



# TONY BONNAIRE

Artificial Intelligence Fellow @ENS | PSL University | PR[AI]RIE

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Machine learning    Statistics    Cosmology    Statistical physics

## EXPERIENCE

### PSL AI Fellow – ENS Paris, PSL University, PR[AI]RIE

Diffusion Models    High-dimensional statistics    AI4Science    Python    PyTorch

Jan. 2023 – Ongoing    Paris, France

- Machine learning theory: nonconvex optimization, generative models.
- AI for cosmology: segmentation, generative modeling, parameter inference.
- ML teacher for master students of PSL University (150 hrs/year).

### Postdoctoral researcher – ENS Paris, PSL University, PR[AI]RIE

High-dimensional statistics    Analytical    Python    PyTorch

Nov. 2021 – Jan. 2023    Paris, France

- Machine learning theory: gradient descent dynamics in high-dimensional non-convex optimization – Reference: Giulio Biroli.

### Ph.D. Student – IAS, Paris-Saclay University

AI4Science    Cosmology    Pattern extraction    Python

Oct. 2018 – Sept. 2021    Orsay, France

- Title: *The cosmic web: identification, characterization, and quantification of cosmological information*. Supervision: Nabila Aghanim, Aurélien Decelle.
- 2D/3D pattern extraction from cosmological data and simulations.
- Statistical analysis of the cosmic web to improve cosmological models.

### Research engineer – Thales

Algorithmics    Pattern extraction    C    Matlab    OpenCL

Sept. 2017 – Sept. 2018    Élancourt, France

- Segmentation and characterization of radar waveforms.
- Design and implementation of supervised and unsupervised algorithms for electronic warfare problems.

## EDUCATION

### Ph.D. in Astronomy and Astrophysics

Université Paris-Saclay

Oct. 2018 – Nov. 2021    Orsay, France

### CentraleSupélec Engineer

CentraleSupélec, track: Applied mathematics

Sept. 2014 – Sept. 2017    Gif-sur-Yvette, France

## LANGUAGES

French    ● ● ● ● ●

English    ● ● ● ● ●

Italian    ● ● ● ● ●

## PROGRAMMING

Python    PyTorch    C    R

Matlab    OpenCL

Objective-C

## REFERENCES

### Prof. Giulio Biroli

@ LPENS

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Laboratoire de Physique de l'École normale supérieure, ENS, Paris, France.

### Dr. Nabila Aghanim

@ IAS

✉ nabila.aghanim@universite-paris-saclay.fr

Institut d'Astrophysique Spatiale, Université Paris-Saclay, Orsay, France.

### Dr. Aurélien Decelle

@ UCM

✉ adecelle@ucm.es

Departamento de Física Teórica I, Universidad Complutense, Madrid, Spain.

## TEACHING

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### Machine Learning – M2 ENS Paris, PSL University

Jan. 2025 – Ongoing Co-instructor

36 hours – Co-supervision of the hands-on sessions of the Machine Learning course from Prof. Marc Lelarge given to M2 students of the International Center for Fundamental Physics (ICFP).

### Machine Learning Principles with Applications in Physics – M1 ENS Paris, PSL University

Sept. 2023 – Ongoing Co-advisor Co-instructor

64 hours – Machine learning introduction for master students of the International Center for Fundamental Physics (ICFP) and supervision of tutored projects.

### Artificial Intelligence and Chemistry – M1 ENS Paris, PSL University

Sept. 2023 – Ongoing Advisor Instructor

32 hours – Introduction to the basics of machine learning for master students of the Department of Chemistry at ENS and supervision of tutored projects.

### PSL AI Hackathons

Jan. 2023 – Ongoing Advisor Co-instructor

50 hours – Preparation, organization, supervision, and participation in final juries of the PSL AI hackathons for master students.

### ENS Data Challenges

École Normale Supérieure and MVA master, Nov. 2022 – Ongoing

Organisation and beta-testing of the data science challenges for the web platform "Challenge Data ENS".

Evaluation of the M2 students from the MVA Master course of Prof. Stéphane Mallat.

## SUPERVISION

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- Mehdi Noor – Co-supervision of Ph.D. Sep. 2024 – Ongoing  
*Emulating the Cosmic Web with Generative AI: Methods and Applications*
- Mehdi Noor – Co-supervision of M2 internship Mar. 2024 – Sep. 2024  
*Generation of Cosmological Simulations via Diffusion-based Models*

## PROJECTS

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- 2024: Membership to the Euclid consortium (Galaxy/AGN Evolution Working Group).
- 2024: Collaborator of an ERC Proof Of Concept (PoC) for the transfer of methodologies developed during my Ph.D. in cosmology to health science with Dr. N. Aghanim and Dr. A. Decelle.

## PRIZES AND GRANTS

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- 2023: 5-year fellowship at PSL University and ENS Paris for research and teaching in Artificial Intelligence.
- 2022: Prix de la Chancellerie des Université de Paris, catégorie Sciences.

## COMMUNITY SERVICES AND SHARING

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- Codes  
**Tree-based Ridge eXtractor (T-ReX):** A publicly-available Python implementation of the filament-finder method.
- Reviewing activities  
**Machine Learning conferences:** NeurIPS 2024 Scientific Methods for Understanding Deep Learning workshop.  
**Physics journals:** MNRAS, Nature Scientific Reports.

## ONGOING PUBLICATIONS AND PREPRINTS

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- [1] **Tony Bonnaire** and Giulio Biroli. “A replica analysis of the asymptotic fluctuations of extreme eigenvalues in non-white Wishart matrices”. 2025.
- [2] Euclid Collaboration. “The connectivity of Galaxy Clusters with Euclid Q1 first data”. 2025.
- [3] **Tony Bonnaire**, Catania Giovanni, Decelle Aurélien, and Seoane Beatriz. “Bipartite generative neural network: the role of the non-linear latent features”. 2025.

## REFEREED PUBLICATIONS

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### Machine learning: theory and applications for science

- [1] **Tony Bonnaire**, Giulio Biroli, and Chiara Cammarotta. “The Role of the Time-Dependent Hessian in High-Dimensional Optimization”. In: *Submitted to J. Stat. Mech.* (Feb. 2025).
- [2] Giulio Biroli, **Tony Bonnaire**, Valentin De Bortoli, and Marc Mézard. “Dynamical regimes of diffusion models”. In: *Nature Communications* 15.1 (Nov. 2024), p. 9957.
- [3] **Tony Bonnaire** et al. “High-dimensional non-convex landscapes and gradient descent dynamics”. In: *Journal of Statistical Mechanics: Theory and Experiment* 2024.10 (Oct. 2024), p. 104004. DOI: 10.1088/1742-5468/ad2929.
- [4] Victor Bonjean et al. “Self-supervised component separation for the extragalactic submillimetre sky”. In: *Astron. Astrophys.* 686, A91 (June 2024), A91. DOI: 10.1051/0004-6361/202245624.
- [5] **Tony Bonnaire**, Aurélien Decelle, and Nabila Aghanim. “Regularisation of Mixture Models for Robust Principal Graph Learning”. In: *IEEE Trans. Pattern Anal.* 44 (Dec. 2021), pp. 9119–9130. DOI: 10.1109/TPAMI.2021.3124973.
- [6] **Tony Bonnaire**, Aurélien Decelle, and Nabila Aghanim. “Cascade of phase transitions for multiscale clustering”. In: *Phys. Rev. E* 103 (Jan. 2021), p. 012105. DOI: 10.1103/PhysRevE.103.012105.
- [7] **Tony Bonnaire**, N. Aghanim, A. Decelle, and M. Douspis. “T-ReX: a graph-based filament detection method”. In: *Astron. Astrophys.* 637 (Sept. 2020), A18. DOI: 10.1051/0004-6361/201936859.

### Statistical analyses for cosmology

- [1] Stefano Gallo et al. “Tracing gaseous filaments connected to galaxy clusters: The case study of Abell 2744”. In: *Astron. Astrophys.* 692 (Dec. 2024), A200.
- [2] Nabila Aghanim et al. “Dissecting a miniature universe: A multi-wavelength view of galaxy quenching in the Shapley supercluster”. In: *Astron. Astrophys.* 689 (Sept. 2024), A332. DOI: 10.1051/0004-6361/202348672.
- [3] **Tony Bonnaire**, Joseph Kuruvilla, Nabila Aghanim, and Aurélien Decelle. “Cosmology with cosmic web environments II. Redshift-space and cross power spectra”. In: *Astron. Astrophys.* 674 (June 2023), A150. DOI: 10.1051/0004-6361/202245626.
- [4] **Tony Bonnaire**, Nabila Aghanim, Joseph Kuruvilla, and Aurélien Decelle. “Cosmology with cosmic web environments I. Real-space power spectra”. In: *Astron. Astrophys.* 651 (May 2022), A146. DOI: 10.1051/0004-6361/202142852.
- [5] C. Gouin, **Tony Bonnaire**, and N. Aghanim. “Shape and connectivity of groups and clusters: Effect of the dynamical state and accretion history”. In: *Astron. Astrophys.* 651 (July 2021), A56. DOI: 10.1051/0004-6361/202140327.

## INVITED SEMINARS

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- **LISN, Paris-Saclay University** Orsay, France, Dec. 2024  
The Generative Dynamics of Optimally-Trained Diffusion Models in Large Dimensions
- **Department of Astrophysics, École Normale Supérieure** Paris, France, Apr. 2024  
Dynamical Regimes of Diffusion Models
- **Department of Astrophysics, École Normale Supérieure** Paris, France, Feb. 2024  
The cosmological information of the cosmic web
- **Centre de Recherche en Informatique, Signal, et Automatique de Lille** Lille, France, Jun. 2023  
The cosmic web: from identification to cosmological parameters
- **Institut de Physique Théorique, cosmology group** Saclay, France, Jun. 2022  
Identifying and quantifying information of the cosmic web
- **University of Geneva, cosmology group** Geneva, Switzerland, Dec. 2021  
Cosmic web environments: from identification to cosmological parameters
- **Laboratoire d’Astrophysique de Marseille** Orsay, France, Dec. 2021  
The cosmic web: filaments identification and quantification of the cosmological information

- **Institut Elie Cartan, Dept. of Probability and Statistics** Nancy, France, Dec. 2021  
Pattern extraction from point-cloud datasets and cosmological applications
- **Madrid University, Dept. of Theoretical Physics** Madrid, Spain, Nov. 2021  
The principal graph of the cosmic web: learning patterns in point-cloud datasets
- **Laboratoire interdisciplinaire des Sciences du Numérique** Orsay, France, Oct. 2021  
Learning patterns from point-cloud datasets and applications to cosmology

## CONFERENCES & WORKSHOPS

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### Invited talks

- **Collège de France, chaire of Prof. S. Mallat** Paris, France, Feb. 2025  
Dynamique des Modèles de Diffusion
- **Workshop on Generative Models** Paris, France, Feb. 2025  
The High-Dimensional Generative Dynamics of Diffusion Models
- **AstroParticle workshop** Orsay, France, Nov. 2024  
Cosmology with cosmic web environments
- **Physics Informed Machine Learning workshop** Los Alamos, USA, Oct. 2024  
The Generative Dynamics of Diffusion Models in Large Dimensions

### Contributed Talks

- **New Strategies For Extracting Cosmology From Future Galaxy Surveys** Sexten, Italy, Jul. 2023  
Improving cosmological constraints using comic web environments
- **Cosmic cartography 2022** (Virtual) Kashiwa, Japan, Mar. 2022  
Cosmology with cosmic web environments
- **Sixteenth Marcel Grossmann Meeting** Virtual, Jul. 2021  
Constraining cosmological parameters with cosmic environments
- **Elbereth conference** (Virtual) Paris, France, Feb. 2021  
Learning the principal graph of the galaxy distribution
- **COSPAR 2021 Workshop on Machine Learning for Space Sciences** Sydney, Australia, Jan. 2021  
Learning the principal graph of the galaxy distribution
- **Workshop Orsay-Tartu** Virtual, Jun. 2020  
Detection of cosmic filaments using galaxy distribution
- **Workshop "The Cosmic Web in the Local Universe"** Leiden, Netherlands, Jan. 2020  
Detecting cosmic filaments from halo distribution
- **Workshop ByoPiC ERC** Hossegor, France, Jun. 2019  
Automatic detection of Cosmic Web elements, a review
- **Elbereth conference** Paris, France, Jan. 2019  
Uncovering cosmic filaments from galaxy distribution

### Posters

- **Les Houches Summer School on Statistical Physics and Machine Learning** Jul. 2022  
Successes of gradient descent in high-dimensional and non-convex landscapes: the phase retrieval case
- **SF2A conference** Virtual, Jun. 2021  
The principal graph of the cosmic web
- **Latin American Workshop on Observational Cosmology** (Virtual) São Paulo, Brazil, Dec. 2020  
Learning the principal graph of the galaxy distribution
- **Ph.D. day of the Institut d'Astrophysique Spatiale** Orsay, France, Nov. 2020  
Automatic filamentary structure detection from galaxy distribution