Spectrochimica Acta Part B: Atomic Spectroscopy 217 (2024) 106950

Contents lists available at ScienceDirect

Spectrochimica Acta Part B: Atomic Spectroscopy

journal homepage: www.elsevier.com/locate/sab

Line identification of atomic and ionic spectra of Holmium in the near infrared spectral range from 700 nm to 1750 nm

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ARTICLE INFO

Keywords:
Atomic data
Line: identification fine structure
Line classification
Fourier spectra

ABSTRACT

The aim of the study is to extend the list of spectral lines of atomic and single ionized holmium (Ho) into the near infrared wavelength range up to 1750 nm. Spectra of a Ho hollow cathode discharge lamp with neon or argon as buffer gases have been measured with a Fourier Transform spectrometer in different spectral ranges. In total, the range from 700 nm to 1750 nm i.e. from 5710 cm^{-1} to 14280 cm^{-1} has been covered. A total of almost 800 spectral lines were detected. Based on the known energy levels of atom and ion Ho, 589 lines could be classified as Ho I transitions and 31 lines as Ho II transitions. The remaining 171 lines could mostly be classified as different Ho I or Ho II, based on different signal-to-noise ratios in spectra measured with different buffer gases. In the wavelength range from 1200 nm to 1750 nm, a list of Ho lines is presented for the first time. In the wavelength range from 700 nm to 1200 nm 216 lines had not been listed in literature up to now.

1. Introduction

Fundamental atomic data from laboratory experiments are essential in astrophysics for quantitatively evaluating element abundances. The study of rare earth elements is particularly important for a comprehensive understanding of the elemental compositions within the context of peculiar stars. Peculiar stars, characterized by their aberrant chemical compositions, often exhibit remarkable overabundances of rare earth elements relative to the standard solar abundances.

Notably, the works of Gray & Corbally [1]; Sneden et al. [2]; Michaud et al. [3] have shed light on the anomalous abundances of these elements across various stellar environments and have underscored the significance of rare earth element spectroscopy in discerning the evolutionary pathways of stars and elucidating the processes governing nucleosynthesis. For such analyses, laboratory data on the fine structure, as provided in the present work, are crucial. The significance of the Ho element in astrophysics has been discussed in detail in our previous articles Başar et al. [4]; Ozdalgic et al. [5].

The spectral properties of Ho are also relevant in other areas of physics and material science. For example, the discussion about possible applications of the element holmium in quantum technology in recent years is well described in the work of Stefanska et al. [6].

Holmium (Ho), with $Z = 67$ is one of the atoms that belong to the lanthanide series. In its natural form it has only one stable isotope ($A = 165$) with a nuclear spin of $I = 7/2$. Ho spectra are very dense and complex, both because the $4f$ electron shell is unfilled, meaning there are many optically active electrons, and because Ho has relatively high multipole moments, $\mu = 4.17\,(3)\,\mu_N$ and $Q = 2.7 - 3.6$ barn [7]. Ho is therefore considered to be among the strong candidates to be studied in various fields of physics, for discovering new energy levels and analysing hyperfine structures.

Studies on the element Ho have been carried out since the 1970s using various methods. The first of these was conducted by Spector [8,9]. The fine and hyperfine structures of Ho have been investigated by different methods, such as Fourier Transform (FT) spectroscopy [4,5,10–18], ABMR method [19], fast-beam laser spectroscopy [20],

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https://doi.org/10.1016/j.sab.2024.106950
Received 23 February 2024; Received in revised form 17 May 2024; Accepted 20 May 2024
Available online 31 May 2024
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crossed beam laser spectroscopy [17], laser-induced fluorescence spectroscopy [21–34] and optogalvanic spectroscopy (OGS) [35]. Semi-empirical investigations of atomic structure of Ho have been done by Kröger et al. [12]; Stefanska and Furmann [33]; Stefanska et al. [34]; Elantkowska et al. [36].

Compilations of spectral lines of Ho I have been published or compiled by Meggers et al. [37]; Nave [14]; Sansonetti and Martin [38]; Smirnov [39]; Kramida et al. [40]. For Ho II, lists of lines were sourced from Meggers et al. [37]; Spector [9]; Smirnov [17]; Sansonetti and Martin [38]; Gurell et al. [11]; Kramida et al. [40] and for Ho III from Martin et al. [41]; Biémont et al. [42]; Zhang et al. [43]. There have also experimental studies concerning Ho transition probabilities in the last years [14,44,45].

Our research group conducted four studies in two different spectral regions to analyse the line definition of the Ho spectrum. Two of the studies were conducted in the near ultraviolet region by Al-Labady et al. [10]; Başar et al. [4], while the other two were carried out in the visible region by Ozdalgic et al. [5,15] using the Fourier Transform (FT) spectroscopy. In the present study, we extend the analysis of Ho spectra to the near infrared region. The experimental setup and classification procedures used in this study are the same as those used in our previous studies. A comprehensive analysis of the FT spectra across all spectral ranges facilitates the discovery of new energy levels and supports the investigation with laser spectroscopic methods.

2. Experiment

The experimental setup in this study are the same as our previous studies of FT spectra of Ho [4,5,10,15]. The measurements have been carried out employing the Ho plasma produced in a hollow cathode discharge lamp [46], into which a 0.127 mm thick Ho foil has been inserted. Either Ne or Ar were used as buffer gases. The central part of the lamp has been cooled by liquid nitrogen to reduce Doppler broadening of spectral lines.

The spectra were recorded with a FT Spectrometer IFS-125 HR (Bruker) at the Laser Centre of the University of Latvia in Riga. The details of the individual measurements are summarised in Table 1. The wavelength range is divided into three sections labelled IR(A), IR(B) and IR(C), which were recorded with different settings of the FT spectrometer, see Table 1.

For the wavelength range 700–840 nm, see column A, the photomultiplier (PMT) Hamamatsu R928 was used. For the wavelengths 840–1750 nm (columns B and C) the InGaAs diode operated in room temperatures was applied. Since its sensitivity diminished steeply above 1670 nm (see column C), to improve the signal-to-noise ratio (S/N) in this range, an edge filter FEL1100 was used to cut off emission at shorter wavelengths. However, this measurement was only carried out with Ne as a buffer gas. Additionally, the measurements with Ne as buffer gas were recorded with more scans, see Table 1, resulting in better S/N for the Ho-Ne spectra than for the Ho-Ar spectra in the corresponding wavelength range. The spectral intensities remain uncalibrated for instrumental response.

Table 1
Parameters of the measurements.

labelling	Ar-IR (A)	Ne-IR(A)		Ar-IR (B)	Ne-IR (B)	Ar-IR (C)	Ne-IR (C)
wavelength range[a] in nm	700–840			840–1000		1000–1750	
hollow cathode							
buffer gas	Ar	Ne	Ar	Ne	Ar	Ne	
gas pressure in mbar	2.2	3.3	2.2	3.3	2.2	3.3	
discharge current in mA	60	60	72	50	72	50	
FT spectrometer							
detector	PMT (Hamamatsu R928)			InGaAs		InGaAs	
beam splitter	quartz beam splitter			CaF beam splitter		CaF beam splitter	
special features						FEL 1100[b]	
aperture in mm	1			1.7		1.7	
resolution incm^{-1}	0.025			0.03		0.03	
number of scans	200			20	100	20	100

[a] : wavelength range that was analysed in the present study.
[b] : FEL 1100: longpass edge filter with cut-on wavelength of 1100 nm in the beam pass of the light.

The comparison of measured wavenumbers of classified atomic and ionic Ar and Ne lines with calculated differences between corresponding energy levels from Minnhagen et al. [47]; Palmeri and Biémont [48]; Saloman and Sansonetti [49]; Saloman [50]; Kramida and Nave [51]; Kramida et al. [52] was utilized for wavenumber calibration. As a result, it can be stated that accuracy of the spectra is better than 0.005 cm^{-1}. The wavelengths in air are calculated from the measured wavenumbers using the dispersion ratio from Peck and Reeder [53].

3. Analysis of spectra and line classification

Fig. 1 shows a representative part of spectra that were measured in the same wavelength range with different noble gases. Ho lines as well as lines of each noble gas can be seen. The measurements with two different gases allowed us to distinguish and only lines that appear in both spectra were assigned to the element Ho. With this recognition feature, 791 lines could be assigned to the element Ho. Fig. 2 shows another part of the spectrum, which demonstrates how close the lines are in some places.

For most lines Ho provides a very nice ”fingerprint” of the hyperfine structure, which is very helpful for an unambiguous classification of a transition. Such fingerprints are clearly visible in Figs. 1 and 2 and are further emphasized by the simulations of the hfs shown in green. A further example of another type of ”fingerprint” is shown in Fig. 3. Without the simulation, one could have thought that this was a superposition of three different lines.

The spectra undergo analysis using the classification program Elements [54,55], which is based on input data of the fine and hyperfine structure data from Ho I and Ho II as well as a list of already known lines from literature. Values for level energy, parity and J quantum number were sourced from Wyart et al. [18]; Martin et al. [41]; Wyart and Camus [56]; Kröger et al. [12]; Hartog et al. [22]; Furmann et al. [31,32] for Ho I and Martin et al. [41]; Hartog et al. [22]; Gurell et al. [11] for Ho II. If available, additionally hfs constants were used from Merzyn et al. [57]; Wyart et al. [18]; Wyart and Camus [56]; Burghardt et al. [19]; Childs et al. [21]; Reddy et al. [35]; Kröger et al. [12]; Stefanska and Furmann [33]; Stefanska et al. [34]; Furmann et al. [29,30]; Ozdalgic et al. [16]; Elantkowska et al. [36]; Furmann et al. [30]; Chomski et al. [28]; Başar et al. [24]; Furmann et al. [32]; Barka et al. [23] for Ho I and Worm et al. [20]; Gurell et al. [11] for Ho II. Information concerning the known spectral lines of Ho I and Ho II comes from Meggers et al. [37]; Spector [9]; Martin et al. [41]; Reader & Corlis [58]; Smirnov [17]; Biémont et al. [42]; Zhang et al. [43]; Nave [14]; Sansonetti and Martin [38]; Gurell et al. [11]; Smirnov [39]; Ferrara et al. [44].

The program Elements is utilized to simulate the hfs and to extract the center of gravity (cg) of the line as well as S/N, and line pattern width W from the spectra. If in a transition the hfs constants for one or both levels are not known, values have been estimate by adjusting the simulated spectrum of corresponding lines to the intensity profile of the FT spectrum. This method leads to appropriate values for the cg of the corresponding line. The same procedure was used for unclassified lines: J-values and hfs constants were selected to reasonably approximate the profile in order to determine the cg. This does not mean that the J-values and hfs constants are necessarily the right ones. The S/N is determined as the amplitude of the highest peak within a line. The line pattern width refers to the distance between the points on either side of a hyperfine

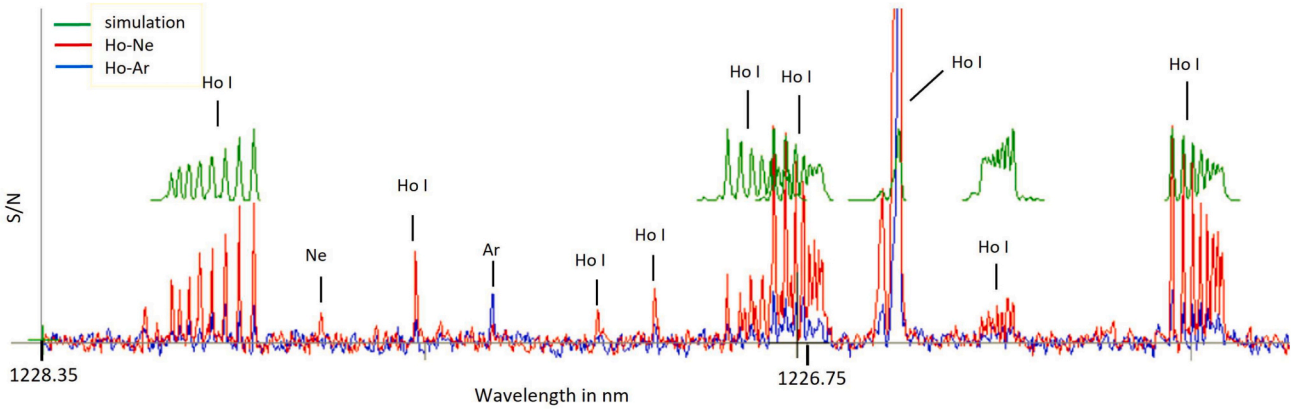

Fig. 1. Representative part of the Fourier Transform spectra with assignment of lines; S/N: signal-to-noise ratio; blue line: Ho-Ar plasma; red line: Ho-Ne plasma; green spectrum: simulation of hfs of the line (intensity not to scale relative to the S/N). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

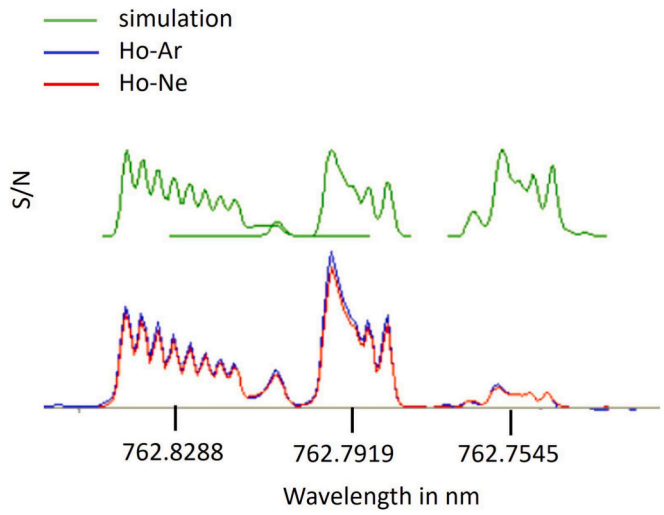

Fig. 2. Section of the Ho-Ar and Ho-Ne spectra showing the density of lines in the Ho spectrum; three classified Ho I lines with their simulation are lying very close to each other; the line at $\lambda = 762.7545$ nm unknown but could be simulated.

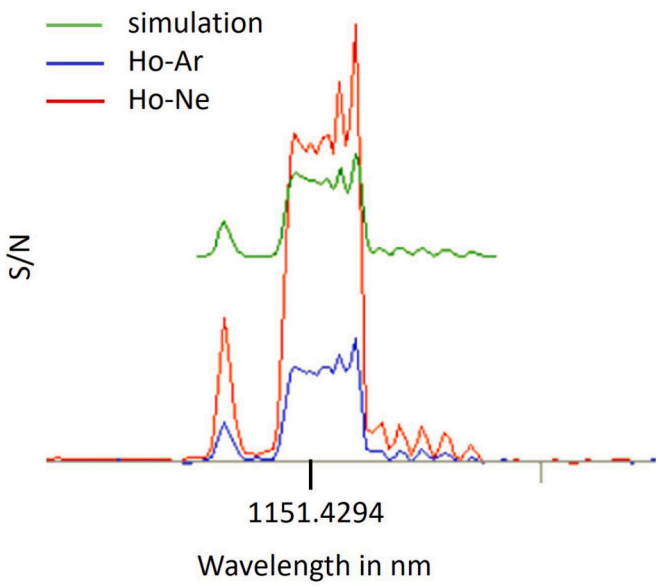

Fig. 3. Section of the Ho-Ar and Ho-Ne spectra at $\lambda = 1151.4294$ nm showing other kind of hyperfine structure "fingerprint".

structure spectrum where the intensity decreases to $1/e^2$ of the highest peak. For very weak lines (S/N< 10), width is defined as the distance between points where the line profile surpasses the noise level.

It is important to emphasize that the spectral line intensities lack calibration for instrumental response. Furthermore, the S/N values do not directly correlate with line intensities due to the omission of the area within the spectral profile. Nonetheless, the S/N value remains informative for comparing hyperfine peaks within a line or comparing a specific line across spectra. The intensity ratio of hyperfine structure components within a line matches their theoretical intensity ratios very good.

A graphical comparison between the simulated hyperfine pattern and the experimental curve can be done with the program Elements. The precise determination of the cg of a line can be achieved by aligning the simulated curve with the experimental one along the wavenumber axis. This method enables the attainment of the cg wavenumber with high accuracy. For lines exhibiting a S/N greater than 10 in the normalized FT spectra, we have observed that the accuracy of the cg is mostly unaffected by the S/N. In such instances, an uncertainty better than 0.0001 nm is estimated, which corresponds to 0.002 cm^{-1} at 700 nm and to 0.0003 cm^{-1} at 1700 nm. Together with the uncertainty of the calibration of 0.005 cm^{-1} this results in a total uncertainty of 0.007 cm^{-1} at 700 nm and to 0.0053 cm^{-1} at 1700 nm. For lines with S/N< 10, the reading uncertainty is higher, but still better than 0.0005 nm, corresponding to 0.01 cm^{-1} at 700 nm and to 0.0015 cm^{-1} at 1700 nm and resulting in a total uncertainty of 0.015 cm^{-1} at 700 nm and to 0.0065 cm^{-1} at 1700 nm.

For the classification of lines, we establish as a necessary condition that the difference $\Delta\sigma$ between the experimental wavenumber σ_{exp} and the calculated difference between the level energies of the upper and lower levels E_u and E_l, respectively, should be smaller than

$$\Delta\sigma = \sigma_{exp} - (E_u - E_l) < 0.25\ cm^{-1}.$$

The permitted deviation is larger than the above discussed accuracy of the measured wavenumber, because the energy values of the levels have large uncertainties, sometimes even on the order of 0.1 cm^{-1}.

With help of the fingerprints, 620 of the 791 Ho lines could be classified, 589 of them as Ho I, 31 as Ho II. The distribution of the lines over the three different measuring ranges is detailed in the first two columns of Table 2. There are also lines that show almost no splitting (at the resolution of our spectra), but even these usually can be clearly

Table 2
Ratio *R* between S/N in the Ho-Ar and S/N in the Ho-Ne spectrum for atomic and ionic Ho lines in the three different parts of the spectra.

	number of lines	*R*		
		mean	min.	max.
IR(A)				
Ho I	153	1.12(18)	0.75	1.67
Ho II	4	3.3(1.9)	1.75	6.0
unclass.	40			
sum	**197**			
IR(B)				
Ho I	61	0.56(61)	0.24	1.00
Ho II	4	1.2(5)	0.88	2.0
unclass.	19			
Sum	**84**			
IR(C)				
Ho I	375	0.31(9)	0.13	0.54
Ho II	23	0.77(19)	0.57	1.00
unclass.	112			
Sum	**510**			
Total	**791**			

assigned if they are located between broadly splitting lines.

In some cases, two or more lines overlapped. In all cases of classified lines, a clear assignment was nevertheless possible. In some cases, there were also overlaps between Ho lines and buffer gas lines. In almost all cases, the S/N value could still be determined even when overlapping with gas lines. Examples of this are given in Fig. 4, once for a very weak Ne line and once for a medium-strong Ne line. Only in three cases it was not possible to determine a suitable S/N value for one of the two spectra. These lines are labelled as blended lines ("bAr" or "bNe").

The spectrum was also examined with regard to lines of doubly ionized Ho. For doubly ionized Ho, lists of spectral lines are given by Biémont et al. [42]; Zhang et al. [43]. In Zhang et al. [43] theoretical oscillator strengths and radiative transition probabilities for strong Ho III transitions are given in the wavelength range from 234 nm up to 925 nm. The lines listed above 700 nm have been checked and were not observed in our spectra. No other lines could be assigned to doubly ionized Ho either. We assume that there are no particularly strong Ho III lines in the wavelength range investigated here. The fact that no weak Ho III lines were excited is due to the conditions of the hollow cathode gas discharge.

As presented in our previous publications on line classifications of Ho [4,5,10,15], in the NIR spectral range also a clear difference in intensity or S/N, respectively, for lines belonging to the neutral atom or the singly ionized ion in the spectra measured with the different buffer gases Ar or Ne is observed. To describe this, we define the quotient *R* as:

$$R = \frac{\mathrm{S/N\,in\,Ho\text{-}Ar\,spec.}}{\mathrm{S/N\,in\,Ho\text{-}Ne\,spec.}}$$

The corresponding values, resulting from the lines in the different spectral ranges (IR(A), IR(B) and IR(C)) are compiled in the last column of Table 2. The mean value is given with the statistical standard deviation in brackets as well as the minimum and maximum values. As discussed in Section 2 the experimental conditions in the different spectral ranges and for the measurements with different buffer gases were very distinct. Therefore, the *R* values in the different ranges are also very distinct. Nevertheless, a clear difference can be seen in all three cases between Ho I lines and Ho II lines. It should be noted that the number of Ho II lines in the first two ranges is very small, which leads to a large statistical standard deviation for the mean value of *R* of Ho II.

Fig. 5 illustrates the very different intensity ratios in the Ho-Ar and Ho-Ne spectra. A Ho I and a Ho II line are shown, and it is clearly visible that for the Ho II line (on the left side) the two S/N values are similar in both spectra, while for the Ho I line (right side) the Ho-Ne spectrum has a significantly larger S/N value.

All Ho lines are listed in Table 3. Based on the results for the *R* value presented in Table 2 we assigned the unclassified lines to Ho I and Ho II.

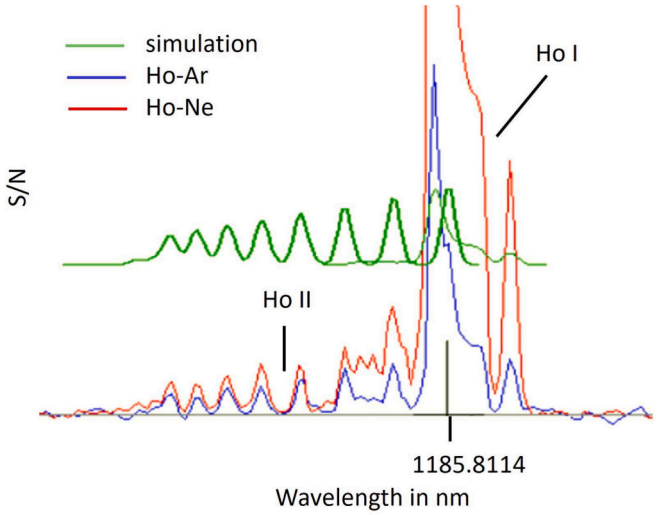

Fig. 5. Overlapped Ho I ($\lambda = 1185.8114$ nm) and Ho II ($\lambda = 1185.8719$ nm) lines from spectra measured with Ar and Ne as buffer gas. Since the hyperfine structure constants of the upper and lower levels of both lines are known, simulations are also given. Line intensities were not taken into account in the simulation.

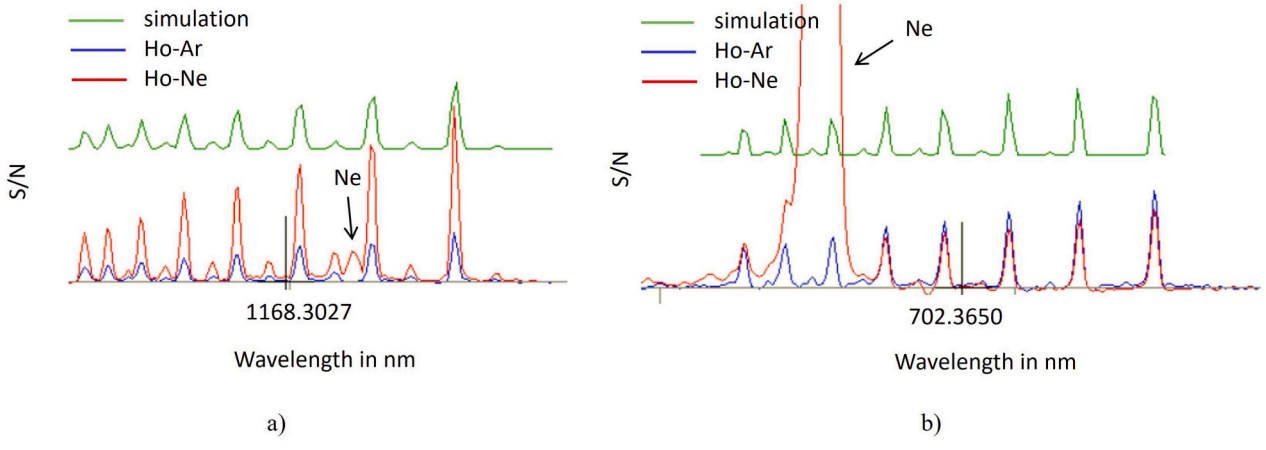

Fig. 4. Section of the Ho-Ar and Ho-Ne spectra; blended Ho lines with Ne: a) Ne line with small intensity, b) Ne line with high intensity.

Table 3
List of Ho I and II lines in the measured FT spectra from 700 nm to 1750 nm or 5710 cm^{-1} to 14,280 cm^{-1}; also available online as formatted text separated by spaces.

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
700.0838	14,280.065	lc	50	43	1.16	Ho I	400+	256	0.045	31,339.46	15/2	o	17,059.35	13/2	e
701.5979	14,249.249	nl	3	3	1.00	Ho I	122+								
702.1056	14,238.945	lc	3	3	1.00	Ho I	271+	213	0.075	38,124.76	17/2	e	23,885.74	17/2	o
702.1874	14,237.286	lc	3	3	1.00	Ho I	188+	−79	−0.056	30,029.36	13/2	o	15,792.13	11/2	e
702.3650	14,233.685	lc	58	46	1.26	Ho I	2420+	2330	0.225	31,116.22	17/2	o	16,882.31	15/2	e
704.7597	14,185.322	lc	24	20	1.20	Ho I	620-	−437	−0.042	26,529.83	11/2	o	12,344.55	13/2	e
705.1472	14,177.528	lc	9	12	0.75	Ho I	820-	−702	−0.018	37,388.72	17/2	e	23,211.21	19/2	o
705.3586	14,173.278	lc	4	3	1.33	Ho I	194-	−32	0.002	30,327.49	17/2	o	16,154.21	15/2	e
706.2209	14,155.972	nl	5	5	1.00	Ho I	530*								
706.9517	14,141.338	lc	10	8	1.25	Ho I	850+	787	0.122	26,480.5	17/2	o	12,339.04	15/2	e
707.2787	14,134.801	lc	7	7	1.00	Ho I	220-	−119	−0.121	24,830.43	11/2	e	10,695.75	9/2	o
707.4074	14,132.229	lc	4	4	1.00	Ho I	150+	77	−0.019	32,623.42	13/2	o	18,491.21	11/2	e
707.9009	14,122.377	nl	5	2	2.50	Ho II	313*								
707.9855	14,120.690	lc	6	6	1.00	Ho I	205*	171	0.030	37,619.29	19/2	o	23,498.57	17/2	e
708.1365	14,117.680	lc	29	26	1.12	Ho I	420+	184	0.000	26,456.72	15/2	o	12,339.04	15/2	e
708.4139	14,112.150	lc	13	11	1.18	Ho I	390+	211	0.020	26,456.72	15/2	o	12,344.55	13/2	e
708.5117	14,110.203	nl	4	4	1.00	Ho I	133*								
709.0963	14,098.570	lc	42	36	1.17	Ho I	340-	−119	0.010	26,443.13	11/2	o	12,344.55	13/2	e
709.2161	14,096.189	nl	4	4	1.00	Ho I	967+								
709.2578	14,095.361	nl	3	3	1.00	Ho I	250-								
709.5909	14,088.744	nl	6	6	1.00	Ho I	100*								
709.8562	14,083.478	lc	5	3	1.67	Ho I	210*	−235	0.012	39,345.04	11/2	o	25,261.55	11/2	e
710.8508	14,063.773		7	7	1.00	Ho I	920-	−836	−0.003	30,773.59	15/2	o	16,709.82	17/2	e
710.8892	14,063.014	lc	5	5	1.00	Ho I	550+	824	−0.024	38,077.21	13/2	o	24,014.22	13/2	e
710.9947	14,060.927	lc	4	4	1.00	Ho I	1015-	−913	−0.057	25,591.43	15/2	o	11,530.56	17/2	e
711.5412	14,050.127	lc	6	6	1.00	Ho I	560+	444	0.003	29,842.26	13/2	o	15,792.13	11/2	e
711.7344	14,046.314	nl	6	6	1.00	Ho I	180-								
711.8035	14,044.950	lc	5	5	1.00	Ho I	730+	−697	0.100	38,405.86	17/2	o	24,360.81	17/2	e
712.1991	14,037.148	lc	3	3	1.00	Ho I	146+	98	0.012	38,051.38	13/2	o	24,014.22	13/2	e
712.3574	14,034.029	nc	9	8	1.13	Ho I	605-	−546	−0.009	38,048.24	11/2	o	24,014.22	13/2	e
712.7390	14,026.516	nl	33	24	1.38	Ho I	320-								
713.1995	14,017.459	nl	12	12	1.00	Ho I	110*								
713.8044	14,005.579	lc	21	19	1.11	Ho I	790-	−713	−0.029	29,086.67	15/2	o	15,081.12	13/2	e
713.9434	14,002.852	lc	4	4	1.00	Ho I	708*	−757	0.018	31,062.22	11/2	o	17,059.35	13/2	e
714.4319	13,993.279	lc	4	4	1.00	Ho I	954*	−1232	−0.049	38,257.19	19/2	o	24,263.96	17/2	e
714.9456	13,983.224	nl	6	6	1.00	Ho I	770*								
715.2414	13,977.441	nl	2	2	1.00	Ho I	684*								
715.3853	13,974.630	nl	10	12	0.83	Ho I	80*								
715.8395	13,965.762	lc	5	5	1.00	Ho I	776-	−724	−0.012	22,392.86	13/2	o	8427.11	15/2	e
718.9394	13,905.546	nl	3	3	1.00	Ho I	187*								
718.9926	13,904.517	nl	3	3	1.00	Ho I	236+								
719.2964	13,898.643	lc	3	3	1.00	Ho I	382*	−238	−0.013	30,582.15	17/2	o	16,683.52	19/2	e
719.4157	13,896.340	lc	22	26	0.85	Ho I	1170-	−112	0.060	38,257.19	19/2	o	24,360.81	17/2	e
719.8667	13,887.634	nl	4	4	1.00	Ho I	150+								
719.9126	13,886.748	lc	28	28	1.00	Ho I	475-	−306	−0.038	26,225.75	13/2	o	12,339.04	15/2	e
720.2006	13,881.196	lc	9	9	1.00	Ho I	430*	−278	0.004	26,225.75	13/2	o	12,344.55	13/2	e
720.6551	13,872.439	lc	8	6	1.33	Ho I	945-	−912	−0.109	30,582.15	17/2	o	16,709.82	17/2	e
720.8208	13,869.251	nl	2	2	1.00	Ho I	429*								
720.8485	13,868.718	lc	4	5	0.80	Ho I	86+	145	−0.048	29,660.80	13/2	o	15,792.13	11/2	e
721.1996	13,861.968	nl	11	4	2.75	Ho II	2381-								
721.6268	13,853.761	lc	6	6	1.00	Ho I	600+	535	0.079	26,198.39	15/2	o	12,344.55	13/2	e
721.8656	13,849.178	lc	4	4	1.00	Ho I	320*	300	0.012	37,734.93	19/2	e	23,885.74	17/2	o
721.8981	13,848.555	nl	3	3	1.00	Ho I	285*								
721.9619	13,847.329	nl	9	5	1.80	Ho I or II	78*								
722.2317	13,842.157	nc	4	4	1.00	Ho I	820*	918	0.063	32,663.47	11/2	o	18,821.25	11/2	e
722.9110	13,829.150	nl	3	3	1.00	Ho I	469*								
724.1780	13,804.956	lc	15	9	1.67	Ho I	115*	−55	−0.026	30,242.96	15/2	o	16,438.03	17/2	e
724.2019	13,804.499		118	110	1.07	Ho I	345+	122	0.031	26,143.57	17/2	o	12,339.04	15/2	e
725.0562	13,788.234	nc	104	96	1.08	Ho I	360-	−181	−0.054	26,127.22	13/2	o	12,339.04	15/2	e
725.3478	13,782.692	lc	24	21	1.14	Ho I	410-	−153	−0.022	26,127.22	13/2	o	12,344.55	13/2	e
726.1887	13,766.733	lc	7	7	1.00	Ho I	140*	127	0.107	38,124.76	17/2	e	24,357.92	15/2	o
726.2725	13,765.143	lc	3	3	1.00	Ho I	350+	479	0.087	32,623.42	13/2	o	18,858.19	13/2	e
726.4331	13,762.100	nc	3	3	1.00	Ho I	450+	300	0.000	37,776.32	13/2	o	24,014.22	13/2	e
726.8301	13,754.583	nl	3	3	1.00	Ho I	416*								
727.3395	13,744.951	lc	4	4	1.00	Ho I	816-	−718	0.109	38,405.86	17/2	o	24,660.80	15/2	e
727.7371	13,737.441	lc	6	8	0.75	Ho I	305-	−290	−0.001	37,623.18	15/2	e	23,885.74	17/2	o
728.1536	13,729.582	nl	4	7	0.57	Ho I	310-								
728.3764	13,725.384		8	8	1.00	Ho I	355*	−279	−0.034	28,861.41	17/2	o	15,136.06	15/2	e
728.8877	13,715.755		8	9	0.89	Ho I	325*	−179	0.005	30,425.58	19/2	o	16,709.82	17/2	e
729.7370	13,699.792	lc	8	7	1.14	Ho I	650+	579	0.048	30,582.15	17/2	o	16,882.31	15/2	e
730.3614	13,688.080	lc	5	3	1.67	Ho I	255-	184	−0.030	29,842.26	13/2	o	16,154.21	15/2	e
730.5539	13,684.474	lc	9	6	1.50	Ho I	290*	6	0.006	26,023.52	15/2	o	12,339.04	15/2	e
730.8496	13,678.936		358	326	1.10	Ho I	360+	52	0.034	26,023.52	15/2	o	12,344.55	13/2	e
731.7731	13,661.673	nl	4	4	1.00	Ho I	340*								

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
731.8674	13,659.914	lc	34	25	1.36	Ho I	390-	−199	−0.024	24,355.64	9/2	e	10,695.75	9/2	o
732.7229	13,643.964	lc	8	8	1.00	Ho I	95-	−64	0.006	30,327.49	17/2	o	16,683.52	19/2	e
734.1349	13,617.723		10	3	3.33	Ho II	115-	−49	−0.001	29,899.577	7	e	16,281.8551	6	o
735.2485	13,597.098	lc	25	22	1.14	Ho I	450-	−356	−0.008	22,024.2	13/2	o	8427.11	15/2	e
735.5924	13,590.742	lc	32	32	1.00	Ho I	285+	108	0.048	26,673.72	13/2	o	13,082.93	11/2	e
736.0789	13,581.759	lc	30	30	1.00	Ho I	515-	−350	−0.019	26,664.67	11/2	o	13,082.93	11/2	e
736.1832	13,579.834	nl	5	5	1.00	Ho I	1540*								
736.2260	13,579.045	nl	7	7	1.00	Ho I	500+								
737.1750	13,561.564	lc	14	14	1.00	Ho I	890-	−842	0.106	28,642.79	11/2	o	15,081.12	13/2	e
737.6564	13,552.714		10	10	1.00	Ho I	405-	−249	−0.014	22,157.86	13/2	e	8605.16	11/2	o
738.7731	13,532.228	nl	11	11	1.00	Ho I	130+								
738.9350	13,529.263		9	4	2.25	Ho II	325-	−278	−0.005	29,811.113	7	e	16,281.8551	6	o
741.9820	13,473.706	lc	18	16	1.13	Ho I	310*	−199	0.014	31,964.93	13/2	o	18,491.21	11/2	e
742.1264	13,471.083	lc	6	6	1.00	Ho I	180-	−122	−0.013	37,356.81	17/2	e	23,885.74	17/2	o
743.4611	13,446.899	lc	19	17	1.12	Ho I	530-	−398	0.001	26,529.83	11/2	o	13,082.93	11/2	e
743.9260	13,438.496		22	22	1.00	Ho I	905-	−768	−0.006	18,858.19	13/2	e	5 419.70	13/2	o
744.5654	13,426.955	nc	8	8	1.00	Ho I	550+	485	0.025	38,087.78	15/2	o	24,660.80	15/2	e
744.5937	13,426.445	lc	11	7	1.57	Ho I	210+	149	0.085	30,146.15	11/2	o	16,719.62	9/2	e
744.6626	13,425.204	lc	33	26	1.27	Ho I	705-	−623	−0.084	28,561.18	13/2	o	15,136.06	15/2	e
745.1499	13,416.423	nc	5	5	1.00	Ho I	970+	888	−0.013	38,077.21	13/2	o	24,660.80	15/2	e
745.4164	13,411.626	lc	9	9	1.00	Ho I	1520+	1387	0.184	37,772.62	19/2	o	24,360.81	17/2	e
745.6683	13,407.097	lc	6	6	1.00	Ho I	380-	−402	−0.057	36,905.61	15/2	o	23,498.57	17/2	e
745.8814	13,403.265		7	7	1.00	Ho I	1110-	−1068	−0.145	31,286.69	17/2	o	17,883.57	19/2	e
745.9753	13,401.580	lc	25	21	1.19	Ho I	1250-	−1165	−0.030	18,821.25	11/2	e	5419.70	13/2	o
746.9921	13,383.336	nl	4	4	1.00	Ho I	390-								
748.2885	13,360.150	lc	37	34	1.09	Ho I	390+	−80	0.050	26,443.13	11/2	o	13,082.93	11/2	e
748.5245	13,355.938	lc	26	20	1.30	Ho I	1135+	1058	0.002	24,678.25	19/2	o	11,322.31	21/2	e
749.2486	13,343.030	lc	9	6	1.50	Ho I	395+	230	0.030	30,280.49	11/2	o	16,937.43	11/2	e
749.4195	13,339.988		5	5	1.00	Ho I	950-	−905	−0.098	30,049.71	19/2	o	16,709.82	17/2	e
749.6180	13,336.456		160	131	1.22	Ho I	390+	44	0.064	18,756.22	15/2	e	5419.70	13/2	o
750.2560	13,325.115	lc	25	25	1.00	Ho I	1150-	−1098	−0.065	31,816.26	13/2	o	18,491.21	11/2	e
750.9126	13,313.464	lc	20	18	1.11	Ho I	820-	−645	−0.064	31,964.93	13/2	o	18,651.53	15/2	e
751.0665	13,310.734		7	3	2.33	Ho II	445*								
752.0448	13,293.420	nl	7	2	3.50	Ho II	288*								
753.0400	13,275.852	lc	7	6	1.17	Ho I	180*	237	0.048	32,134.09	15/2	o	18,858.19	13/2	e
754.0352	13,258.330	lc	17	20	0.85	Ho I	1695+	1616	0.150	37,619.29	19/2	o	24,360.81	17/2	e
754.1808	13,255.770	lc	42	34	1.24	Ho I	630*	−91	0.020	21,682.90	15/2	o	8427.11	15/2	e
754.4251	13,251.478	lc	8	8	1.00	Ho I	1412-	−1341	−0.118	31,816.26	13/2	o	18,564.90	13/2	e
754.7485	13,245.800	lc	9	6	1.50	Ho I	725-	−644	−0.020	22,392.86	13/2	o	9147.08	13/2	e
755.3854	13,234.632		11	11	1.00	Ho I	360+	179	0.038	28,315.79	15/2	o	15,081.12	13/2	e
755.4987	13,232.647	nc	438	365	1.20	Ho I	960-	376	0.003	31,116.22	17/2	o	17,883.57	19/2	e
756.1465	13,221.310	lc	10	6	1.67	Ho I	545*	−390	−0.010	29,013.43	13/2	o	15,792.13	11/2	e
756.9120	13,207.938	nc	14	14	1.00	Ho I	290*	233	0.072	40,165.71	13/2	o	26,957.70	15/2	e
757.1293	13,204.148	lc	6	5	1.20	Ho I	1045+	1186	0.002	37,864.95	17/2	o	24,660.80	15/2	e
757.2252	13,202.476	lc	45	35	1.29	Ho I	885-	−813	−0.086	31,540.19	15/2	o	18,337.80	17/2	e
758.1982	13,185.533		9	8	1.13	Ho I	90*	−55	−0.053	28,315.79	15/2	o	15,130.31	17/2	e
758.4007	13,182.013	lc	12	12	1.00	Ho I	1365+	1296	0.037	37,842.85	15/2	o	24,660.80	15/2	e
758.9150	13,173.079	nc	381	307	1.24	Ho I	430+	121	0.031	21,552.02	17/2	o	8378.91	17/2	e
759.1764	13,168.544	nc	30	28	1.07	Ho I	310*	−243	−0.014	37,029.70	11/2	o	23,861.17	9/2	e
759.3884	13,164.868		64	56	1.14	Ho I	1630-	−1544	−0.138	31,816.26	13/2	o	18,651.53	15/2	e
759.7723	13,158.216	lc	7	7	1.00	Ho I	1055*	−1093	−0.066	29,013.43	13/2	o	15,855.28	15/2	e
760.5259	13,145.177		378	330	1.15	Ho I	330*	−119	0.023	18,564.90	13/2	e	5419.70	13/2	o
760.6131	13,143.670	nc	48	42	1.14	Ho I	675+	604	0.010	31,964.93	13/2	o	18,821.25	11/2	e
760.6641	13,142.788	lc	16	15	1.07	Ho I	325+	−238	0.032	26,225.75	13/2	o	13,082.93	11/2	e
760.9125	13,138.498	nl	10	9	1.11	Ho I	135+								
761.2142	13,133.291		5	6	0.83	Ho I	685+								
761.7025	13,124.872	nc	129	110	1.17	Ho I	365+	182	0.038	21,552.02	17/2	o	8427.11	15/2	e
762.7555	13,106.753	nc	44	38	1.16	Ho I	370*	203	−0.013	31,964.93	13/2	o	18,858.19	13/2	e
762.7919	13,106.128	nc	288	253	1.14	Ho I	480*	230	−0.018	21,485.02	19/2	o	8378.91	17/2	e
762.8288	13,105.494	nc	189	174	1.09	Ho I	485-	−403	−0.034	31,443.26	15/2	o	18,337.80	17/2	e
763.0696	13,101.357	nc	9	9	1.00	Ho I	1140+	1326	0.103	37,762.26	17/2	o	24,660.80	15/2	e
764.1044	13,083.616	nc	20	18	1.11	Ho I	850-	−795	−0.076	37,029.70	11/2	o	23,946.16	11/2	e
764.8103	13,071.540	nc	77	74	1.04	Ho I	495-	−361	−0.030	18,491.21	11/2	e	5419.70	13/2	o
765.3705	13,061.972		6	1	6.00	Ho II	250*	−238	−0.063	29,811.113	7	e	16,749.2043	7	o
765.9879	13,051.445		7	7	1.00	Ho I	215*								
766.4089	13,044.275	nc	40	38	1.05	Ho I	220+	−114	0.015	26,127.22	13/2	o	13,082.93	11/2	e
766.7297	13,038.816	nc	18	16	1.13	Ho I	575-	−509	0.024	36,873.78	13/2	o	23,834.94	15/2	e
767.5731	13,024.491	nc	7	5	1.40	Ho I	760+	691	−0.061	40,165.71	13/2	o	27,141.28	13/2	e
767.9794	13,017.599	nl	5	4	1.25	Ho I	580*								
768.0376	13,016.614	lc	3	3	1.00	Ho I	205+	250	−0.004	33,091.50	15/2	o	20,074.89	15/2	e
768.9150	13,001.760	nc	19	19	1.00	Ho I	1215-	−1151	−0.100	31,339.46	15/2	o	18,337.80	17/2	e
769.0437	12,999.584	nc	947	858	1.10	Ho I	105*	45	0.046	21,378.54	17/2	o	8378.91	17/2	e
769.3106	12,995.074	nc	182	166	1.10	Ho I	375-	−289	−0.064	31,816.26	13/2	o	18,821.25	11/2	e
769.5131	12,991.654	nl	8	6	1.33	Ho I	445+								
769.7008	12,988.486	nc	4	3	1.33	Ho I	1190*	1082	−0.006	24,678.25	19/2	o	11,689.77	19/2	e
770.2218	12,979.701	nc	7	6	1.17	Ho I	625+	533	0.029	21,584.89	13/2	e	8605.16	11/2	o

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	*R*	ion.	*W* (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
770.4837	12,975.289	nc	–	9	bAr	Ho I	130+	95	0.001	31,540.19	15/2	o	18,564.90	13/2	e
771.1504	12,964.071	nc	19	17	1.12	Ho I	105*	−49	−0.001	40,077.35	11/2	o	27,113.28	11/2	e
771.5025	12,958.155	nc	174	153	1.14	Ho I	760-	−693	−0.085	31,816.26	13/2	o	18,858.19	13/2	e
771.9064	12,951.374	nc	326	301	1.08	Ho I	180+	104	0.056	21,378.54	17/2	o	8427.11	15/2	e
772.0523	12,948.926		7	7	1.00	Ho I	600*	−546	−0.036	31,286.69	17/2	o	18,337.80	17/2	e
772.8142	12,936.161	nc	4	4	1.00	Ho I	535*	−762	−0.091	40,077.35	11/2	o	27,141.28	13/2	e
773.3328	12,927.487	nc	7	6	1.17	Ho I	1060*	992	0.133	36,873.78	13/2	o	23,946.16	11/2	e
773.6319	12,922.487		5	4	1.25	Ho I	1400*	−1248	−0.157	30,805.90	17/2	o	17,883.57	19/2	e
773.9007	12,918.000	nc	16	14	1.14	Ho I	615+	305	0.080	36,873.76	13/2	o	23,955.68	13/2	e
774.1774	12,913.383	nc	5	4	1.25	Ho I	75*	−131	0.017	36,859.56	11/2	o	23,946.16	11/2	e
775.2093	12,896.193	nc	16	14	1.14	Ho I	910+	822	0.097	36,731.23	15/2	o	23,834.94	15/2	e
775.6611	12,888.682	nc	160	126	1.27	Ho I	300*	−108	−0.022	31,540.19	15/2	o	18,651.53	15/2	e
776.2860	12,878.307	nc	8	7	1.14	Ho I	560+	499	0.053	31,443.26	15/2	o	18,564.90	13/2	e
776.3587	12,877.101	nc	37	35	1.06	Ho I	455-	−272	0.019	22,024.20	13/2	o	9147.08	13/2	e
776.9677	12,867.008	nc	25	25	1.00	Ho I	355*	−267	0.032	22,014.12	15/2	o	9147.08	13/2	e
777.4239	12,859.457	nc	6	6	1.00	Ho I	470*	392	0.103	36,873.78	13/2	o	24,014.22	13/2	e
777.4385	12,859.215	lc	7	5	1.40	Ho I	290*	−644	0.005	29,013.43	13/2	o	16,154.21	15/2	e
777.9600	12,850.595	nc	7	7	1.00	Ho I	870*	−819	0.065	28,642.79	11/2	o	15,792.13	11/2	e
780.0068	12,816.874	nl	4	4	1.00	Ho I	190*								
781.5419	12,791.700		172	162	1.06	Ho I	540*	296	0.030	31,443.26	15/2	o	18,651.53	15/2	e
781.8260	12,787.051		5	5	1.00	Ho I	860*	788	0.069	27,923.18	17/2	o	15,136.06	15/2	e
782.3610	12,778.307	nc	141	117	1.21	Ho I	1590+	903	0.113	31,116.22	17/2	o	18,337.80	17/2	e
782.9241	12,769.117	nc	9	7	1.29	Ho I	510-	−448	−0.067	28,561.18	13/2	o	15,792.13	11/2	e
782.9971	12,767.927	nc	48	38	1.26	Ho I	280-	−63	0.083	21,373.17	9/2	e	8605.16	11/2	o
783.2370	12,764.015	nc	4	4	1.00	Ho I	425-	−386	−0.015	33,005.31	15/2	o	20,241.31	13/2	e
783.7426	12,755.781	lc	5	6	0.83	Ho I	140-	−114	−0.001	29,465.60	19/2	o	16,709.82	17/2	e
787.0307	12,702.490	nl	4	3	1.33	Ho I	140*								
787.9315	12,687.969	nc	33	31	1.06	Ho I	520-	−452	−0.039	31,339.46	15/2	o	18,651.53	15/2	e
788.2025	12,683.606	lc	23	14	1.64	Ho I	120*	49	−0.046	23,379.31	11/2	e	10,695.75	9/2	o
788.3041	12,681.971	nc	21	15	1.40	Ho I	800+	740	0.029	31,540.19	15/2	o	18,858.19	13/2	e
788.3758	12,680.818	nl	5	2	2.50	Ho II	150*								
789.4660	12,663.306		7	4	1.75	Ho II	445+	311	−0.004	29,412.506	8	e	16,749.2043	7	o
794.3791	12,584.986	nc	35	32	1.09	Ho I	1213+	1144	0.084	31,443.26	15/2	o	18,858.19	13/2	e
797.4977	12,535.773	nc	490	387	1.27	Ho I	255*	−1	0.047	21,682.90	15/2	o	9147.08	13/2	e
802.0569	12,464.515	nc	12	12	1.00	Ho I	1705+	1602	0.175	31,116.22	17/2	o	18,651.53	15/2	e
802.8483	12,452.228	nc	29	29	1.00	Ho I	675+	617	0.042	20,831.18	19/2	o	8378.91	17/2	e
803.6606	12,439.642	lc	7	7	1.00	Ho I	200*	134	0.008	21,044.81	13/2	e	8605.16	11/2	o
809.8501	12,344.569	nc	525	381	1.38	Ho I	280-	−23	−0.019	12,344.55	13/2	e	0	15/2	o
810.2137	12,339.030	nc	2547	1882	1.35	Ho I	555*	4	0.010	12,339.04	15/2	e	0	15/2	o
813.5793	12,287.986	lc	4	4	1.00	Ho I	235+	180	−0.006	23,818.54	15/2	o	11,530.56	17/2	e
816.5030	12,243.986	nc	158	122	1.30	Ho I	262*	−78	−0.016	20,849.13	11/2	e	8605.16	11/2	o
817.1124	12,234.854	nc	42	42	1.00	Ho I	94+	20	0.036	20,613.8	17/2	o	8378.91	17/2	e
819.0221	12,206.327		7	4	1.75	Ho I or II	145-								
820.3449	12,186.644	nc	21	20	1.05	Ho I	295*	88	0.046	20,613.80	17/2	o	8427.11	15/2	e
820.4105	12,185.670	nl	9	5	1.80	Ho I or II	95*								
828.4992	12,066.701	nc	7	6	1.17	Ho I	840-	−750	−0.051	20,493.76	13/2	o	8427.11	15 2	e
831.7959	12,018.877		19	16	1.19	Ho I	478*	69	0.003	24,357.92	15/2	o	12,339.04	15/2	e
846.4701	11 810.521		5	21	0.24	Ho I	104*	21	−0.001	21,552.02	17/2	o	9741.50	19/2	e
851.2948	11,743.586	nc	65	122	0.53	Ho I	200+	126	−0.066	21,485.02	19/2	o	9741.50	19/2	e
859.0900	11,637.027	nc	5	10	0.50	Ho I	130-	−54	0.013	21,378.54	17/2	o	9741.50	19/2	e
861.9685	11,598.166	nc	2	3	0.67	Ho I	120+	76	−0.006	23,942.71	13/2	o	12,344.55	13/2	e
863.2279	11,581.245	nc	1	2	0.50	Ho I	200+	125	0.005	30,146.15	11/2	o	18,564.90	13/2	e
866.7400	11,534.317	nc	2	3	0.67	Ho I	619+	563	0.053	26,664.68	17/2	o	15,130.31	17/2	e
867.0227	11,530.557	nc	37	86	0.43	Ho I	390+	111	0.003	11,530.56	17/2	e	0.00	15/2	o
867.7276	11,521.190	nl	12	15	0.80	Ho I or II	163*								
867.9861	11,517.758	nc	2	4	0.50	Ho I	182+	−117	−0.028	16,937.43	11/2	e	5419.70	13/2	o
868.7593	11,507.508	nc	2	5	0.40	Ho I	444+	455	0.002	26,637.82	17/2	o	15,130.31	17/2	e
870.3268	11,486.782	nc	1	2	0.50	Ho I	241+	172	−0.042	30,242.96	15/2	o	18,756.22	15/2	e
870.8798	11,479.488	nc	1	4	0.25	Ho I	348+	288	0.012	23,818.54	15/2	o	12,339.04	15/2	e
871.3002	11,473.950	nc	1	3	0.33	Ho I	235+	315	0.040	23,818.54	15/2	o	12,344.55	13/2	e
872.1622	11,462.609	nc	1	3	0.33	Ho I	607-	−643	−0.029	16,882.28	15/2	e	5419.70	13/2	o
873.2231	11,448.683	nc	1	2	0.50	Ho I	450+	−413	0.027	26,529.83	11/2	o	15,081.12	13/2	e
880.4458	11,354.765	nl	4	7	0.57	Ho I	277*								
883.4434	11,316.237	nc	11	22	0.50	Ho I	310+	−95	0.013	16,735.95	13/2	e	5419.70	13/2	o
891.5811	11,212.951		2	2	1.00	Ho II	120+	10	−0.002	28,926.813	9	e	17,713.8643	9	o
901.4928	11,089.668	nc	6	12	0.50	Ho I	585+	517	0.012	20,831.18	19/2	o	9741.50	19/2	e
905.3918	11,041.911		3	3	1.00	Ho I or II	95*								
908.6043	11,002.871	nc	3	3	1.00	Ho I	110+	56	−0.001	29,760.74	9/2	o	18,757.87	9/2	e
918.7297	10,881.608	nc	5	8	0.63	Ho I	75*	115	−0.018	26,673.72	13/2	o	15,792.13	11/2	e
919.4887	10,872.625	nc	5	7	0.71	Ho I	370-	−350	−0.085	26,664.67	11/2	o	15,792.13	11/2	e
920.5765	10,859.778	nc	11	19	0.58	Ho I	84*	114	0.002	23,942.71	13/2	o	13,082.93	11/2	e
921.7770	10,845.635		2	3	0.67	Ho I	608+								
923.6893	10,823.181	nc	1	2	0.50	Ho I	314-	−280	−0.051	26,977.34	13/2	o	16,154.21	15/2	e
923.7621	10,822.328		2	3	0.67	Ho I	122+								
924.0879	10,818.513	nc	5	8	0.63	Ho I	640-	−588	−0.073	26,673.72	13/2	o	15,855.28	15/2	e
928.4066	10,768.188	nc	2	3	0.67	Ho I	487+	406	0.002	26,922.40	15/2	o	16,154.21	15/2	e

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
931.0373	10,737.762	nc	7	14	0.50	Ho I	485-	−390	−0.062	26,529.83	11/2	o	15,792.13	11/2	e
931.3243	10,734.452	nc	12	22	0.55	Ho I	361+	147	0.058	16,154.21	15/2	e	5419.70	13/2	o
936.0563	10,680.188		4	7	0.57	Ho I	186+								
936.2995	10,677.414	nc	1	2	0.50	Ho I	110+	62	0.006	21,373.17	9/2	e	10,695.75	9/2	o
937.1466	10,667.763		7	8	0.88	Ho II	284+	219	−0.002	28,926.813	9	e	18,259.052	10	o
937.4483	10,664.329	nc	2	4	0.50	Ho I	165-	−195	−0.059	29,422.14	9/2	o	18,757.87	9/2	e
943.0046	10,601.493	nc	5	8	0.63	Ho I	506-	−445	−0.053	26,456.72	15/2	o	15,855.28	15/2	e
947.2050	10,554.481		4	7	0.57	Ho I	393*								
950.3506	10,519.546	nc	28	47	0.60	Ho I	371-	−139	−0.036	26,673.72	13/2	o	16,154.21	15/2	e
951.9085	10,502.330	nc	8	14	0.57	Ho I	439+	325	0.070	23,585.33	13/2	o	13,082.93	11/2	e
953.5382	10,484.381	nc	3	6	0.50	Ho I	454+	375	0.009	26,922.40	15/2	o	16,438.01	17/2	e
953.6107	10,483.584	nc	23	44	0.52	Ho I	535-	−395	−0.024	22,014.12	15/2	o	11,530.56	17/2	e
954.9447	10,468.939	lc	1	2	0.50	Ho I	493+	890	0.061	20,210.50	21/2	o	9741.50	19/2	e
956.8496	10,448.097		2	3	0.67	Ho I	154+								
962.2184	10,389.801		4	2	2.00	Ho II	418-	−349	−0.006	26,671.65	7	e	16,281.8551	6	o
963.0870	10,380.431		7	8	0.88	Ho I or II	340*								
965.0939	10,358.845	nc	317	512	0.62	Ho I	462+	253	0.035	18,737.79	17/2	o	8378.91	17/2	e
967.7753	10,330.144	nc	8	10	0.80	Ho I	690-	−644	0.036	27,049.80	11/2	o	16,719.62	9/2	e
968.0120	10,327.618	nl	2	2	1.00	Ho I or II	108+								
968.1457	10,326.192	lc	1	2	0.50	Ho I	556+	608	0.098	26,480.50	17/2	o	16,154.21	15/2	e
969.2985	10,313.911	lc	2	2	1.00	Ho I	518-	−690	−0.061	27,049.80	11/2	o	16,735.95	13/2	e
969.6067	10,310.633	nc	147	494	0.30	Ho I	494+	322	0.047	18,737.79	17/2	o	8427.11	15/2	e
970.3691	10,302.531	nc	130	230	0.57	Ho I	64*	4	−0.021	26,456.72	15/2	o	16,154.21	15/2	e
970.5184	10,300.947		6	6	1.00	Ho II	237+	176	0.003	29,412.506	8	e	19,111.556	9	o
976.1616	10,241.397	lc	2	4	0.50	Ho I	86*	−37	−0.007	26,977.34	13/2	o	16,735.95	13/2	e
977.2465	10,230.027		4	2	2.00	Ho II	164+								
977.5739	10,226.601	nc	4	7	0.57	Ho I	572+	536	0.069	26,664.68	17/2	o	16,438.01	17/2	e
978.1989	10,220.067		3	4	0.75	Ho I or II	86*								
978.9052	10,212.693		2	2	1.00	Ho I or II	310*								
979.7304	10,204.091		4	5	0.80	Ho I or II	117+								
979.9418	10,201.890		10	15	0.67	Ho I	302-								
980.1449	10,199.776	lc	5	8	0.63	Ho I	515+	429	0.034	26,637.82	17/2	o	16,438.01	17/2	e
980.7588	10,193.391	nc	454	883	0.51	Ho I	301-	−134	−0.021	18,572.28	15 /2	o	8378.91	17/2	e
981.4319	10,186.401	lc	2	3	0.67	Ho I	610+	649	0.049	26,922.40	15 /2	o	16,735.95	13/2	e
982.3332	10,177.055	nl	3	3	1.00	Ho I or II	54*								
983.2039	10,168.042	nc	8	10	0.80	Ho I	443+	223	0.028	30,242.96	15/2	o	20,074.89	15/2	e
983.7144	10,162.766	nc	1650	3140	0.53	Ho I	146+	98	−0.056	21,485.02	19/2	o	11,322.31	21/2	e
983.8771	10,161.085	nl	8	13	0.62	Ho I	650+								
984.6151	10,153.469	lc	3	5	0.60	Ho I	58*	47	−0.089	20,849.13	11/2	e	10,695.75	9/2	o
984.7235	10,152.351	nc	390	590	0.66	Ho I	359-	−129	−0.011	21,682.90	15/2	o	11,530.56	17/2	e
985.4200	10,145.175	nc	1050	2180	0.48	Ho I	130-	−65	−0.005	18,572.28	15/2	o	8427.11	15/2	e
986.5207	10,133.856	lc	3	5	0.60	Ho I	355+	306	0.034	26,288.10	13/2	o	16,154.21	15/2	e
986.9257	10,129.697	nc	11	24	0.46	Ho I	1103+	946	0.143	19,276.92	15/2	o	9147.08	13/2	e
988.5256	10,113.303	lc	1	3	0.33	Ho I	323-	−262	0.007	33,091.50	15/2	o	22,978.19	13/2	e
991.7214	10,080.713		4	5	0.80	Ho I	94*	35	0.027	30,339.01	13/2	o	20,258.27	13/2	e
994.3663	10,053.900	nc	18	32	0.56	Ho I	710-	−665	−0.080	22,392.86	13/2	o	12 339.04	15/2	e
994.9145	10,048.360	nc	30	53	0.57	Ho I	695-	−637	−0.050	22,392.86	13/2	o	12,344.55	13/2	e
995.5062	10,042.388	lc	2	5	0.40	Ho I	630+	578	0.102	26,480.50	17/2	o	16,438.01	17/2	e
995.5593	10,041.852	nl	5	7	0.71	Ho I	259*								
995.8232	10,039.191	lc	2	2	1.00	Ho I	102+	38	−0.011	30,280.49	11/2	o	20,241.31	13/2	e
997.0228	10,027.112	lc	2	5	0.40	Ho I	407-	−280	0.008	33,005.31	15/2	o	22,978.19	13/2	e
997.5865	10,021.446	nc	166	278	0.60	Ho I	340+	143	0.014	21,552.02	17/2	o	11,530.56	17/2	e
997.8570	10,018.729	nc	304	538	0.57	Ho I	90*	−26	−0.019	26,456.72	15/2	o	16,438.01	17/2	e
999.4587	10,002.674	nl	3	5	0.60	Ho I	231-								
999.5633	10,001.627	lc	4	5	0.80	Ho I	290+	131	0.023	30,242.96	15/2	o	20,241.31	13/2	e
1001.6197	9981.093	nc	38	70	0.54	Ho I	593+	534	0.067	26,664.68	17/2	o	16,683.52	19/2	e
1002.9247	9968.106	lc	1	6	0.17	Ho I	366-	−293	0.024	30,135.31	17/2	o	20,167.18	15/2	e
1004.3190	9954.267	nc	82	191	0.43	Ho I	539+	427	0.033	26,637.82	17/2	o	16,683.52	19/2	e
1004.4966	9952.507	nc	6	6	1.00	Ho II	917+	864	0.001	26,234.363	7	e	16,281.8551	6	o
1005.2535	9945.013	nc	22	65	0.34	Ho I	379-	−314	0.037	26,664.67	11/2	o	16,719.62	9/2	e
1005.9868	9937.764	nc	53	155	0.34	Ho I	335+	104	0.006	26,673.72	13/2	o	16,735.95	13/2	e
1006.8972	9928.779	nc	5	17	0.29	Ho I	429-	−361	−0.059	26,664.67	11/2	o	16,735.95	13/2	e
1007.0900	9926.878	lc	1	2	0.50	Ho I	435*	−364	−0.028	30,425.58	19/2	o	20,498.73	17/2	e
1007.5398	9922.446	lc	3	3	1.00	Ho II	596-	−309	0.000	26,671.650	7	e	16,749.2043	7	o
1007.7928	9919.955		5	11	0.45	Ho I	183*								
1009.3327	9904.821	nc	7	18	0.39	Ho I	121-	−81	0.019	30,146.15	11/2	o	20,241.31	13/2	e
1010.8477	9889.976		2	7	0.29	Ho I	837*								
1012.8892	9870.043		4	5	0.80	Ho II	337-	−173	0.000	29,899.577	7	e	20,029.534	8	o
1012.9627	9869.327	lc	1	4	0.25	Ho I	373-	−173	−0.017	26,023.52	15/2	o	16,154.21	15/2	e
1013.6880	9862.265	nc	563	1780	0.32	Ho I	1158+	59	−0.015	21,552.02	17/2	o	11,689.77	19/2	e
1014.6312	9853.097	nl	2	7	0.29	Ho I	441*								
1015.1618	9847.947	nc	358	1254	0.29	Ho I	107+	67	0.033	21,378.54	17/2	o	11,530.56	17/2	e
1017.9053	9821.405	lc	1	3	0.33	Ho I	319+	239	0.135	28,642.79	11/2	o	18,821.25	11/2	e
1018.5020	9815.651	nl	2	8	0.25	Ho I	209*								
1018.5426	9815.259		3	6	0.50	Ho II	265*	236	−0.002	28,926.813	9	e	19,111.556	9	o
1018.7043	9813.701		13	34	0.38	Ho I	119*								

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1019.0728	9810.153	nc	13	45	0.29	Ho I	419-	−355	0.057	26,529.83	11/2	o	16,719.62	9/2	e
1020.4535	9796.879	nc	30	101	0.30	Ho I	635+	576	0.101	26,480.50	17/2	o	16,683.52	19/2	e
1020.6166	9795.314	nc	50	178	0.28	Ho I	221+	167	−0.064	21,485.02	19/2	o	11,689.77	19/2	e
1020.7621	9793.918	lc	1	3	0.33	Ho I	435-	−401	−0.038	26,529.83	11/2	o	16,735.95	13/2	e
1021.0890	9790.782		2	4	0.50	Ho I	107*	76	0.048	30,049.10	15/2	o	20,258.27	13/2	e
1021.3160	9788.606	nl	2	8	0.25	Ho I	690*								
1021.3723	9788.066	nc	22	55	0.40	Ho I	82*		−0.016	30,029.36	13/2	o	20,241.31	13/2	e
1021.7487	9784.461		2	6	0.33	Ho I	495*								
1023.1906	9770.672	nc	5	18	0.28	Ho I	184-	−99	0.008	26,480.50	17/2	o	16,709.82	17/2	e
1024.2734	9760.343	nc	3	10	0.30	Ho I	365+	298	0.037	26,198.39	15/2	o	16,438.01	17/2	e
1025.1691	9751.816	nl	1	3	0.33	Ho I	198*								
1025.3546	9750.051	nl	8	18	0.44	Ho I	156*								
1025.6737	9747.018	nc	8	30	0.27	Ho I	774-	−702	−0.118	26,456.72	15/2	o	16,709.82	17/2	e
1026.8095	9736.236	nc	62	198	0.31	Ho I	275+	126	0.054	26,673.72	13/2	o	16,937.43	11/2	e
1027.7576	9727.255	nc	6	20	0.30	Ho I	440-	−339	−0.015	26,664.67	11/2	o	16,937.43	11/2	e
1028.4460	9720.744	nc	14	52	0.27	Ho I	425+	247	0.026	26,456.72	15/2	o	16,735.95	13/2	e
1028.9162	9716.302	nc	4	12	0.33	Ho I	362+	68	0.058	15,136.06	15/2	e	5419.70	13/2	o
1029.8842	9707.169	lc	1	5	0.20	Ho I	172-	−83	0.011	26,443.13	11/2	o	16,735.95	13/2	e
1030.0457	9705.647		2	3	0.67	Ho II	190-	−121	0.005	29,588.887	6	e	19,883.235	5	o
1030.1400	9704.759	nl	1	3	0.33	Ho I	364*								
1030.7195	9699.302	nl	3	11	0.27	Ho I	84*								
1031.8414	9688.757	nc	1178	4557	0.26	Ho I	84*	−17	0.013	21,378.54	17/2	o	11,689.77	19/2	e
1032.2214	9685.190	nc	61	230	0.27	Ho I	363-	−293	−0.030	22,024.20	13/2	o	12,339.04	15/2	e
1032.8118	9679.653	nc	115	422	0.27	Ho I	394-	−265	−0.003	22,024.20	13/2	o	12,344.55	13/2	e
1033.2981	9675.098	nc	19	72	0.26	Ho I	453-	−288	−0.018	22,014.12	15/2	o	12,339.04	15/2	e
1033.3745	9674.383	nc	78	190	0.41	Ho I	160+	97	−0.053	30,242.96	15/2	o	20,568.63	17/2	e
1033.8898	9669.561	nc	9	33	0.27	Ho I	320-	−260	0.009	22,014.12	15/2	o	12,344.55	13/2	e
1034.7614	9661.416	nc	4	11	0.36	Ho I	310-	−84	0.004	15,081.12	13/2	e	5419.70	13/2	o
1035.1904	9657.412		2	7	0.29	Ho I	215*								
1036.4044	9646.100	lc	1	3	0.33	Ho I	478-	−328	0.120	33,091.50	15/2	o	23,445.28	15/2	e
1036.4954	9645.253	nl	1	2	0.50	Ho I	383*								
1036.8201	9642.232	nl	1	4	0.25	Ho I	121*								
1042.1315	9593.089	lc	2	10	0.20	Ho I	1667-	−1573	−0.159	33,091.50	15/2	o	23,498.57	17/2	e
1042.9057	9585.968	lc	1	4	0.25	Ho I	103*	43	−0.058	29,660.80	13/2	o	20,074.89	15/2	e
1042.9537	9585.527	nc	5	15	0.33	Ho I	596-	−203	−0.017	26,023.52	15/2	o	16,438.01	17/2	e
1043.0811	9584.356		2	3	0.67	Ho II	147-	−91	−0.038	29,899.577	7	e	20,315.259	6	o
1043.3590	9581.803		2	3	0.67	Ho II	625+	586	0.002	26,331.009	8	e	16,749.2043	7	o
1044.2342	9573.772		1	4	0.25	Ho I	242*								
1045.2943	9564.063	nc	1	6	0.17	Ho I	467-	−337	0.057	32,542.31	11/2	o	22,978.19	13/2	e
1045.7484	9559.910	nc	1	4	0.25	Ho I	530-	−346	0.120	33,005.31	15/2	o	23,445.28	15/2	e
1046.6045	9552.090	lc	1	6	0.17	Ho I	608 -	549	0.060	26,288.10	13/2	o	16,735.95	13/2	e
1051.3621	9508.865	nc	24	101	0.24	Ho I	556+	485	0.005	20,831.18	19/2	o	11,322.31	21/2	e
1051.5795	9506.900	nc	3	18	0.17	Ho I	1648-	−1592	−0.160	33,005.31	15/2	o	23,498.57	17/2	e
1053.9899	9485.158		4	7	0.57	Ho II	944+	904	0.001	26,234.363	7	e	16,749.2043	7	o
1055.0962	9475.213	lc	1	2	0.50	Ho I	193*	127	0.027	27,358.81	21/2	o	17,883.57	19/2	e
1055.6242	9470.473	nc	3	12	0.25	Ho I	207+	126	0.007	26,529.83	11/2	o	17,059.35	13/2	e
1056.5298	9462.356	nc	1	3	0.33	Ho I	646+	571	0.084	26,198.39	15/2	o	16,735.95	13/2	e
1056.7889	9460.036	lc	1	5	0.20	Ho I	126*	−88	0.014	26,143.57	17/2	o	16,683.52	19/2	e
1057.1734	9456.595		1	2	0.50	Ho I	485*								
1057.6047	9452.739	nl	39	85	0.46	Ho I	126*								
1058.3119	9446.422	nl	1	2	0.50	Ho I	372*								
1058.5124	9444.633	nl	2	6	0.33	Ho I	60*								
1059.3877	9436.829	lc	6	15	0.40	Ho I	380+	223	−0.009	29,930.22	11/2	o	20,493.40	11/2	e
1059.7242	9433.833		1	6	0.17	Ho I	840-	−763	−0.083	26,143.57	17/2	o	16,709.82	17/2	e
1060.0026	9431.355	nc	1	5	0.20	Ho I	483+	285	0.005	30,280.49	11/2	o	20,849.13	11/2	e
1060.6975	9425.176	nc	1856	7270	0.26	Ho I	105-	15	0.024	18,572.28	15/2	o	9147.08	13/2	e
1061.4050	9418.894	nl	3	10	0.30	Ho I	1405*								
1061.6868	9416.394	nl	2	5	0.40	Ho I	112*								
1062.3087	9410.881		1	3	0.33	Ho I	540+	634	−0.001	29,979.51	15/2	o	20,568.63	17/2	e
1062.4884	9409.290	nl	1	2	0.50	Ho I	99*								
1062.7146	9407.287	nc	2	4	0.50	Ho II	230*	−228	0.049	29,899.577	7	e	20,492.241	7	o
1062.8921	9405.716	lc	2	5	0.40	Ho I	1146+	1097	0.104	26,288.10	13/2	o	16,882.28	15/2	e
1063.2825	9402.262		3	7	0.43	Ho I	158*								
1065.4686	9382.971	nc	4	7	0.57	Ho II	202*	147	0.001	29,412.506	8	e	20,029.534	8	o
1069.0586	9351.462	nl	1	4	0.25	Ho I	110*								
1069.1610	9350.567	lc	1	2	0.50	Ho I	618+	571	0.103	26,288.10	13/2	o	16,937.43	11/2	e
1069.9281	9343.863	nc	960	2931	0.33	Ho I	71*	−22	−0.003	21,682.90	15/2	o	12,339.04	15/2	e
1070.5627	9338.324	nc	544	1626	0.33	Ho I	78*	6	0.026	21,682.90	15/2	o	12,344.55	13/2	e
1071.8115	9327.444	nc	8	39	0.21	Ho I	130*		−0.044	38,397.18	13/2	o	29,069.78	11/2	e
1072.3796	9322.502	nl	3	10	0.30	Ho I	149*								
1073.1105	9316.153	lc	1	2	0.50	Ho I	298*	238	0.017	31,793.06	17/2	o	22,476.89	17/2	e
1073.8266	9309.940	nc	54	183	0.30	Ho I	638-	−598	−0.010	22,392.86	13/2	o	13,082.93	11/2	e
1074.9054	9300.596	lc	2	4	0.50	Ho I	631+	638	0.024	20,831.18	19/2	o	11,530.56	17/2	e
1074.9361	9300.331	lc	3	13	0.23	Ho I	77*	47	0.079	38,397.18	13/2	o	29,096.77	11/2	e
1074.9934	9299.835	nl	4	7	0.57	Ho I or II	58*								
1075.3196	9297.014	nc	6	17	0.35	Ho I	206+	166	0.006	30,146.15	11/2	o	20,849.13	11/2	e

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1075.4640	9295.766		4	7	0.57	Ho II	321-	−133	0.048	29,325.348	7	e	20,029.534	8	o
1075.6832	9293.871	nl	1	4	0.25	Ho I	218*								
1076.8080	9284.163	nc	2	6	0.33	Ho I	135*	−89	−0.003	32,663.47	11/2	o	23,379.31	11/2	e
1078.0313	9273.628		2	4	0.50	Ho II	116*	−106	0.000	29,588.887	6	e	20,315.259	6	o
1078.7615	9267.351	lc	5	10	0.50	Ho I	90*	−28.6	−0.011	29,760.74	9/2	o	20,493.40	11/2	e
1078.9835	9265.444	lc	1	3	0.33	Ho I	332+	301	−0.024	29,834.05	15/2	o	20,568.63	17/2	e
1079.3504	9262.295	nl	1	3	0.33	Ho I	434*								
1079.4797	9261.185		1	4	0.25	Ho I	900+	734	0.105	26,143.57	17/2	o	16,882.28	15/2	e
1080.0095	9256.642	lc	1	3	0.33	Ho I	1225-	−1122	−0.082	33,091.50	15/2	o	23,834.94	15/2	e
1080.9618	9248.487		1	3	0.33	Ho I	325*								
1081.3789	9244.920	nc	2	8	0.25	Ho I	496+	431	0.020	26,127.22	13/2	o	16,882.28	15/2	e
1083.2864	9228.641	nc	7	26	0.27	Ho I	1153+	1077	0.109	26,288.10	13/2	o	17,059.35	13/2	e
1083.4034	9227.645	nc	8	27	0.30	Ho I	1128-	−114	−0.035	24,357.92	15/2	o	15,130.31	17/2	e
1083.7210	9224.940		2	6	0.33	Ho I	120*								
1085.1301	9212.961	nc	34	110	0.31	Ho I	411+	250	0.019	21,552.02	17/2	o	12,339.04	15/2	e
1085.6532	9208.522	nc	1	3	0.33	Ho I	390-	−314	−0.052	30,425.58	19/2	o	21,217.11	19/2	e
1086.0816	9204.890		1	4	0.25	Ho I	473*								
1086.5666	9200.781		1	8	0.13	Ho I	125*								
1087.6877	9191.298		2	2	1.00	Ho II	409+	251	−0.002	29,074.531	6	e	19,883.235	5	o
1087.8691	9189.765	lc	1	2	0.50	Ho I	183*	−95	0.025	26,127.22	13/2	o	16,937.43	11/2	e
1089.0003	9180.219	lc	3	9	0.33	Ho I	389+	225	0.011	30,029.36	13/2	o	20,849.13	11/2	e
1090.1599	9170.454	nc	1	5	0.20	Ho I	1214-	−1140	−0.084	33,005.31	15/2	o	23,834.94	15/2	e
1090.6469	9166.360	nc	2	6	0.33	Ho I	331+	286	0.040	26,225.75	13/2	o	17,059.35	13/2	e
1091.0433	9163.029	nc	2	4	0.50	Ho I	357-	−198	−0.029	32,542.31	11/2	o	23,379.31	11/2	e
1091.1462	9162.165		16	33	0.48	Ho I	137*								
1091.8734	9156.063		1	6	0.17	Ho I	100+								
1092.3690	9151.909	nc	21	50	0.42	Ho I	411+	151	0.011	27,643.13	11/2	o	18,491.21	11/2	e
1092.9408	9147.121	nc	4	16	0.25	Ho I	187-	−16	−0.041	91 47.08	13/2	e	0.00	15/2	o
1093.6235	9141.411	nc	2	14	0.14	Ho I	851+	554	−0.001	20,831.18	19/2	o	11,689.77	19/2	e
1093.6528	9141.166	lc	2	14	0.14	Ho I	854+	554	0.074	26,023.52	15/2	o	16,882.28	15/2	e
1094.2925	9135.822	nc	3	18	0.17	Ho I	367-	−309	−0.002	33,091.50	15/2	o	23,955.68	13/2	e
1095.6639	9124.387		2	4	0.50	Ho I	434*								
1096.2700	9119.343	nl	1	4	0.25	Ho I	384*								
1096.2950	9119.135		16	46	0.35	Ho I	75*								
1098.4391	9101.335	nc	15	39	0.38	Ho I	43*	−21.9	0.005	30,146.15	11/2	o	21,044.81	13/2	e
1100.6297	9083.220	nc	42	198	0.21	Ho I	104+	41	0.020	20 613.80	17/2	o	11,530.56	17/2	e
1101.2300	9078.269	nc	42	113	0.37	Ho I	135-	−92	−0.039	27,643.13	11/2	o	18,564.90	13/2	e
1101.3462	9077.311	nc	11	52	0.21	Ho I	312-	−221	−0.031	33,091.50	15/2	o	24,014.22	13/2	e
1101.7167	9074.258	nc	1	3	0.33	Ho I	258*	−121	0.082	31,272.03	13/2	o	22,197.69	11/2	e
1102.4957	9067.847	nc	6	19	0.32	Ho I	465+	411	0.023	26,127.22	13/2	o	17,059.35	13/2	e
1103.7744	9057.342		1	2	0.50	Ho I	250*								
1104.7146	9049.633	nc	4	25	0.16	Ho I	384-	−327	−0.003	33,005.31	15/2	o	23,955.68	13/2	e
1105.9572	9039.466	nc	43	160	0.27	Ho I	371+	174	0.034	21,378.54	17/2	o	12,339.04	15/2	e
1109.5631	9010.089	nc	2	4	0.50	Ho II	115*	−50	0.000	29,325.348	7	e	20,315.259	6	o
1111.2657	8996.284	nc	640	1997	0.32	Ho I	229+	153	0.006	18,737.79	17/2	o	9741.50	19/2	e
1111.9070	8991.096	nc	10	80	0.13	Ho I	313-	−239	−0.006	33,005.31	15/2	o	24,014.22	13/2	e
1115.1986	8964.558	lc	1	3	0.33	Ho I	239+	175	0.012	32,331.28	19/2	o	23,366.71	21/2	e
1115.2570	8964.088	nc	1	4	0.25	Ho I	735+	597	0.082	26,023.52	15/2	o	17,059.35	13/2	e
1116.6647	8952.788		1	2	0.50	Ho I	506-								
1117.3656	8947.172		2	2	1.00	Ho II	632*	−655.5	−0.020	28,830.387	6	e	19 883.235	5	o
1118.1078	8941.233	nc	195	736	0.26	Ho I	286-	−226	0.037	22,024.20	13/2	o	13,082.93	11/2	e
1119.1987	8932.518	nc	2	8	0.25	Ho I	588+	514	0.062	27,423.79	13/2	o	18,491.21	11/2	e
1119.6636	8928.809	lc	2	6	0.33	Ho I	167*	−189	−0.069	29,422.14	9/2	o	20,493.40	11/2	e
1120.2618	8924.041	nc	74	342	0.22	Ho I	136+	−42.5	−0.011	20,613.80	17/2	o	11,689.77	19/2	e
1122.3525	8907.418	nc	2	4	0.50	Ho I	390+	270	−0.098	30,280.49	11/2	o	21,373.17	9/2	e
1123.7351	8896.458	nl	1	3	0.33	Ho I	241*								
1123.8723	8895.372		1	4	0.25	Ho I	246*								
1125.1280	8885.445	nc	20	50	0.40	Ho I	123*	−97	−0.035	29,930.22	11/2	o	21,044.81	13/2	e
1125.1572	8885.214	lc	28	73	0.38	Ho I	82*	−2	0.046	27,643.13	11/2	o	18,757.87	9/2	e
1128.1586	8861.575	nc	33	97	0.34	Ho I	350+	99	0.015	23,942.71	13/2	o	15,081.12	13/2	e
1128.5023	8858.877	nc	13	39	0.33	Ho I	468+	271	0.013	27,423.79	13/2	o	18,564.90	13/2	e
1131.7946	8833.107		3	5	0.60	Ho II	343-	−187	0.000	29,325.348	7	e	20,492.241	7	o
1132.5043	8827.571	nc	1	6	0.17	Ho I	285-	−254	−0.031	33,091.50	15/2	o	24,263.96	17/2	e
1133.2369	8821.865	nc	5	12	0.42	Ho I	1019+	954	0.015	27,643.13	11/2	o	18,821.25	11/2	e
1134.0420	8815.602		3	12	0.25	Ho I	382+								
1135.1900	8806.687	nc	55	158	0.35	Ho I	98*	−53	−0.037	23,942.71	13/2	o	15,136.06	15/2	e
1135.8191	8801.809	lc	1	3	0.33	Ho I	461+	383	0.151	20,124.27	19/2	o	11,322.31	21/2	e
1137.9487	8785.337	nc	5	20	0.25	Ho I	821-	−323	−0.007	20,315.89	17/2	o	11,530.56	17/2	e
1137.9986	8784.952	lc	1	6	0.17	Ho I	396*	553	−0.012	27,643.13	11/2	o	18,858.19	13/2	e
1139.5395	8773.073	nc	9	25	0.36	Ho I	292+	151	−0.093	30,146.15	11/2	o	21,373.17	9/2	e
1141.9279	8754.723		12	54	0.22	Ho I	151*								
1142.0692	8753.640	nl	3	9	0.33	Ho I	182*								
1142.5874	8749.670	nc	5	19	0.26	Ho I	194-	−113	0.010	23,885.74	17/2	o	15,136.06	15/2	e
1143.4143	8743.343	nl	3	3	1.00	Ho II	107*								
1143.6715	8741.376	nc	3	18	0.17	Ho I	420-	−272	−0.026	33,005.31	15/2	o	24,263.96	17/2	e
1144.1962	8737.368	nc	14	30	0.47	Ho I	357+	339	0.052	23,818.54	15/2	o	15,081.12	13/2	e

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	*R*	ion.	*W* (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1145.0667	8730.725	nc	62	291	0.21	Ho I	278+	−134	−0.035	33,091.50	15/2	o	24,360.81	17/2	e
1145.1323	8730.225	lc	3	9	0.33	Ho I	743 -	−704	−0.045	21,069.22	15/2	o	12,339.04	15/2	e
1147.1874	8714.586	lc	1	6	0.17	Ho I	288+	179	0.004	33,091.50	15/2	o	24,376.91	15/2	e
1147.9065	8709.127	nc	2	4	0.50	Ho I	225*	−194	0.023	25,591.43	15/2	o	16,882.28	15/2	e
1149.8602	8694.329	nl	2	6	0.33	Ho I	607*								
1150.6635	8688.259	nc	150	518	0.29	Ho I	163+	104	−0.029	23,818.54	15/2	o	15,130.31	17/2	e
1151.4294	8682.480	nc	47	169	0.28	Ho I	415+	187	0.000	23,818.54	15/2	o	15,136.06	15/2	e
1153.4068	8667.595	nc	60	175	0.34	Ho I	168+	108	−0.025	27,423.79	13/2	o	18,756.22	15/2	e
1156.3780	8645.325	nc	18	76	0.24	Ho I	94*	41	−0.055	38,397.18	13/2	o	29,751.91	13/2	e
1156.4834	8644.537	nc	54	323	0.17	Ho I	301-	−152	−0.037	33,005.31	15/2	o	24,360.81	17/2	e
1158.6487	8628.382	lc	5	15	0.33	Ho I	305+	32	0.018	31,042.44	15/2	o	22,414.04	13/2	e
1158.9477	8626.156	nc	5	20	0.25	Ho I	570-	−407	−0.036	20,315.89	17/2	o	11,689.77	19/2	e
1160.1596	8617.145		9	–	bNe	Ho II	276+	224.9	0.000	26,331.009	8	e	17,713.8643	9	o
1164.5521	8584.642	lc	1	3	0.33	Ho I	268*	−2301	−0.042	26,922.40	15/2	o	18,337.80	17/2	e
1167.1469	8565.557	lc	1	4	0.25	Ho I	912+	915	0.043	27,423.79	13/2	o	18,858.19	13/2	e
1168.3027	8557.083	nc	27	99	0.27	Ho I	1580+	1520	0.047	25,616.48	11/2	o	17,059.35	13/2	e
1169.0208	8551.827	nl	2	4	0.50	Ho I	114*								
1170.3890	8541.830	lc	3	11	0.27	Ho I	223-	−27	−0.010	31,042.44	15/2	o	22,500.62	15/2	e
1170.4132	8541.653	lc	1	2	0.50	Ho I	738+	645	0.087	31,018.63	19/2	o	22,476.89	17/2	e
1171.5261	8533.539	lc	2	2	1.00	Ho II	785+	667	−0.003	28,416.771	6	e	19,883.235	5	o
1171.6558	8532.594	nl	2	6	0.33	Ho I	655*								
1173.2932	8520.686	lc	1	3	0.33	Ho I	930*	928	0.044	20,210.50	21/2	o	11,689.77	19/2	e
1173.9330	8516.043	lc	2	7	0.29	Ho I	556+	195	0.067	30,011.00	23/2	o	21,494.89	21/2	e
1175.5718	8504.171	nc	13	38	0.34	Ho I	473+	310	0.039	23,585.33	13/2	o	15,081.12	13/2	e
1182.4158	8454.948		7	7	1.00	Ho II	123+	68	0.001	31,556.609	7	e	23,101.660	8	o
1183.2085	8449.283	nc	17	48	0.35	Ho I	213+	158	−0.013	23,585.33	13/2	o	15,136.06	15/2	e
1185.3024	8434.357	lc	1	2	0.50	Ho I	497+	452	0.143	20,124.27	19/2	o	11,689.77	19/2	e
1185.5802	8432.381	lc	1	2	0.50	Ho I	699-	−623	−0.011	26,770.17	19/2	o	18,337.80	17/2	e
1185.8114	8430.737	nc	46	218	0.21	Ho I	285-	−157	−0.037	33,091.50	15/2	o	24,660.80	15/2	e
1185.8719	8430.307		5	6	0.83	Ho II	804+	895	0.002	24,712.164	7	e	16,281.8551	6	o
1186.3189	8427.130	nc	12	65	0.18	Ho I	127+	64	−0.020	8427.11	15/2	e	0.00	15/2	o
1187.2998	8420.168	lc	6	19	0.32	Ho I	64*	0.3	−0.028	31,286.69	17/2	o	22,866.55	19/2	e
1189.9857	8401.163	nl	3	7	0.43	Ho I	431+								
1191.3381	8391.626	lc	1	3	0.33	Ho I	1064+	1146	0.124	30,589.44	13/2	o	22,197.69	11/2	e
1193.7353	8374.774	nl	1	4	0.25	Ho I	323+								
1194.8344	8367.071	nl	3	7	0.43	Ho I	433*								
1197.1508	8350.881	lc	6	31	0.19	Ho I	290+	98	0.099	33,091.50	15/2	o	24,740.52	13/2	e
1198.0593	8344.549	nc	43	256	0.17	Ho I	316-	−175	−0.039	33,005.31	15/2	o	24,660.80	15/2	e
1199.8182	8332.316	lc	2	7	0.29	Ho I	88*	−36	−0.046	16,937.43	11/2	e	8605.16	11/2	o
1200.7499	8325.850	lc	1	4	0.25	Ho I	246*	−218	−0.040	26,977.34	13/2	o	18,651.53	15/2	e
1201.0837	8323.536	lc	1	2	0.50	Ho I	335*	205	0.014	35,270.88	13/2	o	26,947.33	13/2	e
1203.7303	8305.236	lc	1	4	0.25	Ho I	226+	207	0.044	30,805.90	17/2	o	22,500.62	15/2	e
1204.9648	8296.727	lc	5	20	0.25	Ho I	77*	1	−0.027	30,773.59	15/2	o	22,476.89	17/2	e
1205.6642	8291.914	lc	1	3	0.33	Ho I	614-	−578	0.016	27,049.80	11/2	o	18,757.87	9/2	e
1208.1673	8274.735	lc	7	29	0.24	Ho I	30*	148	0.025	20,613.80	17/2	o	12 339.04	15/2	e
1208.7345	8270.852	lc	1	2	0.50	Ho I	489+	468	0.018	26,922.40	15/2	o	18,651.53	15/2	e
1209.6353	8264.693	lc	12	70	0.17	Ho I	117+	79	0.097	33,005.31	15/2	o	24,740.52	13/2	e
1215.0754	8227.690	nl	1	3	0.33	Ho I	167*								
1215.3208	8226.029	lc	2	9	0.22	Ho I	549-	−298	−0.049	29,443.09	17/2	o	21 217.11	19/2	e
1221.7917	8182.462	lc	4	13	0.31	Ho I	483+	370	0.048	26,673.72	13/2	o	18 491.21	11/2	e
1222.8624	8175.298	lc	1	2	0.50	Ho I	701*	1029	0.102	30,589.44	13/2	o	22,414.04	13/2	e
1223.9135	8168.277	nl	2	7	0.29	Ho I	378*								
1225.9375	8154.791	lc	4	15	0.27	Ho I	752-	−691	−0.071	20,493.76	13/2	o	12,339.04	15/2	e
1226.1258	8153.539	nl	1	2	0.50	Ho I	292*								
1226.3522	8152.034	lc	1	3	0.33	Ho I	485+	423	0.046	31,018.63	19/2	o	22,866.55	19/2	e
1226.5678	8150.601	lc	30	95	0.32	Ho I	154+	122	−0.021	23,942.71	13/2	o	15,792.13	11/2	e
1226.7709	8149.251	lc	3	15	0.20	Ho I	746-	−663	−0.041	20,493.76	13/2	o	12,344.55	13/2	e
1226.8558	8148.687	lc	1	4	0.25	Ho I	950-	−856	−0.077	28,315.79	15/2	o	20,167.18	15/2	e
1227.0654	8147.296	nl	1	3	0.33	Ho I	69*								
1227.1850	8146.502	nl	1	3	0.33	Ho I	212*								
1227.5675	8143.963	nl	2	6	0.33	Ho I	60*								
1227.9848	8141.196	lc	2	10	0.20	Ho I	1203+	1139	0.124	30,339.01	13/2	o	22,197.69	11/2	e
1229.5563	8130.790	lc	3	11	0.27	Ho I	94*	−14	0.000	16,735.95	13/2	e	8605.16	11/2	o
1231.3208	8119.139	lc	1	3	0.33	Ho I	736+	630	0.011	26,977.34	13/2	o	18,858.19	13/2	e
1232.8875	8108.821	lc	1	6	0.17	Ho I	176+	127	−0.001	26,673.72	13/2	o	18,564.90	13/2	e
1233.1775	8106.914	nl	2	9	0.22	Ho I	122*								
1234.2549	8099.838	lc	1	2	0.50	Ho I	444-	−338	−0.068	26,664.67	11/2	o	18,564.90	13/2	e
1236.1370	8087.505	lc	1	3	0.33	Ho I	760-	−581	−0.075	23,942.71	13/2	o	15,855.28	15/2	e
1237.1407	8080.944	lc	1	3	0.33	Ho I	413-	−343	−0.044	23,211.21	19/2	o	15,130.31	17/2	e
1244.9385	8030.328	lc	120	342	0.35	Ho I	87*	10	0.002	30,011.00	23/2	o	21,980.67	23/2	e
1245.2461	8028.345	nl	1	4	0.25	Ho I	484*								
1246.1972	8022.217	lc	1	4	0.25	Ho I	182*	−77	−0.027	26,673.72	13/2	o	18,651.53	15/2	e
1250.1841	7996.634	nl	1	3	0.33	Ho I	167*								
1253.2851	7976.848	lc	4	18	0.22	Ho I	279-	−216	0.002	20,315.89	17/2	o	12,339.04	15/2	e
1253.6927	7974.255	nl	1	6	0.17	Ho I	445*								
1253.7791	7973.705	nl	1	5	0.20	Ho I	194*								

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	*R*	ion.	*W* (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1255.4710	7962.960	lc	4	6	0.67	Ho II	1029+	935	0.000	24,712.164	7	e	16,749.2043	7	o
1256.4170	7956.964	nl	2	6	0.33	Ho I	217+								
1257.4704	7950.298	nl	4	12	0.33	Ho I	875+								
1261.3342	7925.945	lc	4	7	0.57	Ho II	580+	387	0.001	26,331.009	8	e	18,405.063	8	o
1261.5057	7924.867	lc	2	7	0.29	Ho I	1126+	1022	0.103	30,339.01	13/2	o	22,414.04	13/2	e
1262.2936	7919.921	lc	2	5	0.40	Ho I	266*	−140	−0.011	24,357.92	15/2	o	16,438.01	17/2	e
1262.6522	7917.671	nl	2	5	0.40	Ho I	532+								
1264.3907	7906.785	lc	1	7	0.14	Ho I	298-	−249	0.015	26,664.67	11/2	o	18,757.87	9/2	e
1266.7912	7891.802	lc	1	4	0.25	Ho I	403+	270	0.018	26,456.72	15/2	o	18,564.90	13/2	e
1269.6396	7874.097	nl	1	3	0.33	Ho I	212*								
1271.8195	7860.601	lc	1	5	0.20	Ho I	372-	−308	−0.011	26,198.39	15/2	o	18,337.80	17/2	e
1273.1445	7852.420	lc	1	3	0.33	Ho I	1133+	1173	0.050	26,673.72	13/2	o	18,821.25	11/2	e
1275.4357	7838.314	lc	1	3	0.33	Ho I	1015+	964	0.076	30,339.01	13/2	o	22,500.62	15/2	e
1276.9046	7829.297	lc	2	2	1.00	Ho II	520*	705	0.003	26,234.363	7	e	18,405.063	8	o
1278.6297	7818.734	lc	1	3	0.33	Ho I	328+	218	0.136	33,091.50	15/2	o	25,272.63	15/2	e
1278.8842	7817.178	lc	1	3	0.33	Ho I	1014-	−936	−0.118	28,315.79	15/2	o	20,498.73	17/2	e
1279.1587	7815.500	lc	1	4	0.25	Ho I	900+	771	0.030	26,673.72	13/2	o	18,858.19	13/2	e
1280.6303	7806.519	lc	1	5	0.20	Ho I	390+	306	−0.039	26,664.67	11/2	o	18,858.19	13/2	e
1282.8192	7793.199	lc	4	18	0.22	Ho I	470+	333	0.001	23,585.33	13/2	o	15,792.13	11/2	e
1283.5861	7 788.543	lc	2	5	0.40	Ho I	276-	−132	−0.043	23,942.71	13/2	o	16,154.21	15/2	e
1286.3309	7771.924	lc	–	6	bAr	Ho I	454-	−289	0.036	26,529.83	11/2	o	18,757.87	9/2	e
1290.5897	7746.277	lc	5	21	0.24	Ho I	884+	818	0.083	19,276.92	15/2	o	11,530.56	17/2	e
1290.6891	7745.681	lc	1	3	0.33	Ho I	1232-	−1183	−0.121	28,244.29	17/2	o	20,498.73	17/2	e
1291.9586	7738.070	nl	1	4	0.25	Ho I	481+								
1292.8813	7732.547	lc	1	6	0.17	Ho I	249+	200	0.133	33,005.31	15/2	o	25,272.63	15/2	e
1293.0531	7731.520	lc	1	2	0.50	Ho I	245*	−192	0.010	23,885.74	17/2	o	16,154.21	15/2	e
1294.4547	7723.148	lc	1	2	0.50	Ho I	657+	572	0.052	26,288.10	13/2	o	18,564.90	13/2	e
1296.9016	7708.577	lc	1	8	0.13	Ho I	809+	668	0.003	26,529.83	11/2	o	18,821.25	11/2	e
1297.2438	7706.543	nl	1	3	0.33	Ho I	433-								
1298.2579	7700.524	lc	2	4	0.50	Ho I	164+	107	−0.024	26,456.72	15/2	o	18,756.22	15/2	e
1301.3492	7682.231	nl	1	3	0.33	Ho I	408*								
1302.6564	7674.522	nl	1	2	0.50	Ho I	140*								
1303.1418	7671.664	lc	1	3	0.33	Ho I	320+	266	−0.024	26,529.83	11/2	o	18,858.19	13/2	e
1303.3079	7670.686	lc	4	13	0.31	Ho I	153-	−75	−0.016	28,887.78	21/2	o	21,217.11	19/2	e
1304.5718	7663.254	lc	1	5	0.20	Ho I	136*	−99	−0.024	13,082.93	11/2	e	5419.70	13/2	o
1304.9801	7660.857	nl	1	3	0.33	Ho I	240*								
1305.4029	7658.376	nl	1	3	0.33	Ho I	415*								
1306.5038	7651.922	lc	3	10	0.30	Ho I	160+	96	−0.002	31,018.63	19/2	o	23,366.71	21/2	e
1307.7730	7644.496	lc	1	6	0.17	Ho I	760+	656	−0.196	28,861.41	17/2	o	21,217.11	19/2	e
1308.7860	7638.579	nl	1	2	0.50	Ho I	208*								
1309.1350	7636.543	lc	10	35	0.29	Ho I	417+	369	0.027	26,288.10	13/2	o	18,651.53	15/2	e
1309.4098	7634.940	lc	2	7	0.29	Ho I	1124+	1063	0.120	30,049.10	15/2	o	22,414.04	13/2	e
1309.6392	7633.603	nl	1	5	0.20	Ho I	265*								
1311.6624	7621.828	lc	11	38	0.29	Ho I	1045+	986	0.052	26,443.13	11/2	o	18,821.25	11/2	e
1312.3207	7618.005	lc	2	8	0.25	Ho I	773+	719.1	0.125	30,484.68	21/2	o	22,866.55	19/2	e
1312.5098	7616.907	lc	3	10	0.30	Ho I	570+	504	0.033	32,331.28	19/2	o	24,714.34	21/2	e
1316.1766	7595.687	lc	14	44	0.32	Ho I	489+	439	0.063	29,576.42	25/2	o	21,980.67	23/2	e
1317.5025	7588.043	lc	2	5	0.40	Ho I	257+	−102	−0.033	31,964.92	13/2	o	24,376.91	15/2	e
1318.0466	7584.911	lc	11	35	0.31	Ho I	638+	585	0.029	26,443.13	11/2	o	18,858.19	13/2	e
1320.2665	7572.157	lc	2	6	0.33	Ho I	981+	840	0.053	30,049.10	15/2	o	22,476.89	17/2	e
1324.4245	7548.385	lc	2	8	0.25	Ho I	1060+	1005	0.095	30,049.10	15/2	o	22,500.62	15/2	e
1324.7013	7546.808	lc	1	3	0.33	Ho I	415+	391	0.052	26,198.39	15/2	o	18,651.53	15/2	e
1325.7290	7540.957	nl	1	2	0.50	Ho I	271*								
1328.3992	7525.799	nl	2	3	0.67	Ho II	425*								
1329.0723	7521.988	nl	2	6	0.33	Ho I	210*								
1331.2930	7509.441	lc	4	14	0.29	Ho I	642+	597	0.029	31,515.70	21/2	o	24,006.23	23/2	e
1332.5124	7502.569	lc	1	4	0.25	Ho I	809+	735	0.051	29,979.51	15/2	o	22,476.89	17/2	e
1335.1917	7487.514	lc	1	3	0.33	Ho I	530+	352	0.066	31,443.26	15/2	o	23,955.68	13/2	e
1336.1068	7482.385	lc	4	13	0.31	Ho I	700-	−644	−0.055	27,649.51	15/2	o	20,167.18	15/2	e
1337.2936	7475.745	lc	3	15	0.20	Ho I	353-	−297	−0.055	26,127.22	13/2	o	18,651.53	15/2	e
1337.3267	7475.560	lc	3	13	0.23	Ho I	798+	680	0.080	24,357.92	15/2	o	16,882.28	15/2	e
1345.5577	7429.831	lc	6	24	0.25	Ho I	1421+	1216	0.079	26,288.10	13/2	o	18,858.19	13/2	e
1346.5291	7424.471	lc	5	14	0.36	Ho I	226-	−175	−0.021	27,923.18	17/2	o	20,498.73	17/2	e
1348.0533	7416.076	lc	1	3	0.33	Ho I	831+	718	0.074	31,793.06	17/2	o	24,376.91	15/2	e
1349.0073	7410.832	lc	1	2	0.50	Ho I	895-	−624	−0.002	20,493.76	13/2	o	13,082.93	11/2	e
1350.6421	7401.862	lc-	–	11	bAr	Ho I	709-	−298	−0.042	27,643.13	11/2	o	20,241.31	13/2	e
1352.1929	7393.373	nl	2	13	0.15	Ho I	215*								
1352.2759	7392.919	lc	7	21	0.33	Ho I	647-	−201	−0.029	28,887.78	21/2	o	21,494.89	21/2	e
1352.5809	7391.252	lc	1	4	0.25	Ho I	545-	−478	−0.012	27,649.51	15/2	o	20,258.27	13/2	e
1353.0245	7388.829	lc	1	3	0.33	Ho I	695+	628	0.041	31,793.06	17/2	o	24,404.19	19/2	e
1356.1141	7371.995	lc	4	16	0.25	Ho I	158-	−111	−0.005	26,023.52	15/2	o	18,651.53	15/2	e
1360.6130	7347.619	lc	1	2	0.50	Ho I	671+	517	−0.019	29,760.74	9/2	o	22,413.14	11/3	e
1365.9602	7318.856	lc	1	2	0.50	Ho I	355*	−245	0.044	32,280.32	11/2	o	24,961.42	11/2	e
1367.2819	7311.781	lc	16	54	0.30	Ho I	660-	−613	−0.041	22,392.86	13/2	o	15,081.12	13/2	e
1369.7726	7298.486	lc	1	3	0.33	Ho I	864+	660	0.084	24,357.92	15/2	o	17,059.35	13/2	e
1372.0749	7286.240	lc	16	33	0.48	Ho I	277-	218	0.000	29,266.91	23/2	o	21,980.67	23/2	e

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1375.3748	7268.758	lc	4	10	0.40	Ho I	484+	416	0.002	30,135.31	17/2	o	22,866.55	19/2	e
1376.2535	7264.117	lc	17	53	0.32	Ho I	161+	118	0.013	28,481.24	21/2	o	21,217.11	19/2	e
1376.7601	7261.444	lc	1	3	0.33	Ho I	455+	401	0.026	32,809.73	17/2	o	25,548.26	19/2	e
1377.6232	7256.895	lc	6	21	0.29	Ho I	831-	−765	−0.095	22,392.86	13/2	o	15,136.06	15/2	e
1385.4733	7215.777	lc	1	4	0.25	Ho I	376-	−331	0.003	29,692.67	19/2	o	22,476.89	17/2	e
1387.1196	7207.213	lc	39	118	0.33	Ho I	464+	275	0.017	18,737.79	17/2	o	11,530.56	17/2	e
1387.5837	7204.803	nl	1	3	0.33	Ho I	185*								
1391.8981	7182.470	lc	6	16	0.38	Ho I	162+	65	0.010	27,423.79	13/2	o	20,241.31	13/2	e
1394.7163	7167.957	lc	2	5	0.40	Ho I	81*	25	0.003	30,146.15	11/2	o	22,978.19	13/2	e
1395.8825	7161.969	nl	1	4	0.25	Ho I	137*								
1398.0467	7150.882	lc	3	7	0.43	Ho I	772-	−725	−0.102	27,649.51	15/2	o	20,498.73	17/2	e
1398.2722	7149.729	lc	6	16	0.38	Ho I	339-	−87	0.001	27,643.13	11/2	o	20,493.40	11/2	e
1399.6103	7142.893	nl	2	5	0.40	Ho I	395+								
1404.5235	7117.906	lc	8	27	0.30	Ho I	498+	392	0.064	30,484.68	21/2	o	23,366.71	21/2	e
1407.0093	7105.331	nl	1	2	0.50	Ho I	749*								
1411.5354	7082.548	lc	2	7	0.29	Ho I	530+	351	0.042	23,818.54	15/2	o	16,735.95	13/2	e
1412.9356	7075.529	lc	1	2	0.50	Ho I	536-	−341	−0.029	31,339.46	15/2	o	24,263.96	17/2	e
1413.5018	7072.695	nl	1	3	0.33	Ho I	528*								
1416.2648	7058.897	lc	7	24	0.29	Ho I	171+	98	−0.027	30,425.58	19/2	o	23,366.71	21/2	e
1418.4483	7048.031	lc	130	384	0.34	Ho I	244+	191	−0.011	18,737.79	17/2	o	11,689.77	19/2	e
1419.7133	7041.751	lc	92	349	0.26	Ho I	177-	−113	−0.031	18,572.28	15/2	o	11,530.56	17/2	e
1422.6267	7027.330	lc	1	3	0.33	Ho I	1213-	−1133	−0.150	28,244.29	17/2	o	21,217.11	19/2	e
1423.5676	7022.685	lc	1	6	0.17	Ho I	484+	269	0.045	31,286.69	17/2	o	24,263.96	17/2	e
1426.2784	7009.338	lc	1	3	0.33	Ho I	549-	−432	−0.028	29,207.00	11/2	o	22,197.69	11/2	e
1427.1143	7005.232	lc	40	110	0.36	Ho I	117+	133	0.048	23,942.71	13/2	o	16,937.43	11/2	e
1427.4957	7003.361	lc	4	12	0.33	Ho I	650+	599	0.099	23,885.74	17/2	o	16,882.28	15/2	e
1427.5365	7003.160	lc	6	20	0.30	Ho I	211-	139	−0.030	31,380.04	13/2	o	24,376.91	15/2	e
1428.6839	6997.536	lc	1	3	0.33	Ho I	685-	−583	−0.056	31,793.06	17/2	o	24,795.58	17/2	e
1430.5088	6988.609	lc	2	8	0.25	Ho I	851+	719	0.101	29,465.60	19/2	o	22,476.89	17/2	e
1430.7879	6987.246	nl	4	13	0.31	Ho I	523*								
1430.9713	6986.351	lc	135	406	0.33	Ho I	58*	−9	−0.001	28,481.24	21/2	o	21,494.89	21/2	e
1431.4886	6983.826	lc	14	44	0.32	Ho I	777+	721	−0.036	25,805.04	9/2	o	18,821.25	11/2	e
1434.0132	6971.531	lc	106	362	0.29	Ho I	72*	41	0.009	27,470.27	19/2	o	20,498.73	17/2	e
1435.1257	6966.127	lc	3	11	0.27	Ho I	722+	662	0.073	29,443.09	17/2	o	22,476.89	17/2	e
1439.0168	6947.290	lc	1	2	0.50	Ho I	374+	238	−0.020	31,707.40	11/2	o	24,760.13	13/2	e
1439.8908	6943.073	lc	19	65	0.29	Ho I	382-	−242	0.007	22,024.20	13/2	o	15,081.12	13/2	e
1440.0394	6942.357	lc	1	2	0.50	Ho I	803+	827	0.113	29,443.09	17/2	o	22,500.62	15/2	e
1440.9875	6937.789	lc	3	11	0.27	Ho I	974+	925	0.091	19,276.92	15/2	o	12,339.04	15/2	e
1441.3230	6936.174	lc	1	7	0.14	Ho I	959+	898	0.086	23,818.54	15/2	o	16,882.28	15/2	e
1441.9870	6932.980	lc	5	16	0.31	Ho I	293-	−236	0.020	22,014.12	15/2	o	15,081.12	13/2	e
1443.6829	6924.836	lc	3	15	0.20	Ho I	150-	−60	0.014	12,344.55	13/2	e	5419.70	13/2	o
1444.8381	6919.299	lc	2	9	0.22	Ho I	93*	−32	0.041	12,339.04	15/2	e	5419.70	13/2	o
1445.0203	6918.427	lc	1	3	0.33	Ho I	762-	−521	−0.017	29,116.10	11/2	o	22,197.69	11/2	e
1447.3688	6907.201	lc	3	10	0.30	Ho I	454-	−386	−0.091	28,887.78	21/2	o	21,980.67	23/2	e
1450.6629	6891.517	lc	1	3	0.33	Ho I	1010+	944	−0.057	31,605.80	19/2	o	24,714.34	21/2	e
1451.3644	6888.186	lc	4	15	0.27	Ho I	466-	−393	−0.046	22,024.20	13/2	o	15,136.06	15/2	e
1452.2722	6883.880	lc	1	3	0.33	Ho I	500-	−471	−0.070	22,014.12	15/2	o	15,130.31	17/2	e
1452.3934	6883.305	lc	1	4	0.25	Ho I	705+	639	0.055	23,942.71	13/2	o	17,059.35	13/2	e
1453.4939	6878.094	lc	8	31	0.26	Ho I	549-	−388	−0.034	22,014.12	15/2	o	15,136.06	15/2	e
1464.5521	6826.160	lc	5	16	0.31	Ho I	631-	−552	−0.040	29,692.67	19/2	o	22,866.55	19/2	e
1471.4810	6794.017	lc	17	42	0.40	Ho I	103-	−50	−0.017	27,643.13	11/2	o	20,849.13	11/2	e
1474.5181	6780.024	lc	1	4	0.25	Ho I	568+	493	0.036	31,540.19	15/2	o	24,760.13	13/2	e
1474.8472	6778.511	lc	2	8	0.25	Ho I	143-	−144	−0.031	31,042.44	15/2	o	24,263.96	17/2	e
1477.2290	6767.581	nl	1	4	0.25	Ho I	116*								
1477.3823	6766.879	lc	1	2	0.50	Ho I	218*	164	−0.039	30,146.15	11/2	o	23,379.31	11/2	e
1479.0324	6759.330	nl	4	10	0.40	Ho I	190*								
1479.2637	6758.273	lc	1	3	0.33	Ho I	1855+	1660	0.017	25,616.48	11/2	o	18,858.19	13/2	e
1479.9238	6755.258	lc	6	19	0.32	Ho I	652-	−399	−0.038	26,922.40	15/2	o	20,167.18	15/2	e
1480.0758	6754.565	lc	2	6	0.33	Ho I	760+	692	0.105	31,018.63	19/2	o	24,263.96	17/2	e
1481.9596	6745.979	lc	1	3	0.33	Ho I	346+	191	0.001	31,707.40	11/2	o	24,961.42	11/2	e
1484.1410	6736.063	lc	1	3	0.33	Ho I	405-	−221	−0.033	26,977.34	13/2	o	20,241.31	13/2	e
1485.4984	6729.908	nl	1	4	0.25	Ho I	512-								
1487.7630	6719.664	nl	1	3	0.33	Ho I	262+								
1490.7663	6706.127	lc	3	8	0.38	Ho I	295-	−125	−0.057	27,923.18	17/2	o	21,217.11	19/2	e
1491.4667	6702.978	lc	8	24	0.33	Ho I	930+	870	0.072	23,585.33	13/2	o	16,882.28	15/2	e
1491.8740	6701.148	lc	1	4	0.25	Ho I	127*	−100	−0.018	30,067.84	21/2	o	23,366.71	21/2	e
1495.9222	6683.013	lc	1	4	0.25	Ho I	705-	−621	−0.013	30,049.71	19/2	o	23,366.71	21/2	e
1497.9705	6673.875	nl	2	6	0.33	Ho I	391*								
1499.8466	6665.527	lc	1	3	0.33	Ho I	483+	289	0.003	31,042.44	15/2	o	24,376.91	15/2	e
1500.1620	6664.126	lc	14	39	0.36	Ho I	298-	−233	0.004	26,922.40	15/2	o	20,258.27	13/2	e
1503.8394	6647.829	lc	8	24	0.33	Ho I	421+	344	0.071	23,585.33	13/2	o	16,937.43	11/2	e
1504.6758	6644.134	lc	167	464	0.36	Ho I	86*	−29	0.006	26,811.32	15/2	o	20,167.18	15/2	e
1506.4392	6636.357	nl	2	5	0.40	Ho I	440-								
1506.5776	6635.747	lc	94	262	0.36	Ho I	144-	−100	−0.027	30,011.00	23/2	o	23,375.28	25/2	e
1510.1793	6619.921	lc	5	17	0.29	Ho I	332+	196	−0.011	31,380.04	13/2	o	24,760.13	13/2	e
1511.0713	6616.013	nl	1	3	0.33	Ho I	645*								

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1511.4541	6614.338	lc	2	8	0.25	Ho I	1140+	1034	0.102	31,018.63	19/2	o	24,404.19	19/2	e
1512.4780	6609.860	lc	2	7	0.29	Ho I	891-	−817	−0.080	29,086.67	15/2	o	22,476.89	17/2	e
1514.3369	6601.746	lc	123	352	0.35	Ho I	84*	29	0.034	21,682.90	15/2	o	15,081.12	13/2	e
1514.5526	6600.806	lc	10	33	0.30	Ho I	642-	−590	−0.076	22,392.86	13/2	o	15,792.13	11/2	e
1514.9687	6598.993	lc	15	48	0.31	Ho I	589+	497	0.057	29,465.60	19/2	o	22,866.55	19/2	e
1515.0058	6598.831	lc	11	38	0.29	Ho I	57*	14	−0.001	26,673.72	13/2	o	20,074.89	15/2	e
1517.9373	6586.088	lc	3	10	0.30	Ho I	716-	−653	−0.038	29,086.67	15/2	o	22,500.62	15/2	e
1520.1483	6576.508	lc	3	10	0.30	Ho I	489+	441	0.032	29,443.09	17/2	o	22,866.55	19/2	e
1520.5837	6574.625	lc	2	4	0.50	Ho I	451+	312	0.035	27,423.79	13/2	o	20,849.13	11/2	e
1521.6716	6569.925	lc	6	24	0.25	Ho I	893+	835	0.085	26,811.32	15/2	o	20,241.31	13/2	e
1524.8036	6556.430	lc	1	2	0.50	Ho I	630-	−663	−0.030	27,049.80	11/2	o	20,493.40	11/2	e
1525.4794	6553.525	lc	17	51	0.33	Ho I	780+	843	0.045	23,612.92	11/2	o	17,059.35	13/2	e
1525.6016	6553.001	lc	147	477	0.31	Ho I	192+	137	0.049	26,811.32	15/2	o	20,258.27	13/2	e
1527.0324	6546.860	lc	54	158	0.34	Ho I	344-	−123	−0.020	21,682.90	15/2	o	15,136.06	15/2	e
1529.1690	6537.713	lc	1	2	0.50	Ho I	1240-	−1293	−0.133	22,392.86	13/2	o	15,855.28	15/2	e
1531.3364	6528.460	lc	1	6	0.17	Ho I	977+	915	0.040	18,867.54	13/2	o	12,339.04	15/2	e
1531.9360	6525.905	lc	18	60	0.30	Ho I	913+	850	0.075	23,585.33	13/2	o	17,059.35	13/2	e
1535.0188	6512.799	lc	1	3	0.33	Ho I	518-	−353	0.011	29,013.43	13/2	o	22,500.62	15/2	e
1535.7634	6509.641	lc	9	33	0.27	Ho I	88*	48	−0.011	30,773.59	15/2	o	24,263.96	17/2	e
1537.6850	6501.506	lc	2	11	0.18	Ho I	1207-	−1046	−0.116	23,211.21	19/2	o	16,709.82	17/2	e
1537.8912	6500.634	lc	44	138	0.32	Ho I	535-	−193	−0.064	28,481.24	21/2	o	21,980.67	23/2	e
1538.6384	6497.477	lc	19	60	0.32	Ho I	283-	−238	0.023	26,664.68	17/2	o	20,167.18	15/2	e
1543.1644	6478.421	lc	23	66	0.35	Ho I	238+	194	0.029	30,484.68	21/2	o	24,006.23	23/2	e
1543.6923	6476.205	nl	3	13	0.23	Ho I	836*								
1545.0171	6470.652	lc	15	47	0.32	Ho I	399-	−345	−0.012	26,637.82	17/2	o	20,167.18	15/2	e
1546.0834	6466.189	nl	1	4	0.25	Ho I	1025*								
1546.8002	6463.193	nl	1	2	0.50	Ho I	360*								
1549.0365	6453.862	lc	10	32	0.31	Ho I	138-	−103	0.008	27,670.98	19/2	o	21,217.11	19/2	e
1553.2496	6436.357	lc	3	8	0.38	Ho I	351+	289	0.003	31,984.62	17/2	o	25,548.26	19/2	e
1554.1540	6432.611	lc	1	7	0.14	Ho I	172+	28	−0.011	31,394.02	11/2	o	24,961.42	11/2	e
1554.2014	6432.415	lc	6	18	0.33	Ho I	296-	−79	−0.005	26,673.72	13/2	o	20,241.31	13/2	e
1556.2965	6423.756	lc	1	4	0.25	Ho I	731-	−479	−0.086	26,922.40	15/2	o	20,498.73	17/2	e
1556.7864	6421.734	lc	6	19	0.32	Ho I	116+	67	−0.024	21,552.02	17/2	o	15,130.31	17/2	e
1557.5440	6418.611	lc	5	16	0.31	Ho I	343+	149	0.009	31,380.04	13/2	o	24,961.42	11/2	e
1558.1887	6415.955	lc	16	51	0.31	Ho I	331+	149	0.005	21,552.02	17/2	o	15,136.06	15/2	e
1558.9562	6412.796	lc	1	4	0.25	Ho I	245+	168	−0.016	30,773.59	15/2	o	24,360.81	17/2	e
1561.6607	6401.690	lc	2	10	0.20	Ho I	610+	431	0.020	30,805.90	17/2	o	24,404.19	19/2	e
1562.8892	6396.658	lc	4	12	0.33	Ho I	542+	481	0.022	30,773.59	15/2	o	24,376.91	15/2	e
1565.8516	6384.557	lc	5	18	0.28	Ho I	449-	−265	−0.037	28,861.41	17/2	o	22,476.89	17/2	e
1566.5224	6381.823	lc	2	5	0.40	Ho I	382+	157	0.007	26,456.72	15/2	o	20,074.89	15/2	e
1571.7029	6360.788	lc	1	3	0.33	Ho I	126*	−100	0.002	28,861.41	17/2	o	22,500.62	15/2	e
1573.4213	6353.841	nl	3	9	0.33	Ho I	517+								
1573.7995	6352.314	nl	1	5	0.20	Ho I	660+								
1576.3337	6342.102	nl	2	6	0.33	Ho I	520*								
1579.7209	6328.503	nl	1	3	0.33	Ho I	870+								
1580.3308	6326.061	lc	6	19	0.32	Ho I	929-	−879	−0.101	29,692.67	19/2	o	23,366.71	21/2	e
1583.6929	6312.631	lc	26	85	0.31	Ho I	148-	−109	−0.041	26,811.32	15/2	o	20,498.73	17/2	e
1585.7903	6304.282	lc	14	44	0.32	Ho I	497+	426	0.008	31,018.63	19/2	o	24,714.34	21/2	e
1589.4908	6289.605	lc	2	6	0.33	Ho I	848-	−800	−0.065	26,456.72	15/2	o	20,167.18	15/2	e
1589.7514	6288.574	lc	1	2	0.50	Ho I	641-	−584	−0.054	26,529.83	11/2	o	20,241.31	13/2	e
1594.4422	6270.073	lc	35	82	0.43	Ho I	140-	−65	−0.113	27,643.13	11/2	o	21,373.17	9/2	e
1594.6645	6269.199	nl	1	3	0.33	Ho I	479*								
1596.5557	6261.773	nl	4	10	0.40	Ho I	472*								
1598.7490	6253.182	lc	96	326	0.29	Ho I	134+	91	−0.022	27,470.27	19/2	o	21,217.11	19/2	e
1598.8510	6252.783	nl	4	11	0.36	Ho I	210-								
1600.6548	6245.737	nl	2	9	0.22	Ho I	122*								
1600.9018	6244.773	lc	3	8	0.38	Ho I	453+	393	0.027	31,793.06	17/2	o	25,548.26	19/2	e
1601.4957	6242.457	lc	22	78	0.28	Ho I	105+	74	0.023	21,378.54	17/2	o	15,136.06	15/2	e
1602.4478	6238.748	lc	3	7	0.43	Ho I	892-	−844	−0.098	22,392.86	13/2	o	16,154.21	15/2	e
1603.8564	6233.269	lc	8	31	0.26	Ho I	81*	−5	−0.029	18,572.28	15/2	o	12,339.04	15/2	e
1604.1577	6232.098	lc	25	92	0.27	Ho I	439-	−219	−0.028	22,024.20	13/2	o	15,792.13	11/2	e
1608.4682	6215.397	lc	7	23	0.30	Ho I	81*	64	0.013	26,456.72	15/2	o	20,241.31	13/2	e
1611.1098	6205.206	lc	1	3	0.33	Ho I	458+	401	0.034	30,582.15	17/2	o	24,376.91	15/2	e
1611.7898	6202.588	lc	15	50	0.30	Ho I	521+	478	0.082	27,697.56	23/2	o	21,494.89	21/2	e
1612.1746	6201.108	lc	25	97	0.26	Ho I	378+	330	0.032	29,576.42	25/2	o	23,375.28	25/2	e
1612.8606	6198.470	lc	1	6	0.17	Ho I	680-	−634	−0.020	26,456.72	15/2	o	20,258.27	13/2	e
1617.6074	6180.281	lc	2	6	0.33	Ho I	267+	132	0.039	26,673.72	13/2	o	20,493.40	11/2	e
1618.2168	6177.954	lc	4	12	0.33	Ho I	375+	310	0.006	30,582.15	17/2	o	24,404.19	19/2	e
1618.7041	6176.094	lc	11	33	0.33	Ho I	477-	−229	−0.004	27,670.98	19/2	o	21,494.89	21/2	e
1620.5647	6169.003	lc	2	8	0.25	Ho I	986-	−922	−0.083	22,024.20	13/2	o	15,855.28	15/2	e
1621.3606	6165.975	lc	30	95	0.32	Ho I	566-	−319	−0.025	26,664.68	17/2	o	20,498.73	17/2	e
1623.2199	6158.912	lc	5	20	0.25	Ho I	954-	−916	−0.072	22,014.12	15/2	o	15,855.28	15/2	e
1624.8126	6152.875	nl	1	5	0.20	Ho I	118*								
1626.1999	6147.626	nl	1	2	0.50	Ho I	394*								
1626.3229	6147.161	lc	1	5	0.20	Ho I	467-	−352	−0.021	28,561.18	13/2	o	22,414.04	13/2	e
1627.7621	6141.726	nl	1	4	0.25	Ho I	635*								

(*continued on next page*)

Table 3 (*continued*)

λ_{air} (nm)	σ_{vac} (cm^{-1})	com.	S/N (Ar)	S/N (Ne)	R	ion.	W (mK)	ΔW_{hfs} (mK)	$\Delta\sigma$ (cm^{-1})	E_u (cm^{-1})	J_u	p_u	E_l	J_l	p_l
1627.8368	6141.444	nl	7	18	0.39	Ho I	635*								
1628.4458	6139.147	lc	22	75	0.29	Ho I	483-	−426	−0.057	26,637.82	17/2	o	20,498.73	17/2	e
1631.6260	6127.182	nl	1	2	0.50	Ho I	827*								
1632.1645	6125.160	lc	1	3	0.33	Ho I	1133+	1207	−0.050	30,071.27	9/2	o	23,946.16	11/1	e
1639.1967	6098.883	lc	24	78	0.31	Ho I	238+	171	0.007	29,465.60	19/2	o	23,366.71	21/2	e
1644.2055	6080.304	lc	1	4	0.25	Ho I	1398+	1323	0.186	30,484.68	21/2	o	24,404.19	19/2	e
1646.7487	6070.914	nl	1	6	0.17	Ho I	790+								
1648.7596	6063.509	lc	3	8	0.38	Ho I	208+	142	0.021	30,327.49	17/2	o	24,263.96	17/2	e
1649.2573	6061.679	lc	2	4	0.50	Ho I	596-	−298	−0.069	30,067.84	21/2	o	24,006.23	23/2	e
1649.5498	6060.605	lc	1	4	0.25	Ho I	520-	−410	−0.045	28,561.18	13/2	o	22,500.62	15/2	e
1654.5135	6042.422	nl	2	8	0.25	Ho I	1033*								
1655.6906	6038.126	nl	9	27	0.33	Ho I	81*								
1660.3550	6021.164	lc	1	2	0.50	Ho I	793+	664	0.066	28,887.78	21/2	o	22,866.55	19/2	e
1664.9049	6004.709	lc	16	43	0.37	Ho I	606+	535	0.061	30,011.00	23/2	o	24,006.23	23/2	e
1665.9730	6000.859	nl	1	5	0.20	Ho I	950*								
1667.6181	5994.939	lc	4	13	0.31	Ho I	530-	−487	−0.079	28,861.41	17/2	o	22,866.55	19/2	e
1669.5204	5988.108	lc	4	13	0.31	Ho I	699-	−652	−0.008	21,069.22	15/2	o	15,081.12	13/2	e
1672.7851	5976.422	lc	15	53	0.28	Ho I	904-	−861	−0.032	26,143.57	17/2	o	20,167.18	15/2	e
1673.0673	5975.414	lc	90	290	0.31	Ho I	101*	−36	−0.034	27,470.27	19/2	o	21,494.89	21/2	e
1674.4128	5970.612	lc	17	46	0.37	Ho I	133+	81	0.018	31,515.70	21/2	o	25,545.07	21/2	e
1681.4582	5945.595	lc	2	12	0.17	Ho I	1326-	−1276	−0.135	37,388.72	17/2	e	31,443.26	15/2	o
1683.0179	5940.085	lc	1	3	0.33	Ho I	636-	−310	0.035	26,198.39	15/2	o	20,258.27	13/2	e
1683.1904	5939.476	lc	6	14	0.43	Ho I	115+	72	0.004	32,334.47	15/2	o	26,394.99	17/2	e
1684.2534	5935.728	nl	1	3	0.33	Ho I	252*								
1684.9650	5933.221	lc	2	6	0.33	Ho I	870-	−804	−0.061	21,069.22	15/2	o	15,136.06	15/2	e
1687.7932	5923.279	lc	5	11	0.45	Ho I	522+	483	0.021	30,327.49	17/2	o	24,404.19	19/2	e
1689.7880	5916.286	lc	1	3	0.33	Ho I	578+	483	0.064	28,393.24	19/2	o	22,476.89	17/2	e
1696.8518	5891.657	lc	30	97	0.31	Ho I	150+	108	−0.027	29,266.91	23/2	o	23,375.28	25/2	e
1699.7784	5881.513	lc	1	3	0.33	Ho I	1307*		−0.133	37,324.64	15/2	e	31,443.26	15/2	o
1704.8945	5863.864	lc	1	8	0.13	Ho I	650+	329	0.056	27,358.81	21/2	o	21,494.89	21/2	e
1732.5523	5770.256	lc	1	2	0.50	Ho I	912+	722	0.084	30,484.68	21/2	o	24,714.34	21/2	e
1733.3998	5767.434	lc	1	2	0.50	Ho I	203*	−172	−0.034	28,244.29	17/2	o	22,476.89	17/2	e
1748.7303	5716.873	lc	1	2	0.50	Ho I	257*	294	0.007	39,700.28	19/2	e	33,983.40	17/2	o

Notes: λ_{air}: center-of-gravity wavelength in air from the FT spectrum; σ_{vac}: center-of-gravity transition wavenumber in vacuum from the FT spectrum; S/N: signal-to-noise ratio from the FT spectrum with Ar and Ne respectively; R: the ratio between S/N in the Ho-Ar and S/N in the Ho-Ne spectrum; comments (com.): nl: new line, nc: line known, but newly classified, b: blending; W: line pattern widths in mK (1 mK= 0.001 cm^{-1}); behind the line pattern widths an indicator is given to categorize the hyperfine structure: + : clear fingerprint when intensities are increasing with frequency, − : clear fingerprint when intensities are decreasing with frequency, *: no clear increase or decrease visible; ΔW_{hfs}: total separation of the strong hyperfine components in mK (negative if the highest hyperfine component lies at smaller frequencies); $\Delta\sigma = (E_u - E_l) - \sigma_{vac}$: difference between the wavenumber in vacuum and the energy difference of the levels; E_u, J_u, p_u, E_l, J_l, p_l: level energy, total electronic angular momentum and parity of the upper and lower levels, respectively.

If the R-value of a line was in the corresponding R-value range for the corresponding wavelength range (see Table 2), the lines were assigned accordingly. Only lines with an R value between the ranges of the maximum value of R for Ho II and the minimum R value for Ho I could not be assigned clearly and were declared as'Ho I or Ho II' in Table 3.

For all lines the hfs pattern width W was estimated from the FT spectrum by taking the distance between the points at the right and left edges of the line profile where the intensity falls by a factor of $1/e^2$ with respect to the value of the highest intensity within the pattern. For lines with S/N lower than 10, the value of W is determined by measuring the distance between the points where the line profile rises above the noise level. For classified lines, the classification program calculates the total separation ΔW_{hfs} of the strong hyperfine components. ΔW_{hfs} is the distance between the strongest and the weakest of the strong hfs component (i.e. the strong component with the largest F-values and the one with the smallest F-value). If the highest hyperfine component lies at smaller frequencies, ΔW_{hfs} becomes negative. ΔW_{hfs} roughly corresponds to the line pattern width W. Depending on the hfs constants, it can happen that the two strong hfs components used for the calculation of ΔW_{hfs} lie between the other strong components and in these cases the values of W and ΔW_{hfs} deviate greatly from each other.

For all classified lines of Ho I and Ho II, the absolute value of the difference $\Delta\sigma$ between the experimental wavenumber σ_{vac} and the calculated difference between the level energies of the upper and lower levels E_u and E_l is smaller than 0.23 cm^{-1} (due to the condition for $\Delta\sigma$) with a mean value of $|\Delta\sigma|$ was 0.04 cm^{-1}.

Our line list was compared with a list of all already published spectral lines of Ho I and Ho II. The lines that have not been published yet are labelled 'nl' or 'lc' in Table 3, depending on whether they are unclassified (only new line: 'nl') or whether they have also been newly classified ('lc'). Lines that already appear in the lists but were not previously classified and have now been classified have been labelled 'nc' in Table 3.

4. Conclusions

In different FT spectra of Ho-Ar and Ho-Ne covering the range from 700 nm to 1750 nm i.e. from 5710 cm^{-1} to 14,280 cm^{-1} 791 Ho lines were detected. Because measurements were made with two different buffer gases at different experimental conditions, for most unclassified lines an assignment to atomic or singly ionized Ho was possible. Spectral lines of doubly ionized Ho were not detected.

To our knowledge, of the 791 lines, 515 were published for the first time and another 203 lines were classified for the first time, while 22% of the lines remain unclassified, 90% of which are assigned to atomic Ho. This fact shows that despite the relatively large number of publications with new energy levels for Ho I in recent years, there are still many unknown fine structure levels of Ho I. A list of unclassified Ho lines in a wide wavelength range as possible would be helpful in the future search for new energy levels. We have made a contribution to this here.

CRediT authorship contribution statement

Muammer Zengin: Visualization, Formal analysis. **Seda Kın Barka:** Writing – review & editing, Formal analysis. **İpek K. Öztürk:** Writing – original draft, Formal analysis. **Ilze Klincare:** Writing – review & editing, Investigation. **Sophie Kröger:** Writing – original draft, Investigation, Conceptualization. **Gönül Başar:** Writing – review & editing, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We are grateful to Maris Tamanis for participation in the experiments, as well as to Ruvin Ferber and Florian Gahbauer for numerous pieces of advice. Support by the Latvian Council of Science, Project No. lzp-2020/1-0088, is acknowledged.

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