Astrophotography Options (using a digital camera)

Part 1: The Digital Single Lens Reflex Camera

Mike O'Mahony

Camera Evolution

Brownie 127 (1954)

1/30 “ shutter

Halina 35 mm (1960)

- **Shutter speed**
- **Film speed**
- **Exposure& aperture**
- **Focus**
- **All manual**

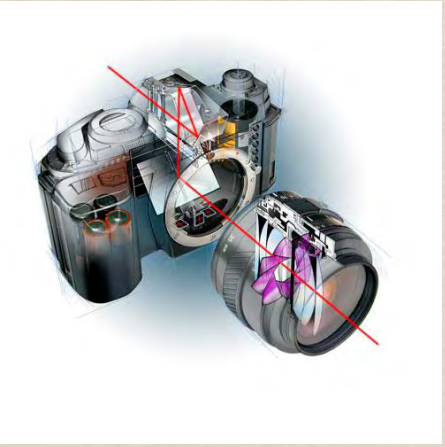
Minolta 101 SLR 35 mm (1966)

- **Shutter speed**
- **Film speed**
- **Exposure & aperture**
- **Focus**
- **Auto + manual**

Canon DSLR

- **Shutter speed**
- **Film speed *****
- **Exposure & aperture**
- **Auto focus**
- **Auto + manual**
- **CMOS sensor**

DSLR: Main Features

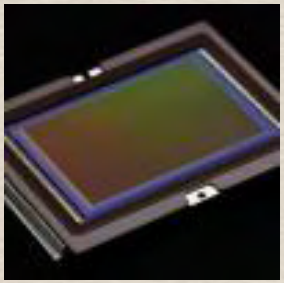


- Interchangeable lens:- ideal for prime focus photography
- Live view & digital zoom: ideal for focusing
- Mirror lock up: avoid camera shake
- Delay shutter; remote operation from computer
- Larger pixels (than compacts) for reduced noise
- Wide range of “film speed” up to ISO 12800
- Noise reduction and dark shots:- ideal for prime focus use.
- RAW and JPEG images
- Video mode as well as still

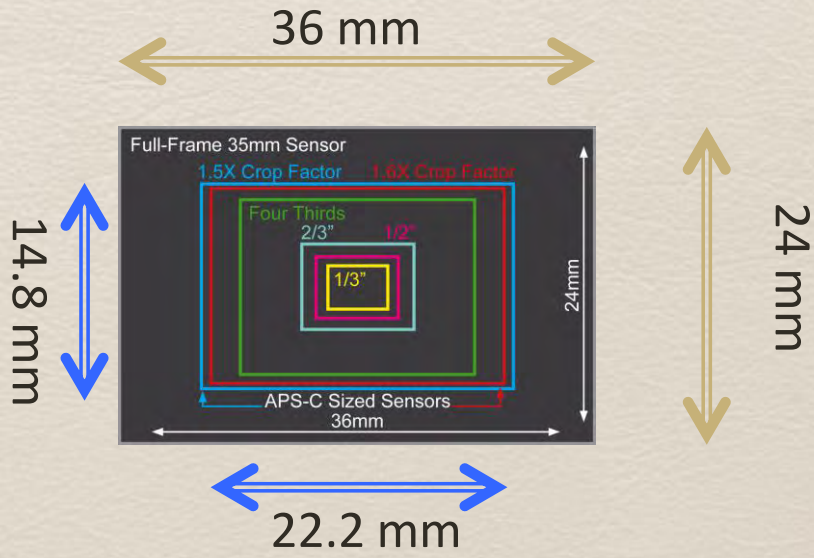
Some negatives for astrophotography

- Internal IR filter limits colour response
- Sensor set fairly deep in body
- No cooling so can be sensitive to temperature (noise)

Sensors

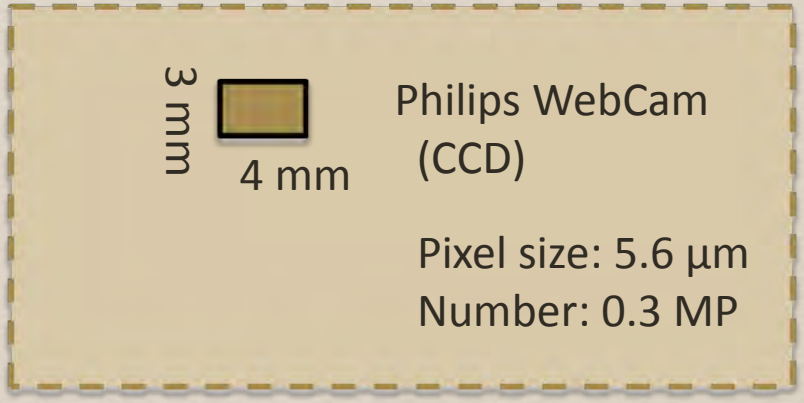


Canon DSLR 1100D
(CMOS APS-C)
4272 x 2848 pixels
Pixel size: 5.2 µm



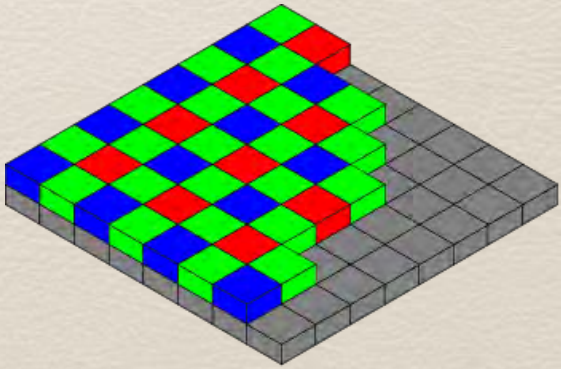
CCD: Charge coupled device, lower noise
expensive for large arrays sensors

CMOS: Complementary Metal Oxide
Semi-conductor- most DSLR



659x494pixels 5.6x5.6um

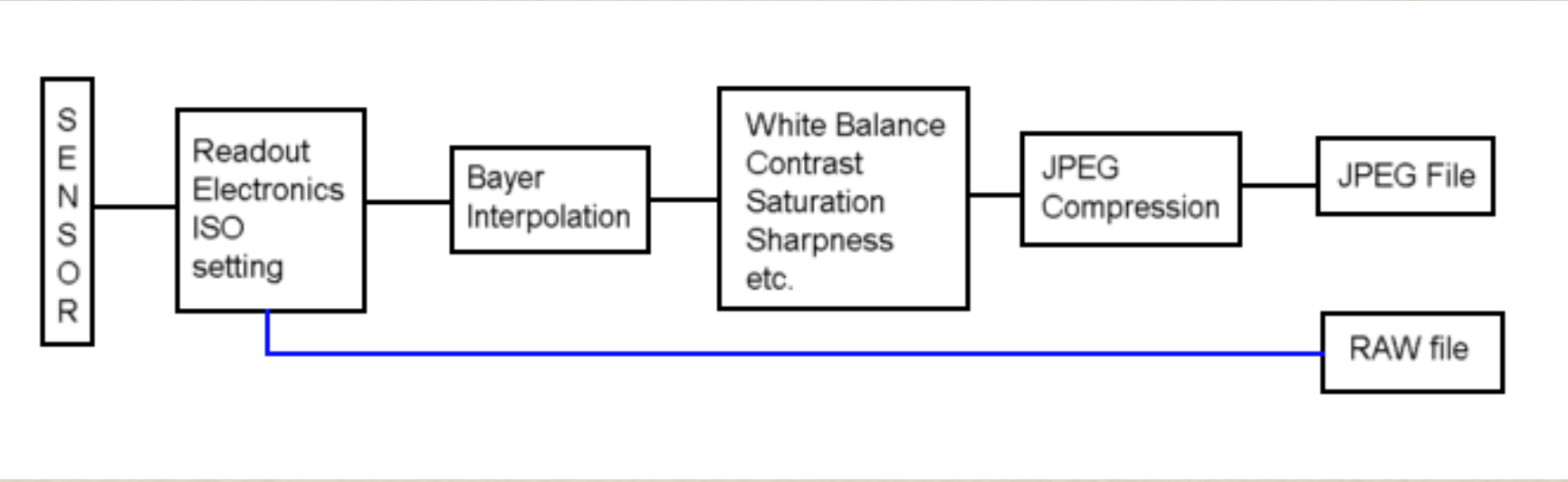
Bayer Matrix: RAW & JPEG images



- A Bayer filter mosaic is a color filter array for arranging RGB color filters on a square grid of photosensors. The filter pattern is 50% green, 25% red and 25% blue.

- Each pixel records only one of three colors, so to obtain a full-color image, various algorithms are used to interpolate a set of complete red, green, and blue values for each point.

- Different algorithms requiring various amounts of computing power done either in-camera, producing a JPEG or TIFF image, or outside the camera using the raw data directly from the sensor.



Pixel Size & Number

- Sensor pixels analogous to a number of red, green, and blue reservoirs. The bigger the reservoirs, the more electrons they can hold.

- Signal-to-noise ratio is proportional to the square root of the number of electrons. The higher the number of electrons per pixel, the higher the signal-to-noise ratio.

- Large pixels store more electrons than small ones, so threshold when the pixel flips from 0 to 1 is more precise➔ less data processing needed by camera (no extrapolation needed).

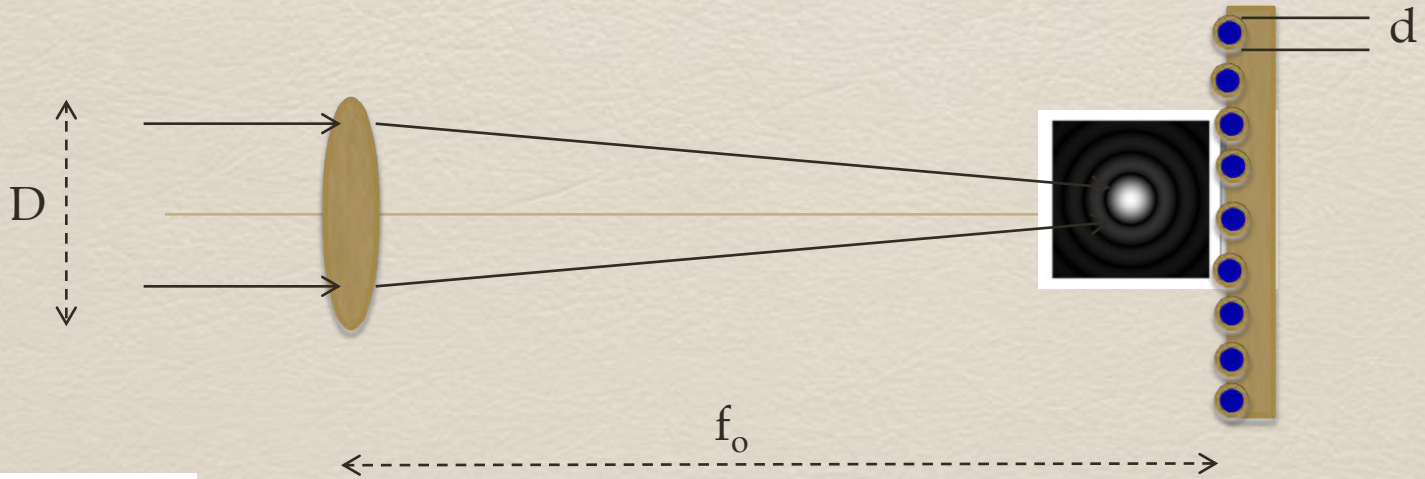
➔***So larger pixels and sensors enhance image quality by producing a higher signal-to-noise ratio & greater dynamic range.***

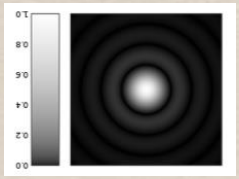
Canon DSLR Comparison Chart - Gary Honis

Camera	*Price 3/11*	*Pixels/Megapixels*	*Pixel Size*	*Sensor Size/Crop Factor*	*ADC - bits*	*Live View*	*Weight*	*Year*
1100D	$600	4272 x 2848 / 12.2	5.2µm	22.2 x 14.7mm /1.6X	14	yes	17.4 oz	2011
450D	$480*	4272 x 2848 / 12.2	5.2µm	22.2 x 14.8mm /1.6X	14	yes	16.8 oz	2008
1000D	$400*	3888 x 2592 / 10.1	5.7µm	22.2 x 14.8mm /1.6X	12	yes	15.9 oz	2008
500D	$700	4752 x 3168 / 15.1	4.7µm	22.3 x 14.9 mm /1.6X	14	yes	16.9 oz	2009
550D	$800	5184 x 3465 / 18.7	4.3µm	22.3 x 14.9 mm /1.6X	14	yes	18.7 oz	2010
	*Refurbished prices							

Focal Ratio & Pixel Size

(matching telescope and sensor)





Airy disk width (m) = 1.22 x λx f_r, where f_r=focal ratio = f_o/D

Allowing factor of 3 for atmospheric smearing, is

Airy disk full width = 2x3x1.22 x λ x f_r = 7.3 x λ x f_r

From Nyquist theory 3 pixels must sample the Airy disk thus

1 pixel = 2.4 λ x f_r = 1.3 x f_r µm (λ = 550 nm)

Fast Dob with f_r=5; pixel width must be less that 6.5 µm

Tomline with f_r =15; pixel width must be less than 33 µm

Imaging using DSLR

Three main techniques

1. **Afocal**
   - Camera (with lens) held to catch exit pupil of eyepiece

2. Prime focus

-Camera sensor sits at focal plane (no eyepiece in place)

3. Projection

- Camera-without lens-positioned some distance behind eyepiece

Prime Focus:-Image Size

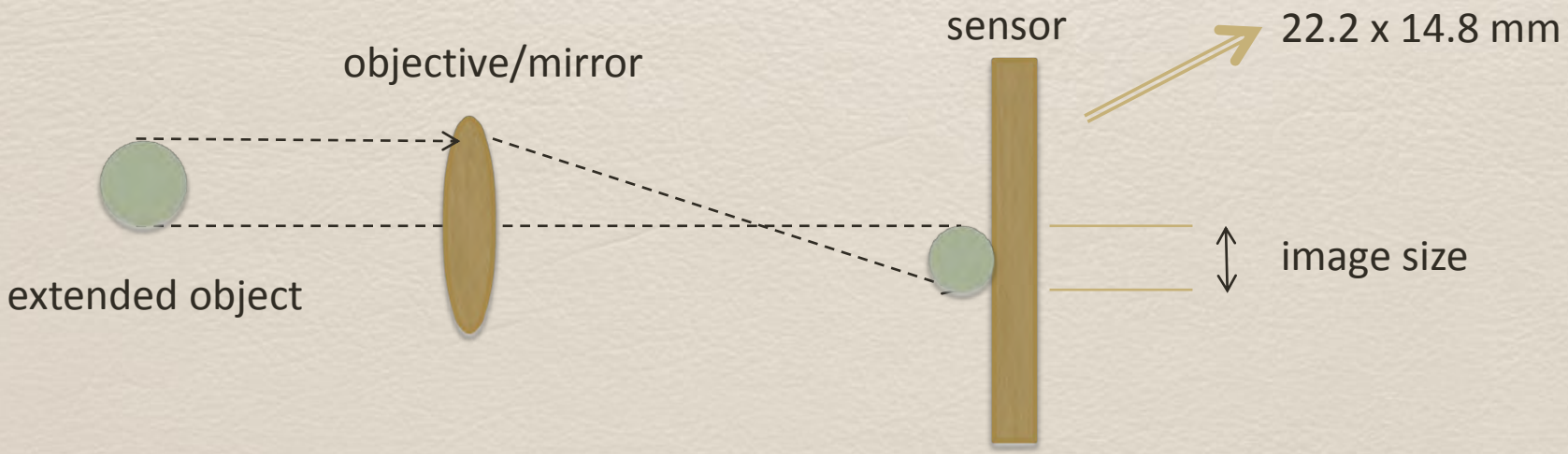


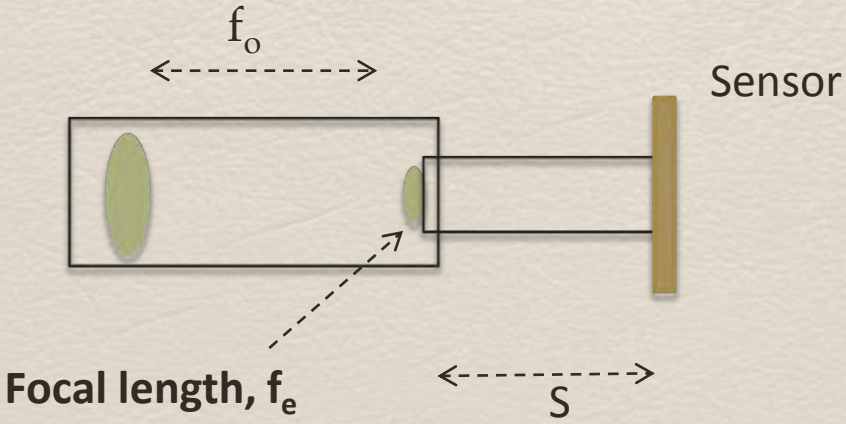
image size (mm) = object size (arc seconds) x focal length (mm)/206265 (arc seconds)

Focal length = 1 m

Object	Object Size	Image Size (mm)
Jupiter	40 “	0.2 mm
Moon	30 ’	9 mm
M31 (And)	185x75 ‘	54 x 22 mm
M42 (Orion)	65 ‘	19 mm

Good for Deep Sky, not so good for planetry
Increase focal length, use eyepiece projection

Eyepiece Projection for Planetary



Meade variable projection

Magnification = $(S-f_e)/f_e$

Example:

10 mm eyepiece with eyepiece to sensor distance 110 mm ➔ M= 10

Focal length of combination f= M x f_o,

For Jupiter image size increases from 0.2 to 2 mm, with f_o = 1m

Noise

- Noise arises due to the spontaneous generation of electrons within the sensor photosites (pixels); also defects in the array will cause unwanted artifacts.

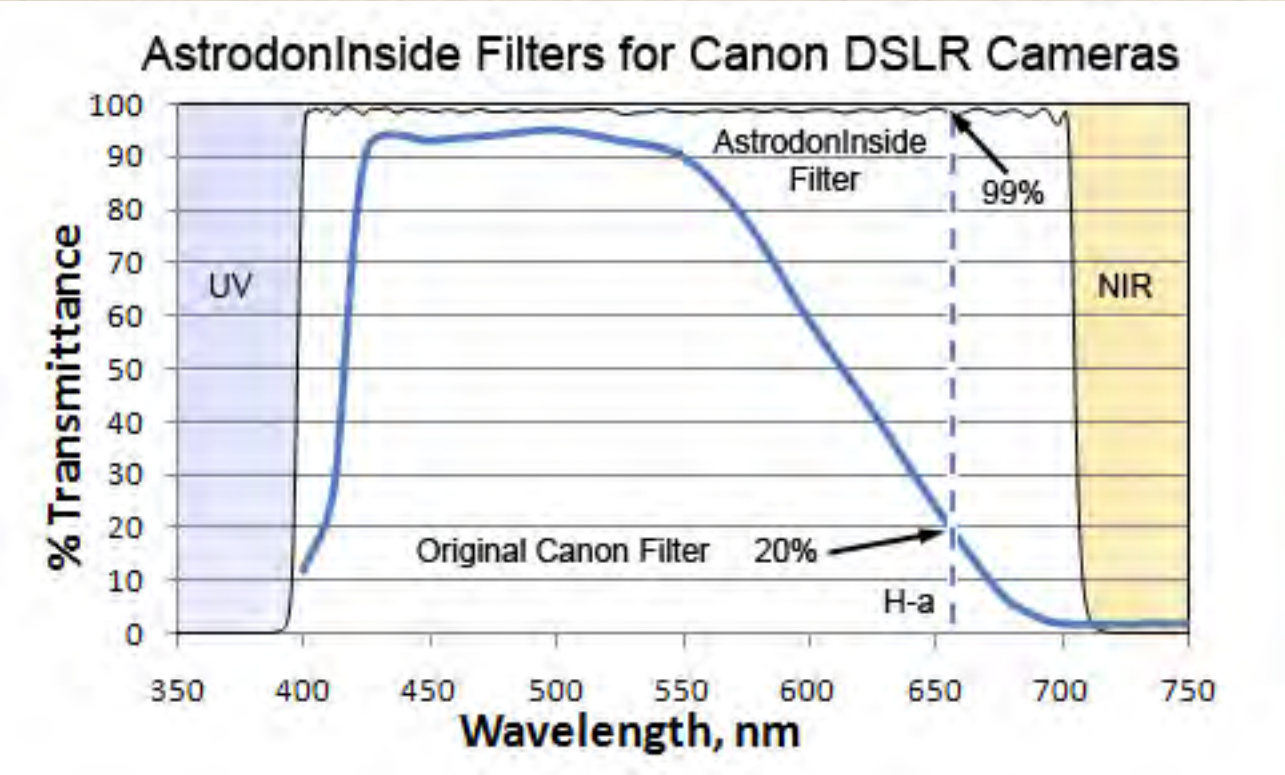
- The level of noise is temperature dependent:-DSLRs do not have any cooling. Noise increase as square root of electron number. Small pixels ➔ more noise.

- The ISO setting on a camera emulates the old “film speed” setting of wet film cameras. Higher sensitivity is achieved by amplifying pixel outputs, hence noise as well as signal electrons get amplified

Long Exposure Noise Reduction:
The camera generates a dark frame which is then subtracted from the original to remove artifacts such as hot pixels. This doubles the time and does not remove random noise.

High ISO Noise Reduction
An algorithm is used to minimise noise

DSLR Colour Response



Barlows, Powermates & Videos

Barlows or Powermates are used to increase focal length and hence image size on sensor. Powermates are 4 element systems comprising 2 doublets which provide magnifying function of a Barlow whilst restoring field rays back to their original direction.

Jupiter & Moons
5x Powermate, 120 mm refractor, 15 images + Registax

Videos via WebCams are often used for imaging planets. The best frames can be retrieved and stacked in programmes such as Registax. The DSLR also has video capabilities which may be used in a similar manner.

Time for the Practical Stuff

Astrophotography Options (using a digital camera)

Part 2: How to do it and what to use!

David Murton

FIRST OF ALL, YOU DON'T NEED **THIS**!!

Types

* Tripod / bean bag mounted.
* Tracking mounted with lens (Barn door, piggyback on telescope or automated tracker).
* Afocal imaging with lens through a telescope eyepiece.
* Prime focus imaging with direct fixing to telescope viewfinder.

Simple Bean Bag Rest

Use with self timer
(Astrophotography doesn't need to be complicated!)

Tripod / bean bag mounted

* Can be done with any camera that allows an exposure time of at least 1 second and the ability to select a high ISA speed.

* Suitable for exposures of up to 30 seconds with a wide angle lens.

* Any exposure over 30 seconds will require tracking

* Longer exposures ok for star trail pictures.

* Use the highest ISO setting and widest aperture (smallest number), available.

* Best if you include something in the foreground to give a sense of scale.

* Try using the flash or a torch on long exposures to “paint” the foreground.

* Best results if done when there is still some twilight in the sky.

* Use self timer or shutter remote to prevent camera shake.

* If possible use the incandescent bulb light setting to help prevent an orange cast from light pollution.

Photographs From Simple Tripod and Fuji S8000fd Bridge Camera

Jupiter & Moons

0.62 sec / f6.3 / ISO1600 / 84mm (486mm equivalent)

ORION CONSTELLATION

1 sec / f8 / ISO 800 / 84mm (486mm equivalent)

Orion constellation with Fuji S8000fd bridge camera

4 seconds / f3.2 / ISO 1600 / 4.7mm

Night sky at Kelling with Canon 1100d DSLR

30 SECONDS / F3.5 / ISO 3200 / 18MM

Felixstowe golf club with Canon 1100d DSLR

19 seconds / f3.5 / ISO1600 / 18mm

Picture taken by moonlight with a DSLR sitting on a bean bag

18 Seconds / f5.6 / ISO800

Star Trails

Star trail photos can be

* Stitched from many short exposures, try 30 seconds, 50 to 100 exposures. This ensures dark sky / foreground can be “painted” on one frame / bad frames are easier to edit / there is less noise and grain / battery failure can be dealt with. Don’t use long exposure noise reduction though as it will introduce gaps.

* One long exposure. Doesn’t need special software or a fast computer.

Tracking mounted using camera lens

Types

* Barn door tracker, manual or automated
* Piggyback on equatorially mounted auto tracking telescope
* Automated tracker (astrotrack/vixen polarie/etc.)

Pros/Cons

* Cheap, simple / needs to be constantly adjusted
* Good for long exposures, can be left running / Needs expensive tracking tripod
* Simple, compact, can be left running / Expensive

Barn Door (Scotch) mount

* Easy to self construct.
* OK for at least 5 minute exposures with a wide angle lens, shorter with a telephoto.
* Needs to be polar aligned.
* Usually worked by hand but can be automated if you wish.
* Needs to be constantly adjusted to follow the stars by turning a screw thread.
* Remote shutter release required.

Typical Barn Door Mount

Remote Shutter Release & Timer

Milky Way & ISS taken using a Barn Door Tracker and Canon 1100d DSLR camera

* 240 sec / f4 / ISO 400 / 18mm

Andromeda Constellation taken with Barn Door tracker and Canon 1100d DSLR camera

* 240 seconds / f4 / ISO400 / 18mm (cropped)

Piggyback on telescope

* Needs to have equatorial motorised tripod/mount.
* Suitable for very long exposures.
* Can be used with a Goto mount.
* Easy to align with object you wish to photograph.
* Can be used with telephoto lens.
* Exposures can be left running or completely automated using a pc.
* Remote timer or computer controlled.

Typical Piggy Back set ups.

Examples of piggy back photography

(not mine I hasten to add!)

Automated Trackers

Vixen Polarie

Astrotrack

Afocal Imaging through a telescope eyepiece

* Needs a suitable bracket.
* Can be done with any type of camera or iphone.
* Suitable for pictures of the moon and brighter planets using an alt/az mount or Dob.
* Can be awkward to align camera with eyepiece.
* Self timer or remote shutter release should be used to prevent camera shake.

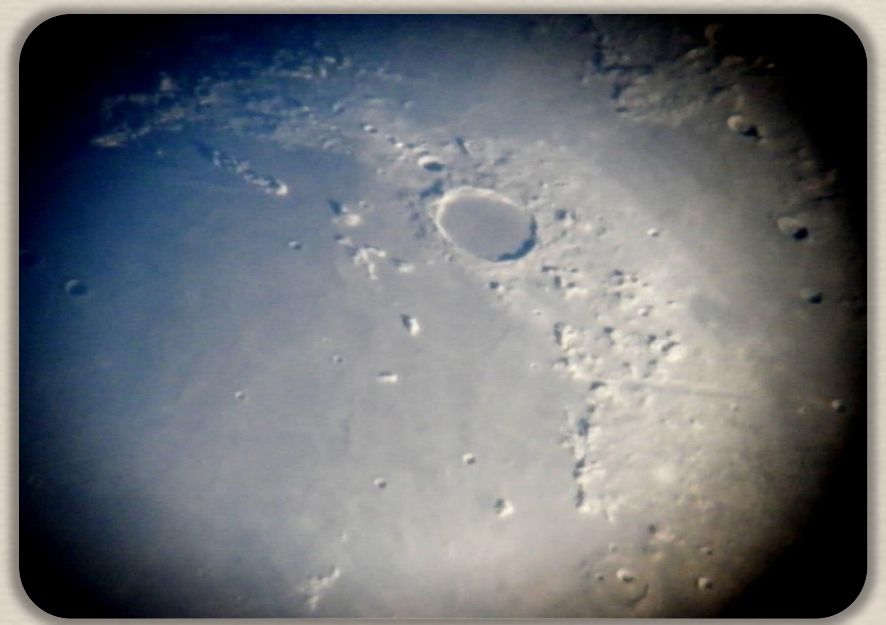
Typical reflector Afocal setup

Refractor with I-Phone adaptor

Pictures taken with a Fuji S8000fd bridge camera and 8” Dobsonian telescope

The Moon

1/40 sec / f4.5 / ISO 800 / 78mm



Saturn

1/10 sec / ISO 800

Prime focus imaging with a DSLR

* The camera requires a camera specific T Mount and eyepiece adaptor tube.
* It can be difficult to achieve focus with some telescope focusers. Especially on reflectors.
* Use of a Barlow or powermate within the adaptor allows magnification of the image. (negative projection method).
* Use of an eyepiece adaptor also allows magnification. (positive projection).

* Positive projection exaggerates any field curvature which can reduce the depth of field.

* A focal reducer can be used to reduce the size of the image, but beware of vignetting.

* Moon and planets are ok on an alt/az mount. An auto tracking equatorial is required for stars/deep sky work (max of about 1 minute without auto guiding though, less with magnification).

Importance of focal (“f”) ratios

* The focal ratio of the telescope is much more important than it is with visual observing!
* Low numbers (f3 to f6) will give brighter, wider field, less magnified pictures. (good for deep sky objects).
* Higher ratios will give darker, narrow field, more magnified images. (good for moon and planets).
* Although focal reducers and barlows can be used to compensate on odd occasions, they do not give as good results as using the correct focal length scope!

* You don't necessarily need a huge scope. Some of the most popular are 80mm short tube refractors with focal lengths of around f5. These are ideal for wide field views of DSO's.
* Don't underestimate the size of some DSO's. Most are much larger than apparent to the naked eye.
* Stellarium and other planetarium programmes can be configured to show a full frame view of objects. This enables you to check that they will fit in your picture.
* Very short focal length reflectors (f4 and less) can be very critical to collimation errors.
* Reflectors can require comma reducers to ensure crisp stars to the edges of the image.
* Refractors benefit from focal reducers/field flatteners to give sharp stars right to the edges of the image.

ALT/AZ MOUNT PROBLEMS

Tracking Alt/Az mounts (e.g. Meade / Celestron) will cause problems with field rotation as stars move in an arc while mount just goes up and across . This can be fixed with a wedge under the mount changing it to an equatorial one (preferable), or stacking short exposures and using field rotation software.

Prime focus on a reflector telescope using a T piece and adaptor ring

Prime focus with direct adaptor ring mounting

Prime focus on a Refractor telescope with a Field flattener and adaptor ring

Examples of Prime Focus on a Dobsonian Mount reflector

ISS

1:400 sec / ISO 800

Examples of Prime focus on an equatorial mounted telescope

M31/M32/M110

15x60 seconds / ISO3200 / f5 200MM Newtonian

M27

3 x 30 Seconds stack/ ISO1600 / f5 200mm Newtonian

M81/M82

6x80 seconds / ISO1600 / f5 200MM Newtonian

M33

6X80 SECONDS / ISO1600 / F5 200MM NEWTONIAN

M42

1x30 seconds / ISO3200 / f5 200MM Newtonian

M81 & M82 (with supernova)

The Moon (obviously!)

1x 1/125second / ISO / f5 200MM Newtonian

M101

7x60 seconds / ISO 800/ f4.72, 71mm William Optics Refractor

NGC 4565

7x60 seconds / ISO 800 / f4.72, 71mm William Optics Refractor

Double cluster

7x60 seconds / ISO 800 / f4.72, 71mm William Optics Refractor

Eyepiece projection adaptor

Individual elements

Typical set up

Prime focus with magnification

5X POWERMATE

Picture by Mike O'Mahony

12MM EYEPIECE PROJECTION

Prime focus with 5x Barlow

Stacking pictures

* Stacking is the process of overlaying several similar frames to create one image.
* It has several benefits.
  i. Primarily, It reduces grain and noise.
  ii. Can enables shorter exposures by combining the light grab from several individual ones (watch out that faint images are not interpreted as noise however).
  iii. Enables dark and light frames to be used. (Preferably at least 20 darks).
* Some excellent free stacking programmes are available. I use Deep Sky Stacker for stills and Registax for video.

Double Cluster Comparison

Single image

Stack of 3 images

M31/M110 Comparison

Single image

Stack of 6 images

M42 comparison

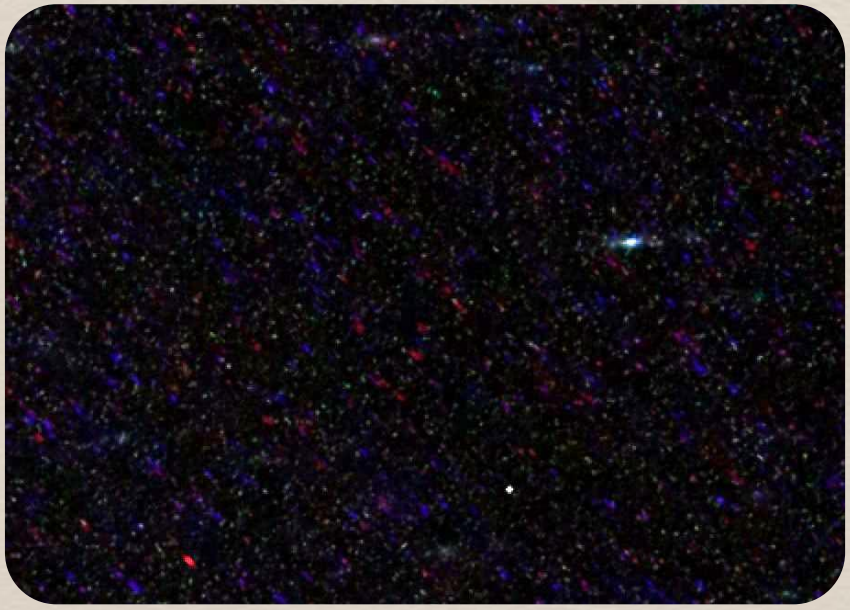
Single image

Stack of 10 images

What is Noise?

* Noise is the speckling seen on an image, especially in dark areas.
* It is caused by the camera's electronics
* It is similar to the background hiss on a hi-fi system.
* It is increased at high ISO ratings as these magnify any deficiencies and reduces slightly in cold weather.
* It is made up of shot noise (per minute of exposure) & read noise (per pressing of the shutter). Therefore one thirty minute exposure is better than thirty one minute ones.
* Can be reduced in camera, through stacking or during processing.

Before

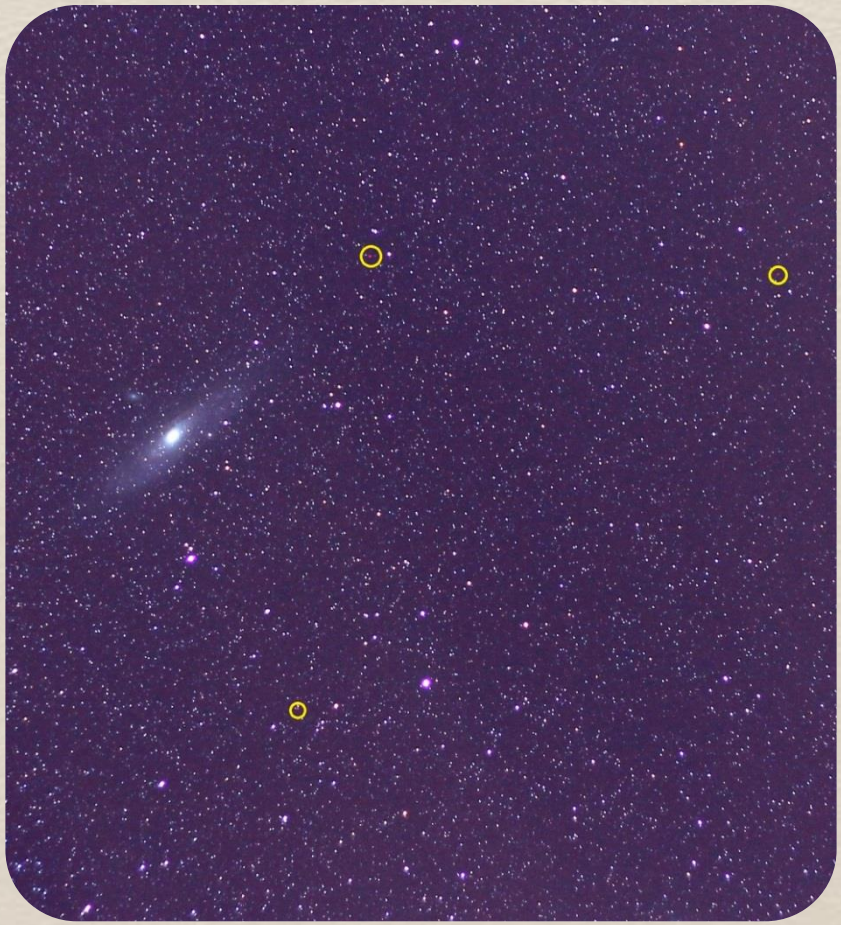


After

Hot Spots?

* These are the random coloured spots or bad pixels on an image caused by the camera's electronics and any "glow" from the sensor heating up.
* Its amount and position are specific to the temperature, exposure length and ISO setting.
* Corrected by taking "Dark frames", (exposures with the lens cap or scope cover on).
* Darks must have the same ambient temperature, exposure time and ISO as the picture images.
* Most SLR's can take automatic dark frames.

Typical hot spots



Handy Points when using SLR's

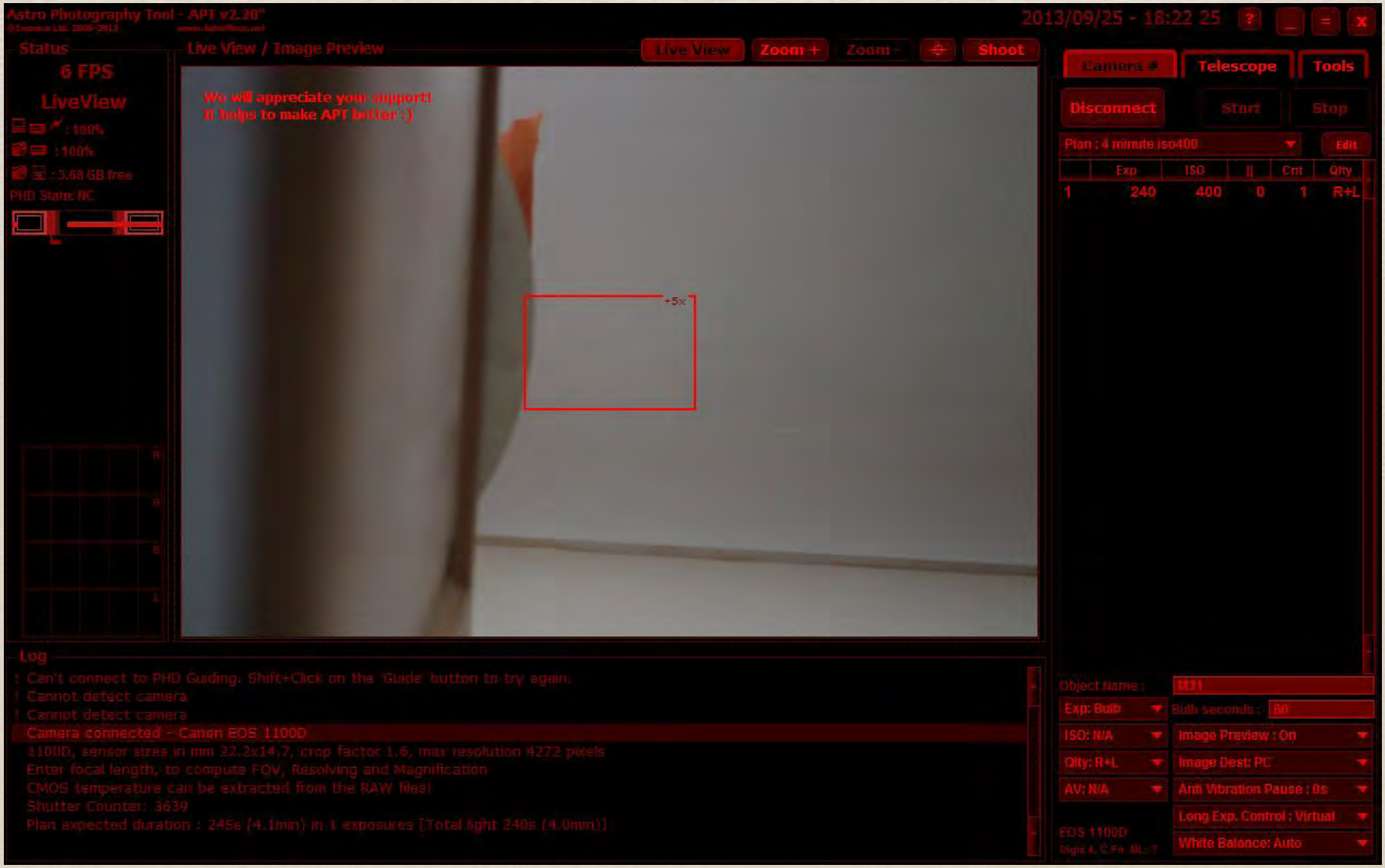
* Photos can be taken as one long exposure, or "stacked" from several shorter ones using suitable software.
* Either take separate dark frames or get the camera to take one automatically to prevent coloured "hot pixels" and "glow" from the sensor.
* Experiment with ISO settings, apertures and shutter speeds as they all affect the brightness of the image and are inter-related.

* Use the “high ISO noise reduction” function on the camera if you don’t intend to stack pictures or process RAW files.
* If possible take photos in RAW format as well as JPEG.
* If possible, use magnified live view for focusing, but don’t leave it on too long, as the sensor will heat up and may interfere with the image. If using exposures of between 1:10 and 10 seconds however, live view will help to prevent mirror vibration if you don’t have a mirror lock on the camera.)

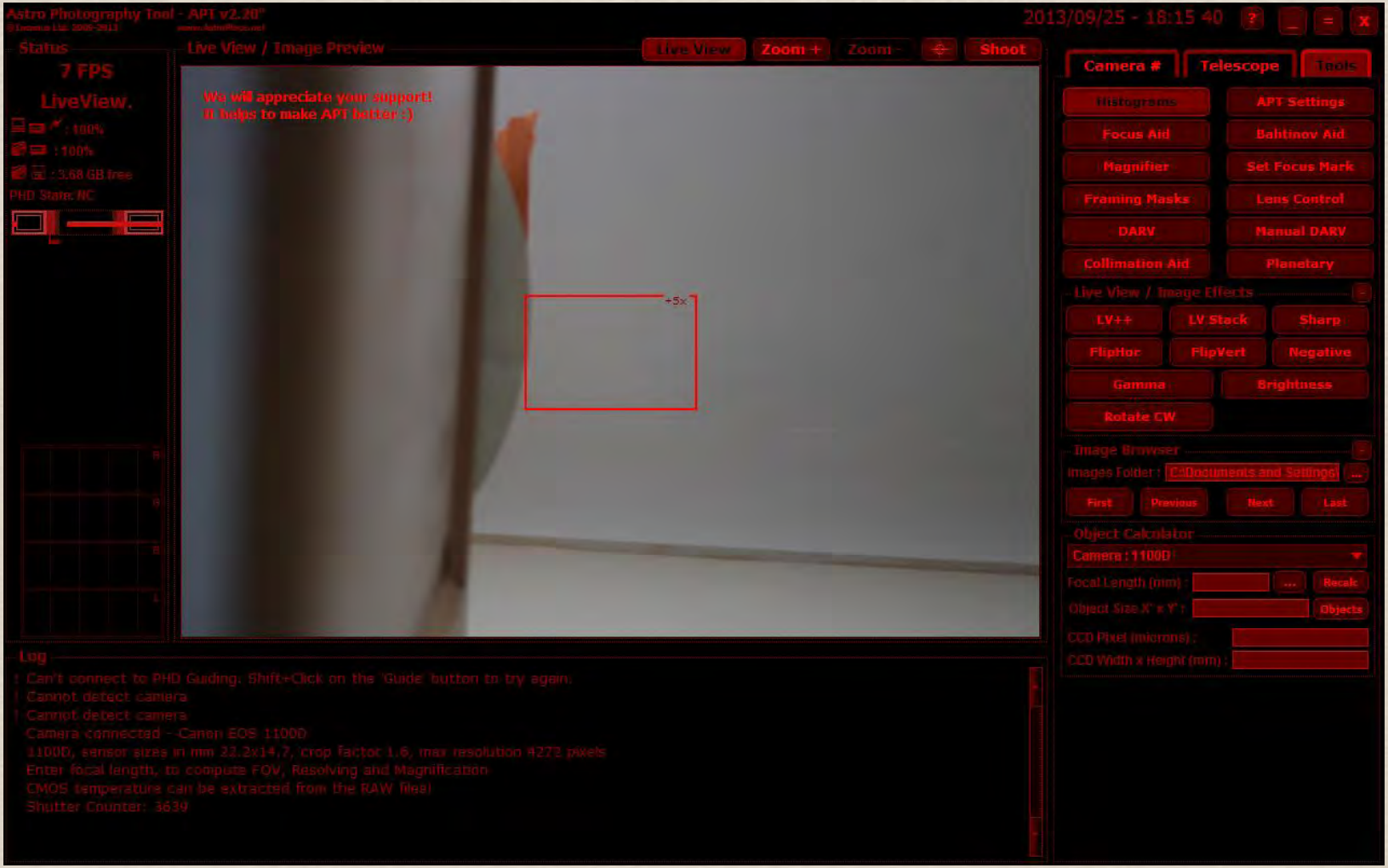
* Always focus manually when taking pictures of anything but the moon.
* Use the “400 rule” (400/focal length of lens) to check the maximum exposure time to prevent trailing, (however see below)
* Stars move faster nearer the horizon than they do overhead.
* Set the colour temperature at 4000k or less to minimise orange light pollution colour cast. (Try incandescent or fluorescent light pre-sets).

* Always carry spare batteries.
* Cold weather gives less digital noise from the sensor, but, uses up batteries quicker.
* All digital cameras record EXIF data along with the picture.
* Long, low ISO exposures are generally better than short, high ISO ones. (less digital noise).
* Try using the camera's video settings for the planets and the moon and then stacking the results into a single image, (you may need to change format though as Registax uses AVI not MOV format files).

* If you intend buying an SLR for astrophotography we would advise getting a Canon as they appear to be accepted as having the best integrated software, but if you already have something else give it a go.
* Beware of aircraft! They will appear at the most in-opportune moments. (especially around here!).
* Cameras can be controlled directly from a pc if you wish using suitable software. This may even be remotely situated indoors using a long lead.


Astro Photography Tool - APT v2.20"
2013/09/25 - 18:22 25
Status
6 FPS
LiveView
: 100%
: 100%
: 3.68 GB free
PHD State: NC
Live View / Image Preview
Live View
Zoom +
Zoom -
Shoot
We will appreciate your support!
It helps to make APT better :)
+5x
Camera #
Telescope
Tools
Disconnect
Start
Stop
Plan : 4 minute iso400
Edit
Exp
ISO
||
Cnt
Qlty
1
240
400
0
1
R+L
Log
! Can't connect to PHD Guiding. Shift+Click on the 'Guide' button to try again.
! Cannot detect camera
! Cannot detect camera
Camera connected - Canon EOS 1100D
1100D, sensor sizes in mm 22.2x14.7, crop factor 1.6, max resolution 4272 pixels
Enter focal length, to compute FOV, Resolving and Magnification
CMOS temperature can be extracted from the RAW files!
Shutter Counter: 3639
Plan expected duration : 245s (4.1min) in 1 exposures [Total light 240s (4.0min)]
Object Name :
M31
Exp: Bulb
Bulb seconds :
60
ISO: N/A
Image Preview : On
Qlty: R+L
Image Dest: PC
AV: N/A
Anti Vibration Pause : 0s
Long Exp. Control : Virtual
EOS 1100D
White Balance: Auto

Remote control software



Taking Video with DSLR's

* A DSLR can be used to shoot video for stacking into a single image.
* This is ideal for lunar and planetary images.
* Images need to be in AVI format for stacking. As canon DSLR's save in MOV format,
    * Either
- Record as MOV file in Canon EOS Utility or other video recording programme, then convert in PIPP (Planetary Imaging Pre-Processor).
    - or
- Use EOS Movie Record software to save the video in AVI format direct (preferred option)

* MOV files have lossy compression whereas AVI ones do not.
* Import the video into stacking software and use this to select clear frames to stack into a single image.
* Helps to gain clear images of the moon and planets by capturing the fleeting moments when the atmosphere is still.
* EOS video record enables video to be recorded as seen on the 5x magnification live view screen.

Video taken on canon DSLR

Note the varying clarity!

Moon image stacked from video taken with DSLR

Canon 1100d camera with cheap 70mm Celestron refractor
60 sec clip with best 5% stacked

Handy Software

* Gimp image processor (freeware)
* Deep sky stacker (freeware) (deep sky objects)
* Registax (freeware) (planets, moon, etc.)
* Canon Digital Photo Professional (free with Canon cameras.
* Canon EOS utility (remote control of camera). (free with Canon cameras).

* Astro photography tool (APT) V:2.2 (Camera and scope control).
* EQMOD / EASCOM (camera / mount control software). (freeware)
* Photodirector 3 (image processor) (free cover disk)
* PHD (autoguiding software) (freeware)
* EOS movie record (freeware)
* PIPP (Planetary Imaging Pre-Processor)(freeware)
* Astro planner (free cover disk on Sky at Night Mag)

Recommended websites

* Ukastroimaging.co.uk/forums
* Photography-on-the-net/forum (large sections on astrophotography).
* Astronomyforum.net/astro-imaging-forum/
* Allens-stuff.com

REMEMBER

* Above all, get out there and try it. Whatever your camera, you can take some great pictures and it isn't as hard as you think.

AND FINALLY!

Sometimes you get lucky!!

ISS taken with 200mm f5 reflector ISO800 / 1:350 sec hand guided.