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STARK BROADENING OF SPECTRAL LINES WITHIN COPPER LIKE EMITTERS

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Abstract. Regularity analysis of Stark line broadening within copper-like emitters was performed, using available Stark data for Cu I, Zn II, Ge III, Ga IV and Kr VIII. Algorithms for temperature and density normalization were developed. Results are presented for fixed values of electron density and temperature: $N_e=10^{22}$ m^{-3} and T=100000 K. Obtained relations can be used for calculation of Stark widths for transitions within copper-like emitters with lack of Stark broadening data and for quality control of available data.

1. INTRODUCTION

Stark broadening data are significant for the investigation of astrophysical and laboratory plasmas. Years of investigation of the Stark effect phenomena leads to the conclusion of regularity existence within the spectral series of the same isoelectronic sequence. In the presented paper, Stark width regularities within the copper isoelectronic sequence are investigated, using available data for Cu I, Zn II, Ga III, Ge IV and Kr VIII.

Copper is widely used in electrical industry as an electrode material, so Stark data of copper are important for industrial laboratories. Stark widths of zinc, gallium, germanium and krypton are of interest for astrophysics. Spectral lines of zinc are used for determination of metallicity and content of dust in cosmic objects. Gallium is present in hot white drafts, while germanium is found in stellar and interstellar atmosphere. Krypton is a product of s (neutron capture in slow time scale orderly evolution of stellar interiors) and r (neutron capture in fast time scale in type I supernovae) processes (Dimitrijevic et al. 2000).

After regularity analysis using available data, predictions of Stark widths can be done for any transition within the copper isoelectronic sequence.

2. THEORETICAL BACKGROUND

The ground state of neutral copper, as well as all members of copper isoelectronic sequence, has electron configuration of ground state: [Ar]$3d^{10}4s$, with term ^2S, where $3d^{10}$ is energetic stable level. All members of the copper isoelectronic sequence have one uncoupled electron, so they can be treated as quasi-one electron systems and they all have similar excited states. It is expected that atomic parameters within copper-like emitters show some regular behaviour.

The regularity approach used in present investigation is based on the work of Puric et al. 1999. Equation (1) is used for regularity investigation.

$$\log \omega^* = \log \frac{\omega}{Z_e^c} = \log a + b \cdot \log(\chi^{-1}) \quad (1)$$

ω^* is the reduced Stark width, χ is the electron binding energy on the upper level of analyzed transition, Z_e is the rest core charge of the emitter; $a = const \cdot N_e \cdot f(T_e)$, b is a fitting coefficient. Parameter c can be found by analyzing the quality of the fit which is determined by factor R^2 (Tapalaga et al. 2018.).

For each analyzed transition for which there are available Stark width data for different temperatures, the dependence of line width on temperature is fitted according to equation (2) (Purić et al. 1999).

$$\omega = A + B \cdot T^{-C} \quad (2)$$

For transitions analyzed in present investigation, the constancy of the ratio $\Delta\lambda/N_e$ is confirmed and linear dependence of Stark widths on electron density has been found as good approximation.

3. RESULTS AND DISCUSSION

Regularity analysis within copper like emitters include 54 spectral lines: Cu I (11), Zn II (11), Ga III (10), Ge IV (17), Kr VIII (5). Stark width data used in the present study are taken from Stark B data base (Sachal-Brechot et al. 2018). Data were complemented with available experimental data of Stark widths. χ values are taken from NIST atomic database (Kramida et al. 2018). Data were complemented with available experimental data of Stark widths.

Fig. 1. represents dependence of R^2 on parameter c for the copper isoelectronic sequence and it can be concluded that c is approximately equal to 4. Value of R^2 has the same value in the range c=3 to c=5.

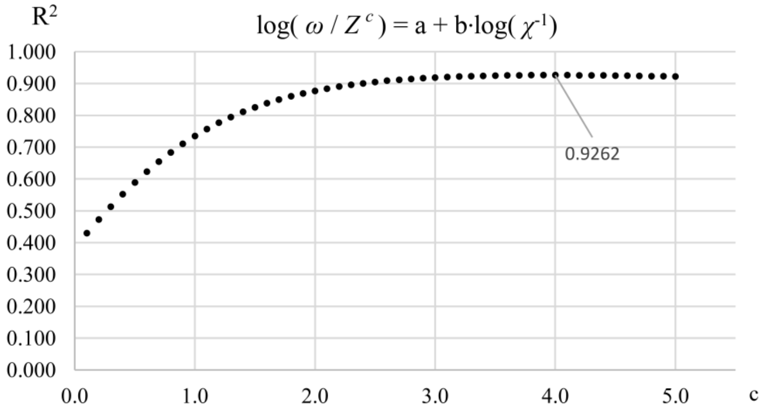

Figure 1: Determination of parameter c

Software for determination of A, B and C parameters has been developed and it enables temperature data normalization. As an example of fitting procedure results, in Table 1, parameters A, B and C are given for 4s-4p transition within analyzed emitters (there is no available Stark width data for 4s-4p transition within Ga III in the database).

Emitter	A	B	C
Cu I	4.08E+07	1.28E+03	75E-02
Zn II	1.08E+09	-9.76E+0.8	83E-04
Ge IV	6.07E+09	6.07E+09	11E-04
Kr VIII	5.31E+07	-8.06E+07	20E-03

Table 1: Parameters A, B and C for 4s-4p transition used for temperature normalization

In the present paper results are presented for $N_e=10^{22}$ m^{-3} and T=100000 K.

Fig. 2. represents dependence of the reduced Stark width on ionization potential of the upper level of transition, for all analyzed spectral lines of the copper isoelectronic sequence, fitted according to equation (1).

According to fitting parameters from Fig. 2, there is an unique formula for Stark width calculation for any line within copper isoelectronic sequence:

$$\Delta\lambda = 1.49 \cdot 10^{-20} \cdot \frac{Z_e^4 N_e}{\chi^{2.62}} \lambda^2 \tag{3}$$

In equation (3) λ and $\Delta\lambda$ are expressed in [m], N_e is expressed in [m^{-3}] and χ is expressed in [eV].

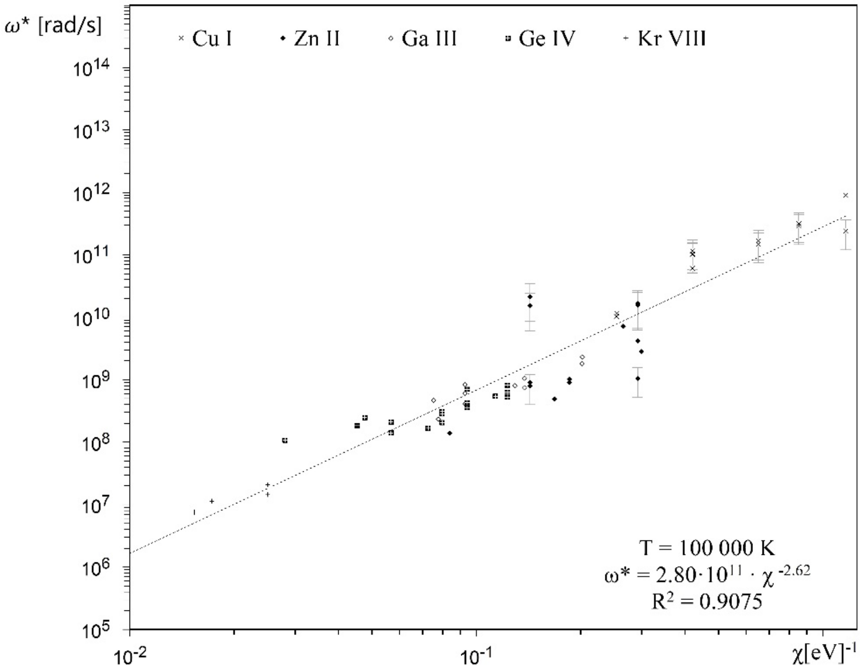

Figure 2: Dependence of ω^* on χ for the copper isoelectronic sequence (N_e=10^{22} m^{-3}, T=100000 K)

4. CONCLUSIONS

Results of presented regularity analysis enable calculation of Stark widths for transitions within copper isoelectronic sequence for which there is no available data in the literature. Also, our results are used as a quality test for experimentally measured Stark broadening values, and for Stark widths calculated using other theoretical methods.

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