

CONTACT INFORMATION Amazon Research Cambridge  
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RESEARCH INTERESTS **Statistical and algorithmic aspects of machine learning:** methods of moments for learning latent variable models; spectral techniques; differential privacy and private multi-party learning; applications to natural language processing, reinforcement learning, and structured prediction; learning under constraints arising in Big Data applications (e.g. tera-scale datasets, on-line learning); statistical and computational learning theory.

PRACTICAL EXPERTISE **Design, analysis, and implementation of machine learning algorithms:** scalable and accurate spectral decompositions for matrices and tensors; convex optimization algorithms for large scale data; secure multi-party computation; statistical natural language processing; experience with Twitter data, time series, and recommendation systems.

EDUCATION **Universitat Politècnica de Catalunya (UPC)**, Barcelona, Spain

PhD Computer Science — July 2013

- *Thesis:* Learning Finite-State Machines: Algorithmic and Statistical Aspects
- *Advisors:* Jorge Castro and Ricard Gavaldà

MSc Applied Mathematics — March 2009

- *Thesis:* On Whitehead's Algorithm for Equivalence Testing in Free Groups
- *Advisor:* Enric Ventura

BSc (5-year degree) Telecommunication Engineering — December 2007

- *Thesis:* An Algebraic Method for Constructing Cycles on DeBruijn's Graph and Applications to Shaft Encoding
- *Advisors:* Josep M. Fuertes and Enric Ventura

BSc (5-year degree) Mathematics — February 2007

- *Merits:* Participation in an exclusive program for interdisciplinary studies (CFIS)

AWARDS AND HONORS

**Awards**

- Extraordinary PhD Thesis Award, Universitat Politècnica de Catalunya, 2015
- Best Paper Award at EACL, 2012
- Best Student Paper Award at ICGI, 2012
- Runner-up for Best Student Paper Award at NIPS, 2012
- Best Undergraduate Thesis in Engineering, Catalan Technological Society, 2008

## Honors

- Oral presentation at NIPS 2012 (5.4% of accepted papers)
- Runner-up of the Valortec Competition on business plans for technology start-ups
- 2nd place in the Zulu Competition 2010 on active learning for finite automata
- My NIPS 2012 paper was featured in Google’s list “Excellent Papers for 2012”

## GRANTS AND FELLOWSHIPS

### Competitive Fellowships

- FPU Doctoral Fellowship, Spanish Ministry of Education  
August 2009 – January 2013
- FPU Travel Award (for visiting NYU), Spanish Ministry of Education  
November 2011 – June 2012
- FI Doctoral Fellowship, Catalan Government  
January 2009 – July 2009
- Undergraduate Research Fellowship, Spanish Ministry of Education  
September 2005 – June 2006

## POSITIONS HELD

### **Amazon.com**, Cambridge, UK

Applied Scientist, Machine Learning Core Group (April 2017 – ongoing)

### **Lancaster University**, Lancaster, UK

Lecturer, Department of Mathematics and Statistics (October 2015 – March 2017)

- Joint affiliation with the Data Science Institute
- Exempt from teaching and administrative duties for the first two years

### **McGill University**, Montreal, Canada

Postdoctoral Fellow, School of Computer Science (October 2013 – September 2015)

- Member of the “Reasoning and Learning Laboratory” working with professors Prakash Panangaden, Joelle Pineau, and Doina Precup

### **Universitat Politècnica de Catalunya**, Barcelona, Spain

Research and Teaching Assistant, Department of Computer Science (January 2009 – July 2013)

- Member of the “Laboratory for Relational Algorithmics, Complexity and Learning”

## RESEARCH VISITS **New York University (NYU)**, New York, NY

- *Department*: Courant Institute for Mathematical Sciences
- *Host*: Mehryar Mohri
- *Period*: November 2011 – June 2012

## INDUSTRIAL EXPERIENCE

### **Quipu**, Barcelona, Spain

Advisor (January 2017 – ongoing)

Board Member (September 2013 – December 2016)

### **Freelance Consultant**, Catalunya, Spain

Statistics and Information Technology (January 2008 – September 2013)

- Consulted for: RCR Arquitectes, Intelligent Pharma, Espuña, Ajuntament de Barcelona, Series.ly, and AqSense

## Ericsson Research, Madrid, Spain

External Collaborator (September 2011 – February 2012)

- Participate in a joint research project with UPC to design and develop a prototype system to predict customer churning out of cellphone providers

## Intelligent Pharma, Barcelona, Spain

Data Scientist (March – September 2008)

- Analyze results from large-scale in-silico experiments for drug discovery
- Write special-purpose tools to solve geometric tasks in computational chemistry

## PUBLICATIONS

### Journal Publications

- [1] A. Gascón, P. Schopmann, B. Balle, M. Raykova, S. Zahur, J. Doerner, and D. Evans. Privacy-Preserving Distributed Linear Regression on High-Dimensional Data. *Proceedings on Privacy Enhancing Technologies*, (4):???–???, 2017. (Acceptance Rate: 22%).
- [2] B. Balle and M. Mohri. Generalization Bounds for Learning Weighted Automata. *Theoretical Computer Science*, 2016. To Appear (SJR Ranking: Q1).
- [3] B. Balle, X. Carreras, F. M. Luque, and A. Quattoni. Spectral Learning of Weighted Automata: A Forward-Backward Perspective. *Machine Learning*, 96:33–63, 2014. ISSN 0885-612. (SJR Ranking: Q1).
- [4] B. Balle, J. Castro, and R. Gavaldà. Adaptively Learning Probabilistic Deterministic Automata from Data Streams. *Machine Learning*, 96:99–127, 2014. ISSN 0885-612. (SJR Ranking: Q1).
- [5] B. Balle, J. Castro, and R. Gavaldà. Learning Probabilistic Automata: A Study In State Distinguishability. *Theoretical Computer Science*, 473:46–60, 2013. ISSN 0304-3975. (SJR Ranking: Q1).
- [6] J. M. Fuertes, B. Balle, and E. Ventura. Absolute-Type Shaft Encoding Using LFSR Sequences With a Prescribed Length. *IEEE Transactions on Instrumentation and Measurement*, 57(5):915–922, 2008. ISSN 0018-9456. (SJR Ranking: Q1).

### Peer-Reviewed Conference Publications

- [7] M. Ruffini, G. Rabusseau, and B. Balle. Hierarchical Methods of Moments. In *Advances in Neural Information Processing Systems (NIPS) (Long Beach, USA, December 2017)*, volume ?? of *Advances in Neural Information Processing Systems (ISSN 1049–5258)*, pages ???–???, 2017. (CORE Rating: A\*; Acceptance Rate: 21%).
- [8] G. Rabusseau, B. Balle, and J. Pineau. Multitask Spectral Learning of Weighted Automata. In *Advances in Neural Information Processing Systems (NIPS) (Long Beach, USA, December 2017)*, volume ?? of *Advances in Neural Information Processing Systems (ISSN 1049–5258)*, pages ???–???, 2017. (CORE Rating: A\*; Acceptance Rate: 21%).
- [9] B. Balle and O.-A. Maillard. Spectral Learning from a Single Trajectory under Finite-State Policies. In *Proceedings of the 34rd International Conference on Machine Learning (ICML) (Sydney, Australia, August 2017)*, volume 70 of *Proceedings of Machine Learning Research (PMLR)*, pages 361–370, 2017. (CORE Rating: A\*; Acceptance Rate: 25%).

- [10] B. Balle, P. Gordeau, and P. Panangaden. Bisimulation Metrics for Weighted Automata. In *Proceedings of the 44rd International Colloquium on Automata, Languages, and Programming (ICALP) (Warsaw, Poland, July 2017)*, volume 80 of *LIPICs*, pages 103:1–103:14, 2017. (CORE Rating: A; Acceptance Rate: 30%).
- [11] B. Balle, M. Gomrokchi, and D. Precup. Differentially Private Policy Evaluation. In *Proceedings of the 33rd International Conference on Machine Learning (ICML) (New York, U.S., June 2016)*, volume 48 of *JMLR Workshop and Conference Proceedings*, pages 2130–2138, 2016. (CORE Rating: A\*; Acceptance Rate: 24%).
- [12] L. Langer, B. Balle, and D. Precup. Learning Multi-Step Predictive State Representations. In *Proceedings of the 25th International Joint Conference on Artificial Intelligence (IJCAI) (New York, U.S., July 2016)*, pages 1662–1668. IJCAI/AAAI Press, 2016. ISBN 978-1-57735-770-4. (CORE Rating: A\*; Acceptance Rate: 25%).
- [13] G. Rabusseau, B. Balle, and S. Cohen. Low-Rank Approximation of Weighted Tree Automata. In *Proceedings of the 19th International Conference on Artificial Intelligence and Statistics (AISTATS) (Cadiz, Spain, May 2016)*, volume 51 of *JMLR Workshop and Conference Proceedings*, pages 839–847, 2016. (CORE Rating: A; Acceptance Rate: 31%).
- [14] C. Zhou, B. Balle, and J. Pineau. Learning Time Series Models for Pedestrian Motion Prediction. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA) (Stockholm, Sweden, May 2016)*, pages 3323–3330. IEEE, 2016. ISBN 978-1-4673-8026-3. (CORE Rating: B; Acceptance Rate: 35%).
- [15] B. Wang, B. Balle, and J. Pineau. Multitask Generalized Eigenvalue Program. In *Proceedings of the 30th AAAI Conference on Artificial Intelligence, AAAI (Phoenix, Arizona, February 2016)*, pages 2115–2121. AAAI Press, 2016. (CORE Rating: A\*; Acceptance Rate: 26%).
- [16] B. Balle and M. Mohri. On the Rademacher Complexity of Weighted Automata. In *Proceedings of the 26th International Conference on Algorithmic Learning Theory, ALT (Banff, Canada, October 2015)*, volume 9355 of *Lecture Notes in Computer Science*, pages 179–193. Springer, 2015. ISBN 978-3-319-24485-3. (CORE Rating: B; Acceptance Rate: 50%).
- [17] B. Balle and M. Mohri. Learning Weighted Automata. In *Proceedings of the 6th International Conference on Algebraic Informatics, CAI (Stuttgart, Germany, September 2015)*, volume 9270 of *Lecture Notes in Computer Science*, pages 1–21. Springer, 2015. ISBN 978-3-319-23020-7. (Invited Paper).
- [18] P. L. Bacon, B. Balle, and D. Precup. Learning and Planning with Timing Information in Markov Decision Processes. In *Proceedings of the 31th Uncertainty in Artificial Intelligence Conference, UAI (Amsterdam, The Netherlands, July 2015)*, pages 111–120. AUAI Press, 2015. ISBN 978-0-9966431-0-8. (CORE Rating: A\*; Acceptance Rate: 34%).
- [19] B. Balle, P. Panangaden, and D. Precup. A Canonical Form for Weighted Automata and Applications to Approximate Minimization. In *Proceedings of the 30th Annual ACM/IEEE Symposium on Logic in Computer Science, LICS (Kyoto, Japan, July 2015)*, pages 701–712. IEEE Computer Society, 2015. ISBN 978-1-4799-8875-4. (CORE Rating: A\*; Acceptance Rate: 35%).

- [20] A. Quattoni, B. Balle, X. Carreras, and A. Globerson. Spectral Regularization for Max-Margin Sequence Tagging. In *Proceedings of the 31th International Conference on Machine Learning, ICML (Beijing, China, June 2014)*, volume 32 of *JMLR Proceedings (ISSN 1938-7228)*, pages 1386–1394, 2014. (CORE Rating: A\*; Acceptance Rate: 25%).
- [21] B. Balle, W. L. Hamilton, and J. Pineau. Methods of Moments for Learning Stochastic Languages: Unified Presentation and Empirical Comparison. In *Proceedings of the 31th International Conference on Machine Learning, ICML (Beijing, China, June 2014)*, volume 32 of *JMLR Proceedings (ISSN 1938-7228)*, pages 1710–1718, 2014. (CORE Rating: A\*; Acceptance Rate: 25%).
- [22] B. Balle, B. Casas, A. Catarineu, R. Gavaldà, and D. Manzano-Macho. The Architecture of a Churn Prediction System Based on Stream Mining. In *Artificial Intelligence Research and Development - Proceedings of the 16th International Conference of the Catalan Association for Artificial Intelligence (Vic, Spain, October 2014)*, volume 256 of *Frontiers in Artificial Intelligence and Applications*, pages 157–166. IOS Press, 2013. ISBN 978-1-61499-319-3. (CORE Rating: N/A).
- [23] B. Balle and M. Mohri. Spectral Learning of General Weighted Automata via Constrained Matrix Completion. In *Advances in Neural Information Processing Systems 25: 26th Annual Conference on Neural Information Processing Systems 2012 (Lake Tahoe, USA, December 2012)*, Advances in Neural Information Processing Systems (ISSN 1049-5258), pages 2168–2176, 2012. (CORE Rating: A\*; Acceptance Rate: 25%).
- [24] B. Balle, J. Castro, and R. Gavaldà. Bootstrapping and Learning PDFAs in Data Streams. In *Proceedings of the 11th International Conference on Grammatical Inference, ICGI (Washington, USA, September 2012)*, volume 21 of *JMLR Proceedings (ISSN 1938-7228)*, pages 34–48, 2012. (CORE Rating: N/A).
- [25] B. Balle, A. Quattoni, and X. Carreras. Local Loss Optimization in Operator Models: A New Insight Into Spectral Learning. In *Proceedings of the 29th International Conference on Machine Learning, ICML (Edinburgh, UK, June 2012)*, 2012. (CORE Rating: A\*; Acceptance Rate: 27%).
- [26] F. M. Luque, A. Quattoni, B. Balle, and X. Carreras. Spectral Learning for Non-Deterministic Dependency Parsing. In *EACL 2012, 13th Conference of the European Chapter of the Association for Computational Linguistics (Avignon, France, April 2012)*, pages 409–419. The Association for Computer Linguistics, 2012. ISBN 978-1-937284-19-0. (CORE Rating: A; Acceptance Rate: 27%).
- [27] B. Balle, A. Quattoni, and X. Carreras. A Spectral Learning Algorithm for Finite State Transducers. In *Machine Learning and Knowledge Discovery in Databases - European Conference, ECML-PKDD. Proceedings, Part I (Athens, Greece, September 2011)*, volume 6911 of *Lecture Notes in Computer Science*, pages 156–171. Springer, 2011. ISBN 978-3-642-23779-9. (CORE Rating: A; Acceptance Rate: 20%).
- [28] B. Balle, J. Castro, and R. Gavaldà. A Lower Bound for Learning Distributions Generated by Probabilistic Automata. In *Proceedings of Algorithmic Learning Theory, 21st International Conference, ALT (Canberra, Australia, October 2010)*, volume 6331 of *Lecture Notes in Computer Science*, pages 179–193. Springer, 2010. ISBN 978-3-642-16107-0. (CORE Rating: B).

- [29] B. Balle, J. Castro, and R. Gavaldà. Learning PDFAs with Asynchronous Transitions. In *Grammatical Inference: Theoretical Results and Applications, 10th International Colloquium. Proceedings (Valencia, Spain, September 2010)*, volume 6339 of *Lecture Notes in Computer Science*, pages 271–275. Springer, 2010. ISBN 978–3–642–15487–4. (Short paper; CORE Rating: N/A).
- [30] B. Balle, E. Ventura, and J.M. Fuertes. An Algorithm to Design Prescribed Length Codes for Single-tracked Shaft Encoders. In *IEEE International Conference on Mechatronics (ICM) (Malaga, Spain, April 2009)*, 2009. ISBN 978–1–4244–4195–2. (CORE Rating: N/A).

#### Workshop Contributions

- [31] B. Balle, M. Gomrokchi, and D. Precup. Differentially Private Policy Evaluation. *Poster at ICML Workshop Theory and Practice of Differential Privacy (New York, NY, U.S.A., June 2016)*, 2016.
- [32] P. Schoppmann, A. Gascón, and B. Balle. Solving Private Systems of Linear Equations with Garbled Circuits. *Poster at the 37th IEEE Symposium on Security and Privacy (San Jose, CA, U.S.A., May 2016)*, 2016.
- [33] L. Langer, B. Balle, and D. Precup. Multi-Step Predictive State Representations. *Poster at NIPS Workshop on Time Series (Montreal, Canada, December 2015)*, 2015.
- [34] B. Wang, B. Balle, and J. Pineau. Multitask Generalized Eigenvalue Program. *Poster at NIPS 2015 Workshop on Transfer and Multi-Task Learning: Trends and New Perspectives (Montreal, Canada, December 2015)*, 2015.
- [35] P. L. Bacon, B. Balle, and D. Precup. Learning and Planning with Timing Information in Markov Decision Processes. *Poster at 2nd Multi-disciplinary Conference on Reinforcement Learning and Decision Making, RLDM (Edmonton, Canada, June 2015)*, 2015.
- [36] P. L. Bacon, B. Balle, and D. Precup. Learning and Planning with Timing Information in Markov Decision Processes. *Talk and Poster at NIPS Workshop From Bad Models to Good Policies (Montreal, Canada, December 2014)*, 2014.
- [37] A. M.S. Barreto, B. Balle, J. Pineau, and D. Precup. Starting to Uncover the Relationship Between Stochastic Factorization and Hidden Markov Models. *Poster at NIPS Workshop Novel Trends and Applications in RL (Montreal, Canada, December 2014)*, 2014.
- [38] B. Balle, J. Castro, and R. Gavaldà. Learning Markovian Models from Time-Evolving Data Streams. *Talk at From Data to Knowledge: Machine-Learning with Real-time and Streaming Applications (Berkeley, California, May 2012)*, 2012.
- [39] B. Balle, A. Quattoni, and X. Carreras. Local Loss Optimization in Operator Models: A New Insight into Spectral Learning. *Poster at New England Machine Learning Day (Cambridge, Massachusetts, May 2012)*, 2012.
- [40] B. Balle. Implementing Kearns-Vazirani Algorithm for Learning DFA Only with Membership Queries. *Talk and Paper at Zulu Competition Workshop (Valencia, Spain, September 2010)*, 2010.

#### Other Publications and Preprints

- [41] B. Balle, P. Panangaden, and D. Precup. Singular Value Automata. *Preprint*, 2016.
- [42] Y. Grinberg, M. Lyman-Abramovitch, B. Balle, and D. Precup. Learning Predictive State Representations from Non-uniform Sampling. *Preprint*, 2015.
- [43] L. Addario-Berry, B. Balle, and G. Perarnau. Diameter and Mixing Time in Random  $d$ -out Digraphs. *Preprint, Arxiv 1504.06840*, 2015.
- [44] B. Balle. Ergodicity of Random Walks on Random DFA. *Technical Report, Arxiv 1311.6830*, 2013.

TEACHING AND  
SUPERVISION  
EXPERIENCE

**Oxford University**, United Kingdom

- Visiting lecturer — February 2016
  - Advanced graduate class on *Automata and Learning* (six 1h sessions)

**Lancaster University**, United Kingdom

- Co-supervisor (MSc Data Science final project) — Summer 2016
  - Syed Jawaad, *Optimizing Heating Policies with Reinforcement Learning*
- Supervisor (EPSRC-funded undergraduate research internship) — Fall 2016
  - Aidan Metcalfe, *The Mathematics of Privacy*

**McGill University**, Montreal, Canada

Reading Group Organizer— Summer 2014

- *Topic*: Spectral learning algorithms
- *Students*:  $\sim 10$

Supervisor (undergraduate honors project) — Summer/Fall 2014

- Chenghui Zhou, *A Spectral Method for Learning Motion Models with Applications to Human Tracking*

Supervisor (undergraduate summer research internships)

- Chenghui Zhou (2014, 2015)
- Lucas Langer (2015)
- Pascale Gourdeau (2015)

**Universitat Politècnica de Catalunya**, Barcelona, Spain

Supervisor (undergraduate final year project) — Spring 2013

- Albert Santiago, *Implementation of a Spectral Method for Learning Finite-State Machines*

Lecturer (Theory of Computation) — Spring 2011

- *Syllabus*: Introduction to language theory, finite automata, context-free grammars, and Turing machines
- *Students*:  $\sim 50$

Teaching Assistant (Information Retrieval) — Spring 2011

- *Responsibilities*: Design and mark computer assignments; explain relation between lectures and assignments
- *Students*:  $\sim 30$

**Invited Talks and Tutorials**

- Invited talk on “Machine Learning Algorithms for Weighted Automata” (5th Highlights of Logic, Games and Automata Conference, London, September 2017)
- Invited talk on “Secure Multi-Party Linear Regression on High-Dimensional Data” (Advances in Data Science, Manchester, May 2017)
- Invited talk on “Secure Multi-Party Linear Regression on High-Dimensional Data” (Workshop on Privacy in Statistical Analysis, Imperial College London, May 2017)
- Invited talk on “Approximation Algorithms for Weighted Automata” (Bellairs Workshop on Algorithmic Aspects of Dynamical Systems, Barbados, March 2017)
- Invited talk on “Differential Privacy and Secure Multi-Party Computation in Linear Regression” (QARMA Workshop on Machine Learning, Marseille, October 2016)
- Invited talk on “Theoretical Guarantees for Learning Weighted Automata” (13th International Conference on Grammatical Inference (ICGI), Delft, October 2016)
- Invited talk on “Statistical Aspects of Modern Machine Learning for Software Engineers” (Dagstuhl Seminar on Machine Learning for Dynamic Software Analysis: Potentials and Limits, April 2016) [*cancelled due to personal reasons*]
- Invited tutorial on “(Co)-Algebraic and Analytical Aspects of Weighted Automata Minimisation and Equivalence” co-presented with A. Silva (13th International Workshop on Coalgebraic Methods in Computer Science (CMCS), Eindhoven, April 2016)
- Invited talk on “Spectral Algorithms for Learning Predictive State Representations with Prior Information” (9th Barbados Workshop on Reinforcement Learning, Barbados, April 2015)
- Tutorial on “Spectral Learning Techniques for Weighted Automata, Transducers, and Grammars” co-presented with X. Carreras and A. Quattoni (Conference on Empirical Methods in Natural Language Processing (EMNLP), Qatar, October 2014)

**Seminar Talks**

- University of Kent (February 2017)
- Trinity College Dublin (January 2017)
- Imperial College London (October 2016)
- University of Leicester (June 2016)
- The University of Edinburgh (March 2016)
- Xerox Research Center Europe (November 2015)
- INRIA Lille (February 2015)
- Université d’Aix-Marseille (September 2014)
- Oxford University (September 2014)
- Toyota Technical Institute Chicago (April 2013)
- Google Mountain View (February 2013)
- McGill University (September 2012)
- Massachusetts Institute of Technology (May 2012)
- Google New York (February 2012)
- New York University (November 2011)
- Tokyo Institute of Technology (November 2010)
- The University of Waikato (October 2010)

**Contributed Workshop Talks**

- “Learning Markovian Models from Time-Evolving Data Streams” (From Data to Knowledge: Machine-Learning with Real-time and Streaming Applications, Berkeley, May 2012)
- “Implementing Kearns-Vazirani Algorithm for Learning DFA Only with Membership Queries” (Zulu Competition Workshop, València, September 2010)

**Organization of Workshops and Other Events**

- Workshop on “Learning and Automata” at LICS 2017
- Workshop on “Privacy and Fairness in Machine Learning” at DALI 2017



- Member of the Steering Committee for the “International Conference in Grammatical Inference” (2016-onwards)
- Workshop on “Private Multi-Party Machine Learning” at NIPS 2016
- Machine learning competition “Sequence Prediction Challenge (SPICE)” within ICGI 2016
- Workshop on “Methods of Moments and Spectral Learning” at ICML 2014
- Workshop on “Spectral Learning” at NIPS 2013
- Workshop on “Spectral Learning” at ICML 2013

#### **Conference and Workshop Program Committees**

- 2017: AISTATS, EACL, ICML, COLT (reviewer), NIPS, PSML (ICML workshop)
- 2016: ICML, NIPS, ACL, EMNLP, AISTATS, ICGI, SPICE, StatFSM (ACL workshop), CAp
- 2015: NIPS (workshops chair), ICML, IJCAI, VSM-NLP (NAACL workshop)
- 2014: NIPS (area chair), ICML, EMNLP, EACL, ICGI
- 2013: ICML, NIPS
- 2012: NIPS
- 2011: ICALP (reviewer), ICML (reviewer)

#### **Reviewer for Journals**

- Theoretical Computer Science
- Machine Learning
- Journal of Machine Learning Research

#### **Other Committees**

- Reviewer for the French National Research Agency evaluation panel on Mathematics and Computer Science (2017)
- External examiner for the PhD viva defense of Naoise Holohan at Trinity College Dublin (January 2017)
- Member of the PhD examining board for Guillaume Rabusseau at Université d’Aix-Marseille (October 2016)