



Pablo Villegas

Curriculum Vitae

Personal data

Date and place of birth: June 16, 1990 (El Ejido, Almería, Spain)

Research interests

Statistical physics, phase transitions and criticality, complex networks, stochastic processes, collective phenomena, biological physics, ecological networks, brain networks.

Research experience

- Sep 2023 - **Scientific researcher**, *Enrico Fermi Center for Study and Research Today (Rome, Italy)*
- Jan 2022 - **Postdoctoral Research Associate**, *Enrico Fermi Center for Study and Research (Rome, Italy)*
Aug 2023
- Sep 2020 - **Postdoctoral Research Associate**, *Networks Unit, IMT (Lucca, Italy)*
Jan 2022
- Jan 2019 - **Postdoctoral Research Associate**, *Institute for Complex Systems (ISC-CNR, Rome, Italy)*
Aug 2020
- Feb 2018 - **Period of Postdoctoral Orientation (POP)**, *University of Granada*
Jan 2019
- Apr 2015 - **Ph.D. Fellowship (Ministerio de Economía y Competitividad)**,
Feb 2018 *Statistical physics group (University of Granada)*

University studies and diplomas

- Oct 2014 - **PhD in physics**, *University of Granada, magna cum laude*
Feb 2018 Dissertation: "*Phases and phase transitions in living matter.*"
Advisor: Miguel Á. Muñoz
- Sep 2014 - **MSc in Teaching Compulsory and Pre-University Secondary Education, Vocational Training and Language Teaching**,
Sep 2015 *University of Granada, 9.1/10*
Thesis: "*Educational applications in Vpython employing cooperative learning.*"
Advisors: Pablo I. Hurtado, Francisco de los Santos

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- Sep 2013 - **MSc FisMat: Biomathematics**, *University of Granada*, 9.7/10
 Jul 2014 Thesis: “*Synchronization: Study and applications of the Kuramoto model*”.
 Advisors: Miguel Á. Muñoz, Paolo Moretti
- Sep 2008 - **BSc+MSc in Physics (Licenciado en Física)**, *University of Granada*,
 Jul 2013 7.5/10

Publications

- 2025 **L.Lucarini, G.Cimini & P.Villegas**, *Geometric Criticality in Scale-Invariant Networks*, Under revision in PRL
- 2025 **G.Iannelli & P.Villegas**, *Chladni states in Ising Spin Lattices*, Submitted.
- 2025 **G.Iannelli, P.Villegas, T.Gili & A.Gabrielli**, *Topological Symmetry Breaking in Antagonistic Dynamics*, Under revision in Nat.Comm.
- 2025 **S.Meloni, A.Gabrielli & P.Villegas**, *Higher-order contagion processes in 1.99 dimensions*, Under revision in PRL
- 2025 **L. Falsi, P. Villegas, T. Gili, A.J. Agranat, & E. DelRe**, *Topological protection breakdown: A route to frustrated ferroelectricity*, Phys. Rev. Research 7, 043038
- 2025 **P.Villegas**, *Strange attractors in complex networks*, Phys. Rev. E 111, L042301
- 2025 **A.Poggialini, P.Villegas, M.A.Muñoz & A.Gabrielli**, *Networks with many structural scales: a Renormalization Group perspective*, Phys. Rev. Lett. 134, 057401
- 2025 **P.Villegas, A.Gabrielli, A.Poggialini & T.Gili**, *Multi-scale Laplacian community detection in heterogeneous networks*, Phys. Rev. Res. 7, 013065
- 2024 **G.Caldarelli, A.Gabrielli, T.Gili & P.Villegas**, *Laplacian renormalization group: an introduction to heterogeneous coarse-graining*, Phys. Rev. E 109, L042402
- 2024 **P.Villegas, T.Gili, G.Caldarelli & A.Gabrielli**, *Evidence of scale-free clusters of vegetation in tropical rainforests*, Phys. Rev. E 109, L042402, Editor’s suggestion and featured in physics by Philip Ball in "Uncovering Networks in Rainforest Plants." Physics 17 (2024): 68
- 2023 **P.Villegas, T.Gili, G.Caldarelli & A.Gabrielli**, *Laplacian Renormalization Group for heterogeneous networks*, Nat. Phys. 19, 445–450, **Cover of the March issue & featured on the news&views**: Klemm, K. *A zoom lens for networks*. Nat. Phys. 19, 318–319 (2023).
- 2022 **P.Villegas, A.Gabrielli, F.Santucci, G.Caldarelli & T.Gili**, *Laplacian paths in complex networks: information core emerges from entropic transitions*, Phys. Rev. Research 4, 033196

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- 2022 **P.Villegas, T.Gili, A.Gabrielli & G.Caldarelli**, *Characterizing spatial point processes by percolation transitions*, *J. Stat. Mech.* 073202
- 2022 **V.Buendía, P.Villegas, R.Burioni & M.A.Muñoz**, *The broad edge of synchronization: Griffiths effects and collective phenomena in brain networks*, *Phil. Trans. R. Soc. A.* 380: 20200424
- 2022 **A.Cavagna, A.Culla, X.Feng, I.Giardina, T.S.Grigerá, W.Kion-Crosby, S.Melillo, G.Pisegna, L.Postiglione & P.Villegas**, *Marginal speed confinement resolves the conflict between correlation and control in natural flocks of birds*, *Nat. Commun.* 13, 2315
- 2021 **P.Villegas, T.Gili & G.Caldarelli**, *Emergent spatial patterns of coexistence in species-rich plant communities*, *Phys. Rev. E* 104, 034305
- 2021 **V.Buendía, P.Villegas, R.Burioni & M.A.Muñoz**, *Hybrid-type synchronization transitions: Where incipient oscillations, scale-free avalanches, and bistability live together*, *Phys. Rev. Res.* 3 (2), 023224
- 2021 **A.Cavagna, X.Feng, S.Melillo, L.Parisi, L.Postiglione & P.Villegas**, *CoMo: A novel co-moving 3D camera system*, *IEEE Trans. Instrum. Meas.*, 70, 1-16
- 2021 **P.Villegas, A.Cavagna, M.Cencini, H Fort & T.S.Griguera**, *Joint assessment of density correlations and fluctuations for analysing spatial tree patterns*, *Roy. Soc. Open Sci.*, 8(1), 202200
- 2020 **V.Buendía, S.di Santo, P.Villegas, R.Burioni & M.A.Muñoz**, *Self-organized bistability and its possible relevance for brain dynamics*, *Phys. Rev. Research* 2, 013318
- 2020 **P.Villegas, M.A.Muñoz & J.A.Bonachela**, *Evolution in the Debian GNU/Linux software network: analogies and differences with gene regulatory networks*, *J. R. Soc. Interface* 17 (163), 20190845
- 2019 **V.Buendía, P.Villegas, S.di Santo, A.Vezzani, R.Burioni & M.A.Muñoz**, *Jensen's force and the statistical mechanics of cortical asynchronous states*, *Sci. Rep.* 9, 15183
- 2019 **P.Villegas, S.di Santo, R.Burioni & M.A.Muñoz**, *Time-series thresholding and the definition of avalanche size*, *Phys. Rev. E* 100, 012133
- 2018 **S.di Santo, P.Villegas, R.Burioni & M.A.Muñoz**, *Non-normality, reactivity, and intrinsic stochasticity in neural dynamics: a non-equilibrium potential approach*, *J. Stat. Mech. Theory Exp.*, 2018(7), 073402
- 2018 **S.di Santo***, **P.Villegas***, **R.Burioni & M.A.Muñoz**, *Landau-Ginzburg theory of cortex dynamics: scale-free avalanches emerge at the edge of synchronization*, *Proc. Natl. Acad. Sci. USA*, 115(7), E1356-E1365. (* Joint 1st authors)

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- 2017 **S.di Santo, P.Villegas, R.Burioni & M.A.Muñoz**, *Simple unified view of branching process statistics: Random walks in balanced logarithmic potentials*, Phys. Rev. E, 95(3), 032115
- 2016 **P.Villegas, J.M. Ruiz, J.Hidalgo & M.A.Muñoz**, *Intrinsic noise and deviations from criticality in Boolean gene-regulatory networks*, Sci. Rep. 6, 34743
- 2016 **P.Villegas, J.Hidalgo, P.Moretti & M.A.Muñoz**, *Complex synchronization patterns in the human connectome network*, Proceedings of ECCS 2014: European Conference on Complex Systems (pp. 69-80). Springer International Publishing
- 2014 **B.Moglia, E.Albano, P.Villegas & M.A.Muñoz**, *Interfacial depinning transitions in disordered media: revisiting an old puzzle*, J. Stat. Mech. Theory Exp., 2014(10), P10024
- 2014 **P.Villegas, P.Moretti & M.A.Muñoz**, *Frustrated hierarchical synchronization and emergent complexity in the human connectome network*, Sci. Rep. 4, 5990

Contributions to Scientific Conferences

- Jul 2025 **Complex Networks and Their Applications – StatPhys29 Satellite Workshop**, Venice (Italy), Talk.
- Jul 2025 **StatPhys29 – The 29th International Conference on Statistical Physics**, Florence (Italy), Talk.
- Jul 2024 **Complex networks: from socio-economic systems to biology and the brain**, Lipari (Italy), Talk.
- Jan 2024 **NetSciX 2024 - International School and Conference on Network Science**, Venice (Italy), Talk.
- Sep 2023 **Granada Seminar: Machine Learning and Physics**, Granada (Spain), Talk.
- Jul 2023 **Complex networks: from socio-economic systems to biology and the brain**, Lipari (Italy), Talk.
- Oct 2022 **Conference on Complex Systems**, Mallorca (Spain), Talk.
- Jul 2022 **Complex networks: from socio-economic systems to biology and the brain**, Lipari (Italy), Talk.
- Jun 2022 **II Conference of the Italian Society of Statistical Physics (SIFS)**, Parma (Italy), Talk.
- Sep 2019 **15th Granada Seminar: Stochastic and Collective Effects in Neural Systems**, Granada (Spain), Talk.
- Jul 2019 **StatPhys27**, Buenos Aires (Argentina), Attendant.

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- Jul 2019 **Workshop: Statistical Mechanics of Swarming Behaviour**, La Plata (Argentina), Talk.
- Jun 2019 **24rd National Conference on Statistical Physics and Complex Systems**, Parma (Italy), Poster.
- Jun 2019 **Statistical mechanics of active matter**, L'Aquila (Italy), Attendant.
- Jun 2018 **23rd National Conference on Statistical Physics and Complex Systems**, Parma (Italy), Poster.
- Apr 2017 **FISES 2017**, Sevilla (Spain), Poster.
- Nov 2016 **III Scientific Conferences of the “Carlos I” Institute of Theoretical and Computational Physics**, Granada (Spain), Poster.
- Jun 2016 **Quantitative Laws II: From physiology to ecology, from interaction structures to collective behavior**, Como (Italy), Talk.
- May 2016 **I Conferences for young researchers: fostering the interdisciplinarity**, Granada (Spain), Talk.
- Oct 2015 **II Scientific Conferences of the “Carlos I” Institute of Theoretical and Computational Physics**, Granada (Spain).
- Oct 2015 **FISES 2015**, Badajoz (Spain), Talk.
- Sep 2015 **Net-Works 2015: Complex networks and their interdisciplinary applications**, Granada (Spain). **Local organizing committee.**
- Jun 2015 **13th Granada Seminar on Computational and Statistical Physics**, La Herradura (Spain). Talk. **Local organizing committee.**
- May 2015 **BIOMAT: Emergence and self-organization in social and biological systems**, Granada (Spain). Attendant.
- Sep 2014 **Summer School on Statistical Physics of Complex Systems**, *IFISC*, Palma de Mallorca (Spain), poster and talk.

Academic service

- 2018-2019 **Complementary training in physics and chemistry (0.75 cr, MSc in Teaching Compulsory and Pre-University Secondary Education, Vocational Training and Language Teaching)**, *University of Granada*, Spain
- 2017-2018 **Physics of complex systems (1.5 cr, degree in Physics), Computational physics (1.5 cr, degree in Physics)**, *University of Granada*, Spain
- 2016-2017 **Computational physics (2.2 cr, degree in Physics), Statistical physics (1.5 cr, degree in Physics)**, *University of Granada*, Spain
Supervision of Master Thesis
- 2022-Today **Lorenzo Lucarini, Ottavia Falconi**

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Co-supervision of PhD Thesis
 2021-2025 **Francesca Santucci**, IMT Lucca
 2022-2025 **Anna Poggialini**, CREF
 2022-2025 **Giulio Iannelli**, CREF
 2022-Today **Gabriele Poidomani**, CREF
 2023-Today **Lorenzo Grimaldi**, CREF
 2024-Today **Lorenzo Lucarini**, CREF
 2024-Today **Ottavia Falconi**, CREF

Secondments & short visits

Nov 2019 **Department of Materials Science**, University of Erlangen-Nürnberg (Germany), invited seminar
 Jul 2019 **IFLYSIB**, University of La Plata (Argentina)
 Jun 2018 **Department of Mathematics, Physics and Computer Science**, University of Parma (Italy)
 May-Aug 2017 **MASTS Marine Population Modelling Group. Department of Mathematics and Statistics**, University of Strathclyde (Glasgow, UK)

Grants

May-Aug 2017 **Mobility grant**, *University of Strathclyde (Glasgow, UK)*
 Advisor: J.A. Bonachela
 MASTS Marine Population Modelling Group. Department of Mathematics and Statistics.
 Funded by MINECO
 Apr 2015 - **Doctoral grant**, *University of Granada*
 Feb 2018 Advisor: Miguel Á. Muñoz.
 Grant (FPI programme) at the Dept. Electromagnetism and Matter Physics.
 Funded by MINECO

Awards

Jan 2020 **Seal of excellence: MSCA-IF High Quality Project. “Statistical Mechanics of Tropical Rainforests ”**, (87.0/100), ISC-CNR (Rome, Italy)

Participation in Funded Projects

Oct 2021 - **Structure and function of cortex neural networks: Connecting fundamental, biomedical and computational aspects**, *P20_00173*, Regional Plan of I+D+i Andalucía 2020
 Jul 2023
 Sep 2021 - **Advances in statistical physics: from fundamentals to the physics of living systems**, *PID2020-113681GB-I00*, National Plan of I+D+i (MINECO)
 Sep 2024

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- Jan 2019 - **Collective Response from Individual Behavior in Groups and Ecosystems (CRIB)**, *ELAC2015/T01- 0593*. *ERANET-LAC 2016 (EU)*
- Jan 2018 - **Frontiers of statistical physics and complex systems: From basic principles to the last developments in condensed matter, neuroscience and systems biology**, *FIS2017-84256-P*, National Plan of I+D+i (MINECO, Spain)
- Apr 2015 - **Statistical physics of complex systems: From basic principles to the frontiers of matter physics, ecology and neuroscience**, *FIS2013-43201-P*, National Plan of I+D+i (MINECO, Spain)

Languages

Spanish: ● ● ● ● ● Mother tongue

English: ● ● ● ● ●

Italian: ● ● ● ● ●

Computer skills

- OS: GNU/Linux, Windows
- Document processing: LyX (\LaTeX), LibreOffice Writer, Word
- Programming: Fortran, C, Python, \LaTeX , R
- Parallel computing: OpenMP, PROTEUS (supercomputer center)
- Others: Matlab, Maxima & Mathematica (Computer algebra systems)

Others

- Nov 2018 **Scientific disclosure for researchers: press, TV and radio**, 15 hours, Granada (Spain). Attendant
- Oct 2018 **Supervision of academic works: PhDs, Master Theses and Graduate Theses**, 20 hours, Granada (Spain). Attendant
- Mar 2016 **Educational tools for peer production**, 20 hours, Granada (Spain). Attendant
- Sep 2016 **Training days: Initiation to University Teaching for FPU and FPI PhD students**, 20 hours, Granada (Spain). Attendant
- 2018-Today **Peer Review**, *Physical Review Letters*, *Physical Review X*, *Science Advances*, *Physical Review E*, *Nature Communications*, *PLoS One*, *Physica D: Nonlinear Phenomena*, *Neurocomputing*, *Scientific Reports*, *Journal of Physics: Complexity*, *Cambridge Elements*

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