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Experimental Investigation of the Hyperfine Structure of Neutral Praseodymium Spectral Lines and Discovery of New Energy Levels

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Abstract

Experimental investigations of Pr I spectral lines were performed by means of laser induced fluorescence spectroscopy, using a hollow cathode discharge lamp as source of free atoms. The wavelengths for the laser excitation were found by the help of a highly resolved Fourier transform spectrum. Altogether we excited 236 unclassified lines and analysed their hyperfine structure, which led, together with the measured wavelengths of the observed fluorescence lines, to the discovery of 32 new even parity and 38 odd parity fine structure energy levels. These levels allow to classify more than 670 spectral lines of Pr I. The wave number calibrated Fourier transform spectrum allowed us to determine the energies of most of these newly discovered levels with an uncertainty of 0.015 cm^{-1}. Angular momenta, parity, and magnetic and electric hyperfine interaction constants (A and B) of the new levels were also determined.

Keywords: praseodymium, new energy levels, laser spectroscopy

1. Introduction

Praseodymium is a rare earth element belonging to the lanthanides group. Its atomic number is 59, and it has naturally occurring only one stable isotope ^{141}Pr with nuclear spin quantum number I = 5/2. The ground state $^4I^{\circ}_{9/2}$ belongs to the electronic configuration [Xe] $4f^3$ $6s^2$, having five valence electrons outside a Xenon-like electron core. Its nuclear magnetic dipole moment amounts to $\mu_I = 4.2754(5)\ \mu_N$ (Macfarlane, Burum & Shelby 1982) and its nuclear electric quadrupole moment is Q = -0.0024b (Böklen, Bossert & Foerster 1975). Due to the five valence electrons, praseodymium has a very large number of fine structure (fs) levels and consequently an extremely line rich spectrum.

The first investigation of hyperfine (hf) structure in the spectrum of praseodymium can be traced back as early as 1929, when H.E. White (White 1929) investigated the wave number separation of hf structure components of 173 spectral lines. He was the first in determining the nuclear spin quantum number of ^{141}Pr. Since 1929 and over the span of five decades, several authors investigated the spectrum of praseodymium and discovered several electronic levels which were then collected and published in 1978 (Martin, Zalubas & Hagan 1978). A major contribution to the understanding and development of the spectrum of praseodymium (atom and singly charged ion) came from A. Ginibre (Ginibre 1981, Ginibre-Amery 1988, Ginibre 1989a, Ginibre 1989b). Her published (and also not yet published) work is based on the study of the fine and hyperfine structures in the configurations $4f^25d6s^2$ and $4f^25d^26s$ of neutral praseodymium. In this work, she calculated the wave numbers for a large number of new fs levels and also determined their hyperfine interaction constants. In 1981, Childs and Goodmann, using an atomic-beam - laser-rf double-resonance technique, determined the hyperfine (hf) constants of several low-lying metastable electronic levels with high accuracy (Childs & Goodman 1981). Kuwamoto et al. (Kuwamoto et al. 1996) investigated the hf structure of Pr I lines by using an atomic beam of neutral praseodymium, crossed perpendicular with an exciting laser beam, and determined A and B constants for 57 levels. The energies of 11 fs levels were determined for the first time. Krzykowski et al. (Krzykowski, Furmann, Stefanska, Jarosz & Kajoch 1997) accurately determined the values of the hf structure constants of some lower levels belonging to the configuration $4f^35d6s$ and for the upper levels of the investigated Pr-I lines, excited by laser light. The group of G. H.

Guthöhrlein (Guthöhrlein 2005) investigated a big number of Pr I lines using laser-induced fluorescence spectroscopy. Unfortunately, most of the results are still not published. Based on the available experimental results, in 2003 J. Ruczkowski et al. applied a semi-empirical method to describe configuration and designation of the known Pr I levels (Ruczkowski, Stachowska, Elantkowska, Guthöhrlein & Dembczyński 2003). In 2006 Furmann et al. (Furmann, Krzykowski, Stefańska & Dembczyński 2006) reported hf structure investigations of Pr I lines and the discovery of 57 new electronic levels with odd parity.

Since 2004, the group in Graz is concerned with experimental investigations of the hf structure of praseodymium lines using laser induced fluorescence (LIF) spectroscopy (Uddin 2006). In parallel to the laser spectroscopic work highly resolved Fourier-transform spectra were also recorded. These spectra led to the discovery of more than 9000 previously unknown Pr I and Pr II spectral lines, from which more than 1100 could been classified (Gamper et al. 2011). Later on, we focused on searching for new fs levels of praseodymium and were able to discover a significant number of levels, some of which have already been published, see refs. (Uddin et al. 2012a, Shamim, Siddiqui & Windholz 2011, Syed et al. 2011, Uddin et al. 2012b, Siddiqui, Shamim & Windholz 2014, Uddin et al. 2012c, Uddin 2014, Gamper, Khan, Siddiqui & Windholz 2013, Siddiqui, Shamim & Windholz 2016, Uddin, Siddiqui, Tanweer, Jilani & Windholz 2015).

The present investigation of the spectrum of praseodymium not only broadens the understanding of the Pr I level scheme but is also of interest to astrophysicists (Ryabchikova, Savanov, Malanushenko & Kudryavtsev 2001, Dolk et al. 2002) in analysing the Pr abundance in various stars.

All wavelengths given in this paper are in Å in standard air. Conversion from wavelength to wave number was performed using the formula given by Peck and Reeder (Peck & Reeder 1972) for the refractive index of air.

2. Experimental Setup

A laser-induced fluorescence (LIF) technique in combination with Fourier transform (FT) spectroscopy is used for the investigation of the hf structure of lines in the spectrum of praseodymium. The experimental setup is shown in Fig. 1, and a detailed description of each component used is given in ref. (Shamim, Siddiqui & Windholz 2011). Excitations of Pr lines were performed by means of a tunable ring dye laser, pumped by a single frequency semiconductor diode pumped Nd-Vanadate (Verdi V-18) laser. The investigations were carried out in the spectral regions of the dyes Rhodamine 6G (5700-6100 Å) , Sulforhodamine B (6100-6300 Å), DCM (6300-6800 Å) and Stilbene 3 (4200-4700 Å). The source of free praseodymium atoms is a dc hollow cathode discharge lamp (HCL), filled with Ar as buffer gas, in which free praseodymium atoms were produced by cathode sputtering. One of the advantages of using a HCL is, that, as a result of collisional processes within the Ar-Pr plasma, free Pr atoms are not only produced in its ground state but also in high lying excited states up to about 25000 cm^{-1}.

Of course the HCL emits all spectral lines of Pr and Ar (and their first ions). In order to distinguish the light emitted from the HCL from LIF intensity, the exciting laser beam is modulated with the help of a mechanical chopper 1 (see Fig. 1). The light emitted by the discharge is dispersed by a monochromator whose output is detected by a photomultiplier. Only lines influenced by the laser light show the same modulation and are detected with the help of Lock-In amplifier 1. The LIF signal together with the transmission signal of a temperature-stabilized marker etalon are digitally stored in a computer for further analysis.

The investigation of a line begins by tuning the laser light wavelength into resonance with the wavelength of a hf component of the investigated line. This wavelength is extracted from the FT spectrum. As a result of the excitation one expects laser-induced fluorescence lines, which are then detected. If the upper level of the excited transition is known, the monochromator transmission wavelength can be set to an expected decay line of this level and the hf structure of the line can be recorded by scanning the laser light frequency over the transition. If the upper level is previously unknown, we first have to set the laser frequency to a strong hf component of the line (wavelength known from the FT spectrum) and to search for LIF lines by tuning the transmission wavelength of the monochromator. The function of chopper 2 and Lock-In amplifier 2 will be explained when discussing the discovery of the level at 19111 cm^{-1}.

3. Data evaluation and Analysis

The analysis of the recorded hf pattern can lead to the knowledge of parameters of the combining fs levels such as total angular momentum J and magnetic dipole and electric quadrupole hf constants A and B, respectively. In case of praseodymium, which has a very small nuclear quadrupole moment, the value of B is very small for most of the levels and is often neglected. Exceptions are high precision Doppler free laser spectroscopic methods like experiments on an atomic beams, where the hf constants can usually be determined with high precision, and so also small B factors are determined reliably (Krzykowski, Furmann, Stefanska, Jarosz & Kajoch 1997, Childs & Goodman 1981). The evaluation of the recorded hf patterns also gives an estimated center-of-gravity (cg) wave number of the excited line. Together with the values of J and A (and sometimes B) and the wavelengths of the experimentally observed fluorescence lines, the identification of the involved fs levels is possible.

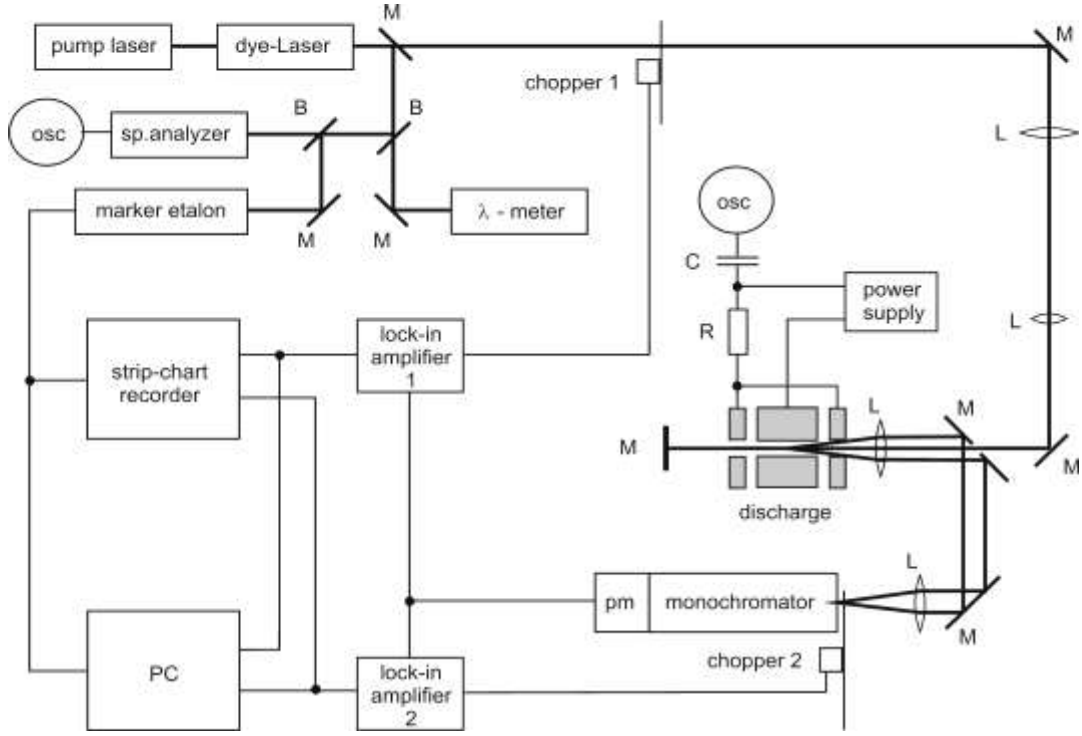

Figure 1. Experimental setup. M mirror, L lens, B beam splitter, R resistor, C capacitor, pm photomultiplier, osc oscilloscope, PC computer

Of special interest is the excitation of lines which cannot be classified as transitions between already known energy levels. In such cases the wavelengths of the fluorescence lines are previously unknown and have to be found by tuning the monochromator which disperses the light emitted by the discharge.

If now one of the combining levels is already known, let us say, the lower level, the energy of the upper combining unknown level is determined by adding the cg wave number of the line to the energy of the lower level. On the other hand, if an upper level is already known, the energy of lower combining unknown level is determined by subtraction of the cg wave number from the energy of the upper level. In the worst case, where both the combining levels are not known, only the observed fluorescence wavelengths can be used for the determination of the energies of the combining levels. For a detailed description of the method see ref. (Uddin et al. 2012a).

In an otherwise slightly simpler situation, where one (or several) of the observed fluorescence lines are in the wavelength range of our laser, laser excitation of a former fluorescence line can be performed and the hf pattern can be recorded on the previously excited line. Since the probability that a previously unknown energy level decays to an already known level is high, the energy of the new upper level can be determined. In each case, at least one of the levels involved in the excited transition must be identified.

4. Discovery of the New Level at 19111.80 cm^{-1}, Even Parity, J = 13/2, A = 762 MHz

A quite prominent line at 5636.940 Å, appearing in the FT spectrum with a high signal-to noise-ratio (SNR) of 140, was experimentally investigated using laser spectroscopy. The line exhibits a well-defined hf structure with clearly visible hf pattern, but with unresolved hf components, see Fig. 1. The line could not be classified using already known level energies, thus we had to assume that a previously unknown energy level is involved in the transition.

Laser excitation was performed by tuning the laser wavelength to the highest peak of the pattern at 5636.92 Å. A single fluorescence line at 5228 Å was observed when tuning the transmission wavelength of the monochromator from 3000 Å to 7000 Å. Observation of only one LIF line can happen when the upper level has only a few number of decay channels or has a very low transition probability for the other lines.

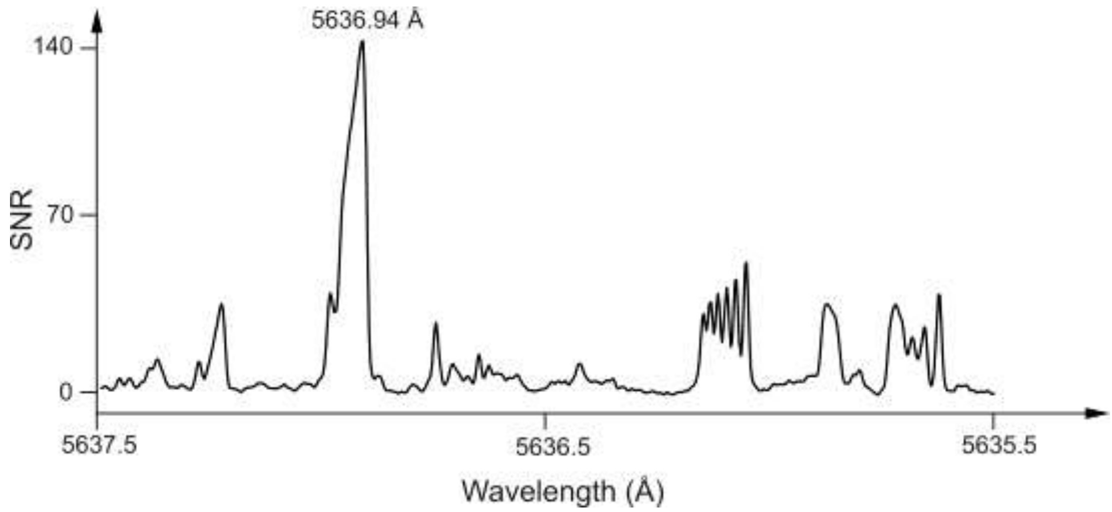

Figure 2. Line 5636.940 Å in the FT spectrum of Praseodymium

The hf structure of the line was recorded by scanning the laser frequency across the line. The LIF spectrum had a good signal-to-noise ratio and showed the hf structure pattern as appearing in FT spectrum, but with higher resolution (Figure 2).

The recorded hf structure was then fitted assuming different pairs of J-values for upper and lower level. For this, the program "Fitter" was used (Guthöhrlein 1998) which minimizes the sum of the squares of the differences between measured and calculated intensity values (ESS). The best fit situation with the lowest ESS value was obtained for J_{up} = 13/2, J_{lo} = 11/2, A_{up} = 762 MHz and A_{lo} = 733 MHz, see Figure 3. The cg wavelength obtained from the fitting procedure was 5636.940 Å.

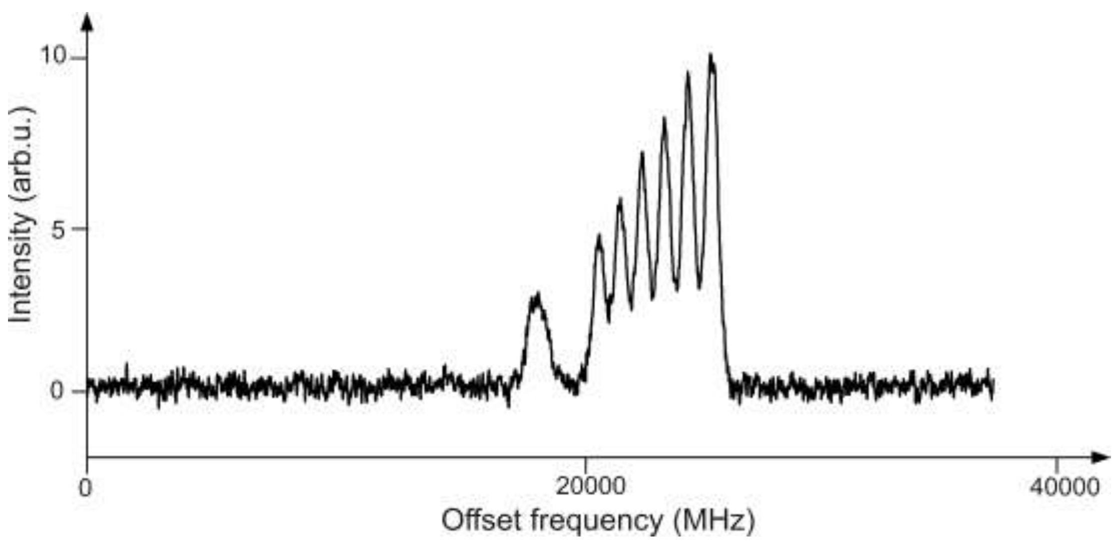

Figure 3. Recorded hf pattern of the line 5636.940 Å (LIF at line 5228 Å)

First we assumed that an unknown upper level is involved in the excitation of the investigated line. Therefore we searched in our database of known energy levels for a level having J = 11/2 and approximately the A-value from the fit. Several levels, having both even or odd parity, fulfilled these requirements (see Table 1). Hypothetical new levels were calculated by adding the cg wave number of the excited line at 5636.940 Å (17735.198 cm^{-1}) to the energies of these levels. Then we calculated possible decay lines of the hypothetical levels, but none of them could explain the observed LIF line at 5228 Å. Thus we repeated the procedure assuming that a new lower level is involved, but still without any success.

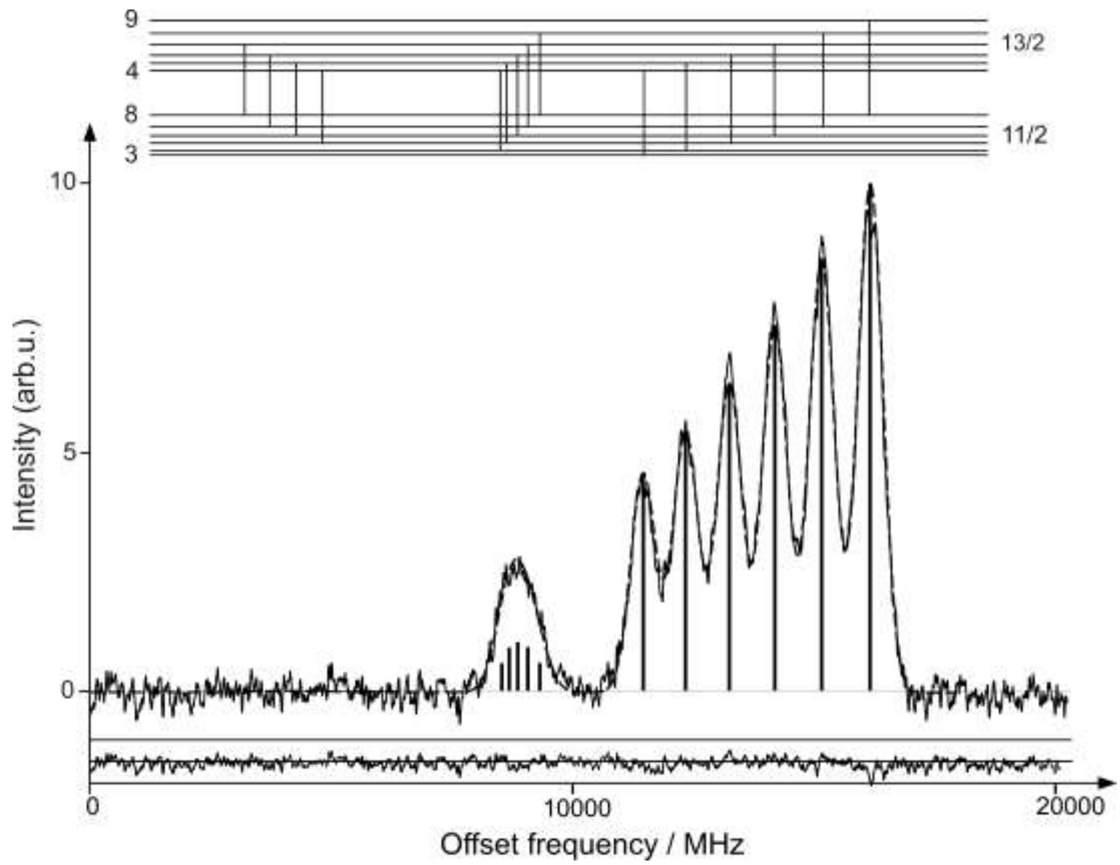

Figure 4. Best fit situation of the recorded hyperfine structure of line 5636.940 Å. The lower trace shows the residual between experimental and fitted hf pattern (x 0.5)

Next we thought about a possible scenario in which both the lower and upper of the combining levels are not known and were yet to be discovered. But to solve such a situation the wavelengths of at least two LIF lines have to be determined with high precision. The method is described e.g. in ref. (Windholz 2016). But here we obtained only one LIF line, so this scenario cannot be resolved.

Nevertheless, we tried to find a more accurate value of the fluorescence wavelength. The light emitted by the HCL was modulated using a second mechanical chopper, working with much higher frequency than the first chopper, modulating the intensity of the exciting laser light. The output of the photomultiplier was given now to two Lock-In amplifiers, one set to the chopping frequency of the laser light and the second one to that of the light emitted by the HCL. The laser frequency was fixed to the strongest hyperfine component of the line 5636.940 Å and the monochromator transmission wavelength was tuned around the line 5228 Å (from 5210 to 5240 Å). Both output signals of the LI-amplifiers were recorded simultaneously (see Figure 4). One trace now shows the LIF signal, obtained when the transmission wavelength of the monochromator agrees with the LIF line. The second trace shows the emission spectrum of the HCL. This spectrum now can be wavelength calibrated with help of the FT spectrum. In this way the high wavelength precision of the FT spectrum can be used to determine the LIF wavelength with an uncertainty of lower than 0.1 Å, despite of the fact that the monochromator used has a resolution of only 1 Å. The determined value of the fluorescence wavelength was 5227.97(10) Å.

In the FT spectrum there is a very strong line (SNR = 5300) at 5227.968 Å, see figure 5. This line is already classified as a transition from the ground level to a known low lying upper level at 19122.567 cm^{-1}, even parity, J = 11/2. Thus we had to believe that the observed LIF line is this strong line.

Thus again we came back to searching for a new lower energy level. But a fit of the recorded structure (Figure 2) is not possible with low ESS taking the hf constants of the level 19122.567 cm^{-1} as fixed values in the fitting procedure. This suggested that the upper level involved in the excitation of line at 5636.940 Å is not 19122.567 cm^{-1}.

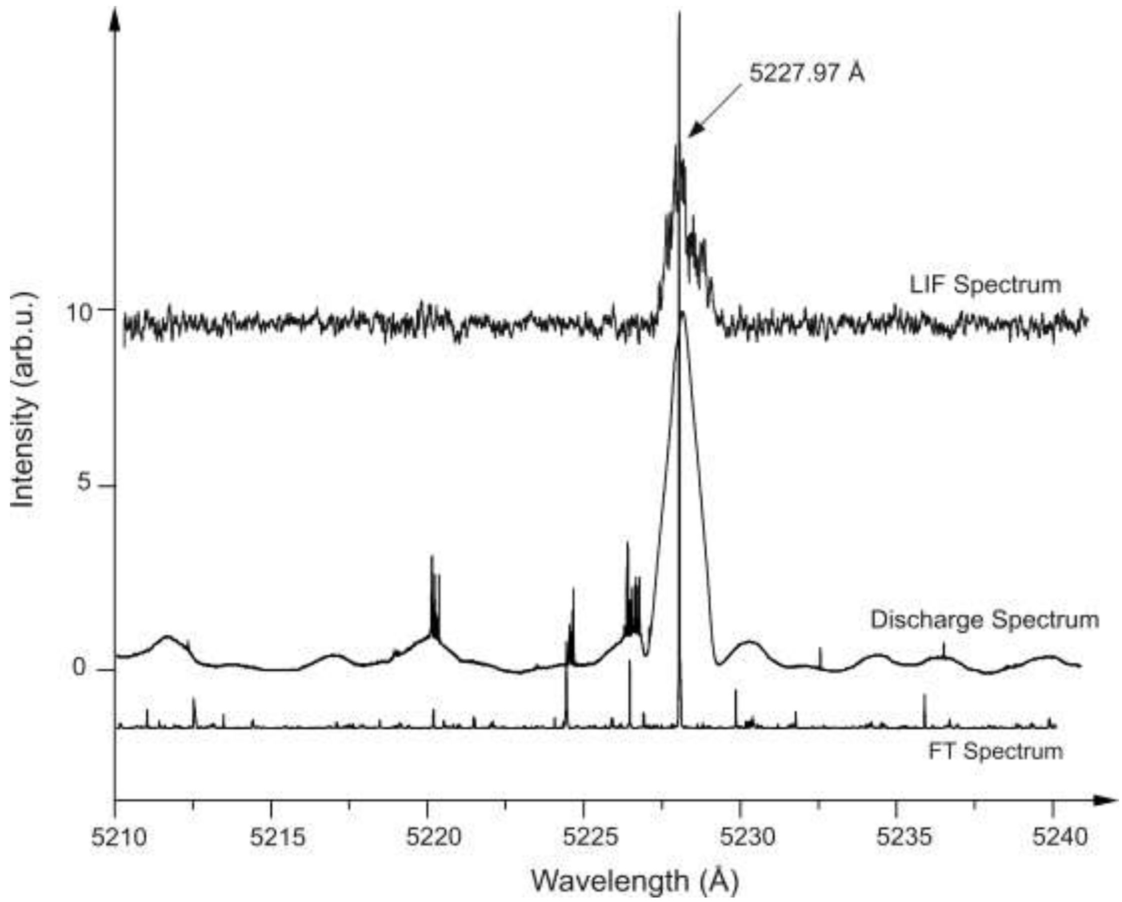

Figure 5. Determination of the fluorescence wavelength 5227.968 Å

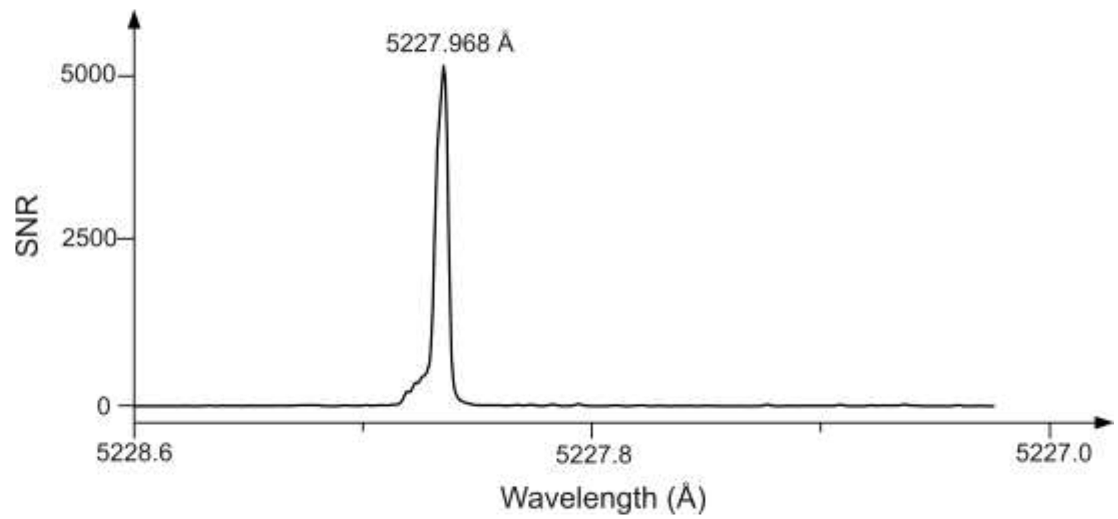

Figure 6. Spectral line 5227.968 Å as appearing in the FT spectrum

Thus we had to conclude that the observed LIF line at 5636.940 Å is not a direct decay line of the new energy level. In this case we have to assume that the new level has an energy close to 19122.567 cm^{-1} and that the laser-induced enhancement of the population of the new level is (at least partly) transferred to 19122.567 cm^{-1} by collisions.

We now treat again the list of lower levels having J = 11/2 and A close to 733 MHz as determined by the fit procedure. For the energy of the level we expect 19122 $\pm$1000 cm^{-1} due to the assumed collisional coupling. The wave number of the excited line is 17735 cm^{-1}. This gives 19122 $\pm$1000 – 17735 = 1387 $\pm$1000 cm^{-1} for the lower level of the excitation. Indeed, as can be seen from Table 1, only one level, 1376.602 cm^{-1}, even parity, is located in the estimated energy region.

Moreover, when fitting the pattern shown in Fig. 2 with A- and B-values for the lower level, the best fit (lowest ESS) is obtained for 1376.602 cm^{-1} as lower level.

The odd parity level at 1376.602 cm^{-1}, J_{lo} = 11/2 and A_{lo} = 730.393 MHz, B_{lo} = -11.877 MHz is the lowest metastable level of Pr I, the nearest neighbour of the ground level. Taking now this level as the lower one of the laser excitation, we obtain a new even parity level at 19111.80 cm^{-1}, having J = 13/2, A = 762(2) MHz. B is assumed to be zero.

The newly calculated hypothetical level was then confirmed by a second laser excitation. First we calculated possible decay lines of the newly introduced level to lower levels. From this list we tried to excite lines in the wavelength range of our lasers. We were successful with the line 6146.45 Å, which appears in the FT spectrum with SNR = 24. Again we observed a strong LIF signal at the collisionally coupled line 5228 Å. The correct cg wavelengths of both excited lines were determined from the FT spectrum, i.e. 5636.940 Å and 6146.447 Å. The energy of the lower levels were already corrected earlier, therefore the energy of the newly discovered level could be determined with less uncertainty to be 19111.800(10) cm^{-1}. The magnetic and electric hf constants for the lower combining levels 1376.605 cm^{-1} and 2846.741 cm^{-1} were determined with high precision using laser-atomic beam spectroscopy [31, 9], therefore from a repeated recording of both laser-excited lines, the electric quadrupole hf constant for the newly discovered upper level could also been determined. Therefore the hf constants of the new upper level are finally A = 760(1) MHz, B = -20(10) MHz.

Table 1 shows the energies of all the possible combinations of known lower levels and calculated upper levels for the line 5636.940 Å. It also displays the ESS value of the best fit situation for each combination of J- and A-values of the combining levels (A- and B-values of the lower levels fixed during the fitting procedure).

Table 1. All the possible combinations of known lower levels and calculated upper levels for the line 5636.940 Å

Assumed lower level, J = 11/2			Calculated upper level, J = 13/2		
Energy (cm^{-1})	A (MHz)	B (MHz)	Energy (cm^{-1})	A (MHz)	ESS (arb.u.)
1	2	3	4	5	6
odd			even		
1376.602	730.393	-11.877	19111.8	761.83	4.98
10431.716	701.7(5)	-10(7)	28166.91	735.84	6.27
22577.235	685.4(5)		40312.43	721.91	7.77
even			odd		
6313.24	756.3		24048.42	782.67	6.16
8829.063	769.4	-31	26564.26	793.72	7.63
9483.518	731.3(2)	-15.4(80)	27218.72	761.15	5.00
9675.029	683.2(5)		27410.23	720.02	8.01
14505.065	777.2		32240.26	800.65	8.72
14981.5	687(1)		32716.7	723.29	7.60

With the help of a calculated list of decay lines of higher lying odd levels to the new level we could classify two further lines in the FT spectrum (7586 and 9632 Å, see Table 2). One additional excitation was also successful (at 7086.57 Å, transition to the upper level 32289.455 cm^{-1}, odd parity). The complete scheme of all transitions in which the new level is involved is shown in Figure 7.

5. Results and Discussion

In similar way as decribed for the level 19111 cm^{-1} in chapter 4, or using methods described in ref. (Windholz 2016), we found altogether 70 previously unknown energy levels of Pr I.

The data of all newly discovered levels are given in Table 2. The levels are listed separately for even and odd parity and are sorted by their value of J and their energy. In col. 1 the value of J is given, in col. 2 the level energy together with its estimated uncertainty (one standard deviation) is given. In col. 3 the magnetic dipole hf constant A is given. With the exception of the level at 19111 cm^{-1}, the electric quadrupole hf constant B could not be determined reliably and therefore was assumed to be zero. In the next column the cg wavelengths at which laser excitation was performed, are given. Values having three figures after the decimal point are determined with help of the FT spectrum, the other values with help of the lambdameter measuring the laser wavelength (uncertainty ± 0.01 Å). Wavelengths of observed fluorescence lines are given in Col. 5. Lines in the FT spectrum classified due to their cg wavelength and hf pattern are given in col.6. Some levels were discovered as lower levels of the excited transitions, and their existence was detected by decay lines of the combining upper levels. In such cases one finds in col. 5 the entry "see Table 3".

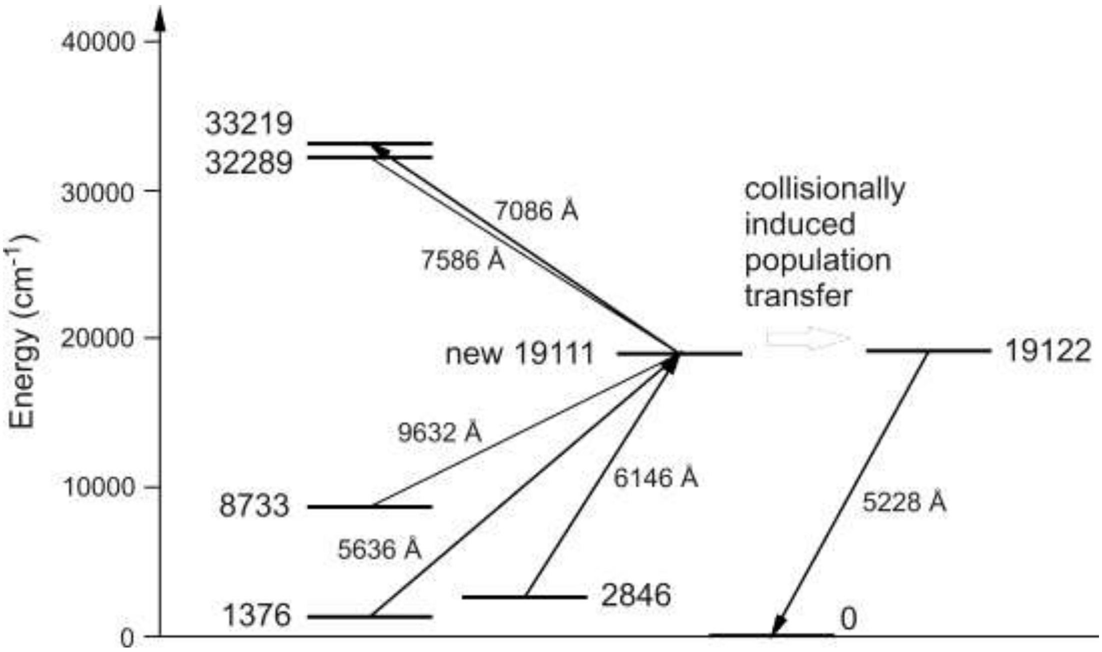

Figure 7. Level scheme of all observed lines classified by the new level at 19111 cm^{-1}. Laser excitations are shown as arrows; lines classified in the FT spectrum as thin full lines. The observed LIF at 5228 Å is an indirect line caused by collisionally induced population transfer. Wave numbers in cm^{-1}

In Table 3 all lines classified by new levels, which were discovered as lower levels of the excited transitions, are listed. Once such (hypothetical) level was introduced, its existence was checked by trying excitation from this level to other known upper levels. In such case we expect laser-induced decay lines from the known upper level. Thus in Table 3 also the observed fluorescence channels are mentioned. In cols. 1-3 the data from Table 2 are repeated (J, energy and A). In cols. 4-6 the excited line is given. If the line appears in the FT spectrum, the cg wavelength is given with three figures after the decimal point, and in col. 6 the SNR is given. If the cg wavelength is given with only two figures after decimal point, the cg wavelength is determined with the lambdameter measuring the laser wavelength, and in col. 6 SNR is set to 1. In col. 5 (C.) a comment is given: nl means a previously unknown spectral line not contained in commonly used spectral tables (e.g. Harrison 1969), cl means that the line was already known (in most cases from the work of A.Ginibre (Ginibre-Amery 1988)), but not classified. e means the line was excited by laser light. The data of the combining upper level are given in cols 7-9. Some of these are previously unknown levels but discovered within this work. If a decay of the upper level was observed, wavelength and SNR in the FT spectrum are given. nl means again a previously unknown line. If in col. 12 SNR = 1 is given, the LIF on this line was observed, but the line does not show up in the FT spectrum. In cols. 13 and 14 J and energy of the lower levels of the LIF lines are given. Finally in col. 15 a reference to the source of hf constant A (given in col. 9), used when determining the A-value of the new level (given in col. 3), is given.

Table 4 contains the lines classified by the newly found even levels, which were discovered as upper levels of the investigated lines. The structure of the table is similar to Table 3. A comment (C.) f means the line was observed as LIF line. The lines classified by the discovered upper odd levels are given in Table 5.

Table 2. Previously unknown energy levels of Pr I discovered within this work

J	Energy (cm^{-1})	A (MHz)	Excitation wavelength (Å)	Fluorescence wavelength (Å)	Lines in FT spectrum. Wavelength (Å)
1	2	3	4	5	6
Even Parity					
7/2	14429.047(15)	911(5)	5704.123, 5820.611	see Table 3	9762.631
7/2	22486.816(20)	948.34	7022.178	4445.802	8448.802
7/2	26121.377(15)	805(5)	5594.030,6792.357	5594.030, 6792.357	
7/2	27123.623(15)	684(3)	6070.12, 6255.292	3685.774, 5296.965, 6494.68	7209.096, 7273.985
7/2	27231.854(15)	773(3)	6135.075, 7153.27, 7217.149	5266.763, 6213.212, 6449.335	
7/2	27381.792(15)	662(3)	6256.568, 6387.551, 6545.725	5668.50, 5976.44	7139.865, 7968.417
7/2	27679.200(20)	654(5)	5802.49, 6045.14	5145.50, 5574.49, 6991.366	
7/2	27998.766(20)	520(4)	6145.299, 6586.785, 6629.709	6145.299, 6586.785	
7/2	30654.508(20)	599(3)	5778.53, 5869.29, 6551.97	4781.251, 5173.255, 5373.53, 5605.879, 6006.045	
7/2	30920.290(20)	420(5)	6439.79	4883.762, 5103.07	6101.124
7/2	31531.300(15)	619(4)	6195.93	3170.53, 5691.024, 5881.793, 5987.943	
7/2	31593.97(3)	641(4)	6050.73, 6171.958	4575.66, 5670.80, 6050.73	
7/2	31664.74(3)	732(4)	6145.11, 5940.46	4916.246, 5940.46	
7/2	31937.43(3)	641(3)	4851.192, 5927.51, 6043.80	4652.58, 5256.68, 5351.44, 5562.418, 6043.80	
9/2	22825.611(20)	570(5)	7145.88	4379.813, 4660.916	
9/2	22996.562(20)	779(5)	7059.610	4624.060	4347.255
9/2	24606.934(10)	777(2)	6111.977, 7052.618	4303.507	
9/2	25744.156(10)	823(3)	5659.740, 5912.451	3883.276	6751.467
9/2	26231.182(10)	645(3)	6327.578, 6705.624	6327.578, 6894.405	6536.480, 8762.130
9/2	27109.750(20)	783(3)	6075.244, 6181.40, 6500.543, 7271.13	3687.661, 5253.579, 5300.862	
9/2	27282.002(15)	750(3)	5647.454, 6630.474	5419.539, 6266.953, 6428.537	8023.198
9/2	27913.895(15)	496(3)	6025.531, 5888.603	3767.21, 5240.04, 6363.744	
9/2	30938.737(15)	634(3)	5981.884, 6094.26	4879.36, 5685.186, 5772.959, 5981.884	7138.169, 7449.325
9/2	31362.709(15)	622(3)	6043.863	4589.47, 4988.56, 5162.365, 5553.338	6010.168, 6261.353, 6497.932
9/2	31721.60(5)	574(3)	6123.70	4900.80, 5180.83, 5442.87, 5523.27, 5644.21	
9/2	32556.286(15)	679(5)	4862.656, 5825.84	3206.29, 4709.75, 5547.27, 5665.50, 6030.118, 6079.293	
9/2	33877.134(15)	609(4)	5727.48, 6111.25	4843.484, 5056.89	
9/2	35607.370(15)	665(5)	4830.293	3973.85, 4744.09, 4946.36, 5244.98, 5526.70	
11/2	23654.406(10)	613(2)	6419.18, 6489.916, 6700.129	6489.916	7156.112, 7860.865, 8615.006
11/2	23865.975(15)	752(2)	6997.854, 7049.349	4445.297	
11/2	25357.817(10)	669(3)	6050.701, 6336.191, 6697.824	3942.441, 4168.755	
11/2	25855.320(10)	683(2)	5838.861, 5873.834	3866.580	6481.778, 6879.052, 7077.868, 7085.725, 7241.556
11/2	26222.282(15)	590(3)	5749.862, 6007.065, 6044.970	4023.706, 4276.771, 6540.285	7131.724, 7140.794
11/2	26467.250(15)	857(2)	5669.98, 7326.027	3984.422, 5956.74	
11/2	26937.739(15)	720(5)	5794.30, 7359.74, 7363.24	3711.208, 5491.679	
11/2	27888.407(20)	570(4)	5726.871, 6193.275	3770.83, 6374.11	7800.123
11/2	27985.186(15)	618(2)	5688.50, 5695.298	3572.299, 5462.66, 6156.364	6844.894
11/2	29524.677(15)	493(3)	6175.40, 6192.193, 7075.92	3551.63, 5012.43, 6534.800, 6891.518	3386.025, 5230.327
11/2	31332.402(15)	628(3)	5844.222, 6273.258, 6761.49	3337.29, 4595.869, 4997.932, 5104.245, 5555.083	
11/2	32672.078(15)	529(3)	5770.52, 5988.29, 6071.057, 6352.019	4684.206, 4835.418, 5675.71, 5786.790, 5874.56	
11/2	32891.473(15)	399(4)	5593.36, 5648.07, 5714.22,	4634.98, 4784.648	

			5799.785, 7202.48		
11/2	32989.188(20)	478(5)	5682.49, 5956.362	4615.624, 4762.376	
11/2	33096.940(20)	660(5)	5647.893, 5995.465	3304.812, 4738.054, 5385.69, 5546.210	
11/2	33254.220(15)	583(5)	5598.150	5340.444, 5498.235, 5582.924	5939.440
11/2	33781.556(15)	517(3)	5687.833, 5759.01, 5933.723	5437.584, 5759.010	3231.67
13/2	19111.800(10)	760(2)	5636.940, 6146.447, 7086.57	5228[a]	9632.785, 7586.509
13/2	22592.830(15)	500(5)	6888.745	5062.883	5489.434, 8384.228
13/2	24722.464(15)	703(2)	4914.712, 6252.560	4282.21, 4570.00	7113.695, 7460.619
13/2	27020.835(15)	632(3)	4415.767, 6026.379, 6368.318, 6747.350, 7305.278	3898.408, 4135.493, 5754.13, 6755.464	7318.457
13/2	27150.550(15)	536(3)	5711.488, 6065.693, 6688.793	3878.79, 4113.421, 5428.225, 6696.766	7236.686, 7249.619, 7603.473
13/2	27340.868(15)	557(2)	5662.01, 5996.449	5650.053, 6438.939	6612.468
13/2	27519.089(15)	487(3)	5933.025, 6172.411, 7520.760	3824.103, 4051.974, 5593.71	6365.865, 7048.643
13/2	27626.232(15)	443(3)	6489.97, 6836.087, 7007.878	6131.847, 6295.526,	
13/2	27821.680(25)	644(5)	6745.932	5828.36, 6218.985, 6408.65	
13/2	33840.270(20)	540(3)	5660.918, 5705.48, 5739.60, 5780.94, 5913.12	3225.548	6230.529
Odd Parity					
7/2	15396.135(15)	719(2)	5682.49, 5714.22, 5825.84, 5878.40, 5995.548, 6043.80, 6123.70, 6145.287, 6171.956, 6195.93, 6273.258, 6439.79, 6551.97, 6616.346, 7075.92	see Table 3	4946.362, 5598.150, 5647.893, 5786.790, 6261.353, 6372.878, 8732.880, 9118.367
7/2	20012.862(15)	1133(5)	7045.286	4976[b]	8793.405, 9903.501
7/2	21975.458(10)	344(3)	5698.62, 6440.004	6189.254	7498.891, 7551.988, 8604.434, 9588.908, 9678.695
7/2	22451.973(15)	1125(4)	6248.204, 7240.105, 7490.283	4743[c]	5547.926, 7289.586, 7976.244, 8156.221, 8265.447, 8943.890, 9169.796, 9637.438
7/2	23293.356(15)	759(3)	5722.36, 5936.053, 5965.723	5300.434	8256.077, 8457.236, 8751.047, 9834.368
7/2	24443.790(10)	1046(3)	7016.088, 7496.383	5582.478	6785.520, 7591.178, 7950.416, 8357.456, 8477.849, 9091.907
7/2	25350.082(15)	1074(3)	5984.123, 6478.297, 7526.755	4779.268, 5290.019, 5313.568	7057.366, 7307.241, 7872.786
7/2	25788.548(15)	138(6)	5624.172, 5831.080	5007.20, 5192.56, 5501.713, 5863.14, 6215.714	7590.434
7/2	26915.490(15)	1122(3)	5613.118, 5808.71, 6547.334, 7055.51	4446.504, 4739.674, 4905.42, 5288.863	7853.830
7/2	27852.358(15)	868(4)	5661.72, 7469.521	4268.629	4671.467, 5043.218
7/2	27890.013(15)	877(5)	5649.665, 6504.25	4261.78, 4530.358, 4663.26, 4681.56, 4931.40, 5033.66, 5219.81	
9/2	17518.399(20)	874(4)	6111.25, 7566.54	see Table 3	7449.325
9/2	21063.222(15)	1093(2)	6967.185, 7055.071, 7435.23	6011.225	8171.588
9/2	22395.393(15)	724(4)	7269.896, 7369.16	5703.289, 6216.347, 6303.498	8194.017, 8304.292, 8917.363, 8996.381, 9839.067
9/2	22524.055(10)	1129(2)	6252.773, 6706.579	6252.773, 6706.579	7542.062, 7666.289, 8603.474, 8816.190, 8893.417, 9045.942, 9109.571, 9247.454, 9449.344
9/2	23008.838(10)	1227(2)	6666.715, 6673.919	5381.616, 5510.442	7275.959, 8525.734, 8850.571, 9035.326, 9278.867, 9531.065
9/2	23934.491(10)	785(3)	5673.386, 5745.890 6126.861	5242.935, 6618.31	7362.963, 7672.215, 8337.793, 9504.223, 9846.492
9/2	24196.152(10)	714(5)	5058.313, 5660.757 6177.590, 7521.18	5171.962, 5441.178, 6297.108, 6428.128	6795.001, 8561.896, 9273.537
9/2	24485.172(10)	1105(3)	6069.198, 6570.021	4985.407, 5095.769, 5569.608	8453.073, 9176.123, 9339.919, 9511.740, 9699.660
9/2	24830.361(10)	940(4)	5807.98, 5944.622	4901.040, 5259.627, 5398.903, 6055.21	6176.266, 8476.085
9/2	26035.395(10)	877(2)	5962.563, 6121.76	4627.654, 4722.595, 4946.052, 5069.024,	7819.677

				5174.218, 5427.976	
9/2	26748.513(15)	912(5)	5865.622, 6423.26, 7406.55, 7507.67	4568.687, 4990.040, 5034.96, 5340.614, 5424.938	4945.946
9/2	27292.757(20)	768(2)	5613.504, 5684.116	4656.388, 4858.07, 5360.746	
9/2	27659.987(15)	927(2)	4303.982, 5966.38, 5972.20, 6411.697	4385.986, 4683.240, 4987.993, 5257.221, 5567.856	
9/2	27980.556(15)	768(3)	5987.19, 6787.042, 6871.86, 7418.838, 7564.350	4245.390, 4511.846, 4661.788, 4740.793, 4909.47	5461.314, 7690.756
11/2	16399.404(20)	541(2)	5913.11, 5933.723, 6352.019	see Table 3	
11/2	21926.369(10)	882(3)	5714.613, 6992.917	5714.613, 6992.917	7898.193, 8022.236, 8574.069, 8640.943, 8691.213, 9634.268, 9646.510
11/2	23042.780(10)	891(4)	7033.518, 7362.643	5371.801, 5500.152, 5805.63	6122.530, 7172.779, 7258.024, 7824.854, 8430.534, 9500.323, 9620.895, 9709.173, 9990.187
11/2	24816.383(10)	744(2)	5927.775, 5955.302, 6060.343, 7387.03	4904.40, 5402.980, 5522.655	6181.599, 6363.059, 6602.604, 7185.876, 8643.863, 8660.299
11/2	25009.019(10)	983(3)	5860.83, 5990.391, 6439.24	5347.309, 5464.505	7709.545, 8997.499
11/2	25746.884(10)	784(2)	5617.818, 5845.29, 6544.171	4690.294, 4787.848, 5017.675, 5144.278, 5222.310, 5252.653, 5909.289	8081.917
11/2	26848.512(15)	590(5)	5634.305, 5686.772	4459.79, 4547.902, 4965.254 5290.319, 5395.656	5312.230, 6272.458
11/2	27944.838(15)	654(4)	5964.78, 6537.026	4519.130, 4921.167, 5352.94, 5415.225	7262.018
13/2	25443.665(15)	491(3)	4858.40, 5715.20, 5994.217	5225.816, 5306.358, 5389.124, 5612.150, 6655.946, 6675.071	6263.873, 7459.513, 7577.607, 7909.719
13/2	25765.460(15)	582(3)	5902.808, 6140.074, 7325.375, 7358.89	4783.593, 5217.247, 5297.234, 5512.568, 5611.961	6132.888, 6213.154, 6536.224, 7284.603, 7627.381
13/2	26810.061(15)	860(3)	5699.239, 5763.547, 5769.892, 7442.26	4877.439, 4947.529, 5301.107	5212.333, 5419.676, 5540.310, 6100.929
13/2	27139.468(15)	776(3)	5662.24, 5747.48, 7264.132, 7413.65 7535.314	5124.323, 5459.858, 5594.186	5440.982
13/2	27500.390(20)	883(2)	5608.43, 5800.911, 7349.556	4416.914, 5548.813	5630.651

[*] For the level at 19111 cm^{-1} the hf constant B could be determined to be B = -20(10) MHz

[a] Indirect fluorescence due to collisional transfer of population from the upper excited level to the even level at 19122.567 cm^{-1} which decay via fluorescence channel 5228 Å to the odd ground level

[b] Indirect fluorescence due to collisional transfer of population from the upper excited level to the even level at 20089.269 cm^{-1} which decay via fluorescence channel 4976 Å to the odd ground level

[c] Indirect fluorescence due to collisional transfer of population from the upper excited level to the even level at 22451.755 cm^{-1} which decay via fluorescence channel 4743 Å to the odd level at 1376.602 cm^{-1}

Abbreviations in col. 16: tw ... this work, G96 (Guthöhrlein 1996-2005), U12 (Uddin 2012b), SSW16 (Siddiqui, Shamim & Windholz 2016)

Table 3. New energy levels discovered as lower levels of the excited transitions

New lower level			Line			Combining upper level			Observed fluorescence line from upper level			Lower level of LIF line		Ref. to col. 9
J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Even						**Odd**							
7/2	14429.047(15)	911(5)	5704.123	nl,e	12	9/2	31955.363	760(2)	3932.829	nl	5	7/2	6535.572	tw
			5820.611	nl,e	20	9/2	31604.60	742(2)	3738.921	nl	6	11/2	4866.515	tw
			9762.631	cl	5	7/2	24669.405	745(1)						G96
	Odd						**Even**							
9/2	15396.135(15)	719(2)	4946.362	nl	4	9/2	35607.370	665(5)						tw
			5598.150	cl	26	11/2	33254.220	583(5)						tw
			5647.893	nl	12	11/2	33096.929	660(5)						tw
			5682.49	nl,e	1	11/2	32989.188	478(5)	4762.376	nl	8	11/2	11997.137	tw
			5714.22	nl,e	1	11/2	32891.473	399(4)	4784.648		6	11/2	11997.137	tw
			5786.793	nl	4	11/2	32672.078	529(3)						tw
			5825.84	nl,e	1	9/2	32556.286	679(5)	4862.656	nl	12	11/2	11997.137	tw
			5878.396	nl,e	12	9/2	32402.860	544(2)	4744.046	nl	25	9/2	11329.696	U12
			5995.548	nl,e	5	7/2	32070.559	668(2)	4820.053		20	9/2	11329.696	U12
			6043.80	nl,e	1	7/2	31937.43	641(3)	4851.192	nl	4	9/2	11329.696	tw
			6123.70	nl,e	1	9/2	31721.60	574(3)	4900.80	nl	1	9/2	11322.443	tw
			6145.11	nl	1	7/2	31664.74	732(4)	4916.246	nl	3	9/2	11329.696	tw
			6145.287	nl,e	3	11/2	31664.262	601(2)	4916.362		12	9/2	11329.696	U12
			6171.956	nl,e	5	7/2	31593.97	641(4)	6050.73	nl	1	9/2	15071.618	tw
			6195.93	nl,e	1	7/2	31531.300	619(4)	5691.024	nl	1	5/2	13964.645	tw
			6261.353	nl	6	9/2	31362.709	622(3)						tw
			6273.258	nl,e	9	11/2	31332.402	628(3)	5555.083		25	13/2	13335.868	tw
			6372.878	nl	7	11/2	31083.290	620(2)						SSW16
			6439.79	nl,e	1	7/2	30920.300	420(5)	4883.761		17	7/2	10449.997	tw
			6551.97	nl,e	1	7/2	30654.508	599(3)	4781.251	nl	5	5/2	9745.334	tw
			6616.346	nl,e	5	9/2	30506.050	675(2)	5213.30	nl	1	9/2	11329.696	G96
			7075.92	nl,e	1	11/2	29524.677	493(3)	3386.024	nl	20	9/2	0.000	
			8732.880	cl	6	11/2	26843.963	624(2)						tw
			9118.367	nl	7	7/2	26360.014	877(5)						G96
9/2	17518.399(15)	847(4)	6111.25	nl,e	1	9/2	33877.134	609(4)	4843.484		8	7/2	13236.606	tw
			7449.325	nl	5	9/2	30938.737	634(3)						
			7566.54	nl,e	1	9/2	30730.841	668(3)	4929.385		15	7/2	10449.997	G96
11/2	16933.404(15)	541(2)	5913.12	nl,e	1	6.5	33840.270	540(3)	3225.548	nl	5	13/2	2846.741	tw
			5933.723	cl,e	20	11/2	33781.556	517(3)	5759.010	nl	5	11/2	16422.282	tw
			6352.019	nl,e	5	11/2	32672.078	529(3)	6071.057		10	13/2	16205.041	tw

Table 4. Lines classified by the newly discovered even levels

Abbreviations in col. 11: CG81 (Childs & Goodman 1981), G96 (Guthöhrlein 1996-2005)

New upper even level			Line			Combining known lower odd levels				Ref. to cols. 9,10
J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	A (MHz)	B (MHz)	
1	2	3	4	5	6	7	8	9	10	11
7/2	22486.816	948(5)	4445.802	nl,f	7	4.5	0.000	926.209	-11.878	CG81
			7022.178	cl,e	53	4.5	8250.141	213.531	-4.136	CG81
			8448.802	nl	3	3.5	10654.060	169(2)		G96
7/2	26121.377	805(5)	5594.030	nl,e,f	22	4.5	8250.141	213.531	-4.136	CG81
			6792.357	nl,e,f	18	3.5	11403.011	1142(3)		G96
7/2	27123.623	684(3)	3685.77	nl,f	3	4.5	0.000	926.209	-11.878	CG81
			5296.965	nl,f	20	4.5	8250.141	213.531	-4.136	CG81
			6070.127	nl,e	8	3.5	10654.053	169(2)		G96
			6255.292	nl,e	21	2.5	11141.576	169(2)		G96
			6494.682	nl,f	10	4.5	11730.668	1365(5)		G96
			7209.096	cl	8	2.5	13256.082	1074(3)		G96
			7273.985	cl	8	4.5	13379.788	932(1)	10(20)	G96
	and so on									

Full version of Table 4: see Appendix

Table 5. Lines classified by the newly discovered odd levels

Abbreviations in col. 11: K96 (Kuwamoto et al. 1996), G96 (Guthöhrlein 1996-2005)

New upper odd level			Line			Combining known lower even levels				Ref. to cols. 9,10
J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	A (MHz)	B (MHz)	
1	2	3	4	5	6	7	8	9	10	11
7/2	20012.862	1133(5)	7045.286	nl,e	10	4.5	5822.890	855.8(4)	-17(7)	K96
			8793.405	nl	12	4.5	8643.824	797(2)		G96
			9903.501	cl	55	3.5	9918.190	1057.4(5)	22(6)	K96

7/2	21975.458	344(3)	5698.622	nl,e	10	4.5	4432.225	923.2(4)	-22(7)	K96
			6189.254	cl,f	10	4.5	5822.890	855.8(4)	-17(7)	K96
			6440.004	nl,e	28	2.5	6451.808	1189.6(6)	-5(5)	K96
			7498.891	nl	11	4.5	8643.824	797(2)		G96
			7551.988	nl	12	2.5	8737.556	1149(5)		G96
			8604.434	nl	7	4.5	10356.737	1406(1)		G96
			9588.908	cl	12	4.5	11549.602	1064(2)		G96
			9678.690	cl	10	2.5	11646.312	1317(10)		G96
	and so on									

Full version of Table 5: see Appendix

6. Conclusion

Experimental investigation of the hyperfine structure of Pr I lines is reported in this paper. The investigation resulted in the discovery of 70 Pr I fs levels having even and odd parity. The magnetic dipole interaction constants A of all new levels could be determined, and for one level also the very small electric quadrupole interaction constant B. The investigation is carried out in the spectral regions of Rhodamine 6G, Sulforhodamine B, DCM and Stilbene 3. Furthermore the discovery of these levels led to the classification of ca. 670 praseodymium spectral lines.

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Appendix: Full versions of Tables 4 and 5

Table 4. Lines classified by the newly discovered even levels.

Abbreviations in col. 11: tw ... this work, CG81 (Childs & Goodman 1981), G96 (Guthöhrlein 1996-2005), K96 (Kuwamoto et al. 1996), KF97 (Krzykowski, Furmann, Stefanska, Jarosz & Kajoch, 1997), SSW16 (Siddiqui, Shamim & Windholz 2016), U12a (Uddin et al. 2012a), SSW14 (Siddiqui, Shamim & Windholz 2014)

New upper even level			Line			Combining known lower odd levels				Ref. to cols. 9,10
J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	A (MHz)	B (MHz)	
1	2	3	4	5	6	7	8	9	10	11
7/2	22486.816(20)	948(5)	4445.802	nl,f	7	9/2	0.000	926.209	-11.878	CG81
			7022.178	cl,e	53	9/2	8250.141	213.531	-4.136	CG81
			8448.802	nl	3	7/2	10654.060	169(2)		G96
7/2	26121.377(15)	805(5)	5594.030	nl,e,f	22	9/2	8250.141	213.531	-4.136	CG81
			6792.357	nl,e,f	17	7/2	11403.011	1142(3)		G96
7/2	27123.623(15)	684(3)	3685.77	nl,f	3	9/2	0.000	926.209	-11.878	CG81
			5296.965	nl,f	20	9/2	8250.141	213.531	-4.136	CG81
			6070.127	nl,e	8	7/2	10654.053	169(2)		G96
			6255.292	nl,e	21	2.5	11141.576	169(2)		G96
			6494.682	nl,f	10	9/2	11730.668	1365(5)		G96
			7209.096	cl	8	2.5	13256.082	1074(3)		G96
			7273.985	cl	8	9/2	13379.788	932(1)	10(20)	G96
7/2	27231.854(15)	773(3)	5266.763	nl,f	14	9/2	8250.141	213.531	-4.136	CG81
			6135.075	nl,e	6	9/2	10936.652	930(1)	0(10)	G96
			6213.214	nl,f	10	2.5	11141.576	169(2)		G96
			6449.336	nl,f	12	9/2	11730.668	1365(5)		G96
			7153.27	nl,e	1	2.5	13256.082	1074(3)		G96
			7217.149	nl,e	9	9/2	13379.788	932(1)	10(20)	G96
7/2	27381.792(15)	662(3)	5668.50	nl,f	20	2.5	9745.334	626.4(3)	5(3)	K96
			5976.44	cl.f	6	7/2	10654.053	169(2)		G96
			6256.568	cl,e	30	7/2	11403.011	1142(3)		G96
			6387.551	cl,e	6	9/2	11730.668	1365(5)		G96
			6545.725	nl,e	8	2.5	12108.867	1275(2)		G96
			7139.865	nl	7	9/2	13379.788	932(1)	10(20)	G96
			7968.417	nl	4	2.5	14835.699	1414(5)		G96
7/2	27679.200(20)	654(5)	3611.792	nl	3	9/2	0	926.209	-11.878	CG81
			5145.496	nl,f	8	9/2	8250.141	213.531	-4.136	CG81
			5574.496	nl,f	22	2.5	9745.334	626.4(3)	5(3)	K96
			5802.49	nl,e	1	7/2	10449.997	541(2)		G96
			6045.14	nl,e	1	2.5	11141.576	169(2)		G96
			6991.366	cl,f	18	9/2	13379.788	932(1)	10(20)	G96
7/2	27998.766(20)	520(4)	6145.299	nl,e,f	9	9/2	11730.668	1365(5)		G96
			6586.785	cl,e,f	8	9/2	12821.044	1127(3)		G96
			6629.709	nl,e	6	7/2	12919.316	180(2)		G96
7/2	30654.508(20)	599(3)	4781.251	nl,f	5	5/2	9745.334	626.4(3)	5(3)	K96
			5173.255	nl,f	12	9/2	11329.696	530(3)		G96
			5373.53	nl,f	1	9/2	12049.942	275(2)		G96
			5605.879	nl,f	10	9/2	12821.044	1127(3)		G96
			5778.53	nl,e	1	9/2	13354.043	1273(3)		G96
			5869.29	nl,e	24	7/2	13621.400	879(1)		G96
			6006.045	nl,f	4	7/2	14009.225	1100(1)		G96
			6551.97	nl,e	1	9/2	15396.135	719(2)		tw
7/2	30920.290(20)	420(5)	4684.624	nl	2	9/2	9579.820	789(1)		G96
			4883.762	cl,f	17	7/2	10449.997	541(2)		G96
			5103.07	nl,f	1	9/2	11329.696	530(3)		G96
			6101.124	nl	6	9/2	14534.393	100(2)		G96
			6439.79	nl,e	1	9/2	15396.135	719(2)		tw
7/2	31531.300(15)	619(4)	3170.53	nl,f	1	9/2	0.000	926.209	-11.878	CG81
			5691.024	nl,f	20	5/2	13964.645	185(2)		G96
			5881.793	nl,f	3	9/2	14534.393	100(2)		G96
			5987.943	nl,f	15	5/2	14835.699	1414(5)		G96
			6195.93	nl,e	1	9/2	15396.135	719(2)		tw
7/2	31593.97(3)	642(4)	4575.66	nl,f	1	5/2	9745.334	626.4(3)		K96
			5670.796	nl,f	10	5/2	13964.645	185(2)		G96
			6050.73	nl,e,f	1	9/2	15071.618	635(3)		G96
			6171.958	nl,e	5	9/2	15396.135	719(2)		tw
7/2	31664.74(3)	732(4)	4916.246	nl,f	3	9/2	11329.696	530(3)		G96
			5940.46	nl,e	1	5/2	14835.699	1414(5)		G96
			6145.11	nl,e	1	9/2	15396.135	719(2)		tw
7/2	31937.43(3)	641(3)	4652.58	nl,f	1	7/2	10449.997	541(2)		G96
			4851.192	nl,e	3	9/2	11329.696	530(3)		G96
			5256.68	nl,f	1	7/2	12919.316	180(2)		G96

			5351.44	nl,f	1	5/2	13256.082	1074(3)		G96
			5562.418	nl,f	20	5/2	13964.645	185(2)		G96
			5927.51	nl,e	1	9/2	15071.618	635(3)		G96
			6043.80	nl,f,e	1	9/2	15396.135	719(2)		tw
9/2	22825.611(20)	570(5)	4379.813	nl,f	5	9/2	0.000	926.209	-11.878	CG81
			4660.916	cl,f	270	11/2	1376.602	730.393	-11.877	CG81
			7145.88	nl,e	1	11/2	8835.389	949.091	-13.721	CG81
9/2	22996.562(20)	779(5)	4347.255	nl	5	9/2	0.000	926.209	-11.878	CG81
			4624.060	nl,f	95	11/2	1376.602	730.393	-11.877	CG81
			7059.610	cl,e	76	11/2	8835.389	949.091	-13.721	CG81
9/2	24606.934(10)	777(2)	4303.507	nl,f	41	11/2	1376.602	730.393	-11.877	CG81
			6111.977	cl,e	62	9/2	8250.141	213.531	-4.136	CG81
			7052.620	nl,e	7	11/2	10431.716	701.7(5)	-10(7)	KF97
9/2	25744.156(10)	823(3)	3883.276	nl,f	10	9/2	0.000	926.209	-11.878	CG81
			5659.740	nl,e	15	11/2	8080.402	238.352	-22.961	CG81
			5912.451	e	45	11/2	8835.389	949.091	-13.721	CG81
			6751.469	cl	20	9/2	10936.652	930(1)	0(10)	G96
9/2	26231.182(10)	645(3)	6327.578	e,f	30	11/2	10431.716	701.7(5)	-10(7)	KF97
			6536.480	nl	8	9/2	10936.652	930(1)	0(10)	G96
			6705.623	nl,e	10	11/2	11322.443	1272(1)	75(50)	G96
			6894.405	cl	20	9/2	11730.668	1365(5)		G96
			8762.130	cl	22	11/2	14821.565	544/2)		SSW16
9/2	27109.750(20)	783(3)	3687.661	nl,f	14	9/2	0.000	926.209	-11.878	CG81
			5253.579	nl,f	14	11/2	8080.402	238.352	-22.961	CG81
			5300.862	cl,f	42	9/2	8250.141	213.531	-4.136	CG81
			6075.244	cl,e	132	7/2	10654.053	169(2)		G96
			6181.40	nl,e	35	9/2	10936.652	930(1)	0(10)	G96
			6500.543	cl,e	7	9/2	11730.668	1365(5)		G96
			7271.13	nl,e	1	11/2	13360.511	151(3)		G96
9/2	27282.002(15)	750(3)	5419.539	nl,f	10	11/2	8835.389	949.091	-13.721	CG81
			5647.454	nl,e	16	9/2	9579.820	789(1)		G96
			6266.953	cl,f	4	9/2	11329.696	530(3)		G96
			6428.537	cl,f	7	9/2	11730.668	1365(5)		G96
			6630.473	cl,e	11	11/2	12204.286	1010(2)		G96
			8023.198	nl	5	11/2	14821.565	544(2)		G96
9/2	27913.895(15)	496(3)	3767.21	cl,f	1	11/2	1376.602	730.393	-11.877	CG81
			5240.04	nl,f	1	11/2	8835.389	949.091	-13.721	CG81
			5888.603	cl,e	18	9/2	10936.652	930(1)	0(10)	G96
			6025.531	cl,e	22	11/2	11322.443	1272(1)	75(50)	G96
			6363.774	cl,f	22	11/2	12204.286	1010(2)		G96
9/2	30938.737(15)	634(3)	4879.36	nl,f	1	7/2	10449.997	541(2)		G96
			5685.186	nl,f	5	9/2	13354.043	1272(3)		G96
			5772.959	nl,f	16	7/2	13621.400	879(1)		G96
			5981.884	nl,f,e	6	11/2	14226.220	869(3)		G96
			6094.26	nl,e	1	9/2	14534.393	100(2)		G96
			7138.169	nl	4	11/2	16933.404	541(2)		tw
			7449.325	nl	5	9/2	17518.399	847(4)		tw
9/2	31362.709(15)	622(3)	4589.47	nl,f	1	9/2	9579.820	789(1)		G96
			4988.56	nl,f	1	11/2	11322.443	1272(1)	75(50)	G96
			5162.365	nl,f	12	11/2	11997.137	585(3)		G96
			5553.338	nl,f	10	11/2	13360.511	151(3)		G96
			6010.168	cl	10	11/2	14728.843	811(2)		G96
			6043.863	nl,e	5	11/2	14821.570	544(2)		SSW16
			6261.353	nl	6	9/2	15396.135	719(2)		tw
			6497.932	cl	5	11/2	15977.45	66(3)		G96
9/2	31721.60(5)	574(3)	4900.80	nl,f	1	11/2	11322.443	1272(1)	75(50)	G96
			5442.87	nl,f	1	9/2	13354.043	1273(3)		G96
			5523.27	nl,f	1	7/2	13621.400	879(1)		G96
			5644.21	nl	1	7/2	14009.225	1100(1)		G96
			6123.70	nl,e	1	9/2	15396.135	719(2)		tw
9/2	32556.286(15)	679(5)	3206.29	nl,f	1	11/2	1376.602	730.393	-11.877	CG81
			4709.75	nl,f	3	9/2	11329.696	530(3)		G96
			4862.656	cl,a	11	11/2	11997.137	585(3)		G96
			5547.27	nl,f	1	9/2	14534.393	100(2)		G96
			5665.50	nl,f	1	9/2	14910.476	611(2)		G96
			5825.84	nl,e	1	9/2	15396.135	719(2)		tw
			6030.118	nl,f	10	11/2	15977.45	66(3)		G96
			6079.29	nl,f	1	7/2	16111.538	1128(3)		G96
9/2	33877.134(15)	609(4)	4843.484	cl,f	8	7/2	13236.606	726(1)		G96
			5056.89	cl,f	1	7/2	14107.700	860(3)		G96
			5727.48	nl,e	2	11/2	16422.282	605(3)		G96
			6111.25	nl,e	1	9/2	17518.394	847(4)		tw
9/2	35607.370(15)	665(5)	3973.85	nl,f	1	7/2	10449.997	541(2)		G96
			4744.09	nl,f	1	9/2	14534.393	100(2)		G96
			4830.293	cl,e	11	9/2	14910.476	611(2)		G96

			4946.36	nl,f	2	9/2	15396.135	719(2)		tw
			5244.98	nl,f	1	11/2	16546.842	429(2)		SSW16
			5526.70	nl,f	1	9/2	17518.399	847(4)		tw
11/2	23654.406(10)	613(2)	6419.185	cl,e	20	11/2	8080.402	238.352	-22.961	CG81
			6489.916	cl,e,f	78	9/2	8250.141	213.531	-4.136	CG81
			6700.129	nl,e	5	13/2	8733.440	854.297	-31.807	CG81
			7156.112	cl	20	13/2	9684.184	991.907	-7.246	CG81
			7860.865	cl	12	9/2	10936.652	930(1)	0(10)	G96
			8615.006	nl	6	9/2	12049.942	275(2)		G96
11/2	23865.975(15)	752(2)	4445.297	nl,f	45	11/2	1376.602	730.393	-11.877	CG81
			6997.854	cl,e	22	9/2	9579.820	789(1)		G96
			7049.349	nl,e	5	13/2	9684.184	991.907	-7.246	CG81
11/2	25357.817(10)	669(3)	3942.441	nl,f	8	9/2	0.000	926.209	-11.878	CG81
			4168.755	nl,f	11	11/2	1376.602	730.393	-11.877	CG81
			6050.701	cl,e	24	11/2	8835.389	949.091	-13.721	CG81
			6336.191	cl,e	20	9/2	9579.820	789(1)		G96
			6697.824	cl,e	40	11/2	10431.716	701.7(5)	-10(7)	KF97
11/2	25855.320(10)	683(2)	3866.580	nl,f	8	9/2	0.000	926.209	-11.878	CG81
			5838.861	nl,e	7	13/2	8733.440	854.297	-31.807	CG81
			5873.834	nl,e	31	11/2	8835.389	949.091	-13.721	CG81
			6481.778	cl	48	11/2	10431.716	701.7(5)	-10(7)	KF97
			6879.052	cl	22	11/2	11322.443	1272(1)	75(50)	G96
			7077.868	nl	8	9/2	11730.668	1365(5)		G96
			7085.725	cl	10	13/2	11746.328	401(1)	50(20)	G96
			7241.556	nl	6	9/2	12049.942	275(2)		G96
11/2	26222.282(15)	590(3)	4023.707	nl,f	13	11/2	1376.602	730.393	-11.877	CG81
			4276.771	nl,f	8	13/2	2846.741	613.240	-12.850	CG81
			5749.862	nl,e	12	11/2	8835.389	949.091	-13.721	CG81
			6007.065	cl,e	9	9/2	9579.820	789(1)		G96
			6044.970	cl,e	62	13/2	9684.184	991.907	-7.246	CG81
			6540.285	nl,f	16	9/2	10936.652	930(1)	0(10)	G96
			7131.724	nl	5	11/2	12204.286	1010(2)		G96
			7140.794	nl	5	13/2	12222.091	1133(4)		G96
11/2	26467.250(15)	857(2)	3984.422	nl,f	7	11/2	1376.602	730.393	-11.877	CG81
			5669.98	cl,e	12	11/2	8835.389	949.091	-13.721	CG81
			5956.74	nl,f	1	13/2	9684.184	991.907	-7.246	CG81
			7326.027	nl,e	8	9/2	12821.044	1127(3)		G96
11/2	26937.739(15)	720(5)	3711.208	nl,f	30	9/2	0.000	926.209	-11.878	CG81
			5491.679	cl,f	95	13/2	8733.440	854.297	-31.807	CG81
			5794.30	nl,e	1	13/2	9684.184	991.907	-7.246	CG81
			7359.74	nl,e	1	9/2	13354.043	1272(3)		G96
			7363.24	nl,e	1	11/2	13360.511	151(3)		G96
11/2	27888.407(20)	570(4)	3770.83	nl,f	1	11/2	1376.602	730.393	-11.877	CG81
			5726.871	nl,e	8	11/2	10431.716	701.7(5)	-10(7)	KF97
			6193.275	cl,e	23	13/2	11746.328	401(1)	50(20)	G96
			6374.113	nl,f	12	11/2	12204.286	1010(2)		G96
			7800.120	nl	5	9/2	15071.618	635(3)		G96
11/2	27985.186(15)	618(2)	3572.299	nl,f	20	9/2	0.000	926.209	-11.878	CG81
			5462.663	nl,f	6	13/2	9684.184	991.907	-7.246	CG81
			5688.503	nl,e	55	13/2	10410.745	655.9(3)	-29(7)	K96
			5695.298	cl,e	51	11/2	10431.716	701.7(5)	-10(7)	KF97
			6156.364	nl,f	8	13/2	11746.328	401(1)	50(20)	G96
			6844.894	cl	12	9/2	13379.788	932(1))	10(20)	G96
11/2	29524.677(15)	493(3)	3386.025	nl	20	9/2	0.000	926.209	-11.878	CG81
			3551.63	nl,f	1	11/2	1376.602	730.393	-11.877	CG81
			5012.43	nl,f	1	9/2	9579.820	789(1)		G96
			5230.327	cl	40	13/2	10410.736	655.9(3)	-29(7)	K96
			6175.40	nl,e	1	13/2	13335.868	895(1)	100(50)	G96
			6192.193	nl,e	17	9/2	13379.788	932(1)	10(20)	G96
			6534.800	nl,f	3	11/2	14226.220	869(3)		G96
			6891.518	nl,f	3	13/2	15018.088	108(3)		G96
			7075.92	nl,e	1	9/2	15396.135	719(2)		tw
11/2	31332.402(15)	628(3)	3337.290	nl	2	11/2	1376.602	730.393	-11.877	CG81
			4595.869	cl,f	9	9/2	9579.820	789(1)		G96
			4997.932	nl	4	9/2	11329.696	530(3)		G96
			5104.245	nl	7	13/2	11746.328	401(1)	50(20))	G96
			5555.083	cl,f	25	13/2	13335.868	895(1)	100(50)	G96
			5844.222	nl	6	11/2	14226.220	869(3)		G96
			6273.258	nl	9	9/2	15396.135	719(2)		tw
			6376.54	nl	1	13/2	15654.235	577(1)		SSW16
			6761.49	nl	1	11/2	16546.842	429(2)		SSW16
11/2	32672.078(15)	529(3)	4684.206	nl,f	4	9/2	11329.696	530(3)		G96
			4835.418	cl,f	17	11/2	11997.137	585(3)		G96
			5675.71	nl,f	1	13/2	15058.01	693(3)		tw
			5770.52	nl,e	1	13/2	15347.431	674(2)		U12a

			5786.790	nl,f	5	9/2	15396.135	719(2)		tw
			5874.56	nl,f	5	13/2	15654.235	577(1)		SSW16
			5988.29	nl,e	1	11/2	15977.45	66(3)		G96
			6071.057	cl,e	10	13/2	16205.041	733(2)		U12a
			6352.019	nl,e	5	11/2	16933.404	541(2)		tw
11/2	32891.473(15)	399(4)	4634.98	nl,f	1	11/2	11322.443	1272(1)	75(50)	G96
			4784.648	cl,f	6	11/2	11997.137	585(3)		G96
			5593.36	nl,e	1	13/2	15018.088	108(3)		G96
			5648.07	nl,e	1	13/2	15191.218	666(5)		U12a
			5714.22	nl,e	1	9/2	15396.135	719(2)		tw
			5799.785	nl,e	7	13/2	15654.235	577(1)		SSW16
			7202.48	nl,e	1	11/2	19011.200	844(5)		tw
11/2	32989.188(20)	478(5)	4615.624	nl,f	4	9/2	11329.696	530(3)		G96
			4762.376	nl,f	8	11/2	11997.137	585(3)		G96
			5682.49	nl,e	1	9/2	15396.135	719(2)		tw
			5956.362	cl,e	5	13/2	16205.041	733(2)		U12a
11/2	33096.940(20)	660(5)	3304.812	nl,f	3	13/2	2846.741	613.240	-12.850	CG81
			4738.054	nl,f	3	11/2	11997.137	585(3)		G96
			5385.69	nl,f	1	9/2	14534.393	100(2)		G96
			5546.210	nl,f	15	9/2	15071.618	635(3)		G96
			5647.893	nl,e	12	9/2	15396.135	719(2)		tw
			5995.465	nl,e	6	11/2	16422.282	605(3)		G96
11/2	33254.220(15)	583(5)	5340.444	nl,f	5	9/2	14534.393	100(2)		G96
			5498.235	nl,f	3	9/2	15071.618	635(3)		G96
			5582.924	nl,f	3	13/2	15347.431	674(2)		U12a
			5598.150	cl,e	26	9/2	15396.135	719(2)		tw
			5939.440	cl	9	11/2	16422.282	605(3)		G96
11/2	33781.556(15)	517(3)	3231.67	nl,f	1	13/2	2846.741	613.240	-12.850	CG81
			5437.584	nl,f	9	9/2	15396.135	719(2)		tw
			5687.833	nl,e	4	13/2	16205.041	733(2)		U12a
			5759.01	nl,e	5	11/2	16422.282	605(3)		G96
			5933.723	cl,e	20	11/2	16933.404	541(2)		tw
13/2	19111.800(10)	760(2)	5636.940	cl,e	140	11/2	1376.602	730.393	-11.877	CG81
			6146.447	nl,e	24	13/2	2846.741	613.240	-12.850	CG81
			7086.57	nl,e	1	13/2	33219.119	671(1)		SSW16
			7586.510	cl	10	11/2	32289.455	665(1)		U12a
			9632.785	cl	4	13/2	8733.440	854.297	-31.807	CG81
13/2	22592.830(15)	500(5)	5062.883	cl,f	205	13/2	2846.741	613.240	-12.850	CG81
			5489.434	nl	18	15/2	4381.072	541.575	-14.558	CG81
			6888.746	cl,e	22	11/2	8080.402	238.352	-22.961	CG81
			8384.228	cl	9	15/2	10668.950	951.310	-2.670	CG81
13/2	24722.464(15)	703(2)	4282.21	nl,f	1	11/2	1376.602	730.393	-11.877	CG81
			4570.00	nl,f	1	13/2	2846.741	613.240	-12.850	CG81
			4914.712	cl,e	160	15/2	4381.072	541.575	-14.558	CG81
			6252.560	cl,e	9	13/2	8733.440	854.297	-31.807	CG81
			7113.695	cl	9	15/2	10668.950	951.310	-2.670	CG81
13/2	27020.835(15)	632(3)	3898.408	nl,f	28	11/2	1376.602	730.393	-11.877	CG81
			4135.493	nl,f	5	13/2	2846.741	613.240	-12.850	CG81
			4415.767	nl,e	4	15/2	4381.072	541.575	-14.558	CG81
			5754.13	nl,f	1	15/2	9646.830	907.515	-23.132	CG81
			6026.379	cl,e	70	11/2	10431.716	701.7(5)	-10(7)	KF97
			6368.318	nl,f	50	11/2	11322.443	1272(1)	75(50)	G96
			6747.350	nl,f	36	11/2	12204.286	1010(2)		G96
			6755.465	cl	20	13/2	12222.091	1133(4)		G96
			7305.278	nl,f	5	13/2	13335.868	895(1)	100(50)	G96
			7318.457	nl	11	11/2	13360.511	151(3)		G96
13/2	27150.550(15)	536(3)	3878.79	nl,f	2	11/2	1376.602	730.393	-11.877	CG81
			4113.421	nl,f	8	13/2	2846.741	613.240	-12.850	CG81
			5428.225	nl,f	5	13/2	8733.440	854.297	-31.807	CG81
			5711.488	nl,e	12	15/2	9646.830	907.515	-23.132	CG81
			6065.693	cl,e	32	15/2	10668.950	951.310	-2.670	CG81
			6688.793	cl,e	14	11/2	12204.286	1010(2)		G96
			6696.766	cl,f	7	13/2	12222.091	1133(4)		G96
			7236.686	cl	11	13/2	13335.868	895(1)	100(50)	G96
			7249.619	cl	12	11/2	13360.511	151(3)		G96
			7603.473	cl	30	11/2	14002.294	566(2)		G96
13/2	27340.868(15)	557(2)	5650.054	nl,f	15	15/2	9646.830	907.515	-23.132	CG81
			5662.01	nl,e	1	13/2	9684.184	991.907	-7.246	CG81
			5996.449	cl,e	28	15/2	10668.950	951.310	-2.670	CG81
			6438.939	cl,f	12	15/2	11814.647	355(2)	0(10)	G96
			6612.468	cl	12	13/2	12222.091	1133(4)		G96
13/2	27519.089(15)	487(3)	3824.103	nl,f	5	11/2	1376.602	730.393	-11.877	CG81
			4051.974	nl,f	4	13/2	2846.741	613.240	-12.850	CG81
			5593.710	nl,f	10	15/2	9646.830	907.515	-23.132	CG81
			5933.025	cl,e	48	15/2	10668.950	951.310	-2.670	CG81

			6172.410	cl,e	47	11/2	11322.443	1272(1)	75(50)	G96
			6365.865	cl	12	15/2	11814.647	355(2)	0(10)	G96
			7048.643	cl	13	13/2	13335.868	895(1)	100(50)	G96
			7520.76	nl,e	4	11/2	14226.220	869(3)		G96
13/2	27626.232(15)	443(3)	6131.847	cl,f	22	11/2	11322.443	1272(1)	75(50)	G96
			6295.526	cl,f	24	13/2	11746.328	401(1)	50(20)	G96
			6489.97	nl,e	5	13/2	12222.091	1133(4)		G96
			6836.090	nl,e	17	15/2	13002.023	317(2)	30(50)	G96
			7007.878	cl,e	6	11/2	13360.511	151(3)		G96
13/2	27821.680(25)	644(5)	5828.360	nl,f	8	15/2	10668.950	951.310	-2.670	CG81
			6218.985	nl,f	6	13/2	11746.328	401(1)	50(20)	G96
			6408.654	cl,f	22	13/2	12222.091	1133(4)		G96
			6745.932	cl,e	15	15/2	13002.023	317(2)	30(50)	G96
13/2	33840.270(20)	540(3)	3225.548	nl,f	5	13/2	2846.741	613.240	-12.850	CG81
			5660.918	nl,e	5	15/2	16180.200	883(2)		SSW14
			5705.48	nl,e	1	13/2	16318.118	281(1)		G96
			5739.60	nl,e	1	11/2	16422.282	605(3)		G96
			5780.94	nl,e	1	11/2	16546.842	429(2)		SSW16
			5913.12	nl,e	1	11/2	16933.404	541(2)		tw
			6230.529	nl	3	15/2	17794.708	221(2)		SSW14

Table 5. Lines classified by the newly discovered odd levels

Abbreviations in col. 11: tw ... this work, CG81 (Childs & Goodman 1981), G96 (Guthöhrlein 1996-2005), K96 (Kuwamoto et al. 1996), U12a (Uddin et al. 2012a)

New upper even level			Line			Combining known lower odd levels				Ref. to cols. 9,10
J	Energy (cm^{-1})	A (MHz)	Lambda (Å)	C.	SNR	J	Energy (cm^{-1})	A (MHz)	B (MHz)	
1	2	3	4	5	6	7	8	9	10	11
7/2	20012.862(15)	1133(5)	7045.286	nl,e	10	9/2	5822.890	855.8(4)	-17(7)	K96
			8793.405	nl	12	9/2	8643.824	797(2)		G96
			9903.501	cl	55	7/2	9918.190	1057.4(5)	22(6)	K96
7/2	21975.458(10)	344(3)	5698.622	nl,e	20	9/2	4432.225	923.2(4)	-22(7)	K96
			6189.254	cl,f	10	9/2	5822.890	855.8(4)	-17(7)	K96
			6440.004	nl,e	28	5/2	6451.808	1189.6(6)	-5(5)	K96
			7498.891	nl	11	9/2	8643.824	797(2)		G96
			7551.988	nl	12	5/2	8737.556	1149(5)		G96
			8604.434	nl	7	9/2	10356.737	1406(1)		G96
			9588.908	cl	12	9/2	11549.602	1064(2)		G96
			9678.690	cl	10	5/2	11646.312	1317(10)		G96
7/2	22451.973(15)	1125(4)	5547.926	nl	34	9/2	4432.225	923.2(4)	-22(7)	K96
			6248.203	nl,e	70	5/2	6451.808	1189.6(6)	-5(5)	K96
			7240.105	cl,e	45	9/2	8643.824	797(2)		G96
			7289.586	nl	5	5/2	8737.556	1149(5)		G96
			7490.283	cl,e	6	9/2	9105.021	689.7(3)	-3(5)	K96
			7976.244	nl	8	7/2	9918.190	1057.4(5)	22(6)	K96
			8156.221	nl	8	7/2	10194.768	855(1)		G96
			8265.447	cl	12	9/2	10356.737	1406(1)		G96
			8943.890	cl	34	7/2	11274.229	1286(1)	-10(20)	G96
			9169.796	cl	19	9/2	11549.602	1064(2)		G96
			9637.438	cl	24	5/2	12078.621	1566(1)		G96
7/2	23293.356(15)	759(3)	5300.434	cl	60	9/2	4432.225	923.2(4)	-22(7)	K96
			5722.360	nl,e	19	9/2	5822.890	855.8(4)	-17(7)	K96
			5936.053	nl,e	55	5/2	6451.808	1189.6(6)	-5(5)	K96
			5965.723	cl,e	12	7/2	6535.572	979(1)	25(30)	G96
			8256.077	cl	12	9/2	11184.396	692(1)	15(30)	G96
			8457.236	cl	8	7/2	11472.410	273(3)		G96
			8751.048	nl	3	7/2	11869.290	210(1)		G96
			9834.371	nl	5	5/2	13127.722	156(1)	0(10)	G96
7/2	24443.790(10)	1046(3)	5582.478	cl,f	90	7/2	6535.572	979(1)	25(30)	G96
			6785.521	nl	7	5/2	9710.600	164(2)		G96
			7016.088	cl,e	8	7/2	10194.768	855(1))		G96
			7496.383	nl,e	6	5/2	11107.696	658(2)		G96
			7591.178	nl	7	7/2	11274.229	1286(1)	-10(20)	G96
			7950.415	nl	3	7/2	11869.290	210(1)		G96
			8357.456	cl	6	5/2	12481.714	937(1)	20(20)	G96
			8477.849	nl	4	9/2	12651.586	723(3)		G96
			9091.907	cl	9	5/2	13448.016	825(1)	25(30)	G96
7/2	25350.082(15)	1074(3)	4779.268	cl,f	45	9/2	4432.225	929(1)	-22(7)	K96
			5290.019	cl,f	35	5/2	6451.808	1189.6(6)	-5(5)	K96
			5313.568	nl,f	25	7/2	6535.572	979(1)	25(30)	G96
			5984.123	cl,e	38	9/2	8643.824	797(2)		G96

			6478.293	cl,e	14	7/2	9918.190	1057.4(5)	22(6)	G96
			7057.366	nl	6	9/2	11184.396	692(1)	15(30)	G96
			7307.241	nl	3	7/2	11668.794	805(2)		G96
			7526.755	nl,e	3	9/2	12067.802	873(6)		G96
			7872.786	nl	12	9/2	12651.586	723(3)		G96
7/2	25788.548(15)	138(6)	5007.20	nl,f	1	9/2	5822.890	855.8(4)	-17(7)	K96
			5192.556	nl,f	7	7/2	6535.572	979(1)	25(30)	G96
			5501.713	nl,f	40	7/2	7617.440	866.9(5)	-4(5)	G96
			5624.172	cl,e	70	7/2	8013.089	168(1)		G96
			5723.065	nl	10	9/2	8320.240	255(2)		G96
			5831.080	nl,e	11	9/2	8643.824	797(2)		G96
			5863.136	nl,f	11	5/2	8737.556	1149(5)		G96
			6215.714	nl,f	15	7/2	9704.744	779(1)	-50(30)	G96
			7590.434	nl	5	7/2	12617.700	883(2)		G96
7/2	26915.490(15)	1122(3)	4446.504	nl,f	12	9/2	4432.225	923.2(4)	-22(7)	K96
			4739.673	nl,f	4	9/2	5822.890	855.8(4)	-17(7)	K96
			4905.42	cl,f	4	7/2	6535.572	979(1)	25(30)	G96
			5288.863	cl,f	40	7/2	8013.089	168(1)		U12a
			5613.118	nl,e	7	9/2	9105.021	689.7(3)	-3(5)	K96
			5808.71	nl,e	1	7/2	9704.744	779(1)	-50(30)	G96
			6547.334	nl,e	6	5/2	11646.312	1317(10)		G96
			7055.51	nl,e	1	9/2	12746.067	982(1)	10(10)	G96
			7853.830	cl	7	9/2	14186.352	910(1)	-60(30)	G96
7/2	27852.358(15)	868(4)	4268.629	nl,f	12	9/2	4432.225	923.2(4)	-22(7)	K96
			4671.467	cl	8	5/2	6451.808	1189.6(6)	-5(5)	K96
			5043.218	cl	38	9/2	8029.275	797(2)		G96
			5661.72	nl,e	1	7/2	10194.768	855(1)		G96
			7469.521	nl,e	3	9/2	14468.303	762(2)	20(20)	G96
7/2	27890.013(15)	877(5)	4261.78	nl,f	1	9/2	4432.225	923.2(4)	-22(7)	K96
			4530.358	nl,f	8	9/2	5822.890	855.8(4)	-17(7)	K96
			4663.26	nl,f	1	5/2	6451.808	1189.6(6)	-5(5)	K96
			4681.56	nl,f	1	7/2	6535.572	979(1)	25(30)	G96
			4931.396	cl.f	4	7/2	7617.440	866.9(5)	-4(5)	K96
			5033.66	nl,f	1	9/2	8029.275	797(2)		G96
			5219.809	nl,f	7	5/2	8737.556	1149(5)		G96
			5649.665	nl,e	21	7/2	10194.768	855(1)		G96
			6504.25	nl,e	1	9/2	12519.705	693(3)		G96
9/2	21063.222(15)	1093(2)	6011.225	cl,f	30	9/2	4432.225	923.2(4)	-22(7)	K96
			6172.386	nl	11	11/2	4866.515	867.997	-50.319	CG81
			6777.789	cl	5	11/2	6313.224	756(1)		G96
			6967.185	nl,e	7	11/2	6714.184	474.692	-29.633	CG81
			7055.071	cl,e	15	11/2	6892.934	551.934	-24.736	CG81
			7435.228	nl,e	5	7/2	7617.440	866.9(5)	-4(5)	K96
			8171.588	nl	8	11/2	8829.063	769(1)	-30(20)	G96
9/2	22395.393(15)	724(4)	5703.289	nl,f	7	11/2	4866.515	867.997	-50.319	CG81
			6216.347	nl,f	10	11/2	6313.224	756(1)		G96
			6303.498	nl,f	21	7/2	6535.572	979(1)	25(30)	G96
			6448.806	cl	42	11/2	6892.934	551.934	-24.736	CG81
			7269.895	cl,e	44	9/2	8643.824	797(2)		G96
			7369.161	nl,e	6	11/2	8829.063	769(1)	-30(20)	G96
			8194.047	cl	10	7/2	10194.768	855(1)		G96
			8304.292	nl	8	9/2	10356.737	1406(1)		G96
			8917.363	nl	7	9/2	11184.396	692(1)	15(30)	G96
			8996.381	cl	18	11/2	11282.865	1049(2)		G96
			9839.067	nl	3	11/2	12234.616	1164(2)		G96
9/2	22524.055(10)	1129(2)	6252.774	cl,e,f	75	7/2	6535.572	979(1)	25(30)	G96
			6706.579	cl,e,f	20	7/2	7617.440	866.9(5)	-4(5)	K96
			7542.062	cl	15	11/2	9268.726	977(1)	-24(20)	G96
			7666.289	nl	3	11/2	9483.518	731(1)	-15(10)	G96
			8603.474	cl	12	11/2	10904.034	301(1)	-20(10)	G96
			8816.190	nl	8	9/2	11184.396	692(1)	15(30)	G96
			8893.417	cl	14	11/2	11282.865	1049(2)		G96
			9045.942	nl	3	7/2	11472.410	273(3)		G96
			9109.571	cl	20	9/2	11549.602	1064(2)		G96
			9247.454	cl	16	9/2	11713.236	818(2)		G96
			9449.344	cl	26	11/2	11944.207	1003(1)		G96
9/2	23008.838(10)	1227(2)	5381.616	cl,f	105	9/2	4432.225	929(1)	-22(7)	K96
			5510.442	nl,f	21	11/2	4866.515	867.997	-50.319	CG81
			6666.715	cl,e	22	7/2	8013.089	168(1)		U12a
			6673.919	cl,e	41	9/2	8029.275	797(2)		G96
			7275.959	nl	7	11/2	9268.726	977(1)	-24(20)	G96
			8525.734	cl	55	11/2	11282.865	1049(2)		G96
			8850.571	cl	16	9/2	11713.236	818(2)		G96
			9035.326	cl	50	11/2	11944.207	1003(1)		G96
			9278.867	cl	32	11/2	12234.616	1169(2)		G96

			9531.065	cl	8	9/2	12519.705	693(3)		G96
9/2	23934.491(10)	785(3)	5242.935	nl,f	14	11/2	4866.515	867.997	-50.319	CG81
			5519.790	cl	20	9/2	5822.890	855.8(4)	-17(7)	K96
			5673.386	cl,e	116	11/2	6313.224	756(1)		G96
			5745.890	cl,e	50	7/2	6535.572	979(1)	25(30)	G96
			6126.861	cl,e	27	7/2	7617.440	866.9(5)	-4(5)	K96
			6618.310	cl,f	7	11/2	8829.063	769(1)	-30(20)	G96
			6816.719	cl	6	11/2	9268.726	977(1)	-24(20)	G96
			7362.963	nl	5	9/2	10356.737	1406(1)		G96
			7672.215	nl	3	11/2	10904.034	301(1)	-20(10)	G96
			8337.793	cl	7	11/2	11944.207	1003(1)		G96
			9504.223	cl	9	7/2	13415.739	797(2)		G96
			9846.493	cl	7	7/2	13781.374	807(1)		G96
9/2	24196.152(10)	714(4)	5058.313	cl,e	105	9/2	4432.225	923.2(4)	-22(7)	K96
			5171.962	nl,f	18	11/2	4866.515	867.997	-50.319	CG81
			5441.178	cl,f	28	9/2	5822.890	855.8(4)	-17(7)	K96
			5660.757	nl,e	28	7/2	6535.572	979(1)	25(30)	G96
			6177.590	cl,e	128	7/2	8013.089	168(1)		U12a
			6297.108	cl,f	22	9/2	8320.240	255(2)		G96
			6428.128	cl,f	21	9/2	8643.824	797(2)		G96
			6795.001	nl	3	11/2	9483.518	731(1)	-15(10)	G96
			6884.620	nl	12	11/2	9675.029	683(1)		G96
			7521.185	nl,e	7	11/2	10904.034	301(1)	-20(10)	G96
			8561.896	cl	11	9/2	12519.705	693(3)		G96
			9273.537	cl	13	7/2	13415.739	797(2)		G96
9/2	24485.172(10)	1110(2)	4985.407	nl,f	10	9/2	4432.225	923.2(4)	-22(7)	K96
			5095.769	cl,f	60	11/2	4866.515	867.997	-50.319	CG81
			5569.608	nl,f	33	7/2	6535.572	979(1)	25(30)	G96
			6069.198	cl,e	19	7/2	8013.089	168(1)		G96
			6570.021	nl,e	6	11/2	9268.726	977(1)	-24(25)	G96
			8453.073	nl	6	11/2	12658.401	995(5)		U12a
			9176.123	cl	27	7/2	13590.311	1151(2)		G96
			9339.919	cl	5	7/2	13781.374	807(1)		G96
			9511.740	cl	15	9/2	13974.732	854(1)	-15(15)	G96
			9699.660	nl	6	11/2	14178.365	986(1)	-20(10)	G96
9/2	24830.361(10)	940(4)	4901.040	cl,f	38	9/2	4432.225	923.2(4))	-22(7)	K96
			5259.627	nl,f	62	9/2	5822.890	855.8(4))	-17(7)	K96
			5398.903	cl,f	90	11/2	6313.224	756(1)		G96
			5807.980	nl,e	10	7/2	7617.440	866.9(5)	-4(5)	K96
			5944.622	cl,e	130	7/2	8013.089	168(1)		G96
			6055.214	nl,f	50	9/2	8320.240	255(2)		G96
			6176.266	nl	8	9/2	8643.824	797(2)		G96
			8476.085	cl	5	11/2	13035.697	796(3)		G96
9/2	26035.395(10)	877(2)	4627.654	nl,f	19	9/2	4432.225	923.2(4))	-22(7)	K96
			4722.595	cl,f	13	11/2	4866.515	867.997	-50.319	CG81
			4946.052	cl,f	22	9/2	5822.890	855.8(4)	-17(7)	K96
			5069.024	cl,f	60	11/2	6313.224	756(1)		G96
			5174.218	nl,f	11	11/2	6714.184	474.692	-29.633	CG81
			5427.976	cl,f	27	7/2	7617.440	866.9(5)	-4(5)	K96
			5962.563	cl,e	14	11/2	9268.726	977(1)	-24(20)	G96
			6121.762	cl,e	8	7/2	9704.744	779(1)	-50(30)	G96
			7819.677	cl	5	11/2	13250.662	424(2)		G96
9/2	26748.513(15)	912(5)	4568.687	nl,f	8	11/2	4866.515	867.997	-50.319	CG81
			4945.946	nl	3	7/2	6535.572	979(1)	25(30)	G96
			4990.040	cl,f	14	11/2	6714.184	474.692	-29.633	CG81
			5034.96	nl,f	1	11/2	6892.934	551.934	-24.736	CG81
			5340.614	nl,f	28	9/2	8029.275	797(2)	-	G96
			5424.938	nl,f	7	9/2	8320.240	255(2)		G96
			5865.622	nl,e	8	7/2	9704.744	779(1	-50(30)	G96
			6423.26	nl,e	1	9/2	11184.396	692(1	15(30)	G96
			7406.55	nl,e	1	11/2	13250.662	424(2)		G96
			7507.67	nl,e	1	9/2	13432.468	559(2)		G96
9/2	27292.757(20)	768(2)	4656.39	nl,f	3	9/2	5822.890	855.8(4)	-17(7)	G96
			4858.07	nl,f	1	11/2	6714.184	474.692	-29.633	CG81
			5360.746	cl,f	70	9/2	8643.824	797(2)		G96
			5613.504	nl,e	22	11/2	9483.518	731(1)	-15(10)	G96
			5684.116	cl,e	41	7/2	9704.744	779(1)	-50(30)	G96
9/2	27659.987(15)	927(2)	4303.982	nl,e	11	9/2	4432.225	923.2(4)	-22(7)	K96
			4385.986	nl,f	10	11/2	4866.515	867.997	-50.319	CG81
			4683.240	cl,f	22	11/2	6313.224	756(1)		G96
			4987.993	nl,f	7	7/2	7617.440	866.9(5)	-4(5)	K96
			5257.221	cl,f	60	9/2	8643.824	797(2)		G96
			5567.856	nl,f	5	7/2	9704.744	779(1)	-50(30)	G96
			5966.38	n,e	1	11/2	10904.034	301(1)	-20(10)	G96
			5972.195	nl,e	10	9/2	10920.365	632(2)		G96

			6411.696	nl,e	10	9/2	12067.802	873(6)		G96
9/2	27980.556(15)	768(2)	4245.390	nl,f	9	9/2	4432.225	923.2(4)	-22(7)	K96
			4511.846	nl,f	3	9/2	5822.890	855.8(4)	-17(7)	K96
			4661.788	nl,f	3	7/2	6535.572	979(1)	25(30)	G96
			4740.793	cl,f	4	11/2	6892.934	551.934	-24.736	CG81
			4909.47	nl,f	1	7/2	7617.440	866.9(5)	-4(5)	K96
			5170.068	nl	8	9/2	8643.824	797(2)		G96
			5461.314	cl	13	11/2	9675.029	683(1)		G96
			5987.193	nl,e	8	11/2	11282.865	1049(2)		G96
			6787.044	nl,e	4	11/2	13250.662	424(2)		G96
			6871.862	nl,e	10	9/2	13432.468	559(2)		G96
			7398.655	nl	10	9/2	14468.303	762(2)	20(20)	G96
			7418.838	nl,e	6	11/2	14505.065	777(3)		G96
			7564.350	nl,e	6	9/2	14764.288	867(2)		G96
			7690.756	cl	14	11/2	14981.5	687(1)		G96
			7767.927	cl	19	7/2	15110.642	947(2)		G96
11/2	21926.369(10)	882(3)	5714.613	cl,e,f	170	9/2	4432.225	923.2(4)	-22(7)	K96
			6992.917	cl,e,f	28	13/2	7630.132	776.286	-43.592	CG81
			7898.193	cl	13	11/2	9268.726	977(1)	-24(20)	G96
			8022.236	cl	7	13/2	9464.440	1056(1)	-15(10)	G96
			8640.941	nl	4	9/2	10356.737	1406(1)		G96
			8691.213	cl	14	13/2	10423.654	869(1)	25(30)	G96
			9634.268	nl	17	9/2	11549.602	1064(2)		G96
			9646.510	cl	9	13/2	11562.762	819(2)		G96
11/2	23042.780(10)	891(4)	5371.801	cl,f	90	9/2	4432.225	923.2(4)	-22(7)	K96
			5500.152	cl,f	170	11/2	4866.515	867.997	-50.319	CG81
			5805.628	nl,f	30	9/2	5822.890	855.8(4)	-17(7)	K96
			6122.530	nl	9	11/2	6714.184	474.692	-29.633	CG81
			7033.518	cl,e	20	11/2	8829.063	769(1)	-30(20)	G96
			7172.779	cl	11	9/2	9105.021	689.7(3)	-3(5)	K96
			7258.024	cl	9	11/2	9268.726	977(1)	-24(20)	G96
			7362.643	cl,e	22	13/2	9464.440	1056(1)	-15(10)	G96
			7824.854	cl	6	13/2	10266.501	972(2)		G96
			7951.713	cl	7	13/2	10470.329	628(3)		G96
			8430.534	nl	5	9/2	11184.396	692(1)	15(30)	G96
			9500.323	cl	7	9/2	12519.705	693(3)		G96
			9620.895	cl	6	9/2	12651.586	723(3)		G96
			9709.173	cl	14	9/2	12746.067	982(1)	10(10)	G96
			9990.187	cl	10	11/2	13035.697	796(3)		G96
11/2	24816.383(10)	744(2)	4904.40	nl,f	1	9/2	4432.225	923.2(4)	-22(7)	K96
			5402.980	cl,f	155	11/2	6313.224	756(19		G96
			5522.655	cl,f	175	11/2	6714.184	474.692	-29.633	CG81
			5927.775	cl,e	16	13/2	7951.323	644(1)	-30(20)	G96
			5955.302	cl,e	120	9/2	8029.275	797(2)		G96
			6060.343	cl,e	45	9/2	8320.240	255(2)		G96
			6181.599	cl	12	9/2	8643.824	797(2)		G96
			6363.059	cl	6	9/2	9105.021	689.7(3)	-3(5)	K96
			6602.604	cl	10	11/2	9675.029	683(1)		G96
			7185.875	nl	5	11/2	10904.034	301(1)	-20(10)	G96
			7387.032	nl,e	5	11/2	11282.865	1049(2)		G96
			8643.863	nl	2	11/2	13250.662	424(2)		G96
			8660.299	nl	7	9/2	13272.613	900(2)		G96
11/2	25009.019(10)	983(3)	5347.309	nl,f	28	11/2	6313.224	756(1)		G96
			5464.505	cl,f	32	11/2	6714.184	474.692	-29.633	CG81
			5860.83	nl,e	1	13/2	7951.323	644(1)	-30(20)	G96
			5990.391	cl,e	10	9/2	8320.240	255(2)		G96
			6439.235	cl,e	6	11/2	9483.518	731(1)	-15(10)	G96
			7434.966	nl	10	13/2	11562.762	819(2)		G96
			7709.545	nl	6	13/2	12041.655	1049(2)		G96
			8997.499	nl	7	13/2	13897.874	900(2)		G96
11/2	25746.884(10)	784(2)	4690.294	cl,f	60	9/2	4432.225	923.2(4)	-22(7)	K96
			4787.848	cl,f	8	11/2	4866.515	867.997	-50.319	CG81
			5017.675	cl,f	65	9/2	5822.890	855.8(4)	-17(7)	K96
			5144.278	cl,f	75	11/2	6313.224	756(1)		G96
			5222.311	nl,f	16	13/2	6603.591	755.456	-48.633	CG81
			5252.653	nl,f	8	11/2	6714.184	474.692	-29.633	CG81
			5617.818	cl,e	80	13/2	7951.323	644(1)	-30(20)	G96
			5845.29	nl,e	20	9/2	8643.824	797(2)		G96
			5909.289	cl,f	23	11/2	8829.063	769(1)	-30(20)	G96
			6544.171	nl,e	7	13/2	10470.329	628(3)		G96
			8081.917	nl	5	11/2	13376.992	868(2)		G96
11/2	26848.512(15)	590(5)	4459.79	nl,f	1	9/2	4432.225	923.2(4)	-22(7)	K96
			4547.902	nl,f	2	11/2	4866.515	867.997	-50.319	CG81
			4965.254	cl,f	6	11/2	6714.184	474.692	-29.633	CG81
			5290.322	nl,f	8	13/2	7951.323	644(1)	-30(20)	G96

			5312.230	nl	18	9/2	8029.275	797(2)		G96
			5395.656	nl,f	24	9/2	8320.240	255(2)		G96
			5634.305	cl,e	40	9/2	9105.021	689.7(3)	-3(5)	K96
			5686.772	nl,e	14	11/2	9268.726	977(1)	-24(20)	G96
			6276.458	nl	5	9/2	10920.365	632(2)		G96
11/2	27944.838(15)	654(4)	4519.130	nl,f	18	9/2	5822.890	855.8(4)	-17(7)	K96
			4921.167	cl,f	5	13/2	7630.132	776.286	-43.592	CG81
			5352.944	nl,f	20	11/2	9268.726	977(1)	-24(20)	G96
			5415.225	nl,f	20	11/2	9483.518	731(1)	-15(10)	G96
			5964.777	cl,e	8	9/2	11184.396	692(1)	15(30)	G96
			6537.026	nl,e	4	9/2	12651.586	723(3)		G96
			7262.018	nl	4	11/2	14178.365	986(1)	-20(10)	G96
13/2	25443.665(15)	491(3)	4858.40	nl,e	1	11/2	4866.515	867.997	-50.319	CG81
			5225.816	cl,f	75	11/2	6313.224	756(1)		G96
			5306.358	cl,f	100	13/2	6603.591	755.456	-48.633	CG81
			5389.124	nl,f	100	11/2	6892.934	551.934	-24.736	CG81
			5612.151	cl,f	40	13/2	7630.132	776.286	-43.592	CG81
			5715.20	nl,e	5	13/2	7951.323	644(1)	-30(20)	G96
			5994.217	cl	30	15/2	8765.542	763.557	-45.805	CG81
			6263.873	cl	8	11/2	9483.518	731(1)	-15(10)	G96
			6655.946	cl,f	15	13/2	10423.654	869(1	25(30)	G96
			6675.071	cl,f	9	15/2	10466.689	1042(2)	-20(30)	G96
			7459.513	nl	4	13/2	12041.655	1049(2)		G96
			7577.607	cl	4	15/2	12250.519	608(1)		G96
			7909.719	cl	10	15/2	12804.468	732(1)		G96
13/2	25765.460(15)	582(3)	4783.593	cl,f	16	11/2	4866.515	867.997	-50.319	CG81
			5217.247	nl,f	14	13/2	6603.591	755.456	-48.633	CG81
			5297.234	cl,f	12	11/2	6892.934	551.934	-24.736	CG81
			5512.568	cl,f	22	13/2	7630.132	776.286	-43.592	CG81
			5611.961	cl,f	145	13/2	7951.323	644(1)	-30(20)	G96
			5902.808	cl,e	27	11/2	8829.063	769(1)	-30(20)	G96
			6132.888	cl	11	13/2	9464.440	1056(1)	-15(10)	G96
			6140.074	cl,e	100	11/2	9483.518	731(1)	-15(10)	G96
			6213.154	nl	28	11/2	9675.029	683(1)		G96
			6536.224	nl	8	13/2	10470.329	628(3)		G96
			7284.604	nl	8	13/2	12041.655	1049(2)		G96
			7325.375	nl,e	15	13/2	12118.039	554(1)	-45(30)	G96
			7358.854	nl,e	8	11/2	12180.207	679(3)		G96
			7627.381	nl	4	11/2	12658.401	995(5)		G96
13/2	26810.061(15)	860(3)	4877.439	cl,f	7	11/2	6313.224	756(1)		G96
			4947.529	nl,f	35	13/2	6603.591	755.456	-48.633	CG81
			5212.333	nl	16	13/2	7630.132	776.286	-43.592	CG81
			5301.107	cl,f	30	13/2	7951.323	644(1)	-30(20)	G96
			5419.676	cl	35	15/2	8363.901	763.306	-48.253	CG81
			5540.310	nl	11	15/2	8765.542	763.557	-45.805	CG81
			5699.239	nl,e	17	11/2	9268.726	977(1)	-24(20)	G96
			5763.547	nl,e	6	13/2	9464.440	1056(1)	-15(10)	G96
			5769.892	nl,e	7	11/2	9483.518	731(1)	-15(10)	G96
			6100.929	cl	12	13/2	10423.654	869(1)	25(30)	G96
			7442.26	nl,e	4	11/2	13376.992	868(2)		G96
13/2	27139.468(15)	776(3)	5124.323	cl,f	110	13/2	7630.132	776.286	-43.592	CG81
			5440.982	cl	40	15/2	8765.542	763.557	-45.805	CG81
			5459.859	cl,f	90	11/2	8829.063	769(1)	-30(20)	G96
			5594.186	cl,f	52	11/2	9268.726	977(1)	-24(20)	G96
			5662.24	nl,e	1	11/2	9483.518	731(1)	-15(10)	G96
			5747.48	nl,e	1	15/2	9745.376	540(2)		G96
			7264.132	nl,e	5	11/2	13376.992	868(2)		G96
			7413.65	nl,e	1	13/2	13654.555	501(1)	20(20)	G96
			7535.314	nl,e	4	11/2	13872.266	872(3)		G96
13/2	27500.390(20)	883(2)	4416.914	nl,f	3	11/2	4866.515	867.997	-50.319	CG81
			5548.813	cl,f	16	11/2	9483.518	731(1)	-15(10)	G96
			5608.428	nl,e	15	11/2	9675.029	683(1)		G96
			5630.651	nl	11	15/2	9745.376	540(2)		G96
			5800.912	cl,e	18	13/2	10266.501	972(2)		G96
			7349.556	nl,e	6	13/2	13897.874	900(3)		G96