Astaroth: A GPU Code for Astrophysical Hydrodynamics

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1. The Code

Astaroth code is a 6th-order finite difference solver for hydrodynamics written with Nvidia CUDA C. It was has been created to find a working method to utilize graphics processing units (GPUs) for astrophysical hydrodynamics. Our aim was to creata a code which would be as functional as possible and thus work as a ground for further development of the methods.

GPUs have shown potential promise for fast floating point computation. However, GPU:s bring with them new programming challenges. To write working GPU code, much work is needed for handling the paraller computation threads and managing the memory use, as doing so effectively with simple directives does not work for many if not most cases.

The code supports only isothermal hydrodynamics with fully realized kinematic viscosity at this point, but full magnetohydrodynamics implementation is in the horizon.

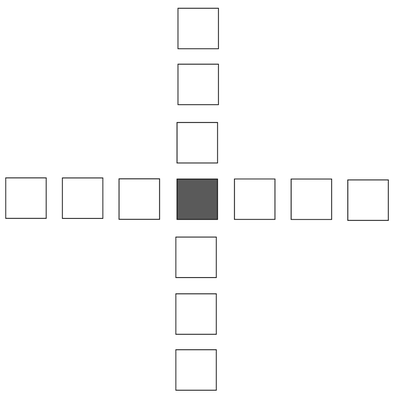

Figure 1: A sample 19-point stencil use by the code.

The primary inspiration for the Astaroth code has been the Pencil Code, a general purpose MHD solver, which is frequently used by the DYNAMO-group. Therefore, the time integration is handled by a 3rd-order Runge-Kutta method, and the derivatives are calculated with 6th-order finite differences.

To our knowledge, no other hydrodynamics code has used as high-order finite difference stencils. With high-order implementation of the finite difference method, the memory latencies with the device create a major bottleneck for the performance.

The full details of the methods used will be published an upcoming paper (Pekkilä & Väisälä, to be submitted).

2. Performance

We find notable performance increase when compared to the Pencil Code:

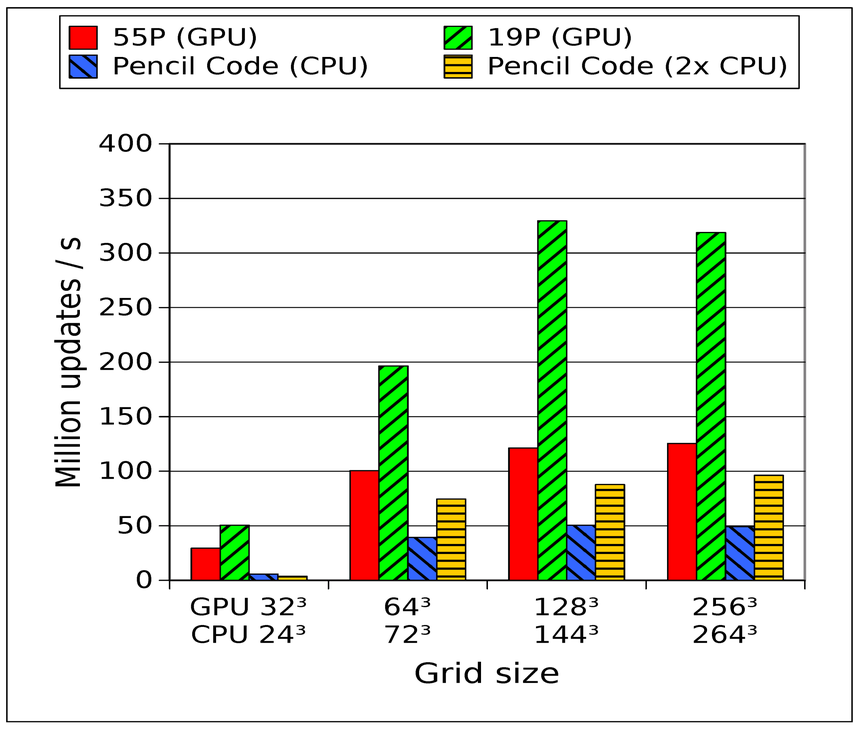

Figure 2: Performance compared to the Pencil Code.

3. References

- Pekkilä, J. & Väisälä, M. *Methods for compressible fluid simulation on GPUs using high-order finite differences*, to be submitted
- Väisälä, M., Käpylä, M., Pekkilä, J., *TBA*

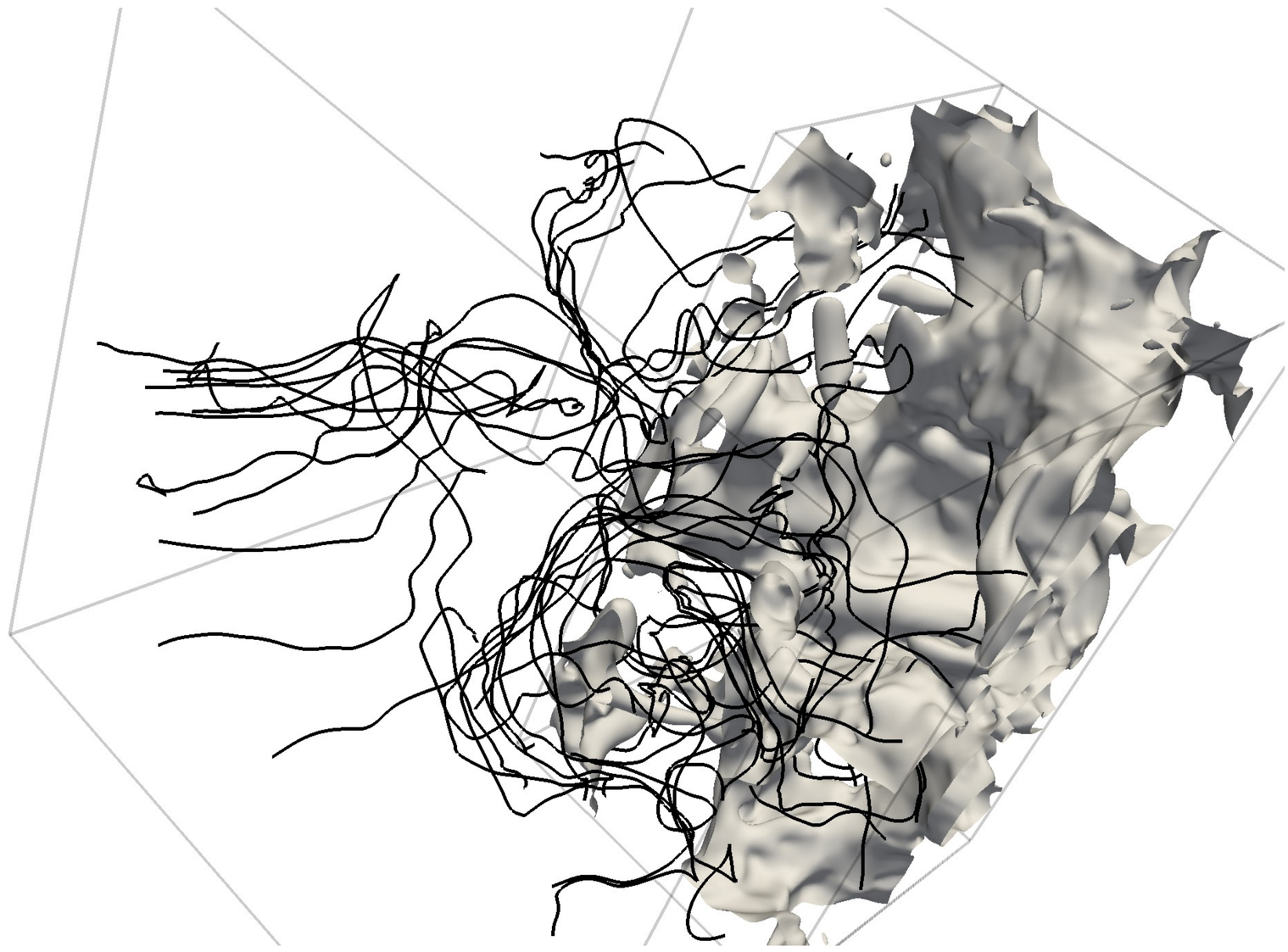

Figure 3: Turbulence produced by the forcing function in the Astaroth code.