

# Planetary Science Institute

ANNUAL REPORT 2011

# PLANETARY SCIENCE INSTITUTE

The Planetary Science Institute is a private, nonprofit 501(c)(3) corporation dedicated to solar system exploration. It is headquartered in Tucson, Arizona, where it was founded in 1972.

PSI scientists are involved in numerous NASA and international missions, the study of Mars and other planets, the moon, asteroids, comets, interplanetary dust, impact physics, the origin of the solar system, extra-solar planet formation, dynamics, the rise of life, and other areas of research.

They conduct fieldwork in North America, South America, Asia, Australia, Africa and Antarctica. They are also actively involved in science education and public outreach through school programs, children's books, popular science books and art.

PSI scientists are based in 16 states, the United Kingdom, France, Switzerland, Russia and Australia with affiliates in China and Japan.

The Planetary Science Institute is located at 1700 E. Fort Lowell, Suite 106, Tucson, Arizona, 85719-2395.

The main office phone number is 520-622-6300, fax is 520-622-8060 and the Web address is <http://www.psi.edu>.

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***On the cover:*** The moon is thought to have formed in a disk of debris, generated around primordial Earth by a giant impact, as first proposed at PSI in 1974-1975 by PSI co-founders Bill Hartmann and Don Davis. This view shows a later stage when the moon mostly assembled and has reached a size large enough that tidal forces cause it to move outward, away from the "placental" disk.

*Painting by William K. Hartmann, Planetary Science Institute Senior Scientist.*

# NOTE FROM THE DIRECTOR

This year has been marked by sadness with the loss of PSI Senior Scientist Betty Pierazzo to a rare form of cancer. She was 47.

Betty was an expert in the area of impact modeling throughout the solar system, as well as an expert on the astrobiological and environmental effects of impacts on Earth and Mars. She provided detailed insights into the Chicxulub impact that caused the extinction of the dinosaurs, constrained the thickness of the ice shell of Jupiter's moon Europa, and explored the rise of life by modeling the delivery of organics to planets and Europa by comets. She also simulated the creation of subsurface hydrothermal systems by impacts that may have been favorable sites for life on Mars.

Betty was an expert on Meteor Crater in Arizona and made several appearances on national and international broadcasts of programs, including National Geographic specials, explaining the formation of this well-known structure. Betty was innovative, rigorous and systematic in her approach to science.

In addition to her science, Betty passionately promoted science education and public outreach. She played a principal role in building PSI's education program, developing interactive websites and impact rock and meteorite kits for classroom use, as well as creating professional development workshops for elementary and middle school science teachers.

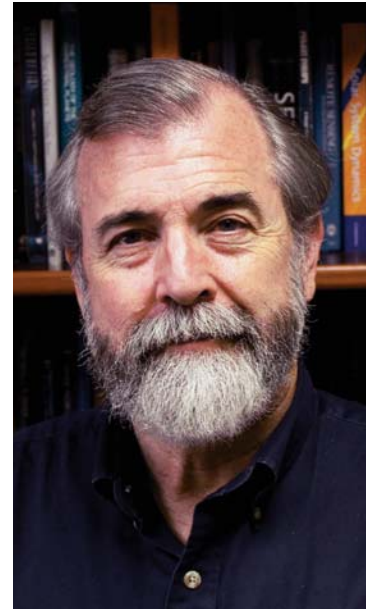
Betty was an active member of the planetary community. She served on numerous NASA review panels, was an associate editor of *Meteoritics & Planetary Science*, reviewed papers for numerous scientific journals, served as an organizer of workshops and meetings on impact cratering held around the world, and was an organizer of the 2007 Meteoritical Society Meeting held in Tucson, Arizona.

Betty was noted for the intensity with which she approached both life and work. She was cherished by many people for her staunch friendship and support. She inspired countless people as a colleague, teacher, mentor and friend.

Betty dealt with her cancer aggressively, and never let it overwhelm her. She was always looking towards the future. In the last week of her life, in the midst of chemotherapy, she was grading class papers, working on research papers, writing reviews and preparing education proposals with her colleagues, all the while finding time to spend precious moments with her family and friends.

With Betty's loss, I look around at our family of PSI scientists and staff and see a microcosm of our profession. They make significant contributions to this nation's solar system exploration efforts and give us its benefits, largely unsung. They give to the communities in which we live. They are artists, athletes, writers, musicians, teachers, activists, friends, and parents and grandparents, in addition to everything else. I deeply appreciate all of them, and it is an honor to work on their behalf.

*Mark V. Sykes*



## Betty Pierazzo Memorial Fund Established by PSI



*Dr. Betty Pierazzo*

PSI established a fund to honor and celebrate the life and achievements of Senior Scientist Betty Pierazzo and to promote science in education, for which she had such passion. This fund will be supporting an award in her name to be created in 2012. As of the end of PSI's fiscal year, January 31, 2012, more than \$20,000 in initial donations have been contributed. We thank these contributors for their generosity.

### INAUGURAL DONORS

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# PSI Expands Scientific Research Strength, Experience

PSI's strength and advantage are in its people. Our culture of openness and high level of mutual support distinguishes us as an organization. In 2011 PSI continued to grow, adding 15 new research staffers.

## NEW PSI STAFF MEMBERS FOR 2011:



**Sarah L. Andre**  
*Research Scientist*



**Amy L. Cranford**  
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**Susanne Douglas**  
*Senior Scientist*



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*Postdoctoral Research Scientist*

## PSI Researchers and Educators Have a Busy Year

Many discoveries were made this year. PSI scientists found small depressions on Mars rich in minerals formed by water that could have been recent habitats. They discovered that huge Mars sand dunes, thought to be frozen in ancient times, are being resculpted on a seasonal basis. They determined that the dipole magnetic field of Mercury is offset hundreds of kilometers — think of Earth's magnetic equator being at the latitude of Costa Rica — and that the elemental composition of Mercury's crust is very different from the moon's. They simulated how the migration of Jupiter in the early solar system kept Mars from growing to the size of Earth. They revealed that the target of NASA's EPOXI spacecraft, comet Hartley 2, has a significantly decelerating rate of rotation — the effect of ejecta jets and tumbling.

PSI scientists also prepared for the launch of Mars Science Laboratory, on which they are participating as Deputy Principal Investigator for the

Chemistry and Mineralogy instrument and Mars Hand Lens Imager, and Co-Investigator for the Mars Descent Imager. The Juno mission launched with PSI leading on JunoCam, allowing public participation in deciding which images will be taken.

PSI researchers and educators established partnerships with Tucson-based museums to extend its outreach activities using meteorites and the latest results from NASA missions.

This year, PSI also signed an Memorandum of Understanding with XCOR Aerospace, laying the groundwork to use their Lynx spacecraft to fly the Atsa Suborbital Observatory. PSI scientists, accompanied by cadets from The Citadel, traveled to NASTAR in Pennsylvania, using its centrifuge to begin designing an astronaut training program for Atsa operators.

# PSI Researcher Hunts for Meteorites in Antarctica

The coldest winter PSI Senior Scientist Melissa Lane ever spent was the summer of 2011 in Antarctica looking for meteorites. While it was winter in the Northern Hemisphere, Lane was summering in Antarctica's sub-freezing temperatures with 24-hour sunlight. The purpose of her trip was to search for rocks from space for the National Science Foundation and NASA, as part of a project called ANSMET (ANTarctic Search for METeorites).

Two teams, a total of 12 people, spent eight weeks in Antarctica, five of those weeks camping on the ice. After a five-hour flight from New Zealand on a C-17 military aircraft, the researchers arrived at the U.S. McMurdo Station, on the coast of the great snowy continent, to begin their Antarctic adventure. Following a week of safety training and preparing cargo in "MacTown," the two teams parted and progressed to their separate field sites on the ice. The eight-person Systematic Team collected every meteorite in a "systematic" sweep — on foot — through their field site in the Trans-Antarctic Mountains.

Lane's four-person Reconnaissance Team traveled to remote areas and rode snowmobiles to cover a lot of ground and assess whether a site had enough meteorites to warrant a future field season by the Systematic Team. They made broad sweeps across the ice fields, driving their snowmobiles abreast of each other, 100 to 1,000 feet apart, depending on the search strategy. Each workday — typically 9 a.m. to 6 p.m. — they would drive 15 to 50 miles across the ice, swiveling their heads left and right to catch a glimpse of a dark meteorite on the bluish-white ice surface.

Almost any dark speck was guaranteed to be a meteorite. When one was spotted, the finder would wave the whole team over to help with its collection. The meteorite was given a specific number, photographed in place, measured for size, and the amount of fusion crust was estimated. Fusion crust is the blackened outer surface of the meteorite that develops as it hurtles through the Earth's atmosphere, becoming charred and melted. The meteorite was then picked up using sterile tongs and placed in a sterile sample bag along with its metal number tag, while the GPS coordinates were recorded.



*Lane holds a counter near a meteorite, being sure not to touch it to avoid contamination, for its close-up field image. The device, into which a unique meteorite number was dialed, was also used for measuring the approximate size of the meteorite before it was collected.*



*Lane rests in the Scott tent, her home for five weeks on the ice. The yellow glow was constant inside the tent because the sun never sets during the Antarctic summer and the tent fabric was yellow. Pockets in the space-cramped tent were well utilized for storage and quick access.*

The meteorites were typically the size of marbles; however, they did find a few 20-pounders. Most of the 302 meteorites found by the Recon Team were "ordinary chondrites," which are stony meteorites with asteroidal compositions that likely originated during the formation of the solar system — 4.5 billion years ago. The team had hoped to find meteorites that appeared to be from the moon or Mars, but didn't. The meteorites found, along with the 900 collected by the Systematic Team, were kept frozen — very important to prevent degradation of the minerals — and taken by ship from McMurdo Station to Los Angeles, then by refrigerated truck to Johnson Space Center, Houston, for drying and curation.

Lane and her teammates experienced temperatures that hovered around 0 degrees F — cold enough to keep their ice cream solid; yes, they brought ice cream into the field for a treat and, surprisingly, they all looked forward to ice cream nights. Camp was literally hundreds of miles from any other life, but they soon got comfortable living in a two-person seven-foot-by-seven-foot tent, with no floor except for a tarp, and nothing but two thin foam pads and a Thermarest® under each sleeping bag. Between the two sleeping bags, each tent had a two-burner propane camp stove that was used for melting ice — which was retrieved daily with an ice pick and bucket — heating water, cooking, and warmth. While awake in the tent, the stove was on; for safety reasons it was turned off when they left or went to sleep. Fortunately, sleeping bags and hot water bottles kept the researchers very warm at night.

Each morning the team either bundled up to head out in search of meteorites or were told it was a tent day. Tent days were called due to weather conditions, such as blowing snow that obscures meteorites and crevasses, or cloud cover that creates "flat light," where the surface and sky blend together, reducing visibility and making navigating undulating snowdrifts hazardous.

In mid-January, the Reconnaissance Team left its windy, snowy camp to return to McMurdo Station, via the South Pole, and rejoin the Systematic Team, to clean and stow their gear. While they were deployed deep into the continent, an ice-breaker was methodically breaking up the sea ice in McMurdo Sound to allow the safe entry of supply ships and, in doing so, allowed the Adelie penguins to come in farther, too. Lane considers her trip to Antarctica a huge success because she saw meteorites and penguins and gained a new fondness for both.

# Atsa Project Moves Closer to Suborbital Research

PSI moved closer to expansion into human space exploration as the Atsa Suborbital Observatory project moved ahead in 2011.

PSI and XCOR Aerospace signed a Memorandum of Understanding that lays the groundwork for flying the human-operated Atsa Suborbital Observatory aboard XCOR's Lynx spacecraft.

"The XCOR vehicle design and capabilities work well for hosting the kind of observing facility we are developing," said PSI Senior Scientist Faith Vilas, the Atsa Project Scientist.

The Lynx spacecraft will fly to space on a customized flight trajectory and will be capable of precision pointing, allowing the Atsa system with its operator to acquire the desired target and make the planned observations. "We are being approached by many potential customers who are interested in supporting observations of the inner solar system," Vilas said. "We will also be able to support target of opportunity observations for newly discovered objects and other phenomena."

The Atsa Suborbital Observatory was invented by Vilas and Luke Sollitt, a PSI Associate Research Scientist who is a professor at The Citadel, The Military College of South Carolina. Vilas, who leads the Atsa project, is a long-time planetary astronomer who formerly served as director of the MMT Observatory (a joint facility of the Smithsonian Institution and the University of Arizona) before joining PSI. Sollitt, the Atsa Deputy Project Scientist, was formerly staff scientist at Northrop Grumman Corp.

PSI scientists and undergraduate students from The Citadel and other South Carolina colleges received training in support of PSI's Atsa Suborbital Observatory at the National Aerospace Training and Research (NASTAR) Center in Southampton, Penn.

The three-day NASTAR Suborbital Scientist Course equips individuals with hands-on knowledge and skills to safely cope with the rigors of suborbital spaceflight and gives an understanding of the challenges involved with conducting experiments in space. The course includes four core elements: Altitude Physiology, G-Tolerance, Space Launch and Re-entry Training, and Distraction Management.

High-altitude physiology training enables trainees to experience the effects of hypoxia or oxygen-deprivation firsthand with an altitude chamber flight to 25,000 feet. Trainees also learn safety protocols and considerations in a loss of cabin pressure event.

G-tolerance flights introduce trainees to the psychological and physiological acceleration effects of spaceflight and teach ways to mitigate the symptoms of gravity-induced loss of consciousness. Simulated space flights are conducted on the NASTAR Phoenix STS-400 centrifuge where trainees learn to handle the maximum acceleration G loads encountered during launch and reentry up to three and one half times Earth's gravity oriented up-and-down (eyeballs-down) and six times Earth's gravity oriented front-to-back (eyeballs-in).

Vilas and Sollitt were present, overseeing the training and collecting information to be used in designing training activities for Atsa operators.

Also participating from PSI were Research Scientist Brent Garry, CEO and Director Mark Sykes, and Senior Scientist Melissa Lane. The undergraduate students are participating in the South Carolina Space Grant consortium's Palmetto Academy program under the supervision of Sollitt and are involved in the design and construction of the Atsa Mark 1 camera. These students included Andrew Strasburger from Wofford College, Daniel Showers from Clemson University, and Ryan Boodee and Daniel Pittman from The Citadel.

Atsa will use crewed suborbital commercial spacecraft with a specially designed telescope to provide low-cost, space-based observations above the contaminating atmosphere of the Earth, while avoiding operational constraints of many satellite telescope systems.

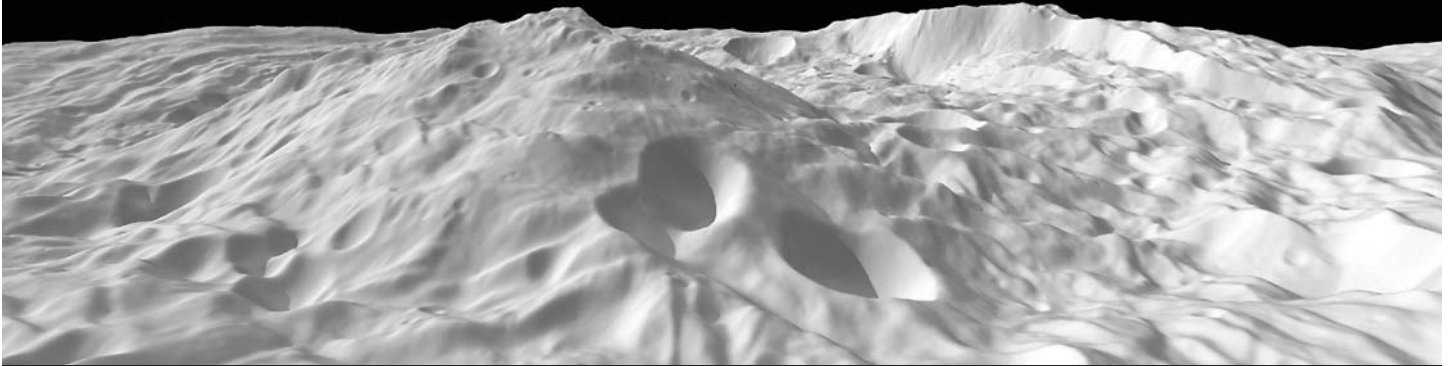
Atsa means "eagle" in the Navajo language. The facility is optimized for observing solar system objects near the sun that are difficult to study from orbital observatories such as Hubble and ground-based telescopes.



Left, NASTAR training group (L-R) Gregory Kennedy (NASTAR), Andrew Strasburger (Wofford College), Daniel Pittman (The Citadel), Ryan Boodee (The Citadel), Daniel Showers (Clemson University), Luke Sollitt (PSI, The Citadel), Brent Garry (PSI), Mark Sykes (PSI), Melissa Lane (PSI) and Brienna Henwood (NASTAR).

Above, Brent Garry experiences up to six Gs in NASTAR's centrifuge.

# Dawn Mission Reaches Vesta, Close-up Work Begins



*This image by PSI Research Scientist David O'Brien of the asteroid Vesta, made from a shape model developed by PSI Senior Scientist Bob Gaskell, shows a tilted view of the topography of the south polar region (the vertical scale is 1.5 times that of the horizontal scale). The prominent peak near the south pole, seen in the center of the image, rises about 13 miles (22 kilometers) above the average height of the surrounding terrain. Another impressive structure is a large scarp, the steep cliff on the right side of the image, which bounds part of the south polar depression.*

NASA's Dawn spacecraft arrived at the giant asteroid Vesta in July to begin a planned year of study orbiting the body before traveling to dwarf planet Ceres.

PSI scientists have been actively involved in the Dawn mission since its inception and include Co-Investigators Mark Sykes, Bill Feldman, and Tom Prettyman, and Participating Scientists Pasquale Tricarico, Jian-Yang Li, Aileen Yingst, David O'Brien, Bob Reedy, and Brent Garry. Tom Prettyman is Principal Investigator of the Gamma Ray and Neutron Detector – GRaND. PSI Dawn associates include Eric Palmer, Dan Berman and Scott Mest.

GRaND is operated and managed by the Planetary Science Institute under the leadership of Prettyman, who is also the lead for geochemistry on Dawn. This work is supported by NASA under a subcontract from the

Jet Propulsion Laboratory to the Planetary Science Institute. GRaND was built by Los Alamos National Laboratory under Prettyman's direction and supervision.

The elemental composition of both Vesta and Ceres will be measured with the GRaND. This instrument uses a total of 21 sensors with a very wide field of view to measure the energy from gamma rays and neutrons that either bounce off or are emitted by a celestial body. Gamma rays are a form of light, while neutrons are particles that normally reside in the nuclei of atoms. Together, gamma rays and neutrons reveal many of the important atomic constituents of the celestial body's surface down to a depth of one meter. Gamma rays and neutrons emanating from the surface of Vesta and Ceres will tell us much about the elemental composition of each.

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## JunoCam Begins Long Journey to Jupiter

NASA's Juno spacecraft launched Aug. 5, 2011 on a five-year journey slated to arrive at Jupiter on July 4, 2016. The science goals of the mission are to study the giant planet's interior structure, magnetic field, the composition of its clouds, and circulation of its atmosphere in order to better understand the evolution of the solar system.

The spacecraft's JunoCam camera will offer the public the opportunity to participate in the mission's science endeavors, said PSI Senior Scientist Candice Hansen, the lead scientist for JunoCam.

JunoCam has a 58-degree field of view, optimized for Juno's unique views in its polar orbit of the pole of Jupiter – territory only seen obliquely by previous spacecraft. Picture-taking opportunities are best in just a few hours before and after perijove – the closest point to Jupiter in Juno's elliptical orbit. Constraints on how much data volume can be stored and transmitted back to Earth will put limits on the number of pictures that can be acquired.

The JunoCam operations team will rely on the international community of amateur astronomers to supply up-to-date images of Jupiter's ever-changing atmosphere to predict what atmospheric features will be in JunoCam's images when they are acquired, she said.

"We are going to have the public help us decide which images we take, and when they will be taken," Hansen said.

Once the data are returned to Earth the public will be invited to process the raw image data and post their results.

On Aug. 26, the team powered JunoCam on for its first post-launch checkup. An image of the Earth and moon from 6 million miles shows how far the spacecraft has already travelled on its epic mission.

# Education, Public Outreach Efforts Expand in 2011

PSI experienced a successful, busy year filled with Education and Public Outreach activities in 2011, with eight active EPO projects. Funding for the year's efforts totaled approximately \$400,000.

PSI continued to help teachers improve science education during the second year of its \$750,000 NASA-supported project Workshops in Science Education and Resources (WISER): Planetary Perspectives. During 2011, two offerings each of the three-day Project WISER workshops "Volcanoes of the Solar System" and "Moon-Earth System" attracted 46 teachers from elementary and middle schools in Arizona.

PSI, in support of the Arizona-Sonora Desert Museum, helped to launch a professional development program entitled Earth Camp for Educators that saw 16 teachers from Tucson and Phoenix participate in investigations of the Colorado River watershed. The program included a four-day river trip on the Colorado River and a four-day design workshop using satellite images in addition to monthly workshops helping teachers integrate inquiry activities into their classrooms. PSI also supported Middle School and High School Earth Camp summer programs for 40 teenage students. Each program engaged campers in hands-on science investigations working alongside scientists to integrate the topics of resource conservation and use of satellite images.

PSI began a new partnership with the Children's Museum Tucson, funded by a new NASA grant, to integrate more space science into public science days at the museum and programming for young children. The first public event celebrated the winter solstice and included hands-on activities for children and families, including investigations of the size and scale of the sun and Earth and viewing the sun in multiple wavelengths of light.

During 2011, PSI meteorite and impact rock kits were used at Family Science Nights and in classroom visits. Children and their families

learned about the origins of different impact crater rocks and meteorites and used magnifying lenses and magnets to discover characteristics of the samples. To their delight, they had the chance to hold very small pieces of Martian and lunar meteorites in their hands.

PSI educators and scientists visited schools and offered presentations on exploring the solar system, meteorites, and other topics. Some of the most popular offered students the opportunity to speak via satellite phone with PSI Senior Scientist Melissa Lane in Antarctica, where she was a participant in the Antarctic Search for Meteorites (ANSMET) program field expedition searching for meteorites on the ice. Schools visited included: Presidio School, Twin Peaks Elementary School, Tucson Waldorf School, Santa Clara Elementary School, Nash Elementary School, St. Gregory School, and Sunrise Drive Elementary School.

PSI also developed and rolled out a volunteer docent program that saw seven people trained who participated in outreach events including popular comet programs where youngsters make model comet nuclei from dry ice and other ingredients. PSI docents supported various outreach events during the year including public events at the Children's Museum Tucson, the Pima Air and Space Museum, and the Arizona-Sonora Desert Museum.

Larry Lebofsky and Sanlyn Buxner co-presented the "Small Bodies, Big Concepts" workshop in Denver with educators from Mid-continent Research for Education and Learning (McREL). Workshop participants learned about integrating planetary science into their classrooms and were supported during the academic year to create and implement new lessons using materials from the workshop.

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## Development Program Sees Continued Success in 2011

The development program at PSI continues to grow and thrive as it completed its first full fiscal year. Highlights of the year included the first annual fundraising dinner held at the Lodge on the Desert in Tucson. One hundred and twenty guests enjoyed learning about the education and outreach programs done at PSI and participated in activities such as learning how to build a model comet nucleus using dry ice and other organic materials. The event's title sponsor was Cox Communications and a number of other companies participated by sponsoring tables.

In addition to the first annual fundraiser held in Tucson, two events were held in California to build the Friends of PSI program. Held in Del Mar and Palos Verdes, and hosted by PSI Trustees, these events highlighted local PSI scientists who shared their mission experiences.

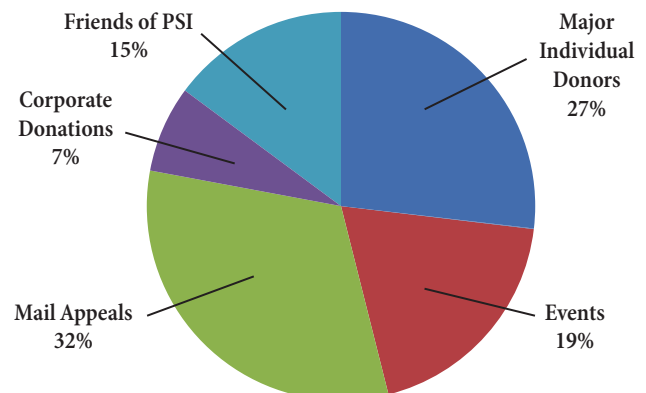
Additionally, CEO and Director Mark Sykes opened his home in Tucson for a New Year's brunch. Current Friends of PSI and other supporters were invited to hear from Mark as he shared news about the Atsa Suborbital Observatory program and recent findings from the Dawn mission.

For the fiscal year, more than \$50,000 was raised to support the operations and outreach programs at PSI. Individual small donations received from mail appeals made up the largest source of revenue with individual major donors contributing a large portion as well. As part of these donations,

more than \$20,000 was raised to honor PSI colleague Dr. Elisabetta Pierazzo who passed away suddenly during the year.

In the coming year we plan to expand PSI's fundraising program, build more individual and corporate partnerships and diversify funding sources in support of PSI's mission.

### Revenue from Non-NASA Fundraising FY 2011-2012





# THANK YOU TO OUR 2011 DONORS

With deep gratitude the Planetary Science Institute acknowledges the following individual and organizational donors who made contributions between Feb. 1, 2011 and Jan. 31, 2012.

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# PSI FINANCIAL REPORT

*Bruce Barnett* Chief Financial Officer

PSI experienced a robust 16 percent annual revenue growth in the fiscal year ended January 31, 2012, with revenues totaling \$8.2 million. Funding from NASA represents \$8.0 million, or 97 percent of total revenues. During the fiscal year, NASA funded 95 grants with a PSI scientist as principal investigator, and 67 contracts issued by other institutions with NASA prime awards.

## REVENUES

Grants and Contracts	\$ 8,162,346
Contributions	77,164
Other	<u>5,564</u>
Total Revenues	\$ 8,245,074

## NASA FUNDING

Grant Awards (95)	\$ 5,441,914
Contracts (67)	<u>2,135,149</u>
Total NASA Funding	\$ 6,857,502

Salaries and related fringe benefits represent 75 percent of PSI's total expenses of \$8.2 million. Operating expenses include \$504,697 paid on subcontracts to other institutions whose scientists are included on PSI awards. Program services expenses are 88 percent of total expenses.

## EXPENSES

Salaries and Benefits	\$ 6,210,062
Operating	1,922,284
Depreciation	87,351
Interest	<u>15,650</u>
Total Expenses	\$ 8,235,347

## EXPENSES BY FUNCTION

Program Services	\$ 7,227,062
Management & General	966,848
Fundraising	<u>41,437</u>
Total Expenses	\$ 8,235,347

PSI's financial records are audited annually by independent auditors. A condensed Statement of Financial Position from PSI's audit report for the year ending January 31, 2012 is reflected below.

Current Assets	\$ 1,027,220
Property & Equipment	<u>477,634</u>
Total Assets	\$ 1,504,854

Current Liabilities	\$ 896,726
Long-term Liabilities	329,271
Property & Equipment	<u>278,857</u>
Total Liabilities & Net Assets	\$ 1,504,854

# NEW PSI RESEARCH GRANTS

Grants listed by *Principal Investigator*, project title and program or funding source.

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**Daniel C. Berman.** Investigations of Transverse Aeolian Ridges on Mars. NASA Mars Data Analysis Program.

**David A. Crown.** Thermophysical properties of mantled volcanic surfaces: Constraints on lava composition and emplacement processes. NASA Planetary Geology and Geophysics Program, University of Pittsburgh subcontract.

**David A. Crown.** Geologic mapping of Daedalia Planum, Mars. NASA Planetary Geology and Geophysics Program.

**Susanne Douglas.** Validating habitability assessment of Martian soil. NASA Mars Fundamental Research Program.

**Marc D. Fries.** Abiotic macromolecular carbon: Its nature, provenance and synthesis from mantle volatiles on Mars and Earth. NASA Mars Fundamental Research Program, Carnegie Institution of Washington subcontract.

**W. Brent Garry.** Geologic mapping of Arsia and Pavonis Montes, Mars. NASA Mars Data Analysis Program, Arizona State University subcontract.

**W. Brent Garry.** Analysis of the emplacement of the Mare Imbrium lava flows on the Moon through quantitative modeling and terrestrial analogue studies. NASA Lunar Advanced Science and Exploration Research Program.

**W. Brent Garry.** Analysis of the morphology and emplacement of volcanic features on the Moon with the Lunar Reconnaissance Orbiter. NASA Lunar Reconnaissance Orbiter Program.

**W. Brent Garry.** The volcanic evolution of Vesta: Morphologic analysis using the framing camera, Dawn Mission. NASA Dawn at Vesta Participating Scientist Program.

**W. Brent Garry.** Study of terrestrial inflated lava flows in Idaho and New Mexico. NASA Planetary Geology and Geophysics Program, Smithsonian Institution subcontract.

**W. Brent Garry.** Analog studies of volcanic features through computer-assisted EVA simulations. NASA Moon and Mars Analog Mission Activities Program.

**Robert W. Gaskell.** OSIRIS-REx asteroid sample return mission. NASA OSIRIS-REx Mission, University of Arizona subcontract.

**Robert W. Gaskell.** Vesta SPC shape and topography. NASA Dawn Discovery Mission, Jet Propulsion Laboratory subcontract.

**Cyrena A. Goodrich.** Differentiation of primitive achondrite parent bodies: Extending the lessons from ureilites. NASA Cosmochemistry Program.

**Cyrena A. Goodrich.** Melt inclusions in olivine in Nakhla as probes of the Martian mantle-determination of alkali and halogen abundances of primary magmas. NASA Cosmochemistry Program, Universities Space Research Association subcontract.

**Tommy Grav.** WISE Moving Objects Processing System (WMOPS). NASA NEO-WISE Program, Jet Propulsion Laboratory subcontract.

**Candice J. Hansen.** HiSCI Co-Investigator. NASA ExoMars Trace Gas Orbiter Mission, University of Arizona subcontract.

**Candice J. Hansen.** Seasonal volatile transport on Triton, Pluto, and Kuiper Belt Objects. NASA Outer Planets Research Program.

**Candice J. Hansen.** Cassini UVIS Co-Investigator. NASA Cassini Mission, University of Colorado at Boulder subcontract.

**Rossman P. Irwin III.** Geomorphology of theater-headed valleys. NASA Mars Fundamental Research Program.

**Rossman P. Irwin III.** Exposed stratigraphy on the floors of Noachian impact craters on Mars. NASA Mars Data Analysis Program.

**Rossman P. Irwin III.** Landscape evolution modeling in the Noachian highlands of Mars. NASA Planetary Geology and Geophysics Program.

**Elizabeth A. Jensen.** Investigating the collisional and dynamical evolution of comets through laboratory impact experiments. National Science Foundation, University Enterprises Inc. subcontract.

**Catherine L. Johnson.** Geophysical structure and evolution of the Moon. NASA Planetary Geology and Geophysics Program.

**Catherine L. Johnson.** Investigations of Mercury's internal magnetic field. NASA MESSENGER Mission, Johns Hopkins University Applied Physics Laboratory subcontract.

**Melissa D. Lane.** The state of sulfur on Mars: Understanding the inter-relationships among the crystal structure, chemistry, and spectroscopy of sulfates and sulfides. NASA Mars Fundamental Research Program.

**Melissa D. Lane.** Integrated spectroscopy of pyroxenes: Composition, structure and thermal history. NASA Planetary Geology and Geophysics Program, Johns Hopkins University Applied Physics Laboratory subcontract.

**Joseph R. Michalski.** Exploring geologic processes in the deeper Martian crust through compositional studies of impact craters. NASA Mars Data Analysis Program.

**Joseph R. Michalski.** Carbonates and hydrothermal phyllosilicates exhumed from deep in the Martian crust: A high priority target for future Mars exploration. NASA Mars Critical Data Products Program, Jet Propulsion Laboratory subcontract.

**Jeffrey P. Morgenthaler.** What drives variation in the Io plasma torus? NASA Outer Planets Research Program.

**Jeffrey P. Morgenthaler.** Enabling wide-field studies of comets by archiving GALEX, MSX, WISP and supporting ground-based observations/Measuring the lifetime of CO using publicly archived GALEX data. NASA Planetary Mission Data Analysis Program.

**Eldar Z. Noe Dobrea.** Compact Reconnaissance Imaging Spectrometer at Mars. NASA Mars Reconnaissance Orbiter Mission, Johns Hopkins University Applied Physics Laboratory subcontract.

**Eldar Z. Noe Dobrea.** Hydrothermal deposits in NW Hellas as landing sites for future missions. NASA Microwave Limb Sounder Program, Jet Propulsion Laboratory subcontract.

**Asmin Pathare.** Quantitative stratigraphy of north-polar basal layers. NASA Mars Data Analysis Program, Smithsonian Institution subcontract.

**Asmin Pathare.** Laboratory study of the effects of impurities on the flow of icy materials on Mars. NASA Mars Fundamental Research Program, Massachusetts Institute of Technology subcontract.

**Asmin Pathare.** The production and modification of small craters on Mars. NASA Mars Data Analysis Program, University of California Los Angeles subcontract.

**Karly M. Pitman.** Spectral characterization of planetary surface materials. NASA Planetary Geology and Geophysics Program, Jet Propulsion Laboratory subcontract.

**Julie A. Rathbun.** Io in the near-infrared: Observations from New Horizons and comparison to Galileo PPR and NIMS. NASA New Horizons at Jupiter Data Analysis Program.

**Nalin H. Samarasinha.** Comprehensive modeling of Comet 1P/Halley's coma variability and morphology. NASA Planetary Atmospheres Program, Lowell Observatory subcontract.

**Joseph N. Spitale.** A new look at Saturn's non-axisymmetric ringlets and ring edges using combined Cassini and historical data sets. NASA Cassini Data Analysis Program.

**Pasquale Tricarico.** Dust particles orbiting the nuclei of Comet 1P/Halley and other comets: Explaining baffling observations. NASA Planetary Atmospheres Program.

**David T. Vaniman.** Clay mineral – Evaporite associations and the petrogenesis of Mars phyllosilicate occurrences. NASA Mars Science Laboratory Program, NASA Ames Research Center.

**Faith Vilas.** Deputy Chief Scientist/Chief Scientist for the NASA Planetary Data System. NASA Planetary Data System Program.

**Faith Vilas.** Characterizing space weathering on Mercury's surface using MESSENGER experimental data. NASA MESSENGER Participating Scientist Program.

**Stuart J. Weidenschilling.** Formation of extrasolar giant planets by core-nucleated accretion. NASA Origins of Solar System Program, University of California Santa Cruz subcontract.

**Catherine M. Weitz.** Geologic investigation of interior layered deposits in Hebes Chasma and Noctis Labyrinthus. NASA Mars Data Analysis Program.

**Catherine M. Weitz.** Investigation of layered sediments and clays at proposed landing sites in Ladon Valles. NASA Mars Future Landing Site Program, Jet Propulsion Laboratory subcontract.

**Rebecca M.E. Williams.** Fluvial geomorphology laboratory in planetary science. NASA Early Careers Fellowship Program.

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## P S I P U B L I C A T I O N S

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**Artemieva, N., E. Pierazzo** (2011). The Canyon Diablo impact event: 2. Projectile fate and target melting upon impact. *Meteorit. Planet. Sci.* 46, 805-829.

Meyer, C., J. Fritz, M. Misgaiski, D. Stöfler, **N. Artemieva**, U. Hornemann, R. Moeller, J.-P. deVera, C. Cockell, G. Horneck, S. Ott, E. Rabbow (2011). Shock experiments in support of the Lithopanspermia theory: The influence of host rock composition, temperature, and shock pressure on the survival rate of endolithic and epilithic microorganisms. *Meteorit. Planet. Sci.* 46, 701-718.

Thomson, B.J., N.T. Bridges, R. Milliken, **A.M. Baldridge**, S.J. Hook, J.K. Crowley, G.M. Marion, C.R. de Souza Filho, A.J. Brown, **C.M. Weitz** (2011). Constraints on the origin and evolution of the layered mound in Gale Crater, Mars, using Mars Reconnaissance Orbiter data. *Icarus* 214, 413-432.

Wray, J.J., R.E. Milliken, C.M. Dundas, G.A. Swayze, J.C. Andrews-Hanna, **A.M. Baldridge**, M. Chojnacki, J.L. Bishop, B.L. Ehlmann, S.L. Murchie, R.N. Clark, F.P. Seelos, L.L. Tornabene, S.W. Squyres (2011). Columbus crater and other possible groundwater-fed paleolakes of Terra Sirenum, Mars. *J. Geophys. Res.* 116, E01001.

**Balme, M.R.**, C. Gallagher, S. Gupta, J.B. Murray (2011). Fill and spill in Lethe Vallis: A recent flood-routing system in Elysium Planitia, Mars. In *Martian Geomorphology* (M.R. Balme, A. Bargery, C. Gallagher, S. Gupta, Eds.), *GSL Special Publications* 356, pp. 203-227.

**Balme, M.R.**, A. Bargery, C. Gallagher, S. Gupta, Eds. (2011). *Martian Geomorphology*. *GSL Special Publications* 356, 307 pp.

Gallagher, C., **M.R. Balme** (2011). Landforms indicative of ground-ice thaw in the northern high latitudes of Mars. In *Martian Geomorphology* (M.R. Balme, A. Bargery, C. Gallagher, S. Gupta, Eds.), *GSL Special Publications* 356, pp. 87-110.

Aston, A., S.L. Conway, **M.R. Balme** (2011). Identifying Martian Gully evolution. In *Martian Geomorphology* (M.R. Balme, A. Bargery, C. Gallagher, S. Gupta, Eds.), *GSL Special Publication* 356, pp. 151-169.

Cockell, C.S., E. Bagshaw, **M.R. Balme**, P. Doran, C.P. McKay, K. Miljkovic, D. Pearce, M.J. Siegert, M. Tranter, M. Voytek, J. Wadham (2011). Subglacial environments and the search for life beyond the Earth. In *Antarctic Subglacial Aquatic Environments* (M.J. Siegert, M.C. Kennicutt, R.A. Bindaschadler, Eds.). *AGU Geophysical Monograph* 192, pp.129-148.

Gallagher, C., **M.R. Balme**, S.J. Conway, P. Grindrod (2011). Sorted clastic stripes, lobes and associated gullies in high-latitude craters on Mars: Landforms indicative of very recent, polycyclic ground-ice thaw and liquid flows. *Icarus* 211, 458-471.

**Benechi, S.D.**, K.S. Noll, D.C. Stephens, W.M. Grundy, J. Rawlins (2011). Optical and infrared colors of transneptunian objects observed with HST. *Icarus* 213, 693-709.

Grundy, W.M., K.S. Noll, F. Nimmo, H.G. Roe, M.W. Buie, S. Porter, **S.D. Benechi**, J.A. Stansberry, D.C. Stephens, H.F. Levison (2011). Five new and three improved mutual orbits of transneptunian binaries. *Icarus* 213, 678-692.

**Berman, D.C.**, **M.R. Balme**, S. Rafkin, J.R. Zimbelman (2011). Transverse Aeolian Ridges (TARs) on Mars II: Distributions, orientations, and ages. *Icarus* 213, 116-130.

Jones, A.P., A.S. McEwen, L.L. Tornabene, V.R. Baker, H.J. Melosh, **D.C. Berman** (2011). A geomorphic analysis of Hale crater, Mars: The effects of impact into ice-rich crust. *Icarus* 211, 259-272.

**Bishop, M.A.** (2011). SRTM DEM and ASTER GDEM use for the spatial geomorphometric analysis of global sand sea patterns. In *Geomorphometry 2011* (T. Hengl, I.S. Evans, J.P. Wilson, M. Gould, Eds.), pp. 147-151.

**Bishop, M.A.** (2011). Aeolian scours as putative signatures of wind erosion and sediment transport direction on Mars. *Geomorph.* 125, 569-574.

Clarke, J., **M.C. Bourke** (2011). Travertine and tufa from Dalhousie Springs (Australia)—Implications for recognizing Martian springs. In *Analogs for Planetary Exploration* (W.B. Garry, J.E. Bleacher, Eds.), *GSA Special Paper* 483, pp. 231-247.

Gardin, E., **M.C. Bourke**, P. Allemand, C. Quantin (2011). Dune features suggest past dune migration and possible geochemical cementation of aeolian sediments on Mars. *Icarus* 210, 590-596.

**Buxner, S.R.**, M.C. Wenger, E.F.C. Dokter (2011). Exploring assessment tools for research and evaluation in astronomy education and outreach. In *Earth and Space Science: Making Connections in Education and Public Outreach* (J.B. Jensen, J.G. Manning, M.G. Gibbs, Eds.) *ASP Conf. Series* 443, pp. 223-226.

- Buxner, S.R.** (2011). Exploring outcomes for teachers who engage in astronomical research with scientists. In *Earth and Space Science: Making Connections in Education and Public Outreach* (J.B. Jensen, J.G. Manning, M.G. Gibbs, Eds.) ASP Conf. Series 443, pp. 125-134.
- Chamberlain, M.A., M.V. Sykes, E.F. Tedesco** (2011). Mid-infrared lightcurve of Vesta. *Icarus* 215, 57-61.
- Chapman, M.G.**, Ed. (2011). *The Geology of Mars: Evidence from Earth-Based Analogs*. Cambridge University Press, United Kingdom, 460 pp.
- Williams, D.A., L.P. Keszthelyi, **D.A. Crown**, J.A. Yff, W.L. Jaeger, P.M. Schenk, P.E. Geissler, T.L. Becker (2011). Volcanism on Io: New insights from global geologic mapping. *Icarus* 214, 91-112.
- Williams, D.A., L.P. Keszthelyi, **D.A. Crown**, J.A. Yff, W.L. Jaeger, P.M. Schenk, P.E. Geissler, T.L. Becker (2011). Geologic Map of Io, U.S. Geological Survey Scientific Investigations Series Map 3168, scale 1:15,000,000.
- Domingue, D.L.**, S.L. Murchie, B.W. Denevi, N.L. Chabot, D.T. Blewett, N.R. Laslo, R.M. Vaughan, H.K. Kang, M.K. Shepard (2011). Photometric correction of Mercury's global color mosaic. *Planet. Space Sci.* 59, 1873-1887.
- Domingue, D.L.**, S.L. Murchie, N.L. Chabot, B.W. Denevi, **F.Vilas** (2011). Mercury's spectrophotometric properties: Update from the Mercury Dual Imaging System observations during the third MESSENGER flyby. *Planet. Space Sci.* 59, 1853-1872.
- Kerber, L., J.W. Head, D.T. Blewett, S.C. Solomon, L. Wilson, S.L. Murchie, M.S. Robinson, B.W. Denevi, **D.L. Domingue** (2011). The global distribution of pyroclastic deposits on Mercury: The view from MESSENGER flybys 1-3. *Planet. Space Sci.* 59, 1895-1909.
- Feldman, W.C., A. Pathare, S. Maurice, T.H. Prettyman, D. Lawrence, R. Milliken, B. Travis** (2011). Mars Odyssey neutron data: 2. Search for buried excess water ice deposits at nonpolar latitudes on Mars. *J. Geophys. Res.* 116, E11009.
- Maurice, S., **W.C. Feldman**, B. Diez, O. Gasnault, D.J. Lawrence, A. Pathare, **T.H. Prettyman** (2011). Mars Odyssey neutron data: 1. Data processing and models of water-equivalent-hydrogen distribution. *J. Geophys. Res.* 116, E11008.
- Lawrence, D.J., V.R. Eke, R.C. Eplhic, **W.C. Feldman**, H.O. Funsten, **T.H. Prettyman**, L.F.A. Teodoro (2011). Technical Comment on "Hydrogen Mapping of the Lunar South Pole Using the LRO Neutron Detector Experiment LEND." *Science* 334, 1058.
- Ross A., A. Steele, **M. Fries**, L. Kater, H. Downes, A. Jones, C. Smith, P. Jenniskens, M. Zolensky, M. Shaddad (2011). MicroRaman spectroscopy of diamond and graphite in Almahatta Sitta and comparison with other ureilites. *Meteorit. Planet. Sci.* 46, 364-378.
- Brown P., P. McCausland, **M. Fries**, E. Silber, W. Edwards, D. Wong, R. Weryk, J. Fries, Z. Krzeminski (2011). The fall of the Grimsby meteorite – I: Fireball dynamics and orbit from radar, video, and infrasound. *Meteorit. Planet. Sci.* 46, 339-363.
- Garry, W.B.**, J.E. Bleacher, Eds. (2011). *Analogs for Planetary Exploration*. GSA Special Paper 483, 567 pp.
- Garry, W.B.**, J.E. Bleacher (2011). Emplacement scenarios for Vallis Schröteri, Aristarchus Plateau, the Moon. In *Recent Advances and Current Research Issues in Lunar Stratigraphy* (W.A. Ambrose, D.A. Williams, Eds.), GSA Special Paper 477, pp. 77-94.
- Gaskell, R.W.** (2011). Optical navigation near small bodies. In *Spaceflight Mechanics 2011* (M.K. Jah, Y. Guo, A.L. Bowes, P.C. Lai, Eds.), 220 pp.
- Sierks, H., **R.W. Gaskell**, 57 co-authors (2011). Images of Asteroid 21 Lutetia: A remnant planetesimal from the early solar system. *Science* 334, 487-490.
- Oberst, J., S. Elgner, F.S. Turner, M.E. Perry, **R.W. Gaskell**, M.T. Zuber, M.S. Robinson, S.C. Solomon (2011). Radius and limb topography of Mercury obtained from images acquired during the MESSENGER flybys. *Planet. Space Sci.* 59, 1918-1924.
- Goodrich, C.A.**, N.T. Kita, M.K. Spicuzza, J.W. Valley, J. Zipfel, T. Mikouchi, M. Miyamoto (2011). The Northwest Africa 1500 meteorite: Not a ureilite, maybe a brachinite. *Meteorit. Planet. Sci.* 45, 1906-1928.
- Hayden, L.A., J.A. Van Orman, W.F. McDonough, R.D. Ash, **C.A. Goodrich** (2011). Trace element partitioning in the Fe-S-C system and its implications for planetary differentiation and the thermal history of ureilites. *Geochim. Cosmochim. Acta* 75, 6570-6583.
- Basu Sarbadhikari, A., **C.A. Goodrich**, Y. Liu, J.M.D. Day, L.A. Taylor (2011). Evidence for heterogeneous enriched shergottite mantle sources on Mars from olivine-hosted melt inclusions in LAR 06319. *Geochim. Cosmochim. Acta* 75, 6803-6820.
- Portyankina, G., A. Pommerol, K.-M. Aye, **C.J. Hansen**, N. Thomas (2011). Polygonal cracks in the seasonal semi-translucent CO<sub>2</sub> ice layer in Martian polar areas. *J. Geophys. Res.* 117, E02006.
- Pommerol, A., G. Portyankina, N. Thomas, K.-M. Aye, **C.J. Hansen**, M. Vincendon, Y. Langevin (2011). Evolution of south seasonal cap during Martian spring: Insights from high-resolution observations by HiRISE and CRISM on Mars Reconnaissance Orbiter. *J. Geophys. Res.* 116, E08007.
- Thomas, N., G. Portyankina, **C.J. Hansen**, A. Pommerol (2011). Sub-surface CO<sub>2</sub> gas flow in Mars' polar regions: Gas transport under constant production rate conditions. *Geophys. Res. Lett.* 38, L08203.
- Hansen, C.J.**, D.E. Shemansky, L.W. Esposito, I.A.F. Stewart, B.R. Lewis, J.E. Colwell, A.R. Hendrix, R.A. West, J.H. Waite Jr., B. Teolis, B.A. Magee (2011). The composition and structure of the Enceladus plume. *Geophys. Res. Lett.* 38, L11202.
- Thomas, N., G. Portyankina, **C.J. Hansen**, A. Pommerol (2011). HiRISE observations of gas sublimation-driven activity in Mars' southern polar regions: IV. Fluid dynamics models of CO<sub>2</sub> jets. *Icarus* 212, 66-85.
- Hansen, C.J., M.C. Bourke**, N.T. Bridges, S. Byrne, C. Colon, S. Diniega, C. Dundas, K. Herkenhoff, A. McEwen, M. Mellon, G. Portyankina, N. Thomas (2011). Seasonal erosion and restoration of Mars' northern polar dunes. *Science* 331, 575-578.
- Popova, O., J. Borovička, **W.K. Hartmann**, P. Spurný, E. Gnos, I. Nemtchinov, J. Trigo-Todríguez (2011). Very low strengths of interplanetary meteoroids and small asteroids. *Meteorit. Planet. Sci.* 46, 1525-1550.
- Housen, K.R., **K.A. Holsapple** (2011). Ejecta from impact craters. *Icarus* 211, 856-875.
- Irwin, R.P. III**, R.A. Craddock, A.D. Howard, H.L. Flemming (2011). Topographic influences on development of Martian valley networks. *J. Geophys. Res.* 116, E02005.
- Grant, J.A., **R.P. Irwin III**, S.A. Wilson, D. Buczkowski, K. Siebach (2011). A lake in Uzboi Vallis and implications for Late Noachian–Early Hesperian climate on Mars. *Icarus* 212, 110-122.
- Thompson, B.J., S.E. Gibson, P.C. Schroeder, D.F. Webb, C.N. Arge, M.M. Bisi, G. de Toma, B.A. Emery, A.B. Galvin, D.A. Haber, B.V. Jackson, **E.A. Jensen**, R.J. Leamon, J. Lei, P.K. Manoharan, M.L. Mays, P.S. McIntosh, G.J.D. Petrie, S.P. Plunkett, L. Qian, P. Riley, S.T. Suess, M. Tokumaru, B.T. Welsch, T.N. Woods (2011). A snapshot of the Sun near solar minimum: The whole heliosphere interval. *Solar Physics* 274, 29-56.

- Ziegler, L.B., C.G. Constable, **C.L. Johnson**, L. Tauxe (2011). PADM2M: A penalized maximum likelihood model of the 0-2 Ma paleomagnetic axial dipole moment. *Geophys. J. Int.* 184, 1069-1089.
- Monteux, J., M. Jellinek, **C.L. Johnson** (2011). Why might planets and moons have early dynamos? *Earth Planet. Sci. Lett.* 310, 349-359.
- Anderson, B.J., **C.L. Johnson**, H. Korth, M.E. Purucker, R.M. Winslow, J.A. Slavin, S.C. Solomon, R.L. McNutt Jr., J.M. Raines, T.H. Zurbuchen (2011). The global magnetic field of Mercury from MESSENGER orbital observations. *Science* 333, 1859-1862.
- Korth, H., B.J. Anderson, J.M. Raines, J.A. Slavin, T.H. Zurbuchen, **C.L. Johnson**, M.E. Purucker, R.M. Winslow, S.C. Solomon, R.L. McNutt Jr. (2011). Plasma pressure in Mercury's equatorial magnetosphere derived from MESSENGER magnetometer observations. *Geophys. Res. Lett.* 38, L22201.
- Kortenkamp, S.J., E.C.S. Joseph** (2011). Transformation of Trojans into quasi-satellites during planetary migration and their subsequent close encounters with the host planet. *Icarus* 215, 669-681.
- Burnett, D.S., **K.R. Kuhlman**, Genesis Science Team (2011). Solar composition from the Genesis Discovery mission. *Proc. Nat. Acad. Sci.* 108, 19147-19151.
- Dyar, M.D., T.D. Glotch, **M.D. Lane**, B. Wopenka, J.M. Tucker, S.J. Seaman, G.J. Marchand, R. Klima, T. Hiroi, J.L. Bishop, C. Pieters, J. Sunshine (2011). Spectroscopy of Yamato 984028. *Polar Sci.* 4, 530-549.
- Dyar, M.D., J.M. Tucker, S. Humphries, S.M. Clegg, R.C. Wiens, **M.D. Lane** (2011). Strategies for Mars remote laser-induced breakdown spectroscopy analysis of sulfur in geological samples. *Spectrochim. Acta, Pt. B: Atom. Spect.* 66, 39-56.
- Farrand, W.H., **M.D. Lane**, B.R. Edwards, **R.A. Yingst** (2011). Spectral evidence of volcanic cryptodomes on the northern plains of Mars. *Icarus* 211, 139-156.
- Lane, M.D.**, T.D. Glotch, M.D. Dyar, C.M. Pieters, R. Klima, T. Hiroi, J.L. Bishop, J. Sunshine (2011). Midinfrared spectroscopy of synthetic olivines: Thermal emission, specular and diffuse reflectance, and attenuated total reflectance studies of forsterite to fayalite. *J. Geophys. Res.* 116, E08010.
- Marra, A.C., **M.D. Lane**, V. Orofino, A. Blanco, S. Fonti (2011). Midinfrared spectra and optical constants of bulk hematite: Comparison with particulate hematite spectra. *Icarus* 211, 839-848.
- Lebofsky, L.A.**, S.W. Anderson, **L.F. Bleamaster III**, **S.R. Buxner**, **T.L. Cañizo**, **S.K. Croft**, **D.A. Crown**, **S. Kortenkamp**, **E. Pierazzo** (2011). Professional Development Workshops for K-8 Teachers at the Planetary Science Institute. In *Earth and Space Science: Making Connections in Education and Public Outreach* (J.B. Jensen, J.G. Manning, M.G. Gibbs, Eds.) ASP Conf. Series 443, pp. 269-272.
- Petro, N.E., **S.C. Mest**, Y. Teich (2011). Geomorphic terrains and evidence for ancient volcanism within northeastern South Pole-Aitken basin. In *Recent Advances and Current Research Issues in Lunar Stratigraphy* (W.A. Ambrose, D.A. Williams, Eds.), GSA Special Paper 477, pp. 129-140.
- Metzger, S.M.**, **M.R. Balme**, M.C. Towner, B.J. Bos, T.J. Ringrose, M.R. Patel (2011). In-situ measurements of particle load and sediment flux in dust devils. *Icarus* 214, 766-772.
- Bos, B.J., D.J. Scott, **S.M. Metzger** (2011). Habitat dust contamination at a Mars analog. In *Analogs for Planetary Exploration* (W.B. Garry, J.E. Bleacher, Eds.), GSA Special Paper 483, pp. 137-155.
- Che, C., T.D. Glotch, D.L. Bish, **J. Michalski**, W. Xu (2011). Spectroscopic study of the dehydration of phyllosilicate and zeolite minerals. *J. Geophys. Res.* 116, E05007.
- Morghenthaler, J.P.**, W.M. Harris, M.R. Combi, P.D. Feldman, H.A. Weaver (2011). GALEX FUV observations of Comet C/2004 Q2 (Machholz): The ionization lifetime of carbon. *Astrophys. J.* 726, 8.
- Belton, M.J.S., **B.E.A. Mueller**, **N.H. Samarasinha**, 70 co-authors (2011). Stardust-NExT, Deep Impact, and the accelerating spin state of 9P/Tempel 1. *Icarus* 213, 345-368.
- Meech, K.J., **B.E.A. Mueller**, **N.H. Samarasinha**, 55 co-authors (2011). Deep Impact, Stardust-NExT and the behavior of Comet 9P/Tempel 1 from 1997 to 2010. *Icarus* 213, 323-344.
- Meech, K.J., **B.E.A. Mueller**, **N.H. Samarasinha**, 194 co-authors (2011). EPOXI: Comet 103P/Hartley 2 observations from a worldwide campaign. *Astrophys. J. Lett.* 734, L1.
- Noe Dobrea, E.**, **J. Michalski**, G. Swayze (2011). Aqueous mineralogy and stratigraphy at and around the proposed Mawrth Vallis MSL landing site: New insights into the aqueous history of the region. *Mars* 6, 32-46.
- Righter, K., **D.P. O'Brien** (2011). Terrestrial planet formation. *Proc. Natl. Acad. Sci.* 108, 19165-19170.
- Walsh, K.J., A. Morbidelli, S.N. Raymond, **D.P. O'Brien**, A.M. Mandell (2011). A low mass for Mars from Jupiter's early gas-driven migration. *Nature* 475, 206-209.
- Lunine, J.I., **D.P. O'Brien**, S.N. Raymond, A. Morbidelli, T. Quinn, A.L. Graps (2011). Dynamical models of terrestrial planet formation. *Adv. Sci. Lett.* 4, 325-338.
- O'Brien, D.P.**, **M.V. Sykes** (2011). The origin and evolution of the asteroid belt – Implications for Vesta and Ceres. *Space Sci. Rev.* 163, 41-61.
- Palmer, E.**, D.S. Laurotta (2011). Aqueous alteration of kamacite in CM chondrites. *Meteor. Plant. Sci.* 46, 1587-1607.
- Palmer, E.**, R.H. Brown (2011). Production and detection of carbon dioxide on Iapetus. *Icarus* 212, 807-808.
- Velbel, M., **E. Palmer** (2011). Fine-grained serpentine in CM2 carbonaceous chondrites and its implications for the extent of aqueous alteration on the parent body: A review. *Clays and Clay Minerals* 59, 416-432.
- Pitman, K.M.**, A.K. Speck, A.M. Hofmeister, A.B. Corman (2011). Optical properties and applications of silicon carbide in astrophysics. In *Silicon Carbide – Materials, Processing and Applications in Electronic Devices* (M. Mukherjee, Ed.), InTech, pp. 256-282.
- Prettyman, T.H.**, **W.C. Feldman**, H.Y. McSween Jr., R.D. Dingler, D.C. Enemark, D.E. Patrick, S.A. Storms, J.S. Hendricks, **J.P. Morgenthaler**, **K.M. Pitman**, **R.C. Reedy** (2011). Dawn's Gamma Ray and Neutron Detector. *Space Sci. Rev.* 163, 371-459.
- McSween, H.Y., R.L. McNutt, **T.H. Prettyman** (2011). Spacecraft instrument technology and cosmochemistry. *Proc. Natl. Acad. Sci.* 108, 19130-19134.
- Stapels, C.J., E.B. Johnson, X.J. Chen, **T.H. Prettyman**, E.R. Benton, J.F. Christian (2011). Space neutron spectrometer design with SSPM-based instrumentation. *Nucl. Instrum. Meth. Phys. Res.* A652, 342-346.
- Pieters, C.M., L.A. McFadden, **T.H. Prettyman**, M.C. Sanctis, T.B. McCord, T. Hiroi, R. Klima, J.-Y. Li, R. Jaumann (2011). Surface composition of Vesta: Issues and integrated approach. *Space Sci. Rev.* 163, 117-139.
- Brückner, J., **R.C. Reedy**, P.A.J. Englert, D.M. Drake (2011). Experimental simulations of planetary gamma-ray spectroscopy using thick targets irradiated by protons. *Nucl. Instrum. Methods B269*, 2630-2640.

- Herzog, G.F., A. Albrecht, P. Ma, D. Fink, J. Klein, R. Middleton, D.D. Bogard, L.E. Nyquist, C.-Y. Shih, D.H. Garrison, Y. Reese, J. Masarik, **R.C. Reedy**, G. Rugel, T. Faestermann, G. Korschinek (2011). Cosmic-ray exposure history of the Norton County enstatite achondrite. *Meteorit. Planet. Sci.* 46, 284-310.
- Rao, M.N., L.E. Nyquist, D.D. Bogard, D.H. Garrison, S.R. Sutton, R. Michel, **R.C. Reedy**, I. Leya (2011). Isotopic evidence for a Martian regolith component in shergottite meteorites. *J. Geophys. Res.* 116, E08006.
- Herzog, G.F., M.W. Caffee, T. Faestermann, R. Hertenberger, G. Korschinek, I. Leya, **R.C. Reedy**, J.M. Siston (2011). Cross sections from 5 to 35 MeV for the reactions  $\text{natMg}(3\text{He},x)26\text{Al}$ ,  $27\text{Al}(3\text{He},x)26\text{Al}$ ,  $\text{natCa}(3\text{He},x)41\text{Ca}$ , and  $\text{natCa}(3\text{He},x)36\text{Cl}$ : Implications for early irradiation in the solar system. *Meteorit. Planet. Sci.* 46, 1427-1446.
- Rodriguez, J.A.**, J.S. Kargel, K.L. Tanaka, **D.A. Crown**, **D.C. Berman**, A.G. Fairén, V.R. Baker, R. Furfaro, P. Candelaria, S. Sasaki (2011). Secondary chaotic terrain formation in the higher outflow channels of southern circum-Chryse, Mars. *Icarus* 213, 150-194.
- Samarasinha, N.H.**, **B.E.A. Mueller**, M.F. A'Hearn, T.L. Farnham, A. Gersch (2011). Rotation of comet 103P/Hartley 2 from structures in the coma. *Astrophys. J. Lett.* 734, L3.
- Adassuriya, J., S. Gunasekara, **N.H. Samarasinha** (2011). Determination of the solar radius based on the annular solar eclipse of 15 January 2010. *Sun and Geosphere* 6, 17-22.
- Lorenz, R.D., B.K. Jackson, J.W. Barnes, **J. Spitale**, J.M. Keller (2011). Ice rafts not sails: Floating the rocks at Racetrack Playa. *Am. J. Phys.* 79, 37.
- Staid, M.I.**, C.M. Pieters, S. Besse, J. Boardman, D. Dhingra, R.O. Green, J.W. Head, P. Isaacson, R. Klima, G. Kramer, J. Mustard, C. Runyon, J. Sunshine, L.A. Taylor (2011). The mineralogy of late-stage lunar volcanism as observed by the Moon Mineralogy Mapper on Chandrayaan-1. *J. Geophys. Res.* 116, E00G10.
- Nettles, J.W., **M.I. Staid**, S. Besse, J. Boardman, R.N. Clark, D. Dhingra, P. Isaacson, R. Klima, G. Kramer, C.M. Pieters, L.A. Taylor (2011). Optical maturity variation in lunar spectra as measured by Moon Mineralogy Mapper data. *J. Geophys. Res.* 116, E00G17.
- Besse, S., J. Sunshine, **M.I. Staid**, N.E. Petro, J. Boardman, R. Green, J.W. Head, P.J. Isaacson, J. Mustard, C.M. Pieters (2011). Compositional variability of the Marius Hills volcanic complex from the Moon Mineralogy Mapper ( $M^3$ ). *J. Geophys. Res.* 116, E00G13.
- Whitten, J., J.W. Head, **M.I. Staid**, C.M. Pieters, J. Mustard, R.N. Clark, J. Nettles, R.L. Klima, L.A. Taylor (2011). Lunar mare deposits associated with the Orientale Impact Basin: New insights into mineralogy, history, mode of emplacement, and relation to Orientale basin evolution from Moon Mineralogy Mapper ( $M^3$ ) data from Chandrayaan-1. *J. Geophys. Res.* 116, E00G09.
- Hicks, M.D., B.J. Buratti, J. Nettles, **M.I. Staid**, J. Sunshine, C.M. Pieters, S. Besse, J. Boardman (2011). A photometric function for analysis of lunar images in the visual and infrared based on Moon Mineralogy Mapper observations. *J. Geophys. Res.*, 116, E00G15.
- Buratti, B.J., M.D. Hicks, J. Nettles, **M.I. Staid**, C.M. Pieters, J.M. Sunshine, J. Boardman, T.C. Stone (2011). A wavelength-dependent visible and infrared spectrophotometric function for the Moon based on ROLO data. *J. Geophys. Res.* 116, E00G03.
- Kramer, G.Y., S. Besse, J. Nettles, J.-P. Combe, R.N. Clark, C.M. Pieters, **M.I. Staid**, E. Malaret, J. Boardman, R.O. Green, J.W. Head, T.B. McCord (2011). Newer views of the Moon: Comparing spectra from Clementine and the Moon Mineralogy Mapper. *J. Geophys. Res.* 116, E00G04.
- Isaacson, P., C.M. Pieters, S. Besse, R.N. Clark, J.W. Head, R. Klima, J. Mustard, N. Petro, **M.I. Staid**, J. Sunshine, L.A. Taylor, K. Thaisen, S. Tompkins (2011). Remote compositional analysis of lunar olivine-rich lithologies with Moon Mineralogy Mapper ( $M^3$ ) spectra. *J. Geophys. Res.* 116, E00G11.
- Green, R.O., **M.I. Staid**, 52 co-authors (2011). The Moon Mineralogy Mapper ( $M^3$ ) imaging spectrometer for lunar science: Instrument description, calibration, on-orbit measurements, science data calibration and on-orbit validation. *J. Geophys. Res.* 116, E00G19.
- Mustard, J.F., C.M. Pieters, P.J. Isaacson, J.W. Head, S. Besse, R.N. Clark, R.L. Klima, N.E. Petro, M.I. Staid, J.M. Sunshine, C.J. Runyon, S. Tompkins (2011). Compositional diversity and geologic insights of the Aristarchus crater from Moon Mineralogy Mapper data. *J. Geophys. Res.* 116, E00G12.
- Klima, R.L., C.M. Pieters, J.W. Boardman, R.O. Green, J.W. Head, P.J. Isaacson, J.F. Mustard, J.W. Nettles, N.E. Petro, **M.I. Staid**, J. Sunshine, L.A. Taylor, S. Tompkins (2011). New insights into lunar petrology: Distribution and composition of prominent low-Ca pyroxene exposures as observed by the Moon Mineralogy Mapper ( $M^3$ ). *J. Geophys. Res.* 116, E00G06.
- Pieters, C.M., S. Besse, J. Boardman, B. Buratti, L. Cheek, R.N. Clark, J.P. Combe, D. Dhingra, J.N. Goswami, R.O. Green, J.W. Head, P. Isaacson, R. Klima, G. Kramer, S. Lundeen, E. Malaret, T. McCord, J. Mustard, J. Nettles, N. Petro, C. Runyon, **M.I. Staid**, J. Sunshine, L.A. Taylor, K. Theisen, S. Tompkins, J. Whitten (2011). Mg-spinel lithology: A new rock type on the lunar farside. *J. Geophys. Res.* 116, E00G08.
- Bieryla, A., J.W. Parker, E.F. Young, L.A. McFadden, C.T. Russell, S.A. Stern, **M.V. Sykes**, B. Gladman (2011). A search for satellites around Ceres. *Astron. J.* 141, 197-199.
- Vaniman, D.**, S. Chipera, K. Brownholland, D. Bish (2011). The Todilto Formation as an analog of short-lived Martian flood evaporites. In *Analogs for Planetary Exploration* (W.B. Garry, J. Bleacher, Eds.), GSA special paper 483, pp. 219-230.
- Weidenschilling, S.J.** (2011). Initial sizes of planetesimals and accretion of the asteroids. *Icarus* 214, 671-684.
- Weitz, C.M.**, J.L. Bishop, P. Thollot, N. Mangold, L.H. Roach (2011). Diverse mineralogies in two troughs of Noctis Labyrinthus, Mars. *Geology* 39, 899-902.
- Williams, R.M.E.**, A.D. Rogers, M. Chojnacki, J. Boyce, K.D. Seelos, C. Hardgrove, **F.C. Chuang** (2011). Evidence for episodic alluvial fan formation in far western Terra Tyrrhena, Mars. *Icarus* 211, 222-237.
- Williams, R.M.E.**, **R.P. Irwin III**, J.R. Zimbelman, T.C. Chidsey Jr., D.E. Eby (2011). Field guide to exhumed paleochannels near Green River, Utah: Terrestrial analogs for sinuous ridges on Mars. In *Analogs for Planetary Exploration* (W.B. Garry, J.E. Bleacher, Eds.), GSA Special Paper 483, pp. 483-505.
- Yingst, R.A.**, B.A. Cohen, L. Crumpler, M.S. Schmidt, C.M. Schrader (2011). Testing Mars-inspired operational strategies for semi-autonomous rovers on the Moon: The geoheuristic operational strategies test in New Mexico. *Mars* 6, 13-31.
- Yingst, R.A.**, M.E. Schmidt, R.F.C. Lentz, J.L. Janzen, **K.R. Kuhlman** (2011). A Mars-oriented image database of hand lens-scale features and textures: The 1996 Skeiðarársandur jökulhlaup example. In *Analogs for Planetary Exploration* (W.B. Garry, J.E. Bleacher, Eds.), GSA Special Paper 483, pp. 301-315.



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