Characterizing and Calibrating CCDs.
Read noise and gain

- Read-noise and gain
  - Most modern CCDs have <10e readnoise; 6e is typical.
  - Gain tells you the number of e/ADUs
- You should always measure this yourself for fun during your run.
Full well and linearity range

- Where and why are you going to saturate?
  - Full-well capacity of CCD is typically 80,000–120,000e– (depending upon manufacturer and pixel size). Smaller pixel sizes usually mean full well is smaller.
  - If your gain is 1.0 e/ADU, you will “saturate” when your signal gets to 65,535.
  - If your gain is >=2 you will likely go non-linear a bit before you reach the full well.
Gain 1.5, full well 100K

Number of ADUs vs Number of electrons
gain 3.0, full well 100K
gain 3.0, full well 100K

Number of ADUs

Number of electrons

0 5×10^4 10^6 1.5×10^6 2×10^6

0 2×10^4 4×10^4 6×10^4 8×10^4
Full well and linearity range

- This has all assumed that you are using a modern 16-bit A/D converter. There are still some 15-bit A/D converters around in which the largest number you can get out is 32,767.
Bias level

When a CCD is read out through a “bias voltage” is added to the amplifier output. Why? Simple! You’re only going to get positive numbers. You don’t want the read-noise to have any chance of taking you into negative territory. This is often overdone; i.e., bias level may be 1000 ADUs even though the read noise is only a few ADUs.
What are the cosmetics like? Are there bad columns, or non-linear areas?

- Can measure this yourself using short vs long exposures.
- Sometimes cosmetic issues (such as bad columns) are REALLY obvious.
DQE as a Function of Wavelength

- DQE = Detector Quantum Efficiency. If 10 photons fall on the CCD, how many get absorbed and how many of them bounce off?
- Depends a lot on what sort of anti-reflective (AR) coating has been applied!
Quantum Efficiency vs. Wavelength (@ room temp)

FIGURE 7 Typical QE curves
Read out time

- What is the read-out time? This allows you to know whether you should bring a good book along with you, and/or how many twilight flats you will be able to get.
Minimum Exposure time for the Shutter

- How good is the shutter? Is it an iris shutter or a double-blade shutter? What is the shortest exposure you can make and still achieve <<1% uniformity?

- This is also very important for knowing what to do about twilight exposures.
Minimum Exposure time for the Shutter

Example: Unibliz shutter
0.5 sec / 10 sec
Minimum Exposure time for the Shutter

- Open/close time of 30 milliseconds. So, want exposure times of 5 seconds or more:

$30 \times 10^{-3} / 5 = 0.6\%$
Pixel scale: should you bin?

- Pixel scale

  - For spectroscopy, will want to know dispersion and wavelength range, but same idea.

- Sometimes the pixel scale is silly for your application: for instance, the Perkins 72-inch PRISM has a scale of 0.4″/pixel. The seeing typically 2.0″. So, FWHM is going to be 5 pixels.
1) To bin or not to bin? Is it nobler in the mind...

Binning means taking $2 \times 2$ pixels (say) and making them one big fat pixel.

Is the resolution worse? Or just the scale?
Pixel scale: should you bin?

● Advantages:
  • Shorter readout times (by about a factor of 3, not 4).
  • Deeper full wells! Sometimes this helps to have a very large dynamic range.

● Disadvantages:
  • Scale is down a factor of 2. Sometimes this matter, and sometimes it doesn’t—resolution!

★ Do you still satisfy the Nyquist sampling?
Choosing a gain

In some CCD cameras you get to specify the gain (basically set by how fast you’re reading out the array; surprise!). Some considerations:

a) You want to sample the read-noise. If the read-noise is 30e−, it made sense to have a gain of 10. If the read-noise is 6, it makes sense to have a gain of 2-ish.

b) You want to map the full well of the chip (100,000 e−?) to the full range of the A/D converter (65,535-1000, say)---→1.5-ish.