OOKAMI PROJECT APPLICATION

Date: 2021 April 29

Project Title: Magnetized Massive Star Winds with Ookami

Usage:

- Testbed

Principal Investigator: Marc Gagné

West Chester University
720 S. Church St., West Chester, PA, 19383 USA
Phone: (610) 436-3014
Email: mgagne@wcupa.edu

Names & Email of initial project users:

Marc Gagné: mgagne@wcupa.edu (West Chester University), Asif ud-Doula: auu4@psu.edu (Penn State Scranton), Dinshaw Balsara: dbalsara@nd.edu and Sethupathy Subramanian: ssubrama@nd.edu (University of Notre Dame).

Usage Description:

Our team has developed an astrophysical magnetohydrodynamics code on a geometrically optimal geodesic mesh that is high-order accurate and computationally efficient, specifically to model the magnetically channeled winds of massive stars. Most astrophysical codes use traditional rectilinear meshes, e.g., in cylindrical and spherical polar coordinates. These meshes have two notable deficiencies: the zones the near polar axis are very small in the azimuthal coordinate. This not only produces a non-isotropic grid, the smaller zones produce correspondingly shorter time steps, thereby increasing the overall compute time. Second, the presence of a coordinate singularity at the poles builds up error along the polar axis. This is the so-called *pole problem.* In the case of magnetic massive stars, the pole problem is especially evident when the magnetic axis is tilted with respect to the rotation axis, and when the star rotates quickly. The GEOMESH code was designed to overcome these deficiencies [BFG+19, FBGG20].

A baseline GEOMESH code, which has some uniquely optimal capabilities for simulating spherical astrophysical systems, is already producing meaningful results. Our long-term goal is to build upon advances in the existing GEOMESH code by including new physics modules to account for radiative line driving, radiative cooling, inverse-Compton cooling, and the possible effects of resistive heating, conduction, and magnetic reconnection. Efficient and accurate mesh refinement of the spherical geodesic mesh will be needed to achieve these scientific goals. The CPU code performs well and scales nearly optimally to 1E4 cores on Stampede2 (Intel Skylake 8120) and Bridges-2 RM (AMD Epyc 7742). The CPU code currently uses MPI and Coarray Fortran. We are beginning the process of re-vectorizing key subroutines to run more optimally on a wider range of CPU, and possibly GPU architectures. The possibility of achieving accelerated performance with A64FX without having to recode in OpenACC or CUDA attracted us to using the Ookami cluster as a testbed for this project.

Computational Resources:

- Total node hours per year: 4,000
- Size and duration for a typical batch job: 8 nodes, 48 hours
- Disk space: home: 1 GB, project: 500 GB, scratch: 500 GB

Personnel Resources:

Assistance vectorizing and compiling parts of our code to run on A64FX nodes.

Required software:

Silo module. VisIt visualization (client/server mode).

If your research is supported by US federal agencies:

Agency: Smithsonian Astrophysical Observatory
Grant number(s): TM1-22001A, GO0-21015E

References

[BFG+19] Dinshaw S. Balsara, Vladimir Florinski, Sudip Garain, Sethupathy Subramanian, and Katharine F. Gurski. Efficient, divergence-free, high-order MHD on 3D spherical meshes with optimal geodesic meshing. *MNRAS*, 487(1):1283–1314, July 2019.

[FBGG20] Vladimir Florinski, Dinshaw S. Balsara, Sudip Garain, and Katharine F. Gurski. Technologies for supporting high-order geodesic mesh frameworks for computational astrophysics and space sciences. *Computational Astrophysics and Cosmology*, 7(1):1, March 2020.