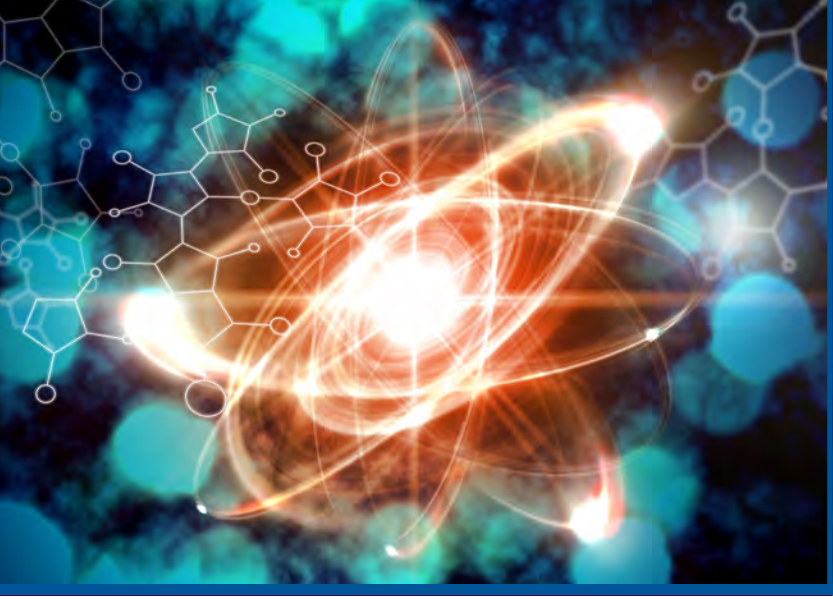
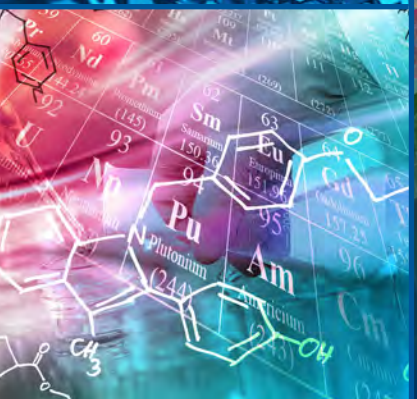


2020

DIRECTORATE FOR

MATHEMATICAL & PHYSICAL SCIENCES



National Science Foundation
WHERE DISCOVERIES BEGIN

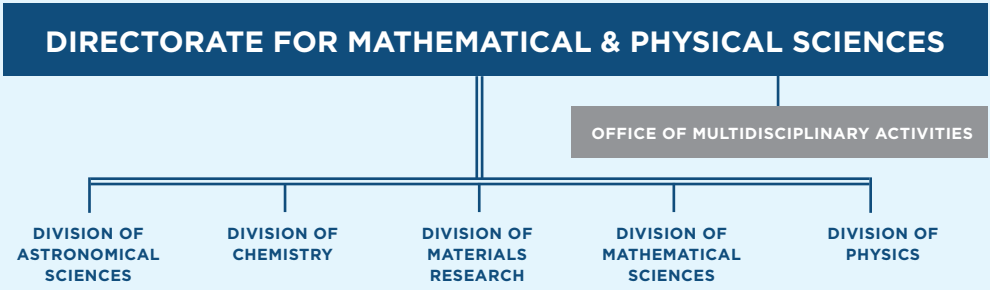
DIRECTORATE FOR

MATHEMATICAL & PHYSICAL SCIENCES

The NSF Directorate for Mathematical and Physical Sciences consists of the Divisions of Astronomical Sciences, Chemistry, Materials Research, Mathematical Sciences, and Physics, as well as the Office of Multidisciplinary Activities. These organizations constitute the basic structure for MPS support of research and workforce development. The MPS divisions support both disciplinary and interdisciplinary activities and partner with each other and with other NSF directorates to promote basic research across the scientific disciplines.

MPS MISSION STATEMENT

The mission of MPS is to harness the collective efforts of the mathematical and physical sciences communities to address the most compelling scientific questions, educate the future advanced workforce, and promote discoveries to meet the needs of the Nation.



NSF MISSION

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

NSF VISION

A Nation that creates and exploits new concepts in science and engineering and provides global leadership in research and education.

Dear Reader:

The Directorate for Mathematical and Physical Sciences (MPS) of the National Science Foundation supports fundamental research in astronomy, chemistry, materials, mathematics, and physics. This research excites our imaginations and changes our lives, expanding the frontiers of knowledge and providing a foundation that supports economic growth, public health, and national security. Fundamental discoveries in the mathematical and physical sciences are the bedrock of technological innovation. MPS investments rest on the long march of transformative ideas to societal benefits: some benefits occur in a few years and others take many decades to develop.

MPS-funded research propels the nation's investments in a host of important areas such as sustainable energy and food supplies, cyberinfrastructure, and new materials. Just a few illustrations of the practical consequences of research in mathematical and physical sciences are the evolution of medical imaging technology, the development of ultrasensitive biological and chemical detectors, advances in improved battery technologies, and transformations in electronics, photonics, and optics. Recent breakthroughs, such as the first image of a black hole, capture the world's imagination and would not have been possible without MPS investment and support of senior researchers and trainees alike.

The MPS annual budget is over a billion dollars, and it funds research that covers a large intellectual space. It supports projects ranging from exploration of the intersections of the life sciences, the physical sciences, and mathematics to discovery of the very nature of matter, space, time, and the physical laws governing the universe. MPS serves as steward for two of NSF's "Big Ideas," Quantum Leap and Windows on the Universe. Quantum Leap funds research on quantum mechanics and materials that will unlock future technologies. Windows on the Universe will expand our understanding of the cosmos through new techniques in observation. The Directorate is also the steward of two new major national initiatives, Quantum Information Sciences and 5G/Spectrum Innovation, and actively participates in AI projects as well. You can learn more about the Big ideas at **https://www.nsf.gov/news/special_reports/big_ideas/** and about the Industries of the Future at **https://www.whitehouse.gov/wp-content/uploads/2020/02/FY21-Fact-Sheet-IOTF.pdf**

This brochure provides an introduction to the research we support at universities and laboratories throughout the nation, and we invite you to learn more about MPS on our web site at **www.nsf.gov/MPS**.

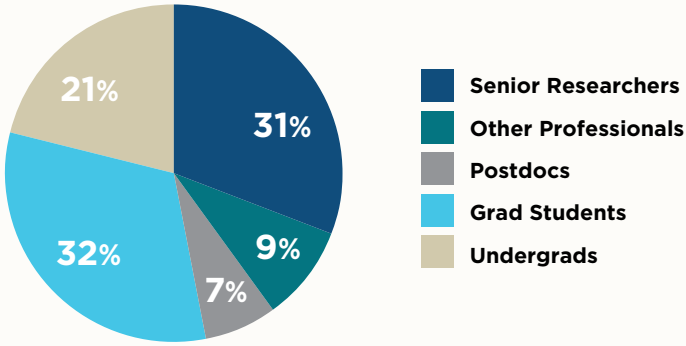
Best regards,

Sean L. Jones

Assistant Director
National Science Foundation
Directorate for Mathematical and Physical Sciences

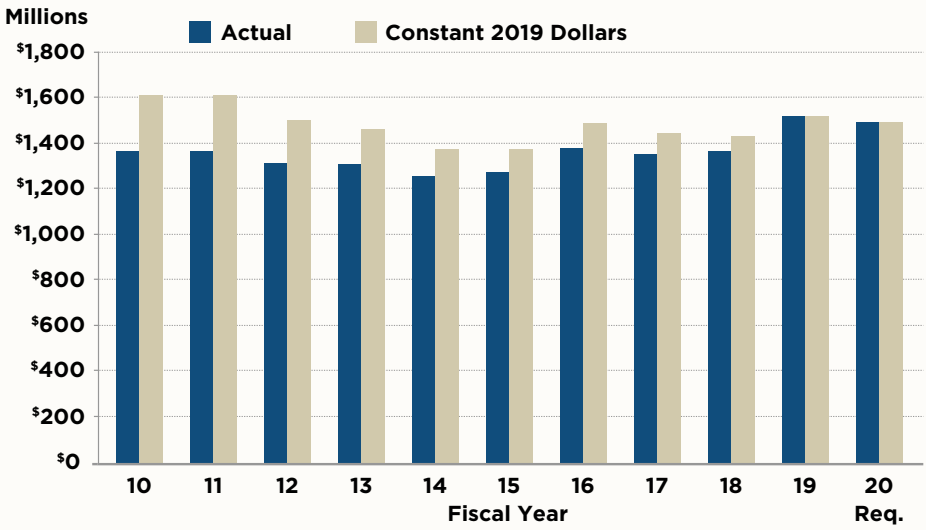
Grant Personnel FY 2019 MPS

Distribution of people supported by MPS.



MPS Research and Related Activities Funding

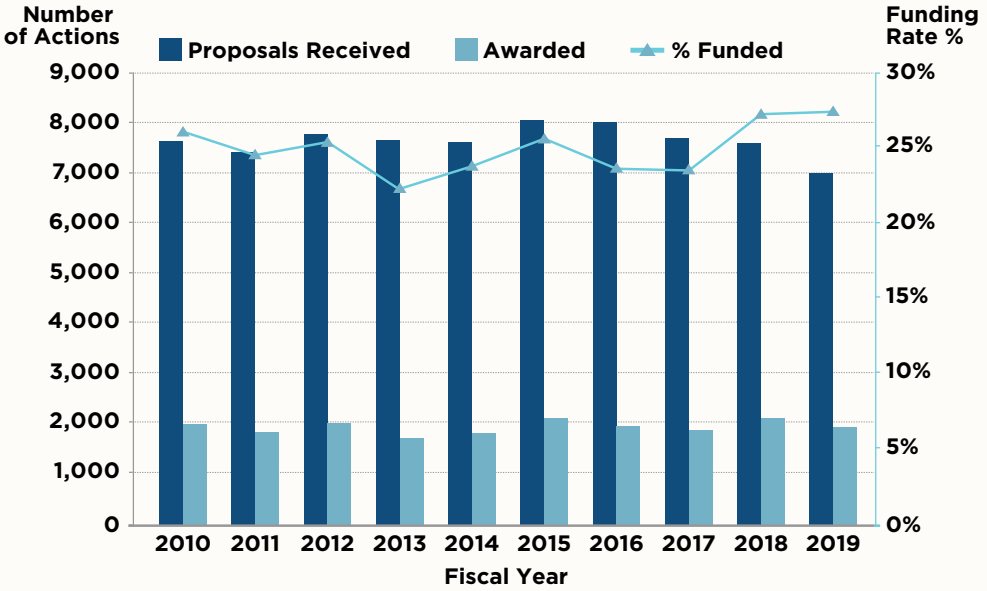
Constant dollars show the purchasing power of the MPS budget.



Req. = Requested
Data provided from NSF Budget Requests to Congress, www.nsf.gov/about/budget

MPS Funding Rates and Number of Actions

Graph shows number of proposals submitted and awarded Research Grants (as defined by NSF) and resultant funding rates. Funding rate is defined as the percentage of new or renewal proposals awarded funding.



Note: The funding reflects the average for the Directorate and may not represent funding rates in individual Divisions or programs

DIVISION OF ASTRONOMICAL SCIENCES (AST)

MISSION

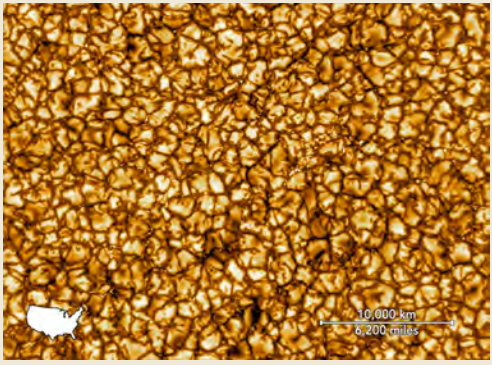
The mission of the Division of Astronomical Sciences is to support forefront research in ground-based astronomy; to help ensure scientific excellence of the U.S. astronomical community; to provide access to world-class research facilities through merit review; to support the development of new instrumentation and next-generation facilities; and to encourage broad understanding of the astronomical sciences by a diverse population of scientists, policy makers, educators, and the public at large.

The division supports research in all areas of astronomy and astrophysics as well as related multidisciplinary studies. Because of the scale of modern astronomical research, the division engages in numerous interagency and international collaborations. Areas of emphasis and the priorities of specific programs are guided by community recommendations and federal advisory committees and developed by National Academies decadal surveys.

ASTRONOMICAL FACILITIES

Through the national observatories and international partnerships, AST supports a system of multi-user telescopes that enables transformational capabilities in radio and optical/infrared astronomy. In FY 2019, AST accomplishments included continued breakthrough science observations with all the Division's facilities. Construction is nearing completion for NSF's Daniel K. Inouye Solar Telescope (DKIST), the largest solar telescope in the world, atop Haleakalā peak on Maui, Hawaii, which will be operational in 2021. Construction of the Vera C. Observatory is also progressing, with survey observations scheduled to begin in FY2023. The division is proud of the unique capabilities and recent discoveries provided by all its observatories.

AST invested 61% of its FY 2019 research appropriation in the management and operation of national, ground-based, astronomical facilities. The researchers using these facilities made a multitude of important discoveries, reported in scientific journals and the popular press.



Credit: NSO/NSF/AURA

First Light for NSF's Daniel K. Inouye Solar Telescope (DKIST)

The DKIST telescope will revolutionize our understanding of the Sun as both a star and as the primary driver of the space weather and solar storms that impact our Earth. With a 4-m aperture, it is the world's largest solar telescope. The image shows the most detailed image of the Sun's surface ever recorded with a resolution of approximately 30 km at the distance of the Sun, and it previews science yet to come.

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PROGRAMS IN ASTRONOMICAL SCIENCES

INDIVIDUAL INVESTIGATOR PROGRAMS

- Astronomy and Astrophysics Research Grants (AAG)
- Astronomy and Astrophysics Postdoctoral Fellowships (AAPF)
- Advanced Technologies and Instrumentation (ATI)
- Faculty Early Career Development Program (CAREER)
- Major Research Instrumentation (MRI)
- Research Experiences for Undergraduates (REU-Sites)
- Spectrum and Wireless Innovation enabled by Future Technologies (SWIFT)

MID-SCALE INNOVATIONS PROGRAM (MSIP)

The Mid-Scale Innovations Program supports astronomical projects up to $30 million. MSIP currently supports an optical survey that will generate over 300 all-sky images per year, an ultra-high-resolution radio telescope program for observing the black hole at the center of the Milky Way galaxy, projects that are exploring the cosmic microwave background, a new wide-field bolometer camera for millimeter-wave observations of distant galaxies, and a low frequency radio array with 350 telescopes to study very early times when the universe transitioned from darkness to being lit by the first stars and galaxies. MSIP is offered every two years.

LARGE FACILITIES

- Arecibo Observatory
- Green Bank Observatory
- NSF's National Optical-Infrared Astronomy Research Laboratory
- National Radio Astronomy Observatory
- National Solar Observatory

LARGE FACILITIES UNDER CONSTRUCTION

- Daniel K. Inouye Solar Telescope
- Vera C. Rubin Observatory

ELECTROMAGNETIC SPECTRUM MANAGEMENT (ESM)

AST represents the interests of NSF and the scientific community in protecting access to the electromagnetic spectrum for research purposes. The sensitivity of telescopes can be compromised by electromagnetic interference from ground, airborne, and satellite radio transmissions and light pollution. ESM personnel protect scientific capabilities by participating in the establishment of regulations, operating procedures, and technical standards related to government, private sector, and international uses of the spectrum.

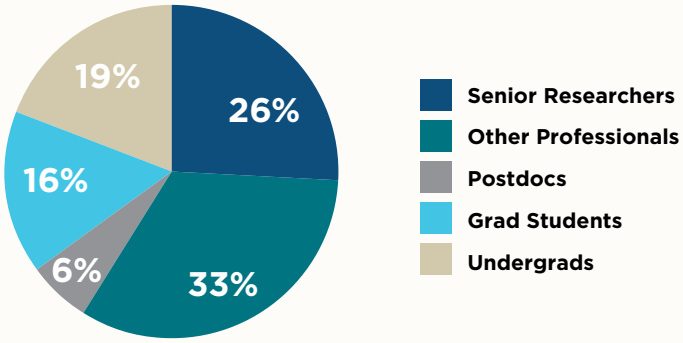
Credit: Event Horizon Telescope collaboration et al.

Image of a black hole captured for the first time

In April 2019, the Event Horizon Telescope collaboration unveiled an image of the black hole at the center of galaxy M87. An immediate popular culture phenomenon, the image was seen by billions of people and featured in all major newspapers. Simultaneous observations from radio telescopes across the globe, notably including NSF-supported facilities Atacama Large Millimeter-submillimeter Array (ALMA) and the South Pole Telescope (SPT) enabled this feat.

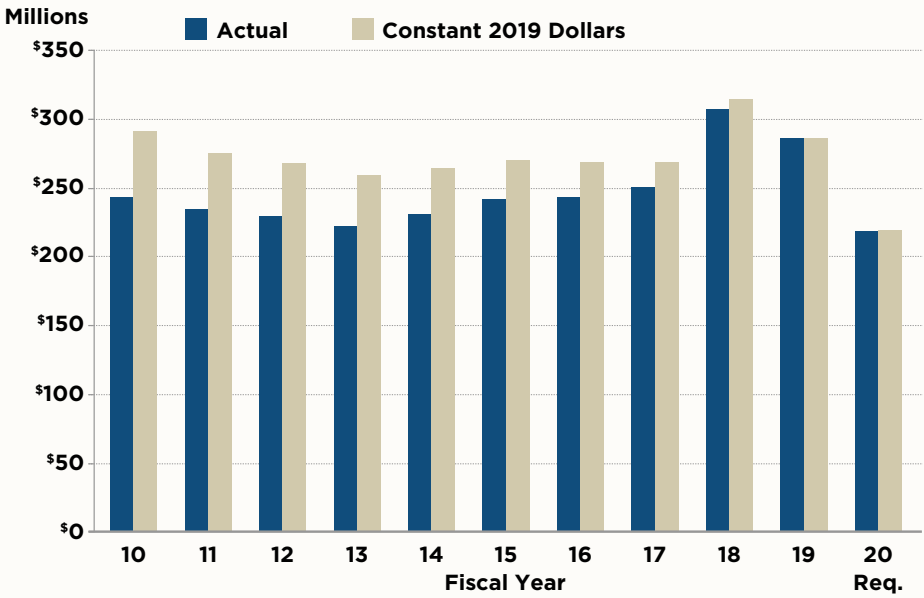
Grant Personnel FY 2019 AST

Distribution of people supported by AST.



AST Research and Related Activities Funding

Constant dollars show the purchasing power of the AST budget.



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AST Funding Rates and Number of Actions

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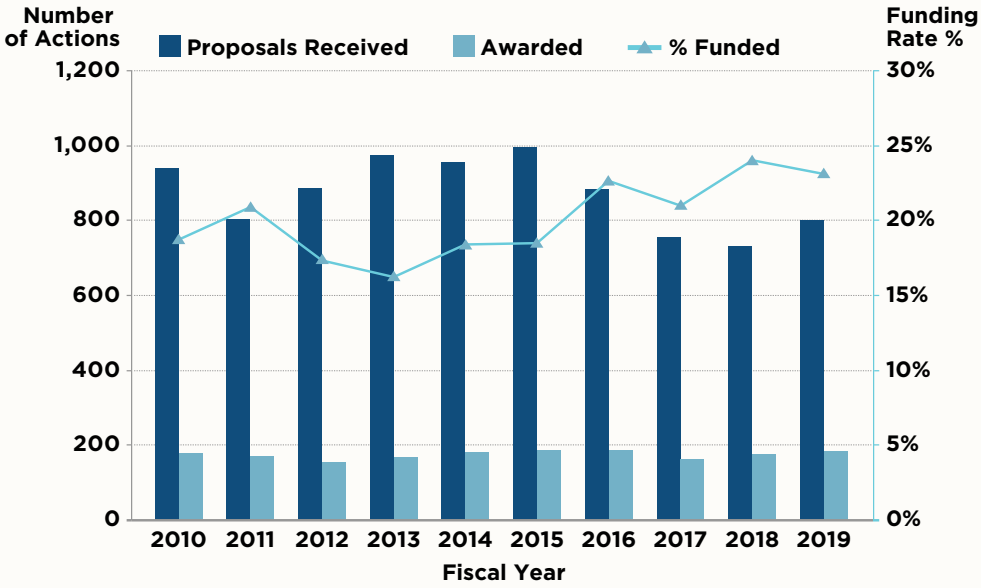
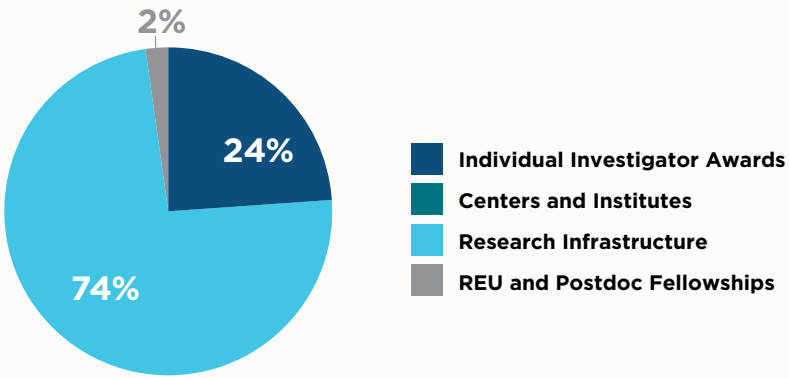


Note: The funding reflects the average for AST and may not represent funding rates in individual programs

AST Modes of Support FY 2019

Individual investigator awards include all of the research grant programs. Research Infrastructure includes MSIP (5%) and ATI (4%) grants, in addition to operation and maintenance of major facilities (61%). REU and Postdoc Fellowships includes REU and RET sites and the AAPF program.



DIVISION OF CHEMISTRY (CHE)

MISSION

The mission of the NSF Division of Chemistry (CHE) is to support innovative research in chemical sciences, integrated with education, through strategic investment in developing a globally engaged U.S. chemistry workforce reflecting the diversity of America.

Central to the modern world economy, the chemical industry converts raw materials (oil, natural gas, water, metals and minerals) into more than 70,000 different products ranging from agricultural fertilizers and plastics to batteries and pharmaceuticals. To prepare the workforce of the future, CHE supports efforts in advanced manufacturing, sustainability, data mining and artificial intelligence for chemical discovery and molecular design, quantum information science, and biotechnologies. The Division supports experimental and theoretical research as expressed in fundamental chemical synthesis, measurement, and computation, as well as in applications at the intersections of biology, computer science, engineering, geosciences, materials, and physics.

PROGRAMS IN CHEMISTRY

INDIVIDUAL INVESTIGATOR PROGRAMS

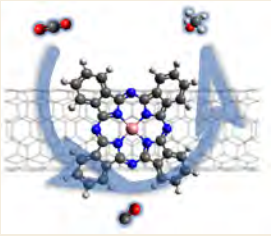
- Chemical Catalysis (CAT)
- Chemical Measurement and Imaging (CMI)
- Chemical Structure, Dynamics, and Mechanisms – A/B (CSDM-A/B)
- Chemical Synthesis (SYN)
- Chemistry of Life Processes (CLP)
- Chemical Theory, Models and Computational Methods (CTMC)
- Environmental Chemical Sciences (ECS)
- Macromolecular, Supramolecular and Nanochemistry (MSN)

INTEGRATIVE CHEMISTRY ACTIVITIES

Centers for Chemical Innovation, Research Experiences for Undergraduates (NSF-wide), Major Research Instrumentation (NSF-wide), Facilities and Research Infrastructure, and Special Projects.

CENTERS FOR CHEMICAL INNOVATION (CCIs)

The CCI Program supports research centers focused on major, long-term, fundamental chemical research challenges. CCIs produce transformative research, lead to innovation, and attract broad scientific and public interest. CCIs respond rapidly to emerging opportunities, enhance collaborations, and may partner with researchers from industry, government laboratories and international organizations. The CCI Program is a two-phase program. Phase I CCIs



Credit: https://doi.org/10.1038/s41586-019-1760-8

Domino electroreduction of CO_2 to methanol

Methanol is one of the most energetically expensive chemical commodities to produce. Using an electrosynthesis technique, researchers have developed a way to produce methanol from easily available CO_2. Their catalytic nanotube allows for a domino effect of sustained and stable production for up to 12 hours.

Contact Information

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receive resources to develop the science, management and broader impacts of a major research center before requesting Phase II funding ($4 million/year for up to 10 years).

FACILITIES AND RESEARCH INFRASTRUCTURE

The NSF's Chemistry and Materials Center for Advanced Radiation Sources (NSF's ChemMatCARS) operates three experimental stations at the Advanced Photon Source (APS), an undulator-based synchrotron source of high-brilliance, high-energy X-rays at Argonne National Laboratory. The instrumentation at ChemMatCARS is used by a broad range of chemistry, biology, engineering, and materials researchers, such as those employing small-molecule crystallography, liquid surface and interface scattering, and small to wide-angle scattering.

The Ion Cyclotron Mass Spectrometry (ICR) at the National High Magnetic Field Laboratory (NHMFL) at Florida State University houses four Fourier Transform Ion Cyclotron Resonance Mass Spectrometers that provide high mass resolution for the analysis of complex mixtures, such as biological (especially carbohydrates and proteomes) or petroleum samples. The facility utilizes the world's highest magnetic field offering unprecedented resolution and data acquisition speeds.

CHE also participates in the NSF-wide Midscale Research Infrastructure (MSRI) Programs. During the inaugural competition, funding was provided to The Ohio State University to establish a new NSF National Extreme Ultrafast Science Facility (NEXUS). While most XUV light sources create pulses at a repetition rate of 1,000 per second, this kilowatt laser will deliver the same pules at a rate of 100,000 per second. The XUV light will allow researchers to master insights needed to create new quantum information technologies and solar energy devices, such as how electrons move in molecules and solids at small time scales and spatial resolutions.

WORKFORCE DEVELOPMENT AND BROADENING PARTICIPATION

CHE supports opportunities for workforce development throughout one's career. Examples include the 70 Research Experiences for Undergraduates (REU) Sites that facilitate undergraduate research and career development in a diversity of settings and on a wide variety of themes. CHE encourages graduate student participation in programs including: the NSF Innovation Corps (I-Corps) Program which catalyzes entrepreneurship through the development of candidates for commercialization; the INTERN Supplement Program that encourages the exploration of non-academic internships to expand workplace skill sets and competencies; and summer schools focused on quantum information science (QIS) and molecular science software development. CHE encourages faculty to support graduate students from underrepresented minorities in the Alliances for Graduate Education and the Professoriate (AGEP) program, which provides stipend support, as well as supplements supporting international faculty, postdoc, and student travel to work with collaborators and use unique facilities outside the U.S. as part of broader workforce development efforts. CHE also supports the National GEM Consortium which aims to improve diversity in the STEM workforce by 1) encouraging selected underrepresented minority (URM) students to pursue graduate degrees in Chemistry by ensuring that the students receive a living stipend and tuition and 2) providing access to paid internships for the selected students, providing pathways for advanced STEM education and careers for URM students.

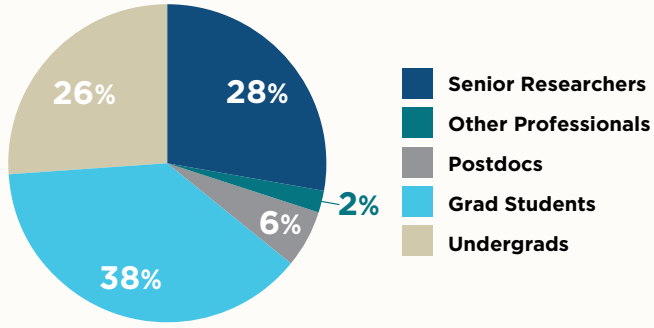
Credit: Jing Tang, Eugene Chen (Colorado State University)

Development of infinitely recyclable plastics

Researchers have developed a type of plastic that can be depolymerized by either thermolysis or catalysis with quantitative selectivity for pure monomer recovery and virgin-quality polymer reproduction. The circular polymers could be recycled infinitely while maintaining useful material properties, thereby addressing an important economic and environmental concern regarding plastic end-of-life issues.

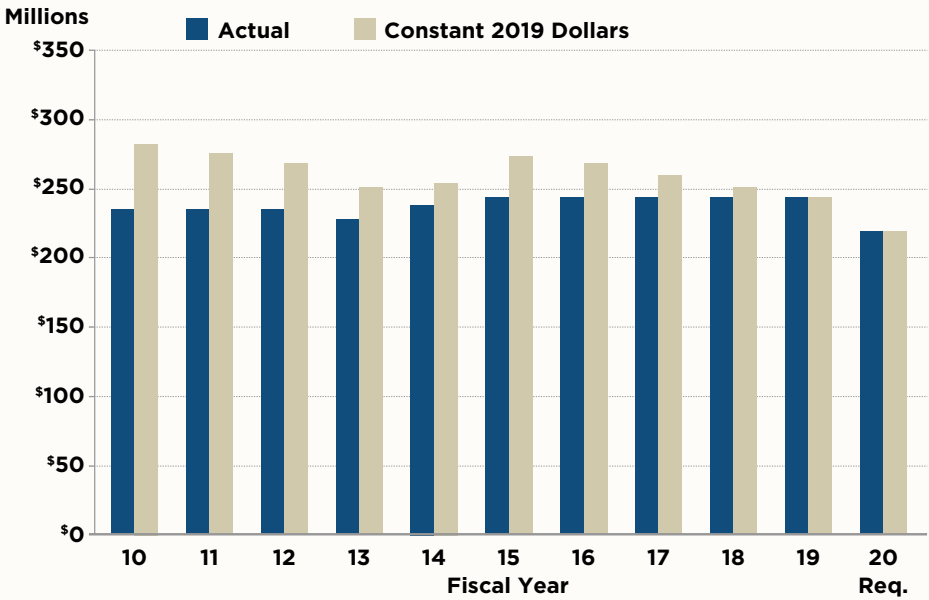
Grant Personnel FY 2019 CHE

Distribution of people supported by CHE.



CHE Research and Related Activities Funding

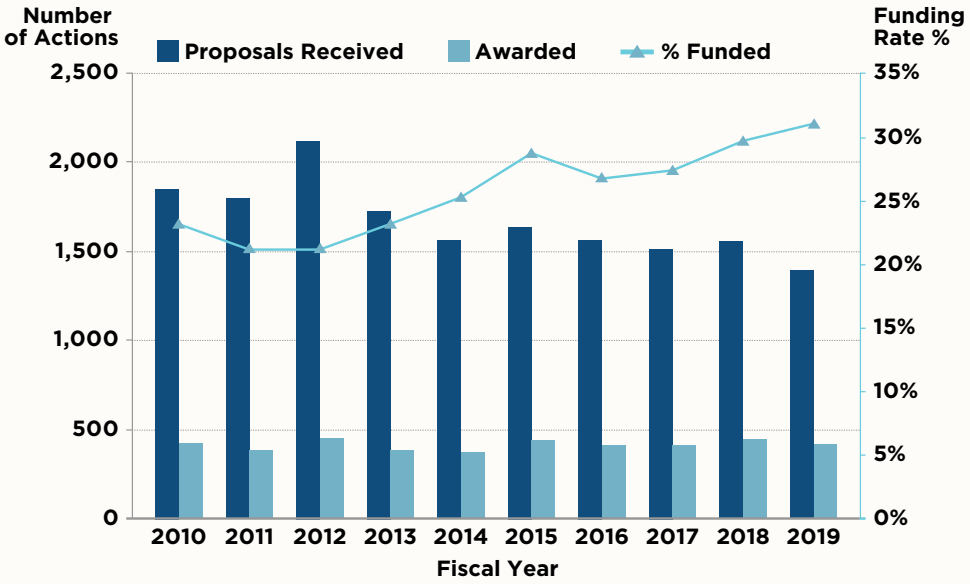
Constant dollars show the purchasing power of the CHE budget.



Req. = Request.
Data provided from NSF Budget Requests to Congress, www.nsf.gov/about/budget

CHE Funding Rates and Number of Actions

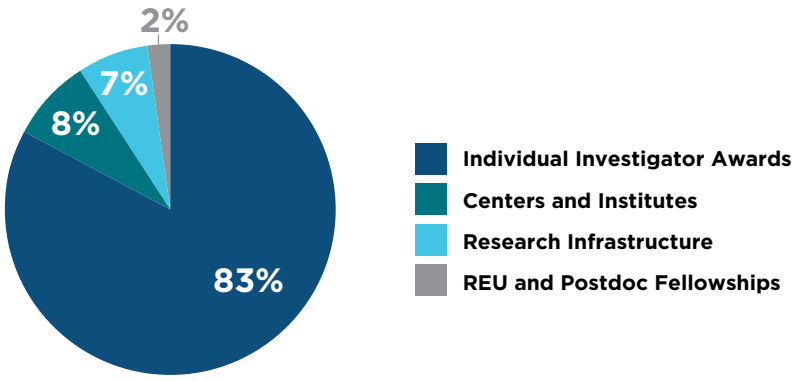
Graph shows number of proposals submitted and awarded Research Grants (as defined by NSF) and resultant funding rates. Funding rate is defined as the percentage of new or renewal proposals awarded funding.



Note: The funding reflects the average for CHE and may not represent funding rates in individual programs

CHE Modes of Support FY 2019

Individual investigator awards include standard grants and cofounding of centers outside CHE. Centers and Institutes include the Centers for Chemical Innovation. Research Infrastructure includes Midscale Research Infrastructure, NHMFL, and NNCI. REU and Postdoc Fellowships includes REU and RET sites, not REU/REU supplements supported in core research grants.



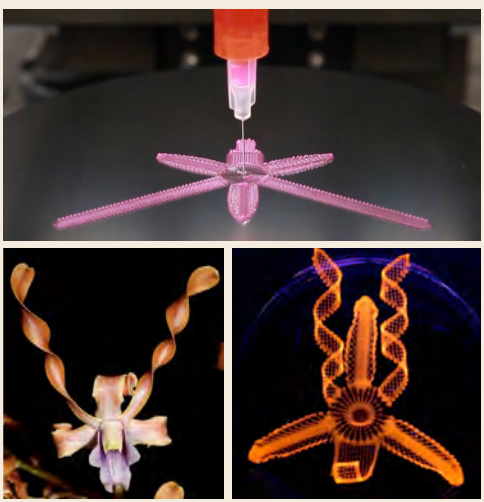
MISSION

The mission of the Division of Materials Research is to discover new knowledge about the behavior of matter and materials phenomena, to address fundamental materials questions that often transcend traditional scientific and engineering disciplines and may lead to new technologies, to prepare the next generation of materials researchers, to develop and support the instruments and facilities that are crucial to advance the field, and to share the excitement and significance of materials science with the general public.

DMR supports experimental and theoretical research, and their interplay with each other and with data, over a broad range of subfields. These include condensed matter and materials physics, solid state and materials chemistry, electronic and photonic materials, metals and metallic nanostructures, polymers, ceramics, and biomaterials. Funding modes range from awards to individual investigators, small groups, and centers to support for instrumentation and major facilities.

WORKFORCE DEVELOPMENT AND BROADENING PARTICIPATION

DMR strives to broaden the participation of women and underrepresented minority groups in science and engineering at all academic levels. One outcome of this vision is the Partnerships for Research and Education in Materials (PREM) program, which develops and supports long-term partnerships between academic institutions serving underrepresented groups and DMR centers and facilities, such as Materials Science and Engineering Centers (MRSECs). PREM was started in 2004 and currently supports 15 awards.



Credit: : A.S. Gladman, E.A. Matsumoto, R.G. Nuzzo, L. Mahadevan, and J.A. Lewis (Harvard University)

Biomimetic 4D Printing

Shape morphing materials may find potential application in smart textiles, robotics, biomedical devices, drug delivery and tissue engineering. Mahadevan and Lewis created a biomimetic hydrogel-cellulose fibril ink for 4D printing. Shear forces in the nozzle induce alignment of the stiff fibrils along the printing direction (top image). When the printed (flat) bilayers are immersed in water, the filaments exhibit anisotropic swelling, i.e., increasing 10% in length and 40% in diameter. When the printed filaments are arranged specific patterns, the forces generated cause the flat structure to buckle out of plane. A mathematical model was developed to predict the print path needed to produce any 3D structure (e.g., the real and 4D printed orchids shown in lower images). The modular ink design enables other matrix and filler materials to be patterned by 4D printing.

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PROGRAMS IN MATERIALS RESEARCH

PROGRAMS FOR INDIVIDUAL INVESTIGATORS AND GROUPS

- Biomaterials
- Ceramics
- Condensed Matter and Materials Theory
- Condensed Matter Physics
- Electronic and Photonic Materials
- Metallic Materials and Nanostructures
- Polymers
- Solid State and Materials Chemistry

CROSSCUTTING DMR PROGRAMS

Material Research Science and Engineering Centers (MRSECs)

MRSECs address fundamental materials research whose scope and complexity require the scale and interdisciplinarity provided by a center. In addition, MRSECs promote active collaboration between universities and other sectors, such as industry, and through the Materials Research Facilities Network (MRFN) support materials research infrastructure across the United States. The MRSEC program currently supports 19 centers. For more information, visit **www.mrsec.org**.

NATIONAL FACILITIES

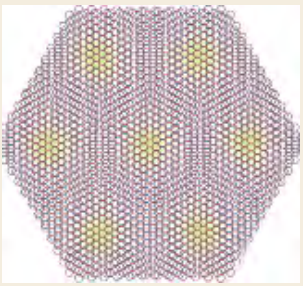
DMR is the steward of the National High Magnetic Field Laboratory (NHMFL). In addition, DMR supports the Center for High-Energy X-Ray Science subfacility at the Cornell High-Energy Synchrotron Source, the Center for High Resolution Neutron Scattering (CHRNS) at NIST, and the National Nanotechnology Infrastructure Network (NNIN). DMR supports four Materials Innovation Platforms (MIPs), midscale user facilities dedicated to accelerating advances in materials research.

DESIGNING MATERIALS TO REVOLUTIONIZE AND ENGINEER OUR FUTURE (DMREF)

DMREF is the primary program by which NSF participates in the Materials Genome Initiative (MGI) for Global Competitiveness. DMREF encourages proposals that involve a collaborative and iterative process integrating experimental, theoretical, and data-driven efforts to achieve more rapid materials discovery, development, and deployment.

RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU) AND TEACHERS (RET)

DMR supports REU sites that focus on research in materials science and related areas, including condensed matter physics, materials chemistry and physics, and materials engineering. REU projects involve students in meaningful ways in ongoing research or in projects specifically designed for the REU program. Most DMR-supported MRSECs and National Facilities offer REU and RET opportunities each summer.



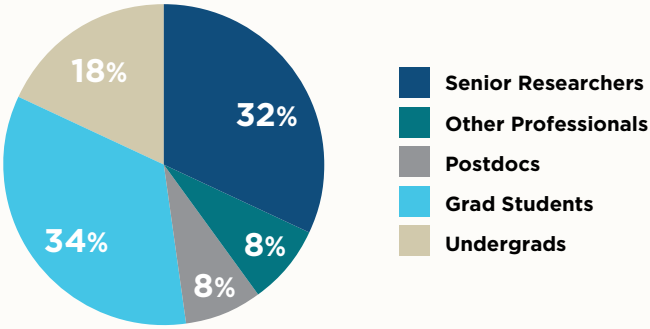
Credit: Pablo Jarillo-Herrero and research group (Massachusetts Institute of Technology)

Twistronics — a new field and a new pathway to future devices

Slightly twisting a bilayer of graphene produces a Moiré pattern. At a specific twist angle, the bilayer becomes superconducting. This discovery has opened up a whole new subfield of materials research, dubbed “twistronics” and holds promise for future work in assembled heterostructures.

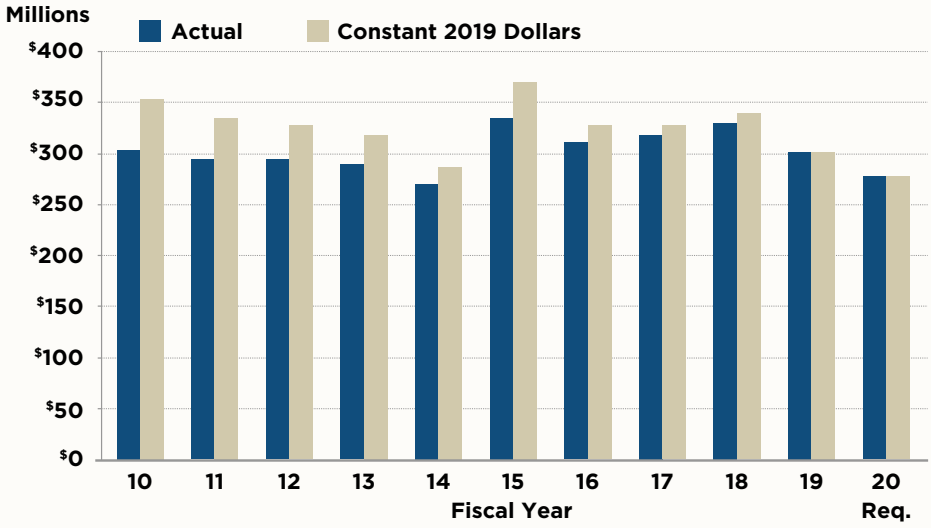
Grant Personnel FY 2019 DMR

Distribution of people supported by DMR.



DMR Research and Related Activities Funding

Constant dollars show the purchasing power of the DMR budget.



Req. = Request.
Data provided from NSF Budget Requests to Congress, www.nsf.gov/about/budget

DMR Funding Rates and Number of Actions

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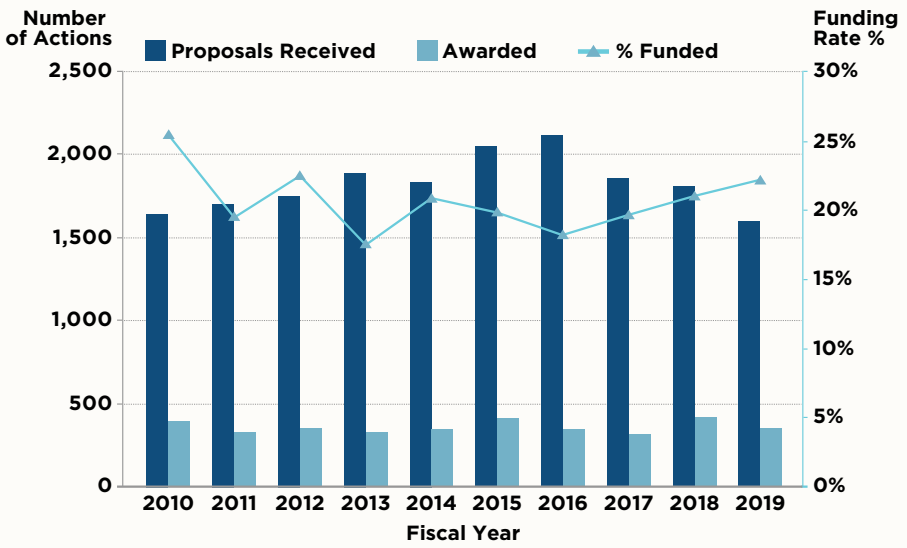
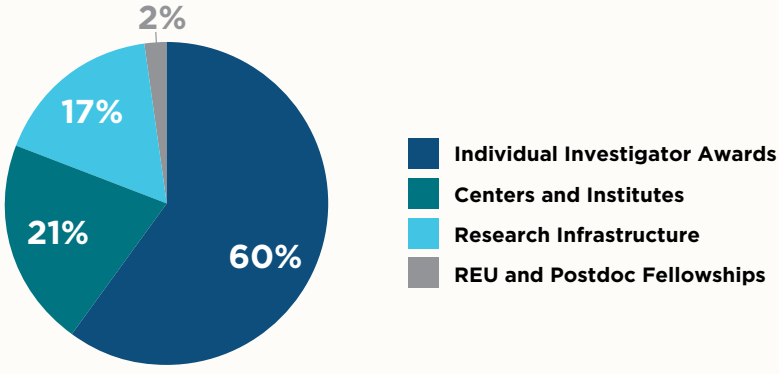


Note: The funding reflects the average for DMR and may not represent funding rates in individual programs

DMR Modes of Support FY 2019

Individual investigator awards include standard grants. Centers and Institutes include MRSEC and Science and Technology Centers. Research Infrastructure includes NHMFL, CHESS/CHEXS, Midscale Research Infrastructure, and NNCI. REU and Postdoc Fellowships includes REU and RET sites.



DIVISION OF MATHEMATICAL SCIENCES (DMS)

MISSION

The mission of the Division of Mathematical Sciences is to support research at the frontiers of discovery in mathematical sciences and to support training of the next generation of mathematical sciences researchers. DMS is responsible for programs with a total annual budget of about $234 million in Fiscal Year 2019. These programs support research and training that expand the knowledge base of the mathematical sciences through awards to individual investigators and small groups, workforce training grants, and a portfolio of national Mathematical Sciences Research Institutes and public-private partnerships such as the NSF-Simons Centers for Mathematics of Complex Biological Systems and the NSF-Simons Research Collaborations on the Mathematical and Scientific Foundations of Deep Learning.

DISCOVERY, CONNECTIONS, COMMUNITY

The influence of mathematical sciences on our daily lives is fundamental and pervasive. For example, every secure commercial transaction on the internet is an application of research in number theory and algebraic geometry. Additionally, improvements in weather prediction, search engines, and industrial design and manufacturing processes rest on advances in algorithms and computational and applied mathematics. DMS invests in discovery in mathematics and statistics; promotes interdisciplinary partnerships across fields of science, engineering, and technology; and cultivates a diverse community of researchers, students, and professionals. The division's top investment priorities — discovery, partnerships, and community — are essential components of the innovation engine that drives the Nation's economy in the 21st century.

NEW INITIATIVES

DMS continues to develop interdisciplinary activities that support national priorities. The new NSF-Simons Research Collaborations on the Mathematical and Scientific Foundations of Deep Learning are attracting broad interest from both the mathematical sciences and AI communities. Two other new activities include a research program in quantum algorithms and another on mathematical models for uncovering rules and unexpected phenomena in biological systems. DMS also continues to support research in NSF-wide programs such as the new Harnessing the Data Revolution Transdisciplinary Research in Principles of Data Science program; Secure and Trustworthy Cyberspace; and Designing Materials to Revolutionize and Engineer our Future, all of which provide opportunities for engagement of the mathematical sciences community. DMS also participates in multi-agency programs such as the joint DMS & National Institute

Credit: https://advances.sciencemag.org/content/6/9/eaaz2717

Unraveling turbulence

Turbulence occurs when ordered fluid flow breaks into small vortices. The mechanics of how this chaos develops has puzzled scientists for centuries. Now, Michael Brenner and his collaborators have identified a fundamental mechanism of how turbulence develops by experimentally smashing vortex rings into each other head-on. Coupling analysis of numerical simulations with data from ultra-high-resolution cameras and 3D visualizations of the collision dynamics, the researchers have gained new insights into how fluid systems transform from order to disorder.

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of General Medical Sciences Activity in Mathematical Biology. The DMS Workforce Program in the Mathematical Sciences offers funding opportunities, including the Mathematical Sciences Graduate Internship program and the Mathematical Sciences Postdoctoral Research Fellowship program, both of which support efforts to increase the number of researchers who pursue careers in the mathematical sciences.

PROGRAMS IN MATHEMATICAL SCIENCES

CORE PROGRAMS

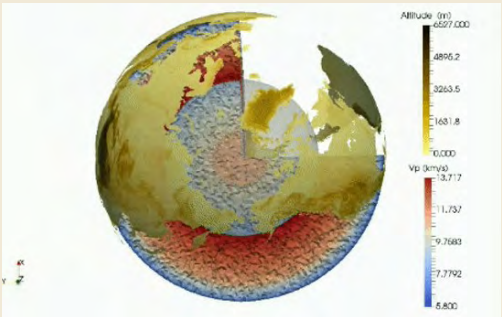
- Algebra and Number Theory
- Analysis
- Applied Mathematics
- Combinatorics
- Computational Mathematics
- Foundations
- Geometric Analysis
- Mathematical Biology
- Probability
- Statistics
- Topology

SPECIAL DMS PROGRAMS

- NSF-Simons Research Collaborations on the Mathematical and Scientific Foundations of Deep Learning (MoDL)
- Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences
- Focused Research Groups in the Mathematical Sciences
- Mathematical Sciences Infrastructure Program
- Joint DMS/NIGMS Initiative in Mathematical Biology
- Algorithms for Threat Detection
- Algorithms for Modern Power Systems
- Workforce Program in the Mathematical Sciences

The Mathematical Sciences Research Institutes program supports a portfolio of projects that advances research in the mathematical sciences, amplifies the impact of the mathematical sciences in other disciplines, catalyzes innovation in the mathematical sciences to respond to national needs, and expands the talent base engaged in mathematical and statistical research in the United States.

The Mathematical Sciences Graduate Internship program aims to provide opportunities to enrich the training of graduate doctoral students in the mathematical sciences by introducing them to interesting applications of mathematical or statistical theories outside of academia. A similar program, the Internship Network in the Mathematical Sciences, aims to provide training and career experiences to graduate students in the mathematical sciences that intentionally prepare them for career paths in business, industry, and government. Engagement of students from under-represented groups will increase diversity in these fields where they can serve as future role models.



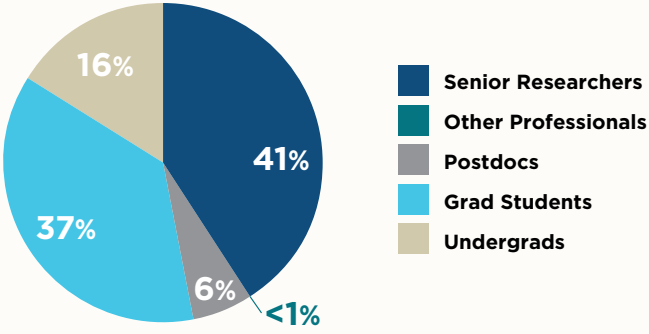
Credit: Maarten V. de Hoop, Rice University

Discovering the Interior Structure of the Earth

Is it possible to reconstruct the inner structure of a mystery object knowing only how fast waves travel between any two points on its boundary? This question leads to a challenging mathematical area in geometry known as an inverse problem. Martin de Hoop and his collaborators are developing new approaches to study these problems in seismology and geodesy. Combining these approaches with broad-band seismic array, GPS, and InSAR data will lead to a better understanding of how to recover the Earth's complex interior structure, with many applications including hydrocarbon exploration and earthquake prediction.

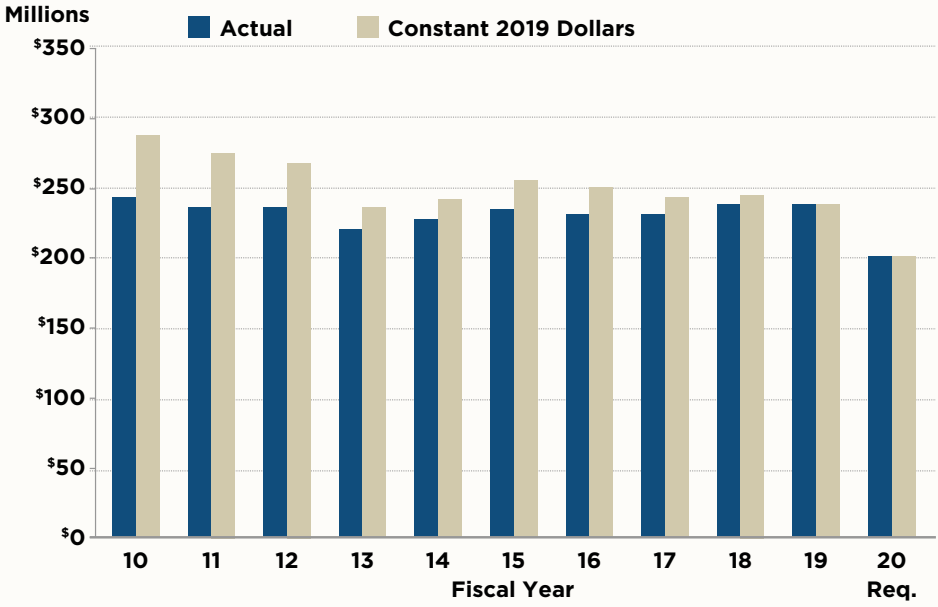
Grant Personnel FY 2019 DMS

Distribution of people supported by DMS.



DMS Research and Related Activities Funding

The purchasing power of the DMS budget.

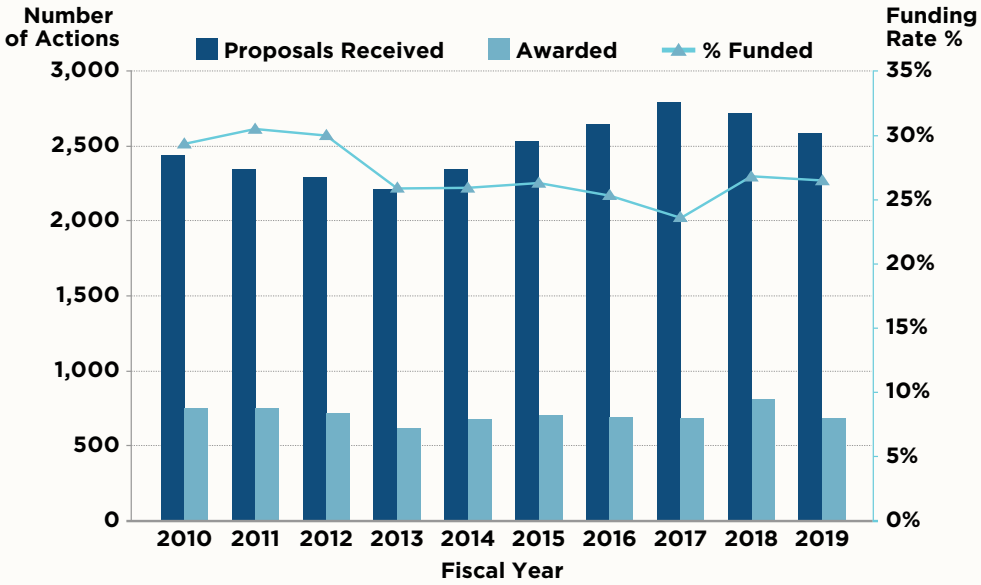


Req. = Request.

Data provided from NSF Budget Requests to Congress, www.nsf.gov/about/budget

DMS Funding Rates and Number of Actions

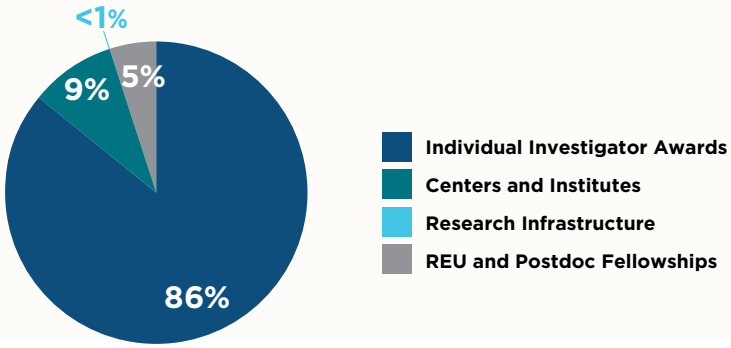
Graph shows number of proposals submitted and awarded Research Grants (as defined by NSF) and resultant funding rates. Funding rate is defined as the percentage of new or renewal proposals awarded funding.



Note: The funding reflects the average for DMS and may not represent funding rates in individual programs

DMS Modes of Support FY 2019

Individual investigator awards include standard grants. Centers and Institutes include TRIPODS, and the Mathematical Sciences Research Institutes. REU and Postdoc Fellowships includes REU and RET sites and the MSPRF program.



MISSION

The mission of the Division of Physics is to support fundamental research across the intellectual frontiers of physics; to support research that has broader impacts on other fields of science and on the health, economic strength, and defense of society; to share the excitement of science with the public through integration of research and education; and to maintain the intellectual capital essential for future advances in physics.

Physics research probes the properties of matter at its most fundamental level, the individual and collective interactions between particles, and the organization of constituents and symmetry principles that lead to the rich structure and phenomena that we observe in the world around us. Physics seeks a deep understanding of processes that led to the formation of the cosmos, to the structure of matter at the very shortest distance scales where quantum effects dominate, and to the structure and dynamics of atomic and molecular systems that shape and control the everyday world of chemistry and biological systems.

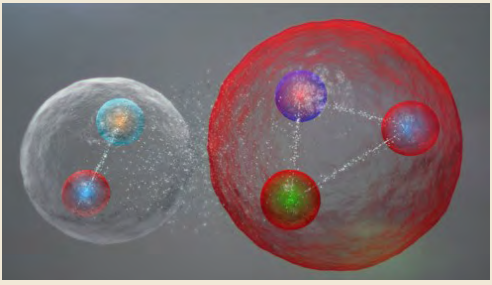
WORKFORCE DEVELOPMENT AND BROADENING PARTICIPATION

PHY strongly supports workforce development and broadening participation at all levels. This includes outreach efforts in large facilities and centers, a variety of opportunities for undergraduates through the Research Experiences for Undergraduates (REU) program, and individual investigator awards. Students of all backgrounds involved in these projects gain skills and knowledge to become members of the nationally critical, technology-centered workforce.

PROGRAMS IN PHYSICS

PROGRAM AREAS FOR INDIVIDUAL INVESTIGATORS AND GROUPS

- Atomic, Molecular, Optical Physics
- Plasma Physics
- Elementary Particle Physics
- Gravitational Physics



Credit: Daniel Dominguez / CERN
(Physical review letters 122, 222001 (2019); DOI: 10.1103/PhysRevLett.122.222001)

LHCb Scientists Shed Light on the Nature of Pentaquarks

Most visible matter in the universe is made of baryons (most commonly protons and neutrons), which contain three quarks each. In 2015 the LHCb experiment at CERN saw the first evidence for particles made up of five quarks. In 2019, with 10X more analyzed LHC data, the same scientists made a startling observation: the pentaquarks behaved less like a single five-quark particle and more like a bound state of a two-quark particle and a three-quark baryon. Pentaquarks will help further our understanding of Quantum Chromodynamics, the theory that rules the strong force in the Standard Model of particle physics.

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- Nuclear Physics
- Particle Astrophysics and Cosmology
- Physics of Living Systems
- Quantum Information Science

CROSSCUTTING PHYSICS PROGRAMS

- Physics Frontier Centers
- National Facilities
  - National Superconducting Cyclotron Laboratory (NSCL)
  - Laser Interferometer Gravitational Wave Observatory (LIGO)
  - Large Hadron Collider (LHC), a joint NSF-DOE-CERN project
  - IceCube Neutrino Observatory
- Midscale Instrumentation
- Intergrative Activities in Physics
- Physics at the Information Frontier
- Research Experience for Undergraduates (REU) and Teachers (RET)

THE PHYSICS FRONTIER CENTERS

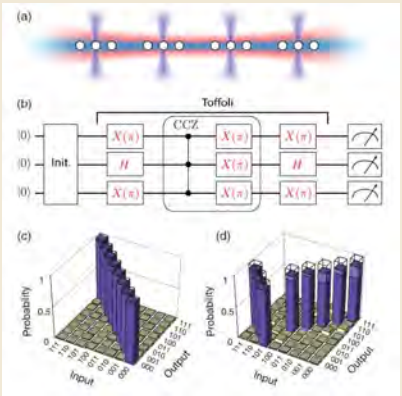
The Physics Frontiers Centers (PFC) program advances the intellectual frontiers of physics by supporting university-based centers and institutes where the collective efforts of a larger group can enable transformational research. Each PFC has a strong emphasis on educating students and postdoctoral researchers and outreach to both the scientific community and general population.

The PFC program supports activities in any of the subfields of physics listed above. Partnerships with other NSF divisions allow for support of interdisciplinary activities in related and emerging areas. Approximately ten centers are supported at any one point in time, and these change on a triennial basis.

PHYSICS AND THE GLOBAL COMMUNITY

PHY participates in numerous international efforts, including large scale facilities such as the LIGO, LHC, and IceCube facilities, and large projects such as particle astrophysics observatories or Neutron EDM experiments. PHY is also a partner in a number of lead agency agreements with funding agencies from other countries to foster collaborations among individuals or small teams focused on specific topics, e.g. gravitational physics, that are of equal interest to both agencies.

Additionally, PHY participates directly in distributed shared cyberinfrastructure, both nationally and internationally, which provides opportunistic computing and storage resources for large NSF-supported international projects.



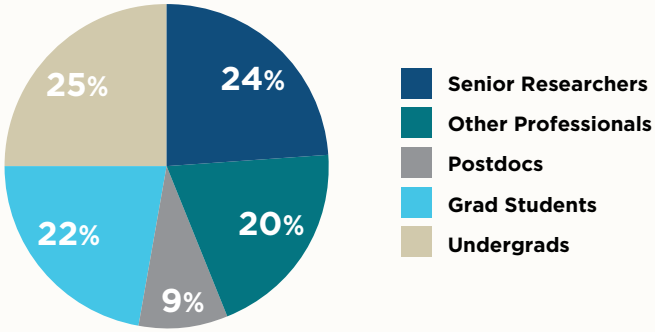
Credit: Levine, H., et al. 2019. Parallel implementation of high-fidelity multiqubit gates with neutral atoms. Physical Review Letters, 123 (17)

High-Fidelity Multiqubit Gates with Neutral Atom

The jury is still out on what will be the best platform for implementing quantum computing. One possible approach that offers some unique advantages is the use of neutral atoms. A team at the Center for Ultracold Atoms, using a special control scheme, excited a group of three atoms such that in each a single electron was placed at a given radius from the nucleus, with its spin in a given direction. When the three atoms were placed close to each other, the spin of the electron in the middle atom flipped, depending on the state of the two neighboring atoms. This configuration, using two qubits to control one, constitutes a doubly-controlled NOT gate, in this case a multi-qubit gate that offers high fidelity and the possibility of implementing some quantum algorithms more efficiently.

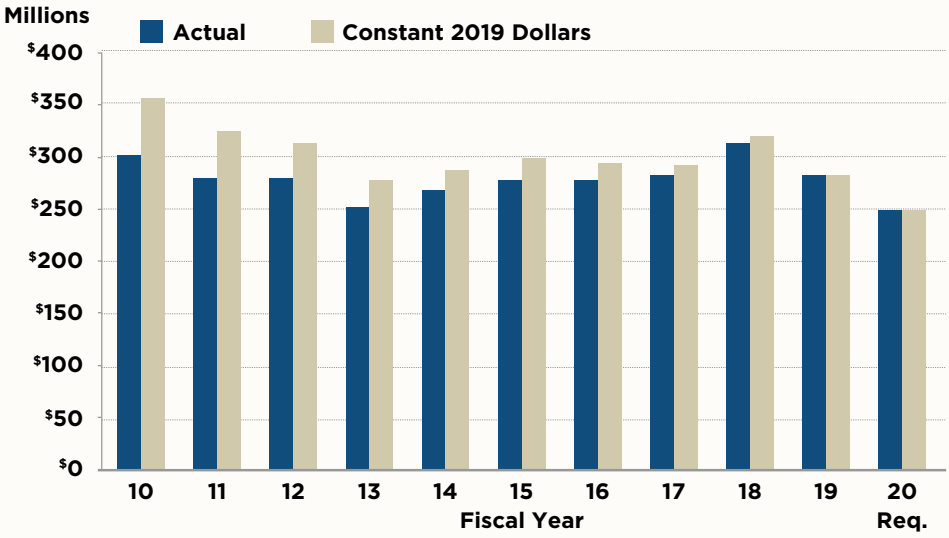
Grant Personnel FY 2019 PHY

Distribution of people supported by PHY.



PHY Research and Related Activities Funding

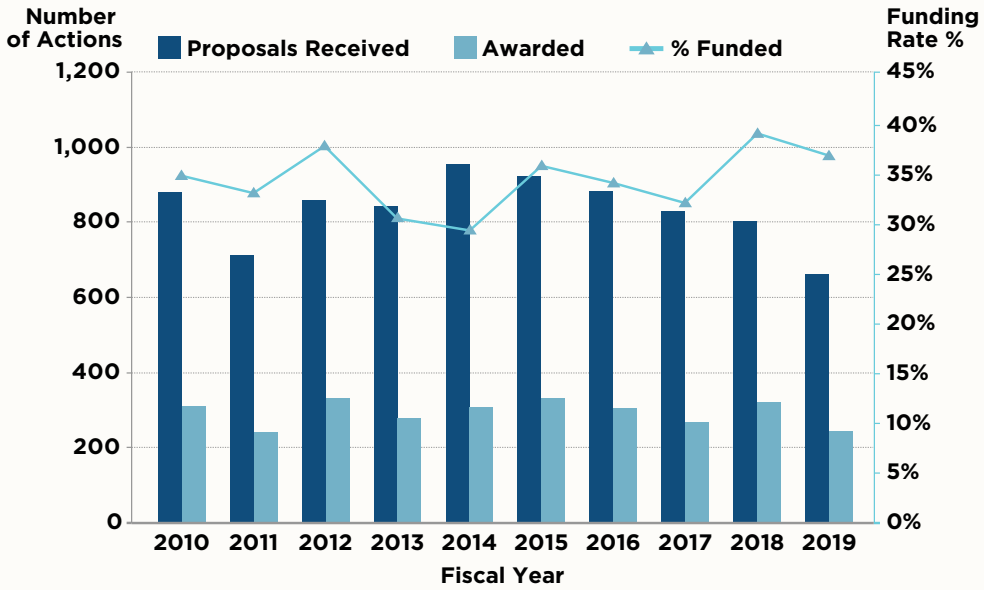
Constant dollars show the purchasing power of the PHY budget.



Req. = Request.
Data provided from NSF Budget Requests to Congress, www.nsf.gov/about/budget

PHY Funding Rates and Number of Actions

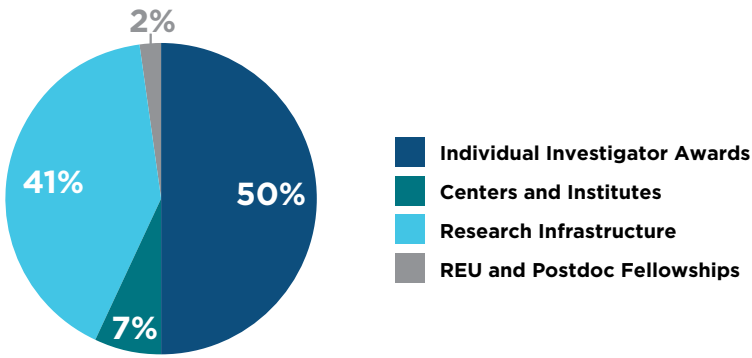
Graph shows number of proposals submitted and awarded Research Grants (as defined by NSF) and resultant funding rates. Funding rate is defined as the percentage of new or renewal proposals awarded funding.



Note: The funding reflects the average for PHY and may not represent funding rates in individual programs

PHY Modes of Support FY 2019

Individual investigator awards include standard grants. Centers and Institutes includes the PFCs and Science and Technology Centers. Research Infrastructure includes Midscale Research Infrastructure and support for LIGO, LHC, NSCL and IceCube. REU and Postdoc Fellowships includes REU and RET sites.



DIRECTORATE FOR MATHEMATICAL & PHYSICAL SCIENCES

Proposal Review: MPS maximizes the quality of the proposals it supports through a competitive, merit-based review process. In FY 2016, more than 90 percent of research funds supported externally reviewed projects.

Committee of Visitors (COV): MPS convenes Committees of Visitors, composed of qualified external evaluators, to review each division periodically. These experts assess the integrity and efficiency of the processes for proposal review. COV reports and relevant directorate responses are available at https://www.nsf.gov/od/iia/activities/cov/covs.jsp.

MPS Advisory Committee (MPSAC): The Mathematical and Physical Sciences Advisory Committee advises MPS on issues such as the mission, programs, and goals that can best serve the scientific community; priority investment areas in MPS-supported research; and promoting workforce development in the mathematical and physical sciences. Minutes from MPSAC meetings are available at https://www.nsf.gov/mps/advisory.jsp.

Office of Multidisciplinary Activities (OMA)

OMA seeds crosscutting research in areas of current or potential future strategic emphasis for MPS as well as areas that might develop into strategic importance; facilities, partnerships with other agencies, national laboratories, industries, state and local governments, and international organizations; and supports innovative experiments in developing the workforce and broadening participation. The purpose of OMA investments is to initiate, but not sustain indefinitely, these activities. OMA also provides support for supplements for graduate students from underrepresented groups, veterans, and researchers with disabilities. OMA does not fund proposals directly but provides cofunding to proposals submitted to programs in the other MPS Divisions.

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Mr. Ryan Bael
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Ms. Kim Elliot
IT Specialist

Mr. Paul Spyropoulos
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Mathematical and Physical Sciences Advisory Committee (MPSAC) Membership List

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Robert Bryant
Duke University

William Zajc
Columbia University

TERM EXPIRES 9/30/2021

Catherine Hunt
University of Virginia

Andrew Millis
Columbia University

Miguel Garcia-Garibay
University of California Los Angeles

David Awschalom
University of Chicago

Jennifer Lewis
Harvard University

Daniel Jaffe
University of Texas

Herbert Levine
Northeastern University

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Jill Pipher
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Susanne Brenner
Louisiana State University

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NSF 21-016

National Science Foundation
WHERE DISCOVERIES BEGIN

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