



Revealing the Planets

Contributing to the study of our neighboring worlds is easier than you might think.

Photographing the Moon and planets has long been a mainstay of both amateur and professional astronomy. Using high-speed digital video cameras and innovative processing techniques, amateurs today regularly produce pictures of our neighboring worlds that resolve tiny details only fleetingly glimpsed in the eyepiece.

Taking high-resolution photos of delicate clouds in the atmosphere of Mars, interacting storms in the belts of Jupiter, or the polar hexagon on Saturn is well within the grasp of anyone with patience and a relatively modest telescope. Here's what you need to get started.

Choosing Your Tools

The resolution of your planetary images will be dependent on the telescope you use. Most any instrument can produce excellent planetary images. But to record the smallest swirls in Jupiter's cloudtops or changes in the receding polar cap on Mars, you'll need an instrument of at least 8 inches aperture.

Each of the most popular optical designs have their strengths and weaknesses, but the Schmidt-Cassegrain telescope (SCT) is perhaps the best compromise between

▲ **AMAZING DETAILS** Resolving details on the planets within our solar system has never been easier. Author Damian Peach shares some tips on how to capture and process your images to reveal tiny features that are only fleetingly glimpsed at the eyepiece. He recorded the montage above using a Celestron C14 Schmidt-Cassegrain telescope and FLIR Systems (formerly Point Grey Research) Grasshopper 3 high-speed video camera.

adequate aperture and a manageable size. The SCT design combines reflective optics with a corrector plate to produce sharp, color-free images while simultaneously housing large-aperture optics in a short optical tube. The drawback is that such compound instruments usually need to be recollimated, especially if you transport the scope to your observing location each night.

Regardless of which kind of telescope you choose, there are a few accessories you'll need to take detailed planetary images. The first is an electric focuser. You don't want to touch the telescope when focusing, as vibrations from your hand are greatly magnified, and you'll simply be fighting with a jiggling image. Not only that, but you'll frequently need to refocus as the temperature changes and seeing conditions fluctuate throughout the night.

Planetary photography requires a focal ratio of about $f/20$ to $f/30$, depending upon the target (with only Mars tolerating the upper end of this scale). Commercial telescopes tend to come in focal ratios of $f/5$ to $f/10$, so you'll need some way to boost your instrument's effective focal length to achieve the image scale necessary to resolve small features on your target planet. So, your next accessory purchase should be either a Barlow lens, eyepiece projection adapter, or another amplification optic like a Tele Vue Powermate.

Another useful tool in a planetary imager's arsenal is an Atmospheric Dispersion Corrector (ADC). This small device consists of two weak prisms in a compact, adjustable housing placed in front of your camera. Changing the tilt between the prisms allow you to correct for *atmospheric dispersion* — the smearing of light into its component colors by the refractive properties of Earth's atmosphere. The closer a planet is to the horizon, the worse the effect becomes. This prismatic separation appears as blue and red fringing on the top and bottom of the target, though the entire view is affected and robbed of small-scale details. These devices can completely tune out this dispersion and present a sharper image than would otherwise be possible. ADC's are widely available, some costing as little as \$150. They are well worth investment, especially for observers at more northerly locations, particularly as planets often appear positioned south of the ecliptic.

Cameras, Computers, and Control

Your next consideration is your camera. Planetary photography is based on a technique known as "lucky imaging," in which you record a series of exposures or a video of your target at a rapid frame rate, then import those frames into a computer program that sorts and stacks only the sharpest ones. Today's planetary cameras feature low-noise CMOS sensors with lightning-fast readouts of more than 100 frames per second transferred to your computer via a USB 3.0 or GigE connection. All typically include software that allows you to control important settings such as exposure, frame rate, and gain.

Nearly all planetary imagers are built around Sony CMOS sensors and are offered as either monochrome or in one-shot-color format. Color cameras are excellent for beginners or casual imagers, while monochrome models require the addition of a color filter wheel and filters if you want to produce color images. Monochrome cameras are particularly useful for recording images in wavelengths beyond the visible spectrum (such as ultraviolet and infrared) as well as several specific wavelengths that can penetrate deeper within Jupiter's atmosphere.

Planetary cameras record video files in either AVI or SER format, though some have the option of recording individual FITS images. You can import these files into the stacking programs discussed later.

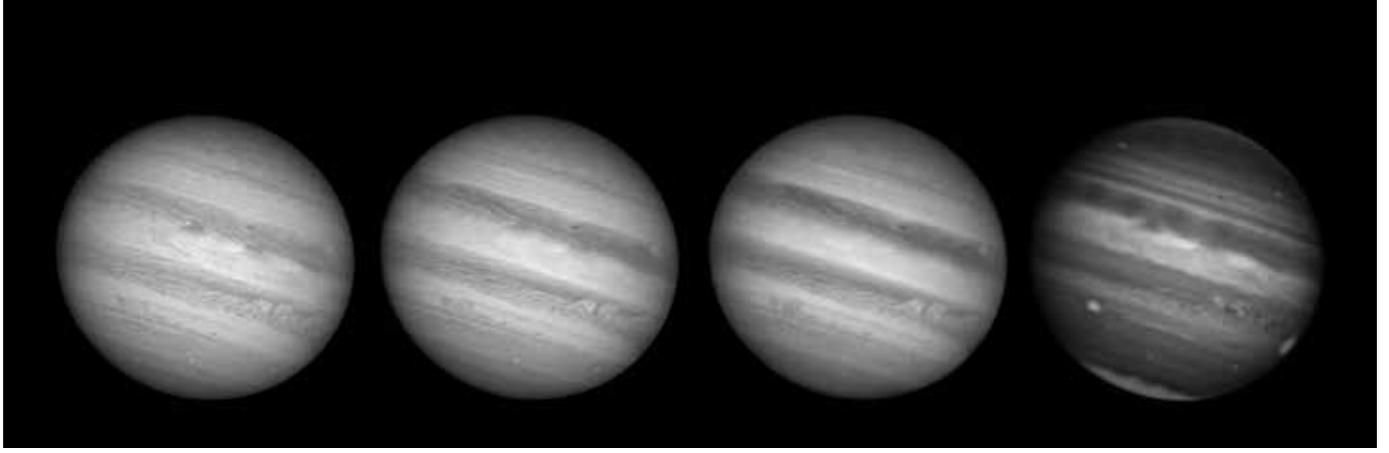
► **EASY SETUP** The author's typical planetary imaging rig on a typical night imaging from his backyard. Although not a requirement, he prefers a high-resolution monitor attached to his laptop to provide a more detailed image, which greatly helps when focusing.



▲ **HIGH-SPEED VIDEO** Several manufacturers offer planetary imaging cameras, including Celestron (celestron.com), FLIR Systems (flir.com), The Imaging Source (theimagingsource.com), Meade (meade.com), QHYCCD (qhyccd.com), and ZWO (astronomy-imaging-camera.com). You can even use a DSLR camera with HD video capabilities, though they weigh much more than the video cameras shown above and require a very sturdy focuser.

Such high-speed cameras produce a massive stream of data, churning out dozens of megabytes of data per second, requiring a computer that incorporates a large hard drive with a fast write speed. Many of the solid-state drives (SSD) found in laptop computers these days can record 300-500 MB per sec-



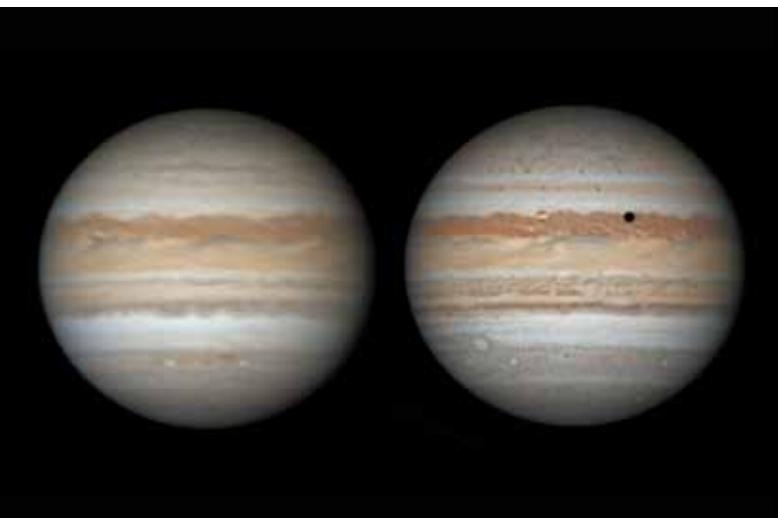


▲ **ISOLATING WAVELENGTHS** A monochrome camera equipped with color filters provides better isolation of individual wavelengths and is particularly desirable for imaging beyond the visible spectrum. The examples of Jupiter above show differences among the red, green, and blue data, as well as the near-infrared wavelength (right) centered at 889 nanometers where methane strongly absorbs light, revealing features deeper within Jupiter's atmosphere.

ond, easily accommodating such fast cameras. Older hard disk drives (HDD), with the exception of 7200 RPM models, have slower write speeds and may struggle with and drop frames during a recording. Be sure to investigate the specifications of your computer to see if it supports USB 3.0 or GigE and fast write speeds. And as you'll quickly accumulate several dozen gigabytes of videos each night, be sure your computer has at least a terabyte of storage space available. Also consider a large external drive to back up your video files.

Although your camera may come with its own control software, most planetary imagers prefer to operate their cameras, filter wheels, and focusers using the third-party program *FireCapture* (firecapture.de). This free PC software includes many useful features specific to planetary imaging, including the ability to pre-program exposure changes for each color filter, region-of-interest cropping, and program presets you can create for each planet.

▼ **VARIABLE SEEING** Even if you've carefully collimated your telescope and made sure it's acclimated to the ambient temperature, turbulence in the atmosphere will still limit the detail in your images. The images of Jupiter below show the results produced on consecutive nights in which conditions were average to poor (left) versus a night with very good to excellent seeing conditions (right).



At the Telescope

Now that you've assembled your equipment, you need to consider several crucial before recording your first video sequence.

First and foremost is making sure your telescope is in perfect collimation. Even a slight misalignment can noticeably degrade the image being recorded. You should check this before starting your first image series of the night, preferably after aiming the scope in the general direction of the planet you are photographing. An excellent tutorial on collimating Newtonian reflectors appear in our April 2019 issue (page 68) and one for collimating SCTs can be found in our February, 2018 issue, page 28.

Another consideration is ensuring your telescope has reached *thermal equilibrium*. If your scope is warmer than the outside air, it will radiate heat, producing a blurry image that is virtually impossible to focus. Give your scope about an hour or more to cool down, especially if you store it indoors. Larger apertures will typically need even more time to cool. You can speed up the process, though, with fans or other active cooling devices.

All these preparations will help you get the most out of your equipment, but your biggest limitation will be the atmospheric seeing conditions. "Seeing" is the amount of blurring imparted on your target by the turbulent mixing of air masses of different temperature in the atmosphere. While we can't control seeing, there are many forecasting tools online today that can help you determine if conditions are good enough to bother setting up or not. One site is meteoblue.com, which offers seeing forecasts for your location under its Outdoor & Sports section.

Focus, Focus, Focus

Once you're at the scope, the most important consideration is focusing. I use a monochrome camera with RGB filters and focus visually with the computer screen by concentrating on the planet's disk. I slowly adjust focus back-and-forth until I'm confident that I've found the sharpest image. I then record a video, switch filters, and refocus for the next filter.

Focusing in good seeing is usually easy, but under poor

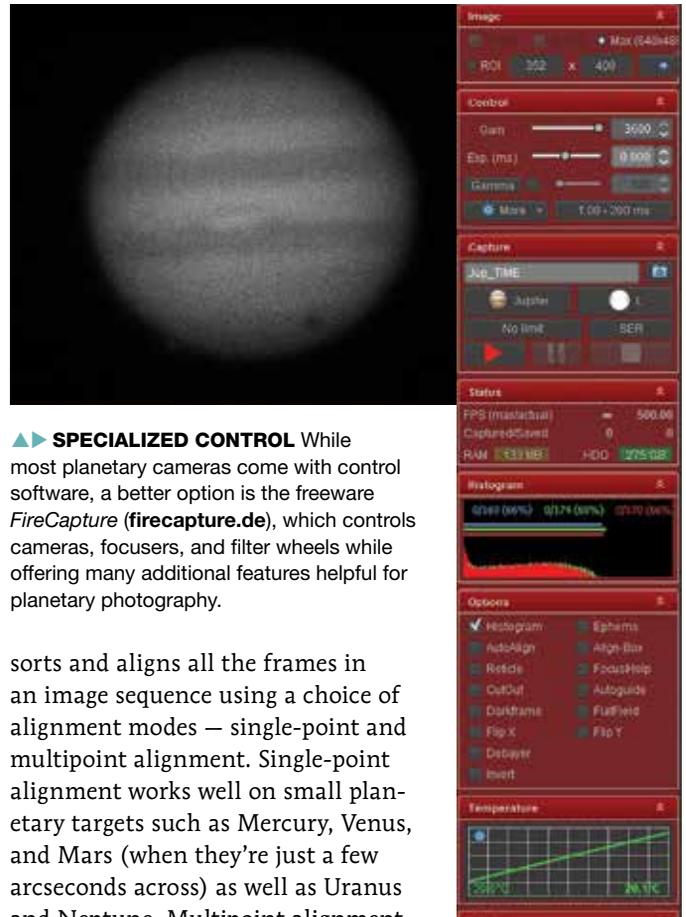
seeing it can be extremely difficult, so don't be discouraged. To gauge focus, use areas of high contrast on your target, such as the Cassini Division in Saturn's rings, albedo features on the Martian surface, and small storms in Jupiter's belts. Venus, Mercury, and even Mars can be difficult to focus when they're far from Earth and feature small disks, but the sunward limb is often a good spot to use to judge whether you're in focus or not. Simply take your time and practice. The more you do it, the better you'll get at it.

When you start recording video, you'll typically be operating your camera at about 30 to 80 frames per second or more, depending on the brightness of your target, capturing a minimum of 1,000 frames for a single image stack. Your camera's frame rate is a balance between the exposure length and gain settings, which are partially dictated by the brightness of the planet. Regardless, try to keep the camera's gain setting well below its maximum. Setting the gain to about 70% is a good starting point, then adjust your exposure until the planet is bright but not over-exposed on the screen. If you use *FireCapture*, be sure the histogram of the image does not go above about 80%. Also, ensure that the gamma setting is at its default value.

Video Reduction

This stage is perhaps the most fun part of the whole process, as you finally get to see what surprises your video sequences have in store. Currently there are two popular choices for stacking your planetary videos: *RegiStax 6* (astronomie.be/registax) and *Autostakkert! 3* (autostakkert.com). While both do an admiral job, *RegiStax 6* includes powerful Wavelet sharpening, which works extremely well, and I often stack my videos in *Autostakkert! 3* and then sharpen the resulting image in *RegiStax 6*.

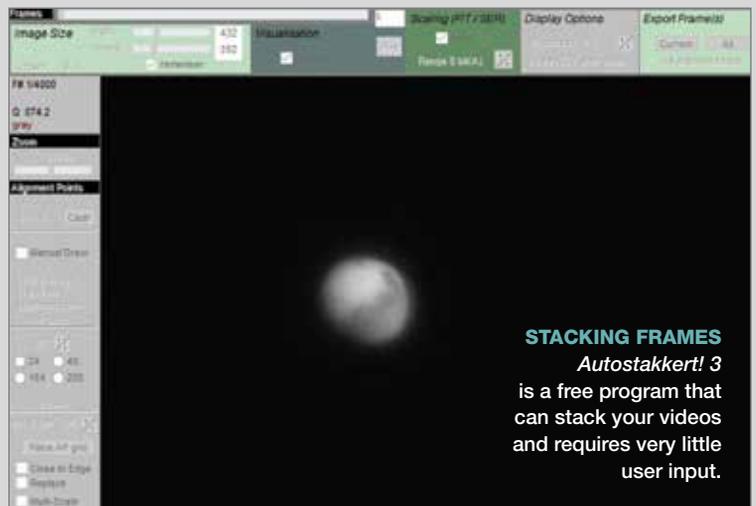
Both programs will stack your videos in basically the same way. (A tutorial on using *Autostakkert!* appeared in the September 2016 issue of *Sky & Telescope*, page 68.) Each program



► **SPECIALIZED CONTROL** While most planetary cameras come with control software, a better option is the freeware *FireCapture* (firecapture.de), which controls cameras, focusers, and filter wheels while offering many additional features helpful for planetary photography.

sorts and aligns all the frames in an image sequence using a choice of alignment modes — single-point and multipoint alignment. Single-point alignment works well on small planetary targets such as Mercury, Venus, and Mars (when they're just a few arcseconds across) as well as Uranus and Neptune. Multipoint alignment permits you to select multiple points to monitor, and the program will stack the best areas around each point, producing a superior result on larger planets like Jupiter, Saturn, Mars, and Venus, and also on lunar close-ups.

Once the software has aligned your video frames, you'll need to determine how many individual frames to stack — the greater the number, the better the signal-to-noise ratio



STACKING FRAMES
Autostakkert! 3 is a free program that can stack your videos and requires very little user input.

of the resulting image, making it less grainy and improving its ability to withstand sharpening. The number of usable frames you stack varies depending on the seeing conditions. Under good seeing you can stack a great many frames (maybe 75% or more), but in poor conditions this goes down to maybe about 30%. Stacking more frames taken under poor seeing simply produces a blurrier result, because more sub-pixel frames are included in the final stack. That said, don't be fooled into thinking just selecting the 100 best frames will work. It may well deliver a sharper result, but it will be extremely noisy when sharpened.

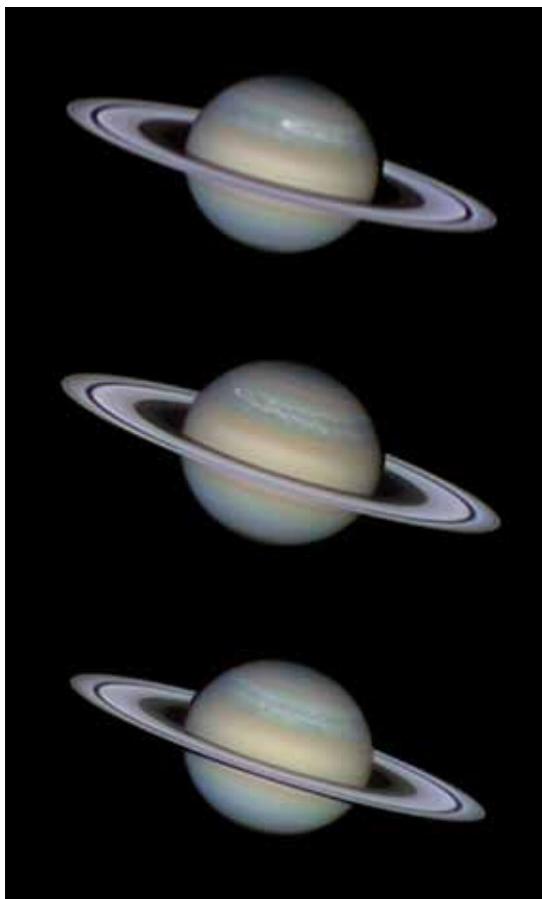
After you've completed reducing your video into stacked images, it's time to sharpen the result. At this step, the best tool to use is the Wavelets in *Registax 6*. This multi-layer sharpening tool quickly reveals subtle details in your images. Its six sliders offer varying ranges of enhancement. Slider 1 affects very fine detail while slider 6 brings out coarser details. I often use sliders 2 and 3 exclusively on my lunar and planetary images, but you should experiment to find a combination that works best for your photos.

Although you might consider your image done at this point, another free program, WINJUPOS, offers a powerful tool that can compensate for the effects of planetary rotation. The program's de-rotation feature permits you to combine several images captured over a long timespan. For example, Jupiter rotates so fast that you must limit your video length to about a minute or less before the planet's fast rotation blurs details in a single stacked video. Combining several stacked and de-rotated images produces even better pictures, allowing you to eke out even more detail in the final planetary portrait. A guide to the technique can be found in our May 2013 issue, page 70.

Contributing Real Science

Monitoring the planets is of considerable interest to professional researchers, and dedicated enthu-

▶ **MONITORING CAMPAIGN** Photographing the planets each clear night and sharing them with several organizations dedicated to their study helps contribute to our understanding of our neighboring worlds. This series of images shows the development of a storm in Saturn's North Temperate region that appeared at the end of 2010 and eventually spread to encircle the entire planet. These shots captured on March 21, and 28, and April 17, 2011 document its changing appearance, and were used by professional astronomers studying the phenomena.



▶ **WAVELET SHARPENING** The best tool for sharpening your stacked videos is the multi-layer Wavelets in the free program *RegiStax 6* (astronomie.be/registax). This powerful tool permits both sharpening and noise control, producing crisp images with minimal processing artifacts.

siasts have made many discoveries. Image quality today is so good that researchers have published detailed papers on the atmospheric dynamics of Jupiter based purely on the analysis of data provided by amateurs.

You can contribute by joining one of the established organizations dedicated to monitoring solar system bodies. Both the British Astronomical Association at britastro.org and the Association of Lunar and Planetary Observers (ALPO) at alpo-astronomy.org welcome new members who want to contribute images and observations. Asian organizations include the International Society of Mars Observers (ISMO) at <https://is.gd/des4ml> and ALPO Japan (alpo-j.sakura.ne.jp/indexE.htm). These groups provide nearly uninterrupted monitoring of solar system bodies — an invaluable resource for planetary scientists.

It's amazing to consider how far planetary imaging has improved in the last 25 years. Amateurs now routinely resolve planetary features that approach the theoretical resolving limit of their instruments. Give it a try yourself.

■ **DAMIAN PEACH** is a dedicated planetary observer based in Hampshire County, UK. Visit his website at damianpeach.com.