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# REGULARITIES OF STARK PARAMETERS FOR MULTIPLY CHARGED ION SPECTRAL LINES*

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*Abstract*. Recently published Stark widths and shifts measured and calculated data and their dependence on the upper level ionization potential $\chi$ are used here to demonstrate the existence of the other kinds of regularities of different elements and their ionization stages. The found relations connecting Stark widths and shifts parameters and upper level ionization potential, rest core charge and electron temperature were used for prediction of new data, avoiding much more complicated procedures.

*Key words*: regularities, stark parameters, atomic processes, atomic data.

## 1. INTRODUCTION

The aim of this paper is to analyze functional dependence of Stark parameters of spectral lines (FWHM) on the upper level ionization potential of the corresponding transition within 3p-3d and 3p-5d spectral arrays of the following ions: Be II, C II, N II, O II, F II, Ne II, Mg II, Al II, Si II, Li II, C III, N III, O III, Ne III, Na III, Al III, Si III, P III, N IV, O IV, Si IV, N V, O V, N VI, S VI, and FVI, taken from [1–8]. This work is in continuation with recently published papers devoted to the checking of Stark widths dependences on the upper level ionization potential within spectral arrays of the ions of different ionization stages [9] and references therein; and within spectral series of neutral helium, magnesium, beryllium and calcium. See reference [10-13]. The emphasis is on the Stark

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parameter dependence on the upper level ionization potential and on the rest core charge of the emitter for the lines from transition arrays of multiply charged ions.

## 2. THEORY

Theoretically derived functional relations for line width and shift, successfully fitted to a number of spectral lines as shown in a series of articles [14–16], are of the form:

$$W, D = N_e f_{1,2}(T) a_{1,2} Z_c^{c_{1,2}} \chi^{-b_{1,2}}, \tag{1}$$

where $W$ and $D$ are the line width and shift, $f_{1,2}(T)$ is function of electron temperature for the Stark width and shift, respectively, $\chi$ is the corresponding upper state ionization potential, $a_{1,2}$ and $b_{1,2}$ are coefficients independent on the electron density and ionization potential for particular transition, and $Z_c$ is the rest core charge of the emitter, as seen by the electron undergoing transition.

However, Stark parameters dependence on the electron temperature is different from line to line for all spectra. Therefore, the correction to the temperature dependence has to be done with great care for all data used, in particular case of the verification of certain type of mentioned dependencies and regularities. For instance, instead of the commonly adopted temperature dependence of $T^{-1/2}$ for widths of ion lines, one has to use, from line to line [14, 16], the whole spectrum of functions of the form:

$$f(T) = A + BT^{-C}. \tag{2}$$

One can determine empirically, from experiment or more sophisticated calculations, averaged empirical values for $A = aN_e f(T)$ and $b$. A general form of that dependence in the case of the particular transition array is

$$W^*, D^* = W, D / z^c = a\chi^{-b}, \tag{3}$$

where $W^*$, $D^*$ is the line width/shift in angular frequency units; $\chi$ is the corresponding upper level ionization potential expressed in $eV$; $z$ is the rest core charge of the emitter as seen by the electron undergoing the transition. The coefficients $a$, $b$ and $c$ are independent of the ionization potential (for particular electron temperature and density) for a given transition. Even more, it has been found that coefficient $c$ is constant approximately equal 5.20 in majority of the cases. The Stark parameter dependence on the electron density is well established, and in the case of nonhydrogenic emitters is linear.

## 3. RESULTS AND DISCUSSION

A comprehensive set of Stark broadening data of the investigated ions has been used here to demonstrate the existence of Stark width and shift data regularities within a group of spectral lines originating from 3p-3d and 3p-5d transition arrays. The procedure for Stark broadening data predictions were described elsewhere [14–16].

Using Stark width and shift data published so far [1–8] we have obtained the reduced Stark width ($W$*) dependence on the inverse value of the upper level ionization potential normalized to electron density $Ne = 10^{23}\,\mathrm{m}^{-3}$ and using the equation (2) to an electron temperature $T = 10^{5}\,\mathrm{K}$, as it is presented in Fig. 1 for 3p-3d transition array and in Fig. 2 for 3p-5d transition array. In Fig. 3 we presented the reduced Stark shift ($D$*) dependence on the inverse value of the upper level ionization potential normalized to electron density $Ne = 10^{23}\,\mathrm{m}^{-3}$ and using commonly adopted temperature dependence of $T^{-1/2}$ to an electron temperature $T = 10^{5}\,\mathrm{K}$.

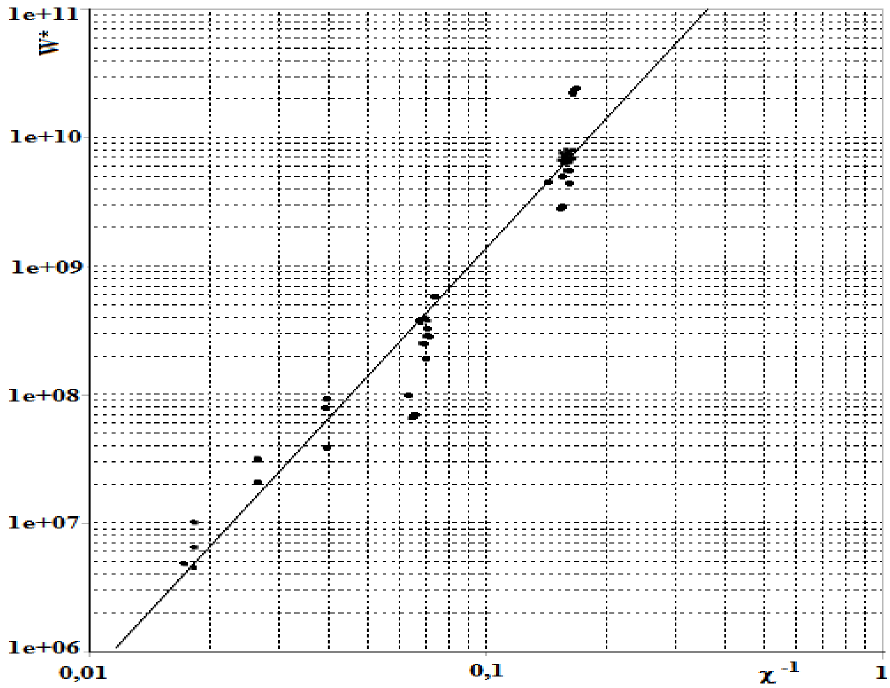


Fig. 1 – Reduced Stark width *versus* inverse value of upper level ionization potential for 3p-3d transition array.

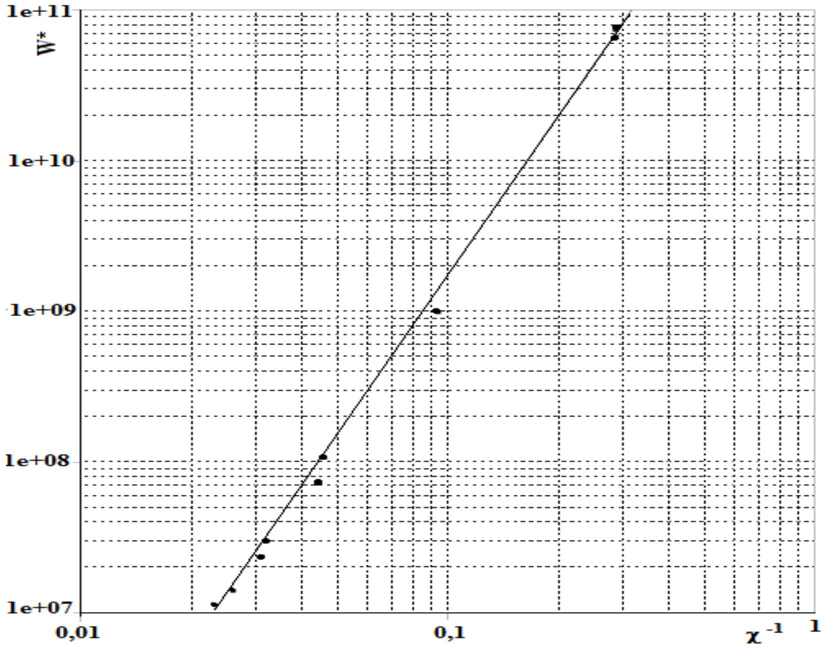


Fig. 2 – Reduced Stark width *versus* inverse value of upper level ionization potential for 3p-5d transition array.

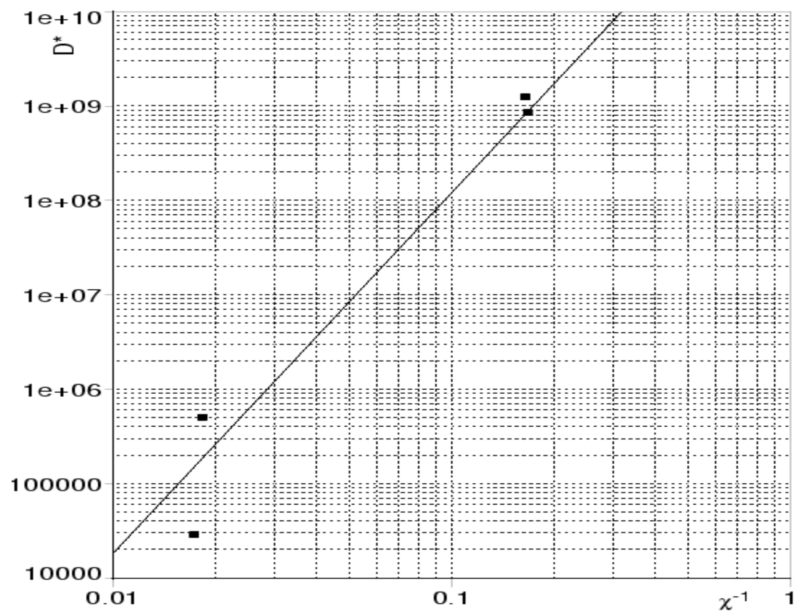


Fig. 3 – Reduced Stark shift *versus* inverse value of upper level ionization potential for 3p-3d transition array.

In this paper we used the theoretical results to find the systematic trends for reduced Stark widths $W^*$ and Stark shift $D^*$ on the inverse value of upper level ionization potential $\chi$ within similar spectra of the multiply charged ion and we are presented in Figs. 1, 2, 3.

In Table 1 we presented appropriate coefficients *a* and *b*.

*Table 1*

Values of coefficients $a_{W^*}$, $b_{W^*}$ (from eq.3 for Stark width) and $a_{D^*}$ and $b_{D^*}$ (from eq.3 for Stark shift)

| *transition* | $a_{W^*}$ | $b_{W^*}$ | $a_{D^*}$ | $b_{D^*}$ |
|---|---|---|---|---|
| 3p-3d | $4{,}22\times10^{12}$ | 3,4 | $7{,}73\times10^{11}$ | 3,81 |
| 3p-5d | $5{,}69\times10^{12}$ | 3,51 | | |

The corresponding correlation's factor for all the charts was almost equal to unity.

## 4. CONCLUSION

Searching for different types of regularities and systematic trends which can simplify complicate theoretical calculations especially used in astrophysics is of great interest. The dependence was verified through introduction of the Stark widths and shifts reduced values $W^* = W \cdot Z^{-5.20}$, and $D^* = D \cdot Z^{-5.20}$, where *z* is the rest core charge of the emitter seeing by the electron undergoing transition ($Z$ = 1, 2, 3, …. for neutral atom, singly, doubly charged ion… respectively) and demonstrating their dependence on the upper level ionization potential. This work successfully proves the existence of the regularities [14, 15].

Temperature dependence is very important for studding Stark parameters regularities and therefore we have used theoretical values obtained by different authors for spectral lines originating from 3p-nd ($n$ = 3, 5) stages of ionizations of investigated elements in order to determine Stark parameters temperature dependence through introduced coefficients *A, B* and *C* for these lines used in systematic trends analysis for temperature data normalization. Normalization at an electron density was used as being linear function for non-hydrogenic emitters.

In studding regularities of Stark widths we have successfully found *a* and *b* coefficients values for the introduced reduced Stark broadening parameters $W^*, D^* = a_{W^*}, a_{D^*} \cdot \chi^{-b_{W^*}, b_{D^*}}$ for the investigated transition arrays separately to determine their dependences on the upper level ionization potential.

Similar procedure was used to obtain Stark shift reduced values dependence on the upper level ionization potential. In this case we had for analysis smaller sample of published data especially for temperature correction.

Therefore, temperature normalization has been done using Stark shift dependence as inverse value of square root of electron temperature. Finally, Stark parameters reduction using their dependence on the rest core charge of the emitter and the found dependences on the upper level ionization potential can be regarded as being well established using the published theoretical and experimental data so far. Therefore they can be used to estimate the needed Stark widths and shift data for the lines not investigated so far.

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