Asymmetries in Solar Active Regions and Flux Emergence Models

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1. Introduction

The structure and evolution of solar Active Regions (ARs) are consistent with the picture of a rising magnetic loop whose top breaks through the solar surface, its legs forming the two opposite polarities of the developing sunspot group. The study of ARs properties can shed some light on the characteristics of the rising flux tubes, such as the erupting magnetic field strength and structure, the process of emergence, and maybe the dynamo process itself.

In the past decade, several groups have studied the dynamics of rising magnetic flux tubes in the solar convection zone, by means of numerical simulations, and found a general good agreement with a variety of observed properties of solar ARs (see the review by Moreno-Insertis, 1994, and recent work in Fan et al 1994 and Caligari et al 1995). In this paper we present a further observational test of these simulations, analyzing one particular property of ARs: the E-W inclination of field lines.

A difference in the inclination with respect to the vertical between the preceding -P- and the following -F- wings of the rising flux tube naturally results from the simulations of Caligari et al (1995) as a consequence of angular momentum conservation along the rise (see also Moreno-Insertis, 1994, Moreno-Insertis et al 1994 and the figures in Fan 1993): the P polarity trails the rotation (i.e. is inclined to the east) by a larger amount than the F polarity leads the rotation. On the base of their model, Caligari et al. (1995) predict that this asymmetry should be more pronounced for ARs with larger magnetic flux values, and should be most visible in the very first days of evolution of the AR. We test this prediction using polarimetric data acquired at Mees Solar Observatory, using the asymmetry in the distribution of magnetic fields in ARs as an indicator of the asymmetry in inclination, as previously done by van Driel-Gesztelyi and Petrovay (1990).

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2. Data

We used vectormagnetograms acquired with the Hawaii Stokes Polarimeter (HSP, Mickey 1985) at Mees Solar Observatory, that provides information of the full vector magnetic field and allows correction for projection factors (see Canfield et al. 1993). We analyzed data for the interval Oct. 1991 - Jun. 1995, choosing simple bipolar regions for which we could clearly define the asymmetry parameter. In this first stage of the study, a total of 144 regions were analyzed, for a grand-total of 612 magnetograms.

The asymmetry of each AR was calculated as the ratio of the distance of the main $P$ spot from the magnetic neutral line and the distance of the main $F$ and $P$ spots. An asymmetry $> 0.5$ indicates that, on the whole, the field lines of the AR are tilted to the east. The magnetic flux of each AR has been calculated as the sum of $|B_z| \times ($pixel area$)$ over all of the pixels with $B_z$ value above the noise.

3. Results

Our results can be summarized as follows:

• The average asymmetry of ARs derived from the HSP data is $0.54 \pm 0.03$. This is in agreement with previous results (van Driel-Gesztelyi and Petrovay, 1990), and indicates an asymmetry in the inclination of the rising flux tubes that later give rise to an AR in the sense predicted by Caligari et al (1995).

• The asymmetry of the magnetic field distribution decreases with age of the AR. This is consistent with the simulations of Caligari et al. (1995), that predict a larger asymmetry in $P$ and $F$ behavior during the first few days of AR growth. A previous, opposite, result by van Driel-Gesztelyi and Petrovay can probably be explained by projection effects due to the use of $B_\parallel$ maps instead of $B_z$ ones.

• The asymmetry of the magnetic field distribution increases with magnetic flux of the ARs. Also this property, a novel result of this analysis, is consistent with the prediction of Caligari et al. (1995).

References