

Frugal Astrophotography

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Who Is This Guy?



- Khalid (“ ... ed” not “ ... eeeeeed”)
- Pharmacist by education
- Open Source Software Development and Consulting by experience (32 years)
- One of the developers of Drupal, a Web Content Management System





Who Runs Drupal?



- The White House (for over 10 years)
- The Economist
- University of Waterloo (over 600 sites)
- Harvard University
- University of Guelph
- Lady Gaga
- Weather.com





Who Runs Drupal?



- NASA
- RASC (Yes, *this* one!)





What About Astronomy? **abits**

- Interest since middle school and high school (~ 1970s)
- No observing clubs in Egypt (at least then)
- Milky Way in summer (near Alexandria, Egypt)
- Relative making telescopes in 1970s
- Hiatus ...
- Binoculars in the 1990s, for Comets (Hyakutake and Hale-Bopp)
- 4.5 inch Bushnell with shaky Alt-Az mount (~ 2001)
- Hiatus ...





What About Astronomy? **abits**

- Lake Huron skies + Milky Way (~ 2014/2015)
- Wanted to take it further ...
- Per advice from a friend: 10 inch Newtonian on Equatorial Mount (April 2016)
- One night mentoring with an experienced life time astronomer (June 2016)
- Bruce Peninsula (end of Aug / early Sep 2016)
- Hiatus (Sept/Oct 2016, then Dec/Jan 2017)





Visual Observing



- Human Eye can see contrast better than cameras
- Try seeing Jupiter and its moons, you will see bands *and* moons
- Cameras can't 'see' them both at the same exposure





Why Astrophotography? **2bits**

- Limitations of the Human Eye
 - Not as sensitive as film/sensors
 - Non visible wavelengths (e.g. infra-red)
- Detail
 - More exposure = more photons = more detail
- Colour
 - Eye can't see colour in dim light
- Documenting what you saw
- Sharing what you saw





Astrophotography Beginnings **abits**

- Started by amateurs
- Experimenting with silver halide on gelatin glass plates
- Purely mechanical mounts (no electricity nor electronics)
- 'Slow' film (requires more exposure time)





Henry Draper



- American physician, amateur astronomer, 1837 – 1882
- His father, William, took the first photo of the moon.
- Orion Nebula M42, (*Nature Vol 22, Issue 573, 1880*)
- “... the aid of a **triple objective of eleven inches aperture** made by Alvan Clark and Sons, and **corrected** especially for the photographic rays. The equatorial stand and driving-clock **I constructed myself**. The exposure was **fifty minutes**.”





Henry Draper (cont'd)



- *Monthly Notices of Royal Ast. Soc., Vol. 42, June 1882*
- "It is worthy of remark also that in this photograph with an **exposure of only 137 minutes** I have depicted stars almost the minimum visible in this telescope, and it is not unreasonable to hope that by still further prolonging the exposure and by still further study of photographic processes, stars and details entirely invisible to the eye may be secured."
- "... I have under consideration **a new form of mounting which will permit of continuous exposure of six hours**"





Henry Draper (cont'd)



- Orion Nebula M42, by Draper 1882





Andrew A. Common



- English businessman, amateur astronomer (1841 - 1903)
- Orion Nebula M42 in 1883
- Awarded medal from Royal Astronomical Society following year

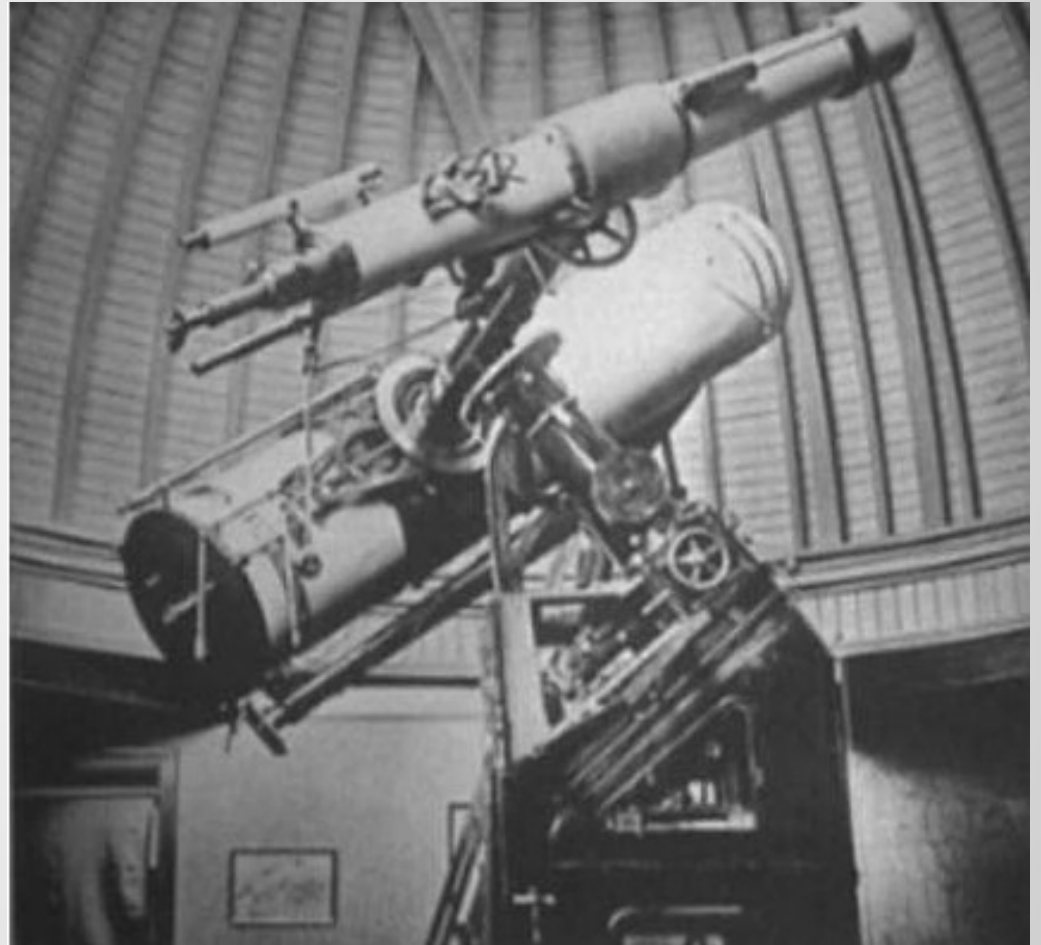




Isaac Roberts



- Welsh businessman (1829 - 1904), retired and pursued '**celestial photography**' as a serious hobby.
- Clark 7 inch refractor, then 20 inch Newtonian
- Rehabilitated the reflector after some 70 years of disuse.





Isaac Roberts (cont'd)



- 2,500 photographic plates
- 90 minutes for M31
- Published a book of celestial photos in 2 volumes
- 3rd volume published posthumously by his wife
- Vol 2 on archive.org: “isaac roberts selection of photographs”





Isaac Roberts (cont'd)



- *Roberts, Issac, Photographs Of Stars, Star-Clusters, and Nebulae, Vol 2, page 20, 21*
- “ ... so far as my experience enables me to judge, after twelve years’ use of the 20 inch reflector, ... **the limit of photographic effect is reached sometime within ten to twelve hours** on clear nights ... ”
- “ ... The Great Nebula in Orion has been photographed with the 20 inch reflector at frequent intervals between the year 1886 and 1898 with exposures varying between one minute and **seven hours thirty-five minutes** ... The Pleiades ... **twelve hours** ... ”





Isaac Roberts (cont'd)



- Started to formulate a theory on **stellar condensation** how objects evolved
 - His book is organized to show this hypothesis
 - That ‘spiral nebulae’ coalesce into stars, and clusters are formed along the lines and curves of the spirals
 - What he named ‘spiral nebulae’, we now know as galaxies
- Also measured some proper motion for ‘nebulae’ based on previous numbers (e.g. Lord Ross)





E. E. Barnard



- 1857 to 1923
- Started as a photographer's assistant, then moved to astronomy
- Never completed a formal education
- Appointed as professor in U Chicago





E. E. Barnard (cont'd)



- Mapped the Dark Nebulas (B catalog)
- Mapped **photographic nebulae**
 - **Barnard's Loop** around Orion (hydrogen region)
 - Nebulosity around The Pleiades





Who's Better Off?



- They had **far better mounts**, that can track for several hours
- They had **darker skies**
- No **colour**
- No **electronics and software** (Sensors, Stacking, Autoguiding [cop-out])
- We have **better understanding of the objects in the universe**
- No portability





Handheld Photos



- Jupiter and its moons, handheld shot from cell phone





Handheld Photos (cont'd) **abits**

- The Moon, handheld shot from cell phone





Handheld Photos (cont'd)

- The Moon





Limited ...



- That is about the limit of what you can do with a cellphone camera
- You can buy a ~ \$15 - \$20 adapter for stability
- You **cannot** control the exposure
 - ISO and shutter speed





Proper Astrophotography

- Scope (preferably flat field, with coma correction)
- Motorized Mount, GOTO preferred, with autoguiding port
- Guide scope + guide camera
- Camera (DSLR or CCD), often cooled to reduce noise, and spectrum modified
- Series of light frames, dark frames, flat frames and bias frames
- Postprocessing for subtraction, stacking, histogram stretching, adjustments





Regular Equipment



- Celestron AVX (\$1,020 new) or CGX (\$2,850)
- Skywatcher HEQ5 (\$1,427) or NEQ6
- Apochromatic Refractors 80 to 100 mm aperture, F/5
- Or SCTs, 8 inch to 10 inch
- DSLR, preferably astro-modified, with T-Ring + Adapter
- Guide Scope + Guide Camera
- Filter wheels
- Laptop with autoguiding software





High End Equipment



- Takahashi Temma (\$4,950 used)
- Astro-Physics AP1200 Mount (\$8,800 used)
- 10micron (\$10,000 US)
- Software Bisque: Paramount MX (\$9,000 US)
- Riccardi-Honders (RH) Oficina Stelare Veloce RH 200. 8 inch, flat field (\$7,000 US)
- MallinCam, QHY or ZWO Cooled cameras \$1,500 +
- Robotic filter wheels, filters,
- Robotic focusers





Perfect vs. Good



- 'Perfect' is the enemy of 'good enough'
- You don't *need* all this high end equipment for acceptable results.
- Your work may not make it to APOD.
- Your work may not be featured in magazines.
- But, it will still be good enough to look at and share.





Cost vs. Benefit



Varies from one person to the next ...





Complexity





Complexity

2bits





My Equipment



- Telescope and Mount (used)
- Eyepieces (32 mm, 25 mm, 10 mm, 7.5 mm, 4 mm)
(eBay, clearance table at KWTelescope)
- DSLR Camera (used, Kijiji)
- Adapters (primefocus, as well as eyepiece projection, eBay)
- Total around \$950 to \$1,000





Telescope/Mount



- Meade DS-10, sonotube, from the 1980s
 - 10 inch Newtonian, F/4.5, 1145 mm focal length
- Mount
 - Equatorial, with an RA drive (only)
 - Meade pedestal/pier mount, 110 volts
- No GOTO
 - Great to learn the sky that way ...
- 1980s ad: *M57 Ring Nebula **4 minutes**, Orion Nebula **6 minutes**, M17 Omega Nebula **5 minutes**,*





Other Equipment



- Telrad
 - Zero power finder
 - 4, 2 and 0.5 degree calibrated circles
 - For the non-GOTO amateur
- 9X50 finder scope





Telescope

2bits





Camera



- Tested Nikon D5100, Canon T3i and Canon XS
- Canon EOS T4i (650D), bought used, ~ \$375
- Stock camera (non astro-modified)
- Canon Xsi available used really cheap ~ \$150
- Canon T2i available used for ~ \$250
- Canon T-Ring and 1.25 inch adapter from eBay ~ \$25
- A/C power supply (eBay) ~ \$20





Fix Ups



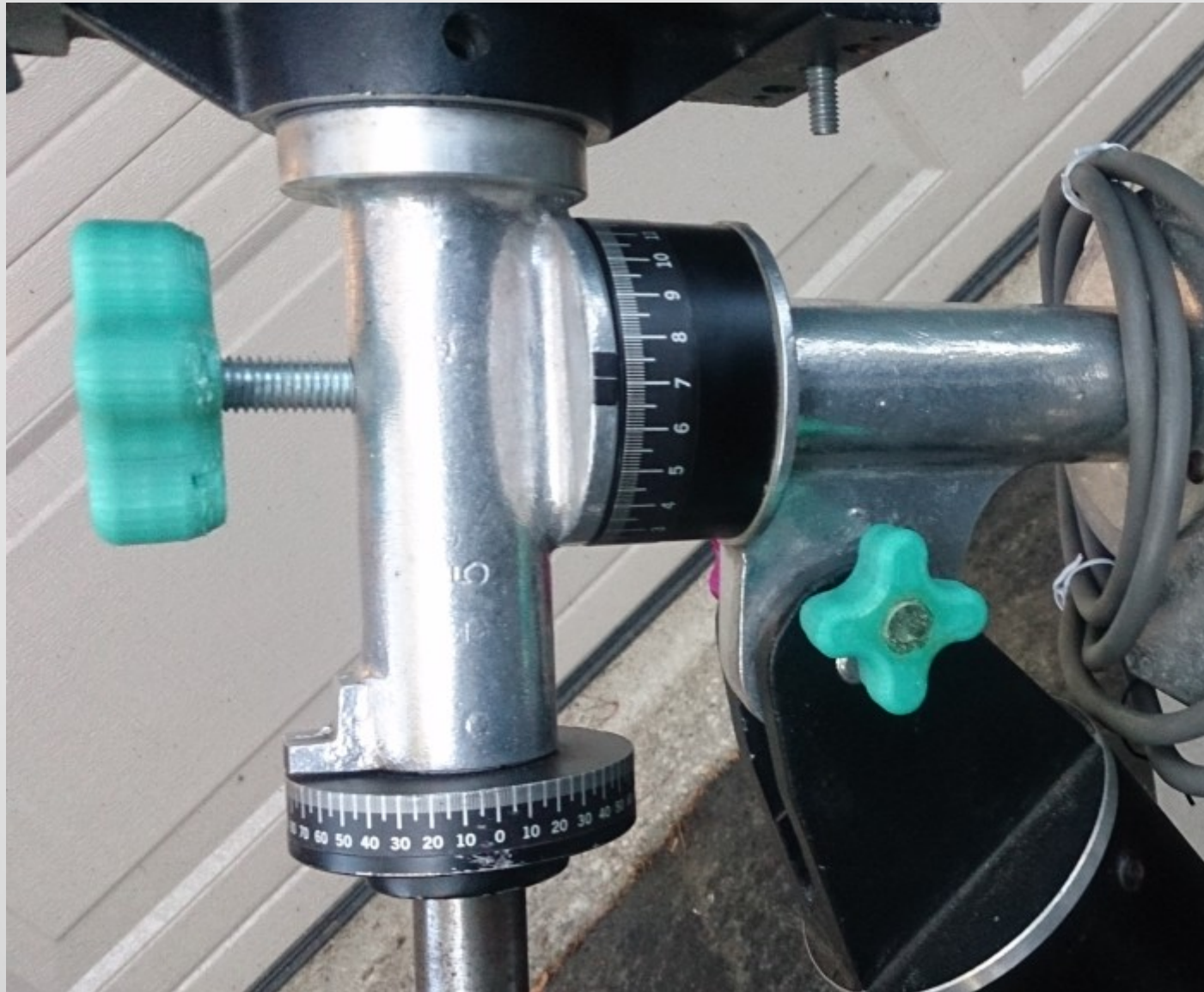
- Made the altitude bolt more rigid with less play (inserted a thin washer)
- Replaced Allen key screws for altitude with screws (and 3D printed knobs)
- Counter weight Allen key screw replaced by a longer bolt (with 3D printed knob)
- Drilled threads in tripod to make levelling easier (no shimming needed)
- Greased the worm gear and focuser
- KwartzLab, open to the public on Tuesdays





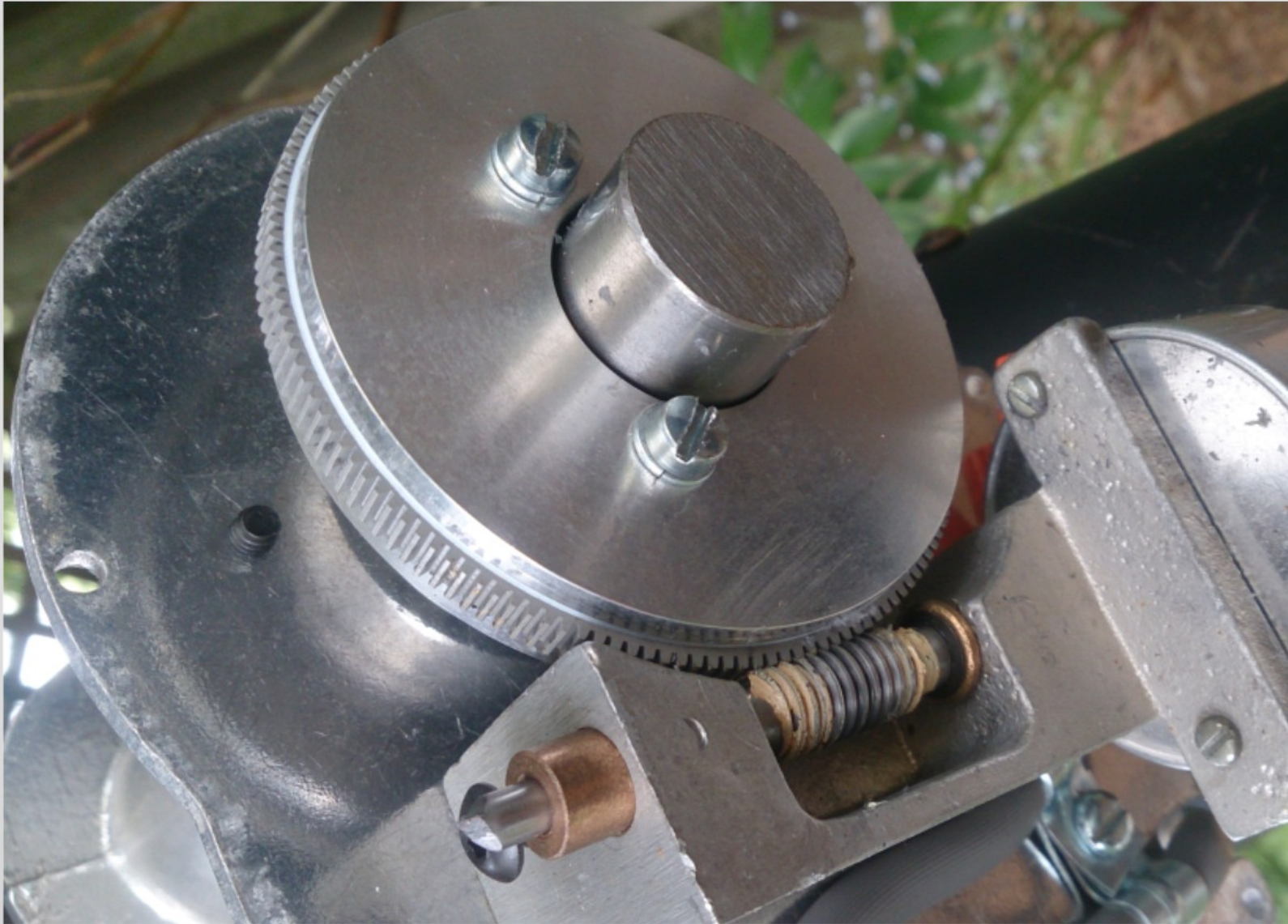
Mount

2bits





RA Gear and Worm





Focal Ratio



- Focal length determines magnification
- Focal ratio = focal length / aperture
- Focal ratio determines exposure time
- Stops: 2.8, 4, 5.6, 8, 11, 16
 - Double the number of seconds
- Thirds: **2.8**, 3.2, 3.5, **4**, 4.5, 5, **5.6**, 6.3, 7.1, **8**, 9, 10, **11**, 13, 14, **16**
- SCT at F/10 = 2.66 X the seconds (30 sec vs. 80 sec)
- Focal reducer 0.5X = F/5 = 0.33 X seconds (30 sec vs. 33 sec)
- Field of view vs. Magnification vs. Depth of field





Workflow



- Take components out
- Collimation check
- Levelling
- Aligning Telrad
- Align finder
- Polar Alignment
- Hunting for Objects
- Balancing
- Focusing
- Framing
- Test Exposures
- Multiple Exposures
- Darks ?





Polar Alignment



- Crucial for good astrophotography, more so when not autoguiding
- Started with 32 mm, 52 degrees Plossl generic eyepiece
- Find Polaris 'clock' position in Stellarium
- Later used the Telrad
- Recently using the DSLR with 4 or 5 minute exposure, then check the star trails (have to wait till dark)
- Does not account for cone error, atmospheric refraction, ...etc. yet 'good enough'





Balancing



- For this scope: the ***most important thing*** for proper tracking
- Use DSLR Live View with 10X zoom and watch a star, and if it does not drift, take a test frame (30 sec) and check it visually
- Always found that:
 - Scope west of mount: counterweight up shaft
 - Scope east of mount, counterweight down shaft





Focusing



- Focusing via eyepiece does **not** mean it is focused for the camera!
- Can only be done visually on brighter stars
- Can try an iterative approach, specially when you don't want to lose a dim object, or framing (trial and error)
- Bahtinov mask (laser cut on plywood, KwartzLab)
 - Requires relatively bright star, and Live View with 10X zoom
- Ordered parfocal rings, to try to make focusing easier





Exposure



- Focal Ratio is fixed, unlike camera lenses
 - Can be changed using focal reducer
- So you are only left with two variables:
 - Shutter time
 - ISO settings
- Sky quality matters, the more exposure with light pollution, the worse the photos are (Photoshop?)
- Start with 30 seconds and ISO 800 as a test, then adjust according to the results





Magic Lantern



- Free software for certain Canon models
- Runs from the SD card, hence does **not** replace the camera's firmware (does not void the warranty)
- Turns a supported Canon camera into an intervalometer
- Allows for exposures more than 30 seconds (using bulb)





Pictures?



Let us see some results ...





Remember ...



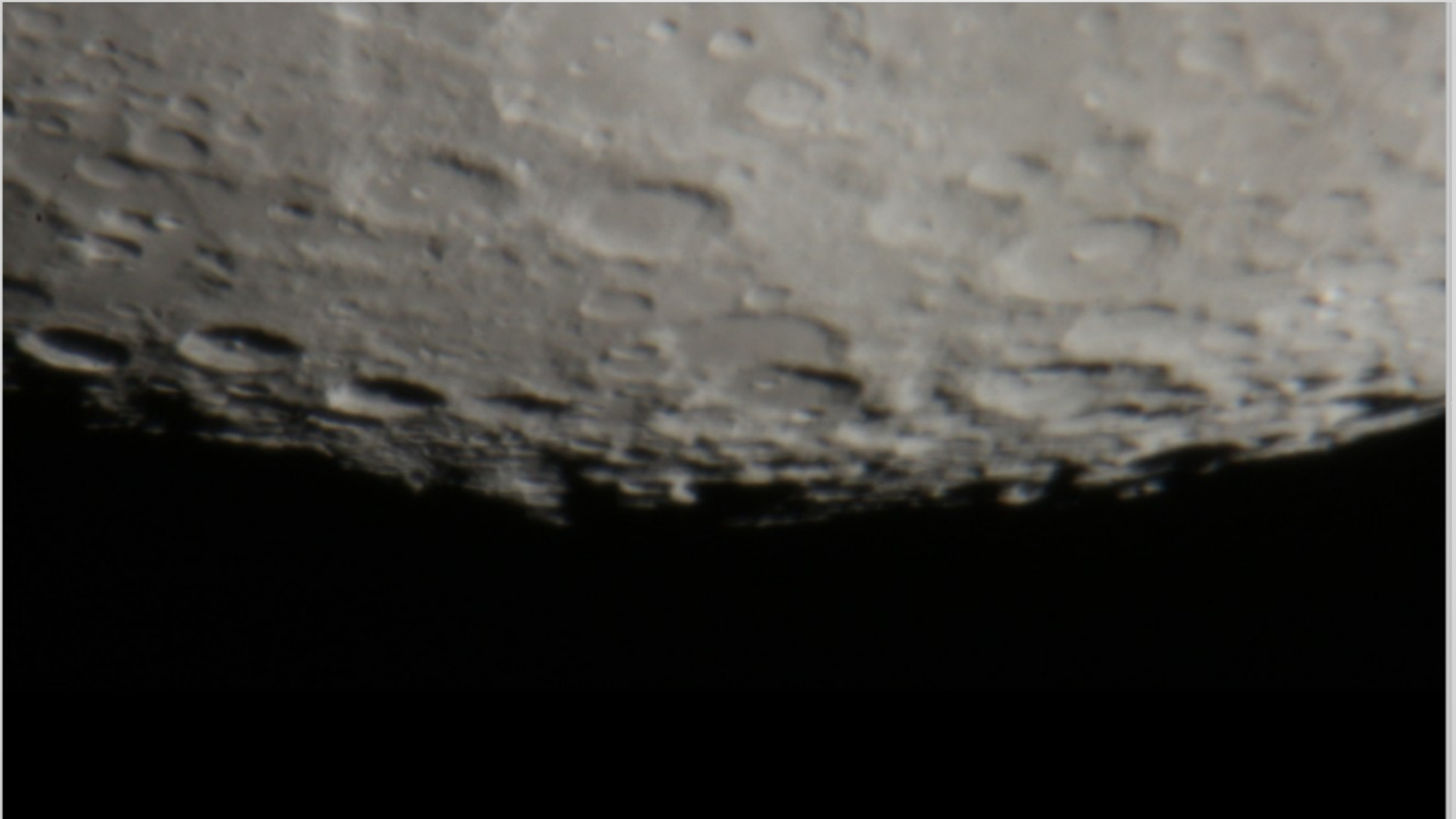
- Only 7 months of experience
 - Some much shorter than that ...
- No GOTO
- No autoguiding
- No stacking
- No post-processing
- All prime focus
 - Except for 'proj', eyepiece projection, 7.5 mm
- Single exposure (mostly 30 seconds, some are 60 seconds)
- JPEG straight from camera





Moon (proj): 1/30 sec @ ISO 800

abits





Jupiter (proj): 1/16 sec @ ISO 400

2bits





Mizar Alcor: 2 sec @ ISO 400

abits





Mizar A/B (proj): 8 sec @ ISO 1600

abits





Castor A & C (proj): 15 sec @ ISO 1600





M45 Pleiades: 30 sec @ ISO 3200

abits





M44 Beehive Cluster: 60 sec @ ISO 400

abits





C14: 15 sec @ ISO 1600

abits





M13 Hercules Cluster: 30 sec @ ISO 6400 **abits**





M8 Lagoon Nebula: 30 sec @ ISO 12800

abits





M16 Eagle Nebula: 30 sec @ ISO 12800

abits





M17 Swan Nebula: 30 sec @ ISO 6400

abits





M20 Trifid Nebula: 30 sec @ ISO 6400

abits





M57 Ring Nebula: 30 sec @ ISO 800

abits





M27 Dumbbell Nebula: 30 sec @ ISO 1600 **2bits**





M42 Orion Nebula: 30 sec @ ISO 1600

abits





M42 Orion Nebula: 30 sec @ ISO 1600

abits





Western Veil Nebula: 63 sec @ ISO 12800

abits





M51 Whirlpool Galaxy: 15 sec @ ISO 3200 **abits**





Leo Triplet: 30 sec @ ISO 3200

abits





M81/M82: 30 sec @ ISO 1600

abits





M81/M82: 30 sec @ ISO 12800

abits





Markarian's Chain: 30 sec @ ISO 3200

abits





Remember ...



- Only 7 months of experience
 - Some much shorter than that ...
- No GOTO
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What Next?



- Siril (Iris for Linux), dark calibration, stacking, ...etc.
- GIMP 2.9.5 (maybe?)
- GOTO Mount?
- Lighter rig?
- Automation
 - INDI on Raspberry Pi (telescope drivers)
 - Gphoto2 (intervalometer, scripting for DSLR)
- iAstroHub





Dream Big ...



- Space Telescope
 - Buy Hubble when JWST launches!





Takeaways



- You don't need high end stuff to get acceptable results
- Get experienced advice *before* you buy equipment
- Fast scopes (low F/ratio) are best
- Read the reviews and forums (Cloudy Nights, ...)
- Consider doing the whole thing incrementally
- Experiment ...





Resources



- <http://adsabs.harvard.edu>
 - Historical scientific papers on Astronomy from various publications





Questions?



Questions? Comments?

