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Multifractal spectrum of solar active region NOAA 10960 in the H_α spectral line

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Abstract. We obtained the H_α images of some solar active regions and prominences. Our astronomical observatory has the telescope-coronagraph which was equipped with the birefringent Halle H_α filter and CCD camera Apogee U4 (2048x2048 pixels). This paper presents multifractal spectra of images of some solar active regions in H_α line obtained with the coronagraph. The Pointwise Hoelder exponents (α) and Hausdorff spectrum $f_n(\alpha)$ for a part of chromosphere with active region and without it, have been obtained. It is visible, that curves $f_n(\alpha)$ for quiet and active regions of chromosphere differ very strongly. In particular, $f_n(\alpha)$ for region with a sunspot and flare has very complicated form, and for region with filament the curves do not considerably differ from quiet chromosphere. The multifractal spectrum of quiet chromosphere shows that the quiet chromosphere is very well described by fractals with different dimensions. We analyze this result.

Keywords. Sun: atmosphere, activity, flares, multifractal spectrum

1. Introduction

Some publications were devoted to research about existence of scale invariant solar magnetic field at a level of photosphere (Abramenko *et al.* (2002), Lawrence *et al.* (1993), Salakhutdinova and Golovko (2004), Stark *et al.* (1997)). They emphasized the following. The quiet-Sun photospheric fields are generated by local dynamo action based on random convective motions at high magnetic Reynolds number. The properties of active region images are determined by the presence of fields generated by the global, mean field dynamo (Lawrence *et al.* (1993)). Fractal and multifractal techniques have been applied to various types of solar data to study the fractal properties of sunspots as well as the distribution of photospheric magnetic fields and the role of random motions on the solar surface in this distribution. Other research includes the investigation of changes in the fractal dimension as an indicator for solar flares (Stark *et al.* (1997)). The B_z field in an active region is an intermittent (multifractal) structure and that the degree of intermittency increases when the flaring activity is rising (Abramenko *et al.* (2002)). The medium is in the state of intermittent turbulence, strongly different from the classic Kolmogorov's turbulence. The difference is observed not only for larger moments of structure functions, but also for smaller ones (Salakhutdinova and Golovko (2004)).
Magnetic fields of the solar chromosphere are frozen into plasma. Therefore the H_α filtergram exhibits a properties of magnetic field of active regions of the Sun. In this work we have considered behaviour of multifractal spectrum of some active phenomena observed in the H_α line at the minimum of solar activity.

2. Observational Data

The Ulaanbaatar astronomical observatory of the RCAG (Research Centre for Astronomy and Geophysics of Mongolian Academy of Sciences) carries out observations of solar active phenomena in the H_α line with the coronagraph telescope equipped with the Halle birefringent filter with the $0.5\mathring{A}$ passband. The telescope was equipped with the Apogee CCD camera with 2048x2048 pixel.
This paper is based on the observations of two active regions: NOAA 10898 (30 June 2006)(Figure 1, left panel), and the activity complex of NOAA 10960 (4 June 2007) (Figure 1, right panel). All digital images were preprocessed using a fast Fourier transform filters (using CCD imaging software MaxIm DL). The flare develops from photosphere to corona (Figure 1, right panel and figure 2). The data used in our investigation, are obtained with this telescope.

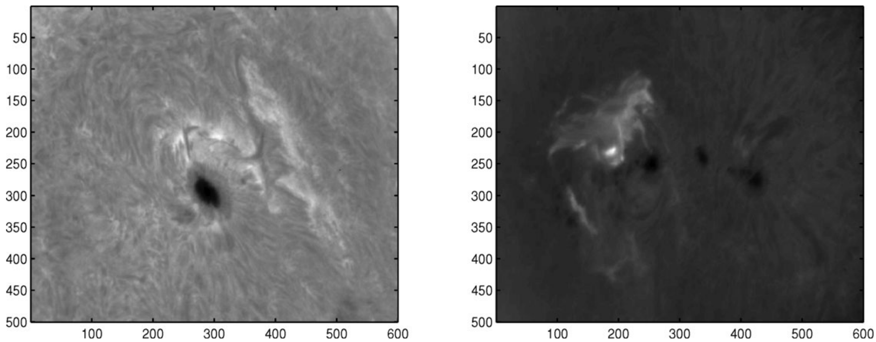

Figure 1. H_α filtergrams for the active regions: left panel- NOAA 10898(30 June 2006) and right panel- NOAA 10960 (04 June 2007). In the images the spatial pixel scale is 0.51arcsec. Observations were made in Ulaanbaatar Astronomical Observatory.

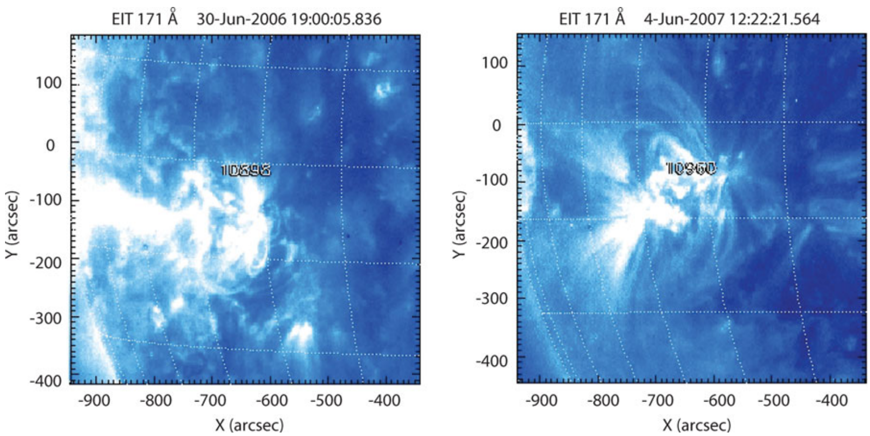

Figure 2. Same active regions(as figure 1) in EIT $171\mathring{A}$ from SOHO station(see soho): left panel- NOAA 10898 and right panel- NOAA 10960.

3. Results and discussion

We have chosen images of active regions with the size 300×200 $pixel^2$ ($1pixel = 0.51arcsec$ in the solar disk) (Fig. 3–12, left panel). We have estimated multifractal spectra of active regions images in H_α line using "FracLab" software (see FracLab). For

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quiet chromosphere areas (Fig. 3, 8; left) multifractal spectrum is stable and a variations (fluctuations) of the singularity are weak (Fig. 3, 8; right).

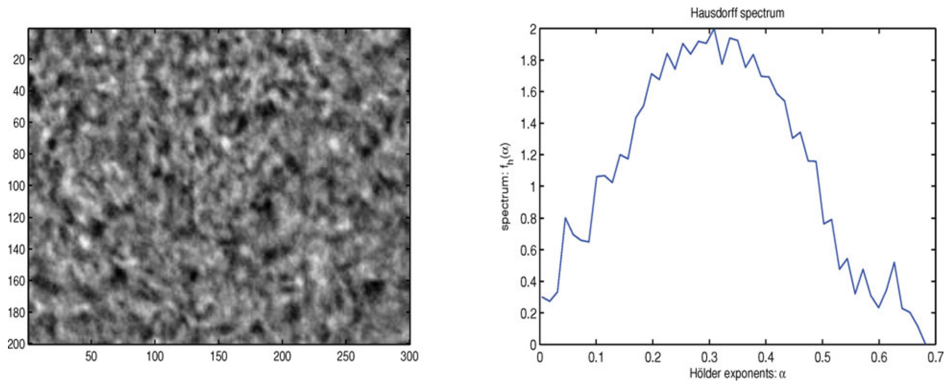

Figure 3. Left panel- H_α filtergram for a some part of the quiet solar chromosphere and right panel- multifractal spectrum for this part.

In figures 4 and 9, the solar area with the filament (near NOAA 10898) and their multifractal spectrum are presented. An effect of the filament to multifractal spectra shows itself in wing, but not considerably.

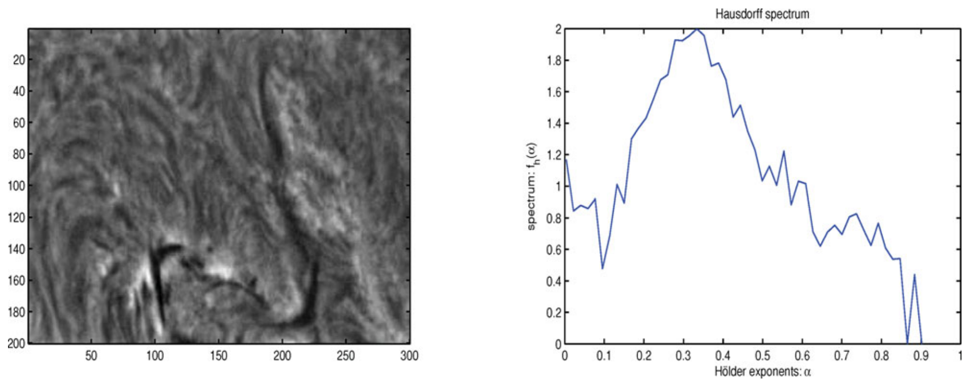

Figure 4. Left panel- H_α filtergram for the filament of the active region NOAA10898 and right panel- multifractal spectrum for this filament.

In the active region NOAA 10960 the flare occured (McIntosh type is Fkc, from (see solarmonitor)). We carried out the series of observations of this active region. Some observations are shown in Figures 5–7 and 10–12. In the Figure 5 multifractal spectrum at pre-flare stage is shown and a fluctuations of the singularity are very strong in comparison to the spectrum of quiet chromosphere (Fig. 3). In the Figure 6 multifractal spectra at flare stage and the right wing with the fluctuations of the singularity of this spectrum are shown. In other words, the width of the spectrum expands strongly and is very different from Fig. 5 (right panel). Figure 7 shows H_α filtergram of image after the flare and the corresponding multifractal spectrum. Here it can be seen,that the process of event goes to the initial state. Thus, primary results show,that multifractal spectra are very sensitive

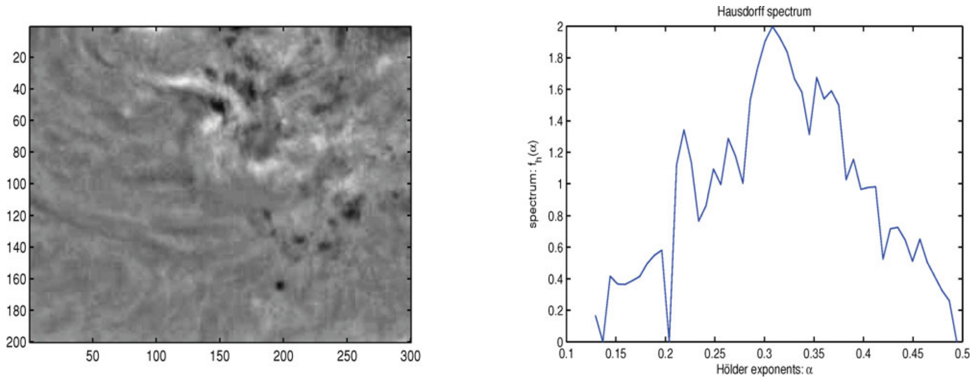

Figure 5. Left panel- H_α filtergram at pre-flare stage of the active region NOAA10960 and right panel- multifractal spectrum for this image. Time: 03:17:41UT.

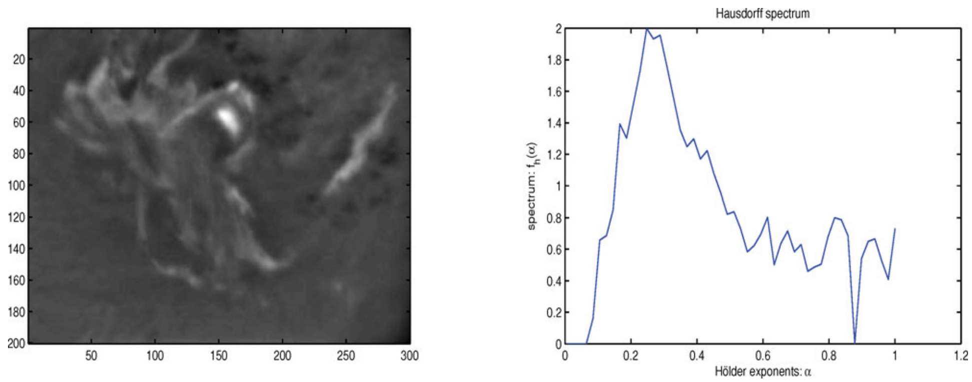

Figure 6. Left panel- H_α filtergram at the flare of the active region NOAA10960 and right panel- multifractal spectrum for this image. Time: 04:17:21UT.

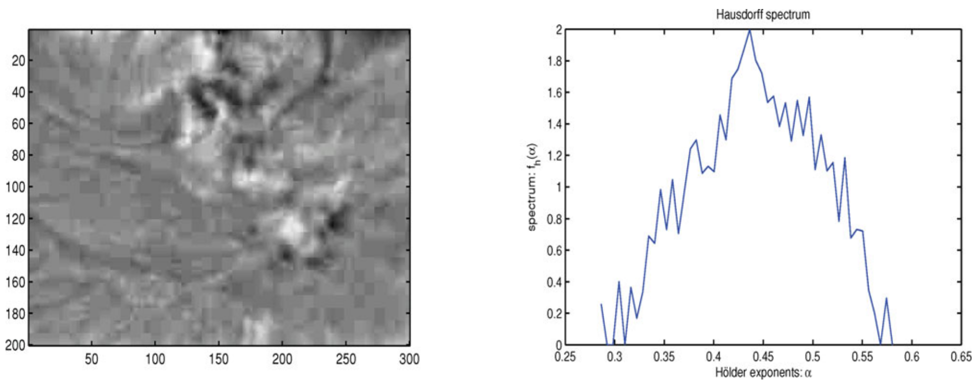

Figure 7. Left panel- H_α filtergram of image after flash of the active region NOAA10960 and right panel- multifractal spectrum for this image. Time: 05:37:16UT.

to reconstruction of structures in the active region. It can be seen, that the changes in the multifractal spectrum can be regarded as an indicator for solar flares.

Also, in the Figures 8–12 were shown Hoelder images and their multifractal spectrum. They yield too the results as previous.

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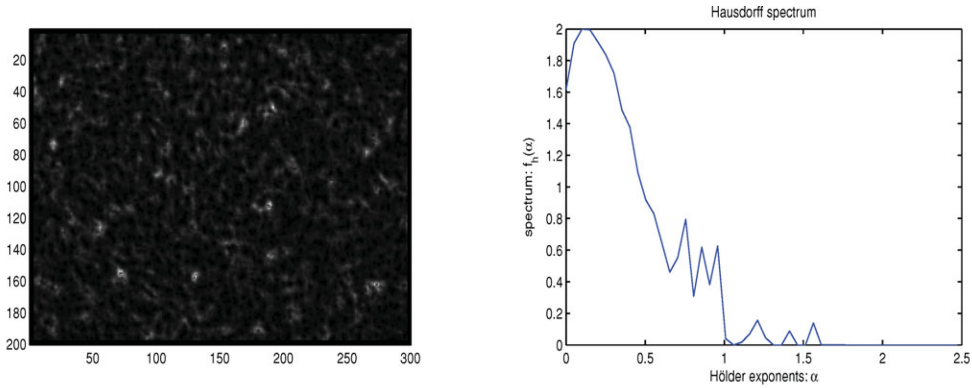

Figure 8. Left panel- Hoelder image for a part of the quiet solar chromosphere and right panel- multifractal spectrum for this part.

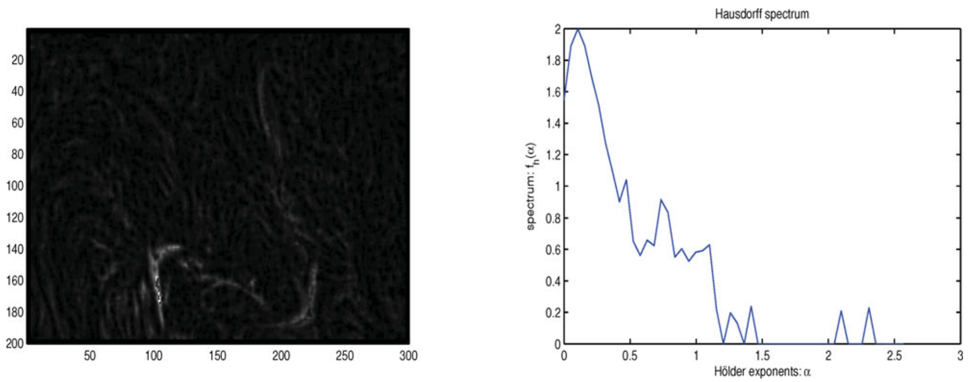

Figure 9. Left panel- Hoelder image for the filament of the active region NOAA10898 and right panel- multifractal spectrum for this image.

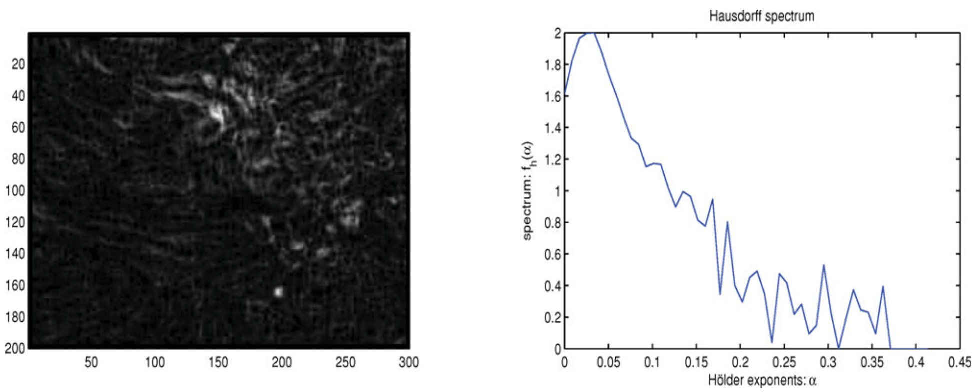

Figure 10. Left panel- Hoelder image at pre-flare stage of the active region NOAA10960 and right panel- multifractal spectrum for this image.

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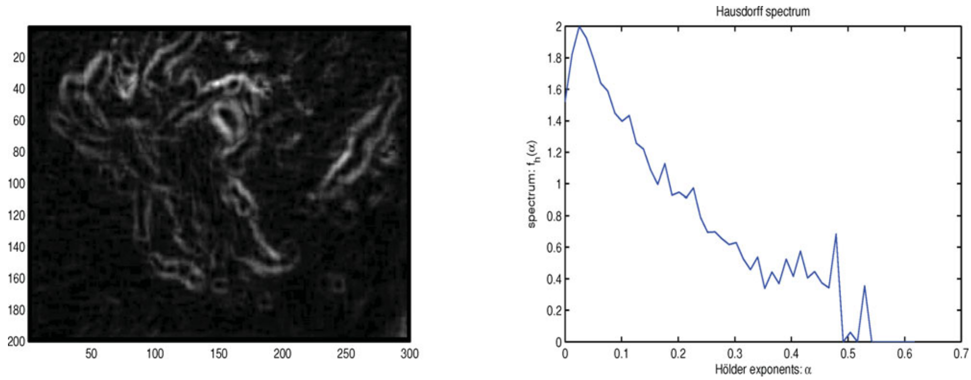

Figure 11. Left panel- Hoelder image at the flare of the active region NOAA10960 and right panel- multifractal spectrum for this image.

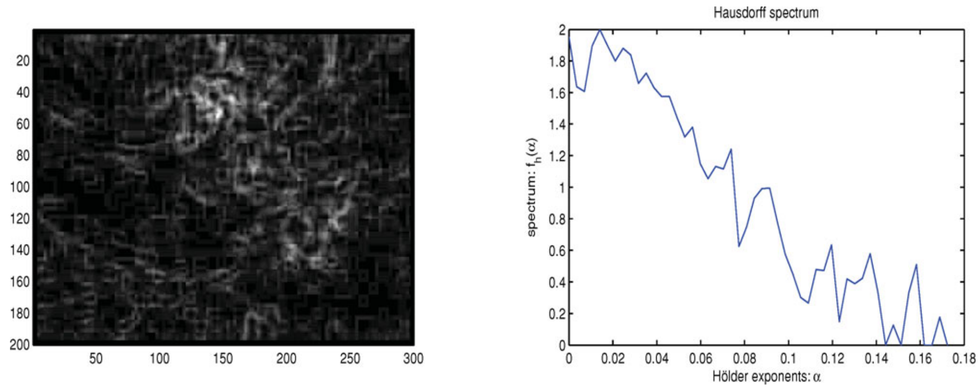

Figure 12. Left panel- Hoelder image after flash of the active region NOAA10960 and right panel- multifractal spectrum for this image.

4. Concluding Remarks

Based on the observation data in H_α line and the software "FracLab" we have obtained Hausdorff spectrum $f_n(\alpha)$ of the active regions at the minimum of solar activity. Multifractal spectra are very variable at different stages of solar activity. In particular, fluctuation of the singularity in the spectrum at different stages of development of the flare noticeably differs each from other (Fig. 5–7, Fig. 10–12; right panel). Also at a phase of flare the width of a spectrum extends. Therefore primary results show that multifractal spectra can be one of indicators of the stage of development of solar active regions.

References

Abramenko, V. I., Yurchyshyn, V. B., *et al.* 2002, *ApJ*, 577, 487
Lawrence, J. K., Ruzmaikin, A. A., & Cadavid, A. C. 1993, *ApJ*, 417, 805
Salakhutdinova, I. I. & Golovko, A. A. 2004, *Solar Phys.*, 225, 59
Stark, B., Adams, M., *et al.* 1997, *Solar Phys.*, 174, 297
FracLab(http://apis.saclay.inria.fr/FracLab/)
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