

**PiAI Seminar Series: Physics informed AI in Plasma Science**  
**9:30-10:30, 31 January 2022 (CET)**  
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**Web Seminar**

Mori-Zwanzig projection operator method as a statistical analysis of  
multivariate time-series data

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Mori-Zwanzig (MZ) projection operator method is a mathematical method developed in non-equilibrium statistical physics [1,2], which decomposes a time propagator into the projected and complementary parts by the Dyson decomposition with a user-defined projection operator. Application of MZ formalism to practical data analysis has been actively studied from the viewpoints of optimal prediction or data-driven learning [3-6].

In this presentation, we will explain the formulation of the projection operator method, the validity range of the method, and the procedure to apply the method to analyze multivariate time-series ensemble data as a practical data analysis tool. As an example, we have analyzed the nonlinear excitation and damping of zonal flows in Hasegawa-Wakatani resistive drift wave turbulence. We found that Reynolds stress of turbulence on zonal flows acts not only a stochastic forcing but also damping via the correlation with the memory term. The applicability of MZ formalism to the physical analysis and the reduced modeling is demonstrated.

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- [2] H. Mori, Prog. Theor. Phys. 33, 423 (1965).
- [3] A. J. Chorin, O. H. Hald, R. Kupferman, PNAS 97, 2968 (2000).
- [4] E. Darve, J. Solomon, A. Kia, PNAS 106, 10884 (2009).
- [5] S. Maeyama, and T.-H. Watanabe, J. Phys. Soc. Jpn. 89, 024401 (2020); Source code is available from <https://github.com/smaeyama/mzprojection>.
- [6] Y. T. Lin, Y. Tian, M. Anghel, D. Livescu, Phys. Fluids 33, 125118 (2021).