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Lithium depletion in solar analogs

Age and mass effects

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Abstract. The goal of this work is to determine the lithium abundances of a sample of around 150 solar-type stars as a function of stellar age and mass to provide constraints for stellar evolution models. The high-resolution (R = 115000) spectra used in this project were taken with the HARPS spectrograph, at ESO's La Silla observatory. We employed the method of high precision differential spectroscopy, measuring equivalent widths of spectral lines to determine atmospheric parameters and infer masses and ages. The lithium abundance was determined via the spectral synthesis method. Our results indicate that stellar age is the most important factor that affects the lithium abundance in Sun-like stars.

Resumo. O objetivo do trabalho é determinar as abundâncias de lítio de uma amostra de cerca de 150 estrelas em função da idade e massa estelar para obter restrições a modelos de evolução estelar. Os espectros de alta resolução (R = 115000) utilizados neste projeto foram obtidos com o espectrógrafo HARPS, no observatório La Silla do ESO. O método empregado foi de espectroscopia diferencial de alta precisão, no qual são medidas larguras equivalentes de linhas espectrais para determinar os parâmetros atmosféricos e inferir massas e idades. As abundâncias de lítio foram determinadas por meio do método de síntese espectral. Os resultados indicam que a idade estelar é o fator que mais influencia a abundância de lítio em estrelas de tipo solar.

Keywords. Stars: abundances – Stars: evolution – Stars: solar-type – Stars: fundamental parameters – Techniques: spectroscopic

1. Introduction

The study of lithium (Li) abundance in stars is essential to stellar astrophysics, because it can provide us with crucial information concerning transport phenomena on stellar interiors, especially near the base of the convective zone. It is known that Li is destroyed in the inner layers of stars via proton capture, at temperatures of around 2.5×10^6 K, something that can only be reached below the convective zone, which has a temperature of 2×10^6 K.

According to the standard model for the Sun, the lithium abundance should be constant over time, because it does not predict a transport mechanism that can take the lithium below the convective zone, to stellar regions with a high enough temperature to deplete this element. However, what is observed is that older stars present lower lithium abundances, indicating that part of their lithium is destroyed as they evolve. Newer models are able to predict lithium depletion, considering stellar rotation effects and extra transport mechanisms, such as convective overshooting and gravitational settling.

The goal of the project is to determine the dependence of Li abundance on stellar age and mass for a sample of ∼150 stars with homogeneous coverage in mass and age, allowing us to compare different non-standard stellar models. The importance of selecting stars within a large range of masses lies in the fact that low-mass stars have thicker convective zones. Therefore, we expect low-mass stars to deplete more Li. A similar effect happens in iron-rich stars.

2. Methods

To conduct our study, we selected high-resolution (R = 115000) spectra taken with ESO's HARPS spectrograph. The spectra were combined using IRAF to reach a total SNR between 250 - 1000.

To determine the atmospheric parameters via the differential line-by-line method (Meléndez et al. 2014), we measured equivalent widths of over 100 FeI and FeII lines for the stars in our sample and for the Sun, which was used as the reference star. The effective temperature, log g, [Fe/H] and microturbulence velocity were obtained with the MOOG code, accessed through the q^2 package.

The Li abundances were determined via the spectral synthesis of the Li line around 6707.8 Å (Fig. 1), adjusting iteratively the abundances of Li and other nearby species (Fig. 2) with the 1D LTE MOOG code.

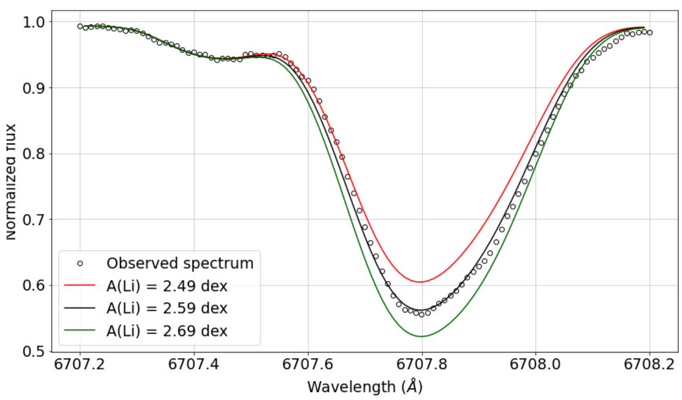

Figure 1. Spectral synthesis of the star HIP 6276.

3. Results

The resulting atmospheric parameters have low uncertainties due to the method employed (typically, $\sigma_{\rm Teff} \sim 5$ K, $\sigma_{\log g} \sim 0.1$

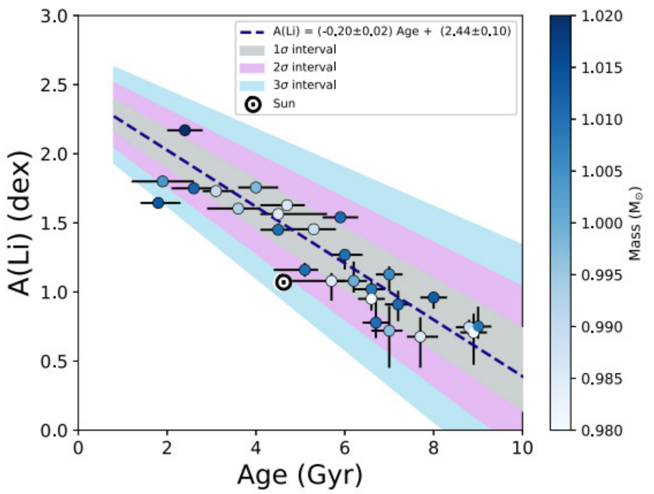

Figure 2. Synthetic solar spectrum and the contributions of different species surrounding the Li line (Carlos et al. 2016).

dex, $\sigma_{[Fe/H]} \sim 0.1$ dex and $\sigma_{vt} \sim 0.1$ km/s), which permits us to perform our analysis of the correlation between Li abundance and stellar parameters with high precision.

Our results confirm the qualitative dependence of lithium abundance with stellar age found in the literature (Carlos et al. 2019). Fig. 3 shows that older stars are the most Li-poor, even when systematically presenting lower iron abundances. This indicates that stellar age is most likely the main factor that influences the Li abundance in solar analogs. Also, our sample of lower mass stars systematically shows lower Li abundances.

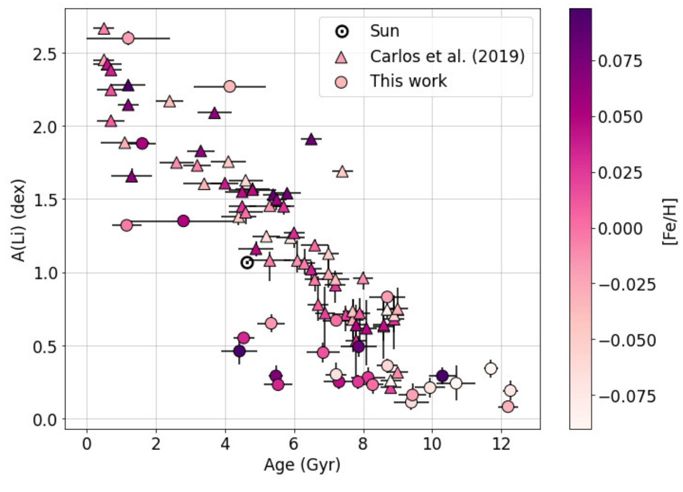

Figure 3. A(Li) plotted against stellar age, color-coded by [Fe/H]

Fig. 3 also shows that some of the stars in our sample (specificaly, those with less than ~0.9 solar masses) are too old. Currently, we are verifying potential problems on some of our sample stars.

4. Conclusions

The present work has a great importance in the study of stellar interiors and transport mechanisms. Our results present low uncertainties and indicate that stellar age is the most important factor that affects the lithium abundance in Sun-like stars. Our next step is to verify the stellar ages and increase the sample.

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