EXPERIMENTAL STARK WIDTHS FOR Ni II

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Abstract: In the present work, we have studied experimentally the Stark widths from several lines of Ni II, some of them not measured before. For doing this, the Laser Induced Breakdown Spectroscopy technique (LIBS) has been used on an Alluminium-Nickel alloy with a lower content of Nickel in a controlled atmosphere. The final results are compared with the ones already published. A study of the plasma conditions has been also made

Keywords: Stark widths – Atomic parameters – Line shapes.

1 Introduction

In the present work, we have studied experimentally the Stark widths from several lines of Ni II, some of them not measured before. The interest in Ni II resides not only on the knowledge of its atomic structure to check the adequacy of theoretical models, but also on its astrophysical importance because the observations of trace metals like nickel or zinc provide an opportunity to study the chemical and dust evolution of galaxies [1].

Besides, the Stark parameters are useful for the determination of plasma characteristics [2]. The Stark broadening is produced due to the interaction of charged particles because of the high electric field formed inside the plasmas as a consequenceof the movement of ions and electrons and in Astrophysics is of importance because this kind of broadening mechanism is the main pressure one in several stars [3].

2 The experiment

The plasma source of Ni II spectrum was produced by laser ablation on an Al-Ni alloy with a lower content of nickel in order to avoid the effects of self-absorption. The neutral atom and other higher ions from Nickel and Aluminium were present in the plasma.

The experimental work was performed by the Experimental Atomic Physics Group based on UCM with the facility located in the José Campos laboratory and used the Laser Induced Breakdown Spectroscopy (LIBS) technique. A Nd:YAG laser beam focused on the surface of the target was used to generate the plasma in a controlled Argon atmosphere.

In order to avoid spectral blending, the same experiments, but with pure Nickel and Aluminium as targets and using Neon as buffer gas were also made. The light emitted by the laser-produced plasma was focused on the input slit of a grating 1-m Czerny-Turner monochromator with a resolution of 30 picometer (pm) in first order, which was coupled with a time-resolved optical multichannel analyzer system (OMA III, EG&G). The spectra were stored in a computer for their further analysis by a software which is able to do the convolution for Voigt profiles, the ones that are used to fit the lines.

3 Plasma conditions

The experimental plasma conditions were obtained from a Boltzmann plot of the temperature, the available results for the Stark broadening of some Al II lines [4] and by means of the Saha equation.

The plasma temperature was obtained from a Boltzmann plot just using the lines measured in this experiment and the transition probabilities published by [5]. It gave a value of $22300 \pm 3800K$.

The electronic density was obtained from the value reported by [4] regarding the line at 281.6 nm of Al II which was also measured in the present work just showing a value of $(1.49 \pm 0.19)10^{17} cm^{-3}$.

With the plasma temperature and electron density we can derive if we are or not in Local Thermodynamic Equilibrium; the Thorne criterion [6] for the assumption of LTE is

$$N_e(cm^{-3}) \gg 1.6 \times 10^{12} \sqrt{T} \Delta E^3 \quad (1)$$

where N_e is the electron density, T is the plasma temperature in Kelvin and ΔE is the higher difference in energies between the upper and lower states for all the studied transitions. For this experiment, we obtained an upper limit for $N_e = 4.74 \times 10^{16} cm^{-3}$, so we can conclude that the plasma is in LTE.

The self-absorption effects of the plasma were estimated by calculation from the obtained electron density. Once the total density of Ni II was deduced from the corresponding electron density and the ratio of the concentration of different stage ions present in the plasma, we integrated the line intensity absorption along the line profile for each line in our experiment. In fact, we calculate the ratio between the observed

intensity and the one emitted by an optically thin plasma, whose condition [6] is that the optical depth would be much lower than 1, that is,

$$K(\lambda) \cdot D(cm) \ll 1 \tag{2}$$

where $K(\lambda)$ is the self-absorption coefficient and D is the plasma thickness (estimated to be around 1 mm in our experiment). If this ratio exceeds 0.97, which would be equivalent to a self-absorption lower than 3%, the plasma can be considered to be optically thin. Since the highest influence was lower than 3% (for the line 212.86 of Ni II) we may consider that the self-absorption of the studied transitions is weak.

4 Results and discussion

Upper Level	Lower Level	Wavelenght (nm)	ω (pm) this work	Other authors
$(^3F)4p\ ^4F_{7/2}$	$(^3F)4s\ ^4F_{7/2}$	216.91	15.7 ± 4.7	
$(^3F)4p\ ^4F_{5/2}$	$(^2F)4s\ ^4F_{3/2}$	220.14	16.3 ± 6.3	
$(^3F)4p\ ^4G_{9/2}$	$(^3F)4s\ ^4F_{9/2}$	222.30	15.6 ± 5.4	
$(^3F)4p\ ^4G_{5/2}$	$(^3F)4s\ ^4F_{3/2}$	225.39	15.4 ± 5.7	
$(^3F)4p\ ^4G_{7/2}$	$(^3F)4s\ ^4F_{5/2}$	226.45	15.6 ± 6.3	$28^a, 16^b, 8^c, 9^d$
$(^3F)4p\ ^4G_{9/2}$	$(^3F)4s\ ^4F_{7/2}$	227.02	15.8 ± 3.9	$25^a, 15^b, 7^c, 9^d$
$(^3F)4p\ ^2D_{3/2}$	$(^3F)4s\ ^2F_{5/2}$	228.71	16.0 ± 6.2	
$(^3F)4p\ ^4G_{9/2}$	$(^3F)4s\ ^2F_{7/2}$	251.09	15.2 ± 6.6	
$(^3F)4p\ ^4G_{7/2}$	$(^3F)4s\ ^2F_{5/2}$	254.59	18.7 ± 6.9	

this work conditions: $T = 22300 \pm 3800K, N_e = (1.49 \pm 0.19)10^{17} cm^{-3}$
Rest of references: $T = 17000K, N_e = 5.5 \cdot 10^{17} cm^{-3}$
^{a} [7], ^{b} [8], ^{c} [9], ^{d} [10]

Table 1: Experimental Stark widhts ω (HWHM)

Our experimental results are presented in Table 1 as well as their comparison with previous experimental [7] and theoretical [8, 9, 10] results available in the literature.

Although the plasma conditions are not the same as those that appear in the published papers, we can say that our results are solid enough considering the evolution of the Stark widths with the electronic density and the temperature. The experimental errors originate from the statistical uncertainties from each line, the experimental error from the spectral calibration (6%) and the values derived for the plasma temperature and electronic density.

5 Summary and conclusions

We present 9 Ni II Stark broadening parameters, some of them firstly measured, for one selected plasma condition $T = 22300 \pm 3800K$ and $N_e = (1.49 \pm 0.19)10^{17} cm^{-3}$. In order to measure these parameters, an accurate fitting process from obtained spectral lines widths from a Ni-Al plasma alloy has been used.

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