Monday 20 October

09:30 → 10:30 **Welcome to Pencil Code school**

1h 4/3-006 - TH Cor

Welcome to the school on Pencil Code!
Introduction to the school. History and scientific summary of Pencil Code.

Speakers: Alberto Roper Pol, Axel Brandenburg (Nordita)

PC_school_welcom...

The Pencil Code

a high-order finite-difference code for compressible MHD

Meetings

27-31 Oct, 2025: 21th meeting [agenda] in Geneva, (CERN) (Switzerland).

23-27 Sep, 2024: 20th meeting [agenda] in Barcelona, Institute of Space Sciences (ICE-CSIC / IEEC) (Spain).

4-8 Sep, 2023: 19th meeting [agenda] in Graz, Institute of Physics, University of Graz (Austria).

4-10 May, 2022: 18th meeting [agenda] in Bangalore, IIA (India).

17-21 May, 2021: 17th meeting [agenda] in Lausanne, EPFL (Switzerland).

27-31 Jul, 2020: 16th meeting [agenda] in Glasgow, Glasgow University (UK).

12-16 Aug, 2019: 15th meeting [agenda] in Espoo, Aalto University (Finland).

11-15 Jun, 2018: 14th meeting [agenda] in Boulder, University of Colorado (USA).

10-14 Jul, 2017: 13th meeting [agenda] in Newcastle, Newcastle University (UK).

Numerical Experiments

Numerical Experiments, School on Astrophysical Turbulence and Dynamos, ICTP Trieste, 20-30 April 2009, by Axel Brandenburg & Boris Dintrans

- LCD workshop2016 (Boulder, 10-12 May 2016)
- MHD course (Stockholm, January 2012)
- Evry Schatzman school'09 in Aussois,
- Solar Physics and MHD course (Stockholm, May 2009)
- Schedule for Trieste, April 2009

September 2009 (PowerPoint Presentation)

Pencil Code home page, Manual, Manual-II, PowerPoint Presentation, https://github.com/pencil-code

Python with the Pencil Code

Additional reading:

Brandenburg, A.: 2003, ``Computational aspects of astrophysical MHD and turbulence,'' in *Advances in nonlinear dynamos (The Fluid Mechanics of Astrophysics and Geophysics, Vol. 9)*, ed. A. Ferriz-Mas & M. Núñez, Taylor & Francis, London and New York, pp. 269-344 *(astro-ph/0109497, ADS, PDF)*

Brandenburg, A., & Subramanian, K.: 2005, ``Astrophysical magnetic fields and nonlinear dynamo theory,'' *Phys. Rep.* **417**, 1-209 *(astro-ph/0405052, ADS, PDF)*

Brandenburg, A.: 2007, ``The solar interior - radial structure, rotation, solar activity cycle,'' in *Handbook of Solar-Terrestrial Environment*, ed. Y. Kamide & A. C.-L. Chian, Springer, pp. 27-54 *(astro-ph/0703711)*

Notes on Solar Physics and Magnetohydrodynamics [pdf] (over 100 pages, most of which is not covered in the course)

Links:

Astrophysical Dynamos (ERC project page)

Homepages of Axel Brandenburg and Boris Dintrans

$Date: 2018/05/13 08:57:49 $, $Author: brandenb $, $Revision: 1.30 $

Numerical Experiments: Schedule

- *Setting up your account and downloading the Pencil Code*

  `Setting up the Pencil Code`

- *High order numerical schemes and Pencil Code*

  Effective wavenumbers, exercise [pdf, 1 page]
  Advection tests, exercise [pdf, 1 page]

- *Nonlinear sound waves and Burgers shock*

  Nonlinear sound waves
  Nonlinear Alfven waves
  Burgers shock

- *Brunt-Väisälä oscillations*

  Brunt-Väisälä oscillations

- *Helical dynamos*

  Helical dynamos, exercise [pdf, 1 page]

- *Setting up new experiments*

  MixedTopics

Numerical Experiments homepage

The Pencil Code Newsletter

Issue 2025/1

September 5, 2025, Revision: 1.78

Contents

1 A new steering committee

Since Friday 23 May 2025, the Pencil Code has a new steering committee (PCSC). As on previous occasions, Matthias Rheinhardt set up the adoodle to perform the anonymous election. Clara Dehman from the University of Alicante acted as an independent observer. Here her abbreviated statement from 23 May:

I hereby confirm, in my role as observer, that the election for the PCSC has been successfully concluded. Below is a detailed summary of the participation and the results. A total of 33 individuals were eligible to vote. Of these, 17 submitted their ballots, resulting in a participation rate of 51.5%. One additional participant accessed the voting page but did not cast a vote, and is therefore considered an attentive non-voter (3.03%). The remaining 15 individuals (45.5%) neither accessed the voting page nor submitted a vote and are thus classified as inattentive voters.

The top five candidates in terms of support were:

If nobody has any significant changes then we would proceed promptly with the merger, after which users would need to pull the GPU-ready version before publishing local changes.

In the wake of this major change, **but unrelated to it**, some potential weaknesses of the handling of the code have been exposed. This led to various discussions about the "Pencil Code philosophy". To have a more detailed account of the different view points, we solicited contributions to this newsletter; see the email to `https://groups.google.com/g/pencil-code-discuss` on May 12.

6 WD: Branches

by Wolfgang Dobler, Berlin, Germany `<wdobler@posteo.de>`

received 20 May 2025

6.1 The problem(s)

The currently dominant development model of the Pencil Code is

- *unstructured:* Commits cannot be grouped predictably, because while you try pushing them, others could push some commits of their own;
- *opaque:* if commits are not grouped, it is hard to see what is going on;
- *hard to test:*
  - Continuous-integration tests (= CI tests, which we sometimes call Pencil tests or autotests) have hard time constraints and thus cannot be thorough;
- *fragile:* as a consequence of being hard to test;
- *obscuring responsibility:* If I made two commits, and A has pushed 3 commits in between (see *unstructured* above), would I be testing my changes or theirs?

6.2 Advantages of branch-oriented development

- Much deeper testing
  - You can take your time to run all tests before merging your branch back into *main* (= *master*). This allows us to have really thorough tests.
  - Independence from CI. CI is nice, but it is dangerous to rely on it (and it limits the amount of testing)
- Clearer identification of responsibility
- Isolates unrelated changes from each other until they really need to get dealt with
- Friendly competition (survival of the most popular branch)
- You can get new features running and ask interested others to test before you finalize them (instead of: everybody immediately has to live with your new feature, although it is not thoroughly tested yet – you had to push it onto *main* before asking the interested others).
- Reduces stress level, because you can properly work on a feature without interfering with others and later do all the tests and push.

6.3 Note

- We have used branches before (e.g. the GPU branch)

6.4 Feedback and criticism

Here is the gist of some responses I got to an earlier version of the proposal below.

- "Risk of fragmentation"
  - But where is the problem if all branches are pushed to the server?
    - ∗ If you need functionality from another branch on your own feature branch, you can (a) merge that branch, or (b) cherry-pick the relevant changes from there.
  - *The important thing is to have all branches pushed to the server.*
    - ∗ Currently: If you are not willing (yet) to push, your changes are only local, which is much worse.
- "For short-lived branches which are not shared with anyone else, I would recommend rebasing, as it keeps the history cleaner (this helps later on if one is bisecting to find when a bug was introduced to the master branch)."

to deal with it once before finally merging the changes; if the branch is short-lived, this should still not be too much of a hassle);

B. you can independently work on multiple things at a time (e.g., if you make a commit partially implementing a new initial condition and you later make another commit fixing a boundary condition, you can choose to push only the latter if both are in separate branches, rather than also being forced to push the half-baked initial condition to the repository).

After adopting this 'micro-branching' development style, it becomes feasible to locally run more extensive tests for each set of changes that you intend to push to the main repository. For example, you can use `bin/pc_isolated-test` or `git worktree` to run tests on a particular branch while you simultaneously work on something else in another local branch.

8 CCY: Any commit or merger should be rejected back to the committer if it does not pass the auto-tests

by Chao-Chin Yang, The University of Alabama, Tuscaloosa, USA `<ccyang@ua.edu>`

received 4 June 2025

The previous suggestion that "any commit that breaks the autotest can be reverted by anyone." still puts pressure on the maintainer. This is the reason a pull request (PR) is better than the current approach: the merger has time to run the auto-tests before merging.

It was pointed out that we already have that in the Travis test. The Travis could be set up to automatically start auto-tests for each commit coming in, so one could also set up a hook to reject for failed commit.

Further:

(1) If no branching is still favorable, any commit that breaks any auto-test should be immediately rejected; if branching is the adopted way to go, any merger needs to pass all auto-tests before merging into main.

(2) No sample can be modified except by the maintainer. Any people interested in changing a sample must collaborate with the maintainer before any commit can be made. If the maintainer of a sample has clearly left the code or is not accountable for maintaining the sample, we need to find a replacement maintainer. If no replacement can be found, we may want to remove the sample or move it to an obsolete folder.

9 DC: It would be good if Pencil were to adopt PRs and branches

by Daniel Carrera, Iowa State University, Ames, USA `<dcarrera@gmail.com>`

received 4 June 2025

(1) Someone wants to propose a feature for Pencil. They clone the git repository, add the feature, and when it's all tested they go to GitHub and create a pull request. Then someone in charge at Pencil can approve or reject the PR.

(2) Branches give people freedom to make changes that temporarily break the code, as all their work is done in an isolated branch. But when they finish coding the feature, they have to make sure that all tests pass before they can merge.

Point #1 is code review, that's how codes like Athena operate. In the software industry code review is done every day. However, I understand it would put too much pressure on the developer team, in essence it means that a set of eyes would be necessary to approve any commit. The automated auto-test to reject commits that fail could be a compromise.

I would add that another argument for branches and pull requests is to use the capabilities of git and github, which have become the standard in software development. As it is, students that use and develop Pencil are not being trained in the new version control paradigm, but in the old one of svn and cvs. That's the fundamental problem of education: we teach today, with the tools of yesterday, the people of tomorrow. Wearing our educator hat, we should strive to teach a transferable skill, as many of our students will go on to become data scientists or software engineers; while it is not our job to be a training ground for industry, it is a shortcoming if we don't equip them for that possibility. And for what? Just so we don't leave our comfort zone and learn something new ourselves?

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Automatic tests

To ensure reproducability, the **Pencil Code** is tested for a number of sample applications. This is important for us in order to make sure certain improvements in some parts of the code do not affect the functionality of other parts. For other users who suspect that a new problem has emerged it could be useful to first see whether this problem also shows up in our own tests. The latest test results for a can be seen online:

level	name	description	time	OK	runs	host	compiler	maintainer
0	minimal	no- & most-modules	minutely	✓	**latest** (**previous**)	pencil-code.org	GNU 9.4	Philippe
0+1	basic	same as **Travis**	minutely	✓	**latest** (**previous**)	Norlx51	GNU 13.3	Axel/Philippe
2	normal	without basic	*/*:15	✗	**latest** (**previous**)	Norlx51	GNU 13.3	Axel/Philippe
0-2	default	basic + normal	*/2:03	✗	**latest** (**previous**)	Norlx65	GNU 13.3	Philippe/Axel
3	extended	without default	*/*:55	✓	**latest** (**previous**)	Norlx51	GNU 13.3	Axel/Philippe
0-3	full test	default + extended	*/6:31	⌛	**latest** (**previous**)	pencil-code.org	GNU 9.4	Philippe
4	fixme	succeeded before	*/6:45	⌛	**latest** (**previous**)	Norlx51	GNU 13.3	Axel/Philippe
5	overlong	runs less often	15:31	🕒	**latest** (**previous**)	Norlx65	GNU 13.3	Philippe/Axel
6-9	defective	known to fail	03:31	🕒	**latest** (**previous**)	Norlx65	GNU 13.3	Philippe/Axel

Legend: */* means every hour, */6:31 means 31 minutes after full hours divisible by 6.
Status of auto-tests: 🕒 scheduled; ⌛ running; ✗ failed; ✓ succeeded.
Tests are triggered only if there are new updates to the code.

Scientific usage of the Pencil Code

Search results using `http://adslabs.org` and Bumblebee `https://ui.adsabs.harvard.edu/`

`http://pencil-code.nordita.org/highlights/`
July 26, 2025

A search using ADS `https://ui.adsabs.harvard.edu/` lists the papers in which the Pencil Code is being quoted. In the following we present the papers that are making use of the code either for their own scientific work of those authors, or for code comparison purposes. We include conference proceedings, which make up 15–20% of all papers. We classify the references by year and by topic, although the topics are often overlapping. The primary application of the Pencil Code lies in astrophysics, in which case we classify the papers mostly by the field of research. Additional applications can also be found in meteorology and combustion.

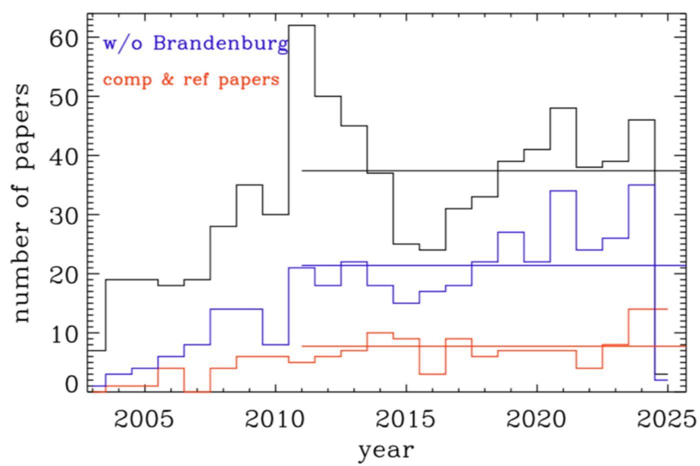

Figure 1: Number of papers since 2003 that make use of the Pencil Code. In red is shown the number of papers that reference it for code comparison or other purposes and in blue the papers that are not co-authored by Brandenburg. The enhanced number of papers during 2011–2013 results from publications related to his ERC Advanced Grant.

1 Papers by year

As of September 2024, the Pencil Code *has been used for a total of 736 research papers; see Figure 1; 379 of those are papers (51%) are not co-authored by Brandenburg. In addition, 138 papers reference it for code comparison or other purposes (see the red line).*

2 times in 2025 (Godines *et al.*, 2025; Iarygina *et al.*, 2025; Srivastava *et al.*, 2025; Hidalgo *et al.*, 2025; Shchutskyi *et al.*, 2025a; Sabelnikov *et al.*, 2025; Tschernitz and Bourdin, 2025;

2 Papers by topic

The Pencil Code has been used for the following research topics

1. **Interstellar and intercluster medium as well as early Universe**

   (a) *Interstellar and intercluster medium* (Korpi-Lagg *et al.*, 2024; Elias-López *et al.*, 2024, 2023; Pavaskar *et al.*, 2023; Gent *et al.*, 2023; Brandenburg and Ntormousi, 2022; Maiti *et al.*, 2021; Gent *et al.*, 2021; Li and Mattsson, 2021; Candelaresi and Del Sordo, 2021, 2020; Li and Mattsson, 2020; Brandenburg and Furuya, 2020; Brandenburg and Brüggen, 2020; Gent *et al.*, 2020; Evirgen and Gent, 2019; Evirgen *et al.*, 2019; Seta and Beck, 2019; Rodrigues *et al.*, 2019; Brandenburg, 2019a; Väisälä *et al.*, 2018; Zhang

2. Planet formation and inertial particles

(a) *Planet formation* (Rice *et al.*, 2025; Eriksson *et al.*, 2025; Shi *et al.*, 2025; Baehr *et al.*, 2022; Yang and Zhu, 2021; Raettig *et al.*, 2021; Baehr and Zhu, 2021b,a; Zhu and Yang, 2021; Klahr and Schreiber, 2021, 2020; Yang and Zhu, 2020; Eriksson *et al.*, 2020; Gerbig *et al.*, 2020; Castrejon *et al.*, 2019; Baehr and Klahr, 2019; McNally *et al.*, 2018; Schreiber and Klahr, 2018; Hernandez *et al.*, 2019; Manser *et al.*, 2019; Yang *et al.*, 2018; Rice and Nayakshin, 2018; Richert *et al.*, 2018; Kuchner *et al.*, 2018;

3. Accretion discs and shear flows

(a) *Accretion discs and shear flows* (Godines *et al.*, 2025; Meftah, 2025; Lyra *et al.*, 2024; Sengupta *et al.*, 2024; Cañas *et al.*, 2024; Zhou, 2024; Mondal and Bhat, 2023; Meftah, 2023; Tharakkal *et al.*, 2023a,b; Hyder *et al.*, 2022, 2021, 2020; Bhat *et al.*, 2017; Singh *et al.*, 2017; Lyra *et al.*, 2017; Bhat *et al.*, 2016a; Tian and Chen, 2016; Lyra, 2014; Lyra *et al.*, 2015; Väisälä *et al.*, 2014; Lyra, 2013; Raettig *et al.*, 2013; Di Bernardo and Torkelsson, 2013; Latter and Papaloizou, 2012; Gaburov *et al.*, 2012; Lyra and Mac Low, 2012; Rice *et al.*, 2011, 2012; Oishi and Mac Low, 2011; Flock *et al.*, 2011; Käpylä *et al.*, 2010a; Käpylä and Korpi, 2011; Fromang *et al.*, 2010; Korpi *et al.*, 2010; Johansen *et al.*, 2009a; Heinemann and Papaloizou, 2009; Fromang *et al.*, 2009; Johansen and Levin, 2008; Workman and Armitage, 2008; Fromang *et al.*, 2007; Fromang and Papaloizou, 2007; Ouyed *et al.*, 2006; Brandenburg, 2005d).

(b) *Shear flows* (Barekat *et al.*, 2020; Singh and Jingade, 2015; Modestov *et al.*, 2014; Vermersch and Brandenburg, 2009; Käpylä *et al.*, 2009c; Green *et al.*, 2008; Yousef *et al.*, 2008; Babkovskaia *et al.*, 2008; Brandenburg *et al.*, 2004a).

(a) *Coronal heating and coronal mass ejections* (Srivastava *et al.*, 2025; Kishore and Singh, 2025a,b; Singh *et al.*, 2025; Vemareddy, 2024; Kesri *et al.*, 2024; Maity *et al.*, 2024b; Dey *et al.*, 2024; Vemareddy *et al.*, 2024; Zhang *et al.*, 2023; Dey *et al.*, 2022; Chatterjee and Dey, 2022; Jakab and Brandenburg, 2021; Zhuleku *et al.*, 2021; Adrover-González and Terradas, 2020; Bourdin, 2014, 2017, 2020; Bourdin *et al.*, 2013a,b, 2014, 2015, 2016; Chatterjee, 2020; Warnecke and Bingert, 2020; Candelaresi *et al.*, 2019; Warnecke and Peter, 2019b; Smiet *et al.*, 2019; Warnecke and Peter, 2019a; Korsós *et al.*, 2018; Cameron *et al.*, 2017; Chatterjee *et al.*, 2016; Candelaresi *et al.*, 2016; Threlfall *et al.*, 2016; Chen *et al.*, 2015; Smiet *et al.*, 2015; Warnecke and Brandenburg, 2014; van Wettum *et al.*, 2013; Bingert and Peter, 2013; Peter and Bingert, 2012; Peter *et al.*, 2012; Warnecke *et al.*, 2012a,b; Warnecke and Brandenburg, 2011a; Zacharias *et al.*, 2011a,b; Warnecke *et al.*, 2011b; Bingert and Peter, 2011; Warnecke and Brandenburg, 2011b; Warnecke *et al.*, 2011a; Warnecke and Brandenburg, 2010; Bingert *et al.*, 2010; Zacharias *et al.*, 2009b,a).

(b) *Large-scale dynamos, helical turbulence, and catastrophic quenching* (Shchutskyi *et al.*, 2025a; Brandenburg *et al.*, 2025b; Brandenburg and Vishniac, 2025; Rogachevskii *et al.*, 2025; Brandenburg *et al.*, 2025a; Mondal *et al.*, 2025; Shchutskyi *et al.*, 2025b; Hidalgo *et al.*, 2025; Zhou and Lai, 2024; Vashishth, 2024; Zhou and Blackman, 2024; Zhu and Shi, 2023; Park *et al.*, 2023; Yang and Zhu, 2022; Prabhu *et al.*, 2021; Brandenburg and Scannapieco, 2020; Park, 2019a; Peng *et al.*, 2019; Nauman and Nättilä, 2019; Park, 2019b; Brandenburg and Oughton, 2018; Bourdin *et al.*, 2018; Bourdin and Brandenburg, 2018; Brandenburg, 2018; Brandenburg and Chatterjee, 2018; Rempel *et al.*, 2019; Brandenburg *et al.*, 2017a,c,b; Rempel *et al.*, 2017; Smiet *et al.*, 2017; Cole *et al.*, 2016; Karak and Brandenburg, 2016; Karak *et al.*, 2015b; Brandenburg and Hubbard, 2015; Subramanian and Brandenburg, 2014; Brandenburg and Stepanov, 2014; Brandenburg, 2014; Bhat *et al.*, 2014; Chian *et al.*, 2014; Park, 2014b; Park *et al.*, 2013; Brandenburg and Lazarian, 2013; Park, 2013b,a, 2014a; Candelaresi and Brandenburg, 2013a; Park, 2013a; Del Sordo *et al.*, 2013; Brandenburg, 2013; Rempel *et al.*, 2013;

(c) *Primordial magnetic fields and decaying turbulence* (Dehman and Brandenburg, 2025; Vachaspati and Brandenburg, 2024; Brandenburg and Banerjee, 2024; Dwivedi *et al.*, 2024; Brandenburg *et al.*, 2024a, 2023d; Mtchedlidze *et al.*, 2024, 2023, 2022; Bhat *et al.*, 2021; Brandenburg, 2023a, 2020a; Brandenburg *et al.*, 2020b, 2019b; Kahniashvili *et al.*, 2020; Brandenburg *et al.*, 2018b; Trivedi *et al.*, 2018; Brandenburg *et al.*, 2017d; Brandenburg and Kahniashvili, 2017; Kahniashvili *et al.*, 2017; Reppin and Banerjee, 2017; Park, 2017; Osano and Adams, 2017; Adams and Osano, 2016; Osano and Adams, 2016b,a; Kahniashvili *et al.*, 2016; Brandenburg *et al.*, 2015; Adams and Osano, 2014; Kahniashvili *et al.*, 2012, 2013; Tevzadze *et al.*, 2012; Candelaresi and Brandenburg, 2011a; Kahniashvili *et al.*, 2010; Del Sordo *et al.*, 2010; Christensson *et al.*, 2005; Yousef *et al.*, 2004).

(d) *Relic gravitational waves & axions* (Iarygina *et al.*, 2025; Sharma *et al.*, 2025c; Brandenburg *et al.*, 2024b,c; Iarygina *et al.*, 2024; Sharma *et al.*, 2023; He *et al.*, 2023; Roper Pol, 2022; Sharma and Brandenburg, 2022; AlbertoRoper, 2022; Kahniashvili *et al.*, 2022; Roper Pol, 2021; Roper Pol *et al.*, 2022b; He *et al.*, 2021b,a; Brandenburg *et al.*, 2021b,d; Brandenburg and Sharma, 2021; Brandenburg *et al.*, 2021a,c; Kahniashvili *et al.*, 2021; Roper Pol *et al.*, 2020b,a).

5. **Miscellanea**

(a) *Turbulent transport and test-field method* (Candelaresi and Beck, 2023; Brandenburg and Protiti, 2023; Mizerski *et al.*, 2023; Carenza *et al.*, 2023; Käpylä and Singh, 2022; Käpylä *et al.*, 2022; Zhou and Blackman, 2021; Haugen *et al.*, 2021a; Käpylä *et al.*, 2020a; Brandenburg and Chen, 2020; Peng *et al.*, 2019; Warnecke *et al.*, 2018; Andrievsky *et al.*, 2015; Snellman *et al.*, 2015; Karak *et al.*, 2014; Rheinhardt *et al.*, 2014; Rüdiger and Brandenburg, 2014; Devlen *et al.*, 2013; Brandenburg *et al.*, 2004b,

7. Solar/Stellar physics

spherical geometry

stars-in-a-box

radiation: $\frac{dI}{d\lambda} = \kappa\rho(I-S)$

already seen

8. Mean-field

$$\overline{u \times b} \equiv \bar{\mathcal{E}} = \alpha \bar{B} - \eta_t \mu_0 \bar{J}$$

α pseudo scalar

kinetic helicity

analogy to CME

Piyali paper

memory effect

9. TFM

$$\frac{\partial A}{\partial t} = U \times B + \ldots$$

$$\frac{\partial \overline{A}}{\partial t} = \overline{U} \times \overline{B} + \overline{u \times b} + \ldots$$

$$\frac{\partial a}{\partial t} = \overline{U} \times b + u \times \overline{B} + u \times b - \overline{u \times b} + \ldots$$

$$\frac{\partial a}{\partial t} = \overline{U} \times b + u \times \overline{B}^{T} + u \times b - \overline{u \times b} + \ldots$$

inhomogeneous!

(homogeneous part secondary, and problematic)

10. Tub contribution

refs.

→ when checked in

How to update

Readme

Manual

, ...

For questions, just email me, or, better still, join the pencil-code-discuss mailing list!