New Mexico State University
Department of Astronomy
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[S0002-7537(99)05101-X]

This report covers events and activities that occurred during the calendar year 1998.

1. PERSONNEL

The faculty of the Astronomy Department includes Professors Kurt S. Anderson, Reta F. Beebe, Bernard J. McNamara, and William R. Webber; Associate Professor René Walterbos (Dept. Head); Assistant Professors Jon A. Holtzman, Anatoly A. Klypin, Jim Murphy, and Mark S. Marley; College Assistant Professors Nicholas Devereux, and Tom Harrison; and Emeritus Professor Herbert A. Beebe.

Adjunct members of the faculty include Jonathan Brinkman (Apache Point), Roger E. Davis (Science & Technology Corp.), Richard B. Dunn (NSO), Nebojsa Duric (UNM), W. Miller Goss (NRAO), Hunt Guitar (Science & Technology Corp.), Virginia Gulick (NASA, ARC), John J. Keady (LANL), David Kuehn (Pittsburg State Univ.), Donald F. Neidig (NSO), Frazer N. Owen (NRAO), Richard A. Perley (NRAO), Richard R. Radick (NSO), George Simon (NSO, Sac Peak), Raymond N. Smartt (NSO), and John Stocke (Colorado).

Lisa Young is the Tombaugh Fellow. Mark Bransford, Paul Mason, and Nancy Chanover are postdoctoral fellows. J.Johnson is an adjunct research associate. Twenty six graduate students are enrolled in 1998. They are Matthew Carlson, Laurianne Flynn, Andrea Folcik, Kerry Forsythe, Vanessa Galarza, Marla Geha, Chris Gelino, Bruce Greenwalt, Salman Hameed, Jennifer Hoffman, Charles Hoopes, Kuochin Kao, Nichole King, Andrey Kravtsov, Dawn Leeber, Neal Miller, Nathaniel Paust, Jason Peterson, Shannon Pelkey, Elizabeth Rizza, Amy Simon, Denise Stephens, Tom Stephens, Matthew Templeton, David Thilker, and Robert Zavala.

Observatory and departmental staff include Marta Castillo, secretary; Cheryl Beer, office manager; Lorenza Sanchez, fiscal specialist; Tylia Kerby and Eryka Garcia, clerical aids; David Summers, observing specialist; Lyle Huber, programmer analyst; Roy Dewitt, research assistant.

2. OBSERVATORIES/INSTRUMENTATION

2.1 Apache Point Observatory

New Mexico State University is a member of the Astrophysical Research Consortium (ARC) and operates the Apache Point Observatory for the Consortium. Apache Point is located at an elevation of 2800m in the Sacramento Mountains of south-central New Mexico. Its principal instrument is the 3.5 meter ARC telescope. The 2.5 meter telescope of the Sloan Digital Sky Survey is presently operational. Also, NMSU has installed a new 1.0 meter imaging telescope at Apace Point.

Apache Point Observatory has three Observing Specialists responsible for 3.5 meter operations; they are Charles Corson, Karen Gloria, Dan Long, and Russet McMillian. Other observatory site staff are Norm Blythe, Project Aide; Jon Brinkmann, Scientific Instruments Engineer; Jon Davis, Telescope Systems Engineer; Bruce Gillespie, Site Manager; Mark Klaene, Deputy Site Manager; Madonna Reyero, Records Technician; Gretchen Van Doren, Technical Writer; John Wagoner, Carpenter; and Dave Woods, Electronics Technician. On-campus support staff include Dacia Pacheco and Marilee Sage. Dr. Kurt Anderson is the observatory's Site Director.

Instrument development and research activities of the ARC facilities at Apache Point Observatory are detailed in a separate Observatory Report. The 3.5 meter telescope has been fully operational for over three years, and used for a variety of imaging and spectroscopic investigations at optical and infrared wavelengths.It has seen daytime use for missile-tracking and intercept experiments as part of a collaboration with White Sands Missile Range. Most of the observational programs, including several synoptic investigations, have been conducted remotely and routinely via INTERNET links. New capabilities and instruments are under development; we also undertook a number of major upgrade efforts in 1997. Mechanical structures of the Sloan telescope are in place, its optics are on-site awaiting installation, and the survey camera has been mounted. The instrument will see ''first light'' early next year.

Significant progress has been made on NMSUs 1.0 meter telescope at Apache Point. This is an f/6 Ritchey-Chrtien instrument on an alt-azimuth mounting; it is presently equipped with a CCD camera and filter system at its Nasmyth focus. Significant work was done on the telescope drive system and the computer control system; the latter was almost entirely rewritten. A simple offset guider and autoguiding software was added in the past year, allowing accurate tracking for long exposures. Current effort is underway to improve the image quality through optical collimation. Scientific testing of the telescope is in progress. The telescope is operated remotely and will eventually be programmed for robotic operation. All of the recent work on the 1m has been performed in house by Professor Jon Holtzman and Observing Specialist David Summers. Professor Kurt Anderson was responsible for the supervision of the original design and construction of this telescope.

2.2 Tortugas Mountain Planetary Observatory

A limited monitoring program is continuing at the Tortugas Mountain Observatory. Multicolor CCD observations obtained with the 0.6 m telescope are reduced, archived and made available to the Planetary community through the Atmospheres Discipline Node of the NASA Planetary Data System, maintained at NMSU. Images collected over the last 29 years are on file and accessible as a climatic data base. Although NASA funding has been reduced, simultaneous

observations are obtained when the 3.5 meter Apache Point telescope is scheduled for near-IR observations of Jupiter.

3. RESEARCH ACTIVITIES

3.1 Cosmology

Klypin, Loken, and Burns were awarded a NASA Astrophysics Theory grant to numerically investigate the evolution of the cluster X-ray luminosity function. The simulations will employ an advanced adaptive-mesh refinement code and include additional physics such as radiative cooling and galaxy feedback. The goal of the research is to resolve the discrepancy between theoretical predictions and observational results concerning the evolution of the X-ray luminosity function.

A.Klypin and A.Kravtsov, in collaboration with A. Khokhlov (NRL) have developed a new *N*-body method for cosmological simulations (ART). The method is the most efficient and fast *N*-body code available at present. The code is build on the Fully Threaded Tree(FTT) structure for adaptive mesh refinement simulations(Khokhlov 1997), with some important modifications required by cosmological simulations. To solve the Poisson equation for gravity, an adaptive, multilevel relaxation technique has been developed, as well as a special technique to advance particle positions on a non-uniform, adaptively refined mesh. At comparable resolution, the gravity solver vastly outperforms a Fast Fourier Transform solver.

Using the code Kravtsov *et al.* (1997) found that density profiles of small halos with rotational velocities 100-200 km/s may have shallower cusps $\rho(r) \propto r^{-0.2}$. This imply that there is no contradiction with the observed rotational curves.

Using both analytic estimates and high resolution numerical simulations Klypin *et al.*(1997) argue that the overmerging problem (erasure of substructures in groups and clusters of galaxies in numerical simulations) is mainly due to the lack of numerical resolution. We find that the force and mass resolution required for a simulated halo to survive in galaxy groups and clusters is extremely high and was almost never reached before: $\sim 1 - 3$ kpc and $10^8 - 10^9 M_\odot$, respectively. We use the high-resolution Adaptive Refinement Tree (ART) *N*-body code to follow the evolution of $\approx 2 \times 10^6$ dark matter particles with dynamic range in spatial resolution of 32,000. We show that in these simulations the halos do survive in regions that would appear overmerged with lower force resolution.

3.2 Planetary Science

Simon, Beebe and Murrell have continued efforts to sustain a climatological data base containing a multispectral imaging data. This includes aggressive use of Hubble Space Telescope WFPC2 images of both Jupiter and Saturn, near IR imaging with GRIM at Apache Point and 0.4 to 1.0 micron observations at Tortugas Mountain Observatory.

A major part of our efforts this year has involved support of the Galileo mission, both probe and orbiter. Our Hubble Space Telescope data provides the global context for interpreting the limited high resolution atmospheric imaging that can be obtained with the Solid State Imaging system and has higher spatial resolution than a major portion of the infrared data. Our access to Voyager and ground-based data provides the temporal framework for interpretation.

A third major thrust has been related to our assumption of operation and improvement of the Atmospheres Discipline Node of the NASA Planetary Data System (PDS). Online access to the data sets maintained by the Atmospheres Node is available through http://atmos.nmsu.edu/ or via FTP to the same site. Huber and Dewitt are maintaining the node and undergraduate assistants Washburn, Chilton and Reinke provide support for ingestion of data and other data handling tasks. This archive includes all atmospheric data that has been obtained with NASA spacecraft as well as some supporting ground-based data. Current data sets that are being prepared for ingestion are the SL-9 data, Galileo Probe, and Mars Pathfinder data.

Marley continued to model the atmospheres of extra-solar giant planets and brown dwarfs. Model temperature profiles derived using a radiative-convective equilibrium code were used to synthesize the spectra of objects of varying masses and ages. Theoretical spectra reproduce the near-infrared observations and constrain the effective temperature and mass of the known brown dwarf Gliese 229 B. Observations by K. Noll (STScI) and T. Geballe (JAC) combined with a project model atmosphere led to the first detection of CO in Gl 229B. Model atmospheres for the recently-discovered extra-solar giant planets provide guidance for efforts to detect the new planets directly. Current research focuses on the reflected component of extra-solar planet spectra and the role of clouds. This work continues in collaboration with W. Hubbard, T. Guillot, J. Lunine, and A. Burrows (U. Arizona), D. Saumon (Vanderbilt), and R. Freedman (NASA/ Ames-Sterling Software).

3.3 Variable Stars

Harrison is nearing completion on a project that uses the Hubble Space Telescope Fine Guidance Sensors to measure precise parallaxes for three dwarf novae. These parallaxes, the first of their kind, will allow for the calibration of the technique of infrared spectroscopic parallax. As part of this program, infrared K-band spectra of moderate resolution (R = 2500) were obtained for the three dwarf novae using CRSP on the KPNO 2.1m. These spectra revealed slightly earlier spectral types for the secondaries of these systems, which results in a change in their spectroscopic parallaxes.

Mason is using the ARC 3.5m telescope to perform phase-resolved spectroscopy of magnetic cataclysmic variables to determine whether the spin and orbital periods of the systems remain locked in phase over long periods. Mason published his multi-wavelength study of BY Cam, firmly establishing it as the prototype of the asynchronous polars.

Johnson, Harrison, and Mason have used the ARC 3.5m telescope to obtain spectra of recent classical novae (e.g., Nova Cas 1995 and Nova Sco 1997). Johnson is combining high resolution optical spectroscopy with outburst spectropolarimetry of Nova Cas 1995 to create a 3D model of the nova ejecta.

Graduate student Leeber, with Harrison, is analyzing optical and infrared data for Nova Centauri 1991 obtained at Siding Spring Observatory. This nova created an optically thick dust shell that exhibited no temperature evolution even though the infrared luminosity of the dust shell declined by a factor of 100 (usually, the dust shells around novae cool with time).

Harrison, Mason, and Johnson have begun a program of optical (CCD) monitoring of cataclysmic variables using a Meade 16 inch telescope that was installed on campus in 1997 September. Targets of this program are highly variable dwarf novae, such as the ER UMa stars, and classical novae.

McNamara, Harrison, Mason, graduate student Templeton, and undergraduates supported by the NSF and the New Mexico AMP completed the calibration and reduction of the multi-year BATSE (10-20 keV) light curve of Sco X-1. Fourier transform and Gabor transform analysis was used to search for periodicity and quasi-periodicity in the data. Mason, McNamara and Harrison have used the RXTE ASM data archive to study the class of Low Mass X-ray Binaries known as Z-sources and determined their galactic distribution.

3.4 High Energy Astrophysics

McNamara, Harrison, Mason, and Johnson have continued their CGRO program to follow up Gamma-ray bursts with optical observations through the BATSE /COMPTEL/ NMSU rapid response network. This network has provided limits on the appearance of optical counterparts to gamma-ray bursts by providing both deep and rapid images of burst error boxes. Mason, McNamara, and Harrison found that a significant excess of Gamma-ray bursts originate from the direction of the X-ray binaries Cygnus X-1 and Scorpius X-1. They find a significant probability that some of the BATSE cataloged Gamma-ray bursts originate from these sources.

3.5 Normal Galaxies

Hoopes and Walterbos and Rand (UNM), studied the diffuse ionized gas (DIG) in five edge-on galaxies. The analysis supports the idea that the extent and brightness of extraplanar DIG is correlated with star formation in the disk. A very deep image of one of the galaxies, UGC 9242, revealed a faint H-alpha halo, comparable in extent to the DIG halo of NGC 891, but much fainter, raising the possibility that more galaxies may have faint halos at levels below the detection limits of earlier images. Hoopes and Walterbos continued a project to determine whether field stars can ionize the DIG. Using the far ultraviolet image of M33 from the Ultraviolet Imaging Telescope along with a ground-based H-alpha image, they determined that an older population of ionizing stars can reproduce the observed UV and H-alpha emission. They are using optical and far-ultraviolet archival HST WFPC2 images of various regions in M33 to determine the spectral types and ionizing luminosities of stars in DIG and HII regions. This can then be compared to the number of ionizing photons required by the DIG to determine if the field OB stars can ionize the DIG, or whether some ionizing photons are leaking out of HII regions.

Thilker, Braun (NFRA), Walterbos, and Fierro developed HIIphot, an automated procedure for HII region photometry. The program incorporates object recognition techniques in order to properly classify center-brightened and ring-like objects. An iterative ''growing'' procedure then permits departure from idealized seed models used during the initial search step. HIIphot is being used to conduct a survey of HII regions in 100 nearby galaxies and is expected to produce luminosity functions about an order of magnitude more sensitive than previous work.

Thilker, Braun (NFRA), Walterbos, and Mashchenko (Laval) continued work on the Las Cruces/Dwingeloo Supershell Survey, a systematic automated analysis of the HI superbubble population in a sample of 20+ galaxies. Major advances were the inclusion of realistic hydrodynamical models during the computation of projected signatures used for cross-correlation with the data (see Mashchenko *et al.* 1998) and the switch to an Origin 2000 supercomputer platform to enable more efficient data processing. The survey will be completed within the upcoming year. This project made use of the supercomputing facilities at NCSA.

Walterbos, Flynn, Thilker, and Fierro analyzed deep H-alpha images of the entire M81/M82 complex. The M82 starburst outflow was traced to 10 kpc from the center, double the known extent, and many HII regions were detected in the extended HI disk/tidal tails around M81, at large radial distances from the center of M81. The data provide unique information on star formation in a low-density outer gas disk.

King, Walterbos, and Braun (1998) published spectroscopy of candidate Luminous Blue Variables (cLBVs) and B[e] supergiants in M31 based on data obtained with the ARC 3.5-m telescope. King *et al.* recently completed ARC 3.5-m optical spectroscopy for the remaining cLBV targets in the NE half of M31. King, Gallagher (U Wisc), and Walterbos are in the process of publishing WIYN 3.5-m color-magnitude diagrams and ARC 3.5-m IR color-magnitude of the OB associations surrounding the cLBVs and known LBVs in M31. The NMSU 1-m telescope was used to calibrate some of the optical images. King, Walterbos, and Bransford are analyzing the Halpha, [SII], and broad band KPNO 0.9-m images of the SW half of M31 that King obtained in 1997 as part of her thesis. They will look for cLBVs and make color-magnitude diagrams of the OB associations in a continued study of high mass stars in M31. In addition, a complete search for Wolf-Rayet nebulae in M31 based on these data is in progress.

Galarza, Walterbos, and Braun (NFRA) have completed an analysis of optical spectra of emission line objects in the northeastern half of M31. The sample includes HII regions, spectroscopically confirmed SNR candidates from the Braun & Walterbos (1994) catalog, four WR stars and a PN candidate. While unable to constrain the abundance gradient in the galaxy precisely due to poor radial sampling, they were able to study a wide range of excitation and ionization properties in the gaseous nebulae. A paper describing a comparison of

the spectral properties of M31 emission-line gaseous objects (HII regions and SNR) and diffuse ionized gas has been submitted for publication to the Astronomical Journal.

Galarza and Wilcots (U.of Wisconsin) are completing their survey of classical HII regions in the Large Magellanic Cloud. Their sample shows a wide range of physical, excitation, and chemical abundance properties. The goals of this project are to compare the properties of these modestly bright (L(Halpha)$\approx 10^{36}$ergs/sec) nebulae to those of their Galactic counter-parts and aid in the development of sequencing parameters based on observed emission-line ratios from which one could, in principle, determine abundances, ionization parameters and temperatures for more distant and unresolved extragalactic HII regions.

Garnett (U.of Minnesota), Galarza and Chu (U.of Illinois) are completing their analysis of HST WFPC2 narrow-band imaging and FOS spectroscopy of the peculiar LMC HII region, N44C. This nebula appears to have a large HeII region which is quite unusual for HII regions ionized by normal OB stars. HST GHRS spectroscopy of the central ionizing star suggests a spectral type of only O8, leaving in question the origin of the He+ ionizing photons. The abundances in the nebula are not distinct from that typically found in the LMC, suggesting that no WR/SN companion has disappeared.

Anderson, in collaboration with W. Baggett (Computer Sciences Corporation) and S. Baggett (STScI)has completed an imaging study for a large sample of disk and lenticular galaxies. Images of a large and homogeneous sample of galaxies have been examined and their surface brightness profiles in V represented by the superposition of a de Vaucouleurs law bulge and an inner-truncated exponential disk. Surprisingly, this succeeds for more than 94% of the 659 disk and lenticular galaxies in the sample. There are no significant trends in fittability with morphological type or inclination. At least 25% of disk profiles are best fit with an inner-truncated exponential, suggesting that such truncations are both real and relatively common. The truncated disk galaxies also seem to form a group distinct from other systems in that they have systematically brighter (by about 1.5 mag/sas) central surface brightness parameters.

Holtzman continued to work to a large extent with data from the Hubble Space Telescope as a member of the Investigation Definition Team for the Wide Field Planetary Camera 2. Work concentrated on understanding the stellar populations in nearby stellar systems and on studying several young globular cluster systems around other galaxies.

An analysis of three fields in the the Large Magellanic Cloud was completed with graduate student Marla Geha which suggested that the star formation history did not vary strongly between the different locations observed. In addition, these data, in conjunction with ground based data around one of the fields, support our previous suggestion that there is a significant component of intermediate aged stars ($>$ 4 Gyr) in the LMC. This is consistent with some recent models of chemical evolution in the LMC.

A technique was developed for deriving star formation histories from the distribution of stars in a color-magnitude diagram. This technique was applied to the LMC data and gave results consistent with previous estimates of the star formation history. However, the technique can be sensitive to small errors in the stellar models used, and, as a result, must be used with caution.

A similar analysis of two fields in the Small Magellanic Cloud was performed. In these inner fields, there appears to be a dominant population of young stars. The star formation history of the SMC, however, may be a strong function of position. Analysis of HST images in several local dwarf spheroidal galaxies was begun. These data will be used to look for any evidence of variations in the IMF from galaxy to galaxy and to attempt to look for any differences in age between the oldest populations in these galaxies. Work was completed on studying deep HST observations in the Galactic Bulge which suggest that the initial mass function in the Bulge is similar to that in the solar neighborhood.

With graduate student Matt Carlson, deep observations of the globular cluster system in NGC 3597 were analyzed. Two systems of clusters were found: a young, blue system, and and older, redder, system. The lack of scatter in the colors of the blue clusters suggests that they are a single-age population, likely formed during a merger event in the galaxy a few hundred million years ago. The luminosity function of these young clusters rises towards fainter magnitudes, and is inconsistent with the presently observed luminosity function of old globular cluster systems, even after correction for evolutionary effects in the stellar populations. This suggests that globular clusters may be destroyed as galaxies evolve. It also suggests that the use of globular cluster systems as distance indicators may be problematical.

Holtzman continued his project to study the effects of dust in spiral galaxies, in collaboration with S. Courteau (NOAO). A project to understand the stellar populations in late type bulges was continued at the CFHT in collaboration with Courteau, J. Gonzalez (UNAM), and S. Charlot (IAP).

3.6 Active Galaxies

Anderson has been monitoring the temporal behavior of the broad-lined radio galaxy 3C390.3. Images in Gunn g and r, plus low resolution (7A) blue and red spectra, have been obtained at intervals of roughly 10 days throughout the year. These observations were made using the double imaging spectrograph on the ARC 3.5 meter telescope at Apache Point Observatory. The intention is to use ''reverberation mapping'' techniques to understand the spatial and kinematic geometry of the broad emission line regions.

AGN monitoring efforts are part of a larger collaborative program which will use optical imaging and spectroscopy of Seyfert and broad-lined radio galaxies to describe and understand both the great similarities and large differences between these two classes of AGN. Program results for the Seyfert galaxy NGC7469 were published this year; results for the 3C390.3 effort have been submitted for publication.

4. EDUCATION

The Sunspot Astronomy Center, a collaborative venture of the NMSU Department of Astronomy, Apache Point Observatory, the Sacramento Peak Solar Observatory, and the

United States Forest Service, opened in July of last year. Adjacent to the National Solar Observatory facilities at Sunspot, NM, and to Apache Point Observatory, the Center serves as a visitor center for the growing complex of astronomical facilities in the Sacramento Mountains. Approximately half of the 5000 square foot area of the main building is an exhibit area, devoted to instructional and interactive exhibits with astronomical themes. Emphasis is on the instruments and research at Apache Point and Sacramento Peak. An auditorium or meeting room/auditorium area is of comparable size. Office space and other visitor facilities occupy the remainder of the area. A system of walking trails joins the Center building to the telescopes and other features of the observatories.

The Sunspot Astronomy Center is funded by a combination of grants from the New Mexico State Legislature and matching funds from the Federal Highway Administrations ISTEA program. Kurt Anderson represents the Department of Astronomy and Apache Point Observatory in this venture.

5. MISCELLANEOUS

Kurt Anderson has served as the Vise President for the New Mexico Academy of Sciences during 1997; he is now the President-elect of the organization.

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A. Klypin