ALLEGATO B

UNIVERSITÀ DEGLI STUDI DI MILANO
selezione pubblica per n._1 posto/i di Ricercatore a tempo determinato ai sensi dell'art.24, comma 3, lettera b) della Legge 240/2010 per il settore concorsuale 01/A2 – GEOMETRIA e ALGEBRA , settore scientifico-disciplinare ___MAT/02-ALGEBA____
presso il Dipartimento di _Matematica "Federigo Enriques"_______________________________________,
(avviso bando pubblicato sulla G.U. n. _17_ del _02/03/2021____________) Codice concorso _4546__

FEDERICO BINDA
CURRICULUM VITAE

INFORMAZIONI PERSONALI (NON INSERIRE INDIRIZZO PRIVATO E TELEFONO FISSO O CELLULARE)

COGNOME	BINDA
NOME	FEDERICO
DATA DI NASCITA	[13, Novembre, 1988]

Federico Binda

Education

Doktor der Naturwissenschaften – Mathematik (Ph.D.)

Institution	Universität Duisburg-Essen, Essen (Germany)	*10 August 2016*
Dissertation title	Motives and algebraic cycles with moduli conditions	
Grade	*summa cum laude*	
Supervisor	Prof. Dr. Marc N. Levine	

Master 2 Recherche, Mathématiques Fondamentales et Appliquées

Institution	Université de Paris Sud, ENS Paris, École Polytechnique	*22 November 2012*
Note	Double degree program (ALGANT project, Erasmus Mundus Master)	

Laurea magistrale in Matematica

Institution	Università degli Studi di Milano	*18 July 2012*
Dissertation title	Hodge-Tate decomposition theorem for Abelian Varieties over p-adic fields	
Grade	*110/110 e lode*	
Supervisor	Prof. Ahmed Abbes, CNRS - IHES (Bures-sur-Yvette, France)	

Laurea triennale in Matematica

Institution	Università degli Studi di Milano	*22 July 2010*
Dissertation title	Units in quadratic number fields	
Grade	*110/110 e lode*	
Supervisor	Prof. Massimo Bertolini	

Work experience

Junior Assistant Professor (Ricercatore Tempo Determinato A)

Università degli Studi di Milano — *June 2019 – present*
MAT 02/Algebra

Postdoctoral researcher

Universität Regensburg, Germany — *Sep 2016 – May 2019*
Arbeitsgruppe Prof. Dr. Moritz Kerz
SFB 1085 Higher Invariants

Wissenschaftlicher Mitarbeiter

Universität Duisburg-Essen, Germany — *Sep 2015 – Aug 2016*
Arbeitsgruppe Prof. Dr. Marc Levine
DFG SPP 1786 Homotopy theory and algebraic geometry

Promotionsstipendium (Ph.D. scholarship)

Universität Duisburg-Essen, Germany — *Nov 2012 – Aug 2015*
Arbeitsgruppe Prof. Dr. Marc Levine

Long research visits

- **Center for Advanced Studies (CAS),**
  Norwegian Academy of Sciences and Letters, Oslo, Norway — *Sep 2020 – Jun 2021*
  Scientific program "Motivic Geometry" Scientific coordinator: Prof. Paul Arne Østvær
  The program was held entirely online due to the COVID-19 pandemic
  https://cas.oslo.no/research-groups/motivic-geometry-article3332-827.html
- **Isaac Newton Institute for Mathematical Sciences, Cambridge, UK** — *15 Mar — 22 May 2020*
  Scientific program "Algebraic K-theory, motivic cohomology and motivic homotopy theory"
  The program was canceled due to the COVID-19 pandemic
  https://www.newton.ac.uk/event/kah

- **Tata Institute of Fundamental Research (TIFR), Mumbai, India** *13-31 Jan 2019*
  Research visit
  Work in collaboration with Prof. Amalendu Krishna (TIFR)
- **Tata Institute of Fundamental Research (TIFR), Mumbai, India** *15 Jan – 11 Feb 2018*
  Research visit
  Work in collaboration with Prof. Amalendu Krishna (TIFR)
  Financed by TIFR and Universität Regensburg (DFG-SFB 1085 - grant Prof. Moritz Kerz)
- **Hausdorff Research Institute for Mathematics (HIM), Bonn, Germany** *08 May – 31 Aug 2017*
  Hausdorff Trimester program "K-Theory and related fields"
  Organizers: Guillermo Cortiñas, Hélène Esnault, Christian Haesemeyer, Holger Reich, Jonathan Rosenberg
- **Institut Mittag-Leffler, Djursholm, Sweden** *26 Mar – 30 Apr 2017*
  Spring term research program "Algebro-geometric and homotopical methods"
  Special thematic trimester
  Financed by Institut Mittag-Leffler
  Organizers: Eric M. Friedlander, Lars Hesselholt, Paul Arne Østvær.
- **Tata Institute of Fundamental Research (TIFR), Mumbai, India** *1 Nov – 10 Dec 2016*
  Research visit
  Work in collaboration with Prof. Amalendu Krishna (TIFR)
  Financed by TIFR and Universität Regensburg (DFG-SFB 1085 - grant Prof. Moritz Kerz)
- **Tata Institute of Fundamental Research (TIFR), Mumbai, India** *15 Sep – 10 Oct 2015*
  Research visit
  Work in collaboration with Prof. Amalendu Krishna (TIFR)
  Financed by TIFR e Alexander Von Humboldt foundation (grant Prof. Marc N. Levine)
- **Tata Institute of Fundamental Research (TIFR), Mumbai, India** *1-19 Sep 2014*
  Research visit
  Work in collaboration with Prof. Amalendu Krishna (TIFR)
  Financed by TIFR e Alexander Von Humboldt foundation (grant Prof. Marc N. Levine)

Talks at international conferences

Sep 2020 **Conference: Motivic geometry**
"Triangulated motives for logarithmic schemes"
Center for Advanced Studies, Oslo, Norway (virtual)

Jul 2020 **Motivic, equivariant and non-commutative homotopy theory**
"Motives for logarithmic schemes"
IHES, Paris, France (virtual)

Sep 2019 **Regulators in Niseko**
"Triangulated categories of log motives over a field"
Hokkaido University Sapporo, Japan

Feb 2019 **International workshop on Motives in Tokyo**
"Semipurity for cycles with modulus"
University of Tokyo, Tokyo, Japan

Sep 2018 Conference **Motives in St. Petersburg: Motives and their applications**
"Rigidity for cycles of relative dimension zero"
Euler International Mathematical Institute, St. Petersburg, Russia

Jul 2018 Workshop **Motives and algebraic cycles**
"Specialisation theorems for cycles of relative dimension zero"
Freiburg Institute for Advanced Studies, (FRIAS), Germany

Mar 2018 Conference **Motives in Tokyo, on the occasion of Shuji Saito's 60th Birthday**
"Rigidity for relative 0-cycles"
University of Tokyo, Tokyo, Japan

Feb 2018 Conference **K-theory, $\mathbb{A}^1$-homotopy and quadratic forms**
"Rigidity for relative 0-cycles"
University of Warwick, Coventry, UK

Jun 2017 Workshop: **K-theory and related fields**

“Towards a motivic (homotopy) theory without A1-invariance”
Hausdorff Research Institute for Mathematics, Bonn, Germany

Feb 2017 **International workshop on Motives in Tokyo**
“Zero cycles with modulus and zero cycles on singular varieties”
University of Tokyo, Tokyo, Japan

Nov 2016 Workshop **Around motives**
Cycles with modulus and non $\mathbb{A}^1$-invariant motives
Università degli studi di Milano

Jun 2016 Workshop **Homotopical approaches to categories and geometry**
“Beyond homotopy invariance: on motives with moduli conditions”
University of Freiburg, Freiburg, Germany

Apr 2016 **Generalizations of $\mathbb{A}^1$-homotopy invariance in algebraic geometry and homotopy theory**
“Zero cycles with modulus and zero cycles on singular varieties”
Freie Universität Berlin, Zinnowitz-Usedom, Germany

Oct 2014 **Conference for Young Researchers in Arithmetic and Algebraic Geometry**
“Algebraic Cycles with modulus and Applications”
University of Bonn, Bonn, Germany

Sep 2011 Summer school **Cohomology theories: a roadmap**
“Model categories, a tour de force”
ALGANT Summer School in Brixen-Bressanone & University of Padova, Italy

Research seminars

Jun 2020 *Triangulated categories of log-motives over a field*
Algebraic geometry seminar (online), Università degli studi di Milano, Italy

Dec 2019 *Triangulated categories of log-motives over a field*
Algebraic and arithmetic geometry seminar, Università di Pisa, Italy

May 2019 *Specialization theorems for cycles of relative dimension zero*
Algebraic geometry seminar, University of Rome “La Sapienza”

Nov 2018 *Motivic cohomology of normal crossing varieties and restriction of zero cycles*
Algebraic and arithmetic geometry seminar, Université de Strasbourg, France

Apr 2018 *Specialization theorems for cycles of relative dimension zero*
Algebraic geometry seminar, Tohoku University, Sendai, Japan

Mar 2018 *Rigidity for relative 0-cycles*
Geometry and topology seminar, Oslo University, Olso, Norway

Feb 2018 *Laumon 1-motives and motives with modulus*
Geometry seminar, Tata Institute of Fundamental Research, Mumbai, India

Nov 2017 *Motivic cohomology of normal crossing varieties and restriction of zero cycles*
Algebraic geometry and topology seminar, Universität Osnabrück, Osnabrück, Germany

Apr 2017 *Towards a motivic (homotopy) theory without $\mathbb{A}^1$-invariance*
Algebro-Geometric and Homotopical Methods - trimester program, Institut Mittag-Leffler, Djursholm, Sweden

Feb 2017 *Towards a non-$\mathbb{A}^1$-invariant motivic theory*
Algebraic geometry seminar, Tohoku University, Sendai, Japan

Jan 2016 *Cycles with modulus, regulators and applications*
Algebraic geometry seminar, Université Grenoble-Alpes, Grenoble, France

Publications and Preprints

1. **Connectivity and purity for logarithmic motives** (with Alberto Merici). (42 pages, 2020). arXiv:2012.08361 [math.AG]. Submitted.
2. **On the cohomology of reciprocity sheaves** (with Kay Rülling and Shuji Saito). (116 pages, 2020). arXiv:2010.03301 [math.AG]. Submitted.

3. **Triangulated categories of logarithmic motives over a field** (with Paul Arne Østvær and Doosung Park). (250 pages, 2020). arXiv:2004.12298 [math.AG]. Submitted.
4. **Bloch's formula for 0-cycles with modulus and higher dimensional Class Field Theory** (with Amalendu Krishna and Shuji Saito). (46 pages, 2020). arXiv:2002.01856 [math.AG]. Submitted.
5. **Rigidity for relative 0-cycles** (with Amalendu Krishna). *Ann. Sc. Norm. Super. Pisa Cl. Sci. (5)*, Volume XXII, Issue 1, pp. 1-27, 2021. Published version.
6. **A Motivic homotopy theory without $\mathbb{A}^1$-invariance**. *Math. Zeitschrift*, Volume 295, pp. 1475-1519, 2020 Published version.
7. **Relative cycles with moduli and regulator maps** (with Shuji Saito). *J. of the Inst. of Math. Jussieu*, Volume 18, Issue 6, November 2019, pp. 1233-1293. Published version.
8. **Zero cycles with modulus and zero cycles on singular varieties.** (with Amalendu Krishna) *Compositio Math.*, Volume 154, 1, January 2018, pp. 120-187. Published version.
9. **Torsion zero cycles with modulus on affine varieties.** *J. of Pure and App. Algebra*, Volume 222, Issue 1, January 2018, pp. 61-74. Published version.
10. **A cycle class map for zero cycles with modulus to higher relative K-groups.** *Documenta Math.*, Volume 23, pp. 407-444, 2018. Published version.
11. **Torsion and divisibility for reciprocity sheaves and 0-cycles with modulus**. (with Jin Cao, Wataru Kai and Rin Sugiyama) *J. of Algebra*, Volume 469, 1 January 2017, pp. 437–463. Published version.

THESIS **Motives and algebraic cycles with moduli conditions.**
Ph.D. thesis, University of Duisburg-Essen (2016).
DuEPublico ID: 41950. Online version.

EDITORIAL ACTIVITY **Motivic homotopy theory and refined enumerative geometry**
with Marc Levine, Oliver Röndigs, Toan Manh Nguyen
Contemporary Mathematics, Volume 745,
American Mathematical Soc., (2020). doi:10.1090/conm/74

Research groups

- Gruppo Nazionale per le Strutture Algebriche, Geometriche e le loro Applicazioni, INDAM — *2020 – present*
- Member of the Collaborative Research Center (SFB) 1085, "Higher Invariants", DFG (Germany). — *1 Sep 2016- 31 May 2019*
  Scientific project: "Cycle Classes in p-Adic Cohomology"
  Coordinator: Moritz Kerz (Regensburg)
  Webpage: `http://www-app.uni-regensburg.de/Fakultaeten/MAT/sfb-higher-invariants/index.php/About`
- Member of the Special Priority Program (SPP) 1786, "Homotopy Theory and Algebraic Geometry", DFG (Germany). — *01 Oct 2015- 30 Aug 2016*
  Scientific project: "Motives with modulus".
  Coordinators: Hélène Esnault (Berlin), Marc N. Levine (Essen), Moritz Kerz (Regensburg).
  Webpage: `https://www.uni-due.de/~bm0032/SPP1786/Web/projects_EsnaultKerzLevine`

Short research visits

Dec 2019 **ETH Zürich**, Switzerland | Host: Joseph Ayoub
Mar 2019 **Oslo University**, Norway | Host: P.-A. Østvær
Apr 2018 **Tohoku University**, Japan | Host: T. Yamazaki
Mar 2018 **Oslo University**, Norway | Host: P.-A. Østvær
Dec 2017 **Tohoku University**, Japan | Host: T. Yamazaki
Feb 2017 **Tohoku University**, Japan | Host: T. Yamazaki

Summer schools and thematic workshops (selection)

Nov 2020 **Masterclass in Condensed Mathematics.** Lecture series by Peter Scholze and Dustin Clausen.
Organizers: Lars Hesselholt, Ryomei Iwasa, Markus Land, Piotr Stragowski.
University of Copenhagen, Denmark (Virtual)

Jun 2019 Workshop **Algebraic K-theory**.
Organizers: Thomas Geisser, Lars Hesselholt, Annette Huber-Klawitter, Moritz Kerz.
Mathematisches Forschungsinstitut Oberwolfach (MFO), Oberwolfach, Germany

Sep 2018 **Motives in St. Petersburg**, Summer school "Motives and related structures".
Organizers: Alexey Ananyeavskiy, Ivan Panin, Grigory Garkusha. Euler International Mathematical Institute, St. Petersburg, Russia

Jul 2016 **Algebraic K-theory and motivic cohomology**
Organizers: Thomas Geisser, Annette Huber-Klawitter, Uwe Jannsen, Marc Levine
Attività di reporter per il workshop Report No. 31/2016
Mathematische Forschungsinstitut Oberwolfach (MFO), Oberwolfach, Germany

Aug 2015 Summer school **Algebraic K-theory and trace methods**. Lecture series by Lars Hesselholt e Chuck Weibel.
University of Regensburg, Regensburg, Germany.

Jul 2015 **AMS Summer Institute (Algebraic Geometry)**
Organizers: Hélène Esnault, Mark Kisin, Peter Scholze, Shou-Wu Zhang
University of Utah, Salt Lake City, USA.

Mar 2015 School **"p-adic arithmetic"**. Lecture series by Gabriel Dospinescu, Laurent Fargues, e Eike Lau.
University of Duisburg-Essen, Essen, Germany.

Nov 2014 **International Workshop on motives in Tokyo**
University of Tokyo, Tokyo, Japan

Oct 2014 Summer school **Continuous K-theory of p-adic rings (after Beilinson)**
Organizers: Hélène Esnault, Moritz Kerz
Universität Regensburg, Germany at Marburger Haus, HirscheggKleinwalsertal, Austria

Nov 2013 **International Workshop on motives in Tokyo**
University of Tokyo, Tokyo, Japan

Sep 2013 Summer school **Motivic Galois group**. Lectures by Joseph Ayoub, Yves André and Marc Levine
Alfréd Rényi Institute of Mathematics, Budapest, Hungary

Teaching

- **Homological algebra** — *spring 2021*
  Laurea Magistrale in Matematica (6 CFU) — *Università degli studi di Milano*
  Lecturer
- **Commutative Algebra** — *fall 2020*
  Master ALGANT / laurea Magistrale in Matematica (9 CFU) — *Università degli studi di Milano*
  Lectures and exercises
- **Matematica del Discreto** — *fall 2019*
  Laurea triennale in Sistemi e Sicurezza delle Reti Informatiche (6 CFU) Lectures and exercises — *Università degli studi di Milano*
- **Commutative Algebra** — *fall 2019*
  Master ALGANT / laurea Magistrale in Matematica (9 CFU) — *Università degli studi di Milano*

Lectures and exercises

- **The Grothendieck-Riemann-Roch theorem** *spring 2018*
  Master and PhD course (3 ECTS) *Universität Regensburg (Germany)*
  Lecturer (in collaboration with Adeel Khan (Uni Regensburg))
  Webpage: https://www.preschema.com/teaching/grr-ss18
- **Zero cycles on singular varieties** *04/2017 - 07/2017*
  Master and PhD course (1 ECTS) *Universität Regensburg (Germany)*
- **Algebraic Geometry III** *10/2015-02/2016*
  Bachelor in Mathematics (26 hours) *Universität Duisburg-Essen (Germany)*
  Teaching assistant (lecturer A. Rodriguez)
  Program: abelian varieties, algebraic and complex theory
  Webpage: https://www.esaga.uni-due.de/marc.levine/Courses/2015/AlgGeom3/
- **Commutative Algebra** *06/10/2015-16/10/2015*
  Intensive course for master students (2 weeks, 28 hours) *Universität Duisburg-Essen (Germany)*
  Lecturer
  Webpage: https://www.esaga.uni-due.de/marc.levine/Courses/2015/ComAlgShort/
- **Algebra II** *04/2015 - 07/2015*
  Bachelor in Mathematics (26 hours) *Universität Duisburg-Essen (Germany)*
  Teaching assistant (lecturer Prof. Marc Levine)
  Program: ring theory, modules, elements of affine algebraic geometry
  Webpage: https://www.esaga.uni-due.de/marc.levine/Courses/2015/Algebra2/
- **Algebra I** *04/2011 - 07/2011*
  Laurea triennale in matematica *Università degli studi di Milano*
  Tutoring (lecturer Prof. Luca Barbieri-Viale)

Student supervision

Master thesis advisor *2021*
Student: Ottavio Bartenor *Università degli Studi di Torino*
Co-supervision with Prof. Elena Martinengo

Organization of workshops & seminars

2-6 Sep 2019 “Yatsugatake workshop 2019: Derived algebraic geometry”, Haramura, Nagano, Japan. Financed by JSPS (Grant Prof. S. Saito and Prof. T. Terasoma). Conference website.

14-18 May 2018 International workshop “Motives and refined enumerative geometry”, Universität Duisburg-Essen (Germany). Financed by the DFG, project SPP 1786, with Euro 14.000. 65 total participants, from 13 different countries. Three short-lecture series by Denis-Charles Cisinski (Regensburg), Jean Fasel (Grenoble) and Marc Levine (Essen), and 9 research talks. Conference website. The proceedings of the conference have been published by the AMS.

fall 2015 Seminar of the algebraic and arithmetic geometry’s research group, Universität Duisburg-Essen (Germany). Topic: “Class Field theory for varieties over finite fields”. Link to official program.

2013-2015 Seminars for graduate school of the University of Duisburg-Essen (3 series: “Intersection theory”, “Hodge theory”, “Deformation theory”)

Referee

- **Referee activity**. Full referee reports or quick opinions for the following journals: Acta Mathematica, Nagoya Journal of Math., Mathematical Research Letters, Journal of the American Math. Soc. (JAMS), Inventiones Math., Inter. Math. Res. Notices (IMRN), Journal of the Inst Math. Jussieu., Canadian Journal of Math., Canadian Math. Bull.
- **Reviewer activity** for Math. Reviews (AMS)

Qualifications

- **Maître de conférences** *Obtained in 2017*

Conseil National des Universités (CNU), France, section 25 (pure mathematics)

- **Abilitazione Scientifica Nazionale** *03/07/2020 – 03/07/2029*
  Bando D.D. 2175/2018, S.C. 01/A2 Geometria e Algebra

Awards and scholarships

- Promotionsstipendium (graduate student scholarship), University of Duisburg-Essen *Nov 2012 – Sep 2015*
- Scholarship for excellent master students "Leonardo da Vinci", financed by Cariplo Foundation, (EUR 10,000) *Sep 2011*
- ALGANT Excellence Scholarship program (ALExS) *2010 and 2011*
- Undergraduate award (tuition waiver based on grades and credits), University of Milan *2007-2010*

Research statement

My research area is arithmetic and algebraic geometry. More precisely, I am mostly interested in the theory of algebraic cycles (notably on singular varities), motives (in the sense of Voevodsky, and its extensions) and K-theory. I am also interested in the applications of the formalism of abstract homotopical algebra to the geometric or arithmetic context, as in motivic homotopy theory and derived algebraic geometry. In what follows I briefly outline the principal (present and future) research directions.

Deligne's conjecture on skeleton sheaves and geometric Class Field Theory

In their study of the rank one case of a conjecture of Deligne (and Drinfeld) on the existence of lisse $\overline{\mathbb{Q}}_\ell$-sheaves associated to so-called "skeleton sheaves" on a variety U over a finite field $\mathbb{F}_q$, Kerz and Saito [KS16] introduced a quotient of the group of zero cycles on U, called the Chow group of zero cycles with modulus $\mathrm{CH}_0(X|D)$, associated to a normal compactification $U \subset X$ with boundary D. The conjecture of Deligne and Drinfeld can be then rephrased in terms of geometric Class Field Theory, and it is implied by the existence of a reciprocity map

$$\rho_U \colon C(U)^0 = \varprojlim_D \mathrm{CH}_0(X|D)^0 \to \pi_1^{et}(U)^{0,\mathrm{ab}},$$

inducing an isomorphism of topological pro-finite abelian groups, where X is a normal compactification of U, D runs over all effective Cartier divisors supported on $X - U$ and $\pi_1^{et}(U)^{0,\mathrm{ab}}$ is the (degree zero part of the) abelianized étale fundamental group of U. This was shown by Kerz and Saito using sophisticated arguments from ramification theory and explicit computations with symbols in Milnor K-theory when the characteristic of $\mathbb{F}_q$ is different from 2.

I have worked on more conceptual proof of the rank 1-case of the Deligne conjecture that avoids ramification theory and removes the restriction on the characteristic. This involves the following two projects.

Cycles on singular varieties. In the paper [BK18] (in collaboration with Amalendu Krishna), we proposed a completely different interpretation of $\mathrm{CH}_0(X|D)$ (for smooth X) by relating it with the so-called *cohomological* Chow groups of zero cycles for singular varieties in the sense of Levine and Weibel, a subtle invariant that is closer to K-theory than the classical (Fulton's) Chow group. More precisely, we showed that if we denote by $S_{X|D}$ the (singular) scheme obtained by glueing two copies of X along the divisor D, the Levine-Weibel Chow group $\mathrm{CH}_0^{LW}(S_{X|D})$ canonically decomposes as a direct sum of $\mathrm{CH}_0(X|D)$ and $\mathrm{CH}_0(X)$ (the classical Chow group). This allowed us to prove a number of results on the Chow groups with modulus by borrowing techniques from the corresponding statements for singular varieties. For example, we proved an analogue of Roitman's torsion theorem for X projective over k (I covered the affine case in [Bin18b] for the torsion prime to the characteristic), and formulate a version of Bloch's conjecture on surfaces (which can be thought as a version of Bloch's conjecture for open surfaces). Our decomposition result has been successfully used in several later works, for example in [Kri19] to prove the cycle-theoretic form of the Bloch-Srinivas conjecture on relative K-groups.

Bloch's formula and geometric CFT. In [BKS] (in collaboration with Amalendu Krishna and Shuji Saito), we combined the "double trick" from [BK18] together with a careful analysis of the construction of the top Chern class from the K-group of vector bundles $K_0(Y)$ on a singular variety Y to the Levine-Weibel Chow group of zero cycles $\mathrm{CH}_0^{LW}(Y)$, in order to show the existence of isomorphisms

$$\mathrm{CH}_0(X|D) \xrightarrow{\simeq} H^2_{\mathrm{Zar}}(X, \mathcal{K}^M_{2,(X|D)}) \xrightarrow{\simeq} H^2_{\mathrm{Nis}}(X, \mathcal{K}^M_{2,(X|D)})$$

for *any* reduced quasi-projective k-scheme of dimension 2 over *any* field. This, together with a Lefschetz hyperplane argument, is enough to give a simple proof of the conjecture of Deligne and Drinfeld, without any restriction on the characteristic, avoiding completely the technical arguments involving ramification theory.

Specialization for cycles of relative dimension zero

Let S be the spetrum of a Henselian DVR R with residue field k and let $\mathcal{X} \to S$ be a regular, flat and projective S-scheme. The group of 1-cycles $\mathrm{CH}_1(\mathcal{X})/n$ for n coprime to the characteristic of k was conjectured to be finite by Colliot-Théléne if k is finite or algebraically closed. This problem was solved by Saito and Sato [SS10] when the reduced special fiber $Y = (\mathcal{X} \otimes_R k)_{\mathrm{red}}$ is a normal crossing divisor in $\mathcal{X}$ (which is enough to imply two conjectures of Colliot-Thélène on the structure of the Chow group of zero cycles for smooth projective varieties over p-adic fields).

Following ideas of Bloch, this theorem has been re-proved by Kerz, Esnault and Wittenberg [KEW16] by constructing (in some cases) a *restriction* morphism $\rho\colon \mathrm{CH}_1(\mathcal{X})/n \to H^{2d}_{\mathrm{cdh}}(Y, \mathbb{Z}/m\mathbb{Z}(d))$ to the cdh motivic cohomology group of the special fiber Y, explicitly described (when Y is normal crossing) in terms of zero cycles. In [KEW16], it is conjectured that ρ should always exist, even without assumptions on the singularities of Y, as a consequence of a more general motivic machinery.

In [BK21] (in collaboration with Amalendu Krishna), we partially answered to this question. By replacing the motivic cohomology group with the Levine-Weibel Chow group of zero cycles on the singular special fiber Y, it is possible to construct the restriction morphisms in a number of new cases, for example if Y has isolated singularities and k is a finite field, or if Y is of dimension 2 and R is equal-characteristic (without any assumption on the singularities of Y). In fact, our method even suggests the possibility of dropping the projectivity assumption on $\mathcal{X}$, replacing source and target of ρ by an appropriate version of Chow groups with compact support. For example, it is possible to prove that the motivic homology group $H_0(\mathcal{X}/S)/n$ is finite, if k is finite or algebraically closed. This is also a current work in progress with Krishna.

Logarithmic geometry: a tool for p-adic applications

The notion of logarithmic structure on a scheme has been introduced by Kato, Fontaine, Illusie and many others in order to formulate the algebro-geometric analogue (notably in positive or mixed characteristic) of the notion of manifold with boundary. Such objects naturally arise when considering toroidal compactifications $U \subset X$ of smooth schemes U, or the special fiber X_0 of a family of varieties $\mathcal{X} \to S$.

This is the context of the monograph [BPØ] (in collaboration with Doosung Park and Paul Arne Østvær). In the paper we extended the motivic formalism to the logarithmic setting: we introduced the ∞-category $\log \mathcal{DM}^{\mathrm{eff}}(k, \Lambda)$, built out of the category of Λ-linear pre-sheaves with log transfers on log smooth log schemes over a field k after performing (1) localization with respect to a new Grothendieck topology (that we called *dividing Nisnevich topology*) and (2) contraction of the compactified avatar of the affine line $(\mathbb{P}^1, \infty)$.

We proved several fundamental results: for example, a suitable version of the localization sequence (which notably fails without $\mathbb{A}^1$-invariance), of the Morel-Voevodsky Thom-space isomorphism, of the projective bundle formula, the blow-up formula and so on. These formulas immediately give new results after realization. For example, under the log-crystalline realization functor (which exists with integral coefficients precisely because we avoid $\mathbb{A}^1$-invariance, currently a work in progress with Park and Østvær), our localization sequence gives directly the Gysin map in log-crystalline cohomology studied by Nakkajima and Shiho [NS08]. In general, this is a completely new area of research and opens the way to further investigation. We outline some of them.

$\mathcal{SH}^{\log}$ and the Bhatt-Morrow-Scholze filtration. Topological Hochschild homology (THH) and topological cyclic homology (TC) are powerful tools for calculating algebraic K-theory of p-adic rings. In [BMS19], Bhatt, Morrow and Scholze discovered a fundamental additional structure on the p-adic topological cyclic homology $\mathrm{TC}(-, \mathbb{Z}_p)$ of p-adic commutative rings, i.e. the existence of a *motivic* filtration $\mathrm{Fil}^{\geq n}\mathrm{TC}(-, \mathbb{Z}_p)$ with associated graded terms $\mathbb{Z}_p(i)[2i]$. These are more or less explicit complexes, and in characteristic p can be identified with the logarithmic de Rham-Witt sheaves. The construction of the filtration is fairly direct: it is a Postnikov tower (actually a sheafified version of it for a "large" topology). Thanks to a fundamental theorem of Geisser and Levine [GL00] (and later generalizations), it is known that the logarithmic de Rham-Witt sheaves compute p-adic motivic cohomology for (formally) smooth algebras over fields of positive characteristic. On the other hand, motivic cohomology appears as the *slices* of algebraic K-theory in Voevodsky's stable homotopy category $\mathcal{SH}$ (another motivic filtration). Unfortunately, neither TC nor THH are representable in $\mathcal{SH}$, once again because they fail to satisfy homotopy invariance. For the same reason, the cyclotomic trace map does not arise as a "motivic morphism" in a suitable sense.

It is therefore tempting to approach the problem of identifying the two "motivic" filtrations, and to expect that they arise from a common machinery, namely a suitable slice tower (the analogue of the Postnikov tower in $\mathcal{SH}$) to be computed in a new and larger category. In order to make this idea precise, we have developed (in collaboration with Elden Elmanto, Doosung Park, Paul Arne Østvær) the analogue of the Morel-Voevodsky stable motivic homotopy category in the logarithmic setting $\mathcal{SH}^{\log}$, and have worked out several important properties. One of our main achievements is the construction of a cyclotomic $\mathbb{P}^1$-spectrum representing (up to dividing sheafification) logarithmic THH (as defined by Rognes [Rog09] and Rognes-Sagave-Schlichtkrull [RSS18]).

Along the way, we have worked on the characteristic zero analogue: in this case topological cyclic homology is replaced by the more classical cyclic homology, and the motivic filtration (i.e. the slice filtration) is expected to agree with the filtration induced by the Andre-Quillen spectral sequence (that collapses in the smooth case, giving the famous Hochschild-Kostant-Rosenberg theorem). We have verified that the S^1-slices of the spectrum HH representing (logarithmic) Hochschild Homology for log smooth log schemes over a field k (of characteristic zero) are precisely given by differential forms.

Log-schemes and analytic motives. Let K be a complete valued field, R its ring of integers and k its residue field. The motivic formalism has been brought to the world of rigid analytic geometry thanks to the work of Ayoub and Vezzani: in short, the category of motives of analytic varieties over K can be defined in analogy with the algebraic case, contracting the unit ball $\mathbb{B}^1$ instead of the affine line. The motivic language has been successfully used to give, for example, a direct and general definition (and prove finite dimensionality when restricted to compact objects) of the overconvergent de Rham cohomology for rigid analytic varieties (actually, for any motive) over K and of the rigid cohomology for algebraic varieties (or motives) defined over k. See [Vez18].

The category of analytic motives over K is generated by the motives of analytic varieties X admitting a formal lift $\mathfrak{X}$ over R with semi-stable reduction: in particular, the special fiber Y of such $\mathfrak{X}$ acquires the structure of log smooth log scheme over the standard log point $(\mathbb{N} \to \mathrm{Spec}(k))$, $1 \mapsto 0$. The special fiber classically encapsulates many interesting invariants: it can be used to describe explicitly the complex computing the de Rham cohomology of X, using the logarithmic de Rham-Witt complex in nice cases (for Y of generalized semistable type), and by looking at the canonical triangle relating the log de Rham–Witt complex of Y over the log point and over the trivial log point, one gets the monodromy operator of Hyodo-Kato. From this, one gets back in a sufficiently functorial way the monodromy operator on rigid cohomology.

In a joint work with Alberto Vezzani, we intend to promote this comparison at the motivic level, by comparing directly the category of analytic motives $\mathrm{Rig}\mathcal{DA}(K)$ and of log motives over the log point $\log\mathcal{DA}((k,\mathbb{N}))$ (in this case constructed after further contracting $\mathbb{A}^1$). In this way it would be possible to easily transport the operations that one can easily define on the logarithmic side (such as Frobenius operator, or the monodromy) to the p-adic side. We can envision several potential applications: for example it would be possible to verify if indeed rigid cohomology can be interpreted in general as the fixed-points of the monodromy operator on log-rigid cohomology.

Morel's connectivity theorem, logarithmic motives and Laumon 1-motives. Smooth k-scheme can be seen as log smooth log schemes with trivial log structure over k, and we get in this way a natural fully faithful functor $\mathcal{DM}(k) \to \log\mathcal{DM}(k)$: actually Voevodsky's category $\mathcal{DM}(k)$ can be described as the full subcategory of $\mathbb{A}^1$-local objects in $\log\mathcal{DM}(k)$ or, equivalently, by the subcategory generated by the motives of smooth and *proper* log smooth k-schemes. In [BM] (in collaboration with with Alberto Merici), we proved an analogue of Morel's connectivity theorem for the logarithmic motivic sheaves, deducing it from an appropriate purity statement. This implies in particular the existence of a canonical t-structure (known as the *homotopy* t-structure) on the (effective) motivic categories $\log\mathcal{DM}(k)$ and $\log\mathcal{DA}(k)$, and that the canonical comparison functor $\mathcal{DM}(k) \to \log\mathcal{DM}(k)$ is t-exact. We get as a byproduct an easy way to extend any sheaf defined a priori only on smooth schemes to log schemes: this is in particular useful to study a log analogue of the embedding of the derived category of Deligne 1-motives in Voevodsky's category of motives $\mathcal{DM}(k)$, studied by Ayoub, Barbieri-Viale and Kahn [ABV09], [BVK16], as well as its (pro)-left adjoint, a new version of the motivic Albanese functor with values in a suitable version of the pro-derived ∞-category of the category of Laumon 1-motives. This is the subject of another work in progress with Merici and Saito.

Algebraic cycles and motives without $\mathbb{A}^1$-invariance

My interest in this subject dates back to my PhD work [Bin16]. The idea of developing a more general theory than Voevodsky's one, not relying on $\mathbb{A}^1$-invariance, has been the subject of investigation by many authors (among others Bloch-Esnault [BE03a], [BE03b], Park [Par09], Rülling [Rül07], Krishna and Levine [KL08]). I outline my contribution:

Higher Chow groups with modulus and regulators In [BS19] (in collaboration with Shuji Saito) and [Bin16, Chap. 5] we proposed a unifying definition of algebraic cycles with "moduli conditions" that is, algebraic cycles on a k-variety X subject to a certain congruence condition along the boundary D of a fixed compactification $X \hookrightarrow \overline{X}$. The closed subscheme D of $\overline{X}$ is the support of a non-reduced effective Cartier divisor, and the congruence condition that we impose on the cycles depends heavily on the multiplicity of D. This construction gives rise to a chain subcomplex $z^r(\overline{X}|D,*) \subset z^r(\overline{X},*)$ of (the cubical version of) Bloch's cycle complex of weight r on $\overline{X}$, that we named the *relative motivic complex* of the pair $(\overline{X}, D)$: the hypercohomology of

$\mathbb{Z}_{\overline{X}|D}(r) = z^r(-|D,*)[-2r]$ is our proposed definition of motivic cohomology of the pair. We performed several computations (and many more have been done later by other authors, see for example Miyazaki's work [Miy19], and the interpretation of Krishna and Park in terms of de Rham-Witt complexes [KP21]), including the construction of regulator maps, compatible with proper push-forward and flat pull-back, to (relative) de Rham, Betti and Deligne cohomology (in characteristic zero), generalizing the classical construction of Beilinson.

I studied the relationship between higher Chow groups with modulus and algebraic K-theory in [Bin18a], where an explicit cycle class map for "higher" zero cycles was constructed, generalizing previous work by Bloch and Levine. Further steps where taken by Iwasa and Kai [IK19] who showed the existence of Chern classes from the relative K-theory groups of the pair to the relative motivic complex, and by Rülling and Saito [RS18] (for Milnor K-theory).

Motivic homotopy theory The trilogy [KMSY21a], [KMSY21b] and [KMSY] by Kahn, Miyazaki, Saito and Yamazaki had the goal of constructing a proper categorical framework in which the higher Chow groups with modulus can be interpreted (as it is the case for usual higher Chow groups, that compute motivic cohomology for smooth X). In [Bin20] I took a further step, by defining and studying an unstable motivic homotopy category "with modulus", modeled on the Morel-Voevodsky homotopy category $\mathcal{H}(k)$ [MV99] and built out of the category of simplicial presheaves on certain diagrams of schemes over a field admitting resolution of singularities: in this setting it is possible to prove the representability of some classical non-homotopy invariant cohomology theories, like Hodge cohomology.

Reciprocity sheaves and their cohomology

See [BRS] (in collaboration with Kay Rülling and Shuji Saito). The category of reciprocity sheaves, introduced in [KSYR16] is an abelian subcategory of the category of Nisnevich sheaves with transfers on smooth k-schemes whose objects satisfy a certain restriction on their sections inspired by the Rosenlicht-Serre theorem on reciprocity for morphisms from curves to commutative algebraic groups. Among reciprocity sheaves we find Voevodsky's homotopy invariant sheaves with transfers, but also non $\mathbb{A}^1$-invariant examples, such as the (absolute and relative) Hodge sheaves $\Omega^i_{-/k}$, the deRham-Witt sheaves $W_m\Omega^i_{-/k}$, or the complexes $R^i\epsilon_*\mathbb{Z}/p^r(n)$, where $\mathbb{Z}/p^r(n)$ is the étale motivic complex of weight n with $\mathbb{Z}/p^r$-coefficients and ϵ is the change of site functor from the étale to the Nisnevich topology.

In [BRS] we proved the existence of an exceptional functoriality (push-forward with proper support) on the cohomology of any reciprocity sheaf and a number of other structural properties (such as a projective bundle formula, or a blow-up formula), offering a unifying approach that simultaneously recovers - for example - the push-forward map in coherent cohomology for the sheaves of differential forms (classical consequence of Grothendieck duality) and the Gysin map of Voevodsky-Déglise for the cohomology of homotopy invariant sheaves. We also obtained new and previously unknown functorialities (such as a refinement of the push-forward map of Gros on the cohomology of Hodge-Witt sheaves). This can be seen as a higher modulus analogue of my results in collaboration with Park and Østvær on logarithmic motives (although the statements do not imply each other).

Thanks to this structural results, we can produce an action of Chow correspondences on the cohomology of any reciprocity sheaf. This gives a number of applications: for example, we construct new birational invariants of smooth projective varieties, generalizing results of Pirutka and Colliot-Théléne–Voisin (see [CTV12]), and we get from the cohomology of reciprocity sheaves obstructions to the existence of zero cycles of degree one for varieties defined over function fields, that recover the classical Brauer-Manin obstruction as a special instance. For some early (and fairly experimental) results on reciprocity sheaves, see [BCKS17].

Derived Azumaya algebras and the Brauer group of derived schemes

In collaboration with Mauro Porta [BP21]. In [Gro68], Grothendieck considered the problem of comparing the cohomological Brauer group $\mathbf{Br}(X) = H^2_{ét}(X, \mathbb{G}_m)$ of a scheme X, proper and flat over a henselian DVR R, and the inverse limit of the Brauer groups $\varprojlim_n \mathbf{Br}(X_n)$, where $X_n = X \otimes_R R/\mathfrak{m}^n$. He could prove that the canonical map $\mathbf{Br}(X) \to \varprojlim_n \mathbf{Br}(X_n)$ is injective under a number of restrictions, notably when X is regular (thanks to the identification of $\mathbf{Br}(X)$ with the Brauer group of Azumaya algebras $\mathbf{Br}_{\mathrm{Az}}(X)$) and if $\lim^1 \mathrm{Pic}(X_n)$ vanishes (for example if the relative Picard scheme $\mathbf{Pic}_{X/S}$ of X/S is *smooth*). Nevertheless, he left as an open problem the question on wether the formal injectivity holds under less restrictive assumptions.

Thanks to the machinery of derived algebraic geometry, the language of ∞-categories and the results of Toën on derived Azumaya algebras and derived Morita theory [To2], [To7], we are able to rephrase Grothendieck's question in terms of a formal GAGA-type problem for smooth and proper *categories*, enriched over the ∞-category $\mathrm{QCoh}(X)$ of quasi-coherent $\mathcal{O}_X$-modules. In this framework we can show that Grothendieck's injectivity conjecture always holds (even without flatness assumption on the structure morphism) for a proper derived scheme $X \to S$ where S is the spectrum of any complete Noetherian local ring, if we are willing to replace the inverse limit $\varprojlim_n \mathbf{Br}(X_n)$ with the Brauer group $\mathbf{Br}(\mathfrak{X})$ of the formal scheme $\mathfrak{X}$ given by the colimit of the thickenings X_n. Then the $\lim^1 \mathrm{Pic}(X_n)$ term appears naturally in the Milnor sequence for a certain tower of spaces. In fact, if we restrict ourselves to torsion classes prime to the residue characteristic (so, in particular, to classes represented by Azumaya algebras), we can further show such $\lim^1$ contribution is irrelevant, thus proving completely the conjecture.

The perspective on the cohomological Brauer group given by derived Azumaya algebras (and actually, by equivalence classes of *invertible*, compactly generated, stable $\mathrm{QCoh}(X)$-linear ∞-categories) is well-suited for explorations in new directions. In a separate work in progress (with Porta), we are investigating the possibility of proving an *adelic descent* theorem for the stack of derived Azumaya algebras, giving a categorified version of the result of Groechenig [Gro17] on perfect complexes (which itself builds on early results of Beilinson). As a consequence, we can produce a new spectral sequence converging to the Brauer group of a scheme X, which is then equipped with a previously unknown filtration of potential arithmetic interest.

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Data	10 Marzo 2021	Luogo	MILANO