Krittika Summer Projects

Image Reduction

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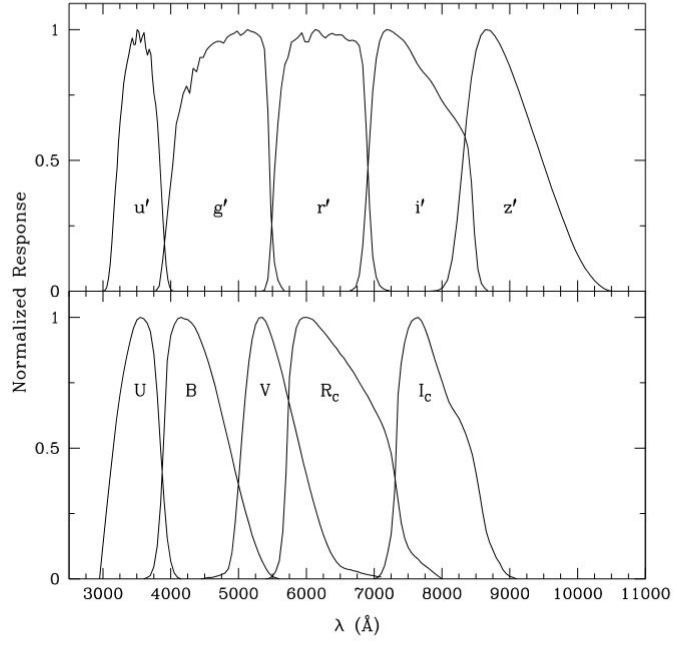
The content for these slides has been taken from GROWTH Astronomy School 2020 Lecture on Image Reduction and University of Sheffield PHY 241 Lecture 06, you may go through them

Photometric Systems

- *Filters* are placed in the light path and allow light of only a specific passband to pass through
- They can be narrow-band or broadband
- Provide spectral information about the source
- Well-defined sets of filters are known as *photometric systems*
- Two common photometric systems – the *UBVRI* (also known as *Johnson-Morgan-Cousins system*) and the *u'g'r'i'z'* (used by SDSS)



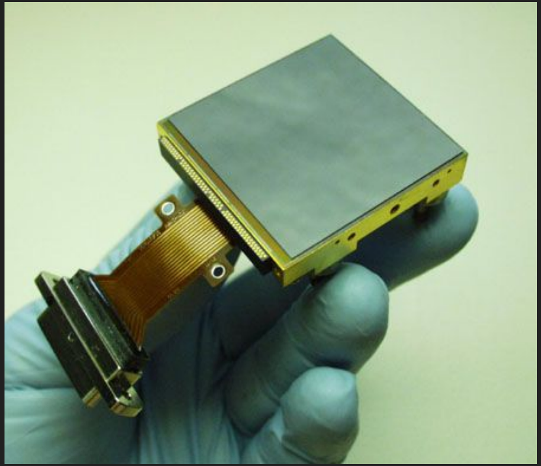
Detectors

A device located in the focal plane of a telescope

Records photons incident upon it

Astronomical sources are very faint – must not waste photons

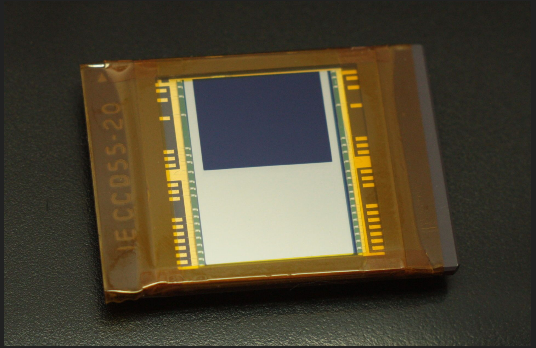
Made of a 2D array of pixels for imaging



NIRCam 2K × 2K HgCdTe detector from Teledyne imaging sensors

CCDs

- Use semiconductors (Silicon being the most popular)
- Based of the photoelectric effect – electrons are excited from the valence to the conduction band by absorbing photons
- *Quantum Efficiency* is the fraction of photons that produce photoelectrons
- The QE of CCDs can reach 90% at optical wavelengths
- After an exposure, each pixel contains electrons proportional to the number of incident photons – now we have to read these

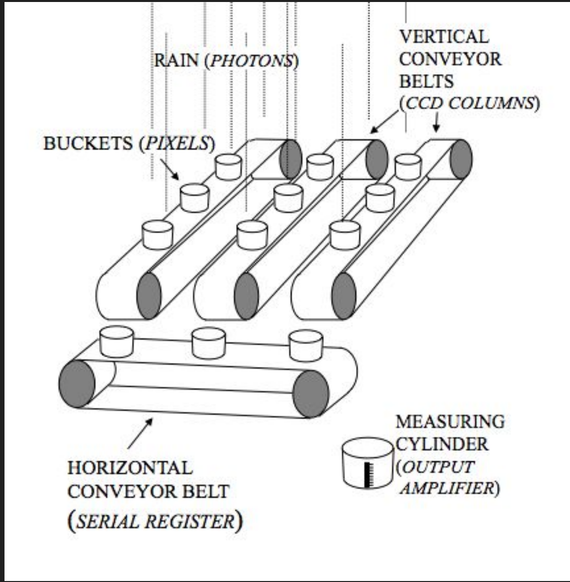


CCDs – Charge Transfer

Think of it as a rectangular array of buckets

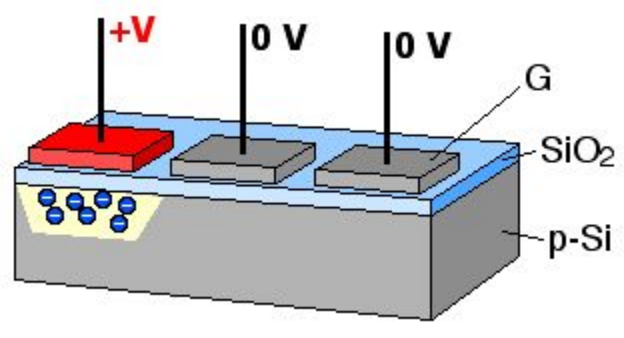
You open the shutter for exposure time and the water collects – now you need to measure the amount of water

Shift the rows one at a time onto the serial register, which takes one bucket at a time to the measuring unit



CCDs – Charge Transfer

- Each pixel consists of three electrodes
- A large positive voltage applied to one will create a potential well which is filled with photo-electrons
- The voltage in an adjacent electrode is raised to the same level – allowing the electrons to flow
- Decreasing the voltage of the original one completes the transfer



CCDs – Reading the Charge

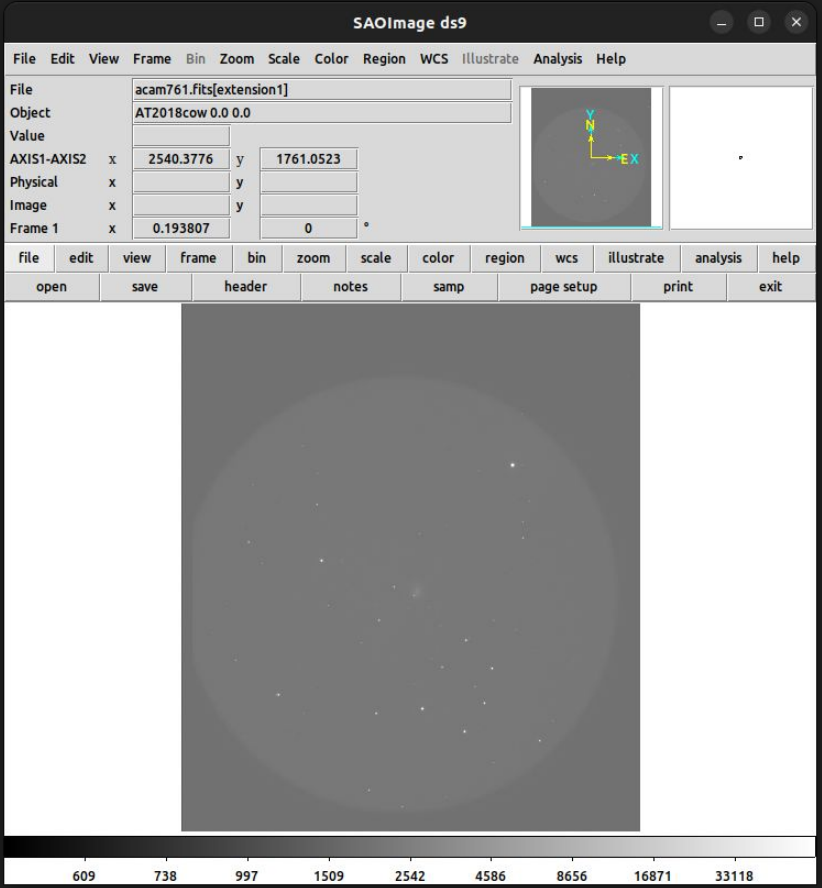
- The voltage of each charge packet is amplified and measured
- The measured voltage is digitized using analogue-to-digital converter (ADC), producing *analogue-to-digital units (ADUs) (or counts)* which are then stored
- *Gain* is number of electrons/ADU – kept close to 1
- Each pixel has a maximum charge carrying capacity – go beyond that and electrons spill into neighbouring pixels (called *blooming*)
- Alternatively, if using a 16 bit ADC, you can record a maximum of 65535 counts

Other Signals

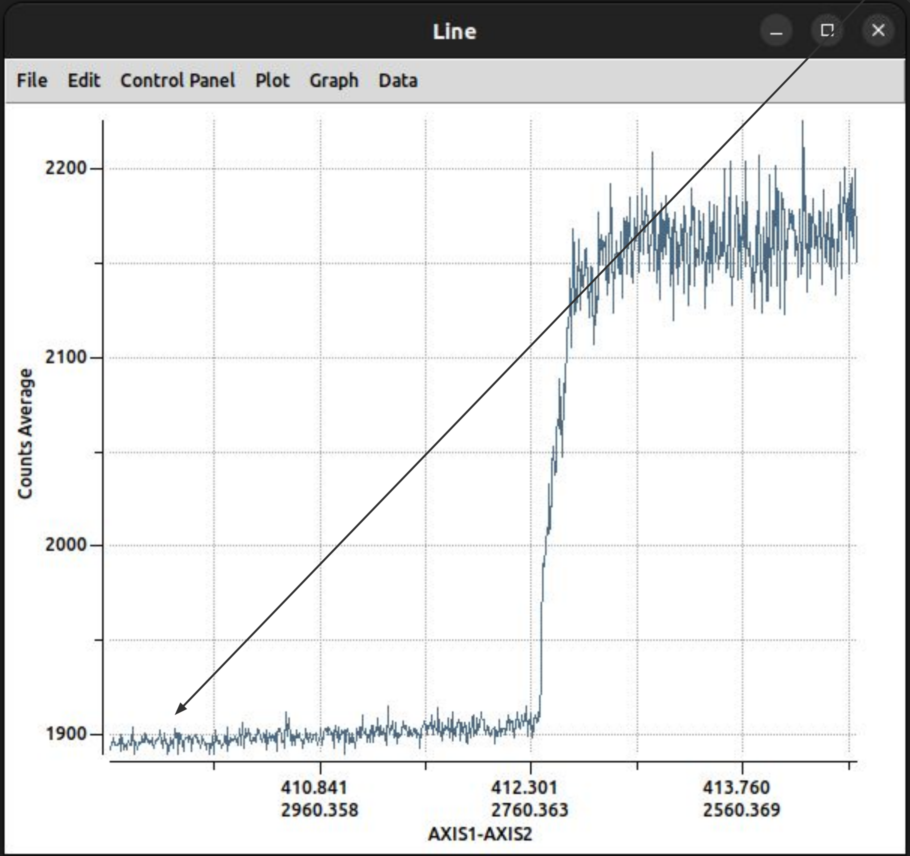
A *bias* voltage is applied to the amplifier, so there are always “counts” even if there is no signal – have to subtract it

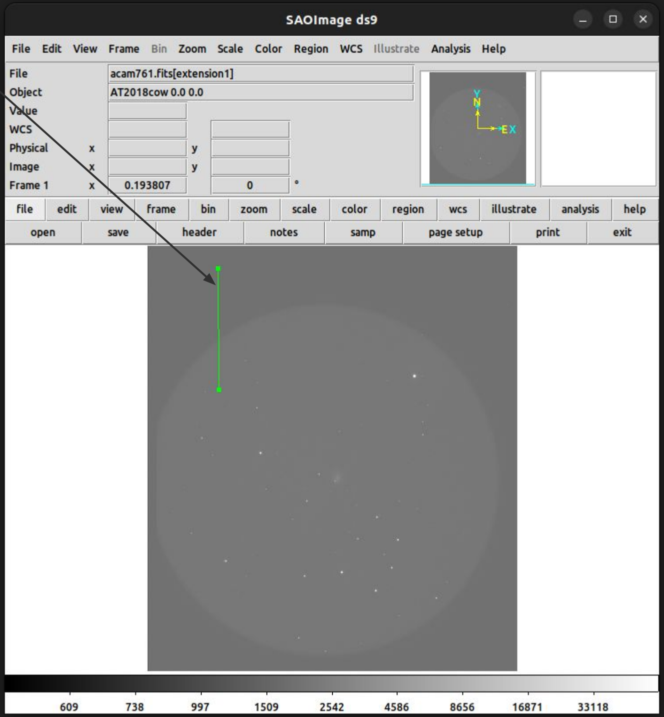
For uncooled detectors, there may also be *dark current* due to thermally excited electrons – it’s generally negligible in optical

What weird thing do you observe in this image?



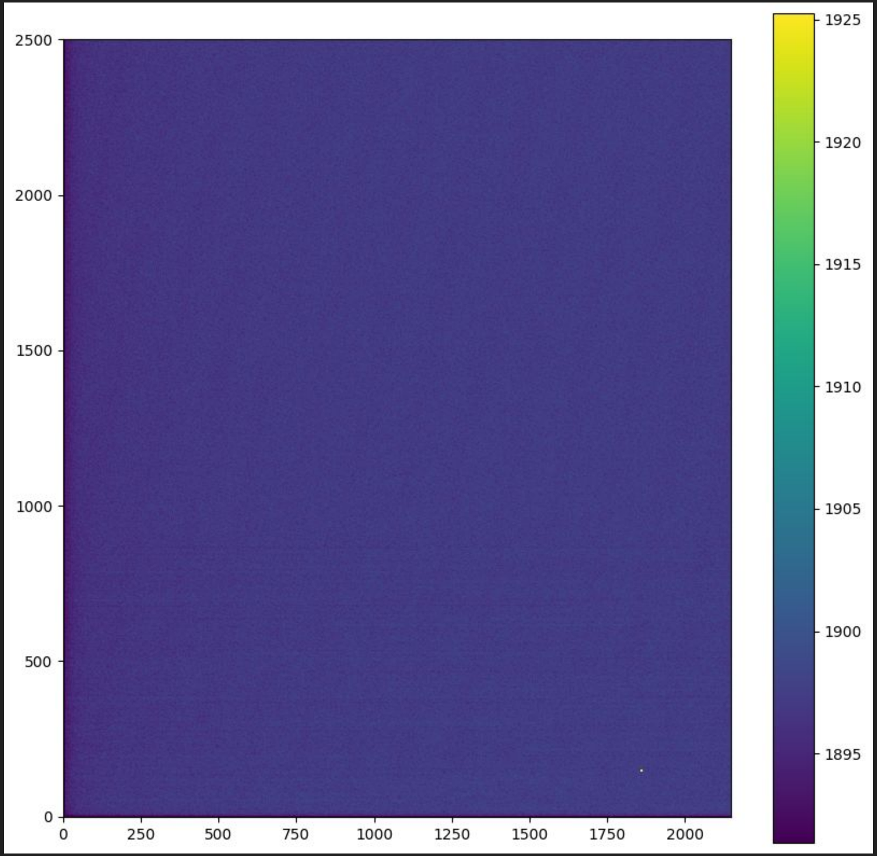
Counts in the unexposed region (called bias)





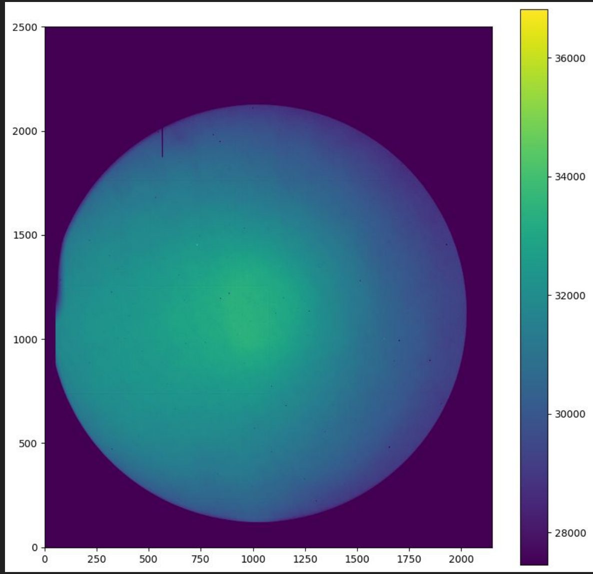
Bias Subtraction

- Need to subtract the bias
- We take a series of zero second exposure images, and median average them to create a “master bias” – average because a cosmic ray still might hit the detector
- We then subtract the master bias from the raw image



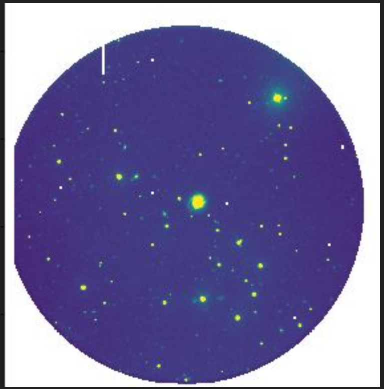
Flat Fielding

- Not every pixel has equal sensitivity
- Vignetting, dust particles, and some other manufacturing artifacts may also result in different sensitivity
- Need to calibrate the relative sensitivity of each pixel
- Point the telescope at a region of sky that is known to be uniform – true intensity does not change with position
- We typically choose twilight sky – when the sky contains enough scattered light from the sun but not so large to saturate the detector



Flat Fielding

- We take a series of flat field images in the same filter that is used for observation and subtract the bias from them
- Now there may be varying levels of intensity between images, so we normalize the flats to have a median of 1
- We combine them using a median average to create a “master flat”
- Each bias-subtracted image is then divided by the “master flat”
- We now have a usable science image



Coaddition

- We usually take multiple exposures of a target
  - We can average out certain artifacts that are present in different location
  - Can take counts before saturation
- Need to add all the science images – increases the signal and hence we can image deeper
- If the telescope didn’t move we can simply add the images
- Otherwise we need to remove the relative offset between images – we do this by by measuring the relative positions of a reference star from image to image and offsetting if the telescope didn’t move much

Tasks

Here is the Google Drive link to the notebook and the data of Task 1. Gaurav will be presenting his work. Ask on the group or DM if you have any questions.

THANK YOU