

CAMERA BASICS

COSMOS Club Presentation by
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I. REVISING BASIC TERMS RELATED TO CAMERA

II. WHY AN ASTRO CAMERA?



III. FACTORS TO CONSIDER IN AN ASTRO CAMERA

IV. THE SENSOR

V. WHY IS A CMOS BETTER THAN A CCD?

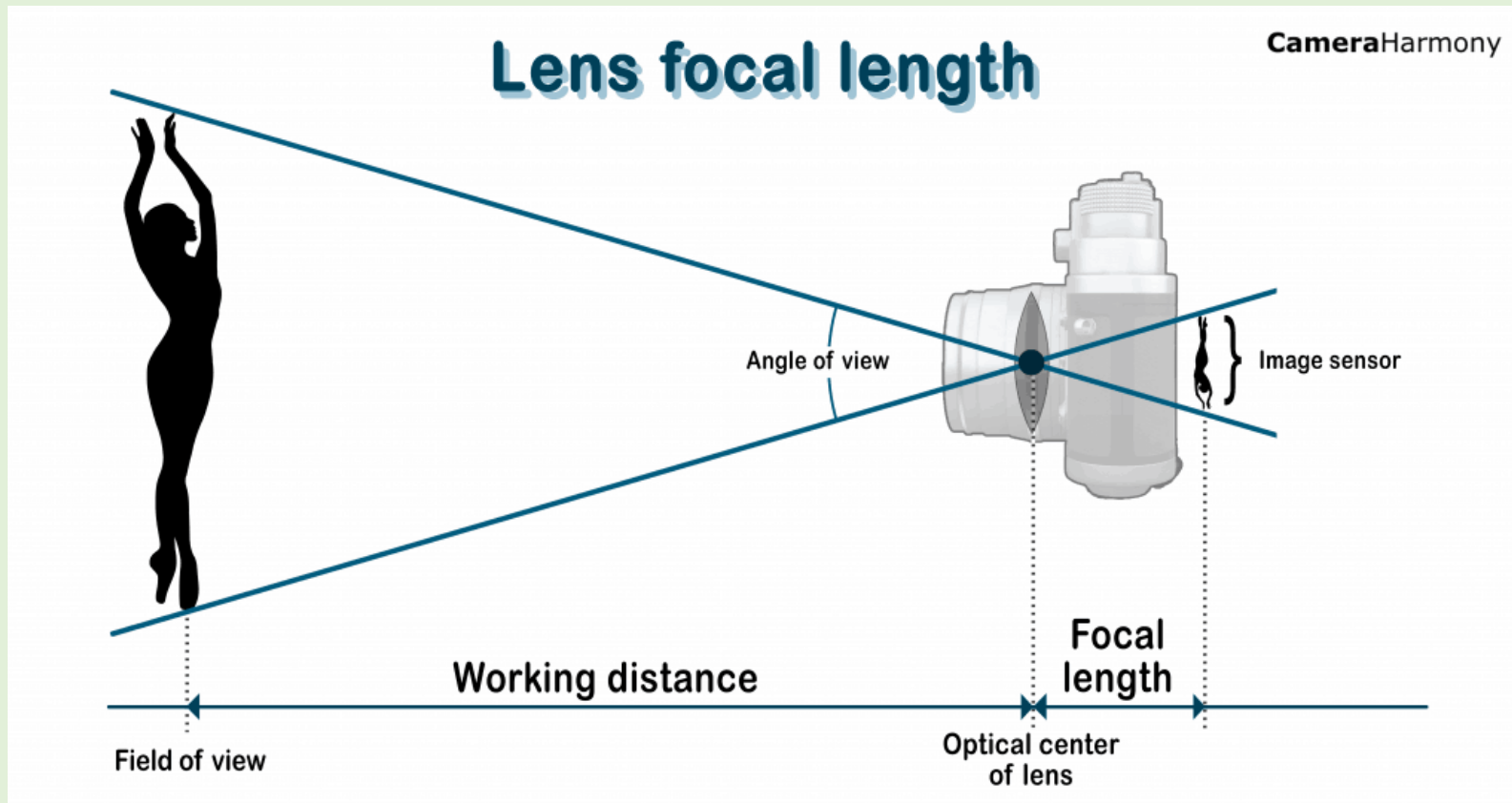
ACKNOWLEDGEMENTS

- DSLRs Vs Dedicated Astro Cameras: <https://www.youtube.com/watch?v=suayk0112A>
- Understanding Camera Specs: <https://www.youtube.com/watch?v=62ggyu0u6f8>
- Advantages of monochrome cam - <https://astrobackyard.com/monochrome-astrophotography-camera-why-to-look-at-a-monochrome-astro-photography-for-camera-society-recorded-3600n5a0yaur56aastrophotography62nsuject1>
- Total shutter and Roller Shutter: Everything You Wanted To Know About Rolling Shutter - DIY Photography
- How a camera sensor works: <https://www.youtube.com/watch?v=KJH2DFKVC64&list=PL5C74961>

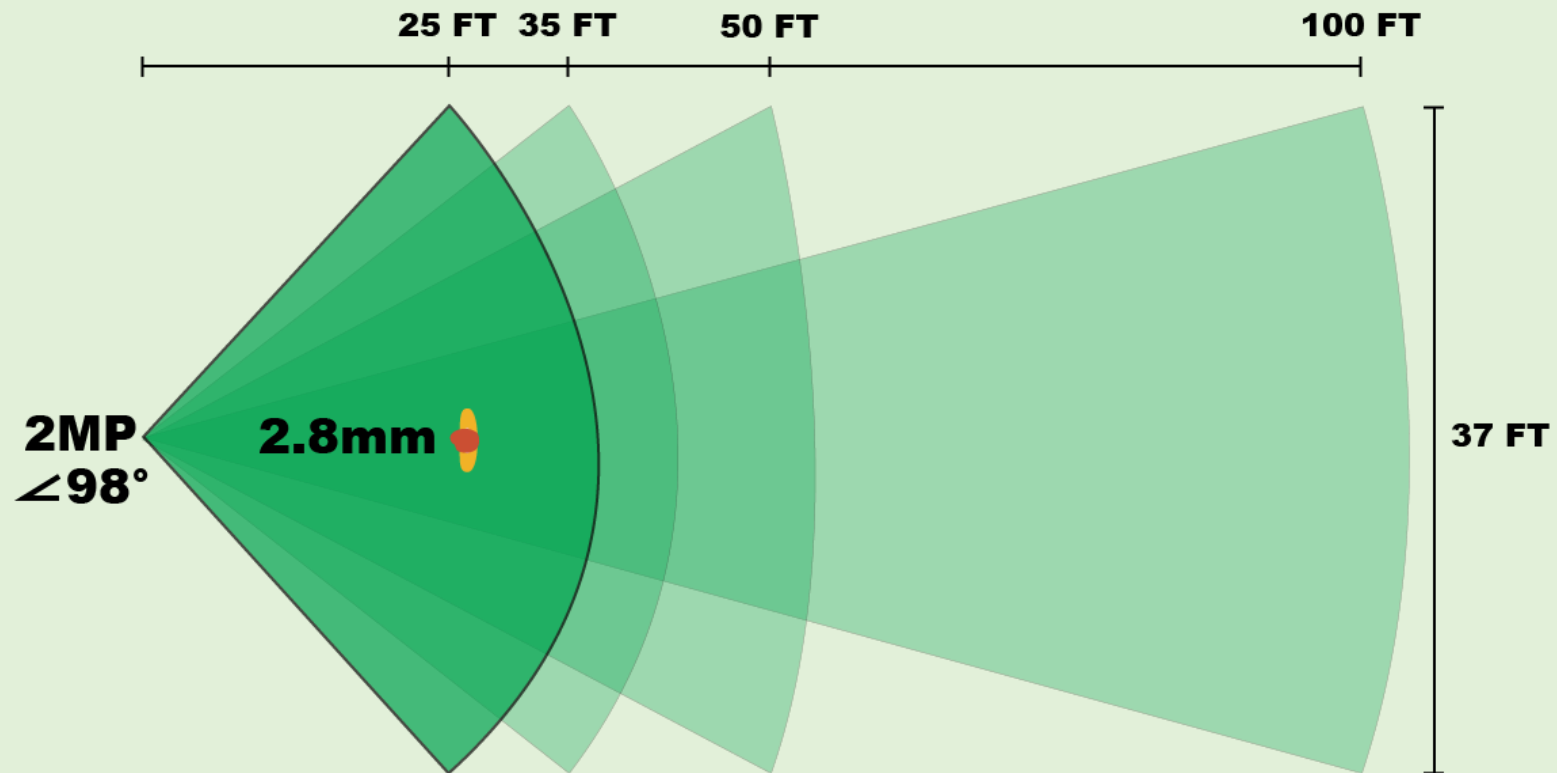
1.



Focal Length (F)



Field of View



APERTURE DIAPHRAGM



f/2.8



f/4



f/5.6



f/8



f/11



f/16



f/22



MORE LIGHT

LESS LIGHT

Shallow Depth of Field

Deep Depth of Field

Aperture

II.



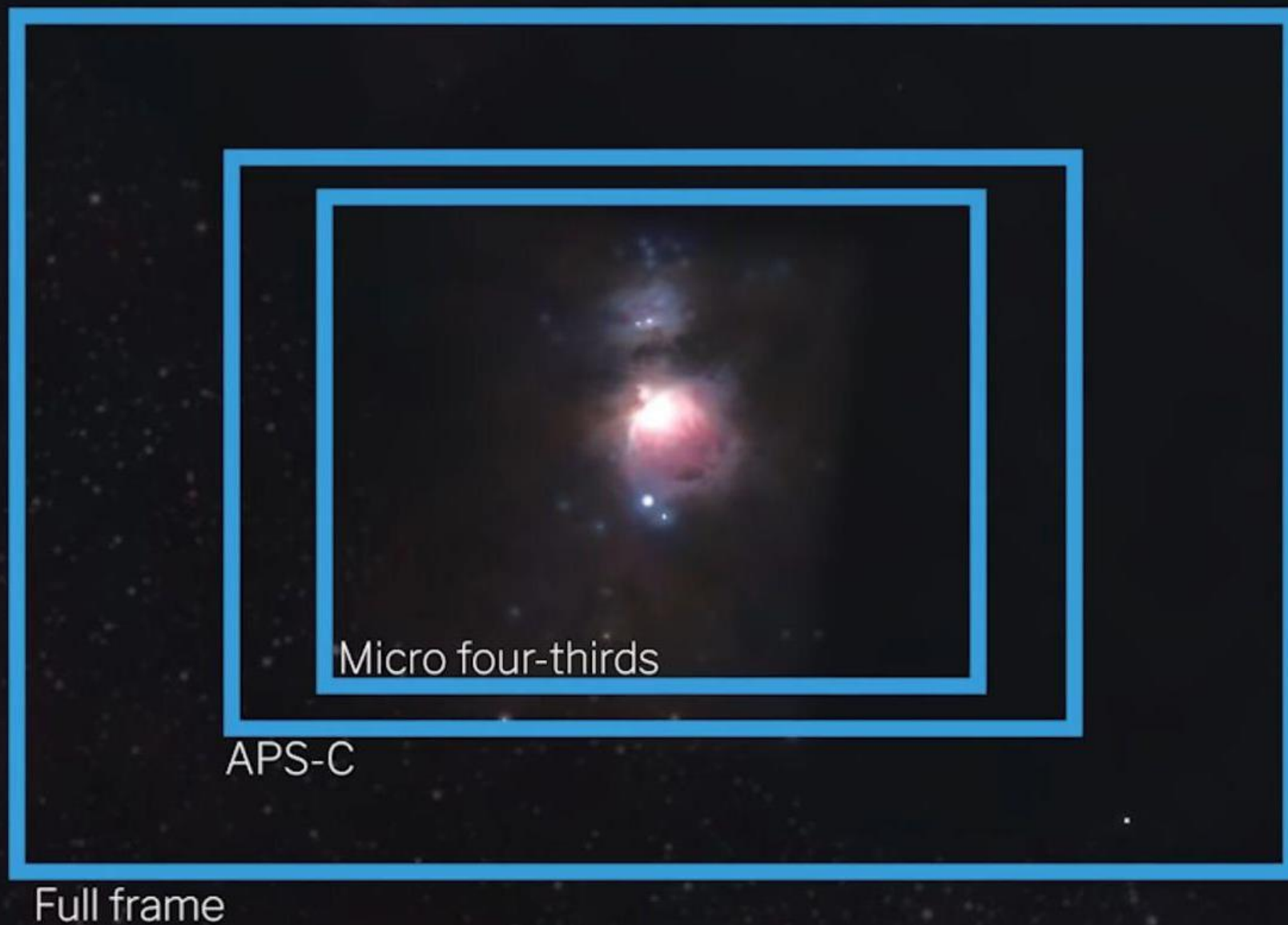
Parameter	DSLR	Astro-Camera
Weight	Comes with a lot of hardware. Increases load on Mount.	Equipped only with Sensor and minimalistic hardware. Tailored for mounts.
Heat generation	The battery & excessive electronics contribute to heating during long working hours.	Could be equipped with cooling mechanism.
Noise	Computes image on its own generating more noise.	Produces .fit format which is ideal for astronomical software.
Filters	Mostly installed with Infrared filters. Limited filter options.	Dedicated filter slots and options.

III.

I. Sensor Size

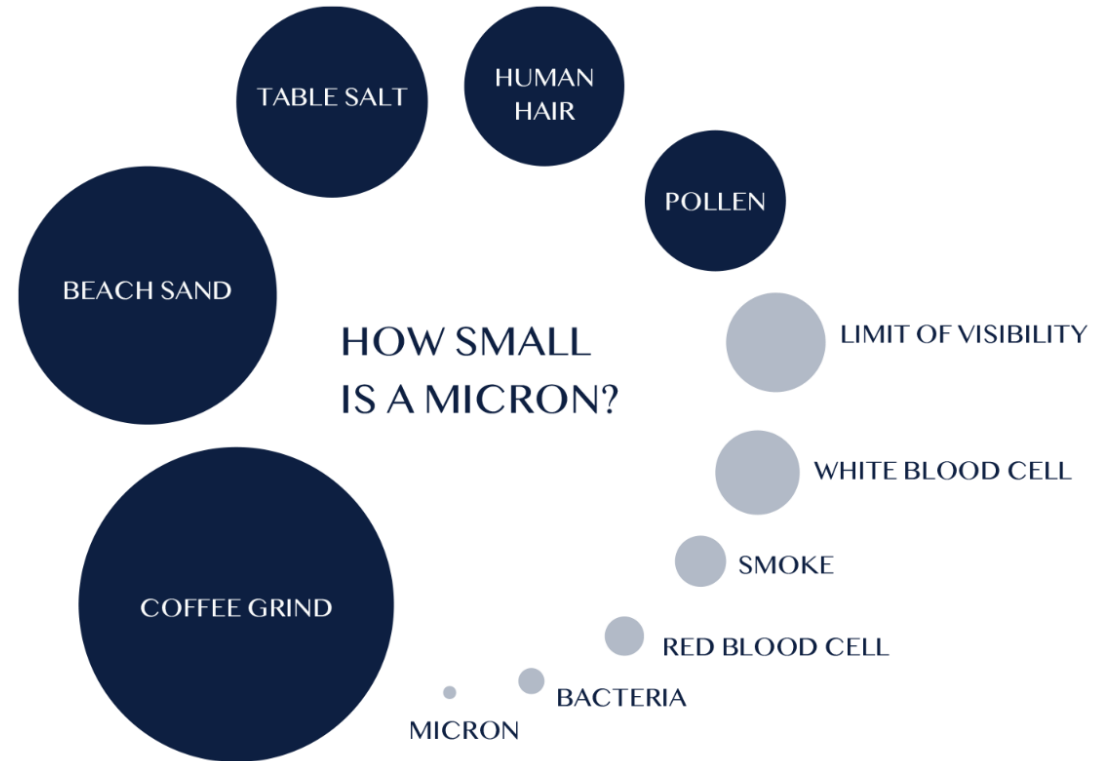
- Determined by Crop Factor (CF).
- Crop Factor - ratio of 35mm film frame to a camera sensor's size.
- Sensor Size \propto Field of View.
- Sensor Size \propto Resolution of Image

Type	Crop Factor	Size(approx)
Micro four-thirds	2X	17.5mm × 13.5 mm
APS- C	1.5X	25.1×16.7 mm
Full Frame	None	35mm×24mm



2. Pixel Size

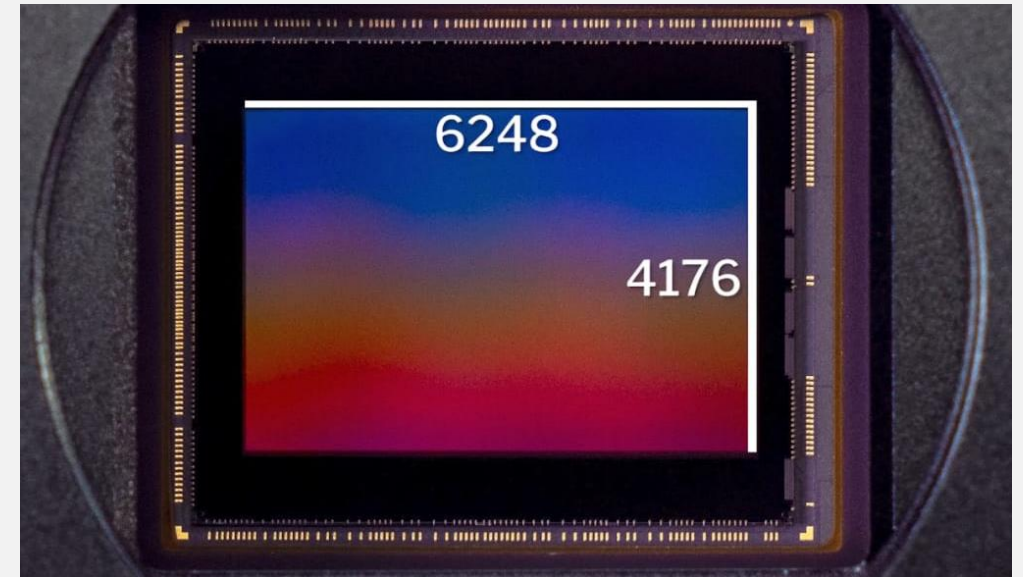
- Measured in Microns (μm)
- Pixel Size \propto 1 / Image Resolution
- Pixel Size \propto Sensitivity (Brightness)
- Application - Smaller pixels are better for planetary, solar or lunar imaging.



* Relative size of an item as compared to other items.
Size and scale are relative.

3. Pixel Array

- Definition - Area Configuration of a sensor. Measured in MegaPixels (MP).
- Example - $6248 \times 4176 = 26$ Million = 26 MP

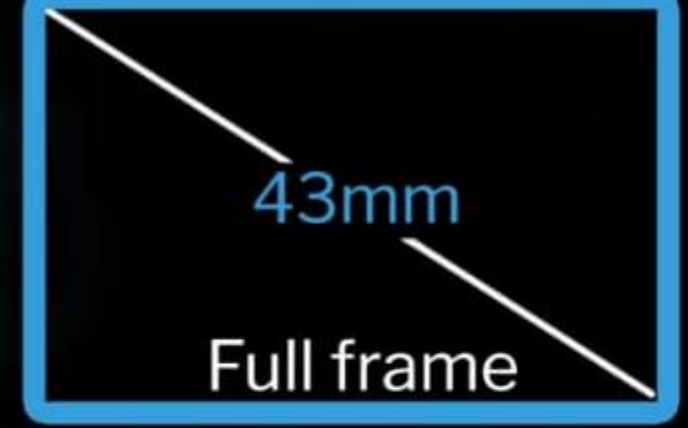




Micro four-thirds



APS-C



Full frame

Minimum Filter Size

1.25"

Minimum Filter Size

36mm

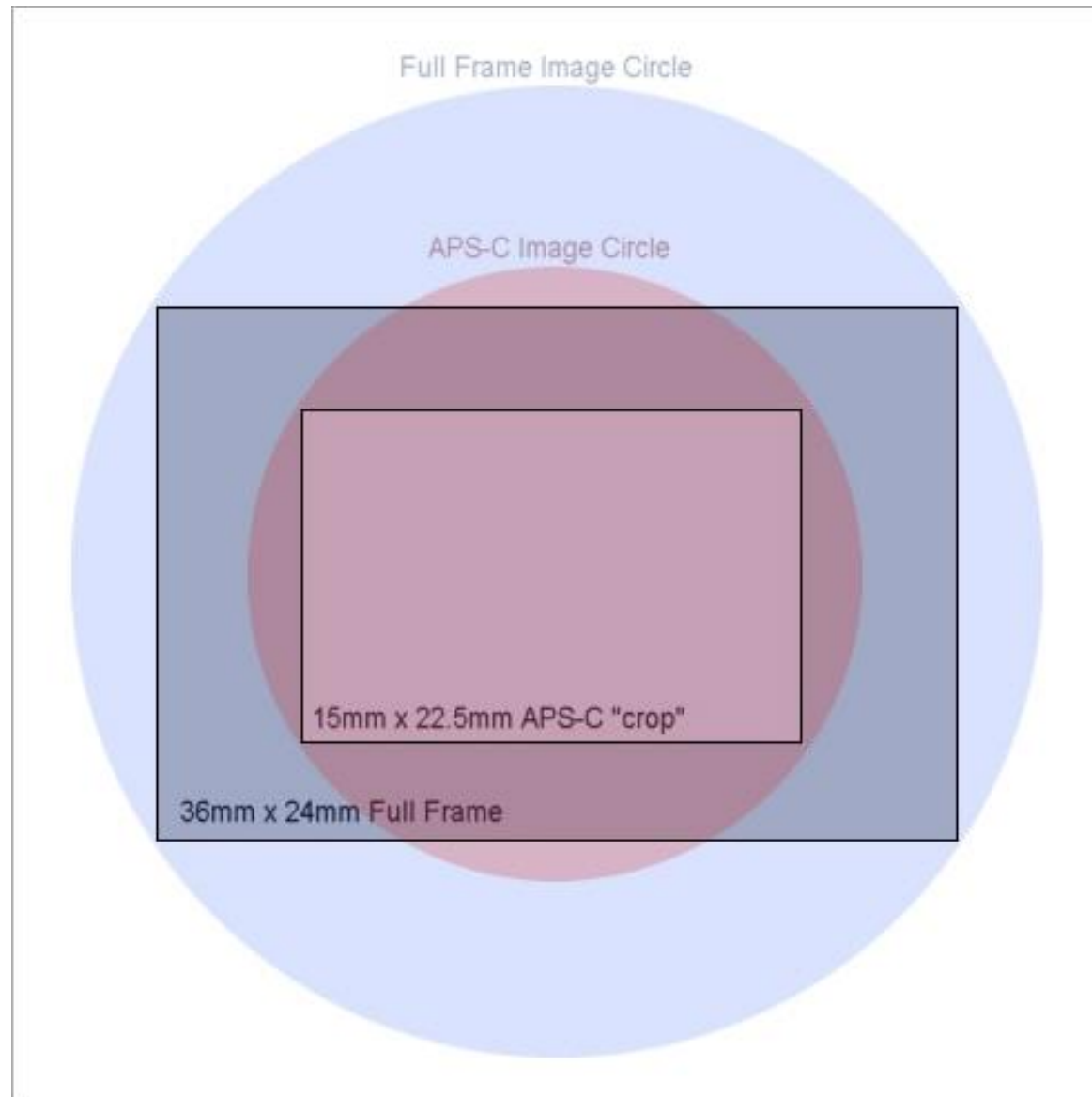
Minimum Filter Size

2"

4. Sensor Diagonal

Conveys information of -

- Supported Image Circle
- Smallest Filter Size

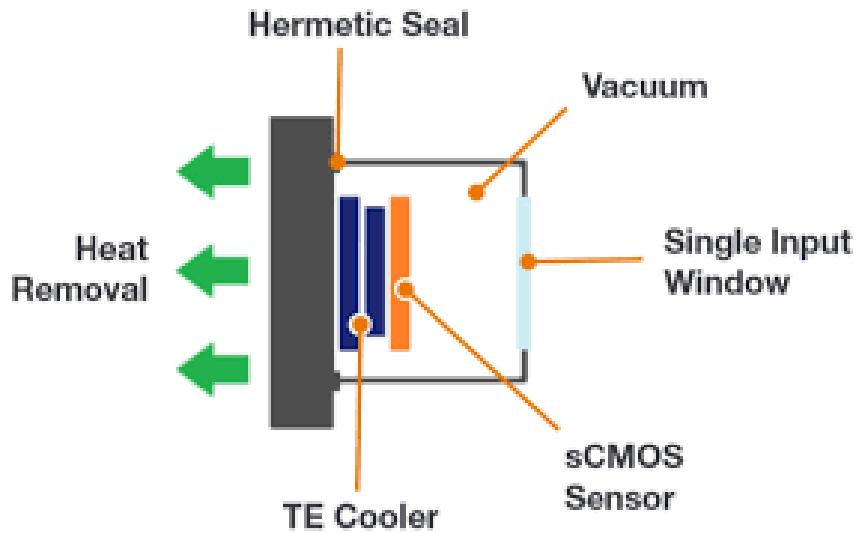


4. Colour Camera Vs Monochromatic Camera

<i>Colour Camera</i>	<i>Monochromatic Camera</i>
Built in Colour filter on sensor pixels, following Bayer Matrix pattern.	Colour Filter needs to be added to the camera's mouth.
Lower photography time.	Higher photography time.
Takes in $\frac{1}{3}$ amount of incident light.	Takes in complete incident light.
Faster image processing speed.	Slower image processing speed
Comparatively lower image resolution.	Higher resolution image output.

5. Cooled vs Uncooled Camera

Cooled Cameras have built-in fan to keep the sensor at a stable low temperature.



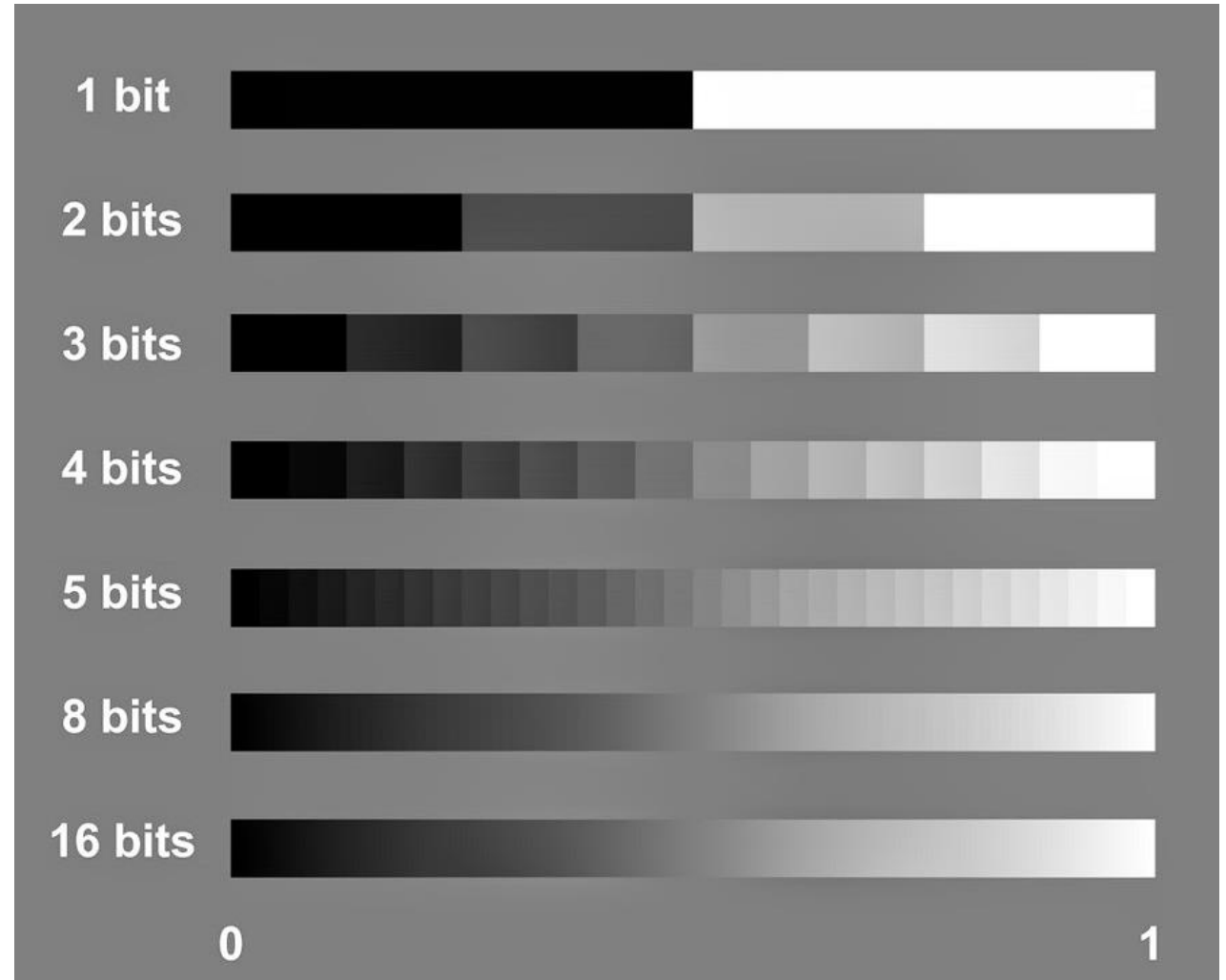
ASI462
MC

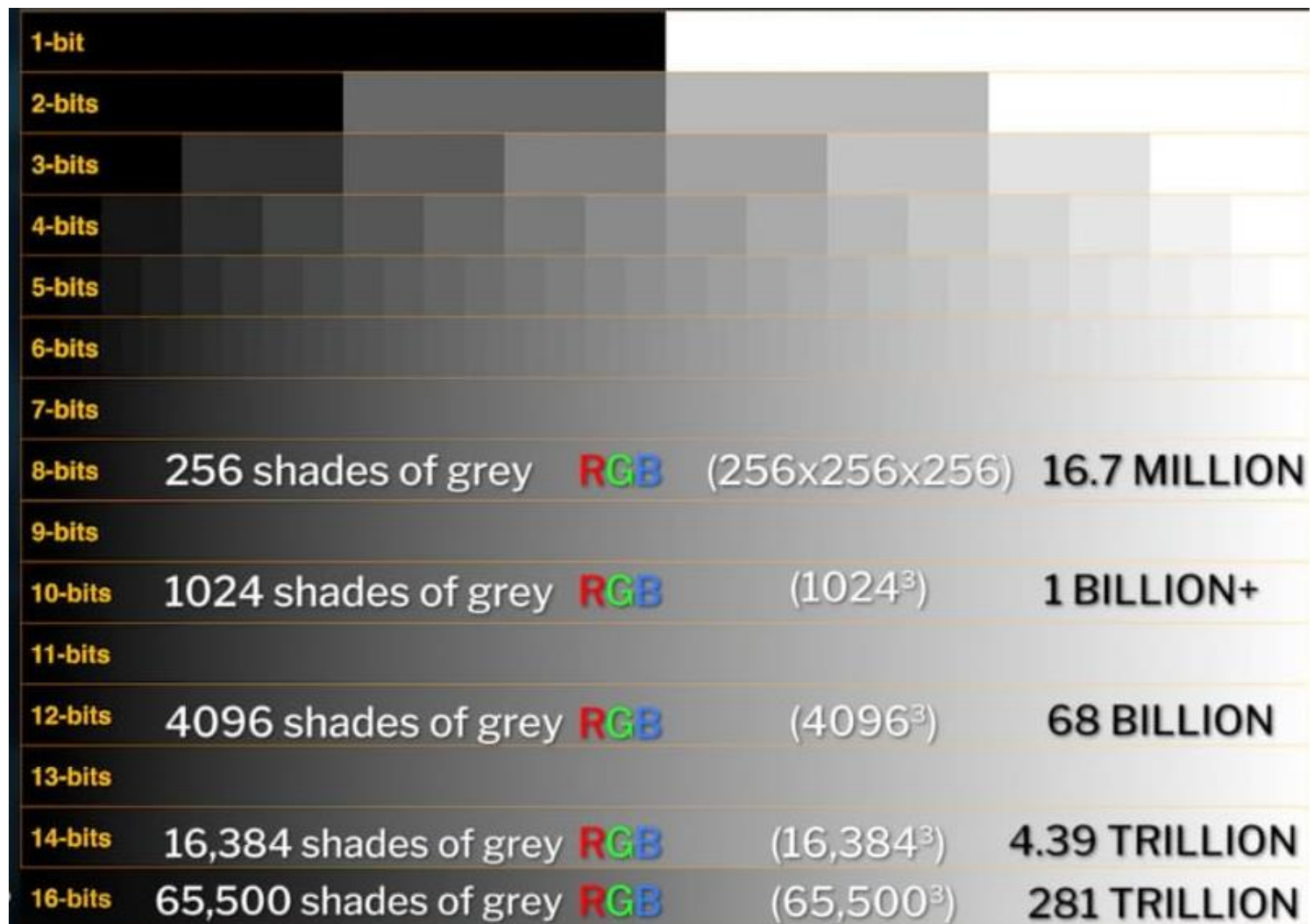


ASI 1600MM
Pro

6. Bit Depth

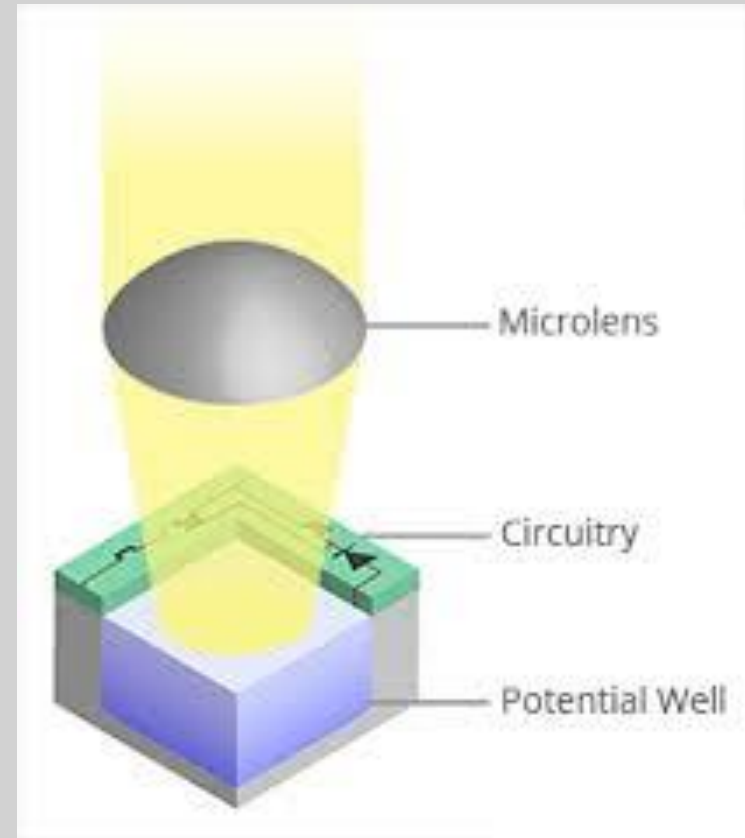
- Bit Depth is number of shades of Grey the sensor can process incoming light into.
- Shades of grey are then translated to colours while processing.
- Decides Gradient and Amount of colours that can be processed by sensor.

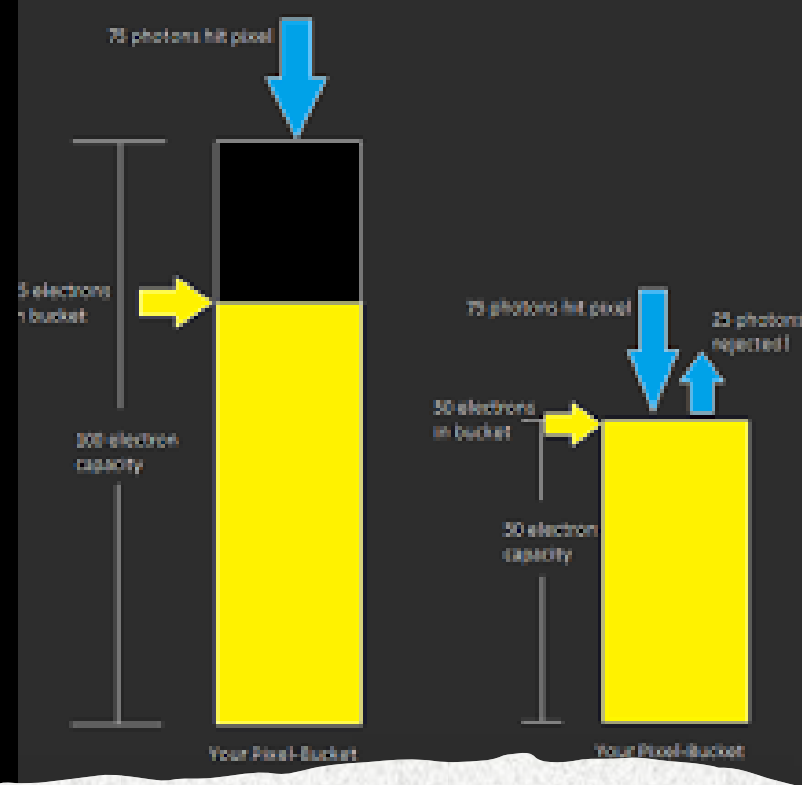




7. FILL WELL DEPTH

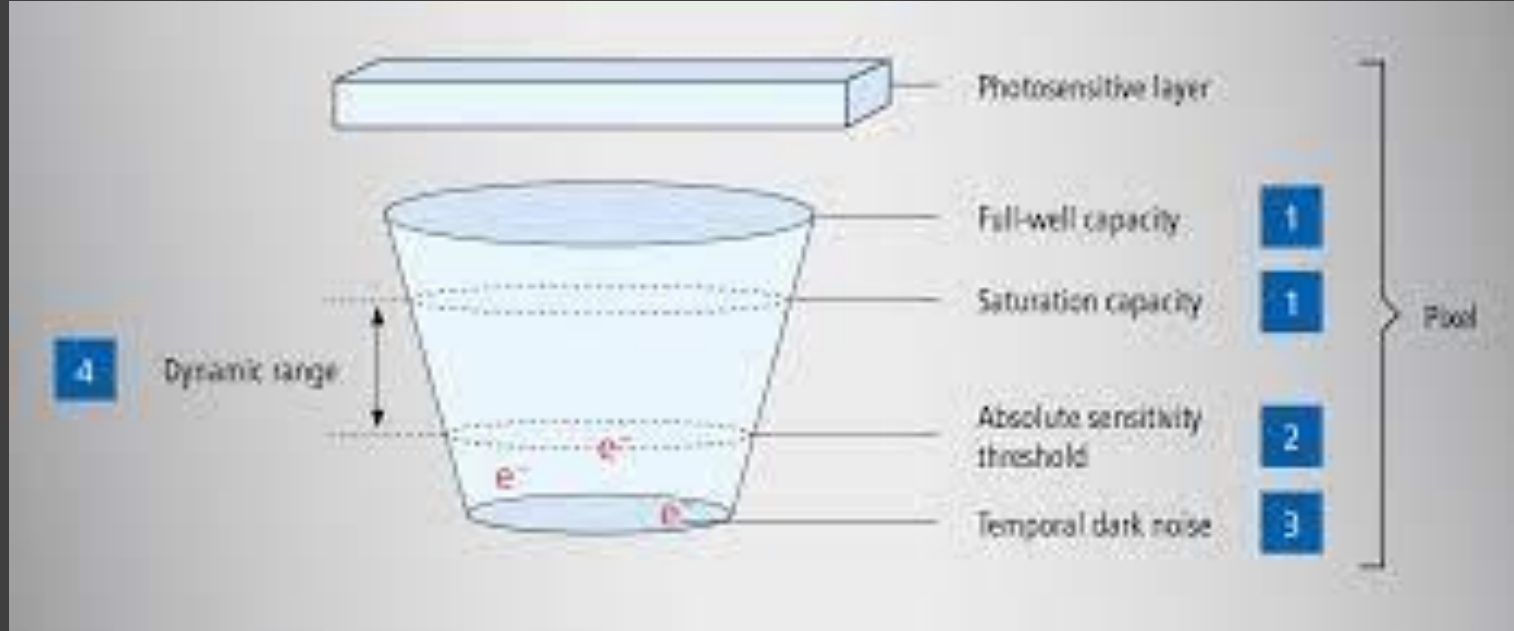
Definition - Amount of electrons (e^-) a pixel can hold until it becomes saturated and turns white.





APPLICATIONS

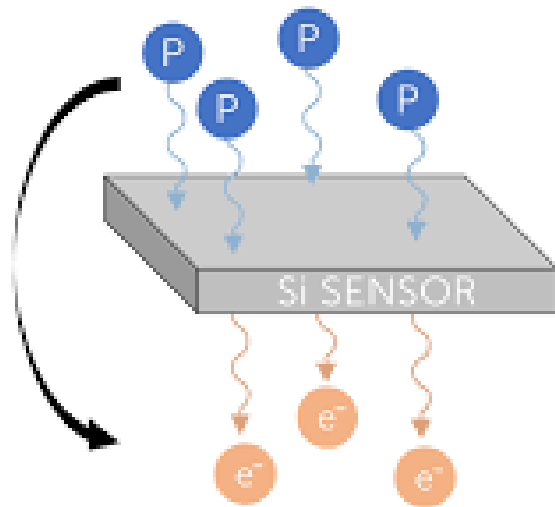
1. Blooming : When a pixel exceeds fill factor it emits light energy onto the next pixel causing blooming.



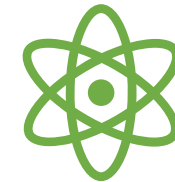
2. DYNAMIC RANGE

The contrast ratio between the darkest and brightest color tones that a camera can capture in a single exposure.

8. Quantum Efficiency (QE)



Definition - Percentage of parallel incident light that hits sensor and gets recorded as signal.

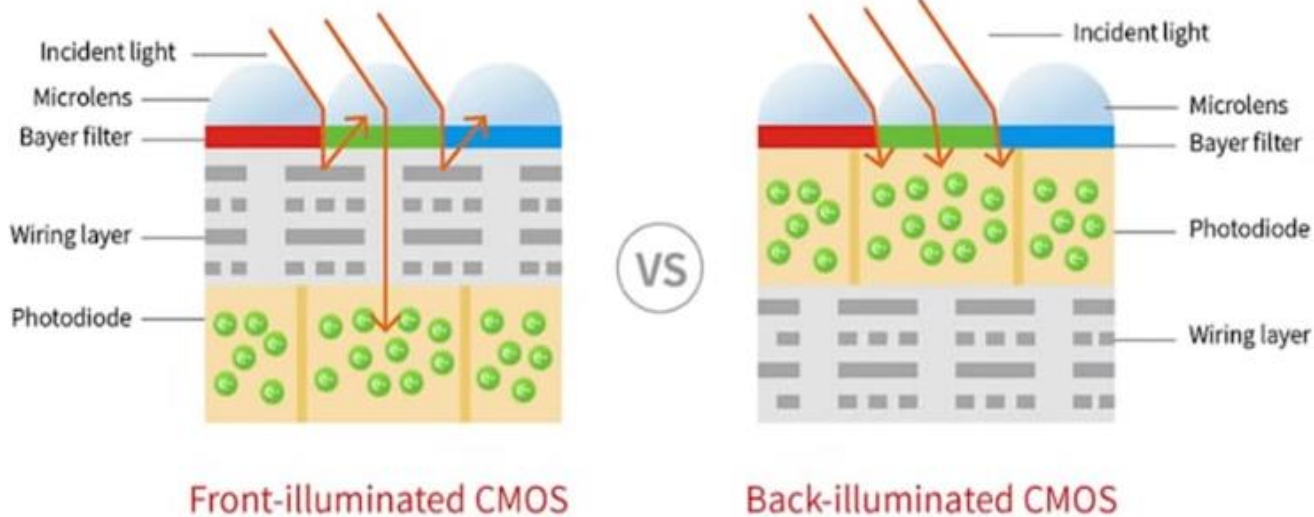


Quantum Efficiency \propto Brightness ; resulting in More Data in less time span.

9. Back Illuminated Sensor

Sensors where pixels first receive the light and then turn on the circuitry to convert the light into electric impulses.

- Applications - i) Reduces noise
ii) Improves Quantum efficiency
iii) Eliminates Amp Glow



10. Frame Rate

Definition - Frame rate is the frequency (rate) at which consecutive images (frames) are captured or displayed.

Unit - Expressed in frames per second (FPS).

Frame rate in video recording mode enables more pictures (frames) in a stipulated time rather than clicking single pictures.

- Frame rate \propto Size of Cropping of sensor
- Application - Helpful in capturing fast moving or light fluctuating objects.
- Limitation - Data transfer speed for image processing.

II. Read noise



Definition - *the amount of noise generated by electronics as the charge present in the pixels is transferred to the camera.*




Unit - Expressed in 'Electrons Rms' (e).

Example - Camera has read noise of 0.5e to 2 e.

Each Pixel can have an error margin of ± 0.5 to 2 electrons per pixel.

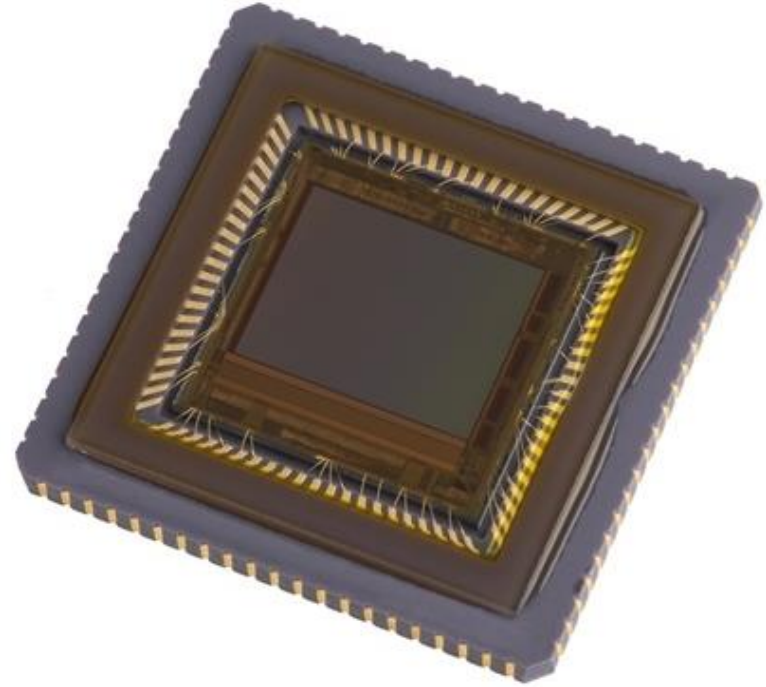
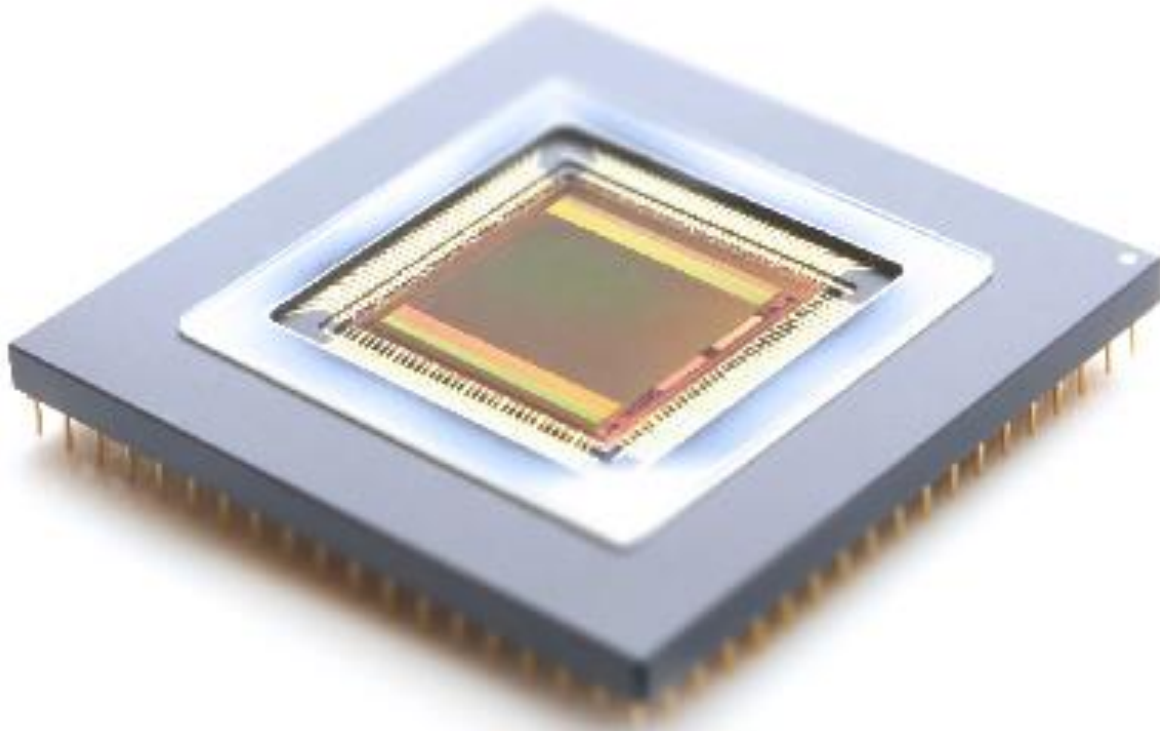
I



What is it?

- A camera sensor is a piece of hardware inside the camera that captures light and converts it into signals which result in an image.
- It operates on the principle of Photoelectric effect





TYPES OF SENSORS

1. CCD
2. CMOS

Steps in Function ing of a Sensor

Light to Charge Conversion

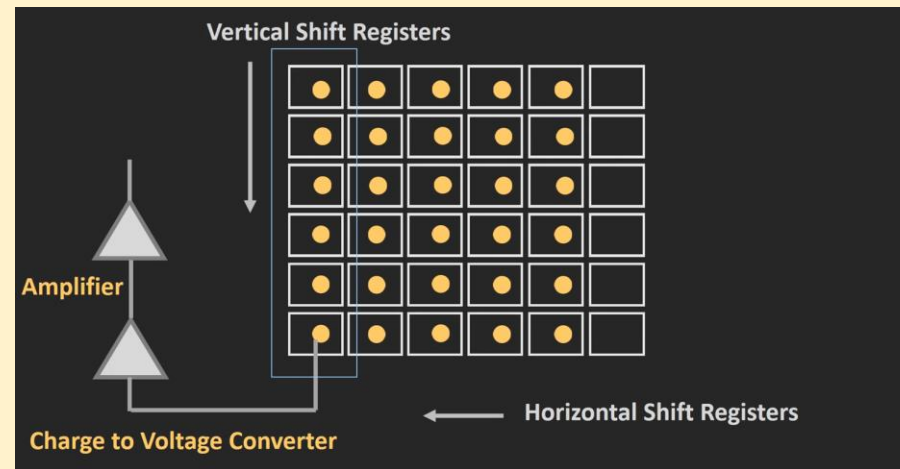
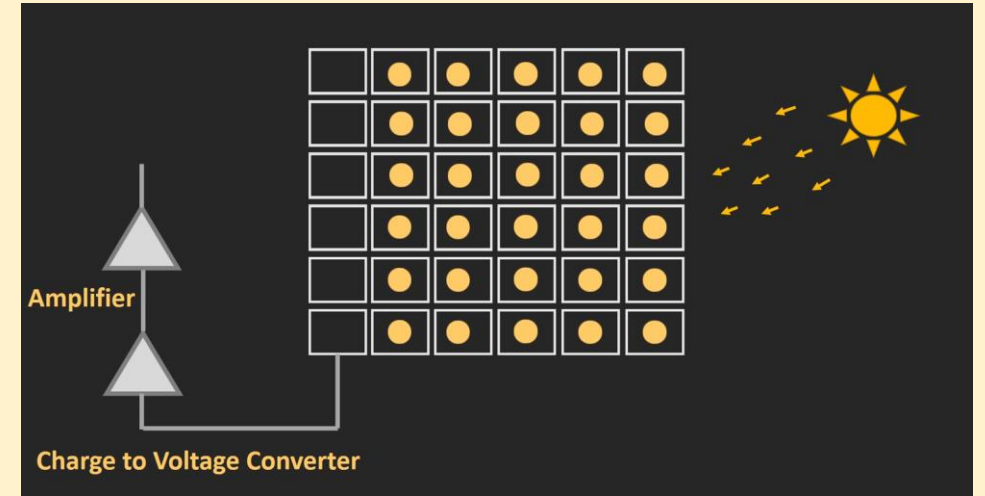
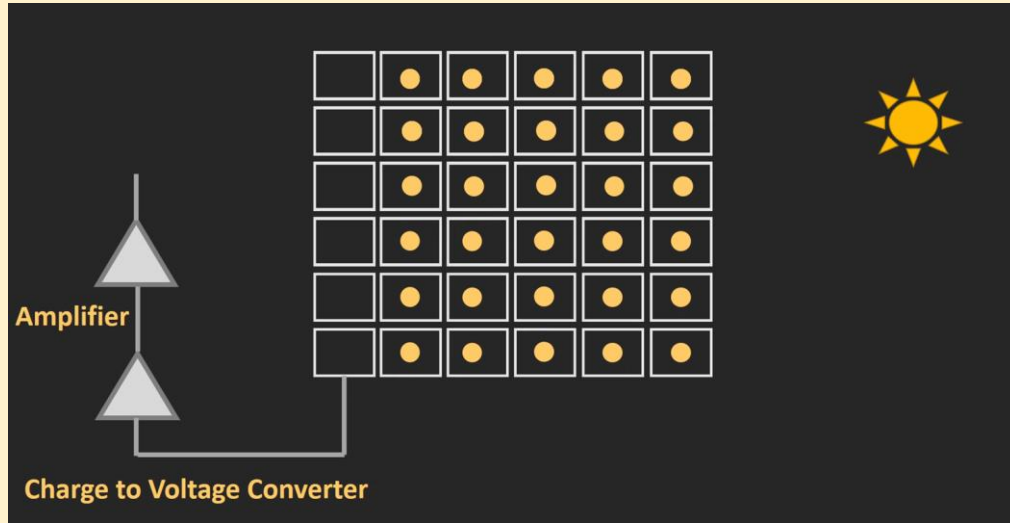
Charge Accumulation

Transfer

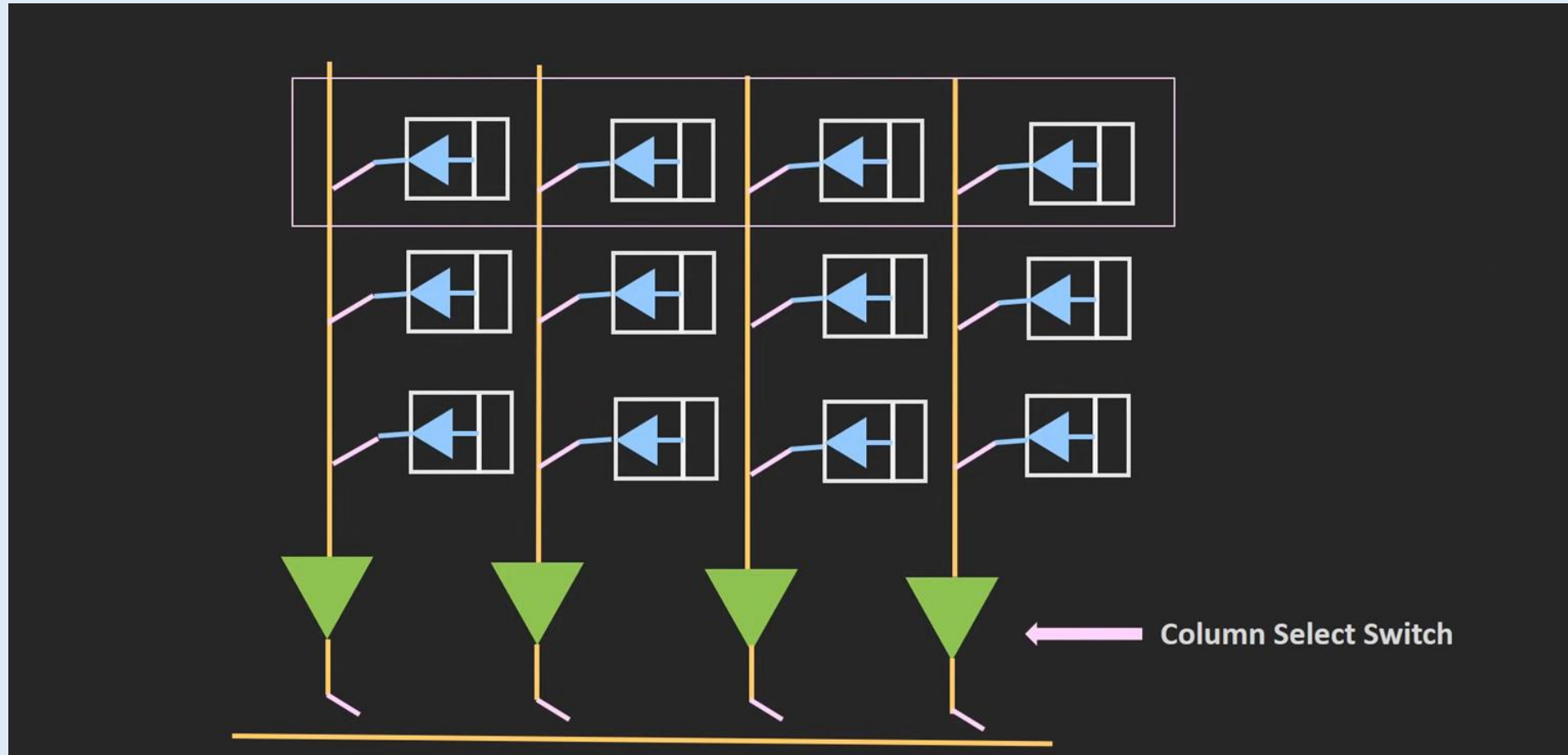
Charge to Voltage Conversion

Amplification

How does a CCD sensor work?

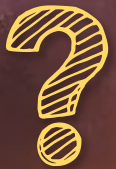


How does a CMOS sensor work?



The background of the slide is a dark, atmospheric illustration of a night scene. A small, dark house with a single glowing yellow window is situated on a grassy hill. The sky is filled with dark, swirling clouds, and a bright, jagged lightning bolt strikes down from the upper right towards the house. The overall mood is mysterious and dramatic.

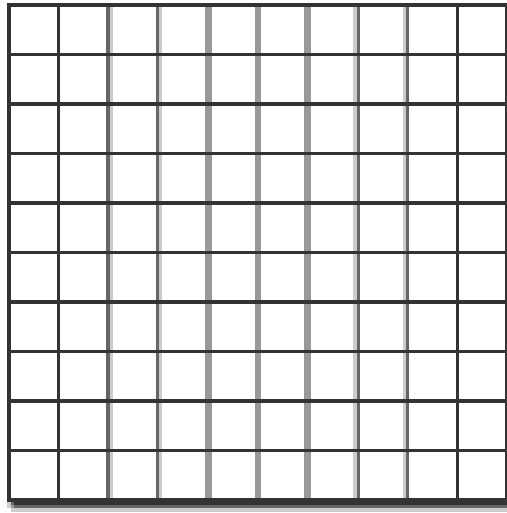
**V. WHY IS A CMOS
BETTER THAN A CCD?**



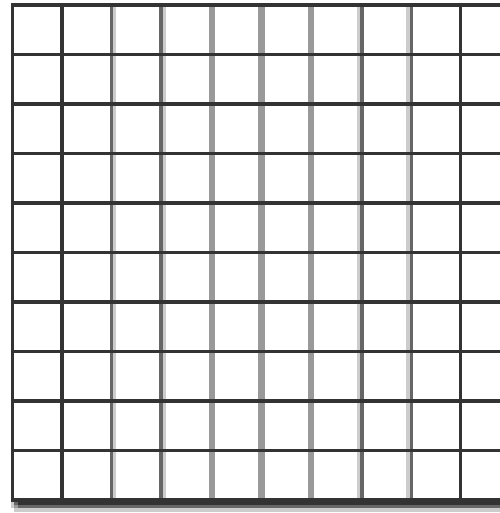
CCD	CMOS
<ul style="list-style-type: none">• Not possible to integrate peripheral components , thus increasing the size of the sensor• Requires multiple sources of power(Usually 7-10 V)• Has slower processing speed• Has higher fill factor(Higher dynamic range)• CCDs has a blooming effect	<ul style="list-style-type: none">• The ability to integrate peripheral components gives us the option to have a SOC(System on chip)• Requires a single source of power(Usually 3.3-5 V)• Has faster processing speed• Has lower fill factor(Lower dynamic range)• CMOS does not have a blooming effect

What is Total Shutter and Rolling Shutter ?

Rolling Shutter



Total Shutter





ZWO AQI 462 MC

- Sensor - Sony IMX462 (CMOS)
- Pixel size - $2.9\mu\text{m}$
- Pixel array - i) Length - 5.6 mm
 - ii) Breadth - 3.2 mm
 - iii) Diagonal - 6.46mm
- Resolution - $1936 \times 1096 = 2.1 \text{ MP}$



Specs

- Bit Depth - 12 Bit (68.7 Billion colours)
- Fill Well Depth - 11.2 ke
- Quantum Efficiency - 90% at 850nm (has a very high QE value at 800 to 1000 nm wavelength)
- Dynamic Range - 12 stops
- Frame Rate –
 - i) 136.1fps (10bit, high-speed mode) or
 - ii) 63.9fps (12 bit, normal mode) at full resolution (2.1MP)
- Read Noise - 0.47e to 2.65e
- Weight - 1.8 Pounds (0.81 kg)
- Connector - USB 3.0

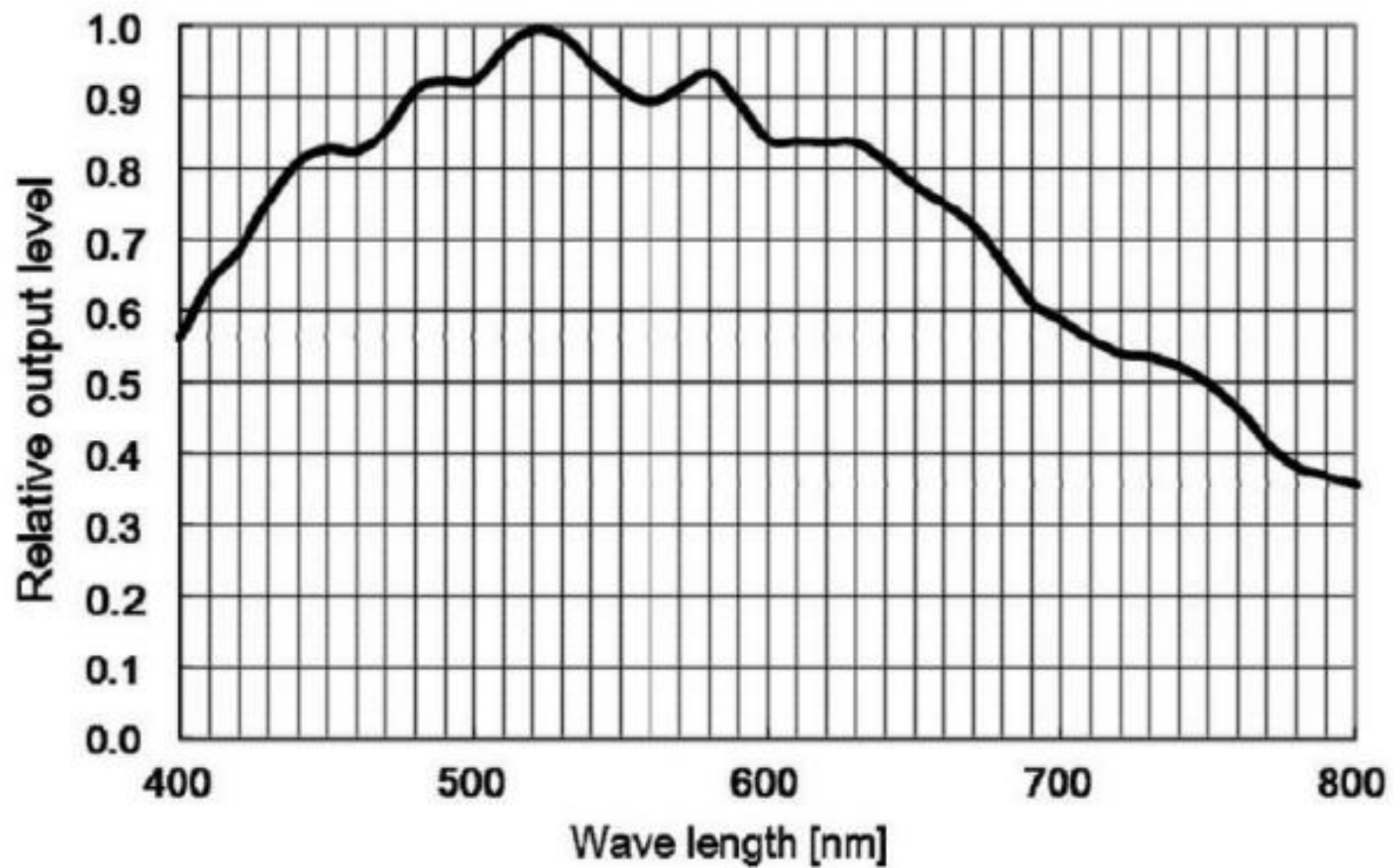
Application of AQI 462 MC

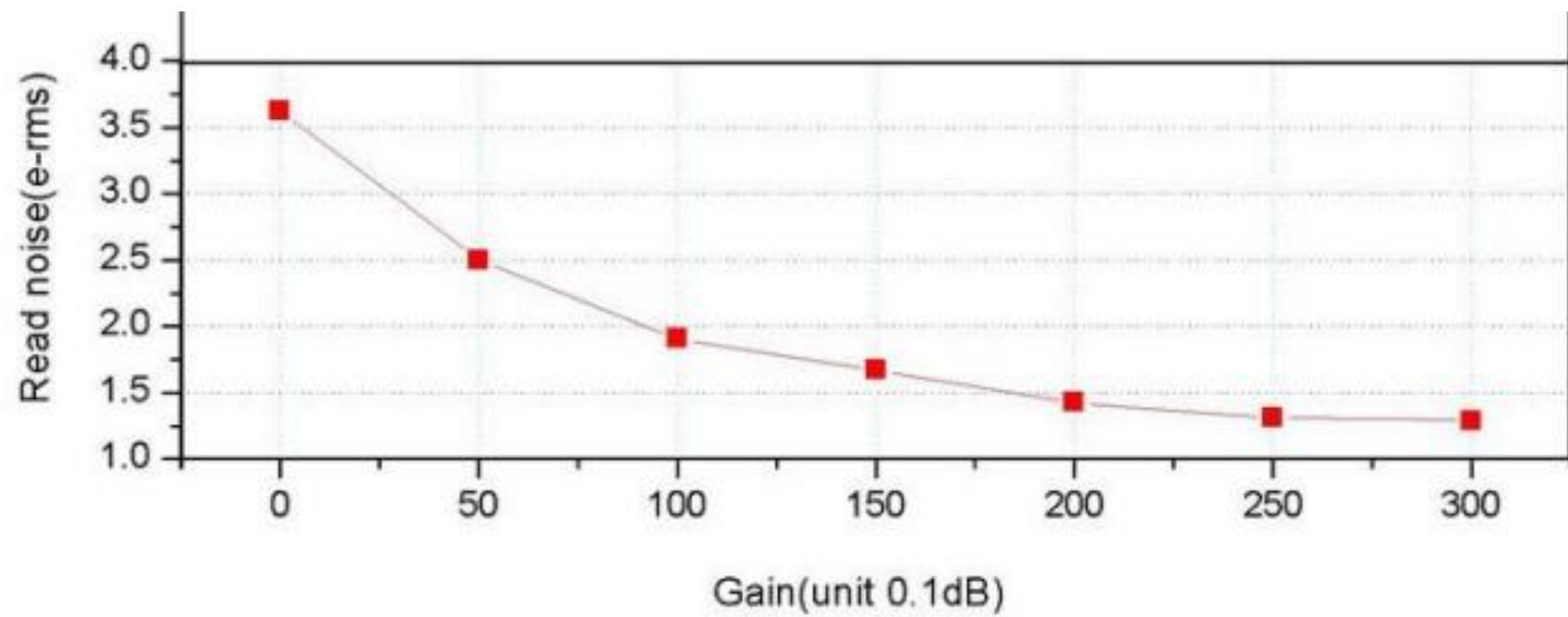
- 1) Planetary Imaging camera - Planetary imaging is an all-encompassing term for photographing solar system objects such as the planets, moon, and even the sun.
 - a) Better Resolution.
 - b) Higher Frame Rate.
 - c) Smaller sensor captures more surface details.
- 2) Guide Camera - Mounted on the Guide Scope and keeps the deep sky image in focus with the help of an autoguider. Prevents Star trails and provides more exposure time.
 - a) Monochromatic Camera - More sensitive to incoming light in FoV.
 - b) Fast output speed.
 - c) Light weight.

ZWO ASI 1600 Pro

- Sensor : Panasonic MN34230AU (Backlit CMOS)
- Pixel Size : $3.8\mu\text{m}$
- Resolution : 4656×3520 (16MP)
- QE peak : $\sim 60\%$
- Full well potential : 20ke
- Supported OS : Windows, Linux & Mac OSX
- Working Temperature : $-5^{\circ}\text{C} - 45^{\circ}\text{C}$







Application of AQI 1600 MM Pro

Deep Sky Imaging - Imaging of huge Celestial bodies/clusters beyond our Solar System including Nebulae, Galaxies, Supernovae and more.

- ★ Larger Pixel allows far away and dim objects to be shot.
- ★ Cooling system allows longer exposure by keeping sensor cool and efficient.
- ★ Bigger Potential Well allows more photons to be captured and recorded as information.



ACKNOWLEDGE MENTS

- DSLRs Vs Dedicated Astro Cameras <https://www.youtube.com/watch?v=szu4kqlfT7A>
- Understanding Camera Specs <https://www.youtube.com/watch?v=07xgyyui6UY>
- Advantages of monochrome cam - <https://astrobackyard.com/monochrome-camera/#:~:text=A%20monochrome%20astrophotography%20camera%20can,recorded%20on%20your%20astrophotography%20subject>
- Total shutter and Roller Shutter : [Everything You Wanted To Know About Rolling Shutter - DIY Photography](https://www.youtube.com/watch?v=FKJFizDfUNE&t=499s)
- How a camera sensor works: <https://www.youtube.com/watch?v=FKJFizDfUNE&t=499s>

A dark, atmospheric night scene with silhouettes of trees against a starry sky. The sky is filled with numerous stars and a soft, hazy glow. The trees are dark and silhouetted against the lighter sky.

Krishna Kapoor :
Basics and Factors

Neeraj : Noise to
Sensors

Saket : Shutter and
CMOS, CCD.

Krishnaraj:
Presentation Edit.

Thank You for Listening!

