IMPACT OF STARK BROADENING ON Co II SPECTRAL LINE MODELLING IN HOT STARS

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Abstract

The ignorance of Stark broadening during the modelling of a spectral line profile in hot star spectra can cause significant errors in abundance determination. We choose several Co II, spectral lines observed in stellar spectra to show how Stark broadening influence on their profiles and we calculated Stark widths which can help to determine the abundance of this element in stellar atmosphere more accurate. Using calculated Stark widths, line profiles are synthesized and compared with isolated lines from existing observed stellar spectra.

Introduction

Stark broadening data are useful for a number of applications as e.g. laboratory plasma diagnostics (Konjević, 1999), the research and modelling of different technological plasmas (Hoffman et al., 2005, Dimitrijević and Sahal-Bréchot, 2014) as well as for inertial fusion (Griem, 1992) and lasers and laser-produced plasmas investigation (Csillag and Dimitrijević, 2004, Dimitrijević and Sahal-Bréchot, 2014). They are particularly useful in astrophysics for a number of problems like for example stellar plasma modelling, abundance determination, and stellar spectra analysis and synthesis (see e.g. Dimitrijević and Sahal-Bréchot, 2014, Majlinger et al. 2020).

In stellar astronomy, Stark broadening data are of particular importance for white dwarfs of DA (Majlinger et al., 2017), DB (e.g. Simić et al., 2013) and DO (e.g. Popović et al., 2001) type, where Stark broadening is the dominant collisional line broadening mechanism. Such data are also of interest for interpretation, analysis and synthesis of A and B type star spectra (see e.g. Lanz et al., 1988; Popović et al., 2001, Dimitrijević et al., 2007).

In particular thanks to large space observatories like Hubble, Chandra, Spitzer, Lyman, and to large, ground-based telescopes, spectra of different celestial objects with very high resolution could be obtained from X to radio wavelength ranges. So the spectral lines of earlier unsignificant trace atoms and ions, like Co II, become important as well as and data for them.

Co II spectral lines are observed in stellar spectra (see e.g. Adelman et al., 1993) and recently Stark broadening parameters for lines of 46 Co II multiplets have been calculated (Majlinger et al., 2018, 2020) by using the modified semiempirical method (MSE, Dimitrijević and Konjević, 1980).

Tab. 1. Stark widths (W_{MSE}) calculated for Co II spectral lines found in Chi Lupi spectrum. Electron density is 10^{23} m^{-3}.

Transitions	λ [Å]	W_{MSE}[Å]				
T[K]		10000	20000	50000	100000	200000
$(^4P)4s\ b^3P$ – $(^4P)4p\ z^3S^o$	2613.4	0.3797E-01	0.2685E-01	0.1698E-01	0.1220E-01	0.9775E-02
$(^4P)4s\ b^3P$ – $(^4P)4py^3D^o$	2533.2	0.5704E-01	0.4033E-01	0.2551E-01	0.1871E-01	0.1599E-01
$(^4P)4s\ b^3P$ – $(^4P)4p\ y^3P^o$	2435.9	0.4265E-01	0.3016E-01	0.1907E-01	0.1381E-01	0.1148E-01
$(^2P)4s\ c^3P$ – $(^2P)4p\ z^3P$	2496.6	0.4223E-01	0.2986E-01	0.1889E-01	0.1371E-01	0.1127E-01
$(^2P)4s\ c^3P$ – $(^2P)4p\ x^3D$	2348.3	0.4682E-01	0.3311E-01	0.2094E-01	0.1519E-01	0.1276E-01
$(^2P)4s\ c^3P$ – $(^2P)4p\ y^3S$	2215.9	0.2819E-01	0.1993E-01	0.1261E-01	0.9018E-02	0.7291E-02
$(^2P)4s\ a^1P$ – $(^2P)\ 4p\ z^1D^o$	2523.7	0.5542E-01	0.3919E-01	0.2478E-01	0.1817E-01	0.1545E-01
$(^2P)4s\ a^1P$ – $(^2P)4p\ ^1S^o$	2479.8	0.5359E-01	0.3789E-01	0.2396E-01	0.1752E-01	0.1486E-01
$(^2P)4s\ a^1P$ – $(^2P)4p\ z^1P^o$	2311.0	0.3792E-01	0.2681E-01	0.1696E-01	0.1221E-01	0.1012E-01
$(^2H)4s\ a^3H$ – $(^2H)4p\ z^3G^o$	2423.0	0.3739E-01	0.2644E-01	0.1672E-01	0.1206E-01	0.9803E-02
$(^2H)4s\ a^3H$ – $(^2H)4p\ z^3I^o$	2431.3	0.4281E-01	0.3027E-01	0.1914E-01	0.1388E-01	0.1148E-01
$(^2H)4s\ a^3H$ – $(^2H)4p\ y^3H^o$	2261.2	0.3556E-01	0.2515E-01	0.1591E-01	0.1143E-01	0.9420E-02
$(^2H)4s\ a^1H$ – $(^2H)4p\ y^1G^o$	2348.5	0.3694E-01	0.2612E-01	0.1652E-01	0.1189E-01	0.9789E-02
$(^2H)4s\ a^1H$ – $(^2H)4p\ y^1H^o$	2282.6	0.3769E-01	0.2665E-01	0.1686E-01	0.1213E-01	0.1010E-01

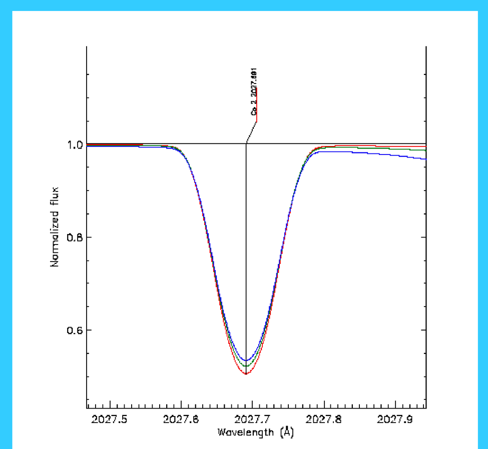

Fig. 1. Influence of gravity on profile of Co II spectral line 2027.681 Å. Synthetic line is simulated by SYNTHE program for stellar model atmosphere with effective temperature T_{eff} = 10000 K and gravity parameters log g = 4 (red), log g = 4.5 (green) and log g = 5 (blue). Electron density is 10^{23} m^{-3}. (Kurucz, 1979, http://kurucz.harvard.edu)

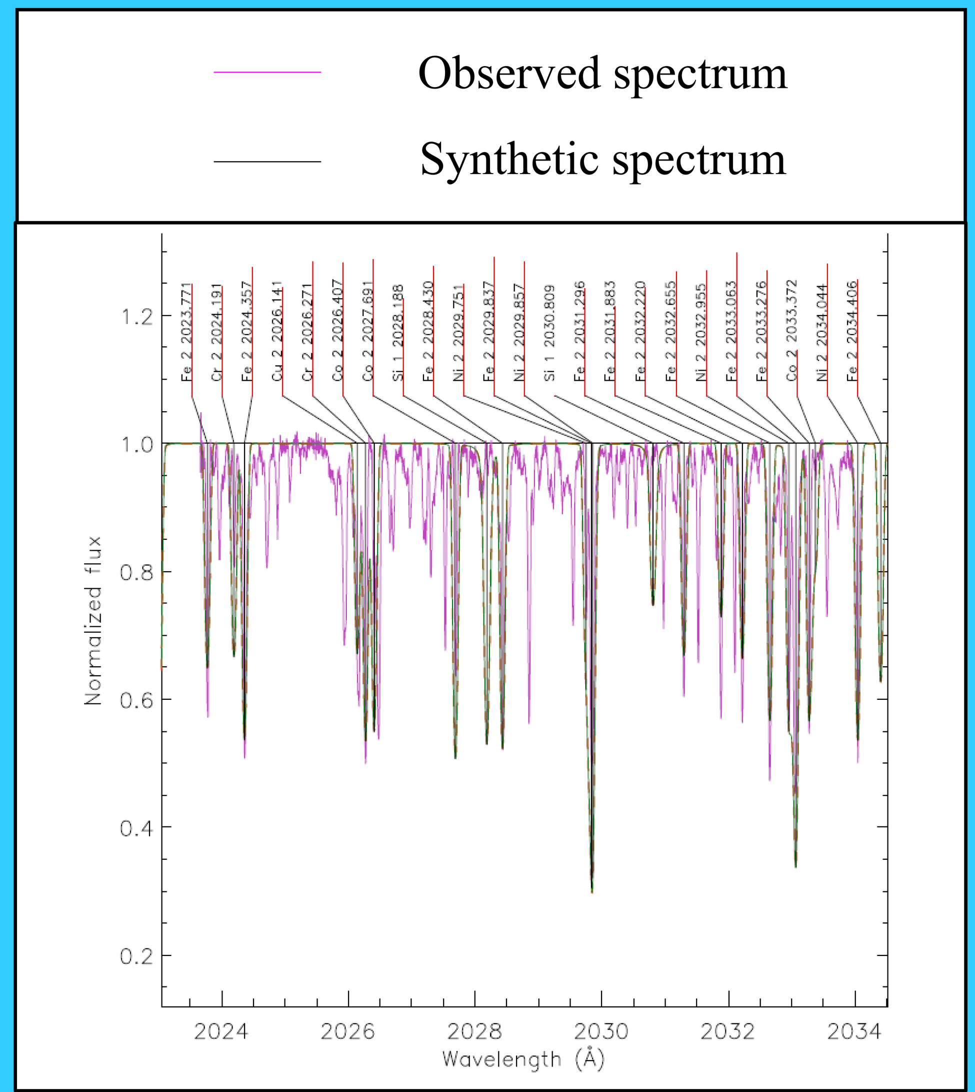

Fig. 2. Comparison of observed Chi Lupi spectrum (from MAST HST, http://archive.stsci.edu) with synthesized spectrum (atomic data form VALD database is used, http://vald.astro.uu.se) obtained by SYNTHE program (http://kurucz.harvard.edu).

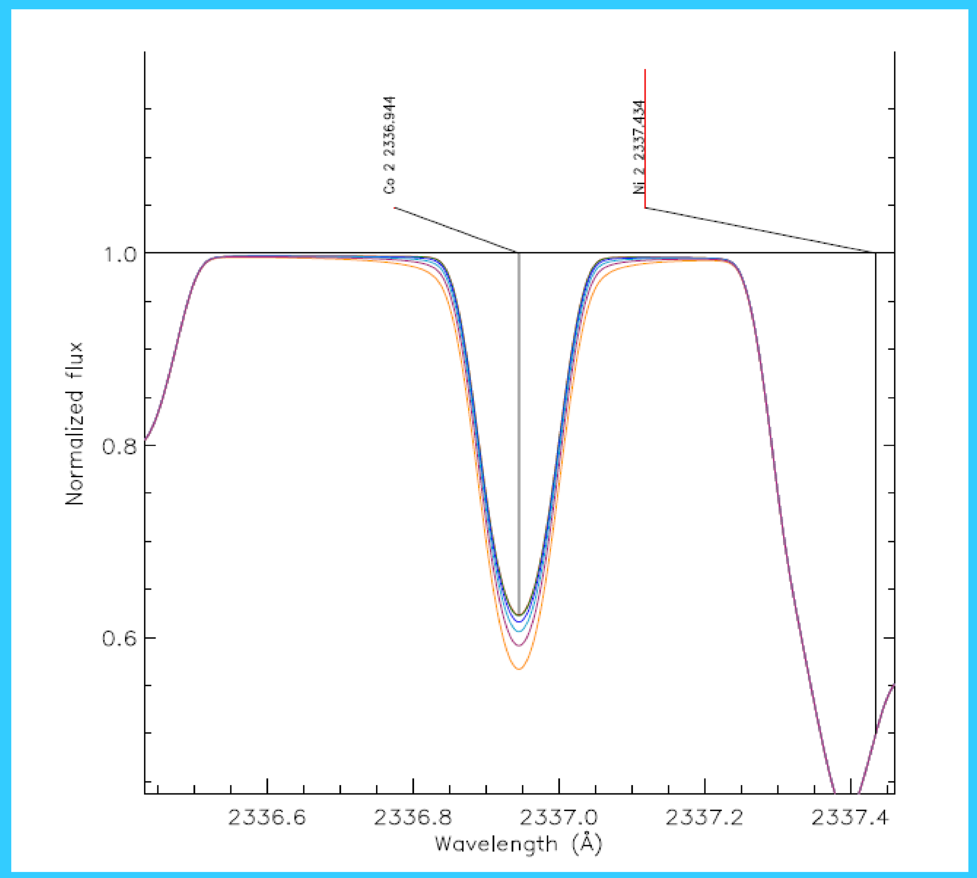

Fig. 4. Effect of increasing the Stark broadening on the profile of the Co II line 2336.399 Å. Simulation is done with SYNTHE application.

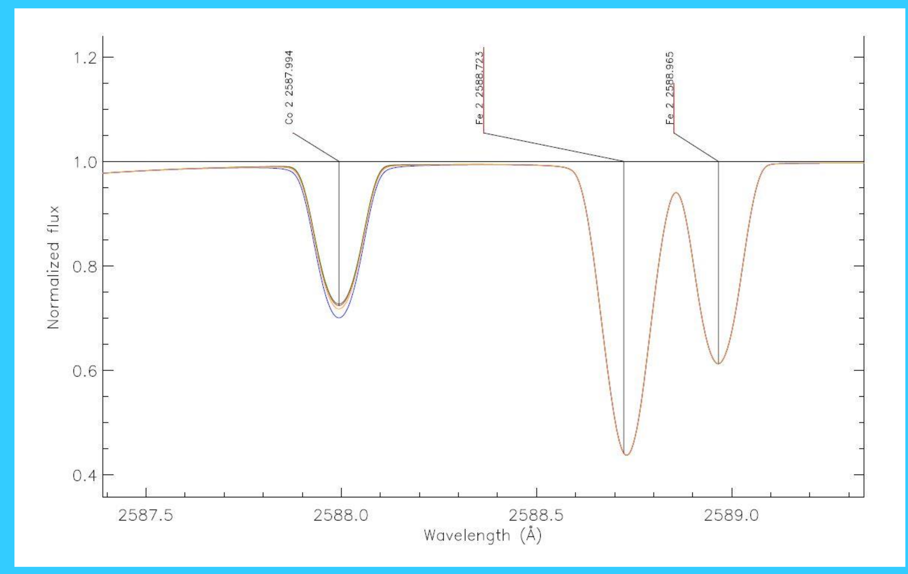

Fig. 3. Effect of increasing the Stark broadening on the profile of the Co II line 2587.994 Å. Profiles are synthesized with SYNTHE program.

Discussion of results and conclusion

The aim of this research was to investigate the importance of Stark broadening of Co II lines in the conditions of stellar atmospheres and to syntethize line profile of a Co II line including Doppler and Stark broadening (for example, gravity can affect on line shapes, see Fig. 1). For this purpose, Stark widths for Co II lines observed in stellar spectrum of Chi Lupi were calculated, using regularity among Stark widths previously obtained by MSE method (Majlinger et al., 2018, 2020), to be useful in our attemptions of synthesizing these lines (Tab. 1). The profiles for observed Co II lines in stellar spectrum were synthesized by SYNTHE program (http://kurucz.harvard.edu) using appropriate model atmosphere (Kurucz, 1979) and compared with the profiles observed in Chi Lupi spectrum (Fig.2). Some of these lines were selected for profile comparison. Although there is no evidence of visible difference between considered synthetic spectral line with or without Stark width, effect of increasing Stark broadening shows influence on shape of line, esspecially on line wings (Figs. 3-4). This effect could be expected only when electron-impact width becomes comparable with thermal width, e. g. for particular spectral line which is measured from deeper layers of the Chi Lupi atmosphere.

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