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Geometry, Dynamics, and Phase Space of Carrollian Stretched Horizons

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The membrane paradigm illustrates a profound link between gravity on a stretched horizon and hydrodynamics. While this connection has been explored semi-classically, it holds potential for illuminating fundamental aspects of quantum spacetime, such as degrees of freedom, symmetries, and dynamics. In this work, we revisit the membrane viewpoint and introduce the concept of stretched Carroll (sCarroll) structures, which are a generalization of Carroll structures of null surfaces, to timelike stretched horizons. We then establish a correspondence between gravity degrees of freedom and dynamics on the stretched horizon and Carrollian hydrodynamics. Furthermore, we demonstrate that the canonical phase space of gravity on the stretched horizon is completely captured by the sCarroll structure. Finally, we discuss the diffeomorphism symmetries of the horizon and, through the Noether theorem, derive Einstein's equation on the surface and the associated Noether charges, particularly including the transverse translation and the spin-2 symmetry.

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