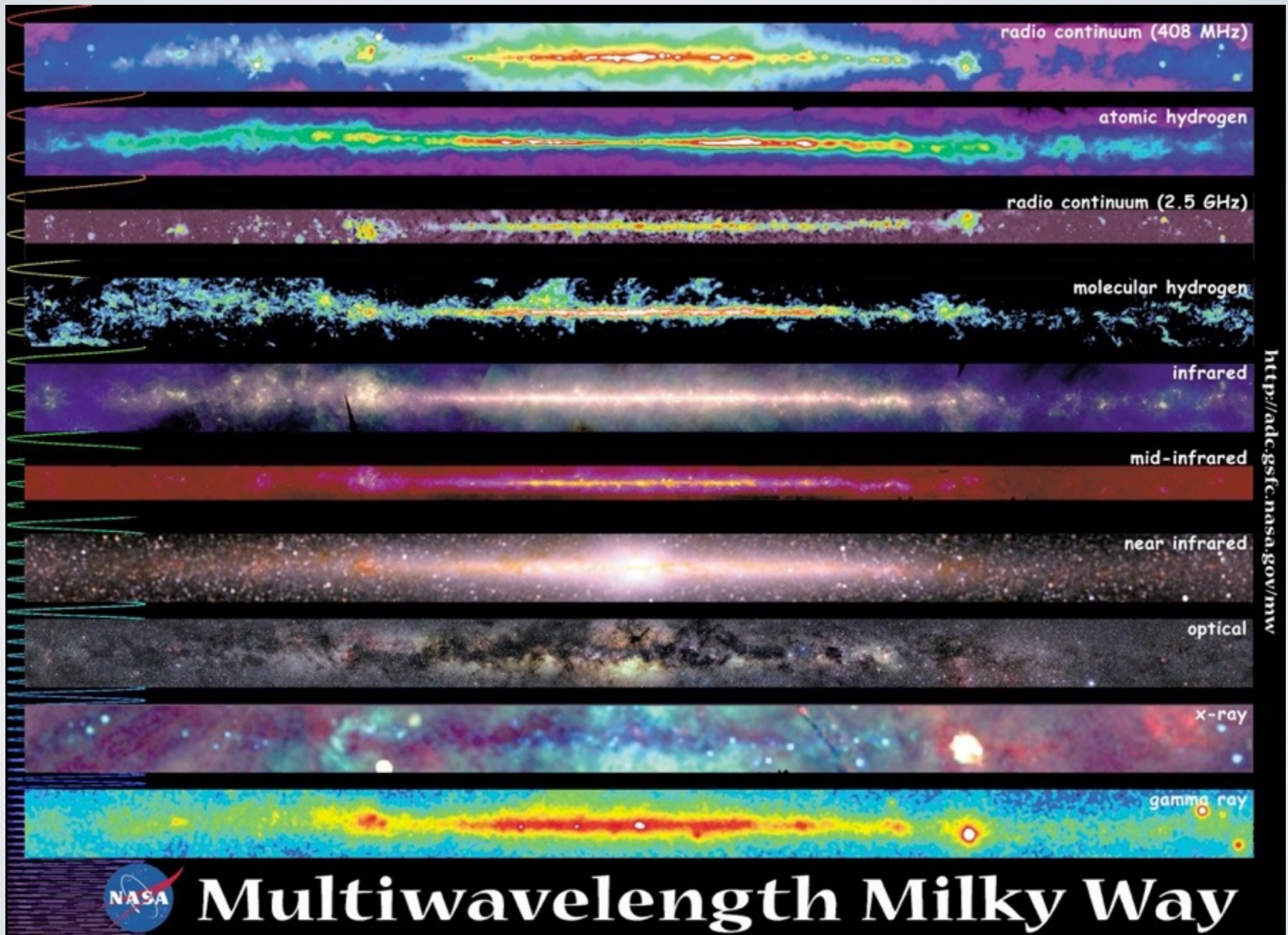


Data Reduction - Optical / NIR Imaging

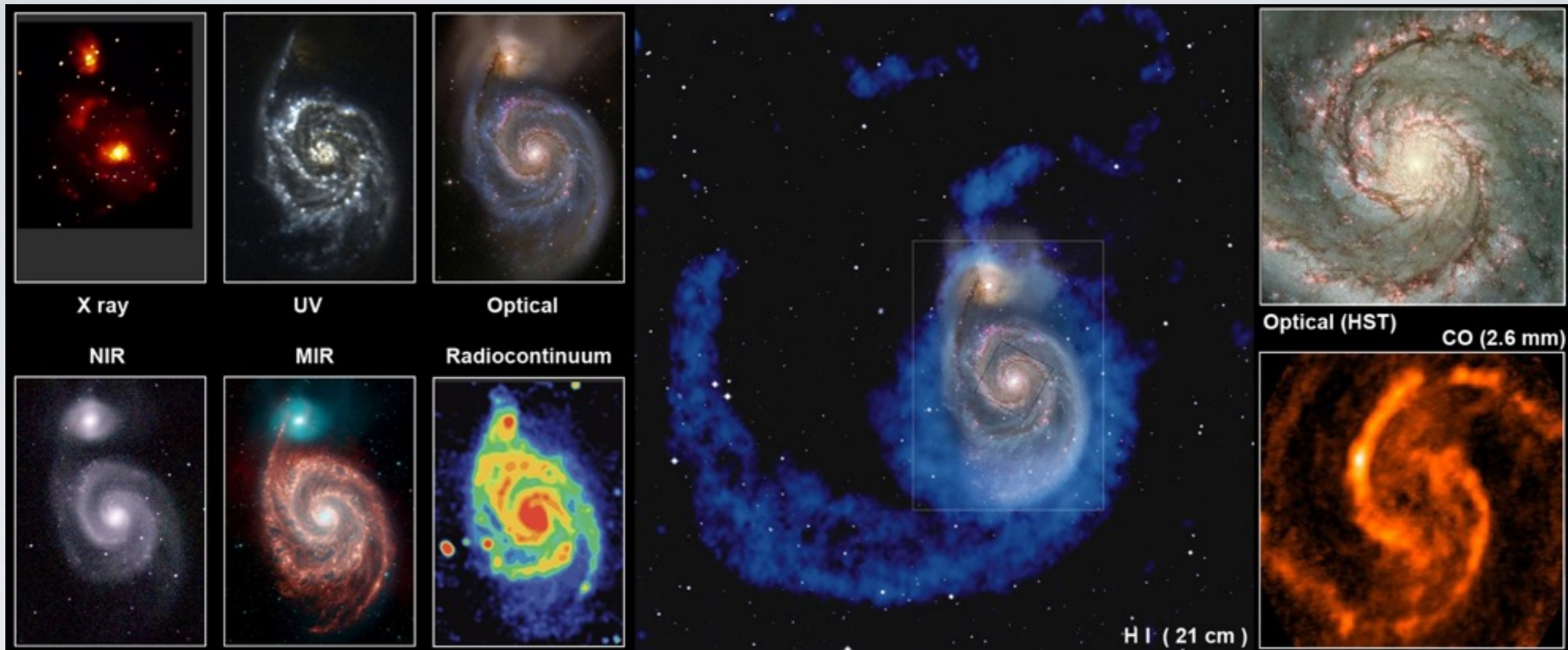
Mark Swinbank & Julie Wardlow
OCW113 & OCW111



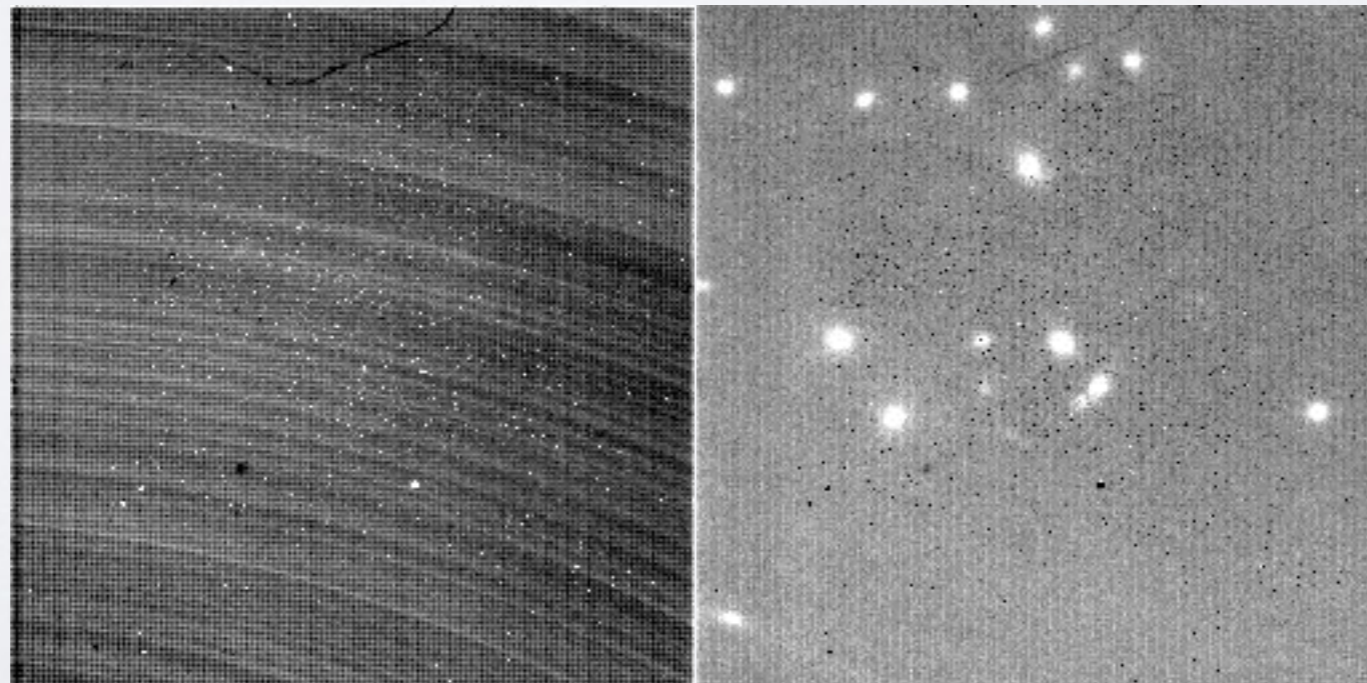
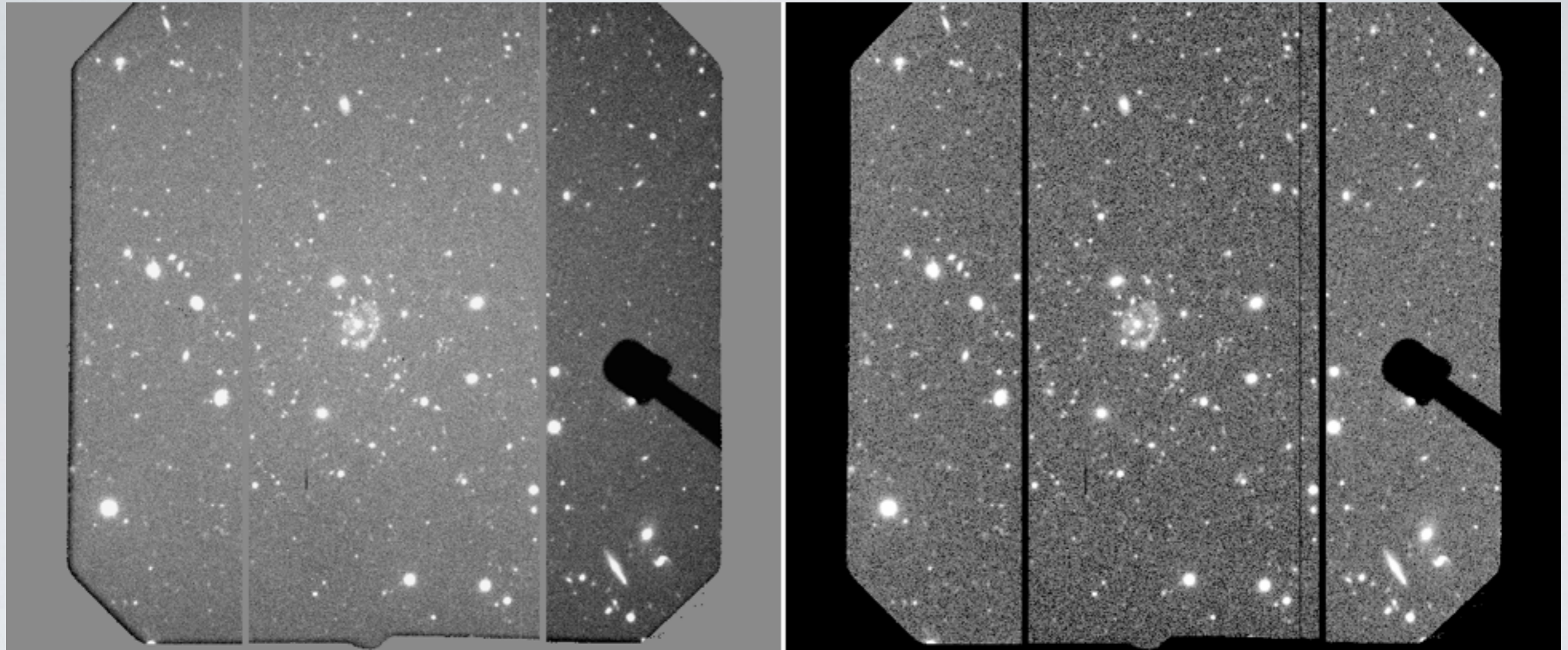
Images at different wavelengths...



Images at different wavelengths...



However, the raw data are always not as pretty



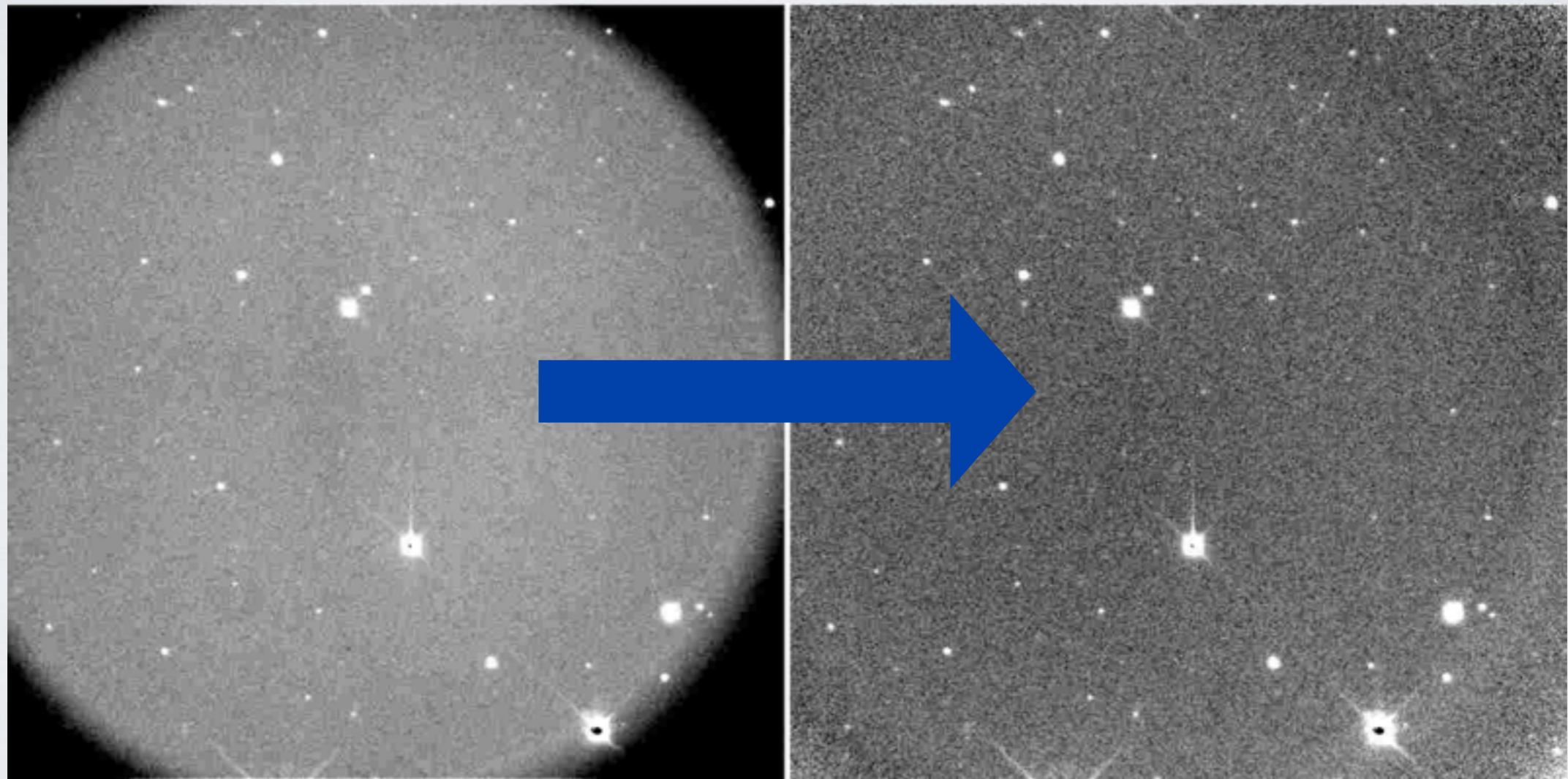
Why?

“The total amount of energy from outside the solar system ever received by all the radio telescopes on the planet Earth is less than the energy of a single snowflake striking the ground”

-Carl Sagan



- Raw images are dominated by sky background and instrumental noises/effects
- Objects of interest are usually faint and require many exposures to detect
- Need to reduce and combine raw data into one final science image



Goal: Learn how to *in principle* do



Why do we learn how to reduce data when there are usually pipelines available?

Pipelines may not work properly.....

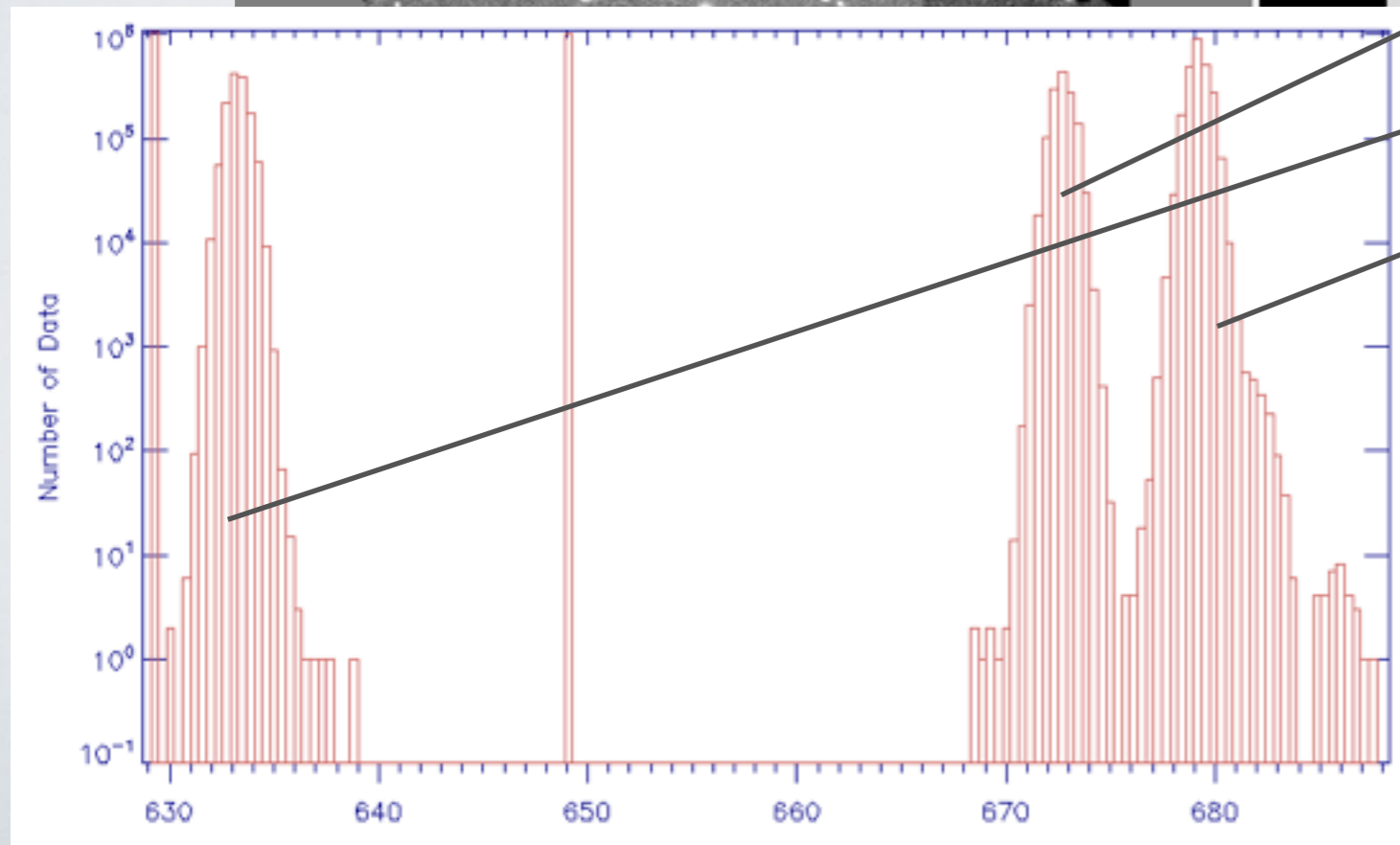
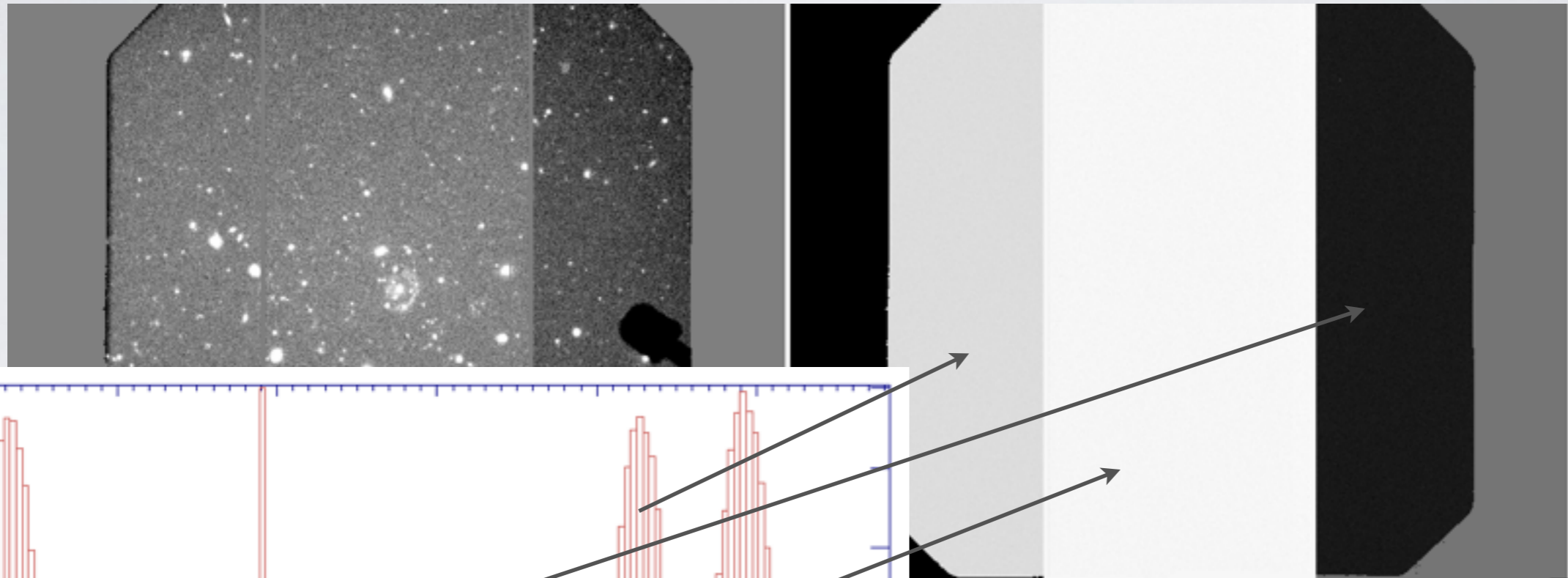
Are data in different wavelengths all reduced in the same way?

No, but the concepts are similar.....

Instrumental noises / effects :

Bias:

An offset to keep the signals positive.



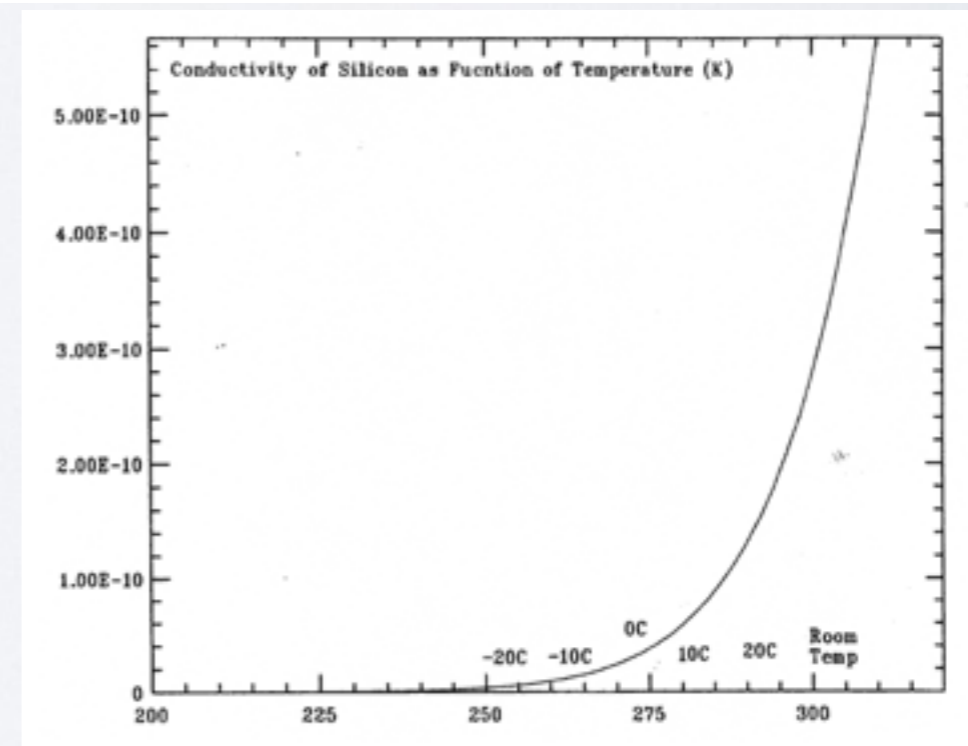
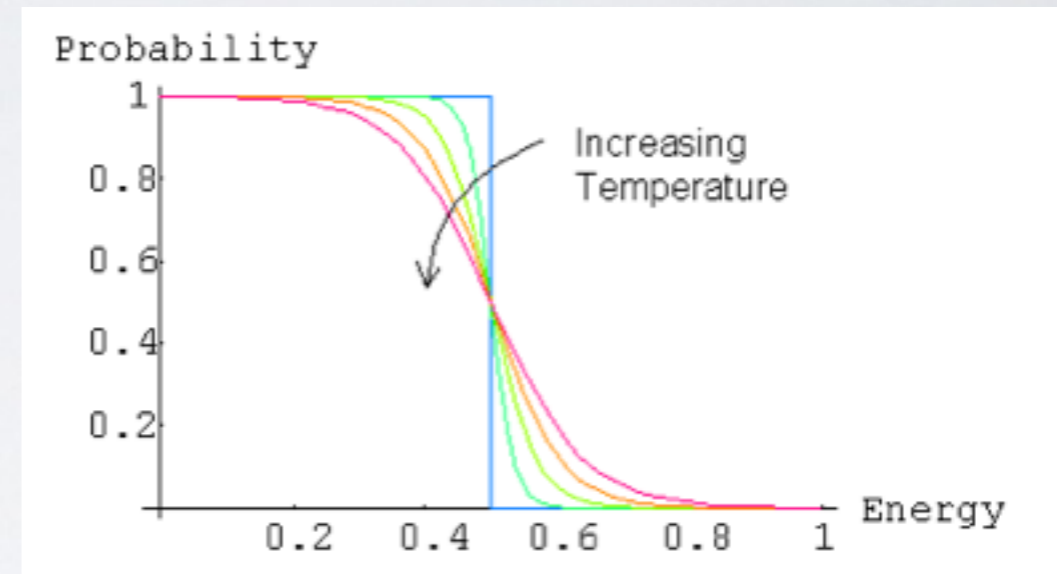
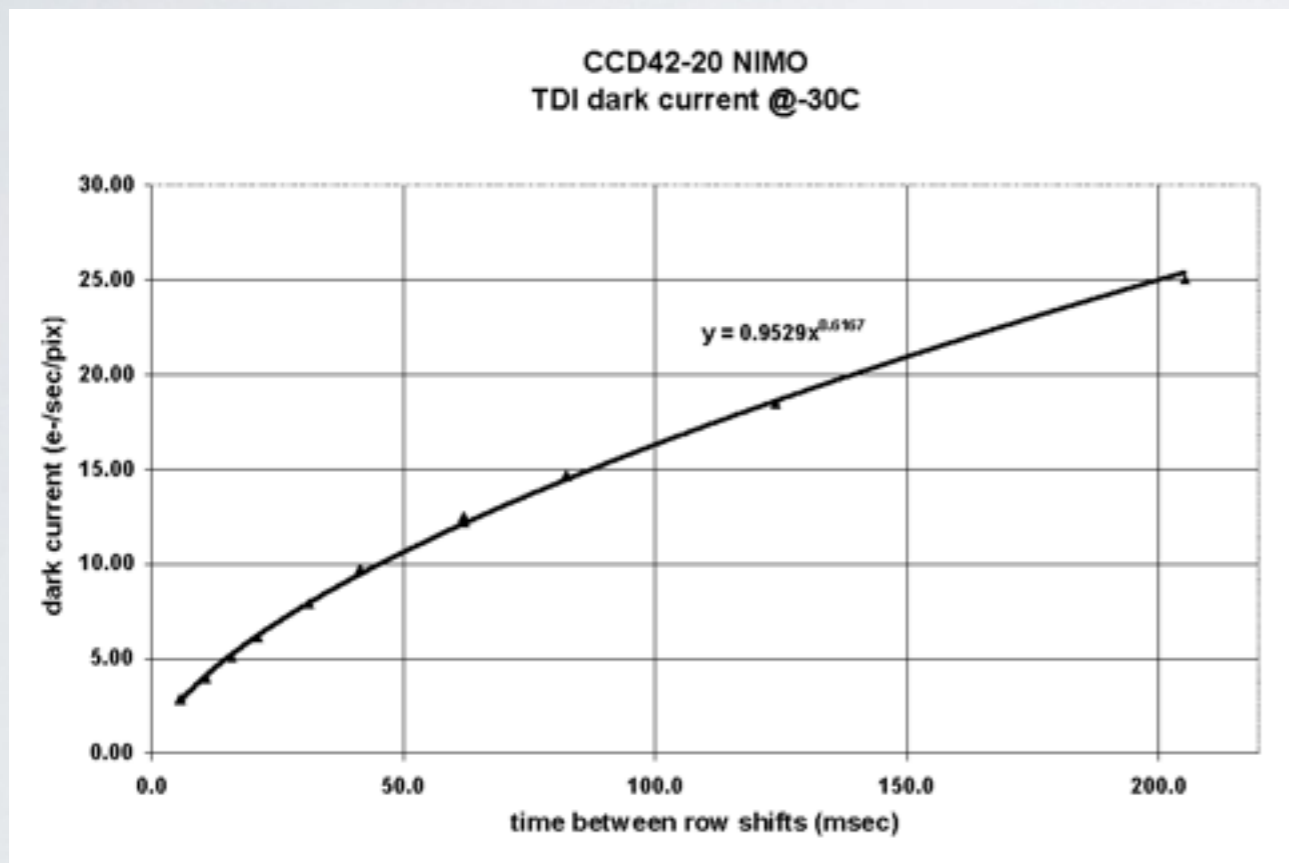
Extra noises:

1. analog to digital conversion
2. spurious electrons (in certain type of CCD)

Instrumental noises / effects :

Dark:

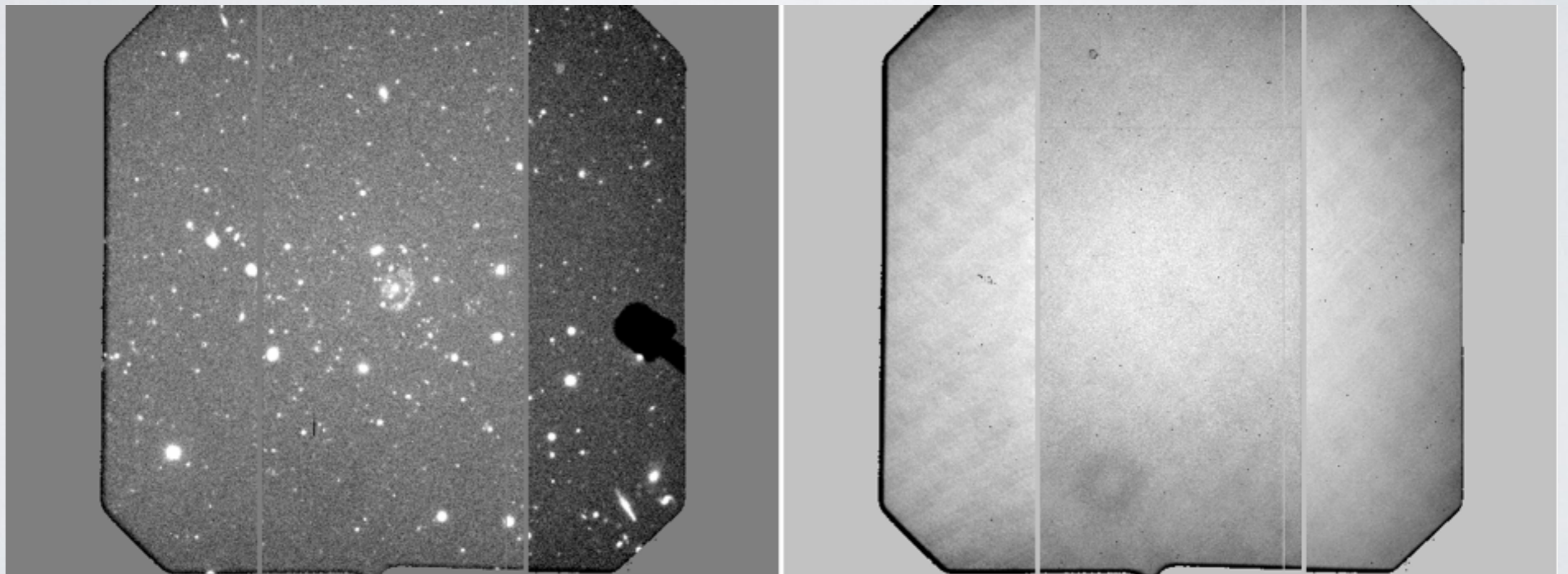
Thermal signals from the detector, highly temperature dependent, non-negligible in NIR.



Instrumental noises / effects :

Flat-field:

Non-uniformity of the quantum efficiency across the whole detector.



Ways to measure them :

Bias:

Obtain by reading-out the CCD with a zero-second exposure.

Dark:

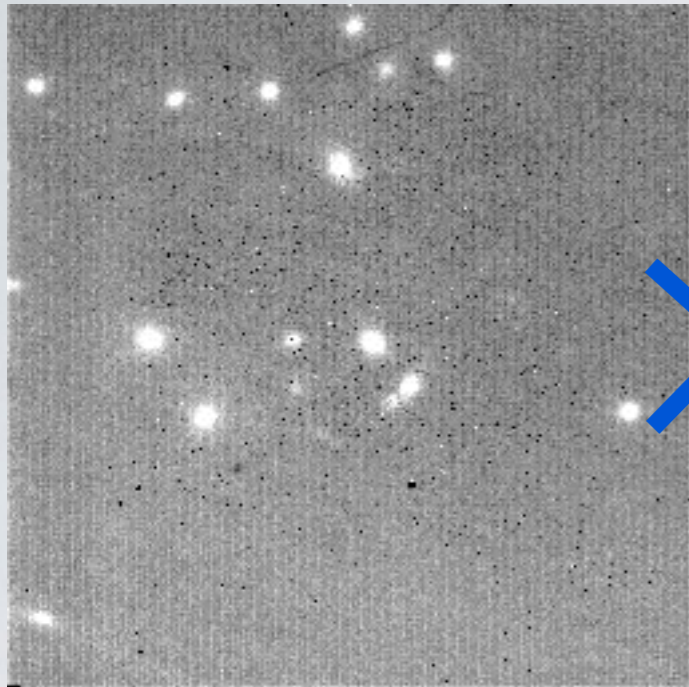
Exposures taken with the shutter closed (dark!), with the same exposure time and temperature as the science images.

Flat-field:

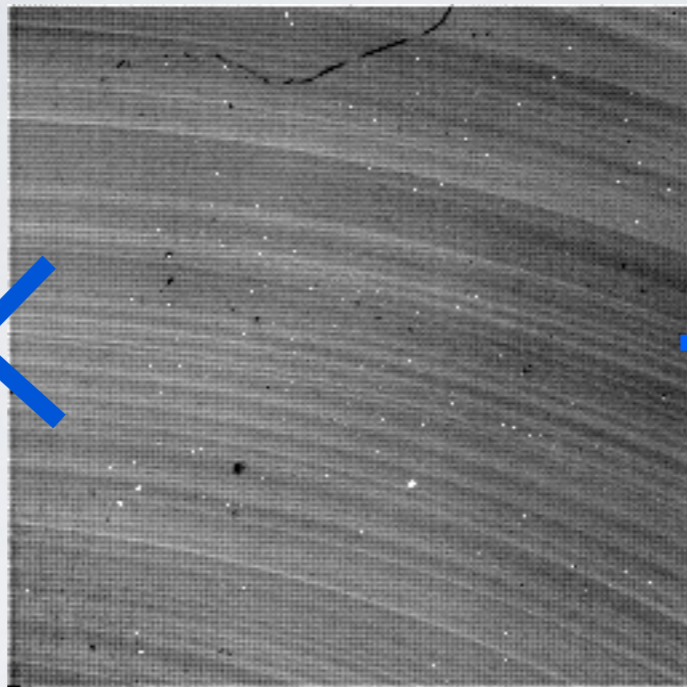
Exposures of a uniformly illuminated source. Type of flatfields: Dome, Twilight, Sky

NOTE: Often will have several exposures for each effect, and they can be averaged together to make a more robust master

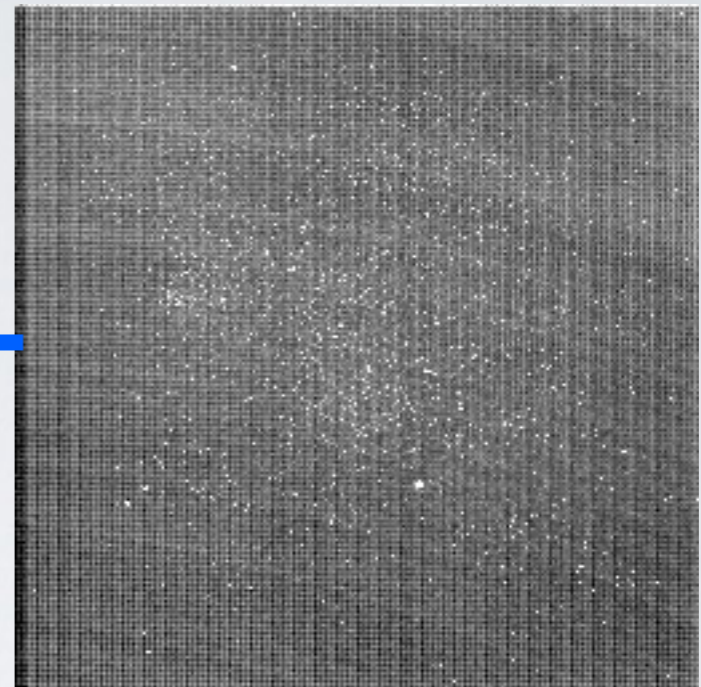
Object



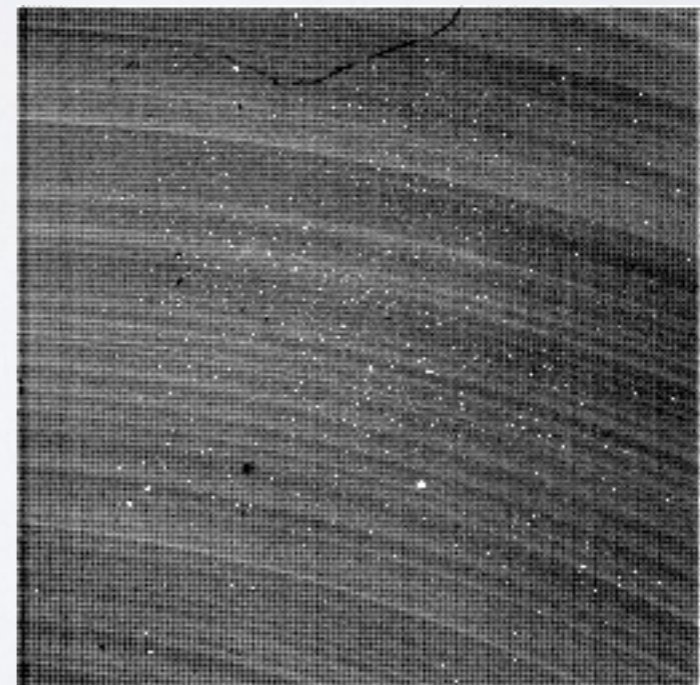
Flat



Bias/Dark



Raw



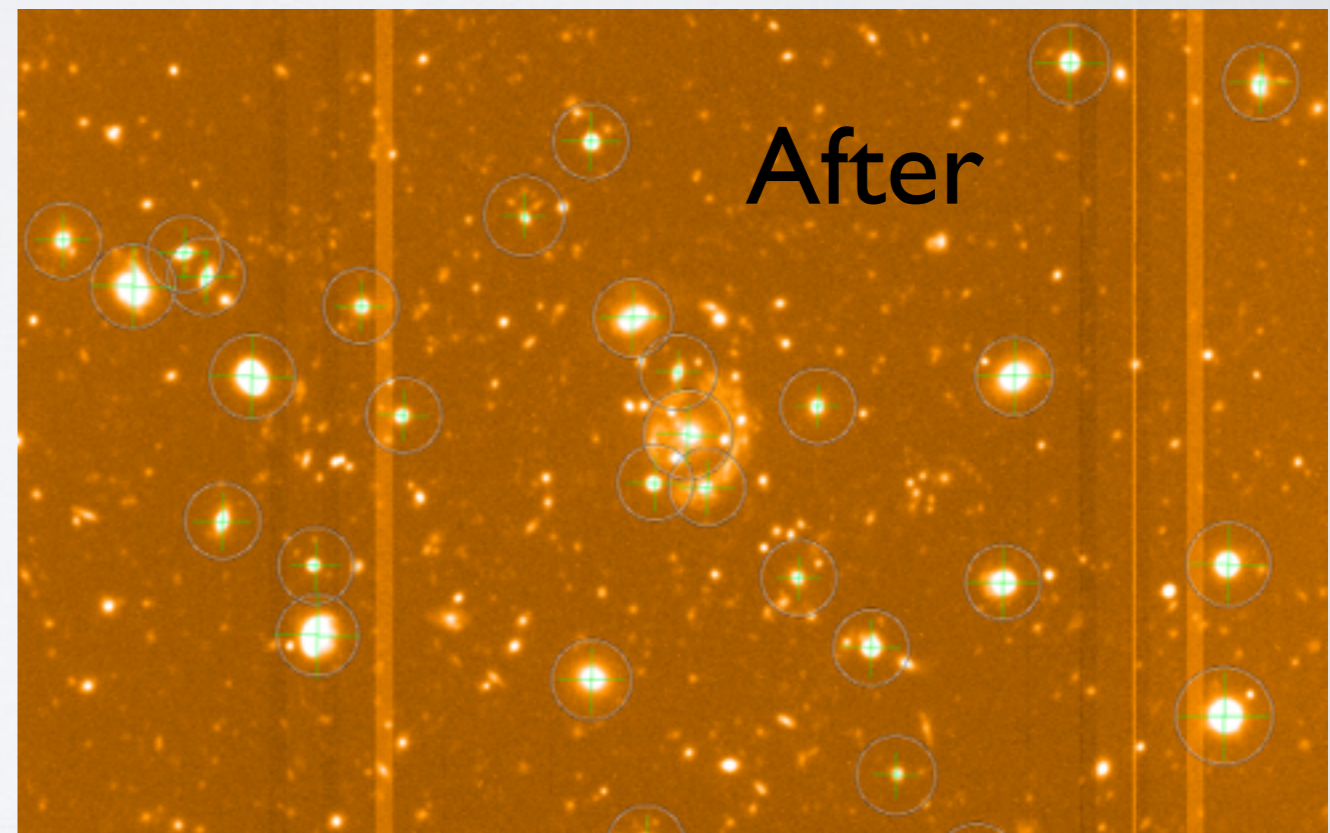
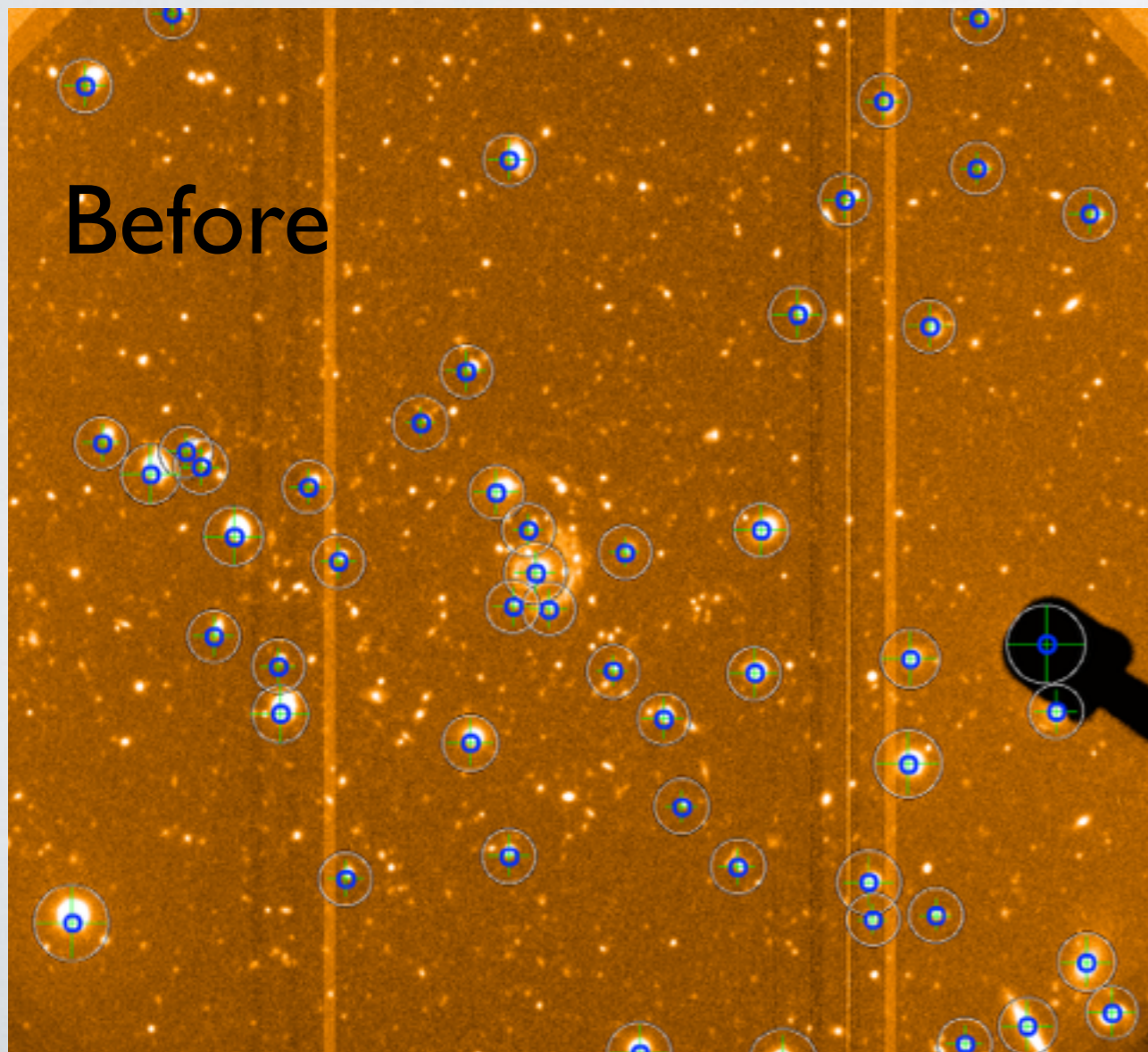
Fundamental Steps :

1. Subtract bias / dark
2. Flat-fielding
3. Co-add all “reduced” frames into one final image
4. Calibrate astrometry and flux using references such as standard stars, and update FITS header.

Calibrations

Astrometry:

The coordinates of the original images might not be accurate. Need to correct for this effect using bright referencing objects.



Calibrations

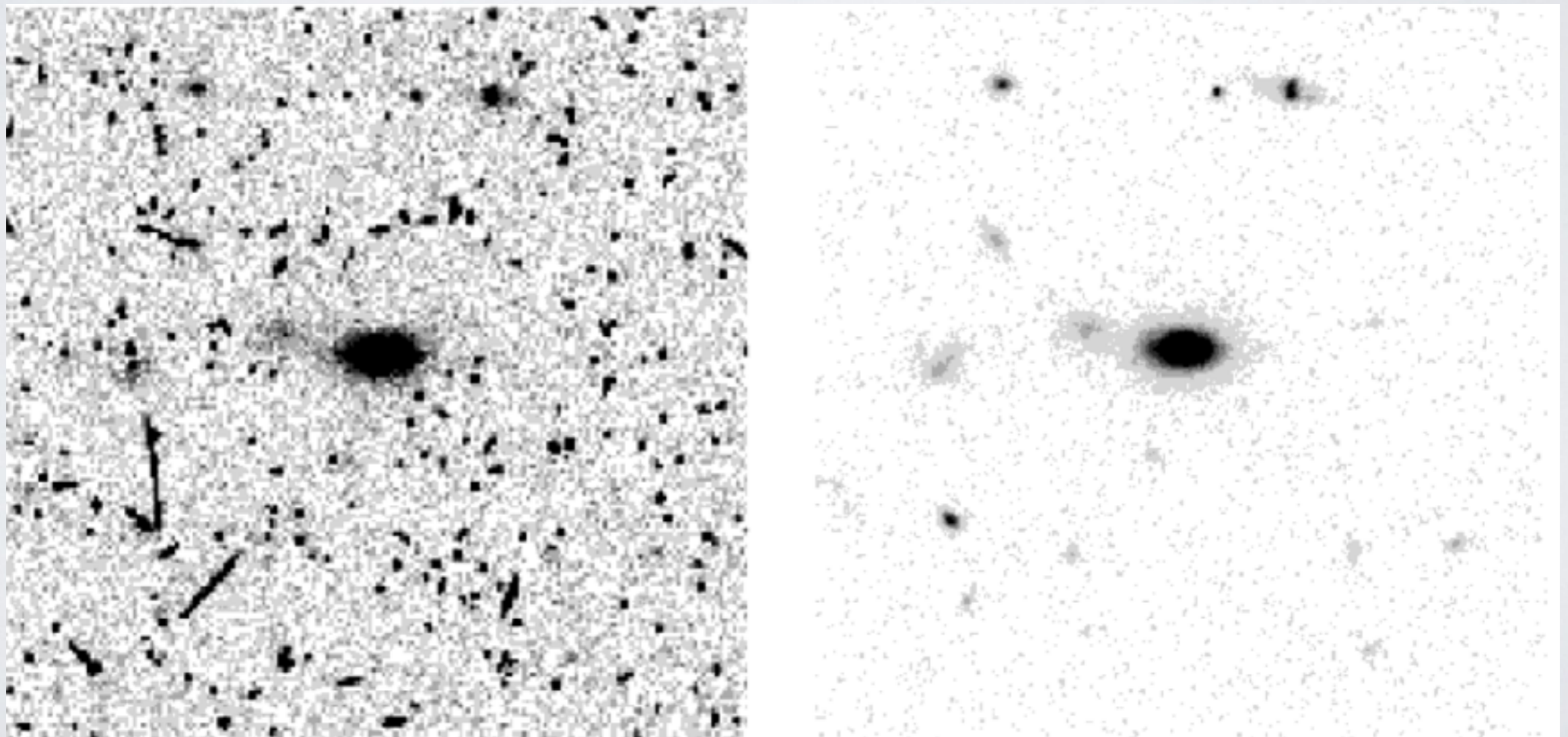
Flux:

The digital values of the reduced images are usually arbitrary. Need to convert those values to physically meaningful values, again using bright referencing objects with known fluxes and that are observed by the same instrument.

Other issues

Cosmic rays:

Cosmic rays often appear on images taken by the space telescopes. Need to be removed.

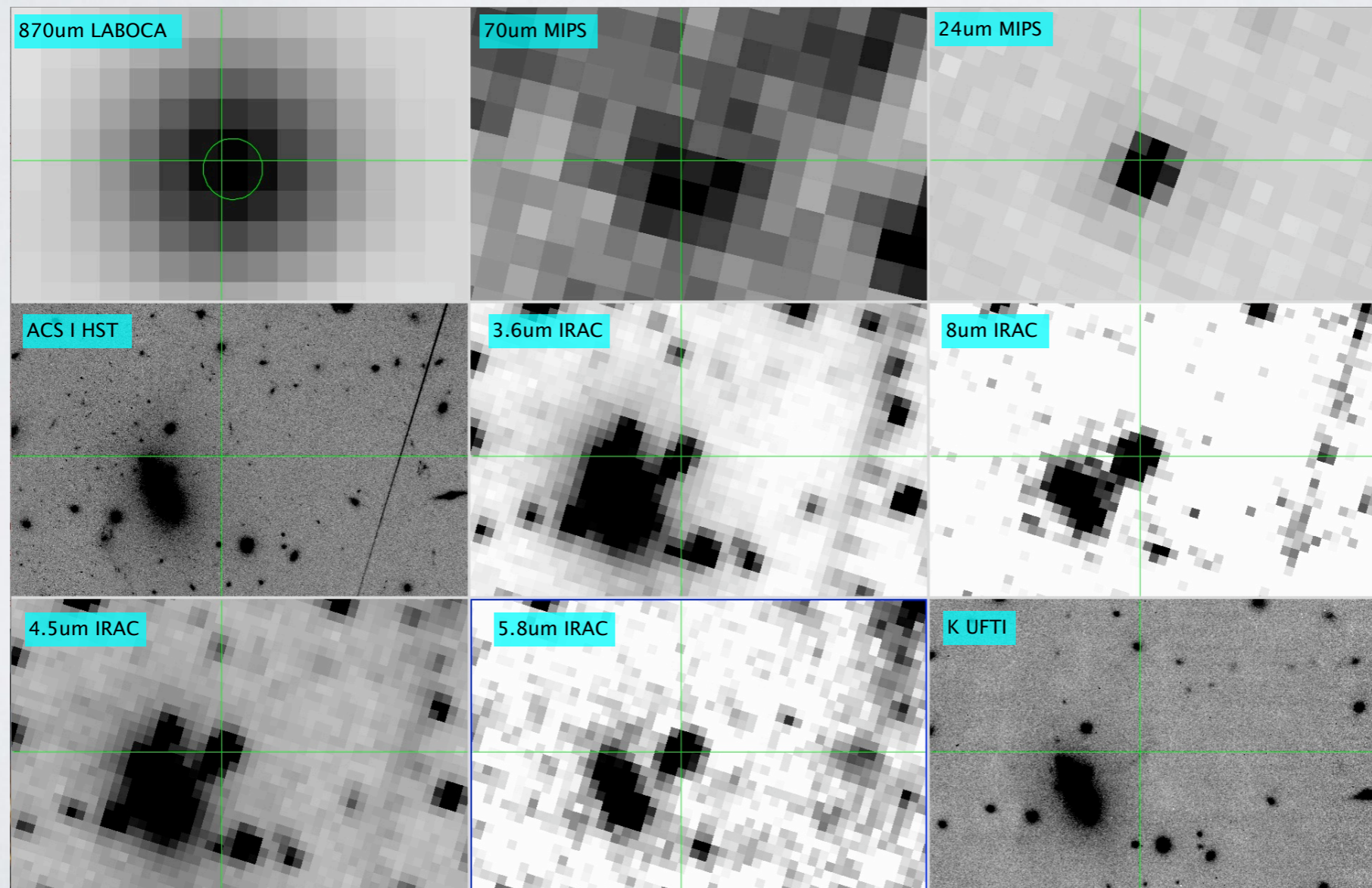


Your toolkit

1. Fundamentally, we're dealing with arithmetic operations on 2D arrays. Use your favorite computer language (IDL, Python, C, IRAF, etc) to manipulate them. Choice is yours.
2. Some invaluable tools: SExtractor (object extraction and photometry), SWarp (image co-add and re-sampling), WCSTools (manipulate/fit astrometry)

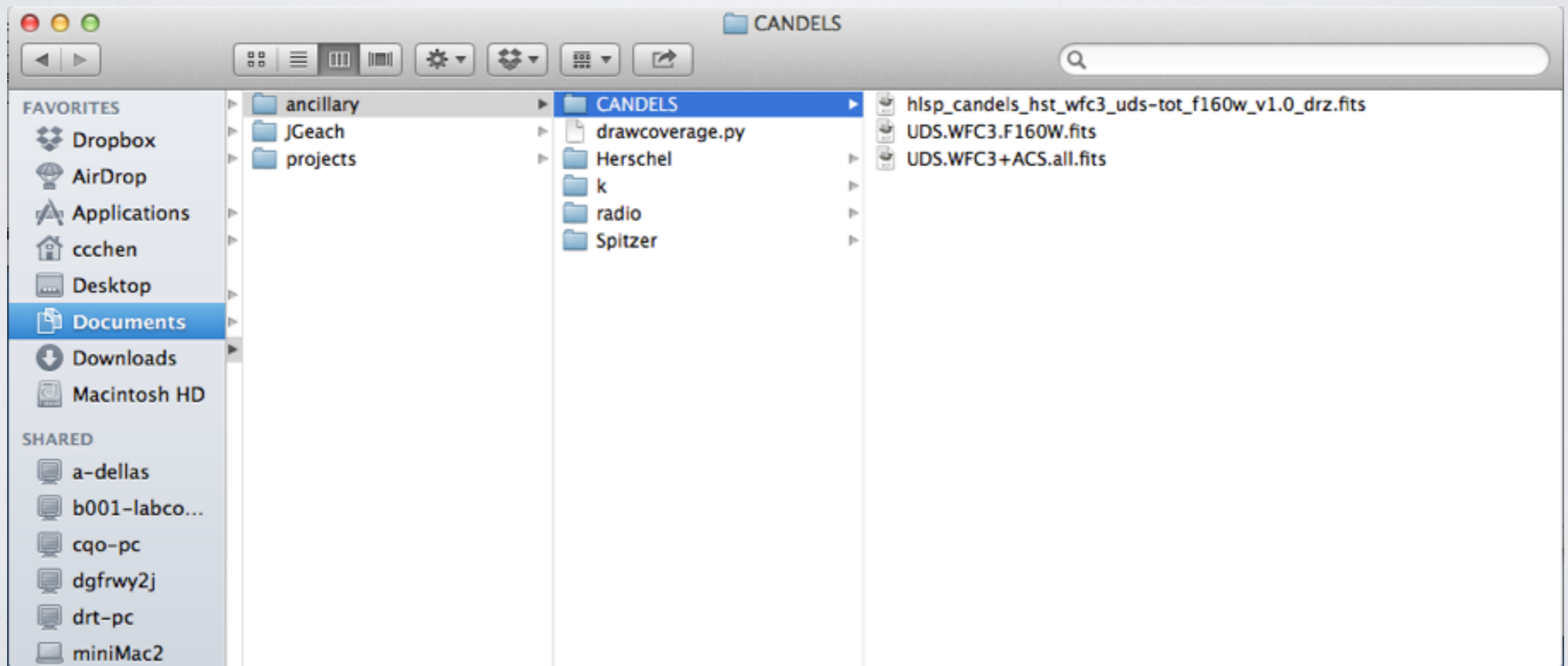
Your toolkit

3. Viewing Tools: ds9, Gaia (for example, ds9 can load many images on different pixel scale and align them).



Things that will help you

1. Naming convention : often a good idea to re-name the cryptically named raw files to something useful describing what the frame is (e.g., r102914.fits becomes object_K_10s.fits).

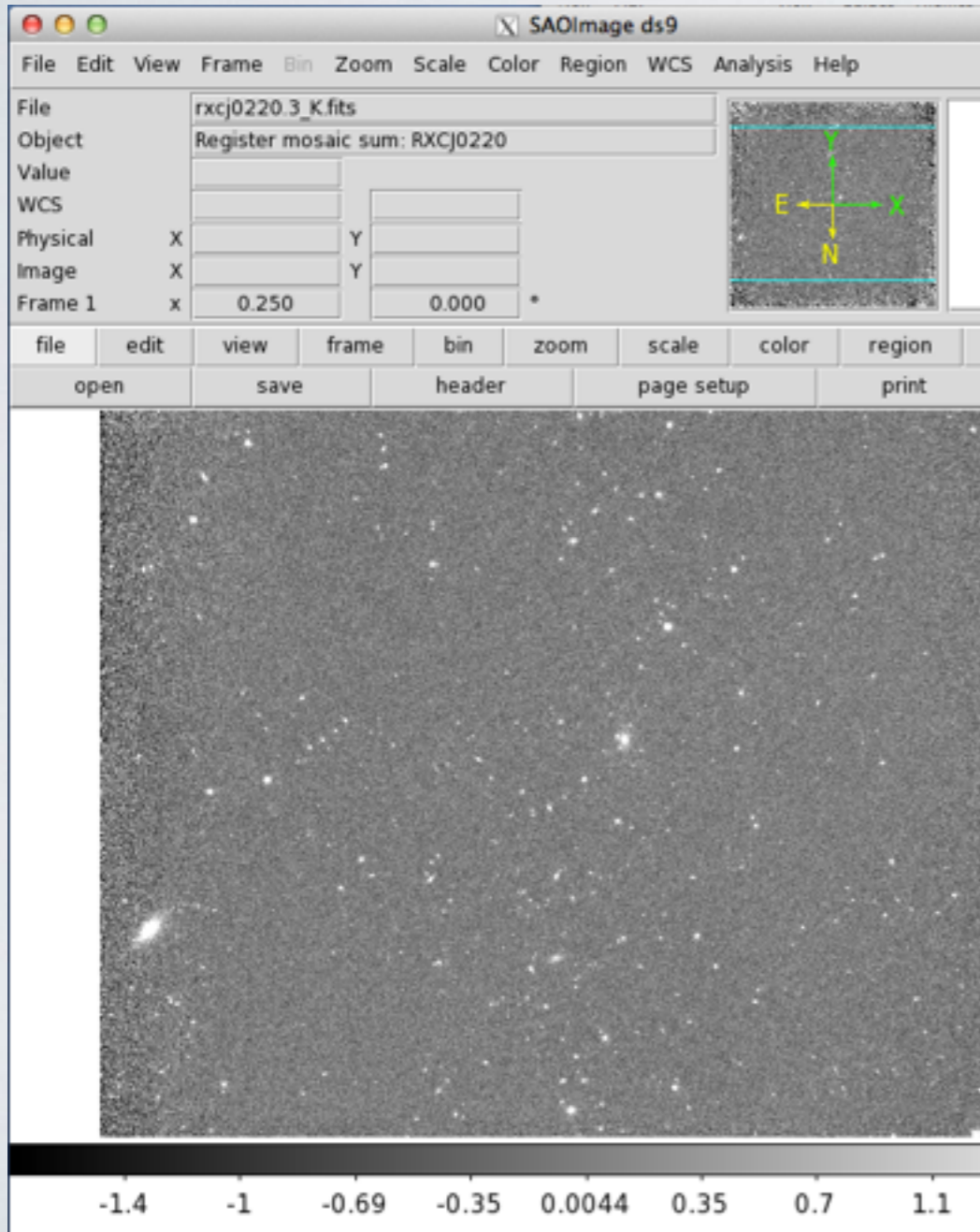


Things that will help you

2. Flexible Image Transfer System (FITS) file format :
Consists of 'header' containing meta-data (most important being world-coordinate system: WCS) and a binary array containing image data. FITS can also support multiple extensions (beware the hidden extension) and some catalogues come in FITS table format.

Hint: Information for sensible re-naming can be found in
the header

FITS Header



```
rxcj0220.3_K.fits
File Edit Font
CSEC12 = '[1025:2048,1:1024]' / ccd section
DSEC12 = '[1025:2048,1:1024]' / data section
TSEC12 = '[1025:2048,1:1024]' / trim section
ASEC21 = '[1:1024,1025:2048]' / amplifier section
BSEC21 = ' ' / bias section
CSEC21 = '[1:1024,1025:2048]' / ccd section
DSEC21 = '[1:1024,1025:2048]' / data section
TSEC21 = '[1:1024,1025:2048]' / trim section
ASEC22 = '[1025:2048,1025:2048]' / amplifier section
BSEC22 = ' ' / bias section
CSEC22 = '[1025:2048,1025:2048]' / ccd section
DSEC22 = '[1025:2048,1025:2048]' / data section
TSEC22 = '[1025:2048,1025:2048]' / trim section
IDETTEMP= 75.82 / Initial detector temperature
FDETTEMP= 75.82 / Final detector temperature
DATE-OBS= '2007-02-10T00:00:00.000' / Date of observation
UT = '00:48:45.0' / UT of TCS coordinates
RA = '02:20:54.92' / right ascension (telescope)
DEC = '-38:28:07.3' / declination (telescope)
EQUINOX = 2000.0 / epoch of RA & DEC
HA = '03:03:13.6' / hour angle (H:M:S)
CRPIX1 = 1292.28125 / Reference pixel on axis 1
CRPIX2 = 1333.415093 / Reference pixel on axis 2
CRVAL1 = 35.23666666666667 / Value at ref. pixel on axis 1
CRVAL2 = -38.48388888888889 / Value at ref. pixel on axis 2
CTYPE1 = 'RA--TAN' / Type of co-ordinate on axis 1
CTYPE2 = 'DEC--TAN' / Type of co-ordinate on axis 2
CDELTA1 = -8.46849148788206E-5 / Pixel size on axis 1
CDELTA2 = -8.47328196270999E-5 / Pixel size on axis 2
PC1_1 = 1.0 / Transformation matrix element
PC1_2 = -3.34986750110235E-4 / Transformation matrix element
PC2_1 = 0.000449691780622417 / Transformation matrix element
PC2_2 = 1.0 / Transformation matrix element
MJD-OBS = 54141.0 / Modified Julian Date of observation
RADESYS = 'FK5' / Reference frame for RA/DEC values
ST = '05:24:26.4' / sidereal time
DOMEAZ = '120.2' / dome azimuth
AIRMASS = '1.274' / airmass
ZD = '38.3' / zenith distance (degrees)
TELEFOCUS= '183753' / Telescope focus
FILTNUM = '4' / Filter number
FILTNAME = 'KA' / Filter name
CRMASK = 'crmask_RXCJ0220_067_flat.pl'
COMMENT = 'dimsum.registar: Tue 17:52:49 06-Nov-2007'
COMMENT = 'dimsum.registar: Header data copied from file RXCJ0220_067_flat.fits'
```

What's next:

- Hands-on workshop next Monday at R216 (1-5pm)
- Step-by-step instructions can be found on the website:
http://www.astro.dur.ac.uk/~cpnc25/pg_dr_imaging.html
- chian-chou_chen@durham.ac.uk / Ph319

Workshop

Two main datasets:

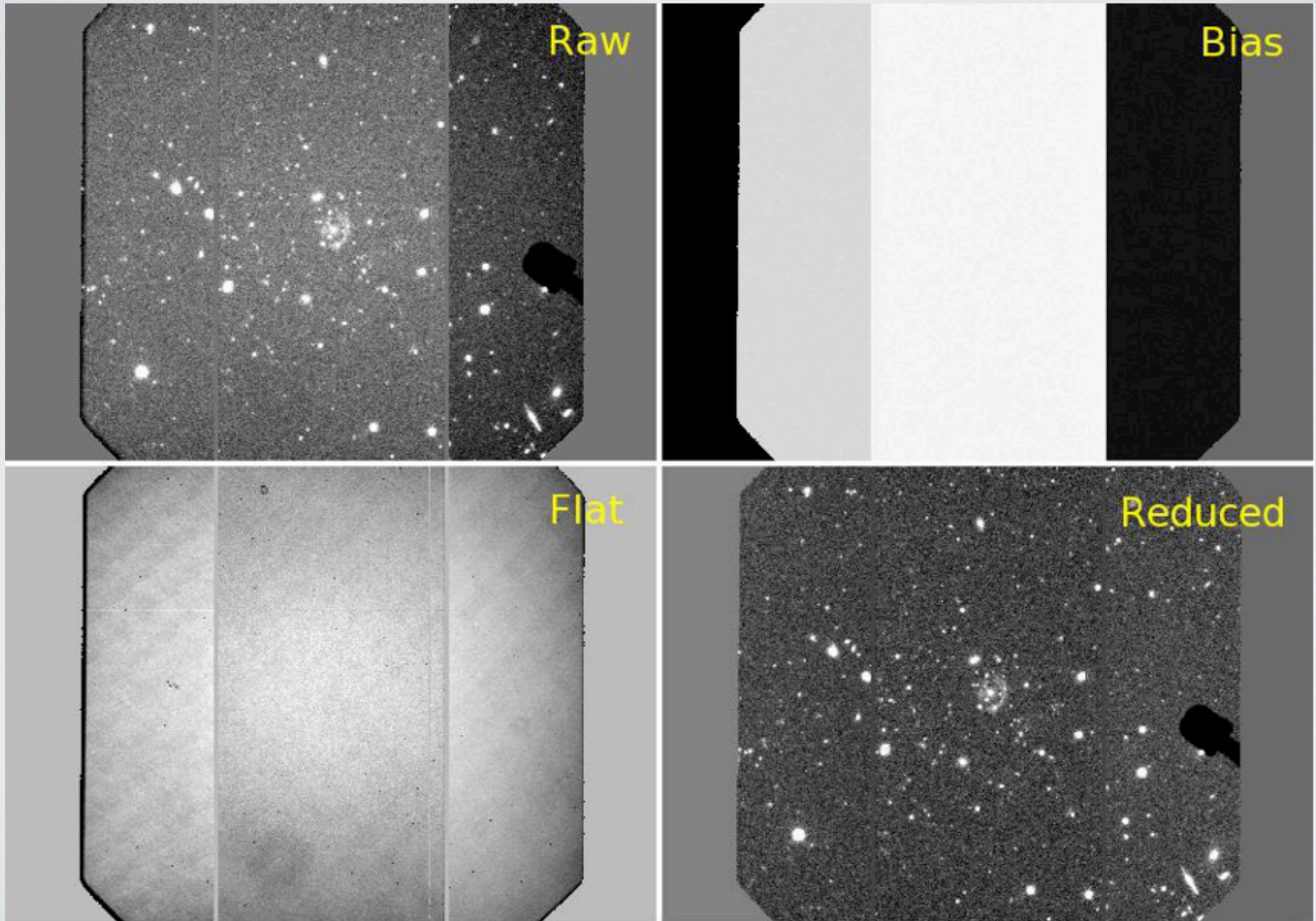
1. Optical Imaging Data: GMOS B-band imaging of cluster RXJC0220.9-3839 (@0220/optical/)
2. Near-IR imaging Data: a gravitationally lensed galaxy in C12243 with NIRC on Keck (@NIR/)

Ancillary datasets:

3. Pre-reduced NIR Imaging Data: J/K-band imaging of cluster RXJC0220.9-3839 (@0220/NIR)

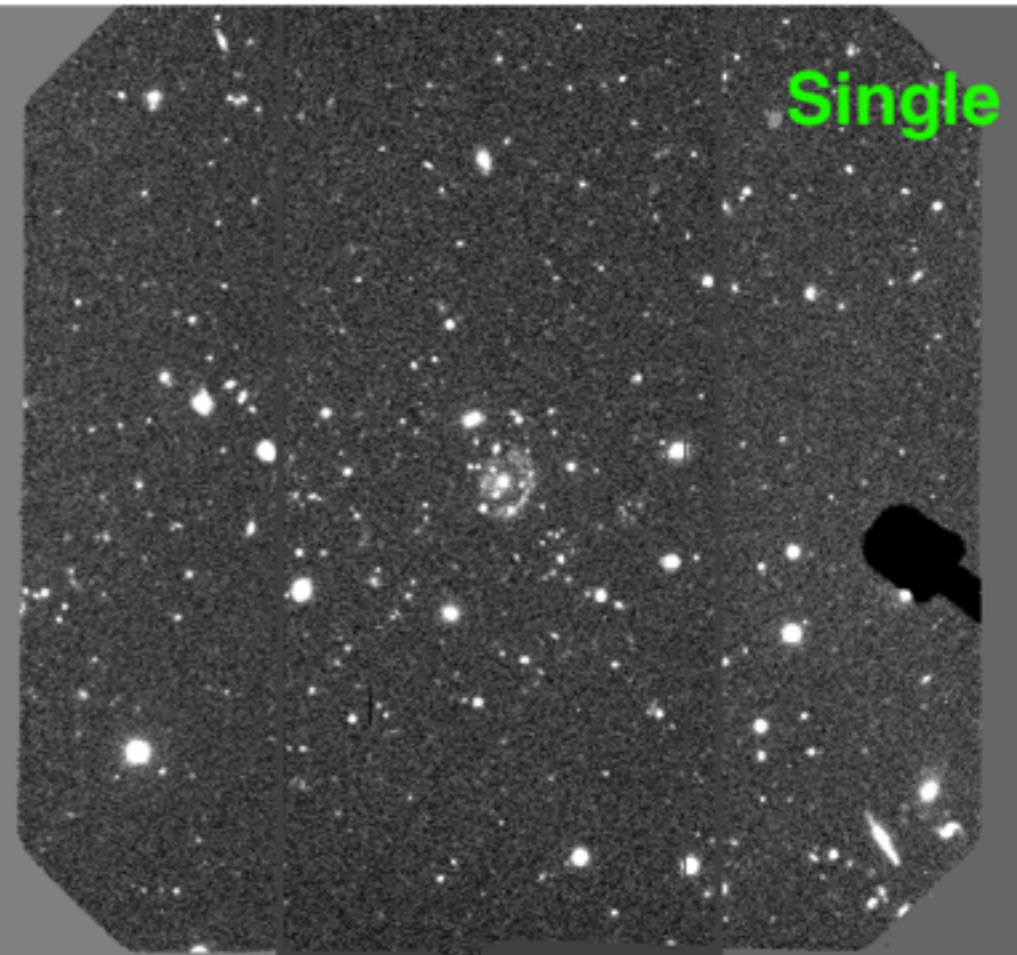
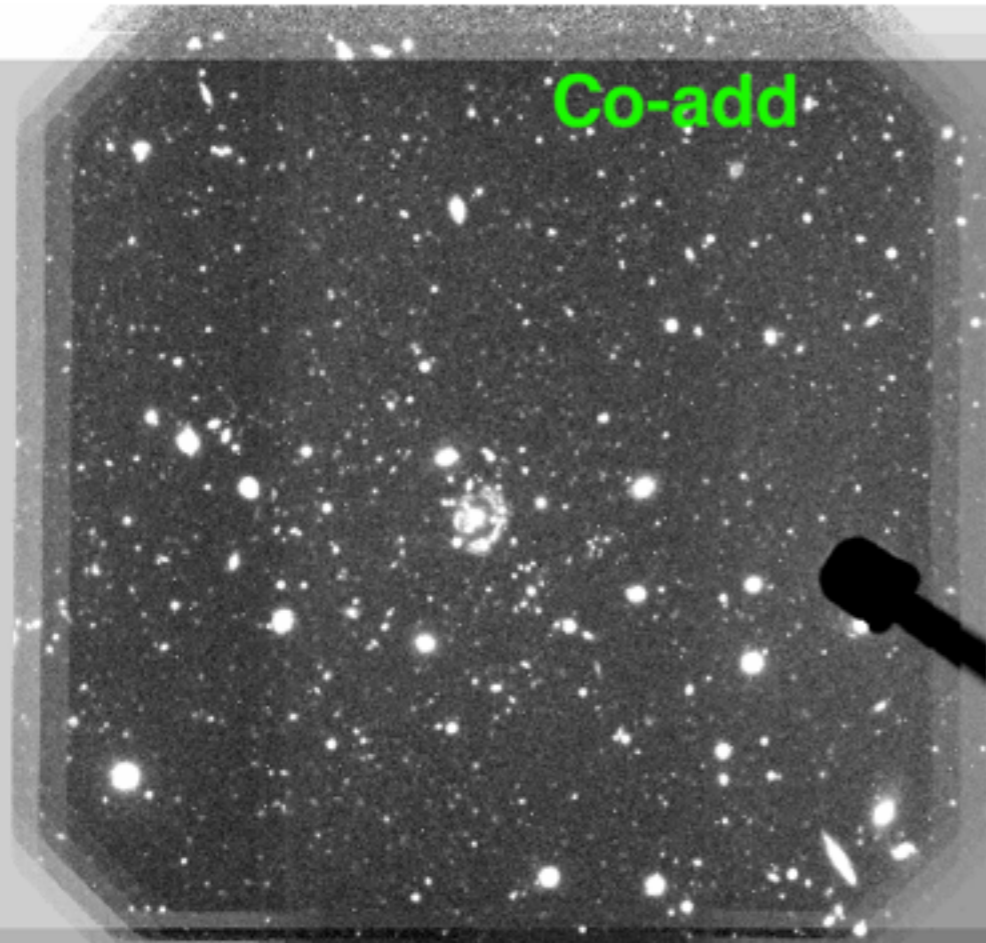
Workshop

Task I: Reduce raw data



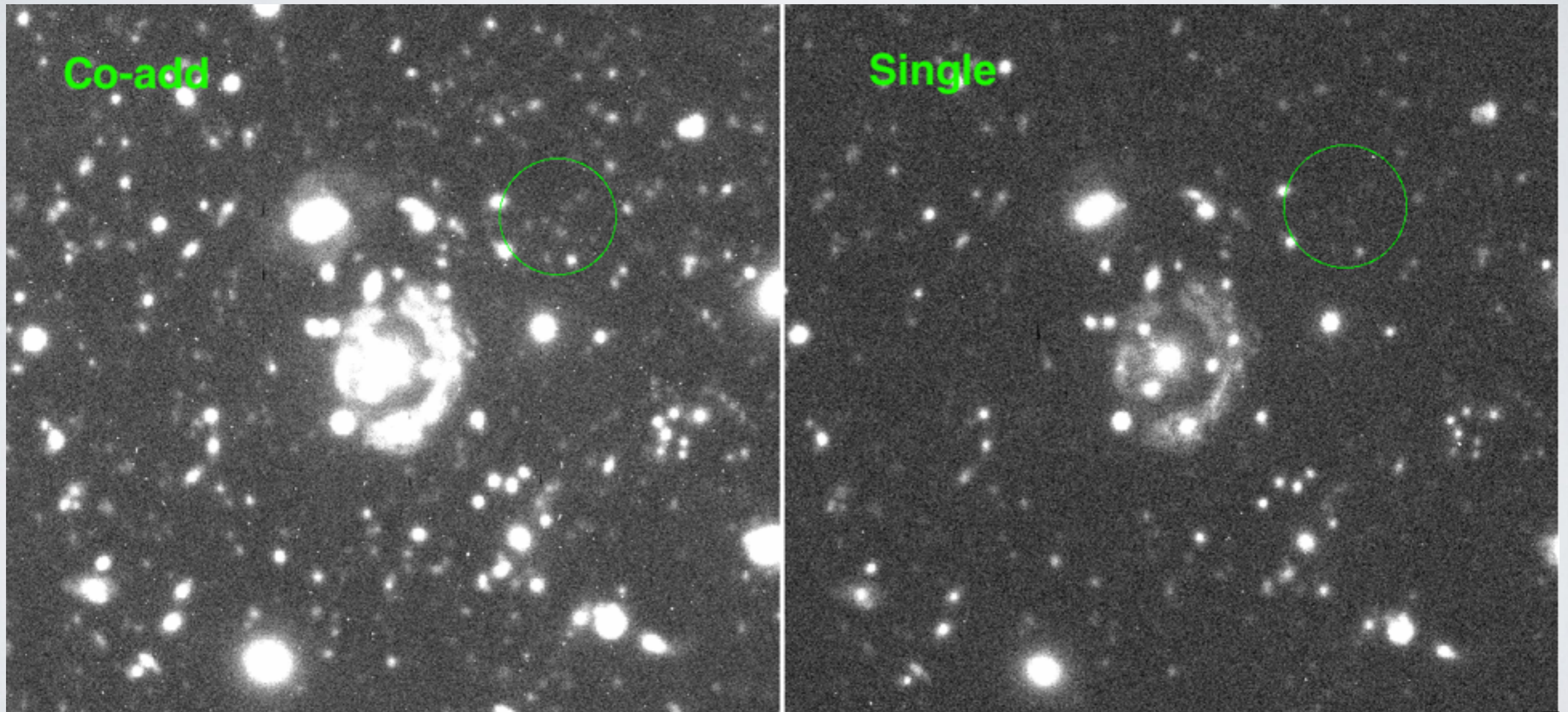
Workshop

Task 2: Co-add reduced frames



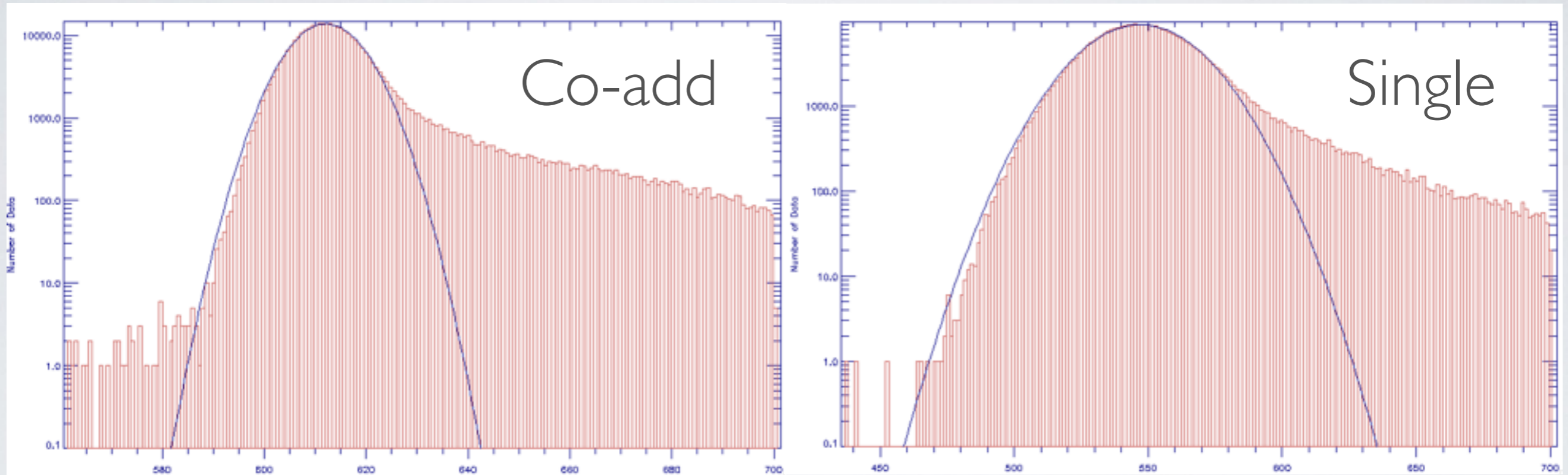
Workshop

Co-adding makes deeper images



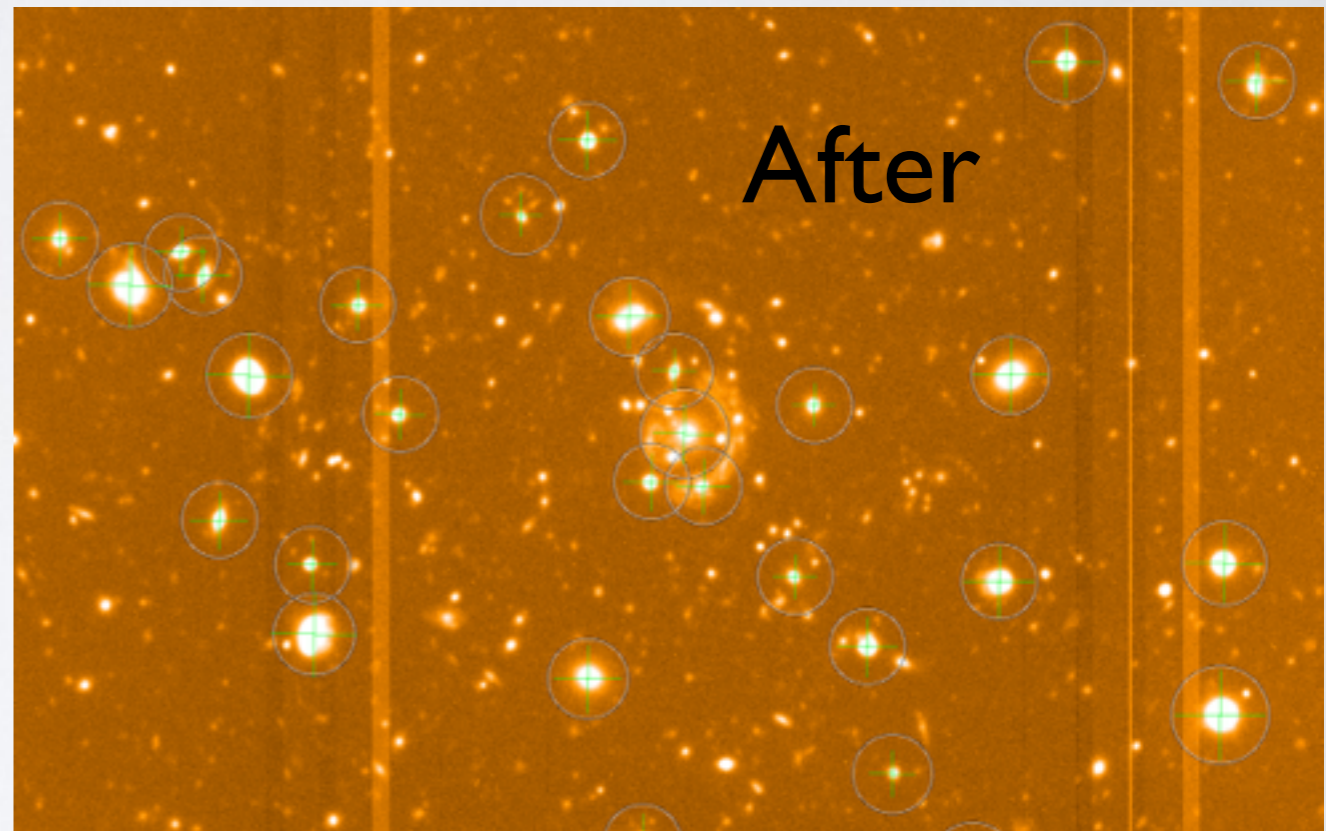
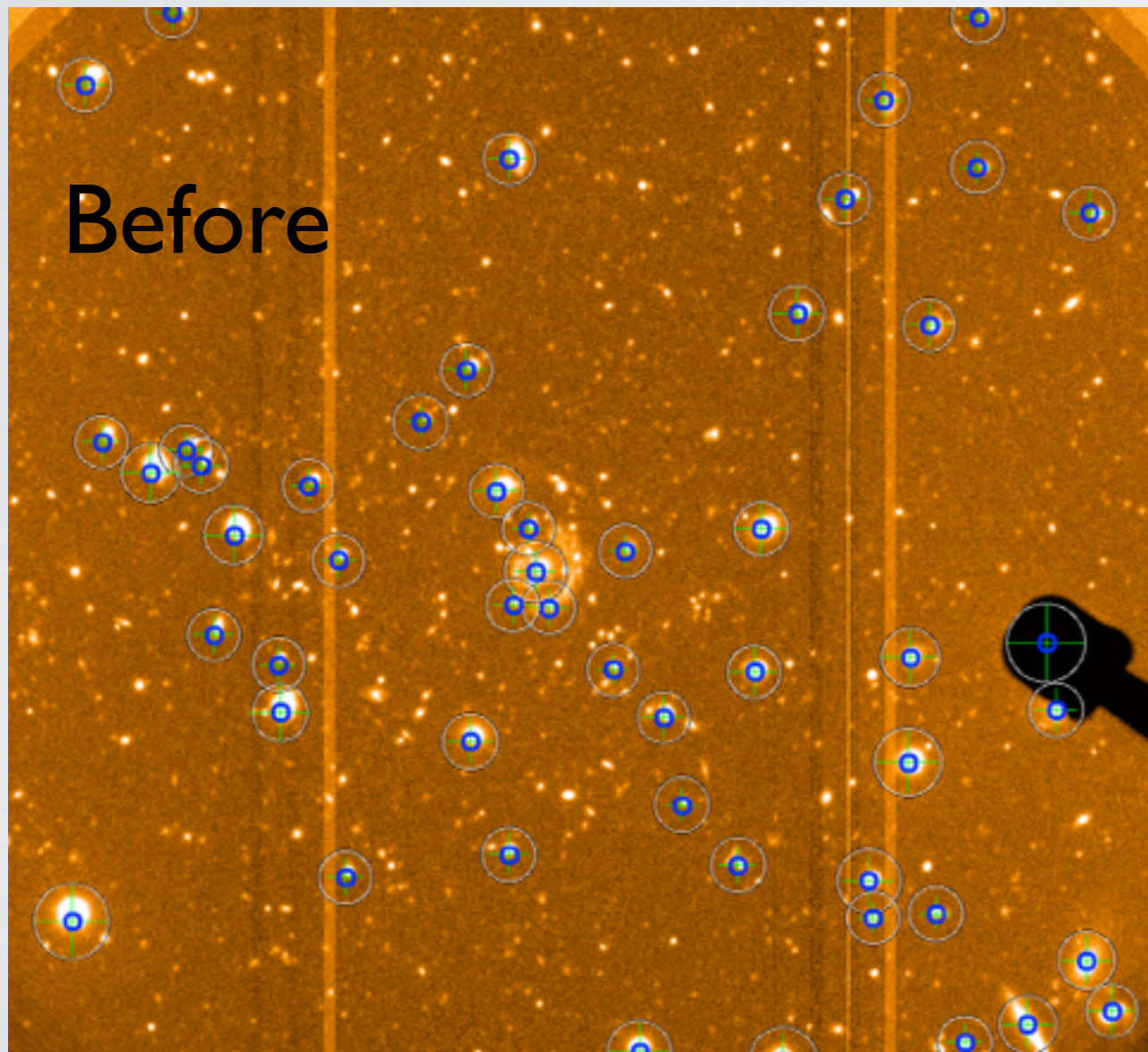
Workshop

Co-adding makes deeper images



Workshop

Task 3: Calibrate Astrometry



Workshop

Task 3: Calibrate Astrometry

Step 1: Open Co-add image in Gaia, adjust to your favorite colors and scales

The image displays two screenshots of the Starlink GAIA-Skycat software interface, illustrating the process of adjusting an astronomical image.

The left screenshot shows the main window with the following parameters for the object **RXJ0220.9-3829 (file: mosaic.fits)**:

X: 1812.0	Y: 1574.0	Value: 607.588
α : 2:21:02.903	δ : -38:33:41.05	Equinox: J2000
Min: 553.644714355469	Max: 5274.67626953125	Auto Cut: <input type="checkbox"/>
Low: 553.645	High: 5274.68	Color Map: <input type="checkbox"/>
Scale: 1x	Color Scale: <input type="checkbox"/>	

The right screenshot shows a zoomed-in view of the same object, with the following parameters:

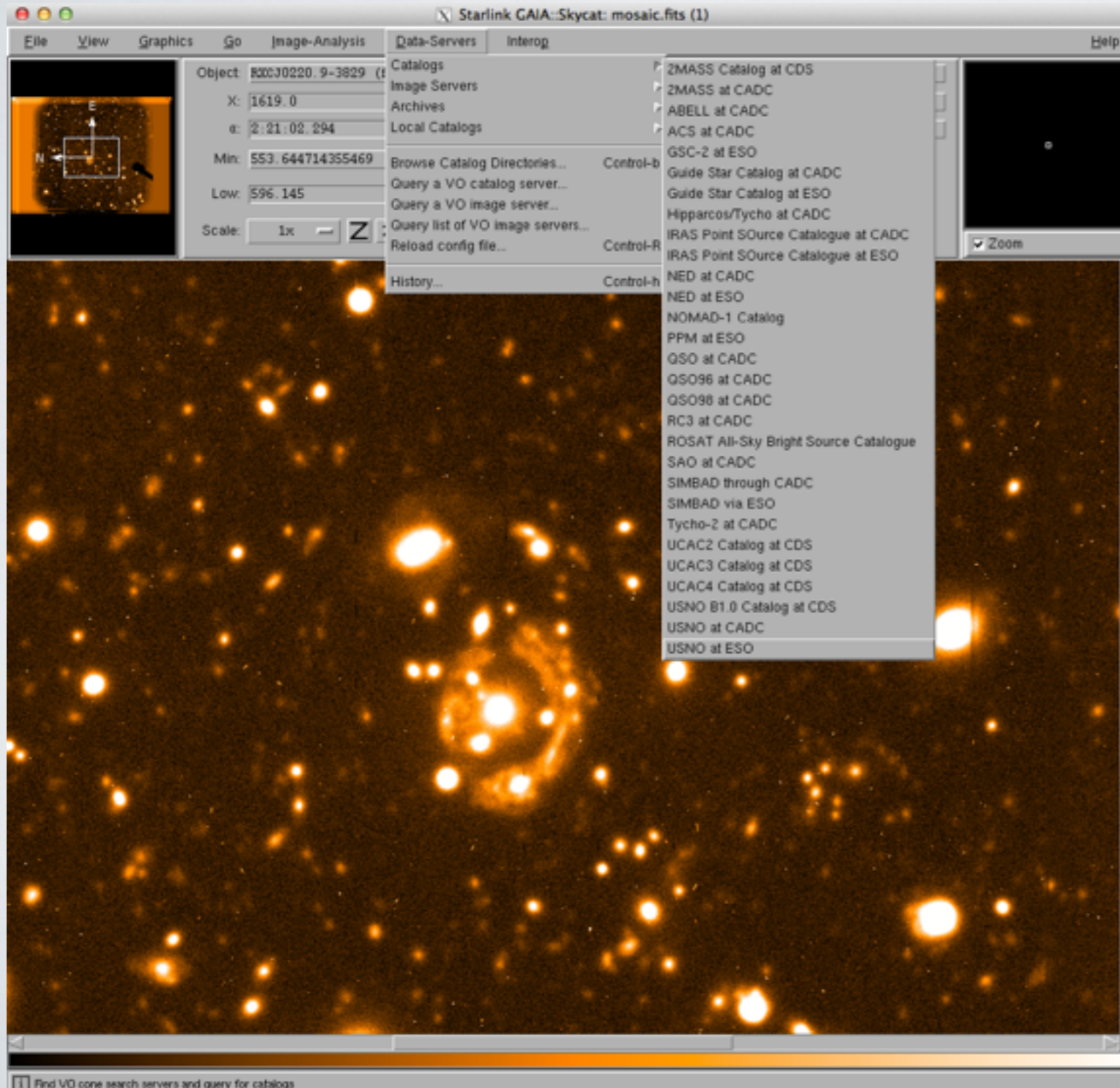
X: 1533.0	Y: 1328.0	Value: 620.869
α : 2:20:59.841	δ : -38:33:00.28	Equinox: J2000
Min: 553.644714355469	Max: 5274.67626953125	Auto Cut: <input type="checkbox"/>
Low: 596.145	High: 736.331	Color Map: <input type="checkbox"/>
Scale: 1x	Color Scale: <input type="checkbox"/>	

Both screenshots show a large field of stars, with a central cluster of bright stars. The interface includes a menu bar (File, View, Graphics, Go, Image-Analysis, Data-Servers, Interrog, Help) and a toolbar with various icons for image manipulation. A status bar at the bottom provides instructions: "image: [icon] = select object, [icon] = scroll image, [icon] = measure WCS, Control [icon] = select region".

Workshop

Task 3: Calibrate Astrometry

Step 2: Go to Data-Servers, Catalogs, bright object catalog USNO at ESO, search



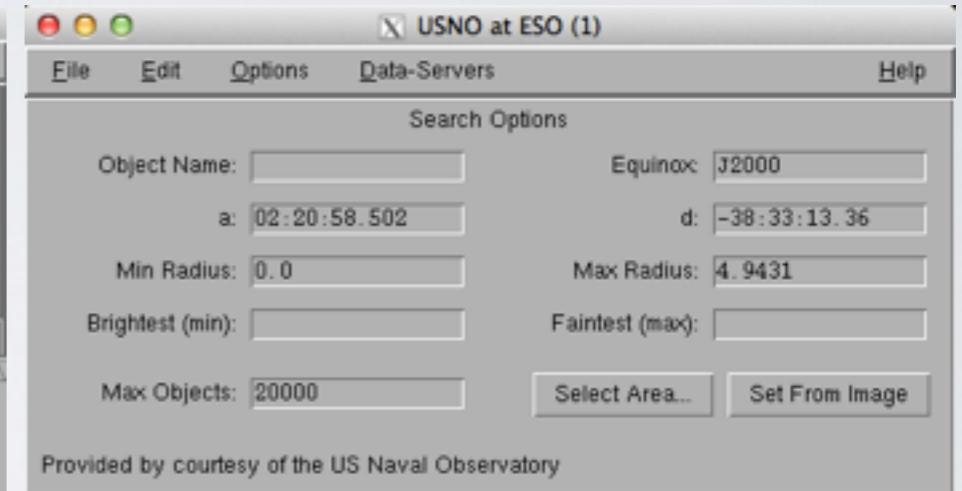
The Starlink GAIA:Skycat interface displays a mosaic of stars. The top menu bar includes File, View, Graphics, Go, Image-Analysis, Data-Servers, Interrog, and Help. The Data-Servers menu is open, showing a list of catalogs. The main window shows a star field with a zoomed-in region in the center.

Object: **R00030220_9-3829** (t)
X: 1619.0
a: 2:21:02.294
Min: 553.644714355469
Low: 596.145
Scale: 1x

Zoom

Find VO cone search servers and query for catalogs

- Catalogs
 - 2MASS Catalog at CDS
 - 2MASS at CADC
 - ABELL at CADC
 - ACS at CADC
 - GSC-2 at ESO
 - Guide Star Catalog at CADC
 - Guide Star Catalog at ESO
 - Hipparcos/Tycho at CADC
 - IRAS Point Source Catalogue at CADC
 - IRAS Point Source Catalogue at ESO
 - NED at CADC
 - NED at ESO
 - NOMAD-1 Catalog
 - PPM at ESO
 - QSO at CADC
 - QSO96 at CADC
 - QSO98 at CADC
 - RC3 at CADC
 - ROSAT All-Sky Bright Source Catalogue
 - SAO at CADC
 - SIMBAD through CADC
 - SIMBAD via ESO
 - Tycho-2 at CADC
 - UCAC2 Catalog at CDS
 - UCAC3 Catalog at CDS
 - UCAC4 Catalog at CDS
 - USNO B1.0 Catalog at CDS
 - USNO at CADC
 - USNO at ESO
- Image Servers
- Archives
- Local Catalogs
- Browse Catalog Directories... Control-b
- Query a VO catalog server...
- Query a VO image server...
- Query list of VO image servers...
- Reload config file... Control-R
- History... Control-h



USNO at ESO (1)

Search Options

Object Name: Equinox: J2000

a: 02:20:58.502 d: -38:33:13.36

Min Radius: 0.0 Max Radius: 4.9431

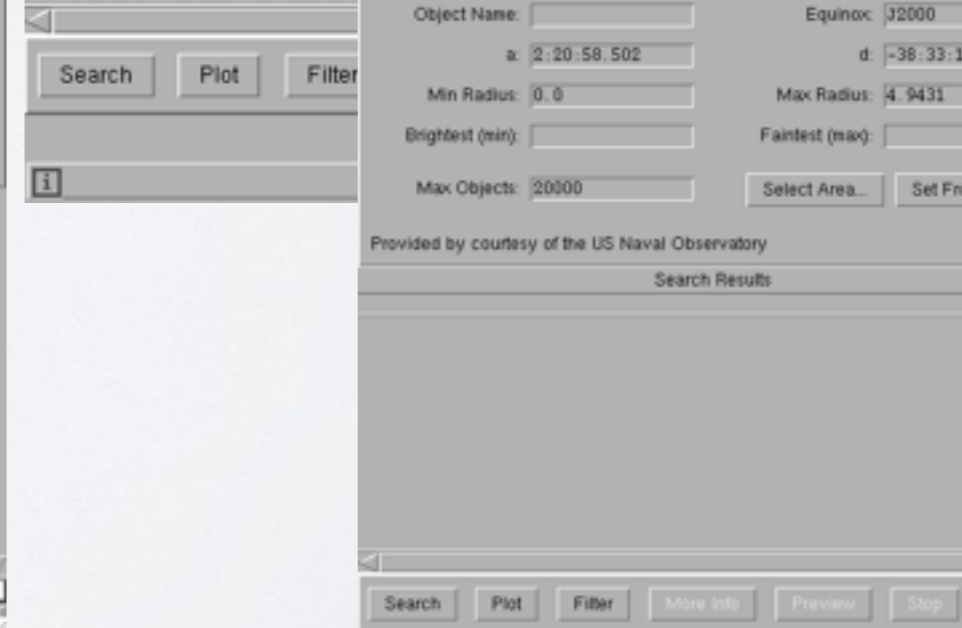
Brightest (min): Faintest (max):

Max Objects: 20000

Provided by courtesy of the US Naval Observatory

Search Results (123)

ID	ra	dec	r_mag	b_mag	field	d'
U0450.00813199	02:21:20.820	-38:32:30.65	14.1	14.8	298	4.421
U0450.00810590	02:20:56.026	-38:35:22.22	14.3	14.5	298	2.202
U0450.00812650	02:21:15.375	-38:36:48.68	14.8	16.4	298	4.874
U0450.00809883	02:20:49.578	-38:30:56.83	14.9	15.3	298	2.868
U0450.00810351	02:20:53.807	-38:30:13.10	15.4	16.8	298	3.142
U0450.00809546	02:20:46.309	-38:34:10.41	15.8	17.4	298	2.566
U0450.00810654	02:20:56.666	-38:28:48.02	15.8	16.0	298	4.437
U0450.00810295	02:20:53.259	-38:34:44.57	15.9	16.5	298	1.833
U0450.00810230	02:20:52.7					
U0450.00809359	02:20:44.3					
U0450.00809574	02:20:46.5					
U0450.00811261	02:21:01.9					



USNO at ESO (1)

Search Options

Object Name: Equinox: J2000

a: 2:20:58.502 d: -38:33:13.36

Min Radius: 0.0 Max Radius: 4.9431

Brightest (min): Faintest (max):

Max Objects: 20000

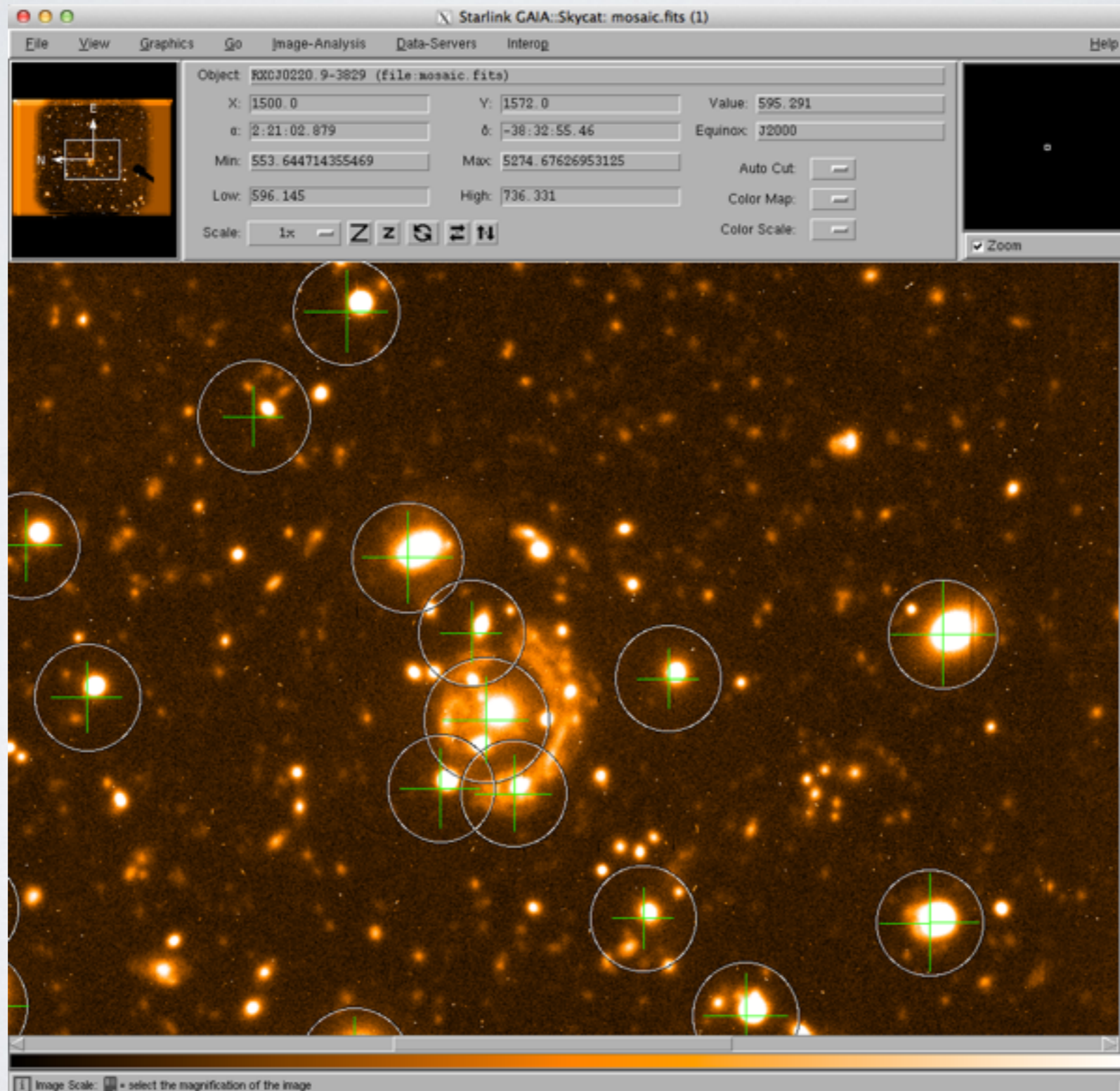
Provided by courtesy of the US Naval Observatory

Search Results

Workshop

Task 3: Calibrate Astrometry

Step 2: Once click search, sources should appear, can see mismatched positions



Workshop

Task 3: Calibrate Astrometry

Step 3: Image-Analysis -> Astrometry calibration -> Fit to star positions -> Select the USNO at ESO catalog

The screenshot displays the Starlink GAIA software interface. The main window is titled "Starlink GAIA::Skycat: mosaic.fits (1)". The "Image-Analysis" menu is open, showing the "Astrometry calibration" submenu. The "Fit to star positions..." option is selected, which has opened a "GAIA: Fit astrometry reference positions (1)" dialog box. This dialog box has a table for "Reference positions" with columns for "id", "ra", "dec", "x", and "y". Below the table are buttons for "New", "Edit", "Delete", "Grab", "Centroid", and "Clip". There are also buttons for "Reset", "Set", "Clear", and "Redraw". A "Transfer" button is located below the buttons. The "Move markers individually:" checkbox is checked. The "Parameters for table coordinates:" section includes "Coordinate type:" set to "Equatorial (RA/Dec)", "Coordinate system:" set to "FK5", "Equinox:" set to "J2000", and "Epoch:".

The "Select a catalogue" dialog box is also open, showing the text "USNO at ESO -- catalog (mosaic.fits)". The "Selection:" checkbox is unchecked. The "OK" and "Cancel" buttons are at the bottom.

The background shows a star field with several stars marked with green crosses and white circles. The "Image-Analysis" menu is open, showing the following options:

- Aperture photometry
- Optimal photometry
- Image regions... Control-r
- STC-S regions... Control-r
- Patch image... Control-u
- Blink images... Control-b
- Overlay axes grid... Control-t
- Astrometry calibration
 - Automatic position matching
 - Fit to star positions... Control-k
 - Tweak an existing calibration... Control-z
 - Copy from another image... Control-y
 - Type in known calibration... Control-w
- Change coordinates
- Object detection... Control-j
- Contouring... Control-h
- Surface photometry...
- Positions...
- Mean X & Y profiles... Control-e
- Polarimetry toolbox...
- Mask image...
- Demonstration mode...

Workshop

Task 3: Calibrate Astrometry

Step 4: Adjust the marker size and width

GAIA: Fit astrometry reference positions (1)

id	ra	y
U0450.00813199	02:21:20.	7284826087748 301
U0450.00810590	02:20:56.	4445946438282 10
U0450.00812650	02:21:15.	2816428632186 25
U0450.00809883	02:20:49.	19285007986271 50
U0450.00810351	02:20:53.	3406935454464 84

Starlink GAIA::Skycat: mosaic.fits (1)

Object: RXCJ0220.9-3829 (file: mosaic.fits)

X: 1332.0 Y: 1508.0 Value: 608.787

α : 2:21:02.083 δ : -38:32:30.91 Equinox: J2000

Min: 553.644714355469 Max: 5274.67626953125

Low: 596.145 High: 736.331

Scale: 1x

Zoom

GAIA: Fit astrometry reference positions (1)

Move markers individually:

Parameters for table coordinates:

Coordinate type: Equatorial (RA/Dec)

Coordinate system: FK5

Equinox: J2000

Epoch:

Image parameters:

Projection type: Gnostic (tangent plane) (-TAN)

prop1:

prop2:

X coordinate type: RA/Longitude

Fit/Test Reset Cancel Accept

Set the marker size

Workshop

Task 3: Calibrate Astrometry

Step 5: Clip objects outside the frame, extended objects, saturated stars

The screenshot displays the Starlink software interface for processing astronomical data. The main window, titled "Starlink GAIA:Skycat: mosaic.fits (1)", shows a field of stars with several reference positions marked by blue dots and green crosses. A control panel on the left allows for object selection and zooming. A secondary window, "GAIA: Fit astrometry reference positions (1)", is open on the right, displaying a table of reference positions and various configuration options.

Starlink GAIA:Skycat: mosaic.fits (1) Control Panel:

- Object: RXCJ0220.9-3829 (file:mosaic.fits)
- X: 2883.0, Y: 3079.0, Value: []
- e: [], l: [], Equinox: []
- Min: 553.644714355469, Max: 5274.67626953125, Auto Cut: []
- Low: 596.145, High: 736.331, Color Map: []
- Scale: 1/2x, [Z], [z], [G], [F], [H], Color Scale: []

GAIA: Fit astrometry reference positions (1) Reference positions table:

id	ra	dec	x	y
U0450.00810767	02:20:57.685	-38:33:03.05	1551.9883688005002	1154
U0450.00810863	02:20:58.547	-38:31:40.93	989.97969532476532	1220
U0450.00811260	02:21:01.927	-38:36:21.13	2907.4972004988199	1496
U0450.00810553	02:20:55.689	-38:34:45.11	2250.4904198979225	995
U0450.00811020	02:20:59.975	-38:31:18.38	835.63503976672098	1338

GAIA: Fit astrometry reference positions (1) Configuration:

- Coordinate type: Equatorial (RA/Dec)
- Coordinate system: FK5
- Equinox: J2000
- Epoch: []
- Image parameters: Projection type: Gonic (tangent plane) (-TAN)
- prop1: []
- prop2: []
- X coordinate type: RA/Longitude

Buttons: New, Edit, Delete, Grab, Centroid, Clip, Fit/Test, Reset, Cancel, Accept

Footer: Remove the selected rows from the table

Workshop

Task 3: Calibrate Astrometry

Step 6: move markers to the right positions of the bright objects

Hint: unclick Move markers individually to move all markers

GAIA: Fit astrometry reference positions (1)

File Edit Options Markers Help

Reference positions					
id	ra	dec	x	y	
U0450.00810590	02:20:56.026	-38:35:22.22	2512.44459464382	1030	
U0450.00809546	02:20:46.309	-38:34:10.41	2021.4516884572799	249	
U0450.00810295	02:20:53.259	-38:34:44.57	2254.8760999972601	807	
U0450.00809574	02:20:46.527	-38:33:31.43	1754.6769460952601	266	
U0450.00809983	02:20:50.495	-38:34:33.88	2181.8371517186602	586	

New Edit Delete Grab Centroid Clip

Reset Set Clear Redraw

Transfer

Move markers individually:

Parameters for table coordinates:

Coordinate type: Equatorial (RA/Dec)

Coordinate system: FK5

Equinox: J2000

Epoch:

Image parameters:

Projection type: Gnomonic (tangent plane) (-TAN)

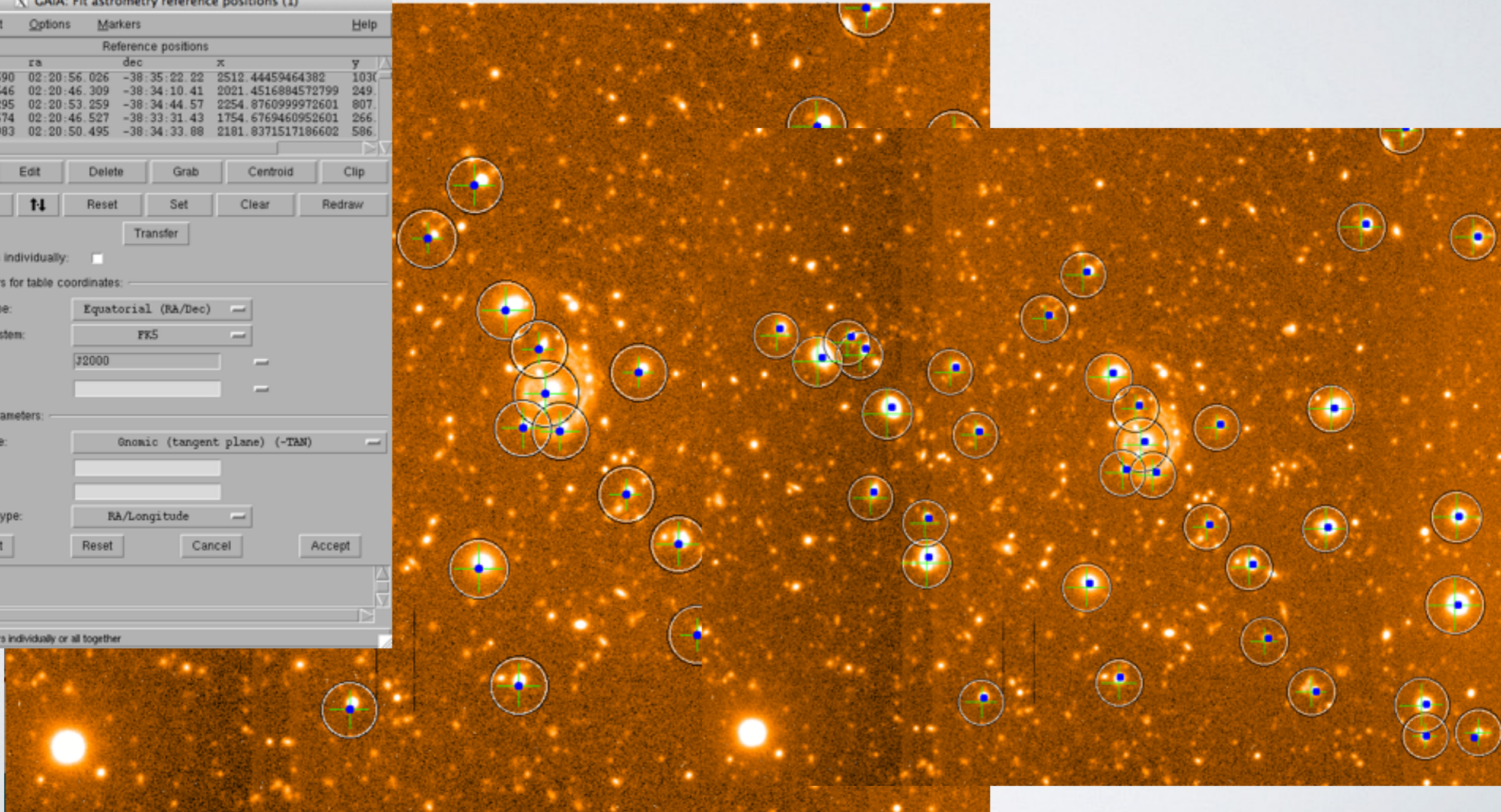
prop1:

prop2:

X coordinate type: RA/Longitude

Fit/Test Reset Cancel Accept

Move markers individually or all together



Workshop

Task 3: Calibrate Astrometry

Step 7: Click Centroid, and Fit/Test, re-center and re-clip till the rms good

The screenshot shows the GAIA software interface for fitting astrometry reference positions. The window title is "GAIA: Fit astrometry reference positions (1)". The interface includes a menu bar (File, Edit, Options, Markers, Help) and a table of reference positions. Below the table are several control buttons: New, Edit, Delete, Grab, Centroid, Clip, and a row of navigation icons (undo, redo, zoom in, zoom out). Further down are buttons for Reset, Set, Clear, and Redraw, along with a Transfer button. A checkbox for "Move markers individually:" is checked. The "Parameters for table coordinates:" section includes dropdown menus for "Coordinate type:" (Equatorial (RA/Dec)), "Coordinate system:" (FK5), and "Equinox:" (J2000). The "Image parameters:" section includes a dropdown for "Projection type:" (Gnomonic (tangent plane) (-TAN)) and input fields for "projp1:" and "projp2:". At the bottom, there are buttons for "Fit/Test", "Reset", "Cancel", and "Accept". A status bar at the very bottom displays fit statistics: "Rms of fit = 0.319886737438299 (arcsec), 2.18618225872857 (pixels)", "x,y scales = 0.146524572861284, 0.14611958904344 (arcsec/pixel)", and "orientation = -268.796383 (degrees)".

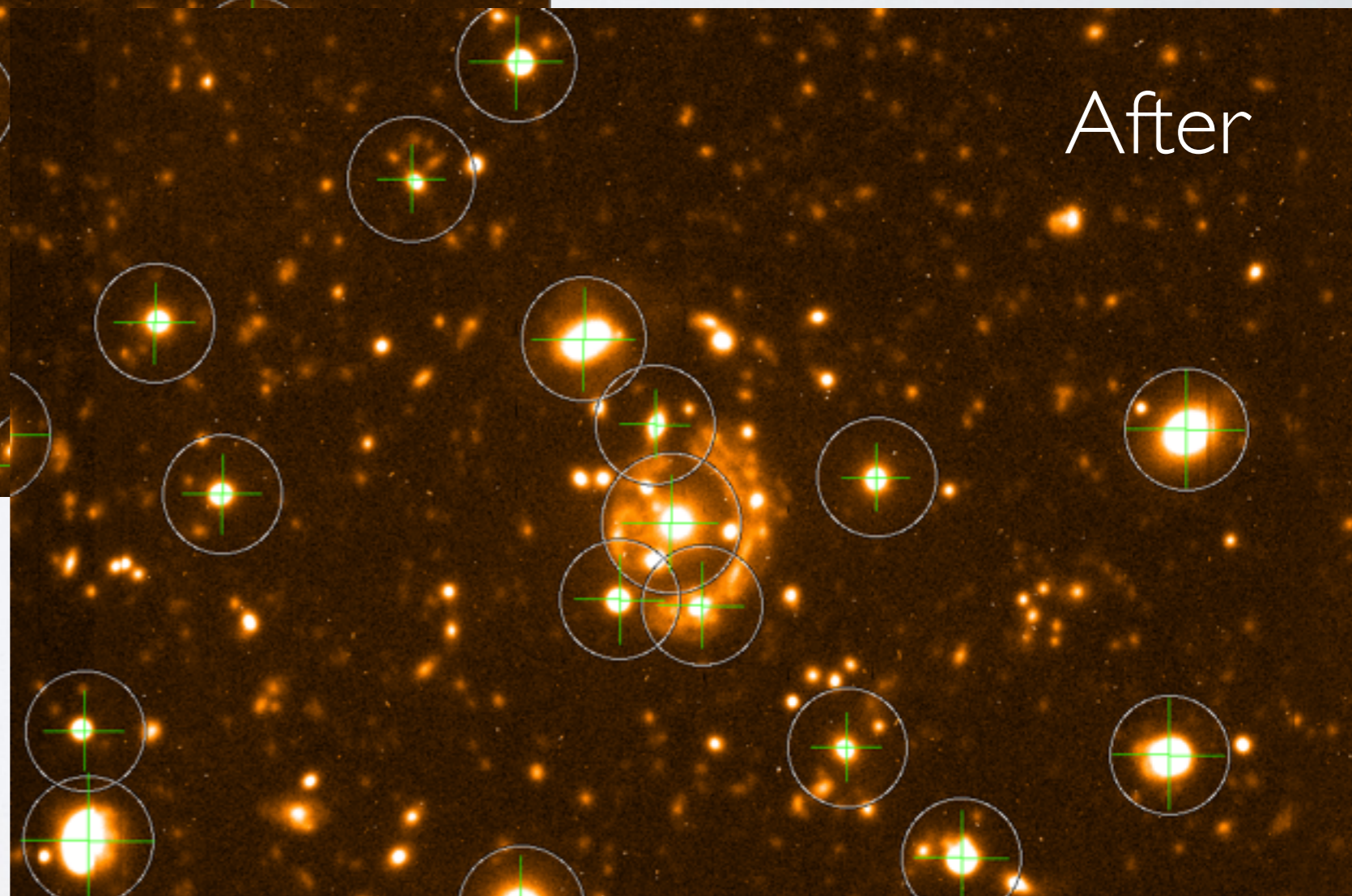
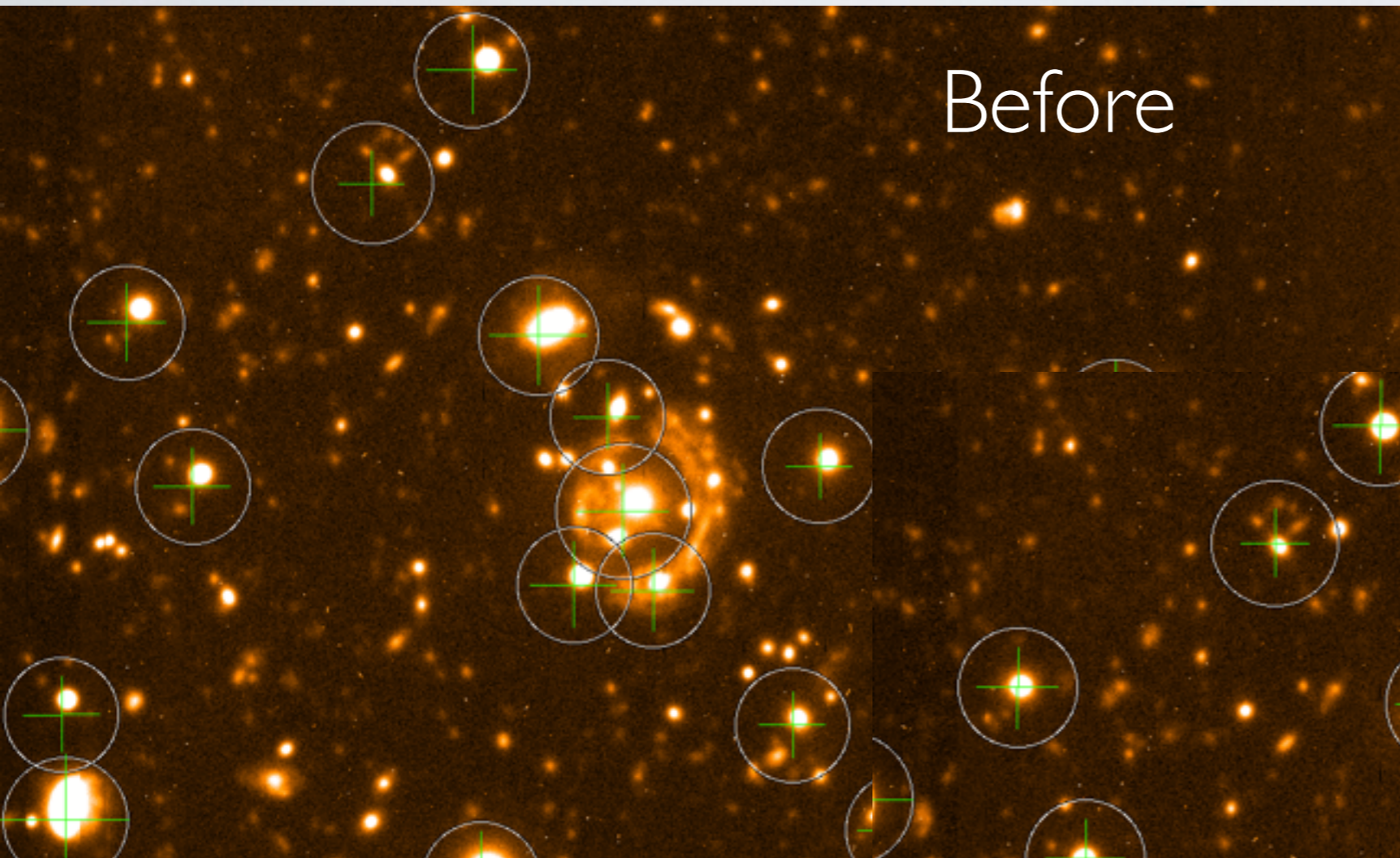
id	ra	dec	x	y
U0450.00810590	02:20:56.026	-38:35:22.22	2509.11	1020.62
U0450.00809546	02:20:46.309	-38:34:10.41	2015.66	245.287
U0450.00810295	02:20:53.259	-38:34:44.57	2251.18	800.964
U0450.00809574	02:20:46.527	-38:33:31.43	1749.73	265.163
U0450.00809983	02:20:50.495	-38:34:33.88	2177.25	579.81

Hint: an rms of $< 0.4''$ is acceptable in this data

Workshop

Task 3: Calibrate Astrometry

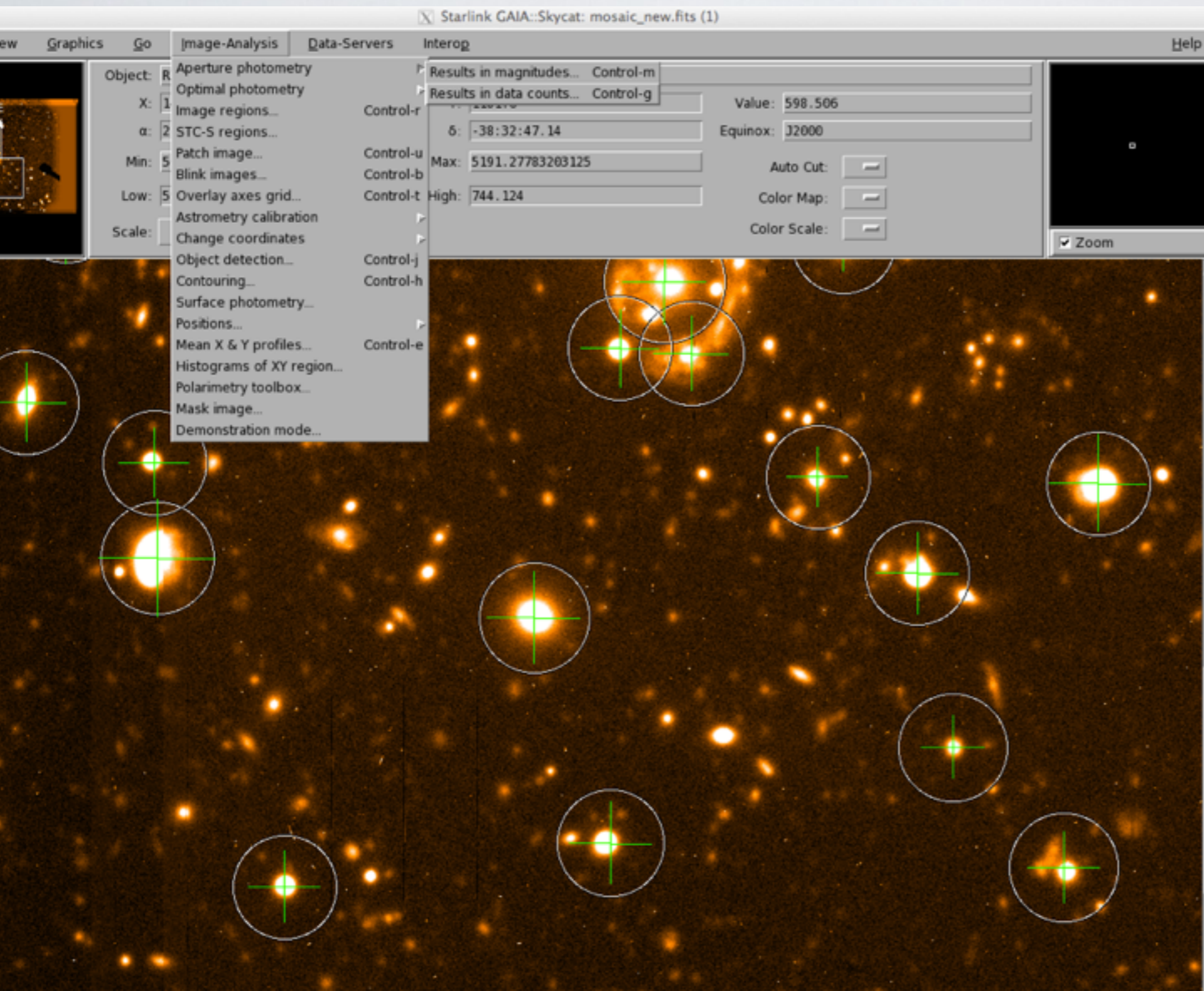
Step 8: when the fit is good, click Accept and save the image



Workshop

Task 4: Flux calibration

Step 1: Image Analysis -> Aperture Photometry -> Results in data counts



Hint:

Goal is to find the zero point (magnitude = $Z_{pt} - 2.5 * \log(\text{flux})$)

Workshop

Task 4: Flux calibration

Step 2: Define an aperture by dragging the cursor -> Calculate results

Hint: Use the B-band magnitude from the catalog as the reference

The screenshot displays the GAIA Aperture photometry software interface. On the left, the 'USNO at ESO (1)' window shows search options and a table of 44 search results. The 'Max Radius' field is set to 2.7. The search results table lists columns: ID, ra, dec, r_mag, b_mag, field, and d'. The row with ID 'U0450.00811310' is highlighted. On the right, the 'GAIA: Aperture photometry -- co...' window shows the 'Results' tab with a table of 'Current object details' and a 'Define object aperture' button.

Search Options

Object Name: Equinox: J2000
a: 02:20:59.000 d: -38:33:11.00
Min Radius: 0.0 Max Radius: 2.7
Brightest (min): Faintest (max):
Max Objects: 20000

Provided by courtesy of the US Naval Observatory

Search Results (44)

ID	ra	dec	r_mag	b_mag	field	d'
U0450.00810685	02:20:56.904	-38:32:56.97	17.9	19.6	298	0.472
U0450.00810793	02:20:57.952	-38:32:09.46	17.9	20.2	298	1.046
U0450.00810817	02:20:58.163	-38:33:27.54	17.9	20.9	298	0.321
U0450.00810871	02:20:58.689	-38:33:01.12	17.9	20.8	298	0.175
U0450.00810981	02:20:59.693	-38:32:01.30	17.9	20.1	298	1.169
U0450.00811079	02:21:00.510	-38:31:27.92	17.9	20.0	298	1.743
U0450.00811103	02:21:00.701	-38:31:05.03	17.9	19.8	298	2.126
U0450.00811310	02:21:02.368	-38:32:44.31	17.9	19.4	298	0.795
U0450.00811427	02:21:03.414	-38:34:50.39	17.9	19.2	298	1.868
U0450.00811722	02:21:06.349	-38:34:27.38	17.9	19.5	298	1.919
U0450.00811805	02:21:07.077	-38:35:03.45	17.9	20.6	298	2.450
U0450.00811826	02:21:07.273	-38:32:55.98	17.9	19.4	298	1.637

Current object details

Aperture index: 1
X position: 1436.31
Y position: 1539.17
Mean count: 361.95
Error in count: 0.16335
Sky value: 613.44
Sum in aperture: 0.29528E+06
Error code: OK
Semimajor axis: 16.2
Eccentricity: 0
Position angle: 0
Annulus inner scale: 1.5
Annulus outer scale: 2.0

Workshop

Task 5: Do some science

1. What is the pixel scale, in arcsecond/pixel, on the GMOS image?
2. What is the seeing (the FWHM of a point source in arcseconds) of the GMOS image?
3. What is the zero-point of the GMOS image?
4. What is the S/N and magnitude of the galaxy at 02:20:53.754 -38:32:45.48?
5. Make a histogram of the S/N of all the detected objects in the frame, as well as a histogram of the magnitudes. What is the 5-sigma limiting magnitude?

There are also reduced J/K-band images available in 0220/NIR/ directory

6. Align these images with the optical image and make a color image (Hint: use `hastrom` in IDL to align the images)
7. Run SExtractor in dual-mode and make a color-magnitude diagram on K vs J-K of all the detected objects. (Hint: see the SExtractor manual for dual-mode extraction)

Workshop

Extra information

SEXtractor (tool to extract objects; HW5,6,7)

To Install:

1. Go <http://www.astromatic.net/software/sextractor> and download the source code, and compile/install in your home directory. The manual can be found in the website.
2. Add the line below in your `.cshrc` file and type `'source .cshrc'`
`'set path = ($path /tmp_mnt/home/YOURDIR/sextractor-2.19.5/src)'`

To run:

1. Need to put the default.* files in the directory where you store your images. The default.* files can be found in the `sextractor/config/` directory if you install it yourself, or in `/tmp_mnt/home/ccchen/sextractor-2.19.5/config/`
2. Edit the default.sex file and input the zero-point, pixel scale, and seeing. Set the output image to `'APERTURES'` to generate an output image.
3. Edit the output parameter file, default.param, to output `'NUMBER, FLUX_BEST, FLUXERR_BEST, MAG_BEST, MAGERR_BEST'`
4. In the command line type: `sex myfile.fits`