Ph 344 Lab 3 Solutions

The purpose of this lab was to become familiar with the Interactive Data Language (IDL) and its interface on the astrolab computer. The initial steps had you start the IDL Developer's Environment (idlde), which is really overkill for what we do in this course, and set up the path which makes available a large number of existing programs useful for astronomy. Most of the lab involved using the RUATV image display tool to display and examine a few images.

5. A two-dimensional array of Gaussian random numbers with zero mean and unit standard deviation produces a speckled image that averages to a uniform gray. Zooming in makes the individual darker and brighter pixels visible.

7. The image statistics for each random realization of the Gaussian distribution will be slightly different, but should be very similar to these:

For 11 x 11 box:

Minimum pixel value:	−2.525
Maximum pixel value:	+2.173
Mean:	−0.0737
Median:	−0.1037
Standard Deviation:	1.0198

For 151 x 151 pixel box:

Minimum pixel value:	−4.125
Maximum pixel value:	+3.886
Mean:	−0.00092
Median:	−0.00221
Standard Deviation:	1.00141

Since each box has only a finite number of values drawn from the distribution, you do not expect the mean to be exactly zero and the standard deviation to be exactly one. For example, the expected standard deviation of the mean of N values is the standard deviation expected for a single value divided by the square root of N (i.e., this is the expected scatter of many such estimates of the mean around the true mean). For the above two samples this is:

11 x 11 box (121 samples):

S.D. of mean = $1.0198 / (121)^{1/2} = 0.0927$

151 x 151 box (22,801 samples):

S.D. of mean = $1.00141 / (22801)^{1/2} = 0.0066$

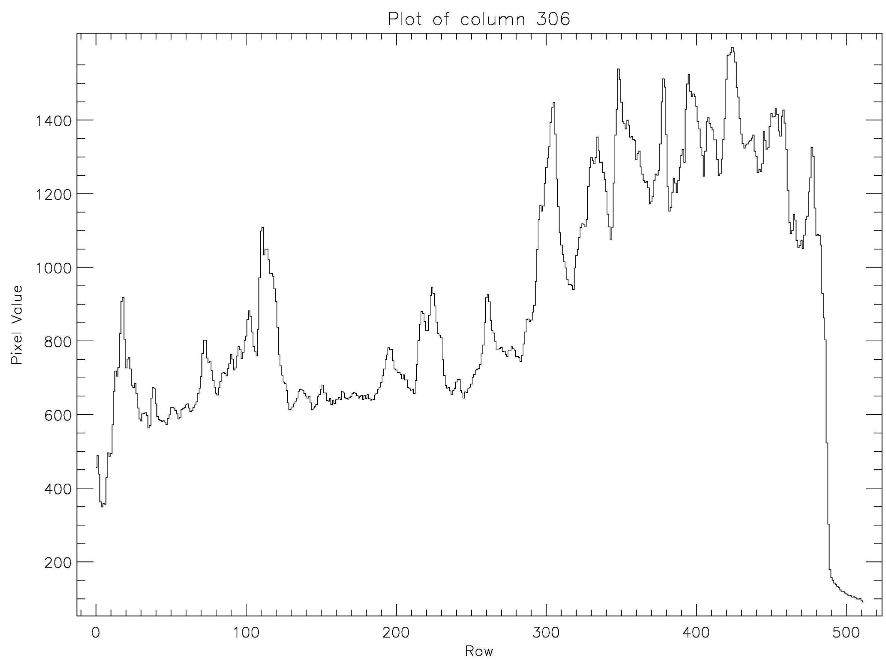
Note that the means and medians differ from 0.000 by amounts comparable to these expectations in each case.

In general, as the sample size gets larger, the precision of the statistical estimators like the mean, standard deviation, etc. gets better. Also, note that in the larger samples the maximum and minimum values get larger, since there is a greater chance of seeing the rare large fluctuations.

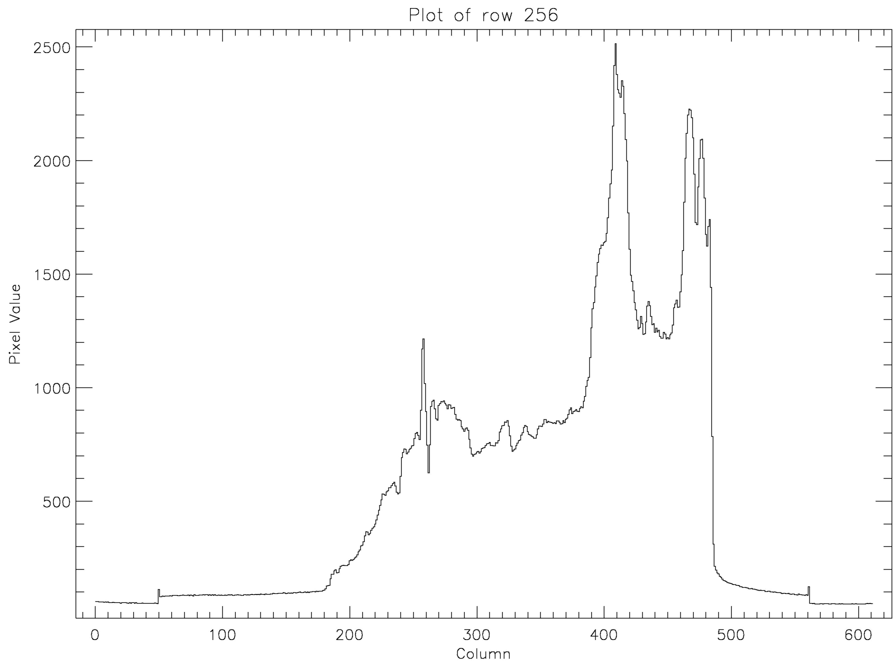
8. The brightest pixel in the Moon image is at (x,y) = (408,241) and has an intensity value of 3458. The lower part of the Moon's limb is cut off in the image, so it is not possible to measure the full diameter of the moon in the vertical direction. The bottom pixel is at y=0, and the top pixel is at y=499, so the partial diameter is 499 – 0 + 1 = 500 pixels. A better estimate of the actual diameter would be to measure along the terminator (the set of points dividing the illuminated and dark portions of the lunar surface), since the Moon is almost at first-quarter phase in this image. I measured the coordinates of the top and bottom of the terminator to be: (311,0) and (134,479), for a diameter of:

$$D = [(311 - 134)^2 + (479 - 0)^2]^{1/2} = 510.6 \text{ pixels}$$

Plots of the center row and column are shown below.



9. From the image header, you find that the exposure time for the sn2011fe.fit image was 30.00 seconds. (Actually, this image is the average of five 30-second exposures, as indicated by the value of the NCOMBINE keyword at the end of the header. We ignored this complication in this lab.) The V filter was used − this is in the yellow-green part of the spectrum, centered at 550 nm. The brightest pixel in the supernova, (390,877), has an intensity value of 24038 ADU. The galaxy M101 is difficult to see in the image because it is nearly swamped by the signal from our bright, light-polluted skies. It did not help that M101 was low in the sky when the image was taken.



10. The photometry of the supernova using the p key gives:

FWHM:	3.62 pixels
Sky:	679.388 ADU
Object counts:	404,821. ADU

11. The photometry of the star at (858,245) gives: (note that the x-value specified in the lab was 10 pixels too small; however, everyone seems to have figured out which star was intended)

FWHM:	3.66 pixels
Sky:	667.873 ADU
Object counts:	31,005.5 ADU

Using the definition of magnitude, as discussed in Lecture 4 or Chapters 5 and 10 of the text, the difference between the magnitudes of the "standard star" and the supernova is

$$V_{sn} - V_{std} = -2.5\log(s_{sn}/s_{std}),$$

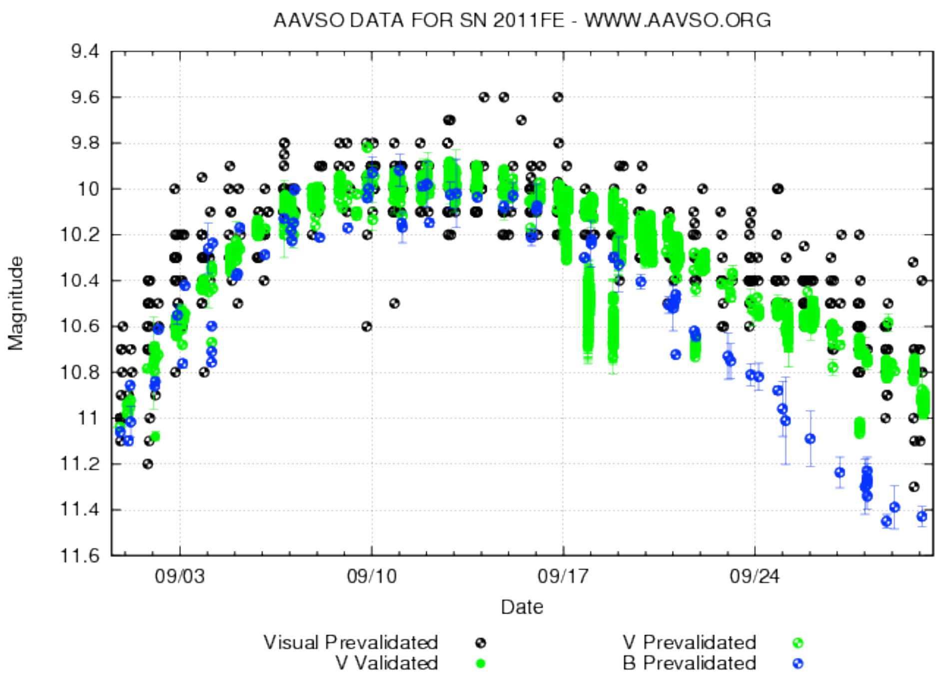
where the signals s_{sn} and s_{std} are the "object counts" for the two objects. The problem gave $V_{std} = 12.751 \pm 0.031$, so

$$V_{sn} = 12.751 - 2.5\log(404{,}821/31{,}005.5) = 9.961.$$

Using the formula for the propagation of errors gives the uncertainty of this magnitude as (see the slides for Lecture 4):

$$\sigma_{Vsn} = [\sigma_{Vstd}^2 + 1.18(1/s_{std} + 1/s_{sn})]^{1/2}$$
$$= [(0.031)^2 + 1.18(1/31005.5 + 1/404821)]^{1/2} = 0.032.$$

Actually, the two signals should really have been multiplied by five because the image is the average of five images. Obviously, this would have had little effect on the estimated uncertainty in the magnitude of the supernova, which is dominated by the uncertainty in the V magnitude of the standard star. A more careful estimate of the uncertainty would include the contribution of the subtracted sky signal (we will include this contribution in Lab 5), but this would again make little difference in the uncertainty for these bright stars. On the September 10, 2011 (UT) date of the image, SN2011fe was just approaching its maximum brightness and numerous amateur and professional measurements yielded a V magnitude just slightly brighter than 10.0, in excellent agreement with our result. The light curve shown below was taken from the American Association of Variable Star Observers (AAVSO) website (http://www.aavso.org/data/lcg).



12. The FWHM of the star at (1979,737) is 5.39 pixels. The fitted function obviously does not fit the profile well, and so the full width parameter of the fit is not meaningful. Since the central brightness of the star should be much greater than the saturation value of ~64000, the half maximum value will be greater than ~32000 and, hence, the radius at which this value is reached will be smaller. Thus, fitting saturated stars gives an overestimate of the real FWHM of stars in the image. Note that if you fit several other un-saturated stars in the image, they all have similar FWHM values, independent of the star's brightness. To obtain useful information on the star at (1979,737), you would need an image with a shorter exposure time.