A Project for Large-Scale Stark Broadening Data Production: Ca IX and Ca X Spectral Lines

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1 Introduction

In a series of papers we have performed large scale calculations of Stark broadening parameters for a number of spectral lines of various emitters [1], [2], [3], [4]. Such data are of interest for a number of problems in astrophysics, physics and plasma technology. One may mention as examples calculation of stellar opacities, stellar atmospheres modelling and investigations, abundance determinations, interpretation and modelling of stellar spectra, laboratory plasma diagnostics, research and modelling, radiative transfer calculations and investigation of laser produced plasmas and plasmas created in fusion research. In order to satisfy the numerous Stark broadening data needs for astrophysical and laboratory plasma research and stellar opacities calculations, we are making a continuing effort to provide Stark broadening data for a large set of atoms and ions. Our calculations are performed within the semiclassical - perturbation formalism [5, 6], for transitions where a sufficiently complete set of reliable atomic data exists and good accuracy for the obtained results is expected.

Extensive calculations have been performed up to now [4] for a number of radiators, and consequently, 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 Ba III, 32 Y III, 10 Ti IV, 39 Si IV, 90 C IV, 5 O IV, 114 P IV, 19 O V, 30 N V, 25 C V, 51 P V, 33 V V, 30 O VI, 21 S VI, 10 O VII, 10 F VII, 20 Ne VIII, 4 Ca IX, 8 Na IX, 48 Ca X, 7 Al XI, 4 Si XI, Si XII, and 26 V XIII multiplets become available.

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

In continuation of our project, we have calculated within the semiclassical-perturbation formalism the electron-, proton-, and He III-impact line widths and shifts for 4 Ca IX and 48 Ca X multiplets, as a function of temperature and perturber density.

2 Results and Discussion

A summary of the formalism has been published several times [7], and will not be repeated here. The energy levels for the Ca IX and Ca X lines have been taken from Bashkin and Stoner [8]. In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and He III- impacts have been calculated. Our results for 4 Ca IX and 48 Ca X multiplets for perturber densities from 10^{18} to 10^{22} cm^{-3} and temperatures from 200,000 to 2,000,000 K will be published elsewhere [10, 11].

In Tables 1 and 2, we present a sample of results obtained for Ca IX and Ca X, respectively. We also specify a parameter C [9], which gives an estimate for the maximum perturber density for

which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. For each value given in Tables 1 and 2, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid [5, 6]. When the impact approximation is not valid, the ion broadening contribution may be estimated by using quasistatic estimates [12, 13]. The accuracy of the results obtained decreases when broadening by ion interactions becomes important.

We hope that the present results will be of interest for stellar, laboratory, fusion and laser-produced plasma investigations and modeling, as well as for the testing and developing of Stark broadening theory.

References

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Table 1: Electron- and proton-impact broadening full half-widths (FWHM) and shifts for Ca IX for a perturber density of 10^{18} cm^{-3} and temperatures from 200,000 to 2,000,000 K. By dividing 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.

Perturber	Density	= 1.E+18cm^{-3}			
Perturbers	are:	Electrons		Protons	
Transition	T(K)	Width(Å)	Shift(Å)	Width(Å)	Shift(Å)
Ca IX 3P 5S	200000.	0.768E-03	0.953E-04	0.640E-04	0.103E-03
116.1 A	500000.	0.551E-03	0.932E-04	0.133E-03	0.147E-03
C=0.29E+19	1000000.	0.439E-03	0.893E-04	0.178E-03	0.178E-03
	2000000.	0.355E-03	0.766E-04	0.231E-03	0.211E-03
	3000000.	0.314E-03	0.671E-04	0.262E-03	0.228E-03
	5000000.	0.269E-03	0.562E-04	0.318E-03	0.254E-03

Table 2: Electron- and proton-impact broadening full half-widths (FWHM) and shifts for Ca X for a perturber density of 10^{18} cm^{-3} and temperatures from 200,000 to 2,000,000 K. By dividing 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.

Perturber	Density	= 1.E+18cm^{-3}			
Perturbers	are:	Electrons		Protons	
Transition	T(K)	Width(Å)	Shift(Å)	Width(Å)	Shift(Å)
Ca X 3S 3P	200000.	0.498E-02	-0.601E-04	0.302E-04	-0.282E-04
563.1 A	500000.	0.322E-02	-0.532E-04	0.983E-04	-0.676E-04
C=0.56E+21	1000000.	0.238E-02	-0.679E-04	0.179E-03	-0.113E-03
	2000000.	0.180E-02	-0.605E-04	0.264E-03	-0.160E-03
	3000000.	0.155E-02	-0.581E-04	0.303E-03	-0.188E-03
	5000000.	0.130E-02	-0.561E-04	0.351E-03	-0.214E-03
Ca X 3S 4P	200000.	0.481E-03	0.314E-05	0.138E-04	0.190E-05
111.0 A	500000.	0.321E-03	0.343E-05	0.279E-04	0.438E-05
C=0.84E+19	1000000.	0.244E-03	0.303E-05	0.383E-04	0.691E-05
	2000000.	0.191E-03	0.315E-05	0.441E-04	0.951E-05
	3000000.	0.168E-03	0.310E-05	0.477E-04	0.107E-04
	5000000.	0.145E-03	0.267E-05	0.529E-04	0.123E-04
Ca X 3S 5P	200000.	0.571E-03	0.831E-05	0.366E-04	0.857E-05
82.8 A	500000.	0.395E-03	0.112E-04	0.574E-04	0.152E-04
C=0.22E+19	1000000.	0.310E-03	0.103E-04	0.666E-04	0.208E-04
	2000000.	0.250E-03	0.994E-05	0.761E-04	0.249E-04
	3000000.	0.224E-03	0.910E-05	0.817E-04	0.275E-04
	5000000.	0.196E-03	0.773E-05	0.890E-04	0.310E-04
Ca X 3S 6P	200000.	0.858E-03	0.227E-04	0.830E-04	0.230E-04
73.2 A	500000.	0.614E-03	0.238E-04	0.111E-03	0.358E-04
C=0.97E+18	1000000.	0.494E-03	0.221E-04	0.126E-03	0.432E-04
	2000000.	0.408E-03	0.206E-04	0.142E-03	0.515E-04
	3000000.	0.369E-03	0.185E-04	0.151E-03	0.573E-04
	5000000.	0.327E-03	0.151E-04	0.164E-03	0.632E-04
Ca X 4S 4P	200000.	0.103	-0.161E-02	0.259E-02	-0.175E-02
1475.2 A	500000.	0.698E-01	-0.234E-02	0.534E-02	-0.336E-02