**ISO vs Aperture vs Exposure ( Apr 2023)**

Back in the days of film photography, film sensitivity to light was determined by the size of the photosensitive Lumps of Goo (LoG) spread in the emulsion across the file surface.

A standard daylight film typically had a rating of 100ASA. It had fairly small LoGs, meaning a lot of LoGs were packed into the area of the film surface, which provided an even, fine, high resolution image.

If you needed a more sensitive film, e.g. 200ASA for action photography, then the LoGs became larger, and thus more sensitive to light. But large LoGs meant fewer LoGs could be packed across the film surface, so the resolution decreased, and the image became a little grainy.

If you really needed sharp images for high speed sports or low light photography, you could buy 400ASA file, with even bigger, even fewer LoGs spread out across the film. Now this was getting seriously grainy!

So that’s similar to today’s situation with pixels on sensor chips. Science grade cameras tend to have large pixels, e.g. 13, 19 or even 21 um in size, whereas retail (aka Home body) cameras like a DSLR have pixels around 5-6um. Now that’s still pretty big compared to phone cameras, where the pixel size is more like 1..2 um!! That’s how they squeeze so many pixels into such a small space.

That comes at a cost however. Smaller pixels don’t collect as much light as larger pixels, If you think of the pixels as buckets collecting rain drops, then the smaller buckets fill up much more quickly, and once they’re full, that’s it. No more raindrops (photons of light) for that pixel.

Let’s consider a pixel that’s set up to collect only red light. That pixel will be black if it hasn’t received any red light photons. It will be pure red if it’s full up with red light photons. The smaller the pixel(bucket), the less red light photons it can hold, therefore the fewer number of levels between black (empty) and pure red(full). A larger pixel that can hold more photons gives you more individual levels or shades between black and pure red. More shades of red gives you a more realistic picture. Add to that the pixels that hold Green and Blue light, and the more shades or Red, Green and Blue that your pixels can hold, the more refined and accurate the colours in your photo.

Now we have to consider how to collect as many photons of light as possible onto our sensor. With film, you simply selected a higher ASA rating, with larger chunks of LoG, that were more sensitive to light. Now here’s the drawback with digital photography. The sensor (chip) in your camera comes out of the factory with a certain level of sensitivity that is fixed forever. It cannot be changed. There is no setting on any camera that can change the sensitivity of the chip in the camera to incoming photons.

Now the sensitivity of the chip can be measured by the manufacturer. They can figure out that for every 100 photons received on the surface of a pixel, the pixel will see (register) a certain number of those photons, and convert the photon energy into an electrical charge, which is what’s stored in the pixel. A typical retail DSLR camera only registers about 50-55% of the incoming photons, so it only records about half of all the light making it to the sensor.

The amount of light actually registered is given a technical term, called Quantum Efficiency, usually shortened to QE or QE%.

If you buy an astronomy-specific camera, then for extra $$$, you can buy a camera with a QE of 80% or more. A really top notch, scientific grade camera might get you 95%, meaning that of every 100 photons received, then 95 are actually registered and go into your final image.

The sad news is that your everyday Canon/Nikon/Sony DSLR or phone camera fails to use almost half the photons that make it into the lens.

And there is nothing you can do about that!

This is where we need to understand that ISO in digital camera is not the same as ISO(ASA) in film cameras. Just as you cannot change the size of the pixels, neither can you cannot change the sensitivity (QE) of the pixels. In a digital camera, ISO does something different. You’re using a digital camera, right? That also means a computerised camera. Which means your photo is made up of numbers.

If we have numbers, then we can do Math! Some quick, simple Math that won’t hurt.

To explain further, we need to take a trip back to High School for a moment. You’ve heard of the computer terms “Byte” and “Bits”.

A byte is a unit of 8 bits. Each bit can be turned On or Off. When it’s Off, it has a value of zero, and when it’s On, it has a value of 1. That’s Binary or Base 2.

Here’s a byte representing Zero, consisting of 8 bits, all of them in the Off state

00000000

Here’s the number 1

00000001

Here’s the number 2

00000010

Here’s the number 4

00000100

See what’s happening there? Every time we shift that “1” over to the next column, the value is multiplied by 2. In our normal everyday Math using Base 10, shifting to the next column multiplies by 10, but in binary Base 2, shifting a column multiplies by 2.

If we keep doing that, advancing the 1 to the left, we end up with the value 128 in binary

10000000

How does that help us? Let’s say our byte contains a faint star represented by the 1 in the 4th column from the left, and some noise represented in the 8th column

00010001 (that’s decimal value 17)

If we double the ISO, it multiples that byte by 2. i.e. both 1’s are

Column shifted and double the value.

00100010 (that’s decimal value 34)

When that multiplied byte ends up in your image, then the star is twice as bright. Good stuff huh? Well, Yes, and No.

Look what’s happened to the 1 that represented noise in the image. It too has been multiplied, and now your image is twice as noisy! ☹

That’s what ISO does, it mathematically increases the brightness of the image. It does not add any more information. It does not increase the sensitivity of the sensor.

In fact, if you keep on increasing the ISO, then the value of the byte will be multiplied so much that it will reach the maximum value that the byte(pixel) can hold, and appear white, and the noise will also be multiplied a lot, and your image will have a murky reddish background from the noise.

There’s a follow on Badness to that. Once a pixel has maxed out as white due to ISO, you can never revert back down to less than white in post processing. White is White is Forever White. You’ve blown it! ☹

The Big Question then is

“How do we gather more actual photons if ISO is so Evil?”

Only three things affect how many photons your camera sensor registers:-

1. Aperture of the lens. A big wide lens collects more light in a given time frame.

1. Exposure time. The longer the shutter is open , the more light enters.
2. Quantum Efficiency(QE). The higher the QE (approaching 100%), the more photons that hit the sensor are actually registered and contribute to the electrical charge stored in the pixel.

Note, that ISO does **NOT** get a mention.

The only way to get more photons ( = more data) in your astro image is to increase the aperture size and or exposure time. Preferably do both.

Of course, there’s no such thing as a free lunch in Astrophotography.

Bigger aperture means a more expensive lens.

Longer exposures means star trials, meaning you need a tracking mount, or you need to learn about registering and stacking multiple shorter exposures. And there’s a learning curve to that.

Amateur astronomers who are into Astrophotgraphy takes 4 kinds of images to create a single final photo:-

Light frames : Normal image of the object

Dark frame : Same duration and ISO, but with the lens cap on. This captures the internal noise generated by the camera electronics, which can be subtracted away by processing software.

Bias Frames : A Dark frame taken at the shortest possible exposure (e.g. 1/8000th sec) to capture the electronic noise generated by the process of reading the data off the sensor.

Flat Frames : An image of a pure white scene that records imperfections in the optical train of your camera system. The post-processing uses the flat to even out any odd shading in the image, especially towards the corners of the images.

Retail image editing programs such as Photoshop are not specifically designed to post process images using a workflow that incorporates Lights, Dark, Bias and flat frames. However, there are some good, free programs out there written by Astronomy Nerds that will take all those frames, and spit out a nice image at the end. You could try Deep Sky Stacker or Sequator for starters. Of course you have to off load the images from your camera onto a PC, but that’s probably a Good Thing, as your PC will have more disk space and more crunch power.

Lastly, JPEG images are especially EVIL. They crunch your much loved photo down into a tiny format, and mangle it along the way, which cannot be undone. When you capture your images, make sure that you save them in RAW format in the camera. You can save in JPEG too, if your camera offers that choice, but only ever process the RAW files, which are untouched by the cameras internal software. You can post-process a RAW file to be brighter, or anything you like, and then convert to JPEG when you want to post to social media.

And lastly-lastly, do try to keep your ISO level down. On a typical DSLR, 1600 is ample. On a phone, probably 800 or even less.

And lastly-lastly-lastly. Experiment! Digital “film” is cheap. See what works for your camera!!.

And lastly-lastly-lastly-lastly. Get thee to a very dark place, away from city Light Pollution! See <https://www.lightpollutionmap.info> for your closest dark site. I suggest at least 150km from any large City.

If you’re especially keen, move to Australia, where 80% most of the continent is rated as “darkest available skies.”

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[www.skippysky.com.au](http://www.skippysky.com.au/)

[www.adelaideobservatory.org](http://www.adelaideobservatory.org/)

[www.rivermurraydarkskyreserve.org](http://www.rivermurraydarkskyreserve.org/)

[www.arkaroola.com.au](http://www.arkaroola.com.au)

PS : Would you believe the subject is rather more complicated? I have necessarily simplified and skipped a few issues to get the basics covered.