Telescope Basics:

A Brief Introduction to Telescopes and What you Can Do with them

Yerkes Observatory Workshop: October 1st, 2016

Outline

- Coordinate Systems
- Telescope Basics
- CCD Basics
- Advanced topics

So what *is* a telescope?

So what *is* a telescope?

An instrument used to collect electromagnetic radiation, or light.

http://www.woodlandsobservatory
M2717060675pc.jpg

There are two basic telescope designs

Refractor

https://upload.wikimedia.org/wikipedia/commons/0/01/Yerkes_40_inch_Refractor_Telescope-2006.jpg

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Refractor

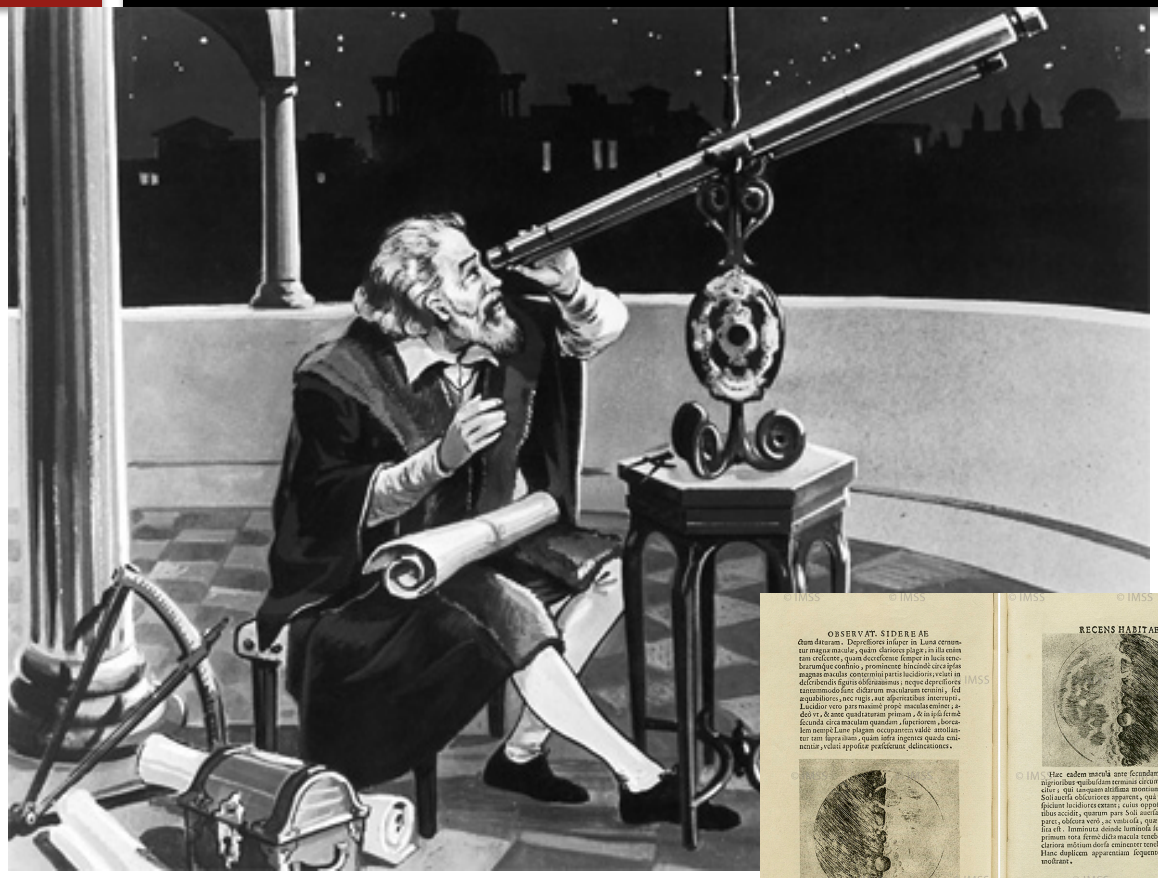
https://upload.wikimedia.org/wikipedia/commons/0/01/Yerkes_40_inch_Refractor_Telescope-2006.jpg

Reflectors

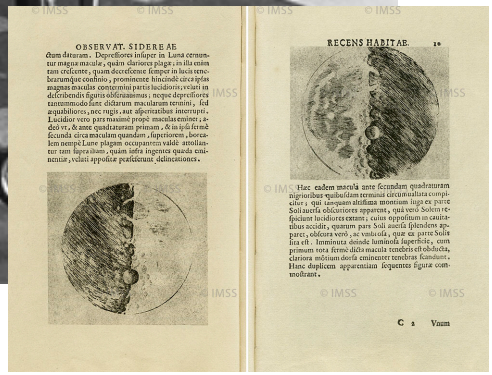
Refracting Telescopes

http://astro.unl.edu/classaction/animations/telescopes/telescope10.html

Refracting Telescopes



http://news.nationalgeographic.com/news/2009/08/photogalleries/galileos-telescope-pictures-anniversary/images/primary/090825-01-galileos-telescope_big.jpg



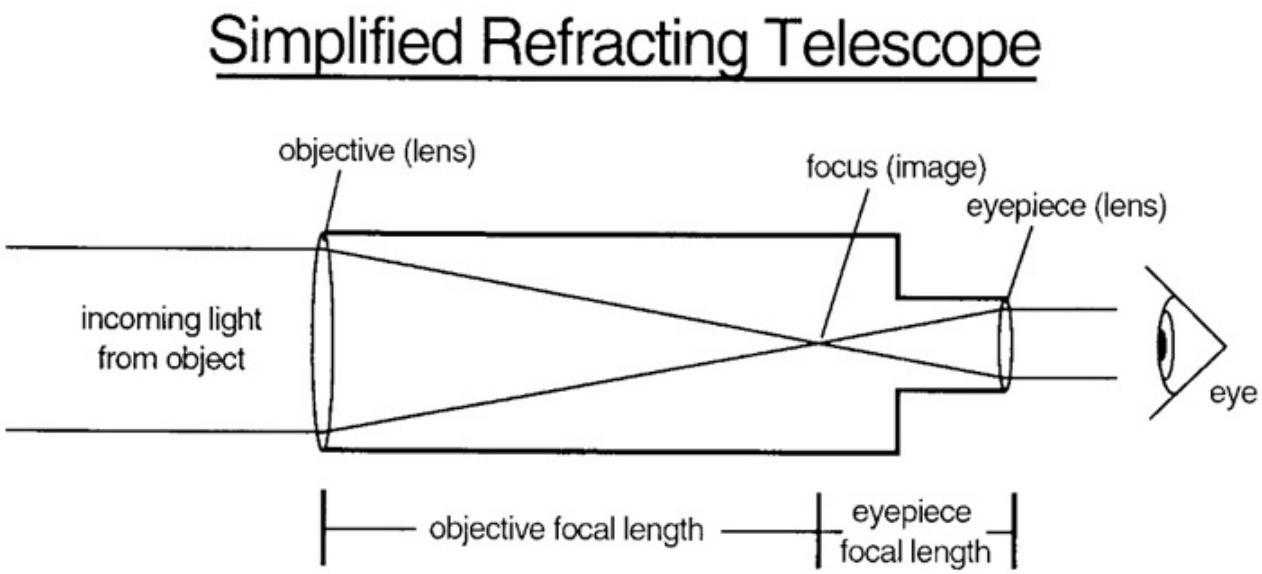
http://www.universetoday.com/15763/galileos-telescope/

- Galileo jumped on the telescope idea after Hans Lippershey created a telescope-type lens in 1608.
- Revolutionized astronomy by observing moon craters and planets, taking comprehensive notes!

Refracting Telescopes

PROS:

- Simple Design and relatively cheap to
- make when small
- Closed optics
- High contrast
- Good for planetary science
- Not a lot of maintenance

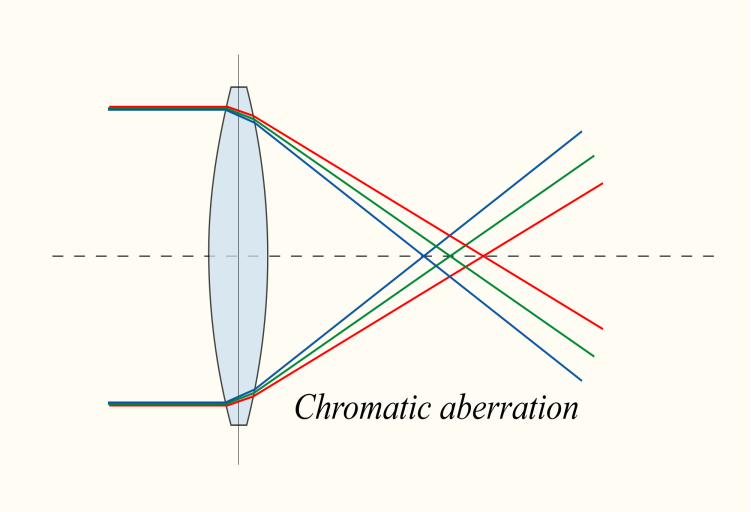


http://www.abramsplanetarium.org/telescopes/refractingscope-diagram-v2.jpg

Refracting Telescopes

CONS:

- Chromatic Aberrations



http://www.universetoday.com/81874/chromatic-aberration/

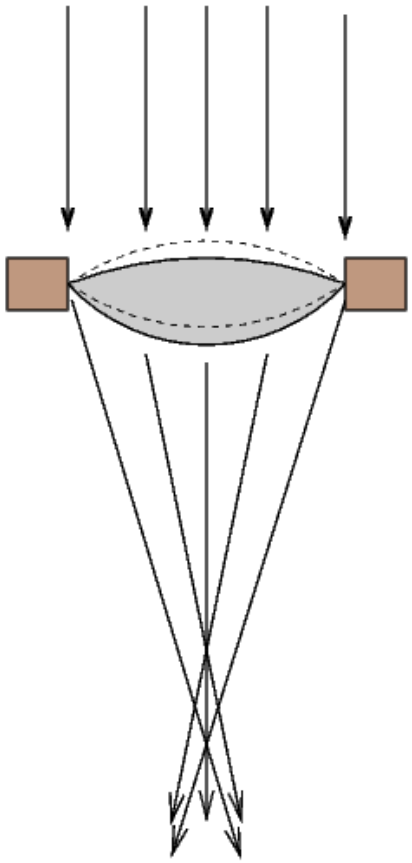
http://spiff.rit.edu/classes/phys301/lectures/optical_tel/optical_tel.html

Refracting Telescopes

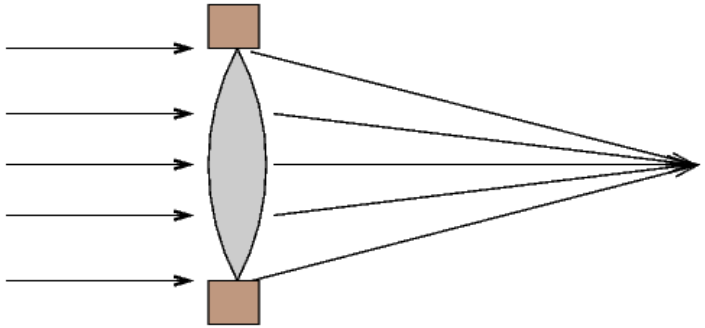
CONS:

- Can get to be very large and heavy
- Lens supported by its side
  - Big lenses sag

... then gravity will distort the lens as it is moved to look straight up.



If one shapes the lens so that it brings light to a focus properly when standing on its edge ...

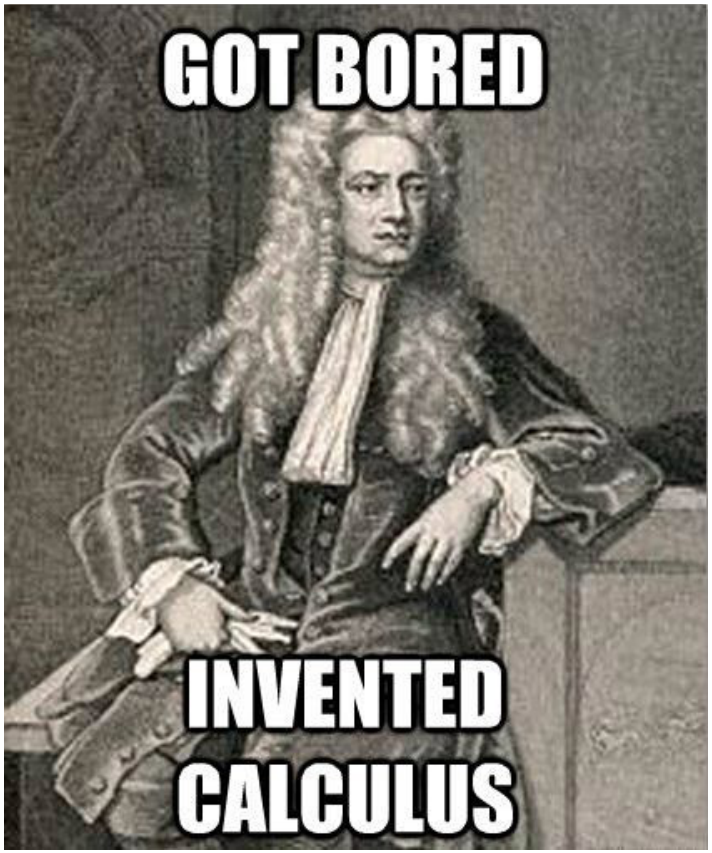


http://spiff.rit.edu/classes/phys301/lectures/optical_tel/optical_tel.html

Reflecting Telescope

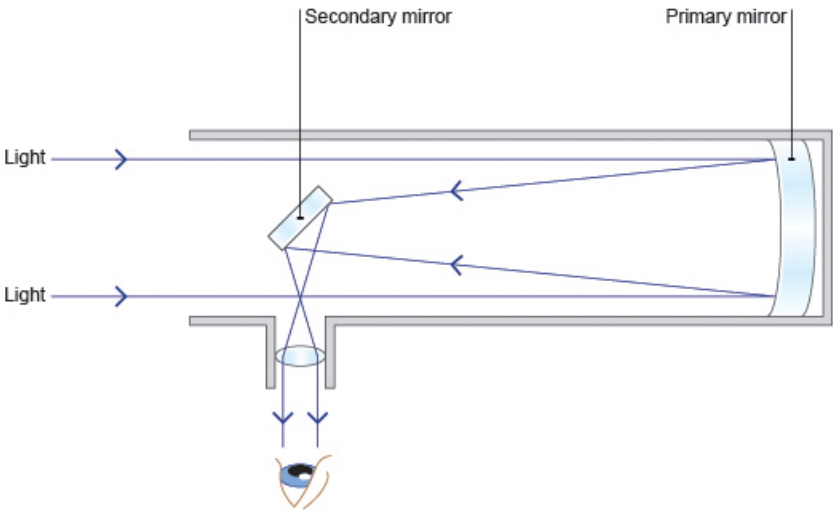
http://www.yorku.ca/pdelaney/phys1070/w06/animation6_2.html

Reflecting Telescopes



http://www.quickmeme.com/meme/3qayl3

Isaac Newton realized that using mirrors to focus light could take care of this chromatic aberration problem by bringing the wavelengths to a common focus.

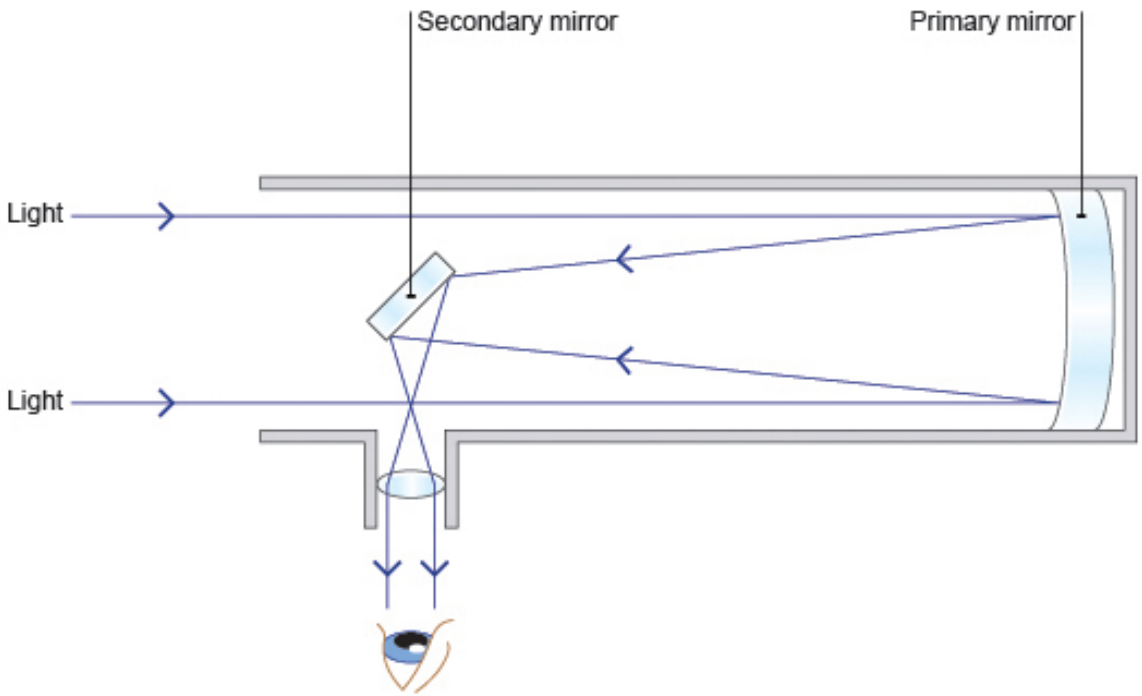


https://aarontriesscience.files.wordpress.com/2014/07/telescope-diagram.jpg

Reflecting Telescopes

PROS:

- Low cost
- Takes care of the chromatic aberration problem
- Good for deep sky viewing
- Bright images

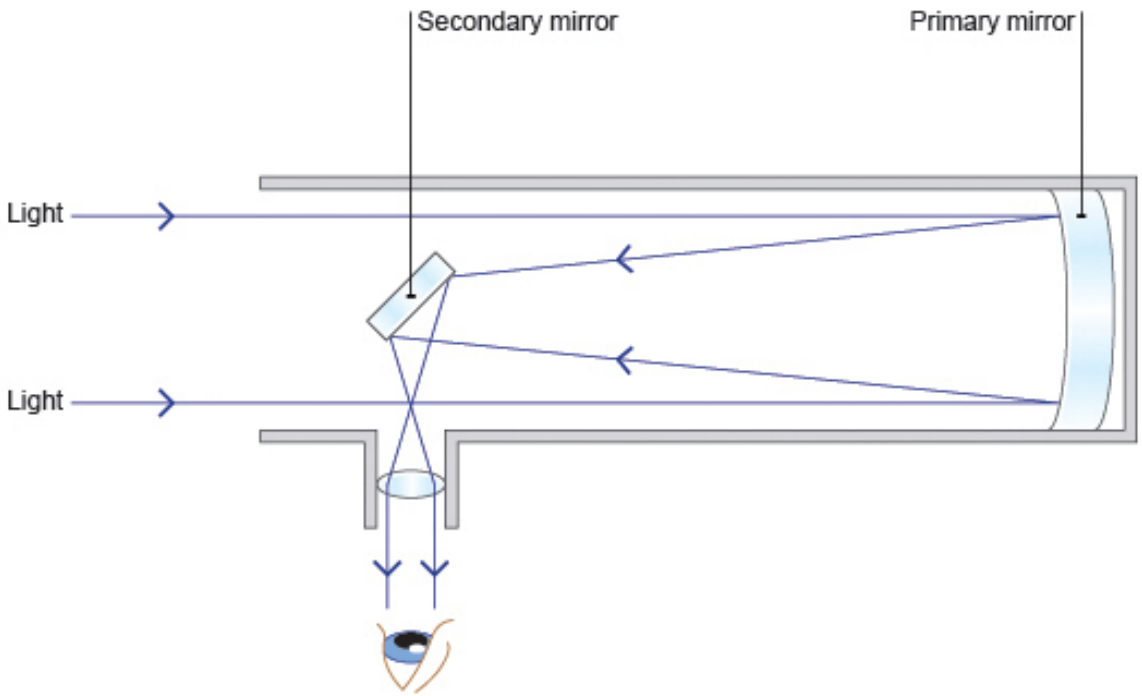


https://aarontriesscience.files.wordpress.com/2014/07/telescope-diagram.jpg

Reflecting Telescopes

CONS:

- Collimation (or alignment)
- Open optics can get damaged so you have to be careful!



https://aarontriesscience.files.wordpress.com/2014/07/telescope-diagram.jpg

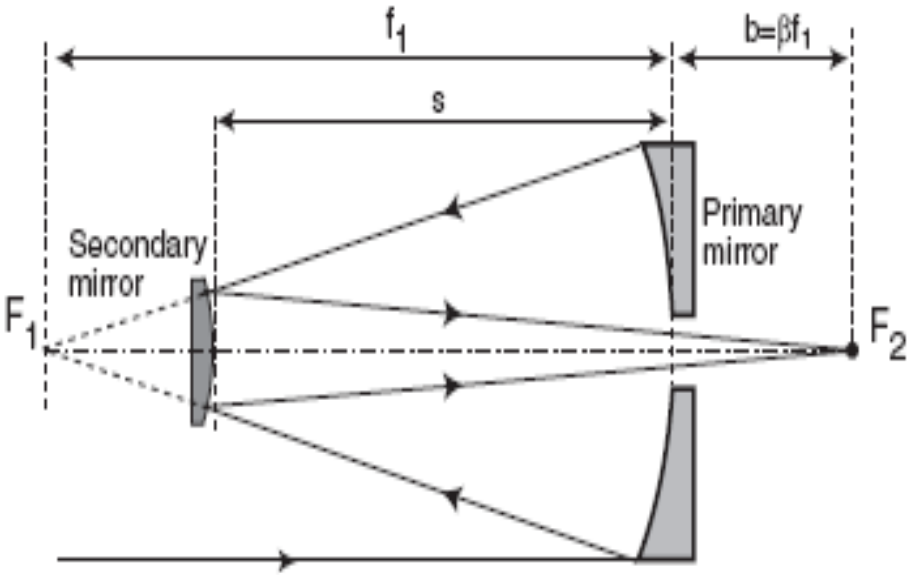
Some Stone Edge Info

These specs can be found on the FAQ part of the voices website!

The telescope is a 20 inch Ritchey-Chretien manufactured by RC Optical. Some typical specs include:

- Primary diameter: 20 inches
- Focal ratio: f8.1
- Focal length: 4115mm
- Scale: 50.1 arc-seconds/mm

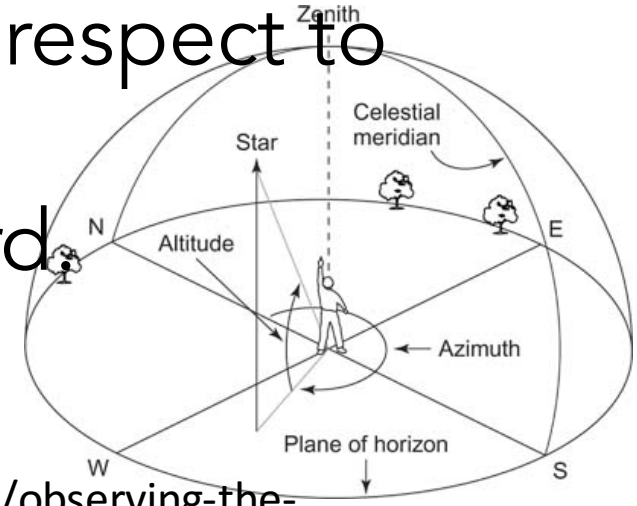
Stone Edge Observatory



http://home.btconnect.com/astronoscope/Articles/RC.PNG

Coordinate systems

- To observe and track an object we need to know its position on the sky.
- What would be the most immediate way to characterize an object's position on the sky?
- By measuring it's altitude above the horizon and angular position respect to some preferred direction.
- These are the horizontal coord



Altitude: Angle from the horizon to the object
Azimuth: Angle from North to the object measured in the clock-wise direction

https://www.cliffsnotes.com/study-guides/astronomy/observing-the-sky/naked-eye-astronomy

Coordinate systems

- We know that objects move across the sky during the night. An object's coordinates in this system will change during the night.
- What can we do then?
- We can refer the objects' positions to a certain point in the sky, for example the Sun-> Galactic coordinate system
- We can also refer the positions to the center of the Earth -> Equatorial coordinate system (our beloved RA and DEC)

Equatorial coordinates

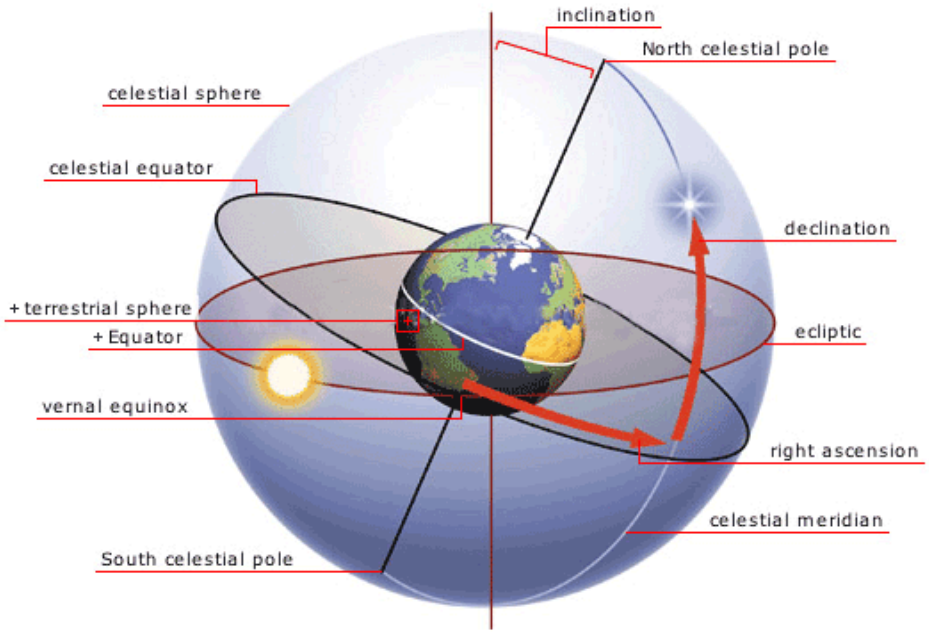
- This is the most widespread coordinate system in astronomy. Positions are referred to the center of the Earth.

- Declination: Angular distance from celestial equator to object in the clock-wise direction.

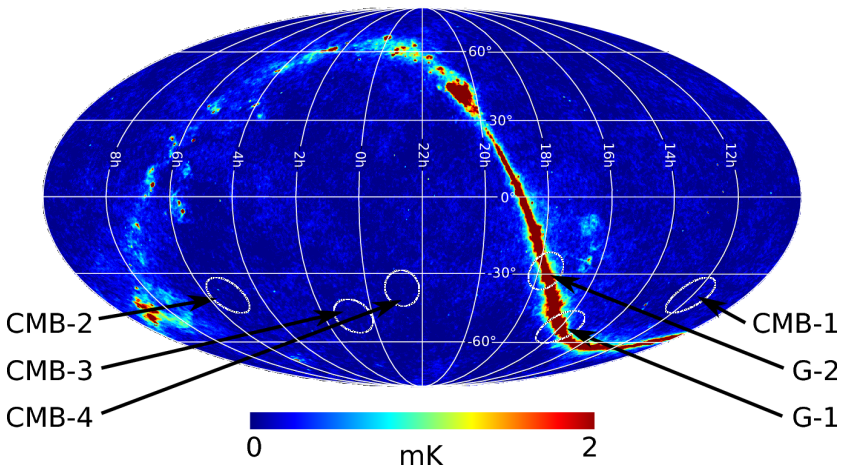
- Right ascension: is the angle between the vernal equinox (the intersection of the ecliptic and the celestial equator) and the intersection of the meridian through a celestial object and the celestial equator. RA is measured from 0h to 24h along the celestial equator eastwards (counterclockwise, the East on the sky is rotated) from the vernal equinox

Equatorial coordinates

Most modern telescopes have equatorial mount which means that they are made in such a way that they follow this coordinate system: This is why the telescope mounts are inclined.



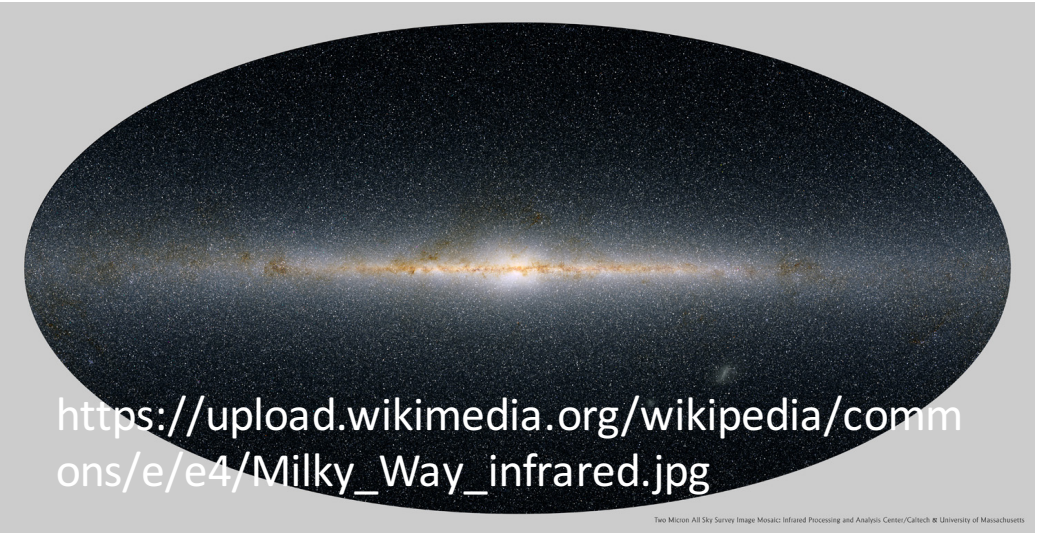
http://www.jtwastronomy.com/tutorials/celestial_coordinates.html



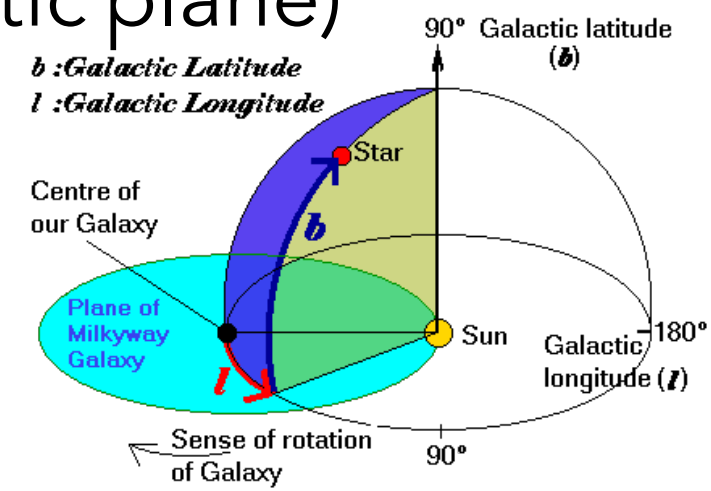
http://quiet.uchicago.edu/results/figures/fig2.png

Galactic coordinates

- It uses the Sun as the center of the coordinate system
- Not very popular in most astronomy experiments but, it's very useful for cosmology (a lot of foregrounds for cosmological signals such as the CMB are located in the galactic plane)



https://upload.wikimedia.org/wikipedia/commons/e/e4/Milky_Way_infrared.jpg



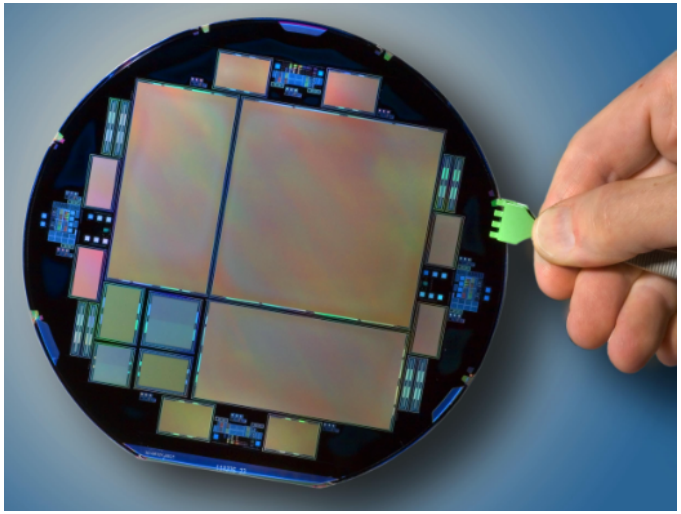
http://www.jtwastronomy.com/tutorials/celestial_coordinates.html

CCD

- Before the introduction of digital cameras, astronomers had to use photographic film to record the astronomical images. The problem is that they were expensive to maintain, delicate and needed a lot of space (and they are more difficult to analyze)

- Thanks to the digital cameras we are able to observe and record unprecedented number of objects (~ 1 billion galaxies for DES in 5 years — now entering its 4th year)

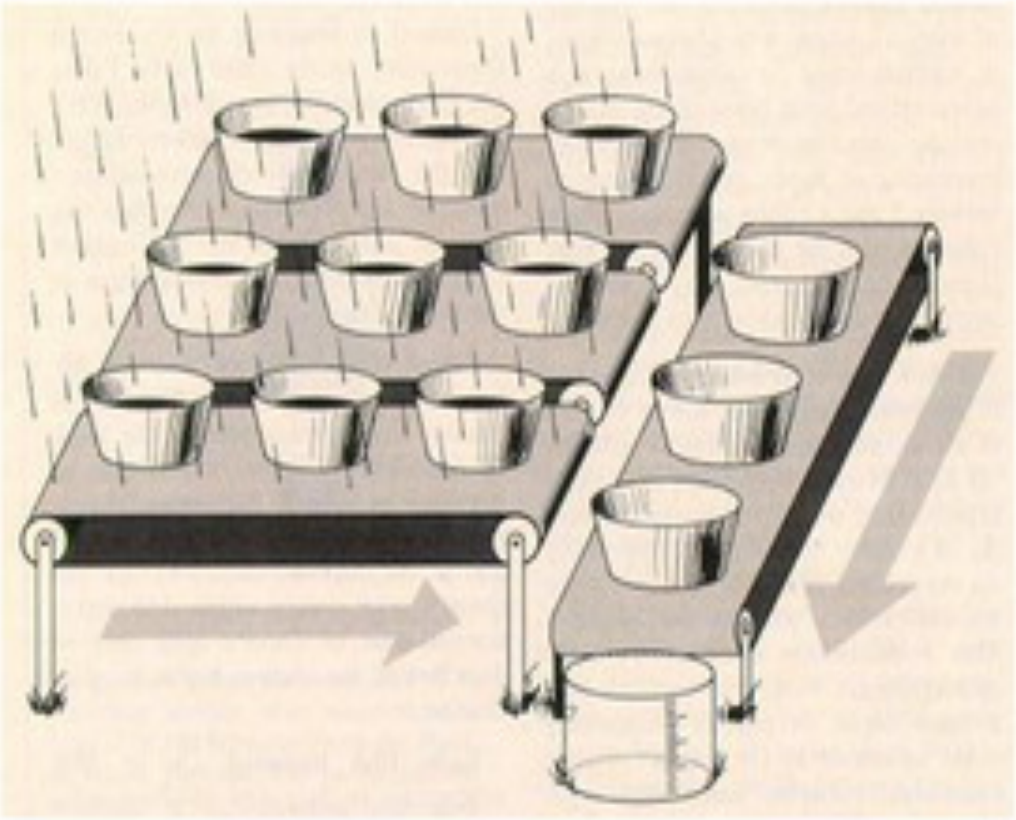
- What are these devices?



http://www-ccd.lbl.gov/4kx4k_8.25in.jpg

CCD

- Kind of like a large network of buckets regularly distributed
- Once filled, the go to conveyer belts to weigh how much water was poured into each bucket

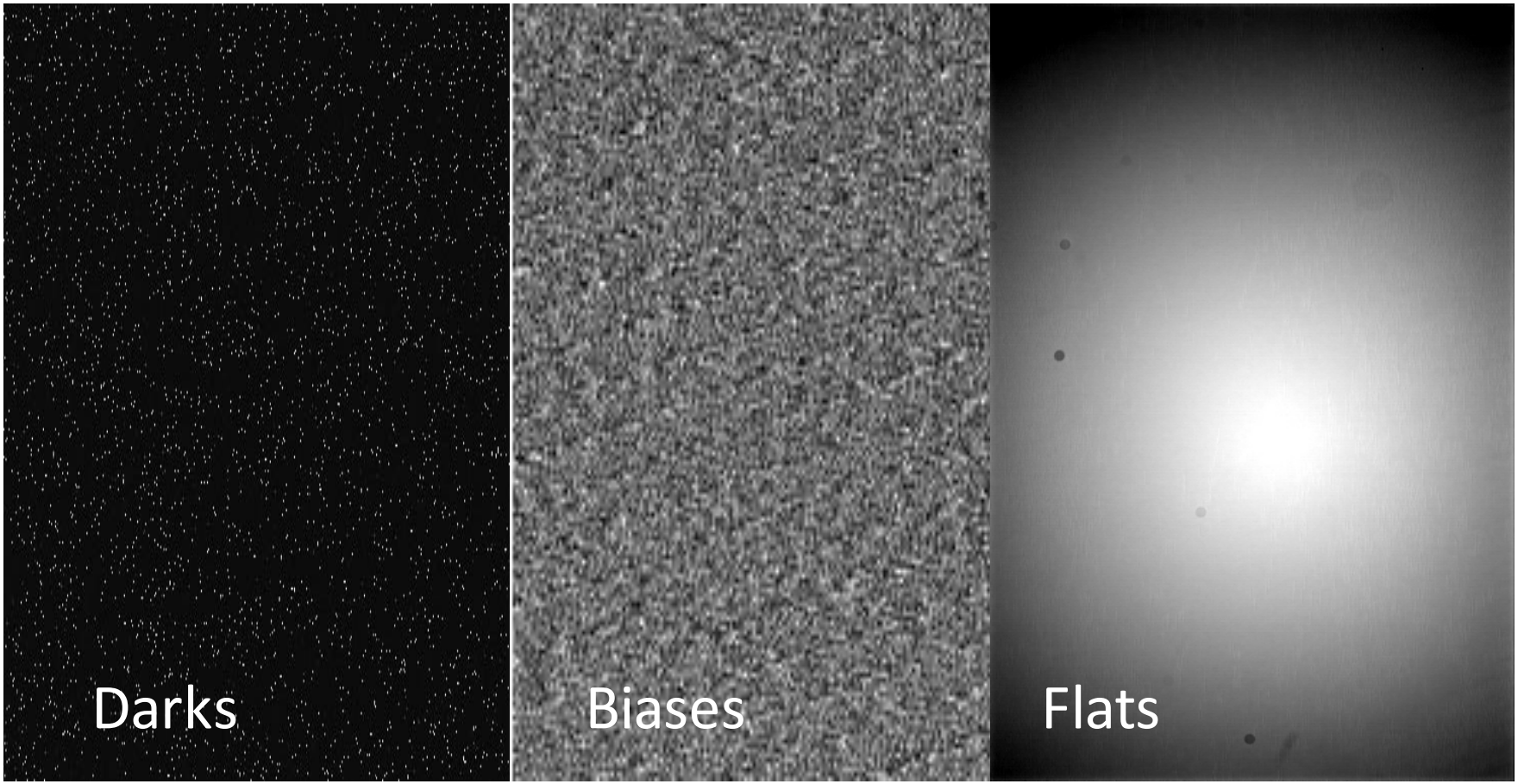


http://www.lpa.ens.fr/spip.php?article258&lang=fr

CCD

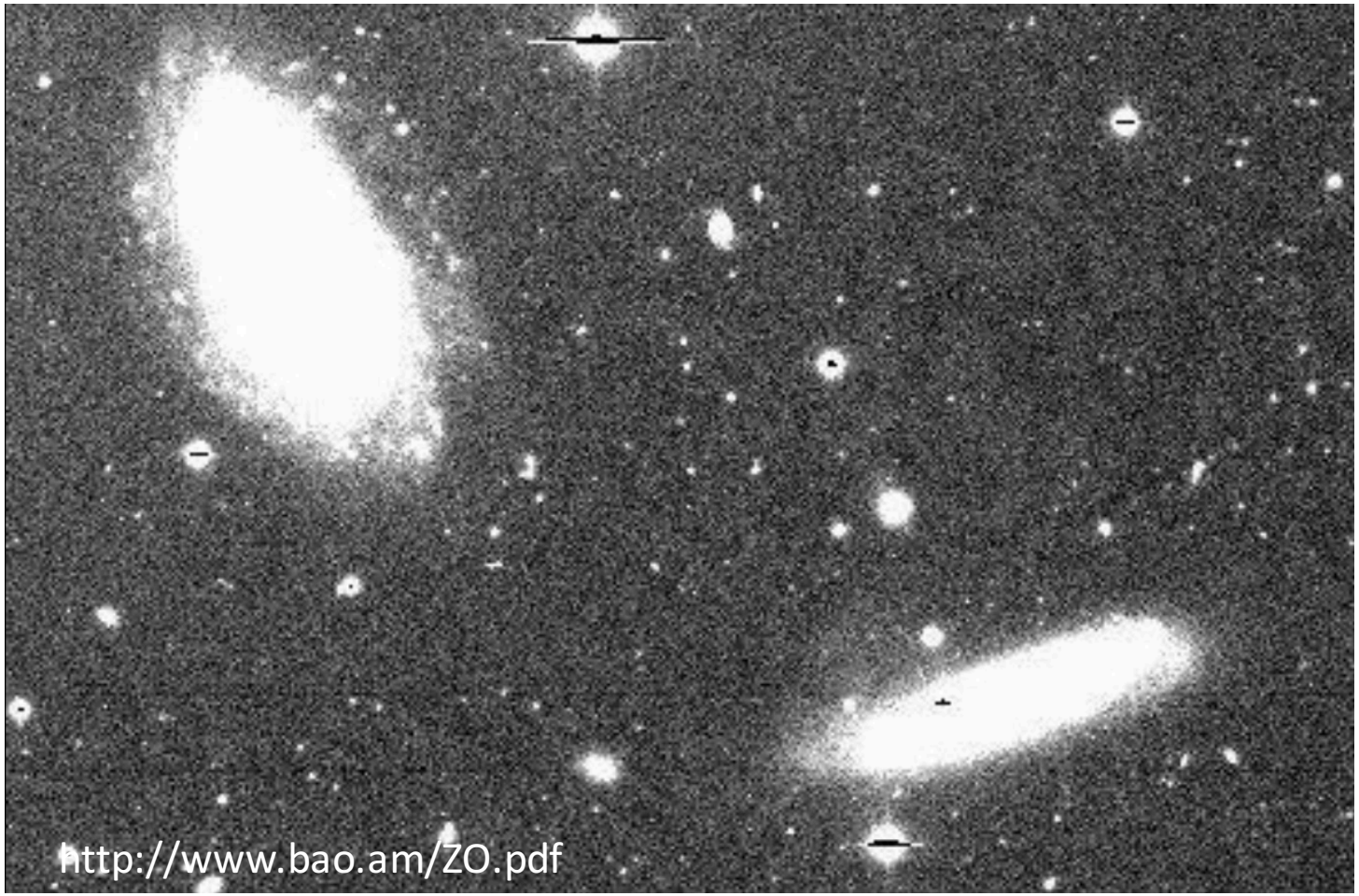
http://support.faulkes-telescope.com/multimedia/ccd/CCD%20Fullscreen.swf

Image Processing

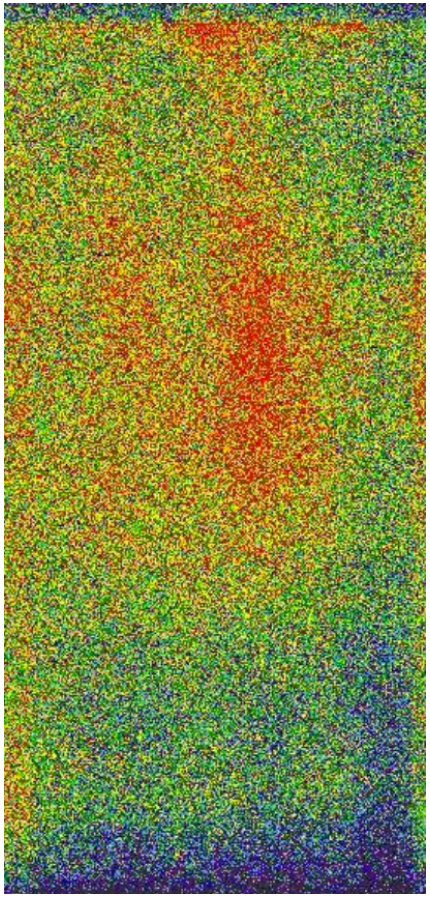


Things you need to reduce your image…

Science Frames



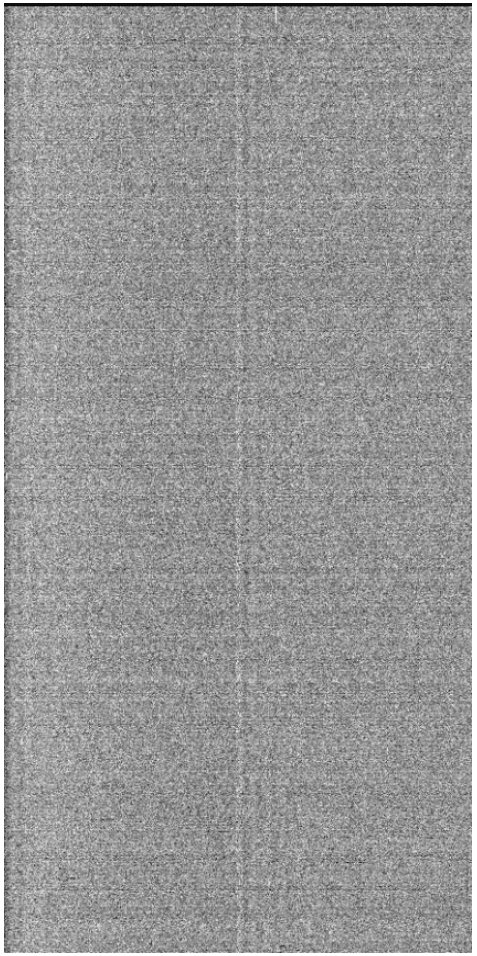
Bias Frame



- basically super short closed-shutter exposures and measure the intrinsic response of each pixel, or the “zero-level” of the CCD.
- You subtract the bias frames to standardize the output.
- On Stone Edge, you can take a bias taking a 0.1 second dark
- Should take them every time you observe because changes in electronics cause different bias levels

http://www.bao.am/ZO.pdf

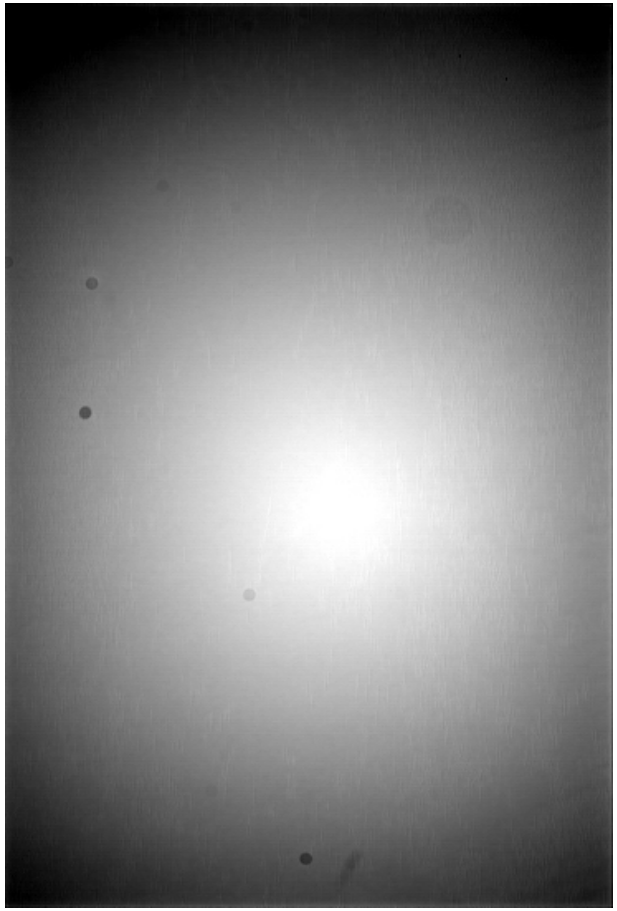
Dark Frame



- Measures the dark signal—shutter closed!
- Take darks using the same exposure time as your images
- Measures CCD response and sensitivity
- The only signal in this image is from thermal electrons

http://www.bao.am/ZO.pdf

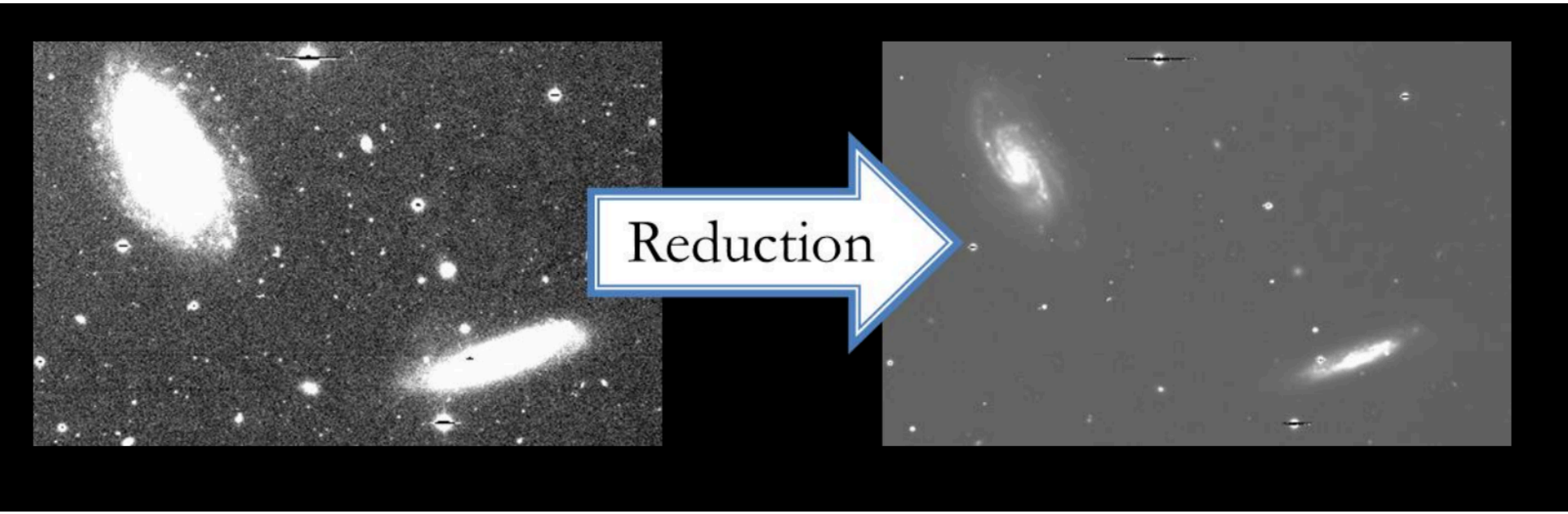
Flat Frames



- Dome Flats: Obtained by taking a picture of a uniformly illuminated board inside the telescope dome
- Twilight Flats: Obtained by taking images of a blank field during twilight
- Flats are used to measure the optical imperfections across the image and variations in pixel-to-pixel sensitivity. Usually you have dust spots on the lens, and the light isn't distributed evenly across the image (usually there's vignetting).
- These are taken automatically by the telescope and you can find them on the stars server.

http://www.bao.am/ZO.pdf

Final Result?



http://www.bao.am/ZO.pdf

Advanced topics

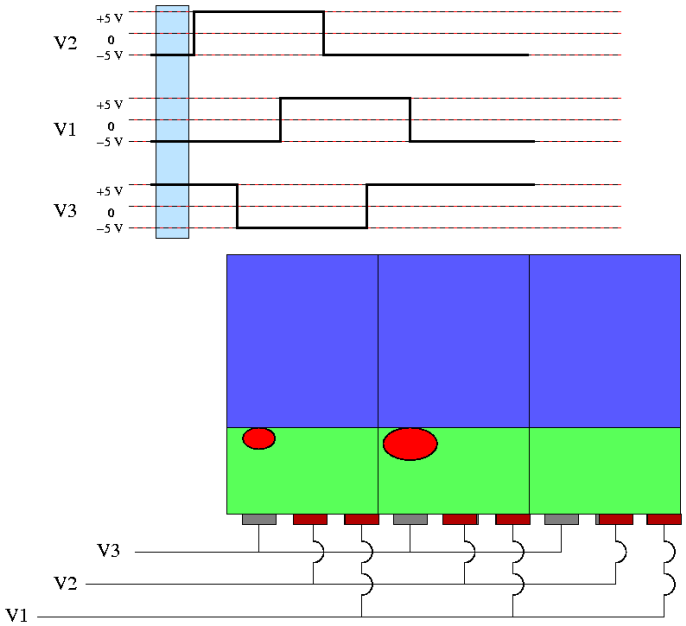
- Adaptive optics: Nowadays telescopes can correct atmospheric effects in real time by changing the shape of the mirrors to get a perfect plane wavefront. They use lasers to generate fake point sources (ideally with plane wavefronts). The distortions of the atmosphere will change them, you can change the mirrors' geometry to make the plane again.

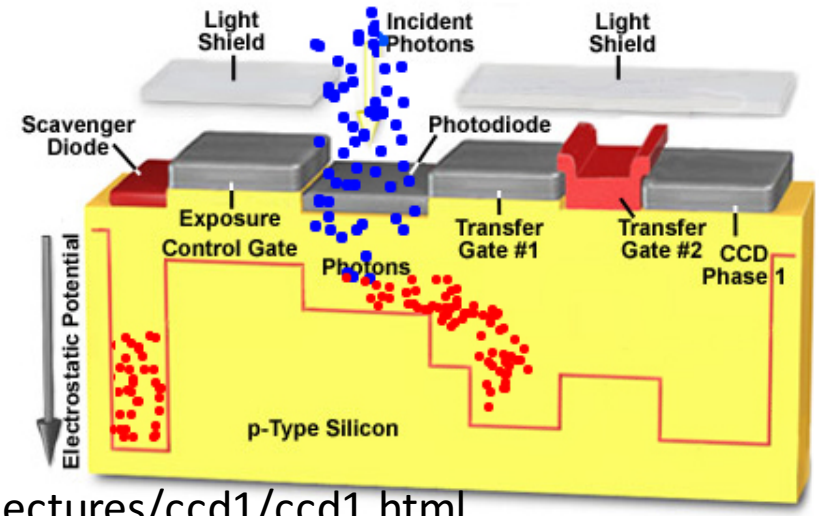
CCD

- CCDs (charge-couple devices) were invented in 1969. It was intended to work as a memory device as well as imaging device.

- The function of a CCD can be visualized as an array of buckets (pixels) collecting rainwater (photons). Each bucket in the array is exposed for the same amount of time to the rain. The buckets fill up with a varying amount of water, and the CCD is then read one bucket at a time. This process is initiated by pouring water into the adjacent empty column. The buckets in this column transfer their 'water' down to a final pixel where the electronics of the camera read-out this pixel (the computer measuring the bucket) and turn it into a number that can be understood and stored by a computer.

CCD





http://spiff.rit.edu/classes/phys373/lectures/ccd1/ccd1.html

- The photons generate electron-hole pairs. The electrons go towards positive potential regions (lower electrostatic potential — they fall into the wells) and they create packets.
- However, even if there are no photons coming, there are electronic motions due to the fact that their temperature is non-zero. This generates spurious signals on the images.