Magnetic tornadoes on the Sun

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Fig. 1: Nature cover page, June 28, 2012.

Recent observations with the ***Solar Dynamics Observatory (SDO)*** and the ***Swedish 1-m Solar Telescope (SST)*** revealed rotating magnetic field structures that extend from the solar surface into the chromosphere and the corona.
This phenomenon has been named ***"magnetic tornadoes"*** *(Wedemeyer-Böhm et al., 2012).*

Small-scale magnetic tornadoes have been detected for the first time in 2008 as rings and spirals of rotating plasma in the Ca II 854.2 nm line core (***"chromospheric swirls", see Fig. 2***). Co-located with the chromospheric swirls, we observe magnetic footpoints in the photosphere and emission in SDO/AIA channels (304, 171, 193, 211). Magnetic tornadoes have typical diameters of (4.0 ± 1.4) arcsec or (2,900 ± 1,000) km and lifetimes of (12.7 ± 4.0) min. It is currently estimated that at least 11 000 magnetic tornadoes exist on the Sun at all times.

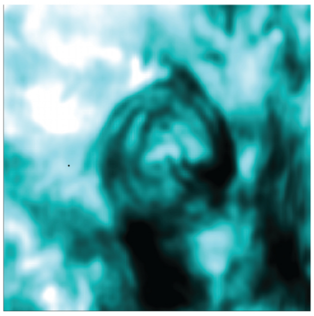

Fig. 2: Intensity image recorded with the SST in the line core of the spectral line of singly ionised calcium (infrared triplet, wavelength 854.2 nm). The detected chromospheric swirl (dark ring) is the observational signature of a magnetic tornado. The first detection was reported by Wedemeyer-Böhm & Rouppe van der Voort (2009).

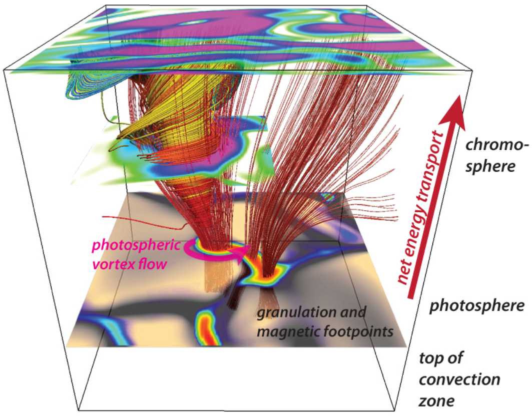

Fig. 3: Visualisation of a close-up region in our advanced 3D numerical simulations produced with CO5BOLD (Freytag et al. 2012). The red mostly vertical lines represent the magnetic field, whereas the spiral lines represent the streamlines of the ionized gas in the magnetic tornado. The lower plane shows the granulation pattern of the solar surface and the magnetic footpoints (red), whereas the swirl signature (pink ring) can be seen on the top. Image produced with VAPOR (Clyne et al. 2007).

These tornadoes are driven by ***photospheric vortex flows*** that cause the footpoints of magnetic field structures to rotate. The magnetic field, which protrudes into the corona, mediates the rotation into the chromosphere and corona ***(see Fig. 3)***.
This mechanism may provide an ***alternative way of channeling energy into the upper solar atmosphere***. The vortex flows generate torsional Alfvén waves, which propate along the rotating magnetic field structure and transport a substantial amount of energy. It has yet to be determined how this energy is dissipated in the corona and how large the resulting net contribution to heating the solar corona is.

Furthermore, we find ***different types of swirls (see Fig. 4)***. Spiral-like swirls (type III) are observed and also appear in CO5BOLD *(Freytag et al. 2012)* and Bifrost *(Gudiksen et al. 2011)* simulations.

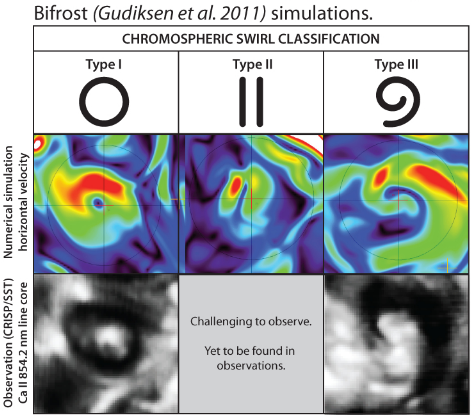

Fig. 4: The three major types of chromospheric swirls: Type I (Ring), type II (Split), and type III (Spiral). The middle row shows the color-coded horizontal velocity in horizontal cross-sections at z = 1000 km for swirls in the CO5BOLD simulation (Wedemeyer-Böhm et al. 2012). Observed examples of type I and III swirls are presented in the bottom row. The images are taken in the line core of the Ca II infrared triplet line at 854.2 nm (Wedemeyer-Böhm & Rouppe van der Voort 2009).

The term 'tornado' has been used repeatedly for phenomena on the Sun, in particular in connection with prominences. Such large-scale tornadoes (here referred to as ***"giant solar tornadoes"***) have been observed before with SoHO/CDS, TRACE, and SDO/AIA (e.g., *Pike & Mason 1998, Li et al. 2012, Su et al. 2012*). The connection to their small-scale analogues, ***magnetic tornadoes***, is yet to be investigated.
SDO observations now suggest that giant solar tornadoes are the ***rotating legs of prominences*** and could thus be important as sources and sinks of prominence material. Moreover, they may build up twist of magnetic field structures in prominences, thus acting as source of instability and potential trigger of eruptions *(Wedemeyer-Böhm et al. 2013b)*. A group of giant tornadoes is shown in ***Fig. 5***. The Dopplergram of a tornado observed with the SST (***see Fig. 6***) suggests that giant tornadoes may rotate but further observations are needed for confirmation.

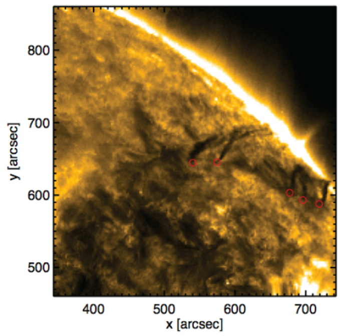

Fig. 5: SDO/AIA 171 image from June 5, 2012, 12:57, showing a group of giant tornadoes as dark elongated structures close to the solar limb.

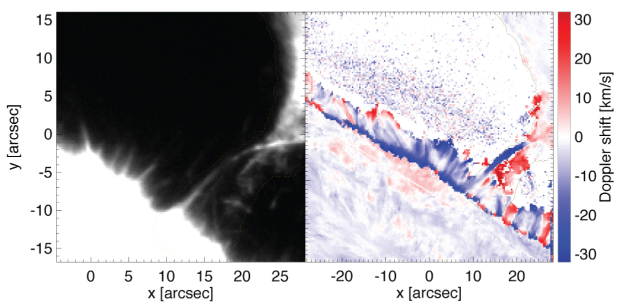

Fig. 6: SST/CRISP observations of a giant tornado on June 8th, 2012: Hα line core image (left) and corresponding Dopplergram (right), revealing (apparent) opposite motion at the tornado base, which can be interpreted as rotation (Wedemeyer-Böhm et al. 2013b).

Vacant position

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Fellowship for up to 3 years with preferred starting date April 1st, 2014 (negotiable).

The Research Council of Norway has funded the project **"Vortex flows and magnetic tornadoes on the Sun and cool stars"** for the period 2014 to 2017. The project combines high-resolution observations of the Sun with the ground-based Swedish 1-m Solar Telescope (SST) and the space-borne observatories Solar Dynamics Observatory (SDO) and Interface Region Imaging Spectrograph (IRIS) and numerical simulations with the 3-D radiative magnetohydrodynamics codes Bifrost and CO5BOLD. The aim is to identify the relevant physical processes behind the formation of magnetic tornadoes and the related energy transport in the Sun and in cool red dwarf stars.
The post-doc will contribute to the VORTEX project and work in a team both on observational and numerical modelling aspects.

Requirements:

- PhD degree in astrophysics, astronomy or space sciences.
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- Experience with 2D/3D numerical simulations and/or the analysis of observations.
- Fortran90 and IDL skills.
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References

Clyne, J., Mininni, P., Norton, A., & Rast, M. 2007, New J. Phys, 9, 1
Freytag, B., Steffen, M., Ludwig, H.-G, Wedemeyer-Böhm, S., Schaffenberger, W., Steiner, O. 2012, J.Co.Phys. 231, 919
Gudiksen, B. V., Carlsson, M., Hansteen, V. H., et al. 2011, A&A, 531, A154
Li, X., Morgan, H., Leonard, D., Jeska, L. 2012, ApJL, 752, L22
Pike, C. D., & Mason, H. E. 1998, SoPh, 182, 333
Su, Y., Wang, T., Veronig, A., Temmer, M., Gan, W. 2012, ApJL, 756, L41
Wedemeyer-Böhm, S. & Rouppe van der Voort, L. 2009, A&A 507, L9
Wedemeyer, S., Scullion, E., Steiner, O., de la Cruz Rodriguez, J., Rouppe van der Voort, L. 2013a, J. of. Phys. Conf. Ser., 440,1, article id. 012005
Wedemeyer, S., Scullion, E., Rouppe van der Voort, L., Bosnjak, A., Antolin, P. 2013b, ApJ, 774, 123
Wedemeyer-Böhm, S., Scullion, E., Steiner, O., Rouppe van der Voort, L., de La Cruz Rodriguez, J.,Fedun, V., Erdélyi, R. 2012, Nature, 486, 505