Selecting a German Equatorial Mount

GEMs are just as popular today among amateur astronomers as they were nearly two hundred years ago

By Dr. James Dire

In the year 1674, the English scientist Robert Hooke first proposed what we would today call an equatorial telescope mount. The concept was to place a telescope with a rotating axis parallel to Earth's spin axis and use a clock drive to rotate that axis at the same rate Earth spins, but in the opposite direction. Then, wherever the telescope was pointed, it would stay centered on the object of interest.

Although there were several crude clock-drive mounts built and used in the 18th century, the first accurate equatorial mount was designed in 1819 by the German optician Joseph von Fraunhofer. Fraunhofer built a 9.6-inch, f/16.6 refractor that used this mount, which was installed in the observatory in Dorpat, Russia in 1824. This was the first telescope that could accurately track stars. Ever since, Fraunhofer's mount design has been known as the German equatorial mount (GEM).

For the next hundred years, large refractors on GEMs were the instruments of choice among professional and amateur astronomers. The size of the optics reached their limit with the 40-inch refractor housed in the Yerkes Observatory in Williams Bay, Wisconsin, which also uses a GEM.

GEMs have their famous "T" shape with the long side of the "T" representing the polar axis, and the cross housing the telescope on one side and counter weights on the other. GEMs are advantageous since they can easily point a telescope to any location in the sky. The biggest disadvantage is the telescope has to be repositioned to the other side of the mount to view objects on the opposite side of the meridian. Fortunately, a properly balanced GEM is easy to maneuver, regardless of size. I found the Yerkes telescope just as easy to manually slew as any small backyard system.

As evident by the number of manufacturers and models, GEMs are just as popular today among amateur astronomers as they were nearly two hundred years ago. With so many choices,

Image 1 - The author's 4-inch apochromatic refractor mounted on an EQ-6 GEM.

Image 2 - Dr. Dire poses next to the Cleveland County (NC) Astronomical Society's vintage Criterion RV-12 Newtonian on its original GEM.

this article will provide tips in how to select the correct one.

First and foremost in selecting a mount are the size and mass of the optical instrument. If a GEM is used on a tripod, ensure that the optical tube assembly (OTA) will not strike a tripod leg when viewing near the zenith. If so, a pier might be a better choice than a tripod. Second, the mount must be able to carry the mass of the instrument, accessories and the counterweights. Even when balanced, if the mass is too great for the GEM, the polar-axis motor will not be able to properly drive the telescope.

Manufacturers usually publish the payload capacity of a mount. Typically this number does not include the mass of the counterweights, but make sure before buying. Also, manufacturers don't always agree on the recommend maximum payload. I have seen different brands, but otherwise identical GEMs, probably made at the same factory, where one company advertises a 25-pound payload, while the other 45 pounds. While both will probably suffice using a 45-pound telescope for visual use, for long-exposure astrophotography, I would not use more than 25 pounds on either mount.

Even for small telescopes, avoid mounts that are not sturdy or wobble when the tripod or pier is tapped. You will be more satisfied with a sturdy GEM rated for a heavier telescope. Plus when aperture fever strikes, you may not have to upgrade the mount.

The smallest GEM I have used came with a featherweight 5-inch Schmidt-Cassegrain telescope. The mount came with a tiny 6-volt polar axis motor. This mount is lightweight, sturdy and when aligned, tracks quite well for visual use. I no longer own the telescope, but kept the mount to use with a much heavier, longer 4-inch APO when I want a lightweight travel system for observing. This lightweight GEM also goes with me when I travel overseas chasing solar eclipses. For astrophotography, I use the same APO on a GEM that costs 10 times more.

The main factors to consider in a GEM are: the recommended payload (discussed earlier), total mount weight (be kind to your spine), polar alignment tools, GoTo capability, computer interfaces, power consumption and type (AC and/or DC), size and material of the right ascension (r.a.) and declination (dec.) worm wheels, size and material of the worm gears, diameters of the r.a. and dec. shafts, ease of polar alignment altitude and azimuth adjustments, periodic error and cycle time, clutches, and finally cost.

One of the biggest concerns in using a GEM, is polar aligning the mount. If the mount is not polar aligned, rotating the polar axis, either manually or with drive motors, will not track the telescope's object. A GEM should have easy-to-use altitude adjustment knobs. Usually there is a scale on mounts to help you dial in the altitude of the celestial pole, which is the same angle as the local latitude. Don't rely on those altitude scales, as in my experience they can be off by as much as 5 degrees. Likewise, the mount should have opposing azimuth adjustment screws to allow the mount to be adjusted al least 5 degrees, to help point it towards true north, for northern hemisphere locations.

Mounts that allow sighting through the polar axis shaft or that contain a polar axis alignment scope (a small telescope inside the mount along the polar axis) are easier to polar align. For visual observing, I can usually get a decent polar alignment looking through the polar shaft at Polaris as I adjust a mount's altitude and azimuth knobs. For imaging, a polar alignment scope speeds up the process. Some computerized mounts come with built-in software routines that aid in obtaining an accurate polar alignment.

Image 3 - A current generation, portable GEM holding an 8-inch reflector. Photo by Stuart McDaniel of Shelby, NC.

If a mount is permanently installed in an observatory, a polar alignment scope is not worth the expense. A GEM mount can be accurately polar aligned in a permanent observatory in about an hour using a technique known as the declination drift method.

Originally, GEMs used clock drives powered by falling weights, like in a grandfather clock. Then, until recent decades, they used AC-powered motors. Today most portable GEMs use a 12-volt DC power source. For field use, a good quality rechargeable lead-acid battery makes the best power source. If AC electricity is available, an AC to DC inverter is required. Make sure the inverter is rated for more amperage than the mount specifies. Otherwise, you risk blowing internal fuses when slewing at the highest speeds. If the mount calls for 5 amps DC, I usually use a 10 or 20 amp power supply. They only cost a few more dollars than a 5 amp supply.

Except for the lower cost entry-level mounts, most GEMs come with GoTo capabilities. These mounts have motors on both axes that can drive the mount to any object in a stored database, once the mount has been leveled, polar-aligned, and the software has been initialized to known star positions (usually two to four stars). GoTo mounts come with a keypad hand controller, which contains the firmware to operate the mount. Additionally, almost all GoTo mounts have a serial port for connecting the mount to a computer. Then with third-party software, the computer can control the position of the mount.

Computer control is advantageous because the computer control software usually has a larger database of celestial objects, and the computer can be located far away from the mount in a climate-controlled room. I have been known, on a cold winter night, to control a remote GEM used for astro-imaging from my laptop computer sitting on a table adjacent to my hot tub. Ah, the rough life of an astronomer.

The GoTo accuracy of a GEM does depend on several hardware considerations. The main ones are the size of the drive worm wheels attached to each of the r.a. and dec. axes, the number of teeth on each worm wheel, and the resolution of the optical encoders tracking the position of each axes. Generally, the larger the wheels, the more teeth they have, and the higher the resolution of the optical encoders, the better the pointing accuracy of the mount. Most high-end mount manufactures provide these specifications in their advertising. Many companies that sell small to medium sized mounts (under 50 pounds payload) usually don't provide this information in their advertising.

Some GEMs have knobs that can lock down each axes. These are usually locked down when using GoTo features, but can be unlocked to slew the telescope manually. Others have clutches to allow manual slewing. If the clutches are too loose, the telescope may drift on it's own, causing the GoTo computer to lose track of where the telescope is pointed. My advice it to avoid GEMs that allow no manual repositioning of the mount. If the power source goes down and the telescope cannot be moved manually, the night's observing session is over.

GEMs used for astronomical imaging, photometry and spectroscopy require more consideration to ensure proper guiding and tracking for long exposures. Due to the nature of worm gears and worm wheels, periodic error (PE) is introduced into the r.a. drive. If not corrected, a star centered in the field of view will oscillate back and forth in r.a. The amplitude of the oscillation is measured in arcseconds. The cycle time of these oscillations is usually in minutes. Many manufacturers publish these values for their mounts, or may provide them. In general, the larger the mount's worm wheels and the more teeth on the wheels, the smaller the PE will be.

Most computerized mounts come with periodic error correction (PEC). This is software that can train the r.a. drive to compensate for the mechanical PE. The other choice is to connect an autoguider to the autoguide port on mounts that are so equipped. An autoguider is usually a digital camera attached to the main scope, or a guide scope, that can be used to keep a guide star centered by sending corrections to the mounts r.a. and dec. motors. While PE only affects the r.a. drive, objects will move in declination if the mount is not properly polar aligned. Plus natural scintillation (twinkling) caused by the atmosphere can move guide stars north or south in declination.

Another last parameter I look for in an imaging mount is the amount of backlash present in each drive gear. Backlash occurs when a drive motor switches direction. Backlash is related to how much the drive gear must turn in the opposite direction before actually engaging the worm wheels teeth and initiating motion. The greater the backlash, the harder it will be to guide on an object. Some GEMs have built in software that can compensate for backlash.

Finally for the most advanced users, the materials used in the construction of a GEM should be considered. Different metals expand and contract differently during temperature changes. For better performance look for high quality, low expansion metals used for the shafts, the worm wheels and drive gears.

Like any product, for more features and higher quality, you must fork out more money. To find just the right GEM, you must consider your intended use and the features you want, weighed against your budget, before making a final decision. Hopefully, you will be just as excited about using a German equatorial mount as Joseph von Fraunhofer was in 1824 when he saw first light in the Dorpat Telescope. ATT