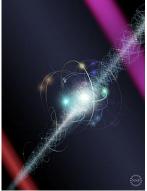


# National Science Foundation Mathematical and Physical Sciences Update



Image credit: NSF/LIGO/ Sonoma State University/A. Simonnet

HEPAP Meeting November 21, 2019

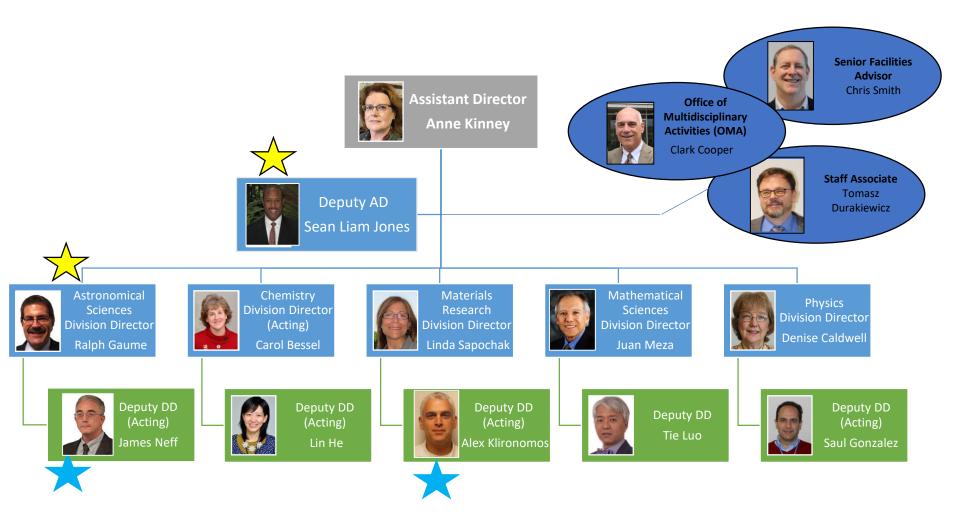


Credit: Nicolle R. Fuller/NSF

University/A. Simonnet Division Director, Physics Directorate for Mathematical and Physical Science

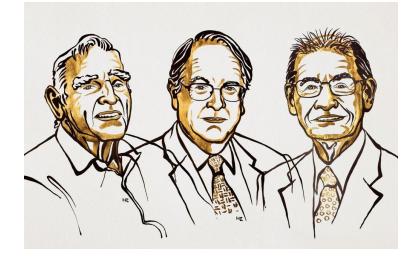
# Staff Changes in MPS



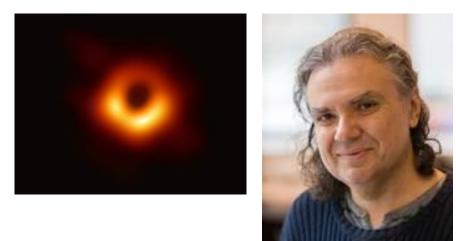


# 2019 Awardees Funded by NSF/MPS





2019 Nobel Laureates in Chemistry



Nobel Prize in Chemistry

 John Goodenough, M. Stanley Wittingham

**Nobel Prize in Physics** 

James Peebles

#### Breakthrough Prize in Physics

• EHT Collaboration

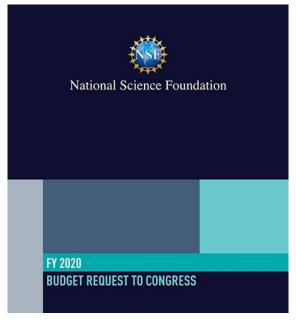
Breakthrough Prize in Mathematics

• Alex Eskin

# NSP

# Budget

- FY 2019 Appropriation
  - \$8.075 billion enacted for NSF
  - \$1.465 billion for MPS



- FY 2020
  - Continuing Resolution until 11/21/19
  - NSF budget request = \$7.226 billion
  - MPS budget request = \$1.255 billion

#### SUMMARY TABLE FY 2020 BUDGET REQUEST TO CONGRESS

#### (Dollars in Millions)

					FY 2020 R	equest
					change	over
	FY 2018	FY 2019	FY 2019	FY 2020	FY 2018 🗸	Actual
NSF by Account	Actual	Annualized CR <sup>1</sup>	Enacte d <sup>2</sup>	Request	Amount	Percent
BIO	\$756.60	-	-	\$683.36	-\$73.24	-9.7%
CISE	960.80	-	-	883.04	-77.76	-8.1%
ENG	977.90	-	-	881.42	-96.48	-9.9%
Eng Programs	767.92	-	-	686.27	-81.65	-10.6%
SBIR/STTR, including Operations	209.98	-	-	195.15	-14.83	-7.1%
IGEO	907.80			787.05	-120.75	-13.3%
MPS	1,503.41	-	-	1,255.82	-247.59	-16.5%
SDE	200.09	-	-	230.00	-20.01	-0.270
OISE	48.98	-	-	46.24	-2.74	-5.6%
OPP	501.72	-	-	403.39	-98.33	-19.6%
U.S. Antarctic Logistics Activities	71.13	-	-	71.00	-0.13	-0.2%
Other Polar Programs	430.59	-	-	332.39	-98.20	-22.8%
IA	471.05	-	-	491.04	19.99	4.2%
U.S. Arctic Research Commission	1 43	-	-	1.52	0.09	6.3%
Research & Related Activities	\$6,380.38	\$6,334.48	\$6,520.00	\$5,662.96	-\$717.42	-11.2%
Education & Human Resources	\$903.87	\$902.00	\$910.00	\$823.47	-\$80.40	-8.9%
Major Research Equipment & Facilities Construction	\$186.30	\$182.80	\$295.74	\$223.23	\$36.93	19.8%
Agency Operations & Award Management	\$328.51	\$328.51	\$329.54	\$336.89	\$8.38	2.6%
National Science Board	\$4.30	\$4.37	\$4.37	\$4.10	-\$0.20	-4.6%
Office of Inspector General	\$15.09	\$15.20	\$15.35	\$15.35	\$0.26	1.7%
Total, NSF Discretionary Funding	\$7,818.43	\$7,767.36	\$8,075.00	\$7,066.00	-\$752.43	-9.6%
Education and Human Resources - H-1B Visa	192.26	192.23	192.23	120.00	-72.26	-37.6%
Donations	29.22	71.76	71.76	40.00	10.78	36.9%
Total, NSF Mandatory Funding	\$221.48	\$263.99	\$263.99	\$160.00	-\$61.48	-27.8%
Total, NSF Budgetary Resources	\$8,039.91	\$8,031.35	\$8,338.99	\$7,226.00	-\$813.91	-10.1%

Totals exclude reimbursable amounts.

<sup>1</sup> Annualized CR amount shown to be consistent with figures presented with the President's budget, which was finalized prior to the enactment of the FY 2019 Omnibus appropriation.

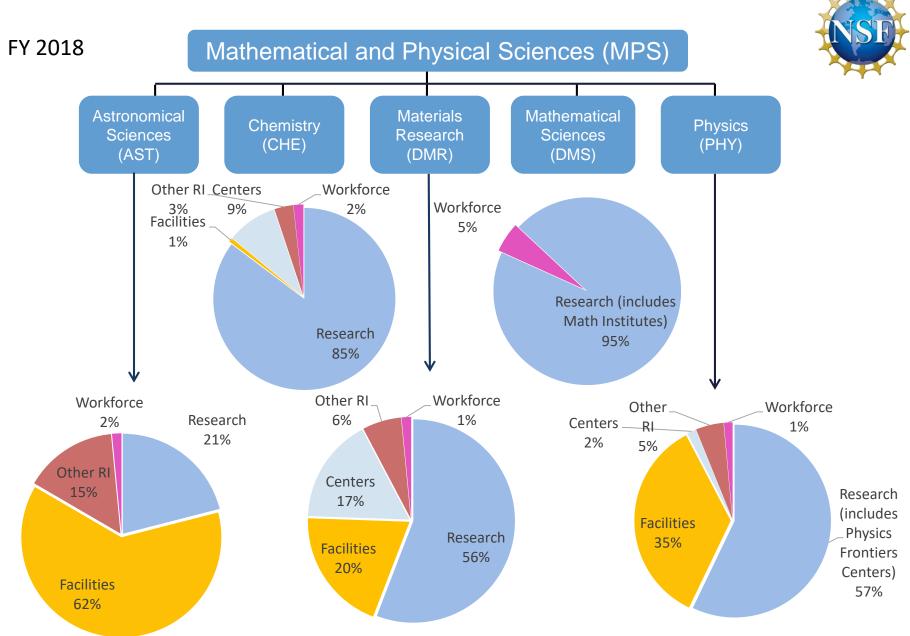
<sup>2</sup> Funding amounts below the account level for the FY 2019 Enacted were not available at the time of printing.



## President's FY 2020 MPS Request \$1,256 M

MPS Funding						
(Do	llars in Millio	ns)				
	FY 2018	FY 2019	FY 2020	Change FY 2018 A		
	Actual	(TBD)	Request	Amount	Percent	
Astronomical Sciences (AST)	\$311.16	-	\$217.08	-\$94.08	-30.2%	
Chemistry (CHE)	246.29	-	214.18	-32.11	-13.0%	
Materials Research (DMR)	337.14	-	273.78	-63.36	-18.8%	
Mathematical Sciences (DMS)	237.69	-	203.26	-34.43	-14.5%	
Physics (PHY)	310.75	-	247.50	-63.25	-20.4%	
Office of Multidisciplinary Activities (OMA)	60.39	-	100.02	39.63	65.6%	
Total	\$1,503.41	-	\$1,255.82	-\$247.59	-16.5%	

\$30 M Quantum Leap\$30 M Windows on the Universe



Source: FY 2018 Actuals Data

### NSF's 10 Big Ideas





### NSF's Role in the National Quantum Initiative



Contribution to national strategy



NATIONAL STRATEGIC OVERVIEW FOR QUANTUM INFORMATION SCIENCE

#### Basic QISE research



31 'quantum' Nobel laureates funded since 1964

Quantum workforce development



# Interagency collaboration



#### https://www.nsf.gov/mps/quantum/quantum\_research\_at\_nsf.jsp



### NSF NQI Response – FY 2019 +



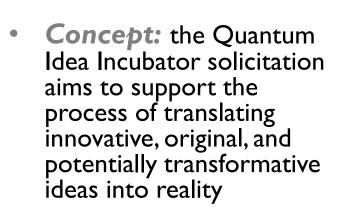
**NSF 19-559 Quantum Leap Challenge Institutes (QLCI);** Total Funding Amt. \$94M; 18 Conceptualization Grants in FY 2019 (\$3M); First full Institute awards in FY 2020; Second group in FY 2021

**QII-TAQS Incubators: Transformational Advances in Quantum Systems;** *Follow-on to extremely successful FY 2018 RAISE (TAQS) awards*; 19 Awards in FY 2019; \$35.5 M over two years

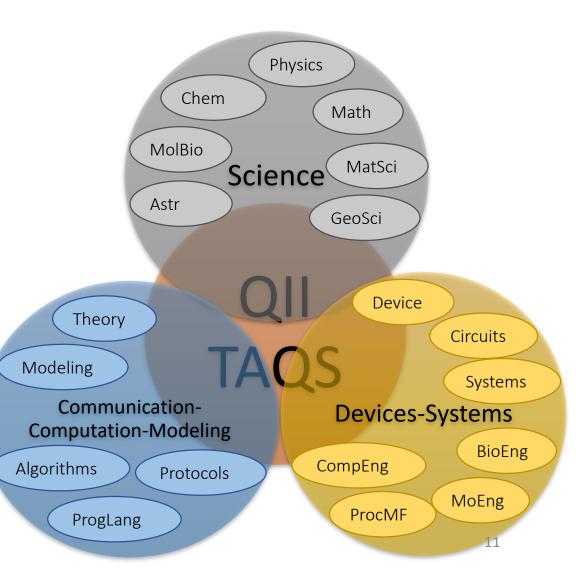
**Quantum Computing and Information Science Faculty Fellows (QCIS-FF)** Two Awards in FY 2019, Each \$250k per year for three years

**Enabling Quantum Leap: Convergent Accelerated Discovery Foundries for Quantum Materials Science, Engineering and Information (Q-AMASE-i);** Award 1906325 "Enabling Quantum Leap: Q-AMASE-i: Quantum Foundry at UCSB"; A. Bleszynski-Jayich; \$25M over six years.

#### NSF 19-532: Quantum Idea Incubator -Transformational Advances in Quantum Systems (QII -TAQS)



• Includes: at least three research disciplines, which preferably come from at least two of the recommended thrust areas



#### QI-TAQS Awards

Convergence

Collaboration

Community



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II-TAQS: Quantum Machine Learning with Photonics Edo Waks University of Maryland College Park	NI-TAQS: Quantum Control of Ultracold Atoms in Optical Lattices for Inertial Sensing for Space Applications	Dana Anderson	University of Colorado at Boulder
	UI-TAQS: Quantum Machine Learning with Photonics	Edo Waks	University of Maryland College Park



- The QLCI program will support large-scale projects driven by a cross-disciplinary challenge research theme for advancing the frontiers of quantum information science and engineering.
- Timely and bold research agenda aimed at making breakthroughs on compelling challenges in a 5-year period.
- Conceptualize, develop, and implement **revolutionary** new approaches and technologies for quantum information processing.
- Research will span the focus areas of quantum computation, quantum communication, quantum simulation, or quantum sensing.

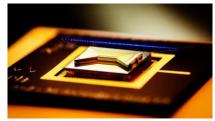


Image Credit: K. Hudek, IonQ&E; E. Edwards JQI



# **Conceptualization Grants (CGs)** funded at a level of \$100,000-\$150,000 for 12 months

**Challenge Institute (CI) awards** funded at a level of up to \$5,000,000/year for 5 years

Two rounds of competition:

ROUND I (2019-2020): **CG or CI proposals** *but not both* ROUND II (2020-2021): **CI proposals only** 



Credit: Brad Baxley/JILA

CG awardees will have the opportunity to submit a CI proposal in Round II





- Conceptualization Grants intend to build capacity among teams to plan for large-scale, interdisciplinary research projects that aim to advance the frontiers of quantum information science and engineering.
- Research at these Institutes will span the focus areas of quantum computation, quantum communication, quantum simulation, and/or quantum sensing.
- The Institutes are expected to foster multidisciplinary approaches to specific scientific, technological, educational, and workforce development goals in these fields.
- Funding up to \$150k, 12 months

### QLCI Conceptualization Grant Awards

Convergence

Collaboration

Community



LCI-CG: Nevada Institute for Quantum Sciences and Technology     Bernard Zygethan     University of Nevada Ias Vegas       LCI-CG: Nevada Institute for Quantum Sciences and Technology     George Scipits     University of Tennessee Knowlife       LCI-CG: Texas Quantum Institute     Junchro Kono     William Marsh Rice University       LCI-CG: Dealing Institute for Quantum Photonic Information Processing     Ryan Canache     Birgham Young University       LCI-CG: Dealing of Novel Functional Materials for Quantum Devices     Junchro Kono     William Marsh Rice University       LCI-CG: Dealing of Novel Functional Materials for Quantum Devices     Junich Sciences     SUNY at Buffalo       LCI-CG: Institute for Quantum Information Processing     Nasili Perebeinos     SUNY at Buffalo       LCI-CG: Conceptualization of The Institute for Quantum Biology on Quantum Computers     Beverly Sanders     University of Horida       LCI-CG: Stabible Integrated Platforms for Quantum Information Processing     Marek Osinski     University of New Mexico       LCI-CG: Conceptualization of The Institute Grouputing and Communication Tested     Eden Figueroa     SUNY at Story Brook       LCI-CG: The Quantum Fronteer Institute     Colorado School of Mines     Juniversity of Revisita       LCI-CG: Towards a Boston Area Quantum Information Bioscience Institute for Quantum Sensing and Simulations in Novel Hybrid     Marek Pocapital     Juniversity of Neval Kensity       LCI-CG: Towards a Boston Area Quantum Information Bioscience Institute for Quantum S			
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#### Mid-scale Research Infrastructure (Mid-scale RI) Opportunities

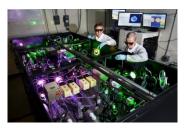


- Mid-scale RI is an NSF Big Idea to address the growing needs for RI to advance research.
- NSF-wide program will support projects in the MRI – MREFC gap (~\$6 to \$70 million range).
- RI is broadly defined, from disciplinary instrumentation to mid-scale facilities, upgrades, cyberinfrastructure, and others.
- Two solicitations released: one for projects between ~\$6 M and ~\$20 M (MSRI-1) and one for ~\$20 - \$70 M (MSRI-2).
- Awards for first group have been made; Full proposals for second are in and under review

#### Mid-Scale RI-1 Awards Related to MPS



Mid-scale RI-1 (M1:IP): A world-class Neutron Spin Echo Spectrometer for the Nation: UD-NIST-UMD Consortium; Award Number: 1935956; Principal Investigator: Norman Wagner; University of Delaware

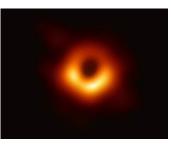


Maksimchuk, Nees @ HERCULES; Credit: Joseph Xu

Mid-scale RI-1 (M1:IP): Zettawatt-Equivalent Ultrashort Pulse Laser System (ZEUS): Award Number: 1935950; Principal Investigator: Karl Krushelnick; U of Michigan Ann Arbor

Mid-scale RI-1 (M1:IP): NSF National EXtreme Ultrafast Science (NEXUS) Facility: Award Number: 1935885; Principal Investigator: Lawrence Baker; Ohio State University

Mid-scale RI-1 (M1:DP): Next Generation Event Horizon Telescope Design: Award Number: 1935980; Principal Investigator: Sheperd Doeleman; Smithsonian Institution Astrophysical Observatory



EHT Black Hole

Mid-scale RI-1 (M1:DP): Consortium Proposal for CMB-S4 Design Development: Award Number: 1935892: Principal Investigator: John Carlstrom; U Chicago

#### PD 18-5115 Program Description: Windows on the Universe: The Era of Multi-Messenger Astrophysics





- Proposals submitted to participating programs in MPS/AST, MPS/PHY and GEO/OPP.
- Proposals funded through "Big Idea" allocation as well as existing programs.
- Criteria: <u>any area of research supported through the</u> <u>participating divisions that address at least one of the</u> <u>following:</u>
  - *Coordination:* Hardware, software, or other infrastructure to coordinate observations involving more than one messenger.
  - Observations: Observations of astrophysical objects or phenomena that are potentially sources of more than one messenger, including the use of existing observatories, experiments, and data archives, as well as the development and construction of new capabilities for advancing multimessenger astrophysics.
  - *Interpretation:* Theory, simulations and other activities to understand or interpret observations of astrophysical objects that are sources of more than one messenger.

https://www.nsf.gov/funding/pgm\_summ.jsp?pims\_id=505593



#### Fiscal 2019 – WoU-MMA



\$30M from WoU-MMA awarded in FY19 66 awards (full or co-funded w/ MPS/PHY/AST/OMA; GEO/PLR) Roughly 2/3 went for support of individual investigators The remaining 1/3 was split between Instrumentation and Facilities

Examples: (Full List at https://www.nsf.gov/awardsearch/)

PI Community (individual investigators) Ice Cube – F. Halzen (Univ. of Wisconsin) Support for 19 institutions to do the scientific analysis of data taken with the IceCube neutrino detector



Instrumentation SNEWS: a Super Nova Early Warning System - R. Lang et al. Analysis of neutrino detector data to provide a prompt alert for an impending supernova ... hours before it will be visible in the sky

Facilities SCIMMA – P. Brady et al. Scalable Cyberinfrastructure Institute for Multi-Messenger Astrophysics





1934700: Collaborative Research: Advancing Science with Accelerated Machine Learning; Philip Harris, PI (+ collaborators); MIT; \$1.8 M

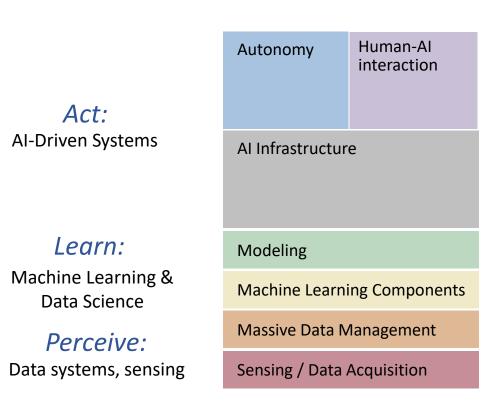
1940209: Collaborative Research: Science-Aware Computational Methods for Accelerating Data-Intensive Discovery: Astroparticle Physics as a Test Case; Christopher Tunnell, PI (+ collaborators), Rice University; \$1.0 M

1934752: A Framework for Data Intensive Discovery in Multimessenger Astrophysics; Patrick Brady, PI (+co-workers); U Wisconsin-Milwaukee; \$2.8 M

All are 2-year planning/conceptualization for FY 2021 Institutes Solicitation



### **AI: more than machine learning**



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### New in FY 2019 and FY 2020

- Al and Society, with the Partnership on Al
  - \$4.5M joint funding: CISE and SBE, with PAI, in FY 2019
- NSF/DARPA Program on Real-Time Machine Learning (RTML)
  - \$11M total, with CISE and ENG beginning in FY 2019
- NSF/Amazon Program on Fairness in Al
  - \$20M joint funding: CISE and SBE, with Amazon, in FY 2020
- DCL on FEAT for CISE: Fairness, Ethics, Accountability, and Transparency for CISE Research (NSF 19-016)



amazon alexa







### National AI Research Institutes

- National nexus points for universities, federal agencies, industry and nonprofits to advance Al research and education
- In FY 2020:
  - Planning grants for future Institutes
  - Launching up to six multidisciplinary, multiinstitutional research *Institutes*
- Anticipated investment: ~\$200M over six years, beginning in FY 2020

