# Rémi Bardenet

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## Research interests

Keywords Probabilistic modelling and inference; Monte Carlo methods; applications to machine learning, particle physics and computational biology.

## Academic positions

February 2015- **Chargé de recherche**, *CNRS & Université de Lille*, Lille (France).
Member of SIGMA, the signal processing team of CRIStAL, the computer science department.
Permanent research position at the French national centre for scientific research.

2013-2015 **Postdoctoral fellow**, *Department of Statistics, University of Oxford*, Oxford (UK).
*2020 Science* fellowship of the EPSRC, working with Chris Holmes on large-scale Markov chain Monte Carlo methods, motivated by biological data analysis.
*2020 science* (`www.2020science.net`) is a network of computational scientists creating effective approaches to answer fundamental life science questions. This program is funded by the British applied science research council (EPSRC).

## Education

2009-2012 **Doctorat (Ph.D.)**, *Université Paris-Sud XI*, Orsay (France), *très honorable*.
**Computer science**, *Towards adaptive learning and inference - Applications to hyperparameter tuning and astroparticle physics*, under the supervision of Balázs Kégl (LAL, LRI, CNRS).

- ▷ *Très honorable* is the highest honours you can get in Université Paris-Sud.
- ▷ My thesis was also awarded the **2nd prize for the best French Ph.D. in computer science for the year 2012/2013 (Gilles Kahn prize of the Société Informatique de France)**.
- ▷ Please ask me for the reports by my thesis reviewers (Éric Moulines and Christian Robert) and viva jury if you want a detailed external opinion on my work.

2008-2009 **Master (M.Sc.)**, *Ecole Normale Supérieure*, Cachan (France), *summa cum laude*.
**Mathematics, computer vision and machine learning**.
Courses given, e.g., by Gabor Lugosi, Francis Bach, Jean-Yves Audibert, Jean-Philippe Vert, Donald Geman, Rémi Munos, Yali Amit.

2008 **Agrégation**, *Université Louis Pasteur*, Strasbourg (France), *national rank 82*.
**Mathematics major, probability & statistics minor**.
The *agrégation* is a national competitive exam, originally meant to hire teachers for undergraduate levels. A large proportion (2800+ candidates that year for 252 positions) of French students in mathematics take it, as it is also considered a sesame to the Ph.D. program.

2005-2009 **Magistère**, *Université Louis Pasteur*, Strasbourg (France), *summa cum laude*.
Applied and fundamental **mathematics**.
*Magistères* are selective university programs made of traditional B.Sc./M.Sc. programs with privileges such as small-group exercise sessions and advanced complementary courses.

## Teaching Experience

2014-2015 **Lecturer**, *École centrale de Lille*, Lille (France).
11 hours, lecturing practical machine learning with applications to the health of businesses (master-level engineering students).

2013-2014 **Lecturer**, *Univ. Oxford*, Oxford (UK).
8 hours, teaching half of the course *Advanced simulation* on Monte Carlo methods (4th year students).

2013 **Class tutor**, *Univ. Oxford*, Oxford (UK).
14 hours, tutoring for the course *Advanced simulation* on Monte Carlo methods (4th year students).

2009–2012 **Teaching assistant**, *Univ. Paris-Sud XI*, Orsay (France).
64 hours per year. Covered topics include Linear and Nonlinear Programming (L3), Stochastic processes (M1), C programming (L2) and orientation of students (L1).
L1, L2, and L3 correspond to the first, second, and third year that lead to a bachelor's degree, M1 and M2 to the two years of master.

2008–2009 **Examiner**, *Lycée J.-B. Say*, Paris (France).
Maths examiner for undergraduate students from "classes préparatoires".
"Classes préparatoires" are competitive undergraduate programmes.

2005–2008 **Private teacher**, Strasbourg (France).
Private courses in Mathematics for undergraduate students from "classes préparatoires".

## Invited lectures

2013 Invited to give the *Markov chain Monte Carlo methods* lecture at the joint Helmholtz-Max Planck Institut winter school on Monte Carlo Methods, Max Planck Institut Munich (Germany).

2012 Invited to give the *Numerical Bayesian methods* lecture at the SOS statistics summer school of the IN2P3 (French national institute for particle and nuclear physics). A book chapter resulted from this lecture.

## Grants and awards

2015 **PEPS JCJC**, *CNRS*, 7k€, 2 people.
Projet ProMo "Projected Monte Carlo".
- ▷ PEPS JCJC is a call for short-term exploratory research projects by young researchers.
- ▷ CNRS is the French national centre for scientific research.

2013 **2nd prize of the *Gilles Kahn* award**, *Société Informatique de France*.
Awarded by the French society of Computer Science for the best French Ph.D. of the academic year.

## Reviewing activities

2009– I have reviewed papers for journals such as *Journal of Machine Learning Research (JMLR)*, *Transactions on Pattern Analysis and Machine Intelligence (TPAMI)*, *Journal of Computational and Graphical Statistics (JCGS)*, and conferences such as *International Conference on Machine Learning (ICML)*, *Advances in Neural Information Processing Systems (NIPS)*, *International conference on learning theory (COLT)*.

## Organisation of scientific meetings

2014 Co-organization of the AutoML workshop at ICML'14, one of the major international machine learning conferences.

## Supervision

2014- **Ph. D. student**, *Univ. Oxford*, Oxford (UK), 33%.
I am co-supervising Ross Johnstone's Ph.D. with Gary Mirams and David Gavaghan (Oxford Computer Science), with industrial collaborators at *Roche labs* (Basel, Switzerland) on *Inference and model comparison for cardiac action potential models.*

2014 **Master student**, *Univ. Oxford*, Oxford (UK), 33%.
I have co-supervised Ross Johnstone's internship with Gary Mirams and David Gavaghan (Oxford Computer Science), with industrial collaborators at *Roche labs* (Basel, Switzerland) on *Inference and model comparison for cardiac action potential models.*

2012 **Master student**, *Univ. Oxford*, Oxford (UK), 33%.
I have co-supervised Joseph Page's internship with Mike Bonsall (Oxford Zoology) and Maria Bruna (Oxford Maths), on *The effect of migration on the resilience and behaviour of coral reefs.*

2012 **Master student**, *Univ. Paris-Sud XI*, Orsay (France), 50%.
I have co-supervised Ahmed Lasmar's master internship with Balázs Kégl, on *Modelling the electro-magnetic component of the Auger tank signal.*

## Computer skills

I have a working knowledge of C, Python, Matlab and Mathematica, and I am a user of CPU grids. My current favourite setup is Python, wrapping up C for performance.

## Languages

French **Fluent** *Mother language.*

English **Fluent** *Main working language.*

German **Fluent** *"Abitur" with highest honours (German equivalent to the French "baccalauréat" or British A-levels).*

## Interests

Music I play the piano, keyboards and synthesizers, and I am teaching myself guitar and drums. I am currently especially interested in free improvised music.

## Track Record

I present my research interests in a loose chronological order.

**Adaptive inference methods.** During my thesis, I have been particularly interested in self-tuning inference and optimization methods, also denoted as *adaptive stochastic search* methods. Indeed, for today's complex and large-scale models resulting from modelling natural phenomena, inference has to be automatized to be realistically undertaken. My main contribution so far to statistical methodology was to propose, apply and study an adaptive Metropolis algorithm with online relabeling [20, 6, 2], that performs Markov chain Monte Carlo simulation with adaptive proposals in models with symmetries, such as mixture models. This algorithm is novel in that it is adaptive both in its proposal mechanism and in the definition of the target distribution, which makes its theoretical study both challenging and interesting, combining tools from stochastic approximation and vector quantization.

**Hyperparameter tuning in machine learning.** My contributions in machine learning (ML) are in the subfield of hyperparameter optimization. With the idea in mind to deliver turn-key algorithms, I first studied and proposed an improvement to Bayesian optimization algorithms [8], a useful paradigm for hyperparameter tuning. In 2011, I was invited to spend a month with Yoshua Bengio's group at Université de Montréal, to develop methods that apply to the automatic tuning of deep learning networks [7]. Deep learning algorithms are a class of state-of-the-art ML algorithms which can have tens of hyperparameters, the tuning of which is usually referred to as black magic by non-experts, thus justifying the development of automatic tuning methods. Motivated by the positive results we obtained in [7], I have used dataset similarity to improve on automatic hyperparameter tuning [9].

**Applications to particle physics**. During my thesis, I was a member of the Pierre Auger collaboration, a team of 300+ researchers and technicians devoted to the construction, maintenance, and data analysis of the Auger cosmic ray observatory. I have thus participated in several internal collaboration conferences, discussed and coauthored a number of journal papers with the full collaboration (see publication list). My direct and personal contributions include probabilistic modelling of the low-level signal [22] and complex empirical Bayes inference procedure [21]. More marginally, I made technical contributions such as radio measurements [23] and spent a month on the site of the observatory in Argentina in 2011 on a shift, monitoring the telescopes of the experiment.

**Scalable Bayesian inference.** Loosely speaking, Bayesian inference for big data faces two main challenges: big data can be *tall* – it contains an overwhelming number of individual data points – and/or it can be large – each data point contains a large number of components. Since my postdoc, I have had a keen interest into scaling up Bayesian inference to tall datasets while maintaining the theoretical properties that make Bayesian inference desirable in the first place. I have given the first MCMC algorithm that both relies on subsamples of the original dataset and leads to provable guarantees [4]. A side-product of this work has been the proof of a novel concentration inequality [1]. Since then, I have improved the above algorithm and given a critical review of the recent abundant literature on the topic in [25, under review].

**Applications to biology.** Since taking part in the 2020 science network – a UK-based network of young computational scientists –, I have started transferring statistical tools to computational biology, in particular cardiac modelling [26, under review]. More marginally, the whole 2020 science network put together their experiences in a paper [24] with generic recommendations for successful cross-disciplinary collaborations.

**Determinantal point processes.** Determinantal point processes (DPPs) are point process models that naturally encode diversity or repulsiveness between the points of a given realization, using algebraic arguments. They arise in many fields, e.g. random matrix theory, combinatorics, quantum physics. My long term motivation is to use DPPs for Monte Carlo integration, since repulsiveness is naturally related to low Monte Carlo error. A side product of my study of DPPs so far has been a novel inference method to learn a DPP [3].

## Publications

My research is multidisciplinary, and publishing habits differ among the relevant disciplines.

In **machine learning**, top journals are *Journal of Machine Learning Research* and *Machine Learning*. However, it is considered as important and prestigious to publish in the following conferences: *NIPS (Neural and Information Processing Systems), ICML (International Conference in Machine Learning), International Conference on Learning Theory (COLT)* (they are all refereed, with an acceptance rate around $20\%$). Short author lists are more common, with the first author being outlined.

In **statistics**, journal papers are more valued than conference papers, and major journals are more numerous. Short author lists are the rule, with the first author being outlined. *Bernoulli* is one of the top journals.

The process of publication in **experimental physics** is pretty different. Journal papers are more valued, but they often have long author lists. As I was a member of the 300+-member Auger Collaboration, I coauthored journal papers that were the result of the work of the full collaboration. *Astroparticle Physics* is the main journal in the field of Astroparticles, to which the Auger experiment is dedicated. My main personal contributions to Auger (modelling and inference) are underlined in "short-author-list" conference proceedings and internal papers (GAP notes). The latter are shown here under technical reports, and are not available outside of the Auger Collaboration.

In **biology**, conferences usually do not issue proceedings either, so that journal publications are more valued as well, similarly to physics. Long author lists are more common as well, with the first ("main") and last ("senior") authors being outlined.

As of November 2013 and according to Google Scholar, my publications in CS have been cited 61 times, and my publications in Physics 550+ times.

### CS journals

[1] R. Bardenet and O.-A. Maillard. Concentration inequalities for sampling without replacement. *Bernoulli*, 21(3):1361–1385, 2015.

[2] R. Bardenet, O. Cappé, G. Fort, and B. Kégl. Adaptive MCMC with online relabeling. *Bernoulli*, 21(3):1304–1340, 2015.

### CS refereed proceedings

[3] R. Bardenet and M. K. Titsias. Inference for determinantal point processes without spectral knowledge. In *Advances in Neural Information Proccessing Systems (NIPS)*, 2015.

[4] R. Bardenet, A. Doucet, and C. Holmes. Towards scaling up MCMC: an adaptive subsampling approach. In *Proceedings of the International Conference on Machine Learning (ICML)*, 2014. http://jmlr.org/proceedings/papers/v32/bardenet14-supp.pdf.

[5] R. Bardenet, M. Brendel, B. Kégl, and M. Sebag. Collaborative hyperparameter tuning. In *International Conference on Machine Learning (ICML)*, 2013.

[6] R. Bardenet, O. Cappé, G. Fort, and B. Kégl. An adaptive Metropolis algorithm with online relabeling. In *Proceedings of the International Conference on Artificial Intelligence and Statistics (AISTATS)*, volume 22, pages 91–99, April 2012.

[7] J. Bergstra, R. Bardenet, B. Kégl, and Y. Bengio. Algorithms for hyperparameter optimization. In *Advances in Neural Information Processing Systems (NIPS)*, volume 24. The MIT Press, 2011.

[8] R. Bardenet and B. Kégl. Surrogating the surrogate: accelerating Gaussian-process-based global optimization with a mixture cross-entropy algorithm. In *Proceedings of the 27th International Conference on Machine Learning (ICML)*, 2010.

### CS refereed workshops

[9] R. Bardenet, M. Brendel, B. Kégl, and M. Sebag. SCoT: surrogate-based collaborative tuning for hyperparameter learning that remembers the past. NIPS workshop on Bayesian Optimization and Decision Making, 2012.

[10] R. Bardenet, B. Kégl, and G. Fort. Relabeling MCMC algorithms in Bayesian mixture learning. Snowbird Learning workshop, 2011.

[11] R. Bardenet and B. Kégl. Sampling-based optimization with mixtures. NIPS workshop on Optimization for Machine Learning, 2009.

### CS book chapters

[12] R. Bardenet. *Proceedings of the 2012 IN2P3 School of Statistics*, chapter Monte Carlo methods. EDP Sciences, 2013.

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### Physics Journals (selected papers)

[13] P. Abreu et al. The lateral trigger probability function for UHE cosmic rays showers detected by the Pierre Auger Observatory. *Astroparticle Physics*, 35:266–276, 2011. Auger Collaboration paper.

[14] P. Abreu et al. Anisotropy and chemical composition of ultra-high energy cosmic rays using arrival directions measured by the Pierre Auger Observatory. *Journal of Cosmology and Astroparticle Physics*, page 022, 2011. Auger Collaboration paper.

[15] P. Abreu et al. Advanced functionality for radio analysis in the Offline software framework of the Pierre Auger Observatory. *Nuclear Instruments and Methods in Physics Research A*, 635:92–102, 2011. Auger Collaboration paper.

[16] P. Abreu et al. The Pierre Auger Observatory scaler mode for the study of solar activity modulation of galactic cosmic rays. *JINST*, 6:01003, 2011. Auger Collaboration paper.

[17] P. Abreu et al. Search for first harmonic modulation in the right ascension distribution of cosmic rays detected at the Pierre Auger Observatory. *Astroparticle Physics*, 34:627–639, 2011. Auger Collaboration paper.

[18] P. Abreu et al. The exposure of the hybrid detector of the Pierre Auger Observatory. *Astroparticle Physics*, 34:368–381, 2011. Auger Collaboration paper.

[19] P. Abreu et al. Update on the correlation of the highest energy cosmic rays with nearby extragalactic matter. *Astroparticle Physics*, 34:314–326, 2010. Auger Collaboration paper.

### Physics refereed proceedings

[20] R. Bardenet and B. Kégl. An adaptive Monte Carlo Markov chain algorithm for inference from mixture signals. In *Proceedings of ACAT'11, Journal of Physics: Conference series*, 2012.

### Physics technical reports

[21] B. Kégl, R. Busa-Fekete, K. Louedec, R. Bardenet, X. Garrido, I.C. Mariș, D. Monnier-Ragaigne, S. Dagoret-Campagne, and M. Urban. Reconstructing $N_{\mu 19}(1000)$. Technical reports 2011-054, Auger Project Technical Note, 2011.

[22] R. Bardenet, B. Kégl, and D. Veberic. Single muon response: The signal model. Technical Report 2010-110, Auger Project Technical Note, 2010.

[23] R. Dallier, R. Bardenet, S. Gambetta, H. Lyberis, and C. Macolino. Radio spectrum measurements at Auger, part 2. Technical Report 2010-032, Auger Project Technical Note, 2010.

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### Biology Journals

[24] B. Knapp, R. Bardenet, M. Bernabeu, R. Bordas, M. Bruna, B. Calderhead, J. Cooper, A. G. Fletcher, D. Groen, B. Kuijper, J. Lewis, G. McInerny, T. Minssen, J. Osborne, V. Paulitschke, J. Pitt-Francis, J. Todoric, C. A. Yates, D. Gavaghan, and C. M. Deane.

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### Under review

[25] R. Bardenet, A. Doucet, and C. Holmes. On Markov chain Monte Carlo methods for tall data. *Preprint, available as http://arxiv.org/abs/1505.02827*, 2015.

[26] R. H. Johnstone, E. T. Chang, R. Bardenet, T. P. de Boer, D. J. Gavaghan, R. H. Clayton, G. R. Mirams, and P. Pathmanathan. Uncertainty and variability in models of the cardiac action potential: Can we build trustworthy models? *Submitted*, 2015.