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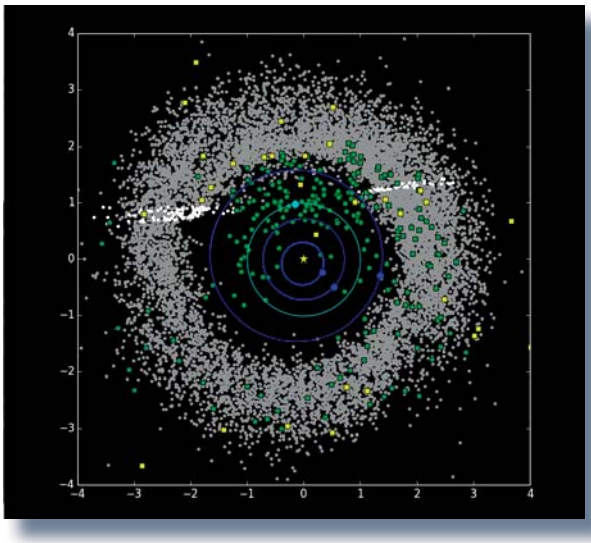
NEOWISE! A Yearlong Look at the Sky *by Alan Fischer*

NASA's Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) spacecraft discovered and studied the physical properties of 44 near-Earth objects (NEOs) and observed many others — including a comet that became January's brightest — since the mission was restarted in December 2013. Eight of the



This wreath of colored dots represents the discoveries of NASA's NEOWISE survey since its restart in December 2013. Each dot represents an asteroid or comet observed by the mission. Green dots represent near-Earth objects (asteroids and comets that come within 1.3 astronomical units (AU) of the sun; one AU equals Earth's distance from the sun). Yellow squares represent comets. Gray dots are all other asteroids, mostly in the main asteroid belt between Mars and Jupiter. The white line is an artifact of the display. The orbits of Mercury, Venus, Earth, and Mars are shown. Credit for images: NASA/JPL

discoveries have been classified as potentially hazardous asteroids (PHAs), based on their size and how close their orbits could come to Earth's orbit.

PSI Senior Scientist **Tommy Grav** is involved in day-to-day operations of the mission and is part of the team that detects and analyzes the moving objects in the images.

"NEOWISE continues to be a work-horse for detecting asteroids and comets, providing data on more than 10,000 objects over the last year," Grav said. "These data are key to better understanding the physical and dynamical properties of the small bodies in our Solar System, especially the Near-Earth asteroid population."

The mission has further observed and characterized over 250 previously known near-Earth objects. From December 2013 to December 2014, NEOWISE discovered three new comets and observed 32 others. One of the others turned into the brightest comet in Earth's night sky in early 2015, Comet C/2014 Q2 (Comet Lovejoy, below).

NEOWISE observed Comet Lovejoy in January 2015.

NEOWISE always looks in the dawn and twilight skies — the direction perpendicular to a line between Earth and the Sun. This unique vantage point makes it easy for NEOWISE to spot NEOs that get particularly close to Earth.

Originally called the Wide-field Infrared Survey Explorer (WISE), the spacecraft was placed in hibernation in 2011 after its primary mission was completed. In September 2013, it was reactivated, renamed NEOWISE, and assigned a new mission to identify the population of potentially hazardous near-Earth objects. It is also studying previously known asteroids and comets to provide information about their sizes and compositions.

NEOWISE is a space telescope that scans the skies for asteroids and comets. The telescope sees infrared light, which allows it to pick up the heat signature of asteroids and obtain better esti-

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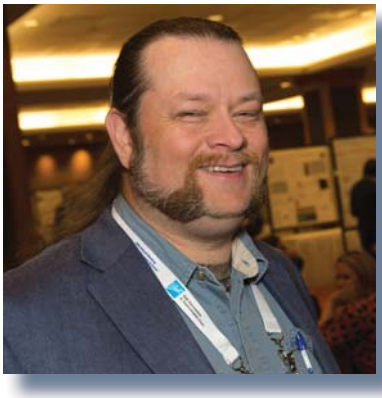
Inside this issue:

Meet NEOWISE Scientist, Tommy Grav

(In his own words)



We have enjoyed working with Tommy Grav since he joined PSI in 2011 as a Research Scientist; in 2014 he was promoted to Senior Scientist. Here is his account of his science journey so far:

I grew up in southern Norway and studied astronomy at the University of Oslo. I was fortunate enough to have been awarded a Smithsonian pre-doctoral Fellowship, which allowed me to do my doctoral thesis research at the Harvard-Smithsonian Center for Astrophysics in Cambridge, MA.

At the Harvard-Smithsonian Center, I worked on understanding the physical and dynamical properties of the irregular satellites of the giant planets in our Solar System and their implication for early planetary formation and migration. I graduated in the fall of 2004 and moved to the Institute for Astronomy, University of Hawaii, as a junior scientist on the Pan-STARRS project. There I worked with the Moving Object Processing System (MOPS) team, developing and testing the software needed to discover and track new and known asteroids in the Pan-STARRS survey data. Pan-STARRS is now the world's leading survey telescope, finding 40 percent of the new near-Earth objects discovered each year.

In 2008, I joined Johns Hopkins University as an Associate Research Scientist to help the faculty take full advantage of their new status as a partner in the Pan-STARRS 1 Science Consortium. While there I was approached by a team of scientists working on the Wide-field Infrared Survey Explorer (WISE). They wanted to use this NASA Astrophysics mission, which was launched in late 2009, to discover and track asteroids found in their survey data.

I joined their NEOWISE team and helped develop and test a modified version of the Pan-STARRS MOPS framework to work on the WISE data, termed WMOPS. Using WMOPS we were able to observe 150,000 asteroids, including more than 30,000 new discoveries. Since the satellite observes the asteroids and comets in the infrared, seeing essentially heat, rather than optical light, this mission provided the largest catalog of sizes and albedos of asteroids known to date.

The satellite operated for a little more than a year before it was put into hibernation, but we continued to analyze the enormous data set, deriving new models and estimates for the risk associated with Potentially Hazardous Asteroids (PHAs), understanding the physical and dynamical properties of the different asteroid populations, and providing new insights into the origins and evolution of our Solar System. In late 2013 we were able to again secure funding to bring the WISE spacecraft back to life, now called NEOWISE.

This extended mission is expected to last three years; the first year has allowed us to observe more than 250 near-Earth objects (NEOs), including 44 new discoveries. Together with the data from the primary mission in 2010, we have now derived physical properties for more than 750 NEOs (almost 10 percent of the known NEO population). This is key in further understanding the risk and possible threats this population poses to our planet.

Having always been interested in nature and how things work made becoming a scientist a pretty natural step. As a kid, I leaned more towards history and fantasy than science or science fiction. While I was working on my master's thesis in fluid dynamics, I took an introductory astronomy course and was able to go to La Palma, Spain, to use the 2.5m Nordic Optical Telescope. As they say, the rest is history!

My heritage is Norwegian; I come from a long line of fishermen and farmers in the south of Norway and it is something I am very proud of. As my family's first American immigrant, my small claim to fame is that I am the only Norwegian to have discovered a moon on another planet: the moon Sao around Neptune. I am also one out of only 15 Norwegians who has an asteroid named after them, joining such names as Fritjof Nansen, (853) Nansenia; Roald Amundsen, (1065) Amundsenia; and Thor Heyerdahl, (2473) Heyerdahl.

When I am not working, I enjoy time with my family, woodworking, and birding. My main passion currently is birdwatching, chasing species across America, which works great with the large amounts of travel involved in astronomy. I have seen White-Crowned Pigeons in the Florida Keys, the Pacific Wren in Arizona, the Black Oystercatcher in California, the Snowy Owl in Indiana and the Caspian Tern in Maryland.

Photo of Tommy Grav by Henry Throop

NEOWISE! A Yearlong Look at the SKy! *(cont'd)*

mates of their true sizes. As a result, NEOWISE can see dark asteroids that are harder for visible-light surveys to find. Nearly all of the NEOWISE discoveries have been large (hundreds of yards, or meters, wide) and very dark, similar to printer toner. When NEOWISE's infrared data on an object is combined with that of a visible-light optical telescope, it helps scientists understand the object's composition.

NASA's Jet Propulsion Laboratory in Pasadena, CA, manages the NEOWISE mission for NASA's Science Mission Directorate in Washington D.C. For more information about NEOWISE, visit: http://www.nasa.gov/neowise

A video depicting the asteroids and comets seen in the past year by NEOWISE is online at: http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA19101

Images of Comet Lovejoy from NEOWISE are at: http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA19102 More information about asteroids and near-Earth objects is at: http://www.jpl.nasa.gov/asteroidwatch

Frontpage masthead : View of Earth from the International Space Station.
Credit: NASA/JPL

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Alan Fischer, Writer and Photographer
Special thanks to Gil Esquerdo, Dianne Janis, Emily Joseph, Carol Neese, and Elaine Owens

Maria Banks: *Have Harp, Will Travel*

In April 2014, Maria Banks joined PSI as a Research Scientist working offsite from New York City. Ever since she was a child growing up in Syracuse, NY, her two loves have been science and music. When she wasn't hunting for fossils or collecting rocks to hide under her bed, she was learning to play the piano and the harp. She played her first gig on the harp when she was 13 years old, and at the age of 17 made her debut as a concerto soloist with the Syracuse Symphony Orchestra.

While working on an undergraduate degree in Fine Arts at the University of Arizona ("they have a wonderful harp department!"), Maria noticed a flier advertising the National Space Grant College and Fellowship program. She applied and began an internship with Dr. Robert Strom, working with radar images of Venus from the Magellan Mission. This was her first real exposure to planetary geology specifically and she became thoroughly fascinated.

Maria during fieldwork in Alaska.

Before venturing on to graduate school to pursue this new direction, Maria decided to first explore the geology of our own planet. She spent the next several years performing as a harpist on cruise ships, visiting six continents and completing three world cruises. Maria would typically perform in a lounge at the top of the ship surrounded by windows where she could watch in awe as they sailed past glaciers, volcanoes, and other natural wonders. One of her favorite experiences was sailing through the gorgeous scenery of the narrow Norwegian Fjords. During her time off, Maria would climb mountains, hike deserts, trek over glaciers, and race to any geologic feature she could find, collecting samples and taking pictures of landforms she hadn't even learned about yet.

Returning to life on land, Maria moved to New York City where she performed in Broadway shows and other freelance music work to support herself while working towards a Bachelor of Science at Queens College, City University of New York.

She found her way back to the University of Arizona and completed her Ph.D. in 2009 with her advisor Dr. Alfred McEwen. During her graduate work, she had the pleasure of working with the science teams for the High Resolution Imaging Science Experiment (HiRISE) onboard Mars Reconnaissance Orbiter (MRO), the Mercury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission, and the education and public outreach and public affairs teams for the Phoenix Mars Mission.

After graduate school, Maria accepted a position as a Postdoctoral Fellow at the Center for Earth and Planetary Studies (CEPS) at the Smithsonian Institution National Air and Space Museum. While at CEPS, she continued working with HiRISE and MESSENGER and began working with the science team for the Lunar Reconnaissance Orbiter Camera (LROC) onboard the Lunar Reconnaissance Orbiter (LRO).

During this time, she was also able to add the final continent to her list, Antarctica. She joined the West Antarctic Ice Sheet (WAIS) Ice Core Project and lived and worked at the WAIS Divide field site as a science technician collecting, documenting, and completing preliminary analyses of ice cores (and she even brought a harp with her!).

Maria Banks in Antarctica with her little lap harp.

While pursuing her studies and research, Maria has kept busy with musical activities with the Arizona Opera Company, Rochester Philharmonic, Radio City Christmas Spectacular Orchestra, and the West Australia Symphony Orchestra. She has performed in venues such as Kasals Hall in Japan, Wachovia Center (with Kanye West), Carnegie Hall, Lincoln Center, Eastman Theater, Perth Concert Hall, Rockefeller Center, Radio City Music Hall, and the famous NYC jazz club, Birdland, to name a few.

In New York City, Maria works on her science research out of her little Manhattan apartment in Hell's Kitchen by day, and by night, she continues to perform in shows on and off Broadway. She is the full-time harpist for "The Fantasticks," and tours as a vocalist and harpist with the Celtic group Four Celtic Voices.

Her research interests include the study of glaciers and ice sheets on Earth and Mars, the measurement of migration rates for sand dunes and ripples on Mars' surface, the morphology of new dated impact events on Mars and implications for the expected seismic response of Mars to these events, and the study of tectonic features, specifically lobate scarps, i.e., thrust faults, on the Moon and Mercury.

We are delighted that Maria has joined PSI's science staff!

Faith Vilas on Japanese TV

In January, a film crew from NHK Japan TV visited PSI to interview Senior Scientist Faith Vilas. The interview appeared Feb. 12 — in Japan only — on NHK's weekly space science program "Cosmic Front."

The crew spent three days interviewing Faith for a story about her research on 1999 JU3, the target asteroid for the Hayabusa 2 mission that just launched. The episode was titled "New Challenge to an Asteroid: Hayabusa 2." The crew consisted of producer Shuji Tachikawa, cameraman Takehiro Mori, soundman Kota Endo and production coordinator Akira Banchi. *Photo: Alan Fischer*

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Director's Note

As a member of the Dawn team since the late 1990s, I would like to share some of the feelings and perspective I feel as Dawn approaches the dwarf planet Ceres.

Dawn was actually the fifth Discovery proposal submitted by our team, which used solar electric propulsion instead of chemical thrusters. We were rejected the first four times in part because the technology was considered too risky. After the thrill of being selected to send Dawn to Vesta and Ceres, we also had the unpleasant experiences of being cancelled, twice, but managed each time to rise from the dead.

We launched in 2007 and finished a very successful year studying the large protoplanetary asteroid Vesta (which I have written about before and will not dwell on here). We departed Vesta in 2012.

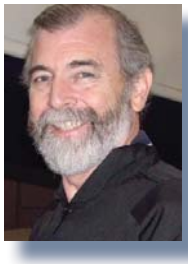
Since the time we submitted the Dawn proposal, we have learned from Hubble observations that Ceres is the only large object in the asteroid belt whose shape is dominated by its gravity, making it a dwarf planet. Thermal evolution models of its interior suggest that it may contain oceans that exist today. Then last year it was announced that the Herschel Space Observatory detected episodic water vapor at two longitudes near Ceres' surface. Could this be evidence of the predicted subsurface oceans?

Ceres is the first planetary body being visited by a spacecraft for the first time since Voyager 2 passed Neptune in 1989. Ceres is the innermost dwarf planet, the rest residing in the outer Solar System beyond Neptune. This July, the New Horizons spacecraft will fly by the double dwarf planet Pluto-Charon.

Dwarf planets are the most common type of planet in our Solar System — perhaps the universe. Being a planet means that we expect to see evidence not just of things hitting the surface, but evidence of interior processes as well. Even at a distance of 46,000 km, Ceres does not disappoint.

We have been watching in particular a "bright" spot, first detected by Hubble, getting closer and closer, but even at a camera resolution now of 4 km/pixel, we have yet to resolve it (see the picture on the next page). Calculations of its reflectivity have increased to the point that we are now hypothesizing that it may be the first evidence of cryovolcanism — heavily mineralized water erupting on the surface and sublimating, leaving behind the kind of white material we see around geysers at Yellowstone National park. We also see a dimmer companion spot that may have a similar origin. Dawn will eventually get down to an altitude of only 374 km and a resolution of 35 m/pixel, allowing us to answer these questions.

If this is the "smoking gun" for the existence of a subsurface ocean, a future mission to the Ceres surface could allow us to answer one of the fundamental questions in Solar System exploration: Does water equal life? It could lead to the most important discovery in human history.



Whether or not this is the case, Ceres is a new world — a new kind of planet — and each image raises new questions. As a scientist, it is a thrilling experience for which my colleagues and I are deeply grateful.

Mark V. Sykes
February 2015

PSI Staff News

Award for Carol Neese

In January, NASA recognized contributions that **Dr. Carol Neese** has made to the Planetary Data System (PDS) project with an award for participation in the PDS4 development project (revised rules for archiving data).

Carol worked on organizing the archiving of the first PDS4 data in PDS, the LADEE lunar dust experiment, and is also involved in planning future PDS4 archiving for missions such as OSIRIS-REx. PDS is the project to preserve data from planetary missions for future studies. Carol is a mainstay of the Small Bodies Node at PSI, a part of the PDS, and is instrumental to our success in this long running project.

Well done, Carol!

Congratulations to our Newest PSI Parents!

Elisabeth Adams has a boy!

PSI Associate Research Scientist **Elisabeth Adams** and her husband Jonathan Foster had their first child, a baby boy, on February 18, 2015. His name is Calvin Jonathan Foster-Adams, he weighed 6 lbs, 4 oz, and measured 20 inches.

It's a boy for Michael Wendell, too!

PSI Software Developer **Michael Wendell** and his wife Dana had their second child, Luke Wendell, September 16, 2014. Their newborn son weighed in at 8 lbs, 11 oz.

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Dawn Zeroing in on Dwarf Planet Ceres

by Alan Fischer

NASA's Dawn spacecraft continues to close in on the dwarf planet Ceres and has obtained images of more than half of Ceres using its framing camera. Scientists at PSI and elsewhere have been studying these images of Ceres and have been able to discern all of the features (bright and dark areas) identified by Hubble and observed by Dawn.

"Reproducing the Hubble observations is important to understanding the nature of Ceres' surface," said PSI Research Scientist Jian-Yang Li, who led the Hubble mapping effort of Ceres. "The recent detection of episodic water vapor near Ceres' surface by the Herschel Space Observatory at a longitude observed by Dawn might arise from activity that could change Ceres' surface over time."

In addition to confirming the Hubble observations, other features are also becoming visible. "Already, the (latest) images hint at first surface structures such as craters," said Andreas Nathues, lead investigator for the framing camera team at the Max Planck Institute for Solar System Research, Gottingen, Germany.

There are also indications that at least one large extended structure might exist. "If it is tectonic, it should provide insight into the interior processes of this small planet," said Mark Sykes, CEO of the Planetary Science Institute and a co-investigator on the mission. "Models of Ceres interior suggest there could be subsurface oceans and an outer ice-rich layer."

The images Dawn captured of Ceres on February 12 exceeded the resolution of the Hubble images. "We are brimming with questions and excitement as we move closer and closer to this new world," Sykes said.

View of Ceres taken by NASA's Dawn spacecraft on Feb 19. from a distance of 29,000 miles, showing a bright spot next to a dimmer spot which may be evidence of cryovolcanism. *(NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)*

Dawn will be captured by Ceres' gravity on March 6, 2015, marking the first time a spacecraft has ever orbited two solar system targets. Dawn orbited and studied the protoplanet Vesta for 14 months. Both Vesta and Ceres are located in the asteroid belt between Mars and Jupiter. Ceres is the largest object in the asteroid belt, with a diameter of about 950 km, and is the only object that is round as a consequence of its own gravity, making it a dwarf planet.

See more images of Ceres at http://www.psi.edu/news/ceresopnav1 .

The Dawn mission to Vesta and Ceres is managed by NASA's Jet Propulsion Laboratory for NASA's Science Mission Directorate. The framing cameras have been developed and built under the leadership of the Max Planck Institute for Solar System Research and are funded by Max Planck Society, DLR, and NASA. The Planetary Science Institute operates Dawn's Gamma Ray and Neutron Detector instrument.