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This report covers departmental activities for the period October 2003 through September 2004.

1. INTRODUCTION

The astronomy and astrophysics program at the University of Colorado exists within the structure of the Astrophysical and Planetary Sciences Department (APS), with its affiliated units – the Center for Astrophysics and Space Astronomy (CASA), the Joint Institute for Laboratory Astrophysics (JILA), and the Laboratory for Atmospheric and Space Physics (LASP). Previous Observatory Reports provide details on the organizational arrangement.

The APS Department offers an academic program leading to the PhD degree in a variety of areas of astrophysics and planetary sciences. Students obtain basic theoretical knowledge common to these related fields, before specializing. The department has developed a new undergraduate Astronomy degree, with two tracks (General Astronomy and Astrophysics/Physics). We now have 131 declared undergraduate majors and 49 graduate students. Our 24 faculty and 90 researchers have active research programs funded by NASA, NSF, and DOE.

In this year's report covering 2003-2004, we emphasize new developments and recent publications specifically within APS, CASA, JILA and its membership. In astrophysics, particular strengths of CASA lie in hot and cool stars, interstellar and intergalactic matter, galaxy formation, quasars, clusters, high-energy astrophysics, solar physics and UV/Xray/IR/sub-mm instrumentation. Particular strengths of JILA include theoretical studies of black holes and accretion flows, formation of stars and planetary systems, supernovae and supernova remnants, helioseismology, solar magnetism, stellar atmospheres, and astrophysical fluid dynamics.

2. SCIENTIFIC DEVELOPMENTS

2.1 Instrumentation

The Far Ultraviolet Spectroscopic Explorer (FUSE) mission was launched in summer 1999. The FUSE spectrograph was designed and built at CASA over a five-year effort led by Dr. James Green. Other members of the FUSE science team are CASA astronomers Drs. Cash, Shull, and Snow, and JILA astronomer Dr. Linsky. The mission is an unqualified success, and many CASA professors, researchers, graduate and undergraduate students are deeply involved with the analysis of FUSE data. The CASA hardware team is now progressing well on the development of the Cosmic Origins Spectrograph (COS), which may be installed in NASA's Hubble Space Telescope in 2007. The powerful ultraviolet instrument has just been completed, together with Ball Aerospace and Technologies Corporation in Boulder. COS will bring the diagnostic power of UV spectroscopy to bear on such fundamental issues as the ionization and baryon content of the intergalactic medium and the origin of large-scale structure in the Universe; the ages, dynamics, and chemical enrichment of galaxies; and stellar and planetary origins. COS will build on the legacies of Copernicus, IUE, GHRS, FOS, STIS, and FUSE, giving HST the greatest possible grasp of faint UV targets, ensuring that Hubble maintains a powerful UV spectroscopic capability through the end of its mission.

Dr. Webster Cash and his group are developing space hardware applicable to several future NASA/ESA missions. The first, and probably nearest-term technology involves Reflection Gratings for high-resolution soft X-ray spectroscopy for NASA's planned Constellation-X mission in the next decade. These gratings, used in the off-plane mode, can deliver X-ray spectral resolution sufficient to study supernova remnants, stellar coronae, neutron star and black hole binaries, and the hot intergalactic medium using diagnostic lines of O, N, Ne, Fe between 0.3 and 1.0 keV.

Cash and Professional Research Assstant Ann Shipley are also working on advanced concepts for X-ray interferometry (MAXIM mission study) and for the New Worlds Imager, a giant pinhole camera concept for imaging extrasolar planets by separating starlight from planets.

CASA also supports many instrumental programs in infrared sub-millimeter, and millimeter-wave astronomy. Dr. Jason Glenn's programs focus on developing bolometer arrays (Bolocam) for mm-wave and sub-mm studies of high-redshift galaxies and star formation, used on the Caltech Submillimeter Observatory and on the Herschel/FIRST satellite later this decade. Newly hired faculty member, Nils Halverson, brings expertise in mm-wave studies of the cosmic microwave background. Drs. Albert Betz and Rita Boreiko work on far-infrared instrumentation for studies of star-forming regions. APS and CASA just completed a near-infrared camera and Fabry-Perot spectrograph (NIC-FPS) for installation on the Apache Point 3.5-meter telescope.

2.2 Space Astronomy

CASA astronomers continue intensive use of NASA spacecraft. In 2003-04, there were awards from the Hubble Space Telescope (HST), FUSE, Chandra, XMM, Spitzer, and Herschel/FIRST. Grants were received from other NASA programs including Astrophysics Theory, Origins of Solar System, Astrophysics Data, Long-Term Space Astrophysics, & High Energy Astrophysics. CASA astronomers were awarded FUSE Cycle-5 observing programs for studies of stars, quasars, interstellar and intergalactic matter.

2.3 Ground-based Astronomy

The Department of Astrophysical and Planetary Sciences, including CASA, has entered into a ground-based telescope consortium (ARC) at the 3.5-meter Apache Point Observatory in southern New Mexico. CU observing programs include studies of clusters of galaxies, dwarf galaxies near intergalactic clouds, stellar outflows, hot stars and the ISM. These and future observing runs on interstellar matter, infrared galaxies, and planets include undergraduate and graduate students in the observations and analysis. CASA just built a near infrared camera to be installed on the telescope in November 2004. APS scientists continue to make extensive use of other national ground-based optical and radio facilities for solar, stellar, interstellar, and extragalactic research.

2.4 Theoretical Astrophysics

Colorado has one the nation's top programs in astrophysical theory. Our research groups are working on such topics as interstellar and intergalactic matter, cosmology (large-scale structure, galaxy formation, reionization by first stars/AGN), formation of stars and planetary systems, black holes and AGN, helioseismology and solar dynamo, plasma astrophysics, supernovae, and stellar atmospheres. Our faculty and researchers have strong funding for theoretical graduate students and postdocs.

3. SELECTED INDIVIDUAL RESEARCH BY TOPIC

3.1 Active Galactic Nuclei

Using UV, optical and X-ray observations Dr. Nahum Arav is studying a wide range of AGN outflow phenomena both in terms of luminosity (broad absorption line quasars to Seyfert galaxies) and in the degree of ionization (neutral atoms to X-ray warm absorbers). Dr. Arav is particularly interested in determining: the connection between the UV and X-ray warm absorber seen in Seyfert outflows, and the chemical abundances, acceleration mechanism and kinetic luminosity of the outflows. These determinations provide the foundation for the long-range goal of my research program: Establishing the effects of AGN outflows on the growth and evolution of their host galaxies. His approach to research combines a strong theoretical background with detailed technical understanding of the observations to maximize the extraction of scientific knowledge from the data.

Since arriving to CASA Dr. Arav is mainly working on the connection between the UV and X-ray warm absorber seen in Seyfert outflows. Recently, Jack Gabel joined Dr. Arav's group as a postdoc.

Dr. Jack Gabel continued his research on mass outflow in active galactic nuclei. His research has focused primarily on intensive observational campaigns designed to extract detailed constraints on AGN outflows from UV and X-ray absorption spectra. He participated in two large collaborations that employed coordinated observations with HST, FUSE, and Chandra of individual Seyfert 1 galaxies, NGC 3783 and Mrk 279. Analysis of variability in the rich absorption spectrum of NGC 3783 has placed tight constraints on the geometric, kinematic, and ionization structure of its outflow.

For Mrk 279, a new fitting technique was developed to overcome uncertainties in extracting the crucial absorption parameters needed for interpretation of the outflow, making use of the highest S/N UV spectrum of an AGN outflow ever obtained.

Analysis of the variability and physical conditions in this object continues. Gabel also collaborated in a study led by Mike Crenshaw (Georgia State University) of the lowest luminosity Seyfert 1 galaxy, NGC 4395. This study revealed the absorption detected in its UV spectrum is likely associated with an outflow, similar to those seen in the majority of Seyfert galaxies. Gabel, with Steve Kraemer (Catholic University of America) and Gary Ferland (University of Kentucky), derived estimates of dielectronic recombination rates for use in photoionization modeling codes and explored the implications of uncertainties in these rates on the interpretation of AGN absorption and emission spectra.

3.2 Cosmology and Galactic Formation

In their study of metal enrichment from the first stars, Drs. Michael Shull and postdoc Fernando Santoro have been working on the influence of the first stars on the formation of second-generation objects at high redshift. They hope to understand the critical metal enrichment of primordial gas in order to radiatively cool and fragment into smaller stars. They solve for the time-dependent cooling of primordial gas with trace amounts of C, Si, O and Fe, using their fine-structure line cooling to derive a condition for cloud fragmentation. Santoro is also collaborating with Prof. Peter Thomas and PhD student Mike MacIntyre from the Department of Physics and Astronomy of the University of Sussex in England, on the merging history of the first star clusters.

Dr. Michael Shull's research group works on a wide range of theoretical and space-observational topics connected with the interstellar medium (ISM), intergalactic medium (IGM), and galaxy formation. With students and postdocs, his recent work includes theoretical models of the first stars and quasars and their effects on reionizing the IGM in hydrogen and helium, and on radiation feedback from galaxy formation.

Recent observational studies involve FUSE/Hubble spectroscopic measurements of galactic halo clouds (Collins, Shull, & Giroux 2003, 2004) with low-metallicity (10-40% solar abundances), a FUSE/Hubble study of multi-phase intergalactic gas toward PKS 2155-304 (Shull *et al.* 2004), and a FUSE study of He II Reionization of the IGM at redshifts $z = 2.3 - 2.9$ (Shull *et al.* 2004; Zheng *et al.* 2004). We also published a Hubble Space Telescope Lyman-alpha survey of the baryon content of the local intergalactic medium (Penton, Stocke, and Shull 2004).

Our theoretical work include models of the reionization of the high-redshift IGM by the first hot stars and the radiative and dynamic feedback from star formation in the first galaxies. Publications on the role of the ''first stars'' include Tumlinson, Shull, and Venkatesan (2003) and Venkatesan, Tumlinson, and Shull (2003) on reionization. We also have used nucleosynthetic yields compared to extremely metal-poor halo stars to constrain the initial mass function of the first stars (Tumlinson, Venkatesan, and Shull 2004). We find that stars between 10-100 solar masses may have done most of the reionization at high redshift. Our current work continues studies of the first stars, simulations of early dwar galaxies (Ricotti, Gnedin, and Shull 2004), and primordial cooling models used to estimate the ‘‘critical metallicity’’ in the high-redshift IGM that governs the transition from the first (zero-metallicity) stars to a more normal mode of star formation.

3.3 Galaxies

Work by Jack Burns and Patrick Motl at CU for the year have included extensive efforts in the simulation of clusters of galaxies. They have pushed the spatial resolution to the level of approximately 1 kpc in a simulation volume 256 Mpc on a side, and have extensively studied the impact of radiative cooling and star formation and supernova feedback on cluster properties. The impact of feedback from active galactic nuclei on the intracluster medium will be included in simulations in the near future. A specific focus of the current research is to explore the efficacy of methods using clusters of galaxies as precision cosmological probes. Presentations of their work were made by Patrick Motl at the 2004 AAS meeting, in a poster ‘‘Sunyaev-Zeldovich Effect Scaling Relations in Simulated Clusters of Galaxies,’’ a talk at the 2004 High Energy Astrophysics Division (HEAD) meeting titled ‘‘Precision Cosmology with Clusters of Galaxies: Insights from Numerical Simulations,’’ a talk at the April 2004 meeting of the American Physical Society titled ‘‘Do Relaxed Clusters of Galaxies Exist?,’’ a talk at the X-ray Radio Connections meeting, ‘‘Energy Balance in Clusters of Galaxies,’’ and a talk at the Cosmology with Sunyaev-Zeldovich Cluster Surveys workshop hosted by the Center for Cosmological Physics at the University of Chicago with the title ‘‘The Sunyaev-Zeldovich Signature from Numerical Clusters of Galaxies.’’ Publications from the past year include ‘‘Formation of Cool Cores in Galaxy Clusters via Hierarchical Mergers’’ by Patrick Motl, Jack Burns, Chris Loken (CITA), Mike Norman (UCSD), and Greg Bryan (University of Oxford)(2004 ApJ, 606, 635), ‘‘Morphology and Evolution in Galaxy Clusters I: Simulated Clusters in the Adiabatic limit and with Radiative Cooling’’ by Nurur Rahman, Sergei Shandarin (University of Kansas), Patrick Motl and Adrian Melott (University of Kansas)(MNRAS, submitted, astro-ph/0405097), ‘‘Simulated Versus Observed Cluster Eccentricity Evolution’’ by Stephen Floor (University of Kansas), Adrian Melott and Patrick Motl (2004 ApJ, 611, 153), and ‘‘The X-Ray Properties of Nearby Abell Clusters from the ROSAT All-Sky Survey: The Sample and Correlations with Optical Properties’’ by Michael Ledlow (Gemini Observatory), Wolfgang Voges (MPI Garching), Frazer Owen (NRAO) and Jack Burns (2003 AJ, 126,2740).

3.4 Interstellar Astronomy

Dr. Joe Collins’ research attempts to understand the origin of the high-velocity clouds (HVCs) seen in HI emission and UV absorption lines. His recent research has centered around a class of highly-ionized HVCs that are not detected in HI. It has been proposed that such objects may trace shock-heated remnants of Local Group formation in the IGM. He has recently completed a survey of FUSE and HST sight lines containing such objects, and finds that their ionization characteristics more closely resemble low-column-density Galactic halo HVCs. He continues to research the origin of the Galactic halo HVC Complex C. This work attempts to measure the metallicity along several sight lines through the cloud in an attempt to investigate possible mixing of infalling and Galactic gas in the HVC.

Dr. Charles Danforth is involved in several ongoing studies of the Interstellar and Intergalactic Medium. He has recently finished analyzing 40 FUSE sight lines toward quasars and active galactic nuclei in a search for warm-hot intergalactic medium (WHIM) absorbers. The signature of this material is absorption in the important far-UV OVI lines as well as CIII and the higher Lyman lines. From this study, Danforth has found roughly fifty WHIM absorbers, a significant improvement over past studies, and has confirmed that the WHIM component makes up about 5.

Danforth is also continuing research into the structure and kinematics of the warm-hot ISM in the Magellanic Clouds using a large set of FUSE observations he put together for his dissertation in 2001-03. These sight lines probe many different ISM structures in the Clouds including superbubbles, supergiant shells, HII regions and supernova remnants and sample regions of dramatically differing ionization and depletion.

Dr. Michael Shull’s observational work includes studies with Hubble Space Telescope and FUSE on a variety of topics: interstellar molecular hydrogen, hot interstellar gas (O VI), interstellar deuterium, metallicity of high-velocity clouds, the distribution, baryon content, and metallicity of low-redshift Lyman-alpha forest, and intergalactic He II absorption at redshifts $z = 2\text{-}3$.

Drs. Remy Indebetouw and Michael Shull (2004a,b) carried out a FUSE/Hubble survey and constructed theoretical models of highly ionized gas (O VI, N V, C IV) in the Galactic halo. We also published large FUSE science-team surveys of highly ionized gas (O VI) in the Milky Way halo (Wakker *et al.* 2003; Savage *et al.* 2003) and in high-velocity clouds (Sembach *et al.* 2003). We made an additional FUSE study (Sembach *et al.* 2004) of the cosmologically significant D/H ratio in a low-metallicity cloud falling onto the Milky Way disk. Browning, Tumlinson, and Shull (2003) published new models of molecular hydrogen (H2) formation, destruction, and rotational excitation, which are being used in our FUSE surveys of H2 in the Milky Way disk (Shull *et al.* 2004, in preparation) and Galactic halo (Gillmon, Shull, and Tumlinson 2004). We have found large ‘‘H2 holes’’ at high Galactic latitude, where the H2 column densities are quite low. These holes may be associated with infalling high-velocity clouds and upwelling gas from the Galactic fountain.

Shull is a member of the Science Teams for FUSE and the Cosmic Origins Spectrograph on Hubble. He also a member of study teams for the Constellation-X (X-ray spectroscopy) and Space Ultra-Violet Observatory (SUVO) missions.

Dr. Ted Snow’s research continues to be centered on the interstellar medium, with emphasis on the unidentified diffuse interstellar bands (DIBs), a large number of interstellar absorption features first noticed more than 80 years ago. Snow's work during the past year has featured detailed studies of the DIBs, including laboratory measurements as well as both absorption- and emission-line astronomical observations. Snow has also continued his work on interstellar abundances and depletions from gas onto dust, using primarily far-UV spectra obtained with the FUSE satellite and using X-ray spectra from the Chandra X-Ray Observatory.

Snow's DIBs work during the past year included further studies of the profiles of the broadest bands, which were found earlier to be well represented by pure Lorentzian profiles, suggesting that at least this subset of the DIBs may be formed by ultra-rapid internal conversion transitions in molecules (see Snow, Zukowski, and Massey 2003; and Drosback *et al.* 2004). In addition, Snow continues his laboratory chemistry studies of potential DIBs-producing molecules, in collaboration with V. M. Bierbaum of Colorado's Chemistry and Biochemistry Department, in which the goal is to narrow down the range of possible DIBs carriers by analyzing the chemical reactivity of candidate molecular ions to see which ones can survive in the diffuse interstellar medium (see papers by Eichelberger *et al.* 2004a, b, c). Snow also heads up a group of investigators using the Apache Point Observatory's 3.5-m telescope to observe and interpret DIBs emission features seen in the unique nebula known as the Red Rectangle, which may help to constrain both the physics and the chemistry of some of the DIBs carrier molecules.

In addition, Snow's work on interstellar gas-phase depletions and properties of dust has included several new studies, one of which is a general survey of oxygen abundances and depletions (Jensen, Rachford, and Snow 2004); and another of which is an analysis of X-ray absorption features due to dust and gas in the interstellar medium, using X-ray spectra from the Chandra X-Ray Observatory (Cunningham, McCray, and Snow 2004). A new survey of interstellar nitrogen depletion is under way (Jensen, Rachford, and Snow 2005). Finally, Snow has also participated in studies of ultraviolet interstellar exticntion due to dust, and two major papers have come out recently (Clayton *et al.* 2003; Sofia *et al.* 2004).

Currently Snow, with co-author B. J. McCall of the University if Illinois, is preparing a major review article on diffuse cloud chemistry, to appear in Annual Reviews of Astronomy and Astrophysics in 2005.

3.5 Millimeter Astronomy

Dr. Jason Glenn works on submillimeter millimeter-wave astronomy and instrumentation. His main efforts over the past year have been observations with Bolocam and design of Z-spec. Bolocam is a large-format, millimeter-wave bolometer camera for use on the Caltech Submillimeter Observatory, built by a collaboration including CU, Caltech, the University of Massachusetts, and the University of Cardiff. We have done a survey for high-redshift submillimeter galaxies toward the Lockman Hole, yielding new galaxy candidates and number counts. We have also commenced a survey with Bolocam at the Caltech Submillimeter Observatory for galaxy clusters via the Sunyaev-Zel'dovich effect. Z-Spec is a millimeter-wave grating spectrometer for measuring the redshifts of submillimeter galaxies and serves as a demonstration of a compact waveguide-coupled grating for a future far-infrared orbital mission. We are building it in collaboration with JPL, Caltech, ISAS in Japan, and CEA in France.

3.6 Star Formation

Dr. John Bally's group has been focused on determining the role of protostellar outflows in star formation feedback. We have used the wide field MOSAIC imagers at Kitt Peak and Cerro Tololo to survey several nearby molecular clouds in narrowband filters looking for shocks from protostellar outflows. We have cataloged dozens of new shocks and are using these data to determine whether shocks can drive turbulence within the molecular cloud. We have completed narrow-band H-alpha and [SII] surveys of the Perseus, Orion A, Orion B, Carina, Chamaeleon I, and rho-Ophiucus regions.

We have completed a narrowband H-alpha imaging survey of the Orion Nebula using the Advanced Camera for Surveys on the Hubble Space Telescope (HST). We have discovered dozens of new proplyds and stellar jets, and have measured proper motions for about a dozen new outflows in the Nebula. We have discovered many new protoplanetary disks seen in silhouette in the outer Nebula. We have been granted time to conduct a similar survey of the Carina Nebula.

In collaboration with Dr. Henry Throop (Southwest Research Institute), we have developed a model of grain growth in photoevaporating protoplanetary disks. These models show that photoevaporation and radiation pressure can increase the metallicity of the disk mid-plane to the point that gravitational instabilities can rapidly produce kilometer-sized planetesimals.

Graduate student Nick Moeckel has been using an SPH code to model the interactions of stars with disks in dense clusters. The models produce capture-formed binaries in which the circumstellar disks are severely perturbed. The dynamical ejection of disk material occurs preferentially along the disk rotation axis of some models. Such ejections may be responsible for the wide-angle bipolar outflows observed in some massive star-forming regions such as OMC1 in Orion. We are exploring the role that disk-mediated star-star interactions in dense clusters play in the formation and evolution of massive stars. The spiral shocks produced by the close-passage of a sibling star (within a few hundred AU) may provide a viable environment for chondrule formation in the early Solar system.

Dr. Nathan Smith's studies of star formation have focussed mainly on investigations of the Carina nebula and the Orion nebula. Until the past few years, the Carina nebula was assumed to be an evolved H II region mostly devoid of star formation, but recent work has revealed several signposts of active star formation, including the discovery of the first stellar jets in Carina, embedded infrared sources, and numerous small cocoons that may harbor young stars and protoplanetary disks. Smith looks forward to working on upcoming programs to survey the Carina nebula with Spitzer and HST.

3.7 Stellar Astronomy

Dr. Cynthia Froning has been pursuing research on compact binary systems, with a particular interest in the physics of accretion disks and disk outflows. Using HST and FUSE, she has observed and modeled the ultraviolet spectra of numerous cataclysmic variables to determine the structure and behavior of disk-accreting systems. She is currently completing a survey of the FUV properties of cataclysm ic variables from the FUSE archive to study the properties of these systems as a function of binary evolution, mass accretion rate, magnetic field effects, and viewing inclination. Dr. Froning is also interested in X-ray binary systems, an d has recently obtained near-infrared spectroscopy of the black hole XRB, A0620-00, with the IRTF and VLT. She is analyzing the spectra to search for anomalies in the donor star resulting from binary evolution effects and to make a precise determination of the mass of the accreting black hole.

Dr. Stephen Skinner's research focuses on observational studies of star-forming regions, Wolf-Rayet (WR) stars, and solar-like stars using a variety of space and ground-based telescopes. He currently makes extensive use of the Chandra and XMM-Newton X-ray observatories, the Spitzer Infrared Telescope, and the Very Large Array radio telescope. In addition, he continues to serve as editor of COOLNEWS, a monthly electronic research newsletter on cool stars that is distributed to more than 600 astronomers worldwide.

During 2004, Dr. Skinner completed an X-ray study of intermediate mass pre-main-sequence stars (Herbig Ae/Be stars) aimed at identifying physical processes that are responsible for their X-ray emission. He was also principal collaborator on a deep Chandra X-ray study of young stars and protostars in the Rho Oph molecular cloud, most of which are deeply embedded and invisible at optical wavelengths. During 2005, he will continue X-ray and infrared studies of young clusters in the Orion region and Ara OB1 assciation, and will collaborate with M. Guedel (Zurich) on a large-scale X-ray survey of the Taurus dark clouds.

Dr. Nathan Smith has concentrated on observational studies of star formation and mass loss from evolved stars. To study mass loss from evolved stars, he has been using UV and visual spectroscopy and imaging with HST, combined with ground-based optical, near-infrared, and thermal-infrared imaging and spectroscopy. The goal of this work is to constrain the geometry, excitation, abundances, and mass of circumstellar nebulae, and the physical properties of stellar winds. In addition to some planetary nebulae, the primary objects of interest have been evolved massive stars like Luminous Blue Variables, especially the enigmatic massive star Eta Carinae.

Dr. Guy Stringfellow's research in star formation focuses on the role played by disk accretion processes in modifying the circumstellar environment during pre-main-sequence evolution. Episodes of enhanced mass accretion within the circumstellar (protoplanetary) accretion disk and onto the young star can result in energetic outbursts which can initiate jets and winds. Examples of such events are the EXor and FUor stars. During the last year a new ground-based program was initiated in collaboration with Dr. Fred Walter (SUNY-Stony Brook) using the SMARTS Consortium suite of small telescopes located at CTIO to follow the temporal evolution of the EXors. We are acquiring UBVRI-JHK photometric imaging and low- to moderate-dispersion optical spectroscopy on many EXors on a regular basis. These data are augmented by further narrow-band imaging and high-dispersion echelle observations on the 3.5m telescope at Apache Point Observatory. Stringfellow also is leading an intensive Spitzer Space Observatory program with collaborators Dr. Peter Abraham and colleagues (Konkoly Observatory, Hungary), Dr. Timo Prusti (European Space Agency, Netherlands), and Dr. Walter investigating the infrared evolution of the EXors. Both programs enable studying EXors when in outburst, and one new EXor-type object discovered this last year (V1647 Ori) has been studied in detail (Abraham *et al.* 2004; Walter, Stringfellow, Sherry, & Field-Pollitou 2004). These observations are continuing throughout the next year. Our goals are to understand accretion physics operating, what triggers the enhanced mass accretion events that result in the energetic outbursts, and the impact such events have on the circumstellar environment. In particular, the potential influence on modifying the chemistry and conditions which lead to planet formation.

Dr. Stringfellow has expanded his studies on novae outbursts. In collaboration with Dr. Fred Walter (SUNY-Stony Brook) a new program utilizing the SMARTS suite of telescopes was begun. We are following intensively the evolution of a few select novae in the optical and infrared shortly after outburst well into and beyond the coronal stage years later. Photometric lightcurves and spectroscopy collected on a regular basis enable a complete picture of individual novae to be assembled. Higher dispersion spectroscopy is also being obtained on the 3.5m telescope at APO. These data allow fundamental properties, including detailed analysis of the chemical composition, to be derived. Preliminary analysis of two novae have been presented this year: Nova V475 Sct (2003) and Nova V1 187 Sco (2004); Stringfellow & Walter 2004a, b. Observations on these and other novae, including new novae outbursts will continue.

3.8 Education

Douglas Duncan completed a book, ''Clickers in the Classroom,'' published by Addison Wesley, which examines how wireless student response systems affect student learning, attitudes, and faculty enjoyment in teaching. CU now uses 6,000 clickers, with physics and astronomy the leading departments.

Duncan continues to serve as Director of Somers Bausch Observatory and Fiske Planetarium. Under a NASA grant Fiske has produced a program highlighting the ''Deep Impact'' mission which will rendezvous with and crash into comet Tempel 1 in 2005. The program is being translated into Spanish and Dutch for international use.

Duncan also participated in the recovery of the ''Berthoud Meteorite'' a 1 kg achondrite which fell north of Boulder the afternoon of October 5, 2004, about 100 ft. from 3 witnesses.

4. PERSONNEL CHANGES DURING 2003

New Research Associates:

Dr. Eric Hallman (University of Minnesota); Dr. Yeong-shang Loh (Princeton University); Dr. Fernando Santoro (University of Sussex).

Research Associate Departures:

Dr. Ken Brownsberger (Ball Aerospace); Dr. Patrick Motl (Louisiana State University); Dr. Mary Putman (University of Michigan); Dr. Brian Rachford (Carleton College); Dr. Jessica Rosenberg (Harvard-Smithsonian Center for Astrophysics); Dr. Erik Wilkinson (Ball Aerospace).

New Graduate Students:

Quyen Hart, Adam Jensen, Robyn Levine, Derek Lamb, Eric Schindhelm, Joshua Schroeder, Jared Workman.

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