BLUE WATERS
SUSTAINED PETASCALE COMPUTING

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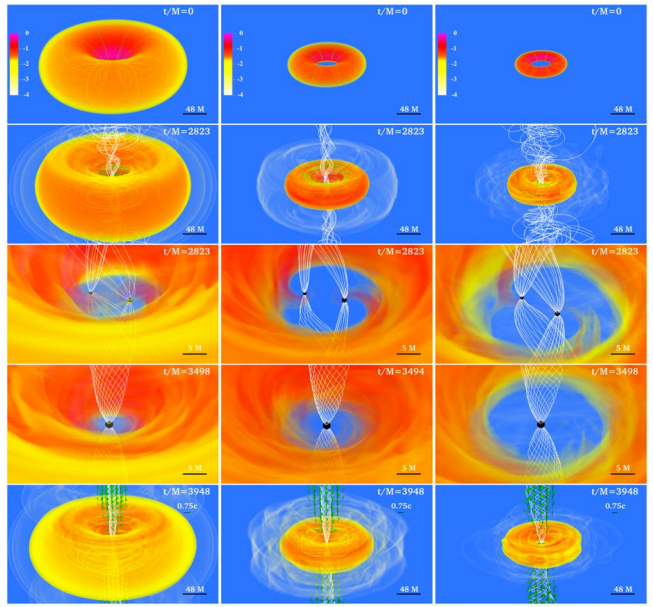
DISKS AROUND MERGING BINARY BLACK HOLES: FROM GW150914 TO SUPERMASSIVE BLACK HOLES

Research Challenge

The coincident detection of gravitational waves (GWs) with electromagnetic (EM) signals from the coalescence of black hole binaries is new observational challenge. Combining GW and EM observations offers a unique probe to understanding black hole cosmological evolution and accretion processes. The project performs general relativity simulations of circumbinary magnetized disks accreting onto non-spinning merging black holes. They survey different disk models to quantify the robustness of previous simulations on the initial disk model. Scaling their simulations to supermassive binary black holes, they find that the observable flow properties such as accretion rate periodicities and the emergence of jets display only modest dependence on the initial disk model.



Rest-mass density (red-orange), magnetic field lines (white), and velocity vectors (green arrows) at select times during inspiral, merger and post-merger, for three initial disk models (columns).

Methods & Codes

Magnetohydrodynamic (MHD) numerical simulations in full general relativity (GR) require the solution of the Einstein field equations to determine the gravitational field, the relativistic MHD equations to determine the flow of matter, and the electromagnetic fields. Together, the equations constitute a large system of highly nonlinear, multidimensional, partial differential equations in space and time. The team solves these equations through independently developed code, “Illinois GRMHD”, which has been built over many years on the Cactus infrastructure and uses the Carpet code for adaptive mesh refinement but employs original algorithms and coding.

Results & Impact

Three initial disk models that differ in their scale heights, physical extent, and in their magnetic field content were simulated in order to test whether previous properties of MHD accretion flows onto binary black holes are sensitive to the initial disk model. Scaling the simulations to LIGO GW150914 black hole collision showed that magnetized disk accretion onto binary black holes could explain both the GWs detected from this system and the EM counterpart GW150915-GBM reported by the Fermi GBM team 0.4seconds after LIGO’s GW150915. When scaling to supermassive black hole binaries, the simulations show that at late times flow properties, temperatures, and thermal frequencies are all robust, displaying only modest dependence on the disk model.

Why Blue Waters

With the Blue Waters next-generation interconnect and processors, our hybrid OpenMP/MPI code exhibits greater scalability and performance than on any other supercomputer we have used. Recently, we were able to build our code with the Blue Waters Intel compilers. This resulted in a significant boost of our code’s performance by about 30%, making Blue Waters unique for tackling the astrophysical problems we want to address.