

Astrophotography for Beginners



**HOW TO SHOOT:
AURORAE
PLANETS
AND MORE!**

Astronomy[®]



Mallincam ships a complete package with its DS2.3 Plus, including cables, software, and a C-mount adapter.

J. THOMPSON

Get started in VIDEO ASTRONOMY

Mallincam's SkyRaider DS2.3 Plus is adept at both solar system and deep-sky video imaging. **by Jim Thompson**

I CAN RECALL PRECISELY THE DATE that I fell in love with using a video camera for astronomical viewing. It was August 26, 2010, the first night I looked at the Moon through an old security camera that I had jury-rigged to my telescope.

Back in 2010, there were few commercially available astro-video camera choices, but that situation has changed. More recent cameras generally have filled specific roles, like cameras with high frame rates for solar system imaging, or those with high sensitivity and low noise for deep-sky work. But few were good at both. That is, until now.

Last year I had an opportunity to try out the Mallincam SkyRaider DS2.3 Plus. During the six months that I had the camera, I tested it on a variety of celestial targets, on a range of telescopes, and under both light-polluted and dark skies.

What's in the box?

When I received it, the camera arrived in a sturdy cardboard box. The package included a rubber dust cap, a 1¼" nose-piece, a 15-foot-long (4.6 meters) USB cable, a 10-foot-long (3m) ST-4 guider cable, and an installation disk.

The DS2.3 Plus is a 2.3-megapixel one-shot color camera containing a Sony IMX302 Exmor CMOS sensor. The sensor measures 13.4mm diagonally and has pixel dimensions of 5.86 x 5.86 micrometers. Potential exposure times range from 25 microseconds to just over 16 minutes with a maximum frame rate of 30 per second.

The camera body measures 80mm wide and 85mm long, and has an integrated fan-cooled heat sink to regulate its temperature. The camera has a standard T-mount interface but also comes with a C-mount adapter. The camera body with its C-mount adapter weighs just under 1 pound (430 grams).

The machining and finishing of the all-metal casing is of high quality, and the little details — such as a sealed sensor chamber, a robust USB 3.0 B-type connector, and a whisper-quiet cooling fan — combine to make a top-notch product.

Getting started

To use the camera, I first installed the drivers and software on my computer. All files necessary were on the provided disk, but I also would have been able to download them from the Mallincam website. I then started the software and plugged the camera into my computer's USB port. I found the software easy to use, with all the camera functions organized in expandable tool boxes along the left-hand side of the screen.

The software comes with a large assortment of features. These include gain and exposure controls, color and gamma adjustments, a histogram with adjustable black and white points, and adjustments for regions of interest, crosshairs, live stacking with star alignments, and dark field correction. The last feature lets you record a number of frames with the telescope covered and then subtract them from the live image.

Installing the camera on my telescope was as easy as slipping an eyepiece into the focuser. The 1¼" nosepiece turns it into essentially a big, fancy eyepiece. For those unfamiliar with video astronomy, scope

alignment and focusing is normally a breeze, with the same being true using the DS2.3 Plus. I set the camera exposure to one second and gain at maximum, which gave me a view with plenty of stars visible and a fast refresh rate. This made it easy to focus and to navigate around the sky to perform my mount's alignment routine.

Sun, Moon and planets

Mallincam doesn't market the DS2.3 Plus as a solar system imager, but I decided to try it in that role nonetheless. First up was the Moon. I had some concerns that the moderately sized sensor pixels of the DS2.3 Plus would hurt its ability to capture fine detail and that I'd need more magnification. Typically that means longer exposure times, which in turn allows more atmospheric distortion.

In the end, I found that the high sensitivity of the IMX302 sensor allowed for generally low exposure times. This sensitivity extends well into the infrared, allowing for the use of an IR pass filter to further improve the image quality.

I then aimed it toward visible planets. On the first evening, I had a look at Jupiter with the IR pass filter. Imaging Jupiter in IR can reveal details in cloud features that you cannot discern visually. Later on, I imaged Jupiter again, but in the visual band, along with Mars and Saturn. Saturn was near the horizon, so I'm surprised I got a useful image. My image of Mars, however, is probably the best I have ever captured from my location in Ottawa, Canada.

Finally, I observed the Sun with the DS2.3 Plus. I used it with white-light, Calcium-K, and Hydrogen-alpha filters. I also had a rare opportunity to use the DS2.3 Plus to observe the May 9, 2016, Mercury transit from the lawn in front of the Canadian Parliament buildings. It was quite an experience sharing my live view of the event with the public and a number of dignitaries, including retired Canadian astronaut Marc Garneau. In all cases, I found the camera worked well for solar imaging, again due to its high sensitivity, which allows short exposure times.

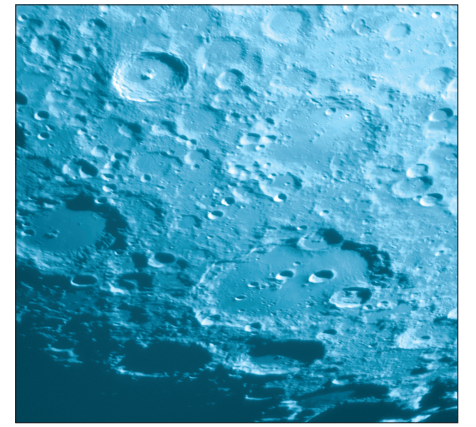
Deep-sky video observing

For many, the main attraction to the DS2.3 Plus is its ability to provide a live view of sky objects. I tested the camera in my light-polluted backyard and from the relatively dark skies at the family cottage. Most of my previous experience had been with an analog video camera with an 8mm sensor that produced a standard

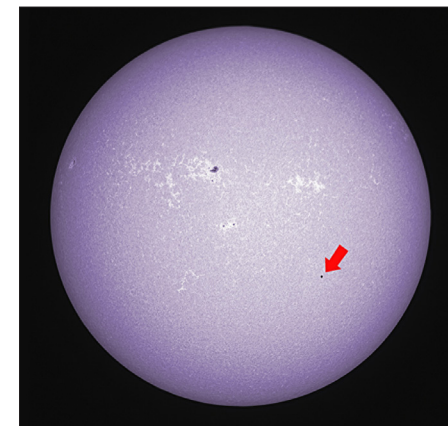


This close-up view of the camera's back panel shows the cooling fan and cable connections.

MALLINCAM



The author captured the Tycho-Clavius region of Moon on April 16, 2016, by connecting the DS2.3 Plus to his 10-inch Ritchey-Chrétien reflector at f/20, using a Baader Moon & Skyglow filter and taking a 20-millisecond exposure. J. THOMPSON



The author imaged Mercury (arrow) transiting the Sun on May 9, 2016. He used a William Optics FLT98 refractor at f/6.3, an Omega Optical CaK filter, and took a 4-millisecond exposure. J. THOMPSON

definition signal. Stepping up to the DS2.3 Plus gave me 7.5 times the resolution plus a 68 percent increase in field of view for the same scope and focal ratio. The result was a big improvement in image quality.

From my backyard, the DS2.3 Plus performed well on bright objects such as those in Messier's catalog. Faint details were easier to see when I used the built-in live stacking function, and color was easy to adjust using the push-button white-balance tool. The histogram tool made it simple to fine-tune the image, and the gamma setting allowed me to brighten faint regions if I needed to.

I found it most convenient to record a library of dark frames at different exposures and gains beforehand that I was able to call up later during my observing session. I also tried for a few dimmer objects, but those were much better when I was under darker skies.

My only complaint with this camera is that there's a delay after you change

PRODUCT INFORMATION

Mallincam SkyRaider DS2.3 Plus

Sensor: CMOS (13.4mm diagonal size)

Pixels: 2.35 megapixels (1936x1216)

Connectivity: USB 3.0

Dimensions: 3.1 by 3.4 inches (79 by 86 millimeters)

Weight: 15.1 ounces (429 grams)

Price: \$899.99

Contact: Procom Electronics
56-5450 Canotek Road
Ottawa, Ontario, Canada K1J-9G4
613.749.7592
www.mallincam.net

settings in the software before you see the effect. User setting changes are not implemented until the next frame refresh. So, if your exposure time is 60 seconds, you'll wait that long to see the impact of your change. This slows down imaging, especially when you use long exposure times.

Jack of all trades

All things considered, Mallincam's DS2.3 Plus is a highly capable camera. I didn't try the camera in a traditional astrophotography role, but there is no reason why you couldn't use it for that. There may be a better-performing camera for doing only solar system imaging or only deep-sky observing, but if you are looking for a camera that gives good results at everything, the DS2.3 Plus is the one for you. ☿

Jim Thompson is an aerospace engineer working for the defense industry in Ottawa, Canada. He enjoys beating back the light pollution of his backyard using video astronomy.

The Statue of Liberty Nebula (NGC 3576) is a wonderful mixture of emission, reflection, and dark nebulosity in the constellation Carina. To capture the data, the author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. He combined 13 hours of exposures through H α , OIII, and SII filters with 2 hours of exposures through RGB filters.



MEET THE filter guy



How an average Joe turned a hobby into an astronomy-based business.
text and images by Don Goldman

When I attend astronomy conventions or star parties, I meet lots of people who know me as “the guy who sells filters.” Fair enough. I’ve been producing high-quality filters for astroimaging through my company, Astrodon, for 14 years. Far fewer people realize that I also love to image. So, when *Astronomy* asked me to briefly describe that part of my life (in words and pictures), I agreed.

It seems like everyone has a unique story about how they became passionate about astroimaging — I do, too. I didn’t get interested until about 2000, despite several events that should have tipped me off to where my interests are.

I earned a Ph.D. from Caltech in its Earth and Planetary Sciences Department, where I studied field geology under Gene Shoemaker, the co-discoverer of Comet Shoemaker-Levy 9, which impacted Jupiter. At Caltech, I heard Carl Sagan and others give inspirational lectures. I analyzed Moon rocks with an electron microprobe in

the wee hours of the morning when others might be out with their telescopes. (Then again, graduate students couldn’t afford telescopes and didn’t have the time for observing anyway.) I even ate lunch with Harrison Schmitt, the astronaut who brought those rocks back from the Moon.

The emphasis for my dissertation was spectroscopy, using light to analyze materials. Such a background was essential when I started my Astrodon business years later.

The beginning

In 2000, I bought a cheap telescope. That’s when I learned three things: First, that you get what you pay for. Second, what 18.3 magnitudes per square arcsecond means in terms of light pollution in my backyard, which at the time was near Sacramento, California. And third, what an average person can expect to see through a telescope.

About that time, I also attended a talk at the local astronomy club about how cooled CCD cameras can cut

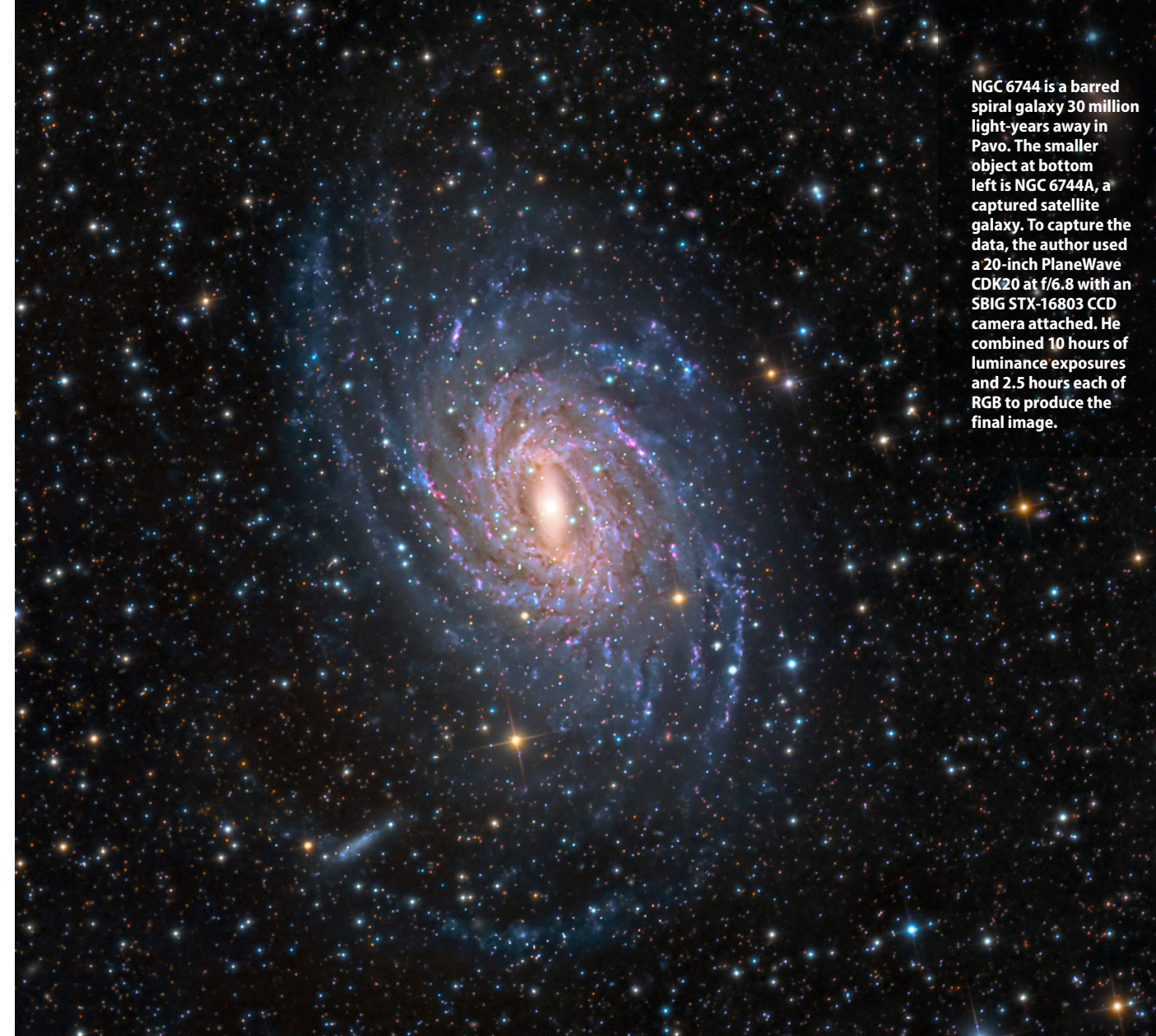
The Cartwheel Galaxy (ESO 350-40) spins through space an incredible 500 million light-years away in Sculptor. To its upper left you can see two adjacent galaxies. Astronomers think one of them passed through the Cartwheel ages ago (when it had a more typical spiral shape), distorting its shape into the ring we see today. To capture the data, the author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. He combined 4.75 hours of luminance exposures with 8.25 hours of RGB exposures.



47 Tucanae (NGC 104) ranks as the second-brightest globular cluster in the sky. Image-processing software counted 17,012 stars in this image. The author used an RCOS Carbon 12.5-inch Ritchey-Chretien reflector at f/9 and an Apogee U16M CCD camera. To create the image, he combined 30-minute exposures through R, G, and B filters.



NGC 6744 is a barred spiral galaxy 30 million light-years away in Pavo. The smaller object at bottom left is NGC 6744A, a captured satellite galaxy. To capture the data, the author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. He combined 10 hours of luminance exposures and 2.5 hours each of RGB to produce the final image.



through some of the light pollution by using specific filters and by combining images. So I jumped in and started to learn about how all the equipment goes together and how to process the resulting data.

The cameras of choice back then had cooled, monochrome CCDs because they provided the highest resolution and sensitivity. As such, they required that colored glass filters be placed between the camera and telescope, generally in a computer-controlled filter wheel.

Such setups produced filtered monochromatic data that astronomers combined to create color images. Even today, it's magical to see a color image on a computer monitor for the first time, realizing that no one has ever seen any of these objects, visually, in full color. Our eyes are simply not sensitive enough, even when we gaze through large telescopes.

This limitation raised a conundrum: If I couldn't see an object in full color, how would I know that computer enhancements produce the "correct" colors?

I sometimes think that if I had waited another decade to get into imaging, things would have been simpler. Today, DSLR cameras let you select a "white point," such as daylight, cloudy, etc. It gives the camera a reference to measure all colors against to allow its internal processor to correct them. For astroimages, different sensors have different sensitivities, and different brands of filters have different spectral responses. In general, it is the combination of the camera's sensitivity and filter's response that controls the resulting broadband color.

One long-standing method is to measure a Sun-like star through your red, green, and blue filters and determine the "weights," or sensitivity factors. That becomes our white point because we define sunlight as white. Done? Well, not quite. Here's where I got to use my background to better understand the problem.

Filtering the universe

Unlike terrestrial subjects, emission nebulae, HII regions in galaxies, planetary nebulae, supernova remnants, and other sources also emit light in narrow wavelength ranges due to the excitation of

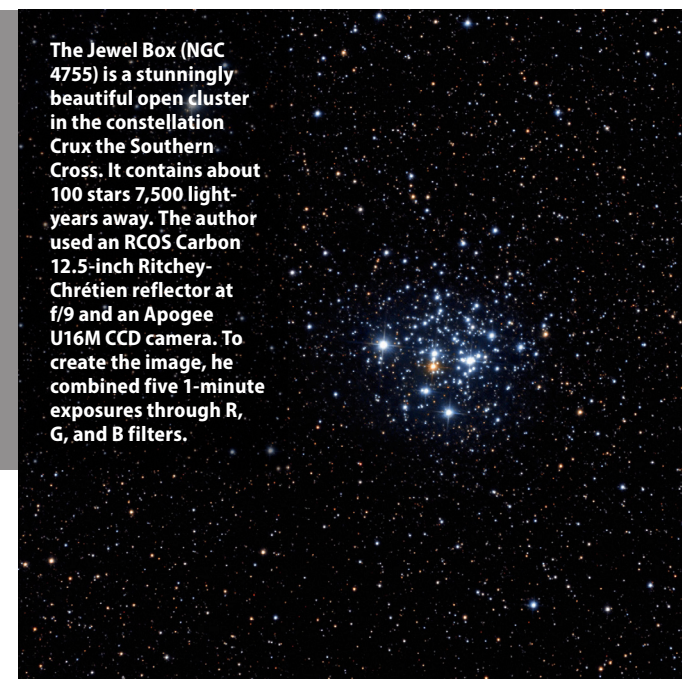
elements such as hydrogen, oxygen, and sulfur. In particular, doubly ionized oxygen (OIII), which is present in many planetary nebulae and supernova remnants, emits light with wavelengths right between the green and blue filters.

Once I applied the broadband color weights described earlier to get "correct" broadband star colors, the distribution of OIII in the blue and green color channels became fixed by the design of the filters. The resulting OIII signals should be nearly equal, resulting in a blue-green or teal color. However, the filter brands of the day were all different; some produced greenish

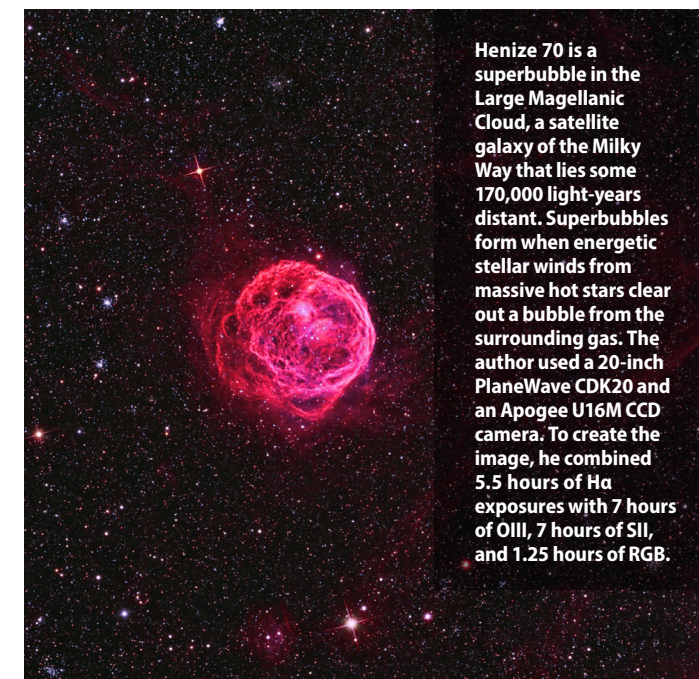
The Gourd Nebula (Sh 2-308) is a large, faint ring nebula surrounding the Wolf-Rayet star EZ Canis Majoris. Also known as WR 6, it's the bright blue star near the center of the image. The author used a 14.5-inch classical Cassegrain reflector at f/8.2 and an Apogee U16M CCD camera. He combined 2.67 hours of Ha, 3 hours of OIII, and 30 minutes of RGB exposures to produce the image.



The Jewel Box (NGC 4755) is a stunningly beautiful open cluster in the constellation Crux the Southern Cross. It contains about 100 stars 7,500 light-years away. The author used an RCOS Carbon 12.5-inch Ritchey-Chretien reflector at f/9 and an Apogee U16M CCD camera. To create the image, he combined five 1-minute exposures through R, G, and B filters.



Henize 70 is a superbubble in the Large Magellanic Cloud, a satellite galaxy of the Milky Way that lies some 170,000 light-years distant. Superbubbles form when energetic stellar winds from massive hot stars clear out a bubble from the surrounding gas. The author used a 20-inch PlaneWave CDK20 and an Apogee U16M CCD camera. To create the image, he combined 5.5 hours of Ha exposures with 7 hours of OIII, 7 hours of SII, and 1.25 hours of RGB.



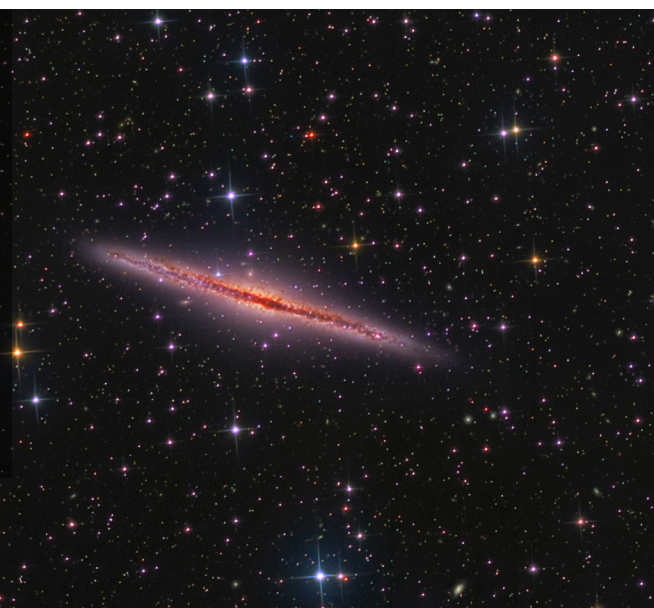
VBRC2 is a planetary nebula some 3,900 light-years away in Vela. This image is the first to clearly show the object's extended halo structure, which the Galactic Planetary Nebula Halo Survey team discovered in August 2014. The author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. To create this image, the author combined 8.5 hours of H α exposures with 4.5 hours of OIII and 2 hours of RGB.



NGC 6872 is the barred spiral galaxy to the upper right. In 2016, measurements by the GALEX spacecraft indicated the extent of its long arms is 522,000 light-years, making it the largest barred spiral known. The bright elliptical galaxy below and left of NGC 6872 is NGC 6876. The author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. He combined 7.5 hours of luminance exposures with 7.25 hours of RGB exposures.



NGC 891 is an edge-on spiral galaxy in the constellation Andromeda. It belongs to a group of about a dozen galaxies known as the NGC 1023 group, which lies some 30 million light-years away. The author used a 16-inch RCOS reflector and an Apogee U16M CCD camera. He combined 7 hours of luminance exposures with 9 hours of RGB exposures to produce this image.



and others bluish cores in the Dumbbell Nebula (M27), for example. They both can't be right. So, I saw it as a design issue.

Also, back then the broadband filters (colorless, red, green, and blue) had different thicknesses compared with the narrow-band filters, such as a hydrogen-alpha (H α) filter. That required you to refocus your telescope in the middle of a run (in other words, in the middle of the night), and few electronically controlled focusers or automation programs existed.

All these factors led me to the initial design of Astrodon filters. I engineered them to be "balanced" for the majority of sensors in the market at the time. This meant that you could combine equal exposures of red, green, and blue with equal weights, use only one dark exposure time (which lets you subtract so-called "hot" pixels — those on your chip that are always on), and get the correct white point and OIII teal color. As I refined my techniques, I made the decision to manufacture all my filters to the same exacting thickness to minimize refocusing as you moved from one filter to the next.

My goal was to help simplify an already technically demanding hobby. I ran my own corporation during the day — building chemical analyzers — so the filter project was an evening adventure on top of an already busy life. At the time, the adage "don't quit your day job" applied.

By the way, I named the company Astrodon to combine "astronomy" and "Don," but did you know that the sauro-pod *Astrodon johnstoni* is the official dinosaur of the state of Maryland because of the star pattern found in its tooth? My first logo had a dinosaur in it for this reason.

Never in my wildest dreams did I think my part-time venture would grow into a real business that would allow me to sell my day company and retire from the corporate world in 2007. But that's what happened. Astrodon LRGB and narrowband filters are now sold worldwide and are highly sought after for their performance and durability. I actually use them myself!

To grow my business, I improved the filters and expanded the offerings through the years and also engineered photometric filters for professional research. Some of these are customized and need to be quite large (diameters greater than 100mm) for meter-class telescopes, such as the ones at McDonald and Palomar observatories. Now my business funds this amazing hobby that still excites and challenges me.

As noted in the story, the author has gotten interested in terrestrial photography. This image is of Castle Geyser, Yellowstone. This geyser is just a 15-minute walk from Old Faithful. He captured it with a Sony a7Rii full-frame mirrorless DSLR and a Sony 16-35mm lens set at f/4 and 18mm. He set the camera at ISO 3200 and took a 20-second exposure.



Passion for photons

That includes imaging from remote, dark sites, like Cerro Tololo, in Chile, the New Mexico Skies Observatories, and the Sierra Remote Observatories near Yosemite National Park. I currently have a 20-inch system at iTelescope.net's remote imaging site at Siding Spring Observatory, New South Wales, Australia. Imaging from the Southern Hemisphere is like finding a new candy store with treats you've never tried.

My interests have focused on narrow-band imaging. I like to stay off the beaten track and capture faint halos around planetary nebulae or bring out unusual details in Wolf-Rayet nebulae or supernova remnants. I remember back when I started Astrodon, a color image of a galaxy might require a total of two to three hours of exposure time. Many of my recent narrow-band images have taken between 15 and 40 hours depending on how faint the feature is. What amateurs lack in telescopic aperture, we can often make up in the amount of time we spend imaging the object.

Recently, I've expanded my interests into daylight photography, traveling the world with my wife, Nicolle. Processing astroimages is largely about bringing out faint signals while reducing noise. Doing that has helped considerably in my daylight photography processing. Different



NGC 1097 is a beautiful barred spiral galaxy about 50 million light-years away in Fornax. In its center lies a supermassive black hole some 100 million times as massive as the Sun. To capture the data, the author used a 20-inch PlaneWave CDK20 at f/6.8 with an SBIG STX-16803 CCD camera attached. He combined 4.5 hours of luminance exposures with 6 hours of RGB.

guidelines apply, such as the rule of thirds, depth of field, and leading lines. Shooting a landscape or wildlife isn't exactly the same as centering a spiral galaxy with everything in focus. But then, a galaxy doesn't fly away when you point the telescope toward it, as wildlife sometimes does.

When I've submitted astrophotos of galaxies or nebulae to our local camera club competitions, the judges often do not quite know how to critique them, because they don't know what they're looking at. There is no common frame of reference for

most people. However, take a picture of the Milky Way rising over a bristlecone pine or above an arch in Canyonlands National Park in Utah, and everyone gets it.

Sensing no cure for the photo bug that's bitten me, I hope to continue imaging bright daytime scenes, dimly lit nightscapes, and ultra-faint deep-sky objects for many more years — all to show what a truly spectacular universe we live in. 🌌

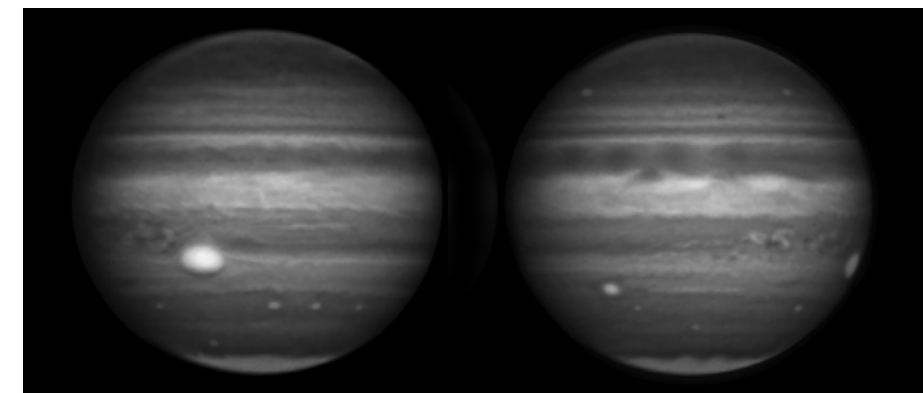
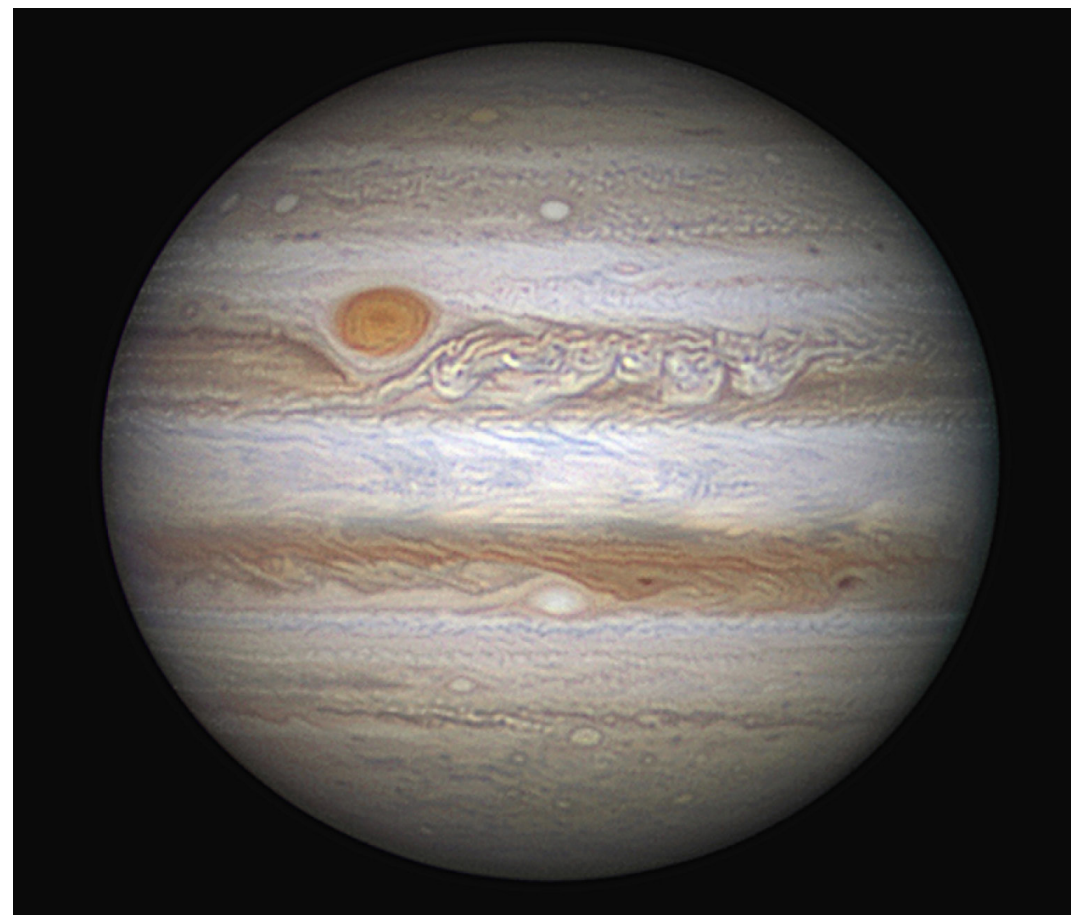
Don Goldman runs Astrodon from his home in Roseville, California.

Image the GIANT planets

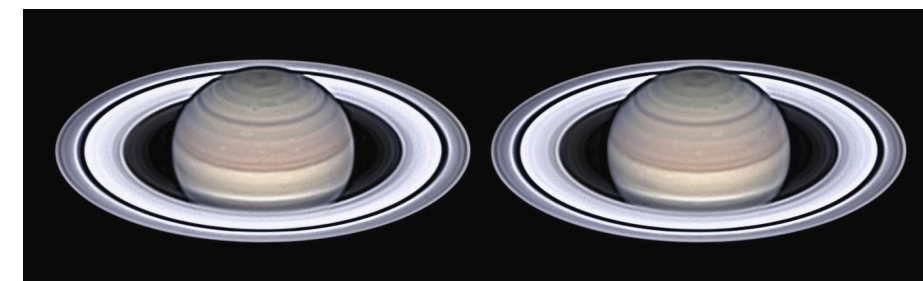
With the right camera and a small telescope, you can go on the same planetary “Grand Tour” that the Voyagers took.
Text and images by Damian Peach



The author uses this 14-inch Celestron Schmidt-Cassegrain telescope for many of the images he has produced during the past several years.



On March 18, 2016, the author imaged Jupiter through an 889-nanometer methane band filter. Methane absorbs sunlight, producing the dark regions. Brighter areas, such as the Great Red Spot, contain little methane and probably represent high-altitude ammonia clouds.



Above: Several storms are visible at different latitudes in this pair of Saturn images, taken during a period of excellent seeing June 11, 2016. The author captured the left image at 3h28m18s UT and the right one at 4h20m12s. North is up.

Left: A wealth of detail is visible across Jupiter's disk. The author took this image March 18, 2016, at 3h18m UT through his 14-inch telescope.

Photographing the planets has long been a mainstay of both amateur and professional astronomers. It wasn't so long ago that images from Voyager were wowing astronomers and scientists while amateurs struggled with photographic film to capture clear images of our nearest neighbors. It's fair to say they were falling well short of not only the images spacecraft were taking, but even the sketches visual observers were recording with pencil and paper.

Since then, a revolution has occurred within this field of astronomy. Gone are the days of blurry and fuzzy photographs showing little fine detail. Major leaps in technology have enabled today's amateur astronomers to produce images better than

the best film photographs ever obtained with the world's largest telescopes.

Telescopes for planetary imaging

Telescopes come in many designs, shapes, and sizes, and selecting the right one for high-resolution imaging is important. In general, almost any good-quality telescope can produce great images, but certain designs are more favored than others. Today the most popular choices among experienced amateurs are large-aperture Newtonian or Schmidt-Cassegrain telescopes. These provide plenty of light-gathering power at affordable prices and, in experienced hands, can produce highly detailed images.

With modern cameras, even a 6-inch

telescope can record considerable detail on Jupiter, while larger apertures are needed for Saturn, Uranus, and Neptune. Regardless of the type of telescope you decide to use, there are several key points to consider from a telescope/hardware perspective:

- **Collimation of the optics.** This is vital, especially with reflectors. Many guides are available online and are often provided with the purchase of a new telescope. Also keep in mind that it is a good idea to check the telescope collimation regularly, especially if you store it indoors and must move it outside each time.

- **Thermal equilibrium.** Allow the telescope as much time as possible to reach the same temperature as the outside air. This is especially important for larger apertures.

- **Focusing.** Do not fight an inadequate focusing mechanism, such as the standard focusing knob on a Schmidt-Cassegrain. Invest in a decent motorized system that allows fine focusing adjustments without touching the telescope.

- **Usability.** Overlook this at your peril! Nothing is worse than ending up with a telescope that is difficult and cumbersome to use. Choose one that you think you'll be able to use easily and frequently.

- **Focal length.** Invest in a high-quality Barlow lens to increase your telescope's focal length and image scale. Aim for an f-ratio between f/20 and f/30.

- **Dispersion.** Planets low in the sky are affected by an atmosphere-induced effect, known as optical dispersion, that causes their light to spread out into a spectrum.

A dispersion corrector can remove the deleterious effects and help sharpen the view.

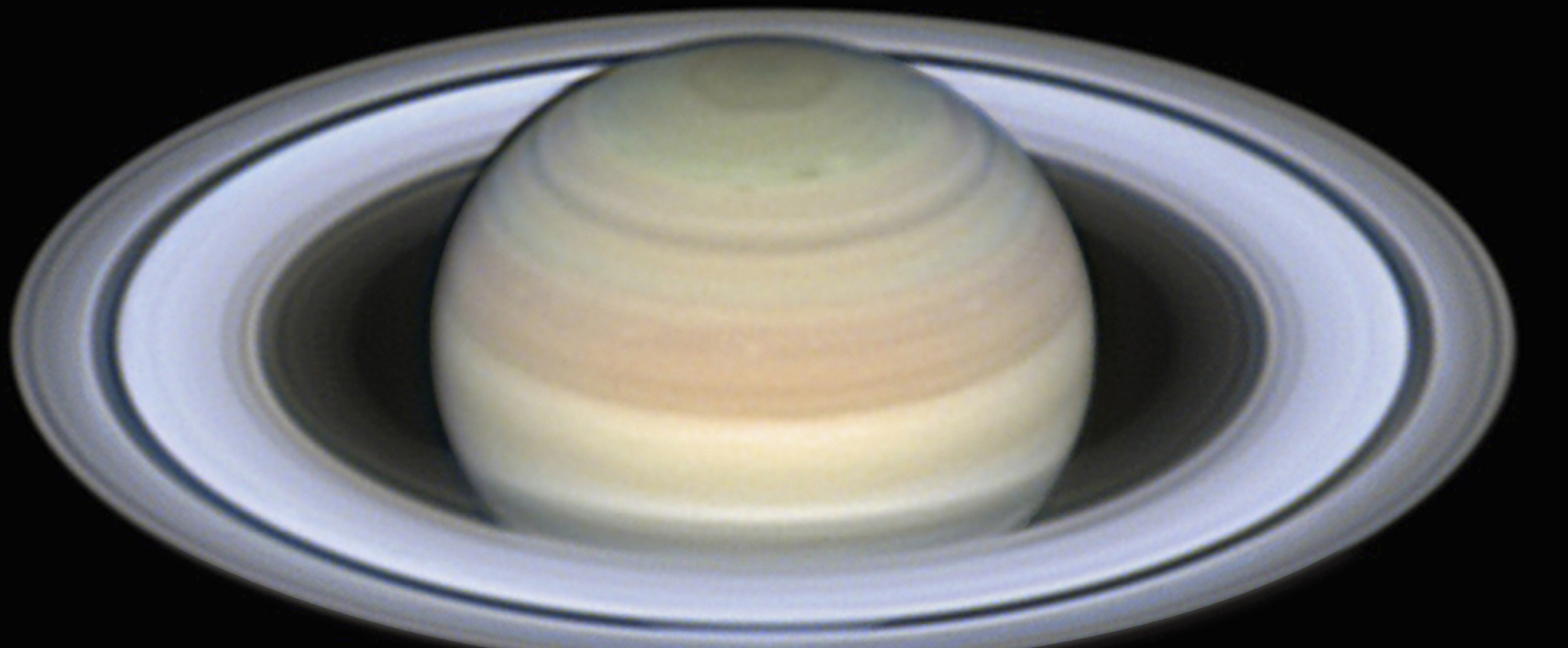
Cameras, filters, and software

Camera technology is a fast-moving field and is primarily responsible for the vast leaps in image quality over the past decade. Gone are the slow transfer rates of old CCD cameras, when a photographer could obtain perhaps only one image every few seconds. The best cameras in use by amateurs today can shoot at rates of more than 100 frames per second (fps). All typically operate via similar software packages that allow control over important settings such as exposure, frame rate, and gain.

For those starting out, I recommend a one-shot color camera. For more

experienced observers, a monochrome camera with a set of filters will provide higher-quality results. A wide range of camera choices that perform well is available today from several different manufacturers. Companies such as ZWO Optical and Point Grey Research have led the way in recent years, but other companies, such as Imaging Source and Celestron, also produce an excellent range of cameras for planetary imaging.

Any serious planetary observer should own a set of filters to image in different wavelengths. Longer-wavelength filters, such as infrared (IR), allow us to see deeper into planetary atmospheres, while shorter-wavelength filters focus on the high-altitude regions. Also available are specialized filters that focus on specific absorption



The author considers this image of Saturn — taken June 18, 2016, at 3h41m UT — the finest he's ever captured with his 14-inch telescope. Note the great detail visible within the ring system and on the planet's globe.

bands. By far the best for planetary imaging is the 889-nanometer methane band filter. This narrowband IR filter focuses on sunlight absorption due to methane in the atmospheres of the giant planets and is especially useful for Jupiter and Saturn.

One particularly nice aspect of planetary imaging today is that many software packages you'll need are available for free. Below you'll find a few of the key titles:

- **Firecapture.** This program is by far the most popular for planetary camera operation. It supports almost every model and has an advanced and well-designed user interface. (www.firecapture.de)
- **Autostakkert!** For aligning and stacking the frames taken by today's planetary cameras, this software leads the way. (www.autostakkert.com)
- **Registax.** This program has gone hand in hand with the advancements we have seen in planetary imaging over the past decade or so. It allows both image alignment and processing of image data. (www.astronomie.be/registax)
- **WINJUPOS.** Originally intended to measure the position of atmospheric features within the jovian atmosphere, this program now contains sophisticated

processing routines that allow imagers to compensate for rapid planetary rotation, thereby creating higher-quality images. (<http://jupos.org/gh/download.htm>)

Image the giant

The solar system's largest planet is the jewel of the night sky. Jupiter is one of the few truly dynamic astronomical objects that can be studied closely with amateur equipment. Its huge size means it presents a large apparent disk as seen from Earth, and even small telescopes can show considerable detail. It also rotates rapidly — a jovian day lasts 9 hours, 55 minutes — so you can see much of the planet during just a single night under the right circumstances.

Jupiter's rapid rotation makes it challenging to photograph. The time window available before rotation begins to smear detail is quite short compared with the other planets. For those using large apertures in good seeing conditions, 60 seconds is probably the upper limit per single capture. For an RGB sequence, 3 minutes is the upper limit before too much rotation occurs between the color channels.

Having a smooth routine in place is really important to use every second for RGB imaging of Jupiter, and this only comes from practice. Such a routine also helps render the tones of the planet accurately. Of course, for those using color

cameras, the procedure is far less frantic. Using image de-rotation in WINJUPOS allows a much longer capture window overall (up to 15 minutes), making the process much easier.

In terms of video frame rate, shooting through the R and G filters at around 80 fps should work well. You'll have to use a slower rate when you image through a B filter, though. Because most camera chips are more sensitive to red light than blue, your frame rate in blue may need to be as much as one-half that as with the other filters. Finally, you'll need to stack at least a thousand frames to create a reasonably noise-free result that will allow sharpening.

Narrowband methane filters also can help bring out lots of detail. Such filters are typically quite expensive but a worthwhile investment for those keenly interested in imaging Jupiter with the highest quality.

Image the ringed world

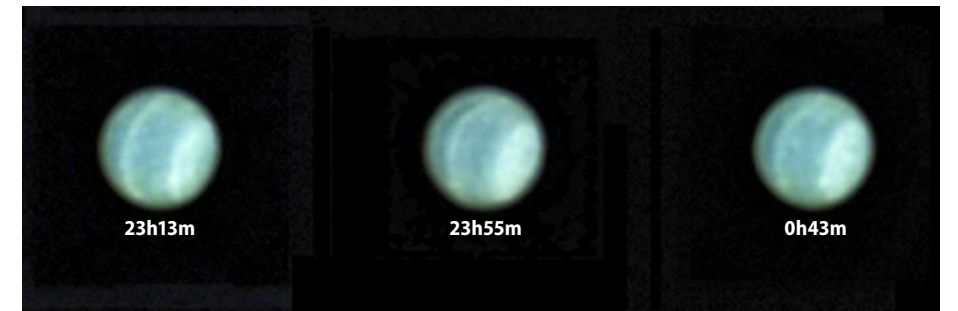
With its captivating ring system, Saturn is without question one of the most spectacular sights visible through any telescope. Larger amateur scopes can capture a wealth of detail across the globe and rings.

Minor storms appear as small bright spots and are typically quite frequent. Larger storms also can erupt, such as during the 2011 apparition when observers were treated to a planet-encircling storm,

the largest seen on Saturn in more than 20 years. The ring system also shows many interesting details, such as brightness variations, and occasionally you can image even the famous spoke features. When the rings are presented edge-on to Earth, large scopes will allow you to capture shadow transits of the saturnian moons easily.

Photographically, Saturn is challenging. Although it has a large angular diameter, its low surface brightness means that larger scopes (8 inches or more) are needed to get detailed results, and the frame rates achievable are much lower compared with its larger and brighter neighbor. Using typical RGB filters, frame rates will range from around 20 to 40 fps. Color cameras work well with the planet, and around 50 fps should be achievable. During RGB imaging, you can speed things along by taking a luminance image, as the frame rates are much higher and the resulting shorter exposure time can help produce a sharper result.

Saturn rotates more slowly than Jupiter, and at only half the apparent angular diameter (not including the rings), a far more generous capture window is usable. For a single capture, 3 to 4 minutes is usable, and for a total RGB capture, twice this length works fine. It can help to take a series of images over a 30-minute period to show any small spots or features that move



Distant Uranus showed some belts and bands in its atmosphere October 7/8, 2015. The author took these shots through a near-infrared filter and then processed them to give the planet the correct color appearance based on how it looks to the eye. At the time of these images, the planet's diameter was only 3.68".



The author captured Neptune and Triton September 19, 2015, at 23h15m UT (left) and five days later on the 24th. The earlier shot was a 50-minute exposure, and the later one was 25 minutes. Both images show bright storms. Amateur astronomers have discovered several such bright spots in recent years.

with rotation, because sometimes these features are not immediately apparent.

Image the ice giants

The distant ice giants have been two largely neglected worlds in terms of amateur study, although this has started to change. At their great distances, they present only tiny disks even through large telescopes. Both planets exhibit interesting activity with occasional bright storms, though any hope of capturing such events is reserved for those using large apertures.

Both planets are also challenging objects to photograph well at high resolution. RGB or color imaging serves little purpose with these planets because much of the transient activity and even the belt and zone patterns are best seen in near-infrared wavelengths.

An important filter to use on these planets is a near-IR 600nm long-pass filter. For larger apertures, a 700nm IR filter (which passes somewhat less light) works well. These filters stand the best chance of picking up atmospheric detail while still delivering a bright enough image that is realistically usable with amateur-size telescopes. All of the most detailed images of these planets produced in recent years have been through IR filters. Because both planets are so distant and rotate fairly slowly, time windows of around

15 minutes are usable for single captures, and you should try to stack plenty of data into each single image — up to 30 minutes' worth works well. Bright storms have been detected on both planets in recent years, most of them discovered by amateurs.

Not just pretty pictures

While the majority of deep-sky work is primarily aesthetic in its appeal, this is not the case with planetary images. Amateur work on the outer planets remains important to professional researchers, and in recent years many discoveries have been made using amateur data. Science based on amateur images is also more detailed and credible than it has ever been. Image quality today is good enough that detailed papers about the atmospheric dynamics of Jupiter have been written based purely on the analysis of amateur data.

With recent advances in camera technology, we have moved even further, discovering storms on the distant worlds of Uranus and Neptune.

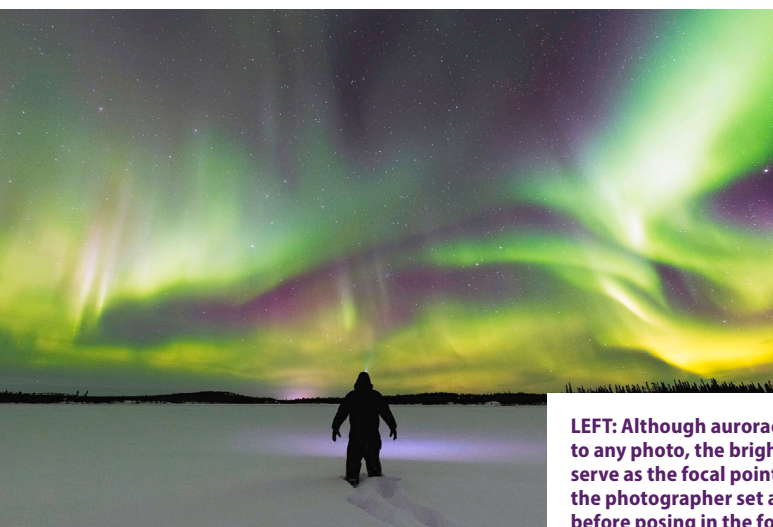
Indeed, amateurs continue to make significant discoveries and contributions to studying the four planets of Voyager. ☾

Damian Peach is one of this planet's finest astroimagers. He collects photons from around the world and processes them from his home in Selsey, England.

How to photograph aurorae

No matter your photography skills, a few simple tricks can help you capture the best images possible.

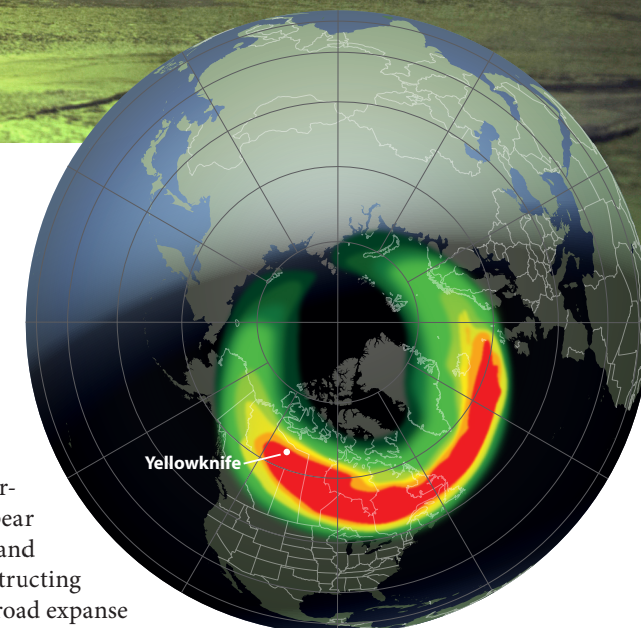
Text and images by Steve Cullen



LEFT: Although aurorae add an ethereal look to any photo, the bright streaks can't always serve as the focal point of an image. Here, the photographer set a timer on his camera before posing in the foreground.



ABOVE: A frozen lake is a prime location to capture the shimmering glow of aurorae, as the landscape is largely free of obstructions.



Probability of visible aurorae
10% 50% 90%

Early on New Year's Day 2016 (UT), aurorae hunters across the northern United States and Canada were treated to a spectacular show when the auroral oval expanded south and intensified. NOAA/NASA

If you ever decide to head to the small town of Yellowknife (population 20,000) in the Northwest Territories of Canada and expect to get good pizza, you might want to reconsider your choice of destination. But if you go there hoping to watch and photograph some of the most amazing displays of the northern lights you will ever see, you have certainly chosen wisely.

Now, don't get me wrong. I'm not saying there isn't good pizza to be had in Yellowknife, but my takeout order consisted of crust, some kind of makeshift white sauce, cheddar cheese, and a slice of pepperoni or two. However, that's just the

risk you take when you venture to one of Canada's most remote northern towns. On the flip side, coming up with a location that is better situated to catch the northern lights in North America would be next to impossible.

Embedded in the auroral oval

Yellowknife is about 250 miles (400 kilometers) south of the Arctic Circle. One of its most notable claims to fame is being featured on the first season of the TV show *Ice Road Truckers*. The town serves as the home base for convoys of trucks that brave the frozen-lake ice roads 24 hours a day, seven days a week for about two months

each winter. But for us, the most important thing about Yellowknife is that it sits directly under the auroral oval.

The auroral oval is a gigantic ring that circles Earth's geomagnetic north pole. It represents the point along Earth's magnetic field where charged particles from the Sun collide with atoms and molecules of oxygen and nitrogen in the upper atmosphere, causing them to release the colored light we call aurorae. Theoretically, aurorae could be any color in the spectrum, but the most prominent is a green hue often accompanied by violet, blue, yellow, pink, and red wisps. Besides being perfectly positioned for auroral displays, Yellowknife (for the

most part) checks off many of the boxes for other criteria you would want to consider in selecting a place to capture the northern lights: its levels of light pollution, its geography, and the overall weather.

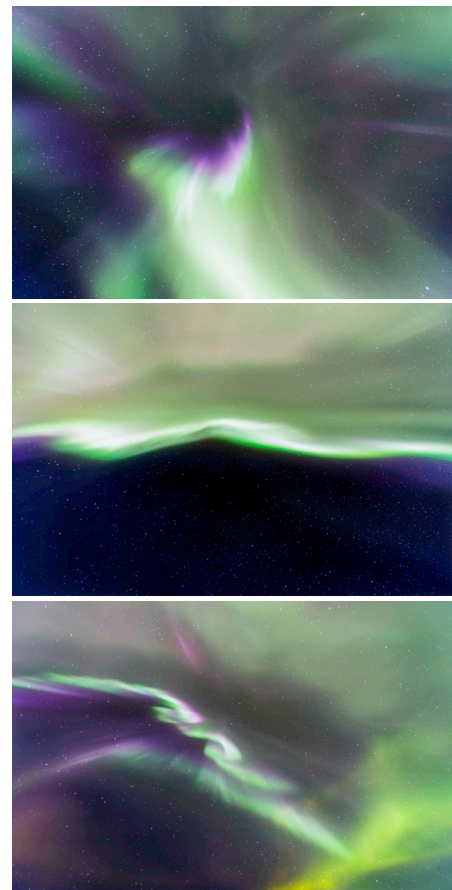
Given its remoteness, Yellowknife has very dark skies once you venture away from the town itself. A 30-minute drive will get you far enough away from light pollution to have excellent sky conditions. The darker the sky, the more the aurorae will stand out against the inky blackness. That said, even in town, the northern lights often glow bright enough to be easily seen, albeit with reduced contrast against the background sky. From a geological and

topographical perspective, the area is fairly flat and dotted with a multitude of lakes left over from the retreat of ice-age glaciers. This is important because aurorae can appear almost anywhere in the sky, and with no large mountains obstructing the view, you can take in a broad expanse of the heavens.

The lakes are a huge benefit from January through March because they are frozen over to a thickness that allows you to drive across them. Being in the middle of a lake eliminates everything that might block your view of what's going on above.



When it comes to photographing aurorae, sometimes less is more. Even relatively faint aurorae will give most images a subtle, elegant feel.



When you stand directly below the incoming flow of charged particles from the Sun, the aurora borealis at the zenith is a psychedelic menagerie of violet and green against the inky black backdrop of space.

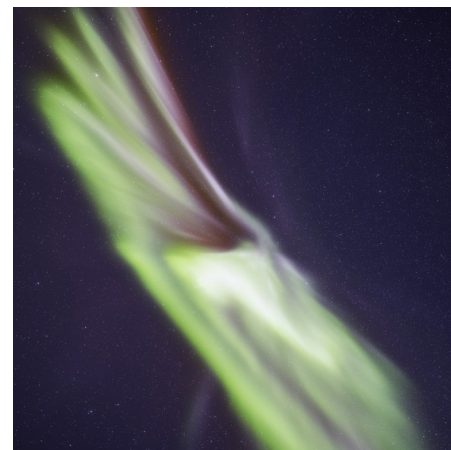
I have to admit, it is a bit disconcerting the first time you drive over the surface of a frozen lake, but you soon get used to it. You might even come to enjoy the unique ride.

Fortunately, Yellowknife is in a region with relatively good weather, especially considering its far northern latitude. Rain isn't a major concern for aurorae viewing, since the sky stays too bright for many displays from April through August, which is when most of the rain falls there. Snow is also surprisingly light. The region will have some amount of it for about 190 days of the year. But the monthly totals are bearable, with November being the worst, experiencing an average of 14 inches (36 centimeters), while the rest of the snowy months average less than 9 inches (23 cm).

As a photographer, the main thing you have to worry about is the cold. Temperatures early in the year can be brutal, with an average in January of -14 degrees Fahrenheit (-26 degrees Celsius). When I was there in March, the overnight temperatures dipped to -25 F (-32 C), with a wind chill of -40 F (-40 C). Luckily, I had brought along an Alpine climbing snowsuit that I stuffed with heat packs, which kept me mostly comfortable while standing outside for four or five hours. Make no mistake: These kinds of temperatures are not to be taken lightly, so you should definitely plan accordingly.

In fact, a lot of camera gear will simply stop working properly in such extreme environments. The mirror on my Nikon D850 would frequently stick and refuse to move when I pressed the shutter button. The legs on my tripod also completely froze in the open position. And even though the air is drier in the winter, whenever I was near any open water, there would be enough humidity for ice crystals to form on my lens.

The solution? I went to the local sundry shop and bought some hair scrunchies, which are now part of my permanent photography travel kit. I wrapped one around



It is a magical moment when you look straight up to see an incoming aurora. Dancing ribbons of light seemingly descend right above your head.

the lens to hold a heat pack or two tight against the body, and it provided enough heat to keep the ice crystals at bay.

Another issue is that batteries do not perform as well in cold environments. I kept a few batteries warm in my pocket at all times. I usually needed to swap them out once or twice during a session. On the positive side of the ledger, the bitter cold temperatures lowered the amount of noise in my photographs.

The final major question to answer when deciding to photograph the northern lights is when to go. As spring arrives, the Sun sets later and later at high northern latitudes. From early April to late August, the sky never reaches astronomical twilight, and it is as bright as civil twilight from late May to mid-July. That pretty much eliminates those months as options.

This brings me to an interesting phenomenon that scientists are still investigating. There seems to be more prominent auroral displays in the weeks around the vernal and autumnal equinoxes. This is called the Russell-McPherron effect. The prevailing hypothesis is that during these windows, Earth's magnetic field is better aligned with the stream of charged particles raining down on us from the Sun, leading to heightened auroral activity. So, if you're looking to nudge the odds in your favor, I would suggest timing your visit around one of the equinoxes.

Imaging aurorae

With the trip planning covered, let's get down to brass tacks — what's the best way to photograph aurorae?

Your gear should consist of at least two camera bodies if possible. If you're making such a large time and travel investment to journey to the Northwest Territories, having a backup only makes sense. (My guess is that Amazon Prime won't make next-day deliveries to Yellowknife.)

You should also bring a sturdy and reliable tripod. There are differing schools of thought about whether twist lock legs or clamp lock legs are better for the cold. Mine are all twist locks, and they absolutely were prone to freezing up as the temperatures reached double-digit negatives.

Because aurorae can appear anywhere in the sky, a fast wide-angle lens also is an important part of your kit. A lens in the 14mm to 24mm focal length range would be best, preferably with f/2.8 optics.

As with all night-sky photography, you'll want to practice sound composition techniques. Because many of your shots



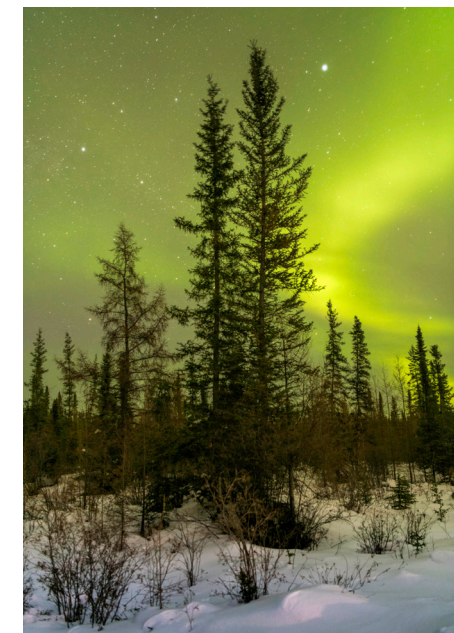
If you find a reflective surface, such as an unfrozen lake or pond, try to capture the reflection of an aurora in your shot.

will be wide angle, try to place an interesting foreground subject in your frame. Use the aurorae as you would the Milky Way; it should be a strong supporting element, but it doesn't have to be the hero. Trees, rocks, snow formations, water, and other close-in objects tend to draw the viewer's eye into the image more than an image looking straight up at the sky. If you're just starting out with night photography, keeping it simple is probably the best approach. Don't worry about stacking images or shooting to combine the foreground and the sky in post-processing. These are all techniques for getting improved results, but not necessary early on.

Plan to set your camera to a high ISO, probably 1600 or above. Of course, this will depend on your camera's capabilities and performance at higher ISOs. Set your aperture as wide open as your lens allows.

And, finally, set your shutter to be open for anywhere from 10 to 30 seconds. Once you're in the field, you can experiment with the exposure time. However, keep in mind that the northern lights are constantly in motion, and they will appear "fuzzier" the longer you leave your shutter open. If you are a more advanced night-scape photographer, many of the skills you already know for Milky Way photography will also apply to aurorae photography.

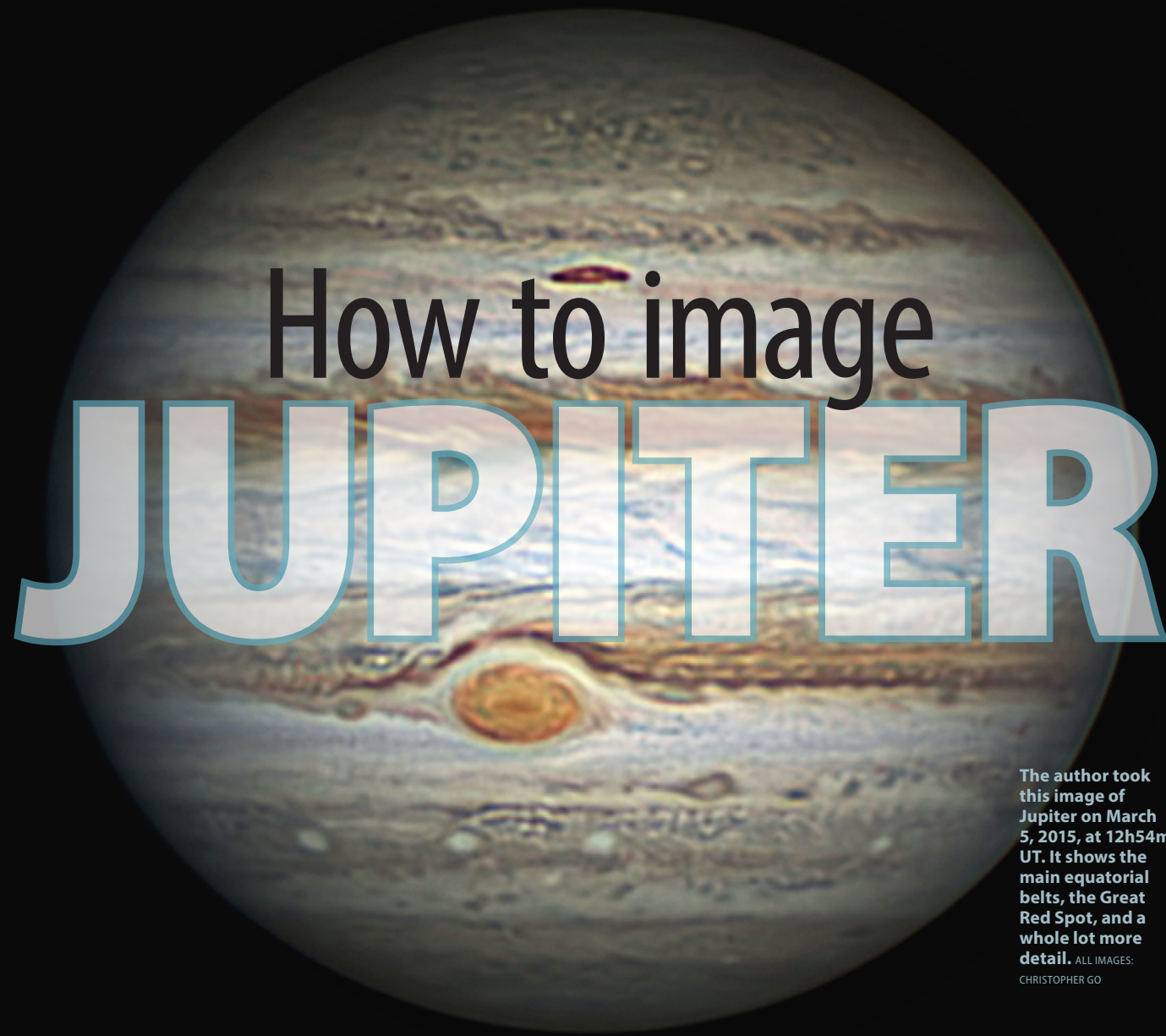
Photographing aurorae is a fun and



Though wide-angle shots are great for capturing aurorae, occasionally an aurora is best used as an intriguing background for a close-up shot.

challenging experience. But if you go, make sure to appreciate the journey. And more importantly, take time away from the camera to simply look up and enjoy the show. ▸

Steve Cullen is a product photographer who pursues his life-long passion for landscape and astrophotography in his free time.



How to image JUPITER

The author took this image of Jupiter on March 5, 2015, at 12h54m UT. It shows the main equatorial belts, the Great Red Spot, and a whole lot more detail. ALL IMAGES: CHRISTOPHER GO

Longtime photographer **Christopher Go** takes you step by step through the process of imaging this gas giant.

Besides Earth, Jupiter is the easiest planet to capture photographically. Its high surface brightness and large angular diameter make detailed imaging accessible to any telescope size. Even a small scope can resolve major features, like the Great Red Spot.

And now's a great time to start shooting the gas giant because it lies high in the sky. Professional astronomers at the Jet Propulsion Laboratory are requesting amateur images to support the Juno spacecraft, which will arrive at Jupiter in July.

As someone who has been imaging Jupiter for a decade, I've seen and tried a lot of equipment and many processing techniques. Because I have "been there, done that," the tips and techniques I've developed can help you get started the right way. Take it slow, be sure you understand an idea before you move to the next one, join an online imaging forum, ask lots of questions, and then head out and shoot!

Lucky imaging

Currently, the method I and most other amateurs use to capture planets is called "lucky imaging." This uses a small video camera attached to a telescope. You later process the video with software that lets you stack frames. The program has a routine to perform a check on each frame. It then arranges them in order of quality, letting you stack the best ones to produce a final image.

Which camera?

One of the most common questions people ask is whether to get a monochrome or color camera. Color cameras are easy to use and less expensive overall because you don't need additional accessories like filters and filter wheels.

For beginners I always recommend a color camera. And I have one other tip: When your target planet lies below an altitude of 70°, use an atmospheric dispersion corrector to offset the effects thicker layers of air have on images.

For the highest-quality images, amateur astronomers should use monochrome cameras because their pixels lie closer together than those in color cameras. Monochrome models also are more sensitive.

I use a Celestron Skyris 236M (pictured at lower right) for my monochrome imaging and the Celestron NexImage 5 for my color images.

Telescope and mount

Almost any telescope can produce decent images of Jupiter. That said, use the largest aperture you can. Long-focal-length telescopes are ideal for imaging Jupiter because they offer higher magnifications.

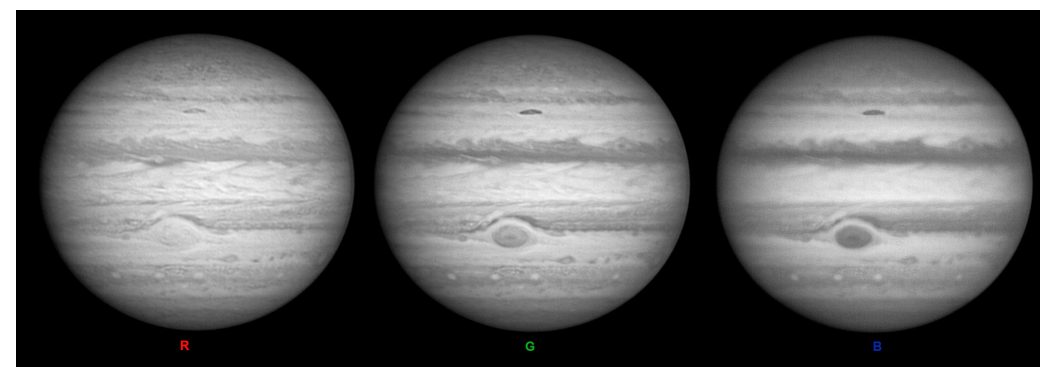
An optical tube is only as good as its mount, however. As much as it is up to you, choose a sturdy polar-aligned mount.

Christopher Go has produced images of Jupiter nearly every clear night for a decade from Cebu, Philippines. Contact him at chris@stoneind.com.



This image of the giant planet, which the author captured April 9, 2015, at 10h59m UT, shows great detail and accurate color. The Great Red Spot at the left edge is just starting to rotate into view.

If you use a monochrome camera to shoot Jupiter, you have to capture exposures through red, green, and blue filters to produce a color image.



This necessity (I think it's more than an accessory) will make your imaging easier.

Other accessories

If you select a monochrome camera, you'll need a filter wheel with a red, green, and blue (RGB) filter set to produce color shots. Beyond standard color images, I often use a methane-band filter, an ultraviolet filter, and an infrared filter. Each of these reveals different layers in Jupiter's atmosphere. Note that the images you'll get through these filters will not be as pleasing to the eye as your color shots.

I also suggest a motorized focuser. This accessory will allow fine focus, which is necessary to get the best image.

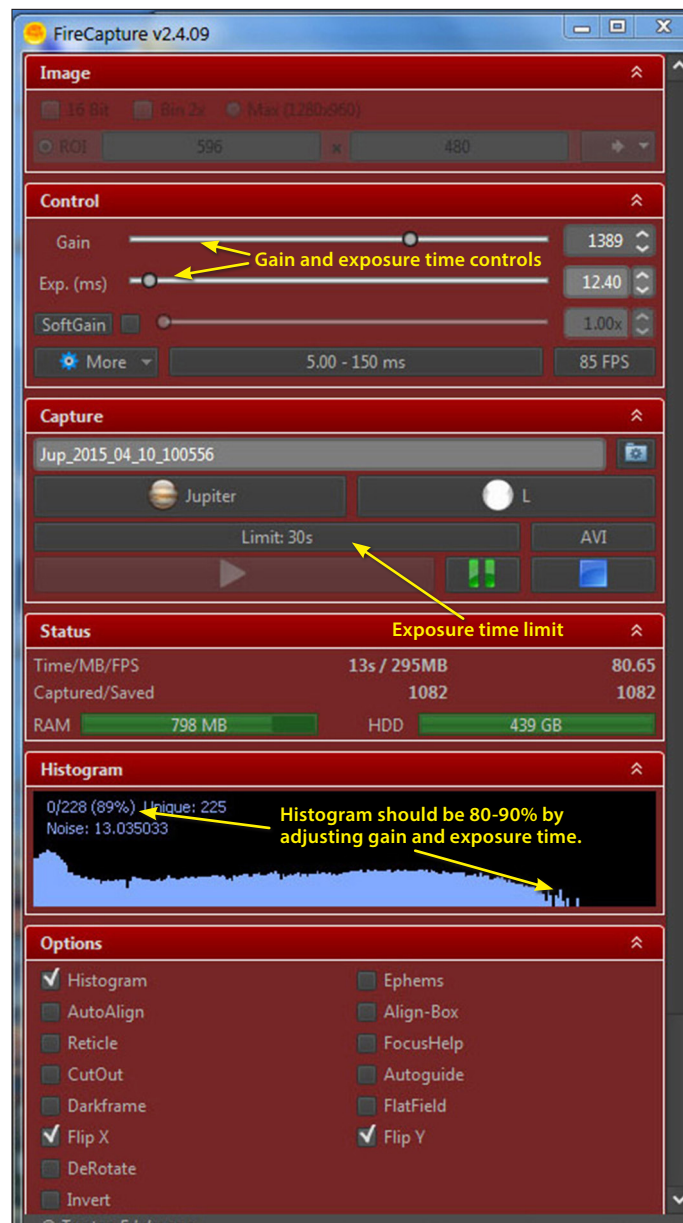
You also may want to use a Barlow lens to increase image size, but I can't tell you which one exactly. Its magnification depends on the focal ratio of the camera, and your typical seeing conditions (how steady the air above your imaging site is). A variable Barlow, like the Astro-Physics Advanced Convertible Barlow, allows flexibility.

Imaging preparation

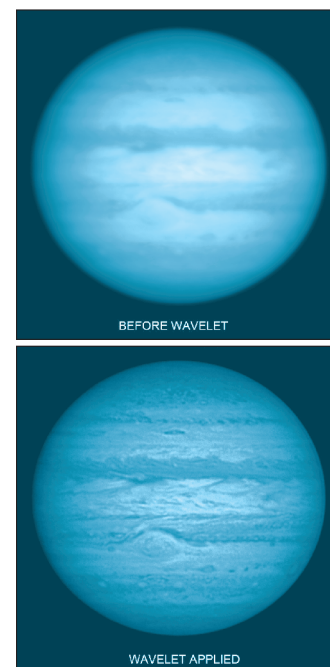
The most important step before you start to image is to make sure that the telescope is at ambient temperature. A telescope warmer than its surroundings will cause tube currents that negatively affect image quality. Also, avoid imaging close to asphalt that's been in the Sun all day, a hot roof, or other such structures.

FOR THE HIGHEST-QUALITY IMAGES, AMATEUR ASTRONOMERS SHOULD USE MONOCHROME CAMERAS BECAUSE THEIR PIXELS LIE CLOSER TOGETHER THAN THOSE IN A COLOR CAMERA.





The most important factor in getting the best image is seeing. This means the site you choose for capturing data is critical. If possible, try to image for three or four days straight from several locations, then pick the one with the highest-quality air. Selecting a site



If you use the "Wavelet" area in Registax carefully, your images will dramatically improve.

based on seeing is far more important than selecting a dark site. After all, Jupiter usually ranks as the fourth-brightest object in the sky.

Image capture

FireCapture is currently the standard image-capture software. It supports different camera manufacturers and controls ASCOM (short for Astronomy Common Object Model) compliant mounts, filter wheels, and focusers. Also important to some people: This software is free. Here are some tips on using FireCapture:

1. In "Capture Settings," make sure that the file name includes the object's name, the date, and the Universal Time. Also, synchronize your computer's clock with an atomic clock. When doing monochrome imaging, make sure you indicate the filter used.

2. Use "Region of Interest" (ROI) to reduce the capture frame size. Using ROI creates smaller files, increases the maximum frame rate, and makes processing faster. You can do ROI by hold-pressing your mouse's left button and outlining the area around Jupiter. Make sure you leave some space for inaccuracies in your mount's drive.

3. Set a time limit for capturing Jupiter. This is the "Limit" button on the control panel of FireCapture. Because of the planet's fast rotation, there are constraints on how long an exposure can be for each frame. For apertures smaller than 8 inches, the length is around 60 seconds; 40 seconds for an 11-inch; and 30 seconds for a 14-inch scope.

4. Two controls affect the brightness of Jupiter. These are "Gain" and "Exposure Time." A higher gain brightens Jupiter but will produce a grainy image. Faster exposure times would allow faster frame rates, but they will dim the object.

Use the image's histogram as a guide for these two settings. When imaging Jupiter, the histogram should peak at around 80 to 90 percent.

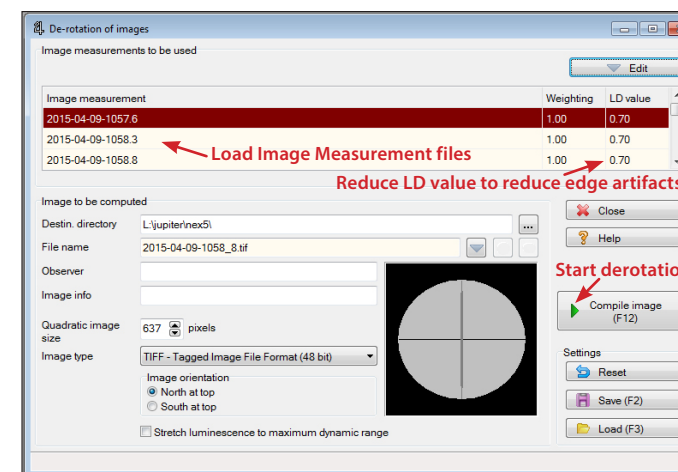
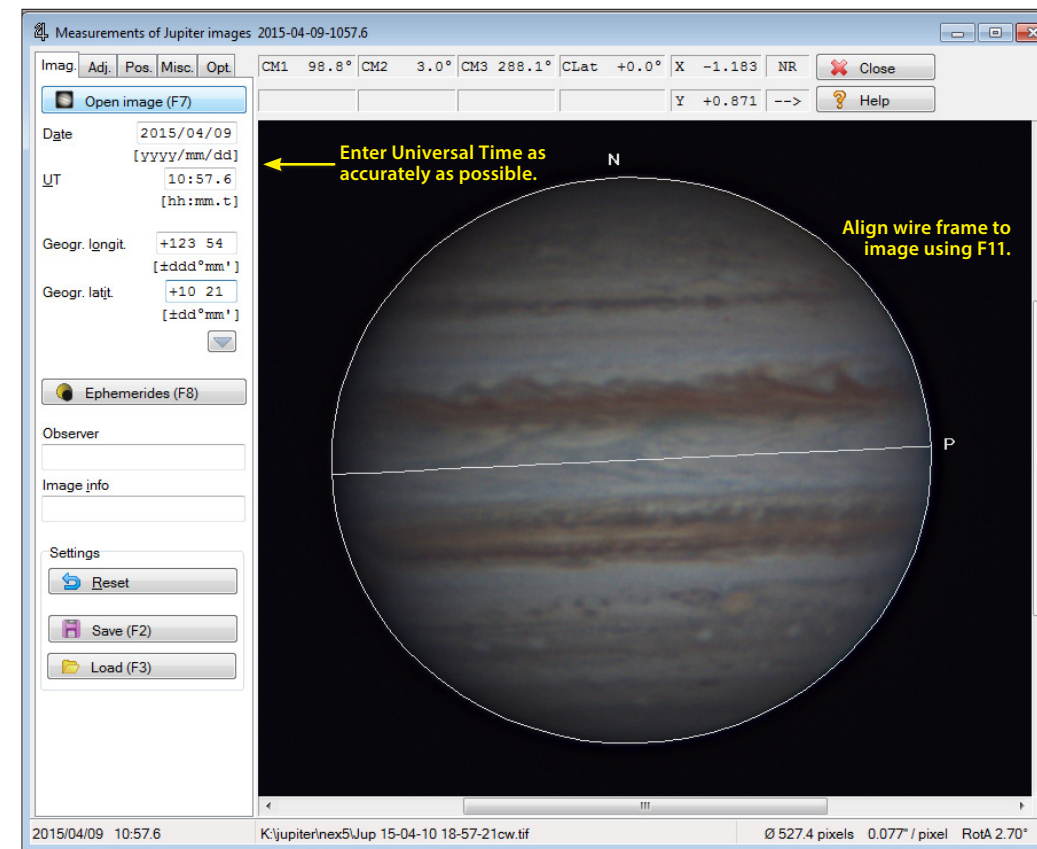
One other thing to remember is that the frame rate functions as the inverse of the exposure time. I recommend exposure times for Jupiter between 1/50- and 1/60-second, then setting the gain to achieve the recommended histogram. But this is not a hard rule. Exposure times will depend on your seeing.

5. When imaging using the narrowband methane or ultraviolet filters, bin your images at 2x2. This technique allows the camera to use four pixels (in a 2x2 matrix) as though they were a single pixel. Exposure times for these filters vary from 0.25 second to 2 seconds.

Stacking

Stacking software sorts video frames by quality. You then choose how many frames to stack for your final image. I recommend AutoStakkert!2 (AS!2). One nice feature is its ability to do batch processing by opening multiple files for stacking. Beginners find AS!2 easy to use. Here are the steps:

1. Open the file.
2. Press the "Place AP on Grid" button. I recommend alignment point (AP) sizes of

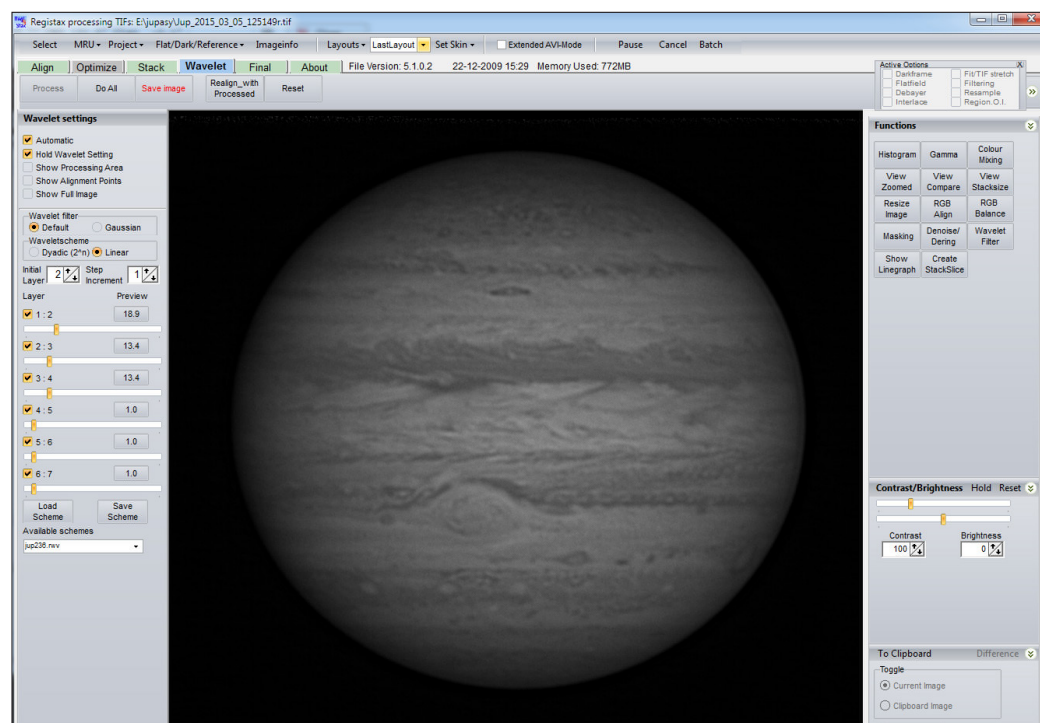


To derotate an image of the giant planet, first open the "Image Measurement" window in WinJupos.

The second step is to open the "De-rotation of images" window.

FireCapture's control screen offers numerous options for processing planetary images.

Many planetary imagers cut their teeth on Registax, which came onto the amateur astronomy scene in May 2002.



50 or 100 depending on the size of the image.

3. In the "Stack Options" section, use percentage for the amount of image you want to stack. When the seeing is good use 70 to 80 percent. For bad seeing, use 50 to 60 percent.

I normally use 1.5x drizzle for most of my images to increase their size. Test different drizzle settings, and find out which works best for your conditions and setup. AS!2 will save the resulting stacked images in a folder automatically.

Wavelet sharpening

Registax was early stacking software that started the amateur planetary imaging revolution. Its most powerful tool is the wavelet-sharpening function, which I highly recommend. Here are some tips for using wavelet:

1. The "Layer" sliders control sharpening. Slider 1 is for fine sharpening, and it gets coarser as the slider number increases. I normally use only sliders 1, 2, and 3 and leave sliders 4 through 6 set at 1.0.

Larger images require higher slider values. Don't push too much or you will introduce more grain in the image.

2. Increasing the value of the "Initial Layer" and the "Step Increment" will help sharpen your image. Test different settings to see which works best with your setup. Then save them when you find the sweet spot.

Color combine

Color camera users can skip this step. Image processing



On June 3, 2010, the author imaged an impact scar (arrow) in Jupiter's atmosphere discovered by Australian amateur astronomer Anthony Wesley.

WHEN SEEING IS GOOD, THREE OR FOUR IMAGE SETS ARE SUFFICIENT, BUT WHEN CONDITIONS ARE BAD, CAPTURE MORE IMAGE SETS.



software like Photoshop and Gimp can be used to align colors. Note: Apply wavelets before you color combine. Here's how to combine colors in Photoshop:

1. Open the wavelet-processed files.
2. Convert the images into gray scale ("Image," then "Mode," then "Grayscale")
3. Next, at the "Channels" windows, use the "Merge Channels" function, and use the "RGB Color" option. Make sure each file corresponds to the correct color channel.
4. Use the "Move" tool to do alignment adjustment. I suggest you align the Red and Blue channels to the Green channel. Save your color image using the Green filter time.

Derotation


The fast rotation of Jupiter limits the exposure time. Fortunately, WinJupos software has added a feature called "De-rotation," which allows exposure times beyond what was possible with a single image. Now, you can capture and derotate multiple image sets into an image, which will produce less noise than a single image.

For color, you capture multiple consecutive images. But for monochrome, you must

MEET THE AUTHOR

Imaging wizard

Christopher Go has sent an astounding 977 sets of images of Jupiter to *Astronomy* magazine, starting in early 2007, and he carefully processes each shot before sending it. This amount of work alone places him in the top tier of planetary imagers. Recently, he began teaching others how to image Jupiter.



Christopher Go

COURTESY CELESTRON

capture three sets (R, G, and B) of sequences. Do not do consecutive captures with the same filter, or the resulting image will have red and blue edges. You have to do an RGB set.

When seeing is good, three or four image sets are sufficient, but when atmospheric conditions are bad, capture more image sets. De-rotation is a two-stage process.

STAGE 1:

1. Under "Recording," open the "Image Measurement" window.
2. Load the image. Enter the median observation time. For color images, this is the time on the file name plus half of your exposure time. For monochrome images, this should be the green start time plus half the time you exposed on one channel. Make sure you enter the time accurately.
3. Press F11 to automatically align the wire frame to the image. If there seems to be some offset on the auto-align, use the arrow keys to adjust the X and Y positions, the "N" and "P" keys to adjust rotation, and "Page Up" and "Page Down" to adjust the size of the wire frame. Save the image measurement. Repeat these procedures for the image set.

STAGE 2:

1. Open the "De-rotation of Images" window under "Tools."
2. Load the Image Measurement (*.ims) files that you made in Stage 1.
3. Choose the output file type and orientation preference.
4. Compile the image. Your

result will carry the midtime of the component images.

Final processing

Using image-processing software, apply slight unsharp masking to improve the image. Some useful tools in Photoshop are the "Despeckle" and the "Dust and Scratches" filters, which remove noise and grain. You'll find them in the "Filters," then "Noise" menus.

Impact detection

Since June 2010, amateur imagers have detected four impact events. In response, programmers developed Jupiter Impact Detection (JID) software to search for them automatically.

So be sure to run all of your captured video streams through JID. Who knows? You might get lucky and achieve your 15 minutes of fame.

Support research

Finally, you can help the cause of science by uploading your images to the Jupiter section of the Association of Lunar and Planetary Observers, the International Outer Planets Watch website, and the JPL Juno support website. This will allow professionals to use your images to give us all a better understanding of Jupiter.

When submitting images, include the date and time of capture, name of imager and location, and the three central meridian system timings of Jupiter. You'll find them in WinJupos under "Tools," then "Ephemerides." ↗