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## New 2D multifractal tools delve into Pollock's expressionism

*The temperature changes hour to hour and day to day, exchange rates behave no differently. Wherever studies of the variability of similar one-dimensional time series are concerned, analyses based on multifractals have managed to gain recognition. Now, these tools have been developed and successfully applied to two-dimensional cases, including the study of abstract paintings by Jackson Pollock.*

Abstract paintings elude easy verbal descriptions. What is difficult to express using subjective words can now be captured with objective numbers, thanks to the recently proposed innovative technique of two-dimensional multifractal analyses. This new research tool was created by a team of theorists from the Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Cracow, the University of Rzeszow (UR) and the Cracow University of Technology (PK), and is discussed in the scientific journal *Chaos*. Using specific examples, the researchers demonstrate here that the presented formalism leads to significant results. Multifractal 'tortures' were applied, among others, to images of the surface of Mars, the Crab nebula, and paintings representing key phases of the evolution of Jackson Pollock's abstract expressionism.

*"Multifractal analyses, even in one-dimensional cases, are computationally quite complex, requiring professionalism. In our work, we presented the most complete – yet practical – computational algorithm that allows for the detection of a possible hierarchical, multifractal organization of structures on a plane, that is, in two dimensions. We are therefore also able to identify the potential directional asymmetry of this sort of organization and analyze its characteristics,"* says Prof. Stanislaw Drozd (IFJ PAN, PK).

The basic idea of the proposed formalism is simple and somewhat resembles tomography. The procedure begins with selecting a point on the surface under study, usually at the edge or corner. From this point, the surface is scanned at successive angles, in each direction within strips of several widths (usually three). Within each strip, standard multifractal analyses are performed, including calculating multifractal components of the spectrum and studying their variability. The scanning process is designed in such a way that it guarantees complete coverage of the analyzed area. The final stage involves the skillful determination of the resulting multifractal spectrum.

*"While the very idea of scanning a surface in successive directions is simple, its practical implementation is not trivial. The main issue arises from the fact that if we mishandle the detected multifractal dependencies, for example if we add them purely mechanically, the result of our work may be mere noise, in which the multifractal dependencies simply disappear,"* notes Prof. Rafal Rak, first author of the article presenting the achievement.

In order to illustrate and verify the usefulness of the proposed technique, the researchers analyzed two astronomical photographs. The first image, taken by the Mars Global Surveyor probe, depicted structures with visually easy-to-identify linear directionality: the surface of Mars covered with numerous long, parallel depressions formed by wind erosion. The second image featured the M1 Crab nebula, which, as a still-expanding remnant of a supernova explosion, exhibits a natural radial directionality. In both cases, the final multifractal spectra reproduced the main features of the images. The 'martian' spectrum was characterized by the presence of a single minimum around the di-

rection corresponding to the dominant azimuth of the geological formations, which, as expected, was best visible in scans with the smallest width strips. In turn, the spectrum of the Crab nebula had a richer structure, with clear asymmetry and several more or less prominent local maxima, persisting for all strip widths used during scanning.

The last application presented in the discussed article concerned a less obvious case: the paintings of Jackson Pollock. His three famous paintings, according to critics marking characteristic phases in the evolution of the artist's work, were put under the multifractal magnifying glass: *Mural* (1943), *Lavender Mist* (1950) and *Convergence* (1952). The analyses revealed that the first of these paintings had the most developed spectrum of multifractality, with the greatest directional variability. The spectrum exhibited right-sided asymmetry, which the researchers believe indicates that the multifractality was more developed not so much in the main, easily noticeable streaks, but in the finely crafted details of the painting. In the case of *Lavender Mist*, the multifractal spectrum turned out to be almost flat, proving the disappearance of multifractality and directionality. The last of the analyzed works, *Convergence*, visually seems to be a composition of approaches seen in earlier paintings – and this is exactly the effect visible in the multifractal spectrum, admittedly also quite flat, but nevertheless beginning to show signs of right-sided asymmetry. Using the new procedure of 2D multifractal analyses, it was thus possible to visualize the gradual evolution of Pollock's painting and document the quantitative characteristics of this evolution.

*“Assessing abstract paintings has so far been subjective and highly imprecise, often relying on suitably convincing hand waving. The multifractal formalism we have proposed allows for more objective classification, at least in certain aspects,”* states Prof. Drożdż, adding that the issue is not only in the evaluation: *“Multifractal surface analysis has the potential to become established in art analysis as a supporting tool to help determine the authenticity of paintings, identify their authorship, classify the workshop of master painters, and thus perhaps even in valuing works of art.”*

The researchers emphasize that an important feature of the presented multifractal surface analysis technique is its practicality: calculations can be performed on typical computers, and the execution times in the most advanced cases did not exceed several hours.

The main purpose of the current article in *Chaos* was to present the new statistical tool and demonstrate its usefulness. The authors are currently working on further improvements of the proposed multifractal procedures and expanding their functionality.

The Henryk Niewodniczański Institute of Nuclear Physics (IFJ PAN) is currently one of the largest research institutes of the Polish Academy of Sciences. A wide range of research carried out at IFJ PAN covers basic and applied studies, from particle physics and astrophysics, through hadron physics, high-, medium-, and low-energy nuclear physics, condensed matter physics (including materials engineering), to various applications of nuclear physics in interdisciplinary research, covering medical physics, dosimetry, radiation and environmental biology, environmental protection, and other related disciplines. The average yearly publication output of IFJ PAN includes over 600 scientific papers in high-impact international journals. Each year the Institute hosts about 20 international and national scientific conferences. One of the most important establishments of the Institute is the Bronowice Cyclotron Centre (CCB), which is an infrastructure unique in Central Europe, serving as a clinical and research centre in the field of medical and nuclear physics. In addition, IFJ PAN runs four accredited research and measurement laboratories. IFJ PAN is a member of the Marian Smoluchowski Kraków Research Consortium: “Matter-Energy-Future”, which in 2012-2017 enjoyed the status of the Leading National Research Centre (KNOW) in physics. In 2017, the European Commission granted the Institute the HR Excellence in Research award. As a result of the categorization of the Ministry of Education and Science, the Institute has been classified into the A+ category (the highest scientific category in Poland) in the field of physical sciences.

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#### **SCIENTIFIC PUBLICATIONS:**

*“Quantifying multifractal anisotropy in two dimensional objects”*  
R. Rak, S. Drożdż, J. Kwapien, P. Oświęcimka  
*Chaos* 34, 103137 (2024)  
DOI: [10.1063/5.0231211](https://doi.org/10.1063/5.0231211)

**LINKS:**

<http://www.ifj.edu.pl/>

The website of the Institute of Nuclear Physics, Polish Academy of Sciences.

<http://press.ifj.edu.pl/>

Press releases of the Institute of Nuclear Physics, Polish Academy of Sciences.

**IMAGES:**

**IFJ250115b\_fot01\_PLs.jpg**

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Jackson Pollock paintings (fragments) and their multifractal spectra: *Mural* (left), *Lavender Mist* (right top), and *Convergence* (right bottom). All multifractal spectra at the same scale, with an angular range from 0 to 180 degrees on the horizontal axis. Scans using the narrowest stripes are marked in red, and the widest ones in blue. (Source: IFJ PAN / [www.jackson-pollock.org](http://www.jackson-pollock.org))