# Volume inside old black holes, or how to store our Universe inside a ping pong ball

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Can we store our observable Universe inside a ping pong ball? The answer is in the affirmative, provided that the surface of that ball is a black hole horizon formed at least $10^{58}$ billion years ago. This little unrealistic example is based on results about black hole physics with possible important consequences about our understanding of black holes, and particularly about the information paradox. The dynamical nature of the interior of black holes allows the volume enclosed inside the horizon to grow with time, even though the horizon area remains constant. This was recently shown in [1], where a generally covariant definition of volume using maximal surfaces was proposed. The result was expanded in [2], which represents the main reference my talk will be based on. After a brief review of the volume definition, I will show how the latter can be applied to evaporating black holes modeled via an ingoing Vaydia metric. The result is that, even though the horizon area is now shrinking, the volume monotonically increases as $V \sim m_0^2 v$, where $m_0$ is the initial mass of the hole and $v$ is the advanced time at past null infinity. This behavior is valid until the horizon area has reached Planckian dimensions, i.e. after a time of order $v \sim m_0^3$. At this stage the hole is usually called a remnant, widely regarded as a small object due to its tiny exterior area. The result presented in this talk, however, shows that it bounds a very large interior volume of the order $V \sim m_0^5$. This in turn can invalidate standard objections against the remnant scenario as a viable solution to the information paradox, such as infinite pair production and their impossibility of storing a large amount of information.

## References

[1] M. Christodoulou and C. Rovelli, *How big is a black hole?*, *Phys. Rev.* **D91** (2015) 064046, [1411.2854].

[2] M. Christodoulou and T. De Lorenzo, *Volume inside old black holes*, *Phys. Rev.* **D94** (2016) 104002, [1604.07222].