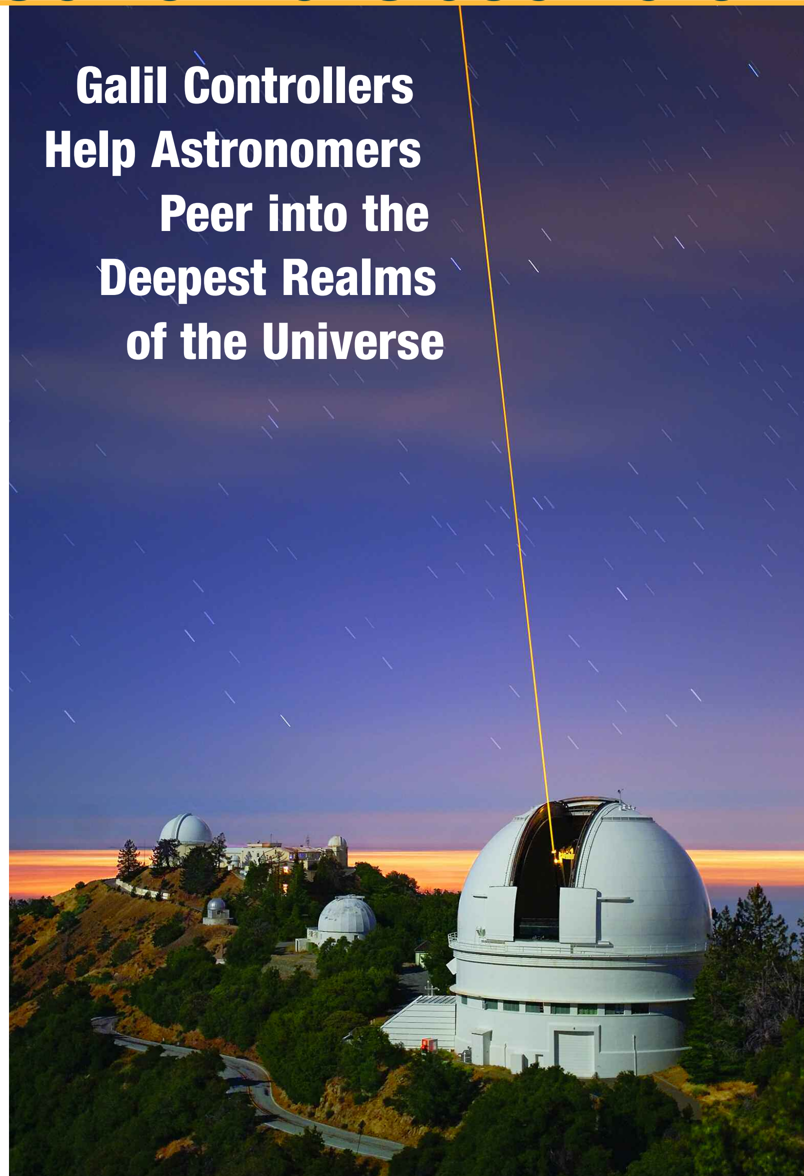
University of California Observatories

Galil Controllers Help Astronomers Peer into the Deepest Realms of the Universe



Lick Observatory sits on the 4,200-foot summit of Mt. Hamilton in San Jose, CA.

How did galaxies form? What is "dark matter"? How old is the universe? Is the universe expanding and picking up speed? Helping to solve such mysteries of the universe and its origin is one of the driving goals of astronomers working for University of California Observatories (UCO), a Multi-Campus Research Unit of the University of California (UC).

As part of their quest, the UCO team is working on creating the first comprehensive map of the distant universe. Called the Deep Extragalactic Evolutionary Probe (DEEP), this multi-year program uses twin 10-m W.M. Keck Telescopes located in Hawaii, the Lick Observatory on top of Mount Hamilton in California, and the orbiting Hubble Space Telescope (HST) to conduct its survey of distant and faint galaxies.

The task involves collecting light first emitted from stars or galaxies up to and about 14 billion years ago and which is now reaching Earth's confines at the speed of light (186,000 miles per second). Being able to detect and analyze this light requires a complex compliment of advanced mechanical, electronic and optical instruments, sensors and software.

One of the key components of the Keck II telescope is the Deep Imaging Multi-Object Spectrograph (DEIMOS). Able to magnify the telescope's capacity by a factor of seven for faint-galaxy optical spectroscopy, DEIMOS features

1. An optical beam camera with advanced optics and three 13-inch diameter calcium fluoride crystals lenses
2. A "slitmask" system that allows observation of 140 galaxies simultaneously
3. The largest spectroscopic charge-coupled device (CCD) detector of its type ever made (five inches square, contains 67 million pixels)
4. Sophisticated software for rapid setup and flexure compensation to keep the mirrors stabilized and aligned to prevent images from moving about on the detector. Conventional spectrographs that suffer from severe flexure make calibration and data reduction difficult.

The multiple detectors on each of the Keck telescopes, the DEIMOS spectrograph and other related instruments require extremely precise motion control of a wide array of elements such as filter wheels, focusing, apertures and positioning stages. To handle such tasks, Galil motion controllers have been specified for over 15 years by Barry Alcott, development engineer at UCO.

For example, Alcott is using Galil's RIO Pocket PLC to automate portions of the older, manually operated Hamilton Spectrograph system, the first cross-dispersed spectrograph installed at the Lick Observatory. It operates by having light fed to a grating that sends it in one direction and then immediately feeds it to a prism that disperses it at a 90-degree angle. This results in very high-resolution spectra with large coverage of the light spectrum.

Alcott configured the multiple I/O points provided by the RIO to automatically control four pneumatic stages used

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for moving an iodine cell into a beam, opening a light port, moving a mirror into a beam and opening a mirror cover. The logic control provided by the RIO ensured proper sequencing of events. Its built-in Ethernet port also proved crucial as all communication for the motion and I/O control is Ethernet.

"A major benefit of automating the control of these functions is the ability to enable our astronomers to remotely control the telescope instruments from a home base," said Alcott. "They no longer need to come to the Mount Hamilton Observatory to adjust the instrumentation."

"I've found that the RIO fills an important niche for us. It has the advantages of being small and easy to use, and is a time saver for both hardware and software development. In fact, with the RIO, I was able to put together this control system in under two weeks. I've used the Galil controllers for the past 14 years and feel confident and comfortable adding the RIO to my list of tools. Importantly, our software group is familiar with the Galil controller command language and that has cut control software development time."

In addition to the RIO upgrade, the "home grown" 6502 MPU system of the Hamilton Spectrograph is being replaced with Galil's DMC-4080 Accelera Series controller. In this application, Galil's dual-loop position mode is used specifically for sub-micron, precise positioning and guidance of the correct light wavelength onto the detectors. This is accomplished by allowing dual position feedback from a .01-micron resolution encoder placed on the stage and an auxiliary encoder placed on the motor.

Alcott reports that additional upgrades using Galil controllers are in process at the Mt. Hamilton location. The 68000 MPU based system of the Kast spectrograph is being replaced with a pair of DMC-4080 controllers. Additionally, a spectrograph is being built for a new remotely operated 2.4 meter Automatic Planet Finder (APF) telescope that will be used to search for extra-terrestrial planets.

While the Lick Observatory sits atop the summit of 4200-foot Mt. Hamilton in the Diablo Range east of San Jose, CA, the W.M. Keck Observatory is positioned at the 14,000-foot summit of Mauna Kea, a dormant volcano on the Big Island of Hawaii. Its Keck I and Keck II are considered to be the world's largest optical and near-infrared telescopes, each capable of collecting four times more light than the world renowned Palomar 200-inch (5-meter) telescope located in San Diego, CA.

To accomplish this, each of the Keck telescopes is equipped with a mirror 33 feet in diameter and uniquely composed of 36 hexagonal segments mosaicked together. Keck I has been in operation since 1993 while the Keck II was commissioned in 1996.

According to a UCO data report, the beginnings of 8- to 10-meter astronomical telescope development began at UCO/Lick, with the genesis of what eventually became the Keck telescopes. UCO/Lick faculty member Jerry Nelson designed the unique Keck mirrors, while UC Santa Cruz Professor Steve Vogt is credited for designing and building Keck I's flagship optical spectrograph, the High Resolution Spectrograph (HIRES). With the help of Galil controllers, the HIRES is often used for precise velocity work and has been instrumental in the search for extra-terrestrial planets.

A second spectrograph at the Keck Observatory, the Eshelette Spectrograph and Imager (ESI), features Galil's DMC-1500 motion controllers and was recently shipped and commissioned by the UCO/Lick team. DEIMOS, which also features the DMC-1500, represents the third and most advanced optical spectrograph built by UCO/Lick.

In addition to the three spectrographs, Alcott said that the UCO's Atmospheric Dispersion Corrector (ADC) was built using a Galil DMC-2200 controller for the Keck I telescope. "This essentially helps to improve the differential refraction of the telescope as seen by the existing cassegrain instrument."

Sandra Faber, a UCO astronomer, UOC professor and a founder of the Keck Observatory, said, "A great telescope like the Keck allows us to explore the River of Time back toward its source. Keck will allow us, like no other telescope in history, to view the evolving universe that gave us birth."

In fact, UC Irvine scientists recently announced that with the aid of data obtained from the Keck telescope, they have discovered the minimum mass for galaxies in the universe: 10 million times the mass of the sun. "By knowing this minimum galaxy mass, we can better understand how dark matter behaves, which is essential to one day learning how our universe and life as we know it came to be," said Louis Strigari, lead author of this study and a McCue Postdoctoral Fellow in the Department of Physics and Astronomy at UCI.

On another front, UC Berkeley professor of astronomy Alex Filippenko was able to capture the visible light created from the very beginning of a supernova, dubbed SN 2008D, from his post at the Lick Observatory on Mt. Hamilton. "I am really thankful to have the opportunity to study a Type Ib supernova in its infancy. The death of a massive star marks the birth of its explosion, along with the creation and ejection of heavy elements like oxygen and calcium, necessary for life as we know it." ■

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