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Research Article

Laser Spectroscopic Investigations of Praseodymium I Transitions: New Energy Levels

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We report the discovery of about 140 new energy levels of the neutral praseodymium atom, found by means of laser-induced fluorescence spectroscopy. Their energy has been determined with an uncertainty of 0.010 cm^{-1} using a wave number calibrated Fourier-transform spectrum.

1. Introduction

This work is a continuation of our systematic investigation of the praseodymium atomic spectrum (Pr I) with the goals of a more complete knowledge of its energy level scheme and to widen the classification of its spectral lines.

Praseodymium belongs to the rare earth elements, which have in common an open 4f electron shell. In nature one finds only one stable isotope, $^{141}Pr_{59}$, with the electronic ground state [Xe] $4f^3\ 6s^2$, $^4I^\circ_{9/2}$ and nuclear spin quantum number I = 5/2. Its nuclear magnetic dipole moment is $\mu_I = 4.2754(5)\,\mu_N$ [1], and its nuclear electric quadrupole moment Q = −0.0024b [2]. Due to the open 4f shell, Pr has a huge number of energy levels. This in turn leads to a very rich line spectrum.

In 1978, the electronic levels discovered by several authors were collected and published, see [3]. Later, great progress was achieved by Ginibre [4–6]. She evaluated high resolution Fourier transform (FT) spectra, thereby discovering a large number of electronic levels of Pr I and Pr II and determined their parities, angular momenta, and hyperfine (hf) constants. Using an atomic-beam-magnetic resonance method, hf constants of many known low-lying metastable levels were determined with high accuracy by Childs and Goodman [7]. Investigation of the hf structure of Pr I lines was performed later by Kuwamoto et al. [8], Krzykowski et al. [9], and Furmann et al. [10]. Our group has been concerned with investigations of the hf structure of Pr I lines since 1999. First values of hf constants have been published in [11]. Later on we concentrated mainly on the discovery of unknown energy levels. Some of the results are published in [12–15].

The spectrum and level structure of the Pr atom are of astrophysical interest [16, 17] and of course are indispensable for a thorough theoretical description of the level scheme [11].

2. Experimental Details

Our investigations are based on a combination of laser-induced fluorescence (LIF) and Fourier-transform (FT) spectroscopy. Spectral lines of Pr were excited by laser light, generated by means of a tunable single-frequency dye laser system. Our source of free atoms was a dc hollow cathode discharge, which produced free Pr atoms by cathode sputtering. Due to the collision processes within the Ar plasma, also high-lying Pr levels are populated, thus the laser

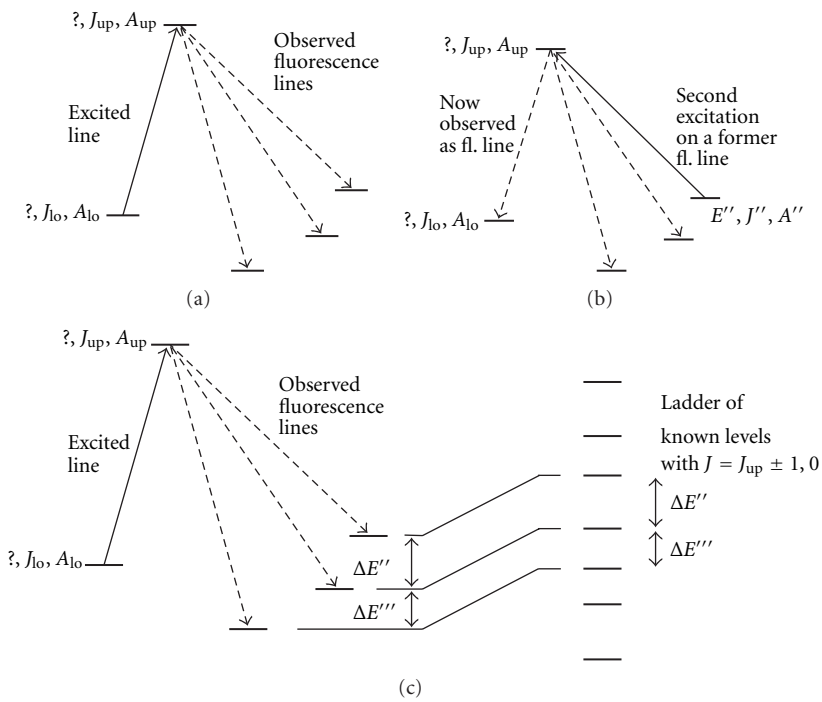

Figure 1: (a) Excitation of a transition for which both combining levels are unknown. (b) Identification of a known lower level by excitation of a former fluorescence line. (c) Finding of the lower levels of fluorescence lines by means of energy differences. See text for further details.

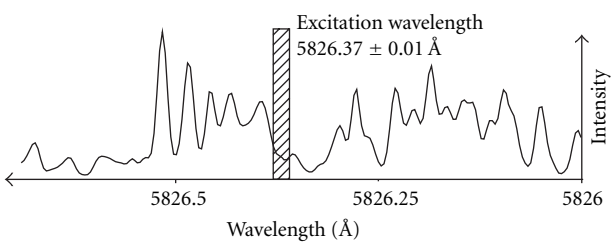

Figure 2: Part of the FT spectrum. Excitation cg wavelength λ = 5826.37 ± 0.01 Å. The excited hf pattern is not present in the FT spectrum. The cg wavelength of the line left of the marked range is λ = 5826.461 Å.

light could excite also atoms being in states with energies of up to 25000 cm^{-1}. A detailed description of the experimental setup is given in [13].

First the laser wavelength was set to a selected value (extracted either from a wavelength table [18] or from a FT spectrum). The light emitted from the discharge was dispersed by a monochromator and detected by a photomultiplier. By scanning the monochromator wavelength, we could find laser-induced fluorescence signals with the help of a phase-sensitive Lock-In amplifier. This was possible because only laser-induced fluorescence light, emitted together with the complete Ar- and Pr-spectrum of the discharge, is modulated bearing the chopping frequency of the exciting laser beam.

Then we set the monochromator to one of the fluorescence lines and scanned the laser frequency over the hyperfine structure of the spectral line. In this way, we recorded the hf pattern of the excited transition.

3. Data Evaluation

Evaluating the recorded hf pattern, we determined the values of total angular momentum J and hyperfine constants A of the levels involved in the investigated transition (in most cases, the B-factors could be neglected due to the small quadrupole moment of the Pr nucleus). This information, together with an estimated center-of-gravity (cg) wave number of the excited transition and the measured wavelengths of all fluorescence lines, usually allowed the determination of the energy of the excited level.

In most cases, the lower level involved in the transition could be identified on the basis of J and A. Then a hypothetical upper level is introduced; its energy is calculated by adding the cg wave number to the energy of the lower level. Since the J-value of the new upper level is known from the evaluation of the observed hf structure, a list of possible transitions to known lower levels can be calculated. If this list explains the observed fluorescence lines, one can assume that a new upper level has been found.

Sometimes it turned out, that the fluorescence lines could be attributed to the decay of an already known upper level. In this case we had to assume, that the lower level of the transition is not yet known. The energy of the new lower level could be found by subtracting the cg wave number from the energy of this known upper level.

The situation was more complicated in cases where neither the lower nor the upper level of the excited transition

Table 1: New even levels discovered as lower levels of the excited transitions.

New even lower level			Investigated/observed spectral line			Combining odd upper level					Observed fluorescence decay of the odd upper level			Final level of the decay	
J	Energy/cm^{-1}	A/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Ref. to columns 9 and 10	λ/Å	C.	SNR	J	Energy/cm^{-1}
3/2	12051.488	1071 (3)	4548.484	nl	4	5/2	34030.654	704 (2)	—	[19]					
			4716.39	nl, f	1	3/2	33248.19	860 (8)		[13]					
			4809.56	nl, e	1	1/2	32837.514	−20 (10)	—	[19]	5047.996	nl	1	3/2	13033.280
			4897.184	nl	4	5/2	32465.793	598 (2)	—	[19]					
			5143.41	nl, e	1	1/2	31488.533	74 (5)	—	[19]	4577.773	nl	1	3/2	9649.970
			5181.917	nl, f	1	3/2	31343.998	1123 (3)	—	This work					
			5342.725	nl	12	5/2	30763.323	981 (2)	—	This work					
			5448.506	nl, f	1	1/2	30400.042	1890 (10)		[13]					
			5457.12	nl, f	1	3/2	30371.081	535 (4)		[13]					
			5477.134	nl, f	8	5/2	30304.145	818 (2)	—	This work					
			5518.794	nl, f	14	3/2	30166.356	1106 (4)		[13]					
			5616.551	nl	7	5/2	29851.062	922 (7)		[13]					
			5729.86	nl, e	1	3/2	29499.100	260 (5)		[13]	4337.685	nl	3	5/2	6451.808
			5779.18	nl, e	1	3/2	29350.190	584 (4)		[13]	5090.336	cl	12	5/2	9710.600
			5781.93	nl, e	1	1/2	29341.96	915 (7)		[13]	5720.195	nl	6	1/2	11864.887
			5833.12	nl, e	1	3/2	29190.205	553 (1)	0 (10)	This work	5444.773	nl	15	5/2	10829.070
			5837.356	nl	8	3/2	29177.805	655 (3)		[19]					
			6429.72	nl, e	1	1/2	27599.953	2039 (6)		[13]	5569.489	nl	16	3/2	9649.970
			7520.74	nl, e	1	5/2	25344.394	692 (2)	0 (10)	[19]	5315.176	cl	55	7/2	6535.572
			8866.58	nl, e	1	5/2	23326.729	415 (1)	30 (15)	[19]	5924.318	nl	10	5/2	6451.808
			9084.938	nl	10	3/2	23055.698	−280 (2)		This work					
			9246.821	cl	13	5/2	22863.048	502 (4)		[13]					
5/2	12646.996	892 (2)	4923.423	nl	3	7/2	32952.378	838 (2)	—	[19]					
			5178.994	nl	5	7/2	31950.447	784 (2)	—	[19]					
			5299.097	nl	8	3/2	31512.878	649 (3)	—	[19]					
			5308.651	cl	11	7/2	31478.935	731 (6)		This work					
			5661.86	nl, e	1	5/2	30304.145	818 (2)	—	This work	4854.534	nl	4	5/2	9710.600
			5700.74	nl, e	1	7/2	30183.720	600 (4)		This work	5042.225	nl	8	9/2	10356.737
			5949.52	e	15	7/2	29450.410	783 (6)		This work	4231.161	nl	7	9/2	5822.890
			7429.512	nl	5	5/2	26103.121	904 (3)	—	[19]					
			9337.905	cl	6	7/2	23353.101	862 (3)		This work					
			9586.286	cl	15	5/2	23075.703	428 (2)	—	[19]					
			9812.968	cl	8	7/2	22834.799	1227 (3)	—	[19]					
			9965.499	cl	18	5/2	22678.865	580 (2)		This work					

Table 1: Continued.

New even lower level			Investigated/observed spectral line			Combining odd upper level					Observed fluorescence decay of the odd upper level			Final level of the decay	
J	Energy/cm^{-1}	A/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Ref. to columns 9 and 10	λ/Å	C.	SNR	J	Energy/cm^{-1}
11/2	12658.401	995 (5)	4941.41	nl, e	1	11/2	32889.914	694 (3)	—	[19]	3693.482	cl	12	9/2	5822.890
			5052.605	nl, f	1	11/2	32444.655	697 (2)		This work					
			5266.366	nl	12	13/2	31641.543	735 (2)	—	[19]					
			5288.376	nl, f	1	11/2	31562.535	665 (8)		This work					
			5368.993	nl, f	17	13/2	31278.686	662.8 (40)		[10]					
			5384.011	nl	9	13/2	31226.756	641.4 (20)	—	[10]					
			5643.521	nl, f	1	9/2	30372.918	830 (3)		This work					
			5671.81	nl, e	1	13/2	30284.567	681 (2)	—	This work	4850.767	cl	6	11/2	9675.029
			5720.274	nl, e	9	13/2	30135.234	587 (6)		This work					
			5728.21	nl, e	1	11/2	30111.020	786 (2)	—	This work	4252.777	nl	6	13/2	6603.591
			5733.53	nl, e	1	11/2	30094.834	825 (2)	—	This work	5394.551	nl	1	13/2	11562.762
			5747.20	nl, e	1	11/2	30053.346	759 (2)	—	This work	5220.665	nl	14	11/2	10904.034
			5765.104	nl, e	10	13/2	29999.333	681 (1)	—	[19]	4872.926	cl	20	11/2	9483.518
			5788.33	nl, e	1	9/2	29929.748	934 (3)	—	[19]	5254.583	nl	21	11/2	10904.034
			5800.05	nl, e	1	13/2	29894.855	537 (3)	—	[19]	3994.341	nl	20	11/2	4866.515
			6315.678	nl, e	1	13/2	28487.636	672 (2)	—	This work	4967.870	cl	60	15/2	8363.901
			6389.825	cl	11	13/2	28303.954	600 (3)	—	[19]					
			7446.558	nl, e	3	9/2	26083.725	929 (1)	—	[5]	4711.836		70	11/2	4866.515
			7627.381	nl	3	13/2	25765.475	582 (3)		This work					
			8453.073	nl	6	9/2	24485.172	1105 (3)		This work					
			8509.730	cl	7	11/2	24406.428	559 (5)	—	[5]					
			8581.240	cl	10	9/2	24308.530	535 (1)	−3 (4)	[8]					
			9078.497	cl	8	11/2	23670.416	535 (3)	—	[19]					
			9280.772	cl	9	9/2	23430.407	561 (1)	—	[19]					

Table 1: Continued.

New even lower level			Investigated/observed spectral line			Combining odd upper level					Observed fluorescence decay of the odd upper level			Final level of the decay	
J	Energy/cm^{-1}	A/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Ref. to columns 9 and 10	λ/Å	C.	SNR	J	Energy/cm^{-1}
7/2	13415.739	797 (2)	4542.707	nl	4	9/2	35422.868	569 (3)		[19]					
			5039.718	nl	12	5/2	33252.618	684 (2)		This work					
			5356.994	nl, f	6	7/2	32077.740	651 (2)		This work					
			5392.35	nl, f	1	9/2	31955.363	760 (2)		This work					
			5477.231	nl	9	7/2	31668.068	852 (3)	—	This work					
			5544.107	nl	6	9/2	31447.902	665 (1)	—	This work					
			5828.51	nl, e	1	5/2	30568.035	735 (3)		[13]	4355.961	nl	4	7/2	7617.440
			5919.58	nl, e	1	5/2	30304.145	818 (2)	—	This work	5277.699	nl	5	3/2	11361.762
			6419.42	nl, e	1	7/2	28989.170	959 (3)	—	[19]	4315.405	nl	24	9/2	5822.890
			7736.765	nl, e	1	9/2	26337.481	810 (1)	—	[19]	4873.218	cl	20	9/2	5822.890
			7821.265	nl, e	1	5/2	26197.878	1201 (3)	—	[19]	5084.456		300	7/2	6535.572
			8489.433	nl	19	5/2	25191.854	925 (4)		[13]					
			9110.822	nl	12	5/2	24388.695	1116 (2)		This work					
			9273.537	cl	12	9/2	24196.152	714 (4)		This work					
			9504.223	cl	9	9/2	23934.491	786 (2)		This work					
			9534.246	nl	10	7/2	23901.371	640 (2)		This work					
			9698.774	cl	7	7/2	23723.500	815 (5)	—	This work					
			9789.259	cl	9	7/2	23628.218	562 (2)		This work					
			9804.987	cl	7	7/2	23611.834	270 (2)		This work					

C: comment; nl: new line, not listed in commonly used wavelength tables; cl: classification of a "known" line (i.e., listed as praseodymium line but not yet classified); e: excited line; f: observed as fluorescence line.

Table 2: New odd levels discovered as lower levels of the excited transitions.

New odd lower level			Investigated/observed spectral line			Combining even upper level				Observed fluorescence decay of the even upper level			Final level of the decay	
J	Energy/cm^{-1}	A/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	Ref. To Col. 9	λ/Å	C.	SNR	J	Energy/cm^{-1}
3/2	11992.788	225 (2)	5592.594	nl	30	5/2	29868.604	805 (1)	This work					
			5612.128	nl, f	1	5/2	29806.394	779 (3)	This work				+	
			5635.687	e	40	5/2	29731.957	774 (3)	This work	4818.968	cl	10	3/2	8986.421
			5703.786	e	30	3/2	29520.139	24 (5)	This work	4868.681	cl	15	3/2	8986.421
			5746.61	nl, e	1	5/2	29389.516	749 (2)	This work	5089.150	cl	30	5/2	9745.334
			5798.372	e	38	3/2	29234.227	1038 (4)	[13]	5525.571	nl	20	5/2	11141.576
			5832.58	nl, e	1	5/2	29133.111	684 (3)	[19]	4962.215	cl	23	3/2	8986.421
			5882.885		32	3/2	28986.540	637 (4)	[13]					
			5916.167	e	30	5/2	28890.950	765 (4)	[13]	5022.587	cl	37	3/2	8986.421
			6188.963	nl	20	3/2	28146.114	874 (4)	This work					
			6251.794	nl, f	1	3/2	27983.773	723 (5)	[13]					
			6416.478	nl, f	5	5/2	27573.343	747 (3)	[13]					
			6458.657	e	10	5/2	27471.606	755 (4)	[13]	5408.240	nl	22	3/2	8986.421
			6551.942	nl	6	5/2	27251.230	335 (6)	[13]					
13/2	15347.431	674 (2)	5359.55	nl, f	5	15/2	34000.50	462 (2)	This work					
			5415.298		10	15/2	33808.503	480 (6)	This work					
			5632.008	e	10	15/2	33098.154	480 (1)	This work	5454.430	nl	6	15/2	14769.529
			5658.46	nl, f	1	13/2	33015.188	570 (2)	This work					
			5786.87	nl, e	1	13/2	32623.126	591 (2)	This work	5434.186	nl	1	11/2	14226.220
			5824.04	nl, e	1	13/2	32512.894	595 (15)	This work	4872.926	cl	20	11/2	9483.518
			5847.09	nl, e	1	13/2	32445.227	666 (1)	This work	6155.861	cl	14	13/2	16205.041
			5868.310	nl, e	12	15/2	32383.385	573 (2)	This work	3570.114	nl	9	15/2	4381.072
			5871.61	nl, e	1	11/2	32373.816	660 (1)	This work	4906.194	cl	12	11/2	11997.137
			5884.389	e	18	15/2	32336.849	475 (2)	This work	5747.837	nl	30	17/2	14943.825
			5896.28	e	6	13/2	32302.560	571 (3)	This work	3393.941	nl	12	13/2	2846.741
			6044.092	e	9	15/2	31887.920	563 (4)	This work	3442.400	nl	15	13/2	2846.741
			6253.81	nl, e	6	13/2	31333.250	576 (4)	This work	5554.82	nl	18	13/2	13335.868
			6265.263	nl	7	13/2	31304.033	622 (1)	This work					
			6297.43	nl, e	1	11/2	31222.519	596 (6)	This work	5025.4	nl	4	9/2	11329.696
			6353.15	nl, f	1	11/2	31083.290	620 (2)	This work					
			6455.085	nl	7	13/2	30834.807	666 (1)	This work					
			6502.304	e	6	13/2	30722.335	679 (4)	This work	3586.348	nl	4	13/2	2846.741
			6554.134		9	13/2	30600.763	656 (2)	This work					
			6693.514		5	15/2	30283.139	475 (5)	[19]					
			6711.57	nl	1	15/2	30242.928	462 (5)	This work					
			6966.875	nl	6	11/2	29697.090	784 (3)	[19]					
			9000.200	nl	10	13/2	26455.240	637 (5)	[5]					
			9080.342	nl	5	11/2	26357.200	745 (5)	[5]					

Table 2: Continued.

New odd lower level			Investigated/observed spectral line			Combining even upper level				Observed fluorescence decay of the even upper level			Final level of the decay	
J	Energy/cm^{-1}	A/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	Ref. To Col. 9	λ/Å	C.	SNR	J	Energy/cm^{-1}
15/2	15399.063	889 (2)	5430.487	nl	3	15/2	33808.503	480 (6)	This work					
			5643.260		32	17/2	33114.399	422 (2)	This work					
			5648.44	nl, e	1	15/2	33098.154	480 (2)	This work	5917.931	cl	10	13/2	16205.041
			5704.20	nl, e	1	17/2	32925.138	562 (2)	This work	5559.785	nl	5	17/2	14943.825
			5886.15	nl, f	1	15/2	32383.385	573 (2)	This work					
			5902.322	nl, e	6	15/2	32336.849	475 (2)	This work	5690.809	nl	15	15/2	14769.529
			6063.02	nl, e	1	15/2	31887.920	563 (4)	This work	3442.400	nl	15	13/2	2846.741
			6195.60	nl, e	1	13/2	31535.092	509 (3)	This work	3314.865	nl	5	11/2	1376.602
			6298.97	nl, f	1	15/2	31270.290	579 (2)	This work					
			6424.668	nl	8	15/2	30959.764	573 (5)	This work					
15/2	16180.200	883 (2)	5651.35	nl	5	13/2	33870.186	594 (3)	This work					
			5851.804	nl	6	17/2	33264.211	545 (2)	This work					
			6399.562		19	17/2	31801.951	503 (3)	This work					
			6429.23	nl	4	13/2	31729.874	432 (2)	This work					
			6567.346	nl, e	1	15/2	31402.846	631 (2)	This work	5918.088	cl	10	15/2	13565.490
			6625.036	nl, e	5	15/2	31270.290	579 (2)	This work	5557.136	nl	8	17/2	13280.404
			8009.742	nl	3	15/2	28661.560	550 (2)	This work					
13/2	16205.041	732 (3)	5554.308		20	15/2	34204.080	442 (2)	This work					
			5617.85	nl, e	1	15/2	34000.515	462 (2)	This work	5359.557	nl	1	13/2	15347.431
			5663.129	nl	8	15/2	33858.230	467 (5)	This work					
			5679.13	nl, e	1	15/2	33808.503	480 (6)	This work	5506.819	cl	50	13/2	15654.235
			5917.931	e	10	15/2	33098.154	480 (2)	This work	5506.798	cl	17	17/2	14943.825
			5947.143	nl, f	10	13/2	33015.188	570 (2)	This work					
			6050.93	nl, e	1	13/2	32726.817	565 (3)	This work	5554.632	nl	4	11/2	14728.843
			6071.057	nl, e	10	11/2	32672.078	529 (3)	This work	4835.418	cl	17	11/2	11997.137
			6155.861		14	13/2	32445.227	666 (1)	This work					
			6179.393	f	7	15/2	32383.385	573 (2)	This work					
			6374.618	nl, f	10	15/2	31887.920	563 (4)	This work					

C: Comment; nl: new line, not listed in commonly used wavelength tables; cl: classification of a "known" line (i.e., listed as praseodymium line but not yet classified); e: excited line; f: observed as fluorescence line.

Table 3: New levels discovered as upper levels of the excited transitions.

J	Energy/cm^{-1}	A/MHz	B/MHz	$\lambda_{exc.}$/Å	$\lambda_{fl.}$/Å
New even levels					
5/2	27993.770	754 (2)		5765.513, 5932.304	6361.250
	29389.516	749 (2)		5746.61, 5842.38	5089.150
	29806.394	779 (3)		5703.42, 5920.05	4801.743, 5164.812
	30123.235	657 (1)		5811.02, 5920.20	4905.908, 5081.628
	30590.721	622 (2)		5760.72, 5891.36	4988.161
	30963.451	661 (2)		5764.73, 5881.14	4873.488
	31299.695	800 (3)		5767.06, 5781.93	4794.892
7/2	28412.971	1025 (3)		5720.439, 5788.313	4958.234, 5629.412
	29468.524	623 (2)		5739.401, 5758.885	5313.584, 6005.252
	30461.496	692 (3)		5667.216, 5843.786	4787.551
	31005.715	692 (2)		5750.72, 5866.55	4665.944, 5080.914
	32070.559	668 (2)		5700.92, 5881.09	4820.053, 5995.548
	32166.080	736 (2)		5670.03, 5695.74	4797.956
9/2	24706.503	975 (2)	−5 (5)	4285.139, 6012.973	6074.993
	28883.730	835 (2)		5719.002, 5938.79	5178.856, 5570.391
	28936.490	615 (2)		5701.793, 7082.750	5554.061, 5675.712
	29340.605	530 (2)		6087.97, 6207.92	4875.446, 5059.117
	29523.953	647 (2)		5796.830, 5985.32	5012.608
	29698.580	629 (2)		5664.587, 5714.56	5193.739
	29766.734	699 (2)		5899.57, 5919.355	4952.322
	29980.012	672 (2)		5826.24, 5859.80	5624.088
	30232.222	737 (2)		5741.84, 5925.44	4840.699
	30356.677	788 (2)		5733.22, 5882.05	4811.703
	30447.257	695 (2)		4999.286, 5703.59	4790.816, 6081.770
	30625.599	643 (1)	25 (50)	5788.26, 5790.43	3264.301, 4750.218
	31677.736	433 (2)		5728.571, 5831.55	4913.107
	32402.860	544 (2)		5768.327, 5878.396	4553.938, 4744.046
11/2	28889.260	639 (1)	40 (50)	5693.32, 5826.37	5177.373
	29071.100	635 (2)		5765.268, 5933.423	6173.640
	29128.761	544 (2)		5746.121, 5751.336	5340.960
	29377.729	683 (3)		5665.093, 5751.95	5049.631
	29718.506	660 (1)		5708.06, 5713.87	4964.182, 5177.821
	31010.172	705 (2)		5875.80, 5878.00	5079.762
	31664.262	601 (2)		5733.00, 5827.91	4916.362, 5903.148
	31771.680	718 (2)		5799.77, 5865.94	5055.597
	31900.665	525 (2)		5748.69, 5821.88	5385.041
	32373.816	660 (2)		5724.69, 5871.61	4906.194
13/2	19654.709	800 (2)		5947.91	5469.506
	29051.938	540 (2)		5776.87, 5799.77	5933.903, 5940.178
	29111.856	581 (3)		5779.674, 5919.103	3806.251
	30600.763	656 (2)		6314.88, 6586.72	5439.581, 5640.794
	32623.126	591 (2)		5678.62, 5786.874	5434.186
15/2	27265.604	738 (3)		5931.364, 6470.303	4368.535
	31402.846	631 (2)		5918.099, 6166.705	6166.957
	32336.849	475 (2)		5690.809, 5911.88	5884.389
	33098.154	480 (2)		5648.44, 5657.19	5454.430, 5506.798
17/2	30826.745	580 (2)		5608.63, 5791.715	5244.434, 5590.891
	30848.885	507 (1)		5690.43, 6385.226	5238.350, 5583.974

Table 3: Continued.

J	Energy/cm^{-1}	A/MHz	B/MHz	$\lambda_{exc.}$/Å	$\lambda_{fl.}$/Å
19/2	29309.810	434 (1)		5697.855, 5746.624	6236.808,6889.914
	30466.597	403 (3)		5705.81, 5789.467	6199.288
New odd levels					85
3/2	29190.205	553 (1)	0 (10)	5698.408, 6350.60	5132.144, 5444.773
	29804.574	1115 (4)		5916.390, 8035.004	5347.001, 5420.660
	31343.998	1123 (3)		5715.42, 5833.47	4422.278, 4621.188
5/2	28800.063	1057 (2)		5704.28, 5769.52	5220.453
	28920.891	1012 (3)		5665.220, 5693.46	4465.960
	29075.845	829 (2)		5743.208, 5871.61	4435.258
	30304.145	818 (2)		5661.86, 5919.58	5277.699, 5477.134
	30679.627	933 (2)		5695.81, 5721.43	4766.274
	30763.323	981 (2)		5668.78, 5694.15	4538.864
7/2	24899.621	961 (2)		5920.24	4884.455
	25172.325	708 (2)		5826.151, 5831.653	5364.250
	26371.971	997 (3)		6549.43, 6582.51	5039.832, 5330.562
	27096.093	918 (3)		6470.79, 6498.944	5132.395, 5238.807
	28204.331	781 (5)		6467.24, 7764.48	4205.426, 4466.734
	28339.709	798 (2)		5709.230, 5739.15	4918.284
	28525.358	843 (2)		5739.705, 5795.12	4403.570, 5453.846
	28859.879	538 (2)		5749.67, 5807.763	4339.625, 5060.635
	28978.464	1047 (3)		5736.02, 5768.02	4839.335
	29579.960	720 (2)		5702.76, 5792.82	4338.231
	29675.405	865 (1)		5671.88, 5681.28	5005.949
	30975.616	734 (2)		5703.705, 5843.45	5031.837, 5051.337
	31668.068	852 (2)		5673.09, 5747.12	4969.170, 5100.550
	34243.714	655 (2)		5763.922	3608.018, 4734.423
9/2	25634.179	674 (1)		5673.44, 5774.092	4715.227
	26337.481	810 (1)		7736.76, 7935.73	4563.835, 4873.218
	26718.738	826 (2)		5729.066, 5875.89	4997.468
	27394.138	792 (3)		6470.73, 6522.91	4742.301, 4792.854
	27745.272	862 (2)		5696.259, 5749.322	4753.538, 5363.244
	28579.596	765 (2)	40 (50)	5661.189, 5747.116	5014.710, 5061.743
	29149.204	730 (1)		4377.825, 5785.463	5028.688
	30035.792	884 (2)		5707.45, 5739.56	4459.377, 4813.971
	30896.170	733 (2)		5781.92, 5841.280	3987.182, 4371.907
	30901.231	730 (2)		5780.229, 5839.55	4370.938, 4491.623
	31447.902	665 (2)		5744.87, 5887.789	4866.273
	31528.624	746 (2)		5789.76, 5793.565	5531.149
	33687.796	744 (2)		5691.05, 5764.22	3468.665
11/2	25900.352	858 (2)		5686.67, 5856.16	4656.763
	26159.533	672 (3)		5707.577, 5861.933	4915.860
	29195.032	805 (2)		5718.648, 5894.447	4705.958, 5581.246
	29614.075	900 (5)		5697.63, 5714.00	4614.926, 4966.186
	29985.372	775 (2)		5799.086, 7848.97	5222.124, 5239.264
	30053.346	759 (2)		5701.741, 5747.20	5052.454, 5220.665
	30094.834	825 (2)		5733.53, 5762.500	5314.286, 5394.551
	30111.020	786 (2)		5728.21, 5757.13	4252.777, 4272.879
	30347.477	700 (3)		6430.416, 6470.81	4836.005, 5029.500
	31895.205	668 (2)		5910.73, 5938.70	3698.720
	32289.455	665 (1)		5716.368, 5806.88	5458.571
	32513.960	655 (2)		5643.92, 5786.83	4535.186, 4749.025

Table 3: Continued.

J	Energy/cm^{-1}	A/MHz	B/MHz	$\lambda_{exc.}$/Å	$\lambda_{fl.}$/Å
13/2	24781.116	858 (2)	−20 (10)	5828.953, 5940.199	5588.731
	28487.636	672 (2)		5685.54, 6561.17	4967.870, 5201.762
	28851.007	584 (2)		5690.540, 5756.26	5437.904
	28921.386	697 (2)		5726.28, 5733.026	4959.956
	29663.117	651 (3)		5698.02, 5736.137	4693.694
	29774.999	615 (2)		5661.92, 5704.72	4758.430
	29836.950	535 (2)		5679.492, 5684.625	5388.150
	30284.567	681 (2)		5671.81, 5719.21	4994.092, 5317.344
	30412.010	658 (2)		5825.433, 5868.635	5442.042, 5499.812
	30562.652	537 (1)		5703.92, 5740.23	4742.700, 4964.105
	30644.652	628 (2)		5789.57, 5810.44	4943.974
	31005.761	586 (2)		5761.69, 5834.90	4867.409, 5141.807
	32608.542	620 (3)		5701.20, 5800.11	3844.331, 4515.808
	33052.848	555 (2)		5785.33, 5860.70	3982.695
	33932.700	737 (1)		5667.90, 5709.27	5165.634, 5260.914
15/2	26332.040	506 (2)	−45 (5)	5926.883, 5691.075	5345.561
	27294.906	790 (5)		6314.57, 7709.96	5280.870
	27950.530	824 (1)		5703.941, 6314.40	5210.956, 5407.968
	28754.446	639 (2)		5781.568, 5788.44	5466.620
	29094.822	634 (2)		5702.23, 5751.989	4728.263
	29942.851	583 (2)		5650.598, 5810.239	4949.732, 5150.310
	29989.064	528 (2)		5794.67, 5817.55	5570.287
	30788.090	528 (2)		5762.395, 5834.890	4919.547
	31039.972	553 (1)		5689.099, 5750.352	4091.104, 4860.176
	31668.549	544 (2)		5729.96, 5919.86	5625.687
	31817.886	437 (2)		5716.08, 5762.81	4911.429, 4916.388
	32672.439	601 (2)		5680.510, 5778.688	5014.698, 5031.823
	32849.815	540 (2)		5720.040, 5735.74	4467.124, 5623.828
17/2	25909.173	854 (2)	−45 (5)	5697.960, 5831.453	5831.453, 5697.960
	27844.889	602 (2)	−40 (50)	5752.739, 5774.425	5239.809
	29622.951	501 (1)	15 (20)	5754.650, 5920.309	5035.700, 5412.236
	29899.954	529 (1)		5664.331, 5847.876	5161.717, 6143.342
	30346.200	518 (1)		5699.110, 5913.005	5913.005, 5699.110
	31270.847	512 (2)		5798.136, 5863.62	4820.511, 4968.937
	33305.483	450 (2)		6404.22, 6470.68	5775.171, 6231.393
	35453.400	595 (1)		5820.62, 5848.02	3888.734, 5629.604
19/2	29950.715	418 (2)		5783.441, 5807.582	5482.025
21/2	30543.982	392 (2)		5909.466, 6801.441	5155.184, 5591.534
	32741.057	332 (2)		5917.00	5230.205

was known, and none of the combining levels could be identified by J- and A-values (Figure 1(a)). If one of the fluorescence lines was in the wavelength range of our laser light sources, we tried to perform a second excitation at this wavelength. With some luck, we were able to identify the lower level of the new excitation. Then the energy of the unknown upper level could be determined, and in sequence, using the wave number of the first excitation, the energy of the new lower level (Figure 1(b)). If none of the fluorescence lines could be reached with our available lasers, we had to choose the following procedure: if there were more than two fluorescence lines whose wavelengths could be determined accurately, we had a chance to find the positions of the levels by explaining the wave number differences of the fluorescence lines as differences between the energies of already known levels (Figure 1(c)). Of course, we had to consider the ladders of even and odd levels separately, since we did not know the parity of the upper unknown level.

In 2007, we were able to record a highly resolved FT emission spectrum, which contains more than 25000 spectral lines, using our hollow cathode discharge as light source. A first analysis led to the classification of about 1200 lines as

Table 4: Spectral lines explained by the new even levels.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
13/2	19654.709	800 (2)		5469.506	f	190	11/2	1376.602	730.393	−11.877	[7]
				5947.91	nl, e	5	13/2	2846.741	613.240	−12.850	[7]
				6545.421		30	15/2	4381.072	541.575	−14.558	[7]
9/2	24706.503	975 (2)		4285.139	nl, e	11	11/2	1376.602	730.393	−11.877	[7]
				6012.973	nl, e	12	11/2	8080.402	238.352	−22.961	[7]
				6074.993	f	135	9/2	8250.141	213.531	−4.136	[7]
				7003.424		16	11/2	10431.716	701.7 (5)	−10 (7)	[9]
15/2	27265.604	738 (3)		4368.535	nl, f	8	15/2	4381.072	541.575	−14.558	[7]
				5394.523	nl	11	13/2	8733.440	854.297	−31.807	[7]
				5931.364	e	17	13/2	10410.745	655.9 (3)	−29 (7)	[8]
				6023.642	f	70	15/2	10668.950	951.310	−2.670	[7]
				6441.818		55	13/2	11746.328	401 (1)	50 (20)	[19]
				6470.303	nl,e	12	15/2	11814.647	355 (2)	0 (10)	[19]
				6645.548		24	13/2	12222.091	1133 (4)	—	This work
				7837.664	nl	4	13/2	14510.207	1085 (2)	—	This work
5/2	27993.770	754 (2)		5765.513	e	20	7/2	10654.070	169 (2)	—	[19]
				5932.304	e	25	5/2	11141.576	169 (2)	—	[19]
				6025.783	nl	8	7/2	11403.011	1142 (3)	—	[19]
				6293.545	nl	5	5/2	12108.867	1275 (2)	—	[19]
				6361.250	nl	15	7/2	12277.935	1760 (4)	—	[19]
				7148.782	nl	4	7/2	14009.225	1100 (1)	—	[19]
7/2	28412.971	1025 (3)		3518.513	nl	16	9/2	0.000	926.209	−11.878	[7]
				4958.234	nl, f	6	9/2	8250.141	213.531	−4.136	[7]
				5629.412	f	45	7/2	10654.070	169 (2)	—	[19]
				5720.439	e	90	9/2	10936.652	930 (1)	0 (10)	[19]
				5788.313	e	75	5/2	11141.576	169 (2)	—	[19]
				5877.279		18	7/2	11403.011	1142 (3)	—	[19]
9/2	28883.730	835 (2)		5178.856	nl, f	14	9/2	9579.820	789 (1)	—	[19]
				5570.391	nl, f	25	9/2	10936.652	930 (1)	0 (10)	[19]
				5719.002	e	48	7/2	11403.011	1142 (3)	—	[19]
				5938.79	nl, e	1	9/2	12049.942	275 (2)	—	[19]
				6020.327	nl, f	1	7/2	12277.935	1760 (4)	—	[19]
				6223.887	nl, f	6	9/2	12821.044	1127 (3)	—	[19]
				6262.198	nl, f	12	7/2	12919.316	180 (2)	—	[19]
				6440.183	nl, f	1	11/2	13360.511	151 (3)	—	[19]
11/2	28889.260	639 (1)	40 (50)	5177.373	f	220	9/2	9579.820	789 (1)	—	[19]
				5690.96	nl, e	1	11/2	11322.443	1272 (1)	75 (50)	[19]
				5693.32	nl, e	1	9/2	11329.696	530 (3)	—	[19]
				5826.37	nl, e	1	9/2	11730.668	1365 (5)	—	[19]
				5831.69	nl, e	1	13/2	11746.328	401 (1)	50 (20)	[19]
				5918.27	nl, e	1	11/2	11997.137	585 (3)	—	[19]
				6817.989	nl	4	11/2	14226.220	869 (3)	—	[19]
9/2	28936.490	615 (2)		5554.061	nl, f	12	9/2	10936.652	930 (1)	0 (10)	[19]
				5675.712	nl, f	1	11/2	11322.443	1272 (1)	75 (50)	[19]
				5701.793	nl, e, f	16	7/2	11403.011	1142 (3)	—	[19]
				5920.23	nl, e	1	9/2	12049.942	275 (2)	—	[19]
				6203.512	f	13	9/2	12821.044	1127 (3)	—	[19]
				6225.390	nl, f	1	11/2	12877.682	1139 (2)	—	[19]

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
				6694.189	f	23	11/2	14002.294	566 (1)	—	[19]
										−125 (50)	
				7082.750	e, f	34	11/2	14821.565	544 (2)		This work
13/2	29051.938	540 (2)		3612.294	nl	3	11/2	1376.602	730.393	−11.877	[7]
				3814.953	nl	4	13/2	2846.741	613.240	−12.850	[7]
				5776.87	nl, e	8	13/2	11746.328	401 (1)	50 (20)	[19]
				5799.77	nl, e	1	15/2	11814.647	355 (2)	0 (10)	[19]
				5933.903	nl, f	38	11/2	12204.286	1010 (2)	—	This work
				5940.178	f	35	13/2	12222.091	1133 (4)	—	This work
				6455.473	nl, e	10	15/2	13565.490	917 (1)	10 (10)	[19]
11/2	29071.100	635 (2)		5765.268	nl, e	5	9/2	11730.668	1365 (5)	—	[19]
				5873.411	nl, e	5	9/2	12049.942	275 (2)	—	[19]
				5927.159	nl	6	11/2	12204.286	1010 (2)	—	This work
				5933.423	nl, e	30	13/2	12222.091	1133 (4)	—	This work
				6152.120	nl	6	9/2	12821.044	1127 (3)	—	[19]
				6173.640	nl, f	40	11/2	12877.682	1139 (2)	—	[19]
				6360.753		12	9/2	13354.043	1272 (3)	—	[19]
13/2	29111.856	581 (3)		3604.491	nl	4	11/2	1376.602	730.393	−11.877	[7]
				3806.251	nl, f	10	13/2	2846.741	613.240	−12.850	[7]
				5420.630	nl	15	15/2	10668.950	951.310	−2.670	[7]
				5779.674	nl, e	5	15/2	11814.647	355 (2)	0 (10)	[19]
				5919.103	nl, e	15	13/2	12222.091	1133 (4)	—	This work
				6158.141	f	19	11/2	12877.682	1139 (2)	—	[19]
11/2	29128.761	544 (2)		3432.049	nl	26	9/2	0.000	926.209	−11.878	[7]
				5340.960	f	37	13/2	10410.745	655.9 (3)	−29 (7)	[8]
				5746.121	nl, e	22	9/2	11730.668	1365 (5)	—	[19]
				5751.336	nl, e	6	13/2	11746.328	401 (1)	50 (20)	[19]
				5853.578	nl	5	9/2	12049.942	275 (2)	—	[19]
19/2	29309.810	434 (1)		5697.855	e	5	17/2	11764.216	892.5 (7)	−10 (25)	[9]
				5746.624	e	55	19/2	11913.115	829.9 (2)	2 (8)	[9]
				6236.808	f	105	17/2	13280.404	208 (2)	20 (50)	[19]
				6889.914	f	23	19/2	14799.842	126 (5)	—	[19]
				8593.623		5	17/2	17676.472	856 (2)	—	This work
				9477.685		12	19/2	18761.608	870 (1)	—	This work
9/2	29340.605	530 (2)		4875.446	nl, f	1	11/2	8835.389	949.091	−13.721	[7]
				5059.117	f	11	9/2	9579.820	789 (1)	—	[19]
				5548.412	nl, f	18	11/2	11322.443	1272 (1)	75 (50)	[19]
				5833.94	nl	1	11/2	12204.286	1010 (2)	—	This work
				6087.97	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				6207.92	nl, e	1	7/2	13236.606	726 (1)	—	[19]
				6614.387	nl, e	1	11/2	14226.220	869 (3)	—	[19]
11/2	29377.729	683 (3)		5049.631	f	120	9/2	9579.820	789 (1)	—	[19]
				5276.688	nl	8	11/2	10431.716	701.7 (5)	−10 (7)	[9]
				5665.093	nl, e	15	9/2	11730.668	1365 (5)	—	[19]
				5751.95	nl, e	1	11/2	11997.137	585 (3)	—	[19]
				6239.035	nl	5	9/2	13354.043	1272 (3)	—	[19]

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
5/2	29389.516	749 (2)		4899.854	nl	10	3/2	8986.443	1029 (3)	—	This work
				5089.150	f	30	5/2	9745.334	626 (1)	5 (3)	[4]
				5746.61	nl, e	1	3/2	11992.788	225 (5)	—	This work
				5842.38	nl, e	1	7/2	12277.935	1760 (4)	—	[19]
7/2	29468.524	623 (2)		5313.584	nl, f	1	7/2	10654.070	169 (2)	—	This work
				5394.610	nl	10	9/2	10936.652	930 (1)	0 (10)	[19]
				5511.504	nl	10	9/2	11329.696	530 (3)	—	[19]
				5739.401	e	45	9/2	12049.942	275 (2)	—	[19]
				5758.885	nl, e	4	5/2	12108.867	1275 (2)	—	[19]
				6005.252	nl, f	5	9/2	12821.044	1127 (3)	—	[19]
				6040.912	nl, f	1	7/2	12919.316	180 (2)	—	[19]
				6308.548	nl, f	1	7/2	13621.400	879 (1)	−10 (10)	This work
9/2	29523.953	647 (2)		5012.608	f	35	9/2	9579.820	789 (1)	—	[19]
				5772.18	nl, e	1	11/2	12204.286	1010 (2)	—	This work
				5796.830	nl, e	10	7/2	12277.935	1760 (4)	—	[19]
				5985.32	nl, e	1	9/2	12821.044	1127 (3)	—	[19]
				6005.688		20	11/2	12877.682	1139 (2)	—	[19]
9/2	29698.580	629 (2)		5193.739	f	25	7/2	10449.997	541 (2)	—	[19]
				5664.587	e	15	9/2	12049.942	275 (2)	—	[19]
				5714.56	nl, e	1	11/2	12204.286	1010 (2)	—	This work
				5923.396	nl	35	9/2	12821.044	1127 (3)	—	[19]
				6118.984		8	11/2	13360.511	151 (3)	—	[19]
				6218.279		12	7/2	13621.400	879 (1)	−10 (10)	This work
				6719.928	nl	6	11/2	14821.565	544 (2)		This work
11/2	29718.506	660 (1)		3363.940	nl	53	9/2	0.000	926.209	−11.878	[7]
				4964.182	f	55	9/2	9579.820	789 (1)	—	[19]
				5177.821	f	50	13/2	10410.745	655.9 (3)	−29 (7)	[8]
				5434.435	nl, f	12	11/2	11322.443	1272 (1)	75 (50)	[19]
				5708.06	nl, e	1	11/2	12204.286	1010 (2)	—	This work
				5713.87	nl, e	1	13/2	12222.091	1133 (4)	—	This work
				6118.737		25	9/2	13379.788	932 (3)	10 (20)	[19]
9/2	29766.734	699 (2)		3521.355	nl	2	11/2	1376.602	730.393	−11.877	[7]
				4952.322	f	15	9/2	9579.820	789 (1)	—	[19]
				5692.390	nl	6	11/2	12204.286	1010 (2)	—	This work
				5899.57	nl, e	1	9/2	12821.044	1127 (3)	—	[19]
				5919.355	nl, e	18	11/2	12877.682	1139 (2)	—	[19]
5/2	29806.394	779 (3)		4801.743	f	18	3/2	8986.443	1029 (23)	—	This work
				5164.812	f	5	7/2	10449.997	541 (2)	—	[19]
				5219.846	nl, f	7	7/2	10654.070	169 (2)	—	This work
				5356.188	f	15	5/2	11141.576	169 (2)	—	[19]
				5612.128	nl, f	1	3/2	11992.788	225 (5)	—	This work
				5648.942	nl, f	13	5/2	12108.867	1275 (2)	—	[19]
				5703.42	nl, e	1	7/2	12277.935	1760 (4)	—	[19]
				5920.05	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				6310.689	nl, f	1	5/2	13964.645	185 (2)	—	[19]
				6328.498	nl, f	1	7/2	14009.225	1100 (1)	—	[19]

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
9/2	29980.012	672 (2)		4900.548		10	9/2	9579.820	789 (1)	—	[19]
				5624.088	nl, f	1	11/2	12204.286	1010 (2)	—	This work
				5826.24	nl, e	1	9/2	12821.044	1127 (3)	—	[19]
				5859.80	nl, e	1	7/2	12919.316	180 (2)	—	[19]
5/2	30123.235	657 (1)		4729.763		12	3/2	8986.443	1029 (3)	—	This work
				4905.908	f	12	5/2	9745.334	626 (1)	5 (3)	[4]
				5081.628	f	15	7/2	10449.997	541 (2)	—	[19]
				5107.293	nl, f	4	3/2	10548.845	34 (5)		[19]
				5811.02	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				5920.20	nl, e	1	7/2	13236.606	726 (1)	—	[19]
				6186.947	nl, f	5	5/2	13964.645	185 (2)	—	[19]
				6204.063	nl	5	7/2	14009.225	1100 (1)		[19]
9/2	30232.222	737 (2)		4840.699	f	80	9/2	9579.820	789 (1)	—	[19]
				5498.333	nl, f	1	9/2	12049.942	275 (2)	—	[19]
				5741.84	nl, e	1	9/2	12821.044	1127 (3)	—	[19]
				5760.58	nl, e	1	11/2	12877.682	1139 (2)	—	[19]
				5774.44	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				5925.44	nl, e	1	11/2	13360.511	151 (3)	—	[19]
9/2	30356.677	788 (2)		4811.703	f	22	9/2	9579.820	789 (1)	—	[19]
				5529.822		36	7/2	12277.935	1760 (4)	—	[19]
				5733.22	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				5882.05	nl, e	1	11/2	13360.511	151 (3)	—	[19]
9/2	30447.257	695 (2)		4790.816	f	18	9/2	9579.820	789 (1)	—	[19]
				4999.286	e	5	7/2	10449.997	541 (2)	—	[19]
				5703.59	nl, e	1	7/2	12919.316	180 (2)	—	[19]
				5808.79	nl, e	1	7/2	13236.606	726 (1)	—	[19]
				5857.48	nl, e	1	9/2	13379.788	932 (3)	10 (20)	[19]
				6081.770	nl, f	1	7/2	14009.225	1100 (1)	—	[19]
7/2	30461.496	692 (3)		4787.551	f	5	9/2	9579.820	789 (1)	—	[19]
				5667.216	nl, e	12	9/2	12821.044	1127 (3)	—	[19]
				5843.786	nl, e	15	9/2	13354.043	1272 (3)	—	[19]
19/2	30466.597	403 (3)		5705.81	nl, e	1	19/2	12945.474	837.1 (3)	−7 (6)	[9]
				5789.467	e	27	21/2	13198.637	785.8 (5)	−85 (20)	[9]
				5817.01	nl, e	1	17/2	13280.404	208 (2)	20 (50)	[19]
				6199.288	f	58	17/2	14340.174	245 (1)	−20 (15)	[19]
				6381.18	nl, e	4	19/2	14799.842	126 (5)	—	[19]
				8541.018		9	19/2	18761.608	870 (1)	—	This work
5/2	30590.721	622 (2)		4988.161	f	18	3/2	10548.845	34 (5)		[19]
				5760.72	nl, e	1	7/2	13236.606	726 (1)	—	[19]
				5767.20	nl, e	1	5/2	13256.082	1074 (3)	—	[19]
				5891.36	nl, e	1	7/2	13621.400	879 (1)	−10 (10)	This work
13/2	30600.763	656 (2)		3420.845	nl	3	11/2	1376.602	730.393	−11.877	[7]
				3602.055	nl	4	13/2	2846.741	613.240	−12.850	[7]
				5439.581	nl, f	14	13/2	12222.091	1133 (4)	—	This work
				5640.794	nl, f	1	11/2	12877.682	1139 (2)	—	[19]
				5868.55	nl, e	1	15/2	13565.490	917 (1)	10 (10)	[19]
				6314.88	nl, e	1	15/2	14769.529	806 (2)	—	This work
				6554.134		9	13/2	15347.431	674 (2)	—	This work

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
9/2	30625.599	643 (1)	25 (50)	3264.301	nl, f	15	9/2	0.000	926.209	−11.878	[7]
				4750.218	nl, f	2	9/2	9579.820	789 (1)	—	[19]
				4950.613	nl, f	5	11/2	10431.716	701.7 (5)	−10 (7)	[9]
				5632.903	nl	10	11/2	12877.682	1139 (2)	—	[19]
				5646.143	nl	7	7/2	12919.316	180 (2)	—	[19]
				5749.176	nl, e	6	7/2	13236.606	726 (1)	—	[19]
				5788.26	nl, e	1	9/2	13354.043	1272 (3)	—	[19]
				5790.43	nl, e	1	11/2	13360.511	151 (3)	—	[19]
				5796.90	nl, e	1	9/2	13379.788	932 (3)	10 (20)	[19]
				6325.752		15	11/2	14821.565	544 (2)		This work
17/2	30826.745	580 (2)		5244.434	nl, f	1	17/2	11764.216	892.5 (7)	−10 (25)	[9]
				5590.891	nl, f	1	19/2	12945.474	837.1 (3)	−7 (6)	[9]
				5608.63	nl, e	1	15/2	13002.023	317 (2)	30 (50)	[19]
				5791.715	e	45	15/2	13565.490	917 (1)	10 (10)	[19]
				6063.863	nl, f	1	17/2	14340.174	245 (1)	−20 (15)	[19]
				6226.007	nl, f	1	15/2	14769.529	806 (2)	—	This work
				6294.331	nl	1	17/2	14943.825	808 (3)	—	[19]
				6394.270	nl, e	9	15/2	15192.075	730 (5)		This work
				7160.474	nl	4	15/2	16865.034	291 (4)		This work
17/2	30848.885	507 (1)		5238.350	nl, f	1	17/2	11764.216	892.5 (7)	−10 (25)	[9]
				5583.974	f	14	19/2	12945.474	837.1 (3)	−7 (6)	[9]
				5690.43	nl, e	1	17/2	13280.404	208 (2)	20 (50)	[19]
				5784.296	e	15	15/2	13565.490	917 (1)	10 (10)	[19]
				6055.730	nl	7	17/2	14340.174	245 (1)	−20 (15)	[19]
				6217.433		8	15/2	14769.529	806 (2)	—	This work
				6385.226	nl, e	12	15/2	15192.075	730 (5)		This work
5/2	30963.451	661 (2)		4873.488	f	30	7/2	10449.997	541 (2)	—	[19]
				4897.088	nl	3	3/2	10548.845	34 (5)		[19]
				4922.460	nl	3	7/2	10654.070	169 (2)	—	This work
				5764.73	nl, e	1	7/2	13621.400	879 (1)	−10 (10)	This work
				5881.14	nl, e	1	5/2	13964.645	185 (2)	—	[19]
7/2	31005.715	692 (2)		4665.944	f	5	9/2	9579.820	789 (1)	—	[19]
				5080.914	f	12	9/2	11329.696	530 (3)	—	[19]
				5273.970	nl, f	1	9/2	12049.942	275 (2)	—	[19]
				5750.72	nl, e	1	7/2	13621.400	879 (1)	−10 (10)	This work
				5866.55	nl, e	1	5/2	13964.645	185 (2)	—	[19]
11/2	31010.172	705 (2)		5079.762	nl, f	3	9/2	11329.696	530 (3)	—	[19]
				5316.005	nl	5	11/2	12204.286	1010 (2)	—	This work
				5875.80	nl, e	1	13/2	13995.931	1067 (1)	200 (50)	[19]
				5878.00	nl, e	1	11/2	14002.294	566 (1)	−125 v	[19]
5/2	31299.695	800 (3)		4794.892	f	25	7/2	10449.997	541 (2)	—	[19]
				5767.06	nl, e	1	5/2	13964.645	185 (2)	—	[19]
				5781.93	nl, e	1	7/2	14009.225	1100 (1)	—	[19]
15/2	31402.846	631 (2)		5743.251	nl	3	13/2	13995.931	1067 (1)	200 (50)	[19]
				5918.099	e	10	13/2	14510.207	1085 (2)	—	This work
				6166.705	nl, e	30	13/2	15191.218	666 (5)		This work
				6166.957	f, e	50	13/2	15191.891	730 (5)		This work
				6167.03	nl, e	1	15/2	15192.075	730 (5)		This work

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
11/2	31664.262	601 (2)		4916.362	f	12	9/2	11329.696	530 (3)	—	[19]
				5658.274	nl	12	13/2	13995.931	1067 (1)	200 (50)	[19]
				5733.00	nl, e	1	11/2	14226.220	869 (3)	—	[19]
				5827.91	nl, e	1	13/2	14510.207	1085 (2)	—	This work
				5836.135	nl, e	3	9/2	14534.393	100 (2)	—	[19]
				5903.148	nl, f	1	11/2	14728.843	811 (2)	—	[19]
				5935.647	nl, e	5	11/2	14821.565	544 (2)		This work
				6145.287	nl, e	7	9/2	15396.135	719 (8)		This work
9/2	31677.736	433 (2)		4913.107	nl, f	35	9/2	11329.696	530 (3)	—	[19]
				5728.571	nl, e	6	11/2	14226.220	869 (3)	—	[19]
				5831.55	nl, e	1	9/2	14534.393	100 (2)	—	[19]
				5898.450	nl	5	11/2	14728.843	811 (2)	—	[19]
11/2	31771.680	718 (2)		5055.597	f	14	11/2	11997.137	585 (3)	—	[19]
				5799.77	nl, e	1	9/2	14534.393	100 (2)	—	[19]
				5865.94	nl, e	1	11/2	14728.843	811 (2)	—	[19]
11/2	31900.665	525 (2)		5385.041	nl, f	5	13/2	13335.868	895 (1)	100 (50)	[19]
				5748.69	nl, e	1	13/2	14510.207	1085 (2)	—	This work
				5821.88	nl, e	1	11/2	14728.843	811 (2)	—	[19]
7/2	32070.559	668 (2)		4820.053	f	20	9/2	11329.696	530 (3)	—	[19]
				5700.92	nl, e	1	9/2	14534.393	100 (2)	—	[19]
				5881.09	nl, e	1	9/2	15071.618	635 (3)	—	[19]
				5995.55	nl, e, f	1	9/2	15396.135	719 (8)		This work
7/2	32166.080	736 (2)		4797.956	f	18	9/2	11329.696	530 (3)	—	[19]
				5670.03	nl, e	1	9/2	14534.393	100 (2)	—	[19]
				5695.74	nl, e	1	7/2	14613.96	760 (3)	—	[19]
15/2	32336.849	475 (1)		5690.809	nl, e	15	15/2	14769.529	806 (2)	—	This work
				5747.837	nl, e	30	17/2	14943.825	808 (3)	—	[19]
				5772.48	nl, e	1	13/2	15018.088	108 (3)	—	[19]
				5884.389	f	18	13/2	15347.431	674 (2)	—	This work
				5902.322	nl, e	6	15/2	15399.063	889 (2)	—	This work
				5911.88	nl, e	1	13/2	15426.436	737 (2)	—	This work
11/2	32373.816	660 (2)		3225.165	nl	12	11/2	1376.602	730.393	−11.877	[7]
				4906.194	f	12	11/2	11997.137	585 (3)	—	[19]
				5695.696	nl	10	11/2	14821.565	544 (2)		This work
				5724.69	nl, e	1	9/2	14910.476	611 (2)	—	[19]
				5760.19	nl, e	1	13/2	15018.088	108 (3)	—	[19]
				5871.61	nl, e	1	13/2	15347.431	674 (2)	—	This work
				5979.354	e	12	13/2	15654.235	577 (1)		This work
9/2	32402.860	544 (2)		4553.938	nl, f	1	7/2	10449.997	541 (2)	—	[19]
				4744.046	nl, f	25	9/2	11329.696	530 (3)	—	[19]
				5656.45	nl, e	1	11/2	14728.843	811 (2)	—	[19]
				5715.19	nl, e	1	9/2	14910.476	611 (2)	—	[19]
				5768.327	nl, e	17	9/2	15071.618	635 (3)	—	[19]
				5878.396	nl, e	12	9/2	15396.135	719 (8)		This work
13/2	32623.126	591 (2)		3357.401	nl	10	13/2	2846.741	613.240	−12.850	[7]
				5434.186	nl, f	1	11/2	14226.220	869 (3)	—	[19]
				5678.62	nl, e	1	13/2	15018.088	108 (3)	—	[19]
				5786.874	nl, e	5	13/2	15347.431	674 (2)	—	This work
				5891.506	e	14	13/2	15654.235	577 (1)		This work

Table 4: Continued.

New upper even level				Line			Combining known lower odd level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
15/2	33098.154	480 (2)		3481.252	nl,	2	15/2	4381.072	541.575	−14.558	[7]
				5454.430	nl, f	6	15/2	14769.529	806 (2)	—	This work
				5506.798	f	17	17/2	14943.825	808 (3)	—	[19]
				5529.417	nl, f	1	13/2	15018.088	108 (3)	—	[19]
				5582.878	nl, f	1	13/2	15191.218	666 (5)		This work
				5632.008	e	10	13/2	15347.431	674 (2)	—	This work
				5648.443	nl, e	1*	15/2	15399.063	887 (3)	—	This work
				5657.192	nl, e	1*	13/2	15426.436	737 (2)	—	This work
				5917.931	e	10	13/2	16205.041	733 (2)	—	This work
				6128.250	nl, f	1	15/2	16784.797	297 (5)	—	This work
				6520.162	nl, f	1	13/2	17765.348	490 (3)	—	[19]

C: comment; nl: new line; e: excited; f: observed as fluorescence line. Lines, for which SNR 1 is given, do not show up in our FT spectrum, but could be excited or were observed as fluorescence lines.

transitions between already known levels (in the wavelength range 3977 to 9878 Å) and to the discovery of 23 new levels [11]. But it turned out that this spectrum is also very helpful in improving earlier laser spectroscopic data, since a huge number of excited lines and/or lines observed as fluorescence transitions can be clearly identified in the FT spectrum due to their characteristic hf patterns. Moreover, after calculating all possible combinations from a level together with their expected hf patterns, one can have a look at the FT spectrum if these patterns appear and classify in this way spectral lines. Having determined the A-factors from the laser spectroscopic recording, the cg wavelength can be determined with an accuracy of 0.001 Å adjusting a calculated hf pattern to the pattern of the line taken from the FT spectrum. In this way, the cg wave number of the line can be determined with high accuracy. Using already corrected energy values of known levels, the energy of the new levels could be determined now with an accuracy of 0.010 cm^{-1}.

Not all of the excited transitions appear clearly in the FT spectrum. Due to the huge number of energy levels, blend situations, in which different pairs of combining levels possess the same wave number difference, are observed quite frequently. Then the corresponding hf patterns overlap, so one observes their sum curve, weighted with their relative intensities, in the FT spectrum. In such cases, it is not always possible to determine reliable cg wavelengths. It is also possible, that a transition is quite weak in the emission spectrum, thus the corresponding line has an intensity below the noise of the FT spectrum. Nevertheless, sometimes it is possible to excite such a weak transition and to observe a LIF signal with good signal-to-noise ratio (SNR). Sometimes also LIF signals can be observed having wavelengths not appearing in our FT spectrum. Most of the fluorescence decays of the new levels were clearly visible lines in the FT spectrum with high SNR. In these cases, their cg wave number could be used to determine the energy of the decaying level with good accuracy.

Only for a few new levels neither the excited nor the fluorescence lines showed up in the FT spectrum, and it was also not possible to find other lines that could be explained as transitions combining with the new level. In such cases, we used a new method to determine the excitation wavelength with high accuracy (explanation see Example 2).

4. Examples for Finding New Levels

Example 1. Level pair 12646.996(10) cm^{-1}, $J = 5/2$, even parity, $A = 892(2)$ MHz −30304.145(10) cm^{-1}, $J = 5/2$, odd parity, $A = 818(2)$ MHz.

When exciting in the hollow cathode plasma with an estimated cg wavelength $\lambda = 5746.49$ Å, we observed an hf pattern, which could be attributed to a transition between two levels having both $J = 5/2$, $A_{\mathrm{up}} = 818$ MHz, and $A_{\mathrm{lo}} = 892$ MHz. Fluorescence was observed on several lines, amongst them $\lambda_{\mathrm{fl}} = 5919$ Å and 4485 Å (the reading of the monochromator is accurate to ±2 Å). None of the levels in our database possessed matching J- and A-values, thus we had to assume that for this transition two unknown levels combine. Fortunately, one of the fluorescence lines, 5919 Å, was in the range of our dye laser. Thus we tuned the monochromator, used for selecting the LIF wavelength, to the second fluorescence line $\lambda_{\mathrm{fl}} = 4485$ Å. The laser wavelength was then set to $\lambda_{\mathrm{start}} = 5919$ Å and tuned until an LIF signal was observed (at $\lambda = 5919.58$ Å). Again the observed hf pattern was evaluated, and this time the lower level could be identified to be 13415.739 cm^{-1}, even parity, $J = 7/2$, $A = 797$ MHz, found by us earlier. This allowed us to calculate the energies of the combining levels of the line $\lambda = 5746.49$ Å. Later, with the help of the wave numbers and hf patterns of the fluorescence lines, we could determine the energies with high accuracy.

Example 2. Level 28889.260(10) cm^{-1}, $J = 11/2$, even parity, $A = 639(1)$ MHz.

This level was discovered when tuning the exciting laser wavelength to $\lambda = 5826.37$ Å (a small peak in the FT spectrum). A strong LIF signal was detected at wavelength $\lambda_{\mathrm{fl}} = 5177$ Å. The recorded hf pattern could be interpreted

Table 5: Spectral lines explained by the new odd levels.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
13/2	24781.116	858 (2)	−20 (10)	5020.041	nl	14	11/2	4866.515	867.997	−50.319	[7]
				5588.731	f	60	11/2	6892.934	551.934	−24.736	[7]
				5828.953	e	70	13/2	7630.132	776.286	−43.592	[7]
				5940.199	nl, e	75	13/2	7951.323	644 (1)	−30(20)	[19]
				6535.168		15	11/2	9483.518	731 (1)	−15(10)	[19]
				6985.811	nl	6	13/2	10470.329	628 (3)	—	[19]
7/2	24899.621	961 (2)		4884.455	f	170	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				5240.529		35	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				5920.24	nl, e	5	7/2	8013.089	168 (1)	—	This work
				6581.885		7	5/2	9710.600	164 (2)	—	[19]
				6673.086		20	7/2	9918.190	1057.4 (5)	22 (6)	[8]
7/2	25172.325	708 (2)		5340.248	nl	30	5/2	6451.808	1189 (6)	−5 (5)	[8]
				5364.250	f	80	7/2	6535.572	979 (1)	25 (30)	[19]
				5826.151	nl, e	5	7/2	8013.089	168 (1)	—	This work
				5831.653	nl, e	26	9/2	8029.275	797 (2)	—	[19]
				7338.656	nl	6	9/2	11549.602	1064 (2)	—	This work
9/2	25634.179	674 (1)		4715.227	f	30	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4813.833		8	11/2	4866.515	867.997	−50.319	[7]
				5673.44	nl, e	1	7/2	8013.089	168 (1)	—	This work
				5774.092	nl, e	9	9/2	8320.240	255 (2)	—	[19]
				6048.242		18	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				6108.743		18	11/2	9268.726	977 (1)	−24 (20)	[19]
				6275.949		20	7/2	9704.744	779 (1)	−50 (30)	[19]
11/2	25900.352	858 (2)		4656.763	f	60	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4752.913	nl	6	11/2	4866.515	867.997	−50.319	[7]
				5180.774		55	13/2	6603.591	755.456	−48.633	[7]
				5569.785	nl	20	13/2	7951.323	644 (1)	−30 (20)	[19]
				5686.67	nl, e	1	9/2	8320.240	255 (2)	—	[19]
				5793.302	e	60	9/2	8643.824	797 (2)	—	[19]
				5856.16	nl, e	1	11/2	8829.063	769 (1)	−30 (20)	This work
				6161.500		15	11/2	9675.029	683 (1)	—	[19]
				9469.298		15	9/2	15342.804	1103 (5)	—	This work
17/2	25909.173	854 (2)	−45(5)	5697.960	e, f	120	15/2	8363.901	763.306	−48.253	[7]
				5831.453	e, f	210	15/2	8765.542	763.557	−45.805	[7]
				7589.454		13	17/2	12736.621	904 (1)	20 (20)	This work
				8139.425	nl	5	19/2	13626.672	865 (3)	—	[19]
11/2	26159.533	672 (3)		4601.217	nl	4	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4915.860	f	40	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				5037.316	nl	46	11/2	6313.224	756 (1)	—	This work
				5112.113	nl	29	13/2	6603.591	755.456	−48.633	[7]
				5188.885	nl	11	11/2	6892.934	551.934	−24.736	[7]
				5514.111		75	9/2	8029.275	797 (2)	—	[19]
				5707.577	nl, e	10	9/2	8643.824	797 (2)	—	[19]
				5861.933	nl, e	7	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				6720.082		8	11/2	11282.865	1049 (2)	—	This work
				6848.946	nl	5	13/2	11562.762	819 (2)	—	This work
				9697.559	nl	5	13/2	15850.483	926 (3)	—	[19]
15/2	26332.040	506 (2)	−45(5)	5067.409		85	13/2	6603.591	755.456	−48.633	[7]
				5345.561	f	62	13/2	7630.132	776.286	−43.592	[7]
				5691.075	e	36	15/2	8765.542	763.557	−45.805	[7]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
				5926.883	e	110	13/2	9464.440	1056 (1)	−15 (10)	[19]
				6222.781		9	13/2	10266.501	972 (2)	—	This work
				7390.274	nl	6	15/2	12804.468	732 (1)	—	This work
9/2	26337.481	810 (1)		4563.835	f	30	9/2	4432.225	923.2 (4)	−22(7)	[8]
				4656.148	f	8	11/2	4866.515	867.997	−50.319	[7]
				4873.218	f	20	9/2	5822.890	855.8 (4)	−17(7)	[8]
				4992.551		8	11/2	6313.224	756 (1)	—	This work
				5141.397	nl	14	11/2	6892.934	551.934	−24.736	[7]
				5340.384	nl	8	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				5801.393	nl	7	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				5931.678		13	11/2	9483.518	731 (1)	−15 (10)	[19]
				7736.76	nl, e	1	7/2	13415.739	797 (2)	—	This work
				7842.72	nl, e	1	7/2	13590.311	1151 (2)	—	[19]
				7852.18	nl, e	1	9/2	13605.665	681 (2)	—	This work
				7928.03	nl, e	1	11/2	13727.482	949 (1)	−30 (20)	[19]
				7935.73	nl, e	1	7/2	13739.706	1128 (1)	—	[19]
7/2	26371.971	997 (3)		4556.661	nl	6	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				5039.832	f	45	7/2	6535.572	979 (1)	25 (30)	[19]
				5330.562	f	40	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				5445.441	nl, f	1	7/2	8013.089	168 (1)	—	This work
				6242.330	nl	12	9/2	10356.737	1406 (1)	—	This work
				6549.43	nl, e	1	5/2	11107.696	658 (2)	—	This work
				6582.51	nl, e	1	9/2	11184.396	692 (1)	15 (30)	This work
				7217.048	nl	10	9/2	12519.705	693 (3)	—	[19]
9/2	26718.738	826 (2)		4574.911	nl	16	11/2	4866.515	867.997	−50.319	[7]
				4784.302		25	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4899.268		20	11/2	6313.224	756 (1)	—	This work
				4997.468	f	15	11/2	6714.184	474.692	−29.633	[7]
				5042.526		60	11/2	6892.934	551.934	−24.736	[7]
				5433.716	nl	14	9/2	8320.240	255 (2)	—	[19]
				5729.066	nl, e	6	11/2	9268.726	977 (1)	−24 (20)	[19]
				5800.466	nl	15	11/2	9483.518	731 (1)	−15 (10)	[19]
				5875.89	nl, e	1	7/2	9704.744	779 (1)	−50 (30)	[19]
				5950.538	nl	13	7/2	9918.190	1057.4 (5)	22 (6)	[8]
7/2	27096.093	918 (3)		4862.332	nl, e	12	7/2	6535.572	979 (1)	25 (30)	[19]
				5132.395	f	55	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				5238.807	f	35	7/2	8013.089	168 (1)	—	This work
				6470.79	nl, e	1	5/2	11646.312	1317 (10)	—	[19]
				6498.944	nl, e	15	9/2	11713.236	818 (2)	—	[19]
				6652.28	nl, e	1	9/2	12067.802	873 (6)	—	[19]
15/2	27294.906	790 (5)		5280.870	f	110	15/2	8363.901	763.306	−48.253	[7]
				5395.339	nl	12	15/2	8765.542	763.557	−45.805	[7]
				5606.822		42	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5870.913		140	13/2	10266.501	972 (2)	—	This work
				5925.599		44	13/2	10423.654	869 (1)	25 (30)	This work
				5942.039	nl	5	13/2	10470.329	628 (3)	—	[19]
				6314.57	nl, e	1	13/2	11462.895	804 (1)	—	This work
				6322.77	nl, e	1	15/2	11483.427	987 (1)	—	This work
				7709.96	nl, e	1	13/2	14328.241	620 (2)	30 (30)	[19]
				9052.188		8	13/2	16250.885	892 (1)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
9/2	27394.138	792 (3)		4634.502	nl	4	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4742.301	f	55	11/2	6313.224	756 (1)	—	This work
				4792.854	f	24	7/2	6535.572	979 (1)	25 (30)	[19]
				4834.250	f	12	11/2	6714.184	474.692	−29.633	[7]
				5162.555	nl	11	9/2	8029.275	797 (2)	—	[19]
				5331.761		40	9/2	8643.824	797 (2)	—	[19]
				6068.572		12	9/2	10920.365	632 (2)	—	[19]
				6470.73	nl, e	1	11/2	11944.207	1003 (1)	—	This work
				6522.91	nl, e	1	9/2	12067.802	873 (6)	—	[19]
9/2	27745.272	862 (2)		4288.237	nl	11	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4664.604	nl, f	1	11/2	6313.224	756 (1)	—	This work
				4753.538	nl, f	5	11/2	6714.184	474.692	−29.633	[7]
				4794.287	f	7	11/2	6892.934	551.934	−24.736	[7]
				5233.749		18	9/2	8643.824	797 (2)	—	[19]
				5363.244	nl, f	7	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				5474.405		27	11/2	9483.518	731 (1)	−15 (10)	[19]
				5696.259	e	18	7/2	10194.768	855 (1)	—	[19]
				5749.322	e	25	9/2	10356.737	1406 (1)	—	This work
				6218.547	nl	8	7/2	11668.794	805 (2)	—	[19]
				6235.786	nl	5	9/2	11713.236	818 (2)	—	[19]
17/2	27844.889	602 (2)	−40 (50)	5131.780	nl	7	15/2	8363.901	763.306	−48.253	[7]
				5239.809	f	30	15/2	8765.542	763.557	−45.805	[7]
				5752.739	e	75	15/2	10466.689	1042 (2)	−20 (30)	This work
				5774.425	e	185	17/2	10531.951	546 (3)	—	[19]
				6617.063	nl	4	17/2	12736.621	904 (1)	20 (20)	This work
				6939.693		5	15/2	13439.009	916 (3)	—	[19]
				7235.894	nl	3	17/2	14028.707	357 (2)	—	[19]
				7338.171	nl	4	15/2	14221.272	345 (1)	−25 (20)	[19]
15/2	27950.530	824 (1)		4683.201	nl	4	13/2	6603.591	755.456	−48.633	[7]
				5104.101		35	15/2	8363.901	763.306	−48.253	[7]
				5210.956	f	130	15/2	8765.542	763.557	−45.805	[7]
				5407.968	f	45	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5491.426	nl, f	25	15/2	9745.376	540 (2)	—	[4]
				5703.941	nl, e	12	13/2	10423.654	869 (1)	25 (30)	This work
				5739.40	nl, e	1	17/2	10531.951	546 (3)	—	[19]
				6063.467	f	22	13/2	11462.895	804 (1)	—	This work
				6100.423	f	30	13/2	11562.762	819 (2)	—	This work
				6314.38	nl, e	1	13/2	12118.039	554 (1)	−45 (30)	This work
				6367.664	e	3	15/2	12250.519	608 (1)	—	This work
7/2	28204.331	781 (5)		4205.426	nl, f	8	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4466.734	nl, f	9	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4595.880	nl, f	1	5/2	6451.808	1189 (6)	−5 (5)	[8]
				4955.233	f	12	9/2	8029.275	797 (2)	—	[19]
				5110.917	nl, f	1	9/2	8643.824	797 (2)	—	[19]
				5135.527	nl, f	8	5/2	8737.556	1149 (5)	—	[19]
				5405.734	nl	8	5/2	9710.600	164 (2)	—	[19]
				6467.24	nl, e	1	9/2	12746.067	982 (1)	10 (10)	This work
				6535.31	nl, e	1	5/2	12907.057	1336 (4)	—	This work
				6630.96	nl, e	1	5/2	13127.722	156 (1)	0 (10)	[19]
				7764.48	nl, e	1	5/2	15328.721	976 (3)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
7/2	28339.709	798 (2)		4181.612	nl	11	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4567.454	nl	4	5/2	6451.808	1189 (6)	−5 (5)	[8]
				4918.284	nl, f	1	7/2	8013.089	168 (1)	—	This work
				5364.764	nl	9	7/2	9704.744	779 (1)	−50 (30)	[19]
				5709.230	nl, e	12	5/2	10829.070	980 (1)	−15 (15)	[19]
				5739.15	nl, e	1	9/2	10920.365	632 (2)	—	[19]
				5801.542	nl	15	5/2	11107.696	658 (2)	—	This work
				5996.809	nl, e	5	7/2	11668.794	805 (2)	—	[19]
				6319.363	nl	7	9/2	12519.705	693 (3)	—	[19]
13/2	28487.636	672 (2)		4232.307	nl	10	11/2	4866.515	867.997	−50.319	[7]
				4508.438	nl	12	11/2	6313.224	756 (1)	—	This work
				4568.259	nl	4	13/2	6603.591	755.456	−48.633	[7]
				4793.097		4	13/2	7630.132	776.286	−43.592	[7]
				4967.870	f	60	15/2	8363.901	763.306	−48.253	[7]
				5201.762	f	30	11/2	9268.726	977 (1)	−24 (20)	[19]
				5255.278	f	25	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5260.554		18	11/2	9483.518	731 (1)	−15 (10)	[19]
				5685.54	nl, e	1	11/2	10904.034	301 (1)	−20 (10)	This work
				5810.730	nl, e	10	11/2	11282.865	1049 (2)	—	This work
				6315.68	nl, e	1	11/2	12658.401	995 (5)	—	This work
				6561.17	nl, e	1	11/2	13250.662	424 (2)	—	[19]
7/2	28525.358	843 (2)		4403.570	nl, f	9	9/2	5822.890	855.8(4)	−17 (7)	[8]
				4529.039	nl	8	5/2	6451.808	1189 (6)	−5 (5)	[8]
				4546.291	nl	4	7/2	6535.572	979 (1)	25 (30)	[19]
				4781.539		10	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				4873.768	nl	3	7/2	8013.089	168 (1)	—	This work
				4877.62	nl, f	1	9/2	8029.275	797 (2)	—	[19]
				5028.391	nl	10	9/2	8643.824	797 (2)	—	[19]
				5311.844	nl	7	7/2	9704.744	779 (1)	−50 (30)	[19]
				5453.846	f	27	7/2	10194.768	855 (1)	—	[19]
				5739.705	nl, e	5	5/2	11107.696	658 (2)	—	This work
				5765.09	nl, e	1	9/2	11184.396	692 (1)	15 (30)	This work
				5795.12	nl, e	1	7/2	11274.229	1286 (1)	−10 (20)	This work
9/2	28579.596	765 (2)		4934.613	nl, f	1	9/2	8320.240	255 (2)	—	[19]
				5014.710	nl, f	10	9/2	8643.824	797 (2)	—	[19]
				5061.743	f	22	11/2	8829.063	769 (1)	−30 (20)	This work
				5176.989	nl	6	11/2	9268.726	977 (1)	−24 (20)	[19]
				5288.254	nl	5	11/2	9675.029	683 (1)	—	[19]
				5486.089	nl, f	8	9/2	10356.737	1406 (1)	—	This work
				5661.189	nl, e	2	9/2	10920.365	632 (2)	—	[19]
				5747.116	nl, e	15	9/2	11184.396	692 (1)	15 (30)	This work
				5911.742	nl	15	7/2	11668.794	805 (2)	—	[19]
				5927.318		10	9/2	11713.236	818 (2)	—	[19]
				6047.884		18	7/2	12049.465	871 (2)	−10 (50)	[19]
				6276.511	nl	6	9/2	12651.586	723 (3)	—	[19]
				6755.704		5	7/2	13781.374	807 (1)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
15/2	28754.446	639 (2)		4513.233	nl	5	13/2	6603.591	755.456	−48.633	[7]
				4805.628		4	13/2	7951.323	644 (1)	−30 (20)	[19]
				5182.588		30	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5266.081		20	17/2	9770.273	905.498	−40.819	[7]
				5407.426	nl	8	13/2	10266.501	972 (2)	—	This work
				5453.786		22	13/2	10423.654	869 (1)	25 (30)	This work
				5466.620	nl, f	25	15/2	10466.689	1042 (2)	−20 (30)	This work
				5467.709		24	13/2	10470.329	628 (3)	—	[19]
				5781.568	nl, e	10	13/2	11462.895	804 (1)	—	This work
				5788.44	nl, e	1	15/2	11483.427	987 (1)	—	This work
				7638.106	nl	3	17/2	15665.796	906 (1)	—	[19]
5/2	28800.063	1057 (2)		5220.453	f	60	3/2	9649.970	1555 (3)	—	[19]
				5294.612	nl	12	7/2	9918.190	1057.4 (5)	22 (6)	[8]
				5704.28	nl, e	1	7/2	11274.229	1286 (1)	−10 (20)	This work
				5769.52	nl, e	1	7/2	11472.410	273 (3)	—	[19]
13/2	28851.007	584 (2)		4783.424		25	13/2	7951.323	644 (1)	−30 (20)	[19]
				5213.404		100	11/2	9675.029	683 (1)	—	[19]
				5232.600		22	15/2	9745.376	540 (2)	—	[4]
				5379.327	nl	6	13/2	10266.501	972 (2)	—	This work
				5425.204	nl	18	13/2	10423.654	869 (1)	25 (30)	This work
				5437.904	nl, f	4	15/2	10466.689	1042 (2)	−20 (30)	This work
				5690.540	nl, e	32	11/2	11282.865	1049 (2)	—	This work
				5749.46	nl, e	1	13/2	11462.895	804 (1)	—	This work
				5756.26	nl, e	1	15/2	11483.427	987 (1)	—	This work
				8062.490		6	15/2	16451.306	1037 (3)	—	[19]
7/2	28859.879	538 (2)		4339.625	nl, f	6	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4706.240	nl, f	1	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				4799.287	nl, f	2	9/2	8029.275	797 (2)	—	[19]
				5060.635	f	15	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				5219.079	nl, f	1	7/2	9704.744	779 (1)	−50 (30)	[19]
				5277.892	nl, f	7	7/2	9918.190	1057.4 (5)	22 (6)	[8]
				5749.67	nl, e	1	7/2	11472.410	273 (3)	—	[19]
				5807.763	nl, e	10	5/2	11646.312	1317 (10)	—	[19]
5/2	28920.891	1012 (3)		4465.960	nl, f	9	7/2	6535.572	979 (1)	25 (30)	[19]
				5204.093		15	5/2	9710.600	164 (2)	—	[19]
				5665.220	nl, e	5	7/2	11274.229	1286 (1)	−10 (20)	This work
				5693.46	nl, e	1	3/2	11361.762	54 (3)	—	[19]
				7415.517	nl, e	3	7/2	15439.372	855 (3)	—	[19]
13/2	28921.386	697 (2)		4959.956	f	8	15/2	8765.542	763.557	−45.805	[7]
				5143.164	nl	10	11/2	9483.518	731 (1)	−15(10)	[19]
				5418.237	nl	5	13/2	10470.329	628 (3)	—	[19]
				5548.664	nl	5	11/2	10904.034	301 (1)	−20 (10)	This work
				5667.837	nl, e	5	11/2	11282.865	1049 (2)	—	This work
				5726.28	nl, e	1	13/2	11462.895	804 (1)	—	This work
				5733.026	nl, e	10	15/2	11483.427	987 (1)	—	This work
7/2	28978.464	1047 (3)		4072.794		10	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4437.939		6	5/2	6451.808	1189 (6)	−5 (5)	[8]
				4768.436	nl	1	7/2	8013.089	168 (1)	—	This work
				4839.335	f	35	9/2	8320.240	255 (2)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
				5736.02	nl, e	1	9/2	11549.602	1064 (2)	—	This work
				5768.02	nl, e	1	5/2	11646.312	1317 (10)	—	[19]
				7477.73	nl, e	1	5/2	15609.100	1148 (3)	—	[19]
5/2	29075.845	829 (2)		4435.258	f	8	7/2	6535.572	979 (1)	25 (30)	[19]
				5160.890	nl	5	7/2	9704.744	779 (1)	−50 (30)	[19]
				5294.835	nl	5	7/2	10194.768	855 (1)	—	[19]
				5743.208	e	18	7/2	11668.794	805 (2)	—	[19]
				5810.13	nl, e	1	7/2	11869.290	210 (1)	—	[19]
				5871.61	nl, e	1	7/2	12049.465	871 (2)	−10 (50)	[19]
15/2	29094.822	634 (2)		4728.263	f	16	13/2	7951.323	644 (1)	−30 (20)	[19]
				4917.638	nl	5	15/2	8765.542	763.557	−45.805	[7]
				5366.732		33	15/2	10466.689	1042 (2)	−20 (30)	This work
				5367.781	nl	9	13/2	10470.329	628 (3)	—	[19]
				5669.96	nl, e	1	13/2	11462.895	804 (1)	—	This work
				5702.23	nl, e	1	13/2	11562.762	819 (2)	—	This work
				5751.989	nl, e	12	17/2	11714.352	970 (1)	−15 (10)	This work
				5935.079		18	15/2	12250.519	608 (1)	—	This work
				6111.447	nl	4	17/2	12736.621	904 (1)	20 (20)	This work
				6136.902		11	15/2	12804.468	732 (1)	—	This work
9/2	29149.204	730 (1)		4116.998	nl, f	2	11/2	4866.515	867.997	−50.319	[7]
				4285.798	nl	1	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4377.825	nl, e	8	11/2	6313.224	756 (1)	—	This work
				4643.001	nl	8	7/2	7617.440	866.9 (5)	−4(5)	[8]
				4875.407	nl, f	1	9/2	8643.824	797 (2)	—	[19]
				4919.852	nl, f	18	11/2	8829.063	769 (1)	−30 (20)	This work
				4987.587	nl	1	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				5028.688	nl, f	1	11/2	9268.726	977 (1)	−24 (20)	[19]
				5083.612	nl	1	11/2	9483.518	731 (1)	−15 (10)	[19]
				5133.577	nl	19	11/2	9675.029	683 (1)	—	[19]
				5785.463	nl, e	10	7/2	11869.290	210 (1)	—	[19]
				5810.65	nl, e	1	11/2	11944.207	1003 (1)	—	This work
3/2	29190.205	553 (1)		4396.612	nl, f	1	5/2	6451.808	1189 (6)	−5 (5)	[8]
				4887.976	e	3	5/2	8737.556	1149 (5)	—	[19]
				5116.221	nl, f	1	3/2	9649.970	1555 (3)	—	[19]
				5132.144	nl, f	5	5/2	9710.600	164 (2)	—	[19]
				5444.773	nl, f	15	5/2	10829.070	980 (1)	−15 (15)	[19]
				5528.670	nl, f	1	5/2	11107.696	658 (2)	—	This work
				5607.458	nl, f	1	3/2	11361.762	54 (3)	—	[19]
				5698.408	nl, e	6	5/2	11646.312	1317 (10)	—	[19]
				5833.12	nl, e	1	3/2	12051.488	1071 (3)	10 (20)	This work
				6350.60	e	1	5/2	13448.016	825 (1)	25 (30)	This work
				6468.65	nl, e	1	5/2	13735.298	775 (3)	5 (20)	[19]
				6518.00	nl, e	1	1/2	13852.32	1218 (8)	0	This work
11/2	29195.032	805 (2)		4705.959	f	15	13/2	7951.323	644 (1)	−30 (20)	[19]
				5581.246	nl, f	11	11/2	11282.865	1049 (2)	—	This work
				5718.648	nl, e	14	9/2	11713.236	818 (2)	—	[19]
				5795.22	nl, e	1	11/2	11944.207	1003 (1)	—	This work
				5894.447	e	15	11/2	12234.616	1169 (2)	—	[19]
				7826.958	nl	4	13/2	16422.190	960 (3)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
7/2	29579.960	720 (2)		4338.231	f	6	7/2	6535.572	979 (1)	25 (30)	[19]
				4882.665	e	4	9/2	9105.021	689.7 (3)	−3 (5)	[8]
				5029.989		20	7/2	9704.744	779 (1)	−50 (30)	[19]
				5702.76	nl, e	1	7/2	12049.465	871 (2)	−10 (50)	[19]
				5792.82	nl, e	1	7/2	12321.991	871 (3)	—	[19]
11/2	29614.075	900 (5)		4344.622	nl	5	13/2	6603.591	755.456	−48.633	[7]
				4365.606	nl, f	1	11/2	6714.184	474.692	−29.633	[7]
				4614.926	nl, f	17	13/2	7951.323	644 (1)	−30 (20)	[19]
				4694.881	nl, f	1	9/2	8320.240	255 (2)	—	[19]
				4966.186	nl, f	1	11/2	9483.518	731 (1)	−15 (10)	[19]
				5167.167	nl	5	13/2	10266.501	972 (2)	—	This work
				5538.225	nl	5	13/2	11562.762	819 (2)	—	This work
				5697.63	nl, e	1	9/2	12067.802	873 (6)	—	[19]
				5714.00	nl, e	1	13/2	12118.039	554 (1)	−45 (30)	This work
17/2	29622.951	501 (1)	15 (20)	5029.391		20	15/2	9745.376	540 (2)	—	[4]
				5035.700	nl, f	8	17/2	9770.273	905.498	−40.819	[7]
				5218.772	nl, f	1	15/2	10466.689	1042 (2)	−20 (30)	This work
				5236.613	f	65	17/2	10531.951	546 (3)	—	[19]
				5412.236	nl, f	8	19/2	11151.433	876.1 (3)	−31(12)	[8]
				5511.292	nl, f	1	15/2	11483.427	987 (1)	—	This work
				5582.361	nl	50	17/2	11714.352	970 (1)	−15 (10)	This work
				5754.650	e	75	15/2	12250.519	608 (1)	—	This work
				5920.309	e	30	17/2	12736.621	904 (1)	20 (20)	This work
				6177.255	nl, f	1	15/2	13439.009	916 (3)	—	[19]
				6410.850	nl, f	1	17/2	14028.707	357 (2)	—	[19]
				6525.580	nl, f	1	17/2	14302.875	775 (3)	—	[19]
				6735.772	nl, f	1	15/2	14780.940	912 (3)	—	[19]
				6804.052	nl, f	6	15/2	14929.886	646 (3)	—	[19]
				7256.122	f	6	19/2	15845.280	185 (2)	—	[19]
				9027.313	nl	4	15/2	18548.497	573 (5)	—	[4]
13/2	29663.117	651 (3)		4693.694	f	8	15/2	8363.901	763.306	−48.253	[7]
				4783.907		4	15/2	8765.542	763.557	−45.805	[7]
				4901.942	nl	2	11/2	9268.726	977 (1)	−24 (20)	[19]
				4949.436		2	13/2	9464.440	1056 (1)	−15 (10)	[19]
				4954.177	nl, f	1	11/2	9483.518	731 (1)	−15 (10)	[19]
				5001.586		4	11/2	9675.029	683 (1)	—	[19]
				5019.251		65	15/2	9745.376	540 (2)	—	[4]
				5196.203		17	13/2	10423.654	869 (1)	25 (30)	This work
				5208.841	nl	13	13/2	10470.329	628 (3)	—	[19]
				5329.268	nl, f	1	11/2	10904.034	301 (1)	−20 (10)	This work
				5698.02	nl, e	1	13/2	12118.039	554 (1)	−45 (30)	This work
				5736.137	e	14	11/2	12234.616	1169 (2)	—	[19]
				6244.930	nl	7	13/2	13654.555	501 (1)	20 (20)	[19]
7/2	29675.405	865 (1)		4320.337		14	7/2	6535.572	979 (1)	25 (30)	[19]
				5005.949	f	8	7/2	9704.744	779 (1)	−50 (30)	[19]
				5330.417	nl	9	9/2	10920.365	632 (2)	—	[19]
				5671.88	nl, e	1	7/2	12049.465	871 (2)	−10 (50)	[19]
				5681.28	nl, e	1	5/2	12078.621	1566 (1)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
13/2	29774.999	615 (2)		4580.896	nl	7	13/2	7951.323	644 (1)	−30 (20)	[19]
				4758.430	f	10	15/2	8765.542	763.557	−45.805	[7]
				4973.743	nl, e	4	11/2	9675.029	683 (1)	—	[19]
				4991.212		15	15/2	9745.376	540 (2)	—	[4]
				5177.675		15	15/2	10466.689	1042 (2)	−20 (30)	This work
				5178.652	nl	15	13/2	10470.329	628 (3)	—	[19]
				5661.92	nl, e	1	13/2	12118.039	554 (1)	−45 (30)	This work
				5681.90	nl, e	1	11/2	12180.131	679 (3)	—	[19]
				5704.72	nl, e	1	15/2	12250.519	608 (1)	—	This work
3/2	29804.574	1115 (4)		5347.001	f	15	5/2	11107.696	658 (2)	—	This work
				5420.660	nl, f	1	3/2	11361.762	54 (3)	—	[19]
				5699.767	nl	9	1/2	12264.864	1534 (2)	—	[19]
				5916.390	nl, e	1	5/2	12907.057	1336 (4)	—	This work
				8035.00	nl, e	1	5/2	17362.452	451 (3)		[19]
13/2	29836.950	535 (2)		5388.150	nl, f	10	11/2	11282.865	1049 (2)	—	This work
				5617.903	nl	1	13/2	12041.655	1049 (2)	—	This work
				5642.124	nl	10	13/2	12118.039	554 (1)	−45 (30)	This work
				5679.492	e	10	11/2	12234.616	1169 (2)	—	[19]
				5684.625	nl, e	6	15/2	12250.519	608 (1)	—	This work
				6446.205	nl	3	13/2	14328.241	620 (2)	30 (30)	[19]
17/2	29899.954	529 (1)		5161.717	f	280	17/2	10531.951	546 (3)	—	[19]
				5332.271	nl, f	1	19/2	11151.433	876.1 (3)	−31 (12)	[8]
				5428.396	nl, f	9	15/2	11483.427	987 (1)	—	This work
				5497.328	nl, f	18	17/2	11714.352	970 (1)	−15 (10)	This work
				5664.331	e	75	15/2	12250.519	608 (1)	—	This work
				5847.876	e	10	15/2	12804.468	732 (1)	—	This work
				6143.342	f	7	19/2	13626.672	865 (3)	—	[19]
15/2	29942.851	583 (2)		4632.848	nl	1	15/2	8363.901	763.306	−48.253	[7]
				4949.732	f	10	15/2	9745.376	540 (2)	—	[4]
				5134.011	f	95	13/2	10470.329	628 (3)	—	[19]
				5150.310	f	105	17/2	10531.951	546 (3)	—	[19]
				5439.158	nl, f	1	13/2	11562.762	819 (2)	—	This work
				5484.391	nl, f	1	17/2	11714.352	970 (1)	−15 (10)	This work
				5584.666	nl, f	5	13/2	12041.655	1049 (2)	—	This work
				5608.601	nl, f	15	13/2	12118.039	554 (1)	−45 (30)	This work
				5650.598	nl, e	10	15/2	12250.519	608 (1)	—	This work
				5810.239	nl, e	7	17/2	12736.621	904 (1)	20 (20)	This work
				5833.24	nl, e	1	15/2	12804.468	732 (1)	—	This work
				6057.517	f	19	15/2	13439.009	916 (3)	—	[19]
				6067.944	nl	10	13/2	13467.373	599 (1)	—	[19]
				6305.292	nl	21	13/2	14087.545	657 (3)	—	[19]
19/2	29950.715	418 (2)		5482.025	f	85	17/2	11714.352	970 (1)	−15 (10)	This work
				5783.441	e	11	21/2	12664.765	825 (2)	—	[19]
				5807.582	e	12	17/2	12736.621	904 (1)	20 (20)	This work
				6278.876	e	11	17/2	14028.707	357 (2)	—	[19]
				6388.890		8	17/2	14302.875	775 (3)	—	[19]
				8640.361	nl	3	17/2	18380.305	903 (3)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
11/2	29985.372	775 (2)		4471.969	nl	2	13/2	7630.132	776.286	−43.592	[7]
				4537.158	nl	10	13/2	7951.323	644 (1)	−30 (20)	[19]
				4876.245	nl	5	11/2	9483.518	731 (1)	−15 (10)	[19]
				5069.870	f	18	13/2	10266.501	972 (2)	—	This work
				5222.124	nl, f	1	11/2	10841.407	530 (3)	—	[19]
				5239.264	f	25	11/2	10904.034	301 (1)	−20 (10)	This work
				5799.086	e	12	9/2	12746.067	982 (1)	10 (10)	This work
				7848.97	nl, e	1	13/2	17248.351	775 (3)	—	[19]
15/2	29989.064	528 (2)		4274.956	nl	13	13/2	6603.591	755.456	−48.633	[7]
				5120.900		12	15/2	10466.689	1042 (2)	−20 (30)	This work
				5121.857		20	13/2	10470.329	628 (3)	—	[19]
				5396.267		10	13/2	11462.895	804 (1)	—	This work
				5570.287	f	38	13/2	12041.655	1049 (2)	—	This work
				5635.875		36	15/2	12250.519	608 (1)	—	This work
				5794.67	nl, e	1	17/2	12736.621	904 (1)	20 (20)	This work
				5817.55	nl, e	1	15/2	12804.468	732 (1)	—	This work
				6383.593		20	13/2	14328.241	620 (2)	30 (30)	[19]
9/2	30035.792	884 (2)		4214.208	nl	29	11/2	6313.224	756 (1)	—	This work
				4254.083	nl	4	7/2	6535.572	979 (1)	25 (30)	[19]
				4319.77	nl, e	1	11/2	6892.934	551.934	−24.736	[7]
				4459.377	nl, f	1	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				4813.971	nl, f	1	11/2	9268.726	977 (1)	−24 (20)	[19]
				4917.212	nl, f	1	7/2	9704.744	779 (1)	−50 (30)	[19]
				5331.018	nl, f	1	11/2	11282.865	1049 (2)	—	This work
				5456.237	nl, f	5	9/2	11713.236	818 (2)	—	[19]
				5707.45	nl, e	1	9/2	12519.705	693 (3)	—	[19]
				5739.56	nl, e	1	7/2	12617.700	883 (2)	—	[19]
11/2	30053.346	759 (1)		4211.092	nl	16	11/2	6313.224	756 (1)	—	This work
				4523.203	nl	22	13/2	7951.323	644 (1)	−30 (20)	[19]
				4855.627	e	6	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5052.454	nl, f	1	13/2	10266.501	972 (2)	—	This work
				5220.665	nl, f	14	11/2	10904.034	301 (1)	−20 (10)	This work
				5451.014	nl	11	9/2	11713.236	818 (2)	—	[19]
				5701.741	e	20	9/2	12519.705	693 (3)	—	[19]
				5747.20	nl, e	1	11/2	12658.401	995 (5)	—	This work
				5949.782	nl, f	1	11/2	13250.662	424 (2)	—	[19]
11/2	30094.834	825 (2)		3895.616	nl	20	9/2	4432.225	923.2 (4)	−22 (7)	[8]
				4255.709	nl	6	13/2	6603.591	755.456	−48.633	[7]
				5082.164		10	13/2	10423.654	869 (1)	25 (30)	This work
				5314.286	nl, f	1	11/2	11282.865	1049 (2)	—	This work
				5394.551	nl, f	1	13/2	11562.762	819 (2)	—	This work
				5733.53	nl, e	1	11/2	12658.401	995 (5)	—	This work
				5762.500	nl, e	9	9/2	12746.067	982 (1)	10 (10)	This work
11/2	30111.020	786 (2)		4252.777	nl, f	6	13/2	6603.591	755.456	−48.633	[7]
				4272.879	nl, f	3	11/2	6714.184	474.692	−29.633	[7]
				4305.776	nl, f	1	11/2	6892.934	551.934	−24.736	[7]
				4511.432	nl, f	1	13/2	7951.323	644 (1)	−30 (20)	[19]
				5077.984	nl	8	13/2	10423.654	869 (1)	25 (30)	This work
				5090.053	nl	5	13/2	10470.329	628 (3)	—	[19]
				5309.716	nl	9	11/2	11282.865	1049 (2)	—	This work

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
				5728.21	nl, e	1	11/2	12658.401	995 (5)	—	This work
				5757.13	nl, e	1	9/2	12746.067	982 (1)	10 (10)	This work
13/2	30284.567	681 (2)		4273.830	nl, f	1	11/2	6892.934	551.934	−24.736	[7]
				4476.374	nl, f	1	13/2	7951.323	644 (1)	−30 (20)	[19]
				4756.985	nl, f	1	11/2	9268.726	977 (1)	−24 (20)	[19]
				4850.767	e	6	11/2	9675.029	683 (1)	—	[19]
				4867.379	f	12	15/2	9745.376	540 (2)	—	[4]
				4994.092	nl, f	4	13/2	10266.501	972 (2)	—	This work
				5317.344	nl, f	15	15/2	11483.427	987 (1)	—	This work
				5450.940	nl, f	1	11/2	11944.207	1003 (1)	—	This work
				5480.058	nl, f	1	13/2	12041.655	1049 (2)	—	This work
				5538.643	nl, f	1	11/2	12234.616	1169 (2)	—	[19]
				5671.81	nl, e	1	11/2	12658.401	995 (5)	—	This work
				5719.21	nl, e	1	15/2	12804.468	732 (1)	—	This work
				5833.38	nl, e	1	13/2	13146.584	1070 (1)	45 (20)	This work
5/2	30304.145	818 (2)		4484.846	nl, f	1	7/2	8013.089	168 (1)	—	This work
				4854.534	nl, e	4	5/2	9710.600	164 (2)	—	[19]
				5277.699	nl, f	5	3/2	11361.762	54 (3)	—	[19]
				5477.134	nl, f	8	3/2	12051.488	1071 (3)	10 (20)	This work
				5661.86	nl, e	1	5/2	12646.996	892 (2)	—	This work
				5746.49	nl, e	1	5/2	12907.057	1336 (4)	—	This work
				5788.492	nl	7	3/2	13033.280	905 (4)	—	This work
				5919.58	nl, e	1	7/2	13415.739	797 (2)	—	This work
17/2	30346.200	518 (1)		4852.82	nl, e	3	15/2	9745.376	540 (2)	—	[4]
				5208.303		25	19/2	11151.433	876.1 (3)	−31 (12)	[8]
				5677.152	nl	10	17/2	12736.621	904 (1)	20 (20)	This work
				5699.110	e, f	27	15/2	12804.468	732 (1)	—	This work
				5913.005	nl, e, f	25	15/2	13439.009	916 (3)	—	[19]
11/2	30347.477	700 (3)		4791.616	nl	7	11/2	9483.518	731 (1)	−15 (10)	[19]
				4836.005	f	22	11/2	9675.029	683 (1)	—	[19]
				5029.500	f	20	13/2	10470.329	628 (3)	—	[19]
				5293.851	nl	6	13/2	11462.895	804 (1)	—	This work
				5679.79	nl, e	1	9/2	12746.067	982 (1)	10 (10)	This work
				6430.416	nl, e	3	11/2	14800.680	618 (2)	−30 (20)	[19]
				6470.81	nl, e	1	9/2	14897.721	722 (2)	—	This work
13/2	30412.010	658 (2)		4250.671	nl, f	1	11/2	6892.934	551.934	−24.736	[7]
				4772.488	nl, f	1	13/2	9464.440	1056 (1)	−15 (10)	[19]
				5012.309	f	10	15/2	10466.689	1042 (2)	−20 (30)	This work
				5281.546	nl, f	1	15/2	11483.427	987 (1)	—	This work
				5442.042	nl, f	5	13/2	12041.655	1049 (2)	—	This work
				5483.374	nl	1	11/2	12180.131	679 (3)	—	[19]
				5499.812	nl, f	10	11/2	12234.616	1169 (2)	—	[19]
				5753.37	nl, f	1	11/2	13035.697	796 (3)	—	This work
				5790.316	nl, e	1	13/2	13146.584	1070 (1)	45 (20)	This work
				5825.433	nl, e	7	11/2	13250.662	424 (2)	—	[19]
				5868.635	nl, e	10	11/2	13376.992	868 (2)	—	[19]
				5899.937	nl, f	1	13/2	13467.373	599 (1)	—	[19]
				6053.742	nl	5	13/2	13897.874	900 (3)	—	This work

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
21/2	30543.982	392 (2)		5155.184	nl, f	11	19/2	11151.433	876.1 (3)	−31 (12)	[8]
				5591.534	f	90	21/2	12664.765	825 (2)	—	[19]
				5909.466	e	35	19/2	13626.672	865 (3)	—	[19]
				6801.441	e	15	19/2	15845.280	185 (2)	—	[19]
13/2	30562.652	537 (1)		4742.700	f	6	11/2	9483.518	731 (1)	−15 (10)	[19]
				4925.667	nl, f	1	13/2	10266.501	972 (2)	—	This work
				4964.105	f	6	13/2	10423.654	869 (1)	25 (30)	This work
				5185.335	f	16	11/2	11282.865	1049 (2)	—	This work
				5454.607	nl, f	10	11/2	12234.616	1169 (2)	—	[19]
				5703.92	nl, e	1	11/2	13035.697	796 (3)	—	This work
				5740.23	nl, e	1	13/2	13146.584	1070 (1)	45 (20)	This work
				5999.018	nl, f	1	13/2	13897.874	900 (3)	—	This work
13/2	30644.652	628 (2)		3878.157	nl	15	11/2	4866.515	867.997	−50.319	[7]
				4158.377	nl	5	13/2	6603.591	755.456	−48.633	[7]
				4343.862	nl	3	13/2	7630.132	776.286	−43.592	[7]
				4724.321	nl	4	11/2	9483.518	731 (1)	−15 (10)	[19]
				4943.974	nl, f	1	13/2	10423.654	869 (1)	25 (30)	This work
				4954.519	f	6	15/2	10466.689	1042 (2)	−20 (30)	This work
				4955.416		6	13/2	10470.329	628 (3)	—	[19]
				5713.331	nl	9	13/2	13146.584	1070 (1)	45(20)	This work
				5789.57	nl, e	5	11/2	13376.992	868 (2)	—	[19]
				5810.44	nl, e	1	15/2	13439.009	916 (3)	—	[19]
				5884.15	nl, e	1	13/2	13654.555	501 (1)	20 (20)	[19]
5/2	30679.627	933 (2)		4766.274	f	8	7/2	9704.744	779 (1)	−50 (30)	[19]
				5107.932	nl	4	5/2	11107.696	658 (2)	—	This work
				5488.378	nl	6	3/2	12464.369	712 (4)	—	[19]
				5695.81	nl, e	1	5/2	13127.722	156 (1)	0 (10)	[19]
				5721.43	nl, e	1	3/2	13206.325	256 (2)	0 (15)	[19]
5/2	30763.323	981 (2)		4319.208	nl	7	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				4538.864	nl, f	1	5/2	8737.556	1149 (5)	—	[19]
				5303.009	nl	10	3/2	11911.350	920 (3)	—	[19]
				5342.725	nl	12	3/2	12051.488	1071 (3)	10 (20)	This work
				5668.78	nl, e	1	5/2	13127.722	156 (1)	0 (10)	[19]
				5694.15	nl, e	1	3/2	13206.325	256 (2)	0 (15)	[19]
15/2	30788.090	528 (2)		4919.547	nl, f	1	15/2	10466.689	1042 (2)	−20(30)	This work
				5762.395	e	6	15/2	13439.009	916 (3)	—	[19]
				5834.890	nl, e	7	13/2	13654.555	501 (1)	20 (20)	[19]
				7071.443	nl	4	15/2	16650.602	904 (1)	45 (20)	[19]
				7391.172	nl	5	15/2	17262.152	905 (3)	—	[19]
				7520.285	nl, e	5	17/2	17494.382	468 (3)	—	[19]
9/2	30896.170	733 (2)		3987.182	nl, f	7	9/2	5822.890	855.8 (4)	−17 (7)	[8]
				4371.907	nl, f	5	9/2	8029.275	797 (2)	—	[19]
				4492.645	nl, f	3	9/2	8643.824	797 (2)	—	[19]
				4622.460	nl, f	1	11/2	9268.726	977 (1)	−24 (20)	[19]
				5211.516	f	20	9/2	11713.236	818 (2)	—	[19]
				5781.92	nl, e	1	9/2	13605.665	681 (2)	—	This work
				5841.280	nl, e	6	7/2	13781.374	807 (1)	—	[19]
				5855.35	nl, e	1	9/2	13822.494	1050 (2)	—	

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
9/2	30901.231	730 (2)		4293.625	nl, e	1	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				4370.938	nl, f	9	9/2	8029.275	797 (2)	—	[19]
				4491.623	nl, f	4	9/2	8643.824	797 (2)	—	[19]
				4621.378	nl, f	1	11/2	9268.726	977 (1)	−24 (20)	[19]
				5210.141	nl, f	1	9/2	11713.236	818 (2)	—	[19]
				5273.622	nl, f	1	11/2	11944.207	1003 (1)	—	This work
				5308.229	nl, f	10	9/2	12067.802	873 (6)	—	[19]
				5780.229	nl, e	7	9/2	13605.665	681 (2)	—	This work
				5821.23	nl, e	1	11/2	13727.482	949 (1)	−30 (20)	[19]
				5839.55	nl, e	1	7/2	13781.374	807 (1)	—	[19]
7/2	30975.616	734 (2)		5031.837	nl, f	12	5/2	11107.696	658 (2)	—	This work
				5051.337	f	12	9/2	11184.396	692 (1)	15 (30)	This work
				5074.370	nl, f	1	7/2	11274.229	1286 (1)	−10 (20)	This work
				5172.051	nl	4	5/2	11646.312	1317 (10)	—	[19]
				5232.415	nl	6	7/2	11869.290	210 (1)	—	[19]
				5405.685	nl	8	5/2	12481.714	937 (1)	20 (20)	[19]
				5445.728	nl, f	1	7/2	12617.700	883 (2)	—	[19]
				5703.705	nl, e	6	5/2	13448.016	825 (1)	25 (30)	This work
				5755.47	nl, e	1	9/2	13605.665	681 (2)	—	This work
				5776.93	nl, e	1	5/2	13670.175	18 v	—	Be99v
				5843.45	nl, e	1	7/2	13867.177	740 (3)	—	This work
13/2	31005.761	586 (2)		3824.580	nl, f	2	11/2	4866.515	867.997	−50.319	[7]
				4096.840	nl, f	1	13/2	6603.591	755.456	−48.633	[7]
				4336.346	f	5	13/2	7951.323	644 (1)	−30 (20)	[19]
				4495.097	nl, f	3	15/2	8765.542	763.557	−45.805	[7]
				4645.053	nl	5	11/2	9483.518	731 (1)	−15 (10)	[19]
				4867.409	f	15	15/2	10466.689	1042 (2)	−20 (30)	This work
				4868.272	nl, f	1	13/2	10470.329	628 (3)	—	[19]
				5141.807	nl, f	1	13/2	11562.762	819 (2)	—	This work
				5292.972	f	45	13/2	12118.039	554 (1)	−45 (30)	This work
				5325.844	nl, f	5	11/2	12234.616	1169 (2)	—	[19]
				5563.265	nl, f	1	11/2	13035.697	796 (3)	—	This work
				5761.69	nl, e	1	13/2	13654.555	501 (1)	20 (20)	[19]
				5834.90	nl, e	5	11/2	13872.266	872 v	—	
15/2	31039.972	553 (1)		4091.104	f	25	13/2	6603.591	755.456	−48.633	[7]
				4694.712	nl	9	15/2	9745.376	540 (2)	—	[4]
				4860.176	f	25	13/2	10470.329	628 (3)	—	[19]
				4874.778		7	17/2	10531.951	546 (3)	—	[19]
				5320.654	nl	18	15/2	12250.519	608 (1)	—	This work
				5689.099	nl, e	20	13/2	13467.373	599 (1)	—	[19]
				5750.352	nl, e	7	13/2	13654.555	501 (1)	20 (20)	[19]
17/2	31270.847	512 (2)		4364.261	nl, f	1	15/2	8363.901	763.306	−48.253	[7]
				4442.150	nl, f	1	15/2	8765.542	763.557	−45.805	[7]
				4649.737	nl, f	1	17/2	9770.273	905.498	−40.819	[7]
				4820.511	f	5	17/2	10531.951	546(3)	—	[19]
				4968.937	f	12	19/2	11151.433	876.1 (3)	−31 (12)	[8]
				5413.742	nl	8	15/2	12804.468	732 (1)	—	This work
				5606.390	nl, f	1	15/2	13439.009	916 (3)	—	[19]
				5798.136	nl, e	30	17/2	14028.707	357 (2)	—	[19]
				5863.62	nl, e	1	15/2	14221.272	345 (1)	−25 (20)	[19]
				7256.759	nl	6	17/2	17494.382	468 (3)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
3/2	31343.998	1123 (2)		4422.278	nl, f	4	5/2	8737.556	1149 (5)	—	[19]
				4621.188	nl, f	1	5/2	9710.600	164 (2)	—	[19]
				5075.323	nl, f	1	5/2	11646.312	1317 (10)	—	[19]
				5181.915	nl, f	1	3/2	12051.488	1071 (3)	10 (20)	This work
				5239.869	nl, f	1	1/2	12264.864	1534 (2)	—	[19]
				5715.42	nl, e	1	1/2	13852.32	1218 (8)	0	This work
				5752.43	nl, e	1	5/2	13964.855	564 (5)	90 (50)	[19]
				5833.47	nl, e	1	3/2	14206.294	184 (2)	—	[HH]
				6056.019	nl	6	5/2	14836.072	1340 (3)	—	[19]
9/2	31447.902	665 (2)		4591.588	nl	3	11/2	9675.029	683 (1)	—	[19]
				4866.273	f	4	11/2	10904.034	301 (1)	−20 (10)	This work
				4933.601	nl	4	9/2	11184.396	692 (1)	15 (30)	This work
				5428.768	nl	7	7/2	13032.634	893 (3)	—	[19]
				5544.107	nl	6	7/2	13415.739	797 (2)	—	This work
				5744.87	nl, e	1	7/2	14045.878	463 (2)	—	This work
				5791.62	nl, e	1	9/2	14186.352	910 (1)	−60 (30)	[19]
				5887.789	e	5	9/2	14468.303	762 (2)	20 (20)	[19]
9/2	31528.624	746 (2)		4180.965	nl	10	7/2	7617.440	866.9 (5)	−4 (5)	[8]
				5045.179	nl	7	9/2	11713.236	818 (2)	—	[19]
				5405.078	nl	11	7/2	13032.634	893 (3)	—	[19]
				5531.149	nl, f	1	7/2	13454.218	432 (5)	—	[19]
				5789.76	nl, e	1	9/2	14261.524	825 (1)	−30 (20)	[19]
				5793.565	e	13	9/2	14272.877	731 (3)	—	This work
7/2	31668.068	852 (2)		4229.144	nl	4	9/2	8029.275	797 (2)	—	[19]
				4342.026	nl	4	9/2	8643.824	797 (2)	—	[19]
				4969.170	nl, f	1	9/2	11549.602	1064 (2)	—	This work
				4993.174	nl, f	1	5/2	11646.312	1317 (10)	—	[19]
				5100.550	nl, f	1	9/2	12067.802	873 (6)	—	[19]
				5673.09	nl, e	1	7/2	14045.878	463 (2)	—	This work
				5747.12	nl, e	1	9/2	14272.877	731 (3)	—	This work
15/2	31668.549	544 (2)		4729.807		7	17/2	10531.951	546 (3)	—	[19]
				5625.687	f	30	13/2	13897.874	900 (3)	—	This work
				5729.96	nl, e	1	15/2	14221.272	345 (1)	−25 (20)	[19]
				5919.86	nl, e	1	15/2	14780.940	912 (3)	—	[19]
15/2	31817.886	437 (2)		4911.429	nl, f	1	13/2	11462.895	804 (1)	—	This work
				4916.388	nl, f	1	15/2	11483.427	987 (1)	—	This work
				4972.862		8	17/2	11714.352	970 (1)	−15 (10)	This work
				5354.323		32	13/2	13146.584	1070 (1)	45 (20)	This work
				5447.928	nl	4	13/2	13467.373	599 (1)	—	[19]
				5716.08	nl, e	1	13/2	14328.241	620 (2)	30 (30)	[19]
				5762.81	nl, e	1	13/2	14470.042	830 (3)	—	[19]
11/2	31895.205	668 (2)		3698.720	f	10	11/2	4866.515	867.997	−50.319	[7]
				5054.927		30	13/2	12118.039	554 (1)	−45 (30)	This work
				5910.73	nl, e	1	11/2	14981.500	687 (1)	—	[19]
				5923.09	nl, e	1	9/2	15016.789	719.2	—	Bh
				5938.70	nl, e	1	11/2	15061.167	930 (4)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
11/2	32289.455	665 (1)		5286.050	nl	8	11/2	13376.992	868 (2)	—	[19]
				5458.571	nl, f	15	9/2	13974.732	854 (1)	−15(15)	[19]
				5716.368	nl, e	10	11/2	14800.680	618 (2)	−30(20)	[19]
				5806.88	nl, e	1	13/2	15073.268	756 (2)	—	[19]
				7586.509		10	13/2	19111.800	762 (3)	—	This work
11/2	32513.960	655 (2)		4535.186	nl, f	5	13/2	10470.329	628 (3)	—	[19]
				4749.025	nl, f	1	13/2	11462.895	804 (1)	—	This work
				4806.181	nl	7	9/2	11713.236	818 (2)	—	[19]
				4901.572	f	6	13/2	12118.039	554 (1)	−45 (30)	This work
				5643.92	nl, e	1	11/2	14800.680	618 (2)	−30 (20)	[19]
				5786.83	nl, e	1	11/2	15238.143	1006 (7)	25 (15)	[19]
13/2	32608.552	620 (3)		3844.331	nl, f	4	13/2	6603.591	755.456	−48.633	[7]
				4054.460	nl, f	1	13/2	7951.323	644 (1)	−30 (20)	[19]
				4515.808	nl, f	2	13/2	10470.329	628 (3)	—	[19]
				4687.869	nl, f	1	11/2	11282.865	1049 (2)	—	This work
				4727.781	nl, f	1	13/2	11462.895	804 (1)	—	This work
				4732.376	nl, f	1	15/2	11483.427	987 (1)	—	This work
				4750.215	nl, f	1	13/2	11562.762	819 (2)	—	This work
				5136.795	nl, f	1	13/2	13146.584	1070 (1)	45 (20)	This work
				5701.20	nl, e	1	13/2	15073.268	756 (2)	—	[19]
				5728.26	nl, e	1	13/2	15156.070	1187 (1)	—	This work
				5800.11	nl, e	1	13/2	15372.271	642 (1)	—	This work
15/2	32672.439	601 (2)		5014.698	nl, f	14	17/2	12736.621	904 (1)	20 (20)	This work
				5031.823	nl, f	1	15/2	12804.468	732 (1)	—	This work
				5492.256	nl	8	13/2	14470.042	830 (3)	—	[19]
				5680.510	nl, e	20	13/2	15073.268	756 (2)	—	[19]
				5778.688	e	23	13/2	15372.271	642 (1)	—	This work
				8296.640	nl	5	13/2	20622.677	642 (1)	40 (50)	This work
21/2	32741.057	332 (2)		4979.610		8	21/2	12664.765	825 (2)	—	[19]
				5230.205	f	60	19/2	13626.672	865 (3)	—	[19]
				5917.00	nl, e	1	19/2	15845.280	185 (2)	—	[19]
15/2	32849.815	540 (2)		4015.170	nl,	4	13/2	7951.323	644 (1)	−30 (20)	[19]
				4326.956	nl, e	5	15/2	9745.376	540 (2)	—	[4]
				4467.124	nl, e	5	13/2	10470.329	628 (3)	—	[19]
				4674.446	nl, f	1	13/2	11462.895	804 (1)	—	This work
				4696.376	nl, f	1	13/2	11562.762	819 (2)	—	This work
				5578.830	nl, f	1	15/2	14929.886	646 (3)	—	[19]
				5623.828	nl, f	10	13/2	15073.268	756 (2)	—	[19]
				5720.040	nl, e	13	13/2	15372.271	642 (1)	—	This work
				5735.74	nl, e	1	13/2	15420.120	1020 (5)	—	This work
13/2	33052.848	555 (2)		3738.704	nl	7	11/2	6313.224	756 (1)	—	This work
				3982.695	nl, f	8	13/2	7951.323	644 (1)	−30 (20)	[19]
				4789.605		5	11/2	12180.131	679 (3)	—	[19]
				4805.810		6	15/2	12250.519	608 (1)	—	This work
				5785.33	nl, e	1	13/2	15772.545	938 (3)	—	[19]
				5860.70	nl, e	1	15/2	15994.780	814 (2)	—	[19]
				5886.62	nl, e	1	13/2	16069.885	1050 (3)	—	[19]

Table 5: Continued.

New upper odd level				Line			Combining known lower even level				
J	Energy/cm^{-1}	A/MHz	B/MHz	λ/Å	C.	SNR	J	Energy/cm^{-1}	A/MHz	B/MHz	Reference to col. 10, 11
17/2	33305.483	450 (2)		4389.829	nl, e	1	17/2	10531.951	546 (3)	—	[19]
				5775.171	nl, f	10	15/2	15994.780	814 (2)	—	[19]
				5876.880	f	16	15/2	16294.378	825 (1)	—	This work
				6114.815	nl, f	7	15/2	16956.282	808 (3)	—	[19]
				6231.395	nl, f	3	15/2	17262.152	905 (3)	—	[19]
				6404.22	nl, e	1	17/2	17695.093	1059 (3)	—	[19]
				6470.68	nl, e	1	17/2	17855.428	947 (2)	—	[19]
9/2	33687.796	744 (2)		3468.665	f	7	11/2	4866.515	867.997	−50.319	[7]
				5691.05	nl, e	1	11/2	16121.221	742 (1)	40 (20)	[19]
				5764.22	nl, e	1	7/2	16344.206	674 (3)	—	[19]
13/2	33932.700	737 (1)		3658.060	nl	6	13/2	6603.591	755.456	−48.633	[7]
				5165.634	nl, f	6	15/2	14579.390	873 (3)	—	[19]
				5260.914	nl, f	66	15/2	14929.886	646 (3)	—	[19]
				5667.90	nl, e	1	15/2	16294.378	825 (1)	—	This work
				5694.73	nl, e	1	11/2	16377.460	560 (2)	—	This work
				5709.27	nl, e	1	13/2	16422.190	960 (3)	—	[19]
7/2	34243.714	655 (2)		3608.018	nl, f	1	7/2	6535.572	979 (1)	25 (30)	[19]
				4286.343	nl, e	1	9/2	10920.365	632 (2)	—	[19]
				4713.198	nl, f	1	7/2	13032.634	893 (3)	—	[19]
				4734.423	nl, f	1	5/2	13127.722	156 (1)	0 (10)	[19]
				5763.922	e	20	9/2	16899.229	216 (2)		This work
				6502.982		15	5/2	18870.4	886 (2)		This work
				7261.724	nl	4	9/2	20476.674	550 (1)	50 (50)	This work
17/2	35453.400	595 (1)		3888.734	f	6	15/2	9745.376	540 (2)	—	[4]
				4011.474	nl, f	1	17/2	10531.951	546 (3)	—	[19]
				5052.260	nl, f	8	17/2	15665.796	906 (1)	—	[19]
				5629.604	nl, f	1	17/2	17695.093	1059 (3)	—	[19]
				5820.62	nl, e	1	15/2	18277.874	581 (3)	—	[19]
				5848.02	nl, e	1	15/2	18358.336	477 (3)	—	[19]

C: Comment; nl: new line; e: excited; f: observed as fluorescence line. Lines, for which SNR 1 is given, do not show up in our FT spectrum but could be excited or were observed as fluorescence lines.

as transition between levels having $J_{\text{up}} = 11/2$ and $J_{\text{lo}} = 9/2$ with $A_{\text{up}} = 370$ MHz and $A_{\text{lo}} = 1365$ MHz. The cg wavelength of the structure was 5826.37 ± 0.01 Å. The known lower level 11730.668 cm^{-1}, odd parity, had compatible values, and we calculated an energy of 28889.29 cm^{-1} for a hypothetical new even parity level. The strong fluorescence line could be explained as decay to the lower level 9579.820 cm^{-1}, odd parity, $J = 9/2$. This interpretation was confirmed thereafter by three further laser excitations (λ = 5690.96, 5693.32 and 5831.69 Å). Figure 2 shows part of the FT spectrum around the line 5826.37 Å. The accuracy of the cg wavelengths is determined by our lambdameter to be 0.01 Å. This level explains one further line in the FT spectrum with respect to wavelength and hf pattern, λ = 6817.989 Å (cg wavelength from FT spectrum).

When we tried to determine the energy of the level with higher precision, it turned out that we could not find suitable lines in our FT spectrum: none of the 4 excited transitions appears in the FT spectrum. The line λ = 6817.989 Å (SNR = 4 in the FT spectrum) is a transition to a lower level whose energy is not accurately known, and the quite strong line λ = 5177.373 Å (SNR $\approx$ 220) is blended by another strong line. Nevertheless, we tried to use the high wavelength accuracy of the FT spectrum (0.001 Å compared to 0.01 Å of our lambdameter) for a determination of the excitation wavelength. As can be noticed in Figure 3(a), the interesting wavelength is in the neighborhood of a well-resolved line (cg wavelength λ = 5826.461 Å). We scanned the laser frequency over this line and detected a strong LIF signal at λ_{fl} = 5107 Å. After having passed the first 3 strong hyperfine components of this line, we switched the monochromator to the fluorescence line λ_{fl} = 5177 Å, without interrupting the scan. Thus we obtained a recording in which the signals received on both fluorescence lines were contained next to one another (Figure 3(b)).

Using our fit program and the known hf constants of all 4 involved levels, it was possible to find the wave number

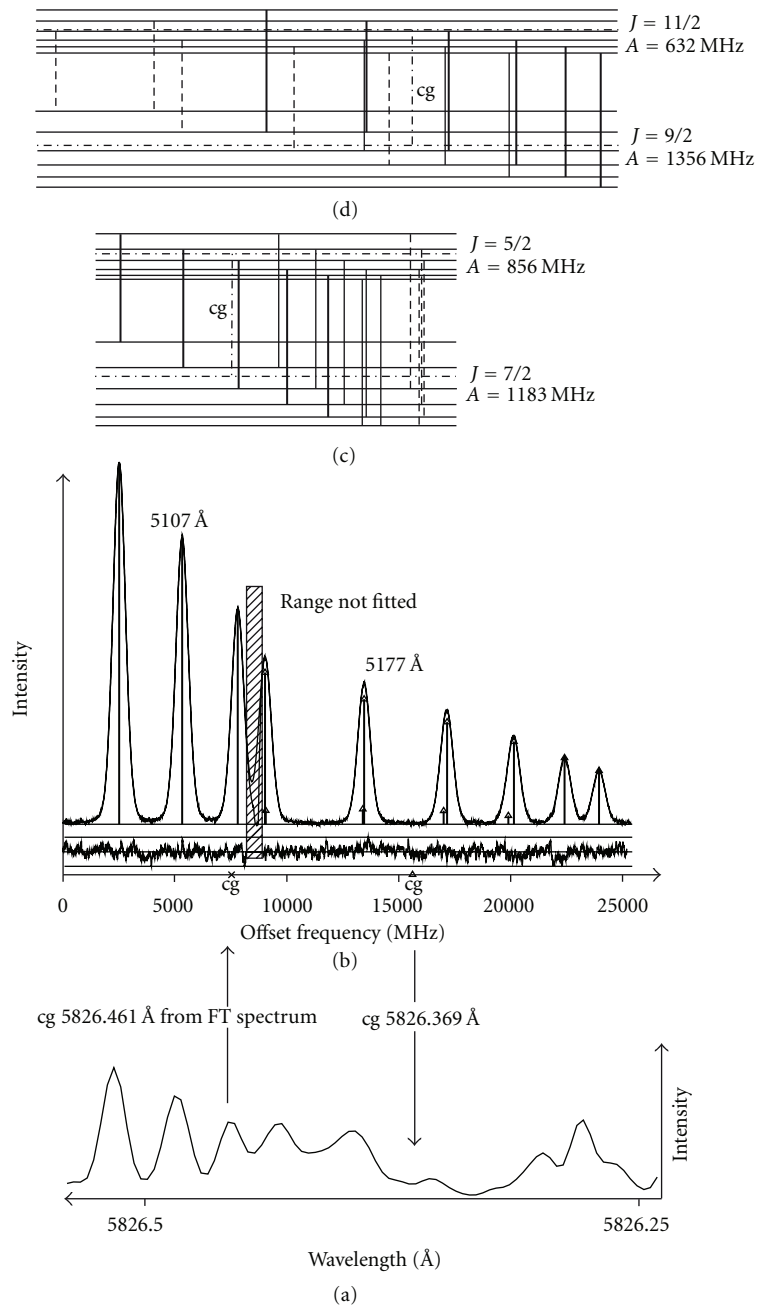

Figure 3: Finding of the cg wavelength of line $\lambda = 5826.369$ Å. (a) Part of the FT spectrum showing the well-resolved line $\lambda = 5826.461$ Å, but not the excited line $\lambda = 5826.369$ Å. (b) Laser spectroscopic scan over the wavelength region shown in (a). The left part (0-9000 MHz) was detected at fluorescence wavelength $\lambda_{\mathrm{fl}} = 5107$ Å, the right part at $\lambda_{\mathrm{fl}} = 5177$ Å. Each part was fitted using the hf structure constants of the corresponding combining level pairs (components outside the detected range were excluded). Lower trace: residuals between recording and fit, magnified by a factor 3.5. From the frequency difference between the centers of gravity, we could find the unknown excitation wavelength $\lambda = 5826.369$ Å. (c) Hyperfine level scheme of the line $\lambda = 5826.461$ Å. (d) Hyperfine level scheme of the line $\lambda = 5826.369$ Å.

difference of the cg's of both lines with high precision. By adding this value to the cg wave number of the line $\lambda = 5826.461$ Å, we were able to find an accurate value for the cg wave number of the excitation to level 28889 cm^{-1}. The corresponding wavelength is $\lambda = 5826.369(1)$ Å. With the new cg wave number, the energy of the new level was determined to be 28889.260(10) cm^{-1}. For confirmation, similar procedures were performed with two other excitations, and we found the wavelengths $\lambda = 5831.692$ and $\lambda = 5693.323$ Å, which both confirmed the energy of this new level.

5. Results

In Table 1 we report data of low-lying even levels, discovered as lower levels of excited transitions. In columns 1 to 3, values

of J, the energy, and the A-factor are given. Columns 4–6 contain all lines known to us who can be classified with help of this level. The wavelength in column 4 is given with 3 digits after the decimal point if it is extracted from our FT spectrum. Two digits are given for excitation wavelengths measured with help of our lambdameter (accuracy 0.01 Å). For fluorescence lines having SNR = 1, the wavelengths calculated from the level energies are given. All wavelengths are given in air. In column 5, a comment is entered: nl means that it is a new line, not contained in commonly used spectral tables (e.g., [18]). If cl is given, it is an already known line which could be classified with help of the new level. e indicates that the line was excited, f that it was observed as a fluorescence line after excitation of the upper combining level. In column 6 the SNR of the line in our FT spectrum is given. If there is given SNR = 1, the line does not appear in the FT spectrum, but was observed as excited (comment e) or as fluorescence line (comment f). In columns 7 to 11, information on the combining upper level is entered. The citations in column 11 refer to the A- and B-values of columns 9 and 10. If a line of column 4 was excited, we additionally give in columns 12 to 16 information concerning the observed fluorescence line(s). nl and cl in column 13 have the same meaning as in column 5.

Table 2 contains data of low-lying odd levels, discovered as lower levels of excited transitions, and is built similar to Table 1.

In Table 3 all levels discovered as upper levels are listed, divided in two groups: even parity and odd parity. Within each group, the levels are sorted with respect to J (column 1) and for each J with increasing energy (column 2). Column 3 contains the A-factor and column 4 the B-factor if we were able to determine it reliably. In column 5, excitation wavelengths are given (not more than 2) and in column 6 fluorescence wavelengths (not more than 2).

Table 4 contains detailed information concerned with the new even levels. The table is built analogously to Table 1 (but here the columns 12 to 16 of Table 1 are not needed).

Table 5 contains detailed information concerned with the new odd levels and is built similarly to Table 4.

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