Image Processing:

A Brief Introduction to Calibrating and Reducing Images

Yerkes Observatory Workshop: January 28th, 2017

Outline

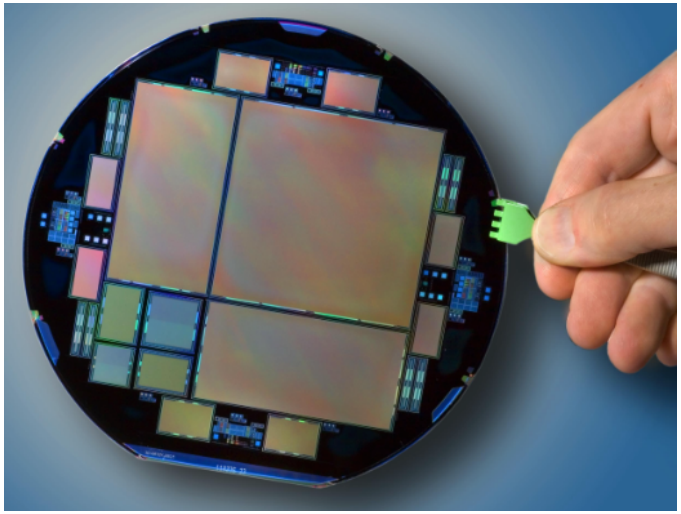
- Calibrations: Darks, Flats, and Bias subtraction
- Creating a color image
- A short introduction on photometry

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)

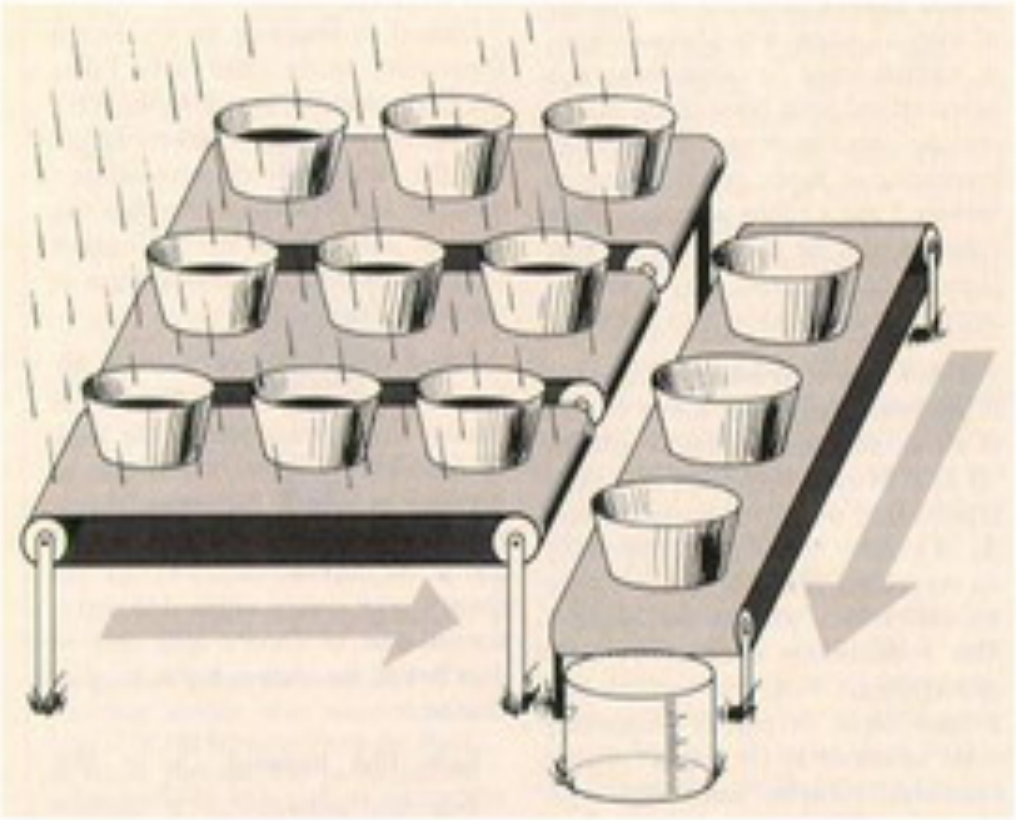
- What are these devices?



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

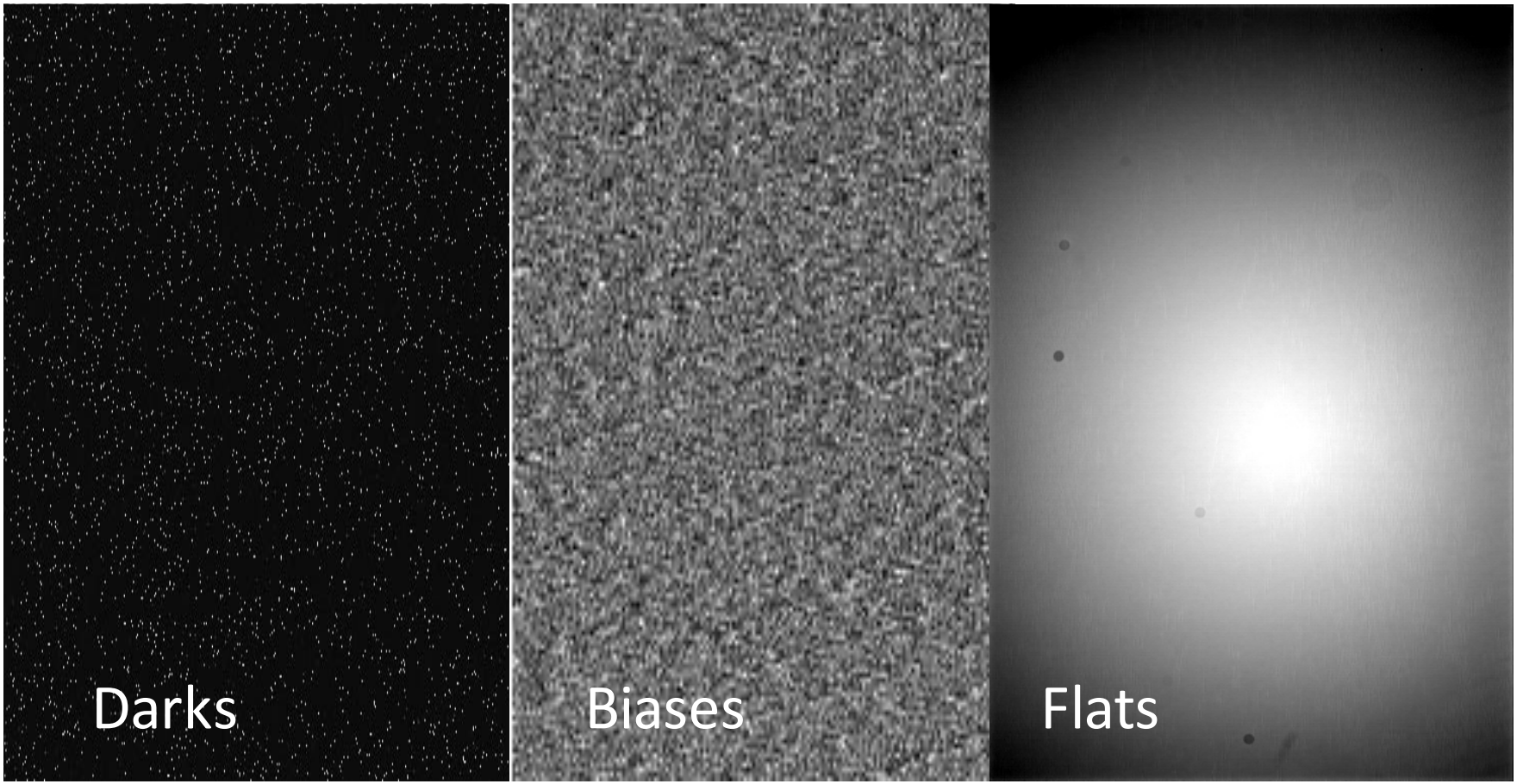


http://www.lpa.ens.fr/spip.php?article258&lang=fr

CCD

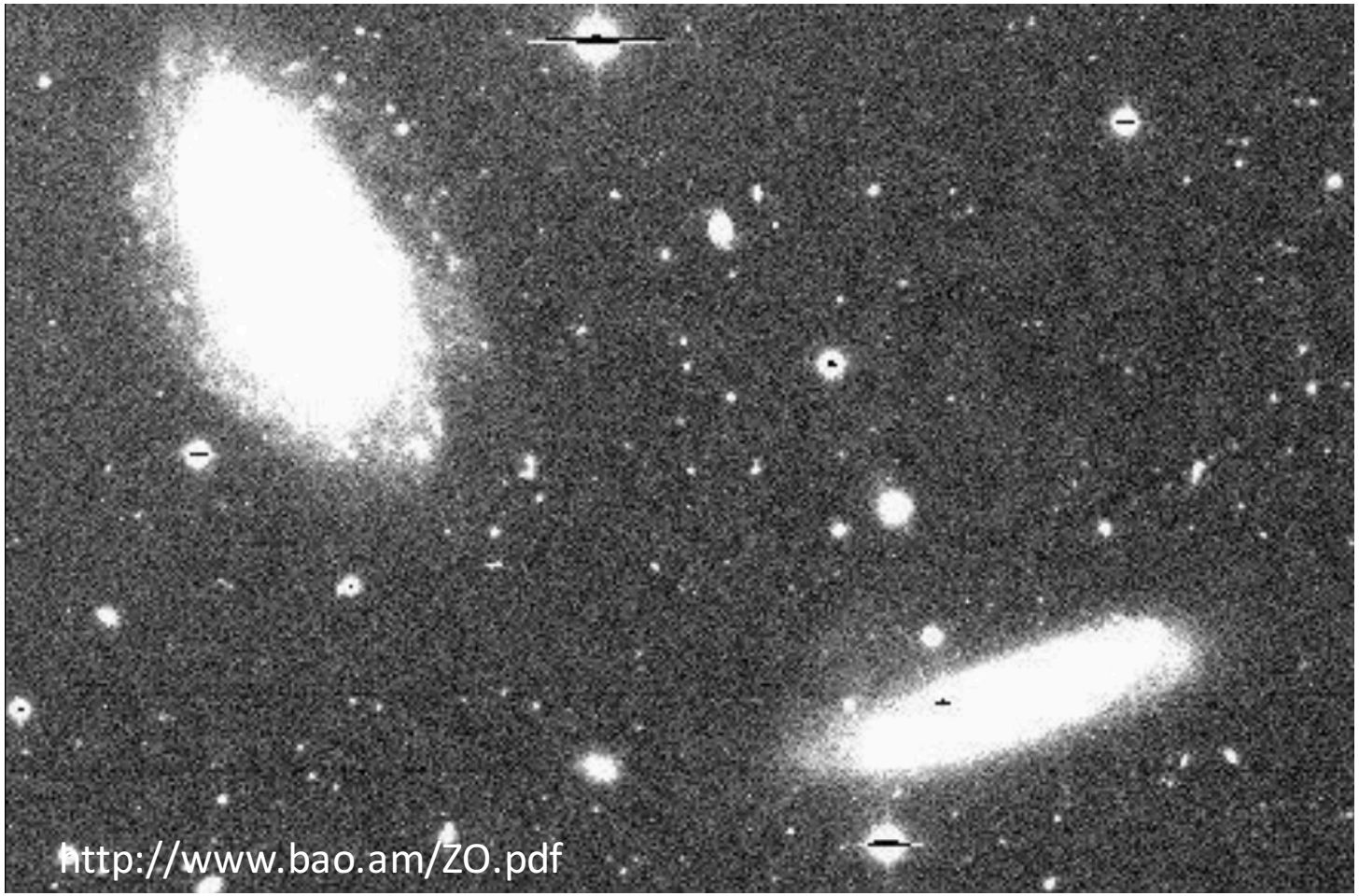
http://support.faulkes-telescope.com/multimedia/ccd/CCD%20Fullscreen.swf

Image Processing

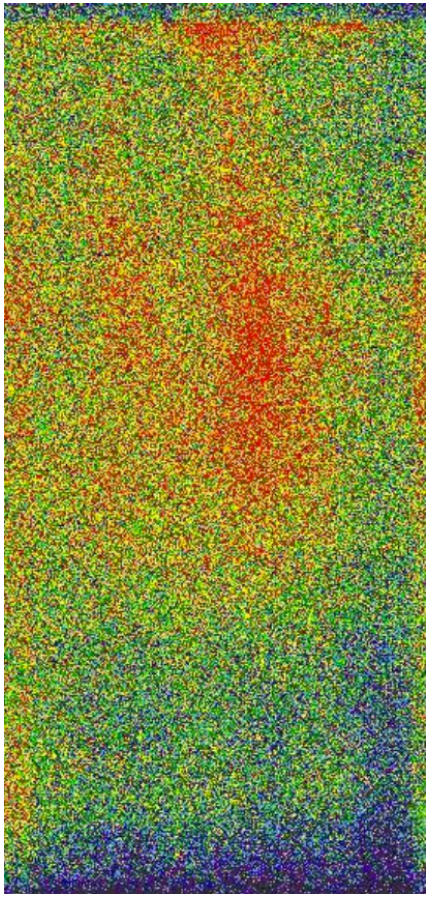


Things you need to reduce your image…

Science Frames



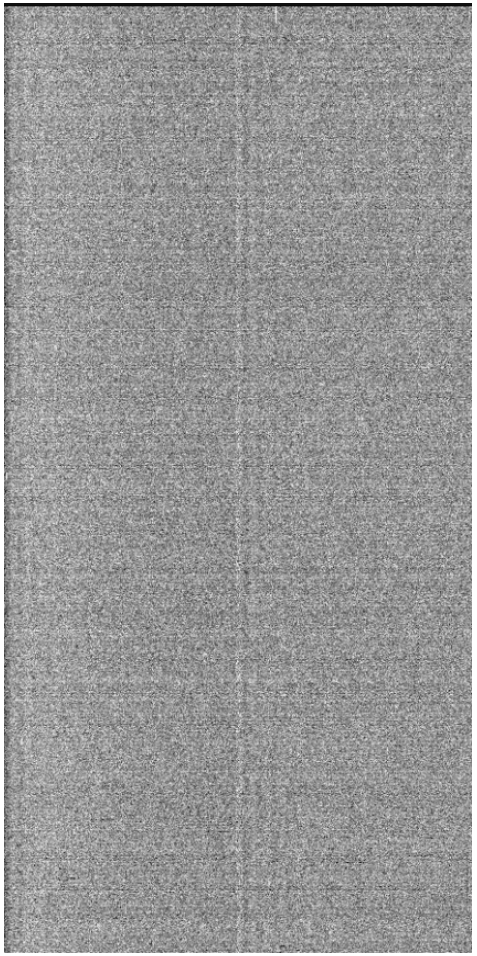
Bias Frame



- 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

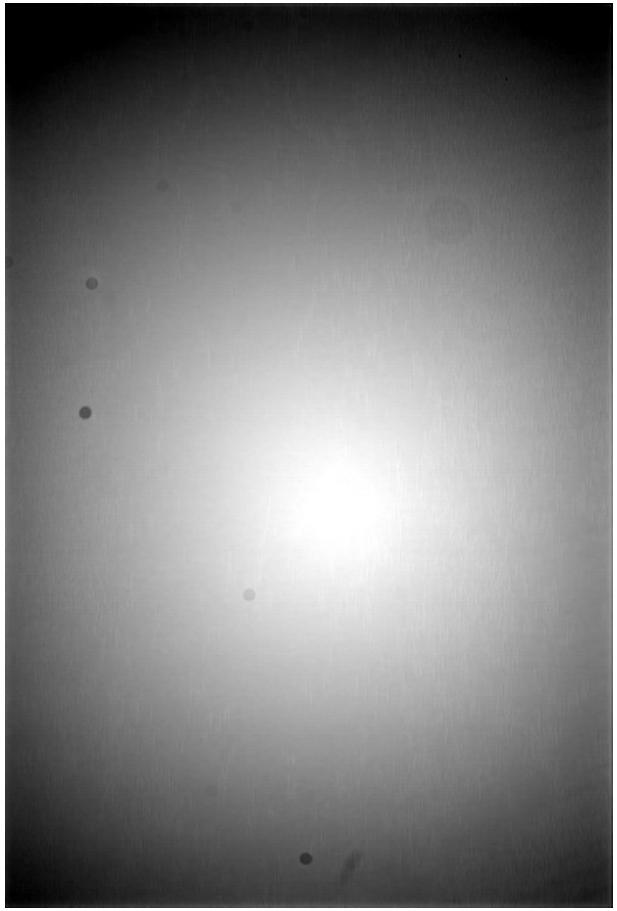
Dark Frame



- 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

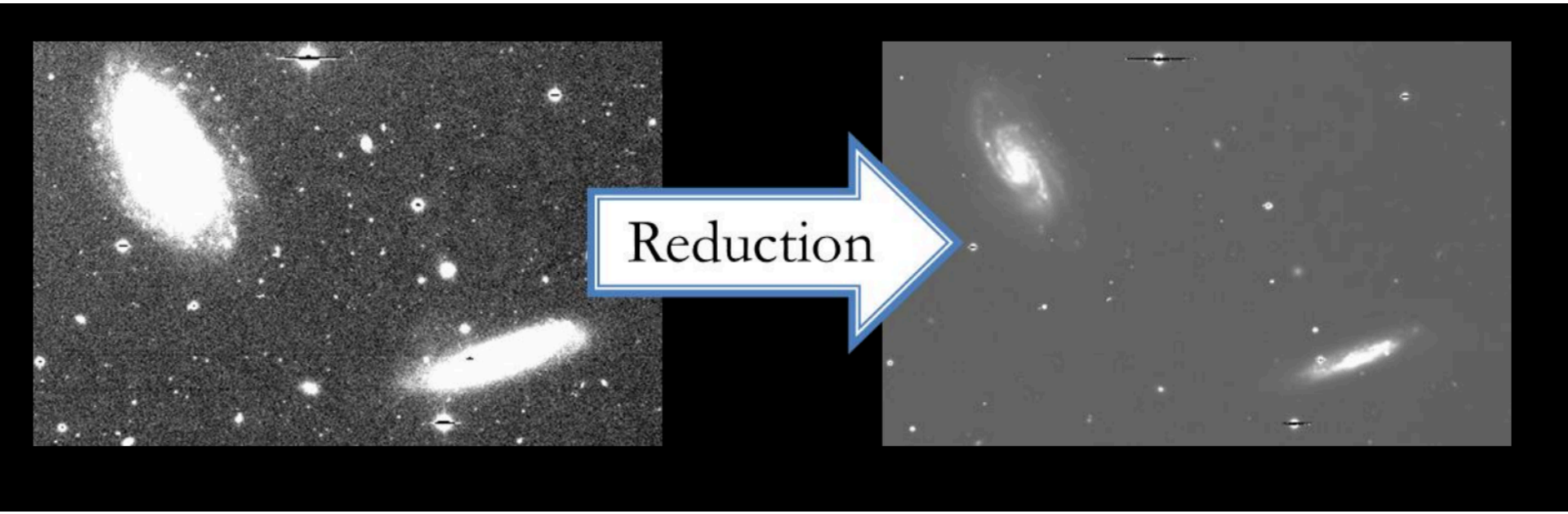
Flat Frames



- 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

Images

- What is an image?

Images

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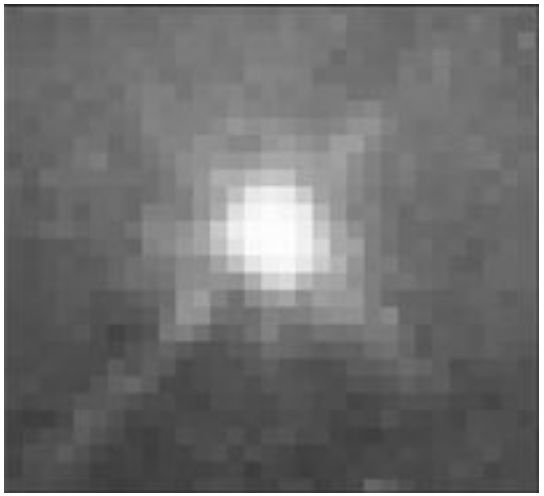
- An array of square pixels arranged in columns and rows.

- Greyscale (0 to 255 intensity)



What is a color image?

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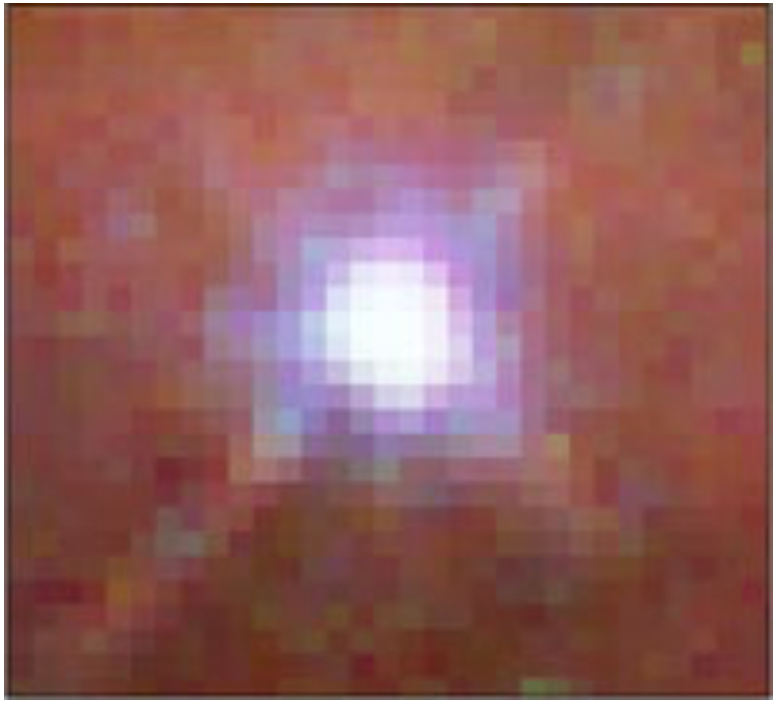
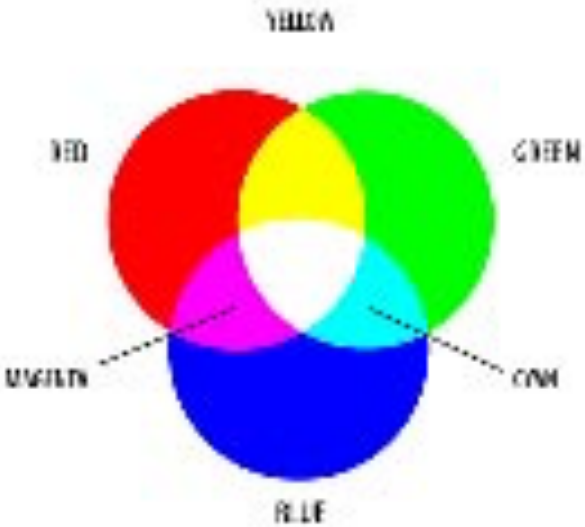
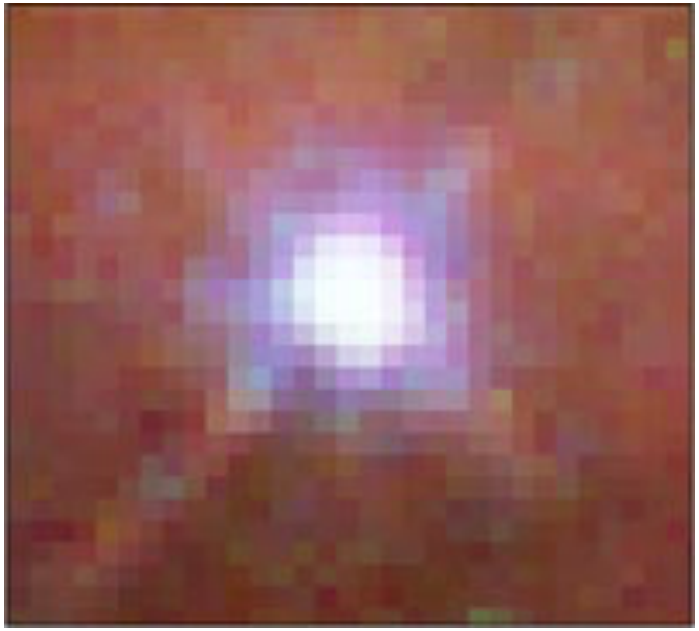
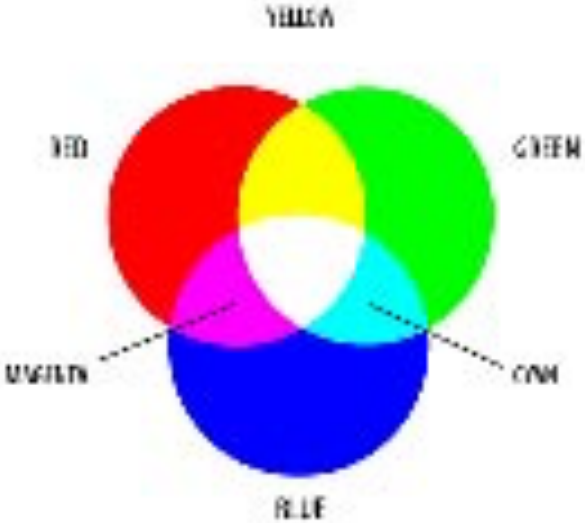




What is a color image?

- Using RGB color bands is closest to a "true color," or what we would see with our own eyes.



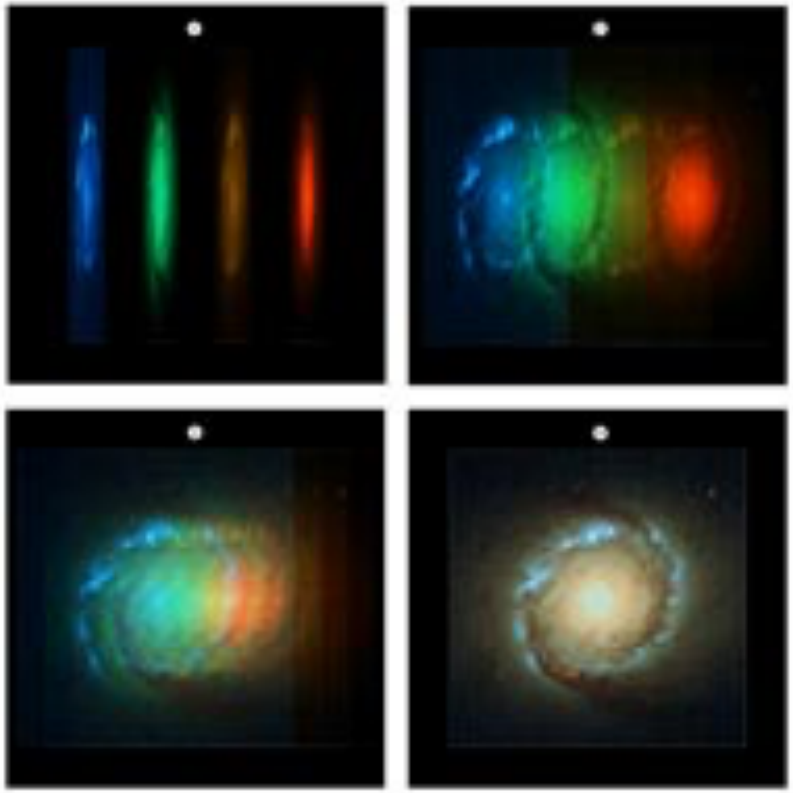


You *could* use more than on band

- Sometimes narrowband filters will bring out sharper features (We will be getting an H-alpha filter soon!)

You *could* use more than on band

- But also, you can use multiple broadband images to create striking images.



Magnitudes

- What is magnitude?

Magnitudes

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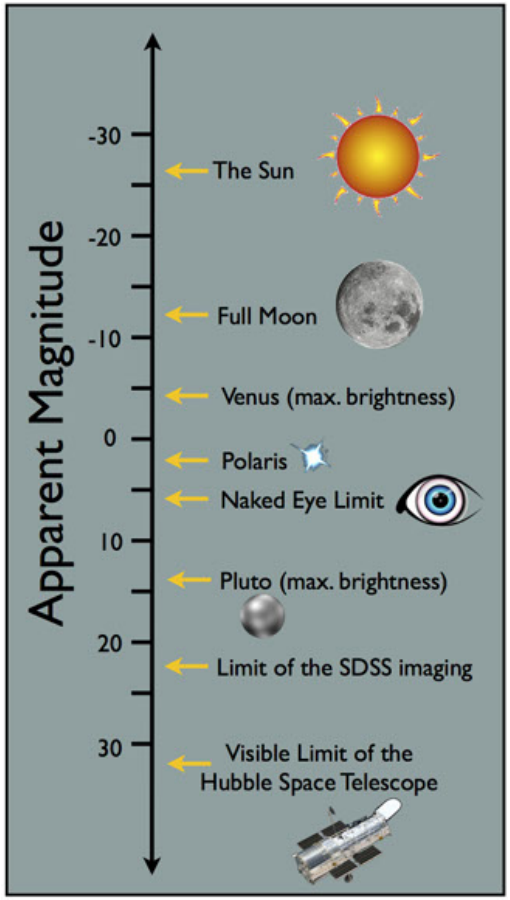
- It is a way to quantify how bright an object is, as *compared* to a standard such as Vega.
- Kind of like how freezing of water is set arbitrarily at 0C.

Magnitudes

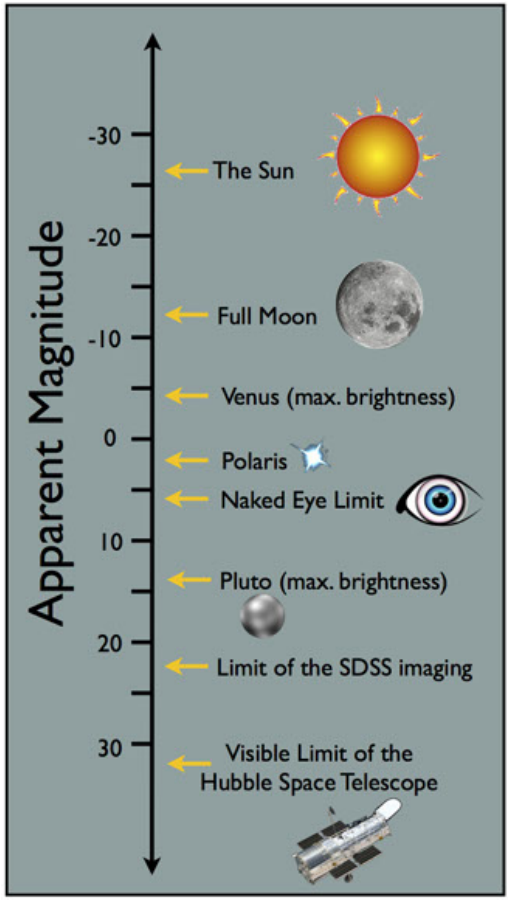
- What is magnitude?



- What is the difference between absolute and apparent magnitude?

Magnitudes

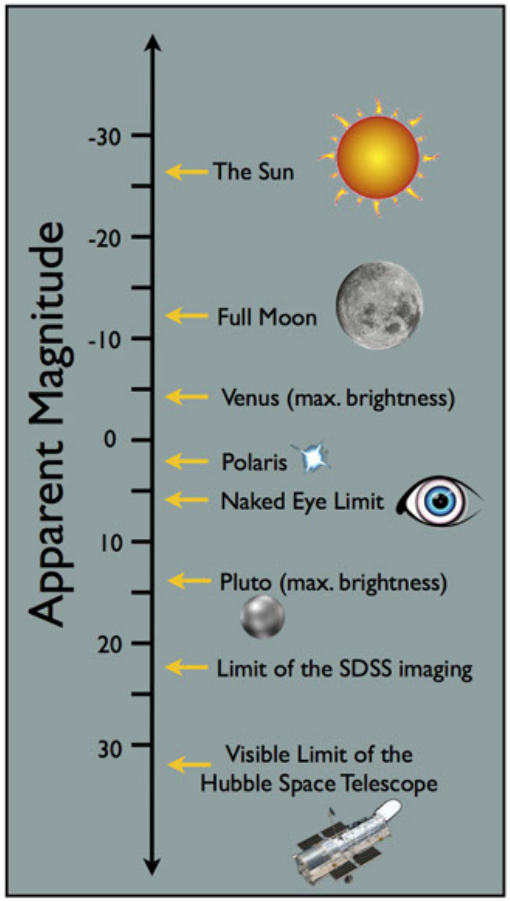
- How do we measure magnitude?



- **We look at the flux that an object emits!**
- **That flux depends on the aperture that you use**
- **m = -2.5 x log10 (F / F_Vega)**

Magnitudes

- What is magnitude?



- What is the difference between absolute and apparent magnitude?

  Absolute magnitude takes into account the distance of the object!

Advanced topics

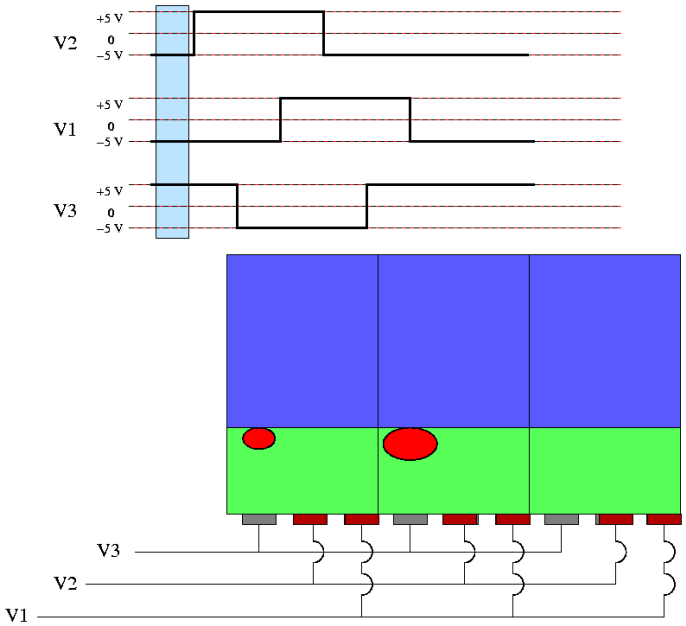
- Adaptive optics: Nowadays telescopes can correct atmospheric effects in real time by changing the shape of the mirrors to get a perfect plane wavefront. They use lasers to generate fake point sources (ideally with plane wavefronts). The distortions of the atmosphere will change them, you can change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

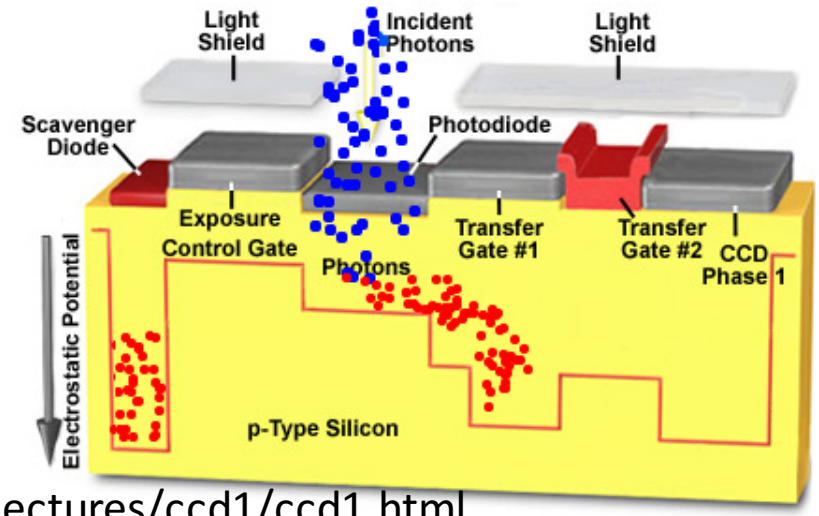
CCD

- 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.