J. Quant. Spectrosc. Radiat. Transfer Vol. 49, No. 2, pp. 157–164, 1993
Printed in Great Britain.

0022-4073/93 \$6.00 + 0.00

STARK BROADENING OF Ca II SPECTRAL LINES

M. S. DIMITRIJEVIĆ†‡ and S. SAHAL-BRÉCHOT§

†Astronomical Observatory, Volgina 7, 11050 Beograd, Yugoslavia and §Laboratoire "Astrophysique, Atomes et Molécules", Unité associée au C.N.R.S. No 812, Département Atomes et Molécules en Astrophysique, Observatoire de Paris-Meudon, 92190 Meudon, France

(Received 17 December 1991; received for publication 21 March 1992)

Abstract—Using a semiclassical approach, we have calculated electron-, proton-, and ionized-helium-impact line widths and shifts for 28 Ca II multiplets. The resulting data have been compared with existing experimental values.

INTRODUCTION

Calcium is among the most abundant elements in stellar plasmas after hydrogen and helium. Particularly important for stellar spectral analysis are the well known resonance lines of Ca II, which are present in all spectra starting with B-type stars and reaching maximal intensity in stars of the K0 spectral type. Consequently, knowledge of reliable Ca II Stark-broadening parameters is of great importance for detailed investigation of stellar atmospheres, as well as for opacity research. Furthermore, Ca II lines are of particular interest for investigations of laboratory plasmas, since calcium is often present as an impurity. By using the semiclassical-perturbation formalism,[1,2] we have calculated electron-, proton-, and ionized-helium-impact line widths and shifts for 28 Ca II multiplets. A summary of the formalism is given in Ref. 3. Here, we present and discuss the results for Ca II, along with a comparison with experimental data[4–15] and other theoretical results.[13,16–19]

RESULTS AND DISCUSSION

Energy levels for Ca II lines have been taken from Ref. 20. Oscillator strengths have been calculated by using the method of Bates and Damgaard.[21,22] For higher levels, the method described in Ref. 23 has been used. In the case of the $3d$-$4p$ and $4s$-$4p$ transitions, the contribution of resonances has been neglected. The method for estimation of resonance contributions described in Ref. 4 assumes the existence of a series of resonances below the corresponding excitation threshold. This condition is especially well satisfied for multicharged ions and for higher transitions. For $3d$-$4p$ and $4s$-$4p$ Ca II transitions, conditions for the utilization of the proposed method are not satisfied, and the resonance contribution is overestimated.

In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton- and ionized-helium-impacts have been calculated. In this manner, we have provided Stark-broadening data for all of the important charged perturbers in stellar atmospheres. Our results are shown in Table 1 for a perturber density of $10^{15}\,\mathrm{cm}^{-3}$ and temperatures $T = 5000$–$50{,}000$ K. For perturber densities lower than $10^{15}\,\mathrm{cm}^{-3}$, all of the data are practically linear functions of the density because the effect of Debye screening is negligible. We also specify a parameter[24] c which, when it is divided by the corresponding electron-impact full width at half maximum, gives an estimate for the maximum perturber density for which the line may be treated as isolated.

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.[1,2] 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 estimates.[19,25] The accuracy of the results

‡To whom all correspondence should be addressed.

Table 1. This table shows electron-, proton-, and ionized-helium-impact broadening parameters for Ca II lines and for perturber densities of 10^{15} cm^{-3} and temperatures from 5000 to 50,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. By using c [see Eq. (5) of Ref. 24], we obtain an estimate for the maximum perturber density 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 = 0.1D+16(cm-3)							
PERTURBERS ARE		ELECTRONS		PROTONS		IONIZED HELIUM	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
CA II 3D-4P	5000.	0.134E-01	0.818E-03	0.404E-03	-0.758E-04	0.576E-03	-0.741E-04
8581.1 A	10000.	0.105E-01	0.304E-03	0.669E-03	-0.138E-03	0.834E-03	-0.128E-03
C= 0.86E+19	20000.	0.856E-02	0.229E-03	0.928E-03	-0.212E-03	0.101E-02	-0.185E-03
	30000.	0.776E-02	0.881E-04	0.101E-02	-0.258E-03	0.109E-02	-0.222E-03
	50000.	0.707E-02	0.748E-04	0.112E-02	-0.310E-03	0.118E-02	-0.255E-03
CA II 3D-5P	5000.	0.303E-02	-0.382E-03	0.249E-03	-0.936E-04	0.290E-03	-0.808E-04
2132.3 A	10000.	0.241E-02	-0.235E-03	0.312E-03	-0.130E-03	0.332E-03	-0.108E-03
C= 0.17D+18	20000.	0.207E-02	-0.233E-03	0.360E-03	-0.157E-03	0.373E-03	-0.130E-03
	30000.	0.196E-02	-0.185E-03	0.390E-03	-0.175E-03	0.390E-03	-0.144E-03
	50000.	0.189E-02	-0.147E-03	0.410E-03	-0.199E-03	0.402E-03	-0.162E-03
CA II 3D-6P	5000.	0.413E-02	-0.140E-02	0.558E-03	-0.279E-03	0.586E-03	-0.226E-03
1644.1 A	10000.	0.358E-02	-0.106E-02	0.652E-03	-0.339E-03	0.667E-03	-0.279E-03
C= 0.48D+17	20000.	0.333E-02	-0.812E-03	0.732E-03	-0.404E-03	0.723E-03	-0.328E-03
	30000.	0.328E-02	-0.654E-03	0.757E-03	-0.439E-03	0.747E-03	-0.365E-03
	50000.	0.332E-02	-0.556E-03	0.806E-03	-0.481E-03	0.746E-03	-0.375E-03
CA II 3D-7P	5000.	0.721E-02	-0.315E-02	0.120E-02	-0.659E-03	0.121E-02	-0.539E-03
1474.4 A	10000.	0.645E-02	-0.266E-02	0.137E-02	-0.802E-03	0.135E-02	-0.667E-03
C= 0.21D+17	20000.	0.619E-02	-0.202E-02	0.149E-02	-0.935E-03	0.141E-02	-0.753E-03
	30000.	0.631E-02	-0.169E-02	0.161E-02	-0.103E-02	0.143E-02	-0.816E-03
	50000.	0.649E-02	-0.143E-02	0.161E-02	-0.106E-02	0.153E-02	-0.881E-03
CA II 3D-4F	5000.	0.174E-02	0.716E-03	0.133E-03	0.588E-04	0.160E-03	0.505E-04
1839.2 A	10000.	0.137E-02	0.549E-03	0.178E-03	0.824E-04	0.188E-03	0.694E-04
C= 0.16D+18	20000.	0.116E-02	0.429E-03	0.206E-03	0.101E-03	0.213E-03	0.831E-04
	30000.	0.112E-02	0.384E-03	0.223E-03	0.112E-03	0.225E-03	0.920E-04
	50000.	0.109E-02	0.323E-03	0.242E-03	0.127E-03	0.239E-03	0.103E-03
CA II 3D-5F	5000.	0.784E-02	0.225E-02	0.145E-02	0.136E-02	0.124E-02	0.112E-02
1554.1 A	10000.	0.673E-02	0.197E-02	0.181E-02	0.166E-02	0.157E-02	0.131E-02
C= 0.31D+16	20000.	0.591E-02	0.158E-02	0.210E-02	0.192E-02	0.171E-02	0.153E-02
	30000.	0.552E-02	0.137E-02	0.242E-02	0.213E-02	0.190E-02	0.166E-02
	50000.	0.512E-02	0.115E-02	0.238E-02	0.224E-02	0.228E-02	0.173E-02
CA II 3D-6F	5000.	0.170E-01	0.550E-02	*0.409E-02	*0.348E-02	*0.345E-02	*0.282E-02
1433.3 A	10000.	0.154E-01	0.485E-02	*0.466E-02	*0.415E-02	*0.379E-02	*0.323E-02
C= 0.17D+16	20000.	0.139E-01	0.378E-02	*0.551E-02	*0.481E-02	*0.415E-02	*0.384E-02
	30000.	0.131E-01	0.329E-02	*0.625E-02	*0.532E-02	*0.475E-02	*0.412E-02
	50000.	0.122E-01	0.278E-02	0.692E-02	0.618E-02	*0.543E-02	*0.414E-02
CA II 4S-4P	5000.	0.296E-02	-0.526E-03	0.108E-03	-0.372E-04	0.150E-03	-0.355E-04
3946.3 A	10000.	0.228E-02	-0.425E-03	0.174E-03	-0.633E-04	0.214E-03	-0.564E-04
C= 0.18E+19	20000.	0.188E-02	-0.327E-03	0.238E-03	-0.901E-04	0.255E-03	-0.776E-04
	30000.	0.177E-02	-0.278E-03	0.259E-03	-0.106E-03	0.275E-03	-0.871E-04
	50000.	0.171E-02	-0.257E-03	0.287E-03	-0.122E-03	0.301E-03	-0.999E-04

continued opposite

Table 1—*continued*

PERTURBER DENSITY = 0.1D+16(cm-3)							
PERTURBERS ARE		ELECTRONS		PROTONS		IONIZED HELIUM	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
CA II 4S-5P	5000.	0.191E-02	-0.175E-03	0.157E-03	-0.582E-04	0.181E-03	-0.504E-04
1650.6 A	10000.	0.151E-02	-0.157E-03	0.195E-03	-0.810E-04	0.207E-03	-0.671E-04
C= 0.10D+18	20000.	0.129E-02	-0.166E-03	0.225E-03	-0.975E-04	0.232E-03	-0.809E-04
	30000.	0.122E-02	-0.144E-03	0.241E-03	-0.108E-03	0.242E-03	-0.900E-04
	50000.	0.118E-02	-0.129E-03	0.255E-03	-0.122E-03	0.253E-03	-0.985E-04
CA II 4S-6P	5000.	0.283E-02	-0.899E-03	0.377E-03	-0.186E-03	0.395E-03	-0.151E-03
1342.1 A	10000.	0.244E-02	-0.644E-03	0.439E-03	-0.227E-03	0.449E-03	-0.186E-03
C= 0.32D+17	20000.	0.226E-02	-0.541E-03	0.494E-03	-0.271E-03	0.486E-03	-0.220E-03
	30000.	0.222E-02	-0.458E-03	0.510E-03	-0.293E-03	0.502E-03	-0.244E-03
	50000.	0.225E-02	-0.398E-03	0.543E-03	-0.322E-03	0.501E-03	-0.251E-03
CA II 4S-7P	5000.	0.505E-02	-0.218E-02	0.833E-03	-0.457E-03	0.841E-03	-0.373E-03
1226.8 A	10000.	0.451E-02	-0.184E-02	0.950E-03	-0.556E-03	0.937E-03	-0.462E-03
C= 0.15D+17	20000.	0.432E-02	-0.142E-02	0.104E-02	-0.648E-03	0.979E-03	-0.522E-03
	30000.	0.440E-02	-0.119E-02	0.112E-02	-0.715E-03	0.998E-03	-0.566E-03
	50000.	0.452E-02	-0.101E-02	0.112E-02	-0.737E-03	0.106E-02	-0.610E-03
CA II 4P-5S	5000.	0.935E-02	0.385E-02	0.216E-03	0.294E-03	0.222E-03	0.255E-03
3727.6 A	10000.	0.671E-02	0.308E-02	0.364E-03	0.410E-03	0.356E-03	0.340E-03
C= 0.12D+19	20000.	0.510E-02	0.246E-02	0.506E-03	0.493E-03	0.456E-03	0.410E-03
	30000.	0.456E-02	0.229E-02	0.585E-03	0.549E-03	0.511E-03	0.455E-03
	50000.	0.421E-02	0.194E-02	0.700E-03	0.620E-03	0.600E-03	0.502E-03
CA II 4P-4D	5000.	0.605E-02	0.275E-02	0.237E-03	0.228E-03	0.273E-03	0.198E-03
3173.5 A	10000.	0.457E-02	0.208E-02	0.370E-03	0.317E-03	0.363E-03	0.260E-03
C= 0.38D+18	20000.	0.368E-02	0.161E-02	0.468E-03	0.383E-03	0.440E-03	0.313E-03
	30000.	0.343E-02	0.143E-02	0.526E-03	0.422E-03	0.490E-03	0.348E-03
	50000.	0.320E-02	0.121E-02	0.594E-03	0.474E-03	0.539E-03	0.390E-03
CA II 4P-5D	5000.	0.588E-02	0.333E-02	0.581E-03	0.417E-03	0.581E-03	0.340E-03
2110.3 A	10000.	0.485E-02	0.272E-02	0.707E-03	0.508E-03	0.678E-03	0.416E-03
C= 0.79D+17	20000.	0.438E-02	0.220E-02	0.833E-03	0.609E-03	0.793E-03	0.503E-03
	30000.	0.423E-02	0.194E-02	0.920E-03	0.665E-03	0.821E-03	0.538E-03
	50000.	0.418E-02	0.164E-02	0.102E-02	0.743E-03	0.935E-03	0.599E-03
CA II 4D-5P	5000.	0.645	-0.251	0.362E-01	-0.263E-01	0.407E-01	-0.229E-01
26778.0 A	10000.	0.504	-0.191	0.484E-01	-0.349E-01	0.485E-01	-0.288E-01
C= 0.27D+20	20000.	0.441	-0.154	0.586E-01	-0.418E-01	0.566E-01	-0.344E-01
	30000.	0.422	-0.132	0.656E-01	-0.467E-01	0.600E-01	-0.376E-01
	50000.	0.411	-0.111	0.709E-01	-0.515E-01	0.650E-01	-0.422E-01
CA II 4D-6P	5000.	0.551E-01	-0.217E-01	0.625E-02	-0.362E-02	0.645E-02	-0.294E-02
5662.9 A	10000.	0.471E-01	-0.174E-01	0.736E-02	-0.440E-02	0.732E-02	-0.360E-02
C= 0.57D+18	20000.	0.437E-01	-0.138E-01	0.857E-02	-0.529E-02	0.819E-02	-0.426E-02
	30000.	0.433E-01	-0.119E-01	0.912E-02	-0.585E-02	0.850E-02	-0.458E-02
	50000.	0.440E-01	-0.101E-01	0.946E-02	-0.626E-02	0.871E-02	-0.502E-02

continued overleaf

Table 1—*continued*

PERTURBER DENSITY = 0.1D+16(cm-3)							
PERTURBERS ARE		ELECTRONS		PROTONS		IONIZED HELIUM	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
CA II 4D-7P	5000.	0.572E-01	-0.251E-01	0.882E-02	-0.508E-02	0.886E-02	-0.414E-02
4055.2 A	10000.	0.513E-01	-0.217E-01	0.102E-01	-0.620E-02	0.994E-02	-0.517E-02
C= 0.16D+18	20000.	0.489E-01	-0.169E-01	0.111E-01	-0.720E-02	0.104E-01	-0.580E-02
	30000.	0.498E-01	-0.145E-01	0.120E-01	-0.791E-02	0.105E-01	-0.631E-02
	50000.	0.514E-01	-0.124E-01	0.122E-01	-0.833E-02	0.113E-01	-0.685E-02
CA II 4D-4F	5000.	0.407E-01	-0.134E-02	0.164E-02	-0.576E-03	0.203E-02	-0.532E-03
8923.7 A	10000.	0.350E-01	-0.122E-02	0.233E-02	-0.859E-03	0.257E-02	-0.754E-03
C= 0.30D+19	20000.	0.334E-01	-0.116E-02	0.278E-02	-0.116E-02	0.293E-02	-0.948E-03
	30000.	0.339E-01	-0.131E-02	0.301E-02	-0.129E-02	0.313E-02	-0.106E-02
	50000.	0.352E-01	-0.127E-02	0.330E-02	-0.146E-02	0.331E-02	-0.121E-02
CA II 4D-5F	5000.	0.744E-01	0.158E-01	0.131E-01	0.124E-01	0.111E-01	0.102E-01
4720.6 A	10000.	0.640E-01	0.135E-01	0.165E-01	0.152E-01	0.143E-01	0.120E-01
C= 0.29D+17	20000.	0.566E-01	0.110E-01	0.190E-01	0.175E-01	0.154E-01	0.140E-01
	30000.	0.534E-01	0.958E-02	0.217E-01	0.195E-01	0.171E-01	0.151E-01
	50000.	0.500E-01	0.784E-02	0.219E-01	0.205E-01	0.209E-01	0.159E-01
CA II 4D-6F	5000.	0.118	0.362E-01	*0.279E-01	*0.239E-01	*0.235E-01	*0.194E-01
3758.4 A	10000.	0.107	0.314E-01	*0.319E-01	*0.284E-01	*0.260E-01	*0.222E-01
C= 0.12D+17	20000.	0.969E-01	0.241E-01	*0.376E-01	*0.330E-01	*0.285E-01	*0.263E-01
	30000.	0.916E-01	0.208E-01	*0.428E-01	*0.366E-01	*0.325E-01	*0.284E-01
	50000.	0.855E-01	0.175E-01	0.473E-01	0.425E-01	*0.373E-01	*0.285E-01
CA II 5S-5P	5000.	0.141	-0.544E-01	0.871E-02	-0.499E-02	0.978E-02	-0.435E-02
11878.9 A	10000.	0.107	-0.426E-01	0.111E-01	-0.665E-02	0.113E-01	-0.547E-02
C= 0.53D+19	20000.	0.903E-01	-0.339E-01	0.131E-01	-0.803E-02	0.130E-01	-0.661E-02
	30000.	0.857E-01	-0.296E-01	0.144E-01	-0.892E-02	0.136E-01	-0.716E-02
	50000.	0.834E-01	-0.250E-01	0.152E-01	-0.984E-02	0.144E-01	-0.800E-02
CA II 5S-6P	5000.	0.349E-01	-0.139E-01	0.425E-02	-0.224E-02	0.444E-02	-0.182E-02
4475.8 A	10000.	0.297E-01	-0.115E-01	0.496E-02	-0.273E-02	0.500E-02	-0.224E-02
C= 0.36D+18	20000.	0.274E-01	-0.904E-02	0.573E-02	-0.329E-02	0.551E-02	-0.264E-02
	30000.	0.272E-01	-0.793E-02	0.607E-02	-0.361E-02	0.569E-02	-0.285E-02
	50000.	0.277E-01	-0.675E-02	0.624E-02	-0.391E-02	0.581E-02	-0.309E-02
CA II 5S-7P	5000.	0.405E-01	-0.176E-01	0.645E-02	-0.358E-02	0.654E-02	-0.292E-02
3407.9 A	10000.	0.362E-01	-0.151E-01	0.743E-02	-0.437E-02	0.726E-02	-0.365E-02
C= 0.11D+18	20000.	0.345E-01	-0.121E-01	0.807E-02	-0.508E-02	0.762E-02	-0.408E-02
	30000.	0.352E-01	-0.104E-01	0.866E-02	-0.559E-02	0.769E-02	-0.444E-02
	50000.	0.364E-01	-0.884E-02	0.877E-02	-0.587E-02	0.817E-02	-0.483E-02
CA II 5P-5D	5000.	0.110	0.508E-01	0.848E-02	0.697E-02	0.822E-02	0.565E-02
8235.7 A	10000.	0.897E-01	0.439E-01	0.105E-01	0.848E-02	0.996E-02	0.698E-02
C= 0.12D+19	20000.	0.813E-01	0.377E-01	0.127E-01	0.101E-01	0.115E-01	0.819E-02
	30000.	0.787E-01	0.330E-01	0.140E-01	0.110E-01	0.127E-01	0.914E-02
	50000.	0.779E-01	0.278E-01	0.154E-01	0.120E-01	0.132E-01	0.936E-02

continued opposite

Table 1—*continued*

PERTURBER DENSITY = 0.1D+16(cm-3)							
PERTURBERS ARE		ELECTRONS		PROTONS		IONIZED HELIUM	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
CA II 5D-6P	5000.	7.36	-3.46	0.654	-0.498	0.640	-0.412
56116.1 A	10000.	6.31	-2.85	0.808	-0.617	0.750	-0.503
C= 0.56D+20	20000.	5.89	-2.40	0.955	-0.718	0.885	-0.593
	30000.	5.77	-2.15	1.02	-0.799	0.894	-0.627
	50000.	5.87	-1.81	1.14	-0.822	1.02	-0.709
CA II 5D-7P	5000.	0.506	-0.244	0.671E-01	-0.443E-01	0.664E-01	-0.362E-01
11385.3 A	10000.	0.457	-0.208	0.794E-01	-0.541E-01	0.737E-01	-0.437E-01
C= 0.13D+19	20000.	0.442	-0.176	0.906E-01	-0.633E-01	0.804E-01	-0.507E-01
	30000.	0.449	-0.153	0.974E-01	-0.691E-01	0.895E-01	-0.574E-01
	50000.	0.465	-0.130	0.102	-0.749E-01	0.859E-01	-0.592E-01
CA II 5D-5F	5000.	1.30	0.735E-01	0.198	0.191	0.163	0.154
18843.3 A	10000.	1.12	0.809E-01	0.248	0.229	0.213	0.189
C= 0.46D+18	20000.	1.02	0.646E-01	0.287	0.265	0.232	0.208
	30000.	0.983	0.552E-01	0.315	0.300	0.264	0.234
	50000.	0.942	0.436E-01	0.341	0.313	0.314	0.249
CA II 5D-6F	5000.	0.748	0.186	*0.167	*0.146	*0.141	*0.118
9319.1 A	10000.	0.679	0.158	*0.196	*0.173	*0.160	*0.134
C= 0.71D+17	20000.	0.622	0.121	*0.230	*0.202	*0.174	*0.160
	30000.	0.593	0.105	*0.261	*0.225	*0.192	*0.172
	50000.	0.559	0.863E-01	0.282	0.258	*0.227	*0.175

obtained decreases when broadening by ion interactions becomes important. At high densities, the results are no longer linear with density due to Debye screening. This effect is more important for the shift than for the width. Stark-broadening parameter tables for high densities will be published elsewhere.[26]

Since the carrier gas was argon in most experiments and since the impact approximation may often be used for $3d$-$4p$ and $4s$-$4p$ Ca II multiplets with Ar^+-impact broadening of the Ca II

Table 2. As in Table 1 but for Ar^+-impact-broadening parameters for Ca II lines at an Ar^+ density of 10^{17} cm^{-3}.

PERTURBER DENSITY = 0.1D+18(cm-3)
PERTURBER IS IONIZED ARGON

TRANSITION	T(K)	WIDTH(A)	SHIFT(A)
CA II 3D-4P	5000.	0.744E-01	-0.586E-02
8581.1 A	10000.	0.971E-01	-0.103E-01
C= 0.86E+21	20000.	0.111	-0.151E-01
	30000.	0.119	-0.170E-01
	50000.	0.125	-0.199E-01
CA II 4S-4P	5000.	0.190E-01	-0.263E-02
3946.3 A	10000.	0.241E-01	-0.425E-02
C= 0.18E+21	20000.	0.277E-01	-0.593E-02
	30000.	0.295E-01	-0.666E-02
	50000.	0.311E-01	-0.780E-02

Table 3. Comparison between the experimental Stark full half-halfwidths of Ca II lines (Wm) with different calculations. Semi-classical calculations: WDSB—present results; WJBG—Jones, Benett, and Griem (1971);[18,19] WHC—Hildum and Cooper (1971);[13] quantum-mechanical calculations: WQ—Barnes (1971)[16] and Barnes and Peach (1970);[17] N = electron density.

Transition	λ(A)	T(K)	N/10+17(cm-3)	Wm(A)	Wm/WDSB	Wm/WJBG	Wm/WHC	Wm/WQM	Ref.
3d-4p	8542.09	13000	1.08	0.95	0.91	0.64		1.10	4
	8662.14	13000	1.08	0.95	0.91	0.64		1.10	4
4s-4p	3933.66	11400	0.40	0.039	0.45	0.33	0.41	0.42	6
		11600	0.64	0.079	0.57	0.43	0.52	0.54	6
		12240	0.80	0.0914	0.53	0.41	0.49	0.51	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.180	0.65	0.50	0.60	0.63	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.0	5.15	3.95	4.81	5.05	9
		19000	1.00	0.172	0.91	0.69	0.51	0.45	10
		25100	1.00	0.22	1.22	0.92	1.15	1.25	11
		28000	1.00	0.25	1.40	1.07	1.32	1.44	8
		29200	1.00	0.18	1.01	0.78	0.95	1.05	11
		30000	2.35	0.24	0.58	0.47	0.53	0.63	9
	3968.47	7450	1.00	0.210	0.82	0.67	----	----	5
		12240	0.80	0.0846	0.49	0.38	0.46	0.47	7
		13000	1.08	0.235	1.04	0.78	0.95	0.99	4
		13350	1.32	0.161	0.59	0.44	0.54	0.56	7
		16000	1.00	0.16	0.81	0.62	0.75	0.78	8
		17500	10.0	10.3	5.31	4.07	4.95	5.20	9
		18560	1.00	0.188	0.98	0.75	0.93	1.04	13
		25100	1.00	0.20	1.11	0.84	1.04	1.14	11
		28000	1.00	0.25	1.40	1.07	1.32	44	8
4p-5s	3736.20	7500	10.0	18.2	2.37	2.98			9
		10000	1.00	0.69	1.03	1.00			14
		13000	1.12	0.79	1.21	0.94			4
		25100	1.00	0.30	0.63	0.53			11
	3706.03	10000	1.00	0.70	1.04	1.01			14
		13000	1.12	0.79	1.21	0.94			4
		17500	10.0	13.7	2.68	2.24			9
4p-4d	3179.33	13000	1.13	0.66	1.40	1.03			4
	3158.87	13000	1.13	0.66	1.40	1.03			4
		25100	1.00	0.32	0.90	0.74			11
		29200	1.00	0.30	0.87	0.71			11
	3181.28	13000	1.13	0.66	1.40	1.03			4

Table 4. As in Table 3 but for the shift (d).

Transition	λ(A)	T(K)	N/10+17(cm-3)	dm(A)	dm/dDSB	dm/dJBG	dm/dQM	Ref.
4s-4p	3933.66	11400	0.40	-0.0046	0.30	0.09	0.11	6
		11600	0.64	-0.0155	0.64	0.19	0.24	6
		13000	1.08	-0.048	1.18	0.38	0.45	4
		14200	1.00	-0.09	2.49	0.71	0.94	15
		16000	1.00	-0.01	0.29	0.09	0.11	8
		25100	1.00	-0.06	2.11	0.60	0.72	11
		28000	1.00	-0.04	1.40	0.35	0.48	8
		29200	1.00	-0.05	1.79	0.52	0.60	11
	3968.47	13000	1.08	-0.048	1.18	0.38	0.45	4
		14200	1.00	-0.09	2.49	0.71	0.94	15
		16000	1.00	-0.01	0.29	0.09	0.11	8
		25100	1.00	-0.06	2.11	0.60	0.72	11
		28000	1.00	-0.04	1.40	0.35	0.48	8
		29200	1.00	-0.06	2.15	0.62	0.72	11
4p-5s	3736.20	7500	10.0	4.16	1.33	1.13		9
		10000	1.00	0.186	0.61	0.51		14
		13000	1.12	0.390	1.22	1.03		4
		14200	1.00	0.18	0.64	0.53		15
		25100	1.00	0.16	0.66	0.53		11
	3706.03	10000	1.00	0.238	0.79	0.65		14
		13000	1.12	0.390	1.22	1.03		4
		14200	1.00	0.17	0.60	0.50		15
		17500	10.0	3.3	1.30	1.03		9
		25100	1.00	0.17	0.71	0.57		11
4p-4d	3179.33	13000	1.13	0.295	1.40	1.05		4
	3158.87	13000	1.13	0.295	1.40	1.05		4
		14200	1.00	0.18	1.00	0.73		15
		25100	1.00	0.15	1.00	0.70		11
		29200	1.00	0.15	1.05	0.72		11
	3181.28	13000	1.13	0.295	1.40	1.05		4

multiplets (see Refs. 1,2 and the discussion in Ref. 27), the corresponding Stark-broadening parameters are provided in Table 2. In Tables 3 and 4, the present results are compared with experimental data[4–15] and with other semiclassical[13,18,19] and quantum mechanical strong coupling calculations.[16,17] For the Ca II 4*s*-4*p* and 4*p*-5*s* multiplets, semiempirical calculations also exist.[28] We see that the widths fall within the error bars of both methods. However, for the shifts, larger disagreements exist. It should be noted that the shifts are of lesser accuracy for semiclassical calculations than are the widths.[29–31] Additional reliable experimental data for the shifts would be very helpful from the theoretical point of view. This is also the case for the 4*s*-4*p* Ca II widths, for which new experimental data, especially at lower temperatures, will be of great interest.

Acknowledgements—One of us (M.D.) has been supported by the Observatory of Paris-Meudon. This work has also been supported by the French C.N.R.S. and is a part of French–Yugoslav collaboration through the project "L'élargissement Stark des raies spéctrales des plasmas astrophysiques et de laboratoire". It is also a part of the project "Physics and Dynamics of Celestial Bodies" supported by RFN of Serbia.

REFERENCES

1. S. Sahal-Bréchot, *Astron. Astrophys.* **1,** 91 (1969).
2. S. Sahal-Bréchot, *Astron. Astrophys.* **2,** 322 (1969).
3. M. S. Dimitrijević, S. Sahal-Bréchot, and V. Bommier, *Astron. Astrophys. Suppl. Series* **89,** 581 (1991).
4. C. Fleurier, S. Sahal-Bréchot, and J. Chapelle, *JQSRT* **17,** 595 (1977).
5. J. F. Baur and J. Cooper, *JQSRT* **17,** 311 (1977).
6. M. Yamamoto, *Phys. Rev.* **146,** 137 (1966).
7. C. Goldbach, G. Nollez, P. Plomdeur, and J. P. Zimmermann, *Phys. Rev.* **28,** 234 (1983).
8. D. E. Roberts and A. J. Barnard, *JQSRT* **12,** 1205 (1972).
9. H. J. Kusch and H. P. Pritschow, *Astron. Astrophys.* **4,** 31 (1970).
10. W. W. Jones, A. Sanchez, J. R. Grieg, and H. R. Griem, *Phys. Rev. A* **5,** 2318 (1972).
11. D. Hadžiomerspahić, M. Platiša, N. Konjević, and M. Popović, *Z. Phys.* **262,** 169 (1973).
12. J. R. Roberts and K. L. Eckerle, *Phys. Rev.* **159,** 104 (1967).
13. J. S. Hildum and J. Cooper, *Phys. Lett. A* **36,** 153 (1971).
14. R. Hühn and H. J. Kusch, *Astron. Astrophys.* **28,** 159 (1973).
15. J. Purić and N. Konjević, *Z. Phys.* **249,** 440 (1972).
16. K. S. Barnes, *J. Phys. B* **4,** 1377 (1971).
17. K. S. Barnes and G. Peach, *J. Phys. B* **3,** 350 (1970).
18. W. W. Jones, S. M. Benett, and H. R. Griem, "Calculated Stark Broadenining Parameters for Isolated Spectral Lines from the Atom Helium through Calcium and Cesium", Univ. Maryland, Tech. Rep. No 71-097, College Park, MD (1971).
19. H. R. Griem, *Spectral Line Broadening by Plasmas*, Academic Press, New York, NY (1974).
20. S. Bashkin and J. J. Stoner Jr., *Atomic Energy Levels and Grotrian Diagrams*, Vol. 1, North Holland, Amsterdam (1975).
21. D. R. Bates and A. Damgaard, *Trans. R. Soc. London, Ser. A* **242,** 101 (1949).
22. G. K. Oertel and L. P. Shomo, *Astrophys. J. Suppl. Series,* **16,** 175 (1968).
23. H. Van Regemorter, Hoang Binh Dy, and M. Prud'homme, *J. Phys. B* **12,** 1073 (1979).
24. M. S. Dimitrijević and S. Sahal-Bréchot, *JQSRT* **31,** 301 (1984).
25. S. Sahal-Bréchot, *Astron. Astrophys.* **245,** 322 (1991).
26. M. S. Dimitrijević and S. Sahal-Bréchot, *Bull. Obs. Astron. Belgrade* **145,** 83 (1992).
27. A. Mazure and G. Nollez, *Z. Naturf.* **339,** 15 (1978).
28. M. S. Dimitrijević and N. Konjević, *Astron. Astrophys.* **102,** 93 (1981).
29. H. R. Griem and C. S. Shen, *Phys. Rev.* **125,** 196 (1962).
30. D. E. Roberts, *J. Phys. B* **1,** 53 (1968).
31. M. S. Dimitrijević, N. Feautrier, and S. Sahal-Bréchot, *J. Phys. B* **14,** 2559 (1981).