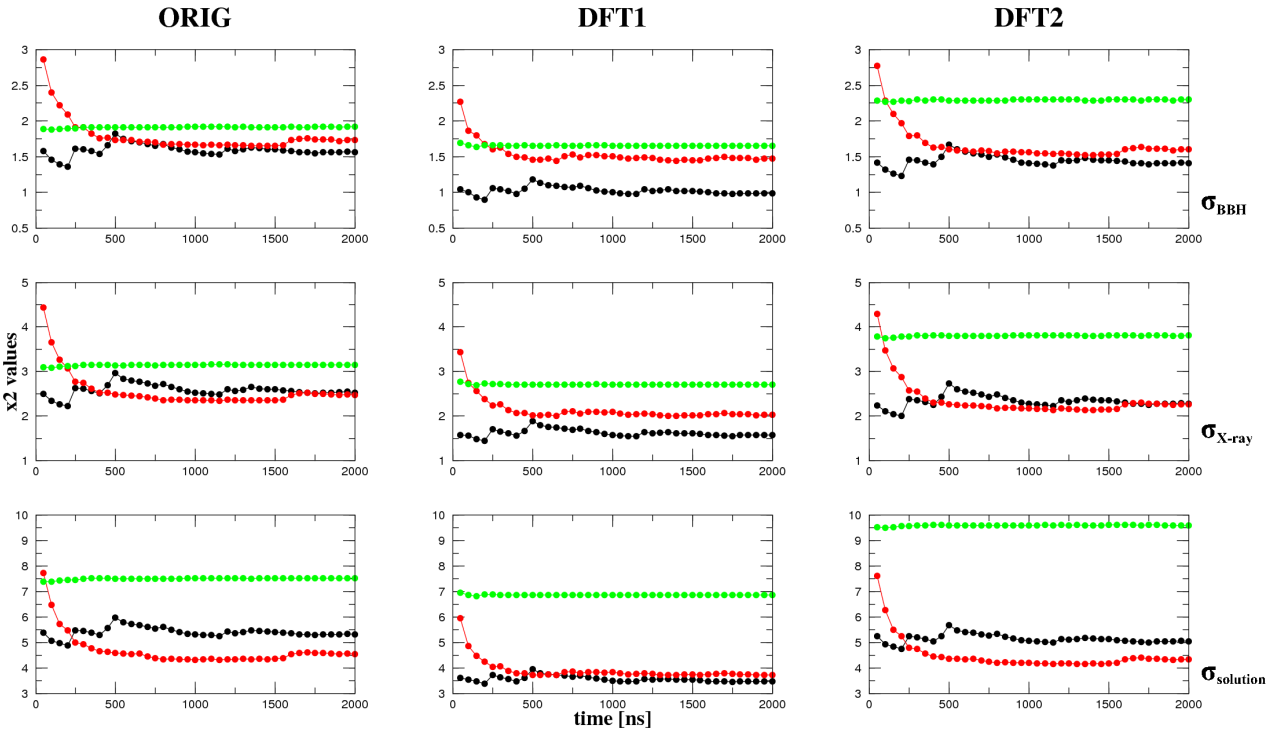
Supplementary Material for

Using J-coupling constants for force field validation: Application to hepta-alanine

Panagiota S. Georgoulia & Nicholas M. Glykos*

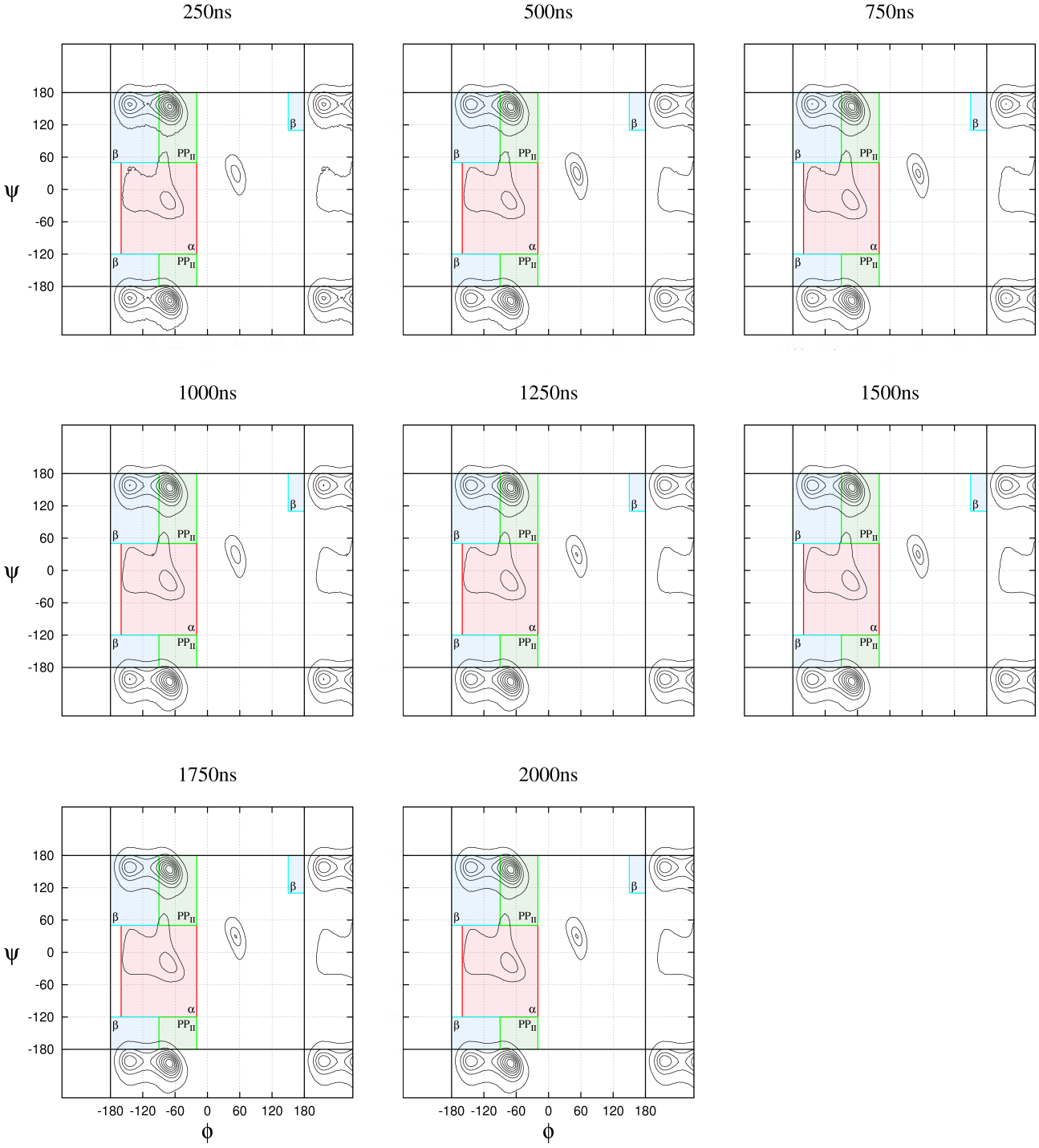
Department of Molecular Biology and Genetics, Democritus University of Thrace, University campus, 68100 Alexandroupolis, Greece, Tel +30-25510-30620, Fax +30-25510-30620, http://utopia.duth.gr/~glykos/ , glykos@mbg.duth.gr

Figure S1



Sufficient sampling and convergence : Variation of the χ^2 values for the three forcefields as a function of simulation time. For the calculation we have used all possible combinations of the three Karplus-equation parameter sets ORIG, DFT1, DFT2 with the three error sets, σ_{BBH}, $\sigma_{X\text{-}RAY}$, $\sigma_{SOLUTION}$, (see section §2.3 for details). The color code follows that of Figure 1, using black for AMBER, red for CHARMM and green for OPLS.

Figure S2



Cumulative Ramachandran plots vs. simulation time : Variation of cumulative Ramachandran plots for the AMBER force field as a function of simulation time. The diagrams are normalized such that the sum of their respective densities is constant. The α, β, and polyproline (PPII) Ramachandran regions are also shown using the definitions given by Best et al.[9]

Table S1

Residue	J-coupling	CHARMM			OPLS			AMBER			GROMOS[7]	Exp[7]
		ORIG	DFT1	DFT2	ORIG	DFT1	DFT2	ORIG	DFT1	DFT2		
2	$^3J(H_N,H_\alpha)$	6.511 (2.171)	6.325 (2.836)	6.676 (2.605)	7.726 (1.915)	7.858 (2.491)	8.415 (2.325)	6.980 (2.113)	6.901 (2.749)	7.339 (2.510)	5.5 (2.6)	5.61 (0.04)
	$^3J(H_N,C')$	1.312 (0.938)	1.404 (1.249)	1.226 (1.284)	0.693 (0.816)	0.630 (1.094)	0.522 (1.067)	1.127 (0.899)	1.184 (1.208)	1.009 (1.239)	1.5 (1.2)	1.15 (0.02)
	$^3J(H_\alpha,C')$	2.173 (1.499)	2.019 (1.545)	2.213 (1.611)	2.129 (0.619)	2.129 (0.795)	2.391 (0.867)	2.031 (0.980)	1.944 (1.096)	2.159 (1.158)	1.8 (1.2)	1.89 (0.32)
	$^3J(H_N,C_\beta)$	1.568 (0.918)	2.850 (2.065)	2.245 (1.675)	1.459 (0.802)	2.800 (1.721)	2.123 (1.416)	1.482 (0.935)	2.771 (2.056)	2.146 (1.679)	1.8 (0.8)	2.31 (0.05)
	$^1J(N,C_\alpha)$	10.850 (0.948)	10.850 (0.948)	10.850 (0.948)	11.307 (0.937)	11.307 (0.937)	11.307 (0.937)	11.351 (0.798)	11.351 (0.798)	11.351 (0.798)	10.4 (0.9)	11.37 (0.01)
	$^2J(N,C_\alpha)$	8.585 (0.317)	8.585 (0.317)	8.585 (0.317)	8.633 (0.246)	8.633 (0.246)	8.633 (0.246)	8.533 (0.353)	8.533 (0.353)	8.533 (0.353)	8.6 (0.2)	9.17 (0.02)
	$^3J(H_N,C_\alpha)$	0.598 (0.211)	0.598 (0.211)	0.598 (0.211)	0.687 (0.124)	0.687 (0.124)	0.687 (0.124)	0.698 (0.137)	0.698 (0.137)	0.698 (0.137)	0.6 (0.1)	0.71 (0.02)
3	$^3J(H_N,H_\alpha)$	6.563 (2.201)	6.387 (2.872)	6.798 (2.655)	7.737 (1.930)	7.875 (2.510)	8.428 (2.353)	6.925 (2.111)	6.853 (2.750)	7.280 (2.537)	5.4 (2.5)	5.66 (0.01)
	$^3J(H_N,C')$	1.213 (0.915)	1.270 (1.210)	1.089 (1.228)	0.689 (0.822)	0.624 (1.098)	0.522 (1.073)	1.092 (0.899)	1.119 (1.182)	0.981 (1.269)	1.5 (1.2)	1.20 (0.02)
	$^3J(H_\alpha,C')$	2.147 (1.439)	2.001 (1.496)	2.202 (1.564)	2.149 (0.671)	2.149 (0.832)	2.412 (0.902)	2.210 (1.364)	2.105 (1.413)	2.325 (1.467)	1.9 (1.4)	1.85 (0.20)
	$^3J(H_N,C_\beta)$	1.614 (0.892)	2.973 (1.990)	2.336 (1.621)	1.457 (0.796)	2.795 (1.707)	2.118 (1.406)	1.539 (0.895)	2.870 (1.985)	2.227 (1.623)	1.9 (0.7)	2.20 (0.10)
	$^1J(N,C_\alpha)$	10.687 (0.910)	10.687 (0.910)	10.687 (0.910)	11.134 (1.006)	11.134 (1.006)	11.134 (1.006)	11.103 (0.877)	11.103 (0.877)	11.103 (0.877)	10.2 (0.8)	11.27 (0.02)
	$^2J(N,C_\alpha)$	7.628 (1.228)	7.628 (1.228)	7.628 (1.228)	8.325 (0.760)	8.325 (0.760)	8.325 (0.760)	8.174 (1.033)	8.174 (1.033)	8.174 (1.033)	7.7 (1.0)	8.52 (0.03)
	$^3J(H_N,C_\alpha)$	0.528 (0.222)	0.528 (0.222)	0.528 (0.222)	0.645 (0.168)	0.645 (0.168)	0.645 (0.168)	0.618 (0.179)	0.618 (0.179)	0.618 (0.179)	0.5 (0.2)	0.66 (0.01)
4	$^3J(H_N,H_\alpha)$	6.771 (2.114)	6.675 (2.759)	6.996 (2.566)	7.738 (1.923)	7.877 (2.500)	8.424 (2.347)	7.091 (2.014)	7.104 (2.624)	7.391 (2.441)	5.5 (2.4)	5.77 (0.02
	$^3J(H_N,C')$	1.206 (0.941)	1.271 (1.254)	1.145 (1.290)	0.694 (0.826)	0.632 (1.104)	0.531 (1.080)	1.145 (0.927)	1.189 (1.213)	1.136 (1.377)	1.5 (1.1)	1.20 (0.05
	$^3J(H_\alpha,C')$	2.344 (1.622)	2.212 (1.641)	2.422 (1.705)	2.155 (0.691)	2.155 (0.844)	2.418 (0.913)	2.533 (1.722)	2.430 (1.711)	2.656 (1.755)	2.0 (1.5)	1.80 (0.14
	$^3J(H_N,C_\beta)$	1.533 (0.897)	2.749 (2.007)	2.158 (1.626)	1.453 (0.798)	2.782 (1.712)	2.109 (1.409)	1.440 (0.892)	2.597 (2.015)	2.011 (1.636)	1.9 (0.7)	2.23 (0.02
	$^1J(N,C_\alpha)$	10.650 (0.906)	10.650 (0.906)	10.650 (0.906)	11.127 (1.003)	11.127 (1.003)	11.127 (1.003)	11.014 (0.896)	11.014 (0.896)	11.014 (0.896)	10.1 (0.7)	11.22 (0.02
	$^2J(N,C_\alpha)$	7.370 (1.275)	7.370 (1.275)	7.370 (1.275)	8.171 (0.887)	8.171 (0.887)	8.171 (0.887)	7.852 (1.224)	7.852 (1.224)	7.852 (1.224)	7.4 (1.0)	8.29 (0.03
	$^3J(H_N,C_\alpha)$	0.504 (0.221)	0.504 (0.221)	0.504 (0.221)	0.623 (0.182)	0.623 (0.182)	0.623 (0.182)	0.586 (0.190)	0.586 (0.190)	0.586 (0.190)	0.4 (0.3)	0.56 (0.04
5	$^3J(H_N,H_\alpha)$	6.947 (2.145)	6.883 (2.793)	7.283 (2.627)	7.764 (1.905)	7.910 (2.477)	8.448 (2.327)	7.264 (1.992)	7.310 (2.590)	7.633 (2.405)	5.9 (2.4)	5.92 (0.02)
	$^3J(H_N,C')$	1.092 (0.943)	1.128 (1.251)	0.990 (1.261)	0.700 (0.832)	0.641 (1.116)	0.543 (1.095)	1.083 (0.910)	1.121 (1.204)	1.055 (1.334)	1.3 (1.0)	1.19 (0.06)
	$^3J(H_\alpha,C')$	2.229 (1.378)	2.125 (1.428)	2.345 (1.494)	2.161 (0.686)	2.164 (0.838)	2.427 (0.906)	2.427 (1.522)	2.351 (1.528)	2.583 (1.572)	2.0 (1.4)	1.56 (0.25)
	$^3J(H_N,C_\beta)$	1.530 (0.875)	2.810 (1.942)	2.187 (1.580)	1.438 (0.801)	2.749 (1.722)	2.082 (1.414)	1.402 (0.899)	2.551 (2.005)	1.963 (1.630)	1.9 (0.8)	2.23 (0.08)
	$^1J(N,C_\alpha)$	10.618 (0.867)	10.618 (0.867)	10.618 (0.867)	11.150 (1.002)	11.150 (1.002)	11.150 (1.002)	11.063 (0.890)	11.063 (0.890)	11.063 (0.890)	10.1 (0.7)	11.29 (0.01)
	$^2J(N,C_\alpha)$	7.252 (1.291)	7.252 (1.291)	7.252 (1.291)	8.165 (0.893)	8.165 (0.893)	8.165 (0.893)	7.694 (1.287)	7.694 (1.287)	7.694 (1.287)	7.1 (1.0)	8.22 (0.04)
6	$^3J(H_N,H_\alpha)$	7.282 (2.118)	7.335 (2.750)	7.563 (2.636)	7.914 (1.835)	8.107 (2.385)	8.621 (2.242)	7.348 (1.983)	7.408 (2.577)	7.743 (2.388)	6.2 (2.4)	6.04 (0.03)
	$^3J(H_N,C')$	1.191 (1.008)	1.282 (1.345)	1.217 (1.353)	0.681 (0.830)	0.623 (1.117)	0.547 (1.108)	1.068 (0.908)	1.111 (1.210)	1.036 (1.314)	1.3 (1.1)	1.10 (0.04)
	$^3J(H_\alpha,C')$	2.444 (1.520)	2.370 (1.534)	2.595 (1.598)	2.212 (0.700)	2.231 (0.834)	2.499 (0.897)	2.360 (1.389)	2.299 (1.410)	2.533 (1.456)	2.2 (1.6)	1.67 (0.20)
	$^3J(H_N,C_\beta)$	1.319 (0.892)	2.310 (1.972)	1.786 (1.597)	1.386 (0.795)	2.642 (1.712)	1.990 (1.403)	1.372 (0.906)	2.504 (2.008)	1.921 (1.634)	1.7 (0.8)	2.21 (0.04)
	$^1J(N,C_\alpha)$	10.900 (0.885)	10.900 (0.885)	10.900 (0.885)	11.080 (1.032)	11.080 (1.032)	11.080 (1.032)	11.189 (0.867)	11.189 (0.867)	11.189 (0.867)	10.1 (0.7)	11.29 (0.01)
	$^2J(N,C_\alpha)$	7.131 (1.314)	7.131 (1.314)	7.131 (1.314)	8.182 (0.881)	8.182 (0.881)	8.182 (0.881)	7.742 (1.279)	7.742 (1.279)	7.742 (1.279)	7.2 (1.1)	8.24 (0.01)
7	$^3J(H_N,H_\alpha)$	8.142 (1.621)	8.396 (2.112)	8.942 (1.953)	8.377 (1.636)	8.706 (2.129)	8.694 (2.298)	8.134 (1.807)	8.395 (2.348)	8.628 (2.201)	6.4 (2.7)	6.60 (0.03)
	$^3J(H_N,C')$	0.566 (0.764)	0.480 (1.043)	0.421 (1.036)	1.353 (1.070)	1.598 (1.468)	1.584 (1.360)	1.073 (0.925)	1.179 (1.264)	1.145 (1.269)	1.3 (1.2)	1.25 (0.05)
	$^3J(H_\alpha,C')$	2.221 (0.477)	2.268 (0.650)	2.549 (0.712)	2.314 (0.551)	2.385 (0.696)	2.621 (0.783)	2.283 (0.708)	2.325 (0.834)	2.574 (0.893)	2.2 (1.4)	2.03 (0.14)
	$^3J(H_N,C_\beta)$	1.365 (0.758)	2.624 (1.633)	1.962 (1.335)	0.709 (0.686)	1.060 (1.528)	0.752 (1.206)	1.013 (0.872)	1.806 (1.911)	1.328 (1.549)	1.6 (0.9)	1.99 (0.12)
	$^2J(N,C_\alpha)$	7.536 (1.330)	7.536 (1.330)	7.536 (1.330)	8.259 (0.740)	8.259 (0.740)	8.259 (0.740)	7.972 (1.165)	7.972 (1.165)	7.972 (1.165)	7.3 (1.1)	8.18 (0.02)
	$^3J(H_N,C_\alpha)$	0.590 (0.187)	0.590 (0.187)	0.590 (0.187)	0.765 (0.145)	0.765 (0.145)	0.765 (0.145)	0.680 (0.185)	0.680 (0.185)	0.680 (0.185)	0.5 (0.2)	0.59 (0.00)

Complete list of the J-coupling measurements from the molecular dynamics simulations with the three forcefields, CHARMM, OPLS, AMBER and the three Karplus-equation parameter sets, ORIG, DFT1 and DFT2 (see section §2.3 for details). The experimental scalar couplings (EXP) and the calculated ones for the GROMOS force field (GROMOS) were taken from Graf et al.[7]

Table S2

Force fields	Parameter set: ORIG	DFT1	DFT2	Exclusions	Error set
AMBER	**1.56**	**0.99**	**1.41**	NONE	σ_{BBH}
	1.43	0.73	1.00	$^3J(H_N, H_\alpha)$	
	1.84	1.17	1.65	$^3J(H_N, C')$	
	1.43	0.84	1.01	$^3J(H_\alpha, C')$	
	1.03	0.97	1.53	$^3J(H_N, C_\beta)$	
	1.78	1.12	1.60	$^1J(N, C_\alpha)$	
	1.68	1.01	1.51	$^2J(N, C_\alpha)$	
	1.70	1.07	1.54	$^3J(H_N, C_\alpha)$	
CHARMM	**1.73**	**1.47**	**1.60**	NONE	
	1.77	1.45	1.39	$^3J(H_N, H_\alpha)$	
	2.00	1.67	1.82	$^3J(H_N, C')$	
	1.72	1.51	1.39	$^3J(H_\alpha, C')$	
	1.44	1.36	1.85	$^3J(H_N, C_\beta)$	
	1.85	1.55	1.70	$^1J(N, C_\alpha)$	
	1.49	1.18	1.33	$^2J(N, C_\alpha)$	
	1.83	1.54	1.69	$^3J(H_N, C_\alpha)$	
OPLS	**1.92**	**1.65**	**2.30**	NONE	
	1.43	0.96	1.25	$^3J(H_N, H_\alpha)$	
	2.16	1.82	2.53	$^3J(H_N, C')$	
	2.05	1.73	2.14	$^3J(H_\alpha, C')$	
	1.30	1.51	2.38	$^3J(H_N, C_\beta)$	
	2.19	1.89	2.63	$^1J(N, C_\alpha)$	
	2.22	1.91	2.67	$^2J(N, C_\alpha)$	
	2.03	1.74	2.46	$^3J(H_N, C_\alpha)$	
AMBER	**2.53**	**1.56**	**2.28**	NONE	$\sigma_{X\text{-}RAY}$
	2.30	1.11	1.56	$^3J(H_N, H_\alpha)$	
	2.98	1.85	2.67	$^3J(H_N, C')$	
	2.27	1.28	1.57	$^3J(H_\alpha, C')$	
	1.61	1.50	2.46	$^3J(H_N, C_\beta)$	
	2.89	1.78	2.60	$^1J(N, C_\alpha)$	
	2.83	1.69	2.53	$^2J(N, C_\alpha)$	
	2.78	1.71	2.50	$^3J(H_N, C_\alpha)$	
CHARMM	**2.47**	**2.03**	**2.25**	NONE	
	2.45	1.92	1.82	$^3J(H_N, H_\alpha)$	
	2.84	2.29	2.55	$^3J(H_N, C')$	
	2.36	2.01	1.81	$^3J(H_\alpha, C')$	
	1.89	1.76	2.59	$^3J(H_N, C_\beta)$	
	2.70	2.20	2.45	$^1J(N, C_\alpha)$	
	2.37	1.84	2.11	$^2J(N, C_\alpha)$	
	2.66	2.17	2.42	$^3J(H_N, C_\alpha)$	
OPLS	**3.15**	**2.71**	**3.81**	NONE	
	2.32	1.53	2.02	$^3J(H_N, H_\alpha)$	
	3.55	2.97	4.18	$^3J(H_N, C')$	
	3.36	2.82	3.51	$^3J(H_\alpha, C')$	
	2.10	2.46	3.94	$^3J(H_N, C_\beta)$	
	3.61	3.10	4.36	$^1J(N, C_\alpha)$	
	3.68	3.16	4.45	$^2J(N, C_\alpha)$	
	3.41	2.92	4.14	$^3J(H_N, C_\alpha)$	
AMBER	**5.31**	**3.47**	**5.04**	NONE	$\sigma_{SOLUTION}$
	4.07	1.73	2.33	$^3J(H_N, H_\alpha)$	
	6.26	4.10	5.92	$^3J(H_N, C')$	
	5.24	3.28	4.31	$^3J(H_\alpha, C')$	
	3.47	3.40	5.49	$^3J(H_N, C_\beta)$	
	6.08	3.97	5.77	$^1J(N, C_\alpha)$	
	6.12	3.95	5.80	$^2J(N, C_\alpha)$	
	5.89	3.84	5.58	$^3J(H_N, C_\alpha)$	
CHARMM	**4.54**	**3.73**	**4.32**	NONE	
	3.85	2.87	2.40	$^3J(H_N, H_\alpha)$	
	5.22	4.20	4.88	$^3J(H_N, C')$	
	4.55	3.84	3.87	$^3J(H_\alpha, C')$	
	3.27	3.09	4.96	$^3J(H_N, C_\beta)$	
	5.08	4.14	4.83	$^1J(N, C_\alpha)$	
	4.81	3.85	4.55	$^2J(N, C_\alpha)$	
	4.97	4.06	4.72	$^3J(H_N, C_\alpha)$	
OPLS	**7.51**	**6.86**	**9.60**	NONE	
	4.35	2.72	3.37	$^3J(H_N, H_\alpha)$	
	8.53	7.64	10.71	$^3J(H_N, C')$	
	8.35	7.57	9.90	$^3J(H_\alpha, C')$	
	5.56	6.58	10.20	$^3J(H_N, C_\beta)$	
	8.61	7.86	11.00	$^1J(N, C_\alpha)$	
	8.83	8.07	11.30	$^2J(N, C_\alpha)$	
	8.27	7.54	10.59	$^3J(H_N, C_\alpha)$	

The full set of χ^2 values after excluding one of each of the seven types of J-couplings for all combinations of forcefields, Karplus-equation parameter sets (ORIG, DFT1, DFT2) and error sets

(σ_{BBH}, $\sigma_{X\text{-}RAY}$, $\sigma_{SOLUTION}$, see §2.3 for parameter and error set definitions). The values typeset with bold font are the χ^2 values obtained without excluding any type of J-couplings from the calculation.