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

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The Laboratory for Astronomy and Solar Physics (LASP) continues to conduct a broad program of research and instrument technology development in ultraviolet and infrared astronomy and in optical/UV, X-ray, gamma-ray, and visible-light studies of the Sun. The program encompasses theoretical, observational, and experimental work, using platforms in space such as the Hubble Space Telescope (HST) Space Telescope Imaging Spectrograph (STIS) and ground-based supporting facilities. The staff provides important enabling services to the scientific community in support of major NASA observatory missions in space astronomy and solar physics. The current missions include Hubble Space Telescope/Space Telescope Imaging Spectrograph (HST/STIS), the Solar Heliospheric Observatory (SOHO), and the Transition Region and Coronal Explorer (TRACE). Future missions being supported are the Microwave Anisotropy Probe (MAP), the HST Wide Field Camera (WFC3), Space Infrared Telescope Facility/Infrared Array Camera (SIRTF/IRAC), the High Energy Solar Spectroscopic Imager (HESSI), and the Next Generation Space Telescope (NGST).

Besides the above spacecraft and others mentioned in the report below, the Laboratory conducts experiments through the Spacelab program of Shuttle-attached payloads and via balloon and airborne observatories, such as the Stratospheric Observatory for Infrared Astronomy/Submillimeter and Far Infrared Experiment (SOFIA/SAFIRE). We also conduct rocket experiments for solar and ultraviolet astronomy. We manage or support several ground-based facilities for research in instrument development, solar physics, and cometary science (as it pertains to physics of the solar wind).

Updates on facility and instrumental progress and research highlights, including a bibliography of recent contributions, appear below. The nominal reporting period is July 1, 1999 - June 30, 2000.

Richard Fisher continued as Laboratory Chief with Edward Sullivan and John Wolfgang as Assistant Laboratory Chiefs. Charles Bennett remained as Infrared Astrophysics Branch Head, and Larry Orwig continued as Acting Head of the Instrument and Computer Systems Branch. Douglas Rabin from the National Solar Observatory joined the Laboratory as the Solar Physics Branch Head. Susan Neff has given up her UV/Optical Astronomy Branch Head position to devote more time to research activities and Ronald Oliversen has been the Acting Head of the Branch.

1.0. INFRARED ASTROPHYSICS BRANCH (C.L. BENNETT, HEAD)

1.A. INTRODUCTION

The Branch engages in theoretical and observational infrared, submillimeter, and radio astrophysics, notably in studies of diffuse infrared and microwave background radiations, both galactic and cosmic. The Branch develops detectors for infrared, submillimeter, and X-ray astronomy, and develops instruments for suborbital projects and space missions. The Branch develops instrumentation for the Hubble Space Telescope (HST), Space Infrared Telescope Facility (SIRTF), the Microwave Anisotropy Probe (MAP), the Next Generation Space Telescope (NGST), the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Far-Infrared and Submillimetre Telescope (FIRST).

1.B. PERSONNEL

The permanent staff includes: C. Bennett, E. Cheng, W. Danchi, E. Dwek, D. Gezari, M. Greenhouse, G. Hinshaw, A. Kogut, J. Mather, S. H. Moseley, R. Shafer, R. Silverberg, and E. Wollack.

W. Danchi joined the permanent civil service, and M. Freund joined the Branch as a term hire civil servant. J. Mather is a member of the National Academy of Sciences, and J. Mather and S. H. Moseley are Goddard Senior Fellows. Scientific resident associates and long-term visitors in the Branch include: R. Arendt, A. Bier, D. Benford, D. Cottingham, J. Felten, D. Figer, M. Fioc, D. Fixsen, C. Froning, N. Gorkavyi, C. Holt, A. Kashlinsky, K. Misselt, T. Kelsall, A. Kutyrev, K. Long, E. Oh, P. Oh, J. Orloff, L. Ozernoy, N. Phillips, B. Rauscher, M. Regan, S. Satyapal, T. Sodroski, J. Weiland, R. Windhorst, and X. Zhang.

1.C. FLIGHT PROGRAMS

NGST. The Next Generation Space Telescope (NGST) is a large aperture follow-on mission to the Hubble telescope under the Origins program. It is an 8 m class cooled infrared telescope optimized to observe the first stars and galaxies, and was given top priority by the National Academy of Sciences Decadal Survey. It is planned for launch in 2008. Mather serves as the NGST Study Scientist, while Greenhouse is the Deputy Study Scientist for instruments, and is the prime NGST contact for the six NASA-funded instrument studies as well as Canadian and ESA studies. Greenhouse led a GSFC engineering team to design the Yardstick instrument package for NGST, which would implement the recommendations of the NGST report ''Visiting a Time when Galaxies were Young.'' This package includes a four-bay near IR camera, a multi-object spectrometer with a micro-mirror array as an object selector, and a mid-IR camera and spectrometer. Greenhouse also leads the development of many key technologies for NGST instruments, such as tunable filters. E. Smith (681) serves as Deputy Study Scientist with main responsibilities in scientific program development. New technology is required to enable high accuracy thin mirrors with low weight. The NEXUS technology demonstration for NGST would fly in 2004. Mather and Fixsen are studying algorithms for use in flight supercomputers for NGST, including cosmic ray rejection, and optical phase correction.

HST. Cheng served as the Project Scientist for the HST Flight Systems and Servicing Project, and as the Mission Scientist for the Hubble Orbital Systems Test (HOST) shuttle mission. HOST demonstrated the first successful operation of a highcapacity mechanical cryocooler in space. This cryocooler, to be deployed during the next HST servicing mission, will provide the necessary cooling to restore the NICMOS instrument on HST. The Wide Field Camera 3 instrument development has been approved for HST Servicing Mission 4 (2003). The scientific staff includes members from the STScI and JPL, as well as an external Scientific Oversight Committee. Detector characterization is under development and all residual WF/PC (1) hardware have been relocated to GSFC.

Astro-E/AXAF/XRS. AXAF was conceived as part of the NASA Great Observatory series, but was re-scoped as two missions. Moseley served as a Co-I for the X-Ray Spectrometer (XRS), which was to be flown on the AXAF-S mission. He is the originator of the detector concept, which is based on cryogenic microcalorimeters capable of resolving X-ray energies at 6 keV to better than 10 eV. The XRS instrument was successfully delivered to Japan for integration into the Astro-E spacecraft, however, the launch was unsuccessful and the mission was lost. A proposal to fly the XRS on a SMEX mission, JOULE, has been submitted, and ISAS is considering a re-flight.

SIRTF. This mission is one of the NASA Great Observatory series. Moseley serves as the Instrument Scientist for the Infrared Array Camera (IRAC) and has taken an active role in the instrument's development. The flight instrument is nearly complete and will soon be integrated to the spacecraft. M. Greenhouse serves on the SIRTF Community Task Force and has taken an active role in the development of the SIRTF Legacy observing program. Arendt, Fixsen, and Moseley derived algorithms for self-calibration of the IRAC instrument.

MAP. The Microwave Anisotropy Probe (MAP) was approved as a MIDEX-class mission in April 1996. Its purpose is to determine which cosmological structure formation model best fits the cosmic microwave anisotropy data. It will test inflation and measure the basic properties of our universe. If a particular model fits the anisotropy data well, then the values of all of the key cosmological parameters can be derived with great accuracy. Bennett serves as the P.I. with Hinshaw, Kogut, and Wollack as Co-Is. Kogut has directed the instrument test program and Wollack has directed the instrument integration. MAP completed definition and entered into its design and development phase upon mission confirmation in July 1997. The MAP instrument and spacecraft are now complete and the integrated Observatory is scheduled to launch in early 2001, following full system-level environmental tests to be conducted during Fall/Winter 2000-2001. See http://map.gsfc.nasa.gov for more information.

FAME. W. Danchi was appointed as the Project Scientist for the FAME MIDEX mission, an astrometric explorer mission led by the Naval Observatory and by the Naval Research Laboratory.

SOFIA. The Submillimeter and Far Infrared Experiment (SAFIRE) is an approved instrument for the Stratospheric Observatory for Infrared Astronomy (SOFIA). Moseley is the P.I., Shafer, Benford, and Dwek are Co-Is, and there are other Co-I's at Johns Hopkins, Cornell, and Caltech. SAFIRE is a high resolution far infrared and submillimeter spectrometer, which will employ newly conceived two-dimensional superconducting bolometer arrays now being developed at GSFC to provide unprecedented sensitivity and large format. SAFIRE will provide imaging spectroscopic submillimeter observations of star forming regions and the interstellar medium of the Milky Way and other galaxies. (See *http://pioneer.gsfc.nasa.gov/public/safire* for further information.).

The High-Resolution Airborne Wideband Camera (HAWC) is a facility instrument for SOFIA. D. A. Harper (U. Chicago) is the P.I. and Moseley is a Co-I with responsibilities for numerous subsystems, including a large-format far-infrared detector array. This ‘‘pop-up bolometer array’’ will contain 384 detectors (the largest ever developed for this wavelength band). M. Freund is leading the detector testing effort. (See *http://pioneer.gsfc.nasa.gov/public/hawc* for further information.)

NIRS. M. Freund is analyzing data from the Near Infrared Spectrometer (NIRS), a broadband 24 channel spectrophotometer operating between 1.4-4 microns with a $8' \times 8'$ field of view. It flew as part of the IRTS satellite, and surveyed 7% of the sky. The final data set will yield a point source catalog (PSC) of $\sim$10,000 high quality spectra, which will facilitate the study of late-type stars (K, M-giants). Diffuse background maps are also in preparation.

FIRST. H. Moseley (P.I.) is one of the U.S. members of the Spectral and Photometric Imaging Receiver (SPIRE) team on FIRST. The SPIRE instrument provides diffraction limited photometric and spectral imaging over the 200 to 670 micron spectral range. A primary scientific goal of the mission is the study of galaxy and structure formation at high redshift. The execution phase of the mission is just beginning for a launch in 2007. (See *http://pioneer.gsfc.nasa.gov/public/spire* for further information.)

TPF. Gezari led an effort to organize a science team to assist in a proposal to study new concepts for the Terrestrial Planet Finder (TPF) mission to detect extra-solar earth-like planets. The proposal was accepted and the study is being done by an industry consortium led by Boeing-SVS Corporation of Albuquerque, NM.

1.D. SCIENTIFIC RESEARCH AND TECHNOLOGY HIGHLIGHTS

Cosmic Microwave Background Experimental Research. TopHat is a cosmic microwave background anisotropy experiment to test cosmological theories of structure formation in the Universe. TopHat is a balloon-borne experiment for mapping a 48 degree diameter patch of sky centered on the South Celestial Pole. It has completed instrument tests and was shipped to Palestine, Texas for integration and system testing in June 2000. TopHat is designed to return high sensitivity, large area maps with very low systematic uncertainties. It is scheduled to launch from Antarctica in December 2000.

A. Kogut, E. Wollack, and D. Fixsen, with M. Seiffert and S. Levin of JPL and P. Lubin from UCSB, are leading a project to use centimeter-band measurements to probe the epoch of reionization when the first stars began burning hydrogen to helium. The Diffuse Microwave Emission Survey (DIMES) was a mission concept study supported by NASA to answer fundamental questions about the content and history of the universe. DIMES would measure the frequency spectrum of the cosmic microwave background (CMB) at centimeter wavelengths to study the formation of structure during the ''cosmic dark ages'' prior to the formation of the first stars and galaxies. DIMES will fix the epoch of reionization by measuring the total column of freefree emission to the redshift $z\sim10–30$ when the first collapsed objects ionized the intergalactic medium. By measuring the chemical potential of the CMB, DIMES would fix the total energy budget of the early universe including the decay of massive neutrinos, primordial black holes, turbulence, and sub-horizon density perturbations. A balloon-borne demonstration payload, ARCADE, is currently under development and is expected to fly within the year. See http://map.gsfc.nasa.gov/DIMES/ for more information.

Cosmic Microwave Background Analytical Research. Kogut and Hinshaw, with A. Banday at MPfA, are re-analyzing the time-ordered data from the COBE-DMR mission to generate full-sky polarization maps at 53 and 90 GHz. The resulting maps should provide the first look at polarized foregrounds at frequencies of interest for MAP. Numerical simulations by Kogut and Hinshaw of CMB polarization in the presence of polarized Galactic emission show that the cosmological temperature-polarization signal generated at recombination is unlikely to be significantly degraded by expected Galactic foregrounds, so that detailed modelling of the foregrounds will not be required in order to detect the cosmological signal. Polarization of the CMB is a powerful probe for primordial gravitational waves and provides important information on the epoch of reionization, but the predicted signal is faint and could be obscured behind polarized Galactic emission.

Tests for non-Gaussian statistics in the CMB anisotropy provides a test of inflationary models for cosmology. Several authors have used the COBE-DMR maps to reject Gaussian models. Kogut and N. Phillips test the power of different statistical tests against a physically motivated non-Gaussian defect model. Even though the Central Limit theorem pushes these models close to Gaussian statistics on large angular scales, the genus and extrema correlation function retain statistical power to discriminate successfully between models. Acting on a cut sky, the bispectrum has no statistical power against these models.

Far-Infrared Astronomy Experimental Research. Moseley and N. Wang (Caltech) led the development of a 350 and 450 micron imaging detector for the Caltech Submillimeter Observatory (CSO) Submillimeter High Resolution Array Camera (SHARC). This instrument saw first light in October 1995, and has been used extensively since that time. The SHARC employs monolithic silicon bolometer arrays developed at GSFC. These bolometer arrays allow high sensitivity to be combined with large format for the SHARC II instrument, greatly extending submillimeter imaging limits. Work is under way to increase the detector focal plane from 20 to 192 elements. Multiplexed arrays of transition edge semiconductor (TES) bolometers are being developed by Moseley and colleagues for use in the SOFIA SAFIRE instrument and future space missions.

Near- and Mid Infrared Astronomy Experimental Research . Danchi and Gezari made new 12 ìm observations of Orion BN/KL on the Keck Telescope, which show that BN is resolved into two sources, with a weak source about 1.5 arcsec to the west of the bright component. Previously observed only at radio wavelengths, this is the first time a mid-infrared source component has been seen. Also, IRc2 breaks up into a set of components that are similar to, but not identical in appearance to those observed at 3.8 ìm. There is more complexity to IRc2 than was apparent from previous work at 3.8 ìm. Besides the 12.5 ìm mosaic, a complete set of maps was made at 4.8, 8.0, 8.9, 10.4, 11.7, and 12.5 ìm, encompassing n, IRc7, and IRc2, as well as a map of BN and IRc2 at 18.7 ìm.

A. Kutyrev (Raytheon-STX) developed a high-throughput spectrometer, called Brackett Alpha Measurements (BAM), to map the diffuse ionized gas throughout the Milky Way galaxy, and particularly in the plane of the galaxy where the H alpha line is heavily attenuated by dust. The longer wavelength Brackett alpha and gamma lines penetrate the entire galactic plane. Two observing runs using the instrument with an array detector were carried out in the summers of 1997 and 1998 along side of the IRTF on Mauna Kea, Hawaii.

W. Danchi, in close collaboration with the University of California at Berkeley, completed the third telescope for the Infrared Spatial Interferometer (ISI). Danchi supervised the completion of the heterodyne detection system, a key subsystem of the interferometer. This telescope is now essentially completed and will be delivered to Mt. Wilson, California in September 2000. This third telescope will be added to the previous two telescopes to make the ISI into the world's only imaging interferometer in the mid-infrared. During the past year several papers using infrared interferometric data were completed and are published or in press, including: a paper on the distribution of dust surrounding the symbiotic star R Aquarii; a paper on only the second Wolf-Rayet star with a spiral dust pattern (WR 98A); a paper with new precise (1%) diameters of Alpha Orionis and Omicron Ceti at 11 microns (these diameters are very important because at 11 microns, limbdarkening should have only a very small effect ($<0.5\%$) on the diameters, much smaller than at other wavelength regions); measurement of a bipolar and time-variable dust envelope for the carbon star CIT 6; and a paper describing a proper motion study of dust clumps ejected from the carbon star IRC +10216, showing directly the acceleration of the clumps from the star.

D. Gezari has continued to develop the NASA Catalog of Infrared Observations (CIO), the only actively published infrared astronomical catalog. It is a product of the computerized Goddard Infrared Astronomical Database, a compilation of all infrared (1-1000 micron) observations published in the scientific literature since 1965. The database now contains over 380,000 individual observations of over 63,000 sources.

The Catalog is on the Internet searchable website *http://ircatalog.gsfc.nasa.gov/)*. The 5th Edition of the CIO was released as Web Version 5.0, and the printed version has been discontinued. An accelerated effort is being made to bring the database up to date to produce a 6th edition to be incorporated as a tool in the SIRTF observing proposal process.

Theoretical Infrared Astronomy Research. E. Dwek, in collaboration with the COBE/DIRBE team, published five papers on the COBE search for the diffuse cosmic infrared background (CIB). Dwek led the interpretation of the positive detection of the CIB in the 140 to 1000 micron regime, as well as the research leading to the tentative detection of the CIB at 3.5 microns. M. Hauser (STScI) and Dwek are currently preparing an extensive review paper for the Annual Review of Astronomy and Astrophysics on the detection and interpretation of the CIB. Arendt, Moseley, and Dwek published an interpretation of ISO observations from the supernova remnant Cas A that revealed the presence of newlysynthesized elements and dust in the fast moving supernova ejecta. A detailed model was published by Dwek describing the evolutionary cycle of dust in the Galaxy, including its formation in the various sources and its growth and destruction in the interstellar medium. The nature of interstellar dust was investigated by Smith and Dwek, who analyzed the X-ray scattering halos around Nova 1992. The X-ray scattering model is now being used to test for the presence of large interstellar dust particles (detected by Ulysses spacecraft in the solar system) in the general interstellar medium. Dwek and Fioc are publishing the most detailed compilation of visible to far infrared photometric properties of opticallyselected normal galaxies. This library of galactic spectra will be used to model the spectral evolution of galaxies from the UV to far-infrared wavelengths, and model their contribution to the extragalactic background light. De Jager and Dwek led the interpretation of the observed TeV gammay-ray spectra from Mrk 501 and 421. The analysis shows evidence for absorption in the TeV spectrum of Mrk 501, which is being used to set limits on the CIB intensity in the 5 to 60 micron wavelength region.

Technology Research and Development. The large antennas required for CMB spectrum measurements at long wavelengths, if machined from solid aluminum stock, would weigh over 200 pounds and could dominate the mass budget of a Small Explorer-class mission. Kogut, Wollack, and K. Segal (code 543) are testing lightweight antennas made from plated composites, designed to withstand repeated thermal cycling to 3K without degradation of RF properties. By using composites, a mass savings of over 95% can be achieved without sacrificing either beam performance or insertion loss.

Measurements at far-IR and sub-mm wavelengths are currently limited by the sensitivity of available detectors. Kogut and Moseley, with M. DiPirro (Code 552) and C. Allen (Code 553), are developing an integrating bolometer for use in large arrays. The combination of a non-dissipative sensor coupled with a fast heat switch provides breakthrough capabilities in both sensitivity and operation. The bolometer temperature varies linearly with the integrated infrared power and may be sampled intermittently without loss of information between samples. The sample speed and consequent dynamic range depend only on the heat switch reset cycle and can be selected in software. Not only does this allow for a significant reduction in data rate for deep space missions, but it allows a single readout device (SQUID) to multiplex a large number of devices, greatly reducing the complexity, power requirements, and cost of readout electronics for large pixel arrays.

Hinshaw and Wollack have been studying devices for coupling polarized input signals to bolometers via striplined-based multiplexing frequency filters. These devices have potential application in measurements of polarized signals at mm and sub-mm wavelengths.

2.0. SOLAR PHYSICS BRANCH (D. RABIN, HEAD)

2.A. MISSION

At the center of the solar system is a magnetic variable star that modulates all space from the surface of the star (our Sun) to at least the orbit of Jupiter, including the near-Earth environment and the Earth's atmosphere. The goal of the Solar Physics Branch is to gain a better understanding of the physical processes that govern the Sun and the Sun-Earth connection.

The solar physics program is centered on the goals of NASA's Space Science Enterprise. We play significant roles in all of the ongoing solar space missions. Specifically, the Branch provides

•The US Project Scientist, several instrument Co-I's and the Experiment Operations Facility for the joint ESA/NASA Solar and Heliospheric Observatory (SOHO).

•The prime US data depository and archive for the joint ISAS/NASA Yohkoh mission.

•One of two US data centers for the Transition Region And Coronal Explorer (TRACE).

•The Mission Scientist and several Co-I's on the High Energy Solar Spectroscopic Imager (HESSI), scheduled for launch in 2001.

•The Project Scientist and two instrument Co-I's on the Solar Terrestrial Relations Observatory (STEREO), scheduled for launch in 2004.

•An instrument Co-I on the ISAS/NASA/UK Solar-B mission, scheduled for launch in 2004.

•The Lead Scientist for the Living With a Star (LWS) program and the Discipline Scientist for one of its component missions, the Solar Dynamics Observatory (SDO).

The Branch conducts an active suborbital program, anchored by the Solar Extreme-ultraviolet Research Telescope and Spectrograph (SERTS) sounding rocket. SERTS has played key roles in exploring the solar EUV spectrum, in calibrating spacecraft experiments, and in developing EUV detector technology. The SPARTAN 201 coronal physics payload has flown several times on the Space Shuttle. The ground-based program continues to support flight missions by providing high-quality, full-disk spectromagnetograms and spectroheliograms from the National Solar Observatory/NASA facility on Kitt Peak. A theoretical program in atomic physics and high-energy processes supports solar physics missions and has wider applications in astronomy and physics.

2.B. PERSONNEL

The permanent staff includes: W. Behring, A. Bhatia, C. Crannell, J. Davila, B. Dennis, U. Desai, R. Drachman, T. Duvall, K. Glass, J. Gurman, G. Holman, H. Jones, S. Jordan, L. Orwig, A. Poland, D. Rabin, M. Swartz, A. Temkin, R. Thomas, and B. Thompson. Rabin joined the Branch in 2000 August. C. Delannée and J. Sato were National Research Council Resident Research Associates.

2.C. SOHO

In the approximately five years since launch at solar minimum in 1995 December, SOHO has monitored the rise of the solar cycle to what appears to be an early maximum. Recent observations and analyses have emphasized the evolution of solar phenomena through the cycle, as driven by the global restructuring of the magnetic field. The SOHO experiment teams have continued to devote much of their observing time to coordinated campaigns. For the period 1999 July–2000 July, the SOHO campaign database (http://sohodata.nascom.nasa.gov/cgibin/soho_campaign_search) lists a total of 135 coordinated observations between SOHO instruments and ground-based observatories and/or other spacecraft. A large amount of work has continued toward understanding the impact of solar activity on the Earth environment and toward instrument calibration to improve quantitative analyses.

I. RECENT SCIENTIFIC HIGHLIGHTS

Variability of the Tachocline. Data from SOHO/MDI and the ground-based Global Oscillation Network Group (GONG) show that the contrast in speed between layers in the tachocline (the thin, turbulent interface between the rigidly rotating interior and the differentially rotating convection zone) can change by 20% in six months. The observed quasiperiodic oscillation has a period of 15-16 months, much shorter than the nominal 11-year period of the sunspot cycle. The tachocline may well be the seat of the solar dynamo.

Seeing behind the Sun. Two instruments on SOHO have demonstrated independent techniques to monitor the far side of the Sun. SWAN observed enhanced emission from active regions on the far side as projected onto the ''screen'' of hydrogen atoms permeating the solar system. Recently, MDI was able to detect a far-side active region by means of ''acoustic holography,'' a technique in which the presence of magnetic fields in the invisible hemisphere can be recognized from subtle changes in the sound waves observed on the visible hemisphere (a similar technique has been applied in geophysics).

Speedy Solar Wind. The UVCS team has discovered that the high-speed solar wind in coronal holes achieves its unexpectedly high velocity (up to 800 km s^{-1}) by ''surfing'' magnetic waves in the Sun's outer atmosphere.

Coronal Mass Ejections and Space Weather. Statistics on coronal mass ejections (CME's) and their geomagnetic effects have been enabled by SOHO/LASCO observations. A comparison of the timing of Earth-directed CME's with the Kp geomagnetic storm index in the days following the CME illustrates the key role SOHO now plays in the international space weather warning system. Of 25 front-side ''halo'' CME's (which symmetrically surround the solar disk) seen by LASCO and EIT during 1996 and 1997, over 85% caused geomagnetic storms with $Kp = 6$, and only 15% of such storms were not predicted. This is a major advance over the state of the art as recently as 1995, during which only 27% of 173 geomagnetic storms were forecast correctly, while 63% of 126 forecast were false alarms.

Comet Finder. Instruments on SOHO have also proved to be the most prolific comet finders in the history of astronomy, with a total of 167 found as of 2000 July 1, an increase of nearly 100 from the year before. All but one of the SOHO comet discoveries were made with the LASCO instrument (a set of coronagraphs). One comet was discovered by the SWAN instrument, observing the cloud of hydrogen resulting from dissociation of water vapor streaming from the nucleus. Initially, SOHO scientists found most of the SOHO comets, but now amateur astronomers accessing SOHO data on the Internet find the majority. Most comets observed by LASCO are Kreutz sungrazers which do not survive the close encounter with the Sun. SOHO has increased the number of known sungrazers by a factor of four, implying that there could be as many as 20,000 fragments from the gradual break-up of a large comet.

II. OTHER RECENT STUDIES

With colleagues P. Brekke (ESA) and T. N. Woods and F. G. Eparvier of the Laboratory for Atmospheric and Space Physics at Boulder, W. T. Thompson (Emergent) produced a calibrated solar EUV irradiance spectrum in the ranges 307-380 Å and 515-632 Å , using the Normal Incidence Spectrometer (NIS) of CDS. The relatively high spectral resolution (0.3-0.6 Å) allowed the separation of blends and the differentiation of weak emission lines. The full-disk spectrum taken on 1997 May 15 was compared with simultaneous well-calibrated EUV irradiance measurements from a NASA/LASP rocket payload. The spectrum includes emission lines formed in the temperature range 10^4 to over 10^6 K. This measurement should represent well solar minimum conditions for ''the Sun as a star.'' A modest spatial resolution, constrained by the observing mode used, allows for the discrimination between quiet and active Sun.

J. Newmark (Emergent) completed calibration work on the Naval Research Laboratory EIT Calibration Rocket (CalRoc). CalRoc provides flat field and absolute calibration for EIT. Newmark also used differential emission measure (DEM) techniques to produce solar EUV irradiances based on EIT data.

F. Auchere (USRA, Cooperative Program in Space Science) has been assisting with the EIT calibration: he determined the EIT plate scale by comparing EIT and MDI data; used intercalibrations of EIT with the NRL CalRoc and MXUVI sounding rockets to help determine the EIT flat field and stray light calibrations; and used observations of the 1999 November 15 Mercury transit to obtain absolute calibration of the EIT plate scale and stray light level.

Auchere completed his thesis research at Goddard for a Ph.D. at Institut d'Astrophysique Spatiale, Universite Paris XI. He analyzed EIT observations of the 304 A HeII line in the solar corona, extending some diagnostics commonly used for the hydrogen Lyman alpha line to the second most abundant element. The EIT observations suggest the possibility of an accumulation of He^{+} ions in the polar coronal holes, an effect predicted by some theoretical models of solar wind expansion.

Month-long coordinated observations for the Third Whole Sun Month Campaign took place in 1999 August and September. A workshop was held at GSFC to begin the organization and analysis of the data. The campaign and the workshop were organized by D. A. Biesecker (Emergent) and S. Gibson (Catholic U.). Studies on coronal structure and diagnostics and on sigmoid-shaped active regions are underway. Some early results were presented at the Spring AGU meeting; a special session featuring Whole Sun Month results will be held at the Fall AGU meeting.

T. Kucera (Emergent), U. Feldman and K. Widing (NRL), and W. Curdt (MaxPlanck-Institut) have identified in SOHO/SUMER and Skylab flare data all remaining previously unidentified lines arising from transitions within levels of the Fe XX ground configuration. The lines span the wavelength range 300-2665 Å . These lines are fairly prominent in low density plasmas and can be used to determine properties of hightemperature astrophysical plasmas. Since spontaneous decay rates of forbidden transitions from the same upper level are known quite accurately, these lines can be used for calibrating spectrometers over wide wavelength ranges.

S. Plunkett (USRA/NRL) studied the origin of coronal mass ejections, including a detailed study of a prominence eruption and associated CME on 1998 June 2, using both SOHO (LASCO/EIT) and ground-based H-alpha data from the Ondrejov observatory. A magnetic flux rope was observed near the top of the erupting prominence, and this flux rope could be seen in EIT images taken before the eruption began. Plunkett also studied the statistical properties of CME source regions in EIT data near solar minimum (1997-1998), finding that the latitudinal distribution of CME's observed by EIT was very different to that observed higher in the corona by LASCO. The EIT activity is often observed to occur near one leg of the CME.

In a collaborative study of halo CME's using combined Yohkoh Soft Xray Telescope (SXT) and SOHO/EIT data, D. M. Zarro (Emergent) and Thompson worked with A. Sterling and H. Hudson in tracking the evolution of coronal structures associated with the halo CME's from the sigmoidal shape of the preflare loops to the post flare loop arcades.

2.D. HESSI AND SOLAR X-RAYS

The Branch is collaborating with R. Lin (Space Sciences Laboratory, UCB) on the High Energy Solar Spectroscopic Imager (HESSI), a SMEX mission now being readied for launch in 2001. HESSI is aimed at understanding the fundamental solar flare processes of particle acceleration and energy release from the coronal magnetic field. It will make images of flares and obtain highresolution spectra in X-rays and gamma rays from 3 keV to 20 MeV with finer angular resolution (down to 2 arcseconds) and spectral resolution ($\sim$1 keV) than has previously been possible.

In 2000 March, HESSI suffered a serious setback when the fully integrated spacecraft was undergoing final vibration tests at JPL prior to the planned launch in 2000 July. Because of a malfunctioning vibration table, HESSI was subjected to an inadvertent over-test with levels far exceeding the design limits. As a result, the imaging telescope tube broke loose and damaged the spacecraft structure and the solar panels. Luckily, none of the grids or detectors were damaged. Recovering from this unfortunate mishap has been expensive and time consuming. NASA Headquarters has now given its approval for continuation of the mission with launch scheduled for 2001 March. This will allow observations during at least two years of high solar activity and allow HESSI to achieve all of its original scientific objectives.

HESSI uses a Fourier-transform imaging technique to achieve its high angular resolution and nine hyper-pure germanium detectors cooled to 80 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. HESSI will provide such images with subsecond time resolution for the more intense flares, thus allowing high fidelity movies to be made for public display. More importantly, the HESSI observations will 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. HESSI will also provide 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 Branch is responsible for the nine pairs of flight grids that form the modulation collimators used to achieve 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. 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 arcmin for the finest grids.

In addition to the hardware involvement, the Branch is developing the software to display, analyze, interpret, and archive all calibration and flight data. The software will carry out basic data manipulation functions to produce catalogs, light curves, images, spectra, etc. Already several preliminary versions of the software package have been released and are available for testing. Extensive software has also been developed to analyze prelaunch data and provide support for grid characterization, alignment, and tests. Preparations are underway for making all of the HESSI data and basic access and analysis software available after launch to all interested members of the scientific community through the facilities of the Solar Data Analysis Center. The Branch is participating in an extensive HESSI education and public outreach activity. Many students and teachers work at Goddard on HESSI activities ranging from hands-on help with processing the flight grids, analyzing data from the grid characterization facilities, and upgrading the HESSI website at www://hesperia.gsfc.nasa.gov/hessi/.

Holman and colleagues from Stanford, UCB, NRL, Raytheon/ITSS and GSFC are continuing the development of numerical codes for the interpretation of HESSI and related data. The codes will compute x-ray and radio images and spectra from flare models. These computations will be compared with HESSI and ground-based radio observations to obtain an understanding of the physics of electron acceleration and propagation in solar flares. Holman presented a public lecture at the Goddard Visitor Center about the High Energy Solar Spectroscopic Imager entitled ''HESSI: Studying the Fundamental Aspects of Solar Flares.''

As a proof of concept, Desai, Orwig and collaborators L. Mertz (Digiphase Technology), C. Gaither (CAN Corporation), W. Gibson (Center for Xray Optics, SUNY Albany) have designed, fabricated, and tested a novel hard X-ray telescope. The concept uses two coarse Fresnel zone plates (FZP) as a bi-plane coder. This two-plane coder produces the Fourier transformation of the source distribution on the image plane. The major constraints to achieving high angular resolution in single plane coded aperture imaging are (1) the limitations of how fine a feature one can make in thick high-Z materials used as the coder , and (2) the limitation of spatial resolution to resolve such features in the image plane detector. In the bi-plane coder using FZP's, one does not have to resolve the fine features of the coder. The Moiré fringes generated by the bi-plane coder can be easily resolved by a detector with coarse spatial resolution and can provide high angular resolution. We have used zone plates made from 1-mm-thick tungsten with 144 zones and a narrowest zone of 41microns. The total thickness of 2 mm of both the plates enables casting of shadows up to 250 KeV. We presented some results of the exposure of such a telescope to the X-ray beam facility at NASA's MSFC.

Desai and Orwig presented a new concept of a stacked detector that provides high spectral resolution over a wide energy band (keV-MeV). The idea is to use detectors of appropriate energy bandwidth to avoid saturation effects in the single detectors normally used. Specifically, a silicon PIN detector is used for sub-keV to 60 keV; a 2-mm thick CZT detector for 20 keV to 60 keV; a 5-mm thick CZT detector for harder X-rays; and a 2-cm-thick scintillator viewed by a PIN to extend the range to MeV photons. The significant advantages of this concept over a single detector are (1) charged particle rejection capability, (2) low internal noise, and (3) identification of Compton interactions.

2.E. SERTS

The Solar Extreme-ultraviolet Research Telescope and Spectrograph (SERTS) was flown on 1999 June 24, obtaining high spectral resolution, well calibrated, spatially resolved, coordinated observations with CDS and EIT on SOHO. Thomas, Davila, W. Thompson (Emergent), and J.Brosius (RITSS) used these coordinated observations to derive a preliminary calibration correction curve for the CDS Normal Incidence Spectrometer's NIS-1 waveband. This is especially important owing to CDS calibration variations due to loss of control of SOHO during the summer and fall of 1998. A similar CDS calibration correction based upon coordinated SERTS and CDS observations acquired 1997 November 18 was derived, verified, and incorporated into the CDS calibration software. Brosius mentored K. Talbot, a 6th grade public school teacher, as part of the SUNBEAMS program; her students flew memorabilia on SERTS-99 in a container specially designed and built by D. Linard.

F. P. Keenan, E. O'Shea (Queen's University, Belfast), Thomas, Brosius, and collaborators presented new calculations of Si X electron impact excitation rates, and compared theoretical values for both density-sensitive and density-insensitive line intensity ratios with measured ratios from SERTS-89. Results provide observational support for the general accuracy of the Si X atomic data. Keenan, Thomas, Brosius, and collaborators carried out a similar study for the S XI ion, with similar results.

Jordan, V. Andretta (Osservatorio Astronomico di Capodimonte, Italy), Brosius, Davila, Thomas, Behring, W. Thompson, and A. Garcia (U. da Coimbra, Portugal) presented observational evidence from SERTS and SOHO for the effect of microturbulent velocities in enhancing the intensity of the He II 304 Å line with respect to other transition region lines and NLTE predictions for a static atmosphere. Jordan was the summary speaker at a workshop on helium line formation held in April 2000 in Naples.

J. Schmelz and H. Winter (U. Memphis), J. Saba and K. Strong (Lockheed Martin), and Brosius derived the emission measure distribution for an active region using coordinated SERTS and Yohkoh/SXT observations. They carefully derived corrections to the Yohkoh/SXT filter response curves due to improvements in adopted coronal elemental abundances as well as differences in adopted ionization equilibrium computations. Brosius, Thomas, and Davila used SERTS-95 spectra to measure wavelength shifts of coronal emission lines in the core of NOAA region 7870 relative to its immediate surroundings. Results suggest a net upflow of heated material and a net downflow of cooler (but still coronal) material. Brosius, Thomas, Davila, and W. Thompson used SERTS-97 spectra of NOAA region 8108 to find relative blueshifts in the southern portion of the active region, with relative redshifts in the north. Brosius, Thomas, Davila, and E. Landi (MPIA) used an average spectrum of NOAA region 8108 from SERTS-97 to find a number of Fe XV emission lines not previously seen in solar EUV spectra. In addition, they measured nonthermal line widths of 35 km s^{-1} for all available ionization stages of iron from X through XVI (and Ni XVIII), derived mutually consistent electron densities using several different line intensity ratios, and derived the DEM using the iterative method of Landi and Landini (1997). Brosius continued his collaboration with N. Gopalswamy (Catholic U.) and Landi to derive 3-dimensional coronal magnetograms from coordinated SERTS-97, CDS, EIT, VLA, and SXT observations of NOAA region 8108.

2.F. ATOMIC PHYSICS

Research by Temkin and collaborators on partial wave dispersion relations continues. The joint paper with D. Bessis has now appeared. That work, which applies to potential scattering, is being extended in joint work, with D. Vrinceanu and A. Msezane of Clark Atlanta U., to include exchange. The approach is rigorous, but it assumes exponentially damped potentials. In real electron-atom scattering, longer range (polarization) potentials are present, for which the method developed by Temkin and Drachman can effectively be applied. An initial paper is being published, and further developments are being made to apply the method first to e-hydrogen scattering. As input, one needs to have total (partial wave) cross sections. A calculation using a previously developed (complex correlation Kohn T - CCKT) method is being applied by Temkin and Bhatia to the physical e-hydrogen problem.

Finally, a new approach has been developed to calculate angular distributions in atomic scattering directly, without the use of partial wave decompositions. Initial calculations using this method are being pursued with J. Shertzer of Holy Cross College (Worcester, MA).

A conference on Atomic Data Needs for X-ray astronomy was held in 1999 December at Goddard Space Flight Center. Physical properties such as temperature and electron density of solar and astrophysical plasmas can be inferred from EUV and X-ray emission lines observed from space. In order to compare observed intensities with the calculate ones, energy levels, transition rates, and excitation cross sections are required.

C IV emission lines have been observed from various astrophysical objects. Bhatia and Drachman carried out a very accurate calculation using their polarization model that includes Lamb shift, relativistic and retardation corrections. They also calculated energy levels for O VI and Ne VIII. Bhatia and Drachman also studied static properties and the Stark effect of the ground state of HD molecular ion by using the degenerate perturbation theory and pseudostates.

Bhatia and Kastner (deceased) continued their studies on opacity of emission lines and published a paper entitled ‘‘Global and local Doppler profile factors for plane-parallel geometry.’’

In addition to his work with Bhatia and Temkin, Drachman continued work on positronium resonances with J. DiRienzi of the College of Notre Dame of Maryland. Drachman’s short review article on Rydberg states of Lithium and other systems was published.

2.G. OTHER RESEARCH AND PROGRAM ACTIVITY

Jones continues to represent the Branch at the National Solar Observatory (NSO) to complement NASA flight-mission observations of the Sun (e.g., Yohkoh, SOHO, TRACE, SERTS, and Flare Genesis) with data from the NASA/NSO Spectromagnetograph (SPM) at the Kitt Peak Vacuum Telescope (KPVT) and to help develop it’s replacement, the SOLIS Vector Spectromagnetograph. Of particular interest were joint campaigns with SOHO in June, 1999 with CDS and, in collaboration with D. Hassler (SwRI), with SUMER in 1999 November to look for coronal hole outflows. Excess blue absorption consistent with radial outflows was observed in the He I 1083 nm line in disk-center coronal holes. A preliminary report with summer student C. Bender (UIUC) was presented at the Atlanta AAS meeting, and a more complete analysis of the SPM and SOHO data is underway with D. Hassler. Jones with collaborators K. Harvey (SPRC), C. Schrijver (LMSAL), and M. Penn (CSUN) used multiline SPM observations together with TRACE data to find that the majority of flux cancellation events are associated with magnetic submergence rather than emergence. Jones *et al.* found that sunspots and surrounding plage are highly correlated with spacecraft observations of solar irradiance variations in accordance with previous models, but that the majority of solar magnetic flux variations is poorly coordinated with irradiance. Extension of these irradiance comparisons to a longer time base and refinement of magnetogram classification is in progress. Jones, with summer student J. Ceja (CSUN), presented a preliminary comparison of the SOHO/MDI, prototype GONG+, and SPM magnetograms at a recent workshop on polarimetry at NSO/Sacramento Peak and found that MDI measures line-of-sight fluxes about 40 stronger than either GONG+ or SPM. The MDI scale is consistent with the older Diode Array Magnetograph which was used at the KPVT until 1992, and the results suggest that both the SPM and GONG+ data suffer from stray light caused by atmospheric and instrumental effects. Jones will refine the analysis techniques, extend the time base for the comparison, and include the SOLIS/VSM when it becomes operational.

Duvall, with Stanford graduate student L. Gizon, studied supergranulation using the time-distance technique. By filtering the doppler data to admit only the f mode (a surface gravity wave), it has been possible to develop a detector of horizontal flows averaged over the 1000 km just below the photosphere. This is a significant advance over using the normal doppler shift, which only gives the line-of-sight velocity. Interesting flow patterns have been observed, including horizontal inflows into active regions on a large scale, Evershed flow in sunspots, Coriolis ‘‘swirling’’ of supergranules, meridional circulation, and the small flows riding on top of rotation known as torsional oscillations. In addition to using the advection of the waves as a direct measure of flows, also the pattern of flow divergence due to supergranulation has been used for correlation tracking. This results in a somewhat different technique that may teach us about flows throughout the supergranular layer.

Davila collaborated with Leon Ofman (RITSS) on two-fluid, two-dimensional MHD models of the solar wind. The models show that Alfvén wave motion may explain the broad Lyman-alpha lines observed in coronal holes by the SOHO Ultraviolet Coronagraph Spectrometer (UVCS). Davila collaborated with V. Nakariakov (U. Warwick), Ofman, E. DeLuca (Harvard CfA), and B. Roberts (U. St. Andrews) on the analysis of TRACE observations of coronal loop oscillations excited by a solar flare. The team used the damped loop oscillations to estimate the dissipation coefficient in the corona, and found that the coefficient is many orders of magnitude larger than the classical value.

Davila collaborated with V. Airapetian (CSC), Ofman, R. Robinson (CUA), and Carpenter on the study of winds from luminous late-type stars. The team adapted the two-dimensional MHD solar wind code to study winds in late type stars. They found that Alfvén waves can generate both the slow/rarefied and the fast/dense winds in cool supergiant stars.

B. Thompson's work in the past year has primarily involved mission development, fabrication and operation. She served as Project Scientist for the Solar Dynamics Observatory, scheduled to fly in 2006 as part of NASA's new Living With a Star program, and served on the program's preformulation team. She continued operations and scientific support for the SOHO and TRACE missions.

3.0 UV AND OPTICAL ASTRONOMY BRANCH (R.J. OLIVERSEN, ACTING HEAD)

3.A. INTRODUCTION

The Branch concentrates on astrophysical research in the ultraviolet and visible part of the spectrum. Its members pursue programs including the design and development of scientific instruments, with an emphasis on space instrumentation; observations and analysis of data from astronomical systems ranging from the nearby interstellar medium through stars to clusters of galaxies and quasi-stellar objects; theoretical modeling of astrophysical plasmas and stellar evolution; and scientific software development and data archiving.

3.B. PERSONNEL

The permanent staff includes C. Bowers, K.G. Carpenter, J.F. Dolan, R.P. Fahey, W.A. Feibelman, J.P. Gardner, T.R. Gull, S.R. Heap, R.A. Kimble, S.G. Neff, M.B. Niedner, R.J. Oliversen, A.M. Smith, E.P. Smith, G. Sonneborn, T.P. Stecher, A.V. Sweigart, D. Unkle, and B.E. Woodgate.

J.C. Bouret, R. Cavallo, E. Chatzichristou, and K. Ishibashi are National Research Council Associates. T.M. Brown, D.H. Devine, C. Grady, K. Grogan, I.H. Hubeny, C.J. Pun, M. Sahu, A. Smette, H.I. Teplitz, and G.M. Williger are Space Telescope Imaging Spectrograph Research Associates.

Visiting scientists from other institutions during all or part of the year include F.C. Bruhweiler (Catholic U.), R. Iping (U. Guam), and K. Long (STScI).

Fahey continues as Acting Director of Goddard's University Program Office. He also continued an Outreach Project by which physics and engineering majors from the U.S. Naval Academy were stationed at GSFC to do research as part of their summer duty.

Feibelman continued as Editor of the Annual Lab Report.

3.C. RESEARCH PROJECTS

I. SEARCH FOR ORIGINS

Hubeny, M.A. Barstow (U. Leicester), and J.B. Holberg (U. Arizona) continued their study of hot, metal-rich white dwarfs. They have constructed non-LTE line-blanketed model atmospheres taking into account stratification of iron, and showed that resulting predicted spectrum provides a better match to the observed spectrum of DA white dwarf G191-B2B than previous model assuming homogeneous abundance stratification. Together with the Tuebingen group, they have also studied DO white dwarfs, and presented the first evidence for the direct detection of nickel in the photosphere of a hot DO white dwarf (REJ 0503-289). Intriguingly, iron, which is observed to be more abundant than Ni in the hot DA white dwarfs, was not detected.

Hubeny has developed an IDL package CLOUDSPEC that combines the spectrum synthesis program SYNSPEC with Ferland's photoionization code CLOUDY. With the ionization structure of the interstellar medium given by CLOUDY, CLOUDSPEC solves the radiative transfer along a chosen line-of-sight to yield detailed line profiles. The code was applied to an analysis of the spectrum of the $z=2.73$ Galaxy, MS1512-cB58, where it provided a unified model that includes stellar as well as interstellar contributions.

Sweigart has computed new grids of horizontal-branch evolutionary tracks in order to determine whether the upward sloping horizontal branches in the metal-rich globular clusters NGC 6388 and NGC 6441 might be explained by a spread in metallicity. These tracks indicate that a spread in metallicity from [Fe/H] = -0.5 to -2.3 can reproduce the upward slope found in HST color-magnitude diagrams, implying that the low metallicity is primarily responsible for the blue horizontal-branch population in these clusters.

Sweigart has participated in an on-going study of the physical parameters of the hot horizontal-branch stars in the globular cluster NGC 6752. Analysis of the spectra shows that the iron abundance is strongly enhanced by radiative levitation in stars hotter than about 11,500 K. While radiative levitation can explain the surface gravities of stars with effective temperatures between 11,500 and 15,000 K, hotter stars between 15,000 and 20,000 K still have anomalous gravities.

Sweigart has investigated whether the onset of radiative levitation and the sudden drop in rotation velocities observed in horizontal-branch stars at an effective temperature of 11,500 K might be associated with the disappearance of surface convection. The models show that surface convection does, in fact, disappear near this temperature, thereby supporting a link among these phenomena. Sweigart has continued his study of the conditions under which gravonuclear instabilities might occur during onset of helium-shell burning following the horizontal-branch phase of low-mass stars. These instabilities are characterized by a series of relaxation oscillations within the helium-burning shell which lead to pronounced loops along the evolutionary tracks. The new calculations demonstrate that these instabilities are not caused by either a high metallicity or small envelope mass.

Sweigart has participated in a study of the RR Lyrae stars in the globular clusters NGC 6388 and NGC 6441. The observations show that the pulsation periods of these variables are anomalously long, thus raising the possibility that they might represent a new Oosterhoff group.

Carpenter and R. Robinson (Catholic U.), along with D. Mullan and G. Harper (U. Colorado), have utilized the Sobolev with Exact Integration (SEI) computer code to analyze winds in cool stars and derived parameters of the winds for several evolved cool stars, including estimates of their mass-loss rates. Results were published for the K supergiant Lambda Vel.

V. Airapetian (Computer Sciences Corp.), Carpenter, Davila *et al.* have modeled winds from high-luminosity, late-type stars using a 2.5-dimensional, nonlinear MHD computer code for two cases of atmospheric topology. Case I (longitudinally uniform density distribution and isotropic radial magnetic field) calculations produce a wind with a terminal velocity of 22 km/s and a mass-loss rate on the order of E-6 solar masses/yr, about as expected for a cool supergiant such as Alpha Ori. Case II (isotropic, radial magnetic field with a transverse density gradient, i.e. an ''atmospheric hole'') calculations predict a two-component wind: a fast (25 km/s) and relatively dense wind outside of the atmospheric hole and a slow (15 km/s), rarified wind inside of the hole, which could explain the two wind components recently proposed by Robinson *et al.* for the K5 III hybrid star Gamma Dra.

Gull continues to collaborate with K. Davidson and R. Humphreys (U. Minnesota), S. Johansson (U. Lund), F. Hamann (U. Florida), J. Hillier (U. Pittsburgh) and Ishibashi on studies of Eta Carinae with STIS. In the past year they have found that Eta Carinae continues to brighten by 2.5x since December 1997 and the immediate nebulosity by 4.5x. Three complete spectra have been accomplished of the star, Weigelt Blobs B and D and the Integral Nebula in March 1998, February 1999 and March 2000. Major changes have occurred in the stellar P-Cygni profiles. The Weigelt Blobs now show recombination lines of doubly-ionized species, and the scattered stellar light indicates that the stellar line profiles change between the equatorial and polar regions. A bright emission filament has been noticed that shows many neutral and singly-ionized lines of heavy elements including strontium, titanium, cobalt and iron. Further observations in March 2000 confirmed these identifications and many more lines are in the process of being identified from heavy elements, seemingly due to s-process nuclear reactions. Mapping with STIS and a 52x0.1 aperture was done near the Balmer lines in H-alpha and H-beta. The scattered stellar light, with nebular absorptions, and nebular emission lines are being used to map the expanding ejecta in order to obtain a three dimensional model of the Homunculus and the emission substructures.

Dolan searched for dying pulse trains, the signatures of a black hole event horizon, in Cyg XR-1 using UV photometry with 0.1 ms time resolution obtained with the HST High Speed Photometer. Millisecond pulses originating in the accretion disk around the compact object are common in the UV. Two sets of pulses with characteristics similar to those expected from dying pulse trains were detected in 3 hours of observations.

P.T. Boyd, A.P. Smale (both Lab. High Energy Astrophysics) and Dolan studied the LMC X-3 binary system by analyzing integrated X-ray observations from the Roentgen X-Ray Timing Explorer (RXTE) and UV observations from HST. The results are consistent with the X-ray emitter being an accreting black hole.

Brown, Kimble, Bowers, and Sweigart have detected hot horizontal branch stars in M32; these data confirm that these stars are responsible for the UV upturn phenomenon, a key indicator of age and metallicity in elliptical galaxies. A STIS far-UV image of the galaxy cluster CL0016+16 ($z=0.55$) provided the most distant measurement of the UV upturn yet obtained, to a lookback time of 5.6 billion years; the map of the UV upturn evolution is consistent with a formation redshift of 4 for massive elliptical galaxies in clusters.

II. STRUCTURE AND EVOLUTION OF THE UNIVERSE

Smette, Gull, and A. Fruchter (STScI) found a Lyman jump in the near UV Spectrum of GRB20000301c consistent with $z=3.03$. This measurement establishes the redshift of this system and enables observers with the Keck Telescope to identify a series of faint absorption lines. Further work indicates that this burster is not directly associated with the host galaxy, or at a distance of $\sim$50 kpc at the adopted redshift. A neutron star-neutron star annihilation model is consistent with this result, but a very faint dwarf galaxy might not be detectable with STIS at $z = 3$.

Gardner, Teplitz, Brown, and Kaiser, along with a large team from the STScI, completed initial work on the STIS imaging of the HST Deep Field - South, which achieved the diffraction limit of the HST in the optical. Galaxy number counts were determined to fainter than 30 mag, and showed no sign of a turnover, reaching nearly 1000 galaxies per square arcminute. The ultraviolet images were used to search for high-redshift dropouts caused by the Lyman break and Lyman alpha forest.

Gardner and Satyapal analyzed the sizes and isophotal filling factor of galaxies in the HDF-South data. It was determined from the HDF-N and other deep WFPC2 imaging that fainter galaxies are smaller. This trend continues to AB=29 in the high resolution HDF-S STIS image, where galaxies have a typical half-light radius of 0.1 arcseconds. They ran extensive Monte Carlo simulations of the detection of galaxies in the HDF-S, and showed that the small measured sizes are not due to selection effects until fainter than 29th mag. They compared observed sizes in the optical and near-infrared using the HDF-S NICMOS image. After correcting for the resolution of the images, the galaxies are smaller in the NIR, as the bulge becomes more prominent.

Hubeny, O. Blass (U. California, Santa Barbara), E. Agol and Krolik (both Johns Hopkins U.) computed a grid of vertical structure AGN disk models and theoretical spectral energy distribution and polarization for a large range of black hole masses and mass acretion rates.

Palunas (Catholic U.), Collins, Gardner, Heap, Hill, Malamuth, Smette, Teplitz, Williger and Woodgate searched for QSO's in the Hubble Deep Field - South QSO J2223-6033 using narrowband imagery tuned to Lyman alpha at z = 2.24. The identified 154 candidate QSO's brighter than B = 23 using color selection, and 10 pointlike objects using narrowband emission. One emission line object is a z = 1.56 QSO, B =20, 6.7 arcmin from J2223-6033.

Heap, Williger, Smette, Hubeny, Sahu, E. Jenkins and T.M. Tripp (U. Princeton), and N. Winkler (Kansas Stae U.) analyzed spectra of QSO 0302-003 (z = 3.286) to investigate the He II Gunn-Peterson effect. They found that the He II Lyman-alpha absorption is produced by discrete clouds close to the QSO, but a diffuse gas component and a soft UV background is necessary farther away. At z = 3.05, there is a distinct gap in He II opacity where He is doubly ionized, possibly by an AGN.

Williger, Smette, and N. Hazard (U. Pittsburgh and U. Cambridge) found correlations in the Lyman-alpha forest between z = 2.60 and z = 3.37 between 10 lines of sight to QSO's in a 30 arcminute field toward the south galactic pole. This shows that coherent structures may exist over a distance of 7 Mpc or more at z = 3.

Dolan, Michalitsianos (deceased), Q.T. Nguyen (San Diego State U.) and Hill showed that the Lyman alpha and O VI 1037 A emission lines in the gravitationally lensed quasar QSO 0957+561 vary independently of each other and of the surrounding continuum. They speculate that the fluxes in lines with significantly different ionization potentials will vary independently of each other and of the flux level in the continuum in all QSO's.

The same authors also used the two lines of sight to the lensed image to determine that the density of Lymanalpha forest clouds in the direction of Q0957+561 must change significantly over distance R = 160 (+120, -70) kpc, where the absorbers are treated as spherical clouds and R is their radius. The spherical absorbing cloud model can acceptably represent the characteristic dimension of clouds in the direction of six different gravitationally lensed QSO's with a single value of radius; the 95% confidence interval is 50–950 kpc (using H(0) = 50 km/s Mpc, q(0) = 0.5, and no cosmological constant). The characteristic dimension R must be physically associated with the structure of the absorbing medium producing the Lyman-alpha forest.

Feibelman continued UV studies of planetary nebulae and symbiotic stars in collaboration with colleagues at U.California (LA), U. Korea, Catholic U., Queen's U. (Belfast), Kapteyn Astr. Inst. (The Netherlands), STScI, and GSFC.

Feibelman also combined IUE and HST-GHRS UV data for a detailed analysis of the Hybrid/PG 1159-Type central star of NGC 7094 which was found to display numerous absorption features, including line blanketing from Fe VI and Fe VII. The C IV and O V P-Cygni profiles exhibit variability.

Feibelman examined about 3 dozen archival IUE high-dispersion spectra of planetary nebulae in search for the 1909.60A transition of the isotope 13C. In collaboration with C.L. Miskey and F.C. Bruhweiler (Catholic U.), definite identifications and determination of the 12C(1908.77A)/13C(1909.60A) ratio was found for NGC 2440 and NGC 6302, with values of 39 and 23, respectively, which are considerably lower than the solar value of 89.

Feibelman collaborated with S.R. Pottasch and D.A. Beintema (Kapteyn Astr. Inst.) in a study of IUE and ISO spectra of the planetary nebulae NGC 6537 and He 2-111 for determination of abundances.

C. Grady, Devine, Kimble, and Woodgate are involved in two STIS GTO programs studying protoplanetary disks and outflows associated with young stars. STIS CCD coronographic imaging confirmed the presence of circumstellar disks associated with Herbig Ae stars AB Aurigae and HD 163296 which show structure on scales as small as 0.1'' (12 -14 AU). The HD 163296 disk contains a 50 AU gap at r = 350 AU that may be due to planet formation or chemical processing. The data also showed the unexpected presence of an outflow associated with HD 163296. Subsequent STIS observations revealed a Lyman-alpha bright jet that can be traced to within an unprecedented 7.5 AU of HD 163296. These observations show that the outflow stage for young stars may last up to ten times longer than previously believed.

Devine was also the PI on an HST GO program studying HH29 with J. Bally and B. Reipurth (U. Chicago). The PC images of HH29 revealed shock structures on spatial scales of order 15 AU and confirmed that HH29 results from a fast wind overtaking quasistationary material. These first epoch observations will be used to study the time evolution of shocks associated with protostellar outflows and how these outflows impact the surrounding molecular cloud.

Neff spent summer 1999 as a visiting scientist at the Oberservatoire de Strasbourg, where she carried out a multiwavelength study of recent star formation in the nearby galaxy merger NGC4038/4039 and began data analysis of HST UV imaging and spectroscopy studies of the same system (collaboration with J. Hutchings at DAO). In summer 2000, she was a visiting scientist at the Dominion Astrophysical Observatory where she continued analysis of HST observations NGC4038/9 and of HST archival data on other merger systems.

Chatzicristou, NRC fellow, continued her work on Seyfert galaxies selected by IR spectra. She also began analysis of HST observations (collaboration with W. Jaffe, Leiden) of the stellar and gaseous dynamic in the famous radio quasar 3C48.

A. Smith, C. H. Lyu and F. C. Bruhweiler are pursuing their search for molecules in interstellar diffuse and translucent clouds by looking for their absorption signatures in the vacuum ultraviolet spectra of moderately reddened stars. They have tentatively identified the molecules CH2 and CS in the spectra of HD 154368 and zeta Oph.

A. Smith has studied the star formation revealed in vacuum ultraviolet and optical imagery of the edge-on galaxy NGC 4631.

III. EXPLORATION OF THE SOLAR SYSTEM

Grogan continues work on a multi-waveband model of the zodiacal thermal emission based on physically motivated modeling techniques. The contribution of dust from asteroid family members to the cloud has been determined.

Oliversen and F. Scherb (U Wisconsin) continue work on Io's atmosphere and its interaction with the plasma torus through extensive groundbased high resolution [O I] 6300A observations. A correlation between line intensity and line width was discovered. Oliversen and K.D. Rutherfords are the leads on the HST Io-Galileo compaign (PI: F. Bagenal/U Colorado) for the neutral atmosphere discipline. Oliversen and R.C. Woodward (U. Wisconsin) continue work on HST and groundbased observations on the Io plasma torus, particularly, on the determination of the amount of newly created sulfur ions.

IV. INSTRUMENTATION

Gull and other members of the STIS GTO team and STScI STIS team continue their work on characterization of instrument performance. The FUV MAMA was tested with the repeller wire voltage on and off to confirm that resolving power for the smallest apertures can be improved from ~180,000 to nearly 210,000, especially near Lyman-alpha where the telescope PSF limits the overall instrumental performance. Gull and R.S. Hill (Raytheon ITSS Corp.) are conducting studies of a ghost caused by the CCD housing window to provide corrections for extended object studies.

Lindler (AAC Corp.) and Ishibashi have improved the CCD dispersion relationships leading to residuals of 0.1 pixels. This has been done with the onboard platinum lamp and confirmed using the emission lines of Weigelt Blobs B and D near Eta Carinae.

Malamuth has developed a routine to correct for CCD fringing caused by the transparency of the back-illuminated CCD at wavelengths beyond 8000A.

V. FUTURE MISSIONS

Carpenter and C. Schrijver (LMMS/ATC) have investigated a new mission concept for a large, space-based UV-optical interferometer designed to image the surfaces of nearby stars, probe their subsurface layers through asteroseismology, and improve our understanding of the solar and stellar dynamos and thus our ability to predict solar activity and its effect on astrobiology and life. The Stellar Imager and Seismic Probe (SISP) is envisioned as a 500-meter baseline array with 9 or more one-meter class telescopes configured around a central hub, located perhaps at L2. Information on this mission can be found at URL: http://hires.gsfc.nasa.gov/~sisp.

Moseley, Gardner, Woodgate, Kimble, Bowers, Teplitz and Malamuth are studying a MEMS micro-shutter array for programmable multi-object spectroscopy with NGST. Low-resolution prism spectroscopy outperforms filter imaging in the determination of ''photometric redshifts.'' In the prime discovery space of NGST, very faint galaxies at high redshift, prism spectroscopy reaches almost two magnitudes fainter with the same level of accuracy.

4.0. INSTRUMENT AND COMPUTER SYSTEMS BRANCH (L.E. ORWIG, ACTING HEAD)

The Branch plans, develops and operates computer software and hardware systems for the reduction, analysis and interpretation of Laboratory experimental data and for the theoretical study of the structure, dynamics and other phenomena of the Sun, stars, interstellar medium, and galaxies. The Branch develops applications software to support Laboratory research and designs, implements, and maintains local area networks needed to connect Laboratory computer systems ranging from personal computers to Project facilities.

4.A. PERSONNEL

The permanent staff includes: P. Haas, M. Horn, P. Kenny, Y. Kondo, D. Linard III, J. Novello, L. Payne, D. Unkle, and the following co-located staff from Applied Engineering and Technology Directorate: D. Amato, M. Amato, J. Bogert, W. Muney, T. Plummer, C. Wade, and L. White.

4.B. SCIENTIFIC RESEARCH

Kondo continued to serve as NASA EUVE Project Scientist. [The science operations of EUVE and the guest observing program have been transferred to Berkeley]. The IUE Final Archive, with 100,00 plus ultraviolet spectra, continues to serve astronomical research; the IUE data are still being used for scientific publications at a rate of several dozen refereed papers a year.

Kondo has been invited to join the Kepler proposal team (at NASA Ames Research Center) as a co-investigator. Kepler is designed to detect Earth-sized planets in 2005 - 2009.

Kondo organized and chaired an AAAS (American Association for the Advancement of Science) symposium ''Space Access & Utilization Beyond 2000,'' which was held on February 18 in Washington. The proceedings of this symposium will be published by the American Astronautical Society with an opening chapter by NASA Administrator Daniel S. Goldin.

Kondo continued to serve on the board of Directors of Division V (Variable Stars) of the International Astronomical Union. He also served as editor of ''Comments on Astrophysics'' and as consulting editor of ''Earth Space Research.''

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