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Affiliations

Adjunct Faculty (Full-time) Jan 2025 – *present*	Texas A&M University – San Antonio, (TAMU-SA), 1 University Way, San Antonio, TX, 78224, USA.
PhD; Physics 2019 – 2025	University of Texas at Dallas, (UTD), 800 W. Campbell Rd., Richardson, TX, 75080, USA.
Bachelor's and Master's 2012 – 2018	Indian Institute of Science Education and Research, Kolkata, (IISER-K), Mohanpur, Haringhata Farm, West Bengal, 741246, India.

Research Experience

- **Spacetime Structure of Accelerating Black Holes:**

  We investigate the structure of the spacetime around accelerating black holes in General Relativity. When a black hole accelerates, the spacetime around it becomes distorted in ways that differ significantly from the well-known Schwarzschild or Kerr solutions for stationary black holes. As it accelerates, it generates conical defects on its axis that are interpreted as cosmic strings/struts. The introduction of external gravitational or electromagnetic fields can regularize the axis, as such external fields 'explain' the source of acceleration. Physically, they model realistic astrophysical scenarios where black holes interact with external forces, such as those from nearby massive objects, cosmic fields, or in dynamic environments like galaxy mergers. We investigate the structure of spacetime around such local/distorted black hole systems.

- **Near-horizon Symmetries of Axisymmetric Black Holes:**

  In recent years, analyses of near-horizon symmetries of black holes have gained prominence after Hawking's 2015 proposal that such symmetries could encode information which can address the black hole information paradox. This has led to a substantial body of literature studying near-horizon symmetries and their associated algebras in various black hole spacetimes. We study the near-horizon symmetries of "local" black holes that can either have spherical or toroidal horizon topologies, despite being solutions of vacuum Einstein's equations. Physically, local black holes represent all static axisymmetric electrically neutral black holes which are distorted by external gravitational fields. Building on earlier works in the literature that primarily focused on black holes with spherical horizons, we compute the algebra of the Killing vector fields that preserve the asymptotic structure near the horizons and the algebra of the associated Noether-Wald charges under the boundary conditions that produce the BMS and the Heisenberg-like algebras. We show that a similar analysis extends to all local axisymmetric black holes.

- **Shadows of Black Holes:**

  As part of my Master's thesis, we constructed the shadow of non-commutative (NC) geometry inspired Ayón Beato García (ABG) black hole. ABG black hole is a non-singular exact black hole solution of the Einstein field equations coupled to nonlinear electrodynamics that satisfies the weak energy condition. Shadows are the apparent shapes of black holes that form as a result of light bending around them, in contrast to the usual shadows that form as a result of opacity. One of the approaches to quantum gravity is to introduce non-commutativity in classical spacetime geometry. Specifically, NC black hole solutions differ from classical ones by

having no singularities at the center due to the smearing effect of non-commutative coordinates. We investigated the differences in shadows due to the two types of holes.

Notable Short Research Projects

- **2017**: **Classical 3-body problem simulation using VPython.**

  We developed an interactive software to simulate the classical 3-body problem, with options to edit parameters and initial conditions. This tool can be used for visual exploration of the complex interactions that arise in such chaotic systems, dynamics around the Lagrange points, and stability of the orbits. VPython for simulations and TKinter for the user interface were used.

- **2015**: **Design, fabrication and characterization of polymer lenses.**

  Designed a lens system for low-cost mobile phone microscopy and realized the new fabrication technique to develop polymer lenses. The lenses were then characterized and showed to produce a magnification of about 100X with a resolution of 2.19μm over a wide field of view.

- **2014**: **Controlled flotation of droplets for fabrication of polymer lenses.**

  Developed a new polymer lens fabrication technique, based on a simple density gradient profile of the polymer and controlled flotation of water droplets while curing. These low-cost polymer lenses can be used for mobile phone microscopy. A patent has been filed at the Intellectual Property Cell, IISc Bengaluru, but was rejected due to uncertainty on large-scale implementation.

Teaching Experience

- **General and University Physics**
  - I have been teaching undergraduate algebra and calculus-based introductory physics courses (both lectures and labs) for approximately six years. Served as a primary instructor at TAMU-SA and a teaching assistant (TA) at UTD.
  - Worked with both science and non-science majors. Consistently received excellent feedback on teaching performance.
  - Collaborated with another TA during the COVID-19 pandemic to create instructional lab videos, enabling students to complete lab work remotely.
  - Responsible for teaching, grading, maintaining laboratory equipment, and holding office hours.
  - Conducted weekly recitation sessions that led to significant improvements in student exam scores. Was awarded the Best Teaching Assistant Award in recognition of this achievement.
- **Undergraduate Theoretical Physics**
  - While serving as a TA for this course, I prepared complete solutions to all homework assignments.
- **Graduate Mathematical Physics I and II**
  - I was given the opportunity to serve as a TA for these courses based on my strong performance as a graduate student.
- **Graduate Quantum Mechanics I and II**

- Stepped in to teach a few Quantum Mechanics I lectures when the instructor was unavailable due to health reasons. Also contributed by developing midterm and final exam questions.
- I was chosen to serve as a TA for Quantum Mechanics II based on my strong performance and subject knowledge as a graduate student.

- **Graduate Electrodynamics II**
  - Assisted a first-time instructor by helping in preparing lecture notes, homework solutions, and midterm and final exam questions.

Mentorship Experience

- **Summer 2024**: **Mentored a summer research student from the REU Program.**

  We investigated near-horizon symmetries and the associated group algebra in spherically symmetric, non-asymptotically flat spacetimes. This work addresses the universality of the hidden symmetries approach to explain the information paradox. The work resulted in a poster presentation.

- **Summer 2023**: **Mentored high school students during their summer research projects on Quantum Computing and Quantum Information.**

  Developed and taught a course on the basics of quantum mechanics suitable for the level of high school students. This internship was a joint outreach exercise by the Computer Science and the Physics departments at UTD, and was the first of its kind. I was given the opportunity to teach the necessary basics. Later, I developed interactive teaching material using the IBM quantum lab for potential future courses.

- **Summer 2021**: **Co-mentored a summer research student from the REU program.**

Publications

M. M. Akbar, S. M. Modumudi; **Near-horizon symmetries of local black holes**, arXiv: 2503.13420.

M .M. Akbar, C. P. Brewer, S. M. Modumudi; **Spacetime Structure of Regular Accelerating Black Holes in General Relativity**, arXiv:2503.09915.

A. Agashe, S. M. Modumudi; **On the Effects of Non-metricity in an Averaged Universe**, Universe, 10, 261, (2024), 10.3390/universe10060261.

A. Saha, S. M. Modumudi, S. Gangopadhyay; **Shadow of a noncommutative geometry inspired Ayón Beato García black hole**, Gen. Rel. Grav., 50:103, (2018), 10.1007/s10714-018-2423-z.

Presentations

Presentation **Solving the black hole information paradox**, Graduate Students in Physics seminar, Oct 2024, Department of Physics, UTD.

Presentation **Near Horizon Symmetries of Local Black Holes**, Physics-2024 Conference, Boston, MA, USA.

Presentation **Black Hole Entropy and Thermodynamics** at Graduate Students in Physics seminar, Mar 2024, Department of Physics, UTD.

Series of presentations on differential forms, peeling theorems in general relativity and gravitational waves in asymptotically flat spacetimes, at a student-organized lecture series, Spring 2022, Department of Mathematics, UTD.

Presentation **On the shadow of black holes** at Graduate Students in Physics seminar, Feb 2020, Department of Physics, UTD.

Presentation **Floating droplet based polymer lens fabrication for applications in mobile phone microscopy**, International Conference on Optics and Photonics, 2015, University of Calcutta.

Leadership Roles

- 2019 – 22: Co-chair of the **Graduate Students in Physics Seminar Committee**, responsible for organizing student seminars.
- 2015: Co-founded **Ek Pehal**, a student-led organization providing free education to underprivileged children in rural India. Developed the organizational structure and designed a system for seamless course continuity among multiple instructors.

Awards and Achievements

- Won the **Best Teaching Assistant Award** for the academic year 2023, Department of Physics, UTD.
- Recepient of **INSPIRE Scholarship**, Department of Science and Technology, Government of India.
- Ranked 77 (out of ∼8,000 participants) in the Joint Entrance Screening Test (JEST), a nationwide Ph.D. screening exam conducted in India.
- Ranked 7358 (out of ∼450,000 participants) in the Indian Institute of Technology Joint Entrance Exam (IIT-JEE), a nationwide undergraduate screening exam conducted in India.

Skills and Miscellaneous

- Fluent in English, Telugu and Hindi.
- Good in LaTeX, Gnuplot, MATLAB, Mathematica, Maple, and Python.
- Helped organize the 64^{th} Texas Geometry and Topology Conference at UTD.