Challenger Center for Space Science Education
Department of Space Science Research

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This report addresses scientific and science-education research efforts conducted within the Department of Space Science Research of Challenger Center for Space Science Education in Alexandria, Virginia. Education and public outreach programs of the Department also are described. The period covered by this report is November 1, 2001 through October 31, 2002.

1. FOREWORD

Challenger Center for Space Science Education is a global not-for-profit organization created in 1986 by the families of the crew of the space shuttle *Challenger*, STS 51-L, to carry out the science and mathematics education mission of that flight. Challenger Center's most visible activity in pursuit of this goal is the network of Challenger Learning Centers (forty-six at writing) in the United States, Canada, and the United Kingdom, in which student crews man a simulated mission-control center and a simulated spacecraft to experience an adventure in collaborative learning about space flight and the space environment. Challenger Center is responsible for a range of classroom products, and for education and public outreach programs of national scope, including *Journey through the Universe*, space flight mission-related E&PO services (presently supporting the MESSENGER mission to Mercury), an International Faculty of space science educators, and teacher-training programs. Challenger Center is the lead organization (with the Smithsonian Institution and NASA) in the *Voyage* scale-model solar system exhibition on the National Mall in Washington, DC, and is responsible for supporting replication of the model at other participating sites.

The Department of Space Science Research (SSR) was created within Challenger Center in 1998 to make a home for practicing scientists engaged in active scholarly research who also have the desire to contribute to public knowledge and understanding of science. Challenger Center staff scientists are engaged in observational and theoretical astronomical and Earth science investigations using ground- and space-based facilities, working on-site, in the field, and also with collaborators at Goddard Space Flight Center, the Space Telescope Science Institute, the University of Virginia, the University of Illinois, the University of Haifa, Universitat Politécnica de Catalunya, Universitat de Barcelona, ISO Data Centre, Instituto Astrofí sica de Canarias, Universitat zu Köln, and the University of Nanjing. SSR staff are responsible for ensuring the highest level of scientific accuracy in all Challenger Center products. SSR members are actively engaged in education and public outreach activities through: collaboration in the preparation and production of curricular materials; leading educator workshops; visiting classrooms; and presenting Family Science Night programs.

2. PERSONNEL

2.1 Present Staff

The professional staff of the Department of Space Science Research, and their research interests, consists of

Jeffrey J. (Jeff) Goldstein, Vice President for Space Science Research (Ph.D. University of Pennsylvania, 1989) — *Planetary atmospheric dynamics and structure; infrared heterodyne spectroscopy.*

Matthew (Matt) Bobrowsky, Staff Researcher, Astrophysics (Ph.D. University of Maryland, College Park, 1985) — *Formation and early evolution of (proto-) planetary nebulae, late stages of stellar evolution, solar radio astronomy, gravitational influence of solar system bodies on spacecraft orbits.*

Agnes Pasco Conaty, Staff Researcher, Environmental Science (Ph.D. University of the Philippines, 1999) — *Space-based remote-sensing of terrestrial oceanic water quality and properties.*

Timothy A. (Tim) Livengood, Staff Researcher, Astrophysics (Ph.D. The Johns Hopkins University, 1992) — *Composition and structure of planetary atmospheres, planetary aurorae, infrared and ultraviolet remote-sensing of planetary systems.*

Mary L. Radnofsky, Staff Researcher, Education and Human Development (Ph.D. Vanderbilt University, 1992) — *Education in space sciences, interdisciplinary curriculum design, Socratic teaching strategies, and program evaluation.*

Harri A. T. Vanhala, Staff Researcher, Astrophysics (Ph.D. University of Oulu, 1997) — *Stellar and planetary formation processes.*

SSR staff also include personnel with specific responsibilities to support education and public outreach programs of the department.

2.2 Changes in 2002

The Department of Space Science Research has experienced significant growth in the past year. Total department staff now number thirteen, six more than at the end of October 2001. Two members of the professional staff joined the department in 2002 and one member has departed:

Agnes P. Conaty came from Caelum Research Corporation, working at NASA's Goddard Space Flight Center with Josefino Comiso.

Harri A. T. Vanhala came from Arizona State University, where he held a post-doctoral position working with Sumner Starrfield.

Jean-Marc Perelmuter left the department.

3. FACILITIES

Challenger Center owns and occupies a building at Pitt Street Centre in Alexandria, Virginia. The Department of Space Science Research resides on the third floor. On-site

facilities include the Challenger Learning Center of Greater Washington and the EdVenture Lab, a prototype ''smart-classroom'' facility with multimedia capabilities for colloquia and other presentations. Additional space is available for future expansion and for possible optics laboratory facilities.

4. RESEARCH ACTIVITIES

4.1 Planetary Atmospheres

T. A. Livengood investigates chemical abundances, thermal profiles, and dynamics in planetary atmospheres, in collaboration with Th. Kostiuk and colleagues at NASA's Goddard Space Flight Center (GSFC), using GSFC's Heterodyne Instrument for Planetary Winds and Composition (HIPWAC). Livengood reported at the 2001 AAS Division for Planetary Sciences meeting on observations of nonthermal emission by CO_2 in the upper atmosphere of Mars; at the 2002 DPS meeting on prospects for the detection of ethane emission from the stratosphere of Uranus; and at the 2002 AMOS Technical Conference on the utility of IR heterodyne spectroscopy in investigations of planetary atmospheres. Livengood contributed to a presentation by A. Kutepov at the 2002 European Geophysical Society (EGS) meeting on the possibility of Earth-orbit observations of terrestrial non-LTE mesospheric emissions measured by a space-borne IR heterodyne spectrometer. This is a new direction being considered for research with IR heterodyne spectroscopy.

A collaboration has been started between Livengood, H. B. Hammel (Space Science Institute), and GSFC colleagues to measure the abundance of ethane in the stratosphere of Uranus as a possible probe of seasonal dependence in hydrocarbon photochemistry and as a marker of wind velocity in the upper atmosphere measured by the Doppler shift of ethane lines. Continuing research projects include nonthermal infrared emission of CO_2 in the atmosphere of Mars, thermal emission from Saturn's rings, hydrocarbon abundance and thermal profile in the atmosphere of Titan, and horizontal distribution of composition and thermal profile in the atmospheres of Jupiter and Saturn.

J. Goldstein is collaborating with F. Schmülling (First Physical Institute, Universitat zu Köln) in the study of atmospheric dynamics on Venus and the subsolar-to-antisolar flow. Livengood and Goldstein together are collaborating with Th. Kostiuk in improvements to the retrieved wind direction of the bulk zonal flow on Titan, pursuing advanced measurements of the stratospheric ethane Doppler shift using 8–10m-class telescopes with HIPWAC.

T. A. Livengood's research effort is supported by a Cooperative Agreement between Challenger Center and Goddard Space Flight Center. J. Goldstein's research effort is supported by Challenger Center operating funds.

4.2 Star Formation

H. A. T. Vanhala is investigating the hypothesis of the triggered origin of the solar system — the idea that the formation of the solar system was initiated when an interstellar shock wave propagating from a nearby explosive stellar event impacted on a molecular cloud core from which the solar system was formed. This research has been conducted in collaboration with A. P. Boss (Carnegie Institution of Washington). An appreciable fraction of radioactive isotopes carried by the shock wave could have been injected into the forming solar system, in this manner leaving a record of the event in meteoritic material. Calculations reveal that the distribution of radioactive species in the early solar system could have been spatially or temporally heterogeneous.

4.3 Late Stages of Stellar Evolution and Planetary Nebulae

M. Bobrowsky has pursued his interest in the formation of planetary nebulae by observational investigations of proto-planetary nebulae. He, in collaboration with A. Riera, P. Garcí a-Lario, A. Manchado, and R. Estalella, investigated the proto-planetary nebula Hen 3−1475, finding that it shows a remarkable highly collimated optical jet with an S-shaped string of shock-excited knots. Moreover, extremely high velocities have been observed in the innermost regions of its jet. In an effort headed by A. Riera, a detailed analysis of the kinematic structure and the excitation conditions in the shock-excited knots based on ground-based high dispersion spectroscopy and high angular resolution images obtained with the HST WFPC2 instrument has been presented. Similarities between the jet of Hen 3−1475 and the HH jets have been investigated. Both exhibit double-peaked and extremely wide profiles, a decrease of the radial velocities with distance to the source in a step-like fashion, and high tangential velocities. The overall picture of Hen 3−1475 supports the description of the system as the result of time-dependent ejection velocity variability. An investigation headed by M. Meixner modeled HD 161796, a Star-Obvious Low-level-Elongated (SOLE) proto-planetary nebula, and IRAS 17150−3224, a DUst-Prominent Longitudinally-EXtended (DUPLEX) proto-planetary nebula. The physical parameters derived for HD 161796 and IRAS 17150−3224 demonstrate that they are physically quite different and that their observed differences cannot be attributed to inclination angle effects. Both HD 161796 and IRAS 17150−3224 are viewed nearly edge-on. However, the more intensive superwind mass loss experienced by IRAS 17150−3224, 2.8×10^{-3} $M_\odot$ yr^{-1} and an $\dot{M}_{equator}/\dot{M}_{pole} = 160$, has created a high optical depth dust torus (A_V=35) which obscures its central star. In contrast, HD161796; which underwent a lower rate superwind, $\dot{M}=3.9\times10^{-5}$ $M_\odot$ yr^{-1} and an $\dot{M}_{equator}/\dot{M}_{pole} = 9$; has an optically thinner dust shell which allows the penetration of direct star light. If these calculations reflect a more general truth about SOLE vs. DUPLEX PPNe, then these two subgroups of PPN are physically distinct.

H. A. T. Vanhala, with S. G. Starrfield (Arizona State University) and W. R. Hix (University of Tennessee / Oak Ridge National Laboratory), has continued the development of a numerical simulation code to investigate classical nova outbursts. Calculations carried out with the code are expected to answer open questions about thermonuclear runaways in the accreted hydrogen rich envelope on the white

dwarf component of a close binary system, the source of classical nova outbursts.

4.4 Environmental Science

A. Conaty is collaborating with L. Hilliard and other scientists at the Goddard Space Flight Center Laboratory for Hydrospheric Processes to develop a process for fitting Earth remote-sensing data to a 1 km-spacing grid defined by the L-Band brightness temperature and backscatter parameters for natural storage media such as soil moisture, sea surface salinity, and thin sea ice. The resulting Co-registered Land, Ice Melt, BackScatter/Brightness Extracting Total Hydrology (CLIMBETH) tool will be applied to look at all three phases of water. The initial testbed will be the RadSTAR airborne L-Band platform. CLIMBETH also can be the testbed for linking GPS backscatter data to RadSTAR data. Eventually, CLIMBETH will be applicable to a variety of data sets.

4.5 Science Education and Outcome Evaluation

M. Radnofsky's research focuses on evaluating the educational efficacy of interdisciplinary education programs centered on science and integrating other academic as well as non-academic classroom subjects, using both qualitative and quantitative instruments to evaluate outcome. Radnofsky and M. Bobrowsky are collaborating on the development of a handbook to facilitate sky-observing nights in elementary schools, so as to better convey astronomical concepts to young children. Radnofsky's current work with The Socrates Institute includes the design of an e-book that allows the reader to pursue individual interests in different disciplines related to the book's themes, through an integrated encyclopedia covering each of the traditional school subjects. Radnofsky also is working with the University of Nanjing on the creation of a new professional development curriculum for university professors and classroom teachers in China.

5. EDUCATION AND PUBLIC OUTREACH INITIATIVES OF SSR

The Department of Space Science Research is the lead department at Challenger Center in several education and public outreach (E&PO) efforts of local and of national scope.

5.1 *Journey through the Universe*

The *Journey through the Universe* (JttU) program was renamed from *Window on the Universe* in mid-2002. Five ''*Journey* Weeks'' were held since October 2001, in: Montgomery/Tuskegee, Alabama; Nogales, Arizona; Marquette, Michigan; Labette County, Kansas; and culminating in this reporting year with Washington, DC in October 2002. A total of 25,458 students were contacted directly by 43 different scientists in classroom visits (including SSR staff and volunteer Visiting Researchers); teacher workshops were held in each *Journey* Week, preparing 773 teachers to use Challenger Center curricular materials; and 6,588 students, teachers, and family members attended 8 Family Science Night events to experience a family field trip to the frontier of space exploration. The new educational module ''*Voyage*: a Journey Through Our Solar System'' was completed and used for the Spring *Journey* Weeks. A special compendium of Earth science curriculum materials was completed for the 2002 Washington, DC *Journey* Week. Challenger Center materials have been adopted to constitute the DCPS Earth and Space Science curriculum for the 6th grade. All *Journey* education module components are developed consistent with the National Science Education Standards; in Washington, DC, the annual compendia have been developed tied to the DCPS content and performance standards.

The national *Journey through the Universe* program is supported by grants from NASA Headquarters' Minority University Research and Education Division and by NASA's Offices of Space Science, Space Flight, and Earth Science. The Washington, DC *Journey* effort is supported by donations from Lockheed-Martin Corporation, from the National Space Club, from Sodexho Corporation, and from Trinity College. J. Goldstein is the PI of the *Journey through the Universe* program.

5.2 *Voyage*: A Journey Through Our Solar System

The *Voyage* scale model of the solar system opened on the National Mall in October 2001 (just before the current reporting period) as a partnership with the Smithsonian Institution and with NASA, led by Challenger Center. Curricular materials supporting *Voyage* are nearing completion at the end of the reporting period. A subset of these curricular materials was adopted into the JttU education module ''*Voyage*: a Journey Through Our Solar System,'' distributed in Spring, 2002.

The creation of the *Voyage* scale model and supporting materials was supported by grants from NASA Headquarters' Office of Space Science and Education Division. J. Goldstein is the PI of the *Voyage* program.

5.3 MESSENGER Education and Public Outreach

Challenger Center is responsible for a large fraction of materials development and public presentations for the MESSENGER mission to Mercury's E&PO component. An announcement of opportunity is being prepared for a MESSENGER Fellowship program to be disseminated in January 2003, to be followed by a workshop for selected Fellows in June 2003. SSR members Vanhala and Radnofsky have been leading the development of grade 5–12 curricular materials for the first MESSENGER education module due to be completed in 2003; this module will be disseminated at Fellowship workshops and in JttU programs. Members of the MESSENGER engineering team have participated as consultants in materials development and as visiting researchers in *Journey* Weeks, including the October 2002 Washington, DC *Journey* Week.

Challenger Center's participation in MESSENGER E&PO programs is supported by a contract from the Carnegie Institution of Washington.

5.4 Family Science Night at the National Air and Space Museum

Challenger Center conducts a regular series of Family Science Nights in the Lockheed-Martin IMAX theater of the National Air and Space Museum, for schools within the Washington, DC metropolitan area. This program is independent of Family Science Night events within the *Journey through the Universe* program. The FSN program consists of an after-hours tour of the central Milestones of Flight Gallery, a half-hour talk on a space science theme by a Challenger Center or volunteer scientist, and showing of an IMAX film on a related theme.

The FSN program at the National Air and Space Museum is funded by the National Space Club.

5.5 Educator Professional Development

In the past year, the Department has collaborated for the first time with the Challenger Learning Center of Greater Washington to conduct professional development workshops and to run simulated space flight missions for teachers in the Washington, DC metropolitan area, offering continuing education credits as officially granted by the school district.

PUBLICATIONS

The publication list includes all refereed papers published between November 1, 2001 and October 31, 2002 by SSR staff.

Livengood, T. A., T. Hewagama, T. Kostiuk, K. E. Fast and **J. J. Goldstein**, 2002, ''Improved Determination of Ethane (C_2H_6) Abundance in Titan's Stratosphere,'' Icarus, 157, 249–253.

Fast, K., T. Kostiuk, P. Romani, F. Espenak, T. Hewagama, A. Betz, R. Boreiko and **T. Livengood**, 2002, ''Temporal Behavior of Stratospheric Ammonia Abundance and Temperature Following the SL9 Impacts,'' Icarus 156, 485–497.

Meixner, M., T. Ueta, **M. Bobrowsky** and A. Speck, 2002, ''Two Subclasses of Proto-Planetary Nebulae: Model Calculations,'' Astrophys. J. 571, 936–946.

Riera, A., P. Garcí a-Lario, A. Manchado, **M. Bobrowsky** and R. Estalella, 2002, ''New Observations of the High-Velocity Outflows of the Proto-Planetary Nebula Hen 3-1475, Emission Lines from Jet Flows,'' Revista Mexicana de Astronomma y Astrofmsica, 13, 127–132.

Vanhala, H. A. T. and A. P. Boss, 2002, ''Injection of Radioactivities into the Forming Solar System,'' Astrophys. J. 575, 1144-1150.

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