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This report covers the period from 9/95 to 9/96.

1. PERSONNEL

The faculty in the astronomy group of the Department of Physics and Astronomy included G. Gatewood, C. Hazard, D.J. Hillier, R.E. Schulte-Ladbeck, and D.A. Turnshek.

F.H. Briggs continued his association with the University of Pittsburgh as an adjunct professor. V.K. Khersonsky held the position of visiting professor, J. Stein that of adjunct assistant professor, and B.R. Espey that of research assistant professor. S. Rao continued as a research associate, and S. Sherer in the position of research specialist. Research associate D.L. Miller left Pittsburgh to assume a position with the University of Arizona. M.M. Crone and L.W. Lee joined the group as research associates.

The following graduate students worked with astronomy faculty this year: J. Birriel, J. Busche, K. Chae, J. Herald, M. Kopko, R. Kurosawa, E. Lauzier, L. Lee, E. Monier, C. Sirola, and S. Taramopoulos.

Several Ph.D.'s were earned in the reporting period. S. Taramopoulus presented a thesis entitled ''VLBA Study of Neutral Gas in Absorption against the Nuclei of Radio Galaxies'' prepared under the supervision of Briggs. C. Sirola defended a thesis on ''The Large-Scale and Small-Scale Geometry of Broad Absorption Line Regions of Quasi-Stellar Objects'' advised by Turnshek. L. Lee, also advised by Turnshek, submitted a thesis on ''A Study of the Systematics of QSO Spectra.''

The following undergraduate students worked in the astronomy/astrophysics group: M. Anticole, J. Hill, G. Vaux, A. Landrum (Mt. Holycke), G. Mitchell, P. Morris, and D. Noll. D. Noll won the departmental Halliday-Resnick award for her undergraduate research.

2. FACILITIES

The local observing facility of the University of Pittsburgh's astronomy/astrophysics group is Allegheny Observatory.

In May 1996 the University of Pittsburgh CCD Camera was installed on the 1.5-m Maidanak Observatory Telescope under a joint agreement with the Sternberg Astronomical Institute (Moscow State University, Russia) and the Tashkent Astronomical Institute (Uzbekistan). Lauzier assisted with the installation.

Within the Department of Physics and Astronomy the main facilities are a system of workstations. During the period covered by this report, several new PCs and harddisks were acquired, and the memory of several workstations was upgraded. The Department of Physics and Astronomy also purchased a color laser printer.

3. STELLAR ASTRONOMY

Gatewood continued to use the Multichannel Astrometric Photometer (MAP), which is mounted as a dedicated instrument on the Allegheny Observatory's 30-inch refractor, in parallax and planetary detection programs. The possible discovery of planets around the nearby star Lalande 21185 at Allegheny Observatory was featured in many news articles and received much public attention.

Hillier and Schulte-Ladbeck have been collaborating on investigations related to the physical properties and evolution of the most massive stars in galaxies. Their approach involves both observations using imaging, spectroscopy, and spectropolarimetry, as well as theoretical modeling using a radiative transfer code.

Hillier and Miller continued their development of a sophisticated non-LTE radiative transfer code for the spectroscopic analysis of objects with extended outflowing atmospheres. Objects in this class include O stars, Wolf-Rayet (W-R) stars, Luminous Blue Variables (LBVs), novae, and supernovae. Non-LTE line blanketing due to CNO and the iron group elements has been incorporated, and extensive testing is underway. To allow the modeling of supernovae they have begun to develop a procedure to incorporate relativistic terms into the transfer equation.

Schulte-Ladbeck was engaged in a range of new observing projects. In collaboration with a large number of colleagues from around the world, Schulte-Ladbeck gathered about 6 years of spectroscopy and spectropolarimetry data of the LBV AG Car during its recent S Dor-like outburst. Hillier, Schulte-Ladbeck, and Kurosawa are developing a model to interpret the spectropolarimetric line profiles of AG Car. AG Car, like most other LBVs, shows strong evidence for intrinsic polarization, and the existence of a preferred axis in its flow. Preliminary work suggests that a factor of 2 density contrast between the polar and equatorial flows can explain the observed level of polarization. The presence of intrinsic polarization associated with some LBVs and W-R stars of the WN subtype suggests that rotation may be influencing the dynamics of the wind, and the formation of the spectrum. Therefore Busche and Hillier are investigating the influence of rotation on wind line profiles.

In several collaborations with A. Nota and M. Clampin (STScI), Schulte-Ladbeck and Hillier are investigating the morphology and physical properties of the extended, resolved nebulae around LBVs. The nebulae contain additional clues about the mass-loss history of massive stars, and new observations with the HST/WFPC2 and with ISO have been acquired. A direct image of the inner nebula of HR Car with the WFPC2 was obtained that exhibits more detail than previously published ground-based coronography. Imaging polarimetry of the ''Homunculus'' nebula around η Car, also with the WFPC2, was collected and is now in the process of being reduced in collaboration with A. Pasquali (STScI).

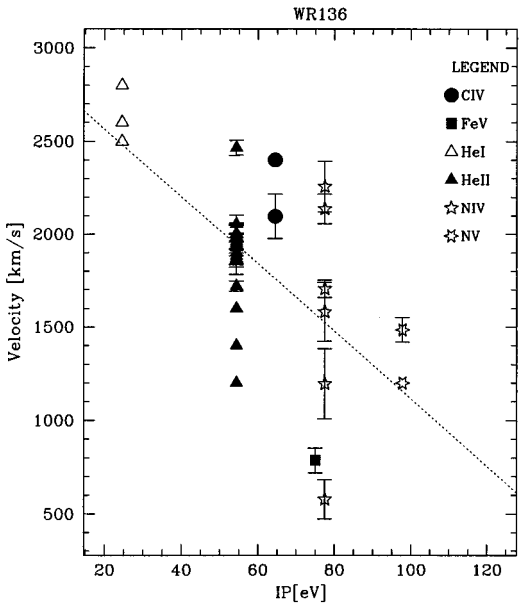

FIG. 1. The full width at half maximum velocity of emission lines in the spectrum of the W-R star WR 136 is shown plotted against the ionization potential of the respective ion in which the line emission is formed. In an accelerated wind, the negative slope of the FWHM vs. IP relationship (dashed line) is interpreted to indicate that the stellar wind has a stratified ionization structure: highly ionized species reside closer to the star than ions of lower ionization potential.

Hillier, Schulte-Ladbeck, and Kurosawa are analyzing spectroscopic and polarization observations of the W-R WC5 star HD 165763 (WR111). HD 165763 shows no intrinsic polarization which, combined with the presence of flat topped profiles, suggests that its wind is spherically symmetric. They estimate that the density contrast between the polar and equatorial flows must be less than 20%.

In conjunction with Hamann and colleagues in Germany, HST observations of six LMC W-R stars of the WC subtype and one W-R star of the WO subtype are being analyzed by Hillier and Miller. The final HST WO observation was obtained in March, 1996. Using the latest non-LTE codes they are determining the stellar parameters and abundances in these stars in order to place constraints on the evolution of massive stars.

Hillier, Schulte-Ladbeck, Miller, and Herald have begun to analyze Astro-2/HUT far-UV observations of several galactic WN stars covering a variety of spectral types. New blanketed models are being used which will allow, for the first time, accurate O, Fe, P, S, and Si abundances to be derived. Schulte-Ladbeck and Hillier successfully proposed for far-UV spectroscopy observations of WC stars with the ORFEUS II observatory, to be flown on the space shuttle in November of 1996.

Schulte-Ladbeck and Herald, in collaboration with P. Eenens (I.N.A.O.E., Mexico) and P. Morris (ISO Center, Spain), continued to investigate the ionization stratification in the winds of W-R stars. The sample of WN stars analyzed was increased and allowed for some statistical investigations

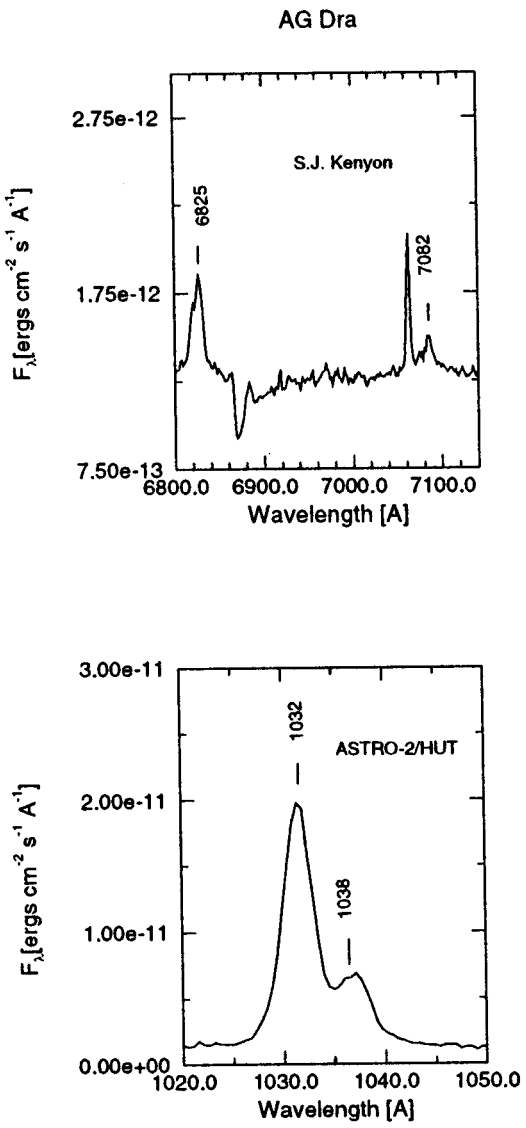

FIG. 2. The optical spectrum of the symbiotic binary Z And (top), courtesy of S. Kenyon (CfA), shows two broad lines which have been identified as OVI lines from the hot component of the binary Raman scattered at neutral hydrogen near the cool component. The far-UV spectrum of Z And (bottom), taken with HUT/Astro-2, shows that OVI lines at 1032 and 1038Å are indeed present.

of expected relations. It was found that the strength of the ionization stratification in WN winds correlates with wind performance number, in the sense that stars with small performance numbers show weak ionization stratification and stars with large performance numbers show strong ionization stratification. The data suggest that the winds of W-R stars can be accelerated by radiation pressure.

Schulte-Ladbeck continued the analysis of Astro-2 data of symbiotic stars. Together with Birriel and Espey, the presence of OVI lines in the spectra of symbiotic stars was quantified. Using ORFEUS I and ground-based data obtained by various observers around the time of the Astro-2 mission, a

table was generated comparing the presence of OVI lines in the far-UV and that of the Raman-scattered lines in the optical spectrum. In collaboration with J.J. Johnson and C.M. Anderson (U.Wisc.), an observing run at the WIYN telescope with the HPOL spectropolarimeter was carried out to investigate the linear polarization in the Raman-scattered features of symbiotic stars. The observations of AG Dra were analyzed over the summer.

Schulte-Ladbeck also continued to collaborate with Astro-2/WUPPE team members on the interpretation of space-based and ground-based spectropolarimetric observations of a variety of objects. With J.J. Johnson and the WUPPE team, the ultraviolet polarization of three novae in outburst was investigated. The data show that the nova ejecta are not spherically symmetric. Together with K.S. Bjorkman (U. Toledo), WIYN/HPOL observations of the T-Tauri star RY Tau were acquired. The object displayed a high degree of polarization which it had not frequently shown in the past. In collaboration with G.C. Clayton (LSU), WIYN and PBO HPOL data of R CrB were interpreted to indicate the existence of a bipolar outflow.

4. EXTRAGALACTIC ASTRONOMY

D.A. Turnshek's main research efforts continued to be in the area of observational cosmology. At Pittsburgh he has worked with several graduate and undergraduate students, and with Khersonsky, Rao, Lee, Espey, and Hazard.

One area of research centered on the study of Broad Absorption Line (BAL) QSOs as a means of studying the QSO phenomenon, with particular emphasis on placing constraints on unified models of QSOs and deriving constraints on the covering factors, ionization structure, and metal abundances of the QSO BAL region gas. Broad Absorption Line QSOs have been the subject of a number of studies with, for example, optical telescopes, HST, ROSAT and IRAS, with the aim of investigating the properties of BAL regions, including their chemical composition, the possible presence of dust, levels of ionization, photoionization effects within BAL clouds, covering factors, large-scale and small-scale cloud geometries, models for anisotropic continuum and line emission, and radiative transfer effects in the NV line. Some emphasis was placed on investigations of the gravitationally-lensed Cloverleaf BAL QSO.

Turnshek advised three graduate students with their thesis research on QSOs. Kopko is continuing his thesis work on investigating chemical compositions and modeling ionization effects in BAL QSOs. Sirola completed his Ph.D. thesis work, which included: (i) a study of geometry effects pertaining to BAL QSOs based on an analysis of QSO properties and observations of the Cloverleaf QSO and (ii) an analysis of the optical variability properties of BAL and non-BAL QSOs undertaken with the Swope 40-inch Telescope of the Carnegie Observatories at Las Campanas, Chile. Lee completed his Ph.D. thesis work, which included: (i) a study of the correlations between the properties of QSO BALs and broad emission lines and (ii) an investigation of the nature of the NV broad emission line which has relevance to the chemical evolution of QSOs and models for the BAL region. Rao, Espey, Khersonsky, and graduate student Monier worked on observational investigations of the Cloverleaf QSO. Khersonsky and Turnshek advised graduate student Chae on a project to model the Cloverleaf as a gravitationally lensed system. Sherer and undergraduates Mitchell, Morris, and Noll assisted with some of the efforts.

Another area involved the study of ''intervening'' QSO absorption line systems in order to investigate problems in the areas of the gaseous extent of galaxies, galaxy formation, and the intergalactic medium. Turnshek is a member of the HST QSO Absorption Line Key Project Team and this has facilitated a number of different studies of the evolution of the properties of the various types of intervening QSO absorption line systems, including Lyman-alpha forest systems, metal line and Lyman limit systems, and damped Lyman-alpha systems. Work on the damped Lyman-alpha systems with Khersonsky and Rao is proceeding in several new directions. In particular, Khersonsky and Turnshek have worked on interpreting the evolution of the damped systems in a way that is more closely tied to a star formation scenario in the galaxy population as a whole, as opposed to linking the damped systems to only disk galaxies. Rao and Turnshek have begun a new HST UV survey for low-redshift damped systems. Khersonsky, Turnshek, and Sherer found evidence for possible inhomogeneous HI Gunn-Peterson absorption near redshift $z \approx 0.7$ along the sight-line towards one QSO. If real, the absorption is taken to be inhomogeneous due to the absence of such absorption along many other QSO sight-lines. Monier continued with his thesis work aimed at placing constraints on intervening QSO absorber size scales. Landrum assisted with some aspects of the work.

Khersonsky worked separately on problems involving (i) the distribution and properties of dark matter particles in galaxy clusters and (ii) the connection between the interstellar cloud mass spectrum and the stellar mass spectrum in star forming regions as a way of eventually making more realistic studies of the evolution of the galaxy population.

Khersonsky, with Turnshek and Crone, began investigating certain aspects of galaxy merger scenarios.

Most of Crone's work has involved using N-body simulations to develop cosmological tests based on the structure of clusters of galaxies. The shapes of clusters contain information about their formation history, and constrain cosmological parameters such as the cosmic density Ω_o. Crone continued her work on this topic with A. Evrard and D.O. Richstone at the University of Michigan, and also began to collaborate with the cosmology computing group at the University of Washington. Recently, she has also started analyzing cluster data, using the cosmological test developed in the N-body studies.

Schulte-Ladbeck continued to work on stellar populations in irregular galaxies. In collaboration with U. Hopp (Munich Observatory), the interpretation of broad-band, single-star photometry of 10 resolved, dwarf irregular galaxies was started. The data themselves were published in an A&AS paper last year. Work is now underway to study the morphology and color-magnitude diagrams of these galaxies, to investigate their stellar content. Additional, unpublished observations in Hα were included over the summer to trace the young stellar component in these galaxies. Schulte-Ladbeck

and Hopp also succeeded in obtaining multi-filter HST/WFPC2 data of one of the galaxies, UGC 6456, from their sample. UGC 6456 is the closest blue compact dwarf galaxy, and only slightly more metal-rich than I Zw 18. In their ground-based observations, this galaxy was barely resolved. The WFPC2 images, currently being reduced in collaboration with Crone, show a wealth of very well resolved stellar images.

Hazard's work has continued to focus on quasar surveys.

5. EDUCATIONAL PROGRAMS

Allegheny Observatory continued to be used for student education, public tours and an annual public open house.

Schulte-Ladbeck has served as chair of the new departmental undergraduate recruitment committee. Activities included a departmental open house for high-school students, and the development of more attractive introductory-level physics courses for non-science majors. D.A. Turnshek designed a new astronomy course for non-science majors, ''Astronomy for Everyone – From Stonehenge to Hubble.''

Schulte-Ladbeck continued to give public lectures on her results from the Astro-2 space shuttle mission. Gatewood presented public lectures on his discovery of planets around Lalande 21185 at Allegheny Observatory.

D.A. Turnshek and D.E. Turnshek continued to promote science and astronomy education at the elementary- and middle-school level with the aid of a NASA IDEA grant.

D.A. Turnshek, Sherer, M. Ratcliffe (Carnegie Science Center), Anticole, D.E. Turnshek, and Espey obtained a NASA IDEA grant to operate an outreach program centered, in part, around a mobile solar observatory.

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