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The dynamic core of black holes

A new study investigates the internal dynamics of black holes and their implications for future astrophysical observations

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Black holes continue to captivate scientists: they are purely gravitational objects, remarkably simple, yet capable of hiding mysteries that challenge our understanding of natural laws. Most observations thus far have focused on their external characteristics and surrounding environment, leaving their internal nature largely unexplored. A new study, conducted through a collaboration between the University of Southern Denmark, Charles University in Prague, Scuola Internazionale Superiore di Studi Avanzati (SISSA) in Trieste, and Victoria University of Wellington in New Zealand, and published in *Physical Review Letters*, examines a common aspect of the innermost region of various spacetime models describing black holes, suggesting that our understanding of these enigmatic objects may require further investigation.

According to the corresponding author, postdoc Raúl Carballo-Rubio from the research center CP3-Origins at the University of Southern Denmark, the key insight from this study is that “the internal dynamics of black holes, which remain largely uncharted, could radically transform our understanding of these objects, even from an external perspective.”

The Kerr solution to the equations of General Relativity is the most accurate representation of rotating black holes observed in gravitational astrophysics. It depicts a black hole as a maelstrom in spacetime, characterized by two horizons: an outer one, beyond which nothing can escape its gravitational pull, and an inner one that encloses a ring singularity, a region where spacetime as we know it ceases to exist. This model aligns well with observations, as deviations from Einstein's theory outside the black hole are regulated by new physics parameters, which govern the core's size and are expected to be quite small.

However, a recent study conducted by the international team mentioned above has highlighted a critical issue concerning the interior of these objects: while it was known that a static inner horizon is characterised by an infinite accumulation of energy, the study demonstrates that even more realistic dynamic black holes are subject to significant instability over relatively short timescales. This instability is due to an accumulation of energy that grows exponentially over time until it reaches a finite, but extremely large, value, capable of significantly influencing the overall geometry of the black hole and thus altering it.

The ultimate outcome of this dynamic process is still unclear, but the study implies that a black hole cannot stabilise in Kerr geometry, at least over long timescales, although the speed and magnitude of deviations from Kerr spacetime remain under investigation. As Stefano Liberati, professor at SISSA and one of the study's authors, explains: “This result suggests that the Kerr solution—contrary to previous assumptions—cannot accurately describe observed black holes, at least on the typical timescales of their existence.”

Understanding the role of this instability is therefore essential for refining theoretical models of the interior of black holes and their relationship to the overall structure of these objects. In this sense, it could provide a missing link between theoretical models and potential observations of physics beyond General Relativity. Ultimately, these results open new perspectives for studying black holes, offering an opportunity to deepen our understanding of their internal nature and dynamic behaviour.

USEFUL LINKS
Full paper: Physical Review Letters

IMAGE
Credits: lexAntropov86/Pixabay

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