Lowell Observatory

Flagstaff, Arizona 86001

This report covers the interval 1 July 2003 through 30 June 2004.

1 PERSONNEL

William Lowell Putnam, grandnephew of Percival Lowell, continued as Trustee of the Observatory.

The scientific staff included A. S. Bosh, E. L. G. Bowell, M. W. Buie, E. W. Dunham, J. L. Elliot, O. G. Franz, W. M. Grundy, J. C. Hall, D. A. Hunter, K. L. Jessup (until mid-April), B. W. Koehn, G. W. Lockwood, G. Mandushev, P. L. Massey, R. L. Millis (Director), M. S. Oey, D. G. Schleicher, C. S. Shoemaker, J. R. Spencer (until mid-January), L. H. Wasserman, N. M. White, and L. M. Woodney. H. L. Giclas, though officially retired, has been involved in Observatory activities. Amanda S. Bosh was Boston University staff resident at Lowell.

Scientific support staff included T. A. Bida, B. A. Skiff, S. Strosahl, B. W. Taylor, M. E. Van Ness, and G. Walth.

Technical and administrative staff included J. J. Bailey, A. S. Beiser (Librarian), L. P. Bright, J. L. Darwin, M. L. Evans, H. S. Horstman, P. J. Houlahan (Information Technology Manager), M. M. Inge, M. Linzey, G. R. McGlothlin, R. M. Melena (Secretary–Treasurer), C. J. Millette, Jr., D. Millis, K. S. Morefield, R. A. Nye, C. J. Ochser (Director of Development), R. C. Oliver, K. A. Phillips (Manager, Media Relations and Public Affairs, until September), B. Welling, and S. Wotkyns (Public Relations Manager, beginning September).

Directly involved with the operation of the NPOI were E. K. Isbrecht, B. O'Neill, J. A. Shannon, S. Strosahl, D. Theiling, W. Wack, and N. M. White.

In March, T. Sebring began work as Project Manager of the new 4-meter Discovery Channel Telescope. Other members of the Project Team were M. de Kock, E. Gummerman (until mid-March), B. Smith, K. Westcott (beginning mid-April), and O. Wiecha.

Working in the Observatory's educational program were R. C. Burgoon, J. P. DeDecker, M. E. DeMuth, J. C. Hall (Associate Director for Education and Special Programs), G. Hardwick, E. Hillyer, S. A. Karcz, A. Kiefer, E. Kuefler, S. Lamb, H. M. Landau, C. LeBlanc, M. Mayrand, K. Moore, T. A. Rodriquez, K. S. Schindler, P. R. Stiers, S. Strosahl, R. P. Tweed, and R. A. Winner.

K. A. Phillips (Manager, Media Relations and Public Affairs) left Observatory employ in September to attend graduate school.

In January, Astronomer John Spencer departed to join the research staff of the Southwest Research Institute (SWRI) in Boulder, Colorado. Post doc Kandis Lea Jessup followed Spencer in mid-April. Having accepted a faculty position at the University of Michigan in Ann Arbor, Astronomer Sally Oey left at the beginning of June. Astronomers Lisa Prato and Sydney Barnes were hired and will take up their positions at Lowell in August.

Volunteers made a considerable contribution to the Observatory. Martin Hecht served as archival assistant. Ava Stone and Ed Nettell assisted in the library, Julia Millis in the business office, and Henry Holt with Shoemaker. Volunteering for the Public Program were J. Adams, D. Chalke, B. Cole, C. Dechambre, T. Fisk, J. Gordon, R. Helm, A. J. Inman, F. June, S. Karcz, H. Lacey, J. McFarland, G. Mishkin, S. Nichols, A. Odell, D. S. F. Portree, C. Sapio, M. Schimmelpenninck, A. Sherwood, D. Smith, and B. Sommers.

Russell Tweed, Senior Supervisor for Outreach Programs, was named 2003 Employee of the Year, in recognition of his excellent work for the Observatory's Public Program, particularly the development and organization of the First Annual Lowell Observatory Star Party.

Approximately 30 visiting astronomers, in addition to several from Boston U., were awarded time on Lowell telescopes. Included in this number are several from the National Undergraduate Research Observatory consortium (NURO). Students accompanied the NURO observers at the telescope.

2 FACILITIES

2.1 Anderson Mesa Telescopes

Powered ventilation of the space above the primary mirror of the Perkins Telescope was installed in collaboration with Boston University. This modification resulted in a consistent improvement of roughly 0.1 arcsec in the FWHM of stellar images. The partnership with Boston University for the shared use of the telescope was renewed for an additional five years.

Replacement of the optics in the Hall Telescope commenced toward the end of the reporting period.

New control electronics were put in service at the Perkins Telescope and will be incorporated at the Hall telescope during the optics upgrade period. This is part of a longer-term upgrade to the control computer software.

2.2 NPOI at Lowell Observatory

The Navy Prototype Optical Interferometer (NPOI) project is a collaboration among the Naval Research Laboratory, U. S. Naval Observatory, and Lowell Observatory. The six-beam interferometer and vacuum light path enables observations in the visible spectral region and fifteen simultaneous baselines. The instrument can function as a four-beam astrometric interferometer or a six-beam imaging interferometer.

Lowell observers continued science and engineering observations on a nightly basis throughout the report year. Lowell staff played significant roles in operating the instrument, site maintenance, instrument deployment, and electronics development. Progress by the collaborators continued in the areas of improved data reduction software, the long

optical delay lines, improving the astrometric precision and refinement of the instrument and its operation.

Significant effort continued towards implementing and testing the long optical path length system that is necessary for efficient use of baselines longer than 100 meters. The six 100-meter vacuum tanks are in place, and 12 ''pop up'' mirrors have been installed in each tank. The remote control and repeatability of the mirrors, which allow for discrete lengths of optical path to be inserted or removed from the overall path length within each tank, were designed and tests continued.

Astrometric precision depends upon the constancy of the optical paths between fixed mirrors within the light path. In practice, despite operating in a vacuum and robust mechanical mounts, the path lengths were not constant at the micron level. An additional laser metrology system was designed and successfully tested. Its purpose is to measure ''constant'' path length corrections, which can then be used to improve the astrometric precision.

Instrument refinements dealt with improving the quality of the observations, automation, and calibrations of various parts of the instrument. Observations using three- to six-way beam combinations occurred on most useable nights. Up to 240 scientific observations have been made in a single night, which approaches the originally anticipated number of 250. Scheduled research programs included double stars, cool stars, Hα measurements of Be stars, fast rotating stars, planet searches, and general survey work.

2.3 Mars Hill Telescopes

Remote operation of the 16-inch telescope via the Internet was beta tested by a number of individuals around the country. Full implementation of this capability has been delayed by an exasperating intermittent sidereal tracking error.

2.4 Discovery Channel Telescope

Testing of the proposed site near Happy Jack continued on an intensive schedule through December and intermittently through the remainder of the reporting period. The former ACIC building was gutted and rebuilt to serve as headquarters for the project team. A partnership with media giant Discovery Communications was announced in October, at which point the name of the telescope was changed from the Next-Generation Lowell Telescope to the *Discovery Channel Telescope*. Three additional engineers (Wiecha, Smith, and de Kock) and an administrative assistant (Westcott) joined project manager Sebring and project scientist Dunham during this reporting period. Contracts for design studies were issued to Goodrich, Vertex RSI, M3 Engineering and Technology, e2v, and the Astronomy Technology Center. ULE blanks for the 4.3-meter primary and the secondary mirror were ordered from Corning. Application for a Special Use Permit to build the telescope at the Happy Jack site, which is within the Coconino National Forest, was submitted to the U. S. Forest Service. The environmental assessment of the site required by the National Environmental Policy Act (NEPA) was commenced.

2.5 Instrumentation

The two-channel, high-speed photometer (HIPO) for use on SOFIA was brought to near completion in the Lowell shops. It was tested on the Perkins Telescope in conjunction with FLITECAM, an IR instrument built at UCLA. HIPO will be used early in the coming quarter for testing and commissioning of the SOFIA telescope.

PRISM, an optical imager and polarimeter built at Boston University under the direction of K. Janes, was delivered to Lowell during this period. Lowell provided the detector, control electronics, and operating software. After a period of commissioning and optimization, the instrument came into full use as the primary CCD camera on the Perkins.

Work continued at Boston University on Mimir, an IR imager/spectrometer/polarimeter designed by D. Clemens in collaboration with Buie. Lowell provided control electronics and operating software. The instrument will begin commissioning on the Perkins Telescope in August 2004.

Under the direction of Bida, work began on renovation of the White Spectrograph (on loan to Lowell from KPNO). A new CCD detector package will be fitted to the spectrograph, an optical modification will be made to match the spectrograph to the Perkins Telescope's f/ratio, a number of mechanisms will be re-worked, a slit-viewing camera will be fitted, and calibration sources added.

2.6 Library

During the report period, 51 individuals accessed the Lowell Observatory Archives. Included were publishers, historians of astronomy, and amateur astronomers from the United States, Japan, Great Britain, Australia, New Zealand, and France.

Volunteer E. Nettell continues to update the historical photographic database; Martin Hecht, Lauren DeMuth, and Nicole Martin sorted and indexed archival correspondence and manuscripts. Beiser continues to oversee daily operations in the library and archive. Evans assists with updating of library and archival databases as needed.

2.7 Computer Facility

The network infrastructure was overhauled to include Cisco ''layer 3'' managed switches that allow better segmentation of our networks for security and bandwidth control through implementing VLANs. This upgrade, which required major rewiring of the Slipher Building network, also relieved our critical shortage of IP addresses. In addition, our service provider upgraded our telecom connections from analog to digital, giving access to increased bandwidth. A Windows 2003 server was added for new Business Office software systems (Blackbaud). A new SUN server was installed to replace the old mail server that failed.

3 RESEARCH

3.1 The Solar System

Lockwood continues a long-term program to monitor seasonal and secular variability of the albedos of Titan, Uranus, and Neptune, using photoelectric photometry in the *b* and *y* Strömgren passbands.

Lockwood and visiting astronomer M. Jerzykiewicz (Wroclaw, Poland) completed a re-analysis of photometry of Uranus and Neptune carried out at Lowell from 1950 to 1966, which, in combination with the *b,y* photometry from 1972–2003, now covers a substantial part of the seasonal variation of these two objects. Observations supported by NASA Planetary Astronomy will continue through the *Cassini* encounter with Titan (summer 2004), Neptune southern solstice (2005), and Uranus equinox (2007).

3.1.1 Planets, Satellites, and Their Atmospheres

With the assistance of Grundy, Buie continued monitoring Pluto with ground-based observations using photometry and IR spectroscopy. These studies continue to provide important input into our understanding of the evolution of Pluto's surface and atmosphere as it recedes from the Sun. The photometric monitoring is accomplished via the 31-inch robotic telescope at Anderson Mesa developed by Buie. A new addition to the system this year includes a low-cost pointing reference camera that is bore-sighted with the telescope.

Olkin, Wasserman, and Franz completed their determination of the mass ratio of Charon to Pluto from *Hubble Space Telescope* astrometry with the Fine Guidance Sensors.

Grundy conducted infrared spectroscopic observations of icy, outer solar system objects, mostly at NASA's IRTF telescope on Mauna Kea, resulting in the discovery of heterogeneous longitudinal distributions of N_2, CH_4, and H_2O ices on Neptune's moon Triton, as well as confirmation of long-term evolution of Pluto's CH_4 ice. A study of the distribution of CO_2 ice on Uranus' moon Ariel is also underway, as is a search for short-term variability on Triton, in collaboration with L. Young (SWRI).

3.1.2 Asteroids

Bowell and Koehn are trying to increase the known population of near-Earth asteroids and comets (collectively, near-Earth objects or NEOs) by undertaking an observational and theoretical effort using a CCD-mosaic camera mounted on a 59-cm Schmidt telescope at Anderson Mesa. Observation and moving-object detection have been largely automated. Their approach favors the detection of NEOs larger than 1 km in diameter, the size range considered to be potentially hazardous to civilization. Secondary and tertiary science goals comprise the discovery of non-Earth-approaching asteroids (main-belt, the brightest members of the transneptunian population, etc.) and a suite of non-solar system projects, respectively. During the reporting interval, the LONEOS system was operated on 133 nights, resulting in 619,000 asteroid detections, of which 1,451 were of NEOs. Most of the observations were published in the *Minor Planet Circulars*. Forty-two near-Earth asteroids ($q < 1.30$ AU) were discovered, of which 7 are thought to be larger than 1 km in diameter, 13 were potentially hazardous asteroids: 2 Atens, 26 Apollos, and 14 Amors. Four discoveries warranted press releases and media attention: 2003 EH_1, a high-inclination Amor, was shown by P. Jenniskens (NASA Ames) to be the parent body of the Quadrantid meteor stream. 2003 SQ_{222} made the closest approach yet to Earth (at a distance of 88,000 km) of any asteroid having a well-determined orbit. 1937 UB (69230 Hermes) was rediscovered after being lost since its discovery apparition; and 2004 JG_6, having a semimajor axis smaller than that of Venus, is the ''second rock from the Sun.'' LONEOS continues a collaboration with Minor Planet Research, Inc., a Phoenix-based nonprofit organization that is developing an ''Asteroid Discovery Station,'' soon to become operational at the Discovery Center in Mesa, Arizona.

3.1.3 Kuiper Belt Objects

Millis, Buie and Wasserman, with collaborators at MIT, U. Hawaii, UC Berkeley, and U. Pennsylvania, continued the Deep Ecliptic Survey with the MOSAIC cameras on NOAO's 4-meter Mayall and Blanco Telescopes. During the survey period, 110 KBOs were discovered in our survey and received provisional designations from the Minor Planet Center. This represents 88% of all KBOs receiving designations during this interval. One binary KBO, 03UN284, was found directly by DES team member Kelly Clancy in scanning the DES images. Another, 03QY90 was found by MIT colleagues in follow-up observations at the Magellan telescopes. All MOSAIC images recorded since the project began in 1998 have been submitted to the NOAO archive and are available to the general community through that source. Additional information about the survey can be found in the ''Research'' section of the Lowell website.

Grundy developed algorithms and software for determining the orbits of satellites of KBOs, in collaboration with K. Noll and D. Stephens (Space Telescope Science Institute). The group worked out the orbits for two KBO satellites they recently discovered: 58534 (1997 CQ29) and 66652 (1999 RZ253). From the satellite orbits, the mass of each system was calculated; and from that, estimates of their sizes and albedos. Both objects have intriguingly high albedos, suggestive of fresh, exposed ice on their surfaces.

3.1.4 Comets

Buie continued work with K. Meech (U. Hawaii) to provide ground-based observational support work for the NASA Deep Impact Mission to comet P/Tempel-2.

Schleicher obtained narrowband photometric measurements of seven comets with the 42-inch Hall Telescope during the reporting interval. Additional observations of southern targets were obtained by collaborator P. Birch (Perth Observatory). Targets of focused observing campaigns included long-period comets LINEAR-NEAT (2001 HT50), NEAT (2001 Q4), and LINEAR (2002 T7), and short-period comet 2P/Encke. Extensive narrowband imaging was also obtained for these objects from Lowell Observatory by Schleicher and L. Woodney (U. Central Florida).

Schleicher and Woodney conducted a major photometry and imaging campaign of Comet Encke from September

through November. Encke made an exceptionally close pass to Earth (0.26 AU), permitting the acquisition of rotational lightcurve data of the nucleus, along with compositional measurements as a function of distance from the Sun for the gas species. Narrowband imaging was also obtained over a wide range of viewing geometries, confirming that Encke's strong sunward fan is composed of gas, not dust, and unexpectedly revealing that almost the entire coma is emitted and remains on the sunward side of the nucleus. This is, by far, the most asymmetric gas coma ever observed in a comet. These data will permit the unambiguous determination of the rotation period of the nucleus, and the direction and velocity of gas outflow for several different species, including water.

In support of the *Stardust* flyby of Comet 81P/Wild 2 on January 2, Schleicher acquired photometry eleven days prior to the encounter and imaging two days after. Both observational sets were obtained under extreme viewing conditions, since the comet was nearly behind the Sun and only observable at optical wavelengths during dawn twilight. The photometric observations were fully reduced and results provided to the mission team in time for the closest approach distance of the spacecraft to be altered if necessary. Dust measurements indicated the amount of small-grain (micron-sized) dust was somewhat higher (less than a factor of two) than Schleicher had predicted, based on measurements of the comet at previous apparitions, but that Wild 2 had not recently undergone a major outburst that could have posed a danger to the spacecraft.

Schleicher and N. Samarasinha (NOAO) adapted their respective Monte Carlo comet jet models to accommodate the dispersion of daughter species when parent molecules dissociate, to better match the observed spiral CN gas jets in Comet Hyakutake during the comet's close approach to Earth during March 1996. Preliminary results imply that CN's effective excess velocity is less than 0.5 km/sec, well below the expected value of approximately 1 km/sec from HCN dissociation. If HCN is the primary parent of CN, then this lower velocity may be due to the effects of collisions in the inner coma. This possibility will be tested by intercomparing the derived effective dissociation velocities for each of the observed molecules.

3.2 Stars

3.2.1 Solar–Stellar

Hall and Lockwood continued their solar-stellar spectrograph program with NSF support. The goal is to monitor long-term (cycle timescale) magnetic activity and to compare that with irradiance variations of the Sun and sunlike stars. Recently, Hall and Lockwood completed an analysis of more than 3200 observations of 46 sunlike stars and nearly 1000 comparable observations of the Sun. Although approximately one-third of the stars are observed in flat states, these stars do not always exhibit overall magnetic activity well below that of solar minimum. While flat activity stars may be in a period of extended magnetic minima analogous to the solar Maunder Minimum (1645–1715), a significant reduction in magnetic activity (and an implied reduction in total irradiance) is not necessarily implied by the data.

Lockwood and collaborators R. Radick (AFGL), G. Henry (Tennessee State U.), and S. Baliunas (CfA) have extended the parallel times series of Mount Wilson HK measurements and *b,y* photometry to nearly two decades. They have shown that (1) a power-law relationship between mean chromospheric activity and rms brightness variations shows the Sun to be a significant outlier with roughly 40% the variability of close solar analogs and (2) by Monte Carlo modeling, 15+ years of observation are required to characterize cycle-length variations.

Lockwood and J. Lester (U. Toronto) completed tests of a Bomen Fourier Transform Spectrometer to determine if the spectrometer is suitable for an intended recalibration of absolute solar spectral irradiance in the 0.3 to 2.0 micron region. Nye and Darwin fabricated a heliostat and optical bench arrangement for some preliminary solar measurements made recently at Anderson Mesa.

3.3 Extragalactic

Hunter and collaborator B. Elmegreen (IBM) published results of Hα imaging collected over the past 10 years which they use to measure the integrated star formation rates, determine the extents of star formation in the disks, and compare azimuthally-averaged radial profiles of current star formation to older starlight. Their sample includes 94 galaxies with morphological classifications of Im, 26 Blue Compact Dwarfs (BCDs), and 20 Sm systems. They found that the integrated star formation rates of Im galaxies span a range of a factor of 10^4 with 10% Im galaxies and one Sm system having no measurable star formation at the present time. The BCDs fall at the high star formation rate end of the range. They found no correlation between star formation activity and proximity to other catalogued galaxies. Most of the star formation is found within 3 disk scale-lengths, but in some galaxies HII regions are traced as far as 6 scale-lengths.

A comparison of Hα surface photometry with *V*-band surface photometry shows that the two approximately follow each other with radius, but in most BCDs there is an excess of Hα emission in the centers that drops with radius. The BCDs require a significant fraction of their gas to migrate to the center in the last Gyr to fuel the star formation activity there. There are possible torques that could have caused this without leaving an obvious signature, including dark matter bars and past interactions or mergers with small galaxies or HI clouds.

Hunter and collaborators V. Rubin (DTM), S. Levine (USNO), L. Sparke (U. Wisconsin), and R. Swaters (JHU) have measured the stellar velocity dispersion in the irregular galaxy NGC 4449 from long-slit absorption spectra. The average dispersion is 26 $\pm$ 2 km/s. Assuming a maximum rotation speed of the stars from a model derived from the gas kinematics, they find the ratio V/σ_{stars} is 3.0 $\pm$ 0.2. This value is comparable to those measured for spiral galaxies, and implies that the stellar disk in NGC 4449 is kinematically cold and thin. This conclusion is at odds with studies of the distribution of apparent minor-to-major axis ratios that suggest that irregular galaxies are thick disks or triaxial.

Hunter and collaborator E. Wilcots (U. Wisconsin), with undergraduates E. Bowsher and V. Goad and graduate stu-

dent A. Kepley, traveled to Green Bank in July to observe the extended HI around the dwarfs Sextans A and NGC 2366 using the single-dish Green Bank Telescope (GBT). Huchtmeier and collaborators had reported in the 1980s that these galaxies have very extended HI disks, but Hunter and Wilcots had failed to detect the extended gas with VLA mosaic observations. The unparalleled sensitivity and reduced sidelobes of the GBT enabled them to observe the gas associated with these galaxies to a level not achieved before. Bowsher reduced and mapped data for Sextans A, finding that the gas reported by Huchtmeier is not there; they were probably confused by high-velocity clouds from the Milky Way in the vicinity and/or by sidelobes. Instead, Sextans A has a normal HI distribution.

Hunter and collaborator E. Anderson (NAU) had telescope time on the KPNO 2.1-meter telescope in January and March to extend their study of the extreme outer parts of irregular galaxy disks. They reached a surface brightness level of 28.5 mag arcsec^{-2} in *V*.

Hunter, C. Simpson (Florida International U.), and P. Knezek (WIYN) finished an HI and optical study of the gas-rich dwarf irregular galaxy DDO 88. Although DDO 88's global optical and HI parameters are normal for its morphological type, it hosts a large (3 kpc diameter) and unusually complete ring of enhanced HI emission. The normal appearance of this galaxy in the optical and the outer regions of the HI give no hint of the presence of the striking HI ring in the inner regions. The gas ring is located at approximately one-third of the total HI radius and one-half the optically defined Holmberg radius, and contains 30% of the total HI of the galaxy. The ring surrounds a central depression in the HI distribution. If the HI ring was formed by the energy input from winds and supernova explosions of massive stars formed in a starburst, the star-forming event would have formed 0.1–1% of the total stellar mass of the galaxy.

Hunter participated in a study of super star clusters in irregular galaxies with S. Larsen (ESO/ST-ECF) and J. Brodie (Lick Observatory). They obtained high-dispersion spectra for four massive star clusters in the dwarf irregular galaxies NGC 4214 and NGC 4449, using the HIRES spectrograph on the Keck I telescope. Combining the velocity dispersions of the clusters with structural parameters and photometry from images taken with the *Hubble Space Telescope,* they estimate mass-to-light ratios and compare these with simple stellar population models in order to constrain the stellar initial mass functions (IMFs) of the clusters. They find the data for all clusters to be consistent with a normal Kroupa-type IMF, and rule out any IMF that is significantly deficient in low-mass stars. The four clusters have virial masses ranging between 1.6 x 10^5 M_{solar} and 1.4 x 10^6, half-light radii between 3.0 and 5.2 pc, estimated core densities in the range 1.4 x 10^3 M_{solar} pc^{-3} to 1.7 x 10^5 M_{solar} pc^3, and ages between 200 Myr and 800 Myr. These properties are consistent with the clusters being young versions of the old globular clusters.

Massey is leading a team of collaborators in an optical survey of Local Group galaxies currently forming stars. Images in UBVRI as well as Hα, [OIII], and [SII] have been obtained with the Kitt Peak and Cerro Tololo 4-meter telescopes, with essential calibration being done at Anderson Mesa with the 1.1-meter Hall Telescope. The data and photometry will be made available to others for general use and will be used to directly answer a number of questions concerning massive star evolution. All images have now been taken, reduced, and placed in the fledgling NOAO Science Archive. Photometric calibration is complete for M33 due to efforts by REU student W. Schlingman (U. New Mexico), and production of the catalog of this and the other galaxies in the sample is nearing completion.

Massey and collaborators R. Kudritzki, F. Bresolin (U. Hawaii), J. Puls and A. Pauldrach (U. München) completed a study of the physical parameters of 20 of the hottest and most massive stars known in the Magellanic Clouds. Using sophisticated non-LTE model atmospheres, they modeled very high (500) signal-to-noise optical ground-based spectra, with stellar wind parameters determined from recent *HST* UV observations. They found that in general the effective temperature scale of O-type stars is about 3,000–4,000°K hotter in the Magellanic Cloud stars than for stars of similar type in the Milky Way, due to the decreased importance of wind emission, wind blanketing, and metal-line blanketing at the lower metallicities that characterize the Magellanic Cloud sample. A follow-up study of a larger sample is currently underway.

Massey and collaborators D. Silva (ESO), P. Henning (U. New Mexico), and K. Eastwood (Northern Arizona U.) obtained NIR images of HIZSS 3, a nearby irregular galaxy previously identified as a possible Local Group member. The new images were obtained with ESO's 8.2-meter VLT under beautiful sub-arcsecond conditions and revealed the stellar content of this nearby galaxy directly for the first time. In accord with Massey's early study (Massey, Henning, and Kraan-Korteweg 2003, AJ 126, 2362), the new data places the distance of HIZSS 3 at about 1.8 - Mpc, just outside the zero-velocity boundary of the Local Group. Analysis of the HII region using MMT data reveals that the galaxy is relatively metal-poor, similar to that of IC$\sim$1613, WLM, and Pegasus, with log O/H $\sim$ 12 $\approx$ 7.8.

Oey, N. King, and J. Parker (SWRI) completed work on the clustering properties of massive stars in the Magellanic Clouds. They find that the clustering law follows a smooth power law all the way down to individual field massive stars. This strongly suggests that the formation of field massive stars is a continuous process with those in associations, and that the field stars do not originate from a different star formation mode. The results are consistent with the model that field massive stars represent the most massive members in groups of smaller stars, as expected if the clustering law applies to much lower masses as is expected from the stellar initial mass function.

Oey and G. Garcia-Segura (UNAM/Ensenada) are completing a study on the effect of ambient interstellar pressure on the evolution of superbubbles generated by OB associations. They compiled a variety of evidence suggesting that interstellar pressures may be systematically underestimated, and that they are high in star-forming regions. Numerical simulations are presented that demonstrate high ambient

pressures may be responsible for the unexpectedly small sizes of OB superbubbles.

Oey, Walth, A. Watson (UNAM/Morelia), and student K. Kern (U. Wisconsin) are completing work on the stellar content of a Galactic star-forming region, IC 1795. This association is part of a series of hierarchical shells, apparently due to triggered star formation. The age determination for IC 1795 is intermediate between that of the Perseus superbubble and the W3 embedded sources, thus providing some of the strongest evidence to date of star formation triggered by superbubbles.

Oey, Walth, G. Meurer (JHU), students E. Levesque (MIT) and E. Furst (Bucknell U.), and the SINGG collaboration are examining the relation between classical HII regions and the diffuse warm ionized medium (WIM) in the preliminary sample of galaxies observed in Hα by the Survey of Ionization in Neutral-Gas Galaxies (SINGG; PI Meurer). Roughly 100 galaxies are being numerically processed to isolate the HII regions and WIM.

4. EDUCATIONAL PROGRAMS

The Steele Visitor Center was open daily throughout the year, and on a varying number of nights per week seasonally. Programs for on-site visitors consisted of a spoken multimedia program in the Giclas Lecture Hall, followed by either a tour of the campus (daytime) or telescope viewing (evenings, weather permitting). When not precluded by high wind, viewing is done through the 108-year-old Clark refractor. Lowell's education and outreach programs enjoyed good attendance and several successful events during the report period. A total of 57,633 visitors attended the daytime and evening programs between June 2003 and May 2004, up from a total of 51,695 for the previous reporting period. An additional 10,402 K–12 students came to Lowell's campus for group programs.

Funding from the Flagstaff Cultural Partners enabled construction of a new Dark Skies Exhibit for the exhibit hall in the Steele Visitor Center. This exhibit and a new, computer-based ''Explore the Universe'' exhibit are the first in a set of new displays that will completely overhaul the existing 10-year-old ''Tools of the Astronomer'' exhibits. Several special events and demonstrations were held in connection with National Astronomy Day on May 24, including the premiere program in a new series of multimedia presentations. An experiment in online booking began in January 2004, with the auctioning of three-hour blocks of time on the Clark Telescope on eBay. This has been a highly successful venture, resulting in significant buyer interest.

The second annual Lowell Star Party was held June 17–20. Approximately 133 registrants from all over the United States attended. The event included all-night observing at the Arizona Snowbowl, tours of Anderson Mesa and the U. S. Naval Observatory, presentations by Lowell astronomers and a USGS scientist, an astronomy vendor marketplace, and late-night viewing on the 24-inch Clark Telescope.

The Observatory participated in the Flagstaff Festival of Science, held for ten days beginning September 26. The Festival is a collaborative effort of local government, private agencies, research institutions, and industry. Staff members presented talks, special programs were held at the Steele Visitor Center, and tours of the Naval Observatory Prototype Interferometer at the Anderson Mesa dark-sky site were available.

The Lowell Observatory Navajo and Hopi Astronomy Outreach Program continued. Initiated in 1996 by Bosh and Hunter, the purpose of this program is to help teachers excite students about science through astronomy-related classroom activities. The focus is 5th through 8th grades, to reach students in the transition period during which negative attitudes form towards science. In 2003–2004, Bosh, Grundy, Hunter, Oey, and Portree participated in the program.

The annual MIT Astronomy Field Camp took place in January. Undergraduates Kelly Clancy, Kaia Dekker, Shavonne Hilton, Julia Kane, Emily Levesque, and Jessica Young; teaching assistant Susan Kern; and Lowell astronomer/MIT Professor James Elliot and Mrs. Elaine Elliot were in residence at Lowell for most of the month. Projects ranged from automating telescopes, to analyzing the contents of distant galaxies, to studying the rings of Saturn, to creating a model that compares the stellar atmospheres of O stars within the Small Magellanic Cloud, Large Magellanic Cloud, and the Milky Way. The students worked with Lowell astronomers Bosh, Bowell, Koehn, Massey, Millis, Oey, and Wasserman. At the end of their stay, research results were presented in a seminar before the Lowell community.

A new group of REU students arrived in early June. Welcomed were Wendy Hawley, Emily Levesque, Maureen Teyssier (UC Berkeley), and Kyle Willett (Carleton College). The students will be working with Schleicher, Massey, Buie, and Hunter, respectively. Their visit will culminate with presentations of their work.

Microbiology major Brandon Webb was the recipient of the 2004 Lowell Prize. Mr. Webb received the $500 award for maintaining the highest average (4.0) of scholarship in science, math, or a closely related field during four years of residence at Northern Arizona University. Constance Lowell established the Lowell Prize in 1918 in memory of her husband, Percival Lowell.

5. OTHER ACTIVITIES

The Lowell Observatory Advisory Board met in Flagstaff on June 11–12. Presentations to the members addressed many aspects of the Observatory, but focused on the Discovery Channel Telescope and strategic and financial planning. Members of the Board are Drew Barringer, Jack Clifford, Nicholas B. Clinch, Robert Furlong, Henry L. Giclas, John P. Giovale, Patricia C. Hecht, John S. Hendricks, David C. Henley, James F. Henriot, Gerald E. Kron, Katherine G. Kron, Edward B. Lopez III, Frances B. McAllister, James P. McCarthy, Greg Mort, Patrick M. Nackard, Michael C. J. Putnam, John Radway, Gibson Reaves, Pamela A. Ross, Vera C. Rubin, Brad Ryan, Carolyn M. Shoemaker, Earl Slipher, Paul Sloan III, Arthur R. Szeglin, Donald F. Trantow, Edward E. Vaill, Marcus R. Van Baalen, John M. Wolff, and Margaret Zimmermann.

Barringer and McCarthy joined Clifford, Furlong, Giovale, Hendricks, Ross, Ryan, and Trustee Putnam as the Ex-

ecutive Committee of the Board. The Committee meets quarterly to discuss a variety of issues.

During the reporting period, two valued Board members, John Rhodes and William Sinton, passed away. Rhodes served in the U. S. House of Representatives for 30 years and played a key role in securing funds for the Observatory's Steele Visitor Center. Sinton was a member of Lowell's scientific staff for a period of years before spending the majority of his career at the University of Hawaii.

The 2003 Lowell Workshop, *The Next Decade of Stellar Cycles Research,* was held October 9–11. Organized by Lockwood and Hall, the workshop provided a forum for 16 solar and stellar experts, who reviewed stellar cycles research: its historical development and the present status of the field. They traced the important threads of the past 50 years and reviewed current relevant programs. A web document (www.lowell.edu/users/jch/scr/scr.htm) presents results and recommendations brought forward by the attendees. These recommendations present a road map for lines of study likely to be fruitful over the next ten years.

Four issues of the Observatory's newsletter, *The Lowell Observer*, were published. Consultant Cynthia Webster–Kanner served as Editor.

The Lowell Colloquium Series has been chaired by Lockwood. Twenty-seven speakers presented colloquia at Lowell during the reporting period. (A complete list is posted at www.lowell.edu/ Research/Colloquium/archive/.)

Bowell completed his three-year term as President of Commission 20 of the International Astronomical Union. He has been elected as Vice President of IAU Division III (Planetary Systems Sciences).

Koehn and Bowell are maintaining seventeen URLs concerning asteroid science. They comprise catalogs (asteroid orbits and stars), observational aids (asteroid ephemerides, finder charts, optimum observing strategy, survey coverage, etc.), asteroid target selection, and a description of LONEOS and its discoveries.

Bowell maintains an asteroid orbital database, currently comprising up-to-date osculating elements of about 253,000 asteroids. Daily updates of the database have entailed the computation of about 50,000 asteroid orbits/month. Much of the database is publicly accessible at www.lowell.edu/users/elgb. It is updated automatically on a daily basis, as are a list of minimum orbital intersection distances (MOIDs) between planets and planet- approaching asteroids, and our version of the ''critical list'' of asteroids (numbered and unnumbered asteroids in need of astrometric measurement). A new URL uses the method of statistical ranging for the computation of ephemerides of short-arc NEAs, along with a probabilistic assessment of their types (e.g., Aten, Apollo, Amor). The TNO work has been carried out in collaboration with J. Virtanen and M. Granvik (U. Helsinki).

Buie and Meech are conducting a pilot study to evaluate the use of an automated telescope facility within high school and undergraduate education.

Buie, Grundy, and collaborators at SWRI were awarded Cycle 11 *HST* time with the new Advanced Camera for Surveys (ACS) to image the surface of Pluto and from which a new epoch of maps will be derived. The observations were successful, and Buie developed a 16-computer parallel processing cluster to assist with the data reduction. This project will lead to a new high-quality two-color map of the surface of Pluto.

Grundy, with Millis, Buie, Wasserman, and collaborators E. Chiang (UC Berkeley), D. Cruikshank (NASA Ames Research Center), J. Spencer (SWRI), and J. Stansberry (U. Arizona), were awarded over 100 hours of Spitzer Space Telescope time to measure the sizes and albedos of a large sample of KBOs.

Grundy is a member of the science team for *New Horizons*, NASA's mission to Pluto and the Kuiper Belt. His recent mission-related activities include planning for in-flight instrument calibration and for science observations during a possible Jupiter flyby, which would happen in early 2007 if *New Horizons* launches during an early 2006 launch window. Pluto encounter dates range from 2015 to 2018, depending on the launch date, with possible KBO encounters following the Pluto encounter by a few years.

Hunter served as a member of the NRAO Users Committee and presented a colloquium at the Center for Astrophysics.

Lockwood continues to represent the Observatory on matters related to dark sky preservation. Lockwood, C. Luginbuhl (USNOFS), and D. Davis (Planetary Science Institute) are now completing the Flagstaff Lighting and Land Use Survey. This involves a detailed on-the-ground survey of a sample of lighting in Flagstaff residential and commercial areas compiled by NAU student Kevin Pick and a similar survey of NAU campus lighting by another student, Jennifer Selders, supported by a NASA Space Grant. Zoning, parcel identification, and property acreages come from a recently available CD-ROM of Flagstaff's geographical information system database. They will compare the calculated inventory uplight with sky glow models originally computed by R. Garstang (JILA), now being recoded and updated by a U. Arizona student supervised by Davis. The modeling effort is funded in part by Coconino County.

Millis completed his service on the NASA Planetary Systems Science and IRTF/Keck MOWG, and the SIRTF Science Center Oversight Committee. He continues as a member of the AURA Observatories Council and the NOAO Solar System TAC.

Schleicher served as chairperson for NASA's Planetary Atmospheres Review panel and continued to serve on the NAU/NASA Space Grant Steering Committee.

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