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The following report covers CASP activities from 1 October 1999 through 30 September 2000.

## 1. INTRODUCTION

### 1.1 Company Background

Raytheon ITSS was founded in 1973 as Systems and Applied Sciences Corporation, and subsequently changed its name to STX. On October 1, 1991, STX was acquired by Hughes Aircraft Company and became Hughes STX Corporation headquartered in Lanham, Maryland. During 1997, the company was acquired by Raytheon as part of a merger between Hughes and Raytheon, and became Raytheon STX. During 1999, we became fully integrated into the Raytheon corporate structure and renamed Raytheon Information Technology and Scientific Services (RITSS).

Raytheon ITSS is a for profit corporation of more than 2,000 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.

RITSS offers on site professional support at locations such as NASA's 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, the National Environmental Satellite and Data Information Service, NASA's Ames Research Center, JPL and the National Science Foundation's South Pole Station.

This report focuses on RITSS science and computer support for a number of NASA's scientific programs at NASA's GSFC in Greenbelt, MD.

### 1.2 CASP

RITSS 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 RITSS, and is one of the RITSS centers of excellence,

CASP is made up of roughly 75 RITSS Astronomers and Space Scientists, primarily on site at GSFC. Its purpose is to provide RITSS scientists with a framework 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 produces a newsletter in which RITSS 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 RITSS to support company scientists while writing personal science proposals and to fund travel to scientific meetings and to cover publication costs, when no other sources are available. In addition, during this past year, CASP scientist Dieter Bilitza was awarded a RITSS/CASP sabbatical. Under this program, CASP scientists are awarded 50% support for six months by company funds to pursue their own scientific research.

CASP is a corporate affiliate of the Astronomical Society of the Pacific, primarily because RITSS supports the ASP's strong commitment to educational and public outreach. CASP member, K. Borne, is a member of the ASP Publications Committee.

### 1.3 Personnel

As of October 2000, Raytheon ITSS staff scientists with astronomy, solar physics or space physics related interests include: J. Allen, R. Arendt, E. Bell, D. Berdichevsky, D. Bilitza, J. Blackwell, S. Boardsen, K. Borne, L. Breedon, J. Brosius, L. Brown, R. Cebula, S. Chen, N. Collins, J. Cooper, R. Cornett, A. Danks, M. Deland, M. Dueterhaus, E. Einfalt, R. Fettig, D. Fixsen, M. Freed, 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, S. Kashlinsky, P. Keegstra, E. Kemper, C. Klipsch, A. Kutyrev, M. Kuznetsova, W. Landsman, P. Lawton, P. Leonard C. Lisse, E. Malumuth, D. Massa, L. Mayo, J. Mullins, T. Norton, N. Odegard, S. Odenwald, J. Offenbergl, L. Ofman, B. O'Neel, M. Peredo, B. Perry, E. Pier, T. Powers, L. Roberts, G. Rohrbach, G. Schneider, R. Schwartz, J. Silvis, K. Smale, J. Staguahn, A. Szabo, L. Tan, W. Taylor, B. Thomas K. Tolbert, M. Tripicco, N. Tsyganenko, P. Tyler, P. Uribe, F. Varosi, W. Waller, W. Warren, J. Weiland, D. Williams.

## 2. SPACE INSTRUMENTATION AND MISSION SUPPORT

Raytheon ITSS scientists and IT professionals provide support for the following projects.

**FUSE:** *FUSE* is a NASA-supported astronomy mission that was launched on June 24, 1999 to explore the Universe using the technique of high-resolution spectroscopy in the far-ultraviolet spectral region. The Johns Hopkins University has the lead role in developing and now operating the mission, in collaboration with The University of Colorado at Boulder,

The University of California at Berkeley, the Canadian Space Agency (CSA) the French Space Agency (CNES), and corporate sponsors. The spectral region opened up by *FUSE* allows astronomers to measure the cosmic abundance of deuterium (a primary constraint on cosmological models), molecular hydrogen (a fundamental constituent of the interstellar medium) and highly excited gas in the hot stars and galaxies which cannot be examined at other wavelengths. RITSS is involved with science support and software development for *FUSE*. More information about the *FUSE* satellite is available from:

<http://fuse.pha.jhu.edu/>

**GLAST:** The Gamma-ray Large Area Space Telescope (*GLAST*) is a proposed astrophysics mission to study the high-energy gamma-ray sky at energies between 10 MeV and 300 GeV. The primary instrument is a pair-conversion telescope based on solid-state particle-tracking technology. *GLAST* will be 30 times more sensitive than the Energetic Gamma Ray Experiment Telescope (EGRET) on board the *Compton Gamma Ray Observatory, CGRO*. *GLAST* is a two-year mission (with planning for five years) with an anticipated launch in 2005. Observing targets include 1) active galactic nuclei, 2) gamma-ray burst sources, 3) pulsars, 4) supernova remnants, 5) diffuse emission sources (including interstellar gas in our Galaxy, and the isotropic component which is probably extragalactic), 6) unidentified EGRET sources, and 7) solar flares.

*GLAST* is a collaboration of several institutions. GSFC scientists are deeply involved in the planning of the project and Raytheon ITSS scientists are assisting all levels of the effort including simulations of its astronomical performance.

More information about *GLAST*'s science objectives can be found at

<http://glast.gsfc.nasa.gov/>

**HEASARC:** The High Energy Astrophysics Science Archive and Research Center (HEASARC) supports a multi-mission archive facility in high energy astrophysics for scientists all over the world. Data from space-borne instruments on spacecraft, which include *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/>

**HESSI:** is the High Energy Solar Spectrometer-Imager (*HESSI*), a Small Explorer, or SmEx mission currently under development for a planned March 2001 launch. Using Fourier transform imaging and spectroscopy of solar X- and  $\gamma$ -radiation derived from observations through rotating grids, *HESSI* will provide uniquely high resolution spectral and image data of solar flares and related events. RITSS scientists support includes instrument characterization and testing, data system development, design and integration of the software system (being developed world-wide by the science team), and will include pipeline and analysis software and processing.

More information about *HESSI* is available from

<http://hesperia.gsfc.nasa.gov/hessi/>

**IMAGE:** is a MIDEX mission, was launched on March 25, 2000, to study the global response of the Earth's magneto-

sphere to changes in the solar wind. *IMAGE* will use neutral atom, ultraviolet, and radio imaging techniques to:

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

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

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

<http://image.gsfc.nasa.gov/>

RITSS scientists are involved with developing tools to reduce and interpret *IMAGE* data. This includes software to simulate the expected observations, models which will be used to interpret the physical processes *IMAGE* will observe and complex algorithms to reduce the raw data into a usable form.

The *IMAGE* Mission Team is also committed to a strong program of Public Outreach, and Education, and Raytheon ITSS scientists are also contributing to this aspect of the mission as well.

**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 the Spring of 2001 and will measure temperature differences ("anisotropy") in the cosmic microwave background radiation over the entire sky in bands from 22 to 90 GHz. RITSS support has included hardware specification and benchmarking, data system design, development, and integration, and pipeline and analysis software development, and instrument integration and test support.

For further information on *MAP*, see

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

**NGST:** *The Next Generation Space Telescope, NGST* is a mission currently under study by NASA as a follow on to the *Hubble Space Telescope, HST*. Its aims are to further our understanding of how the universe evolved following the Big Bang using capabilities unavailable in either existing ground-based or space telescopes. Simply put, its goal is to observe the first stars and galaxies in the Universe. Launch is scheduled for 2008, and the project has just completed its Phase A, or the conceptual development stage. Currently, RITSS scientists Cornett, Danks, Fixsen, Kuttyrev and Offenbergl are working with Lockheed Martin and GSFC scientists on several *NGST* studies. These include acting as an interface between Lockheed Martin and GSFC scientists in characterizing the *NGST* Integrated Science Instrument Module (ISIM) and studies of onboard computational capabilities. More information about *NGST* is available from

<http://ngst.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 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 *LI* Lagrangian point. Further information may be obtained at

<http://sohowwww.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 Center (ADC) and Space Physics Data Facility (SPDF)

The ADC acquires, verifies, formats, and distributes astronomical catalog data in computer-readable form. The ADC's archives contain more than 2500 catalogs and journal tables of astrometric, photometric, morphological, spectroscopic, polarization, kinematic, and multi-wavelength data for stellar and non-stellar objects. The ADC group also develops and maintains software tools to access these data. The ADC is part of an international federation of astronomical data centers. The capabilities of the ADF and ADC allow researchers to identify scientifically interesting objects and correlations, to carry out archival data-mining searches, to locate existing archival data on user-selected objects, and to prepare observing lists for further observational studies. The ADC can be accessed via

<http://adc.gsfc.nasa.gov/>

The ADC has also become a leader in the development of XML tools for astronomy. XML (eXtensible Markup Language) is an emerging standard for digital information markup. It allows information (data, metadata, documentation, resources of any kind) to be expressed in a structured, flexible, and easily parsible manner. XML allows for contents-based tagging of any information resource, and consequently it will allow for powerful, focused, and efficient contents-based search and retrieval of information. Such a system must be in place if wide spread, distributed data mining is ever to become a reality. More information and on XML can be obtained from the ADC page:

<http://tarantella.gsfc.nasa.gov/xml/>

The ADC has recently developed several new data visualization tools which can be accessed *via*

<http://tarantella.gsfc.nasa.gov/viewer/>

These include the ADC Catalog Viewer which enables the user to browse ADC catalogs and journal tables, AEQ (ADC External Query) which culls catalogs non-interactively, and IMPReSS, which enables the user to plot observation footprints and access multi-mission data.

The SPDF also part of the SSDOO and 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 and is now providing a unique combination of spectrographic and imaging capabilities in the UV and visible. In addition to

general science support, A. Danks (Raytheon ITSS) is a Co-Investigator on the STIS science team.

With the STIS now fully functional, RITSS support for STIS is peaking. RITSS astronomers: R.S. Hill, N.R. Collins, R.H. Cornett, R.J. Hill, W.B. Landsman and E.M. Malumuth are contributing to the scientific calibration and to the analysis and interpretation of the observations. Contributions by several RITSS STIS team members will be found throughout this report. Further information about STIS can be found at:

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

**TopHat:** the The Optimally Positioned Half-Degree Anisotropy Telescope. TopHat is an instrument that has been designed to collect data on the Cosmic Microwave Background Radiation. Its mission is to study light in the microwave and infrared wavelengths and will be flown at the South Pole during this year.

The TopHat experiment includes a spinning telescope and a detector system. It will map a 48 degree diameter disk of the sky above the Southern Polar Cap. To accomplish this, the telescope will simply spin at a constant rate about its vertical axis. As the Earth rotates, the entire polar cap will be observed each day.

RITSS astronomer D. Fixsen is involved in the design, construction and integration of the HopHat instrument. More information on TopHat can be found at:

<http://topweb.gsfc.nasa.gov/>

### 3. RESEARCH

#### 3.1 Instrumentation and Data Processing

E. Shaya (RITSS) continued as PI of a NASA funded research project applying XML to ADC data center activities. Working with B. Thomas, J. Gass, B. Holmes, J. Blackwell, and G. Schneider (all of RITSS), the entire ADC repository was converted to XML and issues of query methods and informational display were studied. A pipeline was setup to extract bibliographic and tabled data from articles published at the UC Press and convert them from SGML to ADC's XML language (dataset.dtd). In addition, a general XML format for containing scientific data was developed, the eXtensible Data Format (XDF). Additional elements were added to XDF specifically to hold FITS keywords by the creation of yet another language FITSML.dtd.

K. Borne (RITSS) has carried out a number of "proof-of-concept" archival projects that are directly applicable to the new National Virtual Observatory (NVO) initiative. He has reviewed the science requirements for specific scientific user scenarios that would benefit from an NVO. He has also participated in community forums on this subject. In one such archival project, Borne explored several on-line databases (at the ADC, at the HEASARC, at NED/IPAC, and at STScI/MAST) to estimate the galaxy interaction fraction within a newly published catalog of galaxies (the "Updated Zwicky Catalog" (Falco *et al.* 1999, PASP, 111, 438). It was estimated from these multi-archive cross-mission archives that the galaxy interaction rate in the local universe is approximately 8%.

D. Fixsen (RITSS) and R. Arendt (RITSS) continued their work with H. Moseley (GSFC) to develop a self-calibration

algorithm for the Infrared Array Camera (IRAC) imaging array to fly on *Space Infrared Telescope Facility*, *SIRTF*. For testing purposes, they applied the current code to the *HST* NICMOS observations of the Hubble Deep Fields (both North and South) with encouraging results (Fixsen *et al.* 2000). They also developed optimal observing strategies to perform the self-calibrations (Arendt *et al.* 2000).

D. Fixsen and J. Offenbergl (RITSS) along with J.D. Hanisch (STScI), R.J. Mather (GSFC) and others developed an algorithm to optimally process uniformly sampled array image data obtained with a non-destructive readout. The algorithm discards full wells, removes cosmic-ray (particle) hits and other glitches, and makes a nearly optimum estimate of the signal on each pixel. The algorithm also compresses the data. The computer requirements are modest, and the results are robust. The results are shown and compared to results of Fowler-sampled and -processed data. Non-ideal detector performance may require some additional code, but this is not expected to cost much processing time. Known types of detector faults were addressed.

E. Malumuth (RITSS) devised a model of the fringing in the *HST* Space Telescope Imaging Spectrograph (STIS) CCD slitless spectra mode based on known and fitted properties of the STIS CCD. The model allows a user to form a calibration “fringe flat” for any object in a slitless spectra. Using the model improves the fringing by a factor of about 5. R. Hill (RITSS) planned a set of STIS calibration observations to analyze reflection ghosts on its CCD window. He also explored the behavior of STIS CCD hot pixels and different rejection schemes.

D. Massa (RITSS) continued his work with the *FUSE* science team. Their work on the calibration of the *FUSE* spectrograph and the development of the *FUSE* science data pipeline software is detailed in Sahnou *et al.* (2000). Massa also collaborated with E. Fitzpatrick (U. Villanova) on enhancing the accuracy of *IUE* data. They showed that the low-dispersion *IUE* New Spectroscopic Image Processing System (NEWSIPS) data contain serious systematic effects which compromise their utility for certain applications. They demonstrated that NEWSIPS low-resolution data are internally consistent to only 10%-15% at best and that the NEWSIPS flux calibration is inconsistent by nearly 10%. They formulated and applied algorithms to correct these effects to the  $\sim 3\%$  level – a factor of 5 improvement in accuracy. Finally, they placed the *IUE* data onto *HST* FOS system (Massa & Fitzpatrick 2000).

J. Staguhn (RITSS) continued his work within the BIMA group at the (U. Md.) on water vapor radiometry in order to improve the phase coherence for mm wave interferometers. Working with A. Eckart and E. Schinnerer (U. Md.) on high resolution observations of a nearby QSO, they were able to image a kiloparsec molecular ring in the rotational ground state transition of CO for the first time.

W. Warren (RITSS), in collaboration with C.B. Sande (CSC), and D.A. Tracewell (GSFC), completed Version 3 of the SKY2000 Master Star Catalog, the source catalog for NASA satellite acquisition and attitude determination. One-dimensional spectral types and photovisual and photographic magnitudes, which serve as consistency checks for more

modern data, were completely replaced in a consistent way. Numerous individual corrections, mostly for multiple stars, were made.also

### 3.2 Space Physics

N. Tsyganenko (RITSS) investigated the magnetic field response of the Earth’s magnetospheric tail to the dynamical pressure of the solar wind, the interplanetary magnetic field (IMF), and the Dst-field observed at the ground. His study covered a wide interval of distances between 10 and 60 earth radii and was based on multi-year sets of magnetometer and plasma instrument data from *Geotail*, *AMPTE/IRM*, *ISEE-2*, *IMP 8*, and *Wind* spacecraft. The goal of this work was to find an optimal set of input variables for parameterizing the cross-tail electric current in the data-based magnetosphere models. A search was made for the best combination of the solar wind pressure and IMF related quantities, providing the highest multiple correlation coefficient  $R$  between the predicted and observed tail lobe field. In the near magnetotail, a very good fit ( $R=0.967$ ) was obtained using a simple four-parameter regression relation, and the largest contribution was found to come from the pressure-related term (Tsyganenko, 2000a). In the same study, time lag effects were investigated by using the data from one-hour “trails” of the solar wind parameters, accompanying each tail lobe data record. In the inner magnetotail, the contribution from the pressure dependent term was found to increase with growing time lag, suggesting a significant average delay between the changes of the solar wind pressure and the reaction of the lobe field. At larger distances, the tail field was found to respond with much shorter delays, which implied a greater role of directly-driven processes there.

N. Tsyganenko also developed a quantitative model of the inner magnetospheric magnetic field, which combined the asymmetric ring current with field-aligned currents, generated owing to the azimuthal variation of the plasma pressure. The model ring current and associated Birkeland currents were derived from average radial profiles of particle pressure and anisotropy, observed by *AMPTE/CCE* spacecraft, and their fields were represented by expansions, fitted by least squares to the field, obtained using the Biot-Savart integral. The goal of this work was to devise a realistic and computationally efficient description of the asymmetric ring current, to be included in an advanced model of the external geomagnetic field (Tsyganenko, 2000d).

D. Bilitza (RITSS) was the recipient of a half-year sabbatical research leave from Raytheon ITSS. During the sabbatical he developed a model for the electron density in the topside ionosphere based on a large data base of topside sounder data from the *Alouette* and *ISIS* satellites (Bilitza & Williamson, 2000). D. Bilitza organized and chaired a session on “Modeling the Topside Ionosphere and Plasmasphere” during the COSPAR General Assembly in Warsaw, Poland. Collaboration continued with a team at the International Center for Theoretical Physics (ICTP) in Trieste, Italy on improvements of the electron density model in the International Reference Ionosphere (IRI) (Bilitza *et al.* 2000) and with a team at the Polytechnical University in Barcelona, Spain on using GPS data to updated the IRI model. Version

2000 of the IRI model was prepared following the decisions made at the Warsaw meeting (Bilitza, 2000).

### 3.3 Solar Physics

L. Ofman (RITSS) collaborated with J.M. Davila (GSFC) on two-fluid two-dimensional magnetohydrodynamic (MHD) models of the solar wind. The models show that Alfvén wave motion may explain the broad Ly- $\alpha$  lines observed in coronal holes by the SOHO Ultraviolet Coronagraph Spectrometer (UVCS). Ofman also collaborated with V.M. Nakariakov (U. Warwick), E. DeLuca (Harvard CfA), B. Roberts (St. Andrews U.), and J.M. Davila on the analysis of the *Transition Region and Coronal Explorer*, (*TRACE*) Observation of coronal loop oscillations excited by a solar flare. The team used the damped loop oscillations to estimate the dissipation coefficient in the corona, and found that the coefficient is many orders of magnitude larger than the classical value. Ofman, Nakariakov, and T.D. Arber (St. Andrews) performed a nonlinear study of dissipative spherical Alfvén waves in solar coronal holes. They found that the wave dissipation is dramatically increased by the nonlinear transfer of energy to smaller scales. Ofman also collaborated with V.M. Nakariakov and N. Sehgal (Yale) on an investigation of the dissipation of slow magnetosonic waves in coronal plumes. They investigated the parametric dependence of the wave properties, and found that the nonlinear steepening of the waves leads to enhanced dissipation owing to compressive viscosity at the wave fronts. Ofman also investigated the Source Regions of the Slow Solar Wind in Coronal Streamers by performing three-fluid 2.5D MHD simulations of the solar wind. Using the model he found that the enhancement of the oxygen line emission occurs due to the enhanced abundances of  $O^{5+}$  ions in the legs of streamer caused by the Coulomb friction with the outflowing protons.

L. Ofman collaborated with A. Viñas (GSFC), and S.P. Gary (Los Alamos) to investigate the constraints on the  $O^{5+}$  anisotropy in the solar corona. They performed hybrid simulations of the solar wind plasma and found that the high  $O^{5+}$  anisotropy leads to the ion-cyclotron instability and consequently, the ion anisotropy will decrease. The instability constrains the value of the anisotropy that can be sustained in the solar wind plasma. He also collaborated with M. Romoli (U. Florence), G. Poletto (Arcetri) G. Nocci (U. Florence), and J.L. Kohl (CfA) on the observations and the interpretation of compressional waves in solar coronal holes. The detection of compressional waves in coronal holes has important implications on theories of fast solar wind acceleration and heating. Finally, Ofman contributed to the study of the magnetic cloud of October 18-20, 1995 by M. Collier (GSFC) and his group. Several interesting phenomena that were observed in the cloud indicate that reconnection of the clouds' magnetic field took place near the Sun.

J. Brosius (RITSS) continued his collaboration with N. Gopalswamy (Catholic U.) and E. Landi (NRL) to derive 3-dimensional coronal magnetograms from coordinated SERTS-97, CDS, EIT, VLA, and SXT observations of NOAA region 8108. This method yields measurements of coronal magnetic fields that can be compared with extrapolations from photospheric magnetograms. In collaboration

with S. White (U. Md.) and Peter Gallagher (BBSO/NJIT), new coordinated observations (including also OVRO and *TRACE*) were obtained during an observing campaign in July 2000.

Brosius, R. Thomas, J. Davila (both GSFC), and W. Thompson (Emergent) used coordinated SERTS-99 and CDS observations from the 24 June 1999 sounding rocket flight to derive a preliminary calibration correction curve for the CDS Normal Incidence Spectrometer's NIS-1 waveband. This is especially important owing to CDS calibration variations due to loss of control of *SOHO* during the summer and fall of 1998. A similar CDS calibration correction based upon coordinated SERTS and CDS observations acquired 18 November 1997 was derived, verified, and incorporated into the CDS calibration software. Brosius, Thomas, Davila, and Thompson also used SERTS-97 spectra of NOAA region 8108 to find relative blueshifts in the southern portion of the active region, with relative redshifts in the north (Brosius *et al.* 2000b). Brosius, Thomas, Davila, and Landi used an average spectrum of NOAA region 8108 from SERTS-97 to find a number of Fe xv emission lines not previously seen in solar EUV spectra (Brosius *et al.* 2000a). In addition, they measured nonthermal line widths of  $35 \text{ km s}^{-1}$  for all available ionization stages of iron from x through xvi (and Ni xviii), derived mutually consistent electron densities using several different line intensity ratios, and derived the DEM using the iterative method of Landi and Landini (1997).

Brosius also participated in the Max Millennium Observing Campaign during March 2000. He began analysis of EUV flare observations obtained with CDS in search of evidence for particle beams during a solar flare. A beam of nonthermal alpha particles would manifest itself through an enhancement in the red wing of the He II line at  $303.78 \text{ \AA}$ , without a corresponding blue wing enhancement.

R. Schwartz (RITSS) continues to develop imaging and spectroscopic analysis software in preparation for the launch of *High Energy Solar Spectroscopic Imager (HESSI)* in March 2001. He is working in collaboration with the *HESSI* science team, PI R. Lin, J. McTiernan, D. Smith, A. Csillaghy, and G. Hurford (U. Cal.), B. Dennis, D. Zarro, and E. Schmahl (GSFC), and A. Zehnder and M. Fivian (Paul Scherrer Inst.). Schwartz also continues his collaborations with Gerard Trotter and Ludwig Klein (Paris Obs., Meudon) with two papers in preparation.

M. DeLand and R. Cebula (RITSS) continued their analysis of the *Nimbus-7* SBUV solar UV spectral irradiance data set. The original version of the data set, archived in 1988, contained significant long-term calibration errors in the later portion of the 8-year record (November 1978 to October 1986). Later work by Schlesinger and Cebula in 1992 greatly improved the instrument characterization, but did not produce a publicly available data set. Recent work by DeLand and Cebula focused on three areas. An improved correction for long-term wavelength scale drift was derived from observations of solar absorption lines. Refinements were made to the instrument sensitivity change correction to reduce errors in the final two years of the *Nimbus-7* data record. An anomalous periodic variation affecting only short wavelength data was characterized empirically, but no correction

was applied to the final data set. The *Nimbus-7* SBUV solar irradiance data have been reprocessed with all available instrument characterization corrections. These data can be obtained electronically as daily spectra binned to 10Å intervals over the wavelength range 1700-4000Å. This format is consistent with irradiance products from the SME, NOAA-11 SBUV/2, UARS SUSIM, and UARS SOLSTICE instruments. Comparisons with overlapping SME data during 1982-1986 show similar representations of short-term and long-term solar UV variability during solar cycle 21. Separate comparisons with NOAA-11 SBUV/2 data indicate that solar cycles 21 and 22 had similar magnitudes and long-term behavior in UV irradiance, but demonstrated differences in short-term and medium-term variations. A complete discussion of this work has recently been submitted for publication.

### 3.4 Planetary Physics

J.F. Cooper (Raytheon ITSS) continued collaborations with C.M.S. Cohen (Caltech), R.E. Johnson (Univ. of VA), B.H. Mauk (APL/JHU), H.B. Garrett (JPL), N. Gehrels (GSFC) and others on analysis and modeling of energetic particle data from the *Galileo* Orbiter spacecraft's continuing five year tour of the Jovian satellite system and the magnetosphere. The work with Cohen and Gehrels uses high energy trapped ion data for oxygen and sulfur from the Heavy Ion Counter (HIC) instrument in the vicinity of the Galilean satellite Io. The objectives for Io are to use data from the observed ion-satellite interactions to constrain the ionic charge states of the ions and the magnetic models for the Io interaction with the Jovian magnetosphere. Several conference presentations and one published article (Cohen *et al.* 2000) have resulted from this work. Another objective has been to use medium energy ion and electron data from the Energetic Particle Detector (EPD) instrument on the *Galileo* Orbiter to model the irradiation of the four Galilean satellite surfaces by magnetospheric particles. The outer three satellites (Europa, Ganymede, and Callisto) were the subject of other conference presentations and of a lengthy article (Cooper *et al.* 2000) on the irradiation effects. A particularly interesting result is the specification of yields for production of oxidants (O<sub>2</sub>, H<sub>2</sub>O<sub>2</sub>) on the surface of Europa; these oxidants and other irradiation products provide resources for potential evolution of biological life forms in the putative ocean below the European ice crust.

M. Freed (RITSS) continued her research with R. Oliverson (GSFC) and F. Scherb (U. Wisc.) on the time variability of [O I] 6300Å emission from Io and the Io plasma torus interaction. This work included development of a database that contains information on the over 2000 spectra collected from 1990-1999 and is intended for public release in the near future. Results based on the data presently analyzed indicate that Io can be used as a probe to study the three-dimensional structure of the Io Plasma Torus.

C.M. Lisse, together with D. Christian (STScI), J. Truemper, K. Dennerl, J. Englhauser, M. Desch, F.E. Marshall, R. Petre, S. Snowden (GSFC), obtained the first *Chandra* ACIS-BI images and low-resolution X-ray spectra of a comet, C/LINEAR 1999 S4, in July 2000. Line emission from charge exchange between solar wind minor ions and

cometary gaseous species was successfully detected during a solar flare, as well images of the emission structure with unprecedented detail. An extended series of *EUVE* observations (PI Lisse) was also carried out, in order to obtain photometry at energies (20 - 300 eV) below the cutoff of *Chandra*, and to allow us to compare the new comet to our *EUVE*/*ROSAT* X-ray photometry database of 15 comets. A related program, the *FUSE* Comet Study of H. Weaver, in collaboration with C.M. Lisse and D. Christian (STScI), will be obtaining the first *FUSE* high resolution far-EUV spectrum of comet C/McNaught-Hartley 1999 T1 in late 2000. The goal of this program is to determine the presence or absence of far-EUV line emission from charge exchange between solar wind minor ions and cometary gaseous species. Analysis of this database to date has determined the following about this new phenomenon: the X-ray emission is confined to the cometary coma between the nucleus and the Sun in a region 10<sup>5</sup> - 10<sup>6</sup> km in extent, it is not correlated with extended dust or plasma tails, nor is it correlated in time with the solar X-ray flux or solar wind flux; the spectrum of the emission is very soft  $E < 0.70$  keV, with pronounced lines at 650 eV due to charge exchange onto O VI; roughly 25% of the time comets show luminosity outbursts correlated with increases in solar wind density and solar wind magnetic field; and all comets within 2 AU of the Sun and brighter than  $V \sim 12$  mag have been detected in the X-ray. The last comet to be observed by *ROSAT*, 55P/Tempel-Tuttle, showed typical X-ray behavior over the longest temporal baseline to date, January 15 - Feb 5, 1998 (Lisse *et al.* 2000). Comparison of the outburst times of the 4 brightest comets shows that a simple latitude-independent model of the solar wind sector boundaries correlates better than the more complicated, currently accepted potential field model of Hoeksema *et al.* (1983) applied to photospheric magnetic field observations made at the Wilcox Solar Observatory.

Lisse also participated in an archival study of *ROSAT* and *EUVE* X-ray lightcurves of C/Hyakutake 1996 B2. Using the *SOHO* solar wind record, they demonstrated a strong correlation between the solar wind flux and the X-ray flux, with large, frequent outbursts which Neugebauer, Lisse, *et al.* (2000) suggest is due to compositional variations in the solar wind. A comparison of the observed X-ray spectra and morphology to that derived for Ne XI/Ne X in an electron beam trap (Biersdorfer, Lisse, & Olson 2000) suggests a reworking of the theoretical assumptions used in previous models of charge exchange emission, as well as the possibility of using the spectra to diagnose the density and CM velocity of the solar wind in cometary comae.

C.M. Lisse, in collaboration with Y. Fernandez and M.F. A'Hearn (U. Md.) and S.B. Peschke and E. Gruen (MPIE), continued a campaign of simultaneous optical and infrared (0.4 - 20.0 μm) observations of cometary dust and nuclei, observing 3-5 comets per year. Fourteen comets have been observed with signal-to-noise ratios (S/N) large enough to allow detailed modeling of the emitted dust, and 7 comets with high enough S/N and contrast between the nucleus and coma (i.e., either nearby comets or low activity comets) to obtain good estimates of the thermal emission from the nucleus alone and hence the nuclear size. Results so far in-

clude the detection of thermal infrared emission from the nuclei of comets C/Hyakutake 1996 B1, 2P/Encke 1997, 55P/Tempel-Tuttle, 9P/Tempel 1 and C/LINEAR 1999 S4 (Fernandez *et al.* 1999), the probable detection of infrared emission from the nucleus of comet C/Hale-Bopp (Fernandez *et al.* 2000), and an analysis of the comets detected by *COBE* as compared to the IRAS comet database (Lisse *et al.* 2000). We have demonstrated the unusual nature of comet Hyakutake, concerning its anomalously large activity and near breakup rotation rate (Lisse *et al.* 1999). 40% of our survey comets have Halley-like dust emission, dominated by small particles easily detected in the optical, while the remaining 60% of comets emit the majority of their dust mass in large, dark grains. These very large grains are the origin of cometary dust trails, and are copious enough to supply the interplanetary dust cloud. The two different classes of comets found in our survey are also found in 60 comets reported to have been observed in the infrared in the literature. The differences in emission behavior trend with cometary type and age, suggesting evolutionary effects, although definitive determination of this explanation awaits a much larger statistical database. A paper entitled detailing our findings was presented at IAU 181 in Canterbury, England in April 2000, and has been submitted for publication.

C.M. Lisse has been serving on the science staff of the Deep Impact Discovery mission project. The goal of this mission is to impact comet 9P/Tempel 1 with a 500 kg mass of copper at a relative velocity of approximately  $10 \text{ m s}^{-1}$ , thereby digging a deep crater in the comet which will expose pristine material. Observations of this crater by a flyby spacecraft will allow determination of the sub-surface structure and composition of the cometary nucleus. Lisse also continued his work year modeling the expected impactor targeting sensitivity of comets, given that the nucleus of the comet is embedded in a bright dust/gas coma; estimating the dust impact hazard for the impactor and flyby spacecraft, allowing design and implementation of the spacecraft ACS and protective “Whipple” dust shield; and contributions at the DI Cratering Workshop (Feb 2000) to the initial draft of the MSSR. Current work includes the photometric reduction and analysis of measurements of the dust and nucleus of the comet using the Keck/LWS camera combination.

### 3.5 Stars and Stellar Clusters

W. Landsman (RITSS) continued his study of hot stars in globular clusters. Together with S. Moehler (Bamberg) and B. Dorman (RITSS) he analyzed optical spectroscopy of hot stars in the globular clusters 47 Tuc and NGC 362 (Moehler *et al.* 2000a), and concluded that clusters with primarily red horizontal branches can still contain genuine hot horizontal branch stars. In collaboration with Moehler and U. Heber (Bamberg) and A. Sweigart (STScI), Landsman continued his study of radiative levitation in hot horizontal branch stars in the globular cluster NGC 6752. They conclude that radiative levitation of iron can explain most – but not all – of the long-standing discrepancy between theoretical and observed gravities in hot horizontal branch stars (Moehler *et al.*

2000b). Landsman also continued his work with J. Goebel (NASA’s Ames) analyzing ISO spectra of oxygen-rich AGB stars.

D. Massa (RITSS) continued his work on hot stars and their winds with A. Fullerton (JHU) and the *FUSE* Science team. In Bianchi *et al.* (2000), they analyze and contrast the wind lines of two O7 supergiants – one in the LMC and one in the SMC (Sk – 67° 111 and AV 232, respectively). Model fits to the S IV, S VI, P IV, P V, N III, and N IV wind lines provide the first direct measurement of the ionization balance in O star winds. In Crowther *et al.* (2000), they analyze a combination of *FUSE* and *HST* spectra of Sand 2, an LMC WO-type WR star. Together with Mount Stromlo 2.3 meter optical spectra these data were analyzed using a spherical, non-LTE, line-blanketed stellar atmosphere code. Their study revealed exceptional stellar parameters:  $T_{eff} \sim 150,000 \text{ K}$ ,  $v_{\infty} = 4100 \text{ km s}^{-1}$ ,  $\log(L/L_{\odot}) = 5.3$ , and  $\dot{M} = 1 \times 10^{-5} M_{\odot} \text{ yr}^{-1}$ , for a volume filling factor of 10%. In Fullerton *et al.* (2000), they compared the stellar wind features in far-UV spectra of Sk–67° 111, an O7 Ib(f) star in the LMC, with Sk 80, an O7 Iaf+ star in the SMC. The most striking differences are that Sk 80 has a substantially lower terminal velocity, much weaker O VI absorption, and stronger S VI emission. They used line-blanketed, hydrodynamic, non-LTE atmospheric models to explore the origin of these differences. The far-UV spectra require systematically lower stellar temperatures than previous determinations for O7 supergiants derived from plane-parallel, hydrostatic models of photospheric line profiles. At these temperatures, the O VI in Sk – 67° 111 must be due primarily to shocks in the wind. Finally, Massa *et al.* (2000) examined time resolved *FUSE* spectra for three Magellanic Cloud O stars (Sk 80, Sk – 67° 05, and Sk – 67° 111). Their observations revealed wind variability in all of the program stars and distinctive differences in the ionization structure and timescales of the variability. Sk – 67° 111 demonstrated significant wind variability on a timescale less than 10 hr, and the coolest O star had the largest variations in O VI.

D. Massa and E.L. Fitzpatrick (U. Villanova) described a new approach to fitting the UV-to-optical spectra of B stars to model atmospheres and presented initial results (Fitzpatrick & Massa 1999a). Using lightly reddened stars, they demonstrate that excellent fits can be obtained to combined low-dispersion UV and optical photometry as long as the following they used: 1) an extended grid of models; 2) recalibrated *IUE* NEWSIPS data; 3) and all of the model parameters and the effects of interstellar extinction were solved for simultaneously. In that case, the temperatures, gravities, abundances, and microturbulence velocities of B0-A0 V stars were determined to high precision. They also showed the same procedures can be used to fit the energy distributions of reddened stars and that UV extinction curves can be simultaneously derived. They verified their approach through comparisons with angular diameter measurements and the parameters derived for an eclipsing B-star binary. We also found that a near zero microturbulence velocity provides the best fit to all but the hottest or most luminous stars (where it may become a surrogate for atmospheric expansion). They have applied the same approach to the A stars (Fitzpatrick &

Massa 1999b) and to the analysis of an eclipsing binary in the LMC (Fitzpatrick *et al.* 2000). In this case, the analysis provides a precise means of measuring the distance to the LMC.

Massa also continued his work on Cepheids with N. Evans (CfA). Most recently, they used new velocities of the long-period Cepheid T Mon from the ground and velocities of its hot companion obtained with the *HST* and *IUE* to determine a preliminary orbit and derive the orbital parameters of the system and their uncertainties (Evans *et al.* 1999). The velocities for the companion appear to be inconsistent with binary orbital motion, and it is likely that the companion is itself a binary in a short-period orbit. The *HST* spectrum of the companion shows that it is a chemically peculiar star, probably magnetic.

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

### 3.6 Nebulae, Interstellar Medium and Galactic Structure

D. Fixsen (RITSS), C.L. Bennet (GSFC) and J.C. Mather (GSFC) analyzed the *COBE* Far Infrared Absolute Spectrophotometer (FIRAS) observations over the wavelength range from 100  $\mu\text{m}$  to 1 cm covering 99% of the sky. Using an improved FIRAS calibration, they improved the signal-to-noise ratio of the spectral lines by a factor of 2 over previous results. They observed the CO chain from  $J=1-0$  to  $J=8-7$  toward the Galactic center. The line ratios were roughly consistent with a 40 K excitation temperature. The 157.7  $\mu\text{m}$  C II and 205.3  $\mu\text{m}$  N II lines were seen over most of the sky. The 370.4 and 609.1  $\mu\text{m}$  lines of C I and the 121.9  $\mu\text{m}$  line of N II were observed in the Galactic plane. The line ratios at the Galactic center are consistent with a density of  $n_0 \sim 30 \text{ cm}^{-3}$  and a UV flux of  $G_0 \sim 15 \mu\text{W m}^{-2} \text{ sr}^{-1}$ . The 269  $\mu\text{m}$  H<sub>2</sub>O line is observed toward the Galactic center in absorption.

T. Danks and G. Vieira and W. Landsman (all RITSS) collaborated with N. Walborn (STScI) to use *HST* STIS spectroscopy to study temporal changes in interstellar lines observed toward the Carina nebula. These observations (Danks *et al.* 2000) are among the first to show temporal variations in a dominant interstellar ion. Danks (Danks 2000) also analyzed observations of the Vela SNR in the ISM species Ca II and Na I. These data were presented and discussed in the context of the “break-down” of the Spitzer-Routly effect. Variations in the line profiles with time are demonstrated, and eventually a thorough statistical approach and description of cloud structure will be possible. The interstellar lines in approximately 70 sightlines are used to determine an accurate distance to the Vela SNR of  $250 \pm 30$  pc. Finally a discussion of future observations was given relating information obtained from measurements of near-by interstellar medium to the more distant intergalactic medium.

### 3.7 Galaxies and Extragalactic Astronomy

K. Borne (RITSS) and his colleagues continued their studies of Ultra-Luminous Infrared Galaxies (ULIRGs). In the past year, they have expanded their studies beyond the *HST* imaging surveys to include multi-fiber integral-field spectroscopy for several ULIRGs in their imaging sample. In each case, unusual spectroscopic properties were seen, particularly in off-nuclear regions. L. Colina (CSIC-UC, Spain), S. Arribas (now at STScI), and Borne published the results for 3 ULIRGs this past year. In every case, they found multiple line emission sources, frequently in regions detached from the cores of the galaxies or from any other region that is luminous in continuum light. These line-emitting regions have spectral characteristics of H II regions, LINERS, or AGN. In some cases, these line-emitting clouds may be simply reflecting the emission from a dust-obscured nuclear source. In the case of Mrk 273, they found a LINER nucleus and an extended off-nucleus Seyfert 2 nebula. In the case of IRAS 12112+0305, they found that the observed ionized gas distribution is decoupled from the stellar main body of the galaxy, with the dominant continuum and emission-line regions separated by projected distances of up to 7.5 kpc. The two optical nuclei are detected as faint emission-line regions, and their optical properties are consistent with being dust-enshrouded weak O I LINERS. In the case of IRAS 08572+3915, they found no evidence for a LINER or Seyfert-like nucleus in either of the galaxies, contrary to previous claims. This is unusual for a warm ULIRG such as IRAS 08572+3915. Tidal-induced star-forming knots, approximately 7kpc from the nuclei and along the tidal tails, are traced by the presence of bright [O III] emission.

Borne, H. Bushouse (STScI), Colina, and R. Lucas (STScI) also completed several papers on their *HST* imaging survey. One of the major results was the discovery that at least 20% (and probably much more) of the ULIRGs show evidence for multiple (two or more) merger events. These ULIRGs may be dynamical descendants of compact groups of galaxies. Borne, Bushouse, Colina, and Lucas also analyzed the morphological characteristics of their ULIRG sample to deduce that nearly 99% of all ULIRGs show signs of tidal interaction or recent merger activity. This result was based on more than 120 ULIRGs, by far the largest sample studied to date, to address this interaction frequency question. In the past, many values for the interaction rate of ULIRGs have been published, ranging from 30% to 100%, but none of those results were based on a sample of this size and quality. High *HST* imaging resolution images were required to identify close companions, short tidal tails, and other interaction signatures that were previously undetectable in ground-based imaging.

Borne and D. Patton (U. Toronto) worked on a new *HST* imaging survey of moderate-redshift galaxy pairs that have been selected on the basis of close proximity in space and redshift. These “kinematic pairs” are therefore nearly certain to be physical pairs. Their *HST* images are being used to estimate the more general galaxy interaction rate at intermediate redshifts ( $z=0.1-0.5$ ). In many cases, strong signs of interaction and morphological disturbances have been noted in the *HST* images. Detailed comparisons between these

high-quality single-passband (I-band) *HST* images and multi-color ground-based images are now underway, which will provide some insight into tidally induced star formation in such pairs at intermediate redshifts and which will be applicable to interpretations of the Butcher-Oemler effect in clusters of galaxies at similar redshifts.

M. Freed (RITSS) began work with a group led by S. Heap (GSFC) in quantifying the UV morphology of galaxies at  $z \approx 0.1 - 0.22$ . STIS data were used to obtain FUV and optical imagery of the 56 galaxies, from 13 different groups. The ability of several morphological parameters to distinguish between different types of galaxies was investigated. These parameters were then used to compare the FUV and optical morphologies of each galaxy.

R. Hill, E. Malumuth, N. Collins (all RITSS) and H. Teplitz (NOAO and GSFC) authored a paper on galaxy photometric redshifts and correlation functions in a 0.6 square degree field surrounding the HDF South, as observed with the Big Throughput Camera at CTIO.

E. Malumuth, B. Hill (both RITSS), J. Gardner (GSFC), E. Smith (GSFC), and S. Heap (GSFC) have been investigating the Far-UV morphological and spectral energy distribution properties of galaxies in 3C groups of galaxies at redshifts of about 0.1-0.2. Over 50 galaxies in 20 fields have been observed with the STIS FUV-mama and CCD.

E. Malumuth and others have investigated the utility of using a prism as part of a multi-object spectrograph aboard *NGST* to obtain "photometric redshifts" of large numbers of galaxies. The low resolution prism out performs a series of filters and a camera for the same purpose in almost all circumstances. Malumuth was also involved in a study to investigate the spatial distribution of galaxies in a wide field centered on the Hubble Deep Field South field. They used multi-band photometry to estimate the redshift of about 20000 galaxies and compared the spatial distribution in different redshift bands to models of the distribution.

E. Shaya continued his research collaboration with P.J.E. Peebles (Princeton) and R.B. Tully (U. Hawaii) to develop numerical action methods to calculate the trajectories and masses of nearby galaxies from their positions and peculiar velocities. This technique has consistently given values of the matter density of  $\Omega_0 \sim 0.2$ , for more than a decade. The group recently invented and began to use a new technique that simultaneously accounts for both the redshift and distance uncertainties in the orbit calculations.

### 3.8 Cosmology

A. Kashlinsky and S. Odenwald (both RITSS) completed their earlier work in collaboration with J. Mather (GSFC) on the analysis of COBE DIRBE IR sky maps. They discovered fluctuations in the cosmic infrared background (CIB) which not only confirms the existence of structure in the CIB, but implies that such a background exists. The work resulted in detections of the CIB anisotropies between 1 and 5  $\mu\text{m}$  and in significant upper limits between 10 and 100  $\mu\text{m}$  (Kashlinsky & Odenwald 2000).

Kashlinsky continued this line of work in collaboration with Odenwald, J. Mather and M. Skrutskie (U. Mass.) with

2MASS data, probing the structure of the CIB on smaller angular scales. A related activity is the review on the CIB A. Kashlinsky is writing for Physics Reports.

Kashlinsky collaborated with F. Atrio-Barandela (U. Salamanca, Spain) to develop a new method for measuring cosmological bulk flows via the kinematic Sunyaev-Zeldovich effect. This will be done by combining X-ray data on clusters of galaxies with the upcoming maps of the cosmic microwave background radiation (CMB). The results are very promising: cosmological bulk flows of the magnitude which has recently been measured would be detected very accurately by this method from the upcoming *MAP* and *Planck* data.

Dale Fixsen (RITSS) and the MSAM collaboration obtained new cosmic microwave background (CMB) anisotropy results from the combined analysis of three flights of the Medium Scale Anisotropy Measurement (MSAM1) balloon-borne bolometric instrument. They measured about 10 deg<sup>2</sup> of sky at half-degree resolution in four frequency bands from 5.2 to 20 cm<sup>-1</sup> with a high signal-to-noise ratio. They presented an overview of their analysis methods, and derived new constraints on the CMB power spectrum (Wilson et al, 2000).

### 4. EDUCATION AND PUBLIC OUTREACH

Brosius (RITSS) mentored G. Isa, a public school science resource teacher from the District of Columbia, during her summer 2000 visit to GSFC as part of the SUNBEAMS (Students United with NASA Becoming Enthusiastic About Math and Science) program. He helped develop lesson plans, participated in Parents' Night activities, and interacted with students visiting GSFC. He also spoke with several groups of teachers who visited GSFC.

During 2000, S. Odenwald (RITSS) has been actively involved with the *IMAGE* satellite program. The *IMAGE* satellite launched on March 25 from Vandenberg Air Force Base. He has presented teacher training workshops on magnetospheric research at the National Science Teacher Convention and the National Council of Teachers of Mathematics convention. He continues to manage the Education and Public Outreach program of the *IMAGE* mission. He has developed new education products for the NASA, Sun-Earth Connection Education Forum including a lithograph set detailing the basic science, and various web site products for SECEF. Dr. Odenwald was awarded the AAS/Solar Physics Division "Popular Science Writing Award" for his Washington Post article on Space Weather. His book "The 23-rd Cycle: Learning to live with a stormy star" will be published by Columbia University Press in December, and featured at the American Geophysical Union's Fall convention in San Francisco on December 16. His Previous book, "The Astronomy Cafe" has been translated into Japanese and is now available. Meanwhile, his web site

[www.theastronomycafe.net](http://www.theastronomycafe.net)

continues to attract over 200,000 visitors per year. Dr. Odenwald is currently completing the manuscript for a new book "Patterns in the Void: Why nothing is important" which will be published in early 2002. He continues to be a speaker with the Shapley Lecture Series.

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