Santiago Barbieri

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Part-time lecturer - Universitat Politècnica de Catalunya

Contacts

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Spoken languages

Italian	French	English	Portuguese	Catalan	Spanish

Career and Education

2024-Now   **Part-time lecturer -** *Universitat Politècnica de Catalunya*

2023-Now   **Postdoctoral Researcher -** *Universitat de Barcelona*

2022-2023   **Attaché Temporaire d'Enseignement et de Recherche (Lecturer) -** *Université Paris Dauphine*

2019-2023   **PhD in pure mathematics -** *Université Paris-Saclay - Università degli studi Roma Tre*

2016-2017   **Master 2 in Analysis and Probability -** *Université Paris Dauphine*

2015-2016   **Master 2 in Dynamics of Gravitational Systems**   **-** *Sorbonne Universités*

2014-2015   **Master 1 of Physics**   **-** *Sorbonne Universités*

2010-2014   **Bachelor of Physics**   **-** *Alma Mater Studiorum Università di Bologna*

Publications, Preprints and Research

Articles

- S. Barbieri, L. Niederman, *Sharp Nekhoroshev estimates for the three-body problem around periodic orbits*, **Journal of Differential Equations** 268, pages 3749-3780, 2020
- S. Barbieri, *On the algebraic properties of exponentially stable integrable Hamiltonian systems*, **Annales de la Faculté des Sciences de Toulouse**, 31(5), pages 1365-1390, 2022
- S. Barbieri, J. P. Marco, J. E. Massetti *Analytic smoothing and Nekhoroshev estimates for Hölder steep Hamiltonians*, **Communications in Mathematical Physics**, 396(1), pages 349-381, 2022.
- S. Barbieri, L. Niederman *Bernstein-Remez inequality for algebraic functions: a complex analytic approach*, **Nonlinear Analysis**, 237, 113371, 2023.

Preprints

- S. Barbieri *Semi-algebraic geometry and generic Hamiltonian stability*, https://hal.science/hal-04213250
- S. Barbieri, G. Farré, *Nearly-optimal effective stability estimates around Diophantine tori of Hölder Hamiltonians*, https://arxiv.org/abs/2402.10764

Field of research

The study of the stability and instability of solutions of Hamiltonian dynamical systems that are close to integrable covers a wide range of aspects; it contributes to answering fundamental questions involving mechanics, analysis and geometry, and has relevant physical applications (e.g. in space debris, satellite motions, interactions in crystals, hydrodynamics etc...).

Within this framework, one has

- **Kolmogorov-Arnold-Moser (KAM) theory**, which is valid for small perturbations of generic integrable hamiltonians. It provides **Cantor sets of big measure where the solutions are quasi-periodic.** However, for systems depending on more than two degrees of freedom, **instabilities may occur in the complementary** of these sets (a phenomenon known as **Arnold diffusion**).

- **Nekhoroshev Theory**, which ensures that if the unperturbed Hamiltonian is regular enough and **steep**, i.e. if its gradient verifies a generic transversality condition, **all solutions are stable over a long time.** In particular all quasi-convex functions are steep.

My results and works in progress in this field are described hereafter.

Currently, I collaborate with researchers in **Spain (Catalunya), France, Italy and Brazil.**

Ongoing projects

1. **Arnold diffusion for steep non-convex systems** and optimal estimates for their Nekhoroshev time of stability - with M. Guàrdia and E. Fontich (U. Barcelona), T. Seara (U. Politècnica de Catalunya), J.P. Marco (Sorbonne Universités)

2. **Nekhoroshev estimates for infinite-dimensional lattices** - with M. Guàrdia (U. Barcelona) and J. Massetti (U. Roma Tor Vergata).
   Possible applications: FPU problem, interactions in crystals.

3. Existence of **KAM tori for the "coin billiard map"**, in order to answer a question by M. Bialy - with A. Clarke (U. Politècnica de Catalunya).
   Possible applictions: hydrodynamics.

4. Refined estimates of stability for perturbations of Diophantine-steep Hamiltonians (a wider class than steep ones) in order to **answer a question by Fields laureate J. C. Yoccoz on the maximal class of functions which are Nekhoroshev stable** - with B. Langella (SISSA) and A. Bounemoura (U. Paris Dauphine).

5. Proof of a **conjecture by Arnold-Kozlov and Neishtadt** on the measure of the complementary set of invariant tori in KAM theory - with L. Biasco and L. Chierchia (U. Roma Tre).

6. Numerical study of explicit criteria for steepness to concrete models (e.g. maps) - with A. Vieiro (U. De Barcelona).
   Possible applications: celestial mechanics, space debris.

Future projects

1. **Topological properties of the algebraic varieties containing the Taylor polynomials of non-steep functions** through the theories of fewnomials and syzygies - with J.P. Marco (Sorbonne Universités) and T. Dias Oliveira-Silva (U. Federal Rural de Pernambuco)

2. **Relying the steepness condition to the abundance of rational points in suitable semi-algebraic sets** in order to have a characterization of steepness based on tools of number theory - with L. Niederman (U. Paris-Saclay and Observatoire de Paris) and L. Stolovitch (U. Côte d'Azur).

Achievements

1. By combining techniques of real-algebraic geometry and complex analysis, I obtained a **new proof of the genericity of steep functions.** Namely, I used Yomdin's Theorem on the analytic reparametrization of semi-algebraic sets to prove that the Taylor polynomials of non-steep functions lie in a semi-algebraic set of positive codimension in the space of polynomials.

2. I found **sufficient explicit algebraic criteria ensuring that a given Hamiltonian is steep**, by carefully combining reduction algorithms of real-algebraic geometry with the results of the previous point.

   Possible applications: satellite motions, space debris.

3. As a byproduct of the previous points, together with L. Niederman (U. Paris-Saclay and Observatoire de Paris) I developed a **new proof on the controlled growth of the derivatives of analytic algebraic functions of bounded degree (Bernstein-Remez type inequality).** This proof relies on the structure of complex algebraic curves and on tools of complex analysis, while other approaches to the problem in the literature exploit analytic geometry or potential theory.

4. By developing a new estimates in analytic smoothing techniques, I was able to find **refined Nekhoroshev estimates of stability for nearly-integrable systems of Hölder regularity.** Joint work with J.P. Marco (Sorbonne Universités) and J. Massetti (U. Roma Tor Vergata).

5. I applied results on quantitative Morse-Sard Theory in order to prove a **first step of a conjecture by Arnold-Kozlov and Neishtadt on the measure of the complementary set of invariant tori in KAM theory** (joint with L. Biasco (U. Roma Tre)).

6. In a joint work with G. Farré (U. Politècnica de Catalunya), we used improved techniques of analytic smoothing for Hölder functions in order to prove **near-optimality for the Nekhoroshev time of stability of nearly-integrable Hölder systems close to a Diophantine torus.**

7. I worked on **applications of Nekhoroshev Theory to models in celestial mechanics**, in particular to the Sun-Jupiter-Saturn and Sun-Jupiter-astroid systems.

   Possible applications: satellite motions, space debris.

Teaching

2023-2024	**Calculus II (28h), 1st year, BA of Industrial Engineering and Economic Analysis (GTIAE)** *Universitat Politècnica de Catalunya*
2022-2023	**Calculus I (77h), 1st year, BA of Mathematics and Computer Science** *Université Paris Dauphine*
2021-2022	**Elements of Mathematics I (64h), 1st year, Technical University Diploma (DUT) in Chemistry** *IUT Orsay - Université Paris Saclay*
2020-2021	**Elements of Mathematics II (64h), 2nd year, Technical University Diploma (DUT) in Chemistry** *IUT Orsay - Université Paris Saclay*
2019-2020	**Elements of Mathematics I (64h), 1st year, Technical University Diploma (DUT) in Chemistry** *IUT Orsay - Université Paris Saclay*

Other academic activities

- In the academic year 2020-2021, I have tutored a university student with special needs for a total of 30h (outside of the normal teaching time) within the framework of the Service for people with disabilities of the Université Paris-Saclay, where I was teaching (see above).

- In 2018-2019, I have been the representative of PhDs and postdocs at the Office for wellbeing, diversity and inclusion and against discriminations (Comitato Unico di Garanzia) of the University of Padova.

As an invited speaker

2024 - January
Semi-algebraic Geometry and generic Hamiltonian stability
Séminaire Géométrie, Analyse et Dynamique
https://math.univ-cotedazur.fr/ emiliton/seminaire/seminar.php
Université de la Côte d'Azur, Nice, France

2023 - December
Semi-algebraic Geometry and generic Hamiltonian stability
Quantum and Dynamical Christmas in Milano
https://qdc2023.unimi.it/
Università degli studi di Milano, Italy

2023 - November
Bernstein-Remez inequality for algebraic functions: a topological approach
Conference: *Aspects mathématiques de la mécanique celeste et Hamiltonienne*
https://perso.imcce.fr/alain-albouy/Avignon2023.html
Avignon Université, France

2022 - April
On the genericity of effectively-stable integrable systems and on their algebraic properties
Seminario de sistemas dinâmicos
Universidade Federal Rural de Pernambuco, Recife, Brazil

2022 - March
On the genericity of effectively-stable integrable systems and on their algebraic properties
Séminaire SYMPA
https://lamfa.u-picardie.fr/SymPA/seminaire/2022
Université de Picardie Jules Verne, Amiens, France

2022 - January
On the genericity of effectively-stable integrable systems and on their algebraic properties
Séminaire de Systèmes Dynamiques, Analyse et Géométrie
https://math.univ-avignon.fr/seminaires/seminaire-de-systemes-dynamiques-analyse-geometrie/
Avignon Université, Avignon, France

2022 - January
On the genericity of effectively-stable integrable systems and on their algebraic properties (Part I and II)
Working group in Hamiltonian and symplectic dynamics of Jussieu-Dauphine
https://annafloriomath.wordpress.com/working-group-2021-2022/
Sorbonne Université, Université Paris-Dauphine, France

2022 - January
On the genericity of effectively-stable integrable systems and on their algebraic properties
Working group of dynamical systems and ergodic theory
https://www.imo.universite-paris-saclay.fr/ thierry.bousch/tesd/arc2122.html
Université Paris-Saclay, Orsay, France

2021 - December
On the genericity of effectively-stable integrable systems and on their algebraic properties
Seminar of dynamical systems of UB-UPC
http://www.maia.ub.es/ssd/ssd.21-22.shtml
Universitat Politècnica de Catalunya, Barcelona, Spain

2021 - October
Flexibility and analytic smoothing in averaging theory
Working group in Hamiltonian and symplectic dynamics of Dauphine-Jussieu
https://annafloriomath.wordpress.com/working-group-2021-2022/
Sorbonne Universités, Paris, France

2021 - July
On the generic "double-pendulum" behaviour of near-integrable hamiltonian systems with two degrees of freedom
Working group in dynamical systems of Roma Tre
Università degli Studi Roma Tre, Italy

2020 - March	***On the mathematical stability of the Sun-Jupiter-Saturn system.*** *Seminar of PhD students of Université Paris-Dauphine* **Université Paris Dauphine, Paris, France**
2019 - March	***On new algebraic conditions for steepness in the space of five-jets of smooth functions*** *Seminar of Analysis and Dynamical systems* **https://crm.sns.it/course/6021/** **Centro Ennio De Giorgi - Scuola Normale Superiore, Pisa, Italy**
2018 - October	***Sharp Nekhoroshev estimates for the three-body problem around periodic orbits*** *Seminar of Dynamical systems* **Università degli Studi di Milano, Italy**

As a contributed speaker

2023 - May	***Bernstein-Remez inequality for algebraic functions: a topological approach (poster)*** *International school on conformally symplectic dynamics* **https://conferences.cirm-math.fr/2878.html** **CIRM, Marseille, France**
2022 - July	***Semi-algebraic geometry and effective hamiltonian stability (poster)*** *Conference GLADS 2022* **https://www.crm.cat/glads-22/** **Centre de Recerca Matematica, Barcelona, Spain**
2018 - September	***Sharp Nekhoroshev estimates for the three-body problem around periodic orbits.*** *Conference AMC_{70}* **http://adams.dm.unipi.it/~2018amc70** **Università di Pisa, Italy**
2018 - June	***Sharp Nekhoroshev estimates for the three-body problem around a periodic torus.*** *Conference: perspectives in Hamiltonian Dynamics (Venezia, Italy)* **https://events.math.unipd.it/ercvenice/** **Università degli Studi di Padova, Italy**
2017 - March	***Ideas on Nekhoroshev theorem*** *Groupe de travail sur le problème des N-corps* **https://www.ceremade.dauphine.fr/~fejoz/nbp.php** **Observatoire de Paris, France**

Participation to projects

From Jan - 2024	*Premi ICREA 2018 (PI prof. M. Guàrdia) - Team Member* **https://memoir.icrea.cat/academia_awardees/guardia-munarriz-marcel/**
Jun/Dec - 2023	*ERC Project 757802 Haminstab (PI prof. M. Guàrdia) - Team Member* **https://www.ub.edu/dynsys/grants/haminstab/**

Personal Interests

Sociology
Macroeconomics and history of economic thinking
Literature
History of art