Manganese Abundances in the Stars with Metallicities $-1 < [\text{Fe/H}] < +0.3$

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Abstract. We estimate the Mn abundances in the atmospheres of 247 F-G-K-type dwarf stars belonging to the thin and thick disk populations in the metallicity range $-1 < [\text{Fe/H}] < +0.3$. The observations were conducted using the 1.93 m telescope at Observatoire de Haute-Provence (OHP, France) equipped with the echelle type spectrographs ELODIE and SOPHIE. The abundances were derived under the LTE approximation; the synthetic spectrum for the Mn lines was computed accounting for the hyperfine structure. Starting from the results obtained, we discuss the evolution of the $[\text{Mn/Fe}]$ ratio with respect to $[\text{Fe/H}]$ in the galactic disk.

1. Introduction
Mn (Z=25) is an element of the iron group. Previous works (e.g., [1] and references therein) showed that in metal-poor stars Mn has a different behavior with respect to Fe compared to other iron-peak elements. Concerning the galactic disk, the uncertainties affecting the nucleosynthesis in thermonuclear supernovae (SNe Ia) [2] are a major limitation to our understanding of the evolution of Mn. For instance, while it is clear that SNe Ia produced most of the Mn in the solar system (e.g., [3]), the reproduction of the observed $[\text{Mn/Fe}]$ trend in the galactic disk by theoretical galactic chemical evolution models requires robust SNIa abundance yields and a defined picture of the contribution from different types of SNe Ia (e.g., [4]). In this work we provide: 1) the measurement for Mn abundances for 247 F-G-K-type dwarf stars belonging to the different galactic disk populations and 2) the discussion on the origin of the Mn production in the galactic disk.

2. Observation, atmospheric parameters, and abundance determination
The spectra of the high-resolution echelle spectrographs SOPHIE and ELODIE on board 1.93m telescope of OHP (France) with resolving power $R = 75000$ and 42000 for the wavelengths range 4400 – 6800 Å were used. The models by [5] were applied to determine Mn abundance. The atmospheric parameters of stars were taken from [6]. The Mn abundance were obtained with the LTE STARSP software package [7] and the VALD atomic data [8] using the lines of Mn I 4783,
4823, 5432, 6013 and 6021 Å with taken into account the HFS. As [9] found the LTE [Mn/Fe] ratio might underestimate the real Mn abundances up to 0.5-0.6 dex for the metal-poor stars, and about 0.1 dex for stars of solar like metallicities. The difference in the NLTE corrections varies for lines of different multiplets are often exceeds 0.10 dex. The LTE Mn abundances obtained from the lines of different multiplets must show the systematic difference between them. As we can see from figures 1, 2 there is no systematic trend observed. Furthermore, the development of an adequate model of the Mn atom is complicated by the absence of detailed computations of atomic data. Therefore, the LTE determinations of the Mn abundance are correct, and the total measurement error does not exceed 0.10 dex accounting for the uncertainty in the stellar parameters and the accuracy of the synthetic spectrum fitting.

Figure 1. The difference between Mn abundances determined with the lines 4783 and 6013 Å on Teff for thin disk stars.

Figure 2. The difference between Mn abundances determined with the lines 4783 and 6013 Å on [Fe/H] for thin disk stars.

3. Results and discussion
In the figure 3 the dependence of [Mn/Fe] vs. [Fe/H] is shown for our stellar sample: thin disk stars are marked as open symbols, thick disk stars as full symbols, the Hercules stream stars and unclassified stars are marked as black asterisks and points, respectively.

Figure 3. [Mn/Fe] vs. [Fe/H]

For stars with [Fe/H] < -1, the [Mn/Fe] ratio is dominated by core-collapse supernovae (CCSNe, e.g., [3]). In massive stars the only stable isotope of Mn (\(^{55}\text{Mn}\)) is formed mostly by the SN explosion in incomplete explosive Si-burning conditions as \(^{56}\text{Co}\) (e.g., [10], [11], [12]). As odd-Z element, in principle Mn production is increasing with the increasing of the initial metallicity (e.g., [11], [13]). Most of Fe is produced as radiogenic \(^{56}\text{Fe}\) from radioactive \(^{56}\text{Ni}\). This isotope is mainly made under complete explosive Si-burning conditions as primary product (i.e., independently from the initial metallicity of the star). Present uncertainties related to the
CCSN engine, to the relevance of asymmetries before and after the CCSN, and the SN-shock propagation through the massive star progenitor (e.g., [14], [15], [16], [17]) affect the final Mn/Fe ratio in the SN ejecta, possibly explaining the large [Mn/Fe] spread observed in the early Galaxy. Given that CCSNe produced about 30-50% of the Fe observed in the solar system, this means that 12-20% of the solar Mn is made by CCSNe. For [Fe/H] > -1, the [Mn/Fe] ratio in disk stars is increasing up to the solar ratio (figure 3), due to the contribution from thermonuclear supernovae (SNIa, e.g., [2]) which on average is larger for Mn than for Fe.

The rising [Mn/Fe] trend has been proposed as a evidence of: 1) a gradual enrichment by SNIa ejecta of the ISM [18]; 2) the increasing Mn/Fe ratio with the increasing in the SNIa yields of the progenitor metallicity [19]; 3) the overlapping contribution of different types of SNIa. Thus, this trend may be used for indirect diagnostic of the relative contribution from different types of SNIa [4], [20].

4. Conclusions
– Within the metallicity range of our target stars, we confirm that the [Mn/Fe] ratio is increasing with the increase of metallicity. This is due to the contribution to the Galactic chemical evolution of Mn from SNe Ia, which is increasing compared to Fe with the increasing of the metallicity of the supernova progenitor.
– The possibility to use the [Mn/Fe] as a diagnostic of the relative contribution from different types of SNe Ia is appealing, but the impact of the different uncertainties in the stellar yields and from galactical chemical evolution simulations need to be fully considered.

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