

# All about prime-focus imaging

Capture star clusters, nebulae, and galaxies using a telescope as your camera's lens. **by Michael A. Covington**

**F**or many astronomy enthusiasts, deep-sky imaging through a telescope marks the pinnacle of astrophotography. Amateurs today can image galaxies, nebulae, and star clusters and get results that rival those from professional observatories. Best of all, some deep-sky objects are bright enough that photographers can capture them under modestly light-polluted skies.

The techniques required for taking high-quality photos through a telescope are similar to those for piggybacking (see my March 2011 article) but more exacting. You will need to build your skills over time. The best way is to master piggybacking first. In both techniques, you use a digital single-lens reflex (DSLR) camera or a cooled CCD camera to take a series of sub-exposures, each 2- to 5-minutes long, then stack and process them with software such as *Deep Sky Stacker* (available for free from <http://deepskystacker.free.fr>).

## Tracking the stars

In prime-focus astrophotography, the telescope both gathers light and magnifies the image. This means it has to track the stars perfectly. That's why experienced imagers advise spending more money on the mount than on the telescope itself. Get an equatorial mount so the target keeps the same orientation in your field of view as Earth rotates. Then accurately polar-align the mount as I described in my previous article. Polar-alignment errors will turn stars into

**The Witch Head Nebula (IC 2118)** in Eridanus is a reflection nebula that scatters light from the bright bluish star Rigel (at top right). The imager took this photo through a 4-inch Takahashi FSQ-106 refractor at f/5 and an SBIG STL-11000 CCD camera (RGB image with exposures of 90, 90, and 120 minutes, respectively). *Jason Jennings*

north-south streaks. You'll get stars elongated east-west from periodic error in the drive's gears. You can counteract this by recording a set of corrections that the drive's computer then plays back.

The best way to make guiding corrections during exposures is to use an autoguider. This can be a self-contained instrument or a software package (try *PHD Guiding*, free from [www.stark-labs.com](http://www.stark-labs.com)) used with a webcam or planetary video camera. The autoguider watches a star and sends signals to the drive to keep it centered.

This instrument can use a separate guide scope piggybacked on the main telescope. Alternatively, it can view the star through an off-axis guider, a gadget that uses a small mirror to pick off part of the main telescope's image, out of the main camera's field. The trouble with off-axis guiding is that it can be difficult to find a suitably placed star and a challenge



**▲ The Southern Whirlpool Galaxy (M83)** in Hydra has bright spiral arms that wind out from the ends of a bar rich in stars, gas, and dust. The imager took this photo through a 24-inch RC Optical Systems Ritchey-Chrétien telescope and an SBIG STL-11000 CCD camera (LRGB image with exposures of 210, 60, 60, and 60 minutes, respectively). *Adam Block/Mount Lemmon SkyCenter/University of Arizona*

**◀ The large, dim supernova remnant CTB 1** in Cassiopeia formed thousands of years ago when a massive star exploded. The imager took this photo through a 4-inch Takahashi FSQ-106 refractor at f/5 and an SBIG STL-11000 CCD camera (H $\alpha$ RGB image with exposures of 360, 60, 60, and 90 minutes, respectively). *Steve Cannistra*



**The Cocoon Nebula** (IC 5146) is a giant stellar nursery in Cygnus. The imager took this photo through a 24-inch RC Optical Systems Ritchey-Chrétien telescope and an SBIG STL-11000 CCD camera (LRGB image with exposures of 165, 50, 40, and 50 minutes, respectively). Adam Block/Mount Lemmon SkyCenter/University of Arizona



**The nearby dwarf galaxy Leo I** glows dimly above the 1st-magnitude star Regulus. The imager took this photo through a 4-inch Tele Vue NP-101 refractor at f/5.4 and an SBIG ST-2000XM CCD camera (LRGB image with exposures of 336, 84, 42, and 42 minutes, respectively). Bernhard Hubl

to get both the main camera and the autoguider into focus at the same time.

Autoguiding can correct for imperfections in the drive and in polar alignment, but I find that tracking is seldom as smooth with these corrections as it is when I don't have to make corrections. That's the reason many astroimagers opt to do without it. Instead, they get a mount that tracks smoothly, they polar-align carefully, and then they let the mount do all the work.

This technique is much less risky than in the days of film photography because you can view digital images almost immediately to confirm you're tracking precisely. Instead of exposing for half an hour at a time, expose for a couple of minutes and simply throw out poorly guided frames. If you go this route, choose an equatorial mount designed specifically for astrophotography. It also helps if the mount has a polar-alignment finder scope built into its polar axis.

### Setting up the optics

You can use the telescope either in prime-focus mode or with a compressor lens. Prime focus means you directly couple the camera to the scope — the camera takes the place of the eyepiece. The whole system's  $f$ /ratio is that of the telescope itself.

Because you need a bright image and low  $f$ /ratio for the best results, never use a Barlow lens to magnify the image. But you can go the opposite route. A compressor lens operates as sort of an anti-Barlow that makes the image smaller and brighter. If you reduce the image to 70 percent of its original size, you also cut the  $f$ /ratio to 70 percent of what it was — and the image brightness doubles.

A compressor has other advantages. By shrinking the image scale, the image sensor covers a wider field in the sky. Understand that the compressor does not make your telescope into a wider-field instrument; it just shrinks the existing image. But if the image started out bigger than the sensor, more of it will fall on the sensor and end up in the final photo.

A properly designed compressor also can correct off-axis aberrations. The popular Meade and Celestron  $f$ /6.3 compressors for their  $f$ /10 Schmidt-Cassegrain telescopes flatten the field considerably; the telescope actually produces sharper images with the compressor than without.

The compressor has to intercept the light coming from the primary lens or mirror a considerable distance ahead of the focal plane, so be sure to use a compressor designed specifically for your telescope. For it to work as intended, all the distances have to be exact. A randomly chosen lens likely won't even reach focus.

What  $f$ /ratio should you aim for? I find somewhere around  $f$ /4 to  $f$ /6 works well for most purposes. With bright globular clusters and planetary nebulae, you can get nice results at  $f$ /10 or even  $f$ /15. At the other end of the scale, the Hyper-Star system from Starizona (<http://starizona.com>) and the earlier Celestron Fastar system allow you to use your Schmidt-Cassegrain's primary without the secondary as an  $f$ /2 system. With such super-fast speeds, you can take

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**Globular cluster M22** in Sagittarius boasts hundreds of thousands of stars and ranks as the brightest such object visible from mid-northern latitudes. The imager took this photo through a 4-inch Tele Vue NP-101 refractor at f/5.4 and an SBIG ST-2000XM CCD camera (LRGB image with exposures of 64, 25, 25, and 25 minutes, respectively). Bernhard Hubl



**Dark nebula Barnard 22** in Taurus surrounds the emission nebula IC 2087 (center). The imager took this photo through a 12-inch Astro Systeme Austria N2 astrograph at f/3.5 and an SBIG STL-11000M CCD camera (LRGB image with exposures of 300, 120, 120, and 120 minutes, respectively). Thomas V. Davis

15-second sub-exposures, which makes guiding much less critical.

### Focus, focus, focus

For through-the-telescope imaging, you can use either a DSLR or a cooled CCD camera. If it's a DSLR, you may want to

have it modified to extend its sensitivity to red light. (Most DSLRs have a filter that blocks infrared radiation to make daytime color photos look realistic. Unfortunately, the filter also blocks Hydrogen-alpha light — a major emission line in most bright nebulae.)



**The Perseus Cluster** (Abell 426) contains thousands of galaxies and spans more than 1 million light-years. The imager took this photo through a 20-inch RC Optical Systems Ritchey-Chrétien reflector at f/8 and an SBIG STL-11000 CCD camera (H $\alpha$ LRGB image with exposures of 435, 945, 180, 108, and 216 minutes, respectively). R. Jay GaBany



**The Wild Duck Cluster** (M11) in Scutum swarms with thousands of stars and anchors a rich Milky Way field. The imager took this photo through a 5.2-inch Astro-Physics AP-160 StarFire EDF refractor at f/7.5 and an SBIG ST-10XME CCD camera (LRGB image with 30 minutes of exposure through each filter). Anthony Ayiomamitis

Removing the filter makes faint emission nebulae pop but hardly affects stars and galaxies. If you choose cooled a CCD camera, you'll have to bring a computer and power supply along.

Whichever way you go, focusing is critical. There's no substitute for examining the electronic image either on the computer screen or in the magnified live-focusing mode (Canon calls it "Live View") on the DSLR's display. Focus on a

moderately dim star; a bright one will never look like a pinpoint. In fact, concentrate on stars that pop into view only when you reach correct focus. If your DSLR doesn't have live focusing, take some 5-second test exposures and view them magnified. The control software on CCD cameras lets you analyze star images in detail to find the point of best focus.

Regardless of your focusing technique, use stars located about a third of the way

from the field's center to its edge. This provides the best compromise for dealing with field curvature. If you focus at the center, the edges are more likely to be out of focus, and vice versa.

#### Color me satisfied

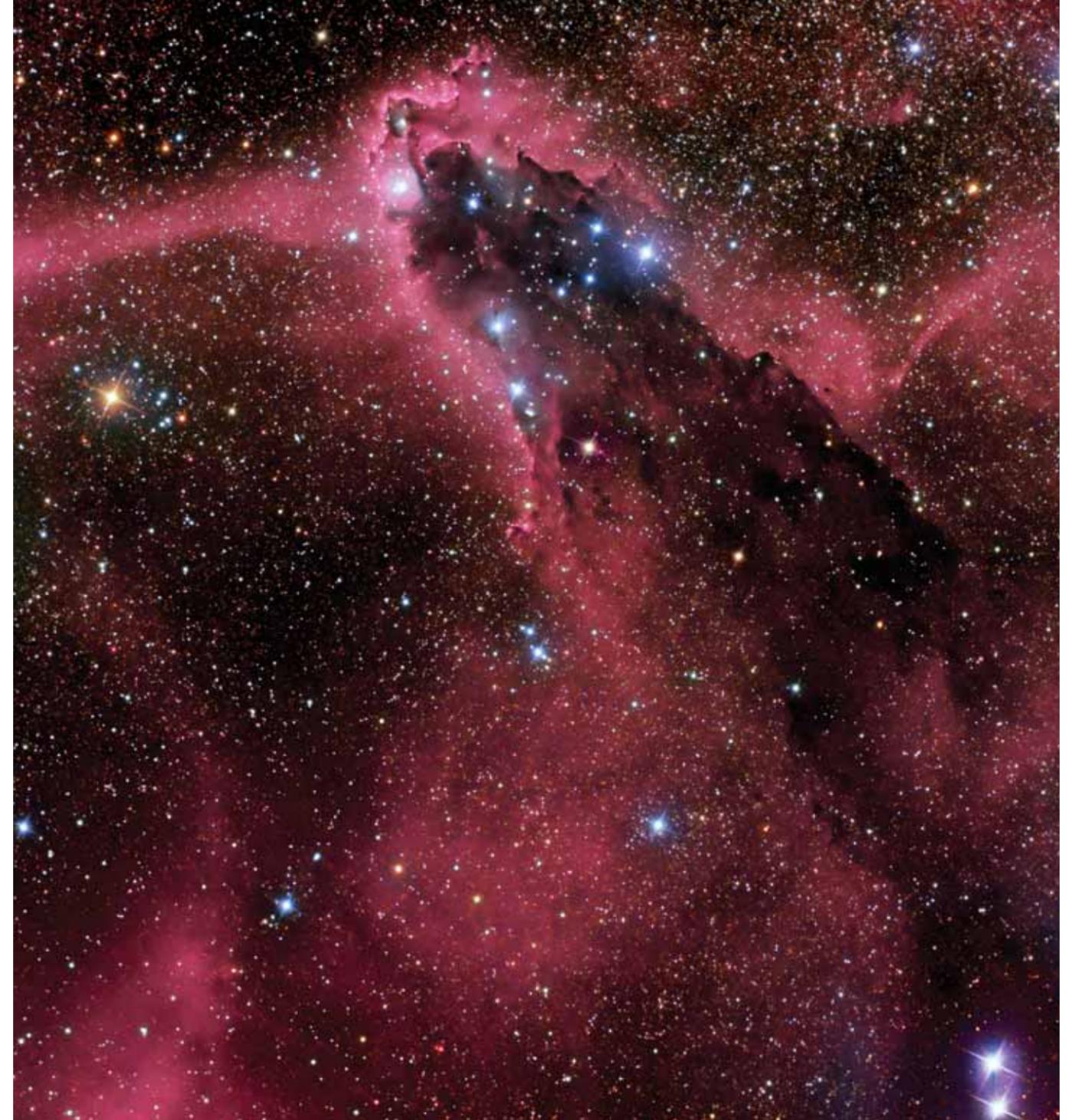
A DSLR produces a color image directly because it has alternating red, green, and blue pixels on the sensor. Most CCD cameras require you to take separate exposures through red, green, and blue filters and then combine them to make a color image. Although using filters seems tedious, it opens up interesting possibilities. You can take a fourth, monochrome (luminosity) image to bring out faint objects and then combine all four in a technique called LRGB.

And your color filters don't need to correspond to visual red, green, and blue. If it suits you, "red" can be in the near-infrared part of the spectrum (CCDs pick up this longer-wavelength radiation well) and "green" can be visible red or yellow, resulting in a false-color image. You also can experiment with narrowband filters, equating Hydrogen-alpha with red and Hydrogen-beta with green, for example.

*This is part four of Michael Covington's imaging series. He will look at solar, lunar, and planetary astrophotography in a future issue.*



**The Helix Nebula** (NGC 7293) in Aquarius is the closest planetary nebula (450 light-years from Earth). The imager took this photo through a 13-inch Cassegrain reflector at f/7.5 and an SBIG STL-11000 CCD camera (H $\alpha$ RGB image with exposures of 120, 49, 63, and 63 minutes, respectively). James R. Foster



**This cometary globule** in Scorpius may resemble a comet, but it's actually a dust cloud that glows around the edges from newly formed stars. The imager took this photo through a 14.5-inch RC Optical Systems Cassegrain

reflector at f/8.2 and an Apogee Alta U16M CCD camera (H $\alpha$ RGB image with 3.5 hours of exposure through the Hydrogen-alpha filter and 5 hours combined exposure through red, green, and blue filters). Don Goldman

The resulting images have false colors but often show marvelous detail.

In addition to the 2- to 5-minute sub-exposures of your celestial target, you also need to record dark frames of the same length with the camera or telescope covered. And, if possible, take flat fields (short exposures of the blank daytime sky or a lightbox). The software combines all of these to correct for camera defects.

Dark frames are vital because they get rid of hot pixels — pixels that always show up bright even when no light hits them. Shoot these with the same exposure time, camera settings, and temperature as the frames that record your subject. Flat fields correct for vignetting and dust on the sensor.

Once you've mastered these techniques, you're ready for an astrophotog-

raphy adventure. Take aim at a nebula, star cluster, or galaxy, grab several 2- to 5-minute exposures and an equal number of dark frames, and combine the results on your computer. You'll be amazed at what you can accomplish with modest effort. ☺

 To read the previous three installments of this series, visit [www.Astronomy.com/toc](http://www.Astronomy.com/toc).