Method for reconstructing nonlocal characteristics of tokamak plasma density fluctuations from correlation reflectometry [[1]](#footnote-1)\*)

DOI: 10.34854/ICPAF.2022.49.1.043

1,2 Kukushkin A.B., 1Kulichenko A.A.

1National Research Center «Kurchatov Institute», Moscow, Russia
2National Research Nuclear University «MEPhI», Moscow, Russia

One of the most important properties of stochastic nonlinear processes, including the turbulence of the hydrodynamic motion of continuous media, is distant spatial correlations. To describe them, an approach [1] was proposed, based on a linear integro-differential equation with a slowly decaying kernel, which corresponds to superdiffusion (nonlocal) transfer in the regime of Lévy walks (i.e. Lévy flights when the finite velocity of the carriers is taken into account). The obtained scaling laws made it possible to establish qualitatively the connection with the Richardson scaling law *r* ~ *t*3/2 for hydrodynamic turbulence space-time correlation function and the Kolmogorov scaling laws for an isotropic homogeneous turbulence.

Here, we formulate a similar approach based on the application of the Lévy walks concept to the description of the nonlocal properties of density fluctuations in a turbulent medium. This approach makes it possible to formulate the problem of determining these properties from the scattering spectra of electromagnetic (EM) waves and the cross-correlation reflectometry. A system of equations for density fluctuations is proposed, which is reduced in particular cases to an integral equation for the pair correlation function of plasma density fluctuations. This equation is expressed in terms of the Holstein functional, which is characteristic of a wide range of nonlocal transfer processes, including the transfer of resonance radiation in plasmas and gases in the Biberman-Holstein model (see, e.g. [2,3]). A universal description of the relationship between the observed quasi-coherent component in the spectrum of scattered EM waves in plasmas and a process of the Mandelstam-Brillouin scattering type is obtained. It is shown that the nonlocality of spatial correlations in a turbulent medium, which corresponds to the deviation of the pair correlation function of plasma density fluctuations from the Gaussian one, is due to long-free-path carriers of medium’s density fluctuations, for which the free path distribution function is described by the Lévy distribution.

The effectiveness of the proposed method and the obtained scaling laws is shown by the example of the interpretation of the data of cross-correlation reflectometry of EM waves in the radio-frequency range for the diagnosis of turbulent plasma in magnetic confinement devices for axisymmetric toroidal thermonuclear plasma, including the experimental data from T-10 tokamak [4,5]. The power-law model of the Holstein function and the respective solutions of the transport of the Lévy-walks type [6-8] are used.

References

1. M.F. Shlesinger, B.J. West, J. Klafter 1987 Phys. Rev. Lett. 58, 11.
2. L.M. Biberman, V.S. Vorob’ev, I.T. Yakubov 1987 Consultants Bureau: New York, NY, USA, ISBN 978-1-4684-1667-1.
3. V.A. Abramov, V.I. Kogan, V.S. Lisitsa 1987 In *Reviews of Plasma Physics*; Leontovich M.A., Kadomtsev B.B., Eds.; Consultants Bureau: New York, NY, USA; Volume 12, p. 151.
4. V.A. Vershkov, D.V. Sarychev, G.E. Notkin*, et al.* 2017 Nucl. Fusion **57** 102017.
5. A.O. Urazbaev, V.A. Vershkov, S.V. Soldatov *et al.* 2006 Plasma Physics Reports, vol. 32, no. 6, pp. 443–460.
6. A.A. Kulichenko, A.B. Kukushkin 2020 J. Exp. Theor. Phys., Vol. 130, No. 6, pp. 873–885.
7. A.B. Kukushkin, A.A. Kulichenko, A.V. Sokolov 2021 J. Exp. Theor. Phys., Vol. 132, No. 5, pp. 865–881.
8. A.B. Kukushkin, A.A. Kulichenko, V.S. Neverov, P.A. Sdvizhenskii, A.V. Sokolov, V.V. Voloshinov 2021 Symmetry, 13(3), 394.
1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLIX/Mu/ru/BW-Kukushkin.docx) [↑](#footnote-ref-1)