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Die Tagung fand unter der Leitung von Herrn S. Böcherer (Mannheim), Herrn T. Ibukiyama (Osaka) und Herrn W. Kohnen (Heidelberg) statt.
In 27 Vorträgen wurde über den derzeitigen aktuellen Stand der Forschung auf dem Gebiet der Modulformen berichtet. Dabei sorgte die angenehme Atmosphäre des Instituts dafür, daß oft bis spät in die Nacht die in den Vorträgen aufgeworfenen Fragen und Probleme weiter diskutiert wurden.
Die Zukunft wird zeigen, welche Impulse die 50 Teilnehmer aus Indien, Italien, Japan, Korea, den USA und Deutschland mit nach Hause genommen haben.

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Abstracts

D. Ramakrishnan **Modularity of Rankin-Selberg L-series**

Let f, g be newforms (holomorphic or otherwise) of levels N and M, respectively, on the upper half-plane. Their L-functions (normalized to satisfy the functional equation with respect to $s \mapsto 1-s$) are:

$$L(s,f) = \sum_{n\geq 1} a_n\, n^{-s} = \prod_{p\nmid N} \{(1-\alpha_p p^{-s})\,(1-\beta_p p^{-s})\}^{-1} \prod_{p|N} L_p(s,f)$$

and

$$L(s,g) = \sum_{n\geq 1} b_n\, n^{-s} = \prod_{p\nmid M} \{(1-\alpha_p' p^{-s})\,(1-\beta_p' p^{-s})\}^{-1} \prod_{p|M} L_p(s,g).$$

We put

$$L^*(s,f\times g) = \prod_{p\nmid NM} \{(1-\alpha_p\alpha_p' p^{-s})(1-\alpha_p\beta_p' p^{-s})(1-\beta_p\alpha_p' p^{-s})(1-\beta_p\beta_p' p^{-s})\}^{-1}.$$

This function is closely related to the convolution L-function $\sum_{n\geq 1} a_n\, b_n\, n^{-s}$ whose beautiful properties where first studied by Rankin and Selberg.
A basic question, first raised by Langlands, is to know if there exists an automorphic form $f \boxtimes g$ on GL_4 over $\mathbb{Q}$, which is an eigenfunction for Hecke operators, such that its standard L-function, after removing the archimedian and bad factors, equals $L^*(s,f\times g)$.

Theorem. *This conjecture of Langlands is true, in fact with the base field $\mathbb{Q}$ replaced by any number field F.*

A consequence of this theorem is the meromorphic continuation and functional equation of four-fold convolutions $L(s,f_1\times f_2\times f_3\times f_4)$ with no pole outside $s=1$.

H. Katsurada **Koecher-Maaß Dirichlet series for Siegel modular forms**

(Joint work with T. Ibukiyama.) We have talked about a reasonable expression of the Koecher–Maaß Dirichlet series for Siegel modular forms, especially for Eisenstein series of Klingen type. For a Siegel modular form F of weight k belonging to the symplectic group $\mathrm{Sp}_n(\mathbb{Z})$ we let $L(F,s)$ be the Koecher-Maaß Dirichlet series for F.

Then first we express $L(F,s)$ in terms of the standard zeta function of F. Next we apply this result to the case of Klingen Eisenstein series. To be more precise, for a cusp form f for $\mathrm{Sp}_r(\mathbb{Z})$ let $[f]_r^n$ be the Klingen Eisenstein series for $\mathrm{Sp}_n(\mathbb{Z})$ attached to f. Then we express $L([f]_r^n, s)$ in terms of a certain Dirichlet series attached to f. In particular, we give an explicit form of $L([f]_1^n, s)$ by using a Dirichlet series of Kohnen-Zagier type attached to f when n is even. Also, a formula in the odd case is presented.

H. Saito **Explicit form of zeta functions for prehomogeneous vector spaces**

The purpose of this talk is to explain the shape of the explicit formula of the zeta functions of the space of symmetric matrices which was obtained by Ibukiyama and the speaker in the setting of prehomogeneous vector spaces

Let (G, ρ, X) be a prehomogeneous vector space defined over an algebraic number field F. We assume it is irreducible, regular, reduced and also $\ker \rho = \{1\}$. Let P be the relative invariant of (G, ρ, X) and χ the character associated with it. Then for $\Phi = \prod \Phi_v \in S(X(\mathbb{A})_F)$ the zeta function is defined by

$$Z(\Phi, s) = \int_{G(\mathbb{A}_F)/G(F)} |\chi(g)|^s \sum_{x \in X^{ss}(F)} \Phi(gx)\, dg,$$

where $X^{ss} = \{x \in X : P(x) \neq 0\}$. Assuming that this converges absolutely we try to reduce this integral into the local ones. We fix a point $x \in X^{ss}(F)$ and set $\Pi = G_x/G_x^0$. First we divide the sum over $X^{ss}(F)$ into the sums over $X^{ss}(F, \widetilde{a}) = \{x \in X^{ss}(F) : \varphi(x) = \widetilde{a}\}$ for $\widetilde{a} \in H^1(F, \Pi)$. Here the map φ is defined by the diagram

$$\begin{array}{ccccc} & & H^1(F,G) & & \\ & & \uparrow & & \\ H^1(F,G_x^0) & \to & H^1(F,G_x) & \to & H^1(F,\Pi) \\ & & \uparrow & & \uparrow \varphi \\ & & G(F)\backslash X^{ss}(F) & \leftarrow & X^{ss}(F). \end{array}$$

The reason why we introduce this division is that if $y, z \in X^{ss}(F, \widetilde{a})$ then G_y^0 and G_z^0 are inner forms of each other.

To treat the sums over $X^{ss}(F, \widetilde{a})$ it is better to consider $Y_y = G/G_y^0$ for $y \in X^{ss}(F, \widetilde{a})$. To take care of the difference $Y_y(\mathbb{A}_F) \supset G(\mathbb{A}_F)Y_y(F)$, we consider the abelian group $A(H)$ for a connected reductive group H introduced by Kottwitz. Let $L_y : A(G_y^0) \to$

$A(G)$. Then the main result is

$$\begin{aligned}
Z(\Phi, s) &= \sum_{\tilde{a} \in H^1(F,\Pi)} \sum_{\varepsilon \in \widehat{\ker L_\nu}} Z(\Phi, s, \tilde{a}, \varepsilon), \\
Z(\Phi, s, \tilde{a}, \varepsilon) &= \prod_{\nu} Z(\Phi_\nu, s, \tilde{a}, \varepsilon_\nu), \\
Z(\Phi_\nu, s, \tilde{a}, \varepsilon_\nu) &= \int_{X^{ss}(F_\nu)} \varepsilon_\nu(x_\nu) \Phi_\nu(x_\nu) |P(x_\nu)|^s dx_\nu.
\end{aligned}$$

This formula explains well our result on the zeta functions of the space of symmetric matrices and gives some generalizations.

L. Walling **Hecke operators of Siegel modular forms in the language of lattices**

(Joint work with James Lee Hafner.) A degree n Siegel modular form F has a Fourier expansion supported on even integral $n \times n$-matrices T with $T \geq 0$. We consider each T to be a quadratic form on a rank n $\mathbb{Z}$-lattice Λ relative to some basis for Λ. As T varies, the pair (Λ, T) varies over all (orientated) isometry classes of rank n lattices with even integral positive semi-definite quadratic forms. Also the (orientated) isometry class of (Λ, T) is that of (Λ, T') iff $T' = T[G]$ for some $G \in \mathrm{GL}_n(\mathbb{Z})$ (with $\det G = 1$ in the case k, the weight of F, is odd). Since $F(\tau[G]) = (\det G)^k F(\tau)$ for $G \in \mathrm{GL}_n(\mathbb{Z})$, it follows that $a(T[G]) = a(T)$ (where $\det G = 1$ if k is odd). Hence, using the language of lattices, we can rewrite the Fourier expansion of F in the form

$$F(\tau) = \sum_{\mathrm{cls}\, \Lambda} a(\Lambda) e^*\{\Lambda\tau\}$$

where $a(\Lambda) = a(T)$ for T any matrix representing the quadratic form on Λ (where Λ is orientated if k is odd) and

$$e^*\{\Lambda\tau\} = \sum_{G} \exp(\pi i \mathrm{tr}(T[G]\tau)).$$

Here G varies over $O(\Lambda) \setminus \mathrm{GL}_n(\mathbb{Z})$ if k is even and over $O^+(\Lambda) \setminus \mathrm{SL}_n(\mathbb{Z})$ if k is odd. We evaluate the action of the Hecke Operators $T(p)$ and $T_j(p^2)$ $(1 \leq j \leq n)$ on the Fourier coefficients of F. We first develop an algorithm which simultaneously computes the coset representation giving the action of the Hecke operators and associates each representative with a particular lattice structure. We then form simple linear combinations $\widetilde{T}_j(p^2)$ of the operators $id = T_0(p^2), \ldots, T_j(p^2)$ $(j = 1, \ldots, n)$.

Theorem. *The Λ-coefficient of $F|\widetilde{T}_j(p^2)$ is*

$$\sum_{p\Lambda\subset\Omega\subset\frac{1}{p}\Lambda} p^{E_j(\Lambda,\Omega)}\alpha_j(\Lambda,\Omega)a(\Omega)$$

where $E_j(\Lambda,\Omega)$ is an explicit constant depending on the invariant factors $\{\Lambda:\Omega\}$, and $\alpha_j(\Lambda,\Omega)$ reflects the geometry of $(\Lambda\cap\Omega)/p(\Lambda+\Omega)$.

We also derive an analogous formula for the Λ-coefficient of $F|T(p)$, recovering a theorem of Maaß.

D. Zagier — Periods of holomorphic and non-holomorphic modular forms

The classical period theory of Eichler-Shimura-Manin associates to a cusp form $f\in S_{2k}(\Gamma)$ a polynomial $r_f(X)$ defined (among other ways) as $\int_0^\infty f(\tau)(X-\tau)^{2k-2}\,d\tau$ satisfying

$$r_f(X)+X^{2k-2}r_f(-\tfrac{1}{X})=r_f(X)+X^{2k-2}r_f(1-\tfrac{1}{X})+(X-1)^{2k-2}r_f(\tfrac{1}{1-X})=0 \quad (1)$$

or equivalently the *three-term functional equation*

$$r_f(X)=r_f(X+1)+(X+1)^{2k-2}r_f(\tfrac{X}{X+1}). \quad (2)$$

I described some aspects of this (in particular, that it leads to an interesting arithmetical function $D_f:\mathbb{Q}/\mathbb{Z}\to\overline{\mathbb{Q}}$ which is the analogue of the classical Dedekind sum corresponding to $f=E_2$) and then reported on work of John Lewis and joint work of Lewis and myself which gives an analogous construction for Maaß wave forms. If $u(z)=\sqrt{y}\sum_{n\neq0}a_nK_{s-\frac12}(2\pi|n|y)e^{2\pi inx}$ $(z=x+iy\in\mathbb{H})$ is a Maaß wave form of eigenvalue $s(1-s)$ for the hyperbolic Laplacian then one can – again in several ways – associate to u a "period function" $\psi(z)$ which is a holomorphic function $\psi:\mathbb{C}\setminus]-\infty,0]\to\mathbb{C}$ satisfying (2) (with r_f replaced by ψ and $1-k$ by s). One of the ways is to define a holomorphic function $f:\mathbb{C}\setminus\mathbb{R}\to\mathbb{C}$ by $f(z)=\pm\sum_{n=1}^\infty n^{s-\frac12}a_{\pm n}e^{\pm2\pi inz}$ for $\pm\mathrm{Im}\,z>0$. Then the function $\psi:\mathbb{C}\setminus\mathbb{R}\to\mathbb{C}$ defined by $\psi(z)=f(z)-z^{-2s}f(-\frac1z)$ automatically satisfies (2) and extends across the positive real axis if (and only if) $u(z)$ is Γ-invariant. Moreover, $\lim_{\varepsilon\to0}(a\pm i\varepsilon)$ both exist and are equal whenever $a\in\mathbb{Q}$. Denoting the limit by $f(a)_0$ then the function $f:\mathbb{Q}/\mathbb{Z}\to\mathbb{C}$ is the analogue if the above mentioned "Dedekind sum" and the function $\phi:\mathbb{Q}/\mathbb{Z}\to\mathbb{C}$ defined for $a\neq0$ by $\psi(a)=f(a)-|a|^{-2s}f(-\frac1a)$ agrees with the previous ψ an $\mathbb{R}_+\cap\mathbb{Q}$, extends to a C^∞-function on all of $\mathbb{R}$ and satisfies the equation (1) (with the same replacements as above). This leads to a cocycle interpretation of the $u \mapsto \psi$ correspondence elaborated in joint work with Joseph Bernstein. The construction also works for groups other than $\mathrm{PSL}_2(\mathbb{Z})$. An example for $\Gamma_0(2)$ was described in which $s = \frac{1}{2}$ (i.e. the eigenvalue of u is $\frac{1}{4}$), the coefficients a_n are in $\mathbb{Z}$ and are the coefficients of a certain Artin L-series, and the function $f(z)$ in the upper and lower half-plane is one of Ramanujan's "mock theta functions".

J.-H. Bruinier **Borcherds products and Chern classes of Hirzebruch-Zagier**

We construct for each Hirzebruch-Zagier cycle T_m a certain "generalized Borcherds product" Ψ_m. This can be used to determine the Chern class of T_m explicitely and thereby to obtain a new construction of the Doi-Naganuma-mapping. One can deduce that every meromorphic Hilbert modular form F with divisor(F) = $\sum_{j=1}^{N} c_j T_j$ can be written as a Borcherds product in the form $F = \prod_{j=1}^{N} \Psi_j^{c_j}$.

J. Dulinski **The structure of Hecke algebras for Jacobi groups**

If $\mathcal{H}(L)$ is the Jacobi-Hecke algebra associated to a maximal lattice in a regular quadratic space over a p-adic field F of characteristic $\neq 2$, then the main results given are:

- a decomposition $\mathcal{H}(L) \simeq \mathcal{H}(L)^+ \times \mathcal{H}(L)^-$, where $\mathcal{H}(L)^-$ is finite dimensional and semi-simple,
- the construction of a Satake homomorphism

$$\Omega : \mathcal{H}(L) \longrightarrow \mathbb{C}[X^{\pm 1}],$$

  such that $\ker(\Omega) = \mathcal{H}(L)^-$ and $\Omega \restriction \mathcal{H}(L)^+$ is an isomorphism onto $\mathbb{C}[X^{\pm 1}]^W$, where $W = \{\mathrm{id}, X \mapsto X^{-1}\}$,
- the rationality of a certain formal power series over $\mathcal{H}(L)$.

B. Heim **On the twisted spinor L-function**

The first part of the talk was on my approach towards the twisted spinor L-function, the L-function attached to two cuspidal irreducible automorphic representations (Π, π) of $\mathrm{GSp}_2 \times \mathrm{GL}_2$, where the natural eight-dimensional representation r of the corresponding L-group is considered. This L-function $L(\Pi \times \pi, r, s)$ was first studied by Piatetski-Shapiro, Novodvorsky, Gelbart and Soudry for generic representations or forms which have a special Bessel model. Furusawa then considered the remaining most difficult case of holomorphic Siegel modular forms, i.e.

$$Z_{G\otimes h}(s) = L(\Pi \times \pi, r, s),$$

where G, h are cuspidal Siegel Hecke eigenforms of weight k and degree 2 and 1, respectively, corresponding to Π and π.
I have presented a new integral representation of $Z_{G\otimes h}(s)$ which can be viewed as a generalization of Garrett's approach towards the Rankin triple L-function. The second part was a report on a joint paper with S. Böcherer, in which we regard G and h of different weights k_G and k_h. In this situation $Z_{G\otimes h}(s)$ also satisfies a functional equation.
Finally the nature of the critical special values of $Z_{G\otimes h}(s)$ was discussed. Moreover the occurrence of a hidden triangle condition was explained. It was shown that for $k_h \geq 2k_G$ and G a Saito-Kurokawa lift, the elliptic cusp form dominates the nature of the special value. In the opposite case, everything can be proved by standard techniques, essentially due to G. Shimura.

S. Breulmann, M. Kuß — On a conjecture of Duke-Imamoḡlu

The following conjecture is due to W. Duke and Ö. Imamoḡlu:

Conjecture (DIC). *Let k, n be positive even integers and $f \in M_{2k-n}(\Gamma_1)$ be a Hecke eigenform. Then there exists a Hecke eigenform $F \in M_k(\Gamma_n)$ such that*

$$L_F^{st}(s) = \zeta(s) \prod_{j=1}^{n} L_f^H(s+k-j). \qquad (*)$$

(Notation: $L_F^{st}(s)$: Standard L-function of F, $\zeta(s)$: Riemann zeta-function, $L_f^H(s)$: Hecke L-function of f.)

Results:
1) $n = 2$: The DIC is true (Saito-Kurokawa correspondence).
2) Arbitrary n, k: a) f cuspidal iff F cuspidal, b) Siegel Eisenstein series fulfill $(*)$.
3) $n = 4$, $k = 8$: The Schottky form J and the Delta-function Δ satisfy a local version of $(*)$ for the primes $p \leq 7$.
4) $n = 12$, $k = 12$: No correspondence like $(*)$ can exist.

A. Murase — On metaplectic representations of unitary groups

Let M be a metaplectic representation of $G = U(n)$ defined over F, a finite extension of $\mathbb{Q}_p$. It is a well-known fact that M splits: Namely there exists a $\mathbb{C}^\times$-valued

function α on G such that $g \mapsto \mathcal{M}(g) = \alpha(g)M(g)$ is a representation of G. Then the natural question is to find an explicit form of α. This question is answered by Kudla as a special case of his work on splitting of metaplectic covers of dual reductive pairs. His method uses a calculation of cocycles of M on the Schrödinger model due to Perrin-Rao.
One of the goals of this talk is to give a "model independent" splitting of M by using a realization of M due to Moeglin-Vigneras-Waldspurger, which is also model independent. In this setting, the normalizing factor $\alpha(g)$ is expressed in terms of the "discriminant" of $g-1$ and Weil constants. In the split case, by making a small computation, we can show that Kudla's splitting and ours coincide. Our construction is also available for the archimedian case and the global case. Moreover our method works for the symplectic group. This eventually gives rise to a double covering of $\mathrm{Sp}_n(F)$. As an application of the splitting in the unitary case, we get a character formula for $\mathcal{M}$ under the assumption that G is quasi-split over F. Here we use a trace formula for $\mathcal{M}(g)$ on the lattice model. (The character formula seems to be already obtained by Howe, but the proof is different.)

T. Yang On the central derivative of Hecke L-series

Let $p \equiv 3 \mod 8$ and $k \in \mathbb{N}_0$ even. Let $E = \mathbb{Q}(\sqrt{-p})$. In this talk, we consider a Hecke character μ of E satisfying
(1) $\mu(\bar{a}) = \overline{\mu(a)}$,
(2) $\mu(\alpha\mathcal{O}) = \pm\alpha^{2k+1}$,
(4) The conductor of μ is $\sqrt{-p}\mathcal{O}_E$.
Such Hecke characters exist and can be constructed easily. They are arithmetic in nature and are very closely related to elliptic curves $A(p)$ constructed by Gross. By the conditions we put on p and k the functional equation for $L(s,\mu)$ has the "$-$" sign. So the central L-value $L(k+1,\mu)$ equals zero. The purpose of this talk is to give an explicit formula for $L'(k+1,\mu)$. More precisely, we obtain explicit formulae for each $L'(k+1,\mu,C)$ where $L(s,\mu,C) = \sum_{\mathfrak{a}\in C}\mu(\mathfrak{a})(\mathrm{N}\mathfrak{a})^{-s}$ is the partial L-series of μ for an ideal class C of E.

J.-S. Li The discrete spectrum of $\mathrm{SL}_2 \times E_{7,3}$

Let $\pi_{\min}$ be the minimal representation of the rank 4 real of E_8 constructed by Gross and Wallach. We determine the discrete spectrum for the restriction of $\pi_{\min}$ to the symmetric subgroup $E_{7(-25)} \times \mathrm{SL}(2)$. The decomposition takes the form

$$\pi_{\min}|E_{7(-25)} \times \mathrm{SL}(2) = \left(\bigoplus_{|k|\geq 2} \Theta_k \otimes \pi_k\right) \oplus (\text{continuous part})$$

where π_k is the holomorphic or anti-holomorphic discrete series with extremal weight k. We show that $\Theta_k = \sigma_k \oplus \sigma_k'$ with σ_k' a highest weight irreducible module which is in the discrete series when $k \geq 10$. For all $k \geq 4$ one has $\sigma_k \simeq R_q^s((k-10)\gamma)$ with $q = l \oplus u$ and the Levi l comes from a real form of type $E_{6(-14)}$. In particular, for $k \geq 10$ we have $\sigma_k \simeq A_q((k-10)\gamma)$, a unitary representation with non-zero cohomology at the (minimal) degree 11. In this way we show that there is an arithmetic lattice $\Gamma \subset E_{7(-25)}$ such that $H^2(\Gamma) \neq \{0\}$.

T. Arakawa **Kohnen-Ibukiyama plus space of degree n**

The purpose of this talk is to explain some basic properties of Siegel modular forms of the plus space via those of Jacobi forms of index one. The plus space $M_{k-\frac{1}{2}}^{+(n)}$ of degree n and even weight k consists of holomorphic functions f on the Siegel upper half plane of degree n satisfying the two conditions:

(i) $f(M\tau) = j^{(n)}(M,\tau)^{2k-1} f(\tau)$ for any $M \in \Gamma_0^{(n)}(4)$,

(ii) f has a Fourier expansion of the form $f(\tau) = \sum_{T\geq 0} a(T)\, e(\mathrm{tr}(T\tau))$,

where, for a semi-positive definite integral symmetric matrix T, $a(T) = 0$ unless $T \equiv -\lambda^t\lambda \bmod 4\mathrm{Sym}_n^*$ with some integral row vector $\lambda \in \mathbb{Z}^n$, Sym_n^* denoting the lattice of half-integral symmetric matrices of size n. Here $j^{(n)}(M,\tau)$ for $M \in \Gamma_0^{(n)}(4)$ is the factor of automorphy given by

$$j^{(n)}(M,\tau) = \frac{\Theta^{(n)}(M\tau)}{\Theta^{(n)}(\tau)} \text{ with } \Theta^{(\tau)}(\tau) = \sum_{\lambda \in \mathbb{Z}^n} e(\lambda\tau\lambda^t).$$

This space was introduced by Kohnen for $n = 1$ and by Ibukiyama for $n > 1$. An interesting point is that there exists a natural isomorphism from $J_{k,1}(\Gamma_n)$, the space of Jacobi forms of weight k, index 1 and degree n, onto the plus space $M_{k-\frac{1}{2}}^{+(n)}$. This isomorphism has been given by Kohnen, Eichler-Zagier and Ibukiyama. Via this is morphism several interesting properties of $M_{k-\frac{1}{2}}^{+(n)}$ are derived from those of $J_{k,1}(\Gamma_n)$ such as

(i) Construction of Cohen Eisenstein series $C_{k-\frac{1}{2}}^{(n)}(\tau) \in M_{k-\frac{1}{2}}^{+(n)}$ by the Jacobi Eisenstein series $E_{k,1}^{(n)}(\tau, z)$.

(ii) Direct sum decomposition of $M_{k-\frac{1}{2}}^{+(n)}$ into subspaces of Klingen Eisenstein series.

(iii) Siegel's formula for $C_{k-\frac{1}{2}}^{(n)}(\tau)$

(iv) A solution to a basis problem for $M^{+(n)}_{k-\frac{1}{2}}$, namely this space is spanned by a certain family of theta series

(v) A conjecture on the explicit form of the functional equation satisfied by real analytic Cohen Eisenstein series $C^{(n)}_{k-\frac{1}{2}}(\tau, s)$ of degree n.

S. Rallis Endoscopy and L-functions

(Joint work with D. Ginzburg and D. Soudry.) We show in this lecture how it is possible to obtain from a self dual automorphic module Π of $\mathrm{GL}(N)$ all the various cuspidal modules σ on a classical group G which weakly lift to the GL( ) ("weakly lift" means that we have the Langlands functoriality at almost all primes). The method uses the determination of certain Gelfand-Graev models. For example, if we take on Sp_{2n} ($4n \times 4n$-matrices) an Eisenstein series $E(\tau, s, \chi)$ based on the Siegel parabolic

$$\mathrm{ind}^{\mathrm{Sp}_{2n}}_{\mathrm{GL}_{2n}}(\tau \otimes |\ |^s); \text{ normalized induction and i.e. } s \mapsto -s,$$

then the Eisenstein series has a possible pole at $s = \frac{1}{2}$ controlled by $L(\tau, \wedge^2, s)$, which has a pole at $s = 1$ and $L(\tau, \wedge^2, \frac{1}{2}) \neq 0$. Let $X = \mathrm{res}_{s=\frac{1}{2}} E(\tau, s, \chi)$. If $X \neq 0$, take the Fourier-Jacobi coefficient of X relative to the partition $(2n, 1_{2n})$. Then $X_{(2n,1_{2n})} \neq 0$ is a $\widetilde{\mathrm{Sp}}_n$ module, which is cuspidal and contains all ψ-generic $\widetilde{\mathrm{Sp}}_n$ modules which weakly lift to Π. This is a prototype for obtaining the generic representation δ, the L-packet in $\widetilde{\mathrm{Sp}}_n$ corresponding to τ.

D. Bump Icosahedral Galois representations and elliptic curves

(Report on the Stanford dissertation of Edray Goins.) Let $\rho : \mathrm{Gal}(K/\mathbb{Q}) \to \mathrm{GL}(2;\mathbb{C})$ be a Galois representation. The image of ρ in $\mathrm{PGL}(2;\mathbb{C})$ is classified by Klein as cyclic, dihedral, tetrahedral (A_4), octahedral (S_4) or icosahedral (A_5). By work of Langlands and Tunnell, all cases of the Artin-Langlands conjecture are settled except the icosahedral case. This conjecture states that $L(s,\rho) = L(s,f)$ for an automorphic form f which is a modular form of weight one in the case $\det\rho\,(\text{complex conjugation}) = -1$.
In the icosahedral case, Buhler gave the following example: If K is the splitting field of $Z^5 + 10Z^3 - 10Z^2 + 35Z - 18$, he proved the existence of a modular form of weight 1 and level 800 attached to a 2-dimensional complex representation of $\mathrm{Gal}(K/\mathbb{Q})$. Other examples were given by members of Frey's seminar.
Recently Taylor has been investigating whether methods of Wiles used in the solution of the semistable Shimura-Taniyama conjecture can be brought to bear on

the icosahedral Artin conjecture. The thesis of Goins also investigates this question focussing on Buhler's example. It follows form Klein's icosahedron that there exists an infinite family of elliptic curves E, indexed by a moduli space of genus zero (a $\overline{\mathbb{Q}}/\mathbb{Q}(\xi_5)$-form of $X(5)$) such that if E is defined over F then the restriction to $\mathrm{Gal}(K/F)$ of the Galois representation is essentially given by the action on the 5-division points of E. Goins shows for Buhler's case that we may take $F = \mathbb{Q}(\sqrt{5})$ and $E = \{y^2 = x^3 + 2\sqrt{5}(\frac{\sqrt{5}-1}{2})x^2 + \sqrt{5}x\}$. The restriction of ρ to $\mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}(\sqrt{5})$ has the following description: The action of $\mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}(\sqrt{5})$ on $E[5]$ takes values in $\mathrm{GL}^+(2,\mathbb{F}_5)$, the subgroup of elements with determinant ± 1. This subgroup has a 2-dimensional complex representation; composition with the Galois representation gives Buhler's representation.
The curve E has remarkable properties. It is a $\mathbb{Q}$-curve (isogenous to its Galois conjugate). Twisting its L-function by a Hecke character gives a base change lift of a modular form of weight 2 and level 160, congruent to Buhler's modular form. The corresponding 5-adic Galois representation is a deformation of Buhler's.

T. Oda Various spherical functions on $\mathrm{Sp}(2,\mathbb{R})$

§1. In the local theory of automorphic forms, various (generalized) spherical realizations of representations ρ of groups over local fields play fundamental roles. The definition of a spherical function is given as follows:
Let G be a semisimple group over a local field F, R a closed subgroup of G, π a smooth G-module, ξ a smooth R-module and $\mathrm{Ind}_R^G(\xi)$ its induction from R to G. Consider the intertwining space $\mathrm{Hom}_G(\pi, \mathrm{Ind}_R^G(\xi))$ and the image $\mathrm{Im}(T)$ of a non-zero operator T in it. Then the elements in $\mathrm{Im}(T)$ are spherical functions if the above intertwining space has finite dimension. The desirable case is when this intertwining space has dimension 1. (Here we might replace $\mathrm{Ind}_R^G(\xi)$ by smaller G-modules consisting of moderate growth functions at ∞ or of exponential decreasing at ∞ to have such multiplicity one result.)
§2. We discuss the above problem for the real field $F = \mathbb{R}$ and $G = \mathrm{Sp}(2;\mathbb{R})$ (4×4-matrices). In addition to the well-known spherical subgroups $N_{\min}$, the unipotent radical of the minimal parabolic subgroup $P_{\min}$ (and ξ being a character of $N_{\min}$,), there are other important spherical subgroups in $\mathrm{Sp}(2;\mathbb{R})$:
(a) Let $P_S = L_S \ltimes N_S$ be the Siegel parabolic subgroup with Levi-decomposition. Given a character $\eta : N_S \to \mathbb{C}^{(1)}$ ($\begin{pmatrix} 1_2 & B \\ 0 & 1_2 \end{pmatrix} \mapsto \exp(2\pi i \mathrm{tr}(BH_\eta))$) we consider $\mathrm{SO}(\eta)$, i.e. the identity component of the stabilizer of η in L_S. (Here we assume H_η is non-degenerate.)
(b) For the Jacobi parabolic subgroup P_J, we can consider the Jacobi subgroup $R_J = \mathrm{SL}_2(\mathbb{R}) \ltimes H$, H being a Heisenberg group of dimension 3.
(c) $\mathrm{SL}_2(\mathbb{R}) \times \mathrm{SL}_2(\mathbb{R})$.

For each of the above 3 cases an explicit integral expression or power series of spherical functions of minimal K-types for the large discrete series representation π of $\mathrm{Sp}(2;\mathbb{R})$ is obtained by Miyazaki, Hirano and Moriyama.

§3. When $R = K$ the maximal compact subgroup of $\mathrm{Sp}(2;\mathbb{R})$, the corresponding spherical functions are classical ones, i.e. matrix coefficients of representations. For this case, we consider the matrix coefficients with minimal K-types. By using the Schmid operator (i.e. composition of a gradient operator and a projector of the irreducible decomposition of the tensor product of representations of K), we have a certain holomorphic system of ram 4 (i.e. a difference-differential equation, involutive, whose solution space is locally of dimension 4 at regular points of the system). We have an explicit formula of these matrix coefficients in terms of modified systems of Appell's F_2 hypergeometric series of 2 variables.

Needless to say, this matrix coefficient is also a reproducing kernel of the discrete series representation in question.

S. Friedberg — Rankin-Selberg integrals in two complex variables

(Joint work with D. Bump and D. Ginzburg.) We present three new examples of Rankin-Selberg integrals – integrals which unfold to products of 2 different Langlands L-functions on separate complex variables – and give applications to the study of L-functions. In each example the automorphic representation is on a group of symplectic similitudes, and the integral represents the product of the standard and spin L-functions. The integrals themselves are new variations on the Rankin-Selberg method.

The first is an integral against a product of two different maximal parabolic Eisenstein series on the group, the second is an integral against two different maximal parabolic Eisenstein series on different embedded groups and the third is an integral against an Eisenstein series induced from a parabolic subgroup, which is not maximal.

The applications to L-functions are obtained by combining them with the Siegel-Weil formula. One suggests that an automorphic representation on $\mathrm{GSp}_6(\mathbb{A}_F)$ (cuspidal, generic, with trivial central character) cannot simultaneously be a lift from G_2 and from Spin_6.

J. Hoffstein — Cubic twists of automorphic L-series

(Joint work with S. Friedberg and D. Bump.) Let f be an automorphic form on $\mathrm{GL}(2)$ over $\mathbb{Q}(\sqrt{-3})$. Let $\chi_d(x) = (\frac{d}{x})_3$ be the cubic residue character for any $d \in \mathcal{O}_{\mathbb{Q}(\sqrt{-3})}$, with d cube-free. We discuss a program which has as one of its consequences the following

Theorem. *There exist finite Dirichlet polynomials*

$$P_{d_0,d_1}(s) = \prod_{p^\alpha \| d_1} P_{d_0,p^\alpha}(s), \text{ such that}$$

for $d \in \mathcal{O}_{\mathbb{Q}(\sqrt{-3})}$, $d = d_0 d_1^3$, *where* d_0 *is cube-free, such that the double Dirichlet series*

$$Z(s,w) = \sum_{d \equiv 1\,(3)} \frac{L(s,f,\chi_{d_0})\, P_{d_0,d_1}(s)}{(N d_0 d_1^3)^w}$$

has a meromorphic continuation in the complex variables s, w. *The function* $Z(s,w)$ *is analytic except for the polar lines* $w = 1$ *and* $w + 2s = \frac{5}{3}$ *(and some reflections of these). We also have*

$$Res_{w=1} Z(s,w) = c \cdot L(3s, f, \vee^3),$$

i.e. the residue at $w = 1$ *of* $Z(s,w)$ *is the symmetric cube L-series of* f *at the argument* $3s$. *The analyticity of* $L(3s, f, \vee^3)$ *at all points (except possibly* 1*) follows from properties of* $Z(s,w)$. *Another consequence is the non-vanishing at a fixed point* s *of infinitely many distinct cube twists* $L(s, f, \chi_d)$.

Y. Hironaka **Spherical functions on p-adic homogeneous spaces**

First we give a formula of spherical functions on certain spherical homogeneous spaces on a p-adic number field, where representation theoretical methods based on Casselman are useful.
Then, applying it, we complete the theory of the spherical functions on the space X of non-degenerate unramified hermitian forms on a p-adic field k. We give an explicit expression for the spherical functions, whose main part is written by Hall-Littlewood polynomial. Then we consider the spherical Fourier transform and prove that the space of Schwartz-Bruhat functions on $K\backslash X$ is a free $\mathcal{H}(G,K)$-module of rank 2^n, where K is the usual maximal compact subgroup of G. We also present the Plancharel formula on this space and the inversion formula for the spherical Fourier transform, and parameterize all spherical functions on X.
As an application, we give explicit expressions of local densities of representations of hermitian forms in two ways. The first one comes from the fact that spherical functions can be viewed as generating functions of local densities. For the second one we use Gaussian sums and local zeta functions on the space of hermitian forms in the sense of prehomogeneous vector spaces.

Y. Choie **Differential operators and Jacobi forms**

The differential operator $D = \frac{d}{d\tau}$ has played an important role in the theory of modular forms. In this talk, the following three perspectives of roles of differential operators in the theory of elliptic modular forms will be discussed to get the analogous theory for the higher genus Siegel modular forms as well as for Jacobi forms:

- Satisfying a nonlinear differential equation,
- Bol's result which has played an important role for the theory of periods of modular forms,
- A way to complete or construct modular forms using differential operators, in particular study Rankin-Cohen brackets.

H. Yoshida **Absolute CM-periods**

Let K be a CM-field. We define the absolute period symbol g_K using division values of the multiple gamma function and conjecture that Shimura's period symbol p_K coincides with g_K up to the multiplication by algebraic numbers. We present a refined version of this conjecture taking the action of $\mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q})$ into account. We discuss numerical examples which support the conjectures.
We also report on recent advances concerning the invariants which are used to define g_K. Let F be a totally real field and E_F^+ be the totally positive unit group of F. Let $C = \cup_j C_j$ be a fundamental domain of E_F^+ with C_j being an open simplicial cone. Let $\mathfrak{b}$ and $\mathfrak{f}$ be integral ideals and c be an ideal class modulo $\mathfrak{f}\infty_1 \cdots \infty_n$. Assume that $\mathfrak{bf}$ and c belong to the same narrow ideal class.

Theorem 1.

$$\sum_{\substack{z \in C \\ (z)\mathfrak{bf} \equiv c}} (z^{(i)})^{-s}|_{s=0} = \frac{1}{n}\zeta_F(0,c)$$

for $1 \leq i \leq n$, where $\zeta_F(s,c)$ is the partial zeta function.

Theorem 2. *$V(c)$ is of the form $\sum_{i=1}^m a_i \log \varepsilon_i$, $a_i \in \tilde{F}$, $\varepsilon_i \in E_{\tilde{F}}^+$ where $\tilde{F}$ is the normal closure of F over $\mathbb{Q}$.*

These theorems are interrelated, but Theorem 2 is much deeper than Theorem 1.

J. Sengupta **Nonvanishing of symmetric square L-functions of cusp forms inside the critical stripe**

(Joint work with W. Kohnen.) Let $f \in S_k$ be a normalized cuspidal Hecke eigenform of integral weight k on the full modular group $\mathrm{SL}(2,\mathbb{Z})$ and denote by $D_f^*(s)$, $(s \in \mathbb{C})$ the symmetric square L-function of f completed with its archimedian Γ-factors. As is well-known, $D_f^*(s)$ has holomorphic continuation to the entire complex plane and is invariant under $s \mapsto 2k-1-s$. It is also known that zeroes of $D_f^*(s)$ can occur only inside the critical strip $k-1 < \sigma = \mathrm{Re}(s) < k$. According to the generalized Riemann hypothesis, the zeroes of $D_f^*(s)$ should all lie on the critical line $\mathrm{Re}\,(s) = k - \frac{1}{2}$. The last statement is of course far from being settled. On the other hand it turns out to be comparatively easy to prove non-vanishing results for $D_f^*(s)$ on the average. We have the following result:

Theorem. *Let $t_0 \in \mathbb{R}$ and $0 < \varepsilon < \frac{1}{2}$ be given. Then there exists a positive constant $c(t_0, \varepsilon)$ depending only on t_0 and ε, such that for every even $k > c(t_0,\varepsilon)$ the function*

$$\sum_{\nu=1}^{g_k} \frac{D^*_{f_{k,\nu}}(s)}{\langle f_{k,\nu}\, ,\, f_{k,\nu}\rangle} \quad \textit{is nonzero for } s = \sigma + it_0,$$

$k-1 < \sigma < k - \frac{1}{2} - \varepsilon$, $k - \frac{1}{2} + \varepsilon < \sigma < k$. *Here $\{f_{k,1}, \dots, f_{k,g_k}\}$ is a basis of S_k consisting of normalized Hecke eigenforms, where $g_k = \dim S_k$.*

M. Furusawa **The fundamental lemma for the Bessel and Novodvorsky subgroups of $\mathrm{GSp}(4) \subsetneq \mathrm{GL}(4)$**

(Joint work with J. Shalika.) We have proved, in the case of the group GSp(4), an equality of two local integrals. One is a Kloosterman integral on the Bessel subgroup of GSp(4) and the other is a Kloosterman integral on the Novodvorsky subgroup of GSp(4). We conjecture that Jacquet's relative trace formula for GL(2), where Jacquet has given another proof of Waldspurger's result on the central critical value of the degree two L-function, generalizes to GSp(4). We believe that this approach will lead us to a proof and also a precise formulation of a conjecture of Böcherer on the central critical value of the spinor L-function for GSp(4). Our result serves as the fundamental lemma for our conjectural relative trace formula for the main relevant double cosets.

T. Ikeda **On the gamma factor of the triple L-function**

Let $f_i \in S_{k_i}(SL_2(\mathbb{Z}))$ $(i = 1,2,3)$ be normalized Hecke eigenforms. The Satake parameter $A_{i,p}$ is defined by $\mathrm{tr}A_{i,p} = a_i(p)$, where $a_i(p)$ is the p^{th} Fourier coefficient of f_i and $\det A_{i,p} = p^{k_i-1}$. Then the triple product L-function is defined by

$$L(s, f_1 \times f_2 \times f_3) = \prod_p \det\left(1_8 - A_{1,p} \otimes A_{2,p} \otimes A_{3,p}p^{-s}\right)^{-1}.$$

The expected gamma factor is

$$\begin{cases} \Gamma_{\mathbb{C}}(s)\Gamma_{\mathbb{C}}(s-k_1+1)\Gamma_{\mathbb{C}}(s-k_2+1)\Gamma_{\mathbb{C}}(s-k_3+1) & \text{if } k_1 < k_2+k_3, \\ \Gamma_{\mathbb{C}}(s)\Gamma_{\mathbb{C}}(s-k_2-k_3+2)\Gamma_{\mathbb{C}}(s-k_2+1)\Gamma_{\mathbb{C}}(s-k_3+1) & \text{otherwise.} \end{cases}$$

Here $\Gamma_{\mathbb{C}}(s) = 2(2\pi)^{-s}\Gamma(s)$ and we have assumed $k_1 \geq k_2 \geq k_3$.
When f_i $(i = 1,2,3)$ are all even Maaß wave forms, we can also define the triple product L-function $L(s, f_1 \times f_2 \times f_3)$. The expected gamma factor is

$$\prod_{e_1,e_2,e_3 \in \{\pm 1\}} \Gamma_{\mathbb{R}}(s + e_1\sigma_1 + e_2\sigma_2 + e_3\sigma_3).$$

Here $\Gamma_{\mathbb{R}}(s) = \pi^{-\frac{s}{2}}\Gamma(\frac{s}{2})$ and the eigenvalue of the Laplacian of f_i is $\frac{1}{4} + \sigma_i^2$. In the lecture we have calculated the archimedian local integral and proved that the local integral is equal to the expected gamma function for some good local data.

D. Jiang **Arithmeticity of certain discrete subgroups and Euler product of L-functions**

(Joint work with Piatetski-Shapiro.) Let G be a simple $\mathbb{R}$-group with $\mathrm{rank}_{\mathbb{R}}(G) \geq 1$, Γ be a sublattice of G. A basic question is: When is Γ arithmetic?
By definition, Γ is arithmetic if there exists a $\mathbb{Q}$-simple $\mathbb{Q}$-group H $(\mathrm{rank}_{\mathbb{Q}}(H) \geq 1)$ and a $\mathbb{R}$-epimorphism $\tau : H \to G$ such that $\ker(\tau)$ is not compact and $\tau(H(\mathbb{Z}))$ and Γ are commensurable. By Margulis' theorem, if $\mathrm{rank}_{\mathbb{R}}(G) \geq 2$ or Γ is of infinite index in $\mathrm{Comm}_G(\Gamma) = \{g \in G : g\Gamma g^t \text{ and } \Gamma \text{are commensurable}\}$, then Γ is arithmetic.

Theorem 1. *Let G, Γ be as before, but $\mathrm{rank}_{\mathbb{R}}(G) = 1$. If there exist $\Delta_n = \{\delta_1, \ldots, \delta_n\} \subset G$ satisfying*
(1) If $i \neq j$, then $[\delta_i] \neq [\delta_j]$ where $[\delta] = \Gamma\delta$,
(2) There exists $\gamma_0 \in \Gamma$ and an $\delta_i \in \Delta_n$ such that $C_i = \{\delta_i^m\gamma_0\delta_i^{-m} : m \in \mathbb{Z}\}$ is not discrete in G,

(3) $\mu_G(\Gamma^{\Delta_n} \setminus G) < \infty$ *where* $\Gamma^{\Delta_n} = \{\gamma \in \Gamma : [\Delta_n] = [\Delta_n] \cdot \gamma\}$,
then Γ *is arithmetic.*

In the case of $G = \mathrm{PGL}_2(\mathbb{R})$ we will test our conditions:

Theorem 2. *Γ is arithmetic iff there exists p such that $\Gamma \setminus \Gamma\Delta_{p,\lambda}\Gamma$ is finite in $\Gamma \setminus G$ where* $\Delta_{p,\lambda} = \{\delta_a = \left(\begin{smallmatrix} 1 & a\lambda \\ 0 & p \end{smallmatrix}\right), \delta_p = \left(\begin{smallmatrix} p & 0 \\ 0 & 1 \end{smallmatrix}\right) : a = 0, 1, \ldots, p-1\}$

Theorem 3. *Assume there exists a p such that $\Gamma \setminus \Gamma\Delta_{p,\lambda}\Gamma$ is discrete in $\Gamma \setminus G$. If there exists a Laplacian eigenform in $L_0^2(\Gamma \setminus G)$ which is also a Hecke eigenform for T_p, i.e. $T_p(f)(g) = \frac{1}{p}\sum_{\delta \in \Delta_{p,\lambda}} f(\delta g) = \lambda_p f(g)$, then Γ is arithmetic.*

By the uniqueness of a certain type Whittaker function we can attach an L-function $L(s, f)$.

Theorem 4. *(1) $L(f, s)$ converges absolutely for* $\mathrm{Re}\, s \gg 0$, *has meromorphic continuation and satisfies a functional equation.*
(2) Assume p and Γ as in Theorem 3. If $L(s, f) = (1 - \lambda_p p^{-s} + p^{-1-2s})^{-1} D_p(s, f)$ where $D_p(s, f)$ is the Dirichlet series without p, then Γ is arithmetic.

K. James — Selmer groups of quadratic twists of elliptic curves

Let $E/\mathbb{Q}$ be a modular elliptic curve, denote by $E(D)$ the D-th quadratic twist of E and denote by $S(E(D))_\ell$ the ℓ-Selmer group of E. In this talk I will discuss the following theorem of Ken Ono and myself:

Theorem. *If $E/\mathbb{Q}$ is a modular elliptic curve then for every sufficiently large prime number ℓ*

$$\sharp\{|D| \leq X : D \text{ square-free}, S(E(D))_\ell = \{1\}\} \gg_{E,\ell} \frac{\sqrt{X}}{\log X}.$$

To prove this theorem we study the behaviour of the U_p and V_p operator on the "Waldspurger cusp forms" of weight $\frac{3}{2}$ associated to E. We then use standard results about Galois representations, the Chebotasev density theorem and a result of Kolyvagin bounding $\mathrm{ord}_\ell(w(E(D)))$ to establish the theorem.

K. Takase **An extension of Weil's generalized Poisson summation formula and its applications**

The Riemann-Jacobi theta series

$$\vartheta[\alpha](z,w) = \sum_{l \in \mathbb{Z}^n} e(\tfrac{1}{2}\langle l+\alpha', (l+\alpha')z\rangle + \langle l+\alpha', w+\alpha''\rangle),$$

where $\alpha = (\alpha', \alpha'') \in \mathbb{R}^{2n}, z \in \mathbb{H}_n, w \in \mathbb{C}^n, e(\tau) = exp(2\pi i t), \langle x,y\rangle = xy^t$, has a transformation formula with respect to the paramodular group

$$\Gamma(e) = \{\gamma \in \mathrm{Sp}(n,\mathbb{R}) \mid L\gamma = L\}, \; (L = \mathbb{Z}^n \times \mathbb{Z}^n e).$$

The formula involves a unitary matrix $U(\gamma, \alpha, \alpha_1, \cdots, \alpha_N) \in U(N, \mathbb{C})$. It depends on $\gamma \in \Gamma(e), \alpha \in \mathbb{R}^{2n}, \{\alpha_1, \cdots, \alpha_N\}$ resp. of $\mathbb{Z}^n e^{-1} \times \mathbb{Z}^n \,/\, \mathbb{Z}^{2n}$. Also there is an automorphy factor involved: $\det(cz+d)^{\frac{1}{2}} = \det J(\gamma, z)$ for $\gamma = \left(\begin{smallmatrix} a & b \\ c & d \end{smallmatrix}\right) \in \Gamma(e)$. Usually the proof of the transformation formula is based on some geometric facts; the abelian variety attached to $z \in \mathbb{H}_n$, the line bundle associated to the polarization determined by e, etc. In this lecture, I will discuss : representation theoretic mechanism from which the unitary matrix appears. In addition I will remove the ambiguity of $\det J(\gamma, z)$ in its signature.

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