CLUSTERS IN SOLAR ACTIVE REGIONS

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ABSTRACT

The most popular approaches of the p-f asymmetry in active regions are reviewed. Their common feature is that a well known property of regular sunspot groups, the stronger compactness in the preceding part than in the following one, is described as a consequence of other kinds of asymmetries, furthermore all of these proposed mechanisms contain some controversies. The present contribution provides data of the compactness asymmetry on a sunspot group material of several years. Comparison is given between these data and other possible asymmetry parameters defined on magnetograms, filtergrams and high energy observations. A possible scenario is outlined in which the key role in flux emergence is played by a local compression of the toroidal flux ropes and by the resulting enhancement of the buoyancy. The compression necessary for emergence would be exhibited by the compactness of the leading part of a well developed sunspot group.

Key words: sunspot groups, asymmetry, flux emergence.

1. INTRODUCTION

The well developed regular bipolar sunspot groups exhibit certain characteristic asymmetries. These features are certainly related to each other, but they are not equally examined, while their roles and possible connections are extensively studied theoretically. According to the general expectations all these asymmetry features are somehow related to the connection of the emerged flux rope with the subsurface velocity fields as well as the process of the emergence.

The most thoroughly investigated feature is the difference between the distances of the bulges of the p- and f- magnetic fluxes from the magnetic neutral line (Van Driel Gesztelyi and Petrovay, 1990, Petrovay et al. 1990). They found on a large material that the preceding bulge is further away from the neutral line than the following one and they also provided a possible scenario, in which an internal differential rotation profile would interact with the vertical flux rope and it would cause different tilts and bends in the p- and f- parts, in accordance with the theoretical predictions of Moreno-Insertis et al. (1994) and Caligari et al. (1995). They argue that the stronger bend of the f- rope would cause a higher fluting instability and this could result in a more fragmented f-region. The problematic issue of the scenario is the *ad hoc* internal velocity profile which has not been confirmed by later observations. Anyhow, the asymmetry exists and all other kinds of asymmetries should be treated with consideration to it.

Fan et al. (1993) have carried out a series of three dimensional simulations concerning the emergence of the magnetic flux ropes in the convective zone (compressible, non-magnetic fluid) and found that the process of emergence results in Coriolis forces in the flux tubes which drive the plasma from the preceding to the following parts within the tubes. Thus the total internal pressure (kinetic plus magnetic) decreases in the p-part and it increases in the f-part which results in the compression of the p-part and fragmentation of the f-part. They argue that this might be the cause of the compactness asymmetry. As an observational basis they refer to Babcock (1961), Bray and Loughhead (1979) and Zwaan (1981) by stating that the p/f ratio of the effective magnetic fluxes appearing in spots is about 3:1. Their result has been checked observationally by Cauzzi et al.(1996) who found that in fact there exists a stream between the emerging p- and f-regions but right in the opposite direction to that predicted by Fan et al.(1993). So this question also remains open.

An extensive study has been published by Tsinganos (1980) about the Kelvin-Helmholtz instabilities acting upon the uprising flux ropes. He found that these instabilities result in the fragmentation of the ropes but he did not report any differences between the p- and f-parts.

These results motivated the first attempt (Ludmány et al. 1999, Paper I.) to study the differences in the compactness of the leading and following parts as the most striking form of p-f asymmetry. The present study provides some more properties and the outlines of a possible aproach.

2. OBSERVATIONAL DATA AND METHOD

The employed data were taken from the Debrecen Photoheliographic Data (DPD) for the years 1986 and 1987 (Győri et al. 1996, 1998). This catalogue contains the position and area data of each spot on the solar disc for all days, this is the only suitable database for this purpose. In order to separate the preceding and following polarities magnetograms of the Okayama and Kitt Peak Observatories as well as the Solnechnye Dannye were used.

Like in the Paper I., the concept of the compactness was formulated in the following way. An F parameter of fragmentation (or dispersion) was computed for both parts:

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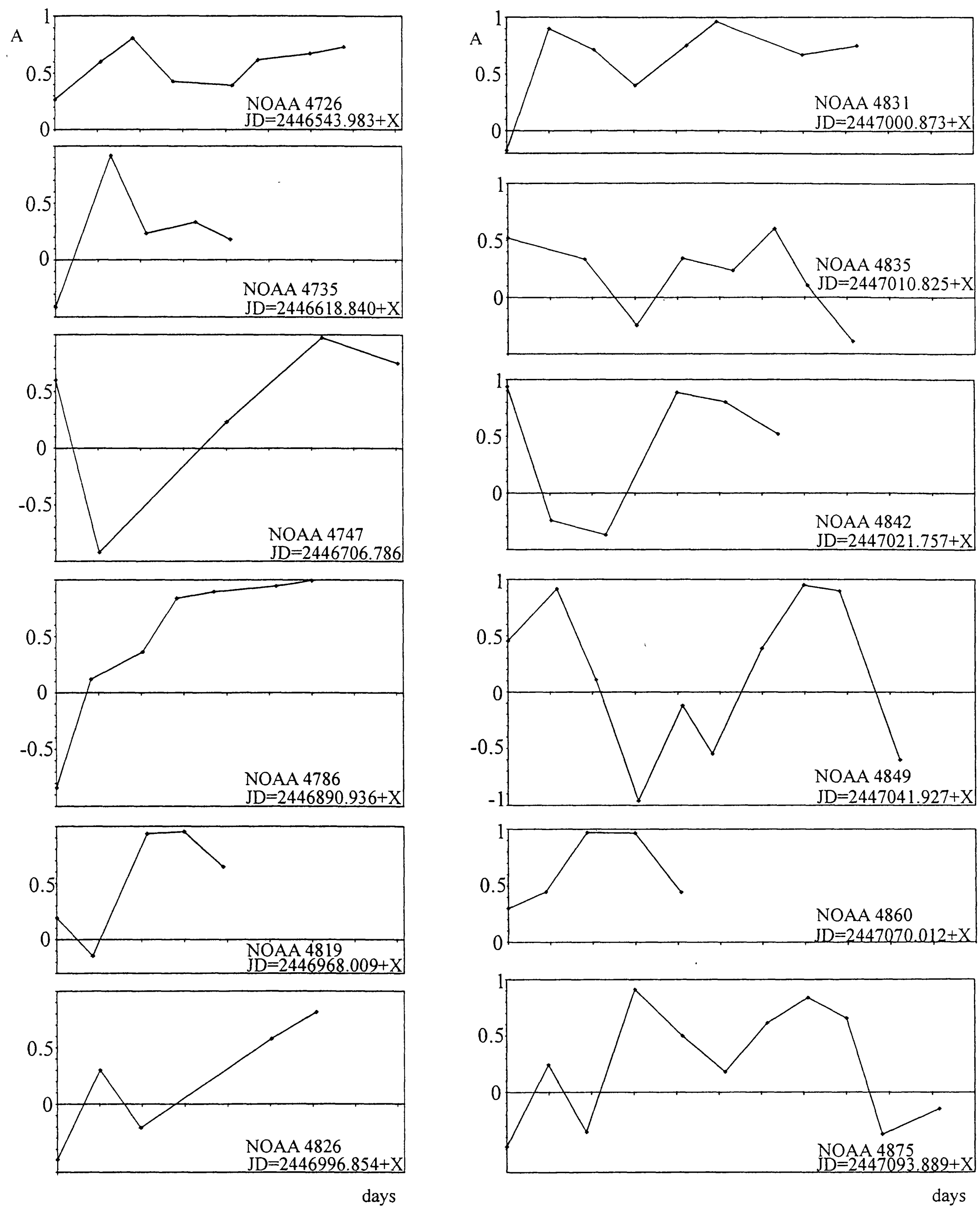

Figure 1. Evolution of the A asymmetry index depicted on consecutive days for the 12 sunspot groups of the years 1986 and 1987.

$$F = \sum_{i=1}^{n} \frac{|\vec{r}_i - \vec{r}_0|}{a_i} \qquad (1)$$

where $\vec{r}_i$ are the positions of the specific spots, a_i are their areas and $\vec{r}_0$ is their center of weight:

$$\vec{r}_0 = \frac{\sum_{i=1}^{n} \vec{r}_i a_i}{\sum_{i=1}^{n} a_i} \qquad (2)$$

The value of the F parameter is high if the spots in the given subset are small and far from each other. The compactness-asymmetry can be described by the following formula:

$$A = \frac{F_f - F_p}{F_f + F_p} \qquad (3)$$

The parameter A is positive if the following part is more dispersed than the preceding one as it is in most cases.

3. RESULTS

There were 48 sunspot groups in the years 1986 and 1987. The most obvious selection principle was that the group should have been unambiguously bipolar. However, some further restrictions were also necessary. It became obvious that single values of the parameter A at arbitrarily chosen moments are not too informative simply because the emergences of new spots result in abrupt changes in the F values. It can be expected, however, that a group in its most developed state exhibits the most characteristic rate of asymmetry. Therefore we restricted ourselves to those bipolar groups which reached their most evolved state on the visible hemisphere. 12 groups out of the total 48 regions have met this requirement.

Figure 1. shows the asymmetry runs of the 12 groups. At the first glance one can hardly recognize any common features in the curves, but they confirm the original expectation, namely, the values are heavily fluctuating as new spots are taken into account but in the second halves of the examined periods the A parameter has mostly positive values in the domain $A = 0.5 - 0.9$. This means that the positive asymmetry can be regarded as an inheritant property of the well developed bipolar regions, apparent exceptions may probably prove to be temporary deviations in the course of the evolution of the active region.

Previous studies concentrated on other asymmetry properties (tilts, bends, distances from neutral line, streams, etc.) so it is not surprising that they considered the above mentioned type of asymmetry as a consequence of others. We suggest that another approach is also worth considering, namely, the compactness-asymmetry might play the central role and it may even be the cause of the emergence. The key issue may be that the global torus is a loose cluster of fluxtubes at the bottom of the convective zone, where the buoyancy force is insufficient to drag them upwards. However, the buoyancy may increase if a region of the fluxtubes becomes more compact for some reasons, when the filling factor of the fluxtubes becomes comparable with the characteristic sizes of the convective cells at the given depth. In this case the convective drag (a dynamic buoyancy) plus the ordinary buoyancy (caused by the density difference) together would be able to start rising the flux rope. Thus the leading part would be more active in the active region, it would play the key role, actually this is what emerges, its compactness would reflect the condition of rising up.

The reason of getting the flux tubes compact may also be interesting, it is generally assumed that the twist of the rope may be the cause. In this case the helicity of the emerged flux may be treated in accordance with the compactness asymmetry, this will also be the topic of further examinations.

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