NASA's Goddard Space Flight Center
Laboratory for Astronomy & Solar Physics

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The following report covers the period from July 2001 through June 2002.

1. INTRODUCTION

The Laboratory for Astronomy and Solar Physics (LASP) conducts a broad program of observational and theoretical scientific research. Galactic and extragalactic observations are carried out at wavelengths extending from the EUV to the sub-millimeter with space-based observatories, balloons, and ground-based telescopes. Research projects in astronomy cover the fields of stellar astrophysics, the interstellar and intergalactic medium, star formation, active galactic nuclei, galaxy formation and evolution, solar system phenomena, and studies of diffuse infrared and microwave background radiation – both Galactic and cosmic.

Studies of the sun are carried out in the gamma-ray, x-ray, EUV/UV and visible portions of the spectrum from space and the ground. Solar physics research includes studies of solar active regions, the solar corona, solar eruptions and the science of space weather, helioseismology and photospheric magnetic fields.

In order to carry out these observational programs, the Lab has a number of development efforts to produce ultraviolet and infrared detectors, lightweight mirrors, Fabry-Perot spectrographs, coronagraphs, MEMS-based microshutter arrays, and interferometry testbeds. New and innovative instruments and telescopes have also been developed for suborbital missions using both rockets and balloons.

A fairly large number of post-doctoral and graduate students work in the Lab on research projects. LASP is committed to NASA's Education and Public Outreach effort. A vigorous summer internship program provides both High School and graduate students an opportunity to enrich their educational experience through hands on scientific research.

LASP is organized into four Branches: (1) the Solar Physics Branch, (2) the UV/Optical Astronomy Branch, the (3) IR Astrophysics Branch, and (4) the Instrument and Computer Systems Branch. These branches work together to carry out NASA's strategic plan as embodied in the Origins, Structure and Evolution of the Universe, and Sun-Earth Connection themes. The Lab website is: http://lasp.gsfc.nasa.gov.

A list of acronyms is provided at the end of this report.

1.1 Year in Review

The 2001/2002 year was an eventful one in LASP. At the very beginning of this reporting cycle, the Microwave Anisotry Probe (MAP) was successfully launched, and, over a 3 month period, traveled to its final destination of the Earth-Sun Lagrange point L2. MAP has now surveyed the whole sky twice, and the instrument is working quite well. Gary Hinshaw, Ed Wollack, Al Kogut, and Principal Investigator Chuck Bennett and the MAP Team have been working hard to provide the first results early in 2003.

On February 5, 2002, we celebrated the successful Pegasus air-launch of the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), after many years of waiting. LASP team members include Brian Dennis (Lead co-invesigator), Carol Crannell, and Gordon Holman. The instruments and spacecraft are working well and gathering data on solar energetic events. An extensive review of RHESSI is given later in this report.

A team headed by Harvey Moseley, Alex Kutyrev and Bob Silverberg was selected by NASA HQ to develop a microshutter array as a multi-object selector for the Near-Infrared Spectrograph (NIRSpec) on NGST (now JWST). Also, in the last year, the Infrared Array Camera (IRAC) successfully completed testing at GSFC, and was delivered for integration into SIRTF. We all look forward to the launch of SIRTF in January 2003. Moseley is the Instrument Scientist for IRAC.

Servicing Mission 3B to upgrade and repair the Hubble Space Telescope (HST) was a rousing success. HST now has new rigid solar arrays, a new instrument – the Advanced Camera for Surveys (ACS) – and a new mechanical cooler installed to revive the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), which depleted its expendable solid nitrogen coolant in January 1999. Both ACS and NICMOS are now working exceptionally well, thanks to the team at Space Telescope Science Institute, NASA, and GSFC. LASP members Niedner and Carpenter are members of the HST Project, and Kimble is a co-investigator on ACS.

In other good news, the Far Ultraviolet Spectroscopic Explorer (FUSE) is back in operation with no loss in scientific capability, after experiencing some hardware failures in its attitude control system. Several major surveys were completed by the FUSE team this year: a survey of the deuterium abundance in the local interstellar medium, an extensive survey of O VI in the Galactic halo, and surveys of O VI and molecular hydrogen in the Magellanic Clouds. George Sonneborn is the FUSE Project Scientist, and a detailed review is given later in this report.

ARCADE (Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission) enjoyed a successful first balloon flight in November 2001, and the second flight will occur in Fall 2002. The Principal Investigator is Al Kogut, and other members of the team from LASP include Ed Wollack, P. Mirel, D. Fixsen, and M. Limon.

2. PERSONNEL

Richard Fisher stepped down as Laboratory Chief in March 2002 to assume the Directorship of the Sun-Earth Connection Division in the Office of Space Sciences at NASA Headquarters. Nicholas White is the Acting Chief until the position is filled. From the period March through June 2002, William Oegerle, Head of the UV/Optical Astronomy Branch, was the Acting Associate Lab Chief, carrying out the day-to-day running of the Lab. John Wolfgang is the Assistant Chief, and also is the Acting Head of the Instrument and Computer Systems Branch. Doug Rabin is Head of the Solar Physics Branch and William Danchi is Head of the Infrared Astrophysics Branch.

The civil service scientific staff includes: William Behring, Dominic Benford, Charles Bennett, Anand Bhatia, Charles Bowers, Kenneth Carpenter, Edward Cheng, Carol Crannell, Joseph Davila, Brian Dennis, Upendra Desai, Joseph Dolan, Richard Drachman, Tom Duvall, Eli Dwek, Richard Fahey, Jonathan Gardner, Daniel Gezari, Matthew Greenhouse, Theodore Gull, Joseph Gurman, Sara Heap, Gary Hinshaw, Gordon Holman, Harrison Jones, Stuart Jordan, Randy Kimble, Alan Kogut, Yoji Kondo, Terry Kucera, John Mather, Harvey Moseley, Susan Neff, Malcolm Niedner, Ronald Oliversen, Larry Orwig, Arthur Poland, Richard Shafer, Robert Silverberg, Andrew Smith, George Sonneborn, Marvin Swartz, Allen Sweigart, Aaron Temkin, Roger Thomas, Barbara Thompson, Ed Wollack, and Bruce Woodgate.

Eric Smith, who was Deputy Project Scientist for NGST, left LASP in the Fall of 2001 to become the NGST Progam Scientist at NASA Headquarters. Walter Feibelman, Ted Stecher and Ed Sullivan retired and entered the Emeritus program.

The civil service engineering and computing staff includes John Bogert, Patrick Haas, Michael Horn, Peter Kenney, David Linard, William Muney, Joseph Novello, Thomas Plummer, John Stewart, Clarence Wade, and Larry White.

The following Scientists are National Research Council Resident Research Associates: Sergei Ipatov, K. Ishibashi, M. Limon, Neal Miller and Jason Rhodes.

Research associates in the Lab include R. Arendt (SSAI), A. Bier (GST), J. Brosius (CUA), P. Chen (CUA), N. Collins (CUA), D. Cottingham (GST), A. Danks (Emergent Tech), J. Felten, D. Fixsen (SSAI), C. Grady (NOAO), K. Grogan (UMd), R. J. Hill (SSAI), G. Hilton (SSAI), I. Hubeny (NOAO), R. Iping (CUA), S. Kashlinsky (SSAI), L. Koesterke (CUA), S. Kraemer (CUA), A. Kutyrev (SSAI), W. Landsman (SSAI), T. Lanz (UMd), D. Lindler (Sigma Scientific), E. Malumuth (SSAI), D. Massa (GST), P. Mirel (SSAI), T. Norton (Raytheon), S. Odegard (SSAI), P. Palunas (CUA), N. Phillips (SSAI), M. Sahu (CUA), A. Smette (NOAO), J. Staguhn (SSAI), H. Teplitz (CUA), E. Verner (CUA), G. Vieira (CUA), E. Wassell (CUA), G. Williger (NOAO), and X. Zhang (SSAI).

Fred Bruhweiler is a long-term visitor from Catholic University of America (CUA).

Graduate students carrying out their thesis research in LASP are: Lisa Mazzuca (U of Md), Sophia Khan (U of Md)

A. Dekas (Harvard University) was a summer research intern.

2.1 A Special Tribute

Three exceptional LASP scientists retired in 2002. After 42 years of service to NASA, Edward Sullivan retired from his position as Assistant Lab Chief in May 2002. Ed started work at NASA before GSFC was even built! Ed was a mathematician and computer scientist, and over his career Ed developed software that: (1) made the first geodetic calculations from satellite data, (2) determined the shape of the earth's magnetosphere, (3) determined cross-sections of atomic interactions, and (4) simulated impact craters on the moon. He also created the LASP computer facility and supported numerous flight experiments – IUE, GHRS, STIS, UIT, RHESSI, and MAP just to name a few. Ed has joined the Emeritus program, so he can still be found lurking around the halls.

Theodore Stecher retired in January 2002 and also entered the Emeritus Program. Ted has been at GSFC since its inception, and was a true pioneer of space-based astronomy. During his career, he was a co-investigator on the OAO-B mission, US Project Scientist for the Astronomical Netherlands Satellite (ANS), Starlab Project Scientist, and Principal Investigator for the Ultraviolet Imaging Telescope (UIT). He was the recipient of the first Lindsay Award, GSFC's highest scientific achiement award, for his work on OAO-B, and for the discovery of the 2200 Å bump in the interstellar extinction curve. He later co-authored papers ascribing this bump to graphite. His seminal paper in 1967 with D. A. Williams on the photodestruction of H_2 is widely cited by today's theorists working on primordial star formation.

Walter Feibelman retired on June 30, 2002 and also entered the Emeritus program. Walt joined GSFC in 1969, and began work on development of the International Ultraviolet Explorer (IUE). Walt spent much of his career studying planetary nebulae and symbiotic stars with IUE. In 1966, during Saturn's ring plane crossing, Walt obtained a deep exposure of the planet at Allegheny Observatory, and discovered a faint outer ring. This would later be called the E ring. Walt has published over 200 refereed journal papers, and, amazingly, 69 of these are single-author papers. These numbers are only a snapshot however – he continues to publish as an Emeritus.

Today, our work in LASP builds on the legacy left behind by these exceptional individuals.

3. RESEARCH PROGRAMS

3.1 Solar Physics

T. Duvall with J. Zhao and A. Kosovichev (Stanford U.), has studied the mass flows beneath a sunspot using the tomographic technique of time-distance helioseismology. They found evidence for converging, downward-directed flows at depths of $1.5-5$ Mm below the solar surface, but strong outflows at greater depths. The convergent flows agree with Parker's (1979) model of sunspot stability, but only if the spots are relatively shallow ($5-6$ Mm) phenomena. These results were deemed of sufficient interest to the general public that NASA organized a "Space Science Update" panel discussion on November 6, 2001, and the results were broadly reported in the popular media.

T. Kucera studied the temperature distributions of motions in solar prominences using ultraviolet data from SOHO spectrographs CDS and SUMER and the TRACE spacecraft, and Hα data from the Swedish Vacuum Solar Telescope on La Palma. These studies shed light on the mechanisms which energize material seen flowing in these solar structures.

J. Brosius and colleagues advanced the technique for measuring solar coronal magnetic fields from coordinated extreme-ultraviolet (EUV) and radio observations. They obtained three-dimensional maps of a sunspot's coronal field strength and concluded that the sunspot field was not potential. Brosius continues to collaborate with S.M. White (U. Md.), E. Landi, J.W. Cook, and J.S. Newmark (NRL) in the acquisition and analysis of coordinated Solar and Heliospheric Observatory (SOHO) satellite EUV and Very Large Array (VLA) radio observations of solar active regions.

Brosius continued his collaborative EUV spectroscopy work with R.J. Thomas, J.M. Davila, and F.P. Keenan, A.C. Katsiyannis, K.M. Aggarwal, M. Mathioudakis, and D.J. Pinfield of The Queen's University of Belfast, Northern Ireland. Comparisons between emission line intensity ratios measured with GSFC's Solar EUV Research Telescope and Spectrograph (SERTS) sounding rocket experiment and those derived from theoretical calculations generally reveal good agreement between theory and observation. Ions studied most recently include Si IX, Mg VI, and Fe XI. Accurate atomic physics calculations enable (1) reliable identification of lines in solar and stellar spectra, (2) use of line intensity ratios to derive the density of the emitting plasma, (3) use of lines formed at different temperatures to derive the differential emission measure of the emitting plasma, and (4) verification or modifification of the relative radiometric calibration of satellite instruments via density- and temperature-insensitive line intensity ratios.

Brosius analyzed solar flare spectra obtained with SOHO's Coronal Diagnostic Spectrometer (CDS) to look for evidence of alpha particle beams. The high time resolution of CDS solar flare spectra reveal a variety of phenomena, including precursor activity, blueshifted and redshifted emission corresponding to Doppler velocities of hundreds of kilometers per second, and nonthermal line broadening corresponding to hundreds of kilometers per second.

3.2 Atomic Physics

The understanding of space data is often dependent on knowledge of atomic cross sections of excitation processes, whose decay radiation is what is observed. In this context, threshold cross sections are often crucial, because the relevant reactions are initiated by electrons and/or photons whose temperature corresponds to a mean energy much less than that needed to initiate the reaction. Thus only those few in the immediate vicinity of threshold ultimately effect the reaction whose cross section is needed for the diagnostic interpretation of the data. With that as background, A. Temkin has worked on three major research problems during this year: (1) With J. Shertzer (Holy Cross College), he has worked on an extension of a method for accurately calculating low and medium energy electron-atom scattering cross sections, where the Born or such approximations are not accurate, without making a partial wave expansion. In the present work, account is taken of the identity of the incident electron with the orbital electron (the target is taken as hydrogen). This generalization is nontrivial, but the calculations have been completed and a journal article is expected to be written by the end of September 2002. (2) Temkin and D. Tabakov (Whittier College) have worked on the derivation of the threshold law for impact ionization of atoms by electrons. The threshold laws so far derived are controversial. To shed additional light on the subject, the threshold law for a model e-H problem has been investigated, wherein the Coulomb repulsion between the electrons is replaced by a simpler interaction. The present, but still incomplete, result is consistent with a previous purely numerical calculation by another group which has given what seems to be an E^2 threshold behavior, where E is the energy above threshold. The new derivation, in addition to being analytical, gives considerably more insight into how this result comes about. The numerical work is being performed by Tabakov, an undergraduate at Whittier College, who was at GSFC on a summer intern program. (3) A third research was motivated by a recent experiment for threshold ejection of 2 electrons from a neutral atom by photon impact. The experiment revealed non-smooth behavior of the cross section, reminiscent of an effect explained by a theory of Temkin's, called the C-D threshold law for ionization by electron impact. There is a fundamental difference in the physics of the two different projectiles (photon vs. electron). The current approach taken by Temkin and A. Bhatia is to retain the basic ideas of the C-D theory, but also take into account the theoretical differences that arise from the two different projectiles.

R. Drachman continued his program of investigating the fundamentals of atomic theory. He is especially interested in unusual phenomena, those difficult or impossible to observe in the laboratory. His particular expertise lies in understanding systems containing exotic particles: positrons or muons. During this year he worked on the theory of resonances in the scattering of positronium from hydrogen atoms and the low-energy scattering of positronium from helium. Both of these problems are difficult to analyze completely, and they are only now beginning to be accessible experimentally.

Solar active-region observations obtained with SERTS were used by Drs. Lanzafame, Thomas and collaborators to test a new method for determining differential emission measures of the inner solar corona. This method applies a ‘‘data adaptive smoothing’’ approach which takes into account the density dependence of both ionization fractions and excitation coefficients according to the atomic theory implemented in ADAS, the Atomic Data and Analysis Structure. A systematic survey was made to check the validity and limitations of DEM analyses for extracting information such as abundances, spectral line identifications, intensity predictions, and verifications of atomic cross-sections. In particular, it was shown that multiple peaks in DEM distributions derived in previous studies may be spurious, resulting from inaccurate treatment of population densities or from improper smoothing.

3.3 Solar System

R. Oliversen, F. Scherb (U. Wisconsin) and collaborators continue work on Io's atmosphere and its interaction with the plasma torus through extensive and continuing high-resolution ground-based [O I] 6300 Å observations. Their published results show Io is a probe of the plasma torus as the average [O I] emission intensity is correlated to Io's location within the plasma torus. Furthermore, the data indicate that current time independent torus models are inadequate to explain the torus conditions being probed by Io.

Oliversen and F. Scherb, W. Harris, and J. Morgenthaler (U. Wisconsin) continue work on neutral (O, OH, C, and H) emission from comet Hale-Bopp. Large aperture [O I] 6300 Å measurements suggest a revision in the standard OH to O (^{1}D) branching ratio. The OH, C, and H measurements all indicate a large and complex, collisionally thick, coma environment and highlight the need for comprehensive global modeling of the system.

M. Niedner is collaborating with colleagues J. Brandt (U. New Mexico), M. Snow (U. of Colorado), and others, on a study to identify the mechanism(s) responsible for the production of disconnection events (DEs) in cometary plasma tails. The effort utilizes the DE database developed through the years by Niedner, Brandt, and colleagues, as well as solar-wind and interplanetary magnetic field data from interplanetary and cometary encounter spacecraft. A paper is in preparation which gives added support to the Niedner-Brandt frontside magnetic reconnection model of DEs.

3.4 Stellar Astrophysics

A spectroscopic analysis of ''blue hook'' stars by A. Sweigart, S. Moehler (U. Kiel), W. Landsman, and S. Dreizler (U. Tuebingen) suggests that the these stars are the progeny of those which have undergone extensive internal mixing during a helium-core flash on the white dwarf cooling curve.

Sweigart, B. Pritzl (NOAO), H. Smith (Michigan State U.), and M. Catelan (PUC), using HST data, found that the pulsation periods of the RR Lyrae stars in the metal-rich globular cluster, NGC 6388 are anomalously long, suggesting that NGC 6388 might represent a new Oosterhoff group. Their observations also found several candidate Population II Cepheids which would make NGC 6388 the most metal-rich cluster known to contain such variables. Sweigart has computed new stellar evolutionary sequences to determine if the long pulsation periods of the RR Lyrae variables in Oosterhoff II globular clusters might be due to evolution from the blue horizontal branch. Stars which evolve through the instability strip from the blue horizontal branch will be brighter and have longer periods than stars near the zero-age horizontal branch. However, the calculations show that such stars spend too little time within the instability strip to explain the observed number of RR Lyrae variables in such Oosterhoff II clusters as M15.

Sweigart, S. Moehler (U. Kiel), W. Landsman, and F. Grundahl (Aarhus U.) participated in a study of the physical properties of the hot horizontal branch stars in the second parameter globular clusters M3 and M13. The stars hotter than 12,000 K in both M3 and M13 show evidence for helium depletion due to gravitational settling and iron enrichment due to radiative levitation. Their spectroscopic study indicates that model atmospheres with highly nonsolar abundance ratios may be necessary to fully resolve the low gravity problem of the blue horizontal branch stars.

K. Carpenter continued his collaborative studies, with E. Bohm-Vitense (U. of Washington) and R. Robinson (CUA), of the mechanisms heating the chromospheres, transition regions, and coronae of cool stars. They use ultraviolet, low-resolution spectra from observations with the Space Telescope Imaging Spectrograph (STIS) aboard HST, of Hyades main-sequence F stars to obtain measurements of chromospheric and transition layer emission line fluxes and assess their dependence on B-V, rotation and age. The results show that the line-flux decrease observed near spectral type F5 is not due to a change in the surface filling factor but rather due to a change of the relative importance of different heating mechanisms. Carpenter also collaborated with Drs. N. Evans (CfA) and R. Robinson in HST studies designed to obtained improved mass estimates of Cepheid stars in binary systems. The observations were obtained near the end of this reporting period and are currently under examination.

Sonneborn, with Massa, A. Fullerton (JHU) and J. Hutchings (DAO) completed a study of the stellar wind ionization balance in massive stars by analyzing spectra of 25 O stars in the LMC observed by the Far Ultraviolet Spectroscopic Explorer (FUSE). The analysis used wind line profiles for C III, N III, S IV, P V, S VI, and O VI. Because several of these lines are unsaturated, they were able to determine meaningful optical depths as a function of normalized velocity (v/v_∞). They found that, with the exception of O VI in all stars and S VI in later O-type stars, that the ionization in the wind shifts toward lower ionization states with higher v/v_∞, contrary to the expectations of the nebular approximation. This result implies that the dominant production mechanism for O VI and S VI in the later O stars differs from the other ions. A paper on this work was submitted to ApJ.

Sonneborn, in collaboration with Massa, Fullerton, N. Walborn (STScI), published an atlas of the $900-1200$ Å region in the spectra of 47 OB stars in the Large and Small Magellanic Clouds, observed at high resolution by FUSE. The systematic trends in the numerous stellar-wind features in this region, some from species (and ionizations) not represented at longer wavelengths, are charted as a function of the optical spectral types. The FUSE sample is by far the most powerful to date for that purpose. Most of these stars were previously observed at longer ultraviolet wavelengths by HST and in the optical from the ground with high-resolution, digital instruments. Therefore, very comprehensive physical modeling of these OB atmospheres and winds now becomes possible. This atlas will serve as a guide to the FUSE Magellanic Cloud OB database for that purpose. The Magellanic Cloud sample provides a very important complement to the FUSE database of Galactic OB counterparts, both because the lower extinction and interstellar H_2 absorption toward the Cloud stars allow a much clearer view of the stellar spectra below 1100 Å , and because of the metallicity differences among the three galaxies. In particular, most wind features in the SMC spectra are significantly weaker than those in the LMC at the same spectral types.

D. Massa, R. Prinja (UCL) and A. Fullerton (JHU) conducted a survey of stellar wind variability in B supergiants. Massa also remained actively involved with FUSE data on two projects. One involves highly ionized gas in the Galactic halo and the other deals with the variability of O VI in the winds of early type stars. Massa continued his collaboration with E. Fitzpatrick (Villanova) on modelling the atmospheres of main sequence B stars. Their most recent project used eclipsing binaries composed of main sequence B stars to determine the distance to the Large Magellanic Cloud.

R. Iping, Gull, Massa, Sonneborn, and J. Hutchings (DAO) are studying the far-UV spectra of several Luminous Blue Variables. FUSE observations were obtained for Eta Carinae, P Cygni, and AG Carinae. The observed flux from Eta Car at 1160 Å in the FUSE 30×30 arcsec aperture is 20 times larger than observed by HST/STIS/E140M at the same wavelength through a 0.2×0.2 arcsec aperture. This difference implies that the observed far-UV spectrum is formed in an extended $\sim 2-3$ arcsec diameter UV scattering envelope. The flux level declines toward the Lyman limit where converging molecular and atomic hydrogen features completely blanket the spectrum. The shape of the spectrum shortward of 1110 Å is dominated by strong absorption bands of interstellar molecular hydrogen. In addition to many strong interstellar atomic species, the spectrum contains several prominent broad absorption features (N I, Fe II, P II, C III) that they identify with high-velocity gas. These features are broad ($\sim$200 km s^{-1}) with unsaturated absorption, whereas Fe II lines in the STIS spectrum are highly saturated, implying that the high-velocity material is patchy and/or only partly covers the UV emitting surface. The far-UV spectra of P Cygni and AG Carinae are very similar and indicate a cooler atmosphere than Eta Car.

B. Woodgate, C. Grady and collaborators have continued a program of circumstellar coronagraphy using HST/STIS, on young $1-2$ $M_{\odot}$ stars of ages $2-10$ Myr. They have found several previously unknown highly structured disks and jets. Some of the disks show clearings possibly caused by planets. At least four jets have been found, two previously unknown, extending the era of jets to about 6 Myr, into the era of planet formation.

B. Woodgate, with P. Palunas (U. Texas), C. Grady, J. Rhodes and E. Wassell, have used the GSFC Fabry-Perot as a narrow band coronagraph to provide velocity information with two spatial dimensions for the jets of young Herbig AeBe stars and T Tauri stars identified in HST/STIS coronagraphic surveys. They have found large well-collimated extensions of the jets of two T Tauri stars (previously unknown), determined the velocity of the jet in DL Tauri, and found an extension of the jet in HD163296.

Heap performed coronagraphic observations of β Pictoris with HST/STIS. The superb, high-resolution images show that the inner part of the disk is inclined by about 5 degrees with respect to the main disk. Long-slit coronagraphic spectrograms oriented along the inner disk indicate that the reflectance of the inner disk at $r = 3'' = 60$ AU is neutral over the spectral region, 3000−5600 Å .

S. Heap, Lanz, and colleagues are making an extensive analysis of 17 O-type stars in the Small Magellanic Cloud that have been observed by HST and FUSE. The analysis, which involves detailed NLTE atmospheric models recently constructed by Lanz & Hubeny, has the following goals: (1) calibration of spectral properties in terms of fundamental parameters; (2) resolution of the discrepancy between spectroscopic masses and evolutionary masses; and (3) evidence for mixing of nuclear-processed elements. They derive a significantly lower temperature scale for O-type stars than previously assumed; hence, the luminosities, inferred masses, and ionizing fluxes are lower. They also find a wide (30×) range in the atmospheric nitrogen abundance. While some nitrogen enrichment is expected in rapidly rotating stars, half the stars in their sample have much higher nitrogen abundances than is predicted by evolutionary models with rotation.

Heap and colleagues recently completed an observing program with STIS to obtain UV spectra of stars like the early Sun and reported their preliminary results at several conferences. Their project, aimed at improving our understanding of the UV photochemistry of the early Earth, has three phases: (1) to establish the far-UV flux of the early Sun from observations of young solar analogs (YSAs); (2) to construct photochemical models of the early Earth using the UV flux as a boundary condition; and (3) to evaluate the effect of the solar EUV-UV flux on the habitability of the early Earth. Their observations indicate that the far-UV spectra of YSAs are dominated by the chromospheric emission of Lyman α. After correcting the observed flux for absorption by the intervening interstellar medium, they estimate that the UV luminosity of the Sun at the time when life first formed on Earth was about 7 times greater than at present.

C. Bowers has collaborated with H. Dinerstein (U. Texas) and others on a planetary nebulae observation program that uses absorption spectroscopy from both STIS and FUSE to probe the nebular envelope looking particularly for the presence of molecular hydrogen in the ultraviolet spectra. The primary goals are to produce a highly sensitive search for the presence or absence of H_2 and determine under what conditions such a neutral species exists, and to use the spectra obtained to investigate the conditions within the photodissociation regions which are subjected to intense ultraviolet flux from the nearby star. A detailed analysis of the first H_2 source has been completed. An unexpected result of this project was the discovery of enhanced Ge abundance from an ultraviolet line in one of our targets (BD+30°3639), an element synthesized in the initial steps of the s-process and which can be self-enriched in planetary nebulae.

With the goal of explaining the origin of strong and rich Fe II spectra in astrophysical objects, E. Verner, T. Gull , F. Bruhweiler (CUA), S. Johansson (U. Lund), K. Ishibashi, and K. Davidson (U. Minnesota) focused on the analysis of Fe II emission in the spectrum of the very bright Weigelt Blobs, B and D, located within a light day of Eta Carinae. The testing of Fe II simulations not only revealed details of physical conditions in the emitting region but also indicated shortcomings in the atomic data for the Fe^{+} ion. They plan further observations of Eta Carinae with HST/STIS to further refine their model.

Gull has worked with an international team that continues to build observations of Eta Carinae with HST, Chandra, RXTE, FUSE and several ground-based observatories including the CTIO 4-Meter and the UVES on the VLT. Successful proposals for Eta Carinae observations have been submitted by K. Davidson (U. Minnesota) for HST, M. Corcoran (GSFC) for Chandra, Gull for FUSE, and Kerstin Weis (MPI/Germany) for the UVES on the VLT. In July of 2002 he and Bruce Balick (U. Washington) organized the biannual workshop on Eta Carinae to focus on the kinematics of the Homunculus and to discuss plans for monitoring the upcoming minimum of the Central Source. Gull is directly coordinating the HST Treasury program to observe Eta Carinae at key times before, during and after the minimum, predicted to begin around June 19, 2003.

A number of graduate students at the Universities of Lund and Minnesota and Catholic Univ of America have used the large dataset on Eta Car in their research programs. T. Zethson and H. Hartman (Lund) have identified [Sr II] and Sr II in the emission line spectrum. N. Smith (Minnesota) has defended his thesis on the variations in the stellar wind with polar latitude. His research support was funded by the NASA Graduate Student Research Program through GSFC with Gull as his mentor. Wissing (CUA), Bruhweiler and Gull performed studies with archived IUE spectra of Eta Carinae. The IUE observations, over an eighteen year interval, are found to be consistent with excitation varying with a 2020 day period. During the broad maximum, N III], Fe III, Si IV, and Fe II emission lines are strong, but they start to fade as the period progresses and completely disappear during the minimum that lasts several months.

Ishibashi and Gull completed a study of the Little Homunculus of Eta Car, an ionized bi-lobed structure within the classically known Homunculus. Based upon the kinematics and structure, they determined that this structure likely is ejecta thrown out of Eta Carinae in the 1890's when a secondary eruption was known to have occurred (the primary eruption being in the 1840's).

G. Vieira, A. Danks, and Gull have been studying the absorption spectra of ejecta in the line of sight to Eta Car's Central Source with the UV echelle modes of STIS. Between 2400 and 3160 Å , over 500 absorption lines have been identified, many with up to twenty absorption components. Some of these systems have been identified as lines of Fe II, Cr II, and Fe I. In addition, Ti II and V II are also found, the latter of which has never been detected in the ISM.

Gull and Davidson (U. Minnesota) headed several very successful proposals to use the STIS on HST to follow the changes in the Central Source and the Weigelt Blobs in the early to middle stages of the spectroscopic period. The exceptional angular resolution of HST, coupled with the various spectral formats of STIS, have allowed the separation of the broad P-Cygni profiles of the Central Source from the narrow emission-line regions as close as 0.1″ from the bright source. The extracted nebular spectrum was studied by T. Zethson (U. Lund) for his doctoral thesis. Over 2000 emission lines were identified between 1640 and 10400 Å .

P. Lundqvist (Univ of Stockholm, Sweden), Gull and others have successfully obtained time-tagged optical/UV spectra of several pulsars, including the Crab Pulsar. The pulse profile of pulsar PSR0656+14 is most peculiar when compared to its radio and x-ray profiles. Modeling is underway to understand this peculiarity.

Gezari has also been actively collaborating with W. Danchi on mid-infrared imaging observations of star formation regions and mass-losing stars using the Keck 10-meter telescope. Dramatic images of Orion BN/KL are being analyzed and are the basis for three papers in preparation; one on the luminous sources imbedded near IRC2, one on unusual new time-variable structure observed in the BN Object, and one on the global structure and energetics of the entire complex and the relationship with molecular, maser and radio continuum sources.

3.5 Supernovae

Sonneborn, Iping, and Massa, with P. Lundqvist (Stockholm), W. Blair (JHU), and M. Shull (Colorado) have used FUSE to detect O VI 1032, 1038 Å emission from the circumstellar gas around SN 1987A. O VI is the highest ionization state yet detected in line emission from the SN 1987A circumstellar material. The O VI emission line profiles are narrow ($FWHM < 35$ km s^{-1}) and have a heliocentric radial velocity of $+280$ km s^{-1}. This places the emitting gas at rest relative to the supernova. Spectra obtained in 2000 Oct. and 2001 Sept. have essentially the same O VI fluxes. Simultaneous spectra obtained in the other FUSE apertures, positioned about 100 arcsec from SN 1987A, show nothing at the O VI wavelengths, eliminating diffuse emission in the LMC as a possible source of the O VI feature. The FUSE spectra of the two B-type stars near SN 1987A provide the line profiles of interstellar absorption on the sight lines within 3 arcsec of SN 1987A. The interstellar line profiles show that that intervening absorption has a negligible effect on the shape of the O VI emission. The narrow O VI emission probably originates from the H II region of very low density ($n < 100$ cm^{-3}) unshocked gas near the inner circumstellar ring that was ionized by the supernova outburst in 1987. It is unlikely that the narrow O VI emission is the result of recent reionization of circumstellar gas by X-rays produced by shock interactions. The observed O VI fluxes are in agreement with recombination models (Lundqvist 1999, ApJ, 511, 389) for the circumstellar material.

Sonneborn, with J. Pun (Hong Kong), E. Michael and R. McCray (Colorado), R. Kirshner (CfA), and the Supernova Intensive Study collaboration, analyzed HST/STIS long-slit spectra of the optical and ultraviolet (1150−10270 Å) emission lines of the rapidly brightening spot 1 on the equatorial ring of SN 1987A between 1997 September and 1999 October (days 3869−4606 after outburst). The emission is caused by radiative shocks created where the supernova blast wave strikes dense gas protruding inward from the equatorial ring. Nebular analysis showed that optical emission lines come from a region of cool ($T_e \sim 10^4$ K) and dense ($n_e \sim 10^6$ cm^{-3}) gas in the compressed photoionized layer behind the radiative shock. The observed line widths indicate that only shocks with shock velocities $v_s < 250$ km s^{-1} have become radiative, while line ratios indicate that much of the emission comes from yet slower ($v_s < 135$ km s^{-1}) shocks. The observed UV flux brightening of the spot can be explained by the increase in shock surface areas as the blast wave overtakes more of the protrusion. The observed flux ratios of optical to highly ionized UV lines are a factor of $\sim 2-3$ larger than predictions from the radiative shock models.

3.6 Interstellar Medium

Sonneborn, in collaboration with W. Moos (JHU), K. Sembach (STScI), A. Vidal-Madjar (IAP), D. York (Chicago), and other members of the FUSE Science Team, completed the first study with FUSE of deuterium in the Local Interstellar Medium. Sonneborn led the analysis of the sight line toward BD $+28$ 4211, one of seven lines of sight used to determine the column densities of D I, N I, and O I in the local interstellar medium (LISM) at distances from 37 to 179 pc. The eight D/H papers were published in the same issue of ApJ Supplements. Five of the sight lines are within the Local Bubble, and two penetrate the surrounding H I wall. The weighted mean of D/H for these five sight lines is $(1.52 \pm 0.08)\times 10^{-5}$ (1 σ uncertainty in the mean). It is likely that the D/H ratio in the Local Bubble has a single value. The D I/O I ratio for the five sight lines within the Local Bubble is $(3.76\pm 0.20)\times 10^{-2}$. It is likely that O I column densities can serve as a proxy for H I in the Local Bubble. The weighted mean for O I/H I for the seven FUSE sight lines is $(3.03\pm 0.21)\times 10^{-4}$, comparable to the weighted mean $(3.43\pm 0.15)\times 10^{-4}$ reported for 13 sight lines probing larger distances and higher column densities.

Sonneborn, B. Savage and B. Wakker (U. Wisconsin), K. Sembach (STScI), Oegerle and other members of the FUSE Science Team, completed a major study of O VI 1031.93 and 1037.62 Å absorption associated with gas in and near the Milky Way, as detected in the FUSE spectra of 100 extragalactic targets and two distant halo stars. This project was one of the primary scientific objectives of the FUSE mission. Strong O VI absorption over the velocity range ~ -100 to 100 km s^{-1} reveals a widespread but highly irregular distribution of halo (thick disk) O VI, implying the existence of substantial amounts of hot gas with $T \sim 3\times 10^{5}$ K in the Milky Way halo. Large irregularities in the distribution of the absorbing gas were found to be similar over angular scales of $<1°$ to $\sim 180°$, implying a considerable amount of small and large scale structure. The inferred small-scale structures must be quite common in order to provide a large sky covering factor of halo O VI along paths to extragalactic objects. High velocity O VI ($-500 < v_{LSR} < +500$ km s^{-1}, excluding the -100 to 100 km s^{-1} range of the halo and disk gas) traces a variety of phenomena, including tidal interactions with the Magellanic Clouds, accretion of gas, outflowing material from the Galactic disk, and intergalactic gas in the Local Group. Some of the high-velocity O VI features are associated with known H I 21-cm high-velocity structures (the Magellanic Stream, Complexes A and C, etc.). The study concludes that collisions in hot gas are responsible for most of the O VI, and not photoionization, even if the gas is irradiated by extragalactic UV background radiation. Consideration of possible sources of collisional ionization favors production of some O VI at the boundaries between warm/cool clouds of gas and a highly extended ($r > 70$ kpc), hot ($T > 10^{6}$ K), low density ($n \sim 10^{-4} - 10^{-5}$ cm^{-3}) galactic corona or Local Group medium. Such a medium is consistent with predictions

R. Iping and Sonneborn, with E. Jenkins and D. Bowen (Princeton) are analyzing interstellar O VI 1031.9 Å absorption toward several O and WR stars in the Tr 16 cluster in Carina, based on high-resolution FUSE spectra. The objective of this study is to investigate the distribution of O VI absorption within the cluster. The target stars include CPD -59 2628, CPD -59 2627, CPD -59 2632, HDE 303308, CPD -59 2600, CPD -59 2603, HD 93205, HD 93204, HD 93162, HD 93250 and HD 93308 (Eta Car). Two interstellar molecular hydrogen transitions, Lyman 6-0 P(3) 1031.19 Å and Lyman 6-0 R(4) 1032.35 Å , are located very close to the interstellar O VI feature. These lines are being modelled by analyzing other P(3) and R(4) transitions in the FUSE spectra. The column densities and distribution of the O VI ion in the Carina Nebulae iare being determined by using Gaussian profile fitting procedures and apparent optical depth techniques.

Sonneborn, in collaboration with J. Tumlinson and M. Shull (Colorado) and other members of the FUSE Science Team, completed a survey of molecular hydrogen along 70 sight lines to the Small and Large Magellanic Clouds, using hot stars as background sources. FUSE spectra of 67% of observed Magellanic Cloud sources (52% of LMC and 92% of SMC) exhibit absorption lines from the H_2 Lyman and Werner bands between 912 and 1120 Å . The survey is sensitive to $N(H_2) > 10^{14}$ cm^{-2}. The highest column densities are log $N(H_2) = 19.9$ in the LMC and 20.6 in the SMC. They found reduced H_2 abundances in the Magellanic Clouds relative to the Milky Way, with average molecular fractions $f(\mathrm{H_2}) > 0.010^{+0.005}_{-0.002}$ for the SMC and $f(\mathrm{H_2}) > 0.012^{+0.006}_{-0.003}$ for the LMC, compared with $f(\mathrm{H_2}) > 0.095$ for the Galactic disk over a similar range of reddening. These results imply that the diffuse H_2 masses of the LMC and SMC are 8×10^{6} and $2\times 10^{6} M_{\odot}$, respectively, 2% and 0.5% of the H I masses derived from 21 cm emission measurements. The LMC and SMC abundance patterns can be reproduced in ensembles of model clouds with a reduced H_2 formation rate coefficient and incident radiation fields ranging from 10-100 times the Galactic mean value. We find that these high-radiation, low formation rate models can also explain the enhanced $N(J=4)/N(J=2)$ and $N(J=5)/N(J=3)$ rotational excitation ratios in the Clouds.

Sonneborn, in collaboration with C. Mallouris, D. York, D. Welty (U. Chicago), studied the interstellar medium in the northeastern part of the main ''bar'' of the Small Magellanic Cloud by analyzing absorption lines in FUSE spectra of the Wolf-Rayet binary Sk 108. Both the Galactic and SMC gas toward Sk 108 seem to be predominantly neutral, although a significant fraction of the SMC gas is ionized. The column densities of P II, S II, and Ar I are consistent with essentially solar ratios, relative to Zn II, in both the Galactic and SMC gas; the column density of N I remains somewhat uncertain. Strong absorption from N III, S III, and Fe III has revealed a significant ionized component, particularly in the SMC. O VI is present, but relatively weak, especially in the Galactic gas. The N(C IV)/N(O VI) ratio varies somewhat within the SMC, suggesting that several processes may contribute to the observed high ion abundances.

Oegerle, E. Jenkins, D. Bowen (Princeton U.), R. Shelton and P. Chayer (JHU) neared completion of a FUSE survey of OVI 1032 interstellar absorption along the line of sight to 25 white dwarfs within the local interstellar medium out to distances of $\lesssim 100$ pc from the Sun in the Galactic plane. The OVI absorption is observed to be quite weak and patchy in all directions. The strength of the absorption is weaker than predicted by evaporative interface models, implying that conduction at the surfaces of the cool clouds may be inhibited by magnetic fields. The OVI data appears to be inconsistent with the model proposed by Breitschwerdt & Schmutzler (1994), in which highly ionized gas at low kinetic temperature ($\sim$50,000 K) permeates the Local Bubble.

3.7 Extragalactic Astronomy

Woodgate, in collaboration with D. York (U. Chicago) and V. Kulkarni (U. South Carolina), has used the GSFC Fabry-Perot tunable narrow band imager to search for Lyman α galaxies associated with QSO Lyman α absorption lines, and have identified two candidate galaxies. These require spectroscopic confirmation.

R. Fahey has performed quasi-realistic modelling of the observable emission and absorption effects of the presence of a wind in conjunction with the broad emission line forming region in the AGN NGC 4151 and NGC 3516.

P. Palunas, Collins, Gardner, Malumuth, Rhodes, Hill, Smette, Teplitz, Williger and Woodgate obtained deep $UBVRI+$ narrow band images of a 0.5 square degree region around and including the HDF-South using the Big Throughput Camera on the CTIO 4-m telescope. The data have been used to search for quasars, and to measure the evolution of the angular galaxy-galaxy correlations as a function of photometric redshift. The catalog and images were made publicly available through the World Wide Web, and a paper describing the dataset was submitted to the Astrophysical Journal Supplement.

Using HST/STIS, H. Teplitz, Collins, Gardner, Hill, Heap, Lindler, Rhodes and Woodgate obtained slitless spectra of $\sim$160 square arcminutes in parallel to prime HST observations as part of the STIS Parallel Survey (SPS). They identified 131 low to intermediate redshift galaxies detected by optical emission lines. The sample contains 78 objects with emission lines that were inferred to be redshifted [OII] 3727 emission at $0.43<z<1.7$. The co-moving number density of these objects is comparable to that of Hα-emitting galaxies in the HST/NICMOS parallel observations. They measured the luminosity function of [OII]-emitting galaxies at a median redshift of $z=0.9$. The luminosity function showed strong evolution from the local value, as expected. By using random lines of sight, the SPS measurement complements previous deep single field studies. The density of inferred star formation at this redshift is consistent with a $(1+z)^4$ evolution in global star formation since $z\sim1$. To reconcile the density with similar measurements made by surveys targeting Hα may require substantial extinction correction.

J. Gardner and Teplitz, working with a team led by K. Nandra, analyzed the X-ray properties of a large sample of $z\sim3$ Lyman break galaxies in the region of the Hubble Deep Field-North, derived from the 1 Msec public Chandra observation. Of the sample of 148 galaxies, four are detected individually and are probably AGN. Stacking the remainder gave a 6σ detection of the average X-ray luminosity of 3.4×10^{41} ergs s^{-1} per galaxy in the rest-frame $2-10$ keV band. A comparison sample of 95 $z\sim1$ ''Balmer break'' galaxies have a mean luminosity a factor of ~5 lower than the high redshift sample (excluding obvious AGN). The average ratio of ultraviolet to X-ray luminosities is the same in both samples, allowing the team to constrain the star formation rate at $z\sim3$ from an X-ray perspective, implying that the star formation rate is $60M_\odot$ yr^{-1}. This value is in agreement with the extinction-corrected UV estimates, and provides an external check on those estimates.

T. Gull and R. Kimble continue to work with the HST Gamma Ray Burster Team for Cycle 11 (an activity that started in Cycle 9). Triggers to activate studies have been very limited in recent months with the shutdown of BeppoSax. The team is prepared to obtain ultraviolet spectroscopy of a GRB as was successfully demonstrated with GRB000301C.

S. Neff, in collaboration with J. Ulvestad (NRAO) and S. Campion (UMd and SSAI) neared completion of a large VLA (radio) study of compact radio sources in an age-ordered galaxy merger series. Thermal radio sources, detected in the early-stage mergers, are thought to be very young massive star-clusters, which may evolve into globular clusters. Obscured massive-star masses of $10^4-10^{5.5}$ M$_\odot$ and ionized gas masses of 10^3-10^5 M$_\odot$ are derived for the thermal sources, suggesting that they are composed of several typical or one super-star cluster (SSC). Supernova rates of $0.2-2$ per year are deduced, typically about an order of magnitude larger than the currently observed O-star populations in these systems. Keck mid-IR follow-up observations are planned for several of these sources in collaboration with K. Johnson (U. Wisc. and NRAO).

Neff, in collaboration with S. Teng (U. Md) and J. Ulvestad discovered a compact radio source with a very inverted spectrum in the merger system Arp 299. The source was initially thought to be the most massive obscured super-star-cluster (SSC) yet discovered. Analysis of many (30+) archival data sets showed that the possible SSC varied in brightness, casting doubt on its identity as a cluster in Arp 299. Further observations are planned to resolve this question. The same group conducted a VLBA study of the centers of the galaxies in Arp 299 (to search for weak AGN, which they did not find) and plan VLBA observations of the possible SSC.

Neff, S. Campion (UMd and SSAI) and J. Ulvestad, in a study of the galaxy merger NGC 3256, identified several compact radio sources with Ultra-luminous X-ray sources (found by Lira *et al.* in new Chandra observations). The radio sources are associated with regions of star formation; their properties rule out identification of the sources with micro-quasars or background BL-Lac objetst. They are consistent with SNe detonating in dense environments or possibly with very massive (1000+ $M_\odot$) X-ray binaries.

Neff, in collaboration with G. Fabbiano, A. Zensus, and A. Rots (CfA) completed an initial radio/X-ray investigation of the hot ISM in the prototypical disk-disk merger ''the Antennae.'' Comparisons between the non-thermal diffuse radio emission and the diffuse soft X-ray emission discovered in the Chandra images show that there is extensive dust absorption of X-rays in front of parts of the system, sharp boundaries (probably shocks) where the X-ray and radio emission are interleaved, and a wide range of ISM temperature. Neff, Iping (PI) and Sonneborn, successfully proposed for FUSE observations of the hot ISM associated with ''the Antennae.'' Observations have been unfortunately delayed because of the FUSE pointing constraints.

Neff, in collaboration with J. Hutchings (DAO) and a host of others completed an HST project to image the host galaxies of QSOs. This work primarily focused on methods for removing the PSF response from the AGN in order to study the underlying galaxy. They found that host galaxy bulge mass measurement may be severely corrupted by improper PSF removal, and therefore that the assumption that AGN BH mass is correlated with galaxy bulge mass is an oversimplification .

N. Miller used radio emission to select active galaxies in Abell clusters in order to study the effect of the cluster environment on galaxy evolution. He and F. Owen (NRAO) completed an optical spectroscopic study of nearby clusters, which revealed a population of star-forming galaxies with weak or absent [OII] emission. These galaxies were shown to be the result of high nuclear dust extinction, and appear to be located more toward the centers of clusters than normal star-forming galaxies. This suggests that they are the result of some cluster environmental process. The study also noted the importance of active galaxies lacking any optical emission lines, as they form a significant fraction of radio-selected galaxies and must be understood in order to determine whether high redshift analogs are powered by star formation or active nuclei.

Miller and Owen also investigated the μJy radio populations of two clusters (A2255 and A2256) believed to be among the better examples of cluster-cluster mergers. The kinematics of the two clusters were investigated in depth along with Oegerle, J. Hill (Univ of Arizona), and R. Ganguly (STScI). A2255 exhibited a strong excess in its fraction of galaxies with radio emission, which was shown to be caused primarily by optically-faint star-forming galaxies. This cluster appears to be in the process of assembly, with numerous outlying groups and evidence for a recent merger. The radio population of A2256 appears normal when compared with other clusters. However, the radio-selected star-forming galaxies in A2256 belong primarily to a group which recently merged with the cluster. These results indicate the importance of the hierarchical build-up of large-scale structure on galaxy evolution.

M. Postman (STScI), T. Lauer (NOAO), Oegerle, and M. Donahue (STScI) completed the KPNO Deeprange Distant Cluster Survey catalog. An automated search for galaxy clusters was conducted within a contiguous 16 square degree $I-$ band survey in the north Galactic hemisphere. A matched filter detection algorithm was used to identify 444 cluster candidates in the range $0.2 \leqslant z \leqslant 1.2$. The full catalog along with the results from a follow-up spectroscopic survey was submitted for publication to the Astrophysical Journal. The estimated redshift distribution of the cluster candidates is consistent with a constant comoving density over the range $0.2 \leqslant z_{est} \leqslant 0.8$. A decline in the cluster space density by more than a factor of 3 over this redshift range is rejected at $>99.9\%$ confidence level. The space density of $\Lambda_{CL} \geqslant 40$ clusters in the survey was found to be ~ 1.5 times higher than the local distribution of comparably rich Abell RC $\geqslant 0$ clusters. The Λ_{CL} distribution is consistent with a power-law. The discrepancy between the space density of Abell clusters and the clusters in this survey declines quickly as Λ_{CL} increases, suggesting that the difference at lower richness is due to significant incompleteness in the Abell catalog. A percolation analysis revealed that $10-20\%$ of the spectroscopically confirmed distant clusters are linked into superclusters at overdensities between $10 < (\delta\rho/\rho) < 50$, similar to what is seen in the local cluster distribution. This suggests that there has been little evolution of the cluster-cluster correlation length for $z \leqslant 0.5$.

Oegerle and colleagues L. Cowie, E. Hu (U. of Hawaii), A. Davidsen, K. Sembach (JHU), J. Hutchings (DAO), and E. Murphy (U. of Virginia) completed a far ultraviolet spectroscopic study with FUSE of the cores of the massive cooling flow clusters Abell 1795 and Abell 2597. As the intracluster gas cools through 3×10^5 K, it should emit strongly in the OVI 1032,1038 Å resonance lines. However, OVI emission was not detected in A1795. OVI 1032 was detected in A2597, but was quite weak compared to expectations from cooling flow models. CIII 977 was detected in A2597 and very weakly in A1795. These observations provide evidence for a direct link between the hot (10^7 K) cooling flow gas and the cool (10^4 K) gas in the optical emission line filaments. Several explanations for the lack of detection of OVI emission in A1795 and the weaker than expected flux in A2597 were considered, including extinction by dust in the outer cluster, and quenching of thermal conduction by magnetic fields. It was concluded that a turbulent mixing model, with some dust extinction, could explain our OVI results while also accounting for the puzzling lack of emission by FeXVII in cluster cooling flows.

Heap and collaborators presented preliminary results on the low-redshift Lyα forest based on their STIS spectrum of 3C 273. A total of 121 intergalactic Lyα-absorbing systems were detected, of which 60 are above the 3.5σ completness limit, $\log N_{\mathrm{HI}} \approx 12.3$. The median line-width parameter, $b = 27$ km s^{-1}, is similar to that seen at high redshift. However the distribution of HI column densities has a steeper slope, $\beta = 2.02 \pm 0.21$, than is seen at high redshift. Overall, the observed N_{HI}–b distribution is consistent with that derived from a ΛCDM hydrodynamic simulation.

The same spectrum of 3C 273 was used to study the metallicities of two Lyα clouds in the vicinity of the Virgo Cluster. Heap and collaborators found that the $z = 0.00530$ absorber has a gas-phase carbon abundance that is roughly 1/15 solar, and a silicon abundance that is overabundant relative to C by ~ 0.2 dex. The high Si/C abundance ratio suggests that the gas was enriched by SN II ejecta delivered to the IGM by galactic winds.

Despite excellent new data on the Lyα forest toward 3C 273 gained from high-resolution HST/STIS spectra, the connection between the Lyα forest and galaxies remains elusive. Specifically, Heap *et al.* found: (1) no correlation of Lyα absorbers with galaxies except for the Virgo cluster of galaxies; (2) no significant clustering of Lyα absorbers; (3) no

Lyα void larger than 5500 km s^{-1} across, i.e. no larger than what would be expected from a random distribution of absorbers.

Heap and colleagues also obtained HST/STIS spectra of the QSO PKS 0405-123 ($z=0.574$) as part of their project to determine the physical properties of the Lyα forest at low redshift. They detected 59 Lyα absorbers at 4.0σ significance to an 80% completeness limit of log$N_{HI}=13.3$ over $0.002<z<0.423$. They found evidence for a significant void in the Lyα forest at $0.032<z<0.081$. They also found velocity correlations of up to 250 km/s between Lyα absorbers with log$N_{HI}\geqslant13.3$ and 45 galaxies.

Using HST/STIS, Heap and colleagues obtained an ultraviolet spectrum of the QSO HE 2347-4342 to investigate the Gunn-Peterson effect. They used the STIS spectrum together with a Keck-HIRES spectrum covering the corresponding H I Lyα forest to calculate a one-dimensional map of the softness, S, of the ionizing radiation along the line of sight toward HE 2347-4342. (S is the ratio of the H I to He II photoionization rates.) They found that the HeII-ionizing background is generally soft, which naturally accounts for most of the large Si IV/C IV ratios seen in other quasar absorption line spectra. There are however large, important variations in S. They propose that the particularly large softness observed at $z\simeq2.86$ is due to the presence of bright soft sources close to the line of sight.

G. Kriss (STScI), J. M. Shull (U. of Colorado), Oegerle and other members of the FUSE GTO team have also investigated the intergalactic medium along the line of sight to the quasar HE2347-4342. Observations in the 1000$-$1187 Å band were obtained with FUSE at a resolving power of 15,000. The He II Lyα absorption was resolved as a discrete forest of absorption lines in the redshift range 2.3 to 2.7. About 50% of these features have H I counterparts with column densities log N(HI)$>$12.3 that account for most of the observed opacity in He II Lyα. The He II to H I column density ratio ranges from 1 to $>$1000 with an average of $\sim$80. Ratios of $<$100 are consistent with photoionization of the absorbing gas by a hard ionizing spectrum resulting from the integrated light of quasars, but ratios of $>$100 in many locations indicate additional contributions from starburst galaxies or heavily filtered quasar radiation. The presence of He II Lyα absorbers with no H I counterparts indicates that structure is present even in low-density regions, consistent with theoretical predictions of structure formation through gravitational instability.

T. Tripp (Princeton U.) and Oegerle continued their studies of the low-redshift hot intergalactic medium. T. Tripp, M. Giroux, J. Stocke, J. Tumlinson (U. of Colorado) and Oegerle studied the ionization and metallicity of an intervening O VI absorption line system at $z_{abs}=0.1212$ using a far UV spectrum of the QSO H1821+643 ($z_{em}=0.297$) obtained with FUSE. Several galaxies are close to the sight line at the absorber redshift, including an actively star-forming galaxy at a projected distance of 144 kpc. The strongest Ly-α line in the cluster appears to be composed of a mildly saturated component with a typical b-value blended with a broad component with $b=85$ km s^{-1}. The O VI absorption is well-aligned with this broad H I line. The only detected species ($>4\sigma$) in this intervening system are O VI and H I despite coverage of strong transitions of other abundant elements. Based on these constraints, it was determined that the absorption line properties can be produced in collisionally ionized gas with temperatures and abundances of roughly $5.3<\log T<5.6$ and $-1.8<[O/H]<-0.6$. However, photoionization is also viable if the pathlength l through the absorbing gas is long enough; simple photoionization models require $85<l<1900$ kpc and $-1.1<[O/H]<-0.3$.

Oegerle and J. Hill (U. of Arizona) completed a decade-long spectroscopic study of a sample of cD galaxy clusters, and published the results in the December 2001 issue of the Astronomical Journal. The goal of this program was to study the dynamics of the clusters, with emphasis on determining the nature and frequency of cD galaxies with peculiar velocities. Redshifts were obtained for 50$-$150 galaxies in each of 25 clusters containing a central cD galaxy. A dynamical analysis of the sample was carried out in a uniform manner to test for the presence of substructure and to determine peculiar velocities and their statistical significance for the central cD galaxy. It was concluded that cD galaxies are nearly at rest with respect to the cluster potential well but have small residual velocities due to subcluster mergers.

J. Rhodes spent the past year working primarily on weak lensing using space-based observations. Weak lensing, or cosmic shear, provides a unique method to measure the amount and distribution of dark matter in the universe. With colleagues at Princeton and Cambridge Universities, he published the highest signal-to-noise space-based detection of weak lensing to date. Using these results, they set constraints on the clustering of dark matter that match recent results from more traditional methods. With Drs. Gardner, Collins and Hill, he is currently measuring weak lensing in archival HST/STIS data, and these data are consistent with previous results.

Rhodes is a member of the SuperNova/Acceleration Probe (SNAP) collaboration and is using his experience with space-based weak lensing to influence the design of the SNAP telescope and the execution of the SNAP mission.

3.8 Cosmic Infrared Background

E. Dwek and Barker (U. Florida) reanalyzed the observed correlation between radio and infrared (IR) fluxes in local star-forming galaxies to derive an analytical expression for the relation between the cosmic infrared and radio backgrounds which can be used to predict the relative contribution of star forming galaxies and AGNs to the cosmic radio background.

D. Fixsen and Dwek presented the first derivation of the spectrum of the zodiacal cloud at far-IR to submillimeter wavelengths. The cloud spectrum declines faster than a blackbody at wavelengths above 100 μm, from which they deduced a typical radius for its constituent dust particles and the cloud mass.

R. Arendt and Dwek decomposed the near-IR sky maps obtained by the Diffuse infrared Background Experiment (DIRBE) instrument onboard the COBE satellite into Galactic stellar and interstellar medium components, and an extragalactic background, after correcting the maps for emission from the zodiacal dust cloud. The procedure used a multicolor-extinction corrected template to remove the Galactic starlight from the maps. The analysis yielded new constraints on the spectrum of the cosmic IR background at 1.25, 2.2, 3.5, and 4.9 μm.

Dwek and Arendt continued the development of a galaxy count model and confusion limits in order to simulate the appearance of the extragalactic sky at infrared and submillimeter wavelengths.

S. Odegard, Dwek, Arendt and Sodroski worked in collaboration with Reynolds and Haffner (U. Wisconsin) on the determination of the cosmic infrared background, allowing for foreground dust emission from the warm ionized interstellar medium in addition to that from the neutral atomic gas.

Zubko (U. Kentucky), Dwek, and Arendt constructed a new interstellar dust model, consistent with interstellar extinction, diffuse infrared emission, interstellar abundances, and X-ray scattering constraints. The results show that there is no unique interstellar dust model. Dust models consisting of bare silicate, graphite and polycyclic aromatic hydrocarbons (PAHs) and models consisting of the above plus composite particles containing silicates, organic refractories and water ice, provided equally good fits to the observational data.

3.9 Cosmology

R. Fahey and J. Felten calculated solutions to the Friedmann-Lemaitre equations for two non-interacting fluids with various cosmological constants and pressures, and the age and size of the universe for various parameters. Fahey continued collaborating with NASA summer faculty fellow, J. DiRienzi (College of Notre Dame, MD) on quantum measurement problems, and with J. Crawford (Penn State U.) on curved spacetimes with torsion.

A. Kogut and N. Phillips develop neural networks as a tool to pull cosmological information from large, stochastic data sets such as galaxy redshift surveys or maps of the cosmic microwave background. Neural networks are particularly well suited for topological or non-Gaussian tests, where information is coded into the phase distribution of the data.

4. OPERATING ORBITAL FLIGHT MISSIONS AND INSTRUMENTS

4.1 The Microwave Anisotropy Probe (MAP)

The purpose of the Microwave Anisotropy Probe (MAP) mission is to determine the geometry, content, and evolution of the universe via a 13 arcmin full-width-half-max (FWHM) resolution full sky map of the temperature anisotropy of the cosmic microwave background radiation with uncorrelated pixel noise, minimal systematic errors, multifrequency observations, and accurate calibration. These attributes were key factors in the success of NASA's Cosmic Background Explorer (COBE) mission, which made a 7 degree FWHM resolution full sky map, discovered temperature anisotropy, and characterized the fluctuations with two parameters, a power spectral index and a primordial amplitude. Following COBE, considerable progress has been made in higher resolution measurements of the temperature anisotropy. With 45 times the sensitivity and 33 times the angular resolution of the COBE mission, MAP will vastly extend our knowledge of cosmology. MAP will measure the physics of the photon-baryon fluid at recombination. From this, MAP measurements will constrain models of structure formation, the geometry of the universe, and inflation.

MAP, a partnership between Princeton University and GSFC, was selected as a MIDEX mission in 1996, confirmed for development in 1997, and launched in 2001. The launch and early operations were highly successful, and the satellite has now been on-station at the second Lagrange point, L2 for a year. All systems, including the instrument, are working well. The MAP Science Team is now engaged in the analysis of the data, with the goal of announcing the initial results to the scientific community in early 2003.

Data from the MAP mission will be archived and disseminated to the community via a newly approved cosmic microwave background thematic data center: the Legacy Archive for Microwave Background Data Analysis (LAMBDA). LAMBDA will be operated out of the LASP, and will serve data and value-added analysis tools for the professional research community.

4.2 Far Ultraviolet Spectroscopic Explorer (FUSE)

The Far Ultraviolet Spectroscopic Explorer (FUSE) was launched on June 24, 1999. FUSE provides high resolution spectra in the 905-1187 Å wavelength region. FUSE is a cooperative project of NASA and the space agencies of Canada and France. FUSE is operated for NASA by Johns Hopkins University in Baltimore, MD. The FUSE Principal Investigator is W. Moos (JHU). Sonneborn and Woodgate are Co-Is. Sonneborn is the Project Scientist. Iping, Massa, Oegerle, Sonneborn, and Woodgate are members of the FUSE Science Team and are participating in a wide range of PI Team Guaranteed Time Observing programs. Bruhweiler (CUA), Grady, Gull, Iping, Kraemer, Lanz, and Massa were the PIs of successful Cycle 3 observing proposals. Massa and D. Lindler (Sigma Scientific) supported the continuing development of the FUSE science data pipeline and instrument calibration.

The Guest Investigator program received a majority of FUSE observing time through the Cycle 3 proposal review held in August 2001. In Cycles 1 and 2 most of the observing time went to guaranteed time programs of the FUSE PI team. Interest in utilizing the capabilities of the mission in the astronomical community has increased significantly. NASA's Senior Science Review in June 2002 ranked FUSE highly for its scientific results to date and the expectation of continued scientific achievement. Based on this assessment, FUSE was authorized to continue operations through 2004, and through 2006 pending confirmation in the next Senior Review in 2004.

FUSE has observed almost every type of astronomical object, from distant quasars to Solar System objects. Analysis of seven sight lines within 200 pc of the Sun showed that the atomic deuterium-to-hydrogen ratio (D/H) is uniform within 100 pc, but appears to have increasing scatter at greater distances. The dispersion in D/H is a key tracer of the chemical evolution of the Galaxy. FUSE spectra of the quasar HE2347-4342 were the first to resolve the He II Lyman-α forest into discrete absorbing clouds in the intergalactic medium. Comparison of He II with H I on the same sight line indicates that the ionizing radiation responsible for producing the He II in the IGM is not uniform.

FUSE made the first detection of H_2 on Mars at a level indicating that the Red Planet at one time had more water per unit mass than the Earth. Protoplanetary disks have emerged as a important area of research in the far ultraviolet, particularly as a probe of their molecular hydrogen content. In β Pictoris, FUSE set an upper limit on the H_2 column density that was a tiny fraction of the value inferred from H_2 IR emission measurements by ISO and the ultraviolet CO measurements from HST. This discrepancy suggests that the β Pictoris disk is extremely clumpy and that the H_2 may be locked up in millions of comet-like objects swirling around the star.

FUSE operations suffered a temporary setback when two reaction wheels failed in late 2001. Faced with potential mission failure, the FUSE project, led by the PI team at JHU, developed a new pointing control system that uses the two remaining wheels and the satellite's magnetic torquer bars to maintain three-axis pointing. This was the first time that a NASA mission had utilized a combination of wheel and magnetic control to achieve precision (arc second) pointing. The new control system allowed FUSE to recover nearly full sky coverage by mid-2002 with no loss of scientific capability. Work continued on the design and development of the "gyroless" control system in response to further evidence of shortened lifetimes of the FUSE laser ring gyros. This system is a new version of the satellite's two-wheel control software that is designed to ensure mission health and safety and perform slews and target acquisitions in the event of future gyro failures. The new system is scheduled for completion and uplink in late 2002.

D. Massa has continued his work supporting the development of the FUSE science data processing pipeline and the FUSE calibration programs.

4.3 HST Servicing Mission 3B

M. Niedner continued in his role as the HST Deputy Senior Project Scientist and participated in Servicing Mission 3B in March, 2002. In the planning for SM3B, as well as during it, he paid particular attention to potential electrical noise issues involving the ACS. The highlight of this effort was the completely successful on-orbit functional test of ACS during SM3B.

K. Carpenter continued in his role as Project Scientist for HST Operations. This work also included supporting preparations for and participating in the execution of Servicing Mission 3B, for which he was the lead scientific advisor on the GSFC Planning Shift. His HST Project work also included assisting in the development of joint science instrument and HST cooler operations, the setting of priorities for Servicing Missions 3B and 4, the defense of the HST Research Funding levels during the annual budget reviews, and the provision of scientific oversight, for the HST Project, of HST Operations in general and of the Space Telescope Science Institute (STScI) in particular.

4.4 Space Telescope Imaging Spectrograph (STIS)

B. Woodgate is the Principal Investigator (PI) of the STIS instrument on board HST, and directs a number of research projects with the instrument. STIS continues to perform extremely well. C. Bowers has developed models for phase retrieval, and coronagraphy, and has continued to participate in various calibration activities for STIS. Bowers assisted in the modeling which allows fringes to be removed from slitless spectra of STIS and has developed an algorithm with D. Lindler to properly calibrate shifted, STIS echelle spectra, using un-shifted calibration spectra obtained at an earlier epoch, reducing the need for more frequent calibrations.

4.5 Solar & Heliospheric Observatory (SOHO)

SOHO entered its seventh year of continuous solar observations and in-situ measurements of the solar wind, with six of the twelve Principal Investigator teams continuing to staff the Experimenters' Operations Facility for daily planning meetings and command generation. LASP scientists J. B. Gurman (US project scientist) and T. Kucera (Deputy US project scientist), A. Poland, S. Jordan, R. Thomas, and B. Thompson remain directly involved in science operations and analysis, along with more than thirty colleagues from ESA and the PI teams also located at GSFC.

4.6 Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI)

The LASP team led by B. Dennis is collaborating with Principal Investigator, Robert Lin (Space Sciences Laboratory, University of California, Berkeley) on the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), a Small Explorer (SMEX) mission. RHESSI is aimed at understanding the fundamental solar flare processes of particle acceleration and energy release from the coronal magnetic field. It provides X-ray and gamma-ray images and spectra of flares at energies from $\sim$3 keV to 17 MeV with finer angular resolution (down to 2.3 arcseconds below 100 keV increasing to 36 arcseconds above 1 MeV) and spectral resolution ($\sim$1 keV at 3 keV increasing to $\sim$5 keV at 5 MeV) than has previously been possible.

RHESSI was launched by a Pegasus XL rocket on February 5, 2002. After the successful launch, the spacecraft was spun up to $\sim$15 rpm and the germanium detectors were cooled down to their $\sim$75 K operating temperature using the GSFC-supplied Stirling-cycle cooler. The first flare, a GOES C2 event, was detected on February 12, just one week after launch.

Once the spacecraft and instrument were operating successfully, the PI team requested that the mission be officially renamed after Reuven Ramaty, a GSFC astrophysicist who died in March 2001. Ramaty had a long and distinguished career in the Laboratory for High Energy Astrophysics developing much of the theoretical framework for solar gamma-ray line spectroscopy. He was a founding member of the original HESSI team, and his active involvement and enthusiastic support were critical to the realization of HESSI and to its selection by NASA for launch during the current maximum in solar activity. This is the first time that a spacecraft has been named after a NASA scientist, and this great honor was recognized at a GSFC ceremony on May 17, 2002.

During the following seven months of observations through August 2002, RHESSI has detected over 1900 flares at energies above 12 keV and over 600 above 25 keV. The first GOES X-class flare was detected on April 21, 2002. A movie was made of the rising phase of this flare in two energy bands – 12 to 25 keV and 50 to 100 keV – with the images overlaid on a TRACE 195 Å movie of the same event. These and other early results were presented at a press conference and in a special session at the 200th American Astronomical Society meeting in Albuquerque on June 6, 2002. The first gamma-ray-line flare was detected on June 23, 2002 and RHESSI obtained the first ever gamma-ray images and high-resolution gamma-ray spectra.

The value of these RHESSI flare results is greatly enhanced by observations at longer wavelengths and measurements of the escaping energetic particles. These are made with instruments on the fleet of spacecraft already in place – SOHO, WIND, TRACE, ACE, SAMPEX, Ulysses, and GOES – and at many ground-based observatories. These complementary observations provide crucial information on the thermal, magnetic, and morphological context of the flaring region and on the associated solar phenomena that accompany the X-ray and gamma-ray emissions. RHESSI uses a Fourier-transform imaging technique to achieve its high angular resolution, and nine hyper-pure germanium detectors cooled to 75 K to achieve the high spectral resolution. The basic imaging principle involves the use of nine rotating modulation collimators with a germanium detector behind each one to measure many spatial Fourier components of the source distribution of the high-energy emissions. In a manner that is mathematically identical to the production of images in radio interferometry, the temporally modulated signal from the detectors can be used to reconstruct images of solar flares at many energies simultaneously. The energy spectrum at each location in an image can be determined, thus allowing for true imaging spectroscopy for the first time. RHESSI is providing such images with sub-second time resolution for the more intense flares, thus allowing high fidelity movies to be made for public display. More importantly, the RHESSI observations allow the location and spectrum of the energetic electrons that produce the observed bremsstrahlung X-rays to be determined throughout many flares. This information is crucial to determining how the electrons are accelerated and what physical processes are operative in releasing the coronal magnetic energy to produce the flare. RHESSI is also providing information on the location and spectra of the energetic ions that produce the observed gamma-ray lines. In particular, it will provide the first imaging of energetic protons, relativistic electrons, neutrons, and positrons; the first information on the angular distribution of accelerated ions; and detailed information of elemental abundances for both the ambient plasma and the accelerated ions.

The Laboratory was responsible for the nine pairs of flight grids that form the modulation collimators used to achieve the high-resolution imaging. The fabrication of these grids with the required pitch (34 microns to 2.75 mm), pitch accuracy (1 part in 10,000), slit widths (20 microns to 1.5 mm), and thicknesses (1.2 mm to 30 mm) has been a major technological achievement. The four finest pairs of grids were fabricated by Thermo Electron Tecomet in Woburn, MA under the direction of Michael Appleby. They etched the required slit pattern for each grid pitch in many thin sheets of tungsten (molybdenum was used for the 34-micron pitch grids). Then they stacked the number of sheets needed to reach the desired thickness. The remaining five grid pairs were fabricated by Co-investigator, Frank van Beek, in The Netherlands. He used many tungsten blades to form the slats of the grid and put stainless steel spacers between them to produce the slits. Precisely machined Invar reference frames allowed him to achieve the required pitch accuracy. Upon delivery to GSFC, the grids were characterized using our optical and x-ray grid characterization facilities designed specifically for this purpose. Vibration and thermal cycling were conducted to qualify all the grids for flight. In addition, titanium and aluminum mounts were fabricated and tested to attach the grids to the fight trays. Preliminary alignment of the grids on their mounts was carried out prior to shipping all grids to Switzerland. There, the grids were mounted on the flight trays and aligned so that the slits of the front and rear grids of a pair making up a modulation collimator are parallel to within the required tolerance of 0.3 arc minutes for the finest grids.

In addition to the hardware involvement, the Laboratory has developed software to display, analyze, interpret, and archive all calibration and flight data. The software is being used to carry out basic data manipulation functions to produce catalogs, light curves, images, spectra, etc. All of the RHESSI data and the basic access and analysis software are available on-line to all interested members of the scientific community. The LASP RHESSI team is involved in an extensive education and public outreach activity. Many students and teachers work at GSFC on RHESSI activities ranging from hands-on help with analyzing flight data, testing the data analysis software, and upgrading the RHESSI websites at /tt `http://hesperia.gsfc.nasa.gov/rhessi/`.

5. FLIGHT MISSIONS AND INSTRUMENTS UNDER DEVELOPMENT

5.1 Solar Dynamics Observatory (SDO)

Living With a Star (LWS) is a program within the Sun-Earth Connection (SEC) theme for NASA's Office of Space Science (OSS). LWS is a space weather-focused and applications-driven research program. Its goal is to develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth system that directly affect life and society. LWS consists of a series of research and development efforts, including targeted research missions such as the Solar Dynamics Observatory (SDO). Gurman, Poland, St. Cyr, Kucera, Thompson, Rabin, Davila are playing active roles on the science team. These roles include the support of missions, committees, and meetings which involve the broader LWS community.

SDO is scheduled to launch in 2007 and consists of a set of investigations designed to understand the origins of the flow of energy from the solar interior, through various regions of the Sun out to the solar corona. With SDO, astronomers will be able to investigate the Sun's transient and steady-state behavior and understand the solar drivers of variability at Earth. B. Thompson is the SDO Project Scientist.

5.2 Solar Terrestrial Relations Observatory (STEREO)

The solar magnetic field is constantly generated beneath the surface of the Sun by the solar dynamo. To balance this flux generation, there is constant dissipation of magnetic flux at and above the solar surface. The largest phenomenon associated with this dissipation is the Coronal Mass Ejection (CME). SOHO has provided remarkable views of the corona and CMEs, and served to highlight how these large interplanetary disturbances can have terrestrial consequences.

STEREO is the next logical step to study the physics of CME origin, propagation, and terrestrial effects. Two spacecraft with identical instrument complements will be launched on a single launch vehicle in November 2007. One spacecraft will drift ahead and the second behind the Earth at a separation rate of 22 degrees per year. Observation from these two vantage points will for the first time allow the observation of the three-dimensional structure of CMEs and the coronal structures where they originate

Each STEREO spacecraft carries a complement of 10 instruments, which include (for the first time) an extensive set of *both* remote sensing and in-situ instruments. The remote sensing suite is capable of imaging CMEs from the solar surface out to beyond Earth's orbit (1 AU), and in-situ instruments are able to measure distribution functions for electrons, protons, and ions over a broad energy range, from the normal thermal solar wind plasma to the most energetic solar particles.

It is anticipated that these studies will ultimately lead to an increased understanding of the CME process and eventually to the ability to predict CME occurrence and thereby forecast the condition of the near-Earth environment.

LASP is involved in the STEREO mission in two ways. As a part of the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI) we are responsible for the COR1 coronagraph. This coronagraph will provide images of the inner corona from $1.3-4.5R_{\odot}$. In addition, J. Davila is Project Scientist for the STEREO mission. In this capacity he is responsible for the science implementation and requirements for the mission. L. Orwig of the Solar Physics Branch is serving as the Instrument Manager for the COR1 program at GSFC.

5.3 Advanced Solar Coronal Explorer (ASCE)

ASCE will obtain crucial imaging and spectroscopic information necessary to understand fundamental physical processes in the solar corona. ASCE is truly the next generation solar mission. It provides simultaneous, high quality spectra with state of the art coronagraphic images to produce a comprehensive view of coronal processes. Dr. John Kohl (Smithsonian Astrophysical Observatory) is the Principal Investigator. GSFC (J. Davila, CoI) will provide support for the assembly of four intensified CCD cameras, and optical coatings for the ASCE project.

5.4 Submillimeter and Far Infrared Experiment (SAFIRE)

The Submillimeter and Far Infrared Experiment (SAFIRE) is a far infrared imaging spectrometer for the Stratospheric Observatory for Infrared Astronomy (SOFIA). It is being built at GSFC (S. H. Moseley, D. Benford, R. Shafer, and J. Staguhn) in collaboration with F. Pajot (Institut d'Astrophysique Spatiale), K. Irwin (NIST), and G. Stacey (Cornell University). The instrument provides background limited sensitivity with a resolving power of $\sim$1500 over the 125μm to 650μm spectral range. The instrument will employ a 16×32 element array of superconducting transition edge sensor (TES) bolometers operating at 0.1 K. This detector will employ a novel multiplexing scheme using superconducting SQUID amplifiers developed at NIST. The instrument is scheduled for first light in 2006. In the current year, we have developed detector production techniques, developed new detector test facilities, procured an instrument test dewar, and completed the adiabatic demagnetization refrigerator required to cool the detectors. Work in the next year will focus on the development of prototype detector arrays, which will be tested in ground-based facilities.

5.5 Infrared Array Camera (IRAC)

The Infrared Array Camera (IRAC) (G. Fazio, Principal Investigator, SAO; S. H. Moseley, Instrument Scientist) for the Space Infrared Telescope Facility (SIRTF) completed its test program at GSFC and was delivered for observatory level tests in fall 2001. IRAC is a four-band $3-9\mu$m camera for SIRTF. One of its primary science goals is the study of galaxy evolution, where it will obtain galaxy luminosity functions out to $z\sim3$. This high performance camera will offer revolutionary capabilities for a wide variety of astronomical investigations during the five year lifetime of SIRTF. IRAC has performed well and has exceeded its sensitivity requirements. IRAC has successfully passed all system level tests, and the SIRTF payload is being prepared for its January 2003 launch. The current and future work at GSFC (Drs. R. Arendt, D. Fixsen, S. H. Moseley, is focusing on the development of algorithms and analysis tools to establish optimal observing and analysis procedures for IRAC.

5.6 Wide Field Camera 3 (WFC3)

Wide Field Camera 3 is an instrument in development for installation on HST in Servicing Mission 4. It will provide a panchromatic imaging capability from the near UV to the near infrared, enabling a broad science program including the observation of high-z galaxies in formation, star formation processes in nearby galaxies, and resolved stellar populations. E. Cheng served as Instrument Scientist for this HST facility instrument. The principal technical contribution of laboratory personnel to the WFC3 effort has been in performance testing of candidate Charged Coupled Device (CCD) and IR detectors in the Detector Characterization Laboratory. In the past year, flight CCD detectors have been selected and delivered to Ball Aerospace for integration into the instrument; tests of the HgCdTe IR detectors for dark current, quantum efficiency, stability, and noise have guided fabrication efforts at Rockwell Science Center. Those fabrication runs are nearing completion. In the coming year, the flight IR devices will be selected and LASP personnel will support the general integration and test of the instrument.

5.7 Galaxy Evolution Explorer (GALEX)

The Galaxy Evolution Explorer (GALEX) is a Small Explorer (SMEX) mission that will conduct an all-sky survey at ultraviolet wavelengths (1350 − 3000 Å). The PI team, led by Christopher Martin at California Institute of Technology, will use the data to determine the history of star-formation over 80% of the age of the universe, when galaxies and gas evolve dramatically. GALEX is managed by the Explorers Office at GSFC; Susan Neff is the NASA Project Scientist. The Guest Investigator (GI) program for GALEX will be managed at GSFC, and an AO for the GI program will be released shortly before launch (currently early February 2003).

5.8 Next Generation Space Telescope (NGST)

NGST (now JWST) is a large aperture follow-on mission to HST under the Origins program (see the NGST website: /tt http://jwst.gsfc.nasa.gov/. It is a 6-m cooled infrared telescope optimized to observe the first stars and galaxies. It is planned for launch in 2010. J. Mather serves as the NGST Senior Project Scientist, while M. Greenhouse is the Integrated Science Instrument Module (ISIM) Project Scientist and is the prime NGST contact for science instrumentation and instrument technology development. The ISIM completed phase A development during FY02. This activity included a wide range of design work on the flight module, its science instruments, and enabling technologies. Greenhouse also leads the development of many key technologies for NGST instruments, such as MEMS programmable aperture masks for multi-object spectroscopy (MOS), a ground-based MEMS MOS facility instrument for the KPNO 4-m telescope, near- and mid-infrared detector systems, ultra-low background detector test facilities, and MEMS tunable infrared filters. J. Gardner was appointed as the NGST Deputy Senior Project Scientist in place of E. Smith who has joined NASA HQ as NGST Program Scientist.

Mather and Greenhouse provided support to NASA HQ in preparation of the Announcement of Opportunity (AO) for NGST Flight Investigations. The Near Infrared Camera (NIRCAM) team, the NGST Science Working Group, and the US part of the Mid-infrared Instrument (MIRI) science team were selected by NASA HQ through this AO. A third instrument, the Near-infrared Spectrograph (NIRSpec) is being built by the European Space Agency. Moseley's team was competitively selected by the NGST Project to build the microshutter array for NIRSpec.

5.9 Kepler

Y. Kondo serves as co-investigator for the Kepler observatory to detect Earth-like planets in our Galaxy. Kepler is a Discovery mission which was competitively selected by NASA Headquarters for launch in 2007 for a four-to-five year operation period. Kondo will be responsible for the participating scientist (i.e., guest observer) program to continuously observe from one to five years, a variety of variable stars such as instrinsic variables (including micro-variables), eclipsing variables, interacting binaries (including X-ray binaries), and cataclysmic variables. Some 3,000 objects may be selected each year for the participating scientist program.

5.10 Mission Concept Studies

The Single Aperture Far-Infrared (SAFIR) Observatory, recommended by the National Academy of Sciences Decadal Review, has been studied at GSFC as a possible successor mission to NGST. Led by D. Benford, a team consisting of J. Mather, S.H. Moseley, W. Danchi, D. Leisawitz (GSFC) and M. Amato has developed a mission concept for this highly capable, 10-m diameter, far-infrared optimized observatory. If approved for funding, SAFIR could launch in 2017. The scientific objective of SAFIR is to conduct investigations into the earliest stages of star and planet formation and the formation of the first galaxies and stars in the universe.

Mission concepts for the next large aperture (4-8m) UV/optical space telescope are under study by a working group consisting of scientists and engineers from GSFC, JPL and the community. The concepts will explore different telescope and optical designs to carry out the science drivers coming out of the Hubble Science Legacy meeting held in Chicago in April 2002. Led by W. Oegerle, the GSFC team consists of J. Gardner, B. Woodgate, S. Heap, C. Bowers and R. Kimble.

W. Danchi is leading the development of the Fourier-Kelvin Stellar Interferometer (FKSI), with Drs. D. Benford, D. Leisawitz , D. Gezari, and L.G. Mundy (U. Md) as Co-Is. FKSI is a space-based mid-infrared imaging interferometer mission concept being developed as a precursor for the Terrestrial Planet Finder (TPF) mission. It provides 3 times the angular resolution of NGST and demonstrates the principles of interferometry in space.

Dan Gezari has been active in developing proposals for studies under the Terrestrial Planet Finder (TPF) program to detect and characterize extrasolar planets. He was PI of an international team proposing an apodized square aperture (ASA) high contrast imaging coronagraphic telescope observatory as MidEx mission. He was also a Co-I on a successful TPF architecture industry study by the Boeing/SVS team, and is Co-I on an ongoing TPF technology study. The ASA team is preparing to propose the concept as a Discovery mission.

K. Carpenter, R. Lyon (GSFC), L. Mazzuca, G. Solyar, W. Danchi, and S. Neff, in collaboration with Drs. C. Schrijver (LMMS/ATC), L. Mundy (UMd), D. Mouzurkewich, T. Armstrong, and T. Pauls (NPOI/NRL), R. Allen (STScI), M. Karovska (CfA), and J. Marzouk (Sigma Sp.) continue the development of a mission concept for a large, space-based UV-optical interferometer, named Stellar Imager (SI). SI is designed to image the surfaces of nearby stars, probe their subsurface layers through asteroseismology, and improve our understanding of the solar and stellar dynamos. The ultimate goal of this mission is to achieve the best-possible forecasting of solar activity as a driver of climate and space weather on time scales ranging from months up to decades, and an understanding of the impact of stellar magnetic activity on life on earth and elsewhere in the Universe. It is envisioned as a 500-meter baseline array orbiting the Sun-Earth L2 point and consisting of 10-30 one-meter class apertures precision formation-flying with a beam-combining hub located at the prime focus of the virtual ''mirror'' formed by the array. A ground-based experiment, the Fizeau Interferometry Testbed (FIT) is under construction. It will be used to explore the principles of and requirements for the the SI concept and other Fizeau Interferometers and Sparse Aperture Telescope missions. Further information on this mission and the FIT can be found at URL: /tt http://hires.gsfc.nasa.gov/~si.

Oliversen continues work with W. Harris (U. Wisconsin) to develop a solar system EUV/UV mission concept called SCOPE (Solar Connections Observatory for Planetary Environments) to study planetary magnetospheres and upper atmospheres and their interactions with the solar wind and radiation.

6. SUBORBITAL MISSIONS

6.1 EUNIS

The Solar Physics branch is assembling an EUV Normal Incidence Spectrograph (EUNIS), to be flown in 2003 as a sounding rocket payload. This new instrument builds on technical innovations achieved by the Solar Extreme ultraviolet Research Telescope and Spectrograph (SERTS) experiment over its past ten flights. The new design features nearly two orders of magnitude greater sensitivity as well as improved spatial and spectral resolutions. The high sensitivity will enable new studies of transient coronal phenomena, such as the rapid loop dynamics seen by TRACE, and searches for non-thermal motions indicative of magnetic reconnection or wave heating. It will also be possible to obtain EUV spectra 2−3 solar radii above the limb, where the transition between the static corona and the solar wind is expected to occur.

The new design features two independent optical systems, more than doubling the spectral bandwidth covered on each flight. The 300−370 Å bandpass includes He II 304 Å and strong lines from Fe XI-XVI, extending the current SERTS range of 300−355 Å to further improve our ongoing series of calibration under-flights for SOHO/CDS and EIT. The second bandpass of 170−205 Å has a sequence of very strong Fe IX-XIII lines and will allow under-flight support for two more channels on SOHO/EIT, two channels on TRACE, one on Solar-B/EIS, and all four channels on the STEREO/EUVI instrument. Continuing the emphasis on flight technology development established by SERTS, EUNIS will employ six Active Pixel Sensors, high-speed and low-power focal plane arrays being developed by the Jet Propulsion Laboratory. The optical design (by R. Thomas) of the EUNIS telescopes breaks new ground in terms of compactness and efficiency.

The EUNIS payload will also carry an EUV solar flux monitor provided by USC; its readings will be used to validate calculations of atmospheric EUV transmission over the rocket's trajectory and to provide an updated calibration for SOHO/CELIAS. As for SERTS, end-to-end radiometric calibrations will be carried out after each flight in the same facility used to characterize the SOHO/CDS experiment at Rutherford Appleton Laboratories, using the same EUV light source specially re-calibrated by PTB against the primary EUV radiation standard of BESSY-I. These measurements will establish the absolute response of the spectrographs to within 25%.

EUNIS underwent a successful critical design review and is entering fabrication.

In collaboration with the EUNIS team, DiRuggiero (U. Maryland) continued her investigation of the survivability of thermophilic microorganisms under space conditions. The hypothesis under test is that extremely thermophilic, terrestrial microorganisms may include strains with potential for interplanetary microbial transmission, due to their robust physiological properties and their effective DNA repair systems.

6.2 ARCADE

Research on the cosmic microwave background included two flights of the Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission (ARCADE) balloon instrument (A. Kogut, D. Fixsen, M. Limon, P. Mirel, and E. Wollack, with additional collaborators at JPL and UCSB). ARCADE uses a novel open-aperture cryogenic design to compare the spectrum of the cosmic microwave background to a precision blackbody at frequencies 10 and 30 GHz. It will measure the free-free emission from the ionized intergalactic medium to determine the redshift at which the universe became reionized. A second-generation payload, covering the frequency range 3−100 GHz, is under development. A number of interns ranging from high school through graduate school participated in the ARCADE integration and testing.

6.3 TopHat

TopHat is a balloon borne experiment designed to study the anisotropy of the cosmic microwave background. Silverberg, Cheng, Fixsen, and Cottingham and collaborators from U. Chicago, U. Wisconsin, and U. Massachusetts flew TopHat successfully from McMurdo Station, Antarctica in January, 2001. Since then, analysis of the data spanning a nearly circular patch of sky ∼57 degrees in diameter around the South Celestial Pole has been progressing.

6.4 Explorer of Diffuse Galactic Emission (EDGE)

A proposal to develop a mission of opportunity instrument under the MIDEX opportunity was submitted by S. Meyer of the University of Chicago with Cheng, Silverberg, Fixsen, Cottingham as collaborators and other collaborators at U. Mass., U. C. Davis, and U. Wisconsin. The EDGE mission would study the anisotropy of the Cosmic Infrared Background to determine the details of the structure and evolution of early galaxy formation. The proposal was highly rated scientifically, but the technology required was deemed to be immature and would require additional development and demonstration of performance. The collaboration was awarded a two-year grant to demonstrate that the technical goals set out in the proposal can be achieved.

7. INSTRUMENTATION AND NON-FLIGHT PROGRAMS

SPEctral Energy Distribution (SPEED) camera. The SPEED camera is being developed by E. Cheng, Silverberg, Fixsen and Cottingham and collaborators from U. Chicago, U. Massachusetts, and U. Wisconsin, to measure the spectral energy distribution of high redshift galaxies. The camera will use Frequency Selective Bolometers to provide a 16 element (4 pixels $\times$ 4 spectral bands) array of superconducting transition edge sensor (TES) bolometers to efficiently observe high redshift galaxies using the Heinrich Hertz 10-m telescope. The instrument is being designed so it may also be used on the 50-m Large Millimeter Telescope (LMT) being built in Mexico.

Near-infrared Spectrometer. A. Kutyrev, Moseley and Bennett are developing a high resolution near-infrared cryogenic temperature tunable spectrometer with solid Fabry-Perot etalons. Several different candidate materials have been studied for possible use as substrates for these solid etalons. Silicon and germanium have been identified as the best materials, having high refractive coefficients, allowing the etalons to be tuned with reasonably small changes in temperature. Both Ge and Si etalons have been fabricated and tested in the lab for spectral performance. The temperature range required for tuning the etalons in the current design is within the range easily achievable with the temperature control system. The etalons operate at a liquid nitrogen temperature or slightly above it. The high refractive index of these materials has enabled the building of a very compact spectrometer equivalent to a gas-spaced Fabry-Perot interferometer of 80 mm in diameter. First successful field tests of the spectrometer with a double silicon etalon was carried out last summer. This project is a continuation of a previous development of the pressure scanned cryogenic Fabry-Perot spectrometer of the diffuse ionized hydrogen in the Galactic plane. The spectrometer has been considered as one of the possible instruments at the observatory in Antarctica.

7.1 Detector Development

S. Moseley, G.Voellmer and C. Dowell (Caltech) led the development of an engineering prototype detector array for the HAWC instrument on SOFIA. Other members of the team included Drs. D. Benford and J. Staguhn. This prototype array has been installed in the Submillimeter High Resolution Array Camera (SHARC) II instrument, which was commissioned at the Caltech Submillimeter Observatory in July 2002. Containing 384 pixels, this is currently the world's largest cryogenic bolometer array camera. This bolometer array allows high sensitivity to be combined with large format, greatly improving submillimeter imaging speed.

A program, led by A. Kogut, to develop large-format arrays of the ideal integrating bolometer (in the wavelength range 100 to 1000 microns) is underway. Dissipationless sensors coupled with a superconducting heat switch allow a bolometer to function as an ideal integrator, with sensitivity much higher than semiconductor or transition-edge devices. Kogut's team has produced such a device as a single pixel proof-of-principle detector and is currently testing it.

B. Woodgate, R. Kimble, P. Haas and L. Payne, with T. Norton, J. Stock (Swales) and G. Hilton continued development of UV detectors for future flight missions, with the goal of making high QE, large format, zero read noise photon counting arrays. In 2002 the team deposited CsO negative affinity layers on p-doped GaN to increase the QE of NUV detectors, and worked with JPL in designing an event sensing CMOS advanced pixel sensor for readout into a GSFC centroider. The team is also monitoring the development, via a Small Business Innovative Research (SBIR) program, of silicon microchannel plates made by NanoSciences Inc. They plan to deposit the high QE photocathodes on these new chemically cleaner microchannel plate intensifiers.

Oliversen, S. Howell (Planetary Science Institute) and collaborators are characterizing the performance of an Orthogonal Transfer CCD for high photometric precision and possible space applications.

7.2 Microshutter arrays

Moseley, Silverberg, Kutyrev, and Woodgate, in collaboration with the engineering division at GSFC are developing a programmable multi-object field selector for the NGST Near Infrared Spectrometer (NIRSpec). The device is a large microshutter array of 100μm $\times 100\mu$m shutters fabricated using micro-electro-mechanical systems (MEMS) techniques. This is an all-transmissive design that offers higher contrast, lower diffraction and scattered light and simpler optical design than reflective devices (ie. micromirrors). The goal for the NIRSpec array is a 2048$\times$2048 array, which will be assembled from a mosaic consisting of 16 512$\times$256 microshutters. Arrays of size 256$\times$256 have been constructed and tested at cryogenic temperatures (30K). The possibility of building a demonstration device for use on ground-based telescopes is also being explored.

7.3 Hard X-ray Imager and Detectors

U. Desai and L. Orwig have been evaluating a new concept for high angular resolution imaging for hard x-rays and gamma-rays. RHESSI images the Sun in hard x-rays using temporal modulation with a bi-grid coder. They use spatial rather than temporal modulation to image hard x-rays. The significant advantage of this concept will be the capability to unambiguously deconvolve even if there are fast time variations during the transient event. We use a bi-plane coder that acts as a Fourier transformer. Two Fresnel zone plates made out of tungsten (1 mm thick, 2.4 cm diameter) with a finest zone of 41 μm have been used for the proof of concept. The telescope was exposed at the MSFC x-ray beam facility and the results have been published.

They are working on an instrument development concept for solar and other transient events such as gamma-ray bursts to achieve appropriate sensitivity. The main advantage of this concept is that it offers measurements with high angular resolution even using a coarsely pixilated detector. The technology is scalable, cheap, and would enable imaging at high energies ($>$250 keV). J. B. Stephen (Instituto TeSRE, Bologna) has submitted a joint proposal to the Italian space agency to carry out simulations of astrophysical observations using this imaging concept.

7.4 Optical Modeling

C. Bowers and B. Dean (GSFC Optics Branch) established the relation between the optimal defocus positions in phase diverse phase retrieval and the exit pupil phase error spectrum in the case of small phase errors. This relationship indicates the optimal defocus positions in cases where a single phase frequency is dominant and is particularly useful with periodic structures such as the deformable mirrors to be used with NGST. Bowers also has developed coronagraphic modeling capabilities which were used for the GSFC proposal for a Near-infrared Camera on NGST, and are being used to improve the coronagraphic imaging capability of the GSFC Fabry-Perot instrument in conjunction with B. Woodgate.

Gull, D. Lindler, C. Grady, and Nick Collins have worked to determine the spectroscopic point spread function of the CCD modes of HST/STIS, and to characterize optical ghosts and reflections in the instrument. D. Lindler and C. Bowers have produced a data reduction tool that provides an excellent determination of the echelle blaze angle as the spectral format is moved around the MAMA detector surface.

7.5 Lightweight Mirrors

Rabin and Davila collaborated with D. Content, R. Keski-Kuha and S. Antonille (GSFC Optics Branch) to develop metrology and imaging performance tests for ultra-precise UV/EUV mirrors in anticipation of the delivery of a 55-cm lightweight (4.6 kg) ULE parabolic mirror from Eastman Kodak. This fast (f/1.2) parabolic mirror is specified to have rms figure accuracy of 6.3 nm rms and microroughness less than 1 nm rms.

The GSFC program aims to verify this performance through a complete determination of the surface power spectral density, optical imaging performance, and, finally, UV imaging performance. A computer generated hologram has been obtained to facilitate the optical imaging test. For the UV test, a 90-cm collimator has been refigured and coated for use in a vertical test stand with the Kodak mirror and a focal plane assembly that will use micron-scale pinholes to sample the final point spread function.

The near-term goal of the UV/EUV mirror program is to incorporate the Kodak mirror into a sounding rocket or balloon payload that will obtain 0.1-arcsec imaging of the Sun. The longer term goal is to guide the development of meter-class and larger lightweight mirrors that can be used in orbital missions such as the Terrestrial Planet Finder (TPF), the Next Hubble Space Telescope (NHST), and the Stellar Imager. In addition to the Kodak design, the team is evaluating lightweight mirror technologies based on silicon foam and ceramic composites.

P. Chen, and S. Neff, continued work on the development and testing of composite mirrors. A number of mirrors, some with simple laminated facesheet construction and some with composite cores sandwiched between facesheets, were tested in vacuum with liquid nitrogen cooling. Both types showed little or no change when subjected to vacuum. The plate mirrors generally developed increasing amounts of astigmatism with decreasing temperature. The core mirrors developed much less astigmatism but tended to show core print-through upon cooling. The data are being analyzed to understand the thermal behavior and to develop manufacturing techniques for less thermally sensitive lightweight mirrors.

One goal of this work is to develop very lightweight mirrors with figures good enough for arcsecond-scale UV imaging. Mirror figures continue to improve; a significant result is the achievement of a 15-cm f/6 spherical mirror with a figure accuracy of 0.033 nm rms (0.30 nm peak-to-valley) at 632.8 nm. This is the best performance to date (of which we are aware) of a graphite fiber substrate mirror, and may be considered diffraction-limited using the Marechal criterion. A serendipitous discovery was made that a thin composite flat, when subjected to cooling in vacuum, assumed the shape of a very long focus ($\sim$ f/100) sphere. This phenomenon may lead to a novel, cost-effective way to fabricate meter class spherical mirrors with very long radius of curvature, of the type required by the Stellar Imager and similar missions.

Chen and Oliversen continued work on the development of extremely lightweight precision mirrors under the NASA Gossamer Spacecraft Technology Development Program. They have successfully fabricated mirrors with areal densities of 1.8, 3.4 and 5.6 kg m^{-2}. The mirror surfaces remained smooth,with microroughness $\sim$20 Å rms, after vacuum drying for a week at the NASA's MSFC Space Optics Manufacturing Technology Center. The two lightest mirrors exhibited some high order ripples and needed reworking. However the 5.6 kg m^{-2} unit showed an otherwise excellent figure with only some astigmatism. Previous work had shown that the astigmatism could be removed with simple active control mechanisms. The 5.6 kg m^{-2} mirror is being used to make a lightweight Cassegrain telescope for astronomical research. Results of the Gossamer program were reported at a Gossamer Workshop Conference held at NASA's JPL in Pasadena, CA.

Work progressed well on the development of a non-contact process for modifying the optical figure of a composite mirror. The process uses a localized chemical reaction to remove surface resin in a deterministic manner. Preliminary results showed the removal of up to five microns of material in a matter of minutes. There were no measurable changes in the surface microroughness at the 20 Å rms level. The result is encouraging. The process promises to enable the generation of large aperture mirrors with highly accurate figures and supersmooth surfaces at low cost.

7.6 Virtual Solar Observatory

J. Gurman and George Dimitoglou (L-3 Analytics) are working with a small group of colleagues at Stanford University, Montana State University, and the National Solar Observatory to formulate a prototype architecture for the Virtual Solar Observatory (VSO). If the solar physics community finds the design useful, the prototype system will be built within the next one to two years. As currently envisioned, the VSO will consist of an extremely simple, standards-based core and entirely distributed data archives for space- and ground-based solar physics data, with peer-reviewed competitions for adding features such as analysis software, event lists, intelligent agents, and/or grid computing to the baseline VSO.

7.7 Conferences

An international meeting, the ‘‘Workshop on New Concepts for Far-Infrared and Submillimeter Space Astronomy’’ was held at the University of Maryland in March 2002. The organizing committee, led by D. Leisawitz, included Drs. D. Benford and R. Silverberg. 130 participants attended the two-day meeting, with 70 presentations. The conference proceedings, *New Concepts for Far-Infrared and Submillimeter Space Astronomy*, edited by Leisawitz and Benford, contains a record of this GSFC- and HQ-sponsored workshop.

Neff was a co-organizer (with Kaaret, Fabbiano, Grindlay (CFA) and King (U Leister)) of a conference at the Aspen Center for Physics on ‘‘Compact Object Populations in External Galaxies.’’ The conference explored formation and evolution of Super Star Clusters, identification and characterization of ‘‘Super-Eddington’’ X-ray sources, and the connection of both to star-formation processes in galaxies.

Oegerle was a co-organizer of the conference ‘‘Hubble's Science Legacy: Future Optical-UV Astronomy from Space,’’ held April 2-5, 2002 at the University of Chicago. The conference was attended by $\sim$150 astronomers from a wide range of institutions in the US and Europe, and was sponsored by NASA, AURA, GSFC, ESA, and the University of Chicago. The co-chairs of the meeting were Garth Illingworth (UC Santa Cruz) and Rob Kennicutt (U of Arizona). A short roadmap was produced after the meeting to feed into the NASA Strategic Planning process, and a longer (15 page) whitepaper will be produced. LASP members B. Woodgate and J. Mather gave invited talks at the meeting.

7.8 Education and Public Outreach

SUNBEAMS is now in its fifth year as an educational partnership between NASA GSFC and the District of Columbia Public Schools (DCPS). Crannell and S. Brown (DCPS) lead the program, which continues to evolve as a model urban intervention technique for sixth grade teachers and students by empowering the teachers and inspiring the students through participation in the process and excitement of science and technology. Each spring, fifteen teachers of 6th-grade math and science from the DCPS are invited to GSFC for a five-week paid internship. During the summer, each teacher is paired with a mentor from the scientific and technical staff. The teachers participate in current scientific and technical research and partner with the mentors to develop lessons for middle school students which they subsequently pilot in their own schools and post on the SUNBEAMS web site.

During the school year, each teacher brings a class of up to thirty students to GSFC for a week of total immersion in math and science activities. The activities, based on national standards, are designed to give the students an understanding of the actual methods used by scientists, engineers, and technicians to do space science and technology. Following their week at GSFC, the teacher and students work together to plan a Family Night at their school to provide the school community and their GSFC partners an opportunity to share in the students' impressions and reactions to their experiences.

Research groups at the University of Minnesota and at Temple University are currently designing outreach programs based on the successful SUNBEAMS model.

C. Grady has also been active in several NASA sponsored education and public outreach programs including Young Space Explorers: IDEAS in the Library, served as a scientist mentor for the SUNBEAMS program, and is the science lead for the Accessible Universe program, where in collaboration with a team of regular and special educators in the Howard County Public Schools they have identified a suite of resources, curriculum modifications, and assistive technology tools which can more successfully teach the elementary space science curriculum to special needs students receiving their science instruction in a comprehensive (mixed ability) classroom. This project continued into 2002.

T. Gull continues to work with Native American students at South Dakota School of Mines and Technology and Oglala Lakota College. Several undergraduate students have been at GSFC during the summer months and the annual six week summer program continues.

8. ACRONYMS

ACE – Advanced Composition Explorer
ACS – HST/Advanced Camera for Surveys
ADAS – Atomic Data and Analysis Structure
ANS – Astronomical Netherlands Satellite
ARCADE – Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission
ASCE – Advanced Solar Coronal Explorer
CDS – Coronal Diagnostic Spectrometer
CELIAS – SOHO/The Charge, Element, and Isotope Analysis System
DIRBE – COBE/Diffuse infrared Background Experiment
EDGE – Explorer of Diffuse Galactic Emission
EIT – SOHO/Extreme Ultraviolet Imaging Telescope
EUNIS – EUV Normal Incidence Spectrograph
EUV – Extreme ultraviolet
FKSI –Fourier-Kelvin Stellar Interferometer
FUSE – Far Ultraviolet Spectroscopic Explorer
GALEX – Galaxy Evolution Explorer

GHRS – HST/Goddard High Resolution Spectrograph
GOES – Geostationary Operational Environmental Satellite
GSFC – Goddard Space Flight Center
HDF – Hubble Deep Field
HST – Hubble Space Telescope
IR – Infrared
IRAC – SIRTF/Infrared Array Camera
ISIM – NGST/Integrated Science Instrument Module
IUE – International Ultraviolet Explorer
JWST – James Webb Space Telescope (aka NGST)
LASP – Laboratory for Astronomy & Solar Physics
LAMBDA – Legacy Archive for Microwave Background Data Analysis
LWS – Living with a Star
MAP – Microwave Anisotropy Probe
MEMS – micro-electro-mechanical systems
NGST – Next Generation Space Telescope
NHST – Next Hubble Space Telescope
NICMOS – HST/Near Infrared Camera and Multi-Object Spectrometer
NIRCam – NGST/Near Infrared Camera
NIRSpec – NGST/Near Infrared Spectrograph
OAO – Orbiting Astronomical Observatory
RHESSI – Reuven Ramaty High Energy Solar Spectro- scopic Imager
SAFIR – Single Aperture Far-Infrared Observatory
SAFIRE – SOFIA/Submillimeter and Far Infrared Experiment
SAMPEX – Solar Anomalous and Magnetospheric Par- ticle Explorer
SDO – Solar Dynamics Observatory
SERTS – Solar EUV Research Telescope and Spectrograph
SHARC – Submillimeter High Resolution Array Camera
SI – Stellar Imager
SIRTF – Space Infrared Telescope Facility
SOFIA – Stratospheric Observatory for Infrared Astronomy
SOHO – Solar and Heliospheric Observatory
SPEED – SPEctral Energy Distribution Camera
SQUID – superconducting quantum interference device
STEREO – Solar Terrestrial Relations Observatory
STIS – HST/Space Telescope Imaging Spectrograph
SUMER – SOHO/Solar Ultraviolet Measurements of Emitted Radiation
SUNBEAMS – Students United with NASA Becoming Enthusiastic About Math and Science
TES – Transition Edge Sensor
TPF – Terrestrial Planet Finder
TRACE –Transition Region and Coronal Explorer
UIT – Ultraviolet Imaging Telescope
UV – ultraviolet
VLA – Very Large Array
VSO – Virtual Solar Observatory
WFC3 – HST/Wide Field Camera 3 ≠wline

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