

## ON THE STARK BROADENING OF NEUTRAL CALCIUM LINES

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**Abstract.** Using a semiclassical approach, we have calculated electron-, proton-, He II-, Mg II-, Si II-, and Fe II-impact line widths and shifts for 189 neutral calcium lines, as a function of temperature and perturber density. Perturbers selected here, are the main perturbers in solar and stellar atmospheres.

## 1. INTRODUCTION

Neutral calcium lines are very important for stellar spectra synthesis and stellar plasma analysis due to cosmical abundance of this element. Stark broadening parameters of Ca I are important as well for laboratory plasma diagnostics, modelling and investigation. In order to complete as much as possible Stark broadening data needed for astrophysical and laboratory plasma research and stellar opacities calculations, we have published in a series of papers, results of large scale calculations of Stark broadening parameters for a number of spectral lines of various emitters (Dimitrijević, 1996, 1997 and references therein). Our calculations have been performed within the semiclassical - perturbation formalism (Sahal-Bréchet, 1969ab), for transitions when a sufficiently complete set of reliable atomic data exist and the good accuracy of obtained results is expected.

Up to now, Stark broadening parameters for 79 He I, 62 Na, 51 K, 61 Li, 25 Al, 24 Rb, 3 Pd, 19 Be, 270 Mg, 31 Se, 33 Sr, 14 Ba, 28 Ca II, 30 Be II, 29 Li II, 66 Mg II, 64 Ba II, 19 Si II, 3 Fe II, 2 Ni II, 12 B III, 23 Al III, 10 Sc III, 27 Be III, 32 Y III, 20 In III, 2 Tl III, 10 Ti IV, 39 Si IV, 90 C IV, 5 O IV, 114 P IV, 2 Pb IV, 19 O V, 30 N V, 25 C V, 51 P V, 34 S V, 26 V V, 30 O VI, 21 S VI, 2 F VI, 14 O VII, 10 F VII, 10 Cl VII, 20 Ne VIII, 4 K VIII, 6 Kr VIII, 4 Ca IX, 30 K IX, 8 Na IX, 57 Na X, 48 Ca X, 4 Sc X, 7 Al XI, 4 Si XI, 18 Mg XI, 4 Ti XI, 10 Sc XI, 9 Si XII, 27 Ti XII, 61 Si XIII and 33 V XIII multiplets become available.

Data for particular lines of F I, B II, C III, N IV, Ar II, Ga II, Ga III, Cl I, Br I, I I, Cu I, Hg II, N III, F V and S IV also exist.

In order to continue our project to provide to physicists and astrophysicists an as much as possible complete set of needed reliable Stark broadening data, we have

calculated within the semiclassical-perturbation formalism, electron-, proton-, He II-, Mg II-, Si II-, and Fe II - impact line widths and shifts for 189 neutral calcium lines, as a function of temperature and perturber density. Perturbers selected here, are the main perturbers in solar and stellar atmospheres.

## 2. RESULTS AND DISCUSSION

A summary of the formalism has been published several times (see e. g. Dimitrijević and Sahal-Bréchet 1984). Energy levels have been taken from Sugar and Corliss (1979).

Our results for 189 Ca I multiplets as a function of the perturber density and temperature and the comparison with available experimental and theoretical data will be published in Dimitrijević and Sahal-Bréchet (1999a,b).

**Table 1**

This table shows electron- and proton-impact broadening full half-widths (FWHM) and shifts for Ca I for a perturber density of  $10^{16} \text{ cm}^{-3}$  and temperatures from 2,500 up to 50,000 K. By deviding C with the full linewidth, we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used (Dimitrijević and Sahal-Bréchet 1984). 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-Bréchet, 1969ab). Values for  $NV > 0.5$  are not given and values for  $0.1 < NV \leq 0.5$  are denoted by an asterisk.

PERTURBER DENSITY = 1.E+16cm-3					
PERTURBERS ARE :		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
4S - 4P	2500.	0.103E-01	0.578E-02	0.581E-02	0.155E-02
4227.9 Å	5000.	0.115E-01	0.665E-02	0.587E-02	0.178E-02
C= 0.17E+20	10000.	0.124E-01	0.795E-02	0.592E-02	0.202E-02
Singlet	20000.	0.143E-01	0.807E-02	0.600E-02	0.229E-02
	30000.	0.162E-01	0.724E-02	0.605E-02	0.245E-02
	50000.	0.193E-01	0.585E-02	0.613E-02	0.268E-02
4S - 5P	2500.	0.672E-01	0.474E-01	*0.180E-01	*0.110E-01
2722.5 Å	5000.	0.726E-01	0.456E-01	*0.197E-01	*0.137E-01
C= 0.42E+18	10000.	0.798E-01	0.364E-01	0.216E-01	0.163E-01
Singlet	20000.	0.864E-01	0.289E-01	0.238E-01	0.190E-01
	30000.	0.878E-01	0.245E-01	0.254E-01	0.206E-01
	50000.	0.887E-01	0.185E-01	0.276E-01	0.228E-01

Table 1 continued

PERTURBER DENSITY = 1.E+16cm-3

PERTURBERS ARE :

TRANSITION	T(K)	ELECTRONS		PROTONS	
		WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
5S - 5P	2500.	7.36	3.52	* 1.85	* 1.07
29288.1 Å	5000.	9.21	2.15	2.00	1.32
C= 0.49E+20	10000.	11.4	0.952	2.17	1.57
Singlet	20000.	12.7	0.146	2.38	1.82
	30000.	13.4	-0.315	2.52	1.97
	50000.	14.0	-0.477	2.73	2.17
5S - 6P	2500.	1.82	0.810	*0.616	*0.172
11959.2 Å	5000.	2.24	0.884	*0.644	*0.212
C= 0.14E+20	10000.	2.83	0.902	*0.661	*0.251
Singlet	20000.	3.54	0.705	0.676	0.291
	30000.	3.99	0.624	0.686	0.315
	50000.	4.49	0.565	0.700	0.347
4P - 5S	2500.	0.363	0.219	0.826E-01	0.581E-01
12678.8 Å	5000.	0.407	0.275	0.897E-01	0.680E-01
C= 0.83E+20	10000.	0.441	0.325	0.979E-01	0.784E-01
Singlet	20000.	0.496	0.321	0.107	0.894E-01
	30000.	0.535	0.290	0.113	0.963E-01
	50000.	0.618	0.241	0.122	0.106
4P - 4D	2500.	0.394	-0.172	0.873E-01	-0.537E-01
7328.2 Å	5000.	0.428	-0.111	0.948E-01	-0.654E-01
C= 0.30E+19	10000.	0.466	-0.625E-01	0.103	-0.770E-01
Singlet	20000.	0.475	-0.263E-01	0.114	-0.889E-01
	30000.	0.481	-0.437E-02	0.121	-0.962E-01
	50000.	0.488	0.320E-02	0.132	-0.106
4P - 5D	2500.	0.460	-0.241	*0.134	*-0.540E-01
5190.3 Å	5000.	0.511	-0.225	*0.143	*-0.693E-01
C= 0.16E+19	10000.	0.581	-0.164	*0.151	*-0.838E-01
Singlet	20000.	0.697	-0.119	*0.160	*-0.984E-01
	30000.	0.758	-0.105	0.166	-0.107
	50000.	0.825	-0.808E-01	0.175	-0.119
5S - 5P	2500.	2.24	1.53	0.704	0.360
19897.4 Å	5000.	2.64	1.49	0.746	0.436
C= 0.47E+20	10000.	3.13	1.05	0.791	0.511
Triplet	20000.	3.93	0.687	0.844	0.590
	30000.	4.34	0.593	0.879	0.638
	50000.	4.72	0.388	0.929	0.702

4P - 5S	2500.	0.820E-01	0.652E-01	0.208E-01	0.168E-01
6143.9 Å	5000.	0.983E-01	0.777E-01	0.232E-01	0.198E-01
C= 0.19E+20	10000.	0.114	0.925E-01	0.259E-01	0.229E-01
Triplet	20000.	0.124	0.993E-01	0.290E-01	0.262E-01
	30000.	0.130	0.100	0.309E-01	0.282E-01
	50000.	0.136	0.912E-01	0.336E-01	0.309E-01
4P - 6S	2500.	0.146	0.104	*0.326E-01	*0.237E-01
3966.5 Å	5000.	0.172	0.127	0.367E-01	0.296E-01
C= 0.32E+19	10000.	0.190	0.149	0.411E-01	0.353E-01
Triplet	20000.	0.202	0.150	0.462E-01	0.411E-01
	30000.	0.211	0.143	0.494E-01	0.447E-01
	50000.	0.222	0.121	0.538E-01	0.493E-01
4P - 4D	2500.	0.943E-01	-0.316E-01	0.244E-01	-0.998E-02
4446.3 Å	5000.	0.106	-0.174E-01	0.252E-01	-0.118E-01
C= 0.23E+19	10000.	0.126	-0.237E-02	0.261E-01	-0.137E-01
Triplet	20000.	0.141	0.108E-01	0.273E-01	-0.157E-01
	30000.	0.149	0.137E-01	0.281E-01	-0.169E-01
	50000.	0.157	0.164E-01	0.294E-01	-0.185E-01

As a sample of our results, the Stark broadening parameters for Ca I spectral lines broadened by electron and proton impacts, for a perturber density of  $10^{16} \text{ cm}^{-3}$ , are shown in Table 1.

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