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This report covers the period 1 July 1999 through 30 June 2001.

1. PERSONNEL

Astronomy faculty in the Department of Physics and Astronomy were William G. Bagnuolo, Jr., D. Michael Crenshaw, Douglas R. Gies, Todd J. Henry, Harold A. McAlister (CHARA Director), H. Richard Miller (Director of Graduate Studies in Astronomy), Mark A. Shure, Paul J. Wiita, and David W. Wingert. Todd J. Henry joined the faculty at the rank of Associate Professor in 2000, and D. Michael Crenshaw joined the faculty at the rank of Associate Professor in 2001. Stephen Ridgway continued a half-time appointment as a CHARA visiting scientist and Technical Manager of the CHARA Array project along with his primary appointment as Astronomer at NOAO. Dr. Stuart Taylor joined CHARA in Atlanta as an Academic Professional/Research Scientist in April 2000. The resident staff at the CHARA Array on Mt. Wilson included: Theo ten Brummelaar (CHARA Associate Director), Robert Cadman (Site Manager), Stephen Ridgway (half-time CHARA Visiting Scientist and Adjunct Professor), Laszlo Sturmann (Research Scientist), Nils Turner (former Post-Doctoral now Research Scientist) and Judit Sturmann (Post-Doctoral Research Associate). Dr. Michael Hrynevich, now at the Keck Interferometer, spent a term as a Visiting Scientist on Mt. Wilson. John W. Wilson was the Coordinator of Laboratories, and Alexandra Land was the CHARA business manager.

Gies acted as Technical Editor for the paper version of the Be Star Newsletter (http://www.limber.org/benews) for issue 34 (June 2000). Wiita was a Visiting Professor in the Department of Astrophysical Sciences at Princeton University during the 2000–2001 academic year. He was also a Visiting Professor at the National Centre for Radio Astrophysics (NCRA), Pune, India, in June 2001. Gang Bao accepted a position with Columbia University upon completing his postdoctoral research associateship.

Our continuing graduate students during this period were Thomas Fallon, Elizabeth Ferrara, Kenneth Guyton, Michael E. Hahula, Janak Desai, David Berger, A. Benjamin Hocking, Huang Wenjin, Wei-Chun Jao, John McFarland, Mary V. McSwain, Reed Riddle and Amy Williams. The following students joined the graduate program in this period: Frank Bello, Tammy Josephs, Kevin Marshall, Chad Ogden, Angela Osterman and Debra Wallace. Riddle received his Ph.D. in 1999 and accepted a position at Iowa State University. Ferrara received her Ph.D. in 2000 and accepted a position with General Dynamics Corp. Roberts finished his Ph.D. in 1999 and joined Rocketdyne Technical Services, where he works on the Air Force AEOS Telescope in Hawaii. Hocking finished his M.S. in 2000.

Visitors included Gopal Krishna (NCRA, Pune), Jagbir Hooda (IPST), Anthony Moffat (Montreal), Nilakshi (State Observatory, Naini Tal, India), Brian Mason (USNO), Matthew Golombek (JPL), Andrew Boden (JPL), Kirpal Nandra (GSFC), Michael Crenshaw (GSFC), Smita Mathur (Ohio State), Michelle Thaller (IPAC), Rafael Wiemker (Philips, Hamburg), Karen Bjorkman (Toledo), Laura Penny (Charleston), Donna Weistrop (UNLV), and Alan Marscher (Boston Univ.).

2. HARD LABOR CREEK OBSERVATORY

Hard Labor Creek Observatory is operated by Georgia State University and houses the 1-m Multiple Telescope Telescope (MTT) and the 16’’ Boller & Chivens Classical Cassegrain telescope, formerly at KPNO and awarded to GSU by the National Science Foundation through a grant to CHARA. In addition, a grant by Miller allowed the recent purchase of a 16’’ Meade, primarily used for public viewing. The observatory hosted 17 public nights during 1999-2000 with well over 2000 visitors.

The Multiple Telescope Telescope, a 1-m class instrument for high dispersion spectroscopy, has proved to be an effective tool for spectroscopic studies of bright objects (over 1600 science spectra were taken during 1999-2000). Riddle and Bagnuolo continued efforts in 1999-2000 to improve the user interaction with the MTT, with the goal of making the telescope as efficient as possible. These efforts have continued in 2001 with participation from McAlister, Riddle, Charles Hopper (Technician), Bagnuolo, and undergraduate students Farrington, and Seymour. Upgrades include better computers and displays (allowing an all-LINUX operation), a modern motor drive card, a new auxilliary tracking telescope, new cameras for tracking and mirror centering control (allowing stars as dim as 13th magntiude to be tracked), a new focusing system, a new lower-resolution grating, and the erection of a new dome.

The spectrograph CCD camera control system was rewritten by Riddle to operate under LINUX. Other spectrograph improvements include new temperature control, flat fielding, and grating alignment systems. Three gratings are available for science operations (600, 1200 and 2160 grooves / mm), and current performance is a SNR of 100 per pixel for a 6.0 magnitude star at 600 nm with the 600 g/mm grating in second order (R=14,800) in five minutes; the spectrograph can work effectively at resolutions up to R=60,000. We expect performance to improve significantly when the new focusing system is completed. A standard IRAF package for data reduction was completed by Riddle and Bagnuolo; an entire night of data can be reduced in 45 min.

The MTT has been used for various projects, but the primary uses of the MTT have been spectroscopic studies of massive binary stars and improving orbits for CHARA Array binary targets. The MTT is also contributing to the education of graduate students in using instrumentation; the Astronomy Instrumentation course in 1999-2001 used the MTT extensively, and the Spectroscopy course for Fall, 1999 used the MTT for a major portion of the course. Two versions of the MTT were developed elsewhere: one is at the Japanese National Defence Academy (NDA) under Profs. E Kambe and A. Yamasake, and the other is the Sydney University Multiple MIrror Telescope (SUMMIT) under Drs. J Davis and A. Moore. (Dr. Moore was awarded a Ph.D. for this work in 2000.) We anticipate new joint spectroscopic programs on short period variables and binary stars where the extended longitudinal coverage will greatly reduce diurnal gaps in observations.

Miller, Wilson, Ferrara, Marshall, McFarland and Williams have initiated a program for monitoring the optical variability of variable AGN utilizing the Photometrics CCD camera at the B&C 16$''$telescope. The primary focus of the program is to provide temporally extended studies of the microvariability for bright blazars. Of particular interest were coordinated optical/EGRET observations of 3C 279 which detected a possible simultaneous flare of 3C 279 at both γ-ray and optical wavelengths. We anticipate expanding the program utilizing the new Meade telescope equipped with a CCD camera.

3. CENTER FOR HIGH ANGULAR RESOLUTION ASTRONOMY

3.1 The CHARA Array

The CHARA Array is an optical/IR interferometric telescope located on Mt. Wilson, California. Construction of the facility, which began on 13 Jul 1996, was funded by the National Science Foundation, the W.M. Keck Foundation, the David and Lucile Packard Foundation, and by Georgia State University. A dedication ceremony, attended by nearly 300 people, was held on Mt. Wilson on 4 Oct 2000 and featured remarks by Carl Patton (GSU President), James Breckinridge (NSF), Sydney Wolff (NOAO), Robert Jastrow (Mount Wilson Institute Director), Terry Ellis (U.S. Forest Service), Mercedes Talley (W.M. Keck Foundation), Joe Frank Harris (former Governor of Georgia), and Harold McAlister (CHARA Director).

The CHARA Array consists of six 1-meter aperture telescopes arranged in a Y-shaped configuration yielding baselines ranging from 34 to 330 m. The primary support facilities include the Beam Synthesis Facility (a 12,000 sq.ft. laboratory building housing the optical delay lines and beam combination subsystems), the Operations Facility (housing staff offices and the control room), and a machine shop (occupying the former beam combining laboratory of the Mark III Interferometer). An electronics bunker housing control computers and other telescope support hardware accompanies each telescope enclosure.

A very significant milestone in the project was reached on 23 Nov 99 when the first starlight fringes were obtained in the K-band from the S1 and S2 telescopes (34 m baseline). This event signaled the transition from what has primarily been a design and construction program since before groundbreaking to an effort focused on continuing integration of components and subsystems coupled with the pursuit of initial science goals. Proof of performance observations were carried out in the months following first fringe using single-pixel InSb detectors on loan to CHARA from NOAO. This detector system constituted CHARAs prototype beam combiner that enabled the first fringe demonstration in advance of the delivery of our primary science detector systems. Completion of the infrared camera and its delivery to Mt. Wilson occurred in early 2001. This camera, designed and built by Mark Shure with funding from the NSF, employs a Rockwell PICNIC chip and is modeled after the camera developed by the IOTA interferometry group at Mt. Hopkins.

By the end of the term of this report, all six telescopes were in place with their primary and secondary mirrors installed. Telescopes S1, S2 and E1 were fully installed for interferometric application, a status requiring installation and alignment of numerous relay mirrors, delay line carts and beam size reducers. The first science targets include verification objects such as binary systems and resolved stars measured by other interferometers along with objects not previously observed with high spatial resolution. The Array is capable of making simultaneous (or nearly so) observations at multi-wavelengths ranging (eventually) from 0.5 to 2.4 microns. We thus plan to select a group of cool giants, including several long-period variables, with the goal of accurately determining their diameters for the first time and, especially, measuring the effects of limb darkening for these stars.

Taylor and McAlister, with the assistance of graduate student Rusty Harvin, have compiled a bibliographic catalog of orbital elements of spectroscopic binaries using the last Batten Catalogue published by the DAO as its starting point. A literature survey has brought this catalog up to date. This resource, which will serve as a primary input catalog for CHARAs program of high-resolution binary star studies, will be made available to the community in early 2002.

Activities in Atlanta have centered on bringing up a remote operations facility in a campus research laboratory to allow Atlanta-based staff to participate in real-time observations from Mt. Wilson. Eventually, we plan to have the ability to operate completely remotely. For the near term, however, faculty, staff and graduate students will participate as collaborators in observing runs enabling broader and more frequent participation than our travel budget would otherwise allow. Graduate student Tom Fallon has taken the lead role in creating this new facility.

The efforts of the Mt. Wilson-based CHARA staff have been monumental and too numerous to detail here. Suffice it to say that an optical interferometer is a highly complex system of finicky subsystems, and the current operational state of the Array is the result of the dedicated efforts of Theo ten Brummelaar, Steve Ridgway, Laszlo Sturmann, Judit Sturmann, Nils Turner and Bob Cadman. Charles Hopper, manager of the Physics and Astronomy shop in Atlanta, has also played a vital role in contributing to this progress. More information about the CHARA Array can be found at http://www.chara.gsu.edu/CHARA/index.html.

3.2 Adaptive Optics Imaging of Binaries

The CHARA adaptive optics program has continued through NSF funding of time on the Air Force Advanced

Electro-Optical System (AEOS), 3.7-meter telescope on Haleakala, Hawaii. Ten Brummelaar and Turner are leading this effort. This has been an extension of the work done previously using the Natural Guide Star Adaptive Optics system on the Mount Wilson 100-inch telescope and the Adaptive Optics system on the 3.5-meter telescope at Starfire Optical Range in Albuquerque, NM. The work has a focus in two areas: differential photometry of binary stars systems and the search for faint companions. We have published the first of a two paper series on the results of the faint companion search to nearby stars. Our present project involves searching for faint companions to O stars. In addition, a paper on frame-to-frame variations in adaptive optics is in press.

We have entered into a collaboration with a research group at JPL that has built a magneto-optical filter camera system. The filter system works by passing the light from the object through a linear polarizer. It then goes through a cell with potassium vapor in a buffer gas. A strong longitudinal magnetic field is maintained along the cell that causes Zeeman splitting of the potassium resonance lines. Additional magneto-optical effects occur as the light passes through the cell – circular birefingence and circular dichroism. These cause the Zeeman splits on either side of the potassium resonance to have different circular polarization imparted on them. Passing through a second polarizer causes the light to form two narrow (40 angstrom) passbands about 200 angstroms apart. Use of calcite crystals enables the physical separation on the detector of the two passbands. In conjunction with the adaptive optics system on the AEOS telescope, we have proposed to map the zonal wind profile of Uranus.

3.3 Binary Star Speckle Interferometry

CHARAs speckle program, begun at Georgia State in 1977, was retired in June 1999 with the departure of Prof. William I. Hartkopf for the U.S. Naval Observatory. William Hartkopf joined Brian Mason (GSU doctoral recipient) at the USNO to continue that observatory's long tradition in double star astronomy using speckle interferometry as their principle observational tool. CHARAs Double Star Library was subsequently transferred to Washington, and this valuable resource can now be found at http://ad.usno.navy.mil/wds/dsl.html.

3.4 Spectroscopy with the Multi-Telescope Telescope

There are several ongoing science projects associated with the MTT. Through the use of a tomography algorithm it is possible to separate binary star spectra into spectra of each component. Using this algorithm, Bagnuolo, Riddle, Gies and collaborators have studied several systems and discovered interesting new results for each. For example. Bagnuolo, Riddle, Gies, and Donald Barry (recent GSU PhD receiptient) examined the binary star system Iota Ori, and in a 2001 paper determined that the stars are not co-evolved and possibly resulted from a binary-binary collision. There is a continuing survey of massive O-B binary stars, which will allow further insight into the physical processes (mass transfer and winds, orbital dynamics, collisions between binary systems) of these massive stars. The ''Struve-Sahade'' effect was examined for seven stars; 700 spectra of them formed the basis of Riddle's 2000 Ph.D. dissertation.

An extensive survey of O-B binary systems by Bagnuolo and Riddle, using the MTT, is underway, with the goal of understanding mass transfer, orbital interactions, and determining physical parameters of the systems. Many, if not most, binary stars have poorly characterized orbital parameters, and it is usually the binary star information that is lacking when determining physical parameters (such as mass) from combining spectroscopic data with, for example, astrometry. With the advent of the CHARA Array, it is necessary to improve the spectroscopic observations of selected target binary stars. Data from the MTT will be combined with Array measurements in an effort to improve the accuracy of mass determinations for a large sample of binaries. (This is in fact the main motivation for the improvements in this instrument.)

Riddle has untaken a program of stellar seismology, starting with the interesting binary Spica, which is also a traditional interferometry target. His dissertation showed that the accepted typings should be revised slightly, and found recent evidence of non-radial pulsations in the primary star; this work is continuing.

4. STELLAR ASTRONOMY

Gies, Peters (USC), and Huang are reanalyzing *IUE* spectra of Be stars using cross-correlation techniques to study the temporal variations in the UV photospheric lines. These variations take the form of blue-to-red moving subfeatures which cross the profiles on timescales of hours. A working hypothesis is that the variations result from photospheric nonradial pulsations (NRP) which effectively redistribute the flux in rotationally broadened lines to create the moving patterns. The presence of the variations in rapidly rotating Be stars may be related to the mass loss processes that lead to the formation of circumstellar disks. The goal is to combine these spectroscopic studies of the photospheric lines with data on the continuum flux variations to develop pulsational models for the Be stars, and then to compare the photospheric variations with those observed in the UV wind lines in order to search for a connection between pulsation and mass loss. Huang and Gies are investigating the large amplitude line profile variations in the early B-type star, ϵ Per, and they are comparing the observed variations with realistic NRP models that account for the broadening and temperature sensitivities of a wide variety of photospheric absorption lines.

Gies, Bagnuolo, Harvin, McSwain, Wingert, Riddle (Iowa State), and Penny (College of Charleston) are continuing a long term program of determining the physical properties of the components of massive close binaries using a Doppler tomography algorithm to reconstruct the individual spectra. The original application was a study of archival *IUE* spectra to determine spectral classifications and projected rotational velocities, and to model the light curves to determine limits on the orbital inclinations and masses. Harvin and collaborators have recently discovered the secondary component in *IUE* spectra of the bright, O-giant, δ Ori, and they find that both primary and secondary components are extremely overluminous for their masses (probably as the result of a common envelope interaction). The tomographic reconstruction work has now been extended to optical spectroscopy using data from the GSU Multi-Telescope Telescope (MTT), the KPNO Coude Feed Telescope, the Mount Stromlo Observatory 74-inch Telescope, and the CASLEO 2-m telescope. The target systems include triples discovered in the CHARA speckle interferometry program and many new eclipsing and/or ellipsoidal variables discovered by the Hipparcos satellite. Some of these new binaries will be key targets for direct resolution with the CHARA Array.

Gies and collaborators are using high S/N spectroscopy (from the KPNO Coude Feed telescope, the MSO 74-inch telescope, and the McDonald Observatory 2.1-m telescope) to study the properties of a number of highly evolved massive binaries. These range from systems like RY Scuti which is beginning active mass loss and transfer to fully developed Algol-type systems like RY Per. McSwain, Gies, Riddle, Wingert, and Wang (MIT) are studying the Hα variations in the Be X-ray binaries, HDE 245770, V615 Cas, V662 Cas, and X Per, to search for variations related to the orbital motion of the neutron star companion. This GSU team has begun an extended program of optical spectroscopy to investigate the spectral variations in a number of massive X-ray binaries, including Cyg X-1 and SS 433. McSwain and colleagues recently discovered that the microquasar, LS 5039, is a 4.1 day binary with a very eccentric orbit. This indicates that the supernova event that created the system ejected more than $15M_{\odot}$ of gas. Most of these X-ray binary targets are currently included in the X-ray survey program of the XTE All Sky Monitor instrument, and Gies and collaborators will study how modulation of the mass transfer rate (as observed in Hα) ultimately results in X-ray flux variations.

Gies and Huang have recently completed a program of CTIO and WIYN Hydra, multi-object spectroscopy of O- and B-stars in young clusters to study the distributions of projected rotational velocity as a function of cluster age. The data will help test the hypothesis that many rapid rotators (including the Be stars) are spun up through mass transfer in a close binary. The spectra also will be used to search for the early spin-down in massive stars in order to estimate what magnetic fields are present, search for a proposed He enrichment with age due to mixing, estimate the incidence of spectroscopic binaries in clusters of different ages, and study the radial velocities and dynamics of the massive star population.

Miller, Wilson, Ferrara, and McFarland have obtained high-time resolution photometry of the cataclysmic variable star, PG 2337+12 utilizing the Photometrics CCD camera on the B&C $16''$ telescope. Although variations have been detected on timescales ranging from minutes to days, no periodic modulation of these variations has been found.

Wiita has continued to collaborate with Vinod Krishan (Indian Inst. Astrophys., Bangalore) and S. Ramadurai (Tata Inst. Fund. Res., Bombay) on studies of flares above accretion disks. A recent investigation of chromospheric evaporation in the context of advection dominated accretion disks has relevance for both low mass X-ray binaries and active galactic nuclei. This mechanism can produce sub-millisecond timescales in binary systems through the presence of a very large number of microflares.

5. ASTROMETRY

Todd Henry joined the Georgia State faculty in the fall of 2000, and brought the Research Consortium on Nearby Stars (http://www.chara.gsu.edu/RECONS) to GSU. In this capacity, Henry plays the role of a‘‘stellar cartographer’’ by developing a comprehensive map of the solar neighborhood. Astronomers with wide-ranging specialties make up the international RECONS team: G. Fritz Benedict (University of Texas, Austin — space astrometry, radial velocities), Otto Franz (Lowell Observatory — multiple systems, ground and space astrometry), David Golimowski (Johns Hopkins University — optical/infrared companion searches via high resolution imaging), Philip Ianna (University of Virginia — astrometry, optical photometry), Hartmut Jahreiss (Astronomiches Rechen, Heidelberg, Germany — astrometry, kinematics), Donald McCarthy, Jr. (University of Arizona — infrared and high resolution techniques), Rene Mendez (European Southern Observatory, Santiago, Chile — astrometry, optical photometry). Together, the RECONS members are investigating the nature of the Sun’s nearest stellar neighbors, both individually and as a population. The goals are to discover ‘‘missing’’ members of the sample of stars within 10 parsecs (32.6 light years), and to characterize all stars within that distance limit. New members are found via astrometric, photometric, and spectroscopic techniques, or through companionship studies at small and large separations. Characterization includes photometry and spectroscopy at both optical and infrared wavelengths, as well as determinations of the luminosity function, mass function, and multiplicity fraction of the nearby stars.

Henry is leading a RECONS effort known as CTIOPI (Cerro-Tololo Interamerican Observatory Parallax Investigation) with Ianna and Mendez that utilizes the 0.9m and 1.5m telescopes in the Chilean Andes. The purpose of CTIOPI is to discover nearby white, red, and brown dwarfs that lurk unidentified in the solar neighborhood. More than 200 southern star systems are targeted for parallax measurements accurate to 3 milliarcseconds. Through the generous support of NOAO, including 6 nights per month of observing time as part of the NOAO Surveys Program, RECONS hopes to increase the population of stars known within 25 pc of the Sun by 20 % in the southern sky in only three years. Joining in this effort are graduate student Wei-Chun Jao (GSU), whose thesis project involves characterizing all objects that have proper motions larger than 1 arcsecond/year, and research assistant John Subasavage (GSU) whose specialities include investigating the sample of nearby white dwarfs, as well as astrometry and photometry reductions.

Dana Backman (Franklin & Marshall College) and Henry are the two Program Scientists for NASA’s Nearby Stars Project (NStars), which has the mission to develop the most current, complete and accurate source of scientific data about all objects beyond the solar system but within 25 parsecs of the Sun. NStars provides research grade internet capabilities to astronomers and other scientists, supports several NASA space missions, and presents basic star information to students and amateur sky observers. Undergraduate student Jacob Bean (Georgia Institute of Technology) has been working with Henry to collect optical/infrared photometric data from the literature and 2MASS and has developed a sample of probable new nearby multiple systems as part of the NStars effort.

Henry leads two efforts to determine stellar masses and to map out the relation between stellar luminosity and mass. A long-term Hubble Space Telescope program to determine the masses for very low mass red dwarfs and brown dwarf candidates continues into its sixth year. This work is carried out with RECONS members Benedict (U. Texas), Franz (Lowell Obs.), Ianna (U. Virginia) and McCarthy (U. Arizona). In addition, Henry is a Science Team member for the Space Interferometry Mission (SIM). The program selected, known as MASSIF (Masses and Stellar Systems with Interferometry), has the ultimate goals of determining the mass-luminosity relation in five stellar clusters of known age and metallicity, and to measure masses for several classes of exotic objects, including supermassive stars, white dwarfs, brown dwarfs, and black hole candidates. This work is carried out with several RECONS members and D. Gies (GSU), B. McArthur (U. Texas), E. Nelan (STScI), and G. Torres (Harvard-Smithsonian CfA).

6. EXTRAGALACTIC ASTRONOMY

Crenshaw, Kraemer (CUA), Bruhweiler (CUA), and Ruiz (CUA) obtained low-dispersion spectra of NGC 3227 with the Space Telescope Imaging Spectrograph (STIS) to study the intrinsic UV absorption and the reddening of the nucleus in this Seyfert 1 galaxy. The UV spectra show a wealth of absorption lines at the systemic redshift that span a wide range in ionization state (Mg I to N V). The equivalent widths of the lines are consistent with an earlier prediction that a ‘‘lukewarm absorber’’ ($T_e = 18{,}000$ K at the ionized face) with a substantial column of gas ($N_H = 2 \times 10^{21}$ cm^{-2}) is present and likely responsible for the reddening of the nucleus. The lukewarm absorber is also responsible for most of the absorption in the X-rays at energies less than 1 keV, although a more highly ionized ‘‘warm absorber’’ is needed to account for the O VII and O VIII ionization edges. NGC 3227 is the first Seyfert galaxy in which a strong link between the reddening and intrinsic UV absorption has been found. By comparing the STIS UV and optical spectra with those of the unreddened Seyfert NGC 4151, they determined a reddening curve for the nuclear continuum source in NGC 3227 over the 1150 – 10,200 Å range. The reddening curve does not show a 2200 Å bump, and is steeper in the UV than reddening curves derived for the Galaxy, LMC, and SMC, suggesting a preponderence of small dust grains near the nucleus.

Crenshaw, Kraemer (CUA), Turner (UMBC), Collier (OSU), Peterson (OSU), Brandt (PSU), Clavel (ESA), George (UMBC), Horne (St. Andrews, UT), Kriss (STScI), Mathur (OSU), Netzer (Tel Aviv), Pogge (OSU), Pounds (Leicester), Romano (OSU), Shemmer (Tel Aviv), and Wamsteker (ESA) have used *Hubble Space Telescope* UV and optical spectra of the narrow-line Seyfert 1 (NLS1) galaxy Akn 564 to investigate its internal reddening and properties of its emission-line and intrinsic UV absorption gas. They find that the extinction curve of Akn 564, derived from a comparison of its UV/optical continuum to that of an unreddened NLS1, lacks a 2200 Å bump and turns up towards the UV at a longer wavelength (4000 Å) than the standard Galactic, LMC, and SMC curves. The emission-lines and continuum experience the same amount of reddening, indicating the presence of a dust screen that is external to the narrow-line region (NLR). Echelle spectra from the Space Telescope Imaging Spectrograph show intrinsic UV absorption lines due to Lyα, N V, C IV, Si IV, and Si III, centered at a radial velocity of -190 km s^{-1} (relative to the host galaxy). Photoionization models of the UV absorber indicate that it has a sufficient column ($N_H = 1.6 \times 10^{21}$ cm^{-2}) and is at a sufficient distance from the nucleus ($D > 95$ pc) to be the source of the dust screen. Thus, Akn 564 contains a dusty ‘‘lukewarm absorber’’ similar to that seen in NGC 3227.

Crenshaw and Kraemer (CUA) have investigated the origin of the ‘‘dusty lukewarm absorbers.’’ They are characterized by saturated UV absorption lines (C IV, N V) near the systemic velocity of the host galaxy, and is likely responsible for reddening both the continuum and the emission lines (including those from the narrow-line region) from these Seyferts. Furthermore, reddened, inclined Seyfert galaxies observed at moderate to high spectral resolution all show evidence for dusty lukewarm absorbers. There is strong evidence that these absorbers lie in the plane of the host galaxy at distances $>$ 100 pc from the nucleus, and are physically distinct from the majority of intrinsic absorbers that are outflowing from the nucleus.

Kraemer (CUA), Crenshaw, and Gabel (CUA) obtained observations of the UV absorption lines in the Seyfert 1 galaxy NGC 3783 with the medium resolution echelle gratings of STIS. The spectra reveal the presence of three kinematic components of absorption in Lyα, C IV, and N V, at radial velocities of -1365, -548, and -724 km s^{-1} with respect to the systemic velocity of the host galaxy (Components 1, 2 and 3, respectively); Component 1 also shows absorption by Si IV. Component 3 was not detected in any of the earlier Goddard High Resolution Spectrograph (GHRS) spectra,and the C IV absorption in the other components has changed since the most recent GHRS observation obtained $\sim$ 5 yr earlier. Somewhat unexpectedly, each component has a covering factor (of the continuum source + broad emission line region) of $\sim$ 0.6. There is no evidence for a correlation between the characteristics of the UV absorbers and the UV continuum flux, and, by inference, the ionizing continuum. Hence, it is likely that the variations observed in the GHRS and STIS spectra are due in a large part to changes in the column densities of the absorbers as the result of transverse motion.

Kraemer (CUA), Crenshaw (GSU), Hutchings (DAO), George (UMBC), Danks (Raytheon), Gull (GSFC), Kaiser (JHU), Nelson (UNLV), and Weistrop (UNLV) have examined the physical conditions in intrinsic UV-absorbing gas in the Seyfert galaxy NGC 4151, using echelle spectra from STIS. They confirm the presence of the kinematic components detected in earlier Goddard High Resolution Spectrograph (GHRS) observations, all of which appear to be outflowing from the nucleus, as well as a new broad absorption feature at a radialvelocity of -1680 km s^{-1}. The UV continuum of NGC 4151 was a factor of about 4 lower than in observations taken over the previous two years, indicating changes in the column density of the low ionization absorption lines associated with the broad component at -490 km s^{-1} are due to a decrease in the ionizing flux. The densities for this kinematic component and several others have been constrained from the strength of absorption lines from metastable states of C III and Fe II, and/or the ratios of ground and fine structure lines of O I, C II, and Si II. Photoionization models not only successfully match the ionic column densities for each component during the present low flux state, but also those seen in previous high flux states with the GHRS and STIS, confirming that the absorbers are photoionized and respond to the changes in the continuum flux. Based on the model parameters (ionization parameter and density), the relative radial positions of the absorbers have been mapped for the first time. Interestingly, the absorbing gas decreases in density with distance. None of the UV absorbers is of sufficiently large column density or high enough ionization state to account for the observed X-ray absorption, while the scatterer is too highly ionized.

Miller and co-workers continue their program investigating the very rapid low amplitude variations in the optical and ultraviolet portions of the electromagnetic emission from active galactic nuclei (AGN). This group was the first to show that microvariability was both real and common, at least for the blazar class of active galactic nuclei (BL Lacertae objects and Optically Violently Variable Quasars). Miller, Carini (Western Kentucky U.) and Noble (Boston U./Lowell Obs.) continue their detailed program of studying the variability for individual blazars on timescales of minutes to decades. The most recent study published was for 3C 371, with similar studies of OJ 131 and 3C 66A currently in preparation.

Miller and Noble have investigated samples of X-ray selected versus radio selected blazars and have found that there are is a correlation between the Lorentz factor associated with the jet and the presence of microvariability. The results of these studies has been submitted for publication.

Miller and co-workers have also embarked upon a program to study the character of the microvariability for a large sample of EGRET blazars. Preliminary results suggest that large amplitude variations are present, independent of whether the blazar is in a flaring state or in a quiescent state. The analysis of the observations obtained in a coordinated campaign utilizing CGRO, RXTE, and ASCA to study the variability of PKS 1622−297 is expected to be completed in the next few months. Observations obtained in a coordinated multiwavelength campaign utilizing optical, CGRO, RXTE, and ASCA to study the variability of 3C 279 found no clear pattern of time correlation between the different wavebands. Miller's group has participated in a number of other multifrequency monitoring programs to study blazars from gamma-rays to radio wavelengths. The objects studied have included PKS 2155−304, 3C454.3, PKS 0528+13, ON 231, 2A 1219+305, Mkn 421, Mkn 501, and PKS 1510−089.

This group is also studying a set of high-luminosity blazars and contrasting the findings for these objects with a sample of low-luminosity blazars. In addition, a major effort is currently underway to intensively study and characterize the microvariability of a small sample of TeV blazars.

Miller and Ferrara have completed an investigation of a sample of narrow-line Seyfert 1 galaxies (NLS1). This class of objects is known to exhibit giant-amplitude X-ray variability. No evidence was found relating the giant X-ray variability and the optical variability for the NLS1 galaxies. Preliminary results have demonstrated that in at least one case, IRAS 1322−3809, extremely rapid, but small amplitude, optical variability is present. X-ray observations have been requested, using RXTE, in order to determine if the X-ray/optical variations are simultaneous. Carini, Miller and Noble have studied the microvariability of 5 Seyfert 1 galaxies and have detected microvariability in only one object.

Ferrara and Miller completed a coordinated multiwavelength study of the X-ray/optical variability for the Seyfert 1 galaxy, Akn 120. This program spanned more than two years with sampling every three days as well as three days of nearly uninterrupted observations. Cross correlations of the two data sets indicate that the long term variations are correlated with zero lag to within the sampling timescale of three days. The combined PDS of the short and long timescale observations showed a high frequency inflection at 4.4 hours, a slope of -2, and a low frequency inflection (knee) at 19 days. The "knee" implies a black hole mass of $\sim 10^8$ solar masses for the central SMBH.

Wiita has continued a collaboration with Ram Sagar and others at the State Observatory, Naini Tal, India, along with Gopal-Krishna (NCRA) on optical observations of rapid variability in radio quiet quasars. Twenty-one such objects have now been observed over the course of 10 observing seasons. We have found excellent evidence for microvariability in several sources and hints of very rapid changes in several others. Radio quiet QSOs appear to be somewhat less frequently variable than radio-loud QSOs; furthermore, their variations appear to be confined to shorter time periods than those of blazars. Current studies of a several sets of Blazars, Radio Loud QSOs, and Radio Quiet QSOs, each matched in redshift and luminosity, should provide a powerful means of discriminating among various theoretical mechanisms proposed for the origin of optical microvariability in active galactic nuclei.

Gopal-Krishna and Wiita have extended their studies of HYMORS (HYbrid MOrphology Radio Sources) — radio galaxies with FR I type morphologies on one side of the host galaxy and FR II morphologies on the other side, and have recently added two more examples to the earlier list of 9 found in an examination of over 1400 radio maps. The mere existence of such sources poses severe problems for models for these two fundamental types of radio galaxies by postulating intrinsic differences in any of the following: jet composition; nature of the accretion process; spin of the black hole. Rather, HYMORS do support models in which interaction of the jet plasma with the ambient medium basically controls morphology, in that asymmetries in the external environment could naturally produce them, albeit very seldom.

By extending this model, they have been able to explain the Owen–Ledlow diagram, which delineates the positive dependence of the radio power corresponding to the boundary between FR I and FR II sources upon the optical luminosity of the host galaxy.

Gopal-Krishna and Prasad Subramanian (NCRA), Wiita and Peter Becker (George Mason U.), have recently revisited the question of the need for *in situ* particle acceleration in the hotspots of radio galaxies. They analyzed all 15 hotspots in which optical or near-infrared detections of synchrotron emission have been confirmed in both radio galaxies and quasars. Special relativistic effects were properly accounted for. They conclude that as long as the synchrotron losses during the travel down the jet are modest, the absolutely unavoidable inverse Compton losses against the microwave background do not demand that the radiating electrons be reaccelerated in the hotspots, as is usually assumed to be necessary.

The influence of active galaxies upon cosmology is being studied by Wiita and Osterman, along with Gopal-Krishna and Vasant Kulkarni (NCRA). Recent evidence for extended active lifetimes ($>10^8$ yr) for radio galaxies implies that many large radio lobes were produced during the ''quasar era,'' $1.5<z<3$, when the comoving density of radio sources was 2 – 3 dex higher than the present level. However, both adiabatic and inverse Compton losses against the intense microwave background substantially reduce the ages and numbers of sources that are detected in flux-limited surveys so there are many undetectable radio lobes. Coupling this with the recent realization that the galaxy forming material in those epochs was concentrated in filaments occupying a small fraction of the total volume then leads to the conclusion that radio lobes permeated much of the volume occupied by the protogalactic material during that era. The sustained overpressure in these extended lobes probably played an important role in triggering the high inferred rate of star formation at $z>1.5$ and in the magnetization of the cosmic network of filaments. Ramifications of this exciting result are currently under investigation.

7. SPACE BASED ASTROPHYSICS

Gies, Bagnuolo, Hartkopf (USNO), Mason (USNO), and Nelan (STScI) are continuing a multi-year project with the Fine Guidance Sensors (FGS) aboard HST to obtain astrometric measurements of the O-star binary 15 Monocerotis. This binary is now close to periastron in its 25 year orbit, and HST/FGS measurements of separation and position angle have documented the orbital motion during this close passage. Both TRANS and POS mode observations are being made to obtain both the relative and absolute orbital dimensions. Precise radial velocities for the binary are being obtained with the GSU Multi-Telescope Telescope and fiber-fed spectrograph. Continued astrometric (HST/FGS, USNO speckle camera, CHARA Array) and spectroscopic observations of the system will lead to a combined orbital solution and, hence, masses and a distance for this important massive binary.

Gies and collaborators made a first attempt to record the FUV flux of SS 433 using HST/STIS. This binary system was observed during a low flux state and was unfortunately too faint for reliable detection. Nevertheless, this observation places an upper limit on the temperature of an equivalent blackbody source ($T<21{,}000$ K for $A_V=7.8$) when combined with NUV and optical fluxes. The continuum source (the accretion disk and its wind) has a radius of approximately half the binary separation which may be larger than the Roche radius of the compact star. Complementary observations from the KPNO Coude Feed Telescope have provided a contemporary radial velocity curve for the relativistic jets, and the appearance of the emission line spectrum suggests that the binary is embedded in an expanding thick disk (detected in recent radio observations) which is fed by the wind from the super-Eddington accretion disk.

Wallace, Gies, and Moffat (Montreal) are pursuing a two-part investigation of massive Wolf-Rayet (WR) stars using observations obtained with HST. The first part involves the study of high resolution images of WR stars made with WFPC2 to search for nearby companion stars (in the angular range down to 0.2 arc-seconds). The second part is a search for much closer companions (as close as 0.007 arcseconds) using the FGS interferometers. One of the main goals of this work is to search for companions that could produce colliding winds regions between the stars, a possible explanation for the non-thermal radio emission and excess X-ray flux observed in many WR stars.

Miller has served as P.I. on programs utilizing RXTE and CGRO for a multiwavelength monitoring program investigating the nature of the variability of the Seyfert galaxy AKN 120. Extremely rapid variations have been detected in the X-ray and optical bands, and the results described earlier in this report.

B. M. Peterson and collaborators (including Miller) have proposed to NASA for a MIDEX (3–5 year) mission (KRONOS) which will provide the capability of obtaining simultaneous optical, UV, and X-ray monitoring for a number of variable AGN. The goal of this mission would be to obtain continuous observations of several objects for a period of up to 3 months with a time resolution of a few seconds at all three wavelengths.

Miller is a co-Investigator (S. Chakrabarti, Boston U. - P.I.) on the NASA SMEX mission SPIDR (Spectroscopy and Photometry of the IGM Diffuse Radiation) which is currently in a Phase A study.

Miller is pursuing preliminary discussions with scientists at NASA/GSFC preparatory to proposing a mission within the SMEX program to establish a Lunar UltraViolet Imaging Telescope (LUVIT) and an all-sky X-ray monitor(ASM) on the surface of the Moon.

Additional information on the astronomy research program can be found at URL http://www.chara.gsu.edu.

8. SUPPORT

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