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THE ANALYSIS OF THE SIMPLIFIED FORMULA FOR THE STARK BROADENING OF NEUTRAL ATOM LINES

M. S. DIMITRIJEVIĆ and N. K. TODOROVIĆ
Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia
E–mail mdimitrijevic@aob.aob.bg.ac.yu

Abstract. The approximate semiclassical formula of Dimitrijević and Konjević for isolated neutral atom spectral lines has been applied to neutral helium lines. The desagreements with the more sophisticated full semiclassical calculations of Griem are within 20 per cents. It is demonstrated as well how one can introduce simple corrections in order to achieve even better agreement. With such corrections the largest desagreement is 2 percents.

1. INTRODUCTION

Starting from the semiclassical approach for Stark broadening parameters of neutral atom lines, in the version adapted for practical calculations by Griem, Jones and Benett (see *e.g.* Griem, 1974), Freundenstein and Cooper (1978) developed a simple approximate method for line width (w) calculation. This method has been improved and adapted as well for the shift (d) by Dimitrijević and Konjević (1986). Our objective here is to analyse the applicability of this method. Since the method has been derrived from the more sophisticated Griem's semiclassical approach, we will compare results obtained by both methods in order to see desagreements due to the additional simplifications introduced in the approach of Dimitrijević and Konjević (1986). The neutral helium lines have been choosen first of all since Stark broadening of neutral helium lines is well described within the semiclassical theory (Griem, 1974), and a comprehensive set of theoretical data checked by numerous experiments exists (see *e.g.* Griem, 1974)

2. RESULTS AND DISCUSSION

By using the methods of Freundenstein and Cooper (1978) (FC) and Dimitrijević and Konjević (1986) (DK), Stark broadening widths (w_{FC}, w_{DK}) and shifts (d_{DK}) for 12 neutral helium multiplets have been calculated at an electron density $N_e = 10^{16}$ cm^{-3} and temperatures 5000 - 40000 K.The ratios of obtained results and Griem's (1974) values (w_G, d_G) are shown in Table 1 for the width and in Table 2 for the shift. The corresponding averaged values denoted as $(...)_{av}$ are shown as well One can see in Tables 1 and 2 that the desagreements with the more sophisticated full semiclassical calculations of Griem are within 20 per cents. Since the error bars of the semiclassical method are estimated on 30 per cents (Griem, 1974), the corresponding error bars of the approach of Dimitrijević and Konjević (1986) may be estimated as 50 percents which is in accordance with the estimated error bars for the semiempirical method (see *e.g.* Griem, 1974).

TABLE 1

Ratios w_{DK}/w_G and w_{FC}/w_G for neutral helium spectral line widths (w) for an electron density of $N_e = 10^{16}$ cm^{-3}. DK - present calculations by using the method of Dimitrijević and Konjević (1986); FC - present calculations by using the method of Freundenstein and Cooper (1978); G - Griem (1974)

SINGLETS			
	T [K]	w_{DK}/w_G	w_{FC}/w_G
2s - 3p $\lambda = 501,7$ nm	5000	1,248	2,103
	10000	1,278	1,947
	20000	1,275	1,808
	40000	1,242	1,624
2s - 4p $\lambda = 396,5$ nm	5000	1,184	1,720
	10000	1,190	1,590
	20000	1,163	1,500
	40000	1,118	1,390
2p - 4s $\lambda = 504,8$ nm	5000	1,038	1,000
	10000	1,148	1,110
	20000	1,178	1,140
	40000	1,121	1,090
2p - 5s $\lambda = 443,8$ nm	5000	1,056	1,030
	10000	1,152	1,130
	20000	1,145	1,130
	40000	1,080	1,070
2p - 3d $\lambda = 667,8$ nm	5000	1,156	2,430
	10000	1,199	2,320
	20000	1,232	2,200
	40000	1,252	1,980
2p - 4d $\lambda = 492,2$ nm	5000	1,060	1,660
	10000	1,045	1,770
	20000	1,042	1,570
	40000	1,029	1,480
2p - 5d $\lambda = 438,8$ nm	5000	0,996	1,400
	10000	0,984	1,330
	20000	0,976	1,280
	40000	0,965	1,220

Table 1 (continued)

TRIPLETS			
	T [K]	w_{DK}/w_G	w_{FC}/w_G
2s - 3p $\lambda = 388,9$ nm	5000	1,529	1,910
	10000	1,526	1,930
	20000	1,470	1,790
	40000	1,384	1,640
2s - 4p $\lambda = 318,8$ nm	5000	1,438	1,690
	10000	1,402	1,670
	20000	1,326	1,530
	40000	1,246	1,390
2s - 5p $\lambda = 294,5$ nm	5000	1,398	
	10000	1,354	
	20000	1,260	
	40000	1,177	
2p - 4s $\lambda = 471,3$ nm	5000	1,000	
	10000	1,009	
	20000	1,185	
	40000	1,165	
2p - 5s $\lambda = 412,1$ nm	5000	1,029	
	10000	1,137	
	20000	1,189	
	40000	1,138	

T [K]	$(w_{DK}/w_G)_{av}$	$(w_{FC}/w_G)_{av}$
5000	$1,178 \pm 0,177$	$1,660 \pm 0,664$
10000	$1,210 \pm 0,148$	$1,644 \pm 0,380$
20000	$1,204 \pm 0,122$	$1,550 \pm 0,330$
40000	$1,160 \pm 0,107$	$1,430 \pm 0,280$

TABLE 2

Ratios d_{DK}/d_G for neutral helium spectral line shifts (d) for an electron density of N_e = 10^{16} cm^{-3}. DK - present calculations by using the method of Dimitrijević and Konjević (1986); G - Griem (1974)

λ (nm)	d_{DK}/d_G 5000 K	10000 K	20000 K	40000 K
501,7	0,892	0,830	0,763	0,720
396,5	1,178	0,786	0,732	0,722
504,8	1,222	1,112	0,972	0,849
443,8	1,172	1,063	0,919	0,823
667,8	0,992	0,969	0,913	0,851
492,2	0,885	0,877	0,856	0,818
438,8	0,845	0,834	0,818	0,794
388,9	1,040	0,912	0,823	0,772
318,8	1,032	0,920	0,858	0,826
294,5	0,988	0,888	0,839	0,818
471,3	1,231	1,129	1,023	0,892
412,1	1,170	1,082	0,968	0,854

$(d_{DK}/d_G)_{av}$ 5000 K	10000 K	20000 K	40000 K
1,054 ± 0,132	0,950 ± 0,114	0,873 ± 0,084	0,812 ± 0,049

The accuracy of an approximate method may be improved if we have a set of theoretical or experimental data of higher accuracy, like the Griem's (1974) semiclassical calculations in the considered case. We will take into account that the ratios of corrected values w_c, d_c and the corresponding Griem's values must be close to unity, and we will search correction functions $f_w(n,T)$ and $f_d(n,T)$ such that $w_c = f_w(n,T)w_{DK}$ and $d_c = f_d(n,T)d_{DK}$, where the principal quantum number is denoted with n The obtained corrected width is

$$w_c = \frac{aT^m + C_1 \ln T + C_2}{(w_{DK}/w_G)_m} \cdot w_{DK} \quad .$$

Since $aT^m + C_1 \ln T + C_2 \approx 1$ one can also use the approximation $f_w(n,T) \approx \frac{1}{(w_{DK}/w_G)_m}$, so we have $w_c \approx \frac{w_{DK}}{(w_{DK}/w_G)_m}$. Here $(w_{DK}/w_G)_m$ is the mean value formed by grouping results for similar transitions on the same temperature. For the shift one obtains the completely analogous expression. For width we obtain a = 1.407, m = -0.039, C_1 = 0.038, and C_2 = -0.330 and for shift a = 3.88, m = -0.139, C_1 = 0.145 and C_2 = -1.419.

TABLE 3

Ratio of our corrected (w_c) and Griem's (w_G) width values at different temperatures for He I spectral lines ($N_e = 10^{16}$ cm^{-3}).

λ	w_c/w_G			
(nm)	5000 K	10000 K	20000 K	40000 K
501,7	1,042	1,078	1,057	1,029
396,5	0,990	1,004	0,964	0,928
504,8	1,008	0,969	0,978	0,930
443,8	1,026	0,973	0,950	1,054
667,8	0,967	1,010	1,020	1,038
492,2	1,030	1,005	1,032	1,000
438,8	0,967	0,946	0,966	0,942
388,9	1,049	1,063	1,042	1,145
318,8	0,987	0,979	0,947	1,033
294,5	0,960	0,945	1,046	0,976
471,3	0,971	1,056	0,982	0,967
412,1	1,000	0,958	0,987	0,944

$(w_c/w_G)_{av}$			
5000 K	10000 K	20000 K	40000 K
0,999 ± 0,103	0,999 ± 0,040	0,998 ± 0,038	0,999 ± 0,060

TABLE 4

Ratio of our corrected (d_c) and Griem's (d_G) shift values at different temperatures for He I spectral lines ($N_e = 10^{16}$ cm^{-3}).

λ	d_c/d_G			
(nm)	5000 K	10000 K	20000 K	40000 K
501,7	1,024	0,980	0,868	0,892
396,5	0,712	0,926	0,834	0,902
504,8	1,026	0,986	1,108	1,052
443,8	0,984	1,068	1,047	1,020
667,8	0,982	0,974	1,041	1,049
492,2	1,020	1,035	0,976	1,014
438,8	0,968	0,984	0,933	0,984
388,9	1,027	0,916	0,935	0,970
318,8	1,018	0,926	0,977	1,029
294,5	0,979	1,048	0,958	1,012
471,3	1,035	1,002	1,164	1,104
412,1	0,983	1,087	1,103	1,058

$(d_c/d_G)_{av}$			
5000 K	10000 K	20000 K	40000 K
0,980 ± 0,084	0,994 ± 0,053	1,000 ± 0,100	1,007 ± 0,060

In tables 3 and 4, ratios of corrected values for widths and shifts and the corresponding Griem's values are shown, as well as the averaged values. One can see that the largest desagreement now is 2 per cents.

References

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