

Data reduction and photometry for an exoplanet based on PYTHON

Goal

This notebook presents the basic data reduction and differential photometry for an exoplanet monitored by the 60/90-cm Schmidt telescope, which is operated by BATC Group at NAO. Let the audience learn how to use PYTHON for basic data reduction and differential photometry for variable objects. **The data are independently processed by myself and it is strongly encouraged to write your own code using PYTHON and compare the results.**

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Acknowledgement:

- Thank Y.H. Wang for sharing the data. He was once a PhD. student in our group, studying exoplanet. The object of HAT-P-32b is one of the targets of TEMP program, (Transit Exoplanet Monitoring Program by the Schmidt telescope and Xinglong 60-cm telescope).
- Observers @ Schmidt telescope and BATC group

software for astronomical data reduction (this course using pure PYTHON code)

- IRAF: for imaging processing and photometry
- SCAMP: astrometry
- Astronomy.net: astronomy
- ccdproc: Python package for CCD imaging processing
- photutils: Python package for source detection and photometry
- SExtractor: Photometry

Information about the exoplanet

- HAT-P-32b: a Hot Jupiter
- RA: 02:04:10.278 (31.042825 deg) DEC +46:41:16.2 (46.68783 deg) (J2000)
- V mag: 11.44 mag
- Transit depth: 0.0244 mag
- Aladin online viewer for finding chart <https://aladin.u-strasbg.fr/AladinLite/> (<https://aladin.u-strasbg.fr/AladinLite/>).
- Another useful tools if the target is at high-Galactic latitude: <https://www.legacysurvey.org/> (<https://www.legacysurvey.org/>).

Information about the Schmidt telescope

- 60-cm aperture and 90-cm reflector
- Focal ratio: F/3
- 4096x4096 CCD with a pixel scale of 0.137"
- gain: 3. e-/ADU
- readout noise: 7 e-
- adopted filter: R

Data directory in demo

- note that all data taken by the Schmidt telescope were overscan-subtracted when the images were taken. Image direction for the raw data: north is down, east is left. No dark frame was taken due to very low dark current

RAW DATA in "raw_data" directory

1. d*BIAS*.fit: zero (bias) full frames with overscan subtracted (size: 4096x4096)
2. d*FLATR*.fit: dome flat full frames with overscan subtracted
3. d*UW32R*.fit: truncated science frames (an subregion with size of 512x512, origin point stored in CRVAL in the FITS header)

Reduced DATA in "reduced_data" directory (generated during this course)

1. p*UW32R*.fit: reduced data with correction of the bias and flat-fielding
2. p*UW32R*-cat.fit: catalog with aperture photometry

Data reduction

dependency

- Python3
- astropy
- numpy
- matplotlib
- photutils
- jupyter-notebook

data reduction steps

- Combining bias and flats
- Correction of bias and flats
- image alignment
- Source detection and Photometry
- Differential photometry
- Open questions ...

```
In [2]: # let's first see an example of the FITS header and check the data
from astropy.io import fits
from matplotlib import pyplot as plt
import numpy as np
head=fits.getheader('raw_data/d4466637UW32R008.fit')
data=fits.getdata("raw_data/d4466637UW32R004.fit")
print(head)

f,axs=plt.subplots(1,2,figsize=(16,8))
axs[0].imshow(data,vmin=300,vmax=600,origin='lower')
axs[0].set_title("north down, east left")
axs[1].imshow(np.flipud(data),vmin=300,vmax=600,origin='lower')
axs[1].set_title("north up, east left")
```

```

SIMPLE = T / NORMAL FITS IMAGE BITPIX = 2 / NUMBER OF IMAGE DIMENS
16 / DATA PRECISION NAXIS = 512 / NUMBER OF COLUMNS NA
IONS NAXIS1 = 512 / NUMBER OF ROWS BLOCKED =
XIS2 = 512 / NUMBER OF ROWS BLOCKED =
T / CHECK FOR POSSIBLE BLOCKING CRVAL1 = 1100 / COLUMN ORIGIN
CRVAL2 = 1920 / ROW ORIGIN CDELTA1 =
1 / COLUMN BINNING CDELTA2 = 1 / ROW BINNING
IMNAME = ' UW32' / OBSERVATION SEQUENCE NAME DATE-OBS= ' 10/12/
13' / DATE OF START OF OBSERVATION TIME = ' 12:19:44.0' / UT TIME
EXPOSURE= 70 / EXPOSURE TIME (SEC) RA = ' 02:03:33.
20' / RIGHT ASCENSION DEC = ' 46:46:30.0' / DECLINATION
HA = ' ' / HOUR ANGLE EPOCH = ' 201
3.9' / EPOCH OF RA AND DEC VOLT1 = -130.899994 / EXPOSURE START DETEC
TOR TEMPERATURE VOLT2 = /
VOLT3 = / MPP =
0 / MPP STATE VOLT5 = /
VOLT6 = / VOLT7 =
/ OBJECT = 'HAT-32
INSTRUME= '#7_CCD READ-SPD=
40 / DCS READ SPEED STATUS = 'RAW' / IMAGE PROCESSING STATE
GAIN = 0 / DCS GAIN INDEX RAWMESS = '/data/d8.ccd 70
00R 32*2 column overscan ' OBSERVER= ''S.H.Wang & X.N.Guan'
BZERO = 32000.00 / ZERO POINT BIAS BSCALE = 1.000
000 / IMAGE SCALE FACTOR LICK = 'FITS2' / SPECIAL LICK FLAG
CRPIX1 = 1 / PIXEL CORRESPONDING TO CRVAL1 CRPIX2 =
1 / PIXEL CORRESPONDING TO CRVAL2 COMMENT = '* BAO Schmidt CCD Data-Taking system
' COMMENT = '
' COMMENT = '
' TELESCOP= 'UNKNOWN' / TELESCOPE USED TTIME =
70.00 / REAL EXPOSURE TIME IN FLOAT
END

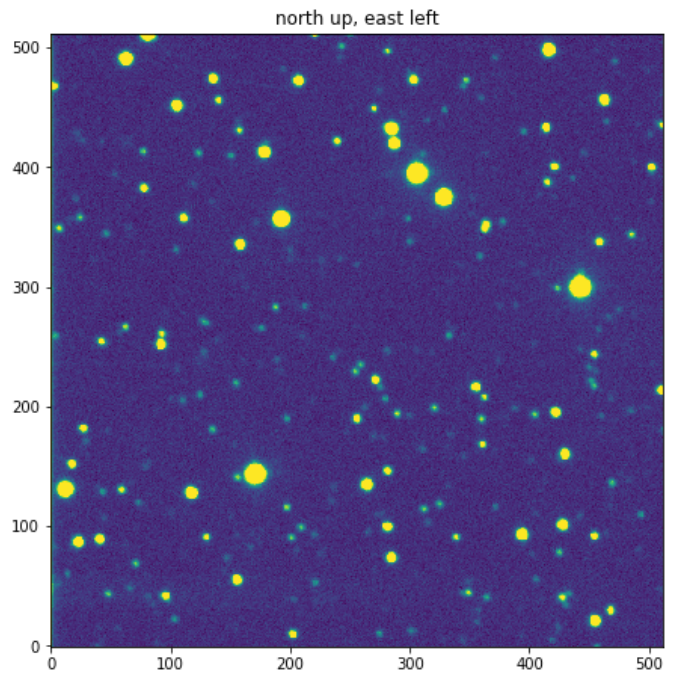
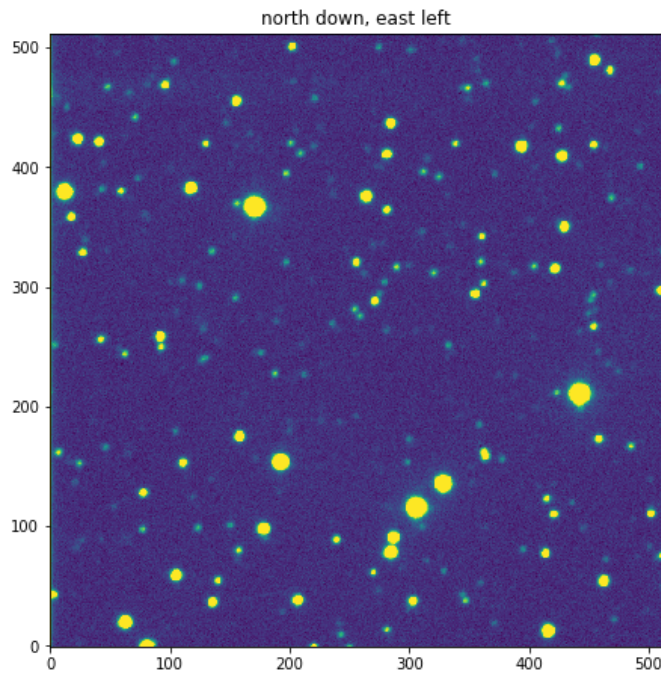
```

```

WARNING: Unexpected bytes trailing END keyword: ' / END OF HEADER'; these bytes
will be replaced with spaces on write. [astropy.io.fits.header]
WARNING: File may have been truncated: actual file length (530048) is smaller than the expected size (53280
0) [astropy.io.fits.file]
WARNING: VerifyWarning: Verification reported errors: [astropy.io.fits.verify]
WARNING: VerifyWarning: Card 'OBSERVER' is not FITS standard (invalid value string: "'S.H.Wang & X.N.Gua
n"). Fixed 'OBSERVER' card to meet the FITS standard. [astropy.io.fits.verify]
WARNING: VerifyWarning: Note: astropy.io.fits uses zero-based indexing.
[astropy.io.fits.verify]

```

Out[2]: Text(0.5, 1.0, 'north up, east left')



combining bias frame to get a super-bias

```
In [3]: ## let's fist check the bias image
import glob
bfiles=glob.glob("./raw_data/d*BIASR*.fit")
bfiles.sort()
allbias=[]
print("combining bias ...")

for i,ifile in enumerate(bfiles):
    print("reading bias:", i+1,len(bfiles),ifile)
    data=fits.getdata(ifile)
    allbias.append(data)
allbias=np.stack(allbias)
print(allbias.shape)
superbias=np.median(allbias,axis=0)
fits.writeto('./reduced_data/bias.fit',superbias.astype('float32'),overwrite=True)
```

combining bias ...

reading bias: 1 12 ./raw_data/d4466637BIASR213.fit

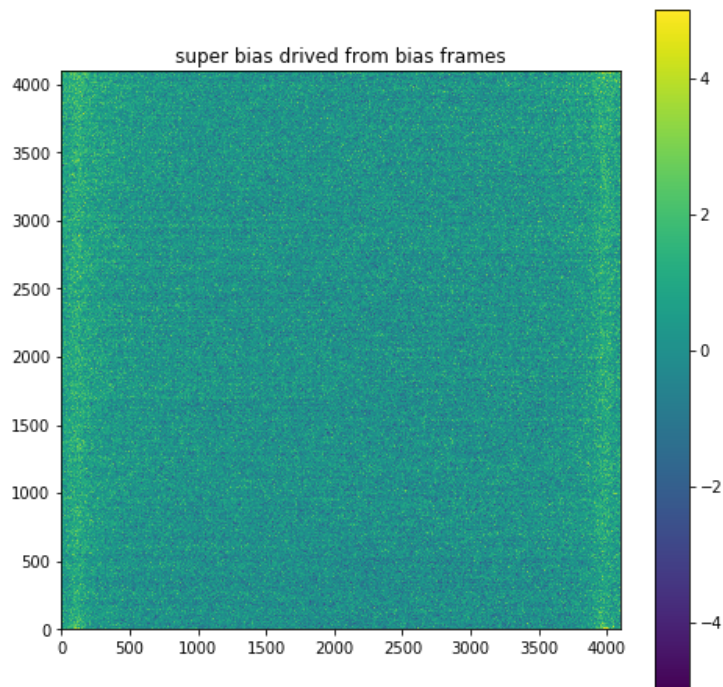
WARNING: Unexpected bytes trailing END keyword: ' / END OF HEADER'; these bytes will be replaced with spaces on write. [astropy.io.fits.header]

WARNING: File may have been truncated: actual file length (33560192) is smaller than the expected size (33560640) [astropy.io.fits.file]

reading bias: 2 12 ./raw_data/d4466637BIASR214.fit
reading bias: 3 12 ./raw_data/d4466637BIASR215.fit
reading bias: 4 12 ./raw_data/d4466637BIASR216.fit
reading bias: 5 12 ./raw_data/d4466637BIASR217.fit
reading bias: 6 12 ./raw_data/d4466637BIASR218.fit
reading bias: 7 12 ./raw_data/d4466637BIASR219.fit
reading bias: 8 12 ./raw_data/d4466637BIASR220.fit
reading bias: 9 12 ./raw_data/d4466637BIASR221.fit
reading bias: 10 12 ./raw_data/d4466637BIASR222.fit
reading bias: 11 12 ./raw_data/d4466637BIASR223.fit
reading bias: 12 12 ./raw_data/d4466637BIASR224.fit
(12, 4096, 4096)

```
In [4]: ## display the super bias
plt.figure(figsize=(8,8))
plt.imshow(superbias,vmin=-5,vmax=5,origin='lower')
plt.colorbar()
plt.title("super bias driven from bias frames")
```

Out[4]: Text(0.5, 1.0, 'super bias driven from bias frames')



combining dome flats (with bias correction)

```
In [6]: ffiles=glob.glob("./raw_data/d*FLATR*.fit")
ffiles.sort()
allflat=[]
print("combining dome flats...")
for i,ifile in enumerate(ffiles):
    print("reading flat:", i+1,len(ffiles),ifile)
    # flat-fielding: subtract bias and then normalize the flat images
    data=fits.getdata(ifile)-superbias
    mflat=np.median(data[1500-256:1500+256,1500-256:1500+256])
    data/=mflat
    print("median flat:",mflat)
    allflat.append(data)
allflat=np.stack(allflat)
print(allflat.shape)
domeflat=np.median(allflat,axis=0)
fits.writeto('./reduced_data/domeflat.fit',domeflat.astype('float32'),overwrite=True)
```

combining dome flats...

reading flat: 1 12 ./raw_data/d4466637FLATR201.fit

WARNING: Unexpected bytes trailing END keyword: ' / END OF HEADER'; these bytes
will be replaced with spaces on write. [astropy.io.fits.header]

WARNING: File may have been truncated: actual file length (33560192) is smaller than the expected size (335
60640) [astropy.io.fits.file]

median flat: 8986.0

reading flat: 2 12 ./raw_data/d4466637FLATR202.fit

median flat: 9160.0

reading flat: 3 12 ./raw_data/d4466637FLATR203.fit

median flat: 9150.0

reading flat: 4 12 ./raw_data/d4466637FLATR204.fit

median flat: 9214.0

reading flat: 5 12 ./raw_data/d4466637FLATR205.fit

median flat: 8802.0

reading flat: 6 12 ./raw_data/d4466637FLATR206.fit

median flat: 8786.0

reading flat: 7 12 ./raw_data/d4466637FLATR207.fit

median flat: 8832.0

reading flat: 8 12 ./raw_data/d4466637FLATR208.fit

median flat: 8754.0

reading flat: 9 12 ./raw_data/d4466637FLATR209.fit

median flat: 8694.0

reading flat: 10 12 ./raw_data/d4466637FLATR210.fit

median flat: 8684.5

reading flat: 11 12 ./raw_data/d4466637FLATR211.fit

median flat: 8906.5

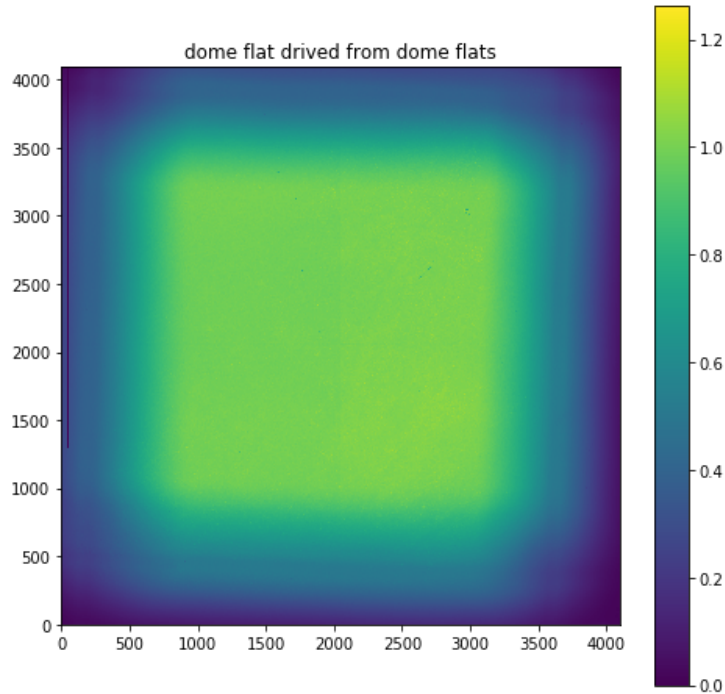
reading flat: 12 12 ./raw_data/d4466637FLATR212.fit

median flat: 9171.0

(12, 4096, 4096)

```
In [7]: ## display the super flat
plt.figure(figsize=(8,8))
plt.imshow(domeflat,origin='lower')
plt.colorbar()
plt.title("dome flat drived from dome flats")
```

```
Out[7]: Text(0.5, 1.0, 'dome flat drived from dome flats')
```



We can calculate gain and readout noise from pairs of bias and flats

The algorithm come from the IRAF FINDGAIN program, please refer to its help information

```
In [8]: ## calculate gain and read noise
from astropy.stats import sigma_clipped_stats
biasfile1='./raw_data/d4466637BIASR213.fit'
biasfile2='./raw_data/d4466637BIASR214.fit'
flatfile1='./raw_data/d4466637FLATR201.fit'
flatfile2='./raw_data/d4466637FLATR202.fit'
bias1=fits.getdata(biasfile1)[1500-256:1500+256,1500-256:1500+256]
bias2=fits.getdata(biasfile2)[1500-256:1500+256,1500-256:1500+256]
flat1=fits.getdata(flatfile1)[1500-256:1500+256,1500-256:1500+256]
flat2=fits.getdata(flatfile2)[1500-256:1500+256,1500-256:1500+256]
mean_flat1=np.median(flat1)
mean_flat2=np.median(flat2)
mean_bias1=np.median(bias1)
mean_bias2=np.median(bias2)

_,_,std_biasdiff=sigma_clipped_stats(bias1-bias2,sigma=4.0,maxiters=2)
_,_,std_flatdiff=sigma_clipped_stats(flat1-flat2,sigma=4.0,maxiters=2)
print(mean_bias1,mean_bias2,mean_flat1,mean_flat2,std_biasdiff,std_flatdiff)
gain=((mean_flat1+mean_flat2)-(mean_bias1+mean_bias2))/((std_flatdiff**2-std_biasdiff**2))
rdnoise=gain*std_biasdiff/np.sqrt(2)
print("gain: ",gain, "readout noise:",rdnoise)
```

```
WARNING: Unexpected bytes trailing END keyword: ' / END OF HEADER'; these bytes
will be replaced with spaces on write. [astropy.io.fits.header]
WARNING: File may have been truncated: actual file length (33560192) is smaller than the expected size (335
60640) [astropy.io.fits.file]
```

```
0.0 0.0 8986.0 9160.0 2.905397 72.79242
gain: 3.430054470497312 readout noise: 7.046792664146595
```

adding keywords to the header, subtract bias and flat-fielding and flipping the image (making north is up)

Although we don't use the WCS parameters in the following analyses, but they are necessary for astrometric solutions


```

In [9]: ## get the center of FoV (pointing to the target) and adding parameters to the FITS header
from astropy.coordinates import SkyCoord
import astropy.units as u
import glob,os

c=SkyCoord("02:04:10.278","+46:41:16.2",frame='icrs',unit=(u.hourangle,u.degree))
ra=c.ra.degree; dec=c.dec.degree
print("ra:", ra, "dec:",c.dec.degree)
epoch=2000.0
pixscale=0.137 # in arcsec

# add keywords to FITS header of science frames
outdir="./reduced_data/"
sfiles=glob.glob("./raw_data/d*UW32R*.fit") # science frames
sfiles.sort() # in alphabetic order
for i,ifile in enumerate(sfiles):
    print("reducing (debias, flat-fielding, and flipping) :", i+1,len(sfiles),ifile)
    indir,infile=os.path.split(ifile)
    rootname,_=os.path.splitext(infile)
    # we change the first character from "d" to "p" for new files and ensure not to cover the raw data
    outfile=os.path.join(outdir,"p"+rootname[1:]+'.fit')
    head=fits.getheader(ifile,output_verifystr="silentfix")
    # get the origin of the subregion
    col_origin=head['CRVAL1']
    row_origin=head['CRVAL2']
    subflat=domeflat[row_origin:row_origin+512,col_origin:col_origin+512]
    subbias=superbias[row_origin:row_origin+512,col_origin:col_origin+512]
    if i==0:
        ## to show an example of the subsection of bias and flat
        fits.writeto('reduced_data/subflat.fit',subflat.astype('float32'),overwrite=True)
        fits.writeto('reduced_data/subbias.fit',subbias.astype('float32'),overwrite=True)
        #break
    data=fits.getdata(ifile)

    # de-bias and flat-fielding
    data=(data-subbias)/subflat
    # set the initial reference point in the WCS parameters if doing astrometry
    head['epoch']=2000.0
    head['CRVAL1']=ra
    head['CRVAL2']=dec
    head['CRPIX1']=head['NAXIS1']/2.0
    head['CRPIX2']=head['NAXIS2']/2.0
    head['CDELTA1']=-pixscale/3600.0 # minus for left east
    head['CDELTA2']=pixscale/3600.0
    head['CTYPE1']='RA---TAN' # projection type
    head['CTYPE2']='DEC--TAN'
    head['GAIN']=(gain,'GAIN in e-/ADU')
    head['RDNOISE']=(rdnoise,'readout noise in electron')
    print("writing to "+outfile)
    # flip up down to make the image with north up and east left
    fits.writeto(outfile,np.flipud(data),header=head,overwrite=True,output_verify="silentfix")

```

WARNING: IERSStaleWarning: leap-second file is expired. [astropy.utils.iers.iers]

ra: 31.042824999999997 dec: 46.68783333333333

reducing (debias, flat-fielding, and flipping) : 1 172 ./raw_data/d4466637UW32R004.fit

writing to ./reduced_data/p4466637UW32R004.fit

reducing (debias, flat-fielding, and flipping) : 2 172 ./raw_data/d4466637UW32R005.fit

writing to ./reduced_data/p4466637UW32R005.fit

reducing (debias, flat-fielding, and flipping) : 3 172 ./raw_data/d4466637UW32R007.fit

writing to ./reduced_data/p4466637UW32R007.fit

WARNING: Unexpected bytes trailing END keyword: ' / END OF HEADER'; these bytes
will be replaced with spaces on write. [astropy.io.fits.header]

WARNING: File may have been truncated: actual file length (530048) is smaller than the expected size (532800) [astropy.io.fits.file]


```
reducing (debias, flat-fielding, and flipping) : 156 172 ./raw_data/d4466637UW32R160.fit
writing to ./reduced_data/p4466637UW32R160.fit
reducing (debias, flat-fielding, and flipping) : 157 172 ./raw_data/d4466637UW32R161.fit
writing to ./reduced_data/p4466637UW32R161.fit
reducing (debias, flat-fielding, and flipping) : 158 172 ./raw_data/d4466637UW32R162.fit
writing to ./reduced_data/p4466637UW32R162.fit
reducing (debias, flat-fielding, and flipping) : 159 172 ./raw_data/d4466637UW32R163.fit
writing to ./reduced_data/p4466637UW32R163.fit
reducing (debias, flat-fielding, and flipping) : 160 172 ./raw_data/d4466637UW32R164.fit
writing to ./reduced_data/p4466637UW32R164.fit
reducing (debias, flat-fielding, and flipping) : 161 172 ./raw_data/d4466637UW32R165.fit
writing to ./reduced_data/p4466637UW32R165.fit
reducing (debias, flat-fielding, and flipping) : 162 172 ./raw_data/d4466637UW32R166.fit
writing to ./reduced_data/p4466637UW32R166.fit
reducing (debias, flat-fielding, and flipping) : 163 172 ./raw_data/d4466637UW32R167.fit
writing to ./reduced_data/p4466637UW32R167.fit
reducing (debias, flat-fielding, and flipping) : 164 172 ./raw_data/d4466637UW32R168.fit
writing to ./reduced_data/p4466637UW32R168.fit
reducing (debias, flat-fielding, and flipping) : 165 172 ./raw_data/d4466637UW32R169.fit
writing to ./reduced_data/p4466637UW32R169.fit
reducing (debias, flat-fielding, and flipping) : 166 172 ./raw_data/d4466637UW32R170.fit
writing to ./reduced_data/p4466637UW32R170.fit
reducing (debias, flat-fielding, and flipping) : 167 172 ./raw_data/d4466637UW32R171.fit
writing to ./reduced_data/p4466637UW32R171.fit
reducing (debias, flat-fielding, and flipping) : 168 172 ./raw_data/d4466637UW32R172.fit
writing to ./reduced_data/p4466637UW32R172.fit
reducing (debias, flat-fielding, and flipping) : 169 172 ./raw_data/d4466637UW32R173.fit
writing to ./reduced_data/p4466637UW32R173.fit
reducing (debias, flat-fielding, and flipping) : 170 172 ./raw_data/d4466637UW32R174.fit
writing to ./reduced_data/p4466637UW32R174.fit
reducing (debias, flat-fielding, and flipping) : 171 172 ./raw_data/d4466637UW32R175.fit
writing to ./reduced_data/p4466637UW32R175.fit
reducing (debias, flat-fielding, and flipping) : 172 172 ./raw_data/d4466637UW32R176.fit
writing to ./reduced_data/p4466637UW32R176.fit
```

Do astronomy and photometry

Here we get relative position shift between different exposures and do aperture photometry using the python package of photutils.

For astrometry, there are several open softwares, including SCAMP (<https://www.astromatic.net/software/scamp> (<https://www.astromatic.net/software/scamp>)), Astronomy.net (<http://astrometry.net/> (<http://astrometry.net/>)), which are used to get the astrometric solution from matching the observed stars with stars in a reference catalog, such as UCAC4, 2MASS, GAIA, etc.

Usually, we need to do astrometry for transforming CCD positions of objects to the sky positions, so that we can find the same objects in different observations by cross-matching the catalogs.

Another important aspect in the data reduction is the photometric calibration, which can convert CCD counts to the physical flux. We don't make flux calibration here, since we aim to get light curve from relative photometry.

An example for source detection and photometry

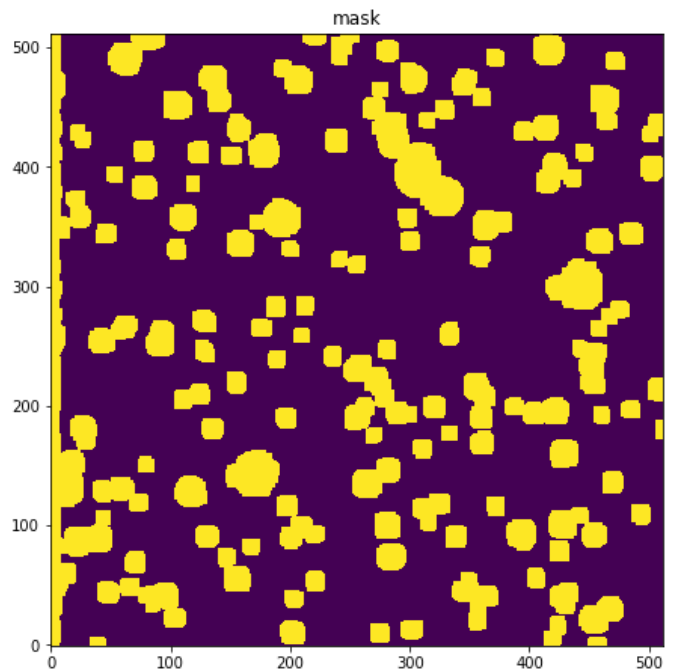
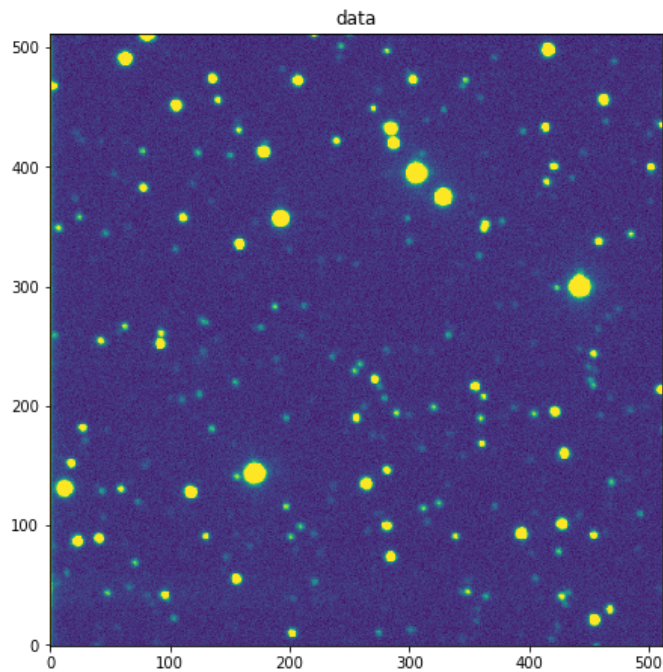
get sky and sky mask

```
In [10]: import photutils as pht
data=fits.getdata('reduced_data/p4466637UW32R004.fit')
## here we can show some statistics about the sky
mean, median, std = sigma_clipped_stats(data, sigma=3.0)
print((mean, median, std))
## or first mask sources then estimate the sky background
mask = pht.make_source_mask(data, nsigma=3, npixels=5, dilate_size=11)
mean, median, std = sigma_clipped_stats(data, sigma=3.0, mask=mask)
print((mean, median, std))

f,axs=plt.subplots(1,2,figsize=(16,8))
axs[0].imshow(data,vmin=300,vmax=600,origin='lower')
axs[0].set_title("data")
axs[1].imshow(mask,origin='lower')
axs[1].set_title("mask")
```

```
(345.92813, 345.4576, 11.851039)
(344.46753, 344.30936, 10.897236)
```

```
Out[10]: Text(0.5, 1.0, 'mask')
```



```
In [11]: ## get 2D sky map
from astropy.stats import SigmaClip
sigma_clip = SigmaClip(sigma=3.)
bkg_estimator = pht.SExtractorBackground()
bkg = pht.Background2D(data, (64, 64), mask=mask,filter_size=(3, 3), sigma_clip=sigma_clip, bkg_estimator=bkg_estimator)
```

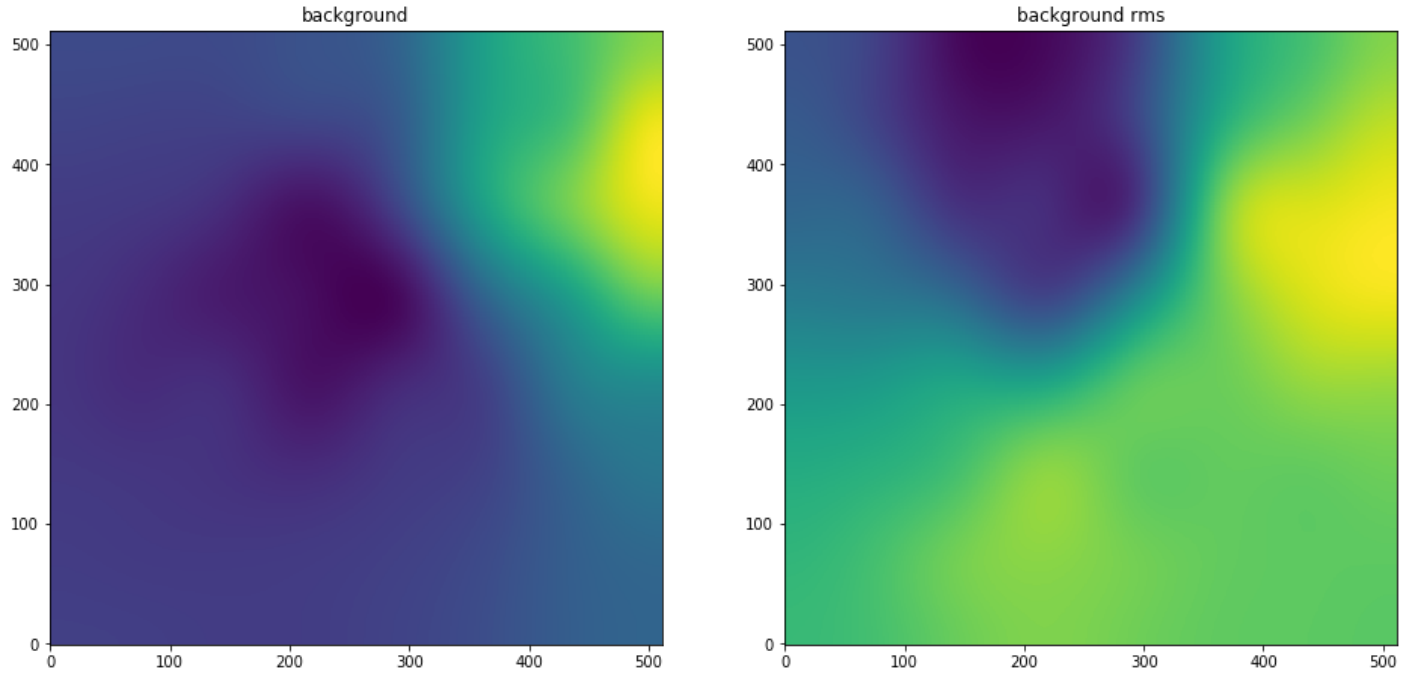
```
In [12]: print(bkg.background_median,bkg.background_rms_median)
```

```
343.99630221863436 10.9261981672283
```



```
In [13]: f,axs=plt.subplots(1,2,figsize=(16,8))
axs[0].imshow(bkg.background,origin='lower')
axs[0].set_title("background")
axs[1].imshow(bkg.background_rms,origin='lower')
axs[1].set_title("background rms")
```

```
Out[13]: Text(0.5, 1.0, 'background rms')
```



Source detection

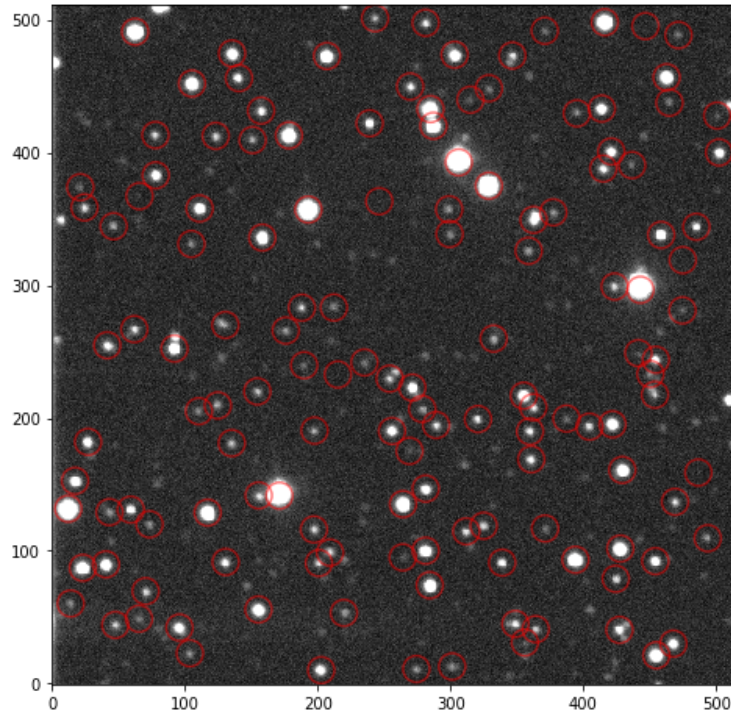
```
In [14]: ## find objects and calculate basic information
daofind = pht.IRAFStarFinder(fwhm=3.0, threshold=5.*bkg.background_rms_median,exclude_border=True, sharplo=
0.5, sharphi=2.0, roundlo=0.0, roundhi=0.7)
sources = daofind(data - bkg.background_median)
```

```
In [15]: print(sources)
print(sources.colnames)
```

id	xcentroid	...	flux	mag
1	202.52317765442623	...	2135.579620361328	-8.323789419433997
2	274.23682072549207	...	466.221248626709	-6.671480157898289
3	301.1955941174819	...	406.49029541015625	-6.522625454160221
4	455.04379401124675	...	8510.512329101562	-9.824889263021205
5	103.63470115305438	...	494.94272232055664	-6.736387356831772
6	467.86152350106914	...	2569.0262145996094	-8.524421339682867
7	356.00389976041885	...	194.00198936462402	-5.7195154584035155
8	427.2714697272269	...	1393.9393615722656	-7.8606097042985335
9	364.1309320920382	...	675.0591125488281	-7.073354510335784
10	95.78920530844535	...	2232.3724670410156	-8.371916643769978
...
129	206.92882932723228	...	7683.51171875	-9.713899394967111
130	346.544254004609	...	679.3000717163086	-7.080154151102151
131	303.0703993404151	...	4352.287841796875	-9.09679402507216
132	135.38234734537872	...	3814.6747436523438	-8.953643784915371
133	471.73219800948095	...	353.23854064941406	-6.3701702046917985
134	62.36936141194771	...	20297.468994140625	-10.76860471665392
135	370.98097344325055	...	194.77102661132812	-5.723810883426898
136	446.83568008636536	...	111.86316728591919	-5.121717779374989
137	281.2432187904541	...	955.0812911987305	-7.450100844709469
138	416.21048980288003	...	21057.294189453125	-10.80850641165284
139	243.13505865155935	...	715.3463134765625	-7.136290858417685

Length = 139 rows
['id', 'xcentroid', 'ycentroid', 'fwhm', 'sharpness', 'roundness', 'pa', 'npix', 'sky', 'peak', 'flux', 'mag']

```
In [16]: from photutils import CircularAperture
positions = np.transpose((sources['xcentroid'], sources['ycentroid']))
apertures = CircularAperture(positions, r=10.)
plt.figure(figsize=(8,8))
plt.imshow(data, cmap='Greys_r', origin='lower', vmin=300, vmax=600, interpolation='nearest')
apertures.plot(color='red', lw=1.5, alpha=0.5)
```



Error estimation for an image

error including photon position error + background error, from SExtractor manual: $\sigma_{\text{tot}} = \sqrt{\sigma_{\text{bkg}}^2 + \frac{I}{g_{\text{eff}}}}$, where σ_{bkg} is 1σ background RMS and I is the background-subtracted flux and g_{eff} is the effective gain.

```
In [17]: from photutils.utils import calc_total_error
error=calc_total_error(data-bkg.background, bkg.background_rms, gain)
print(np.median(error))
```

```
10.952328441170703
```

aperture photometry: an example

```
In [19]: ## aperture photometry
from astropy.table import Table
from astropy import table
radii=[3,4,5,6,8,10,12,15,20,25] ## aperture radii in pixels
positions=[(ix,iy) for ix,iy in zip(sources['xcentroid'],sources['ycentroid'])]
aper_phot = [pht.CircularAperture(positions, r=r) for r in radii]
aper_phot= pht.aperture_photometry(data - bkg.background, aper_phot, error=error)
print(aper_phot.colnames)
```

```
#convert flux to magnitude, using a instrumental zeropoint of 25
for i in range(len(radii)):
    fcol='aperture_sum_'+str(i)
    ecol='aperture_sum_err_'+str(i)
    flux=aper_phot[fcol]
    fluxerr=aper_phot[ecol]
    mag=-2.5*np.log10(flux)+25
    magerr=2.5/(flux*np.log(10))*fluxerr
    aper_phot[fcol]=mag
    aper_phot[ecol]=magerr
    aper_phot.rename_column(fcol,'mag_'+str(i))
    aper_phot.rename_column(ecol,'magerr_'+str(i))
```

```
['id', 'xcenter', 'ycenter', 'aperture_sum_0', 'aperture_sum_err_0', 'aperture_sum_1', 'aperture_sum_err_1', 'aperture_sum_2', 'aperture_sum_err_2', 'aperture_sum_3', 'aperture_sum_err_3', 'aperture_sum_4', 'aperture_sum_err_4', 'aperture_sum_5', 'aperture_sum_err_5', 'aperture_sum_6', 'aperture_sum_err_6', 'aperture_sum_7', 'aperture_sum_err_7', 'aperture_sum_8', 'aperture_sum_err_8', 'aperture_sum_9', 'aperture_sum_err_9']
```

```
In [20]: #d=np.array(aper_phot[112].as_void().tolist())
#x=np.array(radii)
#idx=np.arange(10)*2+3
#y=d[idx]
#yerr=d[idx+1]
```

```
In [21]: print(aper_phot)
```

id	xcenter pix	...	mag_9	magerr_9
1	202.52317765442623	...	14.274815052469858	0.02399992950829931
2	274.23682072549207	...	15.970128644690814	0.1145455808545451
3	301.1955941174819	...	16.14782009588319	0.13835048236483433
4	455.04379401124675	...	12.709346619622915	0.0066356821906582205
5	103.63470115305438	...	13.839236486619008	0.018343728410507982
6	467.86152350106914	...	12.730832342398399	0.0068471798906083415
7	356.00389976041885	...	14.309229194932326	0.028274274047316934
8	427.2714697272269	...	14.220852227400869	0.02608640667664619
9	364.1309320920382	...	14.279462007972928	0.027514453918700287
10	95.78920530844535	...	13.656162833892724	0.015613603794023887
...
130	346.544254004609	...	15.133300794789864	0.059903038724317834
131	303.0703993404151	...	13.6164353955551	0.015005194522869471
132	135.38234734537872	...	13.394932756575805	0.01226608768231487
133	471.73219800948095	...	17.528771867229622	0.5401800700161851
134	62.36936141194771	...	11.817727902506013	0.0030514331908058673
135	370.98097344325055	...	nan	-0.8946189369072621
136	446.83568008636536	...	16.845249439548176	0.2721627512706111
137	281.2432187904541	...	15.340402640637274	0.06591745122110966
138	416.21048980288003	...	12.032858153891295	0.003454566251485354
139	243.13505865155935	...	15.033439145432514	0.0473634299142818

Length = 139 rows

aperture photometry for all objects

```

In [22]: cfiles=glob.glob("./reduced_data/p*UW32R*.fit") # science frames
cfiles.sort() # in alphabetic order
radii=[3,4,5,6,8,10,12,15,20,25] ## aperture radii in pixels

for i,ifile in enumerate(cfiles):
    print("aperture photometry :", i+1,len(cfiles),ifile)
    rootname,_=os.path.splitext(ifile)
    catfile=rootname+'-cat.fits'
    data=fits.getdata(ifile)
    ## or first mask sources then estimate the sky background
    mask = pht.make_source_mask(data, nsigma=3, npixels=5, dilate_size=11)
    bkg_estimator = pht.SExtractorBackground()
    bkg = pht.Background2D(data, (64, 64), mask=mask,filter_size=(3, 3), sigma_clip=sigma_clip, bkg_estimator=bkg_estimator)
    print(bkg.background_median,bkg.background_rms_median)
    daofind = pht.IRAFStarFinder(fwhm=3.0, threshold=5.*bkg.background_rms_median,exclude_border=True, sharplo=0.5, sharpphi=2.0, roundlo=0.0, roundhi=0.7)
    sources = daofind(data - bkg.background)
    positions=[(ix,iy) for ix,iy in zip(sources['xcentroid'],sources['ycentroid'])]
    apertures = [pht.CircularAperture(positions, r=r) for r in radii]
    error=calc_total_error(data-bkg.background, bkg.background_rms, gain)
    aper_phot= pht.aperture_photometry(data - bkg.background, apertures, error=error)
    print(len(aper_phot))
    #convert flux to magnitude, using a instrumental zeropoint of 25
    #for j in range(len(radii)):
    #    fcol='aperture_sum_'+str(j)
    #    ecol='aperture_sum_err_'+str(j)
    #    flux=aper_phot[fcol]
    #    fluxerr=aper_phot[ecol]
    #    mag=-2.5*np.log10(flux)+25
    #    magerr=2.5/(flux*np.log(10))*fluxerr
    #    aper_phot[fcol]=mag
    #    aper_phot[ecol]=magerr
    #    aper_phot.rename_column(fcol,'mag_'+str(j))
    #    aper_phot.rename_column(ecol,'magerr_'+str(j))
    aper_phot.write(catfile,overwrite=True)

```

aperture photometry : 1 172 ./reduced_data/p4466637UW32R004.fit
343.99630221863436 10.9261981672283
139

aperture photometry : 2 172 ./reduced_data/p4466637UW32R005.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

337.81934916722537 10.862038364108464
130

aperture photometry : 3 172 ./reduced_data/p4466637UW32R007.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

337.24261313690835 10.713095260025911
169

aperture photometry : 4 172 ./reduced_data/p4466637UW32R008.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

333.992603525385 10.652550010960669
159

aperture photometry : 5 172 ./reduced_data/p4466637UW32R009.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

331.0787012828004 10.698852813544086
159

aperture photometry : 6 172 ./reduced_data/p4466637UW32R010.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

278.956306112798 9.732731506675892
155

aperture photometry : 7 172 ./reduced_data/p4466637UW32R011.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

272.48774440109594 9.609181420103791
160

aperture photometry : 8 172 ./reduced_data/p4466637UW32R012.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

268.588247949665 9.576648060778448
175

aperture photometry : 9 172 ./reduced_data/p4466637UW32R013.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.48783333725686 9.55165394281023
153

aperture photometry : 10 172 ./reduced_data/p4466637UW32R014.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.20324910713305 9.47879748772316
170

aperture photometry : 11 172 ./reduced_data/p4466637UW32R015.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.56799660334184 9.50053243181502
169

aperture photometry : 12 172 ./reduced_data/p4466637UW32R016.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.43531456681404 9.514778840902563

147

aperture photometry : 13 172 ./reduced_data/p4466637UW32R017.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.07702733180287 9.538885352147553

131

aperture photometry : 14 172 ./reduced_data/p4466637UW32R018.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.65501690017845 9.534661488454985

148

aperture photometry : 15 172 ./reduced_data/p4466637UW32R019.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.52122210186286 9.503082245212495

163

aperture photometry : 16 172 ./reduced_data/p4466637UW32R020.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.5164581840156 9.526172422927143

131

aperture photometry : 17 172 ./reduced_data/p4466637UW32R021.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.1617565233596 9.436060025256328

141

aperture photometry : 18 172 ./reduced_data/p4466637UW32R022.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.67074860014395 9.43260718909698

125

aperture photometry : 19 172 ./reduced_data/p4466637UW32R023.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.3813242998283 9.390421864652563

141

aperture photometry : 20 172 ./reduced_data/p4466637UW32R024.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.66215129645695 9.482564917502938

134

aperture photometry : 21 172 ./reduced_data/p4466637UW32R025.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.63967012861565 9.519645034228997

128

aperture photometry : 22 172 ./reduced_data/p4466637UW32R026.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.74291092478904 9.487548298840707

133

aperture photometry : 23 172 ./reduced_data/p4466637UW32R027.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.34307535731307 9.539815509009681

135

aperture photometry : 24 172 ./reduced_data/p4466637UW32R028.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.2468548893972 9.481652967397416

94

aperture photometry : 25 172 ./reduced_data/p4466637UW32R029.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.2069065981681 9.38017728958376

123

aperture photometry : 26 172 ./reduced_data/p4466637UW32R030.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.8296841981017 9.465036352238286

111

aperture photometry : 27 172 ./reduced_data/p4466637UW32R031.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.0797091994708 9.521226016461721

118

aperture photometry : 28 172 ./reduced_data/p4466637UW32R032.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.9560861118408 9.351592705269155

128

aperture photometry : 29 172 ./reduced_data/p4466637UW32R033.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.0431853924806 9.407085879125722

134

aperture photometry : 30 172 ./reduced_data/p4466637UW32R034.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.32030345535804 9.435447498738487

111

aperture photometry : 31 172 ./reduced_data/p4466637UW32R035.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.62617518928664 9.384435291475171

138

aperture photometry : 32 172 ./reduced_data/p4466637UW32R036.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.4249767858148 9.469489413845686

119

aperture photometry : 33 172 ./reduced_data/p4466637UW32R037.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.11276151684626 9.526139337662777

136

aperture photometry : 34 172 ./reduced_data/p4466637UW32R038.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.86874433278 9.488995523156438

144

aperture photometry : 35 172 ./reduced_data/p4466637UW32R039.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.76337871287274 9.394037448069444

146

aperture photometry : 36 172 ./reduced_data/p4466637UW32R040.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.343520891524 9.412663546211252

144

aperture photometry : 37 172 ./reduced_data/p4466637UW32R041.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.092503867476 9.418035418967973

135

aperture photometry : 38 172 ./reduced_data/p4466637UW32R042.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.8951646921587 9.422107536626196

148

aperture photometry : 39 172 ./reduced_data/p4466637UW32R043.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.2547700470691 9.33586955461098

158

aperture photometry : 40 172 ./reduced_data/p4466637UW32R044.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.78550409049274 9.509272393718604

156

aperture photometry : 41 172 ./reduced_data/p4466637UW32R045.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.48349086260487 9.4803025130026

135

aperture photometry : 42 172 ./reduced_data/p4466637UW32R046.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.5957416408571 9.500116977906341

138

aperture photometry : 43 172 ./reduced_data/p4466637UW32R047.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.50847954997084 9.31511142248969

146

aperture photometry : 44 172 ./reduced_data/p4466637UW32R048.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.1278278391969 9.438798978842678

144

aperture photometry : 45 172 ./reduced_data/p4466637UW32R049.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.4122787597851 9.468474183635335

141

aperture photometry : 46 172 ./reduced_data/p4466637UW32R050.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.51219047791636 9.317391797411505

146

aperture photometry : 47 172 ./reduced_data/p4466637UW32R051.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.1086802313227 9.416807259429866

134

aperture photometry : 48 172 ./reduced_data/p4466637UW32R052.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.35842955016824 9.372927988846536

138

aperture photometry : 49 172 ./reduced_data/p4466637UW32R053.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.2858500063436 9.396650719313502

142

aperture photometry : 50 172 ./reduced_data/p4466637UW32R054.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.878603190449 9.365237001048316

149

aperture photometry : 51 172 ./reduced_data/p4466637UW32R055.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.2817206113361 9.378343071927436

143

aperture photometry : 52 172 ./reduced_data/p4466637UW32R056.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

272.65223652750285 9.550723633870108

139

aperture photometry : 53 172 ./reduced_data/p4466637UW32R057.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.9259147526679 9.493896972749011

113

aperture photometry : 54 172 ./reduced_data/p4466637UW32R058.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

270.642775750713 9.524948179504923

137

aperture photometry : 55 172 ./reduced_data/p4466637UW32R059.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.5319288827134 9.495800538999404

140

aperture photometry : 56 172 ./reduced_data/p4466637UW32R060.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.49251709508326 9.408016430986812

139

aperture photometry : 57 172 ./reduced_data/p4466637UW32R061.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

269.1691629527369 9.530303727147455

128

aperture photometry : 58 172 ./reduced_data/p4466637UW32R062.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

269.91891688830435 9.61969260358013

127

aperture photometry : 59 172 ./reduced_data/p4466637UW32R063.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.22335374700015 9.55589294702045

123

aperture photometry : 60 172 ./reduced_data/p4466637UW32R064.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.84376105450883 9.429573933305111

147

aperture photometry : 61 172 ./reduced_data/p4466637UW32R065.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

269.00585644101034 9.5644667003797

146

aperture photometry : 62 172 ./reduced_data/p4466637UW32R066.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

269.2584330785834 9.509378650689966

137

aperture photometry : 63 172 ./reduced_data/p4466637UW32R067.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.71720272814935 9.44462100547599

136

aperture photometry : 64 172 ./reduced_data/p4466637UW32R068.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.0300341055296 9.427536183524396

151

aperture photometry : 65 172 ./reduced_data/p4466637UW32R069.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.24239625435064 9.52839151619609

149

aperture photometry : 66 172 ./reduced_data/p4466637UW32R070.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.9696267919305 9.39997110062776

145

aperture photometry : 67 172 ./reduced_data/p4466637UW32R071.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.85641635992164 9.43776996727548

125

aperture photometry : 68 172 ./reduced_data/p4466637UW32R072.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.8481719222427 9.367909756108936

127

aperture photometry : 69 172 ./reduced_data/p4466637UW32R073.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.84533202687595 9.318002058896075

141

aperture photometry : 70 172 ./reduced_data/p4466637UW32R074.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.0748279887259 9.44350133923234

130

aperture photometry : 71 172 ./reduced_data/p4466637UW32R075.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.4139184500306 9.381683588251

136

aperture photometry : 72 172 ./reduced_data/p4466637UW32R076.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.5499462915877 9.50386452846459

141

aperture photometry : 73 172 ./reduced_data/p4466637UW32R077.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.18851798848465 9.380871118099428

135

aperture photometry : 74 172 ./reduced_data/p4466637UW32R078.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.80665068456693 9.339222790642417

130

aperture photometry : 75 172 ./reduced_data/p4466637UW32R079.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.65719146951915 9.435957994568387

123

aperture photometry : 76 172 ./reduced_data/p4466637UW32R080.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.5667005279454 9.346825974676769

135

aperture photometry : 77 172 ./reduced_data/p4466637UW32R081.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.486938798274 9.289859674699429

137

aperture photometry : 78 172 ./reduced_data/p4466637UW32R082.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.85877885888368 9.362977288462016

136

aperture photometry : 79 172 ./reduced_data/p4466637UW32R083.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

253.42819623725478 9.333132005065412

107

aperture photometry : 80 172 ./reduced_data/p4466637UW32R084.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.09622984244913 9.364305394958441

137

aperture photometry : 81 172 ./reduced_data/p4466637UW32R085.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.62521594613966 9.376376223389068

116

aperture photometry : 82 172 ./reduced_data/p4466637UW32R086.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

254.95325636578076 9.251861537675023

108

aperture photometry : 83 172 ./reduced_data/p4466637UW32R087.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.64285712158863 9.272147211492559

125

aperture photometry : 84 172 ./reduced_data/p4466637UW32R088.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

253.1389356487214 9.319924743567881

105

aperture photometry : 85 172 ./reduced_data/p4466637UW32R089.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.5502852891366 9.3943972472068

127

aperture photometry : 86 172 ./reduced_data/p4466637UW32R090.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.5918793104391 9.350501639629154

125

aperture photometry : 87 172 ./reduced_data/p4466637UW32R091.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.3144428837232 9.412836122001247

134

aperture photometry : 88 172 ./reduced_data/p4466637UW32R092.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.5916451627444 9.3458558028523

122

aperture photometry : 89 172 ./reduced_data/p4466637UW32R093.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.27258603736374 9.29819027066156

120

aperture photometry : 90 172 ./reduced_data/p4466637UW32R094.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

254.58001383068586 9.32237454198657

114

aperture photometry : 91 172 ./reduced_data/p4466637UW32R095.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.623442270125 9.311593730972582

121

aperture photometry : 92 172 ./reduced_data/p4466637UW32R096.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.9495229103505 9.45393489414955

115

aperture photometry : 93 172 ./reduced_data/p4466637UW32R097.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

254.74928459817323 9.304285321768354

122

aperture photometry : 94 172 ./reduced_data/p4466637UW32R098.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

252.80062550890892 9.321785357519413

119

aperture photometry : 95 172 ./reduced_data/p4466637UW32R099.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

253.8688448093232 9.371800015309002

112

aperture photometry : 96 172 ./reduced_data/p4466637UW32R100.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.026767838335 9.460577030643044

141

aperture photometry : 97 172 ./reduced_data/p4466637UW32R101.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.4633333924678 9.354456540800898

138

aperture photometry : 98 172 ./reduced_data/p4466637UW32R102.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

254.86939440694067 9.339112165556298

127

aperture photometry : 99 172 ./reduced_data/p4466637UW32R103.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.5473877826004 9.340028209213877

149

aperture photometry : 100 172 ./reduced_data/p4466637UW32R104.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.67997261588147 9.501219509457654

123

aperture photometry : 101 172 ./reduced_data/p4466637UW32R105.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.827952006647 9.483122742753352

140

aperture photometry : 102 172 ./reduced_data/p4466637UW32R106.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

263.498471519325 9.388778400816442

141

aperture photometry : 103 172 ./reduced_data/p4466637UW32R107.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.4122893831316 9.398033126897953

131

aperture photometry : 104 172 ./reduced_data/p4466637UW32R108.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.79853067883883 9.38719557595697
126
aperture photometry : 105 172 ./reduced_data/p4466637UW32R109.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

253.76710489953967 9.396978004541081
120
aperture photometry : 106 172 ./reduced_data/p4466637UW32R110.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.32356114432605 9.431706491373692
129
aperture photometry : 107 172 ./reduced_data/p4466637UW32R111.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.91592912082191 9.36872614069088
110
aperture photometry : 108 172 ./reduced_data/p4466637UW32R112.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.35716206088756 9.367009302749121
113
aperture photometry : 109 172 ./reduced_data/p4466637UW32R113.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

264.8169300207022 9.52869084642086
115
aperture photometry : 110 172 ./reduced_data/p4466637UW32R114.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.72643416600295 9.608754272366713
121
aperture photometry : 111 172 ./reduced_data/p4466637UW32R115.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.21148479727526 9.51984350296478
133
aperture photometry : 112 172 ./reduced_data/p4466637UW32R116.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

265.56981654744516 9.539750404454182
138
aperture photometry : 113 172 ./reduced_data/p4466637UW32R117.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

266.0020382484527 9.63963553151218
108
aperture photometry : 114 172 ./reduced_data/p4466637UW32R118.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.4673266269189 9.414001857309355
121
aperture photometry : 115 172 ./reduced_data/p4466637UW32R119.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.6856087782314 9.409136686885912
123
aperture photometry : 116 172 ./reduced_data/p4466637UW32R120.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.99544422910805 9.375023687356125

148

aperture photometry : 117 172 ./reduced_data/p4466637UW32R121.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.5595744501891 9.5100941334547

123

aperture photometry : 118 172 ./reduced_data/p4466637UW32R122.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.94180459899485 9.431802546261233

129

aperture photometry : 119 172 ./reduced_data/p4466637UW32R123.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.36376018340974 9.430936385189607

129

aperture photometry : 120 172 ./reduced_data/p4466637UW32R124.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.74247831427147 9.380685260989626

125

aperture photometry : 121 172 ./reduced_data/p4466637UW32R125.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.05452490850564 9.386050504608498

126

aperture photometry : 122 172 ./reduced_data/p4466637UW32R126.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.18789136294026 9.44844362803137

113

aperture photometry : 123 172 ./reduced_data/p4466637UW32R127.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.8712140584604 9.467174740393839

106

aperture photometry : 124 172 ./reduced_data/p4466637UW32R128.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.3768788798356 9.512775523831353

112

aperture photometry : 125 172 ./reduced_data/p4466637UW32R129.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.12351083797284 9.367140581307401

127

aperture photometry : 126 172 ./reduced_data/p4466637UW32R130.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

261.2023707478242 9.467951289808584

150

aperture photometry : 127 172 ./reduced_data/p4466637UW32R131.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.75929319161736 9.36272540593179

122

aperture photometry : 128 172 ./reduced_data/p4466637UW32R132.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.5454523657827 9.341466652569753

116

aperture photometry : 129 172 ./reduced_data/p4466637UW32R133.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

262.0061587694363 9.557390758900361

127

aperture photometry : 130 172 ./reduced_data/p4466637UW32R134.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.94591356926696 9.433678603125774

111

aperture photometry : 131 172 ./reduced_data/p4466637UW32R135.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

255.2519727824273 9.338641982564466

121

aperture photometry : 132 172 ./reduced_data/p4466637UW32R136.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

256.87312739332083 9.37640958904236

116

aperture photometry : 133 172 ./reduced_data/p4466637UW32R137.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

258.4196218437745 9.45699383803847

120

aperture photometry : 134 172 ./reduced_data/p4466637UW32R138.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

268.93602571671056 9.647723750942523

129

aperture photometry : 135 172 ./reduced_data/p4466637UW32R139.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

267.2085547140953 9.540799829412087

128

aperture photometry : 136 172 ./reduced_data/p4466637UW32R140.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.1070244429166 9.405452156461264

137

aperture photometry : 137 172 ./reduced_data/p4466637UW32R141.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

259.9094683729455 9.456838119158569

121

aperture photometry : 138 172 ./reduced_data/p4466637UW32R142.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.9238802700688 9.369168002447037

124

aperture photometry : 139 172 ./reduced_data/p4466637UW32R143.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

260.3386115389407 9.470545926689645
116
aperture photometry : 140 172 ./reduced_data/p4466637UW32R144.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

257.26690091953515 9.377881334480351
93
aperture photometry : 141 172 ./reduced_data/p4466637UW32R145.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

252.96652972075373 9.29599282647386
102
aperture photometry : 142 172 ./reduced_data/p4466637UW32R146.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

254.50379579982322 9.424231932893399
118
aperture photometry : 143 172 ./reduced_data/p4466637UW32R147.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

252.3590626167904 9.209278900493395
112
aperture photometry : 144 172 ./reduced_data/p4466637UW32R148.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

246.18860560416016 9.190954777502569
116
aperture photometry : 145 172 ./reduced_data/p4466637UW32R149.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

248.31673926792524 9.253127881266451
109
aperture photometry : 146 172 ./reduced_data/p4466637UW32R150.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

248.89741360334892 9.271620333528524
123
aperture photometry : 147 172 ./reduced_data/p4466637UW32R151.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

244.38503799001052 9.13499004935743
134
aperture photometry : 148 172 ./reduced_data/p4466637UW32R152.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

241.04397149435562 9.087177375436568
140
aperture photometry : 149 172 ./reduced_data/p4466637UW32R153.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

238.52832053461782 9.173792789050738
111
aperture photometry : 150 172 ./reduced_data/p4466637UW32R154.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

235.3937231609251 9.028164585025465
141
aperture photometry : 151 172 ./reduced_data/p4466637UW32R155.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

232.1933081214856 8.932971583762289
127
aperture photometry : 152 172 ./reduced_data/p4466637UW32R156.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

233.25711657091216 8.967522268001407
101
aperture photometry : 153 172 ./reduced_data/p4466637UW32R157.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

232.19469495915007 8.951460042204992
125
aperture photometry : 154 172 ./reduced_data/p4466637UW32R158.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

227.09795880351038 8.78910671940481
108
aperture photometry : 155 172 ./reduced_data/p4466637UW32R159.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

224.1231747749153 8.83306077439682
125
aperture photometry : 156 172 ./reduced_data/p4466637UW32R160.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

221.56652238392246 8.745016234102673
135
aperture photometry : 157 172 ./reduced_data/p4466637UW32R161.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

221.17076166031774 8.773074135470202
110
aperture photometry : 158 172 ./reduced_data/p4466637UW32R162.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

220.0568192432222 8.792575523889463
103
aperture photometry : 159 172 ./reduced_data/p4466637UW32R163.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

219.56192686903074 8.741586398453173
121
aperture photometry : 160 172 ./reduced_data/p4466637UW32R164.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

217.5160766063637 8.693356772574372
112
aperture photometry : 161 172 ./reduced_data/p4466637UW32R165.fit
WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

215.5576212792612 8.656549346958474
118
aperture photometry : 162 172 ./reduced_data/p4466637UW32R166.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

213.85957630633243 8.631020812206163

133

aperture photometry : 163 172 ./reduced_data/p4466637UW32R167.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

214.5241147699063 8.715530393139087

122

aperture photometry : 164 172 ./reduced_data/p4466637UW32R168.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

212.5488835881934 8.540434642498777

137

aperture photometry : 165 172 ./reduced_data/p4466637UW32R169.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

207.45777123680176 8.48156241223165

132

aperture photometry : 166 172 ./reduced_data/p4466637UW32R170.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

205.0325823882671 8.44409087135373

132

aperture photometry : 167 172 ./reduced_data/p4466637UW32R171.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

202.71437416884334 8.36544917806573

130

aperture photometry : 168 172 ./reduced_data/p4466637UW32R172.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

201.02378283721762 8.340306420568382

132

aperture photometry : 169 172 ./reduced_data/p4466637UW32R173.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

198.85857796341995 8.393218025550691

120

aperture photometry : 170 172 ./reduced_data/p4466637UW32R174.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

195.86957765758092 8.239447998114336

133

aperture photometry : 171 172 ./reduced_data/p4466637UW32R175.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

190.9338307973086 8.13223225163597

131

aperture photometry : 172 172 ./reduced_data/p4466637UW32R176.fit

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

187.4524774877422 8.181003220547716

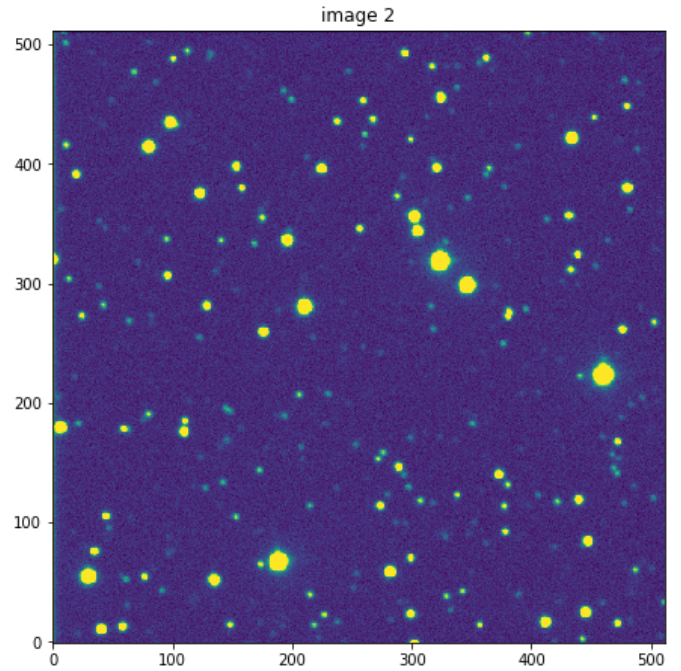
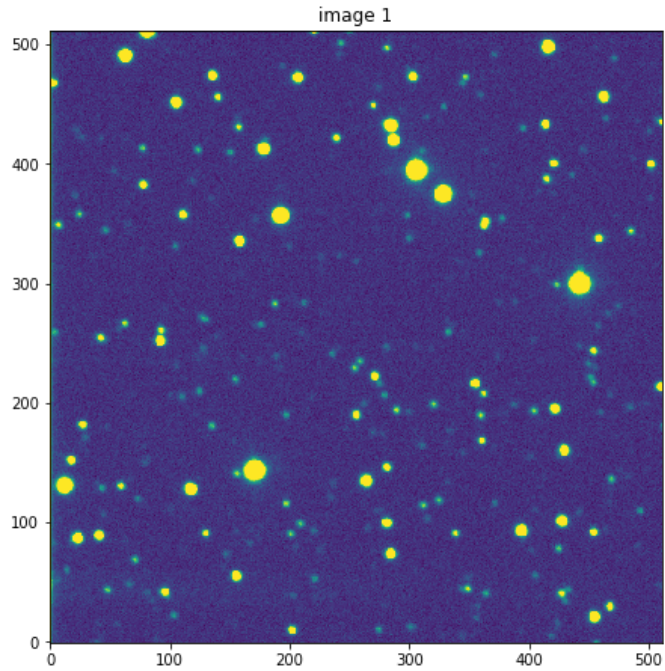
123

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

display two images to see the shift between two images

```
In [23]: f,axs=plt.subplots(1,2,figsize=(16,8))
data1=fits.getdata('reduced_data/p4466637UW32R004.fit')
data2=fits.getdata('reduced_data/p4466637UW32R007.fit')
axs[0].imshow(data1,vmin=300,vmax=600,origin='lower')
axs[0].set_title("image 1")
axs[1].imshow(data2,vmin=300,vmax=600,origin='lower')
axs[1].set_title("image 2")
```

```
Out[23]: Text(0.5, 1.0, 'image 2')
```



example: calculate average shifts between two different images

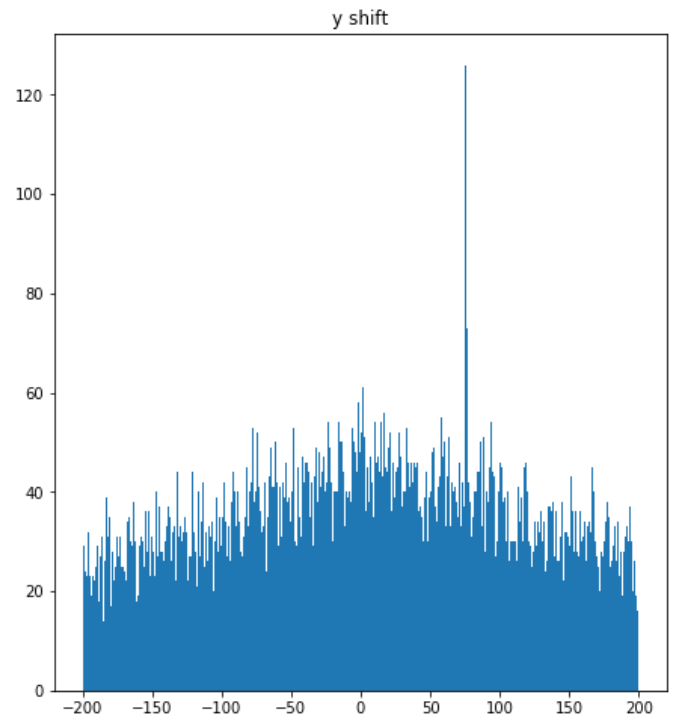
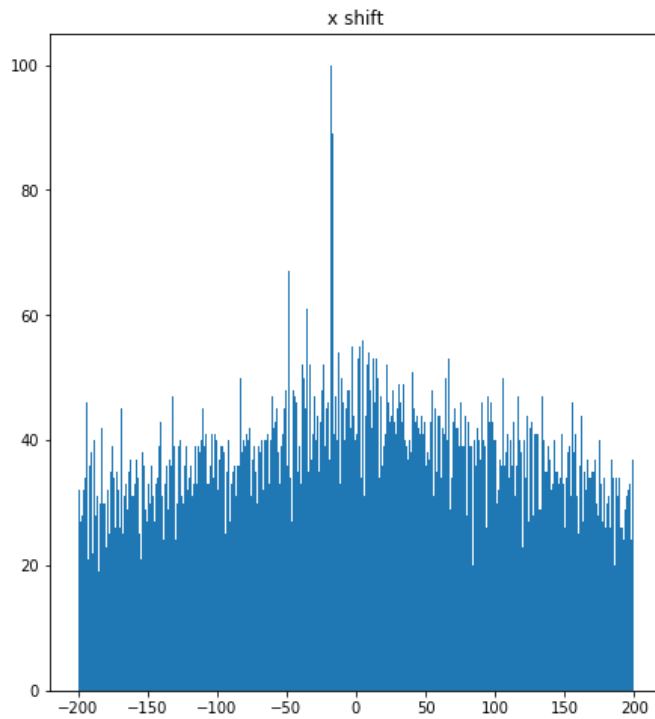
```

In [24]: cat1 = Table.read('reduced_data/p4466637UW32R004-cat.fits')
cat2 = Table.read('reduced_data/p4466637UW32R007-cat.fits')
x1=cat1['xcenter']
y1=cat1['ycenter']
x2=cat2['xcenter']
y2=cat2['ycenter']
ncat1=len(cat1)
ncat2=len(cat2)
XX=[]
YY=[]
for i in range(ncat2):
    XX.extend((x1-x2[i]))
    YY.extend((y1-y2[i]))
XX=np.array(XX)
YY=np.array(YY)
xhist,xbins=np.histogram(XX,range=[-200,200],bins=401)
yhist,ybins=np.histogram(YY,range=[-200,200],bins=401)
print(np.median(xhist),np.median(yhist))
f,axs=plt.subplots(1,2,figsize=(16,8))
axs[0].hist(XX,range=[-200,200],bins=401)
axs[0].set_title("x shift")
axs[1].hist(YY,range=[-200,200],bins=401)
axs[1].set_title("y shift")

```

38.0 35.0

Out[24]: Text(0.5, 1.0, 'y shift')



In []:

calculate shifts and update catalogs

```

In [25]: for i,ifile in enumerate(cfiles):
          rootname,_=os.path.splitext(ifile)
          catfile=rootname+'-cat.fits'
          print("calculate shifts :", i+1,len(cfiles),ifile)
          if i==0:
              cat1=Table.read(catfile)
              x1=cat1['xcenter']
              y1=cat1['ycenter']
              if 'x_sht' not in cat1.colnames:
                  xcol=Table.Column(x1,name='x_sht')
                  ycol=Table.Column(y1,name='y_sht')
                  cat1.add_columns([xcol,ycol])
              else:
                  cat1['x_sht']=x1
                  cat1['y_sht']=y1
              cat1.write(catfile,overwrite=True)
          else:
              cat2=Table.read(catfile)
              ncat2=len(cat2)
              x2=cat2['xcenter']
              y2=cat2['ycenter']
              XX=[]; YY=[]
              for j in range(ncat2):
                  XX.extend((x1-x2[j]))
                  YY.extend((y1-y2[j]))
              XX=np.array(XX)
              YY=np.array(YY)
              xhist,xbins=np.histogram(XX,range=[-200,200],bins=401)
              yhist,ybins=np.histogram(YY,range=[-200,200],bins=401)
              idx=np.argmax(xhist)
              xsht0=(xbins[idx]+xbins[idx+1])/2.0
              idx=np.argmax(yhist)
              ysht0=(ybins[idx]+ybins[idx+1])/2.0
              print("initial shift:",xsht0,ysht0)
              mask=(np.abs(XX-xsht0)<3) & (np.abs(YY-ysht0)<3)
              print(mask.sum())
              xsht1=np.median(XX[mask])
              ysht1=np.median(YY[mask])
              print("finetuned shift:",xsht1,ysht1)
              if 'x_sht' not in cat1.colnames:
                  xcol=Table.Column(x2+xsht1,name='x_sht')
                  ycol=Table.Column(y2+ysht1,name='y_sht')
                  cat2.add_columns([xcol,ycol])
              else:
                  cat2['x_sht']=x2+xsht1
                  cat2['y_sht']=y2+ysht1

              cat2.write(catfile,overwrite=True)

```

```
calculate shifts : 1 172 ./reduced_data/p4466637UW32R004.fit
calculate shifts : 2 172 ./reduced_data/p4466637UW32R005.fit
initial shift: -0.9975062344139616 1.4210854715202004e-14
117
finetuned shift: -0.8541405545123197 0.011293750962522608
calculate shifts : 3 172 ./reduced_data/p4466637UW32R007.fit
```

WARNING: VerifyWarning: Keyword name 'aperture_photometry_args' is greater than 8 characters or contains characters not allowed by the FITS standard; a HIERARCH card will be created. [astropy.io.fits.card]

initial shift: -17.955112219451365 75.81047381546136
107
finetuned shift: -17.65718734828613 76.06000164040421
calculate shifts : 4 172 ./reduced_data/p4466637UW32R008.fit
initial shift: -17.955112219451365 75.81047381546136
108
finetuned shift: -18.157689883592717 76.21520931644683
calculate shifts : 5 172 ./reduced_data/p4466637UW32R009.fit
initial shift: -25.935162094763086 14.96259351620948
118
finetuned shift: -26.145437294659516 15.06043804671674
calculate shifts : 6 172 ./reduced_data/p4466637UW32R010.fit
initial shift: -21.945137157107226 -34.91271820448877
116
finetuned shift: -21.432149505769942 -34.76182602758328
calculate shifts : 7 172 ./reduced_data/p4466637UW32R011.fit
initial shift: -62.84289276807979 74.81296758104739
97
finetuned shift: -62.85840657980019 75.26394362374253
calculate shifts : 8 172 ./reduced_data/p4466637UW32R012.fit
initial shift: -62.84289276807979 74.81296758104739
97
finetuned shift: -63.29039763602992 75.2437337141564
calculate shifts : 9 172 ./reduced_data/p4466637UW32R013.fit
initial shift: -62.84289276807979 75.81047381546136
97
finetuned shift: -63.24295040171587 75.77426722952225
calculate shifts : 10 172 ./reduced_data/p4466637UW32R014.fit
initial shift: -63.840399002493754 75.81047381546136
96
finetuned shift: -64.00639045307109 75.90390231144451
calculate shifts : 11 172 ./reduced_data/p4466637UW32R015.fit
initial shift: -63.840399002493754 75.81047381546136
100
finetuned shift: -64.06361493461611 76.10689265176622
calculate shifts : 12 172 ./reduced_data/p4466637UW32R016.fit
initial shift: -63.840399002493754 75.81047381546136
95
finetuned shift: -64.12189603135778 76.04558592542236
calculate shifts : 13 172 ./reduced_data/p4466637UW32R017.fit
initial shift: -64.83790523690773 75.81047381546136
93
finetuned shift: -65.08294786838981 76.00768372868959
calculate shifts : 14 172 ./reduced_data/p4466637UW32R018.fit
initial shift: -64.83790523690773 76.80798004987534
96
finetuned shift: -65.08611851916302 76.3590788865597
calculate shifts : 15 172 ./reduced_data/p4466637UW32R019.fit
initial shift: -65.83541147132169 76.80798004987534
99
finetuned shift: -65.94339108440101 76.77578504386594
calculate shifts : 16 172 ./reduced_data/p4466637UW32R020.fit
initial shift: -65.83541147132169 76.80798004987534
89
finetuned shift: -65.98059303450998 77.03718116399465
calculate shifts : 17 172 ./reduced_data/p4466637UW32R021.fit
initial shift: -66.83291770573565 76.80798004987534
93
finetuned shift: -66.96651898657936 76.82249903157276
calculate shifts : 18 172 ./reduced_data/p4466637UW32R022.fit
initial shift: -66.83291770573565 76.80798004987534
87
finetuned shift: -67.18629465631824 76.81946316718378
calculate shifts : 19 172 ./reduced_data/p4466637UW32R023.fit
initial shift: -66.83291770573565 77.80548628428929
91
finetuned shift: -66.98623353783023 77.56448940134601
calculate shifts : 20 172 ./reduced_data/p4466637UW32R024.fit
initial shift: -67.83042394014963 77.80548628428929
92
finetuned shift: -67.67133202921715 77.65187291590519
calculate shifts : 21 172 ./reduced_data/p4466637UW32R025.fit
initial shift: -67.83042394014963 77.80548628428929
92
finetuned shift: -67.92725134384862 77.73948362384054
calculate shifts : 22 172 ./reduced_data/p4466637UW32R026.fit

initial shift: -67.83042394014963 77.80548628428929
91
finetuned shift: -67.9850165281718 78.03506370715255
calculate shifts : 23 172 ./reduced_data/p4466637UW32R027.fit
initial shift: -68.82793017456359 77.80548628428929
90
finetuned shift: -68.51682401445461 77.8865660459009
calculate shifts : 24 172 ./reduced_data/p4466637UW32R028.fit
initial shift: -68.82793017456359 77.80548628428929
66
finetuned shift: -68.27118810655605 78.05682720612795
calculate shifts : 25 172 ./reduced_data/p4466637UW32R029.fit
initial shift: -67.83042394014963 78.80299251870326
81
finetuned shift: -68.1154200022068 78.78434013820447
calculate shifts : 26 172 ./reduced_data/p4466637UW32R030.fit
initial shift: -68.82793017456359 78.80299251870326
78
finetuned shift: -68.90378107645499 78.56834821200758
calculate shifts : 27 172 ./reduced_data/p4466637UW32R031.fit
initial shift: -68.82793017456359 78.80299251870326
87
finetuned shift: -69.13800266465039 78.65825146104714
calculate shifts : 28 172 ./reduced_data/p4466637UW32R032.fit
initial shift: -68.82793017456359 78.80299251870326
91
finetuned shift: -69.07822006703688 78.90990778373526
calculate shifts : 29 172 ./reduced_data/p4466637UW32R033.fit
initial shift: -68.82793017456359 78.80299251870326
91
finetuned shift: -68.64684728614145 78.91915440945668
calculate shifts : 30 172 ./reduced_data/p4466637UW32R034.fit
initial shift: -69.82543640897755 78.80299251870326
79
finetuned shift: -69.60179530041023 78.73557069048974
calculate shifts : 31 172 ./reduced_data/p4466637UW32R035.fit
initial shift: -69.82543640897755 78.80299251870326
90
finetuned shift: -70.04119361329276 78.60542144824176
calculate shifts : 32 172 ./reduced_data/p4466637UW32R036.fit
initial shift: -68.82793017456359 78.80299251870326
80
finetuned shift: -69.20307352619893 78.83859605493348
calculate shifts : 33 172 ./reduced_data/p4466637UW32R037.fit
initial shift: -69.82543640897755 78.80299251870326
93
finetuned shift: -70.00095311995557 78.96457365375502
calculate shifts : 34 172 ./reduced_data/p4466637UW32R038.fit
initial shift: -69.82543640897755 78.80299251870326
95
finetuned shift: -69.82308971203366 78.8714405376618
calculate shifts : 35 172 ./reduced_data/p4466637UW32R039.fit
initial shift: -69.82543640897755 78.80299251870326
93
finetuned shift: -70.14561153791425 78.34189598980147
calculate shifts : 36 172 ./reduced_data/p4466637UW32R040.fit
initial shift: -70.82294264339151 78.80299251870326
90
finetuned shift: -70.35034199181285 78.93082607144196
calculate shifts : 37 172 ./reduced_data/p4466637UW32R041.fit
initial shift: -70.82294264339151 78.80299251870326
91
finetuned shift: -70.35392283632993 78.98482892066141
calculate shifts : 38 172 ./reduced_data/p4466637UW32R042.fit
initial shift: -70.82294264339151 78.80299251870326
94
finetuned shift: -70.9331291539935 79.00113227134713
calculate shifts : 39 172 ./reduced_data/p4466637UW32R043.fit
initial shift: -70.82294264339151 78.80299251870326
95
finetuned shift: -70.6928144209017 79.21122008924957
calculate shifts : 40 172 ./reduced_data/p4466637UW32R044.fit
initial shift: -70.82294264339151 78.80299251870326
95
finetuned shift: -71.05127404038902 79.05982332163775
calculate shifts : 41 172 ./reduced_data/p4466637UW32R045.fit

initial shift: -71.82044887780548 78.80299251870326
92
finetuned shift: -71.73392949968 79.18968340813218
calculate shifts : 42 172 ./reduced_data/p4466637UW32R046.fit
initial shift: -70.82294264339151 78.80299251870326
95
finetuned shift: -71.21459376611898 79.09240650794897
calculate shifts : 43 172 ./reduced_data/p4466637UW32R047.fit
initial shift: -71.82044887780548 78.80299251870326
94
finetuned shift: -71.95185198030003 79.06712359161355
calculate shifts : 44 172 ./reduced_data/p4466637UW32R048.fit
initial shift: -71.82044887780548 78.80299251870326
92
finetuned shift: -71.84705387331027 79.23656309862415
calculate shifts : 45 172 ./reduced_data/p4466637UW32R049.fit
initial shift: -71.82044887780548 78.80299251870326
92
finetuned shift: -72.08912092085859 79.13108392211491
calculate shifts : 46 172 ./reduced_data/p4466637UW32R050.fit
initial shift: -72.81795511221944 78.80299251870326
94
finetuned shift: -72.81640587714456 79.2880470946012
calculate shifts : 47 172 ./reduced_data/p4466637UW32R051.fit
initial shift: -72.81795511221944 79.80049875311724
87
finetuned shift: -72.85526286325091 79.51585426482671
calculate shifts : 48 172 ./reduced_data/p4466637UW32R052.fit
initial shift: -72.81795511221944 79.80049875311724
91
finetuned shift: -72.88439849285905 79.33852752316542
calculate shifts : 49 172 ./reduced_data/p4466637UW32R053.fit
initial shift: -72.81795511221944 79.80049875311724
92
finetuned shift: -72.97787271557405 79.37484272788811
calculate shifts : 50 172 ./reduced_data/p4466637UW32R054.fit
initial shift: -72.81795511221944 79.80049875311724
94
finetuned shift: -73.11014283664983 79.68940108916601
calculate shifts : 51 172 ./reduced_data/p4466637UW32R055.fit
initial shift: -73.81546134663341 79.80049875311724
91
finetuned shift: -73.74051395807905 79.73808892754488
calculate shifts : 52 172 ./reduced_data/p4466637UW32R056.fit
initial shift: -73.81546134663341 79.80049875311724
89
finetuned shift: -73.73464013325082 79.27347174869402
calculate shifts : 53 172 ./reduced_data/p4466637UW32R057.fit
initial shift: -73.81546134663341 79.80049875311724
81
finetuned shift: -74.05903192022308 79.83216472812659
calculate shifts : 54 172 ./reduced_data/p4466637UW32R058.fit
initial shift: -74.81296758104737 79.80049875311724
92
finetuned shift: -74.97194158547049 79.91722331953204
calculate shifts : 55 172 ./reduced_data/p4466637UW32R059.fit
initial shift: -74.81296758104737 79.80049875311724
89
finetuned shift: -75.13834971679933 80.02237816232861
calculate shifts : 56 172 ./reduced_data/p4466637UW32R060.fit
initial shift: -74.81296758104737 79.80049875311724
94
finetuned shift: -75.06417049057093 80.05891489869578
calculate shifts : 57 172 ./reduced_data/p4466637UW32R061.fit
initial shift: -74.81296758104737 79.80049875311724
88
finetuned shift: -74.63058841938337 80.07786313282222
calculate shifts : 58 172 ./reduced_data/p4466637UW32R062.fit
initial shift: -75.81047381546134 80.79800498753119
90
finetuned shift: -75.88087334189989 80.27492537904685
calculate shifts : 59 172 ./reduced_data/p4466637UW32R063.fit
initial shift: -75.81047381546134 79.80049875311724
86
finetuned shift: -76.07729334075796 80.14916373570401
calculate shifts : 60 172 ./reduced_data/p4466637UW32R064.fit

initial shift: -75.81047381546134 79.80049875311724
92
finetuned shift: -75.95099420595952 80.14944073561247
calculate shifts : 61 172 ./reduced_data/p4466637UW32R065.fit
initial shift: -76.80798004987531 79.80049875311724
93
finetuned shift: -76.70766102523737 80.18607231771284
calculate shifts : 62 172 ./reduced_data/p4466637UW32R066.fit
initial shift: -75.81047381546134 79.80049875311724
92
finetuned shift: -76.00970505591346 80.20488230764224
calculate shifts : 63 172 ./reduced_data/p4466637UW32R067.fit
initial shift: -76.80798004987531 79.80049875311724
91
finetuned shift: -76.65943941437735 80.21903882129334
calculate shifts : 64 172 ./reduced_data/p4466637UW32R068.fit
initial shift: -76.80798004987531 79.80049875311724
91
finetuned shift: -76.96537018220562 80.06598549198964
calculate shifts : 65 172 ./reduced_data/p4466637UW32R069.fit
initial shift: -76.80798004987531 79.80049875311724
94
finetuned shift: -77.02166549970573 80.07722025182318
calculate shifts : 66 172 ./reduced_data/p4466637UW32R070.fit
initial shift: -77.80548628428927 79.80049875311724
89
finetuned shift: -77.43536619088326 80.1955753020909
calculate shifts : 67 172 ./reduced_data/p4466637UW32R071.fit
initial shift: -77.80548628428927 79.80049875311724
88
finetuned shift: -77.93973808894668 80.18593771023441
calculate shifts : 68 172 ./reduced_data/p4466637UW32R072.fit
initial shift: -77.80548628428927 79.80049875311724
87
finetuned shift: -77.91644790378115 80.07068633051045
calculate shifts : 69 172 ./reduced_data/p4466637UW32R073.fit
initial shift: -77.80548628428927 79.80049875311724
93
finetuned shift: -78.19688010160621 80.01592663523309
calculate shifts : 70 172 ./reduced_data/p4466637UW32R074.fit
initial shift: -77.80548628428927 79.80049875311724
90
finetuned shift: -77.85101918073373 79.94217804720495
calculate shifts : 71 172 ./reduced_data/p4466637UW32R075.fit
initial shift: -77.80548628428927 79.80049875311724
88
finetuned shift: -78.14527307955538 80.2409497789827
calculate shifts : 72 172 ./reduced_data/p4466637UW32R076.fit
initial shift: -77.80548628428927 80.79800498753119
92
finetuned shift: -78.07535245695865 80.33751263320804
calculate shifts : 73 172 ./reduced_data/p4466637UW32R077.fit
initial shift: -77.80548628428927 79.80049875311724
92
finetuned shift: -78.25831537700597 80.19577162963243
calculate shifts : 74 172 ./reduced_data/p4466637UW32R078.fit
initial shift: -78.80299251870323 79.80049875311724
89
finetuned shift: -79.13232621156504 80.25221864600593
calculate shifts : 75 172 ./reduced_data/p4466637UW32R079.fit
initial shift: -78.80299251870323 80.79800498753119
84
finetuned shift: -78.6055795928412 80.321896271439
calculate shifts : 76 172 ./reduced_data/p4466637UW32R080.fit
initial shift: -78.80299251870323 80.79800498753119
89
finetuned shift: -79.00434883106351 80.43403158822042
calculate shifts : 77 172 ./reduced_data/p4466637UW32R081.fit
initial shift: -78.80299251870323 80.79800498753119
90
finetuned shift: -78.93788925698419 80.78833876745222
calculate shifts : 78 172 ./reduced_data/p4466637UW32R082.fit
initial shift: -79.80049875311721 79.80049875311724
91
finetuned shift: -79.30269574179306 80.29007124377486
calculate shifts : 79 172 ./reduced_data/p4466637UW32R083.fit

initial shift: -79.80049875311721 80.79800498753119
76
finetuned shift: -79.95370573183905 80.90187236623365
calculate shifts : 80 172 ./reduced_data/p4466637UW32R084.fit
initial shift: -79.80049875311721 80.79800498753119
93
finetuned shift: -79.75014550992398 80.95124914262419
calculate shifts : 81 172 ./reduced_data/p4466637UW32R085.fit
initial shift: -79.80049875311721 80.79800498753119
81
finetuned shift: -80.22275072993767 80.90156156067866
calculate shifts : 82 172 ./reduced_data/p4466637UW32R086.fit
initial shift: -79.80049875311721 80.79800498753119
80
finetuned shift: -80.10722572447841 80.85636800178938
calculate shifts : 83 172 ./reduced_data/p4466637UW32R087.fit
initial shift: -79.80049875311721 80.79800498753119
84
finetuned shift: -80.10493023728728 80.93288039624024
calculate shifts : 84 172 ./reduced_data/p4466637UW32R088.fit
initial shift: -80.79800498753116 80.79800498753119
72
finetuned shift: -80.64586629926134 80.53884706126088
calculate shifts : 85 172 ./reduced_data/p4466637UW32R089.fit
initial shift: -79.80049875311721 79.80049875311724
87
finetuned shift: -79.92834868799343 80.28898715666253
calculate shifts : 86 172 ./reduced_data/p4466637UW32R090.fit
initial shift: -81.79551122194513 80.79800498753119
80
finetuned shift: -81.22802588514082 80.70157683913732
calculate shifts : 87 172 ./reduced_data/p4466637UW32R091.fit
initial shift: -81.79551122194513 79.80049875311724
88
finetuned shift: -81.7953027610607 80.22809023574672
calculate shifts : 88 172 ./reduced_data/p4466637UW32R092.fit
initial shift: -82.7930174563591 80.79800498753119
85
finetuned shift: -82.33568848079284 80.34480403392332
calculate shifts : 89 172 ./reduced_data/p4466637UW32R093.fit
initial shift: -81.79551122194513 79.80049875311724
83
finetuned shift: -82.29145450015363 80.11980288384929
calculate shifts : 90 172 ./reduced_data/p4466637UW32R094.fit
initial shift: -82.7930174563591 80.79800498753119
81
finetuned shift: -82.38636779814817 80.35535320915676
calculate shifts : 91 172 ./reduced_data/p4466637UW32R095.fit
initial shift: -82.7930174563591 79.80049875311724
81
finetuned shift: -82.92508775320812 80.21812038386952
calculate shifts : 92 172 ./reduced_data/p4466637UW32R096.fit
initial shift: -82.7930174563591 79.80049875311724
82
finetuned shift: -83.09917937488807 79.99565901400331
calculate shifts : 93 172 ./reduced_data/p4466637UW32R097.fit
initial shift: -83.79052369077306 79.80049875311724
82
finetuned shift: -84.06924372024739 80.06874657707291
calculate shifts : 94 172 ./reduced_data/p4466637UW32R098.fit
initial shift: -84.78802992518703 79.80049875311724
82
finetuned shift: -84.9293780794514 79.83632352391834
calculate shifts : 95 172 ./reduced_data/p4466637UW32R099.fit
initial shift: -84.78802992518703 79.80049875311724
75
finetuned shift: -84.66641218927072 80.06488534054438
calculate shifts : 96 172 ./reduced_data/p4466637UW32R100.fit
initial shift: -84.78802992518703 79.80049875311724
89
finetuned shift: -85.16113785044774 79.9210209606558
calculate shifts : 97 172 ./reduced_data/p4466637UW32R101.fit
initial shift: -84.78802992518703 79.80049875311724
91
finetuned shift: -85.11133604565347 79.81148118953809
calculate shifts : 98 172 ./reduced_data/p4466637UW32R102.fit

initial shift: -85.785536159601 79.80049875311724
86
finetuned shift: -85.28766940126884 79.96452854386393
calculate shifts : 99 172 ./reduced_data/p4466637UW32R103.fit
initial shift: -85.785536159601 79.80049875311724
90
finetuned shift: -85.85052373783459 80.0519349997281
calculate shifts : 100 172 ./reduced_data/p4466637UW32R104.fit
initial shift: -85.785536159601 79.80049875311724
86
finetuned shift: -85.69181058429749 79.92366700284394
calculate shifts : 101 172 ./reduced_data/p4466637UW32R105.fit
initial shift: -85.785536159601 79.80049875311724
90
finetuned shift: -86.07784794529321 80.10507972850728
calculate shifts : 102 172 ./reduced_data/p4466637UW32R106.fit
initial shift: -85.785536159601 79.80049875311724
87
finetuned shift: -85.89967103460566 80.0408813033732
calculate shifts : 103 172 ./reduced_data/p4466637UW32R107.fit
initial shift: -85.785536159601 79.80049875311724
85
finetuned shift: -85.98325445179705 79.93525081925162
calculate shifts : 104 172 ./reduced_data/p4466637UW32R108.fit
initial shift: -85.785536159601 79.80049875311724
87
finetuned shift: -86.15838691366693 79.9887415610958
calculate shifts : 105 172 ./reduced_data/p4466637UW32R109.fit
initial shift: -86.78304239401496 79.80049875311724
83
finetuned shift: -86.29016823559954 79.9063120370673
calculate shifts : 106 172 ./reduced_data/p4466637UW32R110.fit
initial shift: -86.78304239401496 79.80049875311724
84
finetuned shift: -87.0252395346522 79.95820757120717
calculate shifts : 107 172 ./reduced_data/p4466637UW32R111.fit
initial shift: -86.78304239401496 79.80049875311724
77
finetuned shift: -87.17743743123202 79.80114041309281
calculate shifts : 108 172 ./reduced_data/p4466637UW32R112.fit
initial shift: -87.78054862842893 79.80049875311724
77
finetuned shift: -87.49779865247831 80.04720038602392
calculate shifts : 109 172 ./reduced_data/p4466637UW32R113.fit
initial shift: -86.78304239401496 79.80049875311724
81
finetuned shift: -87.1131937599034 80.11530124542493
calculate shifts : 110 172 ./reduced_data/p4466637UW32R114.fit
initial shift: -86.78304239401496 79.80049875311724
79
finetuned shift: -87.10093091297486 79.9079814410112
calculate shifts : 111 172 ./reduced_data/p4466637UW32R115.fit
initial shift: -86.78304239401496 78.80299251870326
87
finetuned shift: -87.23055526956276 79.30173049202716
calculate shifts : 112 172 ./reduced_data/p4466637UW32R116.fit
initial shift: -87.78054862842893 79.80049875311724
87
finetuned shift: -88.08822420333419 79.73841280170625
calculate shifts : 113 172 ./reduced_data/p4466637UW32R117.fit
initial shift: -88.77805486284288 78.80299251870326
72
finetuned shift: -88.65601354997875 79.29179959865525
calculate shifts : 114 172 ./reduced_data/p4466637UW32R118.fit
initial shift: -87.78054862842893 78.80299251870326
82
finetuned shift: -88.29111055967925 79.1748729753848
calculate shifts : 115 172 ./reduced_data/p4466637UW32R119.fit
initial shift: -88.77805486284288 78.80299251870326
85
finetuned shift: -88.89758803148192 79.26213673541753
calculate shifts : 116 172 ./reduced_data/p4466637UW32R120.fit
initial shift: -88.77805486284288 79.80049875311724
81
finetuned shift: -88.96000653922704 79.3720405952121
calculate shifts : 117 172 ./reduced_data/p4466637UW32R121.fit

initial shift: -88.77805486284288 79.80049875311724
83
finetuned shift: -88.89749023527656 79.88465992140323
calculate shifts : 118 172 ./reduced_data/p4466637UW32R122.fit
initial shift: -88.77805486284288 78.80299251870326
83
finetuned shift: -88.73140476801728 79.2527672255626
calculate shifts : 119 172 ./reduced_data/p4466637UW32R123.fit
initial shift: -89.77556109725685 78.80299251870326
80
finetuned shift: -89.2820673662505 79.0854375976409
calculate shifts : 120 172 ./reduced_data/p4466637UW32R124.fit
initial shift: -89.77556109725685 79.80049875311724
84
finetuned shift: -89.2711924814042 79.35944056336962
calculate shifts : 121 172 ./reduced_data/p4466637UW32R125.fit
initial shift: -89.77556109725685 78.80299251870326
83
finetuned shift: -89.7231963213215 79.26267100027758
calculate shifts : 122 172 ./reduced_data/p4466637UW32R126.fit
initial shift: -89.77556109725685 78.80299251870326
74
finetuned shift: -90.08828653717121 79.17169559466186
calculate shifts : 123 172 ./reduced_data/p4466637UW32R127.fit
initial shift: -89.77556109725685 79.80049875311724
72
finetuned shift: -89.63604449774817 79.38480917750127
calculate shifts : 124 172 ./reduced_data/p4466637UW32R128.fit
initial shift: -90.77306733167082 78.80299251870326
78
finetuned shift: -90.33233863196294 79.18500105173416
calculate shifts : 125 172 ./reduced_data/p4466637UW32R129.fit
initial shift: -89.77556109725685 78.80299251870326
85
finetuned shift: -90.14636121777173 79.23793849029528
calculate shifts : 126 172 ./reduced_data/p4466637UW32R130.fit
initial shift: -90.77306733167082 78.80299251870326
90
finetuned shift: -90.85463965216472 79.14235279137088
calculate shifts : 127 172 ./reduced_data/p4466637UW32R131.fit
initial shift: -91.77057356608478 78.80299251870326
81
finetuned shift: -91.67220174675498 79.24248772800549
calculate shifts : 128 172 ./reduced_data/p4466637UW32R132.fit
initial shift: -90.77306733167082 78.80299251870326
78
finetuned shift: -90.99811910389474 79.00718114891842
calculate shifts : 129 172 ./reduced_data/p4466637UW32R133.fit
initial shift: -91.77057356608478 78.80299251870326
85
finetuned shift: -91.79702986627814 79.06907697669878
calculate shifts : 130 172 ./reduced_data/p4466637UW32R134.fit
initial shift: -91.77057356608478 78.80299251870326
79
finetuned shift: -92.08332946166973 78.83698303343317
calculate shifts : 131 172 ./reduced_data/p4466637UW32R135.fit
initial shift: -91.77057356608478 78.80299251870326
81
finetuned shift: -92.12563309921546 78.85244052770844
calculate shifts : 132 172 ./reduced_data/p4466637UW32R136.fit
initial shift: -91.77057356608478 78.80299251870326
79
finetuned shift: -92.006376097947 78.90041313843875
calculate shifts : 133 172 ./reduced_data/p4466637UW32R137.fit
initial shift: -91.77057356608478 78.80299251870326
82
finetuned shift: -91.84010837803676 78.9295209586714
calculate shifts : 134 172 ./reduced_data/p4466637UW32R138.fit
initial shift: -91.77057356608478 78.80299251870326
84
finetuned shift: -92.06551568549224 79.14931447566538
calculate shifts : 135 172 ./reduced_data/p4466637UW32R139.fit
initial shift: -91.77057356608478 78.80299251870326
87
finetuned shift: -92.06413349980299 78.93306886214756
calculate shifts : 136 172 ./reduced_data/p4466637UW32R140.fit

initial shift: -91.77057356608478 78.80299251870326
86
finetuned shift: -91.81629667334872 78.86850660459801
calculate shifts : 137 172 ./reduced_data/p4466637UW32R141.fit
initial shift: -91.77057356608478 78.80299251870326
82
finetuned shift: -91.96829304025798 78.90711443829383
calculate shifts : 138 172 ./reduced_data/p4466637UW32R142.fit
initial shift: -91.77057356608478 78.80299251870326
84
finetuned shift: -91.81137609670682 78.74663847641057
calculate shifts : 139 172 ./reduced_data/p4466637UW32R143.fit
initial shift: -91.77057356608478 77.80548628428929
75
finetuned shift: -91.94499667555993 78.21623706085512
calculate shifts : 140 172 ./reduced_data/p4466637UW32R144.fit
initial shift: -91.77057356608478 77.80548628428929
63
finetuned shift: -91.96726827064174 78.11542167721143
calculate shifts : 141 172 ./reduced_data/p4466637UW32R145.fit
initial shift: -91.77057356608478 77.80548628428929
72
finetuned shift: -91.60087263284846 78.21956434754395
calculate shifts : 142 172 ./reduced_data/p4466637UW32R146.fit
initial shift: -91.77057356608478 78.80299251870326
80
finetuned shift: -91.92465383575379 78.6500618604799
calculate shifts : 143 172 ./reduced_data/p4466637UW32R147.fit
initial shift: -91.77057356608478 78.80299251870326
73
finetuned shift: -91.7253560168856 78.20405167238948
calculate shifts : 144 172 ./reduced_data/p4466637UW32R148.fit
initial shift: -91.77057356608478 77.80548628428929
81
finetuned shift: -91.64392427132287 78.00125421870482
calculate shifts : 145 172 ./reduced_data/p4466637UW32R149.fit
initial shift: -91.77057356608478 78.80299251870326
77
finetuned shift: -91.70573637314573 78.66840452331598
calculate shifts : 146 172 ./reduced_data/p4466637UW32R150.fit
initial shift: -91.77057356608478 78.80299251870326
87
finetuned shift: -91.9491011235194 78.8490056519885
calculate shifts : 147 172 ./reduced_data/p4466637UW32R151.fit
initial shift: -91.77057356608478 78.80299251870326
87
finetuned shift: -92.11097723618366 78.32533759160106
calculate shifts : 148 172 ./reduced_data/p4466637UW32R152.fit
initial shift: -91.77057356608478 78.80299251870326
88
finetuned shift: -91.9776600159606 78.77272819933911
calculate shifts : 149 172 ./reduced_data/p4466637UW32R153.fit
initial shift: -92.76807980049875 77.80548628428929
78
finetuned shift: -92.66191072606597 78.32531099100652
calculate shifts : 150 172 ./reduced_data/p4466637UW32R154.fit
initial shift: -91.77057356608478 78.80299251870326
88
finetuned shift: -92.20508066742849 78.88918268911712
calculate shifts : 151 172 ./reduced_data/p4466637UW32R155.fit
initial shift: -91.77057356608478 78.80299251870326
85
finetuned shift: -91.73224966900347 78.84596974825996
calculate shifts : 152 172 ./reduced_data/p4466637UW32R156.fit
initial shift: -91.77057356608478 78.80299251870326
73
finetuned shift: -91.77033575369711 78.71733193963752
calculate shifts : 153 172 ./reduced_data/p4466637UW32R157.fit
initial shift: -91.77057356608478 78.80299251870326
85
finetuned shift: -91.81636386302478 78.36984995819029
calculate shifts : 154 172 ./reduced_data/p4466637UW32R158.fit
initial shift: -91.77057356608478 78.80299251870326
72
finetuned shift: -92.0151455051633 78.69381749883937
calculate shifts : 155 172 ./reduced_data/p4466637UW32R159.fit

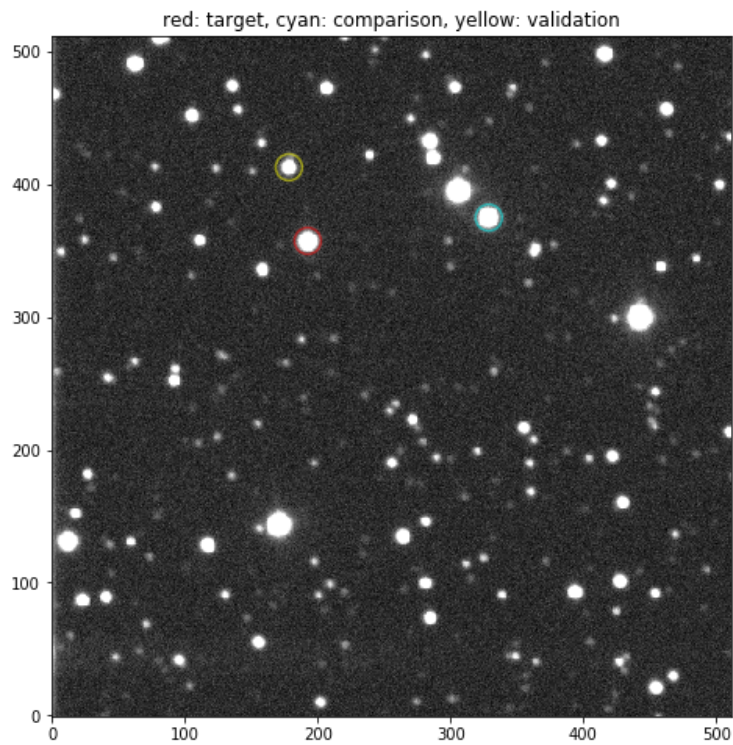
initial shift: -92.76807980049875 78.80299251870326
82
finetuned shift: -92.23808287476704 78.67083088541469
calculate shifts : 156 172 ./reduced_data/p4466637UW32R160.fit
initial shift: -91.77057356608478 78.80299251870326
87
finetuned shift: -92.12631050737866 78.33424170519143
calculate shifts : 157 172 ./reduced_data/p4466637UW32R161.fit
initial shift: -92.76807980049875 77.80548628428929
76
finetuned shift: -92.65911282986245 78.16387325770373
calculate shifts : 158 172 ./reduced_data/p4466637UW32R162.fit
initial shift: -92.76807980049875 78.80299251870326
68
finetuned shift: -92.25262334857226 78.35137246247295
calculate shifts : 159 172 ./reduced_data/p4466637UW32R163.fit
initial shift: -92.76807980049875 78.80299251870326
81
finetuned shift: -92.70803348772733 78.83041119953873
calculate shifts : 160 172 ./reduced_data/p4466637UW32R164.fit
initial shift: -91.77057356608478 77.80548628428929
77
finetuned shift: -92.15236830685288 78.15657123134162
calculate shifts : 161 172 ./reduced_data/p4466637UW32R165.fit
initial shift: -91.77057356608478 78.80299251870326
80
finetuned shift: -92.12954789848419 78.6452284437004
calculate shifts : 162 172 ./reduced_data/p4466637UW32R166.fit
initial shift: -92.76807980049875 77.80548628428929
85
finetuned shift: -92.8398502381861 78.26312008896201
calculate shifts : 163 172 ./reduced_data/p4466637UW32R167.fit
initial shift: -92.76807980049875 77.80548628428929
82
finetuned shift: -92.65858342601231 78.09826783450632
calculate shifts : 164 172 ./reduced_data/p4466637UW32R168.fit
initial shift: -92.76807980049875 77.80548628428929
85
finetuned shift: -92.60066836772376 78.00287965999769
calculate shifts : 165 172 ./reduced_data/p4466637UW32R169.fit
initial shift: -92.76807980049875 77.80548628428929
85
finetuned shift: -92.2476096656024 78.27614497777193
calculate shifts : 166 172 ./reduced_data/p4466637UW32R170.fit
initial shift: -91.77057356608478 77.80548628428929
83
finetuned shift: -91.79889076066192 78.04043042914265
calculate shifts : 167 172 ./reduced_data/p4466637UW32R171.fit
initial shift: -91.77057356608478 77.80548628428929
86
finetuned shift: -92.0060486395126 77.89921051192391
calculate shifts : 168 172 ./reduced_data/p4466637UW32R172.fit
initial shift: -91.77057356608478 77.80548628428929
86
finetuned shift: -91.7221144031113 77.8535079731854
calculate shifts : 169 172 ./reduced_data/p4466637UW32R173.fit
initial shift: -91.77057356608478 77.80548628428929
83
finetuned shift: -91.78866354472689 77.78758336242447
calculate shifts : 170 172 ./reduced_data/p4466637UW32R174.fit
initial shift: -91.77057356608478 77.80548628428929
85
finetuned shift: -91.86121277448983 77.76379198510551
calculate shifts : 171 172 ./reduced_data/p4466637UW32R175.fit
initial shift: -91.77057356608478 77.80548628428929
87
finetuned shift: -91.99167108142368 77.7946330753997
calculate shifts : 172 172 ./reduced_data/p4466637UW32R176.fit
initial shift: -92.76807980049875 77.80548628428929
79
finetuned shift: -92.56103798362176 77.33836498102119

define target, comparison and validation stars

We select these stars visually from the FITS image. It might be some iterations to find proper comparison and validation stars. More complicate algorithm can be create to automatically construct a good comparison star.

```
In [26]: data=fits.getdata('reduced_data/p4466637UW32R004.fit')
x_targ,y_targ=(193.39-1,358.18-1)
#x_comp,y_comp=(159.54-1,336.61-1)
#x_vali,y_vali=(111.89-1,358.47-1)
x_comp,y_comp=(329.82-1,375.68-1)
x_vali,y_vali=(179.24-1,413.60-1)
aper_targ = CircularAperture((x_targ,y_targ), r=10.)
aper_comp = CircularAperture((x_comp,y_comp), r=10.)
aper_vali = CircularAperture((x_vali,y_vali), r=10.)
plt.figure(figsize=(8,8))
plt.imshow(data, cmap='Greys_r', origin='lower', vmin=300,vmax=600, interpolation='nearest')
aper_targ.plot(color='red', lw=1.5, alpha=0.5)
aper_comp.plot(color='cyan', lw=1.5, alpha=0.5)
aper_vali.plot(color='yellow', lw=1.5, alpha=0.5)
plt.title('red: target, cyan: comparison, yellow: validation')
```

```
Out[26]: Text(0.5, 1.0, 'red: target, cyan: comparison, yellow: validation')
```



```

In [30]: from astropy.time import Time
naper=len(radii)
nfiles=len(cfiles)
lc_targ=np.zeros((1+2*naper,nfiles))
lc_comp=np.zeros((1+2*naper,nfiles))
lc_vali=np.zeros((1+2*naper,nfiles))

print("calculating light curves...")
for i,ifile in enumerate(cfiles):
    rootname,_=os.path.splitext(ifile)
    head=fits.getheader(ifile)
    datestr=head['DATE-OBS']
    date=np.array(datestr.split('/')).astype('int')
    date[2]=2000
    timestr=head['TIME']
    datetime="%4d-%2d-%2d"% (date[2],date[1],date[0])+'T'+timestr.strip()
    t=Time(datetime,format='isot',scale='utc')
    jd=t.mjd
    lc_targ[0,i]=jd
    lc_comp[0,i]=jd
    lc_vali[0,i]=jd

    print("MJD: ",datetime,jd)
    catfile=rootname+'-cat.fits'
    print("reading:", i+1,len(cfiles),ifile)

    cat=fits.getdata(catfile)
    x=cat['x_sht']
    y=cat['y_sht']

    # get target star
    d=np.sqrt((x-x_targ)**2+(y-y_targ)**2)
    idx=np.argmin(d)
    icat=cat[idx]
    dt=d[idx]
    if d[idx]<2:
        for j in range(naper):
            lc_targ[j+1,i]=icat['aperture_sum_'+str(j)]
            lc_targ[naper+j+1,i]=icat['aperture_sum_err_'+str(j)]
    else:
        lc_targ[1:,i]=np.nan

    # get comparison star
    d=np.sqrt((x-x_comp)**2+(y-y_comp)**2)
    idx=np.argmin(d)
    icat=cat[idx]
    dc=d[idx]
    if d[idx]<2:
        for j in range(naper):
            lc_comp[j+1,i]=icat['aperture_sum_'+str(j)]
            lc_comp[naper+j+1,i]=icat['aperture_sum_err_'+str(j)]
    else:
        lc_comp[1:,i]=np.nan

    # get validation star
    d=np.sqrt((x-x_vali)**2+(y-y_vali)**2)
    idx=np.argmin(d)
    icat=cat[idx]
    dv=d[idx]
    if d[idx]<2:
        for j in range(naper):
            lc_vali[j+1,i]=icat['aperture_sum_'+str(j)]
            lc_vali[naper+j+1,i]=icat['aperture_sum_err_'+str(j)]
    else:
        lc_vali[1:,i]=np.nan

    print(dt,dc,dv)

```

calculating light curves...

MJD: 2000-12-10T12:10:40.0 51888.50740740741
reading: 1 172 ./reduced_data/p4466637UW32R004.fit
0.4891744363194606 0.29596970708974923 0.321017404555759
MJD: 2000-12-10T12:12:24.0 51888.50861111111
reading: 2 172 ./reduced_data/p4466637UW32R005.fit
0.5167903663487056 0.4775263325822888 0.3406265404215718
MJD: 2000-12-10T12:18:00.0 51888.5125
reading: 3 172 ./reduced_data/p4466637UW32R007.fit
0.2095255594238134 0.42244232426968165 0.3366718735534705
MJD: 2000-12-10T12:19:44.0 51888.513703703706
reading: 4 172 ./reduced_data/p4466637UW32R008.fit
0.4594392926931432 0.328575787081086 0.409360036277513
MJD: 2000-12-10T12:22:06.0 51888.51534722222
reading: 5 172 ./reduced_data/p4466637UW32R009.fit
0.5101214215281387 0.2986032277035594 0.39007776507760705
MJD: 2000-12-10T12:25:44.0 51888.51787037037
reading: 6 172 ./reduced_data/p4466637UW32R010.fit
0.3569196230127137 0.34640887968344436 0.4277254954747869
MJD: 2000-12-10T12:39:11.0 51888.52721064815
reading: 7 172 ./reduced_data/p4466637UW32R011.fit
0.122550952149238 0.4761337073341793 0.37011546447045596
MJD: 2000-12-10T12:40:45.0 51888.52829861111
reading: 8 172 ./reduced_data/p4466637UW32R012.fit
0.39731359222217527 0.3305033876143217 0.4324172805314206
MJD: 2000-12-10T12:42:19.0 51888.529386574075
reading: 9 172 ./reduced_data/p4466637UW32R013.fit
0.47784597465357553 0.2972020602786654 0.47401723714858934
MJD: 2000-12-10T12:43:54.0 51888.530486111114
reading: 10 172 ./reduced_data/p4466637UW32R014.fit
0.5163560620060069 0.3055844994476993 0.3580893071913862
MJD: 2000-12-10T12:45:29.0 51888.53158564815
reading: 11 172 ./reduced_data/p4466637UW32R015.fit
0.5037210427335553 0.27633761254842343 0.3738031328914612
MJD: 2000-12-10T12:47:03.0 51888.53267361111
reading: 12 172 ./reduced_data/p4466637UW32R016.fit
0.47112109133661445 0.30472991805021227 0.3703199722518145
MJD: 2000-12-10T12:48:38.0 51888.53377314815
reading: 13 172 ./reduced_data/p4466637UW32R017.fit
0.4853456837841154 0.2955867705399801 0.36194431350473055
MJD: 2000-12-10T12:50:13.0 51888.53487268519
reading: 14 172 ./reduced_data/p4466637UW32R018.fit
0.48037414996577293 0.3524763777993344 0.42210335465926496
MJD: 2000-12-10T12:51:47.0 51888.53596064815
reading: 15 172 ./reduced_data/p4466637UW32R019.fit
0.5369583373863472 0.2705574165951567 0.32610767158212
MJD: 2000-12-10T12:53:22.0 51888.53706018518
reading: 16 172 ./reduced_data/p4466637UW32R020.fit
0.4893960247116098 0.3034921390267855 0.33608365432222526
MJD: 2000-12-10T12:54:57.0 51888.53815972222
reading: 17 172 ./reduced_data/p4466637UW32R021.fit
0.515761521424319 0.2887169154096072 0.3383878148861882
MJD: 2000-12-10T12:56:33.0 51888.53927083333
reading: 18 172 ./reduced_data/p4466637UW32R022.fit
0.5041724518566983 0.30373266222335593 0.4689608205107674
MJD: 2000-12-10T12:58:07.0 51888.540358796294
reading: 19 172 ./reduced_data/p4466637UW32R023.fit
0.4995269938286362 0.6145348224277162 0.28017939353243393
MJD: 2000-12-10T12:59:41.0 51888.541446759256
reading: 20 172 ./reduced_data/p4466637UW32R024.fit
0.2339060719230333 0.7115552642715538 0.6709491308105289
MJD: 2000-12-10T13:01:15.0 51888.54253472222
reading: 21 172 ./reduced_data/p4466637UW32R025.fit
0.5191758653594443 0.289362373433921 0.3139645706681824
MJD: 2000-12-10T13:02:50.0 51888.54363425926
reading: 22 172 ./reduced_data/p4466637UW32R026.fit
0.5204504336494796 0.29312191425511563 0.35592119373063935
MJD: 2000-12-10T13:04:25.0 51888.5447337963
reading: 23 172 ./reduced_data/p4466637UW32R027.fit
0.33307838177108884 0.30777741011448073 0.3834794343877042
MJD: 2000-12-10T13:06:00.0 51888.54583333333
reading: 24 172 ./reduced_data/p4466637UW32R028.fit
0.4973986198788106 0.3003905282672348 0.4137352551120866
MJD: 2000-12-10T13:07:34.0 51888.5469212963
reading: 25 172 ./reduced_data/p4466637UW32R029.fit
0.5092286122754727 0.2650369208881819 0.3185697324230657

MJD: 2000-12-10T13:09:10.0 51888.54803240741
reading: 26 172 ./reduced_data/p4466637UW32R030.fit
0.4867973361930927 0.6007126335331812 0.26137208289641606
MJD: 2000-12-10T13:10:47.0 51888.549155092594
reading: 27 172 ./reduced_data/p4466637UW32R031.fit
0.48418556180044614 0.6430235540474133 0.47480182591365144
MJD: 2000-12-10T13:12:21.0 51888.55024305556
reading: 28 172 ./reduced_data/p4466637UW32R032.fit
0.48382189532161024 0.30007350468206223 0.3576117370154583
MJD: 2000-12-10T13:13:57.0 51888.551354166666
reading: 29 172 ./reduced_data/p4466637UW32R033.fit
0.2070002889109438 0.40971412473577634 0.3151011806192018
MJD: 2000-12-10T13:15:31.0 51888.55244212963
reading: 30 172 ./reduced_data/p4466637UW32R034.fit
0.28353765168198053 0.7147013070530963 0.28697642923234457
MJD: 2000-12-10T13:17:07.0 51888.55355324074
reading: 31 172 ./reduced_data/p4466637UW32R035.fit
0.4800412710139013 0.19545170827020236 0.4715712770516673
MJD: 2000-12-10T13:18:42.0 51888.55465277778
reading: 32 172 ./reduced_data/p4466637UW32R036.fit
0.4557807078054474 0.2862361340128449 0.4811546886531394
MJD: 2000-12-10T13:20:16.0 51888.55574074074
reading: 33 172 ./reduced_data/p4466637UW32R037.fit
0.5160687069071463 0.29577927629457457 0.3633501124250359
MJD: 2000-12-10T13:21:51.0 51888.55684027778
reading: 34 172 ./reduced_data/p4466637UW32R038.fit
0.521285380537706 0.28059764714390667 0.3488231115452437
MJD: 2000-12-10T13:23:26.0 51888.55793981482
reading: 35 172 ./reduced_data/p4466637UW32R039.fit
0.48896434299488273 0.1524704167669758 0.4200639134141857
MJD: 2000-12-10T13:25:01.0 51888.55903935185
reading: 36 172 ./reduced_data/p4466637UW32R040.fit
0.4427562848789946 0.3107277737652934 0.43978886524175037
MJD: 2000-12-10T13:26:37.0 51888.56015046296
reading: 37 172 ./reduced_data/p4466637UW32R041.fit
0.38112372854927323 0.2956544844905883 0.39776330850193387
MJD: 2000-12-10T13:28:12.0 51888.56125
reading: 38 172 ./reduced_data/p4466637UW32R042.fit
0.5089286890822995 0.29847798098669653 0.3742741446588242
MJD: 2000-12-10T13:29:46.0 51888.56233796296
reading: 39 172 ./reduced_data/p4466637UW32R043.fit
0.17726747223488332 0.43042736558204475 0.34369888187485786
MJD: 2000-12-10T13:31:21.0 51888.5634375
reading: 40 172 ./reduced_data/p4466637UW32R044.fit
0.5057398932527911 0.2995583236241799 0.3852792094573483
MJD: 2000-12-10T13:32:56.0 51888.56453703704
reading: 41 172 ./reduced_data/p4466637UW32R045.fit
0.10031196288623388 0.4688699089688693 0.3819730786556358
MJD: 2000-12-10T13:34:31.0 51888.56563657407
reading: 42 172 ./reduced_data/p4466637UW32R046.fit
0.47211831911554175 0.2733331367956828 0.45309787942909996
MJD: 2000-12-10T13:36:05.0 51888.566724537035
reading: 43 172 ./reduced_data/p4466637UW32R047.fit
0.5178227813644725 0.3010953110972464 0.3366948360307021
MJD: 2000-12-10T13:37:39.0 51888.5678125
reading: 44 172 ./reduced_data/p4466637UW32R048.fit
0.10606679416759272 0.4897334877570133 0.36326000902948896
MJD: 2000-12-10T13:39:14.0 51888.56891203704
reading: 45 172 ./reduced_data/p4466637UW32R049.fit
0.5159795069245333 0.28466721122899585 0.33855396092115786
MJD: 2000-12-10T13:40:48.0 51888.57
reading: 46 172 ./reduced_data/p4466637UW32R050.fit
0.09721313388847047 0.503450379049169 0.4081932063706049
MJD: 2000-12-10T13:42:22.0 51888.57108796296
reading: 47 172 ./reduced_data/p4466637UW32R051.fit
0.2395855972747517 0.7011997052052806 0.6376043657404318
MJD: 2000-12-10T13:43:56.0 51888.572175925925
reading: 48 172 ./reduced_data/p4466637UW32R052.fit
0.07853739082599033 0.5192902836058475 0.4180931963360668
MJD: 2000-12-10T13:45:31.0 51888.573275462964
reading: 49 172 ./reduced_data/p4466637UW32R053.fit
0.10500274638636614 0.4173601968120889 0.5119220822105263
MJD: 2000-12-10T13:47:05.0 51888.57436342593
reading: 50 172 ./reduced_data/p4466637UW32R054.fit
0.5191756492849465 0.2986859643083259 0.34162380301030276
MJD: 2000-12-10T13:48:40.0 51888.57546296297

reading: 51 172 ./reduced_data/p4466637UW32R055.fit
0.2908350886975404 0.24009731775466644 0.3171987387538777
MJD: 2000-12-10T13:50:15.0 51888.5765625
reading: 52 172 ./reduced_data/p4466637UW32R056.fit
0.11902025664408732 0.46762933386572025 0.3933693944941881
MJD: 2000-12-10T13:51:50.0 51888.57766203704
reading: 53 172 ./reduced_data/p4466637UW32R057.fit
0.5611419480108474 0.2990258262837825 0.533321018576232
MJD: 2000-12-10T13:53:24.0 51888.57875
reading: 54 172 ./reduced_data/p4466637UW32R058.fit
0.4840686749499057 0.29041409816495095 0.3354750076926965
MJD: 2000-12-10T13:54:58.0 51888.57983796296
reading: 55 172 ./reduced_data/p4466637UW32R059.fit
0.5013394815001257 0.2871163380972061 0.36042547345709286
MJD: 2000-12-10T13:56:33.0 51888.5809375
reading: 56 172 ./reduced_data/p4466637UW32R060.fit
0.468868577923873 0.30051016183487383 0.36269138474328505
MJD: 2000-12-10T13:58:07.0 51888.582025462965
reading: 57 172 ./reduced_data/p4466637UW32R061.fit
0.1962661363275052 0.4018899122169549 0.34566631365620293
MJD: 2000-12-10T13:59:41.0 51888.58311342593
reading: 58 172 ./reduced_data/p4466637UW32R062.fit
0.08556572710737084 0.497960101955587 0.4023554400979704
MJD: 2000-12-10T14:01:15.0 51888.58420138889
reading: 59 172 ./reduced_data/p4466637UW32R063.fit
0.5110775520278993 0.3002752856294515 0.3485968577967477
MJD: 2000-12-10T14:02:50.0 51888.58530092592
reading: 60 172 ./reduced_data/p4466637UW32R064.fit
0.5136059684626338 0.2829474610487234 0.356212953558364
MJD: 2000-12-10T14:04:24.0 51888.586388888885
reading: 61 172 ./reduced_data/p4466637UW32R065.fit
0.19150417849710272 0.4072716398411403 0.3300902450555399
MJD: 2000-12-10T14:05:58.0 51888.587476851855
reading: 62 172 ./reduced_data/p4466637UW32R066.fit
0.5136273153166548 0.29962897230463864 0.3802021027050266
MJD: 2000-12-10T14:07:32.0 51888.58856481482
reading: 63 172 ./reduced_data/p4466637UW32R067.fit
0.1810784029345175 0.43426089110755395 0.3844349824715202
MJD: 2000-12-10T14:09:07.0 51888.58966435185
reading: 64 172 ./reduced_data/p4466637UW32R068.fit
0.502936806706438 0.2814781643483687 0.3813942141757244
MJD: 2000-12-10T14:10:42.0 51888.59076388889
reading: 65 172 ./reduced_data/p4466637UW32R069.fit
0.5362785952091551 0.30120772923740224 0.3766977217016444
MJD: 2000-12-10T14:12:16.0 51888.59185185185
reading: 66 172 ./reduced_data/p4466637UW32R070.fit
0.3850235840422742 0.32355987550095805 0.44480459367997693
MJD: 2000-12-10T14:13:52.0 51888.59296296296
reading: 67 172 ./reduced_data/p4466637UW32R071.fit
0.5088591548926902 0.2915393262083811 0.36049069649310145
MJD: 2000-12-10T14:15:27.0 51888.5940625
reading: 68 172 ./reduced_data/p4466637UW32R072.fit
0.5147138970903624 0.2661601776540353 0.3448976142035381
MJD: 2000-12-10T14:17:02.0 51888.59516203704
reading: 69 172 ./reduced_data/p4466637UW32R073.fit
0.5144468758262082 0.2660633657011172 0.36955678735677294
MJD: 2000-12-10T14:18:36.0 51888.59625
reading: 70 172 ./reduced_data/p4466637UW32R074.fit
0.12916107751203834 0.44248564647775346 0.3679549529327019
MJD: 2000-12-10T14:20:10.0 51888.597337962965
reading: 71 172 ./reduced_data/p4466637UW32R075.fit
0.4784510577466102 0.3081804094498141 0.4157191618631034
MJD: 2000-12-10T14:21:46.0 51888.598449074074
reading: 72 172 ./reduced_data/p4466637UW32R076.fit
0.49842720139672736 0.3496720007247439 0.46484108226235293
MJD: 2000-12-10T14:23:21.0 51888.59954861111
reading: 73 172 ./reduced_data/p4466637UW32R077.fit
0.4754996406081841 0.29172482842667824 0.4075521044630304
MJD: 2000-12-10T14:24:56.0 51888.600648148145
reading: 74 172 ./reduced_data/p4466637UW32R078.fit
0.4371166532872785 0.3682883608436545 0.4710294185677361
MJD: 2000-12-10T14:26:31.0 51888.601747685185
reading: 75 172 ./reduced_data/p4466637UW32R079.fit
0.26362139446757593 0.43641159816352765 0.42525448216316275
MJD: 2000-12-10T14:28:06.0 51888.602847222224
reading: 76 172 ./reduced_data/p4466637UW32R080.fit

0.05967650396128107 0.5950160723211514 0.4878236569464386
MJD: 2000-12-10T14:29:41.0 51888.603946759256
reading: 77 172 ./reduced_data/p4466637UW32R081.fit
0.5509882082338322 0.26009363053741086 0.35737774868654565
MJD: 2000-12-10T14:31:14.0 51888.60502314815
reading: 78 172 ./reduced_data/p4466637UW32R082.fit
0.4292561316206966 0.326671187882552 0.42625530130495415
MJD: 2000-12-10T14:32:49.0 51888.60612268518
reading: 79 172 ./reduced_data/p4466637UW32R083.fit
0.5583754002350876 0.2594015382422054 0.5328259056170097
MJD: 2000-12-10T14:34:23.0 51888.60721064815
reading: 80 172 ./reduced_data/p4466637UW32R084.fit
0.15666748978380426 0.438733598513246 0.3241426304168436
MJD: 2000-12-10T14:35:57.0 51888.608298611114
reading: 81 172 ./reduced_data/p4466637UW32R085.fit
0.49544188910882025 0.29345358855197556 0.49805383825873034
MJD: 2000-12-10T14:37:31.0 51888.60938657408
reading: 82 172 ./reduced_data/p4466637UW32R086.fit
0.507978709776898 0.28663762669258125 0.5167276784945426
MJD: 2000-12-10T14:39:06.0 51888.61048611111
reading: 83 172 ./reduced_data/p4466637UW32R087.fit
0.5260547536435631 0.30901376159802685 0.5182613746900404
MJD: 2000-12-10T14:40:40.0 51888.61157407407
reading: 84 172 ./reduced_data/p4466637UW32R088.fit
0.13558038236586362 0.21409908402516012 0.09052151444075042
MJD: 2000-12-10T14:42:15.0 51888.61267361111
reading: 85 172 ./reduced_data/p4466637UW32R089.fit
0.057344624759858465 0.18477689925563617 0.415415603384885
MJD: 2000-12-10T14:43:50.0 51888.61377314815
reading: 86 172 ./reduced_data/p4466637UW32R090.fit
0.4882802532071491 0.24080684092606236 0.4848282736081803
MJD: 2000-12-10T14:45:24.0 51888.61486111111
reading: 87 172 ./reduced_data/p4466637UW32R091.fit
0.15017707290352716 0.43102952655112753 0.37284053492917735
MJD: 2000-12-10T14:46:59.0 51888.615960648145
reading: 88 172 ./reduced_data/p4466637UW32R092.fit
0.44679032997028595 0.35855020314125546 0.5328146917821202
MJD: 2000-12-10T14:48:34.0 51888.617060185185
reading: 89 172 ./reduced_data/p4466637UW32R093.fit
0.504462936833276 0.29292229957638133 0.38995952010504
MJD: 2000-12-10T14:50:09.0 51888.618159722224
reading: 90 172 ./reduced_data/p4466637UW32R094.fit
0.3648573921051785 0.376887572504795 0.526065052576493
MJD: 2000-12-10T14:51:44.0 51888.619259259256
reading: 91 172 ./reduced_data/p4466637UW32R095.fit
0.4753434730355725 0.26968890474387924 0.37241163766313506
MJD: 2000-12-10T14:53:19.0 51888.620358796295
reading: 92 172 ./reduced_data/p4466637UW32R096.fit
0.5167736625944189 0.29674971609472 0.5132964604178749
MJD: 2000-12-10T14:54:54.0 51888.621458333335
reading: 93 172 ./reduced_data/p4466637UW32R097.fit
0.5009565527420802 0.28933973888063325 0.36813463965539484
MJD: 2000-12-10T14:56:28.0 51888.6225462963
reading: 94 172 ./reduced_data/p4466637UW32R098.fit
0.537569181191866 0.23262076025717496 0.3134871864839953
MJD: 2000-12-10T14:58:02.0 51888.62363425926
reading: 95 172 ./reduced_data/p4466637UW32R099.fit
0.20850043119704167 0.37036309765839315 0.276175642233036
MJD: 2000-12-10T14:59:37.0 51888.6247337963
reading: 96 172 ./reduced_data/p4466637UW32R100.fit
0.5420625309150902 0.2708570714621587 0.3366427166172698
MJD: 2000-12-10T15:01:11.0 51888.62582175926
reading: 97 172 ./reduced_data/p4466637UW32R101.fit
0.511136715466895 0.20315903154020085 0.2976733972995269
MJD: 2000-12-10T15:02:46.0 51888.626921296294
reading: 98 172 ./reduced_data/p4466637UW32R102.fit
0.4922947669312266 0.2731289907696106 0.4523834183890059
MJD: 2000-12-10T15:04:20.0 51888.62800925926
reading: 99 172 ./reduced_data/p4466637UW32R103.fit
0.1441760717031212 0.4375331100921786 0.3157388319035051
MJD: 2000-12-10T15:05:55.0 51888.629108796296
reading: 100 172 ./reduced_data/p4466637UW32R104.fit
0.3492182341125786 0.39611429925055475 0.3162156559082067
MJD: 2000-12-10T15:07:30.0 51888.630208333336
reading: 101 172 ./reduced_data/p4466637UW32R105.fit
0.49901215399753845 0.29707596550015597 0.37411330918328234

MJD: 2000-12-10T15:09:04.0 51888.6312962963
reading: 102 172 ./reduced_data/p4466637UW32R106.fit
0.1476597579108339 0.42814453818586773 0.32262363330314414
MJD: 2000-12-10T15:10:39.0 51888.63239583333
reading: 103 172 ./reduced_data/p4466637UW32R107.fit
0.3470990746578177 0.24919840266102744 0.30821311047017863
MJD: 2000-12-10T15:12:14.0 51888.63349537037
reading: 104 172 ./reduced_data/p4466637UW32R108.fit
0.5438812056684669 0.2747736440181703 0.35910122916965287
MJD: 2000-12-10T15:13:49.0 51888.63459490741
reading: 105 172 ./reduced_data/p4466637UW32R109.fit
0.4849922011588603 0.273076567439873 0.44691269896373803
MJD: 2000-12-10T15:15:23.0 51888.63568287037
reading: 106 172 ./reduced_data/p4466637UW32R110.fit
0.5209419052380402 0.2712906283848545 0.34243309945754147
MJD: 2000-12-10T15:16:58.0 51888.636782407404
reading: 107 172 ./reduced_data/p4466637UW32R111.fit
0.5312037331577911 0.2799999983609015 0.5002921505652793
MJD: 2000-12-10T15:18:32.0 51888.637870370374
reading: 108 172 ./reduced_data/p4466637UW32R112.fit
0.2537770050732787 0.3518254231459175 0.327594431883545
MJD: 2000-12-10T15:20:07.0 51888.638969907406
reading: 109 172 ./reduced_data/p4466637UW32R113.fit
0.5038778480112184 0.2930991271012918 0.5149407695746125
MJD: 2000-12-10T15:21:42.0 51888.640069444446
reading: 110 172 ./reduced_data/p4466637UW32R114.fit
0.5478607579542887 0.2536713816959955 0.47605426228541176
MJD: 2000-12-10T15:23:17.0 51888.641168981485
reading: 111 172 ./reduced_data/p4466637UW32R115.fit
0.46398643527179584 0.3209667070355865 0.4175669301386374
MJD: 2000-12-10T15:24:51.0 51888.64225694445
reading: 112 172 ./reduced_data/p4466637UW32R116.fit
0.5074016282379672 0.2467287240144847 0.3202900713330204
MJD: 2000-12-10T15:26:27.0 51888.64336805556
reading: 113 172 ./reduced_data/p4466637UW32R117.fit
0.16681472405473718 0.42709121930760024 0.3854137240105068
MJD: 2000-12-10T15:28:00.0 51888.64444444444
reading: 114 172 ./reduced_data/p4466637UW32R118.fit
0.4142193202440049 0.29136279439712637 0.4705992446741616
MJD: 2000-12-10T15:29:34.0 51888.645532407405
reading: 115 172 ./reduced_data/p4466637UW32R119.fit
0.5093204313784709 0.49852457545351875 0.38889238458836883
MJD: 2000-12-10T15:31:09.0 51888.646631944444
reading: 116 172 ./reduced_data/p4466637UW32R120.fit
0.05198560325970421 0.5641497092307902 0.473259425923051
MJD: 2000-12-10T15:32:43.0 51888.64771990741
reading: 117 172 ./reduced_data/p4466637UW32R121.fit
0.5287388777584218 0.47276158135451357 0.3176542456991517
MJD: 2000-12-10T15:34:17.0 51888.64880787037
reading: 118 172 ./reduced_data/p4466637UW32R122.fit
0.18628281765030308 0.4007593442356715 0.37256659955008475
MJD: 2000-12-10T15:35:52.0 51888.64990740741
reading: 119 172 ./reduced_data/p4466637UW32R123.fit
0.49251980363587555 0.25932526617431256 0.37036668677922163
MJD: 2000-12-10T15:37:25.0 51888.650983796295
reading: 120 172 ./reduced_data/p4466637UW32R124.fit
0.4403710500250972 0.3481233879893998 0.5202288379603817
MJD: 2000-12-10T15:39:00.0 51888.652083333334
reading: 121 172 ./reduced_data/p4466637UW32R125.fit
0.1900193470776994 0.3991916728751653 0.3267075643984162
MJD: 2000-12-10T15:40:34.0 51888.6531712963
reading: 122 172 ./reduced_data/p4466637UW32R126.fit
0.49041656916023424 0.25019982853635664 0.339046919023742
MJD: 2000-12-10T15:42:10.0 51888.654282407406
reading: 123 172 ./reduced_data/p4466637UW32R127.fit
0.17560994956817932 0.5181887869277637 0.15770895137182858
MJD: 2000-12-10T15:43:45.0 51888.655381944445
reading: 124 172 ./reduced_data/p4466637UW32R128.fit
0.4708692585394305 0.26948415909021717 0.4870749367557393
MJD: 2000-12-10T15:45:19.0 51888.65646990741
reading: 125 172 ./reduced_data/p4466637UW32R129.fit
0.4558368686411126 0.2905485719654782 0.3939364117569018
MJD: 2000-12-10T15:46:53.0 51888.65755787037
reading: 126 172 ./reduced_data/p4466637UW32R130.fit
0.1444751986866399 0.43891413082059927 0.3523605370097928
MJD: 2000-12-10T15:48:28.0 51888.65865740741

reading: 127 172 ./reduced_data/p4466637UW32R131.fit
0.15279156837872584 0.4279584465343483 0.11767073673965532
MJD: 2000-12-10T15:50:02.0 51888.65974537037
reading: 128 172 ./reduced_data/p4466637UW32R132.fit
0.5317233918008449 0.2821111295646431 0.5496960562869415
MJD: 2000-12-10T15:51:36.0 51888.660833333335
reading: 129 172 ./reduced_data/p4466637UW32R133.fit
0.1582104111314308 0.4001633104453195 0.342735177314935
MJD: 2000-12-10T15:53:12.0 51888.661944444444
reading: 130 172 ./reduced_data/p4466637UW32R134.fit
0.5374960440021213 0.23418108418224048 0.3409286248295348
MJD: 2000-12-10T15:54:46.0 51888.66303240741
reading: 131 172 ./reduced_data/p4466637UW32R135.fit
0.49479495265223133 0.26693005107183926 0.34475289617745764
MJD: 2000-12-10T15:56:21.0 51888.664131944446
reading: 132 172 ./reduced_data/p4466637UW32R136.fit
0.49447618613304467 0.29298854103507405 0.3475326830071488
MJD: 2000-12-10T15:57:55.0 51888.66521990741
reading: 133 172 ./reduced_data/p4466637UW32R137.fit
0.14359502163009247 0.41743835289420284 0.3238380826573701
MJD: 2000-12-10T15:59:31.0 51888.66633101852
reading: 134 172 ./reduced_data/p4466637UW32R138.fit
0.5065573493311222 0.2741357555793708 0.3734072918307207
MJD: 2000-12-10T16:01:07.0 51888.66744212963
reading: 135 172 ./reduced_data/p4466637UW32R139.fit
0.5100889848112823 0.27431592847252806 0.3973143494077226
MJD: 2000-12-10T16:02:42.0 51888.668541666666
reading: 136 172 ./reduced_data/p4466637UW32R140.fit
0.5613328900966467 0.25195352190829634 0.32338202343824624
MJD: 2000-12-10T16:04:16.0 51888.66962962963
reading: 137 172 ./reduced_data/p4466637UW32R141.fit
0.5089593615392076 0.2863487334090605 0.3911414620158993
MJD: 2000-12-10T16:05:51.0 51888.67072916667
reading: 138 172 ./reduced_data/p4466637UW32R142.fit
0.25861974155223044 0.39101571320069706 0.28701684262695043
MJD: 2000-12-10T16:07:25.0 51888.67181712963
reading: 139 172 ./reduced_data/p4466637UW32R143.fit
0.07482100754875368 0.2959294999177158 0.37909258061477025
MJD: 2000-12-10T16:08:59.0 51888.67290509259
reading: 140 172 ./reduced_data/p4466637UW32R144.fit
0.5078525199336323 0.30781180306875194 0.5726325844930945
MJD: 2000-12-10T16:10:34.0 51888.67400462963
reading: 141 172 ./reduced_data/p4466637UW32R145.fit
0.22193857670875627 0.34787752438997166 0.3821303984962477
MJD: 2000-12-10T16:12:10.0 51888.67511574074
reading: 142 172 ./reduced_data/p4466637UW32R146.fit
0.2182919320841012 0.19441666349803693 0.6899957314989903
MJD: 2000-12-10T16:13:45.0 51888.67621527778
reading: 143 172 ./reduced_data/p4466637UW32R147.fit
0.16600291728764477 0.4496280264370133 0.12099722789860602
MJD: 2000-12-10T16:15:19.0 51888.677303240744
reading: 144 172 ./reduced_data/p4466637UW32R148.fit
0.2189074666006782 0.4078572879238962 0.3727363429237597
MJD: 2000-12-10T16:16:53.0 51888.678391203706
reading: 145 172 ./reduced_data/p4466637UW32R149.fit
0.25345143492850136 0.32882265301529456 0.7106710702403443
MJD: 2000-12-10T16:18:27.0 51888.67947916667
reading: 146 172 ./reduced_data/p4466637UW32R150.fit
0.49017694152810165 0.2754480589916358 0.32948995460598385
MJD: 2000-12-10T16:20:03.0 51888.68059027778
reading: 147 172 ./reduced_data/p4466637UW32R151.fit
0.4584028190554797 0.33696301317068705 0.42616132303919085
MJD: 2000-12-10T16:21:37.0 51888.68167824074
reading: 148 172 ./reduced_data/p4466637UW32R152.fit
0.5180431565330762 0.22625847955708148 0.289309804361178
MJD: 2000-12-10T16:23:11.0 51888.6827662037
reading: 149 172 ./reduced_data/p4466637UW32R153.fit
0.11682372178533752 0.46987401218336905 0.39594080457147685
MJD: 2000-12-10T16:24:46.0 51888.68386574074
reading: 150 172 ./reduced_data/p4466637UW32R154.fit
0.5272174259298384 0.2567747572408085 0.49761415801972675
MJD: 2000-12-10T16:26:20.0 51888.684953703705
reading: 151 172 ./reduced_data/p4466637UW32R155.fit
0.32650284066699475 0.4227884696355732 0.3217390170912605
MJD: 2000-12-10T16:27:55.0 51888.68605324074
reading: 152 172 ./reduced_data/p4466637UW32R156.fit

0.2693377414159875 0.20924363957278594 0.25375875003689013
MJD: 2000-12-10T16:29:29.0 51888.68714120371
reading: 153 172 ./reduced_data/p4466637UW32R157.fit
0.1437500574918147 0.5092247671724859 0.45168279560513647
MJD: 2000-12-10T16:31:04.0 51888.68824074074
reading: 154 172 ./reduced_data/p4466637UW32R158.fit
0.5257129487431301 0.27188815124661225 0.5292183533205371
MJD: 2000-12-10T16:32:40.0 51888.689351851855
reading: 155 172 ./reduced_data/p4466637UW32R159.fit
0.4879016226745736 0.6573014147421637 0.4717413803739652
MJD: 2000-12-10T16:34:14.0 51888.69043981482
reading: 156 172 ./reduced_data/p4466637UW32R160.fit
0.4777329187746583 0.3816397847476832 0.42589937688804425
MJD: 2000-12-10T16:35:47.0 51888.691516203704
reading: 157 172 ./reduced_data/p4466637UW32R161.fit
0.18753462283652492 0.402247287304817 0.37700622059560057
MJD: 2000-12-10T16:37:22.0 51888.69261574074
reading: 158 172 ./reduced_data/p4466637UW32R162.fit
0.4599513844370491 0.40573705232953006 0.6241800766053126
MJD: 2000-12-10T16:38:56.0 51888.693703703706
reading: 159 172 ./reduced_data/p4466637UW32R163.fit
0.5926582600314697 0.41797062081992553 0.335159857682961
MJD: 2000-12-10T16:40:30.0 51888.69479166667
reading: 160 172 ./reduced_data/p4466637UW32R164.fit
0.45795759050288365 0.2723808509678992 0.4745453435288844
MJD: 2000-12-10T16:42:04.0 51888.69587962963
reading: 161 172 ./reduced_data/p4466637UW32R165.fit
0.4739935971900639 0.1677828710690945 0.4566490303082276
MJD: 2000-12-10T16:43:38.0 51888.696967592594
reading: 162 172 ./reduced_data/p4466637UW32R166.fit
0.13832252717066254 0.4679241899866798 0.39052756549045337
MJD: 2000-12-10T16:45:12.0 51888.69805555556
reading: 163 172 ./reduced_data/p4466637UW32R167.fit
0.16916638676098017 0.42579364307040224 0.29974089022597933
MJD: 2000-12-10T16:46:46.0 51888.69914351852
reading: 164 172 ./reduced_data/p4466637UW32R168.fit
0.2400015095639051 0.4108471305615227 0.32341823654433083
MJD: 2000-12-10T16:48:22.0 51888.70025462963
reading: 165 172 ./reduced_data/p4466637UW32R169.fit
0.4465153420805212 0.3369204188828916 0.5024563030891248
MJD: 2000-12-10T16:49:56.0 51888.70134259259
reading: 166 172 ./reduced_data/p4466637UW32R170.fit
0.17657132472504805 0.2722036461557725 0.33249366396609215
MJD: 2000-12-10T16:51:31.0 51888.70244212963
reading: 167 172 ./reduced_data/p4466637UW32R171.fit
0.5311409117076384 0.2500721619193943 0.3442493433032926
MJD: 2000-12-10T16:53:06.0 51888.70354166667
reading: 168 172 ./reduced_data/p4466637UW32R172.fit
0.3387585793479143 0.27279818900880565 0.3267052607528326
MJD: 2000-12-10T16:54:41.0 51888.7046412037
reading: 169 172 ./reduced_data/p4466637UW32R173.fit
0.28981962500327335 0.23269810131675253 0.3024672270648245
MJD: 2000-12-10T16:56:15.0 51888.705729166664
reading: 170 172 ./reduced_data/p4466637UW32R174.fit
0.5087257499933268 0.26529671443459485 0.31620543998043793
MJD: 2000-12-10T16:57:48.0 51888.70680555556
reading: 171 172 ./reduced_data/p4466637UW32R175.fit
0.5070442022983331 0.20415740275865152 0.31250821311565163
MJD: 2000-12-10T16:59:22.0 51888.70789351852
reading: 172 172 ./reduced_data/p4466637UW32R176.fit
0.2399621190658772 0.43119659990419934 0.4295912289047454

plot light curves

```

In [31]: iaper=4 # for iaper aperture
rlc_targ=lc_targ[iaper+1,:]/lc_comp[iaper+1,:]
rlc_vali=lc_vali[iaper+1,:]/lc_comp[iaper+1,:]

a1=1.0/lc_comp[iaper+1,:]; e1=lc_targ[iaper+naper+1,:]
a2=lc_targ[iaper+1,:]/lc_comp[iaper+1,:]**2; e2=lc_comp[iaper+naper+1,:]
rlcerr_targ=np.sqrt(a1**2*e1**2+a2**2*e2**2)
a1=1.0/lc_comp[iaper+1,:]; e1=lc_vali[iaper+naper+1,:]
a2=lc_vali[iaper+1,:]/lc_comp[iaper+1,:]**2; e2=lc_comp[iaper+naper+1,:]
rlcerr_vali=np.sqrt(a1**2*e1**2+a2**2*e2**2)

print('photerr for target/comparison:',np.median(rlcerr_targ))
print('photerr for validation/comparison:',np.median(rlcerr_vali))

idx=np.argmin(np.abs(lc_targ[0,:]-51888.67))
norm_targ=np.median(rlc_targ[idx:])
norm_vali=np.median(rlc_vali[idx:])
tmpx=[np.min(lc_targ[0,:]),np.max(lc_targ[0,:])]
plt.figure(figsize=(16,8))
plt.plot(lc_targ[0,:],rlc_targ/norm_targ,'r.')
plt.plot(lc_targ[0,:],rlc_vali/norm_vali+0.08,'b.')
plt.plot(tmpx,[1.0,1.0], 'g-',linewidth=2)
plt.plot(tmpx,[1.08,1.08], 'g-',linewidth=2)
plt.ylim([0.9,1.15])
plt.xlabel('MJD',fontsize=20)
plt.ylabel('$\Delta m$')
plt.title("red: exoplanet transit, blue: validation star")

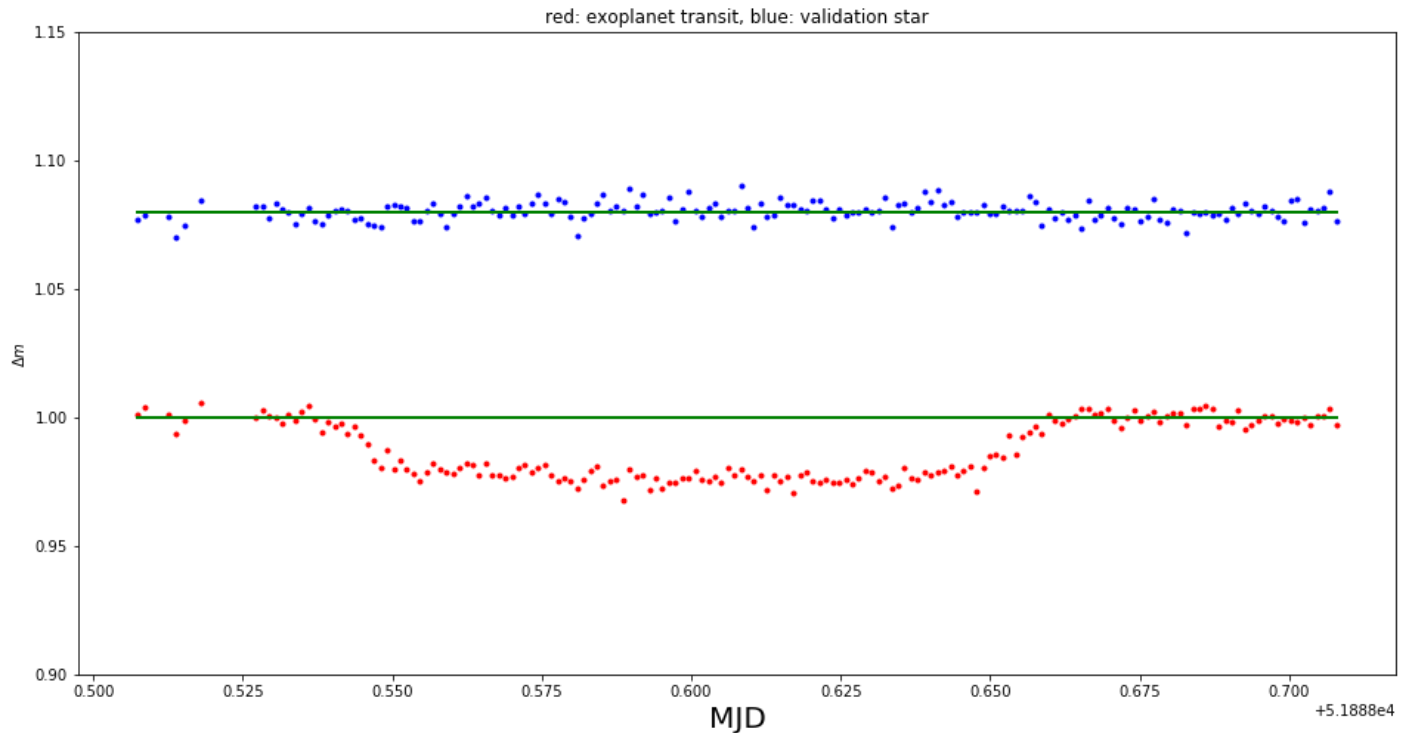
print(sigma_clipped_stats(2.5*np.log10(rlc_vali),sigma=3,maxiters=3))

```

```

photerr for target/comparison: 0.0009090872917237385
photerr for validation/comparison: 0.00044490494960693875
(-1.7927863191505704, -1.7927581752841855, 0.0038202598576284655)

```



Exercise

1. Try different comparison and validation stars to get better light curve for the transit of exoplanet.
2. Try different aperture fluxes to get better light curve (which aperture is better)
3. can be get better light curve through combining several comparison stars?
4. how to make the comparison stars be selected automatically?
5. what we can get from the light curve of the transit?

Open questions for data reduction of time-domain surveys

1. Survey -> Large FoV -> higher-accuracy data reduction
2. make everything automatic
3. understand the factors that affect the measurement accuracy of the light curves: source center, aperture, comparison stars, photometric method (aperture, PSF, aperture correction?, imaging quality: defocus, variable PSF)
4. how to select comparison stars / how to synthesize a comparison star, considering brightness, colors, distance etc.
5. how to face different image quality?
6. how to rapidly identify the transits / different types of variables from the light curves whether sparse or not?

In []: