Planetary Science Institute and San Juan Institute

Tucson, Arizona 85705-8331

This report covers the activities of the Institute from September 1995 through August 1996.

1. INTRODUCTION

Planetary Science Institute (PSI) is a non-profit educational and scientific research organization which conducts a variety of basic research programs in planetary astronomy, lunar and planetary geology, and planetary geophysics and dynamics. PSI is a division of the San Juan Institute (SJI) in San Juan Capistrano, California, which is a research and educational institute in the field of planetary science.

PSI was established in Tucson, Arizona, in 1972, and joined with SJI in 1995. We conduct our research and education activities under grants from NASA, NSF, and other funding organizations. We also provide research opportunities for students in astronomy, physics, and planetary science through internships funded by the NASA Space Grant program and the NSF Research Experience for Undergraduates program.

Our scientists have participated in NASA spacecraft missions such as *Mariner 9*, *Viking*, and *Mars Observer*, and are presently involved in the *Galileo* mission to Jupiter, the *NEAR* mission to the asteroid Eros, and the *Mars Global Surveyor* and Russian *Mars-96* missions. We also regularly use many of the world's ground-based observatories.

The PSI and SJI World Wide Web site addresses are **http://www.psi.edu/** and **http://www.sji.org**.

2. PERSONNEL

The research staff at PSI includes Donald R. Davis (Senior Scientist and PSI Division Manager), William K. Hartmann (Senior Scientist), Carol Neese (Staff Scientist), Eileen V. Ryan (Research Scientist) and Stuart J. Weidenschilling (Senior Scientist). Visiting scientists at PSI this year include Paolo Farinella from Università di Pisa, Francesco Marzari from Università di Padova, and Ian Giblin from Università di Pisa. Student research interns at PSI this year included Alejandro Diaz, Gilbert Esquerdo, Adrienne Herzog, and Adriana Reyes. The research staff at SJI includes Bruce Betts (Research Scientist) and Doug Nash (Senior Scientist and Director of SJI/PSI).

3. STAFF CHANGES

This year the following changes occurred in the PSI/SJI scientific staff. Dr. Clark Chapman and Dr. William Merline left PSI to work at the Southwest Research Institute in Boulder, Colorado. Dr. Fred Ringwald completed his postdoctoral appointment at PSI and is now working at Pennsylvania State University. Dr. Steve Howell left PSI to accept a position at the University of Wyoming. Dr. Eileen Ryan is on leave of absence at New Mexico Highlands University for the 1996-97 academic year.

4. RESEARCH PROGRAMS

Weidenschilling (1996) has carried out studies of the formation of planetesimals in the outer solar system. In the presence of the gaseous solar nebula, the relative motions of sub-km-sized solid bodies are dominated by drag forces rather than gravity. Numerical modeling of collisional evolution of a particle swarm in such an environment shows a stage in which the size distribution has most of the mass concentrated in bodies tens to hundreds of meters in diameter. This result is due to the non-monotonic variation of drag-induced radial velocities with size. Collisional velocities have a minimum in the size range corresponding to the transition from drag-dominated to gravitational accretion, and planetesimals are likely to preserve structure on this scale. The model accounts for the inhomogeneities and weak ''rubble pile'' structure inferred for cometary nuclei.

A startling recent development in astrophysics is the detection by radial velocity surveys of massive planets in orbits close to their stars. Accepted cosmogonical theory predicts that jovian-type planets could only form outside the ''snow line'' in a circumstellar disk. In collaboration with F. Marzari (U. di Padova), Weidenschilling has suggested that these planets formed in multiple systems with unstable orbits. Gravitational scattering could eject one planet from the system while leaving another in a smaller orbit (Weidenschilling and Marzari 1996). Numerical modeling of orbital evolution is in progress to determine the statistical distribution of outcomes.

Davis and P. Farinella (U. di Pisa) put forth a new paradigm for the evolution of short period comets as part of their studies of the collisional evolution of small bodies of the solar system. In the past year, they finished the first phase of a study of the collisional evolution of Edgeworth-Kuiper Belt Objects (EKOs) using the methodology developed for exploring asteroid collisional evolution. Even though there are many differences between asteroids and EKOs, the average collision rate in the two populations is very similar, although the impacts speeds among the EKOs is hundreds of m/s, an order of magnitude less than for the asteroids. Thus collisions have been a major process affecting EKOs over solar system history and at sizes below about 50-100 km diameter and the population is a collisionally relaxed one. A major result from this work is that collisions can inject fragments into dynamical resonances in the outer solar system. Some of these fragments are then transported to the inner solar system to become short period comets. Short period comets are not as primitive in their physical nature as scientists had once thought. This work was published in *Science* (Farinella and Davis 1996), and a more detailed version is now in press in *Icarus* (Davis and Farinella 1996).

Hartmann continued work on the cratering of planetary surfaces, including simulations with Robert Gaskell (JPL), of the saturation equilibrium condition on heavily cratered surfaces. A paper on this topic has been accepted for a forthcoming issue of *Meteoritics & Planetary Science* (Hartmann

1997a). Hartmann is extending this work under the NASA Lunar and Asteroid Data Analysis Program to study the consequences of the Yarkovsky effect and other effects that may remove small asteroidal fragments (size <30m) from the asteroid belt, and thus affect surface characteristics of belt asteroids through reduced ''sandblasting'' by small debris.

Hartmann and Neese are collaborating on an observational program to obtain spectra of the presumeably captured outer satellites of Jupiter and related faint outer solar system bodies, using the new PSI spectrograph. These satellites will be related to their potential source populations in the main asteroid belt, the trojan swarms, and the outer solar system. Spectra were obtained on asteroids to magnitude V = 18 during 1996.

Hartmann is continuing his role as Participating Scientist on the imaging team of the *Mars Global Surveyor* mission, and as a U.S. Co-Investigator on the Russian *Mars-96* mission. He is also on the editorial board of *Meteoritics & Planetary Science*.

During the year, Hartmann completed a project to publish a book, with the National Science Teachers Association, of high school science lessons using the theme of cratering, and has continued the updating of his college-level astronomy textbooks, co-authored with Christopher Impey (U. of Ariz). Hartmann has also been active this year in the discovery of the first known campsite of the Coronado expedition on its march through the southwest in 1540-42, and has two research papers in press on this work (Hartmann 1997b, Duffen and Hartmann 1997).

Betts and Nash are using on-site laboratory facilities to obtain and analyze laboratory mid-infrared spectra of several materials with planetary implications: (1) SO_2 and H_2S frosts and gas with applications to Io and Europa; (2) lunar samples with applications to the Moon and Mercury; and (3) shocked and unshocked Meteor Crater samples with applications to the understanding the effects of planetary impact phenomena. Nash also contributed to the interpretation of Mercury IR spectra obtained by Ann Sprague (U. Arizona).

Nash is also collaborating with John Spencer (Lowell Observatory) and his team to make observations of Io with the Hubble Space Telescope; Nash is providing lab spectra of material candidates that explain Io's surface spectra.

Nash is beginning collaboration with Jeff Kargel (USGS Flagstaff), providing lab spectra of sulfur-mineral samples that Kargel has collected and is having analyzed for chemical composition. The goal is to compare compositional variations due to various contaminants and mixed phases with their reflectance spectra and apply these results to the interpretation of Io spectra.

Betts is also involved in the study of thermal and visible images of Mars including the study of possible future landing site areas with implications for understanding the current physical state of the surface and past geologic history.

Esquerdo, under the guidance of Weidenschilling and Howell, completed early developmental work on a system by which extra-solar planets can be detected with commercially available components. A photometric method was chosen for its simplicity, as well as the large sample of stars it is able to study. Current calculations estimate detections of Neptune- to Jupiter-sized objects could occur at a rate of approximately six per year. The project is currently awaiting proposal review prior to further development of the hardware.

Davis, Neese, and Tholen (U. of Hawaii) constitute the Asteroid Subnode of the Small Bodies Node (SBN) of the Planetary Data System (PDS), a long-term NASA project whose goal is to archive spacecraft and earthbased planetary data in a fully documented and accessible form for current and future researchers. A number of new datasets were incorporated into the SBN this past year, including a collection of both groundbased and Galileo spacecraft data on the asteroids Gaspra and Ida. Current information on SBN activities and access to datasets is available at the SBN Homepage at **http://pdssbn.astro.umd.edu**.

Neese, Davis, Chapman, Howell, Mannery (U. of Washington) and Corbally (Vatican Observatory) completed construction of a high-throughput, low-resolution spectrograph designed to cover the spectral range 3500–11000 Å in a single exposure. This instrument is intended to observe solid surfaces of solar system bodies, particularly asteroids. Several observing runs have been carried out with the spectrograph at the VATT telescope on Mt. Graham and the Steward 90'' on Kitt Peak.

PUBLICATIONS

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Carol Neese