News from NSF Physics

Denise Caldwell
Division Director
Division of Physics
The 2nd Observational Run (O2) ended in August 2017 with an impressive collection of achievements:

- Jan. 4: LIGO detects the 3rd binary black hole merger (BBH)
- June 8: LIGO detects the 4th BBH merger
- Aug. 14: First triple detection of a BBH merger (LIGO + Virgo)
- Aug. 17: First detection of a binary neutron star (BNS) merger
- Oct. 3: Weiss, Thorne and Barish win the 2017 Nobel Prize in Physics
The joint observation of the first BNS merger by GW and EM observatories was a milestone in astronomical history, heralding the new era of Multimessenger astronomy.

- Only 1.7 seconds after the GW detection, a gamma-ray burst (GRB) was detected by NASA’s Fermi satellite.
- A massive EM follow-up campaign determined that the event was located in the galaxy NGC 4993 (40 Mpc, 130 My).
- First direct evidence of the BNS merger as progenitors of short duration GRBs.
- First clear observation of a kilonova (emissions of the radioactive decay of the BNS merger ejecta).
- New determination of the Hubble constant independent of any form of the cosmic “distance ladder”
LIGO and Virgo are currently undergoing commissioning tasks to prepare for O3

- O3 Start in late Fall 2018
- Planned duration: 9 months
- Sensitivity at 2/3 of design level
- Virgo expected to join in from the start
- LIGO India currently in land acquisition process. Ground-breaking planned for mid 2018
Major Sub-Areas of Physics (Experiment and Theory)

Research Support through Individual Investigator Awards > 50% of Budget

Gravitational Physics  (Includes Support of LIGO Scientific Collaboration (LSC))

Atomic, Molecular, and Optical Physics

Quantum Information Science and Revolutionary Computing

Nuclear Physics

Particle Physics (Elementary Particle Physics and Particle Astrophysics)

Physics of Living Systems

Plasma Physics

Plus Cross-Cutting Activities through Integrative Activities in Physics
  (REU, Special Center Awards, Outreach, Broadening Participation)

(Note that Condensed Matter Physics is NOT included – Housed in DMR)
Facilities in Physics Division

Laser Interferometer Gravitational Wave Observatory (LIGO)

ATLAS and CMS Detectors at Large Hadron Collider (LHC)

National Superconducting Cyclotron Laboratory (NSCL)

IceCube
Physics Frontiers Centers

FY 2017 Competition Concluded

PFC@JILA, University of Colorado
Institute for Quantum Information and Matter, CalTech (With CISE/CCF)

Center for Theoretical Biological Physics, Rice U (Joint with MPS/DMR, BIO/MCB)
PFC@JQI, U Maryland

NANOGrav, U Wisconsin Milwaukee (With MPS/AST)

Center for the Physics of Living Cells, UIUC (Joint with MPS/CHE, BIO/MCB)

Center for Ultracold Atoms, MIT/Harvard (With CISE/CCF)

JINA: Joint Institute for Nuclear Astrophysics, Michigan State

Center for the Physics of Biological Function, Princeton (Joint with BIO/MCB; IOS) (new in 2017)

Kavli Institute for Theoretical Physics, UCSB (With MPS/DMR, MPS/AST)

Programs now funded through Integrative Activities in Physics (IAP) program
Kavli Institute for Cosmological Physics, U Chicago (With GEO/PLR)
PFC support phased out over two years
Major Thrust – Fostering Connections

Focus on Science Question, not Discipline or Subarea

Partner with Others whenever Possible to Promote Science

Partnering within Division – AMO-Nuclear, AMO-Particle, AMO-Gravity, Nuclear-Particle

Partnering with other NSF divisions on specific topics – MPS/AST,CHE,DMR,DMS; BIO/MCB,IOS,DBI; GEO/PLR,AGS; ENG/ECCS,CBET; CISE/CCF,OAC

Participation in NSF priority areas jointly with other Directorates/Divisions - Big Ideas

Partnering with DOE in Particle Physics, Nuclear Physics, Plasma Physics

Partnering with NASA in Gravitational Physics and Plasma Physics

Public-Private Partnerships – Gordon & Betty Moore Foundation, SU2C
# MPS Funding

(Dollars in Millions)

<table>
<thead>
<tr>
<th></th>
<th>FY 2017 Actual</th>
<th>FY 2018 (TBD)</th>
<th>FY 2019 Request</th>
<th>Change over FY 2017 Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomical Sciences (AST)</td>
<td>$252.05</td>
<td>-</td>
<td>$230.69</td>
<td>-$21.36</td>
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<tr>
<td>Chemistry (CHE)</td>
<td>246.24</td>
<td>-</td>
<td>230.58</td>
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<tr>
<td>Materials Research (DMR)</td>
<td>314.31</td>
<td>-</td>
<td>295.05</td>
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<td>Mathematical Sciences (DMS)</td>
<td>233.54</td>
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<td>218.82</td>
<td>-14.72</td>
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<tr>
<td>Physics (PHY)</td>
<td>281.43</td>
<td>-</td>
<td>266.73</td>
<td>-14.70</td>
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<tr>
<td>Office of Multidisciplinary Activities (OMA)</td>
<td>34.86</td>
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<td>103.45</td>
<td>68.59</td>
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<td><strong>Total</strong></td>
<td><strong>$1,362.43</strong></td>
<td>-</td>
<td><strong>$1,345.32</strong></td>
<td><strong>-$17.11</strong></td>
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## PHY Funding

(Dollars in Millions)

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<th>Category</th>
<th>FY 2017 Actual</th>
<th>FY 2018 (TBD)</th>
<th>FY 2019 Request</th>
<th>Change Over FY 2017 Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>$281.43</td>
<td>-</td>
<td>$266.73</td>
<td>-$14.70</td>
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<tr>
<td><strong>Research</strong></td>
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<td>-</td>
<td>159.01</td>
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<td><strong>CAREER</strong></td>
<td>10.04</td>
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<td>7.30</td>
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<td><strong>Centers Funding (total)</strong></td>
<td>4.60</td>
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<td>5.00</td>
<td>0.40</td>
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<tr>
<td>STC: Center for Bright Beams</td>
<td>4.60</td>
<td>-</td>
<td>5.00</td>
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<td><strong>Education</strong></td>
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<td>4.92</td>
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<td><strong>Infrastructure</strong></td>
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<td>102.80</td>
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<td>IceCube Neutrino Observatory (IceCube)</td>
<td>3.50</td>
<td>-</td>
<td>3.50</td>
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<tr>
<td>Large Hadron Collider (LHC)</td>
<td>16.00</td>
<td>-</td>
<td>16.00</td>
<td>-</td>
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<td>Laser Interferometer Gravitational Wave</td>
<td>41.93</td>
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<td>45.00</td>
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<td>Observatory (LIGO)¹</td>
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<td>National Superconducting Cyclotron Laboratory (NSCL)</td>
<td>24.00</td>
<td>-</td>
<td>24.00</td>
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<td>Midscale Research Infrastructure</td>
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<td>Pre-construction Planning:</td>
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<td>High-Luminosity LHC Upgrade Planning</td>
<td>5.71</td>
<td>-</td>
<td>6.30</td>
<td>0.59</td>
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</table>

¹FY 2017 includes one-time supplemental funding of $2.50 million for a critical vacuum repair.
FY18 Base Program

• CAREER Solicitation
  • 11 proposals (~typical)
  • 1 award. Karagiorgi (Columbia)
• Physics Division Solicitation
  • 51 proposals (~40% increase)
• MRI
  • 2 proposals relevant to EPP-relevant
  • (~typical)
• AGEP-GRS Supplements
  • 3 proposals

FY18 Projects and Operations

• ATLAS and CMS Operations
• ATLAS, CMS Phase I Upgrades
• LHCb Upgrade
• MREFC Process for ATLAS and CMS Phase II Upgrades
  • PDRs
  • Internal reviews prior to NSB Review
Planning for a possible MREFC in support of the high-luminosity upgrades of the ATLAS and CMS detectors at CERN; Preliminary Design under review

Coordinating with the DOE in support of the US-CMS and US-ATLAS Teams

NSF has identified well-defined scope independent of DOE scope
Particle Astrophysics

• Cosmic Phenomena
  Research that uses astrophysical sources and particle physics techniques to study fundamental physics. This includes gamma-rays, cosmic-rays, and neutrinos.

• Underground Physics
  Research that locates experiments in low background environments. This includes studies of solar, underground, and reactor neutrinos; neutrino mass measurements; searches for the direct detection of Dark Matter.

• IceCube Research Support
  Research that utilizes the facilities of IceCube at the South Pole. Currently supported activities include: searches for ultra-high energy neutrinos and studies of the properties of neutrinos.

FY18 PA Program

• CAREER Solicitation
  • 9 proposals
  • 1 award: S. Wissel (CalPoly)

• Physics Division Solicitation
  • 65 proposals
  • Awards Pending

• MRI Solicitation
  • 7 proposals
  • Under review
PA Program Scope – Supported Projects

• Direct Dark Matter Detection – WIMP and non-WIMP experiments
  SuperCDMS at SNOLAB, XENON100/1T/nT, DArkSide-50/20k, PICO, COSINE-100, SABRE, DAMIC, HAYSTAC (ADMX-HF), ALPS2 and Light mass DM experiments

• Indirect Dark Matter Detection
  VERITAS, HAWC, IceCube

• Cosmic Ray, Gamma Ray, and UHE Neutrino Observatories
  IceCube, VERITAS, HAWC, Auger, Telescope Array, ARA, ARIANNA

• Cosmic Microwave Background
  SPT and BICEP

• Neutrino Properties
  Double Chooz, Project 8, IceCube, IsoDAR, CHANDLER

• Solar, SuperNova and Geo-Neutrinos
  Borexino, SNEWS

• Detector R&D
  NaI/CsI, LiSc/QuDots
A vibrant, intellectually diverse Theory program is vital to the success of the entire Particle Physics mission. We capitalize on the talents and creativity of the Theory community by supporting the best, most cutting-edge investigator-driven research in two programs:

• Theoretical High-Energy Physics

• Theoretical Particle Astrophysics and Cosmology

These two theory programs interface regularly with many other programs at NSF (EPP, PA, Gravity Theory, Nuclear Theory, Astronomy, Materials Research, Mathematical Sciences, etc.) We also coordinate, as needed, with DOE.

Approximately 110 separate active grants supporting ~180 PIs; ~30 large university groups.

Supporting individuals, RUI's, and special facilities or initiatives (Aspen Center for Physics, TASI summer school, LHC Theory Initiative, etc.)
Preparing for FY 2019

FY19 Base Program

• CAREER Solicitation
  • Deadline July 20, 2018
• Physics Division Solicitation
  • New Deadlines ***Tentative
  • November 28, 2018 for IAP
  • December 5, 2018 for EPP, PA, NP
  • December 12, 2018 for THY
• MRI
  • Submission Window
  • January 1 – 22, 2019

FY19 Planning: Stay Tuned...

• DCL on Instrumentation R&D
• Internal discussions...Midscale considerations and opportunities
• Stay alert to NSF-wide calls
10 Big Ideas for Future NSF Investments

• Bold questions that will drive NSF’s long-term research agenda
• Catalyze investment in fundamental research
• Collaborations with industry, private foundations, other agencies, universities
• Solve pressing problems and lead to new discoveries
Looking Ahead: Ten Big Ideas

RESEARCH IDEAS

- Navigating the New Arctic
- Harnessing Data for 21st Century Science and Engineering
- Work at the Human-Technology Frontier: Shaping the Future
- Understanding the Rules of Life: Predicting Phenotype
- The Quantum Leap: Leading the Next Quantum Revolution
- Windows on the Universe: The Era of Multi-messenger Astrophysics

PROCESS IDEAS

- Growing Convergent Research at NSF
- NSF-Includes: Enhancing Science and Engineering through Diversity
- Mid-scale Research Infrastructure
- NSF 2050: Seeding Innovation
<table>
<thead>
<tr>
<th>Big Ideas</th>
<th>FY 2019 Request</th>
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<tbody>
<tr>
<td><strong>Research Ideas</strong></td>
<td>$180.00</td>
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<tr>
<td>Harnessing the Data Revolution for 21st-Century Science and Engineering - HDR (CISE/ITR)</td>
<td>30.00</td>
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<tr>
<td>Navigating the New Arctic - NNA (GEO/ICER)</td>
<td>30.00</td>
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<tr>
<td>The Future of Work at the Human-Technology Frontier - FW-HTF (ENG/EFMA)¹</td>
<td>30.00</td>
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<tr>
<td>The Quantum Leap - QL (MPS/OMA)</td>
<td>30.00</td>
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<tr>
<td>Understanding the Rules of Life - URoL (BIO/EF)</td>
<td>30.00</td>
</tr>
<tr>
<td>Windows on the Universe - WoU (MPS/OMA)</td>
<td>30.00</td>
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<tr>
<td><strong>Process Ideas</strong></td>
<td>$102.50</td>
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<tr>
<td>Growing Convergence Research - GCR (IA)</td>
<td>16.00</td>
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<tr>
<td>Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science - NSF INCLUDES (EHR)</td>
<td>20.00</td>
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<tr>
<td>Mid-Scale Research Infrastructure (IA)</td>
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<td>NSF 2026 Fund (IA)</td>
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<tr>
<td><strong>Total, NSF Big Ideas</strong></td>
<td>$282.50</td>
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</tbody>
</table>
The goal of “Windows on the Universe” is to bring electromagnetic waves, high-energy particles, and gravitational waves together to study the universe and probe events in real time in a way that was previously impossible.
Quantum Leap: Leading the next Quantum Revolution

**Today:**
- lasers, atomic clocks, GPS, semiconductors, storage media

**Tomorrow:**
- Ultra-secure communication
- Ultra-precise sensing, measurement
- Quantum simulators
- Computing beyond the scale of supercomputing

Trapped ion computation (JQI – University of Maryland)
Builds on 20-Year NSF Investment in

Quantum Information Science

“Advancing Quantum Information Science: National Challenges and Opportunities”, NSTC, July 2016

Quantum Leap is an NSF-Wide Activity Involving Multiple Directorates that extends QIS into new regimes of materials science and engineering

Division of Physics participation is built on foundation of disciplinary programs and centers

- Atomic, Molecular and Optical Physics
- Quantum Information and Revolutionary Computing

PFC@JQI – Physics Frontier Center at Joint Quantum Institute, U Maryland
PFC@JILA – Physics Frontier Center at JILA
Center for Ultracold Atoms – Physics Frontier Center at MIT/Harvard
Institute for Quantum Information and Matter – Physics Frontier Center at CalTech
Taking the Leap: First Steps

Quantum Computing Ideas Lab:

DCL: Engineering Quantum Integrated Platforms for Quantum Communication (EQuIP)

DCL: Enabling QL: Achieving room-temperature quantum logic

DCL RAISE: Practical demonstrations in Quantum Leap:

DCL: Quantum Leap in Chemistry: molecular approaches

Technologies and devices

Triplets:

Quantum workshops

NSF/DOE/AirForce summer school:

Understanding natural and engineered systems

EFRIs: quantum memory, repeaters, topological metamaterials, networks

Enabling Practical-scale Quantum Computing: Expeditions in Computing

Braiding DCL:

FY 17-18 Activities underway

DCL: Engineering Quantum Integrated Platforms for Quantum Communication (EQuIP)
NSF Funding Activities – Details of FY17 and FY18

Emerging Frontiers in Research and Innovation 2016 (EFRI-2016): “Advancing Communication Quantum Information Research in Engineering (ACQUIRE)”
NSF News Release 16-091: $12M to support six interdisciplinary teams of 26 researchers

Dear Colleague Letter NSF 17-053— “A Quantum Leap Demonstration of Topological Quantum Computing”, EAGERs to demonstrate topological qubits (MPS/DMR)

“Convergence QL: NSF/DOE Quantum Science Summer School” DMR-1743059
(Funded by: NSF; DOE/BES, DOE/ASCR, + (recent) AFOSR)
First school held: Johns Hopkins University, 5-16 June 2017

“Quantum Information Science and Engineering Network” of “triplets” of students, faculty, industry partners to work on Quantum Leap challenges (OIA, DMR, CHE, PHY, ECCS, CCF, OAC, SES, OMA)

UChicagoNews
Nationwide program launches to train new generation of quantum engineers
NSF-funded project pairs graduate students with industry, academia
http://news.uchicago.edu/article/2018/05/08/nationwide-program-launches-train-new-generation-quantum-engineers
Solicitation NSF 17-548 “Ideas Lab: Practical Fully-Connected Quantum Computer Challenge (PFCQC)”
A co-design approach to integrating hardware, software and quantum algorithms”
Ideas Lab was held in fall, 2017; Proposals have been submitted
Review is complete and awards are being processed


Letters of intent have been received and invitees selected