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STARK BROADENING OF NEUTRAL GERMANIUM SPECTRAL LINES IN ASTROPHYSICAL PLASMA

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Abstract. Stark broadening of the eleven transitions of neutral germanium within the 4p^2 - 4p5s transition array has been analyzed within the frame of the semiclassical perturbation method. A part of obtained results for 4p^2 $^1S - 5s^1S^o$ multiplet is presented and compared with available experimental and theoretical data.

1. INTRODUCTION

The astrophysical interest in atomic and spectroscopic data on as much as possible larger number of atomic and ionic species, increased considerably with space born spectroscopy development. With satellite born instruments stellar spectra are obtained with such resolution that number of different spectral lines which may be identified and analyzed in detail increases quickly. For example, in the spectrum of Przybylski's star Cowley et al (2000) indentified lines belonging to 75 various atom/ion species, which apart from the Sun, was unimaginable before the epoch of satellite born astronomy. Consequently, Stark broadening of neutral germanium spectral lines is of interest not only for laboratory but also for astrophysical plasma research as e.g. for germanium abundance determination and opacity calculations (Seaton 1988). The origin of germanium atoms is commonly associated with slow-neutron-capture nucleosynthesis in stellar interiors (see e.g. Leckrone *et al*. 1993). Also germanium lines are present in Solar (see e.g. Moore et al. 1966, Grevesse 1984) spectrum and with the help of Goddard High Resolution Spectrograph (GHRS) on Hubble Space Teloscope (HST) presence of germanium is confirmed e.g. for χ Lupi binary star (Leckrone et al. 1993). The primary component of this system has T_{eff} = 10 650 K and log g = 3.8 and the secondary T_{eff} = 9200 K and log g = 4.2. Since around T = 10 000 K hydrogen is mainly ionized, Stark broadening is the principal pressure broadening mechanism in such plasma conditions. It is interesting to note as well that beginning with germanium (Z = 32) and extending to heavier elements, there is a "dramatic increase in the magnitude of overabundances" (Leckrone et al. 1993) in chemically peculiar (CP) star spectra. The good illustration of the increasing astrophysical interest for trace element spectra is also the work of Cardelli et al. (1991). With the GHRS on the HST, they have for the first time detected in interstellar medium the presence of trace elements like germanium and krypton, so that data on germanium spectral line shapes are obviously of interest for astrophysical plasma research. Stark broadening parameters of germanium lines are also of interest in the consideration of regularities and systematic trends (see e. g. Sarandaev et al. 2000), and the corresponding results may be of interest in astrophysics at interpolation of new data and critical evaluation of existing ones.

The first discussion on the Stark broadening of germanium lines, has been published in Minnhagen (1964), who considered correlation between observed wavelength shifts produced in electrodeless discharge tube and predicted Stark shifts in the spectrum of neutral germanium. Shifts in the wavelength of spectral lines in spark discharges have been investigated as well in the first experimental work on Ge I Stark broadening (Kondrat'eva 1970). After these pioneering works, reliable data on Ge I spectral lines Stark broadening parameters have been obtained experimentally by Jones & Miller (1974) and Musiol et al. (1988). For Ge I 4p^2 $^1S - 5s^1S^o$ multiplet, Dimitrijević and Konjević (1983) performed semiclassical calculation within the frame of the theory developed by Griem et al (1962) (see also Griem 1974). Moreove, Lakićević (1983) estimated on the basis of regularities and systematic trends Stark broadening parameters for Ge I 4p^2 $^3P - 5s^3P^o$ multiplet. The estimates based on regularities and systematic trends, performed also Sarandaev et al. (2000) for Ge I 4p^2 $^1S - 5s^1P^o$ and 4p^2 $^1S - 5s^3P^o$ multiplets. Here, we will calculate within the semiclassical perturbation approach, Stark broadening parameters of 11 Ge I transitions within the 4s^{2}4p^2 - 4s^{2}4p5s transition array, for conditions typical for astrophysical and laboratory plasmas. The obtained results will be compared with available experimental and theoretical values.

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 germanium, 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 & Jovanović 2003) so that we note here only that the atomic energy levels needed for calculations have been taken from Sugar & Musgrove (1993).

Results for electron-, proton-, and Ar II-impact broadening parameters for 11 Ge I transitions for perturber density of 10^{16}cm^{-3} and temperatures from 2,500 K up to 50,000 K will be published in Dimitrijević and Jovanović (2003), together with the complete comparison of available experimental and theoretical data and discussion. As a sample of our results, in Table 1 are shown electron-, and proton-impact widths (FWHM) and shifts for Ge I 4p^2 $^1S - 5s^1P^o$ multiplet. Complete comparison of our results with existing experimental and theoretical ones will be presented and discussed in Dimitrijević and Jovanović (2003). In Table 2, as an example, our results for Ge I 4p^2 $^3P - 5s^3P^o$ multiplet, are compared with experimental results of Musiol et al. (1988). With W_m are denoted experimental full widths at half maximum in [Å], with W_{DJe} our theoretical values for electron-impact broadening and with W_{DJei} our values for electron-, plus ion-impact broadening. Ion broadening is calculated as 50 percent of proton and 50 percent of ionized argon broadening.

Table 1: This table shows electron− and proton−impact broadening parameters for Ge I 4p^2 $^1S - 5s^1P^o$ multiplet, for perturber density of 10^{16}cm^{-3} and temperatures from 2500 up to 50,000 K. Transitions and averaged wavelengths for the multiplet (in Å) are also given in Table. By dividing C by the corresponding full width at half maximum (Dimitrijević et al. 1991), we obtain an estimate for the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

ELECTRON DENSITY IS 1.E+16cm-3					
PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(Å)	SHIFT(Å)	WIDTH(Å)	SHIFT(Å)
	2500.	0.168E-01	0.139E-01	0.439E-02	0.370E-02
Ge I 4p^2 ^{1}S -	5000.	0.201E-01	0.162E-01	0.489E-02	0.429E-02
5s^{1}P^o	10000.	0.235E-01	0.190E-01	0.546E-02	0.491E-02
4227.8 Å	20000.	0.261E-01	0.211E-01	0.611E-02	0.558E-02
C = 0.12E+20	30000.	0.272E-01	0.213E-01	0.652E-02	0.600E-02
	50000.	0.290E-01	0.202E-01	0.709E-02	0.656E-02

Table 2: Comparison of our theoretical results for Stark broadening of spectral lines within Ge I 4p^2 $^3P - 5s^3P^o$ multiplet, with experimental results of Musiol et al. (1988). With W$_m$ are denoted experimental full widths at half maximum in [Å], with W$_{DJe}$ our theoretical values for electron-impact broadening and with W$_{DJei}$, our values for electron-, plus ion-impact broadening. Ion broadening is calculated as 50 percent of proton and 50 percent of ionized argon broadening. Experimental electron density is 0.57 10^{17}cm^{-3} and temperature 12450 K. Error bars of experimental results are critically estimated in Konjević and Wiese (1990) to be within ±50%.

Wavelength	W$_m$(Å)	W$_{DJe}$(Å)	W$_{DJei}$(Å)
2754.59	0.0509	0.0502	0.0594
2709.62	0.0434	0.0490	0.0580
2651.57	0.0358	0.0466	0.0551
2651.17	0.0421	0.0517	0.0612
2592.53	0.0452	0.0494	0.0585

One can see that the influence of ion broadening is strong. However, Musiol et al. (1988) do not report the composition of their plasma, stating only that various mixtures of Ge H_4 and Ar have been used. Consequently, the proper estimate of ion broadening is difficult.

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 useful as well for research and modelling of astrophysical plasmas.

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