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TWO "LENSES" TO VIEW GRAVITY – WHEN MATHEMATICS BUILDS A BRIDGE BETWEEN TWO UNIVERSES

Two researchers from the Vatican Observatory (www.vaticanobservatory.org - www.vaticanobservatory.va), **Fr. Gabriele Gionti, S.J.**, and **Fr. Matteo Galaverni**, have uncovered a surprising result: there are two different mathematical frameworks - known as the **Jordan frame** and the **Einstein frame** - for describing gravity when a scalar field is involved. Yet with the right mathematical tools, they not only describe the same physics, but can **generate entirely new solutions of the Einstein Equations (which describe the universe on large scales) and describe physically inequivalent scenarios of the universe**.

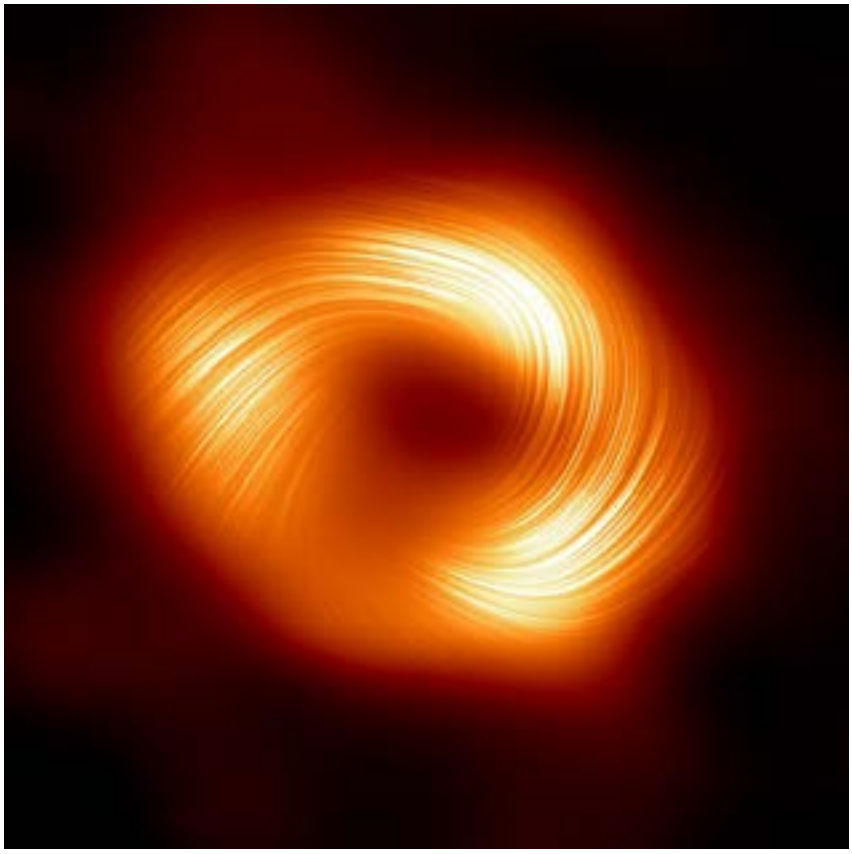
To prove this, the two scientists applied **ADM–Hamiltonian formalism**, which rigorously accounts for all aspects of the theory. This method makes it clear that, fixing specific conditions, the two frames are **mathematically equivalent**. Without using ADM–Hamiltonian formalism, this equivalence remains hidden. The results of this research were published in the *European Journal of Physics* https://epjc.epj.org/articles/epjc/abs/2025/07/10052_2025_Article_14447/10052_2025_Article_14447.html

A groundbreaking aspect of their work is the careful treatment of **boundary terms**—the mathematical terms at the edges of the space-time surfaces that have to be considered to derive the dynamical equations. As they explain: **"One must carefully consider the boundary terms of the problem. Only by handling these boundary terms properly can the correct equations of the theory be written. Previous results in the literature derived incomplete equations of motion."**

By correctly including these boundary components, Gionti and Galaverni were able to derive the **full and correct equations of motion** in both frames for the first time. Previous studies, by contrast, led to incomplete equations.

The researchers further explored what happens when you switch from one frame to the other using a **canonical transformation**. They found that if this transformation is **regular**, the two frames remain equivalent: every solution in the Jordan frame corresponds to one in the Einstein frame. But when the transformation becomes **singular**, something remarkable happens: completely **new gravitational solutions** appear, such as **black holes** or **naked singularities**, which would be invisible if one remained in a single frame. The mathematics thus "creates" new universes.

This discovery has important implications. It shows that the **choice of mathematical framework** is not just a matter of convenience; it can **change the physical solutions we uncover**. This insight could reshape our understanding of **Black Holes**, the **Big Bang model**, and the quest for a consistent theory of **Quantum Gravity**.



A view of the Milky Way supermassive black hole Sagittarius A in polarised light*
Credit: EHT Collaboration

High Resolution:
https://www.eso.org/public/images/eso2406a/

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