

Astérisque

From probability to geometry (I) - Volume in honor of the 60th birthday of Jean-Michel Bismut - Pages préliminaires

Astérisque, tome 327 (2009), p. I-XIII

[<http://www.numdam.org/item?id=AST_2009__327__R1_0>](http://www.numdam.org/item?id=AST_2009__327__R1_0)

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ASTÉRISQUE

2009

FROM PROBABILITY TO GEOMETRY (I)
VOLUME IN HONOR OF THE 60th BIRTHDAY
OF JEAN-MICHEL BISMUT

Xianzhe DAI, Rémi LÉANDRE, Xiaonan MA and Weiping ZHANG, editors

SOCIÉTÉ MATHÉMATIQUE DE FRANCE

Publié avec le concours du CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

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Classification mathématique par sujet (2000). — 60-XX, 58-XX, 14-XX, 19-XX, 32-XX, 35-XX, 53-XX.

Mots-clefs. — Probabilité, géométrie différentielle, géométrie d'Arakelov, processus stochastique, analyse stochastique, analyse sur les variétés, théorème de l'indice d'Atiyah-Singer, théorème de Riemann-Roch opérateurs elliptiques, opérateurs de Dirac, cohomologie équivariante, K -théorie, torsion analytique, invariant éta.

Remerciements. — Nous tenons à remercier l'Institut de Mathématiques de Jussieu (Paris) et l'Institut de Mathématiques de Bourgogne (Dijon) pour leur soutien financier.

FROM PROBABILITY TO GEOMETRY (I)
VOLUME IN HONOR OF THE 60th BIRTHDAY
OF JEAN-MICHEL BISMUT

Xianzhe Dai, Rémi Léandre, Xiaonan Ma and Weiping Zhang, editors

Abstract. — These two volumes contain original research articles submitted by colleagues and friends to celebrate the 60th birthday of Jean-Michel Bismut.

These articles cover a wide range of subjects in probability theory, in global analysis and in arithmetic geometry, to which Jean-Michel Bismut has made fundamental contributions.

Résumé (De Probabilité à Géométrie, volume en l'honneur du 60^e anniversaire de Jean-Michel Bismut)

Ces deux volumes regroupent des articles originaux soumis par des collègues et amis à l'occasion des 60 ans de Jean-Michel Bismut.

Ces articles portent sur la théorie des probabilités, sur l'analyse sur les variétés et sur la géométrie arithmétique, domaines où Jean-Michel Bismut a fait des contributions fondamentales.

TABLE OF CONTENTS

Preface by Paul Malliavin	xv
Preface by Sir Michael Atiyah	xvii
A letter from a friend	xix
Curriculum vitæ of Jean-Michel Bismut	xxi
 The mathematical work of Jean-Michel Bismut: a brief summary	 xxv
1. From probability theory... ..	xxv
2. ...to Index Theory	xxvi
2.1. Superconnections, Quillen metrics and η -invariants	xxvi
2.2. Analytic torsion and complex geometry	xxvii
2.3. From loop spaces to the hypoelliptic Laplacian	xxviii
3. Conclusion	xxix
References	xxix
 Shigeki Aida — <i>Semi-classical limit of the lowest eigenvalue of a Schrödinger operator on a Wiener space: I. Unbounded one particle Hamiltonians</i>	 1
1. Introduction	1
2. Preliminaries	2
3. Results	8
References	15
 Sergio Albeverio & Sonia Mazzucchi — <i>Infinite dimensional oscillatory integrals with polynomial phase function and the trace formula for the heat semigroup</i>	 17
1. Introduction	17
2. Infinite dimensional oscillatory integrals	19
3. The asymptotic expansion	27
4. A degenerate case	30
Appendix. Abstract Wiener spaces	41
References	43

Richard F. Bass & Edwin Perkins — <i>A new technique for proving uniqueness for martingale problems</i>	47
1. Introduction	47
2. Some estimates	49
3. Proof of Theorem 1.1	51
References	53
 Martin Grothaus, Ludwig Streit & Anna Vogel — <i>Feynman integrals as Hida distributions: the case of non-perturbative potentials</i>	 55
1. Introduction	55
2. White Noise Analysis	56
3. Hida distributions as candidates for Feynman Integrands	57
4. Solution to time-dependent Schrödinger equation	59
5. General construction of the Feynman integrand	62
6. Examples	63
6.1. The Feynman integrand for polynomial potentials	64
6.2. Non-perturbative accessible potentials	65
References	67
 Hiroshi Kunita — <i>Smooth Density of Canonical Stochastic Differential Equation with Jumps</i>	 69
1. Introduction and main results	69
2. Malliavin calculus for canonical SDE	73
3. SDE's for derivatives of stochastic flow	76
4. Alternative criterion for the smooth density	80
5. Relation with Lie algebra	83
6. Appendix. An analogue of Norris' estimate	87
References	90
 James R. Norris — <i>Two-parameter stochastic calculus and Malliavin's integration-by-parts formula on Wiener space</i>	 93
1. Introduction	93
2. Integration-by-parts formula	94
3. Review of two-parameter stochastic calculus	96
4. A regularity result for two-parameter stochastic differential equations	100
5. Derivation of the formula	109
References	113
 Ichiro Shigekawa — <i>Witten Laplacian on a lattice spin system</i>	 115
1. Introduction	115
2. Witten Laplacian in finite dimension	116

3. Witten Laplacian acting on differential forms	118
4. Witten Laplacian in one-dimension	121
5. Positivity of the lowest eigenvalue for the Witten Laplacian	124
References	129

Anton Alekseev, Henrique Bursztyn & Eckhard Meinrenken —
***Pure Spinors on Lie groups***

<i>Pure Spinors on Lie groups</i>	131
0. Introduction	131
1. Linear Dirac geometry	134
1.1. Clifford algebras	134
1.2. Pure spinors	136
1.3. The bilinear pairing of spinors	136
1.4. Contravariant spinors	137
1.5. Action of the orthogonal group	138
1.6. Morphisms	139
1.7. Dirac spaces	141
1.8. Lagrangian splittings	142
2. Pure spinors on manifolds	146
2.1. Dirac structures	146
2.2. Dirac morphisms	148
2.3. Bivector fields	150
2.4. Dirac cohomology	152
2.5. Classical dynamical Yang-Baxter equation	154
3. Dirac structures on Lie groups	155
3.1. The isomorphism $TG \cong G \times (\mathfrak{g} \oplus \bar{\mathfrak{g}})$	155
3.2. η -twisted Dirac structures on G	156
3.3. The Cartan-Dirac structure	157
3.4. Group multiplication	159
3.5. Exponential map	161
3.6. The Gauss-Dirac structure	164
4. Pure spinors on Lie groups	167
4.1. $\text{Cl}(\mathfrak{g})$ as a spinor module over $\text{Cl}(\mathfrak{g} \oplus \bar{\mathfrak{g}})$	167
4.2. The isomorphism $\wedge T^*G \cong G \times \text{Cl}(\mathfrak{g})$	170
4.3. Group multiplication	174
4.4. Exponential map	175
4.5. The Gauss-Dirac spinor	178
5. q -Hamiltonian G -manifolds	182
5.1. Dirac morphisms and group-valued moment maps	182
5.2. Volume forms	184
5.3. The volume form in terms of the Gauss-Dirac spinor	187
5.4. q -Hamiltonian q -Poisson $\mathfrak{g}$ -manifolds	188
5.5. $\mathfrak{k}^*$ -valued moment maps	191
6. K^* -valued moment maps	192

6.1. Review of K^* -valued moment maps	193
6.2. P -valued moment maps.	194
6.3. Equivalence between K^* -valued and P -valued moment maps	195
6.4. Equivalence between P -valued and $\mathfrak{k}^*$ -valued moment maps	196
References	196
 Moulay-Tahar Benameur & Paolo Piazza — <i>Index, eta and rho invariants on foliated bundles</i>	201
Introduction and main results	202
1. Group actions	208
1.1. The discrete groupoid $\mathcal{G}$	208
1.2. C^* -algebras associated to the discrete groupoid $\mathcal{G}$	209
1.3. von Neumann algebras associated to the discrete groupoid $\mathcal{G}$	209
1.4. Traces	211
2. Foliated spaces	213
2.1. Foliated spaces	213
2.2. The monodromy groupoid and the C^* -algebra of the foliation	215
2.3. von Neumann Algebras of foliations	216
2.4. Traces	218
2.5. Compatibility with Morita isomorphisms	221
3. Hilbert modules and Dirac operators	226
3.1. Connes-Skandalis Hilbert module	226
3.2. Γ -equivariant pseudodifferential operators	231
3.3. Functional calculus for Dirac operators	235
4. Index theory	242
4.1. The numeric index	242
4.2. The index class in the maximal C^* -algebra	244
4.3. The signature operator for odd foliations	246
5. Foliated rho invariants	246
5.1. Foliated eta and rho invariants	247
5.2. Eta invariants and determinants of paths	250
6. Stability properties of ρ^ν for the signature operator	255
6.1. Leafwise homotopies	255
6.2. $\rho^\nu(V, \mathcal{F})$ is metric independent	258
7. Loops, determinants and Bott periodicity	261
8. On the homotopy invariance of rho on foliated bundles	263
8.1. The Baum-Connes map for the discrete groupoid $T \rtimes \Gamma$	264
8.2. Homotopy invariance of $\rho^\nu(V, \mathcal{F})$ for special homotopy equivalences	266
9. Proof of the homotopy invariance for special homotopy equivalences: details	268
9.1. Consequences of surjectivity I: equality of determinants	268
9.2. Consequences of surjectivity II: the large time path	269
9.3. The determinants of the large time path	271

9.4. Consequences of injectivity: the small time path	273
9.5. The determinants of the small time path	278
References	284

Alain Berthomieu — *Direct image for some secondary K -theories* 289

1. Introduction	289
2. Various K -theories	293
2.1. Preliminaries	293
2.1.1. Connections and vector bundle morphisms	293
2.1.2. Chern-Simons transgression forms	294
2.2. Definitions of the considered K -groups	295
2.2.1. Topological K -theory	295
2.2.2. K^0 -theory of the category of flat bundles	295
2.2.3. Relative K -theory	296
2.2.4. “Free multiplicative” or “non hermitian smooth” K -theory	297
2.3. Chern-Simons class on relative K -theory	297
2.4. Relations between the preceding K -groups	298
2.5. Symmetries associated to hermitian metrics	299
2.6. Borel-Kamber-Tondeur class on $\widehat{K}_{\text{ch}}$	301
3. Direct images for K -groups	303
3.1. The case of topological K -theory	303
3.1.1. Preliminary: construction of family index bundles	303
3.1.2. Definition of the direct image morphism for K_{top}^0 and K_{top}^1	304
3.2. The case of the K^0 -theory of flat bundles	306
3.3. The case of relative K -theory	307
3.3.1. The notion of “link”	307
3.3.2. Definition of the direct image for K_{rel}^0	307
3.4. The case of multiplicative, or smooth, K^0 -theory	309
3.4.1. Transgression of the family index theorem	309
3.4.2. Direct image for multiplicative/smooth K^0 -theory	310
3.5. Hermitian symmetry and functoriality results	311
3.5.1. Direct images and symmetries	311
3.5.2. Double fibrations	312
4. Proof of Theorems 25 and 27	312
4.1. Proof of Theorem 25	312
4.1.1. Links and exact sequences of vector bundles	312
4.1.2. Link with “positive kernel” family index bundles	313
4.1.3. Deformation of ψ , h^ξ and ∇_ξ	314
4.1.4. General construction (and proof of Theorem 25)	315
4.2. Proof of Theorem 27	316
4.2.1. Reduction of the problem	316
4.2.2. Sheaf theoretic direct images and short exact sequences	317

4.2.3. “Adiabatic” limit of harmonic forms	318
4.2.4. End of proof of Proposition 43	319
5. η -forms	320
5.1. $\mathbb{Z}_2$ -graded theory	320
5.1.1. $\mathbb{Z}_2$ -graded bundles and superconnections	320
5.1.2. Special adjunction	321
5.2. Adaptation of Bismut’s superconnection	322
5.2.1. Definition of Bismut and Lott’s Levi-Civita superconnection ...	322
5.2.2. Properties and asymptotics of the Chern character of C_t	323
5.2.3. Calculating C_t for the product with the real line	324
5.2.4. $t \longrightarrow 0$ asymptotics of the infinitesimal transgression form	325
5.2.5. Adapting C_t to some suitable triple	326
5.2.6. $t \longrightarrow +\infty$ asymptotics of the infinitesimal transgression form ..	327
5.3. Proof of the first part of Theorem 28	328
5.3.1. Chern-Simons transgression and links	328
5.3.2. Definition of the η -form and check of its properties	329
5.3.3. Invariance properties of η	330
5.4. Anomaly formulae and their consequences	332
5.4.1. Anomaly formulae	332
5.4.2. End of proof of Theorem 28	334
5.4.3. Proof of Theorem 29	334
5.4.4. Proof of Theorem 31	334
5.4.5. Influence of the vertical metric and the horizontal distribution ..	336
6. Fiberwise Hodge symmetry	337
6.1. Symmetries induced on family index bundles	337
6.1.1. The fiberwise Hodge $*$ operator	337
6.1.2. Symmetry induced by $*_Z$ on fiberwise twisted Euler operators ..	338
6.1.3. Odd dimensional fibre case	338
6.1.4. Symmetry on canonical links	339
6.1.5. Symmetry on connections on the infinite rank bundle $\mathcal{E}$	341
6.2. Proof of results about K_{flat}^0 and K_{rel}^0	342
6.2.1. End of proof of Theorem 32	342
6.2.2. Results on $\pi_{\leftarrow}$	342
6.3. End of proof of Theorem 33	344
7. Double fibrations	346
7.1. Topological K -theory	346
7.1.1. Fiberwise exterior differentials:	347
7.1.2. Fiberwise Euler operators	347
7.1.3. Introducing some intermediate suitable triple	348
7.1.4. Estimates on the operator A_4^θ	349
7.1.5. Spectral convergence of Euler operators	350
7.1.6. Construction of the canonical link (proof of Theorem 61)	351
7.2. Flat and relative K -theory	352

7.2.1. Leray spectral sequence	353
7.2.2. Compatibility of topological and sheaf theoretic links	353
7.2.3. Proof of Theorem 34	355
7.3. Multiplicative and smooth K -theory	356
7.3.1. Calculation of $\pi_{2!}^{\text{Eu}} \circ \pi_{1!}^{\text{Eu}} - (\pi_2 \circ \pi_1)_!^{\text{Eu}}$	356
7.3.2. Proof of Theorem 35	357
References	358

Jean-Benoît Bost & Klaus Künnemann — *Hermitian vector bundles and extension groups on arithmetic schemes II. The arithmetic Atiyah extension*

0. Introduction	361
1. Atiyah extensions in algebraic and analytic geometry	370
1.1. Definition and basic properties	370
1.2. Cotangent complex and Atiyah class	375
1.3. $\mathcal{C}^\infty$ -connections compatible with the holomorphic structure	377
2. The arithmetic Atiyah class of a vector bundle with connection	378
2.1. Definition and basic properties	378
2.2. The first Chern class in arithmetic Hodge cohomology	383
3. Hermitian line bundles with vanishing arithmetic Atiyah class	386
3.1. Transcendence and line bundles with connections on abelian varieties	386
3.1.3. Line bundles with connections on abelian varieties	387
3.1.4. The complex case	389
3.1.5. An application of the Theorem of Schneider-Lang	390
3.1.8. Reality I	391
3.1.10. Reality II	392
3.1.12. Conclusion of the proof of Theorem 3.1.1	393
3.2. Hermitian line bundles with vanishing arithmetic Atiyah class on smooth projective varieties over number fields	394
3.3. Finiteness results on the kernel of $\hat{c}_1^H$	398
4. A geometric analogue	399
4.1. Line bundles with vanishing relative Atiyah class on fibered projective varieties	399
4.1.1. Notation	399
4.2. Variants and complements	402
4.3. Hodge cohomology and first Chern class	404
4.3.1. Hodge cohomology groups	404
4.3.2. The first Chern class in Hodge cohomology	406
4.4. An application of the Hodge Index Theorem	407
4.4.1. The Hodge Index Theorem in Hodge cohomology	407
4.4.3. An application to projective varieties fibered over curves	407
4.5. The equivalence of VA1 and VA2	409
4.6. The Picard variety of a variety over a function field	410

4.7. The equivalence of VA2 and VA3	412
Appendix A. Arithmetic extensions and Čech cohomology	414
Appendix B. The universal vector extension of a Picard variety	416
References	422



This volume is dedicated to Jean-Michel Bismut.

The editors : Xianzhe Dai, Rémi Léandre, Xiaonan Ma and Weiping Zhang.

PREFACE BY PAUL MALLIAVIN

Jean-Michel Bismut has had a career with an incredibly wide scope. At the beginning of the seventies, after a strong scientific curriculum at École Polytechnique, he received from the French state a life appointment as an engineer in charge of supervising the strategic French national stockpile of crude oil.

To fulfill the forecasting duties of his position, he started econometrical studies which led him to Statistics and subsequently to Probability. He discovered in the mid seventies an object which is now called the *backward stochastic differential equations*; this concept was so innovative that referees of probability Journals to which he submitted the corresponding paper rejected it “as obviously wrong”. Finally he succeeded by publishing several papers on the subject. Fifteen years after this publication, Pardoux, starting from Bismut’s paper, built a full theory which stands now as a major tool of Mathematical Finance, on which superhedging theory in a risky market is based.

In 1980 Jean-Michel Bismut published a six hundred pages Lecture Notes on *Random Mechanics* which marks the turn of his career to Pure Mathematics. In 1984 Bismut published a two hundred pages book “Large Deviations and the Malliavin Calculus” in which he merges Differential Calculus on the Wiener space with extremal problems associated to computing probability of rare events. Fifty pages of this book are devoted to the Stochastic Calculus of Variations of Brownian motion on a Riemannian manifold; he enriched the classical orthonormal frame bundle approach to this problem by introducing *infinitesimal rotations of the Wiener space*. This innovative idea remained unnoticed for around five years until Daniel Stroock and Bruce Driver showed its full potential. In many papers dealing with infinite dimensional stochastic analysis, it appears as the *Bismut formula*. The same year, Bismut proved the Atiyah-Singer index formula by an intrinsic computation of the small time expansion of the heat kernel through stochastic analysis.

In the beginning of the eighties, I had the pleasure to see Jean-Michel Bismut every week at my seminar at École Normale. Then Bismut moved towards *Global Analysis* and our common mathematical discussions became, unfortunately for

me, less frequent. The extraordinary drive who brought Bismut from Petroleum Industry to Probability, has, once more, taken him towards new mathematical horizons.

Paul Malliavin,
June 2008

PREFACE BY SIR MICHAEL ATIYAH

Many years ago I first heard the name of Jean-Michel Bismut from my colleagues in the probability world. He was an up and coming young man in the field. My first personal encounter with him was at the colloquium held in Paris in 1983 in honour of Laurent Schwartz. In my lecture I described Witten's approach to the index theorem via a fixed-point argument in the loop-space. This was not rigorous mathematics but it was a beautiful idea. Bismut later told me that this was what converted him from a probabilist into a differential geometer.

Moreover much of Bismut's subsequent work consisted of providing rigorous proofs for the heuristic physical ideas coming from Witten and other theoretical physicists. It turned out to be an extremely fruitful field and a logical follow-on to Bismut's earlier work in probability.

As index theory developed, focus shifted from global topological formulae to more precise local differential-geometric ones. By integration these reproduced the topological formulae but they contained more information. This was the area in which Bismut specialized and his work embodied many subtle geometric and analytic ideas.

Perhaps the most striking application of the more precise local formulae was to Arakelov theory, also called arithmetic geometry. This involves algebraic geometry defined over number fields in which the infinite prime has to be treated by complex analysis. As yet the theory is in its infancy but its potential as a link from number theory via geometry and analysis to theoretical physics holds out enormous promise. If this aim is eventually achieved, Bismut's many contributions will be seen as essential links in the chain.

Although Bismut has moved beyond classical probability theory, his background in that field certainly fits well with the probabilistic ideas embodied in quantum theory and the Feynman integral. He has shown the broader outlook, ignoring disciplinary boundaries, which is characteristic of great mathematics.

Michael Atiyah
February, 2008

A LETTER FROM A FRIEND ⁽¹⁾

Dear Jean-Michel,

I'm very sorry that I can't be present to help celebrate your birthday. But it helps a lot that we have been able to spend the last few months together. We have had many good times.

You are one of the world's deepest and most original mathematicians, with a unique perspective and unique abilities. In your chosen field, you are simply orders of magnitude beyond everyone else. In my view, you are a true and worthy successor to Atiyah and Singer.

The work that we did together was one of the great mathematical experiences of my life. In some ways it was also one of the most humbling—particularly at those times when I would be sitting with a blank look on my face and you would be writing away, while at the same time, singing gaily to yourself, just loud enough so that I could hear it. Really, that was too much!

But the truth is that the close friendship that we have shared—especially all the heated discussions—is by far more important to me than the math that we did. You are a wonderful friend.

So enjoy your party and remember that you are still a young man—well maybe not so young—anyhow, at least you can say that you are younger than I am.

Jeff Cheeger

⁽¹⁾ Dai, Ma and Zhang organized a conference “Geometry and Analysis on Manifolds” at the Chern Institute of Mathematics from April 8 until April 14, 2007, in honour of Jean-Michel Bismut. We reproduce here a letter of Jeff Cheeger, which was read by Jean-Pierre Bourguignon during the conference.

CURRICULUM VITÆ OF JEAN-MICHEL BISMUT

Jean-Michel Bismut, born on 26th February 1948 in Lisbon (Portugal). French. Married, 3 children.

Education

- 1967-1970 Graduate from École polytechnique
- 1973 Docteur d'État in Mathematics, Université Paris VI, with a thesis entitled "Analyse convexe et probabilités".

Career

- 1970-1976 "Ingénieur du Corps des Mines"
- 1975-1987 Maître de Conférences at École polytechnique
- 1976-1980 Associate professor at Department of Mathematics, Université Paris-Sud (Orsay)
- 1981- Professor at Department of Mathematics, Université Paris-Sud (Orsay)
- 1984 Member of I.A.S. (Princeton)
- 1986 Invited lecture in the Geometry section, International Congress of Mathematicians (ICM) in Berkeley
- 1987-1988 Visitor at I.H.É.S
- 1994 Member of I.A.S. (Princeton)
- 1989-2008 Editor of *Inventiones Mathematicae*
- 1996-2008 Managing Editor of *Inventiones Mathematicae* (with Gerd Faltings)
- 1998 Plenary speaker, International Congress of Mathematicians (ICM) in Berlin
- 1990-1998 Member of the scientific committee of the Isaac Newton Institute for Mathematical Sciences at Cambridge (UK)
- 1992-2002 Senior member of Institut Universitaire de France
- 1998-2002 Member of the Executive Committee, International Mathematical Union (IMU)

- 2000-2006 Chairman of Fachbeirat of the Max-Planck Institut für Mathematik of Bonn
- 2002-2006 Vice-President of the International Mathematical Union (IMU)

Honors and Prizes

- Montyon Prize of Académie des Sciences (1984)
- Ampère Prize of Académie des Sciences (1990)
- Corresponding member of Académie des Sciences (1990)
- Member of Académie des Sciences (1991)
- Member of Academia Europaea (1998)
- Member of Deutsche Akademie Leopoldina (2004)

The Ph.D. students of Jean-Michel Bismut

- | | | |
|--------------|----------------------|---|
| June 1984 | Patrick Cattiaux | Université Paris-Sud |
| | Dissertation title : | Diffusions avec une condition frontière:
hypoellipticité du semi-groupe associé
conditionnement et filtrage |
| October 1984 | Rémi Léandre | Université de Franche-Comté |
| | Dissertation title: | Extension du théorème de Hörmander à
divers processus de sauts |
| May 1985 | Carl Graham | Université Paris VI |
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un domaine à paroi collante et problèmes
de martingales avec réflexion |
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| | Dissertation title : | Torsion analytique complexe |
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