scaling_and_combining

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1 Processing Science Images

1.1 Scaling and Combining

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1.1.1 ⋆ Importing necessary libraries

[1]:
```
import numpy as np
import astropy
import ccdproc
from ccdproc import CCDData, combiner
from astropy import units as u
import matplotlib.pyplot as plt
from matplotlib.colors import LogNorm
from photutils.centroids import centroid_2dg
from scipy.ndimage import shift
from photutils import CircularAperture
from photutils import aperture_photometry
import os
```

1.1.2 ⋆ Collecting and Loading the Shifted Science images

[2]:
```
# function 'image_collect' that collects all the images from a specified band //
 ↪ reads .fit in adu
## 2 arguments --> directory: location of the .fit
##             --> band: type of filter

def image_collect(directory, band):
    cwd = os.getcwd()                # saving current directory
    os.chdir(directory)              # changing directory
    images = ccdproc.ImageFileCollection(".", glob_include = band)
 ↪   # collects all specified band images in the directory
```

```
    scim = [CCDData.read(fn, unit = "adu") for fn in images.files_filtered()]
    # defines "scim" to read the CCD data in adu
    os.chdir(cwd)                       # returning to the defined current directory

    return scim                         # returns (value) array
```

1.1.3 ⋆ Aperture Photometry

[3]:
```
# function 'photometry' does photometry aperture on the specified/bright stars / prints out the photometry (flux values) table
## 2 arguments --> star_position: (x,y) coordinates of bright stars
##             --> radius: radius of circular aperture

def photometry(star_position, radius):

    apertures = CircularAperture(star_position, r = radius)       # apertures defined by a circle with radius 'r' pixels that will surround the star
    phot_table = aperture_photometry(scim[0], apertures)          # defining a photometry table that calculates and displays the flux for each star in the first image
    print("\n",

          "PHOTOMETRY TABLE FOR FIRST IMAGE",

          "\n",

          phot_table,

         "\n")

    phot_table=[]       # creates a new array for all our science image photometry tables

    print("\n",

          "PHOTOMETRY TABLE FOR ALL IMAGES")

    for idx, thisimage in enumerate(scim):                                  # for loop that runs through all shifted science images
        phot_table.extend([aperture_photometry(thisimage, apertures)])    # calculates the flux for each star in all science image
        print("\n",

              idx, phot_table[idx],
```

```
            "\n")

    return phot_table

    # printing out flux values in adu for each star in first image
    print("\n",

          "APERTURE SUM OF STARS (Flux Values) FOR FIRST IMAGE",

          "\n",

          phot_table[0]['aperture_sum'])
```

1.1.4 ⋆ Positions of bright stars for B, V, R and I band

- Manually picked in ds9 - I picked the stars that would be great for aperture photometry (ones that had a defined circular appearance) - Chosen from the first science image

[4]:
```
# bright stars gathered into an array
## coordinates of stars in the first science image

position_MAR09_V = [(563.394,321.438), (522.479,299.957), (685.053,46.082),␣
↪(259.311, 50.565), (185.395,39.328), (408.040,430.484), (415.553, 98.852),␣
↪(30.863,217.533), (124.637,370.334), (517.631,174.968), (593.371,221.861)]
position_MAR09_B = [(522.664,300.336), (563.243, 321.768), (185.549, 39.929),␣
↪(441.632, 163.022), (429.312, 327.290), (407.941, 431.066), (429.162,327.
↪251), (226.350,77.914), (239.797,135.189), (259.315,50.801)]
position_MAR09_R = [(563.794,321.598), (408.146,430.232), (294.930,56.057),␣
↪(259.531,49.832), (30.926,217.501), (124.916,370.236), (408.212,430.140),␣
↪(522.99,299.781), (49.627,27.463), (329.471,416.622), (415.754,98.519)]
position_MAR09_I = [(592.363,221.662), (48.246,26.965), (293.889,55.849), (258.
↪523,49.820), (607.125,86.216), (592.409,221.516), (406.849,430.163)]

position_MAR29_V = [(602.816,456.921), (354.656,494.391), (381.877,66.898),␣
↪(304.334,77.417), (664.473,127.188)]
position_MAR29_R = [(183.279,408.884), (106.253,449.351), (381.617,66.790),␣
↪(227.294,174.99), (106.054,449.626)]
position_MAR29_I = [(183.558,408.779), (197.279,273.663), (602.400,456.617),␣
↪(354.483,494.117)]
```

- The shifted images for the R and I filter are extremely saturated, therefore the flux is most likely going to be an overestimate for those images - Since I-band stars were saturated, many of the stars nearing the middle of the cluster were merged, therefore must pick more 'isolated' stars to avoid including other stars during aperture photometry

1.1.5 ⋆ Photometry Tables & Cross checking fluxes using best ('most photometric') image

Cross check by calculating the flux ratio of the first star and the best image - Where best image also known as our reference image is the best photometric one - Stars are well round and well defined - Clear (no blurring)

[5]:
```
# function 'cross_check' calculates the flux ratio // reference image over the␣
↪all science images
## 1 argument --> best image: our reference image

def cross_check(best_image):
    print("\n",

          "CROSS CHECKING"

          "\n")

    for idx, thisimage in enumerate(scim):      # running through all science␣
↪images
        print("\n",

              "Flux ratio of Best Image over Image ",

              idx,

              "\n")                                 # prints the index for each␣
↪image (0 is the first image in this case)

        print(phot_table[best_image]['aperture_sum']/
↪phot_table[idx]['aperture_sum'])                 # we use our "best" image as␣
↪our reference image

        print("\n",

              "Median value of Flux across the image:",

              "\n",

              np.ma.median(phot_table[best_image]['aperture_sum']/
↪phot_table[idx]['aperture_sum']))  # calculates the median value of the flux␣
↪for each image
```

[6]:
```
# function 'photometry' does photometry aperture on the specified/bright stars /
↪/ prints out the photometry (flux values) table
## 4 arguments --> directory: location of the .fit
```

```
##             --> best_image: reference image
##             --> band: type of filter
##             --> filename: name of final combined image

def scale_and_combine(directory, best_image, band, filename):
    # just changing the directories...
    cwd = os.getcwd()
    os.chdir(directory)

    # collecting images...
    images = ccdproc.ImageFileCollection(".",glob_include = band)
    scim = [CCDData.read(fn) for fn in images.files_filtered()]

    ## scaling
    # for loop calculates median flux ratio for each image and displays them
    for idx, thisimage in enumerate(scim):
        m = np.ma.median(phot_table[best_image]['aperture_sum'] /␣
↪phot_table[idx]['aperture_sum'])
        print("Image ", idx, ": ", m)                                    #␣
↪scaling values
        scim[idx] = scim[idx].multiply(m * u.adu)      # implement the scaling␣
↪(multiplying all science images with the scaled value 'm')

    ## median combine
    #calculates median for the images and combines them
    sci_median = ccdproc.combine(scim, method = 'median',dtype = np.float32,
                                 minmax_clip = True, minmax_clip_min = -500)

    os.chdir(cwd)                      #  return to defined directory

    #sci_median.write(filename)        # writes the median combined image as a .
↪fit

    return sci_median

    del(scim)
```

[7]:
```
def median_statistics(star_position, radius, best_image):
    apertures = CircularAperture(star_position, r = radius)
    print('Median combine',

          "\n")

    phot_table_median = aperture_photometry(sci_median, apertures)    #␣
↪calculates and displays flux count for each star
    print("\n", 'Median pixel value', np.ma.median(sci_median)) # calculates␣
↪median pixel value in ADU
```

```
   print('Standard deviation', np.std(sci_median[400:500,400:500]))  #␣
↪calculating the standard devitation between 400 to 500 pixels

   print("\n",

         "PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE",

         "\n",

         phot_table_median,

        "\n")

   print("\n",

         "Cross Checking: flux ratio with best image",

         "\n",

       phot_table[best_image]['aperture_sum']/
↪phot_table_median['aperture_sum'],

        "\n")

   print("\n",

         "Median value of the flux ratio: ",

       np.ma.median(phot_table[best_image]['aperture_sum']/
↪phot_table_median['aperture_sum']))  # median value for the flux ratio
```

1.1.6 ⋆ Scaling and Combining each band

1.1.7 ——————————————————————————B-Band——————————————————————————

Date: March 9th | **Exposure Time:** 60.0s

[8]:
```
scim = image_collect("../040_shift/data/shifted/march_09_2018","NGC_3201_B*")

phot_table = photometry(position_MAR09_B, 10)

cross_check(6)

sci_median = scale_and_combine("../040_shift/data/shifted/
↪march_09_2018",6,"NGC_3201_B*","NGC_3201_B_median_60.0s.fits")
```

```
median_statistics(position_MAR09_B, 10, 6)
```

```
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```

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the FITS file. [astropy.nddata.ccddata]

 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
       pix     pix          adu
--- ------- ------- ------------------
  1 522.664 300.336  6607.220769274922
  2 563.243 321.768  5178.479063131144
  3 185.549  39.929 12419.013626436328
  4 441.632 163.022   9265.33240632489
  5 429.312  327.29  7019.043643020897
  6 407.941 431.066   6487.13608558205
  7 429.162 327.251  7015.509733441118
  8  226.35  77.914  10363.34142993159
  9 239.797 135.189  5320.588495851454
 10 259.315  50.801 3857.4032620085413


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
       pix     pix          adu
--- ------- ------- ------------------
  1 522.664 300.336  6607.220769274922
  2 563.243 321.768  5178.479063131144
  3 185.549  39.929 12419.013626436328
  4 441.632 163.022   9265.33240632489
  5 429.312  327.29  7019.043643020897
  6 407.941 431.066   6487.13608558205
```

```
  7 429.162 327.251  7015.509733441118
  8  226.35  77.914  10363.34142993159
  9 239.797 135.189  5320.588495851454
 10 259.315  50.801 3857.4032620085413
```

```
 1  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6198.905739060042
  2 563.243 321.768  5005.977026012943
  3 185.549  39.929 12253.822894041481
  4 441.632 163.022  9056.803052745092
  5 429.312  327.29  6914.087103585866
  6 407.941 431.066   6146.00651113385
  7 429.162 327.251  6908.938636561433
  8  226.35  77.914  10099.73858065651
  9 239.797 135.189  5687.044656617889
 10 259.315  50.801 3841.7406528189013
```

```
 2  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6072.587221519783
  2 563.243 321.768   4651.96758270558
  3 185.549  39.929 12562.920767995969
  4 441.632 163.022  9356.465423879074
  5 429.312  327.29  6810.009430587892
  6 407.941 431.066  6314.486552269069
  7 429.162 327.251  6807.686779860529
  8  226.35  77.914  9933.204951220514
  9 239.797 135.189  5849.990386195633
 10 259.315  50.801 3947.4480755146415
```

```
 3  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336   6281.80883544404
  2 563.243 321.768  5002.680161798939
  3 185.549  39.929 12109.073573693413
  4 441.632 163.022  9285.968094724643
  5 429.312  327.29  6845.848058278303
  6 407.941 431.066  6278.332946753922
  7 429.162 327.251  6845.957385608324
  8  226.35  77.914  9422.792223957127
  9 239.797 135.189  5607.626768291351
```

```
 10 259.315  50.801 3746.7323788743424
```

```
 4  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6241.100506542085
  2 563.243 321.768  4806.794720325082
  3 185.549  39.929 12120.079175402247
  4 441.632 163.022  8959.645906230673
  5 429.312  327.29  6937.588504400932
  6 407.941 431.066   6159.54384211299
  7 429.162 327.251  6932.377791854591
  8  226.35  77.914  9612.320163378528
  9 239.797 135.189  5773.581680835558
 10 259.315  50.801  3842.312162990638
```

```
 5  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6384.895829176901
  2 563.243 321.768  4898.130856927649
  3 185.549  39.929 12015.971627518513
  4 441.632 163.022  8985.052515773074
  5 429.312  327.29  6894.819869618276
  6 407.941 431.066  6528.213326998526
  7 429.162 327.251  6888.697760559973
  8  226.35  77.914  9863.635114878256
  9 239.797 135.189  5736.955565225662
 10 259.315  50.801  3584.800752592043
```

```
 6  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6370.058350414198
  2 563.243 321.768  5020.053482595061
  3 185.549  39.929 12422.584985852329
  4 441.632 163.022  9069.876735252168
  5 429.312  327.29   6928.93451807119
  6 407.941 431.066  6119.139286595797
  7 429.162 327.251  6927.976763069666
  8  226.35  77.914   9878.69527952157
  9 239.797 135.189   5569.46866598556
 10 259.315  50.801  3613.450449987572
```

```
 7  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6346.120247550724
  2 563.243 321.768  4448.512705017532
  3 185.549  39.929 12459.811602770957
  4 441.632 163.022  9304.669171779533
  5 429.312  327.29  6697.821402072732
  6 407.941 431.066  6398.894265490177
  7 429.162 327.251  6708.822486839521
  8  226.35  77.914  9912.215644261934
  9 239.797 135.189   5670.53162404625
 10 259.315  50.801 3694.5943469772155


 8  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6422.076406235161
  2 563.243 321.768  4751.614390534742
  3 185.549  39.929 12517.752874780093
  4 441.632 163.022  8844.773245279175
  5 429.312  327.29  6723.285830611241
  6 407.941 431.066  6002.322548997939
  7 429.162 327.251 6721.3876062998825
  8  226.35  77.914  9744.168341522096
  9 239.797 135.189  5487.690643928564
 10 259.315  50.801 3847.9728531200144


 9  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 522.664 300.336  6297.932477747077
  2 563.243 321.768  4904.727540651042
  3 185.549  39.929 12175.248070369937
  4 441.632 163.022  9307.727713834027
  5 429.312  327.29  7120.350394092262
  6 407.941 431.066  6439.042886033432
  7 429.162 327.251 7121.2513995090785
  8  226.35  77.914  9786.818780820136
  9 239.797 135.189  5555.700881081304
 10 259.315  50.801 3624.4602595646543


 10  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
```

```
  1 522.664 300.336  6622.095833301028
  2 563.243 321.768  5050.571963301394
  3 185.549  39.929 12595.309939922277
  4 441.632 163.022  9411.286822799122
  5 429.312  327.29  7002.650122790268
  6 407.941 431.066  6354.600110449381
  7 429.162 327.251 7002.9688357292225
  8  226.35  77.914 10038.685321047466
  9 239.797 135.189 5836.2218621482025
 10 259.315  50.801   3744.59759376635
```

```
 11  id xcenter ycenter    aperture_sum
      pix     pix          adu
--- ------- ------- ------------------
  1 522.664 300.336  6460.897038432111
  2 563.243 321.768  4965.949388714905
  3 185.549  39.929 11919.971817100968
  4 441.632 163.022  9388.671735476566
  5 429.312  327.29 6967.6832163153995
  6 407.941 431.066  6167.296698039216
  7 429.162 327.251  6974.316689485702
  8  226.35  77.914  9668.894288042937
  9 239.797 135.189  5868.247489714513
 10 259.315  50.801 3774.9723762196954
```

```
 12  id xcenter ycenter    aperture_sum
      pix     pix          adu
--- ------- ------- ------------------
  1 522.664 300.336  6504.353680823001
  2 563.243 321.768  4860.312363287718
  3 185.549  39.929 12313.484261484977
  4 441.632 163.022  9309.158603003165
  5 429.312  327.29 7139.3430080057005
  6 407.941 431.066     6165.712682039
  7 429.162 327.251  7145.622813558567
  8  226.35  77.914  9929.970815214576
  9 239.797 135.189  5526.501162375377
 10 259.315  50.801  3843.567685773189
```

```
 13  id xcenter ycenter    aperture_sum
      pix     pix          adu
--- ------- ------- ------------------
  1 522.664 300.336  6188.380821012854
  2 563.243 321.768  4918.512590323346
  3 185.549  39.929 12125.698170776213
```

```
  4 441.632 163.022  9337.498881225229
  5 429.312  327.29  7125.883386245498
  6 407.941 431.066  6075.532206225753
  7 429.162 327.251  7130.859706440004
  8  226.35  77.914  9764.216009714053
  9 239.797 135.189  5665.600739119491
 10 259.315  50.801 3650.5887228032852


 14  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- -----------------
  1 522.664 300.336 6489.915027969548
  2 563.243 321.768 4897.109625505027
  3 185.549  39.929 12239.06203589201
  4 441.632 163.022 9254.762775514228
  5 429.312  327.29 7190.261379113985
  6 407.941 431.066 6756.893173315544
  7 429.162 327.251  7179.64165234014
  8  226.35  77.914 9975.843812943638
  9 239.797 135.189 5763.247294976112
 10 259.315  50.801 3428.405378023278


 15  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- -----------------
  1 522.664 300.336  6147.743058520405
  2 563.243 321.768  4813.058583297816
  3 185.549  39.929 12197.346989598504
  4 441.632 163.022  9106.721104252616
  5 429.312  327.29  6870.858371897227
  6 407.941 431.066    6435.0755712462
  7 429.162 327.251   6872.87297295906
  8  226.35  77.914  9951.582430622966
  9 239.797 135.189  5814.507460740561
 10 259.315  50.801 3788.8320747819544


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[0.96410557 0.96940693 1.00028757 0.97890462 0.98716219 0.94327284
 0.98752294 0.95323457 1.04677681 0.93675724]

 Median value of Flux across the image:
```

```
 0.974155776210782

 Flux ratio of Best Image over Image  1

[1.02761013 1.00281193 1.0137722  1.00144352 1.00214742 0.99562851
 1.00275558 0.97811396 0.97932564 0.94057636]

 Median value of Flux across the image:
 1.0017954678495578

 Flux ratio of Best Image over Image  2

[1.0489859  1.07912478 0.98882937 0.96936998 1.01746328 0.96906363
 1.01766973 0.99451238 0.95204749 0.91538898]

 Median value of Flux across the image:
 0.9916708724243924

 Flux ratio of Best Image over Image  3

[1.01404842 1.0034728  1.02589062 0.97672926 1.01213677 0.97464396
 1.0119807  1.04838301 0.99319532 0.96442716]

 Median value of Flux across the image:
 1.007726752467131

 Flux ratio of Best Image over Image  4

[1.02066268 1.04436611 1.02495906 1.01230303 0.99875259 0.99344033
 0.99936515 1.02771184 0.96464707 0.94043646]

 Median value of Flux across the image:
 1.0058340914145099

 Flux ratio of Best Image over Image  5

[0.99767616 1.02489166 1.03383941 1.00944059 1.00494787 0.93733752
 1.00570195 1.00152684 0.97080561 1.00799199]

 Median value of Flux across the image:
 1.0053249077063695

 Flux ratio of Best Image over Image  6

[1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0
```

```
 Flux ratio of Best Image over Image  7

[1.00377208 1.12847907 0.99701226 0.97476617 1.03450571 0.95628073
 1.03266658 0.99661828 0.98217752 0.97803713]

 Median value of Flux across the image:
 0.996815271077313

 Flux ratio of Best Image over Image  8

[0.99190012 1.05649429 0.99239737 1.02545045 1.03058753 1.01946192
 1.03073609 1.01380589 1.01490208 0.939053  ]

 Median value of Flux across the image:
 1.017182002915656

 Flux ratio of Best Image over Image  9

[1.01145231 1.02351322 1.02031473 0.97444586 0.97311707 0.95031814
 0.97285946 1.00938778 1.00247814 0.99696236]

 Median value of Flux across the image:
 0.9997202476615366

 Flux ratio of Best Image over Image  10

[0.96193992 0.99395742 0.98628657 0.96372334 0.98947318 0.9629464
 0.98929139 0.98406265 0.95429351 0.96497697]

 Median value of Flux across the image:
 0.9745198113454703

 Flux ratio of Best Image over Image  11

[0.98594024 1.01089502 1.04216563 0.96604472 0.9944388  0.99219149
 0.99335563 1.02169855 0.94908551 0.95721242]

 Median value of Flux across the image:
 0.9927735599207974

 Flux ratio of Best Image over Image  12

[0.97935301 1.03286643 1.00886026 0.97429608 0.97052831 0.99244639
 0.96954135 0.99483629 1.00777481 0.94012926]

 Median value of Flux across the image:
 0.9858996990905458
```

```
 Flux ratio of Best Image over Image  13

[1.02935785 1.02064463 1.0244841  0.97133899 0.97236148 1.00717749
 0.9715486  1.01172437 0.98303232 0.98982677]

 Median value of Flux across the image:
 0.9985021315248825

 Flux ratio of Best Image over Image  14

[0.98153186 1.02510539 1.01499485 0.98002261 0.96365544 0.90561433
 0.96494743 0.99026162 0.96637683 1.05397409]

 Median value of Flux across the image:
 0.9807772317078833

 Flux ratio of Best Image over Image  15

[1.0361621  1.04300694 1.01846615 0.99595416 1.00845253 0.95090403
 1.00801758 0.99267582 0.95785734 0.9537109 ]

 Median value of Flux across the image:
 1.0019858668500257
Image  0 :  0.974155776210782
Image  1 :  1.0017954678495578
Image  2 :  0.9916708724243924
Image  3 :  1.007726752467131
Image  4 :  1.0058340914145099
Image  5 :  1.0053249077063695
Image  6 :  1.0
Image  7 :  0.996815271077313
Image  8 :  1.017182002915656
Image  9 :  0.9997202476615366
Image  10 :  0.9745198113454703
Image  11 :  0.9927735599207974
Image  12 :  0.9858996990905458
Image  13 :  0.9985021315248825
Image  14 :  0.9807772317078833
Image  15 :  1.0019858668500257
Median combine


 Median pixel value -0.23077520728111267
Standard deviation 10.668675

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
```

```
      pix     pix          adu2
--- ------- ------- -----------------
  1 522.664 300.336 6149.809363802981
  2 563.243 321.768 4804.110507302923
  3 185.549  39.929 11920.41365651146
  4 441.632 163.022 8865.445168952981
  5 429.312  327.29  6784.20306173722
  6 407.941 431.066 6206.831912135498
  7 429.162 327.251 6783.850324494577
  8  226.35  77.914  9613.93225756432
  9 239.797 135.189  5584.52093384316
 10 259.315  50.801 3617.784645514511
```

```
Cross Checking: flux ratio with best image
[1.03581395 1.04494963 1.04212701 1.02305937 1.0213336  0.9858716
1.02124552 1.02753951 0.99730464 0.99880198] 1 / adu
```

```
Median value of the flux ratio:  1.0221964828724026 1 / adu
```

Photometry table for images: - using a radius of 10 due to the stars having an average value radius below this - The flux values in ADU for the stars are all consistent across the images

Cross checking: - Using image 7 as the reference/best image - An image with a greater flux than our reference image will give us a value less than 1, whereas if it was smaller it would be greater than 1. - scalar values are all close to 1, this is a good sign

- Median value of the flux ratio: 1.0221964828724026 1 / adu

Happy with stack!

1.1.8 ——————————————————————————V-Band——————————————————————————

Date: March 9th | **Exposure Time:** 60.0s

[9]:
```
scim = image_collect("../040_shift/data/shifted/march_09_2018","NGC_3201_V*")

phot_table = photometry(position_MAR09_V, 10)

cross_check(12)

sci_median = scale_and_combine("../040_shift/data/shifted/
 ↪march_09_2018",12,"NGC_3201_V*","NGC_3201_V_median_60.0s.fits")

median_statistics(position_MAR09_V, 10, 12)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
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adu in the FITS file.
```

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INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
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the FITS file. [astropy.nddata.ccddata]
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the FITS file. [astropy.nddata.ccddata]
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the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
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the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
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the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]

 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
       pix     pix          adu
--- ------- ------- ------------------
  1 563.394 321.438  23059.00372338719
  2 522.479 299.957  30209.34029628841
  3 685.053  46.082  5084.412647702884
  4 259.311  50.565 16578.703209771124
  5 185.395  39.328    69799.739733222
  6  408.04 430.484 31858.525772908233
  7 415.553  98.852 15747.968708749137
  8  30.863 217.533  9605.452504655312
  9 124.637 370.334  9557.265468204023
 10 517.631 174.968   30029.6834492013
 11 593.371 221.861 10873.762048949564


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
       pix     pix          adu
--- ------- ------- ------------------
  1 563.394 321.438  23059.00372338719
  2 522.479 299.957  30209.34029628841
  3 685.053  46.082  5084.412647702884
  4 259.311  50.565 16578.703209771124
  5 185.395  39.328    69799.739733222
  6  408.04 430.484 31858.525772908233
  7 415.553  98.852 15747.968708749137
  8  30.863 217.533  9605.452504655312
```

```
  9 124.637 370.334  9557.265468204023
 10 517.631 174.968   30029.6834492013
 11 593.371 221.861 10873.762048949564
```

```
 1  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438  22952.47606524699
  2 522.479 299.957 29971.400039994034
  3 685.053  46.082  4907.408595176685
  4 259.311  50.565 16442.238045097234
  5 185.395  39.328  68563.78610612525
  6  408.04 430.484 31317.311429468376
  7 415.553  98.852  15608.01201725754
  8  30.863 217.533  9781.412072482191
  9 124.637 370.334  10171.74471104311
 10 517.631 174.968 29343.781443553475
 11 593.371 221.861 10185.236831871984
```

```
 2  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22862.127161808683
  2 522.479 299.957  29517.98088580228
  3 685.053  46.082   4495.07589416516
  4 259.311  50.565  16502.87034776438
  5 185.395  39.328  68122.18086879101
  6  408.04 430.484 31068.207630547608
  7 415.553  98.852 15449.731978210948
  8  30.863 217.533  9898.569916931654
  9 124.637 370.334  9736.839618119517
 10 517.631 174.968 29022.274891303077
 11 593.371 221.861  10380.97752474178
```

```
 3  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438  22550.09181551532
  2 522.479 299.957 29655.339153481174
  3 685.053  46.082  4921.371450368062
  4 259.311  50.565 16101.384476353041
  5 185.395  39.328  67460.75274621834
  6  408.04 430.484  31015.85655192077
  7 415.553  98.852  15292.12420162498
  8  30.863 217.533  9444.514817268524
```

```
  9 124.637 370.334 10036.961714812096
 10 517.631 174.968  28992.61103693522
 11 593.371 221.861 10262.497320575872


 4  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22130.210071735688
  2 522.479 299.957  29857.94438030263
  3 685.053  46.082   4587.73440329876
  4 259.311  50.565 15989.634301553324
  5 185.395  39.328  67723.61444597777
  6  408.04 430.484  31285.73386797773
  7 415.553  98.852 15605.356416173257
  8  30.863 217.533  9763.040197985025
  9 124.637 370.334  9665.279370747288
 10 517.631 174.968 28979.860520009148
 11 593.371 221.861 10695.725219611493


 5  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22672.525540611467
  2 522.479 299.957  29784.89873532179
  3 685.053  46.082  4780.124745930052
  4 259.311  50.565 16083.757232454478
  5 185.395  39.328  68150.27733968943
  6  408.04 430.484 31165.445500434245
  7 415.553  98.852   15248.7977405393
  8  30.863 217.533  9599.331836678377
  9 124.637 370.334  9698.085851700056
 10 517.631 174.968  29163.95664807718
 11 593.371 221.861 10735.789015891758


 6  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22288.123896913574
  2 522.479 299.957 29775.176251128803
  3 685.053  46.082  5183.349340142736
  4 259.311  50.565 16214.351772180054
  5 185.395  39.328  67887.17833703246
  6  408.04 430.484   30948.2792044632
  7 415.553  98.852  14986.14644003195
  8  30.863 217.533  9765.028880437178
```

```
  9 124.637 370.334  9556.035627393727
 10 517.631 174.968  29465.34804477718
 11 593.371 221.861   10586.8199087573
```

```
 7  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22855.253971459373
  2 522.479 299.957  29633.64047339194
  3 685.053  46.082  4639.183718043103
  4 259.311  50.565  16116.90398115268
  5 185.395  39.328  67876.90401109475
  6  408.04 430.484 31034.199543978197
  7 415.553  98.852 15149.322292110697
  8  30.863 217.533   9783.26750886122
  9 124.637 370.334  9632.351580338822
 10 517.631 174.968 29066.172505473827
 11 593.371 221.861 10589.915113434674
```

```
 8  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22857.912782652827
  2 522.479 299.957 30257.763620114394
  3 685.053  46.082  4900.257803576627
  4 259.311  50.565  16480.90345921965
  5 185.395  39.328  69653.81965244845
  6  408.04 430.484 31421.520772081218
  7 415.553  98.852  15843.52821764463
  8  30.863 217.533 10174.343926982641
  9 124.637 370.334  9778.862113984278
 10 517.631 174.968 29542.848311303154
 11 593.371 221.861 10544.718717336747
```

```
 9  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438  22708.80019332862
  2 522.479 299.957  29767.78029247115
  3 685.053  46.082  4779.114143753887
  4 259.311  50.565  16907.10715160853
  5 185.395  39.328  69423.49156601471
  6  408.04 430.484 30878.990624894785
  7 415.553  98.852 15745.415112224051
  8  30.863 217.533 10340.704032230999
```

```
  9 124.637 370.334  9726.584405860991
 10 517.631 174.968 29556.370072009257
 11 593.371 221.861  10245.97393148238


 10  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 23126.392489561673
  2 522.479 299.957  29988.10135094118
  3 685.053  46.082  4800.088062785375
  4 259.311  50.565  16596.70027851055
  5 185.395  39.328  68688.06733066773
  6  408.04 430.484  30689.75498786162
  7 415.553  98.852 15810.776511919663
  8  30.863 217.533  9797.864085236513
  9 124.637 370.334  9662.220447615775
 10 517.631 174.968 29280.857112596226
 11 593.371 221.861  10947.84555576044


 11  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22644.471695480737
  2 522.479 299.957 29739.705908410946
  3 685.053  46.082 4902.1726191288235
  4 259.311  50.565 16110.348921525438
  5 185.395  39.328  68227.98812402462
  6  408.04 430.484 30917.759640378656
  7 415.553  98.852 15960.612872851958
  8  30.863 217.533 10049.707549896812
  9 124.637 370.334  9492.671532840644
 10 517.631 174.968 29651.769495361506
 11 593.371 221.861 10361.499904088367


 12  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438  22712.19467400459
  2 522.479 299.957 30019.801827322695
  3 685.053  46.082  4819.352624762082
  4 259.311  50.565 16261.386070373483
  5 185.395  39.328  68599.23087381855
  6  408.04 430.484 31279.172329931265
  7 415.553  98.852 15696.289182868524
  8  30.863 217.533  9886.477658966312
```

```
  9 124.637 370.334  9744.783171950316
 10 517.631 174.968 29408.785816209067
 11 593.371 221.861 10578.273627213435


 13  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22968.551189386504
  2 522.479 299.957  30328.18706945405
  3 685.053  46.082  4881.992921193877
  4 259.311  50.565  16527.49514238697
  5 185.395  39.328  68575.17917880564
  6  408.04 430.484  30931.33308945522
  7 415.553  98.852 15756.386743667606
  8  30.863 217.533  9945.428275048225
  9 124.637 370.334  9622.078044463156
 10 517.631 174.968 29472.513806652696
 11 593.371 221.861 10710.828400617222


 14  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22858.839130353663
  2 522.479 299.957 29662.861123871036
  3 685.053  46.082  4852.447340536082
  4 259.311  50.565 16206.760027964045
  5 185.395  39.328  68607.32219766286
  6  408.04 430.484 31103.494701977528
  7 415.553  98.852 15563.709728007809
  8  30.863 217.533   9990.24425513966
  9 124.637 370.334   9679.13085831818
 10 517.631 174.968 28976.161025538466
 11 593.371 221.861 10627.627503182688


 15  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.394 321.438 22886.170824979672
  2 522.479 299.957  29912.89653263554
  3 685.053  46.082  4996.180097803178
  4 259.311  50.565 16182.724822191729
  5 185.395  39.328  68478.70108697256
  6  408.04 430.484  31297.93736632952
  7 415.553  98.852 15462.221640707703
  8  30.863 217.533  9972.347036544244
```

```
  9 124.637 370.334  9734.221091812782
 10 517.631 174.968  29262.79352266401
 11 593.371 221.861 10417.715441078886


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[0.98495993 0.99372583 0.94786811 0.98085995 0.98280067 0.98181481
 0.99671834 1.02925684 1.01962043 0.97932387 0.97282556]

 Median value of Flux across the image:
 0.982800668541289

 Flux ratio of Best Image over Image  1

[0.98953135 1.00161493 0.98205652 0.98900077 1.00051696 0.99878217
 1.00565589 1.01074135 0.95802475 1.00221527 1.03858887]

 Median value of Flux across the image:
 1.0005169604787933

 Flux ratio of Best Image over Image  2

[0.99344188 1.01700052 1.07214044 0.98536713 1.00700286 1.00679037
 1.01595867 0.99877838 1.00081582 1.01331773 1.01900554]

 Median value of Flux across the image:
 1.0070028586716326

 Flux ratio of Best Image over Image  3

[1.00718857 1.01228995 0.97927024 1.00993713 1.01687616 1.00848971
 1.02642962 1.04679572 0.97088974 1.01435451 1.03076993]

 Median value of Flux across the image:
 1.0122899512952876

 Flux ratio of Best Image over Image  4

[1.0262982  1.00542092 1.05048641 1.0169955  1.01292926 0.99979027
 1.00582702 1.01264334 1.00822571 1.01480081 0.98901883]

 Median value of Flux across the image:
 1.0126433424914878
```

```
 Flux ratio of Best Image over Image  5

[1.00174966 1.00788665 1.00820646 1.01104399 1.0065877  1.00364913
 1.02934601 1.02991311 1.00481511 1.00839492 0.98532801]

 Median value of Flux across the image:
 1.0078866506845745

 Flux ratio of Best Image over Image  6

[1.01902676 1.00821576 0.92977577 1.00290078 1.01048876 1.01069181
 1.04738661 1.01243711 1.01975166 0.99808038 0.99919274]

 Median value of Flux across the image:
 1.0104887631836905

 Flux ratio of Best Image over Image  7

[0.99374064 1.01303118 1.03883634 1.00896463 1.01064172 1.00789364
 1.03610504 1.01054966 1.01167229 1.01178736 0.9989007 ]

 Median value of Flux across the image:
 1.0106417178751366

 Flux ratio of Best Image over Image  8

[0.99362505 0.99213551 0.98348961 0.9866805  0.98485957 0.99546972
 0.99070668 0.97170665 0.99651504 0.9954621  1.00318215]

 Median value of Flux across the image:
 0.9921355128627712

 Flux ratio of Best Image over Image  9

[1.00014948 1.00846625 1.00841965 0.96180771 0.98812706 1.01295968
 0.99687999 0.95607394 1.00187103 0.99500669 1.03243222]

 Median value of Flux across the image:
 1.0001494786447136

 Flux ratio of Best Image over Image  10

[0.98208982 1.0010571  1.00401338 0.97979633 0.99870667 1.01920567
 0.99275891 1.00904417 1.0085449  1.00436902 0.9662425 ]

 Median value of Flux across the image:
 1.0010571018155012
```

```
 Flux ratio of Best Image over Image  11

[1.00299071 1.00941825 0.98310545 1.00937516 1.00544121 1.01168949
 0.983439   0.98375775 1.02655856 0.99180542 1.02092108]

 Median value of Flux across the image:
 1.005441209099103

 Flux ratio of Best Image over Image  12

[1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  13

[0.9888388  0.98983173 0.98716911 0.98389901 1.00035073 1.01124553
 0.99618583 0.99407259 1.01275246 0.99783771 0.98762423]

 Median value of Flux across the image:
 0.9940725915011813

 Flux ratio of Best Image over Image  14

[0.99358478 1.01203325 0.99317979 1.00337057 0.99988206 1.00564816
 1.0085185  0.98961321 1.00678287 1.01493037 0.99535608]

 Median value of Flux across the image:
 1.003370571435326

 Flux ratio of Best Image over Image  15

[0.9923982  1.00357389 0.96460747 1.00486082 1.00176011 0.99940044
 1.01513803 0.99138925 1.00108505 1.00498901 1.01541203]

 Median value of Flux across the image:
 1.0017601062072266
Image  0 :  0.982800668541289
Image  1 :  1.0005169604787933
Image  2 :  1.0070028586716326
Image  3 :  1.0122899512952876
Image  4 :  1.0126433424914878
Image  5 :  1.0078866506845745
Image  6 :  1.0104887631836905
Image  7 :  1.0106417178751366
Image  8 :  0.9921355128627712
Image  9 :  1.0001494786447136
```

```
Image  10 :  1.0010571018155012
Image  11 :  1.005441209099103
Image  12 :  1.0
Image  13 :  0.9940725915011813
Image  14 :  1.003370571435326
Image  15 :  1.0017601062072266
Median combine


 Median pixel value -0.790734052658081
Standard deviation 50.465797

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu2
--- ------- ------- ------------------
  1 563.394 321.438 22369.942581790114
  2 522.479 299.957 29233.376587826515
  3 685.053  46.082  4778.992010974711
  4 259.311  50.565 16095.178830298008
  5 185.395  39.328  67771.73038589348
  6  408.04 430.484  30775.74116897171
  7 415.553  98.852 15415.267606227158
  8  30.863 217.533  9810.155718206186
  9 124.637 370.334  9622.549228162843
 10 517.631 174.968 28708.955591173428
 11 593.371 221.861 10355.721389627997


 Cross Checking: flux ratio with best image
 [1.01529964 1.02690162 1.00844542 1.01032652 1.01221011 1.01635805
 1.01823008 1.00777989 1.01270286 1.02437672 1.02149075] 1 / adu


 Median value of the flux ratio:  1.0152996410680588 1 / adu
```

Photometry table for images: - using a radius of 10 due to the stars having an average value radius below this - The flux values in ADU for the stars are all consistent across the images

Cross checking: - Using image 13 as the reference/best image - scalar values are all close to 1, this is a good sign

- Median value of the flux ratio: 1.0152996410680588 1 / adu

Date: March 29th | **Exposure Time:** 30.0s

[10]:
```
scim = image_collect("../040_shift/data/shifted/march_29_2018","NGC_3201_V_30*")

phot_table = photometry(position_MAR29_V, 10)
```

```
cross_check(0)

sci_median = scale_and_combine("../040_shift/data/shifted/
 ↪march_29_2018",0,"NGC_3201_V_30*","NGC_3201_V_median_30.0s.fits")

median_statistics(position_MAR29_V, 10, 0)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.

INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]

 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 602.816 456.921 32726.209431331776
  2 354.656 494.391   16661.7214099244
  3 381.877  66.898 14352.402681000436
  4 304.334  77.417  5934.319534584272
  5 664.473 127.188  4759.432135554327


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 602.816 456.921 32726.209431331776
  2 354.656 494.391   16661.7214099244
  3 381.877  66.898 14352.402681000436
  4 304.334  77.417  5934.319534584272
  5 664.473 127.188  4759.432135554327


 1  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 602.816 456.921  32861.23916883422
  2 354.656 494.391 16843.393389825476
  3 381.877  66.898 14967.379819654536
  4 304.334  77.417  5878.441909655217
```

```
  5 664.473 127.188  4389.996647788392


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  1

[0.99589091 0.98921405 0.95891217 1.00950552 1.08415393]

 Median value of Flux across the image:
 0.99589091157492
Image  0 :  1.0
Image  1 :  0.99589091157492
Median combine


 Median pixel value -0.19105854630470276
Standard deviation 10.965036

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix          adu2
--- ------- ------- ------------------
  1 602.816 456.921 32726.209488205408
  2 354.656 494.391 16717.952057592975
  3 381.877  66.898 14629.140069966596
  4 304.334  77.417  5894.303192472091
  5 664.473 127.188  4565.694966301491


 Cross Checking: flux ratio with best image
 [1.         0.99663651 0.98108314 1.00678899 1.04243323] 1 / adu


 Median value of the flux ratio:  0.9999999982621381 1 / adu
```

Only has 2 images to stack | Photometric night

Photometry table for images: - using a radius of 10 due to the stars having an average value radius below this - The flux values in ADU for the stars are all consistent across the images

Cross checking: - Using image 1 as the reference/best image - scalar values are all close to 1, this is a good sign

- Median value of the flux ratio: 0.9999999982621381 1 / adu

1.1.9 ——————————————————————R-Band——————————————————————

Date: March 9th | **Exposure Time:** 60.0s

[11]:
```
scim = image_collect("../040_shift/data/shifted/march_09_2018","NGC_3201_R*")

phot_table = photometry(position_MAR09_R, 12)

cross_check(8)

sci_median = scale_and_combine("../040_shift/data/shifted/
↪march_09_2018",8,"NGC_3201_R*","NGC_3201_R_median_60.0s.fits")

median_statistics(position_MAR09_R, 12, 8)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
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adu in the FITS file.
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INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
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```
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
```

```
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
```

```
 PHOTOMETRY TABLE FOR FIRST IMAGE
```

id	xcenter pix	ycenter pix	aperture_sum adu
1	563.794	321.598	49347.7055435901
2	408.146	430.232	69935.0288178974
3	294.93	56.057	16548.799903665145
4	259.531	49.832	32903.43284247434
5	30.926	217.501	19127.18579309169
6	124.916	370.236	17899.781057173503
7	408.212	430.14	69950.67597139889
8	522.99	299.781	64723.02518420777
9	49.627	27.463	17050.716344066524
10	329.471	416.622	7639.677165858882
11	415.754	98.519	34608.66830194586

PHOTOMETRY TABLE FOR ALL IMAGES

0

id	xcenter pix	ycenter pix	aperture_sum adu
1	563.794	321.598	49347.7055435901
2	408.146	430.232	69935.0288178974
3	294.93	56.057	16548.799903665145
4	259.531	49.832	32903.43284247434
5	30.926	217.501	19127.18579309169
6	124.916	370.236	17899.781057173503
7	408.212	430.14	69950.67597139889
8	522.99	299.781	64723.02518420777
9	49.627	27.463	17050.716344066524
10	329.471	416.622	7639.677165858882
11	415.754	98.519	34608.66830194586

1

id	xcenter pix	ycenter pix	aperture_sum adu
1	563.794	321.598	49283.28136365284
2	408.146	430.232	69449.40911588716
3	294.93	56.057	16109.626398011425
4	259.531	49.832	32889.114119263955
5	30.926	217.501	19148.159553878995
6	124.916	370.236	18232.71110620803
7	408.212	430.14	69463.74247563099
8	522.99	299.781	65211.12519117253
9	49.627	27.463	17209.800304321467
10	329.471	416.622	7317.673481764564
11	415.754	98.519	34139.729051104994

 2 id xcenter ycenter   aperture_sum
      pix   pix   adu
--- ------- ------- ------------------
  1 563.794 321.598 49630.57790042639
  2 408.146 430.232 70276.65189823956
  3 294.93 56.057 16726.713734768073
  4 259.531 49.832 32920.35508295438
  5 30.926 217.501 18797.80964481464
  6 124.916 370.236 18357.47794680097
  7 408.212 430.14 70272.27530381523
  8 522.99 299.781 65409.08009749469
  9 49.627 27.463 17566.601209291144
 10 329.471 416.622 8262.921687239517
 11 415.754 98.519 34172.74948850931

 3 id xcenter ycenter   aperture_sum
      pix   pix   adu
--- ------- ------- ------------------
  1 563.794 321.598 49845.19697487554
  2 408.146 430.232 70799.81462985312
  3 294.93 56.057 16540.336480928734
  4 259.531 49.832 32773.483115157665
  5 30.926 217.501 18935.13207647297
  6 124.916 370.236   18859.3738243234
  7 408.212 430.14   70795.0299654727
  8 522.99 299.781 65430.80037078853
  9 49.627 27.463 17348.54457876888
 10 329.471 416.622 7968.710379911718
 11 415.754 98.519 34326.10398495864

 4 id xcenter ycenter   aperture_sum
      pix   pix   adu
--- ------- ------- ------------------
  1 563.794 321.598 49378.905727015546
  2 408.146 430.232 69900.25033927668
  3 294.93 56.057 16774.39819671311
  4 259.531 49.832 33110.01378994098
  5 30.926 217.501 19248.605443729146
  6 124.916 370.236 18364.897019930395
  7 408.212 430.14 69896.44300414651
  8 522.99 299.781 65256.89672432493
  9 49.627 27.463 17328.632643672616
 10 329.471 416.622 7532.7444240820005
 11 415.754 98.519 34749.92234843879

```
 5  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  49122.69377295535
  2 408.146 430.232  70073.55120779305
  3  294.93  56.057 16405.932245854794
  4 259.531  49.832  32790.42222763268
  5  30.926 217.501  19611.35907934241
  6 124.916 370.236  18718.15219533102
  7 408.212  430.14  70080.80168460615
  8  522.99 299.781  64993.57371883767
  9  49.627  27.463 17419.782036564873
 10 329.471 416.622  8194.169972061616
 11 415.754  98.519  34128.61858311924
```

```
 6  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  49902.16802615232
  2 408.146 430.232  70333.55123130104
  3  294.93  56.057  16523.43383400294
  4 259.531  49.832 32773.530766622265
  5  30.926 217.501 19685.621859407394
  6 124.916 370.236 18810.822278358573
  7 408.212  430.14  70341.01263709743
  8  522.99 299.781  65337.67021752418
  9  49.627  27.463  17372.69525391745
 10 329.471 416.622  8116.348951031116
 11 415.754  98.519 34592.865203480826
```

```
 7  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598 50022.220954996126
  2 408.146 430.232  71036.58407511961
  3  294.93  56.057 16793.643437688486
  4 259.531  49.832 33301.666638494564
  5  30.926 217.501 19225.621592471012
  6 124.916 370.236 18521.158093369355
  7 408.212  430.14  71044.33384377751
  8  522.99 299.781  65460.55149461358
  9  49.627  27.463  17856.53016921489
 10 329.471 416.622  7868.116872337608
 11 415.754  98.519 34337.119952926114
```

```
 8  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598   49948.8449727155
  2 408.146 430.232  70302.90967957859
  3  294.93  56.057 17209.900230612686
  4 259.531  49.832  33392.27732169248
  5  30.926 217.501 18919.183166456918
  6 124.916 370.236 18489.395020298387
  7 408.212  430.14  70303.92205565603
  8  522.99 299.781 65219.230692008045
  9  49.627  27.463  17496.41493820747
 10 329.471 416.622 8084.7719086776215
 11 415.754  98.519  35178.74771471775
```

```
 9  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  50573.11766952514
  2 408.146 430.232   71925.0168834333
  3  294.93  56.057  16951.37407352586
  4 259.531  49.832  34034.23687583976
  5  30.926 217.501 19317.463282292883
  6 124.916 370.236 19095.657221761307
  7 408.212  430.14  71916.79588874732
  8  522.99 299.781  67056.90042523138
  9  49.627  27.463 17801.421386167967
 10 329.471 416.622  8018.393658778619
 11 415.754  98.519   35621.2001712855
```

```
 10  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598 51334.435587259286
  2 408.146 430.232  72171.02796558946
  3  294.93  56.057  16762.79172900246
  4 259.531  49.832  33863.09787636933
  5  30.926 217.501 19768.684293530383
  6 124.916 370.236 19157.907293373617
  7 408.212  430.14  72169.60866362351
  8  522.99 299.781  66745.19337618517
  9  49.627  27.463  18206.35925435921
 10 329.471 416.622  7905.963353001169
 11 415.754  98.519  35637.29348299703
```

```
 11  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  50239.70385908648
  2 408.146 430.232   71288.9365886011
  3  294.93  56.057 17319.933871428504
  4 259.531  49.832  33549.30047564359
  5  30.926 217.501    19198.308999089
  6 124.916 370.236 19074.362882906156
  7 408.212  430.14   71286.2901501153
  8  522.99 299.781  66414.03761555033
  9  49.627  27.463 17911.418450099314
 10 329.471 416.622  8078.748008663228
 11 415.754  98.519  35747.62542425423


 12  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598 50396.157013448974
  2 408.146 430.232  72050.87986798015
  3  294.93  56.057 17169.679125629285
  4 259.531  49.832  34294.46449014002
  5  30.926 217.501 19397.492395456742
  6 124.916 370.236 18750.056167299124
  7 408.212  430.14  72059.35232914129
  8  522.99 299.781  66997.50638559178
  9  49.627  27.463  17749.37935127486
 10 329.471 416.622  8173.931758775725
 11 415.754  98.519  36270.17858615249


 13  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598 50779.522664441574
  2 408.146 430.232  71692.21656570531
  3  294.93  56.057 17334.439956848346
  4 259.531  49.832   33844.7723839925
  5  30.926 217.501 19719.497162171097
  6 124.916 370.236  18720.42945548887
  7 408.212  430.14  71686.79081646845
  8  522.99 299.781  66790.17503907175
  9  49.627  27.463  17866.34201646848
 10 329.471 416.622   7953.10687780872
 11 415.754  98.519  35560.41055918297
```

```
 14  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  50596.94932459436
  2 408.146 430.232  72074.32243178111
  3  294.93  56.057 17293.067694355796
  4 259.531  49.832  34312.27384282342
  5  30.926 217.501 19755.277820588082
  6 124.916 370.236 19367.891241917096
  7 408.212  430.14  72069.31191112171
  8  522.99 299.781  66716.53528484587
  9  49.627  27.463 17978.924422984062
 10 329.471 416.622  8098.895608901919
 11 415.754  98.519  35962.55428321424
```

```
 15  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598   50852.1244229903
  2 408.146 430.232   71635.9072925188
  3  294.93  56.057 17352.756669257487
  4 259.531  49.832  33776.34496359645
  5  30.926 217.501 19941.138798196866
  6 124.916 370.236  19149.93843810496
  7 408.212  430.14  71634.48950987178
  8  522.99 299.781  66755.17771874592
  9  49.627  27.463  17795.36911011216
 10 329.471 416.622  8222.271800164664
 11 415.754  98.519  36144.43988125278
```

```
 16  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 563.794 321.598  51129.67229291249
  2 408.146 430.232  71706.35926505591
  3  294.93  56.057 17694.422025434586
  4 259.531  49.832  34374.60127725628
  5  30.926 217.501   19852.6574468264
  6 124.916 370.236 19011.863206999744
  7 408.212  430.14  71696.26367553994
  8  522.99 299.781  66943.23867245283
  9  49.627  27.463 18254.631951806878
 10 329.471 416.622  8217.502493078166
 11 415.754  98.519  35794.33246689709
```

```
 17  id xcenter ycenter    aperture_sum
      pix     pix          adu
--- ------- ------- ------------------
  1 563.794 321.598  50485.78253884093
  2 408.146 430.232  71234.45688835628
  3  294.93  56.057 17953.940898307053
  4 259.531  49.832  34449.45229216147
  5  30.926 217.501 19839.981799815152
  6 124.916 370.236    19505.108409157
  7 408.212  430.14   71244.2535903418
  8  522.99 299.781  66883.14367662386
  9  49.627  27.463 18336.689655677077
 10 329.471 416.622  8053.404761431242
 11 415.754  98.519  36266.96929930773


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[1.01218171 1.00526032 1.03994854 1.01485694 0.98912529 1.03293973
 1.00504993 1.0076666  1.02613958 1.05826094 1.01647216]

 Median value of Flux across the image:
 1.0148569446099587

 Flux ratio of Best Image over Image  1

[1.01350486 1.01228953 1.06829915 1.01529878 0.98804186 1.01407821
 1.01209522 1.0001243  1.01665415 1.10482818 1.0304343 ]

 Median value of Flux across the image:
 1.0140782088080669

 Flux ratio of Best Image over Image  2

[1.00641272 1.00037363 1.02888711 1.01433527 1.00645679 1.00718601
 1.00045034 0.99709751 0.99600456 0.97843986 1.02943861]

 Median value of Flux across the image:
 1.0064127214663439

 Flux ratio of Best Image over Image  3

[1.0020794  0.99298155 1.04048066 1.01888094 0.99915771 0.98038223
```

```
 0.99306296 0.99676651 1.0085235  1.01456466 1.02483951]

 Median value of Flux across the image:
 1.0020793978985019

 Flux ratio of Best Image over Image  4

[1.01154216 1.00576048 1.0259623  1.00852502 0.98288591 1.00677913
 1.00582975 0.9994228  1.00968237 1.07328371 1.01234033]

 Median value of Flux across the image:
 1.0085250200601625

 Flux ratio of Best Image over Image  5

[1.01681812 1.00327311 1.04900471 1.0183546  0.96470536 0.98777886
 1.00318376 1.00347199 1.00439919 0.98664928 1.03076975]

 Median value of Flux across the image:
 1.0034719890022752

 Flux ratio of Best Image over Image  6

[1.00093537 0.99956434 1.04154502 1.01887946 0.96106607 0.98291264
 0.9994727  0.99818727 1.0071215  0.99610945 1.01693651]

 Median value of Flux across the image:
 0.9995643394768781

 Flux ratio of Best Image over Image  7

[0.99853313 0.98967188 1.02478657 1.00272091 0.98406094 0.99828504
 0.98957817 0.99631349 0.97983286 1.02753582 1.02451073]

 Median value of Flux across the image:
 0.9982850384997071

 Flux ratio of Best Image over Image  8

[1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  9

[0.98765604 0.97744725 1.01525104 0.98113783 0.97938238 0.9682513
 0.97757306 0.97259537 0.98286617 1.00827825 0.98757896]
```

```
 Median value of Flux across the image:
 0.9811378302240416

 Flux ratio of Best Image over Image  10

[0.97300855 0.9741154  1.02667268 0.98609635 0.95702794 0.96510515
 0.97414858 0.97713749 0.9610057  1.02261692 0.98713298]

 Median value of Flux across the image:
 0.9741485835587208

 Flux ratio of Best Image over Image  11

[0.99421058 0.98616858 0.99364699 0.99531963 0.98546092 0.96933225
 0.9862194  0.98200972 0.97683023 1.00074565 0.98408628]

 Median value of Flux across the image:
 0.9861685844086476

 Flux ratio of Best Image over Image  12

[0.99112408 0.97573978 1.00234257 0.97369292 0.9753417  0.98609811
 0.97563911 0.97345758 0.98574799 0.98909217 0.96990831]

 Median value of Flux across the image:
 0.9757397801164345

 Flux ratio of Best Image over Image  13

[0.98364148 0.98062123 0.99281547 0.98663028 0.95941509 0.9876587
 0.98070957 0.97647941 0.97929475 1.01655517 0.9892672 ]

 Median value of Flux across the image:
 0.983641482862781

 Flux ratio of Best Image over Image  14

[0.98719084 0.97542242 0.99519071 0.97318754 0.9576774  0.95464162
 0.97550428 0.97755722 0.97316249 0.9982561  0.97820492]

 Median value of Flux across the image:
 0.9755042776370223

 Flux ratio of Best Image over Image  15

[0.98223713 0.98139205 0.99176751 0.98862909 0.94875139 0.96550676
 0.9814256  0.97699134 0.98320045 0.98327714 0.97328241]
```

```
 Median value of Flux across the image:
 0.9814256028999496

 Flux ratio of Best Image over Image  16

[0.97690524 0.98042782 0.97261726 0.97142297 0.95297988 0.97251883
 0.98058    0.97424672 0.9584644  0.98384782 0.98280217]

 Median value of Flux across the image:
 0.9742467198385755

 Flux ratio of Best Image over Image  17

[0.98936458 0.9869228  0.95855836 0.96931229 0.95358874 0.94792578
 0.9868013  0.97512209 0.95417522 1.00389489 0.96999414]

 Median value of Flux across the image:
 0.9699941405191871
Image  0 :  1.0148569446099587
Image  1 :  1.0140782088080669
Image  2 :  1.0064127214663439
Image  3 :  1.0020793978985019
Image  4 :  1.0085250200601625
Image  5 :  1.0034719890022752
Image  6 :  0.9995643394768781
Image  7 :  0.9982850384997071
Image  8 :  1.0
Image  9 :  0.9811378302240416
Image  10 :  0.9741485835587208
Image  11 :  0.9861685844086476
Image  12 :  0.9757397801164345
Image  13 :  0.983641482862781
Image  14 :  0.9755042776370223
Image  15 :  0.9814256028999496
Image  16 :  0.9742467198385755
Image  17 :  0.9699941405191871
Median combine


 Median pixel value -1.2888884544372559
Standard deviation 95.049095

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu2
--- ------- ------- ------------------
  1 563.794 321.598  48480.05293399519
```

```
 2 408.146 430.232  68720.05083996928
 3  294.93  56.057 16426.597641856177
 4 259.531  49.832 32312.206605528634
 5  30.926 217.501  18748.86635619373
 6 124.916 370.236  18180.41592721467
 7 408.212  430.14  68720.80545516478
 8  522.99 299.781  63722.51545704149
 9  49.627  27.463 17033.385245009296
10 329.471 416.622   7761.83981571042
11 415.754  98.519  34120.30796252038


Cross Checking: flux ratio with best image
[1.03029683 1.02303344 1.04768502 1.03342609 1.00908411 1.01699516
1.02303693 1.02348801 1.02718366 1.0416051  1.03102081] 1 / adu


Median value of the flux ratio:  1.0271836564803722 1 / adu
```

Date: March 29th | **Exposure Time:** 30.0s

[12]:
```
scim = image_collect("../040_shift/data/shifted/march_29_2018","NGC_3201_R_30*")

phot_table = photometry(position_MAR29_R, 12)

cross_check(0)

sci_median = scale_and_combine("../040_shift/data/shifted/
 ↪march_29_2018",0,"NGC_3201_R_30*","NGC_3201_R_median_30.0s.fits")

median_statistics(position_MAR29_R, 12, 0)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.

INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]


 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 183.279 408.884  5111.872869120605
  2 106.253 449.351 4169.3415797833595
  3 381.617   66.79    34507.889097606
```

```
  4 227.294  174.99  23966.52959177344
  5 106.054 449.626  4199.150019085888


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 183.279 408.884  5111.872869120605
  2 106.253 449.351 4169.3415797833595
  3 381.617   66.79    34507.889097606
  4 227.294  174.99  23966.52959177344
  5 106.054 449.626  4199.150019085888


 1  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- -----------------
  1 183.279 408.884 5583.374937918987
  2 106.253 449.351 4465.464123962514
  3 381.617   66.79 33722.55306830391
  4 227.294  174.99 24169.46190821471
  5 106.054 449.626 4479.623620665803


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  1

[0.9155525  0.93368605 1.02328815 0.99160377 0.93738903]

 Median value of Flux across the image:
 0.9373890252105089
Image  0 :  1.0
Image  1 :  0.9373890252105089
Median combine


 Median pixel value -0.17398445308208466
```

```
Standard deviation 15.365399

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu2
--- ------- ------- ------------------
  1 183.279 408.884  5172.833654697573
  2 106.253 449.351 4177.6093186807375
  3 381.617   66.79 33059.519871166754
  4 227.294  174.99 23311.358928051537
  5 106.054 449.626  4199.150017599176


 Cross Checking: flux ratio with best image
 [0.9882152  0.99802094 1.04381096 1.02810521 1.        ] 1 / adu


 Median value of the flux ratio:  1.0000000003540506 1 / adu
```

1.1.10 I-Band

Date: March 9th | **Exposure Time:** 60.0s

[13]:
```
scim = image_collect("../040_shift/data/shifted/march_09_2018","NGC_3201_I*")
phot_table = photometry(position_MAR09_I, 12)
cross_check(9)

sci_median = scale_and_combine("../040_shift/data/shifted/
 ↪march_09_2018",9,"NGC_3201_I*","NGC_3201_I_median_60.0s.fits")

median_statistics(position_MAR09_I, 12, 9)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
```

```
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
```

```
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]

 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25371.983549553115
  2  48.246  26.965  17486.51645234865
  3 293.889  55.849 18594.365505805654
  4 258.523   49.82   36454.4189374111
  5 607.125  86.216 13108.936922339377
  6 592.409 221.516 25420.114566892567
  7 406.849 430.163  87125.33717119593


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25371.983549553115
  2  48.246  26.965  17486.51645234865
  3 293.889  55.849 18594.365505805654
  4 258.523   49.82   36454.4189374111
  5 607.125  86.216 13108.936922339377
  6 592.409 221.516 25420.114566892567
  7 406.849 430.163  87125.33717119593


 1  id xcenter ycenter    aperture_sum
```

	pix	pix	adu
1	592.363	221.662	25815.977422850614
2	48.246	26.965	18284.427545482584
3	293.889	55.849	18761.434008223707
4	258.523	49.82	37004.95495409862
5	607.125	86.216	13267.973179401137
6	592.409	221.516	25852.73728179967
7	406.849	430.163	88079.93318730357

2

id	xcenter	ycenter	aperture_sum
	pix	pix	adu
1	592.363	221.662	25471.282083471786
2	48.246	26.965	18514.322204514436
3	293.889	55.849	18747.536133110938
4	258.523	49.82	37252.8845794815
5	607.125	86.216	13045.678339743026
6	592.409	221.516	25508.8683433447
7	406.849	430.163	87551.05888546185

3

id	xcenter	ycenter	aperture_sum
	pix	pix	adu
1	592.363	221.662	25982.60670001528
2	48.246	26.965	18018.657878465005
3	293.889	55.849	18761.090974672272
4	258.523	49.82	37458.33046846254
5	607.125	86.216	12854.457640459397
6	592.409	221.516	26011.317342345857
7	406.849	430.163	88128.54602156515

4

id	xcenter	ycenter	aperture_sum
	pix	pix	adu
1	592.363	221.662	25839.140054258845
2	48.246	26.965	18154.947157229308
3	293.889	55.849	18707.360005630348
4	258.523	49.82	37808.82143659146
5	607.125	86.216	13304.438453020819
6	592.409	221.516	25869.03269432567
7	406.849	430.163	87889.31293820639

5 id xcenter ycenter aperture_sum

```
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25442.323919701856
  2  48.246  26.965 18044.846985124794
  3 293.889  55.849  19332.50142144782
  4 258.523   49.82  37369.52599094913
  5 607.125  86.216 13327.712540735823
  6 592.409 221.516 25473.611160907527
  7 406.849 430.163  87735.61961340306
```

```
 6  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25548.59954409535
  2  48.246  26.965 18687.511332920763
  3 293.889  55.849 18942.173502113008
  4 258.523   49.82 37462.664549275534
  5 607.125  86.216 13364.424041220354
  6 592.409 221.516 25582.107893830937
  7 406.849 430.163  87594.69495018953
```

```
 7  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25664.91178602397
  2  48.246  26.965 18616.888659811255
  3 293.889  55.849  18990.59428463454
  4 258.523   49.82  37340.21882085418
  5 607.125  86.216 12837.116166230144
  6 592.409 221.516 25705.810813098542
  7 406.849 430.163  88208.24053923758
```

```
 8  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25619.447053229567
  2  48.246  26.965  18291.70510381512
  3 293.889  55.849 18819.170178453147
  4 258.523   49.82  37244.80292478148
  5 607.125  86.216   12747.9359793876
  6 592.409 221.516 25644.396684371357
  7 406.849 430.163  88222.66455269002
```

```
 9  id xcenter ycenter    aperture_sum
```

```
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25692.24533050238
  2  48.246  26.965 18002.500531388716
  3 293.889  55.849  18827.65313882666
  4 258.523   49.82  37384.88547552344
  5 607.125  86.216 13204.536131360135
  6 592.409 221.516  25715.42980272297
  7 406.849 430.163  88369.60013054848


 10  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25615.04555830236
  2  48.246  26.965 17883.887572019146
  3 293.889  55.849 18906.699049579565
  4 258.523   49.82   37289.3279778211
  5 607.125  86.216   13150.0413953666
  6 592.409 221.516  25673.60303022074
  7 406.849 430.163  88570.88226072513


 11  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25687.81126045601
  2  48.246  26.965 18038.334708055107
  3 293.889  55.849 19105.822031298558
  4 258.523   49.82  37797.95613121078
  5 607.125  86.216 13489.758972678508
  6 592.409 221.516 25712.248900747647
  7 406.849 430.163  88684.01198082797


 12  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25497.478361282396
  2  48.246  26.965 18169.468818395453
  3 293.889  55.849 19269.547296483473
  4 258.523   49.82  37634.24367744861
  5 607.125  86.216 13545.131921858636
  6 592.409 221.516  25531.00033827984
  7 406.849 430.163  89116.95010371595


 13  id xcenter ycenter    aperture_sum
```

```
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25248.605803958573
  2  48.246  26.965 18433.605166182453
  3 293.889  55.849 19584.726875616583
  4 258.523   49.82 38409.413458851726
  5 607.125  86.216 13553.624406424078
  6 592.409 221.516 25278.800692560202
  7 406.849 430.163  89340.95761067863
```

```
 14  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25992.853497359498
  2  48.246  26.965  18158.84013140043
  3 293.889  55.849 18938.269455655303
  4 258.523   49.82   37824.5600835025
  5 607.125  86.216 13338.452936291296
  6 592.409 221.516 26021.506359906693
  7 406.849 430.163   89255.9362263435
```

```
 15  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  26171.95380985336
  2  48.246  26.965  18067.45833280003
  3 293.889  55.849 18900.543250889983
  4 258.523   49.82   38179.0540282782
  5 607.125  86.216 13413.460001840369
  6 592.409 221.516  26204.73790151602
  7 406.849 430.163  88424.21326471752
```

```
 16  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25657.593004837603
  2  48.246  26.965  18500.00758628761
  3 293.889  55.849  18974.17791389044
  4 258.523   49.82  37613.22567177059
  5 607.125  86.216 13247.492831095216
  6 592.409 221.516 25702.216394651798
  7 406.849 430.163  88789.60218821875
```

```
 17  id xcenter ycenter    aperture_sum
```

```
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662  25723.32443251353
  2  48.246  26.965  18509.02397750224
  3 293.889  55.849 19225.005119264613
  4 258.523   49.82  37708.93649041095
  5 607.125  86.216 13404.417918610387
  6 592.409 221.516 25760.413537433604
  7 406.849 430.163  89063.68110965542


 18  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25864.450741553806
  2  48.246  26.965 18554.856599076717
  3 293.889  55.849 19296.761631222595
  4 258.523   49.82  37776.45279961345
  5 607.125  86.216  13327.39171712157
  6 592.409 221.516 25896.193319629936
  7 406.849 430.163  89125.54602561047


 19  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 592.363 221.662 25846.769334949182
  2  48.246  26.965  18389.94476090466
  3 293.889  55.849  19364.26770928367
  4 258.523   49.82 38265.528062788486
  5 607.125  86.216 13574.189474302739
  6 592.409 221.516  25871.23649763382
  7 406.849 430.163   89785.2237213824


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[1.01262265 1.02950754 1.01254615 1.02552411 1.00729267 1.01161738
 1.0142813 ]

 Median value of Flux across the image:
 1.0126226544457502

 Flux ratio of Best Image over Image  1
```

```
[0.99520715 0.98458103 1.00352953 1.01026702 0.99521878 0.99468886
 1.00328868]

 Median value of Flux across the image:
 0.9952187838200118

 Flux ratio of Best Image over Image  2

[1.008675   0.97235537 1.00427347 1.00354337 1.01217704 1.00809763
 1.0093493 ]

 Median value of Flux across the image:
 1.008097633207322

 Flux ratio of Best Image over Image  3

[0.98882478 0.9991033  1.00354788 0.99803929 1.02723401 0.98862466
 1.00273526]

 Median value of Flux across the image:
 0.9991032990811375

 Flux ratio of Best Image over Image  4

[0.99431503 0.99160303 1.00643026 0.98878738 0.99249105 0.99406229
 1.00546468]

 Median value of Flux across the image:
 0.9940622870047866

 Flux ratio of Best Image over Image  5

[1.00982306 0.99765327 0.97388603 1.00041102 0.99075787 1.00949291
 1.00722603]

 Median value of Flux across the image:
 1.000411016307192

 Flux ratio of Best Image over Image  6

[1.00562245 0.96334393 0.99395421 0.99792382 0.9880363  1.00521153
 1.00884649]

 Median value of Flux across the image:
 0.9979238243011309

 Flux ratio of Best Image over Image  7
```

```
[1.00106502 0.96699835 0.9914199  1.00119621 1.02862169 1.0003742
 1.0018293 ]

 Median value of Flux across the image:
 1.0010650161086194

 Flux ratio of Best Image over Image  8

[1.00284152 0.9841893  1.00045076 1.00376113 1.03581757 1.00276993
 1.00166551]

 Median value of Flux across the image:
 1.0027699274514383

 Flux ratio of Best Image over Image  9

[1. 1. 1. 1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  10

[1.00301384 1.00663239 0.99581916 1.0025626  1.00414407 1.00162917
 0.99772745]

 Median value of Flux across the image:
 1.0025625964018225

 Flux ratio of Best Image over Image  11

[1.00017261 0.99801344 0.98544062 0.98907161 0.97885634 1.00012371
 0.9964547 ]

 Median value of Flux across the image:
 0.9964546952347233

 Flux ratio of Best Image over Image  12

[1.00763868 0.9908105  0.97706775 0.99337417 0.97485475 1.00722375
 0.99161383]

 Median value of Flux across the image:
 0.9916138291054879

 Flux ratio of Best Image over Image  13

[1.01757085 0.97661311 0.96134367 0.97332612 0.97424392 1.01727254
```

```
 0.98912752]

 Median value of Flux across the image:
 0.9766131133379907

 Flux ratio of Best Image over Image  14

[0.98843497 0.99139044 0.99415911 0.98837595 0.98996009 0.98823755
 0.99006972]

 Median value of Flux across the image:
 0.9899600946548456

 Flux ratio of Best Image over Image  15

[0.9816709  0.99640471 0.99614349 0.97919884 0.98442431 0.9813275
 0.99938237]

 Median value of Flux across the image:
 0.9844243118142844

 Flux ratio of Best Image over Image  16

[1.00135057 0.97310774 0.99227767 0.99392926 0.99675737 1.0005141
 0.99526969]

 Median value of Flux across the image:
 0.9952696932149788

 Flux ratio of Best Image over Image  17

[0.99879179 0.9726337  0.9793315  0.99140652 0.98508837 0.99825377
 0.99220691]

 Median value of Flux across the image:
 0.9914065193811574

 Flux ratio of Best Image over Image  18

[0.993342   0.97023119 0.97568978 0.98963462 0.99078172 0.99301969
 0.99151819]

 Median value of Flux across the image:
 0.99078172320818

 Flux ratio of Best Image over Image  19

[0.99402154 0.97893174 0.97228841 0.97698601 0.97276793 0.99397761
```

```
 0.98423322]

 Median value of Flux across the image:
 0.9789317350022925
Image  0 :  1.0126226544457502
Image  1 :  0.9952187838200118
Image  2 :  1.008097633207322
Image  3 :  0.9991032990811375
Image  4 :  0.9940622870047866
Image  5 :  1.000411016307192
Image  6 :  0.9979238243011309
Image  7 :  1.0010650161086194
Image  8 :  1.0027699274514383
Image  9 :  1.0
Image  10 :  1.0025625964018225
Image  11 :  0.9964546952347233
Image  12 :  0.9916138291054879
Image  13 :  0.9766131133379907
Image  14 :  0.9899600946548456
Image  15 :  0.9844243118142844
Image  16 :  0.9952696932149788
Image  17 :  0.9914065193811574
Image  18 :  0.99078172320818
Image  19 :  0.9789317350022925
Median combine


 Median pixel value -1.2894936800003052
Standard deviation 118.6329

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu2
--- ------- ------- ------------------
  1 592.363 221.662  24946.26259368543
  2  48.246  26.965  17620.51211760581
  3 293.889  55.849 18337.996638644305
  4 258.523   49.82 36573.331328175365
  5 607.125  86.216 12857.814176298376
  6 592.409 221.516 24981.305728838786
  7 406.849 430.163  85979.22874114578


 Cross Checking: flux ratio with best image
 [1.02990359 1.02167862 1.02670174 1.02218978 1.02696586 1.02938694
 1.02780173] 1 / adu
```

```
Median value of the flux ratio:  1.0269658551840712 1 / adu
```

Date: March 29th | **Exposure Time:** 30.0s

[14]:
```
scim = image_collect("../040_shift/data/shifted/march_29_2018","NGC_3201_I_30*")

phot_table = photometry(position_MAR29_I, 12)

cross_check(0)

sci_median = scale_and_combine("../040_shift/data/shifted/
 ↪march_29_2018",0,"NGC_3201_I_30*","NGC_3201_I_median_30.0s.fits")

median_statistics(position_MAR29_I, 12, 0)
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu in the FITS file.

INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]
INFO: using the unit adu passed to the FITS reader instead of the unit adu in
the FITS file. [astropy.nddata.ccddata]

 PHOTOMETRY TABLE FOR FIRST IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 183.558 408.779  6523.741985363817
  2 197.279 273.663 11707.725346667197
  3   602.4 456.617 101869.98829378605
  4 354.483 494.117  53573.67858406845


 PHOTOMETRY TABLE FOR ALL IMAGES

 0  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
  1 183.558 408.779  6523.741985363817
  2 197.279 273.663 11707.725346667197
  3   602.4 456.617 101869.98829378605
  4 354.483 494.117  53573.67858406845


 1  id xcenter ycenter    aperture_sum
      pix     pix           adu
--- ------- ------- ------------------
```

```
  1 183.558 408.779 6173.8472291241615
  2 197.279 273.663 11693.946542334954
  3   602.4 456.617 101884.78368754599
  4 354.483 494.117  54048.08359342972


 CROSS CHECKING


 Flux ratio of Best Image over Image  0

[1. 1. 1. 1.]

 Median value of Flux across the image:
 1.0

 Flux ratio of Best Image over Image  1

[1.0566737  1.00117829 0.99985478 0.99122254]

 Median value of Flux across the image:
 1.000516534151745
Image  0 :  1.0
Image  1 :  1.000516534151745
Median combine


 Median pixel value -0.20419490337371826
Standard deviation 14.126107

 PHOTOMETRY TABLE FOR MEDIAN COMBINE IMAGE
  id xcenter ycenter    aperture_sum
      pix     pix          adu2
--- ------- ------- ------------------
  1 183.558 408.779   6350.38914558529
  2 197.279 273.663 11703.856238576955
  3   602.4 456.617 101903.69899084457
  4 354.483 494.117  53824.83974480573


 Cross Checking: flux ratio with best image
 [1.02729799 1.00033058 0.99966919 0.99533373] 1 / adu


 Median value of the flux ratio:  0.9999998873423787 1 / adu
```

Best to use Median and not an average combine of an image for this case

1.1.11 ⋆ Displaying and Checking the final scaled and median stacked images

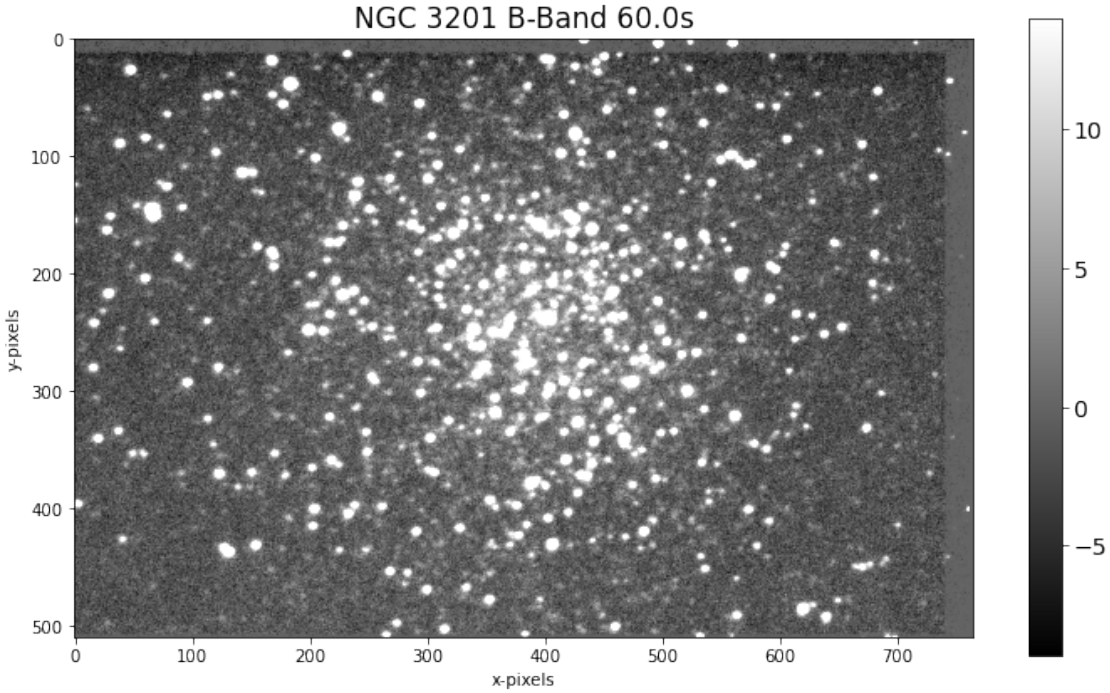
[15]:
```
def display(directory, file, vmax_, vmin_, title):
    cwd = os.getcwd()
    os.chdir(directory)
    image = CCDData.read(file, unit="adu")
    fig, ax = plt.subplots(figsize = (12,7))

    plt.rcParams.update({'font.size':14 })
    plt.imshow(image, cmap='gray', vmax=vmax_, vmin=vmin_)
    plt.xlabel('x-pixels')
    plt.ylabel('y-pixels')
    plt.title(title)
    plt.colorbar()
    os.chdir(cwd)
```

[16]:
```
display("march_09_2018_stacked", "NGC_3201_B_median_60.0s.fits", 14, -9, "NGC␣
↪3201 B-Band 60.0s")
```

```
INFO:astropy:using the unit adu passed to the FITS reader instead of the unit
adu2 in the FITS file.

INFO: using the unit adu passed to the FITS reader instead of the unit adu2 in
the FITS file. [astropy.nddata.ccddata]
```



Displaying the images using ds9 instead of mayplotlib since images are scaled down and blurry…

- In terminal: "ds9 -zscale NGC_3201*"

1.1.12 ⋆ NOTES:

- The 30.0 second exposures from the photometric night (29th of March) only had 2 images to stack (except the B-band which only had 1 - no need to stack…)
  - Out of all the bands, each set always had 1 blurry image
- The I-band and R-band both have indistguishable stars nearing the centre of the cluster, this is because a lot of the stars ended up merging after stacking…This occured due to the over saturation of the raw images and noticeable shifts.
- You can notice that each band picked up a lot of faint stars, the noise has also decreased (number of counts per pixel decreases across the background of the image)
- Best stacked images were from the B and V bands

[ ]: