A

Tables for Representations of GSp(4)

A.1 Non-supercuspidal Representations

Table A.1 below gives a list of all irreducible, admissible, non-supercuspidal representations of $\mathrm{GSp}(4, F)$. We have organized these representations into eleven groups. Groups I to VI contain representations supported in the minimal parabolic subgroup B; groups VII to IX contain representations supported in the Klingen parabolic subgroup Q; and groups X and XI contain representations supported in the Siegel parabolic subgroup P.

All the information in Table A.1, as well as the notations, are taken from [ST]. A more detailed description of the representations listed can be found in Sect. 2.2. The "tempered" column shows the conditions on the inducing data under which a representation is tempered. The "ess. L^2" column indicates the essentially square-integrable representations, i.e., those representations that become square-integrable after suitable twisting. Finally, the rightmost column indicates the generic representations (see Sect. 2.1 for the precise definition).

Table A.1. Non-supercuspidal representations of $\mathrm{GSp}(4,F)$

		constituent of	representation	tempered	ess. L^2	generic
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)		χ_i, σ unit.		•
II	a	$\nu^{1/2}\chi \times \nu^{-1/2}\chi \rtimes \sigma$	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	χ, σ unit.		•
	b	$(\chi^2 \neq \nu^{\pm 1}, \chi \neq \nu^{\pm 3/2})$	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$			
III	a	$\chi \times \nu \rtimes \nu^{-1/2}\sigma$	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	χ, σ unit.		•
	b	$(\chi \notin \{1, \nu^{\pm 2}\})$	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$			
IV	a	$\nu^2 \times \nu \rtimes \nu^{-3/2}\sigma$	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	σ unit.	•	•
	b		$L(\nu^2, \nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$			
	c		$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$			
	d		$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$			
V	a	$\nu\xi \times \xi \rtimes \nu^{-1/2}\sigma$	$\delta([\xi, \nu\xi], \nu^{-1/2}\sigma)$	σ unit.	•	•
	b	$(\xi^2 = 1,\ \xi \neq 1)$	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$			
	c		$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \xi\nu^{-1/2}\sigma)$			
	d		$L(\nu\xi, \xi \rtimes \nu^{-1/2}\sigma)$			
VI	a	$\nu \times 1_{F^\times} \rtimes \nu^{-1/2}\sigma$	$\tau(S, \nu^{-1/2}\sigma)$	σ unit.		•
	b		$\tau(T, \nu^{-1/2}\sigma)$	σ unit.		
	c		$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$			
	d		$L(\nu, 1_{F^\times} \rtimes \nu^{-1/2}\sigma)$			
VII		$\chi \rtimes \pi$ (irreducible)		χ, π unit.		•
VIII	a	$1_{F^\times} \rtimes \pi$	$\tau(S, \pi)$	π unit.		•
	b		$\tau(T, \pi)$	π unit.		
IX	a	$\nu\xi \rtimes \nu^{-1/2}\pi$	$\delta(\nu\xi, \nu^{-1/2}\pi)$	π unit.	•	•
	b	$(\xi \neq 1,\ \xi\pi = \pi)$	$L(\nu\xi, \nu^{-1/2}\pi)$			
X		$\pi \rtimes \sigma$ (irreducible)		π, σ unit.		•
XI	a	$\nu^{1/2}\pi \rtimes \nu^{-1/2}\sigma$	$\delta(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	π, σ unit.	•	•
	b	$(\omega_\pi = 1)$	$L(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$			

A.2 Unitary Representations

Table A.2 below lists all the irreducible, admissible, unitarizable representations of $\mathrm{GSp}(4, F)$. The table represents a reformulation of Theorem 4.4, Proposition 4.7 and Proposition 4.9 of [ST]. We include this table for completeness only; the unitary property is largely irrelevant for the paramodular newform theory.

Table A.2 uses the notation e for the *exponent* of an essentially square integrable representation. We only need the following two special cases. If χ is a character of $F^\times$, then $e(\chi)$ is defined by $|\chi(x)| = |x|^{e(\chi)}$ for $x \in F^\times$. If π is a supercuspidal representation of $\mathrm{GL}(2, F)$, then $e(\pi)$ is defined by the condition that $\nu^{-e(\pi)}\pi$ is unitarizable.

Table A.2. Unitary representations of $\mathrm{GSp}(4, F)$

		representation	conditions for unitarity
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$e(\chi_1) = e(\chi_2) = e(\sigma) = 0$
			$\chi_1 = \nu^\beta \chi,\ \chi_2 = \nu^\beta \chi^{-1},\ e(\sigma) = -\beta,$ $e(\chi) = 0,\ \chi^2 \neq 1,\ 0 < \beta < 1/2$
			$\chi_1 = \nu^\beta,\ e(\chi_2) = 0,\ e(\sigma) = -\beta/2,$ $\chi_2 \neq 1,\ 0 < \beta < 1$
			$\chi_1 = \nu^{\beta_1}\chi,\ \chi_2 = \nu^{\beta_2}\chi,\ e(\sigma) = (-\beta_1 - \beta_2)/2,$ $\chi^2 = 1,\ 0 \leq \beta_2 \leq \beta_1,\ 0 < \beta_1 < 1,\ \beta_1 + \beta_2 < 1$
II	a	$\chi \mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$e(\sigma) = e(\chi) = 0$
			$\chi = \xi\nu^\beta,\ e(\sigma) = -\beta,\ \xi^2 = 1,\ 0 < \beta < 1/2$
	b	$\chi \mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	$e(\sigma) = e(\chi) = 0$
			$\chi = \xi\nu^\beta,\ e(\sigma) = -\beta,\ \xi^2 = 1,\ 0 < \beta < 1/2$
III	a	$\chi \rtimes \sigma \mathrm{St}_{\mathrm{GSp}(2)}$	$e(\sigma) = e(\chi) = 0$
	b	$\chi \rtimes \sigma \mathbf{1}_{\mathrm{GSp}(2)}$	$e(\sigma) = e(\chi) = 0$
IV	a	$\sigma \mathrm{St}_{\mathrm{GSp}(4)}$	$e(\sigma) = 0$
	b	$L(\nu^2, \nu^{-1}\sigma \mathrm{St}_{\mathrm{GSp}(2)})$	never unitary
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GSp}(2)}, \nu^{-3/2}\sigma)$	never unitary
	d	$\sigma \mathbf{1}_{\mathrm{GSp}(4)}$	$e(\sigma) = 0$

		representation	conditions for unitarity
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$e(\sigma)=0$
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	b	$\tau(T,\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$e(\sigma)=0$
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	$e(\sigma)=0$
VII		$\chi\rtimes\pi$ (irreducible)	$e(\chi)=e(\pi)=0$
			$\chi=\nu^\beta\xi,\ \pi=\nu^{-\beta/2}\rho,\ 0<\beta<1,$ $\xi^2=1,\ \xi\neq1,\ e(\rho)=0,\ \xi\rho=\rho$
VIII	a	$\tau(S,\pi)$	$e(\pi)=0$
	b	$\tau(T,\pi)$	$e(\pi)=0$
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	$e(\pi)=0$
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	$e(\pi)=0$
X		$\pi\rtimes\sigma$ (irreducible)	$e(\sigma)=e(\pi)=0$
			$\pi=\nu^\beta\rho,\ e(\sigma)=-\beta,\ 0<\beta<1/2,\ \omega_\rho=1$
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$e(\sigma)=e(\pi)=0$
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$e(\sigma)=e(\pi)=0$
π supercuspidal			$e(\omega_\pi)=0$

A.3 Jacquet Modules

The two tables in this section list the semisimplifications of the normalized Jacquet modules of all non-supercuspidal representations with respect to the unipotent radical of the Siegel and Klingen parabolic subgroups. The Jacquet modules with respect to the unipotent radical of the Siegel parabolic are representations of $\mathrm{GL}(2,F) \times F^\times$, and the Jacquet modules with respect to the unipotent radical of the Klingen parabolic are representations of $F^\times \times \mathrm{GSp}(2,F)$. Note that $\mathrm{GSp}(2,F) = \mathrm{GL}(2,F)$; to translate into standard GL(2) notation, use the formula $\chi \rtimes \sigma = \chi\sigma \times \sigma$. The last column lists the number of irreducible constituents. These Jacquet modules were computed using Section 2 of [ST], pages 93–94.

Table A.3. Jacquet modules: The Siegel parabolic

		representation	semisimplification	#
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$(\chi_1 \times \chi_2) \otimes \sigma + (\chi_1^{-1} \times \chi_2^{-1}) \otimes \chi_1\chi_2\sigma$ $+(\chi_1 \times \chi_2^{-1}) \otimes \chi_2\sigma + (\chi_2 \times \chi_1^{-1}) \otimes \chi_1\sigma$	4
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$\chi\mathrm{St}_{\mathrm{GL}(2)} \otimes \sigma + \chi^{-1}\mathrm{St}_{\mathrm{GL}(2)} \otimes \chi^2\sigma$ $+(\chi\nu^{1/2} \times \chi^{-1}\nu^{1/2}) \otimes \chi\nu^{-1/2}\sigma$	3
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	$\chi\mathbf{1}_{\mathrm{GL}(2)} \otimes \sigma + \chi^{-1}\mathbf{1}_{\mathrm{GL}(2)} \otimes \chi^2\sigma$ $+(\chi\nu^{-1/2} \times \chi^{-1}\nu^{-1/2}) \otimes \chi\nu^{1/2}\sigma$	3
III	a	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$(\chi \times \nu) \otimes \sigma\nu^{-1/2} + (\nu \times \chi^{-1}) \otimes \chi\sigma\nu^{-1/2}$	2
	b	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$(\chi \times \nu^{-1}) \otimes \sigma\nu^{1/2} + (\nu^{-1} \times \chi^{-1}) \otimes \chi\sigma\nu^{1/2}$	2
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	$\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)} \otimes \nu^{-3/2}\sigma$	1
	b	$L(\nu^2, \nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	$\nu^{3/2}\mathbf{1}_{\mathrm{GL}(2)} \otimes \nu^{-3/2}\sigma + (\nu \times \nu^{-2}) \otimes \nu^{1/2}\sigma$	2
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$	$\nu^{-3/2}\mathrm{St}_{\mathrm{GL}(2)} \otimes \nu^{3/2}\sigma + (\nu^2 \times \nu^{-1}) \otimes \nu^{-1/2}\sigma$	2
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	$\nu^{-3/2}\mathbf{1}_{\mathrm{GL}(2)} \otimes \nu^{3/2}\sigma$	1

		representation	semisimplification	#
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	$\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}\otimes\nu^{-1/2}\sigma$ $+\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}\otimes\xi\nu^{-1/2}\sigma$	2
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$\nu^{-1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}\otimes\nu^{1/2}\sigma$ $+\nu^{1/2}\xi\mathbf{1}_{\mathrm{GL}(2)}\otimes\xi\nu^{-1/2}\sigma$	2
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	$\nu^{-1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}\otimes\xi\nu^{1/2}\sigma$ $+\nu^{1/2}\xi\mathbf{1}_{\mathrm{GL}(2)}\otimes\nu^{-1/2}\sigma$	2
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$\nu^{-1/2}\xi\mathbf{1}_{\mathrm{GL}(2)}\otimes\xi\nu^{1/2}\sigma$ $+\nu^{-1/2}\xi\mathbf{1}_{\mathrm{GL}(2)}\otimes\nu^{1/2}\sigma$	2
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	$2\cdot(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}\otimes\nu^{-1/2}\sigma)$ $+\nu^{1/2}\mathbf{1}_{\mathrm{GL}(2)}\otimes\nu^{-1/2}\sigma$	3
	b	$\tau(T,\nu^{-1/2}\sigma)$	$\nu^{1/2}\mathbf{1}_{\mathrm{GL}(2)}\otimes\nu^{-1/2}\sigma$	1
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$\nu^{-1/2}\mathrm{St}_{\mathrm{GL}(2)}\otimes\nu^{1/2}\sigma$	1
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	$2\cdot(\nu^{-1/2}\mathbf{1}_{\mathrm{GL}(2)}\otimes\nu^{1/2}\sigma)$ $+\nu^{-1/2}\mathrm{St}_{\mathrm{GL}(2)}\otimes\nu^{1/2}\sigma$	3
VII		$\chi\rtimes\pi$	0	0
VIII	a	$\tau(S,\pi)$	0	0
	b	$\tau(T,\pi)$	0	0
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	0	0
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	0	0
X		$\pi\rtimes\sigma$	$\pi\otimes\sigma+\tilde{\pi}\otimes\omega_\pi\sigma$	2
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$\nu^{1/2}\pi\otimes\nu^{-1/2}\sigma$	1
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$\nu^{-1/2}\pi\otimes\nu^{1/2}\sigma$	1

Table A.4. Jacquet modules: The Klingen parabolic

		representation	semisimplification	#
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$\chi_1 \otimes (\chi_2 \rtimes \sigma) + \chi_2 \otimes (\chi_1 \rtimes \sigma)$ $+\chi_2^{-1} \otimes (\chi_1 \rtimes \chi_2\sigma) + \chi_1^{-1} \otimes (\chi_2 \rtimes \chi_1\sigma)$	4
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$\chi\nu^{1/2} \otimes (\chi\nu^{-1/2} \rtimes \sigma)$ $+\chi^{-1}\nu^{1/2} \otimes (\chi\nu^{1/2} \rtimes \chi\nu^{-1/2}\sigma)$	2
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	$\chi\nu^{-1/2} \otimes (\chi\nu^{1/2} \rtimes \sigma)$ $+\chi^{-1}\nu^{-1/2} \otimes (\chi\nu^{-1/2} \rtimes \chi\nu^{1/2}\sigma)$	2
III	a	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$\chi \otimes \sigma\mathrm{St}_{\mathrm{GSp}(2)} + \chi^{-1} \otimes \chi\sigma\mathrm{St}_{\mathrm{GSp}(2)}$ $+\nu \otimes (\chi \rtimes \sigma\nu^{-1/2})$	3
	b	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$\chi \otimes \sigma\mathbf{1}_{\mathrm{GSp}(2)} + \chi^{-1} \otimes \chi\sigma\mathbf{1}_{\mathrm{GSp}(2)}$ $+\nu^{-1} \otimes (\chi \rtimes \sigma\nu^{1/2})$	3
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	$\nu^2 \otimes \nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)}$	1
	b	$L(\nu^2, \nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	$\nu^{-2} \otimes \nu\sigma\mathrm{St}_{\mathrm{GSp}(2)} + \nu \otimes (\nu^2 \rtimes \nu^{-3/2}\sigma)$	2
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$	$\nu^2 \otimes \nu^{-1}\sigma\mathbf{1}_{\mathrm{GSp}(2)} + \nu^{-1} \otimes (\nu^2 \rtimes \nu^{-1/2}\sigma)$	2
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	$\nu^{-2} \otimes \nu\sigma\mathbf{1}_{\mathrm{GSp}(2)}$	1
V	a	$\delta([\xi, \nu\xi], \nu^{-1/2}\sigma)$	$\nu\xi \otimes (\xi \rtimes \nu^{-1/2}\sigma)$	1
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	$\xi \otimes (\nu\xi \rtimes \xi\nu^{-1/2}\sigma)$	1
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \xi\nu^{-1/2}\sigma)$	$\xi \otimes (\nu\xi \rtimes \nu^{-1/2}\sigma)$	1
	d	$L(\nu\xi, \xi \rtimes \nu^{-1/2}\sigma)$	$\nu^{-1/2}\xi \otimes (\xi \rtimes \nu^{1/2}\sigma)$	1
VI	a	$\tau(S, \nu^{-1/2}\sigma)$	$\nu \otimes (1_{F^\times} \rtimes \nu^{-1/2}\sigma) + 1_{F^\times} \otimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	2
	b	$\tau(T, \nu^{-1/2}\sigma)$	$1_{F^\times} \otimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	1
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	$1_{F^\times} \otimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	1
	d	$L(\nu, 1_{F^\times} \rtimes \nu^{-1/2}\sigma)$	$1_{F^\times} \otimes \sigma\mathbf{1}_{\mathrm{GSp}(2)} + \nu^{-1} \otimes (1_{F^\times} \rtimes \nu^{1/2}\sigma)$	2

		representation	semisimplification	#
VII		$\chi \rtimes \pi$	$\chi \otimes \pi + \chi^{-1} \otimes \chi\pi$	2
VIII	a	$\tau(S, \pi)$	$1_{F^\times} \otimes \pi$	1
	b	$\tau(T, \pi)$	$1_{F^\times} \otimes \pi$	1
IX	a	$\delta(\nu\xi, \nu^{-1/2}\pi)$	$\nu\xi \otimes \nu^{-1/2}\pi$	1
	b	$L(\nu\xi, \nu^{-1/2}\pi)$	$\nu^{-1}\xi \otimes \nu^{1/2}\pi$	1
X		$\pi \rtimes \sigma$	0	0
XI	a	$\delta(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	0	0
	b	$L(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	0	0

A.4 The P_3-Filtration

Let V be an irreducible, admissible representation of $\mathrm{GSp}(4,F)$ with trivial central character, and let $0 \subset V_2 \subset V_1 \subset V_0 = V_{Z^J}$ be the P_3-filtration from Theorem 2.5.3. The tables in this section list the semisimplifications of the quotient V_0/V_1 and V_1/V_2. The last column lists the number of irreducible constituents. These semisimplifications are obtained from the semisimplifications of the Jacquet modules of V with respect to the Siegel and Klingen parabolic subgroups from Section A.3, using $V_0/V_1 \cong \tau_{\mathrm{GL}(2)}^{P_3}(V_{N_Q})$ and $V_1/V_2 \cong \tau_{\mathrm{GL}(1)}^{P_3}(V_{U,\psi_{-1,0}})$. See Theorem 2.5.3. Note that the factor $\nu^{3/2}$ appearing in all the entries in Table A.6 is a consequence of the fact that the Jacquet modules in Table A.3 are normalized, while the P_3-filtration involves no normalizations.

Table A.5. P_3-filtration: V_0/V_1

		representation	s.s.(V_0/V_1)	#
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi_1\chi_2\sigma \times \chi_1\sigma))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi_1\chi_2\sigma \times \chi_2\sigma))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi_1\sigma \times \sigma))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi_2\sigma \times \sigma))$	4
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi^2\sigma \times \nu^{1/2}\chi\sigma))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\nu^{1/2}\chi\sigma \times \sigma))$	2
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	$\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi^2\sigma \times \nu^{-1/2}\chi\sigma))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\nu^{-1/2}\chi\sigma \times \sigma))$	2
III	a	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$\tau_{\mathrm{GL}(2)}^{P_3}(\nu\chi\sigma\mathrm{St}_{\mathrm{GL}(2)})$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu\sigma\mathrm{St}_{\mathrm{GL}(2)})$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\nu^{1/2}\chi\sigma \times \nu^{1/2}\sigma))$	3
	b	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\chi\sigma\mathbf{1}_{\mathrm{GL}(2)}))$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu\sigma\mathbf{1}_{\mathrm{GL}(2)})$ $+\tau_{\mathrm{GL}(2)}^{P_3}(\nu(\nu^{-1/2}\chi\sigma \times \nu^{-1/2}\sigma))$	3

		representation	s.s.(V_0/V_1)	#
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu^2\sigma\mathrm{St}_{\mathrm{GL}(2)})$	1
	b	$L(\nu^2,\nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	$\tau^{P_3}_{\mathrm{GL}(2)}(\sigma\mathrm{St}_{\mathrm{GL}(2)})$ $+\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{3/2}\sigma\times\nu^{-1/2}\sigma))$	2
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-3/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu^2\sigma\mathbf{1}_{\mathrm{GL}(2)})$ $+\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{1/2}\sigma\times\nu^{-3/2}\sigma))$	2
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	$\tau^{P_3}_{\mathrm{GL}(2)}(\sigma\mathbf{1}_{\mathrm{GL}(2)})$	1
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{1/2}\sigma\times\nu^{1/2}\xi\sigma))$	1
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{1/2}\xi\sigma\times\nu^{-1/2}\sigma))$	1
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{1/2}\sigma\times\nu^{-1/2}\xi\sigma))$	1
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\sigma\times\xi\sigma))$	1
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{1/2}\sigma\times\nu^{1/2}\sigma))$ $+\tau^{P_3}_{\mathrm{GL}(2)}(\nu\sigma\mathrm{St}_{\mathrm{GL}(2)})$	2
	b	$\tau(T,\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\sigma\mathrm{St}_{\mathrm{GL}(2)})$	1
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\sigma\mathbf{1}_{\mathrm{GL}(2)})$	1
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\sigma\mathbf{1}_{\mathrm{GL}(2)})$ $+\tau^{P_3}_{\mathrm{GL}(2)}(\nu(\nu^{-1/2}\sigma\times\nu^{-1/2}\sigma))$	2
VII		$\chi\rtimes\pi$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\chi\pi)+\tau^{P_3}_{\mathrm{GL}(2)}(\nu\pi)$	2
VIII	a	$\tau(S,\pi)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\pi)$	1
	b	$\tau(T,\pi)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu\pi)$	1
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu^{3/2}\xi\pi)$	1
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	$\tau^{P_3}_{\mathrm{GL}(2)}(\nu^{1/2}\xi\pi)$	1
X		$\pi\rtimes\sigma$	0	0
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	0	0
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	0	0

Table A.6. P_3-filtration: V_1/V_2

		representation	s.s.(V_1/V_2)	#
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\chi_1\chi_2\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\sigma)$ $+\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\chi_1\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\chi_2\sigma)$	4
II	a	$\chi \mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\chi^2\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\sigma)$ $+\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\chi\sigma)$	3
	b	$\chi \mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\chi\sigma)$	1
III	a	$\chi \rtimes \sigma \mathrm{St}_{\mathrm{GSp}(2)}$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\chi\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\sigma)$	2
	b	$\chi \rtimes \sigma \mathbf{1}_{\mathrm{GSp}(2)}$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\chi\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	2
IV	a	$\sigma \mathrm{St}_{\mathrm{GSp}(4)}$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{3/2}\sigma)$	1
	b	$L(\nu^2, \nu^{-1}\sigma \mathrm{St}_{\mathrm{GSp}(2)})$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	1
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-3/2}\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\sigma)$	2
	d	$\sigma \mathbf{1}_{\mathrm{GSp}(4)}$	0	0
V	a	$\delta([\xi, \nu\xi], \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\xi\sigma)$	2
	b	$L(\nu^{1/2}\xi \mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	1
	c	$L(\nu^{1/2}\xi \mathrm{St}_{\mathrm{GL}(2)}, \xi\nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\xi\sigma)$	1
	d	$L(\nu\xi, \xi \rtimes \nu^{-1/2}\sigma)$	0	0
VI	a	$\tau(S, \nu^{-1/2}\sigma)$	$2\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\sigma)$	2
	b	$\tau(T, \nu^{-1/2}\sigma)$	0	0
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	1
	d	$L(\nu, 1_{F^\times} \rtimes \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	1
VII		$\chi \rtimes \pi$	0	0
VIII	a	$\tau(S, \pi)$	0	0
	b	$\tau(T, \pi)$	0	0
IX	a	$\delta(\nu\xi, \nu^{-1/2}\pi)$	0	0
	b	$L(\nu\xi, \nu^{-1/2}\pi)$	0	0
X		$\pi \rtimes \sigma$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\omega_\pi\sigma) + \tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\sigma)$	2
XI	a	$\delta(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{1/2}\sigma)$	1
	b	$L(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	$\tau^{P_3}_{\mathrm{GL}(1)}(\nu^{3/2}\nu^{-1/2}\sigma)$	1

A.5 L-Parameters

Table A.7 gives the L-parameters $\varphi = (\rho, N)$ of each non-supercuspidal representation of $\mathrm{GSp}(4, F)$, as defined in Sect. 2.4. For groups I – VI, an entry $\tau_1, \ldots, \tau_4$ in the "ρ" column stands for the map $W_F \ni w \mapsto \mathrm{diag}(\tau_1(w), \ldots, \tau_4(w)) \in \mathrm{GSp}(4, \mathbb{C})$. For groups VII – XI, let π be the supercuspidal representation of $\mathrm{GL}(2, F)$ as in Table A.1. The symbol φ_π stands for the L-parameter $W_F \to \mathrm{GL}(2, \mathbb{C})$ of π, and φ'_π is defined in (2.1). The character ω_π is the central character of π, identified with a character of W_F. Alternatively, $\omega_\pi(w) = \det(\varphi_\pi(w))$. The entries in the ρ column are to be read in diagonal block notation for groups VII – XI. The nilpotent elements listed in the "N" column are defined as follows.

$$N_1 = \begin{bmatrix} 0 &&& \\ & 0 & 1 & \\ && 0 & \\ &&& 0 \end{bmatrix}, \qquad N_2 = \begin{bmatrix} 0 &&& 1 \\ & 0 && \\ && 0 & \\ &&& 0 \end{bmatrix}, \qquad N_3 = \begin{bmatrix} 0 &&& 1 \\ & 0 & 1 & \\ && 0 & \\ &&& 0 \end{bmatrix},$$

$$N_4 = \begin{bmatrix} 0 & 1 && \\ & 0 && \\ && 0 & -1 \\ &&& 0 \end{bmatrix}, \qquad N_5 = \begin{bmatrix} 0 & 1 && \\ & 0 & 1 & \\ && 0 & -1 \\ &&& 0 \end{bmatrix}.$$

To define N_6, let S be the symmetric matrix from Lemma 2.4.1. Then

$$N_6 = \begin{bmatrix} 0 & B \\ 0 & 0 \end{bmatrix}, \qquad \text{where} \qquad B = \begin{bmatrix} & 1 \\ 1 & \end{bmatrix} S$$

(see 2.45). Finally, the last column lists the number of elements of

$$\mathcal{C}(\varphi) = \mathrm{Cent}(\varphi)/\mathrm{Cent}(\varphi)^0\, \mathbb{C}^\times,$$

where $\mathrm{Cent}(\varphi)$ denotes the centralizer of the image of φ, where $\mathrm{Cent}(\varphi)^0$ denotes its identity component, and where $\mathbb{C}^\times$ stands for the center of $\mathrm{GSp}(4, \mathbb{C})$.

Table A.7. *L*-parameters

		representation	ρ	N	$\#\mathcal{C}$
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	$\chi_1\chi_2\sigma,\ \chi_1\sigma,\ \chi_2\sigma,\ \sigma$	0	1
II	a	$\chi \mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	$\chi^2\sigma,\ \nu^{1/2}\chi\sigma,\ \nu^{-1/2}\chi\sigma,\ \sigma$	N_1	1
	b	$\chi \mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$		0	1
III	a	$\chi \rtimes \sigma \mathrm{St}_{\mathrm{GSp}(2)}$	$\nu^{1/2}\chi\sigma,\ \nu^{-1/2}\chi\sigma,\ \nu^{1/2}\sigma,\ \nu^{-1/2}\sigma$	N_4	1
	b	$\chi \rtimes \sigma \mathbf{1}_{\mathrm{GSp}(2)}$		0	1
IV	a	$\sigma \mathrm{St}_{\mathrm{GSp}(4)}$	$\nu^{3/2}\sigma,\ \nu^{1/2}\sigma,\ \nu^{-1/2}\sigma,\ \nu^{-3/2}\sigma$	N_5	1
	b	$L(\nu^2, \nu^{-1}\sigma \mathrm{St}_{\mathrm{GSp}(2)})$		N_4	1
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$		N_1	1
	d	$\sigma \mathbf{1}_{\mathrm{GSp}(4)}$		0	1
V	a	$\delta([\xi, \nu\xi], \nu^{-1/2}\sigma)$	$\nu^{1/2}\sigma,\ \nu^{1/2}\xi\sigma,\ \nu^{-1/2}\xi\sigma,\ \nu^{-1/2}\sigma$	N_3	2
	b	$L(\nu^{1/2}\xi \mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$		N_1	1
	c	$L(\nu^{1/2}\xi \mathrm{St}_{\mathrm{GL}(2)}, \xi\nu^{-1/2}\sigma)$		N_2	1
	d	$L(\nu\xi, \xi \rtimes \nu^{-1/2}\sigma)$		0	1
VI	a	$\tau(S, \nu^{-1/2}\sigma)$	$\nu^{1/2}\sigma,\ \nu^{1/2}\sigma,\ \nu^{-1/2}\sigma,\ \nu^{-1/2}\sigma$	N_3	2
	b	$\tau(T, \nu^{-1/2}\sigma)$			
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$		N_1	1
	d	$L(\nu, 1_{F^\times} \rtimes \nu^{-1/2}\sigma)$		0	1
VII		$\chi \rtimes \pi$	$\chi\omega_\pi\varphi'_\pi,\ \varphi_\pi$	0	1
VIII	a	$\tau(S, \pi)$	$\omega_\pi\varphi'_\pi,\ \varphi_\pi$	0	2
	b	$\tau(T, \pi)$			
IX	a	$\delta(\nu\xi, \nu^{-1/2}\pi)$	$\xi\nu^{1/2}\omega_\pi\varphi'_\pi,\ \nu^{-1/2}\varphi_\pi$	N_6	1
	b	$L(\nu\xi, \nu^{-1/2}\pi)$		0	1
X		$\pi \rtimes \sigma$	$\sigma\omega_\pi,\ \sigma\varphi_\pi,\ \sigma$	0	1
XI	a	$\delta(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$	$\nu^{1/2}\sigma,\ \sigma\varphi_\pi,\ \nu^{-1/2}\sigma$	N_2	2
	b	$L(\nu^{1/2}\pi, \nu^{-1/2}\sigma)$		0	1

A.6 L- and ε-factors (degree 4)

The following Table A.8 lists the L-factors $L(s,\varphi)$ (degree 4) for the L-parameters φ of the non-supercuspidal, irreducible, admissible representations of $\mathrm{GSp}(4,F)$ (not necessarily with trivial central character). For a character χ of $F^\times$, the symbol $L(s,\chi)$ in the tables below has the usual meaning:

$$L(s,\chi) = \begin{cases} (1-\chi(\varpi)q^{-s})^{-1} & \text{if } \chi \text{ is unramified,} \\ 1 & \text{if } \chi \text{ is ramified.} \end{cases}$$

Table A.9 lists the ε-factors $\varepsilon(s,\varphi)$ for the L-parameters φ of the non-supercuspidal, irreducible, admissible representations of $\mathrm{GSp}(4,F)$ with trivial central character. See Sect. 2.4, in particular (2.48) and (2.49), for the definitions.

Table A.8. L-factors $L(s,\varphi)$ (degree 4)

		representation	$L(s,\varphi)$
I		$\chi_1\times\chi_2\rtimes\sigma$ (irreducible)	$L(s,\chi_1\chi_2\sigma)L(s,\sigma)L(s,\chi_1\sigma)L(s,\chi_2\sigma)$
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)}\rtimes\sigma$	$L(s,\chi^2\sigma)L(s,\sigma)L(s,\nu^{1/2}\chi\sigma)$
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)}\rtimes\sigma$	$L(s,\chi^2\sigma)L(s,\sigma)L(s,\nu^{1/2}\chi\sigma)L(s,\nu^{-1/2}\chi\sigma)$
III	a	$\chi\rtimes\sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$L(s,\nu^{1/2}\chi\sigma)L(s,\nu^{1/2}\sigma)$
	b	$\chi\rtimes\sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$L(s,\nu^{1/2}\chi\sigma)L(s,\nu^{1/2}\sigma)L(s,\nu^{-1/2}\chi\sigma)L(s,\nu^{-1/2}\sigma)$
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	$L(s,\nu^{3/2}\sigma)$
	b	$L(\nu^2,\nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	$L(s,\nu^{3/2}\sigma)L(s,\nu^{-1/2}\sigma)$
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-3/2}\sigma)$	$L(s,\nu^{3/2}\sigma)L(s,\nu^{1/2}\sigma)L(s,\nu^{-3/2}\sigma)$
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	$L(s,\nu^{3/2}\sigma)L(s,\nu^{1/2}\sigma)L(s,\nu^{-1/2}\sigma)L(s,\nu^{-3/2}\sigma)$
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)L(s,\nu^{1/2}\xi\sigma)$
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)L(s,\nu^{1/2}\xi\sigma)L(s,\nu^{-1/2}\sigma)$
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)L(s,\nu^{1/2}\xi\sigma)L(s,\nu^{-1/2}\xi\sigma)$
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)L(s,\nu^{1/2}\xi\sigma)L(s,\nu^{-1/2}\sigma)L(s,\nu^{-1/2}\xi\sigma)$
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)^2$
	b	$\tau(T,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)^2$
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)^2L(s,\nu^{-1/2}\sigma)$
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)^2L(s,\nu^{-1/2}\sigma)^2$
VII		$\chi\rtimes\pi$	1
VIII	a	$\tau(S,\pi)$	1
	b	$\tau(T,\pi)$	1
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	1
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	1
X		$\pi\rtimes\sigma$	$L(s,\sigma)L(s,\omega_\pi\sigma)$
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)$
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\sigma)L(s,\nu^{-1/2}\sigma)$

Table A.9. ε-factors $\varepsilon(s,\varphi)$ (degree 4)

		inducing data	$a(\varphi)$	$\varepsilon(1/2,\varphi)$
I			$a(\chi_1\sigma)+a(\chi_2\sigma)+2a(\sigma)$	$\chi_1(-1) \quad (=\chi_2(-1))$
II	a	$\sigma\chi$ unr.	$2a(\sigma)+1$	$-\sigma(-1)(\sigma\chi)(\varpi)$
		$\sigma\chi$ ram.	$2a(\chi\sigma)+2a(\sigma)$	$\chi(-1)$
	b	$\sigma\chi$ unr.	$2a(\sigma)$	$\chi(-1)$
		$\sigma\chi$ ram.	$2a(\chi\sigma)+2a(\sigma)$	$\chi(-1)$
III	a	σ unr.	2	1
		σ ram.	$4a(\sigma)$	1
	b	σ unr.	0	1
		σ ram.	$4a(\sigma)$	1
IV	a	σ unr.	3	$-\sigma(\varpi)$
		σ ram.	$4a(\sigma)$	1
	b	σ unr.	2	1
		σ ram.	$4a(\sigma)$	1
	c	σ unr.	1	$-\sigma(\varpi)$
		σ ram.	$4a(\sigma)$	1
	d	σ unr.	0	1
		σ ram.	$4a(\sigma)$	1
V	a	σ, ξ unr.	2	-1
		σ unr., ξ ram.	$2a(\xi)+1$	$-\sigma(\varpi)\xi(-1)$
		σ ram., $\sigma\xi$ unr.	$2a(\sigma)+1$	$-\sigma(-1)(\sigma\xi)(\varpi)$
		σ, $\sigma\xi$ ram.	$2a(\xi\sigma)+2a(\sigma)$	$\xi(-1)$
	b	σ, ξ unr.	1	$\sigma(\varpi)$
		σ unr., ξ ram.	$2a(\xi)$	$\xi(-1)$
		σ ram., $\sigma\xi$ unr.	$2a(\sigma)+1$	$-\xi(-1)(\sigma\xi)(\varpi)$
		σ, $\sigma\xi$ ram.	$2a(\xi\sigma)+2a(\sigma)$	$\xi(-1)$

		inducing data	$a(\varphi)$	$\varepsilon(1/2,\varphi)$
V	c	σ, ξ unr.	1	$-\sigma(\varpi)$
V	c	σ unr., ξ ram.	$2a(\xi)+1$	$-\sigma(\varpi)$
V	c	σ ram., $\sigma\xi$ unr.	$2a(\sigma)$	$\xi(-1)$
V	c	σ, $\sigma\xi$ ram.	$2a(\xi\sigma)+2a(\sigma)$	$\xi(-1)$
V	d	σ,ξ unr.	0	1
V	d	σ or ξ ram.	$2a(\xi\sigma)+2a(\sigma)$	$\xi(-1)$
VI	a	σ unr.	2	1
VI	a	σ ram.	$4a(\sigma)$	1
VI	b	σ unr.	2	1
VI	b	σ ram.	$4a(\sigma)$	1
VI	c	σ unr.	1	$-\sigma(\varpi)$
VI	c	σ ram.	$4a(\sigma)$	1
VI	d	σ unr.	0	1
VI	d	σ ram.	$4a(\sigma)$	1
VII			$2a(\pi)$	$\chi(-1) \quad (=\omega_\pi(-1))$
VIII	a		$2a(\pi)$	1
VIII	b		$2a(\pi)$	1
IX	a		$2a(\pi)$	$\xi(-1)$
IX	b		$2a(\pi)$	$\xi(-1)$
X			$a(\sigma\pi)+2a(\sigma)$	$\sigma(-1)\varepsilon(1/2,\sigma\pi)$
XI	a	σ unr.	$a(\sigma\pi)+1$	$-\sigma(\varpi)\varepsilon(1/2,\sigma\pi)$
XI	a	σ ram.	$a(\sigma\pi)+2a(\sigma)$	$\sigma(-1)\varepsilon(1/2,\sigma\pi)$
XI	b	σ unr.	$a(\sigma\pi)$	$\varepsilon(1/2,\sigma\pi)$
XI	b	σ ram.	$a(\sigma\pi)+2a(\sigma)$	$\sigma(-1)\varepsilon(1/2,\sigma\pi)$

A.7 L- and ε-factors (degree 5)

Below we describe a homomorphism $\rho_5 : \mathrm{GSp}(4,\mathbb{C}) \to \mathrm{SO}(5,\mathbb{C})$. If $\varphi : W'_F \to \mathrm{GSp}(4,\mathbb{C})$ is an L-parameter, then the composition $\rho_5 \circ \varphi$ is a 5-dimensional representation of W'_F. The following Table A.10 lists the resulting L-factors $L(s, \rho_5 \circ \varphi)$ (degree 5) for the L-parameters of the non-supercuspidal, irreducible, admissible representations of $\mathrm{GSp}(4,F)$ (not necessarily with trivial central character). Table A.11 lists the ε-factors $\varepsilon(s, \rho_5 \circ \varphi)$ for the L-parameters of the non-supercuspidal, irreducible, admissible representations of $\mathrm{GSp}(4,F)$ (not necessarily with trivial central character). See Sect. 2.4, in particular (2.48) and (2.49), for the definitions.

GSp(4) and SO(5)

It is known that the projective group PGSp(4) is isomorphic to

$$\mathrm{SO}(5) = \{g \in \mathrm{SL}(5) : {}^t g J_5 g = J_5\}, \qquad J_5 = \begin{bmatrix} &&&&1\\ &&&1&\\ &&1&&\\ &1&&&\\ 1&&&& \end{bmatrix}, \tag{A.1}$$

as algebraic groups. Over a field k of characteristic not equal to 2 this isomorphism can be realized as follows. Let $V = k^4$ be the space of column vectors of length 4 over k, and let e_1, e_2, e_3, e_4 be the standard basis of V. The group $\mathrm{GSp}(4,k)$ acts on V by matrix multiplication from the left, and then also on the 16-dimensional tensor product space $V \otimes V$. Let us denote by ρ this action on $V \otimes V$ twisted with the inverse of the multiplier homomorphisms, i.e., $\rho(g)(v \otimes w) = \lambda(g)^{-1}(gv) \otimes (gw)$. Then ρ is trivial on the center of $\mathrm{GSp}(4,k)$, and we get an action of $\mathrm{PGSp}(4,k)$. We introduce on V the symplectic form

$$(v, v') := {}^t v \begin{bmatrix} &&&1\\ &&1&\\ &-1&&\\ -1&&& \end{bmatrix} v',$$

and on the tensor product $V \otimes V$ the symmetric bilinear form $\langle v \otimes w, v' \otimes w' \rangle = (v, v')(w, w')$. Both bilinear forms are obviously invariant under the action of $\mathrm{Sp}(4,k)$, and one checks easily that $\langle\, , \,\rangle$ is even preserved by the action ρ of $\mathrm{GSp}(4,k)$. Now consider the embedding

$$V \wedge V \longrightarrow V \otimes V, \qquad v \wedge w \longmapsto \frac{1}{2}(v \otimes w - w \otimes v).$$

The restriction of $\langle\, , \,\rangle$ to $V \wedge V$ is given by

$$\langle v \wedge w,\, v' \wedge w' \rangle = \frac{1}{2}\big((v, v')(w, w') - (v, w')(w, v')\big).$$

Let X be the image of the 5-dimensional subspace spanned by

$$\mathbf{x}_1 = e_1 \wedge e_2, \quad \mathbf{x}_2 = 2e_1 \wedge e_3, \quad \mathbf{x}_3 = e_1 \wedge e_4 - e_2 \wedge e_3,$$
$$\mathbf{x}_4 = e_2 \wedge e_4, \quad \mathbf{x}_5 = 2e_4 \wedge e_3.$$

One computes that the matrix of $\langle\,,\,\rangle$ with respect to this basis is J_5 as in (A.1). A computation shows that X is invariant under the action ρ of $\mathrm{GSp}(4,k)$. Since $\langle\,,\,\rangle$ is preserved by this action, we get a homomorphism $\rho_5 : \mathrm{GSp}(4,k) \to \mathrm{SO}(5,k)$. On the Siegel parabolic subgroup P the homomorphism ρ_5 is explicitly given as follows. Let

$$\mathrm{Ad}:\ \mathrm{GL}(2,k) \longrightarrow \mathrm{SO}(3,k),$$
$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} \longmapsto \frac{1}{ad-bc}\begin{bmatrix} a^2 & -ab & -b^2/2 \\ -2ac & ad+bc & bd \\ -2c^2 & 2cd & d^2 \end{bmatrix}.$$

Then Ad induces an isomorphism $\mathrm{PGL}(2,k) \cong \mathrm{SO}(3,k)$. On the standard Levi component of the Siegel parabolic subgroup we have

$$\rho_5(\begin{bmatrix} A & \\ & uA' \end{bmatrix}) = \begin{bmatrix} u^{-1}\det(A) & & \\ & \mathrm{Ad}(A) & \\ & & u\det(A)^{-1} \end{bmatrix}, \tag{A.2}$$

while on the unipotent radical ρ_5 is given by

$$\rho_5(\begin{bmatrix} 1 & & x & z \\ & 1 & y & x \\ & & 1 & \\ & & & 1 \end{bmatrix}) = \begin{bmatrix} 1 & 2y & 2x & -z & 2(yz-x^2) \\ & 1 & & & z \\ & & 1 & & -2x \\ & & & 1 & -2y \\ & & & & 1 \end{bmatrix}. \tag{A.3}$$

On the Levi component of the Klingen parabolic subgroup we have

$$\rho_5(\begin{bmatrix} y & & & \\ & a & b & \\ & c & d & \\ & & & y^{-1}(ad-bc) \end{bmatrix}) = \begin{bmatrix} \frac{ya}{ad-bc} & \frac{2yb}{ad-bc} & & & \\ \frac{yc}{2(ad-bc)} & \frac{yd}{ad-bc} & & & \\ & & 1 & & \\ & & & a/y & -2b/y \\ & & & -c/(2y) & d/y \end{bmatrix}, \tag{A.4}$$

and on the unipotent radical

$$\rho_5(\begin{bmatrix} 1 & x & y & z \\ & 1 & & y \\ & & 1 & -x \\ & & & 1 \end{bmatrix}) = \begin{bmatrix} 1 & & 2y & xy-z & -2y^2 \\ & 1 & -x & -x^2/2 & xy+z \\ & & 1 & x & -2y \\ & & & 1 & \\ & & & & 1 \end{bmatrix}. \tag{A.5}$$

The map ρ_5 is clearly surjective. Its kernel is the center of $\mathrm{GSp}(4,k)$, so we get an isomorphism $\mathrm{PGSp}(4,k) \cong \mathrm{SO}(5,k)$.

Table A.10. L-factors $L(s,\rho_5\circ\varphi)$ (degree 5)

		representation	$L(s,\rho_5\circ\varphi)$
I		$\chi_1\times\chi_2\rtimes\sigma$ (irreducible)	$L(s,\chi_1)L(s,\chi_1^{-1})L(s,\chi_2)L(s,\chi_2^{-1})L(s,1_{F^\times})$
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)}\rtimes\sigma$	$L(s,\nu^{1/2}\chi)L(s,\nu^{1/2}\chi^{-1})L(s,1_{F^\times})$
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)}\rtimes\sigma$	$L(s,\nu^{1/2}\chi)L(s,\nu^{-1/2}\chi)$ $L(s,\nu^{1/2}\chi^{-1})L(s,\nu^{-1/2}\chi^{-1})L(s,1_{F^\times})$
III	a	$\chi\rtimes\sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$L(s,\chi)L(s,\chi^{-1})L(s,\nu)$
	b	$\chi\rtimes\sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$L(s,\chi)L(s,\chi^{-1})L(s,\nu)L(s,\nu^{-1})L(s,1_{F^\times})$
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	$L(s,\nu^2)$
	b	$L(\nu^2,\nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	$L(s,\nu^2)L(s,\nu)L(s,\nu^{-2})$
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-3/2}\sigma)$	$L(s,\nu^2)L(s,1_{F^\times})L(s,\nu^{-1})$
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	$L(s,\nu^2)L(s,\nu)L(s,1_{F^\times})L(s,\nu^{-1})L(s,\nu^{-2})$
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	$L(s,\nu\xi)L(s,\xi)L(s,1_{F^\times})$
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$L(s,\nu\xi)L(s,\xi)L(s,1_{F^\times})$
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	$L(s,\nu\xi)L(s,\xi)L(s,1_{F^\times})$
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$L(s,\nu\xi)L(s,\nu^{-1}\xi)L(s,\xi)^2L(s,1_{F^\times})$
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	$L(s,\nu)L(s,1_{F^\times})^2$
	b	$\tau(T,\nu^{-1/2}\sigma)$	
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	$L(s,\nu)L(s,1_{F^\times})^2$
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	$L(s,\nu)L(s,\nu^{-1})L(s,1_{F^\times})^3$
VII		$\chi\rtimes\pi$	$L(s,\chi)L(s,\chi^{-1})L(s,\mathrm{Ad}\circ\mu)$
VIII	a	$\tau(S,\pi)$	$L(s,1_{F^\times})^2L(s,\mathrm{Ad}\circ\mu)$
	b	$\tau(T,\pi)$	
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	$L(s,\nu\xi)L(s,\mathrm{Ad}\circ\mu)L(s,\xi)^{-1}$
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	$L(s,\nu\xi)L(s,\nu^{-1}\xi)L(s,\mathrm{Ad}\circ\mu)$
X		$\pi\rtimes\sigma$	$L(s,\mu)L(s,\det(\mu)^{-1}\mu)L(s,1_{F^\times})$
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\mu)L(s,1_{F^\times})$
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$L(s,\nu^{1/2}\mu)L(s,\nu^{-1/2}\mu)L(s,1_{F^\times})$

Table A.11. ε-factors $\varepsilon(s,\rho_5\circ\varphi)$ (degree 5)

		representation	$a(\rho_5\circ\varphi)$	$\varepsilon(1/2,\rho_5\circ\varphi)$
I		$\chi_1\times\chi_2\rtimes\sigma$ (irreducible)	$2a(\chi_1)+2a(\chi_2)$	$\chi_1(-1)\chi_2(-1)$
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)}\rtimes\sigma$	χ unr. : 2, χ ram. : $4a(\chi)$	1
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)}\rtimes\sigma$	$4a(\chi)$	1
III	a	$\chi\rtimes\sigma\mathrm{St}_{\mathrm{GSp}(2)}$	$2a(\chi)+2$	$\chi(-1)$
	b	$\chi\rtimes\sigma\mathbf{1}_{\mathrm{GSp}(2)}$	$2a(\chi)$	$\chi(-1)$
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	4	1
	b	$L(\nu^2,\nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	2	1
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-3/2}\sigma)$	2	1
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	0	1
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	ξ unr. : 2, ξ ram. : $4a(\xi)$	1
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	ξ unr. : 2, ξ ram. : $4a(\xi)$	1
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	ξ unr. : 2, ξ ram. : $4a(\xi)$	1
	d	$L(\nu\xi,\xi\rtimes\nu^{-1/2}\sigma)$	$4a(\xi)$	1
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	2	1
	b	$\tau(T,\nu^{-1/2}\sigma)$		
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	2	1
	d	$L(\nu,1_{F^\times}\rtimes\nu^{-1/2}\sigma)$	0	1
VII		$\chi\rtimes\pi$	$2a(\chi)+a(\mathrm{Ad}\circ\mu)$	$\chi(-1)\varepsilon(\frac12,\mathrm{Ad}\circ\mu)$
VIII	a	$\tau(S,\pi)$	$a(\mathrm{Ad}\circ\mu)$	$\varepsilon(\frac12,\mathrm{Ad}\circ\mu)$
	b	$\tau(T,\pi)$		
IX	a	$\delta(\nu\xi,\nu^{-1/2}\pi)$	ξ unr. : $a(\mathrm{Ad}\circ\mu)+2$ ξ ram. : $2a(\xi)+a(\mathrm{Ad}\circ\mu)$	$\xi(-1)\varepsilon(\frac12,\mathrm{Ad}\circ\mu)$
	b	$L(\nu\xi,\nu^{-1/2}\pi)$	$2a(\xi)+a(\mathrm{Ad}\circ\mu)$	$\xi(-1)\varepsilon(\frac12,\mathrm{Ad}\circ\mu)$
X		$\pi\rtimes\sigma$	$2a(\mu)$	$\det(\mu)(-1)$
XI	a	$\delta(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$2a(\mu)$	1
	b	$L(\nu^{1/2}\pi,\nu^{-1/2}\sigma)$	$2a(\mu)$	1

A.8 Paramodular Dimensions and Atkin–Lehner Eigenvalues

Table A.12 below contains the dimensions of the spaces $V(m)$ of $\mathrm{K}(\mathfrak{p}^m)$ invariant vectors for each irreducible, admissible, non-supercuspidal representation V of $\mathrm{GSp}(4,F)$ with trivial central character. The "N" column gives the minimal paramodular level of the representation, provided the representation is paramodular; a "—" indicates the representation is not paramodular. The dimensions listed in the "$\dim V(m)$" column hold for any $m \geq N$. If $m < N$, then the dimension of $V(m)$ is zero. The last column of the table gives, for the paramodular representations, the eigenvalue ε of the Atkin–Lehner involution u_N on the local newform (the essentially unique paramodular vector at level $\mathfrak{p}^N$).

See Theorem 5.6.1 and Theorem 5.7.2 for proofs of the statements made in Table A.12.

Iwahori-spherical representations

The dimension information given in Table A.13 below is already contained in Table A.12. Listed are the Iwahori-spherical representations of $\mathrm{GSp}(4,F)$ with trivial central character; thus, all the characters in the inducing data are assumed to be unramified. The column named "$V(k)$" contains the dimension of the space $V(k)$ of $\mathrm{K}(\mathfrak{p}^k)$ invariant vectors. For $k = 0,\ldots,3$ we indicated under the dimension the eigenvalues of the Atkin–Lehner involution u_k. These eigenvalues are correct if one assumes that

- in group II, where the central character is $\chi^2\sigma^2$, the character $\chi\sigma$ is trivial.
- in groups IV, V and VI, where the central character is σ^2, the character σ itself is trivial.

If these assumptions are not met, then one has to interchange the plus and minus signs in the $V(1)$ and the $V(3)$ column.

The "a" column gives the conductor of the local parameter attached to the representation; see Sect. 2.4. Except for VIb, which shares an L-packet with VIa, this number coincides with the minimal paramodular level. Finally, the column "$\varepsilon(1/2,\varphi)$" gives the value of the ε-factor at $s = 1/2$ of the L-parameter of each representation. In each case, this sign coincides with the eigenvalue of the Atkin–Lehner involution on the newform.

It is not hard to obtain the information contained in Table A.13 by direct computations. See Theorem 3.2.9 for details.

Table A.12. Paramodular dimensions and Atkin–Lehner eigenvalues

		inducing data	N	$\dim V(m)$	ε
I			$a(\chi_1\sigma)+a(\chi_2\sigma)+2a(\sigma)$	$[\frac{(m-N+2)^2}{4}]$	$\chi_1(-1)\quad(=\chi_2(-1))$
II	a	$\sigma\chi$ unr.	$2a(\sigma)+1$	$[\frac{(m-N+2)^2}{4}]$	$-\sigma(-1)(\sigma\chi)(\varpi)$
		$\sigma\chi$ ram.	$2a(\chi\sigma)+2a(\sigma)$		$\chi(-1)$
	b	$\sigma\chi$ unr.	$2a(\sigma)$	$[\frac{m-N+2}{2}]$	$\chi(-1)$
		$\sigma\chi$ ram.	—	0	—
III	a	σ unr.	2	$[\frac{(m-N+2)^2}{4}]$	1
		σ ram.	$4a(\sigma)$		
	b	σ unr.	0	$m+1$	1
		σ ram.	—	0	—
IV	a	σ unr.	3	$[\frac{(m-N+2)^2}{4}]$	$-\sigma(\varpi)$
		σ ram.	$4a(\sigma)$		1
	b	σ unr.	2	$[\frac{m}{2}]$	1
		σ ram.	—	0	—
	c	σ unr.	1	m	$-\sigma(\varpi)$
		σ ram.	—	0	—
	d	σ unr.	0	1	1
		σ ram.	—	0	—
V	a	σ, ξ unr.	2	$[\frac{(m-N+2)^2}{4}]$	-1
		σ unr., ξ ram.	$2a(\xi)+1$		$-\sigma(\varpi)\xi(-1)$
		σ ram., $\sigma\xi$ unr.	$2a(\sigma)+1$		$-\sigma(-1)(\sigma\xi)(\varpi)$
		σ, $\sigma\xi$ ram.	$2a(\xi\sigma)+2a(\sigma)$		$\xi(-1)$
	b	σ, ξ unr.	1	$[\frac{m+1}{2}]$	$\sigma(\varpi)$
		σ unr., ξ ram.	$2a(\xi)$	$[\frac{m-N+2}{2}]$	$\xi(-1)$
		σ ram., $\sigma\xi$ unr.	—	0	—
		σ, $\sigma\xi$ ram.	—	0	—

		inducing data	N	$\dim V(m)$	ε
V	c	σ, ξ unr.	1	$[\frac{m+1}{2}]$	$-\sigma(\varpi)$
		σ unr., ξ ram.	—	0	—
		σ ram., $\sigma\xi$ unr.	$2a(\sigma)$	$[\frac{m-N+2}{2}]$	$\xi(-1)$
		σ, $\sigma\xi$ ram.	—	0	—
	d	σ, ξ unr.	0	$\frac{1+(-1)^m}{2}$	1
		σ or ξ ram.	—	0	—
VI	a	σ unr.	2	$[\frac{(m-N+2)^2}{4}]$	1
		σ ram.	$4a(\sigma)$		
	b	σ unr.	—	0	—
		σ ram.	—	0	—
	c	σ unr.	1	$[\frac{m+1}{2}]$	$-\sigma(\varpi)$
		σ ram.	—	0	—
	d	σ unr.	0	$[\frac{m+2}{2}]$	1
		σ ram.	—	0	—
VII			$2a(\pi)$	$[\frac{(m-N+2)^2}{4}]$	$\chi(-1) \quad (= \omega_\pi(-1))$
VIII	a		$2a(\pi)$	$[\frac{(m-N+2)^2}{4}]$	1
	b		—	0	—
IX	a		$2a(\pi)$	$[\frac{(m-N+2)^2}{4}]$	$\xi(-1)$
	b		—	0	—
X			$a(\sigma\pi) + 2a(\sigma)$	$[\frac{(m-N+2)^2}{4}]$	$\sigma(-1)\varepsilon(1/2, \sigma\pi)$
XI	a	σ unr.	$a(\sigma\pi) + 1$	$[\frac{(m-N+2)^2}{4}]$	$-\sigma(\varpi)\varepsilon(1/2, \sigma\pi)$
		σ ram.	$a(\sigma\pi) + 2a(\sigma)$		$\sigma(-1)\varepsilon(1/2, \sigma\pi)$
	b	σ unr.	$a(\sigma\pi)$	$[\frac{m-N+2}{2}]$	$\varepsilon(1/2, \sigma\pi)$
		σ ram.	—	0	—

Table A.13. Iwahori-spherical representations of $\mathrm{GSp}(4,F)$

		representation	a	$\varepsilon(1/2,\varphi)$	$V(0)$	$V(1)$	$V(2)$	$V(3)$	$V(n)$
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	0	1	$\underset{+}{\mathbf{1}}$	$\underset{+-}{2}$	$\underset{+++-}{4}$	$\underset{\substack{+++\\---}}{6}$	$\left[\frac{(n+2)^2}{4}\right]$
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	1	$-(\sigma\chi)(\varpi)$	0	$\underset{-}{\mathbf{1}}$	$\underset{+-}{2}$	$\underset{++--}{4}$	$\left[\frac{(n+1)^2}{4}\right]$
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	0	1	$\underset{+}{\mathbf{1}}$	$\underset{+}{1}$	$\underset{++}{2}$	$\underset{++}{2}$	$\left[\frac{n+2}{2}\right]$
III	a	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	2	1	0	0	$\underset{+}{\mathbf{1}}$	$\underset{+-}{2}$	$\left[\frac{n^2}{4}\right]$
	b	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	0	1	$\underset{+}{\mathbf{1}}$	$\underset{+-}{2}$	$\underset{++-}{3}$	$\underset{++--}{4}$	$n+1$
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	3	$-\sigma(\varpi)$	0	0	0	$\underset{-}{\mathbf{1}}$	$\left[\frac{(n-1)^2}{4}\right]$
	b	$L(\nu^2, \nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	2	1	0	0	$\underset{+}{\mathbf{1}}$	$\underset{+}{1}$	$\left[\frac{n}{2}\right]$
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-3/2}\sigma)$	1	$-\sigma(\varpi)$	0	$\underset{-}{\mathbf{1}}$	$\underset{+-}{2}$	$\underset{+--}{3}$	n
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	0	1	$\underset{+}{\mathbf{1}}$	$\underset{+}{1}$	$\underset{+}{1}$	$\underset{+}{1}$	1
V	a	$\delta([\xi,\nu\xi], \nu^{-1/2}\sigma)$	2	-1	0	0	$\underset{-}{\mathbf{1}}$	$\underset{+-}{2}$	$\left[\frac{n^2}{4}\right]$
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	1	$\sigma(\varpi)$	0	$\underset{+}{\mathbf{1}}$	$\underset{+}{1}$	$\underset{++}{2}$	$\left[\frac{n+1}{2}\right]$
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)}, \xi\nu^{-1/2}\sigma)$	1	$-\sigma(\varpi)$	0	$\underset{-}{\mathbf{1}}$	$\underset{+}{1}$	$\underset{--}{2}$	$\left[\frac{n+1}{2}\right]$
	d	$L(\nu\xi, \xi \rtimes \nu^{-1/2}\sigma)$	0	1	$\underset{+}{\mathbf{1}}$	0	$\underset{+}{1}$	0	$\frac{1+(-1)^n}{2}$
VI	a	$\tau(S, \nu^{-1/2}\sigma)$	2	1	0	0	$\underset{+}{\mathbf{1}}$	$\underset{+-}{2}$	$\left[\frac{n^2}{4}\right]$
	b	$\tau(T, \nu^{-1/2}\sigma)$	2	1	0	0	0	0	0
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)}, \nu^{-1/2}\sigma)$	1	$-\sigma(\varpi)$	0	$\underset{-}{\mathbf{1}}$	$\underset{-}{1}$	$\underset{--}{2}$	$\left[\frac{n+1}{2}\right]$
	d	$L(\nu, 1_{F^\times} \rtimes \nu^{-1/2}\sigma)$	0	1	$\underset{+}{\mathbf{1}}$	$\underset{+}{1}$	$\underset{++}{2}$	$\underset{++}{2}$	$\left[\frac{n+2}{2}\right]$

A.9 Hecke Eigenvalues

Table A.14 lists the Hecke eigenvalues of the Hecke operators $T_{0,1}$ and $T_{1,0}$ defined in Sect. 6.1 on the newform of an irreducible, admissible representation of $\mathrm{GSp}(4, F)$ with trivial central character. The "N" column in Table A.14 gives the minimal paramodular level. Representations with no paramodular vectors have been marked by a "—" in the N, λ and μ columns. Otherwise λ denotes the eigenvalue of $T_{0,1}$ on the local newform, and μ denotes the eigenvalue of $T_{1,0}$. See Theorem 7.5.2 for how these eigenvalues are computed.

For typesetting reasons, some of the eigenvalues are given as (A), (B), (C) below.

(A) $q^2\big(\chi_1(\varpi) + \chi_2(\varpi) + \chi_1(\varpi)^{-1} + \chi_2(\varpi)^{-1} + 1 - q^{-2}\big)$
(B) $q^{3/2}(q+1)(\chi(\varpi) + \chi^{-1}(\varpi)) + q^2 - 1$
(C) $q^2(\chi(\varpi) + \chi^{-1}(\varpi) + q + 1) + q - 1$

Table A.14. Hecke eigenvalues

	inducing data	N	λ	μ
I	σ, χ_1, χ_2 unr.	0	$q^{3/2}\sigma(\varpi)\big(1 + \chi_1(\varpi) + \chi_2(\varpi) + \chi_1(\varpi)\chi_2(\varpi)\big)$	(A)
	σ unr., χ_1, χ_2 ram.	$a(\chi_1) + a(\chi_2)$	$q^{3/2}(\sigma(\varpi) + \sigma(\varpi)^{-1})$	0
	σ ram., $\sigma\chi_i$ unr.	$2a(\sigma)$	$q^{3/2}((\chi_1\sigma)(\varpi) + (\chi_2\sigma)(\varpi))$	0
	σ ram., $\sigma\chi_i$ ram.	$2a(\chi_1\sigma) + 2a(\sigma)$	0	$-q^2$
IIa	σ, χ unr.	1	$q^{3/2}(\sigma(\varpi) + \sigma(\varpi)^{-1}) + (q+1)(\sigma\chi)(\varpi)$	$q^{3/2}(\chi(\varpi) + \chi(\varpi)^{-1})$
	σ, χ ram., $\chi\sigma$ unr.	$2a(\sigma) + 1$	$q(\chi\sigma)(\varpi)$	$-q^2$
	σ unr., $\chi\sigma$ ram.	$2a(\chi)$	$q^{3/2}(\sigma(\varpi) + \sigma(\varpi)^{-1})$	0
	σ ram., $\chi\sigma$ ram.	$2a(\sigma) + 2a(\chi\sigma)$	0	$-q^2$
IIb	σ, χ unr.	0	$q^{3/2}(\sigma(\varpi) + \sigma(\varpi)^{-1}) + q(q+1)(\sigma\chi)(\varpi)$	(B)
	σ, χ ram., $\chi\sigma$ unr.	$2a(\sigma)$	$q(q+1)(\sigma\chi)(\varpi)$	0
	$\chi\sigma$ ram.	—	—	—

	inducing data	N	λ	μ
IIIa	σ unr.	2	$q(\sigma(\varpi)+\sigma(\varpi)^{-1})$	$-q(q-1)$
	σ ram.	$4a(\sigma)$	0	$-q^2$
IIIb	σ unr.	0	$q(q+1)\sigma(\varpi)(1+\chi(\varpi))$	(C)
	σ ram.	—	—	—
IVa	σ unr.	3	$\sigma(\varpi)$	$-q^2$
	σ ram.	$4a(\sigma)$	0	$-q^2$
IVb	σ unr.	2	$\sigma(\varpi)(1+q^2)$	$-q(q-1)$
	σ ram.	—	—	—
IVc	σ unr.	1	$\sigma(\varpi)(q^3+q+2)$	q^3+1
	σ ram.	—	—	—
IVd	σ unr.	0	$\sigma(\varpi)(q^3+q^2+q+1)$	$q(q^3+q^2+q+1)$
	σ ram.	—	—	—
Va	ξ,σ unr.	2	0	$-q^2-q$
	σ unr., ξ ram.	$2a(\xi)+1$	$\sigma(\varpi)q$	$-q^2$
	σ ram., $\sigma\xi$ unr.	$2a(\sigma)+1$	$-\sigma(\varpi)q$	$-q^2$
	$\sigma,\sigma\xi$ ram.	$2a(\xi\sigma)+2a(\sigma)$	0	$-q^2$
Vb	ξ,σ unr.	1	$\sigma(\varpi)(q^2-1)$	$-q^2-q$
	σ unr., ξ ram.	$2a(\xi)$	$\sigma(\varpi)q(q+1)$	0
	σ ram., $\sigma\xi$ unr.	—	—	—
	$\sigma,\sigma\xi$ ram.	—	—	—
Vc	ξ,σ unr.	1	$-\sigma(\varpi)(q^2-1)$	$-q^2-q$
	σ unr., ξ ram.	—	—	—
	σ ram., $\sigma\xi$ unr.	$2a(\sigma)$	$-\sigma(\varpi)q(q+1)$	0
	$\sigma,\sigma\xi$ ram.	—	—	—
Vd	ξ,σ unr.	0	0	$-(q^3+q^2+q+1)$
	ξ or σ ram.	—	—	—

	inducing data	N	λ	μ
VIa	σ unr.	2	$2q\sigma(\varpi)$	$-q(q-1)$
	σ ram.	$4a(\sigma)$	0	$-q^2$
VIb	σ unr.	—	—	—
	σ ram.	—	—	—
VIc	σ unr.	1	$\sigma(\varpi)(q+1)^2$	$q(q+1)$
	σ ram.	—	—	—
VId	σ unr.	0	$2q(q+1)\sigma(\varpi)$	$(q+1)(q^2+2q-1)$
	σ ram.	—	—	—
VII		$2a(\pi)$	0	$-q^2$
VIIIa		$2a(\pi)$	0	$-q^2$
VIIIb		—	—	—
IXa		$2a(\pi)+1$	0	$-q^2$
IXb		—	—	—
X	σ unr.	$a(\sigma\pi)$	$q^{3/2}(\sigma(\varpi)+\sigma(\varpi)^{-1})$	0
	σ ram.	$a(\sigma\pi)+2a(\sigma)$	0	$-q^2$
XIa	σ unr.	$a(\sigma\pi)+1$	$q\sigma(\varpi)$	$-q^2$
	σ ram.	$a(\sigma\pi)+2a(\sigma)$	0	$-q^2$
XIb	σ unr.	$a(\sigma\pi)$	$q(q+1)\sigma(\varpi)$	0
	σ ram.	—	—	—
super-	generic	≥ 2	0	$-q^2$
cuspidal	non-generic	—	—	—

A.10 Parahori-invariant Vectors

For the convenience of the reader, in this final section we list the dimensions of the subspaces of vectors fixed by $\mathrm{GSp}(4,\mathfrak{o})$, $\mathrm{K}(\mathfrak{p})$, $\mathrm{Kl}(\mathfrak{p})$, $\mathrm{Si}(\mathfrak{p})$ and I in Iwahori-spherical representations. This table appears on p. 269 of [Sch2]. The Atkin–Lehner eigenvalues for $\pi(u_1)$ listed in this table are correct if one assumes that: in group II, where the central character is $\chi^2\sigma^2$, the character $\chi\sigma$ is trivial; in groups IV, V and VI, where the central character is σ^2, the character σ itself is trivial. If these assumptions are not met, then one has to interchange all plus and minus signs.

Table A.15. Iwahori-spherical representations: Dimensions of spaces of parahori-invariant vectors

		representation	a	$\varepsilon(1/2,\varphi)$	$\mathrm{GSp}(4,\mathfrak{o})$	$\mathrm{K}(\mathfrak{p})$	$\mathrm{Kl}(\mathfrak{p})$	$\mathrm{Si}(\mathfrak{p})$	I
I		$\chi_1 \times \chi_2 \rtimes \sigma$ (irreducible)	0	1	1	2 +−	4	4 ++ −−	8 ++++ −−−−
II	a	$\chi\mathrm{St}_{\mathrm{GL}(2)} \rtimes \sigma$	1	$-(\sigma\chi)(\varpi)$	0	1 −	2	1 −	4 +−−−
	b	$\chi\mathbf{1}_{\mathrm{GL}(2)} \rtimes \sigma$	0	1	1	1 +	2	3 ++−	4 +++−
III	a	$\chi \rtimes \sigma\mathrm{St}_{\mathrm{GSp}(2)}$	2	1	0	0	1	2 +−	4 ++−−
	b	$\chi \rtimes \sigma\mathbf{1}_{\mathrm{GSp}(2)}$	0	1	1	2 +−	3	2 +−	4 ++−−
IV	a	$\sigma\mathrm{St}_{\mathrm{GSp}(4)}$	3	$-\sigma(\varpi)$	0	0	0	0	1 −
	b	$L(\nu^2,\nu^{-1}\sigma\mathrm{St}_{\mathrm{GSp}(2)})$	2	1	0	0	1	2 +−	3 ++−
	c	$L(\nu^{3/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-3/2}\sigma)$	1	$-\sigma(\varpi)$	0	1 −	2	1 −	3 +−−
	d	$\sigma\mathbf{1}_{\mathrm{GSp}(4)}$	0	1	1	1 +	1	1 +	1 +
V	a	$\delta([\xi,\nu\xi],\nu^{-1/2}\sigma)$	2	-1	0	0	1	0	2 +−
	b	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	1	$\sigma(\varpi)$	0	1 +	1	1 +	2 ++
	c	$L(\nu^{1/2}\xi\mathrm{St}_{\mathrm{GL}(2)},\xi\nu^{-1/2}\sigma)$	1	$-\sigma(\varpi)$	0	1 −	1	1 −	2 −−
	d	$L(\nu\xi,\xi \rtimes \nu^{-1/2}\sigma)$	0	1	1	0	1	2 +−	2 +−
VI	a	$\tau(S,\nu^{-1/2}\sigma)$	2	1	0	0	1	1 −	3 +−−
	b	$\tau(T,\nu^{-1/2}\sigma)$	2	1	0	0	0	1 +	1 +
	c	$L(\nu^{1/2}\mathrm{St}_{\mathrm{GL}(2)},\nu^{-1/2}\sigma)$	1	$-\sigma(\varpi)$	0	1 −	1	0	1 −
	d	$L(\nu,1_{F^\times} \rtimes \nu^{-1/2}\sigma)$	0	1	1	1 +	2	2 +−	3 ++−

Frequently Used Notations

F	non-archimedean local field of characteristic zero	27
$\mathfrak{o}$	ring of integers of F	27
$\mathfrak{p}$	maximal ideal of $\mathfrak{o}$	27
ϖ	generator of $\mathfrak{p}$	27
v	normalized valuation	27
ν	normalized absolute value (same as $\|\,\|$)	27
q	number of elements of $\mathfrak{o}/\mathfrak{p}$	27
ψ	character of F, trivial on $\mathfrak{o}$, non-trivial on $\mathfrak{p}^{-1}$	27
$a(\chi)$	conductor of the character χ	27
J	standard symplectic form	27
$\mathrm{GSp}(4)$	group of similitudes of a 4-dimensional symplectic space	27
λ	multiplier homomorphism on $\mathrm{GSp}(4)$	27
$\mathrm{Sp}(4)$	kernel of λ	27
Z	center of $\mathrm{GSp}(4)$	28
B	Borel subgroup of $\mathrm{GSp}(4)$ (upper triangular matrices)	28
U	unipotent radical of B	28
P	Siegel parabolic subgroup of $\mathrm{GSp}(4)$	29
Q	Klingen parabolic subgroup of $\mathrm{GSp}(4)$	29
A'	conjugate-inverse-transpose of the 2×2 matrix A	29
G^J	Jacobi subgroup of $\mathrm{GSp}(4)$	30
Z^J	center of G^J	30
W	the eight-element Weyl group of $\mathrm{GSp}(4)$	30
s_1, s_2	Weyl group elements	30
$\mathrm{K}(\mathfrak{p}^n)$	paramodular group of level $\mathfrak{p}^n$	31
u_n	Atkin–Lehner element	31
t_n	special element in $\mathrm{K}(\mathfrak{p}^n)$	31
$\mathrm{Kl}(\mathfrak{p}^n)$	Klingen congruence subgroup of level $\mathfrak{p}^n$	32
$\mathrm{Si}(\mathfrak{p}^n)$	Siegel congruence subgroup of level $\mathfrak{p}^n$	32
$\pi^\vee$	contragredient of the representation π	33
ω_π	central character of the representation π	33
δ	modulus character	33
Ind_P^G	normalized induction	33
R_U	normalized Jacquet module	33
ψ_{c_1,c_2}	character of $U(F)$	34
$\mathcal{W}(\pi,\psi_{c_1,c_2})$	Whittaker model of π with respect to ψ_{c_1,c_2}	34
$\chi_1 \times \chi_2 \rtimes \sigma$, $\pi \rtimes \sigma$, $\chi \rtimes \pi$	parabolic induction	35
$\tau\pi$	twist of π by the character τ	36
$\mathrm{St}_{\mathrm{GL}(2)}$	Steinberg representation of $\mathrm{GL}(2,F)$	37
$\mathbf{1}_{\mathrm{GL}(2)}$	trivial representation of $\mathrm{GL}(2,F)$	37
$e(\chi)$	exponent of the character χ	38
$X^*(T)$	algebraic homomorphisms $T \to \mathbb{G}_m$	41
$X_*(T)$	algebraic homomorphisms $\mathbb{G}_m \to T$	41

Ψ	based root datum	41
$(\hat{G}, \iota)$	dual group	41
W_F, W'_F	Weil group and Weil–Deligne group of F	47
(ρ, N)	representation of the Weil-Deligne group	47
V_ρ^{nil}	certain subspace of $\mathfrak{gl}(n, \mathbb{C})$ consisting of nilpotent elements	47
$\mathcal{C}(\varphi)$	$= \mathrm{Cent}(\varphi)/\mathrm{Cent}(\varphi)^0\,\mathbb{C}^\times$, the component group of φ	48
sp(2), sp(4)	certain representations of the Weil-Deligne group	52
$N_1, \ldots, N_6$	certain nilpotent elements in the Lie algebra of GSp(4)	53
$L(s, \varphi)$	L-factor of the W'_F-representation φ	60
$\varepsilon(s, \varphi, \psi)$	ε-factor of the W'_F-representation φ	60
$a(\varphi)$	conductor of the W'_F-representation φ	60
P_3	important subgroup of GL(3)	62
$\tau_{\mathrm{GL}(k)}^{P_3}$	representations of P_3	64
V_{Z^J}	space of coinvariants with respect to Z^J	63
V_0, V_1, V_2	certain subspaces of V_{Z^J} ($V_2 \subset V_1 \subset V_0$ is the P_3-filtration)	66
$Z(s, W)$	local zeta integral	76
$I(\pi)$	zeta integral ideal	78
$L(s, \pi)$	L-function of a generic representation π	81
$\gamma(s, \pi, \psi_{c_1,c_2})$	γ-factor of a generic representation π	81
$\varepsilon(s, \pi, \psi_{c_1,c_2})$	ε-factor of a generic representation π	82
$V(n)$	space of $\mathrm{K}(\mathfrak{p}^n)$ invariant vectors	85
V_{para}	space of all paramodular vectors (direct sum of the $V(n)$)	89
θ, θ'	level raising operators $V(n) \to V(n+1)$	91
η	level raising operator $V(n) \to V(n+2)$	92
N_π	minimal paramodular level	95
S	certain summation operator	100
I	Iwahori subgroup	104
δ_1, δ_2, δ_3	level lowering operators	111
p	the projection map $V \to V_{Z^J}$	119
P_W	zeta polynomial	126
λ_i^j	certain linear functionals on a Whittaker model	130
[ ]	greatest integer function	147
L_i, M_i	certain elements of $\mathrm{GSp}(4, \mathfrak{o})$	153
$\Gamma_1(\mathfrak{p}^n)$	congruence subgroup of $\mathrm{GL}(2, \mathfrak{o})$	156
$a(\tau)$	conductor of the L-parameter of the $\mathrm{GL}(2, F)$ representation τ	156
N_τ	level of the $\mathrm{GL}(2, F)$ representation τ	156
λ, μ	eigenvalues of $T_{0,1}$ resp. $T_{1,0}$ on the newform	213
R	certain summation operator	248
$Z_N(s, W)$	simplified zeta integral	248
Ad	homomorphism $\mathrm{GL}(2) \to \mathrm{SO}(3)$	287
ρ_5	homomorphism $\mathrm{GSp}(4) \to \mathrm{SO}(5)$	287

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