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The present conference was organized by Christopher Deninger (Münster), Peter Schneider (Münster) and Anthony J. Scholl (Durham).

The 18 talks gave an overview of recent results and current trends in algebraic number theory.

Abstracts

The signs of symplectic epsilon constants

Ted Chinburg

My talk was about joint work with Georgios Pappas and Martin Taylor on a consequence of a form of the Birch Swinnerton-Dyer conjecture.

Suppose G is a finite group acting tamely on a regular flat projective curve $\mathcal{X}$ over $\mathbf{Z}$. Let V be a complex representation of G. The L-function $L(s,V,\mathcal{Y})$ of V over $\mathcal{Y} = \mathcal{X}/G$ has a conjectural functional equation which involves a constant $\epsilon(\mathcal{Y},V)$. This constant is a product

$$\epsilon(\mathcal{Y},V) = \prod_v \epsilon_v(\mathcal{Y},V)$$

of local factors as v runs over the places of $\mathbf{Q}$. In the first part of the talk I explained the following prediction of the Birch and Swinnerton-Dyer conjecture and the functional equation:

$$\textbf{FE} + \textbf{BSD prediction}: \quad \epsilon(\mathcal{Y},V) = 1 \quad \text{if} \quad V \quad \text{is irreducible and symplectic.}$$

The result we can prove about this is:

Theorem 1. *Suppose the action of G on $\mathcal{X}$ is tame, $\mathcal{X}$ and $\mathcal{Y}$ are regular, and that irreducible components of the special fibers of $\mathcal{Y}$ are smooth with normal crossings and multiplicities prime to the residue characteristic. If every subgroup of order 4 in G is cyclic, then*

$$\operatorname{sign}(\epsilon_v(\mathcal{Y},V)) = 1 \quad \text{for all places } v.$$

In particular, the FE+BSD prediction is true.

Note that if G is a generalized quaternion group, then every subgroup of order 4 in G is cyclic, such groups have irreducible symplectic representations. The proof of the Theorem uses an equivariant form of Bloch's formula for conductors, and work of T. Saito on ϵ-factors.

The functional equation of the L-function (with Γ-factors) of a complex representation V of G relative to the base $\mathcal{Y} = \mathcal{X}/G$ is conjectured to have the form

$$L(s,V,\mathcal{Y}) = \epsilon(\mathcal{Y},V) \cdot A(\mathcal{Y},V)^{-s} L(2-s,V^*,\mathcal{Y}).$$

The conductor $A(\mathcal{Y},V)$ is a positive integer, and the ϵ-factor $\epsilon(\mathcal{Y},V)$ has a product expansion

$$\epsilon(\mathcal{Y},V) = \prod_v \epsilon_v(\mathcal{Y},V)$$

in which v runs over the places of $\mathbf{Q}$ and $\epsilon_v(\mathcal{Y},V)$ is a local ϵ-constant. An equivariant form of the Birch Swinnerton-Dyer conjecture going back to work of Tate and Beilinson predicts that if V is irreducible, then

$$\operatorname{ord}_{s=1} L(s,V,\mathcal{Y}) = \text{multiplicity of } V \text{ in } \operatorname{Pic}^0(\mathcal{X})$$

where $\operatorname{Pic}^0(\mathcal{X})$ is the group of Weil divisor classes on $\mathcal{X}$ which have degree 0 on the generic fiber of $\mathcal{X}$.

Iwasawa theory for elliptic curves with supersingular reduction

Masato Kurihara

For an elliptic curve E defined over a number field, if E has ordinary reduction at every prime above p, we know in a $\mathbf{Z}_p$-extension how the orders of the p-components of the Tate-Shafarevich groups of E grow by Mazur's theorem, his conjecture, and usual Iwasawa theory. I reported in the case that E is defined over $\mathbf{Q}$ and has supersingular reduction at p, we can get an asymptotic formula of the orders of the p-components of the Tate-Shafarevich groups of E over K_n (where we denoted by K_n the n-th layer of the cyclotomic $\mathbf{Z}_p$-extension of an abelian field K) by using *fractional* invariants. I also gave a conjecture on the structure of the Selmer group of E over K_n. If p does not divide the L-value and the Tamagawa factor, this conjecture can be verified for $\mathbf{Q}_n$.

Hasse-Witt invariants for trace forms of arithmetic schemes

Martin Taylor

The talk concerned joint work with Ph. Cassou-Naguès and B. Erez on the relation between various invariants defined in mod 2 étale cohomology attached to tame odd covers of schemes. Our results build on the work of Serre, Esnault-Kahn-Viehweg.

The first invariant considered is the Hasse-Witt invariant of the square root of the inverse different with trace form. The second invariant is constructed using the representation, of the tame fundamental group, which corresponds to the cover. The formula obtained is valid in arbitrary dimension.

This work contains two main contributions. Firstly we show how to eliminate the ramification and reduce to the étale case - dealt with by Esnault-Khan-Viehweg. Secondly we provide a very detailed analysis of local structure, using partial normalisations, to circumvent the difficulties arising from the crossings on the ramification locus.

Non-Abelian Iwasawa Theory and Applications to Elliptic Curves

Susan Howson

We first discuss an approach to determining, up to pseudoisomorphism, the structure of a central-torsion module over the Iwasawa algebra of a pro-p, p-adic, Lie group containing no element of order p. We then consider the properties of certain invariants ('equivariant Euler Characteristics') which may prove useful in determining the structure of such a module and relating the algebraic side of the theory to the analytic side. Finally, the case of pro-p open subgroups of $\mathrm{GL}_2(\mathbb{Z}_p)$ is described in more detail and we give some applications to the theory of non-CM elliptic curves, concentrating particularly on the modular curves $X_0(11)$ and $X_1(11)$, for which the theory is the most developed.

Infinite dimensional p-adic Galois representations

Jean Marc Fontaine

Let $\overline{K}$ be an algebraic closure of a finite extension K of $\mathbb{Q}_p$ and $C = \mathbb{C}_p$ the p-adic completion of $\overline{K}$. An almost $\mathbb{C}_p$-representation of G is a p-adic Banach space X equipped with a continuous and linear action of G, such that there exists $d \in \mathbb{N}, V_1 \subset X, V_2 \subset C^d$, finite dimensional sub $\mathbb{Q}_p$-vectorspaces stable under G and an action on $X/V_1 \cong C^d/V_2$. These representations form an abelian category $\mathcal{P}(G)$, containing the category of finite length B_{dl}^+-modules equipped with a semilinear and continuous action of G as a full subcategory. There is a unique additive function $d : x \mapsto (d_c(x), d_{\mathbb{Q}_v}) \in \mathbb{N} \times \mathbb{Z}$ on $Ob(\mathcal{P}(G)$ such that $d(c) = (1, 0)$ and $d(V) = (0, \dim_{\mathbb{Q}_v}(V))$ if $\dim_{\mathbb{Q}_v} V < \infty$. If X and Y are objects of $\mathcal{P}(V)$, the $\mathrm{Ext}^i(X, Y)$ can be defined, they are finite dimensional $\mathbb{Q}_p$-vectorspaces, $= 0$ if $i \notin \{0, 1, 2\}$ and $\sum_{i=0}^{2}(-1)^i \dim_{\mathbb{Q}_p} \mathrm{Ext}^i(X, Y) = -[K : \mathbb{Q}_p] d_{\mathbb{Q}_p}(X) d_{\mathbb{Q}_p}(Y)$.

Crystalline sheaves and polylogarithms

T. Tsuji

In this talk, I discussed a relation between the two p-adic realizations: the p-adic étale and crystalline realizations of the classical motivic polylog and the elliptic motivic polylog, using the p-adic Hodge theory. More precisely, I proved that the p-adic realization is a crystalline sheaf on $\mathbf{P}^1_{\mathbf{Q}_p} \backslash \{0, 1, \infty\}$ in the classical case. For an elliptic curve E over a number field K and a finite place $\mathbf{p}$ such that K is unramified at $\mathbf{p}$ and E has good reduction at $\mathbf{p}$, we can also prove that the p-adic étale realization of the motivic elliptic polylog on $E_{K_\mathbf{p}} \backslash \{0\}$ is crystalline. Combining with the results of K. Bannai on the crystalline realizations and p-adic classical polylog functions or p-adic L-functions of CM elliptic curves, we immediately obtain the corresponding results for the p-adic realizations, which have been proven by another method.

A local proof of the equality of the $\mathcal{L}$-invariants attached to modular forms

A. Iovita

I report on joint work with R. Coleman. We proove that the Frobenius and monodromy operators on the *log*-crystalline cohomology of a semi-stable curve over the ring of integers of a local field (mixed characteristic), with smooth generic fibre, with coefficients in a filtered *log*-F isocrystal can be explicitly described using p-adic interpolation on the de-Rahm cohomology of the generic fibre of the curve with coefficients in the respective filtered *log*-F isocrystal, under a certain assumption on the isocrystal.

¿From this we deduce the equality of the $\mathcal{L}$-invariants.

Lubin-Tate Groups and p-adic Fourier Theory

J. Teitelbaum

I report on joint work with Peter Schneider. We study the spacs of locally L-analytic functions on the additive group of integers $\mathcal{O} \subseteq L$, where L is a finite extension of $\mathbb{Q}_p$. Generalizing work of Amice and Lazard, we show that the dual of the locally analytic functions on $\mathcal{O}$ can be identified with the ring of rigid functions on the L-analytic character group $\hat{\mathcal{O}}$ of $\mathcal{O}$. When $L = \mathbb{Q}_p$, $\hat{\mathbb{Z}}_p$ is isomorphic to the open unit disc over $\mathbb{Q}_p$. By contrast, for $L \neq \mathbb{Q}_p$, $\hat{\mathcal{O}}$ is a rigid variety NOT isomorphic to a disc over any discretely valued field, but $\hat{\mathcal{O}}$ is isomorphic over $\mathbb{C}_p$ to the open disc. The proof of this result is an application of the theory of Lubin-Tate groups, and in particular of Tate's p-adic Hodge Theory for p-divisible groups. I discribed an application to the construction of a p-adic L-function for a CM elliptic curve that is supersingular at p.

A proof of Mazur's conjecture on higher Heegner points via the André-Oort conjecture

Christophe Cornut

Inspired by the work of Gross-Zagier, it was B. Mazur who, in his 83'ICM Talk first established the relevance of Heegner points of conductor p^n in the study of the arithmetic of elliptic curves $E/\mathbb{Q}$ along the anticyclotomic $\mathbb{Z}_p$-extension H_∞ of an imaginary quadratic field K. However, these points are initially only defined over a finite extension of H_∞, namely the union $K[p^\infty]$ of all singular classfields of conductor p^n: to use his own control theorems, he therefore had to assume their trace from $K[p^\infty]$ to H_∞ was generically nontorsion, a statement which he conjectured to be always true.

We prove this conjecture by computing the Zariski closure of the involved set of Heegner points in $X_0(N)^{\mathrm{Gal}(K[p^\infty]/H_\infty)}$, by means of a (proven) special case of the André-Oort conjecture.

Ramification of local fields in imperfect residue field case

Takeshi Saito

In classical theory of ramification, we need to assume that the residue field extension is separable to define the upper numbering filtration. In a joint work with A.Abbes, I defined it without any condition on the residue field. Let K be a complete discrete valuation field and L be a finite separable extension. We define the set $\pi_0(Hom_{O_K}(O_L, O_\Omega/m^a))$ of connected components where Ω is a separable closure of K and $m^a = \{x \in O_\Omega | ord\ x \geq a\}$. To define it, we use some idea from rigid geometry. Using the set $\pi_0(Hom_{O_K}(O_L, O_\Omega/m^a))$, we define the upper numbering filtration. In the talk, I gave some examples and discussed further problems.

p-adic Galois representations p-adic differential equations

P. Colmez

The talk was a survey of the works of André, Berger, Kedlaya and Mebkhout leading to the proof of the monodromy conjectures of Crew on the differential side and Fontaine on the Galois side.

Rank four symplectic motives and Taylor-Wiles systems

Jacques Tilouine

The talk presented a result obtained with A. Genestier concerning the modularity of certain four-dimensional symplectic p-adic Galois representations ρ. The basic assumption is that their reduction modulo p is modular, associated to a holomorphic Siegel cusp eigenform. The prime p must be chosen larger than the Hodge-Tate weights of the representation and prime to its conductor. Since we follow the Taylor-Wiles method as used in the unpublished manuscript of Harris-Taylor, we need also to assume a minimality condition for ρ at p and at the primes dividing its conductor. At p we assume ordinarity (althoug ρ crystalline at p is probably enough).

The main step in the construction is a calculation of vanishing cycles for some Siegel varieties with parahoric bad reduction. We also need to establish an Eichler-Shimura relation at Taylor-Wiles primes.

Potential application to rk 4 symplectic motives/$\mathbb{Q}$ coming from deformations of the Fermat quintic are also mentioned.

An Eichler-Shimura type isomorphism for Drinfeld modular forms

G. Böckle (ETH Zürich)

In recent work R. Pink and myself have developed a cohomological theory of what we call crystals over function fields. The basic idea is to define for each scheme X a category of sheaves with some extra structure that on the one hand contains the categories of Drinfeld modules or more generally t-motives over X, and on the other allows the definition of functors f^*, $\otimes$ and $Rf_!$ for any morphism $f: X \to Y$ between schemes of finite type over $\mathbf{F}_q$. The novelty in comparison with earlier work by others on this is the existence of $Rf_!$, which does not exist on either of the above-mentioned subcategories.

I explain, how this theory can be used to define an Eichler-Shimura type isomorphism between the space of Drinfeld modular cusp forms of weight k and level $\mathfrak{n}$ and a suitably defined cohomology group $M_k(\mathfrak{n})$ in a category of crystals, that arises from the universal Drinfeld module on the moduli space $\mathfrak{Y}_1(\mathfrak{n})$ of rank 2 Drinfeld modules with a level $\Gamma_1(\mathfrak{n})$-structure. This isomorphism provides us with an étale realization of Drinfeld modular cusp forms, and hence allows it to attach Galois representations to eigenforms. One has the Eichler-Shimura relation $\mathrm{Frob}_{\mathfrak{q}} = T_{\mathfrak{q}}$ between Frobenius elements and Hecke operators. The function played by $M_k(\mathfrak{n})$ is analogous to that of the singular realization of classical modular forms.

One can define a similar crystal for double cusp forms. This gives a complete description of Galois representations attached to eigenforms which are not doubly cuspidal, namely as finite order characters of conductors dividing $\mathfrak{n}$.

p-adic Arakelov theory

Amnon Besser

We describe an analogue of Arakelov theory of curves with p-adic coefficients. The setup is as found in the theory of p-adic height pairings and the emphasis is on finding an analogue of the canonical Green function. The idea is to use the theory of Coleman integration, generalized to higher dimensions, and the analogue of the $\overline{\gamma}$ operator that takes Coleman forms "with one step integration" on the space X, to $\mathrm{H}^1_{\mathrm{dR}} \otimes \Omega^1(X)$. One then defines log functions as p-adic functions behaving like the log of a norm in the classical setting, and $\overline{\gamma}$ is used to define an analogue of the curvature form of such a log function. We find conditions for the existence of log functions with given curvature. One then finds on $\Theta(\Delta)$ a canonical log function whose curvature is analogous to the one found in the classical case. The required Green function is then just log(1). One can continue to define the analogue of the Faltings volume, and most results of Arakelov theory have easily provable analogues.

Tame coverings of arithmetic schemes

A. Schmidt

Let $\overline{X}$ be a regular connected and proper scheme over $Spec(\mathbb{Z})$ and let $X \subset \overline{X}$ be an open subscheme. We consider the profinite group

$$\pi_1^t(\overline{X}, \overline{X} - X)$$

which classifies finite étale coverings of X which are tame along the boundery $\overline{X} - X$. We show that its maximal abelian quotient

$$\pi_1^t(\overline{X}, \overline{X} - X)^{ab} = \pi_1^t(X)^{ab}$$

is finite and independent of the choice of the compactification $\overline{X}$ (i.e. depends only on X). The finiteness part of this statement requires weaker assumptions and we get the following generalisation of a result of Katz and Lang: "Let $\mathcal{O}$ be the ring of integers of a numberfield k and X a flat $\mathcal{O}$ scheme of finite type whose geometric generic fibre $X \otimes_{\mathcal{O}} \overline{k}$ is connected. Assume that $X \longrightarrow Spec(\mathcal{O}_k)$ is surjective and that X is normal. Then $\pi_1^{et}(X)^{ab}$ is finite".

Then we explain how singular homology of schemes of finite type over $Spec(\mathbb{Z})$ is defined and explain the existence of a surjective reciprocity homomorphis

$$rec : h_0(X) \longrightarrow \pi_1^t(X)^{ab}$$

for regular X. We conjecture that CM is an isomorphism of finite abelian groups and we explain, how much of the conjecture is proven up to now.

On the image of Galois in l-adic representations associated to motives

J.-P. Wintenberger

(joint work with J. Coates and R. Sujatha)

We consider $X \longrightarrow K$, K number field, X smooth projective variety over K. For each prime l, we consider the l-adic $G_K = \mathrm{GL}(\overline{\mathbb{Q}}/K)$-representation $V_{\mathbb{Q}_l} = \mathrm{H}^m(X_K, \mathbb{Q}_l)$. We prove that for big l, the image of Galois $\rho(G_K)$ contains homotheties $(\mathbb{F}_l^t)^{mc(d)}$, $c(d)$ a constant which only depends on $d = \dim \mathrm{H}^m(X(\mathbb{C}), \mathbb{Q})$. This implies for $m \neq 0$, $l >> 0$, if $V_{\mathbb{Z}_l} \subset \mathrm{H}^m(X_K, \mathbb{Q}_l)$ is a lattice stable by G_K the vanishing of cohomology groups $\mathrm{H}^i(\rho(G_K), V_{\mathbb{Q}_l}/V_{\mathbb{Z}_l})$. For each l, in the case m is odd, X has potentially good reduction at one prime v dividing l, if furthermore $\rho_{\mathbb{Q}_l}(G_K)$ has no element of order l the Euler characteristic

$$\chi(\rho_{\mathbb{Q}_l}, W_{\mathbb{Q}_l}/W_{\mathbb{Z}_l}) = 1.$$

An analogue of Grothendieck conjecture for higher dimensional local fields

Victor Abrashkin

Let $n \in \mathbb{N}$ and let K be an n-dimensional complete discrete valuation field. We assume that $\mathrm{char}K = 0$ or p, all residue fields of K are of characteristic p and the last residue field is finite. We provide K with additional F-structure given by its i-dimensional subfields $K_{i,e}$ which are supposed to be algebraically closed in K. We consider also $\mathcal{P}$-topology of K which unifies its n valuation topologies. Under above assumptions we define a decreasing sequence of subgroups in $\Gamma_K = \mathrm{Gal}(K_{sep}/K)$ which gives generalisation of classical concept of ramification filtration (known earlier only for 1-dimensional fields). Let $\mathrm{Aut}_{F\mathcal{P}}(K)$ be a group of $\mathcal{P}$-continuous automorphisms $g : \overline{K} \longrightarrow \overline{K}$ such that $g(K_{i,e}) = K_{i,e}$ for all $1 \leq i \leq n$. Let $\mathrm{Aut}_{rf}^{\mathcal{P}}$ be the group of all automorphisms of Γ_K which are compatible with ramification filtration and $\mathcal{P}$-continuous on each abelian subquotient. Characteristic 0 version of our result states:

the natural embedding $\mathrm{Aut}_{F\mathcal{P}}K \hookrightarrow \mathrm{Aut}_{rf}^{\mathcal{P}}\Gamma_K$ is isomorphism if $\mathrm{char}K = 0$.

Geometric realisation of local Langlands correspondences - computation of ϵ-constants in the tame case

M. Strauch

Let $\mathcal{X}/\overline{\mathbb{F}}_q$ be a p-divisible group and $(M.)$ the tower of rigid analytic spaces constructed by Rapoport and Zink from some deformation data of $\mathcal{X}$; in this case, R. Kottwitz conjectured a decomposition of the cuspidal part of $\mathrm{H}^* = \varinjlim \mathrm{H}^*(M. \otimes \hat{\overline{F}}, \mathbb{Q}_l)$ in terms of Langlands correspondences for the groups G $(\supset \varprojlim \mathrm{Aut}(M. \mid M_0))$, $J \supset \mathrm{Aut}(\mathcal{X})$ and W_F the Weilgroup of F. In the talk we discuss local approaches to this conjecture, namely: a trace formular argument for the $G \leftrightarrow J$ correspondence and an approach to compute ϵ-constants of the representation π of G (in the case $G = \mathrm{GL}_n$) and σ of W_F using formulas of Bushnell-Fröhlich and Laumon, respectively. Here we suppose F to be of positive characteristic and σ to be tamely ramified.

For the Lefschetz trace formula for rigid spaces, we introduce compactifications of deformation spaces of a one-dimensional $\mathcal{O}_F$-module in the category of adic spaces. Moreover, we give an expression of the Fourier transform of the cohomology in terms of the cohomology of an Artin-Schreier sheaf on a fibre bundle of deformation spaces over a punctured open disc.

Edited by Heinrich Utz (Karlsruhe)

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