Astrophotography 101 Class Index and Appendix List

This is a beginning class to give you an overview of the hardware and software you need for astrophotography.

What will be covered in the class & What do you need?
Types of Cameras - *Any camera will work!*
Using Film Cameras
Methods for Still Images *- for Digital or Film Cameras*
The "f-number" of the Telescope or a Camera Lens
Digital Cameras - Canon, Nikon, Sony and others
CCD (charge-coupled device)
CMOS (complementary metal-oxide semiconductor)
Cell Phone Cameras
Infra-Red, Heat Detecting & Specialty Cameras (A. to F.)
Spectroscopic Cameras & Home-Made Spectroscope
Spectroscope Image Viewing & Processing
Hardware for the Camera
Black & White, Black & White w/Color Filters & Color Imaging
Software for Capturing Images and Video
Techniques for Eclipses, Northern Lights & "Quick" Events
Urban photography problems and some solutions

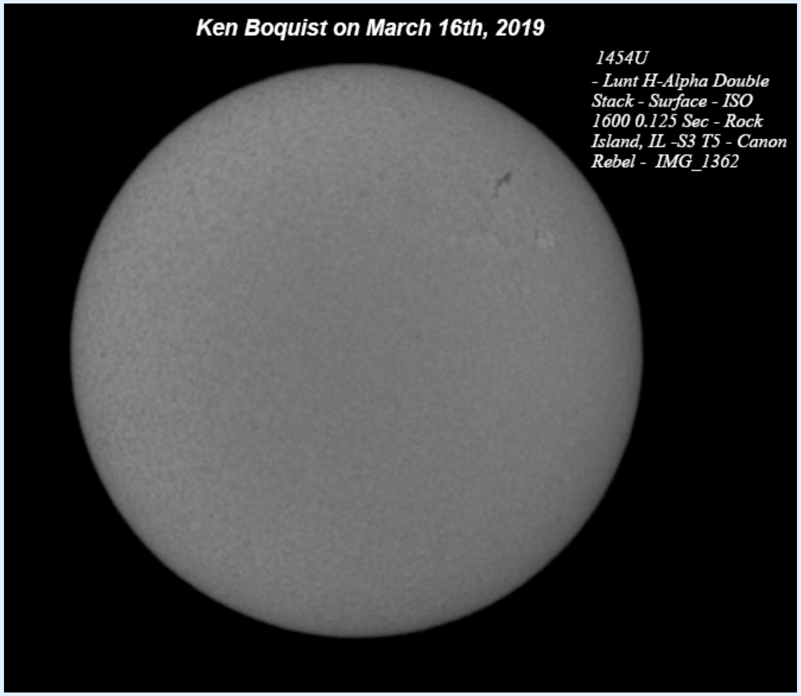
Planetary and Deep Sky Photography Demonstration– Terry Dufek
R2 Demonstration – Rusty Case
Time to Answer Your Questions!

Appendix A "Using Firecapture", Terry Dufek
Appendix B: "Create your own Color Hubble Images", Zolt Leva (includes Layering Images in Photoshop)
Appendix C: Astronomical League *Reflector*, "Three Cheers for the Photosphere", Jim Daley, Dec 2017
Appendix D: AL *Reflector*, "Basic Small-Scope Lunar Imaging", Jamey L. Jenkins, March 2019
Appendix E: PAC *Reflections,* "A solar report from Ken Boquist on March 16th, 2019", April-2019
Appendix F: *Sky & Telescope*, "The Quest for Round Stars", Ron Brecher, June 2019

Welcome to **Astrophotography 101 – A Beginning Class on Producing Astronomy Photographs**

Please hold all questions until the end of this class!

Write down your questions in your notebook…



Your instructors are Dino Milani, Terry Dufek & Rusty Case

The class PDF document can be downloaded from the website https://ncral2019.org/downloads

What will be covered in the class

Watch and learn! Review the class with the class download (then review it again and again...)
Write down your questions. They will be answered at the end of the class.

How to Get Your Shot Dino Milani will instruct you on cameras, mounts, lenses, telescopes, filters, software and more
First Demonstration Terry Dufek will show Planetary and Deep Sky photography methods and software
Second Demonstration Rusty Case will demonstrate the R2 camera

Dino Milani Lunar Eclipse
4-15-2014 1:30am
Canon 40D – Manual Mode
Sigma f-2.8 200mm Lens
178mm 2.5-Seconds ISO-1600

What do you need?

1. A camera to record your photos or videos.

2. A Camera Mount, something to keep the camera steady when taking the image.
    - The steadier the mount the better!
    - It can be a Tripod, Camera Sky Tracker or Telescope Mount.

3. A computer with software to record the image and edit the photo or video.

4. ***Patience!*** It takes time and practice to take the shot and to make it look good.

Suggestions:
We often leave the photo as a digital image. Try printing the image to see how it looks.
Keep a journal with your notes and results to see what works.

Types of Cameras - *Any camera will work!*

1. You may record Still Images or Video Recordings.

2. For Still Images you may use Film or Digital cameras, astronomy CMOS or CCD cameras, Infra-Red, Heat Detecting, Spectroscopic and Cell Phone cameras.

3. For Video Recordings use an astronomy CMOS or CCD camera, a computer Web-Cam, Cell Phone cameras or many of the Digital Cameras.

Still Images:

- Still images can be enhanced and stacked together for a better image.
- JPEG files are altered by the camera, reduced in size and may also loose clarity so the image is not as sharp.
- It's best to use RAW formats. They are full sized, keep the color format and easily enhanced.

Video Recordings:

- The videos can be enhance. Poor frames can be removed and the best frames stacked together for a better image.

Using Film Cameras

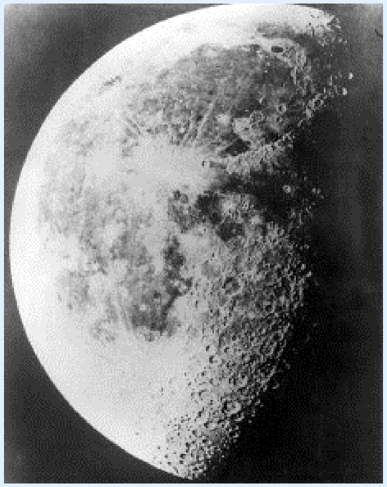
1. For **Fast** exposures use a **High-ASA** film (ASA 400 to 1600). For **Long** exposures use a **Low-ASA** film (ASA 50 to 200). Note: Digital cameras use ISO (International Standards Organization) speeds instead of ASA (American Standards Association) speeds.

- Low ASA produce a better image but take longer to expose the film.
- High ASA produce an image quickly but there is more "graining" and loss of detail so it's not as sharp!

2. If possible, use a large-sized negative (only a few photographers have these cameras).

- Medium format film at 4"x4" or 120mm-120mm.
- Larger sized film at 8"x10" or 12"x12", etc.

Note: Traditional methods for Hyper-Enhancing and cooling the film **is out-of-date**! Kodak stop making their high ASA and enhanced films and digital methods have vastly improved the images.



John W. Draper, 1863 12"x12"
Oldest Photograph of the moon

Clyde Tombaug's 13" telescope
with 12x12 Film holder

Methods for Still Images - ***for Digital or Film Cameras***

1. To see the sky **without moving the camera** (star trails, northern lights) place the camera on a tripod or post and take long exposures, often using “Bulb” mode. Also, you can stack the images to see more of the stars rotation or improve contrast in low light areas.

Photographer Babak A. Tafreshi, Sky & Telescope.
Star Trails: Long-Exposure Nightscape Live Webinar, By: Sean Walker March 29, 2019

2. To see a **moving object** with detail and in good focus you must **guide your camera** on a telescope mount or tracking mount.

Rusty Case 5-14-14
Sony ILCE-3000
1/160-Second ISO-100

3. Use **Manual Mode** on the camera (film or digital cameras). Normally you should not use the other functions (Automatic, Program, Tv, Av, etc.) unless you know their use for a specific image.

4. If using a camera lens instead of a telescope, set the lens aperture to its **widest setting**. The image takes less exposure time and you eliminate seeing the aperture shutters distorting the image (this example shows 8 streaks radiating from the star).

Sirius, from earthsky.org

5. **If a smaller aperture is needed** for a sharper image (i.e., going from f-2.8 to f-8.0) use an aperture cover on the end of the camera lens. (Galileo did the same thing on his first telescope!) For the cover, you can cut a circular hole in cardboard and tape it to the end of the lens or place it in a Cokin holder on the end of the camera lens. Also, small-holed adaptors (instead of cardboard) can go into the Cokin holder, as well as color filters for black and white photography.

Cokin P Holder with 70mm Adaptor

38mm Adaptor

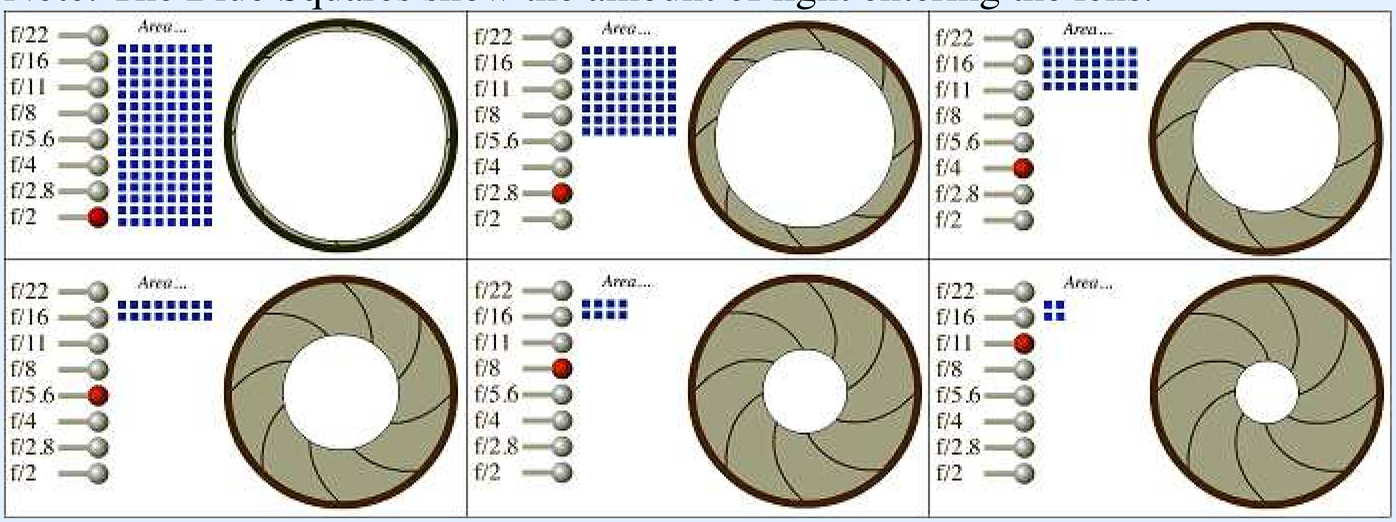
Cokin A Holder with 28mm Adaptor in place

5. **If a smaller aperture is needed** (continued)

Aperture Settings of the Camera Lens

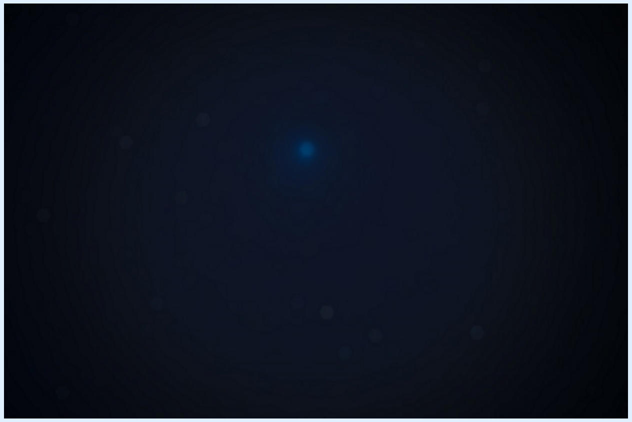
The **lowest Aperture** allows more light to enter for a faster exposure but the focus area is very small and, sometimes, details are lost or areas are out-of-focus. Low ISO settings works well.
A **higher Aperture** reduces the amount of light entering so the exposure time is increased but the focus area is much greater. More details are retained and more areas are in focus. A higher ISO is often needed when using a higher Aperture.

Note: The Blue Squares show the amount of light entering the lens.



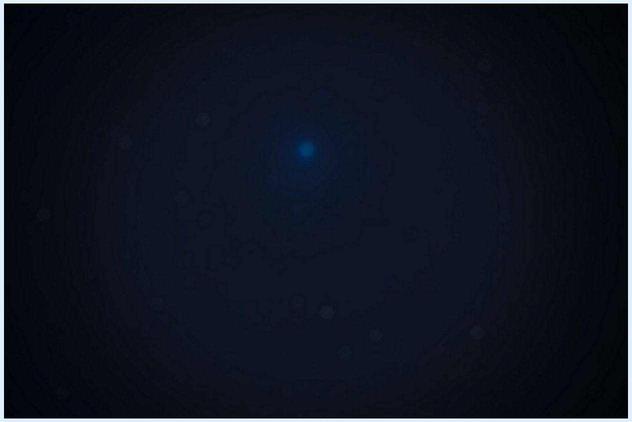
6. Focus Methods

- **Turn Off Autofocus**. Always manually focus the camera.
- **Back-and-Forth Focusing** – Traditional method. Bring the image close to focus, then past the focus, then slowly reverse the direction until the focus returns. (Al Sheidler photo, 46P-Wirtanen)



Close to Focus

Forward to In-Focus



Forward to Out-of-focus

Backward to In-Focus

6. Focus Methods (Continued)

- **Bahtinov Focus Mask Filter & Home-Made Focus Filters**. Used to produce a better focus, for sharper images. Place the Bahtinov mask on the aperture and photograph a bright star. Move the focus lever forward and back and take photographs with each move. The distorted image will appear aligned side-to-side with the best focus. Various sizes will fit camera lenses and most telescopes.

Note: Home-made versions of the Bahtinov Focus Mask work well.


Bahtinov Focus Mask


In Focus


Out of Focus

Two Home-Made Focus Masks

7. Decrease or increase the exposure time for the best image.

- Faint objects may require 30 seconds to 60 minutes (or more) exposure time.
- For long exposures, use your watch and time the shot while using “Bulb” mode.

Note: Always choose RAW formats, do not use JPEG. Also, always include a Dark Frame photograph, with the lens cap ON, which is used for noise level reduction in the software.

Note: There are older methods for setting the aperture and exposure time on a camera.

Do you remember the “Sunny Day 16” method for daytime photos?
There’s also the “Looney 11” method for full moons photos.

Sunny Day 16

	Sunny	Sunny	Cloudy Bright	Cloudy	Overcast
	Bright Sand or Snow	Distinct Shadow	Soft Shadow	Barely Visible Shadow	No Shadow
F-Stop	F/22	F/16	F/11	F/8	F/5.6
ISO 100	1/100	1/100	1/100	1/100	1/100
ISO 200	1/200	1/200	1/200	1/200	1/200
ISO 400	1/400	1/400	1/400	1/400	1/400
ISO 800	1/800	1/800	1/800	1/800	1/800

Looney 11

ISO-100	**f-11**	**Speed 1/100 or 1/125**
ISO-200	**f-11**	**Speed 1/200 or 1/250**
ISO-400	**f-11**	**Speed 1/400 or 1/500**

8. ISO settings: Typical cameras start their ISO at 50 and go to 2400, or higher. Some go to an extreme of ISO 102000!

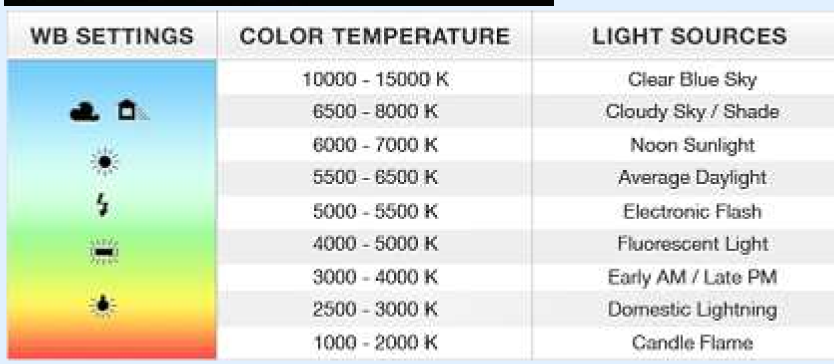
- Use a **Lower ISO** for **more details and less digital noise** but the **exposure time is longer**.
- A **High ISO** will get the image with **short exposure time** but with **more digital noise**.

(see Appendix D: AL *Reflector*, “Basic Small-Scope Lunar Imaging”, Jamey L. Jenkins, March 2019)

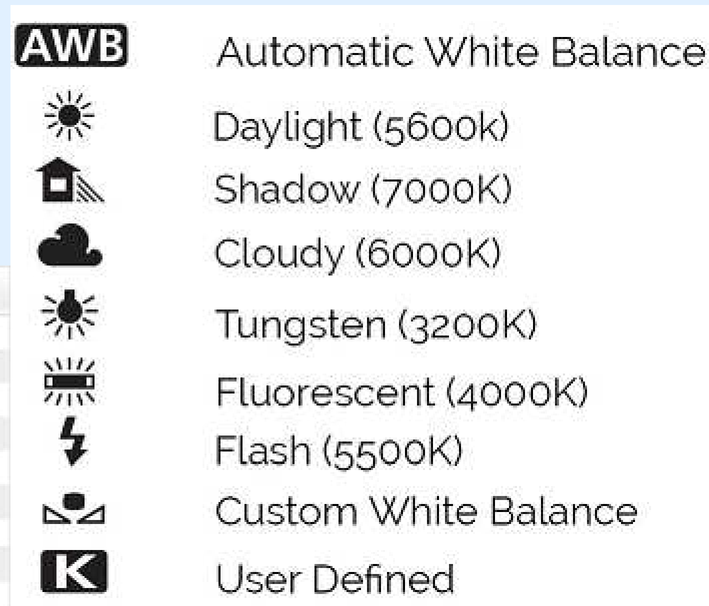
Dino Milani
Lunar Eclipse 1-20-19 1100pm
f-6.5 6-Seconds ISO-100

9. White Balance. Used to set the correct color for the photographed object.

- For JPEG images, set the White Balance to AWB (Average White Balance) or Cloudy.
- RAW images allow you to **correct** the WB in software to better match the objects color.



WB SETTINGS	COLOR TEMPERATURE	LIGHT SOURCES
	10000 - 15000 K	Clear Blue Sky
	6500 - 8000 K	Cloudy Sky / Shade
	6000 - 7000 K	Noon Sunlight
	5500 - 6500 K	Average Daylight
	5000 - 5500 K	Electronic Flash
	4000 - 5000 K	Fluorescent Light
	3000 - 4000 K	Early AM / Late PM
	2500 - 3000 K	Domestic Lightning
	1000 - 2000 K	Candle Flame

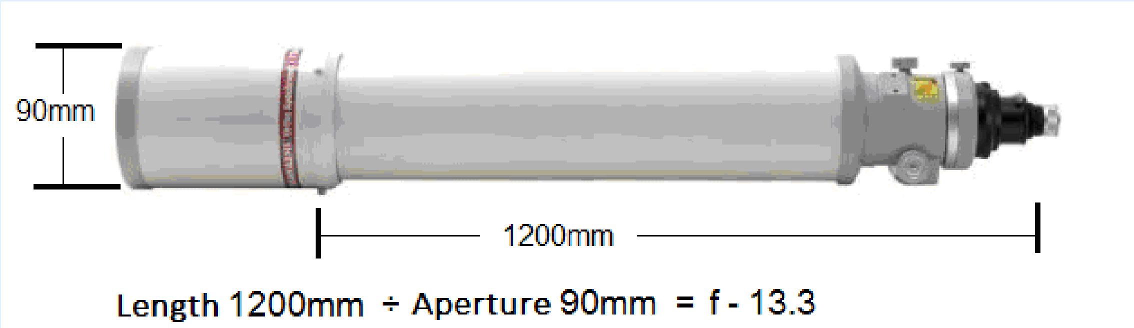


The "f-number" of the Telescope or a Camera Lens

f-number

To find the **f-number** (Telescope Length ÷ Aperture) for any lens or telescope:
Take the Length (total length of tube) divided by the Aperture size (width of lens) = f

Example: A telescope with an Aperture width of 90mm and a Length of 1200mm
1200 ÷ 90 = f-13.3



Note:

- **High f-numbers** (f-8 to f-16) means the area in focus is long but more light is needed for the image. Stars in that image usually do not show as much trailing as low f-number telescope but you need to expose the image much longer and use a high ISO. **Autoguiding** is often needed.
- **Low f-numbers** (f-2 to f-6) means the area in focus is short but the image gets more light in a shorter time. Stars do not show trailing unless the alignment is bad. The exposure time is much shorter and you can use a low ISO for better details (a sharper image).

Digital Cameras - ***Canon, Nikon, Sony and others***

Sensor sizes for still images and video recordings:

		(Lens Size x Crop = Apparent Size)
APS-C	16mm-24mm	1.5x-Nikon, 1.6x-Canon crop
4/3	22mm-18mm	2x crop
Full Frame	24mm-36mm	no crop

Sony Sensor

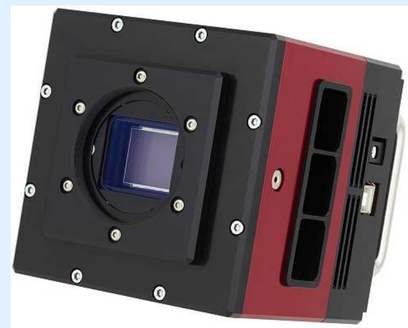
"Astro-Enhanced" digital cameras (i.e., Nikon D810A, Canon 6 Da, or others) have their IR filters removed from their sensors for better night imaging of reddish colors (hydrogen-alpha nebulosity).

CCD (charge-coupled device)

Traditional for video of dim targets with 1/2.7" to 2/3" sensor sizes and with BNC and power connections or USB (for both video and power).
They can be used for video and still images and for **Auto Guiding** the telescope.


ZWO asi120mc-s USB-3 camera

ZWO with filters kit


ATIK camera


Starlight Xpress SXVR-H18 w/filter wheel & cooling fan

Starlight Xpress SXVR-H18 w/cooling fan

CMOS (complementary metal-oxide semiconductor)

Traditional used on digital cameras. Used for video and still images of dim targets. 1/2.7" to 2/3" sensor sizes. Improved CMOS astrophotography camera sensors for still images and videos make this a valid camera for your images. They are often a superb camera for planetary, lunar, solar and meteor capture videos. Sensor sizes range from 2.99µm to 6.00µm or larger.

QHY 5III174 CMOS USB-3


QHYCCD QHY128C Cooled CMOS Color

Celestron NexImage 5-MP Color

Sensor Size Comparison

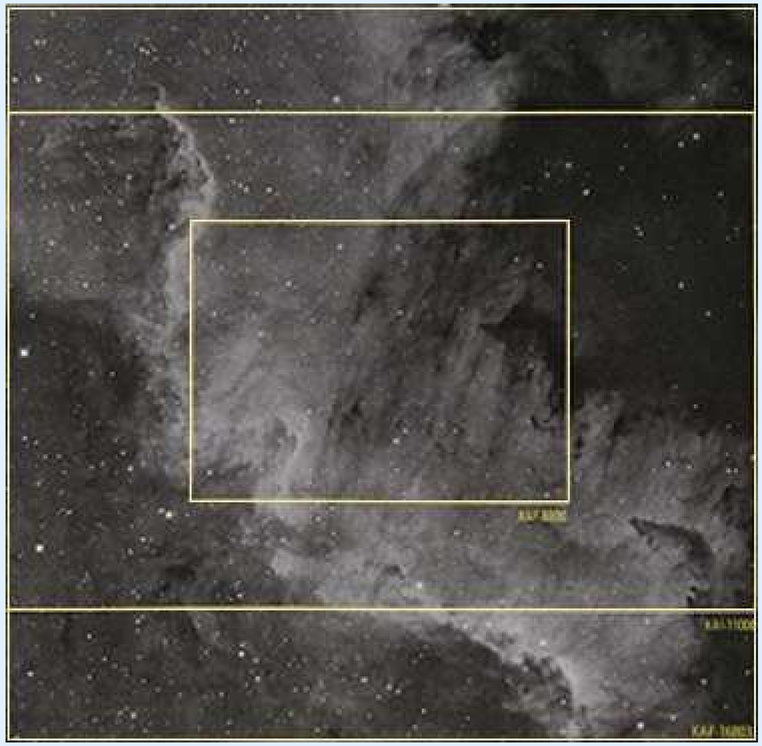
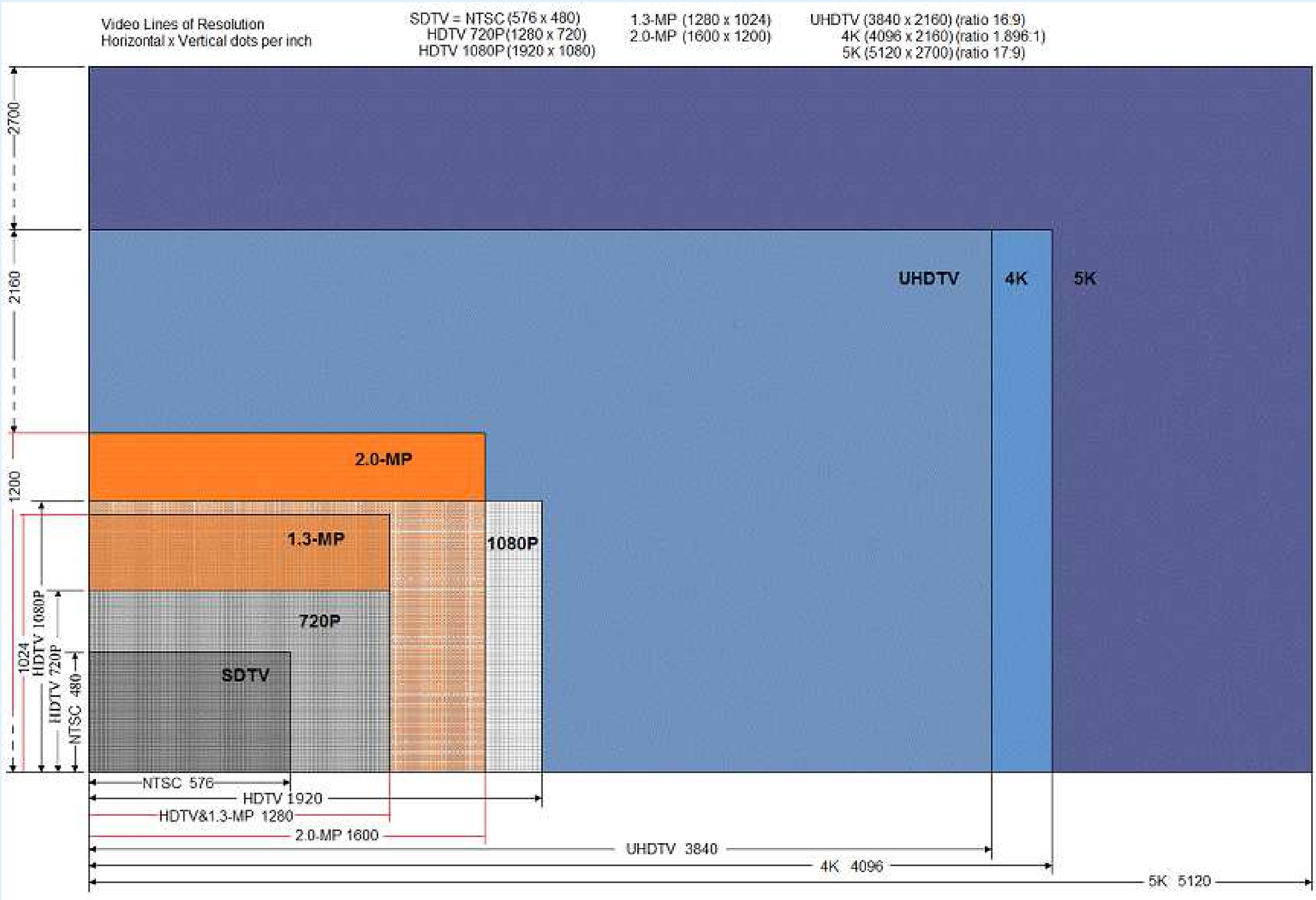


Image sizes for KAF-8300, KAI-1100 and KAF-16803 sensors.

(S&T July 2016, Dennis di Cicco, page 65)

(Image below shows different resolutions.)


Video Lines of Resolution
Horizontal x Vertical dots per inch
SDTV = NTSC (576 x 480)
HDTV 720P (1280 x 720)
HDTV 1080P (1920 x 1080)
1.3-MP (1280 x 1024)
2.0-MP (1600 x 1200)
UHDTV (3840 x 2160) (ratio 16:9)
4K (4096 x 2160) (ratio 1.896:1)
5K (5120 x 2700) (ratio 17:9)
UHDTV
4K
5K
2.0-MP
1.3-MP
1080P
720P
SDTV
2700
2160
1200
1024
HDTV 1080P
HDTV 720P
NTSC 480
NTSC 576
HDTV 1920
HDTV&1.3-MP 1280
2.0-MP 1600
UHDTV 3840
4K 4096
5K 5120

Cell Phone Cameras

Usually CMOS chips but with quickly changing designs for good results and a very light weigh.

- They are good for still images and video recordings.

New Sony 48-MP Smartphone Camera

Celestron NexYZ 3-Axis Universal Smartphone Adapter
Dial the phone left, right, in or out for the best image.

Specialty Telescope

Celestron Rowe-Ackermann Schmidt Astrograph (RASA) with a very low **focal length of f-2.2**.
The camera is attached at the front of the telescope.
Extremely sharp details in the image but with some vignetting when using an APS-C camera, so a full frame camera is needed.

Infra-Red, Heat Detecting & Specialty Cameras (A. to F.)

Sometimes expensive, but cool!

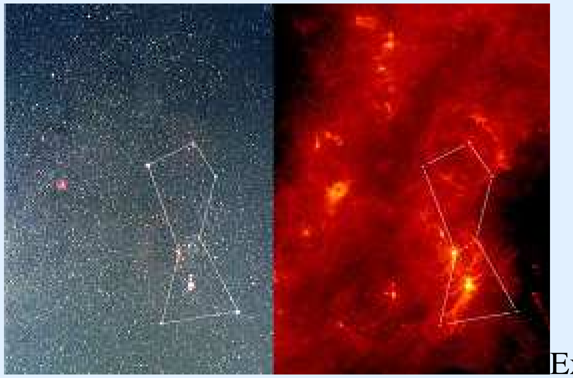
A. Infra Red Filter

An Infra Red Filter can be screwed on the telescope eyepiece (this is the least expensive option).

Photographer Jon Greif, April 29, 2017, 2130pm.
Stellarvue 90mm refractor, QHYCCD MiniCam 5F camera,
with Methane 12nm narrow band filter centered at 889nm.

B. Infra Red, Heat Vision & Night Vision Cameras (A. to F.)

Each camera has different lens and video connections and requires different equipment.
Your IR images may be small with reduced clarity (not a sharp focus) and with digital noise.


Example: ESA AKARI Telescope, Orion at 140 micrometres infrared wavelength.


MoviTHERM IRSX Smart Infrared video camera, with 2” telescope adaptor.

C. Commercial IR Video Cameras

Inexpensive CCTV (CCD) low-light video camera for night-time or Infra Red images.
Note: Recordings are usually done using H.264 video compression of the video file.


Commercial IR Camera with **C width threads** (lens connection thread size) lens attached.

Commercial IR Camera, **12mm-width threads** (lens connection thread size) and 25mm lens.

D. Commercial Heat Detecting Cameras

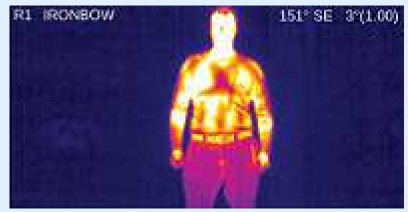
Difficult to connect to the telescope with **increased digital noise levels** on the images.

Larson Heat Detecting 3.1-MP Camera, with WiFi and Bluetooth, reads -40°C to 2,000°C, focuses from 0.45m to Infinity, $59,400.

Fluke Heat Detecting Camera, $1,300 to $1,999

E. Night Vision Cameras

Also difficult to connect to the telescope with **increased digital noise levels** on the images.



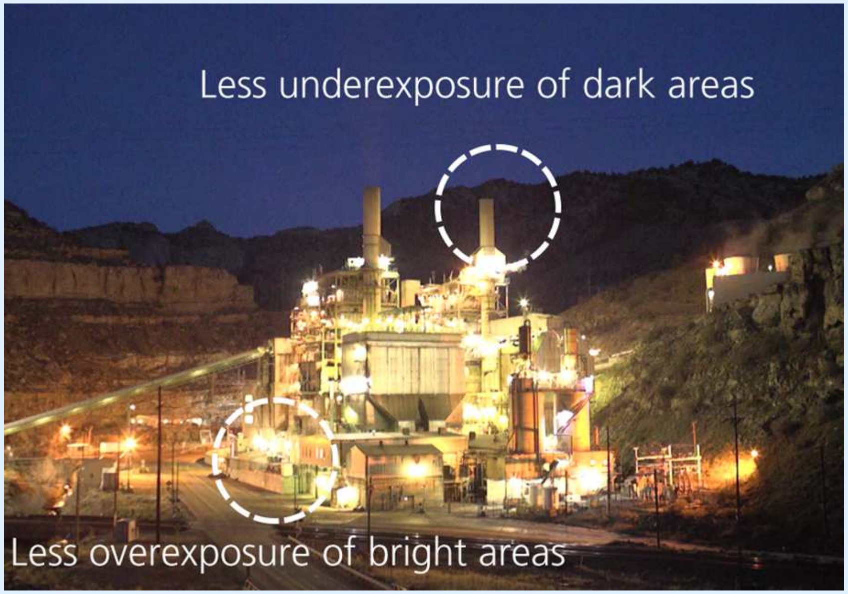
Flur Thermal Long-wave infrared sensitivity 7.5 - 13.5µm at $2,495

TNV/TVS Gen3 Pinnacle night vision $2,800

Note: Professional Infra Red, Heat Vision & Night Vision Cameras are expensive and difficult to use on your telescope. There are very few available for amateur astronomers.

F. Specialty Cameras

ME20F-SH Multi-Purpose Camera



The Canon ME20F-SH is a multi-purpose camera that utilizes an image sensor and image processing platform developed by Canon to achieve a minimum subject illumination of 0.0005 lux[1] or less[2], the highest sensitivity in the industry[3]. Even in dark places where it is difficult to discern subjects with the naked eye, this camera can make it look like images were captured in broad daylight. The camera is used for such applications as nighttime surveillance, natural-disaster confirmation and wildlife-related biological research.

The ME20F-SH, a balance of both has been considered, and the camera uses a resolution of 1,920 x 1,080 ideal for HD video recording as well as a large pixel size of 19 x 19 micrometers[4]. In addition, to ensure that the light that reaches each pixel can be converted to electricity without any waste, microlenses are positioned over the pixels to deliver as much light as possible to the photodiodes. Note: Canon EF Lens mount.

F. Specialty Cameras (Continued)

From: Sky & Telescope, “Insect Eyes on the Deep Sky”, Richard Wright, Jr. May 2019

The Dragonfly System: This is a multiple-stacked telescope. It has inter-connected hexagonal aluminum frames that have a camera lens and camera inside. **24 to 48 frames** are stacked together. Each frame has a Canon 400mm f-2.8 camera lens ($12,000 each) with an SBIG STF-8300M CCD camera, an Intel Compute Stick computer with Windows 10 and TheSky Professional software. The Intel computers are them controlled by a central server and the images saved.

Image of the 24 stack of cameras (Photos from Sky & Telescope, May 2019, pages 64 to 69.)

Spectroscopic Cameras & Home-Made Spectroscope

An alternate is to photos and video is to record **the spectrum of suns and planets**.
(see also; Reflector, "Adventures of a Starlight Detective", Jamey Jenkins, June 2018, pages 14-15.)

PIXIS Spectroscopic Camera 120 nm to 1100 nm (UV to NIR)

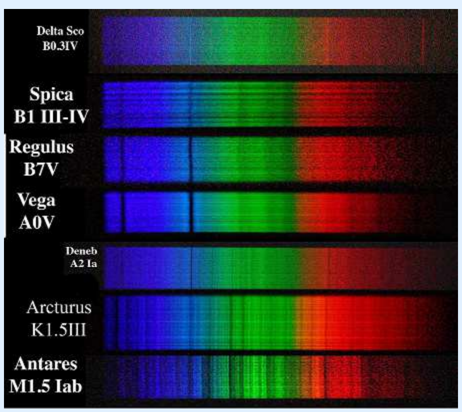
Home-made spectroscope, 500-lines-mm film, 12.5° bend
SA 100 Grating Filters can also be used

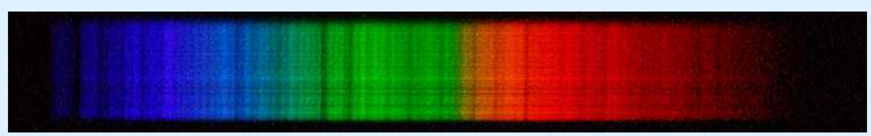
Rigel Systems RS-Spectroscope - attach to lens and camera

Spectroscope Image Viewing & Processing

Three applications for processing RAW image photographs (do not use JPEG format):

1. **Digital Photo Professional** (download from Canon): Converts RAW images from Canon's CR2 format to 8-bit TIFF (File, Convert and Save, 8-bit TIFF).
2. **Photoshop**: Cropping (Image, Crop), rotation (Image, Rotate Canvas) and skewing (Distort, Skew) of the spectrum image. Also use to generation the spectrum continuum image (Blur, Motion Blur, 0 degrees, 50 pixels).
3. **ImageJ** (freeware): Scale the spectrum continuum image (Process, Math, Multiply by 0.7) and then subtract (Process, Image Math, Subtract) from the cropped/rotated/skewed spectral image to enhance the spectral lines.
4. **Photoshop**: Finally, tweak the contrast (Image, Auto Contrast) of the final spectrum image.





Hardware for the Camera

Use a **Tripod** for non-tracing or a **Tracking Mount** to track the sky.
Note: If you wish better polar alignment (and better star tracking) on equatorial tracking mounts, use the **Pole Master.** It will give you a better polar alignment on your telescope.

Tripod

Camera Tracking Mount
(iOptron Sky Tracker)

Telescope Mount
(Equatorial Tracking)

To attach the camera directly to a telescope use a camera **T2 Adaptor** - with 42mm thread - and a **Prime-Focus Adaptor** or a **Tube T-Adaptor** - with 42mm thread.
Note: Astronomy cameras often have a 42mm thread connection.

Camera T2 Adaptor


1.25” Tube T-Adaptor

D-Mount ring with 42mm outside thread, 1” inside thread and 17.5mm back-focus length.
Note: A D-Mount ring will screw into the T2 adaptor (both have 42mm threads).


D-Mount 42mm outside thread, 1” inside thread for C-lenses

D-Mount with C sized lens attached

Prime Focus Adaptors connect the camera directly to the telescope end tube.
Example: 2” Telescope Nose Piece with 42 mm thread adaptor. This screws into the 42mm thread on camera’s T-Adaptor.

Prime Focus Adaptors with 42mm thread

Digital Camera Lens to CCD Camera Adaptor

FotoDiox is an Illinois manufacturer of cameras adaptors, including a **C-Mount Adaptor** for various cameras. A camera lens is mounted in front (sized per camera) and a C mount thread at the rear to connects a CCD camera to the lens. (Shown below with a Canon EF lens attached.)

Barlow at 2x, 2.25x, 3x, 4x or 5x. A Barlow is placed before the eyepiece or Adaptor and it multiplies the magnification of the image.
Note: A 2x Barlow doubles the magnification of the eyepiece.

Example: 12mm eyepiece + 2x Barlow ≈ 6mm

2x Barlow for 1.25” eyepieces

Focal Reducer. The 0.5X Focal Reducer cuts your telescope's focal length in half.
Sometimes needed to keep the image corners sharp (in focus).
Note: A 0.5x Focal Reducer divides the magnification of the eyepiece.

Example: 12mm eyepiece + 0.5x Focal Reducer ≈ 24mm

Field Flattener with Focal Reducer. Often used to make the full image sharp (and flat) without star elongations on the sides. They include a 0.8x **Focal Reducer - to reduce an f-7 focal ratio to f-5.6**.
Note: An M42 x .75” extension tube or spacer ring may be needed to make sure the back focus (distance from the back of the flattener to the sensor) matches that of the flattener/reducer (55 mm).
Note: A 0.8x Focal Reducer also divides the magnification of the eyepiece.

Example: 12mm eyepiece + 0.8x Focal Reducer ≈ 21.6mm

USB Cable used to power a USB camera and transfer the images to the computer. Different cables exist for USB-2, USB-3 and Connected USB (with screws). It's best to **tie down the cable** to the camera and the telescope to get better images so that there are no unwanted movements because the cable dropped or slipped.

USB-2

USB-3

Connected USB-2 Mini (w/screws)

Video cable with BNC or RCA Connectors

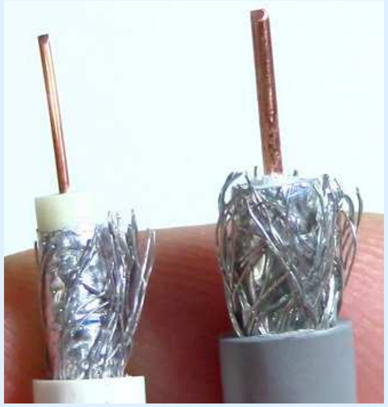
Used for transferring video images from the CCD or CMOS cameras to the computer. If possible, use an RG59 or RG6 video cable. Some video cameras often include a very thin and “cheap” video cable that can cause connection and video recording problems. Heavier RG59 and RG6 cables have fewer connection and transfer problems.

Note: With heavier RG59 and RG6 cables it’s best to **tie down the cable** to the camera and the telescope so that there are no unwanted movements because the cable dropped or slipped.

2nd Note: Some users like the cheaper and thinner cables because they move easily with the telescope (without being tied down) even though they sometimes cause connection problems.

Video Cable with BNC Male Ends

Video Cable with RCA Ends



RG59 and RG6 Cables

Camera on Telescope Mount

Various camera adaptors for telescopes and mounts are available.

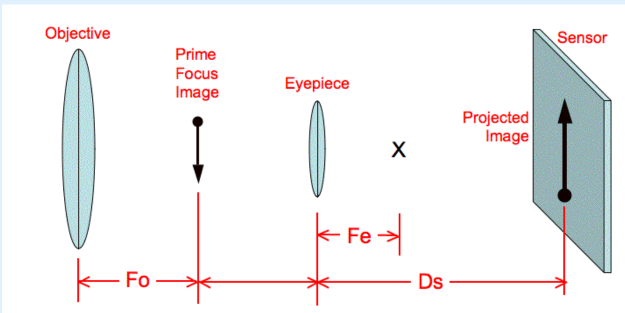
Home-made camera mount

Camera to Telescope Lens Adaptor – Quick-Adapt

"Quick-Adapt" for connecting the camera to a 2” eyepiece.
The top screw is an 8-32. Replace it with a 2” 8-32 screw for 1.25” eyepieces.

Eyepiece Projection with your DSLR Using Quick-Adapt (continued)

For DSLRs, prime focus astrophotography is the prefered method (see adapter below) but for planets and other small objects, especially with short focal length telescopes, the image may be too small to show much detail. **Eyepiece projection** with the camera lens removed from the DSLR provides a lot more magnification for small objects.



Quick-Adapt, ZWO camera, ball-head

In **eyepiece projection** the telescope's objective lens or mirror creates a prime focus image just in front of the eyepiece. The eyepiece collects the light from the prime focus image and reimages (projects) it onto the sensor in the DSLR. The effective **magnification boost** (M) obtained by eyepiece projection is calculated from the focal length of the eyepiece lens (Fe) and the distance from the eyepiece lens to the SLR sensor (Ds) as:

$$\mathbf{M = (Ds-Fe)/Fe}$$

The smaller the focal length of the eyepiece (Fe) and/or the greater the distance between the eyepiece the SLR sensor (Ds) the greater the magnification boost from eyepiece projection. Ds can be roughly measured from where the eyepiece lens body joins it's eyepiece tube (the part of the eyepiece that slides into the telescope 1.25 or 2 inch draw tube) to the camera's sensor plane.

Information from: http://rigel.datacorner.com/rigelsys/quikadapt.html

Color Filters and Specialty Filters

77mm Red Green and Blue Filters for B&W images – for B&W and Color images

Baader LRGB CCD Filter set – Luminance, Red, Green & Blue

#8 Light Yellow, #12 Yellow and #21 Red filters – for viewing Mars

ProPlanet 642 BP IR filter – for Black & White and Color images

Seymour Solar Film Sun filter – good for Black & White images

Baader Planetarium Fringe Killer Filter

Astronomik CLS Light Pollution Filter

Filter Wheels used to move filters in front of the eyepiece. Wheels can hold 4 to 8 filters.

Front side

Back side

Pole Master for better polar alignment: Per Mike Ombrello, *"The best equipment ever!"*

Pole Master with Connected USB-2 Mini cable (with screws)

Autoguiding using a Video Camera

Astro-video software often includes Autoguiding. With it, a star is tracked with a camera and the telescope is moved to keep the star aligned. It greatly improves keeping your telescope aligned for long exposures. Some filter wheels have a prism lens so an Autoguider can be attached to it.

An Autoguider cable is connected from the camera to the telescope's RS-232 serial controller port. The cable has 6 strands with RG-12 connectors (it looks like a three-line telephone cable).

Note: Autoguiding is included in Stellarium and Cartes du Ciel.

Starlight filter wheel w/autoguider

ZWO ASI174MM Mini (as Autoguider)

iOptron Telescope RS-232 Autoguide Port

Better Star Tracking - *for long exposures*

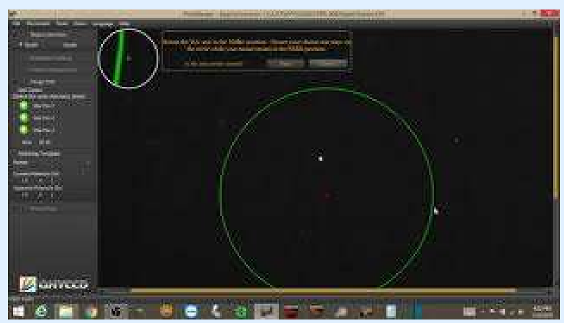
(see Appendix F: *Sky & Telescope*, “The Quest for Round Stars”, Ron Brecher, June 2019)

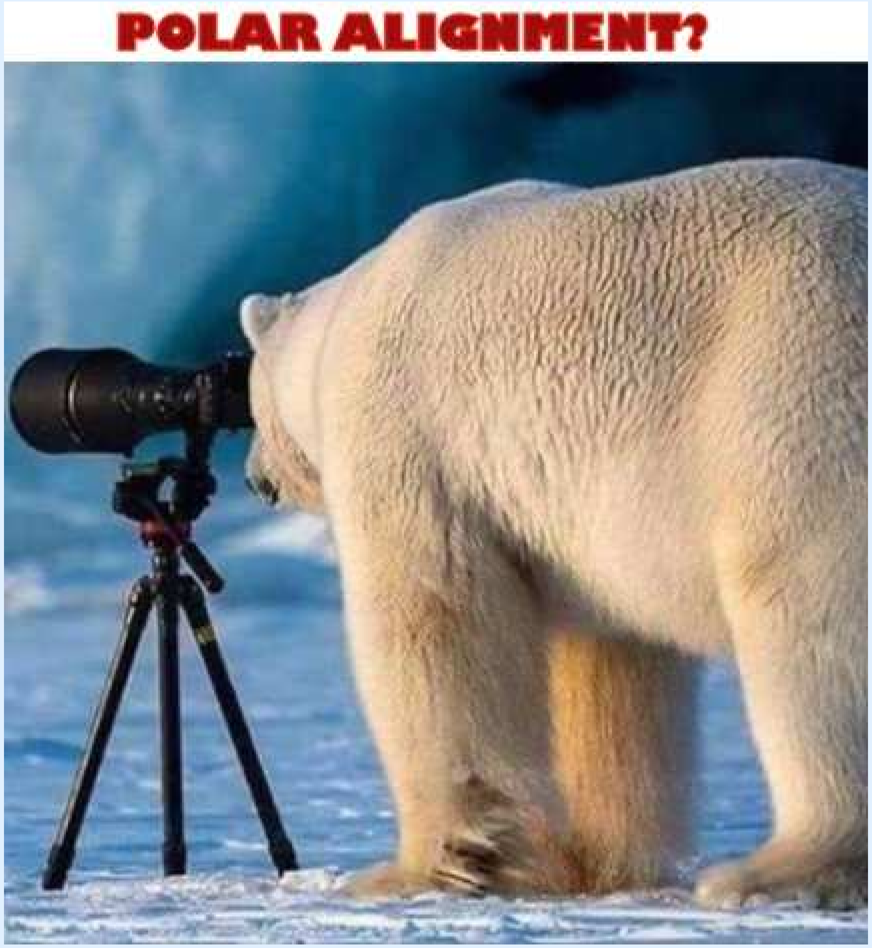
1. Align all items, tightly! No Loose Parts! Make sure all items fit correctly and tightly. Tie down all loose cables to prevent slips which can misbalance and flex camera parts and the telescope.

From *Sky & Telescope*, “The Quest for Round Stars”, Ron Brecher, June 2019

2. Poor Polar Alignment prevents correct tracking! Spend time to correctly align the telescope on the pole. Equatorial mounts often include a Polar Alignment Viewfinder. Use this to place Polaris in its correct position to the North Pole or the four stars for the South Pole.

One way to improve the Polar Alignment on **Equatorial Mounts** use **Pole Master.** It can improve the telescope's polar alignment. ALT-AZ mounts do not polar align. Some alignment issues occur but can be corrected with better star alignments and by using an Autoguider.





Thanks to Terry Dufek!

3. Instead of a 1 star alignment use a 2 or 3 star alignment for better tracking for longer times.

Elongation of stars in the image can be caused by **poor tracking of the stars**, as the sky revolves. Find the additional methods to improve the tracking on your telescope mount.

(Yes, that means reading the manual!)

Mounts using GPS have additional methods to improve its tracking

iOptron AZ Pro with 32-Point GPS. “Sync to Target” improves the local GOTO accuracy to the synced star.

4. Balance the telescope. A poorly balance telescope may cause the motor drive to halt, move too slowly or too fast and create tracking errors (periodic tracking errors).

- Place the camera, cables and all other equipment on the telescope before balancing it.
- First balance the telescope on the declination axis.
- Second, on the right ascension axis, move the counter weight on the shaft.

From *Sky & Telescope*, “The Quest for Round Stars”, Ron Brecher, June 2019

5. *Are items flexing out of place when the telescope is horizontal?*

1. Take images when the telescope is pointed up, then when it's sideways, to see if it moves out of place or stays correctly in place.

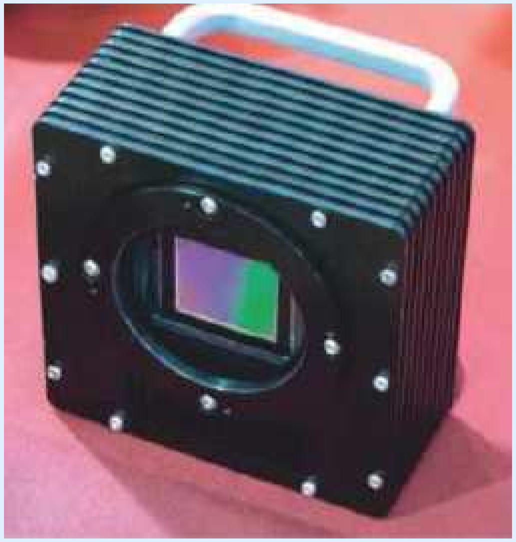
2. If images are good when pointed straight up but bad when horizontal then you have unwanted movement on the telescope.

3. Tighten all hardware to remove the flexing.

Note: Sometimes, the focuser bends too much when horizontal.
If that is so, replace the focuser with a stronger one.

6. Correctly Center the Camera - without tilting its sensor.

- This is more important if the camera has a large image sensor.
- Make sure the center of the sensor is aligned to the center of the telescope or eyepiece.



Sensor Collimation

"Cameras with large CCD and CMOS detectors are highly sensitive to having the sensor square to the telescope's optical axis. Some (such as the Starlight Xpress camera at left) include a push/pull adjustment plate at the front of the camera that allows users to fine-tune the squareness of the detector."

From *Sky & Telescope*, "The Quest for Round Stars", Ron Brecher, June 2019

Black & White, Black & White w/Color Filters & Color Imaging

It's a personal choice, B&W or Color?

Color images are quick to produce. One shot (even if it's a long one) gets the image.

B&W with color filters can bring out more details but require much more time to produce.

- B&W cameras produce color images by combining multiple photos, each with a color filter attached. One photo is taken with a Red filter, a second with the Green filter, another with the Blue filter and others with Luminance, H_α, O-III, S-II or IR, etc., and a black (dark) photo is taken which helps remove any "Hot Spots" added by the camera sensor.
- How much time is needed? If each photo needs 60 minutes exposure, then three photos need 180 minutes, 4 need 240 minutes, 5 need 300 minutes… This adds up quickly!

Note: Color cameras produce good color images but can miss the extra details seen with H_α, O-III and S-II filters used on B&W cameras.

Colors

Color temperatures in Kelvin (K)
Spectrum Colors in nanometers (nm)
RGB colors and Additive and/or Subtractive colors.

Degrees Kelvin	Type of Light Source	Indoor (3200k) Color Balance	Outdoor (5500k) Color Balance
1700-1800K	Match Flame		
1850-1930K	Candle Flame		
2000-3000K	Sun: At Sunrise or Sunset		
2500-2900K	Household Tungsten Bulbs		
3000K	Tungsten lamp 500W-1k		
3200-3500K	Quartz Lights		
3200-7500K	Fluorescent Lights		
3275K	Tungsten Lamp 2k		
3380K	Tungsten Lamp 5k, 10k		
5000-5400K	Sun: Direct at Noon		
5500-6500K	Daylight (Sun + Sky)		
5500-6500K	Sun: through clouds/haze		
6000-7500K	Sky: Overcast		
6500K	RGB Monitor (White Pt.)		
7000-8000K	Outdoor Shade Areas		
8000-10000K	Sky: Partly Cloudy		

Based on information from the book [digital] Lighting & Rendering
Chart and colors (c)2003 Jeremy Birn for www.3dRender.com

Color Designations in Photoshop and Spectrum Wavelengths

Red 640nm 0º or 360º

H 0 S 100 B 100	L 54 a 81 b 70
R 255 G 0 B 0 #ff0000	C 0 M 99 Y 100 K 0

Green 540nm 120º

H 120 S 100 B 100	L 88 a -79 b 81
R 0 G 255 B 0 #00ff02	C 63 M 0 Y 100 K 0

Hα 656nm

H 0 S 100 B 88	L 48 a 73 b 63
R 224 G 0 B 0 #e00000	C 6 M 100 Y 100 K 1

S-II 672nm

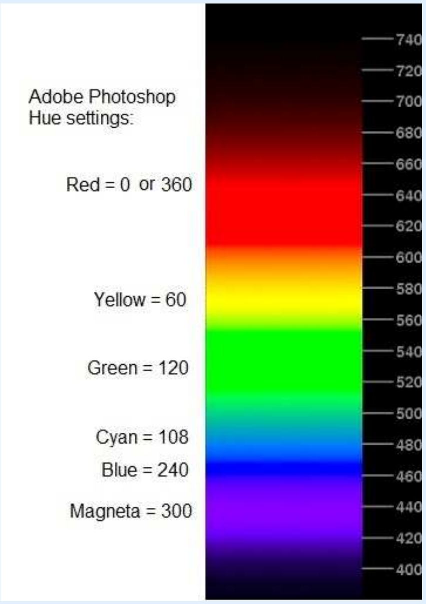
H 0 S 100 B 49	L 25 a 47 b 38
R 124 G 0 B 0 #7e0000	C 29 M 100 Y 100 K 40

Blue 440nm 240º

H 240 S 100 B 54	L 13 a 43 b -71
R 0 G 0 B 137 #000089	C 100 M 98 Y 11 K 12

O-III 500nm

H 156 S 100 B 84	L 76 a -60 b 29
R 0 G 214 B 130 #00d682	C 68 M 0 Y 70 K 0

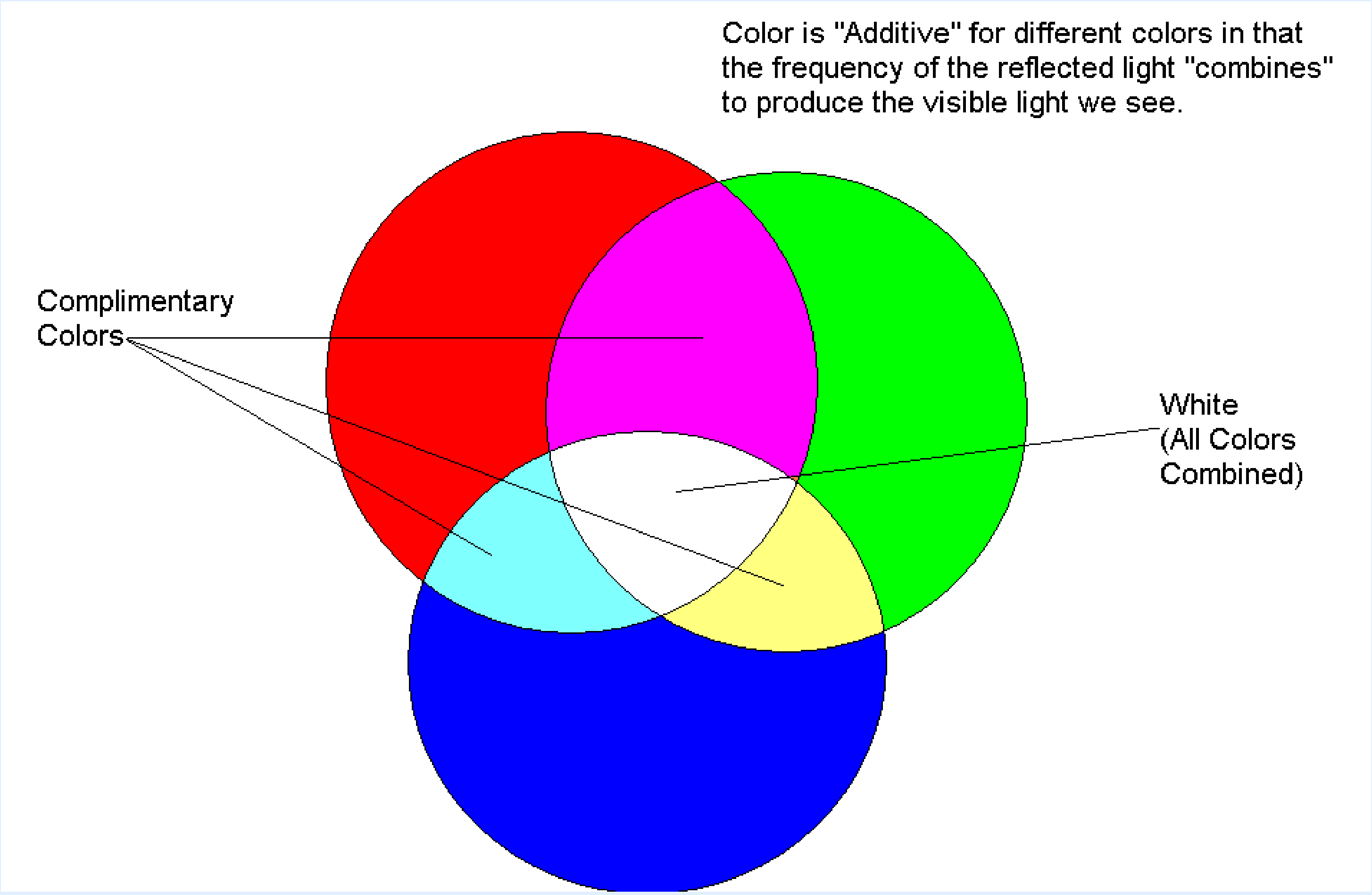


2 Samples:
(from Hubble ST Cameras)

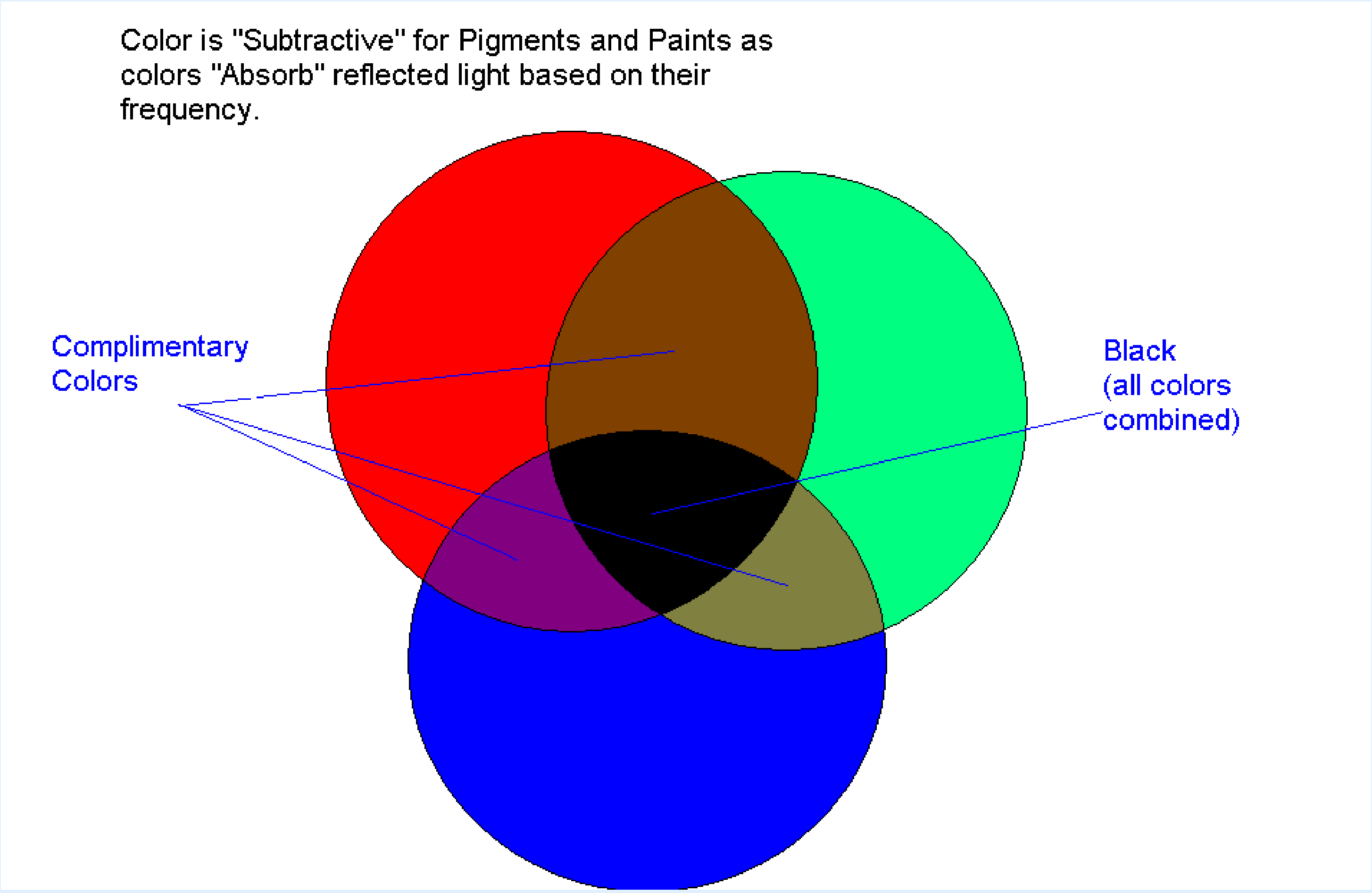
93u/5306W I336W
f439w 439w
f555wa 555w
f547m 547m

SN1987a LMC Super-Nova Cluster
x0c9101t 597s
x0cj010bt 822s

Additive Colors – Red, Green, Blue, Cyan, Magenta, Yellow and White



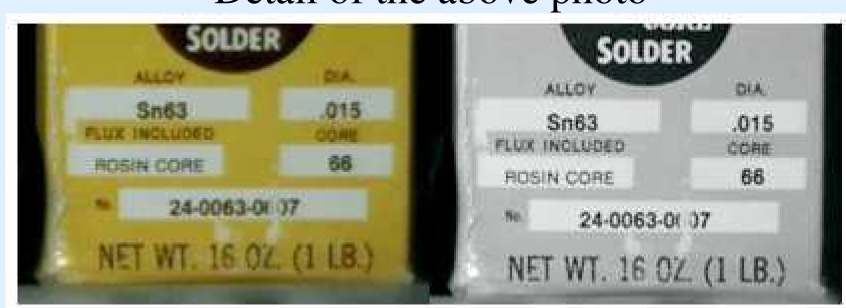
Subtractive Colors – Red, Green, Blue, Brown, Purple, Tan and Black



Sample Image in Color and Black & White

Note: More details are visible in the B&W image than in the color image. The word "Shimano" is clearly visible in B&W but not as visible in color.

Detail of the above photo



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Software for Capturing Images and Video

1. Recording (Sharpcap or Fire Capture or Digicam)
   Note: Use 8-bit instead of 16-bit recordings and no Bayer stacking.

2. Stacking (Registax, AutoStakkert, Deep Sky Stacker or others such as live stacking with Sharpcap)
3. Enhancing images (Registax, Photoshop or Lightroom)
4. Post editing (Registax, Photoshop, Lightroom, RGB Color designation, Sharpening and High Dynamic Resolution - HDR)
5. FITS (Sharpcap, Fire Capture or Photoshop FITS Liberator) for full frame images and improvements on some images.

   (see Appendix B: “Create your own Color Hubble Images”, Zolt Leva)

   NASA FITS: http://hla.stsci.edu

   Best Images From the Hubble ST cameras:
   WFPC2 Wide Field and Planetary Camera 2
   WFC3 Wide Field Camera 3
   ACS Advanced Camera for Surveys
   Narrowband Filters Used: F435W, F439W, F450W, F555W, F606W, F675W, F702W, F791W, F814W
   Wideband used Filters Used: F437N and F502N (O-III), F656N (H-Alpha), F658N (N-II), F673N (S-II)

   FITS Viewer
   http://fits.gsfc.nasa.gov/fits_viewer.html

NASA FITS (continued)

FITS Libraries
http://fits.gsfc.nasa.gov/fits_libraries.html
http://www.cv.nrao.edu/fits/
samples:
http://www.cv.nrao.edu/fits/data/samples/hst/

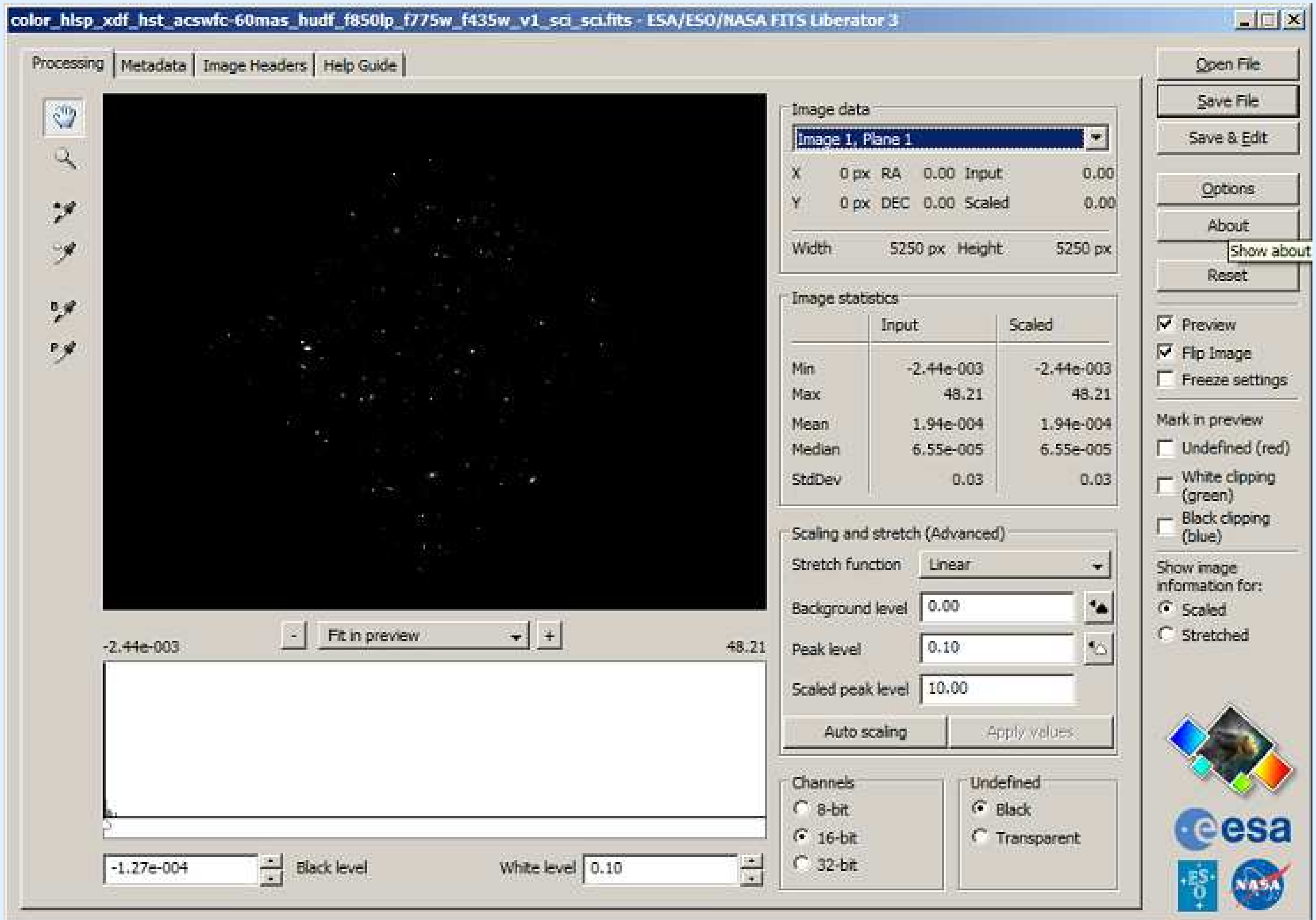
Image Processing Resources for Astronomy Teaching
http://www.phy.duke.edu/~kolena/imagepro.html

FITS Liberator
http://www.spacetelescope.org/projects/fits_liberator/

M51 Site
http://www.spacetelescope.org/images/heic0506a/

Band Wavelength Telescope
Optical B 435nm Hubble Space Telescope ACS
Optical V 555nm Hubble Space Telescope ACS
Optical H-alpha + Nii 658nm Hubble Space Telescope ACS
Infrared I 814nm Hubble Space Telescope ACS

Note: Magazines are available on Astrophotography: (example)
https://www.amateurastrophotography.com/magazine



FITS Program viewing the Hubble Deep Field

Techniques for Eclipses, Northern Lights & "Quick" Events

Transit of Venus from Jabiru, Kakadu National Park, Australia
06 June 2012 Local Jabiru Time
1st Contact 7:46:40:06 am
2nd Contact 8:04:44:03 am
3rd Contact 1:58:10:53 pm
4th Contact 2:15:28:15 pm

Roy observing transit with beautiful weather.
Nothing is too dangerous for PAC members!
(Note the crocodiles wanting to visit Roy...)

Lunar Eclipses allow you more time for your photographs. Take photos every few minutes.

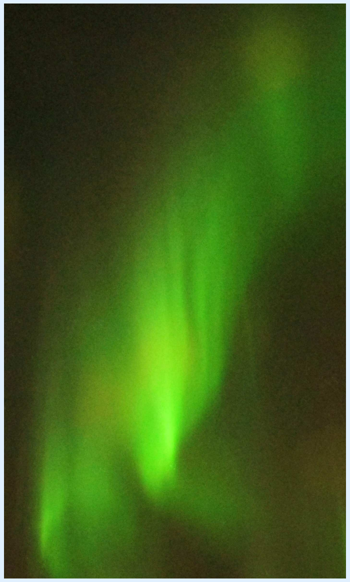
Camera Settings for a Lunar Eclipse - Times in Seconds with f-numbers

Event	**ASA 100**	**ASA200**	**ASA 400**	**ASA 800**
Full Moon	1/250 f/11	1/250 f/16	1/250 f/22	1/500 f/22
Penumbra Shadow	1/60 f/11	1/60 f/16	1/125 f/16	1/250 f/16
2nd and 3rd contact	1 f/2.8	1 f/4	1/4 f/2.8	1/8 f/2.8
Totality	2 f/2	2 f/2.8	1 f/2.8	1/2 f/2.8

Solar Eclipses are quick! So practice setting everything up and take practice photographs. You only have a few seconds before the eclipse is gone. Remove your solar filters during the full eclipse to image the corona but be sure to not view through the telescope or camera when the sun emerges or you will **permanently damage your eyes!** Replace the solar filter for the rest of the solar eclipse.

Northern Lights or *Aurora Borealis*

- Dark areas are best for to see and photograph the northern lights.
- Set your camera on a tripod and take long exposures of 30 seconds to several minutes.
- Keep the ISO setting low (ISO-50 to ISO-800) and increase it only if you cannot get enough detail.



Taken in Norway above the Arctic Circle, December 2013, Sylvia Roba

Urban Photography Problems and Some Solutions

Light Pollution Filters, Urban Filters and others

- Broadband filters keep bad light out and let good light in. They are best for viewing galaxies and star clusters whose own light spans the entire visible spectrum.
- Narrowband filters aggressively block light pollution, but dim star clusters and galaxies. The filters are for spectral bands such as hydrogen and oxygen emissions. They are both light-pollution and nebula filters.
- Light-pollution filters block the colors emitted by older streetlights and transmit light from objects in the sky.
- Oxygen-III filters transmit only a narrow slice of the spectrum for oxygen ions emitting a greenish light. They enhance planetary nebulae and a few supernova remnants.
- Hydrogen-beta filters transmit one blue-green emission line from hydrogen atoms. They are optimal for extremely faint targets, i.e. the California Nebula, IC 434 and the hydrogen gas in the Horsehead Nebula.

The trouble with the new LED Lights

The new LED lights appearing in cities usually are “Blue” in color - about 5000-K - and may prevent light pollution filters from working. There are other LED lights with better colors – “soft white” at 3200-K – but manufacturers have been using 5000-K lights and many never change. Try to find areas where the majority of the light is blocked by buildings, fences, etc.

next

Part 2: Planetary and Deep Sky photography - Terry Dufek

then

Part 3: R2 demonstration - Rusty Case

Finally…

Time to Answer Your Questions!

Appendix A: “Using Firecapture”, Terry Dufek

USING FIRECAPTURE (TIPS)

- Set up capture folder
- Save default camera settings (if needed)
- Center object in the view screen for the appropriate resolution used.
- Use Region of Interest (ROI) to reduce file size for faster processing
- Set up gain and exposure (review histogram until it is about 60 - 70% **BUT** try to get 80-90%)
- Frame rate should be low 90 – 100 fps
- USB set at about 80 (under more settings)
- Time of exposure 1 ½ minutes (8000 frames) Jupiter
- Set gamma about 50 (or **try turning gamma off**)
- Set camera profile settings
- Set camera filter settings (?)
- Set length of time of exposure
- Set video type (AVI or SER) most common types – uncompressed
- Set auto align
- Set up crop to cut down excess video recording
- Debayer **unchecked** (checked will show you a color version)
- Then check color balance levels before unchecking debayer
- RESTORE or SAVE camera settings is under control/ more (side arrow down)

CAPTURE SECRETS

- Find the sweet spot of your imaging system. Have a capture routine for each target object.
- Make sure your filename includes the UT date and time. Use the fastest frame rate possible.
- Don’t be afraid to push gain to Don’t be afraid to push gain to 100%.
- Turn off Gamma!!
- Spend time to focus the telescope.
- Use Region of Interest (ROI) to reduce file size for faster processing.

JUPITER

- Keep histogram level around 80 to 90% on all channels.
- Keep total integration time below 2 minutes.
- Use focal length of around 30X of your aperture 5-micron pixel your aperture 5 micron pixel cameras and 20X the aperture for 3.75 micron cameras.

SATURN

- Saturn has very low surface brightness.
- Use Winjupos Derotation so that the final image will be smooth.
- Use 50% histogram level for red and green and 30% for blue.
- Keep total integration time to around 3 minutes.
-

MARS

- Use focal length around 50X the aperture for 5 micron pixel cameras and 30X the aperture for 3.75 micron cameras.
- Keep histogram level of the Red Channel at around 8090%.
- Keep Green at around 90%.
- Keep Green at around 60-70% and Blue around 30 - 40%.
- Total integration time can be as long as 4 minutes.
- UV-IR should be blocked to get true colors. Make sure your blue channel has no IR leakage.

Website for Firecapture:
http://www.firecapture.de/'

The tutorial videos take a while to go through but #2 is where he [the author] uses the program:
https://www.youtube.com/watch?v=DJ1SpbCmM9U&t=21s

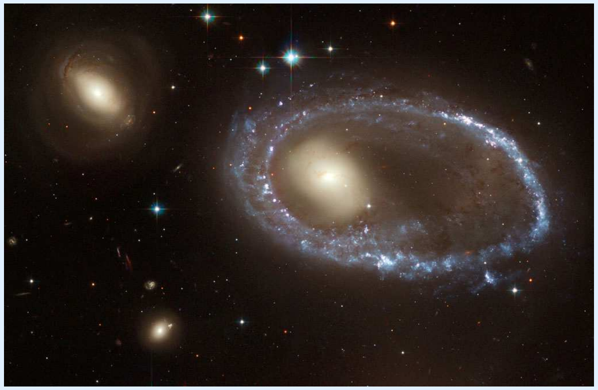
Terry Dufek

Appendix B: Create your own Color Hubble Images, Zolt Leva

Create your own Color Hubble Images
Zolt Levay, Office of Public Outreach

Until recently, making presentable images from Hubble data has been fairly cumbersome, requiring some experience with specialized software such as IRAF or IDL, used to analyze astronomy data. Now the process has been significantly streamlined with the introduction of the Photoshop FITS Liberator. If you have a basic understanding of astronomical data, digital photography and a working knowledge of Adobe Photoshop you can transform astronomical data in the FITS format into pretty pictures, in black and white or in color. The resulting images may be used as any digital photo: reproduced in print, displayed on a web page, emailed, etc.

FITS, the Flexible Image Transport System is a file format used for many years in astronomy to store and move images from telescope-based instruments. It has been designed to provide capabilities needed by astronomers but is not a generally known format such as JPEG or TIFF.



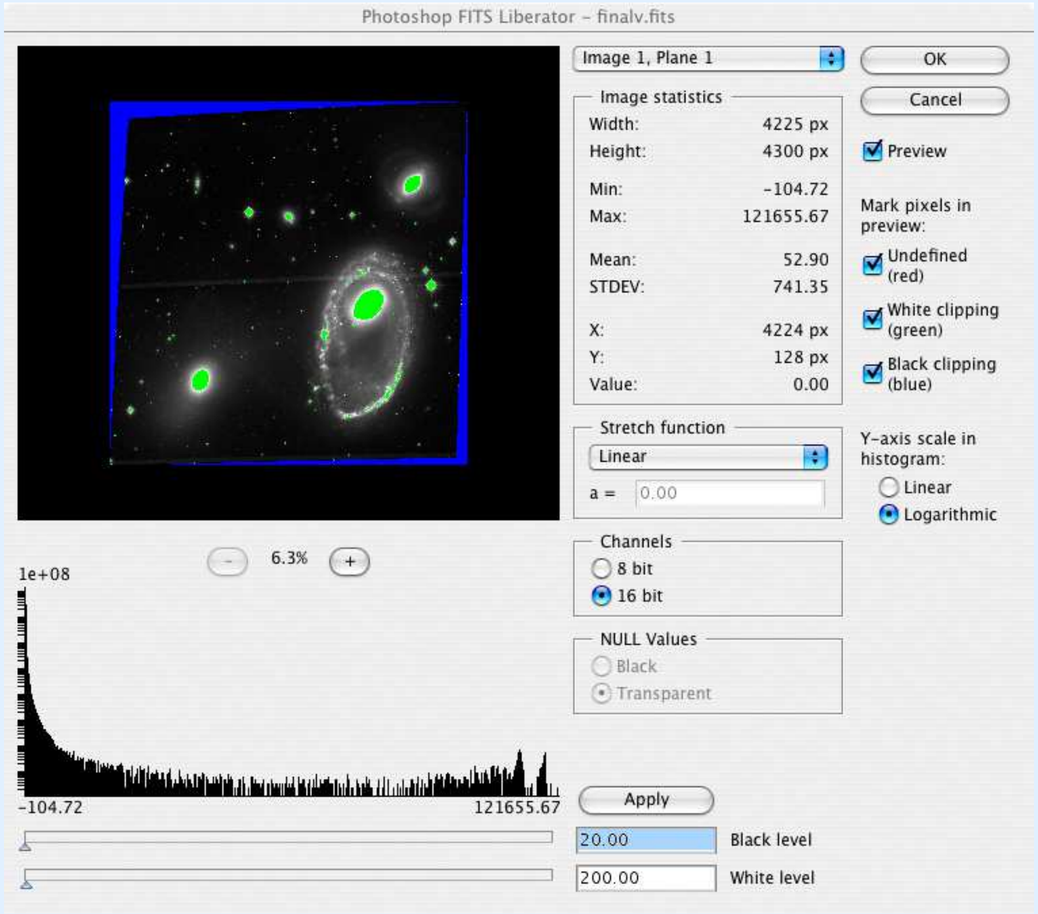
Adobe Photoshop is the industry-standard “digital darkroom” software for working with photos. It includes many tools to work with images to improve tonal range, color, contrast, in addition to combining multiple exposures, adding annotation, and a whole suite of more artistic capabilities. But Photoshop has not recognized FITS data, until now.

The Software

The primary tool in the process is a software plugin to Adobe Photoshop called the FITS Liberator. This free software was developed by the European Space Agency (ESA), European Southern Observatory (ESO) and the National Aeronautics and Space Administration (NASA) and is available for free download from ESA along with instructions for the simple installation, sample data, and much more information. See this page in our Content Creator’s Toolbox for more information.

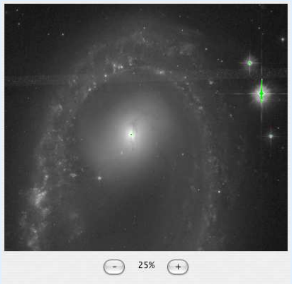
The plugin is available for PC/Windows and Mac systems and works identically on both. It provides full functionality with Photoshop CS (also known as version 8.0) but it also works with Photoshop version 7.0 as well as Photoshop Elements versions 3.0 and 2.0, with more limited functionality.

After installing the plugin, Photoshop recognizes FITS files as a known, native format. To begin, start Photoshop and open a FITS image using the File > Open (keyboard shortcut: CTRL/CMD+O). You will see the FITS Liberator dialog:



The main components of the dialog are:

- The **preview window** at uper left shows a representation of the image as it will appear once opened in Photoshop. The image initially is sized to fit entirely within the window but the "+" and "-" buttons below may be used to zoom in and out. In addition, clicking and dragging within the window will pan a zoomed image.

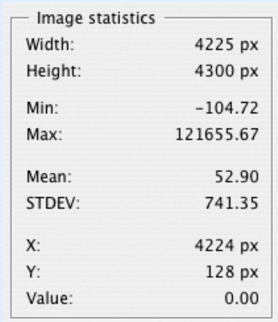


- A **"histogram"** below plots the number of pixels of each data value in the image.

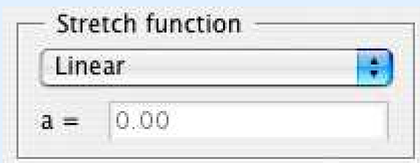
- **Sliders and numeric input** to specify the range of data values to import.

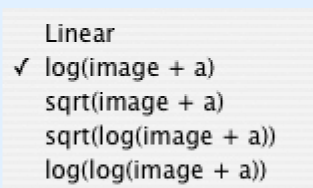
- A **menu of the available image planes/extensions,** if applicable to the FITS data.

- **Image statistics** include image size, minimum and maximum data value, etc. Moving the pointer within the display window shows the location and value of the pixel at the pointer's location.



- The **"stretch function"** specifies how the image data values should be transformed into pixel values in the Photoshop document. Selections are: linear, log, square root, sqrt(log) and log(log).





- Various **switches** control other functionality: whether to use 8-bit or 16-bit channels in the Photoshop document, whether to translate FITS null values to black or transparent pixels, whether to show the image preview, how to preview out-of-range pixels, and how to display the histogram.

The Data: Obtaining FITS Images

The FITS Liberator will accept valid FITS data from any source. Several sample datasets from various sources are available from the European Space Agency.

Data from Hubble Space Telescope and several other missions are available from the Multimission Archive at Space Telescope (MAST) . Because of the size and complexity of the archive and the data, only a very brief introduction will be given here. Various tools are available for searching and retrieving data from the extensive collections, from a very comprehensive cross-mission search, to more directed search by specific mission, coordinate, instrument, etc., or more sophisticated searches by pointings (HST only), scrapbook , etc. For a limited set of observations, initial processing has been performed to produce High-Level Science Products more suitable for display and analysis than individual datasets.

Once the desired observations are identified, datasets may be retrieved from the archive, made available via anonymous ftp (alternately, you may register as an archive user). Complete instructions and tutorials are online and help is available via email.

Be aware that HST image datasets are quite large, and observation sets generally include numerous exposures. Be prepared with plenty of disk space and RAM. A single HST ACS/WFC exposure from the archive is a 170MB FITS file. A single WFPC2 exposure is 10MB. Many HST datasets available from MAST can be used as-is. In some cases, "on-the-fly" processing (OTF) combines associated datasets into a single image. Others require more extensive processing after retrieval to produce useable data.

Orange
Cyan
Blue
Green
Yellow
Red
Purple
Infra Red

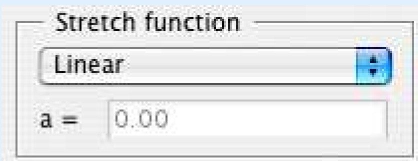
Colour	Name (In NanoMeters)	Type	Wheel	Slot	Notes	In WF/PC-1?	$\overline{\lambda}$(Å) Angstroms	$\Delta\overline{\lambda}$(Å)	Peak T (%)	Peak λ (Å)
	F122M	A	1	4	H Ly α - Red Leak	Y	1259	224.4	19.3	1240
	F130LP	B	2	1	CaF2 Blocker (zero focus)	N	2681	5568.3	94.5	8852
	F160AW	A	1	3	Woods A - redleak from pinholes	N	1471	457.2	10.1	1403
	F160BW	A	1	2	Woods B	N	1446	457.1	12.1	1400
	F165LP	B	2	2	Suprasil Blocker (zero focus)	N	3301	5533.2	95.4	5796
	F170W	A	8	1	-	N	1666	434.6	30.7	1655
	F185W	A	8	2	-	N	1899	297.4	25.9	1849
	F218W	A	8	3	Interstellar feature	N	2117	367.9	21.1	2092
	F255W	A	8	4	-	N	2545	408.2	14.8	2489
	F300W	A	9	4	Wide U	N	2892	727.6	50.8	2760
	F336W	A	3	1	WFPC2 U, Strömgren *u*	Y	3317	370.5	82.6	3447
	F343N	A	5	1	Ne V	N	3427	23.5	9.3	3432
	F375N	A	5	2	[OII] 3727 RS	Y	3732	24.4	19.5	3736
	F380W	A	9	1	-	N	3912	694.8	65.0	3980
	F390N	A	5	3	CN	N	3888	45.0	36.5	3886
	F410M	A	3	2	Strömgren *v*	N	4086	147.0	70.4	4097
	F437N	A	5	4	[OIII]	Y	4369	25.2	52.0	4368
	F439W	A	4	4	WFPC2 B	Y	4283	464.4	68.2	4176
	F450W	A	10	4	Wide B	N	4410	925.1	91.4	5060
Blue	F467M	A	3	3	Strömgren *b*	N	4663	166.4	75.3	4728
Blue	F469N	A	6	1	He II	Y	4694	25.0	52.4	4697
Cyan	F487N	A	6	2	H β	Y	4865	25.9	58.6	4862
Green	F502N	A	6	3	[OIII]	Y	5012	26.9	63.7	5008
Green	F547M	A	3	4	Strömgren y (but wider)	Y	5446	486.6	91.3	5360
Green	F555W	A	9	2	WFPC2 V	Y	5202	1222.6	94.6	5148
Green	F569W	A	4	2	F555W generally preferred[a]	Y	5524	965.7	94.2	5310
Yellow	F588N	A	6	4	He I & Na I (NaD)	Y	5893	49.0	91.4	5894
Orange	F606W	A	10	2	Wide V	Y	5767	1579.0	96.7	6186
Red	F622W	A	9	3	-	Y	6131	935.4	95.6	6034
Red	F631N	A	7	1	[OI]	Y	6306	30.9	85.7	6301
Red	F656N	A	7	2	Hα	Y	6564	21.5	77.8	6562
Red	F658N	A	7	3	[NII]	Y	6591	28.5	79.7	6591
Red	F673N	A	7	4	[SII]	Y	6732	47.2	87.0	6732
Purple	F675W	A	4	3	WFPC2 R	Y	6714	889.5	97.3	6780
Purple	F702W	A	10	3	Wide R	Y	6940	1480.6	97.1	6538
Infra Red	F785LP	A	2	3	F814W generally preferred[a]	Y	9283	2096.1	91.7	9959
Infra Red	F791W	A	4	1	F814W generally preferred[a]	Y	7969	1304.6	95.9	8082
	F814W	A	10	1	WFPC2 I	Y	8203	1758.0	94.8	8387
	F850LP	A	2	4	-	Y	9650	1672.4	89.2	10028
	F953N	A	1	1	[SIII]	N	9546	52.5	95.6	9528
	F1042M	A	11	2	-	Y	10437	611.0	81.6	10139

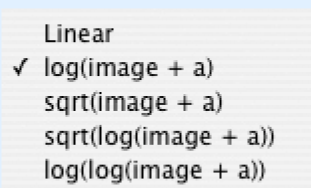
a. Filters F555W and F814W are generally preferred, as they are part of the "standard" WFPC2 filter set, and will tend to have slightly better photometric calibration.

The Process: Making a Black & White Image

The key element in producing presentable images from data is how to scale the image from the pixel values in the input file into values in the image that are displayed as a range of gray brightness levels. This is accomplished by selecting the range of input values and specifying the function to transform the input data into displayed pixel values. Astronomical images tend to include a very large range of brightness levels, from the very dark sky background to much brighter stars, galaxy nuclei, etc. Often small numbers of pixels have values well outside the usual range. "Dead" detector elements or other causes can result in values of zero or much less than the normal sky background. Cosmic rays can produce much higher counts than moderately bright stars. Using a data range including the minimum and maximum data values often does not produce a very exciting image. Although celestial objects appear very dim in the sky to our eyes, long exposures with sensitive detectors on large telescopes yield a large range of numerical values in the resulting images (technically referred to as large dynamic range, made possible by image formats with high bit-depth).

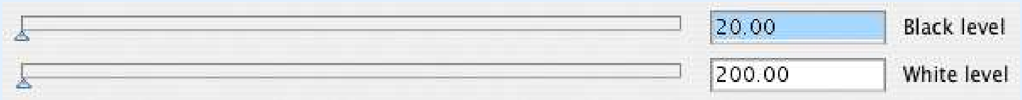
Select the function from the “stretch function” menu.





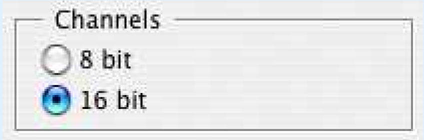
In many cases, log scaling provides the best results for astronomical images. This conveniently serves to enhance contrast and bring out details in the darker areas of the image, where the interesting stuff often goes on in astronomical images. In addition, it suppresses the much brighter areas such as the centers of stars, where the detail is not so critical. Sometimes square root (sqrt) stretch works better for certain types of images. Try different functions to see which result appears more pleasing in the preview.

FITS Liberator will select an initial data range based on the distribution of data values, but will most likely not produce the best image. Adjust the data range using either the sliders under the histogram plot or the numeric input values labeled “Black level” and “White level”. You will see the result in the preview display. As you increase the black level the image will darken overall and whole areas will become black (clipped). If the “Black clipping” check box is selected those pixels whose value is smaller than the black level will show as blue in the preview but will become black in the Photoshop document. Conversely, as you decrease the white level, the image will brighten overall and more pixels will become white (saturated). If the “White clipping” check box is selected the pixels whose value is greater than the white level will show as green in the preview and will become white in the Photoshop document. You can experiment with the data range to achieve a pleasing result.



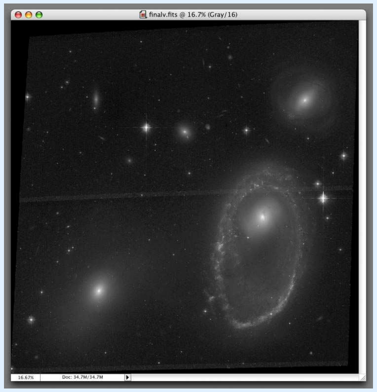
By paying attention to the out-of-range indicators in the image preview, it is possible to scale the image such that the background (shadows, in photo terminology) is dark, but not completely clipped and the brightest areas (highlights) are not saturated or rendered totally white.

Select whether to scale the data to 8-bit or 16-bit pixels in Photoshop.



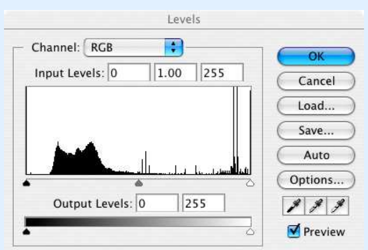
The advantage of using 16-bits/pixel channels is that there are many more gray levels available. The disadvantage is that it makes the resulting image files twice as large in disk storage. Having more gray levels available means that you can adjust the image a great deal.

When you are satisfied with the result, click “OK” to accept the image as adjusted and read the image into a black and white (gray) Photoshop document. Note that there is no provision for automatically recording the settings, so you may wish to write down the scaling function and black and white levels. The result will be a gray image in a Photoshop document window:

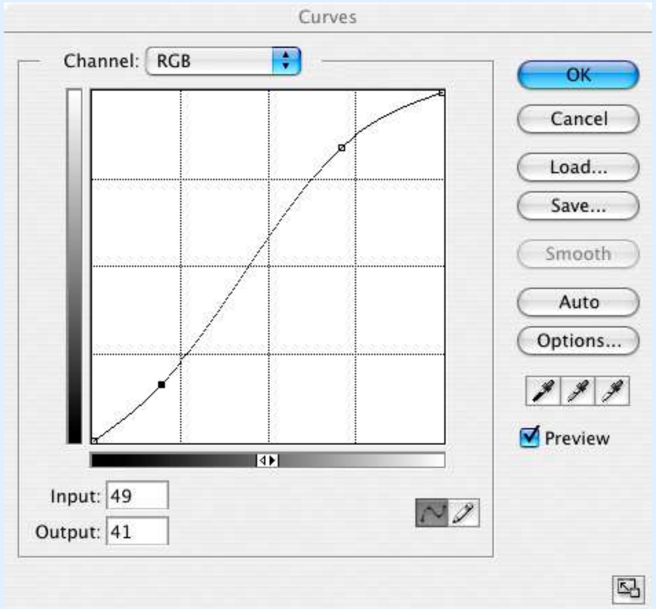


Photoshop Adjustments

Once the image is in Photoshop, a vast suite of tools is available to adjust and manipulate the image. Perhaps the most useful of these are the “levels” and “curves” adjustments. Levels (Image > Adjustments > Levels or CTRL/CMD-L) allows you to adjust the brightness and contrast of the image overall by specifying the minimum data value to assign black and the maximum data value to assign white (similar to the black and white levels in the FITS Liberator). In addition, it permits an intermediate adjustment (sometimes referred to as “gamma”) that changes the functional transformation between the pixel values and displayed pixel brightness (something like the selection of the stretch function in the Liberator but with continuous variation rather than fixed functions).



Curves (Image > Adjustments > Curves or CTRL/CMD-M) permits much more flexible changes to the brightness and contrast of the image with a graphical representation of an arbitrary transform function.



Note that it is usually preferable to apply adjustments as an "adjustment layer" rather than modifying the image layer directly. Create an adjustment layer using Layer > New Adjustment Layer or the New Adjustment icon on the Layers Palette.

A further refinement is to apply adjustments only to areas that need it. For example, you can brighten fainter regions without blocking up (saturating) brighter areas by applying a mask to the adjustment, if it is applied using an adjustment layer. Paint in the layer mask with black to prevent the adjustment from applying.

The goal of such adjustments is an image with a more balanced range of tones, from black to white, making visible those features in the data that are of most interest. For example, a well-crafted curves adjustment can enhance relatively faint outer arms of a galaxy without saturating brighter areas near the nucleus.

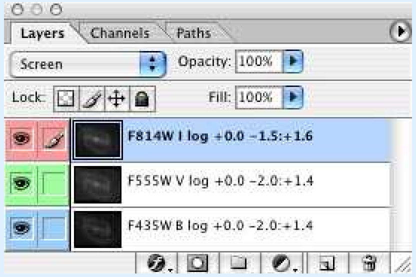
Save your work. If you save as a Photoshop document all features will be available for recovering and modifying again, including full 16-bit image layers, adjustment layers, masks, etc.

The Next Step: Making a Color Composite

A more sophisticated exercise is to combine multiple exposures into a color composite. Registered exposures of the same object made using different color filters may be used to reconstruct a color image. In general the colors will not be “real” as in what we would see visually. But the colors do represent actual physical properties of the subject. The basic idea is to combine the images using Photoshop's "layers" which permits multiple images to be combined in a single document. There are various ways to combine the images; the most flexible is to put the separate images in separate layers and colorize each. This method permits adjusting the hue more or less arbitrarily, combining two or more images, and applying numerous adjustments to each gray image separately.

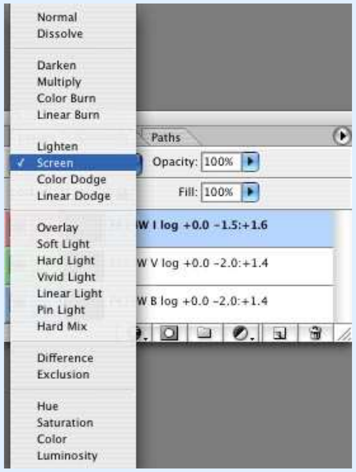
In this case we will "colorize" the image by applying a different hue to each layer, making use of the "additive" color model, in which varying intensities of the primary hues red, green and blue add together to produce the range of all possible visible colors. This is accomplished by "projecting" each layer onto the virtual screen of a displayed image using Photoshop's "Screen layer blend" mode.

To begin, open each image as a gray Photoshop document using the FITS Liberator. Copy each to a separate layer by dragging and dropping each in one of the documents. Note that if you hold down the Shift key while dropping, the dropped image will be centered in the existing document. It's best if the images are registered (the features in all the images line up pixel for pixel) beforehand, which may be done using external software. However it is possible to register them manually in Photoshop, but that's a little beyond this exercise. The Photoshop "Layers Palette" will graphically show the order of layers in the document.

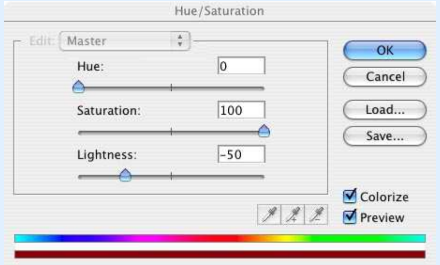


(Note that you can assign a color and name to each layer using the "Layer properties". In this case, the name (the text to the right of each thumbnail) was used to identify the source of each image. The color has nothing to do with the color applied to the image pixels but serves only to further label and identify the layer.)

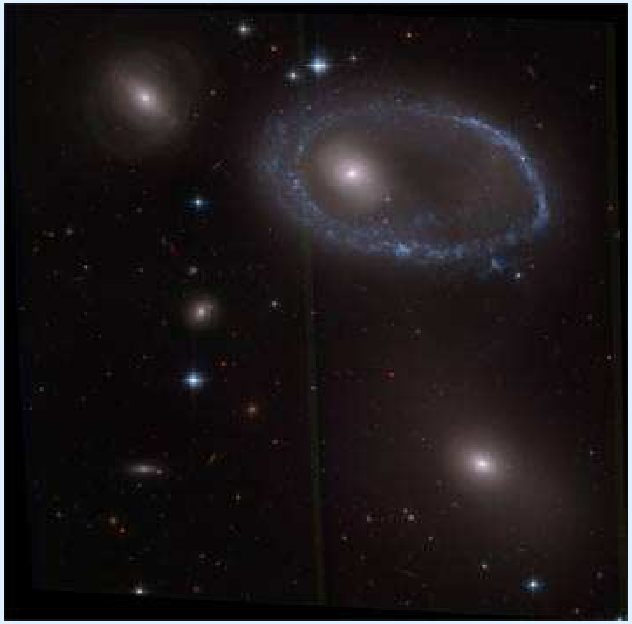
Convert the grayscale document to RGB color: Image > Mode > RGB Color , select Don't Merge when asked. Set the "layer blend mode" of each layer to "Screen" using the drop-down menu in the Layers palette or Layer > Layer Style > Blending Options...:

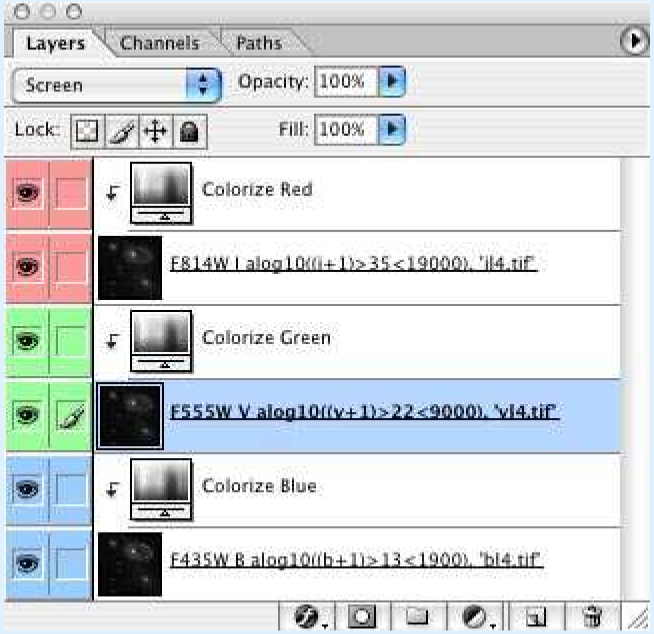


To colorize each layer use "Hue/Saturation" adjustment, preferably using an adjustment layer (Layer > New Adjustment Layer > Hue/Saturation...).



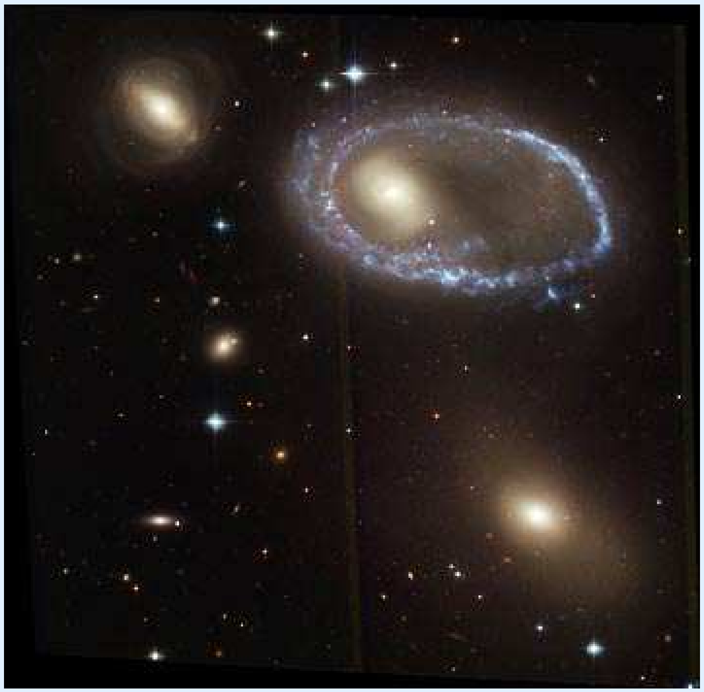
Select the "Hue" of the layer to convert the gray image to a color layer. The numerical hue values correspond to angles around a color wheel: 0 is red, 60 is yellow, 120 is green, 108 is cyan, 240 is blue, 300 is magenta, and intermediate values result in intermediate colors. Make sure the "Colorize" box is checked, set "Saturation" to 100 and "Lightness" to -50. This will ensure that the colors for that layer will range from black (for 0 pixel value) to the brightest possible value of the given hue (for the maximum pixel value, 255 for 8-bit channels). Finally, to apply the Hue/Saturation adjustement only to the appropriate image layer, "Group" the Hue/Saturation colorize layer with the corresponding pixel layer by highlighting the adjustment layer and using the menu Layer > Create Clipping Mask (or CTRL/CMD-G on the keyboard).

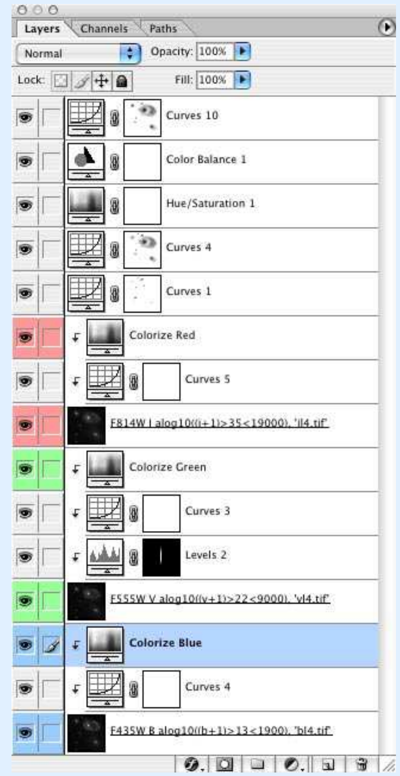




Note that applying the "additive primaries" red, green and blue to three layers provides the broadest range of colors in the final image.You may certainly use any combination of these, but the range of possibilities is seemingly endless. The values suggested here result in the most predictable results and the widest range of reproduced colors. In the example above we have used the colorize values as described above and have inserted a descriptive Layer Name to make note of the intent of each.

In general the resulting color composite is not very sastisfying, appearing dull, or having a particular color cast. Again, you can apply any of the numerous Photoshop adjustmets to improve brightness, contrast, color, etc., just as with any digital photo. Adjustments may be applied to each gray image layer by inserting a Levels, Curves, etc. adjustment layer between the image layer and its corresponding Hue/Saturation colorize adjustment layer. In addition, you may adjust the composite as a whole by inserting adjustment layers above all of the image and adjustment layers.





Again, save your work, and don't forget to save often; you never know when a system crash or other disaster may strike.
http://hubblesource.stsci.edu/services/articles/2005-02-10/ Hubble Legacy Archive http://hla.stsci.edu

Appendix C: AL *Reflector*, "Three Cheers for the Photosphere", Jim Daley, Dec 2017

ZWO ASI-120 Imaging and Processing

The principal imaging detector is a ZWOASI120MM CMOS fast (monochrome) framing camera. The angular field of each pixel is 0.165 arc seconds, thus well oversampled for maximum possible resolution. AVI video files are captured with Sharp Cap 2.9 and video frame stacking is performed with Auto Stakkert! Final image enhancement is done in RegiStax6 using wavelet processing. These programs are all free Internet down loads.

The typical frame rate for roughly 60-arcsecond fields (380 x 380pixels) is 58 frames per second and typical exposure times run about 340 microseconds, which completely "freezes" the atmospheric seeing. Because of various seeing phenomena, including coherence of seeing (which is a frame-to-frame, turbulence-caused image distortion that is mostly correctable in Auto Stakkert! and which increases in harmfulness with greater field angles), this frame size is the one most used in my observations.

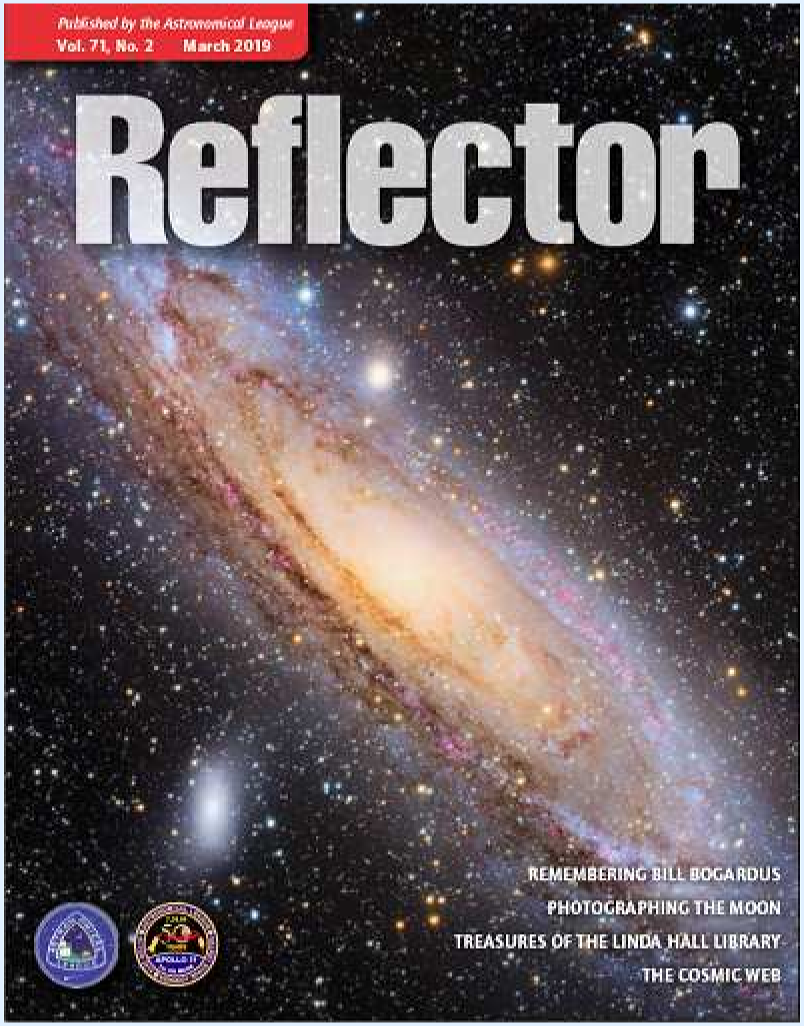
It is vital in this type of solar work to operate from a darkened room (you must be comfortably seated and see the computer screen perfectly). My observatory has a small attached computer room to the north where the camera's USB cable leads from the telescope, through the wall and directly to the laptop. For high-speed video the cable is necessarily short and some thought must be given to the layout to allow at least a few hours of observation without cable tug disturbing the telescope pointing.

Operationally, I begin an observing run by judging the image quality (and setting the telescope focus) of the free-running video on my Dell laptop. As powerful as LI is, good seeing is still very important. It is also important to open the histogram feature and set the exposure to about 60 percent full-well (avoiding saturation at the upper limit). The capture program allows you to set the gamma or contrast value (1to 100). I usually set it at about 40.

One soon senses the cadence of the seeing and learns to start a recording at the best moments. Recording can be stopped and captured any time the seeing "blows up" or wind induced angle jitter becomes excessive. Typically, four really good videos (an eyeball estimate) of at least 20 seconds duration are selected for processing from the 25 or so recorded during an observing run. The best video frames from each good recording are computer selected (in Auto Stakkert!) by a contrast algorithm and presented in descending order of quality. I use the percent quality value feature to decide the number, where 100 percent is (relatively) the best. I usually cut the number of frames at 90 percent quality and use the displayed value of frames within these bounds to stack. Some videos provide only five or six good frames meeting the aforementioned criteria, while others, under great seeing, can yield up to 200 sharp frames, yet the final (after wavelet sharpening in RegiStax) results are sometimes rather similar!

From the Astronomical League magazine Reflector, "Three Cheers for the Photosphere", Jim Daley, December 2017, pages 20-21

Appendix D: AL *Reflector*, “Basic Small-Scope Lunar Imaging”, Jamey L. Jenkins, March 2019

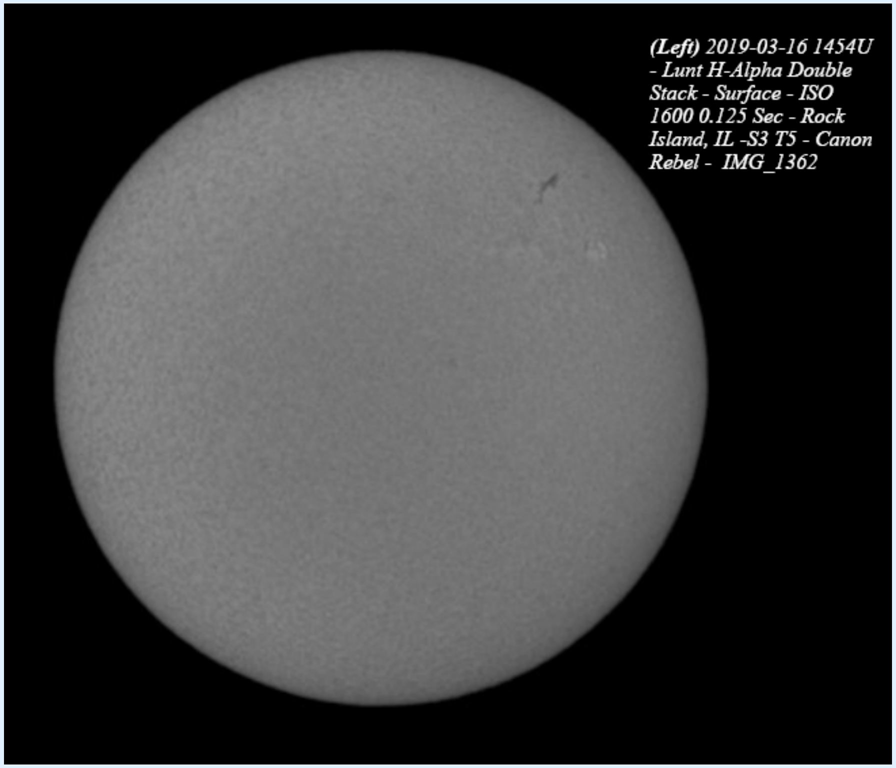


Pages 14 to19

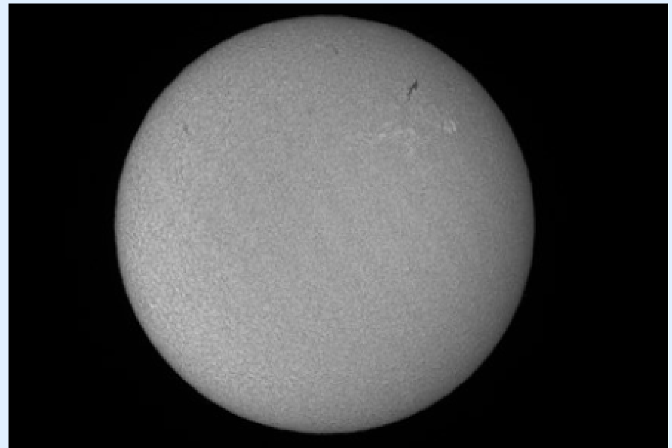
Appendix E: PAC *Reflections,* "A solar report from Ken Boquist on March 16th, 2019", April 2019

Member Observations (written, visual or photographic welcome)

A solar report from Ken Boquist on March 16th, 2019:
Today was a pretty good day for imaging the sun, being clear late morning, and also a nice deep blue sky. About a week or two ago I saw an article somewhere that discussed whether the Sun was now starting to come out of a solar minimum. I think this might be the case, as I finally saw a filament that actually had pretty high contrast and stood out well. There were a couple of prominences, but they were extremely faint, and never im-aged well, so I didn't retain any pics of the prominences.
I started out the morning using my Canon Rebel DSLR like I have always used in the past. The pic that says Canon Rebel is the pic in question. This pic was slightly pro-cessed using MS Picture Manager. It shows the filament in question, along with a plague and a much smaller filament to the lower right of the prominent one. This pic is fairly similar in quality to what I have been able to achieve in the past.
I then took some pics using a new Mallincam (the DS287m SkyRaider) that I bought. This is a small CMOS video camera. It is not the one that I used for the deep sky pictures that I have been sending the last couple of months. The other two pics show the end result of what happened with that camera (they both have the name "DS287" in the file name). I thought the camera took far superior images compared to the DSLR. I think the whole disk picture clearly shows more fine detail in the solar granulation. The closeup pic was, I thought, really good!
What's really interesting about this camera is just how fast it is. With the DSLR, I always had to use an ISO of 1600 to keep the exposures to a reasonable duration, which gen-erally has been around 1/8th to ½ seconds. With the DS287, I was using exposures of only about 1 to 20 milliseconds, and this was with a very low gain of anywhere of 1 to 5 on a scale of 1 to 50 on the whole disk images. The camera happens to be quite inexpensive compared to a DSLR, and yet it took some very good picture. Needless to say, this really kept noise to a minimum.
Anyway, I thought you might be in-terested in seeing the difference be-tween a general purpose DSLR ver-sus a camera designed specifically for astronomical applications. It looks like I'll probably take all of my future pics with the Mallincam.
Ken Boquist



(Left) *2019-03-16 1454U - Lunt H-Alpha Double Stack - Surface - ISO 1600 0.125 Sec - Rock Island, IL -S3 T5 - Canon Rebel - IMG_1362*



(Above) *2019-03-14 1704U - Lunt H-Alpha Double Stack - Surface - Gain 2.67 0.00085 Sec - Rock Island IL - S3 T5 - DS287M short reducer + Ext*

(Below) *2018-03-14 1557U - Lunt H-Alpha Double Stack - Surface Closeup - Gain 2.67 0.004 Sec - Rock Island, IL - S3 T5 - DS287M*

Appendix F: *Sky & Telescope*, “The Quest for Round Stars”, Ron Brecher, June 2019

Sky & Telescope, June 2019, pgs 64-67