Maximizing Precision of Variable Star Photometry with Digital Cameras in Suburban Environments

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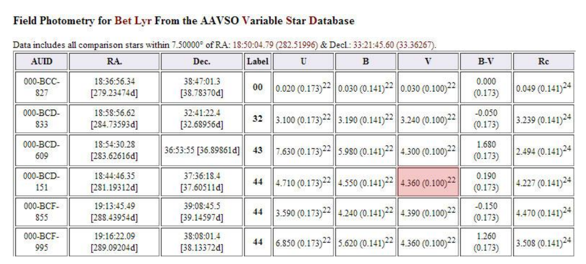
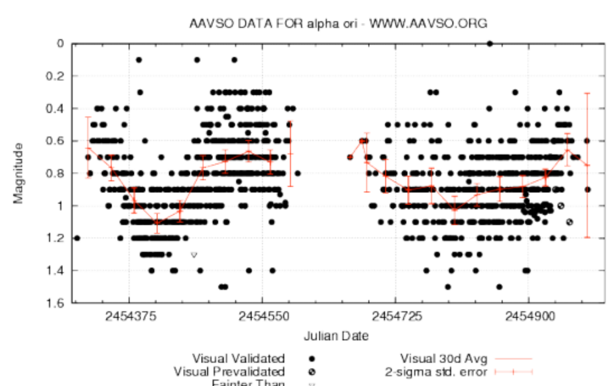
Introduction:
Many variable stars are too bright to be observed by the larger telescopes used by astronomers.

Citizen scientists can use Digital Single Lens Reflex (DSLR) cameras such as the Canon Rebel XTi below to make estimates of a star's brightness.

The American Association of Variable Star Observers (AAVSO) provides resources including suggested comparison stars, and collects estimates from many observers to create average light curves.

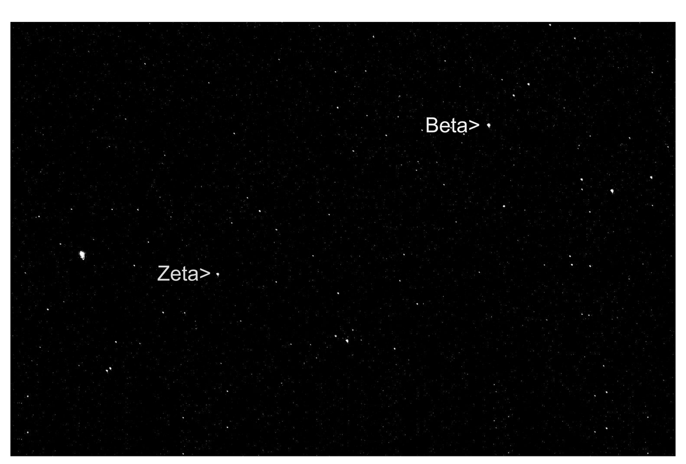


Chosen as a comparison star for Beta Lyrae, Zeta Lyra's magnitude in the green (visible) band is highlighted (4.360, but nearby stars gave it an effective magnitude of 4.089). Other comparison stars were too bright, or were also variable.



Aim:
Determine which error reduction strategies are necessary to obtain three significant figures in estimates of star brightness accurately and precisely.

Examine the effect of different variables, including camera focus, type of flat frame used, number of dark frames used, and typ of sky annulus average used.



Primary Setup:
Canon Rebel XTi
55mm
F5.6
1600 ISO
6 second exposure

Image source: Wikimedia Commons courtesy of Soerfm

Data Analysis:
Images were processed using DeepSkyStacker (DSS) and measurements taken in Aperture Photometry Tool (APT).

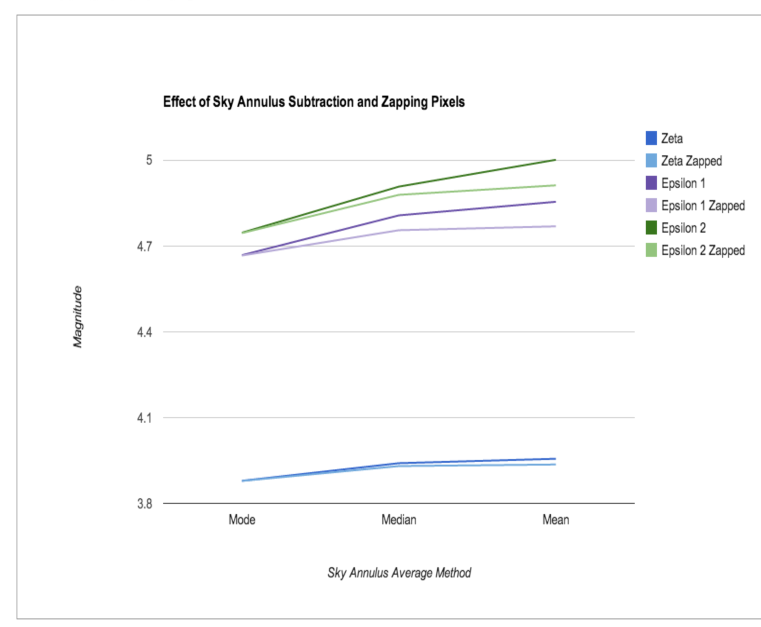
Dark frames and flat frames were applied to image in DSS. This is also where the images were converted from Raw format to .FITS, which is needed for APT.

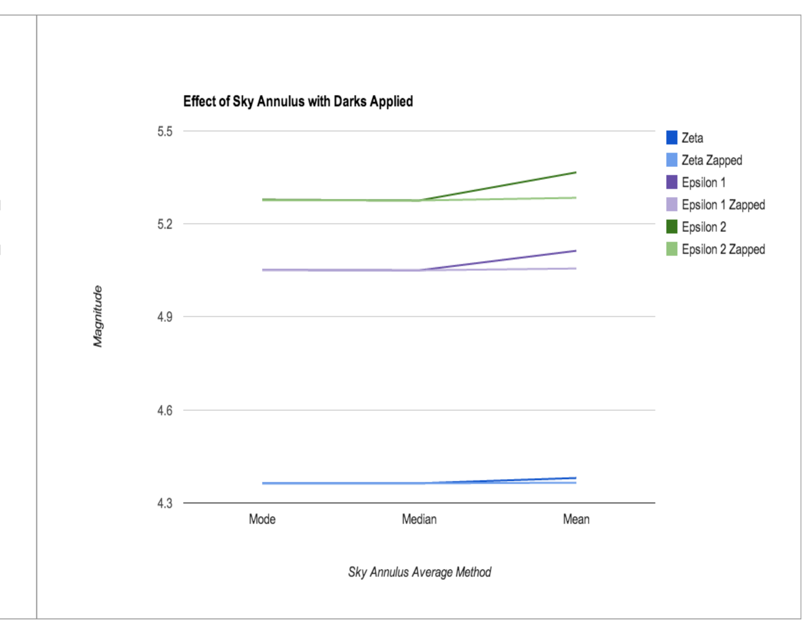
Definitions:
Dark frames: image of darkness taken with identical camera settings to account for pixel noise on sensor
Flat frames: image taken of evenly lit surface to account for difference in brightness between center and corners of image

Data Analysis (continued):
Sky annulus subtraction and calibration against the comparison star (to account for several uncontrollable variables) were done in APT, giving a unitless magnitude of the variable target as the output

Results:
When no darks are applied, the type of average used on the sky annulus causes varies. and whether bright pixels and other stars are zapped helps with mean and median averages, but introduces human error

When darks are applied, median and mode methods give identical results, mean still needs zapping, but will produce better results than before.

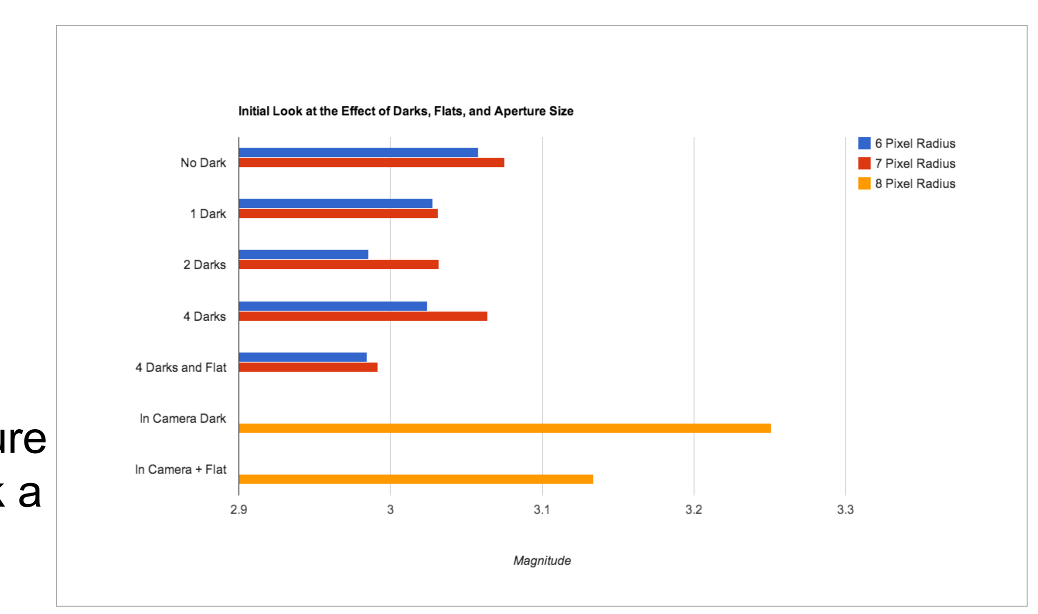


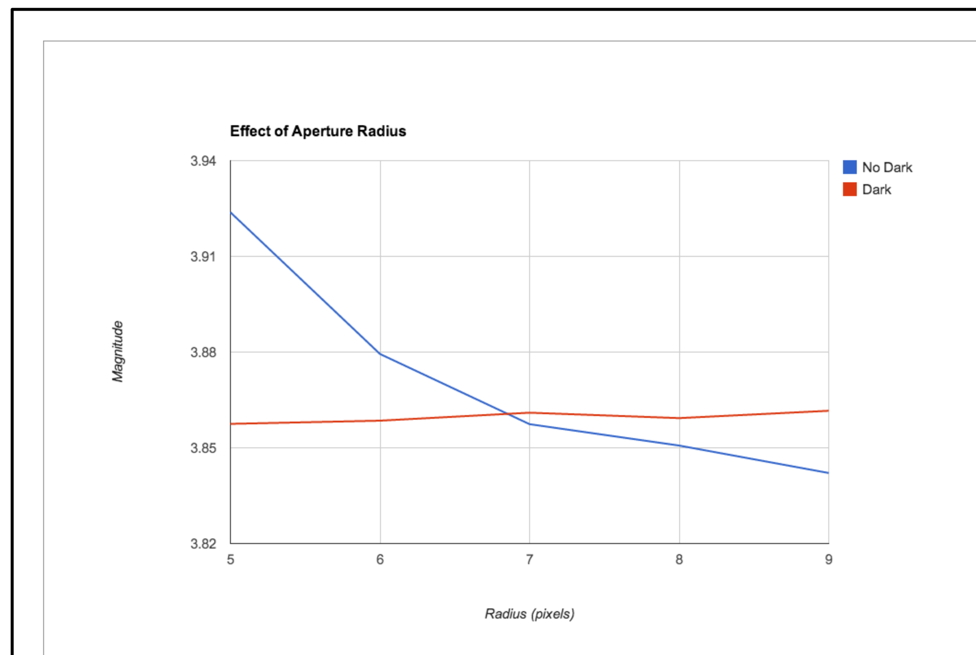


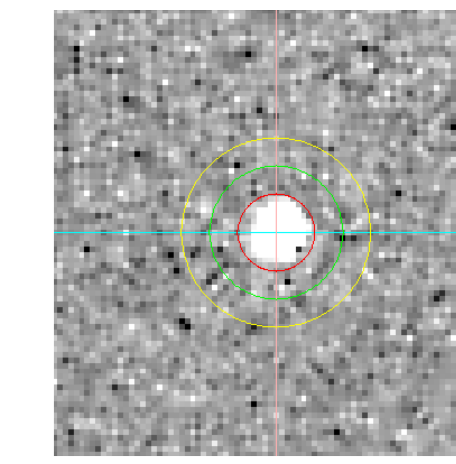
Looking more closely at the number of darks, as well as applying flat frames, we notice that the number of darks can have an erratic effect, but applying a flat frame consistently has the same effect, about 0.1 magnitudes brighter.

This means flats are critical, even when the target and comparison stars are fairly well centered.

Initial results for aperture radius varied, so I took a closer look.







Screenshot from APT of aperture around Beta Lyrae (Sheliak)

Aperture radius has significant effect, but only when darks aren't applied

Camera focus has a huge effect between well focused (7 pixel radius) and out of focus, but slightly out of focus (9 pixels) and strongly out of focus (12 pixels) are closer together, For precision in measurements one night to the next, take slightly out of focus images.

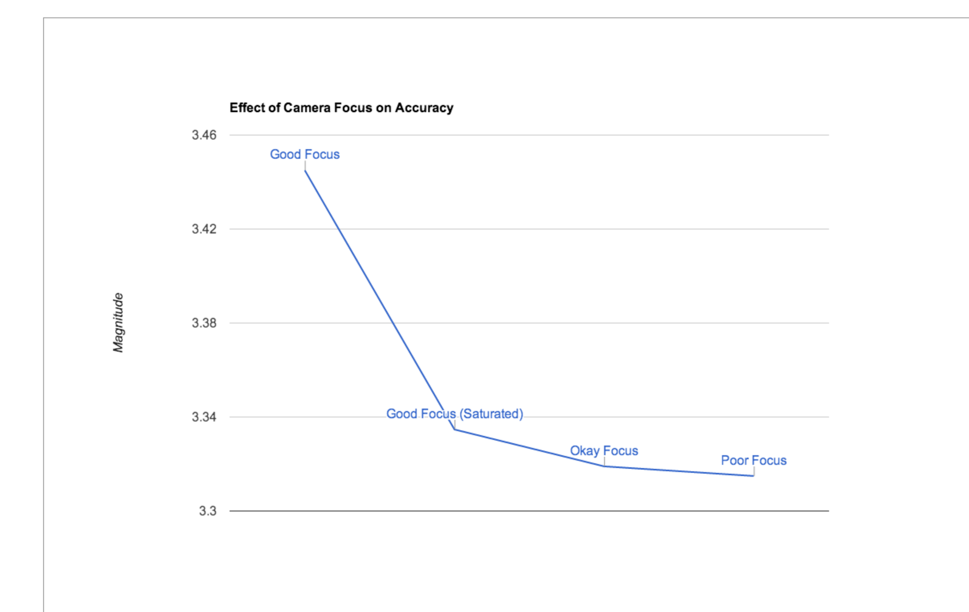
The number of darks taken continues to have baffling results

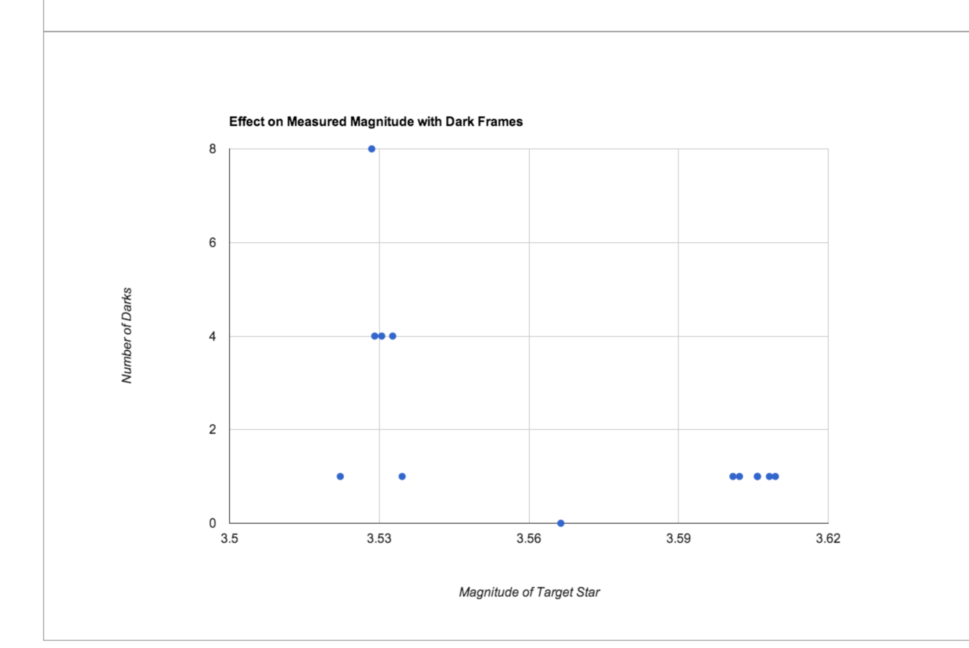
Different combinations of four darks have similar effects, even when the individual darks each had an opposite effect

Eight darks is similar to four

Number of darks might introduce some error, but needed for precision in other variables (sky annulus, etc…)

Four darks should give consistent results





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