I. INTRODUCTION

I am pleased to introduce the first B.A.A.S. report of the Center for Astrophysical Sciences, Department of Physics and Astronomy, The Johns Hopkins University. It includes faculty and staff from several of the University's academic departments, as well as some members of the scientific staff of the Space Telescope Science Institute. President Steven Muller has informally indicated to us that he plans to respond fully to the opportunity that is presented to Hopkins by the presence of the Space Telescope Science Institute on our Campus. Tentative plans include 1) a new building for the Department of Physics and Astronomy, participation in a large new ground-based optical telescope, and 3) a doubling of the Departmental budget. A bond issue has been floated for the new building, and the architects are to be at work by January, 1986. It is our hope that the building will be located as a part of the new Space Telescope Science Institute (STSCI), facilitating mutually beneficial interaction.

II. PERSONNEL

Darrell Strobel has been appointed Professor in the Department of Earth and Planetary Sciences, with a minor appointment in the Department of Physics and Astronomy. Gerard Kriss has accepted appointment as an Associate Research Scientist. Garth Illingworth, Deputy Director of STSCI, has accepted appointment as a Research Professor. Other permanent staff members contributing to research in astronomy and astrophysics are: L. Cowie, D. Davidson, J. Dooling, P. D. Feldman, R. Giaconi (Director, STSCI), B. R. Judd, R. C. Henry, C. W. Kim, H. W. Moos, C. Norman, Professors; and J. Krolik, Assistant Professor; Robert Brown and Holland Ford; Research Professors; Michael Fall, Associate Research Professor; Steven Lubow, Assistant Research Professor; K. S. Long Jr., Research Scientist; W. P. Blair; S. T. Durrance, R. Kimble, and H. Weaver, Associate Research Scientists; and W. G. Fastie, Adjunct Research Professor. C. Bowers, R. Pudritz, P. D. Tennyson and T. N. Woods are Postdoctoral Research Fellows.

III. THE HOPKINS ULTRAVIOLET TELESCOPE PROJECT

The Hopkins Ultraviolet Telescope (HUT) is a 0.9-m prime focus telescope and spectrometer designed to carry out moderate resolution (approximately 3 Å) spectrophotometry throughout the far UV and extreme UV wavelength regions (425-1850 Å). It is one of three UV instruments which make up the Astro-Observatory, planned for three missions aboard the space shuttle in 1986 and 1987. Astro-1 is scheduled for launch on March 6, 1986, and will make extensive observations of Comet Halley during the Vega and Giotto fly-by missions. A broad range of other observations, ranging from EUV spectroscopy of nearby hot white dwarf to far UV studies of high redshift quasars, will also be begun on this first 9-day mission. These investigations will continue on the Astro-2 mission, planned for October 1986, and on Astro-3, planned for July 1987.

The HUT instrument was delivered to NASA's Kennedy Space Center in March, 1985, and has successfully undergone integration tests with the space medical systems which will support the Astro-Observatory. Additional testing and mission simulations will continue throughout the period until launch.

The Principal Investigator for the HUT project is Arthur Davidson and the Project Scientist is Knox Long. Other members of the Center for Astrophysical Sciences contributing to the project include William Blair, Charles Bowers, Samuel Durrance, William Fastie, Paul Feldman, Richard Henry, Randy Kimble, Gerard Kriss, Warren Moos, and Harold Weaver. Graduate students Kenneth Chambers and Henry Ferguson have played major roles in the development of HUT. Continuing engineering support is provided by Steven Conard, Vaclav Kavana and Clive Thomas, and by several staff members of the Johns Hopkins Applied Physics Laboratory.

IV. THEORY

Brian R. Judd has had a long interest in optical spectroscopy, particularly the application of the theory of Lie groups to the analysis of atomic energy levels. This work now centers on orthogonal operators. Their application to the configurations p of has been carried out with Grenville Lister, Hoang Dothe, Mark Suskin of The Johns Hopkins University, and, playing a crucial role, Jorgen Hanaen of the Zeeman Laboratory, Amsterdam. Richard Leavitt, who helped construct all scalar orthogonal operators for the d shell, is now extending his perspective on the theory of the Raman effect by visiting the experimental group of Norman Edelstein at the Lawrence Berkeley Laboratory.

Julian K. Krolik has devoted the bulk of his efforts to two major projects: a detailed study of the physics of radiation field- driven shocks in the winds from hot stars, and an investigation of the dynamical character of the environments of active galactic nuclei. He completed, with John Raymond (CPA), a calculation of the radiation force exerted on time-steady shocks in stellar winds; he has begun preparations for a 1-d radiation hydrodynamics simulation of shock propagation through stellar winds that will include all the necessary time-dependent ionization effects. His work on the second major problem included a prediction of significant alteration of the broad emission line profiles due to electron scattering in the hot interstellar medium (this...
in collaboration with T. R. Kallman at GSFC) and the creation of a physical model for the "intermediate zone", the region between the broad and narrow emission line regions.

During the past year Stephen Lubow, in collaboration with Steven Balbus (Virginia) and Lennox Cowie, completed the first major phase of an investigation of the dynamics of galactic spiral density waves. The study included for the first time in a time-steady calculation the dynamical effects of gas gravity, as well as the effects of viscosity caused by a cloudy ISM. The approach fully allows the gas gravity to reshape the gas and the stars. The gas dynamics was solved by means of a nonlinear viscous fluid equations; the stars were solved through linearized stellar dynamic equations. The gas gravity has a dramatic effect on the waves and leads to qualitatively new predictions. The new nonlinear gas waves are found to be sometimes symmetrical, without shocks. The gas acceleration timescale is \(10^{18}\) yr, while wave damping timescale caused by the star-gas interaction is \(10^9\) yr. The study has opened a number of fundamental issues that can now be investigated.

Norman, May and van Albada showed that a massive black hole in the central mass concentration in a triaxial galaxy can have a significant effect on the galaxy shape over the order of a Hubble time. May, Norman and van Albada developed a self-consistent model for box- or peanut-shaped bulges. May, van Albada and Norman discovered long period global oscillations in a perturbed triaxial galaxy. Furthermore, oscillations of triaxial galaxy is in progress with McGlynn. Carlborg, Lake and Norman ran a series of large N-collisions models with dissipation and obtained a good fit to the profile for the resulting dissipated, and presumably luminous, material and an density profile for the dissipationless matter. The study, with the collaborating in a large scale supercomputing project on galaxy formation, structure and evolution.

Ikeuchi and Norman are preparing a study of a universe with two significant components in its dark matter giving two characteristically different scales. First, the implications for the intergalactic medium, dwarf galaxies and large scale structure are analyzed, and subsequently the detailed implications for galaxy formation and evolution. Norman has investigated the structure and evolution of dwarf galaxies and predicted that core-dominated Virgo dwarfs should have lower density than their mass counterpart. Norman and Renzini have recently begun a long-term study of population evolution in galactic nuclei.

Norman and Heyvaerts have shown that during collapse of a flattened, magnetized protostar, anomalously resistive magnetic field reconnection can be excited at high densities of order \(10^{16}\) cm\(^{-3}\). Pudritz and Norman have analyzed, in considerable detail, the energy, momentum, and angular momentum flow in a protostar, disk, wind and bipolar flow model. Detailed similarity solutions are currently under investigation. Kylafis and Norman have developed an essentially non-equilibrium maser theory that alone can account for the most powerful water masers. Norman, Pudritz, and Monger are studying the morphology of star burst sources and detailed models are being developed.

Heyvaerts and Norman have studied the production of the \(\alpha\) line of positronium from the interaction of electron-position jets with clouds in circumnuclear environments. The extension of this work has initiated an analysis of anomalous conduction fronts associated with physical processes.

Ralph Pudritz has been working primarily on bipolar outflows from star forming regions, star formation in molecular disks, and the nature of starburst galactic nuclei. A self-consistent theory has been developed to show that hydromagnetic winds from molecular disks resolves the angular momentum problem of star formation, driving an accretion flow through a disk and onto a protostellar core (Pudritz 1985). Pudritz and Norman (1986) extended this work to show that both the inner radio and optical emission line jets and the more extensive CO flows in star forming regions could be accounted for in terms of a centrifugally driven disk wind theory. The analysis was extended to explain Herbig-Haro objects and FU Orionis type outbursts in O.1. with C. A. Norman an IRAS grant to do theoretical work on the nature of starburst galaxies. An integrated model which features hot nuclear winds, X-ray emission, and coherent star formation in nuclear molecular "toroids" is being developed. Pudritz in collaboration with N. Panagia is also developing the theory of radio emission from ionized disk and jet systems in order to understand the radio properties of protostellar objects. Pudritz and Silk have completed a study of ionization regulated star formation in magnetized molecular clouds. The early growth of protostellar cores in nearly centrifugally supported contracting disks was determined as such systems undergo magnetic braking and ambipolar diffusion. A profound effect on the type of cloud ionization (i.e., cosmic rays, radioactive decay, exposure to protostellar X-rays) was demonstrated.

Darrell F. Strobel conducts a research program on the chemistry, dynamics, and physics of planetary atmospheres. In addition, he is actively studying the Io plasma torus. As a Co-Investigator on the Voyager Ultraviolet Spectrometer (UVS) Experiment, he is involved in the analysis and interpretation of Voyager data obtained from the Jovian and Saturnian systems. With R. A. Smith, the energetics and energy partitioning in the Io plasma torus were investigated with a local thermodynamic state model described by a set of coupled quasi-linear equations for the distribution functions of the five major ions. The velocity distributions were found to be highly non-Maxwellian at the UV power loss rates observed by the Voyager UVS. With E. C. Sittler, in situ plasma electron observations made by the Plasma Science Experiment on Voyager during its passage through the Io torus are in the final stages of analysis and interpretation.

V. OTHER RESEARCH AND ACTIVITIES

W. P. Blair has continued an ongoing program to obtain and analyze optical and ultraviolet spectroscopic data on galactic and
extragalactic supernova remnants (SNRs). Several papers have been written on various aspects of the peculiar galactic remnant CTB 80 and further research is in progress on this enigmatic object. Improved optical red spectra of SNRs in CTB 80 have recently been published, and blue data are being obtained this fall. Spectra of many SNRs in the Magellanic Clouds have been obtained during an observing run to Cerro Tololo and analysis is progressing. An optical survey of the emission line properties of galactic SNRs has been completed. The optical spectra of the Cygnus Loop SNR have been obtained and an attempt to detect the oxygen-rich SNR in the SMC with IUE will be made this fall. A popular level article on the extraordinary SNR in NGC 4449 has been published in Mercury.

E. M. Hu, L. L. Cowie, and Z. Wang completed analysis of long slit spectroscopy on a sample of central galaxies of clusters with known X-ray properties, including seven systems which contain systems of optical emission filaments at their cores. Based on this work, it has been demonstrated that the occurrence of optical emission does indeed correspond to cases where the central core is thought to host hot cluster gas - a fraction of Hubble time. Kinematics analysis of the emission line gas using these moderate resolution spectra indicate that the nuclear emission exists in a rotating disk, not aligned with the major or minor axes of the parent D or cD galaxy. Unlike in the case of nearby clusters, these filaments are seen to vary from roughly half solar to factors of a few times solar from cluster to cluster.

Suggestions of anomalous Balmer decrements in the optical spectra of emission systems prompted E. M. Hu, L. L. Cowie, and J. C. Blades to undertake a program of UV observations with IUE to study Ly a in the brightest systems. To date we have found three systems have extinctions E_b < 0.1, implying for these rich high latitude clusters, that dust may be present in the central cluster regions, but that dust to gas ratios in the host cluster gas is extremely low. Using spectroscopic and CCD imaging data on the cores of rich clusters, L. L. Cowie and E. M. Hu have shown, that within the central 20 h^{-2} kpc, there is an excess concentration of galaxies corresponding to a bound population with velocity dispersion of ~300 km/s. The theory of dynamical friction predicts an amplitude and characteristic scale for the excess which are in excellent agreement with the observed data. Unlike previous studies, there was no pre-selection by magnitude of objects for red-shift determination, since all orientations were chosen for other purposes.

Analysis of optical absorption line spectra towards early-type supergiants in the Magellanic Clouds by A. Songaila Cowie, J. C. Blades, E. M. Hu, and L. L. Cowie has led to a kinematic picture of the Clouds as fragmented, extended objects. The intermediate velocity features previously supposed to be halo gas may be intrinsic to the Magellanic Clouds.

Songaila, Cowie and Blades with York (Chicago) made the first optical detection of a 21 cm high velocity cloud complex against an RR Lyrae star. This shows that a least this complex (C3) is within 2-3 kpc and has significant metal abundances.

Arthur Davidsen has been appointed the first director of the Center for Astrophysical Sciences. He will coordinate efforts by the faculty, staff, and university administration to develop a major research center in astrophysics and related sciences on the Johns Hopkins Homewood Campus. His major research effort continues to be the direction of the Hopkins Ultraviolet Telescope Program. In addition, Davidsen is a Co-Investigator on the Faint Object Spectrograph team for Space Telescope, and is planning for the establishment of an FOS team eastern data analysis facility in the Center for Astrophysical Sciences. He continues to serve on the AURA Board of Directors, the Space Telescope Institute Council, the Space Science Working Group, and the U.S. National Committee for the I.A.U. As chairman of the Local Organizing Committee, he has begun planning for the Twentieth General Assembly of the I.A.U., to be held in Baltimore in August 1988.

William G. Fastie continued application of optical and ultraviolet spectroscopy to a wide variety of problems in auroral and planetary physics, and astrophysics. In addition to his work concerning Space Telescope (he is a Telescope Scientist), he continued his work on evaluation of optical components, particularly gratings, and played his usual substantial role in the Johns Hopkins sounding rocket and Space Shuttle ultraviolet astronomy program.

Paul D. Feldman directs the NASA supported sounding rocket program, which has as its main focus the development of new instrumentation for far- and extreme-ultraviolet astronomy. The UVX shuttle program to measure UV background is also part of this program. In January 1985, the HUT prototype spectrograph was successfully flown on the last scientific mission of an Aerobee rocket to study the terrestrial airglow between 500 and 1800 A at 2X resolution. The last rocket in our program will be a Black Brant V to observe Halley's Comet in February 1986. Similarly, this year's sounding rocket efforts will concentrate on a SPARTAN payload to be carried into space aboard the Space Shuttle and which will provide ~40 hours of observing time, in contrast with the 5 minutes available to sounding rocket experiments. In February 1985 we began design work on a SPARTAN payload whose planned launch date is in late 1987. This payload is intended to observe extended faint sources in the extreme ultraviolet with the two main targets for the first mission being the Io plasma torus about Jupiter and the Cygnus Loop supernova remnant. The instrument consists of a 4/6 Cassegrain telescope with a clear area of 1100 cm², a 1 m Rowland circle grating spectrometer, and slit-jaw camera. The optics will be coated to enhance the reflectivity near 1025 A. The spectrometer will observe in the wavelength region 750 to 1150 A with 2A spectral resolution and 9 arc-second spatial resolution. The camera will provide an image of the field of view as well as offset errors to control the orientation of the secondary mirror with a
tracking accuracy of 4 arc-seconds. A two dimensional intensified array detector is currently being developed for the camera and the spectrometer, together with a combination of hardware and software centroiding algorithms. The principal contributors to the SPARTAN development are T. S. Woods, P. D. Tennyson and K. Dymond. Feldman has also continued his program of ultraviolet spectroscopy of comets using IUE (with M. F. A'Hearn of the University of Maryland). Observations of Comet Giacobini-Zinner were carried out from June 1985 through IUE encounters. The on-band/off-band interference filter program of observations of Comet Halley (in collaboration with A'Hearn, H. A. Weaver, M. C. Festou and others) was begun with the first ever observation of this famous comet from space on September 11, 1985.

During the past year H. Ford, in collaboration with R. Clardulullo (UCLA) and W. Jacoby (KPNO), has worked on three continuing ground based observational programs. Two of these are directed at the distance scale problem. The goal of the first distance scale program is to determine if the H-alpha luminosity of novae can be used as a standard candle. Ford and his collaborators have used an RCA CCD on the KPNO 0.9-m to survey a complete sample of active galaxies for similar activity. So far, they have found no turn up interesting examples of a large loop, a prominent bubble, and a symmetrical S-shaped emission region (imbedded in an otherwise normal elliptical galaxy) which may be the result of nuclear activity.

Ford and A. Kinney are presently working on superb KPNO 4-m CCD pictures and ICD spectra of the filaments in M87's cooling accretion flow. Their objectives are to use the geometry, velocity gradients, line broadening, and densities to understand how the radio lobes are modulating the flow.

Ricardo Giacconi, the director of the Space Telescope Science Institute (STScI) which is located on the Homewood Campus of The Johns Hopkins University, is also professor of astrophysics in the Hopkins Department of Physics and Astronomy. Giacconi led the group of scientists who were first to make astronomical observations using the X-ray part of the spectrum, thereby establishing X-ray astronomy as a significant field of astrophysical research. In 1970, the Uhuru satellite, conceived by Giacconi and developed under his direction, became the first orbiting X-ray observatory. In 1978 the launch of the Einstein Satellite permitted the extension of X-ray observation to all classes of objects of greatest astrophysical interest. His main field of current interests are the nature of the X-ray background, the origin and dynamical evolution of clusters and the early structures in the universe. He is co-author of a book entitled A Face of Extremes: The X-ray Universe which was published in 1985 by Harvard University Press.

Giacconi's most recent awards include the 1982 Gold Medal of the Royal Astronomical Society and the 1982 A. Cressy Morrison Award in Natural Sciences from the New York Academy of Sciences. In May 1983 he was awarded an honorary degree from the University of Chicago, in February 1984, he received an honorary degree from the University of Padua. Giacconi
is currently serving on the Space Science Board's Task Group on Major Directions in Space Science: 1995-2015. He has been chosen as Interdisciplinary Scientist on the Advanced X-ray Astrophysics Facility (AXAF), and is a member of NASA's Astrophysics Council. He was elected this year to the Comitato Scientifico del Centro Internazionale di Storia dello Spazio a del Tempo; the Fachbeirat of the Max-Planck Institut fur Physik und Astrophysik; and a Foreign Member of the Accademia Nazionale del Lincei.

R. Giaconi is in the midst of synchronizing the efforts of the Space Telescope Science Institute toward the planned 1986 August launch of the Hubble Space Telescope.

Richard C. Henry conducts research on the interstellar medium, cosmology, and ultraviolet background radiation. Targets have been selected in the wavelength range of 1900 Å - 3000 Å for the UVASPEC far ultraviolet spectrophotometer, which we plan to use to study cosmic gas, stars, and galaxies. Recently, his team undertook an interstellar medium survey of several regions of the Galaxy. A number of the redshifts observed in the survey are of particular interest, since they may well be the first evidence of quasars in the early universe. A number of the redshifts observed in the survey are of particular interest, since they may well be the first evidence of quasars in the early universe.

G. Illingworth has been working on the interstellar medium, cosmology, and ultraviolet background radiation. Targets have been selected in the wavelength range of 1900 Å - 3000 Å for the UVASPEC far ultraviolet spectrophotometer, which we plan to use to study cosmic gas, stars, and galaxies. Recently, his team undertook an interstellar medium survey of several regions of the Galaxy. A number of the redshifts observed in the survey are of particular interest, since they may well be the first evidence of quasars in the early universe. A number of the redshifts observed in the survey are of particular interest, since they may well be the first evidence of quasars in the early universe.

Garth Illingworth’s research interests are in the areas of the structure and dynamics of galaxies, characterizing the relationship of active to normal galaxies the stellar populations and chemical history of galaxies, and of the interstellar medium. On this latter topic, a program is being undertaken with M. Aaronson and K. Cook of Steward Observatory to determine the interstellar medium of galaxies using the 4 m Prime Focus CCD system at Kitt Peak. M101 is the nearest SC1 galaxy to us, and its distance is important in the calibration of other interstellar medium programs. A variety of interstellar medium measurements have been made, e.g., the interstellar medium in M101 has a range of velocities.

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Randy A. Kimble has continued work with S. Bowyer (UCB) on the extreme ultraviolet and far ultraviolet radiation fields and their relationship to the local interstellar medium, using data obtained some time ago from the P78+1 satellite. He notes in passing the importance of this instrument in recent U.S. ASAT tests. He also has investigated optical designs for possible future Space Telescope instrumentation.

G. A. Kriss has recently joined the Hopkins program as an Associate Research Scientist after completing a three year term as a Michigan Fellow at the University of Michigan. He will be working primarily with the Hopkins Ultraviolet Telescope and the First Object Spectrograph programs. While at Michigan he has studied the dynamics of clusters of galaxies and of cD galaxies using a combination of imaging X-ray data and optically determined galaxy velocities and velocity dispersions. An analysis in collaboration with D. Richstone (Michigan) of a high resolution X-ray image from the Einstein Observatory of the hot gas surrounding the cD galaxy in the cluster A2029 based on a cooling flow model produces a mass distribution that agrees well with Dressler’s model determined from surface photometry and the velocity dispersion profile of the cD galaxy. With E. Malumuth (U. of VA) he has studied the phase space distribution function of the galaxies in the poor cluster MKW 4. The inferred mass distribution agrees well with that derived from a cooling flow model of the X-ray emitting gas in this cluster. He also has continued work on multiwavelength observations of quasars and active galaxies. Investigations of the correlations between the X-ray, Lyman α, and Hβ luminosities of quasars and Seyfert 1 galaxies provide some evidence that the interiors of the broad-line clouds in these active galaxies are powered by the X-ray emission and are producing enhanced Balmer radiation. With Claude Canizares (MIT) he has definitively established...
that the x-ray to optical luminosity ratio of optically selected quasars does decrease with increasing optical luminosity. Although this effect is not seen in x-ray selected samples, a significant portion of the disagreement can be explained by the effects of reddening and internal absorption within the host galaxies of x-ray selected quasars.

Knox S. Long continues to devote most of his time to the Hopkins Ultraviolet Telescope for which he the Project Scientist. As a Co-Investigator on JHU Spartan program. He has a long-standing interest in the properties of supernova remnants and the x-ray characteristics of normal galaxies. During the year, long and graduate student Y. Matsui, have investigated the properties of the supernova remnants 3C400.2 and W25, which have shell-like radio but centrally peaked x-ray morphologies, concluding that these objects are most likely relativistic bubble-like objects, and the only hot interior is seen at x-ray wavelengths due to the significant amount of absorption along the line of sight to the SNRs. Long, with D. A. Leahy, S. Naranan and D. Venkatesan, concluded an investigation of the remnant HB3, which exhibits an unusual ring of emission at x-ray wavelengths, in addition to radio and optical. In addition, long presented a review of the properties of "Extragalactic Supernova Remnants" at the 18th Easal Symposium.

Warren Moos is using the IUE satellite to study the outer planets with S. T. Durrance, P. D. Feldman, and G. Ballester. Studies have been performed to determine the structure of the central part of the Io torus, the longitudinal emissions of the jovian auroras, and auroral emissions from Uranus and Saturn. Moos serves as a member of the Far Ultraviolet Spectroscopic Explorer Working Group and the Committee on Planetary and Lunar Exploration. Recent laboratory work is concerned with the development of pulse-coupled intensified two-dimensional solid-state arrays for space astronomy. Moos is using emissions from impurities injected into high-temperature tokamak plasmas to study the physics of the highly ionized atoms relevant to astrophysics. Haro, A. Weaver, Jr. is continuing her work on UV and IR excitation processes existing in comet and cometary comae. In December 1985 and March 1986 he will attempt to observe the water molecule directly in comet Halley from NASA's Kuiper Airborne Observatory. If successful, these observations will nicely complement the in situ data obtained during the Halley flyby missions, as well as data obtained during the Astro Mission. Weaver is also part of a team proposing an IR spectrometer for the Comet Rendezvous-Asteroid Flyby (CRAF) mission that will hopefully be launched by NASA sometime in the 1990's.

I would like to thank Professor Richard Henry for co-ordinating the preparation of this report.

Arthur Davidsen
Director

REFERENCES


