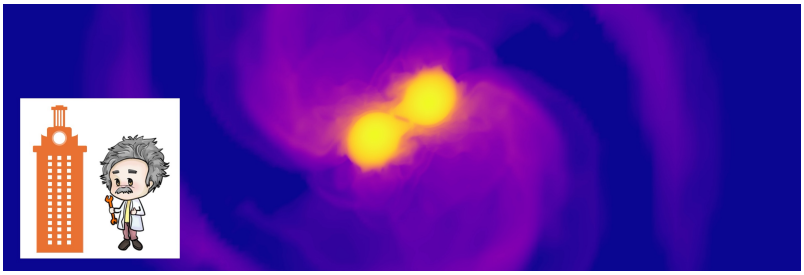

Contribution ID: **17** Type: **not specified**

BHaHAHA: A Fast, Robust Apparent Horizon Finder Library using Hyperbolic Relaxation

Thursday 12 June 2025 14:00 (1 hour)

We present BHaHAHA (BlackHoles@Home Apparent Horizon Algorithm), a new open-source apparent horizon (AH) finder that uses hyperbolic relaxation, reformulating the elliptic Marginally Outer Trapped Surface (MOTS) equation as a damped scalar wave equation on the 2-sphere via a reference-metric approach. As such, it exists as the first-ever hyperbolic flow method. Key techniques—such as multigrid-inspired refinement, over-relaxation, OpenMP parallelization, and dynamic tracking optimizations (e.g., extrapolated initial guesses, reduced-volume interpolation)—make BHaHAHA both efficient and robust. Benchmarks show BHaHAHA is scale-invariant across 16 orders of magnitude in mass (where AHFinderDirect struggles), and 2.1x faster in dynamic scenarios like GW150914 while maintaining similar accuracy (relative area errors ˜1e-5). It also reproduces high-precision results in difficult cases like a q=4 common horizon and a 3-BH Brill-Lindquist critical radius. BHaHAHA is infrastructure-agnostic and has been integrated with both the Einstein Toolkit and BlackHoles@Home frameworks so far, with more infrastructure implementations in development.

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