Activity report based on time used on HPC2N, PDC, and Nordic HPC since October 2011

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October 24, 2012

An important goal is to show that at large enough magnetic Reynolds numbers Rm, the dynamo effect survives and is independent of Rm. We have now performed new high resolution runs on Lindgren and have extended the plot of our earlier proposal; see Figure 1, where we show the scaling of the magnetic helicity production, $-2\overline{\boldsymbol{\mathcal{E}}}\cdot\overline{\boldsymbol{B}}$, which is either balanced by the resistive term, $2\eta\overline{\boldsymbol{j}\cdot\boldsymbol{b}}\sim\mathrm{Rm}^{-1}$ (for small Rm) or by the magnetic helicity flux divergence, $\boldsymbol{\nabla}\cdot\overline{\boldsymbol{F}}_\mathrm{f}$ (for larger Rm). As anticipated in the previous proposal, these jobs require large computational resources and will be extended into the next period.

Most of the calculations have been carried out using the Pencil Code which is hosted by Google Code (`http://pencil-code.googlecode.com`)[1]. In the following I describe the research outcome by quoting published papers since October 2011 in refereed journals. The numbering of the papers coincides with that of my full list of publications on `http://www.nordita.org/~brandenb/pub`. All the papers quoted below acknowledge SNAC and none of those papers were mentioned in the activity report of the previous period.

1 Dynamo action in spherical shells

Our simulations of astrophysical flow in spherical shells are now well developed and have led to detailed measurements of the resulting differential rotation in simulations driven by convection in rotating spherical shells. Particularly important is the development of what looks like coronal mass ejections above a spherical surface [272,276]. This work is now being extended to flows driven by convection. We shall also allow for the development of what corresponds to a solar wind in the outer parts.

276. Warnecke, J., Käpylä, P. J., Mantere, M. J., & Brandenburg, A.: 2012, "Ejections of magnetic structures above a spherical wedge driven by a convective dynamo with differential rotation," *Solar Phys.* **280**, 299–319

272. Warnecke, J., Brandenburg, A., & Mitra, D.: 2012, "Magnetic twist: a source and property of space weather," *J. Spa. Weather Spa. Clim.* **2**, A11

2 Dynamo action, helicity, and vorticity in Cartesian domains

Successful small-scale dynamo action has now been shown to exists for magnetic Prandtl numbers down to 0.01 [273]. Magnetic helicity and its fluxes have been investigated in [260]. This work

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[1] The Pencil Code was written by Brandenburg & Dobler (2002) as a public domain code. The current number of project members on the google page is 82.

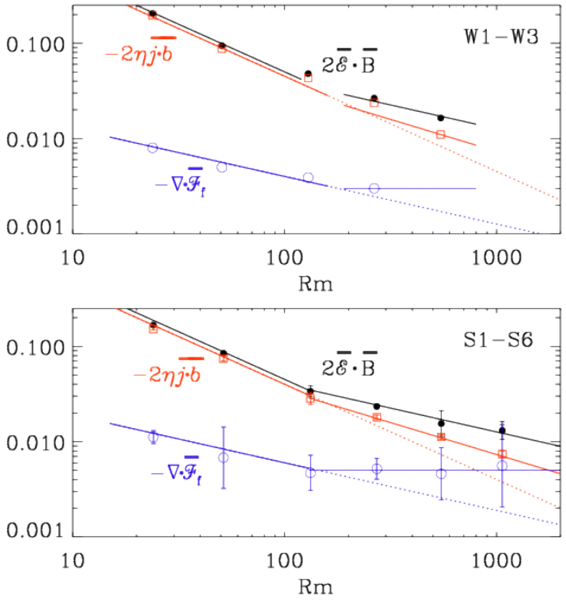

Figure 1: Scaling properties of the vertical slopes of $2\overline{\boldsymbol{\mathcal{E}}}\cdot\overline{\boldsymbol{B}}$, $-2\eta\mu_0\overline{\boldsymbol{j}\cdot\boldsymbol{b}}$, and $-\boldsymbol{\nabla}\cdot\overline{\boldsymbol{F}}_\mathrm{f}$ for Models W1, W2 and W3 (upper panel) and for Models S1–S6 (lower panel). The second panel shows that for a stronger wind the contribution from the advective term becomes approximately independent of Rm for Rm > 200 (blue line), while that of the resistive term decreases approximately like $\mathrm{Rm}^{-2/3}$ (red line), and $2\overline{\boldsymbol{\mathcal{E}}}\cdot\overline{\boldsymbol{B}}$ decreases approximately like $\mathrm{Rm}^{-1/2}$ (black line).

is also relevant to the early Universe where helical magnetic fields might have been produced by the QCD phase transition [277]. New work with the so-called linear forcing function have been performed [261].

277. Tevzadze, A. G., Kisslinger, L., Brandenburg, A., & Kahniashvili, T.: 2012, "Magnetic Fields from QCD Phase Transitions," *Astrophys. J.* **759**, 54

273. Brandenburg, A., Sokoloff, D., & Subramanian, K.: 2012, "Current status of turbulent dynamo theory: From large-scale to small-scale dynamos," *Spa. Sci. Rev.* **169**, 123–157

261. Brandenburg, A., & Petrosyan, A.: 2012, "Reynolds number dependence of kinetic helicity decay in linearly forced turbulence," *Astron. Nachr.* **333**, 195–201

260. Hubbard, A., & Brandenburg, A.: 2012, "Catastrophic quenching in $\alpha\Omega$ dynamos revisited," *Astrophys. J.* **748**, 51

3 Negative effective magnetic pressure instability

It is generally believed that the solar dynamo operates in the shear layer beneath the convection zone. This idea faces several difficulties that might be avoided in distributed solar dynamos shaped by near-surface shear. In that scenario, active regions would form due to large-scale (mean-field) instabilities in the near-surface shear layer. One candidate has been the negative effective magnetic pressure instability (NEMPI). Until recently, this possibility remained uncertain, because it was based on results from mean-field calculations using turbulent transport coefficients determined from direct numerical simulations (DNS). A breakthrough has now been achieved through the direct detection of this instability in simulations; see our report of last year. This has now led to significant extensions that have led to 3 new papers [257,265,275].

275. Kemel, K., Brandenburg, A., Kleeorin, N., Mitra, D., & Rogachevskii, I.: 2012, "Spontaneous formation of magnetic flux concentrations in stratified turbulence," *Solar Phys.* **280**, 321–333

265. Brandenburg, A., Kemel, K., Kleeorin, N., & Rogachevskii, I.: 2012, "The negative effective magnetic pressure in stratified forced turbulence," *Astrophys. J.* **749**, 179

257. Kemel, K., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2012, "Properties of the negative effective magnetic pressure instability," *Astron. Nachr.* **333**, 95–100

4 Turbulent transport coefficients

The test-field method is now a well developed tool. It has been applied to the nonlinear regime [249]. Of particular importance is the application to stratified layers [264] in connection with passive scalar diffusion [248,254,255,259].

264. Kitchatinov, L. L., & Brandenburg, A.: 2012, "Transport of angular momentum and chemical species by anisotropic mixing in stellar radiative interiors," *Astron. Nachr.* **333**, 230–236

259. Brandenburg, A., Rädler, K.-H., & Kemel, K.: 2012, "Mean-field transport in stratified and/or rotating turbulence," *Astron. Astrophys.* **539**, A35

255. Rheinhardt, M., & Brandenburg, A.: 2012, "Modeling spatio-temporal nonlocality in mean-field dynamos," *Astron. Nachr.* **333**, 71–77

254. Snellman, J. E., Brandenburg, A., Käpylä, P. J., & Mantere, M. J.: 2012, "Verification of Reynolds stress parameterizations from simulations," *Astron. Nachr.* **333**, 78–83

249. Hubbard, A., Rheinhardt, M. & Brandenburg, A.: 2011, "The fratricide of $\alpha\Omega$ dynamos by their α^2 siblings," *Astron. Astrophys.* **535**, A48

248. Rädler, K.-H., Brandenburg, A., Del Sordo, F., & Rheinhardt, M.: 2011, "Mean-field diffusivities in passive scalar and magnetic transport in irrotational flows," *Phys. Rev. E* **84**, 4

5 Other work

The inverse cascade in two-dimensional turbulence has red to new work using the GPU cluster Lunarc [263].

263. Chan, C. K., Mitra, D., & Brandenburg, A.: 2012, "Dynamics of saturated energy condensation in two-dimensional turbulence," *Phys. Rev. E* **85**, 036315