Stefano Boccelli

NPP Postdoctoral fellow, NASA Goddard Space Flight Center, Greenbelt, MD, USA.

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Research Experience

2024–Present **NASA Goddard Space Flight Center**, Greenbelt, MD, USA
NPP Postdoctoral fellow

- Research topic: modeling water-vapor plumes on Jupiter's icy moons using particle and fluid methods.
- Supervisor: Dr. O.J. Tucker.

April/May 2023 **Stanford University**, Stanford CA, USA
Visiting Postdoctoral Scholar programme

- Research topic: modeling cross-field electron transport in Hall thruster plasma discharges, using the 10 and 14-moment maximum-entropy moment methods.
- Supervisor: Prof. K. Hara.

2021–2023 **University of Ottawa**, Ottawa ON, Canada
Postdoctoral Researcher

- Research topic: characterizing the thermodynamics of special-relativistic gases in non-equilibrium conditions, and developing maximum-entropy moment models (hyperbolic PDEs) to describe the transport of relativistic electrons.
- Supervisor: Prof. J.G. McDonald.

Education

2017–2021 **Politecnico di Milano**, Milan, Italy
PhD in Aerospace Engineering—Doctor Europaeus
Graduated cum Laude

- Thesis: "Moment methods for non-equilibrium low-temperature plasmas with application to electric propulsion"
- Collaborative PhD at the von Karman Insitute for Fluid Dynamics (VKI).
- Supervisors: Prof. Aldo Frezzotti (PoliMi), Prof. Thierry Magin (VKI).
- Visiting PhD at the École Polytechnique, Laboratory of Plasma Physics (LPP), France.

2016–2017 **von Karman Institute for Fluid Dynamics**, Sint-Genesius-Rode, Belgium
Research Master in Fluid Dynamics (second-level master program)
Graduated with Honors—Best performance of the year

- Research topic: studying the concentration of free electrons in ionized meteor trails, and their interaction with electromagnetic waves.
- Supervisor: Prof. Thierry Magin (VKI).

2009–2016 **Politecnico di Milano**, Milan, Italy

• MSc in Aeronautical engineering (2013–2016)—Final grade: 110 cum Laude

- Thesis: "Development of a Lagrangian solver for thermochemical nonequilibrium flows"
- Supervisor: Prof. Aldo Frezzotti.

• BSc in Aerospace engineering (2009–2013)—Final grade: 108/110

Grants and Awards

2024 AssoAMA—Angelo Marcello Anile doctoral prize (ex-aequo with another candidate).

2022 – *NVIDIA Academic Hardware Grant*
• Total commercial value: approx 40 000 $.

2019 AIAA Best Student Paper in Thermophysics (co-author).

2017 Prince Alexandre of Belgium award for the best presentation (VKI).

2017 Theodore von Karman Prize for the best Resarch Master performance (VKI).

Relevant skills and software projects

Computer-related:

• Numerical analysis & solution of PDEs (especially the Finite-Volume method) • Stochastic particle-based methods (PIC, DSMC) • HPC (`Fortran`, `C++`, `CUDA`, `OpenMP`, `MPI`) • Linux OS for computation, system administration, DIY Beowulf clusters • Various: Matlab/Octave, LaTeX, bash, Python etc.

Main software contributions:

`Hyper2D` a CUDA-enabled finite volume solver for hyperbolic systems of PDEs, focused on hydrodynamics in translational non-equilibrium (moment methods). Open-source (github) [Maintainer]

`PANTERA` a particle-based MPI code for the simulation of gases (DSMC) and plasmas (PIC). [Developer]

`brODErs++` a suite of `C++` solvers for hypersonic atmospheric entry flows. It includes the reacting shock-relaxation software "`Shocking`" and the Lagrangian recomputation tool "`Larsen`". [Maintainer]

Other engineering skills:

• Workshop: arc (MMAW) and TIG welding, soldering, machining etc • Basic practical electronics (analog & digital), basic circuit design and SPICE simulation.

My research is numerical/theoretical. However, in the free time, I complement my simulations with some simple plasma experiments, in homebuilt vacuum systems (`boccelliengineering.altervista.org`).

Languages

English (professional working proficiency), Italian (native speaker), French (elementary).

Memberships

- Society for Industrial and Applied Mathematics (SIAM);
- Canadian Society for Mechanical Engineering (CSME);
- Ontario Society of Professional Engineers (OSPE).

Service to the community, teaching and mentoring

Since the last few years, I serve as a **reviewer** for: Physics of Fluids, Physics of Plasmas, IEEE Transactions in Plasma Science, Plasma Science and Technology, Frontiers in Physics, BioRob2021/2022.

In the academic years 2019/20 and 2020/21, I was responsible for **teaching** the Direct Simulation Monte Carlo DSMC method (theory & practice, 10 hours per year). This was part of the *Fundamentals of Hypersonic Flows* course held at Politecnico di Milano (PoliMi) by Prof. A. Frezzotti. Besides that, I was TA-ing, following the student projects and carrying examinations.

In April 2022, I was part of the **MSc graduation committee** at PoliMi as an external examiner ("contro-relatore"). Since 2017, I have been mentoring three **MSc thesis projects** (PoliMi) and a **Research Master project** (VKI) related mostly to low-temperature plasmas.

Invited talks

2023 **RWTH Aachen**, Germany, *The maximum-entropy moment method: hypersonics and electric propulsion.*

2023 **NASA Ames**, USA, *Non-equilibrium maximum-entropy methods for atmospheric entry.*

2023 **Stanford University**, USA, *Non-equilibrium fluid modeling of hypersonic flows and low-temperature plasmas using maximum-entropy moment methods.*

2022 **University of Cambridge**, UK, *Fluid and kinetic modelling of non-equilibrium flows: atmospheric entry of meteoroids and plasma space propulsion devices.*

2022 **University of Southampton**, UK, *Non–equilibrium Hydrodynamics: the Maximum–Entropy Moment Method - Rarefied Gases, Plasmas and some Special Relativity.*

List of publications [see Google Scholar for an updated list]

Journal publications

2024 **Boccelli, S.**, Kaufmann, W., Magin, T.E. & McDonald, J.G., *Numerical simulation of rarefied supersonic flows using a fourth-order maximum-entropy moment method with interpolative closure*, Journal of Computational Physics, 2024.

2023 **Boccelli, S.**, *Hyper2D: A finite-volume solver for hyperbolic equations and non-equilibrium flows*, Software Impacts, 2023.

2023 **Boccelli, S.,** Parodi, P., Magin, T.E. & McDonald, J.G., *Modelling high-Mach-number rarefied crossflows past a flat plate using the max-entropy moment method*, Physics of Fluids, 2023.

2022 **Boccelli, S.** & McDonald, J.G., *Realizability conditions for relativistic gases with a non-zero heat flux*, Physics of Fluids, 2022.

2022 **Boccelli, S.**, McDonald, J.G. & Magin, T.E., *14-moment maximum-entropy modelling of collisionless ions for Hall thruster discharges*, Physics of Plasmas, 2022.

2021 **Boccelli, S.**, Magin, T.E. & Frezzotti, A., *Numerical Investigation of Reversed Gas-Feed Configurations for Hall Thrusters*, Journal of Propulsion and Power, 2021.

2020 **Boccelli, S.**, Giroux, F., Magin, T.E., Groth, C.P.T., & McDonald, J.G., *A 14-moment max-entropy description of electrons in crossed electric and magn. fields*, Physics of Plasmas, 2020.

2020 **Boccelli, S.**, Charoy, T., Alvarez Laguna, A., Chabert, P., Bourdon, A., Magin, T.E., *Collisionless ion modeling in Hall thrusters: analytical axial velocity distribution function and heat flux closures,* Physics of Plasmas, 2020.

2020 Bariselli, F., **Boccelli, S.**, Dias, B., Hubin, A. & Magin, T.E., *A Self-Consistent Method for the Simulation of Meteor Trails with Application to Radio Observations* Astron. & Astrophys., 2020.

2020 Babaiasl, M., **Boccelli, S.**, Chen, Y., Yang, F., Ding, J-L. & Swensen, J.P., *Predictive mechanics-based model for depth of cut (DOC) of waterjet in soft tissue for waterjet-assisted medical applications.* Medical & Biological Engineering & Computing, 2020.

2020 Ramjatan, S., Lani, A., **Boccelli, S.**, Van Hove, B., Karatekin, Ö., Magin, T.E. & Thoemel, J., *Blackout analysis of Mars entry missions.* Journal of Fluid Mechanics, 2020.

2019 **Boccelli, S.**, Bariselli, F., Dias, B. & Magin, T. E., *Lagrangian diffusive reactor for detailed thermochemical computations of plasma flows.* Plasma Sources Science and Technology, 2019.

Theses

2021 **Boccelli, S.**, *Moment methods for non-equilibrium low-temperature plasmas with application to electric propulsion*, PhD thesis, Politecnico di Milano, 2021.

2017 **Boccelli, S.**, *Simulations of electron concentration in the wake of meteors and application to radio observations*, Research Master final report, von Karman Institute, 2017.

2016 **Boccelli, S.**, *Development of a Lagrangian solver for thermochemical nonequilibrium flows*, MSc thesis, Politecnico di Milano, 2016.

Selected conference papers and presentations

2023 **Boccelli, S.,** Parodi, P., Magin, T.E. & McDonald, J.G., *Modelling high Mach number low-collisional flows using the max-ent moment method*, SIAM CSE, Amsterdam, 2023 [Accepted].

2022 **Boccelli, S.,** & McDonald, J.G., *Maximum-entropy moment methods for low-temperature plasmas and space propulsion devices*, IOP 48th Annual Plasma Phys. Conf., Liverpool, 2022.

2021 Parodi, P., **Boccelli, S.,** Le Quang, D., Lapenta, G. & Magin, T.E., *PIC-MCC Characterization of Expanding Plasma Plumes for a Low-Density Hypersonic Aerodynamics Facility.* 74th Gaseous Electronics Conference, 2021.

2020 **Boccelli, S.,** Parodi, P., Vallisa, L., Kaufmann, W., Barbante, P., McDonald J.G., & Magin, T.E., *Maximum-entropy 14 moments description of non-equilibrium electrons in crossed electric and magnetic fields.* 73rd Gaseous Electronics Conference, 2020.

2020 Babaiasl, M., Yang, F., **Boccelli, S.,** & Swensen, J., *Fracture-directed Waterjet Needle Steering: Design, Modeling, and Path Planning* Proceedings of the 8th IEEE RAS/EMBS BioRob 2020.

2019 Bariselli, F., **Boccelli, S.**, Dias, B., Hubin, A. & Magin, T. E., *Detailed simulations of meteor trails with application to radio observations.* FAR International Conference on Flight Vehicles, Aerothermodynamics and Re-Entry Missions & Engineering, Monopoli, 2019.

2019 Mani, K. V., **Boccelli, S.**, Cervone, A. & Topputo, F., *Electric Propulsion Characterization for a Stand-Alone Mars CubeSat,* International Electric Propulsion Conference, Vienna, 2019.

2018 Bariselli, F., **Boccelli, S.**, Magin, T. E., Frezzotti, A. & Hubin, A., *Aerothermodynamic modelling of meteor entry flows in the rarefied regime.* In 2018 Joint Thermophysics and Heat Transfer Conference (p. 4180).