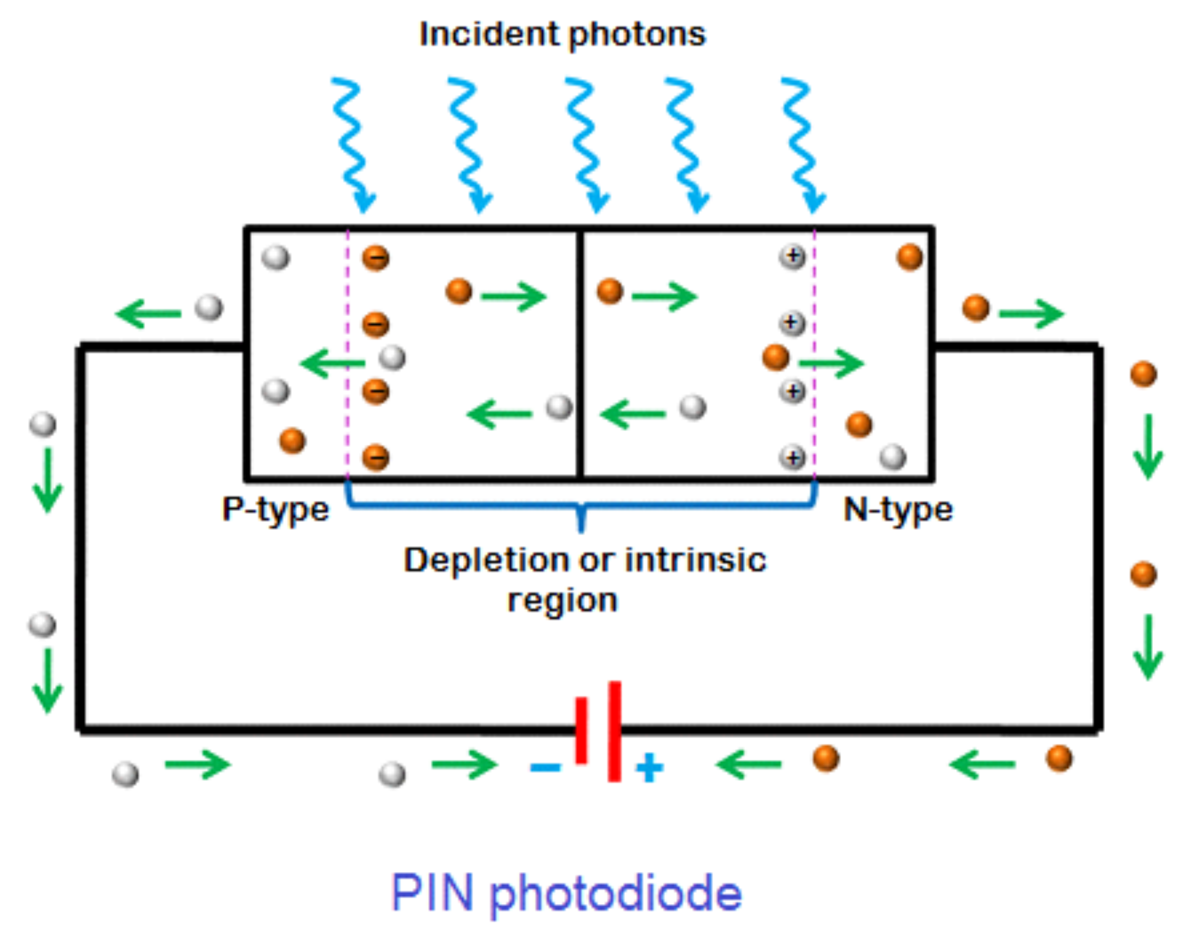
ASTC02 - LECTURE 2 - PROF. HANNO REIN

CCD/CMOS SENSORS


Acrux (α1 Cru - α2 Cru) - HIP 60718 A
Type: double star
Magnitude: 1.25
Absolute Magnitude: -3.71
Color Index (B-V): -0.15
RA/Dec (J2000.0): 12h26m35.83s/-63°05'56.1"
RA/Dec (J2017.7): 12h27m35.82s/-63°11'47.9"
Hour angle/DE: 11h11m46.13s/-63°11'47.9"
Az/Alt: +185°27'11.6"/+7°35'57.8"
Ecliptic longitude/latitude (J2000.0): +221°52'10.4"/-52°52'43.7"
Ecliptic longitude/latitude (J2017.7): +222°08'53.0"/-52°52'49.2"
Galactic longitude/latitude: -59°52'24.9"/-0°21'45.2"
Distance: 320.70 ly
Spectral Type: B0.5IV
Parallax: 0.01017"
Pictor
Volans
Apus
Atria
Ara
Girtab
Chamaeleon
Triangulum Australe
Miaplacidus
Circinus
Norma
Musca
Rigil Kent
Carina
Hadar
Acrux
δ Vel
Regor
Mimosa
Crux
S
Earth, Cape Town, 25m
FOV 58.5°
18.5 FPS
2017-09-19 18:29:37 UTC-04:00

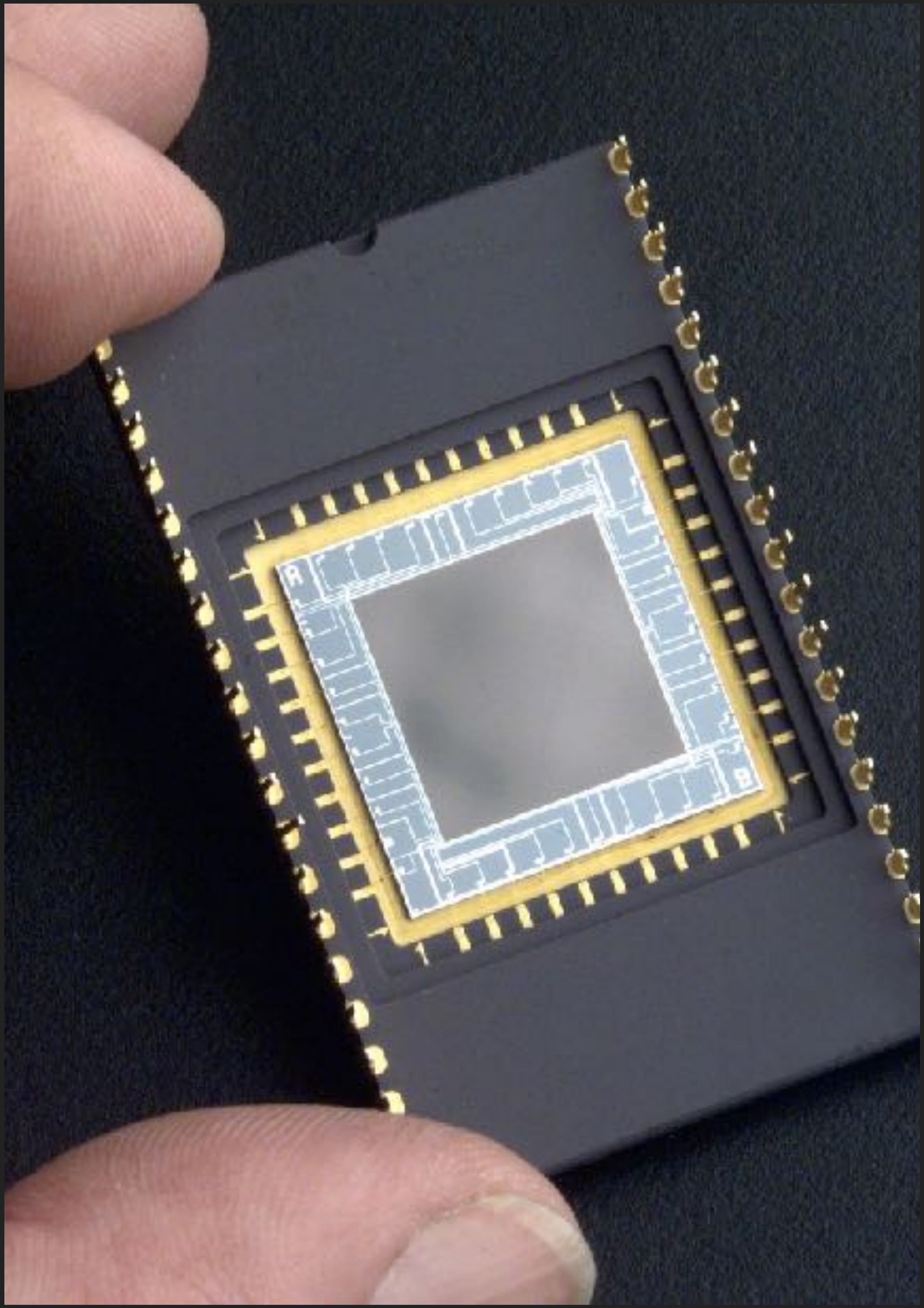
PHOTODIODE



- 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 10^5 electrons per pixel
- One typically doesn't measure individual electrons (=photons) but amplifies the charge before reading it out

CHARGE-COUPLED DEVICE (CCD)

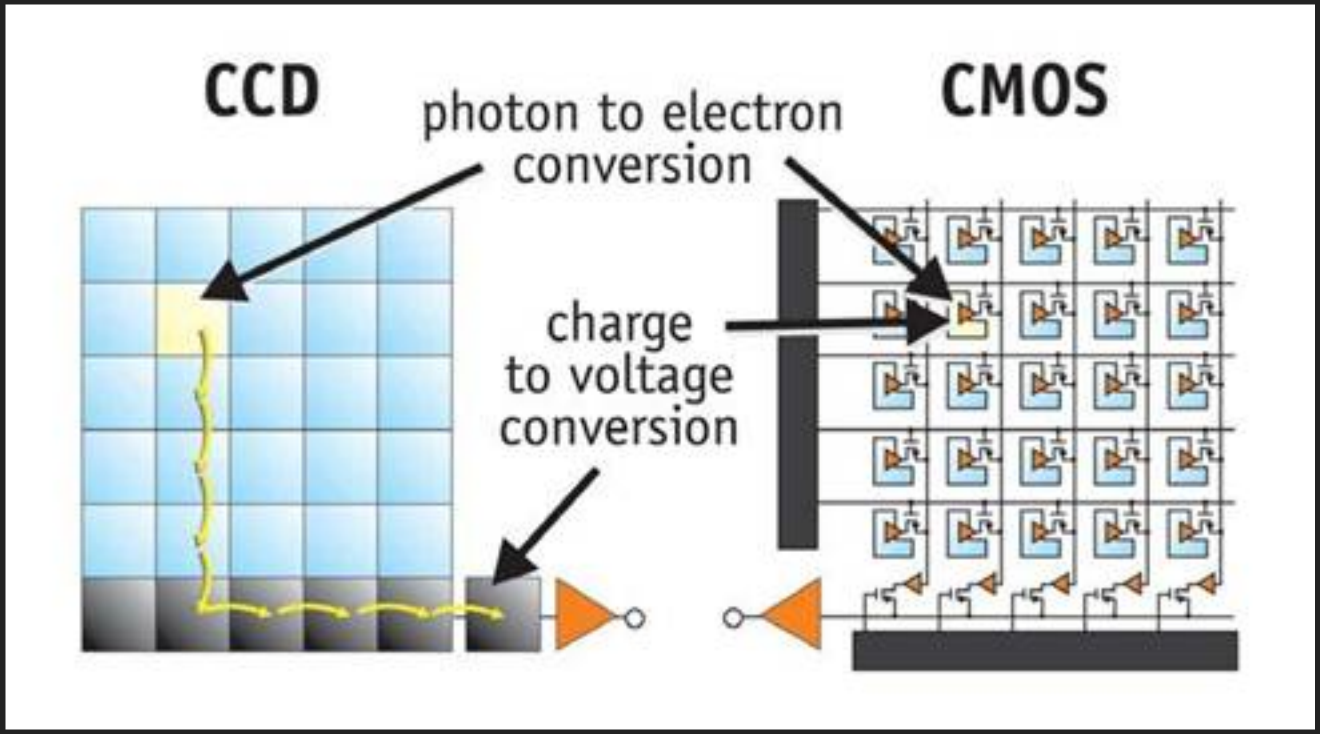
- Canadian invention by Willard Boyle and George E. Smith
- 2009 Nobel Prize for Physics
- Very high photon efficiency
- Often used in scientific application



COMPLEMENTARY METAL-OXIDE-SEMICONDUCTOR (CMOS)

- We use a CMOS sensor, Canon 450D, also your phone
- Less efficient, cheaper
- Difference to CCD is how image is read out
- CMOS read out more reliable

Passive pixels



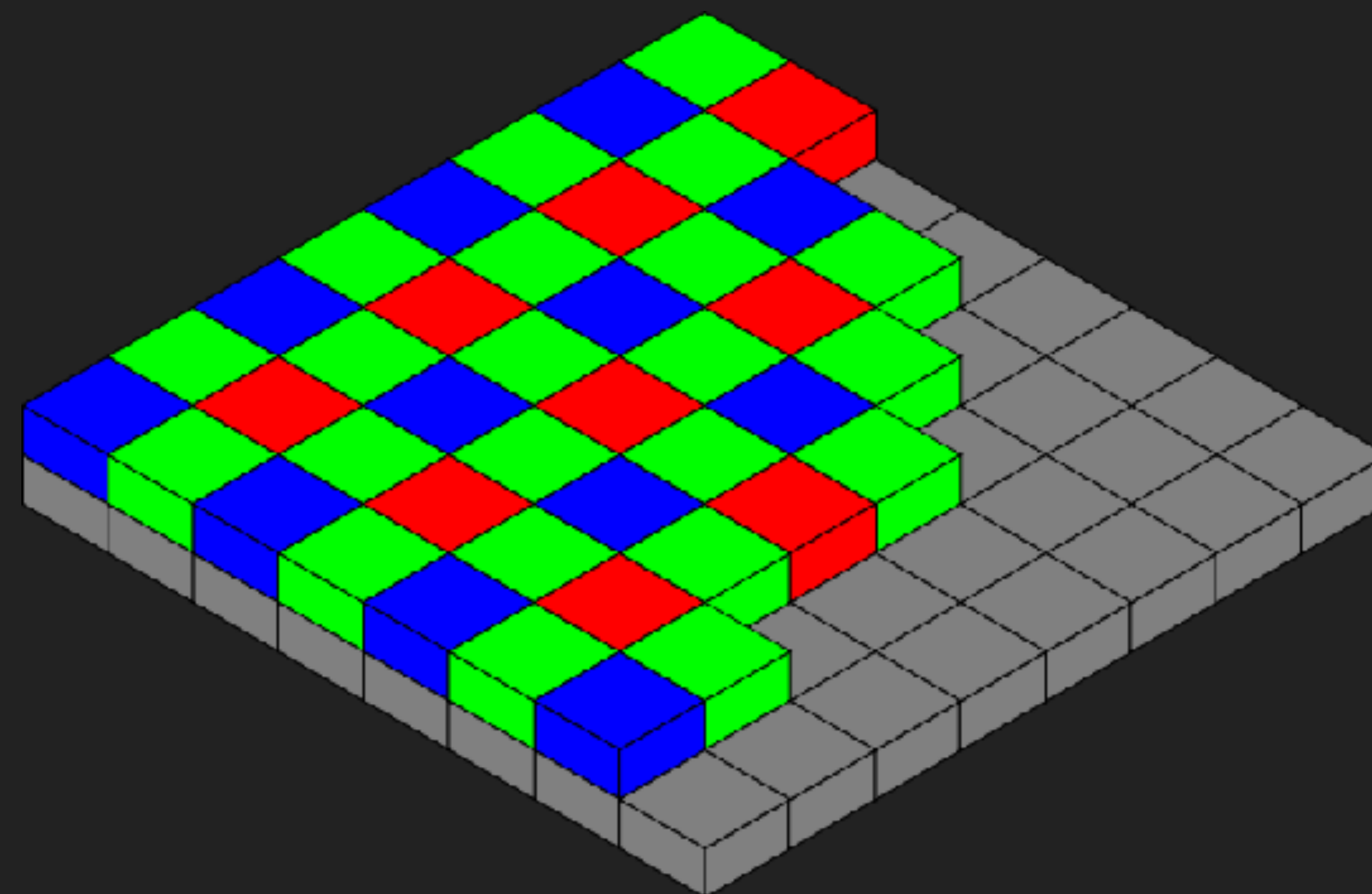
Active pixels

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
- To be as precise as possible, we want to do this ourselves.



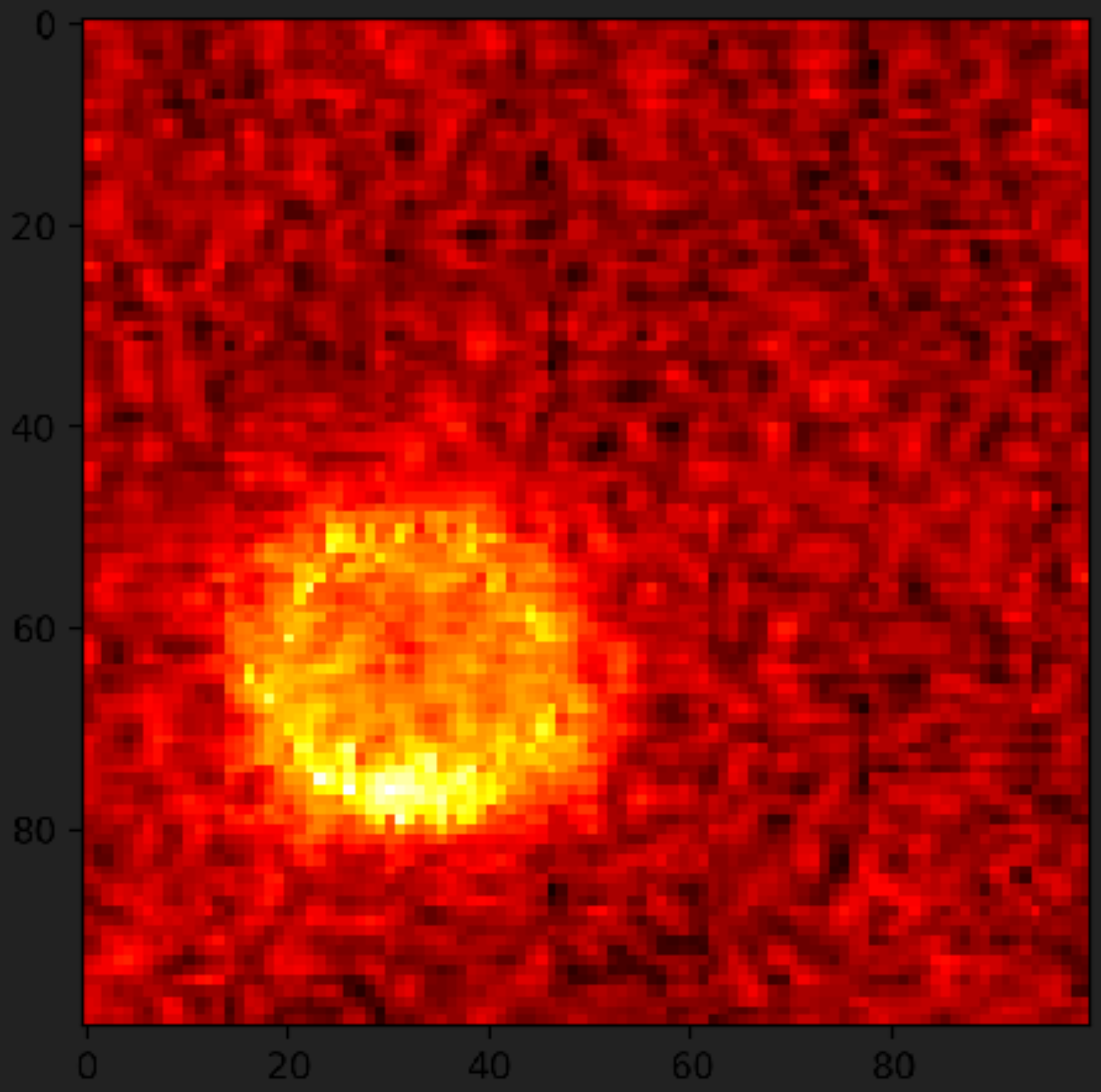
JPEG

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

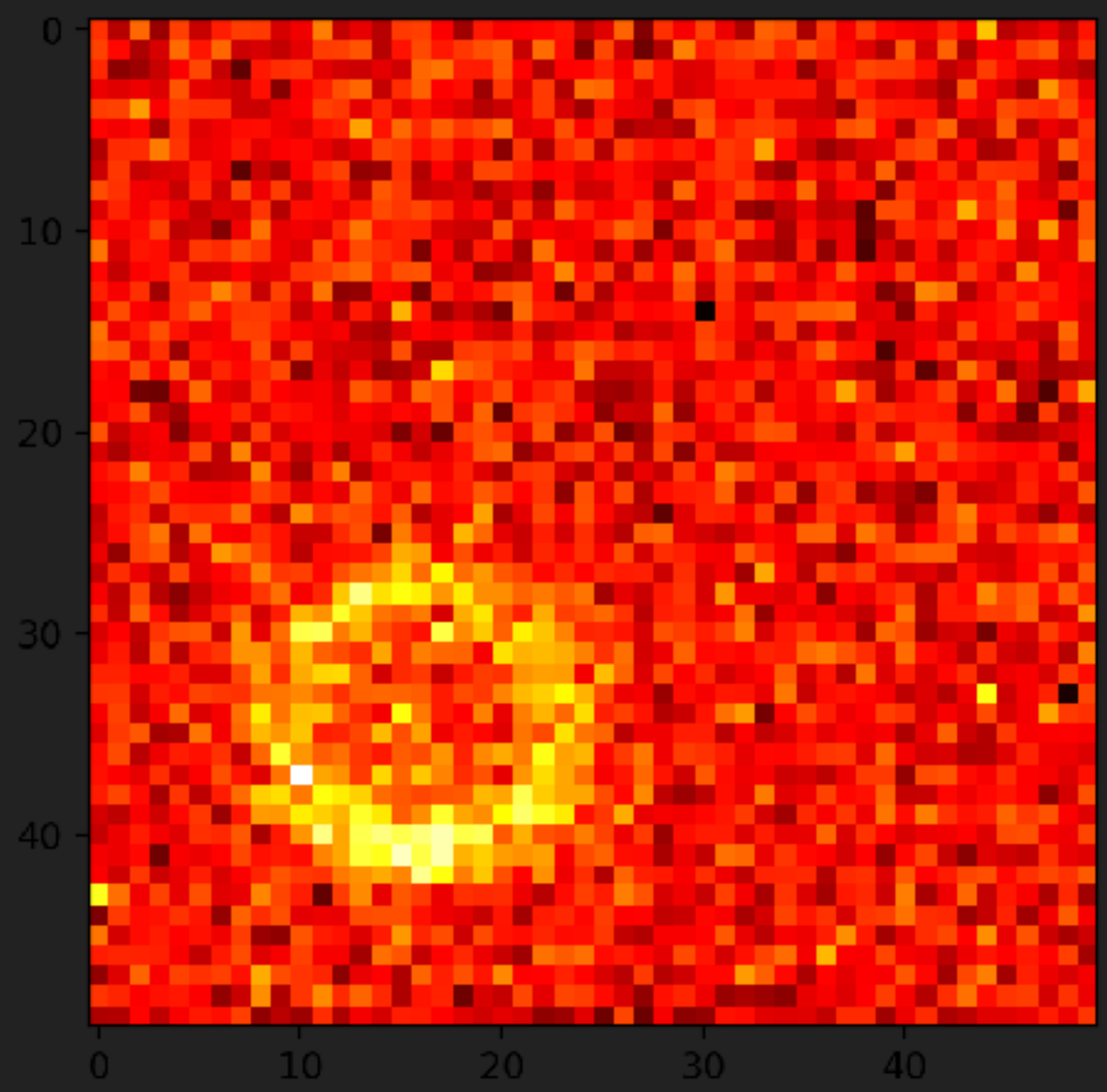
RAW

- 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



RAW



DARK FRAME

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

$$I_{\mathrm{exposure}} - I_{\mathrm{dark}}$$

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

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

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 *day*

WHEN IS CALIBRATION WITH DARK/FLAT FRAMES IMPORTANT?

- High precision measurements
- Photometry
- Spectrometry
- Not so much for discovery (such as the Pluto picture we took last week)
- You will have to take them during observations of star clusters and galaxies later in the course!