Hughes STX CASP

Lanham, Maryland 20706

The following report covers the Department activities from 1 October 1995 through 30 Septemper 1996.

1. INTRODUCTION

1.1 Company Background

Hughes STX (HSTX) was founded in 1973 as Systems and Applied Sciences Corporation. On October 1, 1991, STX was acquired by Hughes Aircraft Company and became Hughes STX Corporation headquartered in Lanham, Maryland. HSTX is a for profit corporation of more than 1,400 employees who are skilled in a wide range of technical and administrative disciplines, including scientific research, software systems development, systems integration, and local-area network planning. Approximately 80% of our employees hold academic degrees, with 40% of this group at the Masters or Ph.D. level.

HSTX offers on site professional support at locations such as NASA/Goddard Space Flight Center (GSFC), the EROS Data Center, the Naval Research Laboratory, Edwards Air Force Base, the Pentagon, Marshall Space Flight Center, National Weather Service, and the National Environmental Satellite and Data Information Service. This report focuses on HSTX science and computer support for a number of NASA's scientific programs at NASA/GSFC in Greenbelt, MD.

1.2 CASP

HSTX understands that in order to attract and retain scientists with outstanding credentials, it must support their need to perform *both* project oriented *and* independent research. The Center for Astronomy and Space Physics (CASP) was formed to promote and facilitate these ideals and is one of the HSTX centers of excellence,

http://www.stx.com/about/centers.html

CASP is made up of roughly 80 HSTX Astronomers and Space Scientists, primarily on site at GSFC. Its purpose is to provide HSTX scientists with a frame work in which to meet and discuss scientific and professional matters, to stimulate cross disciplinary ideas, and to provide an identity and voice for our employees, in science related matters. CASP is employee organized and supervised and its current chairperson is A. Danks.

CASP organizes monthly talks, produces a newsletter in which HSTX scientists discuss their science and project contributions, maintains a mailing list to inform its members of announcements of opportunity and encourages employees to apply for grants to pursue independent scientific research. CASP uses a small budget provided by HSTX to support company scientists while writing personal science proposals and to fund travel to scientific meeting and publication costs, when no other sources are available. It also supports the HSTX corporate membership in the AAS.

1.3 Personnel

As of October 1996, HSTX staff scientists with astronomy, solar physics or space physics related interests include: J. Allen, L. Allen, R. Arendt, E. Bell, D. Bilitza, J. Blackwell, S. Boardsen, K. Borne, L. Breedon, J. Brosius, L. Brown, S. Casey, R. Cebula, S. Chen, N. Collins, J. Cooper, R. Cornett, A. Danks, S. Digel, M. Duesterhaus, E. Einfalt, B. Elza, M. Fanelli, D. Fixsen, H. Freudenreich, D. Friedlander, M. Greason, J. Hill, R.J. Hill, R.S. Hill, K. Hilldrup, K. Hills, J. Hollis, Z. Huang, P. Jackson, K. Jensen, R. Johnson, V. Kargatis, S. Kashlinsky, P. Keegstra, E. Kemper, C. Klipsch, A. Kogut, P. Kuin, A. Kutyrev, M. Kuznetsova, W. Landsman, P. Lawton, E. Malumuth, D. Massa, L. Mayo, J. Mullins, T. Norton, N. Odegard, S. Odenwald, J. Offenberg, L. Ofman, N. Oliversen, B. O'Neel, R. Patterer, M. Peredo, B. Perry, E. Pier, T. Powers, B. Puc, G. Reichert, G. Rohrbach, N. Roman, T. Satoh, G. Schneider, R. Schwartz, A. Shaver, J. Silvis, A, Skowronek, K. Smale, C. Standley, A. Szabo, L. Tan, W. Taylor, K. Tolbert, M. Tripicco, P. Tyler, P. Uribe, F. Varosi, S. Voels, W. Waller, W. Warren, J. Weiland, D. Williams

2. SPACE INSTRUMENTATION AND MISSION SUPPORT

HSTX scientists are involved at both the support and research levels with the following major NASA lead research programs at NASA/GSFC.

COBE: The Cosmic Background Explorer (*COBE*) satellite was developed to measure the diffuse infrared and microwave radiation from the early universe and the Milky Way. It carried three instruments, a Far Infrared Absolute Spectrophotometer (FIRAS) which measured the cosmic microwave background radiation, a Differential Microwave Radiometer (DMR) which mapped the distribution of the cosmic radiation precisely, and a Diffuse Infrared Background Experiment (DIRBE) which measured the cosmic IR background radiation.

HEASARC: The High Energy Astrophysics Science Archive and Research Center (HEASARC) supports a multimission archive facility in high energy astrophysics for scientists all over the world. Data from space-borne instruments on spacecraft, such as *ROSAT*, *ASCA*, *CGRO*, *BBXRT*, *HEAO-1*, *HEAO-2*, *EXOSAT*, and *XTE* are provided, along with a knowledgeable science-user support staff and tools to analyze multiple datasets. For further information, see

http://heasarc.gsfc.nasa.gov/

MAP: The Microwave Anisotropy Probe (*MAP*) is a MIDEX class mission, selected by NASA in 1996, to probe conditions in the early universe. *MAP* will measure temperature differences (''anisotropy'') in the cosmic microwave background radiation over the entire sky. For further information, see

http://map.gsfc.nasa.gov/

SoHO: The Solar and Heliospheric Observatory (*SoHO*) is one of ESA and NASA's most ambitious projects for the 1990's. Its mission is to understand the interactions between the Sun and the Earth's environment and to address some of the most perplexing riddles about the Sun, including the heating of its corona, the acceleration of its wind, and the physical conditions of the solar interior. It is giving solar physicists their first long term, uninterrupted view of the Sun by operating from a permanent vantage point 1.5 million km ahead of the Earth in a halo orbit around the *L1* Lagrangian point. *SoHO* will observe the Sun continuously for at least two years. Further information can be found at

http://sohowww.nascom.nasa.gov/

SSDOO: The Space Sciences Data Operations Office (SSDOO) is responsible for the project management of selected missions and the development and operations of data and information systems which support processing, management, archiving and distribution of space physics, astrophysics, and planetary data. The SSDOO includes the Astrophysics Data Facility (ADF) and Space Physics Data Facility (SPDF)

The ADF is responsible for the processing and distribution of proprietary data from missions such as *ROSAT, ASCA*, and *XTE*. In addition, the ADF supports the astrophysics community's access to multi-mission and multispectral data archives through the creation of tools and online archives. This includes the Astronomical Data Center (ADC) which acquires, verifies, formats, and distributes astronomical data in computer-readable form. It also develops and maintains software tools to access these data. The ADC is part of an international federation of astronomical data centers.

The SPDF is responsible for the development of a variety of space physics mission planning tools and facilitating correlative data analysis for the International Solar Terrestrial Physics (ISTP) program. For addtional information, see

http://ssdoo.gsfc.nasa.gov/c630/

STIS: The Space Telescope Imaging Spectrograph (STIS), is one of the second-generation instruments for the Hubble Space Telescope (*HST*). It will be placed into *HST* during the second servicing mission, currently planned for February 1997. In addition to general science support, A. Danks (HSTX) is a Co-Investigator on the STIS science team and responsible for the UV detectors, MAMA's (Multi Anode Microchannel plate Arrays). He has worked consistently with the MCP manufacturers to obtain flight quality hardware and is now participating along with other HSTX scientists in the testing and calibration phase of STIS. The capabilities of STIS were recently summarized in Danks *et al.*, 1995. Further information can be found at:

http://hires.gsfc.nasa.gov/

UIT: The UIT Science support group provides flight operations, data reduction, and science data analysis for the Ultraviolet Imaging Telescope (UIT) Project, and systems and software support for the UIT Interactive Image Processing Facility. The HSTX UIT group, works directly with UIT Principal Investigator T. Stecher (NASA) and S. Neff (NASA).

Digitization of the UIT/Astro-2 flight film was completed and aperture and Point Spread Functio-fit (PSF) photometry for point sources detected in the UIT frames has been completed, as has a final photometric and geometric calibration of the instrument. *IUE* spectra were used to check calibration consistency using fields in the Magallanic Clouds. The team is working towards public archiving of the Astro-2 data in 1997. A detailed description of the instrument and its data has been submitted to PASP. Publication of this document will coincide with delivery of the Astro-2 dataset to the SSDOO/ADF.

HSTX members of the UIT team initiated planning for a scientific conference entitled ''The Ultraviolet Universe at Low and High Redshift'' to be held in May 1997. This conference would highlight UIT and other space-based UV observations of nearby galaxies as local benchmarks for the interpretation of the redshifted ''primeval'' galaxies being observed by the Hubble and Keck telescopes. HSTX, GSFC/LASP, and the University of Maryland will be the official sponsors. The conference will be held at the University of Maryland's Inn and Conference Center during 2-4 May 1997.

In collaboration with K.-P. Cheng (Cal State Fullerton), P. Hintzen (UNLV), and E. Smith (NASA/GSFC), HSTX team members completed the reduction and archiving of optical imagery obtained for interpretation of the Astro-1 UIT dataset. This data was released to the community in the form of a 3 volume set of CD-ROMs, and is also available from the ADF/ADC. Work is now underway to produce a similar product for the optical imagery associated with the Astro-2 data.

In conjunction with the flight program, the UIT project conducts a major ground observing campaign, to provide deep wide-field optical imagery for objects observed with UIT. Several HSTX astronomers are involved in the coordination, observing support, data reduction, calibration, and archiving of these data, in collaboration with E. Smith (NASA/GSFC), K-P. Cheng (Cal State F ullerton), P. Hintzen (UNLV), D. Smith (NRC/GSFC), W. Freedman (OCIW), and B. Madore (IPAC). During the report period data were obtained during several observing runs at KPNO, Mt. Laguna Observatory, CTIO, and Las Campanas Observatory.

Further information on UIT can be obtianed at:

http://fondue.gsfc.nasa.gov/UIT/

XTE: The Rossi X-ray Timing Explorer (*XTE*) is a GSFC mission which was launched on 30 December 1995. It is designed to study time variability in X-ray sources with moderate spectral resolution. Time scales from μsec to months are covered in a spectral range from 2 to 250 keV. It is designed for a required lifetime of two years, with a goal of five years.

http://heasarc.gsfc.nasa.gov/docs/xte/xte.html

3. RESEARCH

3.1 Space Physics

A. Szabo, in collaboration with R.P. Lepping (NASA/GSFC), M. Peredo (HSTX), and T. Hoeksema (Stanford

University), analyzed *WIND* magnetic field data for the first six months after launch of the spacecraft, in order to better understand the properties of the heliospheric current sheet (HCS), the occasionally surrounding plasma sheet, and for a temporal connection of the HCS to the solar surface current sheet using a potential field source surface model, for this quiet phase of the solar cycle. A large number of carefully selected HCS crossings, 212, were used in the study which showed a nearly periodic occurrence of this structure in the early portion and a smooth evolution from 2 to 4 sector structure after a few months. Also it was determined that when the plasma sheet's presence is most apparent, the directional discontinuity in the magnetic field encompassing the thin region of the current sheet appears to be more abrupt than in other cases. Comparison of the results of the source surface model to the in-situ *WIND* magnetic field observations for this rather large data set enabled the team to better estimate the time delay of this structure over 1 AU. There resulted a surprising 'disagreement' or bias of 1 day, based on solar wind convected speed only. There is a possibility that the moderately slow average solar wind speed near the sun, due to acceleration over about 20 $R_{\odot}$, from very slow speeds at the source surface, could be responsible. By incorporating this temporal bias the agreement between the two positions was very good for the full six months. Numerous other properties of the HCS, and preliminarily for the plasma sheet, were determined. A very intriguing one is the existence of apparent wave-like structures on the HCS with scale-lengths of about a few times 103 km; other interpretations for these new findings are possible and being pursued.

A. Szabo, in collaboration with R.P. Lepping, K.W. Ogilvie, L. Burlaga (NASA/GSFC), A. J. Lazarus, J.T. Steinberg (MIT), C. Farrugia and L. Janoo (University of New Hampshire), conducted a study of the well known October 18 - 20, 1995 interplanetary magnetic cloud and stream events, which occurred in interval #1 of the First IACG Science Campaign. They concentrated on the in-situ properties of the event and have started an in depth study of the cloud's effects on the Earth's magnetosphere. They were able to model the magnetic cloud as a force free flux rope of diameter 0.27 AU. Its axis was estimated to be nearly perpendicular to the Earth-Sun line and close to the ecliptic plane, not an uncommon attitude for these structures when observed at 1 AU in the ecliptic plane. The boundaries of the cloud and an upstream shock, which occurred about 8 hours earlier than the front boundary of the cloud, were all studied in detail and shown to be in attitudinal agreement with the axis of the cloud. An abrupt feature internal to the cloud, appearing shock-like in most but not all respects and having an unusual surface normal far off the Earth-Sun line, has been examined; only preliminary conclusions can be given presently concerning its true nature and origin, which are still under consideration.

A. Szabo, in collaboration with R.P. Lepping, K.W. Ogilvie, R. Fitzenreiter (NASA/GSFC), A.J. Lazarus, and J.T. Steinberg (MIT), have examined characteristics of the Earth's bow shock resulting from its interaction with the large interplanetary magnetic cloud of February 8, 1995. The cloud was first observed at *WIND* far upstream of the Earth, and then by *IMP-8* about an 1 hour later which was located fortuitously at the bow shock, which became unusually inflated at the time. The bow shock was estimated to reach at least 32 $R_{\oplus}$ at its nose, and was observed directly to reach 39 $R_{\oplus}$ on the dusk flank. The study, requiring very careful estimations of the bow shock surface normal for the shock's numerous *IMP-8* sightings, revealed that the bow shock tended to expand almost 'isotropically' as the cloud passes. The expansion was apparently due to many factors, one being the high Alfven speed and low Alfven Mach number occurring during the magnetic cloud passage. This kind of situation is expected to occur typically for magnetic cloud interactions with the bow shock, because of the specific properties of a cloud, strong field intensity (and smoothly changing field direction) and low proton temperature, which are defining characteristics.

M. Peredo continued various collaborations with the ISTP *WIND* science team (led by R. Lepping of NASA/GSFC) on investigations of the heliospheric current sheet. Together with J. Slavin and colleagues of the GSFC/LEP, M. Peredo extended his work on the terrestrial bow shock by studying nearly-simultaneous crossings observed by *WIND* and *IMP-8*.

In collaboration with S. Curtis (NASA/GSFC), M. Peredo continued to lead the efforts of the ISTP Theory Group to calibrate and compare global MHD simulations of the magnetosphere, and to develop end-to-end tests for comparison between observations and models to be carried out by the ISTP theory and ground-based investigations. Extensive work also continued at the ISTP Science Planning and Operations Facility (operated jointly by HSTX and CSC staff) on the development, dissemination and implementation of science plans for the ISTP spacecraft and ground-based facilities, including detailed planning of the operations for the *POLAR* DeSpun Platform which houses the three imaging instruments.

Magnetospheric modeling by N. Tsyganenko, D. Stern, and M. Peredo seeks to derive quantitative relationship between conditions in the solar wind and the configuration of the Earth's magnetosphere, based on extensive sets of data from many spacecraft and mathematical models of principal sources of the geospace magnetic field. During the last year, the first version of the new-generation global model of the magnetospheric field was developed by N. Tsyganenko and made available to the space physics community on the WWW. The essential features of the new model, not present in all earlier models, are

1. an explicitly defined boundary with a realistic shape, whose size is controlled by the pressure of the solar wind,
2. interconnection between the geomagnetic and solar wind magnetic fields,
3. taking into account the contribution from the large-scale Birkeland current systems, and
4. a continuous parameterization of the model by the parameters of the solar wind and the Dst-index.

New sets of spacecraft data were prepared and added to the existing database for the magnetospheric field modeling,

including the data of *Hawkeye*, *AMPTE/CCE*, and *CRRES*. This significantly improves the spatial coverage and is expected to result in an increased reliability of future versions of the model in the near magnetosphere and distant polar regions.

M.M. Kuznetsova continued her collaboration with M. Hesse (NASA/GSFC) on theoretical studies of the magnetospheric dynamics. Recently they investigated self-consistent ion dynamics in time-dependent magnetic reconnection (Kuznetsova *et al.*, 1996a). Further studies involved analysis of the micro physics of the nonlinear evolution of the collisionless magnetotail reconnection using a hybrid modeling with finite electron mass (Kuznetsova *et al.*, 1996b). It was demonstrated that after a small initial perturbation is imposed and an X-line is formed the collisionless reconnection proceeds to the strongly nonlinear stage. It was shown that in the vicinity of the X-line nongyrotropic pressure effects dominates over bulk flow inertia. Reconnection fields based only on bulk electron inertia are strongly oscillating.

3.2 Solar Physics

J. Brosius continued his collaborations with J. Davila (NASA/GSFC), R. Thomas (NASA/GSFC), J. Saba (Lockheed), B, Monsignori-Fossi (Arcetri, deceased), H. Hara (U. Tokyo), and S. White (U. Maryland) in the analysis and interpretation of EUV spectra (270 - 420 Å) and spectroheliograms obtained during the 1991 and 1993 flights of GSFC's Solar EUV Rocket Telescope and Spectrograph (SERTS). Brosius *et al.* (1996) obtained active region, quiet-sun, and off-limb densities and temperatures with numerous intensity ratios among emission lines from eight different ionization stages of iron. In addition, they used the emission lines from iron and other ions to derive active region and quiet-sun differential emission measure distributions. Brosius *et al.* (1997) compared soft X-ray images obtained with the Soft X-ray Telescope (SXT) aboard the *Yohkoh* spacecraft with coordinated, coaligned EUV spectroheliograms obtained during the 1993 SERTS flight. They found that the Fe XV and Fe XVI emission trace the soft X-ray emission quite closely, but that emission from He II and Mg IX delineate loop footpoints and possibly some relatively cool loops. Temperatures derived from SXT broadband filter ratios were consistent with temperatures derived from SERTS emission line intensity ratios. Line intensity ratios from the spatially resolved SERTS slit spectra indicated that the density remained constant across the active region, despite the fact that the intensities themselves varied significantly. This demonstrates that the intensity variations are due to path length and/or filling factor variations, rather than to density variations.

Brosius and collaborators (1996, in progress) developed and applied innovative techniques to derive the three-dimensional solar active region coronal magnetic field from SERTS EUV spectra and spectroheliograms, and from coordinated VLA 20 cm and 6 cm radio observations. The derived field strengths are typically greater than those derived from the photospheric magnetogram using a potential model.

Brosius, Davila, and Thomas commenced with the analysis of EUV spectra (170 - 350 Å) and spectroheliograms obtained during the 1995 SERTS flight. Calibration issues were addressed, and nearly 150 emission lines were identified in the spatially averaged active region spectrum. These data will be used for solar coronal plasma diagnostics and atomic parameter validation.

R.A. Schwartz is the Discipline Scientist at the Solar Data Analysis Center (GSFC). He has continued his fruitful collaboration with Markus Aschwanden (U. Md) resulting in several publications on the time-of-flight delay in solar flare hard X-ray bursts. He also continues his work on the calibration of the BATSE detector systems at low energies (6-100 keV) to enhance their utility for spectroscopic quality flare observations as well as reliable gamma-ray burst measurements. He has recently joined with J. Trombka (NASA/GSFC) and R. Starr (Catholic) in the analysis of low-energy solar X-rays (1-10 keV) observed with a P.I.N. detector on the *NEAR* spacecraft.

3.3 Planetary Physics

Greason, Cornett, and Waller, in collaboration with R. Gladstone (SWRI) are continuing their studies of Moon images obtained by UIT during the Astro-2 mission. The high radiant flux of the Moon has caused difficulties in this analysis, and probably has resulted in a significant number of UV photons passing through the CsI photocathode and exciting the shutter grid to release its own photo-electrons that then excite the first-stage phosphor screen. Visible light may be exciting the second-stage bi-alkali photocathode as well. The resulting lunar images show bright highlands and dark maria, contrary to predictions of the Moon's UV albedo structure. Work is continuing to better constrain the effective bandpass of the UIT lunar imagery.

T. Satoh continued his collaboration with J.E.P. Connerney (NASA/GSFC) and R. Baron (U. Hawaii) in analyzing the infrared images of Jupiter's H3+ emissions to monitor the magnetospheric activity in the Jovian system. Their observing program continued at NASA's Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii, and resulted in 12 successful observing nights in April of 1996. High spatial-resolution images of the Jovian auroral emissions were obtained using the NSFCAM (256×256 pixels) infrared camera at the IRTF, operated at 0.15 arcsec platescale and at a wavelength of 3.43 μm. They achieved high spatial-resolution and high signal-to-noise ratio simultaneously, by taking many short-integration (2 sec) images and shift-and-added them together after the standard image reduction. Details of the auroral emissions are obvious in such images. An isolated spot at the instantaneous foot of the Io Flux Tube (IFT) is also clearly visible and its surface position has been measured with higher accuracy than was possible with the ProtoCAM observations. Such measurements will be used to further improvement of the Jovian magnetic field model. The auroral flux measurements were also made from those images and existence of the night-to-night variations in the total flux emitted from the aurorae (Baron *et al.* 1996) have been confirmed. Such monitoring observations will continue during the period of Galileo tour to the Jovian system. They have mapped the distribution of the H3+ emission in Jupiter's polar region through the analysis of ProtoCAM images

using the generalized inverse code. Their analysis revealed that the H3+ aurora consists of several components:

1. a narrow auroral oval,
2. a weak emission poleward of the oval,
3. a weak emission equatorward extending down to near Io's footprint,
4. intensity variation fixed to planet's System-III longitude, and
5. enhancement of emission in planet's local afternoon.

They have found that the System-III fixed component is similar to the pattern of electron precipitations from middle of the magnetosphere. The analysis of ProtoCAM observations, performed at NASA GSFC, were completed and published as a series of three papers in ICARUS. The analysis of NSFCAM data is in progress.

3.4 Stellar Astrophysics

Landsman, in collaboration with A. Sweigart (NASA/GSFC), has studied the 354 hot horizontal branch stars detected on a UIT image of the nearby globular cluster NGC 6752. The UV photometry has been combined with the published visible photometry to create a color-magnitude diagram with excellent temperature and luminosity discrimination. The observations are in excellent agreement with models of the core-helium burning phase, using the NGC 6752 distance derived from recent *HST* observations of the white dwarf cooling curve. However, at most five stars in the cluster are in a hot post-HB phase, whereas more than three times this many stars are predicted from theoretical post-HB evolutionary tracks.

Landsman, in collaboration with A. Crotts (Columbia U.), T. Lanz, and I. Hubeny (USRA) obtained low-dispersion CTIO spectra of seven UV-bright stars in the globular cluster Omega Centauri. Three of the stars have effective temperatures greater than 60,000 K, and are the hottest stars ever found in a globular cluster. The four most luminous stars show helium abundances larger than solar, suggesting possible helium enrichment due to deep mixing along the red giant branch.

Landsman, in collaboration with T. Simon (U. Hawaii), has used *IUE* to survey the ultraviolet colors of A-type stars, in a search for a photometric signature for the onset of convection. No such signature was found, and most of the scatter in the A-star ultraviolet colors can be explained by variations in metallicity and surface gravity.

Landsman, in collaboration with T. Simon (U. Hawaii) and P. Bergeron (U. Montreal) has completed an *IUE* survey of stars with a ultraviolet excess in the TD-1 all-sky survey. Hot white dwarf companions were detected to the stars 56 Per (F6 V) and HR 3643 (F7 II). The HR 3643 detection is particularly interesting because the large luminosity of the primary implies a massive progenitor for the white dwarf.

The final paper on Astro-1 results for the globular cluster M79 (Hill et al. 1996) includes both stellar photometry and surface brightness profiles in UV and optical bands. An erratum for one of the tables is planned for the December, 1996, issue.

A photometric catalog of 2244 objects detected in the near-UV by UIT/Astro-1 was compiled by E. Smith (NASA/GSFC) in collaboration with A. Pica (Salisbury State), R. Cornett, M. Fanelli, W. Landsman, and the UIT Co-Investigators. Based on their NUV-V colors, most of the detected objects are field dwarfs of spectral types A to late-G. The catalog is useful for Galactic stellar population studies.

In a continuing collaboration with B. Woodgate (NASA/GSFC), Brosius developed models for the time dependence of the redshifted Ly α emission from stellar chromospheres subjected to beams of nonthermal protons. Preliminary results indicate that, as the injected protons heat and ionize the initially VAL-like atmosphere, the intensity of the redshifted Ly α emission fluctuates. These fluctuations are due to varying depth penetration by the beam, variations in ionization fraction with depth and/or time, and variations in available neutral hydrogen atoms with depth and/or time. The model calculations will be compared with GHRS flare star observations to deduce chromospheric and beam properties.

In collaboration with J. Dolan (NASA/GSFC), R.J. Hill used UV observations taken with the *HST* to search for pulsations from X-ray binary systems. Pulsations were observed from the 4U0900-40 system with a period and pulse shape consistent with the interpretation that the UV pulses are caused by the reprocessing of X-ray pulses incident on the binary companion of the neutron star in this system. An analysis of archival *IUE* data indicates that the pulsed radiation is emitted primarily in the resonance emission lines of multiply ionized metals.

J. Silvis completed his thesis work on the evolution of circumstellar Fe II features in the Herbig Ae/Be stars. He has uncovered evidence that the strength of these features is an indicator of the age of the disk and that strong C IV absorption appears only after the disk phase has begun, disappearing before the systems reach the main sequence. He is currently working with T.P. Boyd, R. Pradham, B. Smith, and S. Snell on a UV photometric study of η Car. They found a UV outburst which corresponds to an optical S-Dor event observed in the optical.

D. Massa, A. Fullerton (MPIA, Munich), and R. Prinja (UCL) continued their collaboration studying the UV variability of B supergiants. Together with larger team of scientists, they obtained 30 days of UV spectroscopic coverage of 2 B supergiants during the final observing episode of *IUE*. The new data verify earlier observations indicating the presence of surface features on these stars. The same team has also performed a preliminary survey of all B supergiants observed over several epochs with *IUE*, in order to determine the ubiquity of wind variability (Massa *et al.* 1996). The results of the survey demonstrated the universality of wind variability and revealed several distinctive patterns in the nature of the observed variability. This work is continuing with the support of the NASA ADP and NATO visiting scientist programs.

D. Massa, A. Fullerton (MPIA, Munich), and R. Prinja (UCL) also continued their study of B supergiant wind variability with a study of a 6 day *IUE* time series of the rapidly rotating B supergiant γ Ara (Prinja *et al.* 1996). They were able to demonstrate the presence of two distinct sets of wind

variability in the star: one which appears to be associated with a dense, slow moving equatorially enhanced wind, and another associated with a less dense, rapidly expanding and more highly ionized wind originating from higher latitudes. They were also able to identify the signature of a slowly evolving shock in the wind, most likely associated with the interface between the two components of the wind.

D. Massa also extended his work on more luminous B stars to include a study of the wind variability in the main sequence B stars in the young open cluster NGC 6231. He has obtained a *HST*-GHRS time series of one of these stars to determine the flow time in the winds of compact B stars.

In collaboration with N. Evans (CfA), Massa was awarded *HST* time to obtain FOC objective prism spectra of two Cepheid + B star binary systems in an effort to spatially resolve them. Data for one of the systems has been obtained, and the analysis is underway.

D. Massa continued his collaboration with S. Cranmer and S.P. Owocki (Bartol Res. Inst., U. Delaware) on hot star winds by studying the impact of pulsations and waves on hot-star winds. They found that the presence of an accelerating wind can allow low-order and low-degree oscillation modes, normally evanescent, to effectively ''tunnel'' their way out of the interior. The propagation of oscillations into a hot-star wind was modelled by a numerical radiation-hydrodynamics code. It was found that evanescence is indeed not a hindrance to producing wind variability correlated with stellar pulsations. Preliminary models of strong, nonlinear radial wind oscillations of the β Ceph variable BW Vul show good agreement between observed and modeled base ''radial velocity curves'' and wind-contaminated UV profile variability. (Cranmer *et al.* 1996)

3.5 Nebulae, Interstellar Medium and Galactic Structure

Landsman, in collaboration with U.J. Sofia (Villanova U.) and P. Bergeron (U. Montreal), used GHRS echelle observations obtained with *HST* to study interstellar hydrogen and deuterium toward the hot white dwarf HZ 43. HZ 43 provides an excellent probe of interstellar deuterium because the low H I column density is well-determined from EUV spectroscopy, and because the stellar continuum of HZ 43 is well-modeled by a pure hydrogen model atmosphere. The derived value of D/H toward HZ 43 is consistent with other measurements in the local ISM, although the low S/N of the GHRS data is insufficient to improve upon the precision of these other D/H determinations.

Waller, T.P. Stecher (NASA/GSFC), and colleagues have continued their investigation of the UV sky background, as imaged by UIT during the Shuttle-borne Astro-1 and Astro-2 missions. Prominent contributors to the night time UV backgrounds include terrestrial airglow line emission in the FUV band (3-5 times stronger during the 1990 Astro-1 mission than during the 1995 Astro-2 mission), Zodiacal light in the NUV, and Galactic (diffuse) emission at both FUV and NUV bandpasses. After modeling and subtracting the Zodiacal component, the remaining NUV emission correlates strongly with the FIR emission mapped by *IRAS*. At high Galactic and Ecliptic latitudes, the NUV background is profoundly dark ($\sim$27 mags arcsec^{-2}), thus highlighting the ''dark-sky'' advantage of UV imaging in searches for faint emission from the outskirts of nearby galaxies and from the star-forming sites of more distant galaxies. Extrapolation of the NUV-FIR relation to negligible FIR intensities yields a faint residual FUV component, of possibly extragalactic origin, whose nature remains to be explored.

Waller, F. Varosi (HSTX & StarStuff), F. Boulanger (IAS, Paris), and S. Digel (HSTX) have produced from the IRAS Infrared Sky Survey Atlas (ISSA) database a complete 360deg$\times$60deg mapping of the far-infrared emission in the Milky Way. Through spatial filtering techniques, they were able to eliminate the strong gradient in brightness towards the Galactic midplane. The resulting images reveal a ''froth'' of superposed filaments, voids, and shells. The fine-scale structure in the FIR emission consists of both nearby and more distant features in the disk. Analysis of the spatial statistics shows that the structure is self-similar with angular power-law exponents and fractal dimensions similar to those found in isolated cirrus and molecular clouds. On scales larger than 1.5deg, the power spectrum flattens indicating a change in the characteristic structure and perhaps the underlying dynamics.

Waller and W.F. Wall (NASA/GSFC, StarStuff, & INAOE) have compared the fine-scale structure in the far-infrared Milky Way with structure in the H I 21 cm, CO 2.6 mm, and radio-continuum emission. Analysis of positions within 11d of the Galactic plane for all longitudes shows that $\sim$70 % of the FIR structures are correlated with structured H I emission. The preponderance of atomic counterparts to the FIR structures indicates energetics that are sufficient to re-organize the ISM without ionizing it. Many of the correlated FIR-H I features at intermediate latitude may also correlate with the molecular gas phase, which can be tested when higher signal-to-noise mappings of the CO emission become available.

Cornett has compiled a catalog of supernova remnants in M33 that were detected by UIT. Comparison of these data with SNR surveys at optical, radio, and X-ray wavelengths will yield constraints on SNR evolution.

S.W. Digel continued research on diffuse gamma-ray emission in the Galaxy in collaboration with S.D. Hunter (NASA/GSFC) and I.A. Grenier (CE-Saclay). An observation with the *CGRO*/EGRET telescope was obtained toward Monoceros near the plane in the third quadrant to study the distribution of cosmic-ray density and the calibration of molecular mass in the outer Galaxy. The study of the Monoceros region is complementary to one we recently completed in the second quadrant. Other projects included participation in collaborations with S.D. Hunter and A.W. Strong (MPE) on whole-Galaxy models of the diffuse gamma-ray emission.

A related on-going project with S.L. Snowden (USRA, NASA/GSFC) and L. Bronfman (U. Chile) involves analysis of *ROSAT*/PSPC observations of shadowing of diffuse X-rays by interstellar clouds. Like analyses of gamma-ray emission, studies of X-ray shadowing in principle can also measure column densities toward molecular clouds but in practice may be more effective at setting limits on abundances of trace species in clouds and on the spatial distribution of soft X-ray emission.

With D. Leisawitz (NASA/GSFC), Digel is comparing the calibrations of the *IRAS* Infrared Sky Survey Atlas and *COBE*/DIRBE maps in corresponding bands on large angular scales. Zero-level offsets and the dependence of the gain corrections on intensity and direction will be investigated in terms of possible instrumental origins.

With J. Brand (Bologna), E. de Geus (Leiden Obs.), A. Rudolph (Harvey Mudd College), P. Thaddeus (Center for Astrophysics), & J. Wouterloot (Cologne), Digel obtained the first of several planned *ISO* observations of IR lines toward H II regions in the far outer Galaxy. The goal is to measure abundances of trace species in these H II regions and extend knowledge of the metallicity to Galactocentric distances $\sim$17 kpc.

R. Arendt, N. Odegard and J. Weiland joined HSTX this year to continue work on the search for the cosmic infrared background emission using data from the *COBE* Diffuse Infrared Background Experiment (DIRBE) instrument. This work is done in support of the *COBE* Science Working Group whose DIRBE members are M.Hauser (AURA), T. Kelsall, H. Moseley, R. Silverberg, E. Dwek, and D. Leisawitz (NASA/GSFC). Arendt and Odegard are working on characterization of the Galactic foreground, and Weiland, along with Freudenreich (HSTX), are modelling the signal from the interplanetary dust. The HSTX DIRBE team members have also provided support for studies of galactic IR emission, such as the recent work on the Orion region by W. Wall (INAOE) *et al.*

Arendt, Fixsen, Odegard, and Weiland carried out studies of the infrared emission from the Galaxy in collaboration with T. Sodroski (ARC), E. Dwek and T. Kelsall (NASA/GSFC), M. Hauser (STScI), and others. Sodroski et al. (1996) analyzed observations of the Galactic plane by *COBE*/DIRBE in six wavelength bands from 12 to 240 μm. The data at each wavelength was decomposed into components that correlate with tracers of the neutral atomic, molecular, and ionized gas phases for selected galactocentric radius intervals. Radial distributions of the temperature and abundance of the large dust grain component were derived for each gas phase, and radial distributions of the interstellar radiation field, the abundance of PAH molecules, and the optical opacity of the Galactic disk were estimated.

Dwek *et al.* (1996) used *COBE* observations to determine the mean 3.5-1000 μm spectrum of the diffuse ISM at $|b|>45$deg. They developed an interstellar dust model consisting of PAH molecules and bare silicate and graphite grains that gives a very good fit to this spectrum. The model parameters indicate that about 20% of the cosmic carbon abundance is in the form of PAHs, 60-70% of the carbon is in graphite grains, 15% of the oxygen is in silicate grains, and essentially all of the Mg, Si, and Fe is in silicate grains. The abundance of carbon in the neutral gas phase was estimated from the ratio of [C II] 158 μm line emission to H I column density, and the extinction predicted by the dust model was compared with the average interstellar extinction curve.

Sodroski *et al.* (1995) used DIRBE 140 and 240 μm observations and ^{12}CO J = 1-0 line observations to estimate the average ratio of molecular hydrogen column density to CO line intensity for the region within a few hundred parsecs of the Galactic center. The ratio was estimated to be a factor of 3 to 10 lower in the Galactic center region than in the molecular ring. Combined with virial analyses of giant molecular cloud complexes in the Galactic disk, this implies that the ratio increases by more than a factor of 10 from the Galactic center to a radius of 13 kpc. Implications were discussed for the origin of the 'gamma ray deficit' in the Galactic center region and the distribution of molecular hydrogen in the Galactic disk.

H. Freudenreich continued work in the *COBE* group of NASA/GSFC, analyzing the data of the Diffuse Cosmic Background Experiment (DIRBE). In the past year he has worked on modeling the zodiacal dust cloud, but most of his efforts have turned to studying the structure of the Galaxy. He has constructed a three-dimensional model of the Galactic disk, based on DIRBE observations at four near-infrared wavelengths, which he is extending to include Galactic bar (Freudenreich, H.T. 1996).

Arendt has begun analysis of observations of the Cas A supernova remnant using the Infrared Space Observatory's (*ISO*) Short Wavelength Spectrograph (SWS). The data should reveal information on the nature of the dust and gas in the ejecta of the supernova.

A. Danks has continued his work using the ESO and McDonald telescopes to obtain data on several interstellar species. In particular a high resolution study of the molecule C_2 was made in the line of sight of several nearby stars, (Sembach, Danks, Lambert, 1996) and studies of shock fronts in the Vela nebula are continuing, (Danks and Sembach, 1995).

Danks is also participating in an *HST* program to measure the UV interstellar lines in several sightlines to stars in Vela with K. Sembach (JHU) and E. Jenkins (Princeton).

3.6 Local Group Galaxies

J. Hill, J. Hollis, and J. Parker (SWRI) are pursuing two projects on the LMC, using Astro-2 UIT data. These projects use data from

1. the SK66-19 pointing, which contains the H II region N11 and several Lucke-Hodge OB associations, and
2. all regions observed by UIT which contain nebular complexes listed by Davies, Elliott and Meaburn (1975).

The UV fluxes for these regions will be compared with the H α fluxes of Kennicutt and Hodge for most of the DEM regions. PSF photometry was performed for all 17 LMC fields. The process of combining all images from each field to produce a complete catalog of FUV stellar photometry in the UIT LMC fields is underway. Combined tables were constructed for 2 fields, N11 and LMC-BAR, with 2612 and 3619 stars respectively.

R. Cornett, J. Hill, M. Greason, J. Parker (SWRI) are investigating the young stellar populations detected in the entire set of UIT images of the SMC. A catalog of FUV magnitudes for over 11,000 SMC stars was created. A paper incorporating the photometry catalog includes discussion of overall SMC-Bar UV morphology, stellar photometry, and H II region photometry. UV morphology, especially in the

SMC-Bar field, shows evidence of sequential star formation.

From the multi-band photometric data, extinctions, ages, and masses have been derived – using isochronal models to fit the corrected UV-U, UV-B, and UV-V colors. Reddening is measured for about 200 stars in common with the atlas of Azzopardi and Vigneau, and correlates well with other evidence for interstellar material (e.g. H II regions). A more comprehensive study of the spatial distribution of stellar reddening and ages is underway, with the results being compared with H I observations of Stavely-Smith. UV photometry was obtained for 42 DEM H II regions, including both aperture photometry and stellar photometry of stars within the apertures. DEM H II region UV and H α fluxes are modelled well by models with ages of a few million years and appropriate extinction.

W. Waller, in collaboration with B. Skelton (U. Washington), and B. Woodgate (NASA/GSFC) are investigating the line emission from starburst nebulae. Using the Goddard Fabry-Perot Imaging Camera, they have obtained images of several starburst nebulae in the light of H α , [N II], and [S II]. Analysis of the nebular bubble, N70, in the LMC has revealed a strong enhancement with radius in the [S II]/H α intensity ratio, with little variation in the [N II]/H α ratio. Models which include shock ionization of Sulfur but not Hydrogen or Nitrogen seem to provide the best match to the observations. The radiative implications of such low-velocity shocks are being explored in the context of other starburst nebulae.

Waller, E. Malumuth, and J. Parker (SWRI) are investigating the massive stellar populations and their effect on the local ISM in M 33 using *HST*, UIT, and other ground-based data. Through their *HST* GO program, they obtained multiband images of 6 giant H II regions in M 33. These images show that starburst activity need not be in the form of concentrated superclusters but can also be organized in loose OB associations. Photometry of the ionizing stellar populations yields initial mass functions with slopes that are similar to that of the standard Salpeter IMF. Comparison of these results with those obtained for giant H II regions in the Milky Way, LMC, and SMC reveal no evidence for a metallicity dependence on the IMF. Waller has received a NASA/ADP grant to combine these multiwavelength data on starbursts in M 33 and other nearby galaxies, with the aim of delineating the radiative and mechanical energy budgets in these rapidly evolving systems.

3.7 Galaxies and Extragalactic Astronomy

J.K. Hill has compared the FUV and H α emission from the H II regions in M51 revealing a shortfall of ionizing radiation at small galactocentric radii. Possible explanations may be dust in the surrounding nebulae absorbing the EUV emission or enhanced EUV opacity in the hot stellar atmospheres of higher metallicity.

Waller, in collaboration with R. Cornett, M. Fanelli, and T. Stecher (NASA/GSFC), is investigating the orchestration of starbirth activity in disk galaxies, as revealed to great advantage in the far-UV. Analysis of UIT's far-UV image of the giant spiral galaxy M 101 has revealed multiple linear arm segments (''crooked arms'') that can be traced throughout the disk. These features, along with a faint spiral arm and ''curly tail'' feature that links the outermost supergiant H II region with the rest of the galaxy, indicate that tidal processes of both external and internal origin are organizing the current starbirth activity. A paper on this analysis has been accepted for publication in the ApJ.

Waller has compared UIT imagery of the Sa galaxy NGC 4736 with corresponding images at H α, R, and I bands. The remarkable ring and bisymmetric knots evident in the far-UV provide important constraints on the dominant (resonant) dynamics in the inner galaxy. The relatively shallow FUV radial light profile interior to the ring shows that the present-epoch Pop I activity does not match the centrally concentrated populations of older stars that are evident at R and I bands, thus indicating that the ''bulge-like disk'' was created several Gyr ago.

Fanelli completed an initial analysis of the global FUV properties and in- ferred star formation rates of all disk galaxies observed during the Astro-1 and Astro-2 missions. In a few late-type systems the FIR/FUV astration rate ratio is $\sim 2-4$, indicating that the FUV emission directly traces a significant fraction of the recently formed high-mass stars. This result suggests that FUV photometry, with modest extinction corrections, can provide reliable star formation estimates. Surprisingly, even in some dusty, IR-luminous galaxies, where the estimated FIR/FUV star formation rate ratio is $gt10$, substantial FUV luminosity is detected.

For the star-forming irregular galaxy NGC 4449, R.S. Hill devised a approach for aperture photometry with galaxy-internal background subtraction. This technique has been applied to 57 compact sources in H α, H β, and far-UV images. Work began on characterizing the bright, smooth far-UV background within NGC 4449. Hill, in collaboration with Fanelli and D. Smith (NASA/NRC) presented a poster of these results at the Maryland October Astrophysics Conference.

Fanelli and Waller, in collaboration with D. Smith (NASA/NRC) and S. Neff (NASA/GSFC) have explored the FUV light distribution of the Sm/Im galaxy NGC 4214. The FUV light is observed to be more centrally concentrated than the I-band light, and is remarkably well-represented by an $R^{1/4}$ law, suggesting that the centrally concentrated massive star formation is the result of an interaction, either an accretion event or tidal encounter, with a dwarf companion(s). The hybrid disk/starburst-irregular morphology evident in NGC 4214 emphasizes the danger of classifying galaxies based on their high surface brightness components at any particular wavelength.

D. Smith (NASA/NRC), in collaboration with S. Neff (NASA/GSFC), Fanelli, and Waller, examined the FUV morphology of the peculiar spiral galaxy NGC 3310. As in NGC 4214, the radial FUV light profile is best fit by an $R^{1/4}$ law, generally characteristic of dynamically hot stellar systems. The correspondence between the $R^{1/4}$ behavior in the FUV and B-band surface brightness profiles, combined with the very blue colors of NGC 3310, and the presence of low-surface brightness shells at optical wavelengths, argues strongly that the present morphology is the result of a global starburst triggered by a merger with a dwarf companion.

Fanelli and Waller, in collaboration with D. Smith (NASA/NRC) and S. Neff (NASA/GSFC) have initiated a program to study the multi-wavelength properties of starburst systems by combining FUV images from UIT with optical and NIR imagery. High resolution NIR images in the JHK bands of several UIT galaxies were obtained at KPNO in December 1995. Using this unique dataset, the ages, luminosities, and extinction of starburst knots can be determined, and correlated with their spatial morphology.

S. Neff (NASA/GSFC), Hollis, J. Hill, Fanelli, Waller, and D. Smith (NASA/NRC) have combined FUV imagery from UIT and UBVRI images obtained at Las Campanas Observatory to explore the massive stellar content in the interacting/merging system NGC 4038/39, the ''Antennae.'' Significant FUV emission is detected in this merger, despite extensive dust and molecular gas present in the system. The total observed FUV flux of the pair is equivalent to $m_{FUV}\sim 10.3$ mags. For an adopted distance of 19.8 Mpc, this corresponds to an absolute FUV magnitude of ~ -21.2, a value typical of large spiral galaxies observed by UIT. The brightest far-UV knot is found to have absolute far-UV flux about 24 times that of the 30 Dor nebula.

Collins, Fanelli, and A. Smith (NASA/GSFC) are studying the exceptionally bright FUV knots detected in the highly inclined late-type spiral galaxy NGC 4631. Despite its nearly edge-on configuration, observations by the UIT show that NGC 4631 is a copious source of FUV emission. The apparently low obscuration combined with recent intense star formation activity indicate a disturbance in the interstellar medium to large scale heights.

Fanelli, Stecher (NASA/GSFC), Waller, D. Smith (NASA/NRC) and S. Neff (NASA/GSFC) received *HST* Cycle 6 time to study the massive star populations in four nearby irregular/amorphous galaxies, with primary goals to determine the total intensity and spatial distribution of recent ($t<100$ Myr), massive star formation, and to confirm the suspected presence of ''super star-clusters.'' Images using the WFPC2 will be obtained after the second *HST* servicing mission.

Fanelli and Collins compared the high-mass stellar population in the disks of the Seyfert galaxies NGC 1068 and NGC 4151 using FUV and NUV images from Astro-1/UIT. In NGC 1068 the starburst disk dominates the observed FUV luminosity producing 81% of the FUV and 83% of the NUV light. In contrast, the unresolved bright nucleus dominates the UV light distribution in NGC 4151. The high fraction of observed UV luminosity produced by the starburst disk in NGC 1068 demonstrates that even at ultraviolet wavelengths, the fractional contribution of an active nucleus to the global flux can be small.

Fanelli, D. Smith (NASA/NRC) and S. Neff (NASA/GSFC) are investigating the massive stellar populations in several starburst knots in the hybrid AGN/starburst galaxy NGC 1068. Using near-IR long-slit spectra obtained with the KPNO 4 meter telescope in October 1995, they detect spectral features indicative of red supergiants in a few knots.

A multi-wavelength Atlas of Galaxies observed during Astro-1/UIT mission is being developed by P. Marcum (TCU), Fanelli, Waller, Cornett, R. O'Connell (UVa), T. Stecher (NASA/GSFC), W. Freedman (OCIW) and Barry Madore (IPAC). The atlas contains images at far-UV, near-UV, H α, and BVR bandpasses, surface brightness profiles, and tabulated photometry. It should be completed by the end of 1996. A similar treatment of the larger Astro-2 dataset is planned with the aim of producing a single Atlas of Galaxies observed during both missions.

J. Hill and Fanelli are consulting with S. Gessner (U. Alabama) who is completing a dissertation on the FUV morphology and stellar populations of dwarf galaxies observed with UIT. A summary of this research appeared in the June 1996 issue of Sky & Telescope.

K. Borne and his colleagues at the STScI, H. Bushouse, L. Colina, and R. Lucas, have initiated an *HST* imaging study of a comprehensive sample of 160 ultraluminous IR galaxies. Fine structure is seen within radius $<2''$ for each galaxy. In about 20% of the galaxies, the structure is smooth and centrally concentrated, suggestive of a bright nuclear energy source (AGN?). In the other cases, the sub-arcsecond morphology is chaotic and extended, suggestive of strong starburst activity. The peculiar, disturbed morphologies that are seen on large (kpc) scales are continued down to the smallest scales in the cores. A rich variety of morphological features are seen, probably related to the recent interaction-induced starburst episode. These starburst-related features (e.g., numerous bright clumps of star formation, shells, and bubbles) are similar to those seen in previous *HST* imaging observations of strongly interacting and merging galaxies. A very strong and sharp dust lane has been discovered in Mrk 273, whose central regions look very similar to M 82 (i.e., with extended dust filaments and possible outflows). Probing through strong dust features like these is one of the principal goals of our *HST* I-band imaging survey.

K. Borne, R. Lucas (STScI), P. Appleton (Iowa State), C. Struck (Iowa State), and A. Schultz (STScI) have continued to study *HST* images of two collision-induced ring galaxies: the Cartwheel ring and IIZw28. Recent analysis of our Cartwheel images reveals evidence in the core for possible infalling gas clouds. The appearance of comet-like structures are suggestive of material returning to the galaxy following the large splash of matter that occurred when the penetrating companion punched through the Cartwheel galaxy over 200 million years ago. Their *HST* images of the peculiar ring galaxy IIZw28 show considerable new structure in the ring. The galaxy is interesting because it is one of the few well known ring galaxies without an obvious massive companion. The *HST* observation and new VLA H I observations show that IIZw28 has a number of newly discovered nearby gas-rich companions. The H I disk around IIZw28 is significantly larger than the optical ring. Like the similar ring galaxy VI-IZw466, it seems that IIZw28 lies in a small group containing optically faint, but H I-rich galaxies.

K. Borne and L. Colina (STScI) are completing their *ROSAT* HRI study of the X-ray emission morphology in colliding elliptical galaxies in which at least one member is a 3C radio jet source. The results for 3C278 show clearly the strong effects of ram pressure from the hot gas in the colliding companion on the radio jet propagation and morphology. The results for 3C31 and 3C75 suggest different explana-

tions for the bent jet morphologies in those two sources. The twin jets in 3C75 are likely to deflected by buoyancy forces in the hot intergalactic medium of Abell 400. The wiggly jets in 3C31 are probably oscillating spatially due to precession of the central jet engine deep in the core of NGC 383.

P. Huang is continuing his research on clusters of galaxies using *ROSAT* and *ASCA* data. As part of his PhD thesis, he is currently working with his advisor C. Sarazin at the U. Virginia on *ROSAT* observations of a sample of cooling flow clusters of galaxies with the central cD galaxies being strong radio sources. Collaborating with his advisor, he also proposed two AO5 *ASCA* observations of clusters of galaxies. These observations will help to understand the spectral properties in particular the chemical abundance distributions around cD galaxies in these cooling flow clusters.

K. Watanabe is collaborating with M.D. Leising (Clemson U.), and G.H. Share and R.L. Kinzer (NRL) on the measurement of the cosmic gamma-ray background. Their latest results (Watanabe *et al.* 1996) with Solar Maximum Mission (*SMM*) shows no MeV bump which has been claimed by some previous scintillation counter experiments for decades.

Watanabe is also working with D.H. Hartmann (Clemson U.) on a theoretical study of the cosmic gamma-ray background contributions from SN Ia and SN II and Blazars.

A. Danks managed the assembly and testing of a Photometrics designed camera to house a STIS development 2048×2048 thinned CCD. This chip has been mounted into a new dewar and tested at the AAT prime focus in November of last year. These observations were made in collaboration with P. Francis (Melborn) and B. Woodgate (NASA/GSFC), and they resulted in a number of detections of new members of a distant cluster at a $z = 2.3$. Since then P. Francis has confirmed the redshift of several candidates through spectroscopy (Francis, Woodgate, Danks, 1996).

In collaboration with A.G. Michalitsianos and Dolan (NASA/GSFC), Hill has obtained a series of far UV spectra of the gravitational lens system Q0957+561 with the *HST*-FOS. The differences in the damped Lyman-series absorption in the lens components indicates that the region containing the absorbing neutral hydrogen is inhomogenous over length scales of 200 to 500 parsecs, which corresponds to the beam separation of the light travel paths of the two components.

S. Odenwald has been collaborating with A. Kashlinsky (NORDITA) and J. Mather (NASA/GSFC) on a search for intensity variations in the infrared sky which might be contributed by high-redshift galaxies. Using the *COBE*/DIRBE data base, and a technique which removes local foregrounds with non-cosmological infrared colors, this NASA/LTSA-supported effort, now in its third year, has resulted in two papers which place severe upper limits on the contribution of clustered matter to the cosmic infrared background. This work is being expanded to include recent 2MASS observations at J, H and K-band.

R.J. Hill (HSTX) continued his collaboration with W. Freedman (Carnegie Obs.) and others on the Cepheid extragalactic distance scale. Based on V and I observations of Cepheids in the spiral galaxies M101 and M100 made with the Wide Field/Planetary Camera 2 (WFPC2) aboard *HST*, we find the distances to these galaxies to be 7.4 ± 0.6 Mpc and 16.1 ± 1.3 Mpc, respectively.

3.8 Cosmology

A. Kogut and D. Fixsen, with R. Shafer and J. Mather (NASA/GSFC), M. Seiffert and P. Lubin (UCSB), and S. Levin (JPL), are leading a project to measure the long-wavelength spectrum of the cosmic microwave background and diffuse Galactic foregrounds. The Diffuse Microwave Emission Survey (DIMES) is an Advanced Concepts in Astrophysics mission study selected by NASA to answer fundamental questions about the content and history of the universe. DIMES will measure the frequency spectrum of the cosmic microwave background at centimeter wavelengths to study the formation of structure during the ''cosmic dark ages'' prior to the formation of the first stars and galaxies. Many cosmological models predict distortions in the CMB spectrum away from a blackbody at wavelengths of several centimeters or longer. Detecting these distortions or showing that they do not exist constitutes the last frontier of CMB observations.

The Differential Microwave Radiometers (DMR) (one of the *COBE* instruments) provided the first detection of primordial anisotropy in the CMB, providing key evidence for the concept that large-scale structure in the universe evolved from the gravitational infall and collapse of initially small density perturbations. Kogut and collaborators have now performed statistical tests of the 4-year DMR maps which show that the cosmic microwave background is well described by a random Gaussian field, as predicted for inflationary models of cosmology and certain classes of topological defect models. A likelihood comparison of the DMR maps to a set of Gaussian and non-Gaussian toy models selects the exact Gaussian model as the most likely descriptor of the data.

A. Kogut, G. Hinshaw (NASA/GSFC) and A. Banday (MPA) searched the DMR 4-year sky maps for the distinctive spiral patterns from an anisotropic spacetime to derive strict upper limits to the shear or rotation in the Universe. The rotation rate must be less than 5×10^{-8} of the expansion rate in flat or open geometries. The DMR maps provide the best observational evidence that, on the largest scales, spacetime can be described by the Friedmann-Robertson-Walker metric.

The *COBE*-DMR sky maps provide the normalization for ''seeds'' of cosmic structure on the largest physical scales. On smaller scales, anisotropy results from a series of ground-based and balloon-borne instruments are less clear, with considerable scatter between measurements made by different groups on the same physical length scales. A. Kogut and G. Hinshaw (NASA/GSFC) used computer simulations of recent experimental results show that the scatter can be explained by sample variance from the small (non-overlapping) regions of sky observed by different groups. Considered jointly, medium-scale CMB observations provide strong evidence for the increased power on small angular scales expected in most models of structure formation. Models without such an increase are rejected at more than 5 standard deviations. (Kogut & Hinshaw 1996).

A. Kogut *et al.* cross-correlated the *COBE*-DMR and DIRBE data sets to demonstrate the existence of diffuse ionized gas in the interstellar medium whose spatial distribution on large angular scales is traced by the infrared cirrus observed by DIRBE. The results provide the first large-scale template for the distribution of the warm ionized component of the interstellar medium. (Kogut *et al.* 1996c).

The final in-flight instrument calibration of the *COBE*-DMR 4-year data set, derived from observations of the Moon and the Doppler effect of the Earth's orbital motion around the Sun, proved consistent with ground calibration within the 0.7% uncertainties of the in-flight calibration. The DMR data are remarkably free from any instrumental signature; instrumental artifacts in the 4-year sky maps contribute less than 0.4% of the cosmic signal. (Kogut *et al.* 1996d).

A. Kogut and N. Phillips (U. Maryland) used numerical simulations of texture cosmologies to demonstrate that the stress energy in these models is not dominated by the extremely energetic unwinding events, but by the much more numerous configurations in which the order field is only partially wound. (Phillips & Kogut 1996).

D. Fixsen (HSTX) continued his collaboration with the MSAM group: S. Meyer (University of Chicago), E. Cheng (Goddard), P. Timbe (Brown U.), the Danish Space Research Institue, and Bartol Research Institute, on the medium scale cosmic background ansiotropy. The most recent results show that there is a higher level of anisotropy at 30 arcminute scales relative to large angular scales (from *COBE*). This also demonstrates the validity of measurements of this kind from balloon platforms. This collaboration has also produced a frequency selective bolometer which has the promise of allowing multi-spectral measurements with an array format.

Fixsen also continues work on the FIRAS *COBE* data, with J. Mather and R. Shafer (NASA/GSFC), and the *COBE* team. This has produced the best limits on the deviation (50 parts per million *rms*) of the CMB spectrum from a blackbody spectrum and the best temperature to date (2.728 K). Work on the FIRAS high frequency data has also contributed to the understanding of the Galaxy.

4. EDUCATION AND PUBLIC OUTREACH

Members of HSTX/CASP were active in the local community, serving as science fair judges at high schools, giving guest presentations at elementary schools, helping to wire schools to the Internet, consulting in education advisory committee meetings at the Howard B. Owens Science Center, providing astronomical information at science educator conventions, etc. These and other activities were formalized at HSTX this year, through formation of the HSTX Education Committee. The homepage for this group is

http://selsvr.stx.com/edu-outreach/

Sten Odenwald is designing the education and public outreach WWW page for the MIDEX/IMAGE project in collaboration with W. Taylor (HSTX) and J. Green (NASA/GSFC). The URL of this page is:

http://image.gsfc.nasa.gov/poetry.html

Odenwald is also beginning his second year of offering a WWW site called the Astronomy Cafe which includes an archive of over 2000 questions asked by visitors. The Cafe has received over 1 million hits since its inception. This activity is supported by private donations, and a Small Research Grant by the American Astronomical Society. The Cafe can be found at:

http://www2.ari/net/home/odenwald/cafe.html

S. Digel, along with J. Friedlander, S. Geitz (Purdue Univ.) & D. Leisawitz (NASA/GSFC), has prepared a poster with images of the Milky Way in spectral lines and continuum bands spanning the range from radio to gamma ray. The ''Multiwavelength Milky Way'' poster and companion WWW page,

http://adc.gsfc.nasa.gov/mw/milkyway.html

includes explanatory text. These should be useful educational tools for astronomy, with a wide audience.

D. Massa and J.A. Cardelli (Villanova U., deceased), organized and chaired a special session at the 187-th meeting of the AAS in San Antonio, focusing on policy making in astronomy and its impact on the astronomical community. The session concentrated on how policy decisions are crafted by the major astrophysics funding organization, NSF and NASA. The goal of the session was to bring together officials from the AAS, NASA, and the NSF in order to discuss how the policy and decision making process operates and whether it should be changed to better serve the general needs of the professional astronomical community.

PUBLICATIONS

The publication list includes all papers published or submitted between 1 October 1995 and 30 September 1996 by the permanent staff.

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