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Dark Matter Mounds from Supermassive Star Collapse: A General Relativistic Treatment

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The formation history of supermassive black holes (SMBHs) influences the surrounding distribution of dark matter (DM). While slow, adiabatic growth is known to produce high DM density regions referred to as "spikes," more realistic formation scenarios, such as collapse from a stellar progenitor, generate weaker overdensities called "mounds". Upcoming gravitational wave (GW) detectors will be able to probe extreme mass-ratio inspirals (EMRIs) over hundreds of thousands of orbital cycles. Thanks to the long duration of these signals, it will be possible to measure with great precision any effects of the environment around SMBHs on the smaller companion black hole. If DM overdensities do form close to SMBHs, their environmental effects will be distinguishable from vacuum or baryonic matter. Recent studies have shown the importance of taking a fully relativistic approach in modeling the dephasing of GWs from EMRIs due to DM. However, relativistic studies have focused exclusively on the case of idealized adiabatic growth. In our research, we extend the calculation of DM mounds to the full general relativistic regime and consider how a more realistic treatment of stellar collapse may impact the evolution of DM orbits. We find that the distribution function of DM is significantly altered from the adiabatic case near the black hole, with a clear depletion in the low-energy regions of the parameter space. These results will be crucial in modeling future EMRI detections, potentially enhancing our understanding of both the behavior of dark matter in strong gravity regions and the formation history of supermassive black holes.

Primary author(s) : CAIOZZO, Roberto (SISSA)

Co-author(s) : Prof. BERTONE, Gianfrance (University of Amsterdam); Prof. CELOTTI, Annalisa (Sissa); Prof. ULLIO, Piero (Sissa)

Presenter(s) : CAIOZZO, Roberto (SISSA)

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