

- Research interests:** computational and statistical modeling of complex systems.
- My current research is on building quantitative probabilistic and descriptive models of brain function through computational analysis of functional imaging.
 - I am also interested in the development of scientific-computing tools and software engineering best practices for computational sciences.
 - My original training is in physics. I did my PhD on quantum-based atom-optic metrology.

EDUCATION

- PhD** 2005–2007 Université Paris Sud Orsay, FRANCE, direction: prof. Alain Aspect, defense January 18, 2008.
Thesis: [Atomic sources for long-time-of-flight interferometric inertial sensors](#)
- Masters** 2004 Masters in quantum physics (DEA de physique quantique, ENS)
- ENS** 2001–2004 Undergraduate studies at École Normale Supérieure Paris (ENS)

BRAIN IMAGING

2008—Present

Positions

- INSERM** Oct. 2010–Present Post-doctoral fellow, Unicog team, NeuroSpin, supervision: A. Kleinschmidt.
Computational modeling of on-going brain activity.
- INRIA** Oct. 2008–Oct. 2010 Post-doctoral fellow, Parietal team, NeuroSpin, supervision: B. Thirion, J.P. Poline.
Development of statistical methods to study brain resting-state activity.

Research

My main research focus is on **multivariate data analysis** and statistical inference of brain function from **functional MRI**. I develop algorithms and models to study the correlations in the fluctuations of neural activity observed across the brain, i.e. **functional connectivity**. For inference on group data, I introduce explicit models of spatial and functional variability.

Spatial models of on-going activity Spatial Independent Component Analysis (**ICA**) is a widely-used technique in neuroimaging to extract co-activating brain networks. I have improved its reproducibility in multi-subject studies by introducing a multivariate mixed-effect group model [2, 6]. In addition, I have showed that formulating the source separation as the recovery of sparse activated networks gives a good control on sensitivity and specificity [7]. I am currently focusing on introducing subject variability and spatial structure in **sparse decomposition models** of brain activity for unsupervised **segmentation of functional regions** from fMRI [12, 15].

Graphical models of functional connectivity I apply **Gaussian graphical models** to the study of the covariance structure of brain activity [5]. With new task-specific comparison methods, we have isolated modifications of functional connectivity in schizophrenia specific to an elementary memory mechanism [4]. For statistically-principled comparison of connectivity across subjects, I have introduced a new matrix-variate distribution describing **group variability of covariance matrices** for optimal detection on interdependent connectivity parameters [8]. Applying this methodology to **stroke** patients, we have for the first time detected modifications of resting-state networks due to pathologies on single subjects. To alleviate estimation problems when scaling to large-scale individual graphical models, we introduce a **covariance-selection** algorithm that use convex optimization to impose a common conditional-independence structure between brain regions across subjects [11].

Machine learning for inter-subject brain mapping I work on multivariate analysis to map the neuronal coding of cognitive processes across subjects. Subject-to-subject anatomo-functional variability is a fundamental limitation to population studies in brain functional imaging. We adapt state-of-the-art machine learning and computer vision algorithms to model it explicitly in the data analysis. In the standard analysis framework (GLM), we detect **spatially-variable functional landmarks** to map subject specificities [9]. In the context of inverse inference, we learn brain regions that **predict behavior** across subjects. We use greedy algorithms to select predictive parcels by tree cuts on a hierarchical clustering [3], or convex fitting of the data with penalizations selecting clustered voxels [1, 10].

Other

Journal editor Review editor for *Frontiers in NeuroInformatics*.

Reviewer Reviewer for *Human Brain Mapping* (Wiley InterScience), *NeuroImage* (Elsevier), *J. Physiology Paris* (Elsevier), *Journal of Machine Learning Research* (MIT Press) and *Transactions in Medical Imaging* (IEEE).

Publications

Peer-reviewed journals

- [1] V. Michel, A. Gramfort, *et al.* *Total variation regularization for fMRI-based prediction of behavior*, IEEE Transactions on Medical Imaging, In press
- [2] G. Varoquaux, S. Sadaghiani, *et al.* *A group model for stable multi-subject ICA on fMRI datasets*, NeuroImage **51**, p. 288 (2010)
- [3] V. Michel, A. Gramfort, *et al.* *A supervised clustering approach for fMRI-based inference of brain states*, Pattern Recognition, In press
- [4] M.L. Grillon, C. Oppenheim, G. Varoquaux, *et al.*, *Hyperfrontality and hypoconnectivity in schizophrenia during an elementary working memory task*, Submitted to NeuroImage
- [5] G. Varoquaux, A. Gramfort, *et al.* *Markov models for fMRI correlation structure: is brain functional connectivity small world, or decomposable into networks?*, Submitted to J. Physio Paris
- [6] G. Varoquaux, S. Sadaghiani, *et al.* *Model-based extraction of reproducible group-level ICA patterns from fMRI time series*, MICCAI fMRI data analysis workshop 2009
- [7] G. Varoquaux, M. Keller, *et al.* *ICA-based sparse features recovery from fMRI datasets*, IEEE ISBI 2010
- [8] G. Varoquaux, F. Baronnet, *et al.* *Detection of brain functional-connectivity difference in post-stroke patients using group-level covariance modeling*, MICCAI 2010 (oral presentation)
- [9] B. Thirion, G. Varoquaux, J.B. Poline, *Accurate definition of brain regions position through the functional landmark approach*, MICCAI 2010
- [10] V. Michel, A. Gramfort, *et al.* *Total Variation regularization enhances regression-based brain activity prediction*, ICPR 2010 Workshop on Brain Decoding
- [11] G. Varoquaux, A. Gramfort, *et al.*, *Brain covariance selection: better individual functional-connectivity models using population prior*, NIPS 2010
- [12] G. Varoquaux, R. Jenatton, *et al.*, *Sparse structured dictionary learning for brain resting-state activity modeling*, NIPS workshop on sparsity 2010
- [13] P. Ciuciu, G. Varoquaux, *et al.*, *Multifractal analysis of resting-state networks in functional MRI*, ISBI 2011
- [14] G. Varoquaux, A. Gramfort, *et al.*, *Multi-subject dictionary learning to segment an atlas of brain spontaneous activity*, IPMI 2011
- [15] F. Deliglianni, G. Varoquaux, *et al.*, *A probabilistic framework to infer brain functional connectivity from anatomical connections*, IPMI 2011
- [16] V. Fritsch, G. Varoquaux, *et al.*, *Detecting Outlying subjects in high-dimensional neuroimaging datasets with regularized minimum covariance determinant*, MICCAI 2011
- [17] B. Ng, G. Varoquaux, *et al.*, *Connectivity-informed fMRI Activation Detection*, MICCAI 2011

Peer-reviewed conference proceedings

SCIENTIFIC COMPUTING

2005—Present

To bridge the gap between algorithm research and applications, I have been contributing to building a general-purpose **tool stack for computational science using the Python language**. My effort is shared between software development and improving communication and cooperation between scientific software projects and users. I focus on improving code quality as well as documentation and distribution of the tools to ensure reproducibility in computational science.

Positions

- Enthought, consultant** 2008 Consultant on scientific computing solutions in Python for Enthought Inc. (Austin). I contributed to customer-specific data processing and visualization code and general-purpose scientific computing frameworks.
- UC Berkeley** June–Sept. 2008 Junior specialist, scientific computing: development of NeuroImaging computing in Python (Nipy project), supervision: F. Perez.

Computing skills

- Proficient developer, with a specialization in scientific computing and data visualization.
- Expert knowledge of the Python language and scientific computing in Python. Knowledge of C.
- Experience in software project management and software architecture design.
- Experienced Linux system administrator on servers and desktops since 2001.
- Very good knowledge of L^AT_EX and publishing technologies.

Software

Mayavi 2007–Present I am one of the two developers of **Mayavi**, the lead 3D scientific data visualization library and application for Python [17,20]. This project won the FOSS India awards in 2008, and the second price at the MICCAI 2009 visualization awards. It is packaged in all the major Linux distributions and scientific Python environments and comes with a [300-pages long manual](#).

scikit-learn 2009–Present Project manager and core developer for **scikit-learn**, machine learning in Python [19].

Nipy 2008–Present Contributing to and maintaining **Nipy**, a cross-institute project to share neuroimaging algorithms in Python via a consistent library (actors: CEA, INRIA, UC Berkeley, MIT, Stanford).

joblib 2009–Present Author of **joblib**, light-weight and high-performance pipelining of scientific Python code.

Pyreport 2005–Present Author of **pyreport**, a tool for literate programming of scientific Python code, widely used in teaching and tutorials.

SciPy community

EuroScipy conference 2010, 2011 Co-chair and organizer of the 3rd and 4th European Python in science conference (EuroScipy), ENS, Paris, (FRANCE), July 8-11 2010 and August 25-28 2011.

SciPy conference 2008–2009 Chair of the scientific committee for the Python in science conference (SciPy), Caltech, Pasadena (USA), 2008 and 2009. Also organizer and editor of the proceedings.

Code contributions 2007–Present Contributions to various key projects (IPython, Matplotlib, scipy, numpy [18]). In particular, development of a graphical frontend to IPython.

Server administration 2008–Present Administration of the SciPy web servers and documentation and conference applications: www.scipy.org, planet.scipy.org, conference.scipy.org, docs.scipy.org.

Other

Journal editor Member of the editorial board of **ORC** (Open Research Computation)

Conference committees Member of the scientific committees for **ESCO 2010**, **FEMTEC 2011**, and **Py4HPC at ICCS**.

Reviewer Reviewer for *Computing in Science and Engineering* (AIP/IEEE), *Computer physics communications* (Elsevier).

Teaching and training I teach various aspects scientific computing in Python on a regular basis, both introduction courses, and advanced courses, in conferences (SciPy, EuroSciPy, PyConFr), or in research labs.

Publications

Peer-reviewed journals

[18] G. Varoquaux, *Agile computer control of a complex experiment*, *Computing in Science and Engineering*, **10**(2) p. 55 (2008)

[19] P. Ramachandran, G. Varoquaux, *Mayavi: a package for 3D visualization of scientific data*, *Computing in Science and Engineering*, **13**(2), p. 40 (2011)

[20] S. van der Walt, S. Colbert, G. Varoquaux, *The numpy array: a structure for efficient numerical computation*, *Computing in Science and Engineering*, **13**(2), p. 22 (2011)

[21] F. Pedregosa, G. Varoquaux, *et al.*, *scikits.learn: machine learning in Python*, *J. Machine Learning Re-*

search, accepted

Peer-reviewed conference proceedings

[22] P. Ramachandran, G. Varoquaux, *Mayavi: Making 3D Data Visualization Reusable*, *Proceedings of the 7th Python in Science conference*, G. Varoquaux, T. Vaught, J. Millman (Eds.), p. 51 (2008)

[23] G. Varoquaux, T. Vaught, J. Millman (Eds), *Proceedings of the 7th Annual Python in Science Conference – Pasadena, CA, Aug. 19-24, (2008)*

[24] G. Varoquaux, S. van der Walt, J. Millman (Eds), *Proceedings of the 8th Annual Python in Science Conference – Pasadena, CA, Aug. 18-23, (2009)*

LENS Fellow EST Marie Curie European Fellow: LENS (European laboratory for non-linear spectroscopy, Florence, ITALY), quantum degenerate gases group, supervision: prof. M. Inguscio.
Nov. 2007–April 2008

PhD candidate Atom optics group, Institut d’Optique Graduate School, Palaiseau, FRANCE
2005–2007

University of Toronto Guest researcher. Degenerate quantum gases group, prof. J. Thywissen. I implemented a new camera on the world’s first Fermi degenerate gas experiment on chip [16].
Sept.–Oct. 2006

Internships University of Otago, ultra-cold atom group, supervision A. Wilson. Design and construction of a rubidium magneto-optical trap for a new atomic quantum gases experiment.
Jan.–Aug. 2003

Sept.–Oct. 2002 University of Lancaster, liquid-⁴He group, supervision: prof. P. Mc Clintock. Cryogenic work.

Research

Atoms are promising candidates to replace photons in **interferometric measurements of inertial forces**, due to their strong gravitational coupling. In my research, I have addressed two fundamental limits to the scale of atom interferometers: divergence and fall of the atomic source.

Quantum atomic sources I have contributed to experimental techniques for well-controlled production of **quantum gases** to create *atom lasers*, that is maximally coherent and focused atomic sources. New developments include development of light-weight noise-controlled tunable lasers [23], design of a new atom cooling and trapping apparatus [24], and a new atom probing and imaging method [27].

Free-fall atom interferometry The ICE project is a collaboration between Institut d’Optique, ONERA, and Observatoire de Paris for atom interferometry in **microgravity** using a freely-falling plane as a platform for longer interrogation times of falling atoms. I developed the mobile laboratory and atom interferometer for the first test flight (March 2007). I was coordinator of the flight campaign, including designing, planning, and supervising the assembly of the interferometer and the in-flight operations [25]. Our experiment was the second to ever achieve cold atoms in flight and the apparatus is now used in bi-annual measurement campaigns [28].

Matter-wave interferometry measure and estimation The phase measured by atom interferometry is directly linked to the inertial fields [26], but in a freely-falling plane these fields are confounded by acceleration noise. I have introduced **Bayesian statistical modeling** to atom-interferometric inertial sensing and shown that tests of general relativity are possible using a noisy platform [29].

Other

YAO conference Member of the scientific and organizing committees of the Young Atom Opticians conference “YAO2006” (J.B. Trebbia, G. Varoquaux and F. Arcara, *Nature Physics* **8**, p. 287, 2007).
2006

Teaching *Monitorat*: teaching students labs and tutorials in optics and electronics, at the "Institut d’Optique Graduate School" (SupOptique).
2005–2007

Publications

Peer-reviewed journals

[25] R. A. Nyman, G. Varoquaux, *et al.*, *Tapered-amplified AR-coated laser diodes for Potassium and Rubidium atomic-physics experiments*, Review of Scientific Instruments **77**, p. 033105 (2006)

[26] R. A. Nyman, G. Varoquaux, *et al.*, *I.C.E.: a Transportable Atomic Inertial Sensor for Test in Microgravity*, Journal of Applied Physics B, **84** p. 673 (2006)

[27] G. Varoquaux, N. Zahzam, *et al.*, *ICE: an ultra-cold atom source for long-baseline interferometric inertial sensors in reduced gravity*, Proceedings of the international Moriond meetings on gravitational waves and experimental gravity (2007)

[28] E. Varoquaux and G. Varoquaux, *The Sagnac effect in superfluids*, Uspekhi Fizicheskikh Nauk, **2** p. 217 (2008)

[29] J. P. Brantut, J. F. Clément, *et al.*, *Light-shift tomography in an optical-dipole trap for neutral atoms*, Physical Review A, **78**, 031401 (2008)

[30] G. Stern, B. Battelier, *et al.*, *Light-pulse atom interferometry in microgravity* European Physical Journal D **53**, 3 p. 353 (2009)

[31] G. Varoquaux, R. A. Nyman, *et al.*, *How to estimate the differential acceleration in a two-species atom interferometer to test the equivalence principle*, New Journal of Physics **11**, 113010 (2009)

Peer-reviewed conferences

[32] P. Bouyer, G. Varoquaux, *et al.*, *Testing the universality of free fall in a freely-falling two-species atom interferometer: the I.C.E project*, International Conference on Space Optics, Toulouse, France, Oct. 2008

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