Sai Madhav Modumudi

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Education and Employment

Adjunct Professor 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

- **Near-horizon Symmetries of Axisymmetric Black Holes** 2024 – present

  We analyzed the near-horizon symmetries of static, axisymmetric four-dimensional "local/distorted" black holes in vacuum general relativity, with spherical and toroidal horizon topologies. We derived the Killing vector algebra and the corresponding Noether-Wald charge algebra for boundary conditions yielding spin-s BMS_d and Heisenberg-like algebras. We showed that the near-horizon algebra changes considerably for the toroidal horizons. We re-examined the thermodynamics in this context and found that the first law generally fails for nonzero spin parameter s, consistent with soft-hair energy contributions.

- **Spacetime Structure of Accelerating Black Holes** 2023 – present

  We investigated the structure of the spacetime around regularized accelerating black hole pair in General Relativity. We analyzed nodal singularities and the horizon topology via the Gauss-Bonnet theorem, showed both black hole and acceleration horizons are embeddable in $\mathbb{E}^3$, and mapped geometric properties across multiple coordinate systems. We also constructed detailed 2D and 3D conformal diagrams. We showed that the exponential factors introduce curvature singularities at infinity, implying that regularization is achieved at the cost of asymptotic flatness.

- **Shadows of Black Holes** 2017 – 2018

  As part of my Master's thesis, we constructed and investigated the shadow of a non-commutative geometry inspired Ayón-Beato-García black hole. Black hole shadows represent the apparent silhouette cast by the gravitational bending and capture of light near the event horizon, in contrast to ordinary shadows formed by opaque objects. We quantified how various black hole parameters effect the shadow's radius and distortion.

- **Classical 3-body problem simulation** 2016

  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.

- **Controlled flotation of droplets for fabrication of polymer lenses** 2014 – 2015

  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. Designed a lens system for low-cost mobile phone microscopy

based on 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. A patent has been filed at the Intellectual Property Cell, IISc Bengaluru, but was rejected due to uncertainty on large-scale implementation.

Teaching and Mentorship Experience

- **General and University Physics**
  - I have been teaching undergraduate algebra and calculus-based introductory physics courses (both lectures and labs) for more than six years.
  - I work with both STEM and non-STEM majors, consistently receiving excellent feedback on teaching performance.
- **Graduate Teaching Assistant**
  - Served as a teaching assistant for the following courses (in addition to the introductory courses mentioned above):
  - Theoretical Physics (Undergraduate)
  - Mathematical Physics I and II (Graduate)
  - Quantum Mechanics I and II (Graduate)
    - Stepped in to teach a few Quantum Mechanics I lectures when the professor was unavailable due to health issues. Also contributed by developing midterm and final exam questions.
  - Electrodynamics II (Graduate)
- **Mentored students working 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.
  - I also developed interactive teaching material using the IBM quantum lab for potential future courses.
- **Mentored summer research students from the REU program.**

Publications and Presentations

M. M. Akbar, S. M. Modumudi; **Near-horizon symmetries of local black holes**, Phys. Rev. D 112, 064022, (2025), 10.1103/zj3y-mk5t.

M .M. Akbar, C. P. Brewer, S. M. Modumudi; **Spacetime Structure of a Regular Accelerating Black Hole Pair in General Relativity**, Class. Quantum Grav. 42 175004, (2025), 10.1088/1361-6382/adf7fc.

Invited Paper: 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.

Presentation **On 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 – 21: 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.
- Top 1% in the Joint Entrance Screening Test (JEST), a nationwide PhD screening exam conducted in India.
- Top 1.5% 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.