BRIEF

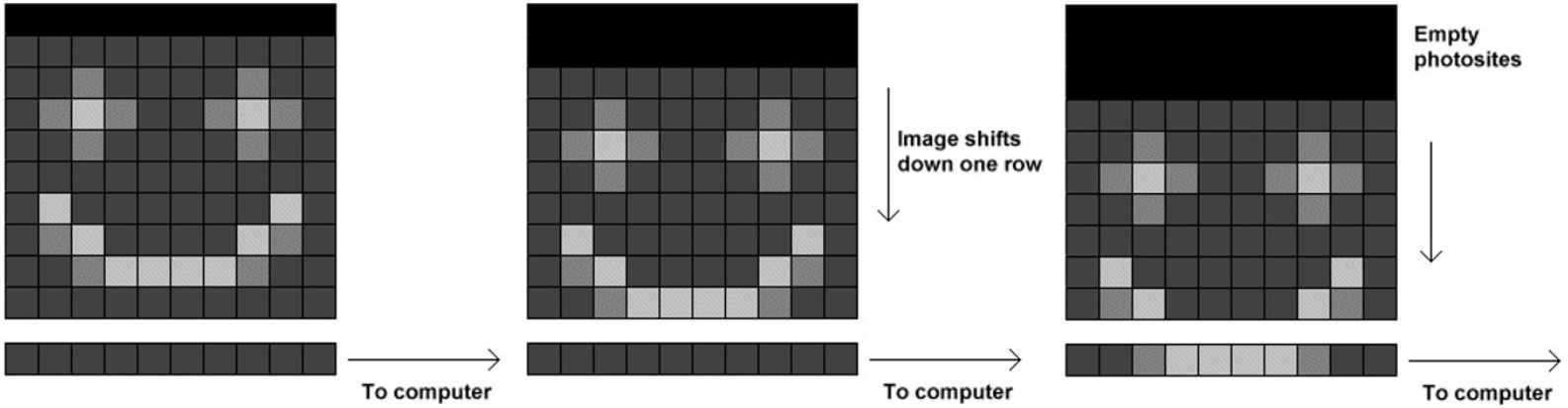
CCD Camera Overview

Overview

Charged Coupled Devices (CCDs) were invented in the 1970s as memory devices.
However, their light sensitive properties made them ideal for imaging applications.

These improved light gathering power of telescopes significantly over what film cameras were producing.

Today's CCD Cameras (CCDs for short) are equivalent to the past observer using film on a 1-meter telescope.



The Bucket Analogy – How a CCD Works

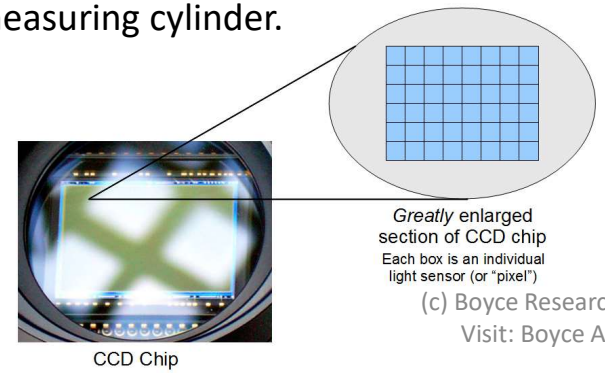
A common analogy for the operation of a CCD is a bucket-carrying conveyor belt.

Each bucket is a pixel. Each pixel is distributed across the CCD chip.

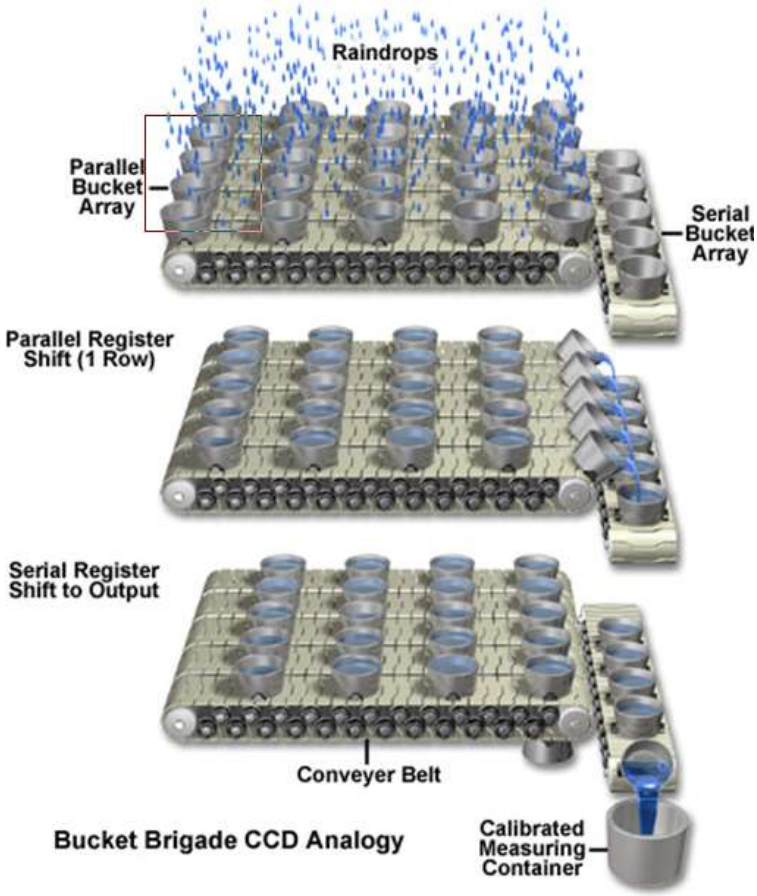
The buckets collect rain which are Photons.

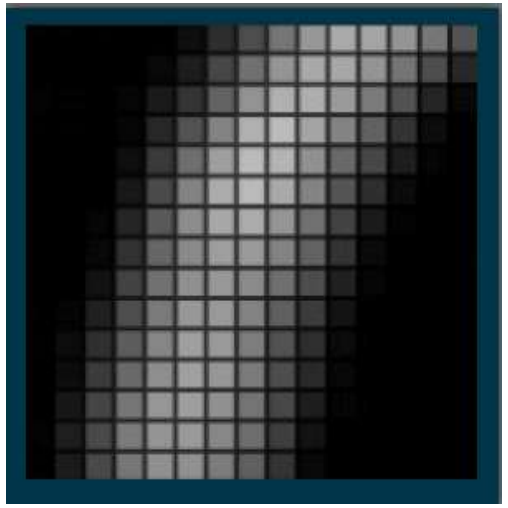
The buckets catch all rain that falls on them during the “exposure” time.

When the exposure is over, the buckets close and transfer the rain, one by one, the a measuring cylinder.



CCD Chip

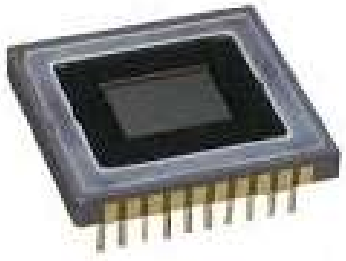


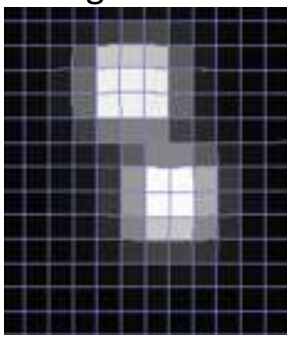


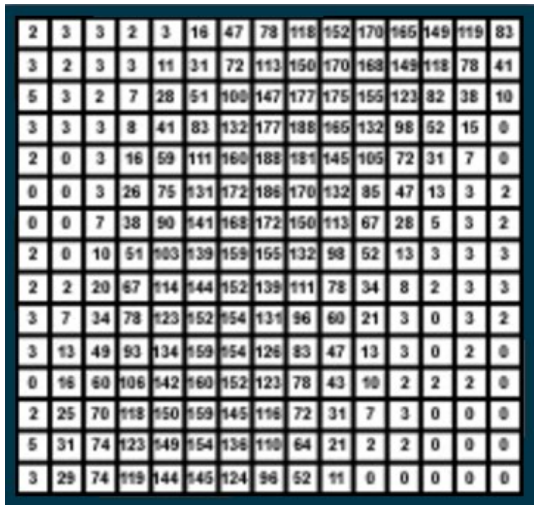
How a CCD Works

- The camera electronics convert this analog signal into a digital number
- The end result is a file containing the position of the pixel on the chip and a digital representation of the amount of charge it held at the end of the exposure.
- Details of the image are accumulated in an image meta file: FITS Header

- After acquiring the images, they must be calibrated. (NOTE: There are video lessons on this process)
- Calibration involves measuring imperfections in the imaging platform.
- Proper imaging and calibration makes each image scientifically useful.

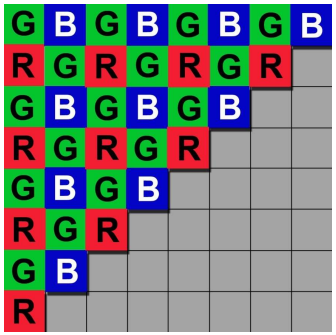






2	3	3	2	3	16	47	78	118	152	170	165	149	119	83
3	2	3	3	11	31	72	113	150	170	168	149	118	78	41
5	3	2	7	28	51	100	147	177	175	155	123	82	38	10
3	3	3	8	41	83	132	177	188	165	132	98	52	15	0
2	0	3	16	59	111	160	188	181	145	105	72	31	7	0
0	0	3	26	75	131	172	186	170	132	85	47	13	3	2
0	0	7	38	90	141	168	172	150	113	67	28	5	3	2
2	0	10	51	103	139	159	155	132	98	52	13	3	3	3
2	2	20	67	114	144	152	139	111	78	34	8	2	3	3
3	7	34	78	123	152	154	131	96	60	21	3	0	3	2
3	13	49	93	134	159	154	126	83	47	13	3	0	2	0
0	16	60	106	142	160	152	123	78	43	10	2	2	2	0
2	25	70	118	150	159	145	116	72	31	7	3	0	0	0
5	31	74	123	149	154	136	110	64	21	2	2	0	0	0
3	29	74	119	144	145	124	96	52	11	0	0	0	0	0

CCD cameras



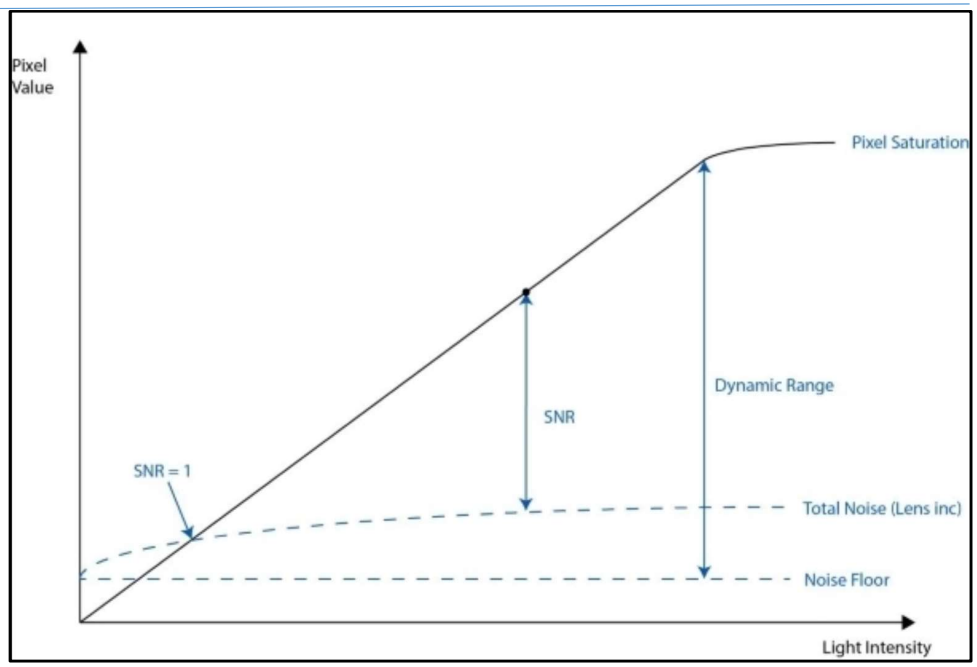
Two basic types:

1. Once Shot Color,
2. Black & White with filters.

Key Elements:

Linearity and well depth

- Pixels in a CCD camera respond in a linear way to photons
- This linearity ends at a certain point and then the photon input is no longer collected.
- Therefore, the chip in the camera can handle only a certain amount of light and still give an accurate readout.

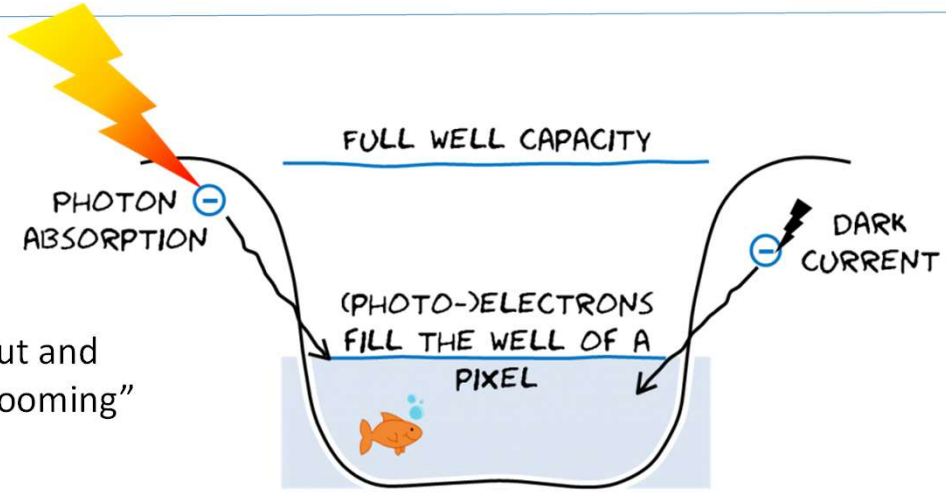


CCD cameras

Key Elements:

"Full Well Depth"

- The term for when this pixel site is full of photons.
- After this point, photons striking that pixel will spill out and contaminate other pixels creating an effect called "blooming"

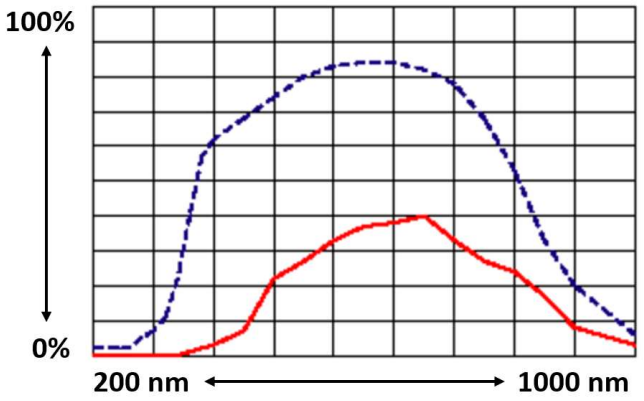


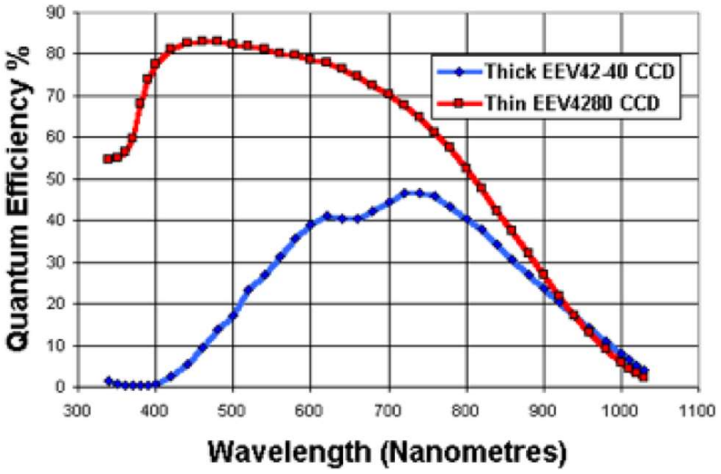
Quantum Efficiency (QE)

The term Quantum Efficiency is the measure of how effective pixels are in collecting incident photons.

Only a fraction of photons falling on a CCD are actually detected

QE measures the percentage of how many are collected



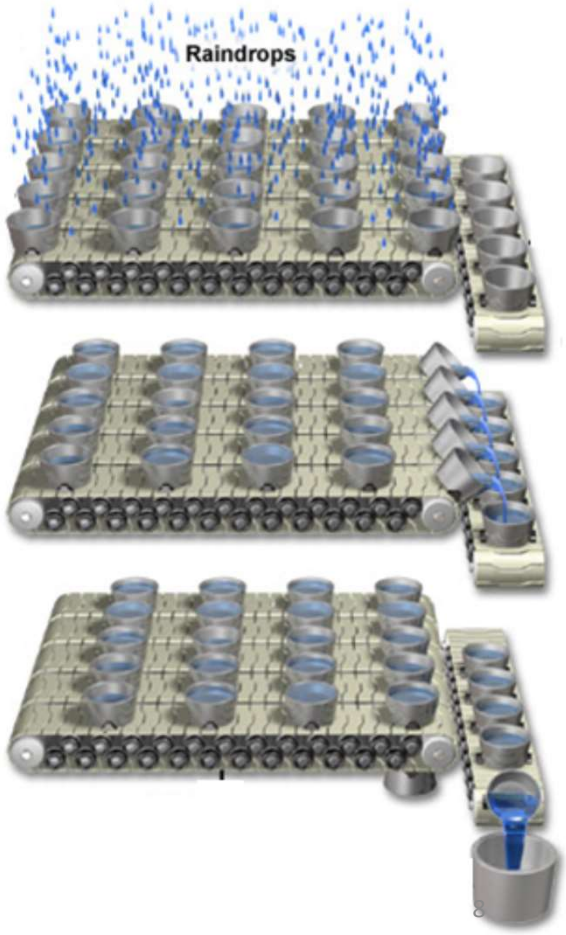


Basic Definitions

Exposure time (a.k.a. Integration Time):

The exposure time, set by the user, controls a mechanical shutter

During the exposure, the signal from a star increases linearly with time…..to a point. This will be discussed more in the class on Linearity and Saturation.



Basic Definitions

Light Frame:

An image of an astronomical object acquired by pointing the image train (Scope and Camera) at the right place in the sky, and opening the shutter to allow light to fall on the CCD.

The signal builds up (integrate) on the CCD for some length of time and then read it out. The exposure time used depends on many things.

The basic goal is to get an image of the source with the best signal to noise ratio (S/N)

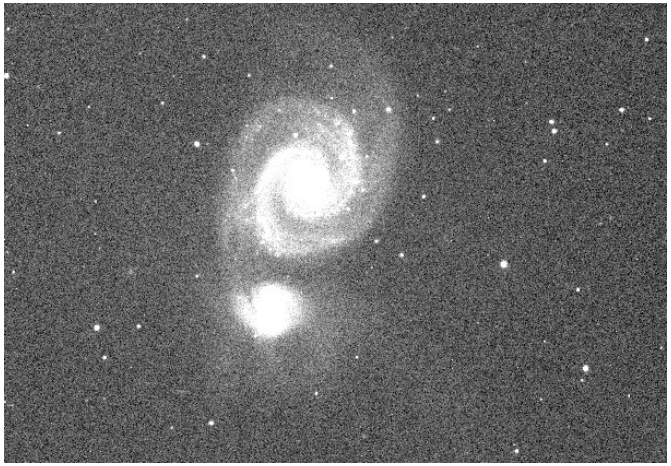
However, each image is not perfect at the moment it is captured.

CCD Chip problems

Over time, CCD chips can develop problems such as

- Hot pixels
- Blocked columns

These can be addressed through the calibration process in post processing.



Summary

- CCDs are the method used to capture astronomical images for pretty pictures or study
- The process heavily involves electronics and in the end, is a matrix of photon counts representing the image
- As result of this process, we have to “clean” each image through a process called “Reduction”
- Reduction removes the following erroneous noise sources:
  - Readout, cosmic ray particles, CCD imperfections, and dust
- These imperfections can be overcome and in the end, the user has a quality pretty picture, or science image

Questions?

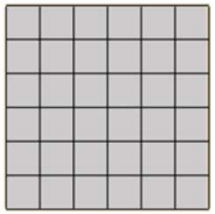
CCD Camera Overview

Basic Concepts

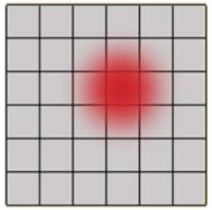
A CCD Camera is a camera with a light sensitive silicon “chip” at the core.

The chip is subdivided into individual pixels. Pixel combinations can be arranged such as the following examples:

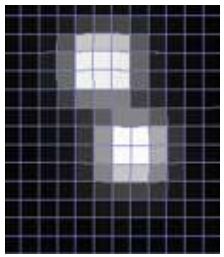
- 512 x 512 (262,144) pixels
- 4096 x 4096 (16,777,216) individual pixels



Pixel sizes are typically 10 to 30 micron square.



In creating a picture, the CCD measures how much light falls on each pixel.



Overview – Stars on a CCD Image

Each night, in the sky, the stars appear to have different sizes.

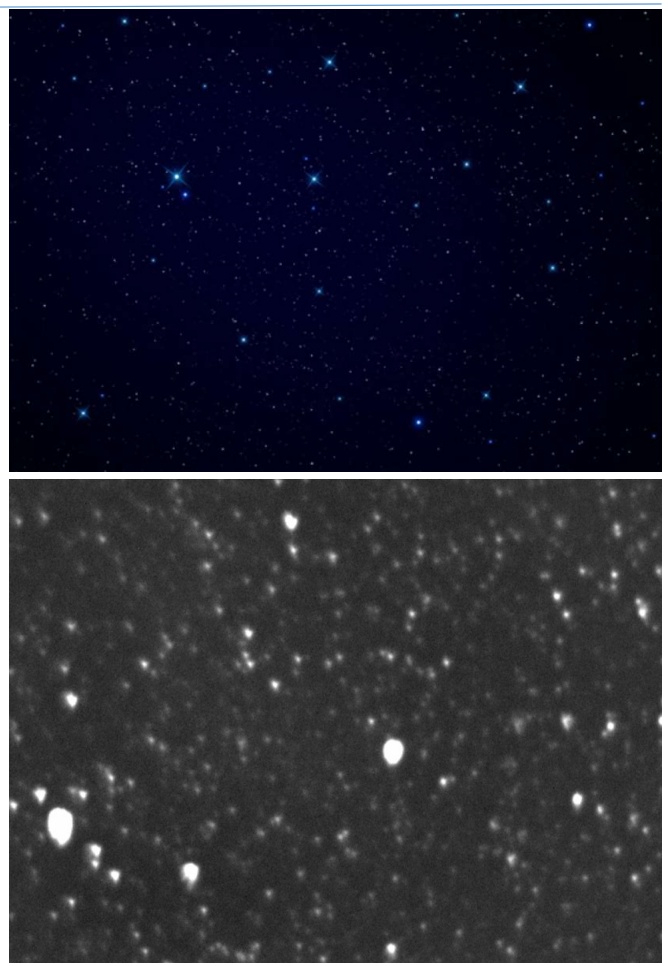
It appears that the bright stars are big and the faint stars are small.

However, this is an illusion of appearance with your eye being deceived by changes in brightness.

The same is true on a CCD image: Stars are the same size at the focal plane.

Therefore, every star in a CCD image can, and should be, considered a point source.

Each point source has a specific shape and size at the focal plane and is known as a Point Spread Function (PSF).

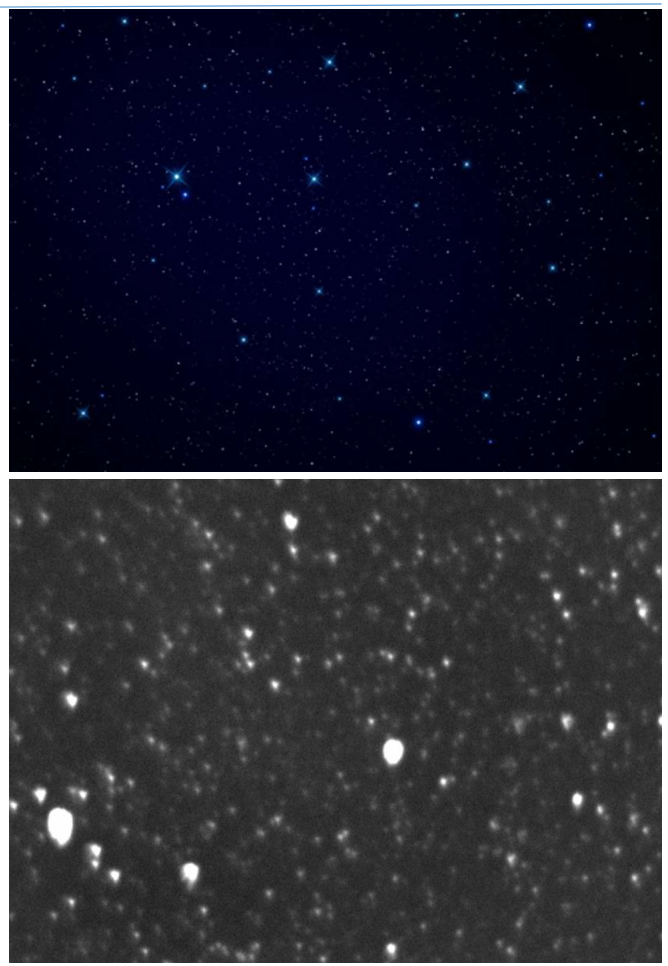


Overview – Stars on a CCD Image

This Point Spread Function (PSF) is mostly determined by something known as Seeing.

Seeing is the smearing of a perfect optical image due to atmospheric disturbances such as turbulence and temperature differentials between the source (Star) and the CCD camera.

Despite all of this, it is important to remember that every star has the same shape and size at the focal plane, all things being equal.



Basic Definitions

Bias frame:

An image of 0-seconds allowing a measure of the difference between Read Noise and a basic CCD image.

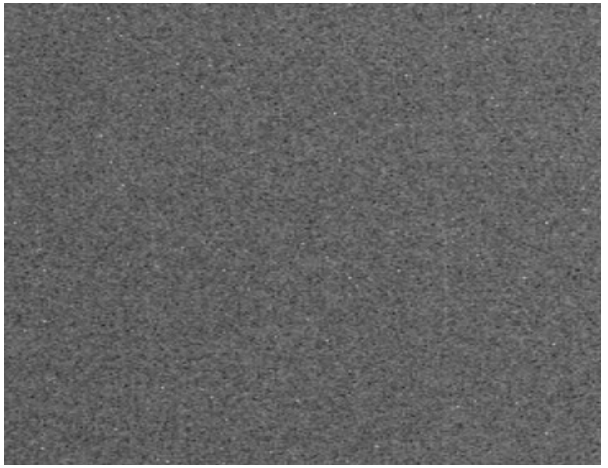
Bias measures Read Noise.

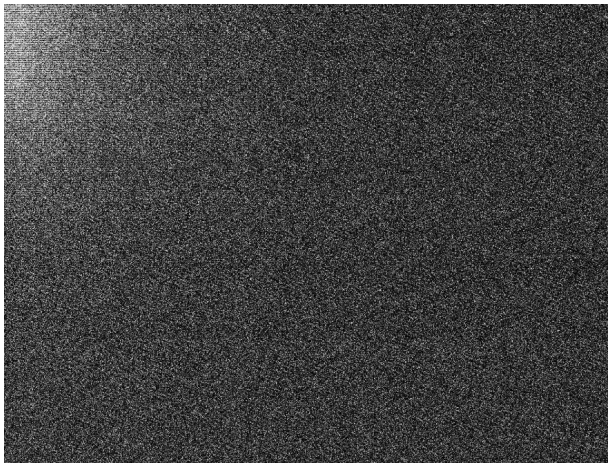
Dark frame:

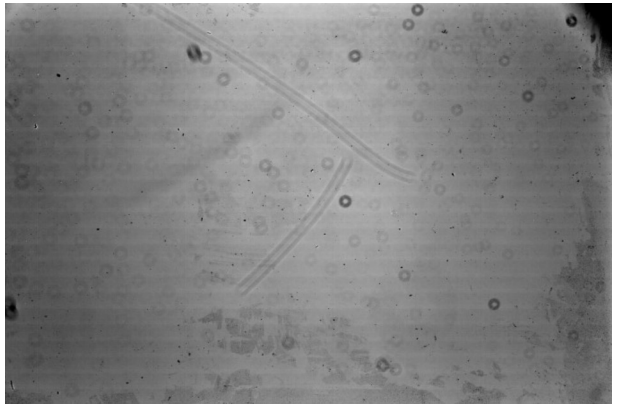
A CCD image taken without light (with the shutter closed)

Measures pixels that are “excited”, thus creating light when there isn’t any light falling on the CCD chip

Varys with CCD temperature, but not completely eliminated







Basic Definitions

Flat frame:

All CCDs have non-uniformities, thus the CCD will not generate an equal signal in each pixel

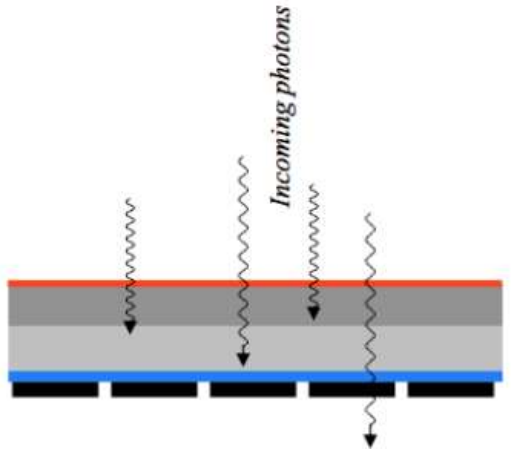
Pixel to pixel non-uniformities are caused by slight differences in pixel sizes to small variations in the silicon thickness across the chip, to dust on the chip

A Flat Frame is an exposure that equals the duration of the Light Image. called a flat, that helps correct for the non-uniformities

Basic Definitions

Front and Back Illuminated CCDs

Front Illuminated: light passes through some of the electronic layers of the CCD before hitting the pixels



Backside Illuminated: The pixels positioned above the electronic layers allowing a higher QE.