Astronomy 350: Lecture 2 - CCDs and Magnitudes

- Electromagnetic radiation revision.
  - Photons are particles of light. Each photon has a wavelength (λ), a frequency such that the speed of light, c is equal to $\nu\lambda$.
  - Electromagnetic radiation consists of γ rays, X rays, UV rays, visible radiation, infra-red, microwaves and radiowaves.
  - All light travels at the same speed, $c = 300,000 km/s$.
  - As the wavelength goes up, the frequency goes down and the energy goes down and vice versa.
- Charge Coupled Devices (CCDs) are instruments attached to the back of telescopes which take a digital image of what the telescope is looking at.
- CCDs convert incident photons to electrons. A CCD image consists of a series of ”numbers” associated with a part or pixel of the CCD image which shows how many electrons were liberated at that point and hence how mancy photons struck that part of the CCD detector.
- However, not all CCD’s are perfect.
- Some of the pixels may be dead, some may liberate far more or far fewer electrons for a given photon input etc.
- This needs to be accounted for.
- A bias frame: an image with a 0s exposure and the shutter closed.
- A dark frame: an image taken with the sutter closed but a longer exposure time.
- A flat field: an image taken of a uniform source of brightness for a reasonable length of time. Could be done in the observatory dome or using the sky just after sunset and just before the stars are clearly visible.
- A science image: the actual science image you are interested in.
- The job of data reduction is take account of the fact that some pixels may be dead, some may be too active etc.
- Create a master bias by averaging all the bias frames.
- Subtract the master bias from all other frames.
- Create a master dark frame by averaging all the darks.

- Subtract the master dark from all the flats and science images.
- Create a master flat frame by averaging all the flats.
- The reduced science image becomes

$$\frac{Science - MasterDark}{MasterFlat}.$$

- Once this is done, the photometric analysis converts the reduced science images to images with a calibrated magnitude.
- Astronomical magnitudes
  - The luminosity of an astronomical object, L is the total energy radiated per unit time (units: J/s or Watts).
  - The brightness of an object is

    $$B = \frac{L}{4\pi d^2},$$

    where B is the brightness and d is the distance of the object. This is an example of an inverse square law.
  - This is sometimes also called the flux or the energy per unit area per unit time.
  - Magnitude is a scale of brightness like cm are a scale of height.
  - The difference in magnitudes between two objects is

    $$\Delta m \approx 2.5 log(F_2/F_1),$$

    or

    $$m_2 - m_1 = -2.5 log(F_2/F_1).$$

  - Hence we can write,

    $$m = -2.5 log F + C,$$

    where C is the zero point of the magnitude scale.
  - Can write this equation at a given wavelength or over the entire range of wavelengths in which case we have a bolometric magnitude.
  - Absolute magnitude is the magnitude of an object at a fixed distance.
  - The distance modulus of an object is a measure of its distance and is

    $$m - M = 5 log(d) - 5,$$

    or

    $$m_\lambda - M_\lambda = 5 log(d) - 5.$$

– We can write

$$M_{bol} = 4.74 - 2.5log(\frac{L}{L_{sun}}).$$

– The color of an object is the difference in magnitudes at two "pass-bands",

$$m_\lambda - m_\nu.$$

– The star Vega defines the "zero point" of the magnitude scale: $m_v = 0$ and all color indices for Vega are defined to be zero.