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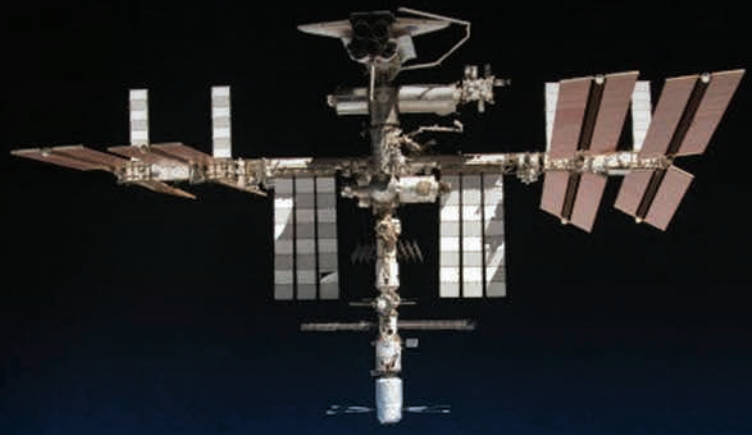
CASPER

CENTER FOR ASTROPHYSICS, SPACE PHYSICS & ENGINEERING RESEARCH

Astrophysics & Space Science Theory Group • Early Universe Cosmology & Strings Group
Gravity, Cosmology & Astroparticle Physics Group • Hypervelocity Impacts & Dusty Plasmas Lab
Space Science Lab • Paul and Jane Meyer Observatory



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CASPER News is an annual publication of the Office of the Vice Provost for Research at Baylor University.

CASPER News highlights the work of faculty and staff of the Center for Astrophysics, Space Physics & Engineering Research, Dr. Truell Hyde, director.

CASPER is located in the Baylor Research and Innovation Collaborative in Waco, Texas.

For more information, go to: http://www.baylor.edu/casper.

Send comments to: research@baylor.edu.

CASPER proposal team awarded NASA/NSF grant for on-orbit dusty plasma research aboard the International Space Station

A team of researchers led by CASPER director Dr. Truell Hyde was informed in February of a decision by NASA and the National Science Foundation to support their proposal to conduct fundamental dusty plasma physics experiments aboard the International Space Station. The CASPER project began in 2017 with funding through at least 2021.

The project, titled PK-4: Self-Ordering of Interactive Complex Plasma Particles in Microgravity, utilizes Plasma Kristall-4, a dusty plasma generator developed by a joint European-Russian collaboration. It was carried to the ISS by a Russian Progress spacecraft in 2014 and was commissioned in 2015.

The PK-4 effort is the latest in a series of experiments that began in 2001 when scientists at the European Space Agency and Roscosmos, the Russian Federal Space Agency, began developing a means of studying the behavior of plasmas and charged particles in orbit. When micron-sized particles become highly charged within a plasma, the resulting system can exhibit gaseous, liquid or solid behavior depending on the inherent operating conditions. PK-4 makes it possible to observe this behavior in a microgravity environment.

"This research will be used to develop comprehensive theories on the interparticle potential and grain-plasma interactions that determine the microscopic and macroscopic properties of a complex plasma, including the external forces acting on the particles, the fundamental interactions between the particles and the thermodynamics and self-organization of the system," Hyde said.

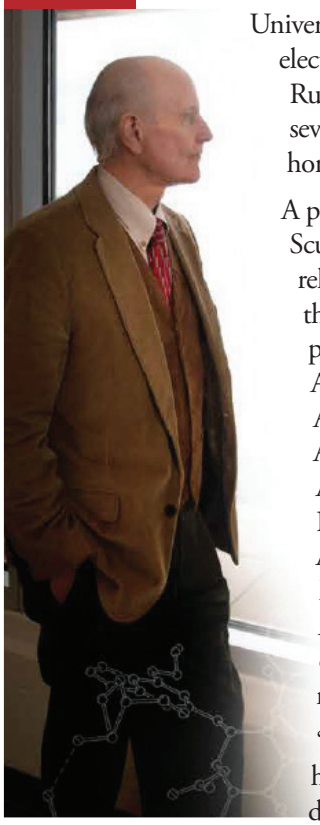
"Microgravity experiments are needed because the influence of gravity in terrestrial experiments limits the length of the dust chains needed for more extensive study," says Associate CASPER Director Dr. Lorin Matthews. "The [Earth's] gravitational force is strong enough that it dominates the other forces acting on the dust, making these forces difficult to measure."

In earlier experiments in the series, high-altitude aircraft and sounding rockets provided microgravity environments lasting from only half a minute to several minutes in duration. The PK-4 on board the ISS will provide a continuous microgravity environment for CASPER experiments carried out by ISS researcher-astronauts using the PK-4 generator.

"The CASPER proposal was exceptionally well received, at least in part due to the fact that two of our assistant directors of research, Oleg Petrov and Vladimir Nosenko, have been involved with this project since its inception," said Hyde. "Their presence on the team, along with another CASPER assistant director of research, Peter Hartmann, DLR researcher; Hubertus Thomas Group Head, Institute of Material Physics in Space, DLR; and Marlene Rosenberg from the University of California San Diego — combined with CASPER's long-time research experience with field-aligned particle strings — led to solid NASA and NSF reviews and approval for funding."

"It's hard to overstate the impact of this project," Hyde added. "These findings will advance research in astrophysics and planetary science in the study of planetary ring systems, dust in protoplanetary disks, and charged dust on the surfaces of airless bodies like the moon and asteroids. In atmospheric physics, the results could help explain the formation of noctilucent clouds and, in fusion research, they could shed new light on dust contamination and operating stability. Materials physics will benefit in the areas of soft matter, metastable states, complex fluids, and granular matter. Even advanced manufacturing could realize improved semiconductor production through refinement in etching and deposition processes," Hyde said. "It's all pretty exciting."

Eminent Baylor scientist, CASPER fellow named to Russian Academy of Sciences



Membership in a National Academy is considered one of the highest honors a scientist can achieve. Dr. Marlan O. Scully, Distinguished Research Academician of Science & Engineering at Baylor University, recently received word of his election as a Foreign Member to the Russian Academy of Sciences—the seventh such organization to so honor Scully.

A pioneer in theoretical quantum optics, Scully has received virtually every award relevant to the field. In addition to this most recent honor, Scully was previously elected to the National Academy of Sciences, the American Academy of Arts & Sciences, the Academia Europaea, the National Academy of Inventors, the Max Planck Society, and the Hungarian Academy of Science. Yet with all his previous accolades, the Russian Academy's letter announcing his election was quite unexpected, but most welcome.

"These things are always a surprise," he said of receiving the news. "I was delighted, simply delighted."

A native of Casper, Wyoming, Scully completed his graduate studies at Yale under Dr. Willis Lamb, winner of the 1955 Nobel Prize in physics. Scully joined Baylor University in 2011, where he established and directs Baylor's Quantum Optics Laboratory in the Baylor Research & Innovation Collaborative. He holds positions at Princeton University and Texas A&M University, where he is a Distinguished Professor and holder of the Herschel Burgess Chair in the department of physics. He also directs Texas A&M's Center for Theoretical Physics.

Scully has engaged in research with scientists abroad for virtually his entire career. "I've collaborated strongly with my colleagues in Europe and the Russians have been a wonderful source of scientific talent and personal collaboration," he said. "This [award] is another step in the direction of cementing those collaborations in the difficult political world that we live in; it's great to see that science can still transcend political differences."

Typically, researchers are elected to academies for their contributions to a particular discipline or area of research over time, rather than for a single discovery. It was his many years of steady, methodical investigation and discovery that earned Scully this recognition."Over the last several decades we have been interested in novel ways to make lasers. Lasers are typically formed by inducing an inversion of the population—having more atoms in the excited state than in the ground state of the atom. Now, using subtle features of quantum mechanics, we don't have that restriction anymore," he said.

Scully refers to quantum mechanics as "the epitome of twentieth century physics" and holds Einstein's Theory of the Quantum in equal if not higher esteem than the great physicist's more familiar work in relativity. In fact, Einstein was awarded the Noble Prize in 1921 specifically for work in quantum theory. "These [quantum concepts] enable us to do things that you wouldn't believe would be possible otherwise," Scully said.

The growing list of innovations flowing from Scully's research includes a means for safely detecting toxic substances— weaponized anthrax, for example—at a distance and in real time, and lasers formed of air itself that are capable of monitoring the condition of agricultural crops. His work has even extended by several orders of magnitude researchers' ability to investigate the infinitesimal subatomic world.

"Before, if we wanted to resolve the features of any very small system we would have to use a wavelength of light smaller, shorter, than the dimensions of the object," Scully explained. "Now we're able to get around that, to go beyond the so-called 'Rayleigh limit.' We're able to see at dimensions that are thousands of times smaller than the wavelength of light that we're using."

The versatility of Scully's work has led to its application in an ever-widening range of disciplines.

"These same quantum tricks are now being applied to biology and biological systems, enabling us to monitor cancer growth, spot a virus and identify different bacteria. These are perhaps the most important [developments] from the perspective of short-term impact and spinoffs to benefit mankind."

Despite the rigors of maintaining laboratories at three universities, Scully remains devoted to family and faith. "My best friend and collaborator is my wife," he says of Judith Bailey Scully, with whom he raised three sons. "And one thing that I do always try to emphasize to my students is that our presence here on Earth is a gift. Science and the spiritual side of the universe are two sides of the same coin; I think that bears repeating and we should always keep it in mind."

CASPER associate director chairs APS committee on women in plasma physics

Dr. Lorin Matthews

Over 20 years ago when Lorin Matthews became one of the first two Baylor physics doctoral candidates (both women) mentored by CASPER director Dr. Truell Hyde, she knew all too well that she was entering a field long-dominated by men. But having spent two years as a multidisciplinary engineer in the aerospace industry, she was well-acquainted with the challenges she would face upon joining the Baylor faculty as the first woman in the department of physics.

Today, Dr. Lorin Matthews is Associate Director of CASPER and heads the center's Astrophysics and Space Science Theory Group. Two years ago she accepted an invitation to chair the American Physical Society's Committee on Women in Plasma Physics, or CWiPP. Matthews sat on the CWiPP for nearly a decade before taking the chair. She is also in her second full year as an APS member at large on the executive committee; she sees both positions as platforms for helping her female colleagues succeed in a male-dominated profession.

Early on she learned about and made use of one of CWiPP's most popular services — a grant to provide funds for childcare so those with young children can attend the society's annual Division of Plasma Physics meeting.

"I actually did that one year when my son was eleven months old and he was still a nursing baby," she said. "I took him with me and during the day I was able to pay someone to watch him while I was at the conference. Before that I had to keep him with me during the presentation and the applause would wake him up!"

As chair, she now reviews applications for childcare grants and recommends candidates to the full committee for approval. And the grants are now available across the board. "Anyone can apply for the childcare grant … the applicants are mostly people who are in their early careers, and that can be both men and women."

Matthews also heads up planning for other CWiPP-sponsored events and performs numerous other administrative duties. But she feels it is important to be a point of contact for other female physicists with ideas or questions, especially those dealing with gender bias. She is quick to say that although she is fortunate in never having experienced gender bias at Baylor, it remains an obstacle for female professionals in many settings.

Studies and surveys continue to reveal a distinct disparity between men and women in the number of papers published, principal authorships, selection for participation in programs, and other aspects of the profession. That may account in part for the significant number of members who choose not to specify their gender.

"Overall, APS membership is about 13 percent women and 80 percent male," she said, adding, "but some divisions — biophysics, for example — are up to 20 percent women. The Division of Plasma Physics has the lowest percentage of women of all APS divisions: only about nine percent." (Note: About seven percent of members do not specify a gender.)

Still, with more than 2,200 researchers in the plasma physics division, that amounts to about 200 female physicists for whom Matthews and the CWiPP are welcome sources of tailor-made support.

"The CWiPP has worked to make sure that women are well-represented in the DPP as session chairs, on committees and as invited speakers," she said. "In the last several years, the percentage of these roles filled by women has exceeded the percentage of women in the DPP. We hope that by making women visible role models for younger DPP members, we can continue to increase the number of women in the field."

More CASPER News on page 24

Co-discoverers Dick Campbell (L) and David Eisfeldt at the Paul and Jane Meyer Observatory

A New Moon!

CASPER associate credited as co-discoverer of moon orbiting an asteroid.

During his 15 years as a lecturer in Baylor's department of mechanical engineering, Dick Campbell always enjoyed taking time to introduce many students to his other great love – astronomy. Now retired since May, Campbell is free to spend more time at the Central Texas Astronomy Society's Paul and Jane Meyer Observatory near Clifton, Texas, pursuing that passion for the cosmos.

Apparently, it is time well spent: this past June, Campbell and fellow CTAS amateur astronomer David Eisfeldt, received credit for discovering a rare astronomical phenomenon — a tiny moon that orbits an asteroid.

Of the over half million known asteroids, only about 300 have been confirmed as having moons accompanying them. Campbell's and Eisfeldt's search began when Paul Maley, a retired NASA worker and long-time member of the International Occultation Timing Association – or IOTA – noted that on March 14, 2017, a 29-mile-wide asteroid known as 113 Amalthea would pass in front of a faint star in the Gemini constellation named TYC 1878-01081-1.

When one astronomical object "occults" or passes in front of another from our perspective on Earth, observers often can uncover much about both objects from the way the light from the objects varies as the nearer object traverses the face of the more distant one. In this case, Amalthea circles the sun every 3.66 years in a path that lies beyond the orbit of Mars, some 144 million miles (231 million kilometers) from Earth, while the background star lies many light-years outside our solar system.

From the IOTA database, Maley also learned that the viewing track of that event would include a narrow strip of the southwestern U.S., from California to Texas. Once word of the upcoming occultation reached skywatchers along the projected path, several volunteered to observe and record the event. Ultimately, seven amateur astronomers across California, Arizona and Texas made ten recordings of the occultation.

For his part, Campbell used the 24-inch telescope at the Meyer Observatory; Eisfeldt set up a separate recording telescope at his home some 45 miles east of the Clifton site, but within a mile of the same latitude.

As it turned out, Campbell and Eisfeldt, were in exactly the right place at exactly the right time: both recorded a disruption in the star's light that was consistent with a companion object alongside the asteroid. At his home observatory, Eisfeldt saw the star wink out briefly as Amalthea dashed across its face, but Campbell missed it.

"Yep, [I was] watching the video screen and had the shortwave radio on with [United States National Institute of Standards and Technology's official time station] WWV running for the time hack," Campbell recalls. "I must have blinked when it happened because it took less than half a second. But when I went back and looked at the video frame-by-frame, I could see it."

Campbell and Eisfeldt packed up their data and sent it in to IOTA for analysis, but Eisfeldt accidently emailed his to the wrong address. When Maley's analysis team reviewed Campbell's data, they were surprised because another observer in Arizona hadn't seen anything unusual at all. The analysts thought Campbell must have done something wrong and called him.

"I said, 'Well, I dunno, what about Dave Eisfeldt's data? He says he saw the same thing.' And they said, 'We don't have his data.' When they finally got Dave's data, they started getting excited because now we might have something odd going on that can't be explained."

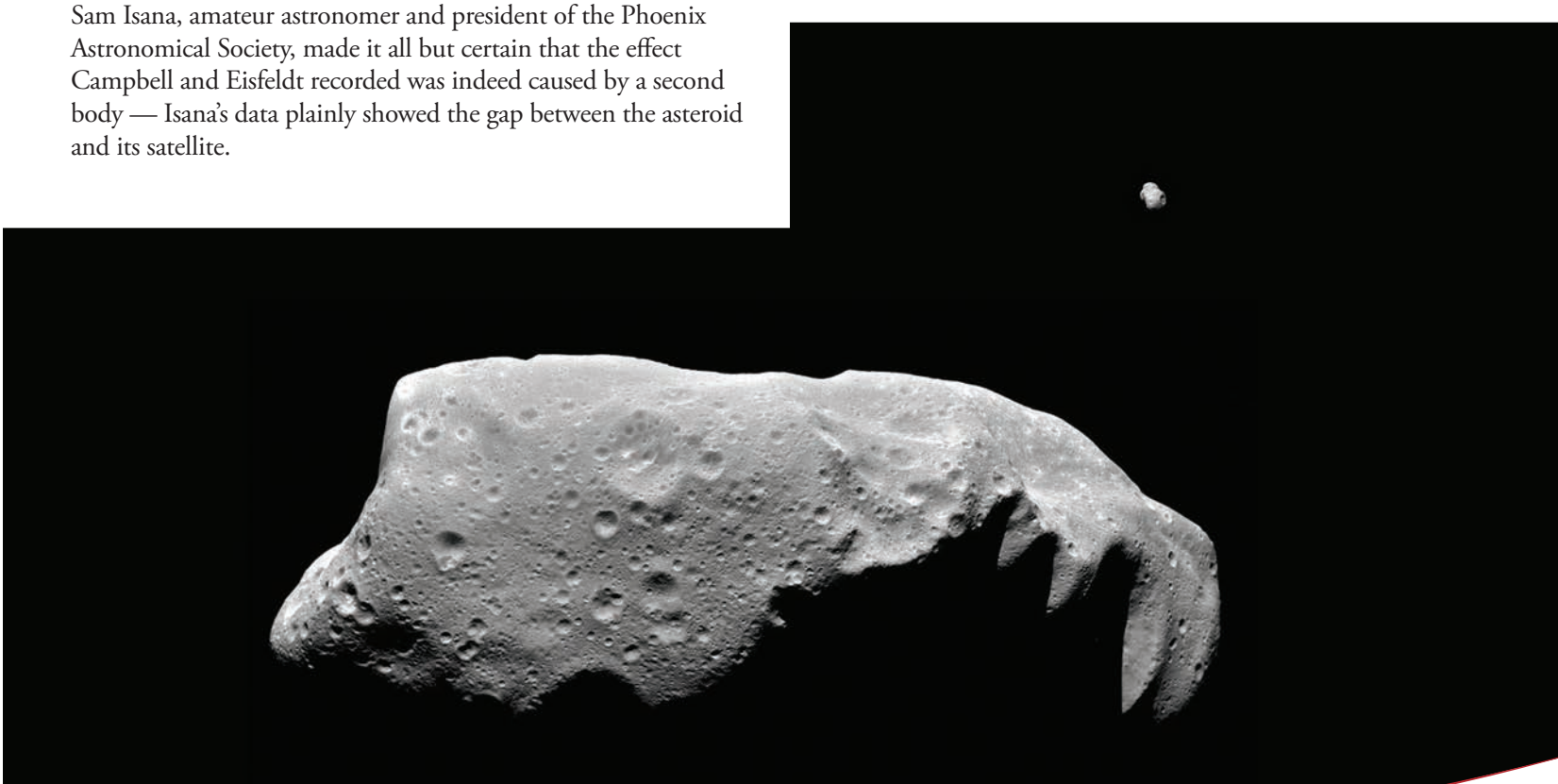
Exhaustive review of the Texas data by IOTA analysts revealed possible evidence of an object accompanying Amalthea. But it was also possible that the variance in the star's light might have been due to an irregular feature on the asteroid's surface — a mound, for example. But data from the Arizona observation by Sam Isana, amateur astronomer and president of the Phoenix Astronomical Society, made it all but certain that the effect Campbell and Eisfeldt recorded was indeed caused by a second body — Isana's data plainly showed the gap between the asteroid and its satellite.

The analysis team thought they were ready to announce their discovery and, for the first time in its history, IOTA submitted the data, their analysis and claim of discovery to Harvard University, which has historically served as the central collector for such discoveries. When they receive such data, Harvard astronomers pore over the materials and decide whether to make an official announcement to the scientific community, traditionally via electronic telegram.

The observers' data and the thoroughness of IOTA analysts' work were so compelling that not only did the Harvard astronomers issue an announcement telegram, but they also assigned the little, four-mile-wide moon its own designation — S2017(113)-1. It was a vote of confidence seldom afforded even professional astronomers' findings and lent credence to the team's claim of credit for the first discovery of an asteroid satellite made by amateur astronomers.

Officially, however, the discovery is listed as a "very strong probable." Confirmation of the discovery will have to come from additional observations. But confirmation could come as early as April, 2018, when Amalthea again occults a star, this time over the north-central U.S. There are three other occultations predicted for next year as well. Campbell is hopeful of early confirmation, but remains realistic.

"It could take years to get confirmation," he says. "But I'm confident in the work the entire team has done to declare that we have a probable discovery, a very strong probable. Confirmation will have to come from someone else. It's out of our control."



Artist depiction of an asteroid and its companion satellite.

CASPER graduate student applies novel mathematics to much-studied physics phenomenon

CASPER Ph.D. candidate Eva Kostadinova is principal author of a favorably received scientific paper on one of the most enigmatic and most studied physics phenomena of the last half-century: Anderson localization.

In his now-classic 1958 physics paper, *Absence of Diffusion in Certain Random Lattices,* then-Bell Laboratories P hysicist Dr. Philip W. Anderson hypothesized that under certain conditions, electrons that typically flow freely in a conductive material can instead congregate—become localized—at various regions within a material, rendering it non-conductive. Though underappreciated for nearly a decade, the concept gradually gained acceptance and won Anderson a Nobel Prize in 1977.

His paper had a seminal effect on the physics world, establishing "condensed-matter physics," a new field that today is the most active area of research in physics. Fully a third of current physicists self-identify as condensed-matter physicists.

Yet, even after five decades of rigorous investigation, much about localization has not been explained. Scores of researchers continue to employ a host of theoretical and experimental tools to gain a deeper understanding of a phenomenon that is vital to the materials sciences.

Kostadinova's *Physical Interpretation of the Spectral Approach to Delocalization in Infinite Disordered Systems* appears in the December 2016 issue of *Materials Research Express*. Former Baylor mathematics professor Dr. Conni Liaw, CASPER associate director Dr. Lorin S. Matthews, and CASPER director Dr. Truell W. Hyde were co-authors of the paper, which describes their use of "spectral analysis"—a new mathematical tool developed by Dr. Liaw—to focus specifically on delocalization, the flip-side of the localization phenomenon.

"Anderson hypothesized that if there is enough disorder (e.g., contamination) in a conducting crystal, the electron wave functions will start localizing more in areas where there is more disorder," Kostadinova says. "It turns out that if you are looking at localization only, by stating the problem that way you are excluding information that you may have if you are also looking for delocalized states. What we figured is, some information about delocalized states at a small disorder is lost because [researchers] are not looking for delocalization; they are looking just for localization."

The Bulgarian-born researcher is well along with a follow-up paper that will report the results of simulations run for a variety of lattice geometries. Ultimately, the team plans to test their findings using dust particles suspended in plasma crystals as a means of simulating the phenomenon at a microscopic scale that can be recorded visually.

"We are taking advantage of new developments in math, trying to translate them into physics, into a new physics experiment," she says. "Actually we have this huge advantage because nobody has done it this way."

COSPAR cancels 2016 assembly

For the first time in the event's history, the Committee on Space Research cancelled a biennial scientific assembly due to security concerns in the host city of Istanbul, Turkey. Originally scheduled for July 30–August 7, 2016, the event would have been the organization's 42nd biennial conference and would have marked COSPAR's 60th anniversary.

Organizers regretted the cancellation and agreed to return all registration fees to those who had planned to attend the assembly. Dr. Lokman Kuzu, chair of the local COSPAR organizing committee, announced the decision on the event's website.

"We were excitedly looking forward to COSPAR 2016," Kuzu wrote. "We were hoping our attendees would assemble, cooperate, collaborate, learn, teach, and enjoy their visit to Istanbul. Unfortunately, that didn't happen this time.

So we hope this gesture [refunding registration fees] can serve as a taste of Turkish hospitality. We look forward to seeing you at future events around the world and in Turkey."

Istanbul had been the target of three terrorist attacks in January and March 2016 that were linked to the Islamic State of Iraq and Levant, or ISIL. A fourth attack on the city's Atatürk Airport on June 28 that killed 45 people and injured 230, coupled with a failed military coup on July 15, prompted cancellation of the event, which typically attracts thousands of scientists, engineers and policymakers from around the world.

The 2018 assembly is scheduled for July 14-22, in Pasadena, California, U.S.A.

Hartmann returns to upgrade instrumentation, conduct experiments

CASPER Assistant Director of Research, Dr. Peter Hartmann, returned to Baylor last November to work with researchers in CASPER's Hypervelocity Impacts and Dusty Plasma Lab experimental research group headed by the center's director, Dr. Truell W. Hyde. In collaboration with the Hungarian Academy of Sciences' Wigner Research Centre for Physics, Hartmann designed and constructed a device that extends the capabilities of one of CASPER's three GEC rf plasma reference cells.

Given the name "RotoDust," the device rotates the electrically charged, strongly interacting dust particles that are present in a low-pressure, gas-discharge complex plasma.

"[RotoDust] allows us to study the magnetic effects of dusty plasmas without having to resort to large and expensive superconducting magnets," said Hartmann. "It even allows researchers to apply significantly larger magnetization effects to the cloud than are possible with currently available magnets."

Along with fellow CASPER researcher Jorge Carmona Reyes and technician Mike Cook, Hartmann performed a series of RotoDust experiments on quasi-magnetized dusty plasmas to verify computer predictions on the effect of the magnetic field on self-diffusion and viscosity, two of the most fundamental transport properties. Researchers are now analyzing the large compilation of raw data resulting from the experiments.

Besides experiments on dust "ensembles," Hartmann performed a series of experiments targeting the gradual reduction in size of a single dust particle in a discharge. Particle size is a key consideration because the dynamics of a dust particle in an electric field are governed by its charge-to-mass ratio. Both the charge and the mass are dependent on the dust particle size, though in significantly different ways. The variation in time of the circular orbit of a single dust grain in a stable RotoDust experiment can be directly linked to its variation in size: the smaller the particle, the faster its orbit.

Using this principle, Hartmann has demonstrated that this novel but still unrefined method can detect a sputtering-induced reduction in particle radius of less than 10 nanometers. These results were presented at the 21st Symposium on Applications of Plasma Processes (SAPP XXI) in Štrbské Pleso, Slovakia, published in The Physics of Plasma (24 060701 2017).

Before returning to Europe, Hartmann discussed current and possible future directions of dusty plasma physics with Dr. Truell Hyde, Director of CASPER and Head of the HIDPL and Dr. Lorin Matthews, associate CASPER director and lead researcher for the theoretical group. He also delivered a CASPER seminar titled *Particle in Cell with Monte Carlo Collisions*.

Nosenko seeks key plasma parameter in new research

During his research visit at CASPER last year, CASPER assistant director of research Dr. Vladimir Nosenko was surprised at a result from one of the last experiments he and CASPER researcher Jorge Carmona Reyes conducted before Nosenko had to depart for his laboratory in Germany. This April he returned to CASPER for a two-week series of experiments to follow up on that earlier work.

"Last year Jorge and I did experimental work on torsion in two-dimensional plasma crystals, and it was going great," Nosenko recalls. "Then in one of the last drives we found something very different; it was not torsion, it was something very different."

Nosenko took the data back home to Germany where he is a researcher for the German aerospace agency DLR. After looking through the data and conferring with colleagues, he realized the unusual effect was an instance of a common and well-known phenomenon known as mode-coupling instability. But Nosenko had not recognized it for what it was for good reason.

"It was unexpected because normally mode-coupling instability happens at low pressure and we were working under at least ten times higher pressure," he explained. "No one ever looked at higher [pressure]. Theory predicts what is called a damping threshold, where you can see [the instability] at a certain pressure but not any higher."

This year Nosenko elected to spend his time at CASPER looking for that pressure at which the instability would disappear. Discovering this damping threshold would bring added insight into another important plasma phenomenon: plasma wakes, that are sometimes used in high-energy particle accelerators. Nosenko is hopeful that the data derived will yield significant new insights that could strengthen existing theories and spawn new ones.

"Theory says that this cut-off pressure depends on plasma wake parameters. If we observe that [threshold], it is very important because then we can also say something new about plasma wakes."

New CASPER Adjunct Faculty

Dr. Eric W. Davis joins CASPER as an Adjunct Professor the Early Universe, Cosmology and Strings theoretical group headed by Dr. Gerald Cleaver. Davis currently holds positions as Senior Research Physicist at the Institute for Advanced Studies at Austin, CEO/Chief Scientist for Warp Drive Metrics, and Chief Scientific oOfficer for EarthTech, Inc., a center for research into non-conventional energy production. He holds a Ph.D. in physics from the University of Arizona and brings more than thirty years' experience in an uncommonly broad range of fields that encompasses spacecraft instrumentation design, alternative spacecraft propulsion, scientific and technical intelligence and analysis for the DoD, DoE and Air Force Research Laboratories, and many other fields. An acknowledged expert in theoretical astrophysics, Davis is a fellow of the British Interplanetary Society, an Associate Fellow of the American Institute of Aeronautics and Astronautics, and a member of both the American Astronomical Society and New York Academy of Sciences.

Also joining CASPER's EUCoS group is Adjunct Assistant Professor **Dr. Ahmad Borzou**, who received his Ph.D. from Baylor in 2016. Borzou earned his M.Sc. in physics from Shahid Beheshti University in Tehran, Iran, and his undergraduate degree from Shahid Bahonar University in Kerman, Iran. He has been a co-author of numerous papers on high-energy particle science conducted by the Compact Muon Solenoid collaboration at the Large Hadron Collider at CERN, the renowned high-energy physics research center in Geneva, Switzerland. Borzou's faculty advisor, Baylor Professor of Physics Dr. Kenichi Hatakeyama, has been a CERN researcher since 2006. Borzou's current research centers on formulation of a quantum theory of gravity through the application of Lorentz gauge theory.

Personal Updates

Dr. Ahmad Borzou has received Baylor's STEM Dissertation of the Year award for the 2016-17 academic year. The award is given each year to the Baylor doctoral candidate in the science, technology, engineering or mathematics disciplines who exhibits exceptional scholarship, research, and writing. He was awarded his Ph.D. last December after successfully defending his dissertation, *Theoretical and Experimental Approaches to the Dark Energy, and the Cosmological Constant Problem*. Botzou accepted the dissertation award at an April 21, 2017, luncheon accompanied by his graduate program director, Dr. Gerald Cleaver, and Dr. Kenichi Hatakeyama, his graduate advisor.

In addition to a certificate of recognition, Borzou received a $1,000 monetary award and will have his dissertation published in an individual volume of *Springer's Physics Outstanding Dissertations* journal series. Borzou's dissertation previously won the Physics Department's Dissertation of the Year award.

The Baylor Dissertation of the Year Award was established as a single prize in 2012, but was split into STEM, Humanities and Social Sciences divisions during the 2014–15 term. For three of the four years the STEM award has been given, the winning dissertation has been submitted by physics candidates associated with CASPER. Previous winners were Dr. Douglas Moore and Dr. V.H. Satheeshkumar.

CASPER Director Appointed IEEE Senior Editor

Founder and director of the Center for Astrophysics, Space Physics and Engineering Research **Dr. Truell W. Hyde** has been appointed Senior Editor of *Transactions in Plasma Physics*, a publication of the Institute for Electrical and Electronics Engineers, the world's largest technical professional association. He will serve as Senior Editor in the field of dusty plasmas, a topic on which he has contributed over a hundred papers as author or co-author.

New CASPER Members (Babies)

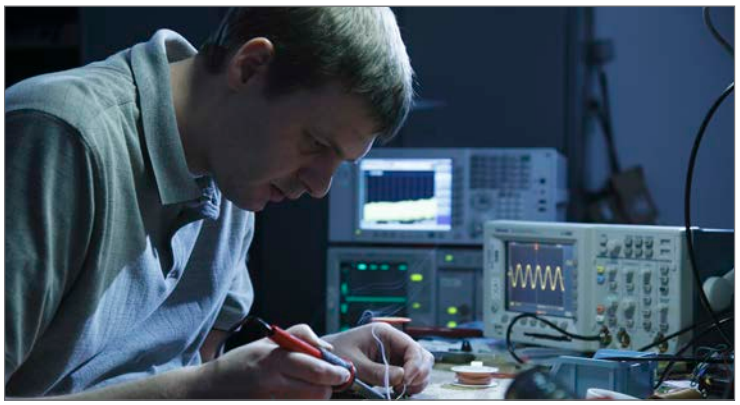
Joanna Chen

8 lbs. 7 oz., 24 in.
Born June 8, 2016
to Mudi and Maggie Chen.

Alvana Leanora Carballido

6 lbs. 8 oz.
Born April 18, 2017
to Augusto and Daria Carballido.

CASPER mourns loss of gifted technician, much beloved friend.



When long time CASPER research fellow Dr. Hans-Peter Röser passed away in December of 2015, the lab mourned his passing deeply and lamented the setback the loss posed to a host of ongoing research projects. But just six months later the CASPER family was dealt still another major blow with the sudden passing of the lab's capable and personable key technician Jimmy Schmoke.

A Waco native, Jimmy earned an Associate of Applied Science degree in semiconductor manufacturing technology from Texas State Technical College in 2001 and soon was awarded a paid internship with CASPER. Immediately impressing everyone with his electronics savvy, resourcefulness and problem-solving abilities, he was soon hired full-time as a research technician for CASPER's experimental lab. As CASPER became an internationally recognized research center with partnerships in Hungary, Moscow, and Germany, Jimmy quickly became the lab's technical "backbone," earning the respect of the numerous American and international researchers he served.

During his 15 years at CASPER, Jimmy also designed and built exhibits and interactive hands-on training devices for CASPER's successful Physics Circus, an educational outreach aimed at giving K-12 students a glimpse into the fascinating worlds of science and engineering. It was during that effort that he met a young Physics Circus actress named Margaret Holmes; the two wed in 2007.

CASPER Director and Baylor Vice Provost for Research, Dr. Truell Hyde, recalls Jimmy as a highly intuitive electronics technician who made much of CASPER's work possible. "He's irreplaceable as both a friend and colleague, absolutely irreplaceable."

Assistant Vice Provost for Research, Director of Technology Commercialization and Industry Engagement retires

Jim Kephart came to Baylor in 2007 from aerospace giant L3 Technologies to serve as Assistant Vice Provost for Research, Director of Technology Commercialization and Industry Engagement. His leadership was central to the Baylor Research and Innovation Collaborative's opening in 2012, as well as to recruiting the first industry partners for the BRIC and to successfully securing intellectual property protection for several innovative concepts developed by Baylor research faculty with the BRIC's industry partners.

An avid fisherman and camping enthusiast, Jim retired in September of 2016, making his Baylor tenure the capstone of a long career that included more than 20 years in the U.S. Air Force and service as program manager on the technically challenging Stratospheric Observatory for Infrared Astronomy project for L3 Technologies. The SOFIA program installed a sophisticated, research-quality telescope in a highly modified Boeing 747SP to conduct astronomical observations at high-altitude.

During a previous stint at United Space Research Association, Kephart formed a close friendship with the late German physicist Dr. Hans-Peter Röser. That relationship led to an ongoing agreement that brings students from the University of Stuttgart to CASPER each year to conduct research. Taking over for Kephart is Todd Buchs, who joins Baylor after a lengthy career in the U.S. Army that included a stint at the Pentagon and multiple tours and deployments to Europe, Korea, Bosnia and Iraq. After retiring from the Army in 2013, he served as Business Development Director for the University of Texas – Arlington Research Institute, and then as Vice President of Programs and Business Development for the Military Child Education Coalition.

Buchs' primary CASPER-related duty involves management of operations at the Baylor Research and Innovation Collaborative where CASPER is located. Buchs holds an undergraduate degree in engineering from the U.S. Military Academy and master's degrees from the Naval Postgraduate School, U.S. Army Command and General Staff College and U.S. Army Senior Service College.

Astrophysics & Space Science Theory Group (ASSTG)
Space Science Lab (SSL)
Hypervelocity Impacts & Dusty Plasma Lab (HIDPL)

58th Annual Meeting of the APS Division of Plasma Physics

CASPER researchers or collaborators authored or were collaborators on nine of the fifteen papers presented during the dusty plasma session of the 58th annual meeting of the American Physical Society's Division of Plasma Physics. The event was held October 31–November 4, 2016, in San Jose, California. A contingent of nine CASPER researchers, led by CASPER director Dr. Truell W. Hyde, attended the conference this year, including Dr. Lorin Matthews, Dr. Jay Kong, Dr. Ke Qiao, Jorge Carmona Reyes, graduate students Mudi Chen, Zhiyue Ding, and Eva Kostadinova, and undergraduate student Kyle Busse, who was a former participant in CASPER's NSF-funded Research Experiences for Undergraduates program. Dr. Matthews chaired the dusty plasma session.

Conference presentations

Busse, K., Kostadinova, E., Matthews, L.S., Liaw, C., Hyde, T.W. "Utilization of Complex Plasma in the Study of Localization Phenomena," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Chen, M., Matthews, L.S., Hyde, T.W. "The Ion Wakefield Inside a Glass Box," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Ding, Z., Qiao, K., Matthews, L.S., Hyde, T.W. "A Quick Method to Determine the Charge on Dust Particles in a Complex Plasma," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Hyde, T.W., Matthews, L.S., Kong, J., Qiao, K., Carmona-Reyes, J., Chen, M., Ding, Z., Kostadinova, E., Zhang, B. "Transitions between Dust Particle Structures in a Complex Plasma," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Kong, J., Qiao, K., Matthews, L.S. "Temperature Measurement for Dust Particles in a GEC Reference Cell," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Kostadinova, E., Liaw, C., Matthews, L.S., Busse, K., Hyde, T.W. "Spectral Approach to Anderson Localization in a Disordered-2D Complex Plasma Crystal," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Meyer, J., **Nosenko, V.**, Thomas, H. "New Large Diameter RF Complex Plasma Device," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Qiao, K., Ding, Z., Kong, J., Matthews, L.S., Hyde, T.W. "The Interparticle Interaction Between a Vertically Aligned Dust Particle Pair in a Complex Plasma," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA.

Shotorban, B. "First Passage Problem of Dust Charge Fluctuations," presented at the *58th annual meeting of the American Physical Society's Division of Plasma Physics*, October 31–November 4, San Jose, CA. (CASPER collaborator)

Astrophysics & Space Science Theory Group
Space Science Lab
Hypervelocity Impacts & Dusty Plasma Lab

Faculty and Staff

Truell W. Hyde
Lorin S. Matthews
Jie Kong
Ke Qiao
René Laufer
Connie Liaw
Oleg Petrov
Peter Hartmann
Vladimir Nosenko
Ray Nazzario
Augusto Carballido
Jorge Carmona Reyes
Michael Cook

Adjunct Faculty

John Fitch
Georg Herdrich
Rainer Sandau
Ralf Srama
Sean Casey
David Lary
Emmanuel Saridakis
Yungui Gong
Jeff Lee

Affiliated Faculty

Phillip Anz-Meador

Graduate Students

Michael Dropmann
Mudi Chen
Indra Ghimire
Bo Zhang
Chuchu Xing
Eva Kostadinova
Zhiyue Ding
Khandaker Jharm Ashrafi

229th Meeting of the American Astronomical Society

The American Astronomical Society held its 229th meeting January 3–7, 2017, at Gaylord Resort & Convention Center in Grapevine, Texas. The AAS is the primary organization of professional astronomers in North America and meets twice yearly in January and June "to enhance and share humanity's scientific understanding of the universe."

Meeting attendees included CASPER Director Dr. Truell Hyde, Associate Director Dr. Lorin Matthews, Assistant Research Professor Dr. Augusto Carballido and physics graduate student Chuchu Xiang. During the session titled *Molecular Clouds, HII Regions, Interstellar Medium & Dust*, Carballido and Xiang presented the two posters.

Conference posters

Carballido, A., Matthews, L.S., Hyde, T.W. "Dust coagulation and magnetic field strength in a planet-induced gap subject to MRI turbulence," presented at the *229th Meeting of the American Astronomical Society*, Gaylord Resort & Convention Center, Grapevine, Texas, January 3–7, 2017.

Xiang, C., Carballido, A., Matthews, L.S., Hyde, T.W. "Aggregate growth in a protoplanetary disk," presented at the *229th Meeting of the American Astronomical Society*, Gaylord Resort & Convention Center in Grapevine, Texas, January 3–7, 2017.

47th Lunar and Planetary Science Conference

CASPER researchers attended the 47th Lunar and Planetary Science Conference March 21-25, 2016 in The Woodlands, Texas. This conference brings together international specialists in petrology, geochemistry, geophysics, geology, and astronomy to present the latest results of research in planetary science.

The conference is organized into topical symposia and problem-oriented sessions.

The CASPER group included Augusto Carballido who presented "Dust Relative Velocities in the Vicinity of a Gap-Opening Jupiter-Mass Planet."

Experimental Astronomy Group

Over the past several years, Experimental Astronomy Group faculty and students have been measuring light curves of exoplanets as they transit their host star. These efforts have yielded much useful data that has been accepted for inclusion in the TRESCA database of the Variable Star and Exoplanet Section of the Czech Astronomical Society. (TRESCA is an acronym for TRansiting ExoplanetS and CAndidates.)

In previous years the group had studied only confirmed exoplanets for which the timing was well known. But last summer a team from the University of Dallas provided the group with a list of possible exoplanets for further observation.

The list came from analysis of a UD sky survey that supplied evidence of possible exoplanet transiting but did not include a detailed light curve. EAG researchers were able to plot a light curve using instrumentation at the Paul and Jane Meyer Observatory near Clifton, Texas. The observatory is managed by the Central Texas Astronomy Society.

The UD group provided the candidate star and an estimated time of transit for the potential exoplanet. Recently retired mechanical engineering senior lecturer and CASPER researcher Dick Campbell and PJMO observation support specialist Willie Strickland, assisted Raquel "Rocky" Katch in taking the measurements. Katch is a senior astrophysics major from Thousand Oaks, California.

Experimental Astronomy Group

Faculty	Undergraduates
Dwight Russell	Raquel Katch
Dick Campbell	Matthew Zakrzewski

"Clearly at the beginning of the run there is a noticeable change in the intensity of the target star that appears to be an egress of a planet during a transit," said EAG Director Dr. Dwight Russell. "If so, then the predicted transit time barely missed the actual transit event."

The researchers made several more attempts to measure the transit as the planet repeated its orbit around the star but were unsuccessful. This prevented them from confirming the event to be an exoplanet transit.
Though the data gathered was limited, it was sufficient to allow Katch and Russell to estimate a lower bound for the radius of the exoplanet compared to that of the star.

"Our analysis showed that if it is an exoplanet it must have a radius greater than 18% of the radius of the parent star," Russell said. "This would put it clearly in the Gas Giant category of exoplanets."

Russell says the experience demonstrates both the promise and challenges of discovering a new exoplanet: "It is exciting and difficult research. We will continue working toward discovering an exoplanet of our own."

Gravity, Cosmology & Astroparticle Physics Group (GCAP)

Over the last year, GCAP researchers have focused on four related areas. The first deals with quantum gravitational effects described by different theories of quantum gravity in the early universe, and current and forthcoming experiments to possibly detect them. This multidisciplinary project has involved GCAP Director Dr. Anzhong Wang and Physics Department Professor Dr. Gerald Cleaver, mathematics faculty Drs. Klaus Kirsten and Tim Sheng, and CASPER Assistant Research Professor Dr. Tao Zhu.

Together with two of Wang's graduate students and Prof. Shinji Mukohyama of Kyoto University, Japan, GCAP faculty are studying a second area, polarization of gravitational waves in our universe, with the goal of further characterizing GWs, which were only first detected in 2015.

GCAP researchers, including some graduate students, also have been studying the formation and thermodynamics of black holes, specifically with regard to gravitational theories having what is known as "breaking Lorentz symmetry." A collaboration between GCAP research and international colleagues from Brazil, China and Japan has resulted in some advances which have attracted much attention. As a result, Wang was invited to write a special review article on the topic for the *International Journal of Modern Physics* D26 (2017)1730014.

Gravity, Cosmology & Astroparticle Physics Group

Faculty and Adjunct Faculty

Anzhong Wang
Klaus Kirsten
Qin (Tim) Sheng
Yumei Wu
Nilton Oscar Santos
Tao Zhu
Rong-Gen Cai
Yungui Gong
Jianxin Lu

Graduate Students

Bao-Fei Li
Xinwen Wang
Madhurima Bhattacharjee
Jared Fier
Jacob Oost
Rafi Sazzad
Xiang Zhao
Baowen Li

Quantization of gravity has been a seemingly intractable problem in physics since the 1920s and is the fourth continuing topic of GCAP study. Together with several graduate students, Wang has been working on the quantization of gravity in the framework of Horava theory and is now focusing on models in low-dimensional spacetimes.

In addition to his research at Baylor, earlier this summer Wang took three graduate students, Madhurima Bhattacharjee, Bao-Fei Li and Baowen Li, to Zhejiang University of Technology in China to collaborate with several colleagues there. During the annual meeting of the Chinese Society of Gravitation and Astrophysics, Chengdu, June 24–30, 2017, students and researchers presented some of the collaboration's findings. Wang also received an invitation to visit Kyoto University during July and to speak at three Japanese universities during his visit.

Early Universe Cosmology & Strings Group (EUCOS)

EUCOS members were very active in 2016-2017, producing eight peer-reviewed journal publications, three book chapters and published proceedings, several presentations, and numerous papers submitted for publication.

Two of the eight published papers were written with faculty members of the Gravitation, Cosmology, and Astrophysics (GCAP) Division of CASPER and are discussed in detail in the GCAP section. These papers investigate aspects of trans-Planckian Physics, Quantum Gravity and their applications to cosmology and black hole physics.

Zhu, T., Wang, A., Cleaver, G., Kirsten, K., Sheng, Q. (2016) "High-Order Primordial Perturbations with Quantum Gravitational Effects," *Physical Review* D93 123525. arXiv:1604.05739 [gr-qc]

Zhu, T., Wang, A., Cleaver, G., Kirsten, K., Sheng Q., Wu, Y. (2016) "Inflationary Spectra with Inverse-Volume Corrections in Loop Quantum Cosmology and Their Observational Constraints from Planck Data," *Journal of Cosmology and Astrophysics* 1603 (2016) 03, 046. arXiv:1510.03855 [gr-qc]

EUCOS Group continued on next page

Early Universe Cosmology and Strings Group

Faculty and Adjunct Faculty

Gerald B. Cleaver
Ahmad Borzou
Eric W. Davis
Jeffery S. Lee

Graduate Students

Abinash Kar
Brandon Mattingly

Undergraduate Students

MD Ali
Andrew Baas
Caleb Elmore
Kameron Scott
Cooper Watson
Felix Yu

Early Universe Cosmology & Strings Group (EUCOS) continued

In March 2017 EUCOS welcomed two adjunct faculty members: Drs. Eric Davis and Ahmad Borzou (See *New Faculty*, p.6). Davis is chief scientist at the Institute for Advanced Studies-Austin, with a long and accomplished research and publication history. He is an internationally recognized leader in advanced propulsion concepts and in the physics of cosmological wormholes.

Davis has 32 years combined experience in aerospace physics and astronomy/astrophysics and 30 years experience in space mission analysis and design engineering disciplines. Davis and Dr. Marc Millis, former director of NASA's Breakthrough Propulsions Physics Program, are co-editors of the "bible" for advanced propulsion methods, *Frontiers of Propulsion Science*, (American Inst. of Aeronautics & Astronautics Press, Reston, VA, first printing 2009, 2nd printing 2012).

Cleaver and Davis have developed two long-term student research projects: (i) analysis of warped spacetime metrics and (ii) calculation of curvature invariants for specific non-trivial spacetime topologies, based on methods introduced in a recent paper by R. Henry and J. Overduin at Johns Hopkins University and K. Wilcomb at Towson University. EUCOS undergraduates Cooper Watson, Caleb Elmore, MD Ali, and Andy Baas are working on both projects under the guidance of EUCOS Ph.D. students Brandon Mattingly (EUCOS Senior Ph.D. Researcher) and Abinash Kar.

Borzou earned a Ph.D. in December 2016 from the physics department at Baylor in experimental high energy physics (HEP) in Baylor's CERN LHC CMS group led by Drs. Jay Dittmann and Kenichi Katakeyama. Before moving to the Baylor CERN group, Borzou was a member of GCAP, working on theoretical aspects of quantum gravity. Borzou's Ph.D. dissertation investigated aspects of both theoretical and experimental high energy physics and gravity. The theoretical part developed a proposal for a Lorentz gauge theory of gravity. The dissertation was voted the Baylor Physics Department Dissertation of the Year and the Baylor STEM Dissertation of the Year for 2016-2017. Borzou is now an assistant professor at the Isfahan University of Technology. With Cleaver, Borzou is investigating the implications of a Lorentz Gauge Theory of Gravity for electron-positron colliders (see arXiv:1705.07525 [gr-qc]).

EUCOS undergraduate student Robert Gill graduated in December 2016 with a senior research project that contributes significantly to a soon-to-be released EUCOS paper on systematic investigations of extended gauge models in free fermion heterotic string theory. Gill has begun a master's program on big data science at SMU, while also having a position at a Dallas investment firm.

Six papers on topics in black hole physics and relativistic thermodynamics were written by Jeff Lee and Dr. Gerald Cleaver, or by EUCOS Ph.D. graduate Yanbin Deng and Cleaver:

Lee, J., Cleaver, G. "White Holes as the Asymptotic Limit of Evaporating Primordial Black Holes", *International Journal of Modern Physics* A31 (2016) 1650162.

Deng, Y., Cleaver, G. "Hawking Radiation from Regular Black Hole as a Possible Probe for Black Hole Interior Structure", *International Journal of Theoretical Physics* 56 (2017) no.3, 741.

Lee, J., Cleaver, G. "Black Suns: Ocular Invisibility of Relativistic Luminous Astrophysical Bodies", *Journal of High Energy Physics, Gravitation & Cosmology* 2(2016) 562.

Lee, J., Cleaver, G. "Relativistic Drag and Emission Pressure in an Isotropic Photonic Gas", *Modern Physics Letters* A31 (2016) 1650118.

Lee, J., Cleaver, G. "Effects of External Radiation on an Alcubierre Warp Bubble", *Physics Essays* 29 (2016) 201.

Lee, J., Cleaver, G. "Relativistic Blackbody Spectrum in Inertial and Non-Inertial Reference Frames," *New Astronomy* 52 (2017) 20.

Dr. Cleaver also contributed a book chapter, “Multiverse: God's Indeterminacy In Action," to *God's Providence and Randomness in Nature: Scientific and Theological Perspectives*, by Robert J. Russell and Joshua Moritz, (West Conshohocken: Templeton Press, 2017). Cleaver's article “Multiverse: Philosophical and Theological Perspectives, Science and Religion” appeared in the peer-reviewed published *Proceedings the 2016 Symposium on the Theological Interpretation of Scripture*, North Park Theological Seminary.

Cleaver's Matter-Antimatter Propulsion via QFT Effects from Parallel Electric and Magnetic Fields appeared in the published *Proceedings of the 2016 Tennessee Valley Interstellar Workshop*.

Education Research Group

CASPER's Education Research Group is teaming with the Baylor School of Education, Education Service Center Region 12, Huckabee, Inc., and several area independent school districts on a growing number and variety of projects. The ERG is now in the third year of a collaborative study of novel classroom furnishings supplied by Fort Worth-based education architectural firm Huckabee, Inc. The new concept gives educators greater flexibility in quickly reconfiguring classrooms for different subjects and modes of instruction. The furniture also facilitates students' "fidgeting," which research suggests may help them stay engaged.

The study is being conducted within the Learning Experience Laboratories—or LExLabs—a learning environment research group created by ESC Region 12. After consultations with specialists at LExLabs' research facility in the BRIC, teachers at Midway ISD's Spring Valley Elementary School tested the concept this spring. Researchers will use what they learn from the pilot study to develop training curricula to help teachers make more effective use of flexible furniture.

Education Research Group

Faculty and Staff

Jorge Carmona Reyes
Truell Hyde
Lorin Matthews

In another collaboration, the ERG is working with Region 12 and the La Vega school district to stimulate interest in STEM professions through a hands-on Microgravity Investigators program. The program will introduce groups of middle school students to principles of microgravity through original touch-screen videos created specifically for the program, and will utilize toys, artifacts from the BRIC/CASPER's $6+ million NASA-loaned collection of space hardware and a portable small-scale drop tower to demonstrate microgravity's effects. The student groups will design experiments of their own to be reviewed by CASPER researchers who will then choose one of their experiments to perform using the BRIC/CASPER research-quality drop tower.

2016 CASPER REU Fellows

REU 2016 participants:
Front row: (L-R) Brenne Gregory (Cleveland Heights, OH); Isabella Pagano (Bethesda, MD);
middle row: Luis Perez (The Bronx, NY); Dustin Sanford (Baylor student);
rear row: Caleb Elmore (Baylor student); Matthew Fournier (Phoenix, AZ); Kyle Busse (Baylor senior mentor); Luke Jarboe (Pryor, OK); Eva Kostadinova (Baylor doctoral student mentor).

REU Mentors

Astronomy

Dick Campbell
Dwight Russell

Complex Plasma & Space Science

Truell Hyde
Lorin Matthews
Jorge Carmona Reyes
Augusto Carballido
Conni Liaw
Mudi Chen
Mike Cook
Ke Qiao
Zhiyue Ding

Education

Jorge Carmona Reyes

Twenty-two consecutive summers have brought high-achieving undergraduate science students to Baylor from across the nation to take part in the National Science Foundation's ten-week Research Experience for Undergraduates (REU) program, hosted by CASPER. The summer 2016 program hosted five non-Baylor and two Baylor undergraduate students. In addition to CASPER faculty a Baylor doctoral graduate student and a physics senior served as mentors. REU fellows conducted research in mathematics, astronomy and theoretical and experimental physics under the direction of CASPER faculty. Their projects may be viewed on the CASPER website at: http://www.baylor.edu/casper/index.php?id=936840.

Activities

Participants took time off from their fast-paced research schedules to dine on pizza, barbecue, submarine sandwiches and other fare at regular Wednesday Lunch Bunch seminars. Each seminar featured an entertaining technical presentation by departmental faculty and practical talks on how to conduct searches of scientific literature, write technical papers, prepare project posters and PowerPoint presentations, and apply to graduate schools. Each Friday, participants updated faculty and fellow participants on the progress of their research.

At the conclusion of the program, the students personally summarized their projects in twelve-minute PowerPoint presentations, after which they were quizzed by faculty and other fellows. Participants enjoyed a catered farewell dinner and awards presentation before departing.

CASPER GRADUATES

Dr. Xinwen Wang successfully defended his dissertation, "Holography and Black Holes in Gravitational Theories without Lorentz Symmetry" on February 24, 2017 and received his Ph.D. last May. His Ph.D. advisor was Dr. Anzhong Wang.

Former CASPER REU Fellow and Baylor master's graduate **James R. Creel**, recently was awarded a Ph.D. in physics from Trinity College Dublin, Ireland, and is now a postdoctoral researcher there.

Dr. Ahmad Borzou also received his Ph.D. in physics in December following a successful oral defense of his dissertation, "Theoretical and Experimental approaches to the Dark Energy and the Cosmological Constant Problem." Dr. Gerald Cleaver served as Borzou's Ph.D. advisor.

Grapevine junior benefits from Baylor B-TRUE research program

Beau Brooks, a junior astrophysics major from Grapevine, Texas, is participating in the inaugural Baylor Transdisciplinary Research Undergraduate Experience program known as B-TRUE. He is conducting research with professor of physics and CASPER Associate Director Dr. Lorin Matthews. The B-TRUE program is an intensive, ten-week summer research-training program for 10 students interested in research-related careers. Participants conduct research in one of six academic programs: biology, physics, chemistry/biochemistry, environmental science, geosciences or psychology/neuroscience. Further information on the program can be found at: http://www.baylor.edu/shllc/index.php?id=941292.

Junior physics student presents research

Dustin Sanford, a junior physics major from Woodway, Texas, participated last summer in the Summer Science Research Program sponsored by the Baylor College of Arts and Sciences. Sanford's work in the program led to his co-authoring a research paper with CASPER Associate Director Dr. Lorin Matthews and CASPER Director Dr. Truell W. Hyde titled "Effects of Heat Transfer in Dust Aggregates on the Photophoretic Force." He presented his research at the 48th Lunar and Planetary Science Conference held at The Woodlands, Texas, March 20-24, 2017. The paper also was published as a two-page conference abstract that can be viewed at: http://www.hou.usra.edu/meetings/lpsc2017/pdf/2994.pdf.

For more information on the Summer Science Research Program, go to: http://www.baylor.edu/summerscience.

SELECTED 2016/17 CASPER SEMINARS

Dr. Craig S. Lent

Freimann Professor of Electrical and Concurrent Professor of Physics, University of Notre Dame

The Freedom of the Physical World: Taking Quantum Mechanics Seriously

(co-sponsored by CASPER and the departments of philosophy and physics)

Abstract: For several centuries, modern science made remarkable progress by considering the physical world as a vast machine, moving forward according to laws of motion. The temporal evolution of a physical system is, on this view, entirely determined by the physical law and initial conditions. The future is contained in the present. This comprehensive view, including mechanical and biochemical systems, animate as well as inanimate matter, has been enormously successful. In the twentieth century, however, we learned that this classical picture, while an extremely useful approximation, is fundamentally incorrect. Quantum mechanics revealed that the physical world is actually not machine-like. The physical law has a different character than we had supposed, under-determining future events. The physical world has a certain kind of freedom. It is a freedom constrained, but not completely constrained, by the physical law. In late 2015 a series of experiments, so-called "loophole-free Bell tests," established this feature of reality in a way that does not depend on the details of our current understanding of physical law. The freedom of the physical world will be demonstrated with a real-time quantum mechanical experiment whose results are not knowable in advance, even in principle. The physical world will make a choice of the outcome during the talk. We will witness physical events which have no preceding cause.

God has created a remarkable world that supports both order and freedom. The physical world is not a mass of chaos; it is governed by physical law and is therefore to a large degree predictable, and can even be engineered. But the world retains some freedom—the future is not contained in the present. The transcript of the history of the universe was not set by physical law and the initial conditions at the Big Bang. The question of human freedom is complex, but it certainly does not follow from the fact that we are physical that we are machines. We should not be intimidated by an outdated view of the world which is too often pressed into the service of a naive, deterministic materialism.

Professor Lent's research is in the area of quantum and single-molecule devices. It is aimed at creating devices that work at the smallest length scale that can still be designed by humans—single molecules that could eventually replace transistors. He is one of the inventors of the quantum-dot cellular automata paradigm that is being pursued by researchers around the world. He has authored or co-authored more than 100 peer-reviewed articles in the scientific literature. Lent received his B.S. in Physics from the University of California at Berkeley and his Ph.D. in physics from the University of Minnesota. He is a leader in the People of Praise, an ecumenical charismatic covenant community with 21 branches in North America and the Caribbean, and serves on the board of Trinity Schools Inc., which operates Christian high schools in several states.

Dr. Karl Stephan

Professor, Ingram School of Engineering, Texas State University

Ball Lightning: Close to a Solution?

Abstract: Ball lightning has been seen by thousands of eyewitnesses, photographed, and studied by physicists such as Faraday, Oliver Lodge, the Nobelist Pyotr Kapitsa, and atmospheric scientist Bernard Vonnegut. Despite these efforts, there is as yet no theory that can completely account for its major characteristics, and no one has yet been able to reproduce it in the laboratory. Ball lightning usually takes the form of a glowing sphere between 10 and 100 cm in diameter. It is usually associated with thunderstorms and lasts only a few seconds before it either disappears or explodes. During its lifetime its motion is erratic and mainly horizontal. Ball lightning has caused significant damage in some cases and a few reported injuries and deaths. But in most instances it is harmless and leaves eyewitnesses astonished but unhurt. In a recent publication, plasma physicist H.-C. Wu has proposed a formation mechanism for ball lightning based upon high-energy lightning phenomena discovered in the last twenty years. Lightning can produce bunches of relativistic electrons with energies exceeding 1 MeV. Wu has shown that if a dense enough electron bunch collides with matter, the energy of the resulting electromagnetic pulse peaks in the microwave spectrum. If the pulse encounters a plasma, computer simulations show that a standing microwave soliton wave can form. The plasma produces a resonant microwave cavity that encloses the electromagnetic field and preserves its energy. If this plasma-walled cavity can contain kJ of energy for a time as long as seconds, this mechanism will explain many of the mysterious properties of ball lightning, including its ability to pass through closed glass windows. In this presentation we will review the history of ball lightning research and recent experimental and theoretical progress, and outline possible experimental tests that might lead to the production of ball lightning in the laboratory.

Stephan writes an engineering ethics blog and teaches electrical engineering at Texas State University, San Marcos, Texas. He has a Ph.D. from the University of Texas at Austin, an M.Eng. from Cornell University, and a B.S. in engineering from the California Institute of Technology. He has also taught at the University of Massachusetts Amherst and has worked in industry.

Eva Kostadinova

Doctoral Candidate, Department of Physics, Baylor University

Complex Plasma Systems: An Answer to Strong Correlations

Abstract: Strongly correlated systems are systems that cannot be effectively described by the physics of free-particle ensembles. Instead, they exhibit anomalous (often technologically useful) collective behavior, which is a result of strong interactions among the entities involved. Some of the most exciting phenomena in modern physics, such as quark-gluon plasma formation, cosmic strings, inflation, and high temperature superconductivity, are believed to be related to strong correlations. However, the development of a unified theory of strong correlations that scales appropriately across vastly different size and time scales is currently one of the most challenging and yet fundamental problems in physics.

In this presentation, Ms. Kostadinova will argue that the underlying physics of many strongly correlated systems can be studied through the use of analogous, experimentally observable, complex plasma systems. Dusty plasma structures exhibit collective behavior (including structure formation, self-organization, phase transitions, waves and instabilities) typical of most microscopic, strongly coupled systems. At the same time, they are characterized by macroscopic size and time scales that allow for direct observation (at the kinetic level) of fundamental interparticle interactions and the resulting collective system behavior across a wide range of coupling regimes. Thus, the field of complex plasma can provide a powerful experimental tool for the development of a comprehensive theory of strong correlations that scales appropriately from the field of quantum mechanics into the realm of classical physics.

Recent Publications

(Additional publications in Group Updates)

Albin, T., Koschny, D., Molau, S., **Srama, R.**, Poppe, B. (2017). "Analysis of the Technical Biases of Meteor Video Cameras Used in the CILBO System." *Geoscientific Instrumentation, Methods and Data Systems* 6, 125–140. doi:10.5194/gi-6-125-2017

Ali, S.S., Shao, J., **Lary, D.J.**, Strem, M.D., Meinhardt, L.W., Bailey, B.A. (2017). "Phytophthora Megakarya and P. Palmivora, Causal Agents of Black Pod Rot, Induce Similar Plant Defense Responses Late During Infection of Susceptible Cacao Pods." *Frontiers in Plant Science 8*. doi:10.3389/fpls.2017.00169

Bickel, K., **Liaw, C.** (2017). "Properties of Beurling-type Submodules via Agler Decompositions." *Journal of Functional Analysis* 272, 83–111. doi:10.1016/j.jfa.2016.10.007

Breuninger, J., Belser, V., **Laufer, R., Dropmann, M., Herdrich, G., Hyde, T., Röser, H.-P.** (2016) "Design of a 1.5 Seconds High Quality Microgravity Drop Tower Facility." *Transactions of the Japan Society for Aeronautical and Space Sciences, Aerospace Technology Japan* 14, Ph_7-Ph_14. doi:10.2322/tastj.14.Ph_7

Capozziello, S., **Saridakis, E.N.**, Bamba, K., Sepehri, A., Rahaman, F., Ali, A.F., Pincak, R., Pradhan, A. (2017). "Cosmic Space and Pauli Exclusion Principle in a System of M 0-Branes." *International Journal of Geometric Methods in Modern Physics* 14. doi:10.1142/S0219887817500955

Carballido, A., Matthews, L.S., Hyde, T.W. (2017) "The Magnetic Field Inside a Protoplanetary Disk Gap Opened by Planets of Different Masses." *Monthly Notices of the Royal Astronomical Society.* doi:10.1093/mnras/stx1816

Carballido, A., Matthews, L.S., Hyde, T.W. (2016) "Dust Relative Velocities in the Vicinity of a Gap - Opening Jupiter - Mass Planet," in: *Lunar and Planetary Science XXXXVIII*. Lunar and Planetary Space Conference.

Carballido, A., Matthews, L.S., Hyde, T.W. (2016) "Dust Coagulation in the Vicinity of a Gap-Opening Jupiter-Mass Planet." *The Astrophysical Journal 823, 80.* doi:10.3847/0004-637X/823/2/80

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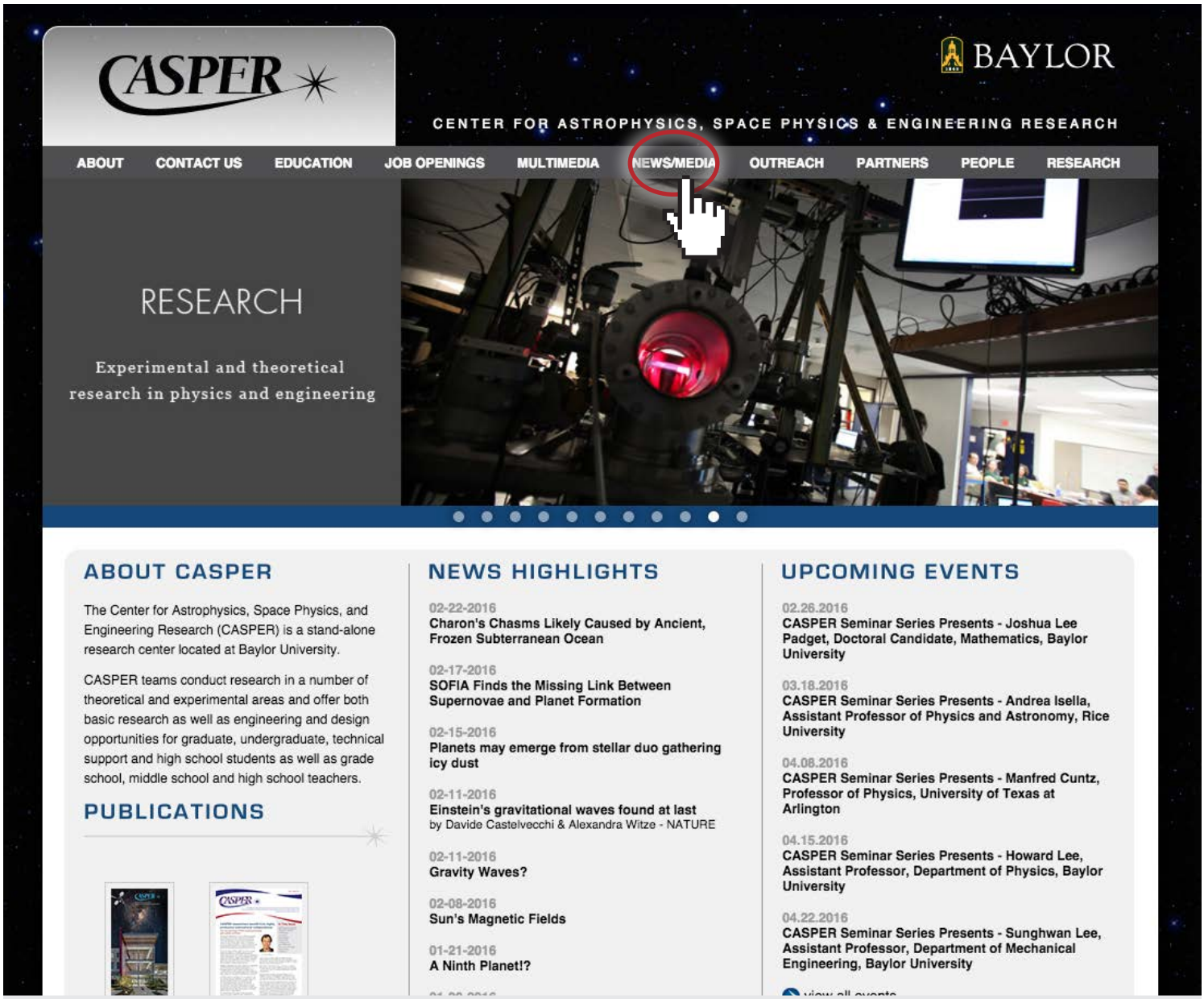

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Space Propulsion Innovator Broadens CASPER Expertise

Dr. Georg Herdrich is one of the worlds foremost experts in alternative spacecraft propulsion.

Author of over 150 technical and scientific publications, Dr. Georg Herdrich is one of the world's foremost experts in plasma physics and alternative means of space vehicle propulsion. A native of Ettenheim, Germany, Herdrich became a CASPER Fellow in 2010 as a result of conversations with the late Dr. Hans-Peter Röser of the University of Stuttgart's Institute for Space Research (IRS) and Röser's colleague, Dr. Rene Laufer, both of whom had been collaborating with CASPER for a number of years.

Later that year, Herdrich traveled to Baylor and met CASPER Director Dr. Truell Hyde for the first time. Herdrich readily credits his collaboration with CASPER as lending new capabilities to his research.

"I want to emphasize the importance of the personal relationships with the people at CASPER, such as Rene Laufer, Michael Dropmann and Truell Hyde. Scientifically, we have been able to make significant advances in our knowledge of magnetohydrodynamics by combining the unique facilities IRS and CASPER," Herdich said. Dropmann was a doctoral student from Stuttgart, and one of several degree candidates who have done their Ph.D. research at CASPER.

Herdrich first became interested in plasmas as a doctoral candidate at IRS in 1996. Over the years his work has come to focus on novel means of space propulsion that may extend and expand the use of satellites in very low orbits.

"There are some several new ideas and projects that have a sort of 'lighthouse effect.' One example is the development of air-breathing electric propulsion that can compensate for the residual drag of the atmosphere on satellites in very low earth orbit," he said. "This opens an absolutely new regime for scientific and application-oriented satellites."

When not considering new ways of keeping satellites in orbit, Herdrich pursues a somewhat more prosaic hobby — stamp collecting. He also enjoys hiking and skiing with his mathematician wife, Andrea, and their two sons. "I also like travelling, although I have to say that this has become very limited since we have our two kids."

Ultimately, Herdrich considers the most beneficial product of collaborative research to be its impact on education.

"Most important is the synthesis of research work with CASPER, ESA, NASA, and others, and the related application-oriented projects that result. Then we really have the chance to insert our most recent discoveries and findings into our lectures for the students. There is always a very sustainable link to education in our work."

CASSINI

space probe's mission ends in spectacular fashion

First proposed in 1982, NASA's Cassini space probe and its partner space probe Huygens were launched in 1997 on a seven-year journey to the planet Saturn. Now, its fuel supply exhausted, Cassini completed its twenty-year mission by plunging into Saturn's atmosphere, providing one last set of telemetry before becoming part of the planet it was made to study. Dr. Dwight Russell, Director of CASPER's Experimental Astronomy Group, has followed the mission closely.

With its spectacular rings and many moons, Saturn represents one of the richest, most varied environments in the solar system. The Cassini/Huygens mission has provided much of our knowledge of this exotic world and is one of the great success stories of outer solar system space exploration.

The Huygens probe's sole purpose was to plunge into the atmosphere of Saturn's largest moon, Titan, and land on its surface. Before Cassini/Huygens it was known that Titan had an extremely cold — less than 100 Kelvin — nitrogen-rich atmosphere that also contains hydrocarbon compounds and has an atmospheric pressure similar to Earth's. Huygens revealed Titan to have clouds, landforms made of ice, rivers, lakes and oceans of liquid methane, as well as seasons. And even though the surface is extremely cold, its processes are remarkably similar to Earth's.

Cassini has shown new features of Saturn as well. The most vivid feature being a hexagonal vortex at Saturn's northern pole.

After thirteen years studying the Saturnian system, on April 26, 2017, mission controllers employed a gravitational assist from Titan to place Cassini in an orbit that brought it perilously close to Saturn. This began the first of twenty-six orbits in the final phase of Cassini's mission, known as the Grand Finale.

In these last twenty-six orbits, Cassini passed between Saturn and the inner edge of its rings to make some of the mission's most extraordinary observations.

Mission scientists expected the orbital path to be clear of particles large enough to damage the spacecraft. But as an extra precaution, the spacecraft used its large antenna as a shield on its first pass through to determine whether it is safe to expose the science instruments during subsequent passes.

Finally, on September 15th, 2017, Cassini entered Saturn's atmosphere, transmitting data on the atmosphere's composition and other phenomena until its signal is lost and it burns up in Saturn's atmosphere. Though Cassini's mission ended, the data and images it has collected will be studied for years to come.

Cassini's Grand Finale can be found at https://saturn.jpl.nasa.gov.

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