Basic Astroimaging

By

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Definitions

APO: Apochromatic refractor. This is a high-end optical system designed to reduce or eliminate false color. True APO telescopes use a combination of glass elements with different refractive characteristics. Color corrected refractors are also called ED for extra dispersion.

SCT: Schmidt- Cassegrain Telescope. This is a common type of catoptric or folded optic reflector telescope. The light path is reflected off the primary mirror and back to a central secondary and then back through a hole in the primary to the eyepiece. This allows for long focal length in a compact space. As with Newtonian reflectors, the main drawback in imaging is field coma. Mirror flop and mirror shift cause problems with tracking and focus. Mirror lock and electronic focusers help.

Ritchey-Chrétien: Catoptric telescope with advanced optics to eliminate coma. This is very good for large aperture imaging but very expensive.

Coma: An optical aberration causing elongated stars near the periphery. This is mostly a problem with reflecting telescopes.

Chromic aberration: introduction of false color by the optical system. This is mostly a problem with achromatic refractor systems. Apochromatic and ED scopes correct for this.

Focal length: The point at which the light beams converge. In the case of a telescope, this refers to the focal length of the objective lenses. Longer focal length means higher magnification.

Objective lens: The front lens on a refractor. The larger the diameter the more resolution and light gathering capacity. Resolution is arithmetically related to the diameter whereas light gathering is exponentially increased by diameter.

f- ratio: Indicates the "photographic speed" of the lens system. This is a ratio of the focal length divided by the objective lens diameter. Lower numbers mean faster exposures. This is something the human eye does not directly appreciate. Since these numbers are related to light gathering capacity, which is a square function of the objective's diameter, the scale is logarithmic. For instance, the following sequence represents one f-stop intervals: f1.4, f2, f2.8, f4, f5.6, f8, f11, f16, f22, f32, f45. Every successive f-stop lets in ½ the light as the one before and will take twice as much time to obtain the same exposure. The disadvantages of lower focal ratios are expense, low magnification, and poor depth of field making focusing more difficult.

Focal reducer: A lens at the rear of the optical system that lowers the focal ratio and increases the fields of view. They also tend to reduce coma in optical systems.

Autoguiding: A technique for using a separate camera to lock onto a guide star. A rapid series of images of the star is taken and analyzed by a computer. The exact coordinates of the star on the sensor chip is recorded and if the star begins to drift, the computer tells the mount to make appropriate corrections to re-center the star. In this way the mount will lock onto the sky's movement and not drift away during the imaging process.

DSLR: Digital single lens reflex camera.

CCD: Charged couple device. This is the type of sensor chip used in a variety of digital cameras, like the CMOS chips used in Canon DSLRs. The term is also used for dedicated Astrocameras. Note: CMOS detectors are making their way into more cameras.

Cooled Chip: High end CCD cameras utilize a Peltier cooling chip behind the CCD chip to reduce thermal noise in the images.

ISO (ASA): A measure of the speed of the film or exposure rate. Generally, the higher the number the more noise and lower resolution or dynamic range. This was especially true with film but is becoming less so with digital imaging. Higher ISO settings will give more exposure for a given shutter time and f-ratio.

Webcam: Camera designed to take movies. They are usually connected to a computer via a USB or Firewire and captured and stored as a movie with multiple individual frames. The individual frames are then processed to sort and stack the best of the images. Webcams are ideally suited for Lunar and planetary imaging. These cameras are usually inexpensive. Some of the more sophisticated webcams have been modified to take longer exposures and can be used for dimmer objects.

Mount: Apparatus to hold the optical tube. Motorized mounts can track the movement of stars. Some can be controlled by computer to "GO-TO" the object. Those mounts suitable for high quality astroimaging can carry large loads, have smooth tracking, and have autoguiding control inputs.

GEM: German Equatorial Mount. The most common polar aligned mount used for guiding a telescope for imaging.

Equatorial Wedge: An inclined wedge on which to mount a scope with an Alt-Az mount to make it behave as a polar aligned tracking system.

Stacking: Combining multiple images of the same object. This is used to reduce noise and improve image quality. By taking multiple images, poor quality frames or those with satellites or planes can be eliminated from the stack.

Dark Frames: Dark images (with shutter closed or lens cap on) taken at same exposure conditions as light images. These are used to capture camera noise that can be subtracted for the light images to give cleaner images.

Stretching: Technique of bringing out dim details for the photos. This is done with astoimaging software or programs like Photoshop.

Image Scale: Usually expressed in Arc Seconds/Pixel ratio. Focal length of the scope and the pixel size of the camera determines this relationship. For a given focal length, the smaller the pixels, the smaller the AS/P ratio is. In other words, there will be a smaller field of view for each pixel. Also, a longer focal length will project a smaller the field of view on each pixel. Ultimately, there is no practical reason to exceed the seeing limits. This is called oversampling. You want to sample a star with a minimum of 2 pixels and preferably 4. The atmosphere and elevation of the stars determine the seeing and is rarely better than about 2-3 arcseconds. If you sample at a minimum of 2 pixels per star you need an AS/P ratio of 1-1.5. This is the optimal ratio for CCD imaging and should be considered when matching optics to camera. The formula is simple: Arcsecs per pixel = **(206.3 * pixel size in uM) / focal length of scope in mm**.

Tips and Recommendations (in order of difficulty)

Widefield: Images taken with short focal length lenses from fisheye up to perhaps 200-300mm. 50mm and wider fields of view can be taken on a tripod.

Webcam: Perfect for imaging solar system objects. Images are captured as an AVI movie file and processed in software such as RegiStax. Examples are Meade LPI, Celestron NextImage, Orion StarShoot, ZWOs, Starlight Xpress, QHY, Atik, Philips ToUCam, and Astrovid Planetcam. Tip: Most planetary cameras can also be used as autoguiders however color is better for planets and monochrome slightly better for autoguiding.

DSLR: Perfect for deep sky objects. Most major companies make suitable cameras, but Canon has become aware of astrophotographers and addressed some of their needs. Live focus is one example (20Da, 40D, 5D MkII, Rebel T models). They are especially nice because you can also use them for terrestrial daytime use. These cameras can be modified for use as a dedicated astroimager by replacing the infrared blocking filter with a modified filter to allow more Ha light to come through to the sensor. This is helpful to get more of the red color in nebulas.

Mirrorless Cameras: Like DSLRs but without the flip mirror. Lighter and less parts to break

One shot color CCD: Similar to DSLR but dedicated to astroimaging. Some have cooled chips to reduce noise. These must be connected to a computer to operate (no viewfinder).

Monochrome CCD: More sensitive than one shot cameras and have better resolution because every pixel is used unlike color sensors which use a matrix of 4 RGBG filters over the pixels and then combine blocks of 4 to make one color pixel. In order to get color images from a monochrome camera, at least 3 sets of images must be taken in RGB or other narrow band filters and combined to make a color image. This uses more sophisticated software and many more images. The results are better but much more difficult. These are suitable for deep sky imaging and high quality optical and tracking systems.

Pearls for the Beginner

Start with wide field photography and work up to tracked images with longer focal lengths. The moon is great place to start and can be imaged with any of the cameras described. It is bright enough to allow for easy focusing and fast exposures without the need for a tracking mount. And you do not have to go to a dark site for best results.

Remember when considering deep sky imaging, start with short focal lengths. An 80mm APO refractor is an ideal starting scope. You can never have enough mount. It is recommended not to exceed 50-60% of the recommended visual payload on most low and median range mounts when using imaging equipment. Accurate polar alignment and autoguiding are essential for long exposures and longer focal lengths.

Deep sky imaging is frustrating in urban areas because of light pollution but not as impossible as you would think. You can still get some good images with imaging processing software, but you will lose some contrast.

Do not bother with film. There are a lot of things that can go wrong with a deep sky image like focus, tracking, or even finding the dim target through the viewfinder. For those reasons digital imaging is far superior for the beginner as it allows instant feedback (and gratification). Since we learn from our mistakes, we can get through them much quicker than with film.

Join a local imaging group and follow the online forums in io.com. Almost every type and brand of telescope, software, mount, and camera has a dedicated online support group.

Check the Orange County Astronomer's website for local information. www.ocastronomers.org

Astrophotography Resources

Right Click on Hyperlink to go to WEB site

Software:

ImagesPlus www.mlunsold.com, by Mike Unsold, provides an on-chip focusing routine, automated series' of long exposures and a complete suite of software astrophoto processing tools. Will need control cable for exposures longer than 30 seconds.

Stark Labs http://www.stark-labs.com **Nebulosity 4** – Image capture and processing and **PHD Guiding** – Autoguiding software (Nebulosity is $95 and PHD 2 is free for a donation)

DSLR Focus (https://www.astrobin.com/gear/27129/chris-venter-dslr-focus-30) by Chris Venter, provides a very easy and accurate method of on-chip focusing of star images...much better than external devices such as Ronchi screens, Hartman masks or parfocal eyepieces. DSLR Focus also allows programmed imaging sessions whereby a series of long exposures can be automated, saving the resulting images to a USB connected PC or leaving them in the camera's memory for later download.

AstroArt 5.0 (http://www.msb-astroart.com), A complete software for image processing, photometry, astrometry, camera control and image stacking for digital and film images. All major CCD cameras are supported by Astroart. Focusing, autoguiding, imaging and scripting become easy and quick. All major telescopes, filter wheels, focusers are supported too. New drivers are released almost every month.

Maxim/DL https://diffractionlimited.com/ Can control both CCDs and DSLRs plus image processing

CCDWare http://www.ccdware.com/ Publishes multiple software tools useful to astroimagers. This includes **CCD Navigator, PemPro, CCD Inspector, Focus Max, CCD Autopilot, and CCD Stack**

PHD2 https://openphdguiding.org/ Superb autoguiding software

Adobe Photoshop (processes Canon Raw) Now by monthly subscription for $9.99/mo or Photoshop Elements $99.99. **Elements** does most of what you need out of **Photoshop**

PixInsight Software https://pixinsight.com dedicated to astroimaging processing. Can download online for ~ $260.

Registax 6 Freeware for processing web cam videos (moon and planets) https://www.astronomie.be/registax/

Filters:

Hutech http://www.sciencecenter.net/hutech/index.htm
Lumicon filters - off axis guiders https://farpointastro.com/
Televue http://www.televue.com
Astrodon astrodon.com Filters and off axis guiders https://farpointastro.com/
Astronomik https://www.astronomik.com/en/ Filters

CCD:

QSI http://qsimaging.com/
Santa Barbara Instrument Group http://www.sbig.com/
Finger Lakes Instrumentation http://www.flicamera.com/
Trifid http://www.yankeerobotics.com/
Starlight Express http://www.starlight-xpress.co.uk/index.htm
Orion http://www.telescope.com/home.jsp
Apogee https://andor.oxinst.com/cameras-for-astronomy

Optics:

Takahashi http://www.takahashiamerica.com/
Astrophysics http://www.astro-physics.com/
Williams Optics http://www.williamoptics.com/
Borg http://www.sciencecenter.net/hutech/index.htm

Vixen http://www.vixenamerica.com/StartPage/
Televue http://www.televue.com
Stellarvue http://www.stellarvue.com/

Mounts:
Astropysics: http://www.astro-physics.com/
Losmandy: http://www.losmandy.com/
Paramount: http://www.bisque.com/sc/
Meade: https://www.meade.com/
Celestron http://www.celestron.com/c3/home.php
Vixen: http://www.vixenamerica.com/StartPage/
iOptron: http://ioptron.com

Check out samples:
OCA Astroimagers https://ocastronomers.org/all-images/ https://astroimagers.wordpress.com/member-astrophotography-links/
Alan Smallbone https://www.pbase.com/snowlep/astrophotography/
Bruce Waddington https://skypionline.com/images/
Chris Cook http://www.abmedia.com/astro/
Russell Croman http://www.rc-astro.com/equipment/index.htm
Dave Kodama http://www.eanet.com/kodama/astro/
Wally Pacholka http://astropics.com/

Canon astroimaging sites:
Rebel http://www.covingtoninnovations.com/dslr/EOS300Dastro.html

Equipment reviews and general information:
Cloudy Nights: http://www.cloudynights.com/
Ed Ting: http://www.scopereviews.com/index.html
Mead Advanced Products Users Group http://www.skymtn.com/mapug-astronomy/index.htm
Noise profiles http://forums.dpreview.com/forums/read.asp?forum=1019&message=3871076
OC Astroimagers Group: https://groups.io/g/Astroimagers/topics **Must be an OCA member**

Reference books:
The New CCD Astronomy
Astrophotography for the Amateur by Michael A. Covington
Astrophotography: An Introduction to Film and Digital Imaging by H.J.P Arnold
Introduction to Digital Astrophotography - Imaging the Universe with a Digital Camera by Robert Reeves
Handbook of Astronomical Image Processing (HAIP) and its integral *AIP for Windows 2.0* image processing software (AIP4Win2.0)
Photoshop for Astrophotographers http://www.astropix.com/PFA/PFA.HTM
Inside PixInsight Warren Keller

Where to buy used equipment:
Astromart http://www.astromart.com/
eBay
OPT http:www.optcorp.com
Telescope Trader https://www.telescopetrader.com/
OCA's Sirius Astronomer Monthly Newsletter

Where to buy new equipment:
OPT http://www.optcorp.com
Land Sea Sky https://www.landseaskyco.com/
Scope City http://www.scopecity.com
Woodland Hills https://telescopes.net/store/
Astronomics http://www.astronomics.com
Anacortes http://www.buytelescopes.com

B&H http://www.bhphotovideo.com
Adorama http://www.adorama.com/catalog.tpl
OC Telescopes http://octelescopes.com
Smart Astronomy Meade Telescopes, Observatory Tent, TeleGizmos, DayStar Solar Filters, Dew-Not Heaters, Peterson Engineering (smartastronomy.com)