
39.783969	0.184818	18.719089	...	-15.095758	31.1144
341.811179	0.27702	28.0577	...	-9.937289	31.082671
53.600708	0.336015	34.032935	...	8.547109	31.138805
50.031236	0.275069	27.860125	...	13.180869	31.166268

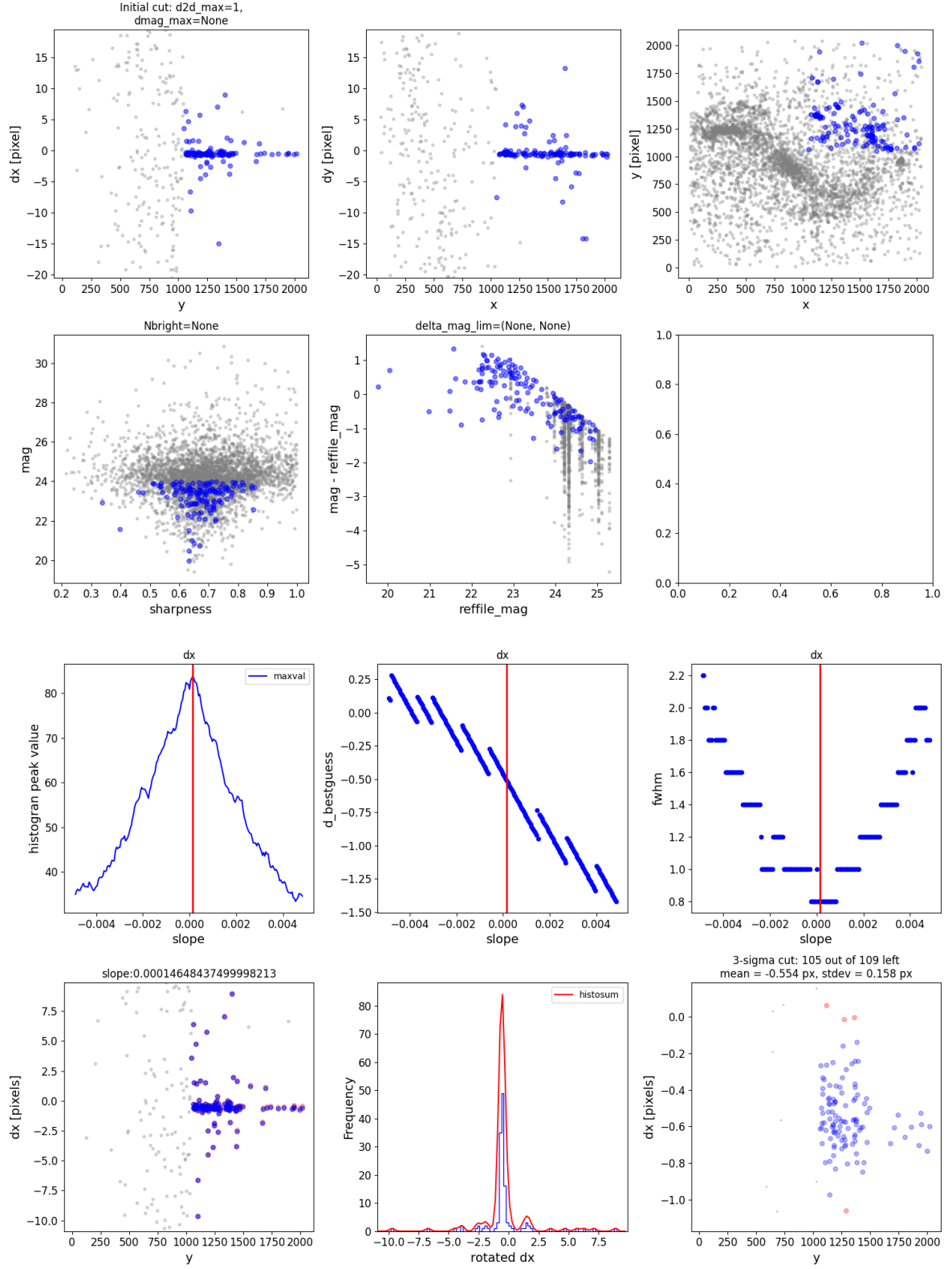
Length = 2756 rows

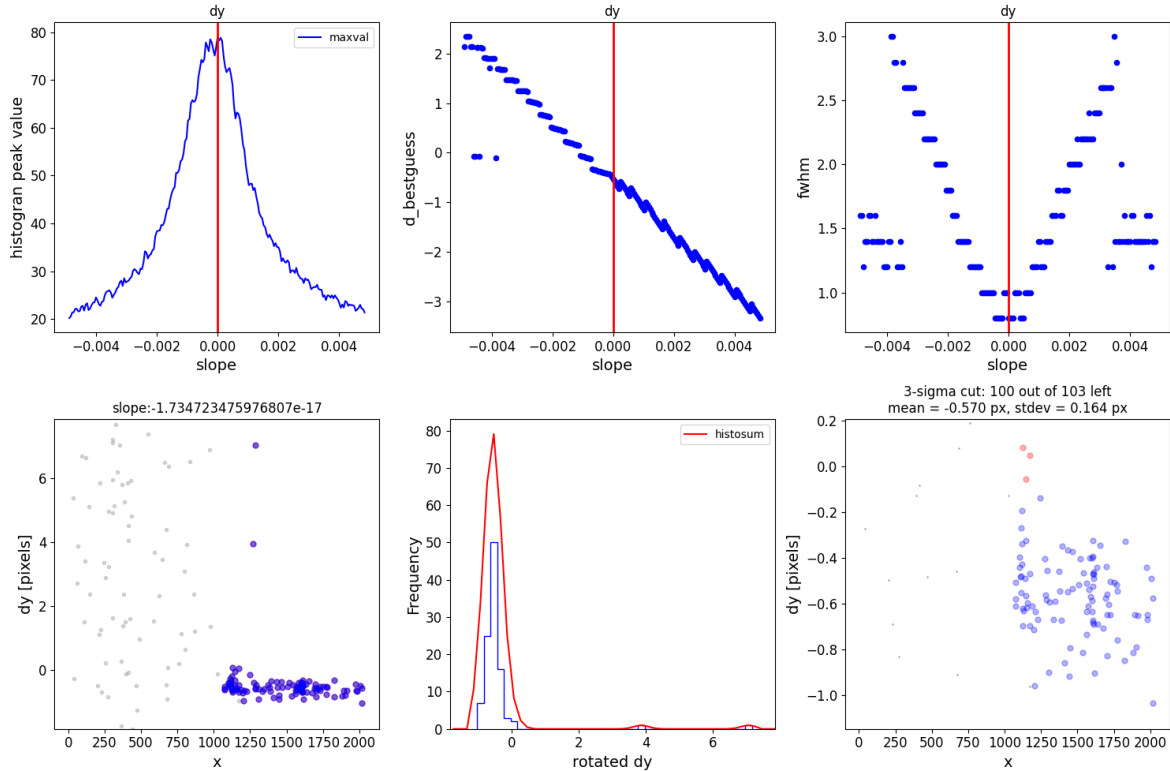
Align the second image

The plots outputted here show the various steps used by jhat to determine the true matching sources in the image, and the subsequent correction needed for optimal alignment.

```
wcs_align = st_wcs_align()

wcs_align.run_all(aligned_image,
                  telescope='jwst',
                  outsubdir='mastDownload',
                  refcat_racol='ra',
                  refcat_deccol='dec',
                  refcat_magcol='mag',
                  refcat_magerrcol='dmag',
                  overwrite=True,
                  d2d_max=1,
                  showplots=2,
                  refcatname=ref_catname,
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,
                  objmag_lim =(14,24))
```





```
0 ./mastDownload/jw02107041001_02101_00001_nrcblong.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
06T19:16:42.721' from MJD-BEG.
Set DATE-AVG to '2022-07-06T19:17:14.932' from MJD-AVG.
Set DATE-END to '2022-07-06T19:17:47.142' from MJD-END'.
warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from
OBSGEO-[XYZ].
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/units/
function/logarithmic.py:47: RuntimeWarning: invalid value encountered in log10
return dex.to(self._function_unit, np.log10(x))
/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:897: RuntimeWarning: invalid value
encountered in log10
phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/flux))
```

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```

*** Note: close plot to continue!
      slope intercept    maxval  index  d_bestguess  fwhm  multimax
0.000146    -0.15 83.958993    76    -0.50978    0.8    False
Keeping 109 out of 109, skippin 0 because of null values in columns d_rot_tmp
median: -0.572386
75.000000 percentile cut: max residual for cut: 0.188131
median: -0.587588
i:00 mean:-0.587588(0.010388) stdev:0.092914(0.007300) X2norm:0.99 Nchanged:0 Ngood:81
↪Nclip:28

mean: -0.580012
i:01 mean:-0.580012(0.012575) stdev:0.121920(0.008845) X2norm:1.00 Nchanged:14 Ngood:95
↪Nclip:14

mean: -0.557890
i:02 mean:-0.557890(0.014267) stdev:0.143378(0.010038) X2norm:1.00 Nchanged:7 Ngood:102
↪Nclip:7

mean: -0.554064
i:03 mean:-0.554064(0.015446) stdev:0.157514(0.010870) X2norm:1.00 Nchanged:3 Ngood:105
↪Nclip:4

mean: -0.554064
i:04 mean:-0.554064(0.015446) stdev:0.157514(0.010870) X2norm:1.00 Nchanged:0 Ngood:105
↪Nclip:4
      slope intercept    maxval  index  d_bestguess  fwhm  multimax
-1.734723e-17 1.776357e-14 79.085569    6    -0.534655    0.8    False
Keeping 103 out of 103, skippin 0 because of null values in columns d_rot_tmp
median: -0.559999
75.000000 percentile cut: max residual for cut: 0.191320
median: -0.559999
i:00 mean:-0.559999(0.010883) stdev:0.094879(0.007646) X2norm:0.99 Nchanged:0 Ngood:77
↪Nclip:26

mean: -0.554858
i:01 mean:-0.554858(0.013144) stdev:0.124003(0.009243) X2norm:1.00 Nchanged:13 Ngood:90
↪Nclip:13

mean: -0.565181
i:02 mean:-0.565181(0.015176) stdev:0.148691(0.010675) X2norm:1.00 Nchanged:7 Ngood:97
↪Nclip:6

mean: -0.564816
i:03 mean:-0.564816(0.016002) stdev:0.158407(0.011258) X2norm:1.00 Nchanged:2 Ngood:99
↪Nclip:4

mean: -0.569514
i:04 mean:-0.569514(0.016529) stdev:0.164459(0.011629) X2norm:1.00 Nchanged:1 Ngood:100
↪Nclip:3

mean: -0.569514
i:05 mean:-0.569514(0.016529) stdev:0.164459(0.011629) X2norm:1.00 Nchanged:0 Ngood:100

```

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```

↳Nclip:3
*** Note: close plots to continue!
/Users/jpierel/CodeBase/tweakreg_hack/tweakreg_hack/tweakreg_step_hack.py:540:↳
↳AstropyDeprecationWarning: The JWSTgWCS class is deprecated and may be removed in a↳
↳future version.
    Use JWSTWCSCorrector instead.
    im = JWSTgWCS(
replacing SIP ./mastDownload/jw02107041001_02101_00001_nrcblong_jhat.fits
./mastDownload/jw02107041001_02101_00001_nrcblong_jhat.fits
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from↳
↳OBSGEO-[XYZ].
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(
*** Note: close plots to continue!

0

```

Check the Output

The reference image has not changed, but let's read in the newly aligned image and compare with the original. subsequent correction needed for optimal alignment.

```

aligned_image = os.path.join('mastDownload', os.path.basename(aligned_image).replace('cal.
↳fits', 'jhat.fits'))
aligned_fits = fits.open(aligned_image)
aligned_data = fits.open(aligned_image)['SCI', 1].data
aligned_y, aligned_x = skycoord_to_pixel(star_location, wcs.WCS(aligned_fits['SCI', 1],
↳aligned_fits))
aligned_cutout = extract_array(aligned_data, (11, 11), (aligned_x, aligned_y))

norm3 = simple_norm(aligned_cutout, stretch='linear', min_cut=-.5, max_cut=3)
fig, axes = plt.subplots(1, 3)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[2].imshow(aligned_cutout, origin='lower',
               norm=norm3, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[2].set_title('Aligned')
for i in range(3):
    axes[i].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```




```
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
→py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from
→OBSGEO-[XYZ]'.
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
warnings.warn(
```

6.2.2 Align to Catalog

You can also align each image to the Gaia DR3 catalog, or you could replace the catalog created in step one with your own catalog of the field.

```
wcs_align.run_all(align_image,
                  telescope='jwst',
                  outsubdir='mastDownload',
                  overwrite=True,
                  d2d_max=.5,
                  showplots=0,
                  refcatname='Gaia',
                  histocut_order='dxdy',
                  sharpness_lim=(0.3, 0.9),
                  roundness1_lim=(-0.7, 0.7),
```

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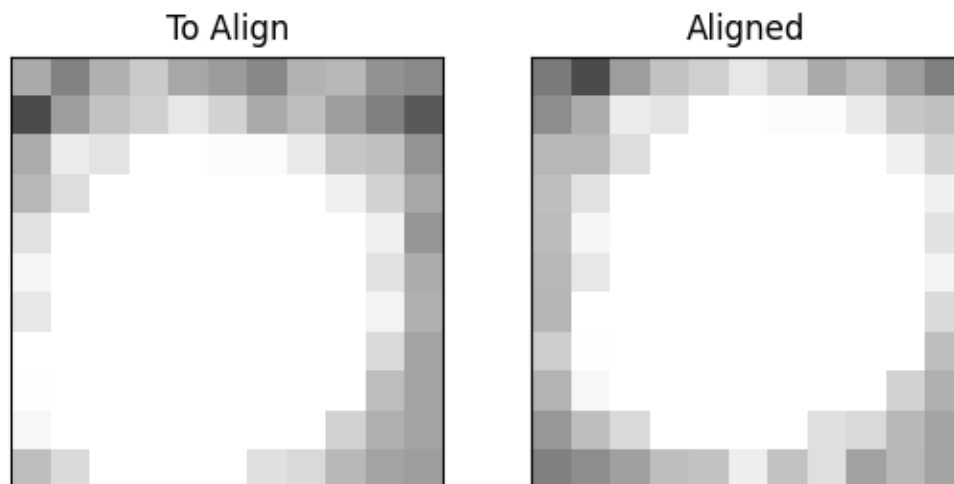
(continued from previous page)

```
SNR_min= 3,
dmag_max=1.0,
objmag_lim =(14,24))

aligned_image = os.path.join('mastDownload',os.path.basename(aligned_image).replace('cal.
↳fits','jhat.fits'))
aligned_fits = fits.open(aligned_image)
aligned_data = fits.open(aligned_image)['SCI',1].data
aligned_y,aligned_x = skycoord_to_pixel(star_location,wcs.WCS(aligned_fits['SCI',1],
↳aligned_fits))
aligned_cutout = extract_array(aligned_data,(11,11),(aligned_x,aligned_y))

norm3 = simple_norm(aligned_cutout,stretch='linear',min_cut=-.5,max_cut=3)
fig,axes = plt.subplots(1,2)
axes[0].imshow(aligned_cutout, origin='lower',
               norm=norm2,cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm3,cmap='gray')
axes[0].set_title('To Align')
axes[1].set_title('Aligned')
for i in range(2):
    axes[i].tick_params(labelcolor='none',axis='both',color='none')

plt.show()
```



```
0 ./mastDownload/jw02107041001_02101_00001_nrcblong.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'datfix' made the change 'Set DATE-BEG to '2022-07-
↳06T19:16:42.721' from MJD-BEG.
Set DATE-AVG to '2022-07-06T19:17:14.932' from MJD-AVG.
Set DATE-END to '2022-07-06T19:17:47.142' from MJD-END'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to  -72.164999 from
↳OBSGEO-[XYZ]'.
Set OBSGEO-B to  -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/units/
↳function/logarithmic.py:47: RuntimeWarning: invalid value encountered in log10
```

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```

    return dex.to(self._function_unit, np.log10(x))
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:897: RuntimeWarning: invalid value_
↳ encountered in log10
    phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/flux))
INFO: Query finished. [astroquery.utils.tap.core]
Number of stars: 21
### NO propoer motion correction!!!
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/pandas/core/_
↳ arraylike.py:402: RuntimeWarning: invalid value encountered in sqrt
    result = getattr(ufunc, method)(*inputs, **kwargs)
Number of stars after removing nan's: 21
    slope intercept maxval index d_bestguess fwhm multimax
0.001367 -1.4 3.661515 35 0.706414 0.8 False
Keeping 5 out of 5, skippin 0 because of null values in columns d_rot_tmp
median: 0.644163
75.000000 percentile cut: max residual for cut: 0.071771
median: 0.646769
i:00 mean:0.646769(0.001950) stdev:0.002758(0.001126) X2norm:0.79 Nchanged:0 Ngood:3_
↳ Nclip:2

mean: 0.646657
i:01 mean:0.646657(0.001725) stdev:0.002440(0.000996) X2norm:1.00 Nchanged:0 Ngood:3_
↳ Nclip:2
    slope intercept maxval index d_bestguess fwhm multimax
0.000537 -0.55 3.0 4 -1.643322 0.8 False
Keeping 3 out of 3, skippin 0 because of null values in columns d_rot_tmp
median: -1.609357
i:00 mean:-1.609357(0.083353) stdev:0.117879(0.048124) X2norm:0.79 Nchanged:0 Ngood:3_
↳ Nclip:0

mean: -1.633248
i:01 mean:-1.633248(0.070913) stdev:0.100286(0.040942) X2norm:1.00 Nchanged:0 Ngood:3_
↳ Nclip:0
/Users/jpierre/CodeBase/tweakreg_hack/tweakreg_hack/tweakreg_step_hack.py:540:_
↳ AstropyDeprecationWarning: The JWSTgWCS class is deprecated and may be removed in a_
↳ future version.
    Use JWSTWCSCorrector instead.
    im = JWSTgWCS(
replacing SIP ./mastDownload/jw02107041001_02101_00001_nrcblong_jhat.fits
./mastDownload/jw02107041001_02101_00001_nrcblong_jhat.fits
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳ py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from_
↳ OBSGEO-[XYZ]'.
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/wcs/wcs.
↳ py:725: FITSFixedWarning: 'obsfix' made the change 'Set OBSGEO-L to -72.164999 from_
↳ OBSGEO-[XYZ]'.
Set OBSGEO-B to -38.353872 from OBSGEO-[XYZ].
Set OBSGEO-H to 1740894174.999 from OBSGEO-[XYZ]'.
    warnings.warn(

```

Total running time of the script: (1 minutes 42.234 seconds)

6.3 Hubble

Aligning HST images with JHAT.

An example HST Dataset is downloaded, and then a series of alignment methods are used. For more information on the key parameters used for alignment see *Useful Parameters*.

```
import sys,os,glob
from astropy.io import fits
from astropy.table import Table
from astropy.nddata import extract_array
from astropy.coordinates import SkyCoord
from astropy import wcs
from astropy.wcs.utils import skycoord_to_pixel
from astropy import units as u
import numpy as np
import matplotlib.pyplot as plt
from astroquery.mast import Observations
from astropy.visualization import (simple_norm,LinearStretch)

import jhat
from jhat import hst_photclass,st_wcs_align
```

6.3.1 Relative Alignment

Download some Data

For this example we download 2 HST DRZ images from MAST. They're the same filter and same field, just separated in time.

```
obs_table = Observations.query_criteria(obs_id='hst_16264_12_wfc3_ir_f110w_iebc12')
obs_table1 = obs_table[obs_table['filters']=='F110W']

obs_table = Observations.query_criteria(obs_id='hst_16264_15_wfc3_ir_f110w_iebc15')
obs_table2 = obs_table[obs_table['filters']=='F110W']

data_products_by_obs = Observations.get_product_list(obs_table1)
data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==3]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
    ↳ 'productSubGroupDescription']=='DRZ'][0]
Observations.download_products(data_products_by_obs,extension='fits')

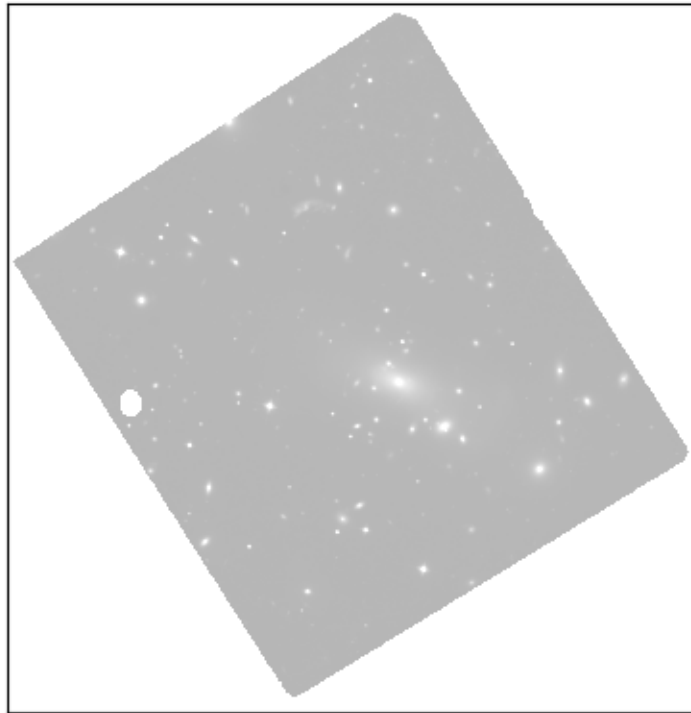
data_products_by_obs = Observations.get_product_list(obs_table2)
data_products_by_obs = data_products_by_obs[data_products_by_obs['calib_level']==3]
data_products_by_obs = data_products_by_obs[data_products_by_obs[
    ↳ 'productSubGroupDescription']=='DRZ'][0]
Observations.download_products(data_products_by_obs,extension='fits')
```

```
Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:HST/product/hst_
↳ 16264_12_wfc3_ir_f110w_iebc12_drz.fits to ./mastDownload/HST/hst_16264_12_wfc3_ir_
↳ f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits ... [Done]
Downloading URL https://mast.stsci.edu/api/v0.1/Download/file?uri=mast:HST/product/hst_
↳ 16264_15_wfc3_ir_f110w_iebc15_drz.fits to ./mastDownload/HST/hst_16264_15_wfc3_ir_
↳ f110w_iebc15/hst_16264_15_wfc3_ir_f110w_iebc15_drz.fits ... [Done]
```

Examine the Reference Image

```
files = glob.glob('mastDownload/HST/*/*drz.fits')
ref_image = files[0]
ref_fits = fits.open(ref_image)
ref_data = fits.open(ref_image)['SCI',1].data
norm1 = simple_norm(ref_data,stretch='log',min_cut=-1,max_cut=15)

plt.imshow(ref_data, origin='lower',
            norm=norm1,cmap='gray')
plt.gca().tick_params(labelcolor='none',axis='both',color='none')
plt.show()
```



Zoom in to see the offset

Here add an artificial offset to the wcs, and then we see the same star in both images at the same ra/dec location, demonstrating a large offset between the images.

```

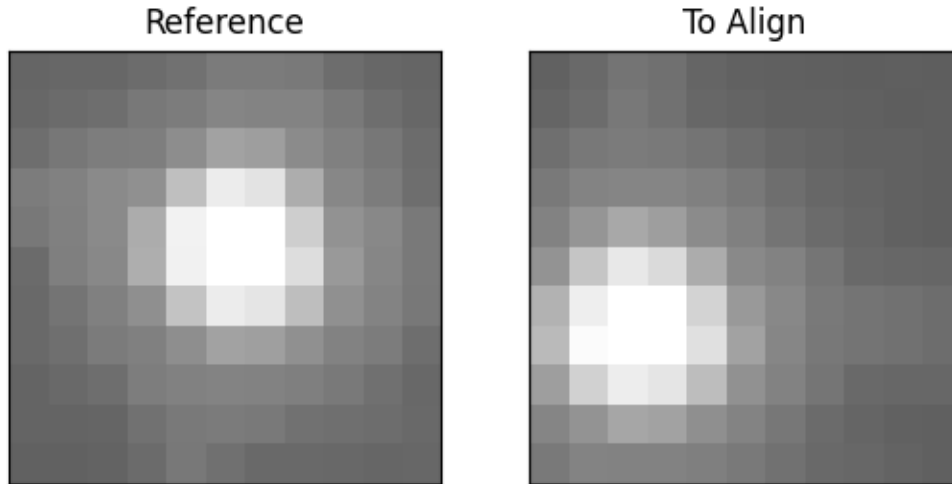
star_location = SkyCoord('21:29:40.5351', '+0:04:42.697', unit=(u.hourangle, u.deg))
align_image = files[1]
align_fits = fits.open(align_image)
align_fits['SCI', 1].header['CRPIX1'] += 2
align_fits['SCI', 1].header['CRPIX2'] += 2
align_fits.writeto(align_image, overwrite=True)

align_data = fits.open(align_image)['SCI', 1].data
ref_y, ref_x = skycoord_to_pixel(star_location, wcs.WCS(ref_fits['SCI', 1], ref_fits))
align_y, align_x = skycoord_to_pixel(star_location, wcs.WCS(align_fits['SCI', 1], align_
    fits))

ref_cutout = extract_array(ref_data, (11, 11), (ref_x, ref_y))
align_cutout = extract_array(align_data, (11, 11), (align_x, align_y))
norm1 = simple_norm(ref_cutout, stretch='log', min_cut=-1, max_cut=200)
norm2 = simple_norm(align_cutout, stretch='log', min_cut=-1, max_cut=200)
fig, axes = plt.subplots(1, 2)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(align_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[0].tick_params(labelcolor='none', axis='both', color='none')
axes[1].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```



Create a Photometric Catalog for Relative Alignment

We choose one of the images to be the reference image, and then create a catalog that we will use to align the other image.

```
hst_phot = hst_photclass(psf_fwhm=1.8, aperture_radius=5)
hst_phot.run_phot(imagename=ref_image, photfilename='auto', overwrite=True)
ref_catname = ref_image.replace('.fits', '.phot.txt') # the default
refcat = Table.read(ref_catname, format='ascii')
print(refcat)
```

```
0 mastDownload/HST/hst_16264_15_wfc3_ir_f110w_iebc15/hst_16264_15_wfc3_ir_f110w_iebc15_
  ↳ drz.phot.txt
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
  ↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
  ↳ which were automatically clipped.
  warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
  ↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
  ↳ which were automatically clipped.
  warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
  ↳ value encountered in log10
  phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
```

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```

/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↪value encountered in log10
  phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
aper_sum_5.0px annulus_median_5.0px aper_bkg_5.0px ... x_idl y_idl
-----
  98.701908      1.222414      96.008154 ... 10.282901 -58.751291
 112.858933      1.215701      95.480899 ...  0.099716 -56.988332
 101.387021      1.221539      95.939432 ... 11.171638 -55.244084
 103.395491      1.223192      96.06924 ... 12.050499 -54.702786
  98.175518      1.216526      95.545731 ...  18.3728 -52.885932
 105.185721      1.21896      95.736903 ... 20.125268 -52.409859
  98.467777      1.222879      96.044673 ...  8.878883 -51.562419
 101.178176      1.223382      96.084188 ...  9.447841 -51.376254
 100.858931      1.222232      95.993843 ...  9.589212 -51.288441
  97.386204      1.211678      95.164984 ... -1.323612 -51.067408
      ...
 106.700574      1.228211      96.463442 ... 38.894969  98.502383
 100.028718      1.227917      96.440353 ... 38.374139  99.52547
  97.812416      1.220746      95.877198 ... 26.977886  99.641609
  97.602401      1.223992      96.132097 ... 37.761718 100.233421
 105.374585      1.219728      95.797236 ... 33.155942 100.494187
  97.821326      1.222629      96.025086 ... 36.519167 101.346028
 102.604081      1.224514      96.173087 ... 22.996227 101.696774
  97.176703      1.223466      96.090817 ... 29.490227 101.683135
 106.491719      1.221887      95.966789 ... 28.696314 105.056795
 136.421682      1.214225      95.364994 ... 36.206768 105.813417
 105.467064      1.229289      96.548109 ... 30.779631 106.393258
Length = 769 rows

```

Align the second image

The plots outputted here show the various steps used by jhat to determine the true matching sources in the image, and the subsequent correction needed for optimal alignment.

```

wcs_align = st_wcs_align()

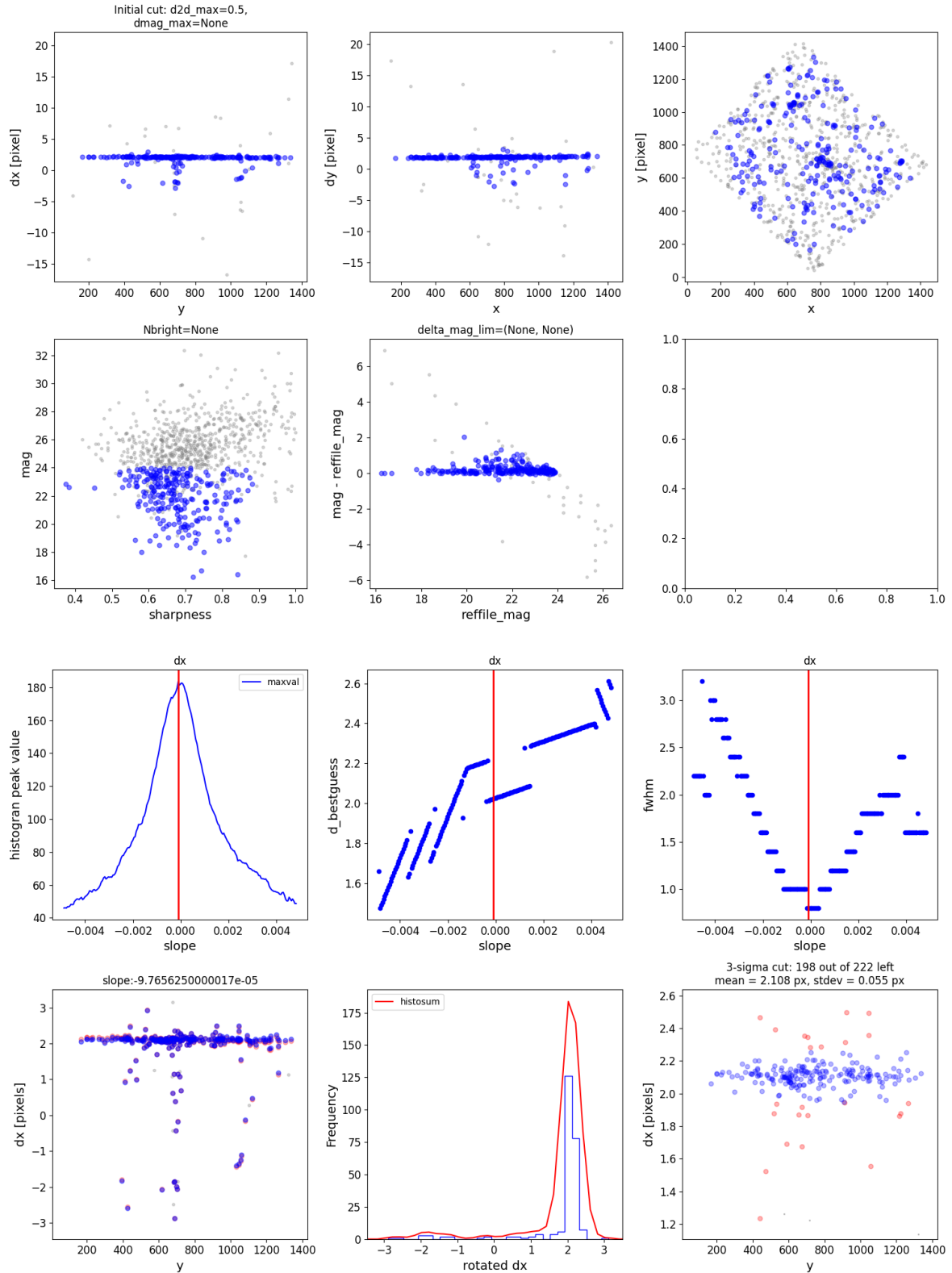
wcs_align.run_all(align_image,
                  telescope='hst',
                  outsubdir='mastDownload',
                  refcat_racol='ra',
                  refcat_deccol='dec',
                  refcat_magcol='mag',
                  refcat_magerrcol='dmag',
                  overwrite=True,
                  d2d_max=.5,
                  showplots=2,
                  refcatname=ref_catname,
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,

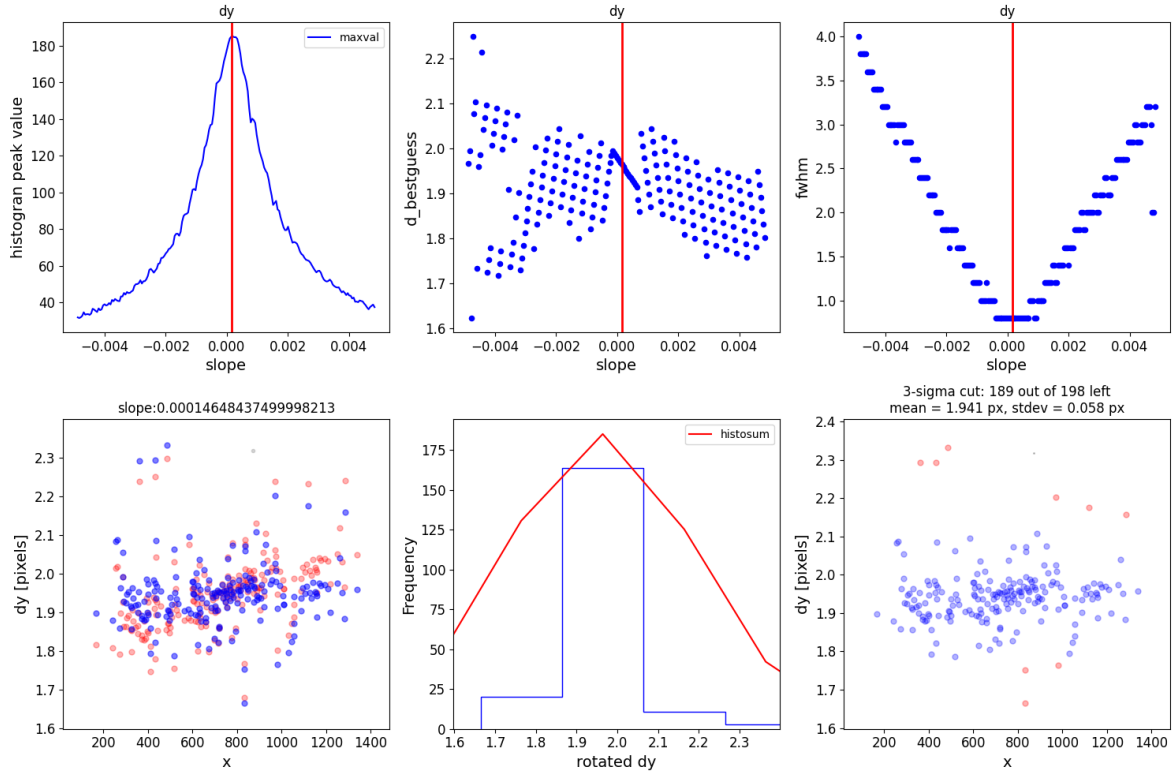
```

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`objmag_lim =(14,24))`





```
Warning: Setting aperture radius to twice the psf_fwhm (4.000000)
0 ./mastDownload/hst_16264_12_wfc3_ir_f110w_iebc12.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
↳ value encountered in log10
phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
/Users/jpierel/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↳ value encountered in log10
phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.name the following_
↳ error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
OrderedDict([('title', 'Instrument used to acquire the data'),
            ('type', 'string'),
            ('enum',
             ['NIRCAM',
              'NIRSPEC',
```

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```

        'MIRI',
        'TFI',
        'FGS',
        'NIRISS',
        'ANY',
        'N/A']],
    ('fits_keyword', 'INSTRUME'),
    ('blend_table', True)])

```

On instance:

```

    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
→ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
→ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
→ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Name of detector used to acquire the data'),
        ('type', 'string'),
        ('enum',
            ['NRCA1',
             'NRCA2',
             'NRCA3',
             'NRCA4',
             'NRCALONG',
             'NRCB1',
             'NRCB2',
             'NRCB3',
             'NRCB4',
             'NRCBLONG',
             'NRS1',
             'NRS2',
             'ANY',
             'MIRIMAGE',
             'MIRIFULONG',
             'MIRIFUSHORT',
             'NIS',
             'GUIDER1',
             'GUIDER2',
             'N/A',
             'MULTIPLE']),
        ('fits_keyword', 'DETECTOR'),
        ('blend_table', True),
        ('blend_rule', 'multi')])

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/

```

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```

↪ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↪ error occurred:
False is not of type 'string'

```

```

Failed validating 'type' in schema:
  OrderedDict([('title', 'Subarray used'),
               ('type', 'string'),
               ('anyOf',
                [{'enum': ['8X8',
                           '32X32',
                           '128X128',
                           '2048X64',
                           'SUB128CNTR',
                           'SUB128DIAG',
                           'SUB128LL',
                           'SUB32CNTR',
                           'SUB32DIAG',
                           'SUB32LL',
                           'SUB8CNTR',
                           'SUB8DIAG',
                           'SUB8LL',
                           'SUBIDSTRIPCENTER',
                           'SUBIDSTRIPLL',
                           'SUBTUNE32CENTERG1',
                           'SUBTUNE32CENTERG2',
                           'SUBTUNE32LLG1',
                           'SUBTUNE32LLG2']},
                 {'enum': ['BRIGHTSKY',
                           'MASK1065',
                           'MASK1140',
                           'MASK1550',
                           'MASKLYOT',
                           'SLITLESSPRISM',
                           'SUB128',
                           'SUB256',
                           'SUB64',
                           'SUBPRISM']},
                 {'enum': ['FULLP',
                           'MASK210R',
                           'MASK335R',
                           'MASK430R',
                           'MASKLWB',
                           'MASKSWB',
                           'SUB160',
                           'SUB160P',
                           'SUB320',
                           'SUB320A335R',
                           'SUB320A430R',
                           'SUB320ALWB',
                           'SUB320B335R',
                           'SUB320B430R',
                           ...

```

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```

    warnings.warn(errmsg, ValidationWarning)
*** Note: close plot to continue!
      slope  intercept      maxval  index  d_bestguess  fwhm  multimax
-0.000098   0.071191 183.673678    28    2.022576   0.8    False
Keeping 222 out of 222, skipping 0 because of null values in columns d_rot_tmp
median: 2.110833
75.000000 percentile cut: max residual for cut: 0.076543
median: 2.112779
i:00 mean:2.112779(0.002520) stdev:0.032375(0.001777) X2norm:1.00 Nchanged:0 Ngood:166
↳Nclip:56

mean: 2.114075
i:01 mean:2.114075(0.002887) stdev:0.038415(0.002036) X2norm:1.00 Nchanged:12 Ngood:178
↳Nclip:44

mean: 2.113588
i:02 mean:2.113588(0.003081) stdev:0.041561(0.002172) X2norm:1.00 Nchanged:5 Ngood:183
↳Nclip:39

mean: 2.113580
i:03 mean:2.113580(0.003189) stdev:0.043262(0.002249) X2norm:1.00 Nchanged:2 Ngood:185
↳Nclip:37

mean: 2.110885
i:04 mean:2.110885(0.003397) stdev:0.046577(0.002396) X2norm:1.00 Nchanged:4 Ngood:189
↳Nclip:33

mean: 2.111600
i:05 mean:2.111600(0.003454) stdev:0.047488(0.002436) X2norm:1.00 Nchanged:1 Ngood:190
↳Nclip:32

mean: 2.112334
i:06 mean:2.112334(0.003631) stdev:0.050314(0.002561) X2norm:1.00 Nchanged:3 Ngood:193
↳Nclip:29

mean: 2.110830
i:07 mean:2.110830(0.003748) stdev:0.052203(0.002643) X2norm:1.00 Nchanged:2 Ngood:195
↳Nclip:27

mean: 2.109305
i:08 mean:2.109305(0.003863) stdev:0.054084(0.002725) X2norm:1.00 Nchanged:2 Ngood:197
↳Nclip:25

mean: 2.108492
i:09 mean:2.108492(0.003929) stdev:0.055147(0.002771) X2norm:1.00 Nchanged:1 Ngood:198
↳Nclip:24

      slope  intercept      maxval  index  d_bestguess  fwhm  multimax
0.000146   -0.10686 185.08144    5    1.964436   0.8    False
Keeping 198 out of 198, skipping 0 because of null values in columns d_rot_tmp
median: 1.946136
75.000000 percentile cut: max residual for cut: 0.064640

```

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```

median: 1.947841
i:00 mean:1.947841(0.002509) stdev:0.030420(0.001768) X2norm:1.00 Nchanged:0 Ngood:148
↳Nclip:50

mean: 1.939984
i:01 mean:1.939984(0.002941) stdev:0.037665(0.002073) X2norm:1.00 Nchanged:17 Ngood:165
↳Nclip:33

mean: 1.938798
i:02 mean:1.938798(0.003106) stdev:0.040264(0.002190) X2norm:1.00 Nchanged:4 Ngood:169
↳Nclip:29

mean: 1.937518
i:03 mean:1.937518(0.003415) stdev:0.045050(0.002408) X2norm:1.00 Nchanged:6 Ngood:175
↳Nclip:23

mean: 1.938289
i:04 mean:1.938289(0.003692) stdev:0.049402(0.002604) X2norm:1.00 Nchanged:5 Ngood:180
↳Nclip:18

mean: 1.939838
i:05 mean:1.939838(0.004048) stdev:0.055060(0.002855) X2norm:1.00 Nchanged:6 Ngood:186
↳Nclip:12

mean: 1.939851
i:06 mean:1.939851(0.004173) stdev:0.057063(0.002943) X2norm:1.00 Nchanged:2 Ngood:188
↳Nclip:10

mean: 1.940734
i:07 mean:1.940734(0.004244) stdev:0.058191(0.002993) X2norm:1.00 Nchanged:1 Ngood:189
↳Nclip:9

mean: 1.940734
i:08 mean:1.940734(0.004244) stdev:0.058191(0.002993) X2norm:1.00 Nchanged:0 Ngood:189
↳Nclip:9
*** Note: close plots to continue!
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.name the following
↳error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
                ('type', 'string'),
                ('enum',
                 ['NIRCAM',
                  'NIRSPEC',
                  'MIRI',
                  'TFI',
                  'FGS',
                  'NIRISS',
                  'ANY',

```

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```

        'N/A']],
        ('fits_keyword', 'INSTRUME'),
        ('blend_table', True)])

```

On instance:

```

    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
→ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
→ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
→ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Name of detector used to acquire the data'),
                  ('type', 'string'),
                  ('enum',
                   ['NRCA1',
                    'NRCA2',
                    'NRCA3',
                    'NRCA4',
                    'NRCALONG',
                    'NRCB1',
                    'NRCB2',
                    'NRCB3',
                    'NRCB4',
                    'NRCBLONG',
                    'NRS1',
                    'NRS2',
                    'ANY',
                    'MIRIMAGE',
                    'MIRIFULONG',
                    'MIRIFUSHORT',
                    'NIS',
                    'GUIDER1',
                    'GUIDER2',
                    'N/A',
                    'MULTIPLE']),
                  ('fits_keyword', 'DETECTOR'),
                  ('blend_table', True),
                  ('blend_rule', 'multi')])

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
→ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

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```

OrderedDict([('title', 'Subarray used'),
             ('type', 'string'),
             ('anyOf',
              [{ 'enum': ['8X8',
                          '32X32',
                          '128X128',
                          '2048X64',
                          'SUB128CNTR',
                          'SUB128DIAG',
                          'SUB128LL',
                          'SUB32CNTR',
                          'SUB32DIAG',
                          'SUB32LL',
                          'SUB8CNTR',
                          'SUB8DIAG',
                          'SUB8LL',
                          'SUBIDSTRIPCENTER',
                          'SUBIDSTRIPLL',
                          'SUBTUNE32CENTERG1',
                          'SUBTUNE32CENTERG2',
                          'SUBTUNE32LLG1',
                          'SUBTUNE32LLG2']},
               { 'enum': ['BRIGHTSKY',
                           'MASK1065',
                           'MASK1140',
                           'MASK1550',
                           'MASKLYOT',
                           'SLITLESSPRISM',
                           'SUB128',
                           'SUB256',
                           'SUB64',
                           'SUBPRISM']},
               { 'enum': ['FULLP',
                           'MASK210R',
                           'MASK335R',
                           'MASK430R',
                           'MASKLWB',
                           'MASKSWB',
                           'SUB160',
                           'SUB160P',
                           'SUB320',
                           'SUB320A335R',
                           'SUB320A430R',
                           'SUB320ALWB',
                           'SUB320B335R',
                           'SUB320B430R',
                           ...
                        ]}],
             ],
            warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/jwst/datamodels/
→ util.py:234: NoTypeWarning: model_type not found. Opening mastDownload/HST/hst_16264_
→ 12_wfc3_ir_f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits as a ImageModel
warnings.warn(f"model_type not found. Opening {file_name} as a {class_name}",

```

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```
*** Note: close plots to continue!
```

```
0
```

Check the Output

The reference image has not changed, but let's read in the newly aligned image and compare with the original. subsequent correction needed for optimal alignment.

```
aligned_image = os.path.join('mastDownload', os.path.basename(aligned_image).replace('drz.'
↪fits', 'jhat.fits'))
aligned_fits = fits.open(aligned_image)
aligned_data = fits.open(aligned_image)['SCI', 1].data
aligned_y, aligned_x = skycoord_to_pixel(star_location, wcs.WCS(aligned_fits['SCI', 1],
↪aligned_fits))
aligned_cutout = extract_array(aligned_data, (11, 11), (aligned_x, aligned_y))

norm3 = simple_norm(aligned_cutout, stretch='log', min_cut=-1, max_cut=200)
fig, axes = plt.subplots(1, 3)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[2].imshow(aligned_cutout, origin='lower',
               norm=norm3, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[2].set_title('Aligned')
for i in range(3):
    axes[i].tick_params(labelcolor='none', axis='both', color='none')

plt.show()
```



6.3.2 Align to Gaia

You can also align each image to the Gaia DR3 catalog, or you could replace the catalog created in step one with your own catalog of the field.

```
wcs_align.run_all(aligned_image,
                  telescope='hst',
                  outsubdir='mastDownload',
                  overwrite=True,
                  d2d_max=.5,
                  showplots=0,
                  refcatname='Gaia',
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,
                  objmag_lim =(14,24))

aligned_image = os.path.join('mastDownload',os.path.basename(aligned_image).replace('drz.'
↪fits','jhat.fits'))
aligned_fits = fits.open(aligned_image)
```

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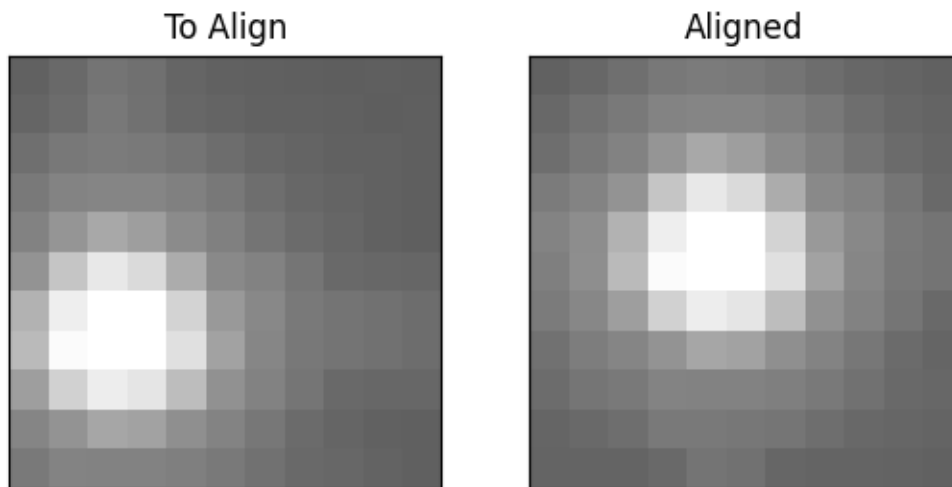
```

aligned_data = fits.open(aligned_image)['SCI',1].data
aligned_y,aligned_x = skycoord_to_pixel(star_location,wcs.WCS(aligned_fits['SCI',1],
↪aligned_fits))
aligned_cutout = extract_array(aligned_data,(11,11),(aligned_x,aligned_y))

norm3 = simple_norm(aligned_cutout,stretch='log',min_cut=-1,max_cut=200)
fig,axes = plt.subplots(1,2)
axes[0].imshow(aligned_cutout, origin='lower',
               norm=norm2,cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm3,cmap='gray')
axes[0].set_title('To Align')
axes[1].set_title('Aligned')
for i in range(2):
    axes[i].tick_params(labelcolor='none',axis='both',color='none')

plt.show()

```



```

Warning: Setting aperture radius to twice the psf_fwhm (4.000000)
0 ./mastDownload/hst_16264_12_wfc3_ir_f110w_iebc12.phot.txt
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_

```

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```

↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
↳value encountered in log10
    phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↳value encountered in log10
    phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.name the following_
↳error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Instrument used to acquire the data'),
                  ('type', 'string'),
                  ('enum',
                   ['NIRCAM',
                    'NIRSPEC',
                    'MIRI',
                    'TFI',
                    'FGS',
                    'NIRISS',
                    'ANY',
                    'N/A']),
                  ('fits_keyword', 'INSTRUME'),
                  ('blend_table', True)])

```

On instance:

```

    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.detector the_
↳following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
↳'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
↳'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Name of detector used to acquire the data'),
                  ('type', 'string'),
                  ('enum',
                   ['NRCA1',
                    'NRCA2',
                    'NRCA3',
                    'NRCA4',
                    'NRCALONG',

```

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```

        'NRCB1',
        'NRCB2',
        'NRCB3',
        'NRCB4',
        'NRCBLONG',
        'NRS1',
        'NRS2',
        'ANY',
        'MIRIMAGE',
        'MIRIFULONG',
        'MIRIFUSHORT',
        'NIS',
        'GUIDER1',
        'GUIDER2',
        'N/A',
        'MULTIPLE']],
    ('fits_keyword', 'DETECTOR'),
    ('blend_table', True),
    ('blend_rule', 'multi'))

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↳ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

```

    OrderedDict([('title', 'Subarray used'),
                  ('type', 'string'),
                  ('anyOf',
                   [{'enum': ['8X8',
                              '32X32',
                              '128X128',
                              '2048X64',
                              'SUB128CNTR',
                              'SUB128DIAG',
                              'SUB128LL',
                              'SUB32CNTR',
                              'SUB32DIAG',
                              'SUB32LL',
                              'SUB8CNTR',
                              'SUB8DIAG',
                              'SUB8LL',
                              'SUBIDSTRIPCENTER',
                              'SUBIDSTRIPLL',
                              'SUBTUNE32CENTERG1',
                              'SUBTUNE32CENTERG2',
                              'SUBTUNE32LLG1',
                              'SUBTUNE32LLG2']}]},
                  {'enum': ['BRIGHTSKY',

```

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```

        'MASK1065',
        'MASK1140',
        'MASK1550',
        'MASKLYOT',
        'SLITLESSPRISM',
        'SUB128',
        'SUB256',
        'SUB64',
        'SUBPRISM']},
    {'enum': ['FULLP',
              'MASK210R',
              'MASK335R',
              'MASK430R',
              'MASKLWB',
              'MASKSWB',
              'SUB160',
              'SUB160P',
              'SUB320',
              'SUB320A335R',
              'SUB320A430R',
              'SUB320ALWB',
              'SUB320B335R',
              'SUB320B430R',
              ...
    warnings.warn(errmsg, ValidationWarning)
INFO: Query finished. [astroquery.utils.tap.core]
Number of stars: 81
### NO propoer motion correction!!!
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/pandas/core/
↳ arraylike.py:402: RuntimeWarning: invalid value encountered in sqrt
    result = getattr(ufunc, method)(*inputs, **kwargs)
Number of stars after removing nan's: 81
    slope intercept maxval index d_bestguess fwhm multimax
0.000537 -0.391553 6.837554      6      1.974222  0.8      False
Keeping 9 out of 9, skipin 0 because of null values in columns d_rot_tmp
median: 1.981504
75.000000 percentile cut: max residual for cut: 0.180525
median: 2.017531
i:00 mean:2.017531(0.051121) stdev:0.114310(0.032998) X2norm:0.91 Nchanged:0 Ngood:6
↳ Nclip:3

mean: 2.001886
i:01 mean:2.001886(0.055165) stdev:0.145953(0.036488) X2norm:1.00 Nchanged:2 Ngood:8
↳ Nclip:1

mean: 2.001886
i:02 mean:2.001886(0.055165) stdev:0.145953(0.036488) X2norm:1.00 Nchanged:0 Ngood:8
↳ Nclip:1
    slope intercept maxval index d_bestguess fwhm multimax
0.000146 -0.10686  5.236      6      2.360891  1.0      False
Keeping 8 out of 8, skipin 0 because of null values in columns d_rot_tmp
median: 2.342233

```

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```

75.000000 percentile cut: max residual for cut: 0.358199
median: 2.342233
i:00 mean:2.342233(0.100460) stdev:0.224635(0.064847) X2norm:0.91 Nchanged:0 Ngood:6
↳Nclip:2

mean: 2.331019
i:01 mean:2.331019(0.114384) stdev:0.302631(0.075658) X2norm:1.00 Nchanged:2 Ngood:8
↳Nclip:0

mean: 2.331019
i:02 mean:2.331019(0.114384) stdev:0.302631(0.075658) X2norm:1.00 Nchanged:0 Ngood:8
↳Nclip:0
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.name the following
↳error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
               ('type', 'string'),
               ('enum',
                ['NIRCAM',
                 'NIRSPEC',
                 'MIRI',
                 'TFI',
                 'FGS',
                 'NIRISS',
                 'ANY',
                 'N/A']),
               ('fits_keyword', 'INSTRUME'),
               ('blend_table', True)])

On instance:
  'WFC3'
  warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.detector the
↳following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
↳'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
↳'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Name of detector used to acquire the data'),
               ('type', 'string'),
               ('enum',
                ['NRCA1',
                 'NRCA2',
                 'NRCA3',
                 'NRCA4',
                 'NRCALONG',
                 'NRCB1',

```

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```

        'NRCB2',
        'NRCB3',
        'NRCB4',
        'NRCBLONG',
        'NRS1',
        'NRS2',
        'ANY',
        'MIRIMAGE',
        'MIRIFULONG',
        'MIRIFUSHORT',
        'NIS',
        'GUIDER1',
        'GUIDER2',
        'N/A',
        'MULTIPLE']],
    ('fits_keyword', 'DETECTOR'),
    ('blend_table', True),
    ('blend_rule', 'multi'))

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
→ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

```

    OrderedDict([('title', 'Subarray used'),
                  ('type', 'string'),
                  ('anyOf',
                   [{'enum': ['8X8',
                              '32X32',
                              '128X128',
                              '2048X64',
                              'SUB128CNTR',
                              'SUB128DIAG',
                              'SUB128LL',
                              'SUB32CNTR',
                              'SUB32DIAG',
                              'SUB32LL',
                              'SUB8CNTR',
                              'SUB8DIAG',
                              'SUB8LL',
                              'SUBIDSTRIPCENTER',
                              'SUBIDSTRIPLL',
                              'SUBTUNE32CENTERG1',
                              'SUBTUNE32CENTERG2',
                              'SUBTUNE32LLG1',
                              'SUBTUNE32LLG2']}]},
                  {'enum': ['BRIGHTSKY',
                              'MASK1065'],

```

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```

        'MASK1140',
        'MASK1550',
        'MASKLYOT',
        'SLITLESSPRISM',
        'SUB128',
        'SUB256',
        'SUB64',
        'SUBPRISM']},
    {'enum': ['FULLP',
              'MASK210R',
              'MASK335R',
              'MASK430R',
              'MASKLWB',
              'MASKSWB',
              'SUB160',
              'SUB160P',
              'SUB320',
              'SUB320A335R',
              'SUB320A430R',
              'SUB320ALWB',
              'SUB320B335R',
              'SUB320B430R',
              ...
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/jwst/datamodels/
util.py:234: NoTypeWarning: model_type not found. Opening mastDownload/HST/hst_16264_
12_wfc3_ir_f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits as a ImageModel
warnings.warn(f"model_type not found. Opening {file_name} as a {class_name}",

```

6.3.3 Large Offsets

Sometimes the initial images are so poorly aligned, that the code fails. Here we read in the same image as in the first example, and add an additional 3 pixel offset in the wcs.

```

files = glob.glob('mastDownload/HST/*/*drz.fits')
align_image = files[1]
align_fits = fits.open(align_image)
align_fits['SCI',1].header['CRPIX1']+=3
align_fits['SCI',1].header['CRPIX2']+=3
align_fits.writeto(align_image,overwrite=True)

align_data = fits.open(align_image)['SCI',1].data
ref_y,ref_x = skycoord_to_pixel(star_location,wcs.WCS(ref_fits['SCI',1],ref_fits))
align_y,align_x = skycoord_to_pixel(star_location,wcs.WCS(align_fits['SCI',1],align_
    fits))

ref_cutout = extract_array(ref_data,(11,11),(ref_x,ref_y))
align_cutout = extract_array(align_data,(11,11),(align_x,align_y))
norm1 = simple_norm(ref_cutout,stretch='log',min_cut=-1,max_cut=200)
norm2 = simple_norm(align_cutout,stretch='log',min_cut=-1,max_cut=200)
fig,axes = plt.subplots(1,2)

```

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```

axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(align_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[0].tick_params(labelcolor='none', axis='both', color='none')
axes[1].tick_params(labelcolor='none', axis='both', color='none')

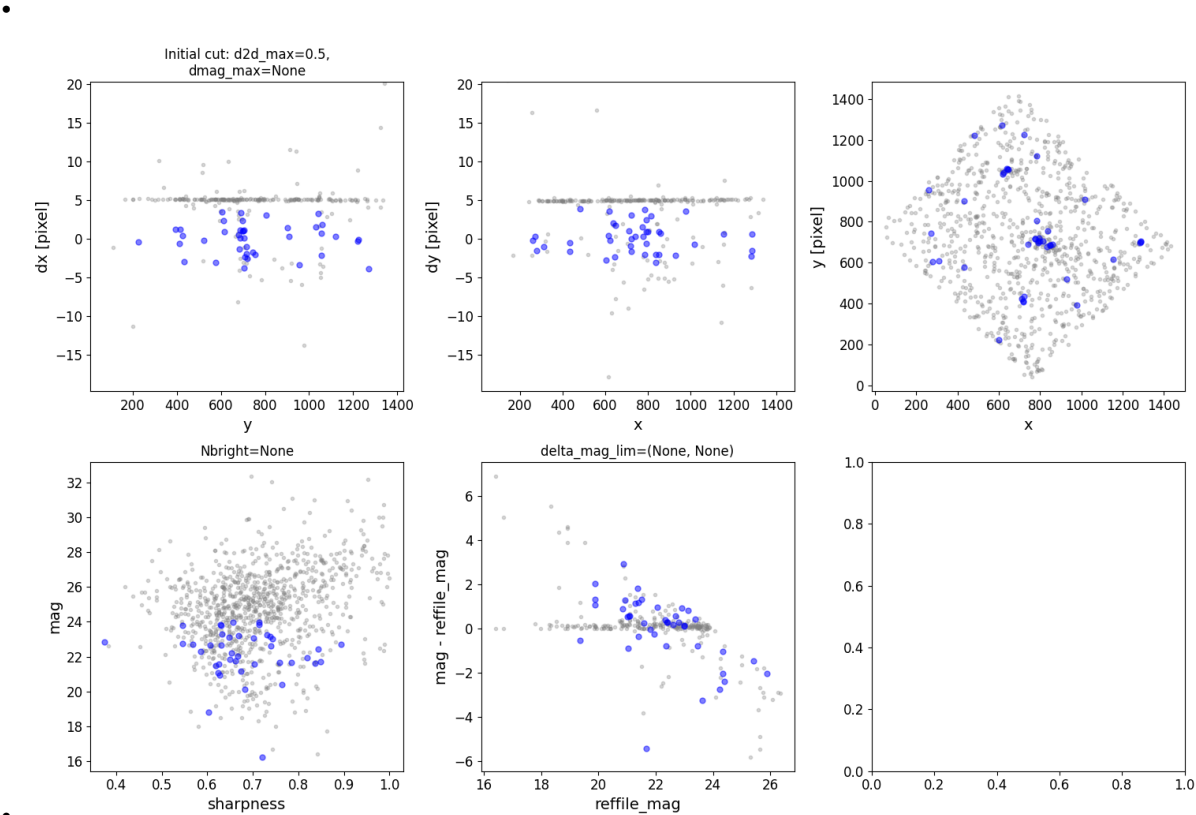
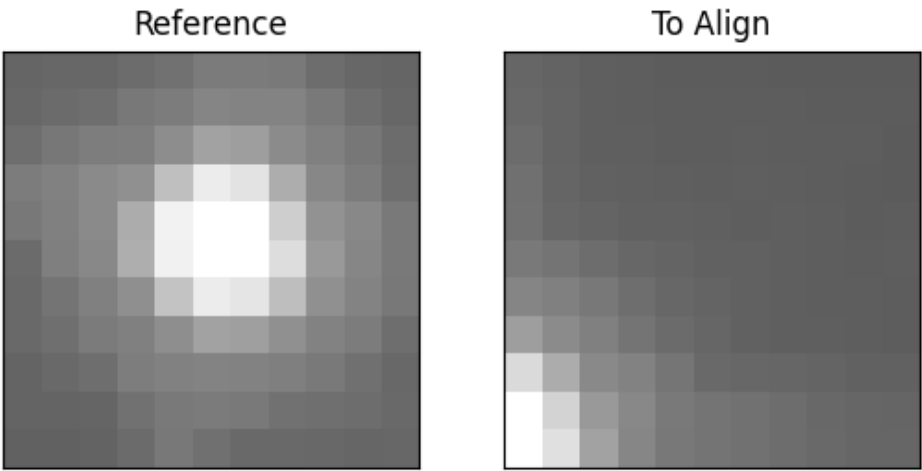
plt.show()

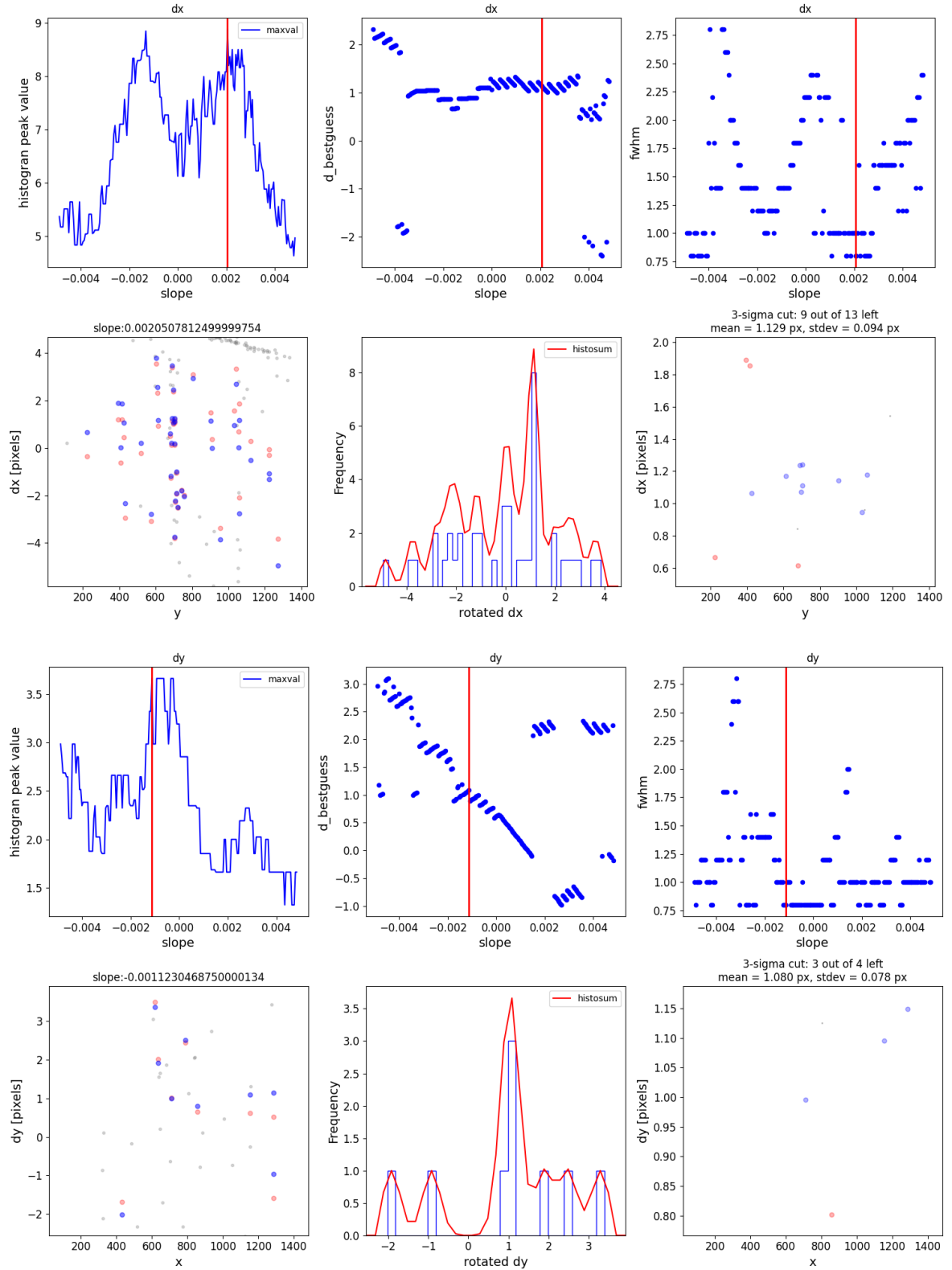
wcs_align = st_wcs_align()

try:
    wcs_align.run_all(align_image,
                     telescope='hst',
                     outsubdir='mastDownload',
                     refcat_racol='ra',
                     refcat_deccol='dec',
                     refcat_magcol='mag',
                     refcat_magerrcol='dmag',
                     overwrite=True,
                     d2d_max=.5,
                     showplots=2,
                     refcatname=ref_catname,
                     histocut_order='dxdy',
                     sharpness_lim=(0.3, 0.9),
                     roundness1_lim=(-0.7, 0.7),
                     SNR_min= 3,
                     dmag_max=1.0,
                     objmag_lim =(14, 24))

except:
    print('Failed for not enough matches!')

```





Warning: Setting aperture radius to twice the psf_fwhm (4.000000)
 0 ./mastDownload/hst_16264_12_wfc3_ir_f110w_iebc12.phot.txt

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```

/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
↳ value encountered in log10
    phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↳ value encountered in log10
    phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.name the following_
↳ error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

```

Failed validating 'enum' in schema:

```

OrderedDict([('title', 'Instrument used to acquire the data'),
              ('type', 'string'),
              ('enum',
               ['NIRCAM',
                'NIRSPEC',
                'MIRI',
                'TFI',
                'FGS',
                'NIRISS',
                'ANY',
                'N/A']),
              ('fits_keyword', 'INSTRUME'),
              ('blend_table', True)])

```

On instance:

```

'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.detector the_
↳ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCA10', 'NRCA11', 'NRCA12',
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↳ 'NRCA1529', 'NRCA1530', 'NRCA1531', 'NRCA1532', 'NRCA1
```

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```

        'NRCALONG',
        'NRCB1',
        'NRCB2',
        'NRCB3',
        'NRCB4',
        'NRCBLONG',
        'NRS1',
        'NRS2',
        'ANY',
        'MIRIMAGE',
        'MIRIFULONG',
        'MIRIFUSHORT',
        'NIS',
        'GUIDER1',
        'GUIDER2',
        'N/A',
        'MULTIPLE']],
    ('fits_keyword', 'DETECTOR'),
    ('blend_table', True),
    ('blend_rule', 'multi'))

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↳ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

```

    OrderedDict([('title', 'Subarray used'),
                  ('type', 'string'),
                  ('anyOf',
                   [{'enum': ['8X8',
                              '32X32',
                              '128X128',
                              '2048X64',
                              'SUB128CNTR',
                              'SUB128DIAG',
                              'SUB128LL',
                              'SUB32CNTR',
                              'SUB32DIAG',
                              'SUB32LL',
                              'SUB8CNTR',
                              'SUB8DIAG',
                              'SUB8LL',
                              'SUBIDSTRIPCENTER',
                              'SUBIDSTRIPLL',
                              'SUBTUNE32CENTERG1',
                              'SUBTUNE32CENTERG2',
                              'SUBTUNE32LLG1',
                              'SUBTUNE32LLG2']}],

```

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```

        {'enum': ['BRIGHTSKY',
                  'MASK1065',
                  'MASK1140',
                  'MASK1550',
                  'MASKLYOT',
                  'SLITLESSPRISM',
                  'SUB128',
                  'SUB256',
                  'SUB64',
                  'SUBPRISM']},
        {'enum': ['FULLP',
                  'MASK210R',
                  'MASK335R',
                  'MASK430R',
                  'MASKLWB',
                  'MASKSWB',
                  'SUB160',
                  'SUB160P',
                  'SUB320',
                  'SUB320A335R',
                  'SUB320A430R',
                  'SUB320ALWB',
                  'SUB320B335R',
                  'SUB320B430R',
                  ...
        warnings.warn(errmsg, ValidationWarning)
*** Note: close plot to continue!
      slope intercept  maxval  index  d_bestguess  fwhm  multimax
0.002051  -1.49502 8.877268    34    1.149103  0.8    False
Keeping 13 out of 13, skipping 0 because of null values in columns d_rot_tmp
median: 1.142187
75.000000 percentile cut: max residual for cut: 0.473790
median: 1.142187
i:00 mean:1.142187(0.034755) stdev:0.098302(0.023170) X2norm:0.94 Nchanged:0 Ngood:9
↳Nclip:4

mean: 1.128891
i:01 mean:1.128891(0.033318) stdev:0.094236(0.022212) X2norm:1.00 Nchanged:0 Ngood:9
↳Nclip:4
      slope intercept  maxval  index  d_bestguess  fwhm  multimax
-0.001123  0.819263 3.661515    19    1.083046  0.8    False
Keeping 4 out of 4, skipping 0 because of null values in columns d_rot_tmp
median: 1.045332
75.000000 percentile cut: max residual for cut: 0.138967
median: 1.095192
i:00 mean:1.095192(0.064008) stdev:0.090521(0.036955) X2norm:0.79 Nchanged:0 Ngood:3
↳Nclip:1

mean: 1.079986
i:01 mean:1.079986(0.055176) stdev:0.078030(0.031856) X2norm:1.00 Nchanged:0 Ngood:3
↳Nclip:1
*** Note: close plots to continue!

```

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```
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.name the following
↳ error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']
```

Failed validating 'enum' in schema:

```
OrderedDict([('title', 'Instrument used to acquire the data'),
              ('type', 'string'),
              ('enum',
               ['NIRCAM',
                'NIRSPEC',
                'MIRI',
                'TFI',
                'FGS',
                'NIRISS',
                'ANY',
                'N/A']),
              ('fits_keyword', 'INSTRUME'),
              ('blend_table', True)])
```

On instance:

```
'WFC3'
warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
↳ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
↳ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
↳ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']
```

Failed validating 'enum' in schema:

```
OrderedDict([('title', 'Name of detector used to acquire the data'),
              ('type', 'string'),
              ('enum',
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                'NRCA2',
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                'NRCA4',
                'NRCALONG',
                'NRCB1',
                'NRCB2',
                'NRCB3',
                'NRCB4',
                'NRCBLONG',
                'NRS1',
                'NRS2',
                'ANY',
                'MIRIMAGE',
                'MIRIFULONG',
                'MIRIFUSHORT',
                'NIS',
                'GUIDER1',
```

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```

        'GUIDER2',
        'N/A',
        'MULTIPLE']],
    ('fits_keyword', 'DETECTOR'),
    ('blend_table', True),
    ('blend_rule', 'multi'))

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↳ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

```

    OrderedDict([('title', 'Subarray used'),
                 ('type', 'string'),
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                             'SUBTUNE32CENTERG2',
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                  {'enum': ['FULLP',
                             'MASK210R',
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```

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```

        'MASKLWB',
        'MASKSWB',
        'SUB160',
        'SUB160P',
        'SUB320',
        'SUB320A335R',
        'SUB320A430R',
        'SUB320ALWB',
        'SUB320B335R',
        'SUB320B430R',
        ...
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/jwst/datamodels/
↳ util.py:234: NoTypeWarning: model_type not found. Opening mastDownload/HST/hst_16264_
↳ 12_wfc3_ir_f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits as a ImageModel
    warnings.warn(f"model_type not found. Opening {file_name} as a {class_name}",
Failed for not enough matches!

```

This is what a failure looks like (compare to the plots above). There are now a couple of options here. You can increase the `d2d_max` parameter, which increases the allowed distance between sources being matched in the reference and target images:

```

wcs_align = st_wcs_align()

wcs_align.run_all(aligned_image,
                  telescope='hst',
                  outsubdir='mastDownload',
                  refcat_racol='ra',
                  refcat_deccol='dec',
                  refcat_magcol='mag',
                  refcat_magerrcol='dmag',
                  overwrite=True,
                  d2d_max=1,
                  showplots=2,
                  refcatname=ref_catname,
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,
                  objmag_lim =(14,24))

aligned_image = os.path.join('mastDownload',os.path.basename(aligned_image).replace('drz.
↳ fits','jhat.fits'))
aligned_fits = fits.open(aligned_image)
aligned_data = fits.open(aligned_image)['SCI',1].data
aligned_y,aligned_x = skycoord_to_pixel(star_location,wcs.WCS(aligned_fits['SCI',1],
↳ aligned_fits))
aligned_cutout = extract_array(aligned_data,(11,11),(aligned_x,aligned_y))

norm3 = simple_norm(aligned_cutout,stretch='log',min_cut=-1,max_cut=200)

```

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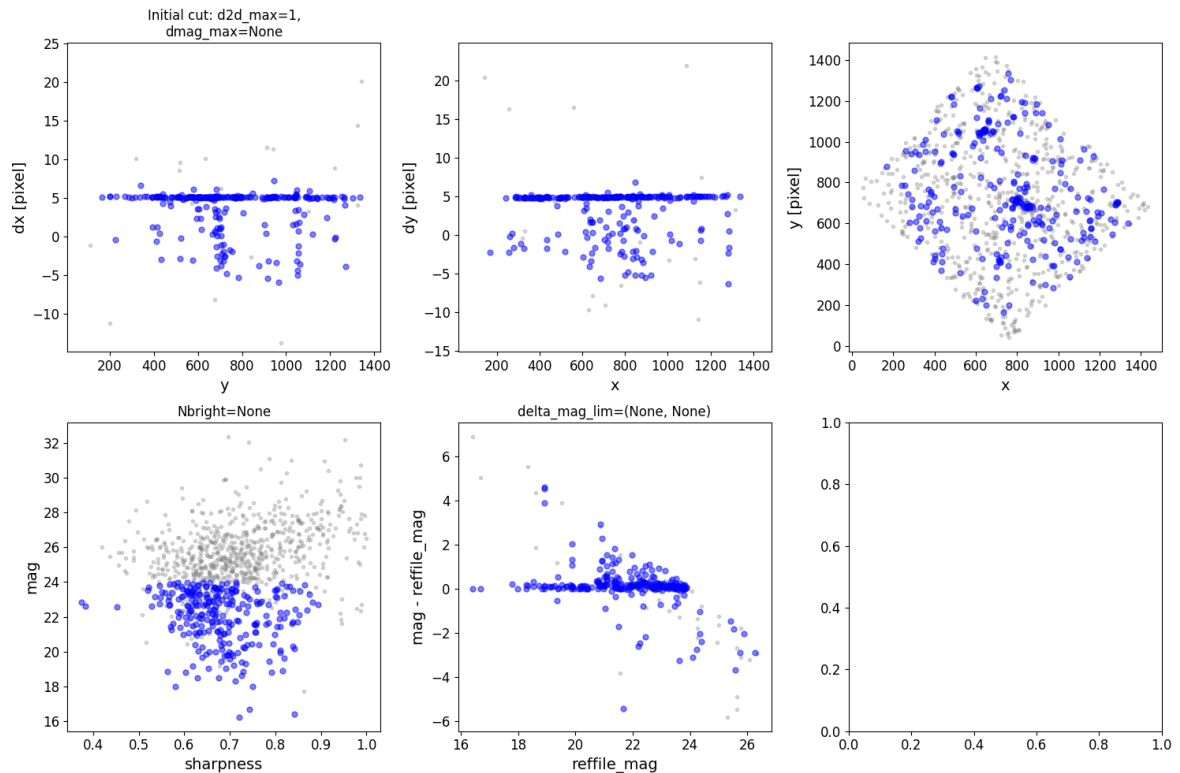
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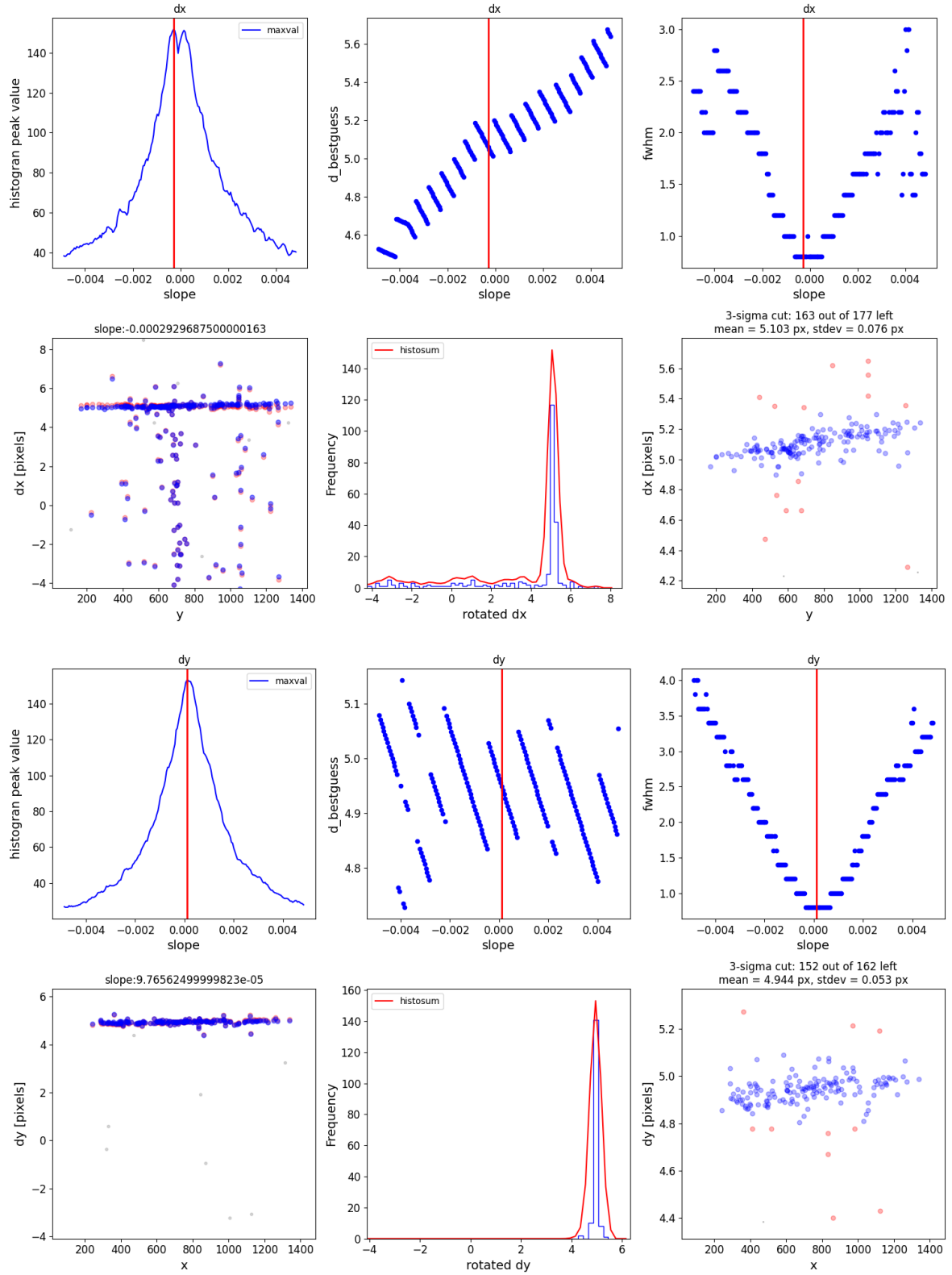
```

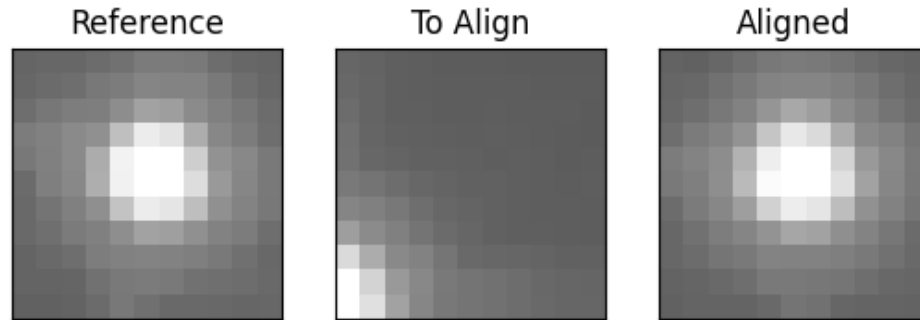
fig, axes = plt.subplots(1, 3)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1, cmap='gray')
axes[1].imshow(align_cutout, origin='lower',
               norm=norm2, cmap='gray')
axes[2].imshow(aligned_cutout, origin='lower',
               norm=norm3, cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[2].set_title('Aligned')
for i in range(3):
    axes[i].tick_params(labelcolor='none', axis='both', color='none')

plt.show()

```







```
Warning: Setting aperture radius to twice the psf_fwhm (4.000000)
0 ./mastDownload/hst_16264_12_wfc3_ir_f110w_iebc12.phot.txt
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
    warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
↳ value encountered in log10
    phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↳ value encountered in log10
    phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.name the following_
↳ error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
               ('type', 'string'),
```

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```

        ('enum',
         ['NIRCAM',
          'NIRSPEC',
          'MIRI',
          'TFI',
          'FGS',
          'NIRISS',
          'ANY',
          'N/A']),
        ('fits_keyword', 'INSTRUME'),
        ('blend_table', True)])

```

On instance:

```

    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
→ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
→ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
→ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Name of detector used to acquire the data'),
                 ('type', 'string'),
                 ('enum',
                  ['NRCA1',
                   'NRCA2',
                   'NRCA3',
                   'NRCA4',
                   'NRCALONG',
                   'NRCB1',
                   'NRCB2',
                   'NRCB3',
                   'NRCB4',
                   'NRCBLONG',
                   'NRS1',
                   'NRS2',
                   'ANY',
                   'MIRIMAGE',
                   'MIRIFULONG',
                   'MIRIFUSHORT',
                   'NIS',
                   'GUIDER1',
                   'GUIDER2',
                   'N/A',
                   'MULTIPLE']),
                 ('fits_keyword', 'DETECTOR'),
                 ('blend_table', True),
                 ('blend_rule', 'multi')])

```

On instance:

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```

'IR'
warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→validate.py:38: ValidationWarning: While validating meta.subarray.name the following
→error occurred:
False is not of type 'string'

Failed validating 'type' in schema:
  OrderedDict([('title', 'Subarray used'),
               ('type', 'string'),
               ('anyOf',
                [{ 'enum': ['8X8',
                           '32X32',
                           '128X128',
                           '2048X64',
                           'SUB128CNTR',
                           'SUB128DIAG',
                           'SUB128LL',
                           'SUB32CNTR',
                           'SUB32DIAG',
                           'SUB32LL',
                           'SUB8CNTR',
                           'SUB8DIAG',
                           'SUB8LL',
                           'SUBIDSTRIPCENTER',
                           'SUBIDSTRIPLL',
                           'SUBTUNE32CENTERG1',
                           'SUBTUNE32CENTERG2',
                           'SUBTUNE32LLG1',
                           'SUBTUNE32LLG2'] },
                 { 'enum': ['BRIGHTSKY',
                           'MASK1065',
                           'MASK1140',
                           'MASK1550',
                           'MASKLYOT',
                           'SLITLESSPRISM',
                           'SUB128',
                           'SUB256',
                           'SUB64',
                           'SUBPRISM'] },
                 { 'enum': ['FULLP',
                           'MASK210R',
                           'MASK335R',
                           'MASK430R',
                           'MASKLWB',
                           'MASKSWB',
                           'SUB160',
                           'SUB160P',
                           'SUB320',
                           'SUB320A335R',
                           'SUB320A430R',
                           'SUB320ALWB',

```

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```

        'SUB320B335R',
        'SUB320B430R',
        ...
    warnings.warn(errmsg, ValidationWarning)
*** Note: close plot to continue!
    slope intercept    maxval index d_bestguess fwhm multimax
-0.000293  0.213574 151.767497    58    5.058877  0.8    False
Keeping 177 out of 177, skipping 0 because of null values in columns d_rot_tmp
median: 5.100640
75.000000 percentile cut: max residual for cut: 0.091924
median: 5.091393
i:00 mean:5.091393(0.004565) stdev:0.052249(0.003216) X2norm:1.00 Nchanged:0 Ngood:132
↳Nclip:45

mean: 5.101872
i:01 mean:5.101872(0.005427) stdev:0.067565(0.003825) X2norm:1.00 Nchanged:24 Ngood:156
↳Nclip:21

mean: 5.103992
i:02 mean:5.103992(0.005907) stdev:0.074955(0.004164) X2norm:1.00 Nchanged:6 Ngood:162
↳Nclip:15

mean: 5.102721
i:03 mean:5.102721(0.006008) stdev:0.076467(0.004235) X2norm:1.00 Nchanged:1 Ngood:163
↳Nclip:14

mean: 5.102721
i:04 mean:5.102721(0.006008) stdev:0.076467(0.004235) X2norm:1.00 Nchanged:0 Ngood:163
↳Nclip:14
    slope intercept    maxval index d_bestguess fwhm multimax
0.000098  -0.07124 153.147275    54    4.948694  0.8    False
Keeping 162 out of 162, skipping 0 because of null values in columns d_rot_tmp
median: 4.942136
75.000000 percentile cut: max residual for cut: 0.062217
median: 4.946718
i:00 mean:4.946718(0.002966) stdev:0.032492(0.002089) X2norm:1.00 Nchanged:0 Ngood:121
↳Nclip:41

mean: 4.942254
i:01 mean:4.942254(0.003583) stdev:0.042396(0.002525) X2norm:1.00 Nchanged:20 Ngood:141
↳Nclip:21

mean: 4.941777
i:02 mean:4.941777(0.003869) stdev:0.046592(0.002727) X2norm:1.00 Nchanged:5 Ngood:146
↳Nclip:16

mean: 4.942611
i:03 mean:4.942611(0.004236) stdev:0.051878(0.002985) X2norm:1.00 Nchanged:5 Ngood:151
↳Nclip:11

mean: 4.943574
i:04 mean:4.943574(0.004317) stdev:0.053053(0.003043) X2norm:1.00 Nchanged:1 Ngood:152

```

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```

↳Nclip:10

mean: 4.943574
i:05 mean:4.943574(0.004317) stdev:0.053053(0.003043) X2norm:1.00 Nchanged:0 Ngood:152
↳Nclip:10
*** Note: close plots to continue!
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.name the following
↳error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
               ('type', 'string'),
               ('enum',
                ['NIRCAM',
                 'NIRSPEC',
                 'MIRI',
                 'TFI',
                 'FGS',
                 'NIRISS',
                 'ANY',
                 'N/A']),
               ('fits_keyword', 'INSTRUME'),
               ('blend_table', True)])

On instance:
  'WFC3'
  warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳validate.py:38: ValidationWarning: While validating meta.instrument.detector the
↳following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
↳'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
↳'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Name of detector used to acquire the data'),
               ('type', 'string'),
               ('enum',
                ['NRCA1',
                 'NRCA2',
                 'NRCA3',
                 'NRCA4',
                 'NRCALONG',
                 'NRCB1',
                 'NRCB2',
                 'NRCB3',
                 'NRCB4',
                 'NRCBLONG',
                 'NRS1',
                 'NRS2',

```

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```

        'ANY',
        'MIRIMAGE',
        'MIRIFULONG',
        'MIRIFUSHORT',
        'NIS',
        'GUIDER1',
        'GUIDER2',
        'N/A',
        'MULTIPLE']],
    ('fits_keyword', 'DETECTOR'),
    ('blend_table', True),
    ('blend_rule', 'multi'))

```

On instance:

```

    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↳ error occurred:
False is not of type 'string'

```

Failed validating 'type' in schema:

```

    OrderedDict([('title', 'Subarray used'),
                 ('type', 'string'),
                 ('anyOf',
                  [{'enum': ['8X8',
                             '32X32',
                             '128X128',
                             '2048X64',
                             'SUB128CNTR',
                             'SUB128DIAG',
                             'SUB128LL',
                             'SUB32CNTR',
                             'SUB32DIAG',
                             'SUB32LL',
                             'SUB8CNTR',
                             'SUB8DIAG',
                             'SUB8LL',
                             'SUBIDSTRIPCENTER',
                             'SUBIDSTRIPLL',
                             'SUBTUNE32CENTERG1',
                             'SUBTUNE32CENTERG2',
                             'SUBTUNE32LLG1',
                             'SUBTUNE32LLG2']}]},
                 {'enum': ['BRIGHTSKY',
                             'MASK1065',
                             'MASK1140',
                             'MASK1550',
                             'MASKLYOT',
                             'SLITLESSPRISM',
                             'SUB128',
                             'SUB256'],

```

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```

        'SUB64',
        'SUBPRISM']},
    {'enum': ['FULLP',
              'MASK210R',
              'MASK335R',
              'MASK430R',
              'MASKLWB',
              'MASKSWB',
              'SUB160',
              'SUB160P',
              'SUB320',
              'SUB320A335R',
              'SUB320A430R',
              'SUB320ALWB',
              'SUB320B335R',
              'SUB320B430R',
              ...
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/jwst/datamodels/
→ util.py:234: NoTypeWarning: model_type not found. Opening mastDownload/HST/hst_16264_
→ 12_wfc3_ir_f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits as a ImageModel
    warnings.warn(f"model_type not found. Opening {file_name} as a {class_name}",
*** Note: close plots to continue!

```

Or you can apply a rough guess for the offset, and then use a smaller d2d_max for matching:

```

wcs_align = st_wcs_align()

wcs_align.run_all(aligned_image,
                  telescope='hst',
                  outsubdir='mastDownload',
                  refcat_racol='ra',
                  refcat_deccol='dec',
                  refcat_magcol='mag',
                  refcat_magerrcol='dmag',
                  overwrite=True,
                  d2d_max=.25,
                  xshift=5,
                  yshift=5,
                  showplots=2,
                  refcatname=ref_catname,
                  histocut_order='dxdy',
                  sharpness_lim=(0.3,0.9),
                  roundness1_lim=(-0.7, 0.7),
                  SNR_min= 3,
                  dmag_max=1.0,
                  objmag_lim =(14,24))

aligned_image = os.path.join('mastDownload',os.path.basename(aligned_image).replace('drz.
→ fits','jhat.fits'))
aligned_fits = fits.open(aligned_image)

```

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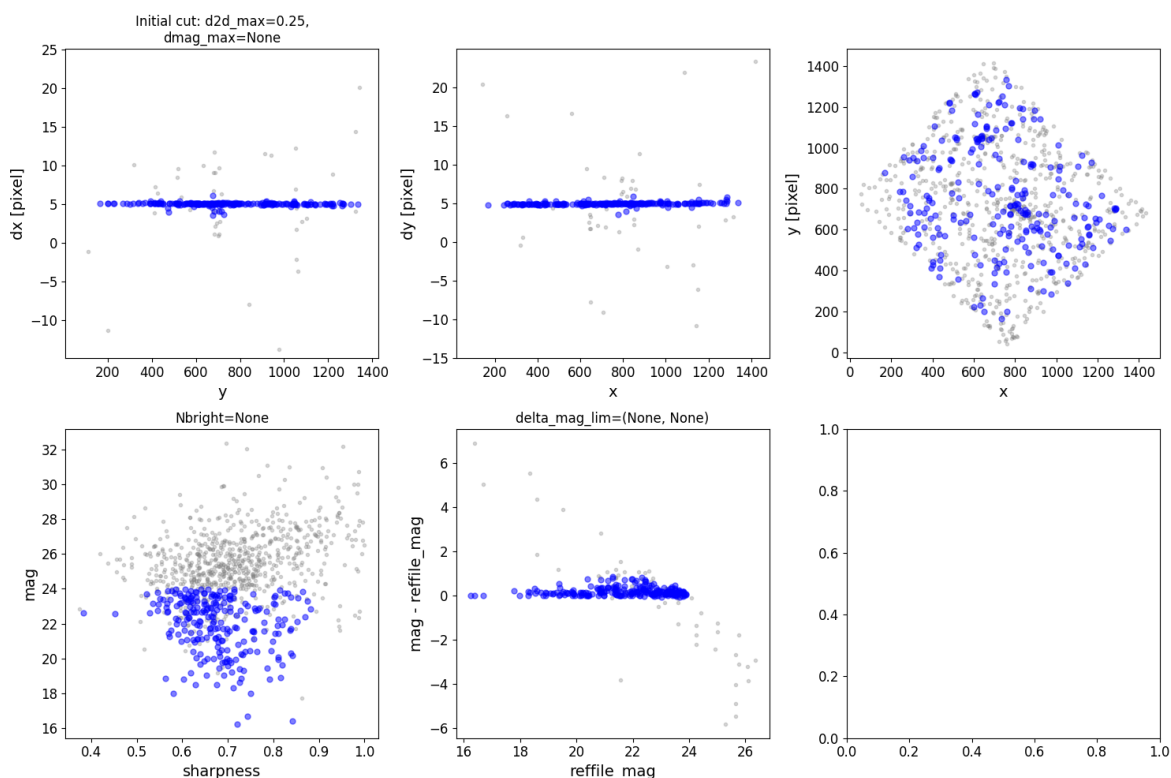
```

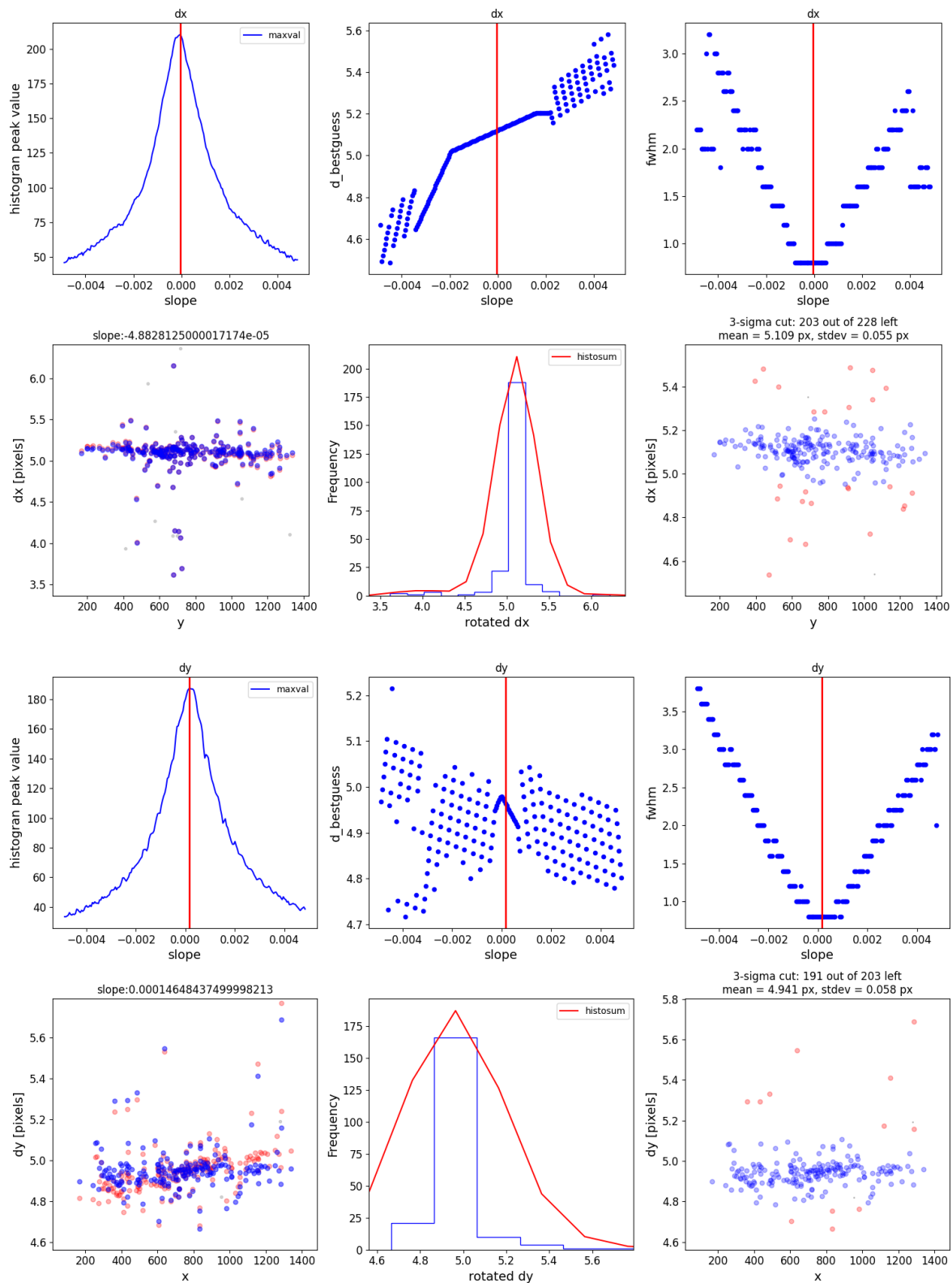
aligned_data = fits.open(aligned_image)['SCI',1].data
aligned_y,aligned_x = skycoord_to_pixel(star_location,wcs.WCS(aligned_fits['SCI',1],
    ↪aligned_fits))
aligned_cutout = extract_array(aligned_data,(11,11),(aligned_x,aligned_y))

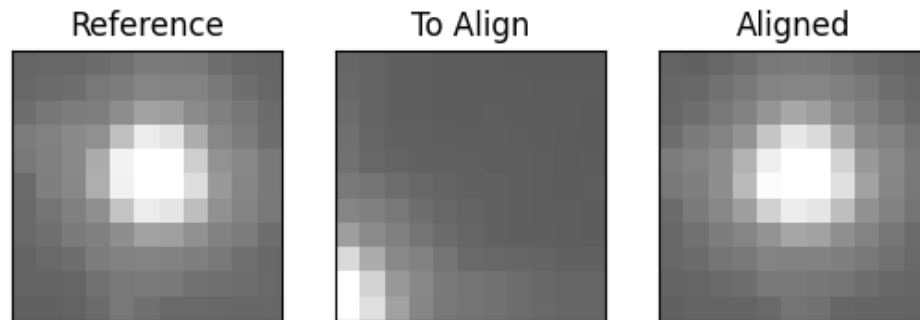
norm3 = simple_norm(aligned_cutout,stretch='log',min_cut=-1,max_cut=200)
fig,axes = plt.subplots(1,3)
axes[0].imshow(ref_cutout, origin='lower',
               norm=norm1,cmap='gray')
axes[1].imshow(aligned_cutout, origin='lower',
               norm=norm2,cmap='gray')
axes[2].imshow(aligned_cutout, origin='lower',
               norm=norm3,cmap='gray')
axes[0].set_title('Reference')
axes[1].set_title('To Align')
axes[2].set_title('Aligned')
for i in range(3):
    axes[i].tick_params(labelcolor='none',axis='both',color='none')

plt.show()

```







```
Warning: Setting aperture radius to twice the psf_fwhm (4.000000)
0 ./mastDownload/hst_16264_12_wfc3_ir_f110w_iebc12.phot.txt
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
  warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/astropy/stats/sigma_
↳ clipping.py:411: AstropyUserWarning: Input data contains invalid values (NaNs or infs),
↳ which were automatically clipped.
  warnings.warn('Input data contains invalid values (NaNs or '
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1942: RuntimeWarning: invalid_
↳ value encountered in log10
  phot['mag'] = -2.5*np.log10(phot['aper_sum_bkgsub'])+ee_corr+zp
/Users/jpierre/CodeBase/jhat/jhat/simple_jwst_phot.py:1945: RuntimeWarning: invalid_
↳ value encountered in log10
  phot['magerr'] = 2.5 * np.log10(1.0 + (fluxerr/phot['aper_sum_bkgsub']))
/Users/jpierre/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.instrument.name the following_
↳ error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
               ('type', 'string'),
```

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```

        ('enum',
         ['NIRCAM',
          'NIRSPEC',
          'MIRI',
          'TFI',
          'FGS',
          'NIRISS',
          'ANY',
          'N/A']),
        ('fits_keyword', 'INSTRUME'),
        ('blend_table', True)])

```

On instance:

```

    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
→ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
→ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
→ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']

```

Failed validating 'enum' in schema:

```

    OrderedDict([('title', 'Name of detector used to acquire the data'),
                 ('type', 'string'),
                 ('enum',
                  ['NRCA1',
                   'NRCA2',
                   'NRCA3',
                   'NRCA4',
                   'NRCALONG',
                   'NRCB1',
                   'NRCB2',
                   'NRCB3',
                   'NRCB4',
                   'NRCBLONG',
                   'NRS1',
                   'NRS2',
                   'ANY',
                   'MIRIMAGE',
                   'MIRIFULONG',
                   'MIRIFUSHORT',
                   'NIS',
                   'GUIDER1',
                   'GUIDER2',
                   'N/A',
                   'MULTIPLE']),
                 ('fits_keyword', 'DETECTOR'),
                 ('blend_table', True),
                 ('blend_rule', 'multi')])

```

On instance:

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```

'IR'
warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↳ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
↳ error occurred:
False is not of type 'string'

Failed validating 'type' in schema:
  OrderedDict([('title', 'Subarray used'),
               ('type', 'string'),
               ('anyOf',
                [{'enum': ['8X8',
                           '32X32',
                           '128X128',
                           '2048X64',
                           'SUB128CNTR',
                           'SUB128DIAG',
                           'SUB128LL',
                           'SUB32CNTR',
                           'SUB32DIAG',
                           'SUB32LL',
                           'SUB8CNTR',
                           'SUB8DIAG',
                           'SUB8LL',
                           'SUBIDSTRIPCENTER',
                           'SUBIDSTRIPLL',
                           'SUBTUNE32CENTERG1',
                           'SUBTUNE32CENTERG2',
                           'SUBTUNE32LLG1',
                           'SUBTUNE32LLG2']},
                 {'enum': ['BRIGHTSKY',
                           'MASK1065',
                           'MASK1140',
                           'MASK1550',
                           'MASKLYOT',
                           'SLITLESSPRISM',
                           'SUB128',
                           'SUB256',
                           'SUB64',
                           'SUBPRISM']},
                 {'enum': ['FULLP',
                           'MASK210R',
                           'MASK335R',
                           'MASK430R',
                           'MASKLWB',
                           'MASKSWB',
                           'SUB160',
                           'SUB160P',
                           'SUB320',
                           'SUB320A335R',
                           'SUB320A430R',
                           'SUB320ALWB',

```

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```

        'SUB320B335R',
        'SUB320B430R',
        ...
    warnings.warn(errmsg, ValidationWarning)
*** Note: close plot to continue!
    slope intercept      maxval index d_bestguess fwhm multimax
-0.000049  0.035596 210.533193    11    5.118499  0.8    False
Keeping 228 out of 228, skipping 0 because of null values in columns d_rot_tmp
median: 5.108273
75.000000 percentile cut: max residual for cut: 0.073336
median: 5.111246
i:00 mean:5.111246(0.002647) stdev:0.034510(0.001866) X2norm:1.00 Nchanged:0 Ngood:171
↳Nclip:57

mean: 5.113886
i:01 mean:5.113886(0.003071) stdev:0.041878(0.002165) X2norm:1.00 Nchanged:16 Ngood:187
↳Nclip:41

mean: 5.113807
i:02 mean:5.113807(0.003391) stdev:0.047237(0.002392) X2norm:1.00 Nchanged:8 Ngood:195
↳Nclip:33

mean: 5.113819
i:03 mean:5.113819(0.003501) stdev:0.049019(0.002470) X2norm:1.00 Nchanged:2 Ngood:197
↳Nclip:31

mean: 5.113098
i:04 mean:5.113098(0.003558) stdev:0.049936(0.002509) X2norm:1.00 Nchanged:1 Ngood:198
↳Nclip:30

mean: 5.111626
i:05 mean:5.111626(0.003673) stdev:0.051807(0.002590) X2norm:1.00 Nchanged:2 Ngood:200
↳Nclip:28

mean: 5.110125
i:06 mean:5.110125(0.003788) stdev:0.053702(0.002672) X2norm:1.00 Nchanged:2 Ngood:202
↳Nclip:26

mean: 5.109359
i:07 mean:5.109359(0.003846) stdev:0.054669(0.002713) X2norm:1.00 Nchanged:1 Ngood:203
↳Nclip:25

mean: 5.109359
i:08 mean:5.109359(0.003846) stdev:0.054669(0.002713) X2norm:1.00 Nchanged:0 Ngood:203
↳Nclip:25
    slope intercept      maxval index d_bestguess fwhm multimax
0.000146  -0.10686 187.297193     5    4.964436  0.8    False
Keeping 203 out of 203, skipping 0 because of null values in columns d_rot_tmp
median: 4.946334
75.000000 percentile cut: max residual for cut: 0.066828
median: 4.947336
i:00 mean:4.947336(0.002530) stdev:0.031086(0.001783) X2norm:1.00 Nchanged:0 Ngood:152

```

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```

↪Nclip:51

mean: 4.940657
i:01 mean:4.940657(0.002958) stdev:0.038228(0.002086) X2norm:1.00 Nchanged:16 Ngood:168↪
↪Nclip:35

mean: 4.938915
i:02 mean:4.938915(0.003185) stdev:0.041767(0.002245) X2norm:1.00 Nchanged:5 Ngood:173↪
↪Nclip:30

mean: 4.937633
i:03 mean:4.937633(0.003487) stdev:0.046521(0.002459) X2norm:1.00 Nchanged:6 Ngood:179↪
↪Nclip:24

mean: 4.939127
i:04 mean:4.939127(0.003714) stdev:0.050106(0.002619) X2norm:1.00 Nchanged:4 Ngood:183↪
↪Nclip:20

mean: 4.939913
i:05 mean:4.939913(0.004011) stdev:0.054843(0.002828) X2norm:1.00 Nchanged:5 Ngood:188↪
↪Nclip:15

mean: 4.939926
i:06 mean:4.939926(0.004134) stdev:0.056835(0.002916) X2norm:1.00 Nchanged:2 Ngood:190↪
↪Nclip:13

mean: 4.940799
i:07 mean:4.940799(0.004205) stdev:0.057955(0.002965) X2norm:1.00 Nchanged:1 Ngood:191↪
↪Nclip:12

mean: 4.940799
i:08 mean:4.940799(0.004205) stdev:0.057955(0.002965) X2norm:1.00 Nchanged:0 Ngood:191↪
↪Nclip:12
*** Note: close plots to continue!
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
↪validate.py:38: ValidationWarning: While validating meta.instrument.name the following↪
↪error occurred:
'WFC3' is not one of ['NIRCAM', 'NIRSPEC', 'MIRI', 'TFI', 'FGS', 'NIRISS', 'ANY', 'N/A']

Failed validating 'enum' in schema:
  OrderedDict([('title', 'Instrument used to acquire the data'),
               ('type', 'string'),
               ('enum',
                ['NIRCAM',
                 'NIRSPEC',
                 'MIRI',
                 'TFI',
                 'FGS',
                 'NIRISS',
                 'ANY',
                 'N/A']),
               ('fits_keyword', 'INSTRUME'),

```

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```
    ('blend_table', True)])
```

On instance:

```
    'WFC3'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.instrument.detector the
→ following error occurred:
'IR' is not one of ['NRCA1', 'NRCA2', 'NRCA3', 'NRCA4', 'NRCALONG', 'NRCB1', 'NRCB2',
→ 'NRCB3', 'NRCB4', 'NRCBLONG', 'NRS1', 'NRS2', 'ANY', 'MIRIMAGE', 'MIRIFULONG',
→ 'MIRIFUSHORT', 'NIS', 'GUIDER1', 'GUIDER2', 'N/A', 'MULTIPLE']
```

Failed validating 'enum' in schema:

```
    OrderedDict([('title', 'Name of detector used to acquire the data'),
                  ('type', 'string'),
                  ('enum',
                   ['NRCA1',
                    'NRCA2',
                    'NRCA3',
                    'NRCA4',
                    'NRCALONG',
                    'NRCB1',
                    'NRCB2',
                    'NRCB3',
                    'NRCB4',
                    'NRCBLONG',
                    'NRS1',
                    'NRS2',
                    'ANY',
                    'MIRIMAGE',
                    'MIRIFULONG',
                    'MIRIFUSHORT',
                    'NIS',
                    'GUIDER1',
                    'GUIDER2',
                    'N/A',
                    'MULTIPLE']),
                  ('fits_keyword', 'DETECTOR'),
                  ('blend_table', True),
                  ('blend_rule', 'multi')])
```

On instance:

```
    'IR'
    warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/stdatamodels/
→ validate.py:38: ValidationWarning: While validating meta.subarray.name the following
→ error occurred:
False is not of type 'string'
```

Failed validating 'type' in schema:

```
    OrderedDict([('title', 'Subarray used'),
                  ('type', 'string'),
```

(continues on next page)

(continued from previous page)

```

('anyOf',
 [{'enum': ['8X8',
            '32X32',
            '128X128',
            '2048X64',
            'SUB128CNTR',
            'SUB128DIAG',
            'SUB128LL',
            'SUB32CNTR',
            'SUB32DIAG',
            'SUB32LL',
            'SUB8CNTR',
            'SUB8DIAG',
            'SUB8LL',
            'SUBIDSTRIPCENTER',
            'SUBIDSTRIPLL',
            'SUBTUNE32CENTERG1',
            'SUBTUNE32CENTERG2',
            'SUBTUNE32LLG1',
            'SUBTUNE32LLG2']}],
 {'enum': ['BRIGHTSKY',
            'MASK1065',
            'MASK1140',
            'MASK1550',
            'MASKLYOT',
            'SLITLESSPRISM',
            'SUB128',
            'SUB256',
            'SUB64',
            'SUBPRISM']}],
 {'enum': ['FULLP',
            'MASK210R',
            'MASK335R',
            'MASK430R',
            'MASKLWB',
            'MASKSWB',
            'SUB160',
            'SUB160P',
            'SUB320',
            'SUB320A335R',
            'SUB320A430R',
            'SUB320ALWB',
            'SUB320B335R',
            'SUB320B430R',
            ...
 warnings.warn(errmsg, ValidationWarning)
/Users/jpierel/miniconda3/envs/tweakreg/lib/python3.10/site-packages/jwst/datamodels/
→ util.py:234: NoTypeWarning: model_type not found. Opening mastDownload/HST/hst_16264_
→ 12_wfc3_ir_f110w_iebc12/hst_16264_12_wfc3_ir_f110w_iebc12_drz.fits as a ImageModel
 warnings.warn(f"model_type not found. Opening {file_name} as a {class_name}",
*** Note: close plots to continue!

```

Total running time of the script: (0 minutes 57.951 seconds)

6.4 API Documentation

6.4.1 jhat

st_wcs_align

Created on Thu Apr 21 14:32:42 2022

@author: arest, bhilbert, mcorrenti, acanipe, jpierel

class jhat.st_wcs_align.st_wcs_align

Main class for alignment.

outrootdir

output root directory. The output directoy is the output root directory + the outsubdir if not None

Type

str

outsubdir

outsubdir added to output root directory

Type

str

overwrite

overwrite files if they exist.

Type

bool

telescope

If None, then telescope is determined automatically from the filename (“jw*” and “hst*” for JWST and HST, respectively)

Type

str

skip_if_exists

Skip doing the analysis of a given input image if the cal file already exists, assuming the full analysis has been already done

Type

bool

verbose

verbosity count (lower is less verbose)

Type

int

SNR_min

mininum SNR for objects in image to be used for analysis

Type

float

use_dq

use the DQ extensions for masking

Type

bool

refcat

reference catalog. Can be a filename or Gaia

Type

str

refcat_racol

RA column of reference catalog. If None, then automatically determined

Type

str

refcat_deccol

Dec column of reference catalog. If None, then automatically determined

Type

str

refcat_magcol

mag column of reference catalog. If None and not one of the default refcats like gaia, then 3rd column is used

Type

str

refcat_magerrcol

magerr column of reference catalog. If None, then not used

Type

str

refcat_colorcol

color column of reference catalog. If None, then not used

Type

str:

refcat_pmflag

Apply the proper motion correction (only for catalogs it is applicable, e.g., gaia

Type

bool

refcat_pmmedian

Apply the MEDIAN proper motion correction (only for catalogs it is applicable, e.g., gaia

Type

bool

photfilename

photometry output filename. if “auto”, the fits in the image filename is substituted with phot.txt

Type

str

load_photcat_if_exists

If the photometric catalog file already exists, skip recreating it.

Type
bool

rematch_refcat

if `load_photcat_if_exists` and the photcat already exists, load the photcat, but rematch with refcat

Type
bool

d2d_max

maximum distance between source in image and refcat object, in arcsec

Type
float

dmag_max

maximum uncertainty of sources in image

Type
float

sharpness_lim

sharpness limits of sources in image (iterable of length 2)

Type
list of float

roundness1_lim

roundness1 limits of sources in image (iterable of length 2)

Type
list of float

delta_mag_lim

limits on mag - refcat_mainfilter (iterable of length 2)

Type
list of float

objmag_lim

limits on mag, the magnitude of the objects in the image (iterable of length 2)

Type
list of float

refmag_lim

limits on refcat_mainfilter, the magnitude of the reference catalog (iterable of length 2)

Type
list of float

slope_min

minimum slope for linear correction applied to dx/dy. This effectively accounts for rotation. slopes go from slopemin to -slopemin

Type
float

Nbright4match

Use only Nbright brightest objects for matching to the ref cat

Type

int

Nbright

Use only Nbright brightest objects in image that are matched to refcat for alignment

Type

int

histocut_order

histocut_order defines whether the histogram cut is first done for dx or first for dy (choices are 'dxdy' or 'dydx')

Type

str

xshift

added to the x coordinate before calculating ra,dec (only impacts ra,dec, not x). This can be used to correct for large shifts before matching!

Type

float

yshift

added to the y coordinate before calculating ra,dec (only impacts ra,dec, not y). This can be used to correct for large shifts before matching!

Type

float

iterate_with_xyshifts

After the first histogram fit, redo the match with refcat with x/yshift=median(dx/dy) and redo histofit. Use this if the offsets are big, since the second iteration will give you better matching with the refcat

Type

bool

showplots

showplots=1: most important plots. showplots=2: all plots (debug/test/finetune)

Type

int

saveplots

saveplots=1: most important plots. saveplots=2: all plots (debug/test/finetune)

Type

int

savephottable

Save the final photometry table

Type

bool

replace_sip

Replace the tweaked fits image wcs with the SIP representation.

Type

bool

sip_err

max_pix_error for SIP transformation.

Type

float

sip_degree

degree for SIP transformation.

Type

int

sip_points

npoints for SIP transformation.

Type

int

ee_radius

encircled energy percentage (multiples of 10) for photometry

Type

int

rough_cut_px_min

first rough cut: best d_rotated+-rough_cut_pix. This is the lower limit for rough_cut

Type

float

rough_cut_px_max

first rough cut: best d_rotated+-rough_cut_pix. This is the upper limit for rough_cut

Type

float

d_rotated_Nsigma

Nsigma for sigma cut of d_rotated. If 0.0, then 3-sigma cut is skipped

Type

float

set_telescope(*telescope=None, imname=None*)

Figuring out which telescope your data come from (HST or JWST). Note that if your filename is non-standard, then you MUST set

simple_jwst_phot

Created on Wed Apr 27 09:21:15 2022

@author: arest, jpierel, mcorrenti

This is class wrapper around doing simple photometry on a single JWST image

class jhat.simple_jwst_phot.hst_photclass(psf_fwhm=2, aperture_radius=None, verbose=0)

The photometry class for HST images.

aperture_phot(filt=None, pupil=None, radii_Nfwhm=None, radius_Nfwhm_sky_in=None, radius_Nfwhm_sky_out=None, radius_Nfwhm_for_mag=None, primaryhdr=None, scihdr=None)

Aperture photometry routine for HST.

Returns

table_aper

Return type

astropy.table.Table

match_refcat(max_sep=1.0, borderpadding=40, refcatshort=None, ix_s_obj=None, ix_s_refcat=None)

Matches the photometry catalog to the reference catalog.

Parameters

- **max_sep** (*float*) – Maximum separation between sources in arcseconds
- **borderpadding** (*float*) – Pixel separation required from border of image
- **refcatshort** (*string, optional*) – Short name of reference catalog that is used as prefix for the column names. The default is None. If None, then refcatshort is set to self.refcat.short
- **indices** (*list*) – The indices to access the photometry catalog, default None (use the full catalog)

Return type

None.

class jhat.simple_jwst_phot.jwst_photclass(verbose=0)

The photometry class for JWST images.

aperture_phot(filt=None, pupil=None, radii_Nfwhm=None, radius_Nfwhm_sky_in=None, radius_Nfwhm_sky_out=None, radius_Nfwhm_for_mag=None, primaryhdr=None, scihdr=None)

Aperture photometry routine for HST.

Returns

table_aper

Return type

astropy.table.Table

find_stars(threshold=3, var_bkg=False, primaryhdr=None, scihdr=None)

Parameters

- **threshold** (*float*) – The absolute image value above which to select sources.
- **fwhm** (*float*) – The full-width half-maximum (FWHM) of the major axis of the Gaussian kernel in units of pixels.

- **var_bkg** (*bool*) – Use Background2D (see description above)

match_refcat(*max_sep=1.0, borderpadding=40, refcatshort=None, ix_obj=None, ix_refcat=None*)

Matches the photometry catalog to the reference catalog.

Parameters

- **max_sep** (*float*) – Maximum separation between sources in arcseconds
- **borderpadding** (*float*) – Pixel separation required from border of image
- **refcatshort** (*string, optional*) – Short name of reference catalog that is used as prefix for the column names. The default is None. If None, then refcatshort is set to self.refcat.short
- **indices** (*list*) – The indices to access the photometry catalog, default None (use the full catalog)

Return type

None.

st_wcs_align_batch

Created on Mon Apr 25 09:39:07 2022

@author: arest

6.5 Citing JHAT

Please use the following bibcode citation for JHAT:

```
@MISC{Rest2023_jhat,
  author = {{Rest}, Armin and {Pierel}, Justin and {Correnti}, Matteo and {Hilbert},
  ↪Bryan and {Canipe}, Alicia and {Sunnquist}, Ben and {Fox}, Ori,
  title = "{The JWST HST Alignment Tool (JHAT)}",
  howpublished = {Zenodo},
  year = 2023,
  month = may,
  eid = {10.5281/zenodo.7892935},
  doi = {10.5281/zenodo.7892935},
  version = {v2},
  publisher = {Zenodo},
}
```

6.6 Primary Contributors



Fig. 1: Armin Rest



Fig. 2: Justin Pierel



Fig. 3: Matteo Correnti



Fig. 4: Alicia Canipe



Fig. 5: Bryan Hilbert



Fig. 6: Ben Sunnquist

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