

## Chapter 2

# A Review of Celestron GoTo Computerized Telescopes

Celestron is an innovator in the use of computer controlled telescopes, beginning with their introduction of the Compustar 8 and their joint venture participation with the Vixen Super Polaris/Sky Sensor German equatorial mounts.

It is important to be familiar with the various incarnations of Celestron GoTo telescopes and mounts in that SkyPortal with Celestron's SkyPortal WiFi module can be used with many of the legacy Celestron telescopes and mounts.

The best way to chart the historical progress of GoTo telescopes and computerized mounts is to examine the evolution of the Celestron fork mounted GoTo telescopes separately from the GoTo computerized German mounts.

### Fork Mounted Celestron SCTs

#### *Celestron Compustar*

In 1987, Celestron introduced its line of GoTo computerized Schmidt–Cassegrain telescopes (SCTs) with the introduction of the Compustar line of SCTs. The Compustar system took the DC drive system to the next logical step with a totally computerized go-to telescope. Although the Compustar models were made in 8", 11" and 14" sizes, the only one less than \$5000 when new was the Compustar 8 (also sometimes referred to as CCC8). Although somewhat cumbersome with its large declination drive cover and display panel, this unit allowed automatic go-to for over 8000 objects. The f/10 optical tube with "Starbright" coatings featured an 8×50 polar axis finder, a 2" star diagonal and 50 mm 2" Plossl, heavy duty wedge



**Fig. 2.1** Celestron Compustar 8 (Celestron)

and tripod and carrying case. Starting in 1993 the Compustar was shipped with a 1-1/4" star diagonal and eyepiece with the 2" accessories as options. The Compustar 8 was the first of the line to be introduced in 1987. It was ahead of its time. Maybe a bit *too* ahead of its time. There have been accuracy and reliability issues. It's mostly a curiosity now, but the model does have some devotees. These innovative telescopes were not cheap for the time, costing \$3500 new (Fig. 2.1).

If purchased in the current used market, the buyer should know the Compustar requires a firmware modification to be Y2K compliant. Many of the newer Celestron accessories, such as StarSense, NexRemote, and the SkyPortal Wifi Module, are not compatible with the ancient Compustar electronics.

### ***Celestron Ultima 2000***

By 1995, Celestron released a long-expected replacement of its popular computerized telescope. The new model addressed the shortcomings of the original Compustar line. The chief problems with the Compustar were its bulk, weight, and expensive price tag. Celestron addressed all these issues admirably with introduction of the new Ultima 2000, and made the best of new computer tracking technologies as well. The form, fit, and function of the Ultima 2000 is the basis of all subsequent

Celestron GoTo telescopes. Like the competing Meade LX200, the Ultima 2000 shipped without a wedge as part of the standard package. Its computer electronics track objects in the sky after alignment of the telescope on two stars. Due to its built-in high resolution encoders, once the initial alignment is made, the telescope can be turned using the hand controller while still maintaining its position memory. The electronics included Periodic Error Correction. Two motors are used to drive the telescope in each axis, one for slow speeds, and another for high speeds. As a result, the telescope could track normally and be guided at 2× or 6×, or could be moved across the sky at speeds up to 10° per second. The slow and fast slews could be accomplished quietly. The telescope was powered by a set of eight AA batteries mounted in the base, or by an external 12 V power source. The preferred method was external power packs, as the AA batteries were very short-lived. Internal wiring paths for the encoders, etc., meant that the control panel on the base was simplified, but it provided inputs for all the necessary options for a fully operational system. Plugs were provided for external power, electronic focusing, the hand control and an “AUX” port for connecting a computer, an auto-guider or other items. The weight of the optical tube and fork was only 31 lbs. Add another 18 lbs for the sturdy tripod and the Ultima 2000 was a featherweight compared to the old Compustar design. A small hand controller replaced the Compustar control panel. With a few buttons and a two line display, it gave access to all of the aligning, setup, identification, positioning and touring features (Fig. 2.2).



**Fig. 2.2** Celestron Ultima 2000 (Celestron)



**Fig. 2.3** The author's Celestron 11 NexStar GPS (Chen)

### ***Celestron NexStar GPS***

The Ultima series eventually evolved into the NexStar GPS in 2001, with integrated global positioning system circuits to aid in the setup and alignment of the Celestron GoTo telescopes. Again, the aperture sizes ranged from 8", 9.25", and 11". New to this implementation of Celestron SCTs was the introduction of carbon-graphite telescope tubes (although a few aluminum OTAs were available), that functioned to ease the weight of the telescopes while presenting a better thermal adjustment when taken from the inside of a home to the outside environment (Fig. 2.3).

### ***Celestron NexStar SE***

The NexStar 8SE, first introduced around 2003 as the NexStar 8i, was the first of the single-sided swing arm ("one armed bandit") computerized scopes. These were given a facelift in the late 2000s with a metallic orange tub, upgraded electronics and the SE nomenclature. The original 2003 version had a gray tube. The newer SE units have the orange tube. The SE line of telescopes ranged from a grab-and-go sized Maksutov–Cassegrain 4 in., and SCTs of 5", 6", and 8". Designed as primarily visual telescopes, their price point was several hundred dollars below the top-of-the-line Celestrons (Fig. 2.4).



**Fig. 2.4** Celestron NexStar 8SE (Celestron)

### ***Celestron CPC***

In 2005, Celestron introduced its CPC line of computerized GoTo telescopes, programmed with their new SkyAlign firmware. SkyAlign simplified the GoTo initial alignment process by eliminating the “point north and level, then align with specified bright stars” process of earlier designs to a “point at any three bright stars, even if you don’t know the name” process. The CPC line included an 8”, 9.25”, and 11” apertures. The CPC telescopes are characterized by fork mounted SCTs with black tubes. These looked somewhat like the original C8s, but the forks were much thicker and bowed outwards with integrated hand holds for lifting the telescope assembly onto the tripod (Fig. 2.5).

### ***Celestron SLT***

In 2001, Celestron introduced a line of intermediate level GoTo telescopes called the GT line, offering 60, 80 and 102 mm refractor models and 114 and 130 mm Newtonian reflector models. In 2005, Celestron introduced a line of intermediate level GoTo telescopes called the SLT line. Utilizing a new upgradeable Nexstar



**Fig. 2.5** Celestron 8 CPC (Celestron)

hand control, the NexStar SLT series is quite similar to the Nexstar GT series. In fact, the SLT line of telescopes replaced the GT line, with the exception of those sold through Costco stores (Fig. 2.6).

The NexStar SLT is offered in 60, 80 and 102 mm refractor models and 114 and 130 mm Newtonian reflector models. The two lines are almost identical cosmetically and functionally, with the exception of the hand controller, with the SLT line utilizing the current three star alignment SkyAlign procedure, and the GT line using the previous point-north-and-level procedure.

The differences between the SLT mount and the Nexstar GT are as follows:

1. Tracking performance is greatly improved with the SLT.
2. The GT aluminum tripod has been replaced with a steel leg model on the SLT.
3. The SLT mount includes an AUX port compatible with the CN-16 GPS module and the Auxiliary Port Accessory Kit. The Aux Port Kit allows, among other things, the motor control firmware to be upgraded by the user.
4. The Nexstar SLT is compatible with Celestron's NexRemote software.
5. The optical tube attaches to the fork arm with the ubiquitous Vixen-style dovetail clamp assembly allowing quick and easy removal. In fact, this allows the SLT mount to carry a wide variety of small optical tubes by attaching a matching dovetail bar. The dovetail is compatible with the CG-5, LXD-55, Vixen GPs, etc.
6. The SLT is equipped with a battery compartment for AA batteries for cord-free use.



**Fig. 2.6** Celestron 102 SLT (Celestron)

The SLT hand control sports the latest version of the Nexstar firmware. This includes features such as Identify and Constellation Tour. This hand control responds to the same PC commands (via the RS-232 port on the bottom) as the Nexstar 8/9.25/11 GPS, so programs compatible with the Nexstar GPS are compatible with the Nexstar SLT.

Neither the GT nor the SLT featured lock and unlocking clutches on their azimuth or altitude axes, which potentially and practically caused many a telescope to require service for stripped drive gears when youngsters grabbed the telescope and tried to redirect the telescope by hand. All motions had to be directed by the hand control.

The SLT hand control has user upgradeability and the Sky Align three-star alignment methods. Future upgrades to the hand control firmware are downloaded via the Internet and owners can apply the upgrades themselves. The new alignment methods are SkyAlign, Auto Two Star Align (first available on the NexStar 8i Special Edition), Solar System Align and One Star Align. In addition to the new alignment methods, the new hand control still has Two Star Align. Removed since the Nexstar GT are Quick Align and Auto Align.





**Fig. 2.7** Celestron 114 LCM (Celestron)

### ***Celestron LCM***

At the entry level of Celestron's GoTo telescopes sits the LCM line. Six complete telescope systems with GoTo mounts are available in the LCM series, with apertures of 60, 70, 76, 80, 90 and 114 mm. Designed to be affordable, the telescopes and mount system are light weight and easily portable. The hand controller included in the LCM series, in recognition of the limitations of the optical tubes in the series, is limited to 4000 objects. Still enough to peak a beginner's interest (Fig. 2.7).

### ***SkyProdigy***

In a category almost to its own, Celestron has the SkyProdigy line of telescopes, whose main selling point is a fully automated alignment procedure. Mounted parallel to the telescope is a specialized CCD scope used solely for alignment purposes. Mated with complementary on-board firmware, the user merely initiates the alignment process using the hand controller, the telescope begins slewing across the night sky as the CCD scope matches star patterns stored in its memory, and within minutes the telescope is ready for use as a GoTo telescope. This is the initial





**Fig. 2.8** SkyProdigy 6 (Celestron)

implementation of Celestron's proprietary StarSense Technology which provides a completely automatic alignment process with no user intervention required. The GoTo capability contains a database that allows the SkyProdigy telescope to GoTo over 4000 celestial objects. The original lineup of the SkyProdigy telescope included a 102 mm short focus achromatic refractor, a 114 mm Newtonian reflector, a 90 mm Maksutov–Cassegrain, and a 6-in. Schmidt–Cassegrain. Currently, only the 114 mm Newtonian and the 6-in. SCT are being offered (Fig. 2.8).

## German Mounted Celestron SCTs

### *Celestron/Vixen Super Polaris Mount with Sky Sensor*

As stated in the previous chapter, the era of computerized GoTo telescopes, and in particular Celestron, began in 1984. Computer controlled telescopes took form during the same period as the development of personal computers. During the 1980s,

the US telescope company Celestron formed a business relationship with Vixen Company, Ltd of Japan. The American company featured its home grown Schmidt–Cassegrain telescope, while importing the Japanese refractors, eyepieces, and equatorial mounts from Vixen, and marketing them under the Celestron brand. Prototypes of the Celestron Compustar 14 first surfaced around the 1986–87 time-frame, according to Celestron co-founder Alan Hale. The Compustar 14 is a large and heavy catadioptric telescope, designed for permanent installation in an observatory and not widely available. However, Vixen of Japan developed the Sky Sensor, an economical system consisting of a GoTo computer control system with motors designed to attach onto their portable German equatorial mount known as the Super Polaris. Celestron sold these Sky Sensor-equipped mounts with their 8" C-8 SCT optical tubes.

The landmark Sky Sensor system was remarkable for its time. As the first consumer affordable GoTo system, it had 472 nebulae, star clusters, and galaxies stored in its memory. This is small, as compared to today's GoTo systems that have 30,000, 40,000, or more stored in their databases (Fig. 2.9).



**Fig. 2.9** The Sky Sensor controller (Hands-on-Optics photo archive)

## *Celestron CGE*

In the mid-1990s, Celestron introduced a pair of German equatorial mounts for their telescopes for astrophotographers who preferred German mounts over the fork-mounted SCTs. The heavy duty CGE was the top-of-the-line mount, designed to handle the mass of the C-14, but could also accommodate a variety of optical tube assemblies. Fully computerized, the CGE is a very heavy duty equatorial mount with GoTo capability using the Celestron hand controller whose firmware contained a 40,000+ deep space object database. Made from CNC-machined aluminum and stainless steel components, the CGE was designed with a 65-lb. payload capacity, Periodic Error Correction, autoguider port, and other features that made it ideal for astrophotographic applications. For tracking accuracy, Celestron used precision machined bronze 180-tooth worm gear, stainless steel worm shaft, two made-in-USA DC servo drive motors, with dual encoders accurate to 1.5 arc min (Figs. 2.8 and 2.10).



**Fig. 2.10** Celestron CGE (Celestron)

The details of the CGE:

1. 40,000 object database with over 100 user-definable objects and expanded information on over 200 objects.
2. Proven NexStar computer control technology.
3. GoTo system is precision accurate to 1.5 arc min.
4. Software Features include: Compass Calibration, Polar Alignment routine, Database Filter Limits, Hibernate, Auto North and Level, Quick Align, and user-defined slew limits.
5. Flash upgradeable hand control software and motor control units for downloading product updates over the Internet.
6. Custom database lists of all the most famous deep-sky objects by name and catalog number; the most beautiful double, triple and quadruple stars; variable star; solar systems; objects and asterisms.
7. Permanent programmable periodic error correction (PEC)—corrects for periodic tracking errors inherent to all worm drives.
8. Precision Bronze Worm Gear—32 pitch, 5.625" pitch diameter, 180-tooth bronze gear manufactured in the U.S.A. by W. M. Berg, Inc. Manufactured to AGMA Quality Class 10 standard, which minimizes total composite error and backlash.
9. Drive Motors—Made in the U.S.A., Pittman® LO-COGT brush-commutated DC motors offer smooth, quiet operation and long life. The motor armatures are skewed to minimize cogging which is required for low speed tracking.
10. Bearing and Shaft—Stainless steel worm shaft has 0.4375 pitch diameter and is preloaded with two ball bearings. The worm is made from a single piece of steel (rather than a two-piece worm-and-shaft assembly) to minimize run-out, which is a source of periodic error.
11. 12VDC Servo Motors with integrated optical encoders with 0.11 arc sec resolution.
12. No-slip clutch system for pointing precision.
13. Autoguider port, PC port and auxiliary ports located on the electronic pier for long exposure astrophotography.
14. Double line, 16-character Liquid Crystal Display Hand Control with backlit LED buttons for easy operation of goto features.
15. RS-232 communication port on hand control to control the telescope via a personal computer.
16. Includes NexRemote telescope control software, for advanced control of your telescope via computer.
17. GPS-compatible with optional CN16 GPS Accessory.

### ***Celestron AS-GT (CG-5GT)***

The second of the mid-1990s GoTo mounts was the computerized version of the venerable CG-5, anointed as the AS-GT, but commonly referred to as the CG-5GT. These GoTo versions of the CG-5 also come loaded with new software



**Fig. 2.11** Celestron AS-GT (Celestron)

features and over 40,000 database objects. Capable of holding over 35 lbs of payload and slewing at  $4^\circ$  per second, users are able to instantly point to any of the celestial objects in the database (Fig. 2.11).

The Advanced GT Series telescopes include these high performance features:

1. GPS-compatible with optional SkySync GPS Accessory (#93969).
2. Proven NexStar computer control technology.
3. RS-232 communication port on hand control to control the telescope via a personal computer
4. Autoguider port for long exposure astrophotography.
5. 40,000+ object database with 100 user-definable objects and expanded information on over 200 objects.
6. Custom database lists of all the most famous deep-sky objects by name and catalog number; the most beautiful double, triple and quadruple stars; variable star; solar system objects and asterisms.
7. Double line, 16-character Liquid Crystal Display Hand Control with 19 fiber optic backlit LED buttons.
8. DC Servo motors with encoders on both axes.
9. Affordable price.

### ***Celestron CGEM, CGEM DX***

Celestron's CGEM mount fits between the Advanced Series and CGE Series. Offering the portability of the Advanced Series and the precision of the CGE and is capable of carrying Celestron's higher-end SCT optical tubes (up to 11") securely and vibration free, which is ideal for both imaging and visual observing. The mount is capable of holding over 40 lbs of payload and slewing at  $5^\circ$  per second (Fig. 2.12).

The CGEM was designed to be ergonomically friendly with large Altitude and Azimuth adjustment knobs for quick and easy polar alignment adjustment. The internal RA and DEC motor wiring provides a clean look and an easy and trouble free set up.

The CGEM series introduced a new innovative Polar alignment procedure called All-Star™. All-Star is a relative of the AltAz SkyAlign, in that it allows users to choose any bright star, while the software calculates and assists with polar alignment. Another feature of the CGEM available for astro-imagers, is the Permanent



**Fig. 2.12** Celestron CGEM (Celestron)

Periodic Error Correction (PEC) which will allow users to train out the worm gears periodic errors, while the mount retains the PEC recordings.

For objects near the Meridian (imaginary line passing from North to South), the CGEM will track well past the Meridian for uninterrupted imaging through the most ideal part of the sky. The CGEM mount has a robust database with over 40,000 objects, 100 user defined programmable objects and enhanced information on over 200 objects.

### ***Celestron CGE Pro***

In January, 2009 Celestron introduced the heavy duty CGE Pro model. CGE Pro is a step up on capacity and stability from the original CGE series. Celestron CGE Pro series is a heavy duty German equatorial mount (GEM) on a steel-legged tripod, utilizing a German equatorial mount specific NexStar hand controller with Sky Align. The series includes 9.25, 11 and 14 in. SCT models. The CGE Pro can also be purchased sans telescope. Think of the CGE Pro as a CGE on steroids (Fig. 2.13).



**Fig. 2.13** Celestron CGE Pro (Celestron)



The CGE Pro series is a very stable platform for a wide variety of optical tubes. It is an excellent platform for both visual and photographic work and is an excellent choice for a permanent observatory setup. For those looking for a more stable astrophotography platform, particularly for imaging with a larger SCT optical tube with many accessories, the CGE Pro is definitely the choice over the CGE and CGEM mounts.

The Celestron CGE Pro features are:

1. Holds a maximum instrument capacity of 90 lbs.
2. Smooth  $\pm 5$  arc sec typical unguided periodic error, which can be further reduced with PPEC.
3. Permanent Programmable Periodic Error Correction (PEC)—corrects for periodic tracking errors inherent to all worm drives.
4. Heavy duty stainless steel tripod adjustable from 38" to 55".
5. One 22 lbs counterweight.
6. Weighs 154 lbs.

In addition to being fully computerized with a database of over 40,000 celestial objects, the New CGE Pro German Equatorial mount has been completely redesigned to offer numerous design advantages for the Astrophotographer:

1. Increased Load Capacity—Able to hold our 14" SCT telescope more securely as well as larger optical tubes up to a maximum instrument capacity of 90 lbs (not including counterweights).
2. All-Star Polar Alignment—Choose any bright alignment star for a software assisted alignment of the mount's polar axis that will have the user ready for imaging even if the North Star can't be seen.
3. No Tool Polar Alignment—Larger hand knobs for both Altitude and Azimuth adjustments.
4. Meridian tracking—Extended tracking past the Meridian of up to 20° of uninterrupted imaging through the best part of the sky.
5. Faster Slew Speed—Improved gearing and motors provide faster slew speeds than ever before with a maximum slew rate of over 5° per second.
6. Power Management—Redesigned electronics deliver constant regulated power to the motors making them capable of driving the telescope even when not perfectly balanced. This allows the CGE Pro to have the payload capacity of that of much larger (and expensive) mounts without sacrificing smooth tracking motion and pointing accuracy across the entire sky.
7. Accuracy—The hallmark of any telescope mount is its ability to find, center and track celestial objects with the highest degree of accuracy. The CGE Pro provides the precision pointing and tracking accuracy needed for demanding visual and imaging pursuits.
8. Pointing—With just a standard hand control alignment, the CGE Pro has the ability to center a star in the eyepiece or CCD chip to within 5 arc min. Using NexStar's advanced pointing features such as Calibration Stars, Sync and Precise GoTo, further improves the pointing accuracy to as low as 1 arc min in the desired region of the sky.

9. Tracking—With larger .75" pitch diameter worm gear and 6" pitch diameter worm wheel, precision made cut-steel gears in gearboxes, and seven slot-skewed armature motors, the CGE Pro delivers smooth  $\pm 5$  arc sec tracking accuracy typical unguided periodic error, which can be further reduced with PPEC.
10. Mount calibration—Celestron's NexStar hand control has built-in compensation features essential for accurately placing small objects on the center of the CCD chip or high power eyepiece. Aligning on multiple Calibration Stars creates a model of the mechanical inaccuracies inherent in all equatorial mounts. This model is stored within the hand control and is used to compensate for these inaccuracies, thus improving the pointing precision each time the telescope is slewed.
11. Mount modeling—Celestron's NexStar hand control has built-in mount modeling features essential for accurately placing small objects on the center of the CCD chip or high power eyepiece. Aligning on multiple Calibration Stars creates a mathematical model of the mechanical inaccuracies inherent in all equatorial mounts. This model is stored within the hand control and is used to compensate for these inaccuracies, thus improving pointing precision each time the telescope is slewed.
12. And of course, the CGE Pro is also fully T-Point compatible (available from Software Bisque) for ultra precise pointing across the entire sky.

In addition to these improvements, the Celestron line of German Equatorial mounts has long been recognized for features preferred by visual observers and astrophotographer alike. These include:

1. Portability: Set up and transportation of the CGE Pro telescopes is made easy by separating the mount into smaller, easy-to-carry components. Unlike fork arm mounted telescopes, the CGE's optical tubes can be quickly removed from their mounts making even the CGE Pro1400 easily assembled in minutes.
2. Stability: Recognized for superior stability, German Equatorial mounts place the center of gravity directly over the tripod legs and can be easily polar aligned without the use of an optional equatorial wedge. This proven design reduces the "tuning fork" vibration that can be associated with undersized fork mounts. An improved Super HD Tripod supports the CGE Pro mount. This fully extendable tripod is made from the finest 2.75" stainless steel and can be raised to a height of 55". The tripod uses a dual leg support for maximum rigidity with an upper leg brace to provide an outward preload and a lower leg brace providing inward tension.
3. Balance: CGE Pro Equatorial mounts can easily be balanced in both axes. Simply sliding the counterweight for Right Ascension and moving the optical tube along its dovetail mounting for Declination, accomplishes balancing the weight of camera equipment and other visual accessories. This means that no additional weight needs to be added to balance the telescope when additional accessories are added.

4. Clearance: CGE Pro mounts support their tubes at a single contact point allowing the tube to move freely around its polar axis without making contact with the telescope's mount. Software features allow the user to set the mounts slew limits to guaranty safe motion. This is particularly useful when adding photographic and CCD instruments that extend from the rear of the telescopes.
5. All CGE mounted telescopes are compatible with Celestron's SkySync GPS accessory. Combine the GPS and built-in real time clock, and these telescopes will keep track and remember their exact location and time without having to enter the information into the hand control.

## ***Celestron VX***

Introduced shortly after the CGEM and the CGE PRO, the VX is the follow-on replacement model for the venerable CG-5GT (Fig. 2.14). The essential features of the VX are:

1. Holds a maximum instrument capacity of 30 lbs.
2. Integer gear ratios and permanently programmable Periodic Error Correction eliminates recurring track errors from the worm gear.
3. New motors offer improved tracking performance and provide more power to overcome load imbalances.
4. Updated industrial design offers more rigidity, less flexure and improved aesthetics.
5. New design allows viewing or imaging across the meridian without interference from the motors housings.
6. Improved latitude range. Can be used between  $7^{\circ}$  and  $77^{\circ}$  latitude.
7. Improved electronics with increased memory for future expansion.
8. NexStar+ hand control offers multiple language programming (English, French, Italian, German, Spanish).

Engineered from the ground up with astro-imaging in mind, the new Advanced VX series improved on the standard set by the CG-5GT in mid-level telescopes. Advanced VX provides the user with many of the features found on Celestron's most sophisticated German equatorial mounts, at an extremely affordable price.

The new Advanced VX mount was specifically designed to provide optimum imaging performance for smaller telescopes. With the Advanced VX, owners of smaller telescopes can take advantage capabilities that the CGEM and CGE Pro users have been enjoying, such as All-Star Polar Alignment and autoguider support. Tracking through long exposures using permanently programmable periodic error correction is available. The amateur astro-imager can now image across the meridian without doing a meridian flip, so the backyard astronomer can seamlessly image the best part of night sky. Advanced VX features significantly larger base castings than the CG-5GT design it replaces, improving stability under heavier loads. Improved motors offer more torque and can handle slight load imbalances with ease.



**Fig. 2.14** Celestron VX (Celestron)

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