LCOlens Photometry and Quasar Magnitude Extraction

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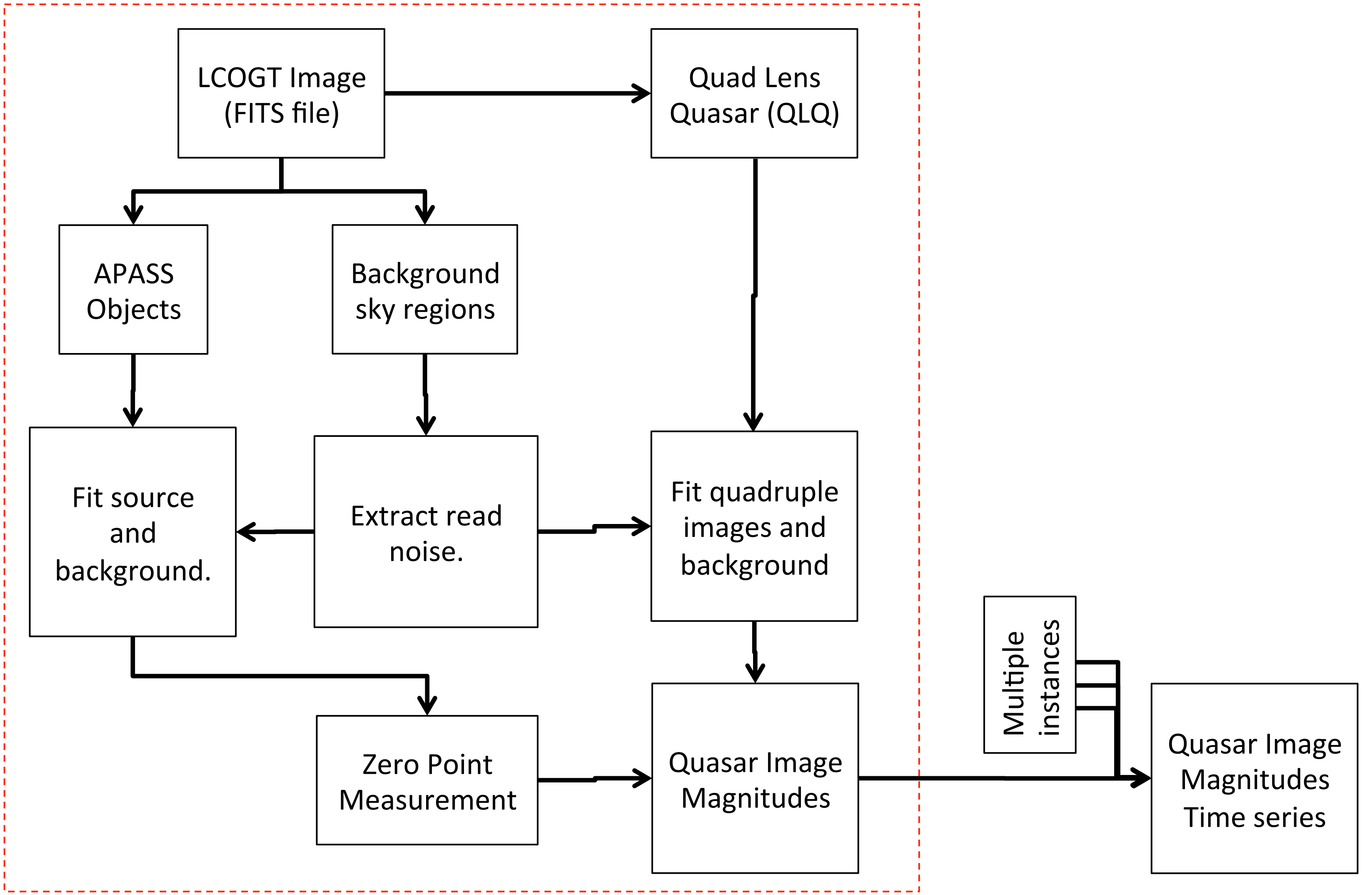
LCOLens Analysis



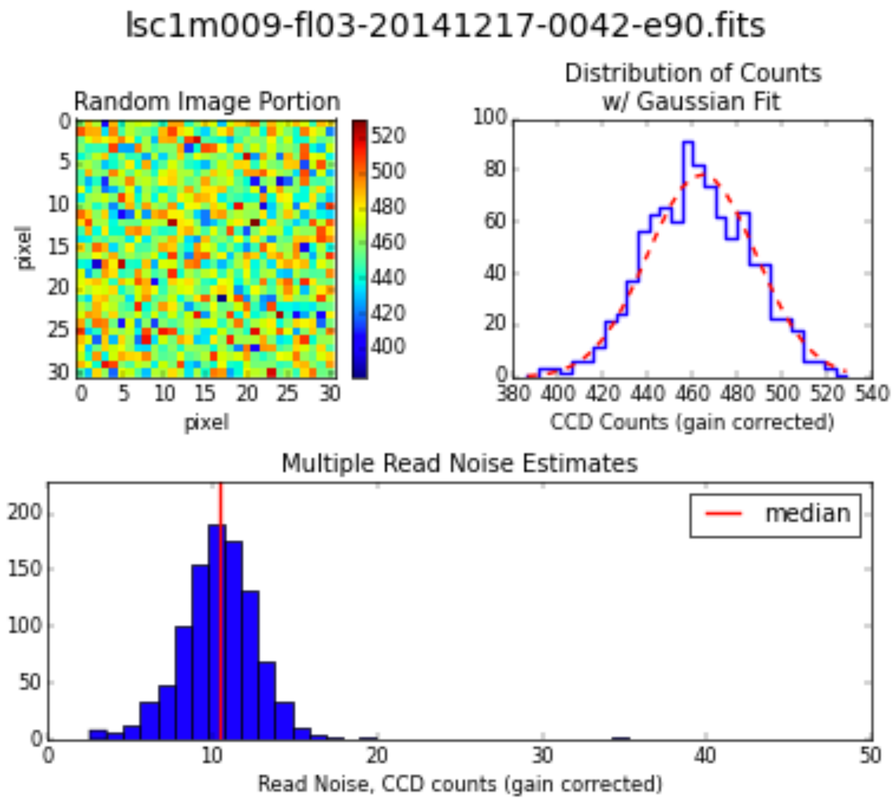
Read Noise Estimation

- Randomly sample 31x31 pixel patches of the FITS image. We exploit the fact that most of the image is background. I also stay 100 pixels away from the edges of the image.

- Fit a Gaussian distribution to the CCD count values in the 31x31 patch.

- Compare the fitted variance to the fitted mean of the patch distributions to estimate the read noise.

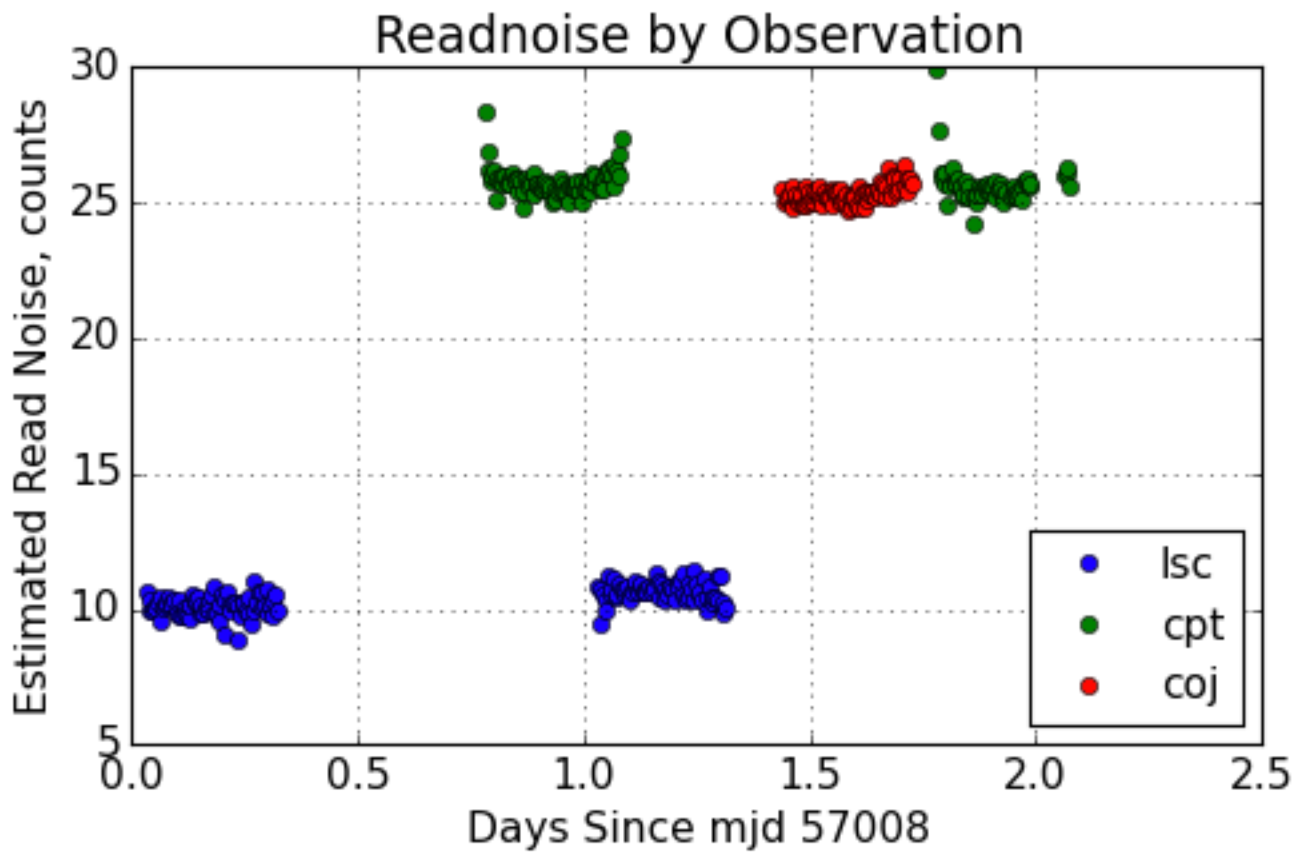
- I run this for 1000 patches and take the median of the distribution. The algorithm sometimes hits a source but most of the time it is dark sky and estimates cluster around this point.



Read Noise

Read noise estimation fairly stable.

There are still some issues when the air mass is high.

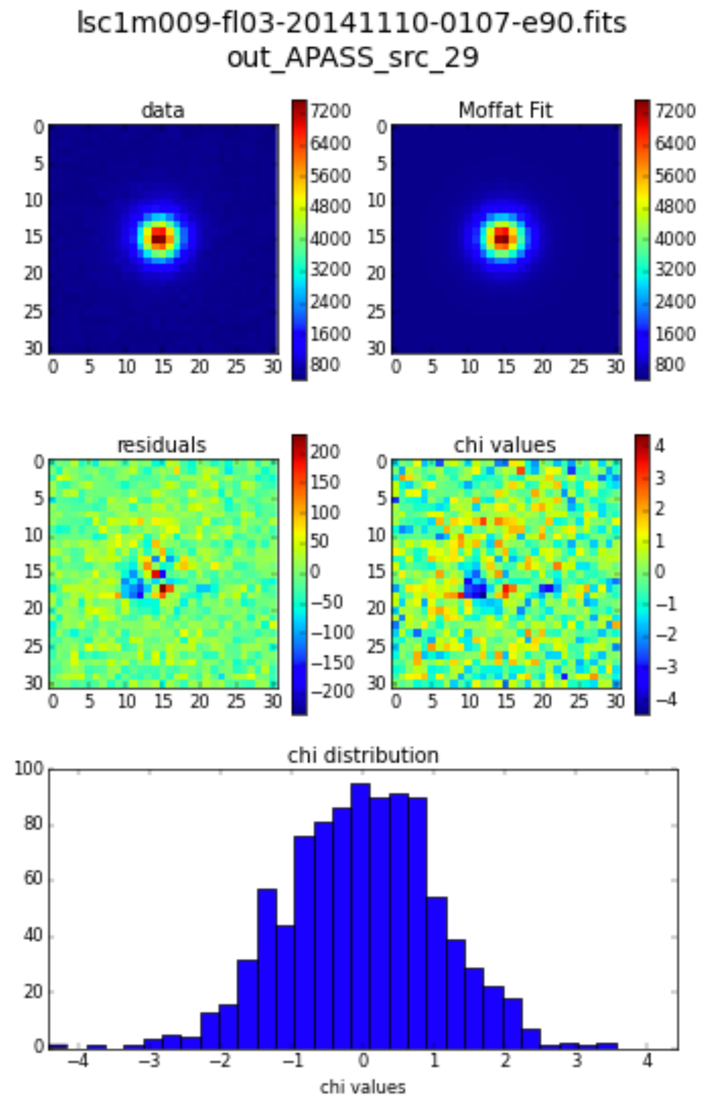


Zero Point Measurement

- Fit a circular Moffat profile with background to the APASS star.
- Estimate how much light came from the star (above background) using the integral to the fitted profile S.
- Estimate the ZP for each star i by comparing the instrument magnitude
- $ZP_i = -2.5\ log_{10}(S_i) + m_{APASS,\ i}$

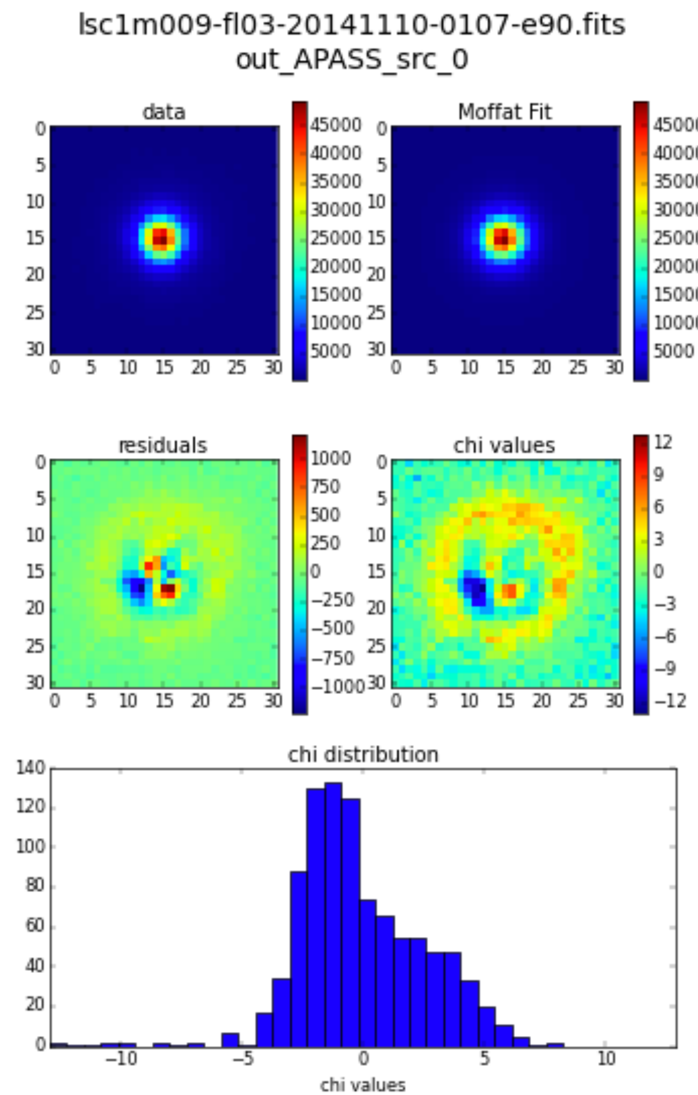
APASS Fitting Example

- Circular Moffat Profile
- Residuals show some evidence of ellipticity.
- Fit works best for the weaker sources.



APASS Fitting Example

- Stronger sources display other structure on the PSF that is not in the model (ellipticity, longer tails, etc.)



Excluded Observations

- First Cut: No quasar image found.
  - **image_261** coj1m003-kb71-20141218-0083-e90.fits
  - **image_262** coj1m003-kb71-20141218-0084-e90.fits
  - **image_263** coj1m003-kb71-20141218-0085-e90.fits
  - **image_264** coj1m003-kb71-20141218-0086-e90.fits
  - **image_265** coj1m003-kb71-20141218-0087-e90.fits
  - **image_337** coj1m003-kb71-20141218-0159-e90.fits
  - **image_364** cpt1m010-kb70-20141218-0103-e90.fits
  - **image_365** cpt1m010-kb70-20141218-0104-e90.fits
  - **image_386** cpt1m010-kb70-20141218-0126-e90.fits

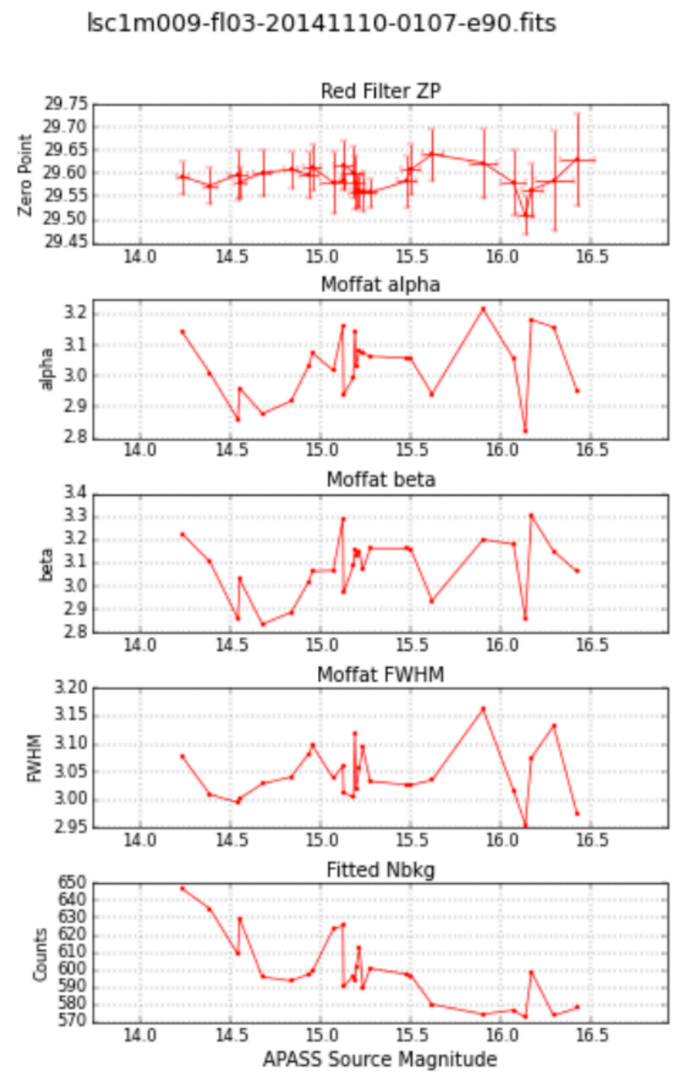
Excluded Observations

- Second Cut: No quasar image found.
  - **image_261** coj1m003-kb71-20141218-0083-e90.fits
  - **image_262** coj1m003-kb71-20141218-0084-e90.fits
  - **image_263** coj1m003-kb71-20141218-0085-e90.fits
  - **image_264** coj1m003-kb71-20141218-0086-e90.fits
  - **image_265** coj1m003-kb71-20141218-0087-e90.fits
  - **image_337** coj1m003-kb71-20141218-0159-e90.fits
  - **image_364** cpt1m010-kb70-20141218-0103-e90.fits
  - **image_365** cpt1m010-kb70-20141218-0104-e90.fits
  - **image_386** cpt1m010-kb70-20141218-0126-e90.fits

APASS Derived Zero Points

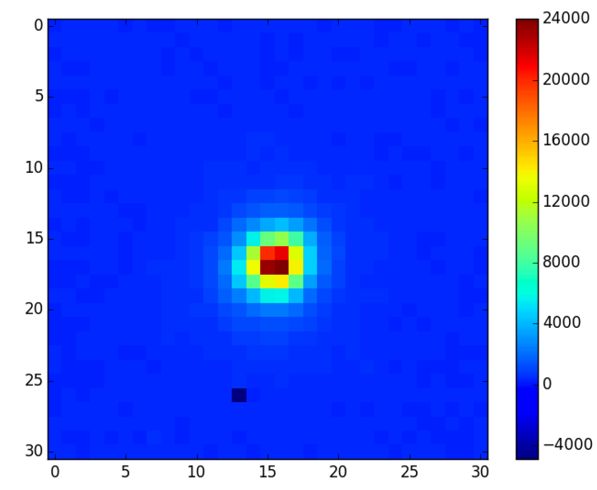
The zero points is estimated as the weighted mean of the sources.

<u>Estimated Uncertainties:</u>
Instrumental magnitude ~ 0.003 (statistical)
APASS ensemble ~ 0.055 (not included in result)
Weighted RMS of Zero points 0.026



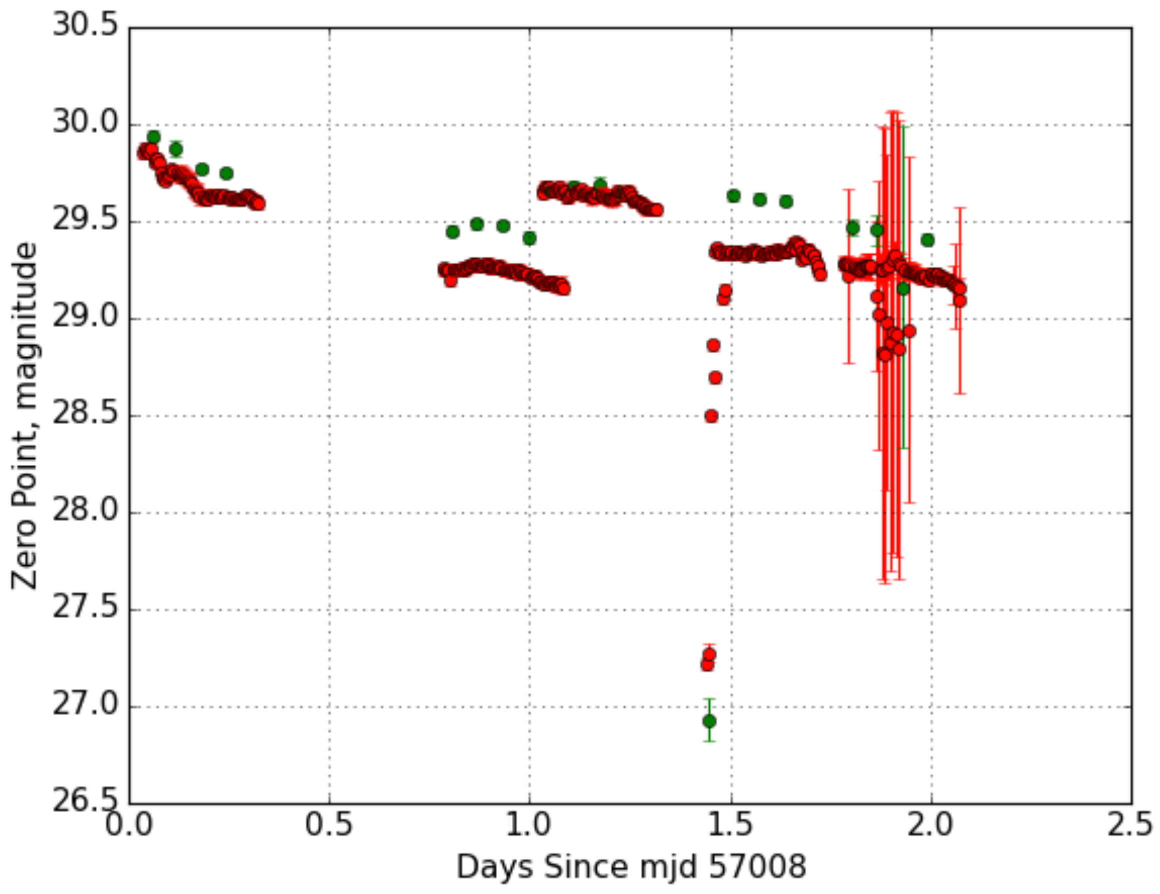
Other Anomalies

- Caution: Negative Values Found in the Array (fixable, just need to add masking).
  - **Image_399** coj1m003-kb71-20141218-0083-e90.fits
  - And others. 398 – 418
  - Tend to run into them while looping through APASS sources.
  - Currently bypassed by a try, except statement. Some APASS sources not being used. This is fixable by masking.

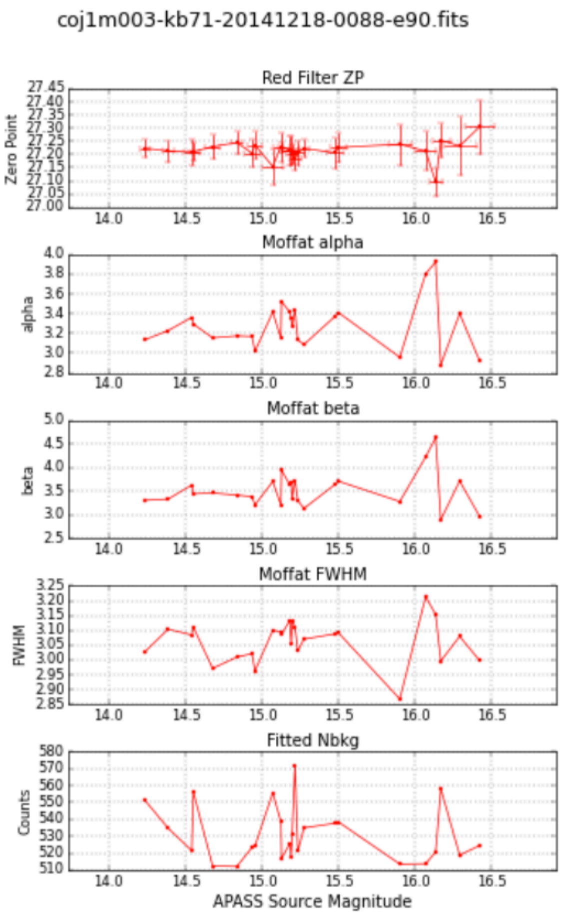


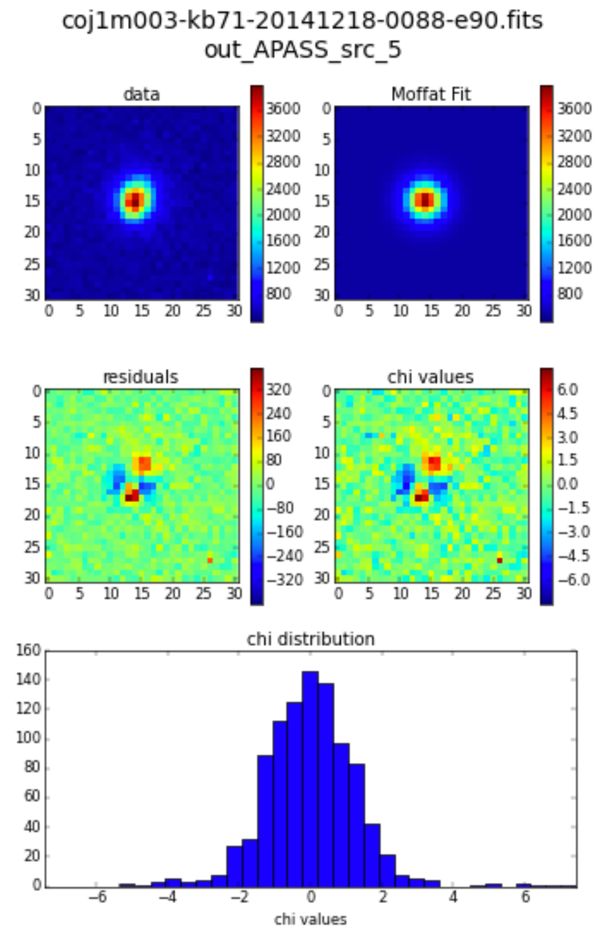
Zero Points

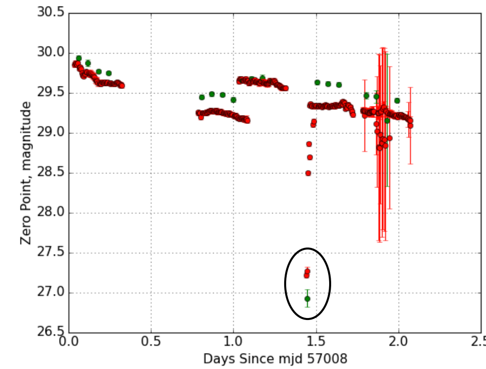
Green and red colored points correspond to the filter used.

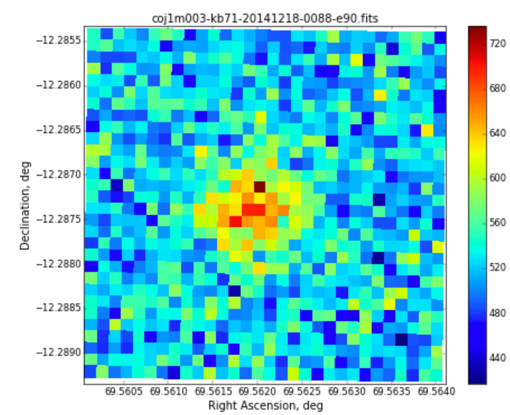


Zero Points



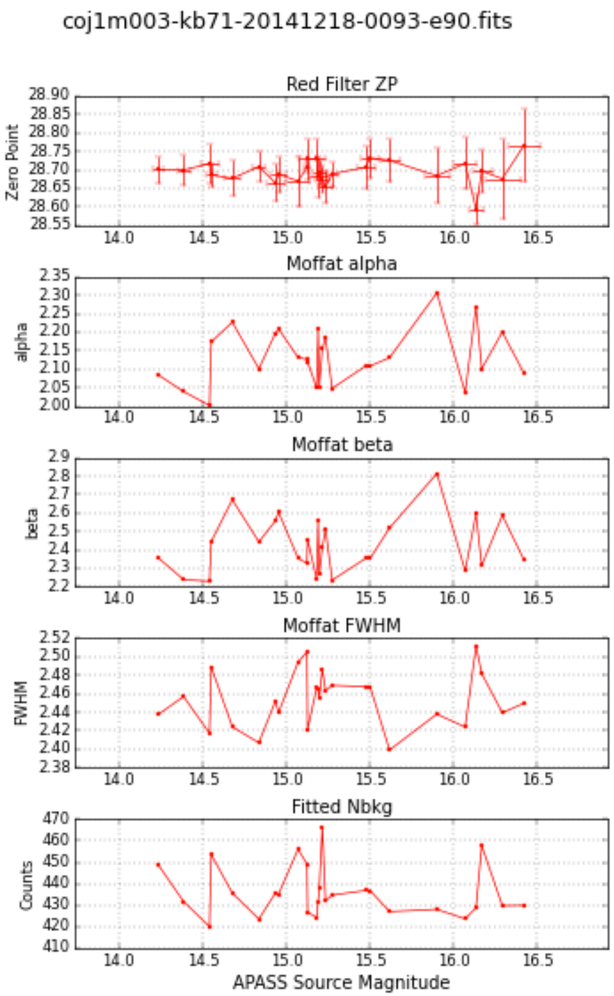


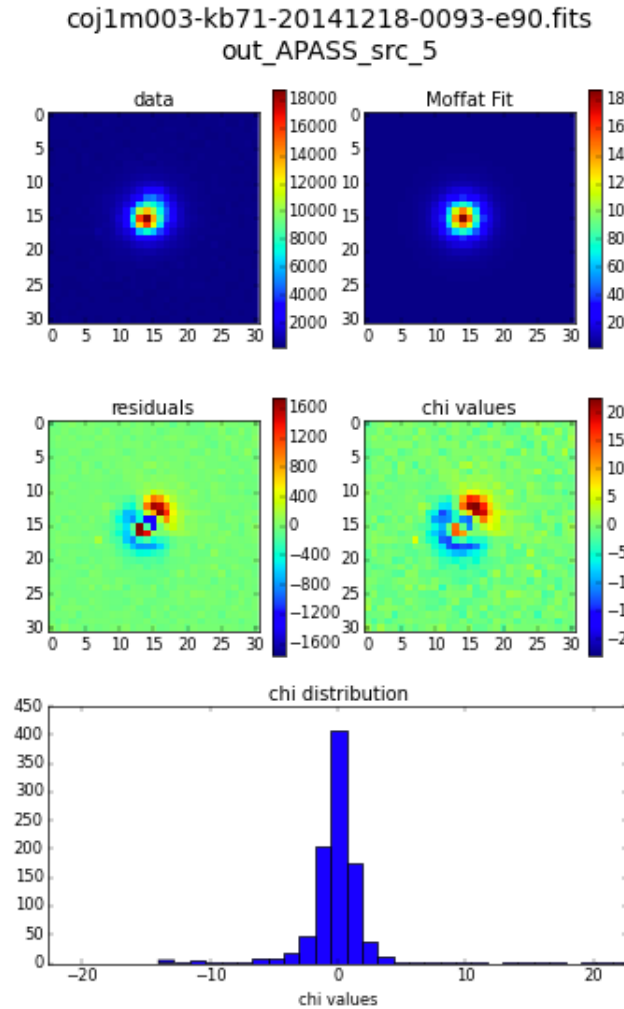


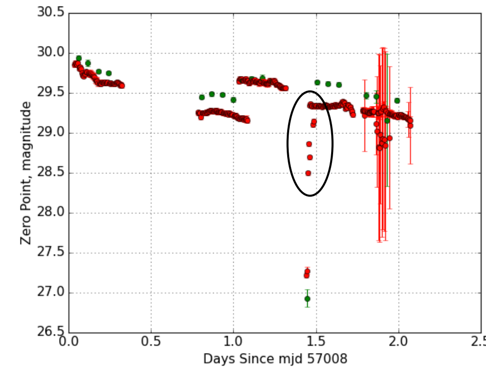


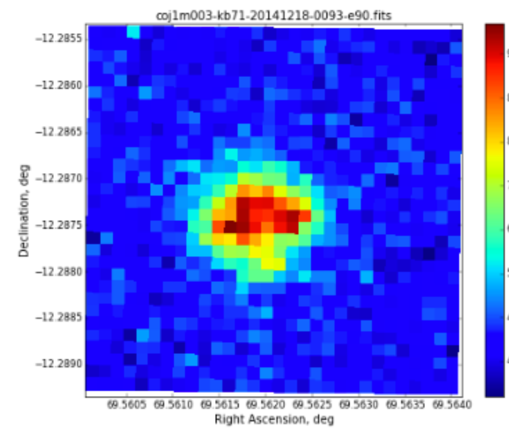
Very faint quasar.
Suspect high air mass

Zero Points

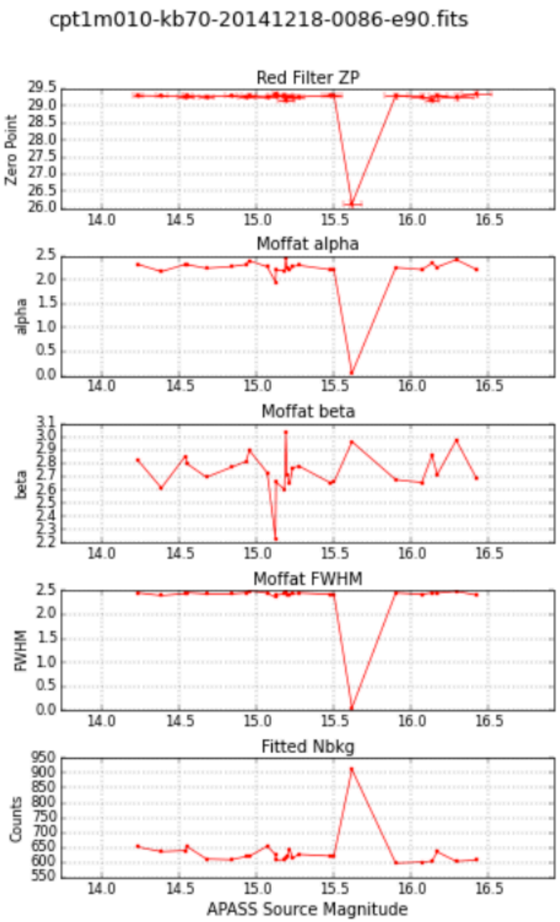

coj1m003-kb71-20141218-0093-e90.fits
Red Filter ZP
Zero Point
Moffat alpha
alpha
Moffat beta
beta
Moffat FWHM
FWHM
Fitted Nbkg
Counts
APASS Source Magnitude

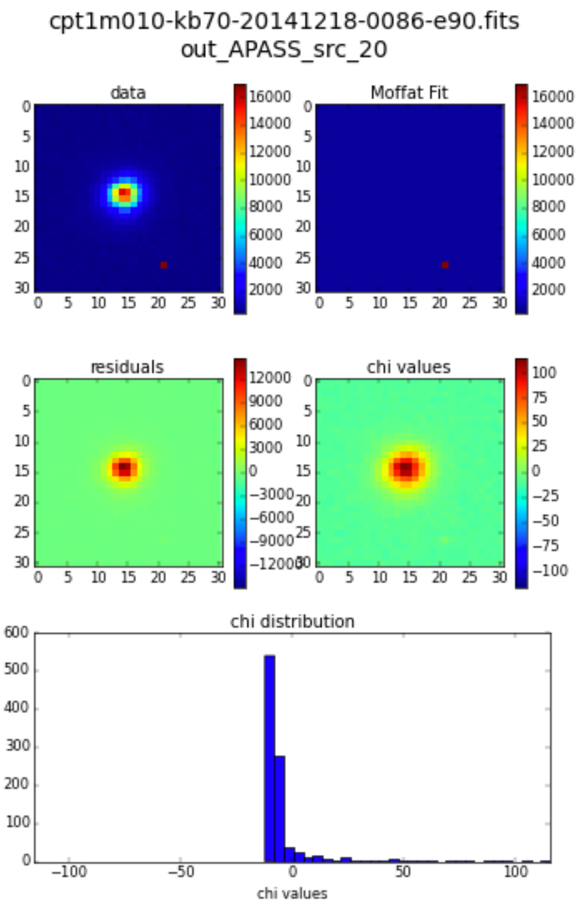

coj1m003-kb71-20141218-0093-e90.fits
out_APASS_src_5
data
Moffat Fit
residuals
chi values
chi distribution
chi values

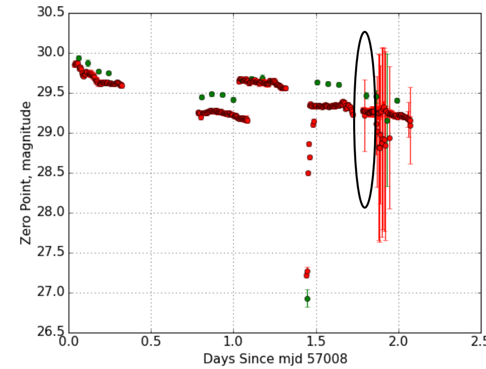

Zero Point, magnitude
Days Since mjd 57008

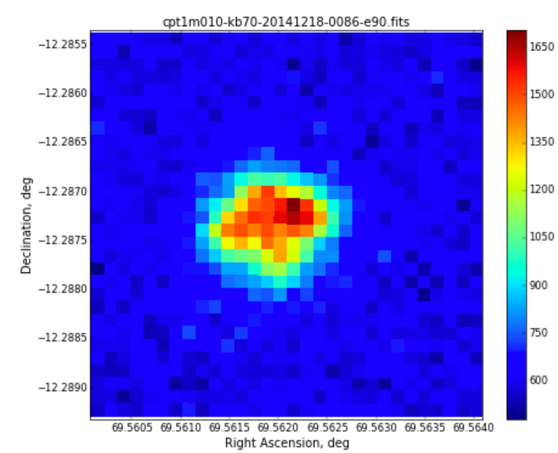

coj1m003-kb71-20141218-0093-e90.fits
Declination, deg
Right Ascension, deg

Zero Points



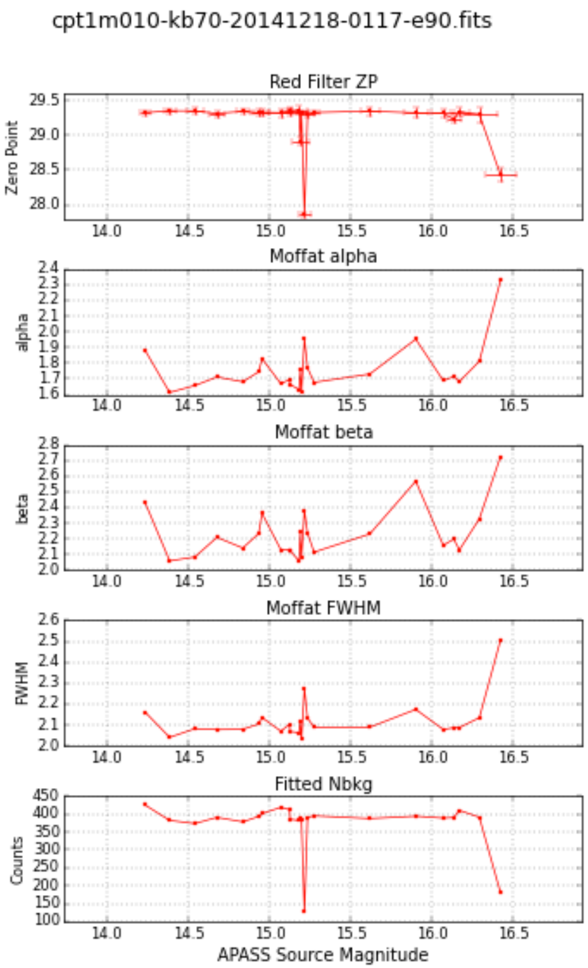


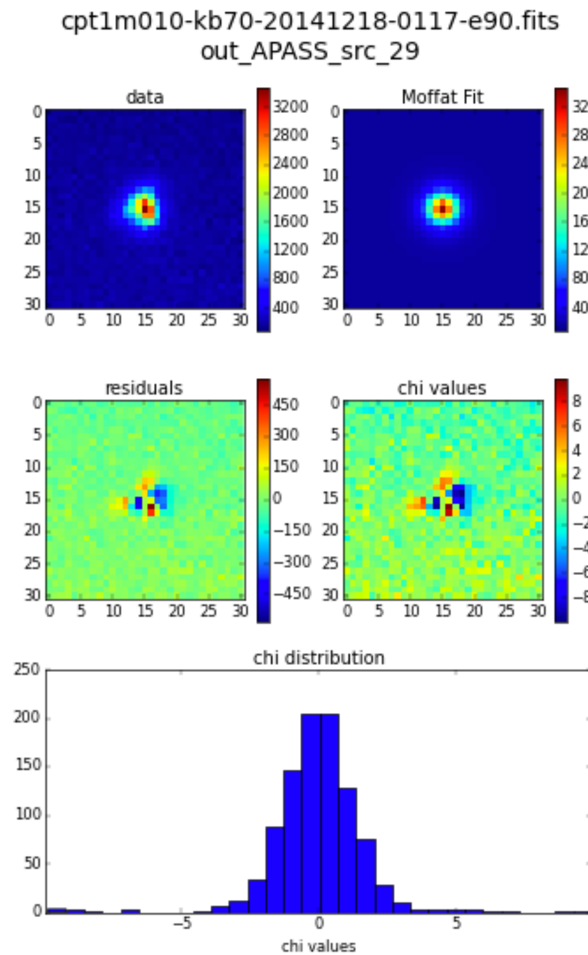


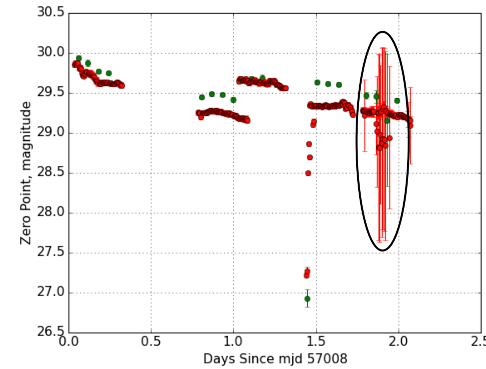


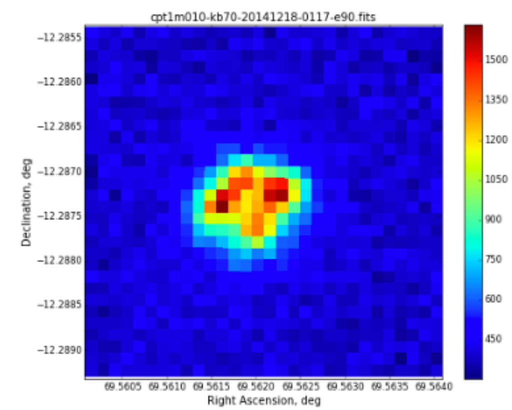
One bad fit due to a cosmic ray. Need more robust handling

Zero Points



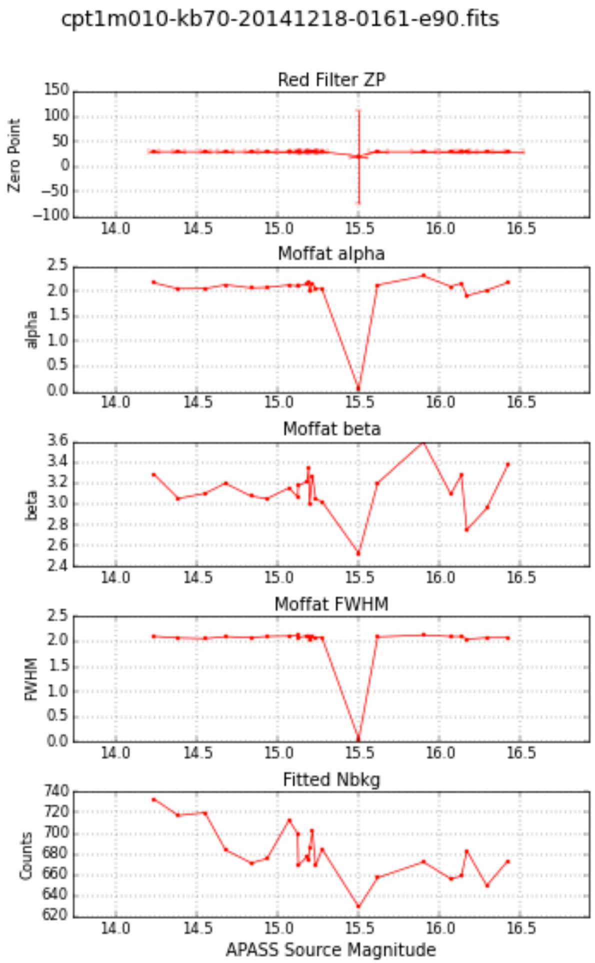


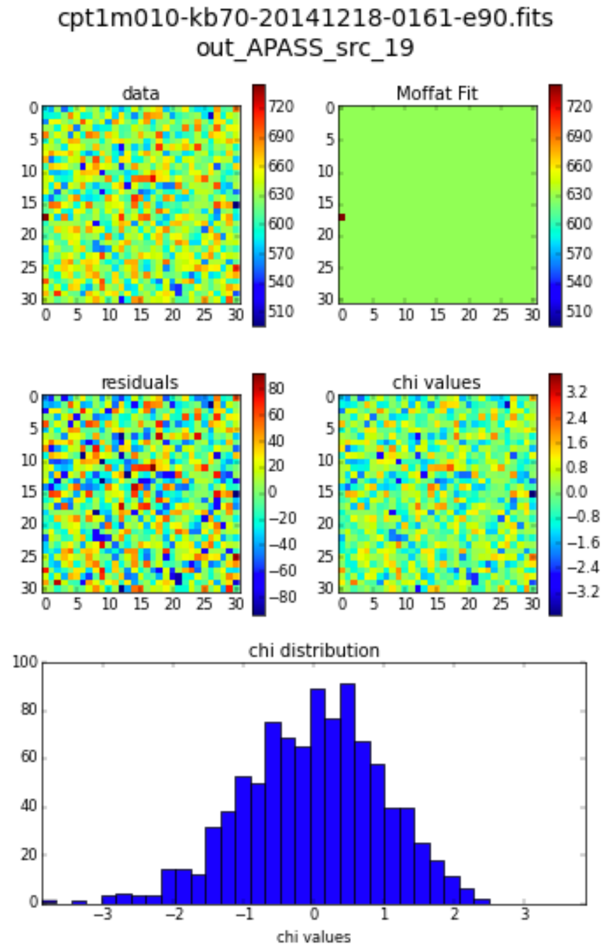


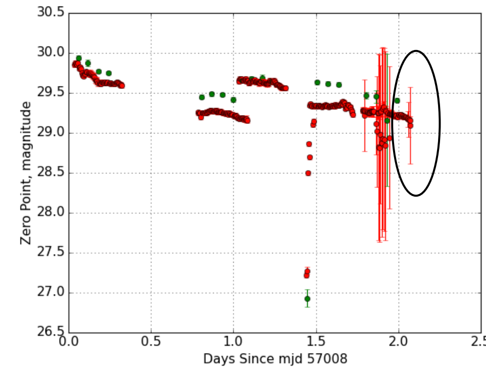


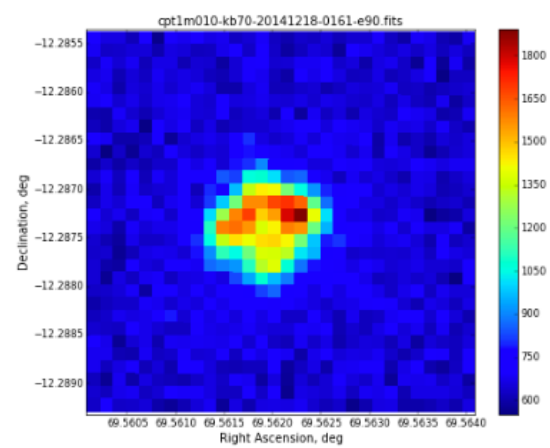
Not entirely clear why we get outliers.
Poor PSF model?

Zero Points



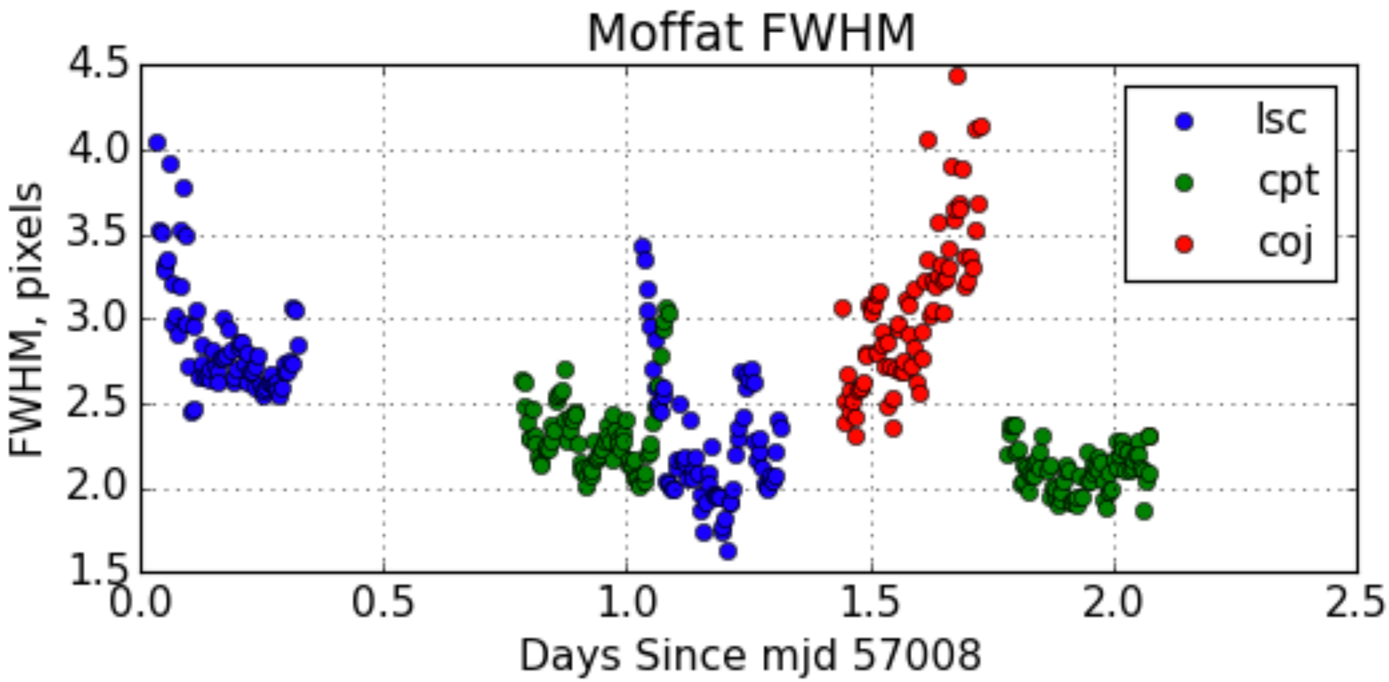






One APASS source was not there!
Its neighbors in magnitude are there
with peak counts of 18000 - 24000

Seeing



Moffat FWHM
4.5
4.0
3.5
3.0
2.5
2.0
1.5
FWHM, pixels
0.0
0.5
1.0
1.5
2.0
2.5
Days Since mjd 57008
lsc
cpt
coj

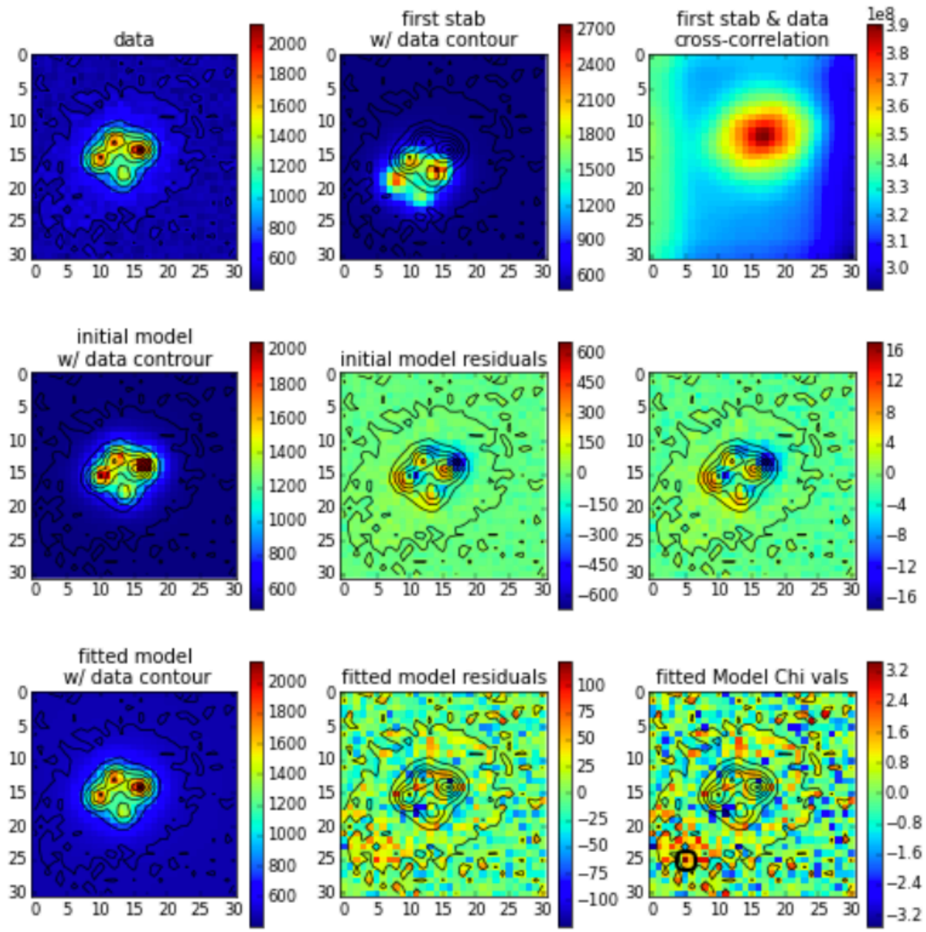
Multiple Quasar Image Fitting

1. Start with a model of the points fixed to a cross and amplitudes.
2. Cross-correlate the model to the data to align the source.
3. Fit a quadruple circular Moffat profile. Free parameters are:

- Position of the system.
- Fouramplitudes
- Background
- moffat alpha and beta.

Fit Moffat profiles on set points on the cross.

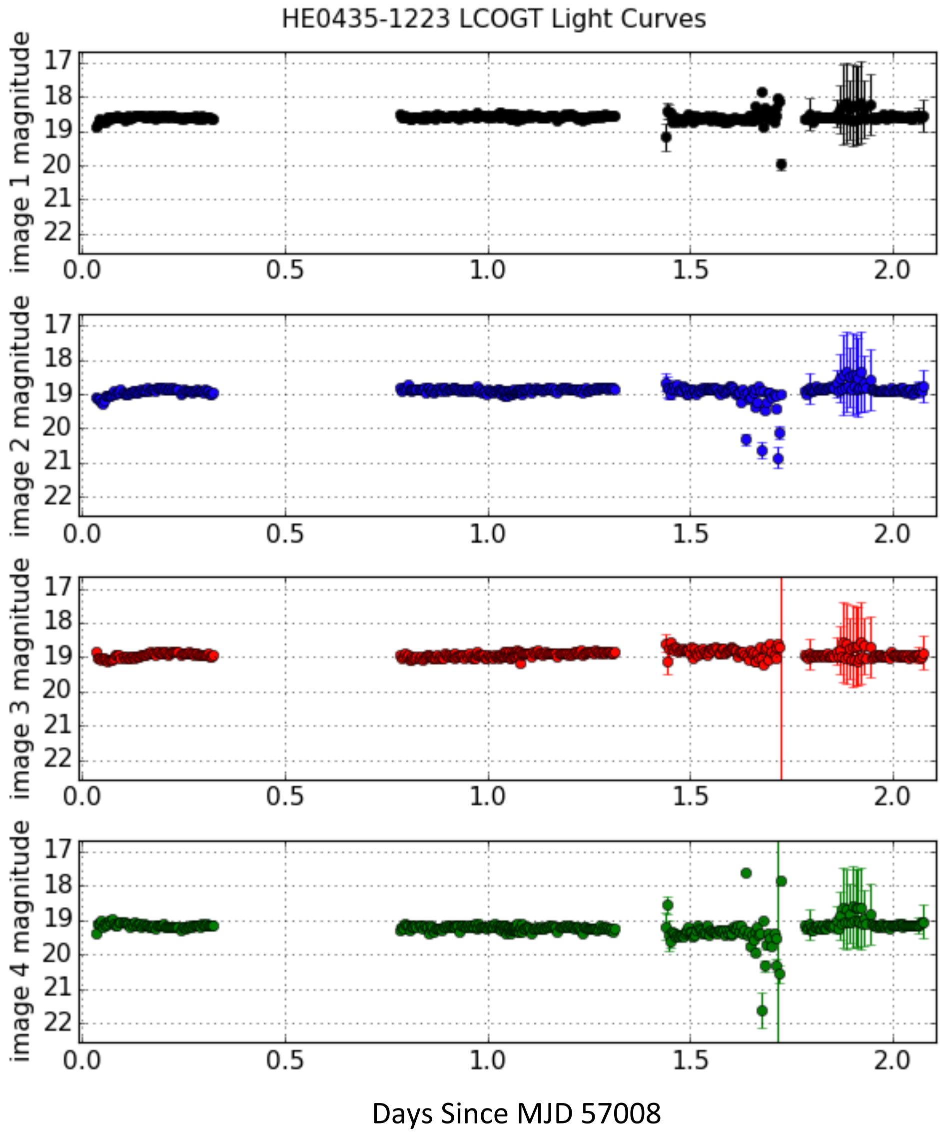
lsc1m009-fl03-20141217-0032-e90.fits



Light Curves

Fit for the amplitudes of the quasars.

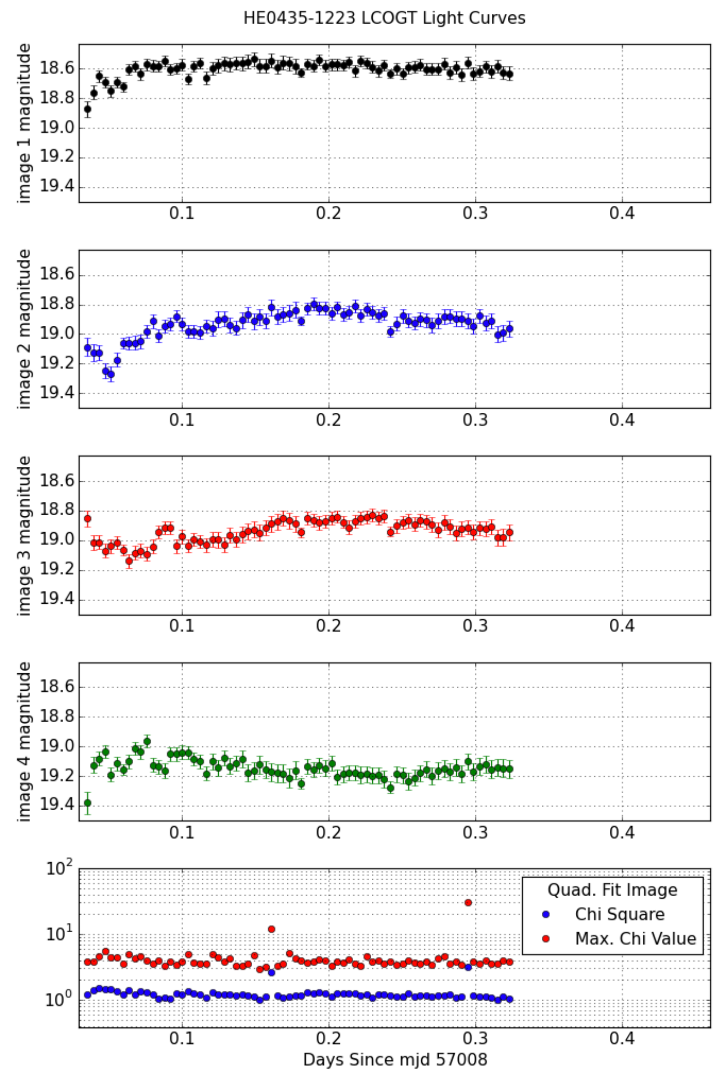
Error bars estimate statistical uncertainties of the amplitude and zero point.



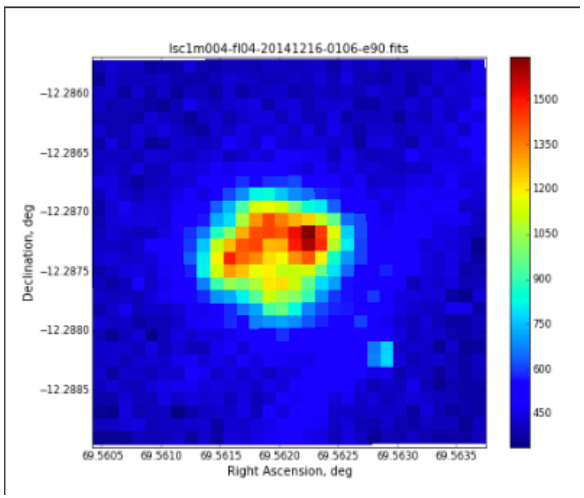
First Set Using LSC

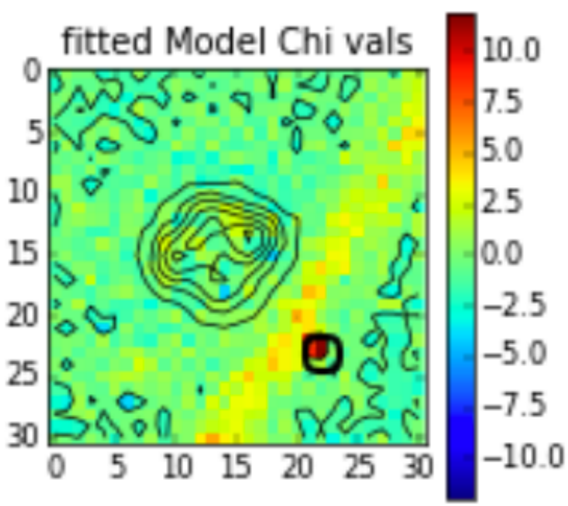
Very stable.
High quality images.
Fitted image chi squared values are close to one.

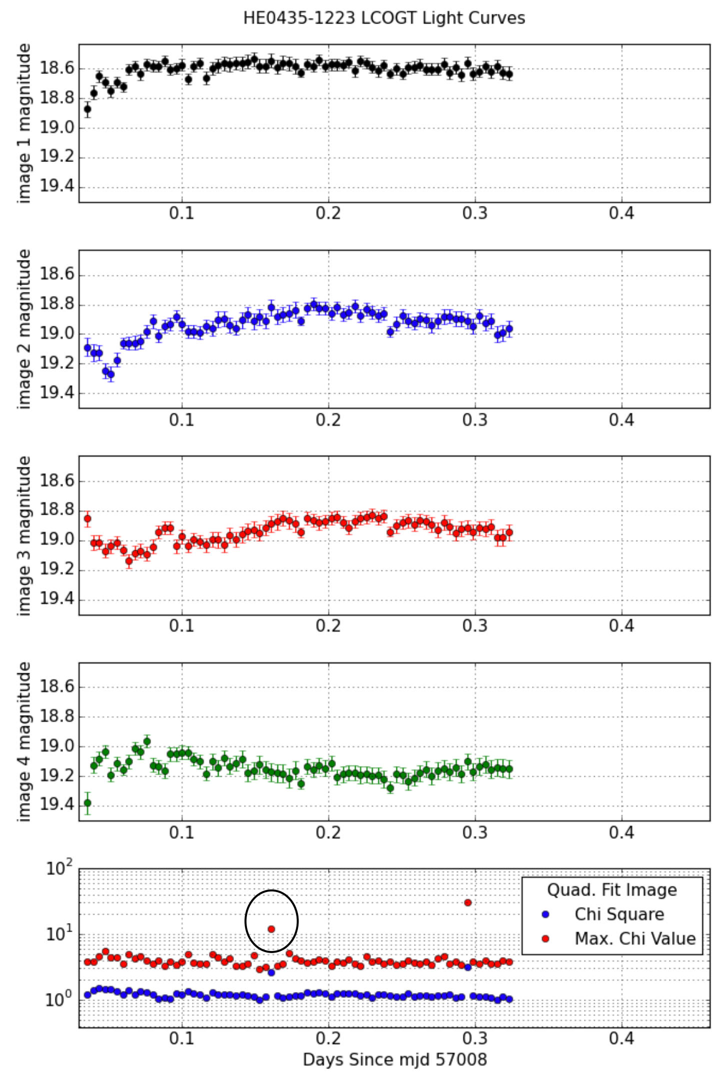
Some outliers in the maximum chi value of the image.



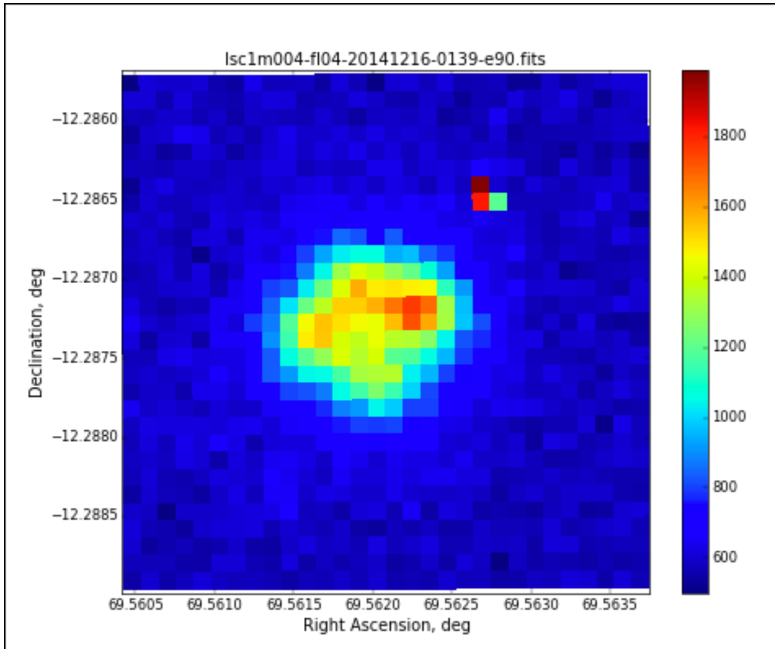
First Set Using LSC

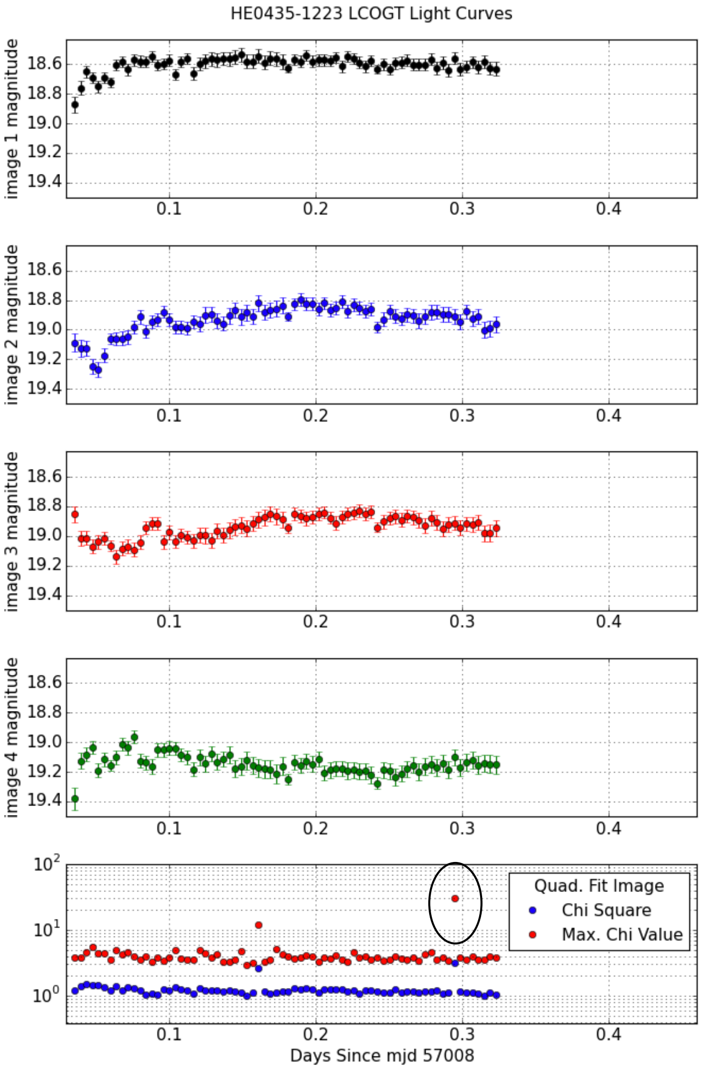






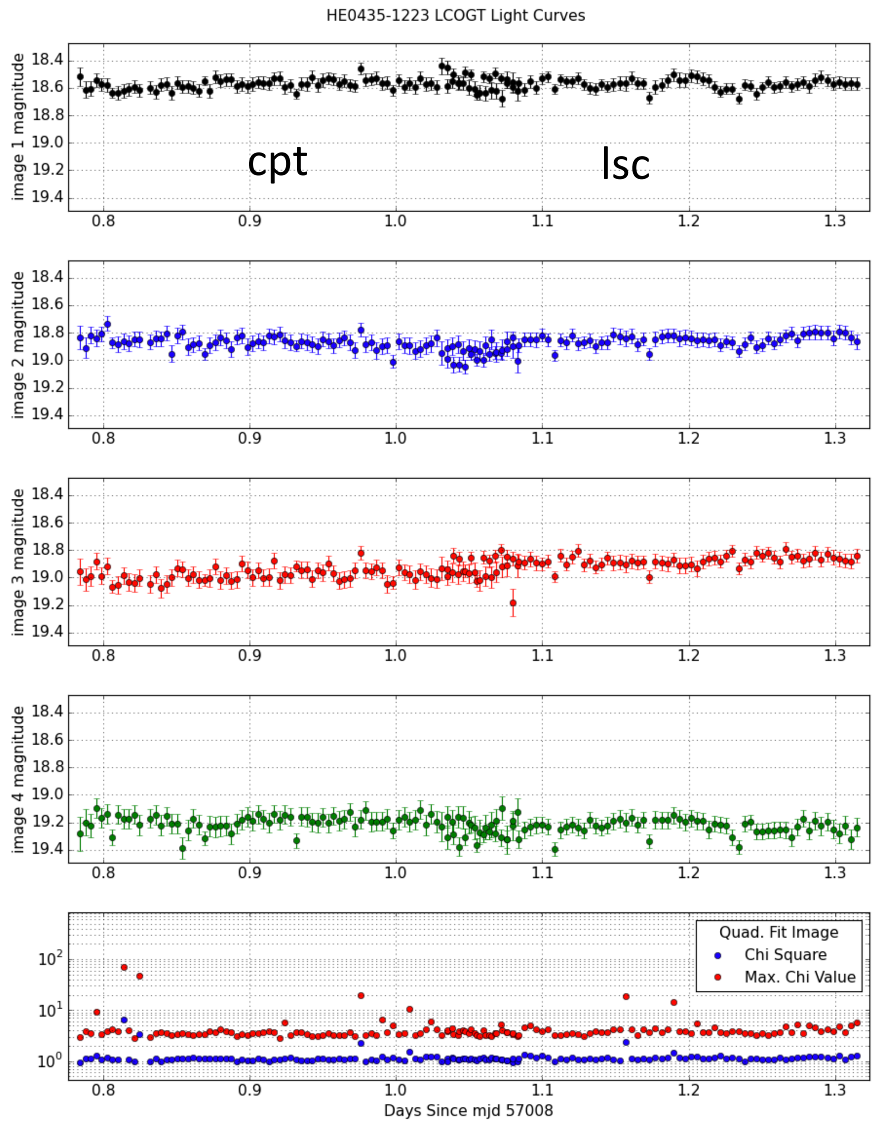
First Set Using LSC





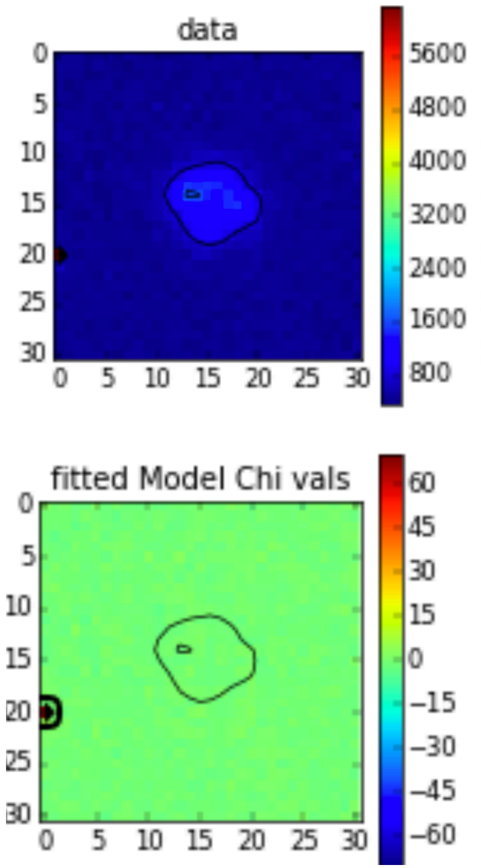
Second Set with CPT and LSC

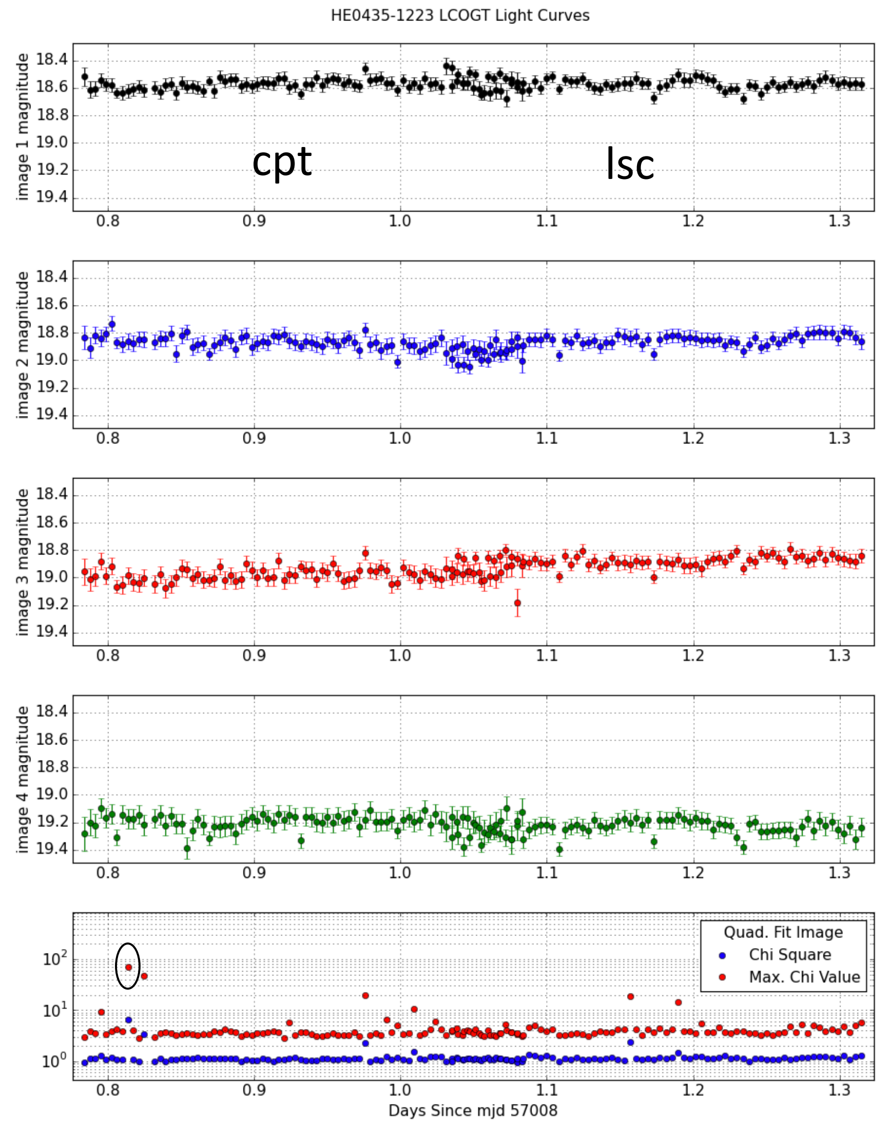
This set has a region where CPT and LSC take every other observation.



Second Set with CPT and LSC

More cosmic rays



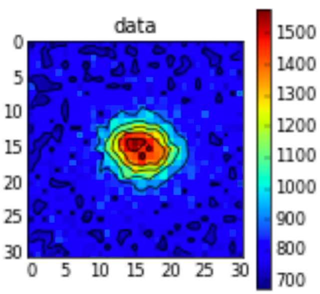


Second Set with CPT and LSC

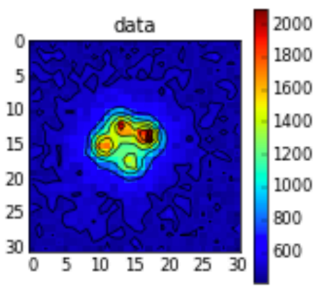
The transition region between CPT and LSC shows mismatches in the quasar magnitudes at the $\lesssim$0.1 magnitude.

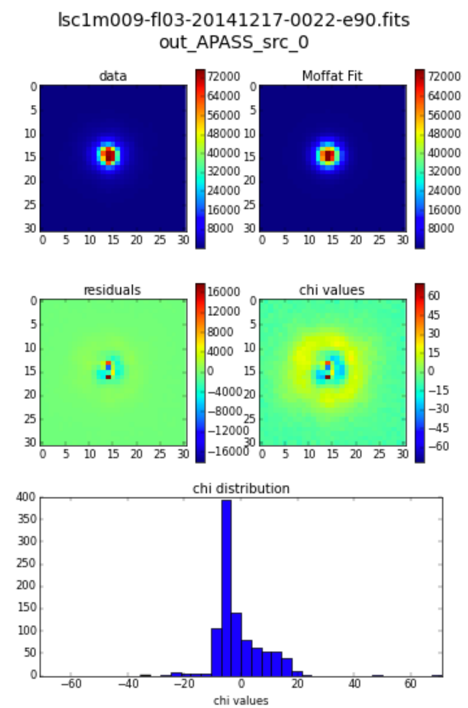
The differences in the PSF are a likely cause.

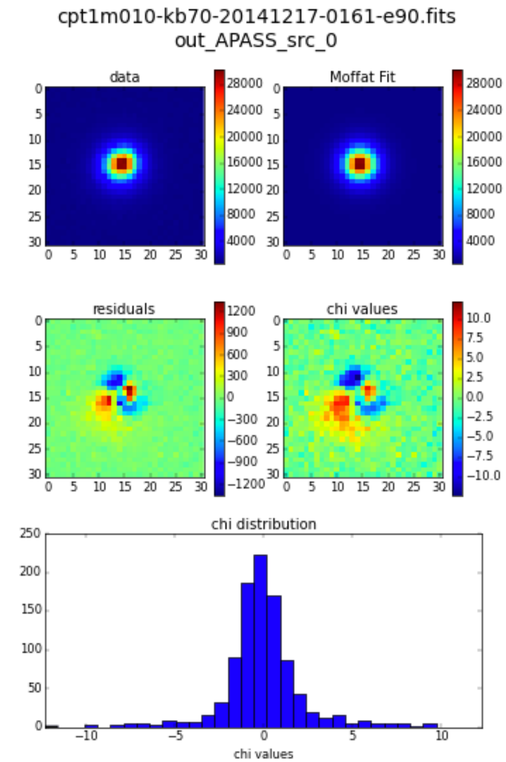
cpt

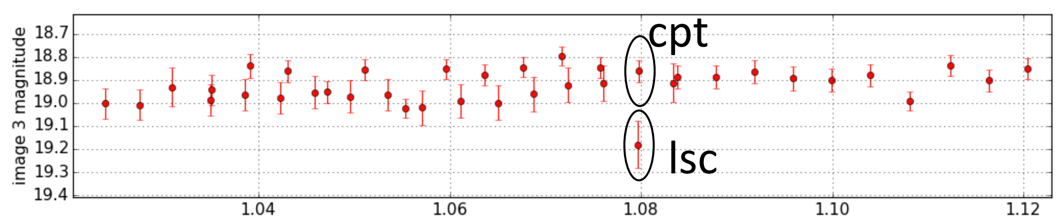


lsc









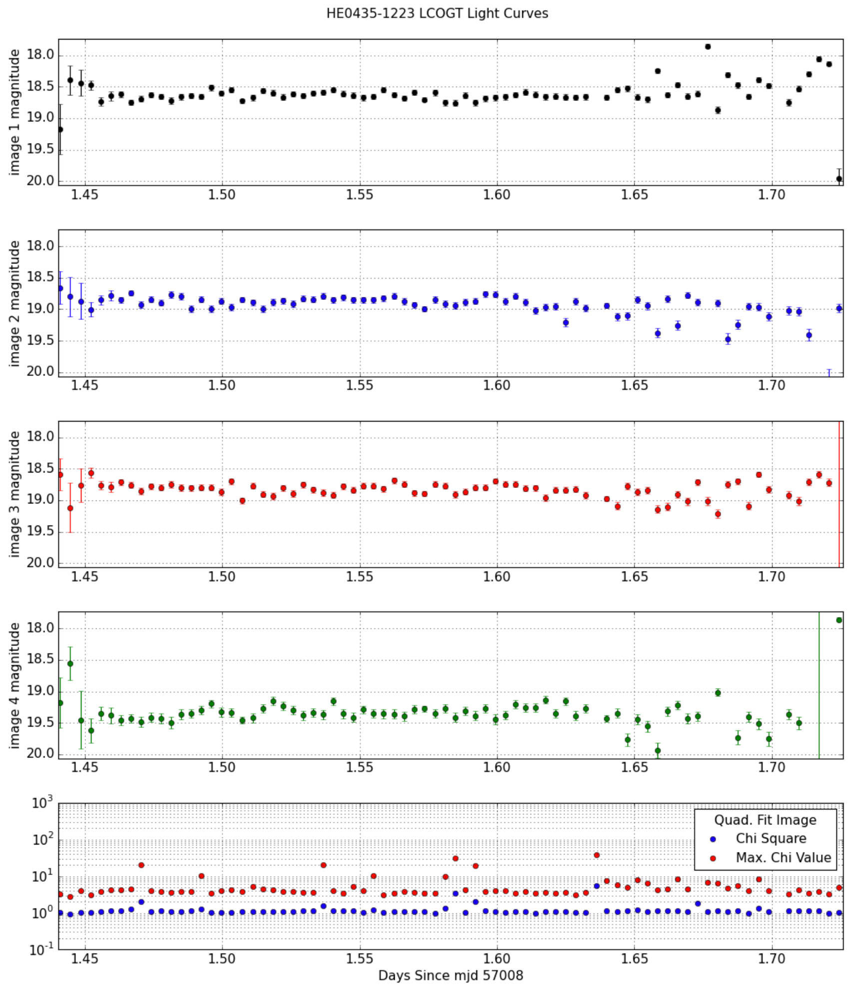
Third Set with COJ

Stable set.

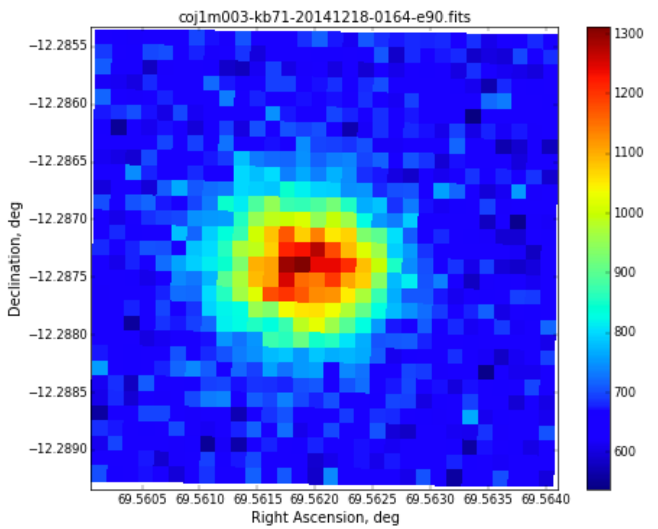
The start of the set has uncertainties due to large air mass (smaller signals).

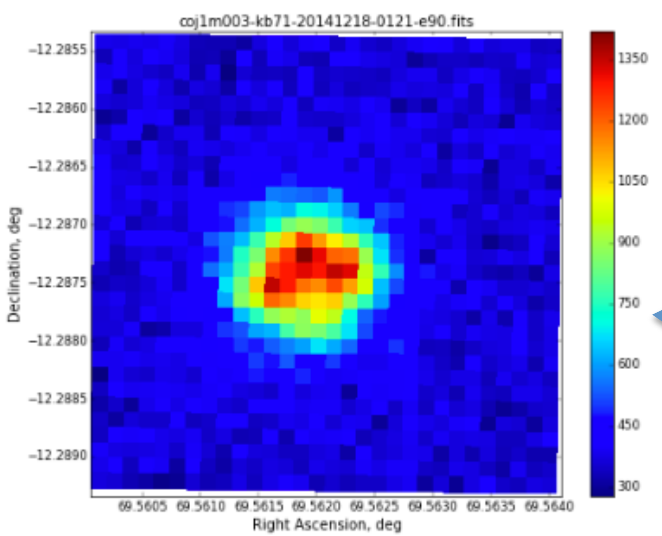
Middle of the run has good data.

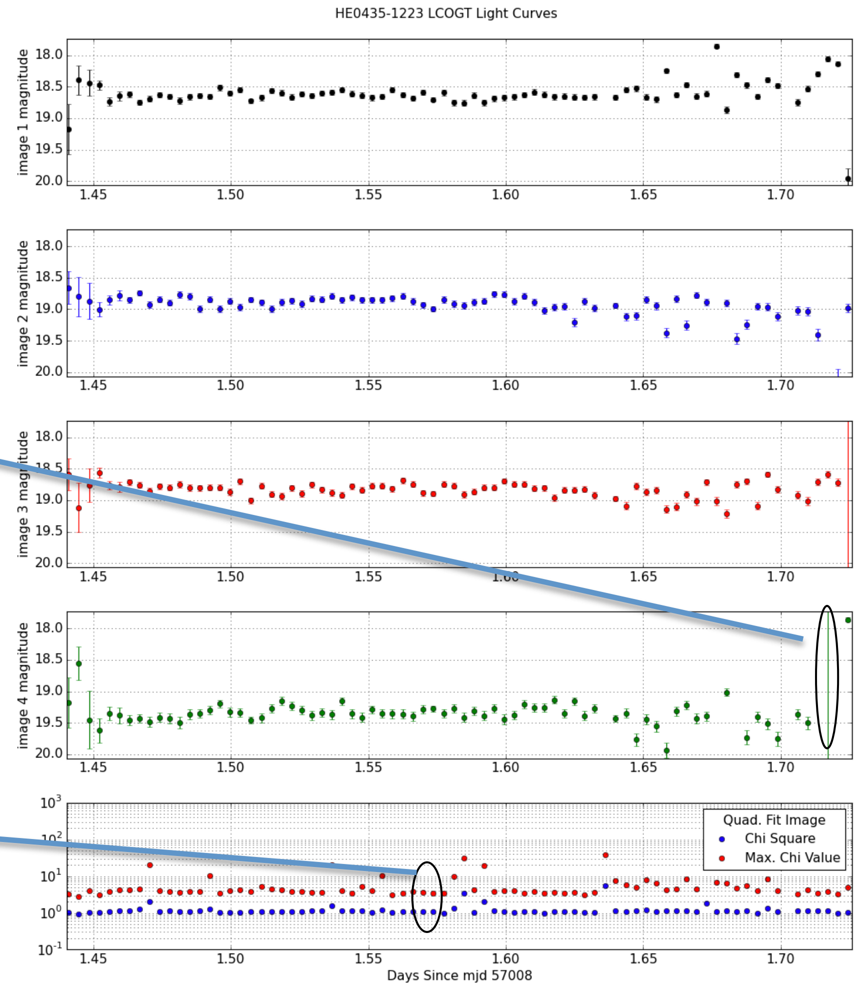
End of the run has low seeing. Variations due high confusion.



Third Set with COJ

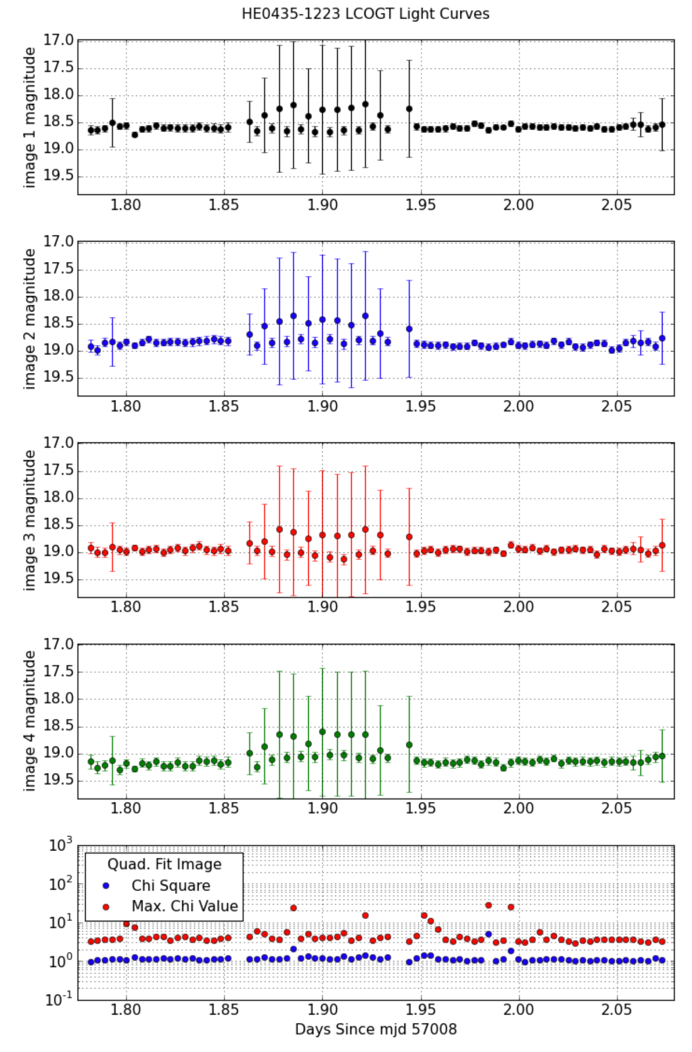






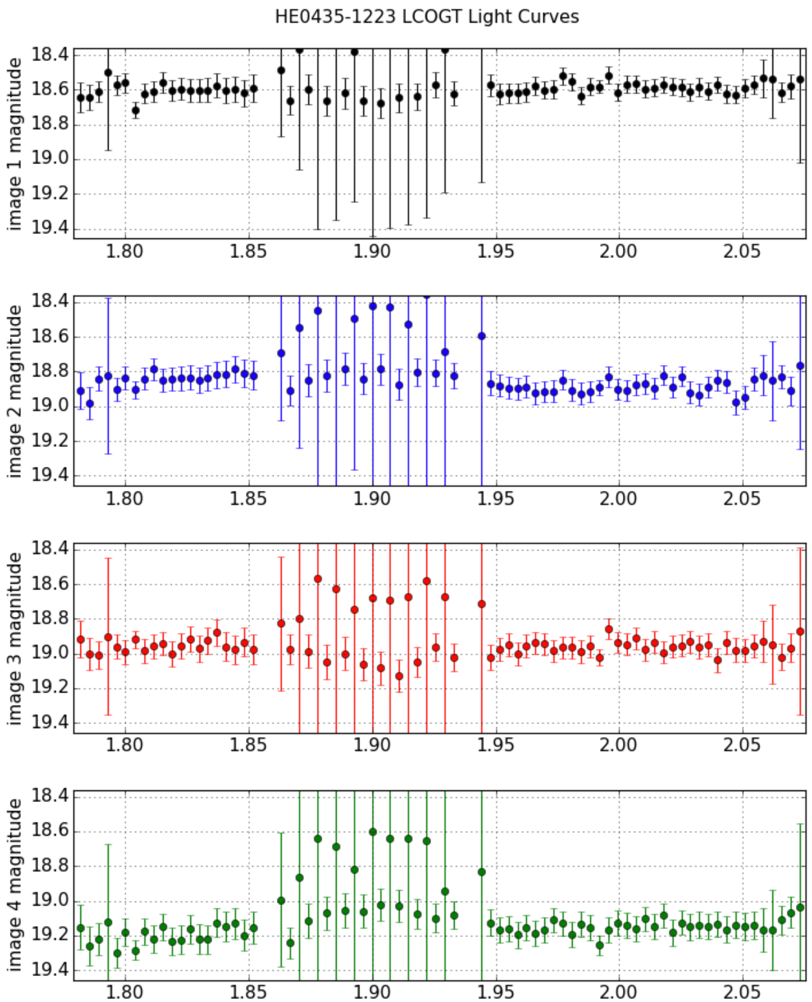
Last set with CPT

Large uncertainties in the middle are propagated from anomalous zero point estimates.



Last Set with CPT

Otherwise the variations are small.



Next Steps

- Take the best data and run it through emcee to estimate the quasar light curve uncertainties.
- Summary
  - 2% of the data had no quasar image in it.
  - 3% of the data gives problems with photometric estimation using APASS sources (part of it is analysis)
  - 8% of the data has a cosmic ray or other anomaly near the quasar image.
  - 87 % of the data is good and fits well.