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Fractal analysis in space physics

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According to the non-linear and the system paradigms, many processes generated in open, non-linear, dynamical systems under influence of a powerful source of energy release are appeared to be short-time, ultra-wideband, non-linear and fractal. In applied physics, there are a lot of such processes and such systems. Therefore, to investigate the fractal properties of the signals and processes generated in the open, non-linear, dynamical systems, the set of corresponding methods are needed. Namely such modern and effective methods had been united in fractal analysis. Suddenly, but these methods are often appeared to be quite unknown for the most part of researchers, which work in space physics. No doubt, this state should be changed.

The purpose of this work is to draw attention of the researchers to the advantages of the fractal analysis methods, in particular, and to the fractal analysis application benefits, at all. To distinguish the purpose, the extended review of the existing fractal analysis methods applicable to investigations of the signal and processes of any origin is proposed. Please, note, this review deals with mono-fractal analysis only. Due to volume limitations of this paper, all existing multi-fractal analysis methods were appeared to be out of the scope of this work.

As a part of the fractal approach in nature created by the famous American researcher Benua Mandelbrot in 1970th, fractal analysis of the signals and processes unite a lot of methods based on calculation, first, of different fractal dimensions. Now there are over sixty methods, which are regularly applied in many branches of science and engineering, in particular, in the physics. As the theoretical bases of these fractal analysis methods, the concepts of one-parametric (the fractal Brownian motion and the fractional Gaussian noise) and multi-parametric (the generalized Cauchy process, the alpha-stable processes, including the Levi's flight, the generalized Ornstein-Uhlenbeck processes) mono-fractal signal models are used. All fractal dimensions calculated in the fractal analysis methods can be divided on two big groups. First of them is based on geometric properties of the signal

investigated. The second of them deals with statistical properties of the signal and their numerical characteristics (for example, with Hurst exponent). In the same time, all fractal analysis methods can be classified as simple (only one fractal dimension is used) and complex (the set of fractal dimensions is calculated) ones. First of them are appeared to be simpler to realize, second are appeared to carry more different and useful information. Let's take a quick look at the list of the most known simple fractal analysis methods. Today there are the Fourier dimension based method, the coarse graining spectral analysis method, the box-counting method, the real box-counting method, the differential box-counting method, the extended counting method, the multiresolution box-counting method, the Minkowski sausages method, the variation method, the Burlaga's and Klein's method, the Higuchi's method, the Katz method, the Petrosian's method, the Mandelbrot's method, the multiresolution length method, the Sevcik's method, the consecutive differences method, the normalized length density method, the critical exponent method, the average normalized autocorrelation method, the Maragos-Sun's method, the Renyi generalized dimensions method, the variational dimension method, the zero-crossing method, the Korcak's method, the Chens' method, the R/S-method, the Mandelbrot's and Wallis' method, the autocorrelation analysis method, the detrended fluctuation analysis, the detrended moving average method, the second moment method, the Peltier – Levi-Vehel's method, the variance plot method, the variogram method, the generalized variogram method, the aggregated dispersion method, the aggregated signal absolute values method, the periodogram method, the wavelet analysis based method, the empirical mode decomposition method, the dispersion analysis method, the signal summation conversion method, the regularization dimension method, the diffusion entropy analysis and other. As the complex fractal analysis methods, in particular, the generalized fractal analysis and the dynamical fractal analysis proposed by the authors of this paper can be considered. On our opinion, the correcting function method created this year by the same authors is appeared to be a useful addition to the all mono-fractal analysis methods. This method is an attempt to improve the accuracy of the fractal dimension estimations.

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