## ASTC02 - PROF. HANNO REIN

# ECTURE 4

CCD/CMOS Sensors Practical 2 Practical 3 Observatory

## **PHOTOGRAPHIC PLATES**



## PHOTODIODE

- Light strikes photo diode
- Photoelectric effect creates free electrons
- Discrete areas on the chip are biased and will attract electrons/holes (otherwise they would recombine)
- Each pixel collects photos for the duration of the exposure
- ▶ Up to 10<sup>5</sup> electrons per pixel
- One typically doesn't measure individual electrons (=photons) but amplifies the charge before reading it out



## CHARGE-COUPLED DEVICE (CCD)

- Canadian invention by Willard
  Boyle and George E. Smith
- 2009 Nobel Prize for Physics
- Very high photon efficiency
- Often used in scientific application



## **COMPLEMENTARY METAL-OXIDE-SEMICONDUCTOR (CMOS)**

- We use a CMOS sensor, Sony IMX224
- Less efficient, cheaper
- Difference to CCD is how image is read out
- CMOS read out more reliable



Active pixels

SONY IMX224



## **UNWANTED EFFECTS**

- In addition to light, thermal processes can also create electron pairs. This leads to a dark current.
- Amplification might be different for different areas of chip (e.g. loss due to shifting charges around on CCD).
- Some pixels might be dead or hot.
- Some pixels might be more or less sensitive.
- We need to account for all of that.



## **BAYER FILTER**

- We use a colour sensor, most astrophysics sensors are monochrome
- Filters in front of each pixel
- 1 blue, 1 red, 2 green
- Later combined in software to create one pixel with three values



### JPEG

- Image format used widely on consumer electronics
- Compressed / small file size
- Looses information
- Artefacts from compression
- One RGB value per pixel (interpolated)

## RAW (TIFF, FITS)

- Contains original data from CMOS sensor with minimal processing
- More brightness levels up to 16,384 compared to 256
- Manual white balance
- Sharper images (no interpolation)
- Large file size, ~25MB/image

JPEG







## DARK FRAME

- Image with same settings, but cover closed
- Should be completely dark
- Instead, we only see noise

## $I_{\text{exposure}} - I_{\text{dark}}$

## **FLAT FRAME**

- Image with same settings, but looking at uniform brightness object
- Can be cloudy sky, sky before sunset, dome
- Should be uniform colour
- Instead we see gradients and noise

$$\frac{I_{\rm exposure} - I_{\rm dark}}{I_{\rm flat} - I_{\rm dark}}$$

## CHARACTERIZE NOISE AS WELL AS YOUR SIGNAL

- How many dark frames should you take?
- Same number of frames as for actual observations!
- Similarly with flat fields: the more the better!
- Ideally dark/flat frame should be taken just before/after observation
- Not so ideal, but still ok: can do those during rainy <u>day</u>

## WHEN IS CALIBRATION WITH DARK/FLAT FRAMES IMPORTANT?

- High precision measurements
- Photometry
- Spectrometry
- Not so much for discovery