OBSERVATIONAL ASTRONOMY – II

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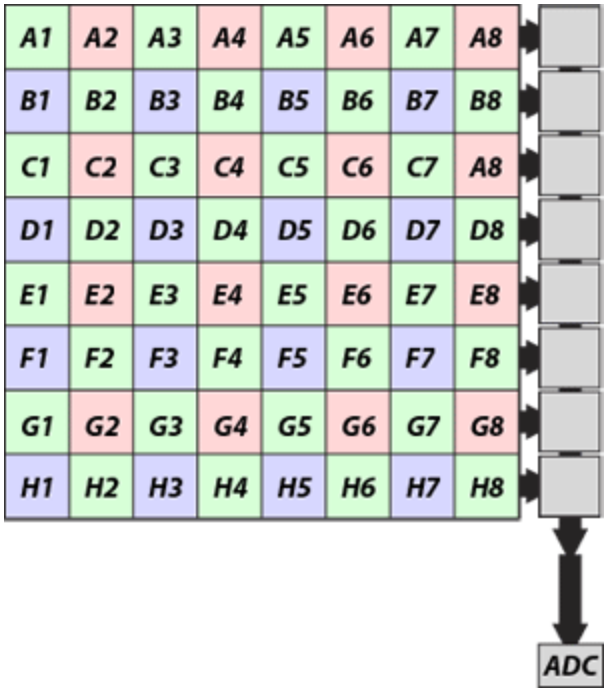
CCD Gain

- What is relationship between electrons in a CCD and pixel values?

The readout register is shifted to the right by one pixel, and the pixel at the bottom right is shifted into a readout capacitor. What's next?



CCD Gain

- The steps involved in reading the value of a pixel are something like this:
  1. Electrons transferred to "amplifier"; really a capacitor. Units are **coulombs**.
  2. The voltage induced by this charge is measured. Units are **volts**.
  3. An Analog-To-Digital (A/D) unit converts the voltage into some other voltage, which may have only one of several discrete levels. Units are still **volts**.
  4. The voltage is converted into a number which is passed from the hardware to the computer software as the pixel's value. Units are **counts**, also called "Analog-to-Digital Units" (**ADUs**).

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- In both steps 3 and 4, one can scale the result by any arbitrary factor and the relative pixel values will remain the same. Some software allows the user to modify the scaling factor dynamically; others have a fixed setting.
- The end result is that there is some factor which relates the initial number of electrons in a pixel to the final number of counts reported by camera software. The ratio of these two numbers is the **gain** of the camera:

$$gain = \frac{Number\ of electrons\ per\ pixel}{Number\ of\ counts\ per\ pixel}$$

CCD Gain

- How should one choose the gain factor? There are several criteria.
  1. **Full-well depth vs. largest pixel value:**
     Each CCD is designed to hold only so many electrons within a pixel before they start to leak outwards to other pixels. This maximum size of a charge packet on the chip is called the **full well depth.**
     There is also a "maximum possible number" in the Analog-to-Digital converter. Most CCDs use 14-bit, 15-bit, or 16-bit A/D units: the corresponding maximum pixel values are $2^{14} = 16384$, $2^{15} = 32768$, and $2^{16} = 65536$.
     It is logical to arrange the gain so that very roughly, the number of electrons in the full-well depth corresponds to the maximum pixel value.

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- How should one choose the gain factor? There are several criteria.

2. **Readout noise vs. smallest pixel value:**
   What are the SMALLEST values that make sense? A typical **readout noise** is 3 or 10 electrons. Therefore, if two pixels have values which differ by only 2 electrons, it's not easy to tell the difference between them. The smallest difference one can represent in an integer image is 1 count. To some extent, it makes sense to arrange the gain so that 1 count corresponds to some moderate fraction of the readout noise. Any finer measurement of the pixel values would yield differences which would be essentially random.

CCD Gain

- BFOSC - Bologna Faint Object Spectrograph & Camera – is an instrument built to allow, with a simple configuration change, the acquisition of both images and spectra.

- The detector is an **EEV LN/1300-EB/1** CCD with 1300 x 1340 pixels, AR Visar coated, back illuminated.
- The detector Readout Noise is **3.06 e^-/pix** and the gain is **2.22 e^-/ADU**.
- Dynamical range is **16 bit**.
- Full-well capacity – **117000 electrons.**