ELUCIDATING THE ALIGNMENT MECHANISM FOR BLACK HOLE ACCRETION DISKS SUBJECT TO LENSE-THIRRING TORQUES

Research Challenge
To study astrophysical accretion onto a spinning black hole in which there is a misalignment between the orbital axis of the incoming gas and the black hole rotation axis. To probe how a time-steady transition occurs between an inner disk region aligned with the equatorial plane of the central mass’s spin and an outer region orbiting in a different plane. To utilize the established physical mechanism for internal stresses which requires a timestep very short in comparison to an orbital timescale, whereas the timescale where the orientation transition may occur is likely many orbital periods long.

Methods & Codes
- A simplified disk model consisting of an isothermal disk orbiting a point-mass in Newtonian gravity with a Keplerian angular velocity distribution. It includes only a lowest-order post-Newtonian term to represent the relativistic Lense–Thirring torque.
- Fortran 95 version of Zeus, an operator-split code that solves the equations of compressible correlated magnetohydrodynamic turbulence

Results & Impact
- Confirmed that the influence of the sound speed can be encapsulated in a simple “lumped-parameter” model.
- Showed for the range of angles the team studied, the alignment process is largely independent of black hole tilt angles.

Why Blue Waters
The unique high-performance capabilities of Blue Waters enabled key linchpin maximum-resolution simulations that support a wider effort involving a suite of less demanding simulations carried out on other systems.

A contour plot of log density after 20 orbits of evolution subject to the external torque. Overlaid is a line showing the equatorial plane for the spin axis of 24° showing how the inner disk has aligned with the black hole.