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STARK BROADENING OF NEUTRAL GALLIUM SPECTRAL LINES IN ASTROPHYSICAL PLASMA

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Abstract. Stark broadening of the eighteen transitions of neutral gallium has been analyzed within the frame of the semiclassical perturbation method. Results for electron-, and proton-impact widths and shifts are presented for temperatures from 2500 K up to 50000 K.

1. INTRODUCTION

The interest for atomic and spectroscopic data, increased considerably in astrophysics with space born spectroscopy development, since the number of stellar spectra obtained with resolution enabling the indentification and analysis in detail of a large number of spectral lines, increases as well. Consequently, Stark broadening of neutral gallium spectral lines is of interest not only for laboratory but also for astrophysical plasma research as e.g. for gallium abundance determination and opacity calculations (Seaton 1988).

Stark broadening parameters of gallium lines are also of interest for the consideration of regularities and systematic trends, and the corresponding results may be of interest in astrophysics for interpolation of new data and critical evaluation of existing ones.

The first investigations of the influence of the Stark broadening mechanism on gallium lines have been performed by Kondrat'eva and Fomichenko (1970) in a spark discharge and by Venkatesan et al. (1981). Lakićević (1983) estimated on the basis of regularities and systematic trends Stark width and shift of the Ga I $4p^2\mathrm{P}^o - 5s^2\mathrm{S}$ transition and N'Dollo and Fabry (1987) calculated within the semiclassical method and experimentally determined Ga I Stark widths. Here, we will calculate within the semiclassical perturbation approach, Stark broadening parameters of 18 Ga I transitions, for conditions typical of astrophysical and laboratory plasmas.

Table 1: Electron− and proton−impact broadening parameters for Ga I spectral lines, for perturber density of 10^{14}cm^{-3} and temperatures from 2500 up to 50,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given. By dividing C by the corresponding full width at half maximum (Dimitrijević et al. 1991), we obtain an estimate of the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+14cm-3					
PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
$4p^2$P^o − $5s^2$S	2500.	0.173E-03	0.142E-03	0.438E-04	0.400E-04
	5000.	0.204E-03	0.166E-03	0.488E-04	0.450E-04
4125.8 A	10000.	0.236E-03	0.196E-03	0.546E-04	0.506E-04
C = 0.14E+18	20000.	0.257E-03	0.223E-03	0.610E-04	0.569E-04
	30000.	0.268E-03	0.209E-03	0.652E-04	0.608E-04
	50000.	0.287E-03	0.204E-03	0.708E-04	0.662E-04
$4p^2$P^o − $4d^2$D	2500.	0.311E-03	-0.181E-03	0.757E-04	-0.452E-04
	5000.	0.311E-03	-0.176E-03	0.793E-04	-0.509E-04
2921.0 A	10000.	0.315E-03	-0.163E-03	0.838E-04	-0.572E-04
C = 0.14E+17	20000.	0.330E-03	-0.129E-03	0.894E-04	-0.644E-04
	30000.	0.339E-03	-0.117E-03	0.933E-04	-0.689E-04
	50000.	0.341E-03	-0.988E-04	0.990E-04	-0.751E-04
$4p^2$P^o − $5d^2$D	2500.	0.124E-02	-0.762E-03	0.297E-03	-0.221E-03
	5000.	0.128E-02	-0.678E-03	0.322E-03	-0.251E-03
2484.0 A	10000.	0.135E-02	-0.496E-03	0.351E-03	-0.285E-03
C = 0.25E+16	20000.	0.140E-02	-0.375E-03	0.386E-03	-0.321E-03
	30000.	0.138E-02	-0.303E-03	0.410E-03	-0.343E-03
	50000.	0.135E-02	-0.219E-03	0.445E-03	-0.375E-03
$5s^2$S−$5p^2$P^o	2500.	0.504E-02	0.368E-02	0.170E-02	0.954E-03
	5000.	0.581E-02	0.339E-02	0.177E-02	0.107E-02
12005.6 A	10000.	0.696E-02	0.268E-02	0.186E-02	0.121E-02
C = 0.24E+18	20000.	0.889E-02	0.155E-02	0.197E-02	0.136E-02
	30000.	0.100E-01	0.105E-02	0.205E-02	0.146E-02
	50000.	0.112E-01	0.508E-03	0.216E-02	0.159E-02
$5s^2$S$_{1/2}$ − $6p^2$P$^o_{1/2}$	2500.	0.110E-01	0.808E-02	0.273E-02	0.210E-02
	5000.	0.119E-01	0.818E-02	0.297E-02	0.239E-02
6415.2 A	10000.	0.126E-01	0.732E-02	0.326E-02	0.271E-02
C = 0.18E+17	20000.	0.136E-01	0.555E-02	0.359E-02	0.305E-02
	30000.	0.141E-01	0.464E-02	0.382E-02	0.327E-02
	50000.	0.144E-01	0.363E-02	0.414E-02	0.357E-02
$5s^2$S$_{1/2}$ − $6p^2$P$^o_{3/2}$	2500.	0.117E-01	0.855E-02	0.286E-02	0.223E-02
	5000.	0.125E-01	0.854E-02	0.313E-02	0.254E-02
6398.3 A	10000.	0.133E-01	0.754E-02	0.344E-02	0.289E-02
C = 0.16E+17	20000.	0.142E-01	0.573E-02	0.380E-02	0.326E-02
	30000.	0.146E-01	0.476E-02	0.404E-02	0.349E-02
	50000.	0.148E-01	0.369E-02	0.439E-02	0.381E-02

Table 1: (continued)

PERTURBER DENSITY = 1.E+14cm-3					
PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
$5s^2S_{1/2} - 7p^2P^o_{1/2}$	2500.	0.311E-01	0.216E-01	0.732E-02	0.591E-02
	5000.	0.324E-01	0.198E-01	0.811E-02	0.684E-02
5361.3 A	10000.	0.338E-01	0.163E-01	0.903E-02	0.783E-02
C = 0.40E+16	20000.	0.344E-01	0.124E-01	0.101E-01	0.890E-02
	30000.	0.341E-01	0.994E-02	0.109E-01	0.957E-02
	50000.	0.333E-01	0.694E-02	0.119E-01	0.105E-01
$5s^2S_{1/2} - 7p^2P^o_{3/2}$	2500.	0.375E-01	0.248E-01	0.898E-02	0.735E-02
	5000.	0.390E-01	0.216E-01	0.100E-01	0.855E-02
5349.6 A	10000.	0.399E-01	0.175E-01	0.112E-01	0.981E-02
C = 0.28E+16	20000.	0.391E-01	0.129E-01	0.126E-01	0.112E-01
	30000.	0.382E-01	0.102E-01	0.136E-01	0.120E-01
	50000.	0.368E-01	0.693E-02	0.151E-01	0.132E-01
$5p^2P^o - 5d^2D$	2500.	0.419E-01	-0.259E-01	0.914E-02	-0.688E-02
	5000.	0.450E-01	-0.263E-01	0.992E-02	-0.782E-02
13004.3 A	10000.	0.479E-01	-0.241E-01	0.108E-01	-0.886E-02
C = 0.68E+17	20000.	0.500E-01	-0.202E-01	0.119E-01	-0.999E-02
	30000.	0.507E-01	-0.175E-01	0.127E-01	-0.107E-01
	50000.	0.509E-01	-0.143E-01	0.138E-01	-0.117E-01
$4d^2D-5p^2P^o$	2500.	0.253	0.147	0.608E-01	0.389E-01
	5000.	0.284	0.168	0.642E-01	0.440E-01
59974.3 A	10000.	0.308	0.175	0.685E-01	0.496E-01
C = 0.60E+19	20000.	0.327	0.161	0.736E-01	0.558E-01
	30000.	0.338	0.144	0.772E-01	0.597E-01
	50000.	0.351	0.122	0.823E-01	0.651E-01
$4d^2D-6p^2P^o_{1/2}$	2500.	0.946E-01	0.649E-01	0.220E-01	0.168E-01
	5000.	0.103	0.681E-01	0.239E-01	0.192E-01
17885.8 A	10000.	0.110	0.639E-01	0.262E-01	0.217E-01
C = 0.14E+18	20000.	0.115	0.542E-01	0.289E-01	0.245E-01
	30000.	0.117	0.467E-01	0.307E-01	0.263E-01
	50000.	0.118	0.365E-01	0.333E-01	0.287E-01
$4d^2D-6p^2P^o_{3/2}$	2500.	0.990E-01	0.678E-01	0.228E-01	0.177E-01
	5000.	0.107	0.701E-01	0.249E-01	0.202E-01
17754.4 A	10000.	0.114	0.647E-01	0.273E-01	0.229E-01
C = 0.12E+18	20000.	0.119	0.544E-01	0.302E-01	0.258E-01
	30000.	0.120	0.465E-01	0.321E-01	0.277E-01
	50000.	0.121	0.360E-01	0.349E-01	0.302E-01
$4d^2D-7p^2P^o_{1/2}$	2500.	0.148	0.100	0.342E-01	0.275E-01
	5000.	0.154	0.908E-01	0.378E-01	0.319E-01
11553.5 A	10000.	0.161	0.733E-01	0.421E-01	0.365E-01
C = 0.18E+17	20000.	0.163	0.506E-01	0.472E-01	0.415E-01
	30000.	0.162	0.364E-01	0.507E-01	0.446E-01
	50000.	0.157	0.268E-01	0.557E-01	0.488E-01

Table 1: (continued)

PERTURBER DENSITY = 1.E+14cm-3					
PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
$4d^2$D$-7p^2$P$^o_{3/2}$	2500.	0.177	0.114	0.416E-01	0.341E-01
	5000.	0.184	0.970E-01	0.464E-01	0.396E-01
11499.2 A	10000.	0.188	0.766E-01	0.519E-01	0.454E-01
C = 0.13E+17	20000.	0.184	0.511E-01	0.586E-01	0.517E-01
	30000.	0.180	0.344E-01	0.632E-01	0.556E-01
	50000.	0.173	0.257E-01	0.701E-01	0.610E-01
$5d^2$D$-6p^2$P$^o_{1/2}$	2500.	24.0	14.7	4.83	3.68
	5000.	26.0	14.6	5.26	4.20
231830.3 A	10000.	27.3	13.2	5.77	4.77
C = 0.22E+20	20000.	28.7	10.0	6.38	5.39
	30000.	29.3	8.31	6.79	5.78
	50000.	29.3	6.75	7.38	6.31
$5d^2$D$-6p^2$P$^o_{3/2}$	2500.	30.6	18.8	6.12	4.70
	5000.	33.0	18.5	6.68	5.37
256416.8 A	10000.	34.6	16.5	7.33	6.10
C = 0.26E+20	20000.	36.2	12.5	8.11	6.90
	30000.	36.8	10.3	8.64	7.40
	50000.	36.7	8.25	9.42	8.07
$5d^2$D$-7p^2$P$^o_{1/2}$	2500.	1.81	1.15	0.385	0.309
	5000.	1.91	1.08	0.427	0.358
37979.6 A	10000.	1.99	0.890	0.475	0.410
C = 0.20E+18	20000.	2.02	0.624	0.532	0.466
	30000.	2.00	0.491	0.571	0.501
	50000.	1.95	0.336	0.628	0.548
$5d^2$D$-7p^2$P$^o_{3/2}$	2500.	2.08	1.30	0.454	0.370
0.0	5000.	2.18	1.14	0.506	0.430
37398.7 A	10000.	2.23	0.917	0.566	0.494
C = 0.14E+18	20000.	2.19	0.620	0.639	0.562
	30000.	2.15	0.486	0.689	0.605
	50000.	2.07	0.310	0.764	0.663

2. RESULTS AND DISCUSSION

For the determination of Stark broadening parameters (the full line width at half maximum - W and the line shift -d) of neutral gallium, the semiclassical perturbation formalism has been used (Sahal−Bréchot, 1969ab). The theory and computer code have been updated and optimized several times and the discussion of updatings and validity criteria, has been briefly reviewed e.g. in Dimitrijević (1996). All details of the determination of Stark broadening parameters will be published elsewhere (Dimitrijević et al, 2003) so that we note here only that the atomic energy levels needed for calculations have been taken from Moore (1971).

Results for electron-, and proton-impact broadening parameters for 18 Ga I transitions for perturber density of 10^{14}cm^{-3} and temperatures from 2,500 K up to 50,000 K are shown in Table 1. The comparison of our results with existing experimental and theoretical data will be presented and discussed in Dimitrijević et al. (2003).

The new experimental determinations of Stark broadening parameters will be of interest for the comparison with our and other existing experimental and theoretical data and will be equally useful for research and modelling of astrophysical plasmas.

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