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Distinguished representations and exceptional poles of the Asai-L-function

Nadir MATRINGE

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Abstract

Let K/F be a quadratic extension of p -adic fields. We show that a generic irreducible representation of $GL(n, K)$ is distinguished if and only if its Rankin-Selberg Asai L -function has an exceptional pole at zero. We use this result to compute Asai L -functions of ordinary irreducible representations of $GL(2, K)$. In the appendix, we describe supercuspidal dihedral representations of $GL(2, K)$ in terms of Langlands parameter.

1 Introduction

For K/F a quadratic extension of local fields, let σ be the conjugation relative to this extension, and $\eta_{K/F}$ be the character of F^* whose kernel is the set of norms from K^* . The conjugation σ extends naturally to an automorphism of $GL(n, K)$, which we also denote by σ . If π is a representation of $GL(n, K)$, we denote by π^σ the representation $g \mapsto \pi(\sigma(g))$.

If π is a smooth irreducible representation of $GL(n, K)$, and χ a character of F^* , the dimension of the space of linear forms on its space, which transform by χ under $GL(n, F)$ (with respect to the action $[(L, g) \mapsto L \circ \pi(g)]$), is known to be at most one (Proposition 11, [F1]). One says that π is χ -distinguished if this dimension is one, and says that π is distinguished if it is 1-distinguished.

Jacquet conjectured two results about distinguished representations of $GL(n, K)$. Let π be a smooth irreducible representation of $GL(n, K)$ and π^\vee its contragredient. The first conjecture states that it is equivalent for π with central character trivial on F^* to be isomorphic to $\pi^{\vee\sigma}$ and for π to be distinguished or $\eta_{K/F}$ -distinguished. In [K], Kable proved it for discrete series representations, using Asai L -functions.

The second conjecture, which is proved in [K], states that if π is a discrete series representation, then it cannot be distinguished and $\eta_{K/F}$ -distinguished at the same time.

One of the key points in Kable's proof is that if a discrete series representation of $GL(n, K)$ is such that its Asai L -function has a pole at zero, then it is distinguished, Theorem 1.4 of [A-K-T] shows that it is actually an equivalence. This theorem actually shows that Asai L -functions of tempered distinguished representations admit a pole at zero.

In this article, using a result of Youngbin Ok which states that for a distinguished representation, linear forms invariant under the affine subgroup of $GL(n, F)$ are actually $GL(n, F)$ -invariant (which generalises Corollary 1.2 of [A-K-T]), we prove in Theorem 3.1 that a generic representation is distinguished if and only if its Asai L -function admits an exceptional pole at zero. A pole at zero is always exceptional for Asai L -functions of discrete series representations (see explanation before Proposition 3.4). As a first application, we give in Proposition 3.6 a formula for Asai L -functions of supercuspidal representations of $GL(n, K)$.

There are actually three different ways to define Asai L -functions: one via the local Langlands correspondence and in terms of Langlands parameters denoted by $L_W(\pi, s)$, the one we use via the theory of Rankin-Selberg integrals denoted by $L_{As}(\pi, s)$, and the Langlands-Shahidi method applied to a suitable unitary group, denoted by $L_{As,2}(\pi, s)$ (see [A-R]). It is expected that the above three L -functions are equal.

For a discrete series representation π , it is shown in [He] that $L_W(\pi, s) = L_{As,2}(\pi, s)$, and in

[A-R] that $L_{As}(\pi, s) = L_{As,2}(\pi, s)$, both proofs using global methods.

As a second application of our principal result, we show (by local methods) in Theorem 4.2 of Section 4 that for an ordinary representation (i.e. corresponding through Langlands correspondence to an imprimitive 2 dimensional representation of the Weil-Deligne group) π of $GL(2, K)$, we have $L_W(\pi, s) = L_{As}(\pi, s)$. We recall that for odd residual characteristic, every smooth irreducible infinite-dimensional representation of $GL(2, K)$ is ordinary.

In the appendix (Section 5), we describe in Theorem 5.4 distinguished dihedral supercuspidal representations, this description is used in Section 4 for the computation of L_{As} for such representations.

2 Preliminaries

Let E_1 be a field, and E_2 a finite galois extension of E_1 , we denote by $Gal(E_2/E_1)$ the Galois group of E_2 over E_1 , and we denote by Tr_{E_2/E_1} (respectively N_{E_2/E_1}) the trace (respectively the norm) function from E_2 to E_1 . If E_2 is quadratic over E_1 , we denote by σ_{E_2/E_1} the non trivial element of $Gal(E_2/E_1)$.

In the rest of this paper, the letter F will always designate a non archimedean local field of characteristic zero in a fixed algebraic closure \bar{F} , and the letter K a quadratic extension of F in \bar{F} . We denote by q_F and q_K the cardinality of their residual fields, R_K and R_F their integer rings, P_K and P_F the maximal ideals of R_K and R_F , and U_K and U_F their unit groups. We also denote by v_K and v_F the respective normalized valuations, and $|\cdot|_K$ and $|\cdot|_F$ the respective absolute values. We fix an element δ of $K - F$ such that $\delta^2 \in F$, hence $K = F(\delta)$.

Let ψ be a non trivial character of K trivial on F , it is of the form $x \mapsto \psi' \circ Tr_{K/F}(\delta x)$ for some non trivial character ψ' of F .

Whenever G is an algebraic group defined over F , we denote by $G(K)$ its K -points and $G(F)$ its F -points. The group $GL(n)$ is denoted by G_n , its standard maximal unipotent subgroup is denoted by N_n .

If π is a representation of a group, we also denote by π its isomorphism class. Let μ be a character of F^* , we say that a representation π of $G_n(K)$ is μ -distinguished if it admits on its space V_π a linear form L , which verifies the following: for v in V and h in $G_n(K)$, then $L(\pi(h)v) = \mu(det(h))L(v)$. If $\mu = 1$, we say that π is distinguished.

We denote by $K_n(F)$ the maximal compact subgroup $G_n(R_F)$ of $G_n(F)$, and for $r \geq 1$, we denote by $K_{n,r}(F)$, the congruence subgroup $I_n + M_n(P_F^r)$.

The character ψ defines a character of $N_n(K)$ that we still denote by ψ , given by $\psi(n) = \psi(\sum_{i=1}^{n-1} n_{i,i+1})$.

We now recall standard results from [F2].

Let π be a generic smooth irreducible representation of $G_n(K)$, we denote by π^\vee its smooth contragredient, and c_π its central character.

We denote by $D(F^n)$ the space of smooth functions with compact support on F^n , and $D_0(F^n)$ the subspace of $D(F^n)$ of functions vanishing at zero. We denote by ρ the natural action of $G_n(F)$ on $D(F^n)$, given by $\rho(g)\phi(x_1, \dots, x_n) = \phi((x_1, \dots, x_n)g)$, and we denote by η the row vector $(0, \dots, 0, 1)$ of length n .

If W belongs to the Whittaker model $W(\pi, \psi)$ of π , and ϕ belongs to $D(F^n)$, the following integral converges for s of real part large enough:

$$\int_{N_n(F) \backslash G_n(F)} W(g)\phi(\eta g)|det(g)|_F^s dg.$$

This integral as a function of s has a meromorphic extension to \mathbb{C} which we denote by $\Psi(W, \phi, s)$.

For s of real part large enough, the function $\Psi(W, \phi, s)$ is a rational function in q_F^{-s} , which actually has a Laurent series development.

The \mathbb{C} -vector space generated by these functions is in fact a fractional ideal $I(\pi)$ of $\mathbb{C}[q_F^{-s}, q_F^s]$.

This ideal $I(\pi)$ is principal, and has a unique generator of the form $1/P(q_F^{-s})$, where P is a polynomial with $P(0) = 1$.

Definition 2.1. We denote by $L_{As}(\pi, s)$ the generator of $I(\pi)$ defined just above, and call it the Asai L -function of π .

Remark 2.1. If P belongs to $\mathbb{C}[X]$ and has constant term equal to one, then the function of the complex variable $L_P : s \mapsto 1/P(q_F^{-s})$ is called an Euler factor. It is a meromorphic function on \mathbb{C} and admits $(2i\pi/\ln(q_F))\mathbb{Z}$ as a period subgroup. Hence if s_0 is a pole of L_P , the elements $s_0 + (2i\pi/\ln(q_F))\mathbb{Z}$ are also poles of L_P , with same multiplicities, we identify s_0 and $s_0 + (2i\pi/\ln(q_F))\mathbb{Z}$ when we talk about poles. A pole s_0 then corresponds to a root α_0 of P by the formula $q^{-s_0} = \alpha_0$, its multiplicity in L_P equal to the multiplicity of α_0 in P .

Let w_n be the matrix of $G_n(\mathbb{Z})$ with ones on the antidiagonal, and zeroes elsewhere. For W in $W(\pi, \psi)$, we denote by \tilde{W} the function $g \mapsto W(w_n^t g^{-1})$ which belongs to $W(\pi^\vee, \psi^{-1})$, and we denote by $\hat{\phi}$ the Fourier transform (with respect to ψ' and its associate autodual Haar measure) of ϕ in $D(F^n)$.

Theorem 2.1. (Functional equation) (Th. of [F2])

There exists an epsilon factor $\epsilon_{As}(\pi, s, \psi)$ which is, up to scalar, a (maybe negative) power of q^s , such that the following functional equation is satisfied for any W in $W(\pi, \psi)$ and any ϕ in $D(F^n)$:

$$\Psi(\tilde{W}, \hat{\phi}, 1-s)/L_{As}(\pi^\vee, 1-s) = c_\pi(-1)^{n-1} \epsilon_{As}(\pi, s, \psi) \Psi(W, \phi, s)/L_{As}(\pi, s).$$

3 Poles of the Asai L -function and distinguishedness

Now suppose $L_{As}(\pi, s)$ has a pole at s_0 , its order d is the highest order pole of the family of functions of $I(\pi)$.

Then we have the following Laurent expansion at s_0 :

$$\Psi(W, \phi, s) = B_{s_0}(W, \phi)/(q_F^s - q_F^{s_0})^d + \text{smaller order terms.} \quad (1)$$

The residue $B_{s_0}(W, \phi)$ defines a non zero bilinear form on $W(\pi, \psi) \times D(F^n)$, satisfying the quasi-invariance:

$$B_{s_0}(\pi(g)W, \rho(g)\phi) = |\det(g)|_F^{-s_0} B_{s_0}(W, \phi).$$

Following [C-P] for the split case $K = F \times F$, we state the following definition:

Definition 3.1. A pole of the Asai L -function $L_{As}(\pi, s)$ at s_0 is called exceptional if the associated bilinear form B_{s_0} vanishes on $W(\pi, \psi) \times D_0(F^n)$.

As an immediate consequence, if s_0 is an exceptional pole of $L_{As}(\pi, s)$, then B_{s_0} is of the form $B_{s_0}(W, \phi) = \lambda_{s_0}(W)\phi(0)$, where λ_{s_0} is a non zero $|\det(\cdot)|_F^{-s_0}$ invariant linear form on $W(\pi, \psi)$. Hence we have:

Proposition 3.1. Let π be a generic irreducible representation of $G_n(K)$, and suppose its Asai L -function has an exceptional pole at zero, then π is distinguished.

We denote by $P_n(F)$ the affine subgroup of $G_n(F)$, given by matrices with last row equal to η .

For more convenience, we introduce a second L -function: for W in $W(\pi, \psi)$, by standard arguments, the following integral is convergent for $\text{Re}(s)$ large, and defines a rational function in q^{-s} , which has a Laurent series development:

$$\int_{N_n(F) \backslash P_n(F)} W(p) |det(p)|_F^s dp.$$

We denote by $\Psi_1(W, s)$ the corresponding Laurent series. By standard arguments again, the vector space generated by the functions $\Psi_1(W, s-1)$, for W in $W(\pi, \psi)$, is a fractional ideal $I_1(\pi)$ of $\mathbb{C}[q_F^{-s}, q_F^s]$, which has a unique generator of the form $1/Q(q_F^{-s})$, where Q is a polynomial with $Q(0) = 1$. We denote by $L_1(\pi, s)$ this generator.

Lemma 3.1. (*[J-P-S] p. 393*)

Let W be in $W(\pi, \psi)$, one can choose ϕ with support small enough around $(0, \dots, 0, 1)$ such that $\Psi(W, \phi, s) = \Psi_1(W, s-1)$.

Proof. As we gave a reference, we only sketch the proof. We first recall the following integration formula (cf. proof of the proposition in paragraph 4 of [F]), for $Re(s) > 0$:

$$\Psi(W, \phi, s) = \int_{K_n(F)} \int_{N_n(F) \backslash P_n(F)} W(pk) |det(p)|_F^{s-1} dp \int_{F^*} \phi(\eta ak) c_\pi(a) |a|_F^{ns} d^* adk. \quad (2)$$

Choosing r large enough for W to be right invariant under $K_{n,r}(F)$, we take ϕ a positive multiple of the characteristic function of $\eta K_{n,r}(F)$, and conclude from equation (2). \square

Hence we have the inclusion $I_1(\pi) \subset I(\pi)$, which implies that $L_1(\pi, s) = L_{As}(\pi, s) R(q_F^s, q_F^{-s})$ for some R in $\mathbb{C}[q_F^{-s}, q_F^s]$. But because L_1 and L_{As} are both Euler factors, R is actually just a polynomial in q_F^{-s} , with constant term equal to one. Noting $L_{rad(ex)}(\pi, s)$ its inverse (which is an Euler factor), we have $L_{As}(\pi, s) = L_1(\pi, s) L_{rad(ex)}(\pi, s)$, we will say that L_1 divides L_{As} . The explanation for the notation $L_{rad(ex)}$ is given in Remark 3.1.

We now give a characterisation of exceptional poles:

Proposition 3.2. *A pole of $L_{As}(\pi, s)$ is exceptional if and only if it is a pole of the function $L_{rad(ex)}(\pi, s)$ defined just above.*

Proof. From equation (2), it becomes clear that the vector space generated by the integrals $\Psi(W, \phi, s)$ with W in $W(\pi, \psi)$ and ϕ in $D_0(F^n)$, is contained in $I_1(\pi)$, but because of Lemma 3.1, those two vector spaces are equal. Hence $L_1(\pi, s)$ is a generator of the ideal generated as a vector space by the functions $\Psi(W, \phi, s)$ with W in $W(\pi, \psi)$ and ϕ in $D_0(F^n)$.

From equation (1), if s_0 is an exceptional pole, a function $\Psi(W, \phi, s)$, with ϕ in $D_0(F^n)$, cannot have a pole of highest order at s_0 , hence we have one implication.

Now if the order of the pole s_0 for $L_{As}(\pi, s)$ is strictly greater than the one of $L_1(\pi, s)$, then the first residual term corresponding to a pole of highest order of the Laurent development of any function $\Psi(W, \phi, s)$ with $\phi(0) = 0$ must be zero, and zero is exceptional. \square

Lemma 3.1 also implies:

Proposition 3.3. *The functional $\Lambda_{\pi, s} : W \mapsto \Psi_1(W, s-1)/L_{As}(\pi, s)$ defines a (maybe null) linear form on $W(\pi, \psi)$ which transforms by $|det(\cdot)|_F^{1-s}$ under the affine subgroup $P_n(F)$. For fixed W in $W(\pi, \psi)$, then $s \mapsto \Lambda_{\pi, s}(W)$ is a polynomial of q_F^{-s} .*

Now we are able to prove the converse of Proposition 3.1:

Theorem 3.1. *A generic irreducible representation π of $G_n(K)$ is distinguished if and only if $L_{As}(s, \pi)$ admits an exceptional pole at zero.*

Proof. We only need to prove that if π is distinguished, then $L_{As}(s, \pi)$ admits an exceptional pole at zero, so we suppose π distinguished.
From equation (2), for $Re(s) < 0$, and π distinguished (so that c_π has trivial restriction to F^*), one has:

$$\Psi(\tilde{W}, \hat{\phi}, 1-s) = \int_{K_n(F)} \int_{N_n(F) \backslash P_n(F)} \tilde{W}(pk) |det(p)|_F^{-s} dp \int_{F^*} \hat{\phi}(\eta ak) |a|_F^{n(1-s)} d^* a dk. \quad (3)$$

This implies that:

$$\Psi(\tilde{W}, \hat{\phi}, 1-s)/L_{As}(\pi^\vee, 1-s) = \int_{K_n(F)} \Lambda_{\pi^\vee, 1-s}(\pi^\vee(k) \tilde{W}) \int_{F^*} \hat{\phi}(\eta ak) |a|_F^{n(1-s)} d^* a dk. \quad (4)$$

The second member of the equality is actually a finite sum: $\sum_i \lambda_i \Lambda_{\pi^\vee, 1-s}(\pi^\vee(k_i) \tilde{W}) \int_{F^*} \hat{\phi}(\eta ak_i) |a|_F^{n(1-s)} d^* a$, where the λ_i 's are positive constants and the k_i 's are elements of $K_n(F)$ independant of s .
Note that there exists a positive constant ϵ , such that for $Re(s) < \epsilon$, the integral $\int_{F^*} \hat{\phi}(\eta ak_i) |a|_F^{n(1-s)} d^* a$ is absolutely convergent, and defines a holomorphic function. So we have an equality (equality 4) of analytic functions (actually of polynomials in q_F^{-s}), hence it is true for all s such that $Re(s) < \epsilon$.
For $s = 0$, we get:

$$\Psi(\tilde{W}, \hat{\phi}, 1)/L_{As}(\pi^\vee, 1) = \int_{K_n(F)} \Lambda_{\pi^\vee, 1}(\pi^\vee(k) \tilde{W}) \int_{F^*} \hat{\phi}(\eta ak) |a|_F^n d^* a dk.$$

But as π is distinguished, so is π^\vee , and as $\Lambda_{\pi^\vee, 1}$ is a $P_n(F)$ -invariant linear form on $W(\pi^\vee, \psi^{-1})$, it follows from Theorem 3.1.2 of [Ok] that it is actually $G_n(F)$ -invariant.
Finally

$$\Psi(\tilde{W}, \hat{\phi}, 1)/L_{As}(\pi^\vee, 1) = \Lambda_{\pi^\vee, 1}(\tilde{W}) \int_{K_n(F)} \int_{F^*} \hat{\phi}(\eta ak) |a|_F^n d^* a dk$$

which is equal to:

$$\Lambda_{\pi^\vee, 1}(\tilde{W}) \int_{P_n(F) \backslash G_n(F)} \hat{\phi}(\eta g) d_\mu g$$

where d_μ is up to scalar the unique $|det(\cdot)|^{-1}$ invariant measure on $P_n(F) \backslash G_n(F)$. But as

$$\int_{P_n(G) \backslash G_n(F)} \hat{\phi}(\eta g) d_\mu g = \int_{F^n} \hat{\phi}(x) dx = \phi(0),$$

we deduce from the functional equation that $\Psi(W, \phi, 0)/L_{As}(\pi, 0) = 0$ whenever $\phi(0) = 0$.
As one can choose W , and ϕ vanishing at zero, such that $\Psi(W, \phi, s)$ is the constant function equal to 1 (see the proof of Theorem 1.4 in [A-K-T]), hence $L_{As}(\pi, s)$ has a pole at zero, which must be exceptional. \square

For a discrete series representation π , it follows from Lemma 2 of [K], that the integrals of the form

$$\int_{N_n(F) \backslash P_n(F)} W(p) |det(p)|_F^{s-1} dp.$$

converge absolutely for $Re(s) > -\epsilon$ for some positive ϵ , hence as functions of s , they cannot have a pole at zero.

This implies that $L_1(\pi, s)$ has no pole at zero, hence Theorem 3.1 in this case gives:

Proposition 3.4. ([K], Theorem 4)

A discrete series representation π of $G_n(K)$ is distinguished if and only if $L_{As}(s, \pi)$ admits a pole at zero.

Let s_0 be in \mathbb{C} . We notice that if π is a generic irreducible representation of $G_n(K)$, it is $|\bar{F}^{s_0}$ -distinguished if and only if $\pi \otimes |\bar{K}^{s_0/2}$ is distinguished, but as $L_{As}(s, \pi \otimes |\bar{K}^{s_0/2})$ is equal to $L_{As}(s + s_0, \pi)$, Theorem 3.1 becomes:

Theorem 3.2. *A generic irreducible representation π of $G_n(K)$ is $|\bar{F}^{s_0}$ -distinguished if and only if $L_{As}(s, \pi)$ admits an exceptional pole at s_0 .*

Remark 3.1. Let P and Q be two polynomials in $\mathbb{C}[X]$ with constant term 1, we say that the Euler factor $L_P(s) = 1/P(q_F^{-s})$ divides $L_Q(s) = 1/Q(q_F^{-s})$ if and only if P divides Q . We denote by $L_P \vee L_Q$ the Euler factor $1/(P \vee Q)(q_F^{-s})$, where the l.c.m $P \vee Q$ is chosen such that $(P \vee Q)(0) = 1$. We define the g.c.d $L_P \wedge L_Q$ the same way.

It follows from equation (2) that if $c_{\pi|F^*}$ is ramified, then $L_{As}(\pi, s) = L_1(\pi, s)$. It also follows from the same equation that if $c_{\pi|F^*} = |\bar{F}^{s_1}$ for some s_1 in \mathbb{C} , then $L_{rad(ex)}(\pi, s)$ divides $1/(1 - q_F^{s_1 - ns})$. Anyway, $L_{rad(ex)}(\pi, s)$ has simple poles.

Now we can explain the notation $L_{rad(ex)}$. We refer to [C-P] where the case $K = F \times F$ is treated. In fact, in the latter, $L_{ex}(\pi, s)$ is the function $1/P_{ex}(\pi, q_F^{-s})$, with $P_{ex}(\pi, q_F^{-s}) = \prod_{s_i} (1 - q_F^{s_i - s})^{d_i}$, where the s_i 's are the exceptional poles of $L_{As}(\pi, s)$ and the d_i 's their order in $L_{As}(\pi, s)$. Hence $L_{rad(ex)}(\pi, s) = 1/P_{rad(ex)}(\pi, q_F^{-s})$, where $P_{rad(ex)}(\pi, X)$ is the unique generator with constant term equal to one, of the radical of the ideal generated by $P_{ex}(\pi, X)$ in $\mathbb{C}[X]$.

We proved:

Proposition 3.5. *Let π be an irreducible generic representation of $G_n(K)$, the Euler factor $L_{rad(ex)}(\pi, s)$ has simple poles, it is therefore equal to $\prod 1/(1 - q_F^{s_0 - s})$ where the product is taken over the $q_F^{s_0}$'s such that π is $|\bar{F}^{s_0}$ -distinguished.*

Suppose now that π is supercuspidal, then the restriction to $P_n(K)$ of any W in $W(\pi, \psi)$ has compact support modulo $N_n(K)$, hence $\Psi_1(W, s - 1)$ is a polynomial in q^{-s} , and $L_1(\pi, s)$ is equal to 1. Hence Proposition 3.5 becomes:

Proposition 3.6. *Let π be an irreducible supercuspidal representation of $G_n(K)$, then $L_{As}(\pi, s) = \prod 1/(1 - q^{s_0 - s})$ where the product is taken over the q^{s_0} 's such that π is $|\bar{F}^{s_0}$ -distinguished.*

4 Asai L -functions of $GL(2)$

4.1 Asai L -functions for imprimitive Weil-Deligne representations of dimension 2

The aim of this paragraph is to compute $L_W(\rho, s)$ (see the introduction) when ρ is an imprimitive two dimensional representation of the Weil-Deligne group of K .

We denote by W_K (resp. W_F) the Weil group of K (resp. F), I_K (resp. I_F) the inertia subgroup of W_K (resp. W_F), W'_K (resp. W'_F) the group $W_K \times SL(2, \mathbb{C})$ (resp. $W_F \times SL(2, \mathbb{C})$) and I'_K (resp. I'_F) the group $I_K \times SL(2, \mathbb{C})$ (resp. $I_F \times SL(2, \mathbb{C})$). We denote by ϕ_F a Frobenius element of W_F , and we also denote by ϕ'_F the element (ϕ_F, I_2) of W'_F .

We denote by $sp(n)$ the unique (up to isomorphism) complex irreducible representation of $SL(2, \mathbb{C})$ of dimension n .

If ρ is a finite dimensional representation of W'_K , we denote by $M_{W'_K}^{W'_F}(\rho)$ the representation of W'_F induced multiplicatively from ρ . We recall its definition:

If V is the space of ρ , then the space of $M_{W'_K}^{W'_F}(\rho)$ is $V \otimes V$. Noting τ an element of $W_F - W_K$, and σ the element (τ, I) of W'_F , we have:

$$M_{W'_K}^{W'_F}(\rho)(h)(v_1 \otimes v_2) = \rho(h)v_1 \otimes \rho^\sigma(h)v_2$$

for h in W'_K , v_1 and v_2 in V .

$$M_{W'_K}^{W'_F}(\rho)(\sigma)(v_1 \otimes v_2) = \rho(\sigma^2)v_2 \otimes v_1$$

for v_1 and v_2 in V .

We refer to paragraph 7 of [P] for definition and basic properties of multiplicative induction in the general case.

Definition 4.1. *The function $L_W(\rho, s)$ is by definition the usual L -function of the representation $M_{W'_K}^{W'_F}(\rho)$, i.e. $L_W(\rho, s) = L(M_{W'_K}^{W'_F}(\rho), s)$.*

- i) If ρ is of the form $\text{Ind}_{W'_B}^{W'_K}(\omega)$ for some multiplicative character ω of a biquadratic extension B of F , we denote by K' and K'' the two other extensions between F and B . If we call σ_1 an element of W'_K which is not in $W'_{K'} \cup W'_{K''}$ and σ_3 an element of $W'_{K''}$ which is not in $W'_K \cup W'_{K'}$, then $\sigma_2 = \sigma_3\sigma_1$ is an element of $W'_{K'}$ which is not in $W'_K \cup W'_{K''}$. The elements $(1, \sigma_1, \sigma_2, \sigma_3)$ are representatives of W'_F/W'_B , and 1 and σ_3 are representatives of W'_F/W'_K .

If one identifies ω with a character (still called ω) of B^* , then ω^{σ_1} identifies with $\omega \circ \sigma_{B/K}$, ω^{σ_2} with $\omega \circ \sigma_{B/K'}$ and ω^{σ_3} with $\omega \circ \sigma_{B/K''}$. One then verifies that if a belongs to W_B , one has:

- $\text{Tr}[M_{W'_K}^{W'_F}(\rho)(a)] = \text{Tr}[\text{Ind}_{W'_{K'}}^{W'_F}(M_{W'_B}^{W'_{K'}}(\omega))(a)] + \text{Tr}[\text{Ind}_{W'_{K''}}^{W'_F}(M_{W'_B}^{W'_{K''}}(\omega))(a)] = \omega\omega^{\sigma_2} + \omega\omega^{\sigma_3} + \omega^{\sigma_1}\omega^{\sigma_2} + \omega^{\sigma_1}\omega^{\sigma_3}.$
- $\text{Tr}[M_{W'_K}^{W'_F}(\rho)(\sigma_1 a)] = \text{Tr}[\text{Ind}_{W'_{K'}}^{W'_F}(M_{W'_B}^{W'_{K'}}(\omega))(\sigma_1 a)] + \text{Tr}[\text{Ind}_{W'_{K''}}^{W'_F}(M_{W'_B}^{W'_{K''}}(\omega))(\sigma_1 a)] = 0.$
- $\text{Tr}[M_{W'_K}^{W'_F}(\rho)(\sigma_2 a)] = \text{Tr}[\text{Ind}_{W'_{K'}}^{W'_F}(M_{W'_B}^{W'_{K'}}(\omega))(\sigma_2 a)] + \text{Tr}[\text{Ind}_{W'_{K''}}^{W'_F}(M_{W'_B}^{W'_{K''}}(\omega))(\sigma_2 a)] = \omega(\sigma_2 a \sigma_2 a) + \omega^{\sigma_1}(\sigma_2 a \sigma_2 a).$
- $\text{Tr}[M_{W'_K}^{W'_F}(\rho)(\sigma_3 a)] = \text{Tr}[\text{Ind}_{W'_{K'}}^{W'_F}(M_{W'_B}^{W'_{K'}}(\omega))(\sigma_3 a)] + \text{Tr}[\text{Ind}_{W'_{K''}}^{W'_F}(M_{W'_B}^{W'_{K''}}(\omega))(\sigma_3 a)] = \omega(\sigma_3 a \sigma_3 a) + \omega^{\sigma_1}(\sigma_3 a \sigma_3 a).$

Hence we have the isomorphism

$$M_{W'_K}^{W'_F}(\rho) \simeq \text{Ind}_{W'_{K'}}^{W'_F}(M_{W'_B}^{W'_{K'}}(\omega)) \oplus \text{Ind}_{W'_{K''}}^{W'_F}(M_{W'_B}^{W'_{K''}}(\omega)).$$

From this we deduce that

$$L(M_{W'_K}^{W'_F}(\rho), s) = L(\omega|_{K'^*}, s)L(\omega|_{K''^*}, s).$$

- ii) Let L be a quadratic extension of F , such that $\rho = \text{Ind}_{W'_L}^{W'_K}(\chi)$, with χ regular, is not isomorphic to a representation of the form $\text{Ind}_{W'_B}^{W'_K}(\omega)$ as in i), then

$$L(M_{W'_K}^{W'_F}(\rho), s) = 1.$$

Indeed, we show that $M_{W'_K}^{W'_F}(\rho)^{I'_F} = \{0\}$. If it wasn't the case, the representation $(M_{W'_K}^{W'_F}(\rho), V)$ would admit a I'_F -fixed vector, and so would its contragredient V^* . Now in the subspace of I'_F -fixed vectors of V^* , choosing an eigenvector of $M_{W'_K}^{W'_F}(\rho)(\phi_F)$, we would deduce the existence of a linear form L on $(M_{W'_K}^{W'_F}(\rho), V)$ which transforms under W'_F by an unramified character μ of W'_F . If we identify μ with a character μ' of F^* , the restriction of μ to W'_K corresponds to $\mu' \circ N_{K/F}$ of K^* , so we can write it as $\theta\theta^\sigma$, where θ is a character of W'_K

corresponding to an extension of μ' to K^* . As the restriction of $M_{W'_K}^{W'_F}$ to W'_K is isomorphic to $\rho \otimes \rho^\sigma$, we deduce that $\theta^{-1}\rho \otimes (\theta^{-1}\rho)^\sigma$ is W'_K distinguished, that is $\theta\rho^\vee \simeq (\theta^{-1}\rho)^\sigma$. But from the proof of Theorem 5.2, this would imply that $\theta^{-1}\rho$ hence ρ , could be induced from a character of a biquadratic extension of F , which we supposed is not the case.

- iii) Suppose $\rho = sp(2)$ acts on the space \mathbb{C}^2 with canonical basis (e_1, e_2) by the natural action $\rho[h, M](v) = M(v)$ for h in W_K , M in $SL(2, \mathbb{C})$ and v in \mathbb{C}^2 . Then the space of $M_{W'_K}^{W'_F}(\rho)$ is $V \otimes V$ and $SL(2, \mathbb{C})$ acts on it as $sp(2) \otimes sp(2)$. Decomposing $V \otimes V$ as the direct sum $Alt(V) \oplus Sym(V)$, we see that $SL(2, \mathbb{C})$ acts as 1 on $Alt(V)$, and $M_{W'_K}^{W'_F}(\rho) \left[1, \begin{pmatrix} x & 0 \\ 0 & x^{-1} \end{pmatrix} \right] (e_1 \otimes e_1) = x^2 e_1 \otimes e_1$. Hence the representation of $SL(2, \mathbb{C})$ on $Sym(V)$ must be $sp(3)$. The Weil group W_F acts as $\eta_{K/F}$ on $Alt(V)$ and trivially on $Sym(V)$, finally $M_{W'_K}^{W'_F}(\rho)$ is isomorphic to $sp(3) \oplus \eta_{K/F}$. Tensoring with a character χ , we have $M_{W'_K}^{W'_F}(\chi sp(2)) = \chi|_{F^*} M_{W'_K}^{W'_F}(sp(2)) = \chi|_{F^*} \eta_{K/F} \oplus \chi|_{F^*} sp(3)$. Hence one has the following equality:

$$L(M_{W'_K}^{W'_F}(\chi sp(2)), s) = L(\chi|_{F^*} \eta_{K/F}, s) L(\chi|_{F^*}, s+1).$$

- iv) If $\rho = \lambda \oplus \mu$, with λ and μ two characters of W'_K , then from [P], Lemma 7.1, we have $M_{W'_K}^{W'_F}(\rho) = \lambda|_{F^*} \oplus \mu|_{F^*} \oplus Ind_{W'_K}^{W'_F}(\lambda\mu^\sigma)$. Hence we have

$$L(M_{W'_K}^{W'_F}(\rho)) = L(\lambda|_{F^*}, s) L(\mu|_{F^*}, s) L(\lambda\mu^\sigma, s).$$

4.2 Asai L -functions for ordinary representations of $GL(2)$

In this subsection, we compute Asai L -functions for ordinary (i.e. non exceptional) representations of $G_2(K)$, and prove (Theorem 4.2) that they are equal to the corresponding functions L_W of imprimitive representations of W'_K .

In order to compute L_{As} , we first compute L_1 , but this latter computation is easy because Kirillov models of infinite-dimensional irreducible representations of $G_2(K)$ are well-known (see [B], Th. 4.7.2 and 4.7.3).

Let π be an irreducible infinite-dimensional (hence generic) representation of $G_2(K)$, we have the following situations for the computation of $L_1(\pi, s)$.

- i) and ii) If π is supercuspidal, its Kirillov model consists of functions with compact support on K^* , hence

$$L_1(\pi, s) = 1.$$

- iii) If $\pi = \sigma(\chi)$ ($\sigma(\chi|_K^{-1/2}, \chi|_K^{-1/2})$ in [B]) is a special series representation of $G_2(K)$, twist of the Steinberg representation by the character χ of K^* , the Kirillov model of π consists of functions of $D(K)$ multiplied by $\chi|_K$. Hence their restrictions to F are functions of $D(F)$ multiplied by $\chi|_F^2$, and the ideal $I_1(\pi)$ is generated by functions of s of the form

$$\int_{F^*} \phi(t) \chi(t) |t|_F^{s-1} |t|_F^2 d^*t = \int_{F^*} \phi(t) \chi(t) |t|_F^{s+1} d^*t,$$

for ϕ in $D(F)$, hence we have

$$L_1(\pi, s) = L(\chi|_{F^*}, s+1).$$

- iv) If $\pi = \pi(\lambda, \mu)$ is the principal series representation (λ and μ being two characters of K^* , with $\lambda\mu^{-1}$ different from $| \cdot |$ and $| \cdot |^{-1}$) corresponding to the representation $\lambda \oplus \mu$ of W'_K .

If $\lambda \neq \mu$, the Kirillov model of π is given by functions of the form $| \cdot |_K^{1/2} \chi \phi_1 + | \cdot |_K^{1/2} \mu \phi_2$, for ϕ_1 and ϕ_2 in $D(K)$, and

$$L_1(\pi, s) = L(\lambda|_{F^*}, s) \vee L(\mu|_{F^*}, s).$$

If $\lambda = \mu$, the Kirillov model of π is given by functions of the form $| \cdot |_K^{1/2} \lambda \phi_1 + | \cdot |_K^{1/2} \lambda v_K(t) \phi_2$, for ϕ_1 and ϕ_2 in $D(K)$, and

$$L_1(\pi, s) = L(\lambda|_{F^*}, s)^2.$$

In order to compute $L_{rad(ex)}$ for ordinary representations, we need to know when they are distinguished by a character $| \cdot |_F^{-s_0}$ for some s_0 in \mathbb{C} , we will then use Theorem 3.2. The answer is given by the following, which is a mix of Theorem 5.4 and Proposition B.17 of [F-H]:

- Theorem 4.1.** a) *A dihedral supercuspidal representation π of $G_2(K)$ is $| \cdot |_F^{-s_0}$ -distinguished if and only if there exists a quadratic extension B of K , biquadratic over F (hence there are two other extensions between F and B that we call K' and K''), and a character of B^* regular with respect to $N_{B/K}$ which restricts either to K' as $| \cdot |_{K'}^{-s_0}$ or to K'' as $| \cdot |_{K''}^{-s_0}$, such that π is equal to $\pi(\omega)$.*
- b) *Let μ be a character of K^* , then the special series representation $\sigma(\mu)$ is $| \cdot |_F^{-s_0}$ -distinguished if and only if μ restricts to F^* as $\eta_{K/F}| \cdot |_F^{-s_0}$.*
- c) *Let λ and μ be two characters of K^* , with $\lambda\mu^{-1}$ and $\lambda^{-1}\mu$ different from $| \cdot |_K$, then the principal series representation $\pi(\lambda, \mu)$ is $| \cdot |_F^{-s_0}$ -distinguished if and only if either λ and μ restrict as $| \cdot |_F^{-s_0}$ to F^* or $\lambda\mu^\sigma$ is equal to $| \cdot |_K^{-s_0}$.*

Proof. Let π be a representation, it is $| \cdot |_F^{-s_0}$ -distinguished if and only if $\pi \otimes | \cdot |_K^{s_0/2}$ is distinguished because $| \cdot |_K^{-s_0/2}$ extends $| \cdot |_F^{-s_0}$, it then suffices to apply Theorem 5.4 and Proposition B.17 of [F-H]. We give the full proof for case a). Suppose π is dihedral supercuspidal and $\pi \otimes | \cdot |_K^{s_0/2}$ is distinguished. From Theorem 5.4, the representation $\pi \otimes | \cdot |_K^{s_0/2}$ must be of the form $\pi(\omega)$, for ω a character of quadratic extension B of K , biquadratic over F , such that if we call K' and K'' two other extensions between F and B , ω doesn't factorize through $N_{B/K}$ and restricts either trivially on K'^* , or trivially on K''^* . But π is equal to $\pi(\omega) \otimes | \cdot |_K^{-s_0/2} = \pi(\omega|_B^{-s_0/2})$ because $| \cdot |_B = | \cdot |_K \circ N_{B/K}$. As $| \cdot |_B^{-s_0/2}$ restricts to K' (resp. K'') as $| \cdot |_{K'}^{-s_0}$ (resp. $| \cdot |_{K''}^{-s_0}$), case a) follows. \square

We are now able to compute $L_{rad(ex)}$, hence L_{As} for ordinary representations.

- i) Suppose that $\pi = \pi(Ind_{W'_B}^{W'_K}(\omega)) = \pi(\omega)$ is supercuspidal, with Langlands parameter $Ind_{W'_B}^{W'_K}(\omega)$, where ω is a multiplicative character of a biquadratic extension B over F that doesn't factorize through $N_{B/K}$.

We denote by K' and K'' the two other extensions between B and F . Here $L_1(\pi, s)$ is equal to one.

We have the following series of equivalences:

$$\begin{aligned} s_0 \text{ is a pole of } L_{As}(\pi(\omega), s) &\iff \pi(\omega) \text{ is } | \cdot |_F^{-s_0} \text{-distinguished} \\ &\iff \omega|_{K'^*} = | \cdot |_{K'}^{-s_0} \text{ or } \omega|_{K''^*} = | \cdot |_{K''}^{-s_0} \\ &\iff s_0 \text{ is a pole of } L(\omega|_{K'^*}, s) \text{ or of } L(\omega|_{K''^*}, s) \\ &\iff s_0 \text{ is a pole of } L(\omega|_{K'^*}, s) \vee L(\omega|_{K''^*}, s) \end{aligned}$$

As both functions $L_{As}(\pi(\omega), s)$ and $L(\omega|_{K'^*}, s) \vee L(\omega|_{K''^*}, s)$ have simple poles and are Euler factors, they are equal. Now suppose that $L(\omega|_{K'^*}, s)$ and $L(\omega|_{K''^*}, s)$ have a common pole s_0 , this would imply that $\omega|_{K'^*} = |_{K'}^{-s_0}$ and $\omega|_{K''^*} = |_{K''}^{-s_0}$, which would mean that $\omega|_{|_B^{s_0/2}}$ is trivial on $K'^*K''^*$. According to Lemma 5.2, this would contradict the fact that ω does not factorize through $N_{B/K}$, hence $L(\omega|_{K'^*}, s) \vee L(\omega|_{K''^*}, s) = L(\omega|_{K'^*}, s)L(\omega|_{K''^*}, s)$. Finally we proved:

$$\boxed{L_{As}(\pi(\omega), s) = L(\omega|_{K'^*}, s)L(\omega|_{K''^*}, s).}$$

- ii) Suppose that π is a supercuspidal representation, corresponding to an imprimitive representation of W'_K that cannot be induced from a character of the Weil-Deligne group of a biquadratic extension of F . Then necessarily π cannot be $|_{|_F^{s_0}}$ -distinguished, for any complex number s_0 of \mathbb{C} .

If it was the case, from Theorem 4.1, it would correspond to a Weil representation $\pi(\omega)$ for some multiplicative character of a biquadratic extension of F , which cannot be. Hence $L_{rad(ex)}(\pi, s)$ has no pole and is equal to one because it is an Euler factor, so we proved that:

$$\boxed{L_{As}(\pi, s) = 1.}$$

- iii) If π is equal to $\sigma(\chi)$, then $L_1(\pi, s) = L(\chi|_{F^*}, s+1)$. We want to compute $L_{rad(ex)}(\pi, s)$, we have the following series of equivalences:

$$\begin{aligned} s_0 \text{ is an exceptional pole of } L_{As}(\sigma(\chi), s) &\iff \sigma(\chi) \text{ is } |_{|_F^{s_0}} \text{ -distinguished} \\ &\iff \chi|_{F^*} = \eta_{K/F} |_{|_F^{s_0}} \\ &\iff s_0 \text{ is a pole of } L(\chi|_{F^*}\eta_{K/F}, s) \end{aligned}$$

As both functions $L_{rad(ex)}(\pi, s)$ and $L(\chi|_{F^*}\eta_{K/F}, s)$ have simple poles and are Euler factors, they are equal, we thus have:

$$\boxed{L_{As}(\sigma(\chi)) = L(\chi|_{F^*}, s+1)L(\chi|_{F^*}\eta_{K/F}, s).}$$

- iv) If $\pi = \pi(\lambda, \mu)$, we first compute $L_{rad(ex)}(\pi, s)$. We have the following series of equivalences:

$$\begin{aligned} s_0 \text{ is an exceptional pole of } L_{As}(\pi(\lambda, \mu), s) &\iff \pi(\lambda, \mu) \text{ is } |_{|_F^{s_0}} \text{ -distinguished} \\ &\iff \lambda\mu^\sigma = |_{|_K^{s_0}} \text{ or } \lambda|_{F^*} = |_{|_F^{s_0}} \text{ and } \mu|_{F^*} = |_{|_F^{s_0}} \\ &\iff s_0 \text{ is a pole of } L(\lambda\mu^\sigma, s) \text{ or of } L(\lambda|_{F^*}, s) \wedge L(\mu|_{F^*}, s) \\ &\iff s_0 \text{ is a pole of } L(\lambda\mu^\sigma, s) \vee [L(\lambda|_{F^*}, s) \wedge L(\mu|_{F^*}, s)] \end{aligned}$$

As both functions $L_{rad(ex)}(\pi(\lambda, \mu), s)$ and $L(\lambda\mu^\sigma, s) \vee [L(\lambda|_{F^*}, s) \wedge L(\mu|_{F^*}, s)]$ have simple poles and are Euler factors, they are equal.

If $\lambda \neq \mu$, then $L_1(\pi, s) = L(\lambda|_{F^*}, s) \vee L(\mu|_{F^*}, s)$. But $L(\lambda\mu^\sigma, s)$ and $L(\lambda|_{F^*}, s) \wedge L(\mu|_{F^*}, s)$ have no common pole. If there was a common pole s_0 , one would have $\lambda\mu^\sigma = |_{|_K^{s_0}}$, $\lambda|_{F^*} = |_{|_F^{s_0}}$ and $\mu|_{F^*} = |_{|_F^{s_0}}$. From $\mu|_{F^*} = |_{|_F^{s_0}}$, we would deduce that $\mu \circ N_{K/F} = |_{|_K^{s_0}}$, i.e. $\mu^\sigma = |_{|_K^{s_0}}\mu^{-1}$, and $\lambda\mu^\sigma = |_{|_K^{s_0}}$ would imply $\lambda = \mu$, which is absurd. Hence $L_{rad(ex)}(\pi, s) = L(\lambda\mu^\sigma, s)[L(\lambda|_{F^*}, s) \wedge L(\mu|_{F^*}, s)]$, and finally we have $L_{As}(\pi, s) = L_1(\pi, s)L_{rad(ex)}(\pi, s) = L(\lambda|_{F^*}, s)L(\mu|_{F^*}, s)L(\lambda\mu^\sigma, s)$.

If λ is equal to μ , then $L_1(\pi, s) = L(\lambda|_{F^*}, s)^2$, and $L_{rad(ex)}(\pi(\lambda, \mu), s) = L(\lambda \circ N_{K/F}, s) \vee L(\lambda|_{F^*}, s)$. As $L(\lambda \circ N_{K/F}, s) = L(\lambda|_{F^*}, s)L(\eta_{K/F}\lambda|_{F^*}, s)$, we have $L_{rad(ex)}(\pi(\lambda, \mu), s) = L(\lambda \circ N_{K/F}, s)$. Again we have $L_{As}(\pi, s) = L(\lambda|_{F^*}, s)L(\mu|_{F^*}, s)L(\lambda\mu^\sigma, s)$.

In both cases, we have

$$\boxed{L_{As}(\pi(\lambda, \mu), s) = L(\lambda|_{F^*}, s)L(\mu|_{F^*}, s)L(\lambda\mu^\sigma, s).}$$

Eventually, comparing with equalities of subsection 4.1, we proved the following:

Theorem 4.2. *Let $\rho \mapsto \pi(\rho)$ be the Langlands correspondence from two dimensional representations of W'_K to smooth irreducible infinite-dimensional representations of $G_2(K)$, then if ρ is not primitive, $\pi(\rho)$ is ordinary and we have the following equality of L -functions:*

$$L_{As}(\pi(\rho), s) = L(M_{W'_K}^{W'_F}(\rho), s)$$

As said in the introduction, combining Theorem 1.6 of [A-R] and Theorem of paragraph 1.5 in [He], one gets that $L(M_{W'_K}^{W'_F}(\rho), s) = L_{As}(\pi(\rho), s)$ for $\pi(\rho)$ a discrete series representation, so that we have actually the following:

Theorem 4.3. *Let $\rho \mapsto \pi(\rho)$ be the Langlands correspondence from two dimensional representations of W'_K to smooth irreducible infinite-dimensional representations of $G_2(K)$, we have the following equality of L -functions:*

$$L_{As}(\pi(\rho), s) = L(M_{W'_K}^{W'_F}(\rho), s)$$

5 Appendix. Dihedral supercuspidal distinguished representations

The aim of this section is to give a description of dihedral supercuspidal distinguished representations of $G_2(K)$ in terms of Langlads parameter, it is done in Theorem 5.4.

5.1 Preliminary results

Let E be a local field, E' be a quadratic extension of E , χ a character of E^* , π be a smooth irreducible infinite-dimensional representation of $G_2(E)$, and ψ a non trivial character of E .

We denote by $L(\chi, s)$ and $\epsilon(\chi, s, \psi)$ the functions of the complex variable s defined before Proposition 3.5 in [J-L]. We denote by $\gamma(\chi, s, \psi)$ the ratio $\epsilon(\chi, s, \psi)L(\chi, s)/L(\chi^{-1}, 1 - s)$.

We denote by $L(\pi, s)$ and $\epsilon(\pi, s, \psi)$ the functions of the complex variable s defined in Theorem 2.18 of [J-L]. We denote by $\gamma(\pi, s, \psi)$ the ratio $\epsilon(\pi, s, \psi)L(\pi, s)/L(\pi^\vee, 1 - s)$.

We denote by $\lambda(E'/E, \psi)$ the Langlands-Deligne factor defined before Proposition 1.3 in [J-L], it is equal to $\epsilon(\eta_{E'/E}, 1/2, \psi)$. As $\eta_{E'/E}$ is equal to $\eta_{E'/E}^{-1}$, the factor $\lambda(E'/E, \psi)$ is also equal to $\gamma(\eta_{E'/E}, 1/2, \psi)$.

From Theorem 4.7 of [J-L], if ω is a character of E'^* , then $L(\pi(\omega), s)$ is equal to $L(\omega, s)$, and $\epsilon(\pi, s, \psi)$ is equal to $\lambda(E'/E, \psi)\epsilon(\omega, s, \psi)$, hence $\gamma(\pi, s, \psi)$ is equal to $\lambda(E'/E, \psi)\gamma(\omega, s, \psi)$.

We will need four results. The first is due to Frhlich and Queyrut, see [D] Theorem 3.2 for a quick proof using a Poisson formula:

Proposition 5.1. *Let E be a local field, E' be a quadratic extension of E , χ' a character of E'^* trivial on E^* , and ψ' a non trivial character of E' trivial on E , then $\gamma(\chi', 1/2, \psi') = 1$.*

The second is a criterion of Hakim:

Theorem 5.1. ([Ha], Theorem 4.1) *Let π be an irreducible supercuspidal representation of $G_2(K)$ with central character trivial on F^* , and ψ a nontrivial character of K trivial on F . Then π is distinguished if and only if $\gamma(\pi \otimes \chi, 1/2, \psi) = 1$ for every character χ of K^* trivial on F^* .*

The third is due to Flicker:

Theorem 5.2. ([F1], Proposition 12) *Let π be a smooth irreducible distinguished representation of $G_n(K)$, then π^σ is isomorphic to π^\vee .*

The fourth is due to Kable in the case of $G_n(K)$, see [A-T] for a local proof in the case of $G_2(K)$:

Theorem 5.3. ([A-T], Proposition 3.1) *There exists no supercuspidal representation of $G_2(K)$ which is distinguished and $\eta_{K/F}$ -distinguished at the same time.*

5.2 Distinction criterion for dihedral supercuspidal representations

As a dihedral representation's parameter is a multiplicative character of a quadratic extension L of K , we first look at the properties of the tower $F \subset K \subset L$. Three cases arise:

1. L/F is biquadratic (hence Galois), it contains K and two other quadratic extensions F, K' and K'' .

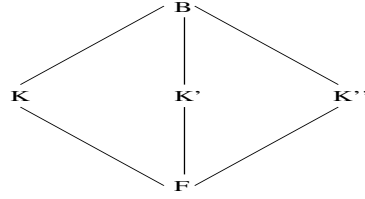


Figure 1:

Its Galois group is isomorphic with $\mathbb{Z}/2\mathbb{Z} \times \mathbb{Z}/2\mathbb{Z}$, its non trivial elements are $\sigma_{L/K}$, $\sigma_{L/K'}$ and $\sigma_{L/K''}$. The conjugation $\sigma_{L/K}$ extend $\sigma_{K'/F}$ and $\sigma_{K''/F}$.

2. L/F is cyclic with Galois group isomorphic with $\mathbb{Z}/4\mathbb{Z}$, in this case we fix an element $\tilde{\sigma}$ in $G(L/F)$ extending σ , it is of order 4.
3. L/F non Galois. Then its Galois closure M is quadratic over L and the Galois group of M over F is dihedral with order 8. To see this, we consider a morphism $\tilde{\theta}$ from L to \bar{F} which extends θ . Then if $L' = \tilde{\theta}(L)$, L and L' are distinct, quadratic over K and generate M biquadratic over K . M is the Galois closure of L because any morphism from L into \bar{F} , either extends θ , or the identity map of K , so that its image is either L or L' , so it is always included in M . Finally the Galois group M over F cannot be abelian (for L is not Galois over F), it is of order 8, and it's not the quaternion group which only has one element of order 2, whereas here $\sigma_{M/L}$ and $\sigma_{M/L'}$ are of order 2. Hence it is the dihedral group of order 8 and we have the following lattice, where M/K' is cyclic of degree 4, M/K and B/F are biquadratic.

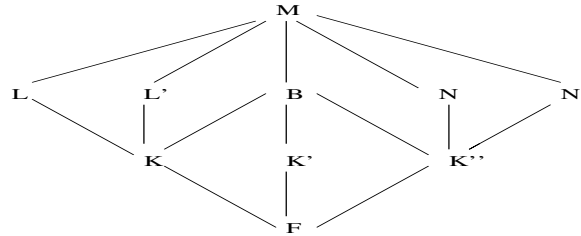


Figure 2:

We now prove the following proposition:

Proposition 5.2. *If a supercuspidal dihedral representation π of $G_2(K)$ verifies $\pi^\vee = \pi^\sigma$, there exists a biquadratic extension B of F , containing K , such that if we call K' and K'' the two*

other extensions between F and B , there is a character ω of B trivial either on $N_{B/K'}(B^*)$ or on $N_{B/K''}(B^*)$, such that $\pi = \pi(\omega)$.

Proof. Let L be a quadratic extension of K and ω a regular multiplicative of L such that $\pi = \pi(\omega)$, we denote by σ the conjugation of L over K , three cases show up:

1. L/F is biquadratic. The conjugations $\sigma_{L/K'}$ and $\sigma_{L/K''}$ both extend σ , hence from Theorem 1 of [G-L], we have $\pi(\omega)^\sigma = \pi(\omega^{\sigma_{L/K'}})$. The condition $\pi^\vee = \pi^\sigma$ which one can also read $\pi(\omega^{-1}) = \pi(\omega^{\sigma_{L/K'}})$, is then equivalent from Appendix B, (2)b)1) of [G-L], to $\omega^{\sigma_{L/K'}} = \omega^{-1}$ or $\omega^{\sigma_{L/K''}} = \omega^{-1}$. This is equivalent to ω trivial on $N_{L/K'}(L^*)$ or on $N_{L/K''}(L^*)$.
2. L/F is cyclic, the regularity of ω makes the condition $\pi(\omega^{-1}) = \pi(\omega)^\sigma$ impossible. Indeed one would have from Theorem 1 of [G-L] $\pi(\omega^\sigma) = \pi(\omega^{-1})$, which from Appendix B, (2)b)1) of [G-L] would imply $\omega^\sigma = \omega$ or $\omega^{\sigma^{-1}} = \omega$. As $\sigma^2 = \sigma^{-2} = \sigma$, this would in turn imply $\omega^\sigma = \omega$, and ω would be trivial on the kernel of $N_{L/K}$ according to Hilbert's Theorem 90. π^\vee can therefore not be isomorphic to π^σ .
3. L/K is not Galois (which implies $q \equiv 3[4]$ in the case p odd). Let $\pi_{B/K}$ be the representation of $G_2(B)$ which is the base change lift of π to B . As $\pi_{B/K} = \pi(\omega \circ N_{M/L})$, if $\omega \circ N_{M/L} = \mu \circ N_{M/B}$ for a character μ of B^* , then $\pi(\omega) = \pi(\mu)$ (cf. [G-L], (3) of Appendix B) and we are brought back to case 1. Otherwise $\omega \circ N_{M/L}$ is regular with respect to $N_{M/B}$. If $\pi^\sigma = \pi^\vee$, we would have $\pi_{B/K}^{\sigma_{B/K'}} = \pi_{B/K}^\vee$ from Theorem 1 of [G-L]. That would contradict case 2 because M/K' is cyclic.

□

We described in the previous proposition representations π of $G_2(K)$ verifying $\pi^\vee = \pi^\sigma$, now we characterize those who are $G_2(F)$ -distinguished among them (from Theorem 5.2, a distinguished representation always satisfies the previous condition).

Theorem 5.4. *A dihedral supercuspidal representation π of $G_2(K)$ is $G_2(F)$ -distinguished if and only if there exists a quadratic extension B of K biquadratic over F such that if we call K' and K'' the two other extensions between B and F , there is character ω of B^* that does not factorize through $N_{B/K}$ and trivial either on K'^* or on K''^* , such that $\pi = \pi(\omega)$.*

Proof. From Theorem 5.2 and Proposition 5.2, we can suppose that $\pi = \pi(\omega)$, for ω a regular multiplicative character of a quadratic extension B of K biquadratic over F , with ω trivial on $N_{L/K'}(K'^*)$ or on $N_{B/K''}(K''^*)$. We will need the following:

Lemma 5.1. *Let B be a quadratic extension of K biquadratic over F , then F^* is a subset of $N_{B/K}(B^*)$*

Proof of Lemma 5.1. The group $N_{B/K}(B^*)$ contains the two groups $N_{B/K}(K'^*)$ and $N_{B/K}(K''^*)$, which, as $\sigma_{B/K}$ extends $\sigma_{K'/F}$ and $\sigma_{K''/F}$, are respectively equal to $N_{K'/F}(K'^*)$ and $N_{K''/F}(K''^*)$. But these two groups are distinct of index 2 in F^* from local classfield theory, thus they generate F^* , which is therefore contained in $N_{B/K}(B^*)$. □

We now choose ψ a non trivial character of K/F and denote by ψ_B the character $\psi \circ \text{Tr}_{B/K}$, it is trivial on K' and K'' .

Suppose ω trivial on K' or K'' , then the restriction of the central character $\eta_{B/K}\omega$ of $\pi(\omega)$ is trivial on F^* according to Lemma 5.1.

As we have $\gamma(\pi(\omega), 1/2, \psi) = \lambda(B/K, \psi)\gamma(\omega, 1/2, \psi_B) = \gamma(\eta_{B/K}, 1/2, \psi)\gamma(\omega, 1/2, \psi_B)$, we deduce from Lemma 5.1 and Proposition 5.1 that $\gamma(\pi(\omega), 1/2, \psi)$ is equal to one, hence from Theorem 5.1, the representation $\pi(\omega)$ is distinguished.

Now suppose $\omega|_{K'} = \eta_{B/K'}$ or $\omega|_{K''} = \eta_{B/K''}$, let χ be a character of K^* extending $\eta_{K/F}$, then $\pi(\omega) \otimes \chi = \pi(\omega\chi \circ N_{B/K})$. As $N_{B/K}|_{K'} = N_{K'/F}$ and $N_{B/K}|_{K''} = N_{K''/F}$, we have

$\chi \circ N_{B/K}|_{K'} = \eta_{B/K'}$ and $\chi \circ N_{B/K}|_{K''} = \eta_{B/K''}$, hence from what we've just seen, $\pi(\omega) \otimes \chi$ is distinguished, i.e. $\pi(\omega)$ is $\eta_{K/F}$ -distinguished.

From Theorem 5.3, π cannot be distinguished and $\eta_{K/F}$ -distinguished at the same time, and the theorem follows. \square

We end with the following lemma:

Lemma 5.2. *Let B be a quadratic extension of K which is biquadratic over F . Call K' and K'' the two other extensions between F and B , then the kernel of $N_{B/K}$ is a subgroup of the group $N_{B/K'}(B^*)N_{B/K''}(B^*)$.*

Proof. If u belongs to $\text{Ker}(N_{B/K})$, it can be written $x/\sigma_{B/K}(x)$ for some x in B^* according to Hilbert's Theorem 90. Hence we have $u = (x\sigma_{B/K'}(x))/(\sigma_{B/K}(x)\sigma_{B/K'}(x)) = N_{B/K'}(x)/N_{B/K''}(\sigma_{B/K}(x))$, and u belongs to $N_{B/K'}(B^*)N_{B/K''}(B^*)$. \square

Corollary 5.1. *The (either/or) in Proposition 5.2 and Theorem 5.4 is exclusive*

Proof. In fact, in the situation of Lemma 5.2, a character ω that is trivial on $N_{B/K'}(B^*)$ and $N_{B/K''}(B^*)$ factorizes through $N_{B/K}$, and $\pi(\omega)$ is not supercuspidal. \square

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