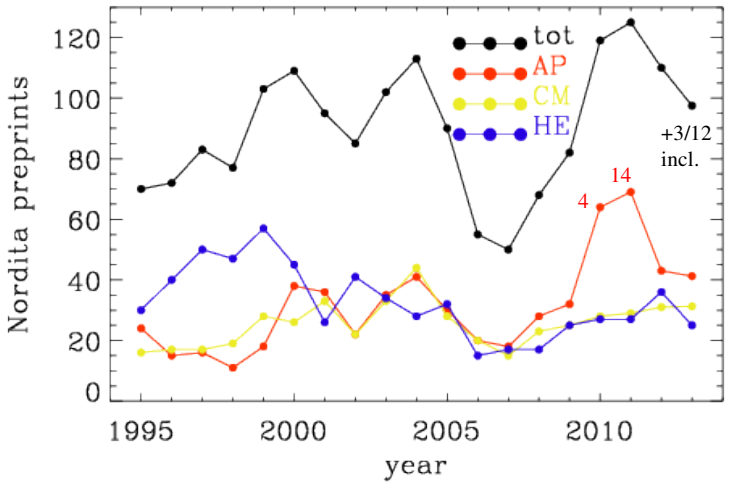
Astrophysics at Nordita



- 2 PhD Students (VR)
- 1→2 post-docs (VR)
- 3 Nordita fellows
- 1 Assistant Prof (ERC)
- 1 Visiting professor (ERC)
- 1 Professor (Nordita, SU)
- Short/long term visitors

- Weekly routine:
  - Group meeting (Tue)
  - Group seminar (Wed)
  - Astro-ph journal club (Thu)
  - Astronomy Seminar (Fri)

Current in-house activity

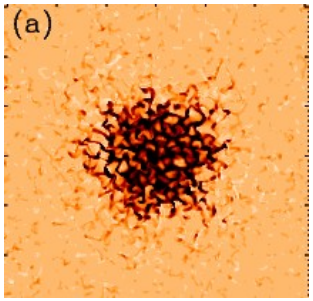
- Current PhD research:
  - Sunspots, active regions, dynamos
- Post-docs:
  - Neutron stars, combustion, front propagration
  - Planetesimal growth, particles in fluids
- Conferences/programs/schools
  - 23 - 27 Sep 2013 Galactic Magnetism in the Era of LOFAR and SKA
  - 8 Apr - 3 May 2013 Differential Rotation and Magnetism across the HR Diagram
  - 7 - 18 January 2013 Nordita Winter School 2013 in High-Energy Astrophysics
  - 15-17 Oct 2012 12th European Workshop on Astrobiology
  - 6-10 August 2012 Astrophysics Code Comparison Workshop
  - 17-21 Oct 2011 The solar course, the chemic force, and the speeding change of water
  - 25 Jul - 19 Aug 2011 Dynamo, Dynamical Systems and Topology
  - 26 Apr - 27 May 2011 Predictability + School on Data Assimilation
  - 14 - 18 Feb 2011 RädlerFest: α effect and beyond

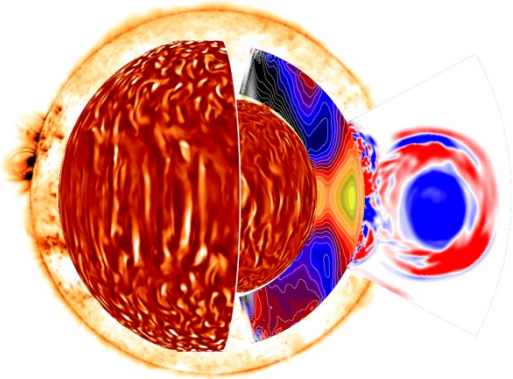
ERC: 3 of the 14 tasks of 2008

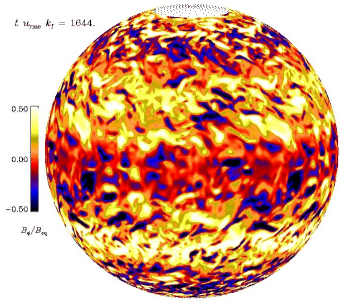
8. *Magnetic flux concentrations near the surface*: Test the scenario that the emergence of active regions and sunspots can be explained as the result of flux concentrations from local dynamo action via negative turbulent magnetic pressure effects [11] or turbulent flux collapse [12].

9. *CME-like features above the surface*: Analyze the nature of the expelled magnetic field in simulations that couple to a simplified version of the lower solar wind. It is possible that the magnetic field above the surface might resemble coronal mass ejections (CMEs), in which case more detailed comparisons with actual coronal mass ejections would be beneficial. (*Phase 3*)

10. *Convective dynamo in spherical shell*: Set up convection in the spherical shell (possibly in collaboration with A. S. Brun, J. Toomre, and collaborators). If the resulting scale of the flows are small enough and there is scale separation it would be useful to simulate the resulting magnetic field, compare with forced turbulence simulations in spherical shells and see whether contact can be made both with the Sun and with improved mean field models. (*Phase 3*)







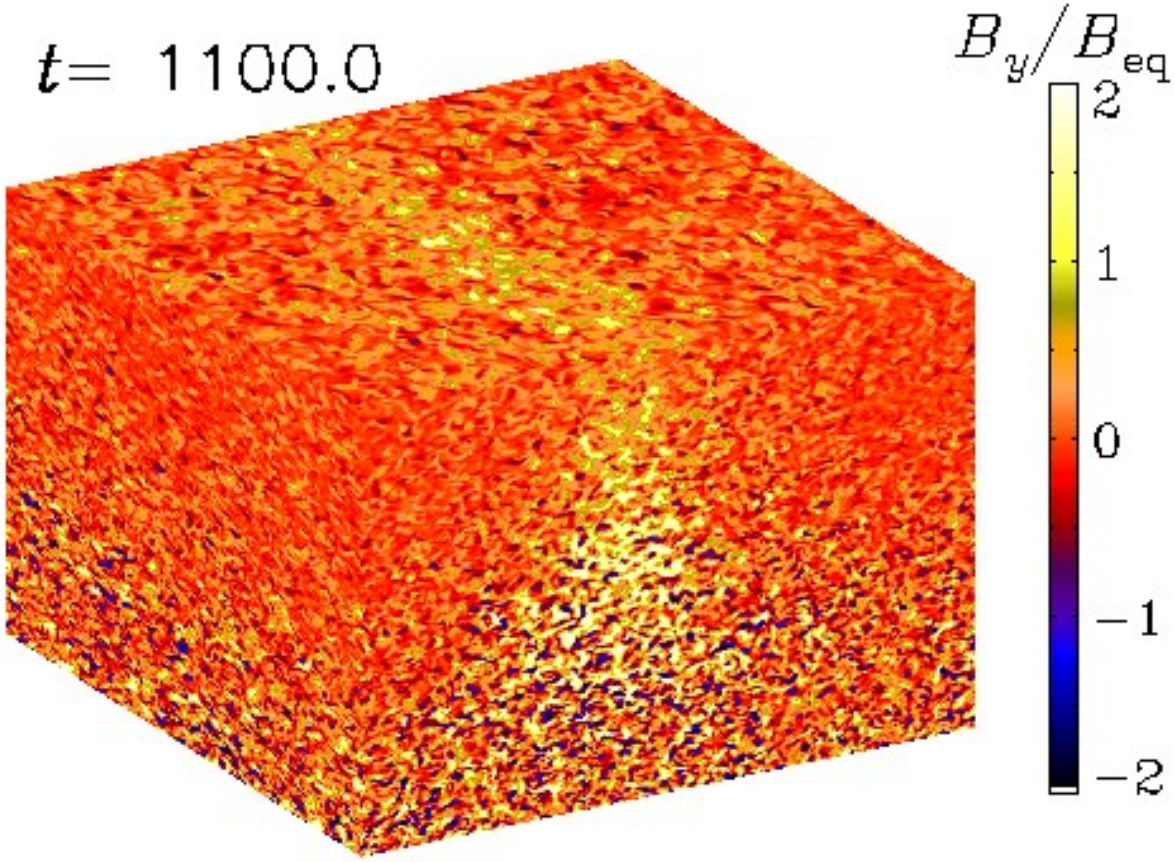
ERC project task 8 (Periods I+II)

8. *Magnetic flux concentrations near the surface. Test the scenario that the emergence of active regions and sunspots can be explained as the result of flux concentrations from local dynamo action via negative turbulent magnetic pressure effects or turbulent flux collapse.* (*Phase 2*)

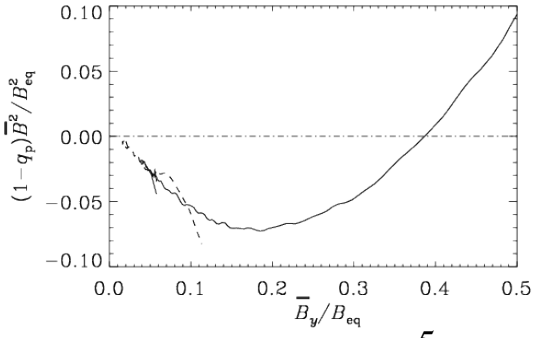
Results from reporting periods I+II. This work constitutes one of the corner stones of our project in that we must explore scenarios for being able to explain the formation of magnetic flux concentrations in the absence of deep-rooted hypothetical flux loops at the bottom of the convection zone. This work has been started with Professors Kleeorin and Rogachevskii, as well as Mr. Kemel (one of our PhD students). The field has now seen a major transformation with the detection of the negative effective magnetic pressure instability in turbulence simulations. This has been a major milestone for this project that contributed to putting this effect on the map. Furthermore, Dr. Käpylä has started look at the possibility of producing magnetic flux concentration in stratified convection.

- Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2010, ``Large-scale magnetic flux concentrations from turbulent stresses,'' *Astron. Nachr.* **331**, 5-13
  (arXiv:0910.1835, ADS, PDF)
- Brandenburg, A., Kemel, K., Kleeorin, N., Mitra, D., & Rogachevskii, I.: 2011, ``Detection of negative effective magnetic pressure instability in turbulence simulations,'' *Astrophys. J. Lett.* **740**, L50
  (arXiv:1109.1270, ADS, DOI, HTML, PDF)
- Brandenburg, A., Kemel, K., Kleeorin, N., & Rogachevskii, I.: 2012, ``The negative effective magnetic pressure in stratified forced turbulence,'' *Astrophys. J.* **749**, 179
  (arXiv:1005.5700, ADS, DOI, PDF)
- Kemel, K., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2012, ``Properties of the negative effective magnetic pressure instability,'' *Astron. Nachr.* **333**, 95-100
  (arXiv:1107.2752, DOI, PDF)
- Käpylä, P. J., Brandenburg, A., Kleeorin, N., Mantere, M. J., & Rogachevskii, I.: 2012, ``Negative effective magnetic pressure in turbulent convection,'' *Mon. Not. Roy. Astron. Soc.* **422**, 2465-2473
  (arXiv:1104.4541, ADS, DOI, HTML, PDF)
- 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
  (arXiv:1112.0279, ADS, DOI, PDF)

Strongly stratified turbulence



- Gas+turb. press equil.
- B increases
- Turb. press. Decreases
- Net effect?



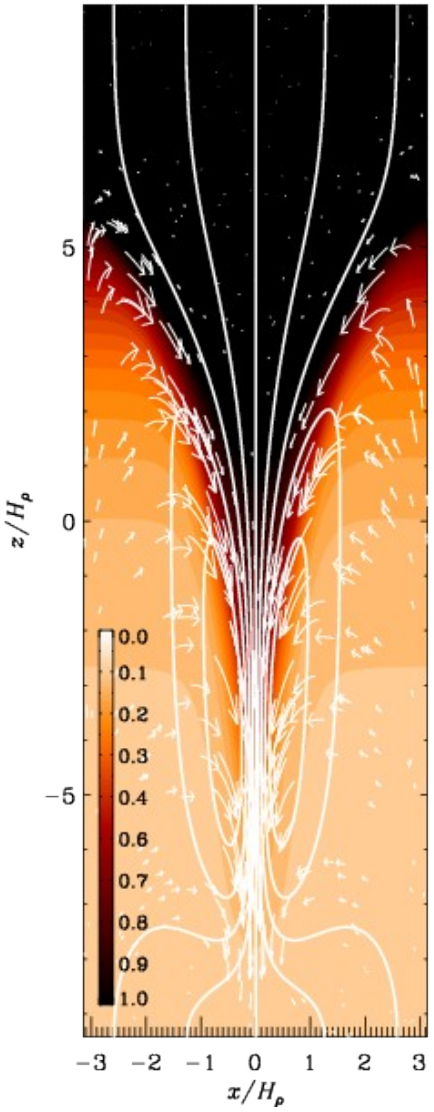
Significant scale separation important!

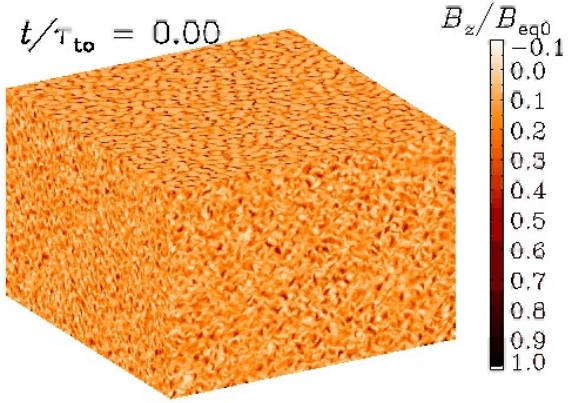
ERC project task 8 (Period III)

New achievements. Major new developments include the detection of strong magnetic spots and even bipolar regions. As advertised, one of the important new developments includes the treatment of radiative transport. A Master's Thesis on this topic has been completed (Ms. Barekat) and this work has been submitted. This and other new papers are listed below.

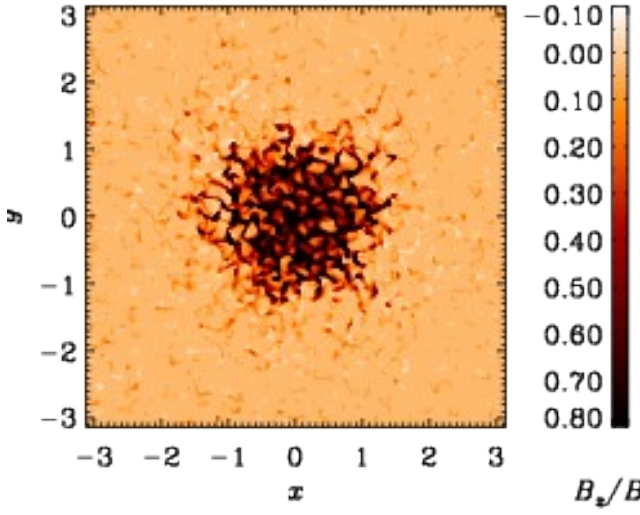
- Losada, I. R., Brandenburg, A., Kleeorin, N., Mitra, D., & Rogachevskii, I.: 2012, ``Rotational effects on the negative magnetic pressure instability,'' *Astron. Astrophys.* **548**, A49 (arXiv:1207.5392, ADS, DOI, PDF)
- Kemel, K., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2013, ``Non-uniformity effects in the negative effective magnetic pressure instability,'' *Phys. Scr.* **T155**, 014027 (arXiv:1208.0517, DOI, PDF
- Kemel, K., Brandenburg, A., Kleeorin, N., Mitra, D., & Rogachevskii, I.: 2013, ``Active region formation through the negative effective magnetic pressure instability,'' *Solar Phys.* **287**, 293-313 (arXiv:1203.1232, DOI, PDF)
- Jabbari, S., Brandenburg, A., Kleeorin, N., Mitra, D., & Rogachevskii, I.: 2013, ``Surface flux concentrations in a spherical α^2 dynamo,'' *Astron. Astrophys.* **556**, A106 (arXiv:1302.5841, ADS, DOI, PDF)
- Losada, I. R., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2013, ``Competition of rotation and stratification in flux concentrations,'' *Astron. Astrophys.* **556**, A83 (arXiv:1212.4077, ADS, DOI, PDF)
- Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2013, ``Self-assembly of shallow magnetic spots through strongly stratified turbulence,'' *Astrophys. J. Lett.*, submitted (arXiv:1306.4915, HTML, PDF)
- Losada, I. R., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2013, ``Magnetic flux concentrations in a polytropic atmosphere,'' *Astron. Astrophys.*, submitted (arXiv:1307.4945, HTML, PDF))
- Warnecke, J., Losada, I. R., Brandenburg, A., Kleeorin, N., & Rogachevskii, I.: 2013, ``Bipolar magnetic structures driven by stratified turbulence with a coronal envelope,'' *Astrophys. J. Lett.*, submitted (arXiv:1308.1080, HTML, PDF))
- Barekat, A., & Brandenburg, A.: 2013, ``Near-polytropic simulations with a radiative surface,'' *Astron. Astrophys.*, submitted (arXiv:1308.1660, HTML, PDF)
- Brandenburg, A., Gressel, O., Jabbari, S., Kleeorin, N., & Rogachevskii, I.: 2013, ``Flux-tube structure from vertical magnetic flux concentrations,'' *Astron. Astrophys.*, submitted (HTML)

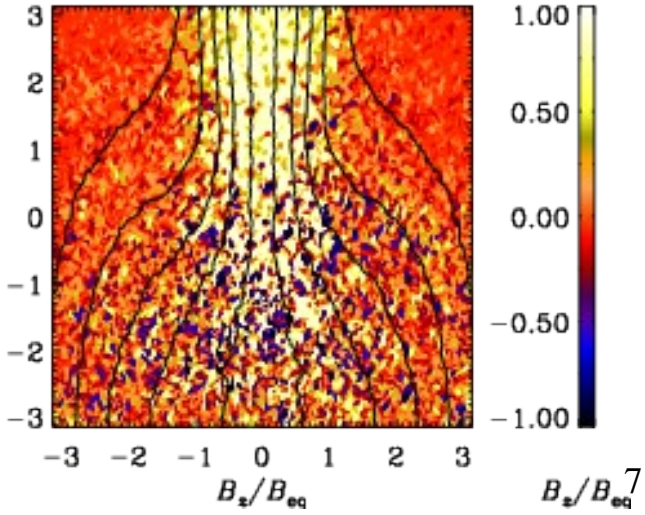
Spontaneous assembly of magnetic spots



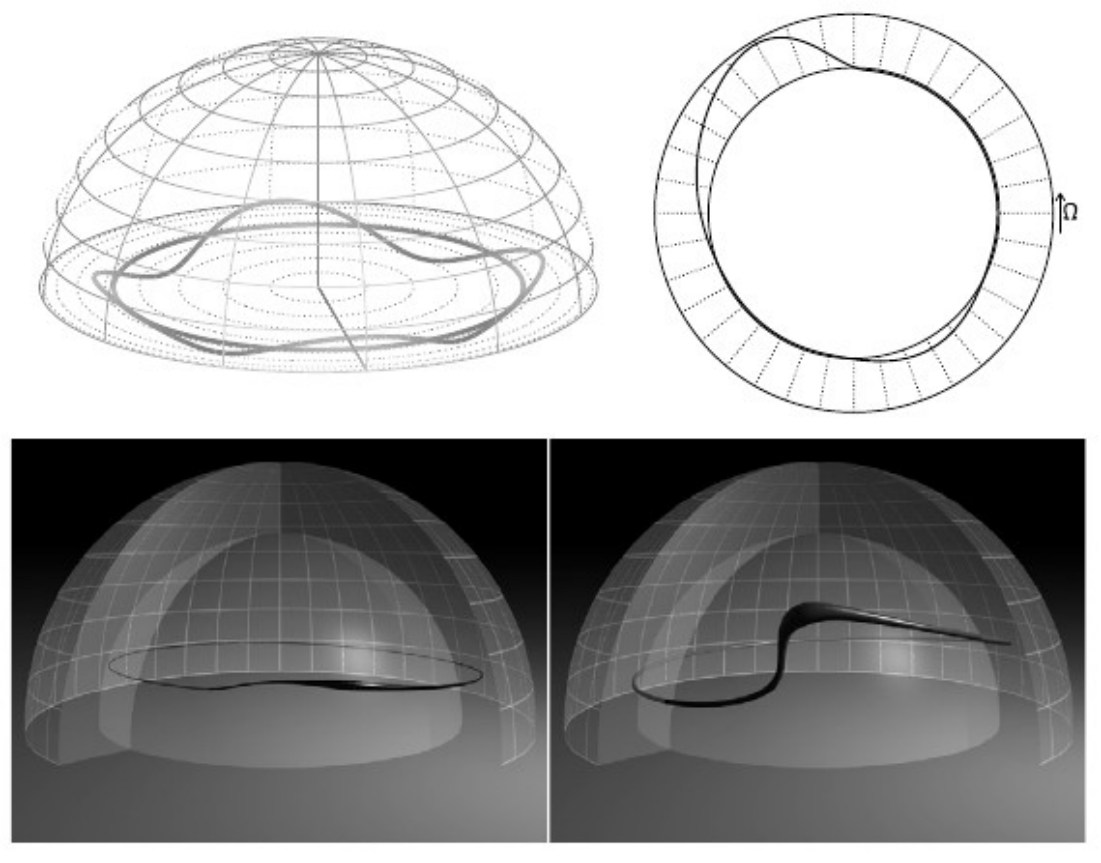


- Minimalistic model
- 2 ingredients:
  - Stratification & turbulence
- Extensions
  - Coupled to dynamo
  - Compete with rotation
  - Radiation/ionization



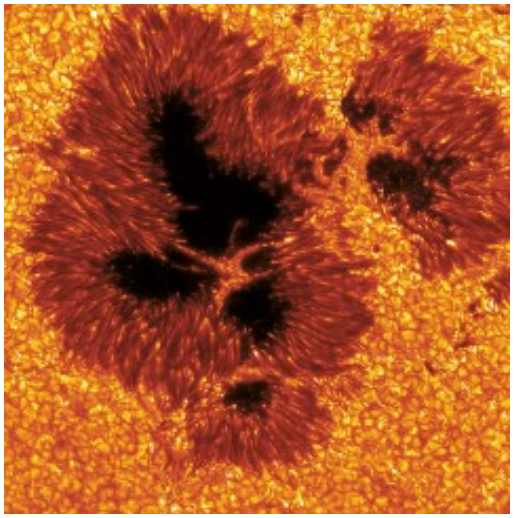


The thin flux tube paradigm



Caligari et al. (1995)

VR-supported Inst. f. Solar Physics to SU



- Co-supervision of PhD students
- Joint work w/ former student
- Joint grant applications
- Need for more realistic physics

Project-oriented activity

Personnel paid during reporting period 3:

S. Candelaresi	13 months	PhD student, task 3
F. Del Sordo	13 months	PhD student, tasks 7 and 11
K. Kemel	10 months	PhD student, task 8
J. Warnecke	18 months	PhD student, tasks 9 and 10
M. Rheinhardt	6 months	visiting professor, task 2
D. Mitra	18 months	assistant professor, tasks 2, 5, and 14

- Less open to out-of-scope topic
- Very different from old Nordita times
- Are we still serving the Nordic community

3 more PhD defenses

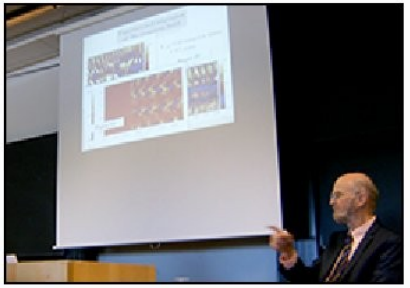
2 more started a year ago

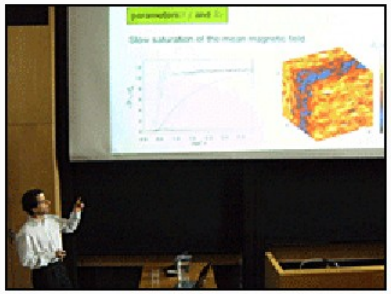
Sarah Jabbari (VR proj. grant)

Illa R. Losada (VR breakthrough research grant)

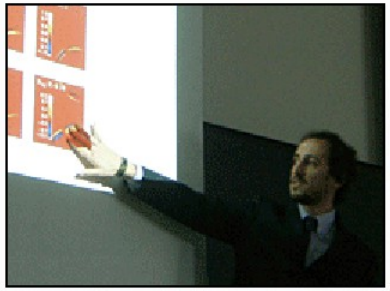
On 31 May 2013, **Jörn Warnecke**, the last of four PhD students supported by the **ERC AstroDyn project**, successfully defended his dissertation on "**Combining Models of Coronal Mass Ejections and Solar Dynamos**".







Simon Candelaresi, "**Magnetic helicity in astrophysical dynamos**"
7 December 2012
Opponent: Renzo Ricca (University of Milano-Bicocca)



Fabio Del Sordo, "**From irrotational flows to turbulent dynamos**"
14 November 2012
Opponent: Mordecai-Mark Mac Low (Department of Astrophysics and American Museum of Natural History)

Upcoming activity

- Global helioseismology
  - f-mode to measure subsurface B-field
- Local helioseismology
  - To determine depth of spots