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STARK BROADENING OF IONIZED NICKEL LINES

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Abstract. Stark widths and shifts for two spectral lines within the a^4F - z^4G^o multiplet have been calculated using semiclassical - perturbation approach. Obtained results have been compared with experimental data and simpler estimates.

1. INTRODUCTION

As a member of the iron-group elements, the nickel spectrum is of interest for astrophysics as well as for laboratory plasma research. Spectral lines of Ni II are often observed in stellar spectra. For example, such lines have been found in the spectra of Gamma Geminorum and 7 Sextantis (Adelman and Philip, 1992), stars of A0 V type, where the main pressure broadening mechanism is the Stark effect. Consequently, the corresponding Stark broadening parameters are needed for various astrophysical problems as *e.g.* abundance determination or modelling of stellar spectra.

The first experimental determination of Ni II Stark widths and shifts has been performed recently (Djeniže *et al.* 1994). and a surprisingly large discrepancy between experimental and theoretical values has been reported. Since the sufficiently complete set of atomic data for the considered Ni II lines exists, it is of interest to performe more sophysticated theoretical analysis within the frame of the semiclassical approach.

By using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969ab), we have calculated Stark broadening parameters for two lines within Ni II a^4F - z^4G^o multiplet. Perturbers are electrons, protons and a singly charged perturber with the mass equal to 35 a.u. corresponding to the averaged mass of perturbing ions in Solar atmosphera. A summary of the formalism is given in Dimitrijević *et al.* (1991).

2. RESULTS AND DISCUSSION

Energy levels for Ni II lines have been taken from Corlis and Sugar (1981). In order to test the applicability of the Coulomb approximation for the considered case, we compared presently calculated oscillator strengths with the experimental values of Bell *et al.* (1960). For Ni II a^4F - z^4G^o, 2270.21Å and 2264.46Å lines Bell *et al.* (1960) obtained oscillator strengths equal to 0.24, while present result within the Coulomb approximation (Bates and Damgaard, 1949) is 0.32, indicating that the Coulomb approximation is applicable for the considered transitions.

Table 1 This table shows Stark broadening full half-widths (FWHM) and shifts in Å for Ni II for a perturber density of 10^{17} cm^{-3} and temperatures from 5,000 up to 150,000 K. Perturbers are electrons, protons and singly charged perturbers with the mass equal to 35 a.u. corresponding to the averaged mass of perturbing ions in Solar atmosphera. By using c [see Eq.(5) in 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 = 1xE+17cm-3

PERTURBERS ARE :		ELECTRONS		PROTONS		He III	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
Ni II 2264.5	5000.	0.984E-01	0.706E-03	0.128E-02	-0.751E-04	0.288E- 02	-0.742E-04
2265.2 A	10000.	0.715E-01	-0.470E-03	0.243E-02	-0.166E-03	0.405E-02	-0.153E-03
C= 0.19E+21	30000.	0.432E-01	-0.493E-03	0.416E-02	-0.423E-03	0.499E-02	-0.310E-03
	50000.	0.355E-01	-0.552E-03	0.459E-02	-0.546E-03	0.537E-02	-0.383E-03
	100000.	0.291E-01	-0.617E-03	0.514E-02	-0.727E-03	0.563E-02	-0.459E-03
	150000.	0.269E-01	-0.562E-03	0.542E-02	-0.808E-03	0.575E-02	-0.511E-03
Ni II 2270.2	5000.	0.976E-01	0.518E-03	0.124E-02	-0.862E-04	0.281E-02	-0.850E-04
2270.9 A	10000.	0.710E-01	-0.557E-03	0.236E-02	-0.190E-03	0.396E-02	-0.173E-03
C= 0.20E+21	30000.	0.428E-01	-0.615E-03	0.408E-02	-0.476E-03	0.490E-02	-0.346E-03
	50000.	0.351E-01	-0.665E-03	0.450E-02	-0.613E-03	0.527E-02	-0.423E-03
	100000.	0.287E-01	-0.751E-03	0.505E-02	-0.800E-03	0.553E-02	-0.506E-03
	150000.	0.264E-01	-0.690E-03	0.533E-02	-0.890E-03	0.564E-02	-0.561E-03

In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-impacts, and to impacts with a singly charged perturber with the mass equal to 35 a.u. corresponding to the averaged mass of perturbing ions in Solar atmosphera, have been calculated. Our results for two lines within the Ni II a^4F - z^4G^o multiplet are shown in Table 1, for a perturber density of 10^{17}cm^{-3} and temperatures T = 5,000 - 150,000K. We also specify a parameter *c* (Dimitrijević *et al.* 1991), which gives an estimate of 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.

In Djeniže *et al.* (1994), the results of their calculations by using the simplified version (SMSE-Dimitrijević and Konjević, 1987) of the modified semiempirical method (MSE-Dimitrijević and Konjević, 1980) have been presented and the ratios of measured and calculated Stark widths equal to 4.4 for 2264.5 Å line and 3.9 for 2270.2 Å line have been reported. However, the calculations of Djeniže *et al.* (1994) have been performed by using atomic energy levels from Moore (1958). Since the more recent and accurate atomic energy levels exist (Corlis and Sugar, 1981) permitting the use of more sophisticated approaches as well, their calculations were repeated here. The ion broadening contribution has also been neglected as well in Djeniže *et al.* (1994). As a working gas they used a mixture of 72% Ar and 28% He. Since there is more Ar and it has lower ionization potential than He, a reasonable assumption is that Ar II-impact broadening parameters may be used to estimate the ion broadening contribution. With more accurate atomic data and with the ion broadening contribution included, we obtain 3.2 and 3.0 as ratios of measured and calculated values for Ni II 2264.5 Å and 2270.2 Å lines instead of 4.4 and 3.9 obtained by Djeniže *et al.* (1994). With the use of the non simplified version of the MSE approach, the corresponding ratios are 2.7 and 2.4, and for the full semiclassical calculations 1.7 and 1.5, which is much better but still not satisfying.

The ratio of the semiclassical and the MSE values is also too large, equal to 1.7 for both lines. If one performs an analysis of the contributions of different types of collisions, for Ni II 2264.5 Å line (T = 20000 K and the electron density 10^{17}cm^{-3}), the inelastic collision contribution is 0.875 10^{10}s^{-1} for the upper and 0.802 10^{10}s^{-1} for the lower level. The elastic collision contribution is 0.948 10^{10}s^{-1}. Moreover, the strong collision contribution to elastic and inelastic part is 0.597 10^{10}s^{-1}. The elastic collisions contribution consists of contributions due to strong collisions, the polarization and the quadrupole potentials. For the considered line the contribution due to the polarization potential is only 0.241 10^{9}s^{-1}. Consequently, for the considered line, elastic collisions, strong collisions and higher order interactions, taken as corrections implicitly in the modified semiempirical approach or neglected, play an important role.

Our results for the shift have a different sign from experimental ones. Since the considered lines are 4s-4p transition with a far 4d perturbing level with smaller influence, it is logical that the shift is around zero or negative. In spite of the fact that the agreement between the theory and experiment is better if one uses the more sophisticated semiclassical - perturbation approach, the differences are still such that a new experiment is of interest.

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