

Florida Institute of Technology
Department of Physics and Space Sciences
Melbourne, Florida 32901-6988

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The following report covers the Department activities from 1 November 1995 to 31 October 1997. Additional information about Florida Tech, the Department and its activities can be found on our homepage at: <http://pss.fit.edu>.

1. PERSONNEL

J. Patterson serves as Department Head, which reports to the Dean of the College of Science and Liberal Arts, G. Nelson. Faculty with instructional and research activities in areas related to Astronomy and/or Space Sciences include Professors J. Blatt, T. Oswalt and J. Patterson; Associate Professors R. Jin, H. Rassoul and M. Wood; Assistant Professors J. Mantovani, M. Moldwin, R. Raffaele; Adjunct Instructors Dwayne Free, J. Simpson and J.A. Smith. Graduate students in Space Sciences (or in Physics and pursuing astrophysical research projects) during this report period include T. Ahrens, B. Bailey, M. Bentley, J. Bocchicchio, R. David, M. Fillingham, M. Kaplan, P. Martin, R. McDaniel, M. Montgomery-Bobertz, N. O'Dosey, M. Putnam, W. Roberts, S. Shufelt, N. Silvestri, J.A. Smith, Asif Ud-Doula and J. Wernow. Full time post-doctoral research staff during this period included O. Giovaninni, Jr., G. Sellar and J. Simpson.

2. ACADEMIC PROGRAMS

The Department offers complete bachelors, masters and doctoral programs in Space Sciences as well as Physics. In 1994 a bachelor's program in Astronomy/Astrophysics was created. Currently, the enrollment in Space Sciences and Astronomy / Astrophysics includes 42 undergraduates and 7 graduate students; of the latter, 3 are in the doctoral track and 1 (Smith) will complete the Ph.D. in Space Sciences in 1997. Enrollments in Physics include 11 undergraduates and 7 graduate students, including 2 in the doctoral track.

3. FACILITIES AND EQUIPMENT

The Department has guaranteed access to 30% of the observing time at the Southeastern Association for Research in Astronomy (SARA) 0.92-m telescope at Kitt Peak National Observatory. Plans are underway to construct an instructional observatory on the main campus.

Florida Tech is the Administrative Institution of SARA, a consortium of the Florida Institute of Technology, East Tennessee State University, University of Georgia, Valdosta State University and Florida International University. Since its dedication in January 1995, the SARA 0.9-m telescope has been in regular use at its new site on Kitt Peak. The SARA telescope has a fully computerized telescope and observatory control system, clocks, weather sensors, four port instrument selector and dome controller. Instrumentation includes a two-channel photo-polarimeter and a 4x4K Axiom/Apogee grade-zero CCD imaging system.

In spring 1995 SARA initiated a Research Experiences for Undergraduates internship program funded by the NSF.

The SARA REU program is the first multi-site internship program in Astronomy and is now one of the largest such programs in the U.S.

Florida Tech is a member of the Upper Atmospheric Research Collaboratory (UARC), a consortium of universities that utilize the Upper Atmospheric Research Facility in Greenland to study the dynamics of the Earth's ionosphere.

Florida Tech also is a founding member of the Florida Space Institute. FSI is a consortium of institutions interested in Space Science education and research. It is made up of Florida Tech, University of Central Florida, Embry-Riddle Aeronautical University, Brevard County Community College, NASA Kennedy Space Center, Cape Canaveral Air Station, and the Boeing Corporation. The FSI conducts "hands-on" undergraduate classes at KSC and CCAS and operates a clean room facility for student-built payload integration and testing.

The Geospace Physics Laboratory has been developed to help coordinate the space and atmospheric research efforts of the department and university. The GPL currently has 12 students active in research activities and provides office space, computational facilities, and lab space for instrument development.

The Department currently supports four Sun SparcStations, a NextStation and a large number of Macs and PCs, almost all of which are linked to the Internet. The University provides a well-equipped machine shop and electronic repair facility, as well as laboratory space at the Applied Research Laboratory off-campus.

4. RESEARCH

4.1 Astronomy and Astrophysics

Oswalt, Smith, and Wood continued an NSF- and NASA-sponsored a study of wide binaries known to have white dwarf (WD) components. The sample includes over 1000 binaries and is one of the deepest surveys of its type. The project's current goal is to derive a high precision luminosity function for WD components which can be used to set important independent constraints on the age of the Galactic disk and the Universe. The results help resolve the current discrepancy between ages derived from globular clusters isochrone fits and observational determinations of the Hubble constant. The observed WD luminosity functions derived are being fit to new theoretical models computed by Wood (1995). Preliminary results, using a carefully chosen completeness-corrected sample of 50 WDs indicate that the age since star formation commenced in the solar neighborhood is ~ 10 Gyr (Oswalt, *et al.* 1996).

Accounting for the time span between the Big Bang and the formation of the Galaxy and any delay between the onset of star formation in the halo and the local disk, Oswalt and collaborators derived a firm minimum age of ~ 12 Gyr for the Universe. New estimates for the age of the Universe,

based on recent revisions to the extra-Galactic distance scale and ages of old globular clusters are now within 1σ of the age derived from the WDLF. Also, the integrated WDLF suggests that stellar remnants in the Solar neighborhood constitute no more than a few percent of the dark matter in the Galaxy. A review of this project was recently presented at the IAU General Assembly in Kyoto, Japan (Oswalt *et al.* 1997)

Under Oswalt's advisement, Smith completed work on a dissertation project in 1997 to determine a definitive WD luminosity function from a much larger sample than was available to Oswalt *et al.* (1996). This work confirmed and substantially improved the precision of the age determination of the Galactic disk. BVRI and JHK data for nearly 250 WDs was collected with telescopes at Cerro Tololo, Kitt Peak, Mauna Kea, McDonald, and SARA. Smith's work will also provide a sequence of faint infrared stellar standards for use with large aperture telescopes. He is now a post-doctoral fellow at the University of Michigan.

Oswalt and Silvestri are studying the kinematics of wide binary sample, based on observations made with the 4.0-m telescopes at Kitt Peak and Cerro Tololo. In a collaboration with N. Reid (Caltech) this work has been extended to the fainter wide binaries using the Keck 10-m telescope. Using the main sequence companions as radial velocity benchmarks, Silvestri (1997) has used this sample to measure nearly 100 gravitational redshift masses for WD components.

During this reporting period T. Ahrens, C. Breglia, C. D'Aubigny, M. Kaplan, D. Marshall, A. Morrill and R. Sirbaugh participated as undergraduate research assistants in the wide binary project. Most of these students participated in observing runs at Kitt Peak and/or Cerro Tololo and presented the results of their research, which directly contributed to the determination of the WD luminosity function, at AAS meetings. Ahrens, Marshall and Sirbaugh were SARA REU summer interns from University of Wisconsin, Colgate University and Middle Tennessee State University, respectively. Ahrens is now a graduate student at Florida Tech and, with Oswalt, is helping to prepare an atlas of ~ 1200 wide binary spectra for publication.

Wood, funded by NSF and the NASA Astrophysics Theory Program, continued his research studying white dwarf evolution, and the use of these numerical model results to explore the age and star-formation history of the local Galactic disk. He has been updating the constitutive physics in the evolutionary models, and has been working with Oswalt on a new determination of the age of the local Galaxy (Oswalt *et al.* 1996). Wood and Oswalt (1997) recently completed a preliminary Monte Carlo study of the kinematics and luminosity function of white dwarf stars, and Wood (1997) presented an invited review at *Joint Discussion 10: Low Luminosity Stars* of the 23rd IAU General Assembly, held August, 1997, in Kyoto, Japan.

Wood and collaborators M. Bolte (UC/Lick Obs.) and C. Claver (NOAO) have observed the old open cluster M67 with the Keck telescope searching for the complete white dwarf cooling track. The cumulative luminosity function of these stars will provide an age estimate for M67 which is

essentially independent of uncertainties in main-sequence evolutionary calculations. The white dwarf age will be compared with the age obtained through isochrone fits, thus cross-calibrating the two techniques. Wood and graduate student Thomas J. Ahrens are reducing and analyzing the data independently as part of Ahrens' Masters thesis project. Wood and a large team of US and Canadian astronomers are using the Hubble Space Telescope to observe white dwarfs in the open cluster NGC 188 and the globular cluster M4 (Richer *et al.* 1997) using the Hubble Space Telescope. The latter observations should help resolve the problem of the age conflict between Hubble expansion ages within the standard inflationary cosmology ($t_0 \approx 8-10$ Gyr) and the main-sequence turnoff ages of the oldest globular clusters ($t_{GC} \approx 12$ Gyr).

Wood and postdoc James C. Simpson are continuing their simulations of the accretion disk dynamics in cataclysmic variable (CV) systems using the method of smoothed particle hydrodynamics (SPH). Simpson and Wood (1997) recently completed a study of the superhump instabilities in low-mass-ratio CVs. They found that the viscous energy dissipation time series of the purely hydrodynamic accretion disk simulations display remarkable similarities with the observed light curves of dwarf novae superhumps in general, and the AM CVn subclass of dwarf novae specifically. The amplitudes and relative phases of the harmonics in the power spectrum during both the superhump growth phase and when the resonance is saturated agree well with the observations. The morphology of the mean pulse profile at saturation appears to be a useful predictor of system mass ratio.

In a follow-on study mentored by Wood and Simpson during the summer of 1997, SARA REU student Christopher J. Burke (Yale) explored the aspect dependency of the pseudo-lightcurves obtained from the SPH simulations. Burke, Wood, and Simpson (1998) and Simpson, Wood, and Burke (1998) found that the "observed" harmonic structure is a function of system inclination, offering the tantalizing promise that we may be able to place constraints on the system inclination of superhumping systems from the harmonic structure alone. In a related project, Wood and Burke participated in the Summer 1997 campaign of the Whole Earth Telescope on the old nova DQ Hercules. DQ Her is a high-inclination ($i \approx 89^\circ$) CV that shows a 71-s photometric periodicity resulting from accretion onto a rapidly rotating magnetic white dwarf. Wood, Burke, Simpson, *et al.* (1998) modeled the structure of the accretion disk in a preliminary attempt to understand the phase variations in the O-C diagram. The variations repeat from orbit to orbit, and must result from variations in the disk height and radius which are stationary in the frame rotating at the binary period. During the 1996 summer SARA REU program, student Nathan A. Miller (Gustavus Adolphus College), Simpson, and Wood (1997) visualized the dynamics of CVs using IBM Data Explorer.

Wood continues his collaboration with the Whole Earth Telescope (WET) network of observers, and uses the SARA Observatory as a node in the network. See the publications section for papers.

4.2 Planetary and Space Physics

Jin has focused his research primarily on the multi-year stochastic inversion of magnetic observatory annual mean data and the analysis of the geomagnetic reversal records. The objective of the analysis of the magnetic observatory data is to improve the prediction of the secular variation of the geomagnetic field while the study of the magnetic reversal records is to ascertain whether the process is a deterministic chaos or a random process.

Moldwin and Rassoul are active in a variety of atmospheric and magnetospheric plasma physics topics including: (1) the structure and dynamics of the Earth's plasmasphere; (2) propagation of ULF waves within the Earth's magnetosphere, and (3) observing upper atmospheric lightning from space and the ground.

The first project is supported by a NASA Space Research and Technology grant and Los Alamos National Laboratory's Space and Atmospheric Sciences Group. It involves analysis of a suite of geosynchronous and geosynchronous-transfer orbit satellites to study the behavior of the low-energy plasma environment. Several undergraduate and graduate students are currently participating in this research.

The second project is supported by a NSF CAREER award and involves developing a meridional ground array of 5 closely spaced pairs of magnetometers from Florida to Canada. The data will be used to better understand the mechanism by which magnetic wave energy propagates throughout the magnetospheric system. The project is being developed in collaboration with the University of California-Los Angeles, Boston University, Newcastle University in Australia, the Johns Hopkins University's Applied Physics Lab, the US Geological Survey and the Canadian Geological Survey.

The third project is being supported by a Research Corporation Cottrell Scholar Award, the Florida Space Grant Consortium, and the Florida Space Institute and involves developing a student built payload to be flown on the space shuttle. The Radio, Optical, Gamma ray, Undergraduate Experiment (ROGUE) project will look for the correlation of Sprites with lightning activity, terrestrial gamma ray bursts, and radio noise. Also, a collaboration with NASA Kennedy Space Center's Lightning Detection and Ranging Facility helps to understand upward propagating lightning phenomena in terms of well studied tropospheric lightning processes.

4.3 Space Sciences

Jin and Rassoul have set up a new experiment in remote sensing for Senior Laboratory in which students are to receive weather pictures from the polar orbiting weather satellites and the geostationary weather satellites.

Patterson has an on-going program funded by NASA and Universities Space Research Association (USRA) on the electron properties of narrow gap semiconductors. Assisting in this work is Mantovani. Patterson and Li have done an extensive set of deep defect calculations on Mercury Cadmium Telluride (MCT) and Mercury Zinc Telluride (MZT). Presently the research is focusing on using scanning tunneling optical spectroscopy to characterize the material. Both of

these materials are important components of infrared detectors used in Astronomy. Patterson and Mantovani are working on the theory of the STM when the sample is illuminated. This has direct bearing on characterizing how well the materials will perform.

Raffaella and Mantovani are interested in synthesizing and characterizing thin film materials that can be used in photovoltaic solar cells for space applications. Multilayered thin films of copper indium diselenide (CIS) are being synthesized by means of the cost-effective method of electrochemical deposition. CIS is a leading alternative to silicon for use in solar cells due to its optical absorption and electrical properties. After fabrication, the multilayered thin film structures are characterized using x-ray diffraction (XRD), energy dispersive spectroscopy (EDS) in a scanning electron microscope (SEM), optical spectroscopy, and scanning tunneling microscopy (STM). This project has been supported in recent years by funding from the Florida Solar Energy Center, Florida Space Grant Consortium, Oak Ridge Associated Universities, and the Southeastern Universities Research Association. Raffaella is currently collaborating on a related project with researchers at the NASA Lewis Research Center in Cleveland. There are three graduate students currently involved in the project, as well as several undergraduate students who are involved on a part-time basis. Raffaella is also currently involved in an undergraduate SEDS project in which the undergraduate students are designing a microgravity experiment intended to fly on a future space shuttle mission as part of a "get-away-special" canister.

4.4 Instrumentation

Blatt continues his work on Moiré Profilometry on structures and has developed optical non-contact methods to measure the shape of a surface or to compare its shape to a finished shape. The technique has applications to robot assembly and space alignment, ranging and docking and automated assembly. He has developed a real time optical processor to do real time 3-D object recognition. Another optical processor can produce real time spectra of an image with military, industrial and law enforcement applications. Neural-net image processing has been used to automatically locate damage in structures. Blatt has received several grants from Holmes Regional Medical Center to study imaging and reconstruction of limbs, to develop eye testing software, and to design instrumentation to aid in the diagnosis of temporomandibular joint disorder (TMJ).

Blatt is working on new designs of visible and near IR hyperspectral imaging spectrometers which would allow the simultaneous acquisition of one or two spatial and one spectral dimensions with one or two CCD sensors. These instruments obtain ~ 102 - 103 spectral channels for ~ 102 - 103 spatial channels simultaneously.

Moldwin is currently the faculty advisor for Florida Tech's Space Shuttle Get-Away Special Canister (GAS-CAN) project. A GAS-CAN is a small self-contained experiment that flies in the space shuttles cargo bay. Florida Tech has proposed to fly two experiments: a materials science experiment led by Raffaella, and an upward propagating light-

ning detector led by Moldwin and Rassoul. Currently approximately 12 undergraduate students are active in developing this GAS-CAN project.

5. OTHER ACTIVITIES

Blatt served as an Associate Editor for the *Journal of Manufacturing Engineering*, and a reviewer for *Applied Optics*, *Optical Engineering*, *Optics Letters*, and the *Journal of the Optical Society (A)*.

Jin was awarded a two-year NSF Grant for laboratory improvement entitled "Implementation of Virtual Instrumentation in a Senior Laboratory."

Moldwin served on NASA's Office of Space Sciences Management Operations Working Group. He also was a reviewer for the *Journal of Geophysical Research* and NASA's Space Research & Technology program.

Oswalt continued to serve as Chairman of the Board of Directors for SARA. He is a Harlow Shapley lecturer for the AAS and public lecturer for the AIP, and since 1990 has served as a Bart and Priscilla Bok Award judge for the AAS and ASP at the annual International Science and Engineering Fairs. He is Editor of the quarterly astronomical journal *IAPPP Communications* and is the Director of the SARA REU summer research internships program. In 1997 Oswalt served as a Science Mentor for National Public Radio.

Patterson, Rassoul, and S. Billings (Univ. Idaho) are developing a book with the working title "Problems in the Space Sciences: Fundamental Physics of the Space Sciences (with Solutions)."

Rassoul was a peer reviewer for the U.S. Environmental Protection Agency for grants, cooperative agreements and applications for Graduate Education Fellowships in environmental fields of study. Rassoul was a reviewer for the *Journal of Geophysical Research* and NASA's Space Research & Technology program.

Wood is a member of the Board of Directors of the SARA Observatory, and Editor of the *Newsletter of the SARA Observatory*.

PUBLICATIONS

The publication list includes all papers published or submitted between November 1995 and October 1997 by the Department staff.

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