



Politecnico
di Torino



Mu1Mo_pro
LIVING SIMULATIONS

Discrete-State Diffusion Modeling for Scientific Applications

Generative diffusion models have achieved remarkable success in human-centric image generation, yet their reliance on continuous-state spaces makes it extremely difficult to enforce hard constraints—such as conservation laws in physical systems. In this seminar, I will introduce a complete theoretical framework for diffusion in discrete-state Markov processes, moving beyond Gaussian-based models to develop a formulation that fundamentally defines how diffusion operates in discrete spaces.

This framework enables generative models to strictly preserve quantities like mass for material generation, and multiphase flow simulations—domains where conventional diffusion models fail. I will present numerical experiments, including Blackout Diffusion, which generates images from an empty state rather than noise, demonstrating the feasibility and power of this approach. By establishing exact formulations for forward and reverse diffusion in discrete spaces, this work opens the door to new applications in engineering and scientific modeling, bridging the gap between genAI and real-world physical constraints.



Aula Denina, 1st floor DISAT



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12:00



Javier E. Santos is a computational earth scientist at Los Alamos National Laboratory (LANL), specializing in generative modeling, numerical simulation, and scientific machine learning. He earned his Ph.D. from The University of Texas at Austin and was a Director's Postdoctoral Fellow at LANL. His recent work has been published in ICML, NeurIPS workshops, and Nature Machine Intelligence, advancing the intersection of generative AI and physics-based modeling. Outside of research, he enjoys rock climbing and skiing—so if you're up for an adventure, let him know!