



Black Holes and Quantum Mechanics

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Why in News?

Recently, research conducted by a team of scientists from **S.N. Bose National Centre for Basic Sciences**, an **autonomous institute of the Department of Science and Technology**, has delved into the intriguing **realm of [black holes](#) and their interaction with [quantum mechanics](#)**.

- This exploration holds the potential to provide valuable insights into the unification of two significant scientific theories: **quantum mechanics and the general theory of relativity, propounded by Einstein**.
- The study focuses on **atoms freely falling into a black hole** and the novel quantum effects on the radiation emitted in this process.

Note:

- **General Theory of Relativity:** Albert Einstein's theory explains how objects move around massive ones. A fundamental consequence of the general theory of relativity is the existence of a black hole.
- **Quantum Theory:** The study of tiny particles' behavior, like atoms, at the smallest level.
- **Einstein's Principle of Equivalence:** The idea that nature's laws are the same in a small region with gravity as without it.
- **Hawking Radiation:** It is a theoretical concept proposed by Stephen Hawking, which suggests that **black holes can emit radiation due to quantum effects** near the event horizon known as Hawking radiation.

What are the Key Highlights of Study?

- Radiation from atoms falling into **black holes exhibits similarities to Hawking radiation**.
- The investigation reveals that the **radiation is generated from two-level atoms, unlike the radiation emitted by black holes** as predicted by Hawking.
- The study introduces the **concept of "horizon brightened acceleration radiation entropy" (HBAR entropy)** to quantify the **amount of disorder in the emitted radiation**.
 - The HBAR entropy follows the area law with logarithmic leading order area corrections and inverse order of area subleading corrections.
- The findings **uphold Einstein's Principle of Equivalence in a general setting**, providing valuable insights into the **interplay of quantum mechanics and general relativity in black hole scenarios**.
- The study adds to our understanding of the mysterious world of quantum effects in black holes.

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BLACK HOLES

ABOUT

- A place in space with **extremely high gravity pull**; even light can't escape (hence, **invisible**)
- The strong gravity is due to matter being squeezed into a tiny space

The term 'black hole' was coined in the mid-1960s by American physicist John Archibald Wheeler

DETECTION

- By seeing how stars very close to black holes act differently than other stars
- In April 2019, scientists at the **Event Horizon Telescope Project** released the first-ever image of a Black Hole (shadow, more precisely)

Albert Einstein and Black Hole

- First predicted their existences in **Theory of General Relativity**
- It showed that when a massive star dies, it leaves behind a small, dense remnant core

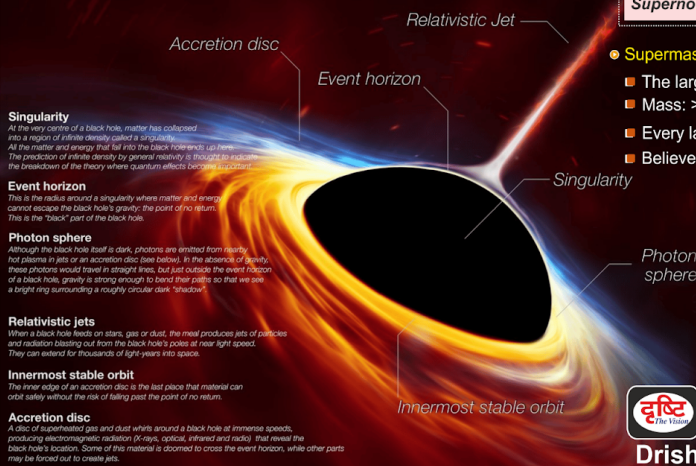
India's first dedicated satellite, **AstroSat** observed for the very first-time rapid variability of high energy X-ray emission from a black hole system

TYPES

- **Miniature (Hypothetical):**
 - The smallest; size of just 1 atom
 - Mass: varies from 1/100th of a milligram to the mass of a large mountain
 - **Believed to be formed** when universe began
- **Stellar:**
 - Mass: **20x the mass of sun**
 - **Believed to be formed due to Supernovae explosion**

Supernova is an exploding star that has reached the end of its life

- **Supermassive**
 - The largest
 - Mass: >1 million suns together
 - Every large galaxy has a supermassive black hole at its centre
 - **Believed to be made at the same time as their home galaxy**



Sagittarius A is the supermassive black hole at the centre of Milky Way (mass: ~about 4 mn suns)

The Sun will never turn into a black hole as it is not big enough to make a black hole



UPSC Civil Services Examination, Previous Year Question (PYQ)

Q. Consider the following phenomena: (2018)

1. Light is affected by gravity.
2. The Universe is constantly expanding.
3. Matter warps its surrounding space-time.

Which of the above is/are the prediction/predictions of Albert Einstein's General Theory of Relativity, often discussed in media?

- (a) 1 and 2 only
- (b) 3 only
- (c) 1 and 3 only
- (d) 1, 2 and 3

Ans: (d)

