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ANNUAL REPORT 2017

OUR MISSION

The Space Science Institute is shaping our future by enabling scientists to advance our understanding of Earth and the Universe; increasing science and technology literacy for people of all ages and backgrounds; and inspiring youth to pursue science-technology education and career opportunities.

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MESSAGE FROM THE CHAIRMAN OF THE BOARD OF DIRECTORS

During my tenure on the Board of Directors, I have had the pleasure of watching the Space Science Institute truly raise the bar for science and for communities. While the external funding environment for nonprofits, science, and education remains a challenging one, SSI's resilience and determination have propelled it to take on and successfully execute high quality and high impact projects that will be long remembered.

In addition to supporting landmark 2017 events such as the total solar eclipse and Cassini's Grand Finale, SSI made great progress on future directions laid out in its 2017-2019 Strategic and Operations Plans. SSI hosted its first major workshop on space plasma physics, added the Center for Polarimetric Remote Sensing to its list of prestigious research centers, and built to a record number of approximately 70 scientists conducting diverse and compelling research. 2017 also brought 561,662 visitors to our traveling exhibits, 7500 and counting members of our *STAR Net* library community, and over 3 million visitors to our informal STEM education websites. That degree of progress is a testament to the commitment of our partners, donors, volunteers, and our staff.

In 2017, Madeleine Zeigler completed her last year on our Board. With her strong background in increasing science literacy for underrepresented minorities, Maddie was an amazing advocate for our informal STEM education programs and we thank her for her many terms of service for SSI. We also welcomed a new member of our Board, Dr. Jack Burns, Professor and Vice President Emeritus for Academic Affairs and Research at the University of Colorado. Jack's experiences in his distinguished career in astronomy and management, coupled with his first hand knowledge of space industry trends from his government advocacy, will surely benefit SSI in the years to come, and we are happy to have him aboard.

As we move forward in 2018 and beyond, I am proud of what SSI accomplished in 2017 and excited about the future. Our community is strong and vibrant, and together we will continue our efforts to "move the needle" on scientific discoveries, literacy, and engagement.

William R. Purcell, Ph.D.

'Our Mission' Image Credit: James Harold, SSI

MESSAGE FROM THE EXECUTIVE DIRECTOR

On behalf of the scientists, educators, and staff at Space Science Institute, it gives me great pleasure to present this year's annual report.

We were fortunate to be at the forefront of two major astronomy events in 2017: the August 21 total eclipse of the Sun and Cassini's Grand Finale.

SSI's National Center for Interactive Learning, with generous support from NASA, the Moore Foundation, Google, and the Research Corporation, sent out 2.1 million eclipse viewing glasses to thousands of public libraries across the U.S. This reached more people than any other educational effort for the 2017 eclipse. The most impressive part of this (other than when the attention drawn by CNN crashed our servers!) is that fewer than 10 people at SSI coordinated this major effort. Our scientists and STEM educators went on location to viewing sites across the nation and shared their knowledge of the event with onlookers. The eclipse was worth the wait; its beauty surprised professional and amateur astronomers alike.

September 15, 2017 marked the end of one of NASA's most enduring and endearing missions: the Cassini-Huygens mission to Saturn, its moons, and rings. I cannot impress upon you enough how much new knowledge came from Cassini, and how many people spent part or all of their careers in service of this mission. In our final report of the impacts of SSI's Cassini scientists and engineers, we salute the CICLOPS team who stood in front of the firehose of data, labored over the images and analyses to get them perfect, and graciously shared their work and enthusiasm with the world.

In this year's report, you'll read more about SSI's first SmallSat concept study. CubeSat and SmallSat small-scale ridealong missions are a trending area for NASA, and we are excited to partner with the engineering community on these new adventures and future education programs like Project BUILD. Please take a moment to get to know our featured scientists here and in our Facebook "Meet A Scientist Monday" posts.

Within these pages are only a fraction of the amazing discoveries and programs that SSI has to offer. We hope you enjoy reading this summary, and thank you for your interest in SSI and in science.

Karly M. Pitman, Ph.D.

Front Cover Image Credit: NASA, JPL-Caltech, SSI; Processing: Maksim Kakitsev

OVERVIEW

Image Credit: NASA/ISS/Expedition 43 - Top 15 Space Station Earth Images of 2015

HISTORY & BACKGROUND

In the early 1990s, when Dr. Paul Dusenbery was conducting space physics research at the University of Colorado Boulder (CU), he recognized that, with regard to space science, a glaring divide stood between the academic world and the general public—and that there was a need for a better link between the two. In response, Dr. Dusenbery engaged other scientists in the field and founded a 501(c)(3) nonprofit, the Space Science Institute (SSI), in 1992. In its initial startup, SSI had a staff of three scientists who focused on advancing research and promoting space science education. By 2000, SSI was garnering national recognition for its advancements in space science. In 2003, SSI moved from the CU campus to its current location on Walnut Street in Boulder, creating more space for business operations and for on-site research scientists.

Through collaborations with NASA and the European Space Agency, SSI scientists secured participation on prestigious space missions, including the Mars Exploration Rovers (2003), Rosetta (2004), Cassini (2004), Mars Reconnaissance Orbiter (2005), Lunar Reconnaissance Orbiter (2009), Mars Science Laboratory (2011), Juno (2011), ExoMars Trace Gas Orbiter (2016), OSIRIS-REx (2016), and Mars 2020 Rover (to be launched in 2020).

SSI has since expanded its impact in science and education through the creation of SSI's National Center for Interactive Learning (2010), Center for Extrasolar Planetary Systems (2013), Center for Space Plasma Physics (2013), Center for Mars Science (2014), and Center for Polarimetric Remote Sensing (2017).

PRESENT

Today, SSI manages 70 scientists working in Colorado, nationally and internationally. SSI also develops educational products and conducts outreach with an ever-expanding network of partners, and it creates exhibits and electronic games that make engaging with science accessible, meaningful and fun for people of all ages and backgrounds. These programs support SSI's overall mission: to shape our future by enabling scientists to advance our understanding of Earth and the Universe; increasing science and technology literacy for people of all ages and backgrounds; and inspiring youth to pursue science-technology education and career opportunities. SSI's role in advancing understanding and opportunity in science, technology, engineering and mathematics (STEM) has been recognized through competitive awards (all currently active) from: the National Science Foundation (STEM Learning in Libraries); the NASA Jet Propulsion Laboratory; the Space Telescope Science Institute; the U. S. Department of Energy; and NASA.

GLOBAL REACH: ON-SITE + OFF-SITE

Map Diagram // SSI employees and affi liates work either on-site at SSI headquarters in Boulder or off -site at locations across the United States and internationally. SSI's education programs operate in all 50 states.

2017 BOARD MEMBERS

- Dr. Jack Burns, Professor & Vice President Emeritus for Academic Affairs & Research, University of Colorado
- Ms. Ann Goldman, Co-Founder, Front Range Source
- Dr. Dick Green (ex officio), Former President and Chief Executive Officer, CableLabs, Inc.
- Ms. Jennifer Griest (Executive Secretary, ex officio), In-House Counsel, Legal, and Policy Specialist, Space Science Institute
- Dr. Marilyn Johnson, Former Science Director, Oregon Museum of Science and Industry
- Dr. Steve Jolly, Systems Engineering Director, Lockheed Martin Corporation
- Dr. Karly Pitman (ex officio), Executive Director / Senior Research Scientist, Space Science Institute
- Dr. Bill Purcell (Chair), Senior Manager Advanced Systems, Ball Aerospace and Technologies Corporation
- Mr. Larry Satkowiak (Treasurer), Retired President and CEO of The Cable Center
- Ms. Maddie Zeigler, Education Consultant

2017 EXECUTIVE ADVISORY COMMITTEE

- Dr. Paul Dusenbery (National Center for Interactive Learning)
- Dr. James Harold (Information Systems and Technology)
- Dr. Carolyn Porco (Cassini ISS Instrument Operations)
- Dr. Ralph Shuping (Research)
- Dr. Michael Wolff (Associate Director)
- Mr. Carl Wuth (Business Operations)

2017 GRANTS & CONTRACTS

SSI gratefully acknowledges support from research and education grants and contracts from the following organizations in 2017:

- JPL (Jet Propulsion Laboratory)
- Malin Space Science Systems
- NASA
- NASA Ames Research Center
- Johns Hopkins University Applied Physics Laboratory
- Arizona State University
- CU Boulder
- Smithsonian Astrophysical Observatory
- SUNY
- Southwest Research Institute
- University of Alabama
- UCLA
- University of California
- University of Delaware
- Universities Space Research Association
- Villanova
- National Science Foundation
- University of Wisconsin
- Space Telescope Science Institute
- City of Bedford (TX)
- Jet Propulsion Laboratory
- Gordon & Betty Moore Foundation
- University of Arizona
- CASIS
- Ohio State University
- SETI Institute
- Science Museum of Minnesota
- University of Michigan
- Colorado Gives Foundation

DONORS

SSI wishes to thank the generous individuals who contributed to the Space Science Institute in 2017:

- Myron McCallum
- Kumkum Sinha
- Greg Wimpey
- Gabriel Kuettel
- Steve Jolly
- Judith Schanzer
- Jennifer Griest
- Michael Wolff
- Raymund M Haddock
- Emily Davis
- Karly Pitman
- Kerry Lightenburger
- Anne Holland
- City of Toccoa, Georgia
- Ron and Nedra Fortune
- Joe Small
- Jennifer Hampton
- Brooks Mitchell
- Thomas Frey
- Meghan Lucarelli
- Beatrice Gerrish
- Brian Warner
- Paul Dusenbery
- Ann Goldman
- Larry Satkowiak
- Courtney Coe
- William Purcell
- Joanne McGee
- Padma Yanamandra-Fisher
- Monarch High School
- Joanne McGee

SSI would also like to thank **FATE Brewing Company** and **Trader Joe's** for their Open House donations.

"The Big Corona" Image Credit & Copyright: Alson Wong / APOD-NASA

WE DISCOVER & EXPLORE

SSI researchers work on the cutting edge of international science. SSI's Research Branch is home to the world's experts in multiwavelength astronomy, Mars atmospheric and surface studies, cometary and outer Solar System research, and space plasma physics. Our researchers come to work here from across the U.S. and abroad, leaving prestigious jobs at universities and national labs (e.g., NASA's Jet Propulsion Laboratory, Caltech and Los Alamos National Laboratory) to pursue the kind of creative freedom and work-life balance that SSI offers. SSI scientists are key team members on high-profile robotic and spacecraft missions for NASA and the European Space Agency, as well as for the exoplanet finding space observatory Kepler, the Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Hubble Space Telescope. SSI is a pioneer in remote employment; nearly 75% of our employees do their scientific observations and calculations while telecommuting, offering freedom of movement to present at conferences around the world and flextime to work throughout the day and night to better collaborate and observe.

SSI is also extremely proud of the work done by the Cassini Imaging Science Subsystem Instrument Operations team, based out of SSI's Boulder office. Approximately 50 scientists from the United States and Europe comprise the imaging team that uses cameras from the Cassini-Huygens mission to investigate many unique features of Saturn, its rings and moons. The Cassini ISS team is arguably the most productive of the Cassini instrument teams in delivering its wealth of data and images to scientists and the general public, and continues to deepen our knowledge about Saturn and the processes by which planets – and whole planetary systems – form and develop with time.

WE EDUCATE & INSPIRE

SSI is home to the National Center for Interactive Learning, which leverages SSI's successful experience in research, museum, science center and library educational programs, public outreach, and digital technologies into accessible and inspiring learning opportunities. We believe that the key to improving our science, technology, engineering, and mathematics (STEM) workforce to meet 21st Century challenges is not just to focus solely on an individual student, or teacher, or even an individual classroom, but instead to explore how we can transform whole communities in how they view and support STEM. NCIL employs a strategy of transforming communities as a way of addressing two critical needs facing our country: 1) Enhancing general STEM literacy because public policy matters often involve complex STEM-related issues and 2) Increasing the number of young people pursuing STEM careers by providing opportunities and encouragement to those who are underserved and underrepresented in STEM disciplines.

A small sample of our strategic project partners in these efforts include: American Geophysical Union; American Library Association; Association of Science-Technology Centers; Astronomical Society of the Pacific; Ball Aerospace & Technologies; Cornell Laboratory of Ornithology; Denver Museum of Nature and Science; EdLab Group/National Girls Collaborative Project; Engineers without Borders; Institute for Learning Innovation; LEGO; Lunar & Planetary Institute; NASA Astrobiology Institute; NASA Goddard Space Flight Center; NASA's Jet Propulsion Laboratory, California Institute of Technology; National Academy of Engineering; National Renewable Energy Laboratory; and the Universities of Arizona, California and Colorado.

For over a decade, NCIL educators have also been exploring the potential of digital media, ranging from interactive experiences for museums and libraries to online games and now smartphone and tablet apps. The potential of digital media only increases as portable, connected devices become more commonplace, allowing us to reach people in a variety of different environments and contexts. This means an increased opportunity to impact formal education and to reach people in all walks of life raising the general science literacy of the public. Our approach is reinforced by NSF's Cyberlearning Task Force, which recently recommended that educators "emphasize the transformative power of information and communications technology for learning, from K to grey," and explore technologies that allow interaction with scientific data and visualizations while bridging multiple learning environments.

SSI RESEARCH BRANCH

SSI's Research Branch scientists participate in a broad array of space science activities, including Earth science, space physics, planetary science, and astrophysics. Our research team's expertise continues to expand, and now encompasses investigations of phenomena on Earth and in the geospace environment surrounding our planet. Our scientists study the atmospheres and surfaces of other bodies in our Solar System as well as explore the early stages of the life cycles of stars and nascent planetary systems around other stars. We also study the mysteries of quasars and other types of distant galaxies.

In 2017, our Research Branch welcomed 4 new scientists and 2 new affiliates to bring our total research staff to 68 members. 9 of these are located on-site in at SSI's Boulder headquarters and the rest are distributed across the U.S. and several countries. While any individual scientist may pursue the subject area of his or her choice, SSI's Research Branch also runs four "Research Centers" to facilitate and promote collaborative research in topical areas of interest: the Center for Mars Science (CMS), the Center for Space Plasma Physics (CSPP), the Center for Extrasolar Planetary Studies (CEPS), and the Center for Polarimetric Remote Sensing (CPRS); see our center updates below for recent activities.

Image Credit: NASA/JPL-Caltech/MSSS - Image of the Day

2017 IMPACTS

Total scientists/affiliates:	44/24
New funded researchers:	4
New affiliates:	2
Papers published:	>195
Invited/Public talks:	>45
Proposals Submitted (PI+co-I):	86
New grants/contracts awarded:	30

NASA and European Space Agency Missions Supported:
Hubble Space Telescope, Kepler (exoplanet space observatory), Stratospheric Observatory for Infrared Astronomy (SOFIA), Mars Exploration Rovers, Rosetta, Cassini, Mars Reconnaissance Orbiter, Lunar Reconnaissance Orbiter, Mars Science Laboratory, Juno, ExoMars Trace Gas Orbiter, OSIRIS-REx (2016), Mars 2020 Rover (to be launched in 2020), TESS, and THEMIS.

RESEARCH CENTER UPDATES

CENTER FOR EXTRASOLAR PLANETARY SYSTEMS

The Center for Extrasolar Planetary Systems (CEPS) gathers SSI researchers that are interested in the exploration and characterization of diverse extra-solar planetary systems. CEPS provides a forum for its members to discuss recent scientific results and discoveries, collaborate on proposals and papers, and discuss and develop proposal strategies. Given the interdisciplinary nature of extrasolar planetary science, CEPS research covers a wide range of topics, including the study of exoplanet atmospheres and chemistry, young stellar objects, stellar formation, the formation of planetary systems, radiative transfer, the determination of planet-host star properties, and the analysis of the signatures of planetary formation as reflected in debris disks. Some of this latter work (by CEPS research Dr. Michael Sitko) was recently featured in the AAS NOVA newsletter, "Trapping Dust to Form Planets" [see image below].

In August 2017, Dr. Savita Mathur stepped down as CEPS director, passing the director position to Dr. Channon Visscher. Today, the Center for Extrasolar Planetary Systems includes 13 scientists. CEPS researchers were very productive in 2017, with nearly 70 peer-reviewed publications in scientific journals, numerous conference and workshop presentations, ongoing education and outreach activities, ongoing observing collaboration (including Hubble, Spitzer, IRTF, ALMA, and VLT), and several proposals submitted.

Because CEPS members are scattered throughout the country, CEPS scientists keep in touch by email and periodic teleconferences. This includes opportunities for bringing in outside speakers to discuss their work, for example, a talk on the formation of open clusters and asteroseismology by Dr. Enrico Corsaro. It also allows for journal club-style discussions of recent scientific studies including, for example, a June discussion on the potential of NASA's TESS (Transiting Exoplanet Survey Satellite) to characterize exoplanet host stars. CEPS maintains a website (http://ceps.spacescience.org/home-page.html), accessible through SSI's main page, to highlight research being done by center members and to provide an interface with the public and other researchers in the exoplanet community.

Dust-trapping vortices to form planets: This artist's impression from Atacama Large Millimeter/submillimeter Array (ALMA) observations show V1247 Orionis, a young, hot star surrounded by a protoplanetary disk of dust and gas. This disk shows a gap between a central ring of matter and a more delicate crescent structure located further out. Based upon collaborative research by CEPS member Dr. Michael Sitko (Kraus et al. 2017).

Image Credit: NASA/JPL-Caltech/R. Hurt, IPAC

CENTER FOR MARS SCIENCE

The SSI Center for Mars Science (CMS) is composed of SSI researchers studying various aspects of the Red Planet. CMS researchers are involved in multiple NASA and ESA missions including the Mars Reconnaissance Orbiter, the Mars Exploration Rovers, and the Mars Science Laboratory rover. CMS researchers can use the periodic CMS "Journal Club" teleconferences to present their results or to hear from guest speakers about their research. Journal Club speakers in 2017 included guest speaker Dr. Steve Ruff of Arizona State University speaking on ": "Silica Deposits on Mars with Features Resembling Hot Spring Biosignatures at El Tatio in Chile" and SSI researchers Luca Montabone and Jorge Pla-Garcia summarizing results of the Mars Atmosphere Modeling and Observations (MAMO) workshop that was held in Granada, Spain. Subsequently, SSI researcher Todd Clancy gave his MAMO presentation on "Global Mars Water Vapor Profiles from CRISM limb observations". Guest speaker Pamela Clark of JPL gave a talk on the potential of using CubeSats for planetary missions. Dr. Clark's presentation was a catalyst for discussions among CMS researchers for the proposing of potential Mars CubeSat missions, an effort which led to Dr. Luca Montabone having a mission study funded.

Individual CMS researchers worked on a number of education and public outreach projects. CMS director Bill Farrand continued with a teacher and students at Centaurus High School in Lafayette, CO. This work culminated in the students suggesting a target for multispectral imaging by the Opportunity rover and then analyzing an image of that region using processing tools they had coded themselves. Dr. Farrand also traveled to Canon City, Colorado to give a talk on the exploration of Mars using rovers to that town's "Super Science Fair". CMS researchers also gave public presentations on some aspects of their work as part of SSI's Open House in the Fall of 2017.

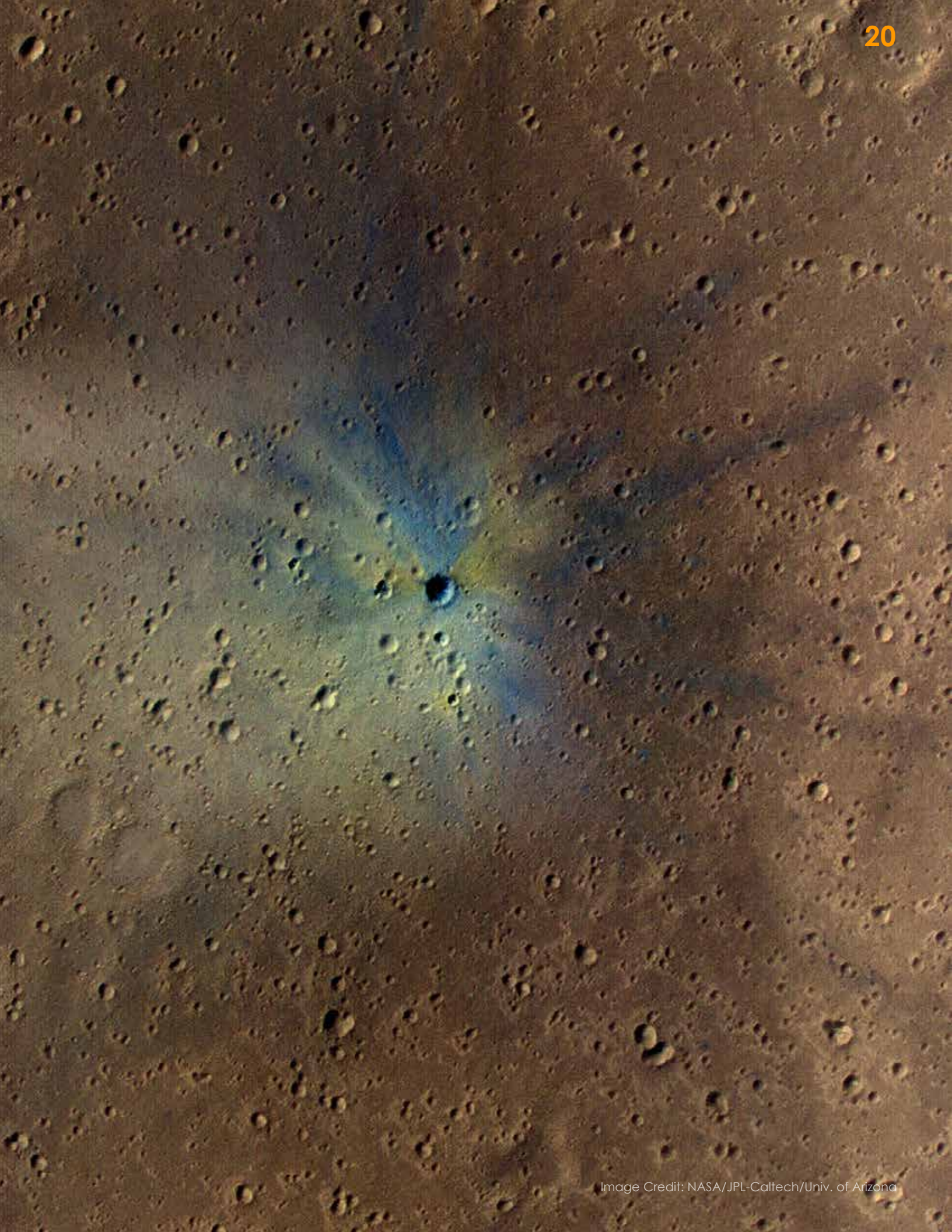
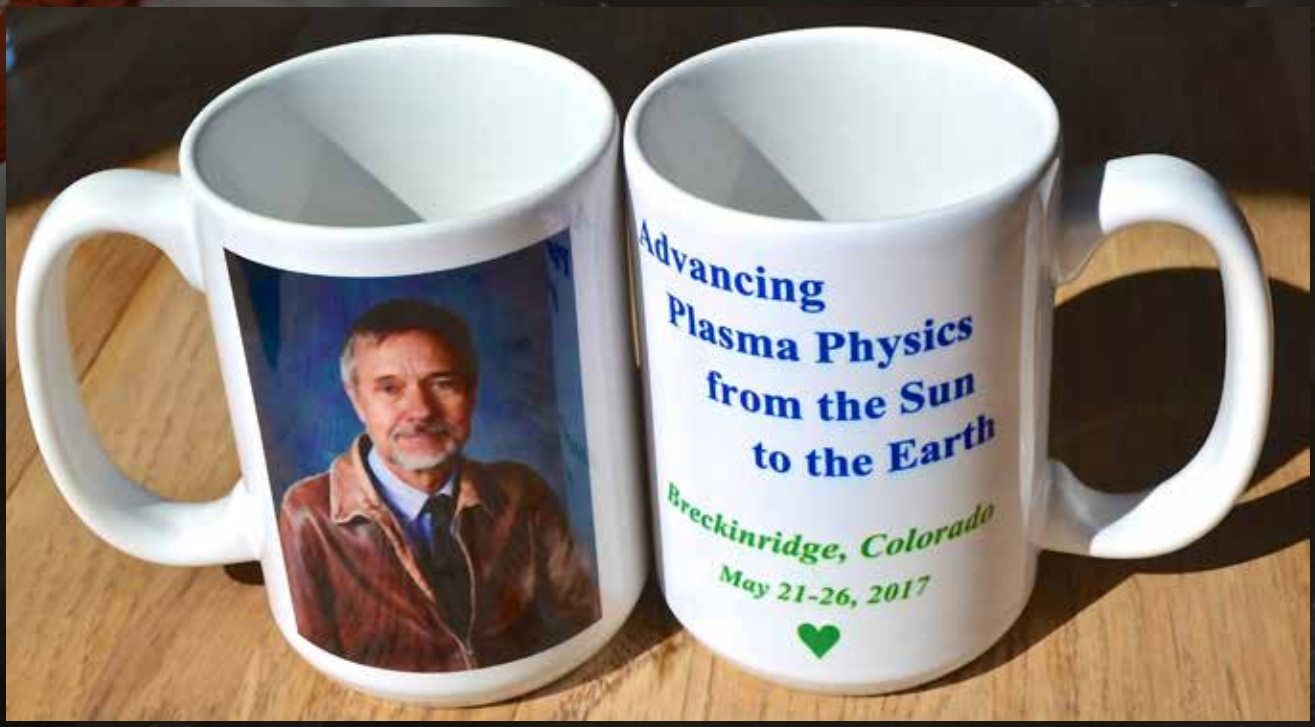


Image Credit: NASA/JPL-Caltech/Univ. of Arizona

CENTER FOR SPACE PLASMA PHYSICS

The Center for Space Plasma Physics (CSPP) provides an umbrella for very broad NASA-sponsored and NSF-sponsored research efforts on plasma physics and the plasmas of the heliosphere. In calendar year 2017 the members of CSPP published 89 papers in refereed journals: 31 papers as primary authors and 58 papers as contributing authors. Research highlights in 2017 dealt with magnetic-field-line reconnection, solar-wind structure, space weather, the coupling of the solar wind to the Earth's magnetosphere, magnetospheric modeling, kinetic plasma instabilities, and turbulence.

In May 21-26, 2017 the CSSP held its first conference, entitled "Advancing Plasma Physics from the Sun to the Earth" in Breckenridge, Colorado. The conference honored Joachim Birn on his 75th year. 52 scientists from 8 countries attended.



Two international workshops are being organized in 2018 by Joe Borovsky and Mick Denton, both workshops in the historic Fuller Lodge in Los Alamos: "Exploring Systems-Science Techniques for the Earth's Magnetosphere-Ionosphere-Thermosphere" July 24-26 and "The Plasmasphere and Warm Plasma Cloak" September 18-20. About 30 scientists will attend each workshop.

Vania Jordanova, Joe Borovsky, and Mick Denton edited a special issue of Journal of Atmospheric and Solar-Terrestrial Physics on "Dynamics of the Sun-Earth System: Recent Observations and Predictions", motivated by a conference that Vania organized in September 2016 in Varna, Bulgaria. The special issue will appear in 2018.

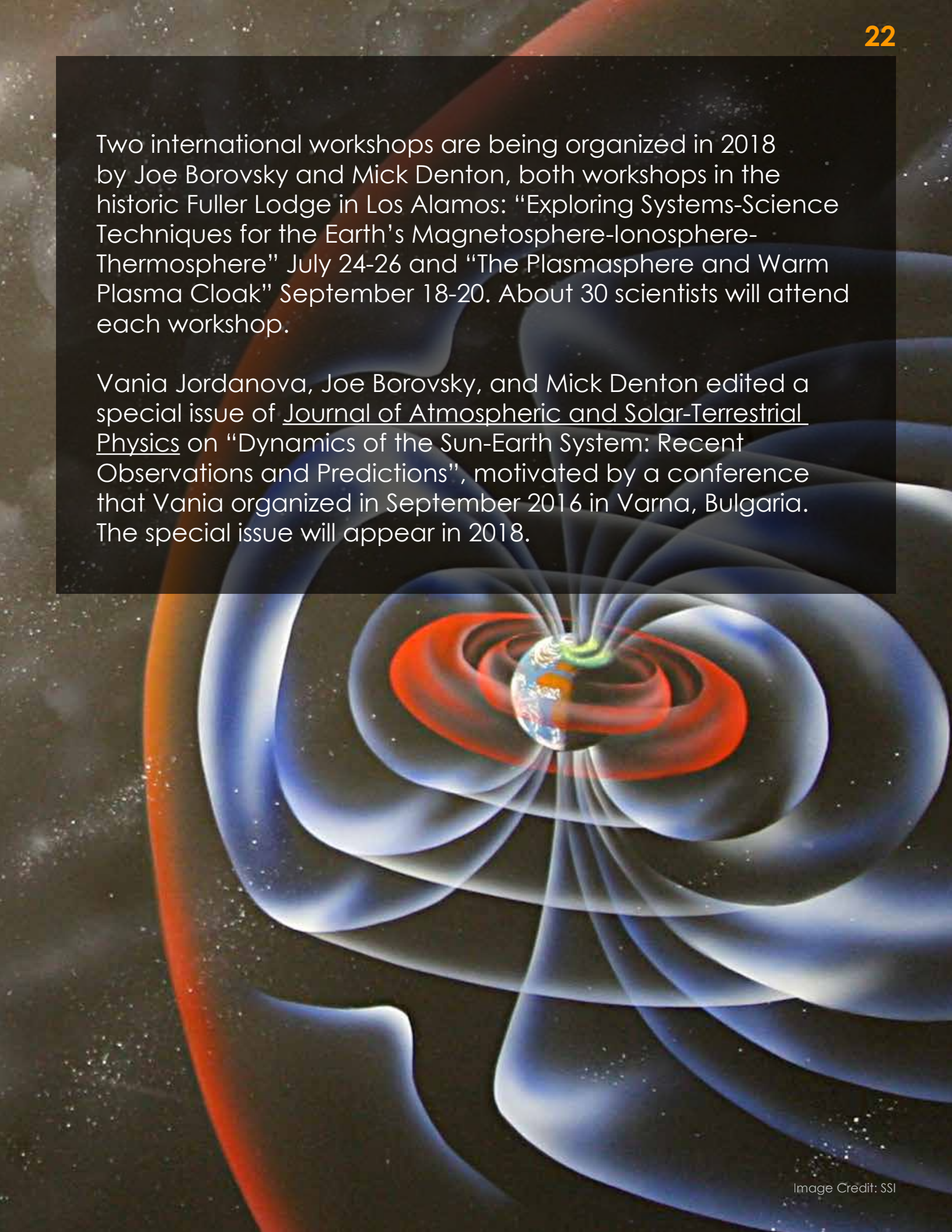


Image Credit: SSI

CENTER FOR POLARIMETRIC REMOTE SENSING

The Space Science Institute has always had a strong concentration of researchers who have utilized polarimetry in their studies. Past SSI research has incorporated ground and mission-based observations of comets, Mars, the Moon, and protoplanetary disks, for example. In 2017, we formed the Center for Polarimetric Remote Sensing (CPRS) to provide an organizational structure to concentrate these pursuits. The Center will bring together scientists who are interested in using polarization as a remote-sensing tool in understanding their individual research areas, capitalizing on a number of senior researchers at SSI with extensive experience in the field. The CPRS will also focus on education and public engagement activities that expose students and the general public to the nature of polarized light, and its utility in science and technology.

Image Credit: NASA/JPL-Caltech

Monitoring the Martian Weather with an Areostationary SmallSat

Dr. Luca Montabone;
Greenbelt, MD Office

Interplanetary SmallSats – defined as satellites with less than 180 kg of mass - are becoming the focus of NASA, after the advantages they offer over larger satellites have been well demonstrated for the case of the Earth. At SSI, Research Scientist Dr. Luca Montabone received funding from NASA's "Planetary Science Deep Space SmallSat Studies" (PSDS3) program to develop a mission concept for a SmallSat dedicated to monitor the weather at Mars - in the form of dust storms and water ice clouds. He built a partnership with ExoTerra Resource LLC for the design of the spacecraft and the mission architecture. Project team members included also SSI Senior Research Scientist Dr. Michael Wolff. The "Mars Aerosol Tracker" (MAT) concept was presented at a dedicated NASA workshop during the 2018 Lunar and Planetary Science Conference. What is this concept about and why is it innovative?

On Mars, the dust cycle – lifting of mineral dust particles from the ground, transport in the atmosphere, and sedimentation back to the ground - is the key process controlling how atmospheric circulation varies on time scales of years, seasons, and days. We observe this cycle in action during dust storms and by studying how dust and water ice aerosols are distributed and change over time in Mars's atmosphere. Studying this is essential for weather monitoring and forecasting for robotic and future human exploration missions. Key scientific questions that can be addressed by martian weather satellites are: What are the processes controlling the onset, transport, and decay of dust and water ice aerosols, and promoting the evolution of regional dust storms into global-scale dust events?

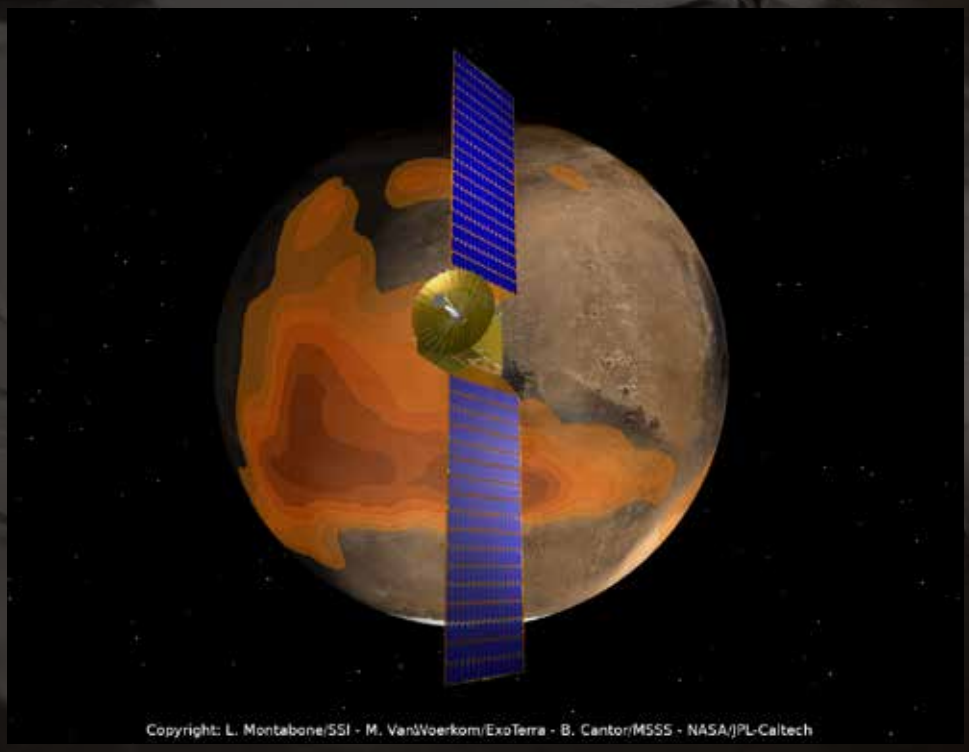
To monitor the dynamics of dust storms and development/destruction of water ice clouds, we need continuous and simultaneous observations of martian aerosols over a large, fixed region from space. We can achieve this by the right choice of the satellite's orbit. None of the satellites already in orbit around Mars (e.g., polar Sun-synchronous orbiters such as the Mars Global Surveyor or the Mars Reconnaissance Orbiter) has the required orbital characteristics. In relation to the martian atmosphere, those satellites have the objective of "globally mapping" the long-term climatology rather than "regionally monitoring" the rapidly evolving meteorological phenomena.

A truly innovative method to obtain continuous and simultaneous observations of martian aerosols would be to use a spacecraft in Mars-synchronous (areosynchronous) orbit, which can also be circular and equatorial (i.e. Mars-stationary, or areostationary, at 17,031.5 km altitude). This would offer the unequaled possibility to monitor the weather on Mars as geostationary satellites do every day here on the Earth, by continuously overlooking the same fixed region while weather systems pass by. Our MAT mission concept is a stand-alone small

spacecraft (SmallSat, about the size of a kitchen refrigerator) in areostationary orbit around Mars. This SmallSat will carry a set of visible and thermal infrared cameras to obtain frequent measurements of aerosol optical depth at multiple local times over a region extending more than 60° from the sub-spacecraft point.

ExoTerra Resource LLC adapted its "Electrically Propelled Interplanetary CubeSat" bus as part of the mission design. MAT is a low-cost, low-weight, small-size, ESPA-class system capable of supporting various tank sizes for gaseous Xenon fuel in order to provide a wide range of ΔV for orbit insertion, science operations, and communication from areostationary orbit. Three possible arrival scenarios have been explored: 1) rideshare on a primary mission directed to Mars with release after Mars capture, 2) rideshare on a primary mission directed to Mars with release several weeks before Mars capture, and 3) rideshare on a primary mission directed to geostationary transfer orbit, followed by an independent journey to Mars. Depending on the chosen scenario, the spacecraft has a wet mass between 35 kg and 65 kg, and a size within or exceeding the 27U CubeSat size standard.

Thanks to NASA's PSDS3 program, now the MAT team has an advanced concept for flying a SmallSat to Mars, putting it in an areosynchronous or areostationary orbit at about 17,000 km altitude, and continuously monitoring the Martian weather for at least one seasonal cycle over a region where dust storms and water ice clouds occur. Next step? Finding the opportunity to transform this concept into a real mission!



The "Mars Aerosol Tracker" (MAT) SmallSat will observe a regional dust storm on Mars from areostationary orbit (about 17,000 km altitude above the equator), and obtain visible images in daytime and measurements of dust absorption during day and night. In this artist's view, the image of Mars has been enhanced from a real mosaic of wide-angle Mars Orbiter Camera (MOC) images. The column dust optical depth field represents a real regional storm that occurred in Martian Year 24, solar longitude LS~220° (October 1999), reconstructed from data in Montabone et al., Icarus 251, pp. 65-95, 2015

Background Image Credit: NASA

A Universal Spin-Mass Relation for Brown Dwarfs and Planets

Dr. Dawn Peterson;
Waltham, MA Office

At birth, stars and planets have an initial mass and angular momentum. The mass fundamentally determines the fate of the objects – it sets the lifetime, radiation output, evolutionary path, and interior structure. The role of the initial angular momentum on the other hand is less obvious. The conservation of angular momentum helps explain phenomena like the increase in rotational speed of a spinning figure skater as the skater's arms are contracted, the Coriolis effect, and precession of tops and gyroscopes.

But low-mass stars do not conserve angular momentum. In the first few million years of their evolution, stars like the Sun lose angular momentum through interaction with disks and magnetic winds. Once on the main sequence, stars' rotation periods increase with stellar mass, a relationship set by the physics of the wind.

Planets, on the other hand, are expected to retain their initial angular momentum, as long as they are not affected significantly by tidal interaction with their host star or with moons. All planets in our Solar System that fulfill this condition (the gas giants plus Mars) show a clear power-law relationship between angular momentum and mass, which can also be observed between rotational velocity and mass.

It has long been known that brown dwarfs in their rotational history are more comparable to giant planets than to solar-mass stars. Brown dwarfs do spin down as they age, but the rotational braking due to winds is very weak compared to stars. Star-disk interaction is thought to be the primary process by which low-mass stars lose angular momentum in the first few million years of their existence, but the braking due to disks is less efficient than in stars. As a result, brown dwarfs retain fast rotation rates of less than a day for gigayears. Their angular momentum, particularly at young ages, may therefore give us insights into the formation process.

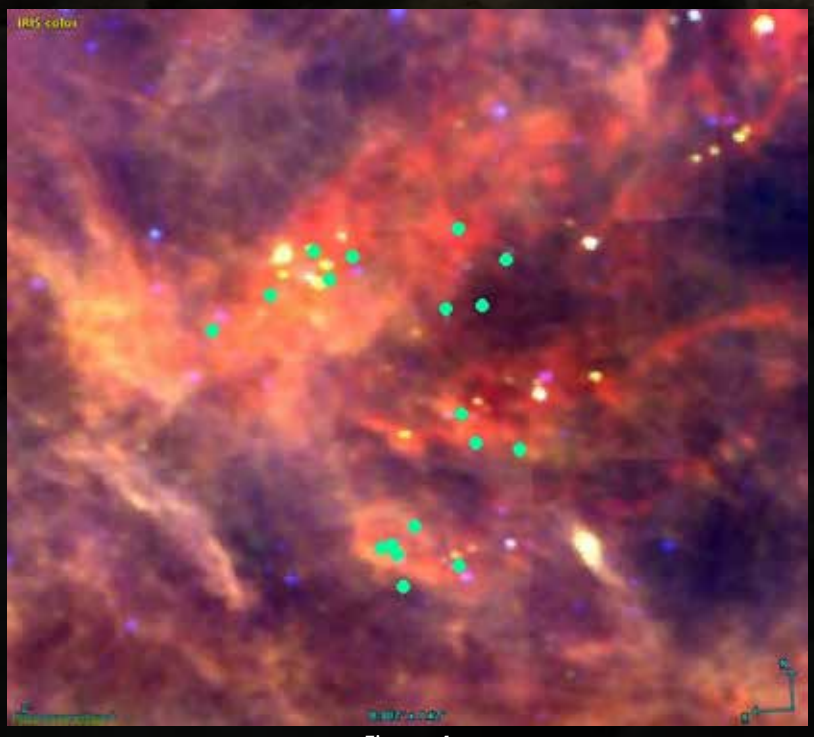


Figure 1

We used lightcurves from the Kepler/K2 mission to measure new rotation periods for 18 young brown dwarfs with ages around 1 million years in the Taurus star-forming region (see Figure 1, left page). These brown dwarfs are mostly distributed in the dusty filaments, as seen in Figure 1, which is an infrared color image created from IRIS (Improved Reprocessing of the IRAS Survey) images at 12, 25, 60, and 100 micron.

We confirmed the presence of a linear increase of the typical rotation period as a function of mass in the brown dwarf regime (see Figure 2). This spin-mass trend holds over six orders of magnitude in mass, including objects from several different formation paths. Figure 2 unambiguously demonstrates that the Taurus brown dwarfs (orange dots) fall onto the planetary spin-mass trend; our solar system planets are represented by blue pentagons (from left to right: Mars, Earth, Uranus, Neptune, Saturn, Jupiter), and the planetary mass companion 2M1207b and free-floating planet PSO J318.5-22 are also represented. Low-mass stars, on the other hand, deviate significantly from the trend, as seen in the Orion Nebula Cloud (ONC) data plotted as green squares.

Our result implies that brown dwarfs by and large retain their initial angular momentum through the first few million years of their evolution. Qualitatively, the relation may originate in the physics of the accretion process and in the way accretion is controlled and ultimately stopped. The fact that the spin-mass relation shown in Figure 2 seems to hold over six orders of magnitude and is obeyed by objects from several very different formation avenues points to the universal importance of accretion in the formation process of planets and brown dwarfs.

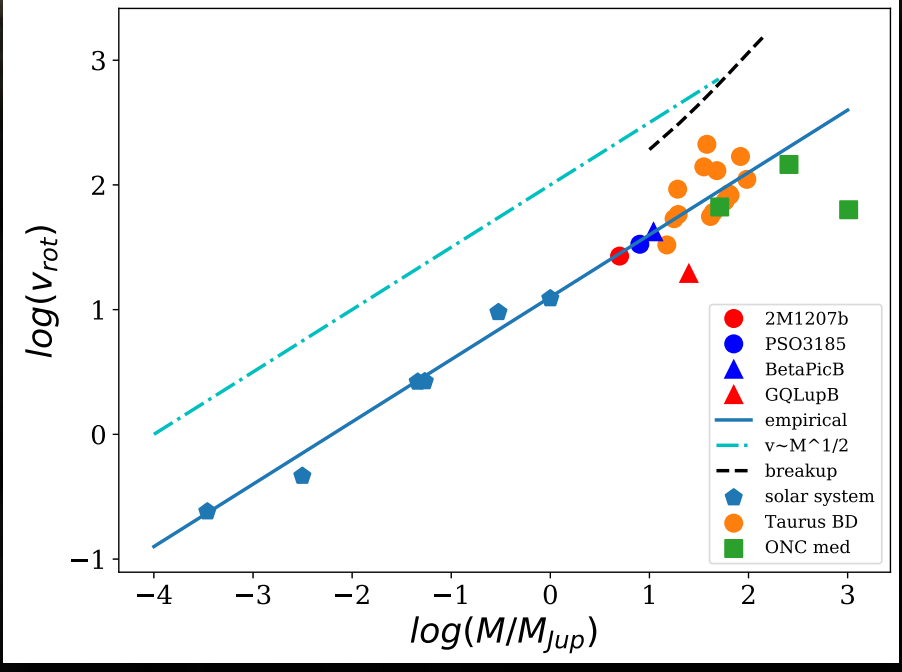


Figure 2

Background Image Credit: NASA/JPL-Caltech

CASSINI IMAGING OPERATIONS

Image Credit: "Proximal Dive" - NASA/JPL-Caltech

CASSINI IMAGING OPERATIONS

The Cassini Solstice Mission is a joint United States and European endeavor. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the mission for NASA's Science Mission Directorate, Washington, D.C. The Cassini orbiter was designed, developed and assembled at JPL. The imaging team consists of scientists from the US, England, France, and Germany. The imaging operations center and team lead (Dr. C. Porco) are based at the Space Science Institute in Boulder, Colorado.

This image of Saturn's rings was taken by NASA's Cassini spacecraft on Sept. 13, 2017. It is among the last images Cassini sent back to Earth.

The view was taken in visible red light using the Cassini spacecraft wide-angle camera at a distance of 684,000 miles (1.1 million kilometers) from Saturn.

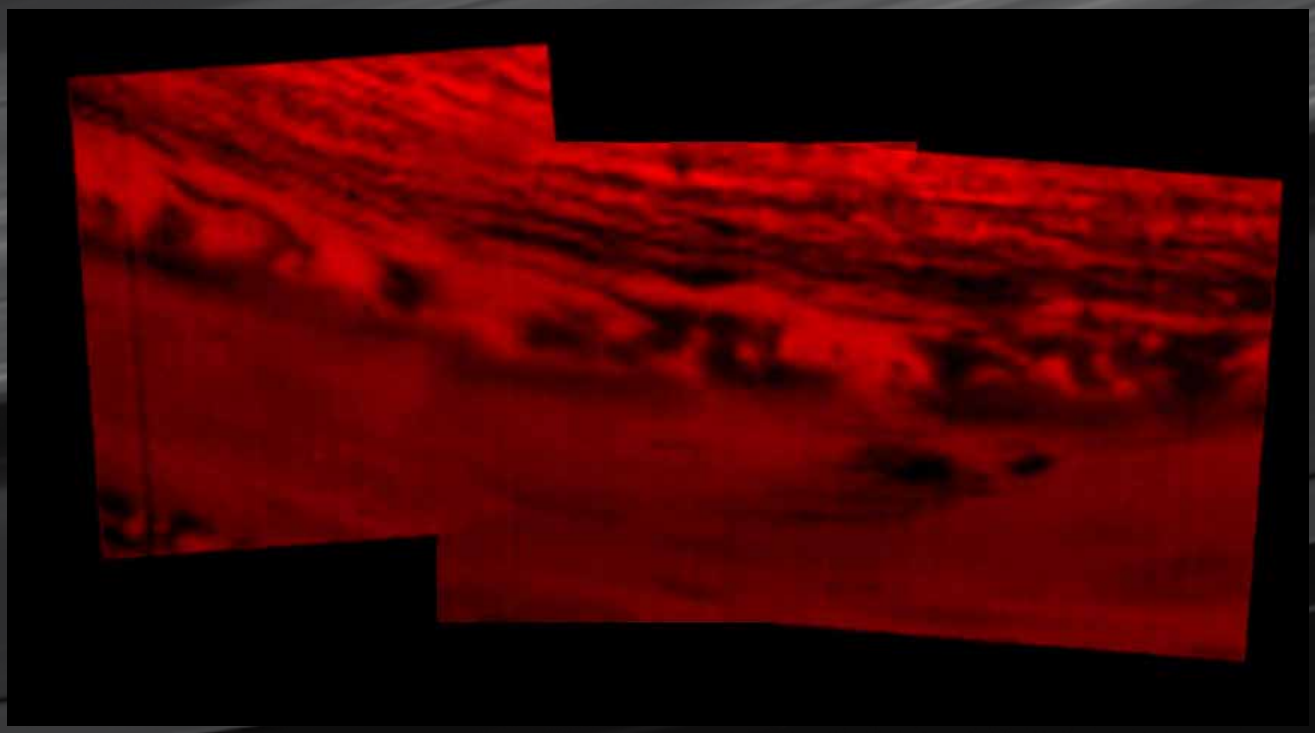


Image Credit: NASA/JPL-Caltech/University of Arizona

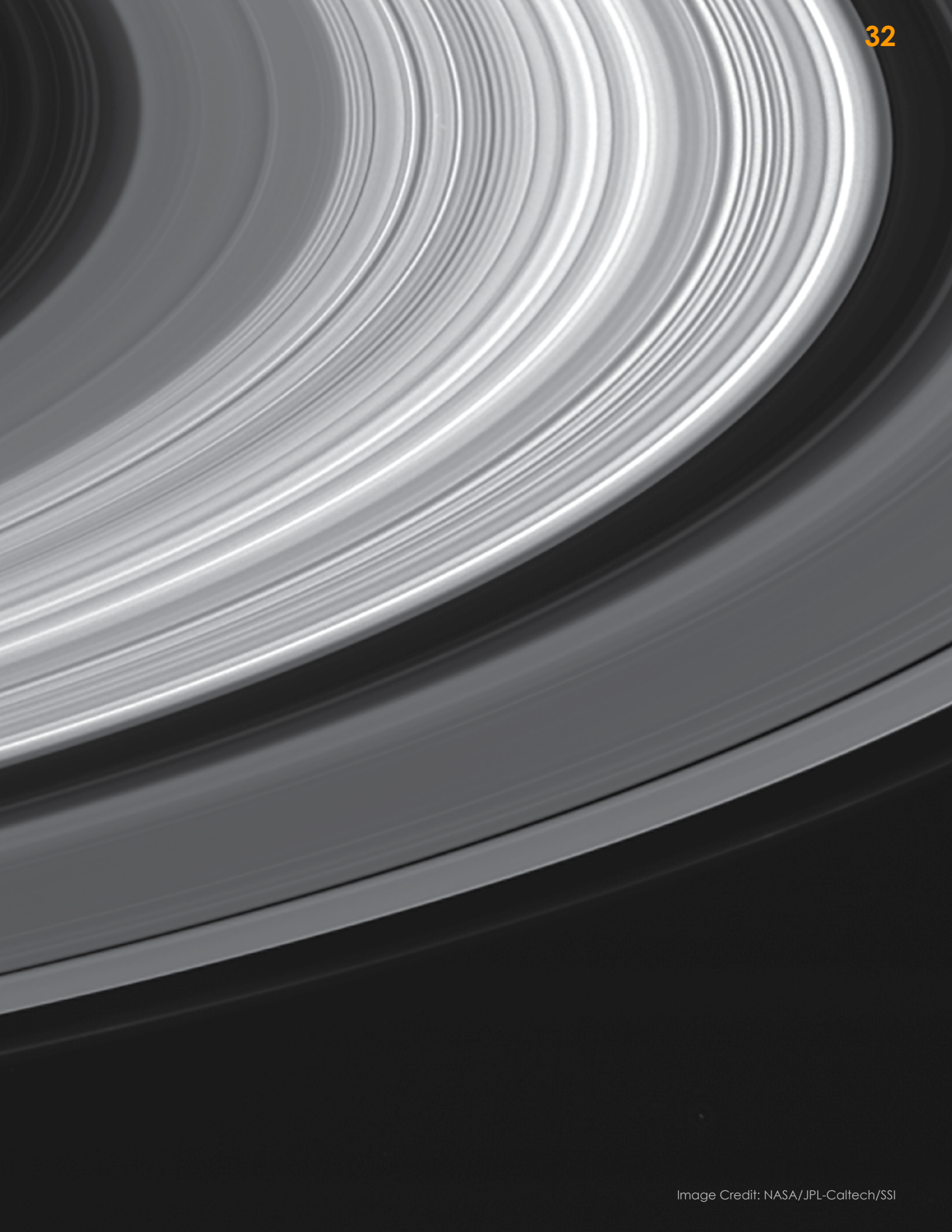
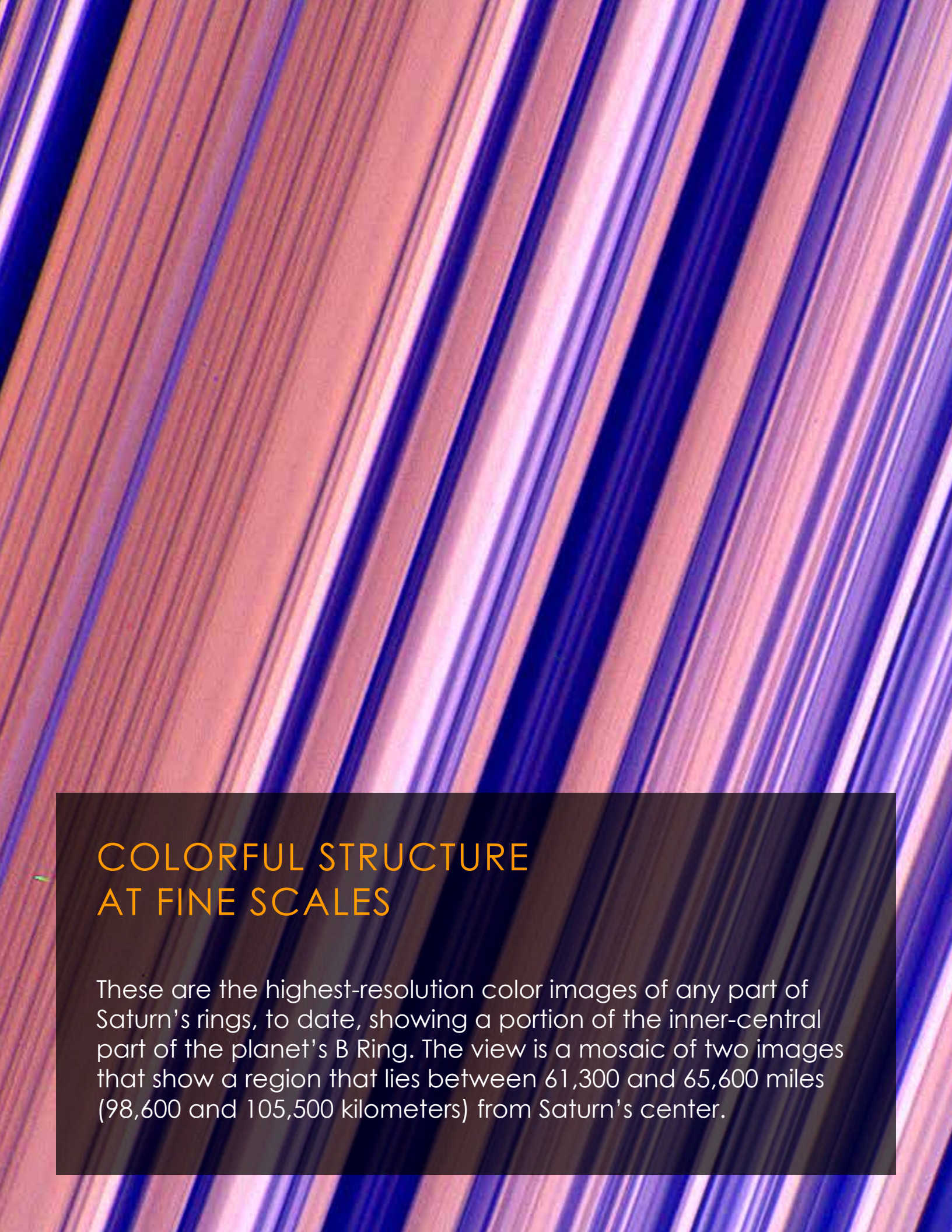
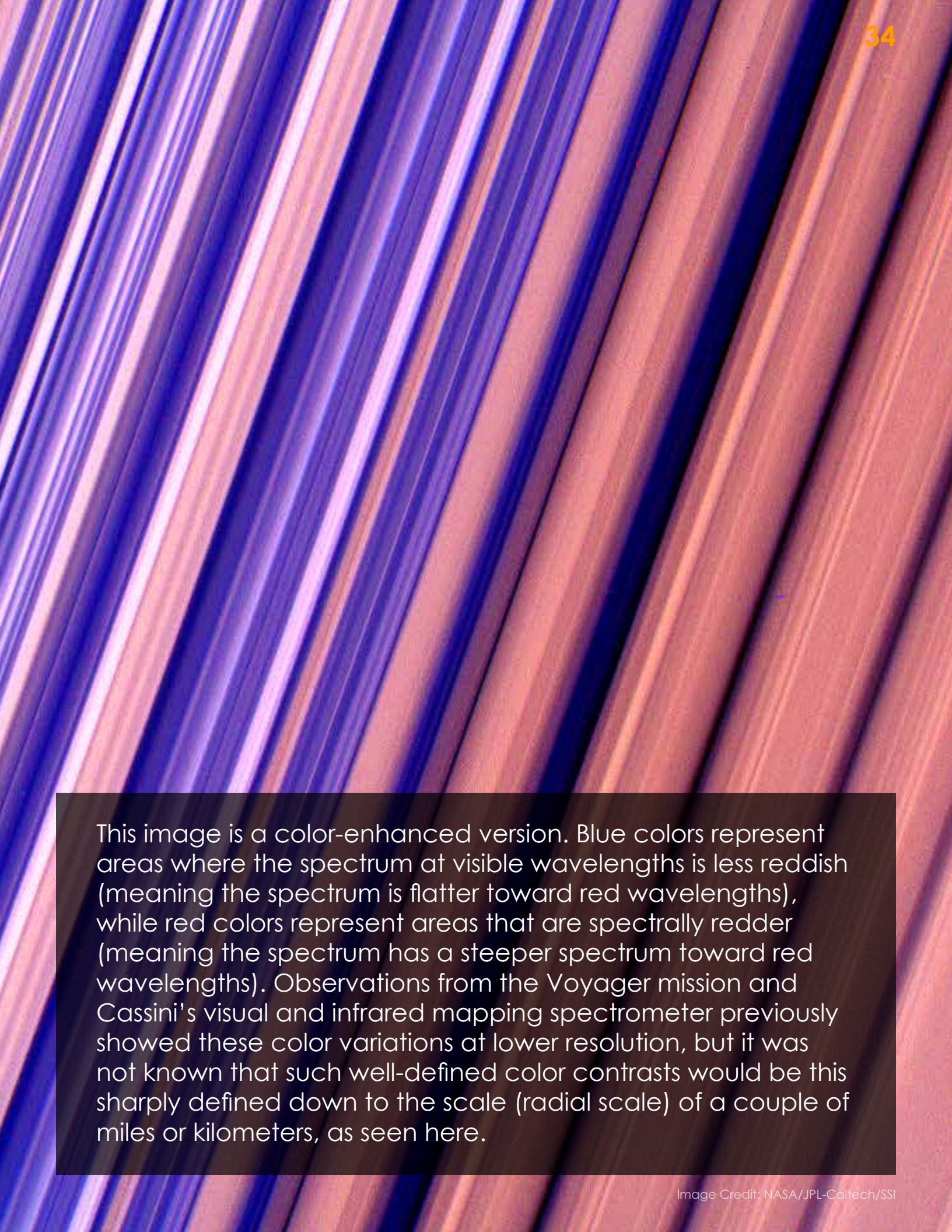


Image Credit: NASA/JPL-Caltech/SSI



COLORFUL STRUCTURE AT FINE SCALES

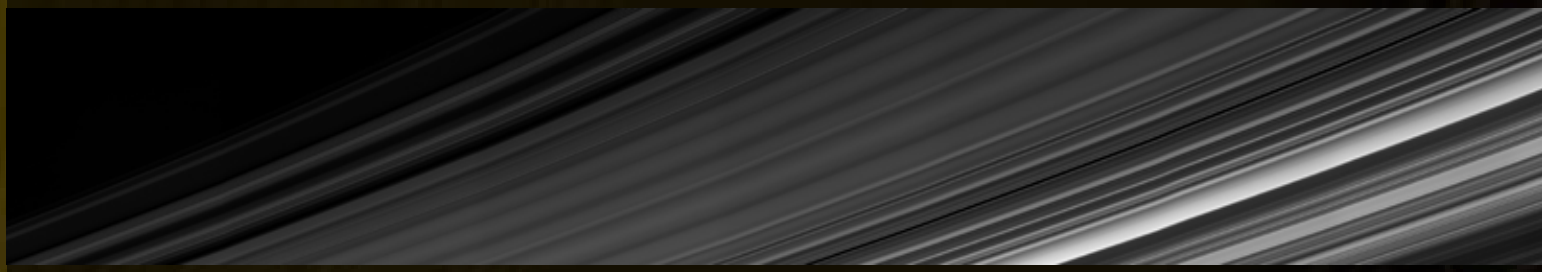
These are the highest-resolution color images of any part of Saturn's rings, to date, showing a portion of the inner-central part of the planet's B Ring. The view is a mosaic of two images that show a region that lies between 61,300 and 65,600 miles (98,600 and 105,500 kilometers) from Saturn's center.



This image is a color-enhanced version. Blue colors represent areas where the spectrum at visible wavelengths is less reddish (meaning the spectrum is flatter toward red wavelengths), while red colors represent areas that are spectrally redder (meaning the spectrum has a steeper spectrum toward red wavelengths). Observations from the Voyager mission and Cassini's visual and infrared mapping spectrometer previously showed these color variations at lower resolution, but it was not known that such well-defined color contrasts would be this sharply defined down to the scale (radial scale) of a couple of miles or kilometers, as seen here.

Image Credit: NASA/JPL-Caltech/SSI

INSIDE-OUT RINGS



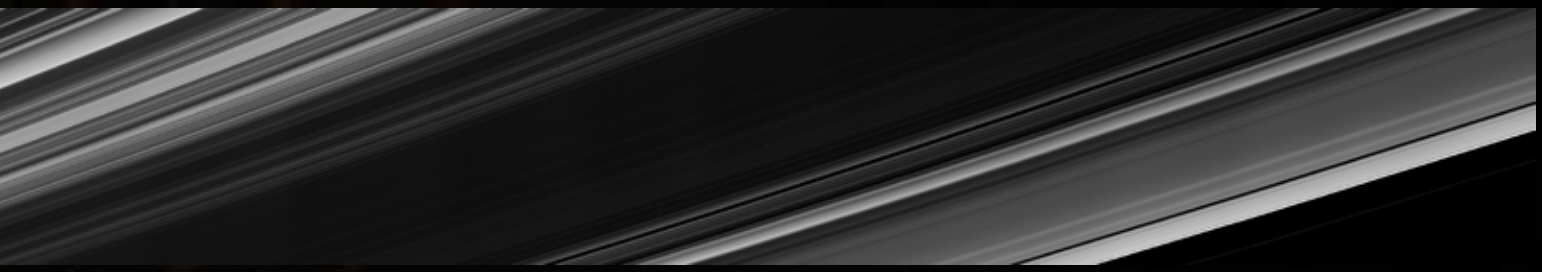
VIEW FROM BENEATH

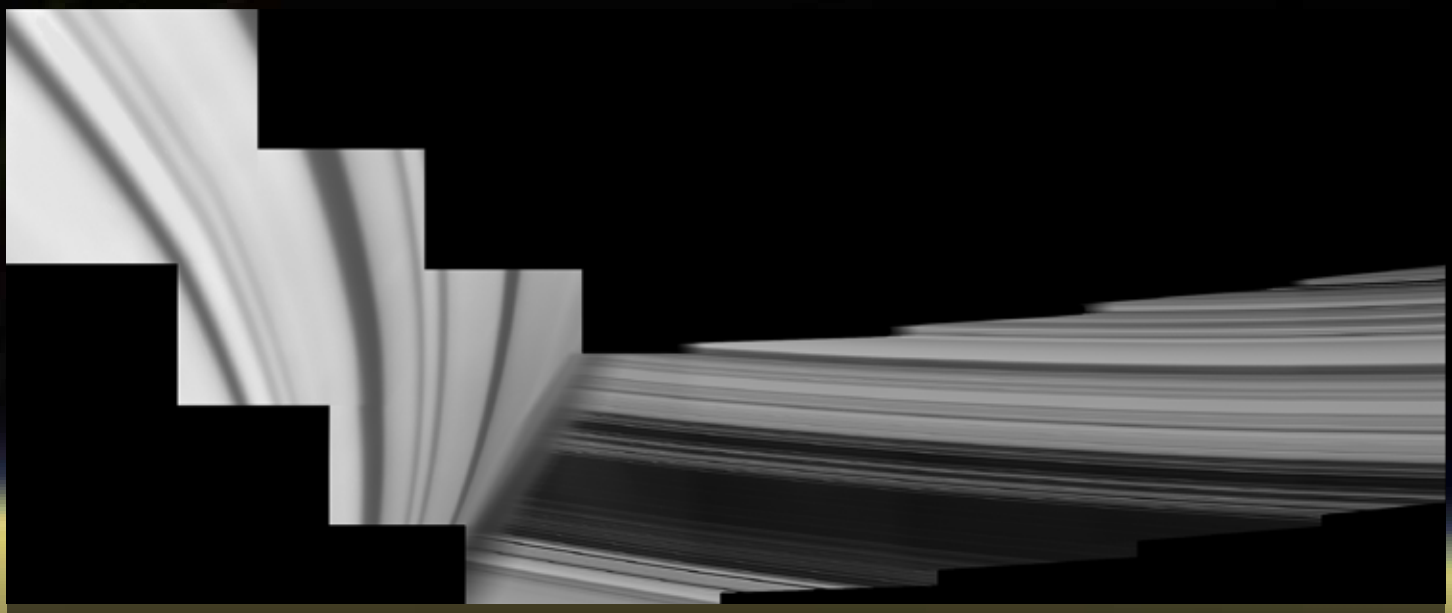
Cassini obtained this panoramic view of Saturn's rings on Sept. 9, 2017, just minutes after it passed through the ring plane. The view looks upward at the southern face of the rings from a vantage point above Saturn's southern hemisphere.

The entirety of the main rings can be seen here, but due to the low viewing angle, the rings appear extremely foreshortened. The C ring, with its sharp, bright plateaus, appears at left; the B ring is the darkened region stretching from bottom center toward upper right; the A ring is seen at far right. This view shows the rings' unilluminated face, where sunlight filters through from the other side.

IN THE BACKGROUND

This false-color view from NASA's Cassini spacecraft gazes toward the rings beyond Saturn's sunlit horizon. Along the limb (the planet's edge) at left can be seen a thin, detached haze. This haze vanishes toward the left side of the scene.





OVER THE LIMB

Cassini obtained the images in this mosaic on May 28, 2017, looking over the horizon just after its sixth pass through the gap between Saturn and its rings as part of the mission's Grand Finale.

In this view, Saturn looms in the foreground on the left, adorned by ring shadows. To the right, the rings emerge from behind the planet's hazy limb, stretching outward from Cassini's perspective. The view is of the rings' unilluminated face, where sunlight filters through from the other side. The part of the planet seen here is in the southern hemisphere.

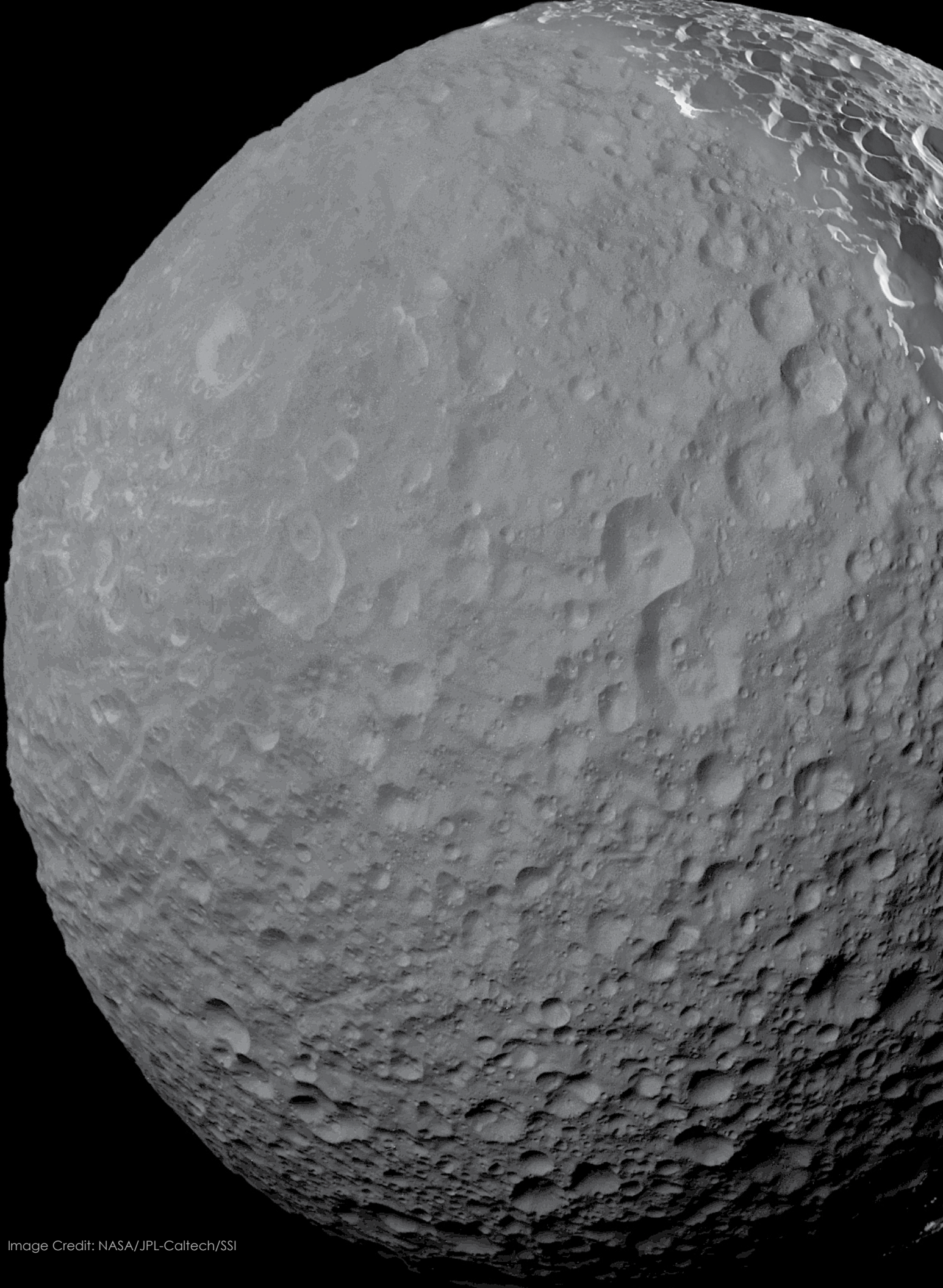
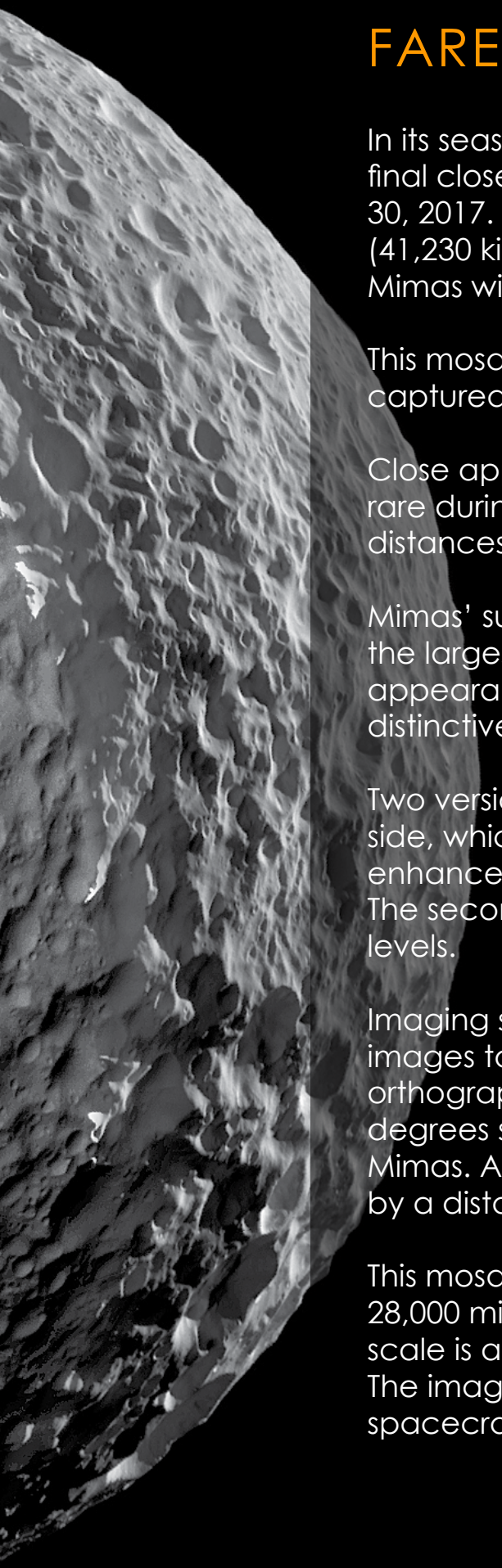


Image Credit: NASA/JPL-Caltech/SSI



FAREWELL TO MIMAS

In its season of "lasts," NASA's Cassini spacecraft made its final close approach to Saturn's moon Mimas on January 30, 2017. At closest approach, Cassini passed 25,620 miles (41,230 kilometers) from Mimas. All future observations of Mimas will be from more than twice this distance.

This mosaic is one of the highest resolution views ever captured of the icy moon.

Close approaches to Mimas have been somewhat rare during Cassini's mission, with only seven flybys at distances of less than 31,000 miles (50,000 kilometers).

Mimas' surface is pockmarked with countless craters, the largest of which gives the icy moon its distinctive appearance. (See PIA12568 for more info on Mimas' distinctive crater, Herschel.)

Two versions of the mosaic are provided. In one, the left side, which is lit by reflected light from Saturn, has been enhanced in brightness in order to show the full surface. The second version features more natural illumination levels.

Imaging scientists combined ten narrow-angle camera images to create this mosaic view. The scene is an orthographic projection centered on terrain at 17.5 degrees south latitude, 325.4 degrees west longitude on Mimas. An orthographic view is most like the view seen by a distant observer looking through a telescope.

This mosaic was acquired at a distance of approximately 28,000 miles (45,000 kilometers) from Mimas. Image scale is approximately 820 feet (250 meters) per pixel. The images were taken in visible light with the Cassini spacecraft narrow-angle camera on Jan. 30, 2017.

A LAST LOOK AT TITAN

As it glanced around the Saturn system one final time, NASA's Cassini spacecraft captured this view of the planet's giant moon Titan. Interest in mysterious Titan was a major motivating factor to return to Saturn with Cassini-Huygens following the Voyager mission flybys of the early 1980s. Cassini and its Huygens probe, supplied by European Space Agency, revealed the moon to be every bit as fascinating as scientists had hoped.

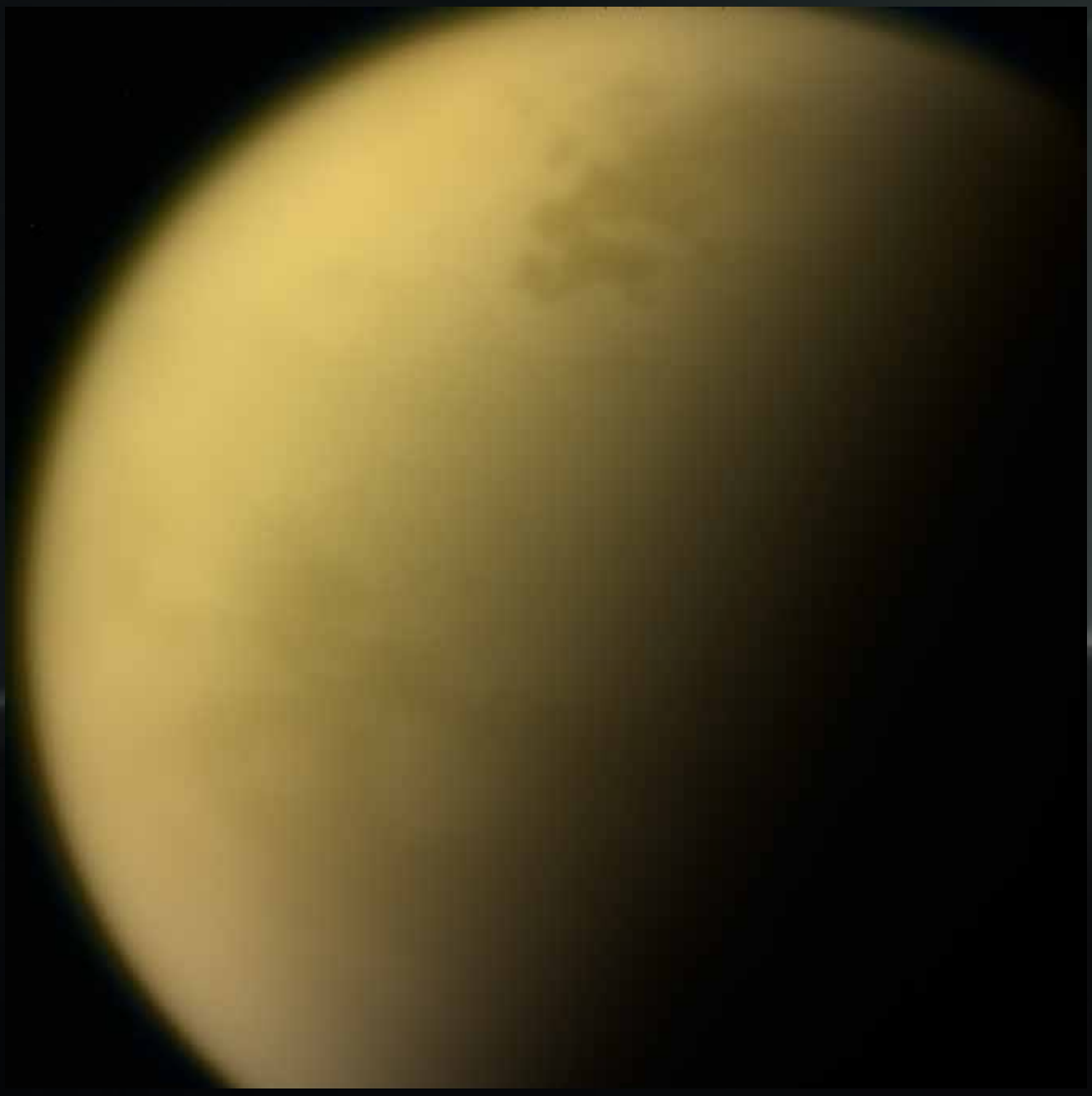


Image Credit: NASA/JPL-Caltech/SSI

Background: This illustration taken from the Cassini Grand Finale movie shows Cassini's fly-through of the Enceladus plume in October 2015.
Image Credit: NASA/JPL-Caltech

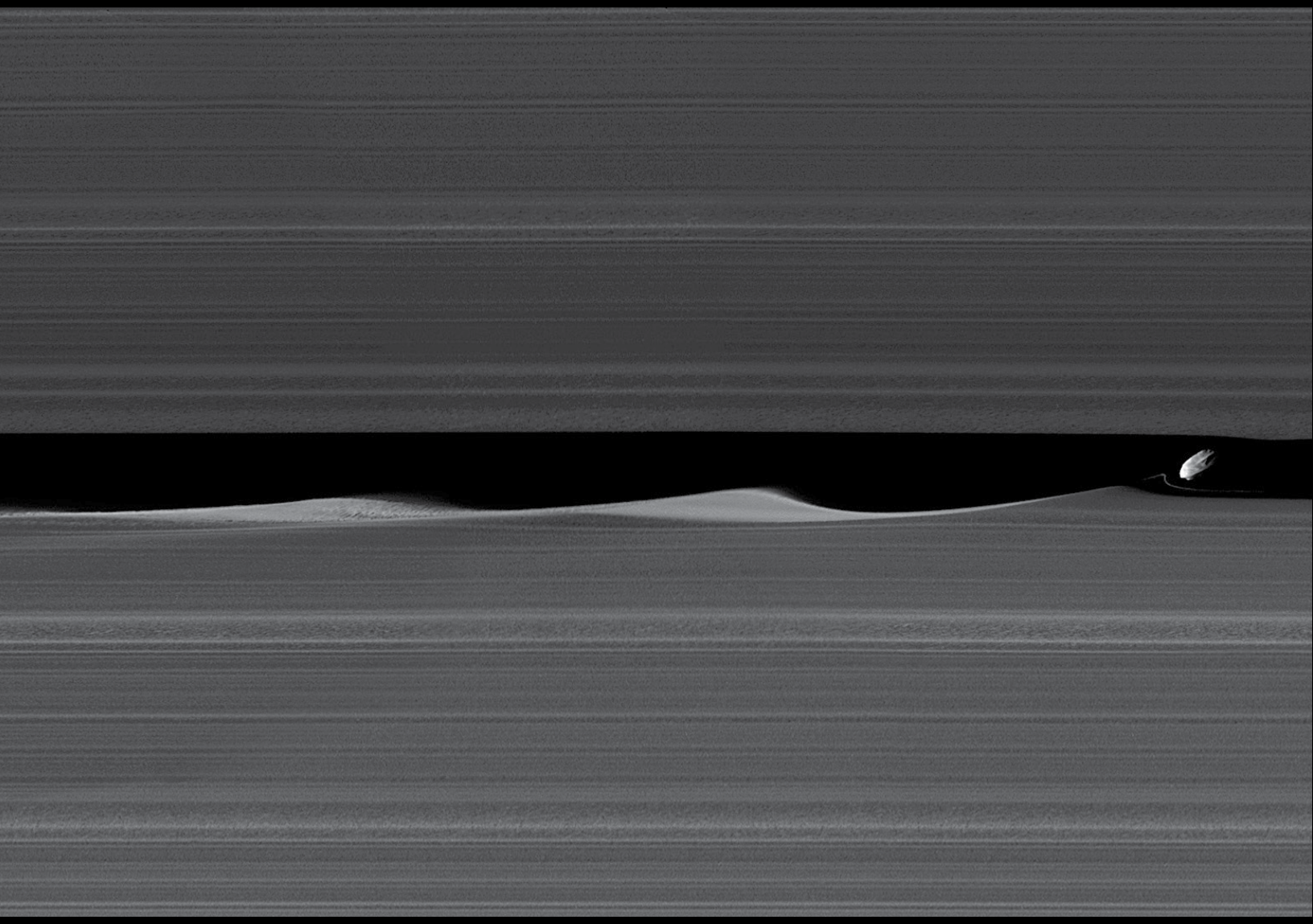


Image Credit: NASA/JPL-Caltech/SSI

THE REALM OF DAPHNIS

Daphnis, one of Saturn's ring-embedded moons, is featured in this view, kicking up waves as it orbits within the Keeler gap. The mosaic combines several images to show more waves in the gap edges than seen in a previously released image, PIA21056.

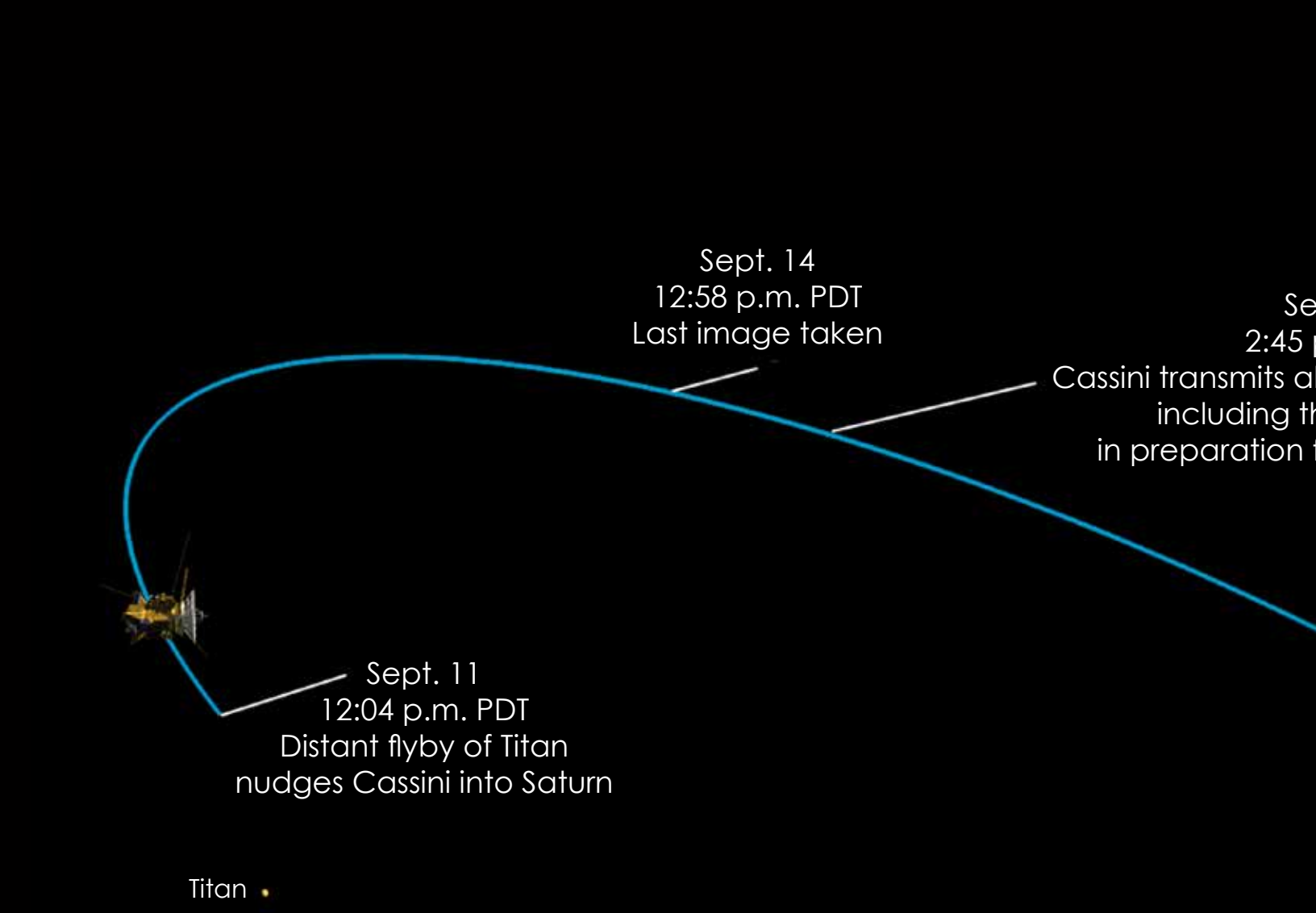
Daphnis is a small moon at 5 miles (8 kilometers) across, but its gravity is powerful enough to disrupt the tiny particles of the A ring that form the Keeler gap's edge. As the moon moves through the Keeler gap, wave-like features are created in both the horizontal and vertical plane. For more about these vertical structures see PIA11654 and PIA11547.

Images like this provide scientists with a close-up view of the complicated interactions between a moon and the rings, as well as the interactions between the ring particles themselves, in the wake of the moon's passage. Three wave crests of diminishing sizes trail Daphnis here. In each subsequent crest, the shape of the wave evolves, as the ring particles within the crests collide with one another.

Close examination of Daphnis' immediate vicinity also reveals a faint, thin strand of ring material that almost appears to have been directly ripped out of the A ring by Daphnis.

The images in this mosaic were taken in visible light, using the Cassini spacecraft narrow-angle camera at a distance of approximately 17,000 miles (28,000 kilometers) from Daphnis and at a Sun-Daphnis-spacecraft, or phase, angle of 71 degrees. Image scale is 551 feet (168 meters) per pixel.

The Cassini Solstice Mission is a joint United States and European endeavor. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the mission for NASA's Science Mission Directorate, Washington, D.C. The Cassini orbiter was designed, developed and assembled at JPL. The imaging team consists of scientists from the US, England, France, and Germany. The imaging operations center and team lead (Dr. C. Porco) are based at the Space Science Institute in Boulder, Colo.



Cassini's Final Plunge

Predicted time; subject to change
Distance not to scale

ept. 14
o.m. PDT
ll data on its recorder,
he last images,
for the final plunge

Sept. 15
1:37 a.m. PDT (ERT)
Spacecraft reconfigures for
real-time science transmission

Sept. 15
4:54 a.m. PDT (ERT)
Loss of signal
10 degrees north latitude
~950 miles above the cloud tops

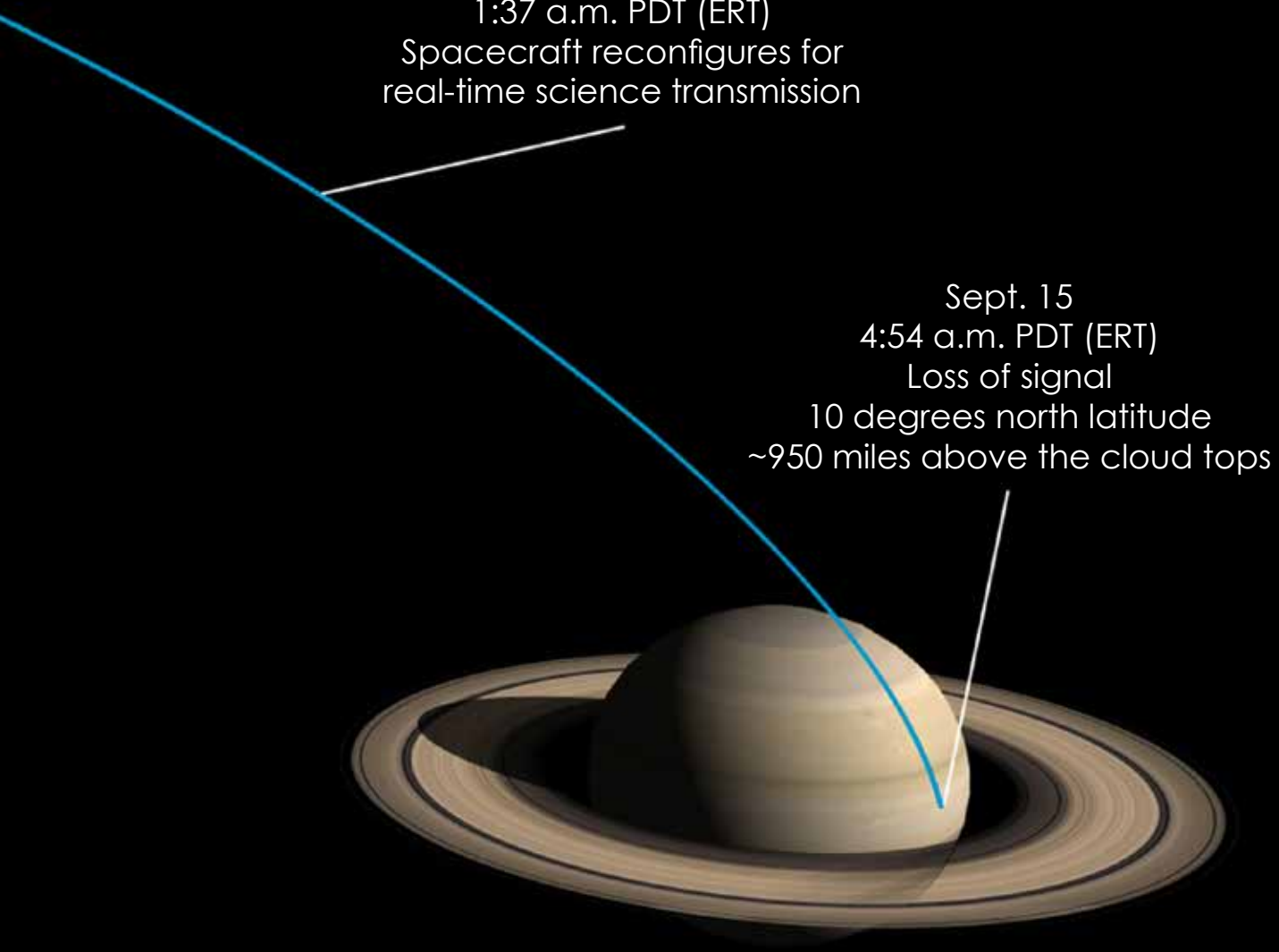


Image Credit: NASA/JPL-Caltech

A FAREWELL TO SATURN

In a fitting farewell to the planet that had been its home for over 13 years, the Cassini spacecraft took one last, lingering look at Saturn and its splendid rings during the final leg of its journey and snapped a series of images that has been assembled into a new mosaic.

Image Credit: NASA/JPL-Caltech/SSI

Cassini's wide-angle camera acquired 42 red, green and blue images, covering the planet and its main rings from one end to the other, on September 13, 2017. Imaging scientists stitched these frames together to make a natural color view. The scene also includes the moons Prometheus, Pandora, Janus, Epimetheus, Mimas and Enceladus.

EDUCATION & INSPIRATION

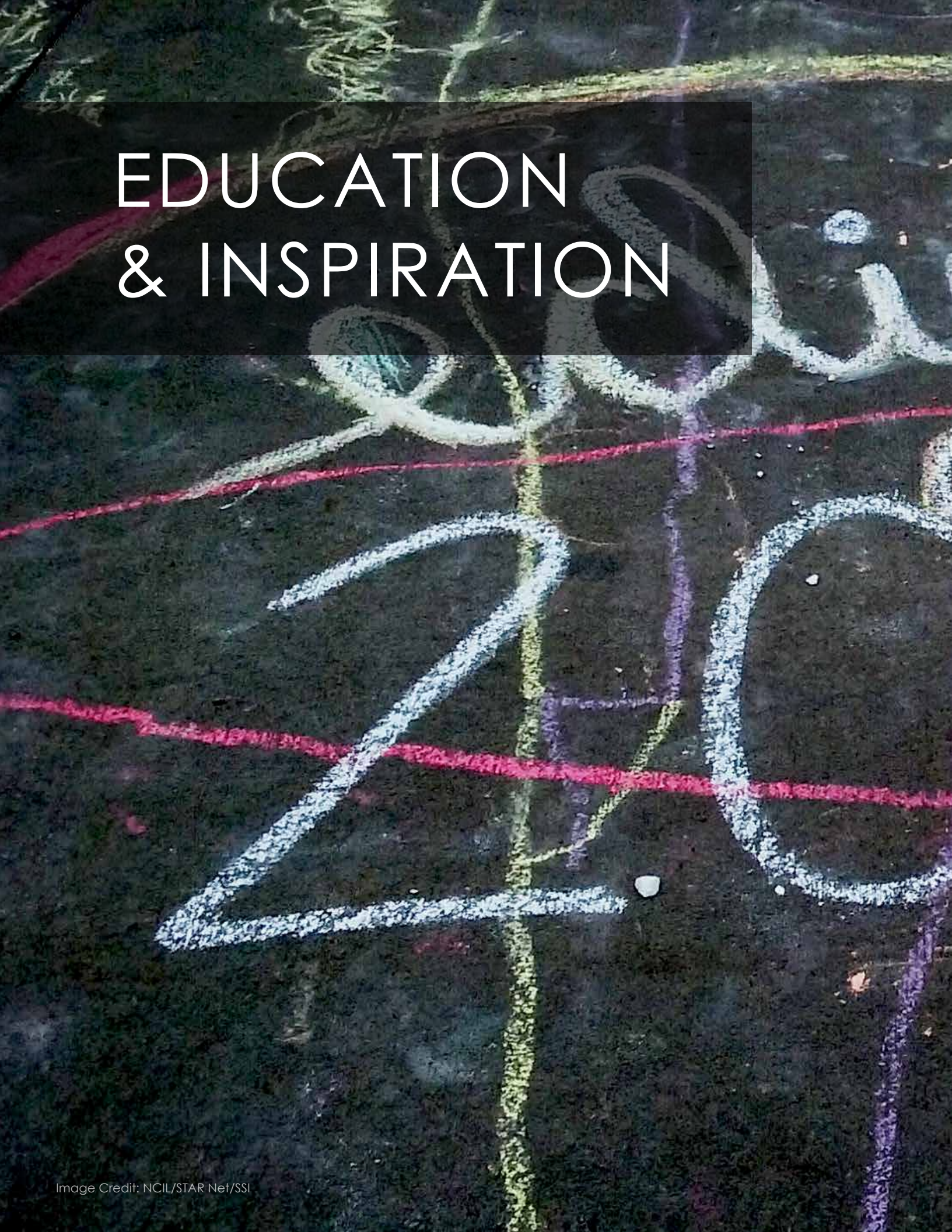
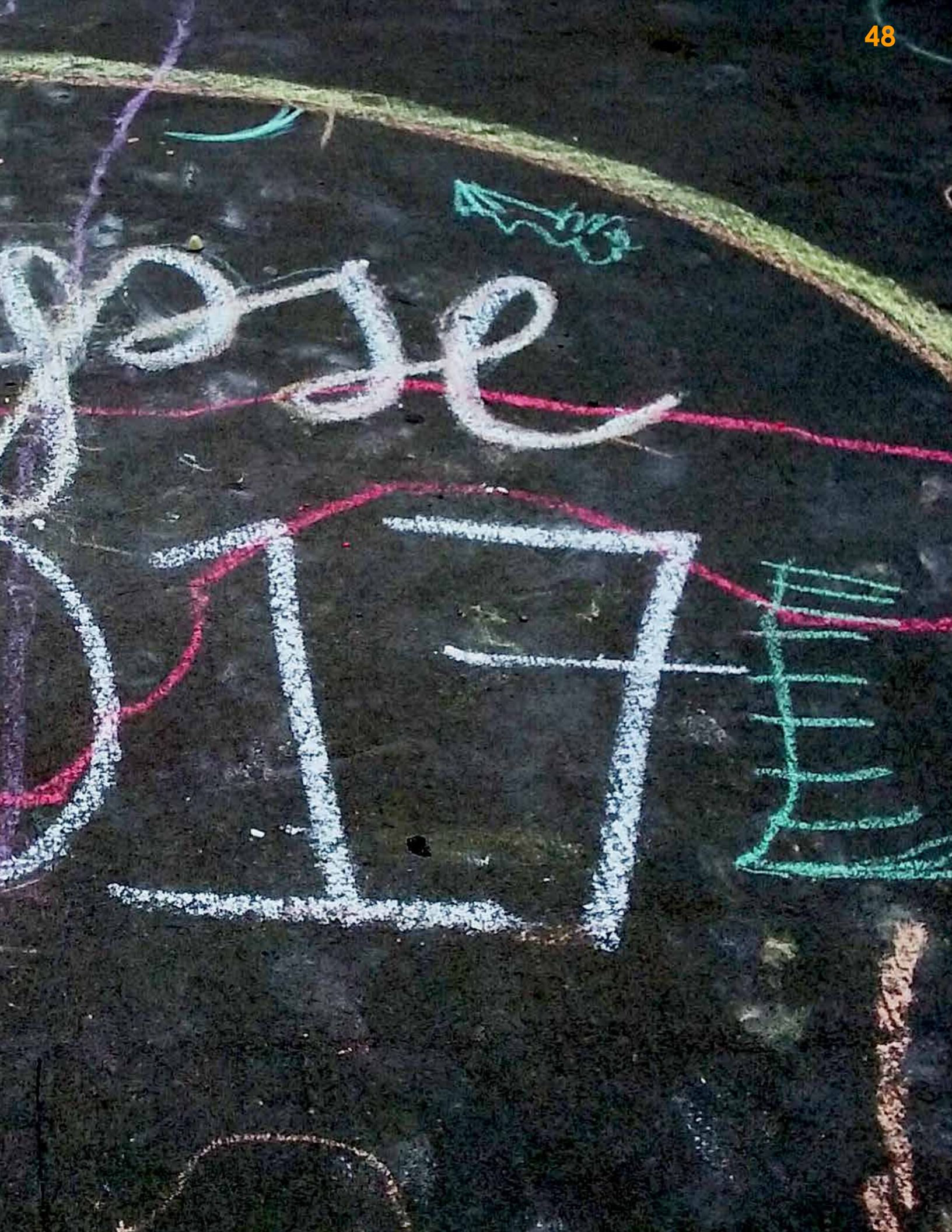


Image Credit: NCIL/STAR Net/SSI



NATIONAL CENTER FOR INTERACTIVE LEARNING

SSI's ***National Center for Interactive Learning*** (NCIL) is led by Dr. Paul Dusenbery (Boulder Office). It is a leader in developing STEM-themed exhibitions and educational games and apps that can be deployed on websites, mobile devices (e.g. smartphones and tablets), and multi-touch tables. NCIL also employs a combination of in-person and online training methods to balance the need to reach a large audience, while laying the foundations for deep, ongoing learning in STEM and STEM facilitation. Through social media, online newsletters, and a recently developed *STEM Activity Clearinghouse*, the center has a national reach that numbers in the millions. NCIL (www.nc4il.org) is organized around four interdependent groups: 1) Exhibition Development, 2) Digital Learning, 3) Professional Development, and 4) Community Engagement.

On August 21, 2017, a spectacular total eclipse of the Sun was visible across the continental U.S. for the first time since 1918. Every state had at least 65% of the Sun covered by the Moon, and lucky people on a narrow path from Oregon to South Carolina saw the stunning beauty of totality that they will remember all their lives. It was a watershed moment for our country. NASA's solar eclipse coverage was one of the biggest internet events in recent history and by far the biggest online event NASA has ever measured (more than 40 million views of their live broadcast on nasa.gov and multiple social platforms were recorded). "The solar eclipse was truly the Super Bowl of Science" (Paul Dusenbery). NCIL, the STAR Library Network (*STAR Net*) program that it manages, and many partners played a key role in supporting the solar eclipse event (see Highlights section). Thousands of public libraries participated in this international event. The public interest in the eclipse also allowed libraries to connect with local STEM experts and resources, including scientists, amateur astronomers, science teachers, museum staff and others. Such connections can be leveraged for future astronomical and terrestrial events that have opportunities for large-scale public engagement.

Image Credit: NCIL/STAR Net/SSI

Image Credit: NCIL/STAR Net/SSI

PROFESSIONAL DEVELOPMENT & COMMUNITY ENGAGEMENT

The Professional Development Group (led by Keliann LaConte, Boulder Office) oversees training and activity development. In 2017, monthly webinars were offered to public library staff to provide insights from leaders in the field, foster discussion between informal educators, and promote free educational resources. NCIL staff also participated in 8 conference sessions last year. The goal of NCIL's Community Engagement Group (led by Anne Holland, Boulder Office) is to keep public and professional communities interested and engaged in the work we do, and to serve their needs. Activities include everything from local community outreach at science festivals and schools, to providing personal attention and assistance to members of our professional learning community, the *STAR Net* Community of Practice.

STAR Net is NCIL's flagship STEM program serving the library community. It began in 2008 and now numbers about 7,500 members. The NCIL team conducted a very successful series of *STAR Net* webinars in 2017. Over 1,500 project partners and public library staff attended 27 NCIL-hosted virtual trainings, presentations, and discussions. On several topics, NCIL staff were joined by guest presenters ranging from SSI researchers, to project partners, to the NASA Director of Social Media. Virtual training has become a pivotal tool for NCIL in reaching their goal of strengthening the infrastructure of STEM education in libraries, and the team looks forward to building upon their success in 2018. NCIL continues to publish a monthly *STAR Net* e-newsletter and published an e-newsletter for libraries participating in the 2017 eclipse. *STAR Net* also has an active social media presence including Facebook, Twitter, YouTube, and Flickr.

DIGITAL LEARNING

NCIL has been exploring the potential of digital media for two decades, ranging from interactive experiences for museums and libraries to online games. The Digital Learning Group is led by Dr. James Harold (Boulder Office). Digital media doesn't simply create more engaging experiences, it can allow learners to interact with data, explore simulations, and connect to each other through social media. Their potential only increases as portable, connected devices become more commonplace, allowing us to reach people in a variety of different environments and contexts.

Screenshot from the Starchitect Game.

Our approach is consistent with the Cyberlearning Task Force's recommendation for NSF to "emphasize the transformative power of information and communications technology for learning, from K to grey", and explore technologies that allow interaction with scientific data and visualizations while bridging multiple learning environments. Recent work has included Starchitect, a Facebook based "create a solar system" game, and apps designed to support librarians in exploring NASA STEM topics with their patrons as part of *STAR Net's NASA@ My Library* initiative.

Image Credit: NCIL

NCIL IMPACTS FOR 2017

TRAVELING EXHIBIT VISITORS (561,662)

• *Discover NASA* Library Exhibit (3 host sites):	58,817
• STAR Net's *Discover Earth* Library Exhibit (4 host sites):	63,530
• STAR Net's *Discover Tech* Library Exhibit (3 host sites):	136,744
• STAR Net's *Discover Space* Exhibit (4 host sites):	57,032
• STAR Net's *Explore Earth* Exhibit (4 host sites):	5,607
• STAR Net's *Explore Tech* Exhibit (4 host sites):	105,919
• STAR Net's *Explore Space* Exhibit (4 host sites):	132,013

• STAR Net Library Program Participants (Discover Exhibit sites, Explore sites, *NASA@My Library*):	117,330
• STAR Net Library Program Participants (eclipse):	1,750,000
• In-person professional development activities:	660
• Webinar Participants:	1,529
• STAR Net Online Community Members:	7,500
• NCIL Outreach Event Participants:	1,250

EDUCATION WEBSITE VISITORS	PAGE VIEWS
• AlienEarths	445,869
• GiantWorlds	33,356
• MarsQuestOnline	225,515
• SciGames	107,223
• SpaceWeatherCenter	457,796
• KillerAsteroids	88,123
• Starchitect	336,577
• STAR Net	1,221,193
• Clearinghouse	125,027
• Totals	**3,050,724**

2017 HIGHLIGHTS

2017 SOLAR ECLIPSE: A CELESTIAL ACHIEVEMENT FOR STEM PROGRAMMING AT PUBLIC LIBRARIES AND BEYOND!

SSI was awarded a grant from the Gordon and Betty Moore Foundation that provided **1.26 million FREE solar viewing glasses and other resources** for 1,500 public libraries across the nation. Dr. Robert Kirshner, Chief Program Officer, Science, at the Moore Foundation, said "The Moore Foundation is pleased to help two million eyes enjoy and understand this astronomical spectacle with astronomical spectacles." The Research Corporation, Google, and NASA also provided glasses and materials that added an additional 750,000 glasses, bringing the total to over 2.1 million glasses that were distributed to 4,000 library organizations (representing more than 7,000 individual library locations) across the country! They included public library branches, bookmobiles, tribal libraries, library consortia, and state libraries. Support for additional training, webinars and activity development was provided by the National Science Foundation, IMLS, and the American Astronomical Society. NCIL managed all facets of the Library Eclipse Project. This was the largest single distribution of free glasses in the entire country and reached more people with glasses and information than any other educational effort for the 2017 eclipse. The final distribution map of participating libraries is shown below. A final report can be downloaded at http://www.starnetlibraries.org/2017eclipse/.

The Moore-funded eclipse project was conceived by three astronomers, Andrew Fraknoi (Foothill College, Los Altos Hills, California), Dennis Schatz (Pacific Science Center, Seattle, WA), and Douglas Duncan (University of Colorado, Boulder, Colorado) together with Paul Dusenbery (Director, NCIL).

An Eclipse Education Kit was developed that included a package of free safe-viewing glasses, plus a 24-page information booklet that combined background on eclipses with instructions on how best to do public outreach programs about the eclipse, along with other resources (such as material for demonstrations for groups). A printed version of the booklet (Authors: Andrew Fraknoi and Dennis Schatz) was sent to the first 2,250 participating libraries. Education materials in the Kit were also made available in easily down-loadable form on the STAR Net website (www.starnetlibraries.org/2017eclipse), so that even libraries and organizations that applied later and could not receive a printed copy would get guidance on how to do public outreach before the eclipse, plus safe eclipse viewing techniques (some of which were not dependent on having a pair of solar viewing glasses, just in case glasses ran out).

Image Credit: NASA/Aubrey Gemignani

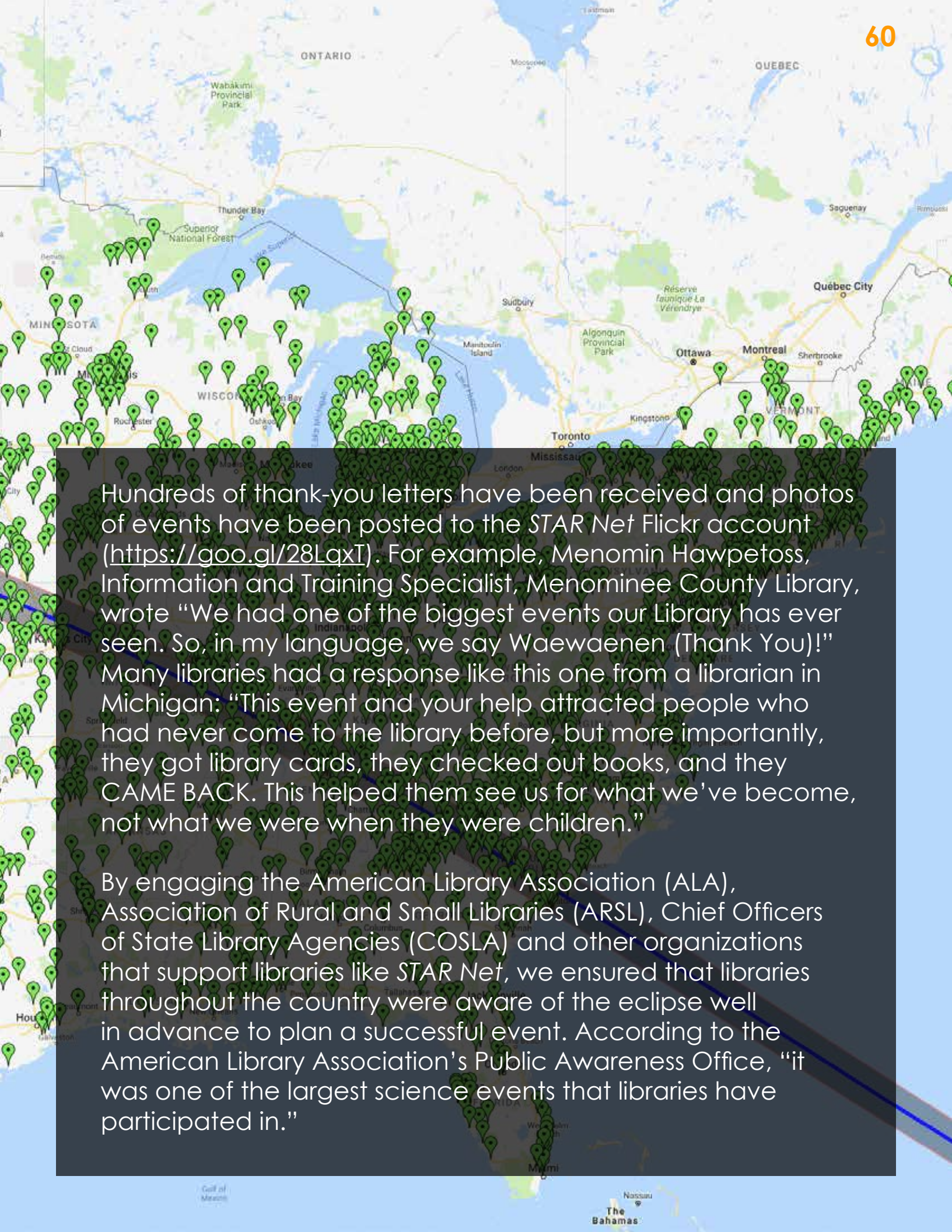
BY THE NUMBERS

It is estimated that the *STAR Net* Library Eclipse Project allowed 6 million people to observe the event safely.

Participating libraries were projected to have conducted around 35,000 science programs before and during the eclipse, reaching an estimated 1,750,000 people.

NASA's Science Mission Directorate (SMD) supports *NASA@ My Library* and was a valuable eclipse library partner. They played an important role in providing essential information about the eclipse as well as streaming the event live from several locations along the path of totality.

Many other partners were involved in the library eclipse project. Astronomers (including many members of the American Astronomical Society), astronomy hobbyists (e.g., members of NASA and the Astronomical Society of the Pacific's Night Sky Network – http://nightsky.jpl.nasa.gov) and NASA's Solar System Ambassadors – http://solarsystem.nasa.gov/ssa), museum educators, park rangers, and science teachers (contacted through the National Science Teachers Association) partnered with libraries in their own communities, helping to put on eclipse outreach events. For example, recent data from NASA's Solar System Ambassador program showed that through the end of August, members had logged 394 programs at libraries that served 55,000 participants. This was a dramatic increase from 2016. The Night Sky Network logged 296 events in libraries that reached 18,800 participants.



Hundreds of thank-you letters have been received and photos of events have been posted to the *STAR Net* Flickr account (https://goo.gl/28LqxT). For example, Menomin Hawpetoss, Information and Training Specialist, Menominee County Library, wrote "We had one of the biggest events our Library has ever seen. So, in my language, we say Waewaenen (Thank You)!" Many libraries had a response like this one from a librarian in Michigan: "This event and your help attracted people who had never come to the library before, but more importantly, they got library cards, they checked out books, and they CAME BACK. This helped them see us for what we've become, not what we were when they were children."

By engaging the American Library Association (ALA), Association of Rural and Small Libraries (ARSL), Chief Officers of State Library Agencies (COSLA) and other organizations that support libraries like *STAR Net*, we ensured that libraries throughout the country were aware of the eclipse well in advance to plan a successful event. According to the American Library Association's Public Awareness Office, "it was one of the largest science events that libraries have participated in."

STAR NET EXPANDS ITS STEM ACTIVITY CLEARINGHOUSE

The *STEM Activity Clearinghouse* was built as part of an Institute of a Museum and Library Services (IMLS) grant to the Maine State Library, with additional support from several *STAR Net* programs: the NSF funded *STAR Net Phase 2* and the NASA funded *NASA@ My Library* initiative. NCIL manages *STAR Net* and the Clearinghouse.

The Clearinghouse was originally planned to reside in a simple folder structure on a prior version of the *STAR Net* website. Due to the addition of funding from the *NASA@ My Library* program, NCIL was able to port the existing *STAR Net* site to an improved Word Press site with increased functionality (at www.starnetlibraries.org). The decision was made to house the Clearinghouse on a separate, but closely linked site (http://clearinghouse.starnetlibraries.org/) with functionality that closely resembles the check-out process on sites like Amazon, allowing users to sort activities by a variety of attributes. The site ended its beta testing phase in December and is now up and running.

To choose the activities that would initially be featured on the site, we started by gathering existing *STAR Net* resources (from our *Discover Earth, Discover Tech, Discover Space, Discover Health* and *Discover NASA* library programs, as well as other informal materials developed for some of our museum programs.) These were added to thematic collections and coded with the attributes suggested by the libraries who participated in the survey. Next, we found new activities relevant to the requested themes by the IMLS pilot sites.

A key feature of this Clearinghouse is that we are not developing most activities from scratch. They have either come from our existing programs, or from other trusted and vetted educational venues. These sites include NASA

Wavelength, How to Smile, WGBH, and other similar sites. Instead of pulling the pdfs from these sites and hosting them on ours, we link directly back to the sites, allowing users to further explore the themes of the chosen activity if they so desire. The Clearinghouse was the number 1 referrer to the NASA Wavelength site in 2017.

Bolstered by the 2017 eclipse, it is very clear that the Clearinghouse is a well-used and trusted resource for library staff conducting STEM activities in their venues. At the end of 2017, it held about 150 activities. We anticipate that the Clearinghouse will continue to grow and thrive, as it continues to be supported by other federal funding. An unintended outcome for the Clearinghouse is the number of home school parents, teachers, girl scout troops, and museum staff who are using the activities. We have received quite a few requests for special call-outs for these groups and will be considering how to make the site welcoming to them in the future.

Credit: SSI/NCIL

SUMMATIVE EVALUATION FINDINGS FOR DISCOVER NASA: FROM OUR TOWN TO OUTER SPACE

"I have been involved in working with exhibits and programs for nearly 25 years and this was the best exhibit we have ever had. It was so very well curated, easy to assemble, and the support from your team was excellent. I believe it is vitally important for people in rural communities to have these experiences. It offers everyone the opportunity to grow a deeper understanding of concepts and activities that they are not often exposed to."

- FOTOS Host Library Staff Member

In 2014 the *National Aeronautics and Space Administration* (NASA) awarded a *Competitive Program for Science Museums, Planetariums and NASA Visitor Centers Plus Other Opportunities* grant to SSI (PI: Paul Dusenbery, Boulder Office) called *From Our Town to Outer Space (FOTOS)*. The three-year grant brought STEM learning experiences around NASA disciplines to six public libraries through a traveling exhibit called *Discover NASA*, associated programming for library patrons, training, resources, and a virtual community of practice for library staff and others who were interested in bringing STEM programming to libraries. The project had a special focus on delivering NASA content and programming to underserved and underrepresented communities across the United States. FOTOS *STAR Net* program.

The *Discover NASA* exhibit included computer interactives, interactive panels, multimedia experiences, standard graphical panels, and a hands-on Discovery Table. Examples of features in the exhibit included an immersive experience with astronauts living on-board the International Space Station, a touch table interactive where users could build their own solar systems, a Wind Tunnel interactive activity, a "Discover NASA Quiz Show" where patrons could test their NASA knowledge , a JPL/NASA produced "Eyes on Exoplanets" touchscreen kiosk that allowed patrons to learn about the search for exoplanets and the latest discoveries with near-real-time updates, and a" Mission to Mars" kiosk that took patrons on a journey to Mars and back.

In addition, asteroids and comets were featured in the "Space Rocks" kiosk that included games such as "What if it Hit My Town", "Asteroid Impact," and "What are the Odds?" Two large meteorite samples were available for patrons to explore using a magnifying glass and bar

Image Credit:ALMA (ESO/NAOJ/NRAO), M. MacGregor; NASA/ESA Hubble, P. Kalas; B. Saxton (NRAO/AUI/NSF)

magnet. Other interactives included a "Daily Planetary Report Station" where patrons used a green screen and costumes to give a weather report from various locations in the Solar System, and a "Discovery Table" that featured various space-themed, hands-on activities such as designing and building robotic rovers using Legos and other equipment.

The summative evaluation of the *FOTOS* project was conducted by Educational Development Center (EDC) and employed a mixed-methods design. The evaluation methods included administration of pre- and post-exhibit surveys to library staff who hosted the exhibit, site visits to two selected libraries, and conducted interviews with staff from all the host libraries, conducted interviews and collected patron surveys, and reviewed final reports from host libraries. Institutional Review Board approval was received for the evaluation plan and instruments before data collection began.

KEY FINDINGS:

- Patrons spent time engaging with the *Discover NASA* exhibit and programming.
- Patron survey results indicate high levels of patron engagement and interest in *Discover NASA* topics.
- Patrons indicated they were interested and planned to learn more about NASA missions, impacts, and space science.
- All host libraries developed and conducted exhibit-related programs and collaborated with outside partner organizations for program development and implementation.
- Library staff reported an increase in their knowledge of *Discover NASA* exhibit-related topics.
- *FOTOS* Library staff see encouraging STEM learning as a role for their library.
- *FOTOS* libraries used a variety of partners to develop and/or provide STEM learning experiences including science museums, universities and colleges, retired teachers/STEM professionals, astronomy societies, and NASA-affiliated groups/individuals.
- *FOTOS* libraries identified audiences historically underrepresented in STEM fields and successfully provided targeted audiences with STEM learning experiences.

FINANCIAL SUMMARY

Image Credit: NASA

SPACE SCIENCE INSTITUTE • SUMMARY STATEMENT OF FINANCIAL POSITION

AS OF DECEMBER 31, 2017 AND 2016

ASSETS	2017	2016
Assets		
Cash and cash equivalents	95,290	660,425
Accounts receivable	1,511,332	1,196,673
Prepaid expenses and deposits	93,536	102,723
Net furniture, equipment, and property	30,105	17,972
Total assets	**$ 1,730,263**	**$ 1,977,793**
LIABILITIES AND NET ASSETS		
Liabilities		
Accounts payable and accrued liabilities	663,328	633,349
Deferred revenues	189,309	103,839
Line of credit	525,000	425,000
Total liabilities	$ 1,377,637	$ 1,162,188
Net assets		
Unrestricted	343,553	323,552
Temporarily restricted	9,073	492,053
Total net assets	$ 352,626	$ 815,605
Total liabilities and net assets	**$ 1,730,263**	**$ 1,977,793**

SUMMARY STATEMENT OF ACTIVITIES

for the years ended December 31, 2017 and 2016

SUPPORT AND REVENUE	2017	2016
Grants, contracts, and cooperative agreements	7,546,599	7,483,571
Contributions	56,495	496,512
Exhibit income	166,966	104,075
Interest income	188	148
Total support and revenue	**$ 7,770,248**	**$ 8,084,306**
EXPENSES		
Program services	6,335,171	5,813,383
Fundraising	21,698	14,600
General and administrative	1,876,358	1,749,230
Total expenses	$ 8,233,227	$ 7,577,213
Change in net assets	(462,979)	507,093
Net assets, beginning of year	815,605	308,512
Net assets, end of year	**$ 352,626**	**$ 815,605**

The summary financial information does not include sufficient detail or disclosures to constitute presentation in conformity with accounting principles generally accepted in the United States of America. If the omitted detail or disclosures were included, they might influence the user's conclusions about the Institute's financial position, changes in net assets, and cash flows. Accordingly such information should be read in conjunction with the Institute's audited financial statements for the years ended December 31, 2017 and 2016, from which the summarized information was derived. A copy is available upon request.

SPACE SCIENCE INSTITUTE

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