

Madhur Mehta

Heising-Simons QuRIOS Postdoctoral Fellow · University of California, Santa Barbara

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Research Profile

Theoretical physicist specializing in **black holes**, **gravitational waves**, **effective field theory**, **black-hole perturbation theory**, and **quantum field theory in curved spacetime**. My research develops analytic and computational frameworks connecting fundamental gravitational physics to observable signatures, with particular emphasis on compact-object response, dissipation, scattering, and gravitational-wave observables. I also develop scientific software and AI-assisted research tools for information retrieval, computational exploration, and scientific reasoning.

Research Experience

University of California, Santa Barbara

Sep. 2025 – Present

Heising-Simons QuRIOS Postdoctoral Fellow

Santa Barbara, CA

- **Black-hole response and cavity effective field theory:** Co-developed a finite-radius effective framework for describing the response of compact gravitational systems and connecting internal dynamics to scattering and gravitational-wave observables.
- **Black-hole perturbation theory:** Developing gravitational response functions for perturbations of Schwarzschild black holes and extending the framework toward spinning black holes.
- **Dissipation and finite-frequency response:** Studying absorption, tidal interactions, fluxes, finite-frequency effects, and the relation between near-horizon dynamics and asymptotic observables.
- **Strong-field signatures of new physics:** Investigating how modifications of classical black-hole behavior can propagate into measurable scattering and waveform signatures.

The Ohio State University

Jan. 2021 – Jul. 2025

Ph.D. in Physics

Columbus, OH

Advisor: Prof. Samir D. Mathur

- **Universal black-hole thermodynamics:** Showed that sufficiently compact horizonless objects reproduce black-hole thermodynamic behavior under broad assumptions, identifying properties that do not depend explicitly on horizon formation.
- **Extremely compact objects:** Studied horizonless compact objects and extensions involving charge and other black-hole-like properties.
- **Electromagnetic entrapment in strong gravity:** Co-developed compact electromagnetic configurations trapped by strong gravitational fields that reproduce several macroscopic properties associated with black holes.
- **D1–D5 conformal field theory:** Studied lifting of superconformal descendants and multi-mode states relevant to the microscopic description of black-hole states.

- **Black-hole information problem:** Investigated microscopic and semiclassical approaches to the information problem, including fuzzball physics, quantum extremal surfaces, and related questions in gravitational entropy.

Indian Institute of Science

Sep. 2019 – Mar. 2020

Master's Thesis Research

Bengaluru, India

Advisor: Dr. Chethan Krishnan

- Studied quantum extremal surfaces, entanglement wedge reconstruction, generalized entropy, and the Page curve in AdS/CFT approaches to the black-hole information problem.

Johannes Gutenberg University Mainz

May – Jul. 2018

DAAD WISE Research Fellow

Mainz, Germany

Advisor: Prof. Sebastian Boeser

- Characterized the timing response of wavelength-shifting optical modules using picosecond light sources and silicon photomultiplier detectors.

University of Tokyo

Jun. – Aug. 2017

UTRIP Research Fellow

Tokyo, Japan

Advisor: Prof. Shuji Hasegawa

- Studied the growth and characterization of $(\text{Bi}_x\text{Sb}_{1-x})_2\text{Te}_3$ topological-insulator materials and associated experimental instrumentation and data analysis.

IISER Bhopal

Apr. – May 2017

Summer Research Intern

Bhopal, India

Advisor: Prof. Surajit Saha

- Studied solid-state spectroscopy techniques, including Raman spectroscopy, for condensed-matter systems.

Education

The Ohio State University

2021 – 2025

Ph.D. in Physics

Columbus, OH

Advisor: Prof. Samir D. Mathur

Thesis: *Through the Horizon and Back: Lifting the Veil on Black Hole Thermodynamics*

The Ohio State University

2022

M.S. in Physics

Columbus, OH

Indian Institute of Science Education and Research Bhopal

2015 – 2020

Integrated B.S.–M.S. in Physics

Bhopal, India

Publications

1. S. B. Giddings and **M. Mehta**, *Deriving Effective Descriptions and Signal Predictions for Dynamical Gravitational Systems*, arXiv:2606.19435, 2026.
2. S. Chakraborty, **M. Mehta**, and G. Patashuri, *Extremal Curves in Single-Trace $T\bar{T}$ -Holography*, *Journal of High Energy Physics* 11 (2025) 128.
3. **M. Mehta**, *Extreme Compactness, Extreme Gravity: Higher-Derivative Corrections to ECOs*, arXiv:2505.09049, 2025. *Honorable Mention, Gravity Research Foundation Essay Competition, 2025.*
4. S. D. Mathur and **M. Mehta**, *The Fuzzball Paradigm*, arXiv:2412.09495, 2024. *Invited chapter for The Black Hole Information Paradox.*
5. S. D. Mathur and **M. Mehta**, *The Universal Thermodynamic Properties of Extremely Compact Objects, Classical and Quantum Gravity* 41 (2024) 23, 235001.
6. P. Heidmann and **M. Mehta**, *Electromagnetic Entrapment in Gravity*, *Journal of High Energy Physics* 03 (2024) 046.
7. M. R. R. Hughes, S. D. Mathur, and **M. Mehta**, *Lifting of Superconformal Descendants in the $D1-D5$ CFT*, *Journal of High Energy Physics* 04 (2024) 129.
8. M. R. R. Hughes, S. D. Mathur, and **M. Mehta**, *Lifting of Two-Mode States in the $D1-D5$ CFT*, *Journal of High Energy Physics* 01 (2024) 183.
9. S. D. Mathur and **M. Mehta**, *The Universality of Black Hole Thermodynamics*, *International Journal of Modern Physics D* 32 (2023) 14, 2341003. *Third Prize, Gravity Research Foundation Essay Competition, 2023.*
10. B. Guo, M. R. R. Hughes, S. D. Mathur, and **M. Mehta**, *Universal Lifting in the $D1-D5$ CFT*, *Journal of High Energy Physics* 10 (2022) 148.
11. **M. Mehta**, *Redefining Entanglement Entropy – Can It Solve the Information Paradox?*, arXiv:2204.00192, 2022.
12. B. Guo, M. R. R. Hughes, S. D. Mathur, and **M. Mehta**, *Contrasting the Fuzzball and Wormhole Paradigms for Black Holes*, *Turkish Journal of Physics* 45 (2021) 6, 281–365.

Scientific and Educational Software

Naksh – Personalized Research Discovery

2026 – Present

- Designed and built an iOS research-discovery application that retrieves recent arXiv papers and ranks them according to a researcher’s active themes, followed authors, publication history, and relevance feedback.
- Developed personalized ranking, research-lens explanations, author prioritization, multi-category arXiv scanning, local caching, and research-journal workflows.
- Integrated arXiv and INSPIRE-HEP data with optional LLM-assisted commentary intended to explain research relevance rather than merely summarize abstracts.

- **Status:** Under iOS App Store review.

WohTara – Stargazing and Cosmic-Scale Exploration

2026 – Present

- Built an iOS prototype combining location-aware stargazing, celestial-object exploration, deep-time visualization, and an interactive journey across astronomical distance scales.
- Implemented astronomical calculations for object positions, altitude and azimuth, visibility, constellation geometry, and location-dependent sky views.
- Integrated device location, motion sensors, compass information, camera functionality, and interactive astronomical visualizations.
- **Technology:** Swift, SwiftUI, Core Location, Core Motion, AVFoundation, SceneKit, and UIKit.
- **Status:** Functional prototype.

BolChaal – Hindi Language and Devanagari Learning

2026 – Present

- Developing an iOS language-learning application focused on practical spoken Hindi together with systematic Devanagari literacy.
- Designed an *Akshar* learning system combining letter recognition, pronunciation, transliteration, stroke-order practice, handwriting, and mnemonic cues.
- Developed the interface around compact lessons, pronunciation support, progress tracking, and accessible typography for new Hindi learners.
- **Status:** Active development.

Selected Talks and Presentations

- *From Interior Dynamics to Exterior Observables: Cavity EFT and Finite-Radius Response Functions*, QuRIOS Collaboration Meeting, July 2026.
- *Extremely Compact Objects and Their Potential Observational Signatures*, High Energy Physics Lunch Seminar, Kavli Institute for Theoretical Physics, October 2025.
- *Universality of Black-Hole Thermodynamics*, QuRIOS Collaboration Meeting, September 2025.
- *What Are Fuzzballs and Extremely Compact Objects?*, TASI Summer School, University of Colorado Boulder, June 2025.
- *Universal Thermodynamics of Extremely Compact Objects*, Strings 2024, poster presentation, June 2024.
- *The Ohio State University David DeMartini Poster Competition*, poster presentation, May 2024.
- *Universal Thermodynamics of Extremely Compact Objects*, APS Eastern Great Lakes Section Meeting, invited speaker, April 2024.
- *The Ohio State University Hayes Forum*, invited talk, March 2024.

Teaching and Mentoring

Physics Summer Research Program Advisor

May – Jul. 2024

The Ohio State University

- Mentored an undergraduate research student and introduced them to general relativity and theoretical-physics research.

Graduate Teaching Assistant

2021 – 2022

The Ohio State University

- Physics 1251: Calculus-Based Electricity and Magnetism, Waves, Optics, and Modern Physics.
- Physics 1201: Algebra-Based Electricity and Magnetism, Waves, Optics, and Modern Physics.
- Physics 5300: Theoretical Mechanics.

Scientific Communication, Outreach, and Service

Stargazing Guide, Alta Vista Tours

2026 – Present

Lead small-group guided stargazing experiences in the Santa Barbara area, using telescopic observations to introduce guests to planets, stars, star clusters, nebulae, galaxies, constellations, and connections between astronomy, mythology, and the human experience of the night sky.

Time Before Space

2021 – Present

Founder and host of a science-communication YouTube channel on fundamental physics and foundational questions. Interviews include Juan Maldacena, Abhay Ashtekar, Gary Horowitz, Niayesh Afshordi, Sera Markoff, and Samir Mathur.

Other Outreach and Service

- Public talk, “Perspectives of Gravity,” Upper Arlington Library, July 2023.
- Physics outreach volunteer, Ohio State Fair Youth Exploration Space, July–August 2023.
- Journal article reviewer, *International Journal of Modern Physics D*, 2021.
- Judge, Metro Capstone Symposium, Metro Early College High School, 2021.

Honors and Awards

- Heising–Simons QuRIOS Postdoctoral Fellowship, 2025–present.
- The Ohio State University Presidential Fellowship, 2024–2025.
- First Prize, The Ohio State University David DeMartini Poster Competition, 2024.

- Third Prize, Gravity Research Foundation Essay Competition, 2023.
- DAAD WISE Fellowship, 2018.
- University of Tokyo Research Internship Program Fellowship, 2017.
- Asian Science Camp Representative for IISER Bhopal, 2016.
- Bharat Ratna Prof. C. N. R. Rao Award, 2015.
- INSPIRE-SHE Scholarship, Department of Science and Technology, India, 2015–2020.

Technical Skills

Physics: General relativity; black-hole perturbation theory; effective field theory; gravitational-wave physics; QFT in curved spacetime; black-hole thermodynamics; compact objects; conformal field theory.

Scientific Computing: Mathematica; Python; analytic and perturbative calculations; symbolic computation; numerical prototyping.

Software Development: Swift; SwiftUI; TypeScript; React; Node.js; Express; REST APIs; mobile application development; iterative testing and debugging.

AI-Assisted Scientific Tools: LLM API integration; scientific-information retrieval; personalized ranking; relevance evaluation; research-workflow prototyping.