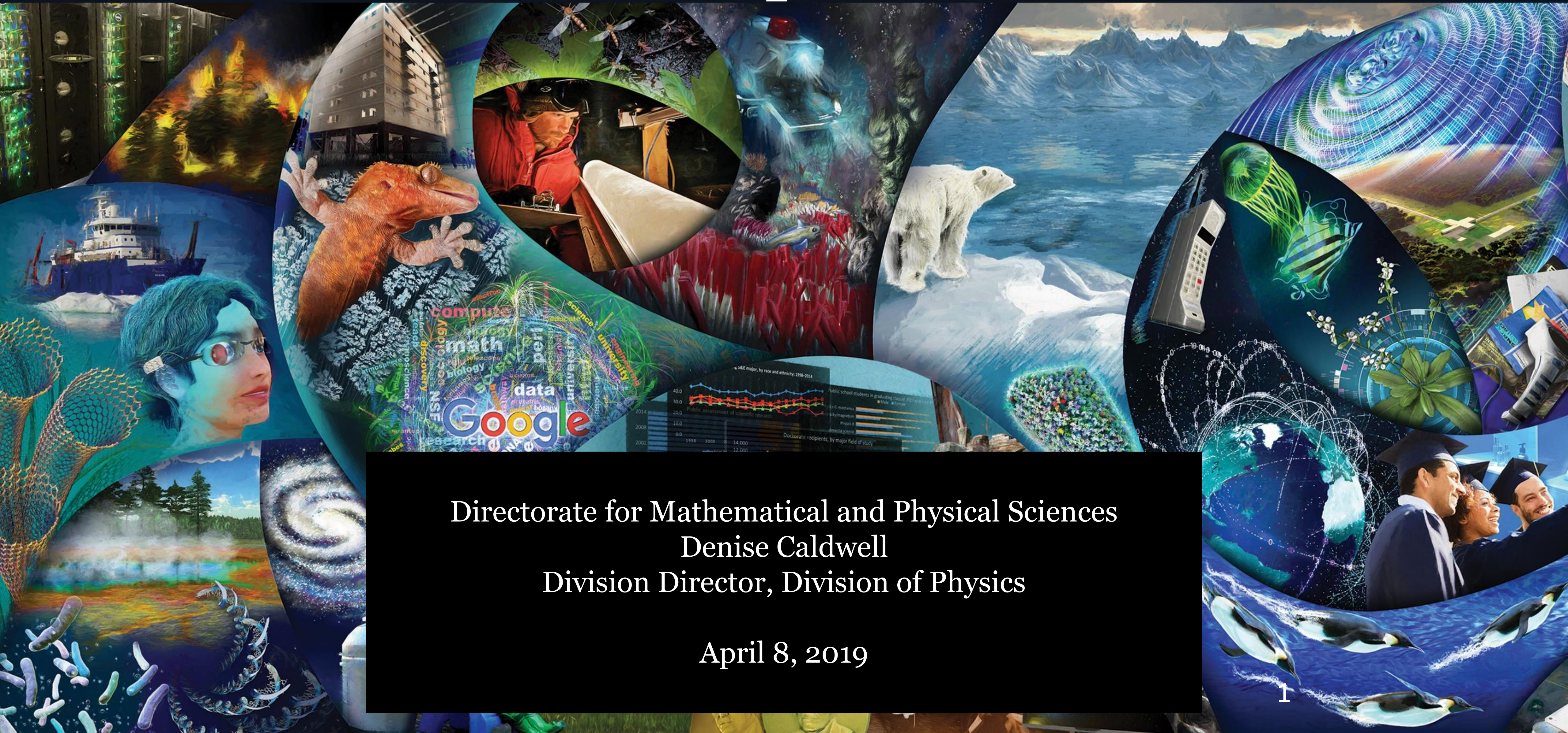
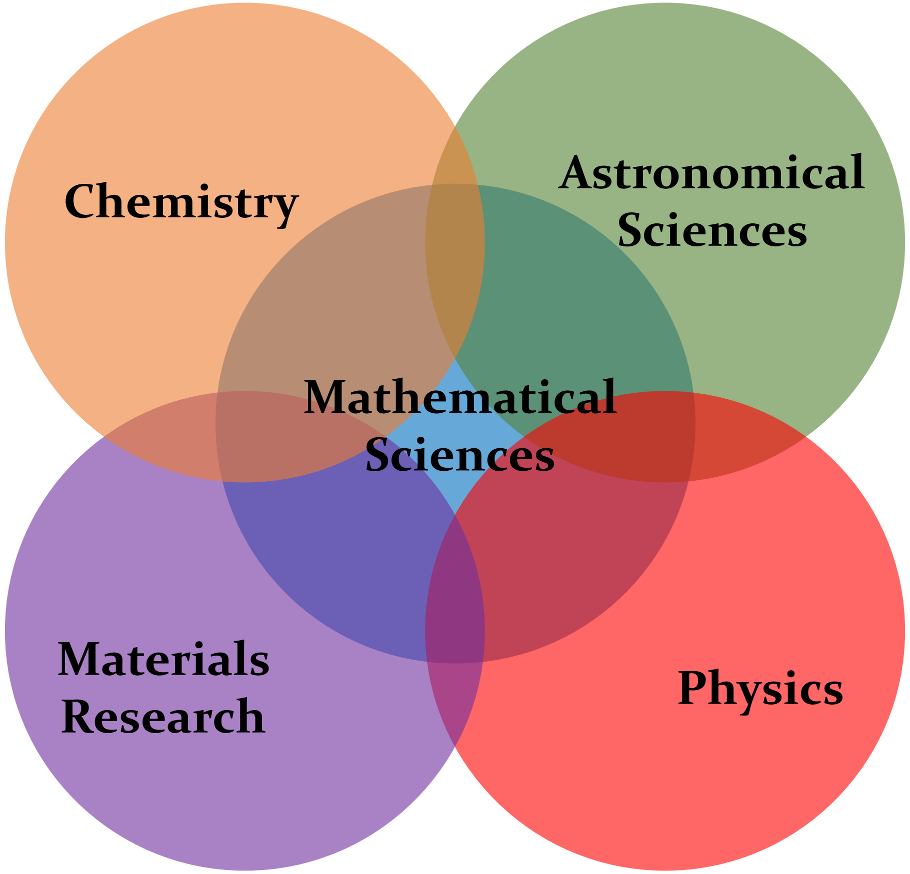
National Science Foundation
NSAC April 2019



Directorate for Mathematical and Physical Sciences
Denise Caldwell
Division Director, Division of Physics

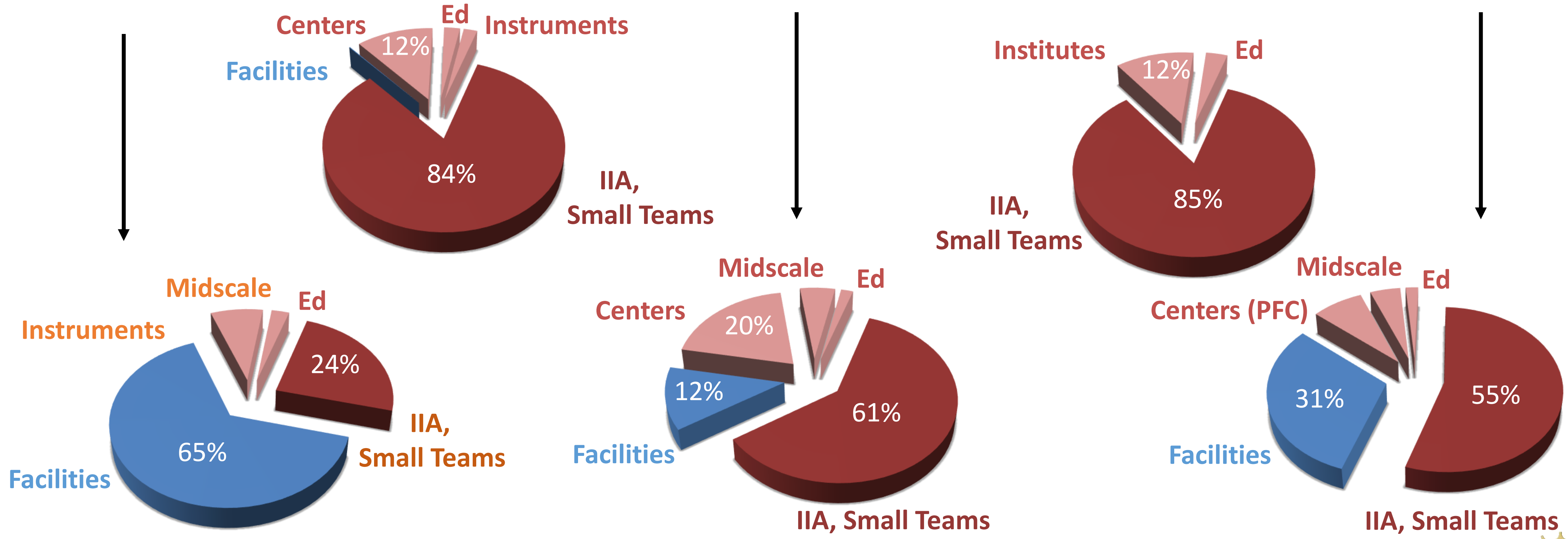
April 8, 2019

MPS Consists of Five Interconnected Divisions

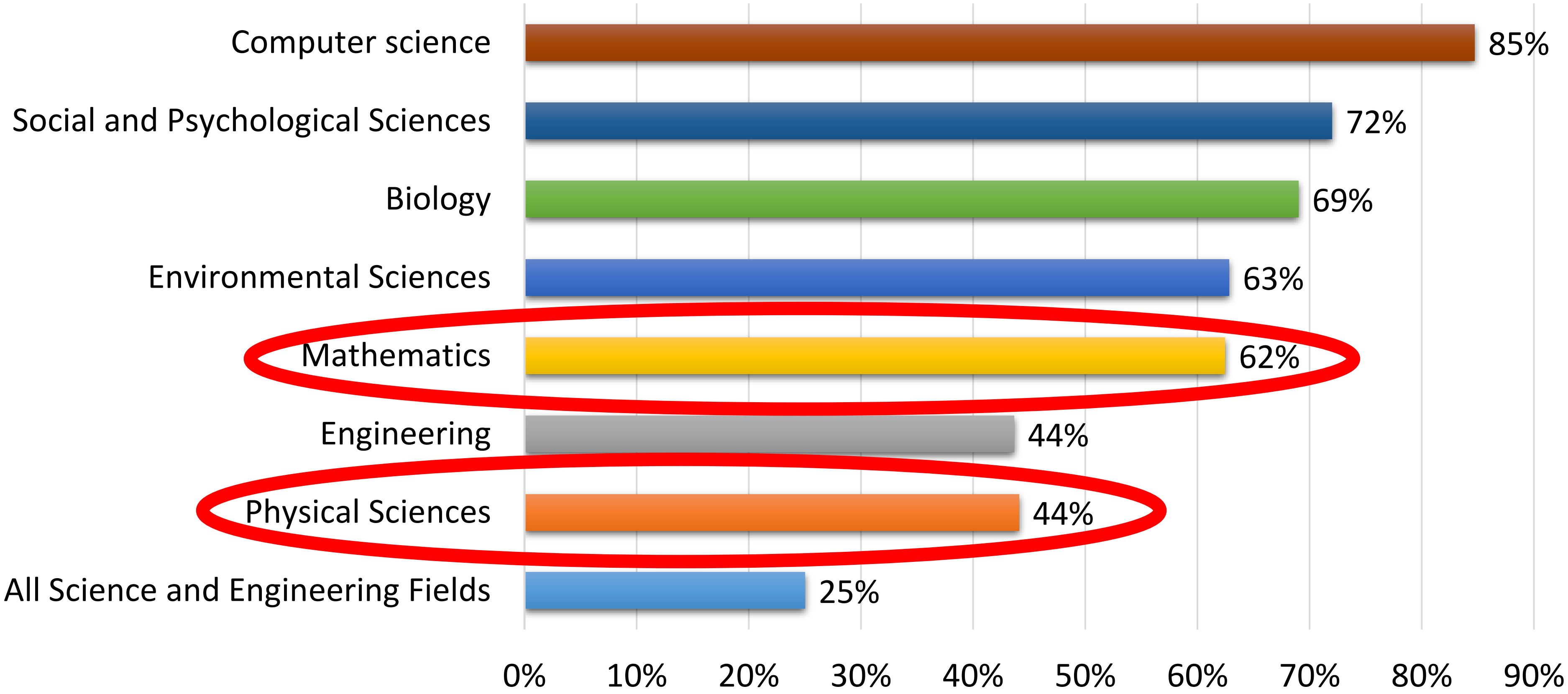


Mathematical and Physical Sciences (MPS)

- Astronomical Sciences (AST)
- Chemistry (CHE)
- Materials Research (DMR)
- Mathematical Sciences (DMS)
- Physics (PHY)



NSF Support of Academic Basic Research in Selected Fields
(as a percentage of total federal support, FY 2016)



Note: Biology includes Biological Sciences and Environmental Biology. Biology and Psychological Sciences exclude National Institutes of Health funding from the total amount of federal support.

Source: NSF/National Center for Science and Engineering Statistics, Survey of Federal Funds for Research and Development

MPS by the Numbers: FY 2018

$ 1.50 B FY 2018 CP

7,619 research proposals

305 panels

27% Research award funding rate

2,072 research awards

29,684 people supported

8,954 senior researchers

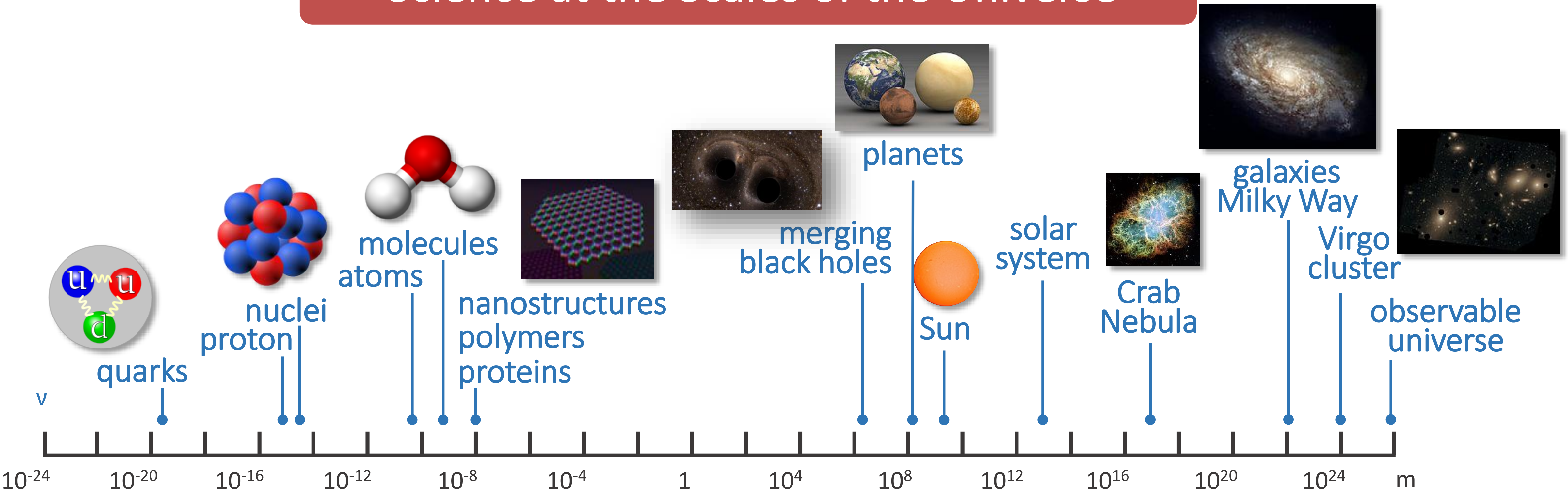
3,562 other professionals

2,276 postdoctoral associates

9,224 graduate students

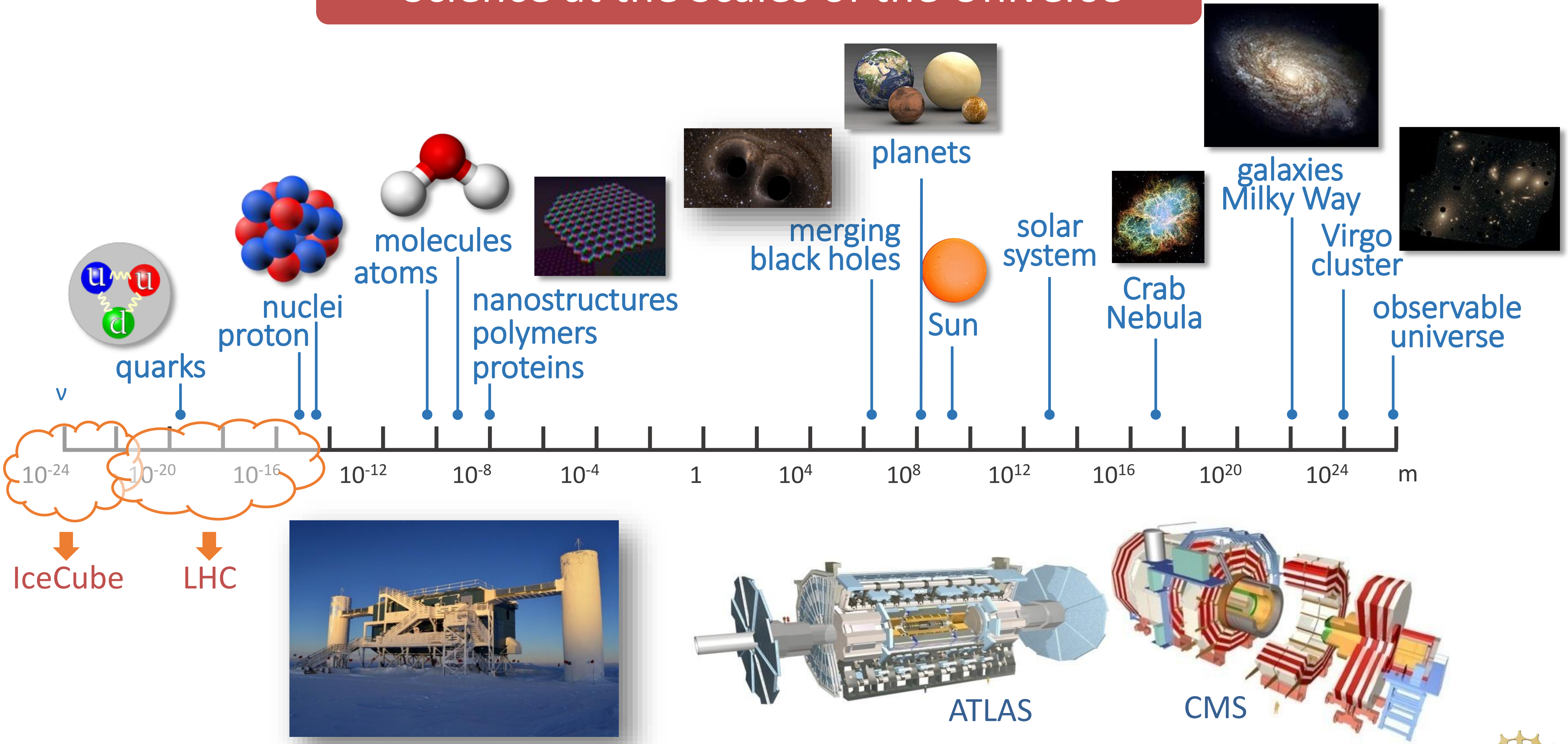
5,668 undergraduate students

Science at the Scales of the Universe

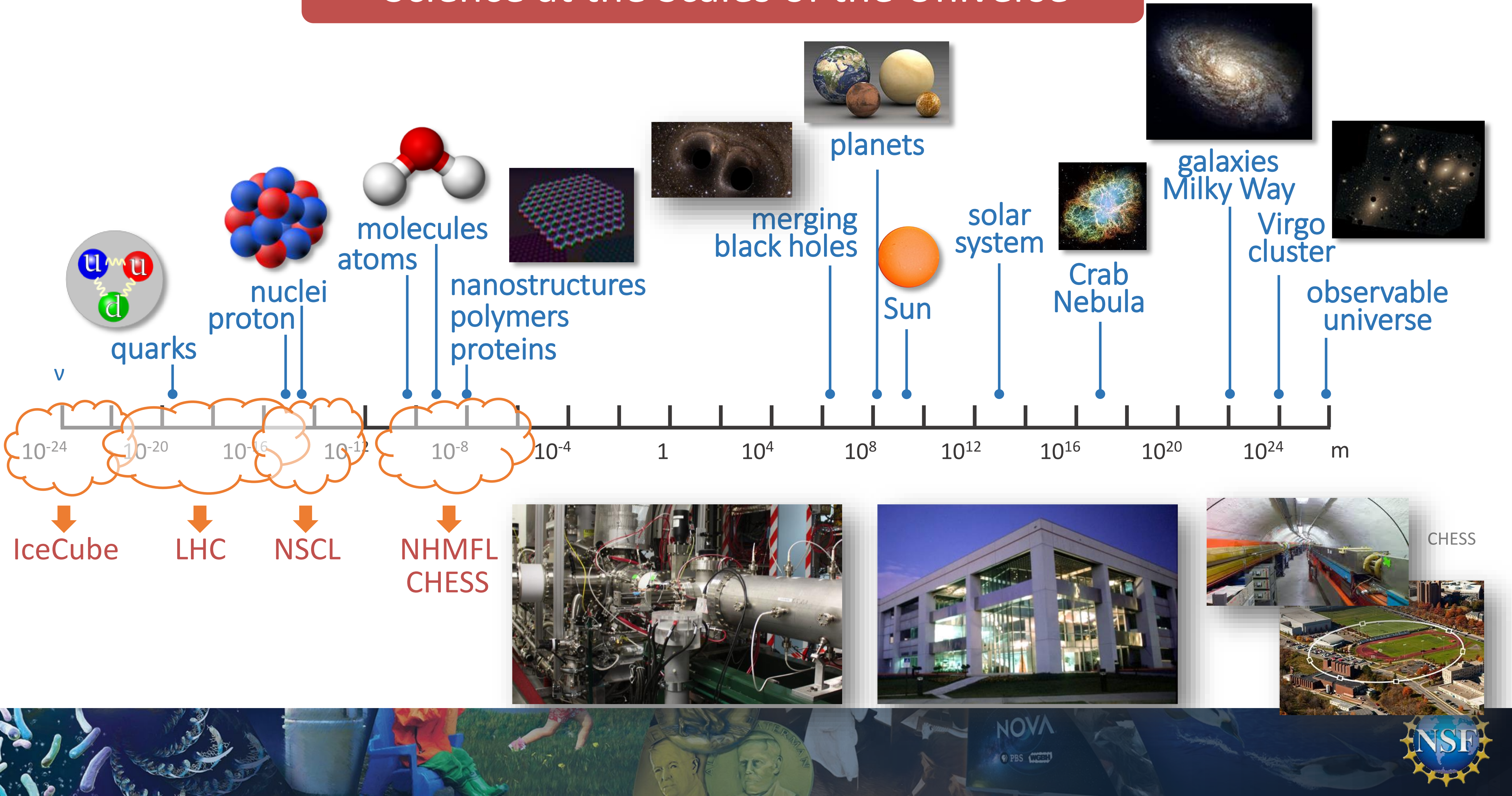


Images from Wikipedia Commons

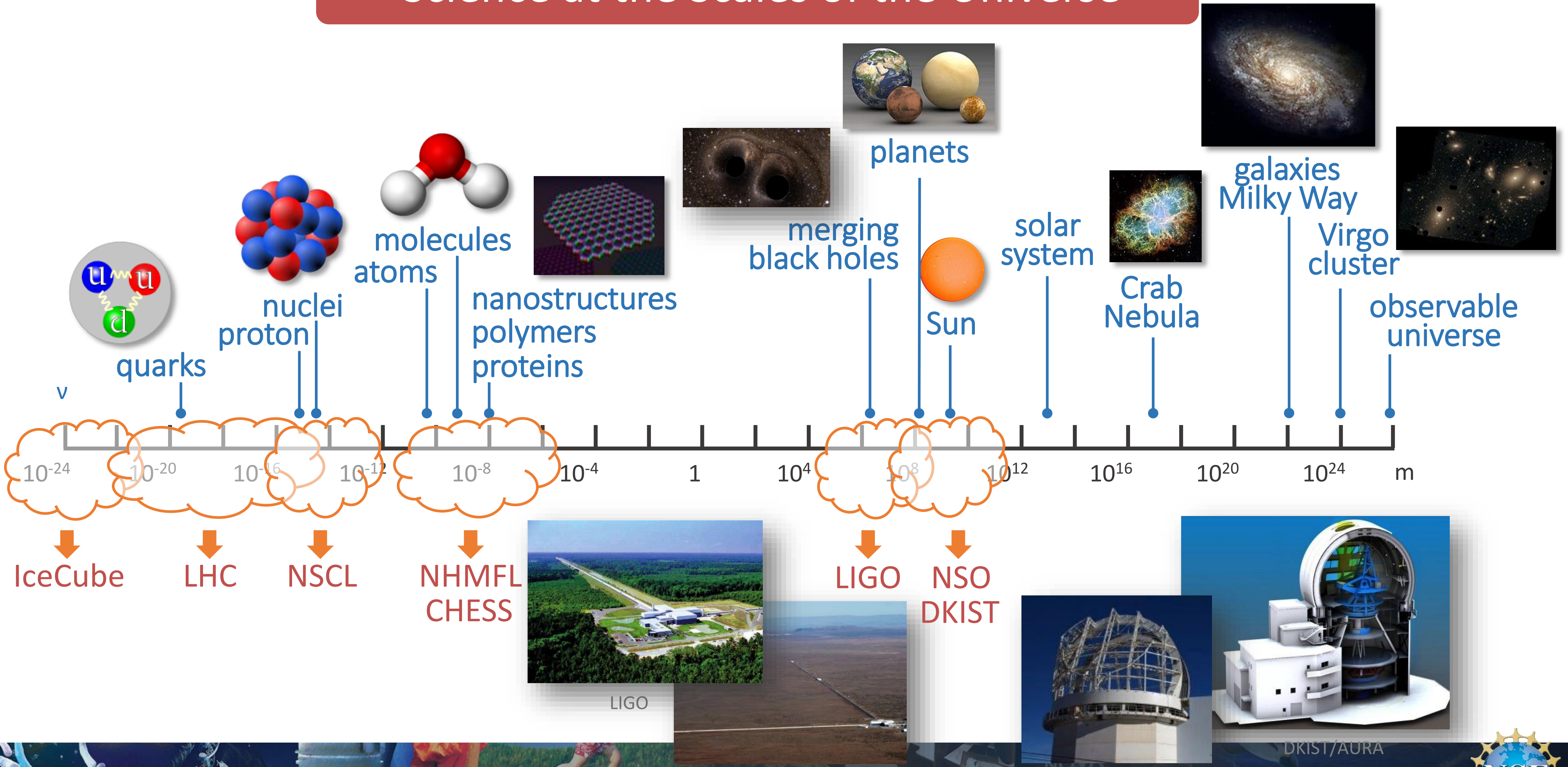
Science at the Scales of the Universe



Science at the Scales of the Universe



Science at the Scales of the Universe

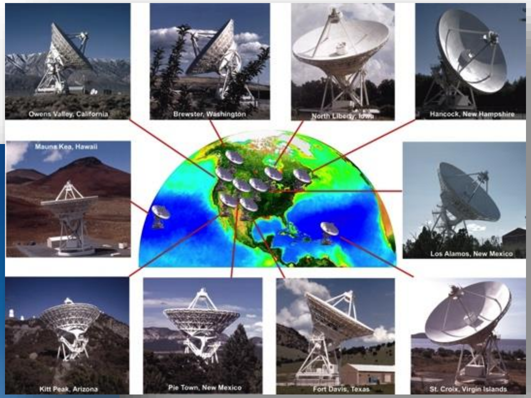


Science at the Scales of the Universe

ALMA

NRAO/VLA

GBT



VLBA

NAIC

10^{-24} 10^{-20} 10^{-16} 10^{-12} 10^{-8} 10^{-4} 1 10^{4} 10^{8} 10^{12} 10^{16} 10^{20} 10^{24} m

IceCube

LHC

NSCL

NHMFL
CHESS

LIGO

NSO
DKIST

NRAO
GBO
VLBA
Arecibo

NOAO
Gemini
LSST

NSF Budget Status ($M)

NSF Actual FY 2018	$ 8,040
R&RA Actual FY 2018	$ 6,380
MPS Actual FY 2018	$ 1,503
NSF Appropriated FY 2019	$ 8,339
Current Plan under Development	
NSF Request FY 2020	$ 7,226
R&RA Request FY 2020	$ 5,663
MPS Request FY 2020	$ 1,256

Directorate Funding – FY 2020 Request

MPS Funding

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual 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%**

Includes $30M extra for Special projects

MPS is the $60 M steward of **Quantum Leap** and **Windows on the Universe** Big Ideas

MPS Priorities – FY 2020

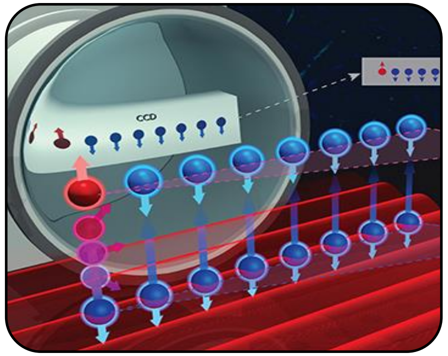
- **Emphasis on Big Ideas**
  - NSF Stewardship: Quantum Leap & Windows on the Universe
  - Expanded Participation: Harnessing the Data Revolution, Mid-Scale Research Infrastructure, and Understanding the Rules of Life
- **Strategic investments** in:
  - Fundamental research
  - Artificial Intelligence, Advanced Manufacturing, and Quantum Information Science
  - Next generation workforce
  - Large, multi-user research facilities
  - Mid-scale research infrastructure
  - External partnerships

NSF's 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*

MPS FY 2020 Big Idea Investments

Steward Directorate



•**Quantum Leap** (QL) *$30.0 million*

- MPS stewards NSF's ($30 million) investment to enable fundamental research in quantum-enabled sciences and technologies, in collaboration with 11 divisions across NSF
- Develop the foundations for and enable quantum computing, sensing, communications, simulation, and other quantum technologies, including the development of the national workforce

Windows on the Universe (WoU) *$30.0 million*

- MPS stewards NSF's ($30 million) investment in multi-messenger astrophysics
- Bring together fundamental research in electromagnetic waves, high-energy particles, and gravitational waves
- Advance the study of the universe
- Grow the nation's MMA, engineering, and data science workforce

Windows on the Universe

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.

Credit: LIGO Laboratory

Credit: IceCube

Credit: AURA

Neutron Star – Neutron Star Merger

GW170817

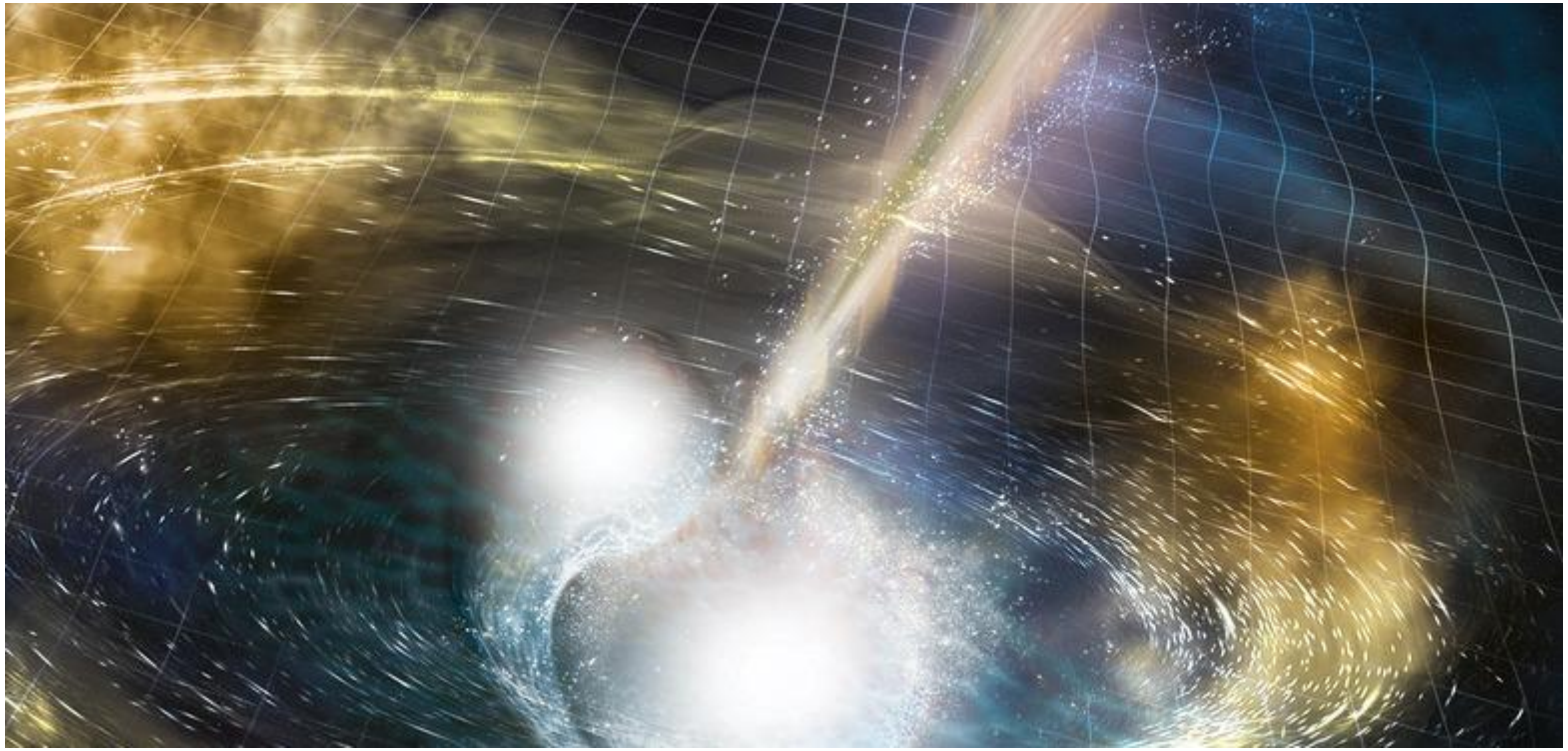
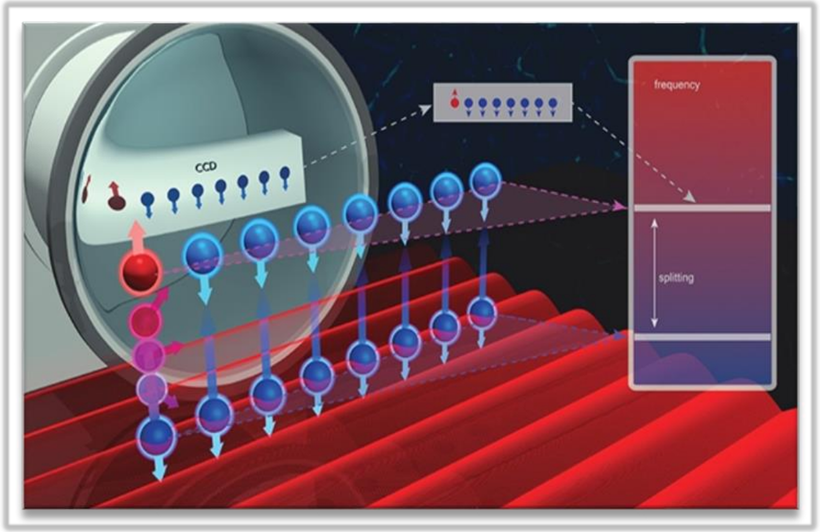


Image credit: NSF/LIGO/Sonoma State University/A. Simonnet

Quantum Leap: Leading the next Quantum Revolution



Trapped ion computation (JQI – University of Maryland)

Today:

- lasers, atomic clocks, GPS, semiconductors, storage media

Tomorrow:

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

Recap: Enabling the Quantum Leap

DCL-RAISE-EQuIP: Engineering Quantum Integrated Platforms for Quantum Communication

DCL-RAISE-TAQS: Transformational Advances in Quantum Systems

Ideas Lab: Practical Fully-Connected Quantum Computer Challenge (PFCQC)

Enabling Practical-scale Quantum Computing: *Expeditions in Computing*

DCL: : Achieving Room-temperature quantum logic through improved low-dimensional materials

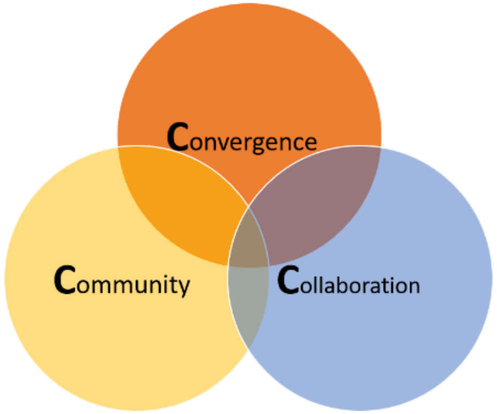
DCL: A Quantum Leap Demonstration of Topological Quantum Computing

DCL: Quantum Leap in Chemistry: molecular approaches

QISE-Net: Quantum Information Science and Engineering Network – “TRIPLETS”

NSF/DOE/AFOSR: Quantum Science Summer School; 2017-2020

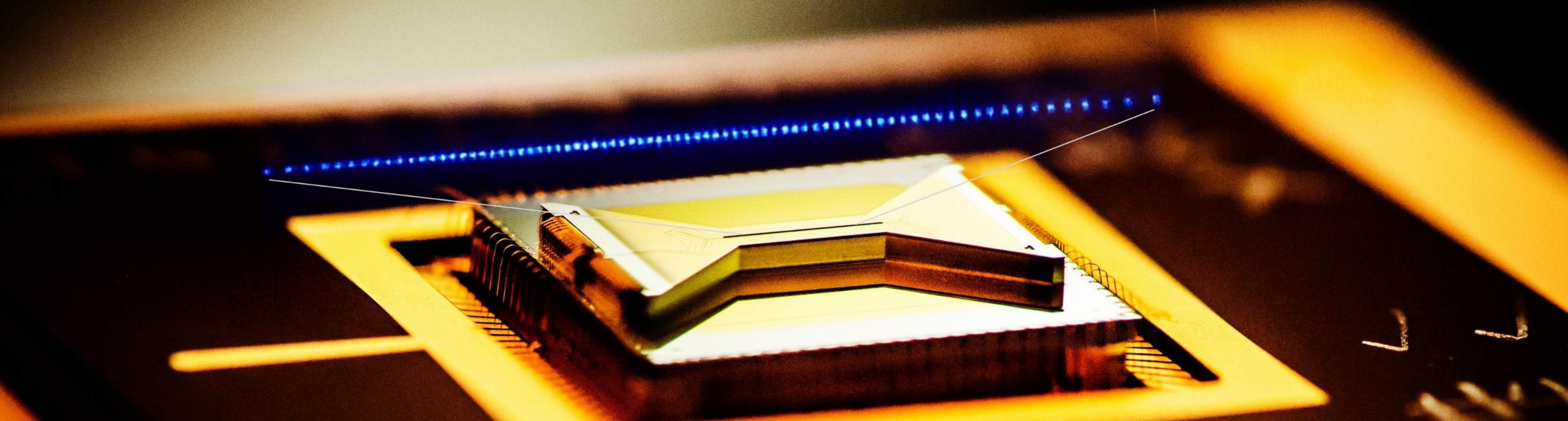
EFRI-ACQUIRE (2016); *Advancing Communication Quantum Information Research in Engineering*



2016 -2018

NSF 17-548 Ideas Lab: Practical Fully-Connected Quantum Computer

brings together physicists, computer scientists, and engineers to construct a quantum computer capable of showing an advantage over current computer technology.



NSF Award 1818914 PFCQC: STAQ: Software-Tailored Architecture for Quantum co-design

$15 million grant for a multi-institution quantum research collaboration. [News Release 18-058]

Trapped ions (superimposed) above a fabricated trap to capture and control ion qubits (quantum bits).
Image Credit: *K. Hudek, Ion Q&E / E. Edwards, JQI*

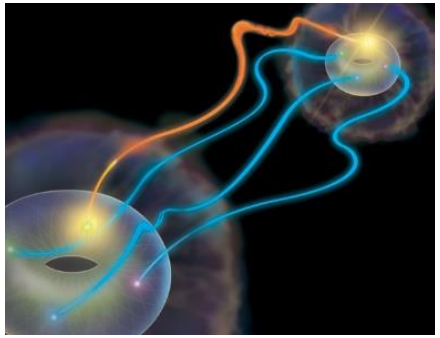
Taking the Leap (2019 and Beyond)

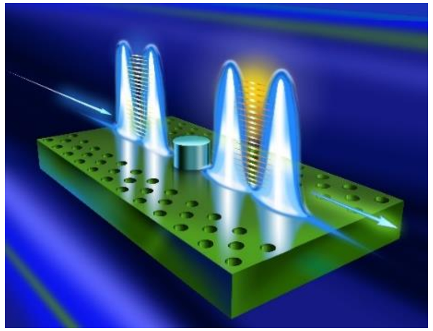
Q-AMASE-I - Enabling Quantum Leap: Convergent Accelerated Discovery ***Foundries*** for Quantum Materials Science, Engineering and Information (NSF 18-578)

Foundries: up to \$25M over 6 years

QII – TAQS - Enabling Quantum Leap: Quantum Idea Incubator for Transformational Advances in Quantum Systems (NSF 19-532)

Small teams: up to \$2M for 3 to 5 years





QCIS-FF - Quantum Computing & Information Science Faculty Fellows (NSF 19-507)

QLCI - Quantum Leap Challenge ***Institutes*** (NSF 19-559)

Institutes: up to \$25M over 5 years, FY2020 funding

All require convergence across multiple disciplines

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 and one for ~$20 - $70 million.
- Preproposals for former are in and under review; Preproposals for second are in and under review

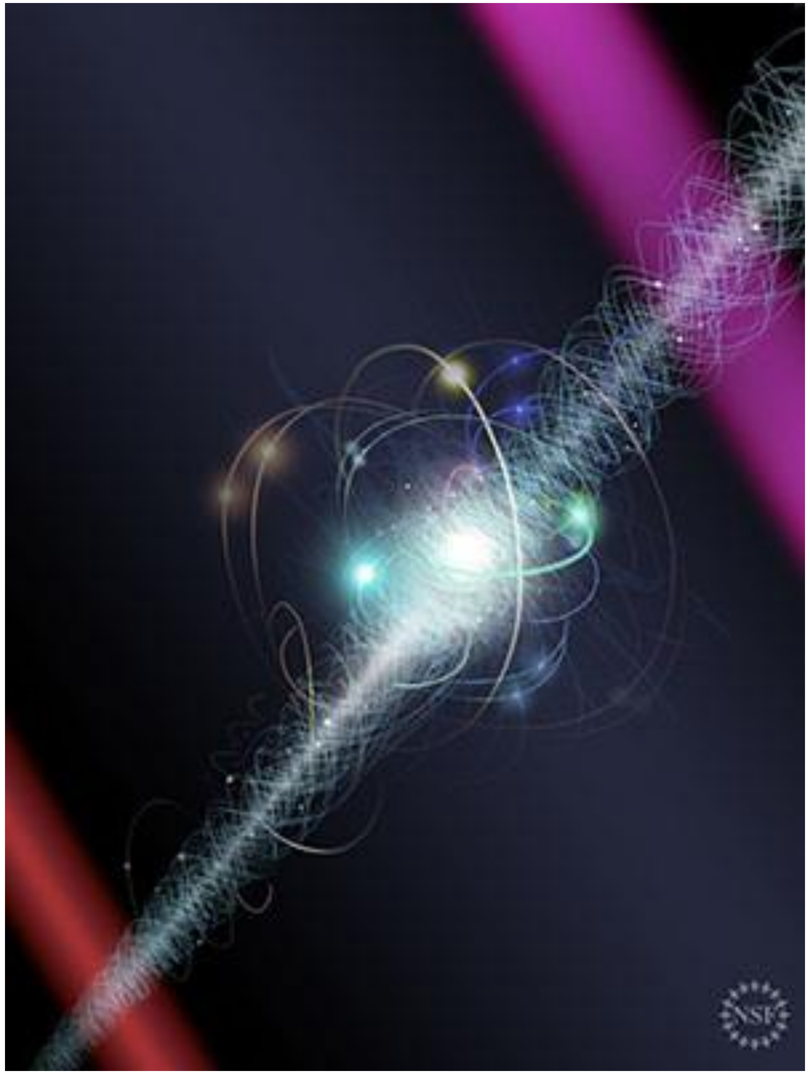
Advanced Cold Molecule Electron Dipole Moment (ACME)

Sets new lower limit on electron dipole moment

$|d_e| < 1.1 \times 10^{-29}$ ecm

This is 8.6 times smaller than the best previous limit, from ACME I, at 90% confidence level.

Result typically limits time-reversal-symmetry-violating new physics to energy scales above $\Lambda \approx 30$ TeV or $\Lambda \approx 3$ TeV



Credit: Nicolle R. Fuller/National Science Foundation

LIGO Catalogue of Detections through 2017

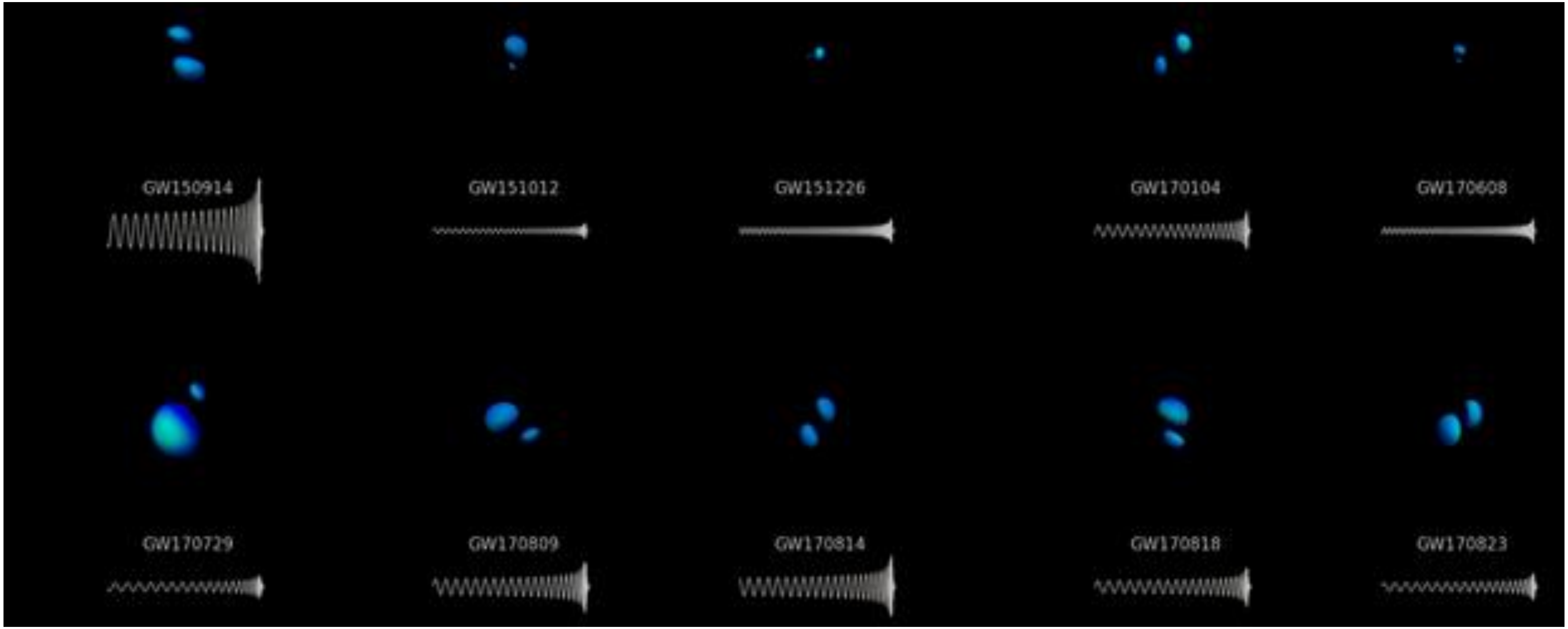


Photo Courtesy LIGO Laboratory