
Academic Report (2022-23)



**Harish - Chandra Research Institute
Chhatnag Road, Jhunsi
Prayagraj - 211019, India**

Tapas K Das

Research Summary:

My broad areas of research are astrophysics, general relativity, and dynamical systems. For last one year, I have been working on black hole accretion, emergent gravity phenomena, theory of traversable wormholes, and application of the theory of dynamical systems in large scale fluid flow under strong gravity. With one of my Ph.D. students and external collaborators, I have started exploring the emergence of nonlinearity and chaotic traits of the dynamics of axially symmetric flow around black holes, and its signatures as revealed in the observed spectra.

I, along with my Ph.D. students and my post doctoral fellows, made two important contributions through our works published in the last one year, which are as follows:

In a set of two papers published in the Physical Review D Letters (Erstwhile Physical Review D Rapid Communication) and Physical Review D, we have demonstrated that an emergent space time can be obtained through nonlinear perturbation of arbitrary order of a transonic flow. As of now, every single work in the literature (on analogue gravity phenomena) constructs the black hole like analogue space time within flowing fluid by linearly perturbing the flow. We have explicitly demonstrated that such analogue space time can be produced even for nonlinear perturbation of higher orders. This proves that the emergent gravity phenomena is not an artifact of the linear perturbation process, rather it has a much deeper physical significance compared to what had been believed in the literature before our works. Our works in this direction have attracted attention in the community and has been highlighted by Nature (journal). One can go through the article published in Nature highlighting our works, the corresponding article, titled 'Model shows how to create a black hole in a lab', was published as a Nature highlights in the journal Nature on 29th of August, 2022. The corresponding URL of the article is

<https://www.nature.com/articles/d44151-022-00093-7>

In another series of published works, we have demonstrated, for the first time in the literature as we believe, how identify and classify the horizons in the emergent space time using the analogue Carter-Penrose diagrams. For the first time the construction of the compactified Causal structures have been used for study of analog spacetime embedded within a natural large scale fluid flow under the influence of strong gravity. Such works will be helpful in future to understand the natures of the analogue black hole horizons in various emergent gravity systems, as we believe.

In addition to the aforementioned works, we have devised an elegant technique which enables one to estimate, completely analytically (without any numerical computation) the multi transonic properties and the nature of related bifurcation phenomena for matter flow in accretion disc around non-spinning black holes.

We have also started working on astrophysical jets in connection to certain type of AGNs, and on traversable acoustic wormholes, which will be reported in the next academic report.

Invited Lectures/Seminars:

1. *Black Holes*, a popular lecture for the college and the university students on the occasion of the Department of Atomic Energy Azadi Ki Amrit Mahotsav iconic week held at HRI, Prayagraj in September 2023.
2. *Supermassive Black Holes in Astrophysics*, public lecture delivered at University of North Bengal, February, 2003.
3. *Massive Black Holes at the centres of the galaxies*, Colloquium presented at Visva-bharati University, Santiniketan, in March 2023.
4. As a part of the public outreach programme, I am involved in advocating the idea of the persuasion of higher education in mother tongue. I use to deliver lectures on popular topics in astrophysics in general, in Bengali language, at several schools and colleges in West Bengal upon invitation. Following is a list such talks I delivered at various undergraduate colleges in last one year. The duration for all such public lectures in Bengal were two hours, including an extensive discussion and question answer sessions:
 - (a) Public lecture in Bengali on the connection of the study of astronomy with various other branches of knowledge, i.e., philosophy and history of sciences, fine arts (classical European paintings), and literature, at Surendranath College, Kolkata , in September 2023.
 - (b) On the history of the discovery of giant black holes in the universe, a public lecture in Bengali at the Lady Brabourne College, University of Calcutta, in February, 2023.
 - (c) On general overview of astrophysical black holes, at Bhairab Ganguly College, West Bengal State University, January, 2023.

Other Activities:

1. Interview in Television:

I have been interviewed by Doordorshan (DD1) to discuss about the state of the art research on black hole astrophysics. The programme has been telecast in two episodes, with duration of thirty minutes for each episode. The YouTube links for the programmes are available at:

- (a) https://youtu.be/7gk_80Vd8H0
- (b) <https://youtu.be/2oVmkPrzTVA>

2. I served as the thesis examiner of a Ph.D. candidates which thesis was submitted in Jadavpur University. The works presented in the aforementioned thesis was on nonlinear dynamics.
3. Taught Mathematical Methods and Dynamical systems, two one semester courses at the M.Sc. course as conducted by HRI.