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BOOK OF ABSTRACTS

Volume 2
May to December 2025

SISSA, International School of Advanced Studies
Trieste, Italy

Fractional Calculus Seminar Series

Editors:
Pavan Pranjivan Mehta
Arran Fernandez

SISSA Liaison:
Gianluigi Rozza

Website: https://mathlab.sissa.it/fractional-calculus-seminars-2025
YouTube: https://www.youtube.com/@FractionalCalculusSeminar

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Volume 2
Fractional Calculus Seminar Series

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YouTube: https://www.youtube.com/@FractionalCalculusSeminar

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Foreword

Over the last few decades, differential operators of fractional (i.e., noninteger) order and associated differential equations have become objects of great, and still increasing, interest. The number of publications in this field has increased dramatically. This includes works on many different aspects including, but not limited to, analytical and numerical questions, the relations to probability theory, and applications of such mathematical models in various disciplines of science, engineering, economics and other fields.

While the quantity of publications in fractional calculus is very high, one has to admit that many of the published works are of a very poor quality, often exhibiting a substantial lack of mathematical rigor, containing serious flaws, or not providing any justification for their claims. For this reason, the reputation of fractional calculus as a whole within the scientific community has been seriously damaged. To repair this damage, it is important to demonstrate that there also exists a substantial amount of sound mathematical and modeling work on a high technical level.

The SISSA Online Seminar Series on Fractional Calculus, organized by Pavan Pranjivan Mehta and Arran Fernandez, addresses this issue by providing an excellent platform for the presentation of top quality work on fractional operators, their properties and their applications. It serves as an entry point for researchers who are new to the field as well as a discussion forum for scientists who are already experienced in the area. The almost 40 presentations given by renowned experts in 2025 whose abstracts are collected in this volume and whose recordings are available on the associated YouTube channel provide a comprehensive overview over the many facets of fractional calculus and stimulate new developments.

The fractional calculus community is very grateful to have this regular series of events and hopes that it can be continued in the future.

December 2025 Kai Diethelm

Preface: Volume 2 (2025)

Fractional calculus is a multifaceted research topic, appealing to scientists ranging from pure mathematicians to physicists and biologists to engineers. The fundamental idea, of integro-differential operators of non-integer orders, is of interest both for the mathematical properties of such operators, generalising those of classical calculus, and for their applications in modelling problems involving non-local phenomena, which are often best captured using non-local operators.

Due to the subject's interest across a wide array of researchers from mathematicians to practitioners, it becomes cumbersome for ideas to flow freely from one community to another. As a result, some results may be rediscovered multiple times in different areas, leading to redundant research, and the field risks growing in directions that may not be useful across the community. The Fractional Calculus Seminar Series aims to connect the fragmented community and build bridges between researchers looking at fractional calculus from different viewpoints, to encourage holistic growth of the field.

Now, in the second year of the seminar series, the horizons are further expanded. Many of last year's seminars focused on fundamentals like general classes of fractional-calculus operators and the mainstream applications in turbulence and stochastic research. This year, our focus sessions have been on adjacent topics of mathematical and scientific research, such as special functions and operator theory, whose connections to fractional calculus are strong and well known although they are not inherently fractional-calculus topics themselves, and also multifractals. There are several reasons to predict future connections between fractional calculus and multifractals: firstly, the obvious philosophical link, both of them being predicated on interpolating a fundamental concept between the whole numbers; secondly, Benoit B. Mandelbrot, widely recognised as the father of fractals, also worked on fractional Brownian motion, and thus it is possible to predict a link via stochastic processes.

We envision many exciting developments in fractional calculus and related fields of science in the near future. This motivates and inspires us in our attempts to collect and document some current developments in the field, and we hope that these resources would be helpful for the next generation of researchers. Our vision is for the research field of fractional calculus to grow in a sustainable and holistic fashion, rather than in many disjointed directions without interconnections.

Special Focus Topics:

- **09 May to 06 June 2025 (6 talks)**: fractional calculus and special functions.
- **13 June, 27 June, 22 August 2025 (3 talks)**: fractional calculus and function spaces.
- **01, 08, 15 August, 12 September, 14, 21, 28 November, 5 December (8 talks)**: fractals and multifractals: theory and applications.

Links: The link to previous year's (2024) and current seminar series (2025).

- Website (2024): https://mathlab.sissa.it/fractional-calculus-seminars
- Website (2025): https://mathlab.sissa.it/fractional-calculus-seminars-2025
- YouTube: https://www.youtube.com/@FractionalCalculusSeminar

Pavan Pranjivan Mehta
Arran Fernandez

Preface: Volume 1 (2024)

Fractional calculus is the field of research that studies fractional derivatives and fractional integrals, which are variously defined as derivatives and integrals to non-integer orders. This is a generalised form of integer-order calculus, with more richness and variety since fractional derivatives and integrals can be defined in many different ways which are not equivalent to each other: there is no single unique answer to a question like "what is the derivative to order one-half of the identity function?"

It is well known that integer-order derivatives are local operators and integer-order integrals are non-local operators. In fractional calculus, since the derivative operators are defined using the integral operators, both fractional integrals and fractional derivatives are non-local operators. Depending on the type of fractional derivative used, these operators may depend on values of the function in a finite region, or in a one-way region modelling a memory effect, or in its entire domain. The non-locality property is one of the reasons why fractional calculus has found many applications: real-world applications of non-local models can be found in turbulence, viscoelasticity, fracture mechanics, economic models, diffusion processes, electrical circuits, and plasma physics. The full range of applications is not yet understood, and new research is ongoing in many of these domains.

The theory and applications of fractional integro-differential operators and equations has not received much attention in the wider scientific community, beyond a few specialists developing the field, so that many fundamental questions remain unanswered and the field is ripe for ongoing research in many directions. Currently, however, there is not a single united research community in fractional calculus, but rather many different groups working on it in different ways. Some research is undertaken without awareness of the established fundamentals of the field or of what other research groups are doing.

Thus, the Fractional Calculus seminar series grew out of the necessity to connect different research communities and to touch on as many aspects of fractional calculus as possible. This seminar series is intended to provide deep knowledge on all aspects of fractional calculus, from analytical mathematics to numerical simulations to modelling applications. Some of the presentations are from long-standing experts who have been working in the field for decades, while some reflect new developments in particular research directions. Some of the topics are of broad interest to anyone working in fractional calculus, but there were also some focus sessions (listed below) which allowed us to drill further into particular broad topics of research in fractional calculus.

Special focus sessions:

- **24 May to 21 June 2024 (7 talks)**: fractional/nonlocal modelling of turbulence.
- **05 July to 02 August 2024 (6 talks)**: stochastic processes and probability theory for fractional PDEs.
- **09 August to 06 September 2024 (5 talks)**: general fractional-calculus operators.
- **13 September to 11 October 2024 (5 talks)**: fractional inverse problems.
- **18 October to 06 December 2024 (10 talks)**: numerical analysis, methods, and singular integral computation.

Pavan Pranjivan Mehta
Arran Fernandez

Fractional Calculus Resources

Books and References

Textbooks on Fractional Calculus

- K.B. Oldham, J. Spanier, *The Fractional Calculus*, Academic Press, New York, 1974.
- S.G. Samko, A.A. Kilbas, O.I. Marichev, *Fractional Integrals and Derivatives: Theory and Applications*, Gordon and Breach, Yverdon, 1993.
- K.S. Miller, B. Ross, *An Introduction to the Fractional Calculus and Fractional Differential Equations*, John Wiley, New York, 1993.
- I. Podlubny, *Fractional Differential Equations*, Academic Press, San Diego, 1999.
- A.A. Kilbas, H.M. Srivastava, J.J. Trujillo, *Theory and Applications of Fractional Differential Equations*, Elsevier, North-Holland, 2006.
- K. Diethelm, *The Analysis of Fractional Differential Equations: an Application-oriented Exposition using Differential Operators of Caputo Type*, Springer, Heidelberg, 2010.
- D. Baleanu, K. Diethelm, E. Scalas, J.J. Trujillo, *Fractional Calculus: Models and Numerical Methods*, World Scientific, New Jersey, 2012.
- J.A.T. Machado (ed.), *Handbook of Fractional Calculus with Applications*, de Gruyter, Berlin, 2019.
- F. Mainardi, *Fractional Calculus and Waves in Linear Viscoelasticity* (2nd ed.), World Scientific, Singapore, 2022.
- D.Y. Xue, L. Bai, *Fractional Calculus: High-Precision Algorithms and Numerical Implementations*, Springer Nature, Singapore, 2024.

Stochastic Processes

- B.B. Mandelbrot, J.W. Van Ness, "Fractional Brownian motions, fractional noises and applications", *SIAM Review* 10(4) (1968), 422–437.
- M.M. Meerschaert, A. Sikorskii, *Stochastic models for fractional calculus*, de Gruyter, Berlin, 2019.
- G. Ascione, Y. Mishura, E. Pirozzi, *Fractional Deterministic and Stochastic Calculus*, de Gruyter, Berlin, 2024.

Numerical Approaches

- K. Diethelm, N.J. Ford, A.D. Freed, Y. Luchko, "Algorithms for the fractional calculus: a selection of numerical methods", *Computer Methods in Applied Mechanics and Engineering* 194 (2005), 743–773.

- C. Li, F. Zeng, *Numerical Methods for Fractional Calculus*, CRC Press, Boca Raton, 2015.

- G. Pang, L. Lu, G.E. Karniadakis, "fPINNs: Fractional physics-informed neural networks", *SIAM Journal on Scientific Computing* 41(4) (2019), A2603–A2626.

- C.P. Li, M. Cai, *Theory and Numerical Approximations of Fractional Integrals and Derivatives*, SIAM, Philadelphia, 2019.

- M. Zayernouri, L.-L. Wang, J. Shen, G.E. Karniadakis, *Spectral and Spectral Element Methods for Fractional Ordinary and Partial Differential Equations*, Cambridge University Press, Cambridge, 2024.

- Y. Yue, N. Liu, F. Lu, T. Gao, S. Jafarzadeh, S. A. Silling. "Nonlocal attention operator: Materializing hidden knowledge towards interpretable physics discovery." Advances in Neural Information Processing Systems 37 (2024): 113797-113822.

- G. Ascione, Y. Mishura, E. Pirozzi, *Fractional Deterministic and Stochastic Calculus*, de Gruyter, Berlin, 2024.

- P. Pranjivan Mehta, G. Rozza. "Jacobi convolution series for Petrov-Galerkin scheme and general fractional calculus of arbitrary order over finite interval" *Numerical Methods for Partial Differential Equations*, 42, no. 1, 2026. DOI: https://doi.org/10.1002/num.70064

Further Reading on Related Topics

- T.J. Osler, *Leibniz Rule, the Chain Rule, and Taylor's Theorem for Fractional Derivatives*, PhD thesis, New York University, 1970.

- J.B. Keiper, *Fractional calculus and its relationship to Riemann's zeta function*, MSc thesis, Ohio State University, 1975.

- V.S. Kiryakova, *Generalized Fractional Calculus and Applications*, CRC Press, Boca Raton, 1993.

- V.E. Tarasov, "Fractional vector calculus and fractional Maxwell's equations", *Annals of Physics* 323(11) (2008), 2756–2778.

- M. Kwaśnicki, "Ten equivalent definitions of the fractional Laplace operator", *Fractional Calculus and Applied Analysis* 20(1) (2017), 7–51.

- F. Ferrari, "Weyl and Marchaud derivatives: A forgotten history", *Mathematics* 6(1) (2018), 6.

- R. Hilfer, Y. Luchko, "Desiderata for fractional derivatives and integrals", *Mathematics* 7(2) (2019), 149.
- R. Gorenflo, A.A. Kilbas, F. Mainardi, S.V. Rogosin, *Mittag-Leffler Functions, Related Topics and Applications* (2nd ed.), Springer, Berlin, 2020.
- A. Lischke, G. Pang, M. Gulian, F. Song, C. Glusa, X. Zheng, Z. Mao, W. Cai, M.M. Meerschaert, M. Ainsworth, G.E. Karniadakis, "What is the fractional Laplacian? A comparative review with new results", *Journal of Computational Physics* 404 (2020), 109009.
- Y. Luchko, "General fractional integrals and derivatives with the Sonine kernels", *Mathematics* 9(6) (2021), 594.
- P. Pranjivan Mehta, "Fractional and tempered fractional models for Reynolds-averaged Navier–Stokes equations", *Journal of Turbulence* 24 (2023), 507–553.
- A. Fernandez, "On complex orders in fractional calculus: floors, ceilings, and analytic continuation", in: S. Victor (ed.), *12th IFAC Conference on Fractional Differentiation and its Applications ICFDA 2024, IFAC-PapersOnLine* 58(12) (2024), pp. 143–148.
- O. Marichev, E. Shishkina, "Overview of fractional calculus and its computer implementation in Wolfram Mathematica", *Fractional Calculus and Applied Analysis* 27(5) (2024), 1995–2062.

Software and Codes

The below list of software / codes provides non-local / fractional / peridynamics capabilities.

- **Peridigm:** https://github.com/peridigm/peridigm
- **PyNucleus:** https://github.com/sandialabs/PyNucleus
  Documentation: https://sandialabs.github.io/PyNucleus/
- **CabanaPD:** https://github.com/ORNL/CabanaPD
- **PDMATLAB2D:** https://github.com/ORNL/PDMATLAB2D/
- **VaYu:** https://mehta-pavan.github.io/vayu/
- **IMEX_FDES:** https://github.com/suzukijo/IMEX_FDEs
- **RHEOS:** https://github.com/JuliaRheology/RHEOS.jl

Other popular open-source software projects

- Finite Element Method and Higher Order Methods
  - **Deal.II:** https://www.dealii.org/
  - **NekTar++:** https://www.nektar.info/
  - **libParanumal:** https://www.paranumal.com/software
  - **FEniCS:** https://fenicsproject.org/
  - **MFEM:** https://mfem.org/
  - **NekRS:** https://github.com/Nek5000/nekRS
- Finite Volume Methods
  - **OpenFOAM:** https://www.openfoam.com/ and https://openfoam.org/
- Reduced Order Modeling
  - **ITHACA-FV:** https://github.com/ITHACA-FV/ITHACA-FV and, https://ithaca-fv.github.io/ITHACA-FV/
- Scientific Machine Learning
  - **DeepXDE:** https://deepxde.readthedocs.io/en/latest/
- Mesh / Grid Generation
  - **Gmsh:** https://gmsh.info/
  - **Cart3D:** https://www.nas.nasa.gov/publications/software/docs/cart3d/
  - **Salome:** https://www.salome-platform.org/
- Visualization
  - **ParaView:** https://www.paraview.org/

Contents

Abstracts

09 May
15:00
CEST

Some analytical inequalities in fractional calculus

Živorad Tomovski

Department of Mathematical Analysis and Applications of Mathematics, Faculty of Science, Palacký University Olomouc, Czech Republic

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 09 May 2025
YouTube: https://www.youtube.com/watch?v=bZiElxX4R8o

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: superadditive functions, Mittag-Leffler function, fractional moment generating function, Sidon inequality, Sidon–Telyakovskii class, trigonometric series, Weyl fractional derivative, L^1 *convergence*

Abstract: Using the concept of superadditive functions, we present some inequalities for one parameter Mittag-Leffler functions. Application is given to probability moment generating functions of fractional order. The second part of the talk is regarding L^1 estimates of fractional derivatives of trigonometric series when the Fourier coefficients belongs to the Sidon–Telyakovski class.

Biography: Currently Zivorad Tomovski is a full time professor of Applied Analysis and Probability at the Department of Mathematical Analysis and Applications of Mathematics, Faculty of Sciences, Palacký University Olomouc, Czech Republic. His PhD was conducted in 2000 under the direction of Prof. S. A. Telyakovskii of the Steklov Mathematical Institute, Moscow, in the area of Approximation Theory and Fourier Analysis. He received the PhD degree at the Faculty of Mathematics and Natural Sciences, Ss. Cyril and Methodius University Skopje in 2000, where in 2010 he received a Full Professorship position and in 2012 he was awarded best scientist. In 2022, he received Habilitation in Applied Mathematics at Ostrava University. His recent research has been focused on the development and the analysis of computational tools for Mathematical modelling of anomalous diffusion, wave propagation and fractional PDE with stochastic analysis. He has published more than 100 papers in international journals of mathematics and physics with impact factor, and 2 Springer monographs, available online on his RG profile: `https://www.researchgate.net/profile/Zivorad_Tomovski` Tomovski has been a principal investigator/co-investigator in numerous international research projects and grants, supported by DAAD-Germany, NWO-Holland, Einstein Foundation Research Program-Berlin, Austrian Agency for Research OeAD-GmbH, Croatian Ministry of Sciences and Sports, Macedonian Ministry of Sciences and Education, NEWFELPRO- Marie Curie FP7 program 2014-2016 and Bilateral grant GACR-DFG.

Bibliography

[1] Ž. Tomovski, R. Metzler, S. Gerhold, Fractional characteristic functions, and a fractional calculus approach for moments of random variables, Fractional Calculus and Applied Analysis, Vol.25 (3) (2022).

[2] S. Iqbal, J. Pecaric, Ž. Tomovski, Analytical Inequalities in fractional calculus (2020), Lambert Academic Publishing book, 307 pp.

[3] Ž. Tomovski, An extension of the Sidon-Fomin type inequality and its applications, Math. Inequal. Appl. 4 (2), (2001) 231-238.

[4] Ž. Tomovski, A note on two inequalities of Telyakovskii type, RGMIA, Research Report Collection, 4 (1), Article 7, (2001) (electronic) (URL: http://melba.vu.edu.au/ rgmia/v4n1.html).

[5] Ž. Tomovski, A note on the Leindler's class, International Workshop of INEQUALITIES in Temisoara, Romania in Jule, 2001; Math. Ineq. Appl.5 (3), (2002), 505-509 .

[6] Ž. Tomovski , Some results on L^1 approximation of the r-th derivative of Fourier series, J. Inequal. Pure Appl. Math., 4 (1) (2002), Article 10, 11 pp. (electronic).

[7] Ž. Tomovski, Some New Integrability Classes of Fourier Coefficients, Constructive Theory of Functions, Varna 2002, DARBA, Sofia, 2003, pp.433-439.

[8] S.A Telyakovskii, On a sufficient condition of Sidon for the Integrability of trigonometric series, Math. Notes, 14 (1973), pp. 742-748

[9] L. Leindler, On the utility of Telyakovskii class, JIPAM 2 (3) (2001).

09 May
16:00
CEST

Multinomial Mittag-Leffler type functions: basic properties and some applications

Emilia Bazhlekova
Institute of Mathematics and Informatics, Bulgarian Academy of Sciences

Time: 16:00 - 17:00 CEST (Rome / Paris)
Date: 09 May 2025
YouTube: https://www.youtube.com/watch?v=nqa5woSPeA8

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: multinomial Mittag-Leffler function, multi-term fractional evolution equation, completely monotone function, Bernstein function

Abstract: The multinomial Mittag-Leffler function, introduced by Yu. Luchko and R. Gorenflo [1], plays a crucial role in the study of evolution equations with multiple fractional time-derivatives. In this talk we first discuss basic properties of this function with main focus on representation of solutions to multi-term fractional evolution equations in terms of functions of this type and useful estimates. Next, the Prabhakar type generalization of the multinomial Mittag-Leffler function is introduced [2, 3]. Its complete monotonicity is studied, based on Bernstein functions' technique [2]. Asymptotic estimates are also given. The presented results extend known properties of the classical Mittag-Leffler function. In addition, we give an example from Physical Chemistry, where multinomial Mittag-Leffler type functions naturally emerge, as well as applications in linear viscoelastic models [4].

Biography: Emilia Bazhlekova is a Full Professor, Doctor of Sciences, at the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences. She received PhD degree in 2001 from Eindhoven University of Technology, The Netherlands. Her PhD thesis "Fractional evolution equations in Banach spaces" is cited more than 900 times. The main field of research of E. Bazhlekova is Fractional Calculus and its applications (analysis of (generalized) fractional evolution equations, subordination principle, operational calculus approach, applications of Fractional Calculus in linear viscoelasticity) with research results published in about 50 papers in international peer-reviewed scientific journals with more than 1000 citations. She is an associate editor of the international journal "Fractional Calculus and Applied Analysis".

Bibliography

[1] Y. Luchko, R. Gorenflo. "An operational method for solving fractional differential equations with the Caputo derivatives". In: *Acta Math. Vietnamica* 24 (1999), pp. 207–233.

[2] E. Bazhlekova. "Completely monotone multinomial Mittag-Leffler type functions and diffusion equations with multiple time-derivatives". In: *Fract. Calc. Appl. Anal.* 24 (2021), pp. 88–111. https://doi.org/10.1515/fca-2021-0005

[3] E. Bazhlekova, I. Bazhlekov. “Identification of a space-dependent source term in a nonlocal problem for the general time-fractional diffusion equation”, In: J. Comput. Appl. Math. 386 (2021), 113213. https://doi.org/10.1016/j.cam.2020.113213

[4] E. Bazhlekova, S. Pshenichnov. “Wave propagation in viscoelastic half-space with memory functions of Mittag-Leffler type”. In: Int. J. Appl. Math. 34 (2021), pp. 423–440. https://doi.org/10.12732/ijam.v34i3.1

16 May
15:00
CEST

Fractional powers of Bessel operator and fractional order Euler-Poisson-Darboux equation

Elina Shishkina

Voronezh State University

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 16 May 2025
YouTube: https://www.youtube.com/watch?v=VNZs5Rjm1r4

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Bessel operator, fractional powers of Bessel operator, fractional singular differential equations

Abstract: We present the definitions and key properties of the fractional Bessel integral and derivative. We also explore fractional ordinary differential equations and the fractional Euler–Poisson–Darboux equation with fractional powers of the Bessel differential operator. By utilizing the Meijer integral transform and its modifications, we derive fundamental solutions to these equations in terms of the Fox–Wright function, the Fox H-function, and their specific cases. Additionally, we provide explicit formulas for the solutions to the corresponding initial value problems, framed in terms of the generalized convolutions introduced in this talk.

Biography: Elina Shishkina is a Full Professor at the Faculty of Applied Mathematics, Informatics, and Mechanics at the Voronezh State University in Voronezh, Russia. She graduated from the Department of Mathematics at Voronezh State University in 2004. Elina Shishkina completed her Ph.D. thesis in 2006 and her doctoral thesis in 2019. Her primary research interests lie in Mathematical Analysis and Differential Equations, with a particular emphasis on Fractional Calculus and its diverse applications.

Bibliography

[1] A. Dzarakhohov, Y. Luchko, and E.L. Shishkina. "Special Functions as Solutions to the Euler–Poisson–Darboux Equation with a Fractional Power of the Bessel Operator". In: *Mathematics* 9.13 (2021), pp. 1–18.

[2] V. Kiryakova. Generalized Fractional Calculus and Applications. New York: Pitman Res. Notes Math. 301, *Longman Scientific & Technical, Harlow, Co-publ. John Wiley*, 1994, p. 274.

[3] V. Kiryakova. "Obrechkoff Integral Transform and Hyper-Bessel Operators via G-function and Fractional Calculus Approach". In: *Global Journal of Pure and Applied Mathematics Proceedings of the 13th Symposium of the Tunisian Mathematical Society* 1.3 (2005), pp. 321–341.

[4] I. G. Sprinkhuizen-Kuyper. “A fractional integral operator corresponding to negative powers of a certain second-order differential operator”. In: *J. Math. Analysis and Applications* 72 (1979), pp. 674–702.

23 May
15:00
CEST

On use of Grünwald–Letnikov fractional derivative in analysis

Tibor K. Pogány

Institute of Applied Mathematics, John von Neumann Faculty of Informatics, Óbuda University, Budapest, Hungary
Faculty of Maritime Studies, University of Rijeka, Croatia

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 23 May 2025
YouTube: https://www.youtube.com/watch?v=D7VolDOrFBI

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Grünwald–Letnikov fractional derivative, hypergeometric type functions, McKay I Bessel distribution, functional bounds for special functions

Abstract: Using the Grünwald–Letnikov (GL) fractional derivative in transforming the integrands for several mathematical models, important simplifications result. More precisely, we obtain closed form representations for integrals in mean field variational Bayes, incomplete Lipschitz-Hankel integrals which define certain Exton's hypergeometric functions and therefore develop functional bounds for a set of related and/or associated hypergeometric type functions. Also, we present a GL form expression for the Toronto function, which implies a closed form expression for the Nuttall Q function applied to a special parameters case of the Kampé de Fériet generalized hypergeometric function of two variables.

Biography: Tibor Pogány (in native Hungarian or Poganj in Croatian) was born in Apatin (former Yugoslavia) in 1954. Education: elementary and high school in Hungarian teaching language, BSc (statistics and Applications major) in 1978, MSc in 1981, PhD in 1986 (both theses in stochastic processes), all with the University of Belgrade, Faculty of Science, Department of Mathematics, habilitation in 2015 in Doctoral School of Applied Mathematics, Óbuda University, Budapest, Hungary. Work: 8 years high school teaching experience (1978-1986), and 33 years teaching students in undergraduate, graduate, master and doctoral study in STEM at the Faculty of Maritime Studies, University of Rijeka, Croatia from 1988. Assistant professor 1987-1991; associate 1992-1997; professor 1997-2002; full professor permanent position 2002-2019; professor emeritus 2020. In the Institute of Applied Mathematics, John von Neumann Faculty of Informatics, Óbuda University, Budapest, Hungary as research professor (2013-2017) and university professor (2017-).

Erdős number 3 in four ways. MR entry record 202, ZfM entry record 212. Editor-in-Chief of the Journal of Classical Analysis, EB member in another 5-6 journals.

Research interests: Special functions and their application in statistics, Whittaker-Kotel'nikov-Shannon sampling reconstruction of deterministic and stochastic signals, Analytic inequalities.

Still Serbian national club-record holder for U-17 in 4x400m relay achieved September 13, 1970. Yugoslav vice-champion for U-19 in 110m hurdles from 1973.

Webpage: https://www.researchgate.net/profile/Tibor-Pogany?ev=hdr_xprf

Bibliography

[1] Tibor Pogány, Saralees Nadarajah, “Explicit forms for three integrals in Wand et al.”, *Math. Commun.* **26** (2021), 101-105.

[2] Tibor K. Pogány, “Functional inequalities for Bessel and hypergeometric type functions via probabilistic approach”, *Math. News.* **35** (2024), No. 1, 16pp.

[3] Katarzyna Górska, Andrzej Horzela, Dragana Jankov Maširević, Tibor K. Pogány, “On distribution of Rice-Middleton model”, *Results Math.* **79** (2024), No. 3, Article No. 106, 22 pp.

[4] Dragana Jankov Maširević, Tibor K. Pogány, Tomislav Burić, “Integral and series representations of the Nuttall function”, *J. Comput. Appl. Math.* **453** (2025), Article No. 116139, 11pp.

[5] Dragana Jankov Maširević, Tibor K. Pogány, Nataša Ujić, “Observations on the the McKay I_ν Bessel distribution II”, *J. Math. Anal. Appl.* 550 (2025), No. 2, Article No. 129569, 16pp.

30 May
15:00
CEST

Multivariate Mittag-Leffler type functions associated with the Prabhakar fractional calculus

Erkinjon Karimov
Ghent University

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 30 May 2025
YouTube: https://www.youtube.com/watch?v=4wIvGLHRYBc

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy
Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: multivariate Mittag-Leffler type functions, Prabhakar fractional calculus, fractional-order differential equations

Abstract: Certain bivariate and trivariate Mittag-Leffler-type functions are investigated, focusing on their Euler-type integral representations [1], [2], as well as upper and lower estimates [3]. These functions arise in the solutions of differential equations involving the Prabhakar fractional derivative [4]. We demonstrate how the derived estimates can be applied to solve direct and inverse problems for subdiffusion and fractional wave equations [3], [5], [6], as well as for certain combinations of these equations [7].

Biography: Dr. Erkinjon Karimov is a Researcher specializing in partial differential equations of integer and fractional order and special functions, connected with such PDEs. He is affiliated with Ghent University, where he conducts research on direct and inverse problems for PDEs. Dr. Karimov has published more than 50 papers, contributing to advancements in direct and inverse problems for fractional-order PDEs and mixed-type PDEs.

Dr. Karimov holds a Ph.D. (2006) and D.Sc. (2020) from V.I.Romanovskiy Institute of Mathematics, Uzbekistan Academy of Sciences, where he focused on direct and inverse problems for PDEs of various types, including mixed-type. Throughout his career, he has collaborated with researchers from the University of Santiago de Compostela, the University of Las Palmas de Gran Canaria, Sultan Qaboos University, etc. His projects have been supported by the State Agency for Science and Technology of the Republic of Uzbekistan, ICMS (Great Britain), ICTP (Italy), TWAS-CAS (China). In addition to his research, Dr. Karimov is actively involved in teaching, mentoring, and managing scientific journals (https://mib.mathinst.uz), demonstrating his commitment to education and the development of future scientists. More information can be found at https://sites.google.com/view/erkinjon-karimov/

Bibliography

[1] A. Hasanov, E. Karimov, Euler-type integral representations for bi-variate Mittag-Leffler-type functions, Cybernetics and Systems Analysis 61(3) (2025), pp. 74–84.

[2] A. Hasanov, E. Karimov, On generalized Mittag-Leffler type functions of two variables, arXiv:2501.03918 (2025).

[3] A. Hasanov, E. Karimov, On a boundary-value problem in a bounded domain for a time-fractional diffusion equation with the Prabhakar fractional derivative, Bulletin of the Karaganda university: Mathematics series, 111(3) (2023), pp. 39–46.

[4] E. Karimov, N. Tokmagambetov, M. Toshpulatov, On a Mixed Equation Involving Prabhakar Fractional Order Integral-Differential Operators, Trends in Mathematics: Extended Abstracts 2021/2022. APDEGS 2021, 2(25) (2023), pp. 221–230.

[5] E. Karimov, K. Turdiev, D. Usmonov, Nonlocal problem for the time-fractional generalized telegraph equation with the Prabhakar fractional derivative, arXiv:2503.08274 (2025).

[6] E. Karimov, K. Turdiev, Inverse problem for the time-fractional generalized telegraph equation, ResearchGate: DOI 10.13140/RG.2.2.18122.89285 (2025).

[7] E. Karimov, N. Tokmagambetov, M. Toshpulatov, Mixed partial differential equation: Forward problem linked with the wave-diffusion process, ResearchGate: 387959072 (2025).

6 Jun.
15:00
CEST

Integral transforms with Fox H-functions in kernels

Oleg Marichev
Wolfram Research

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 6 June 2025
YouTube: https://www.youtube.com/watch?v=7imw0IMdMv4

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Fox H-function, integral transform, fractional integral, fractional derivative

Abstract: In this talk, we demonstrate how the systematic use of the theory of the Mellin transform leads to a simple procedure by which a huge class of integral transforms can be calculated. In particular, these transforms include Weyl and Riemann–Liouville fractional integrals.

Biography: Oleg Igorevich Marichev is a Soviet and American mathematician: `https://en.wikipedia.org/wiki/Oleg_Marichev` He graduated from the University of Belarus, where he continued his studies to earn a Ph.D. His scientific supervisor was Fedor Gakhov. He is the author of more than 10 books on integrals, integral equations, fractional calculus, and special functions. Around 1990, he received the D.Sc. degree (Habilitation) in mathematics from the University of Jena, Germany. In 1991, Marichev began to work with Stephen Wolfram on developing system Mathematica, where he implemented Meijer G and other functions and operations using original algorithms. He is the developer of Wolfram Functions Site with more than 307000 formulas: `https://functions.wolfram.com/`.

Bibliography

[1] Samko S.G., Kilbas A.A., Marichev O.I. (1993) Fractional integrals and derivatives. Gordon and Breach Science Publishers.

[2] Wikipedia. "Oleg Marichev". In: https://en.wikipedia.org/wiki/Oleg_Marichev (2025).

Resolving families of operators for fractional differential equations in Banach spaces and applications

13 Jun
15:00
CEST

Vladimir E. Fedorov

Head of Mathematical Analysis Department / Chelyabinsk State University

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 13 June 2025
YouTube: https://www.youtube.com/watch?v=xm5I3Avaj78

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional differential equation, Cauchy type problem, resolving family of operators, Hille–Yosida type conditions, analytic resolving family, Hilfer fractional derivative, initial boundary value problem

Abstract: The issues of unique solvability of initial problems for equations solved with respect to a fractional derivative are investigated. As an example, the Cauchy type problem for a differential equation with the Hilfer fractional derivative in a Banach space is considered. Necessary and sufficient conditions for the existence of a strongly continuous resolving family of operators for a linear homogeneous equation are obtained in terms of the resolvent of a linear closed operator at an unknown function in equation [1]. These conditions are a generalization of the Hille–Yosida conditions for the case of fractional order equations. A theorem on necessary and sufficient conditions for the existence of an analytical resolving family of the fractional differential equation is also proved [2]. Under such conditions, the solvability of linear inhomogeneous equations and some classes of quasi-linear equations is investigated [3]. Similar results were obtained for fractional differential equations with the Dzhrbashyan–Nersesyan derivative [4], for multi-term differential equations with Riemann–Liouville [5] or Gerasimov–Caputo derivatives [6], for equations with distributed fractional derivatives [7, 8, 9]. Abstract results are used in the study of initial boundary value problems for partial differential equations.

Biography: Vladimir Evgenievich Fedorov. Born on March 01, 1972. Head of the Department of Mathematical Analysis, Faculty of Mathematics, Chelyabinsk State University. Education: Chelyabinsk State University, 1994. Doctor of Physical and Mathematical Sciences (since 2005), Professor (since 2007).

Honorary Professor of Chelyabinsk State University, Honorary Professor of Shadrinsk State Pedagogical University, Honorary Worker of Education of the Russian Federation. Winner of the Prize for Young Scientists of the International Society for Analysis, Its Applications and Computations (ISAAC Award for Young Scientists, 2011) – "for achievements in semigroup theory and control theory".

Editor-in-Chief of Computational Mathematics and Modeling, Deputy Editor-in-Chief of the Chelyabinsk Physical and Mathematical Journal, member of the Editorial Board of the journals: Bulletin of Irkutsk State University. Series Mathematics; Progress in Fractional Differentiation and Applications; International Journal of Mathematical Modelling and Numerical Optimisation.

Bibliography

[1] Vladimir E. Fedorov, Wei-Shih Du, Marko Kostić, Marina V. Plekhanova, Anton S. Skorynin. "Criterion of the existence of a strongly continuous resolving family for a fractional differential equation with the Hilfer derivative". In: *Fractal and Fractional* 9.2 (2025), p. 81.

[2] Vladimir Fedorov, Yusupjon Apakov, Anton Skorynin. "Analytic resolving families of operators for linear equations with Hilfer derivative". In: *Journal of Mathematical Sciences* 277.3 (2023), pp. 385–402.

[3] Vladimir E. Fedorov, Anton S. Skorynin. "A class of quasilinear equations with Hilfer derivatives". In: *Mathematical Notes* 115.5 (2024), pp. 817–828.

[4] Vladimir E. Fedorov, Marina V. Plekhanova, Elizaveta M. Izhberdeeva. "Analytic resolving families for equations with the Dzhrbashyan — Nersesyan fractional derivative". In: *Fractal and Fractional* 6.10 (2022), p. 541.

[5] Vladimir E. Fedorov, Mikhail M. Turov. "Multi-term equations with Riemann—Liouville derivatives and Holder type function spaces". In: *Boletin de la Sociedad Matematica Mexicana* 29 (2023), p.42.

[6] Vladimir E. Fedorov, Kseniya V. Boyko. "Degenerate Multi-Term Equations with Gerasimov–Caputo Derivatives in the Sectorial Case". In: *Mathematics* 10.24 (2022), p. 4699.

[7] Vladimir E. Fedorov, Nikolay V. Filin. "On strongly continuous resolving families of operators for fractional distributed order equations". In: *Fractal and Fractional* 5.1 (2021), p. 20.

[8] Vladimir E. Fedorov, Nikolay V. Filin. "A class of quasilinear equations with distributed Gerasimov – Caputo derivatives". In: *Mathematics* 11.11 (2023), p. 2472.

[9] Vladimir E. Fedorov, Aliya A. Abdrakhmanova. "Linear equations with distributed Riemann–Liouville derivatives given by Stieltjes integrals and their analytic resolving families of operators". In: *Lobachevskii Journal of Mathematics* 44.8 (2023), pp. 3277–3291.

The stochastic heat inclusion with fractional time driven by time-space Brownian and Lévy white noise

13 Jun
16:00
CEST

Bernt Øksendal
Department of Mathematics, University of Oslo, Norway

Time: 16:00 - 17:00 CEST (Rome / Paris)
Date: 13 June 2025
YouTube: https://www.youtube.com/watch?v=NAx8kKh5iTM

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional stochastic heat inclusion, Caputo derivative, Mittag-Leffler function, time-space Brownian white noise, time-space Lévy white noise, additive noise, tempered distributions, mild solution

Abstract: We study a time-fractional stochastic heat inclusion driven by additive time-space Brownian and Lévy white noise. The fractional time derivative is interpreted as the Caputo derivative of order $\alpha \in (0, 2)$. We show the following:

(a) If a solution exists, then it is a fixed point of a specific set-valued map.

(b) Conversely, any fixed point of this map is a solution of the heat inclusion.

(c) Finally, we show that there is at least one fixed point of this map, thereby proving that there is at least one solution of the time-fractional stochastic heat inclusion.

A solution $Y(t, x)$ is called *mild* if $\mathbb{E}[Y^2(t, x)] < \infty$ for all t, x. We show that the solution is mild if $\alpha = 1$ & $d = 1$, or $\alpha \geq 1$ & $d \in \{1, 2\}$.

On the other hand, if $\alpha < 1$ we show that the solution is not mild for any space dimension d.

Biography: Bernt Karsten Øksendal is a Norwegian mathematician with several years of teaching and research in stochastic analysis. He completed his undergraduate studies at the University of Oslo in 1970, and obtained his PhD from the University of California, Los Angeles (UCLA) in 1971. In 1991, he was appointed a Professor at the University of Oslo. In 1992, he was appointed an Adjunct Professor at the Norwegian School of Economics and Business Administration, Bergen, Norway. In 2017, he was appointed an Honorary Doctor at the Norwegian School of Economics.

Between 1992 and 1996, he held a research position as VISTA Professor, appointed by the Norwegian Academy of Science and Letters in cooperation with Den Norske Stats Oljeselskap a.s. (Statoil). In 1996, he was elected as a member of the Norwegian Academy of Science and Letters, and in the same year he won the Nansen Prize for his research in stochastic analysis and its applications. In 2002, he was elected as a member of the Royal Norwegian Science Society. In 2014, he was awarded the University of Oslo Research Prize for excellent research. He has also been chair or coordinator of many research grants and international research programmes (in both Europe and Africa) over the years.

Bibliography

[1] Abel, N. H. (1823): Oppløsning av et par oppgaver ved hjelp av bestemte integraler (in Norwegian). Magazin for naturvidenskaberne 55–68.

[2] Adler, R.J., Monrad, D., Scissors, R.H. & Wilson, R. (1983): Representations, decompositions and sample function continuity of random fields with independent increments. Stoch. Process. Appl. 15(1),3-30.

[3] Aumann, R. J. (1965): Integrals of set-valued functions. J. Math.Anal. 12, 1-12.

[4] Capelas de Oliveira, E.; Mainardi & F.Vaz, J. (2011): Models based on Mittag Leffler functions for anomalous relaxation in dielectrics. ariXir: 1106.1761 v2[cond-mat.Stat-mech] 13 Feb. 2014.

[5] Dalang, R. C. & Walsh, J. B. (1992): The sharp Markov property of Lévy sheets. The Annals of Probability 20 (2), 591-626.

[6] Di Nunno, G., Øksendal, B. & Proske, F. (2009): Malliavin Calculus for Lévy Processes with Applications to Finance. Springer.

[7] Hu, Y. (2019): Some recent progress on stochastic heat equations. Acta Mathematica Scientia 39B(3); 874-914.

[8] Holm, S. (2019): Waves with Power-Law Attenuation. Springer.

[9] H. Holden, B. Øksendal, J. Ubøe, and T. Zhang. Stochastic Partial Differential Equations. Birkhäuser Boston Inc., Boston, MA, 1996.

[10] Ibe, O. C. (2013): Markov Processes for Stochastic Modelling. 2^{nd} edition. Elsevier.

[11] Iafrate, F. & Ricciutu, C.(2024): Some families of random fileds related to multiparameter Lévy processes. J. Theoretical Probability 37: 3055-3088. https://doi.org/10.1007/s10959-024-01351-3.

[12] I.M. Gel'fand and N.Ya. Vilenkin. Generalized Functions. Vol. 4. Academic Press [Harcourt Brace Jovanovich Publishers], New York, 1964 [1977].

[13] Kochubel, A. N., Kondratiev, Y. & da Silva, J. L. (2021): On fractional heat equation. Fractional Calculus & Applied Analysis 24 (1), 73-87.

[14] Meerschaert, Mark M., Sikorskii, Alla (2019): Stochastic Models for Fractional Calculus, 2^{nd} edition. De Greuter.

[15] Mittag-Leffler, M.G. (1903): Sur la nouvelle fonction $E(x)$. *C. R. Acad. Sci. Paris* **137** 554–558.

[16] Moulay Hachemi, R.Y. & Øksendal, B. (2023): The fractional stochastic heat equation driven by time-space white noise. Fractional Calculus & Applied Analysis 26, 513-532. Springer. https://doi.org/10.1007/s13540-023-00134-7.

[17] Nualart, D. & Schoutens, W. (2000): Chaotic and predictable representations for Lé vy processes. Stochastic Process. Appl., 90(1):109-122, 2000.

[18] Patel, A. & Kosko, B. (2007): "Levy Noise Benefits in Neural Signal Detection," 2007 IEEE International Conference on Acoustics, Speech and Signal Processing - ICASSP '07, Honolulu, HI, USA, 2007, pp. III-1413-III-1416, doi: 10.1109/ICASSP.2007.367111.

[19] Pollard, H. (1948): The completely monotone character of the Mittag-Leffler function $E_\alpha(-x)$. Bull. Amer. Math-Soc.54, 1115-1116.

[20] B. Øksendal and F. Proske. White noise of Poisson random measures. Potential Anal., 21(4):375-403, 2004.

[21] Schneider, W.B. (1996): Completely monotone generalized Mittag-Leffler functions. Expositiones Mathematicae 14, 3-16.

20 Jun
15:00
CEST

Spectral analysis of wave propagation in non-local waveguides

Srinivasan Gopalakrishnan

Department of Aerospace Engineering,
Indian Institute of Science, Bangalore, India

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 20 June 2025
YouTube: https://www.youtube.com/watch?v=5xSddizHuZw

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: wave propagation, non-local waveguides, Kramers–Krönig relations, bond-based peridynamics

Abstract: Traditionally, in solid mechanics, classical continuum theories (CCT) of elasticity have been an important tool in the examinations of behavior of solids under external loads. However, due to absence of length scale information in the theory, CCT has been found to be inadequate in examining phenomena such as shear band formations, damage evolution, etc., in solids. Further, with advent of novel solid materials, such as, composites and metamaterials, which necessarily involve microscale structure, a need has arisen to generate knowledge for behavior of solids with microstructure. To address these aspects, generalization or reformulation of continuum elasticity theories has been proposed in the solid mechanics literature. Concepts put forth included: augmenting material particles with additional internal degrees of freedom, augmenting constitutive equation with higher gradients of strain or with atomic potential type interactions, etc. The former type of generalization involves Mindlin type solid, and the later type involves, what now known in the literature as, nonlocal continuum solid. In practice, given a new theory, it is customary to apply the theory to various initial-boundary value problems (IVBPs) for examination of its predictability of experimentally observable characteristics of solids. The IVBPs typically include static, buckling, bending, vibration and wave propagation analyses. Although there exists abundant literature on most of the IVBPs, however, wave motion analyses are few and requires further investigations. In this thesis, nonlocal continuum theories of elasticity are critically examined with respect to wave motion characteristics.

In the first part of the talk, the framework of wave motion spectral analysis is elucidated, on classical theories of elasticity. It involves a Fourier frequency analysis examining frequency spectrum behavior of wavenumber, group speeds and frequency response function. This data is further utilized within the Kramer-Kronig (K-K) relations analysis framework, which is developed for the elasticity theories, to examine the agreement/disagreement of a theory to the principle of primitive causality.

In the second part of the talk, the above framework is applied to nonlocal strain/stress gradients and integral nonlocal elasticity theories. It is observed that, all the theories show at least one of the unphysical wave motion characteristics.

The unphysical characteristics include infinitesimally small or zero group speeds, infinitely large group speeds, negative group speeds and absence of wave attenuation. It is noted that, a theory shows agreement to primitive causality due to existence of wave dispersion as well as attenuation. Relation between boundary conditions and physically justifiable wave motion phenomena is also examined.

Biography: Prof. Gopalakrishnan received his BS degree from Bangalore University, master's degree in engineering Mechanics from Indian Institute of Technology, Madras, Chennai and Ph.D from School of Aeronautics and Astronautics from Purdue University, USA in the year December 1992. After his Ph.D., he was a Postdoctoral Fellow in the Department of Mechanical Engineering at Georgia Institute of Technology. In the year November 1997, he joined the Department of Aerospace Engineering at Indian Institute of Science Bangalore, where currently he is a Senior Professor. His main areas of interest are Wave Propagation in complex media, Computational Material Science, Computational Mechanics, Smart Structures, Structural Health Monitoring, MEMS and Nano Composite Structures.

Prof. Gopalakrishnan has extensively published his work on many top international journals. He has a total of 245international journal papers, 9 graduate level textbooks, two undergraduate books, 15 book chapters, and 180 international conference papers. He has an h-index of 56 in Google scholar with nearly 12,000 citations, which is highest in India for any researchers in Aerospace domain. He is in the editorial board of 5 international journals and is the Editor-in-chief of ISSS Journal for Micro and Smart Systems and Associate editor for Smart Materials and Structures and Structural Health Monitoring international journals. Prof. Gopalakrishnan is decorated with many awards and honors, which include, International Structural Health Monitoring person of the year awards 2016 instituted by SAGE Publications, Fellow of Indian National Academy of Engineering, Fellow of Indian Academy of Sciences, Associate Fellows AIAA, Distinguished Alumnus Award, Indian Institute of Technology, Madras, Chennai, Satish Dhawan Young Scientist Award by Government of Karnataka, Biren Roy Trust award of Aeronautical society of India, Alumni Award of excellence in research at IISc in the year 2013 and the Royal Academy of Engineering, UK Distinguished visiting Fellowship. He was elected Fellow of Institute of Mechanical Engineers, UK in the year 2020. Prof. Gopalakrishnan figures in the Stanford list of top 2% of scientist in the world for four consecutive years. This year he will receive the ASME Founders Medal for his outstanding contributions to Structural health Monitoring and NDE. He has guided 32 Ph.D's, 7 M.Tech (Research) and 23 M.Tech students and has attracted funding of over 5 Million US dollars in research funding.

Bibliography

[1] Gopalakrishnan, S., Elastic Wave Propagation in Structures and materials, *Taylor & Francis/ CRC Press*, UK/ Singapore, 2022

[2] Gopalakrishnan, S., Wave propagation in Structures and Materials, *Taylor & Francis/ CRC Press*, UK/ Singapore, September-2016

[3] Gopalakrishnan, S. and Narendar, S. Wave propagation in Nano Structures, *Springer-Verlag, UK*, November 2013

[4] Mutnuri,V.S., and Gopalakrishnan,S, "Propagation of Elastic Waves in Nonlocal Bars and Beams", Recent Advances in Computational Mechanics and Simulations, Eds: Sandeep Kumar Saha and Moushami Mukharjee, *Lecture Notes in Civil Engineering, Springer Nature Publications*

[5] Gopalakrishnan, S., and Narendar, S, "Wave Propagation in Graphene", Innovative Graphene Technologies, *Rapra-Smithers Publications, UK*, Volume 1, Chapter 11, 391-455, March 2013.

[6] Mutnuri, V.S. and Gopalakrishnan., "A Re-Examination of Wave Dispersion and on Equivalent Spatial Gradient of the Integral in Bond-Based Peridynamics", *Journal of Peridynamics and Nonlocal Modelling*, 2, 243-277 (2020)

[7] Mutnuri, V.S. and Gopalakrishnan., "On causality of wave motion in nonlocal theories of elasticity A Kramers-Kronig relations study", *Annals of Solid and Structural Mechanics*, 12(1- 2), 165-187, (2020)

[8] Mutnuri, V., and Gopalakrishnan, S, "A Comparative Study of Wave Dispersion between Discrete and Continuum Linear Bond-based Peridynamics Systems", *Mechanics Research Communications*, 94, 40-44, 2018.

Abstract wave type equations with almost sectorial operators

27 Jun
10:00
CEST

Joel E. Restrepo
Department of Mathematics, CINVESTAV, Mexico city, Mexico

Time: 10:00 - 11:00 CEST (Rome / Paris)
Date: 27 June 2025
YouTube: https://www.youtube.com/watch?v=g29Urle2dLs

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: abstract wave type equations, almost sectorial operators, classical solutions, non-local operators in time

Abstract: We study homogeneous and non-homogeneous abstract wave type equations by using a non-local operator in time and an almost sectorial operator in space. For the latter kind of operators, we do not need to have dense domains and/or ranges. We find the explicit solution operators in both cases. Moreover, we show that indeed they are classical solutions. Some examples are given to illustrate the main results. Some of the main ideas are derived from [1, 2, 3, 4, 5, 6].

Biography: Joel E. Restrepo is a Colombian mathematician and is a researcher in the Department of Mathematics of Center for Research and Advanced Studies of the National Polytechnic Institute, Mexico City, Mexico. Previously, he was a postdoctoral researcher at different research centers in Belgium, Russia and Kazakhstan. He has carried out mathematical research in a variety of topics connecting different areas of mathematics. His research links several techniques in complex analysis, operator theory, harmonic analysis, PDEs, etc. He also has participated in many international conferences, seminars and other related events and has been involved in the organization of several of these scientific projects as well.

Bibliography

[1] N. Okazawa. A generation theorem for semigroups of growth order α. Tohoku Math. J., 26, (1974), 39–51.

[2] G. Da Prato. Semigruppi di crescenca n. Ann. Scuola Norm. Sup. Pisa, 20(3), (1966), 753–782.

[3] F. Periago, B. Straub. A functional calculus for almost sectorial operators and applications to abstract evolution equations. J. Evol. Equ., 2, (2002), 41–68.

[4] P.E. Sobolevskiĭ. On semigroups of growth α. Dokl. Akad. Nauk SSSR, 196(3), (1971), 535–537.

[5] R-N. Wang, D-H. Chen, T-J. Xiao. Abstract fractional Cauchy problems with almost sectorial operators. J. Differ. Equ. 252(1), (2012), 202–235.

[6] A.V. Zafievskiĭ. On semigroups with singularities summable with a power-weight at zero. Soviet Math. Dokl., 11(6), (1970), 1408–1411.

Fractional hyperbolic diffusions on sphere with random data

04 Jul
15:00
CEST

Nikolai Leonenko
Cardiff University, UK

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 04 July 2025
YouTube: https://www.youtube.com/watch?v=L685oMpHap8

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional hyperbolic diffusion, spherical random fields, fractional telegraph equation, random data.

Abstract: Spherical random fields are very useful for modelling some phenomena in areas such as earth sciences (like, for example, in geophysics and climatology) and cosmology. In fact, the application of statistical methods in cosmology has become increasingly important due to the many experimental data obtained in recent years, and spherical random fields are of particular interest regarding the analysis of Cosmic Microwave Background (CMB).

As is well known, the CMB is a spatially isotropic radiation field spread throughout the visible universe, originated around 14 billion years ago, and it is the main source of information we have about the evolution of the universe. The CMB radiation can be mathematically modelled as an isotropic spherical random field for which there is a spectral representation by means of spherical harmonics.

Our objective is to study the fundamental solutions to fractional hyperbolic diffusion equation in the time variable using the Caputo derivative, and its properties. The exact solutions of the fractional hyperbolic diffusion equation with random data in terms of series expansions of isotropic in space spherical random fields on the unit sphere are derived, and numerical illustration are presented to illustrate the results.

Some limit theorems for spatio-temporal random fields have been obtained in [1, 2].

These are joint results with J.Vaz (UNICAMP, Brazil) and A. Olenko (La Trope University, Melbourne, Australia) [3, 4].

Biography: Nikolai Leonenko is a Professor at Cardiff University (UK) since 2006. He joined Cardiff University in 2000. Before that, he was a full Professor of Kyiv National Taras Shevchenko University, Ukraine and also had some visiting positions in Case Western Reserve University (Cleveland, Ohio) and Queensland University of Technology (Brisbane, Australia).

Selected Honors: N. M. Krylov Medal of Academy of Science of Ukraine (1993), the highest annual award for mathematicians in Ukraine.

Google Scholar: Citation 6952 (Google Scholar); h-index 38, i10-index 138; citation in MathSciNet: 1500, 285 published papers, 2 books.

Collaborators: O.E. Barndorff-Nielsen, C.Heyde, M.Taqqu, M.Meershaert, E.Merzbach, N.-R. Shieh, V.Anh, F.Avram, M.D. Ruiz-Medina, I.Podlubny, J.Vaz, I.Nourdin, among others.

Member of Editorial Board of 5 international journals. In particular, Deputy Editor-in-Chief of the journal "Theory Probability and Mathematical Statistics", AMS, ISSN 1547-7363 (online), ISSN 0094-9000 (print), and Editorial Board member of "Fractional Calculus and Applied Analysis", Springer, ISSN 1314-2224 (electronic), ISSN 1311-0454 (print).

Graduate students advised: 19 scientists who received a Ph.D. in Probability Theory and Mathematical Statistics. They work at different Universities of USA, Australia, Italy, Israel, Uzbekistan, Vietnam, Poland, Ukraine, Croatia and Egypt. Currently supervising 6 PhD students at Cardiff University.

Participated in the programme Fractional Differential Equations (FDE2) (January-April 2022) and in the programme Uncertainty Quantification and Stochastic Modelling of Materials (August 2023) and in the programme "Stochastic systems for anomalous diffusion" (2024) in Isaac Newton Institute for Mathematical Sciences, Cambridge.

https://profiles.cardiff.ac.uk/staff/leonenkon

Bibliography

[1] Leonenko, N., Maini, L., Nourdin, I. and Pistolato, F. (2024) Limit theorems for p-domain functionals of stationary Gaussian fields, Electronic Journal of Probability, 29,1-33

[2] Leonenko, N. and Ruiz-Medina, M.D. (2025) High-Level Moving Excursions for Spatiotemporal Gaussian Random Fields with Long Range Dependence, Journal of Statistical Physics, 192, N2, Paper No. 19, 29pp

[3] Leonenko, N. and Vaz, J. (2020) Spectral analysis of fractional hyperbolic diffusion equations with random data, Journal of Statistical Physics, 179,155-175

[4] Leonenko, N., Olenko, A. and Vaz, J. (2024) On fractional spherically restricted hyperbolic diffusion random field, Communications in Nonlinear Science and Numerical Simulation, 131,107866

Solving variable-coefficients fractional differential equations

18 Jul
15:00
CEST

Fatma Al-Musalhi

Sultan Qaboos University/ Oman

Time: 15:00 - 16.00 CEST (Rome / Paris)
Date: 18th July 2025
YouTube: https://www.youtube.com/watch?v=3t_5OpQl-e0

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional differential equations, explicit solutions, transmutation relations

Abstract: Fractional differential equations (FDEs) are widely used to describe complex processes such as diffusion, material behavior, and control systems.
In this talk, we study two methods for solving FDEs with continuous variable coefficients. The first method employs the fixed point theorem. We consider multi-term fractional differential equations with continuous variable coefficients and Erdélyi-Kober-type differential operators with multiple independent fractional orders [2]. We solve such equations within a general framework, obtaining explicit solutions in the form of uniformly convergent series. By examining several particular cases, we verify the consistency of our results with those previously obtained in the literature [1, 3, 4].
The second method, which builds on the first, is based on the transmutation relations approach. Since classical FDEs can be solved using fixed point theory, we use transmutation relation to extend these results to broader classes of fractional operators. We express the fractional derivative in transmuted form and then transform the FDEs involving these transmuted operators into forms involving more classical fractional derivatives, which have been extensively analyzed and solved in the literature. We consider specific types of fractional operators, including weighted fractional derivatives with respect to a function, tempered derivatives, and Hadamard-type fractional derivatives. These equations are reduced to ones involving the Caputo fractional derivative, whose solutions are already known and can be expressed explicitly in series form in terms of the Riemann-Liouville integral [3].

Biography: Fatma Al-Musalhi is an Omani mathematician, who studied at Sultan Qaboos University between 2006 and 2017 for her bachelor's, master's, and PhD. She has worked in the same university since then: firstly at the Centre of Preparatory Studies from 2019 to 2022, where she was awarded Best Researcher, and then as a full faculty member of the Department of Mathematics since 2023. Her research interests are in fractional differential equations and mathematical modelling of infectious diseases. She has published more than 10 research papers in indexed journals and presented at international conferences in Bulgaria, Finland, etc. She also serves as a peer reviewer for several high-level journals.

Bibliography

[1] Al-Musalhi, F., Al-Salti, N., Karimov, E.: Initial boundary value problems for a fractional differential equation with hyper-Bessel operator. Fract. Calc. Appl. Anal. **21**(1), 200–219 (2018). DOI: 10.1515/fca-2018-0013.

[2] Al-Musalhi, F., & Fernandez, A.: Fractional differential equations involving Erdélyi–Kober derivatives with variable coefficients. Fract. Calc. Appl. Anal., 1-30(2025).

[3] Fernandez, A., Restrepo, J.E., Suragan, D.: On linear fractional differential equations with variable coefficients. Appl. Math. Comput. 432, 127370 (2022)

[4] Al-Saqabi, B., Kiryakova, V.S.: Explicit solutions of fractional integral and differential equations involving Erdélyi–Kober operators. Appl. Math. Comput. **95**(1), 1–13 (1998)

Generalized heterogeneous diffusion and telegrapher's processes

25 Jul
15:00
CEST

Trifce Sandev

Macedonian Academy of Sciences and Arts, Skopje, Macedonia
Institute of Physics, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University in Skopje, Macedonia
Department of Physics, Korea University, Seoul, Korea

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 25 July 2025
YouTube: https://www.youtube.com/watch?v=8Bxcy9GLS10

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: heterogeneous diffusion, fractional calculus, stochastic resetting

Abstract: In this talk I will present fractional generalizations of the heterogeneous diffusion and telegrapher's equations, which can be obtained from the standard heterogeneous diffusion and telegrapher's equations subordinated by Lévy noise. The corresponding processes in the presence of stochastic resetting can be analyzed by using the renewal equation approach. It will be shown that in both cases the systems approach non-equilibrium stationary states in the long-time limit as a result of the resetting of the particle to the initial position. The survival probabilities, the first-passage time densities, and the mean first-passage times in the presence of Poissonian resetting of the particle to the initial position will be obtained, and it will be shown that there are optimal resetting rates at which the mean first-passage times are minimal.

Biography: Trifce Sandev is working as a Research Associate at the Research Center for Computer Science and Information Technologies, Macedonian Academy of Sciences and Arts in Skopje. He also holds a position of Associate Professor of Theoretical Physics at the Institute of Physics, Faculty of Natural Sciences and Mathematics, Ss. Cyril and Methodius University in Skopje and Adjunct Professor of the Department of Physics, Korea University in Seoul. After completing his Ph.D. in theoretical physics in 2012 at Ss. Cyril and Methodius University in Skopje, he was a postdoctoral researcher and guest scientist at the Max Planck Institute for the Physics of Complex Systems in Dresden. He was awarded the Presidential Award for Best Young Scientist in Macedonia in 2011, the National Award "Goce Delcev" in 2023 for his significant contributions to science in Macedonia in 2022, as well as research fellowship for experienced researchers for conducting research at the University of Potsdam in the period 2020 – 2022 from Alexander von Humboldt foundation. His main research interest is in stochastic processes in complex systems, anomalous diffusion, random search and stochastic resetting, as well as quantum mechanical systems with non-local interactions.

Bibliography

[1] T. Sandev, R. K. Singh, V. Méndez, L. Kocarev, Physical Review E 111 (4), 044105 (2025)

[2] T. Sandev, A. Iomin, J. Kurths, L. Kocarev, Physics of Fluids 37 (6), 067101 (2025)

[3] P. Jolakoski, P. Trajanovski, A. Iomin, L. Kocarev, T. Sandev, Europhysics Letters 149 (4), 41004 (2025)

[4] T. Sandev, A. Iomin, Physical Review E 110 (2), 024101 (2024)

[5] A. Pal, V. Stojkoski, T. Sandev, Random resetting in search problems. In Target Search Problems (Springer Nature: Cham, 2024), pp. 323-355

Complexity synchronization and the fractal calculus

01 Aug
15:00
CEST

Bruce J. West

Dept. of Innovation and Research,
North Carolina State University,
Raleigh, NC, USA.

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 01 August 2025
YouTube: https://www.youtube.com/watch?v=o0cKFzBvx6E

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: complexity synchronization (CS); crucial event (CEs); multifractal dimensionality; empirical principles; fractal architecture (FA).

Abstract: Since the turn of the century Network Science and Complexity Theory have been growing dramatically and their nexus has led to profoundly different ways of thinking about physiology, health, disease, and rehabilitation from those based on Newtonian mechanics. The observational ubiquity of inverse power law spectra (IPLS) in complex phenomena entailed a theory for the dynamics capturing the growth of their fractal dimension and statistics. These and other properties, e.g., chaotic and multifractal dimensional (MFD) time series, are consequences of the complexity resulting from nonlinear dynamic networks collectively summarized for biomedical phenomena as the Network Effect (NE). The NE is often described by homogeneous scaling variables with IPL scaling having a time-dependent index $\delta(t)$ which determines the MFD of the time series being a direct measure of the network's evolving complexity and opens the door to a generalized theory of the probability calculus involving 'fractal' derivatives.

In this talk I address the measurable consequences of the NE on time series generated by different parts of the brain, heart, and lung ONs, which are directly related to their inter-network and intra-network interactions. Moreover, these same physiological ONs are shown to generate MFD time series using diffusion entropy analysis (DEA) that have scaling indices with quasiperiodic changes in complexity (scaling index) over time. These time series are generated by different parts of the brain, as well as heart and lung ONs and the results do not depend on the coherence properties of ON time series but demonstrate a generalized synchronization of complexity. This high-order synchrony is among the scaling indices of EEG, ECG and respiratory time series which governs the quantitative interdependence of the MFD behavior of the various ON's dynamics. This consequence of the NE opens the door for an entirely new generalization of the dynamics of complex networks in terms of complexity synchronization (CS) independently of the scientific, engineering, or technological context. CS is a truly transdisciplinary effect whose foundation is determined by the fractal probability calculus, in physics it is referred to as fractal kinetic theory (FKT).

Biography: Dr. Bruce J. West was the Chief Scientist in Mathematical and Information Science at the US Army Research Office (ARO), 1999-2021 (retired 7/1/21); PhD in Physics from the University of Rochester 1970. Over a 50-year career he has published 24 books, including those most closely related to this colloquium: Crucial Event Rehabilitation Therapy (SpringerBriefs in Bioengineering, 2023), Crucial Events (World Scientific, 2021); Fractional Calculus View of Complexity, Tomorrow's Science (CRC Press, 2016); Nature's Patterns and the Fractional Calculus (De Gruyer GmbH, 2017). He has published over 400 scientific articles, essays and opinions in referred scientific journals garnering over 24K citations with an h-factor of 80. Before ARO Dr. West was Professor of Physics, University of North Texas, 1989-1999 and Chair of the Department of Physics 1989-1993. He is a Fellow of the American Physical Society, elected in 1992 and of the American Association for the Advancement of Science, elected in 2012. He has multiple awards for his research including the two most prestigious awards given to civilian researchers, those being the Presidential Meritorious Rank Award 2012 (by Obama) and the Presidential Distinguished Rank Award 2017 (by Trump).

Bibliography

[1] K. Mahmoodi, S.E. Kerick, P. Grigolini, P.J. Franaszczuk and B.J. West, "Complexity synchronization: a measure of interaction between the brain, heart and lungs", *Scientific Reports* 13 (1), 11433 (2023).

[2] BJ West, P Grigolini, SE Kerick, PJ Franaszczuk, K Mahmoodi," Complexity Synchronization of Organ Networks", *Entropy* 25 (10), 1393 (2023).

[3] B.J. West, E. Geneston & P. Grigolini, "Maximizing information exchange between complex networks", *Physics Reports* 468, 1-99 (2008).

[4] D.H. Abney , A. Paxton, R. Dale & C.T. Kello, "Complexity matching of dyadic conversation", *J. Exp. Psychol.: Gen.* 143, 2304 (2014).

[5] Z.M.H. Almurad, C. Roume & D. Delignières, "Complexity matching in side-by-side walking", *Human Movement Science* 54, 125 (2017).

[6] B.J. West, G.F. Massari, G. Culbreth, R. Failla, M. Bologna, R.I.M. Dunbar, and P. Grigolini, "Relating Size and Functionality in Human Social Networks through Complexity", *Journal Proceedings of the National Academy of Sciences* 117, 18355-18358 (2020).

[7] B.J. West, "The Fractal Tapestry of Life: III Multifractals Entail the Fractional Calculus", *Fractal Fract.* 2022, 6(4), 225; https://doi.org/10.3390/fractalfract6040225

[8] B.J. West and P. Grigolini, Crucial Events; Why are catastrophes never expected?, Studies of Nonlinear Phenomena in Life Science - Vol. 17, World ScientiÖc, NJ (2021).

[9] G. Aquino, M. Bologna, P. Grigolini and B.J. West, "Beyond the death of linear response theory: criticality of the 1/-noise condition", *Phys. Rev. Lett.* 105, 040601 (2010).

[10] G. Aquino, M. Bologna, P. Grigolini, and B. J. West, "Transmission of information between complex systems: 1/f resonance", *Phys. Rev. E* 83, 051130 (2011).

[11] N. Piccinini, D. Lambert, B.J. West, M. Bologna and P. Grigolini, "Nonergodic Complexity Management“, *Phys. Rev. E* 93, 062301 (2016).

08 Aug
15:00
CEST

Correspondence between the multifractal model and Navier-Stokes-like equations

John D. Gibbon
Dept. of Mathematics, Imperial College London

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 08 August 2025
YouTube: https://www.youtube.com/watch?v=hJkw6K1I9jY

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: multifractal model; Navier–Stokes equations; Toner–Tu equations

Abstract: The multifractal model (MFM) of Parisi and Frisch (1985) has been fundamental to our understanding and interpretation of homogeneous isotropic turbulence [1, 2]. How it corresponds to the Navier-Stokes equations (NSEs) is the topic of this talk. By studying the NS energy dissipation in higher L_p-norms we look at the properties of Leray-Hopf solutions which can be formally reworked so that these appear to display a spread of dimensions. When compared to the MFM it is found that the range of h, the MFM invariance parameter, lies in the range $-2/3 \leq h \leq 1/3$. It also recovers the inverse Paladin-Vulpiani scale $L\eta^{-1} \sim Re^{1/(1+h)}$. We then briefly discuss the fractional NSEs in a similar context. If time permits, I will also perform a brief survey of the incompressible Toner-Tu equations (ITT) which govern flocking phenomena. These are the NSEs on the LHS with terms $\alpha u - \beta u|u|^2$ on the RHS and share many similar properties of the NSEs themselves.

Biography: John Gibbon joined the Mathematics Department at Imperial College London in 1980 as a 31-year-old lecturer. He had been an undergraduate in Mathematics at the University of Birmingham (1967-70) and studied for his PhD at the University of Manchester Science & Technology (1970-73). For five years he had had postdoc positions and then held a lectureship at UCD Dublin for 2 years. His early work had been on nonlinear waves and solitons before he moved on to the study of Navier-Stokes and Euler turbulence.

Bibliography

[1] G. Parisi, U. Frisch, in: M. Ghil, R. Benzi, G. Parisi (Eds.), Turbulence and Predictability in Geophysical Fluid Dynamics, in: Proc. Int. School of Physics E. Fermi 1983 Varenna, Italy, North-Holland, Amsterdam, 1985, pp. 84–87.

[2] U. Frisch, Turbulence: The Legacy of A. N. Kolmogorov, CUP, Cambridge, 1995.

[3] J. D. Gibbon, Identifying the multifractal set on which energy dissipates in a turbulent Navier–Stokes fluid, Physica D 445 (2023) 133654.

Julia sets of fractional maps and their applications in modelling

15 Aug
15:00
CEST

Syed Abbas
Indian Institute of Technology Mandi

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 15 August 2025
YouTube: https://www.youtube.com/watch?v=l4WvQyYMOrw

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Julia set, fractional derivative, escape time algorithm

Abstract: The filled Julia set of the complex map $f : C \to C$ is defined as the set of initial points such that trajectories starting from this point will be bounded. The boundary of this filled-Julia set is called the Julia set, and the complement of the filled Julia set is called the Fatou set. In this talk, we describe various fractional derivatives and the discrete versions of those fractional derivatives. This presentation describes the fractional map to generate the Julia set by using the escape-time algorithm. The obtained Julia sets are highly sensitive to the parameter values. Using the same approach, we will generate the Julia set of the discrete fractional model. After generating Julia sets, we will control them by designing various controllers. The control of Julia sets is obtained by using the stability of fixed points. Also, the complete synchronization of Julia sets of two different systems is studied in this talk.

Biography: Currently working as a Professor in the School of Mathematical and Statistical Sciences, IIT Mandi since January 2023. He has worked as Associate Professor from October 2017 to January 2023 and Assistant Professor from August 2010 to October 2017 in the School of Basic Sciences at Indian Institute of Technology Mandi. He received his M.Sc. and PhD in Mathematics from Indian Institute of Technology Kanpur in 2004 and 2009 respectively. He has worked as a postdoctoral fellow at University of Bologna, Italy, visiting scientists at TU Dresden, Germany and research associate at University of Fribourg, Switzerland. His teaching experience includes several graduate and undergraduate courses. He received excellence in teaching award for undergraduate teaching. The core areas of his research are delay/functional/abstract differential equations, ecological modelling, difference equations, stochastic control. His research focuses are delay, functional, and abstract differential equations, ecological modeling, structured population model, time scale calculus and nonlinear analysis.

Bibliography

[1] Kumar, M., Abbas, S. (2025). Fractal dimension and control of Julia set generated by the discrete competitive model. *Numerical Algorithms*, 1-36.

[2] Kumar, M., Abbas, S. (2024). Adaptive synchronization and anti-synchronization of Julia sets generated by the competitive model. *Physica Scripta*, 99(11), 115231.

[3] Kumar, M. and Abbas, S., 2025. Fractal dimension and control of Julia set of discrete fractional tumor-immune model. *Discrete and Continuous Dynamical Systems-S*, pp.0-0.

Trace inequality criteria for fractional integrals

22 Aug
15:00
CEST

Alexander Meskhi
Kutaisi International University and A. Razmadze Mathematical Institute

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 22 August 2025
YouTube: https://www.youtube.com/watch?v=CW5gw-KMTAE

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy
Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: trace inequality, two-weight inequality, fractional integral operator

Abstract: Trace inequality for fractional integral operator K_α:

$$\|K_\alpha f\|_{L^q_\mu} \le C\|f\|_{L^p} \qquad (*)$$

plays an important role in harmonic analysis and PDEs. There exist various criteria on a Borel measure μ governing inequality $(*)$. Transparent necessary and sufficient conditions on μ ensuring the trace inequality will be discussed.

One of our aims is to discuss the problem of finding an appropriate Lorentz space $L^{p,s}$ such that the well-known D. Adams-type condition on a measure μ is both necessary and sufficient for the validity of the trace inequality

$$\|I_\alpha f\|_{L^p_\mu} \le C\|f\|_{L^{p,s}}$$

where I_α is the Riesz potential. We show that the desired space is $L^{p,1}$. To study this problem was motivated by the fact that the inequality fails for $p = s$ under the D. Adams-type condition on μ. The latter condition is necessary and sufficient for the validity of the trace inequality $(*)$ for $K_\alpha = I_\alpha$ if and only if $1 < p < q < \infty$.

Furthermore, we give a complete characterization of the trace inequality for some multilinear fractional integral operators T_α:

$$\|T_\alpha(f_1, \cdots, f_m)\|_{L^p_\mu} \le C\prod_{k=1}^{m}\|f_k\|_{L^{p_k}}.$$

Some related inequalities will also be discussed. For example, necessary and sufficient condition on a (non-doubling) measure μ for which the following inequality holds

$$\|J_{\gamma,\mu} f\|_{L^{p,q}_\mu} \le C\|f\|_{L^{r,s}}$$

for a fractional integral operator $J_{\gamma,\mu}$ defined with respect to μ. The latter problem for the classical Lebesgue spaces was studied in [1].

The talk is mainly based on the papers [2-6].

Biography: A. Meskhi is a President of the Georgian Mathematician Union since 2022. In 2024 he was elected as a member of the Georgian National Academy of Sciences. In 1998 A. Meskhi depended his PhD thesis. In 2001 he got degree of Dr. of Science. In 2003-2005 he was the Postdoc of “Scuola Normale Superiore” of

Pisa. A. Meskhi was awarded by Euler Premium for young scientists established by the German Mathematical Association (2000), Award of the Georgian Mathematical Union for the Best Scientific Works (2002, 2009); Andrea Razmadze Prize of the Georgian National Academy of Sciences (2012). In 2017-2022 he was a Scholar of the Georgian National Academy of Sciences. Since 2022 A. Meskhi is Chair of the Organizing committee of the Annual International Conference of the Georgian Mathematical Union, Batumi, Georgia. A. Meskhi is an Editor in Chief of Transactions of A. Razmadze Mathematical Institute. He is head of the department of Mathematical Analysis at A. Razmadze Mathematical Institute of I. Javakhishvili Tbilisi State University and Professor at Kutaisi International University. Since 2016 he is an Invited Professor at San Diego State University (Georgian Branch). He is an author/co-author of 7 monographs and about 150 scientific papers. He was supervisor of 6 PhD theses.

Bibliography

[1] D. E. Edmunds, V. Kokilashvili and A. Meskhi, Bounded and Compact Integral Operators, Kluwer Academic Publishers, Dordrecht, Boston, London, 2002.

[2] A.Meskhi, Measure of Non-compactness for Integral Operators in Weighted Lebesgue Spaces. Nova Science Publishers, New York, 2009.

[3] V. Kokilashvili, A. Meskhi and L. E. Persson, Weighted Norm Inequalities for Integral Transforms with Product Kernels,Nova Science Publishers, New York, 2010.

[4] V. Kokilashvili, A. Meskhi, H. Rafeiro and S. Samko, Integral operators in non-standard function spaces, Volume I: Variable exponent Lebesgue and amalgam spaces, Birkhäuser/ Springer, Heidelberg, 2016, pp. 1-567.

[5] V. Kokilashvili, A. Meskhi, H. Rafeiro and S. Samko, Integral operators in non-standard function spaces, Volume II: Variable exponent Hölder, Morrey-Campanato and grand spaces, Birkhäuser/Springer, Heidelberg, 2016, pp. 568-1003.

[6] V. Kokilashvili, A. Meskhi, H. Rafeiro and S. Samko, Integral operators in non-standard function spaces, Volume III: Advances in Grand Function Spaces, Birkhäuser/ Springer, Helm, 2024, pp 1004-1526.

[7] V. Kokilashvili, A. Meskhi, H. Rafeiro and S. Samko, Integral operators in non-standard function spaces , Volume IV: Progress in Morrey-type spaces and related topic, Birkhäuser/ Springer, Helm, 1527-2077, 2025.

Integral decomposition method and Efros theorem

29 Aug
15:00
CEST

Katarzyna Górska

Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 29 August 2025
YouTube: https://www.youtube.com/watch?v=GIwa-fql8xQ

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: memory effects subordination, operational method

Abstract: The integral decomposition method is widely used to construct solutions to the Volterra-like evolution equations exemplified by those describing anomalous diffusion phenomena and non-Debye dielectric relaxations. In this seminar I present the integral decomposition method as it is emerges from the operational methods involving the Efros theorem. The probabilistic interpretation of integral decomposition (if allowed) guides us to subordination which encodes memory effects. Splitting the integral decomposition on the convolution of so-called parent and leading processes is ambiguous, however, if the parent process is fixed its partner leading process appears to be unique. Commonly assumed parent process given by the Brownian motion is not the only possibility. I illustrate this with the example of the generalized (memory dependent) Cattaneo-Vernotte equation for which I construct two distinct subordinations. For the first of them the parent process is given by the Gaussian, while for the second one I use the fundamental solution to the Cattaneo-Vernotte equation describing diffusion obeying the finite propagation speed. Non-uniqueness in the choice of parent and leading processes is also visible in the case of standard non-Debye relaxation patterns. For example, the Havriliak-Negami relaxation can be expressed as the subordination either of the Debye model or the Cole-Davidson one.

Biography: Katarzyna Górska is full professor at the Theoretical Physics Division of the Institute of Nuclear Physics of the Polish Academy of Sciences in Krakow, Poland. Graduated from the Nicolaus Copernicus University in Toruń, she earned her PhD in theoretical physics there and completed postdoctoral fellowships at the Sorbonne University (Campus Paris 6) and the University of São Paulo. She served as a visiting scientist at research centers and universities in Europe (France, Italy), South and North America (Brazil, USA, Canada). She has authored or co-authored over 60 scientific publications. Her main research interests include transport phenomena, diffusion, heat transfer, dielectric relaxation, evolutionary equations, fractional calculus, stable distributions in probability and physics, integral transformations, umbral calculus, and special functions. Her other scientific interest (sometimes treated as a hobby) are foundations of quantum mechanics, in particular mathematical theory of coherent states.

Bibliography

[1] K. Górska, A. Horzela, E. K. Lenzi, G. Pagnini, and T. Sandev, Generalized Cattaneo (telegrapher's) equations in modeling anomalous diffusion phenomena, Phys. Rev. E 102 (2020) 022128.

[2] K. Górska, Integral decomposition for the solutions of the generalized Cattaneo equation, Phys. Rev. E 104 (2021) 024113.

[3] K. Górska and A. Horzela, Subordination and memory dependent kinetics in diffusion and relaxation phenomena, Fract. Calc. Appl. Anal. 26 (2023) 480.

[4] T. Pietrzak, A. Horzela, and K. Górska, The generalized telegraph equation with moving harmonic source: Solvability using the integral decomposition technique and wave aspects, Int. J. Heat Mass Transf. 225 (2025) 125373.

[5] K. Górska, Operational solution for the generalized Fokker-Planck and generalized diffusion-wave equations, Phys. Rev. E 111 (2025) 024103.

Markovian embeddings of fractional differential equations with applications to problems in hydrodynamics

05 Sep
15:00
CEST

Vishal Vasan

International Centre for Theoretical Sciences
Tata Institute of Fundamental Research

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 05 September 2025
YouTube: https://www.youtube.com/watch?v=TAAsmFDBSJA

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: numerical methods, fractional differential equations, fluid dynamics

Abstract: The Maxey–Riley-Gatignol equation, a fractional differential equation, has been extensively used by the fluid dynamics community to study the dynamics of small inertial particles in fluid flow. The nonlocal behaviour in time arises from the interaction of the fluid disturbance and the particle. In this talk, I'll summarise a perspective on the problem that leads to a Markovian system, in a larger-dimensional state space. I will then show how this perspective can be xploited to obtain a memory-efficient numerical method for systems with nonlocal behaviour in time, whenever a particular 'spectral representation' is available. This more general property also arises in other applications such as the Stefan problem of melting ice, hydrodynamic walkers, among others.

Biography: Vishal Vasan is a faculty member at the International Centre for Theoretical Sciences, a centre of the Tata Institute of Fundamental Research. Dr Vasan obtained a BE in Mechanical Engineering from Anna University, an MS (Mechanical Engg.) from Arizona State University and then an MS and PhD in Applied Mathematics from the Univ. of Washington. Dr Vasan was the S Chowla Research Asst. Professor in the Dept of Mathematics at Pennsylvania State University from 2012-2015 before moving to ICTS. His main interest is the theoretical and numerical analysis of partial differential equations as well as their applications, specifically inverse problems. The application domains include large-scale atmospheric and ocean dynamics, Bose-Einstein condensates and cold atoms, water waves and coastal engineering, growth and its regulation in biological tissues among others. More recently Dr Vasan has been focusing on the theory underlying the data-driven viewpoint of dynamical systems.

Bibliography

[1] S Ganga Prasath, Vishal Vasan and Rama Govindarajan. "Accurate solution method for the Maxey–Riley equation, and the effects of Basset history." In: *Journal of Fluid Mechanics* 868 (2019), pp. 428–460

[2] Divya Jaganathan, Rama Govindarajan and Vishal Vasan. "Explicit integrators for nonlocal equations: The case of the Maxey-Riley-Gatignol equation." In: *Quarterly of Applied Mathematics* 83.1 (2025), pp. 135–158

[3] Divya Jaganathan, and Rahil N Valani. "Markovian embedding of nonlocal equations using spectral representation." *arXiv preprint arXiv:2402.00009* (2023).

From Fractional Calculus to Anti-Infection Catheter Design

12 Sep
15:00
CEST

(Edmond) Tingtao Zhou
California Institute of Technology

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 12 September 2025
YouTube: https://www.youtube.com/watch?v=bnZGUqET-HY

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional Laplacian, active matter, Lévy walk, anti-infection catheters

Abstract: Many active matter systems are known to perform Levy walks during migration or foraging. Such superdiffusive transport indicates long-range correlated dynamics. These behavior patterns have been observed for microswimmers such as bacteria in microfluidic experiments, where Gaussian noise assumptions are insufficient to explain the data [1].

In the first part of this talk, we introduce active Levy swimmers [2] to model such behavior. The focus is on ideal swimmers that only interact with the walls but not with each other, which reduces to the classical Levy walk model but now under confinement. We study the density distribution in the channel and force exerted on the walls by the Levy swimmers, where the boundaries require proper explicit treatment. We analyze stronger confinement via a set of coupled kinetics equations and the swimmers' stochastic trajectories. Previous literature demonstrated that power-law scaling in a multiscale analysis in free space results in a fractional diffusion equation. We show that in a channel, in the weak confinement limit active Levy swimmers are governed by a modified Riesz fractional derivative. Leveraging recent results on fractional fluxes, we derive steady state solutions for the bulk density distribution of active Levy swimmers in a channel, and demonstrate that these solutions agree well with particle simulations. The profiles are non-uniform over the entire domain, in contrast to constant-in-the-bulk profiles of active Brownian and run-and-tumble particles. Our theory provides a mathematical framework for Levy walks under confinement with sliding no-flux boundary conditions and provides a foundation for studies of interacting active Levy swimmers.

In the second part of this talk, I will present a geometric design for anti-infection catheters. Urinary catheters cause lots of infections in hospitalized patients and cost about 30 million US dollars annually. Based on our understanding of microbial transport in channels, specifically how bacteria swim upstream due to flow-induced reorientation, we extend our model for active Levy swimmers to investigate their rheotaxis behaviors. Our modeling enables us to propose and experimentally demonstrate a novel catheter interior design that reduces bacterial contamination by 100-fold [3-5], potentially prevent urinary tract infections associated with indwelling catheters.

Biography: Dr. (Edmond) Tingtao Zhou received his B.S. in Physics from Peking University in China, where he worked on statistical physics of star formation. He then pursued his Ph.D. in Physics at MIT, where his thesis focused on materials sustainability by understanding how phase transitions in porous colloidal media, such as cement or batteries, lead to materials degradation. Currently, he is a Drinkward Postdoc Fellow at California Institute of Technology, where he combines statistical physics and fluid mechanics to study the fundamentals of living matter and its applications in biomedical and responsive materials.

Bibliography

[1] Figueroa-Morales, N., Rivera, A., Soto, R., Lindner, A., Altshuler, E. and Clément, É., 2020. E. coli "super-contaminates" narrow ducts fostered by broad run-time distribution. *Science advances*, 6(11), p.eaay0155.

[2] Zhou, T., Peng, Z., Gulian, M., and Brady, J. F. (2021). Distribution and pressure of active Lévy swimmers under confinement. *Journal of Physics A: Mathematical and Theoretical*, 54(27), 275002.

[3] Zhou, T., Wan, X., Huang, D.Z., Li, Z., Peng, Z., Anandkumar, A., Brady, J.F., Sternberg, P.W. and Daraio, C., 2024. AI-aided geometric design of anti-infection catheters. *Science Advances*, 10(1), p.eadj1741.

[4] Zhou, T. et al. "Anti-infection fluidic channel." U.S. Patent No. 12,128,189. 29 Oct. 2024.

[5] Zhou, T. et al. "Anti-infection fluidic channel." U.S. Patent No. 12,220,539. 11 Feb. 2025

The multifractal nature of a parametrized family of von Koch functions

12 Sep
16:00
CEST

Stéphane Seuret
Université Paris Est Créteil, France

Time: 16:00 - 17:00 CEST (Rome / Paris)
Date: 12 September 2025
YouTube: https://www.youtube.com/watch?v=8g-LbyKaCB0

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: fractals, multifractals, dynamical systems, invariant measures, Hausdorff dimension

Abstract: In a famous paper published in 1904 [1, 2], Helge von Koch introduced the curve that still serves nowadays as an iconic representation of fractal shapes. In fact, von Koch's main goal was the construction of a continuous but nowhere differentiable function, very similar to the snowflake, using elementary geometric procedures, and not analytical formulae. We prove that a parametrized family of functions (including and) generalizing von Koch's example enjoys a rich multifractal behavior, thus enriching the class of historical mathematical objects having surprising regularity properties. The analysis relies on the study of the orbits of an underlying dynamical system and on the introduction of self-similar measures and non-trivial iterated functions systems adapted to the problem.

This is a joint work with Zoltán Buczolich (Eötvös Loránd University) and Yann Demichel (Université Paris Nanterre)

Biography: Stéphane Seuret is Full professor in Mathematics at Université Paris Est Créteil (UPEC). He is an internationaly recognized expert in fractal geometry, multifractals, and their connexion with probability theory, dynamical systems and metric number theory. He was president of the French Mathematical Society (2016-2020) and is now head of the "Laboratoire d'Analyse et de Mathématiques Appliquées" (LAMA), which gathers 120 mathematicians at UPEC.

Bibliography

[1] H. von Koch, Sur une courbe continue sans tangente, obtenue par une construction géométrique élémentaire, Arkiv för matematik astronomi och fysik, 1 681-702 (1904). Reprinted in English in *Classics on Fractals*, G. A. Edgar, Addison-Wesley Publishing (1993) 25–45. https://staff.math.su.se/lenb/dok/von-Koch-1904.pdf

[2] H. von Koch, Une méthode géométrique élémentaire pour l'étude de certaines questions de la théorie des courbes planes, Acta Mathematica, 1 99-04 145–174

19 Sep
15:00
CEST

Fractional PDEs involving general fractional derivatives with Sonin kernels as anomalous diffusion models

Yuri Luchko

Berlin University of Applied Sciences and Technology, Germany

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 19 September 2025
YouTube: https://www.youtube.com/watch?v=j6WgjZpL4Z0

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: anomalous diffusion, continuous time random walks, fractional master equation, regularized general fractional derivative, Sonin kernels, fractional diffusion equation, mean squared displacement

Abstract: Nowadays, the probably most popular mathematical descriptions of anomalous diffusion processes are the Continuous Time Random Walk (CTRW) models ([**1**]) at the micro-level and fractional PDEs involving different types of fractional derivatives at the macro-level ([**2**, **3**]). A strong connection between the CTRW model and fractional PDEs was first established in [**4**], where a fractional master equation involving the Caputo fractional derivative was embedded into the framework of the general CTRW model. In particular, the mean squared displacement (MSD) of the diffusing particles governed by this fractional master equation was shown to be proportional to a power law function of time with the exponent being equal to the order of the fractional derivative.

However, in many applications, deviations of the MSD from the power law with a fixed exponent are observed. Thus, one needs other, more general master equations that would lead to an extension of the class of functions that describe the MSD of the diffusing particles governed by these equations.

In this talk, we introduce and investigate a fractional master equation involving a regularized general fractional derivative (RGFD) with Sonin kernels [**5**, **6**].

Under some conditions, this master equation is equivalent to the CTRW model with the waiting time probability density function in form of a convolution series generated by the Sonin kernel associated with the kernel of its RGFD. Then we derive a fractional diffusion equation involving the RGFDs with Sonin kernels from the CTRW model in the asymptotical sense of long times and large distances and investigate its physical characteristics and mathematical properties. In particular, a concise formula for the MSD of the particles governed by this fractional diffusion equation is deduced in terms of the Sonin kernel associated with the kernel of its RGFD. Thus, variation of the Sonin kernels in the fractional diffusion equation leads to a great diversity of possible forms of the MSD that can be fitted to the measurements data collected for a concrete anomalous diffusion process.

Finally, we discuss some important mathematical aspects of the fractional diffusion equation involving the RGFDs with Sonin kernels, including non-negativity

of its fundamental solution and validity of an appropriately formulated maximum principle for its solutions on the bounded domains.

The talk is mainly based on the recent paper [7] that was published in the framework of the project PN23-16SM-1809 funded by the Kuwait Foundation for the Advancement of Sciences (KFAS).

Biography: Dr. Yuri Luchko is a Full Professor at the Faculty of Mathematics - Physics - Chemistry of the Berlin University of Applied Sciences and Technology in Germany. He studied Mathematics at the Belarussian State University in Minsk and received his PhD degree from the same University in 1993. In 1994, Yuri Luchko got a postdoc position at the Free University of Berlin, Germany, under supervision of Prof. Rudolf Gorenflo and stayed there for six years. From 2000 to 2006, he was a scientific researcher at the University in Frankfurt (Oder), Germany. In 2006, Dr. Yuri Luchko got a professorship at the Technical University of Applied Sciences Berlin, Germany. The main field of his research is Applied Mathematics with a special focus on Fractional Calculus and its applications. Yuri Luchko published about two hundred papers in international peer-reviewed scientific journals and about twenty books and books chapters as author or editor. He is an associate editor of the international journal "Fractional Calculus and Applied Analysis" and editor of several other reputable mathematical journals including ZAA (Zeitschrift für Analysis und ihre Anwendungen).

Bibliography

[1] E. Montroll, G. Weiss. Random walks on lattices II. *J. Math. Phys.* **1965**, *6*, 167–181.

[2] Yu. Luchko. Anomalous Diffusion: Models, Their Analysis, and Interpretation. Chapter in: S.V. Rogosin, A.A. Koroleva (Eds), *Advances in Applied Analysis, Series: Trends in Mathematics*, Birkhäuser, Basel, **2012**, pp. 115–146.

[3] R. Metzler, J. Klafter. The random walk's guide to anomalous diffusion: a fractional dynamics approach. *Physics Reports* **2000**, *339*, 1–77.

[4] R. Hilfer, L. Anton. Fractional Master Equations and Fractal Time Random Walk. *Physical Review E* **1995**, *51*, R848.

[5] A.N. Kochubei. General fractional calculus, evolution equations, and renewal processes. *Integral Equations and Operator Theory* **2011**, *71*, 583–600.

[6] Yu. Luchko. General fractional integrals and derivatives with the Sonine kernels. *Mathematics* **2021**, *9(6)*, 594.

[7] M. Alkandari, D. Loutchko, Yu. Luchko. Anomalous Diffusion Models Involving Regularized General Fractional Derivatives with Sonin Kernels. *Fractal and Fractional* **2025**, *9(6)*, 363.

26 Sep
15:00
CEST

Pre-asymptotic analysis of Lévy flights

Gianni Pagnini
BCAM & IKERBASQUE
BCAM-Basque Center for Applied Mathematics, Alameda de Mazarredo 14, 48009, Bilbao, Basque Country – Spain
IKERBASQUE–Basque Foundation for Science, Plaza Euskadi 5, 48009 Bilbao, Basque Country, Spain

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 26 September 2025
YouTube: https://www.youtube.com/watch?v=hJZGjnTxxpc

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Lévy flights, Kramers–Moyal expansion, Pawula theorem, multi-order space-fractional diffusion equation

Abstract: We study the properties of Lévy flights with index $0 < \alpha < 2$ at elapsed times smaller than those required for reaching the diffusive limit, and we focus on the bulk of the walkers' distribution rather than on its tails. On the basis of the analogs of the Kramers–Moyal expansion and of the Pawula theorem, we show that, for any $\alpha \leq 2/3$, the bulk of the walkers' distribution occurs at wave-numbers greater than $(2/\alpha)^{1/(2\alpha)} \geq 1$, and it remains non-self-similar for a time-scale longer than the Markovian time-lag of at least one order of magnitude. This result highlights the fact that for Lévy flights, the Markovianity time-lag is not the only time-scale of the process and indeed another and longer time-scale controls the transition to the familiar power-law regime in the final diffusive limit. The magnitude of this further time-scale is independent of the index α and may compromise the reliability of applications of Lévy flights to real world cases related with recurrence and transience as optimal searching, animal foraging, and site fidelity.

The talk is based on References [1, 2].

Biography: Gianni Pagnini is permanent at BCAM - Basque Center for Applied Mathematics, Bilbao, Spain, as Ikerbasque Research Associate Professor, where he leads the Statistical Physics line. His research is focused on stochastic processes and diffusion problems with applications also in biology and forest fires. His education reflects his multidisciplinary approach and scientific interests: Laurea in Physics (Bologna, 2000, Italy) on fractional diffusion equations; PhD in Environmental Sciences (Urbino, 2005, Italy) on nonlinear stochastic modelling of turbulence; and the Italian Qualification as Associate Professor in Mathematical Physics. As a young researcher, he studied analytical aspects of applications of Fractional Calculus including Mellin-Barnes integrals and H-Functions. Later, he focused on stochastic modelling of processes governed by fractional differential equation. He is now member of the Editorial Board of the journals "Fractional Calculus and Applied Analysis" and "Communications in Applied and Industrial Mathematics" (the official journal of the Italian Society for Applied and Industrial Mathematics (SIMAI)).

Bibliography

[1] H. A. Araújo, G. Pagnini, Pre-asymptotic analysis of Lévy flights. Chaos, Vol. 34, 073126, 2024

[2] G. Pagnini, S. Vitali, Should I stay or should I go? Zero-size jumps in random walks for Lévy flights. Fract. Calc. Appl. Anal., Vol. 24, 137–167, 2021

03 Oct
15:00
CEST

The Fokas method and its application to fractional PDEs

Arran Fernandez
Department of Mathematics, Eastern Mediterranean University, Famagusta, Northern Cyprus

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 3 Oct 2025
YouTube: https://www.youtube.com/watch?v=zyCrn5lYemc

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional PDEs, unified transform method, complex analysis

Abstract: The unified transform method, or Fokas method, was developed by Athanassios Fokas during the late 1990s, as a method for solving PDEs explicitly using multi-dimensional transforms and complex contour deformations. It has been used to solve various linear and non-linear PDEs, and lends itself well to numerical evaluation in cases where exact calculation is unfeasible. Some years ago, we extended this method to certain families of fractional PDEs, involving a single time derivative and a linear combination of Riemann–Liouville fractional space derivatives. The method is significantly harder to apply in the fractional setting, due to the loss of many nice properties of polynomials which are now replaced by combinations of fractional power functions. This talk will provide an overview of Fokas's method in the classical setting, and then show our work in the fractional setting, with some pointers towards related problems that remain unsolved.

Biography: Arran Fernandez is a pure mathematician and associate professor at the Eastern Mediterranean University, specialising in fractional calculus. He completed his bachelor's, master's, and PhD at the University of Cambridge, where he began as the youngest student at the university (aged 15) and came top of his year to be the youngest-ever senior wrangler. Since completing his PhD in 2018, he has worked at the Eastern Mediterranean University, firstly as an assistant professor and then as an associate professor. He also spent a year working at Sultan Qaboos University, also as an associate professor. His research interests lie in connecting fractional calculus with other branches of mathematics, such as abstract algebra, analytic number theory, and Clifford analysis. His achievements in these directions include extending Mikusiński's operational calculus to fractional PDEs, expressing the Riemann zeta function as a fractional differintegral of an elementary function, and defining fractional d-bar derivatives in complex and hypercomplex settings.

Bibliography

[1] A.S. Fokas, "A unified transform method for solving linear and certain nonlinear PDEs", *Proceedings of the Royal Society Of London A* 453 (1997), pp. 1411–1443.

[2] A.S. Fokas, “Two-dimensional linear partial differential equations in a convex polygon”, *Proceedings of the Royal Society Of London A* 457 (2001), pp. 371–393.

[3] A.S. Fokas, *A Unified Approach to Boundary Value Problems* (Philadelphia: SIAM, 2008).

[4] A. Fernandez, D. Baleanu, A.S. Fokas, “Solving PDEs of fractional order using the unified transform method’, *Applied Mathematics and Computation* 339C (2018), pp. 738–749.

17 Oct
15:00
CEST

Analysis of fractional Cauchy problems and time-changed stochastic processes

Fabrizio Cinque
Sapienza University of Rome, Italy

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 17 October 2025
YouTube: https://www.youtube.com/watch?v=dtInbXAwaU4

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional Cauchy problems, Dzherbashyan–Caputo derivative, convolutional derivative operators, telegraph processes, Laplace and Fourier transforms

Abstract: We study Dzherbashyan–Caputo-fractional Cauchy problems related to equations with derivatives of order νk, for k non-negative integer and $\nu > 0$. The explicit solution is expressed in terms of Mittag-Leffler-type functions and, introducing some additional hypotheses, it reduces into a linear combination of Mittag-Leffler functions with common fractional order ν. We establish a probabilistic relationship, involving the inverse of stable subordinator, between the solutions of differential problems with order $\alpha\nu$ and ν, for $\alpha \in (0, 1)$. Then, we use the described method to solve fractional differential equations arising by fractionalizing the time-operator of the partial differential equations related to the probability law of planar random motions with finite velocities.

The time-changing result is then presented in a more general framework concerning Cauchy problems with fractional differential equations in both space and time variables. Here the solution is expressed in terms of a “stochastic composition” of the solutions to two simpler problems. These Cauchy sub-problems respectively concern the space and the time differential operator involved in the main equation. We provide some probabilistic applications, where the solution can be interpreted as the transition density of a time-changed process.

Biography: Currently working as an Expert in the Bank of Italy, since November 2021. He received his M.Sc in 2020 and PhD in Statistical Sciences (Methodological curriculum) in 2024 from Sapienza University of Rome, where he has been tutoring several times in the graduate courses of stochastic processes and statistical inference. The core areas of his research are random motions with finite velocities (also known as telegraph processes or continuous time random walks), point processes, pseudo-processes, Airy functions and fractional calculus for stochastic processes.

Bibliography

[1] Cinque Fabrizio and Orsingher Enzo. “Analysis of fractional Cauchy problems with some probabilistic applications”. In: J. Math. Anal. Appl. 536 (2024) 128188.

[2] Cinque Fabrizio and Orsingher Enzo. “Higher-order fractional equations and related time-changed pseudo-processes”. In: J. Math. Anal. Appl. 543 (2025) 129026.

[3] Orsingher Enzo and Beghin Luisa. “Fractional diffusions equations and processes with randomly varying time”. In: Ann. Probab. 37(1) (2009) 206–249.

[4] Orsingher Enzo and Toaldo Bruno. “Space-time fractional equations and related stable processes at random time”, J. Theor. Probab. 30 (2017) 1–26.

24 Oct
15:00
CEST

Prabhakar kernels in fractional dynamics: from Matignon-type stability to two-term equations

Eva Kaslik

West University of Timisoara, Romania

Time: 15:00 - 16:00 CEST (Rome / Paris)
Date: 24 October 2025
YouTube: https://www.youtube.com/watch?v=8CxF-1IB8fw

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: Prabhakar fractional calculus; fractional-order systems; stability

Abstract:

The Prabhakar function $E^{\gamma}_{\alpha,\beta}(z)$ and the corresponding kernel $e^{\gamma}_{\alpha,\beta,\omega}(t) = t^{\beta-1}E^{\gamma}_{\alpha,\beta}(\omega t^{\alpha})$ provide a unifying framework for stability analysis and computation in fractional-order systems [1, 2, 3].

I will begin with a kernel-based proof of a slight refinement of Matignon's theorem for commensurate Caputo systems [4], highlighting the role of the Prabhakar kernel and its large-time asymptotic properties.

Moving beyond Caputo derivatives, I will then treat linear systems with Caputo-Prabhakar derivatives [5]. Here the characteristic equation $s^{\beta-\alpha\gamma}\big(s^{\alpha}-\omega\big)^{\gamma} = \lambda$ induces a root-locus boundary $\Psi^{\gamma}_{\alpha,\beta,\omega}$ and a stability region $S^{\gamma}_{\alpha,\beta,\omega}$ that reduces to Matignon's wedge when $\gamma \to 0$. I will also show asymptotic expansions for small/large times and numerical illustrations, including a Hopf-type transition in a Brusselator model as ω varies.

The final part of the talk refers to the stability analysis of two-term Prabhakar FDEs. As an illustrative example, an extension of the Duffing equation is numerically investigated, developing an implicit L1/L2-type scheme adapted to Prabhakar kernels.

Biography: Eva Kaslik is a Full Professor at the Department of Computer Science of the West University of Timisoara, Romania. She earned her PhD in Applied Mathematics in 2006 at Université Sorbonne Paris Nord (Paris 13), through a joint degree program with the West University of Timisoara. She obtained her Habilitation in Mathematics in 2015. She has authored or co-authored over 100 peer-reviewed publications and serves as a member of the Editorial Board of several journals, including "Fractional Calculus and Applied Analysis" and "Mathematics and Computers in Simulation". Her main research focuses on stability theory for fractional-order and delay differential systems, and mathematical modeling in the neurosciences. She also advises graduate students and collaborates widely across applied mathematics, dynamical systems, and computational science.

Bibliography

[1] T. R. Prabhakar. A singular integral equation with a generalized Mittag–Leffler function in the kernel. *Yokohama Mathematical Journal* **19**(1), 7–15 (1971).

[2] R. Garra and R. Garrappa. The Prabhakar or three-parameter Mittag–Leffler function: theory and application. *Communications in Nonlinear Science and Numerical Simulation* **56**, 314–329 (2018).

[3] A. Giusti, I. Colombaro, R. Garra, R. Garrappa, F. Polito, M. Popolizio, and F. Mainardi. A practical guide to Prabhakar fractional calculus. *Fractional Calculus and Applied Analysis* **23**(1), 9–54 (2020).

[4] O. Brandibur, R. Garrappa, and E. Kaslik, Stability of Systems of Fractional-Order Differential Equations with Caputo Derivatives. *Mathematics* **9**(8), 914 (2021).

[5] R. Garrappa and E. Kaslik, Stability of fractional-order systems with Prabhakar derivatives. *Nonlinear Dynamics* **102**(1), 567–578 (2020).

31 Oct
15:00
CET

Variable-order fractional PDEs and their applications in physics and biology

Sergei Fedotov
Department of Mathematics, The University of Manchester

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 31 October 2025
YouTube: https://www.youtube.com/watch?v=3HZnxSXuow4

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: anomalous transport, variable-order fractional PDEs, reaction-subdiffusion

Abstract: I will start with a derivation of variable-order fractional diffusion equations from master equations corresponding to the microscopic local and barrier models. I will then discuss the asymptotic representation of the solution of the space-dependent variable-order fractional diffusion equations. Next, I will talk about how to incorporate reaction terms into heterogeneous fractional PDEs. Finally, I will demonstrate how the coarse-grained fractional reaction-subdiffusion equations are affected by the specific details of the underlying microscopic random walk models. The problem arises from the memory effects of subdiffusive transport systems. Due to these effects, the reaction can change the transport operator for the subdiffusion process. Several examples from physics and biology will be presented to illustrate these effects.

Biography: Prof. Sergei Fedotov obtained his Ph.D. (1986) from Ural Federal University. Fedotov held research positions in London (1990), Aachen (1993–1995), Wuppertal (1997), and Berlin (1998) before joining the Department of Mathematics, UMIST, in Manchester as a lecturer in 1998. Since 2005, he is a professor of applied mathematics at the Department of Mathematics, University of Manchester, UK.

Prof. Fedotov's research focuses on random walk theory and reaction-transport systems. He has successfully applied anomalous random walk ideas to a broad range of analytical studies related to non-Markovian transport phenomena in physics, chemistry, and biology.

Bibliography

[1] Sergei Fedotov and Daniel Han. Asymptotic Behavior of the Solution of the Space Dependent Variable Order Fractional Diffusion Equation: Ultraslow Anomalous Aggregation. *Phys. Rev. Lett.* 123, 050602 (2019).

[2] Sergei Fedotov, Daniel Han, Andrey Yu Zubarev, Mark Johnston and Victoria J. Allan. Variable-order fractional master equation and clustering of particles: non-uniform lysosome distribution. *Philos. Trans. R. Soc. Lond.* A 379, 20200317 (2021).

Fractional operators and fractional stochastic processes

07 Nov
15:00
CET

Yuliya Mishura
Taras Shevchenko National University of Kyiv

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 07 November 2025
YouTube: https://www.youtube.com/watch?v=Eqv7VlxL010

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: fractional integral; fractional derivative; fractional Gaussian process

Abstract: We start with the simplest case of Riemann-Liouville fractional operators to demonstrate how they generate fractional Brownian motion. This is the example of Gaussian-Volterra process with the kernel created by power functions, see [1]. Now two ways are possible: to generalize the kernel itself and obtain the new processes [2] or to consider more general fractional operators and also generate Gaussian processes [3, 4]. We shall realize both ways and consider some properties of the respective processes.

Biography: Yuliya Mishura received her PhD in probability and statistics in Kyiv University in 1978 and completed her postdoctoral degree in probability and statistics (Habilitation) in 1990. She is currently a Professor of the Department of Probability, Statistics and Actuarial Mathematics at Taras Shevchenko National University of Kyiv. Having broad and varied scientific interests, she is the author/coauthor of more than 320 research papers and more than 20 books. Her research interests include theory and statistics of stochastic processes, stochastic differential equations, fractional calculus and fractional processes, stochastic analysis, functional limit theorems, entropies of probability distributions and stochastic systems, financial mathematics and other applications of stochastics. Invited speaker of many international congresses and conferences, organizer of series of conferences. Editor-in-chief of the journal "Theory of Probability and Mathematical Statistics", coeditor-in-chief of the journal "Modern Stochastics: Theory and Applications". Team leader and participant of many international research projects.

Bibliography

[1] Yuliya Mishura "Stochastic calculus for fractional Brownian motion and related processes". *Springer Berlin Heidelberg* (2008)

[2] Yuliya Mishura, Georgij Shevchenko, Sergej Shklyar. "Gaussian processes with Volterra kernels". In: *International Conference on Stochastic Processes and Algebraic Structures Cham: Springer International Publishing* (2019), pp. 249-276

[3] Luisa Beghin, Lorenzo Cristofaro, Yuliya Mishura. "A class of processes defined in the white noise space through generalized fractional operators". In: *Stochastic Processes and their Applications*, 178, 104494 (2024).

[4] Luisa Beghin, Alessandro De Gregorio, A., Yuliya Mishura. "Hadamard fractional Brownian motion: path properties and Wiener integration". In: *arXiv preprint arXiv:2507.13512* (2025)

Intermediate dimensions

14 Nov
15:00
CET

Kenneth Falconer
University of St Andrews

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 14 November 2025
YouTube: https://www.youtube.com/watch?v=9TV4KJJdu3Q

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: fractals, dimension

Abstract: Dimensions are central tools in fractal geometry, with Hausdorff dimension and box-counting dimensions probably the best known. We will show that Hausdorff and box dimensions may be regarded as the extremes of a continuum of dimensions, called Intermediate Dimensions. In recent years a substantial body of theory has developed on the topic with contributions from several researchers. The talk will describe some of the main aspects of intermediate dimensions and will be illustrated by examples.

Biography: Kenneth Falconer took his undergraduate and PhD degrees at the University of Cambridge. Since then he has held positions at Cambridge and Bristol and has been Professor of Pure Mathematics at the University of St Andrews since 1993. In 2017 he was appointed Regius Professor of Mathematics. He has written 5 books and over 130 papers, mainly on aspects of fractal geometry. He is a Fellow of the Royal Society of Edinburgh and was awarded the Shephard Prize of the London Mathematical Society in 2020, and was awarded a CBE for Services to Mathematics in 2024.

Bibliography

[1] Falconer, K J. Fractal Geometry: Mathematical Foundations and Applications, *John Wiley, 3rd Ed.*, 2014.

[2] Falconer, K J., Fraser, J M. and Kempton, T: Intermediate dimensions. *Math. Zeit.* 296 (2020), 813–830.

[3] Falconer, K J. Intermediate dimensions: a survey. Thermodynamic formalism, 469–493, *Lecture Notes in Math., 2290, CIRM Jean-Morlet Ser.*, Springer, Cham, 2021.

21 Nov
15:00
CET

Solving problems in hydrodynamic turbulence by leaning on ideas from many-body systems

Samriddhi Sankar Ray
International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore, India

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 21 November 2025
YouTube: https://www.youtube.com/watch?v=hCMqCeFabLg

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: turbulence, multifractals, intermittency

Abstract: Recent ideas [1] of many-body chaos in classical Hamiltonian systems — namely decorrelators or the classical analogues of OTOCs — have opened an interesting window to revisit problems in non linear, out of equilibrium flows.

In this talk we will introduce this idea through a classical spin chain model [1] and then motivate how the same can be applied to nonlinear, Hamiltonian, thermalised fluids [2] to show how the Lyapunov exponent scales with temperature in a classical many-body system. We then take two further examples from non-Hamiltonian, out-of-equilibrium systems — namely fully developed high Reynolds number classical turbulence [5] and low Reynolds active turbulence of bacterial suspensions [3] — to further exploit such decorrelators in order to see how the Lyaponov exponent λ scales with the Reynolds number Re in the first and activity in the second case. In particular, for the high Reynolds number fully developed turbulence problem, we show $\lambda \propto \mathrm{Re}^{\alpha}$ and investigate the interplay of the competing effects of viscous dissipation and nonlinearity. We obtain a precise value of $\alpha = 0.59 \pm 0.04$ and show that the departure from the Kolmogorov mean field result $\lambda \propto \sqrt{\mathrm{Re}}$ is a consequence of the intermittent fluctuations [4] in the velocity-gradient tensor. The robustness of our results are further confirmed in a local, dynamical systems model for turbulence.

Biography: Samriddhi Sankar Ray is an Associate Professor at the International Centre for Theoretical Sciences of the Tata Institute of Fundamental Research (ICTS-TIFR) in Bangalore, India. Prior to this Samriddhi obtained his PhD in Physics from the Indian Institute of Science (IISc), Bangalore and then a short post-doctoral stint at Observatoire de la Cote d'Azur in Nice, France. His research interests, lying at the interface of statistical physics, applied mathematics and computational fluid dynamics, focusses on high Reynolds number fully-developed turbulence and turbulent transport. He has also worked extensively on problems of thermalisation of finite-dimensional ideal hydrodynamics as well as, most recently, low Reynolds number bacterial suspensions.

Bibliography

[1] A. Das, S. Chakrabarty, A. Dhar, A. Kundu, D. A. Huse, R. Moessner, Samriddhi Sankar Ray, and S. Bhattacharjee. Light-cone spreading of perturbations

and the butterfly effect in a classical spin chain, Physical Review Letters 121, 024101 (2018).

[2] S. D. Murugan, D. Kumar, S. Bhattacharjee, and Samriddhi Sankar Ray. Many-body Chaos in Thermalised Fluids, Physical Review Letters 127, 124501 (2021)

[3] S. Mukherjee, R. K. Singh, M. James and Samriddhi Sankar Ray. Intermittency, fluctuations and maximal chaos in an emergent universal state of active turbulence, Nature Physics 19, 891 (2023)

[4] S. Mukherjee, S. D. Murugan, R. Mukherjee and Samriddhi Sankar Ray. Turbulent flows are not uniformly multifractal, Physical Review Letters 132, 184002 (2024)

[5] A. Banerjee, R. Mukherjee, S. D. Murugan, S. Bhattacharjee, and Samriddhi Sankar Ray. Many-body Chaos in Fully Developed Turbulence,[ArXiv:2505.09538]

21 Nov
16:00
CET

Multi-fractality, universality and singularity in turbulence

Bérengère Dubrulle

CNRS, SPEC, CEA Saclay, Université Paris-Saclay, 91190 Gif sur Yvette Cedex, France

Time: 16:00 - 17:00 CET (Rome / Paris)
Date: 21 November 2025
YouTube: https://www.youtube.com/watch?v=EqJbpmOdbtA

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: turbulence; multifractals; universality; singularity

Abstract: In most geophysical flows, vortices (or eddies) of all sizes are observed. In 1941, Kolmogorov devised a theory to describe the hierarchical organization of such vortices via a homogeneous self-similar process. This theory correctly explains the universal power-law energy spectrum observed in all turbulent flows. Finer observations however prove that this picture is too simplistic, owing to intermittency of energy dissipation and high velocity derivatives. In this review, we discuss how such intermittency can be explained and fitted into a new picture of turbulence. We first discuss how the concept of multi-fractality (invented by Parisi and Frisch in 1982) enables to generalize the concept of self-similarity in a non-homogeneous environment and recover a universality in turbulence. We show how to derive useful bounds on the multifractal spectrum using the Navier-Stokes equations and how it connects with the singular set of Caffarelli, Kohn and Nirenberg.We further review the local extension of this theory, and show how it enables to probe the most irregular locations of the velocity field, in the sense foreseen by Lars Onsager in 1949. Finally, we discuss how the multi-fractal theory connects to possible singularities, in the real or in the complex plane, as first investigated by Frisch and Morf in 1981.

Biography: Bérengère Dubrulle is senior scientist at the Centre National de la Recherche Scientifique and presently Director of the Les Houches Physics School. She received her PhD in astrophysics in 1990 under the supervision of J-P. Zahn. She is a specialist of turbulence, and its application to astro and geophysical flows using theoretical, numerical or experimental approaches. She is fellow of the APS and member of the French Academy of Sciences.

Bibliography

[1] Dubrulle. B (2022) Multi-Fractality, Universality and Singularity in Turbulence. *Fractal Fract.* **6**(10), 613; https://doi.org/10.3390/fractalfract6100613.

[2] Dubrulle, B. and Gibbon. (2022) A correspondence between the multifractal model of turbulence and the Navier-Stokes equations *J., Phil. Trans. R. Soc.* A.3802021009220210092.

[3] Dubrulle, B (2025) From mathematical singularities to physics of turbulence. YouTube: https://www.youtube.com/watch?v=UGhr5y3n8vI

28 Nov
15:00
CET

Fractal interpolation of bicomplex functions

Peter Massopust
Technical University of Munich

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 28 November 2025
YouTube: https://www.youtube.com/watch?v=MITjjGEKsKA

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy
Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: bicomplex number, fractal interpolation, Read–Bajraktarević operator

Abstract: Bicomplex numbers and functions have been applied to problems in physics, engineering and computer science. Prominent areas of application are electrodynamics, fluid dynamics, quantum theory and signal processing.

This talk presents bicomplex functions from the fractal interpolation point of view and introduces a novel approach to approximate and interpolate irregular and non-smooth bicomplex functions by means of iterated function systems and an associated Read–Bajraktarević operator.

Joint work with Emna Marzouki, Technical University of Munich.

Biography: Peter Massopust's main research interests lie in the areas of harmonic analysis, fractal geometry, and Clifford analysis. He is well-known for his contributions to the theory of iterated function systems, fractal interpolation, and wavelets. He is currently at the Technical University of Munich, Germany.

Bibliography

[1] M.E. Luna-Elizarrarás, M. Shapiro, D.C. Struppa, A. Vajiac. *Bicomplex Holomorphic Functions: The Algebra, Geometry and Analysis of Bicomplex Numbers*. Birkhäuser, 2015.

[2] E. Marzouki, P. Massopust. "Fractal Interpolation of Bicomplex Functions". Preprint 2025.

[3] P. Massopust. *Fractal Functions, Fractal Surfaces, and Wavelets*, 2nd ed., Academic Press: San Diego, USA, 2016.

Roughness-informed machine learning by fractal and fractional calculi

05 Dec
15:00
CET

YangQuan Chen

Dept. of Mechanical and Aerospace Engineering, University of California, Merced

Time: 15:00 - 16:00 CET (Rome / Paris)
Date: 05 December 2025
YouTube: https://www.youtube.com/watch?v=4UKaogtdwoY

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**
* SISSA, International School of Advanced Studies, Trieste, Italy
** Eastern Mediterranean University, Northern Cyprus

Keywords: roughness, roughness informed, machine learning, federated learning, fractional calculus, fractal calculus

Abstract:

This talk advocates that machine learning ought to be not only "physics-informed" but also "complexity-informed" so that smarter machine learning becomes possible. After introducing the triangle of "inverse power law - complexity - fractional calculus" we show that both fractal calculus and fractional calculus are mathematical vehicle for tail behavior characterization therefore the exponential law (EL, integer order calculus), stretched exponential law (SEL, fractal calculus) and inverse power law (IPL, fractional calculus) are in a unified view. We then show that roughness concept is important in machine learning when loss landscape roughness is considered. Roughness in the sense of statistics, manifold, geometrical etc. can be quantified by using fractal and fractional calculi. Machine learning algorithms that are aware of roughness and are informed by roughness can perform much better than those conventional machine learning algorithms that do not respect the complexity or roughness information. The take home message is simple: AI/machine learning and fractional calculus should marry.

Biography:

Prof. YangQuan Chen is with the Dept. of Mechanical and Aerospace Engineering at the University of California Merced. He received his B.S. from the University of Science and Technology of Beijing, M.S. from Beijing Institute of Technology, and Ph.D. from Nanyang Technological University Singapore. His research interests include smart mechatronics for sustainability, smart control engineering via digital twins, small multi-UAV based cooperative multi-spectral "remote sensing", applied fractional calculus in complex system controls, modeling, signal processing, and machine learning; distributed measurement and control of distributed parameter systems with mobile actuator and sensor networks. He authored many papers, editorials, patents, research monographs and textbooks. His Google Scholar H index = 107 total citations = 61256. His latest books with CRC Press are *Fractional Calculus for Skeptics (I), (II).*

Bibliography

[1] Mohammad Partohaghighi, Roummel Marcia, YangQuan Chen. "Roughness-Informed Machine Learning – A Call for Fractal and Fractional Calculi." Journal of Information and Intelligence. (Sept. 2025) [DOI: https://doi.org/10.1016/j.jiixd.2025.09.001

[2] Mohammad Partohaghighi, Roummel Marcia, YangQuan Chen. "Roughness-Informed Machine Unlearning." In Proc. of the 2025 ICFDA, Algiers, Algeria (to appear Dec. 2025)

[3] Fractional Calculus for Federated Learning (FC4FL) webpage: https://mechatronics.ucmerced.edu/fc4fl

[4] Mohammad Partohaghighi. "Smart Federated Learning and Unlearning: Theoretical Framework, Benchmark Studies, and Applications," Ph.D. dissertation, EECS, UC Merced, May 2026.

[5] Optimization, Big Data, and AI/ML: A section of *Fractal and Fractional* (ISSN 2504-3110). https://www.mdpi.com/journal/fractalfract/sections/Optimization_Big_Data_AIML

Numerical studies of anomalous diffusion in heterogeneous media

05 Dec
16:00
CET

Yanzhi Zhang
Missouri University of Science and Technology, Rolla, USA

Time: 16:00 - 17:00 CET (Rome / Paris)
Date: 05 December 2025
YouTube: https://www.youtube.com/watch?v=i7jY2Xo0hjk

Hosted at: SISSA, International School of Advanced Studies, Trieste, Italy

Organizers: Pavan Pranjivan Mehta* and Arran Fernandez**

* SISSA, International School of Advanced Studies, Trieste, Italy

** Eastern Mediterranean University, Northern Cyprus

Keywords: variable-order fractional Laplacian, meshfree methods, radial basis functions, anomalous diffusion

Abstract: The transition between different diffusion states is a common feature in highly heterogeneous, fractal-like media. This phenomenon is observed across various fields, including dusty plasma, living human cells, hydrology, proteins, and polymer liquids. The application of nonlocal fractional models to study anomalous diffusion transitions is a relatively recent advancement. In particular, the variable-order fractional Laplacian plays a key role in understanding heterogeneous systems. In this talk, we will explore the challenges and current progress in studying anomalous diffusion in heterogeneous media. We will also introduce our meshfree methods for solving the variable-order Laplacian and discuss their properties. Additionally, we will apply these methods to investigate the solution behaviors of variable-order fractional PDEs in different contexts.

Biography: Dr. Yanzhi Zhang is a Gary Havener Endowed Professor in the Department of Mathematics and Statistics at Missouri University of Science and Technology (Missouri S&T). She received her Ph.D. in Computational Mathematics from the National University of Singapore in 2006, completed a postdoctoral appointment in the Department of Scientific Computing at Florida State University, and joined the faculty at Missouri S&T in 2010. Dr. Zhang's current research interests include data-informed modeling for seismic waves, reduced-order modeling, fractional and nonlocal PDEs, and multiscale/multiphysics modeling and simulation.

Bibliography

[1] Y. Wu and Y. Zhang. “Variable-order Laplacian and its computations with meshfree methods”. *Journal of Scientific Computing* 99 (2024), article 18.

[2] J. Burkardt, Y. Wu, and Y. Zhang, “A unified meshfree pseudospectral method for solving both classical and fractional PDEs”. *SIAM Journal of Scientific Computing*, 43 (2021), pp. A1389– A1411.

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Keyword Index


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