Black holes, white holes, wormholes: their geometry and physics

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For a distant observer with finite lifetime the main characteristic a black hole is trapping of light. The (time-slicing dependent) boundary of a trapped region is the apparent horizon.

Semiclassical description of black holes is based on two common but usually implicit assumptions. The first is a consequence of the cosmic censorship conjecture, namely that curvature scalars are finite at apparent horizons. The second is that horizons form in finite asymptotic time (i.e. according to distant observers), a property implicitly assumed in conventional descriptions of black hole formation and evaporation. On the other hand, traversable wormholes are required to form in finite time and to be sufficiently regular by their design specifications.

Taking these as the only requirements within the semiclassical framework, we find that in spherical symmetry only two classes of black/white hole solutions are admissible: each describing only evaporating black holes and expanding white holes. Wormholes can be analysed in the same framework. We review their properties and present the implications. For example, the null energy condition is violated in the vicinity of the outer and satisfied in the vicinity of the inner apparent/anti-trapping horizon. Horizons are timelike surfaces of intermediately singular behavior, which manifests itself in negative energy density firewalls that are perceived by some observers. A test particle falls into a black hole in a finite time (according to a distant clock), and it is possible to be swallowed by a white hole. Different generalizations of surface gravity to dynamic spacetimes are discordant and do not fully match the semiclassical results. Wormhole solutions are closely related to the concept of trapping.

We conclude by discussing possible signatures of black hole models and the reasons why wormholes are not allowed in semiclassical gravity.

[1] R. B. Mann, S. Murk, and D. R. Terno, *Black holes and their horizons in semiclassical and modified theories of gravity*, Int. J. Mod. Phys. D **31**, 2230015 (2022) [arXiv: 2112.06515].

[2] D. R. Terno, *Inaccessibility of traversable wormholes*, arXiv:22031.03770 (2022).