# 18 years of Pencil code

i. Scientific usage
ii. Changes & developments
iii. GAFD special issue
iv. Code & data DOIs

Aalto-yliopisto

# *The 15th meeting!*

| | | | |
|---|---|---|---|
| 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). |
| 08-12 Aug, 2016: | 12th meeting | [agenda] | in Graz, Space Research Institute, Academy of Sciences (Austria). |
| 11-15 May, 2015: | 11th meeting | [agenda] | in Trondheim, Norwegian University of Science and Technology (Norway). |
| 07-11 Jul, 2014: | 10th meeting | [agenda] | in Göttingen, Max Planck Institute for Solar System Research (Germany). |
| 17-20 Jun, 2013: | 9th meeting | [agenda] | in Lund, Lund Observatory (Sweden). |
| 18-21 Jun, 2012: | 8th meeting | [agenda] | in Helsinki, Physics Department (Finland). |
| 24-28 Oct, 2011: | 7th meeting | [agenda] | in Toulouse, Observatoire Midi-Pyrénées (France). |
| 26-30 Jul, 2010: | 6th meeting | [notes] | in New York, American Museum of National History (USA). |
| 24-28 Aug, 2009: | 5th meeting | [agenda] | in Heidelberg, Max Planck Institute for Astronomy (Germany). |
| 19-22 Aug, 2008: | 4th meeting | [agenda] | in Leiden, Leiden Observatory (Netherlands). |
| 14-17 Aug, 2007: | 3rd meeting | [notes] | in Stockholm, Nordita (Sweden). |
| 13-15 Jul, 2006: | 2nd meeting | [videos] | in Copenhagen, Nordita (Denmark). |
| 26-28 Jun, 2005: | 1st meeting | | in Copenhagen, Nordita (Denmark). |

# Updates since last year

A search using http://adslabs.org or Bumblebee 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 mostly by the field of research.

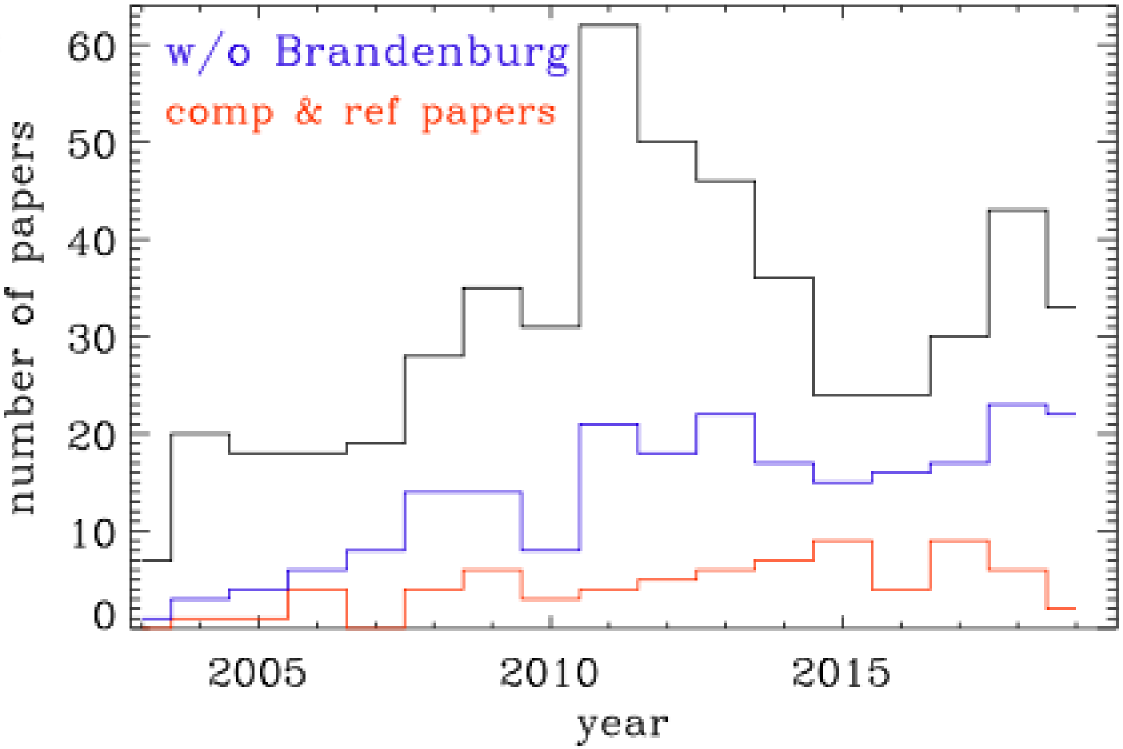
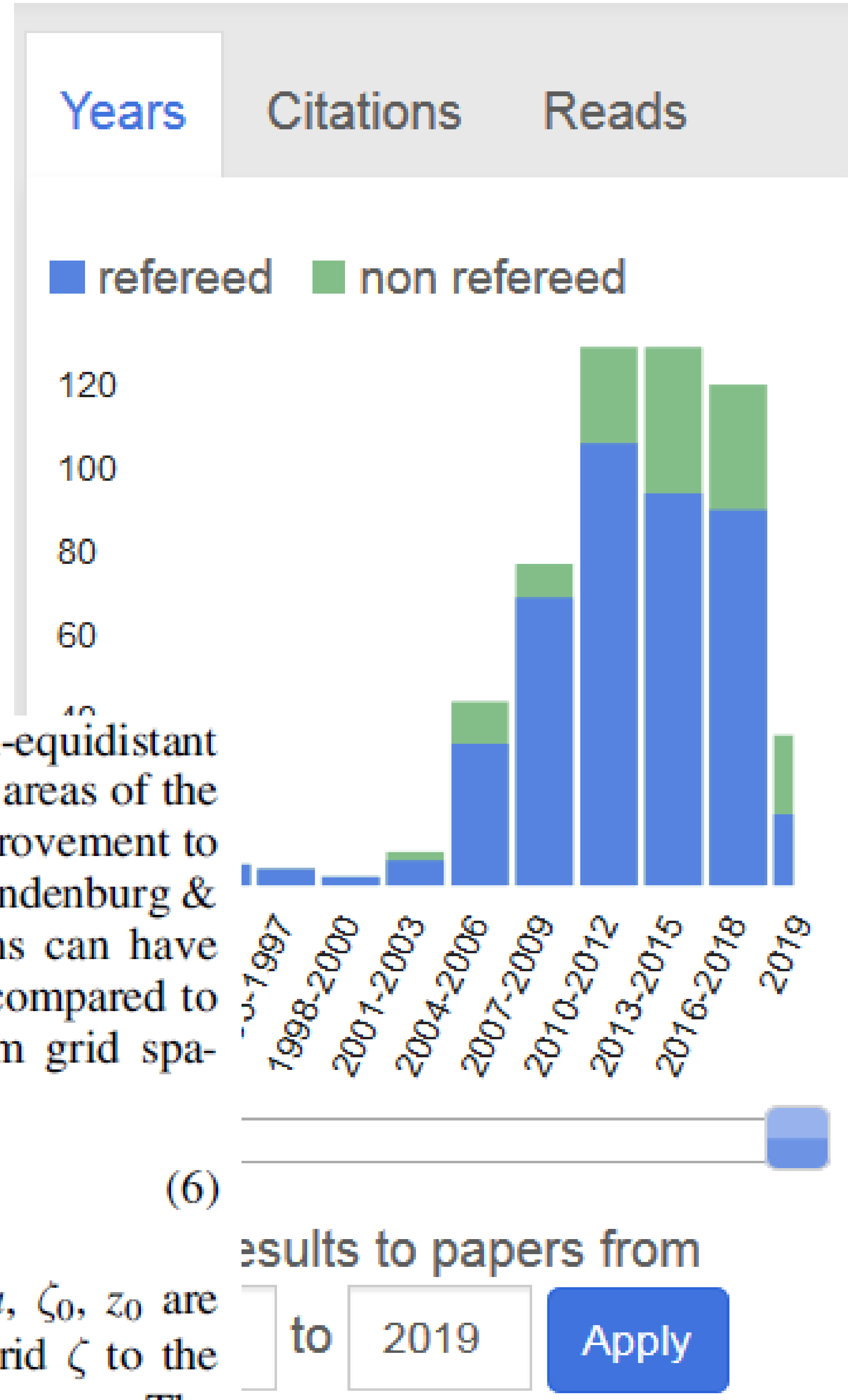



Figure 1: Number of papers since 2003 that make use of the Pencil Code. In red is shown the number of papers that reference it for code comparison or other purposes and in blue the papers that are not co-authored by Brandenburg. The enhanced number of papers during 2011–2013 results from publications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

# ADS:

# full"Pencil Code"

- Pencil Code philosophy as inspiration to others
- Here just one example




The code has also been enhanced to use non-equidistant grids to allow for increased resolution in particular areas of the Milky Way, in this case around Geminga. This improvement to GALPROP is inspired by the the Pencil Code[5] (Brandenburg & Dobler 2002), where the use of analytic functions can have advantages in terms of speed and memory usage compared to purely numerical implementations for non-uniform grid spacing. The current run uses the grid function

$$z(\zeta) = \frac{\epsilon}{a} \tan\left[a(\zeta - \zeta_0)\right] + z_0 \qquad (6)$$

for all spatial coordinates $\zeta = x, y, z$, where $\epsilon$, $a$, $\zeta_0$, $z_0$ are parameters. This function maps from the linear grid $\zeta$ to the

www.sciencemag.org/content/364/6435/66/suppl/DC1

Supplementary Materials for

**A planetesimal orbiting within the debris disc around a white dwarf star**

Christopher J. Manser*, Boris T. Gänsicke, Siegfried Eggl, Mark Hollands, Paula Izquierdo, Detlev Koester, John D. Landstreet, Wladimir Lyra, Thomas R. Marsh, Farzana Meru, Alexander J. Mustill, Pablo Rodríguez-Gil, Odette Toloza, Dimitri Veras, David J. Wilson, Matthew R. Burleigh, Melvyn B. Davies, Jay Farihi, Nicola Gentile Fusillo, Domitilla de Martino, Steven G. Parsons, Andreas Quirrenbach, Roberto Raddi, Sabine Reffert, Melania Del Santo, Matthias R. Schreiber, Roberto Silvotti, Silvia Toonen†, Eva Villaver, Mark Wyatt, Siyi Xu, Simon Portegies Zwart

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DOI: 10.1126/science.aat5330

led to the data collection and discussion of the results. **Competing interests:** The authors declare no conflict of interests. **Data and materials availability:** The data used in this research are available from the ESO VLT archive (36), under proposal number 595.C-0650 (G), and the GTC archive (37), under proposal numbers GTC1-16ITP and GTC25-18A. The ZEEMAN software and the model shown in fig. S5 are available from https://sourceforge.net/projects/zeeman-f/. The PENCIL CODE software is available at https://github.com/pencil-code; we used version #f4f2f16, with the model shown in figs. S6 and S7 in the directory pencil-code/samples/2d-tests/WhiteDwarfDisk.

where $T_0$ is the orbital period at the reference radius $r = 1R_\odot$. Sixth-order hyper-dissipation terms are added to the evolution equations to provide extra dissipation near the grid scale (94). These terms are needed for numerical stability because the high-order scheme of the PENCIL CODE (95) has little overall numerical dissipation (96). They are chosen to produce Reynolds numbers of order unity at the grid scale, but then drop as the sixth power of the scale at larger scales, so they have negligible influence on the large-scale flow. Shock diffusion is added to the equations of motion, to resolve shocks to a differentiable length (97, 98, 99). Extra Laplacian viscosity is added to the equations, with $\alpha = 10^{-2}$ (85).

# *Unknown connections*

- Well-known for helicity studies

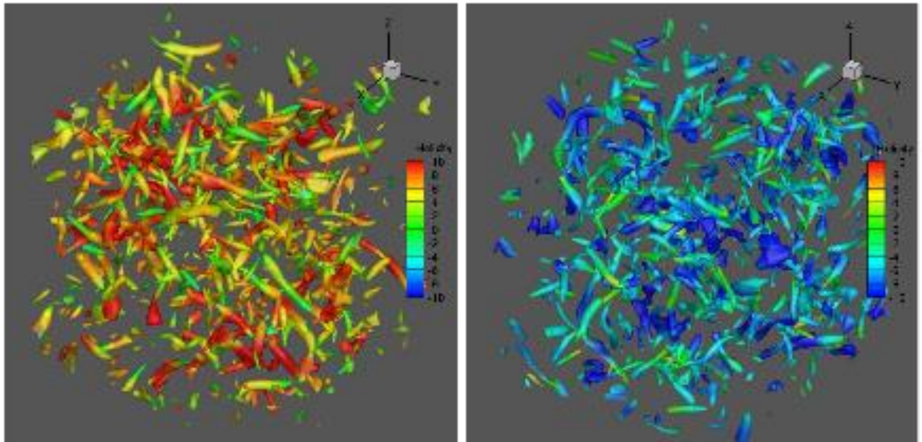
We based our helical and non-helical compressible turbulence analyses on a set of well-controlled direct numerical simulations with periodic boundary conditions. Two programs, the Pencil Code and the OpenCFD, known (the former already worldwide[15] and the latter mainly in China[16], so far) respectively in the astrophysics and aerodynamics communities, have been used for tests. Helicity controlling techniques, with or without helicity injection, say, have been well-developed, as partly already implemented in typical incompressible and compressible turbulence simulation open-source softwares[17]. The discretization grid numbers used are up to $1024^3$, and for statistical steady state statisitcs, long time integrations up to 5 large-eddy turnover times were performed. Such typical 'massive' simulations resolve reasonably well into the details of flow structures, with visibly separated energy-containing, inertial, bottleneck and dissipation regimes in the power

LETTER

## Helicity hardens the gas

Jun Peng[1,2,*], Jin-Xiu Xu[3], Yan Yang[1,2,*] & Jian-Zhou Zhu[2]

**A screw generally works better than a nail, or a complicated rope knot better than a simple one, in fastening solid matter, while a gas is more tameless. However, a flow itself has a physical quantity, helicity, measuring the screwing strength of the velocity field and the degree of the knottedness of the vorticity ropes. It is shown that helicity favors the partition of energy to the vortical modes, compared to others such as the dilatation and pressure modes of turbulence; that is, helicity stiffens the flow, with nontrivial implications for aerodynamics, such as aeroacoustics, and conducting fluids, among others.**



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **479,** 3923–3935 (2018) doi:
Advance Access publication 2018 June 15

# The influence of atomic alignment on absorption and emission spectroscopy

Heshou Zhang,[1,2] Huirong Yan[1,2★] and Philipp Richter[2,3]

[1] *Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, D-15738 Zeuthen, Germany*
[2] *Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam, Germany*
[3] *Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, D-14482 Potsdam, Germany*

### 4.3 Observations from the medium with turbulent magnetic fields

In order to address the issue of how much modulation can be induced with the line-of-sight dispersion of magnetic field, we perform synthetic observation on ISM with turbulent magnetic field from numerical simulation. A three-dimensional (3D) super-Alfvenic ($M_a$ = 1.43) MHD data cube (512 × 512 × 16), which corresponds to a $1pc(x) \times 1pc(y) \times 0.2pc(z)$ diffuse layer of a reflection nebula, is generated by the MHD-simulation with the PENCIL code.[7] Note

[7] See https://code.google.com/archive/p/pencil-code/ for details.

## ACKNOWLEDGEMENTS

We are grateful to Gesa Bertrang, Reinaldo Santos de Lima, Ruoyu Liu, and Michael Vorster for the helpful discussions. We thank the referee for valuable comments and suggestions.

## REFERENCES

Armstrong J. W., Rickett B. J., Spangler S. R., 1995, ApJ, 443, 209
Asplund M., Grevesse N., Sauval A. J., Scott P., 2009, ARA&A, 47, 481
Bommier V., Sahal-Brechot S., 1978, A&A, 69, 57
Chepurnov A., Lazarian A., 2010, ApJ, 710, 853

# Other items

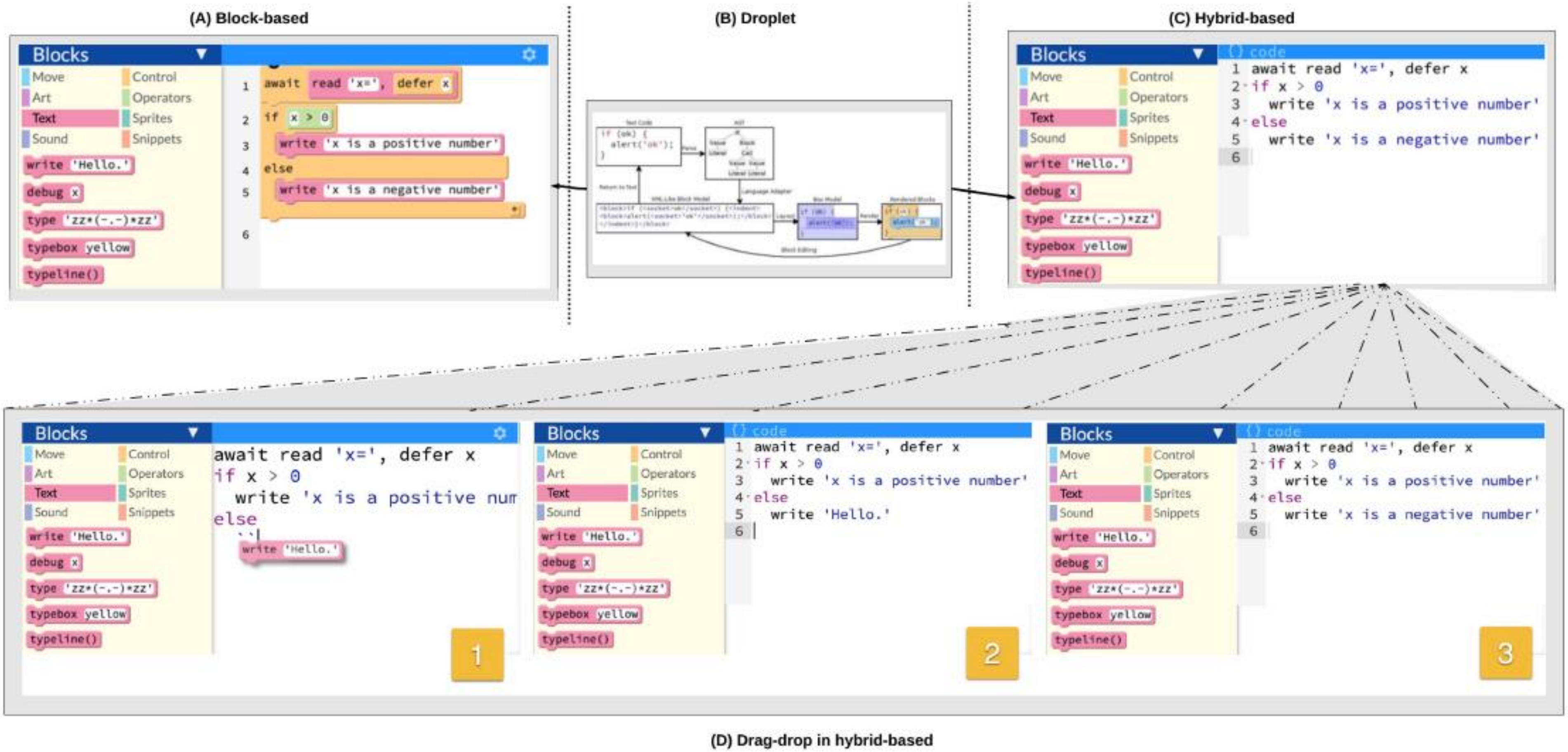
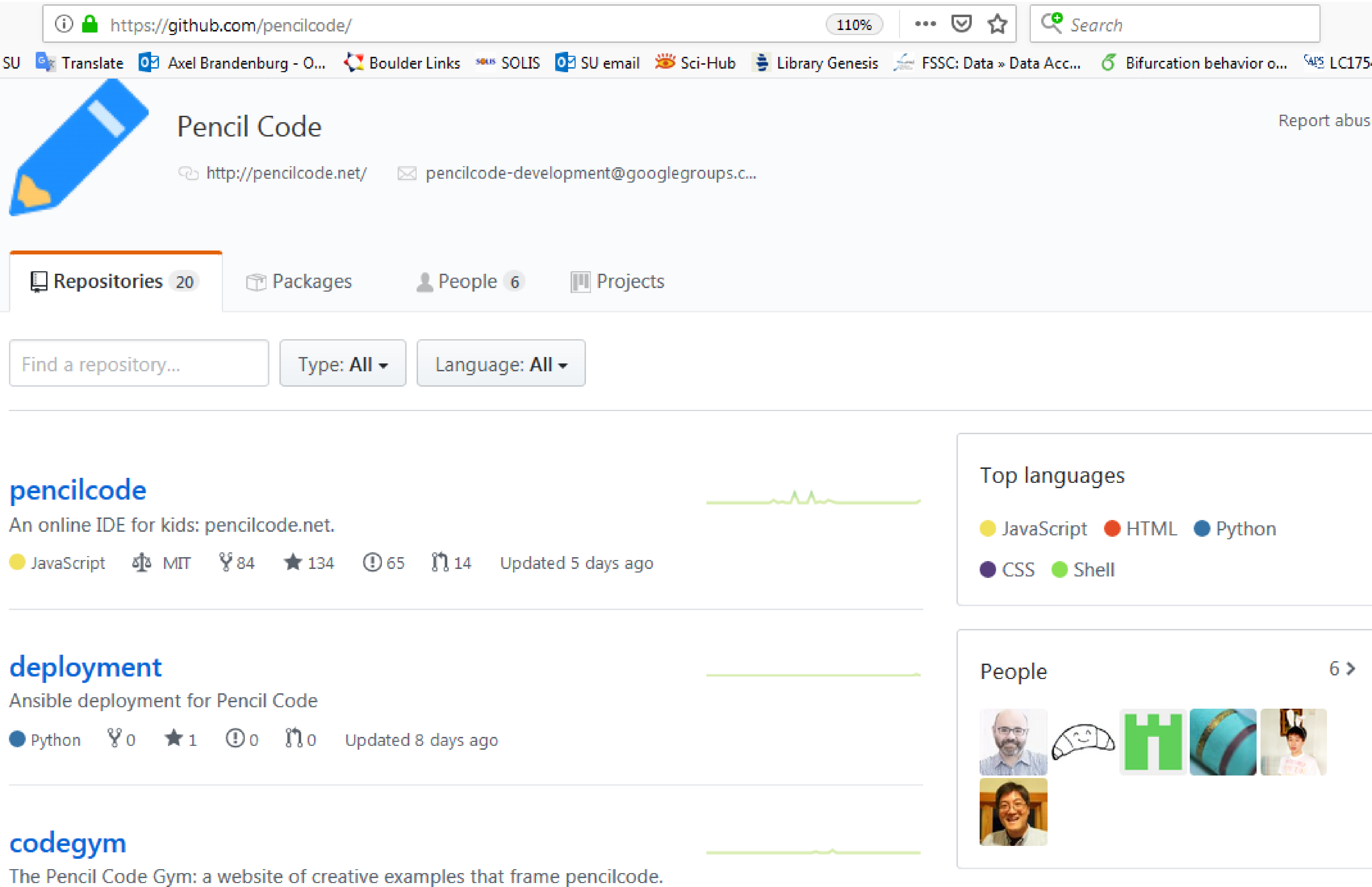


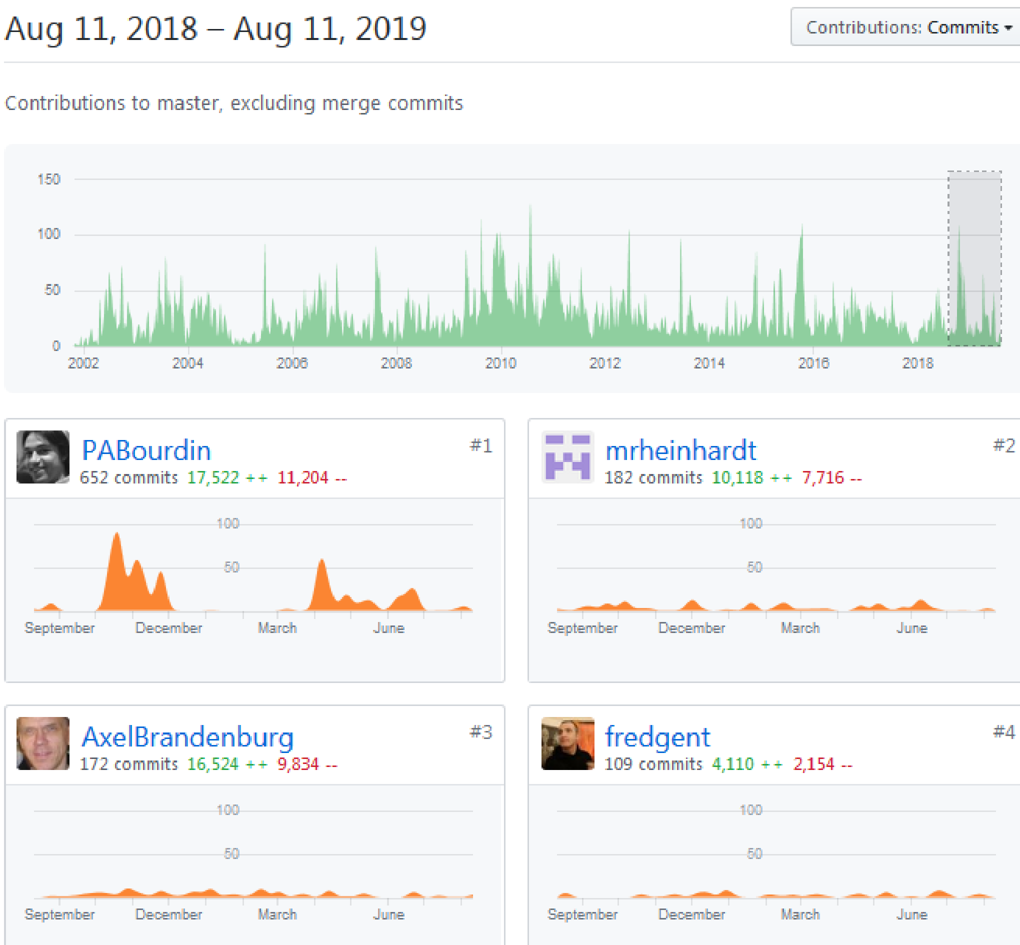

Figure 2: Hybrid-based PencilCode Overview.

# Also on github…



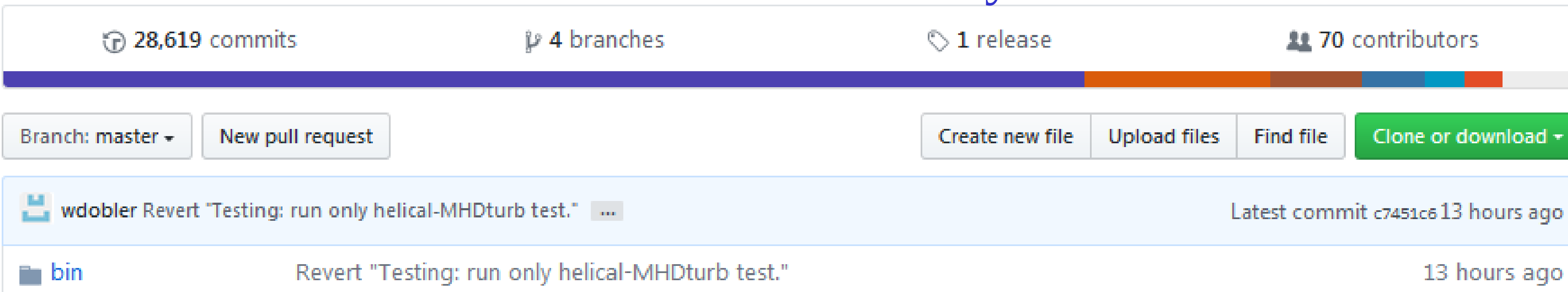
# Now 30,218 commits

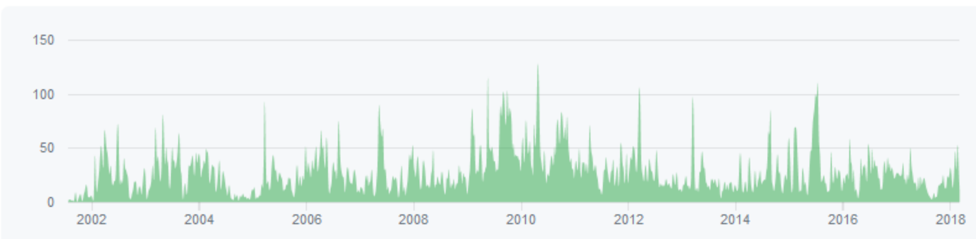

H-index = 34, i.e.,
34 people did >34 commits



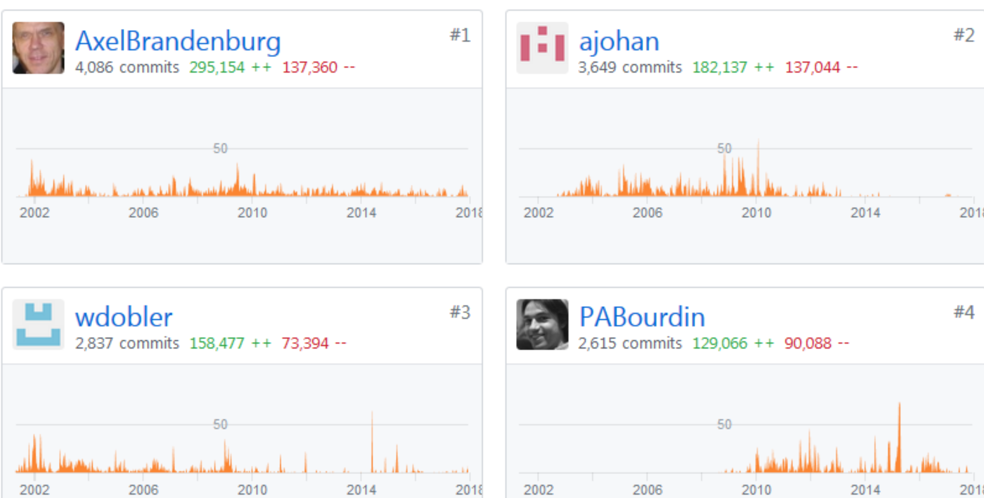

# Last year 28,619 commits

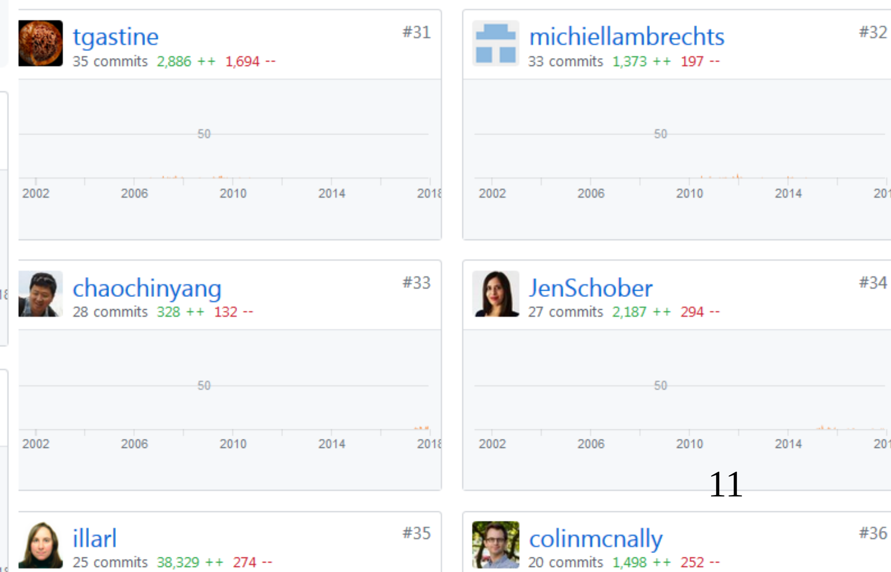
1599 more since last year




H-index = 32, i.e.,
32 people did >32 commits



# Special Issue

## Special issue on ``Physics and Algorithms of the Pencil Code'' in Geophysical & Astrophysical Fluid Dynamics (GAFD)

*Published:*

1) Aarnes, J. R., Jin, T., Mao, C., Haugen, N. E. L., Luo, K., Andersson, H. I.: , 2018, ``Treatment of solid objects in the Pencil Code using an immersed boundary method and overset grids ,'' *Geophys. Astrophys. Fluid Dyn.*, published (arXiv:1806.06776, DOI:10.1080/03091929.2018.1492720)

2) Schober, J., Brandenburg, A., & Rogachevskii, I.: 2019, ``Chiral fermion asymmetry in high-energy plasma simulations,'' *Geophys. Astrophys. Fluid Dyn.*, DOI: 10.1080/03091929.2019.1591393 (arXiv:1808.06624, ADS, HTML, DOI, PDF)

3) Käpylä, P. J., Gent, F. A., Olspert, N., Käpylä, M. J., & Brandenburg, A.: 2019, ``Sensitivity to luminosity, centrifugal force, and boundary conditions in spherical shell convection,'' *Geophys. Astrophys. Fluid Dyn.*, DOI: 10.1080/03091929.2019.1571586 (arXiv:1807.09309, HTML, DOI, PDF)

# Four papers in press

*In press:*

4) Gent, F. A., Mac Low, M.-M., Kä,pylä,, M. J., Sarson, G. R., Hollins, J. F. , 2018, ``Modelling supernova driven turbulence,'' *Geophys. Astrophys. Fluid Dyn.*, in press (arXiv:1806.01570)

5) Roper Pol, A., Brandenburg, A., Kahniashvili, T., Kosowsky, A., Mandal, S.: 2018, ``The timestep constraint in solving the gravitational wave equations sourced by hydromagnetic turbulence,'' *Geophys. Astrophys. Fluid Dyn.*, in press (arXiv:1807.05479, HTML, PDF)

6) Bourdin, P. A.: 2018, ``Driving solar coronal MHD simulations on high-performance computers,'' *Geophys. Astrophys. Fluid Dyn.*, in press

7) Singh, N. K., Raichur, H., Käpylä, M. J., Rheinhardt, M., Brandenburg, A., & Käpylä, P. J.: 2018, ``□-mode strengthening from a localized bipolar subsurface magnetic field,'' *Geophys. Astrophys. Fluid Dyn.*, in press (arXiv:1808.08904, ADS, HTML, PDF)

# Four papers still waiting

*Submitted:*


8) Chatterjee, P. , 2018, ``Testing Alfven wave propagation in a realistic set-up of the solar atmosphere,'' *Geophys. Astrophys. Fluid Dyn.*, submitted (arXiv:1806.08166)

9) Warnecke, J., & Bingert, S.: 2018, *Geophys. Astrophys. Fluid Dyn.*, submitted (arXiv:1811.01572)

10) Brandenburg, A., & Das, U.: 2019, ``The time step constraint in radiation hydrodynamics,'' *Geophys. Astrophys. Fluid Dyn.*, submitted (arXiv:1901.06385, ADS, HTML, PDF)

11) Qian, C., Wang, C., Liu, J., Brandenburg, A., Haugen, N. E. L., & Liberman, M.: 2019, ``Convergence properties of detonation simulations,'' *Geophys. Astrophys. Fluid Dyn.*, submitted (arXiv:1902.03816, ADS, HTML, PDF)

# Run directories related to some past research projects

## Isotropic homogeneous MHD turbulence

- Inverse transfer in non-helical MHD
- Classes of hydrodynamic and MHD decay
- The turbulent chiral - magnetic cascade in the early universe
- Dynamo effect in decaying helical t

## Interstellar medium: cooling insta

- Thermal instability
- Random expansion waves
- Supersonic turbulence

## Convection, ionization, & radiatior

- Cartesian convection with Kramers
- 1-D simulations with hydrogen ioni:
- The time step constraint in radiatic

**Two-scale method of measuring magnetic helicity**

- Large-scale helicity spectra

**Coagulation**

- Coagulation & condensation in turbulent flows
- Effect of turbulence on collisional growth of cloud droplets
- Cloud droplet growth due to supersaturation fluctuations in stratiform clouds

**Miscellanea**

- Spreading layer on neutron stars
- Test-field method for computing dynamo coefficients
- Strong nonlocality variations in a spherical mean-field dynamo
- Negative effective magnetic pressure instability
- Surface flux concentrations in a spherical $\alpha^2$ dynamo

**Other data**

- Spectral magnetic helicity of solar active regions between 2006 and 2017

(last access: 16 December 2018) The DOI of the code is https://doi.org/10.5281/zenodo.2315093. The DNS setup and the corresponding data (Li et al., 2019) are freely available at https://doi.org/10.5281/zenodo.2538027.

# *Some developments*

- HDF5
- Python developments
- GPU
- Superdroplets, Yin-Yang mesh
- Coronal emissions (AIA, XRT, magnetograms)
- Spherical test-fields

# *Where in 20 years?*

- Will the code still be used?
- By others than ourselves?
- Is our samples still up to the task?
- Usage of code/data DOI
- Other thoughts?