Obs & Stats HW 8

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CCD Image Basic Data Reduction

Table 1: Raw FITS image properties

FILTER	ITIME	DTYPE	MIN	MAX
Halpha	0	uint16	48	449
Halpha	0	uint16	48	451
Halpha	0	uint16	48	447
Clear	4	uint16	11993	24614
Clear	4	uint16	11168	23358
Clear	4	uint16	10596	22399
Clear	300	uint16	44	47769
Clear	300	uint16	49	47855
Clear	300	uint16	50	47707
Clear	300	uint16	349	57134
Red	300	uint16	100	53013
Green	300	uint16	108	53055
Blue	300	uint16	72	46778

1. See Table 1, first two columns.
2. See Table 1, last three columns.
3. The dark images all have the same exposure time of 300 seconds, which is the same exposure time as the raw M57 images.
4. See printout.
5. The `bias_master` is used to remove systematic variations from the image. The `dark_master` should not be used because the flat images have not been exposed long enough for hot pixels to have any significant effect.

   Each flat should be normalized by its mode so that the median combining will not be affected by any variations in illumination during exposure.

   The combined image should be normalized by its mode to ensure that most of the image has a value close to unity, providing a slight correction to the raw data to flatten the field.
6. See printouts.

Noise Analysis

Readout Noise

1. The mean of the first bias frame is 103.3 DN, and the standard deviation is 6.9 DN. The mean is nonzero because of variations in the potential across different pixels. The standard deviation is nonzero because of readout noise.

2. The difference histogram has less of a tail because taking the difference of two bias images has removed the systematic variations across the chip, leaving only the readout noise. The standard deviation of the difference image is 9.7 DN, so dividing by $\sqrt{2}$ gives the standard deviation of a single frame as 6.8 DN, very similar to the measurement above.

3. Use the standard formula for averaging normal distributions: $\sigma_3 = \frac{\sqrt{3*\sigma_1}}{3} = 4.0$ DN.

System Gain

1. Using the given formula, and performing the calculation on ten adjacent regions to estimate the uncertainty,
$$G = \frac{\mu_{DN}}{\sigma_{DN}^2} = 1.47 \pm 0.02\ e^-/DN \tag{1}$$

2. The calculated value of the gain is within two standard deviations of the gain given in the FITS header. That is a reasonably close match.

Characterizing Dark Current

1. The mean of the first dark frame is 114.4 DN, and the standard deviation is 148.0 DN. The mean is not much higher than for the bias frame, but the standard deviation is much larger due to large outliers. Defining the upper limit of the main distribution to be just over 10000 DN, only 100 pixels are true "outliers".

2. The standard deviation is much lower because the systematic "hot pixels" are similar in both frames, so subtraction leaves just the random portion of dark current. The readout noise is 9.7 DN, the dark current noise is 7.6 DN, and the combined effect from both is 12.3 DN.

3. The dark current noise from subtracting a three-frame average from the astronomical image is 6.2 DN.

Sky Noise

1. Because it was not specified which reduced image to use, I am using the unfiltered luminance image. The mean sky background is 499.8 DN and the standard deviation is 24.3 DN.

2. The residual noise after subtracting readout and dark current is 23.1 DN. The expected sky noise using Poisson statistics is 22.4 DN, which is a very close match to what was measured.

Photometry Uncertainty

1. The dominant source of noise, by far, is the Poisson noise from the source itself. The second source, the sky noise, is less by almost an order of magnitude.

2. Photometric noise can also arise from atmospheric variations or tracking error, especially in time-series photometry.