Carlo Vanoni

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Research profile. Theoretical and computational physicist studying how correlations, constraints, and geometry govern localization, transport, and quantum dynamics in disordered systems. My work connects resonance-based approaches to Anderson and many-body localization with hyperuniformity and the transport properties of heterogeneous media.

Academic Appointments



Fall 2024–present

Postdoctoral Research Associate
Department of Physics, Princeton University
Princeton, NJ, USA
Advisors: Paul J. Steinhardt and Salvatore Torquato.

Education and Visiting Positions



2020–2024

Ph.D. *cum laude* in Statistical Physics
SISSA - International School for Advanced Studies
Trieste, Italy
Thesis: *Non-equilibrium dynamics and localization in statistical quantum systems.*
Supervisors: Andrea Gambassi and Antonello Scardicchio.



Apr.–Jun. 2023

Visiting Ph.D. Student
Boston University
Boston, MA, USA
Advisor: Anushya Chandran.



2021–2024

Visiting Ph.D. Student
ICTP - International Centre for Theoretical Physics
Trieste, Italy
Advisor: Antonello Scardicchio.



2018–2020

M.Sc. *cum laude* in Physics
University of Milan
Milan, Italy
Thesis: *Localization and Ergodicity in the Discrete Non-Linear Schrödinger Equation.*
Supervisors: Sergio Caracciolo and Antonello Scardicchio.



2015–2018

B.Sc. *cum laude* in Physics
University of Milan
Milan, Italy
Thesis: *Monopartite Euclidean Travelling Salesman Problem in One Dimension.*
Supervisor: Sergio Caracciolo.

Research Directions

- **Localization and quantum dynamics in disordered systems**: resonances, ergodicity, scaling, and finite-size effects.
- **Hyperuniformity and correlated disorder**: wave transport, effective delocalization, transparency, and heterogeneous media.
- **Constraints and emergent statistical structure**: temporal correlations, constrained systems, and sphere packing.

Honors and Awards

2023 Italian Physical Society "Augusto Righi" Prize: Young physicist award for scientific productivity.
2015 Bronze Medal at the national level of the Italian Physics Olympics.
2014 Winner of the Valerio Filippini Physics Prize.
2014 Selected for the scientific preparation of the Italian team at the International Physics Olympiads at ICTP.

Selected Talks, Seminars, and Conference Presentations

Oct. 2026 **Invited speaker**. Workshop on Quantum Matter beyond Ergodicity and Thermalization, International Institute of Physics. *Natal, RN, Brazil.*
Sept. 2026 **Invited fellow and speaker**. Program on Quantum Matter beyond Ergodicity and Thermalization, International Institute of Physics. *Natal, RN, Brazil.*
Apr. 2026 **Tutorial and talk**. Applied Statistical Mechanics Seminar, Boston University. *Boston, MA, USA.*
Dec. 2025 **Seminar**. Young Seminar Series of the Italian Society for Statistical Physics. *Online.*
Dec. 2025 **Short talk**. 129th Statistical Mechanics Conference. *Rutgers University, NJ, USA.*
Nov. 2025 **Seminar**. MURI Collaboration on Hyperuniformity. *Online.*
Mar. 2025 **Contributed talk**. APS Global Physics Summit. *Anaheim, CA, USA.*
Aug. 2024 **Seminar**. Condensed Matter Division, Max Planck Institute for the Physics of Complex Systems. *Dresden, Germany.*
Apr. 2024 **Seminar**. Condensed Matter Theory Group, Boston University. *Boston, MA, USA.*
Mar. 2024 **Seminar**. Department of Mathematics, University of Bologna. *Bologna, Italy.*
Dec. 2023 **Contributed talk**. Non-Equilibrium Quantum Workshop. *IJS, Krvavec, Slovenia.*

Teaching, Mentoring, Outreach, and Academic Service

2026 Guest Lecturer, "Random Heterogeneous Materials," Princeton University.
2024 Mentor, ReMatch undergraduate research mentoring program, Princeton University.
2023 Master's thesis co-supervision: Giulia Tranquillini, University of Trieste. Principal supervisors: Antonello Scardicchio and Fabio Benatti.
2023–2024 Students' representative for the Statistical Physics group, SISSA.
2022–2023 Website management for the Statistical Physics group, SISSA.
2016–2019 Physics Olympics preparation lessons in classical mechanics and electromagnetism, Liceo Scientifico Viale dei Tigli, Italy.

Conference organization

Dec. 2026 *Hidden Order in Disorder: The Expanding Landscape of Hyperuniformity*, PCTS Workshop, Princeton University. Webpage
Oct. 2022 *The Many Facets of Statistical Field Theory*, SISSA, Trieste. Webpage

Refereeing

- Referee for *SciPost*, *Physical Review A*, *Physical Review B*, *Physical Review Research*, *Physical Review X*, *Physical Review Letters*, *Journal of Statistical Mechanics: Theory and Experiment*, and *Annals of Physics*.

Selected Schools, Programs, and Extended Visits

Jun. 2026 Software Engineering Summer School, Research Computing, Princeton University.
Oct. 2024 Bootcamp: Parallel Programming and GPU, Research Computing, Princeton University.
Aug. 2024 Visiting, Condensed Matter Division, Max Planck Institute for the Physics of Complex Systems, Dresden.
May 2024 Program: New Directions in Far-from-Equilibrium Integrability and Beyond, Simons Center for Geometry and Physics, Stony Brook.
Jul. 2023 Boulder Summer School: Non-Equilibrium Quantum Dynamics, University of Colorado Boulder.
Jun. 2023 Visiting, Physics Department, Princeton University.
Jun. 2022 The Beg Rohu Summer School: Non-Equilibrium Dynamics, Saint-Pierre Quiberon, France.
Feb. 2021–2022 GGI Winter School in Statistical Field Theory, Florence.

Publications

Peer-Reviewed

1. **Effective delocalization in the one-dimensional Anderson model with stealthy disorder**. **C. Vanoni**, J. Karcher, M. C. Rechtsman, B. L. Altshuler, P. J. Steinhardt, and S. Torquato. *Physical Review Letters* **136**, 150404 (2026) *(Editors' Suggestion)*. Link to the paper.

2. **Quantifying when hyperuniformity of a many-particle system leads to uniformity across length scales**. **C. Vanoni**, P. J. Steinhardt, and S. Torquato. *Physical Review E* **112**, 044142 (2025). Link to the paper.

3. **Dynamical properties of particulate composites derived from ultradense stealthy hyperuniform sphere packings**. **C. Vanoni**, J. Kim, P. J. Steinhardt, and S. Torquato. *Physical Review E* **112**, 015406 (2025). Link to the paper.

4. **Scaling analysis and renormalization group on the mobility edge in the quantum random energy model**. F. Balducci, G. Bracci Testasecca, J. Niedda, A. Scardicchio, and **C. Vanoni**. *Physical Review B* **111**, 214206 (2025). Link to the paper.

5. **Investigating finite-size effects in random matrices by counting resonances**. A. Kutlin and **C. Vanoni**. *SciPost Physics* **18**, 090 (2025). Link to the paper.

6. **Scaling theory of fading ergodicity**. R. Świątek, M. Hopjan, **C. Vanoni**, A. Scardicchio, and L. Vidmar. *Physical Review Letters* **135**, 170401 (2025). Link to the paper.

7. **Renormalization-group analysis of the many-body localization transition in the random-field XXZ chain**. J. Niedda, G. Bracci Testasecca, G. Magnifico, F. Balducci, **C. Vanoni**, and A. Scardicchio. *Physical Review B* **112**, 144201 (2025). Link to the paper.

8. **Renormalization group for Anderson localization on high-dimensional lattices**. B. L. Altshuler, V. E. Kravtsov, A. Scardicchio, P. Sierant, and **C. Vanoni**. *PNAS* **122**, e2423763122 (2025). Link to the paper.

9. **An analysis of localization transitions using non-parametric unsupervised learning**. **C. Vanoni** and V. Vitale. *Physical Review B* **110**, 024204 (2024). Link to the paper.

10. **Renormalization group analysis of the Anderson model on random regular graphs**. **C. Vanoni**, B. L. Altshuler, V. E. Kravtsov, and A. Scardicchio. *PNAS* **121**, e2401955121 (2024). Link to the paper.

11. **A hydrodynamic approach to Stark localization**. L. Capizzi, **C. Vanoni**, P. Calabrese, and A. Gambassi. *Journal of Statistical Mechanics: Theory and Experiment* , 073104 (2023). Link to the paper.

12. **Interface dynamics in the two-dimensional quantum Ising model**. F. Balducci, A. Gambassi, A. Lerose, A. Scardicchio, and **C. Vanoni**. *Physical Review B* **107**, 024306 (2023). Link to the paper.

13. **Slow melting of a disordered quantum crystal**. F. Balducci, A. Scardicchio, and **C. Vanoni**. *Physical Review B* **107**, 024201 (2023). Link to the paper.

14. **Localization and melting of interfaces in the two-dimensional quantum Ising model**. F. Balducci, A. Gambassi, A. Lerose, A. Scardicchio, and **C. Vanoni**. *Physical Review Letters* **129**, 120601 (2022). Link to the paper.

15. **Localization in the discrete non-linear Schrödinger equation and geometric properties of the microcanonical surface**. C. Arezzo, F. Balducci, R. Piergallini, A. Scardicchio, and **C. Vanoni**. *Journal of Statistical Physics* **186**, 24 (2022). Link to the paper.

16. **Average optimal cost for the Euclidean TSP in one dimension**. S. Caracciolo, A. Di Gioacchino, E. M. Malatesta, and **C. Vanoni**. *Journal of Physics A: Mathematical and Theoretical* **52**, 264003 (2019). Link to the paper.

Preprints

1. **Exact cost of the Euclidean Maximum Traveling Salesman Problem in one dimension**. S Caracciolo, **C. Vanoni**. *arXiv:2610.26536 (2026)*, Link to the paper.

2. **Quantum transmission in 1D disordered stealthy hyperuniform Kronig–Penney-like models**. S Yuan, **C. Vanoni**, S. Torquato. *arXiv:2610.02501 (2026)*, Link to the paper.

3. **Inferring stealthy hyperuniform correlations from quantum transport**. N. C. Costa, M. S. Ferreira, C. Lewenkopf, F. A. Pinheiro, P. J. Steinhardt, S. Torquato, **C. Vanoni**. *arXiv:2608.11188 (2026)*, Link to the paper.

4. **Analysis of Conjectural Improvements to Minkowski's Lower Bound on the Sphere Packing Density**. **C. Vanoni**, A. Guo, S. Torquato. *arXiv:2608.00920 (2026)*, Link to the paper.

5. **Semi-fractality and localization on a chiral Cayley tree**. **C. Vanoni**, V. E. Kravtsov, B. L. Altshuler. *arXiv:2607.18179 (2026)*, Link to the paper.

6. **Two-dimensional stealthy hyperuniform polycrystalline disk packings**. **C. Vanoni**, P. J. Steinhardt, S. Torquato. *arXiv:2606.23628 (2026)*, Link to the paper.

7. **Resonance Proliferation Across Localization Transitions**. **C. Vanoni**, D. M. Long, A. Chandran. *arXiv:2605.05445 (2026)*, Link to the paper.