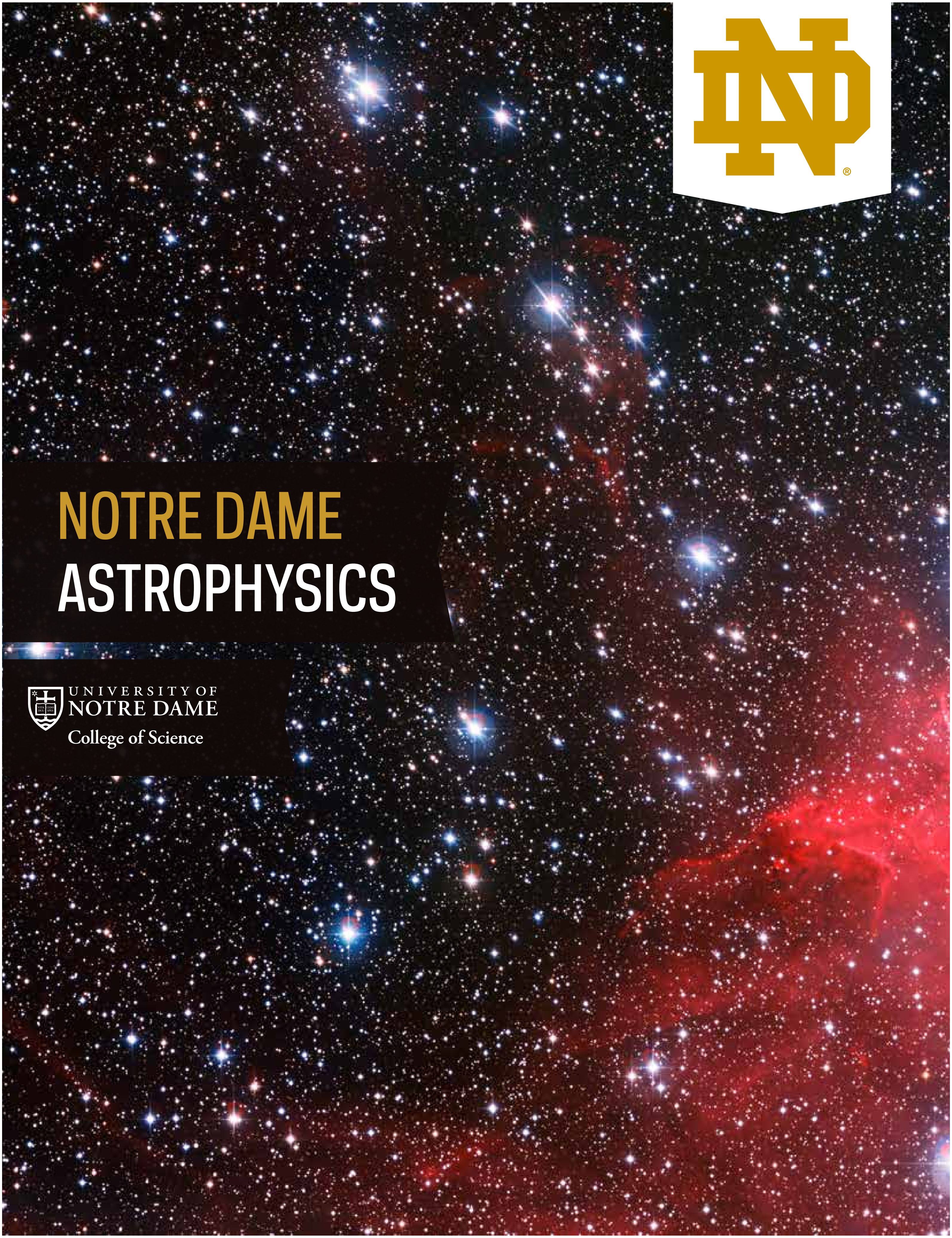
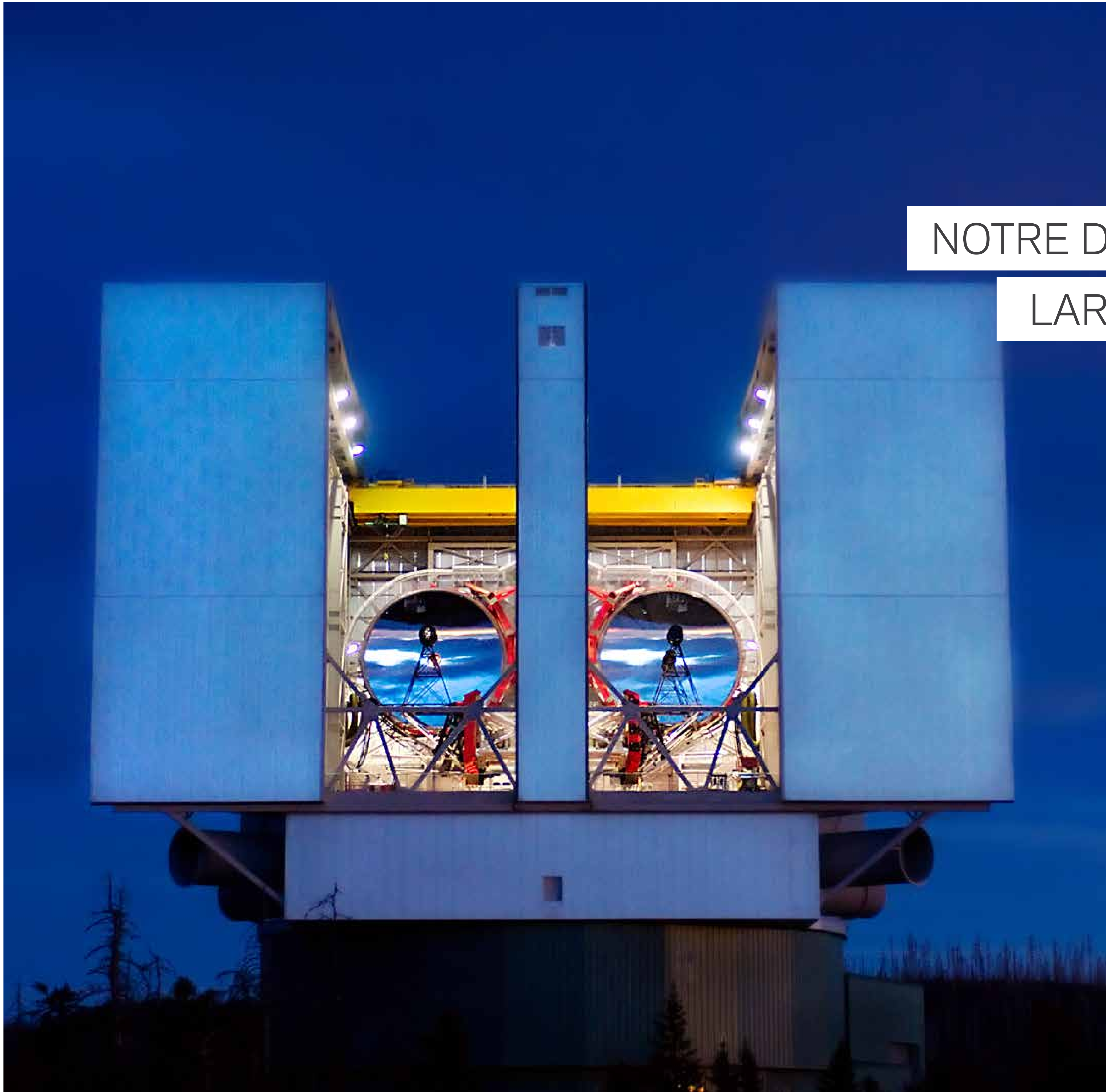


NOTRE DAME ASTROPHYSICS

UNIVERSITY OF NOTRE DAME
College of Science



NOTRE DAME'S PARTNERSHIP IN THE LARGE BINOCULAR TELESCOPE

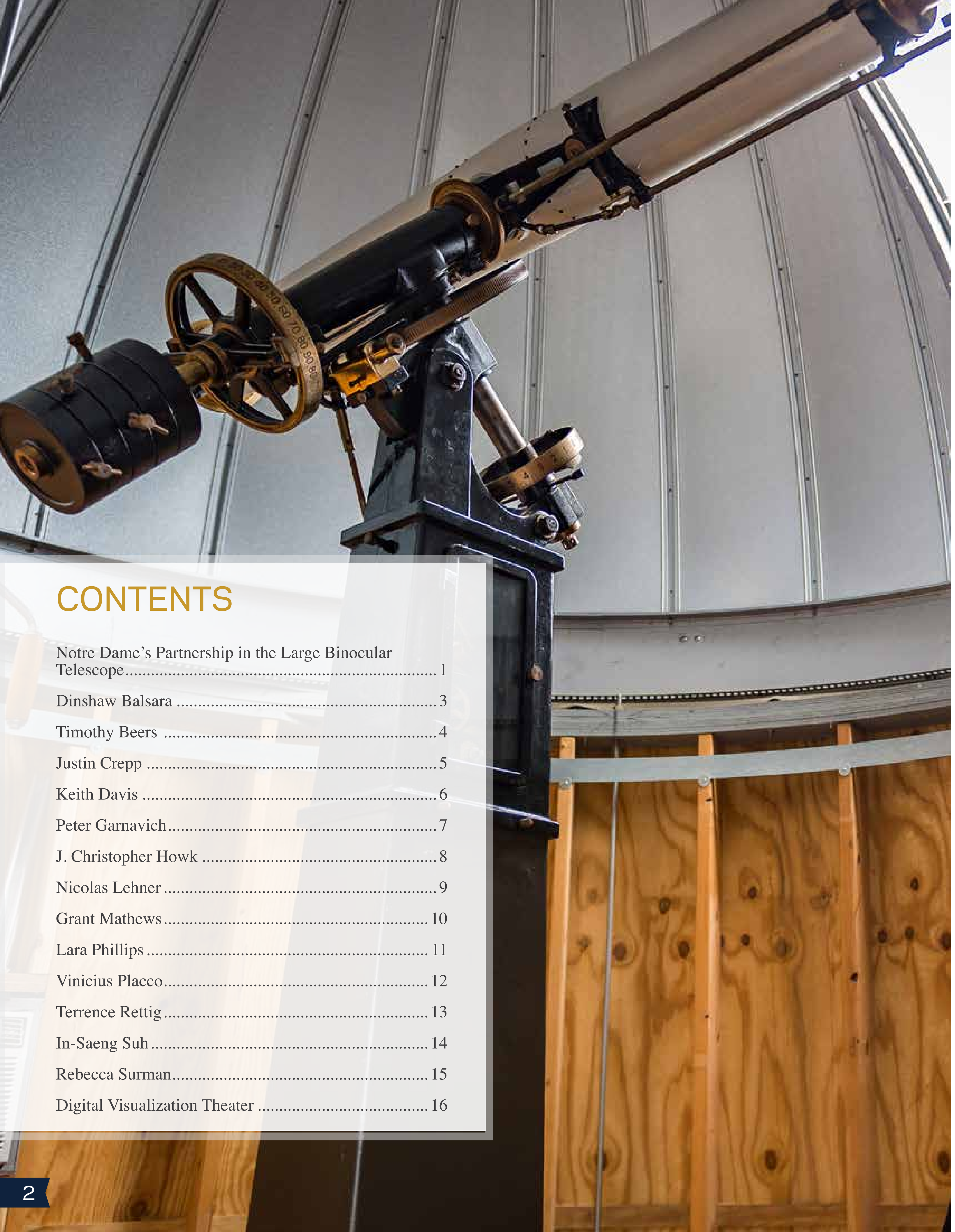
The Large Binocular Telescope (LBT) stands on Mt. Graham in Arizona, at 10,700 feet above sea level, and next to the 1.8-m Vatican Advanced Technology Telescope. The unique facility is actually two 8.4-m telescopes that act in tandem to produce images unlike any seen before. The LBT has the equivalent collecting power of a 12-m and the resolution of a 22-m telescope, far better than any other telescope today. It is the forerunner of the next generation of ultra-large telescopes.

The LBT has extraordinary capabilities. Its design allows it to directly observe distant stars systems and to actually see planets in the systems. Its ability to measure very precise atomic spectra even enables researchers to determine the chemical makeup of the planets' atmospheres. Exploiting the LBT's unique design, Justin Crepp is currently building a novel spectrometer that will detect the small wobble of an Earth-size planet in the habitable zone of a cool star.

Notre Dame faculty are using the LBT to study distant supernovae so they can better understand the nature of dark energy. These same exploding stars are the fiery furnaces that produce most of the elements that make up our bodies. We have incomplete knowledge of how such simple and important elements as carbon and oxygen are created, and the LBT will support our quest for understanding.

Telescopes not only look at distant objects, but also act as time machines. Because light may travel for billions of years before being captured by the LBT's mirrors, the images reveal the Universe as it was long ago. One of the big mysteries uncovered by the Hubble Space Telescope program is the existence of fully formed galaxies in the early universe, much earlier than physicists predicted. Their formation will be a key research program for the LBT and Origins Institute faculty Dinshaw Balsara and Christopher Howk, who aim to understand the dynamics that govern the formation of galaxies and with them the beginnings of life.

With a total cost of $200 million, the LBT is one of the world's greatest observatories. Its suite of instruments allows for versatility and the ability to study an extremely wide range of astrophysical research topics. The LBT has the world's best adaptive optics (AO) system, which reduces the blur caused by the Earth's atmosphere to the point that LBT imaging rivals that of the Hubble Space Telescope. Soon, a state-of-the-art laser guide star system will form points of light in the upper atmosphere to allow the AO system to work anywhere on the sky.



CONTENTS

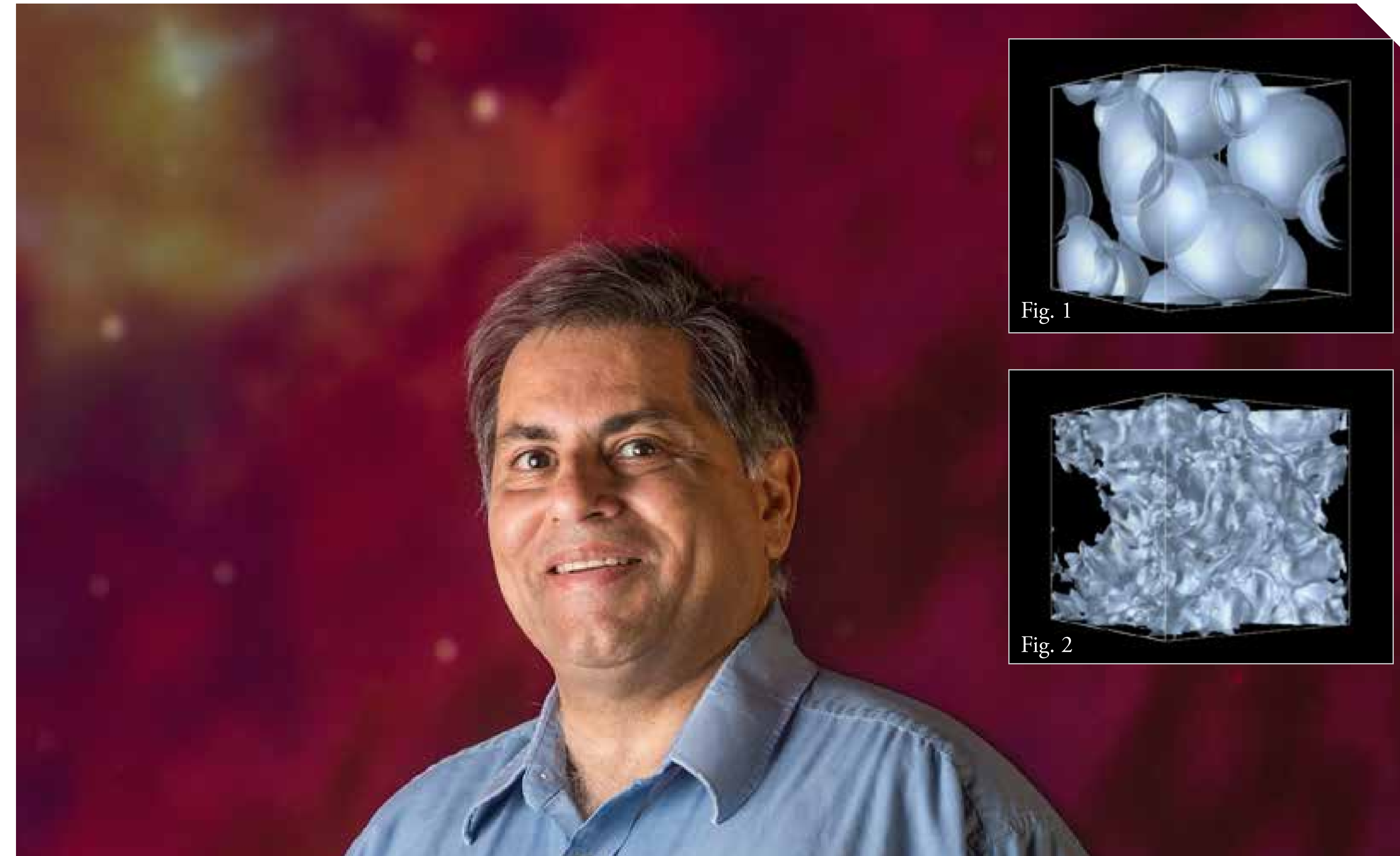


Fig. 1

Fig. 2

DINSHAW BALSARA

Associate Professor

Concurrent Associate Professor, Applied and Computational Mathematics and Statistics

M.S. in Physics, Indian Inst. of Tech., Kanpur, 1982
M.S. in Astronomy, University of Chicago, 1989
Ph.D. in Computational Astrophysics, Univ. of Illinois at Urbana-Champaign, 1990

Defense Department Award of Excellence for significant contributions to the Stockpile Stewardship Program, 2014

Balsara has a dual training in physics and astrophysics. After earning a Ph.D. in computational astrophysics, he subsequently worked on several problems in active galactic nuclei, studying the accretion on to black holes and compact objects, starburst galaxies and galaxies in clusters. More recently, he has developed computational applications in the areas of interstellar medium, turbulence, star formation, planet formation, the physics of accretion disks, compact objects and relativistic astrophysics and he continues to work in all of those areas of research.

Balsara has also played a seminal role in formulating our modern conception of computational astrophysics. His work on divergence-free adaptive mesh refinement for magnetohydrodynamics (MHD) has broken new ground for our understanding of numerical MHD. He has also produced some of the best, most accurate and most robust methods for numerical MHD and has recently begun extending this expertise to radiative transfer as well as non-ideal processes that are often very useful in regulating astrophysical phenomena. Several of Balsara's papers have been cited over a hundred times.

The above-mentioned numerical expertise is routinely applied to problems in all areas of computational astrophysics. In fact, the robust numerics was central to the process of carrying out path-breaking simulations of the supernova explosion-driven ISM turbulence, Fig. 1. That work has resulted in many new insights into the nature of the multi-phase ISM and the evolution of magnetic fields in it.

Star formation in turbulent, magnetized environments has also been a topic of significant recent focus. Balsara's theories and simulations of two-fluid magnetized turbulence have been used to decipher the role of ambipolar diffusion in star formation. Fig. 2 shows linewidth-size relations from observations and Balsara's simulations, indicating a good match between the two.

The dynamics of dust and its role in building planets within turbulent, magnetized, protostellar accretion disks has also been a topic of recent study.

Balsara also has a significant scientific interest in PetaScale and ExaScale computing and has worked with some of the world's fastest supercomputers. He serves on the editorial boards of the *Journal of Computational Physics* and also *Computational Astrophysics and Cosmology.*

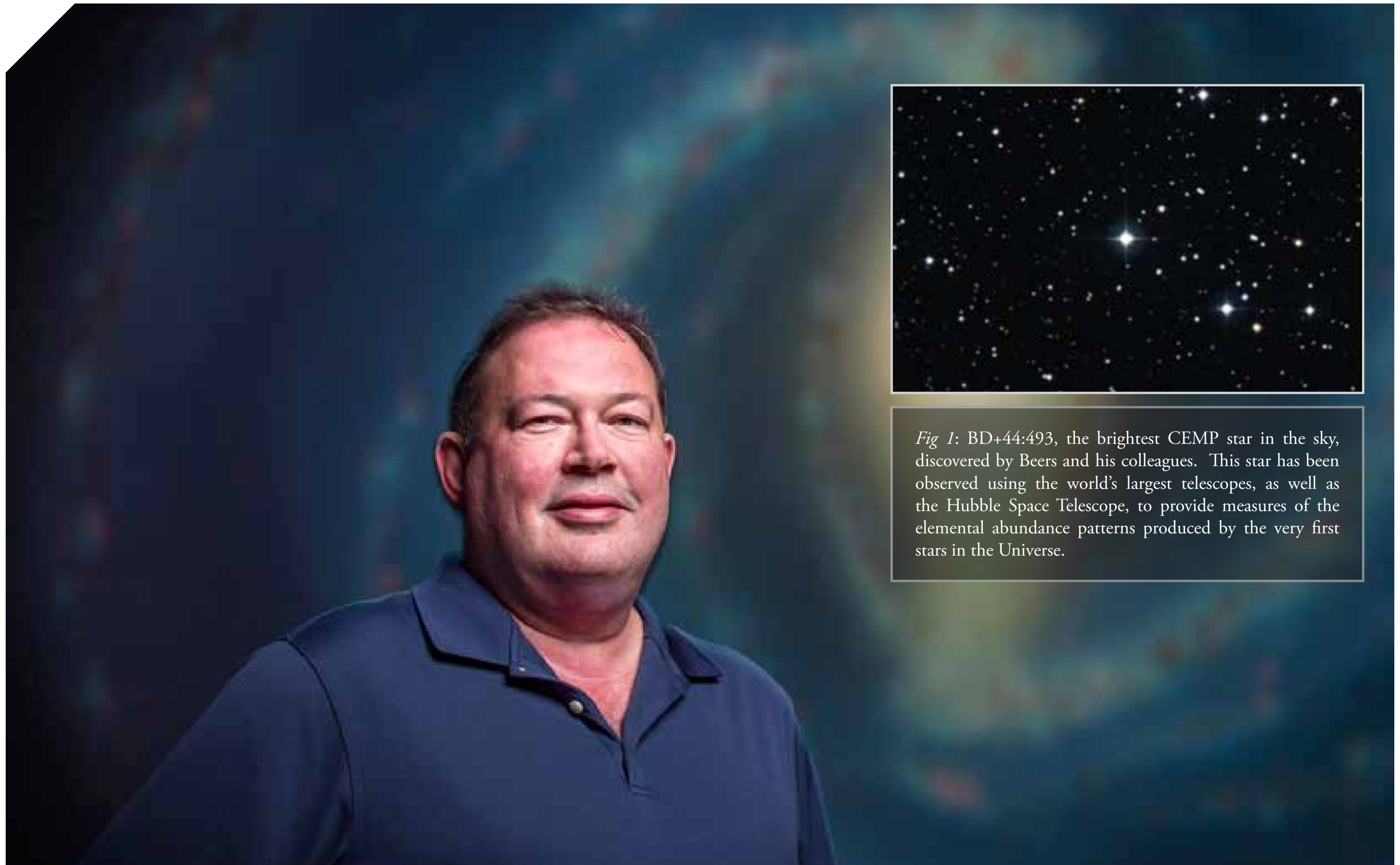


Fig 1: BD+44:493, the brightest CEMP star in the sky, discovered by Beers and his colleagues. This star has been observed using the world's largest telescopes, as well as the Hubble Space Telescope, to provide measures of the elemental abundance patterns produced by the very first stars in the Universe.

TIMOTHY BEERS

Notre Dame Chair of Astrophysics

B.S. in Physics, Purdue University, 1979
B.S. in Metallurgical Engineering, Purdue University, 1979
Ph.D. in Astronomy, Harvard University, 1983

Bantrell Postdoctoral Fellow, Caltech
Humboldt Senior Research Award, 2009
Director, Kitt Peak National Observatory,
University Distinguished Professor Emeritus, Michigan State University
Fellow of the American Physical Society

Timothy Beers is interested in the origin and evolution of the elements in the Universe, and the assembly of large spiral galaxies such as the Milky Way, a field now referred to as Galactic Archaeology. For decades, Professor Beers has designed and executed large-scale surveys of stars in the Milky Way, efficiently sifting through literally millions of individual stars in order to find the rare objects that illuminate the early chemical evolution of our Universe.

His work has led to:

- The discovery of over 30,000 stars in the Galaxy with heavy-element abundances less than 1 percent of the metal abundance of the Sun, including the most chemically primitive stars yet found. These ancient stars are the "fossils of creation" that have recorded the chemical history of the Universe.

- The discovery of carbon-enhanced metal-poor (CEMP) stars, whose properties are revealing the origin of the first elements heavier than helium in the Universe. These stars include objects shown to exhibit characteristic light-element signatures (enhanced C, N, O, Na, Mg), now recognized to be due to nucleosynthesis by the very first stars born after the Big Bang.

- The discovery of r-process-element-enhanced metal-poor stars, crucial for establishing the astrophysical site of the rapid neutron-capture process that accounts for the production of half of the heavy elements in the Periodic Table. Included among these are the first ancient stars with measured abundances of the radioactive chronometers thorium and uranium, used to establish a nuclear-decay lower limit on the age of the Universe.

Beers now leads the involvement of Notre Dame astronomers in SDSS-IV, the third extension of the Sloan Digital Sky Survey. Beers' particular interest in SDSS-IV is the APOGEE-II project, which is obtaining high-resolution near-infrared spectroscopy of several hundred thousand stars in the Milky Way. These stars with help constrain the chemical evolution of all of the stellar populations in our Galaxy, including the thin disk, the thick disk, the bulge, and the inner and outer halo.

Beers is a co-PI and an associate director of the highly successful NSF Physics Frontier Center, JINA: Joint Institute for Nuclear Astrophysics – Center for the Evolution of the Elements, which brings together the work of nuclear physicists and astronomers worldwide to make transformational progress on understanding of the formation of the elements, and the astrophysics of the sites in which they were produced, such as supernovae and neutron stars. This center, which has been in existence for the past decade, was recently awarded a new six-year funding cycle by the NSF.

JUSTIN CREPP

Freimann Assistant Professor

B.S. in Physics, Penn State, 2003
Ph.D. in Physics, University of Florida, 2008

Justin Crepp, the Frank M. Freimann Assistant Professor of Physics, is an experimental astrophysicist. His research involves developing new technologies to detect and study planets orbiting stars other than the Sun, called "exoplanets." Crepp, a winner of the 2013 NASA Early Career Fellowship, is one of 11 researchers designated by NASA as a Kepler Participating Scientist, advancing the goals of the Kepler Mission to discover extrasolar planets including those in the habitable zone where water can exist in liquid form. He has co-discovered more than 80 exoplanets, including the first one found in the habitable zone. Crepp was named to NASA's Transiting Exoplanet Survey Satellite (TESS) science team in 2014.

Crepp designs and builds instruments that operate at visible and near-infrared wavelengths to directly image and study brown dwarfs and extrasolar planets. He also uses the Doppler method to measure the radial velocity "wobble" of stars as they gravitationally interact with their planets.

Crepp is the principle investigator of a new instrument, the Infrared Large binOCulAr Telescope Exoplanet Recovery (iLocater) spectrograph, the first fiber-fed Doppler instrument designed to operate behind an adaptive optics system. The ultra-precise planet-finding spectrometer is being built for the Large Binocular Telescope in Arizona. The work is searching for the presence of life elsewhere in the universe.

Crepp also leads a new observing program called TRENDS that combines the Doppler method with high-contrast imaging to yield highly accurate measures of the mass of objects orbiting stars. In 2016, his laboratory published the discovery of a rare brown dwarf, using TRENDS to photograph the object and ascertain its mass, age, and composition—information that can be used to benchmark the study of the elusive objects.

Crepp came to Notre Dame in 2012 from the California Institute of Technology, where he had been a postdoctoral scholar since 2008.

KEITH DAVIS

Director, Digital Visualization Theater

B.S. in Applied Mathematics, University of Tulsa, May 1999
M.S. in Physics, Clemson University, 2003
Ph.D. in Physics, Clemson University, 2007

As the director of the College of Science's 50-foot planetarium and fulldome theater, the Digital Visualization Theater (DVT), Keith Davis creates and presents customized lectures for the theater and supports other faculty in the use of the DVT to teach topics including astronomy and astrophysics as well as the philosophy of science, psychology, chemistry, literature, and anatomy.

Davis is a strong proponent of interactive teaching in planetariums. He has developed an interactive teaching style that works in the darkness of a planetarium and has created planetarium activities that illustrate naked eye astronomy to all ages. Collaborating with Mark Webb, from Adler Planetarium in Chicago, and Karrie Berglund, from Digitalis Education Solutions, he has helped organize and lead the Live Interactive Planetarium Symposium (LIPS). LIPS is a meeting of planetarium professionals to develop ways to increase interactivity in their presentations. He advises QuarkNet on creating content to teach the physics of the Large Hadron Collider and presented this material at the International Planetarium Society meeting. At the 2016 Great Lakes Planetarium Association's pre-meeting conference, he led a workshop on bringing publicly available data to planetarium presentations and will be adapting it for other meetings in the future.

Davis is a member of the Department of Physics outreach committee and participates in many of the department's outreach programs. The DVT regularly hosts local schools on field trips and public lectures in astronomy. Recently, he team-taught Astronomy: Investigating Our Universe with Lara Arielle Phillips and will be leading the department's plans for observing the 2017 solar eclipse.

Davis' research background is computational hydrodynamics. He studied the interaction of supernova ejecta with the interstellar medium and its relationship to triggering the formation of the solar system using the hydrodynamics code Zeus-2D. He developed an interest in the design elements of scientific visualization. In 2011, Davis oversaw Designing Information, a reading group that brought together scientists, designers, and education specialists to investigate differences in how the principles of design apply to scientists' investigations of data.

PETER GARNAVICH

Professor

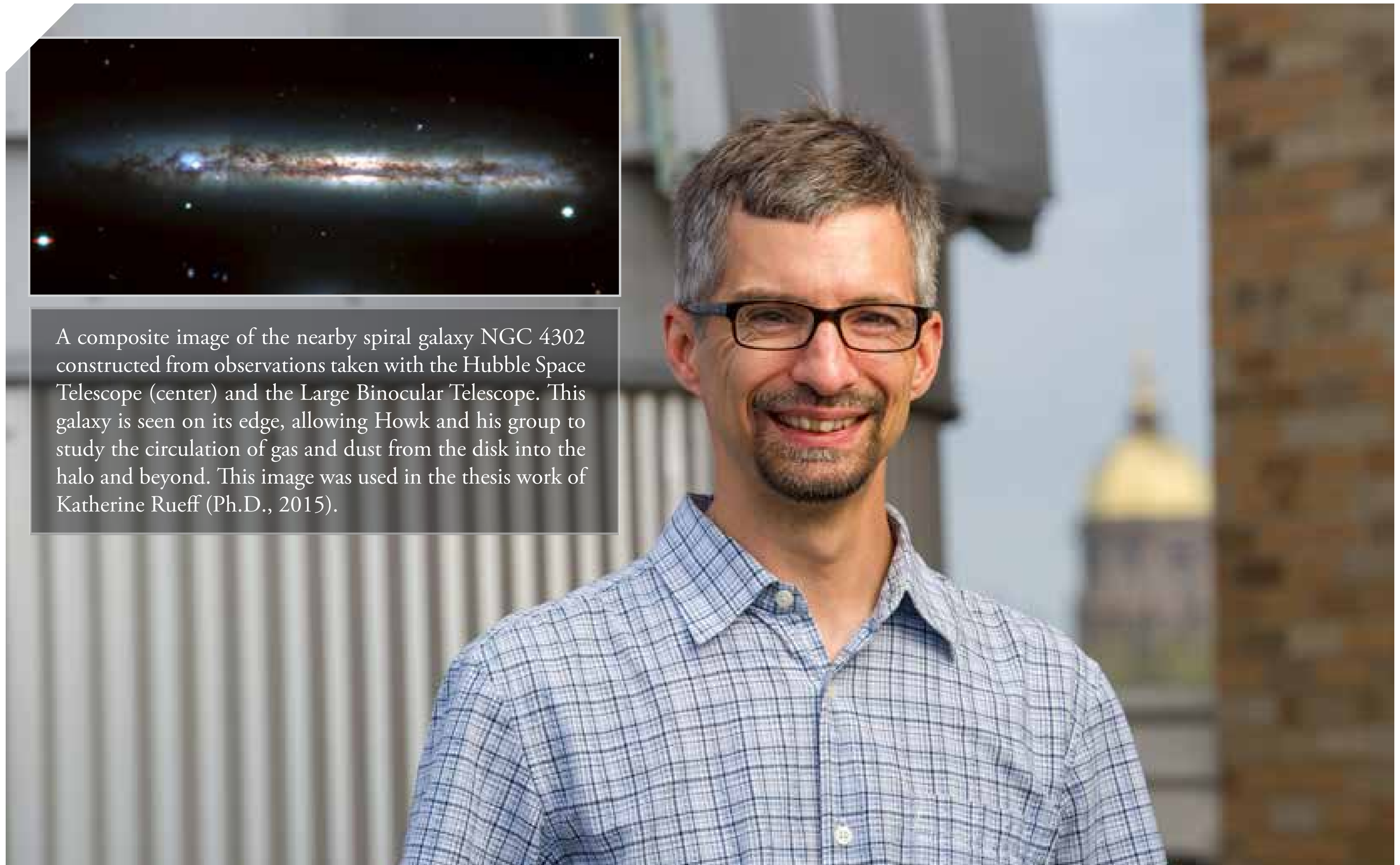
B.S. in Astronomy, University of Maryland, 1980
M.Sc in Physics, Massachusetts Institute of Technology, 1983
Research Associate, Space Telescope Science Institute, 1983-1985
Ph.D. in Astronomy, University of Washington, 1991
Postdoctoral Fellow, Dominion Astrophysical Observatory, 1992-1995
Fellow at the Harvard-Smithsonian Center of Astrophysics, 1995-1999

Co-recipient, Gruber Prize in Cosmology, 2007
Co-recipient, Breakthrough Prize in Fundamental Physics, 2015

Peter Garnavich's research interests cover a wide range of topics in observational astrophysics, focusing on time-domain astrophysics and cosmology. At Harvard, he was a key member of the High-Z Supernova Search Team that discovered that the expansion of the universe is accelerating. That discovery was awarded the 2011 Nobel Prize in Physics as well as the Gruber Prize and the Breakthrough Prize in Fundamental Physics.

Garnavich's primary research area is the study of supernovae and their diversity. These stellar explosions are excellent probes for distance scales relevant to cosmology. Supernovae provide the best way to measure properties of the mysterious dark energy that is accelerating the cosmic expansion. Garnavich was a key member of a team that definitively showed long gamma-ray bursts have their origin in the collapse of massive stars. Long gamma-ray bursts had been a mystery since the 1960s, but careful observation of a nearby burst revealed it to come from the direct collapse of a massive stellar core into a black hole. Garnavich led an international team of astrophysicists that discovered a "shock breakout" in an exploding supergiant star at visible wavelengths. Using the Kepler Space Telescope, the team spent three years observing 50 trillion stars for the chance to watch as supersonic shock waves reached their surfaces after explosions deep in the core.

Garnavich studies the variable sky over a wide range of wavelengths. In addition to using the Hubble, Spitzer, and Kepler Space Telescopes, Garnavich also uses the Large Binocular Telescope in Arizona to understand the nature of interacting binary stars that are the source of novae and supernovae. Recently Garnavich and a Naughton Fellow from Ireland studied a new short-period binary star at ultraviolet wavelengths using the Hubble Space Telescope. They showed that it evolved through a rare path that will eventually lead to a pure helium pair with an orbital period as short as five minutes. These observations are key to understanding the nature and origin of thermonuclear supernovae.



A composite image of the nearby spiral galaxy NGC 4302 constructed from observations taken with the Hubble Space Telescope (center) and the Large Binocular Telescope. This galaxy is seen on its edge, allowing Howk and his group to study the circulation of gas and dust from the disk into the halo and beyond. This image was used in the thesis work of Katherine Rueff (Ph.D., 2015).

J. CHRISTOPHER HOWK

Professor

B.A. in Physics, Hanover College, 1994
Ph.D. in Astronomy, University of Wisconsin-Madison, 1999

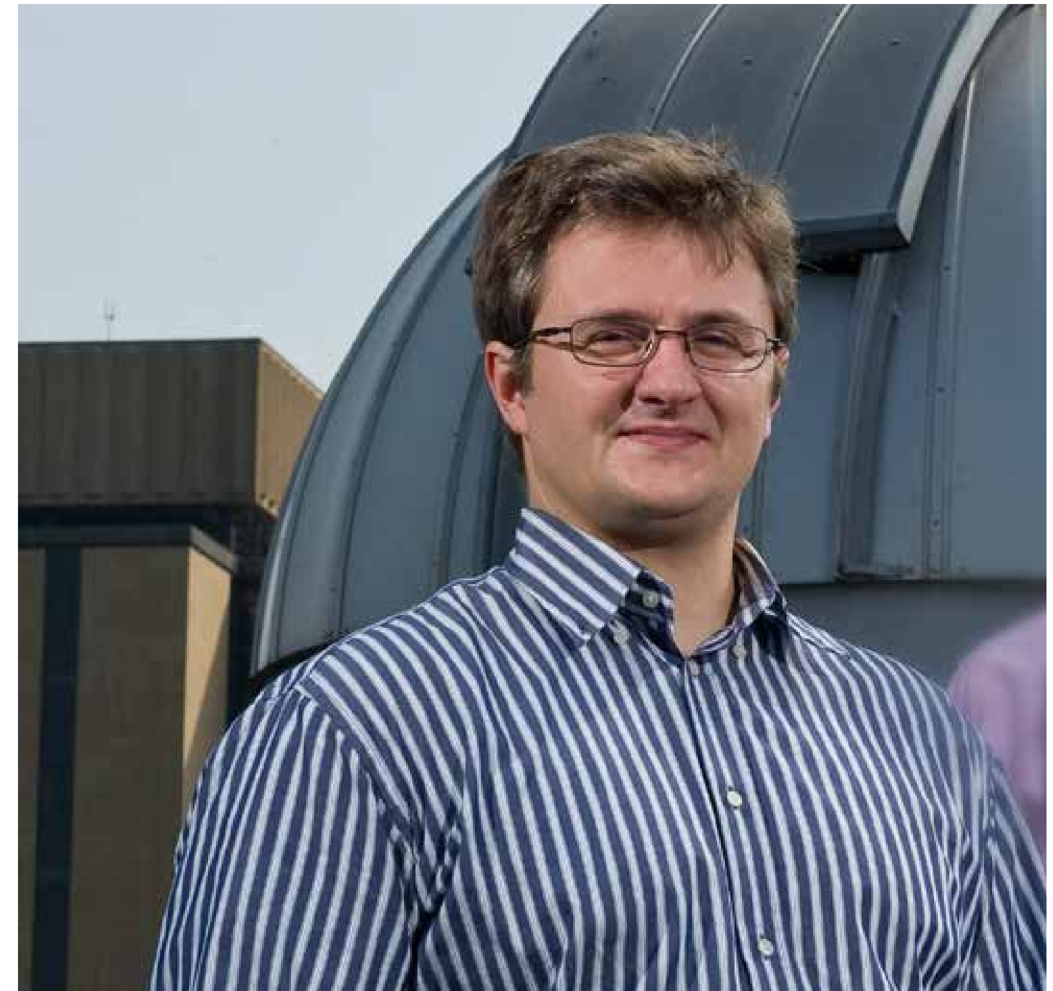
Postdoctoral fellow and research scientist, Johns Hopkins University

J. Christopher Howk and his group work to understand the evolution of the gaseous components of galaxies and the build up of the elements since the Big Bang. The history of star formation in a galaxy is largely dictated by its gas content. Star formation consumes some of this gas, but it may also energize and eject more from the galaxy. At the same time, the infall of new matter from the intergalactic medium—matter that may be largely unpolluted with metals since the Big Bang—fuels additional star formation. Howk's research probes this exchange of matter between galaxies and their surroundings, and tries to assess the impact recently formed stars have on the gas within galaxies.

Howk's group uses large observational facilities on the ground, such as the Large Binocular Telescope and the Keck telescopes, as well as those in space, such as the Hubble Space Telescope. They use spectroscopy to identify the gas near galaxies and spectroscopy and imaging to study the galaxies themselves. They collaborate closely with theoretical astronomers, especially to simulate the inner workings of galaxies within a cosmological context, and have been involved in millions of CPU node-hours worth of computations on high-performance computing facilities of NASA and the NSF.

Howk's group has received more than $4.5 million in funding from the NSF and NASA over the last decade.

In 2013, he was appointed to a three-year term on the Space Telescope Users Committee. The Committee serves to advise the Space Telescope Science Institute and the Goddard Space Flight Center on the scientific operations of the Hubble Space Telescope and recommends changes that will maximize its scientific productivity.



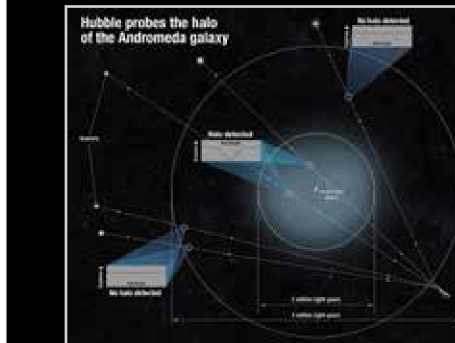


Fig. 1: This diagram shows how Lehner and Howk determine the size of the halo of the Andromeda galaxy. They use the light from quasars, very distant bright cores of active galaxies powered by black holes to search for absorption from the halo of Andromeda in their spectra. By studying the absorption from ions and atoms, they can infer not only the presence of the halo of Andromeda, but also determine its properties, including its ionization states, kinematics, and mass.

NICOLAS LEHNER

Research Associate Professor

B.Sc. in Physics (honors), Universite Louis Pasteur, France, 1994
M.Sc. in Astrophysics, Universite Louis Pasteur, 1995
Ph.D. in Astrophysics, The Queen's University of Belfast, N. Ireland, 2000

Since 2006, Nicolas Lehner has been conducting research with Christopher Howk and their graduate students and postdoc at the University of Notre Dame. To support his research program on determining how galaxies form and evolve into the objects we see today, he has been the PI on several multi-year NASA grants and in 2016 alone has been awarded $1.2 million of NASA funding to address the next several years some of the most fundamental problems in modern astrophysics. His discoveries have been published in major scientific journals, including *Science and Nature*, and have attracted the attention from national and international media.

An example of such discovery is illustrated in Figure 1. Using Hubble ultraviolet spectra of bright background objects known as quasars, they demonstrated for the first time that our nearest massive galactic neighbor, Andromeda (M31), has a massive and extended halo that stretches about 1 million light-years from M31. This is about six times larger and 1,000 times more massive than previously measured. They found that this immense halo contains about as much mass in its diffused gas as the stars in the Andromeda Galaxy. Studying the halos of other galaxies of similar masses, they know that M31 is not peculiar in the Universe, but this is the first time where they can study the halo toward more than one line of sight in a galaxy other than the Milky Way. This, in fact has been a major hindrance to rigorous estimates of the halo properties, such as mass, density, and kinematics. Lehner is the PI of a large (93 orbit) approved Hubble program where he and his colleagues will now pin down the physical state and metal distribution of the halo for a single galaxy, an unprecedented feat never achieved previously.

This is one example among many research projects he has been working on with a team of observers and theoreticians that encompasses several institutions across the nation. They have been awarded about $2 million in research grants from the NSF and NASA in 2015 to support their work on understanding the gaseous streams in the halos of galaxies. Using data from the Large Binocular Telescope, Keck Telescope, and Hubble Space Telescope, as well as new, cutting-edge numerical simulations, he and his colleagues will determine in the coming years how the halos around galaxies have evolved over 12 billion years of cosmic time and whether the gas around galaxies is truly a driver of star formation in the universe.

GRANT MATHEWS

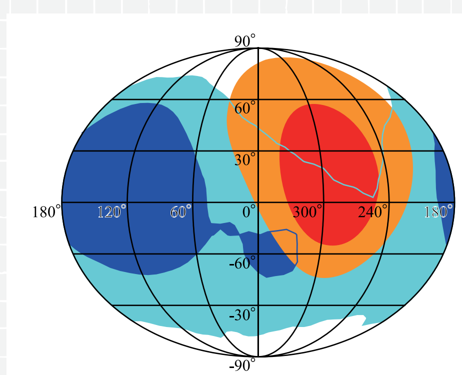
Professor and Director, Center for Astrophysics at Notre Dame

B.S., Michigan State University, 1972
Ph.D. the University of Maryland, 1977
Fellow of the American Physical Society

After post-doctoral positions at the University of California, Berkeley, and the California Institute of Technology, Grant J. Mathews joined the Physics Division of Lawrence Livermore National Laboratory, obtaining the position as group leader in astrophysics. Matthews is a fellow of the American Physical Society. He joined the University of Notre Dame in 1994.

Professor Mathews has published more than 250 papers in top-tier research journals and has presented over 380 invited talks and colloquia on topics in theoretical astrophysics and cosmology. The co-author of books on relativistic hydrodynamics and observational astronomy and cosmology, he has served on various review panels for astrophysics proposals to the Department of Energy, National Science Foundation, and NASA and has served several times as a Siemens competition judge. Most recently, he has taught graduate and undergraduate classes in astronomy, the general theory of relativity, quantum field theory, astrophysics, and cosmology.

His research areas include various aspects of nuclear and particle astrophysics and cosmology including numerical simulations of core collapse supernovae, studies of neutrino interactions and nucleosynthesis in supernovae, as well as various aspects of the Big Bang including constraints from Big Bang nucleosynthesis and the cosmic microwave background on the origin and evolution of the universe, the early moments of the inflating universe, constraints on massive particles and their decay in the early universe, constraints on time-dependent fundamental constants in the early universe. Mathews is also involved in studies of galaxy formation and their chemical evolution along with studies of general relativistic hydrodynamics, stellar evolution and merging binary neutron stars. In addition, Mathews studies the origin of cosmic gamma-ray bursts and their afterglow.



Contours of the possible evidence for cosmic dark flow remaining from the birth of the multiverse.

LARA ARIELLE PHILLIPS

Research Assistant Professor

B.Sc., First Class Honors in Physics, McGill University, Montreal, Canada, 1996
Ph.D. in Astrophysics, Princeton University, 2003

Lara Arielle Phillips is a research assistant professor of Physics at the University of Notre Dame. As a researcher, she studies the interplay between galaxies and the largest structures in the universe. She has transformed computational tools used in medical physics to peer into the different neighborhoods of the cosmic web, studying filaments, voids, and clusters. As a teacher, she co-created a course on Physics and Theatre, Science Play. Part of the Westville Educational Initiative, she is pioneering the teaching of algebra-based physics in a correctional facility. As chair of the outreach committee of the department of Physics, her efforts to involve the broader public in science have reached thousands. She is a member and co-producer of the artistic collaboration High Z, a project to create a hybrid installation based on the 2011 Nobel Prize-winning discovery of the accelerating universe.

How do the neighborhoods that galaxies live in affect their evolution? Phillips and her team have developed tools to find and characterize structure, specifically filaments, clusters, and voids, in large scale simulations and large data sets. This structure finder, coupled with the capacity to run their own simulations of portions of the universe using Center for Research Computing facilities, allows them to explore the environmental history of galaxies and tackle this question. Phillips's team also uses these tools to more broadly answer what the shape of the distribution of objects (galaxies in large scale structure, stars in galaxies) can reveal about the history of baryons in our universe.

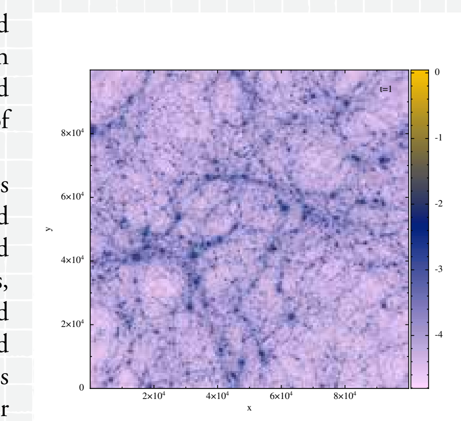


Fig. 1: A view through a (466 light year)^3 simulation of the universe run by Ali Snedden, Ph.D., under the supervision of professor Phillips. Over time, the particles cluster into filaments and clusters, creating empty regions, or voids. Galaxies evolve in all these regions.

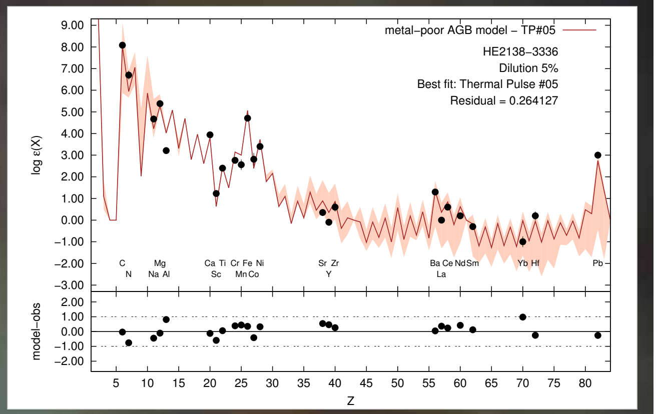


Fig 1: Chemical abundance pattern of the Star HE2138-3336, compared with yields from a Asymptotic Giant Branch stellar model. The dots represent the observed abundances for each chemical element. The shaded area covers the model prediction ranges from the initial to the final abundances, and the solid line shows the abundance pattern for the thermal pulse having the best match to the observed data.

VINICIUS PLACCO

Research Assistant Professor

B.Sc. in Physics & Astronomy, University of Sao Paulo, Brazil, 2005
M.Sc. in Astronomy, University of Sao Paulo, Brazil, 2007
Ph.D. in Astronomy, University of Sao Paulo, Brazil, 2010

Vinicius Placco came to the Department of Physics at the University of Notre Dame as a research assistant professor in April 2015, coming from the Gemini Observatory in Hawaii. As a Science Fellow at Gemini, he spent 50 percent of his time on research and 50 percent on observatory operations, which included user support, instrument commissioning, instrument performance monitoring, and running the observing queue at the telescope. This gave him an unique opportunity to learn about the structure and day-to-day operations of an astronomy observatory. Before that, Placco was a Postdoctoral Fellow at the National Optical Astronomy Observatory, in Tucson, Arizona.

Placco's research focuses in the chemical evolution of the galaxy and the universe, revealed by spectroscopic studies of low-metallicity stars. These stars, due to their low masses (and long lives), are excellent probes of the chemical composition in the early universe. A subset of the low-metallicity stars, the so called ultra metal-poor (UMP) stars are believed to be true second-generation stars. UMP stars were formed from gas polluted by the supernova explosions of the first (Population III) stars, so they hold in their atmosphere the chemical imprint of a very young evolving universe. Placco is especially interested in measuring abundances for elements such as lithium, carbon, nitrogen, oxygen, and neutron-capture (strontium, barium, europium, lead, among others). These abundances are used to constrain theoretical models of both stellar and galactic chemical evolution.

Placco's work ranges from large database manipulation (to identify targets for spectroscopic follow-up), statistical methods, preparing and executing observations, reducing and processing data, to high-resolution spectral synthesis of absorption features in stellar spectra. As an observer, he has more than 3,000 hours of approved observing time in 4-10 m class telescopes as PI and Co-PI in the last eight years. He also has experience with proposal writing, observations, and data processing in telescopes such as the Hubble Space Telescope, Gemini North, Gemini South, Subaru, ESO/VLT, Magellan/Clay, CFHT, ESO/NTT, SOAR, KPNO/Mayall, Southern African Large Telescope, McDonald 82in, among others. The Beers group to which he is a part, is responsible for the spectroscopic follow-up of thousands of metal-poor star candidates over the last decade using these facilities and has many ongoing efforts to increase these numbers even further.

TERRENCE RETTIG

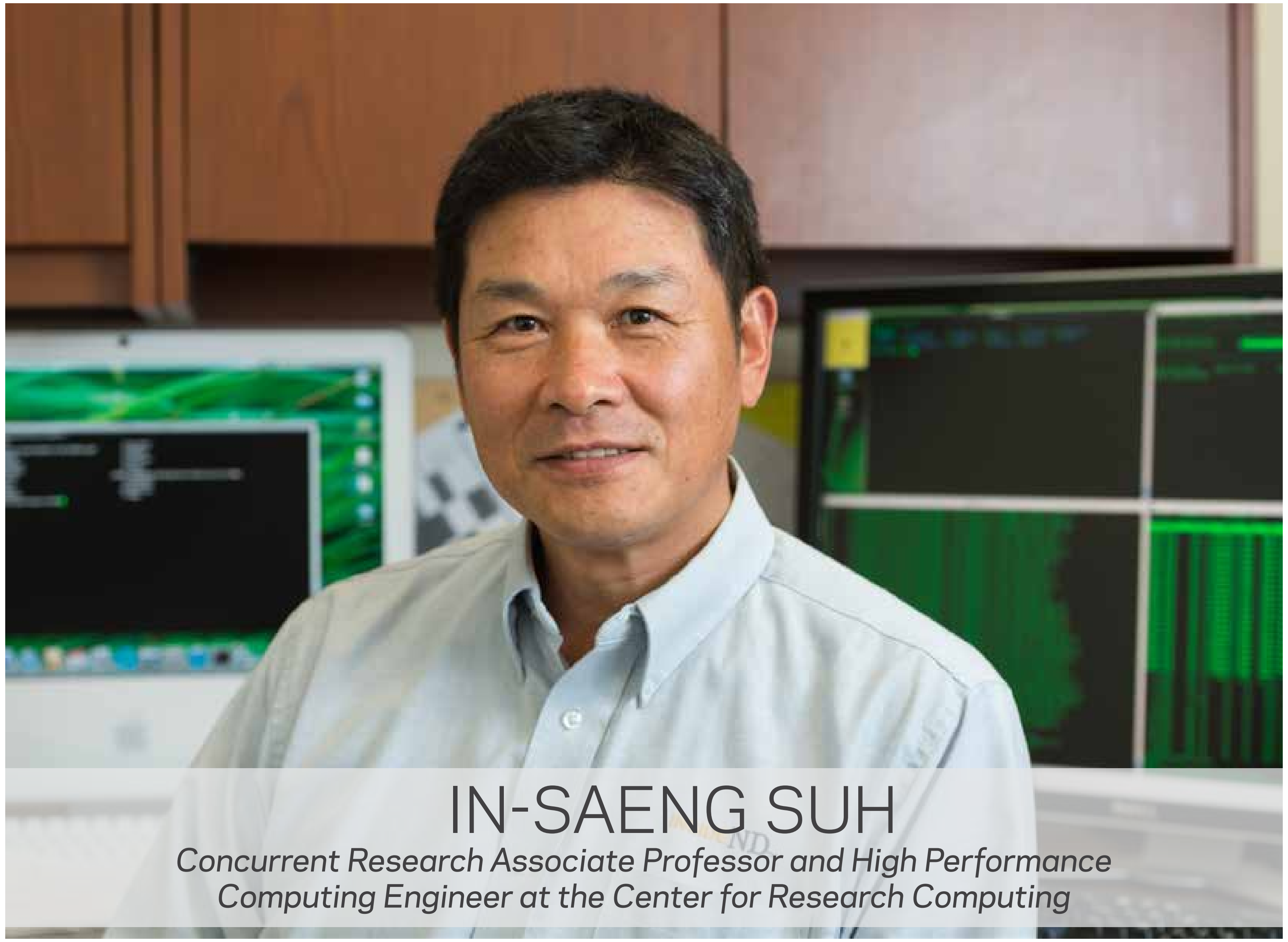
Professor

B.A. in Physics and Mathematics, Defiance College, 1968
M.S. in Physics, Ball State University, 1970
Ph.D. in Astrophysics, Indiana University, 1976

Terrence Rettig's research focuses on understanding the collapse of preplanetary disks and the conditions and constraints under which planets form. Planet formation has been known to be tied to the accretion and evolution of gas and dust in disks around young stars. Researchers have never observationally quantified how the dust settles with respect to the gas, and how this affects the midplane turbulence and the process of planet formation.

His group used high-resolution spectra of ices, dust, and gas phase molecules in the disks of pre-main sequence stars to study the physical conditions in regions where planets form. High-resolution infrared observation of CO has provided the first direct observations of how gas and dust stratify around young stellar objects. Other molecules, such as H2, H3+, and H2O also help researchers understand the chemical processes, environment, and evolution of 'other solar systems' that may be in the process of planet formation. The abundance and excitation of these molecules clarify the time scales and initial conditions for planet building, and may also provide a new technique to find protoplanets. The infrared spectroscopic data have been obtained from the Infrared Telescope (IRTF) and the 10-meter Keck Telescope on Mauna Kea.

In addition, Rettig has recently developed a course, "Earth Focus–The Science of Climate Change," geared to undergraduate sustainability minors and liberal arts majors. He has also written a textbook that will provide the necessary information to critically examine climate change, determine its consequences, and analyze potential solutions. The course builds on the basic rules of science and the scientific method to analyze climate issues and the potential of global warming.



IN-SAENG SUH

Concurrent Research Associate Professor and High Performance Computing Engineer at the Center for Research Computing

B.S. in Physics, Sogang University, 1986
M.S. in Physics, Hanyang University, 1991
Ph.D. in Physics, Hanyang University, 1997

Professor Suh was awarded the Korea Research Foundation Fellowship, after which he spent four years at the Department of Physics, University of Notre Dame. In the Center for Research Computing, he supports students, staff, and faculty with high performance scientific and engineering research computing. He also collaborates with graduate students and faculty members in astrophysics and cosmology in the Department of Physics.

Suh's research interests include theoretical/computational astrophysics in the internal structure of neutron stars, magnetic white dwarfs, strongly magnetized neutron stars (magnetars), soft gamma-ray repeaters (SGR) and anomalous X-ray pulsars (AXP), big bang nucleosynthesis, phase transitions in the early universe, cosmic large-scale structure simulation, and numerical relativistic hydrodynamics. He focuses on magnetars as a source of SGR and AXP which are compact objects showing mysterious astrophysical events. The magnetars are strongly (over ~ 1015 G) magnetized neutron stars. Under such a high magnetic field strength, equation of state and internal structure of neutron stars could dramatically be changed, suggesting the magnetic domain model as an engine for SGR and AXP.

Suh also actively works on the large-scale parallel simulations on the cosmic large-scale structure evolutions and relativistic hydrodynamics to simulate the binary neutron stars and gravitational waves.

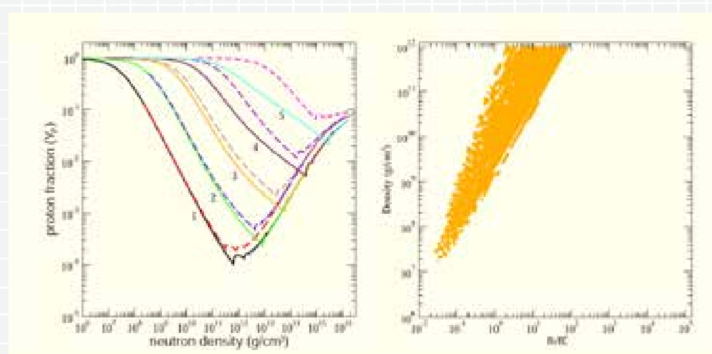
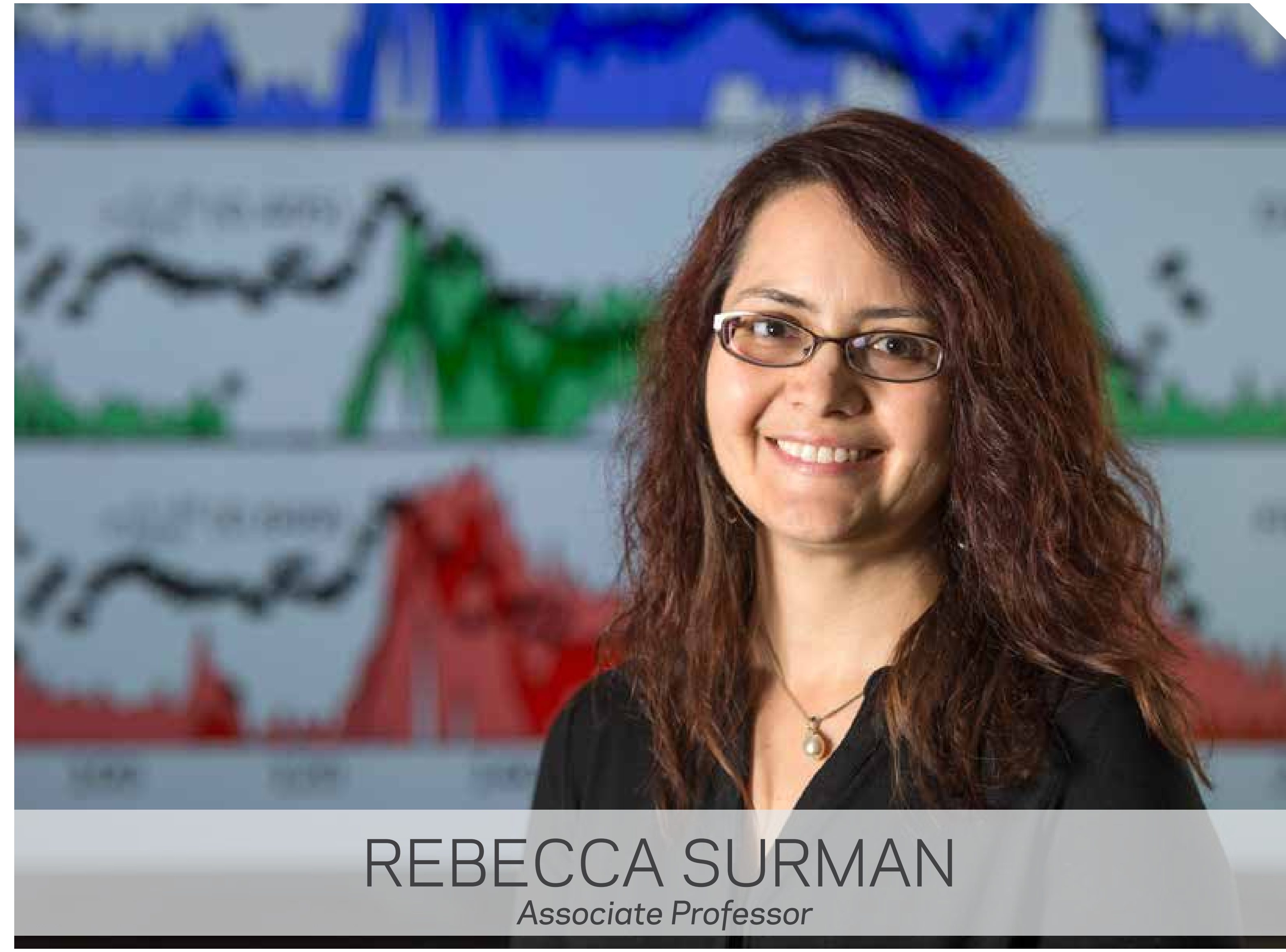


Fig.1: Proton fraction Yp = np / nB with the anomalous magnetic moment included vs. the neutron density inside magnetars for the given value of log (B/Bce) where Bce is the quantum critical magnetic field for electron (left panel) from I. Suh and G. Mathews, Astrophysical Journal, 546,1126 (2001). The unstable regions of the magnetic domain formation at the outer crust of magnetars (right panel) from I. Suh and G. Mathews, Astrophysical Journal, 717, 843 (2010).



REBECCA SURMAN

Associate Professor

B.A. in Physics, summa cum laude, State University of New York College at Geneseo, 1993
M.S. in Physics, Michigan State University, 1995
Ph.D. in Physics, University of North Carolina at Chapel Hill, 1998

Stillman Prize for Excellence in Teaching, Union College campuswide teaching award, 2007

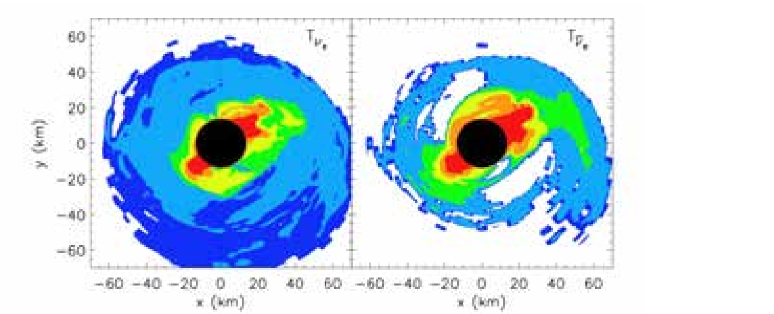
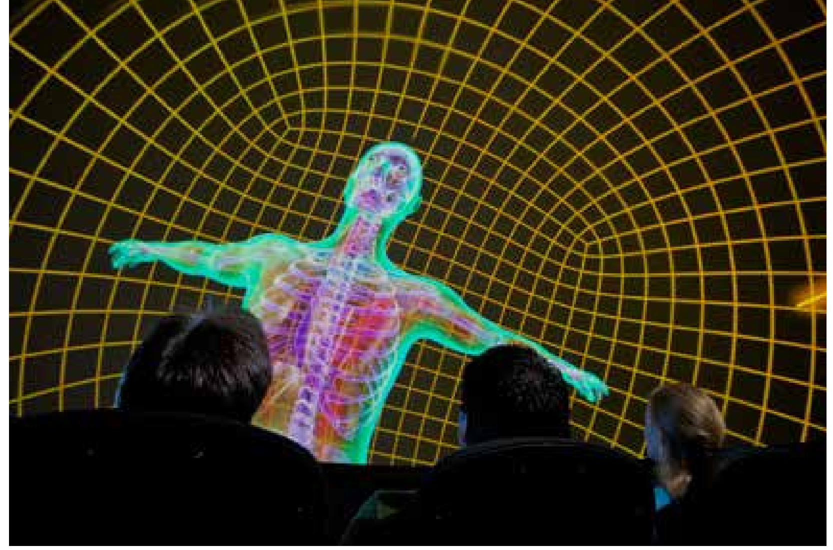


Fig. 1: Plots of the electron neutrino (left panel) and electron antineutrino (right panel) temperatures from the surface of a merger black hole accretion disk. Only regions where the neutrinos are trapped are shown. Contours indicate regions, from blue to red, of temperatures of 1 MeV, 3 MeV, 5 MeV, 7 MeV, 9 MeV, 11 MeV and 13 MeV. The dark center indicates the inner boundary of the numerical merger model. From Surman, McLaughlin, Ruffert, Janka, Hix, Astrophysical Journal Letters 679, L117 (2008).

After earning her Ph.D. at the University of North Carolina at Chapel Hill, Rebecca Surman moved directly to a faculty position at Union College in Schenectady, N.Y. While at Union, she rose to the rank of professor and undertook research leaves at North Carolina State University, Oak Ridge National Laboratory, and the University of Notre Dame.

Rebecca Surman is a theoretical/computational nuclear astrophysicist with a particular interest in the origins of the heaviest elements. While we understand the basics of the nuclear processes that create these elements, we do not yet know where the appropriate astrophysical conditions are found. Many of the potential sites are environments where neutrino interactions shape the resulting nucleosynthesis. The nuclei created are often extremely neutron rich, beyond what has been observed to date but increasingly accessible to radioactive beam experiments.

Surman investigates aspects of the neutrino and nuclear physics of element synthesis in extreme astrophysical environments, such as within supernovae, neutron star mergers, and black hole accretion disk outflows, with a focus on connecting these simulations to spectroscopic and meteoritic observations of elements in the solar system and the old stars at the edges of our galaxy.



DIGITAL VISUALIZATION THEATER

The University of Notre Dame's Digital Visualization Theater (DVT) offers faculty the ability to immerse students in high-resolution, high-fidelity 3D images and animations projected on a 50-foot-diameter dome. Students and visitors can tour the inside of the structure of the human body, cancer cells, DNA, or fly through the Milky Way.

The state-of-the-art facility is controlled by Digital Sky, a planetarium-controlled software provided by Sky-Skan, Inc. Digital Sky enables three separate types of presentations, and provides the ability to switch between, or even integrate them all. The system has a planetarium mode, a real-time 3D mode, and a pre-rendered movie mode. In planetarium and real-time 3D mode, the theater can incorporate 3D models, images, movies, sound files, all in a flexible and integrated way through a common scripting system. The real-time aspect of these modes allow the presenter to respond quickly, piloting through 3D models of the universe or anything else that can be created by leading 3D modeling software.

Eleven computers control the screens on the 50 foot dome, using two Sony SRX-110 digital projectors to achieve a resolution of over 10 million visible pixels for a truly, immersive experience.


physics.nd.edu