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ELECTRON-IMPACT BROADENING OF NEUTRAL STRONTIUM LINES IN STELLAR AND LABORATORY PLASMAS

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Abstract. Using a semiclassical approach, we have calculated electron–, proton–, and ionized helium–impact line widths and shifts for 33 Sr I multiplets for perturber densities 10^{13} cm^{-3} (for stellar plasma research) and 10^{15}– 10^{18} cm^{-3} (for laboratory plasma research) and temperatures T = 2,500 – 50,000 K. A part of results is shown and discussed.

1. INTRODUCTION

We are making a continuous effort to provide an as much as possible more complete set of semiclassical Stark-broadening parameters needed for research of astrophysical, laboratory and laser produced plasma. A review of our results is presented in Dimitrijević, 1996). Such set of data is not only of interest *e.g.* for stellar plasma diagnostic, opacity calculations or the investigation/modelling of stellar spectra or a particular line, but as well for different examinations of regularities and systematic trends for e.g. homologous atoms (Dimitrijević and Popović, 1989) or in general (Purić *et al.* 1991). Strontium lines are present in solar and stellar spectra. E.g. Komarov & Basak (1993) have found neutral strontium lines in the spectra of Sun and two Praesepe's stars. They are also of interest since Sr is one of thermonuclear s - processes product in stars and its overabundance is observed in CH and metal deficient barium stars (Šleivytė & Bartkevičius, 1995). Neutral strontium lines are also of interest for the investigation of laboratory plasmas. Consequently, Kato et al. (1984) investigated wavelength shifts of Sr I lines emitted by an inductively coupled plasma and Karabut et al. (1980) dynamics of strontium line shapes during a pulsed discharge. Such lines have been considered theoretically as well by Davis (1972), for research of a laser - generated barium plasma. In order to continue our research of Stark broadening parameters needed for the investigation of astrophysical and laboratory plasmas and to provide the needed Stark broadening data, we have calculated within the semiclassical-perturbation formalism (Sahal–Bréchot, 1969ab) electron-, proton-, and ionized helium-impact line widths and shifts for 33 Sr I multiplets. The obtained results will be published elsewhere. Here, a part of results is shown as an illustration.

Table 1. This table shows electron-, and proton-impact broadening parameters for Sr I for a perturber density of 10^{15} cm^{-3} and temperatures from 2,500 up to 50,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. If one divides c value with the linewidth value, we obtain an estimate for the maximum perturber density (in cm^{-3}) for which the line may be treated as isolated and tabulated data may be used. The asterisk identifies cases for which the collision volume multiplied by the perturber density (the condition for validity of the impact approximation) lies between 0.1 and 0.5.

PERTURBER DENSITY= 1.E+15cm-3

PERTURBERS ARE :		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
5S - 5P	2500.	0.227E-02	0.326E-04	0.780E-03	-0.119E-03
4608.6 Å	5000.	0.229E-02	0.267E-03	0.782E-03	-0.133E-03
C= 0.33E+18	10000.	0.236E-02	0.419E-03	0.785E-03	-0.150E-03
	20000.	0.258E-02	0.504E-03	0.791E-03	-0.175E-03
	30000.	0.279E-02	0.430E-03	0.797E-03	-0.181E-03
	50000.	0.316E-02	0.337E-03	0.809E-03	-0.197E-03
5S - 6P	2500.	0.828E-02	0.623E-02	0.228E-02	0.160E-02
2932.7 Å	5000.	0.901E-02	0.608E-02	0.246E-02	0.185E-02
C= 0.54E+17	10000.	0.983E-02	0.473E-02	0.268E-02	0.211E-02
	20000.	0.108E-01	0.365E-02	0.294E-02	0.240E-02
	30000.	0.111E-01	0.316E-02	0.311E-02	0.258E-02
	50000.	0.112E-01	0.238E-02	0.337E-02	0.282E-02
5S - 7P	2500.	0.146E-01	0.421E-02	0.350E-02	0.921E-03
2570.2 Å	5000.	0.183E-01	0.573E-02	0.354E-02	0.106E-02
C= 0.31E+17	10000.	0.220E-01	0.673E-02	0.358E-02	0.121E-02
	20000.	0.252E-01	0.667E-02	0.365E-02	0.137E-02
	30000.	0.268E-01	0.603E-02	0.370E-02	0.148E-02
	50000.	0.283E-01	0.515E-02	0.378E-02	0.161E-02
6S - 6P	2500.	0.750	0.417	0.193	0.127
28517.3 Å	5000.	0.896	0.280	0.207	0.146
C= 0.51E+19	10000.	1.12	0.148	0.223	0.167
	20000.	1.28	0.592E-01	0.243	0.189
	30000.	1.35	0.625E-02	0.256	0.204
	50000.	1.42	-0.203E-01	0.276	0.222
6S - 7P	2500.	0.312	0.810E-01	0.758E-01	0.149E-01
12026.3 Å	5000.	0.393	0.105	0.764E-01	0.171E-01
C= 0.67E+18	10000.	0.482	0.118	0.770E-01	0.194E-01
	20000.	0.572	0.974E-01	0.778E-01	0.220E-01
	30000.	0.623	0.910E-01	0.786E-01	0.237E-01
	50000.	0.672	0.876E-01	0.799E-01	0.262E-01
5P - 6S	2500.	0.538E-01	0.355E-01	0.113E-01	0.948E-02
11244.4 Å	5000.	0.608E-01	0.423E-01	0.125E-01	0.108E-01
C= 0.20E+19	10000.	0.663E-01	0.486E-01	0.139E-01	0.123E-01
	20000.	0.707E-01	0.491E-01	0.155E-01	0.139E-01
	30000.	0.734E-01	0.452E-01	0.165E-01	0.149E-01
	50000.	0.790E-01	0.375E-01	0.179E-01	0.163E-01

PERTURBER DENSITY= 1.E+15cm-3

PERTURBERS ARE :		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
5P - 7S	2500.	0.149	0.107	*0.308E-01	*0.247E-01
5971.7 Å	5000.	0.161	0.118	0.346E-01	0.296E-01
C= 0.17E+18	10000.	0.166	0.114	0.389E-01	0.345E-01
	20000.	0.170	0.969E-01	0.438E-01	0.397E-01
	30000.	0.172	0.828E-01	0.470E-01	0.428E-01
	50000.	0.172	0.666E-01	0.515E-01	0.471E-01
5P - 8S	2500.	0.450	0.299		
5166.9 Å	5000.	0.462	0.287		
C= 0.32E+17	10000.	0.472	0.236	*0.125	*0.103
	20000.	0.466	0.179	*0.141	*0.122
	30000.	0.450	0.142	*0.152	*0.133
	50000.	0.427	0.977E-01	*0.168	*0.147
6P - 7S	2500.	2.23	1.45	0.427	0.339
23011.7 Å	5000.	2.55	1.56	0.478	0.405
C= 0.25E+19	10000.	2.79	1.51	0.536	0.471
	20000.	3.00	1.28	0.603	0.541
	30000.	3.09	1.11	0.647	0.584
	50000.	3.12	0.900	0.710	0.641
6P - 8S	2500.	3.49	2.27		
14380.1 Å	5000.	3.63	2.08		
C= 0.25E+18	10000.	3.78	1.56	*0.961	*0.792
	20000.	3.80	1.10	* 1.09	*0.935
	30000.	3.69	0.861	* 1.17	* 1.02
	50000.	3.52	0.524	* 1.29	* 1.13
5P - 5D	2500.	0.498E-01	-0.233E-01	0.107E-01	-0.717E-02
7675.2 Å	5000.	0.516E-01	-0.162E-01	0.115E-01	-0.824E-02
C= 0.37E+18	10000.	0.564E-01	-0.988E-02	0.124E-01	-0.939E-02
	20000.	0.582E-01	-0.530E-02	0.135E-01	-0.106E-01
	30000.	0.590E-01	-0.366E-02	0.143E-01	-0.114E-01
	50000.	0.600E-01	-0.242E-02	0.155E-01	-0.125E-01
5P - 6D	2500.	0.123	-0.666E-01	*0.282E-01	-0.200E-01
5544.9 Å	5000.	0.129	-0.531E-01	0.310E-01	-0.239E-01
C= 0.60E+17	10000.	0.141	-0.350E-01	0.343E-01	-0.278E-01
	20000.	0.150	-0.206E-01	0.383E-01	-0.319E-01
	30000.	0.154	-0.129E-01	0.410E-01	-0.344E-01
	50000.	0.158	-0.668E-02	0.451E-01	-0.378E-01
5P - 7D	2500.	0.124	-0.605E-01	*0.347E-01	-0.172E-01
4966.9 Å	5000.	0.142	-0.490E-01	*0.365E-01	-0.206E-01
C= 0.77E+17	10000.	0.176	-0.317E-01	0.385E-01	-0.240E-01
	20000.	0.213	-0.183E-01	0.410E-01	-0.276E-01
	30000.	0.231	-0.118E-01	0.428E-01	-0.298E-01
	50000.	0.252	-0.390E-02	0.454E-01	-0.327E-01
5P - 8D	2500.	0.236	-0.910E-01		
4689.9 Å	5000.	0.295	-0.594E-01	*0.667E-01	-0.360E-01
C= 0.40E+17	10000.	0.372	-0.382E-01	*0.706E-01	-0.428E-01
	20000.	0.440	-0.166E-01	*0.749E-01	-0.497E-01
	30000.	0.477	-0.750E-02	*0.778E-01	-0.539E-01
	50000.	0.510	0.247E-02	0.820E-01	-0.595E-01

2. RESULTS AND DISCUSSION

The used formalism has been discussed in detail in Sahal - Bréchot (1969ab) and a brief summary is given in Dimitrijević *et al.* (1991). Energy levels for Sr I lines have been taken from Moore (1971). Oscillator strengths have been calculated by using the method of Bates & Damgaard (1949) and the tables of Oertel & Shomo (1968). For higher levels, the method described by Van Regemorter et al. (1979) has been used. We note that Gruzdev (1967) has found that the semiempirical and Hartree - Fock calculations of Sr I oscillator strengths agree fairly well with the f values calculated by the method of Coulomb approximation.

In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and He II- impacts have been calculated. Our results for 33 Sr I multiplets, for perturber densities 10^{13} cm^{-3} (for stellar plasma research) and 10^{15}–10^{18} cm^{-3} (for laboratory plasma research) and temperatures T = 2,500 – 50,000 K, will be published elsewhere (Dimitrijević and Sahal - Bréchot, 1996). As an illustration, a part of results is shown in Table 1, for perturber density of 10^{15} cm^{-3}. For each value given in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal–Bréchot, 1969ab). Values for NV > 0.5 are not given and values for $0.1 < NV \leq 0.5$ are denoted by an asterisk. When the impact approximation is not valid, the ion broadening contribution may be estimated by using quasistatic approach (Sahal–Bréchot 1991 and Griem 1974). The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

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