



GPU enhancement of Pencil Code with Astaroth - a discussion

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MS Coordinated Hydrodynamic and Astrophysical Research, Modeling, and Synthesis What is this all about? We have a code created to enhance Pencil Code like computations with GPUs. It is efficient, flexible and easy to use. It could be useful for the PC community.

Astaroth API

- General stencils
- Domain Specific Language
 36× speedup



"Finnish" – GPU branch

History, current status, future directions Current team: Maarit Käpylä, Oskar Lappi, Johannes Pekkilä, Matthias Rheinhardt, Miikka Väisälä

History & current status (From Maarit)

- 01/01/2011 → 30/06/2014 "Active Suns" research project PId by Petri Käpylä; Miikka Väisälä main developer of the core of Astaroth. Then the group was based in University of Helsinki, dept. of physics
- ... paradigm change: move to Aalto, department of computer science. 2014-2019: ReSoLVE Center of Excellence, Aalto Dynamo Team, Pld by Maarit Käpylä; Johannes Pekkilä started as summer intern, then BSc, and finally MSc thesis worker. Hydro-Astaroth (Pekkilä, Väisälä et al., 2017), DSL library (Pekkilä 2019, Johannes' tutorial), Multi-GPU-single-node-Astaroth (Väisälä et al., to be submitted soon).
- 2019-2023: UniSDyn ERC project, PI Maarit Käpylä: Johannes Pekkilä started as a PhD student, Oskar Lappi as a Master thesis worker 2020.
 multi-GPU-Astaroth-MHD-setup (Johannes' status update, Pekkilä et al., to be submitted soon).

More than 30-fold speedup in comparison to CPUs.

Outlook (From Maarit)

- Astaroth + DSL: ready-to-be-used tool for creating simulation setups with relatively easy-to-use DSL and efficient GPU code. Hopefully practical work towards new simulations setups starts already during the meeting. For example:
 - \circ Miikka's alpha-squared dynamo setup to study LSD and SSD interactions at Pm=1.
 - $\,\circ\,$ GPUizing test methods for constructing sub-grid-scale models for MHD (Johannes' PhD thesis topic)
- Astaroth-Pencil Code interfacing: ongoing work by Matthias Rheinhardt (in the framework of UniSDyn); using the "multiphysics framework" of PC interfaced with the fast GPU core.

Astaroth in scientific use:

Dynamo setup

Exploring large-scale and small-scale dynamo systematically with Pm = 1 and varying **Reynolds numbers** with isothermal resistive MHD, forcing function and periodic domain.





An example helically drive dynamo: 128^3



An example helically drive dynamo: 256^3



An example helically drive dynamo: 512^3





Large-scale dynamo growth

Logarithmic growth rate relation to SSD. LSD and SDD similar at high Rm

Small-scale dynamo growth





SSD power spectra

LSD and SDD at high Rm have similar power spectra during growth LSD power spectra



Alpha quenching





Growth rate: MF-SOCA estimates vs. direct measurement

Some FOSA/SOCA estimates

Speedup from PC + Astaroth Domain Specific Language (DSL)

SLIDES FROM JOHANNES \rightarrow

Motivations

We have the code. We might as well use it. We have done the work. It is in accessible package. Better just make use of it.

Astaroth can be used in its own, but we have preference for Pencil Code. Works for high-order derivatives.

MHD turbulence has been a focus. In principle easy for PC community to adapt for their tasks. **Pencil Code integration** depends on the PC community Current work is limited by manpower. Integration is helped by collaboration. Code will develop based on who will work on it.

Questions

How we combine advantages of both? Speedup is always good. What are advantages of the Pencil Code outside the main loop?

What kind of physics are you interested in? We have only our own things. It would help to know what people are interested in.

Would you like to know more?

Who would like to get in to the loop? Please send me an email expressing to mvaisala@asiaa.sinica.edu.tw Scientific collaborations welcome! You can stay interested without coding.

Future work? Miikka: Star formation modelling Johannes: Test-field methods etc.

How to contact us and access the code? **Repository**: https://bitbucket.org/jpekkila/astaroth/ **Contact Miikka**: mvaisala@asiaa.sinica.edu.tw **Contact Johannes:** johannes.pekkila@aalto.fi