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The first measured Mn II and Mn III Stark broadening parameters

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Abstract

The shapes and shifts of the astrophysically interesting 11 singly and 3 doubly ionized manganese (Mn II and Mn III, respectively) spectral lines have been obtained in the laboratory helium plasma at a 49,000 K electron temperature and 1.3×10^{23} m^{-3} electron density. At mentioned plasma conditions, the Stark broadening has been found as the dominant mechanism in the line shape and shift formation. Our measured Stark widths (W) and shifts (d) are the first experimental data in Mn II and Mn III spectra and many of them represent the first published Mn II and Mn III Stark broadening parameters. Manganese atoms, as impurities in the driving gas, have been introduced by erosion from the manganese bands fixed on the discharge electrodes providing conditions free of self-absorption. Our W and d values are compared with the single calculated data set in the case of two Mn II multiplets, only. An agreement was found in the case of the Stark shift sign. Our measured W values are much higher than the calculated ones. At the above mentioned helium plasma conditions, the line splitting in a hyperfine structure has been overpowered by Stark and Doppler broadenings in the case of the Mn II lines belonging to the $3d^5 4sa^5S_2$–$3d^5 4pz^5P^o_{1,2,3}$ transition (293.3055, 293.9308 and 294.9205 nm). We estimate that at electron densities below 10^{21} m^{-3} and electron temperatures below 8000 K the components in the hyperfine structure can play an important role in the mentioned Mn II line shape formation.

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1. Introduction

The singly and doubly ionized manganese (Mn II and Mn III, respectively) spectral lines are useful for astrophysical plasma diagnostics

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and modeling, especially in the case of the mercury–manganese (HgMn) stars (Khare et al., 2004; Wahlgren and Hubrig, 2004; Cheng and Neff, 2003; Sigut, 2001; Jomaron et al., 1999; Smith and Dworetsky, 1993, and in many other works). However, their Stark broadening parameters (the width (W) and the shift (d)) are poorly known. Only one work (Popović and Dimitrijević, 1997) is dedicated to their theoretical prediction. The authors have been calculated W and d for 16 Mn II and 3 Mn III multiplets up to 50,000 K electron temperature (T) using electrons as perturbers, only. No experimental Mn II and Mn III Stark broadening parameters exist (Konjević et al., 2002, and references therein). On the other hand, experimental investigations of the splitting in the hyperfine structure (hfs) of the Mn II lines have been performed by Villemoes et al. (1991) and Holt et al. (1999) using collinear fast-ion-beam laser spectroscopy and by Booth and Blackwell (1983) and Jomaron et al. (1999) by analyzing some Mn II line shapes in astrophysical spectra. Above-mentioned works refer hfs splitting in a wide range from 0.03 up to 41.59 pm depending on the particular transition. Thus, the hfs can be more prominent than the Doppler or Stark contributions to the line width caused by considerably high electron temperature and electron density (N), respectively. Consequently, it is of an interest to obtain plasma electron density which causes Mn II Stark widths higher than the splitting (Δ_{hfs}) in hfs.

The aim of this paper is to present the first measured Stark full-width at half of the maximal intensity (FWHM W) and Stark shift (d) of 11 prominent Mn II and 3 Mn III lines in an optically thin laboratory helium plasma at an electron temperature of 49,000 K and electron density of $1.3 \times 10^{23}\ m^{-3}$. Manganese atoms were introduced as impurities in the helium plasma during the evaporation of the manganese bands fixed on discharge electrodes. The low density of manganese atoms and ions provides conditions free of self-absorption in the Mn II and Mn III lines. Our experimental W and d values are compared with the single calculated data (Popović and Dimitrijević, 1997) for two Mn II multiplets, only.

2. Experiment

A linear, low-pressure arc has been used as a plasma source. A pulsed discharge was created in a pyrex discharge tube of 5 mm inner diameter and plasma length of 14 cm (Djeniže et al., 1991, 2004a,b, 2005a,b; Bukvić et al., 2004a,b). The tube has an end-on quartz window. Manganese atoms were introduced by eroding of the manganese metal bands fixed on discharge electrodes providing conditions free of self-absorption. The absence of

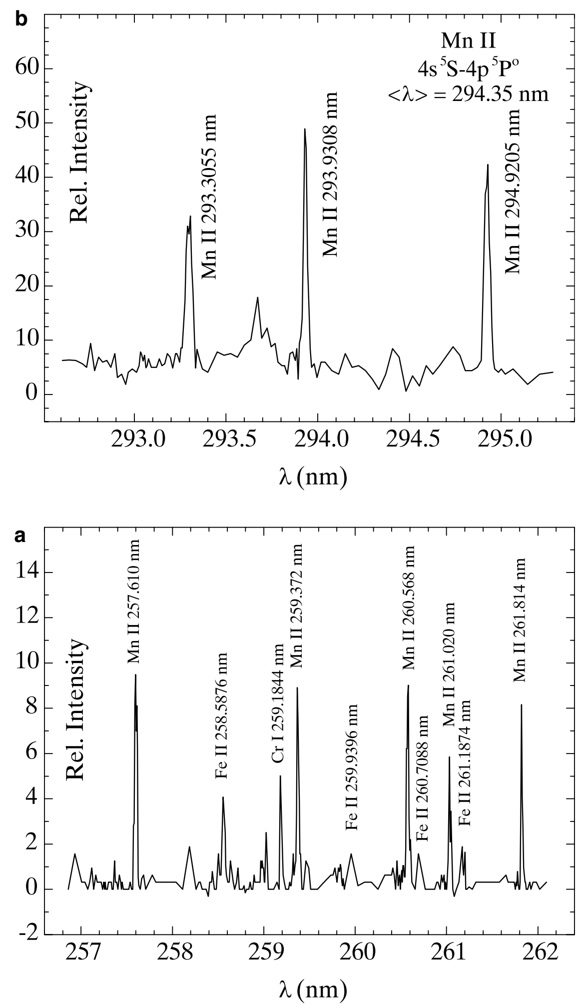

Fig. 1. Recorded Mn II line profiles in various transitions (a,b). Chromine and iron are present as impurities in manganese metal bands. ⟨λ⟩ is the mean wavelength of the multiplet.