The Pencil Code Newsletter

Issue 2023/1

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Contents

1 Pencil Code User Meeting

We are pleased to announce this year's Pencil Code User meeting. The 19th meeting will be held at the University of Graz, Austria from 4th to the 8th of September in hybrid mode. This will open the possibility to participate online as well as in person. The University of Graz is the second oldest university of Austria (founded in 1585). It has a long history of physics research and has been the working place of renown physicists like Erwin Schrödinger, Ludwig Boltzmann and Ernst Mach. The meeting will take place directly at the Institute of Physics. Basic details can be found at `http://pencil-code.nordita.org/UserMeetings/2023/`. If interested, please use the registration form found on the meeting page or under `http://pencil-code.nordita.org/UserMeetings/2023/register.php`.

Figure 1: Graz downtown during the Pencil Code User Meeting in 2016. Back then it was not at the University, but at the Space Research Institute.

Registration deadline is the 31st of July 2023. Participants, who wish to present their work, are requested to

Figure 2: Don't delay filling in the form.

give the title of their talk along with the registration details. More details on the program, sessions and travel information will be updated in time before the meeting. We hope to welcome you in person at the University of Graz. If you have questions or suggestions, feel free to email the organizers at `PC@Bourdin.ch`

On behalf of the organizing committee:
Vartika Pandey

2 PC steering committee

The next Pencil Code Steering Committee (PCSC) meeting will be on June 12, 2023, at 12:00. If you have any items to be discussed, please send them to the chair, Nils E Haugen `<Nils.E.Haugen@sintef.no>`.

The minutes of the previous meeting are posted on: `http://www.nordita.org/~brandenb/pencil-code/PCSC/`.

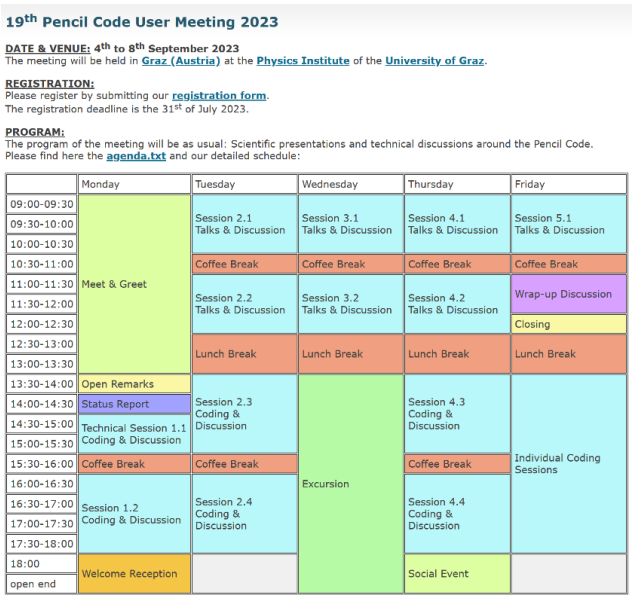

Figure 3: Colorful & plenty of time for code work.

3 PC office hours

We wish to remind you that each second Thursday of the month, at 13:00 CET/CEST, we have the Pencil Code office hours; see `https://www.nordita.org/~brandenb/pencil-code/office_hours/` for potential updates on the timing. This provides a good opportunity for newcomers to get to know members of the Pencil Code community, to ask questions how to get started, etc. At the same time, these meetings provide an opportunity for the experts to see each other (on zoom), and to help both the newcomers and also each other. Sometimes, even just a little bit of brainstorming can be useful before somebody embarks on something major.

4 Autotest improvements

Philippe Bourdin (`Philippe.Bourdin@oeaw.ac.at`) wrote:
The auto-test tools have several new features:

- There is now a link to the output from each stage of the test ([log]). This feature can be activated by providing the `--log_dir=<path>` option to `pc_auto-test` if it is running in `--html` output mode. `<path>` must be accessible by the browser.
- If multiple instances of auto-tests are supposed to run on the same machine, e.g., minutely and

hourly tests with different working copies of the code, it is now possible to run both at the same time by the new `--local-lock` option.

- When an auto-test was fully successful, the SVN revision and GIT hash are saved - and if a later test fails, the information of the previously successful revision is shown.

- The same applies for each individual sample of a test, too. And if two consecutive revisions had been tested, the commit causing the failure is identified and printed. If there are multiple revisions between two auto-test runs, a hint is displayed between which revisions one should search for the mistake. Example from today (March 31st):

```
Fri Mar 31 06:16:06 2023
[...]
minimal/samples/most-modules:  (2/2)
Compiling..     ok 00:11 [log]
Starting..      ok 00:00 [log]
Running..       ok 00:00 [log]
not ok:  [log]
Floating-point exception.
===> Test still succeeded with revision:
SVN: 82477
GIT: 7dfbf785c9371c0db1372bea8ad35ab31e542b5d
Thu Mar 30 18:29:15 2023
===> Test failed at latest with revision:
SVN: 82478
GIT: d4940b894b2db16c41cf780b897112e645a81bb1
Fri Mar 31 06:16:24 2023
===> This is the offending commit from:  (removed)
[...]
--------------------------------------------------
Last fully successful auto-test was:
SVN: 82477
GIT: 7dfbf785c9371c0db1372bea8ad35ab31e542b5d
Thu Mar 30 18:29:19 2023
--------------------------------------------------
```

If the auto-test is not running on a SVN checkout, only GIT hashes are displayed, while an SVN checkout would show both informations. Thanks also to Matthias Rheinhardt for his initial work on implementing the logfile feature.

5 Code developments

5.1 Transferring snapshots

Kishore Gopalakrishnan <kishoreg@iucaa.in> wrote:

Figure 4: Code development, behind the scene.

To transfer snapshots (FORTRAN binary format) to a new processor layout or grid resolution, a PYTHON script pc_migratevar is now available. It also allows one to copy only specified variables from one simulation, to be used as an initial condition for another simulation. If the grid sizes of the source and destination simulations differ, the requested variables are automatically interpolated onto the new grid. An example invocation is

```
pc_start
pc_migratevar --copy-these ss ../src_sim/data
pc_run
```

The above would copy only the entropy field from the source simulation into the current simulation, preserving the values set for the remaining variables by `pc_start`. The script can be easily modified in case one wishes to specify custom initial conditions via PYTHON. For a detailed description of the available options, type `pc_migratevar --help`.

5.2 Remeshing with fewer processors

In addition to the remeshing parameters `mul[xyz]` for increasing the processor number, there are now also the parameters `div[xyz]` for *deceasing* them. The code checks for admissibleness of the combination of both parameter sets. The executable `remesh.x`, being itself parallelized, needs to be run with `nprocx_src/divx * nprocy_src/divy * nprocz_src/divz` processors where `nproc[xyz]_src` are the processor numbers of the setup to be remeshed. This is also checked by code. For producing snapshots, which can be (distributedly) read by applications built on ASTAROTH, set `lastaroth=.true.` in

common.local. Also, the variable fields needs to be set to a proper array of variable names (see example in common.local).

5.3 Snapshot format change with minimal memory

Changing the snapshot format by help of *alternative* I/O doesn't need the array df. Hence, if setting nt=0 and FARRAY_ALLOC=farray_alloc it will not be allocated, allowing to deal with very big setups.

5.4 Caveats for developers

- Getting/putting shared variables by calling get_shared_variable/put_shared_variable doesn't mean that variable values are copied. Instead, merely pointers are associated. That's why these calls have to occur only once, typically in the initialize_* routines. Their argument caller is meant to be the name of the calling routine and is stored as a static variable of the module SharedVariables. Hence, it needs to be set in the calls effectively only once inside a routine (but beware of if constructs!).
- The code, executed during the advancement of the equations (e.g. inside the major mn loop) should be free of stuff, which belongs by its nature to the initialization stage (initialize_* routines). This becomes increasingly important in the context of ongoing efforts to accelerate the code by GPU use and multithreading. Thus, avoid as far as possible the use of lfirstcall or similar, e.g. for reading/writing files only once. Such actions, when performed from threads or the GPU, are highly inefficient and can thus render acceleration pointless.
- mpicomm_double.f90 has been made unnecessary by using variables for the MPI floating and complex datatypes (mpi_precision and MPI_CMPLX. Please use always these in new routines. If you want to inhibit floating point type promotion, use, e.g., real(KIND=rkind4).
- Be aware that updating the f-array in routines *_after_boundary is wrong for communicated variables as communication has already at least been initiated before these calls. Updates should hence be placed in *_before_boundary routines. Be aware, though, that the boundary conditions have not yet been employed at this moment (should be reworked in the future).
- Avoid using start/end labels at short if, do, where, select constructs as they are not enhancing but degrading readability. What 'short" means, is somewhat debatable, but a good guess would be <= 30 lines. Even for longer constructs, better repeat the condition or loop initialization as a comment behind the terminating statement, as it would preserve column alignment, e.g., endif ! (<condition>) .
- Avoid source code line continuation as long as the lines are not longer than, say 100 characters to ease readibility.
- Avoid plain print statements and utilize the routines from the Messages module instead (information, warning, fatal_error, not_implemented etc.) when appropriate.

6 Science teasers

6.1 Pencil Code and AI

Artificial Intelligence can strongly facilitate maintaining of the code. We performed a first test with ChatGPT (chat.openai.com) by asking the following question:

> Analyse the code in https://github.com/pencil-code/ with respect to the criterion that all interprocessor (MPI) communication during the advancement of the partial differential equations should be physically meaningful, in particular, should not accumulate data across pro- cessors such that unrelated points of the global com- putational grid are combined.

Actually, we new the (a) right answer already, but to our big surprise, the bot spat out the following:

> The global reduction in line 2304 of pointmasses.f90 seems to be a hit for your criterion. The calling sequence is run -> time step -> pde -> rhs cpu -> dvvq dt pointmasses pencil -> integrate gasgravity. I'm not completely sure, though.

Full score!

6.2 Dimensional arguments

Here is the induction equation with just the Hall effect:

$$\frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{\nabla} \times \left(-\frac{1}{e n_e} \boldsymbol{J} \times \boldsymbol{B} - \eta \mu_0 \boldsymbol{J} \right), \qquad (1)$$

where η is the magnetic diffusivity and t is time. Using $e = 1.6 \times 10^{-19}\,\mathrm{A\,s}$, $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\,m\,A^{-1}}$, and

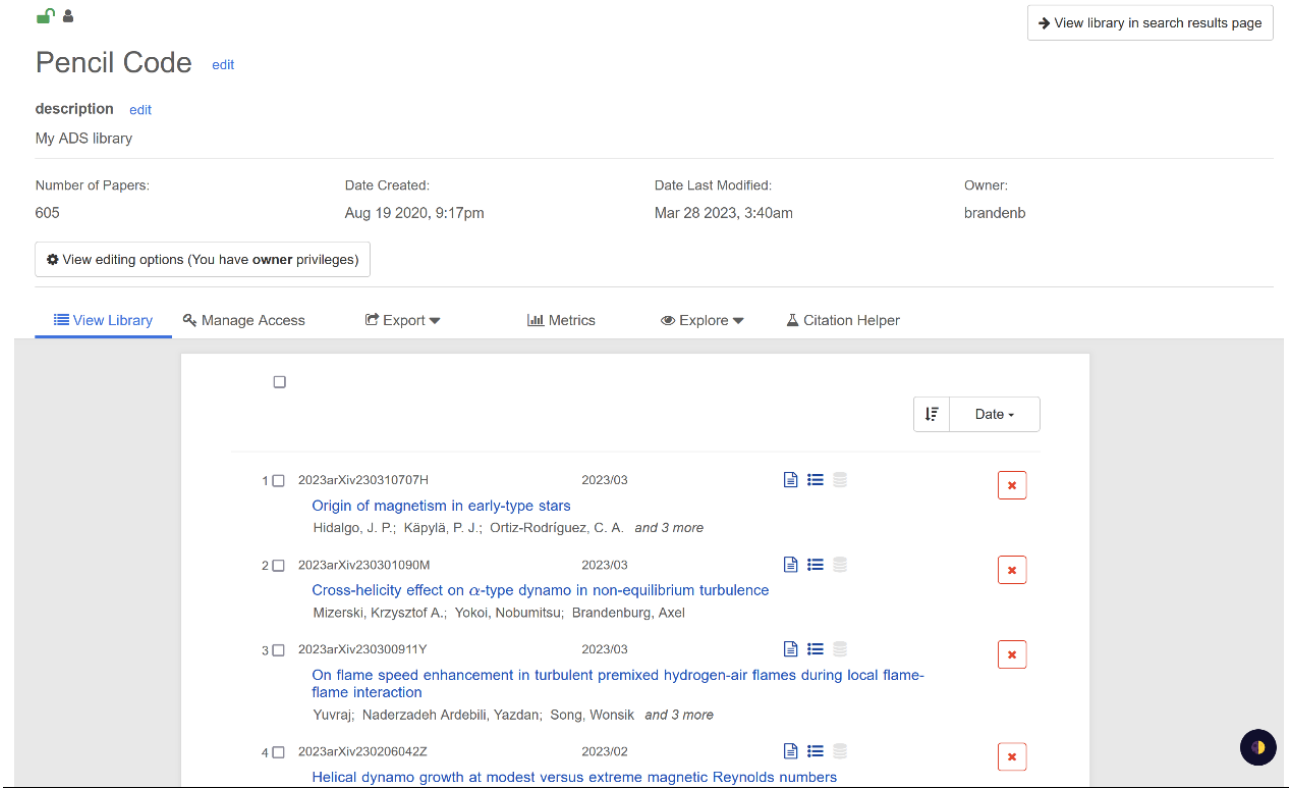

Figure 5: The Pencil Code paper library; see `https://ui.adsabs.harvard.edu/public-libraries/iGR7N570Sy6AlhDMQRTe_A`.

$n_e \approx 2.5\times10^{40}\,\mathrm{m}^{-3}$ for neutron star crusts, we have $en_e\mu_0 \approx 5\times10^{15}\,\mathrm{T\,s\,m}^{-2}$, and therefore

$$\frac{B}{en_e\mu_0} = \frac{B}{5\times10^{15}\,\mathrm{T}}\,\frac{\mathrm{m}^2}{\mathrm{s}}, \tag{2}$$

which is why we can say B has dimensions of $\mathrm{m}^2\,\mathrm{s}^{-1}$. In MHD, by comparison, the ion density ρ is a relevant quantity. Using $\rho = 10^3\,\mathrm{kg\,m}^{-3}$ for the solar surface plasma, $\rho\mu_0 \approx 3.5\times10^{-2}\,\mathrm{T\,s\,m}^{-1}$, or

$$\frac{B}{\sqrt{\rho_0\mu_0}} = \frac{B}{3.5\times10^{-2}\,\mathrm{T}}\,\frac{\mathrm{m}}{\mathrm{s}}, \tag{3}$$

which is why we say that in MHD, B has dimensions of $\mathrm{m\,s}^{-1}$.

In the Hall cascade, the magnetic helicity density now has units of $\mathrm{m}^5\,\mathrm{s}^{-2}$ and the Hosking integral has units of $\mathrm{m}^{13}\,\mathrm{s}^{-4}$, which means that the magnetic correlation length now increases with time $\propto t^{4/13}$. Details are in the recent paper on the *Hosking integral in non-helical Hall cascade* in this issue.

7 Meetings

7.1 The Galactic Magnetic Field

As already advertised in our newsletter 2022/3, there is the Nordita program "Towards a comprehensive model of the galactic magnetic field" during 3–28 Apr 2023; see `https://indico.fysik.su.se/event/7914/`. The program is online and the zoom ID is 689 1834 2463; or `https://stockholmuniversity.zoom.us/s/68918342463`.

7.2 Solar and Stellar Convection Zones

The full details about the IAU Symposium 365 on *Dynamics of Solar and Stellar Convection Zones and Atmospheres*, 21–25 August 2023, Yerevan, Armenia, are posted on `http://iaus365.sinp.msu.ru/`. The abstract deadline is 10 April 2023.

8 Papers since November 2022

As usual, we look here at new papers that make use of the Pencil Code. Since the last newsletter of November 1st, 7 new papers have appeared on the arXiv, and 14 others, some of which were just preprints and have now been published. We list both here, 21 altogether. A browsable ADS list of all Pencil Code papers can be found on: `https://ui.adsabs.harvard.edu/public-libraries/iGR7N570Sy6AlhDMQRTe_A`. If something is missing in those entries, you can also include it yourself in: `https://github.com/pencil-code/pencil-code/blob/master/doc/citations/ref.bib`, or otherwise just email brandenb@nordita.org. A compiled version of this file is available as `https://github.com/pencil-code/website/blob/master/doc/citations.pdf`, where we also list a total of now 102 code comparison papers in the last section "Code comparison & reference". Those are not included in our list below, nor among the now total number of 630 research papers that use the Pencil Code.

References

Brandenburg, A., Hosking integral in non-helical Hall cascade. *J. Plasma Phys.*, 2023a, **89**, 175890101.

Brandenburg, A., Quadratic growth during the COVID-19 pandemic: merging hotspots and reinfections. *J. Phys. A Math.*, 2023b, **56**, 044002.

Brandenburg, A., Kamada, K. and Schober, J., Decay law of magnetic turbulence with helicity balanced by chiral fermions. *arXiv e-prints*, 2023a, arXiv:2302.00512.

Brandenburg, A., Rogachevskii, I. and Schober, J., Dissipative magnetic structures and scales in small-scale dynamos. *Month. Not. Roy. Astron. Soc.*, 2023b, **518**, 6367–6375.

Brandenburg, A., Zhou, H. and Sharma, R., Batchelor, Saffman, and Kazantsev spectra in galactic small-scale dynamos. *Month. Not. Roy. Astron. Soc.*, 2023c, **518**, 3312–3325.

Gent, F.A., Mac Low, M.M., Korpi-Lagg, M.J. and Singh, N.K., The Small-scale Dynamo in a Multiphase Supernova-driven Medium. *Astrophys. J.*, 2023, **943**, 176.

He, Y., Roper Pol, A. and Brandenburg, A., Modified propagation of gravitational waves from the early radiation era. *arXiv e-prints*, 2022, arXiv:2212.06082.

Hidalgo, J.P., Käpylä, P.J., Ortiz-Rodríguez, C.A., Navarrete, F.H., Toro, B. and Schleicher, D.R.G., Origin of magnetism in early-type stars. *arXiv e-prints*, 2023, arXiv:2303.10707.

Käpylä, P.J., Transition from anti-solar to solar-like differential rotation: Dependence on Prandtl number. *Astron. Astrophys.*, 2023, **669**, A98.

Käpylä, P.J. and Singh, N.K., Turbulent Prandtl number from isotropically forced turbulence. *J. Fluid Mech.*, 2022, **952**, R1.

Meftah, J., Hydrodynamic simulations of multiple low-mass migrating black holes in AGN disks; in *Am. Astron. Soc. Meet. Abstr.*, Vol. 55 of *Am. Astron. Soc. Meet. Abstr.*, Jan., 2023, p. 301.46.

Mizerski, K.A., Yokoi, N. and Brandenburg, A., Cross-helicity effect on α-type dynamo in non-equilibrium turbulence. *arXiv e-prints*, 2023, arXiv:2303.01090.

Mtchedlidze, S., Domínguez-Fernández, P., Du, X., Schmidt, W., Brandenburg, A., Niemeyer, J. and Kahniashvili, T., Inflationary and Phase-transitional Primordial Magnetic Fields in Galaxy Clusters. *Astrophys. J.*, 2023, **944**, 100.

Park, K., Cheoun, M.K. and Kim, C.B., Turbulent Magnetic Diffusivity β Effect in a Magnetically Forced System. *Astrophys. J.*, 2023, **944**, 2.

Sengupta, D. and Umurhan, O.M., Turbulence in Particle-laden Midplane Layers of Planet-forming Disks. *Astrophys. J.*, 2023, **942**, 74.

Sharma, R. and Brandenburg, A., Low frequency tail of gravitational wave spectra from hydromagnetic turbulence. *Phys. Rev. D*, 2022, **106**, 103536.

Tharakkal, D., Shukurov, A., Gent, F.A., Sarson, G.R., Snodin, A.P. and Rodrigues, L.F.S., Steady states of the Parker instability. *arXiv e-prints*, 2022, arXiv:2212.03215.

Yuvraj, Naderzadeh Ardebili, Y., Song, W., Im, H.G., Law, C.K. and Chaudhuri, S., On flame speed enhancement in turbulent premixed hydrogen-air flames during local flame-flame interaction. *arXiv e-prints*, 2023, arXiv:2303.00911.

Zhang, J., Hou, Y., Fang, Y., Chen, F., Li, T., Yan, X., Ding, T., Song, Z., Xiang, Y. and Liu, Z., Propagating and Stationary Bright Knots in the Quiet Sun. *Astrophys. J. Lett.*, 2023, **942**, L2.

Zhou, H. and Blackman, E., Helical dynamo growth at modest versus extreme magnetic Reynolds numbers. *arXiv e-prints*, 2023, arXiv:2302.06042.

Zhou, H., Sharma, R. and Brandenburg, A., Scaling of the Hosking integral in decaying magnetically dominated turbulence. *J. Plasma Phys.*, 2022, **88**, 905880602.

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