Hughes STX
CASP

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The following report covers CASP activities from 1 October 1996 through 30 September 1997.

1. INTRODUCTION

1.1 Company Background

Hughes STX (HSTX; http://www.stx/com) 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. Consequently, in addition to providing membership dues to professional societies, such as the AAS, for its professional staff it also established the Center for Astronomy and Space Physics (CASP). CASP's charge is to promote and facilitate professional achievement within HSTX, 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 meetings and publication costs, when no other sources are available. It also supports the HSTX corporate membership in the AAS.

This last year HSTX/CASP also sponsored an international conference on UV astronomy (see § 1.4).

1.3 Personnel

As of October 1997, 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, M. Deland 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, 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, J. Silvis, K. Smale, C. Standley, A. Szabo, L. Tan, W. Taylor, K. Tolbert, M. Tripicco, N. Tsyganenko P. Tyler, P. Uribe, F. Varosi, W. Waller, W. Warren, J. Weiland, D. Williams.

1.4 Ultraviolet Universe Conference

HSTX scientists initiated planning for a scientific conference entitled ''The Ultraviolet Universe at Low and High Redshift: Probing the Progress of Galaxy Evolution'' held on May 2-4 1997 at the U. Maryland Conference Center. This international conference was sponsored by HSTX/CASP, NASA/GSFC Laboratory for Astronomy and Solar Physics (LASP) and the U. Maryland Dept. of Astronomy.

The primary aim of the conference was to bring together researchers of the local and remote universe to gain new insights on the evolution of galaxies and the intergalactic medium. The conference emphasized the UV since our current optical and NIR view of distant, highly red-shifted galaxies is of UV light emitted in their rest frames.

The conference was attended by approximately 100 scientists and the proceedings have been completed and submitted for publication by the American Institute of Physics (AIP) Press (Waller *et al.* 1998).

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.

This last year marked the end of the *COBE* project, bringing to a close one of the most productive projects of recent years which has made lasting contributions to both cosmology and galactic astronomy. As part of the shut down process, the HSTX *COBE* staff completed delivery of the final *COBE* archive, including DIRBE, DMR, FIRAS, and engineering/housekeeping datasets and documentation (comprising about 350 Gbyte of data) to the NSSDC.

As part of the final calibration procedure, D. Fixsen, J. Weiland (HSTX) and other members of the *COBE* team compared the absolute calibrations of the DIRBE and FIRAS instruments. The two instruments observed the sky simultaneously, but provide independent measurements of the infrared sky. Their results (Fixsen *et al.* 1997b) show that the absolute calibrations of both instruments agree to within the quoted errors. Specific scientific contributions by the team can found elsewhere in this report.

DIMES: A. Kogut and D. Fixsen (HSTX), with R. Shafer and J. Mather (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 (CMB) 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. For more information, see

http://ceylon.gsfc.nasa.gov/DIMES/

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* is scheduled for launch in 2000 and 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* is now in place and has been returning spectacular new images and information about the physical processes in the Solar atmosphere, Corona and wind. 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)

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

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 ADC and ADF can be accessed via

http://adc.gsfc.nasa.gov/ http://hypatia.gsfc.nasa.gov/adf/

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 additional information, see

http://nssdc.gsfc.nasa.gov/spdf/spdf.html

STIS: The Space Telescope Imaging Spectrograph (STIS), is one of the second-generation instruments for the Hubble Space Telescope (*HST*). It was successfully installed on *HST* during the second servicing mission in 1997 February. In addition to general science support, A. Danks (HSTX) is a Co-Investigator on the STIS science team and responsible for the UV detectors, Multi Anode Microchannel plate Arrays (MAMA’s). Danks has described the capabilities of STIS in Danks *et al.* (1996) and in Kimble *et al.* (1997).

With the STIS now fully functional, HSTX support for STIS has ramped up dramatically during the last year. HSTX astronomers have contributed to the scientific calibration effort and to the analysis of early release observations. Contributions by several of the HSTX STIS team members will be found throughout this report. Further information about STIS can be found at:

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

UIT: As STIS support ramps up, the Ultraviolet Imaging Telescope (UIT) science support is winding down, with several of the UIT support group moving to the STIS project. UIT was a 38 cm telescope flown aboard the Space Shuttle in 1990 December and again in 1995 March under the direction of Principal Investigator T. Stecher (NASA/GSFC). UIT was a survey instrument designed to provide wide-field, vacuum UV imagery with $3''$ spatial resolution and 10% photometric accuracy. Approximately 200 astronomical targets were observed during both flights. These included nearby galaxies, globular clusters, and the Magellanic Clouds and the fields of a variety of other interesting objects. The UIT/HSTX science support team at GSFC provided flight operations, data reduction, science data analysis, and systems and software support for the UIT Interactive Image Processing Facility. A project website is maintained at

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

During this last year, a final calibration of the Astro-2 dataset was completed and all of the flight data were processed. Archiving of the data by the SSDOO has been initiated and is expected to be complete by the spring 1998. A detailed description of the UIT instrument, calibration and data was completed and published (Stecher *et al.* 1997).

In conjunction with the flight program, the UIT project conducted a major ground observing campaign, to provide deep wide-field optical and near-IR imagery for objects observed with UIT. Recent efforts have focused on completing this program for the dataset obtained during the Astro-2 mission. Several HSTX astronomers are involved in this effort, organized by M. Fanelli, in collaboration with P. Marcum (TCU), E. Smith (GSFC), P. Hintzen (UNLV), D. Smith (NRC), W. Freedman (OCIW), and B. Madore (IPAC). During the report period, data was obtained during observing runs at Palomar Observatory (16 nights), CTIO (3 nights), Las Campanas Observatory (9 nights), and McDonald Observatory (4 nights).

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

N. Tsyganenko (HSTX) derived a new method to construct a simple, realistic, and flexible mathematical model of the magnetospheric substorm current system (current wedge). The model includes variable longitudinal position and width of the current wedge in the local time, and takes into account warping effects with the realistic background field yielded interesting mapping effects of the substorm current system, which can explain the observed formation of the auroral bulge at ionospheric altitudes. The proposed model can also be used in the development of the technique for monitoring real-time evolution of the storm-time magnetosphere, based on simultaneous data from a constellation of spacecraft.

Tsyganenko compiled a new set of ISTP spacecraft data including the magnetospheric field observations by *GEOTAIL* during 1993-1997, tagged by simultaneous data on the solar wind plasma and magnetic field, taken by *WIND* and *IMP-8*. The data set was complemented by 5-minute average values of the magnetic field measured by *ISEE-1/2* spacecraft during the entire period of the magnetometer experiment (1977-1987). Based on these data, a study of the global geometry of the tail current sheet in the interval of distances between 10 and 100 Earth's radii ($R_\oplus$) has been made. Quantitative modeling was performed of the tail response to the Earth's dipole tilt and to the azimuthal component of the interplanetary magnetic field (IMF). It was found that the effects of the Earth's dipole tilt upon the shape of the tail current sheet persist up to large distances down the tail, while the twisting effect of the IMF becomes discernible as close to Earth as at $R = 10 - 20 R_\oplus$. To this end, Tsyganenko devised a new method of modeling the effect of twisting the magnetospheric tail. The new technique will allow one to extend the magnetospheric models to large distances in the deep tail, where the effects of the plasma sheet deformation by the IMF become quite large.

A. Szabo (HSTX) and R.P. Lepping (GSFC), in collaboration with K.I. Paularena (MIT), identified heliospheric current sheet (HCS) crossings in the *IMP-8* Earth magnetosheath data corresponding to interplanetary measurements made by the *WIND* spacecraft. Correlating the two sets of observations, it was found that the HCS is significantly distorted in the magnetosheath in such a way that its surface normal bends towards the local bow shock normal direction. Also, the magnetohydrodynamic type of the HCS discontinuity often changed as it crossed the Earth bow shock most often changing from rotational to tangential.

Szabo, in collaboration with D. Huterer and K.I. Paularena (MIT), analyzed selected *IMP-8* and *WIND* bow shock crossings observed in late 1994. They found that while the fitted shock normal orientations are consistent with model bow shock shapes, the shock speeds were not. In particular, the Rankine-Hugoniot (RH) fit results show outward motion of the shock from Earth for all but one of the considered cases. It was concluded that the standard RH equations that were used may be missing some terms which would provide an accurate description of the balance on both sides of the bow shock. Specifically, the bow shock acceleration at its flanks is not taken into account by these equations.

R.P. Lepping, L.F. Burlaga, Szabo (HSTX), K.W. Ogilvie, W. Mish, D. Vassiliadis (GSFC), A.J. Lazarus, J.T. Steinberg (MIT), C.J. Farrugia, J. Janoo (U. New Hampshire), and F. Mariani (U. Roma, Italy), conducted a study of the well known October 18-20, 1995 interplanetary magnetic cloud and stream events. Both the interplanetary *in-situ* properties and geoeffectiveness of the magnetic cloud have been analyzed in detail. The magnetic cloud was successfully modeled as a force-free flux rope of 0.27 AU diameter. Its axis was estimated to be nearly perpendicular to the Sun-Earth line and close to the ecliptic plane.

Szabo, in collaboration with D.E. Huddleston, C.T. Russell, and G. Le (UCLA), conducted an extensive review study of all the magnetopause crossings of the outer planets by the *Voyager* spacecrafts. In comparing the observations, particular attention was placed on the role of reconnection when signatures of this process could be found.

W. Taylor (HSTX) is a co-Investigator on the *IMAGE* Radio Plasma Imager (RPI) experiment. *IMAGE* is a MIDEX class mission, selected by NASA in 1996 and scheduled for launch in 2000. It will to study the global response of the Earth's magnetosphere to changes in the solar wind. *IMAGE* will use neutral atom, ultraviolet, and radio imaging techniques to:

Identify the dominant mechanisms for injecting plasma into the magnetosphere on substorm and magnetic storm time scales;

Determine the directly driven response of the magnetosphere to solar wind changes; and,

Discover how and where magnetospheric plasmas are energized, transported, and subsequently lost during substorms and magnetic storms.

3.2 Solar Physics

R. Cebula and M. DeLand (STX), in collaboration with E. Hilsenrath (GSFC), continued their studies of solar UV irradiance variability. Cebula and Hilsenrath completed their analysis of data from the 8th and last flight of the Shuttle SBUV (SSBUV) instrument in January 1996. Extensive preflight, inflight, and postflight calibrations have produced excellent absolute and relative accuracy for the SSBUV data. In conjunction with the *UARS* SUSIM and SOLSTICE satellite instruments and the SOLSPEC and SUSIM instruments on the ATLAS Shuttle payload, the SSBUV data have led to a factor of 2 improvement in the knowledge of the absolute solar irradiance for the 2000-4000 Å wavelength region. Cebula also participated in studies of the initial solar measurements from the GOME instrument on the *ERS-2* satellite (Burrows *et al.*, 1997, Weber *et al.*, 1997). Cebula served on the scientific organizing committee for the SOLERS 22 meeting as co-leader of Working Group 2, and co-wrote the WG2 summary report.

Cebula and DeLand have produced a long-term solar UV irradiance data set from the *NOAA-11* SBUV/2 instrument for the maximum and declining phase of solar cycle 22. Data from coincident underflights of SSBUV between 1989 and 1994 were used to provide correction factors for *NOAA-11* end-to-end sensitivity changes (DeLand *et al.*, 1997a, Cebula *et al.*, 1997). These data indicate long-term decreases from February 1989 to October 1994 of approximately 7% at 2050 Å and 3-4% at 2500 Å, where solar variations drive stratospheric photochemistry, and also document the spectral and temporal evolution of solar rotational variability during this period. Comparisons with the *UARS* SUSIM and SOLSTICE measurements between 1991-1994 verify the accuracy of the *NOAA-11* results (DeLand and Cebula, 1997c). Additional information is available at

http://ssbuv.gsfc.nasa.gov/solar.html

J. Brosius (HSTX) continued his collaborations with J. Davila, R. Thomas, S. Jordan (GSFC), J. Saba (Lockheed-Martin), H. Hara (NAO, Japan), S. White (U. Maryland), S. Kastner, A. Bhatia (GSFC), and D. Falconer (NRC/MSFC) in the analysis and interpretation of EUV spectra and spectroheliograms obtained during the 1991 and 1993 flights of GSFC's Solar EUV Rocket Telescope and Spectrograph (SERTS). Brosius, Davila, Thomas, and White (1997) advanced the technique for solar coronal magnetography using SERTS EUV spectra/spectroheliograms and coordinated VLA 20 cm and 6 cm radio observations. Falconer *et al.* (1997) used coordinated SERTS and *Yohkoh* observations to investigate the possibility that strong EUV lines observed with SERTS provide good proxies for estimating the total coronal flux over shorter wavelength ranges.

Brosius, Davila, & Thomas (1997) continued with the analysis of EUV spectra (170 - 350 Å) and spectroheliograms obtained during the 1995 SERTS flight. They used density- and temperature-insensitive line intensity ratios to derive the instrument's relative radiometric calibration, and found self-consistencies among all but a few such ratios. Spatially resolved EUV spectra were used to derive densities and velocity flows across a solar active region.

L. Ofman (HSTX) continued his collaboration with J.M. Davila (NASA/GSFC) on magnetohydrodynamic (MHD) models of the solar wind. Their recent theoretical results (Ofman *et al.* 1997a, 1997b) indicated that nonlinear solitary-like waves may contribute significantly to the solar wind acceleration.

Ofman was a guest investigator on the Ultraviolet Coronagraph Spectrometer (UVCS) instrument on board the *SOHO* spacecraft. He used the White Light Channel (WLC) to observe density fluctuations in the solar wind. His recent observations of density fluctuations in solar coronal holes, in collaboration with M. Romoli (U. Florence), G. Poletto (Arcetri Obs), G. Noci (U. Florence), and J. Kohl (CfA) may be the evidence for the presence of compressional waves in the solar wind (Ofman *et al.* 1997b).

Ofman collaborated with J.M. Davila (NASA/GSFC) and J. Klimchuk (NRL) to developed a new model of coronal loop heating that includes the effects of coupling of the loop density with the chromosphere. This important effect was neglected in earlier models of coronal loops. The understanding of coronal loop formation and heating is one of the keys to understanding the coronal heating mechanism – still an unsolved mystery.

Ofman collaborated with Z. Mouradian (Meudon Obs), T. Kucera (ARC), and A. Poland (NASA/GSFC) on observations of prominences with the *SOHO* Solar Ultraviolet Measurement of Emitted Radiation (SUMER) instrument. They studied in detail the temperature evolution of a prominence and the possible implications for the prominence heating mechanism (Ofman *et al.* 1997c).

3.3 Planetary Physics

L. Mayo (HSTX) completed several projects involving the precipitation cycle in the lower stratosphere and troposphere of Titan (Samuelson *et al.* 1997a, 1997b, Samuelson and Mayo 1997, and Mayo and Samuelson 1997). His primary focus has been the identification of the physical properties of condensate hydrocarbons and nitriles (CH_4, C_2H_6, C_4N_2) and there contribution to particle nucleation and growth. This has involved comparison of *Voyager I* IRIS Titan observations with computer generated models of opacity sources in Titan's stratosphere and troposphere using radiative transfer formalism and taking into account collisional absorption. Additionally, he has been working on developing alternative modelling approaches to defining vibratational and rotational line emission for tri-atomic molecules (e.g. CO_2, HCN).

J. Weiland (HSTX) continued the DIRBE effort to characterize the zodiacal foreground signal in the 10 DIRBE bands from 1.25 to 100 μm. She and M.G. Hauser (STScI) wrote contributing sections concerning zodiacal and Galactic components of the diffuse infrared sky for the upcoming Night Sky Reference paper (Leinert *et al.* 1997).

3.4 Stellar Astrophysics

A. Danks (HSTX) collaborated with the U. College, Gallway in Ireland, to obtain ground based observations using the high speed photon counting capabilities of MAMA detectors to search for a pulsar in 1987a Super nova remnant (Sonneborn *et al.* 1997, Middleditch *et al.* 1997). Using this same detector, Danks collaborated to measure the properties of the optical pulsar in Geminga and recently searched the inner core of M4 for the triple pulsar system PSR B1620-26 (Shearer *et al.* 1996).

W. Landsman (HSTX) continued his investigation of unusual stars detected during the two UIT missions. In collaboration with P. Bergeron, J. Aparicio (U. de Montreal) and R. DiStefano (CfA) he analyzed GHRS spectra of the yellow giant S1040 in the old open cluster M67, which was found to be unexpectedly bright on a UIT image. The spectra showed the presence of an unusually low-mass (0.23 $M_\odot$) white dwarf companion, and provided evidence for a binary mass transfer origin of at least some blue stragglers (Landsman *et al.* 1997, Landsman & Stecher 1997). Landsman continued his long-time collaboration with T. Simon (U. of Hawaii) using GHRS spectra to study the chromospheres of A-type stars (Simon & Landsman 1997a) and the UV colors of A stars (Simon & Landsman 1997b). He also continued his work as part of a collaborations studying UIT images of globular clusters (Dorman *et al.* 1997, O'Connell *et al.* 1997, Whitney *et al.* 1997), and deuterium in the local interstellar medium (Dring *et al.* 1997).

D. Massa (HSTX), continued his collaborations with R. Prinja and I. Howarth (UCL), A. Fullerton (MPI, München), S. Owocki (Bartol), and S. Cranmer (MIT) on the variability of OB star winds and their connection to photospheric activity. They demonstrated that the wind of the rapidly rotating B1 supergiant γ Ara actually consists of two co-existing winds – one in the equatorial regions and another at higher latitudes (Prinja *et al.* 1997). Many of the same collaborators then performed a detailed time series analysis of *IUE* data of the wind lines in the B supergiant HD 64760. Their analysis (Fullerton *et al.* 1997) showed that the data are consistent with the presence of enormous spiral structures (much like standing waves) in the wind of this star. Howarth *et al.* (1998) continued the analysis by examining the variability of the photospheric lines in the star using a cross-correlation technique. These results showed that photospheric disturbances with some periods similar to those found in the wind were also present in the photosphere. Finally, Massa (1998) presented the results of a wind and photospheric time series analysis of a 30 day *IUE* time series of the B0 Ia HD 91969. The results demonstrated a perplexing relationship between the dominant periods in the wind (7.8 days) and the photosphere (3,9 days). While the 2:1 ratio is highly suggestive, it is not clear what physical mechanism could naturally explain this relationship.

Massa and R. Prinja (UCL) continued their investigation into the UV properties of B supergiants. Thus far, their effort has been primarily it the data selection and reduction phase. Progress reports on the project were presented at the Second Boulder-Münich Workshop this past summer (Massa & Prinja 1998, Prinja & Massa 1998).

Massa and E. Fitzpatrick (Princeton) have begun a project aimed at characterizing the physical parameters (T_{eff}, surface gravity, abundances and microturbulent velocity fields) in main sequence B stars from their low dispersion *IUE* spectra. Initial result are very promising, and resulted in a successful ADP proposal to pursue this work over the next 2 years.

In a continuing collaboration with B. Woodgate (GSFC), Brosius (HSTX) completed model calculations for the time dependent, redshifted Lyα emission from stellar chromospheres subjected to beams of nonthermal protons. As the injected protons heat and ionize the atmosphere, the intensity of the redshifted Lyα emission fluctuates. Observations of such fluctuations could be used to deduce the properties of proton beams and stellar chromospheres.

Ofman (HSTX) collaborated with V. Airapetian (CSC), R. Robinson (Catholic U.), K. Carpenter and J. Davila (NASA/GSFC) on models of stellar wind acceleration in cool stars. The aim of this work in progress is to apply the MHD models developed for the sun to the conditions believed to exist in cool stars, based on the Goddard High Resolution Spectrograph (GHRS) data.

W. Warren (HSTX), in collaboration with A.C. Miller, J.R. Myers, C.B. Sande (CSC), and D.A. Tracewell (GSFC), completed a new version of the SKY2000 Master Star Catalog that is now being used by NASA for satellite acquisition and attitude determination. The new catalog contains highly accurate astrometric data and extends photometric data to the near IR (R and I bands) for CCD star trackers (Warren *et al.* 1997a, 1997b, Myers *et al.* 1997). The next version will include *Hipparcos* and Tycho data.

3.5 Nebulae, Interstellar Medium and Galactic Structure

Danks (HSTX) continued his ground based studies of molecular chemistry in the ISM with observations of IS C_2 at

McDonald (Sembach *et al.* 1996), and observations in Chile of CH^+ in the Large Magellanic Cloud, and in Argentina of stars in η Carina.

Danks also contributed to studies by the STIS GTO team of the star CP −59deg2603 in the η Carina Nebula. These *HST* STIS observations were used to examine the spatial and kinematic structure of the η Carina nebula (Walborn *et al.* 1997). Following up on his ground based observations, Danks has also been involved with STIS interstellar medium observations of HD 72089 in Vela nebula (Jenkins *et al.* 1997).

R. Arendt, D. Fixsen, N. Odegard, and J. Weiland (HSTX) 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.* (1997) analyzed observations of the Galactic plane by *COBE*/DIRBE in six wavelength bands from 12 to 240 μm. The data at each wavelength were 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.* (1997) 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.

Arendt has continued an analysis of observations of the Cas A supernova remnant using the Infrared Space Observatory's (*ISO*) Short Wavelength Spectrograph (SWS). The data reveal variations in the line emission from hot gas and thermal emission from dust around the supernova remnant.

S.W. Digel (HSTX) was a visiting professor at the University of Paris VII during November and December, 1996, collaborating on studies of diffuse γ-ray emission with I.A. Grenier (CE-Saclay). A pointed observation of the Monoceros region with the CGRO/EGRET telescope was analyzed together with other EGRET data to study the distribution of cosmic-ray density and the calibration of molecular mass in the outer Galaxy. Related projects included participation in collaborations with S.D. Hunter and A.W. Strong (MPE) on whole-Galaxy models of the diffuse γ-ray emission.

With J. Norris (NASA/GSFC), Digel developed a model of the diffuse γ-ray emission from the Galactic plane with resolution suitable to study the point source detection limits of *GLAST*, a proposed next-generation γ-ray telescope. Simulations of observations for various energy ranges and observing parameters are ongoing.

With D. Leisawitz and Z. Guo (NASA/GSFC), M. Hanson (Steward Obs.), and B. Mendez (Berkeley), Digel is participating in a study of the infrared spectral energy distributions of five Galactic H II regions, using *COBE*/DIRBE data and ground-based near-infrared observations. The goal is to relate the stellar content, to be determined from 2-μm spectroscopy, and the evolutionary state of an H II region to its infrared spectrum.

With M. Almy (U. Wisc.) and L. Bronfman (U. Chile), Digel continued a study of X-ray shadowing of a distant molecular cloud observed with the ROSAT/PSPC. The analysis will permit the determination of the fraction of the soft X-ray background associated with the Galactic halo.

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

A. Kutyrev (HSTX) continued his collaboration with C. Bennett, S. Moseley (NASA/GSFC), R. Reynolds, and F. Roesler (UW-Madison) on the study of the diffuse warm ionized medium in the Galactic plane. The first portion of an H Brackett-γ emission line ($\lambda \sim 2.1655$ μm) Galactic plane survey with the Goddard-Wisconsin cryogenic Fabry-Perot spectrometer was carried out last summer. This dual Fabry-Perot spectrometer with a 256×256 InSb detector is designed specifically for high spectral resolution (resolving power 10^4) observations of extended objects (field of view of 1deg). The Brackett-γ line is relatively unaffected by interstellar extinction, making the detection of emission from the distant H II regions possible.

As part of the *COBE*/DIRBE team, Freudenreich (HSTX) continued his study of the structure of the Galaxy. In a paper in press (Freudenreich 1998), he discusses his findings. Specifically: The disk of the Galaxy is warped like the H I layer; it has a central hole approximately three kpc in radius; spanning that hole is a bright, strong bar viewed at an angle of 14deg from end-on.

Cross-correlating *COBE*-DMR microwave anisotropy maps with maps of the diffuse far-infrared dust continuum shows microwave emission traced by the dust with spectral behavior strongly suggestive of free-free emission. Kogut (HSTX) collaborated with A. de Oliveira-Costa, C.B. Netterfield, L.A. Page (Princeton), M.J. Devlin (U. Penn), and E.J. Wollack (NRAO) to demonstrate that the correlation persists to smaller angular scales over the north celestial polar cap. Subsequent correlation of IRAS with Hα maps over the same region yielded a somewhat weaker correlation. The origin and nature of the observed correlation is an active field of research.

3.6 Local Group Galaxies

R. Cornett (HSTX) continued work on far-UV imagery and photometry of the Small Magellanic Cloud (Cornett *et al.* 1997), obtaining 1620 Å photometry of over 11,000 stars in images which include most of the bar of the SMC. Morphology and luminosity functions for all stars, and color-magnitude diagrams, and spectral-type/UV color relations for stars with available ground-based data, are investigated. 191 of 195 supergiants within the UIT fields with spectral types earlier than F0 are detected in the FUV; the bluest m(1620Å)-V observed colors for spectral types earlier than A0 agree well with those of unreddened Galactic spectral atlas stars, while for later types observed SMC stars range significantly bluer, as predicted by low-metallicity model atmospheres. Redder colors for some stars of all spectral types are probably due to strong FUV extinction arising from even small amounts of SMC dust. A comparison of stellar and total FUV flux associated with H II regions observed by Kennicutt and Hodge shows good correlation of FUV flux with Hα flux, yielding FUV/Hα ratios that are consistent with models with SMC metallicity, ages from 1-5 Myr, and moderate ($0.0<E(B-V)<0.1$) internal SMC extension.

Cornett developed a technique for comparing Hα and FUV morphologies, creating a low-resolution, calibrated ratio (Hα/FUV) image for the LMC from sounding rocket FUV images and widefield Hα images. The value of this ratio is extremely sensitive to stellar age during the first 20 million years after a burst of star formation, and its distribution on the LMC is a striking tool for studying the star formation history of the LMC. The ratio image clearly shows extremely young (e.g. 30 Dor) and more evolved (e.g. Shapley III) star forming regions. These results were presented at the UV Universe Conference and will be published in its Proceedings.

J. Hill, J. Hollis (HSTX), and J. Parker (SWRI) used Astro-2 UIT data of the LMC in two projects:

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 first project is now complete (Parker *et al.* 1996). The intriguing results indicate that there may be a larger population of massive stars in the general LMC field than previously thought.

Work continues on the second project, which uses all the UIT images of the LMC. Point spread function photometry was performed for exposures of all the LMC fields, and photometry for overlapping regions is being combined to produce an overall catalog of UIT FUV photometry of stars in the LMC. The UV fluxes for these regions will be compared with the Hα fluxes of Kennicutt and Hodge for most of the DEM regions, and FUV luminosity functions will be presented and analyzed for differences within and without the DEM regions.

3.7 Galaxies and Extragalactic Astronomy

K. Borne (HSTX) and his colleagues at STScI, H. Bushouse, L. Colina, and R. Lucas, have continued an intensive *HST* imaging study of a nearly complete sample of 120 ultraluminous IR galaxies (ULIRGs) – identified by the IRAS mission in the 1980's as the most powerful galaxies in the universe. They have exploited the unique high-resolution imaging capability of *HST* with the WFPC2 to resolve the energy sources of the ULIRGs. It was found that nearly 100% of these are colliding and merging galaxies. ULIRGs are likely related to quasars because of their similarly disturbed appearance in *HST* images (mergers and collisions) and because of their similarly huge energy outputs (over $10^{12}L_{\odot}$). It has been suggested that ULIRGs may be the ''missing link'' in the evolution from quasars to normal, quiescent galaxies.

Borne and his colleagues have made numerous exciting discoveries from this survey:

1. In the majority of the galaxies, massive evidence for star formation is seen on all scales, including bright young star clusters of the type seen in many other *HST* studies of colliding and merging galaxies (e.g., the Antennae and NGC 7252). This evidence indicates that starbursts are the dominant power source for the majority of ULIRGs.
2. A star-like (Quasar-like) nucleus is seen in 10% of the ULIRGs, for which the dominant power source may be a dust-enshrouded active nucleus (massive black hole).
3. Several of the galaxies show clear evidence for a ring around the central nucleus, very similar to rings seen in *HST* images around the centers of other ''black hole''-powered galaxies (e.g., NGC 4261).
4. There is evidence for at least one classical collisional ring galaxy in the sample, similar to the Cartwheel ring galaxy imaged by the *HST* by K. Borne and his colleagues.
5. Some of the galaxies previously classified as non-interacting from ground-based images now show in high-resolution *HST* images clear evidence for a secondary nucleus (merger partner) or other evidence for interaction (e.g., tidal tails).
6. Many of the ULIRGs appear to have a significant number of small companion galaxies that are physically associated with the ULIRG. These companions may be related to the collision, merger, and subsequent burst of star formation.

Borne, L. Colina (STScI), and J. Lauroesch (Northwestern) have been studying the effects of galaxy collisions on the morphologies of the innermost regions of active galaxies. Archival *HST* images of active galaxies are being used to measure the degree to which tidal interactions may be responsible for inducing the nuclear activity. A control sample of similar, though ''quiet,'' galaxies from the *HST* Archive are being analyzed in the same manner for comparison with the active galaxy sample. This project was motivated by the fact that ground-based surveys of radio FR-I (Fanaroff-Riley type I) and FR-II host galaxies have shown that a majority of these galaxies are ellipticals that are strongly interacting with a close companion. This clearly suggests that there is a connection between the interactions and the nuclear radio activity. Borne and colleagues have analyzed *HST* images of 14 FR-I galaxies drawn from the De Juan, Colina, and Perez-

Fournon (1994) sample. All but four of these radio galaxies are found to have small dust-lanes, many of which were undetected at typical ground-based resolutions. Preliminary analyses of the images have revealed a number of additional morphological peculiarities within the cores of the galaxies, which are perhaps related to the tidal disturbances.

A. Danks (HSTX) collaborated with P. Francis and B. Woodgate, in observations of a cluster of galaxies at $z=2.38$ from the ground and with the *HST* instrument STIS. They characterize this population galaxies in the papers Francis *et al.* (1996, 1997a, 1997b).

Danks also contributed to a *HST* STIS study of the kinematics of the nuclear region of M84 (Bower *et al.* 1997).

Fanelli, Waller (HSTX) and D. Smith (GSFC/NRC) 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 stellar population producing the FUV light may represent a young galactic bulge, still in the process of formation.

Fanelli and Collins (HSTX) have compared the high-mass stellar population in the disks of the nearby Seyfert galaxies NGC 1068 and NGC 4151 using UV images from Astro-1/UIT. In NGC 1068 the starburst disk dominates the observed FUV luminosity while 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. Composite objects like NGC 1068, containing an active nucleus and a substantial young stellar population in close proximity, complicates interpretation of such systems at high redshift.

Fanelli is investigating the global FUV properties of the entire sample of disk galaxies observed by UIT during the Astro-1 and Astro-2 missions. Using spatially resolved light profiles and morphology to characterize the high-mass stellar populations in these systems, a variety of radial light profiles are found, with few objects showing distinct exponential declines. Often infections in the profiles are observed, associated with a prominent star-forming complex. Two systems, NGC 4214 and NGC 3310, exhibit $R^{1/4}$ profiles produced by their Population I stellar component. Initial results were presented at the Ultraviolet Universe Conference.

Fanelli and Stecher (GSFC) received *HST* Cycle 6 time to study the massive star populations in four nearby irregular/amorphous galaxies. The primary goals are 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.'' As of 1 Oct 97, 3 of 6 observations had been completed, consisting of WFPC2 images in 4 bands of NGC 5253, NGC 4214, and NGC 4449. Hundreds of sources are present in the images and reduction is continuing with support of a *HST* grant.

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 (GSFC), W. Freedman (OCIW) and Barry Madore (IPAC). This atlas contains images at far-UV, near-UV, Hα, and BVR bandpasses, surface brightness profiles, and tabulated photometry. 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. The UIT dataset provides the foundation for interpreting the morphology of galaxies observed at high redshift.

D. Smith (NRC/GSFC), in collaboration with S. Neff (GSFC), Fanelli, and Waller, has described 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 $R^{1/4}$ law 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 P. Marcum (TCU), D. Smith (NRC/GSFC), S. Neff (GSFC) have continued 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 Palomar Observatory in March 1997. 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 and Fanelli (HSTX), and D. Smith (GSFC/NRC) have combined FUV imagery from UIT and UBVRIJK images 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 $m_{FUV}\sim 10.3$ mag. 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. High resolution radio observations were obtained at 3.6 and 6 cm using the VLA which show a complex pattern of radio emission, well correlated with the FUV emission.

Fanelli, D. Smith, and S. Neff (NASA/GSFC) are investigating the age, luminosity and stellar content of starburst knots in the hybrid AGN/starburst galaxy NGC 1068. Using near-IR long-slit spectra, they detect spectral features indicative of red supergiants in a few knots, and a featureless continuum in others. The data suggests that star formation may have triggered by nuclear ejecta impacting gas concentrations in the inner disk.

Fanelli is consulting with S. Stewart (USNO) who is completing a dissertation on the FUV morphology and stellar populations of dwarf galaxies observed with UIT. The FUV surface brightness profile of the dwarf galaxy Holmberg 2 exhibits a central depression and two peaks in the surface brightness which are at higher levels than the central region. Comparison of the relative morphologies of the FUV and Hα emission frequently isolates FUV knots embedded in Hα shells. A comparison between the FUV light and neutral gas distribution suggests that none of the bright FUV knots is coincident with striking H I ‘‘holes’’ seen in VLA maps.

R. Arendt, H. Freudenreich, N. Odegard, and J. Weiland (HSTX) have completed work on the search for the cosmic infrared background emission using data from the *COBE* Diffuse Infrared Background Experiment (DIRBE) instrument. This work was 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 worked on characterization of the Galactic foreground, and Weiland and Freudenreich (HSTX), modelled the signal from the interplanetary dust. Arendt and Freudenreich carried out studies to determine the degree of isotropy in the residual emission after the interplanetary and Galactic foregrounds had been removed from the DIRBE data.

R.S. Hill (HSTX) continued his analysis of UIT ultraviolet imagery of the star-forming irregular galaxy NGC 4449. He is also collaborating with J.P. Gardner (LASP/GSFC), N. Collins (HSTX), and S.R. Heap (LASP/GSFC) on analyzing the STIS Parallel Survey, which is a pure-parallel, nonproprietary program of the STScI that uses STIS to obtain slitless spectra of random fields. In connection with the latter, he is analyzing some existing archival near-UV parallels from WFPC2. Hill is a co-Investigator on a STIS GO program on the UV morphology of galaxies.

N. Collins (HSTX) continued his collaboration with A. Smith (NASA/GSFC) on an study of star-forming regions in the edge-on disk galaxy NGC 4631. Fluxes of star-forming knots observed in ground-based optical images and far-UV data from UIT are compared to cluster models based on Kurucz stellar atmospheres and evolutionary tracks of Schaller *et al.* (1992). A preliminary analysis indicates that the observed knot fluxes are consistent with instantaneous burst models with ages between 4-6 million years. Continuous star formation model comparisons are also being investigated. Total cluster masses and star formation rates can be derived from the models and observed data. A poster paper will be presented at the 191st meeting of the AAS detailing these results. Collins and Smith also co-authored a paper on edge-on galaxies observed by UIT. They showed that rest-frame UV images of the edge-on galaxies are morphologically and photometrically similar to the high redshift ‘‘chain galaxies’’ observed in the B and I band by Cowie (1995).

Odenwald, together with Kashlinsky and Mather have developed a collaboration with the *WIRE* and 2-MASS programs to search for the clustered component of the cosmic infrared background based on techniques developed using the *COBE*/DIRBE database. With a 5-year NASA LTSA grant, they are completing their investigation using the *COBE*/DIRBE data. An ADP grant, awarded by NASA during 1997, will permit the extension of this study at 12 and 25 μm using *WIRE* data in collaboration with P. Hacking (IPAC) and H. Moseley (GSFC). Searches in the J, H and K-bands using data from the recently-commissioned 2-MASS project are also underway in collaboration with Dr. Mike Skrutsky (U. Mass.).

Cornett began work to obtain FUV images and photometry of the cluster Abell 2246, which lies in the field imaged most deeply by UIT. Preliminary results show five objects with angular sizes, FUV luminosities and colors appropriate for luminous galaxies at the distance ($z = 0.225$) of this cluster, identifying them as among the most distant and faintest galaxies yet imaged in the UV.

3.8 Cosmology

Kogut, G. Hinshaw (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, space-time can be described by the Friedmann-Robertson-Walker metric.

Kogut and N. Phillips (U. Maryland) used numerical simulations to study the energetics of cosmological models with textures. Unwinding textures are not mono-energetic but have a well-defined energy spectrum which can be used to simulate the anisotropy of the cosmic microwave background. A comparison with the *COBE*-DMR maps is underway.

Kogut and G. Hinshaw (GSFC) use numerical simulations to study the phenomenology of small-scale observations of the cosmic microwave background anisotropy and investigate how instrumental parameters (scan patterns, etc.) and non-cosmological signals propagate into CMB maps. Kogut continued investigation of fast algorithms for cosmological parameter extraction from mega-pixel maps.

Fixsen *et al.* (1997b) analyzed the cosmic microwave background (CMB) anisotropy data from the independent *COBE* FIRAS and DMR observations. They extracted the frequency spectrum of the FIRAS signal that has the spatial distribution seen by DMR and showed that it was consistent with CMB temperature fluctuations. Conversely, they formed a map of the Planckian component of the sky temperature from FIRAS and showed that it correlates with the DMR anisotropy map. The rms fluctuations at angular scales of 7 deg are $48 \pm 14 \mu$K for the FIRAS data versus $35 \pm 2 \mu$K for the DMR data and $31 \pm 6 \mu$K for the combination (1 σ uncertainties). The consistency of these data, from very different instruments with very different observing strategies, provides compelling support for the interpretation that the signal seen by DMR is, in fact, temperature anisotropy of cosmological origin. The data also limit rms fluctuations in the Compton y parameter, observable via the Sunyaev-Zeldovich effect, to $\Delta y < 3 \times 10^{-6}$ (95% CL) on 7 deg angular scales.

4. EDUCATION AND PUBLIC OUTREACH

HSTX and CASP are particularly proud of their extensive education and outreach programs. HSTX scientists and professional are strongly encouraged by HSTX management to participate in local and national volunteer programs. CASP scientists frequently give talks at local elementary schools, help to coordinated summer NASA/GSFC internship programs and judge local science fairs.

W. Taylor (HSTX) continues to direct the INSPIRE program which is an education outreach activity involving over 1100 schools nation-wide. Participating schools are equipped with radio receivers which they assemble from kits, so that they can listen to scheduled broadcasts from the Space Shuttle and the MIR Space Station.

S. Odenwald (HSTX) has been involved in education outreach activities for the Midex *IMAGE* satellite project with W. Taylor (*IMAGE* co-Investigator). These include the design and implementation of the POETRY (Public Outreach, Education, Teaching and Reaching Youth) web site

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

which has won several awards since its inception in April, 1997. A Middle School Teacher's Education Workshop was hosted by *IMAGE*/POETRY at GSFC in July 1997 to solicit suggestions for future education outreach projects for middle school science programs. *IMAGE*/POETRY includes ''Ask the Space Scientist'' (Odenwald) which receives and answers over 100 questions per week and now includes an archive of over 1400 'FAQs'. The POETRY web site is one of the most heavily used (about 100,000 hits/month) at GSFC among individual NASA missions with the exception of *HST*.

Odenwald has also written a book to be published by W.H. Freeman in March 1998 that highlights the 365 most popular questions about astronomy that were received at his publicly-supported ''Ask the Astronomer'' web site (3001 FAQs). This award-winning site, associated with the Astronomy Cafe

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

has also received support from the NASA/AAS Small Research Grants program for 1996 and 1997.

Brosius (HSTX) has written an educational booklet aimed at middle through high school students, and distributed it during classroom visits in which he discusses how astronomers use spectra to learn about the Sun and other stars (Brosius, 1997). Copies of the booklet were also given to the Teacher Resource Center at GSFC.

J. Allen (HSTX) and L. Whitlock (USRA) completely rewrote the StarChild WWW site, included interactive activities and added graphics

http://StarChild.gsfc.nasa.gov/

The site has since won several significant, content-based awards and averages about 150,000 accesses a month. J. Allen, working with L. Whitlock and J. Lochner (USRA), released StarChild and the High-Energy Astrophysics Learning Center on CD-ROM for free distribution to educators (April 1997).

D. Thompson (GSFC) and G. Rohrbach (HSTX) planned and, with the help of many GSFC, USRC and HSTX scientists and staff, executed a highly successful activity for Goddard's Take Our Daughters To Work Day (April 23, 1997). The activity included a scavenger hunt which was met with much enthusiasm by daughters and scientists alike!

J. Allen, M. Arida, J.A. Cliffe, T. Jaffe, and K. Smale (HSTX) along with L. Whitlock, J. Lochner and P. Boyd (USRA) represented the Laboratory for High Energy Astrophysics (LHEA) outreach at several education and scientific conferences, including the NSTA global summit (Dec. 1996) and annual assembly (April, 1997), the Violent Universe Conference (April, 1997), the National Teachers Training Institute meeting in Norfolk, VA (May, 1997), and the AAS meeting in Winston-Salem, NC (June, 1997).

K. Smale, G. Rohrbach, J.A.Cliffe, J. Allen and M. Bene (HSTX) collaborated with L. Whitlock (USRA) and educator K. Granger to design and produce a pair of astrophysics posters featuring the ''Life Cycles of Stars'' as well as accompanying Teacher's Guides with lesson plans, information and additional resources. Two posters and Teacher's Guides were created; one for high school students, one for elementary school students. This is the first educational poster produced by NASA aimed at the elementary level and has been well received by the education community in its first month of circulation.

M. Masetti (HSTX) worked with J. Lochner (USRA) and teacher B. Worth to develop outreach pages for the *RXTE* Learning Center that will give students and teachers direct access to the very latest data from the satellite's All-Sky Monitor (ASM).

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

M. Bene (HSTX) provided web support to completely switch on the order of a thousand pages of the High-Energy Astrophysics Learning Center web site to the new Imagine the Universe! format

http://imagine.gsfc.nasa.gov/

and programming support for StarChild activities.

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