◀ The effect of Earth's rotation (along with the unwelcome trails of some passing aircraft) is easily visible in this unguided, 18-minute exposure. The stars appear to trace concentric circles around the celestial pole. Motorized sky trackers and equatorial mounts can eliminate this trailing, but only if the mount is properly polar aligned.

Mastering Polar Alignment

Setting up your mount correctly is an important first step in creating great astrophotos.

Fast, wide-angle lenses let you capture stunning nightscapes with your camera mounted on a regular photo tripod. But as you increase the focal length of the lens or the exposure time, you'll start to see star trails appearing in your images. This can be an interesting visual effect, but if the goal is natural-looking stars, you'll need to mount your camera on a motorized sky-tracker or equatorial telescope mount.

These devices work by counteracting Earth's rotation and let you take multi-minute exposures with a telephoto lens or even a telescope. But to work properly, such a mount needs to be *polar aligned* — its right-ascension axis has to point directly at the celestial pole to match Earth's axis of rotation. There are several ways to accomplish this: by using a polar scope, by computer-assisted alignment, or by analyzing star drift.

No matter which method you choose, your mount needs to be at least roughly aimed at the celestial pole. Although it's not strictly necessary to level your tripod, doing so helps because you can then use the graduated scale on the side of your mount to correctly set your location's latitude. This ensures the vertical tilt of the mount matches the elevation of the celestial pole.

Next (for those of us in the Northern Hemisphere), you'll need to swivel your mount horizontally so it's facing true north. You can use a compass or even a north-south road or other landmark to get close. After dusk, you can get a more accurate estimate by dropping an imaginary line directly down to the horizon from Polaris, the North Star.

This rough polar alignment may be all you need for relatively short exposures captured with a wide-angle lens. Longer exposures or longer lenses will require greater precision.

Celestial Target Practice

Many equatorial mounts and portable star-trackers use small, low-power optical finders to improve your pointing accuracy. Such polar scopes are either built into the mount or available as an optional accessory. Instead of a simple crosshair like you see in a regular finderscope, polar scopes employ an etched-glass reticle that shows the position of Polaris offset from celestial north. (Polaris doesn't lie *exactly* at true north.) Astrophotographers in the Southern Hemisphere will use the star Sigma Octantis instead.

You can use an app to look up Polaris's precise position relative to the pole for your specific location at the current date and time. Then, by working with the altitude and azimuth adjustments of your mount, you move Polaris to the indicated mark on the reticle. With that, you're all set.

What are the downsides to this method? There are only a few. First, you obviously have to be able to see Polaris from your observing site. Second, at a truly dark sky location your polar scope can reveal a myriad of stars, which can make identifying Polaris tricky. In these situations, it's better to begin alignment during twilight, when

▶ This view of the iOptron SkyTracker Pro shows the removable polar scope (the small black tube on the left side) used to polar align the unit. The tracker's base features knobs that permit fine altitude and azimuth adjustments.

ALL IMAGES COURTESY OF THE AUTHOR

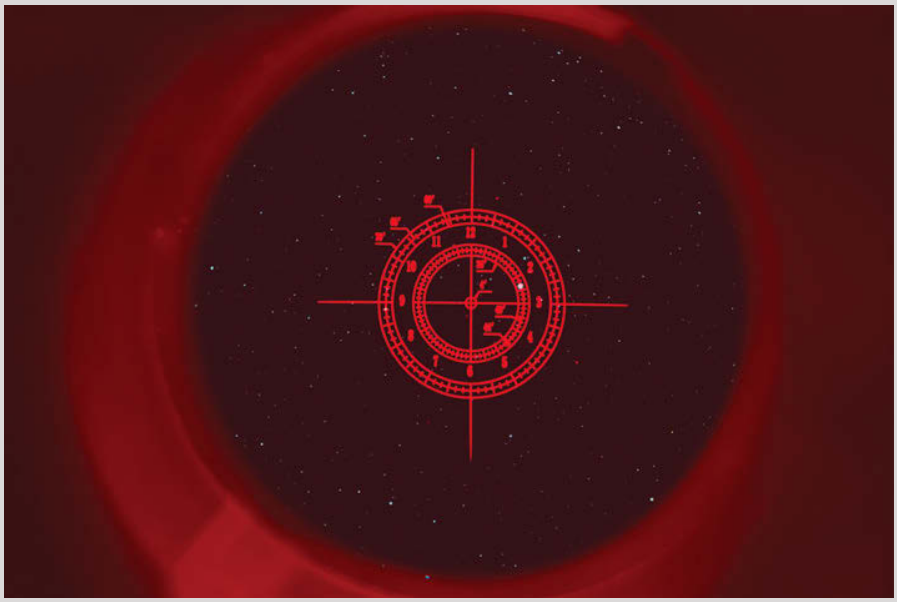
only the brightest stars are visible. Finally, you'll need to perform some odd nocturnal contortions to look through the polar-scope eyepiece since it's pointing skyward at an awkward angle, just a few feet above the ground. You can, however, purchase an optional right-angle viewfinder adapter (see the September issue, page 68), which makes the process less neck-straining.

Masters of the Universe

A new, high-tech method is to use an electronic pole finder, such as the PoleMaster, made by QHYCCD. It's a small digital camera with a wide-angle lens that's used to display the field around the celestial pole on your laptop computer. On-screen text and graphics overlay the live video feed, guiding you through the polar-alignment process step by step. Adjustments take just a few minutes to complete and are extremely accurate. iOptron offers a similar device called the iPolar Scope, which fits many of the company's mounts, replacing the standard optical polar scope.

Electronic polar scopes work very well, but they do require you to spend extra money on a single-purpose device. Luckily, some software packages allow you to use your imaging camera and lens as a virtual polar scope, thereby avoiding the need to purchase extra hardware. *SharpCap Pro* (**sharpcap.co.uk**), a well-respected planetary imaging software, includes a polar-alignment feature that supports a wide range of camera and lens combinations. After you capture an initial image, you rotate the mount 90° to capture a second image. The software automatically compares the two images to determine the mount's center of rotation. Any deviation from the actual celestial pole is displayed and can then be eliminated by tweaking the aim of the mount's altitude and azimuth. Importantly, the method works on any part of the sky within 7° of the pole, so it's a good solution if your view of Polaris is partially obstructed.

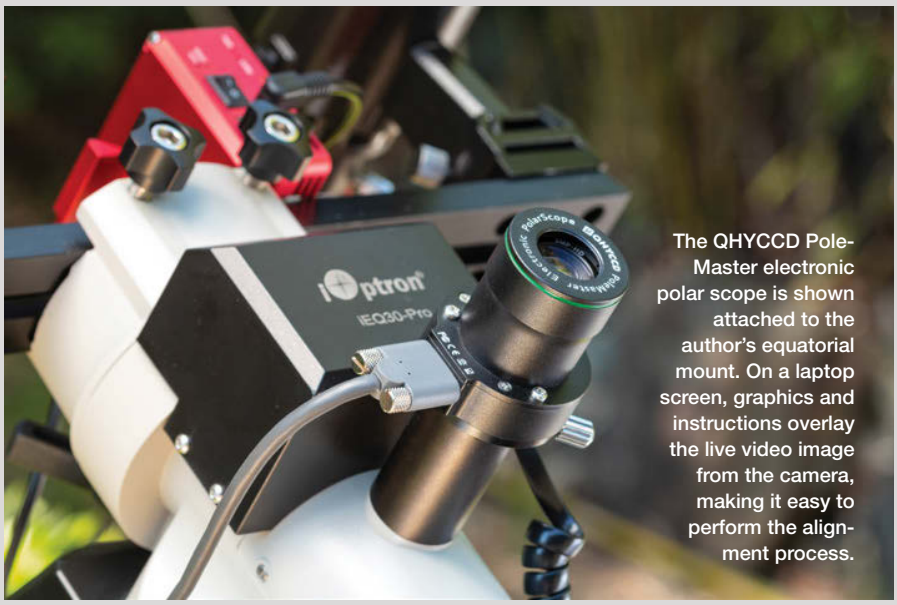
The ASIAIR PRO smart Wi-Fi device by ZWO has a similar feature that works with the cameras it supports. The device connects wirelessly to an app on your phone or tablet — a real plus if you prefer to leave your laptop at home.



▲ Looking through the iOptron polar scope, you'll see an illuminated reticle etched with a clock face and concentric rings, similar to what's shown in this composite image. Many equatorial mounts are equipped with similar optical pole finders. You can download an app that displays precisely where Polaris needs to be placed at a specific date and time from your location.

Drifting Into Alignment

So far we've looked at solutions that measure the position of your mount relative to the celestial pole. A slightly different approach is to monitor how well your mount tracks a star along the celestial equator. The process is known as *drift alignment* and can be performed visually with an illuminated reticle eyepiece, or photographically using your camera. Camera-control software such as *BackYardEOS, BackYardNIKON,* (available at **otelescope.com**) and *Astro Photography Tool* (**astrophotography.app**) include a feature that superimposes a crosshair reticle over the live view from your camera for improved alignment accuracy.



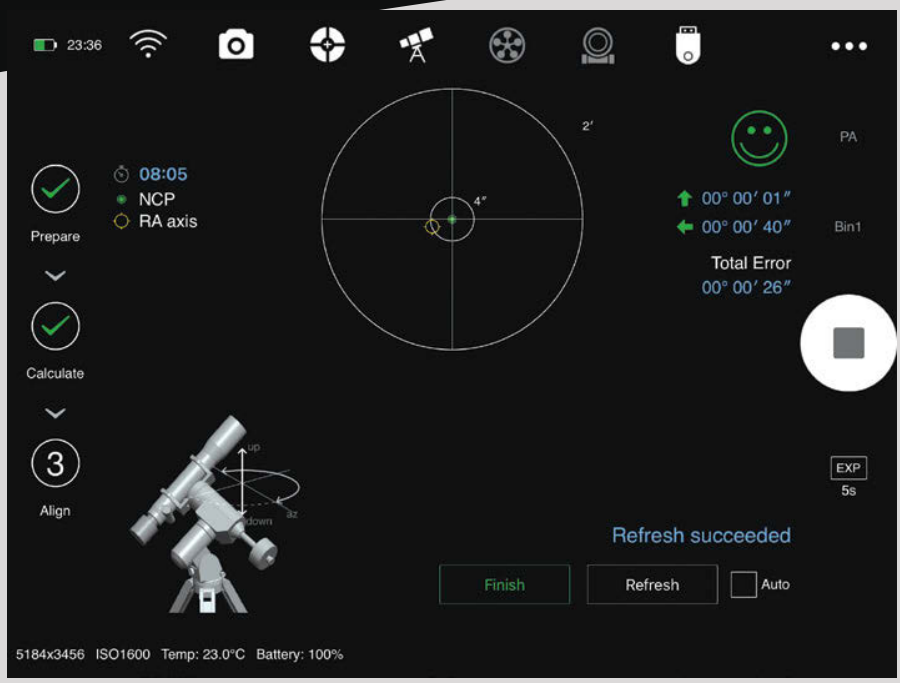
The QHYCCD PoleMaster electronic polar scope is shown attached to the author's equatorial mount. On a laptop screen, graphics and instructions overlay the live video image from the camera, making it easy to perform the alignment process.

So how does drift alignment work? First, you locate a star near the meridian and within 20° of the celestial equator. Center it on the crosshairs, then watch for any movement north or south over time (ignore any east-west motion). If the star drifts south, your mount is pointing too far east. If it drifts north, your mount is aimed too far west. Adjust your mount horizontally as needed and then repeat the observation. You'll make successively smaller and smaller motions as you fine-tune the alignment, and eventually you won't detect any north-south drift.

Next, aim at a star that's low in the eastern sky and near the celestial equator. Again, you monitor for north-south drift, but this time, if the star wanders south, your mount's polar axis is aimed too low. If the star drifts north, your mount is pointed too high. Use the same iterative process to fine-tune the altitude adjustment. (If the eastern sky is blocked, you can use a star in the west, but you'll need to reverse the altitude corrections.)

The drift method is simple and accurate but can be time-consuming to perform. There's a quicker variation called Drift Alignment by Robert Vice (DARV) that utilizes your camera and the mount's hand-controller. Instead of viewing the two target stars, you take individual time exposures of them with your camera.

During the first half of the exposure, slew the mount west at its slowest rate using the hand-controller. Then, during the remaining part, you slew the mount east. If your polar alignment is perfect, the resulting star image will be a single line. Otherwise, it will appear as a V-shaped wedge. Depending on which of the two reference stars you're working with, you then adjust either the altitude or azimuth position of the mount and take another time exposure. As the alignment improves the width of the wedge will narrow, eventually becoming a straight line.



▲ Many apps are available for computers, smartphones, and tablets to guide you through the process of polar alignment using your camera and lens. The ASIAIR PRO Polar Alignment screen is shown in the image above. The app works with the company's smart Wi-Fi unit.

▲ Drift Alignment by Robert Vice (DARV) is a photographic variation of the traditional drift alignment method. As described in the text, DARV involves slewing your mount east then west, while making an exposure of a reference star. Initially the star will appear as a V-shaped wedge, as shown in this test shot. As the alignment improves the wedge will close, eventually becoming a perfectly straight line when polar alignment is achieved.

Drift alignment is a great way to cross-check the accuracy of the other methods and is particularly handy if your view of the celestial pole region is blocked — a common situation.

Although polar alignment can initially feel overwhelming, with a little practice any of the techniques described here will eventually become second nature. The trick is to take your time and proceed methodically. Once you master polar alignment, you'll be on your way to creating beautiful long-exposure astrophotos.

■ **TONY PUERZER** has come to the conclusion that nothing beats a clear dark sky and a well-aligned mount.