Beginners Astrophotography

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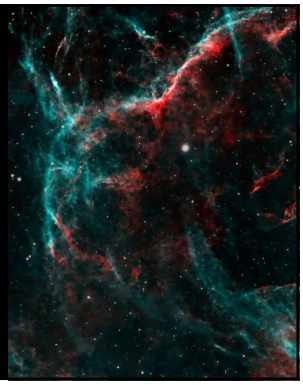
Week 2: Lens, Cameras & Telescopes



1

Basic Concept

- Need long exposures to capture enough light
- But the *earth's motion will result in star trails*
- This gets worse at longer FL

2

'500' Rule

- Approximation of maximum exposure time to avoid star trails
- Divide 500 by the (effective) FL
- Include any crop factor in FL
- Depends on actual equipment set-up- use test shots
- Longer exposures will require use of star tracker

3

'500' Rule

Fixed tripod

In this case we have 500/(2 x 40) = 6.25 s

Star Tracker

More detail & sharper stars possible at much longer exposure

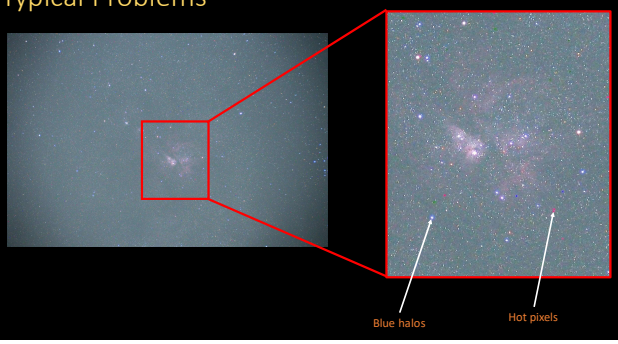
4

Typical (Unpromising) Image

Raw 30s shot of Carina nebula straight from camera

5

Typical Problems



6

Hot Pixels

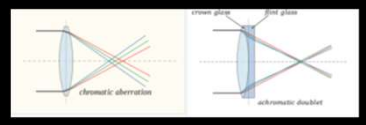
- Spurious coloured pixels due to long exposures
- Sensor gets hot -> random fluctuations
- Worse on hot summer nights
- Can be reduced by:
  - Cooled camera
  - Dithering
  - 'Noise reduction' in camera
  - Dark calibration

WARNING!
In camera noise reduction subtracts 2nd image: increases time,
Potentially removes details
TURN IT OFF

7

Lens Quality

- Prime lens has fixed FL
- Zoom lenses suffer in quality
- Distortions & aberrations



Zoom lens

Prime lens

8

Chromatic Aberration

- CA leads to Halos
- Can be reduced in post processing (e.g. ImagesPlus)
- ✓Lenses with ED glass, doublets or achromatic best

Blue halos due to CA

Halos reduced in software

9

Typical problems

Distorted stars at edges/corners of lens

10

Star Distortions

- If this is same across FOV -> problems with tracking
- If worse at corners likely to be lens
- Causes distortions & soft focus
- On telescopes we use field flatteners to correct this
- Dark signal in each corner is vignetting

11

Vignetting

- Examples using kit zoom lens
- Dark corners very prominent
- Can be fixed by cropping or flat frames (later) or close aperture

12

Focussing

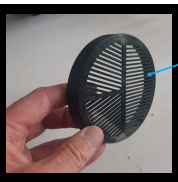
- We need to reliably focus at infinity for astrophotography
- Lens (∞) markings cannot be used
- Lenses are not as good as telescopes for infinity

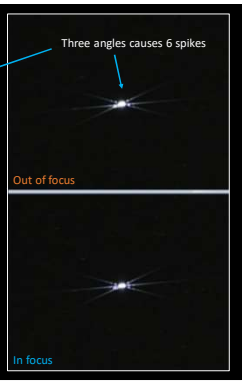
Note: that focus can change throughout the night!

✓Aim at bright star and manually focus until get smallest dot
✓OR use focussing mask (next)

13

Bahtinov Mask



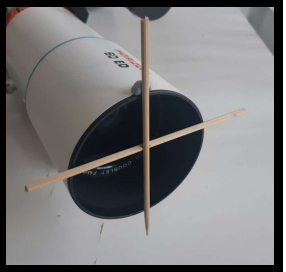


- Aperture specific fit and provides diffraction spikes
- These are symmetrical at infinity focus
- Use live view in camera

14

Diffraction Spikes

- Lens diaphragm can introduce unwanted spikes
  - Open up aperture
- Can be introduced artificially (software or physical) to enhance photos
- Also useful to distinguish star brightness



Kebab sticks and blutak!

15

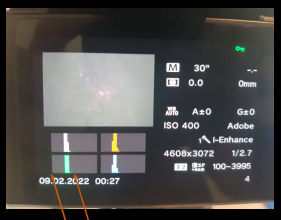
16

Exposure Settings

- Combination of shutter speed and ISO (gain) to get sufficient signal
- Exposure time is limited by set-up (lens speed, FL, tracking etc)
- ➢Increasing ISO will reduce the dynamic range in post processing
- ➢Practical limit will be set by sky conditions
- ➢F-ratio of lens also changes exposure
- Without any calculation: use camera histogram as good estimate

17

Exposure Settings



This is from my Backyard.

In this case LP means exposure was limited to 30 s and ISO 400

Aim is to set exposure based on histogram; keep it away from the left and approx. 1/4 to 1/3 to the middle

18

Exposure Settings

This is from Bortle 3 site.

In this case I could go to 60 s and even then needed to boost ISO to get histogram OK

Aim is to set exposure based on histogram; keep it away from the left and approx. 1/4 to 1/3 to the middle

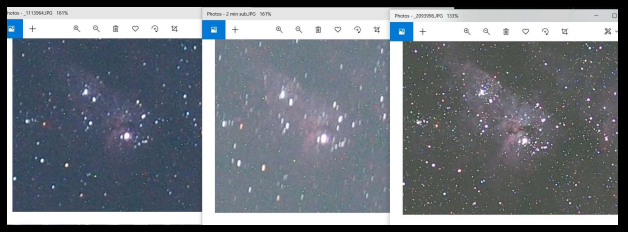
19

f-Ratio

- f-ratio is the ratio of the FL to the aperture
  e.g. 1250/90 = f/14
  360/60 = f/6
- Ideally we need a wide ('fast') aperture as possible
- This will allow *shorter exposures*
- Compare these lenses next..

20

f-Ratio



f/5.6 lens
30 s sub

f/5.6 lens
120 s sub

f/2 lens
30 s sub

21

Bulb Mode

- Use shutter release cable to avoid camera shake
- Most cameras have maximum exposure of 30-60s
- Longer than that need 'bulb mode'
- Will also need intervalometer
- Good to have delay between shots

22

Stacking Data

- Single sub exposure is very noisy
- Basic concept is to collect more (n) data = improve SNR
- Individual sub exposures (t) anywhere between few secs to few min
- Final 'integration time' T = n x t

23

Stacking Example: Helix Nebula

n	1	5	25	50	75
T	2 min	10 min	50 min	1 hr 40 min	2 hr 30 min
SNR	1	2.2	5	7.1	8.7

Effect of increasing number of 2 min subs

24

Stacking Data

- Should aim for 20<n<100 subs depending on t
- Some bright targets 10-20 mins integration time
- More often 1 to several hours needed
- In LP you will always need more data
- Stacking software (DSS, Sequator) required

25

(n=1) 4 min raw sub (n=10) 40 min post-processed

26

Using Star Tracker

Longer exposures mean	Shorter exposures mean
Fewer subs to stack	More subs = stacking errors
Less disk space	More disk space
Susceptible to satellites/airplanes/wind …anything!!!	Fewer wasted shots
Lost data huge % of image	Data loss less important
More prone to tracking errors	Less prone to tracking errors
Better capture details	May miss subtle details

Balance between exposure length

27

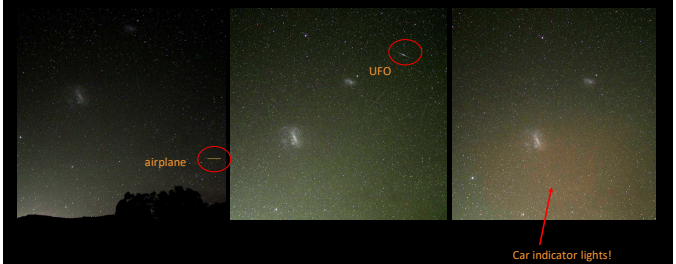
Satellites

1 min at 135 mm 20 s at 360 mm

Currently about 3,000 satellites in space
Elon Musk is aiming for 40,000 in next few years…this will kill astrophotography!

28

Other Impacts



Much worse at wider angle (12 mm)

29

Calibration

- In addition to our sub exposures which we call *light frames*
- You will (*may*) need:
  - ✓*Dark frames*
  - ✓*Flat Frames*
  - ▪ *Bias Frames*
  - ▪ *Dark Flat Frames*

30

Dark Frames

- These remove hot pixels, amp glow- bad effects from long exposure photos
  - Add lens cap
  - Acquire at same settings (ISO/gain, exposure, focus)
  - Should also be at same temperature
  - Software can also reduce hot pixels

31

- Use of Dark Frames

32

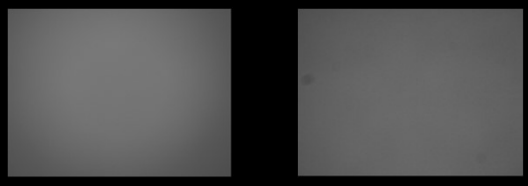
Flat Frames

- These remove vignetting & any dust spots on sensor
- Attach white piece of paper or cloth to lens
- Aim at screen or daylight sky
- Acquire at same ISO/gain, focus and sufficient exposure time

You may get away without needing these especially if you can crop the edges and any problems out easily

33

- Flat frame examples



34

Flat Frames

Dust spot here on left edge
Cannot crop to remove as it is part of image

Either clean sensor
OR
Calibrate with flat frames

35

Typical Workflow

- Acquire light frames
- Attach lens cap and acquire 20+ dark frames same night
- Leave equipment set-up overnight, including any filters
- Next day attach white cloth and acquire 20 flat frames

Has to be done for every new dust spot that appears

36

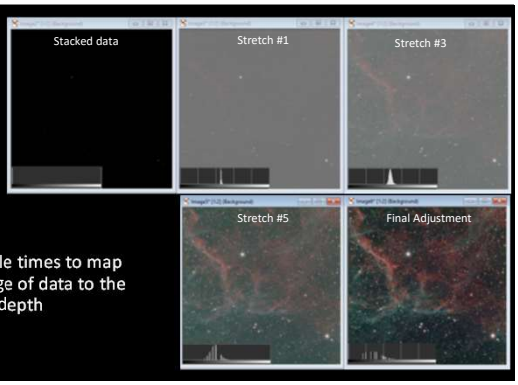
Final Image
Alniyat, M4 & Antares
360 mm ISO 800
49 min

37

Stretching Data

- After stacking the data is in very low range of values
- Need to 'stretch' it several times
- This is process of setting the black and mid point without clipping or losing data
- Done many times to increase dynamic range
- Based on image histogram
- Can also be done automatically in some software

38



- Apply multiple times to map dynamic range of data to the available bit depth

39

Types of Camera

- Standard DSLR or Mirrorless cameras
- Astro modified
- Dedicated Astro (cooled) cameras
- Planetary (video) cameras

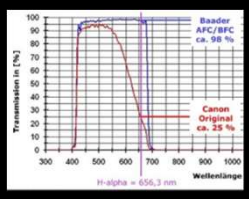
40

Modified

- Stock cameras block IR

…also stop a lot of red spectrum

- Modification replaces filter with wider bandpass
- Costs about $800
- Increases sensitivity to emission nebula (only)



41

Astro Cameras

- Very low read noise
- Allow full computer control (unlike my old mirrorless camera)
- Flexible in terms of filters- already red sensitive
- Cooled cameras allow temperature to be controlled/reduced
  - Darks can be done at any time

❖Will need to be powered

❖Can be expensive

42

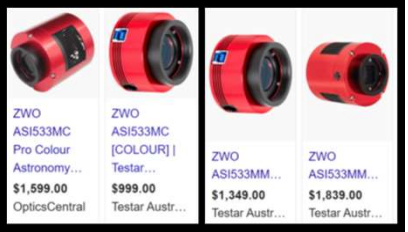
More on Filters

- Common types are AR (just antireflective glass)
- IR/UV cut: defines sharp cut-off above visible light
- IR pass: the opposite of the above
- Duo or triband let in OIII, HII (and S) emissions
- *Monochrome cameras need individual filters for R, G & B and therefore need much more time*

43

Astro Cameras

- Example ZWO cameras
  - MC means colour
  - MM means mono
  - Pro means cooled



44

Planetary Cameras

- Frame rates up to 120 fps
- Can also change FOV to further increase FR
- Colour or monochrome
- Usually very small sensor size

ZWO ASI120MCS
3.75 um
1280 x 960mpixels
1/3" sensor
100g

45

'Seeing'

- Space telescopes have no atmosphere to deal with
- Adaptive optics used on professional observatory terrestrial telescopes
- For the rest of us seeing restricts our quality
  - ➢Resolution limit of telescope (Dawes limit) equal to 115/aperture (mm) e.g. 115/90 = 1.28 arc secs
  - ➢Seeing can be much worse than this limit

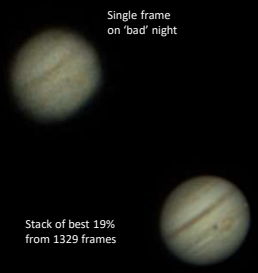
46

'Lucky Imaging'

- Use of FFR cameras to capture windows of good 'seeing'
- Useful technique for moon & planets
- Select the best images to be stacked
- Right balance between too many and too few will improve SNR

47

- In this 'bad seeing' example improvement is clear
- More on this when we cover planets



48

Telescopes

- Refractors
  - Cheaper achromatic suffer from chromatic aberration
  - Apochromatic uses ED glass to reduce chromatic aberration
  - May need field flattener
- Reflectors
  - Cheaper, use mirrors only, has diffraction
  - Require collimation, coma correction
  - No chromatic aberration
- Hybrid
  - Combination of lens and mirror
  - Long FL in short tubes

49

Field Flatteners

- Extra glass that corrects any curvature at edges of field
- For some small sensor cameras you might be OK
- Full frame (DSLR) will need flattener
- Some work as 'flattener reducer'' and shorten FL e.g. 0.8 times
- This is my one for my refractor

This is a x1.0 FF

50

Additional Equipment

- Finderscope
  - Red dot finder or other
  - Wide low mag to assist alignment
- Guidescope
  - Fast frame rate video camera for guiding
- Dew shield/heater
  - Lens hood or integrated dew shield
  - heater strap may also be needed

51

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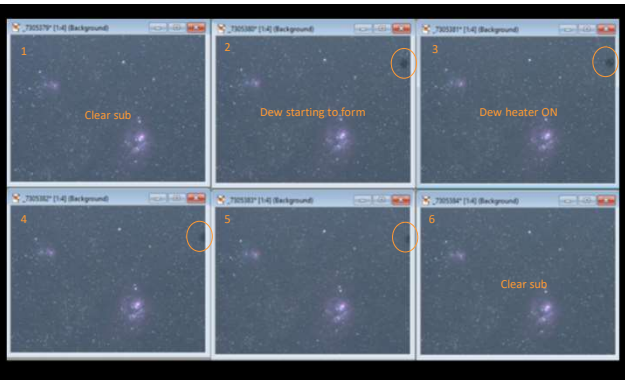
Toilet roll tube!

52

53



54

Summary

- Good Astrophotography is about long enough exposure without star trails or other artefacts
- Ultimately best quality will be with star tracker
- Many images always equals better quality
- Things become progressively more difficult at longer FL
- Some basic processing techniques and equipment will deliver good results

55

Questions?

www.austrophotography.com

56