The 15th Russian-Chinese Workshop on Space Weather

FORERUNNERS AND EFFECTS OF POWERFUL SOLAR FLARES IN THE ACTIVE REGION 12673 IN THE SEPTEMBER, 2017

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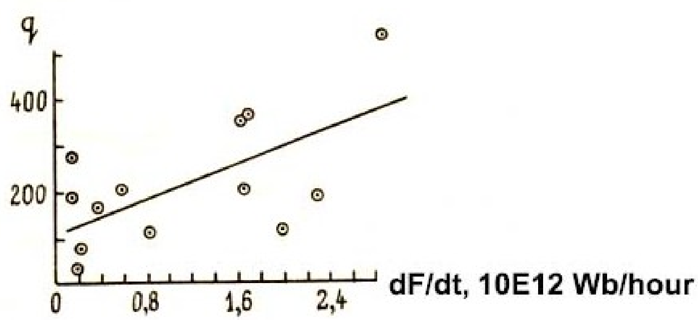
At present, it is actual to create a system of short-time forecast of mighty geoeffective flares. The temporary variation of imbalance of magnetic flux of an active region F(t) may serve some informative parameter. It can be a measure of linkage of AR's magnetic field to large-scale solar magnetic field. There are some backgrounds for such a study.

First, it was found, that long-lived centers of flare activity exist during the periods of magnetic field restructuring (Borovik et at., 2020).

Second, Zvereva and Severny (1970) had noted the relation of the changes of magnetic flux imbalance to solar flares occurrence.

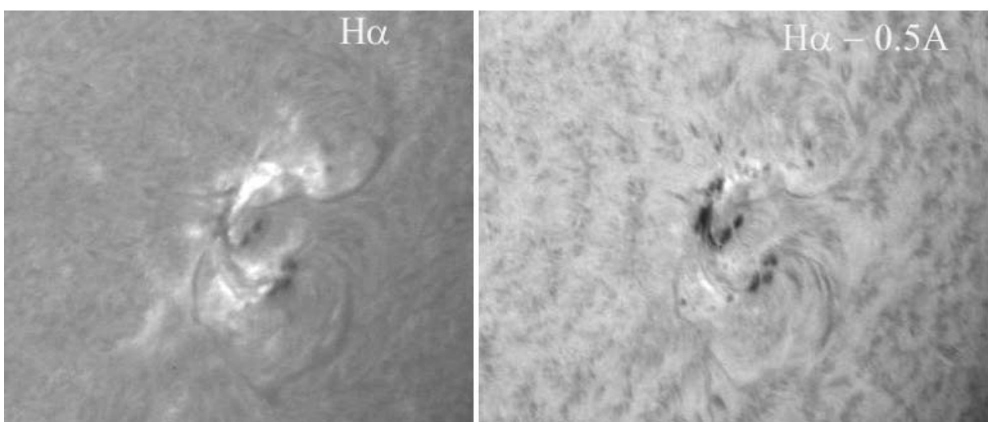
The rapid variation of magnetic flux imbalance, observed simultaneously with solar magnetographs at the Sayan (Russia) and Ondrejov (Czech Republic) observatories at rate 1,65 x10^9 Wb/s, correlate with solar flares occurrence. The result was obtained in the paper by Golovko and Kotrc (1992).



Golovko (1991) obtained, that variation rate F(t) is within 0,1 – 1,7 x 10^9 Wb/s. It correlates (K_{corr}=0,6) to the flare index.

The data of solar magnetographs at HMI SDO and SOT Hinode orbital observatories made possible to investigate this problem at higher level, with fine spatial and time resolution.

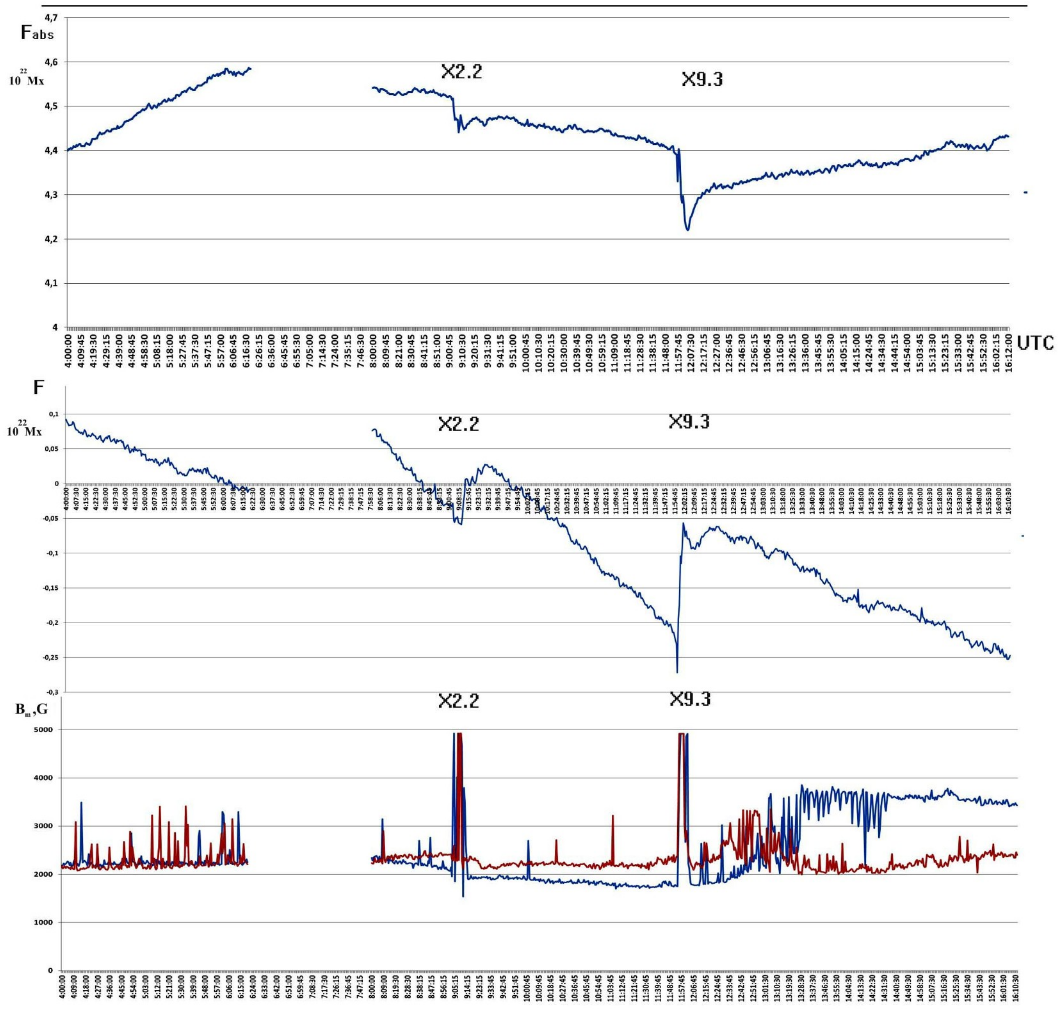
In our work (Golovko and Salakhutdinova, 2023) we investigated the peculiarities of magnetic and velocity fields in the AR 12673, that produced the mighty solar flares at 6 – 10 of September, 2017. Many papers are devoted to study of this active region, that produced the most energetic events of 24-th solar cycle (Hou et al., 2018; Anfinogentov et al., 2019; Peng Zou et al., 2020 and other). We used the method of multifractal analysis. It had shown its efficiency in revealing the new magnetic field emergence (Golovko and Salakhutdinova, (2012, 2015, 2018). Earlier the flare-related variations of multifractal structure of AR's had revealed in the paper by Abramenko V.I., Yurchishyn V.B., Wang H., et al.(2002)



The H-alpha image of AR 12673 at September 7, 2017 obtained at Baikal Astrophysical Observatory

The magnetic field of AR 12673 was observed by SOT Hinode in the spectral lines FeI 6301,5 A, 6302,5 A. A pixel size was 0,15” or 0,3”, noise level 15 G. Also we used the magnetograms of HMI SOHO in the line 6173 A, pixel size 0,5”.

Processing these data gave the opportunity to study the imbalance in more detail.



The unsigned (sum) magnetic flux

$F_{abs} = |F_N| + |F_S|$

Increase 0 – 6 UT

Decrease 8 – 12:30 UT

Abrupt fall during flares

The net magnetic flux (imbalance)

$F = |F_N| - |F_S|$

Negative polarity flux increase 8:30 – 9 UT

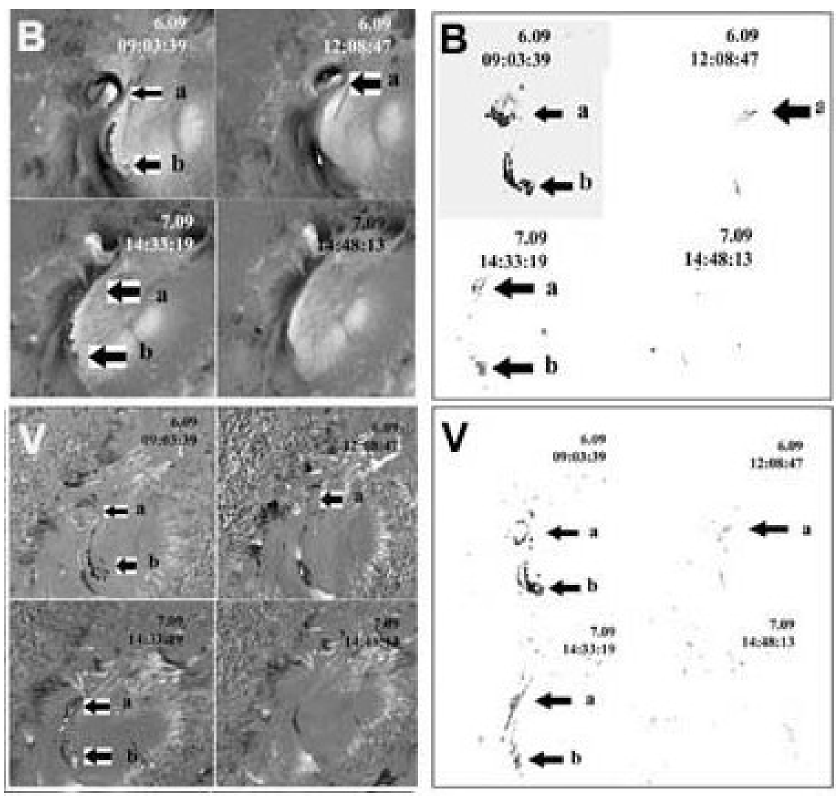
Before X2,2 flare

The same increase 9 – 12 UT

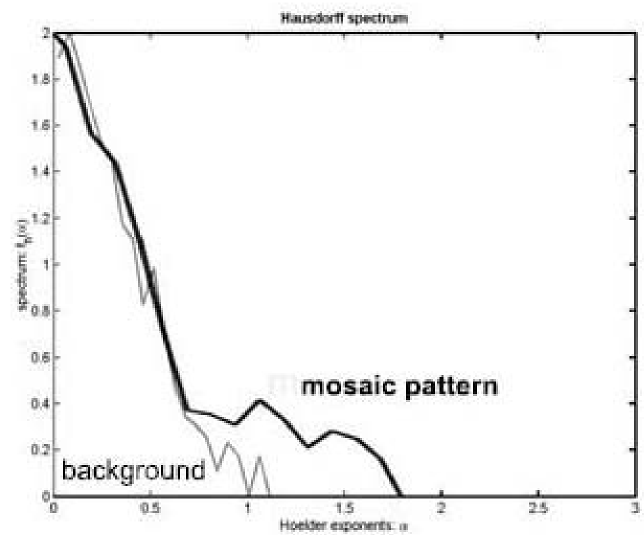
Before X9,3 flare

Maximum magnetic field B_m

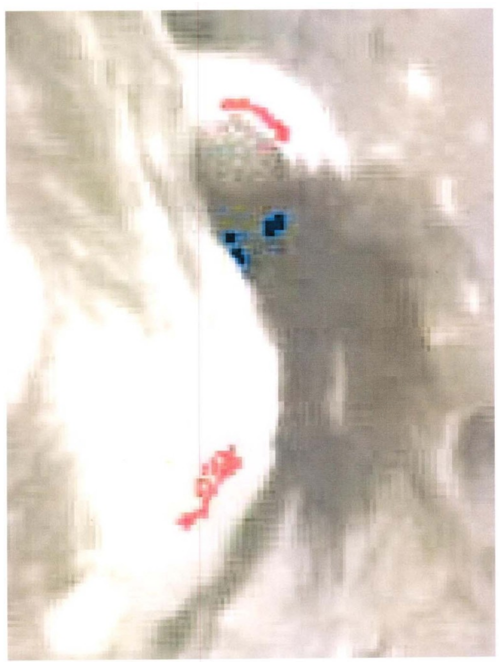
The result about magnetic flux imbalance changes must be confirmed by Independent method, because interpretation of magnetographic data is rather complicated (Demidov et al., 2023). We selected the microcanonical technique of multifractal analysis (Levi-Vehel and Vojak, 1998; Makarenko et al., 2012; Golovko and Salakhutdinova, 2018) to reveal the patches with high intermittency of magnetic field in the active region.

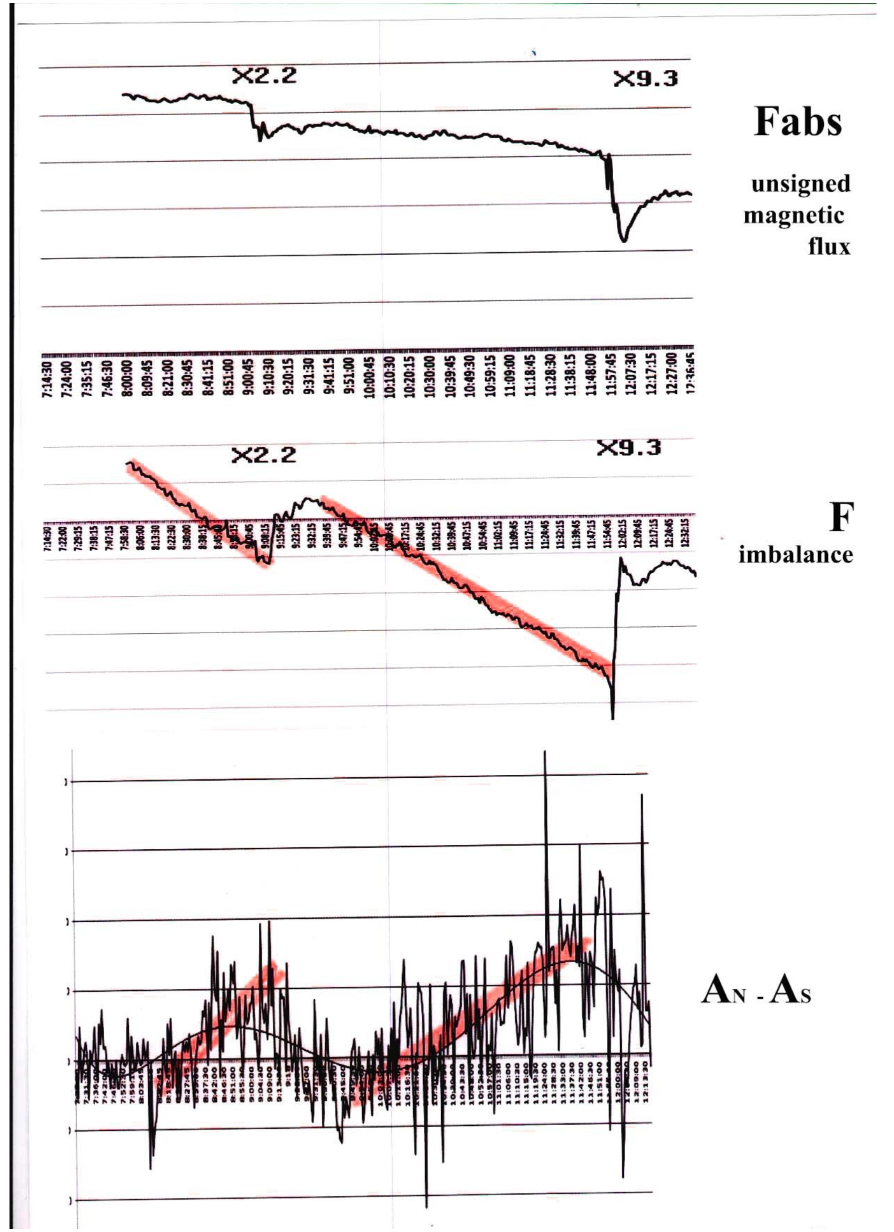


These patches, called “mosaic patterns”, are situated in the two main activity centers “**a**” and “**b**”, where the initial brightening of mighty flares appear. In these patterns the multifractal spectrum is more wide.

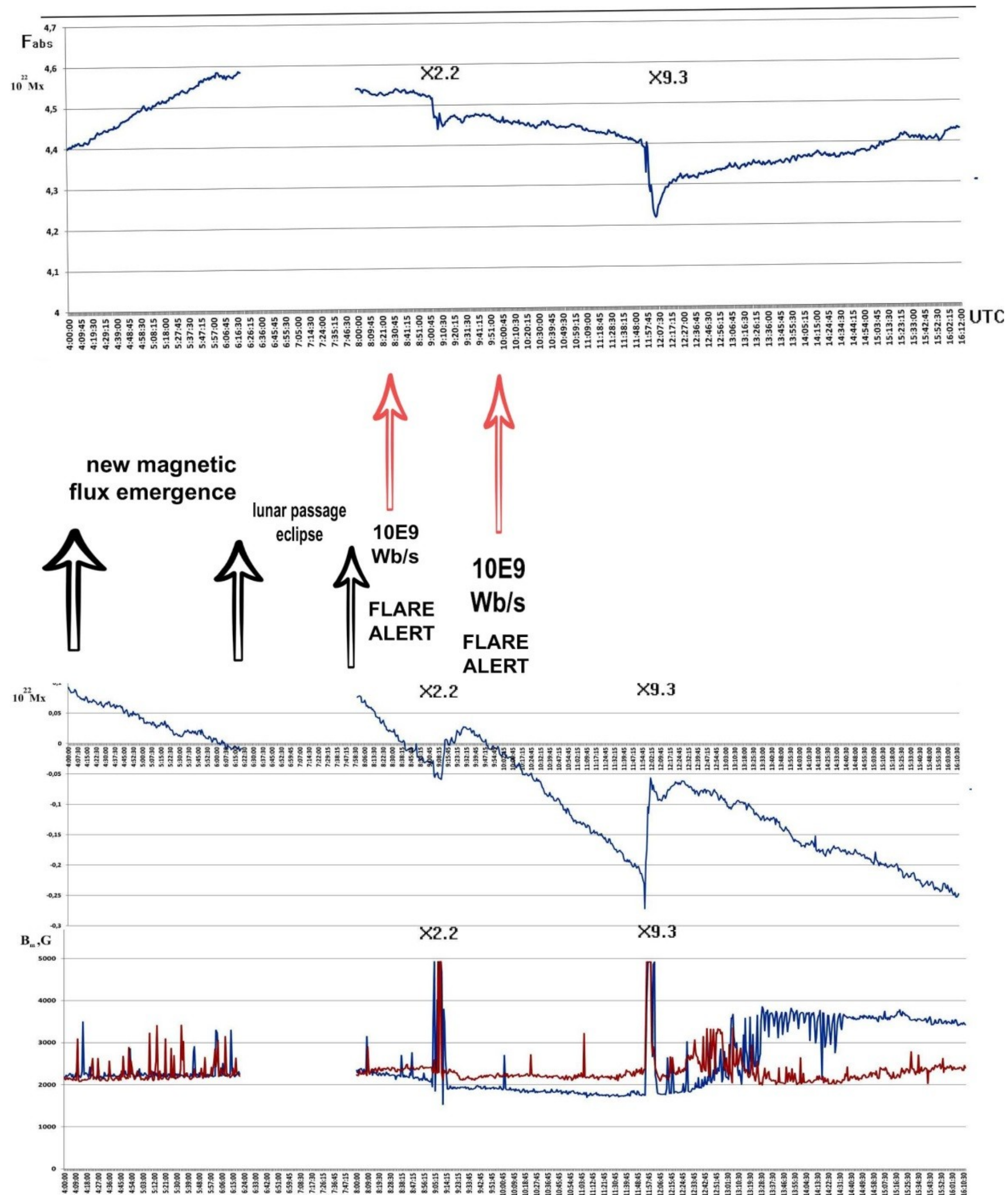


For each mosaic pattern, on each magnetogram (red and blue patches), the area was estimated and plotted across time. The variation of area difference $A_N - A_S$ shows the same behavior, as the imbalance F does. It confirms the result and make possible to use F(t) as a predictor.

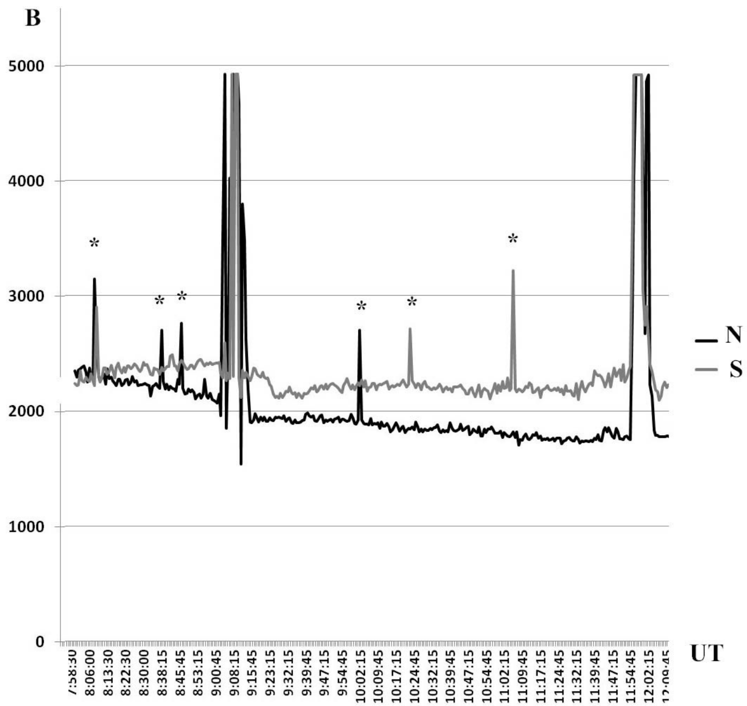


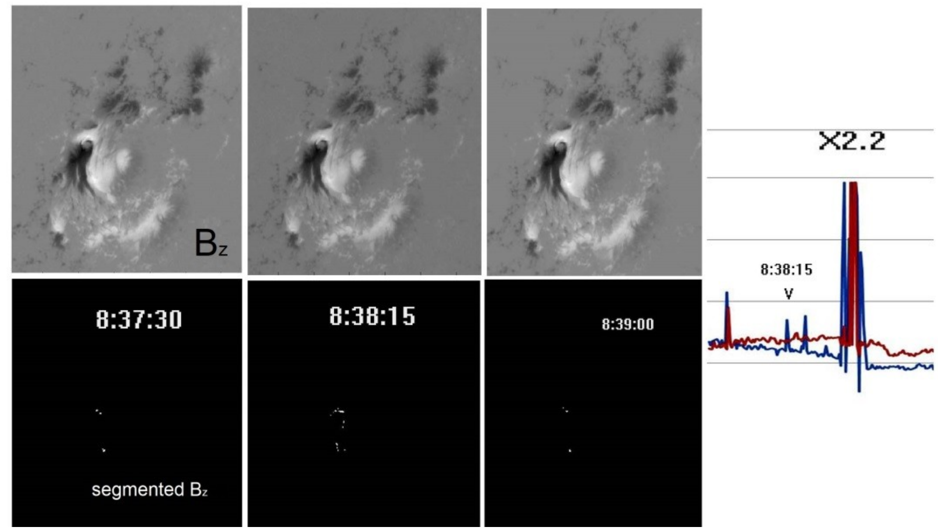


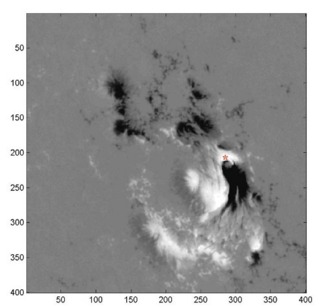
The imbalance F(t) can be used in the practice of forecast.

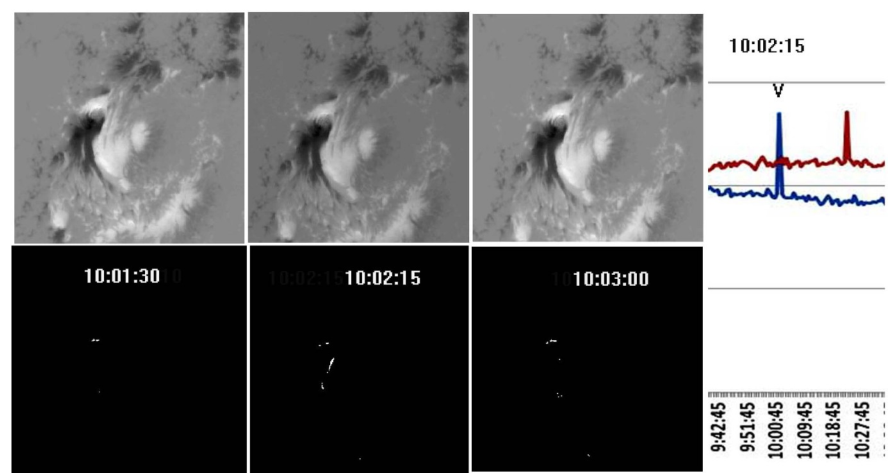


The other phenomenon, preceding flares, is one-minute bursts of the maximum magnetic field strength in the area of AR, detected with observation cadence of 45 s. The investigation showed, that during such a bursts, some activation occurs in the vicinity of the main polarity inversion line.

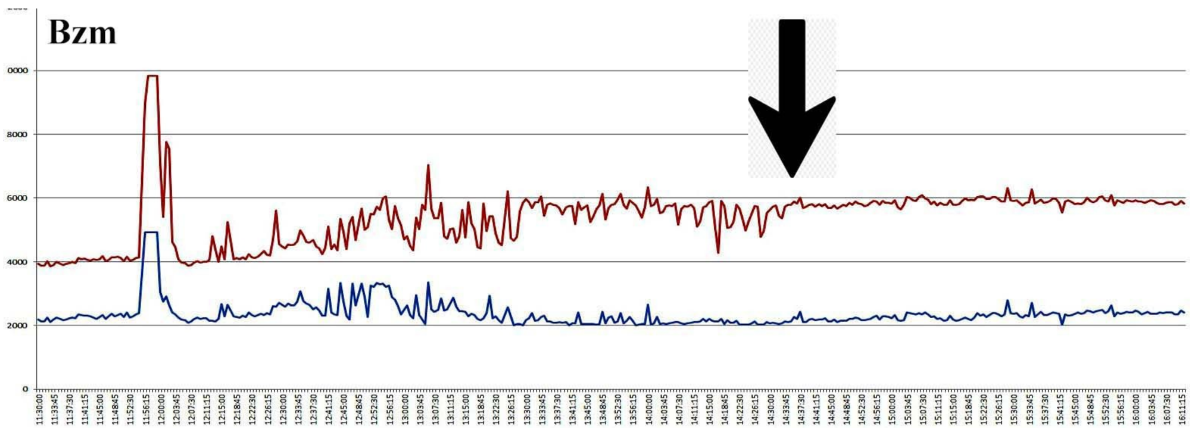


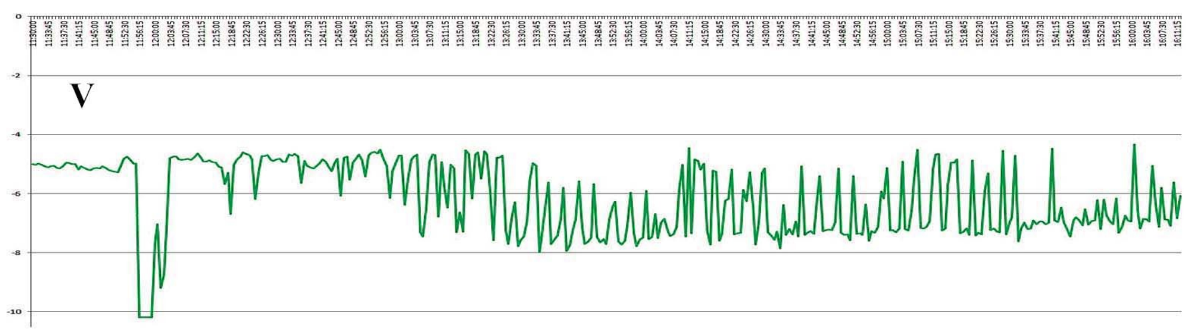


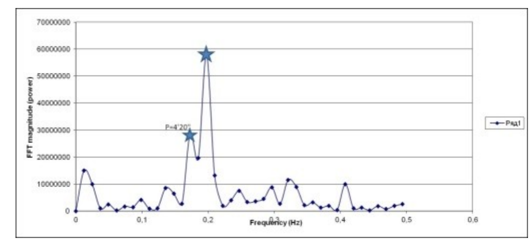




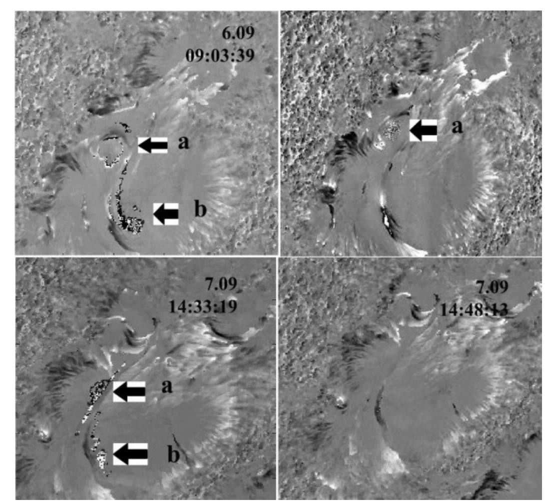
Among many effects of mighty flares, we can mention the 4-minute variations of the maximum measured magnetic field strength, as well of radial velocity.







Fourier spectrum



Also there are re-configurations of the mosaic patterns distribution after flares

The conclusions:

The forerunners of the mighty flares in the active region 12673 are:
- Fast increase of the imbalance of magnetic flux,
- Structural changes which led to imbalance of areas with intermittency of field of both polarities,
- One-minute bursts of the maximum magnetic field strength, accompanied by fast variations near the polarity inversion line.

The effects of flares are:
- Quasiperiodic pulsations of maximum magnetic field and radial velocity,
- Reconfiguration of activity centers location.

We express gratitude to the authors of the joint study of the mentioned active phenomena in September, 2017 and to SDO and Hinode teams who gave the free access to the data.

Thank you for attention!