Lecture 5

Telescopes (part II) and Detectors

Please take a moment to remember the crew of STS-107, the space shuttle Columbia, as well as their families.

Crew of the Space Shuttle Columbia Lost February 1, 2003

Rick D. Husband
mission commander;
Kalpana Chawla
mission specialist;
William C. McCool
pilot.
David M. Brown
Laurel B. Clark
Michael P. Anderson
mission specialists
Ilan Ramon
payload specialist

Telescopes (part II)

- Specifics of stuff from last time
  - Recap of FOV, magnification, resolution
  - Details of seeing
- Telescope operation
  - Mount
    - Positioning and drive

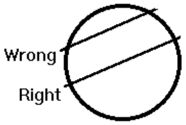
Telescopes (part II) continued

- Instrumentation
  - Detectors
    - Human eye
    - Photographic plates
    - CCD

Field Of View

Usually measured:
Allow star to drift from one edge of view to the other, record drift time.

$$FOV = \frac{(\text{drift time}) * \cos(DEC) * 360 \text{ degrees}}{86{,}164 \text{ seconds}}$$



Magnification

Ratio of focal length of telescope and eyepiece

$$MAG = \frac{fl\_telescope}{fl\_eyepiece}$$

These numbers often written on telescope and eyepiece

If not:
Focal Length = f ratio * aperture

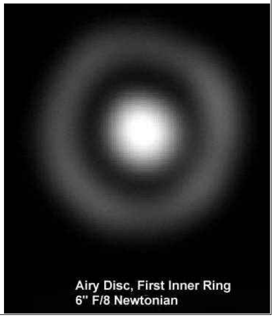
MSU telescope:
fl = f3 * 24 inch = 1828.8 mm

Resolution

Airy Disk -- the disk into which the image of a star is spread. This is a direct result of diffraction by the circular aperture of the telescope. It limits the resolution of the telescope.

Named for English astronomer George Airy who calculated its size in 1834.

This phenomena is purely due to the optics of the system, and represents the best theoretical image possible. For a perfectly in focus image in a refracting telescope, roughly 84% of the light from the star goes into the airy disk, the rest of the light goes to make the rings.



More on the Airy Disk

The size of the Airy disk can be calculated:

$$d = 2.44 * \lambda * f$$

d is measured from the middle of the dark zone between the Airy disk and the first ring.

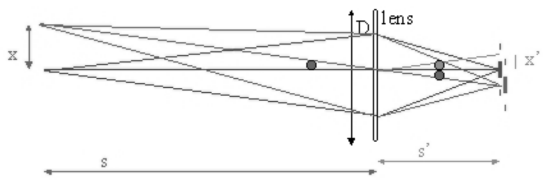
λ is the wavelength of light used

f is the focal ratio of the telescope

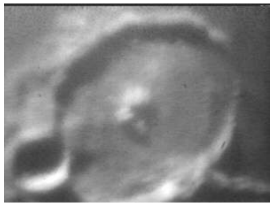
Rayleigh criterion

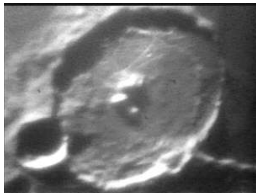
$\theta\_min = 1.22 * \lambda / D$

θ_min - smallest angular separation able to be resolved (radians)
λ - wavelength of light we are working with
D - aperture of telescope



Seeing





Telescope Mounts

Two basic types of mounts:

Alt / Az -
Intuitive, inexpensive, must drive in two directions

Equatorial -
Harder to set up initially, but only need to drive in one direction

Equatorial

Aligned along celestial equator

Points to North celestial pole

Instrumentation

- Human Eye
- Photographic Plates
- CCD
  - image considerations
  - filters

Human Eye

Easy to find, cheap, robust. Rather dependent on the actual observer however.

Need to sketch what you see.

Not sensitive to wavelengths other than optical

Photographic Plates

Early photographs (daguerreotype) were on metal plates

Moon in 1840 (20 minute exposure)

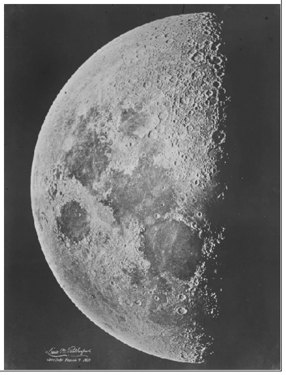
First star in 1850 (Vega)

Photograpic plates of some type used up through 1970's.

Moon plates

Daguerreotype 1852
J. Whipple

Wet plate 1865
Lewis Rutherfurd



Plates

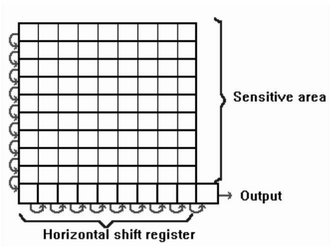
Pros
- Large area
- Good definition of image

Cons
- VERY inefficient (about 1% of light that hit was recorded)
- Long exposure times
- Had to be developed

CCD

An array of small photo-detectors

As light strikes a pixel, charge accumulates. The amount of charge depends on the intensity of the light falling on that pixel. The charge can be read out and an image reconstructed from the data.



Processing a CCD Image

Raw image from a CCD needs to be processed before the information is useful. Some of the things that need to be considered are:

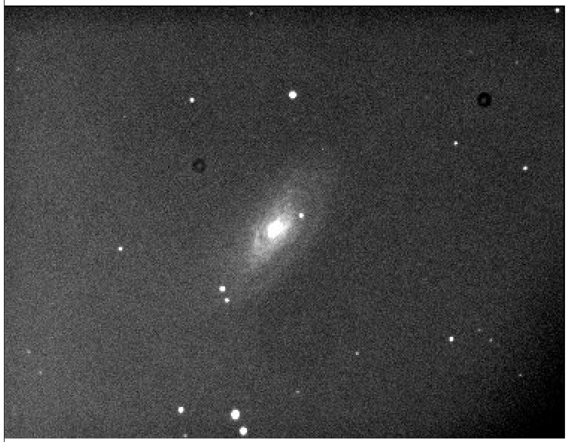
- Gain
- Bias
- Dark frame
- Flat field

Gain

Direct relationship between amount of charge and intensity of light (up to a point).

Once this is known, we can convert the total amount of charge into a count of photons that struck our CCD during our observation.

CCD Image Processing



Raw image of m88

Bias

Need zero point for the CCD.

Take a zero length exposure (essentially leave the shutter closed and immediately read out the data) to find the amount of charge present before an exposure. This needs to be subtracted off. Usually done along with dark frame.

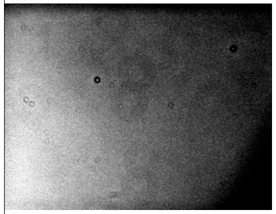
Dark Frame

CCDs suffers from electronic noise and from heat.

Thermal fluctuations will cause false counts to appear on the CCD. These need to be subtracted off. The longer the exposure, the more "dark counts" you will have.

To compensate, take an exposure with the shutter closed that is the same length as the image you are about to take. This, along with the bias, can then be subtracted off.

Flat Field



Each pixel in a CCD should react the same to the same amount of light.

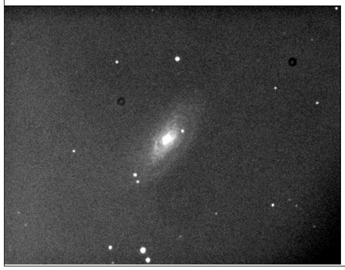
This is not true in practice. We have to correct for the uneven response. Consider it a re-normalization. We have to divide by a field that is uniform:

This uniform field can be created by looking at a blank patch of sky near dusk (for instance).

Final Image (sort of)

Those are the basic reduction steps.
Still need to consider:
- Cosmic Rays
- Saturation and Bleed Trails

Raw



Processed

CCD vs Plate

CCDs
- Much more efficient (60% of light is recorded)
- Lower resolution
- Can be used remotely
- Need not be developed

Plates
- Larger field of view
- No electronic noise
  - No need for cooling