Sky correction

Last time: fit a plane to the sky to subtract: SKY = X*dx + Y*dy + const

After subtracting this sky model, we can look at the residual sky values around each star we did photometry on.

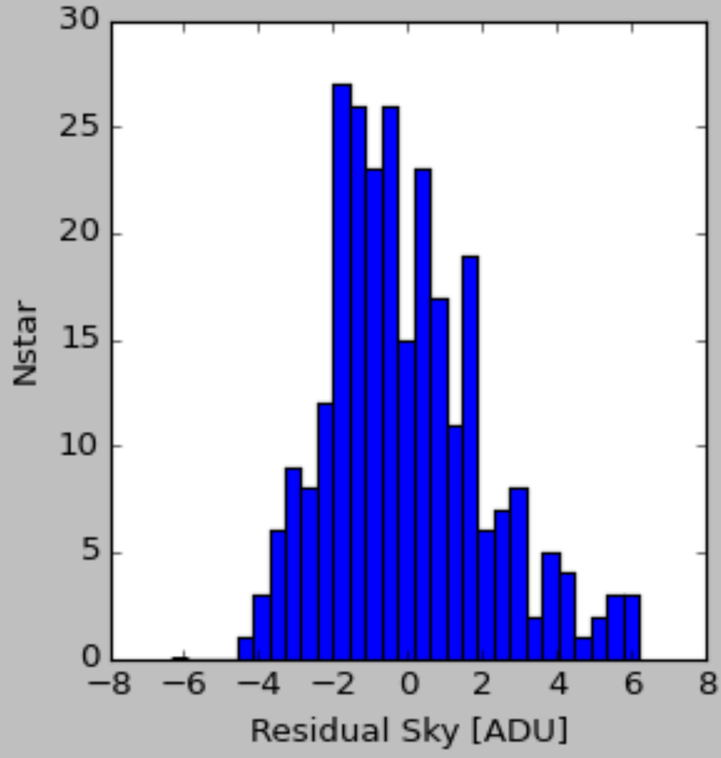
It looks asymmetric, skewed towards positive values.

- Mean = −0.05 ADU
- Median = −0.43 ADU

Why would it be skewed positive?

So the constant sky value is biased to be too bright. We will correct for this by reducing the fitted const value by the median offset.

SKY0 = const − 0.43



Photometric Scaling

The zeropoint converts counts (in ADU) to calibrated magnitude. A star of given magnitude m will have different counts in images with different zeropoints. Since zeropoints are in magnitudes, we can say

$ZP_1 – ZP_2 = −2.5*\log(COUNTS_1/COUNTS_2)$

So we can pick a “master zeropoint” and rescale all the images in intensity so that they have that zeropoint:

$COUNTS\_MASTER = COUNTS * 10^{+0.4*(ZP – MASTERZP)}$

That 10^ term is the photometric scaling we multiply each image by to get them on the master zeropoint.

What do we chose for the MASTERZP?   MASTERZP = np.average(ZP)

Applying corrections to data

imexpression: pyraf command to do complex image math. Conceptually, we want to do the following:

corrected image = (flattened image – sky model) * photometric scaling

using imexpr we say:

I means CCD X coordinate
J means CCD Y coordinate

imexpr
    expr="(a-(I*b+J*c+d+e))*f"
    output = c<imagename>
    a = <imagename>
    b = <dx value for image>
    c = <dy value for image>
    d = <const sky value for image>
    e = <median sky residual for image>
    f = <photometric scaling>

Applying your photometric solution to the master images

Part 1: Instrumental magnitudes

pyraf ‘s qphot task defines an instrumental magnitude in terms of counts/second:

$$m_{inst} = -2.5*\log(COUNTS/EXPTIME) + 25$$

Since we based on zeropoints on qphot measurements of stars, we need to define our instrumental magnitudes the same way.

And since we medianed the images (rather than summing them), our EXPTIME is the exposure time of an individual image:

- V images: 900 seconds (15 mins)
- B images: 1200 seconds (20 mins)

So turn counts into instrumental magnitudes using those values.

Applying your photometric solution to the master images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_{inst,B} - m_B = C_B*(B-V) + ZPMASTER_B$$

$$m_{inst,V} - m_V = C_V*(B-V) + ZPMASTER_V$$

	B	**V**
C (uncert)	0.160 (0.006)	0.289 (0.021)
ZPMASTER (uncert)	3.704 (0.022)	3.514 (0.022)

Applying your photometric solution to the master images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_B = m_{inst,B} - C_B*(B-V) - ZPMASTER_B$$

$$m_V = m_{inst,V} - C_V*(B-V) - ZPMASTER_V$$

	B	**V**
C (uncert)	0.160 (0.006)	0.289 (0.021)
ZPMASTER (uncert)	3.704 (0.022)	3.514 (0.022)

Applying your photometric solution to the master images

Part 2: Turn instrumental magnitudes into real magnitudes

Our photometric solution:

$$m_B = m_{inst,B} - C_B*(B-V) - ZPMASTER_B$$

$$m_V = m_{inst,V} - C_V*(B-V) - ZPMASTER_V$$

	B	V
C (uncert)	0.160 (0.006)	0.289 (0.021)
ZPMASTER (uncert)	3.704 (0.022)	3.514 (0.022)

But wait…

Subtract one from the other:

$$m_B - m_V = [m_{inst,B} - m_{inst,V}] - [C_B - C_V] *(B-V) - [ZPMASTER_B - ZPMASTER_V]$$

$$(B-V) = [m_{inst,B} - m_{inst,V}] - [C_B - C_V] *(B-V) - [ZPMASTER_B - ZPMASTER_V]$$

$$(B-V)*(1 + [C_B - C_V]) = [m_{inst,B} - m_{inst,V}] - [ZPMASTER_B - ZPMASTER_V]$$

$$(B-V) = ([m_{inst,B} - m_{inst,V}] - [ZPMASTER_B - ZPMASTER_V]) / (1 + [C_B - C_V])$$

Applying your photometric solution to the master images

Summary

First measure counts and calculate instrumental magnitudes in each filter:

$$m_{inst,B} = -2.5*\log(COUNTS_B/EXPTIME_B) + 25$$

$$m_{inst,V} = -2.5*\log(COUNTS_V/EXPTIME_V) + 25$$

Then calculate the color:

$$(B-V) = ([m_{inst,B} - m_{inst,V}] - [ZPMASTER_B - ZPMASTER_V]) / (1 + [C_B - C_V])$$

Then insert that color into the photometric solution to calculate magnitudes:

$$m_B = m_{inst,B} - C_B*(B-V) - ZPMASTER_B$$

$$m_V = m_{inst,V} - C_V*(B-V) - ZPMASTER_V$$

or even simpler: $m_V = m_B - (B-V)$

	B	**V**
EXPTIME	1200	900
C (uncert)	0.160 (0.006)	0.289 (0.021)
ZPMASTER (uncert)	3.704 (0.022)	3.514 (0.022)

Final step – correcting for galactic extinction

After all photometry is done and you have your "final" magnitudes and colors, you want to correct for galactic extinction. Dust in the Milky Way (which we are looking through) both dims and reddens the light from M101.

Look up the galactic extinction on NED, using the estimate from Schlafly and Finkbeiner (2011). Then correct for extinction in each band by doing:

$$m_{B,0} = m_{B,obs} - A_B \quad \text{and} \quad m_{V,0} = m_{V,obs} - A_V$$

And then correct the color by doing either

$$(B-V)_0 = (B-V)_{obs} - (A_B - A_V) \quad \text{or} \quad (B-V)_0 = m_{B,0} - m_{V,0}$$

But not both! That is, don't calculate your color from the corrected magnitude and then *also* apply the reddening correction.

Working with your master images

- cd /home/scratch/M101proj
- mv Bdata/M101B.fits .
- mv Vdata/M101V.fits .
- ds9 M101B.fits M101V.fits &

If you are typing these inside a pyraf window, remember to put the "!" in front of each line….

- in ds9:
  - Frame → Single Frame
  - Frame → Lock → Frame → WCS
  - Scale → Scale Parameters → -10 to 3,000
  - Scale → Log
  - Frame → Lock → Scale
  - Frame → Lock → Colorbar

This sets up ds9 so you can zoom, pan, and change the display stretch on one image, then hit "tab" and see the other image similarly displayed.

- ds9 regions (Regions → Shape):
  - Circles: can draw with cursor, then double click inside circle to pull up info box. Set size and center (in different units), click Analysis → Statistics for rough stats.
  - Ruler: will measure distances on image in different units

Doing Quick Photometry:

- stars: use pyraf's imexam task (good method; but use total counts, not mags)
- extended objects: enclose in region, look at regions stats (rough method)