

## Ancient Subterranean Rivers Caused Largest Floods in the Solar System By Alan Fischer

Gigantic groundwater outbursts 3.2 billion years ago on Mars created the largest flood channels in the Solar System. For many years it was thought that this was caused by the release of water from a global water table, but research led by PSI Senior Scientist J. Alexis P. Rodriguez reveals regional deposits of sediment and ice emplaced 450 million years earlier to be the source.

“The flooding is due to regional processes, not global processes,” said Alexis, lead author of “Martian outflow channels: How did their source aquifers form, and why did they drain so quickly?” that appeared in the Sept. 8 *Nature Scientific Reports* article. PSI Research Scientist Daniel C. Berman is a co-author on the paper.

“Deposition of sediment from rivers and glacial melt filled giant canyons beneath a primordial ocean contained within the planet’s northern lowlands. It was the water preserved in these canyon sediments that was later released as great floods, the effects of which can be seen today.”

The canyons filled, the Martian ocean disappeared, and the surface froze for approximately 450 million years. Then, about 3.2 billion years ago, lava beneath the canyons heated the soil, melted the icy materials, and produced vast systems of subterranean rivers extending hundreds of kilometers. This water erupted onto the now-dry surface in giant floods.

Alexis notes that if these terrains developed in the present European continent, fluvial activity would have eroded most of western Russia. Germany, Switzerland, and Italy would be largely

destroyed by collapse over gigantic subterranean rivers, and Spain and France would be extensively covered by catastrophic flood deposits. (See image below.)

“Our investigation suggests that early Mars sedimentation could have buried and trapped enormous volumes of surface water,



What would happen if Europe experienced these phenomena? The small map (above right) shows uplands on Mars dissected by enormous river canyons, in green, that formed over 3 billion years ago; in yellow, zones of subterranean river erosion; and in blue, lower terrains that contain megaflood channels. In the aerial view above, these mapped areas have been superposed on an oblique view of the European continent; most of western Europe would have been resurfaced by subsidence and megafloods.

Martian views were produced using images from the Context Camera (CTX) on NASA’s Mars Reconnaissance Orbiter; Earth images from USGS, Google Earth.

perhaps triggering the transition into the frozen world that Mars has been during most of its history,” Alexis said. “Evidence for ancient environments capable of sustaining Earth-like life forms could be present in subsurface materials that are now exposed.”

“Because the processes of deposition, freezing, heat-

ing, and eruption were regional, there may be vast reservoirs of water ice that are still trapped beneath the Martian surface along the boundaries of its ancient northern ocean as well as within the subsurface of other regions of the planet where contemporaneous seas and lakes formed,” he said. “This could be critical to the future of human activity on Mars.”

This research was partly funded by a grant to PSI from NASA’s Planetary Geology and Geophysics Program.

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## Retreat 2015 Photo Gallery



At the 11<sup>th</sup> annual PSI retreat in August, 85 members from points scattered around the globe assembled at the Westward Look Resort for the three-day meeting. More than half were off-site scientists and many were new members who took the opportunity to showcase their work. On this page are our newest scientists presenting their research at their first PSI retreat. The official retreat group photo is on the back page.

Thanks to retreat photographers Alan Fischer, Gil Esquerdo, and Kim Kuhlman.



Karen Stockstill-Cahill is from Silver Spring, MD.



John Weirich works at PSI's Tucson headquarters.



Roger Clark's home is in Denver, CO.



Oded Ahronson lives in Pasadena, CA.



Matt Siegler is from Dallas, TX.



Cristina Thomas traveled from her home in McLean, VA. (See introduction article on page 4.)



Henry Hsieh traveled from Taipei, Taiwan, for his first PSI retreat.



Darby Dyar lives in Amherst, MA.



Linda Welzenbach lives in Houston, TX.



Haley Sapers, came from her home in Montreal, Canada.



Zou Xiaoduan came to the retreat from Fairfax, VA.



Juan Sanchez relocated to Tucson to work at PSI. (See introduction article on page 3.)



Ryan Clegg-Watkins came to the retreat from her home in St. Louis, MO.



Paul Weissman lives in Pasadena, CA, and joined PSI in August.

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Front page masthead: This mosaic of the Milky Way galaxy from NASA's Wide-field Infrared Survey Explorer, or WISE, shows dozens of dense clouds, called nebulae. NASA/JPL-Caltech



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Special thanks to Gil Esquerdo, Dianne Janis, Emily Joseph, Victoria Klocko, Carol Neese, and Elaine Owens

## Retreat 2015: After hours

However, it's not all work; PSI hosted various evening events. At the Westward Look Resort we threw a welcome reception the night before the meeting, and after the first day's meeting a rooftop soiree for PSI members and *Friends of PSI*. The festive annual retreat banquet was once again held at the Arizona Inn.

Receiving captain's chairs to commemorate their 10 years at PSI were Bruce Barnett, Kim Kuhlman, Dave O'Brien, Alexis Rodriguez, and Becky Williams. And as the administrator with the longest tenure, Office Manager Elaine Owens was honored for her amazing 25 years at PSI! Well done, all!



Pre-banquet jocularly, l-r: Tim Jull (guest), Tim Swindle (UA), Candace Kohl (PSI Board), Larry Lebofsky (PSI), and Linda Welzenbach (PSI).



At the banquet, Kim Kuhlman sits in the captain's chair marking her 10 years at PSI, which was presented to her by PSI Director Mark Sykes.



At the end of Day 1, PSI hosted a soiree on the rooftop of the Westward Look Resort.



Bob Nelson (PSI) and his wife Peggy Renner. Cheers!



Enjoying the rooftop soiree, l-r: Zao Xiaoduan, Jim McElwaine, Ryan Clegg-Watkins, and Frank Chuang (all PSI).

## Juan Sanchez, A New Face at PSI

In October 2014, Juan Sanchez joined PSI as an Associate Research Scientist, moving to Arizona from Germany to do so. His research focuses on mineralogical characterization of asteroids. As spectroscopy is his area of expertise, most of his work involves the use of ground-based telescopes and analysis of meteorite samples.

He has been interested in science and particularly astronomy for as long as he can remember. When he was in high school, he would skip classes



Juan Sanchez at the European Southern Observatory, La Silla, Chile.

to go to a nearby planetarium, the only place he could share his interest in astronomy with other people. Juan studied physics at the Central University of Venezuela, and during the last two years as an undergraduate, he specialized in astrophysics.

Juan carried out his thesis work at the Centro de Investigaciones de Astronomía, where he studied the effect of the large-scale en-

vironmental density on the mass of central black holes and star formation rate in active galactic nuclei. He changed his research field from extragalactic astrophysics to planetary science as he began working toward his master's degree. This was due to his interest in the origin of life on Earth and the role that minor bodies such as asteroids and comets played in the delivery of water and organic material to our planet.

Juan was awarded a scholarship to study for his Ph.D. at the Max Planck Institute for Solar System Research in Germany. There, he specialized in visible and near-infrared spectroscopy of asteroids. As part of this work, he had the opportunity to carry out observations using different telescopes around the world. He obtained and used spectra of asteroids for taxonomic classification and to determine the composition of these objects. Juan's research also focused on studying the effect that temperature variations and phase angle have on the spectra of asteroids and meteorite samples.

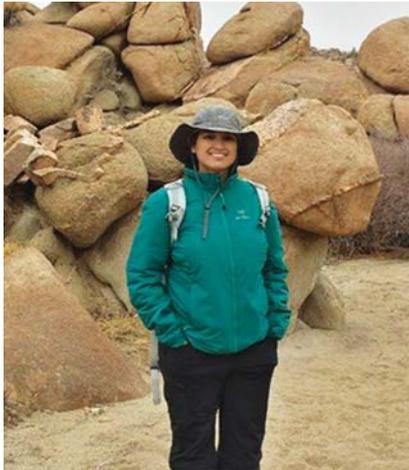
After obtaining his Ph.D. at the Westfälische Wilhelms-Universität Münster in Germany, Juan worked as a postdoctoral research scientist at the Max Planck Institute for Solar System Research. During the last years he has been studying near-Earth asteroids, trying to find the source region of these objects and identifying their meteorite analogs.

When he is not working he enjoys reading, digital drawing, and caring for his Chinese elm bonsai.

PSI is proud to welcome Juan to our science staff!

## Meet Cristina Thomas

Cristina Thomas joined PSI in April 2015 as a Research Scientist. Her work focuses on using visible and near-infrared spectroscopy



**Cristina Thomas at Joshua Tree National Park, CA.**

from ground-based observatories to study the compositions of asteroids, determine meteorite analogs for these asteroids, and understand how the space environment changes the spectral signatures of certain objects through a process called space weathering.

Cristina grew up in southern California and was interested in astronomy and geology from a young age. If she wasn't trying to find Orion in the very bright LA basin sky, she was collecting rocks. She also read a lot of science fiction and particularly loved Star Wars; she was absolutely a planetary scientist in the making.

Cristina grew up in southern California and was interested in astronomy and geology from a young age.

As an undergrad at Caltech, Cristina found that traditional astronomy coursework and research did not involve any study of the Solar System. Fortunately, she quickly discovered the planetary science program, which was wonderfully interdisciplinary. She was instantly hooked. Cristina graduated in 2004 and started

graduate school in the Department of Earth, Atmospheric and Planetary Sciences at MIT. In graduate school, she developed a method to connect ordinary chondrite meteorites to their likely Main Belt source regions. In her spare time, she also stage managed many productions of the MIT Musical Theatre Guild. She received her Ph.D. in 2009.

Cristina's first postdoctoral position was at Northern Arizona University where she led ground-based spectroscopy surveys of near-Earth asteroids in support of a large Warm Spitzer program. It was her first time living in a place with dark skies and she took the chance to volunteer with Lowell Observatory's public program where she learned to operate the historic Clark 24" telescope. Cristina moved to the Washington, D.C. area in 2012 for a NASA Postdoctoral Program Fellowship at Goddard Space Flight Center. She joined PSI as her NASA postdoctoral position was ending, and she continues to have an office at GSFC and live in Arlington, VA.

Currently, she is working on a spectral survey of three Main Belt asteroid families to search for evidence that the parent bodies of the families melted and differentiation occurred. She is also a Co-Investigator on the Mission Accessible Near-Earth Object Survey (MANOS), a collaborator on the OSIRIS-REx mission, and the lead of a Solar System science focus group on near-Earth object observations with the upcoming James Webb Space Telescope. In her spare time Cristina enjoys long-distance running, musical theater, photography, adding stamps to her National Parks passport, hiking, dreaming of Southern California, traveling, and Star Wars.

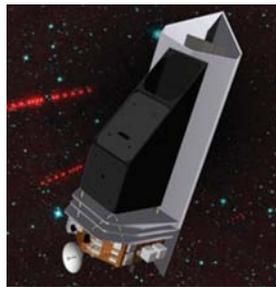
We are delighted that Cristina has joined PSI!

## Four NASA Missions Would Have Ties to PSI

by Alan Fischer

PSI researchers are working on four of five Discovery missions selected for further consideration by NASA. One or two of the missions will be selected for flight opportunities as early as 2020.

Each of the five teams selected will receive \$3 million to conduct concept design studies and analyses. After a detailed review and evaluation of the concept studies, NASA will make the final selections by September 2016 for continued development leading up to launch. Any final selected mission will cost approximately \$500 million, not including launch vehicle funding or the cost of post-launch operations.



**The NEOCam space telescope will survey the regions of space closest to Earth's orbit, where potentially hazardous asteroids are most likely to be found. (Image credit: NASA/JPL-Caltech)**

Three PSI researchers – Mark Sykes, Vishnu Reddy, and Tommy Grav – will serve as Co-Investigators on the Near Earth Object Camera (NEOCam) mission, which would potentially discover 10 times more near-Earth objects than all NEOs discovered to date.

PSI Senior Scientist David Grinspoon is a Co-Investigator on the Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) mission. DAVINCI would study the chemical composition of Venus' atmosphere during a 63-minute descent. It would answer scientific questions that have been considered high priorities for many years, such as whether there are volcanoes active today on the surface of Venus and how the surface interacts with the atmosphere of the planet.

PSI Senior Scientist Thomas Prettyman is a Co-Investigator and member of the gamma ray and neutron spectrometer team on the Psyche mission that would explore the origin of planetary cores by studying the metallic asteroid Psyche. This asteroid is likely the survivor of a violent hit-and-run with another object that stripped off the outer, rocky layers of a protoplanet.

PSI Senior Scientist Darby Dyar is a Co-Investigator on the Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS) team that would fly a shorter-wavelength radar instrument to map Venus again at much higher resolution over the course of three Venus years.

*Created in 1992, the Discovery Program sponsors cost-capped Solar System exploration missions with highly focused scientific goals. It has funded and developed 12 missions to date, including MESSENGER, Dawn, Stardust, Deep Impact, Genesis and GRAIL, and is currently completing development of Insight.*

## Director's Note

Lately, PSI IT Manager Terrill Yuhas and I have been working on the PSI website staff pages to better showcase our scientists. Now everyone inside and outside the Institute can more easily find the people who study specific objects or have worked on specific missions, etc. This task has left me with a profound sense of who we are as an Institute after a decade of massive growth.

We had about 15 PhDs when I joined PSI 11 years ago. Today we have more than 100. They've come from universities, the private sector, government laboratories, and NASA centers. We have scientists late in their careers, some just starting out, and the full range in between. PSI today is an extraordinary community. Our collective experience, skills, and ambitions are simply amazing. I invite everyone in the Institute and anyone who wants to know about us to click through the individual staff pages and know that each page is merely a thumbnail sketch of a remarkable person.

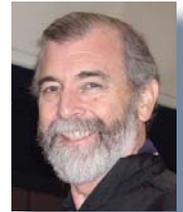
We have people who have contributed to the entire history of modern Solar System exploration stretching back to the 1960s, when we did not know what the back side of the Moon looked like, much less any planetary surface other than Earth. Some were involved with the Apollo missions, the first robotic missions to orbit Mars, the Pioneer and Voyager spacecraft making the first reconnaissance of our Solar System, Galileo to Jupiter, Cassini to Saturn, New Horizons to Pluto and beyond. Our people

have scoured the surface of Mars with orbiters and rovers. Going forward, our scientists are supporting four of the five missions selected for Phase A study by NASA (see page 4), of which hopefully two will be selected for flight, and we are involved with both Mars 2020 and Europa Clipper for the next decade.

Beyond missions, PSI scientists have done field work on every continent on Earth, from the Arctic to Antarctica, from the deserts of South America to mud volcanos in Indonesia and dune fields in Africa. They have mapped worlds, created origin stories for the Moon, and the dynamical evolution of the Solar System. They have taken the richness of all the data that has been collected over the decades and transformed planetary science into comparative planetology. And every person in this Institute has a story worth telling.

The Division for Planetary Science of the American Astronomical Society has started collecting oral histories of scientists at their recent national meeting. They spoke to about eight out of 800 attendees. When I read our staff pages, I wish there was some way to capture the past and future histories of all of the scientists who have come together at PSI. We are in an exciting and challenging business in challenging times and I think everyone here is an inspiration.

*Mark V. Sykes  
December 2015*



## Congratulations, PSI Scientists!



On Nov. 1, PSI Senior Scientist **R. Aileen Yingst** was honored as a Geological Society of America Fellow for her significant research in planetary geology, her leadership in multiple planetary missions, her work in training the next generation of planetary geoscientists through a decade of leadership in

NASA's Space Grant Program, and for contributing to the public awareness of planetary geoscience.

Aileen was involved with the Mars Pathfinder and Mars Polar Lander missions. She was a Participating Scientist on the Mars Exploration Rovers and the Dawn mission when it was at Vesta and is currently a Dawn Associate studying Ceres. She is very involved with the Mars Science Laboratory, Curiosity, as a Co-Investigator on the Mast Camera (Mastcam) and Mars Descent Imager (MARDI), and she is the Deputy Principal Investigator for the Mars HandLens Imager.

PSI Senior Scientist **Natasha Artemieva** received the 2015 Barringer Award in July at the Meteoritical Society meeting in Berkeley, Calif., for her "seminal contributions to the understanding of dynamic impact cratering physics and chemistry."



Natasha studied the effect of terrestrial impact ejecta layers on climate, for which she modeled the Yucatan's Chicxulub crater and thermal radiation from its ejecta, concluding with her colleagues that fires arising from such radiation cannot be responsible for plant extinctions at that time.

She has explored the origin and distribution of lunar water, tracking the volatile transport in the transient atmosphere generated after a comet impact, with a focus on the accumulation of water in polar cold traps. She has also studied the Russian Chelyabinsk meteorite fall, modeling the observed smoke train to better understand the puzzle of the very low recovered mass, and has written a popular article on the event.

PSI Senior Scientist **Joe Spitale**, was elected to the American Astronomical Society's Division for Planetary Sciences Committee. His three-year term began Nov. 2015.



## PSI Staff News...It's a boy!

Giovanni Angelo Balistreri, first child of Tina and **Maui Balistreri** (PSI Controller) was born on October 14, 2015, in Tucson, AZ.

Vital statistics: weight: 7 lb, 9 oz;  
length: 19.75 in; charm: off the charts!

**Bravo, Ladies and Gentlemen!**



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**PSI Retreat 2015**



PSI at retreat, l-r, **Row 1 (seated)**: Bob Tokar, Elaine Owens, Tommy Grav, Haley Sapers, Ryan Clegg-Watkins, Linda Welzenbach, Candace Kohl, Steve Kortenkamp, Bob Reedy. **Row 2**: Mark Sykes, Beatrice Mueller, Amanda Hendrix, Melissa Lane, Hanna Sizemore, Darby Dyar, Cristina Thomas, Victoria Klocko, Rose Early, Chris Holmberg, Kelly Yoder, Gil Esquerdo. **Row 3**: Jeff Morgenthaler, Amara Graps, Roger Clark, Sarah Andre, Kathi Gardner, Bill Feldman, Bob Gaskell, Julie Rathbun. **Row 4**: Joe Spitale, Bryan Travis, John Weirich, Andy Nelson, Matt Siegler, Frank Chuang, Candy Hansen, Maui Balistreri, Paul Weissman, Carol Neese, Henry Hsieh, Kim Kuhlman, Tami Rogers. **Row 5**: Alan Fischer, Pasquale Tricarico, Jesse Stone, Joe Alexander, Liz Jensen, Dave Vaniman, Larry Lebofsky, Alice Baldrige, Jim Rice, Dave O'Brien, Shawn Wright, Stu Weidenschilling. **Back row**: Anthony Villari, Ed Tedesco, Eric Palmer, Faith Vilas, Luke Sollitt, Bob Nelson, Karen Stockstill-Cahill, Thomas Platz, Jules Goldspiel, Oz Pathare, Jim McElwaine, Alexis Rodriguez, Yuki Yamashita, Emily Joseph, Thea Cañizo. More retreat pictures on pages 3 & 4. Photo by Gil Esquerdo.