MPS | DIRECTORATE FOR MATH AND PHYSICAL SCIENCES

NSF Overview

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ASSISTANT DIRECTOR

APRIL 30, 2025

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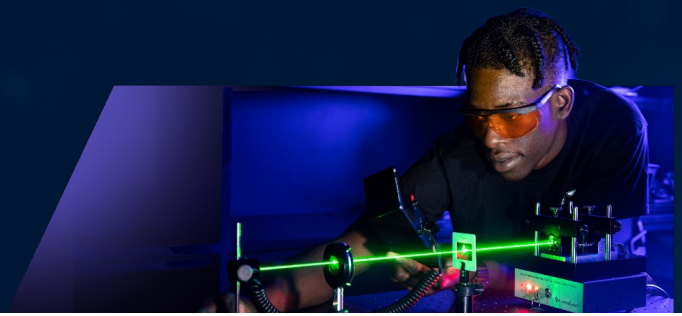
MISSION

PROMOTE
the progress of science

ADVANCE
the national health, prosperity, and welfare

SECURE
the national defense



U.S. National Strategy for QIS - Overview

National Quantum Initiative Act of 2018

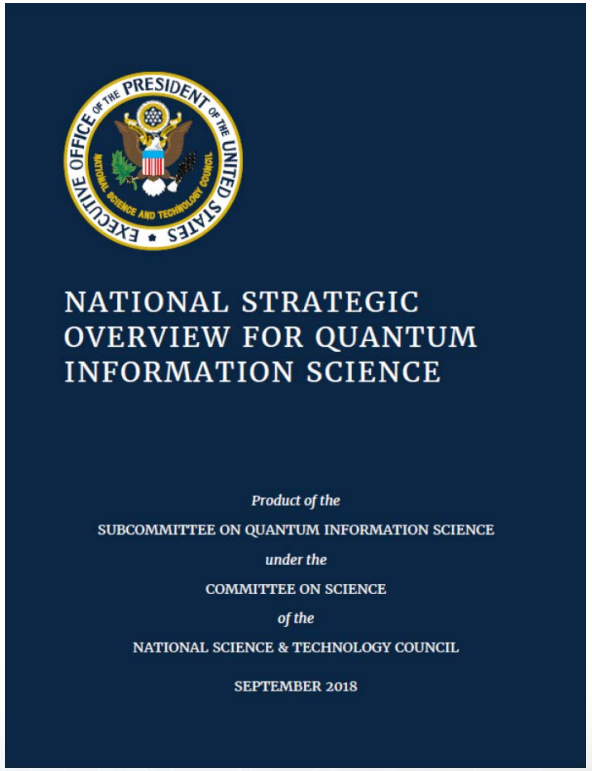
"To provide for a coordinated Federal program to accelerate quantum research and development for the economic and national security of the U.S."

President's Letter to OSTP Director (March 26, 2025)

"How can the U.S. secure its position as the unrivaled world leader in critical and emerging technologies — such as artificial intelligence, quantum information science, and nuclear technology — maintaining our advantage over potential adversaries?"

Six policy thrusts:

1. Use a science-first approach to QIS R&D
2. Build a quantum-capable, diverse workforce
3. Nurture nascent quantum industry
4. Provide key infrastructure
5. Balance economic and national security
6. Encourage international cooperation



Securing U.S. Quantum Leadership: Microsoft's Call to Action

On April 28, 2025, Microsoft Vice Chair and President Brad Smith published a blog post titled "Investing in American leadership in quantum technology: the next frontier in innovation," emphasizing the strategic importance of quantum computing for the United States.

U.S. Strengths & Challenges

- The U.S. leads in quantum talent and research but risks falling behind in hardware and industrial investment.

Microsoft's Breakthrough

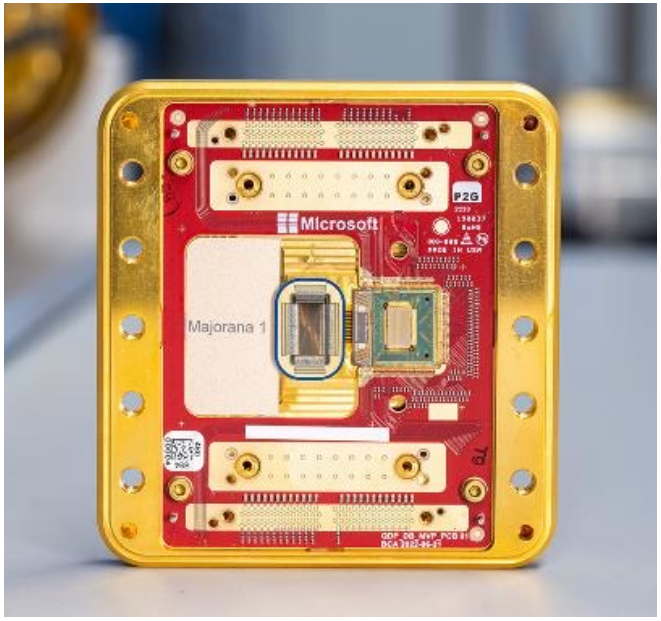
- Microsoft announces a Majorana-based quantum chip, a key step toward scalable, fault-tolerant quantum computing.

Policy & National Strategy

- Highlights the National Quantum Initiative Act and ongoing need for U.S. government coordination.

NSF's Role

- Foundational research funding and talent development.
- Supports quantum centers, workforce pipelines, and partnerships with industry.
- Crucial for sustaining long-term U.S. innovation and competitiveness.



NSF: Enshrining U.S. Leadership in Quantum

NSF Award 0653073: **"Quantum Optics with Superconducting Circuits"**
Rob Schoelkopf

Rob Schoelkopf's student Jerry Chow starts the IBM quantum experience (now called the IBM Quantum Platform)

IBM Newsroom News Media resources Inside IBM Blog

IBM Launches Its Most Advanced Quantum Computers, Fueling New Scientific Value and Progress towards Quantum Advantage

FORTUNE RANKINGS MAGAZINE NEWSLETTERS PODCASTS COVID-19 MORE

TECH · QUANTUM COMPUTER

IBM plans a huge leap in superfast quantum computing by 2023

BY ROBERT HACKETT

NSF Award 0112726: **"Quantum Computing with Trapped Ions"**
Chris Monroe

NSF awardees Chris Monroe and Jungsang Kim found IonQ in 2015. IonQ becomes first quantum computing company to go public on NYSE in 2021

Forbes

IonQ Takes Quantum Computing Public With A $2 Billion Deal

Current Market Cap $5.7B

NSF Award 0134776: **"CAREER: Coherence and Quantum Control of Strongly Interacting Systems"**
Misha Lukin

Leads to Rydberg-atom quantum simulators. Misha Lukin, 5 other Harvard & MIT professors found QuERA Computing in 2018

Researchers create first logical quantum processor

QuEra COMPUTING INC.

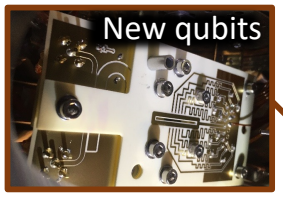
Valued at $400M, sold quantum computer to Japan's AIST for $41M

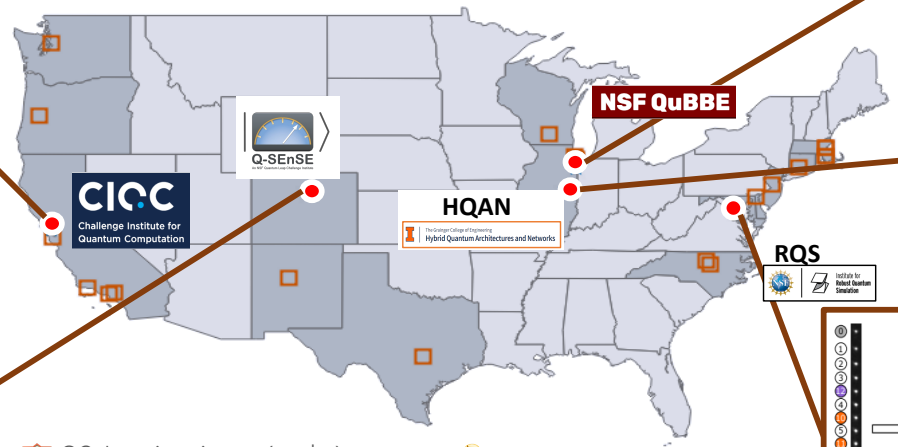
Quantum Leap Challenge Institutes

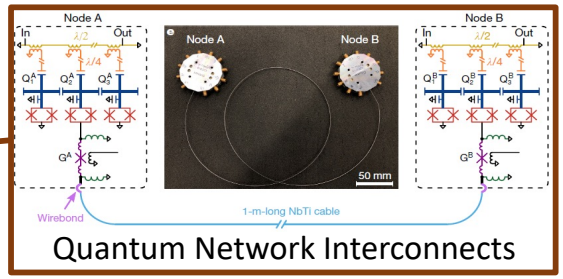
National Quantum Initiative Centers

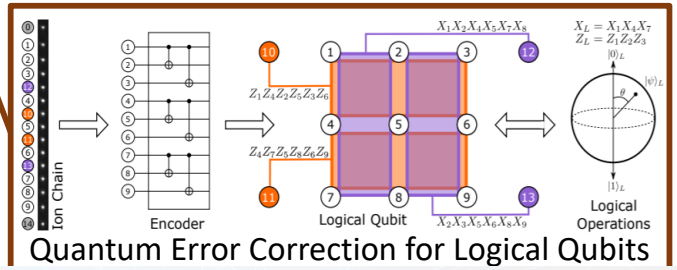
- **CIQC**: Challenge Institute for Quantum Computation
- **QSENSE**: Quantum Sensing with Entangled Sci. & Eng.
- **HQAN**: Hybrid Quantum Architectures and Networks
- **QuBBE**: Quantum Sensing for Biophysics and Bioeng.
- **RQS**: Institute for Robust Quantum Simulation

- Advancing the Frontiers of Quantum Information Science and Engineering
- Research, Education, Coordination, Partnerships









89 Institutions (.edu)
67 Industry Partners
12 Government Labs

181 Faculty
112 Postdocs
403 Students

Physics World Breakthrough of the Year for 2024

World's First Logical Quantum Processor

The first demonstration of an error-corrected quantum computer executing a large-scale algorithm was achieved by researchers supported by an **NSF Physics Frontiers Center (The Center for Ultracold Atoms) and Quantum Leap Challenge Institute (QLCI for Robust Quantum Simulation).**

Published in ***Nature***, their breakthrough used electrically neutral atoms to create a programmable, logical quantum processor with up to 48 logical qubits — a large increase over previous achievements and a potential turning point in the race to create quantum computers capable of tasks beyond the abilities of traditional computers.

Collaboration led by **Harvard** (Mikhail D. Lukin), **MIT** (Vladan Vuletić), **UMD/NIST** (Michael J. Gullans) and **QuERA Computing** (Thomas Karolyshyn)

Highlight: Logical qubit encoding with arrays of trapped neutral atoms

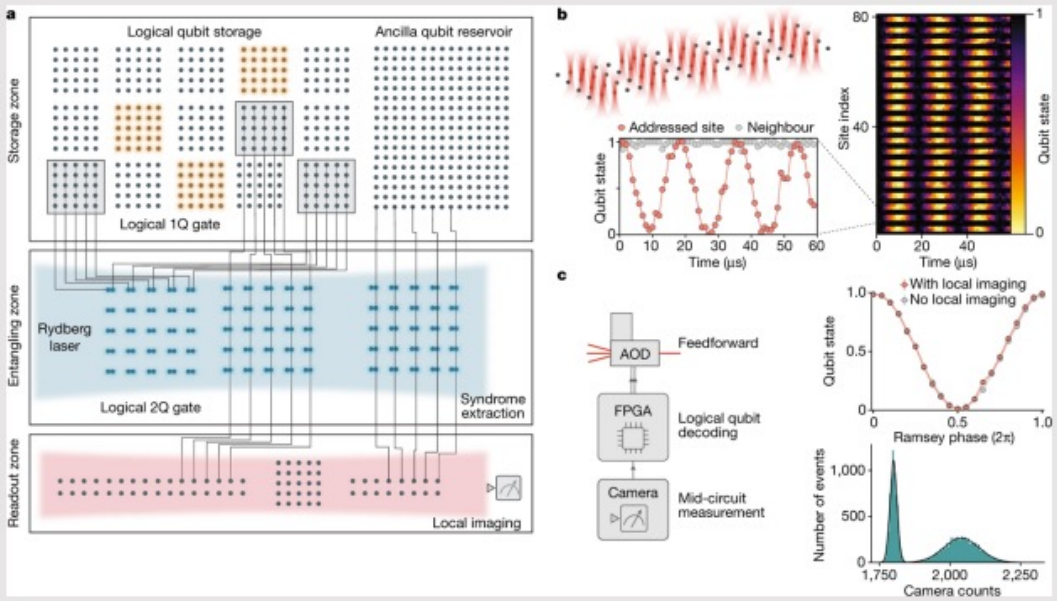
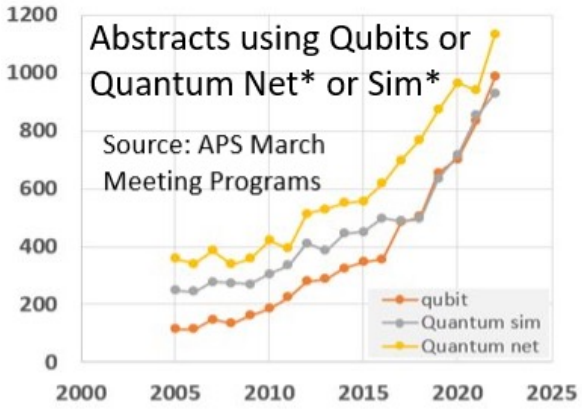


Figure.3.1: Schematic of a neutral-atom based quantum processor and key operations, including single qubit rotations, mid-circuit readout and real-time processing of quantum information.[12]

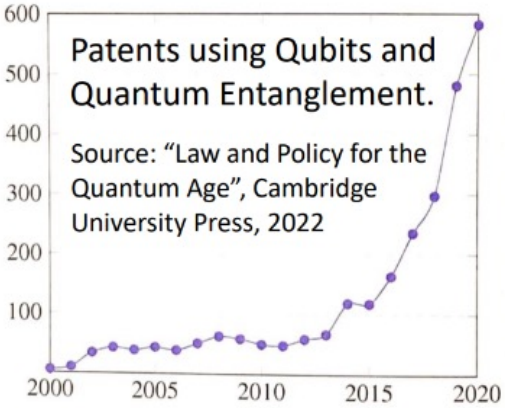
Source: Bluvstein, D., Evered, S.J., Geim, A.A. *et al.* Logical quantum processor based on reconfigurable atom arrays. *Nature* **626**, 58–65 (2024). https://doi.org/10.1038/s41586-023-06927-3

Exponential Growth in QIS Activity

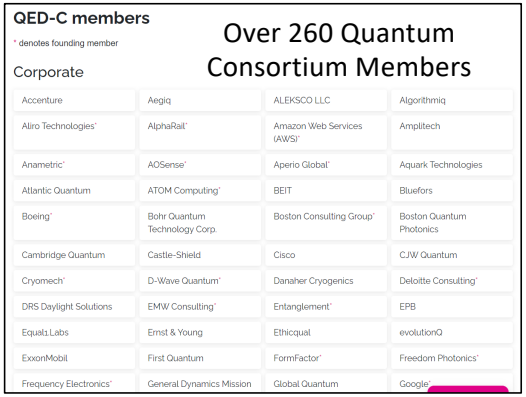
Science



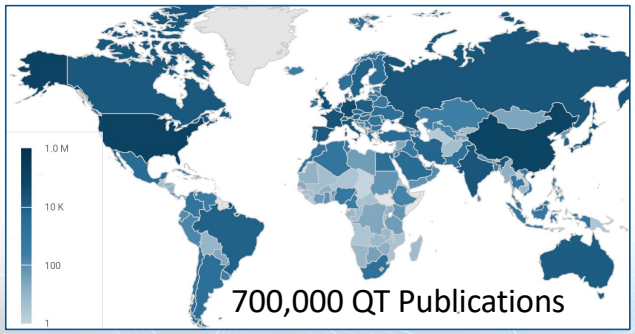
Innovation



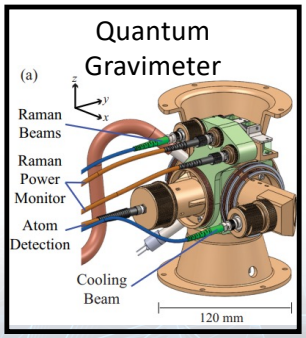
Economy



International



Technology



Jobs

$4 Billion private sector investment in QT in 2024 (mostly in Q.Comp)

Shortage of talent for QT jobs

- 1089 open QT jobs per QED-C
- 700 open QT jobs per McKinsey
- 520 open QT jobs per ORNL

Education & Workforce: National Q-12 Educational Partnership

OSTP and NSF spearheaded partnerships between federal government, industry, professional societies and the education community to foster the expansion of access to K-12 quantum learning tools and inspire the next generation of quantum leaders.

Access to Learning Resources

- High-quality, age-appropriate learning materials and tools
- Quantum Activities in the classroom
- Pathways and content for students, teachers and families to learn about QISE

Careers Outreach

- Community blog to share quantum and STEM
- Networking events to connect QISE experts with students and teachers

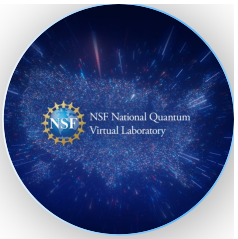
Teacher Support

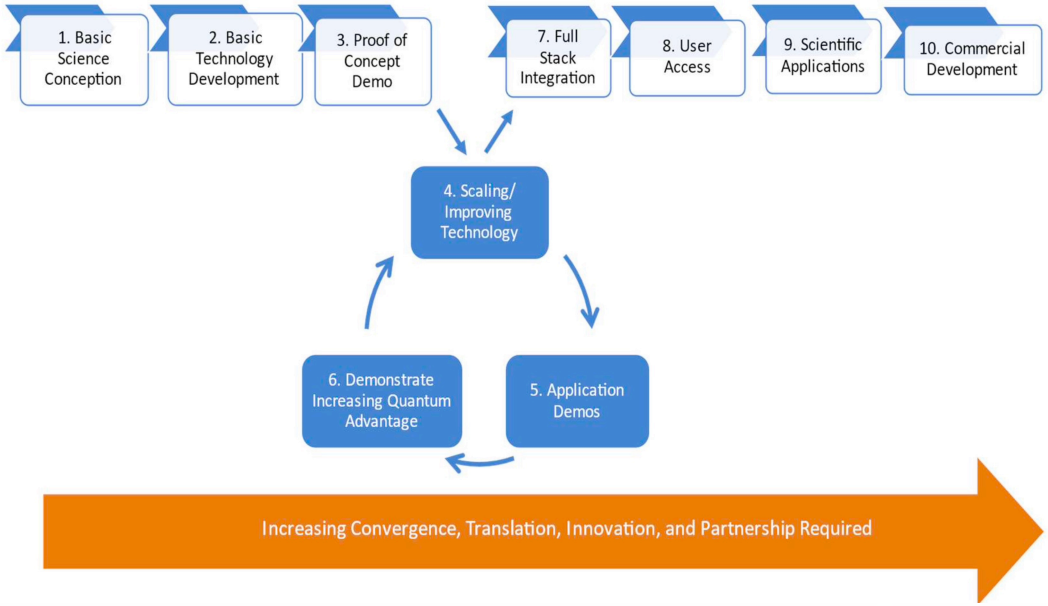
- Summer QIS workshops
- Community Townhalls
- Sharing teacher success stories of quantum in the classroom

Prep for Future Curricula

- Apply NSF QIS Key Concepts to future learners
- Working groups led by teachers to connect Key Concepts to Chemistry, Math, Physics and Computer Science

Infrastructure (testing):
NQVL – National Quantum Virtual Laboratory





Co-design
Discoverers, developers, builders, end users

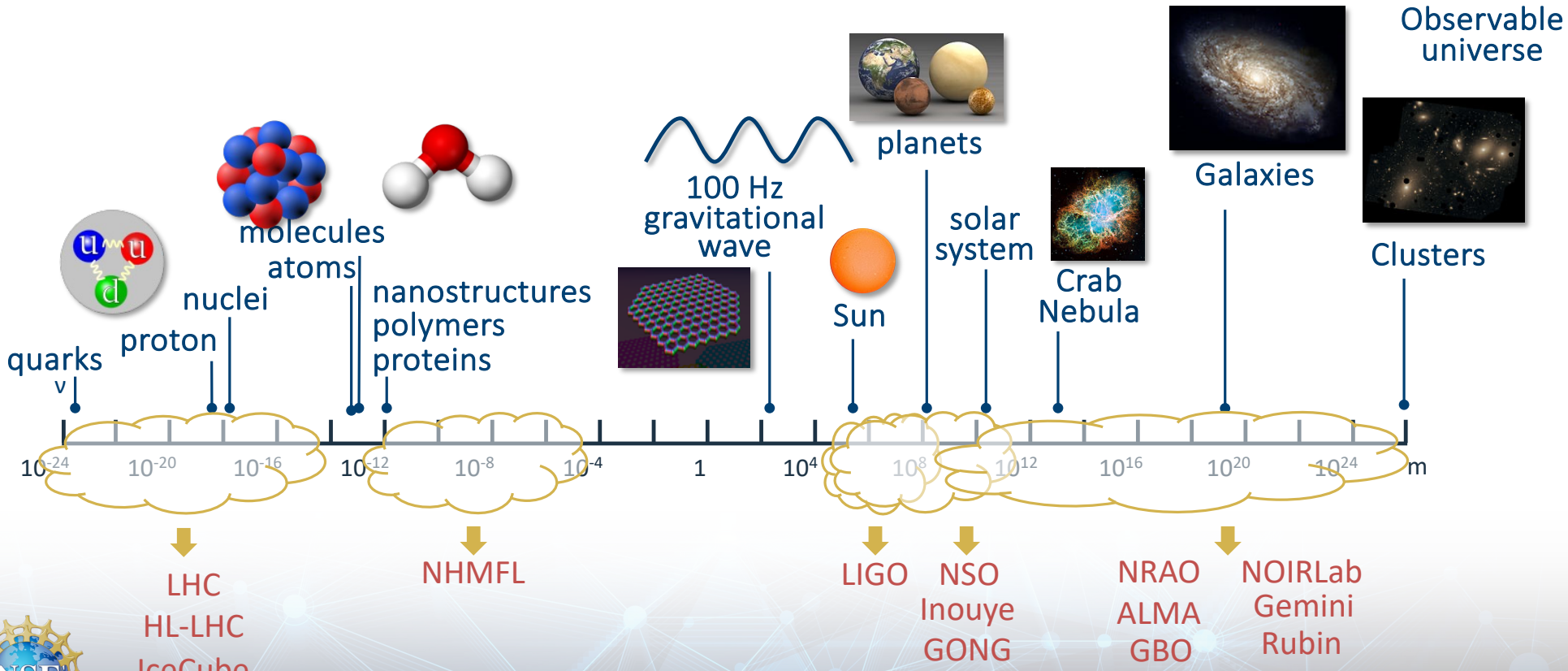
Contributors
Across diverse NSF networks like QLCIs and ExpandQISE

Prototypes
Tools and materials are available to all in the network

Solicitation NSF 23-604:
11 Pilot (phase 1) projects announced in 2024 and 2025

Solicitation NSF 23-586
NQVL Testbeds phase 2 and 3

MPS Major Facilities Portfolio

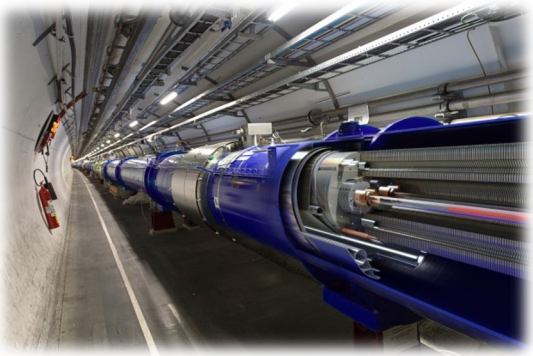


MPS Major Facilities

- Generators of "discovery science"
- Produce enormous amounts of data
- Great potential for harnessing and synthesizing this data through AI

Cornell High Energy Synchrotron Source (CHESS)

Large Hadron Collider (LHC)



National Optical-Infrared Astronomy Research Laboratory (NOIRLab) - e.g., Rubin Observatory

National Solar Observatory (NSO) - e.g., Daniel K. Inouye Solar Telescope

IceCube Neutrino Observatory

National Radio Astronomy Observatory (NRAO) - e.g., Atacama Large Millimeter /submillimeter Array (ALMA)

National High Magnetic Field Laboratory (MagLab)

Laser Interferometer Gravitational-Wave Observatory (LIGO)

LIGO 4th Observing Run (O4)

- LIGO fourth observational run (O4) started on May 24, 2023, and will end in late 2025/ early 2026
- O4 continues very successfully with the participation of Virgo in Italy. So far, 203 binary black hole mergers have been detected in O4, taking the total number of events close to 300
- LIGO is preparing several articles with events of significant importance, to be published in the summer
- A two-month commissioning break started in April 2025 to make some sensitivity enhancements and fix a non-functioning gate valve at Livingston
- Coming off commissioning, LIGO is on track to reach the 190 Mpc sensitivity planned for O4
- Virgo is currently operating at a sensitivity of 55 Mpc (close to the one in the previous run). Virgo is presently undergoing a design overhaul to be implemented after O4

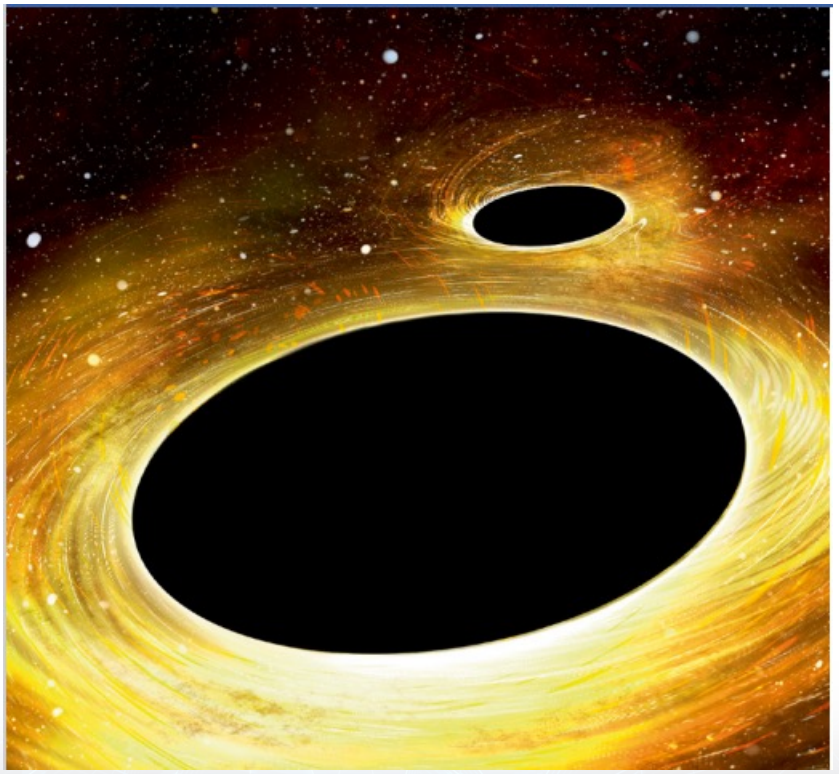


Image: Laurence Datrier
LIGO Livingston (Credit: LIGO.org)

Physics World Breakthrough of the Year for 2025

The ALICE, ATLAS, CMS and LHCb collaborations at the Large Hadron Collider (LHC) at CERN were honored with the Breakthrough Prize in Fundamental Physics by the Breakthrough Prize Foundation.

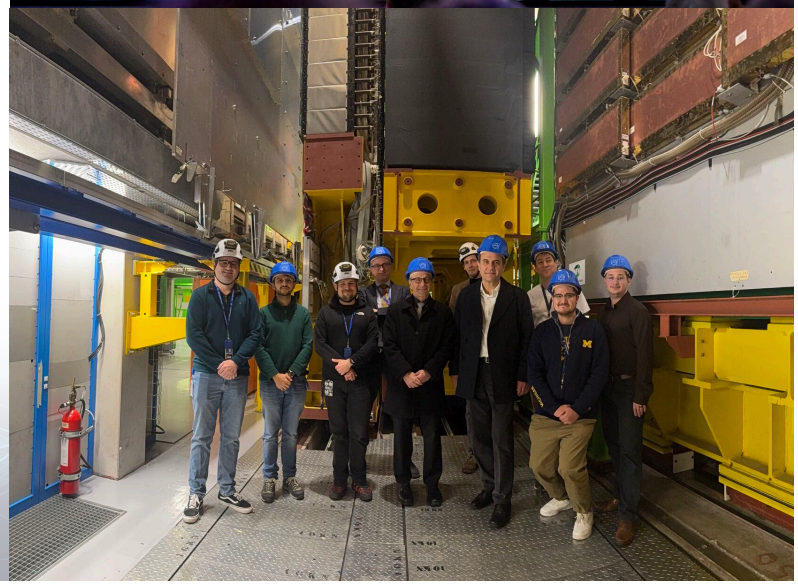
Recognition for:

- Precise Higgs boson measurements
- Discovery of new strongly interacting particles
- Studies on rare processes and matter-antimatter asymmetry
- Exploration at extreme conditions and shortest distances

Global Collaboration: Thousands of researchers from over 70 countries

Prize Details:

- $3 million awarded
- Donated to CERN & Society Foundation
- Funds to support doctoral research at CERN



NSF ZEUS Laser User Facility

Zettawatt Equivalent Ultrashort pulse laser System

- First dedicated high field science user facility with the highest peak power laser in the U.S. (2 PW demonstrated, 3 PW in commissioning)
- Phased-in user operations since November 2023
- Construction completed in March 2025

Science Being Explored:

- Fundamental physics of non-linear QED
- High energy astrophysical phenomena
- Production of GeV ion beams
- Pump-probe femtosecond x-ray experiments

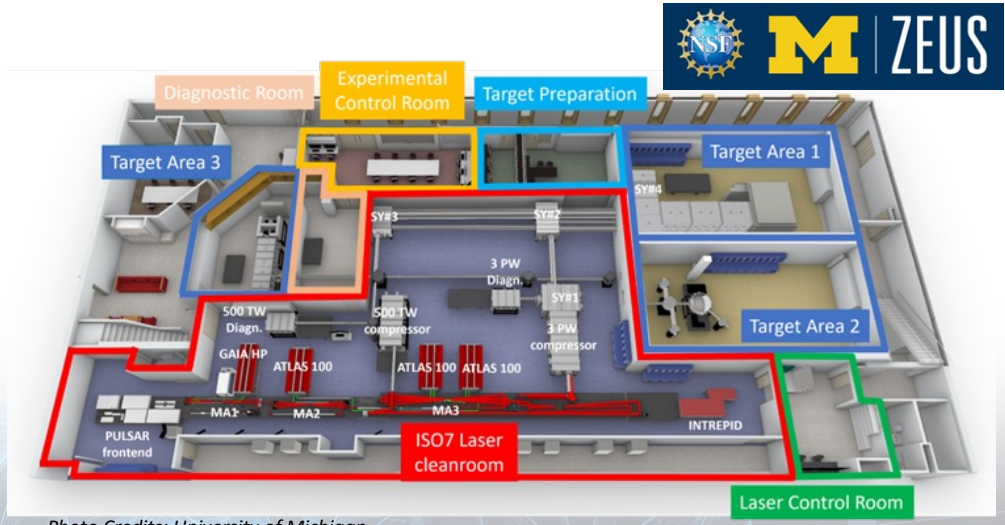


Photo Credits: University of Michigan

Reaching Out to Community: X-Lites User & Facilities Seminar - April 29th

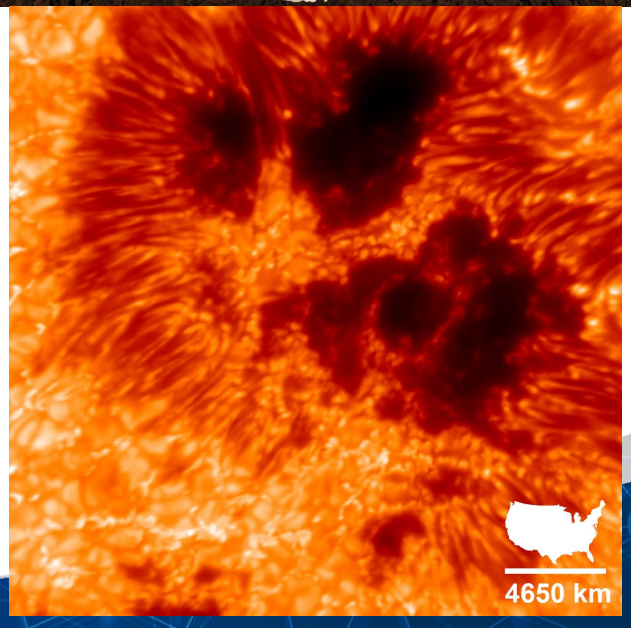
The Extreme Light in Intensity, Time, and Space (X-lites) network fosters worldwide collaboration to harness new extreme light facilities. This network connects facility users with operators, aiming to advance high-impact science and engineering through the utilization of extreme light

X-lites Network hosted the first seminar in its online series showcasing the X-lites Network of extreme light facilities.

This event was hosted by the Facilities & Users working group, which is dedicated to addressing challenges and sharing best practices to enhance facility operations and researcher experiences. The working group's initiatives and opportunities for involvement were also discussed.

Daniel K. Inouye Solar Telescope

- **Ongoing Operations Commissioning Phase**
  - Completing commissioning of telescope and five instruments while also performing observations for the community
  - Cycle 3 for proposals closed June 2024
- **First light achieved with final instrument: the new Visible Tunable Filter (VTF)**
  - Designed and built by the Institut für Sonnenphysik (KIS) in Freiburg, Germany, the VTF is the world's largest imaging spectro-polarimeter
- The newly released image reveals a cluster of sunspots on the Sun's surface with a spatial sampling of 10 km (or 6.2 miles) per pixel.



Very Long Baseline Array (VLBA): NSF/USNO collaboration, Present and Future

- Over the past decade, a strong collaboration between USNO, NSF, and NRAO has created key roles for NSF's infrastructure across important national interests, including time-keeping and navigation (GPS, Earth Orientation Parameters), as well as correlator/receiver construction.
  - USNO provides 50% of VLBA operations support
- Beyond current initiatives, NRAO has responded to USNO requests for analyses and proposals exploring sought-after technological and resilience improvements.
  - Over $30M in improvements enhancing VLBA performance
- NRAO Operations, Data Management, and Procedures have evolved over the past several years to foster the USNO collaboration; broad organizational coupling at this point.

NSF-DOE Vera C. Rubin Observatory

*Executing the **Legacy Survey of Space and Time (LSST)***

- A NSF/DOE collaboration, Rubin Observatory is an **8.4 m telescope** on Cerro Pachón in northern Chile with a **3.2 gigapixel camera**
- Once survey operations begin, Rubin will survey the whole southern sky every ~3 nights for 10 years

- First engineering image through the telescope onto an engineering camera was achieved on 10/24/2024
- ***First images were taken with the fully functional system, including the science camera, on 4/15/2025 !***

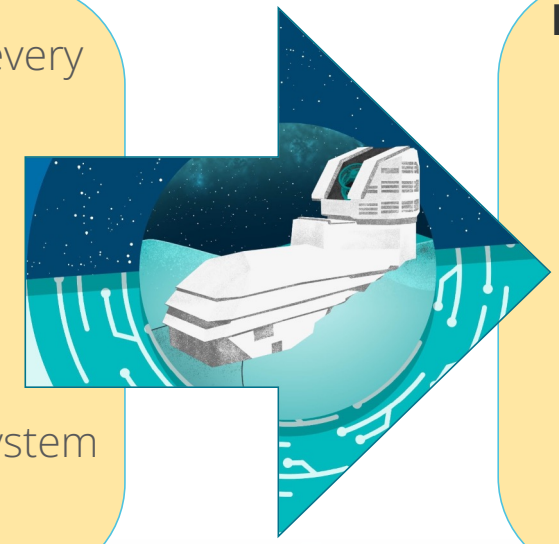
- Looking forward to the release of **First Look** images in Jun/Jul 2025

What is to come from Rubin + LSST?

Big data! 20 TB data/night, every night, for 10 years!

Over the ten-year survey:

- 20 billion galaxies
- 17 billion resolved stars
- 6 million orbits of solar system bodies
- Alerts per night ~ 10 million



Key research areas:

- Probing **dark energy** and **dark matter**
- An inventory of the **solar system**
- Exploring the **transient optical sky**
- Mapping the **Milky Way**

... and much more,
including incredibly engaging Citizen Science

NSF-Simons AI Institute for Cosmic Origins (CosmicAI)

PI: Stella Offner
University of Texas

Lead Institutions

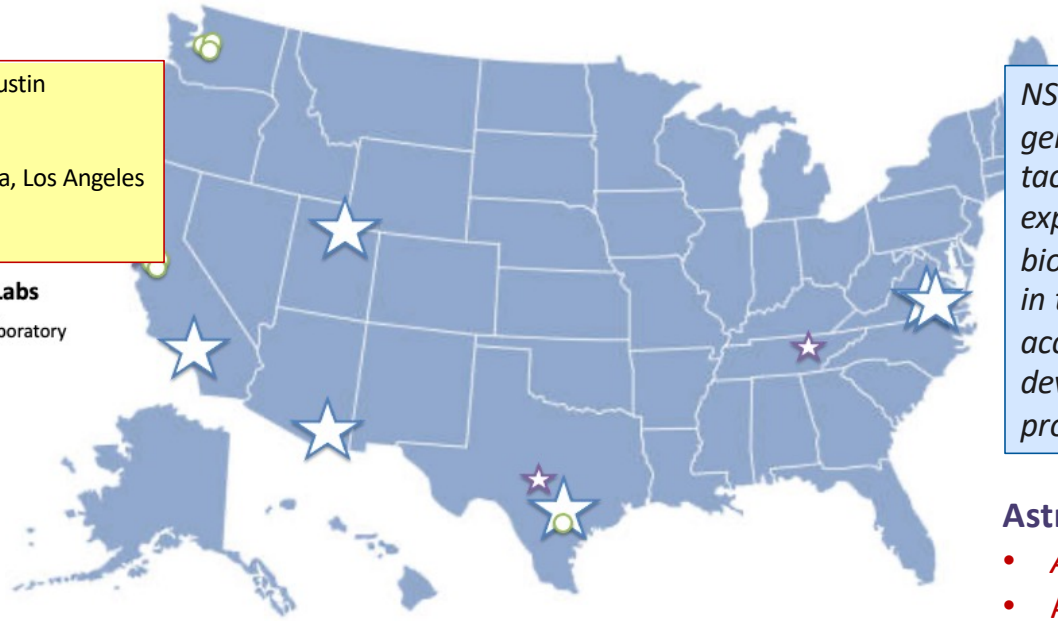
- University of Texas, Austin
- University of Virginia
- University of Utah
- University of California, Los Angeles
- NRAO
- NOIRLab

Academic Parters & Labs

- SLAC National Accelerator Laboratory
- University of Texas Arlington
- University of Tennessee

Industry Partners

- AI2
- Microsoft
- Intel
- NVIDIA
- Sony AI
- Amazon
- SparkCognition



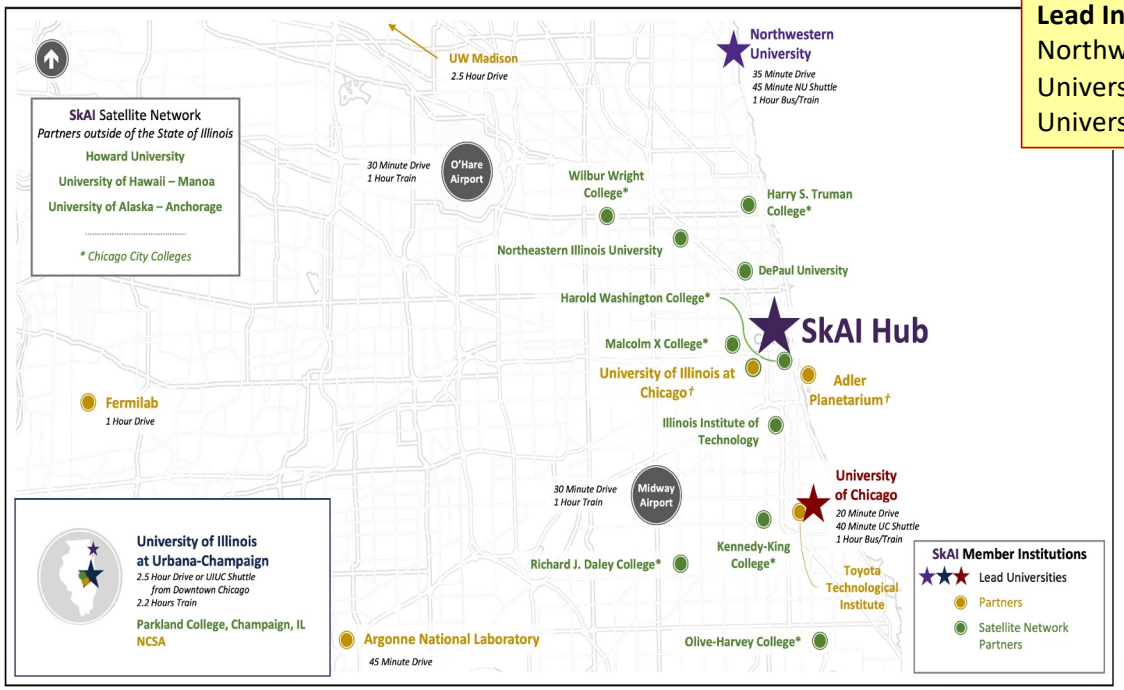
NSF-Simons CosmicAI aims to create next-generation AI tools to accelerate discoveries, tackle the analysis of large astronomical datasets, explore the nature of dark matter, and model pre-biotic molecules that are key to understanding life in the Universe. The institute plans to democratize access to astronomical data and analysis by developing a powerful AI-based assistant that provides accurate responses to scientific queries.

Astronomy research themes

- *AstroCopilot* and Data Platform
- Analysis of large radio datasets
- Dark matter
- Modeling prebiotic molecules

NSF-Simons AI Institute for the Sky (SkAI)

Funded by the U.S. National Science Foundation and the Simons Foundation



Lead Institutions:
Northwestern University
University of Chicago
University of Illinois at Urbana-Champaign

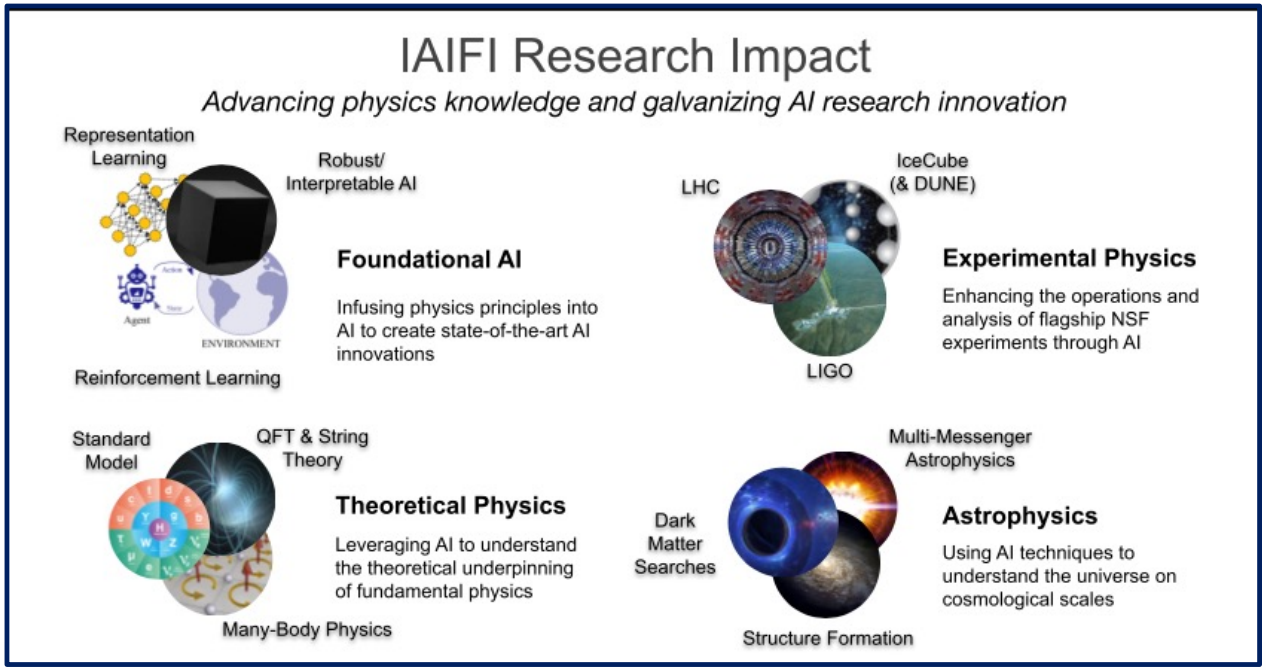
PI: Vicky Kalogera
Northwestern University

NSF-Simons SkAI will tackle exceptionally complex problems in astrophysics and astronomy across a broad range of cosmic scales, from the physics of exotic objects like neutron stars and black holes to the formation of galaxies and the role that dark matter and dark energy play across the entire universe.

Astronomy research themes

- Time domain astronomy
- Precision cosmology
- AI-Accelerated simulations
- Instrument design

The NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)



- Deep Learning (AI) + Deep Thinking (Physics) = Deeper Understanding
- Collaboration of physics and AI researchers at MIT, Harvard, Northeastern, and Tufts.

INTRODUCTION TO THE MOLECULE MAKER LAB INSTITUTE
AN INNOVATION ECOSYSTEM

MOLECULE MAKER LAB INSTITUTE

Huimin Zhao
UIUC, Director

Martin Burke
UIUC

Scott Denmark
UIUC

ENABLING TECHNOLOGIES

- AI / ML
- Dynamic Databases
- Automated Synthesizer
- iBioFAB

AI-enabled Synthesis Planning

Education & Workforce Development

Alphasynthesis & Closed DBTL Loop

AI tools to address:
1. Cold start problem
2. Small data
3. Standard tools failing to give good models

RIT

AI-enabled Catalyst Development

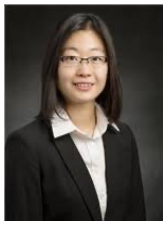
AI-enabled Molecule Manufacturing

AI-enabled Molecule Discovery

Industrial Partnership

abbvie
REVOLUTION MEDICINES
LanzaTech
NVIDIA
AMGEN
IBM

Jiawei Han
UIUC



Ying Diao
UIUC

Rachel Switzky
UIUC

National AI Institutes Led By MPS

Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)

Hub: MIT

(PHY 2019786)

Molecule Maker Lab Institute (MMLI)

Hub: UIUC

(CHE 2019897)

NSF-Simons AI Institute for Cosmic Origins (CosmicAI)

Hub: UT-Austin

(AST-2421782)

NSF-Simons AI Institute for the Sky (SkAI)

Hub: Northwestern University

(AST-2421845)


NSF