

"Astronomy compels the soul to look upwards and leads us from this world to another" - Plato



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# Astronomy Department

### **Columbia University**

Located in New York City, Columbia University offers a graduate program in astronomy and astrophysics with a primary focus on the development of research skills. The goal of this program is to produce creative and independent scientists who will advance the frontiers of our discipline, educate the next generation of astronomers, and engage the public in our endeavor to understand the Universe. Our community includes faculty, researchers, and students in Astronomy and Astrophysics at Columbia University, Barnard College, NASA's Goddard Institute for Space Studies, the American Museum of Natural History and the Simons Center for Computational Astronomy all of whom are pursuing a wide range of theoretical, computational, observational, and experimental research.

# THE GRADUATE PROGRAM



The graduate program for the Ph.D. is designed to foster the intellectual and professional development of our students. To this end, graduate students are fully integrated into all of our Department's activities.

The primary goal of the program is to cultivate the ability to perform original, independent research. Shortly after arrival on campus, incoming students choose their first facultyguided research project. In the first two years, each student will work with two different faculty members in two distinct areas of astronomy. Many students submit the results of these research projects for publication in professional journals. Instead of a traditional qualifying exam, research exams are held at the completion of the first and second year. Our course requirements are designed to impart the knowledge necessary for research in astronomy. The culmination of this two years of preparation comes in the form of a dissertation proposal presented before a committee in the third year. The remaining part of the graduate student's career is devoted to completing a seminal piece of original research.

#### Another important aspect of the Columbia Astronomy Department's graduate program is the development of teaching skills. After a year of apprenticeship, graduate students in their second and third years design and teach their own introductory astronomy laboratory or lecture courses for undergraduates. Additionally, graduate students may choose to become involved with our extensive outreach programs in New York City, or with the education and exhibition activities at the American Museum of Natural History.

We are proud to report that recent graduates have been awarded prestigious postdoctoral fellowships (including the Hubble, Sagan, Chandra, and Einstein Fellowships), and that many of our alumni hold permanent positions at top institutions world-wide (see www.astro.columbia.edu for a complete listing of graduates over the past twenty years).







# FACILITIES

The Astronomy Department is a partner in the MDM Observatory Consortium with a 25% share of the 1.3-meter McGraw-Hill telescope and the 2.4-meter Hiltner telescope on Kitt Peak in Arizona. Graduate students doing observational research receive a large fraction of the 150 nights per year of observing time on the two telescopes. In addition, the Observatory provides an ideal opportunity for designing, building, testing, and using innovative optical and near-IR instrumentation developed in our laboratories. We are also participants in LSST, the Subaru Prime Focus Spectrograph survey, and SDSS-V.

The Columbia Astrophysics Laboratory, a joint endeavor involving the Astronomy and Physics Departments, has extensive experience in the design and construction of new astronomical instruments for rocket, satellite and balloon missions, as well as ground-based telescopes. Facilities at our Nevis site include laboratories and equipment for testing and assembling experiments, an electronics shop, and an instrument machine shop. In addition, there is a fully equipped machine shop available for student use in the Pupin Building and additional laboratories for instrument development. Current projects include NuSTAR (the first hard X-ray imaging satellite launched in 2012), the Cosmic H-alpha Spectrograph, instrumentation for the Laser Interferometer Gravity-wave Observatory, UV instrumentation, laboratory astrophysics, and CCD cameras.



Every week two invited speakers give separate Physics and Astronomy colloquia. The Astronomy Department also holds Thursday seminars, a journal club, astro-ph coffee, and a Pizza Lunch every Tuesday where attendees can informally learn about research activities in the Department.

The Astrophysics Laboratory and Astronomy Department maintain a large network of workstations and each student is assigned a private computer on arrival. Additionally, the Department has access to computing clusters capable of completing complex simulations of astrophysical phenomena and is an affiliate of the new Simons Center for Computational Astrophysics.









#### **MARCEL AGÜEROS (Professor)**

Professor Agüeros received his B.A. in Astronomy from Columbia University before earning an M.Phil in Physics from the University of Cambridge (UK) and his Ph.D. in Astronomy from the University of Washington. He was a National Science Foundation Astronomy and Astrophysics Post-doctoral Fellow in the Columbia Astrophysics Laboratory for four years before joining the faculty. He is also the Director of Columbia's Bridge to the Ph.D. Program in the Natural Sciences.

#### **JAMES H. APPLEGATE (Professor)**

Professor Applegate received his B.S. in Astrophysics from Michigan State University and his Ph.D. in Physics from SUNY at Stony Brook. He was a Bantrell Research Fellow at the California Institute of Technology, and is a former chair of the Astronomy Department at Columbia.





#### **GREG BRYAN (Professor)**

Professor Bryan received his B.Sc. in physics from the University of Calgary (Canada) and his Ph.D. from the University of Illinois. He received a Hubble Fellowship, Lyman Spitzer Fellowship, and an NSF Career Grant. He also received the Leverhulme Trust Prize for "outstanding young researchers." He was a faculty member in the Physics Department at Oxford for three years before coming to Columbia University.

#### **KISHALAY DE (Assistant Professor)**

Professor De was previously a NASA Einstein Fellow and Kavli Institute Fellow at the Massachusetts Institute of Technology, and a Postdoctoral affiliate at the Institute for Theory and Computation at Harvard University. He obtained his PhD in Astrophysics from the California Institute of Technology in 2021, under the supervision of Mansi Kasliwal.







#### JANE HUANG (Assistant Professor)

Professor Huang grew up in Chicago and earned her PhD in Astronomy & Astrophysics from Harvard University. Her research focuses on characterizing the structure and chemistry of protoplanetary disks (primarily using the Atacama Large Millimeter/Submillimeter Array) in order to establish the early conditions of planet formation. Her outreach interests include addressing inequities in the public education system.

#### **DAVID HELFAND (Professor)**

Professor Helfand received his B.A. from Amherst College, and an M.S. in Physics and Ph.D. in Astronomy from the University of Massachusetts. He has also been a visiting scientist at the Danish Space Research Institute and the Sackler Distinguished Visiting Astronomer at the University of Cambridge. He has been a professor in both Physics and Astronomy at Columbia, and was Chair of Astronomy for 18 years. He recently returned from an extended leave during which he served as President & Vice Chancellor of an innovative new institution he helped to design, Quest University, and was also recently President of the American Astronomical Society.





#### **KATHRYN JOHNSTON (Professor)**

Professor Johnston received undergraduate degree from the University of Cambridge in Maths and her Ph.D. in astronomy and astrophysics from UC-Santa Cruz. She was a member of the Institute for Advanced Study at Princeton, and then an assistant professor at Wesleyan University, where she was a recipient of an NSF CAREER Award. She joined the Columbia Astronomy faculty in 2006, and recently served as Chair of the Department.

#### **DAVID KIPPING (Associate Professor)**

Professor Kipping received his B.A. and M.Sc. in Natural Sciences from Cambridge University, after which he earned his Ph.D. in Astrophysics at University College London. He spent six years at the Harvard-Smithsonian Center for Astrophysics, first as a predoc during

his graduate studies and then as a Sagan and Menzel Fellow before coming to Columbia. He was recently named as one of Popular Science magazine's "Brilliant Ten" young scientists.



#### **ANGELA OLINTO (Professor and Provost)**

A trailblazer in astroparticle physics, Angela Olinto has made groundbreaking contributions to understanding the universe's inflationary origins, the cosmological impact of magnetic fields, and the internal structure of neutron stars. Her research has far-reaching implications, influencing everything from cosmic processes to the development of life. Olinto is the principal investigator for two NASA programs investigating high-energy cosmic particles: the Probe of Extreme Multi-Messenger Astrophysics (POEMMA) and the Extreme Universe Space Observatory (EUSO) balloon missions.

#### **FRITS PAERELS (Professor)**

Professor Paerels received his Ph.D. from the University of Utrecht (Netherlands). He was a research scientist at Columbia before becoming a Senior Scientist of SRON Space Research Laboratory in the Netherlands. He is currently serving as the director of undergraduate studies.



Professor Putman received her B.S. in Astronomy and Physics from University of Wisconsin-Madison and her Ph.D. in Astronomy and Astrophysics from the Australian National University (Mt. Stromlo Observatory). She has received a Hubble Postdoctoral Fellowship, the Elizabeth C. Crosby Award, an NSF Award, Cottrell Scholarship, and an NSF CAREER Award, and was Clare Boothe Luce Associate Professor at Columbia University.

#### LORENZO SIRONI (Associate Professor)

Professor Sironi received his undergraduate degrees in Physics from the University of Pisa and his Ph.D. in Astronomy from Princeton. He was an Einstein Fellow at the Institute for Theory and Computation at Harvard before joining the Columbia faculty in 2016. He applies his sophisticated particle-in-cell codes to a wide variety of plasma physics problems ranging from the Sun to magnetized neutron stars to galaxy clusters and the evolution of supermassive black holes and their host galaxies

#### DAVID SCHIMINOVICH (Professor)

Professor Schiminovich received his B.S. in Mathematics and Physics from Yale University and his Ph.D. from Columbia University. Before his return to Columbia as a professor in 2004, he was a postdoctoral research fellow at Caltech and a visiting research scientist at Yale. From 1997 he has been a lead scientist on the Galaxy Evolution Explorer (GALEX) project. He is co-Director of the Columbia Astrophysics Laboratory and Vice-Chair of Astronomy

#### AFFILIATED FACULTY

#### LAURA KAY (Ann Whitney Olin Professor, Barnard)

 Professor Kay received her B.S. in Physics and B.A. in Feminist Studies from Stanford University and her Ph.D. in Astronomy and Astrophysics from the University of California at Santa Cruz. She is lead author of the widely used textbook "21<sup>st</sup> Century Astronomy". She is currently serving as the chair of the Department of Physics and Astronomy at Barnard College.











#### **ELENA APRILE (Professor, Physics)**

Professor Aprile received her "Laurea" from the University of Naples, Italy, and her Ph.D. from the University of Geneva, Switzerland. She is the leader of the XENON experiment that is designed to detect dark matter.

#### **ANDREI BELOBORODOV (Professor, Physics)**

Professor Beloborodov received his M.Sc. from the Moscow Institute of Physics and Technology and his Ph.D. from Lebedev Physical Institute. Prior to joining the Columbia faculty, he was a post-doctoral fellow at the Canadian Institute for Theoretical Astrophysics.

#### LAM HUI (Professor, Physics)

Professor Hui received his B.A. from UC Berkeley and his Ph.D. in Physics from MIT. He held postdoctoral positions at Fermilab and at the Institute for Advanced Study in Princeton, and was a faculty member at the University of Chicago and at Fermilab before becoming an associate professor of Physics at Columbia.

#### **CHUCK HAILEY (Pupin Professor, Physics)**

Professor Hailey received his B.A. from Cornell University and his Ph.D. from Columbia University. He was a research scientist and later a program leader for Astrophysics in the Physics Department at Lawrence Livermore National Laboratory; he also worked at KMS Fusion, Inc. as a senior research scientist before joining the Columbia faculty. He is co-PI of the NuSTAR mission and is co-Director of the Columbia Astrophysics Laboratory.

#### SZABOLCS MARKA (Associate Professor, Physics)

Professor Marka received his Diploma from Kossuth Lajos University (Hungary) and his Ph.D. from Vanderbilt University. He has previously worked at Cornell and Caltech. Currently, he is leader of the Columbia Experimental Gravity Group (a member of LIGO) in addition to being a professor at Columbia. He received an NSF CAREER Award and two GRAND Challenges Explorations Award from the Bill and Melinda Gates Foundation.











#### JANNA LEVIN (Associate Professor, Barnard)

Professor Levin holds a B.A. in Physics and Astronomy from Barnard College and a Ph.D. from MIT in Physics. She has previously worked at the Center for Particle Astrophysics (CfPA) at U.C. Berkeley, and at Cambridge University in the Department of Applied Mathematics and Theoretical Physics. She is the author of several books including *How the Universe Got Its Spots.* 





#### **RESHMI MUKHERJEE (Helen Goodhart Altschul Professor, Barnard)**

Professor Mukherjee received her B.S. from Presidency College, University of Calcutta and her M.A., MPhil, and Ph.D. degrees from Columbia University. In addition to being a professor, she has served as chair of physics and astronomy at Barnard College.

#### **REBECCA OPPENHEIMER (Adjunct Professor, AMNH)**

Professor Oppenheimer received her B.A. in Physics from Columbia University and her Ph.D. in Astronomy from the California Institute of Technology. She was a Hubble Fellow at the University of California at Berkeley and at AMNH, as well as a Kalbfleisch Research Fellow at the AMNH. She is currently a curator in the Astrophysics Department of AMNH and Chair of the Physical Sciences Division there, as well as an adjunct professor at Columbia.





#### MORDECAI-MARK MACLOW (Adjunct Professor, AMNH)

Professor MacLow received a B.A. in Physics from Princeton University and a PhD. in Physics from the University of Colorado at Boulder. He was a postdoctoral fellow at NASA Ames Research Center at Berkeley and at the University of Chicago, and a staff member at the Max-Planck Institute in Heidelberg, Germany. He is a curator in the Department of Astrophysics at the AMNH, and served as chair of the Museum's Physical Sciences Division.

#### MICHAEL SHARA (Adjunct Professor, AMNH)

Professor Shara received his Ph.D. from Tel Aviv University. He was a research assistant professor at Arizona State University prior to moving to the Space Telescope Institute where he became a tenured astronomer prior to coming to New York. In addition to being an adjunct professor at Columbia, he is curator in the Physical Sciences division at AMNH.





#### **KERSTIN PEREZ (Associate Professor, Physics)**

Professor Perez is originally from West Philadelphia and earned her B.A. in physics from Columbia University. She received her Ph.D. from Caltech, for research using the ATLAS detector at the LHC. She was appointed as an Assistant Professor of Physics at Haverford College, before joining MIT as an Assistant Professor of Physics in 2016 and an Associate Professor of Physics in 2021. She returned once again to Columbia University as faculty in 2022.



## **Public Outreach**

"No one regards what is before his feet; we all gaze at the stars." – Quintus Ennius

The Columbia Astronomy Department is dedicated to bringing science to the public. In recent years we have reached over 20,000 New Yorkers through the various events of our public outreach program. Our outreach events include:

- Biweekly public lectures given by an astronomer associated with Columbia (often a graduate student) along with an observatory open house where the public can look through small and mediumsized telescopes on our roof.
- Class visits where Columbia astronomers provide tours of our department along with short programs demonstrating astronomical concepts.
- Middle School outreach with presentations by Columbia astronomers and students at local public schools.
- A program called Rooftop Variables that educates NYC teachers and helps them start astronomy clubs at their schools.

- Harlem Sidewalk Astronomy, where we take telescopes to 125<sup>th</sup> street in Harlem and attract passersby by offering a beautiful view of the moon, planets, and sometimes even deep sky objects.
- Family Astro Saturdays are also held three times a year. This program engages elementary school students and their families in hands-on astronomy
- Various other public lectures and appearances around the City and beyond.

For more information about the Columbia Public Outreach Program, see our webpage or contact the current director at:

outreach.astro.columbia.edu or outreach-admin@astro.columbia.edu





# + FACULTY RESEARCH

### Formation and Evolution of Stars and Planets







Professor Patterson is part of a group that formed the Center for Backyard Astrophysics, a network of primarily amateur astronomers spanning the globe and collaborating on observation of variable stars. This has provided a powerful tool to study periodic processes in cataclysmic variable stars. He has also been working for 20 years to understand the structure of DQ Her stars, often called intermediate polars. One of his major research goals is to understand the structure and evolution of cataclysmic variables, especially the oldest ones (the WZ Sge and AM CVn stars) where both components have evolved to degenerate states. For more on his research, contact him at jop@astro.columbia.edu

#### JAMES APPLEGATE

Professor Applegate is a theoretical physicist with broad interests in astrophysics. He has developed a model for the orbital period variations seen in verv close binaries, such as the Black Widow Pulsar system PSR B1957+20. He also investigated models of the structure and evolution of tidally powered stars. He has also described the consequences of a first order phase transition in quantum chromodynamics on the early evolution of the universe, and shows how this transition might be detectable through its effect on big bang nucleosynthesis. For more on his research, contact him at jha@astro.columbia.edu

#### DAVID HELFAND

Professor Helfand's current research revolves around two large radio sky surveys he has undertaken with colleagues over the past twenty years: the FIRST survey of 10,000 square degrees of the extragalactic sky, and MAGPIS, a survey along the plane of the Milky Way. He also has a long-standing interest in the evolution of neutron stars and supernova remnants. His current projects include the discovery of new supernova remnants and the identification of high energy gammaray sources in MAGPIS, computation of the angular-diameter/redshift relation for double radio sources in FIRST, and studies of radio variability in both Galactic and extragalactic objects. For more on his research, contact him at djh@astro.columbia.edu

## + FACULTY RESEARCH

### Formation and Evolution of Stars and Planets







#### **MARCEL AGÜEROS**

From the earliest days of his research career, Professor Agüeros was drawn to multiwavelength studies of stars and of the by-products of their deaths. His current work ranges from searching for new radio-quiet, Xray dim isolated neutron stars, uncovering the nature of companions to very low-mass white dwarfs, examining the age/rotation/activity relationship in Galactic open clusters, and studying the properties of nuclear star clusters in nearby galaxies. His research typically involves the use of large-scale catalogs such as the Sloan Digital Sky Survey or ROSAT All-Sky Survey and follow-up observations with groundbased or satellite telescopes. For more information, contact him at marcel@astro.columbia.edu

#### **REBECCA OPPENHEIMER (AMNH)**

Professor Oppenheimer is involved in comparative exoplanetary research. Specifically, she focuses on developing advanced optical instruments in order to more accurately measure and analyze the light from planets orbiting stars other than our sun. Her research involves collaboration with scientists from AMNH, Cambridge, Caltech, and NASA/JPL. A large amount of her work takes place at the Rose Center at the American Museum of Natural History (AMNH). Prof. Oppenheimer also works on faint white dwarfs, the remnants of normal stars, and brown dwarfs, star-like objects that are too small to be stars, but too large to be called planets. She is the codiscoverer of the first brown dwarf, called Gliese 229B. For more information about her research, contact her at bro@amnh.org

#### JANE HUANG

Where, when, and how do planets form? Protoplanets are generally not expected to be massive enough to image directly, but their gravitational influence can carve rings, spirals, and asymmetries in protoplanetary disks. I led the calibration and imaging efforts for the Disk Substructures at High Angular Resolution Project (DSHARP), the first ALMA Large Program. DSHARP showed that complex structures were common in disks, but exhibited a wide range of properties. The widespread presence of gaps and ring suggest that giant planet formation can occur rapidly (within a million years or so) at distances past a hundred au from the star. I have also undertaken high-resolution multi-frequency case studies of the TW Hya and GM Aur disks, showing that the radial variations of the millimeter-wavelength spectral index, which is sensitive to dust grain sizes, are closely tied to the locations of gaps and rings in the disk. Jane.huang@columbia.edu

## + FACULTY RESEARCH

### Formation and Evolution of Stars and Planets



#### **KISHALAY DE**

Professor De works with widefield imaging surveys on the ground and in space to discover cosmic fireworks from stellar binaries in our Galaxy and in the distant Universe. Using panchromatic follow-up facilities, he tries to understand the role of stellar cataclysms in shaping the universe as we "see" it in light and "hear" it in gravitational waves. He helped to lead the Palomar Gattini-IR survey, the first widefield infrared time domain survey to study dust obscured eruptions in the Milky Way. Using the Zwicky Transient Facility widefield optical time domain survey, he studied faint and fleeting explosions from the eruptions of helium shells on white dwarfs and births of neutron stars in compact binary systems. For more on his research, contact him at kd3038@ columbia.edu



#### **MICHAEL SHARA (AMNH)**

Professor Shara's research interests focus on novae and supernovae. He leads a group that is conducting an infrared narrowband imaging and spectrographic survey of the Milky Way, trying to locate all 7,000 expected massive star presupernovae (Wolf-Rayet stars). The survey has already located the most massive binary star known, and thousands of pre-supernovae candidates are in hand. If even one of them explodes as a supernova, an important confirmation of stellar evolution theory will have been achieved. He also makes use of the Hubble Space Telescope to search for Wolf-Rayet stars in nearby galaxies. In addition, he is surveying dwarf novae to demonstrate that some have classical nova shells, establishing that there is a metamorphosis between these classes of objects. For more on his research, contact him at mshara@amnh.org



#### DAVID KIPPING

Professor Kipping leads the "Cool Worlds" group, which pursues a variety of science relating to extrasolar planets. From detection to characterization, the group uses astrostatistics and data science methods to understand both unique objects and ensemble populations of alien worlds, particularly thermally cool objects lying near or beyond the habitable-zone. The group is well-known for its expertise with exomoons in particular, leading the Hunt for Exomoons with Kepler project. The Cool Worlds group also researches novel methods to characterize planet hosting stars through a variety of methods such as flicker, stellar anchors, asterodensity profiling, and star spot analysis. For more on his research, contact him at dkipping@astro.columbia.edu

+ FACULTY RESEARCH Structure and Evolution of Galaxies







#### JACQUELINE VAN GORKOM

Professor Van Gorkom's main research interest is the structure and evolution of galaxies and, more specifically, the role of gas in galaxy evolution. She studies the interplay between galaxies and their environments, leading to such questions as: What are the residual signatures of the formation process around galaxies? Do galaxies evolve along the Hubble sequence? If so, how, and in what direction? Do mergers really convert spirals to ellipticals? How does the environment affect the evolution of galaxies? Where and how are SO's made, in clusters or in groups? For more on her research, contact her at jvangork@astro.columbia.edu

#### **MARY PUTMAN**

Much remains unknown today about how galaxies evolve from a pocket of dark matter to a structured galaxy full of gas and stars. Professor Putman is currently researching gas flows into galaxies using multiwavelength observations combined with the results of high-resolution simulations. She explores galaxy evolution by examining the gaseous halos of the Milky Way and other spiral galaxies, dwarf galaxies in the Local Group, star formation in the local universe, and the properties of the intergalactic medium. For more information on Professor Putman's research, e-mail her at mputman@astro.columbia.edu

#### **KATHRYN JOHNSTON**

Professor Johnston is interested in the structure and dynamics of galaxies. Her research focuses in particular on what we can learn about these topics from our own Milky Way Galaxy and its nearest neighbors. She uses models – from simple analytic pictures to full Nbody simulations – to explore the different mechanisms that are thought to structure galaxies. She then examines her models in order to understand what signatures these mechanisms might leave in the dynamics and chemistry of stars within galaxies. For more on her research. contact her at kvj@astro.columbia.edu

FACULTY RESEARCH

### Structure and Evolution of Galaxies



#### **GREG BRYAN**

Professor Bryan's research has tackled a broad range of problems in Professor Mac Low studies the cosmology. He has pioneered the use of adaptive, three--dimensional numerical simulations, and is the principal author of the widely used and publicly available simulation code Enzo. He has worked on understanding the formation of the first stars in the universe, as well as the large--scale cosmic structures that form later, such as galaxies, clusters of galaxies, and the intergalactic medium that fills space between these objects. He is also interested in developing visualization methods for threedimensional simulations, and his work has been featured in exhibits at the American Museum of Natural History, and in the Oscar-nominated IMAX film "Cosmic Voyage". For more on his research, contact him at greg.bryan@columbia.edu



#### **MORDECAI-MARK MAC LOW** (AMNH)

formation and evolution of planets, stars and galaxies, and the structure of the interstellar medium. He has placed a particular emphasis on understanding the role of turbulence and magnetic fields in these processes. Much of his work uses supercomputers to perform numerical gas dynamics and magnetohydrodynamic (MHD) simulations. He has also been lead curator on the Hayden Planetarium Space Show "Journey to the Stars," and had his simulations included in two others. For more information about his research, contact him at mordecai@amnh.org



#### LAURA KAY

Professor Kay's research focuses primarily on the study of active galactic nuclei using a cutting edge technique called spectropolarimetry. This is a process that allows the observer to obtain information about spectroscopy and polarization of the target simultaneously. She also recently co-authored a textbook called 21st Century Astronomy. For more on her research, contact her at lkay@barnard.edu

### + FACULTY RESEARCH Cosmology and Galaxies



**DAVID SCHIMINOVICH** 

Professor Schiminovich is currently studying galaxy formation and the intergalactic medium in order to understand the processes that trigger and quench star formation over cosmic time. He has developed ultraviolet instrumentation to study faint signatures from gas and stars around galaxies. He is currently working on data from the Galaxy Evolution Explorer (GALEX), a UV satellite, as well as the FIREBall experiment, a balloon-borne UV spectrograph designed to produce maps of the cosmic web, the 3D structure of the gaseous universe. In doing so, he is looking for signatures of gas that is primarily involved in star formation. He is continuing to develop novel instrumentation and is planning several future space experiments and satellite missions. For more on his research, contact him at ds@astro.columbia.edu or visit his website: sql.astro.columbia.edu



#### ZOLTAN HAIMAN

Professor Haiman is a theoretical astrophysicist and cosmologist. He is currently involved in three areas of research. He studies the expected properties of the first generation of stars and black holes in order to gain insight into the earliest stages of cosmic structure formation of the early universe. He has worked on possible ways to understand the nature of dark energy and dark matter, especially with techniques looking for tell-tale signatures in large-scale cosmic structures. Finally, he has been interested in the emerging field of gravitational wave astronomy, in particular in the gravitational waves from the collisions of supermassive black holes at the centers of galaxies and the corresponding electromagnetic signatures of such events. For more information about his research, email him at zoltan@astro.columbia.edu



#### FRITS PAERELS

Professor Paerels' main research topics include X-ray astronomy and spectroscopy, the intergalactic medium, and properties of neutron stars. He is involved in the analysis of data coming from the XMM-Newton X-ray observatory. He has also done analysis on data from the Chandra Xray telescope. In addition, he plans to use X-ray data to map high-redshift dust in the intergalactic medium. Finally, he plans to look at the X-ray emission from the local IGM. For more on his research, contact him at *frits@astro.columbia.edu* 

# FACULTY RESEARCH

### High Energy Astrophysics and Cosmology







#### LAM HUI

Professor Hui has broad research interests in theoretical astrophysics and cosmology. He has worked on large-scale structure, the intergalactic medium, gravitational lensing, early universe physics, particle astrophysics and extrasolar planets. His current research focuses on modifications to general relativity on cosmological scales, preinflationary perturbations from bubble collisions, and magnetospheres of neutron stars and black holes. For more on his research, contact him at lh399@columbia.edu

#### **ELENA APRILE**

Professor Aprile's current research includes the experimental study of dark matter. She specifically works to develop dark matter detectors using cryogenic noble liquids such as Xenon and Argon. She is the P.I. for the Xenon Experiment, which is designed to detect the likely components of dark matter – weakly interacting massive particles (WIMPS). For more on her research, contact her at age@astro.columbia.edu

#### **CHUCK HAILEY**

Professor Hailey studies the development of new balloon borne and satellite borne instrumentation and experiments in order to solve astrophysical problems. He is currently working on the NuSTAR project, which is the first high energy astrophysics mission to use hard X-ray optics focused in the 10-70 keV band to conduct a census of black holes in the universe. This instrument provides approximately 300 times the sensitivity of previous missions. The optics for NuSTAR was built and calibrated at Columbia University. Professor Hailey is also involved in the General Anti-Particle Spectrometer experiment (GAPS). This mission will search for cosmic antideuterons that are a byproduct of dark matter interactions with the galactic halo. For more on his research, contact him at chuckh@astro.columbia.edu

### FACULTY RESEARCH High Energy Astrophysics and Cosmology







#### **ANGELA OLINTO**

Angela Olinto has made significant theoretical and experimental contributions to astroparticle physics, including research on neutron stars, cosmic magnetic fields, dark matter, and high-energy cosmic particles. She played a key role in the Pierre Auger Observatory, advancing studies on ultra-high-energy cosmic rays (UHECR). As the U.S. principal investigator for JEM-EUSO, she leads efforts to uncover the origins of cosmic rays. She also directs NASA's EUSO-SPB balloon missions and the POEMMA space mission, aiming to detect astrophysical tau neutrinos. Her work influences multi-messenger astrophysics, with EUSO-SPB2 serving as a precursor to the POEMMA mission.

#### **BRIAN METZGER**

Brian Metzger's research includes the theoretical prediction of electromagnetic counterparts to binary neutron star mergers. Among the most promising counterparts is a thermal optical/infrared signal lasting from days to weeks, powered by the radioactive decay of heavy elements synthesized in the merger ejecta. In 2010, the group made the first predictions for this "kilonova" emission, incorporating a realistic treatment of nuclear heating. The image above illustrates a predicted light curve for 1% of a solar mass of r-process elements ejected at 10% the speed of light. Detecting kilonova emission confirms the production of rare elements like gold, platinum, and uranium.

#### **KERSTIN PEREZ**

Professor Perez's research explores the nature of dark matter, a key mystery in modern physics. While dark matter's gravitational effects shape the universe's large-scale structures, its properties remain unknown, as it neither absorbs nor reflects light. Her work investigates how dark matter particles might decay, annihilate, or influence stellar interiors, leaving detectable cosmic-ray and multi-wavelength signatures. A major challenge is distinguishing these signals from astrophysical processes. Her team contributes to novel detector technology and background analysis. She leads the GAPS Antarctic balloon program, the first experiment optimized for detecting cosmic antinuclei. which could provide groundbreaking evidence of new physics.

# FACULTY RESEARCH

### **High Energy and Theoretical Astrophysics**





#### SZABOLCS MARKA

Professor Marka is an experimental physicist. His research is focused on the effort to directly detect gravitational waves of cosmic origin, which will allow for the study of cosmic processes and objects unreachable through conventional methods based on electromagnetic observations. His current major interest is astrophysical triggerbased data analysis and essential development/diagnostic projects aimed towards enhancing the astrophysical reach and reliability of the Laser Interferometer Gravitational-wave Observatory (LIGO). He also heads up the **Columbia Experimental Gravity** Group (GECo). For more information on GECo, please visit geco.phys.columbia.edu. For more on Professor Marka's research, contact him at smarka@phys.columbia.edu

#### **JANNA LEVIN**

Professor Levin's astrophysicsal research focuses on black hole pairs. In an extreme binary system, a small black hole orbits a supermassive black hole millions of times the mass of the sun. As they orbit, the pair bangs on the drum of spacetime itself thereby emitting a black hole song in the form of gravitational waves. Over time, the orbit decays until the pair merges. Professor Levin non-thermal energies required to also studies the effect of black hole scattering on gravitational waves. In this case, two comparably sized black holes scatter off each other, become gravitationally bound, and emit a gravitational wave with each pass. She also researches various multi-dimensional theories of string cosmology. To find out more about her research, contact her at www.jannalevin.com



#### LORENZO SIRONI

Professor Sironi investigates the origin of non-thermal emission from Pulsar Wind Nebulae (PWNe), AGN jets, fast radio bursts (FRBs), gammaray bursts (GRBs), supernovae, galaxy clusters, and low-luminosity accretion flows like Sqr A\* around the supermassive black hole at the center of our Galaxy. It is still a mystery how these objects can accelerate particles up to the highly explain the observed emission, that typically extends from the radio up to the gamma-ray band. By means of ab initio large-scale plasma simulations, he investigates particle acceleration in shocks, turbulence and magnetic reconnection from first principles, with the aim of using the simulations to interpret the observations, and ultimately unveil the nature of astrophysical nonthermal sources. lsironi@astro.columbia.edu

# FACULTY RESEARCH

### **High Energy and Theoretical Astrophysics**



**ANDREI BELOBORODOV** 

Professor Beloborodov is a theoretical astrophysicist interested in relativistic astrophysics. His work focuses on compact objects such as black holes and neutron stars. His research topics include X-ray binaries, pulsars, active galactic nuclei, and cosmological gamma-ray bursts. These are all cosmological high-energy sources. He is currently developing a new method of gravity estimation called "orbital roulette." This method could be used in the future to estimate the mass of dark matter in our Galaxy, stellar clusters, and clusters of galaxies. For more on his research, contact him at amb@phys.columbia.edu



#### **RESHMI MUKHERJEE**

Professor Mukherjee is currently involved in several projects. She studies GeV/TeV gamma rays from astrophysical sources using VERITAS (Very Energetic Radiation Imaging Telescope Array System). VERITAS is an air Cherenkov telescope located in southern Arizona: it detects Cherenkov radiation from energetic particles produced by the interaction of a gamma-ray primary in the atmosphere using four 12-m optical reflectors on the ground. She is also involved in the Cherenkov Telescope Array (CTA), which is an advanced facility for ground-based gamma-ray astronomy being planned for the future. Her general research topics include experimental astrophysics, gamma ray sources, active galactic nuclei, and the study of high energy sources using the Fermi Gamma-Ray Space Telescope. For more on her research, contact her at muk@astro.columbia.edu







# Columbia Astronomy





### Department of Astronomy

Columbia University Pupin Physics Laboratories Room 1328 Mail Code 5246

550 West 120<sup>th</sup> Street New York, NY 10027 Telephone: +1(212) 854-3278 Facsimile: +1(212) 854-8121 Website: www.astro.columbia.edu Donations are fully tax deductible.

Checks should be made payable to **Columbia University** and sent to:

Department of Astronomy 550 West 120<sup>th</sup> Street Mail Code 5246 New York, NY 10027