

# Pablo J. Bilbao

LEVERHULME-PEIERLS POSTDOCTORAL FELLOW, UNIVERSITY OF OXFORD

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## Affiliations

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- Grupo de Lasers e Plasmas (GoLP)/IPFN, IST, Universidade de Lisboa, PT (2020–2025)
- Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, UK (Since Oct 2025)

## Education

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- Ph.D. in Physics, Instituto Superior Técnico, Portugal, September 2025  
*Thesis: “Kinetic Instabilities in Extreme Plasma Physics: Laboratory and Astrophysical Dynamics”*  
*Advisor: Prof. L. O. Silva*  
*Awarded “Pass with Distinction and Honour” (Highest grade).*
- Master of Physics in Particle Physics with Cosmology, Lancaster University, UK, 2020  
Awarded First Class Honours Degree

## Fellowships

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- Leverhulme–Peierls Fellowship, University of Oxford (2025–2028)  
Competitive independent research fellowship at the Rudolf Peierls Centre for Theoretical Physics  
Includes junior membership of Lady Margaret Hall.

## Invited talks

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- European Physics Society Plasma Physics conference, July 2024 (Salamanca, Spain)  
“Coherent electron cyclotron maser emission triggered by radiation reaction”.
- High Energy Density Laboratory Astrophysics (HEDLA), May 2024 (Tallahassee, FL)  
“Laboratory analogues of astrophysical coherent maser processes”.
- Fifth Purdue Workshop on Relativistic Plasma Astrophysics, May 2024 (Purdue, IN)  
“Radio Masers in the Synchrotron Dominated Regime”.
- 65 Annual Meeting of the American Physics Society Division of Plasma Physics, Nov 2023 (Denver, CO)  
“Kinetically unstable distributions as a result of radiative damping in strong electromagnetic fields”.
- New Perspectives in Numerical Methods for High-Energy Multi-Scale Astrophysics at the Princeton Center for Theoretical Science, April 2023 (Princeton, NJ)  
“A general approach for acceleration of PIC simulations with Machine Learning-based models”.
- LPHYS’22, June 2022 (Online)  
“The Impact of Radiation Reaction on the Topology of the Momentum Space”.

## Colloquia

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- Journal of Plasma Physics (JPP) Frontiers of Plasma Physics Colloquium, 2024 (online)  
“Radiative Dynamics and Instabilities in Strongly Magnetized Relativistic Plasmas”.
- Columbia university/Flatiron institute, Center for Computational Astrophysics, 2024 (New York, NY)  
“Coherent radiation in extreme astrophysical plasmas”.
- Institute for Advanced Studies, 2024 (Princeton, NJ)  
“Radiatively cooled kinetic astrophysical plasmas”.
- UCLA Laser-Plasma research group, 2024 (Los Angeles, CA)  
“Radiatively cooled kinetic plasma physics in astrophysics and the laboratory”.
- Imperial College Plasma Physics Group, 2024 (London, GB)  
“Betatron cooling as a source of ring-beam distributions analogous to synchrotron cooling”.
- Oxford University Plasma Theory Group, 2023 (Oxford, UK)  
“Nonlinear cooling and kinetic instabilities in strong field plasma physics”

## Research Grants

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- **Co-PI** of the project *Realistic sim. relativistic plasmas in astrophysical and laboratory environments*, awarded **30 million CPU hours** in MareNostrum 5 (Spain) by the National Network for Advanced Computing (**RNCA**, Portugal).
- **PI** of the project *Maser in Astrophysical Plasmas (MAPs)* awarded **20 million CPU hours** in Deucalion (Portugal) by the National Network for Advanced Computing (**RNCA**, Portugal).

- **PI** of the project *Maser in Astrophysical Plasmas 2 (MAPs-2)* awarded **30 million CPU hours** in Deucalion (Portugal) by the National Network for Advanced Computing (**RNCA**, Portugal).
- **Co-PI** of the project *Coherent Radiation Mechanisms in Extreme Plasma Physics (CREPE)*, awarded **33 million CPU hours** in LUMI-C (Finland) by the European High Performance Computing Joint Undertaking (**EuroHPC-JU**).

## Reviewer

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- Peer-review for Physics of Plasma (2024-present)
- Peer-review for The Astrophysical Journal (2024-present)

## Research featured in the media

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- Work on the *Fireball* experiment was featured in *Público* (online, 25 June 2024), Portugal's largest newspaper by readership. [publico.pt](https://publico.pt)
- Work on synchrotron-induced electron cyclotron maser emission was featured in *Público* (online and print, 21 April 2025). [publico.pt](https://publico.pt)
- Work on the suppression of beam-plasma instabilities in the *Fireball* experiment (PNAS, 2025) was featured in press releases and institutional communications following the paper's acceptance. [Space.com](https://space.com), [ox.ac.uk](https://ox.ac.uk)

## Supervision & Teaching

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- Co-supervisor of Francisco Assunção Masters Thesis (IST Lisbon, 2025)  
“Particle drifts in the radiatively cooled regime and its applications to astrophysical plasmas”
- Co-supervisor of Joao Joaquim Masters Thesis (IST Lisbon, 2025)  
“Radiation reaction in curved space-times”
- Teaching assistant: Prof. Luís O. Silva’s “Discoveries of modern Physics” course for 100 2nd year Physics undergraduate students (Fall terms 2022, 2023 & 2024).
- Co-supervisor of 2 Bachelor student internships (IST Lisbon, 2023)  
“CERN Fireball” & “Particle Drifts and Radiation Reaction”

## Distinctions

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- Awarded second place for best video at the 62nd Annual Meeting of the American Physical Society Division of Plasma Physics (APS-DPP) 2020 Visual Science Communication Competition.
- Awarded second place for best video at the 63rd Annual Meeting of the American Physical Society Division of Plasma Physics (APS-DPP) 2021 Visual Science Communication Competition.

## Publications

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Published:

- L. Gizzi, E. Boella, L. Labate, F. Baffigi, **P. J. Bilbao** et al. *Scientific reports* 11.1:13728 (2021): “Enhanced laser-driven proton acceleration via improved fast electron heating in a controlled pre-plasma”.
- C. Badiali, **P. J. Bilbao** et al., *Journal of Plasma Physics* 88.6:895880602 (2022): “Machine-learning-based models in particle-in-cell codes for advanced physics extensions.”
- **P. J. Bilbao** & L. O. Silva, *Physical Review Letters* 130.16:165101(2023): “Radiation reaction cooling as a source of anisotropic momentum distributions with inverted populations” (Editor’s suggestion).
- **P. J. Bilbao** et al. *Physics of Plasmas* 31 (5), 052112 (Papers from the 65th APS DPP annual meeting) (2024): “Ring momentum distributions as a general feature of Vlasov dynamics in the synchrotron dominated regime” (Editor’s suggestion).
- C. D. Arrowsmith, P. Simon, **P. J. Bilbao** et al. *Nature Communications* 15.5029 (2024): “Laboratory realization of relativistic pair-plasma beams”.
- **P. J. Bilbao** et al. *Science Advances* 11.15 eadt8912 (2025): “Radiative cooling induced coherent maser emission in relativistic plasmas”.
- R. J. Ewart, M. Nastac, **P. J. Bilbao** et al. *Proceedings of the National Academy of Sciences* 122.17 (2025): “Relaxation to universal non-Maxwellian equilibria in a collisionless plasma”
- C. D. Arrowsmith, F. Miniati, **P. J. Bilbao** et al. *Proceedings of the National Academy of Sciences* 122.45 (2025): “Evidence of suppressed beam-plasma instability in a laboratory analogue of blazar pair jets”.

## Scientific Achievements

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Development of the first self-consistent kinetic theory coupling radiative losses with the collective kinetic properties of plasmas in strong magnetic fields, showing that synchrotron cooling naturally drives the formation of ring momentum distributions unstable to the electron cyclotron maser instability (ECMI),

thereby identifying a fundamental mechanism for coherent emission in magnetized relativistic plasmas relevant to pulsars, magnetars, and Fast Radio Bursts (FRBs).

Discovery of how betatron cooling affects the kinetic properties of beams in plasma wakefield accelerators, showing that radiation reaction in focusing channels induces phase-space bunching and ring formation analogous to synchrotron cooling, establishing a mechanism capable of generating beams ideal for triggering the coherent amplification via the ion-channel laser (ICL) instability.

Key simulation and theoretical support for the CERN Fireball experiment, which achieved the first laboratory realization of a relativistic, charge-neutral electron–positron plasma. Large-scale 3D OSIRIS simulations performed as part of this work explained the experimentally observed suppression of current-filamentation instabilities, revealing the stabilizing effects of finite beam divergence and energy spread and establishing the first experimental upper bound on the CFI growth rate in pair plasmas.

Leadership of large-scale computational campaigns exceeding 100 million CPU hours across Tier-0 systems (Deucalion, MareNostrum 5, and LUMI-C), combining high-performance simulation, kinetic theory, and experiment to advance the understanding of collective and radiative processes in extreme plasmas.

## References

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- Professor Luís O. Silva  
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- Professor Robert Bingham  
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