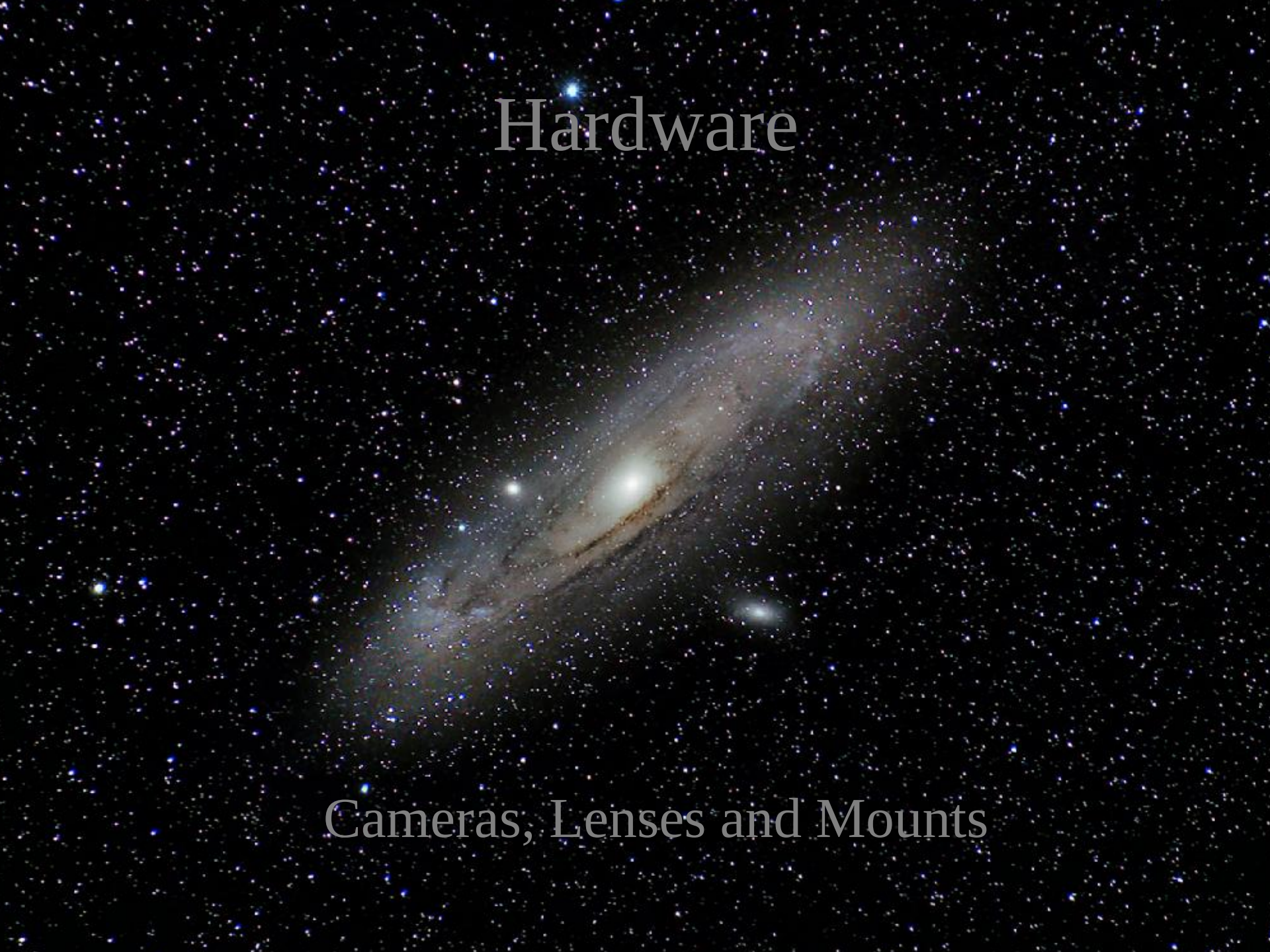
Astrophotography

An intro to night sky photography

Agenda

- Hardware
- Some myths exposed
- Image Acquisition
- Calibration

Hardware



Cameras, Lenses and Mounts

Cameras for Astro-imaging

- Point and Shoot
  - Limited use, but good for bright targets
- DSLR
  - Able to take long exposures
- Astro-imaging CCD
  - The ultimate in low noise performance
- Film
  - What you clean off your sensor before you go imaging
- The best camera to begin with is whatever one you own

Setups for Astrophotography

- Tripod
- Piggyback
- Afocal
- Prime focus
- Eyepiece projection

Lenses and Telescopes

- Any lens or telescope can be used
- Prime or fixed focal length lenses produce better star images
- Stop lenses down one or two stops
- Telescopes produce sharper stellar images in the center of the field than camera lenses
- Lenses produce an *adequate* star image over a wide field but usually have chromatic aberration except in expensive APO designs

Tripod Targets

- Star fields
- Star trails
- Milky Way
- Moon

Tracking Mount

- Required to take long exposure astrophotos
  - Fork mount on wedge
  - German equatorial
- At shorter focal lengths even a barn door tracker will work well

Guiding

- Used to correct for errors in tracking
  - gear errors
  - wind
  - polar alignment errors

Guiding Systems

- Off-axis guider
  - Most often used for SCT's
  - Prevents differential flexure problems and allows tracking through the meridian with SCT's
- Guide scope
  - Wider selection of guide stars
  - Can guide on comets and other moving targets
  - More flexible
  - Can cause problems if not well mounted

Guiding Methods

- Manual
  - Need illuminated reticule eyepiece
- Autoguided
  - Computer assisted – more flexible
  - Stand alone – simpler setup in field
  - Uses additional guiding camera to take short images of a guide star and make automatic corrections to tracking

Image Acquisition

Setup steps

- Carry your mount to the observing site
  - Astronomy really is an aerobic activity
- Attach scope and balance
  - Cuss
- Polar align
  - Really cuss
- Focus
  - Really, really cuss
- Acquire target
- Find a guide star
  - Make up some new cuss words
- Start imaging and look through someone else’s scope
  - I suggest Mark’s

Polar alignment

- In order to take long exposure astrophotos you must:
  - Use an equatorial mount
  - Polar align

What is Polar Alignment

- Polar alignment positions the mount so its polar axis points at the north or south celestial pole
- It allows an equatorial mount to follow a star in the sky by making adjustments in one axis (RA) only
- Different accuracies are required for different purposes
  - Visual observing requires only a rough sighting of Polaris
  - Astrophotography requires careful, accurate alignment

What Polar Alignment Isn’t

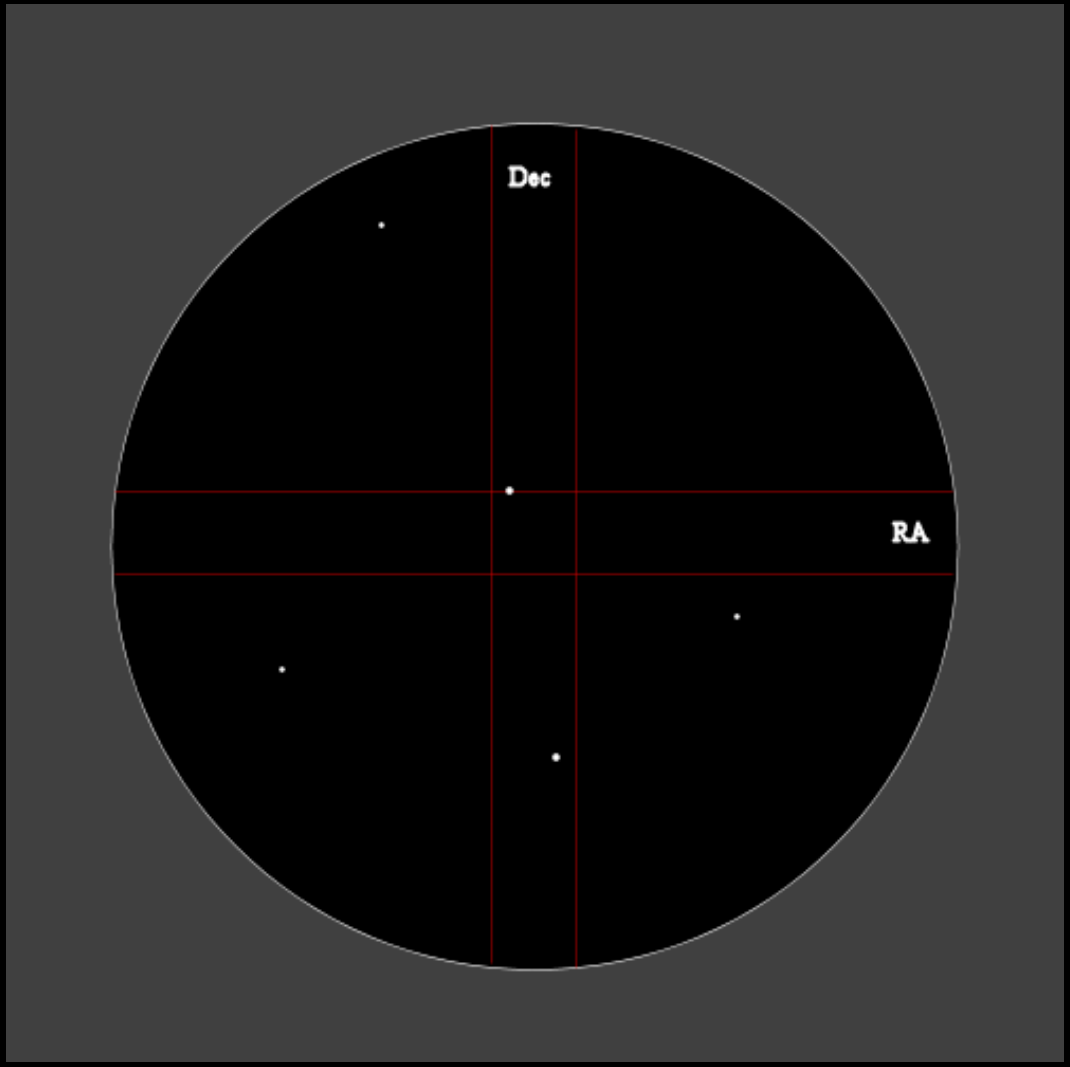
- It is not alignment of a goto telescope
- Telescope alignment **only** tells the scope computer where it is pointed in the sky
- Telescope alignment may need to be fine tuned after polar alignment

Geometry

Setup

- Roughly point the polar axis of the mount at Polaris
- Point the scope at a star on the celestial equator close to due south
  - This position allows isolation of rotation only and drift will not be due to altitude alignment errors
- Insert a reticule eyepiece and use the hand controller to move both ways in RA to identify the RA axis
- Rotate the reticule eyepiece so the RA axis is along one of the cross hair lines and declination on the other
  - Check by using the hand controller to move the mount east and west
- Place a star on a reticule line parallel with the RA axis

Reticule Display



Now wait and note how the star drifts

- We are only interested in declination drift
- RA drift can be ignored or corrected with the hand controller

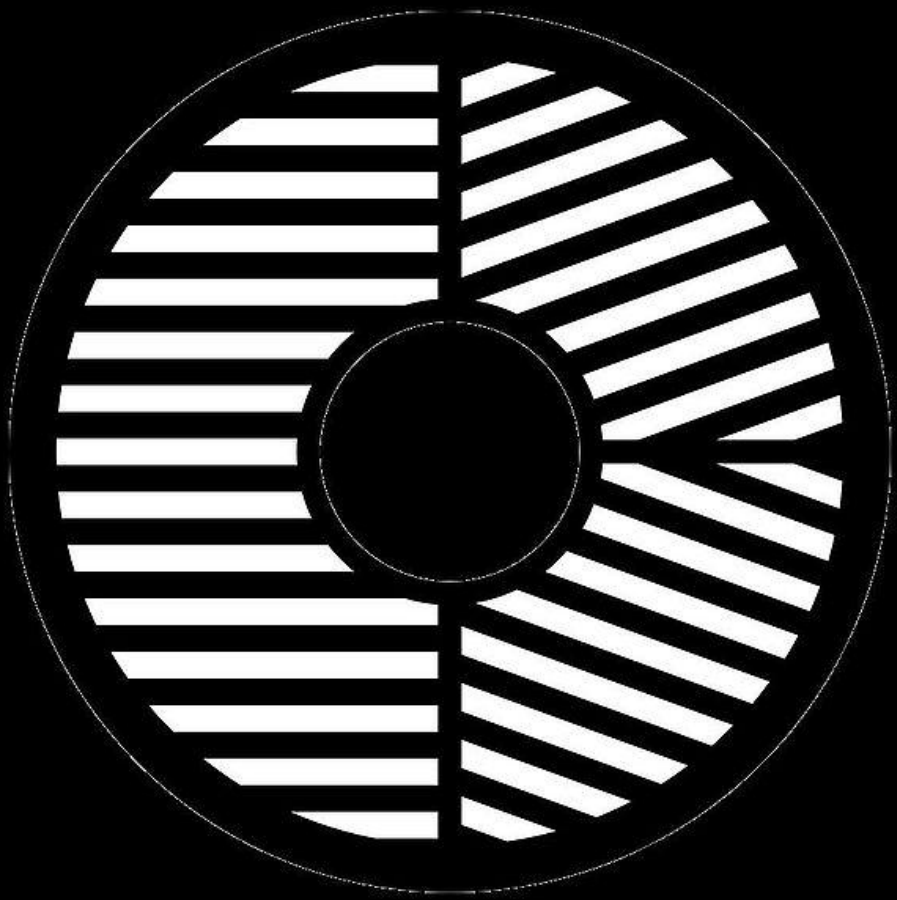
Alignment Procedure

- If you must move the scope north, rotate the mount clockwise
- Repeat until there is no drift
- Point east on equator
- Wait and monitor the drift
- If you must move the scope north, lower the mount
- Repeat until there is no drift

- Aim for two to four minutes with no obvious declination drift
  - Longer drift free times are useful for permanently mounted scopes

Focusing

- Use a diffraction focusing mask
- Bahtinov mask is one of the best
- Surf to http://astrojargon.net and follow the links to a mask generator, print out your mask and cut it out



Out of Focus

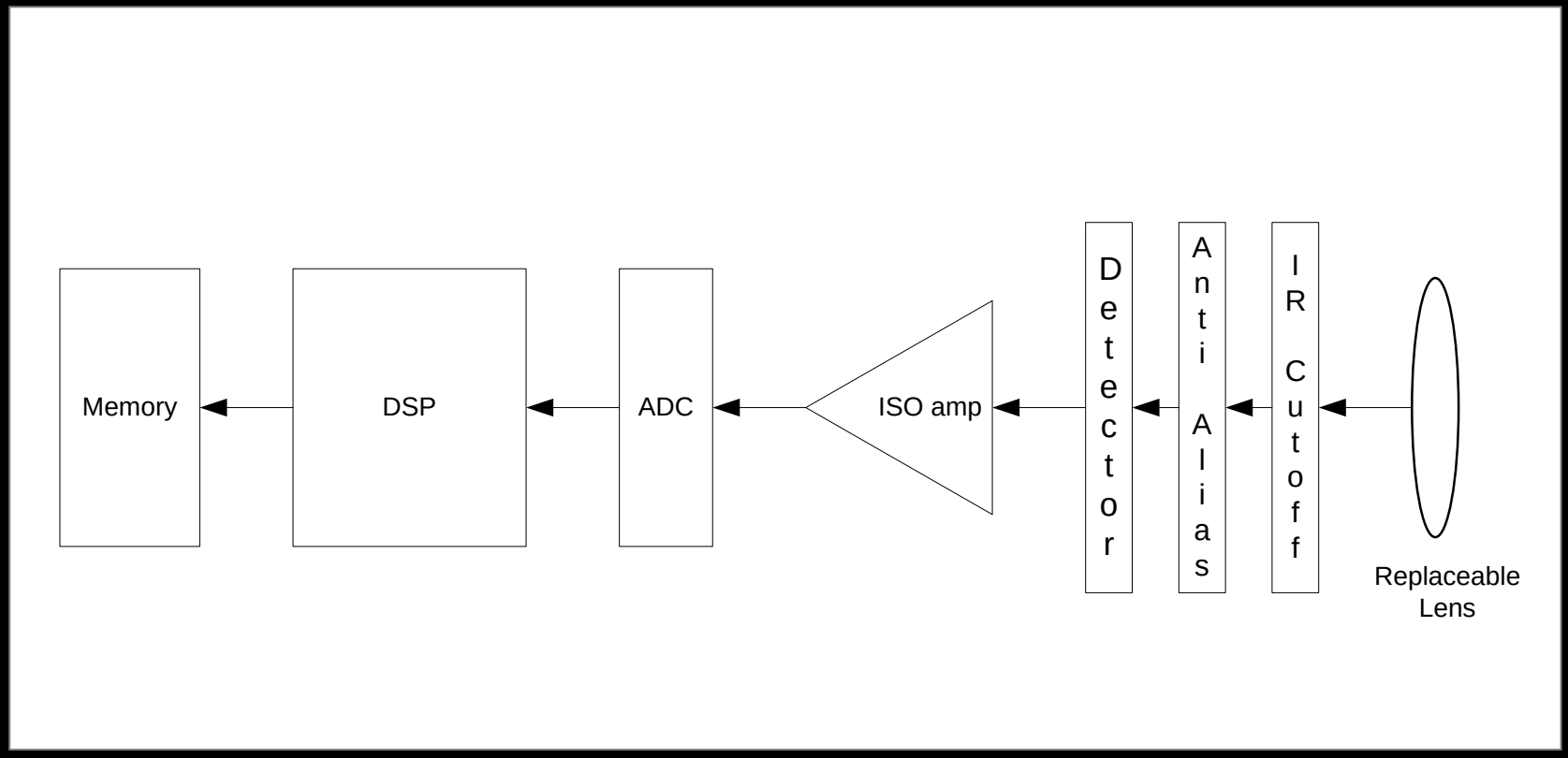
Correct Focus


DSLR Myths

Effects Peculiar to DSLR's

- There are some issues that affect DSLR imaging
  - Bayer matrix reduces SNR because of unfiltered decimation in each colour channel
  - Generally un-cooled, so noisier than astro-only CCD's
  - Can select gain (ISO) to suit the target and conditions
  - View finder makes imaging (focus and framing) much easier
  - Setup is simpler
  - No computer required in the field

DSLR


Memory
DSP
ADC
ISO amp
Detector
Anti Alias
IR Cutoff
Replaceable Lens

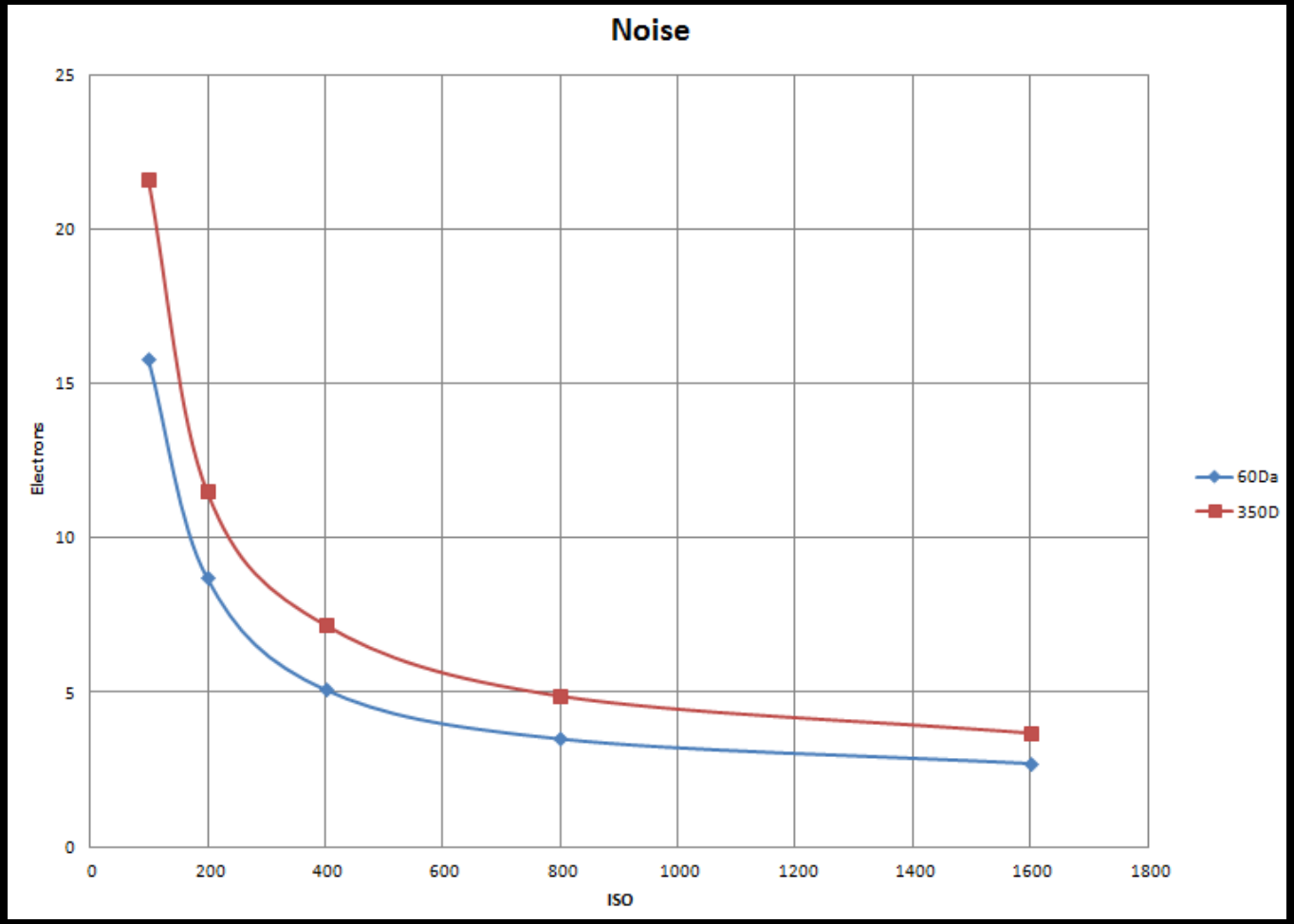
Some Myths Exposed

- Using high ISO's causes images to be noisier
- A lower focal ratio is better than a higher focal ratio because it gives shorter exposures
- Bigger pixels are better

ISO Myth

- Despite what every photo magazine says, using a high ISO does not cause noise
- An image taken at ISO 100 and ISO 1600 have similar SNR's if the exposure ***times*** are the same
- SNR is set by exposure time, not ISO
- Camera noise actually decreases with increasing ISO

Noise Verses ISO

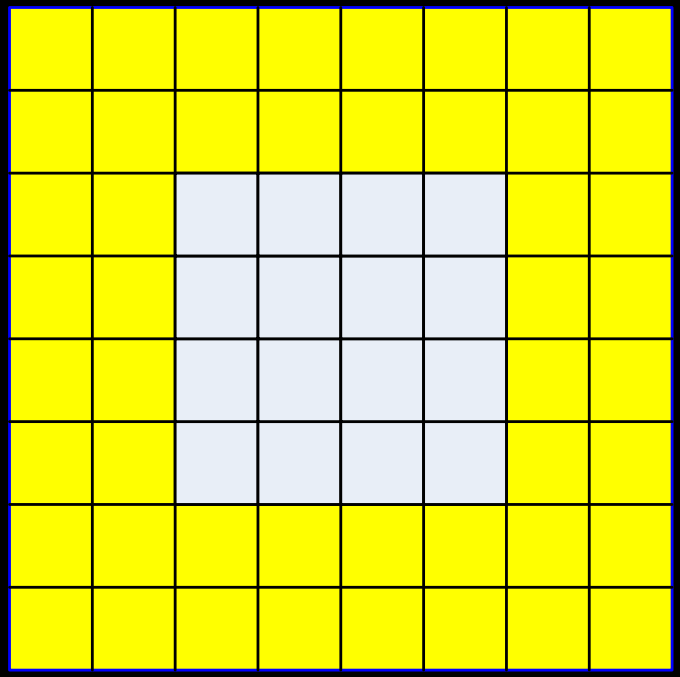


Focal Ratio Myth

- Lower f-ratios produce shorter exposures
  - Only true for individual sub-exposures
- If you process to keep the image scale the same...
  - Total overall exposure depends on aperture and exposure time only

Why focal ration doesn’t matter

- Assume both cases are photon noise limited
- F/8 image spread over yellow squares
- F/4 image over the white squares
- Same number of incident photons in both cases
- Bin pixels 2 by 2 to get the same SNR and image scale



Want proof ? (F/13)

Higher ISO version (f/25)

Binned and cropped to same field

F/13

F/25

Bigger pixels better

- Modern sensors have good micro-lenses
  - Help to collect light from areas that are not photosensitive
  - Pixel binning restores the SNR to a value very close to what you get with larger pixels

DSLR Settings

- ISO 800 to 1600 for the Rebel XT
- White balance - daylight
- Program mode - manual
- Drive - one shot
- Quality - raw
- Noise reduction - off (use darks & flats for more control)
- Bulb exposure

Always Shoot in Raw

- Raw allows
  - 12 to 14 bit dynamic range
  - Dark frame calibration
  - Flat field calibration
  - No in-camera processing
- JPEG format cannot be dark or flat field calibrated as the image has already had a non linear stretch applied in the camera

Let’s take a look at what’s in an Image

- Image data
- Dark signal
  - Each pixel builds up a level that is not related to the light collected
  - Caused by the motion of electrons within the silicon substrate
  - Proportional to integration (exposure) time and temperature
- Bias signal
  - A signal that is caused by bias currents within the sensor
- Noise
  - Random variations in all of the above

Image Noise

- Noise is a random variation in a signal
- If the signal is not random then it can be removed through simple subtraction and is not *noise* for the purposes of this discussion

Sources of Noise in an Image

- Quantum Mechanics
  - Known as photon noise
  - And you thought those physics courses would be wasted
- Camera electronics

Dark Signal noise

- Dark ***signal*** is a repeatable phenomenon that is dependent on the temperature of the sensor and the integration time
- This ***signal*** is what is reduced by long exposure noise reduction
- Dark signal noise is the random variation in the dark signal and cannot be reduced

Read Noise

- Random variations caused by the camera read electronics
  - Noise from the ISO amplifier
  - Noise generated by the ADC
  - Power supply noise

Photon Noise

- A quantum mechanical effect
- The average level is proportional to the square root of the number of photons collected by a pixel
- This is the only noise that matters in post processing as it can be made to swamp all other noise sources if you expose properly

Determining Exposure Length

- Each individual exposure, known as a sub-exposure, or sub, should be long enough to ensure that photon noise swamps all other noise sources
  - This is the definition of sky limited exposures
- This is possible because of the way noises add together.

Warning

Science Content

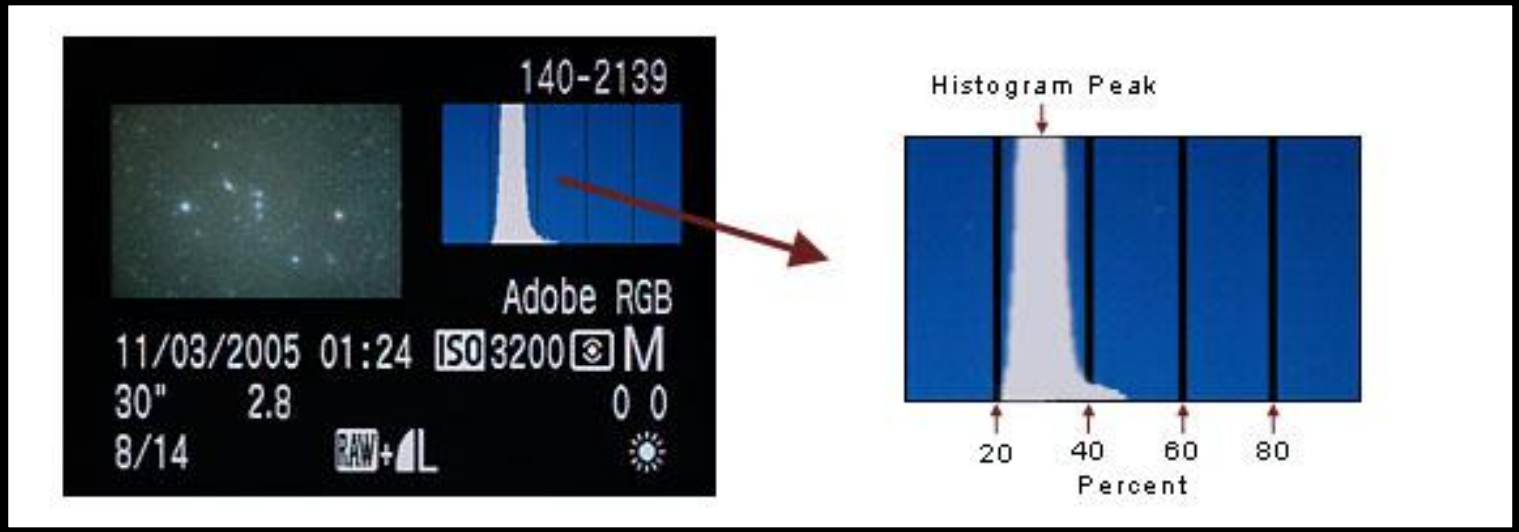
- Noise adds as the square root of the sum of the squares of the individual noise sources

$$noise_{total} = \sqrt{noise_1^{\,2} + noise_2^{\,2}}$$

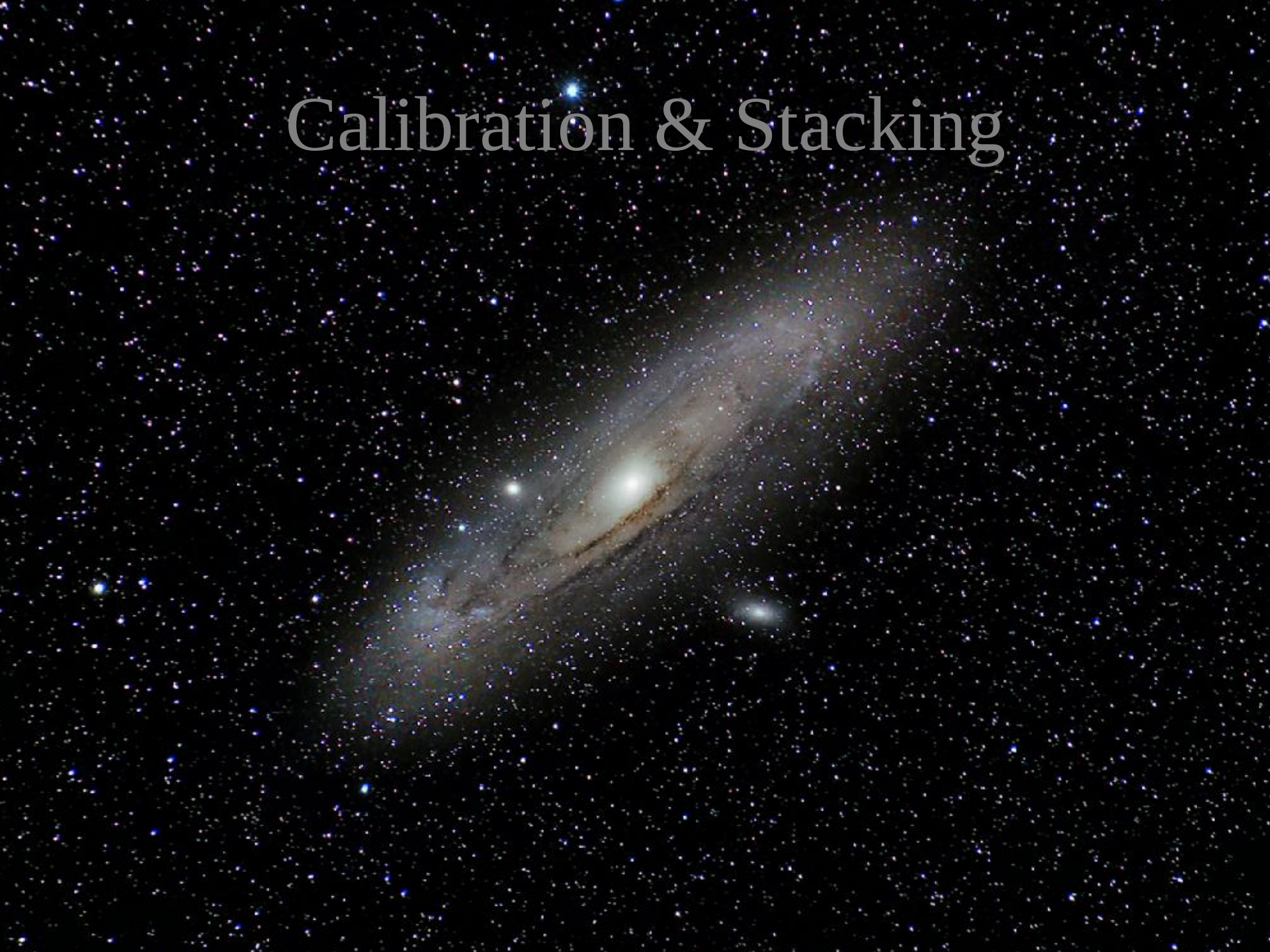
- There is only a small difference in total noise if the dominant noise source is double the smaller noise source
- Fortunately there is an easy way to figure out the exposure required

Use the Histogram

- Typical exposures range from three to ten minutes
- Use a test shot and your camera histogram to determine the correct exposure
  - Once the peak of the histogram is about a one quarter to a third of the way from the left edge you have the correct exposure



Calibration & Stacking



Purpose of calibration

- To remove as many camera and optics induced artifacts as possible

Remember What Makes up an Image

- Light signal (the image we want)
- Photon noise
- Read noise
- Dark signal
- Dark signal noise
- Bias signal

Bias Signal

- A repeatable signal that is generated by bias currents in the silicon
- Measured by taking the shortest possible exposure with the lens cap on
- In all exposures, including dark frames

Dark Frames

- An exposure of the same length as the light frames with the lens cap on
- When subtracted from the light frame it removes the dark and bias signals

A Dark Frame

Flat Field Frames

- A short exposure of an evenly illuminated background
- Must be at the same focus as the light frames
- Once normalized to the average value of the entire frame, it is divided into the light frame to remove vignetting and dust bunny marks

Flat Frames

Flat Dark Frames

- Used to remove the bias and dark signal from the flat frames
- Exposure is the same length and ISO as the flat frame
- **MUST** be used to correct the flats as flats must have the bias removed to work properly

Master Calibration Frames

- Individual calibration frames have lots of noise
- Averaging many calibration frames reduces the noise by the square root of the number of frames averaged
- These master calibration frames produce substantially lower noise in the final image

LENR

- Long exposure noise reduction
- Takes a dark frame after each light frame and subtracts it in the camera
- **Do not use this technique**
  - Doubles the exposure time of each sub
  - Does not produce as low noise an image as using master calibration frames

Stacking

- Averaging many sky limited, calibrated exposures reduces the noise of the result almost to that of a single long exposure equal to the total time of all the sub-exposures
- Benefits
  - Lower noise
  - Easier guiding for each shorter sub-exposure

Stacking Example

Image on the right is actually the average of 16 images

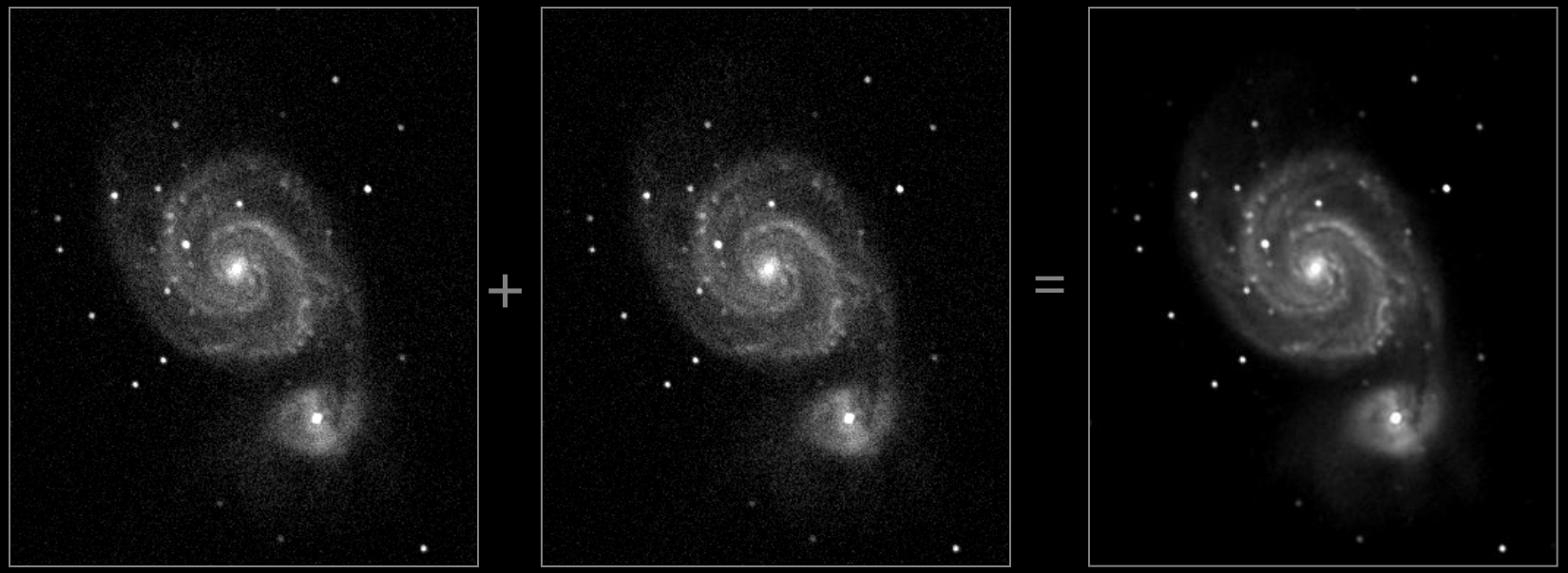
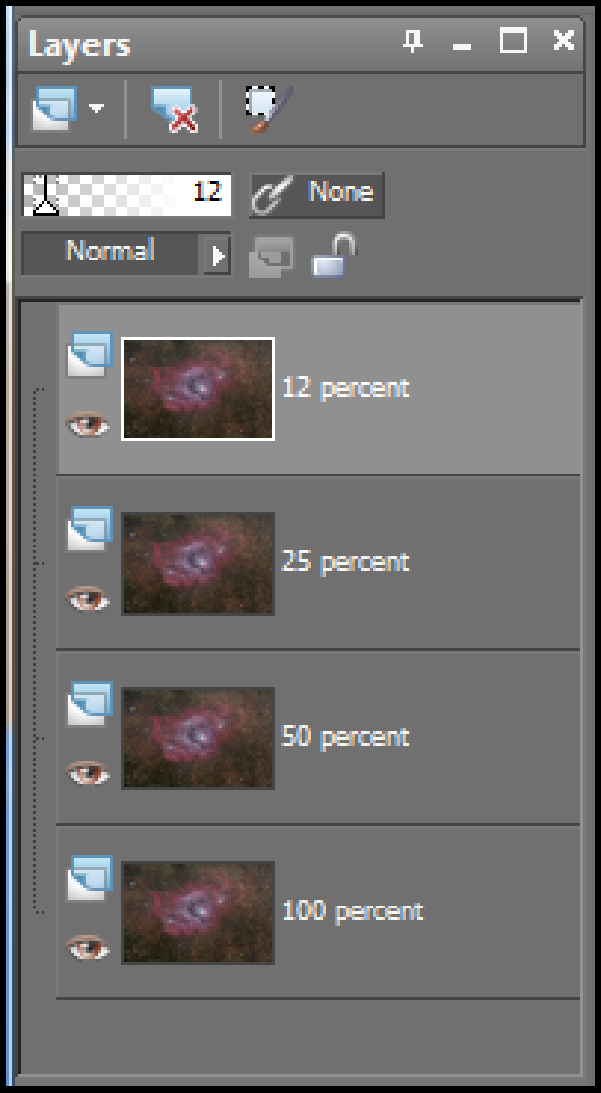


Photo Shop Approach

- Place each sub on a different layer
- Manually align each layer
- Set the opacity of the bottom layer to 100 %
- Each layer has a opacity of half the layer below it
- Finally flatten the stack to average the layers



Before & After

Just to show that capturing the data is only part of the work

Rosette (before)

Rosette (after)

M8 (before)

M8 (after)

M42 (before)

M42 (after)

NGC7000 (before)

Ngc7000 (after)

Saturn (before)

Saturn (After)

Online Resources

Online Resources

- My processing tips site
  - http://www3.ns.sympatico.ca/b.macdonald/gallery/Processing.htm
- Yahoo Canon DSLR Astrophoto Group
  - http://tech.groups.yahoo.com/group/Canon_DSLR_Digital_Astro/
- Deep Sky Stacker web site
  - http://deepskystacker.free.fr/english/index.html
- Michael Covington's web site
  - http://www.covingtoninnovations.com/astromenu.html
- Jerry Lodriguss' web site
  - http://www.astropix.com/
- Focus Magic web site (PhotoShop and Paint Shop Pro plugin)
  - www.focusmagic.com