

Black Hole Spin and Quasi-Periodic Oscillations (QPOs)

Prelims: *Current events of national and international importance | Space*

Why in News?

Scientists at **ARIES** have discovered the physical mechanism showing how a black hole's spin influences variations in X-ray emissions from matter orbiting around it.

ARIES - Aryabhata Research Institute of Observational Sciences.



Black Hole Spin and Quasi-Periodic Oscillations (QPOs)

Parameter	Key information
 Lead institution	ARIES
 Administrative affiliation	Department of Science and Technology (DST), Government of India
 Collaborating institutions	Nicolaus Copernicus Astronomical Center, Poland; M.J.P. Rohilkhand University, Bareilly
 Research method	Numerical computer simulations
 Journal	Journal of High Energy Astrophysics
 Main focus	Effect of black hole spin and viscosity on shock oscillations and QPO frequencies

Methodology

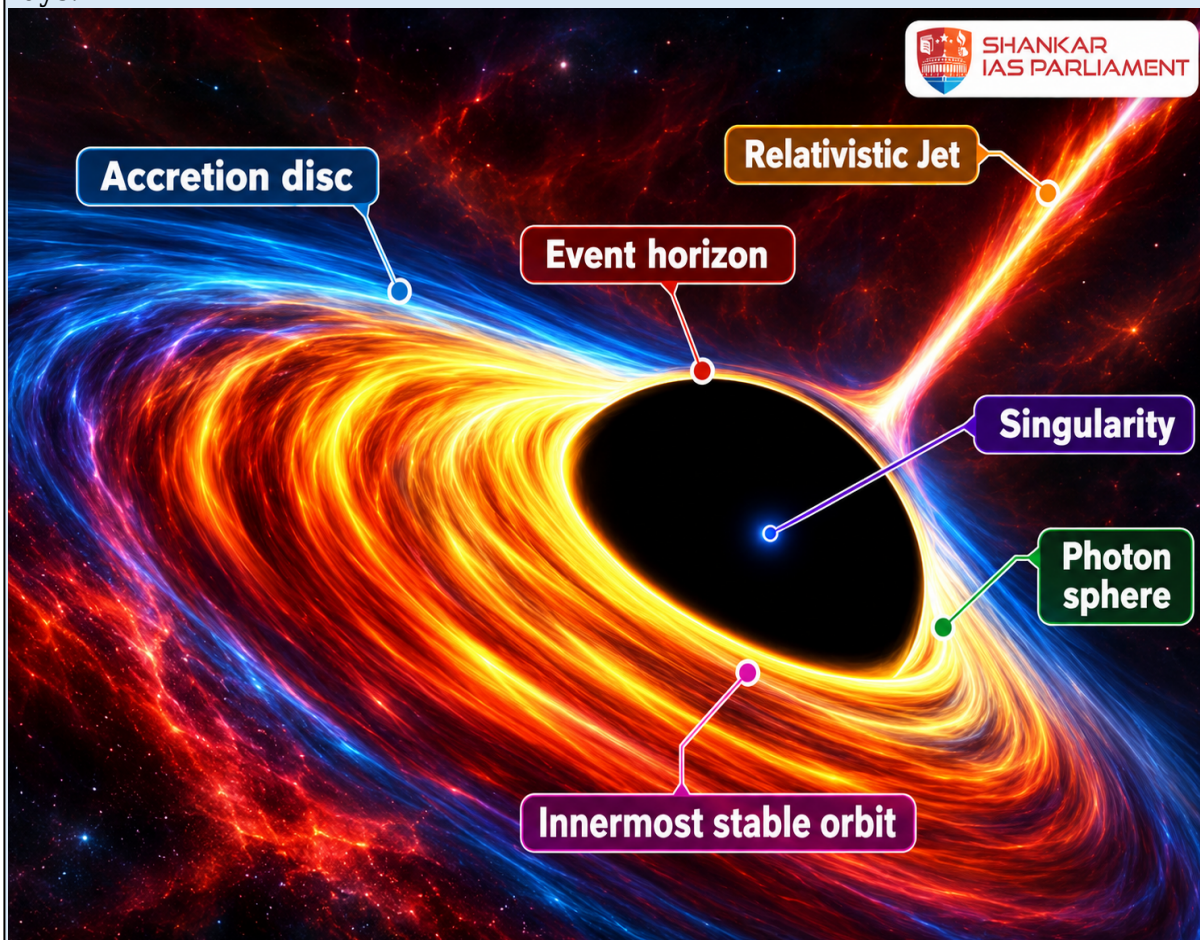
- A numerical simulation developed by the Numerical and Theoretical Astrophysics Group at ARIES was employed.
- The simulation modelled viscous accretion flows surrounding rotating black holes.
- The model accounted for the conservation of key physical quantities, such as mass, energy, and momentum.
- Thermodynamic relations characteristic of a relativistic fluid was incorporated into the simulation.

Black Hole

- An extremely compact astronomical object with an intense gravitational field.
- The gravitational field of a black hole is so strong that it prevents even light from escaping from within its event horizon.
- A black hole can rotate or spin about its axis.
- The spin of a black hole can influence the motion of nearby matter and affect the properties of radiation emitted by that matter.

Accretion Flow and Accretion Disc

- **Accretion flow** - The movement of matter toward a compact object as a result of gravitational attraction.
- **Accretion disc** - A disc-shaped structure that forms as infalling matter accumulates and orbits an astronomical object.
- Viscosity, or internal friction within the flow, facilitates the redistribution of angular momentum and energy.
- Matter within the accretion flow may emit high-energy radiation, such as X-rays.



Quasi-Periodic Oscillations (QPOs)

- QPOs are nearly regular, recurring variations in the brightness of radiation emitted by astronomical systems.
- In black hole X-ray binaries, QPOs manifest as variations in X-ray intensity.
- The frequencies of QPOs range from less than one cycle per second to several hundred cycles per second.
- QPOs provide insights into the physical processes occurring in the vicinity of black holes.

Key findings

- It provides new insights into black hole behaviour and accretion processes.
- The study demonstrates that oscillations in the accretion flow can produce Quasi-Periodic Oscillations (QPOs) over a broad frequency range.
- **Influence of viscosity**
 - If the viscosity of the accretion flow surpasses a critical threshold, a previously stable shock may become unstable.
 - As a result, the shock initiates oscillatory behavior.
 - These oscillations generate variations in the emitted radiation, which are observed as quasi-periodic oscillations (QPOs).
- **Effect of black hole spin**
- **Slowly spinning black holes**
 - The oscillating shock typically remains at a greater distance from the black hole.
 - The resulting quasi-periodic oscillations (QPOs) are predominantly low-frequency.
- **Rapidly spinning black holes**
 - The oscillating shock moves closer to the black hole.
 - Oscillations exhibit increased amplitude.
 - Quasi-periodic oscillations (QPOs) can occur over a broader frequency range, including high frequencies.
- Simulations indicate that for a black hole with approximately ten times the mass of the Sun, QPO frequencies can exceed 100 Hz at very high spin rates.
- The study identified a correlation between QPO frequency and the photon index, which characterises the spectral distribution of emitted photons.

Significance

- **Unified QPO model** - Explains low- and high-frequency QPOs through a single mechanism.
- **Improved black hole studies** - Aids interpretation of X-ray variability and analysis of black hole properties.

Reference

[PIB | Black Hole Spin and Quasi-Periodic Oscillations \(QPOs\)](#)