Lithium Isotopic Abundances in Old Stars

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Summary. Lithium is an element of great importance from a cosmological point of view. Observations of its light isotope ^{6}Li are very delicate and in the literature, detections for only a handful of metal-poor stars are found. High quality spectra ($S/N \sim 450$, $R \sim 100000$) of the Li I 670.8 nm resonance line of six metal-poor stars, taken at the Subaru telescope, are being analysed. The results based on the still early stage of the analysis suggest one possible detection and four possible upper limits (including the two most metal-poor stars in the sample) for ^{6}Li. The observed spectra of the remaining star suggest that there is very little ^{6}Li, if any at all.

1 Introduction

The atmospheres of metal-poor stars are good laboratories to investigate processes which occurred in the early Galaxy. These processes left their signatures printed in these atmospheres contents. The spectral analysis of metal-poor stars can sometimes be difficult, especially when dealing with detections of weak features. Nevertheless, these analysis represent an important way to retrieve some of the information contained within the stellar chemical composition. Most of the lithium observed in metal-poor stars is expected to be produced during Big Bang nucleosynthesis. However, lithium is a fragile element whose abundances could be depleted by mixing processes. These processes alter the initial composition and they do it at a different level depending on the element and on the isotope. Determinations of isotopic lithium abundances can set constraints on the possible amount of depletion and on the degree the observed abundance value of lithium in metal-poor stars (plateau value) might deviate from the primordial value. At the moment, the value derived from standard cosmology in combination with WMAP results disagrees with the plateau value.

The detection of ^{6}Li is still a challenge. High quality spectra and high precision analysis are necessary to detect the slight asymmetry, which is produced by the isotopic shift, in the line profile.

2 Data and Analysis

We have analysed the spectra of six metal-poor stars taken in May 2005 with the High Dispersion Spectrograph mounted at the 8.2-m Subaru telescope. Our intention, with this preliminary analysis, is to show why high precision spectroscopy is required for isotopic lithium abundance determinations, rather than to give final results. Observational data were reduced following the standard procedures, using IRAF. The reduced spectra are of very high quality; typical values reached for the signal-to-noise ratios and the resolving power are $S/N = 300-650$ and $R = 90000-100000$ around the Li I 670.8 line.

Note that isotopic abundance ratios determinations are not too sensitive to changes in the stellar parameters ($T_{\rm eff}$, $\log g$, [Fe/H], ξ). Hence for the purpose of this analysis, we have assumed values, with the exception of metallicity, from the literature ([2] and [3]). Metallicity values were derived spectroscopically from the equivalent width of a set of Fe I lines. The assumed stellar parameter values are given in Table 1.

Table 1. Stellar parameters and ^{6}Li/^{7}Li ratios for the best guess fits

Star	$T_{\rm eff}$	$\log g$	[Fe/H]	ξ	^{6}Li/^{7}Li
BD−04°3208	6338	4.00	−2.21	1.5	≤ 0.05
G 64-37	6318	4.16	−3.12	1.5	≤ 0.05
BD+02°3375	5855	4.16	−2.12	1.5	0.01
BD+20°3603	6092	4.04	−2.15	1.5	≤ 0.03
BD+26°3578	6239	3.87	−2.25	1.5	0.08
LP815-43	6514	4.23	−2.72	1.5	≤ 0.08

Once stellar parameters were specified, MARCS model atmospheres were computed and used in the synthesis of 1D-LTE spectra (BSYN) of the Li I 670.8 nm resonance line (and other lines of interest). The synthetic spectra were convolved with two functions which mimic the instrumental and the stellar line broadening respectively. The observed Th-Ar lamp lines were used to get the widths (FWHM=3.10–3.20 km/s) of the Gaussian describing the instrumental profile, while the observed Ca I line at 612.2 nm was used for the modelling of the macroscopic stellar broadening. A radial-tangential profile was assumed for the stellar broadening (widths= 2.50–4.20 km/s). The detection of the ^{6}Li isotope is based on the detection of the slight asymmetry, produced by the isotopic shift, in the red wing of the stronger ^{7}Li line. The observed and the synthetic line profiles were compared (see Fig. 1). ^{6}Li/^{7}Li ratios together with the total lithium abundances where changed until the best fit was reached.

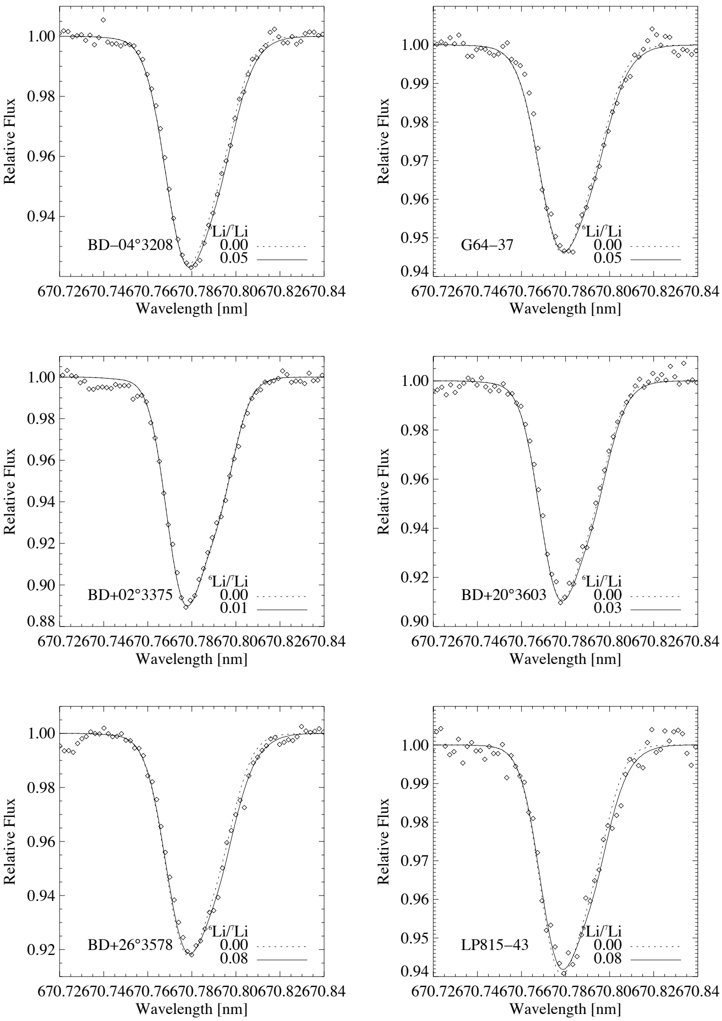

Fig. 1. Comparison of the observed spectra (diamonds) for the Li I 670.8 nm line with the synthetic spectra (solid and dashed lines).

3 Isotopic Abundance Ratios and Our Best Guess Fit

The analysis presented here is still at an early stage, hence we refrain of claiming any certain detection. Instead, we will refer to possible detections or possible upper limits according to our guess for the best fit. They will be confirmed by a proper statistical method like a χ^2-fit later (future publication). There are cases where the possible detection is more clear than in others. For some other stars, the spectral synthesis indicates that if the feature does exist, it is so weak that the high quality of the observed spectra is still not enough for the detection (eg. BD+20°3603, $S/N \sim 400$). Values for our best estimates so far are listed in Table 1, one possible detection and four possible upper limits. It is too soon for a proper discussion and for drawing final conclusions. However, we present the preliminary results (see Table 1) and discuss their limitations.

LP815-34 is an interesting target because of its low metallicity, the second lowest of the observed sample. [1] has reported a detection for this star. We are not yet in a good position to claim any detection, as our fits indicates that $0 \leq {}^6\mathrm{Li}/{}^7\mathrm{Li} \leq 0.08$ values are still compatible with the observations and the signal-to-noise ($S/N \sim 500$). The other metal-poor star, G 64-37 ([Fe/H]=−3.12), may represent a case where the broadening determination was not accurate enough. This would be not a surprise given that only one line was used for this purpose. The inclusion of more lines may improve the situation, but in such metal-poor star, it would be difficult to find suitable ones as the lines in the spectra of these stars are weak. We will investigate the effect of introducing two other free parameters, the wavelength zero-point and the continuum level, on our estimates.

In the case of the possible detections, we have BD+26°3578. This star was one of the first metal-poor stars for which a positive detection was published [4]. Recently, [1] has reported a value of ${}^6\mathrm{Li}/{}^7\mathrm{Li} = 0.01$ for this star, which is in disagreement with the value of 0.05 in [4] and even more with our estimate of 0.08. In order to make a more rigorous comparison, we should await the completion of our more detailed analysis. The other star in common with [1] is BD-04°3208 for which there is a good agreement. It will be very interesting to confirm whether BD+02°3375 has such a low ${}^6\mathrm{Li}$ content which could be a signature of depletion processes acting on the star. Irrespectively, this star is the one with the lowest T_{eff} value in the observed sample.

A more complete analysis will enable us to study in more detail the possible scenarios and mechanism of ${}^6\mathrm{Li}$ production, cosmic ray production by supernovae or by star formation shocks, stellar flares etc. If the results from our preliminary analysis are confirmed by our more detailed analysis, we would have a few interesting detections and some equally interesting non-detections. We have embarked on that task, and the results, along with an analysis of uncertainties, are going to appear in a later publication.

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