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Large-scale unipolar regions generated from undeep magnetic fields

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Abstract. We explain the generation of the large-scale unipolar magnetic field regions (global magnetic regions) by the same dynamo action as for the generation of the sunspots and the polar faculae butterfly diagrams as given by Callebaut (2006). The previous global magnetic regions through meridional circulation now serve as the main seed fields (flux-transport dynamo for the global field regions), possibly supplemented by leftovers from the sunspots and some weak fields generated at the tachocline.

Keywords. dynamo, global magnetic regions, sunspots, polar faculae

1. Introduction

Callebaut (2006) and Callebaut and Khater (2006) obtained the exact solution in spherical coordinates r, ϑ, φ for the equation of evolution of the magnetic field in ideal MHD in the case that the velocity $\mathbf{v}$ is purely azimuthal and depends on r and ϑ only. Starting from a bipolar field (or more generally: a multipolar one) it turned out that a zero order approximation of the butterfly diagrams of the sunspots and the polar faculae could be obtained. A neat separation occurred between both butterfly diagrams, corresponding to the region where $\partial_r \omega = 0$ in agreement with the observations. However, the third great magnetic feature of solar magnetism is constituted by the global field regions. As the same generating mechanism should work for these global regions as for sunspots and polar faculae the question arises which is their seed field.

2. Origin of the global magnetic fields regions

There can not be much doubt about the dynamo action itself: the differential rotation is the driving force and from the evolution equation in ideal MHD follows mathematically the (de)amplification. Resistivity and the α-effect may bring improvements. However, the real problem is to decide which seed field has to be considered. We may think of the following possibilities: (a) Generation of seed fields at the tachocline. (b) Generation by previous global regions brought back by meridional motion. (c) Fields left over from the sunspots.

2.1. *Seed fields at the tachocline*

However, these seed fields at the tachocline are the ones that yield the sunspots and polar faculae. Of course it is not excluded that between the fairly strong seed fields that produce spots are layers of weak fields which may contribute to the global magnetic regions. However, why should these weak fields generate large areas rather than spots? (The question may be inversed.) Hence although the (weak) fields at the tachocline may yield a contribution to the global field regions, we expect it to be a minor one.

2.2. *Previous global regions returning by meridional motion*

The global field regions disappear at the poles. Certainly a large part of the energy has been dissipated, but part of it probably dives into the polar region and is brought back by meridional motion in the convective zone (cf. flux-transport dynamo) and may reach after about 2 cycles the equatorial region where they can be amplified by the field amplification mechanism considered in the introduction and then reach the surface. An argument for this is mentioned by Dikpati (2005): there seems to be a similarity between global field regions of two cycles apart. If some 20% of the original global field regions persists up to the poles and half of this persists during the internal transit from pole to the equatorial region, an amplification factor 10 is required to reach the about the same level. As only part of the convective zone will be used and not its full thickness and amplification mechanism this seems rather at the limit of what we expect to be possible to produce the full new global regions. The meridional motion explains why the new global fields appear mainly in the equatorial region. (Actually in the mid latitudes the amplification works partially the opposite way with nearly no net amplification.) Hence this process contributes to the new global field regions, but it is probably not the only one. This is corrobated by the fact that the relation between the global regions and those of two cyles before them is not very strong, although this may be due to the long trip over the solar surface and in the convective zone.

2.3. *Leftovers from the previous spots*

When sunspots reach the solar surface a lot of magnetic energy energy escapes toward the solar atmosphere. However, part of the energy remains in the Sun as is clear from the dimmings. These have a large extension in the convective zone. However, the large extension and corresponding weak field of the global regions need further explication. The reversal of polarity of the global regions each cycle is a consequence of the one of the sunspots. The fact that global field regions appear much less frequently in the mid and higher latitudes than in the equatorial region indicates that this mechanism is weaker than the one based on the meridional motion. Indeed, there should be a (weak) contribution from the leftovers of the polar faculae, which, however, is practically absent.

3. Conclusions

We indicated 3 possible origins for the seed fields of the global field regions: the one based on the global fields of 2 cycles ago and which returned to the equatorial region by meridional motion seems the main one (flux-transport dynamo for the global field regions). This may be supplemented by the leftovers from previous sunspots and by some weak fields generated at the tachocline. Determining the precise ratio between those three components is a future aim.

References

Callebaut, D. K. 2006, *ApJ*, to be published
Callebaut, D. K. & Khater, A. H. 2006, *IAUS233*, these proceedings
Dikpati, M. 2005, *Adv. in Space Research*, vol. 35, p. 322