$2\nu_2-\nu_2$ and $2\nu_2$ bands of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$: line positions and strengths

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High-resolution spectra of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$ were recorded with a Fourier-transform spectrometer, covering transitions in the (020)–(010) and (020)–(000) bands. The measured line frequencies were used to determine high-accuracy values of rotational energy levels in the (020) vibrational states for the three isotopic species. Measurements of the line strengths were fitted to a model in which 19 transition moment parameters were determined for each band and molecule. The fitting technique did not consider interactions between the (020), (100), and (001) vibrational states. The experimental results provide a more accurate representation of the line positions and strengths than those currently available for these bands.

INTRODUCTION

This study involves high-resolution measurements of line positions and absolute line strengths in the (020)–(010) and (020)–(000) bands of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$. This task complements my recent studies[1,2] of the (010)–(000) bands of $H_2{}^{16}O$[1], $H_2{}^{17}O$, and $H_2{}^{18}O$[2]. Although the (020) vibrational state is located a few hundred inverse centimeters below the (100) and (001) states for each isotopic species, several rotational levels in the (020) state are strongly perturbed by resonance interactions with levels in the (100) and (001) states. This study does not include perturbation calculations but rather includes computed line-strength values for the unperturbed results derived from a one-band least-squares fit of the experimental line strengths. Similar studies of the (100) and (001) vibrational states (and bands connecting the ground and ν_2 states) are under way.

Several reports[3-20] have included measurements and calculations of line positions and strengths for the (020)–(010) and (020)–(000) bands of H_2O. High-accuracy measurements of a few rotational transitions in excited vibrational states were obtained by Pearson *et al.*,[20] using millimeter and submillimeter laboratory techniques. They observed transition frequencies in the (000)–(000), (010)–(010), (020)–(020), (100)–(100), and (001)–(001) bands of $H_2{}^{16}O$, and here their results are compared with values derived from my recent work[1] on the (000) and (010) states and the results obtained in the present study for the (020) state.

As noted above, several rotational levels in the (020) state are perturbed owing to resonance interactions. Included in the scheme are distant interactions (Fermi type) between like rotational levels in the (020) and (100) states. The latter type interactions result in the borrowing of vibrational strength from one band to another [from the (100)–(000) band to the (020)–(000) band, for example). The experimental line strengths for each band of each isotopic species were analyzed by the method that I used in my recent reports.[1,2] Briefly, the method is based on the theory developed by Flaud and Camy-Peyret[14] in which the original 8 elements of the dipole moment expansion are used along with 11 additional terms in a least-squares analysis of the measured line strengths. Transitions that were obviously perturbed by resonance effects were not included in the fits; however, the distant Fermi-type interactions described above did not adversely affect the results.

EXPERIMENTAL DETAILS

The spectra were obtained with a Fourier-transform spectrometer (FTS) located at the McMath solar telescope facility at the Kitt Peak National Observatory. The experimental conditions and extent of the measurements are given in Table 1. The table lists the unapodized spectral resolution, absorption path lengths, total sample pressures, and percent abundance of each isotopic species for each run. The first 15 runs listed were of samples of normal H_2O, whereas the samples of the final 15 runs listed in the table contained enriched ^{17}O and ^{18}O. The $H_2{}^{17}O$ and $H_2{}^{18}O$ samples were purchased from Merck and Company, Inc.; the stated isotopic purities were 98.1% $H_2{}^{18}O$ for one sample and 60.4% $H_2{}^{17}O$ for the other. Because of slight contamination from various H_2O samples used before a given run of O-enriched H_2O, the values of the isotopic abundances were not always the same as the stated values, as is shown in the latter entries in the table. The method used to determine the correct relative amounts in the samples is described in my earlier report.[2] Briefly, the method is based on the knowledge of the manufacturer's stated isotopic purities and the $H_2{}^{17}O$ and $H_2{}^{18}O$ spectral absorptions observed in the $H_2{}^{16}O$ spectra (initial runs listed in Table 1). The $H_2{}^{17}O$ and $H_2{}^{18}O$ liquid samples obtained from the distributor were contained in sealed and evacuated glass tubes. The apparatus and method used to transfer the evaporated gas from the glass containers to the absorption cell are described in Ref. 2.

All the data were obtained with the sample temperatures near or at room temperature (296 K) with sample temperatures inferred from readings of one or more thermistor probes in thermal contact with the absorption cell walls. Total sample pressures were measured with a Baratron gauge. The spectral runs obtained with path lengths

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Table 1. Experimental Conditions of Measurements

Spectral Range (cm^{-1})	Unapodized Resolution (cm^{-1})	Path Length (m)	Sample Pressure (Torr)	Percent Abundance of Isotopic Species		
				$H_2{}^{16}O$[a]	$H_2{}^{17}O$	$H_2{}^{18}O$
1066–2200	0.0056	2.39	0.37	99.6	0.04	0.2
1066–2250	0.0056	2.39	1.18	99.6	0.04	0.2
1300–2300	0.0052	25	0.92	99.6	0.04	0.2
1300–2300	0.0052	97	0.86	99.6	0.04	0.2
1300–2300	0.0052	193	0.92	99.6	0.04	0.2
1300–2300	0.0052	433	0.87	99.6	0.04	0.2
1900–4506	0.011	433	7.10	99.6	0.04	0.2
1900–4506	0.011	433	13.1	99.6	0.04	0.2
2900–4200	0.011	2.39	0.34	99.6	0.04	0.2
2900–4200	0.011	2.39	2.25	99.6	0.04	0.2
2819–4356	0.011	25	1.18	99.6	0.04	0.2
2732–4364	0.011	25	3.86	99.6	0.04	0.2
2693–4364	0.011	76	3.86	99.6	0.04	0.2
2622–4457	0.011	193	3.98	99.6	0.04	0.2
2622–4506	0.011	433	4.01	99.6	0.04	0.2
1170–2149	0.0056	2.39	0.25	ND	0.62	98.1
1061–2192	0.0056	2.39	0.65	ND	0.62	98.1
1009–2192	0.0056	2.39	1.41	ND	0.62	98.1
1009–2299	0.0056	2.39	4.99	ND	0.62	98.1
1170–2129	0.0056	2.39	0.31	ND	42.9	35.8
1102–2198	0.0056	2.39	1.33	ND	52.1	30.7
1061–2224	0.0056	2.39	5.21	ND	59.9	27.3
2954–4124	0.011	2.39	0.30	25	0.47	73.5
2922–4235	0.011	2.39	1.08	17	0.52	81.3
2890–4254	0.011	2.39	5.30	6	0.58	92.2
2881–4298	0.011	2.39	13.8	4	0.60	94.0
2967–4131	0.011	2.39	0.52	15	52.6	31.7
2948–4196	0.011	2.39	1.07	15	54.1	30.5
2887–4292	0.011	2.39	5.06	14	56.8	28.1
2881–4298	0.011	2.39	13.8	14	57.7	26.6

[a]ND, not determined.

greater than 2.4 m ($H_2{}^{16}O$ samples) were made with the use of a 6-m-base-length multiple transversal cell. Unfortunately, when the 6-m cell was used a small amount of formamine was found to be absorbed onto the cell walls, and this was always present in the recorded spectra. Although the presence was minute, it made certain regions inaccessible for measurements of H_2O, namely, the 1550–1640- and 1711–1800-cm^{-1} regions, several areas between 3500 and 3600 cm^{-1}, and the entire region below 1300 cm^{-1}. This problem was noted in Ref. 1.

Another hindrance with either the 2.39-m cell or the 6-m-base-length cell was the added contributions from a combination of narrow, low-pressure absorptions as a result of a small amount of water vapor (50–200-μm total pressure) in the vacuum tank that enclosed the FTS and air-broadened $H_2{}^{16}O$ absorptions that were due to the H_2O content in the open spaces between the infrared source (a Globar) and the vacuum tank.

SPECTRAL ANALYSIS AND ENERGY LEVELS

The line centers were measured with two computer programs. One, labeled LINEFINDER, determines line-center positions and relative absorption peaks, and the other (NLLS) uses the technique of nonlinear least squares, in which absorption line positions, strengths, linewidths, and continuum parameters are fitted simultaneously in an interactive mode. The NLLS technique was used to determine experimental values of line strengths and the majority of line-center values. These computer algorithms have been used in several previous studies and recently in the analysis of data of the ν_2 bands of $H_2{}^{16}O$[1] and $H_2{}^{17}O$ and $H_2{}^{18}O$[2]. The input to the NLLS program for the stronger $H_2{}^{16}O$ lines in the (020)–(000) band included two line positions: one representing the slightly shifted, pressure-broadened contribution and the other for the desired low-pressure feature.

The measured line positions obtained by both techniques were calibrated and corrected to H_2O and N_2O calibration frequencies. The H_2O frequencies measured in the (020)–(010) bands were calibrated to those of the (010)–(000) bands.[1,2] Several of the well-measured transitions in the (020)–(010) band were then used (after correction) to determine a preliminary set of upper state, (020), rotational levels using the values of the (010) state rotational levels given in Refs. 1 and 2. These preliminary values were then used to compute rotational transitions in the (020)–(000) bands. The N_2O calibration was derived from my recent work on N_2O frequencies.[21] The N_2O spectra obtained in the 2500–4300 cm^{-1} region also contained H_2O features because of a small amount of water vapor in the FTS vacuum tank and air-broadened $H_2{}^{16}O$ absorptions. The H_2O low-pressure contributions were measured in the N_2O spectra with the aid of the LINEFINDER program. The computed transitions in the (020)–(000)

band and the measured $H_2{}^{16}O$ frequencies in the (020)–(000) band derived from N_2O were found to be in excellent agreement, and these H_2O transitions were used to calibrate the remainder of the H_2O lines in the 2600–4300-cm^{-1} region observed in the H_2O spectra.

The rotational energy levels in the (020) vibrational states of the three isotopic species were derived by the addition to each measured transition frequency of the (020)–(010) and (020)–(000) bands, the appropriate lower state level given in Ref. 1 for $H_2{}^{16}O$ and Ref. 2 for $H_2{}^{17}O$ and $H_2{}^{18}O$. These results were weighted and then averaged for each level. Table 2 lists values of the rotational

Table 2. Rotational Energy Levels (cm^{-1}) of the (020) Vibrational States of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$[a]

J	K_a	K_c	$H_2{}^{16}O$		$H_2{}^{17}O$		$H_2{}^{18}O$	
0	0	0	3151.63015	5	3144.98051	12	3139.04970	7
1	0	1	3175.44134	3	3168.76987	7	3162.82037	3
1	1	1	3196.09338	3	3189.17376	5	3183.00501	3
1	1	0	3201.91337	5	3195.01050	18	3188.85719	4
2	0	2	3221.96118	3	3215.22971	2	3209.22624	5
2	1	2	3237.91733	4	3230.93737	4	3224.71452	6
2	1	1	3255.34594	3	3248.41705	10	3242.23924	10
2	2	1	3316.14537	5	3308.49234	8	3301.67406	5
2	2	0	3317.21063	4	3309.57493	8	3302.77181	15
3	0	3	3289.24254	3	3282.38741	4	3276.27338	2
3	1	3	3299.99111	6	3292.91109	3	3286.59870	4
3	1	2	3334.62656	6	3327.64464	10	3321.41967	3
3	2	2	3387.68067	6	3379.96116	15	3373.08318	4
3	2	1	3392.74937	4	3385.10552	8	3378.29607	4
3	3	1	3500.51111	6	3491.69413	40	3483.84567	8
3	3	0	3500.63874	2	3491.82603	13	3483.98060	5
4	0	4	3375.29786	4	3368.24726	15	3361.95836	5
4	1	4	3381.70430	6	3374.47825	5	3368.03562	4
4	1	3	3438.57499	2	3431.49385	23	3425.17952	12
4	2	3	3482.06452	3	3474.24200	3	3467.27223	11
4	2	2	3495.93921	6	3488.30125	10	3481.49761	10
4	3	2	3597.86611	3	3588.98313	9	3581.07543	7
4	3	1	3598.72703	4	3589.86929	20	3581.98441	5
4	4	1	3746.76274	2	3736.40785	9	3727.19625	6
4	4	0	3746.77603	4	3736.42177	25	3727.21062	10
5	0	5	3478.98654	3	3471.68411	9	3465.17074	3
5	1	5	3482.48022	5	3475.05882	40	3468.44193	8
5	1	4	3565.45464	2	3558.19745	15	3551.72501	5
5	2	4	3598.51596	5	3590.54463	25	3583.44122	8
5	2	3	3626.92221	3	3619.27547	10	3612.46369	5
5	3	3	3719.49292	5	3710.52236	8	3702.53688	11
5	3	2	3722.73109	4	3713.85137	10	3705.94859	3
5	4	2	3868.87302	2	3858.43889	35	3849.15618	15
5	4	1	3868.98701	3	3858.55736	15	3849.27961	6
5	5	1	4050.50393	11	4038.29844	30	4027.44761	40
5	5	0	4050.51289	11	4038.29961	27	4027.44919	12
6	0	6	3600.05237	4	3592.45943	20	3585.68739	3
6	1	6	3601.85892	2	3594.19274	10	3587.35768	5
6	1	5	3713.08250	3	3705.54385	11	3698.81692	5
6	2	5	3736.17085	5	3727.99455	25	3720.70839	4
6	2	4	3784.67916	5	3776.97220	40	3770.10488	20
6	3	4	3864.96620	5	3855.87651	27	3847.78449	15
6	3	3	3873.79379	4	3864.93430	40	3857.05163	7
6	4	3	4015.51517	4	4004.98960	30	3995.62744	10
6	4	2	4016.05289	5	4005.55062	13	3996.20955	20
6	5	2	4197.33887	4	4185.03532	50	4174.09656	10
6	5	1	4197.36108	4	4184.94476	50	4174.10525	25
6	6	1	4407.04639	4	4392.82048	35	4379.86781	20
6	6	0	4407.15788	13	4392.67089	35	4380.05315	45
7	0	7	3738.60918	3	3730.69386	10	3723.63477	4
7	1	7	3739.51886	3	3731.56124	20	3724.46591	5
7	1	6	3879.33628	4	3871.40435	20	3864.32519	8
7	2	6	3894.16782	3	3885.72495	45	3878.19957	10
7	2	5	3967.48855	5	3959.63485	30	3952.63451	7
7	3	5	4033.61455	5	4024.25917	120	4016.12198	45
7	3	4	4052.83702	6	4044.03085	25	4036.19767	15
7	4	4	4186.56963	8	4175.93925	40	4166.48450	45
7	4	3	4188.39442	3	4177.83937	30	4168.45415	10
7	5	3	4368.54608	3	4356.10953	300	4345.13890	40
7	5	2	4368.63709	6	4356.23510	50	4345.22003	43
7	6	2	4578.88250	3	4564.51379	300	4552.19560	17
7	6	1	4578.97810	10	4563.77795	8	4551.46218	20
7	7	1	4812.19313	21				
7	7	0	4812.19313	21				
8	0	8	3894.79901	7	3886.52931	40	3879.15433	30
8	1	8	3895.25304	3	3886.95931	10	3879.56462	20
8	1	7	4062.83808	8	4054.43257	300	4046.92940	40
8	2	7	4071.73344	5	4062.95883	25	4055.13678	15
8	2	6	4173.22584	8			4157.86052	20
8	3	6	4224.58667	8	4215.11004	15	4206.67214	15
8	3	5	4259.87654	6			4243.31121	15
8	4	5	4381.73551	8	4370.97458	165	4361.40733	10
8	4	4	4386.31325	6			4366.71745	25
8	5	4	4564.03483	10	4551.56987	50	4540.37063	40
8	5	3	4564.36667	5			4540.73940	40
8	6	3	4774.80498	6	4760.32400	300	4747.68711	20
8	6	2	4775.08841	8	4759.39835	40	4746.96530	300
8	7	2	5008.96301	21				
8	7	1	5008.96310	30				
8	8	1	5261.47098	40				
8	8	0	5261.47098	40				
9	0	9	4068.70392	4	4060.04533	25	4052.32482	40
9	1	9	4068.93111	12	4060.25980	19	4052.52760	15
9	1	8	4263.15049	6	4254.22548	135	4246.26202	20
9	2	8	4268.24095	7	4259.07123	50	4250.89710	50
9	2	7	4399.54219	6	4391.00430	40	4383.37656	40
9	3	7	4436.94054	10			4418.47205	40
9	3	6	4493.80443	8			4477.17310	50
9	4	6	4600.49746	10				
9	4	5	4611.79486	7			4591.95867	50
9	5	5	4783.64115	10				
9	5	4	4784.66215	4			4760.86383	40
9	6	4	4994.70297	45				
9	6	3	4996.33150	15				
9	7	3	5229.57686	50				
9	7	2	5229.57915	9				
9	8	2	5483.32345	15				
9	8	1	5483.32345	15				
9	9	1	5748.51286	60				
9	9	0	5748.51286	60				
10	0	10	4260.35188	3	4251.26750	300	4243.16991	20
10	1	10	4260.46692	8	4251.37621	9	4243.27210	10
10	1	9	4480.39238	8			4462.47736	20
10	2	9	4483.22802	7	4473.60735	40	4465.02850	9
10	2	8	4644.21708	9				
10	3	8	4669.73608	5			4650.56735	300
10	3	7	4752.73317	9				
10	4	7	4842.13152	10				
10	4	6	4864.37344	15				
10	5	6	5027.07422	8				
10	5	5	5029.81081	12	5016.93455	20		
10	6	5	5238.38633	25				
10	6	4	5237.42028	12				
10	7	4	5473.80301	220				
10	7	3	5473.81253	270				
10	8	3	5728.02500	600				
10	8	2	5728.02500	600				
10	9	2	5994.37695	200				
10	9	1	5994.37695	200				
10	10	1	6318.36818	400				
10	10	0	6318.36818	400				
11	0	11	4469.73745	7	4460.19366	50	4451.68444	15
11	1	11	4469.79655	5	4460.24799	300	4451.73578	20
11	1	10	4714.81893	11			4695.83585	40
11	2	10	4716.37945	11				
11	2	9	4905.65368	9				
11	3	9	4922.09005	19				
11	3	8	5034.38755	20				
11	4	8	5105.72993	15				
11	4	7	5144.40926	12				
11	5	7	5293.79093	200				
11	5	6	5300.17815	30				
11	6	6	5505.48824	400				
11	6	5	5505.17348	50				
11	7	5	5741.19043	300				
11	7	4	5741.36145	300				
12	0	12	4696.83433	22			4677.83752	300
12	1	12	4696.86542	9	4686.82157	300	4677.86534	40
12	1	11	4966.63309	14				
12	2	11	4967.49095	12			4947.28958	300
12	2	10	5182.09498	15				
12	3	10	5193.88216	15			5173.85749	50

(Table continued)

Table 2. Continued

J	K_a	K_c	$H_2{}^{16}O$	$H_2{}^{17}O$	$H_2{}^{18}O$
12	3	9	5336.32707 80		
12	4	9	5389.55208 35		
12	4	8	5450.88959 300		
12	5	8	5587.51879 15		
12	5	7	5596.31840 400		
12	6	7	5795.73063 400		
13	0	13	4941.60570 50		4921.59710 100
13	1	13	4941.62242 60		4921.59900 300
13	1	12	5235.95804 60		
13	2	12	5236.01263 830		
13	2	11	5477.00637 35		
13	3	11	5483.28000 700		
13	3	10	5654.76131 80		
13	4	10	5695.67200 800		
13	4	9	5781.96170 500		
14	0	14	5204.01500 100		
14	1	14	5204.01570 60		
14	2	12	5786.85327 80		
14	3	12	5790.43269 40		
14	4	10	6134.94002 800		
14	6	9	6443.79063 800		
15	0	15	5483.99625 80		
15	1	15	5483.99625 100		
15	3	12	6345.92236 15		

[a]Estimated uncertainties given in inverse centimeters times 10^5.

Table 3. Matrix Elements Used in the Expansion of the Dipole Moment for B-type Transitions of Water Vapor

j	n	$\langle JK\|A'(j)\|J'K'\rangle/\langle JK\|\Phi(x)\|J'K+\Delta K\rangle$, $\Delta K = \pm 1$
2	1	$J'(J'+1) + J(J+1)$[a]
3	1	$K'^2 + K^2$[a]
4	1	$K'^2 - K^2$[a]
5	1	$K'^2 - K^2 - 2m$[a]
6	1	$(K'^2 - K^2)(K'^2 - K^2 - 2m)$[a]
7	1	$J(J+1) - 2m(m-1) + (2m-1)K\Delta K - K^2 - 1$[a]
8	3	$[(J' - K\Delta K - 1)(J' - K\Delta K - 2)(J' + K\Delta K + 2)(J' + K\Delta K + 3)]^{1/2}$[a]
9	1	$K'^2 J'(J'+1) - K^2 J(J+1)$
10	1	$K'^4 - K^4$
11	1	$(K'^2 - K^2)[J'(J'+1) + J(J+1)]$
12	1	$K'^2(J'^2 + J')^2$
13	1	K'^6
14	1	K'^4
15	1	$K'^2 J'(J'+1)$
16	1	$K'^6 - K^6$
17	1	$J'(J'+1)$ if $m = 0$ and $J = K_c$ or $J' = K_c'$, otherwise 0
18	1	$J'(J'+1)$ if $m = 0$ and $J = K_c$ or $J' = K_c' - 1$, otherwise 0
19	1	$J'(J'+1)$ if $m \neq 0$ and $J = K_c$ and $J' = K_c'$, otherwise 0

[a]From Ref. 14; $J' - J = 0, \pm 1$; $m = [J'(J'+1) - J(J+1)]/2$; $K' - K = n\Delta K$.

energy levels obtained in this study for the (020) states of the three species. Included in the table are estimations of the uncertainties in the values.

LINE STRENGTHS

The strength S of an H_2O transition at frequency ν may be expressed to good approximation by

$$S = C\left(\frac{\nu}{Q}\right)\left(\frac{g}{T}\right)\left[1 - \exp\left(\frac{-\nu}{kt}\right)\right]\exp\left[\frac{-E(L)}{kt}\right]|R(L,U)|^2,$$

where

$$C = 8\pi^3/3hc,$$

$$Q = Q_V Q_R,$$

$$E(L) = E_V(L) + E_R(L), \qquad (1)$$

where Q is the partition function, which can be expressed as the product of the vibrational, Q_V, and the rotational, Q_R, partition functions; g is the degeneracy that is due to the nuclear spin of the lower-state level; k is the Boltzmann constant; T is the temperature; $E(L)$ is the lower-state energy, which is equal to the sum of the lower-state vibrational energy $E_V(L)$ and the rotational energy $E_R(L)$; and $R(L,U)$ is the vibration–rotation dipole moment matrix element connecting the lower state L with the upper state U. When $T = 296$ K, Q_R is 175.0, 175.5, and 176.1 for $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$, respectively, and $Q_V = 1.0004$ for the three species and for temperatures within 30 K of 300 K, $Q(T) = Q(296\text{ K})\,(296/T)^{3/2}$.

Without consideration of near-resonance effects, the vibration–rotation dipole moment element, $R(L,U)$, given in Eq. (1), can be expressed as

$$R(L.U) = \sum_j u(j)x(j),$$

$$x(j) = \langle V'', J'', K_a'', K_c''|A(j)|V', J', K_a', K_c'\rangle, \qquad (2)$$

where $u(j)$ are the dipole moment coefficients, $A(j)$ are the transformed transition moment operators, and prime and double prime denote upper and lower states, respectively. $x(1)$ is the matrix element of the direction cosines in which $A(1) = \Phi_\alpha$ with $\alpha = z$ for A-type transitions and $\alpha = x$ for B-type transitions. The asymmetric top wave functions, $AS(V, J, K_a, K_c)$, are expressed as an expansion of the symmetry-adapted wave functions, $s(J, K, \gamma)$, as

$$AS(V, J, K_a, K_c) = \Psi_v C(J, K_a, K_c\,|\,J, K, \gamma)s(J, K, \gamma), \qquad (3)$$

where the C's are coefficients of the wave functions, thus expressing the lower- and the upper-state wave functions in terms of symmetry-adapted rotational wave functions.

The matrix elements involved in $R(L,U)$ and used in this study are given in Table 3. The elements $j = 2$ to $j = 8$ are those given by Flaud and Camy-Peyret,[14] and the following 11 terms ($j = 9$ to $j = 19$) were empirically derived and found to be necessary in the $H_2{}^{16}O$ analysis[1] of the (010)–(000) band. The analysis of the ν_2 bands of $H_2{}^{17}O$ and $H_2{}^{18}O$[2] used as many as 18 matrix elements ($j = 1$ to and including $j = 18$).

The measured line strengths were least-squares fitted by use of the expressions given in Eqs. (1)–(3) and outlined in Ref. 1. The matrix elements of the direction cosines were computed from the vibration–rotation parameters given in the literature: the (000) and (010) states of $H_2{}^{16}O$ from Ref. 1, the (020) state of $H_2{}^{16}O$ from Ref. 11, the (000) and (010) states of $H_2{}^{17}O$ and $H_2{}^{18}O$ from Ref. 22, and the (020) states of $H_2{}^{17}O$ and $H_2{}^{18}O$ from Ref. 12. It should be noted that the measured line strengths were normalized to 100% of the isotopic sample, and these normalized values were used in the analyses. Values and associated estimated uncertainties of the matrix elements of the expanded dipole moment derived from the fits are given in Table 4. The lowest two rows for each band and isotopic species list the number of lines fitted and the values of the standard deviation in percent, $\sigma\%$, of the line-

Table 4. Effective Dipole Moment Expansion Coefficients (in debyes) Derived from Least-Squares Fits of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$ Measured Line Strengths in the (020)–(010) and (020)–(000) Bands[a]

j	$H_2{}^{16}O$	$H_2{}^{17}O$	$H_2{}^{18}O$	$H_2{}^{16}O$[b]		
(020)–(010) Bands						
1	0.1990(14)	0.1963(32)	0.1951(12)	0.1807(200)		
2	$-1.33(125) \times 10^{-5}$	$-5.31(898) \times 10^{-5}$	$-1.15(309) \times 10^{-5}$			
3	$-1.66(389) \times 10^{-4}$	$3.54(948) \times 10^{-4}$	$2.07(462) \times 10^{-4}$	$-7.24(482) \times 10^{-5}$		
4	$-1.266(14) \times 10^{-2}$	$-1.281(62) \times 10^{-2}$	$-1.137(33) \times 10^{-2}$	$-8.73(200) \times 10^{-3}$		
5	$-4.69(74) \times 10^{-4}$	$-8.0(147) \times 10^{-5}$	$-5.05(51) \times 10^{-4}$			
6	$-7.08(99) \times 10^{-5}$	$-6.10(347) \times 10^{-5}$	$-2.93(68) \times 10^{-5}$	$-1.70(150) \times 10^{-4}$		
7	$3.65(83) \times 10^{-5}$	$1.53(15) \times 10^{-4}$	$2.97(79) \times 10^{-5}$			
8	$-6.49(227) \times 10^{-5}$	$-6.2(115) \times 10^{-5}$	$2.4(301) \times 10^{-6}$			
9	$5.9(143) \times 10^{-6}$	$5.21(481) \times 10^{-5}$	$-5.22(124) \times 10^{-5}$			
10	$1.07(33) \times 10^{-4}$	$1.73(99) \times 10^{-4}$	$9.36(302) \times 10^{-5}$			
11	$-5.98(757) \times 10^{-6}$	$-4.77(237) \times 10^{-5}$	$1.77(71) \times 10^{-5}$			
12	$3.00(219) \times 10^{-8}$	$-6.97(554) \times 10^{-7}$	$2.25(101) \times 10^{-7}$			
13	$5.5(128) \times 10^{-7}$	$5.50(576) \times 10^{-6}$	$4.8(265) \times 10^{-7}$			
14	$-2.18(641) \times 10^{-6}$	$-2.46(245) \times 10^{-4}$	$-9(107) \times 10^{-6}$			
15	$-2.21(435) \times 10^{-6}$	$8.36(565) \times 10^{-5}$	$-2.15(135) \times 10^{-5}$			
16	$-1.31(70) \times 10^{-6}$	$-3.36(163) \times 10^{-6}$	$-1.02(61) \times 10^{-6}$			
17	$1.26(63) \times 10^{-4}$	$1.00(281) \times 10^{-4}$	$2.20(98) \times 10^{-4}$			
18	$4.74(255) \times 10^{-5}$	$8.7(1078) \times 10^{-6}$	$1.44(31) \times 10^{-4}$			
19	$-1.83(473) \times 10^{-5}$	$2.52(219) \times 10^{-4}$	$1.00(64) \times 10^{-4}$			
N[c]	201	98	141	20		
$\sigma\%$[d]	3.4	5.5	4.5	6.6		
(020)–(000) Bands						
				$H_2{}^{16}O$[e]	$H_2{}^{17}O$[f]	$H_2{}^{18}O$[g]
1	$7.742(12) \times 10^{-3}$	$7.813(23) \times 10^{-3}$	$7.850(32) \times 10^{-3}$	$7.266(190) \times 10^{-3}$	$7.193(147) \times 10^{-3}$	$6.842(88) \times 10^{-3}$
2	$-2.95(59) \times 10^{-7}$	$6.22(537) \times 10^{-7}$	$-2.01(28) \times 10^{-6}$	$1.94(109) \times 10^{-6}$	$3.18(170) \times 10^{-6}$	$1.83(84) \times 10^{-5}$
3	$1.22(235) \times 10^{-6}$	$-1.42(87) \times 10^{-5}$	$-1.46(96) \times 10^{-5}$			$7.84(559) \times 10^{-7}$
4	$-2.006(15) \times 10^{-4}$	$-1.82(11) \times 10^{-4}$	$-1.701(46) \times 10^{-4}$	$-1.71(26) \times 10^{-4}$	$-2.49(28) \times 10^{-4}$	$-1.66(12) \times 10^{-4}$
5	$6.942(43) \times 10^{-5}$	$6.83(11) \times 10^{-5}$	$6.660(68) \times 10^{-5}$	$7.22(156) \times 10^{-5}$	$9.60(240) \times 10^{-5}$	$6.98(65) \times 10^{-5}$
6	$1.454(43) \times 10^{-6}$	$1.18(15) \times 10^{-6}$	$9.40(63) \times 10^{-7}$	$-5.04(240) \times 10^{-6}$	$-7.99(359) \times 10^{-6}$	$-2.61(159) \times 10^{-6}$
7	$-3.483(28) \times 10^{-6}$	$-3.71(20) \times 10^{-6}$	$-3.57(10) \times 10^{-6}$	$-3.71(140) \times 10^{-6}$	$-5.12(329) \times 10^{-6}$	$-4.11(109) \times 10^{-6}$
8	$7.60(143) \times 10^{-7}$	$1.43(63) \times 10^{-6}$	$1.54(42) \times 10^{-6}$			
9	$-1.941(44) \times 10^{-6}$	$-1.35(23) \times 10^{-6}$	$-1.896(75) \times 10^{-6}$			
10	$4.99(54) \times 10^{-7}$	$-2.36(117) \times 10^{-6}$	$-1.58(61) \times 10^{-6}$			
11	$9.31(23) \times 10^{-7}$	$7.24(135) \times 10^{-7}$	$8.27(41) \times 10^{-7}$			
12	$-1.32(382) \times 10^{-10}$	$6.65(378) \times 10^{-9}$	$7.18(126) \times 10^{-9}$			
13	$8.50(332) \times 10^{-9}$	$-1.46(87) \times 10^{-7}$	$4.1(434) \times 10^{-9}$			
14	$-4.34(245) \times 10^{-7}$	$4.54(243) \times 10^{-6}$	$1.06(185) \times 10^{-6}$			
15	$2.37(547) \times 10^{-8}$	$-7.43(380) \times 10^{-7}$	$-2.51(134) \times 10^{-7}$			
16	$-1.076(72) \times 10^{-8}$	$2.48(325) \times 10^{-8}$	$2.51(120) \times 10^{-8}$			
17	$2.52(39) \times 10^{-6}$	$1.05(178) \times 10^{-6}$	$2.98(128) \times 10^{-6}$			
18	$1.02(19) \times 10^{-6}$	$1.10(65) \times 10^{-6}$	$8.64(390) \times 10^{-7}$			
19	$1.94(25) \times 10^{-6}$	$9.3(140) \times 10^{-7}$	$2.31(86) \times 10^{-6}$			
N[c]	366	136	252			
$\sigma\%$[d]	3.5	2.6	3.9			

[a]Values given within parentheses are uncertainties in the last digit(s).
[b]From Ref. 17; effective constants were computed from the constants given in that study.
[c]N represent the number of line strengths used in the least-squares fit.
[d]$\sigma\%$ is the standard deviation resulting from the least-squares fit in percent; $\sigma\% = \{\Sigma[(S_{obs} - S_{cal})/S_{obs}]^2/N\}^{1/2} \times 100$.
[e]From Ref. 14. Effective constants were computed from the constants given in that study.
[f]From Ref. 15. Effective constants were computed from the constants given in that study.
[g]From Ref. 16. Effective constants were computed from the constants given in that study.

strength fits. σ% is defined as

$$\sigma\% = 100\left\{\sum [S_{obs} - S_{cal}]/S_{obs}]^2/N\right\}^{1/2}, \tag{4}$$

where N is the number of lines included in the fit. Measured line strengths of transitions strongly affected by resonance effects were not included in the analyses. Included in Table 4 are values of matrix elements derived in other studies: the (020)–(010) band of $H_2{}^{16}O$ by Flaud *et al.*,[17] the (020)–(000) band of $H_2{}^{16}O$ by Flaud and Camy-Peyret,[14] the (020)–(000) band of $H_2{}^{17}O$ by Camy-Peyret *et al.*,[15] and the (020)–(000) band of $H_2{}^{18}O$ by Flaud *et al.*[16] Those studies[14–17] took into account the interactions among the three vibrational states (020), (100), and (001). To compare those results with the present values involves uncoupling the Fermi-type interaction between the (020) and (100) states. The method used here to do this is to apply the expressions

$$C_{32} = h_{32}/(E_3 - E_2),$$
$$C_{23} = h_{32}/(E_2 - E_3),$$
$$C_{22} = C_{33} = (1 - C_{23}{}^2)^{1/2}$$
$$\mu_2{}^0(j) = C_{22}\mu_2(j) + C_{23}\mu_3(j),$$
$$\mu_3{}^0(j) = C_{33}\mu_3(j) + C_{32}\mu_2(j), \tag{5}$$

where h_{32} is the first-order coupling constants between the (100) state (index 3) and (020) state (index 2). E_3 and E_2 are the observed rotationless energy levels for the (100) and (020) vibrational states and $\mu_n(j)$ are the matrix elements obtained in the other studies.[14–17] $\mu_n{}^0(j)$ are the uncoupled constants representing the other studies, and the computed values are included in Table 4. The computed values of $\mu_n{}^0(j)$ were derived from Eqs. (5) with the coupling constant, h_{32}, given in Ref. 11 for $H_2{}^{16}O$ and from Ref. 12 for $H_2{}^{17}O$ and $H_2{}^{18}O$ and the matrix elements, $\mu_n(j)$, given in Refs. 14–17. These computed values represent a first approximation to the uncoupled constants. Higher-order terms, h_{32}', etc., and more involved expressions than those given in Eqs. (5) are involved in obtaining a higher-order approximation of $\mu_n{}^0(j)$. However, the first-order results given in Table 4 are good approximations.

RESULTS

Table 5 lists lines of the transitions observed in the (020)–(010) bands of $H_2{}^{16}O$, $H_2{}^{17}O$, and $H_2{}^{18}O$. Entries for the table include the observed line position, the observed minus the computed line position (o − c), rotational quantum assignments, the observed strength, the estimated uncertainty in the measured strength (%s), the observed

Table 5. Line Positions (cm⁻¹) and Strengths (cm⁻²/atm[a] at 296 K) Observed in the (020)–(010) Bands of $H_2{}^{16}O$, $H_2{}^{17}O$ and $H_2{}^{18}O$[b]

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Mol
1304.2856	-12	6	3	3	7	4	4	6.48E-05	6	-7.7	1.05	6
1315.9257	-58	5	2	4	6	3	3	1.61E-04	5	10.2	1.35	6
1316.12975	13	5	4	1	6	5	2	3.27E-04	2	3.9	1.11	6
1316.5410	12	5	5	1	6	6	0	6.23E-05	4	2.6	1.11	6
1320.32726	-8	5	3	3	6	4	2	1.64E-04	3	0.7	1.17	6
1324.4947	-2	5	3	2	6	4	3	5.02E-04	2	1.3	1.18	6
1327.73560	8	4	1	4	5	2	3	4.00E-04	3	4.9	1.37	6
1337.29574	-5	7	2	5	8	3	6	1.15E-04	2	-1.4	1.10	6
1340.61955	0	4	4	1	5	5	0	6.63E-04	3	-2.4	1.10	6
1340.63498	0	4	4	0	5	5	1	2.21E-04	2	-2.4	1.10	6
1344.59250	5	10	1	10	11	0	11	5.87E-05	2	-0.6	1.03	6
1346.00352	-1	4	3	2	5	4	1	1.03E-03	3	0.1	1.18	6
1347.03157	-4	4	3	1	5	4	2	3.48E-04	3	1.1	1.20	6
1348.5919	-28	5	0	5	5	3	2	2.95E-05	5	-1.2	1.52	6
1351.57014	-2	4	2	3	5	3	2	1.06E-03	5	-1.1	1.22	6
1355.20988	3	5	2	3	6	3	4	5.85E-04	2	-3.7	1.14	6
1356.03840	-16	10	1	10	10	2	9	4.78E-05	15	12.4	1.94	6
1357.2062	49	10	0	10	10	1	9	1.34E-05	10	-5.7	1.62	6
1358.7220	-13	9	1	8	10	2	9	4.40E-05	3	-7.7	0.96	6
1363.56407	-12	9	0	9	10	1	10	1.45E-04	5	-5.1	1.00	6
1363.83430	24	9	1	9	10	0	10	5.44E-05	3	6.8	1.13	6
1369.53155	12	4	2	2	5	3	3	4.20E-04	3	2.8	1.25	6
1370.89231	-9	3	3	1	4	4	0	6.33E-04	2	-0.5	1.20	6
1371.03946	-2	3	3	0	4	4	1	1.92E-03	4	0.5	1.22	6
1377.09005	10	3	1	3	4	2	2	3.40E-04	4	2.2	1.32	6
1378.3371	-29	9	1	9	9	2	8	3.86E-05	5	6.6	1.76	6
1380.6236	-22	9	0	9	9	1	8	1.10E-04	3	-0.2	1.63	6
1381.628	127	3	0	3	3	3	0	1.63E-05	10	2.2	1.52	6
1381.76344	-11	3	2	2	4	3	1	7.39E-04	3	3.0	1.29	6
1382.42319	-2	8	0	8	9	1	9	1.15E-04	4	-3.3	1.04	6
1382.97003	-6	8	1	8	9	0	9	3.59E-04	2	0.8	1.08	6
1383.65332	-2	8	2	7	9	1	8	1.10E-04	3	-4.2	1.00	6
1384.17029	-2	7	1	6	8	2	7	2.68E-04	3	0.6	1.10	6
1387.93363	1	3	2	1	4	3	2	2.15E-03	4	-4.0	1.19	6
1400.08708	1	8	1	8	8	2	7	2.47E-04	3	-2.7	1.54	6
1400.94226	1	7	0	7	8	1	8	7.51E-04	3	0.0	1.09	6
1402.05544	-1	7	1	7	8	0	8	2.46E-04	2	-1.4	1.07	6
1404.16854	2	5	1	4	6	2	5	9.54E-04	2	-1.6	1.14	6
1404.4444	-48	8	0	8	8	1	7	9.50E-05	5	8.4	1.71	6
1406.1886	15	8	3	6	9	2	7	2.80E-05	4	-7.2	0.90	6
1408.52956	0	2	2	1	3	3	0	3.56E-03	3	-2.4	1.24	6
1409.75911	-7	2	2	0	3	3	1	1.23E-03	2	0.5	1.27	6
1410.5015	8	10	2	9	10	3	8	3.03E-05	4	2.1	1.52	6
1414.42225	-2	4	1	3	5	2	4	5.32E-04	2	-0.7	1.18	6
1418.58218	0	2	1	2	3	2	1	2.17E-03	3	-1.5	1.26	6
1420.97888	4	7	1	7	7	2	6	1.70E-04	2	-5.4	1.44	6
1421.21595	3	6	1	6	7	0	7	1.45E-03	2	3.0	1.14	6
1426.44056	4	6	2	5	7	1	6	4.53E-04	3	-0.2	1.07	6
1426.61023	5	3	1	2	4	2	3	2.50E-03	3	2.1	1.24	6
1426.81052	46	9	2	8	9	3	7	3.16E-05	15	13.8	1.65	6
1428.87888	3	7	0	7	7	1	6	5.40E-04	2	-6.1	1.41	6
1436.23315	4	5	0	5	6	1	6	2.42E-03	3	1.8	1.15	6
1437.80136	-19	7	3	5	8	2	6	2.10E-05	6	8.6	1.07	6
1440.57280	0	6	1	6	6	2	5	9.88E-04	2	-3.9	1.41	6
1440.69965	0	5	1	5	6	0	6	7.87E-04	2	0.9	1.13	6
1441.54075	7	8	2	7	8	3	6	1.98E-04	2	-3.8	1.36	6
1441.55834	1	2	1	1	3	2	2	1.12E-03	3	-2.1	1.22	6
1444.75223	-4	9	1	8	9	2	7	9.89E-05	2	1.1	1.43	6
1445.1889	-44	10	3	8	10	4	7	1.59E-05	3	-4.4	1.29	6
1452.25217	-5	5	2	4	6	1	5	2.27E-04	2	-0.8	1.08	6
1452.46881	4	4	0	4	5	1	5	1.20E-03	2	2.5	1.19	6
1452.60703	3	1	1	1	2	2	0	1.27E-03	4	-1.9	1.26	6
1453.61730	-3	9	3	7	9	4	6	1.53E-05	3	-2.2	1.30	6
1453.78864	1	6	0	6	6	1	5	3.81E-04	2	-1.9	1.41	6
1454.21313	-17	7	2	6	7	3	5	1.50E-04	3	-0.6	1.38	6
1458.8659	2	10	4	7	10	5	6	7.50E-06	3	-3.3	1.27	6
1459.60773	2	1	1	0	2	2	1	4.39E-03	3	-1.6	1.25	6
1459.88895	-12	8	3	6	8	4	5	1.18E-04	2	2.2	1.34	6
1460.93765	-6	4	1	4	5	0	5	3.65E-03	7	7.9	1.24	6
1462.10226	-10	8	4	5	8	5	4	4.83E-05	2	-1.8	1.26	6
1462.5273	-77	7	4	4	7	5	3	3.85E-05	5	17.7	1.51	6
1462.65777	-1	6	4	3	6	5	2	1.43E-04	3	-6.3	1.18	6
1462.73198	1	5	4	2	5	5	1	5.44E-05	4	0.1	1.26	6
1462.84380	-2	5	4	1	5	5	0	1.61E-04	2	-1.3	1.25	6
1462.9107	-21	8	5	4	8	6	3	1.69E-05	2	-1.3	1.27	6
1463.1153	1	7	5	3	7	6	2	1.05E-05	4	4.5	1.33	6
1463.17298	-5	6	4	2	6	5	1	5.02E-05	3	-1.2	1.25	6
1463.20339	-7	7	5	2	7	6	1	2.78E-05	3	-8.0	1.17	6
1463.2238	-52	8	5	3	8	6	2	5.00E-06	10	-13.2	1.13	6
1463.37604	-1	6	5	2	6	6	1	3.71E-05	3	2.9	1.30	6
1463.39803	0	6	5	1	6	6	0	1.18E-05	3	-1.8	1.25	6
1463.6486	-10	9	5	4	9	6	3	7.70E-06	3	-1.5	1.28	6
1464.10649	1	7	3	5	7	4	4	8.20E-05	2	1.0	1.31	6
1464.22716	0	7	4	3	7	5	2	9.75E-05	2	0.5	1.27	6
1464.45849	0	6	2	5	6	3	4	8.45E-04	2	-1.9	1.33	6
1464.6143	36	11	2	9	11	3	8	6.86E-06	10	-5.0	1.25	6

(Table continued)

Table 5. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Mol
P1466.18106	-4	8	4	4	8	5	3	1.10E-05	3	-50.7	1.33	6
1466.58454	-6	6	3	4	6	4	3	4.32E-04	2	0.3	1.30	6
1467.0251	2	8	1	7	8	2	6	8.75E-05	3	-3.9	1.32	6
1467.64570	1	3	0	3	4	1	4	4.55E-03	2	0.5	1.18	6
1467.79752	2	5	3	3	5	4	2	2.00E-04	2	-1.3	1.28	6
1468.26682	-3	4	3	2	4	4	1	5.80E-04	2	-0.7	1.29	6
P1468.970	-85	7	6	2	7	7	1	1.76E-06	10	-31.8	1.09	6
P1469.066	-35	7	6	1	7	7	0	5.20E-06	10	-34.0	1.09	6
1470.74848	-22	9	4	5	9	5	4	2.30E-05	4	7.6	1.38	6
1470.86848	-3	5	3	2	5	4	1	6.10E-04	2	-0.4	1.29	6
1472.37346	-6	6	3	4	7	2	5	9.82E-05	2	5.5	1.05	6
1474.62823	2	6	3	3	6	4	2	1.46E-04	2	-0.4	1.28	6
1477.24875	-2	4	2	3	4	3	2	1.73E-03	2	-2.1	1.30	6
1478.12349	4	5	0	5	5	1	4	2.20E-03	4	-0.5	1.38	6
1480.22927	5	3	2	2	3	3	1	4.97E-04	3	-3.6	1.28	6
1480.69765	-8	7	3	4	7	4	3	2.62E-04	2	2.7	1.31	6
1482.47745	2	2	0	2	3	1	3	1.70E-03	3	-0.2	1.20	6
1482.53983	-4	3	1	3	4	0	4	1.35E-03	2	0.2	1.15	6
1485.13356	0	3	2	1	3	3	0	1.57E-03	3	-0.6	1.30	6
1486.74365	5	7	1	6	7	2	5	6.90E-04	2	-1.3	1.32	6
1490.0218	-29	4	2	2	4	3	1	5.25E-04	15	-18.3	1.08	6
1494.8717	11	9	2	7	9	3	6	8.71E-05	7	-0.2	1.27	6
1495.03784	-9	9	3	6	9	4	5	5.00E-05	4	-4.0	1.21	6
1495.61167	0	2	1	2	2	2	1	2.57E-03	3	-0.9	1.31	6
1498.37984	-5	1	0	1	2	1	2	5.05E-03	2	-0.2	1.22	6
1498.5172	32	11	3	8	11	4	7	5.26E-06	6	-0.9	1.24	6
1499.82819	6	4	0	4	4	1	3	1.27E-03	2	-1.8	1.31	6
1502.08947	-1	6	2	4	6	3	3	3.50E-04	4	-1.0	1.26	6
1502.43622	10	8	2	6	8	3	5	9.10E-05	15	10.8	1.41	6
1502.6598	-56	8	1	8	7	2	5	6.00E-06	10	-1.2	2.43	6
1504.61315	2	7	2	5	7	3	4	5.74E-04	2	1.1	1.27	6
1506.0207	9	2	1	2	3	0	3	4.00E-03	8	6.9	1.25	6
1508.3019	-33	5	3	3	6	2	4	4.00E-05	4	-3.4	0.97	6
1511.48584	-2	5	1	4	5	2	3	3.16E-03	2	6.1	1.37	6
1511.85960	4	2	1	1	2	2	0	1.18E-03	2	1.9	1.31	6
1515.29144	3	3	1	2	3	2	1	4.80E-03	2	-1.2	1.27	6
1515.67386	3	4	1	3	4	2	2	1.50E-03	3	1.8	1.30	6
1528.31120	0	2	0	2	2	1	1	2.44E-03	3	0.0	1.27	6
1531.12875	-3	1	1	1	2	0	2	7.44E-04	2	0.5	1.18	6
1534.93548	4	1	0	1	1	1	0	6.33E-03	3	0.3	1.26	6
1543.7319	8	2	2	1	3	1	2	3.88E-04	10	-11.8	0.98	6
1543.8972	-13	4	3	2	5	2	3	1.28E-04	5	-2.7	0.99	6
1547.8894	-74	6	1	6	5	2	3	6.11E-05	5	0.9	1.76	6
1583.3559	-29	1	1	0	1	0	1	5.53E-03	5	-0.8	1.16	6
1586.9943	23	2	0	2	1	1	1	9.42E-04	5	-2.5	1.22	6
1590.3812	-14	2	1	1	2	0	2	2.02E-03	3	-0.7	1.15	6
1592.3218	90	3	1	2	2	2	1	7.32E-04	3	1.3	1.32	6
1601.3467	-33	1	1	1	0	0	0	1.49E-03	4	5.0	1.23	6
1602.72990	6	3	1	2	3	0	3	4.75E-03	3	4.8	1.21	6
1619.36015	0	2	1	2	1	0	1	5.69E-03	5	-1.9	1.16	6
1620.33590	8	3	2	1	3	1	2	3.54E-03	3	3.8	1.16	6
1620.4691	-38	4	2	2	4	1	3	9.92E-04	5	-2.1	1.10	6
1621.1241	35	4	1	3	4	0	4	8.64E-04	3	-0.7	1.13	6
1626.05918	6	5	2	3	5	1	4	1.84E-03	10	-5.7	1.06	6
1639.08384	-8	2	2	1	2	1	2	1.85E-03	3	3.2	1.13	6
1644.68805	0	5	1	4	5	0	5	1.31E-03	2	2.3	1.12	6
1648.19697	5	3	2	2	3	1	3	6.36E-04	3	-4.6	1.05	6
1649.80762	4	4	1	4	3	0	3	6.97E-03	3	-0.6	1.20	6
1657.38970	1	5	0	5	4	1	4	6.35E-03	2	3.8	1.29	6
1657.43828	2	5	1	4	4	2	3	1.45E-03	2	-3.5	1.22	6
1657.75825	3	7	2	5	7	1	6	3.83E-04	3	3.1	1.13	6
1658.27136	-2	6	2	4	5	3	3	9.82E-05	2	-4.0	1.29	6
1660.24435	1	7	3	4	7	2	5	3.24E-04	10	8.7	1.16	6
1660.46770	3	4	2	3	4	1	4	1.57E-03	2	1.3	1.11	6
1662.60295	-15	6	3	3	6	2	4	1.87E-04	3	-1.3	1.04	6
1664.06356	2	8	3	5	8	2	6	4.41E-05	2	6.5	1.12	6
1665.02902	4	5	1	5	4	0	4	2.10E-03	2	0.3	1.22	6
1668.76235	4	5	3	2	5	2	3	9.01E-04	2	4.6	1.11	6
1671.30197	4	6	1	5	6	0	6	1.82E-04	3	-11.6	0.99	6
1675.63950	3	2	2	1	1	1	0	3.60E-03	4	-10.8	0.98	6
1675.68709	22	5	2	4	5	1	5	3.61E-04	10	10.5	1.22	6
1675.82588	1	4	3	1	4	2	2	3.53E-04	2	1.4	1.07	6
1677.22327	-1	6	0	6	5	1	5	1.56E-03	2	-3.3	1.20	6
1681.0918	-53	6	1	6	5	0	5	5.22E-03	2	6.7	1.31	6
1681.30362	3	3	3	0	3	2	1	9.33E-04	2	4.0	1.09	6
1682.24355	3	2	2	0	1	1	1	1.17E-03	2	1.2	1.09	6
1682.8717	-1	8	2	6	8	1	7	4.25E-05	5	0.5	1.08	6
1686.72353	3	3	3	1	3	2	2	2.97E-04	2	1.2	1.07	6
1688.92977	-1	6	1	5	5	2	4	4.47E-04	2	-0.2	1.23	6
1689.84973	0	4	3	2	4	2	3	1.01E-03	2	3.8	1.10	6
1694.03074	5	3	2	2	2	1	1	1.17E-03	3	-0.1	1.09	6
1695.34025	5	5	3	3	5	2	4	2.17E-04	10	-10.8	0.95	6
1695.7761	-9	7	2	5	6	3	4	2.34E-04	5	-0.2	1.31	6
1697.73825	-4	7	1	7	6	0	6	1.08E-03	3	-2.7	1.20	6
1703.68015	7	6	3	4	6	2	5	4.45E-04	2	4.2	1.10	6
1714.6101	6	8	1	8	7	0	7	1.91E-03	7	-5.4	1.18	6
1715.68791	-1	3	2	1	2	1	2	2.19E-03	5	-0.4	1.05	6
1718.05010	-6	7	1	6	6	2	5	1.06E-03	5	7.7	1.32	6
1723.04619	-4	5	2	4	4	1	3	7.25E-04	5	-3.7	1.06	6
1731.03695	-4	9	0	9	8	1	8	1.20E-03	10	9.2	1.38	6
1735.3075	-26	6	2	5	5	1	4	1.66E-03	4	2.3	1.14	6
1757.02465	-8	3	3	1	2	2	0	9.40E-04	6	-5.0	0.97	6
1758.33307	-1	3	3	0	2	2	1	3.25E-03	10	9.8	1.12	6
1778.53099	3	4	3	2	3	2	1	1.93E-03	10	-4.5	0.95	6
1805.32540	4	5	2	3	4	1	4	4.48E-04	4	-5.7	0.94	6
1810.99747	5	6	3	4	5	2	3	7.02E-04	3	-2.6	0.94	6
1814.71469	-2	5	3	2	4	2	3	1.11E-03	4	1.3	0.97	6
1822.42389	3	7	3	5	6	2	4	1.30E-04	7	0.1	0.97	6
1831.99401	2	8	3	6	7	2	5	1.93E-04	3	-2.9	0.95	6
1832.011	-222	6	3	3	6	0	6	4.47E-06	10	-2.0	1.04	6
1832.9259	-118	11	2	9	10	3	8	1.72E-05	6	5.3	1.26	6
1839.14695	2	4	4	1	3	3	0	1.43E-03	3	1.9	0.97	6
1839.32443	-15	4	4	0	3	3	1	4.68E-04	7	0.1	0.95	6
1841.1283	76	9	3	7	8	2	6	3.26E-05	5	3.1	1.03	6
1849.64108	1	6	3	3	5	2	4	1.73E-04	3	2.6	0.93	6
1851.33775	-11	10	3	8	9	2	7	4.42E-05	4	5.6	1.09	6
P1854.1889	-10	6	6	1	6	5	2	1.00E-05	4	26.5	1.12	6
P1854.8108	-4	7	6	1	7	5	2	8.15E-06	4	22.1	1.45	6
1855.1722	37	8	6	3	8	5	4	3.40E-06	10	2.0	1.01	6
1861.85017	10	6	2	4	5	1	5	5.45E-05	5	2.1	0.87	6
1862.95590	0	5	4	2	4	3	1	2.85E-04	3	1.4	0.93	6
1864.17125	-1	5	4	1	4	3	2	8.45E-04	2	0.3	0.92	6
1865.96936	-3	4	3	2	3	0	3	4.10E-05	4	-4.1	0.87	6
1872.1939	-12	7	3	4	7	0	7	4.18E-06	10	-10.9	1.06	6
1885.02076	-5	6	4	3	5	3	2	4.48E-04	2	-0.9	0.88	6
1891.55097	7	7	3	4	6	2	5	1.98E-04	2	4.6	0.88	6
1902.0417	2	5	3	3	4	0	4	1.90E-05	3	5.0	0.90	6
1903.97983	-12	7	4	4	6	3	3	7.21E-05	3	0.4	0.86	6
1916.68207	1	7	4	3	6	3	4	2.08E-04	2	-0.5	0.84	6
1918.86008	-1	8	4	5	7	3	4	9.20E-05	5	-0.5	0.83	6
1920.88517	-5	5	5	1	4	4	0	1.42E-04	2	-2.9	0.87	6
1920.91334	-29	5	5	0	4	4	1	4.41E-04	2	0.6	0.90	6
1924.73505	-7	7	2	5	6	1	6	5.12E-05	2	-4.1	0.73	6
1929.7078	6	9	4	6	8	3	5	1.16E-05	3	-5.1	0.79	6
1937.4611	18	10	4	7	9	3	6	1.43E-05	3	4.6	0.89	6
1941.33656	4	8	3	5	7	2	6	1.96E-05	3	0.4	0.77	6
1944.19954	-7	6	3	4	5	0	5	4.28E-05	2	1.6	0.81	6
1945.47626	-3	6	5	2	5	4	1	2.32E-04	3	-1.3	0.84	6
1945.66567	1	6	5	1	5	4	2	7.80E-05	3	-0.4	0.85	6
P1948.5126	26	12	4	9	11	3	8	1.24E-06	10	-16.1	0.83	6
1969.38050	0	7	5	3	6	4	2	3.74E-05	4	-0.6	0.81	6
1970.25548	-1	7	5	2	6	4	3	1.13E-04	2	0.1	0.81	6
1974.3505	131	4	4	1	3	1	2	1.60E-06	10	-11.4	0.90	6
1981.60202	-8	9	4	5	8	3	6	2.50E-05	3	-10.2	0.68	6
1994.85860	0	8	5	3	7	4	4	1.58E-05	3	-2.0	0.76	6
1998.63808	-38	9	3	6	8	2	7	1.60E-05	7	0.9	0.70	6
P2000.90324	4	6	6	1	5	5	0	8.72E-05	3	6.1	0.90	6
2001.01674	-9	6	6	0	5	5	1	3.30E-05	3	8.4	0.89	6
2011.9509	4	9	5	5	8	4	4	5.82E-06	3	-6.2	0.70	6
2019.96452	-3	9	5	4	8	4	5	1.75E-05	4	-5.3	0.70	6
2022.9431	55	10	4	6	9	3	7	2.80E-06	6	7.8	0.76	6
2026.00265	1	7	6	2	6	5	1	1.57E-05	2	7.6	0.83	6
2026.12062	-9	7	6	1	6	5	2	4.63E-05	3	5.9	0.82	6
2028.3079	18	10	5	6	9	4	5	6.36E-06	4	-0.6	0.74	6
2050.63772	0	8	6	3	7	5	2	1.92E-05	3	0.9	0.73	6
2051.0468	-5	8	6	2	7	5	3	6.63E-06	3	4.5	0.77	6
2071.6827	4	11	4	7	10	3	8	1.84E-06	7	-2.1	0.66	6
P2072.0053	12	8	4	5	7	1	6	5.40E-06	3	-36.5	0.54	6
P2076.6979	-45	9	6	3	8	5	4	6.00E-06	8	23.2	0.77	6
P2128.4552	-3	9	7	2	8	6	3	2.73E-06	10	21.2	0.82	6
1314.14705	-35	5	4	1	6	5	2	3.77E-04	10	2.4	1.28	7
*1314.6774	11	5	5	0	6	6	1	3.10E-04	10	-0.1	1.40	7
1318.1353	-26	5	3	3	6	4	2	2.00E-04	10	10.3	1.43	7
1322.2837	-28	5	3	2	6	4	3	5.08E-04	10	-7.7	1.19	7
1343.8486	-1	4	3	2	5	4	1	1.16E-03	5	5.9	1.33	7
1349.0629	-27	4	2	3	5	3	2	1.13E-03	6	-1.0	1.30	7
1353.1170	-60	5	2	3	6	3	4	6.82E-04	10	4.1	1.33	7
1367.3288	-5	4	2	2	5	3	3	4.66E-04	10	7.5	1.38	7
1368.8937	4	3	3	0	4	4	1	1.95E-03	10	-13.5	1.23	7
1374.2534	7	3	1	3	4	2	2	3.27E-04	10	-4.9	1.27	7
1379.3621	-28	3	2	2	4	3	1	7.49E-04	10	0.4	1.30	7
1380.1335	3	8	1	8	9	0	9	4.11E-04	10	0.1	1.24	7

(Table continued)

Table 5. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Mol
1381.6782	18	7	1	6	8	2	7	2.88E-04	10	4.5	1.18	7
1385.6420	-23	3	2	1	4	3	2	2.22E-03	5	-4.7	1.23	7
1397.2337	72	8	1	8	8	2	7	2.96E-04	10	4.2	1.85	7
1398.1021	-24	7	0	7	8	1	8	8.16E-04	10	-3.7	1.19	7
1401.7261	7	5	1	4	6	2	5	1.02E-03	10	2.0	1.22	7
1406.1634	1	2	2	1	3	3	0	3.85E-03	7	3.5	1.34	7
1407.4152	-38	2	2	0	3	3	1	1.40E-03	10	11.5	1.44	7
1415.85827	-5	2	1	2	3	2	1	2.25E-03	3	0.2	1.31	7
1418.25568	35	6	1	6	7	0	7	1.52E-03	3	-2.0	1.20	7
1422.99515	-26	6	2	5	7	1	6	4.73E-04	10	0.7	1.12	7
1425.69461	-11	7	0	7	7	1	6	6.02E-04	10	-0.2	1.58	7
1433.3589	-12	5	0	5	6	1	6	2.25E-03	10	-12.3	1.07	7
1437.66140	34	5	1	5	6	0	6	8.69E-04	10	3.6	1.25	7
1437.7213	-2	6	1	6	6	2	5	1.03E-03	10	-5.4	1.47	7
1438.9725	-48	2	1	1	3	2	2	1.11E-03	10	-4.5	1.21	7
1449.5920	-46	4	0	4	5	1	5	1.37E-03	10	11.2	1.36	7
1449.9455	22	1	1	1	2	2	0	1.35E-03	5	3.2	1.34	7
1457.80470	3	4	1	4	5	0	5	3.47E-03	3	-2.1	1.18	7
1464.3090	-12	6	3	4	6	4	3	5.04E-04	10	-2.2	1.52	7
1464.7610	-2	3	0	3	4	1	4	4.60E-03	10	-1.1	1.20	7
1466.05085	9	4	3	2	4	4	1	6.15E-04	10	-2.7	1.36	7
1468.71685	0	5	3	2	5	4	1	7.63E-04	10	8.8	1.61	7
1470.90920	2	4	1	4	4	2	3	2.50E-03	10	-4.6	1.35	7
1474.7784	-31	4	2	3	4	3	2	1.83E-03	5	-2.8	1.38	7
1474.83030	-4	5	0	5	5	1	4	2.27E-03	4	-2.7	1.42	7
1477.3884	17	4	2	3	5	1	4	7.72E-04	10	-8.0	1.03	7
1477.8017	-11	3	2	2	3	3	1	5.96E-04	10	11.1	1.53	7
1478.68585	41	7	3	4	7	4	3	3.00E-04	10	-3.7	1.50	7
1479.29913	-1	3	1	3	4	0	4	1.52E-03	3	9.1	1.30	7
1479.5640	4	2	0	2	3	1	3	1.69E-03	6	-2.1	1.19	7
1482.7765	-7	3	2	1	3	3	0	1.65E-03	10	0.6	1.36	7
1483.3318	20	7	1	6	7	2	5	7.19E-04	10	-1.7	1.37	7
1483.46702	0	3	1	3	3	2	2	1.03E-03	10	-0.6	1.36	7
1494.09670	6	5	2	3	5	3	2	1.74E-03	4	0.6	1.40	7
1495.4225	-3	1	0	1	2	1	2	5.16E-03	10	1.8	1.25	7
1496.5920	-30	4	0	4	4	1	3	1.16E-03	6	-10.0	1.20	7
1499.6482	-1	6	2	4	6	3	3	3.56E-04	10	-9.3	1.28	7
1512.5656	1	3	1	2	3	2	1	4.54E-03	5	-7.8	1.20	7
1512.83594	-15	4	1	3	4	2	2	1.60E-03	7	6.6	1.39	7
1513.6656	10	0	0	0	1	1	1	1.28E-03	10	-8.9	1.12	7
1513.68322	0	3	0	3	3	1	2	5.70E-03	5	-3.5	1.24	7
1525.2369	-5	2	0	2	2	1	1	2.32E-03	4	-3.9	1.21	7
1527.71433	6	1	1	1	2	0	2	7.27E-04	10	-1.8	1.15	7
1531.8972	7	1	0	1	1	1	0	6.40E-03	3	2.6	1.27	7
1579.8958	42	1	1	0	1	0	1	5.77E-03	5	4.8	1.21	7
1583.9142	-50	2	0	2	1	1	1	1.00E-03	10	5.1	1.29	7
1586.9572	-36	2	1	1	2	0	2	2.10E-03	7	4.3	1.20	7
1589.6172	10	3	1	2	2	2	1	6.91E-04	5	-2.3	1.25	7
1597.84810	-1	1	1	1	0	0	0	1.50E-03	8	7.2	1.24	7
1599.38444	6	3	1	2	3	0	3	4.70E-03	3	4.9	1.20	7
1609.04007	0	3	0	3	2	1	2	5.44E-03	4	3.0	1.27	7
1615.82229	4	2	1	2	1	0	1	5.60E-03	10	-2.0	1.15	7
1616.40133	0	3	2	1	3	1	2	3.10E-03	4	-10.1	1.02	7
1619.58201	-16	2	2	0	2	1	1	7.54E-04	10	-8.8	1.02	7
1622.0503	52	4	1	3	3	2	2	4.18E-04	10	-1.6	1.24	7
1622.4218	10	5	2	3	5	1	4	2.04E-03	10	4.4	1.17	7
1631.4517	10	3	1	3	2	0	2	2.02E-03	4	-10.4	1.06	7
1632.58152	1	4	0	4	3	1	3	2.19E-03	4	1.7	1.26	7
1641.52405	18	5	1	4	5	0	5	1.36E-03	5	6.1	1.16	7
1654.05785	13	5	0	5	4	1	4	6.43E-03	5	3.8	1.30	7
1655.9583	20	7	3	4	7	2	5	3.48E-04	10	11.6	1.23	7
1656.61563	2	4	2	3	4	1	4	1.67E-03	10	4.9	1.18	7
1661.4471	23	5	1	5	4	0	4	2.22E-03	5	4.9	1.29	7
1664.1393	5	5	3	2	5	2	3	8.44E-04	10	-8.3	1.04	7
1673.80448	-15	6	0	6	5	1	5	1.66E-03	5	0.2	1.28	7
1676.7464	-58	3	3	0	3	2	1	8.50E-04	10	-6.1	1.00	7
1677.51924	8	6	1	6	5	0	5	5.00E-03	10	-0.1	1.26	7
1678.2599	-2	2	2	0	1	1	1	1.18E-03	10	3.1	1.10	7
1685.9930	84	6	1	5	5	2	4	4.25E-04	10	-3.3	1.17	7
1689.6694	-6	6	2	5	6	1	6	5.09E-04	10	-4.9	1.06	7
1689.9682	-20	3	2	2	2	1	1	1.13E-03	5	-2.4	1.06	7
1705.53780	-1	4	2	3	3	1	2	2.65E-03	5	-7.8	0.99	7
1711.0224	50	8	1	8	7	0	7	2.04E-03	4	-3.8	1.26	7
1711.75806	-12	3	2	1	2	1	2	2.25E-03	5	2.5	1.08	7
1727.4539	9	9	0	9	8	1	8	1.11E-03	10	-3.6	1.27	7
1727.8595	-4	9	1	9	8	0	8	4.10E-04	10	6.7	1.40	7
1731.1407	-8	6	2	5	5	1	4	1.60E-03	5	2.1	1.10	7
1752.4663	65	3	3	1	2	2	0	1.05E-03	5	6.4	1.08	7
1752.6355	0	4	2	2	3	1	3	3.71E-04	10	-0.5	1.02	7
1780.4251	-12	4	3	1	3	2	2	6.10E-04	10	-9.5	0.93	7
1791.86460	0	5	3	3	4	2	2	4.39E-04	10	0.4	1.03	7
1806.1648	41	6	3	4	5	2	3	7.84E-04	10	4.4	1.05	7
1810.2821	-20	5	3	2	4	2	3	1.17E-03	10	-0.1	1.02	7
1834.2624	-2	4	4	0	3	3	1	4.85E-04	10	5.0	0.98	7
1859.0940	-7	5	4	1	4	3	2	9.38E-04	10	3.5	1.02	7
1898.618	274	7	4	4	6	3	3	7.50E-05	10	-4.8	0.89	7
1915.3447	-101	5	5	1	4	4	0	1.52E-04	10	-2.3	0.93	7
1915.3675	26	5	5	0	4	4	1	4.72E-04	10	1.1	0.97	7
1939.9009	10	6	5	2	5	4	1	2.82E-04	10	-0.4	1.03	7
1312.2216	31	5	4	2	6	5	1	1.28E-04	10	-0.3	1.30	8
1312.3700	6	5	4	1	6	5	2	3.93E-04	10	1.9	1.33	8
*1313.0047	-13	5	5	0	6	5	1	3.11E-04	10	-0.7	1.41	8
1316.1710	-1	5	3	3	6	4	2	1.60E-04	10	-10.3	1.14	8
1320.4350	-2	5	3	2	6	4	3	5.40E-04	5	-0.2	1.27	8
1322.1127	-25	4	1	4	5	2	3	3.39E-04	4	-8.1	1.16	8
1333.7129	-27	7	2	5	8	3	6	1.31E-04	10	2.3	1.25	8
1336.8391	-107	4	4	1	5	5	0	8.58E-04	10	7.6	1.42	8
1341.91833	-5	4	3	2	5	4	1	1.14E-03	4	2.4	1.31	8
1343.0095	4	4	3	1	5	4	2	3.80E-04	10	2.0	1.31	8
1346.8175	-8	4	2	3	5	3	2	1.10E-03	3	0.8	1.27	8
1351.2461	-6	5	2	3	6	3	4	6.63E-04	4	4.6	1.29	8
1358.3313	-14	9	0	9	10	1	10	1.62E-04	10	-5.6	1.12	8
1365.3591	7	4	2	2	5	3	3	3.84E-04	10	-9.0	1.14	8
1366.9722	9	3	3	0	4	4	1	2.06E-03	3	0.0	1.30	8
1377.2125	-55	3	2	2	4	3	1	7.10E-04	5	-2.7	1.23	8
1377.6053	4	8	1	8	9	0	9	3.99E-04	10	2.7	1.20	8
1377.8532	-17	8	2	7	9	1	8	1.18E-04	10	-7.0	1.07	8
1379.4483	39	7	1	6	8	2	7	2.57E-04	10	-10.0	1.05	8
1383.59278	2	3	2	1	4	3	2	2.33E-03	3	2.0	1.29	8
1395.5685	-25	7	0	7	8	1	8	8.50E-04	7	6.2	1.24	8
1396.5810	17	7	1	7	8	0	8	2.51E-04	10	-5.7	1.10	8
1399.54289	0	5	1	4	6	2	5	9.80E-04	5	-1.1	1.17	8
1404.04681	-1	2	2	1	3	3	0	3.65E-03	4	-1.5	1.27	8
1405.31886	-13	2	2	0	3	3	1	1.25E-03	3	0.4	1.29	8
1413.42388	-2	2	1	2	3	2	1	2.28E-03	3	5.9	1.33	8
1413.5440	-15	6	0	6	7	1	7	5.00E-04	3	1.5	1.18	8
1415.5606	75	7	1	7	7	2	6	1.70E-04	10	-4.7	1.44	8
1415.61710	16	6	1	6	7	0	7	1.49E-03	3	1.3	1.17	8
1419.9340	-12	6	2	5	7	1	6	5.05E-04	5	4.3	1.20	8
1421.81073	0	3	1	2	4	2	3	2.56E-03	4	4.9	1.27	8
1422.8605	0	7	0	7	7	1	6	5.93E-04	10	4.0	1.55	8
1430.7938	-3	5	0	5	6	1	6	2.44E-03	5	0.2	1.16	8
1434.9537	47	5	1	5	6	0	6	8.30E-04	6	3.4	1.20	8
1435.17559	3	6	1	6	6	2	5	1.06E-03	2	4.2	1.51	8
1436.2158	36	8	2	7	8	3	6	2.39E-04	10	9.6	1.64	8
1445.3526	-3	5	2	4	6	1	5	2.65E-04	10	9.4	1.26	8
1447.02485	1	4	0	4	5	1	5	1.20E-03	4	1.6	1.19	8
1447.5673	3	1	1	1	2	2	0	1.33E-03	6	4.7	1.32	8
1452.9880	3	5	1	5	5	2	4	6.36E-04	5	10.7	1.56	8
1454.6385	-17	1	1	0	2	2	1	4.10E-03	10	-6.8	1.16	8
1455.0129	-8	4	1	4	5	0	5	3.39E-03	4	-0.9	1.15	8
1458.7182	43	6	4	3	6	5	2	1.51E-04	10	-10.5	1.25	8
1458.9237	17	5	4	1	5	5	0	1.83E-04	10	1.4	1.42	8
1459.4908	-6	6	2	5	6	3	4	8.74E-04	4	-1.9	1.38	8
1462.18628	6	3	0	3	4	1	4	4.45E-03	4	-1.3	1.16	8
1462.2708	-12	6	3	4	6	4	3	4.65E-04	4	3.2	1.40	8
1464.0669	-4	4	3	2	4	4	1	6.30E-04	5	2.5	1.40	8
1467.3026	-4	5	2	4	5	3	3	4.50E-04	5	-4.9	1.32	8
1468.42665	-3	4	1	4	4	2	3	2.55E-03	5	1.8	1.38	8
1472.56876	-16	4	2	3	4	3	2	1.86E-03	3	2.9	1.40	8
1473.9955	16	4	2	3	5	1	4	8.73E-04	4	0.9	1.17	8
1475.6303	-6	3	2	2	3	3	1	4.80E-04	10	-9.0	1.23	8
1476.8835	-18	7	3	4	7	4	3	2.73E-04	10	1.2	1.37	8
1476.96347	0	2	0	2	3	1	3	1.71E-03	4	1.9	1.20	8
1480.2835	30	7	1	6	7	2	5	6.65E-04	6	-8.6	1.27	8
1480.6686	-23	3	2	1	3	3	0	1.57E-03	5	-1.9	1.30	8
1481.0219	-9	3	1	3	3	2	2	1.00E-03	10	-0.3	1.32	8
1490.49605	5	2	1	2	2	2	1	2.52E-03	6	-1.4	1.29	8
1492.00900	-4	5	2	3	5	3	2	1.68E-03	4	4.0	1.35	8
1492.78316	-10	1	0	1	2	1	2	4.97E-03	4	0.5	1.20	8
1493.70445	-6	4	0	4	4	1	3	1.26E-03	4	-0.7	1.30	8
1497.4586	-14	6	2	4	6	3	3	3.51E-04	10	-2.7	1.26	8
1499.57685	-3	7	2	5	7	3	4	5.80E-04	10	-0.2	1.29	8
1499.6976	-3	2	1	2	3	0	3	3.92E-03	3	5.1	1.23	8
1504.8291	-23	3	2	2	4	1	3	2.40E-04	10	-8.8	1.06	8
1510.1292	15	3	1	2	3	2	1	4.87E-03	10	0.2	1.28	8
1510.2985	-11	4	1	3	4	2	2	1.38E-03	5	-7.3	1.20	8
1510.87535	-2	3	0	3	3	1	2	5.55E-03	4	-5.2	1.20	8
1510.9897	6	0	0	0	1	1	1	1.25E-03	10	-10.4	1.10	8
1522.4928	-7	2	0	2	2	1	1	2.28E-03	10	-4.7	1.19	8
1524.67112	1	1	1	1	2	0	2	7.04E-04	10	-4.5	1.11	8
1529.18567	1	1	0	1	1	1	0	6.40E-03	5	3.5	1.27	8

(Table continued)

Table 5. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Mol
1556.7454	40	4	1	4	3	2	1	3.09E-04	10	2.3	1.45	8
1576.81118	0	1	1	0	1	0	1	5.65E-03	3	1.7	1.19	8
1581.16602	-16	2	0	2	1	1	1	9.55E-04	7	-0.4	1.23	8
1583.9053	-4	2	1	1	2	0	2	2.05E-03	3	0.6	1.17	8
1587.20097	-18	3	1	2	2	2	1	7.58E-04	3	4.5	1.37	8
1594.7293	-4	1	1	1	0	0	0	1.46E-03	5	3.3	1.21	8
1596.4029	12	3	1	2	3	0	3	4.54E-03	3	-0.6	1.16	8
1606.23627	0	3	0	3	2	1	2	5.50E-03	3	2.8	1.28	8
1612.66848	-3	2	1	2	1	0	1	5.95E-03	4	2.6	1.21	8
1612.89803	-3	3	2	1	3	1	2	3.58E-03	2	1.1	1.17	8
1613.2438	4	4	2	2	4	1	3	1.10E-03	10	4.1	1.22	8
1614.9925	30	4	1	3	4	0	4	8.15E-04	3	-8.2	1.07	8
1616.0387	26	2	2	0	2	1	1	8.65E-04	4	1.0	1.17	8
1617.7603	-8	5	2	3	4	3	2	3.06E-04	10	-4.8	1.32	8
1619.18678	-2	5	2	3	5	1	4	2.08E-03	3	1.5	1.20	8
1619.6027	-11	4	1	3	3	2	2	4.46E-04	10	2.1	1.32	8
1628.26481	1	3	1	3	2	0	2	2.25E-03	5	-1.3	1.18	8
1629.6956	1	4	0	4	3	1	3	2.20E-03	6	0.9	1.26	8
1631.6368	-15	2	2	1	2	1	2	1.94E-03	4	3.7	1.19	8
1638.70238	1	5	1	4	5	0	5	1.30E-03	10	-3.1	1.11	8
1640.8202	-21	3	2	2	3	1	3	6.50E-04	10	-6.5	1.07	8
1643.01874	1	4	1	4	3	0	3	7.45E-03	3	4.7	1.28	8
1651.08358	0	5	0	5	4	1	4	6.41E-03	3	2.6	1.30	8
1652.1160	-7	5	1	4	4	2	3	1.40E-03	10	-7.8	1.18	8
1658.2546	-1	5	1	5	4	0	4	2.15E-03	5	0.4	1.25	8
1660.0260	8	5	3	2	5	2	3	9.62E-04	5	5.2	1.18	8
1665.3282	-2	6	1	5	6	0	6	2.01E-04	10	-3.9	1.10	8
1667.1038	30	4	3	1	4	2	2	4.18E-04	10	10.5	1.27	8
1668.0397	35	2	2	1	1	1	0	3.80E-03	10	-8.4	1.04	8
1670.75385	-2	6	0	6	5	1	5	1.71E-03	7	2.7	1.32	8
1674.33498	-6	6	1	6	5	0	5	4.95E-03	3	-1.8	1.25	8
1674.7116	-15	2	2	0	1	1	1	1.24E-03	4	3.9	1.16	8
1678.2685	-46	3	3	1	3	2	2	3.09E-04	5	-6.4	1.11	8
1683.3627	-26	6	1	5	5	2	4	4.50E-04	10	-0.1	1.24	8
1686.3315	2	6	2	5	6	1	6	5.11E-04	5	-5.5	1.07	8
1686.34978	-3	3	2	2	2	1	1	1.23E-03	6	2.7	1.15	8
1687.0822	-72	5	3	3	5	2	4	2.71E-04	10	1.5	1.18	8
1689.2579	4	7	0	7	6	1	6	3.20E-03	10	-8.1	1.19	8
1690.97723	2	7	1	7	6	0	6	1.16E-03	5	-0.0	1.29	8
1691.4169	-8	7	2	5	6	3	4	2.48E-04	10	3.3	1.39	8
1701.8743	8	4	2	3	3	1	2	2.85E-03	10	-3.5	1.06	8
1707.0111	1	8	0	8	7	1	7	7.15E-04	5	0.3	1.38	8
1707.8239	2	8	1	8	7	0	7	2.14E-03	5	-0.0	1.32	8
1712.1433	23	7	1	6	6	2	5	1.05E-03	4	6.5	1.31	8
1724.25837	-43	9	0	9	8	1	8	1.17E-03	5	-1.2	1.34	8
1724.6424	-12	9	1	9	8	0	8	3.98E-04	10	0.8	1.36	8
1727.43150	0	6	2	5	5	1	4	1.55E-03	5	-4.4	1.06	8
1728.8245	-46	5	4	1	5	3	2	3.54E-04	10	10.9	1.32	8
1738.0231	-24	8	1	7	7	2	6	2.06E-04	10	2.4	1.23	8
1741.1290	-8	10	0	10	9	1	9	1.85E-04	10	-6.9	1.30	8
1741.31288	14	10	1	10	9	0	9	5.94E-04	6	1.4	1.40	8
1748.40805	12	3	3	1	2	2	0	9.60E-04	4	-9.9	0.99	8
1749.7621	2	3	3	0	2	2	1	3.06E-03	6	-3.3	1.06	8
1754.3625	-1	8	2	7	7	1	6	6.12E-04	3	-1.0	1.13	8
1757.6911	4	11	0	11	10	1	10	2.88E-04	10	5.7	1.54	8
1761.3855	76	9	1	8	8	2	7	3.07E-04	10	-4.5	1.16	8
1769.78478	-3	4	3	2	3	2	1	2.18E-03	3	3.6	1.07	8
1776.4078	10	4	3	1	3	2	2	6.42E-04	10	-4.9	0.98	8
1787.6560	3	5	3	3	4	2	2	4.38E-04	10	3.5	1.03	8
1788.2920	-14	5	5	0	5	4	1	7.96E-05	10	-2.6	1.43	8
1798.3760	-53	5	2	3	4	1	4	4.20E-04	10	-2.7	0.88	8
1801.8622	38	6	3	4	5	2	3	7.27E-04	4	1.7	0.98	8
1806.3396	-5	5	3	2	4	2	3	1.18E-03	5	7.4	1.03	8
1829.5689	-11	4	4	1	3	3	0	1.55E-03	4	-0.2	1.05	8
1829.7576	-20	4	4	0	3	3	1	4.88E-04	5	-5.9	0.99	8
1853.2859	-15	5	4	2	4	3	1	3.06E-04	10	4.9	1.00	8
1854.57636	6	5	4	1	4	3	2	8.88E-04	4	1.8	0.97	8
1875.1726	-19	6	4	3	5	3	2	4.50E-04	5	2.1	0.88	8
1884.0157	15	7	3	4	6	2	5	1.76E-04	10	4.6	0.78	8
1910.4178	-10	5	5	1	4	4	0	1.60E-04	10	-2.7	0.98	8
1910.4407	0	5	5	0	4	4	1	5.10E-04	8	3.3	1.05	8
1934.9394	-11	6	5	2	5	4	1	2.39E-04	10	1.4	0.87	8

[a] 1 atm = 760 Torr.

[b] o − c, Observed minus computed line positions ($cm^{-1} \times 10^5$). Computed values are derived from the energy levels given in Table 2 and the lower state, (010), levels given in Ref. 1 for $H_2{}^{16}O$ and Ref. 2 for $H_2{}^{17}O$ and $H_2{}^{18}O$. *%s*, Estimated uncertainties in the measured line strengths given in percent. (o − c)%, Percent difference between the observed and computed line strengths. *R*, Ratio of the observed line strength derived in this study to the computed value given in Refs. 17–19. Mol, Isotopic species in which 6 represents $H_2{}^{16}O$, 7 represents $H_2{}^{17}O$, and 8 represents $H_2{}^{18}O$. An asterisk denotes a doubled absorption with the quantum assignment given for the stronger transition. The strength given represents the sum of the strengths of the two comparable transitions. P denotes that the transition is strongly perturbed.

minus the computed line strength in percent [(o − c)%], the ratio *R* of the observed line strength to that given for $H_2{}^{16}O$ in the tabulation by Flaud *et al.*[17] (and in the 1992 edition of the HITRAN database[19] and Ref. 18), and the molecular species (6 denotes $H_2{}^{16}O$; 7, $H_2{}^{17}O$; and 8, $H_2{}^{18}O$). The values for the line strengths are normalized to 100% of the isotopic species in units of inverse square centimeters per atmosphere (1 atm = 760 Torr), whereas the values given in Refs. 17–19 are given in $cm^{-1}/(mol\ cm^{-2})$ and reduced by the normal isotopic abundances (3.7×10^{-4} for $H_2{}^{17}O$ and 2.04×10^{-3} for $H_2{}^{18}O$). Therefore values from Refs. 17–19 were converted into square inverse centimeters per atmosphere by application of the factor 2.48×10^{19} (at 296 K) and division of the result by the proper isotopic abundance in natural water to determine the values of *R* given in Table 5. The experimental line strengths are presented in the table for a temperature of 296 K, whereas the sample temperatures of several of the spectra from which the strengths were determined were slightly different than 296 K. These values were converted to those for $T = 296$ K with the use of Eqs. (1) and the ν_2 rotational levels given in Refs. 1 and 2.

The observed positions are given to three, four, or five decimal places in Table 5, which indicates the accuracy of these measurements. Obviously the most accurate estimates are given with five significant figures past the decimal, and, as was reported in Refs. 1 and 2, the absolute uncertainty for these measurements is $\pm 6 \times 10^{-5}$ cm^{-1}. The computed line positions were derived from the rotational energies given in Table 2 for the (020) states and the levels given for the (010) states given in Ref. 1 for $H_2{}^{16}O$ and Ref. 2 for $H_2{}^{17}O$ and $H_2{}^{18}O$. An asterisk next to the line-position value denotes a doubled absorption for which two transitions were not adequately resolved in the spectra. The quantum assignments given for these features are for the stronger of the two, and the values of the observed and the computed strengths represent the sum of the strengths of the two comparable transitions.

The computed line strengths were derived from the dipole moment expansion coefficients given in Table 4 and Eqs. (1)–(3). Not all the line-strength measurements given in Table 5 were included in the least-squares analyses. Entries with %s = 15% were not included because these transitions resulted in averaged values with uncertainties of as much as 60% to possibly less than 10%. This range of uncertainty for each of these transitions arises for one or more of the following reasons: (a) blending, (b) weakness of transition intensity, and (c) poor agreement between values derived from the various spectra. Other entries not included in the line-strength analyses were those labeled P in Table 5. These transitions are strongly perturbed owing to resonance interactions, and the computed strengths derived for these transitions and used to obtain values of (o − c)% in Table 5 represent the unperturbed values.

The values of R for $H_2{}^{17}O$ and $H_2{}^{18}O$ given in Table 5 were inferred from the $H_2{}^{16}O$ values given by Flaud *et al.*[17] Measurements of the strengths of $H_2{}^{17}O$ and $H_2{}^{18}O$ transitions have not been reported in the literature for the (020)–(010) bands, and therefore values for them given in Refs. 18 and 19 were computed from the transition moment constants of $H_2{}^{16}O$ given by Flaud *et al.*[17]

Table 6 is a listing comparable in content with that of Table 5. This table lists the measurements and computations for the (020)–(000) band of $H_2{}^{16}O$. An added feature for this table is that the computed line-strength values are given in place of the percent differences in the column for (o − c)% if the magnitude of (o − c)% is 14% or greater. The majority of these entries are of transitions that are moderately to strongly perturbed. Also included in Table 6 are two transitions, located at 4077.72 and 4106.87 cm^{-1}, of which the computed strengths given by

Table 6. Line Positions (cm^{-1}) and Strengths (cm^{-2}/atm^a at 296 K) Observed in the (020)–(000) Band of $H_2{}^{16}O^b$

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
2622.5753	-15	9	0	9	10	3	8	3.10E-06	10	1.3	1.06
2670.0044	-3	10	2	9	11	3	8	1.88E-06	5	-12.7	0.90
2681.8148	58	9	1	8	10	4	7	3.54E-06	7	1.5	1.03
2693.3318	41	8	1	8	9	2	7	1.35E-05	4	-0.4	1.05
2730.089	-228	9	2	8	10	3	7	3.60E-06	10	5.3	1.09
2732.49271	-41	7	0	7	8	3	6	2.68E-05	4	-7.0	0.99
2788.8142	3	8	2	7	9	3	6	5.04E-05	8	6.1	1.12
2819.44924	25	6	1	6	7	2	5	1.66E-04	3	-3.7	1.05
2820.48697	-39	9	3	7	10	4	6	1.00E-05	10	0.5	1.04
2830.00743	-34	5	0	5	6	3	4	1.36E-04	3	2.5	1.11
2844.0105	45	7	2	6	8	3	5	7.10E-05	4	3.1	1.10
2864.35029	-84	8	3	6	9	4	5	1.31E-04	3	-4.6	1.00
2871.3305	84	4	0	4	5	3	3	6.00E-05	10	1.2	1.11
2879.70636	-36	5	1	5	6	2	4	1.98E-04	5	0.8	1.11
2883.027	-66	10	5	6	11	6	5	1.31E-05	10	9.0	1.21
2890.1627	14	12	0	12	13	1	13	3.43E-05	7	0.3	1.09
2890.19489	-28	12	1	12	13	0	13	1.10E-04	6	7.0	1.16
2893.07588	6	9	4	5	10	5	6	5.55E-05	2	-3.8	0.99
2893.81418	4	6	2	5	7	3	4	8.11E-04	2	0.2	1.09
2904.43818	19	8	4	5	9	5	4	1.74E-04	2	0.6	1.04
2906.72554	-9	3	0	3	4	3	2	1.45E-04	2	2.6	1.14
2909.4350	-90	11	3	8	12	4	9	9.70E-06	10	10.6	1.13
2909.68935	46	9	5	4	10	6	5	4.10E-05	4	5.1	1.05
2911.33232	8	8	4	4	9	5	5	4.75E-05	3	4.02E-05	1.13
2911.88958	2	11	0	11	12	1	12	2.95E-04	3	-5.7	1.06
2911.95194	1	11	1	11	12	0	12	9.90E-05	5	-4.7	1.07
2912.46818	2	9	3	6	10	4	7	8.70E-05	2	-1.6	1.03
2918.99160	10	8	3	5	9	4	6	8.57E-05	2	-0.8	1.05
2922.1143	22	12	1	12	12	2	11	1.54E-05	10	7.6	1.08
2924.2591	16	12	1	11	13	2	12	1.00E-05	6	7.0	1.10
2930.12835	-1	7	3	4	8	4	5	7.16E-04	2	0.7	1.08
2930.65783	-10	7	4	4	8	5	3	1.76E-04	2	1.1	1.05
2932.65156	-6	8	5	4	9	6	3	1.27E-04	3	2.0	1.02
2933.1213	26	8	5	3	9	6	4	4.10E-05	4	-1.6	0.99
2933.35685	9	10	1	10	11	0	11	8.28E-04	3	2.6	1.13
2933.72895	1	6	3	4	7	4	3	1.53E-03	3	-2.4	1.05
2934.028	-222	12	2	10	13	3	11	4.10E-06	10	2.86E-06	1.10
2935.19362	2	4	1	4	5	2	3	1.92E-03	2	0.7	1.13
2936.7416	-19	2	0	2	3	3	1	1.72E-05	4	2.6	1.15
2936.96703	4	5	2	4	6	3	3	8.90E-04	2	-0.4	1.10
2940.06758	-1	11	1	10	12	2	11	8.87E-05	2	0.7	1.05
2941.76294	-2	11	2	10	12	1	11	3.02E-05	5	2.0	1.06
2941.9863	28	9	6	3	10	7	4	1.10E-05	4	1.41E-05	1.03
2943.1464	-16	11	2	9	12	3	10	2.77E-05	5	0.8	1.01
2944.6606	24	11	1	11	11	2	10	1.74E-05	3	1.1	1.12
2946.0497	-8	6	3	3	7	4	4	5.95E-04	4	-0.3	1.08
2949.1483	8	10	2	8	11	3	9	2.66E-05	5	0.0	1.04
2951.536	-156	10	7	4	11	8	3	5.18E-06	4	3.73E-06	1.27
2951.553	190	10	7	3	11	8	4	1.73E-06	4	1.24E-06	1.27
2953.41383	11	9	2	7	10	3	8	2.07E-04	4	-1.2	1.05
2954.15386	-1	9	0	9	10	1	10	1.93E-03	2	-1.2	1.09
2954.39855	-14	9	1	9	10	0	10	6.81E-04	3	5.8	1.15
2955.1132	-13	5	1	4	5	4	1	9.55E-06	5	24.5	1.23
2955.25618	-1	10	1	9	11	2	10	8.40E-05	3	0.6	1.06
2955.67958	1	6	4	3	7	5	2	1.36E-03	2	0.0	1.05
2956.40613	4	6	4	2	7	5	3	4.62E-04	3	1.2	1.06
2956.90400	-2	7	5	3	8	6	2	1.22E-04	3	4.4	1.03
2956.99441	1	8	2	6	9	3	7	1.65E-04	2	-2.1	1.05
2957.02575	28	7	5	2	8	6	3	3.85E-04	4	7.7	1.09
2958.37995	0	10	2	9	11	1	10	2.51E-04	2	-1.3	1.04
2961.37252	3	7	2	5	8	3	6	1.13E-03	2	-0.9	1.08
2961.71263	0	5	3	3	6	4	2	1.29E-03	2	-0.5	1.08
2961.88288	17	11	3	9	12	2	10	9.91E-06	10	7.6	0.99
2964.21697	10	8	6	3	9	7	2	7.22E-05	2	-3.5	0.97
2964.50474	-12	8	6	2	9	7	3	2.66E-05	2	6.5	1.17
2966.0063	12	5	3	2	6	4	3	4.14E-03	2	1.8	1.11
2966.83284	12	10	1	10	10	2	9	1.53E-04	4	-2.3	1.09
2967.33362	4	10	0	10	10	1	9	5.25E-05	3	-0.2	1.11
2967.98477	-1	6	2	4	7	3	5	8.15E-04	2	0.7	1.11
2969.51627	-2	9	1	8	10	2	9	6.50E-04	2	1.5	1.08
2970.1744	0	5	0	5	5	3	2	6.75E-05	5	8.5	1.17
2973.25241	3	4	2	3	5	3	2	7.00E-03	4	-1.4	1.10
2974.58888	4	8	0	8	9	1	9	1.43E-03	2	0.3	1.12
2974.8280	-45	12	4	9	13	3	10	6.50E-06	8	3.01E-06	1.27
2975.08458	5	8	1	8	9	0	9	4.29E-03	5	0.3	1.11
2975.22271	6	9	2	8	10	1	9	2.16E-04	2	-1.3	1.05
*2975.2944	-68	9	7	2	10	8	3	1.76E-05	2	1.5	0.93
2977.94343	-1	5	2	3	6	3	4	4.95E-03	2	1.3	1.12
2979.07153	5	10	3	8	11	2	9	9.09E-05	2	2.6	1.06
2980.24024	1	5	4	2	6	5	1	1.03E-03	2	-0.5	1.05
2980.38811	-4	5	4	1	6	5	2	3.08E-03	2	-1.0	1.04
2981.14415	-5	6	5	2	7	6	1	9.13E-04	2	1.0	1.03
2981.17111	-4	6	5	1	7	6	2	3.08E-04	3	2.1	1.04
2982.45252	-5	8	1	7	9	2	8	4.85E-04	2	-0.3	1.07
2984.21159	5	3	1	3	4	2	2	1.88E-03	2	1.6	1.15
2987.52481	1	4	3	2	5	4	1	8.06E-03	3	-1.0	1.08
2988.19165	3	7	6	2	8	7	1	7.13E-05	2	0.8	1.01
2988.28775	-1	7	6	1	8	7	2	2.08E-04	2	-2.0	1.00
2988.54570	10	9	1	9	9	2	8	1.39E-04	2	-3.7	1.09
2988.61258	6	4	3	1	5	4	2	2.74E-03	2	-0.2	1.10
2989.62427	4	9	0	9	9	1	8	4.27E-04	2	-3.2	1.09
2991.45528	-4	4	0	4	4	3	1	3.17E-05	3	4.5	1.15
2991.9710	-1	4	2	2	5	3	3	3.08E-03	2	0.3	1.12
2992.65373	-2	8	2	7	9	1	8	1.53E-03	3	0.8	1.09
2993.73595	0	7	1	6	8	2	7	2.95E-03	2	-0.1	1.09
2994.44644	2	7	0	7	8	1	8	8.70E-03	4	3.1	1.15
2995.45513	1	7	1	7	8	0	8	2.85E-03	2	1.0	1.13
2998.97188	0	9	3	7	10	2	8	7.83E-05	2	1.0	1.06
*2999.15758	-18	8	7	2	9	8	1	5.45E-05	4	-2.9	0.92
2999.8623	54	11	4	8	12	3	9	3.22E-06	4	-4.1	0.88
3003.47424	-2	6	1	5	7	2	6	1.83E-03	2	2.9	1.14
3004.6868	46	4	4	1	5	5	0	6.30E-03	4	0.3	1.07
3004.7025	-38	4	4	0	5	5	1	2.10E-03	4	0.2	1.07
3004.98381	-2	12	2	11	12	3	10	1.15E-05	3	-9.2	0.95
3005.4456	17	5	5	1	6	6	0	7.25E-04	5	6.1	1.09
3005.4544	-40	5	5	0	6	6	1	2.18E-03	5	6.4	1.10
3006.42575	0	12	1	11	12	2	10	4.52E-06	3	7.8	1.08
3009.65271	0	8	1	8	8	2	7	1.10E-03	3	1.0	1.14
3010.2322	-26	3	2	1	4	3	2	1.58E-02	3	-1.6	1.11
3011.27736	1	7	2	6	8	1	7	1.05E-03	3	1.3	1.10
3011.90863	9	8	0	8	8	1	7	3.73E-04	2	-1.2	1.12
*3012.0683	16	9	8	1	10	9	2	1.07E-05	7	8.9	0.93
3012.23200	-1	6	6	1	7	7	0	4.55E-04	4	4.84E-04	0.95
3012.34352	-3	6	6	0	7	7	1	1.78E-04	3	-0.8	0.99
3012.37684	1	3	3	1	4	4	0	4.90E-03	2	-0.9	1.09
3013.57316	0	6	0	6	7	1	7	4.98E-03	5	0.5	1.13
3015.61527	-1	6	1	6	7	0	7	1.56E-02	3	4.0	1.17
3021.31066	7	11	2	10	11	3	9	1.47E-05	3	2.2	1.03
*3021.5496	0	10	9	2	11	10	1	6.85E-06	10	1.54E-06	3.08
3022.3662	-3	4	1	3	5	2	4	4.38E-03	3	-0.2	1.13
3022.66503	1	8	3	6	9	2	7	5.33E-04	2	1.2	1.08
*3023.14995	17	7	7	0	8	8	1	1.56E-04	3	-2.6	0.93
3024.15449	16	11	1	10	11	2	9	4.68E-05	3	0.3	1.03
3025.76102	4	2	1	2	3	2	1	1.34E-02	4	-3.1	1.14
3028.90773	-20	10	4	7	11	3	8	3.35E-05	2	13.4	1.12
3029.91060	-2	7	1	7	7	2	6	8.22E-04	2	-0.7	1.13
3030.7266	-18	2	2	1	3	3	0	2.43E-02	3	-3.2	1.10
3031.73414	-1	5	0	5	6	1	6	2.33E-02	3	0.2	1.13
3031.95669	-3	6	2	5	7	1	6	5.52E-03	2	0.1	1.10
3031.99122	-2	2	2	0	3	3	1	8.51E-03	3	0.1	1.14

(Table continued)

Table 6. Continued

Observed		Upper			Lower			Observed			
Position	o − c	J	K_a	K_c	J	K_a	K_c	Strength	%s	(o − c)%	R
3034.26407	-17	3	1	2	4	2	3	1.81E-02	3	-2.3	1.11
3034.39503	-2	7	0	7	7	1	6	2.63E-03	2	-2.0	1.12
3035.78362	-3	5	1	5	6	0	6	7.85E-03	2	0.0	1.13
3037.09961	6	10	2	9	10	3	8	1.48E-04	2	2.3	1.07
3042.42387	15	10	1	9	10	2	8	5.27E-05	2	-1.7	1.03
*3046.6235	0	9	9	0	10	10	1	6.60E-06	5	5.64E-06	0.87
3048.67233	-2	4	0	4	5	1	5	1.06E-02	3	-0.4	1.13
3048.94745	-1	6	1	6	6	2	5	4.98E-03	3	-2.0	1.12
3049.0445	0	2	1	1	3	2	2	8.04E-03	2	-0.9	1.14
3050.70281	3	7	3	5	8	2	6	3.29E-04	2	-2.1	1.06
3052.00952	1	9	2	8	9	3	7	1.42E-04	3	-0.4	1.06
3055.61013	-1	5	2	4	6	1	5	2.73E-03	2	0.3	1.12
3056.35632	-4	4	1	4	5	0	5	3.30E-02	2	2.1	1.16
3057.14658	3	6	0	6	6	1	5	1.95E-03	3	-0.8	1.14
3059.92945	-3	1	1	1	2	2	0	8.27E-03	3	-0.7	1.15
3061.22892	8	9	1	8	9	2	7	5.10E-04	2	-1.1	1.06
3062.2831	36	13	2	11	13	3	10	2.05E-06	10	-4.4	0.89
3062.34785	6	9	4	6	10	3	7	2.45E-05	3	-0.9	1.00
3064.40416	1	3	0	3	4	1	4	3.80E-02	2	-0.6	1.13
3065.61738	0	8	2	7	8	3	6	1.14E-03	2	1.2	1.10
3066.27142	-4	5	1	5	5	2	4	3.07E-03	2	0.4	1.16
3067.01176	1	1	1	0	2	2	1	3.03E-02	3	0.7	1.16
3068.9305	-1	12	3	10	12	4	9	7.10E-06	7	7.92E-06	0.93
3076.2266	-21	12	2	10	12	3	9	2.40E-06	6	2.34E-06	0.88
3077.47344	0	7	2	6	7	3	5	8.65E-04	2	-0.3	1.10
3077.93830	-5	3	1	3	4	0	4	1.23E-02	3	-1.0	1.13
3079.0601	-14	11	3	9	11	4	8	9.70E-06	3	-3.5	0.93
3079.52895	-5	5	0	5	5	1	4	1.21E-02	3	0.2	1.15
3079.6827	0	2	0	2	3	1	3	1.33E-02	2	-0.6	1.15
3079.92632	1	8	1	7	8	2	6	4.98E-04	2	-2.6	1.06
3081.34196	-2	4	1	4	4	2	3	1.37E-02	3	-3.7	1.11
3082.55629	2	6	3	4	7	2	5	1.61E-03	3	0.1	1.09
3082.60700	2	4	2	3	5	1	4	9.55E-03	2	-1.0	1.11
3087.19210	2	6	2	5	6	3	4	5.05E-03	2	-2.2	1.09
3088.1380	4	11	5	7	12	4	8	2.10E-06	10	1.61E-06	1.09
3088.39982	1	10	3	8	10	4	7	1.01E-04	3	-0.6	0.99
3089.6306	19	7	0	7	6	3	4	6.45E-06	8	20.9	1.23
3090.0783	-17	4	0	4	3	3	1	3.40E-06	4	-2.4	1.09
3092.43016	7	11	2	9	11	3	8	4.25E-05	2	0.0	0.98
3093.68955	-12	3	1	3	3	2	2	6.01E-03	2	0.5	1.16
3094.54785	9	5	2	4	5	3	3	2.83E-03	2	-0.7	1.12
3095.94498	0	1	0	1	2	1	2	3.70E-02	4	-0.8	1.15
3096.0554	-10	9	3	7	9	4	6	1.02E-04	3	1.9	1.04
3096.085	83	6	0	6	5	3	3	3.94E-06	10	-2.0	1.03
3096.4696	-3	5	0	5	4	3	2	1.78E-05	2	5.8	1.16
3096.92638	3	7	1	6	7	2	5	4.17E-03	2	0.1	1.11
3098.81641	17	8	4	5	9	3	6	1.69E-04	3	2.9	1.06
3099.54760	-1	4	2	3	4	3	2	1.08E-02	2	-3.4	1.09
3099.80083	3	4	0	4	4	1	3	7.48E-03	2	-1.2	1.14
3101.15571	3	2	1	2	3	0	3	3.34E-02	3	0.1	1.15
3101.87788	-13	8	3	6	8	4	5	7.75E-04	2	1.2	1.06
*3102.174	0	10	10	1	11	11	0	6.90E-07	15	-29.3	0.74
3103.01575	4	2	1	2	2	2	1	1.59E-02	3	0.7	1.17
3105.87046	-8	7	3	5	7	4	4	5.60E-04	2	1.3	1.07
3106.06741	0	10	2	8	10	3	7	5.52E-05	2	-0.4	1.01
3107.33075	-3	3	2	1	3	3	0	1.01E-02	2	-3.2	1.10
3108.24122	-7	6	3	4	6	4	3	2.96E-03	2	-0.5	1.08
3109.37835	-6	5	3	3	5	4	2	1.43E-03	2	1.5	1.11
3109.75826	-4	4	3	2	4	4	1	4.02E-03	3	-0.9	1.09
3110.30902	2	6	1	5	6	2	4	3.28E-03	2	-0.6	1.11
3110.59277	2	4	3	1	4	4	0	1.36E-03	2	-0.2	1.10
3112.09667	0	4	2	2	4	3	1	4.29E-03	2	-0.6	1.12
3112.18363	2	3	2	2	4	1	3	2.91E-03	2	1.8	1.15
3112.38980	2	5	3	2	5	4	1	4.35E-03	3	0.2	1.10
3112.8432	9	8	1	8	7	2	5	5.65E-06	3	2.5	1.08
3114.1790	-4	12	4	9	12	5	8	4.45E-06	6	4.10E-06	0.90
3114.49303	0	0	0	0	1	1	1	9.92E-03	2	0.4	1.16
3115.87673	-1	3	0	3	3	1	2	3.72E-02	2	0.4	1.16
3116.01353	3	6	3	3	6	4	2	1.07E-03	2	0.6	1.08
3116.62315	23	9	2	7	9	3	6	5.83E-04	2	1.6	1.05
3116.71942	0	5	3	3	6	2	4	7.16E-04	2	1.3	1.12
3118.11005	-2	5	2	3	5	3	2	1.09E-02	3	-3.1	1.08
3118.94392	-2	5	1	4	5	2	3	1.91E-02	2	-1.8	1.11
3119.18203	-1	2	1	1	2	2	0	7.77E-03	2	0.3	1.16
3119.94481	0	11	4	8	11	5	7	5.28E-06	4	-8.6	0.86
3121.59985	9	7	3	4	7	4	3	1.89E-03	2	-0.8	1.06
3122.47014	-7	3	1	2	3	2	1	3.28E-02	2	-0.6	1.14
3122.79539	-3	4	1	3	4	2	2	9.77E-03	2	-1.4	1.13
3123.06805	-2	8	2	6	8	3	5	5.70E-04	2	1.9	1.08
3123.13014	-5	6	2	4	6	3	3	2.55E-03	2	0.7	1.11
3123.41248	0	10	4	7	10	5	6	5.50E-05	3	-2.3	0.94
3125.13178	-6	7	2	5	7	3	4	4.00E-03	2	-0.3	1.08
3125.51643	-2	9	4	6	9	5	5	5.00E-05	3	-5.1	0.94
3126.00249	-8	1	1	1	2	0	2	6.55E-03	2	2.3	1.18
3126.5686	-4	8	4	5	8	5	4	3.85E-04	2	2.1	1.03
3126.7852	-5	2	0	2	2	1	1	1.58E-02	3	-0.2	1.16
3127.42006	-4	6	4	2	6	5	1	4.02E-04	2	0.9	1.05
3128.06590	2	10	5	6	11	4	7	1.37E-05	4	1.07E-05	0.96
3128.10084	-5	8	3	5	8	4	4	3.17E-04	2	-0.4	1.04
3128.55876	-6	7	4	3	7	5	2	7.61E-04	2	0.0	1.02
3133.06957	-3	1	0	1	1	1	0	4.20E-02	2	-0.2	1.16
3133.56880	-9	9	3	6	9	4	5	4.03E-04	2	1.3	1.04
3134.4975	16	9	4	5	9	5	4	1.77E-04	5	4.5	1.04
3135.37910	-11	11	3	8	11	4	7	3.90E-05	2	2.7	0.99
3136.27988	-11	10	3	7	10	4	6	4.36E-05	2	-3.5	0.97
3136.41190	4	7	4	4	8	3	5	1.05E-04	3	-0.4	1.03
3136.74535	-1	7	1	7	6	2	4	1.06E-05	3	8.1	1.21
3139.6678	2	10	4	6	10	5	5	2.05E-05	3	-3.0	0.94
3142.77956	-1	2	2	1	3	1	2	4.95E-03	3	2.6	1.17
3145.41371	-2	11	4	7	11	5	6	2.05E-05	3	0.4	0.95
3151.35542	1	4	3	2	5	2	3	2.18E-03	2	-0.8	1.10
3152.10094	-2	10	5	6	10	6	5	2.58E-05	3	4.4	0.96
3152.28080	2	6	5	2	6	6	1	3.17E-04	3	-0.8	0.98
3152.3025	-8	6	5	1	6	6	0	1.06E-04	3	-0.5	0.98
3152.35617	2	7	5	3	7	6	2	8.60E-05	3	-2.5	0.95
3152.3950	-52	9	5	5	9	6	4	2.09E-05	2	-5.2	0.89
3152.42329	8	8	5	4	8	6	3	1.48E-04	3	0.0	0.95
3152.44235	-7	7	5	2	7	6	1	2.56E-04	2	-3.4	0.94
3152.627	0	13	4	9	13	5	8	1.16E-06	5	-10.1	0.80
3152.72461	0	8	5	3	8	6	2	4.95E-05	3	0.1	0.96
3153.27893	-1	9	5	4	9	6	3	6.83E-05	2	2.7	0.97
3154.3484	-46	10	5	5	10	6	4	9.03E-06	3	7.7	0.97
3155.34825	3	6	1	6	5	2	3	1.33E-04	2	1.8	1.17
3156.1317	11	11	5	6	11	6	5	7.90E-06	5	-3.3	0.87
3163.82721	0	3	1	3	2	2	0	5.22E-04	3	1.6	1.18
3164.18558	3	6	3	3	7	2	6	2.84E-04	2	1.6	1.08
3165.66644	5	9	4	5	10	3	8	5.64E-05	3	0.0	1.00
3166.70071	6	5	1	5	4	2	2	1.56E-04	2	-0.5	1.15
3167.1882	23	9	5	5	10	4	6	1.18E-05	6	9.73E-06	0.98
3167.23672	3	7	3	4	8	2	7	3.54E-04	3	-0.7	1.02
3167.9111	12	3	2	1	4	1	4	2.63E-03	2	0.7	1.13
3169.31353	-17	4	2	2	5	1	5	5.53E-04	4	3.5	1.14
3169.54796	1	4	1	4	3	2	1	1.21E-03	2	1.8	1.19
3169.81962	-1	5	3	2	6	2	5	1.50E-03	2	-0.9	1.07
3170.08176	-5	8	4	4	9	3	7	1.54E-04	2	3.28E-05	1.01
3173.15850	4	6	4	3	7	3	4	5.08E-04	2	-1.3	1.03
3174.93228	13	2	2	0	3	1	3	8.32E-04	2	2.2	1.15
3175.2268	30	11	5	6	12	4	9	4.50E-06	6	12.8	0.91
3178.11896	-6	1	1	0	1	0	1	4.42E-02	3	1.2	1.17
3179.49101	-2	8	3	5	9	2	8	4.08E-05	2	-2.7	0.95
3179.66986	4	5	2	3	6	1	6	7.47E-04	3	-0.4	1.08
3181.9027	56	11	4	7	12	3	10	5.60E-06	6	4.55E-06	0.99
3182.27837	1	7	4	3	8	3	6	3.35E-04	2	2.6	1.01
3182.51832	5	4	3	1	5	2	4	6.42E-04	2	-0.2	1.09
3183.0510	-34	10	6	4	10	7	3	2.86E-06	10	3.15E-06	0.82
3183.2679	50	11	6	5	11	7	4	2.85E-06	5	-9.4	0.76
3183.675	0	11	6	6	11	7	5	8.70E-07	10	1.04E-06	0.76
3184.041	15	10	6	5	10	7	4	9.11E-06	4	-3.5	0.88
3184.06814	-3	7	6	2	7	7	1	2.25E-05	4	1.9	0.97
3184.16360	-12	7	6	1	7	7	0	6.42E-05	2	-3.1	0.93
3184.3976	7	8	6	2	8	7	1	1.44E-05	4	-11.5	0.89
3184.73163	9	3	3	1	4	2	2	4.86E-04	2	-0.5	1.11
3184.82405	-1	2	0	2	1	1	1	6.25E-03	3	0.8	1.17
3185.25511	-2	2	1	1	2	0	2	1.57E-02	3	-1.0	1.14
3185.7433	-9	9	6	3	9	7	2	1.08E-05	4	1.46E-05	0.79
3186.78116	16	10	5	5	11	4	8	7.45E-06	4	4.26E-06	0.75
3196.0934	2	1	1	1	0	0	0	1.08E-02	3	2.2	1.18
3196.64586	-7	4	2	3	3	3	0	9.42E-04	2	-1.4	1.12
3197.86481	-10	3	1	2	3	0	3	3.55E-02	2	0.5	1.15
3198.19995	0	6	2	4	7	1	7	1.00E-04	3	-4.4	0.99
3199.35853	2	6	4	2	7	3	5	1.83E-04	2	-0.6	1.01
3199.72497	3	3	1	2	2	2	1	4.42E-03	2	0.0	1.15
3200.1702	-3	9	3	6	10	2	9	4.18E-05	2	4.8	0.94
3200.27642	0	3	3	0	4	2	3	1.42E-03	3	-0.5	1.10
3200.3095	75	10	2	9	9	3	6	1.94E-06	10	8.0	0.99
3203.3260	12	9	5	4	10	4	7	3.30E-05	3	-4.1	0.95
3203.79922	-7	8	5	4	9	4	5	7.70E-05	5	11.7	0.95
3209.74614	-4	3	0	3	2	1	2	3.36E-02	3	0.1	1.16
3210.71974	-8	4	2	2	3	3	1	3.86E-04	2	-1.4	1.12
3214.12290	-8	2	1	2	1	0	1	4.15E-02	3	1.0	1.16
3214.67360	18	5	2	4	4	3	1	3.65E-04	4	-0.2	1.12
3216.52224	1	4	1	3	4	0	4	7.03E-03	2	0.7	1.14

(Table continued)

Table 6. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
3218.0840	82	9	2	8	8	3	5	4.20E-06	3	5.1	1.07
3218.929	0	11	7	5	11	8	4	3.50E-07	15	-9.7	0.75
3219.38352	-5	3	2	1	3	1	2	2.98E-02	3	-2.7	1.10
*3219.515	-394	10	7	4	10	8	3	4.00E-06	10	-10.6	0.77
*3219.7740	10	9	7	2	9	8	1	9.30E-06	10	-9.7	0.79
*3219.9198	14	8	7	2	8	8	1	1.44E-05	6	-9.9	0.82
3220.00824	0	5	4	1	6	3	4	6.83E-04	3	-0.8	1.03
3220.44214	-1	4	2	2	4	1	3	8.72E-03	3	-0.9	1.11
3222.03471	1	2	2	0	2	1	1	7.76E-03	3	1.1	1.15
3223.32582	3	7	2	5	8	1	8	1.24E-04	2	-2.9	0.95
3223.4815	-13	8	5	3	9	4	6	2.46E-05	5	-4.0	0.95
3227.3588	9	6	2	5	5	3	2	6.20E-04	4	-6.0	1.04
3227.46465	-2	5	2	3	5	1	4	1.59E-02	3	-3.7	1.07
3227.596	-98	10	3	7	11	2	10	4.00E-06	10	0.0	0.77
3229.37672	-1	8	2	7	7	3	4	6.15E-05	3	-1.9	1.04
3229.90022	-8	3	1	3	2	0	2	1.51E-02	2	-1.5	1.14
3231.35855	-9	5	3	3	4	4	0	1.03E-04	2	-1.8	1.06
3232.27355	0	4	1	3	3	2	2	2.66E-03	3	0.4	1.14
3232.61891	6	7	2	6	6	3	3	8.16E-05	2	-0.4	1.08
3233.01935	-3	4	0	4	3	1	3	1.32E-02	2	-0.1	1.15
3234.62320	-8	5	3	2	4	4	1	3.25E-04	2	-0.2	1.08
3236.64897	-4	2	2	1	2	1	2	1.75E-02	3	-0.7	1.12
3236.7705	7	7	5	3	8	4	4	4.72E-05	3	8.9	0.95
3237.95050	-10	4	4	1	5	3	2	4.95E-04	3	-1.0	1.04
3240.10670	0	5	1	4	5	0	5	1.13E-02	3	1.0	1.13
3241.77341	7	6	2	4	6	1	5	2.74E-03	3	3.1	1.13
3242.80789	6	4	4	0	5	3	3	1.69E-04	2	-1.4	1.04
3244.40529	-1	5	2	3	4	3	2	1.77E-03	3	-1.5	1.10
3244.94259	-6	4	1	4	3	0	3	4.49E-02	2	-0.6	1.14
3245.40216	-3	3	2	2	3	1	3	6.70E-03	4	1.3	1.14
3245.92850	7	7	5	2	8	4	5	1.24E-04	3	-10.7	0.93
3251.63510	-6	10	6	4	11	5	7	1.32E-05	4	1.76E-06	0.93
3253.0155	-17	8	2	6	9	1	9	1.74E-05	2	0.5	0.87
3254.14814	-1	5	0	5	4	1	4	3.59E-02	2	-1.4	1.13
3254.62489	0	6	3	4	5	4	1	3.87E-04	2	0.5	1.07
3257.22613	0	4	2	3	4	1	4	1.54E-02	2	-1.4	1.10
*3257.8527	-115	9	8	1	9	9	0	2.40E-06	5	-8.8	0.82
3260.42739	-7	5	1	5	4	0	4	1.29E-02	3	0.5	1.14
3263.27440	-2	7	2	5	7	1	6	3.37E-03	2	4.4	1.12
3263.67922	-6	6	3	3	5	4	2	1.39E-04	2	-2.2	1.04
3265.09233	1	5	1	4	4	2	3	8.68E-03	2	-5.4	1.06
3266.1019	29	6	5	2	7	4	3	2.10E-04	8	1.80E-04	1.00
3266.38590	-3	6	1	5	6	0	6	1.95E-03	3	2.9	1.13
3269.61705	-2	6	5	1	7	4	4	5.29E-05	2	6.18E-05	0.95
3270.42704	-5	7	3	4	7	2	5	2.98E-03	2	2.0	1.08
3271.02026	-3	6	3	3	6	2	4	2.03E-03	3	4.1	1.12
3271.89035	-10	5	2	4	5	1	5	3.42E-03	3	1.9	1.12
3272.5182	3	4	3	2	5	0	5	2.04E-04	2	-1.5	1.02
3272.7964	5	5	3	3	6	0	6	6.84E-05	3	-3.2	0.96
3273.42679	-7	6	0	6	5	1	5	9.33E-03	3	0.5	1.14
3273.4389	13	6	4	3	5	5	0	8.40E-05	10	8.4	1.08
3273.77370	7	2	2	1	1	1	0	3.60E-02	4	2.0	1.14
3273.9801	36	6	4	2	5	5	1	2.60E-05	5	0.5	1.00
3275.8342	-6	7	3	5	6	4	2	8.75E-05	3	-2.7	1.01
3276.22039	0	5	3	2	5	2	3	9.60E-03	3	2.0	1.11
3276.51097	-1	6	1	6	5	0	5	2.82E-02	3	-1.2	1.12
3276.96471	-6	8	3	5	8	2	6	4.16E-04	2	7.3	1.12
3277.6127	24	9	6	3	10	5	6	1.86E-04	3	1.42E-05	1.08
3278.4585	15	3	3	1	4	0	4	3.28E-05	2	-5.9	1.00
3278.72262	6	6	3	4	7	0	7	1.51E-04	2	-2.0	0.92
3280.07350	-1	2	2	0	1	1	1	1.06E-02	3	1.8	1.14
3280.7110	4	6	2	4	5	3	3	5.95E-04	2	0.9	1.10
3282.94743	-3	4	3	1	4	2	2	4.11E-03	2	1.6	1.11
3284.9922	6	9	2	7	10	1	10	2.80E-05	8	2.12E-05	0.94
3288.48261	22	3	3	0	3	2	1	1.12E-02	3	2.1	1.13
3288.91839	-7	6	2	5	6	1	6	5.78E-03	2	2.9	1.12
3289.5503	-51	7	3	5	8	0	8	3.30E-05	8	9.0	0.94
3291.35674	-5	7	0	7	6	1	6	1.79E-02	3	-2.9	1.09
3291.88285	7	9	3	6	9	2	7	3.89E-04	4	3.8	1.06
3292.50473	-1	3	2	2	2	1	1	1.00E-02	2	2.7	1.14
3292.72372	8	5	5	1	6	4	2	5.08E-05	2	2.7	0.94
3293.09266	2	7	1	6	7	0	7	2.80E-03	2	2.3	1.10
3293.3494	-1	8	3	6	7	4	3	1.24E-04	2	-4.0	0.97
3293.78772	-26	5	5	0	6	4	3	8.11E-05	2	1.50E-04	0.96
3294.20970	3	3	3	1	3	2	2	3.69E-03	2	-0.1	1.10
3296.11205	-6	7	3	4	6	4	3	3.28E-04	3	-5.2	0.99
3296.87362	-12	6	1	5	5	2	4	2.74E-03	3	0.9	1.10
3297.50380	1	4	3	2	4	2	3	1.18E-02	2	-2.4	1.07
3297.93690	6	7	4	4	6	5	1	2.75E-05	4	-7.6	0.90
3299.79556	0	7	4	3	6	5	2	8.70E-05	4	-4.2	0.93
3300.10742	2	8	6	2	9	5	5	1.12E-05	4	9.35E-06	1.17
3302.65586	4	8	4	5	9	1	8	5.67E-05	2	4.62E-05	0.89
3303.28418	2	5	3	3	5	2	4	3.06E-03	3	2.7	1.11
3303.67912	-4	7	4	4	8	1	7	2.77E-05	5	7.2	0.87
3304.41822	6	8	3	6	9	0	9	5.26E-05	2	4.59E-05	0.85
3305.1650	11	9	3	7	8	4	4	1.43E-05	2	-1.1	0.96
3307.4793	14	9	4	6	10	1	9	9.50E-06	8	7.36E-06	0.79
3307.68855	-6	7	2	6	7	1	7	9.52E-04	2	2.5	1.10
3308.31966	-14	8	0	8	7	1	7	3.50E-03	3	-2.6	1.08
3308.69870	-2	4	2	3	3	1	2	2.28E-02	3	-0.3	1.10
3309.00939	-1	8	1	8	7	0	7	1.10E-02	3	1.6	1.13
3311.3012	16	6	4	3	7	1	6	9.57E-05	2	1.1	0.88
3312.0547	-4	6	3	4	6	2	5	5.30E-03	3	0.9	1.08
3313.25298	-3	3	2	1	2	1	2	2.00E-02	2	1.6	1.12
3314.46457	6	10	3	7	10	2	8	3.48E-05	3	0.8	1.00
3317.0992	-9	10	2	8	11	1	11	4.60E-06	10	2.81E-06	0.82
3318.50978	0	7	2	5	6	3	4	1.37E-03	2	0.2	1.06
3318.77414	-20	8	1	7	8	0	8	4.17E-04	2	2.3	1.07
3320.46258	8	9	2	7	9	1	8	4.23E-04	2	2.8	1.05
3321.8997	-21	8	4	5	7	5	2	5.85E-05	3	-3.7	0.90
3322.4082	8	9	3	7	10	0	10	9.57E-06	3	6.95E-06	0.81
3323.01890	0	5	2	4	4	1	3	5.73E-03	6	2.5	1.11
3323.4875	-8	7	5	3	6	6	0	5.00E-06	10	-1.8	0.88
3323.5798	80	7	5	2	6	6	1	1.53E-05	3	6.5	0.89
3323.8112	-3	7	6	1	8	5	4	1.25E-05	3	4.14E-05	1.29
3324.00634	3	7	3	5	7	2	6	8.88E-04	2	3.0	1.09
3324.5411	-6	9	0	9	8	1	8	5.65E-03	2	0.2	1.09
3324.86730	-7	9	1	9	8	0	8	1.90E-03	2	0.9	1.10
3326.2242	43	10	4	6	10	3	7	2.81E-05	10	7.8	1.10
3326.42480	-2	7	1	6	6	2	5	5.80E-03	3	-1.2	1.05
3326.6671	65	8	4	4	7	5	3	1.30E-05	5	1.38E-05	0.87
3326.8470	0	13	3	10	14	2	13	1.95E-05	4	2.22E-07	0.85
3327.57072	4	8	2	7	8	1	8	1.29E-03	5	3.6	1.08
3328.87554	-5	9	4	5	9	3	6	2.45E-04	2	3.3	1.01
3331.184	-167	11	4	7	11	3	8	2.00E-05	10	-2.9	0.96
3332.1323	-23	8	3	5	7	4	4	8.10E-05	4	10.7	1.12
3336.1554	-8	8	4	4	8	3	5	9.20E-05	3	1.41E-04	1.02
3336.4086	-102	10	5	6	11	2	9	1.50E-05	8	4.97E-06	0.95
3336.71326	-5	6	2	5	5	1	4	1.14E-02	2	0.0	1.07
3338.98627	-7	8	3	6	8	2	7	1.08E-03	3	-2.0	1.02
3340.14170	-1	10	0	10	9	1	9	8.85E-04	2	0.0	1.08
3340.29838	-3	10	1	10	9	0	9	2.68E-03	4	0.9	1.09
3340.63360	-9	12	5	8	13	2	11	2.61E-05	3	3.75E-07	1.02
3342.6263	38	10	3	8	11	0	11	1.80E-05	10	8.62E-06	0.82
3342.98188	-10	9	1	8	9	0	9	5.10E-04	3	2.3	1.05
3343.7227	-25	11	3	8	11	2	9	2.75E-05	4	5.7	1.05
3344.5857	-6	9	4	6	8	5	3	9.27E-06	2	-7.6	0.84
3345.6725	1	9	5	5	10	2	8	5.86E-06	2	3.36E-06	0.75
3346.03775	4	7	4	3	7	3	4	1.47E-03	3	-1.1	1.03
3347.2107	-9	6	6	1	7	5	2	2.89E-05	2	3.29E-05	0.69
3347.2416	30	12	4	9	13	1	12	4.30E-05	3	9.08E-07	1.00
3347.3060	80	4	4	1	5	1	4	2.72E-05	5	5.7	0.98
3347.5109	-18	6	6	0	7	5	3	4.00E-06	4	1.22E-05	1.26
3347.8058	1	11	2	9	12	1	12	1.12E-05	4	3.17E-06	0.85
3347.84030	14	8	5	4	7	6	1	1.40E-05	3	1.60E-05	0.75
3348.03064	-14	9	2	8	9	1	9	1.69E-04	3	0.4	1.02
3351.19876	-2	10	2	8	10	1	9	4.55E-05	3	1.5	1.02
3351.26201	1	7	2	6	6	1	5	2.43E-03	3	3.6	1.08
3353.22984	0	8	1	7	7	2	6	1.17E-03	2	-0.2	1.03
3353.66080	7	4	2	2	3	1	3	3.43E-03	3	2.0	1.09
3354.50397	5	6	4	2	6	3	3	9.45E-04	2	-1.9	1.02
3354.6059	1	9	7	2	10	6	5	2.15E-06	5	1.60E-06	0.56
3355.18740	0	11	0	11	10	1	10	1.10E-03	5	-2.7	1.03
3355.26415	2	11	1	11	10	0	10	3.77E-04	3	-3.2	1.06
3356.53135	-11	8	2	6	7	3	5	2.85E-04	2	-3.3	0.99
3356.55521	18	9	3	7	9	2	8	1.37E-04	2	-0.7	1.01
3356.6282	21	9	4	5	8	5	4	3.22E-05	2	-6.0	0.85
3360.17503	16	5	4	1	5	3	2	4.37E-03	2	-2.6	1.03
3362.11312	-6	8	5	4	9	2	7	2.27E-05	2	1.53E-05	0.76
3362.93345	-4	4	4	0	4	3	1	1.51E-03	3	-2.5	1.03
3363.87708	-1	3	3	0	3	0	3	3.82E-04	3	0.7	1.06
3364.24581	-2	4	4	1	4	3	2	4.68E-03	2	-3.8	1.05
3364.34719	-2	3	3	1	2	2	0	1.06E-02	3	-1.1	1.06
3364.90481	-1	5	4	2	5	3	3	1.55E-03	3	0.9	1.05
3365.73713	1	3	3	0	2	2	1	3.27E-02	3	1.6	1.09
3365.85998	2	10	1	9	10	0	10	6.44E-05	3	4.5	1.03
3366.5366	20	6	4	3	6	3	4	3.05E-03	3	-0.3	1.03
3367.51928	-3	8	2	7	7	1	6	3.92E-03	2	1.5	1.03
3368.6779	-7	10	2	9	10	1	10	1.92E-04	3	3.1	1.02
3369.71632	-22	12	0	12	11	1	11	1.52E-04	3	4.4	1.09
3369.75526	0	12	1	12	11	0	11	4.38E-04	2	0.4	1.05
3369.87518	-7	7	4	4	7	3	5	5.28E-04	2	-1.7	1.01
3371.09574	-3	9	3	6	8	4	5	1.09E-04	3	-6.2	0.91
3371.9990	-9	9	5	5	8	6	2	3.00E-06	10	-9.9	0.74

(Table continued)

Table 6. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
3373.0506	7	9	5	4	8	6	3	9.22E-06	2	-8.5	0.76
3375.42330	9	12	2	10	13	1	13	1.03E-04	2	2.63E-07	1.01
3375.61936	-9	8	4	5	8	3	6	7.08E-04	2	0.2	1.02
3376.10188	0	10	3	8	10	2	9	1.35E-04	2	-3.0	0.99
3376.6746	33	4	3	1	4	0	4	2.58E-04	3	-0.7	1.03
3377.55017	1	9	1	8	8	2	7	1.84E-03	2	2.5	1.02
3379.992	140	8	6	3	7	7	0	2.52E-06	4	-1.5	0.81
3380.80555	-6	11	2	9	11	1	10	3.63E-05	3	4.08E-05	0.94
3383.7578	-1	13	0	13	12	1	12	1.47E-04	3	-4.1	0.98
3383.7778	0	13	1	13	12	0	12	5.10E-05	3	1.9	1.02
3384.2658	-22	9	4	6	9	3	7	8.42E-05	3	-4.6	0.97
3385.35048	0	9	2	8	8	1	7	6.60E-04	4	5.1	1.04
3385.70981	5	4	3	2	3	2	1	1.97E-02	2	-4.1	1.01
3387.21188	-3	12	3	10	13	0	13	3.03E-05	3	1.14E-06	1.10
3389.2617	4	11	2	10	11	1	11	1.96E-05	3	-6.0	0.94
3392.42560	1	4	3	1	3	2	2	6.92E-03	2	1.5	1.06
3393.42608	-5	9	2	7	8	3	6	4.79E-04	2	-1.2	0.97
3393.5280	-10	15	3	12	16	2	15	1.36E-05	4	1.34E-08	1.10
3396.00305	0	10	4	7	10	3	8	7.90E-05	4	-8.3	0.95
*3397.3455	5	14	1	14	13	0	13	6.82E-05	6	4.4	1.04
3397.38318	3	5	3	2	5	0	5	7.24E-04	2	0.7	1.02
3400.00681	-6	10	1	9	9	2	8	2.68E-04	3	0.7	0.96
3401.1693	-51	11	5	6	11	4	7	1.15E-05	7	5.0	1.06
3402.08377	-5	5	2	3	4	1	4	4.54E-03	2	4.0	1.07
3403.7131	-25	5	3	3	4	2	2	4.02E-03	3	1.4	1.05
3404.14825	-8	10	2	9	9	1	8	8.53E-04	2	4.3	0.99
*3410.4805	0	15	0	15	14	1	14	2.00E-05	7	4.5	1.02
3414.9284	-54	6	5	2	7	2	5	1.70E-05	5	1.08E-05	0.58
3418.45555	5	6	3	4	5	2	3	6.12E-03	3	-4.4	0.96
3419.1315	68	12	3	10	12	2	11	3.22E-05	3	1.15E-05	0.87
3421.18462	-11	11	1	10	10	2	9	3.22E-04	2	2.4	0.94
3422.36882	5	5	3	2	4	2	3	1.14E-02	3	1.5	1.03
3423.36084	-31	11	2	10	10	1	9	1.10E-04	10	3.8	0.95
3424.42662	1	9	5	4	9	4	5	1.29E-04	3	2.3	0.96
3427.0974	18	6	3	3	6	0	6	1.33E-04	3	-2.8	0.96
3427.9850	-64	10	2	8	9	3	7	7.50E-05	6	-0.7	0.92
3430.4203	0	3	3	1	2	0	2	1.11E-04	5	5.9	1.09
3430.8411	5	7	3	5	6	2	4	1.11E-03	3	2.7	1.01
3432.5910	-2	8	5	3	8	4	4	1.10E-04	4	-3.4	0.92
3437.3999	7	7	5	2	7	4	3	7.50E-04	3	-1.3	0.94
3439.58102	23	6	5	1	6	4	2	4.20E-04	3	-4.2	0.91
3440.17156	-2	5	5	0	5	4	1	1.57E-03	2	3.9	0.94
3440.3892	-22	5	5	1	5	4	2	4.98E-04	3	-1.2	0.98
3440.61402	6	6	5	2	6	4	3	1.26E-03	2	-5.0	0.96
3440.80205	-2	7	5	3	7	4	4	2.45E-04	3	-5.7	0.95
3441.3263	13	8	5	4	8	4	5	3.28E-04	3	-9.9	0.92
3441.4978	90	12	1	11	11	2	10	3.51E-05	10	-4.9	0.83
3442.17688	14	8	3	6	7	2	5	1.59E-03	3	2.7	0.98
3442.6430	12	12	2	11	11	1	10	1.10E-04	4	-1.1	0.87
3442.757	89	9	5	5	9	4	6	4.05E-05	5	4.68E-05	0.92
3444.2325	84	7	4	3	8	1	8	3.21E-05	10	1.03E-05	0.84
3445.7389	95	10	5	6	10	4	7	3.21E-05	10	4.64E-05	0.83
3454.02827	-50	9	3	7	8	2	6	2.37E-04	2	3.1	0.95
3457.58502	-1	6	3	3	5	2	4	1.76E-03	2	2.3	0.99
3458.05361	-4	6	2	4	5	1	5	6.04E-04	3	6.5	1.03
3461.10447	1	4	3	2	3	0	3	8.42E-04	3	3.7	1.03
3461.34413	-2	4	4	1	3	3	0	1.92E-02	4	0.5	1.01
3461.55660	-4	4	4	0	3	3	1	6.20E-03	3	-2.8	0.97
3466.10313	5	8	4	4	9	1	9	4.58E-03	3	1.24E-06	1.07
3466.5935	12	7	3	4	7	0	7	1.56E-04	2	1.67E-04	0.87
3467.81442	-1	10	3	8	9	2	7	2.82E-04	4	0.7	0.89
3469.52962	15	5	4	1	5	1	4	2.01E-04	3	-4.9	0.92
3471.2782	-77	4	4	0	4	1	3	2.17E-05	10	2.51E-05	0.83
3473.1472	13	6	4	2	6	1	5	8.00E-05	6	9.39E-05	0.83
3484.18026	-3	7	4	3	7	1	6	2.10E-04	8	-7.5	0.95
3485.03049	1	5	4	2	4	3	1	3.56E-03	3	-0.3	0.96
3486.47012	2	5	4	1	4	3	2	1.08E-02	3	0.1	0.96
3497.44032	16	5	3	3	4	0	4	3.26E-04	3	2.8	0.97
3497.60126	-17	5	5	0	6	2	5	5.57E-04	2	2.58E-06	0.92
3499.9255	-6	7	3	4	6	2	5	2.03E-03	4	3.5	0.95
3503.42298	20	8	4	4	8	1	7	5.28E-04	3	2.54E-05	1.05
3504.676	138	10	5	5	11	2	10	3.40E-04	10	4.76E-07	1.24
3506.70319	16	6	4	3	5	3	2	5.45E-03	3	2.7	0.96
3512.0844	-29	6	4	2	5	3	3	1.80E-03	10	0.4	0.92
3514.4989	-35	13	2	11	12	3	10	8.00E-06	8	9.42E-06	0.65
3515.81253	-27	8	3	5	8	0	8	1.53E-05	3	1.81E-05	0.73
3518.44755	2	6	6	1	6	5	2	5.07E-04	2	3.40E-04	0.85
3518.52510	1	6	6	0	6	5	1	1.80E-04	2	1.26E-04	0.82
3519.03389	-9	9	6	3	9	5	4	4.17E-04	5	3.76E-05	0.98
3519.14253	3	7	6	1	7	5	2	4.93E-04	3	2.94E-04	0.83
3519.17660	-11	8	6	2	8	5	3	1.20E-04	4	5.07E-05	0.83
3519.23568	-2	7	6	2	7	5	3	1.55E-04	3	9.80E-05	0.79
3519.6378	-31	8	6	3	8	5	4	2.93E-04	2	1.53E-04	0.88
3519.66745	16	10	6	5	10	5	6	4.15E-05	3	2.14E-05	0.79
3519.7214	-56	9	6	4	9	5	5	4.17E-05	4	2.09E-05	0.86
3520.23623	7	7	2	5	6	1	6	6.56E-04	2	5.4	0.93
3525.02075	9	7	4	4	6	3	3	7.52E-04	2	-2.5	0.87
3528.7247	-3	7	6	2	8	3	5	2.08E-04	3	4.81E-07	0.70
3532.7152	3	9	4	5	9	1	8	5.85E-05	3	4.40E-05	0.81
3537.2554	-25	10	4	6	11	1	11	5.64E-06	10	2.81E-07	0.64
3539.37888	8	8	4	5	7	3	4	9.33E-04	2	3.1	0.88
3539.4155	-15	7	4	3	6	3	4	2.50E-03	4	5.0	0.93
3539.61824	-2	6	3	4	5	0	5	7.25E-04	3	4.0	0.92
3542.24751	0	5	4	2	5	1	5	1.55E-05	5	-2.6	0.82
3542.3515	8	10	6	4	11	3	9	1.37E-05	4	2.14E-07	1.26
3550.20331	28	9	6	3	10	3	8	9.05E-04	3	7.44E-07	1.04
3550.26825	-5	8	3	5	7	2	6	2.20E-04	2	5.5	0.89
3550.3400	31	9	4	6	8	3	5	1.25E-04	6	1.09E-04	0.94
3558.85727	30	8	6	2	9	3	7	2.03E-04	2	5.24E-07	0.93
3559.21243	18	10	4	7	9	3	6	1.14E-04	6	2.8	0.80
3562.3695	-15	5	5	1	4	4	0	2.56E-03	2	1.5	0.90
3562.40485	-23	5	5	0	4	4	1	7.50E-03	5	-0.9	0.90
3564.6897	2	6	6	1	7	3	4	3.50E-02	5	5.46E-07	0.85
3572.86206	2	7	6	1	8	3	6	6.74E-04	3	1.38E-06	0.86
3573.3972	26	4	4	1	3	1	2	6.11E-05	2	-3.5	0.85
3576.327	-149	12	4	9	11	3	8	8.70E-06	10	1.05E-05	0.64
3581.4540	-90	8	5	3	8	2	6	1.73E-05	4	1.16E-05	0.59
3586.2272	4	7	5	2	7	2	5	9.80E-05	3	3.81E-05	0.77
3586.9975	-6	6	5	2	5	4	1	3.90E-03	4	5.4	0.89
3587.24662	5	6	5	1	5	4	2	1.23E-03	2	-0.3	0.85
3590.46368	18	6	6	0	7	3	5	2.31E-04	2	2.07E-07	0.86
3591.8418	-35	10	5	5	10	2	8	3.60E-06	10	8.4	0.29
3594.58785	27	6	5	1	6	2	4	5.27E-05	2	9.38E-06	0.79
*3595.999	54	7	7	0	7	6	1	8.50E-05	10	-12.4	0.58
3604.00231	12	5	5	0	5	2	3	8.44E-04	2	1.16E-05	0.83
3604.4976	5	4	4	0	3	1	3	1.14E-05	2	1.02E-05	0.93
3605.6791	30	9	4	5	8	3	6	3.15E-04	10	9.6	0.83
3608.20422	12	9	3	6	8	2	7	1.73E-04	2	0.0	0.74
3610.76596	17	7	5	3	6	4	2	5.48E-04	2	2.6	0.82
3611.094	-123	6	5	2	7	0	7	1.45E-05	4	6.15E-07	0.44
3611.91220	2	7	5	2	6	4	3	1.71E-03	4	5.9	0.85
3616.0580	37	6	4	3	5	1	4	2.45E-04	4	-1.9	0.80
3632.79782	25	8	5	4	7	4	3	6.09E-04	2	-0.4	0.74
3636.622	-66	8	5	3	7	4	4	1.96E-04	10	-5.6	0.71
3637.5728	5	8	4	5	8	1	8	1.56E-05	5	-5.9	0.62
3638.3429	-13	8	3	6	7	0	7	1.67E-04	4	0.5	0.74
3643.66389	8	7	4	4	6	1	5	7.50E-05	3	-1.6	0.75
3644.14868	6	5	4	1	4	1	4	5.26E-05	2	-2.1	0.77
3648.14195	-5	10	4	6	9	3	7	2.47E-05	2	-1.5	0.64
3651.86548	-2	9	5	5	8	4	4	7.16E-05	2	5.1	0.73
3655.37942	-1	9	2	7	8	1	8	6.90E-05	4	-3.0	0.66
3658.9384	56	7	5	3	7	2	6	7.93E-06	3	6.37E-06	0.67
3661.9535	1	9	5	4	8	4	5	2.13E-04	2	1.3	0.70
3664.96995	-4	6	6	1	5	5	0	1.63E-03	3	2.03E-03	0.76
3665.08455	-18	6	6	0	5	5	1	6.53E-04	3	-3.4	0.73
3666.8387	2	10	5	6	9	4	5	6.12E-05	3	1.9	0.66
3672.3474	-26	10	3	7	9	2	8	1.59E-05	4	1.41E-05	0.71
3678.4344	-10	8	5	4	8	2	7	1.60E-05	8	1.32E-05	0.56
3689.4278	42	6	4	2	5	1	5	1.57E-05	3	-3.0	0.68
3692.87666	-14	9	3	7	8	0	8	1.98E-05	3	-3.3	0.62
3698.2810	21	11	4	7	10	3	8	1.70E-05	2	5.0	0.60
3702.8324	14	6	6	1	7	1	6	1.13E-04	5	7.02E-08	0.88
3714.96933	-5	8	6	3	7	5	2	2.87E-04	3	-8.0	0.65
3715.44167	6	8	6	2	7	5	3	9.92E-05	3	-4.4	0.62
3717.6073	31	9	4	6	8	1	7	1.95E-05	3	-4.6	0.59
3724.0072	29	10	2	8	9	1	9	4.60E-06	3	7.07E-06	0.37
3725.16493	-2	5	5	0	5	0	5	2.75E-04	3	7.27E-07	0.90
3745.6091	19	6	6	0	6	3	3	2.30E-04	3	6.57E-07	0.83
3750.15064	7	5	5	0	4	2	3	7.70E-05	3	1.04E-05	0.99
3758.0676	-2	6	6	1	6	3	4	2.70E-02	3	2.00E-06	0.81
*3767.1348	-24	7	7	0	6	6	1	4.92E-04	3	1.9	0.59
3791.1037	7	11	2	9	10	1	10	3.80E-06	7	5.47E-06	0.32
3799.83402	-2	8	4	4	7	1	7	1.45E-03	2	3.72E-06	1.11
3812.767	-45	12	5	8	12	2	11	7.00E-06	10	2.27E-07	0.93
3817.9348	0	9	7	3	8	6	2	1.30E-05	4	5.4	0.47
3817.96755	2	9	7	2	8	6	3	4.05E-05	2	9.2	0.49
3825.1526	3	10	5	6	9	2	7	7.50E-06	10	6.51E-06	0.49
3842.565	-190	10	7	3	9	6	4	2.90E-06	10	-9.3	0.33
*3866.6566	0	8	8	1	7	7	0	7.20E-05	10	5.59E-05	0.54
3871.9912	27	6	5	2	5	0	5	4.14E-05	2	9.46E-07	0.05
3874.7641	13	7	6	1	7	1	6	1.25E-04	3	3.63E-07	0.79
3892.1983	36	8	6	2	8	1	7	4.50E-05	4	1.41E-07	1.05

(Table continued)

Table 6. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
*3892.6331	-1	9	8	1	8	7	2	3.46E-05	6	1.44E-05	0.76	4006.544	5	11	5	6	10	2	9	2.65E-06	6	3.04E-08	0.21
3898.2343	5	6	6	1	5	3	2	7.40E-02	3	1.40E-06	0.84	4007.5890	15	6	6	1	5	1	4	6.35E-03	2	1.78E-08	0.75
3903.18980	12	6	6	0	5	3	3	3.50E-04	2	4.60E-07	0.75	4018.00805	0	15	3	12	14	2	13	1.14E-04	2	9.02E-11	0.97
3915.27836	-3	10	5	5	10	0	10	1.90E-05	4	6.82E-08	0.43	4021.1890	16	10	6	4	9	3	7	4.46E-05	3	4.28E-09	1.68
3929.99945	12	7	6	1	6	3	4	1.37E-03	3	1.54E-06	0.76	4035.97683	15	7	6	2	6	1	5	8.73E-05	3	7.50E-09	0.71
3932.4485	23	8	6	3	7	3	4	3.20E-04	6	1.19E-06	0.74	4070.5912	35	8	6	3	7	1	6	6.83E-05	2	1.04E-09	0.63
3944.1634	13	10	4	6	9	1	9	2.34E-05	3	1.36E-07	0.45	4077.72	-575	8	7	2	7	4	3	2.90E-07	UL	3.10E-09	0.07
3949.42522	-8	10	5	5	9	2	8	4.95E-04	3	1.89E-07	0.36	4106.87	-49	9	7	2	8	4	5	3.20E-07	UL	5.98E-08	0.08
3955.4666	-46	10	6	5	9	3	6	1.30E-05	10	2.54E-07	0.80	4131.7260	29	7	6	1	6	1	6	1.32E-05	4	8.96E-10	0.80
3958.39407	4	8	6	2	7	3	5	5.12E-04	2	2.83E-07	0.83	4159.3060	-64	10	6	5	9	1	8	9.30E-06	10	8.31E-08	0.52
3959.7943	30	6	6	1	6	1	6	1.19E-04	3	1.42E-08	0.81	4188.6099	70	8	6	2	7	1	7	2.20E-06	5	4.20E-09	0.67
3980.1815	0	14	2	12	13	1	13	1.55E-05	4	4.12E-09	1.55	4252.1690	26	9	6	3	8	1	8	4.80E-06	10	3.84E-08	0.58
3983.76244	0	14	3	12	13	0	13	1.06E-04	2	1.11E-08	1.29	4260.40872	9	12	5	8	11	0	11	3.95E-05	3	5.43E-08	1.11

[a]1 atm = 760 Torr.

[b]o − c, Observed minus computed line positions ($cm^{-1} \times 10^5$). Computed values are derived from the energy levels given in Table 2 and the ground-state levels given in Ref. 1. %s, Estimated uncertainties in the measured line strengths given in percent. (o − c)%, Percent difference between the observed and the computed line strengths or the value of the computed strength if the difference between the observed and the computed values is ≈±14% or larger in magnitude. R, Ratio of the observed line strength derived in this study to the computed value given in Refs. 18 and 19. UL, upper limit; there were no apparent absorption features in any of the spectra within ±0.015 cm^{-1} of the listed frequency. The observed strength given represents the maximum strength that the transition can have, with nearby absorption features of other transitions and also the signal-to-noise ratio of the spectra taken into consideration. An asterisk denotes a doubled absorption with the quantum assignment given for the stronger transition. The strength given represents the sum of the strengths of the two comparable transitions.

Table 7. Line Positions (cm^{-1}) and Strengths (cm^{-2}/atm^a at 296 K) Observed in the (020)–(000) Band of $H_2{}^{17}O^b$

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
2927.3410	32	7	4	3	8	5	4	5.60E-04	10	3.8		3042.9350	-23	2	1	1	3	2	2	8.10E-03	2	0.5	1.24
2927.5810	36	6	3	4	7	4	3	1.50E-03	10	-4.1	1.12	3048.5478	0	5	2	4	6	1	5	2.68E-03	2	-1.5	1.16
2930.5584	56	5	2	4	6	3	3	7.99E-04	10	-8.7	1.08	3049.8176	34	4	1	4	5	0	5	3.29E-02	2	1.4	1.23
2948.0040	-17	9	0	9	10	1	10	1.92E-03	2	-3.0	1.12	3050.463	40	6	0	6	6	1	5	2.02E-03	5	3.3	1.29
2948.2350	19	9	1	9	10	0	10	6.87E-04	5	4.0		3053.74258	0	1	1	1	2	2	0	8.47E-03	4	2.7	1.28
2949.7345	20	6	4	3	7	5	2	1.40E-03	10	0.2	1.17	3058.08305	-13	3	0	3	4	1	4	3.87E-02	2	0.6	1.24
2955.7105	-5	5	3	3	6	4	2	1.27E-03	3	-2.9	1.15	3059.1772	-30	8	2	7	8	3	6	1.10E-03	5	-4.1	1.15
2955.8535	-2	7	2	5	8	3	6	1.16E-03	3	1.9	1.17	3060.8654	17	1	1	0	2	2	1	3.08E-02	3	3.0	1.28
2960.1463	3	5	3	2	6	4	3	4.15E-03	3	1.0	1.20	3071.2902	-8	3	1	3	4	0	4	1.23E-02	3	-1.4	1.21
2962.3611	-35	6	2	4	7	3	5	8.34E-04	10	3.5	1.21	3072.8047	-1	5	0	5	5	1	4	1.19E-02	3	-1.4	1.24
2963.428	105	9	1	8	10	2	9	6.77E-04	10	3.5		3073.32730	0	2	0	2	3	1	3	1.37E-02	3	1.8	1.27
2967.0677	9	4	2	3	5	3	2	6.90E-03	3	-1.2	1.18	3074.4990	-24	6	3	4	7	2	5	1.53E-03	3	-4.9	1.09
2968.3892	39	8	0	8	9	1	9	1.44E-03	4	0.2	1.16	3075.03925	-8	4	1	4	4	2	3	1.43E-02	2	2.1	1.27
2968.8573	-1	8	1	8	9	0	9	4.60E-03	10	6.3	1.24	3075.36258	-2	4	2	3	5	1	4	9.70E-03	3	0.5	1.20
2972.2035	23	5	2	3	6	3	4	4.86E-03	4	0.2	1.18	3080.92261	26	6	2	5	6	3	4	5.17E-03	2	-0.2	1.21
2974.3245	-49	5	4	2	6	5	1	1.10E-03	3	1.4	1.23	3087.4293	3	3	1	3	3	2	2	6.00E-03	2	1.6	1.27
2974.4798	23	5	4	1	6	5	2	3.25E-03	3	-0.3	1.20	3089.54250	-3	1	0	1	2	1	2	3.78E-02	2	0.9	1.26
2977.8327	10	3	1	3	4	2	2	1.83E-03	6	1.4	1.24	3090.0273	22	7	1	6	7	2	5	4.40E-03	7	2.7	1.28
2981.5858	7	4	3	2	5	4	1	8.10E-03	5	-2.5	1.18	3093.11650	-21	4	0	4	4	1	3	7.35E-03	3	-3.2	1.23
2982.7100	0	4	3	1	5	4	2	2.85E-03	4	1.8	1.23	3093.4361	3	4	2	3	4	3	2	1.15E-02	2	3.0	1.27
2986.1218	23	4	2	2	5	3	3	3.05E-03	3	0.1	1.20	3094.3997	-5	2	1	2	3	0	3	3.44E-02	2	2.4	1.26
2986.1579	6	8	2	7	9	1	8	1.60E-03	10	4.4	1.19	3095.6222	19	8	3	6	8	4	5	8.00E-04	10	-1.0	1.18
2987.7522	-24	7	1	6	8	2	7	3.15E-03	4	5.8	1.22	3096.4000	50	3	2	2	3	3	1	3.27E-03	3	-0.6	1.23
2988.2029	-11	7	0	7	8	1	8	8.70E-03	5	2.5	1.20	3096.79208	-2	2	1	2	2	2	1	1.57E-02	2	0.4	1.26
2989.1625	-17	7	1	7	8	0	8	2.80E-03	4	-1.3	1.16	3099.719	136	7	3	5	7	4	4	5.81E-04	10	1.0	
2997.52760	11	6	1	5	7	2	6	1.90E-03	4	6.3	1.24	3101.3375	-26	3	2	1	3	3	0	1.01E-02	3	-3.3	1.20
2997.7850	-17	3	2	2	4	3	1	5.00E-03	3	2.5	1.24	3102.1712	-21	6	3	4	6	4	3	3.10E-03	5	0.8	1.23
2998.7838	10	4	4	1	5	5	0	6.13E-03	5	-8.2	1.14	3103.3627	-37	5	3	3	5	4	2	1.40E-03	5	-3.6	1.19
2998.802	84	4	4	0	5	5	1	2.00E-03	5	-10.9	1.11	3103.5828	-25	6	1	5	6	2	4	3.30E-03	5	-2.1	1.22
*2999.5344	18	5	5	0	6	6	1	2.68E-03	4	-0.2	1.11	3103.77398	-12	4	3	2	4	4	1	4.27E-03	4	1.9	1.27
3004.2996	1	3	2	1	4	3	2	1.62E-02	2	1.6	1.23	3104.6324	-5	4	3	1	4	4	0	1.42E-03	3	0.9	1.26
3004.6257	-22	7	2	6	8	1	7	1.00E-03	10	-4.0	1.11	3104.8306	-1	3	2	2	4	1	3	2.82E-03	3	-1.7	1.18
3006.4576	31	3	3	1	4	4	0	4.75E-03	6	-6.9	1.16	3106.1251	-16	4	2	2	4	3	1	4.54E-03	4	4.8	1.28
3006.5880	-7	5	1	4	6	2	5	8.77E-03	3	0.4	1.19	3106.45393	-4	5	3	2	5	4	1	4.47E-03	2	-0.2	1.22
3006.61685	-15	3	3	0	4	4	1	1.50E-02	2	-1.9	1.21	3108.0493	-10	0	0	0	1	1	1	1.00E-02	5	0.8	1.28
3007.2977	21	6	0	6	7	1	7	5.02E-03	3	0.7	1.20	3108.5615	-6	5	3	3	6	2	4	7.00E-04	10	-1.1	
3009.2520	15	6	1	6	7	0	7	1.50E-02	2	-0.4	1.18	3109.27735	3	3	0	3	3	1	2	3.68E-02	3	-1.0	1.26
3016.3655	-33	4	1	3	5	2	4	4.36E-03	4	-0.5	1.20	3109.735	-85	9	2	7	9	3	6	5.50E-04	6	-10.0	
3019.50149	-10	2	1	2	3	2	1	1.33E-02	2	0.7	1.24	3110.1230	51	6	3	3	6	4	2	1.06E-03	6	-3.7	1.16
3024.72450	-8	2	2	1	3	3	0	2.56E-02	5	2.4	1.26	3112.4039	-11	5	1	4	5	2	3	1.95E-02	3	-1.1	1.23
3025.1088	22	6	2	5	7	1	6	5.52E-03	4	0.1	1.16	3112.9860	13	2	1	1	2	2	0	7.75E-03	3	0.1	1.25
3025.4393	15	5	0	5	6	1	6	2.36E-02	4	0.9	1.21	3115.7351	12	7	3	4	7	4	3	2.04E-03	4	2.6	1.23
3026.01336	9	2	2	0	3	3	1	8.40E-03	3	-0.8	1.22	3116.20892	6	3	1	2	3	2	1	3.35E-02	3	1.1	1.26
3027.8084	51	7	0	7	7	1	6	2.68E-03	3	1.2	1.25	3116.4150	-36	4	1	3	4	2	2	9.75E-03	2	-2.5	1.21
3028.20585	13	3	1	2	4	2	3	1.83E-02	3	-0.8	1.20	3116.9851	-31	6	2	4	6	3	3	2.55E-03	4	-1.0	1.19
3029.3396	0	5	1	5	6	0	6	7.65E-03	5	-3.0	1.16	3118.7700	2	7	2	5	7	3	4	3.87E-03	4	-6.4	1.13
3042.3669	-13	4	0	4	5	1	5	1.05E-02	3	-2.0	1.20	3119.1696	51	1	1	1	2	0	2	7.10E-03	6	9.6	1.37
3042.5832	-16	6	1	6	6	2	5	5.05E-03	3	1.5	1.24	3120.25917	0	2	0	2	2	1	1	1.59E-02	3	0.0	1.26

(Table continued)

Table 7. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
3120.475	-89	8	4	5	8	5	4	4.20E-04	10	-1.3	
3120.9115	-31	6	4	3	6	5	2	1.47E-03	10	12.2	1.41
3120.932	-121	5	4	1	5	5	0	1.30E-03	8	-5.4	1.18
3126.5830	7	1	0	1	1	1	0	4.22E-02	2	-0.1	1.26
3135.3826	35	2	2	1	3	1	2	4.95E-03	3	2.1	1.24
3143.1903	61	4	3	2	5	2	3	2.22E-03	5	0.5	1.19
3156.919	106	6	3	3	7	2	6	2.74E-04	10	-0.0	
3157.484	409	3	1	3	2	2	0	4.83E-04	10	-4.5	
3160.8014	11	3	2	1	4	1	4	2.57E-03	3	-1.1	1.19
3162.2421	11	5	3	2	6	2	5	1.56E-03	7	3.9	1.20
3162.418	-302	4	2	2	5	1	5	4.96E-04	10	-5.4	
3167.6720	-52	2	2	0	3	1	3	8.59E-04	5	5.0	1.28
3171.2372	21	1	1	0	1	0	1	4.36E-02	4	-1.4	1.24
3173.030	-51	5	2	3	6	1	6	7.26E-04	10	1.0	
3174.742	73	4	3	1	5	2	4	6.65E-04	5	3.2	
3176.620	436	3	3	1	4	2	2	4.65E-04	10	-5.8	
3178.29860	0	2	0	2	1	1	1	6.22E-03	2	-0.5	1.26
3178.41238	0	2	1	1	2	0	2	1.57E-02	2	-2.5	1.23
3189.1738	4	1	1	1	0	0	0	1.06E-02	3	-1.0	1.26
3190.474	-24	4	2	3	3	3	0	9.00E-04	10	-5.3	1.18
3191.10688	-14	3	1	2	3	0	3	3.50E-02	3	-2.8	1.22
3193.49930	-7	3	1	2	2	2	1	4.50E-03	3	1.5	1.27
3203.1602	13	3	0	3	2	1	2	3.43E-02	3	1.2	1.28
3207.16385	-1	2	1	2	1	0	1	4.25E-02	3	1.9	1.29
3209.87327	23	4	1	3	4	0	4	7.18E-03	5	0.6	1.26
3211.99541	-2	3	2	1	3	1	2	3.10E-02	3	-0.2	1.23
3213.1707	0	4	2	2	4	1	3	8.85E-03	2	-1.3	1.21
3214.6042	-19	2	2	0	2	1	1	8.10E-03	4	4.1	1.29
3220.8196	-56	6	2	5	5	3	2	6.47E-04	6	1.8	
3222.90650	8	3	1	3	2	0	2	1.55E-02	3	-0.4	1.26
3226.0120	-3	4	1	3	3	2	2	2.50E-03	7	-6.5	1.16
3226.34500	15	4	0	4	3	1	3	1.35E-02	3	0.9	1.27
3229.2651	10	2	2	1	2	1	2	1.78E-02	2	0.0	1.24
3233.53650	4	5	1	4	5	0	5	1.13E-02	4	-1.5	1.21
3234.9759	53	6	2	4	6	1	5	2.72E-03	3	-1.0	1.21
3237.94060	-3	4	1	4	3	0	3	4.57E-02	3	-0.4	1.25
3238.0587	-5	3	2	2	3	1	3	6.65E-03	3	-0.2	1.22
3238.4700	46	5	2	3	4	3	2	1.70E-03	4	-5.6	1.15
3247.37984	-4	5	0	5	4	1	4	3.58E-02	3	-3.0	1.21
3256.7495	62	7	2	5	7	1	6	3.28E-03	3	-2.6	1.18
3258.75817	-36	5	1	4	4	2	3	9.58E-03	4	3.3	1.25
3259.8246	-3	6	1	5	6	0	6	2.15E-03	10	10.3	1.34
3262.65353	-5	7	3	4	7	2	5	3.07E-03	3	3.3	1.19
3262.9735	0	6	3	3	6	2	4	1.90E-03	6	-3.4	1.12
3264.6639	-50	5	2	4	5	1	5	3.38E-03	4	0.4	1.19
3266.30544	4	2	2	1	1	1	0	3.55E-02	3	-1.1	1.22
3266.5792	0	6	0	6	5	1	5	9.38E-03	3	-0.5	1.23
3268.05806	13	5	3	2	5	2	3	9.42E-03	3	-0.2	1.17
3269.53175	0	6	1	6	5	0	5	2.90E-02	3	-0.1	1.24
3272.64375	-7	2	2	0	1	1	1	1.07E-02	2	1.1	1.25
3274.79105	25	4	3	1	4	2	2	4.60E-03	10	12.4	1.34
3280.39036	11	3	3	0	3	2	1	1.12E-02	4	1.4	1.21
3281.7498	21	6	2	5	6	1	6	5.80E-03	5	3.2	1.21
3284.44890	0	7	0	7	6	1	6	1.85E-02	3	-1.6	1.21
3284.9907	8	3	2	2	2	1	1	1.02E-02	2	2.7	1.26
3285.8422	18	7	1	7	6	0	6	6.30E-03	4	-0.5	1.22
3286.2120	-31	3	3	1	3	2	2	3.50E-03	4	-6.0	1.13
3286.4631	-36	7	1	6	7	0	7	2.73E-03	3	-2.3	1.14
3289.5439	-31	4	3	2	4	2	3	1.19E-02	4	-1.6	1.17
3295.3940	-34	5	3	3	5	2	4	2.80E-03	4	-5.7	1.10
3300.5637	69	7	2	6	7	1	7	9.51E-04	2	2.4	1.17
3301.1320	9	4	2	3	3	1	2	2.39E-02	2	2.2	1.24
3301.3670	-37	8	0	8	7	1	7	3.50E-03	4	-5.1	1.15
3302.01842	0	8	1	8	7	0	7	1.12E-02	3	0.8	1.22
3304.2670	-13	6	3	4	6	2	5	5.28E-03	3	1.3	1.16
3305.8784	22	3	2	1	2	1	2	2.00E-02	3	-0.3	1.21
3312.034	0	8	1	7	8	0	8	4.00E-04	10	-3.8	
3312.5625	-15	7	2	5	6	3	4	1.30E-03	10	-6.4	1.08
3313.2791	-16	7	6	1	8	5	4	1.70E-03	10	1.52E-05	1.15
3314.203	-31	9	2	7	9	1	8	4.69E-04	10	7.0	
3315.4143	22	5	2	4	4	1	3	5.87E-03	4	2.3	1.23
3316.342	-81	7	3	5	7	2	6	9.32E-04	4	8.4	1.22
3317.5542	-28	9	0	9	8	1	8	5.97E-03	3	2.3	1.23
3317.8611	-13	9	1	9	8	0	8	2.11E-03	3	7.9	1.30
3319.7950	3	7	1	6	6	2	5	6.40E-03	10	5.8	1.24
3329.11495	-20	6	2	5	5	1	4	1.15E-02	3	-2.1	1.15
3331.4580	-13	8	3	6	8	2	7	1.10E-03	2	-0.3	1.11
3333.127	0	10	0	10	9	1	9	9.00E-04	10	-3.3	1.16
3333.2743	9	10	1	10	9	0	9	2.70E-03	5	-3.4	1.15
3336.122	-148	9	1	8	9	0	9	5.21E-04	10	1.7	
3336.9745	0	7	4	3	7	3	4	1.47E-03	5	2.6	1.11
3343.7275	-62	7	2	6	6	1	5	2.41E-03	3	-1.0	1.15
3345.5637	-13	6	4	2	6	3	3	9.10E-04	3	-1.7	1.07
3348.1525	0	11	0	11	10	1	10	1.15E-03	6	-5.6	1.13
3351.3826	-37	5	4	1	5	3	2	4.40E-03	4	1.5	1.11
3354.2460	22	4	4	0	4	3	1	1.52E-03	5	0.3	1.12
3355.6020	8	4	4	1	4	3	2	4.50E-03	3	-1.8	1.10
3357.6808	4	3	3	0	2	2	1	3.27E-02	2	-0.2	1.18
3357.9177	30	6	4	3	6	3	4	2.92E-03	2	0.1	1.07
3360.0730	14	8	2	7	7	1	6	4.07E-03	3	0.1	1.14
3361.3285	0	7	4	4	7	3	5	5.54E-04	10	8.5	
3362.700	0	12	1	12	11	0	11	4.97E-04	10	2.1	
3367.195	175	8	4	5	8	3	6	7.66E-04	10	13.3	
3370.574	43	9	1	8	8	2	7	1.90E-03	10	-1.4	1.12
3377.54735	0	4	3	2	3	2	1	2.08E-02	4	-0.4	1.16
3377.9722	0	9	2	8	8	1	7	7.00E-04	10	3.4	
3389.192	162	5	3	2	5	0	5	7.14E-04	10	7.1	
3394.97120	-4	5	2	3	4	1	4	4.52E-03	3	1.8	1.16
3395.44395	8	5	3	3	4	2	2	3.95E-03	4	-2.4	1.11
3410.0833	23	6	3	4	5	2	3	6.56E-03	2	-0.2	1.11
3414.41235	-10	5	3	2	4	2	3	1.14E-02	2	-0.2	1.12
3422.399	63	7	3	5	6	2	4	1.14E-03	10	1.5	1.11
3430.9022	-1	5	5	0	5	4	1	1.50E-03	10	1.25E-03	1.10
3431.139	-15	5	5	1	5	4	2	5.00E-04	10	4.16E-04	
3431.3297	-52	6	5	2	6	4	3	1.23E-03	10	1.08E-03	1.01
3433.732	-77	8	3	6	7	2	5	1.53E-03	3	-7.0	1.01
3449.8060	-28	6	3	3	5	2	4	1.66E-03	6	-5.6	1.01
3451.092	3	6	2	4	5	1	5	5.68E-04	7	-0.9	
3452.4452	-31	4	3	2	3	0	3	7.60E-04	10	-5.2	0.98
3452.64003	-6	4	4	1	3	3	0	1.92E-02	4	0.8	1.08
3452.8599	-21	4	4	0	3	3	1	6.50E-03	3	2.3	1.10
3476.2629	0	5	4	2	4	3	1	3.59E-03	2	1.5	1.05
3476.9284	0	6	5	1	7	2	6	3.60E-03	10	1.06E-06	1.19
3477.75143	0	5	4	1	4	3	2	1.10E-02	3	-3.0	1.06
3492.4212	-27	7	3	4	6	2	5	1.96E-03	10	-2.8	0.98
3497.8150	-21	6	4	3	5	3	2	5.22E-03	3	-0.6	0.98
3503.3710	6	6	4	2	5	3	3	1.90E-03	10	6.3	1.05
3508.7420	-69	6	6	1	6	5	2	6.30E-04	2	1.37E-04	
3513.3892	-69	7	2	5	6	1	6	7.50E-04	6	6.27E-04	
3515.952	-46	7	4	4	6	3	3	7.46E-04	10	-3.2	0.93
3531.218	248	6	3	4	5	0	5	7.34E-04	10	8.5	0.99
3545.8357	-34	8	6	2	9	3	7	7.29E-04	10	7.68E-10	1.05
3551.954	-161	6	6	1	7	3	4	2.40E-03	10	3.90E-09	0.94
3553.0616	0	5	5	1	4	4	0	2.57E-03	4	2.04E-03	0.98
3553.0904	-18	5	5	0	4	4	1	7.60E-03	5	6.12E-03	0.96
3577.6376	-32	6	5	2	5	4	1	4.00E-03	2	2.92E-03	0.99
3577.782	-347	6	5	1	5	4	2	1.15E-03	6	9.75E-04	0.97
3578.0600	-14	6	6	0	7	3	5	3.09E-03	3	1.86E-13	1.11
3602.5300	0	7	5	2	6	4	3	1.70E-03	5	1.26E-03	0.91
3623.2740	0	8	5	4	7	4	3	6.51E-04	10	4.82E-04	0.84
3655.1960	-33	6	6	1	5	5	0	2.03E-03	3	3.77E-04	0.86
3679.706	584	7	6	1	6	5	2	6.20E-04	2	1.29E-04	0.90
3710.7410	-21	8	6	2	8	3	5	8.10E-04	4	2.31E-08	1.05
3732.6840	-10	6	6	0	6	3	3	3.00E-03	3	6.85E-08	1.03
3860.89204	6	7	6	1	7	1	6	2.70E-03	4	6.87E-07	1.21
3890.4918	59	6	6	0	5	3	3	4.68E-03	5	1.82E-06	1.13
3916.7057	-5	7	6	1	6	3	4	2.71E-02	3	1.17E-05	1.16
3938.91423	0	10	5	5	9	2	8	1.62E-02	3	6.88E-09	1.25
3944.7885	90	8	6	2	7	3	5	2.08E-03	5	4.72E-06	1.39

[a] 1 atm = 760 Torr.

[b] o − c, Observed minus computed line positions ($cm^{-1} \times 10^5$). Computed values are derived from the energy levels given in Table 2 and the ground-state levels given in Ref. 2. %s, Estimated uncertainties in the measured line strengths given in percent. (o − c)%, Percent difference between the observed and the computed line strengths or the value of the computed strength if the difference between the observed and the computed values is ≈±14% or larger in magnitude. R, Ratio of the observed line strength derived in this study to the computed value given in Refs. 15, 18, and 19. An asterisk denotes a doubled absorption with the quantum assignment given for the stronger transition. The strength given represents the sum of the strengths of the two comparable transitions.

Table 8. Line Positions (cm^{-1}) and Strengths (cm^{-2}/atm^{a} at 296 K) Observed in the (020)–(000) Band of $H_2{}^{18}O$[b]

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R	Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
2892.7945	-62	8	4	5	9	5	4	1.65E-04	10	-9.4	1.09	3053.43097	5	8	2	7	8	3	6	1.08E-03	4	1.8	1.17
2900.47948	0	11	0	11	12	1	12	2.76E-04	2	-5.2	0.99	3054.27365	-9	5	1	5	5	2	4	2.90E-03	3	-1.6	1.23
2900.5349	124	11	1	11	12	0	12	9.26E-05	4	-4.6		3055.38135	-4	1	1	0	2	2	1	3.00E-02	2	1.3	1.29
2908.8325	64	8	3	5	9	4	6	7.91E-05	10	-9.0		3065.36470	1	3	1	3	4	0	4	1.22E-02	2	-0.7	1.22
2919.5619	46	7	3	4	8	4	5	7.20E-04	3	3.1	1.19	3065.4381	29	7	2	6	7	3	5	8.09E-04	7	-1.7	1.15
2921.7095	11	10	0	10	11	1	11	2.60E-04	4	1.2	1.07	3066.7670	-2	8	1	7	8	2	6	4.50E-04	3	-7.2	1.09
2921.8179	14	10	1	10	11	0	11	7.73E-04	2	0.2	1.06	3066.81020	-2	5	0	5	5	1	4	1.14E-02	2	-3.4	1.24
2922.87729	25	4	1	4	5	2	3	1.67E-03	4	-6.3	1.14	3067.3320	37	6	3	4	7	2	5	1.60E-03	3	4.0	1.13
2924.8314	28	5	2	4	6	3	3	8.00E-04	3	-5.3	1.14	3067.65815	-3	2	0	2	3	1	3	1.32E-02	3	-1.0	1.26
2935.1557	-3	6	3	3	7	4	4	5.55E-04	3	-4.3	1.11	3068.91174	3	4	2	3	5	1	4	9.56E-03	2	2.2	1.18
2942.52322	51	9	0	9	10	1	10	1.85E-03	2	-0.7	1.06	3069.41540	-4	4	1	4	4	2	3	1.37E-02	2	-0.8	1.26
2942.7410	48	9	1	9	10	0	10	6.30E-04	3	1.3	1.09	3075.32588	12	6	2	5	6	3	4	5.00E-03	3	1.4	1.21
2944.42395	-23	6	4	3	7	5	2	1.31E-03	2	-3.5	1.11	3081.84274	-5	3	1	3	3	2	2	5.80E-03	3	-0.7	1.27
2945.2189	-35	6	4	2	7	5	3	4.40E-04	4	-3.5	1.11	3082.8452	25	5	2	4	5	3	3	2.77E-03	2	1.3	1.22
2945.7920	3	7	5	2	8	6	3	3.85E-04	5	2.4	1.20	3083.83172	0	1	0	1	2	1	2	3.78E-02	2	1.3	1.30
2946.48584	-8	10	2	9	11	1	10	2.70E-04	3	5.5	1.13	3083.87235	2	7	1	6	7	2	5	4.00E-03	6	0.0	1.21
2946.6749	14	8	2	6	9	3	7	1.70E-04	7	2.9	1.13	3087.1551	-5	4	0	4	4	1	3	7.30E-03	2	-2.4	1.27
2950.3492	-16	5	3	3	6	4	2	1.30E-03	5	3.8	1.22	3087.98053	-8	4	2	3	4	3	2	1.10E-02	2	2.0	1.24
2950.92868	3	7	2	5	8	3	6	1.14E-03	3	3.3	1.16	3088.37779	-6	2	1	2	3	0	3	3.36E-02	2	1.0	1.26
2954.91560	2	5	3	2	6	4	3	3.90E-03	3	-0.8	1.15	3090.03533	-58	8	3	6	8	4	5	7.60E-04	3	2.7	1.14
2955.0047	-5	10	1	10	10	2	9	1.50E-04	10	7.3	1.21	3090.98865	5	3	2	2	3	3	1	3.30E-03	4	3.4	1.27
2957.3428	-32	6	2	4	7	3	5	7.50E-04	3	-3.8	1.10	3091.23865	-7	2	1	2	2	2	1	1.55E-02	2	-0.1	1.28
2957.99467	0	9	1	8	10	2	9	5.95E-04	3	-4.9	1.02	3094.2255	-58	7	3	5	7	4	4	5.41E-04	4	1.7	1.15
2961.5434	1	4	2	3	5	3	2	6.80E-03	3	0.4	1.21	3095.98890	-8	3	2	1	3	3	0	1.05E-02	2	3.5	1.27
2962.8610	27	8	0	8	9	1	9	1.40E-03	2	2.7	1.13	3096.7515	2	6	3	4	6	4	3	2.90E-03	2	1.4	1.16
2963.30698	15	8	1	8	9	0	9	4.18E-03	2	2.0	1.12	3097.57910	4	6	1	5	6	2	4	3.15E-03	4	-1.8	1.21
2967.08095	-11	5	2	3	6	3	4	4.70E-03	2	0.0	1.17	3097.9922	-46	5	3	3	5	4	2	1.42E-03	4	4.6	1.21
2969.0414	-15	5	4	2	6	5	1	1.03E-03	2	0.6	1.16	3098.2800	3	3	2	2	4	1	3	2.83E-03	5	1.2	1.20
2969.20320	-5	5	4	1	6	5	2	3.10E-03	2	0.7	1.16	3098.4318	-6	4	3	2	4	4	1	4.02E-03	3	2.5	1.20
2969.9217	10	6	5	2	7	6	1	9.00E-04	5	-3.1	1.11	3099.3116	-19	4	3	1	4	4	0	1.35E-03	3	2.4	1.21
2969.935	-74	6	5	1	7	6	2	3.00E-04	5	-3.1	1.11	3100.79536	27	4	2	2	4	3	1	4.25E-03	3	1.2	1.22
2971.01988	0	8	1	7	9	2	8	4.76E-04	10	1.5	1.10	3101.2991	8	5	3	3	6	2	4	6.80E-04	5	0.9	1.11
2972.1395	26	3	1	3	4	2	2	1.76E-03	3	-0.2	1.25	3102.30135	30	0	0	0	1	1	1	9.73E-03	3	-1.9	1.28
2976.2824	-9	4	3	2	5	4	1	7.85E-03	2	-0.3	1.17	3103.39048	1	3	0	3	3	1	2	3.65E-02	2	-1.0	1.29
2976.6182	12	9	1	9	9	2	8	1.41E-04	3	6.9		3104.8641	-1	6	3	3	6	4	2	1.05E-03	6	2.2	1.17
2976.78392	0	7	6	1	8	7	2	2.54E-04	10	8.0	1.24	3106.56644	1	5	1	4	5	2	3	1.88E-02	3	-1.4	1.23
2977.4403	11	4	3	1	5	4	2	2.62E-03	2	-1.4	1.16	3106.7348	-5	5	2	3	5	3	2	1.12E-02	2	2.3	1.22
2977.5618	6	9	0	9	9	1	8	4.12E-04	3	2.3	1.19	3107.45610	-2	2	1	1	2	2	0	7.60E-03	2	-0.9	1.26
2980.3742	50	8	2	7	9	1	8	1.55E-03	7	5.8	1.14	3110.4975	-34	7	3	4	7	4	3	1.85E-03	3	0.3	1.13
2980.9013	-4	4	2	2	5	3	3	2.95E-03	4	-0.3	1.19	3110.5318	-7	8	2	6	8	3	5	5.50E-04	8	2.4	1.17
2982.4110	-4	7	1	6	8	2	7	2.87E-03	3	1.2	1.11	3110.62040	1	3	1	2	3	2	1	3.30E-02	2	1.0	1.27
2982.63603	0	7	0	7	8	1	8	8.10E-03	2	-0.0	1.13	3110.7200	-6	4	1	3	4	2	2	9.65E-03	3	-1.3	1.24
2983.55350	-6	7	1	7	8	0	8	2.74E-03	4	1.0	1.14	3111.4945	-28	6	2	4	6	3	3	2.48E-03	5	0.7	1.19
2992.21910	1	6	1	5	7	2	6	1.70E-03	5	-0.7	1.12	3114.43770	11	2	0	2	2	1	1	1.60E-02	2	1.0	1.32
2992.38050	-16	3	2	2	4	3	1	4.71E-03	4	-0.6	1.21	3115.0383	-38	8	4	5	8	5	4	3.87E-04	3	2.5	1.13
2993.51315	0	4	4	1	5	5	0	6.20E-03	3	-0.1	1.16	3115.4772	41	5	4	2	5	5	1	4.32E-04	5	3.4	1.16
2993.5313	7	4	4	0	5	5	1	2.10E-03	4	1.4	1.17	3115.5508	-28	6	4	3	6	5	2	1.14E-03	5	-2.4	1.09
*2994.2545	-55	5	5	0	6	6	1	2.80E-03	5	1.3	1.15	3115.5963	-21	5	4	1	5	5	0	1.25E-03	2	-0.3	1.13
2997.65047	0	8	1	8	8	2	7	1.02E-03	3	0.7	1.20	3116.09426	-66	6	4	2	6	5	1	3.93E-04	5	0.6	1.12
2998.7045	-20	7	2	6	8	1	7	9.70E-04	3	-2.4	1.07	3116.8722	15	8	3	5	8	4	4	2.90E-04	10	-6.6	1.04
2999.00447	2	3	2	1	4	3	2	1.56E-02	3	0.6	1.22	3117.25090	1	7	4	3	7	5	2	7.71E-04	10	2.6	1.13
2999.65912	-34	8	0	8	8	1	7	3.33E-04	3	-5.4	1.14	3120.79695	1	1	0	1	1	1	0	4.25E-02	2	0.6	1.32
3000.8810	-38	6	6	1	7	7	0	4.80E-04	10	-14.3	1.13	3121.9745	67	9	3	6	9	4	5	3.88E-04	4	0.3	1.10
3001.0663	-42	6	6	0	7	7	1	1.85E-04	10	8.0	1.11	3128.79120	5	2	2	1	3	1	2	4.77E-03	3	0.1	1.21
3001.17300	-5	3	3	1	4	4	0	4.90E-03	2	2.1	1.21	3135.9170	15	4	3	2	5	2	3	2.10E-03	2	-0.3	1.12
3001.2742	4	5	1	4	6	2	5	8.50E-03	3	0.7	1.17	*3140.904	158	6	5	2	6	6	1	4.20E-04	5	-3.5	1.06
3001.33703	0	3	3	0	4	4	1	1.48E-02	2	2.6	1.22	3141.0455	43	7	5	2	7	6	1	2.60E-04	6	-4.8	1.04
3001.70085	-1	6	0	6	7	1	7	4.84E-03	2	0.9	1.16	3150.4540	20	6	3	3	7	2	6	2.50E-04	10	-4.9	1.01
3003.57985	-3	6	1	6	7	0	7	1.46E-02	2	0.7	1.17	3151.8156	2	3	1	3	2	2	0	4.60E-04	3	-6.7	1.19
3008.4725	2	8	3	6	9	2	7	5.00E-04	3	-3.6	1.04	3154.2831	-42	7	3	4	8	2	7	3.10E-04	4	-8.0	0.95
3011.0113	-3	4	1	3	5	2	4	4.26E-03	2	-0.2	1.20	3154.46760	9	3	2	1	4	1	4	2.43E-03	2	-4.0	1.14
3013.91526	2	2	1	2	3	2	1	1.29E-02	2	-0.8	1.25	3155.49771	-3	5	3	2	6	2	5	1.38E-03	2	-3.3	1.05
3017.86800	-8	7	1	7	7	2	6	7.91E-04	4	1.3	1.23	3156.0780	10	6	4	3	7	3	4	4.90E-04	4	-0.6	1.03
3019.01406	0	6	2	5	7	1	6	5.33E-03	2	0.8	1.12	3156.28139	-48	4	2	2	5	1	5	5.05E-04	3	-0.2	1.15
3019.36689	-8	2	2	1	3	3	0	2.49E-02	3	2.4	1.26	3157.2360	-34	4	1	4	3	2	1	1.07E-03	3	-2.7	1.22
3019.82450	-1	5	0	5	6	1	6	2.28E-02	2	0.5	1.19	3161.2037	-5	2	2	0	3	1	3	8.00E-04	4	-0.3	1.22
3020.67720	-3	2	2	0	3	3	1	8.35E-03	2	1.4	1.24	3165.10230	1	1	1	0	1	0	1	4.40E-02	2	-0.9	1.30
3021.94045	1	7	0	7	7	1	6	2.58E-03	4	1.5	1.25	3166.7485	21	7	4	3	8	3	6	3.05E-04	7	-4.4	0.96
3022.79949	0	3	1	2	4	2	3	1.82E-02	2	0.5	1.24	3167.1172	-26	5	2	3	6	1	6	6.90E-04	6	-0.6	1.08
3023.59575	5	5	1	5	6	0	6	7.70E-03	2	0.6	1.19	3167.8160	-22	4	3	1	5	2	4	5.90E-04	2	-3.7	1.07
3035.8994	-20	7	3	5	8	2	6	3.25E-04	8	0.3	1.08	3169.3867	49	3	3	1	4	2	2	4.58E-04	10	-3.1	1.11
3036.7428	18	4	0	4	5	1	5	1.05E-02	2	0.3	1.21	3172.3118	0	2	1	1	2	0	2	1.60E-02	3	-0.8	1.30
3036.90661	-22	6	1	6	6	2	5	4.84E-03	3	-0.2	1.23	3172.4775	-9	2	0	2	1	1	1	6.22E-03	2	-0.5	1.30
3037.48350	17	2	1	1	3	2	2	8.28E-03	4	4.0	1.30	3183.00498	-3	1	1	1	0	0	0	1.06E-02	3	-1.6	1.30
3042.2612	15	5	2	4	6	1	5	2.68E-03	3	2.2	1.16	3183.4470	-79	6	4	2	7	3	5	1.93E-04	10	9.3	1.12
3043.98886	-1	4	1	4	5	0	5	3.23E-02	2	1.8	1.23	3185.08300	0	3	1	2	3	0	3	3.55E-02	2	-1.3	1.30
3044.50725	3	6	0	6	6	1	5	1.86E-03	3	-1.8	1.24	3185.3603	-12	3	3	0	4	2	3	1.36E-03	3	-1.0	1.12
3048.0627	34	9	1	8	9	2	7	5.10E-04	7	5.9	1.21	3187.9440	13	3	1	2	2	2	1	4.33E-03	3	-0.8	1.25
3048.22190	1	1	1	1	2	2	0	8.06E-03	3	-1.3	1.26	3190.5464	32	5	4	2	6	3	3	2.24E-04	10	8.3	1.14
3052.44483	1	3	0	3	4	1	4	3.88E-02	2	2.4	1.27	3197.28473	0	3	0	3	2	1	2	3.43E-02	2	1.5	1.31

(Table continued)

Table 8. Continued

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
3199.4026	-43	4	2	2	3	3	1	3.77E-04	3	0.1	1.20
3200.95970	8	2	1	2	1	0	1	4.14E-02	2	-1.2	1.31
3202.7394	70	5	2	4	4	3	1	3.35E-04	4	-1.8	1.15
3203.8970	2	5	4	1	6	3	4	6.60E-04	10	0.9	1.04
3203.9456	9	4	1	3	4	0	4	6.75E-03	3	-5.0	1.24
3205.41310	-6	3	2	1	3	1	2	3.13E-02	2	1.8	1.28
3206.69440	0	4	2	2	4	1	3	8.90E-03	3	1.1	1.26
3207.98334	18	2	2	0	2	1	1	7.73E-03	2	-0.0	1.26
3214.10320	3	5	2	3	5	1	4	1.67E-02	4	1.6	1.26
3214.97960	5	6	2	5	5	3	2	6.03E-04	3	0.1	1.15
3216.67145	19	3	1	3	2	0	2	1.56E-02	2	0.2	1.31
3220.3904	10	4	0	4	3	1	3	1.33E-02	2	0.3	1.29
3221.4673	-11	4	4	1	5	3	2	4.53E-04	5	-5.2	1.01
3222.68544	3	2	2	1	2	1	2	1.79E-02	2	0.7	1.28
3223.3047	-32	5	3	2	4	4	1	3.15E-04	5	-0.6	1.14
3227.67810	-16	5	1	4	5	0	5	1.10E-02	2	-2.7	1.24
3228.92495	24	6	2	4	6	1	5	2.54E-03	2	-3.5	1.19
3231.51515	3	3	2	2	3	1	3	6.45E-03	6	-2.9	1.22
3231.69895	0	4	1	4	3	0	3	4.60E-02	4	0.8	1.30
3233.1720	-7	5	2	3	4	3	2	1.68E-03	4	-2.7	1.14
3241.34224	6	5	0	5	4	1	4	3.68E-02	2	1.2	1.29
3242.9916	5	6	3	4	5	4	1	3.70E-04	5	-1.7	1.11
3243.44385	18	4	2	3	4	1	4	1.56E-02	2	-0.1	1.25
3247.20800	8	5	1	5	4	0	4	1.29E-02	3	0.3	1.28
3248.398	127	6	5	2	7	4	3	1.90E-04	10	5.5	1.00
3250.9402	2	7	2	5	7	1	6	3.15E-03	4	-0.6	1.19
3253.1049	7	5	1	4	4	2	3	9.30E-03	5	3.4	1.24
3253.9707	1	6	1	5	6	0	6	1.83E-03	2	-3.5	1.19
3255.74470	-11	7	3	4	7	2	5	2.86E-03	3	0.5	1.15
3255.8137	-7	6	3	3	6	2	4	1.83E-03	5	-3.7	1.12
3257.0290	32	4	3	2	5	0	5	2.10E-04	10	11.4	1.09
3258.22546	-2	5	2	4	5	1	5	3.34E-03	5	0.3	1.22
3259.65062	-1	2	2	1	1	1	0	3.57E-02	2	-0.5	1.28
3260.47164	-1	6	0	6	5	1	5	9.25E-03	2	0.4	1.25
3260.79000	-1	5	3	2	5	2	3	9.60E-03	4	4.4	1.22
3263.08876	-7	8	3	5	8	2	6	3.75E-04	5	-0.8	1.13
3263.31095	2	6	1	6	5	0	5	2.90E-02	3	2.2	1.28
3263.9344	-6	7	3	5	6	4	2	8.54E-05	10	-5.3	
3266.02315	-1	2	2	0	1	1	1	1.03E-02	2	-2.8	1.25
3267.52495	0	4	3	1	4	2	2	4.03E-03	2	1.7	1.20
3269.5086	-1	6	2	4	5	3	3	5.60E-04	4	-1.5	1.12
3273.1813	-2	3	3	0	3	2	1	1.09E-02	3	0.9	1.20
3275.36212	-4	6	2	5	6	1	6	5.55E-03	5	0.4	1.19
3276.4161	-8	5	5	0	6	4	3	1.63E-04	4	9.7	1.01
3278.3655	-15	8	2	6	8	1	7	3.85E-04	6	-0.0	1.15
3278.9730	-44	9	3	6	9	2	7	3.70E-04	3	0.7	1.14
3279.61970	2	7	1	7	6	0	6	6.33E-03	3	3.3	1.26
3280.54717	-22	7	1	6	7	0	7	2.75E-03	4	1.8	1.20
3282.45531	6	4	3	2	4	2	3	1.19E-02	3	1.1	1.19
3284.6486	-13	6	1	5	5	2	4	2.65E-03	4	-0.3	1.17
3285.16477	11	7	3	4	6	4	3	3.40E-04	3	-2.8	1.09
3288.3688	11	5	3	3	5	2	4	3.00E-03	5	4.1	1.21
3294.38920	-12	4	2	3	3	1	2	2.31E-02	3	0.1	1.25
3295.16780	0	8	0	8	7	1	7	3.60E-03	2	2.1	1.21
3295.78664	-18	8	1	8	7	0	7	1.08E-02	2	1.6	1.21
3297.33351	-13	6	3	4	6	2	5	5.10E-03	2	1.1	1.15
3299.30740	-2	3	2	1	2	1	2	1.96E-02	3	-1.9	1.25
3304.98927	-17	7	6	2	8	5	3	6.90E-04	3	1.55E-05	1.10
3305.0930	-53	7	6	1	8	5	4	1.90E-04	4	4.69E-05	0.94
3306.0166	-45	8	1	7	8	0	8	3.90E-04	3	-2.0	1.11
3307.2522	32	7	2	5	6	3	4	1.30E-03	4	-2.8	1.08
3308.6380	-1	5	2	4	4	1	3	5.77E-03	3	3.0	1.25
3309.5240	-15	7	3	5	7	2	6	8.44E-04	10	2.3	1.14
3311.32580	-28	9	0	9	8	1	8	5.59E-03	3	1.2	1.17
3311.61515	-10	9	1	9	8	0	8	1.88E-03	5	1.9	1.18
3312.1610	0	9	4	5	9	3	6	2.55E-04	10	3.7	1.16
3313.87437	3	7	1	6	6	2	5	6.00E-03	2	4.2	1.18
3314.13780	-24	8	2	7	8	1	8	1.27E-03	3	5.0	1.18
3319.3890	20	8	4	4	8	3	5	1.91E-04	10	-11.0	1.02
3322.34785	-2	6	2	5	5	1	4	1.16E-02	3	2.4	1.20
3324.7576	-39	8	3	6	8	2	7	1.10E-03	4	4.0	1.14
3326.8762	-11	10	0	10	9	1	9	9.33E-04	4	6.9	1.21
3327.01431	0	10	1	10	9	0	9	2.66E-03	4	1.7	1.15
3328.6649	35	6	6	1	7	5	2	4.20E-03	4	4.02E-05	1.11
3328.9045	-11	7	4	3	7	3	4	1.42E-03	4	-1.3	1.09
3330.0037	-53	9	1	8	9	0	9	5.10E-04	10	4.8	1.15

Observed Position	o − c	Upper J	Upper K_a	Upper K_c	Lower J	Lower K_a	Lower K_c	Observed Strength	%s	(o − c)%	R
3334.6027	-80	9	2	8	9	1	9	1.80E-04	10	9.4	1.19
3337.01940	0	7	2	6	6	1	5	2.32E-03	4	-0.0	1.14
3337.59936	-9	6	4	2	6	3	3	9.20E-04	3	-0.4	1.09
3339.92960	5	4	2	2	3	1	3	3.30E-03	4	-2.8	1.20
3340.33205	48	8	1	7	7	2	6	1.19E-03	3	2.6	1.13
3341.8821	-23	11	0	11	10	1	10	1.11E-03	3	-1.6	1.10
3341.94870	0	11	1	11	10	0	10	3.59E-04	2	-4.6	1.06
3342.5628	27	9	3	7	9	2	8	1.33E-04	10	-1.0	1.08
3343.55076	-1	5	4	1	5	3	2	4.40E-03	3	2.4	1.12
3345.0989	14	8	2	6	7	3	5	2.86E-04	4	-3.5	1.06
3346.5080	-10	4	4	0	4	3	1	1.47E-03	3	-1.6	1.09
3347.6440	7	3	3	0	3	0	3	3.70E-04	3	3.5	1.08
3347.90460	-3	4	4	1	4	3	2	4.50E-03	3	-0.4	1.10
3349.06255	0	3	3	1	2	2	0	1.07E-02	2	0.2	1.20
3350.2449	9	6	4	3	6	3	4	2.95E-03	3	0.9	1.09
3350.50475	-5	3	3	0	2	2	1	3.24E-02	2	0.9	1.20
3353.44260	15	8	2	7	7	1	6	3.85E-03	3	0.1	1.11
3355.2262	-19	10	2	9	10	1	10	2.03E-04	10	9.4	1.17
3356.377	0	12	0	12	11	1	11	1.50E-04	10	0.6	1.11
3356.4110	0	12	1	12	11	0	11	4.40E-04	3	-1.6	1.09
3359.7014	-7	8	4	5	8	3	6	6.70E-04	3	-3.8	1.05
3360.7510	60	4	3	1	4	0	4	2.34E-04	2	-1.7	1.00
3362.300	0	10	3	8	10	2	9	1.44E-04	10	2.5	1.15
3370.2761	-5	4	3	2	3	2	1	2.05E-02	2	0.6	1.18
*3370.3922	6	13	0	13	12	1	12	2.03E-04	10	-7.4	1.03
3371.4027	47	9	2	8	8	1	7	6.36E-04	3	-0.3	1.08
3374.8920	0	12	3	10	13	0	13	3.50E-04	10	2.56E-06	1.30
3377.22850	0	4	3	1	3	2	2	6.71E-03	2	-0.7	1.16
3381.6706	-10	9	2	7	8	3	6	4.90E-04	3	-4.9	1.04
3381.90185	1	5	3	2	5	0	5	7.00E-04	10	8.8	1.07
3386.56784	0	10	1	9	9	2	8	3.20E-04	3	12.4	1.23
3388.0775	8	5	3	3	4	2	2	3.99E-03	2	1.7	1.17
3388.63520	7	5	2	3	4	1	4	4.25E-03	3	-2.5	1.15
3390.26550	8	10	2	9	9	1	8	8.55E-04	2	-1.8	1.06
3402.6260	9	6	3	4	5	2	3	6.40E-03	3	1.0	1.13
3407.3284	-1	5	3	2	4	2	3	1.11E-02	3	0.2	1.14
3407.5685	0	11	1	10	10	2	9	3.50E-04	10	-3.3	1.07
3414.88455	43	7	3	5	6	2	4	1.02E-03	5	-5.8	1.03
3419.522	180	7	5	2	7	4	3	8.00E-04	4	2.2	1.02
3421.9175	-23	6	5	1	6	4	2	3.95E-04	2	-11.2	1.01
3422.6564	15	5	5	0	5	4	1	1.45E-03	3	-4.6	1.03
3422.9039	51	5	5	1	5	4	2	5.05E-04	3	-0.4	1.07
3423.06355	0	6	5	2	6	4	3	1.25E-03	3	-6.7	1.01
3423.7344	0	8	5	4	8	4	5	3.65E-04	10	-7.0	1.10
3426.21928	0	8	3	6	7	2	5	1.55E-03	2	-2.5	1.05
3442.88345	1	6	3	3	5	2	4	1.66E-03	2	-2.1	1.06
3444.7383	-46	4	3	2	3	0	3	8.00E-04	3	4.2	1.05
3444.8893	14	4	4	1	3	3	0	1.92E-02	6	2.1	1.11
3445.11605	1	4	4	0	3	3	1	6.30E-03	3	0.4	1.10
3450.918	-109	5	4	1	5	1	4	1.78E-04	10	-3.2	0.83
3466.760	18	7	4	3	7	1	6	2.05E-04	4	3.1	0.95
3468.45360	-6	5	4	2	4	3	1	3.50E-03	2	-0.1	1.06
3469.98793	-6	5	4	1	4	3	2	1.08E-02	2	2.1	1.08
3481.3026	-27	5	3	3	4	0	4	3.51E-04	10	17.1	1.15
3489.89860	0	6	4	3	5	3	2	5.20E-03	2	-0.9	1.02
3495.6129	-38	6	4	2	5	3	3	1.83E-03	3	2.6	1.05
3499.7910	-45	6	6	1	6	5	2	3.85E-04	3	4.63E-04	1.34
3501.2051	-20	7	6	2	7	5	3	1.20E-03	7	1.25E-04	0.96
3501.3183	10	8	6	3	8	5	4	6.88E-04	3	2.10E-04	0.94
3504.8670	5	7	6	2	8	3	5	1.21E-03	3	6.04E-07	0.99
3507.2885	22	7	2	5	6	1	6	5.80E-04	3	-5.3	0.95
3507.8740	-40	7	4	4	6	3	3	7.70E-04	5	-1.9	1.00
3521.85784	5	8	4	5	7	3	4	8.88E-04	3	-9.4	0.94
3523.0712	-32	7	4	3	6	3	4	2.36E-03	5	-2.5	0.98
3536.7125	-88	8	3	5	7	2	6	2.10E-04	4	-3.9	0.98
3544.7746	-39	5	5	1	4	4	0	2.46E-03	8	-7.7	0.95
3549.7570	68	7	6	1	8	3	6	1.00E-03	6	1.82E-06	1.16
3569.3035	-12	6	5	2	5	4	1	4.10E-03	10	3.5	1.04
3618.8435	0	8	5	3	7	4	4	2.10E-04	10	2.61E-04	0.84
3622.894	-34	8	3	6	7	0	7	1.68E-04	10	0.7	0.83
3644.2276	0	9	5	4	8	4	5	2.03E-04	10	3.20E-04	0.74
3646.1839	-81	6	6	1	5	5	0	2.20E-03	5	2.88E-03	0.89
3672.0810	3	7	6	2	6	5	1	1.56E-04	4	4.40E-04	0.91
3696.4840	15	8	6	3	7	5	2	3.85E-04	10	5.76E-04	1.12
3874.13905	8	6	6	1	5	3	2	6.88E-02	2	4.23E-06	1.25
3879.4573	42	6	6	0	5	3	3	4.65E-04	7	1.43E-06	1.28

[a]1 atm = 760 Torr.

[b]o − c, Observed minus computed line positions (cm^{-1} × 10^{5}). Computed values are derived from the energy levels given in Table 2 and the ground-state levels given in Ref. 2. %s, Estimated uncertainties in the measured line strengths given in percent. (o − c)%, Percent difference between the observed and the computed line strengths or the value of the computed strength if the difference between the observed and the computed values is ≈±14% or larger in magnitude. *R*, Ratio of the observed line strength derived in this study to the computed value given in Refs. 16, 18, and 19. An asterisk denotes a doubled absorption with the quantum assignment given for the stronger transition. The strength given represents the sum of the strengths of the two comparable transitions.

Table 9. Observed[a] and Computed Frequencies (cm^{-1}) of Transitions in the (000)–(000), (010)–(010) and (020)–(020) Bands of $H_2{}^{16}O$[b]

J	K_a	K_c	J	K_a	K_c	Band	Observed	Computed[b]	un[c]	Δ[d]
13	6	8	14	3	11	(000)–(000)	8.671080	8.67149	25	−41
14	6	9	15	3	12	(000)–(000)	4.657032	4.65794	30	−91
14	4	10	15	3	13	(000)–(000)	8.253713	8.26239	65	−868
15	6	10	16	3	13	(000)–(000)	5.914661	5.90778	300	688
16	6	11	17	3	14	(000)–(000)	11.309290	11.30540	425	389
5	5	1	6	4	2	(010)–(010)	6.975438	6.97547	6	−3
6	6	1	7	5	2	(010)–(010)	9.795591	9.79556	5	3
6	6	0	7	5	3	(010)–(010)	9.921501	9.92149	7	1
7	4	3	6	5	2	(010)–(010)	19.281922	19.28190	5	2
7	7	0	8	6	3	(010)–(010)	8.787791	8.78783	10	−4
7	7	1	8	6	2	(010)–(010)	8.769325	8.76930	8	3
9	2	8	8	3	5	(010)–(010)	19.803984	19.80400	4	−2
9	6	3	8	7	2	(010)–(010)	14.718144	14.71812	6	2
9	6	4	8	7	1	(010)–(010)	14.634263	14.63431	7	5
10	7	4	9	8	1	(010)–(010)	18.295137	18.29522	13	−8
14	3	12	13	4	9	(010)–(010)	10.792600	10.79264	7	−4
3	2	1	4	1	4	(020)–(020)	11.045102	11.04507	7	3
4	2	2	5	1	5	(020)–(020)	13.459058	13.45899	8	7
6	2	5	5	3	2	(020)–(020)	13.439784	13.43976	6	2
6	5	2	7	4	3	(020)–(020)	8.944492	8.94445	5	4
6	5	1	7	4	4	(020)–(020)	10.791625	10.79145	9	18
7	3	5	6	4	2	(020)–(020)	17.561721	17.56166	7	6

[a]From Ref. 20.
[b]The computed values for the (000)–(000) and (010)–(010) bands were derived from rotational energy levels given in Ref. 1, and those for the (020)–(020) band were calculated from levels given in Table 2 of the present study.
[c]un, Uncertainty of computed frequencies derived from estimated uncertainties given in Ref. 1 and this study; values × 10^5.
[d]Δ, Observed minus computed frequencies × 10^5.

Flaud *et al.*[18] (and included in the HITRAN listing[19]) were much larger than estimated in this study. In fact there were no apparent absorption features in any of the spectra within ±0.015 cm^{-1} of the listed frequencies, and the observed line-strength values represent upper-limit values.

Values of R given in Table 6 were derived from computed line-strength values given in Refs. 18 and 19. It should be noted that the computed values derived by Flaud and Camy-Peyret[14] several years ago differ somewhat from those reported in Refs. 18 and 19. The computed strengths given in Ref. 18 were derived from an analysis or unreported measurements obtained, for the most part, with a grating spectrometer with a spectral resolution of 0.03–0.05 cm^{-1}, and these same values were incorporated into the HITRAN database.[19]

Tables 7 and 8 are listings for the (020)–(000) bands of $H_2{}^{17}O$ and $H_2{}^{18}O$, respectively, and they are similar in content to that of Table 6. The line-strength values are normalized to 100% of the isotopic species. The previous computed values of line strengths used to determine values of R in the two tables were taken from the studies by Camy-Peyret *et al.*[15] for $H_2{}^{17}O$ and Flaud *et al.*[16] for $H_2{}^{18}O$, and these values are also given in the HITRAN database.[19] A few of the transitions given in the tables do not have entries for R, which means that those transitions were not included in the previous calculations.[15,16] This is because Refs. 15 and 16 used an intensity cutoff criterion that included the isotopic abundance.

The high-accuracy measurements of $H_2{}^{16}O$ pure rotational frequencies obtained by Pearson *et al.*[20] are presented in Table 9 for their observations in the (000)–(000), (010)–(010), and (020)–(020) bands. Included in this table are computed frequencies derived from rotational energy levels given in this study and listed in Table 2 and from the energy-level values for the (000) and (010) states given in my recent paper.[1] The table lists the rotational quantum assignments, band, measured frequency given by Pearson *et al.*[20] (converted from megahertz to inverse centimeters with the speed of light as 2.99792458 × 10^{10} cm/s), the computed frequencies from my previous work, the uncertainty (un) of the computed frequency, and the difference (Δ) between the measured and the computed frequencies. In the analysis of the ν_2 band,[1] I incorrectly gave the value of the energy for the 14 3 11 rotational level of the ground state as 2739.45102(15) cm^{-1}, whereas the corrected value used to compute the frequency of the first entry in Table 9 is 2739.42853(20) cm^{-1}. The values of un are based on the estimated uncertainties of the two rotational level energies involved in a transition and are computed from the expression

$$un = (un_1{}^2 + un_2{}^2)^{1/2}, \quad (6)$$

where un_1 and un_2 are the uncertainties of the two involved rotational energies. Inspection of the values of un and Δ shows that there is good agreement, on average, between the measured and the computed frequencies within the limits placed on the computed values.

DISCUSSION AND CONCLUSION

More than 1600 transitions frequencies measured in this study were determined to an absolute accuracy of 0.0001 cm^{-1} (3 MHz) or better for the majority of the lines.

The experimental line strengths were fitted by least squares to a model that included 19 dipole moment expansion coefficients. The fitting technique did not take into account the interactions between the vibrational states (020), (100), and (001), and therefore the computed strengths derived in this study represent unperturbed values. The experimental results for the (100)–(010), (001)–(010), (100)–(000), and (001)–(000) bands of $H_2{}^{16}O$ will be featured in a forthcoming publication,[23] and measurements in the (100)–(000) and (001)–(000) bands of $H_2{}^{17}O$ and $H_2{}^{18}O$ are under way. These results, including those of the present study, will be fitted to a theoretical model that includes interactions between the three interacting vibrational states.

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REFERENCES

1. R. A. Toth, "ν_2 band of $H_2{}^{16}O$: line strengths and transition frequencies," J. Opt. Soc. Am. B **8**, 2236–2255 (1991).
2. R. A. Toth, "Transition frequencies and absolute strengths of $H_2{}^{17}O$ and $H_2{}^{18}O$ in the 6.2-μm region," J. Opt. Soc. Am. B **9**, 462–482 (1992).
3. D. M. Gates, R. F. Calfee, D. W. Hansen, and W. S. Benedict, "Line parameters and computed spectra for water vapor bands at 2.7 μ," Natl. Bur. Stand. (U.S.) Monogr. **71** (August 3, 1964).
4. W. S. Benedict and R. F. Calfee, "Line parameters for the 1.9 and 6.3 micron water vapor bands," U.S. Department of Commerce Environmental Science Services Administration professional paper (Government Printing Office, Washington, D.C., June 2, 1967).
5. G. Guelachvili, "Experimental Doppler-limited spectra of the ν_2 bands of $H_2{}^{16}O$, $H_2{}^{17}O$, $H_2{}^{18}O$ and HDO by Fourier-transform spectroscopy: secondary wave-number standards between 1066 and 2296 cm^{-1}," J. Opt. Soc. Am. **73**, 137–150 (1983).
6. L. A. Pugh and K. Narahari Rao, "Spectrum of water vapor in the 1.9 and 2.7 μ regions," J. Mol. Spectrosc. **47**, 403–408 (1973).
7. L. A. Pugh, "A detailed study of the near-infrared spectrum of water vapor," Ph.D. dissertation (Ohio State University, Columbus, Ohio, 1972; microfilm 72-21,005, University Microfilms, Ann Arbor, Michigan).
8. C. Camy-Peyret, J.-M. Flaud, G. Guelachvili, and C. Amiot, "High resolution Fourier transform spectrum of water between 2930 and 4255 cm^{-1}," Mol. Phys. **26**, 825–855 (1973).
9. J.-M. Flaud and C. Camy-Peyret, "The $2\nu_2$, ν_1, and ν_3 bands of $H_2{}^{16}O$ rotational study of the (000) and (020) states," Mol. Phys. **4**, 811–823 (1973).
10. R. A. Toth and J. S. Margolis, "Spectrum of $H_2{}^{18}O$ in the 2900 to 3400 cm^{-1} region," J. Mol. Spectrosc. **57**, 236–245 (1975).
11. J.-M. Flaud and C. Camy-Peyret, "The interacting states (020), (100), and (001) of $H_2{}^{16}O$," J. Mol. Spectrosc. **51**, 142–150 (1974).
12. C. Camy-Peyret, J.-M. Flaud, and R. A. Toth, "The interacting states (020), (100), and (001) of $H_2{}^{17}O$ and $H_2{}^{18}O$," J. Mol. Spectrosc. **87**, 233–241 (1981).
13. R. A. Toth, "Strengths and air-broadened widths of H_2O lines in the 2950–3400 cm^{-1} region," J. Quantum Spectrosc. Radiat. Transfer **13**, 1127–1142 (1973).
14. J.-M. Flaud and C. Camy-Peyret, "Vibration–rotation intensities in H_2O-type molecules application to the $2\nu_2$, ν_1, and ν_3 bands of $H_2{}^{16}O$," J. Mol. Spectrosc. **55**, 278–310 (1975).
15. C. Camy-Peyret, J.-M. Flaud, and R. A. Toth, "Line positions and intensities for the $2\nu_2$, ν_1 and ν_3 bands of $H_2{}^{17}O$," Mol. Phys. **42**, 595–604 (1981).
16. J.-M. Flaud, C. Camy-Peyret, and R. A. Toth, "Line positions and intensities for the $2\nu_2$, ν_1, and ν_3 bands of $H_2{}^{18}O$," Can. J. Phys. **58**, 1748–1757 (1980).
17. J.-M. Flaud, C. Camy-Peyret, J.-Y. Mandin, and G. Guelachvili, "$H_2{}^{16}O$ hot bands in the 6.3 μm region," Mol. Phys. **2**, 413–426 (1977).
18. J.-M. Flaud, C. Camy-Peyret, and R. A. Toth, *Water Vapour Line Parameters from Microwave to Medium Infrared* (Pergamon, London, 1981).
19. L. S. Rothman, R. R. Gamache, R. H. Tipping, C. P. Rinsland, M. A. H. Smith, D. C. Benner, V. M. Devi, J.-M. Flaud, C. Camy-Peyret, A. Perrin, A. Goldman, S. T. Massie, L. R. Brown, and R. A. Toth, "The HITRAN molecular database: editions of 1991 and 1992," J. Quantum Spectrosc. Radiat. Transfer **48**, 469–507 (1993).
20. J. C. Pearson, T. Anderson, E. Herbst, F. C. De Lucia, and P. Helminger, "Millimeter- and submillimeter-wave spectrum of highly excited states of water," Astrophys. J. **379**, L41–L43 (1991).
21. R. A. Toth, "Line-frequency measurements and analysis of N_2O between 900 and 4700 cm^{-1}," Appl. Opt. **30**, 5289–5315 (1991).
22. C. Camy-Peyret, J.-M. Flaud, and N. Papineau, "La bande ν_2 des especes isotopiques $H_2{}^{17}O$ et $H_2{}^{18}O$," C. R. Acad. Sci. Paris B **290**, 537–540 (1980).
23. R. A. Toth, "ν_1–ν_2, ν_3–ν_2, ν_2, and ν_3 bands of $H_2{}^{16}O$: line positions and strengths," J. Opt. Soc. Am. B (to be published).