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Evolution of lithium in the Galactic discs

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Abstract. We investigate the evolution of lithium in the Galactic discs by means of detailed chemical evolution models in the light of recent spectroscopic data from Galactic stellar surveys. In particular, we focus on the decrease of lithium at high metallicity observed by several surveys, which still remains unexplained by theoretical models. We study the different lithium producers and we confirm that novae are the main source of lithium in the Galaxy, in agreement with other previous studies. Moreover, we show that, by assuming that the fraction of binary systems giving rise to novae is lower at higher metallicity, we can explain the lithium decline at super-solar metallicities: the above assumption is based on independent constraints on the nova system birthrate, that have been recently proposed in the literature. As regards to the thick disc, it is less lithium enhanced due to the shorter timescale of formation and higher star formation efficiency with respect to the thin disc and, therefore, we have a faster evolution and the ”reverse knee” in the log(Li/H)+12 vs. [Fe/H] relation is shifted towards higher metallicities, in agreement with the time-delay model.

Key words. nuclear reactions, nucleosynthesis, abundances - novae, cataclysmic variables - Galaxy: abundances - Galaxy: evolution - galaxies: ISM.

1. Introduction

This is a golden period for Galactic Archaeology, due to the advent of large spectroscopic surveys and missions. Thus, a huge amount of data has been collected, but still there are many open questions that need to be solved by theoretical models. Among these questions, one of the most puzzling topics is represented by the Galactic lithium evolution and the dichotomy between the thick and thin discs; moreover, the decrease of lithium at high metallicity which has been recently observed by several spectroscopic surveys still has to be well-understood by theoretical models. In this context, the aim of this work is to study the evolution of lithium in the Galactic thick and thin discs by means of detailed chemical evolution models in the light of recent spectroscopic data from Galactic stellar surveys.

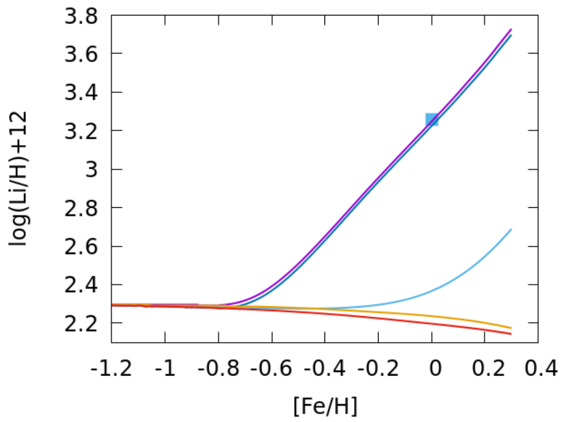

Fig. 1. The predicted lithium abundance as a function of [Fe/H] for the reference model of the Galactic thin disc. The different lithium sources have been isolated: all sources (purple line), only novae (blue line), only GCR (light-blue line), only AGB (orange line), only astration (red line). The meteoritic value is taken by Lodders et al. (2009) (light-blue square).

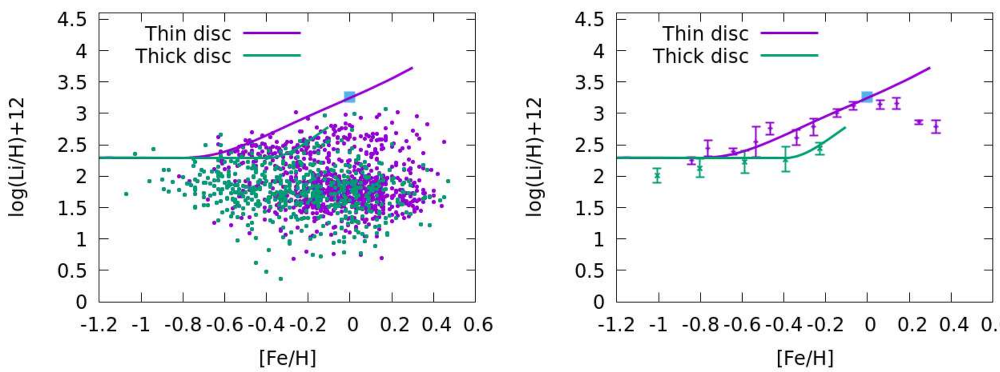

Fig. 2. *Left-hand panel:* The observed and predicted lithium abundance as a function of [Fe/H] for the reference models of the Galactic discs. The predictions are from the parallel model of the thick disc (green line) and thin disc (purple line). The data are from Gaia-ESO Survey (Fu et al. 2018) for the thick disc (green dots) and thin disc (purple dots). The meteoritic value is taken by Lodders et al. (2009) (light-blue square). *Right-hand panel:* Same as the left-hand panel, but the data are from AMBRE (Guiglion et al. 2016).

2. Results

For the Galactic thick and thin discs, we consider the parallel model developed by Grisoni et al. (2017) for the solar neighborhood, and then extended to the other Galactocentric distances in Grisoni et al. (2018). In this scenario, we assume that the Galactic thick and thin discs start forming at the same time, but evolve at different rates. In particular, the thick disc evolve on a shorter timescale of formation (τ_1=0.5 Gyr) and with higher star formation efficiency (ν_1=2 Gyr^{-1}) with respect to the thin disc (τ_2=7 Gyr, ν_2=1 Gyr^{-1}). These parameters have been tuned to reproduce the metallicity distribution function of thick and thin discs stars and the abundance patterns of α-elements (Grisoni et al. 2017, 2018) as well as the ones of neutron-capture elements (Grisoni et al. 2020). Here, we apply the parallel model to follow the evolution of lithium in the Galactic thick and thin discs. Regarding the lithium prescriptions, we adopt:

i) Ventura et al. (2013, private communication) for LIMS (1-6 $M_\odot$) and super-AGB (6-8 $M_\odot$);
ii) the Li ejected during one nova outburst is assumed to be in the range given by Izzo et al. (2015);
iii) Galactic cosmic rays as given by Smiljanic et al. (2009, see also Cescutti & Molaro 2019).

For further details on the model prescriptions, we address the interested reader to Grisoni et al. (2019).

In Fig. 1, we show the predicted lithium abundance as a function of [Fe/H] for the reference model of the Galactic thin disc. Here, the different lithium sources have been isolated and we can see that the main lithium producers in the Galaxy are novae, in agreement with other previous studies. Novae were first included in a detailed chemical evolution model by D'Antona & Matteucci (1990) (see also Romano et al. 1999, 2001, 2003; Matteucci 2010). The importance of novae was recently pointed out by Izzo et al. (2015) and Cescutti & Molaro (2019). AGB stars produce tiny amounts of Li during their lifetimes; indeed, the model that includes only their contribution is barely discernible from the case of pure stellar astration.

In Fig. 2, we show the observed and predicted lithium abundance as a function of [Fe/H] for the reference models of the Galactic discs. We predict a clear dichotomy between the Galactic thick and thin discs, as claimed by many spectroscopic data (Guiglion et al. 2016, Fu et al 2018, Bensby & Lind 2018). As regards to the Galactic thick disc, we predict that it is less lithium enhanced due to the shorter timescale of formation and higher star formation efficiency with respect to the thin disc and, therefore, we have a faster evolution and the "reverse knee" in the log(Li/H)+12 vs. [Fe/H] relation is shifted towards higher metallicities, in agreement with the time-delay model (see Matteucci 2012).

Finally, in Fig. 3, we focus on the evident ISM lithium decline at high metallicities, which has been observed in many observational datasets (Delgado Mena et al. 2015, Guiglion et al. 2016, Fu et al 2018, Bensby & Lind 2018). This feature still needs to be well-understood in terms of Galactic chemical evolution models. Possible explanations that have been proposed in the literature are:

i) lower yields of Li from single stars at high metallicities, even if not physically motivated (Prantzos et al. 2017);
ii) radial migration (Guiglion et al. 2019, Minchev et al. 2019).

Here, we propose a further explanation for the ISM lithium decline at high metallicities, as due to a lower fraction of binary systems giving rise to novae at higher metallicities. This idea has been suggested by the studies of Gao et al. (2014, 2017) and Yuan et al. (2015), and then implemented in our detailed chemical evolution models (Grisoni et al. 2019). In particular, we assume that the fraction of binary systems giving rise to novae α is constant up to [Fe/H]=0 (α=0.1) and then it decreases linearly with metallicity (α=0.1-β[Fe/H] with β=0.1,0.2,0.3,0.33, see Grisoni et al. 2019 for further details). Here, we show our predictions from the parallel model for the thin disc with constant α and with different variable α laws: in this way, we can get the bending at high metallicities.

3. Conclusions

In conclusion, in Grisoni et al. (2019), we analyse the various lithium producers and confirm that novae are the main source of lithium in the Galaxy, in agreement with other previous studies. Moreover, we show that, by assuming that the fraction of binary systems giving rise to novae is lower at higher metallicity, we can suggest a novel explanation to the lithium decline at super-solar metallicities: the above as-

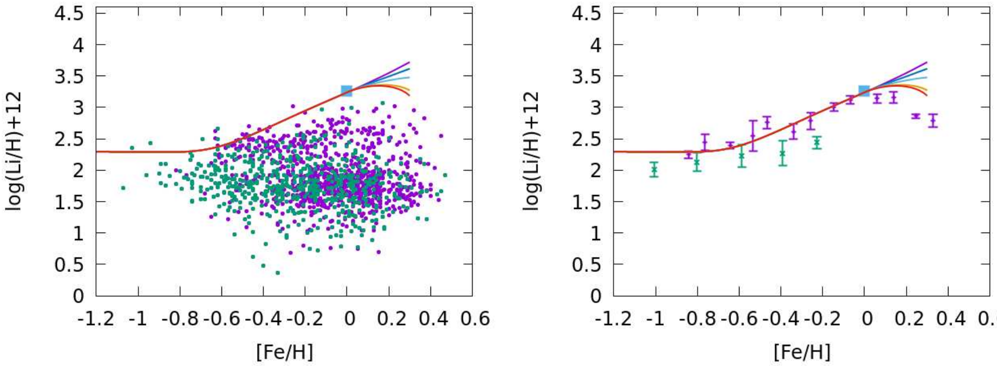

Fig. 3. *Left-hand panel*: The observed and predicted lithium abundance as a function of [Fe/H] for the Galactic thin disc. The predictions are from the parallel model for the thin disc with constant α (purple line) and with different variable α laws (see text for details). The data are from Gaia-ESO Survey (Fu et al. 2018) for the thick disc (green dots) and thin disc (purple dots). The meteoritic value is taken by Lodders et al. (2009) (light-blue square). *Right-hand panel:* Same as the left-hand panel, but the data are from AMBRE (Guiglion et al. 2016).

sumption is based on independent constraints on the nova system birthrate, that have been recently proposed in the literature. As regards to the thick disc, it is less lithium enhanced due to the shorter timescale of formation and higher star formation efficiency with respect to the thin disc and, therefore, we have a faster evolution and the reverse knee in the log(Li/H)+12 vs. [Fe/H] relation is shifted towards higher metallicities, in agreement with the time-delay model.

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