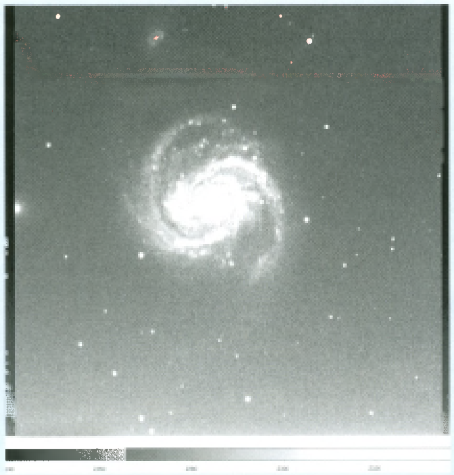


First light for the new CCD. This is the spiral galaxy M100 taken with PRISM on the Perkins Telescope June 5.

signals were increased and two new electronics boards were added. These generate signals and digitize the output of the CCD into the images for the astronomer to analyze. The software that drives the CCD also had to be upgraded, and once again we were able to utilize work that had already been done by the Lowell instrument group.

Ted Dunham and Peter Collins did extensive rewriting of the software code that drives the CCDs for the new 42" camera. The new PRISM detector was able to utilize almost all of this code with few modifications, reducing the amount of time and effort from weeks to days.

The new CCD started operation June 5 of this year with very good results for the science programs that have used it and reported back. While there are still some minor issues that need to be resolved, we can declare the upgrade to be a success.

Stephen Levine Joins DCT Team

Stephen Levine joined the Lowell Observatory staff as the Discovery Channel Telescope Commissioning Scientist in July. Stephen grew up in New York City and received his Ph.D. in astronomy from the University of Wisconsin. After four years working at the Observatorio Astronomico Nacional in Mexico, he joined the United States Naval Observatory Flagstaff Station, where he worked with the Digital Catalogs division and developed software control systems for cameras and telescopes.

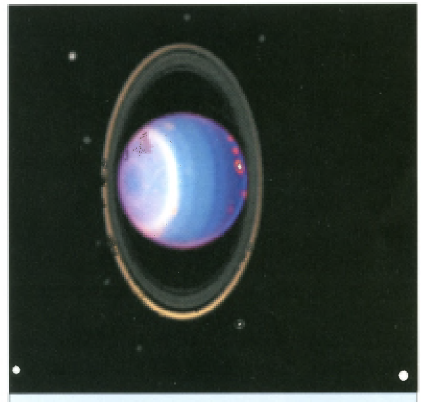
Stephen describes his role with the DCT as that of a facilitator who will work with the engineering team to ensure that scientific requirements of the Lowell astronomers who will use the telescope are met.

Stephen is married to former Lowell astronomer Amanda Bosh.

A Century of Uranus Observation at Lowell

by Wes Lockwood

The distant planet Uranus has been of interest at Lowell for a century beginning with pioneering spectroscopy by Percival Lowell and brothers V.M. and E.C. Slipher around 1900. The 1977 serendipitous discovery of the Uranian ring system by Lowell's Bob Millis and a team headed by MIT's Jim Elliot put Lowell on front pages worldwide. A long-term photometric observation series that began in 1950 continues to record Uranus's seasonal brightness variations.



A Hubble Space Telescope false color composite image of Uranus and its moons and rings. A few transient clouds appear near the limb of the planet.

With a tiny visible disc a quarter the size of Mars and no visible surface features to serve as a clock, the rotation period of Uranus was unknown a century ago, but astronomers recognized that astronomical spectroscopy offered an indirect approach to the problem. By measuring the Doppler shift of spectrum lines on the approaching and receding limbs of the planet, the rotation period could be worked out from the tilt of spectrum lines across the disc. Percival Lowell recognized this as early as 1903, but a test had to wait until the planet moved to a more favorable aspect in its eight-year orbit. Finally, in 1910 V. M. Slipher obtained photographic spectra with the 24-inch Clark telescope. These early spectra of Uranus and the outer planets Jupiter, Saturn, and Neptune would reappear in 1935 when he and Arthur Adel published them in a classic paper in the prestigious journal *Nature,* together with Adel's laboratory spectroscopic measurements of methane gas under high pressure.

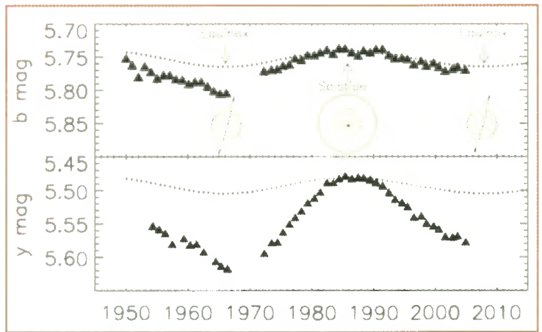
Lowell and Slipher both measured the plates, using a traveling microscope to determine the shift of the spectrum lines across the rotating disc of Uranus. Their tightly clustered individual values indicated a rotation period of 10¾ hours, reported in Lowell Observatory Bulletin No. 53, 1912 by P. Lowell and V.M. Slipher. Measurements by others over the next 75 years closely agreed, so it came as a great surprise when 1986 radio data from Voyager spacecraft revealed a much longer period, 17¼ hours. Likewise, the polar flattening of Uranus (the difference between the polar and equatorial diameters) had been grossly overestimated by early visual observers, who consistently agreed on a value near 10 percent. Modern measurements showed that the flattening is only 2 percent. We can only speculate about how careful observers working

(continued on page 4)

at the limits of telescopic resolution and instrumental precision were led (or misled) to the wrong answer, subtly guided by the known example of Jupiter's 10-hour rotation period and 10 percent flattening. Theoretical calculations relating the flattening of a fluid body to its rotation speed provided further assurance from the laws of physics.

In 1948, Lowell was awarded a contract with the United States Weather Bureau to study planetary atmospheres. Meanwhile, the sun's variability status remained unsettled, and National Oceanic and Atmospheric Administration climatologist Murray Mitchell, Jr., frustrated by delays in the launch of a weather satellite that would also measure the sun, urged Lowell Observatory to resume the planetary measurements. By 1975, observer Don Thompson and I began to understand that planetary "weather" and seasonal variation were swamping any possible solar variability. So, we relabeled the project "Planetary Variations" and continued observing with grant support that still continues today. Lowell observations of Uranus and Neptune, nearly all made at the 21-inch telescope on Mars Hill, are as far as we know the longest (60 years!) series of photoelectric measurements in existence.

The illustration shows several things about Uranus. The variation is essentially seasonal, reaching a maximum when the pole of Uranus points directly at the Earth and the planet's larger equatorial diameter makes the disc appear biggest. But there is more to the story: the dotted curve shows the expected variation, based on the changing apparent size of the planetary disc, but the measurements, especially in yellow light, indicate that the polar regions of the planet reflect more sunlight than the equator. Not only that, the curve is not symmetric, indicating intrinsic temporal changes in the reflectivity of Uranus independent of its orientation. With only a slight abuse of the term, we can call this a manifestation of seasonal "planetary weather," not exactly what the Weather Bureau had in mind in 1950, but interesting nonetheless.



Photometric measurements of Uranus at two wavelengths (blue, above, and yellow, below). Each small division of the vertical stellar magnitude scale indicates a change of about one percent. The accompanying globes show the aspect of Uranus at seasonal extremes. The dotted lines show the variation expected if the disk of Uranus was uniform from equator to pole.

By far the biggest news about Uranus since Slipher's day came in 1977 when the planet and Lowell Observatory made the front page everywhere. A rare opportunity to observe an occultation of a star by Uranus put a major expedition into motion. Jim Elliot and Ted Dunham, then at Cornell University, flew on the Kuiper Airborne Observatory along the occultation track over the Indian Ocean, while Lowell's Bob Millis observed with a telescope at Perth Observatory in Western Australia. All the observers were startled by transient dips in the signal before and after the disc of Uranus passed in front of the star. Later, when the adrenaline rush passed and they all got together in Perth to compare notes, they realized that they had discovered a system of rings around Uranus. Within a few years ring systems were also found around Jupiter and Neptune, but without the Uranus discovery, it's possible that no one would have bothered to look.

Lowell Astronomers - This Summer's Stars

Lowell guests had frequent opportunities to visit with staff astronomers throughout the observatory's *Summer with the Stars* celebration. Left, astronomer Larry Wasserman shares details of his research with a visitor in the Rotunda Museum. Below, post-doctoral researcher Kim Herrmann engages evening visitors with a portable planetarium.