

Foundations play a supporting role in basic science

Philanthropic efforts on behalf of basic research span a range of modalities, from assistance for individual investigators to the establishment of research institutes.

Although philanthropic support for basic research in the US has picked up steam in recent years, it remains an order of magnitude below that of the federal government. Even so, it plays an outsized role in filling gaps and needs that agencies can't or won't fill, such as offering scientists long-term financing that does not require them to produce short-term results, or helping institutions acquire expensive equipment and instrumentation that couldn't be funded by a federal grant.

According to NSF's most recent Higher Education Research and Development Survey, published in July 2017, nonprofit sources doled out \$4.6 billion to fund R&D performed in academic institutions in 2016, compared with \$39 billion in federal funding and \$18 billion contributed by universities to their own research that same year. In 2010 funding from nonprofits totaled \$3.7 billion.

Marc Kastner, a physicist and former dean of science at MIT, says he's disappointed there aren't more donors to physical sciences research. Kastner is president of the Science Philanthropy Alliance (SPA), a nonprofit whose members are foundations that fund basic research (see *PHYSICS TODAY*, May 2015, page 23). A 2016 SPA survey of research institutions showed that 84% of charitable funding went to the life sciences, mainly for biomedical research. The physical sciences received 13%, and mathematics, 3%.

Kastner says he can't tell donors where to spend their money. "When we meet with philanthropists we say do what you want to do. We want to help you support whatever kind of science you want as long as you do it effectively," he says. "If



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VISITING SCIENTISTS MEET at the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara. From left are Sriram Ramaswamy of the Indian Institute of Science, M. Cristina Marchetti of Syracuse University, Bulbul Chakraborty of Brandeis University, and Karin Dahmen of the University of Illinois at Urbana-Champaign.

someone said, 'Well, I am really ambivalent about supporting the physical sciences or the biomedical sciences,' then I would make the case [for the physical sciences]. That has never happened."

The disciplinary boundaries around donations aren't always distinct, however. In 2016 the SPA acted as consultant to Facebook founder Mark Zuckerberg and his wife, Priscilla Chan, when the pair committed to spend \$3 billion over 10 years on basic research. In doing so, the newly formed Chan Zuckerberg Initiative suddenly became one of the largest private supporters of biomedical research.

Physicist Robert Conn, who chairs SPA's board, points out that while the Chan Zuckerberg commitment targets biomedical research, its focus is on developing new research tools. "Almost all of that work is associated with people who are physical scientists or engineers," he says.

Conn, who also is president and CEO of the Kavli Foundation, points out that

the sum of the endowments of the SPA's six founding member philanthropies in 2014 was about \$35 billion. Today, with two dozen members and another about to join, endowments add up to around \$145 billion. Although not all of their spending is devoted to basic research, "there is a lot more conversation about the importance of supporting basic science," Conn says. "There are many new foundations who have joined that are interested in learning how to do it."

A diversity of approaches

Individual philanthropies use a broad variety of funding mechanisms when they support basic research, yet they all desire to fill needs that aren't being met by federal funding agencies.

As one of the larger philanthropies contributing to the physical sciences, the Gordon and Betty Moore Foundation has an annual budget for science of around \$100 million. That amount pales in comparison to funding available from NSF or the Department of Energy's Of-

Office of Science, admits Robert Kirshner, a Harvard University astronomer who is the foundation's chief program officer for science. "We have to be thoughtful and think through whether what we are doing is really going to make a difference, and concentrate on places where there seems to be a shortfall, a problem, or an opportunity to make things go better," he says.

Making a difference may include helping universities to acquire expensive instrumentation that an investigator grant from NSF wouldn't cover, such as the cryoelectron microscope at Caltech that the Moore Foundation paid for, Kirshner says. Or it could be paying for creating samples to be shared in research on quantum materials, which the foundation does as part of its Emergent Phenomena in Quantum Systems program.

The Moore and other foundations can also offer funding that has few or no requirements for short-term deliverables, unlike a typical federal grant. MIT's Pablo Jarillo-Herrero, an investigator supported by the foundation's quantum systems program, led a team that recently reported superconductivity in graphene (see *PHYSICS TODAY*, May 2018, page 15). "When you have really creative

scientists whose judgment you trust, allowing them to follow their inclinations and shift directions can produce some surprising results," says Kirshner. "We choose people who show they have the imagination and skill to advance their field . . . but we don't try to steer them in any detailed way." He adds, "It wasn't our idea to twist two layers of graphene, it was Pablo's."

The Simons Foundation supports outstanding midcareer scientists in mathematics, physics, theoretical computer science, astrophysics, and mathematical modeling of living systems. Each receives \$100,000 annually for five years, with a potential extension of up to five more years. New York University professor Gregory Gabadadze, who heads Simons's physics grant-making program, says that the scientists, known as Simons investigators, can pursue research that they couldn't tackle under a typical three-year NSF grant. "The only requirement is excellence," he says. "If they do an excellent job in whatever they want to do, whether fashionable or not, they will be funded."

In addition, the foundation annually provides support for mathematicians and physicists to take a six-month leave

from their institutions so they can focus intensively on their research. Fifty-two such fellows were chosen in March. Simons also funds multi-university collaborations targeting specific topics in physics and mathematics. One, on the so-called cracking the glass problem, seeks to improve understanding of amorphous materials. Led by Sidney Nagel of the University of Chicago, the international collaboration touches on fundamental issues such as disorder, nonlinear response, and system behavior far from equilibrium.

The Heising-Simons Foundation saw a niche in supporting physics and astronomy, recognizing there "aren't a lot of other people in this space," says Cyndi Atherton, who directs the foundation's science program. (See the interview with Atherton at www.physicstoday.org/atherton.) As a smaller organization—its science program made 60 awards totaling \$20 million last year—Heising-Simons looks for modestly sized research efforts, she says.

The foundation has supported research that lacks preliminary results and isn't far enough along to be included in a proposal to funding agencies. Through grants to the University of Washington



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CHRISTIAN MÜLLER, a researcher at the Flatiron Institute, writes a novel formulation for high-dimensional regression, a method used in statistical data analysis. The institute was established by the Simons Foundation in 2016 to advance research in computational biology, computational astrophysics, and computational quantum physics through data analysis, modeling, and simulation.

and the University of Chicago, Heising-Simons is funding the Axion Dark Matter Experiment, which seeks to discover hypothesized particles whose existence could both account for dark matter and explain why the strong nuclear force does not violate *CP* symmetry. “We’re fully cognizant that there may not be an axion, or if there is an axion we may not discover it in this portfolio or in this period of time,” Atherton says. “But good science will come out of it, and there are things like detector development, new technology, and high-precision measurements.”

Heising-Simons has established a small program to advance the careers of women in physics and astronomy. It is supporting the American Association for the Advancement of Science (AAAS) in developing a project to rate universities on the inclusivity of their hiring and promotion practices. Separately, it funded a grant to sponsor a two-day workshop in professional development at MIT for women who had recently obtained PhDs and expressed interest in academic careers. The two dozen participants gained from the early networking opportunity, while the university got a two-day look at 24 potential hires, Atherton says. The program will be replicated at other universities.

A legacy of institutes

A different mode of basic science philanthropy was used by industrialist and real

estate investor Fred Kavli to provide major support for his legacy of 20 named institutes, all located on university campuses; 14 are in the US, 3 in Europe, and 3 in Asia. (See Kavli’s obituary in *PHYSICS TODAY*, May 2014, page 65.) Thirteen of the institutes are in physics and nanoscience; the others are in neuroscience.

Each institute was set up with an initial endowment of \$7.5 million to \$10 million, some on a cost-shared basis with the hosting institution; Kavli pays at least half the total. Many have grown their endowments to \$30 million or more, with at least half of that contributed by the foundation. In partnership with Norway, the foundation provides funding for the well-known Kavli Prizes in astrophysics, nanoscience, and neuroscience and for science journalism awards that are made jointly with AAAS. It also supports seven endowed professorships at six US universities.

The oldest Kavli institute, the Kavli Institute for Theoretical Physics (KITP) at the University of California, Santa Barbara (UCSB), opened in 1979 with an NSF grant, and it has been continuously funded by the agency ever since. Its naming came as the result of a 2002 donation from Kavli. NSF still supplies the bulk of KITP’s budget, but UCSB, local philanthropists, and the Kavli, Simons, and Heising-Simons Foundations also contribute, says institute director Lars Bildsten. Charles Munger, vice chairman at

Berkshire Hathaway, made the single largest donation: \$65 million for construction of a residence completed in 2017 (see *PHYSICS TODAY*, April 2017, page 32).

Unlike other Kavli institutes, KITP’s major activity is hosting visiting scientists; there are 60 present on any particular day, says Bildsten. Seven UCSB physics faculty, including Bildsten, form the institute’s intellectual core. They mentor 12–15 postdocs and 6 graduate fellows from other institutions who come for six-month appointments. About a dozen programs exploring physics topics in depth are carried out each year. The topics are suggested by the international physics community and are developed further by KITP faculty and an outside advisory board. About half of KITP’s 1000 visitors each year are from outside the US. Two or three programs are going on at once; current topics are the astrophysics of cold dark matter, experimental probes of particle-physics phenomenology beyond the standard model, and interactions at the ocean–atmosphere boundary. Program outcomes vary from the formation of collaborations to new science.

“We are strongly in the model of getting people for extended periods so they can get away from their day-to-day academic life and get back to being a graduate student: research full time all day,” says Bildsten.

The other Kavli institutes were set up mainly to provide targeted support for research at their host institutions. The Kavli Institute at Cornell for Nanoscale Science, for example, funds small teams of Cornell University researchers to develop new tools for nanoscale imaging, manipulation, and control. Three of the seven Kavli neuroscience institutes in the US and Norway resulted from a \$40 million Kavli Foundation commitment to the BRAIN Initiative, the public–private research effort begun in 2013 to develop technologies to improve dynamic understanding of brain function (see *PHYSICS TODAY*, December 2013, page 20).

As for the Kavli Foundation itself, Conn says it will be focusing for now on increasing endowments of the existing institutes rather than establishing new ones.

Hedge-fund billions

A unique model among US philanthropies with a major effort in the physical sciences is the Flatiron Institute, established

in 2016 by the Simons Foundation as a center for computational sciences. Foundation namesake James Simons is a PhD mathematician who made billions of dollars managing hedge funds that are driven by sophisticated statistical analyses of financial data. Flatiron consists of three interdisciplinary centers—computational astrophysics, computational quantum physics, and computational biology—with a core of technical scientific computing staff. Announcement of a fourth computational center is expected in the next several months. When renovation of the institute's 11-story building in Manhattan's Flatiron district is completed later this year, the unit will house 250 scientists and staff.

David Spergel, director of the Flatiron Center for Computational Astrophysics, says advanced computation will help in the analysis of huge data sets, such as the 1.7 billion star positions recently released by the European Space Agency's *Gaia* mission. Enormous data sets also will be created over the next five years by the Large Synoptic Survey Telescope and microwave background experiments. "Understanding and modeling of this

data is computationally demanding," he says. "At the same time, we have a revolution in computer science. We want to incorporate that into astrophysics."

Additionally, the center looks to apply numerical simulations to the enormous range of scales found in astronomy, from black holes to the physical universe itself. "We want to be able to simulate complex nonlinear processes, whether that is the merger of two neutron stars incorporating relativity, or the role of quasars and extragalactic nuclei in driving feedback and the formation of galaxies," Spergel says.

Antoine Georges, codirector of the Flatiron's Center for Computational Quantum Physics, describes the research agenda as the science of large and interacting quantum systems. A major objective is to calculate the properties of interacting quantum systems that have large numbers of particles, such as the electrons in materials. The problem could never be solved simply through brute computing force, he says. The institute instead will rely on theorists' ingenuity to develop new computational methods and algorithms to provide answers.

The center, says Georges, also "functions as a sort of haven for a community. The fact that there is this critical mass of people doing computational physics is going to attract colleagues from around the world to come and participate in the research agenda." When fully staffed—it opened in September 2017—the center will house 15–20 faculty members, 20–25 postdocs, and 10 visitors at any given time.

Compared with an academic research setting, says Georges, Flatiron gathers in one place more scientists who share expertise and interest in various areas of computational sciences. "We have more computational astrophysicists in this building than I think anywhere in the US," notes Spergel. The mingling with computational biologists located in the building provides an opportunity for cross-fertilization. For example, astrophysicists are learning from their biologist colleagues how to optimize software for computation with graphics processing units. Spergel says that most astrophysics codes are still written to run on machines with central processing units.

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