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*Astronomy*

# Formation of Active Regions on the Rising Slope of the 23rd Solar Activity Cycle and the Law of Surface Distribution for Solar Active Regions

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**ABSTRACT. We studied the topology of generation of 91 sunspot groups on the photosphere level in the beginning of the 23rd cycle of solar activity (1997-1999) and its connection to the solar background field structure. The study of distribution of sunspot groups at the solar surface in relation to wide scale background field structure provided us with one more proof of their non-Poisson distribution, which leads us to the idea that generation of active regions on the Sun's surface is not an accidental and rare event. The sunspot generated at the edge of active regions caused serious changes in their structures. During the 23rd cycle of solar activity the activity cycle moved from the southern to northern hemisphere.** *© 2010 Bull. Georg. Natl. Acad. Sci.*

***Key words:*** *solar activity, solar active regions.*

Research into solar activity is one of the most important problems of astrophysics. It is known that changes of the solar activity level affect many different processes occurring in the Earth's atmosphere, causing ionosphere disturbances, geomagnetic storms, Aurora Polaris, disturbances of radio communication conditions and other events. The influence of solar activity spreads to lower layers of the Earth's atmosphere – stratosphere, and even to troposphere layers, where the Earth's weather and climate are formed. These changes are among the most complex causes initiating the fluctuation of climate conditions on Earth. In order to predict conditions in different layers of the Earth's atmosphere and interplanetary space, it is necessary, first of all, to provide a forecast of solar activity events that form these conditions. In this sense, forecasting of the characteristics of solar activity level change is a very interesting problem for Sun and Earth physicists, as well as for all researchers investigating Sun-Earth problems.

Forecasting the development of the characteristics of any event should naturally be based on a common theory explaining all main laws of variations of this event. Unfortunately, no theory is available on the origin and development of solar activity, its cyclicity and causing mechanisms. Therefore, currently forecasting of solar activity can only be done purely by empirical-statistical methods based on large uniform sequences of observations of different solar structures (mainly relative sunspot numbers).

Solar activity forecast tasks are divided into three groups, depending on the task: short-term - of the order of a few days (but less than the period of one solar rotation); long-term – all predictions within a given solar cycle (monthly and quarterly forecasts are called middle-term forecasts, for one to several years – long-term forecasts); super long-term – for a subsequent 11-year cycle or several cycles [1].

Active events on the Sun are observed in limited areas called Activity Centers. In the active regions sunspots play an important role. It is easier to observe them rather than the rest of solar atmospheric structures; they are also characterized by strong magnetic fields, though they hold just a portion of the magnetic field of the whole active region.

Obviously, a newly formed active region and, most of all, a group of sunspots, will affect the structure of the background fields.

In this paper we study the connection between sunspot characteristics and distances from boundaries of background field structures based on direct comparison of daily maps of magnetic fields observed in Kitt Peak National Observatory and Mount Wilson Observatory, also with H-α images and photo-heliograms [2].

For some of the solar activity cycles many authors studied distribution of the active regions at the chromospheric level in relation to the boundaries of large background fields [3-9]. In this work we tried to study the link between sunspot position and background magnetic field structures, i.e. to conduct research to the active regions at the photospheric level.

During 1997-99 newborn active regions were selected which appeared on the solar disc not farther than ±60º from the central meridian. Examination of the materials for three years of solar activity of the 23rd cycle allowed us to identify the following two classes of events: class I – an active region was born far from the boundaries of background field structures (>5º), so that the emerging magnetic field does not touch the boundaries of background field structures; class II active region was born close or at the boundaries of the background field (≤5º) (Fig. 1).

**Methods and discussion of results.** For every sunspot born on the solar disc the following values were defined:

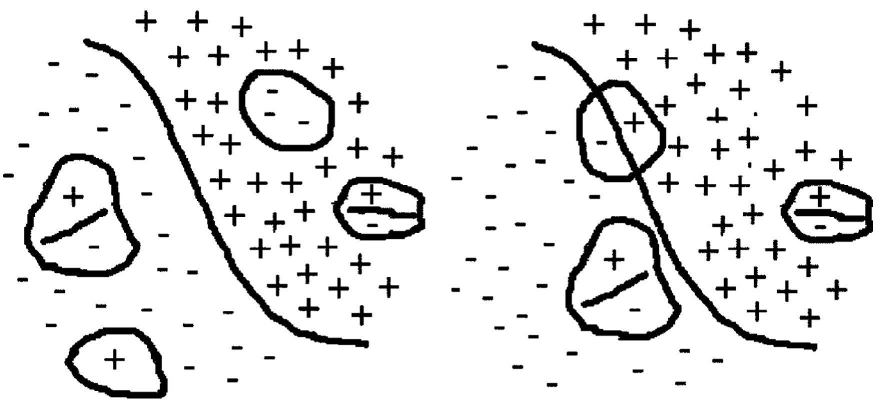
1. Sunspot class (in the sense of the classes defined above);
2. Area in one millionth part of the solar half-disc, on the second day of sunspot existence, S(2);
3. Sunspot maximum area during its movement through the solar disc, S(M);
4. Polarity sign (+/-) of the background field in the place of the active region (further named AR) formation, a day before its birth. The hemisphere in which the sunspots were formed;
5. Distance in degrees from the center of a formed AR to the nearest border of a background field;
6. Presence (or absence) of variations of the background field border which is nearest to AR;
7. Presence (or absence) of an old flocculus in the place of the AR formation.

We studied 91 active regions that were formed on the solar disc within $\pm 60^0$ from the central meridian.

During the studied years (1997-1999) 52.7% of the active regions were formed in the Southern hemisphere, while the rest in the Northern hemisphere.

From Table 1 it is seen that for the sunspots which are formed far from the background field border of the 23rd solar activity cycle, the number of AR in the northern hemisphere is less than in the southern hemisphere; whereas for class II (i.e., for those AR-s formed near the background field borders) at the beginning of the 23rd activity cycle, much more sunspots were formed in the north than in the south. However, this picture changed to its opposite beginning from 1999.

All studied class I sunspots form without changing the background field borders, whereas the formation of nearly all class II active regions is followed by changes of the background field structure. At the same time, the lifetime is longer than 1-2 rotations, as well one often observes the presence of an old flocculus in the place



Class I Class II

Fig. 1. Class I – an active region was born far from the boundaries of background field structures (>5º). Class II - active region was born close or at the boundaries of the background field (≤5º)

Table

Distribution of active regions area in the Southern and Northern hemispheres (1997-1999)

| | Class I | Class II | Sum |
|---|---|---|---|
| South | 21 | 27 | 48 |
| North | 12 | 31 | 43 |
| Total | 33 | 58 | 91 |

of formation of the active region (more precisely – in 53% of cases).

Investigations of the magnetic field polarity has revealed that at the beginning of the 23rd cycle AR is mainly formed in the "+" background field (63%), first comes out the "-" field, and then emerges "+" field, if in the "-" background field AR comes out, then first forms "+" field, and after "-" field can come out, i.e. the AR can become bipolar or remain unipolar.

It should also be mentioned that the ARs observed by us on the solar disc are mainly formed near the solar disc center.

**Poisson distribution**. In this study we aimed to find out what is the probability of active regions formation on the solar disc through a $\Delta t$ time period, i.e. what is the distribution function of the random process of active regions birth, according to the Poisson distribution law for the case of rare events.

Let us represent Poisson distribution [10] as

$$P_k = \lambda k e^{-\lambda}/k!, \quad (1)$$

where $\lambda$ is an average number of AR formation during $\Delta t$ time interval, $k$=1,2,3,..., $\Delta t$=30 days. According to observational data, there were $n$=36 intervals in total. In Poisson distribution (1) $\lambda=N/n$, where $N$ is the number of active regions $N$=9, $n$=36 – number of intervals. $\lambda$=2.5, then $P(k) = 2.5^k e^{-2.5}/k!$, $k$=1,2,3,... Using the Bol'shev

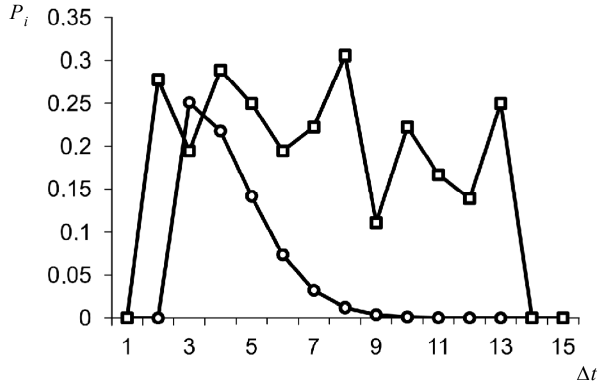



Fig. 2. Poisson distribution and observed frequencies.
○ – theoretical curve of probability between $x_i=k_i$.
□ – the observed frequency of the event appearance.

Chart [11], we found probabilities $P_i$ for each $k_i$ and built up a theoretical curve between $x_i=k_i$ and $P_i$. We also discovered and observed the frequency of the event appearance, i.e. $\nu_k=x_i/n$, where $n$=36, ($\Delta t$ is the number of intervals), $x_i$ is the number of intervals with a similar number of AR formation.

Based on the obtained data we built up dependence curves of the accidental values ($x_i=k_i$) and $\nu_k$ (Fig. 2).

From Fig. 2 it is obvious that the dependence between $x_i$ and $\nu_k$ does not agree with Poisson distribution. In order to test the following hypothesis – does the considered accidental value follow the distribution law or not – it was estimated by the criteria of $\chi^2$. The critical value of $\chi^2$ for the given level at $\alpha$=0.05%.

The distribution of $\chi^2$ depends on the freedom level $r = k$-1, where $k$ is the number of discharges ($k$=13), $\chi^2 = \Sigma(n_i - np_i)^2 / np_i$, ($i$=1,2,3..$k$) $k$=1,2,3…13, (2) (Pustil'nik, *et al.* 1968, Bol'shev, 1983), $n_i$ is the number of $\Delta t$ interval choices, then $\Sigma p_i = 1$, $\Sigma n_i = N$ ($i$=1,2,...$k$).

Considering that $\chi^2$ is the measure of the deviation from the genuine distribution from the hypothetical one, the above hypothesis should be rejected if the value calculated according to a definite choice (2) exceeds some defined critical value. This critical value of $\chi^2$ for the given level at $\alpha$=0.05%, $m$=$k$-1=14-1=13, the level of freedom $\chi^2_{\alpha} = \chi^2_{(13;0.05\%)} \approx 34.821$ and $\chi^2_{obs} \approx 407.1$, i.e. $\chi^2_{(obs0)} >> \chi^2_{(13;0.05\%)}$.

Therefore, we can conclude that the hypothesis that the probability of AR formation is not distributed according to the Poisson law is true. This result reflects the fact that ARs are not random and "rare" events on the Sun.

**Conclusions.**

1. Active regions which are formed at the boundary of the background field induce variations of the structure of background field.

2. For rising slope of the 23rd solar activity cycle one can observe activity shift from the southern to the northern hemisphere.

3. Formation of Active Regions is not distributed according to Poisson law.

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*ასტრონომია*

# მზის აქტივობის 23-ე ციკლის აღმავალ შტოზე აქტიური არეების წარმოქმნა და მათი მზის ზედაპირზე განაწილების კანონზომიერება

ნ. ოღრაპიშვილი*, დ. მაღრაძე*, ე. ხუციშვილი*, ვ. ყულიჯანიშვილი*, თ. კვერნაძე*

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**ნაშრომში შესწავლილია მზის აქტივობის 23-ე ციკლის დასაწყისში (1997-99წწ.) ფოტოსფეროს დონეზე 91 ლაქათა ჯგუფის წარმოშობის ტოპოლოგია და მისი კავშირი ფონური მაგნიტური ველის სტრუქტურასთან. მზის ლაქათა ჯგუფის განაწილების შესწავლამ მსხვილმასშტაბური ფონური ველის სტრუქტურულ ცვლილებასთან მიმართებაში დაადასტურა, რომ მათი განაწილება არ წარმოადგენს პუასონის განაწილებას, რაც ნიშნავს, რომ აქტიური არეების წარმოქმნა მზის ზედაპირზე არ არის შემთხვევითი და იშვიათი მოვლენა, ამასთან ფონური ველის საზღვრებთან წარმოშობილი ლაქები იწვევს მათი სტრუქტურული საზღვრების მნიშვნელოვან ცვლილებას.**

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