Lithium-rich Giants in LAMOST Survey. I. The Catalog

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Abstract

Standard stellar evolution model predicts a severe depletion of lithium (Li) abundance during the first dredge up process (FDU). Yet a small fraction of giant stars are still found to preserve a considerable amount of Li in their atmospheres after the FDU. Those giants are usually identified as Li-rich by a widely used criterion, A(Li) > 1.5 dex. A large number of works dedicated to searching for and investigating this minority of the giant family, and the amount of Li-rich giants, has been largely expanded on, especially in the era of big data. In this paper, we present a catalog of Li-rich giants found from the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey with Li abundances derived from a template-matching method developed for LAMOST low-resolution spectra. The catalog contains 10,535 Li-rich giants with Li abundances from ~1.5 to ~4.9 dex. We also confirm that the ratio of Li-rich phenomenon among giant stars is about 1%—or more specifically, 1.29%—from our statistically important sample. This is the largest Li-rich giant sample ever reported to date, which significantly exceeds amount of all reported Li-rich giants combined. The catalog will help the community to better understand the Li-rich phenomenon in giant stars.

Unified Astronomy Thesaurus concepts: Late stellar evolution (911); Stellar abundances (1577); Late-type giant stars (908); Chemically peculiar stars (226)

1. Introduction

Fragile elements, such as lithium (Li), will be easily destroyed in the deep layers of stellar atmospheres, where the temperatures are usually as high as (if not higher than) millions of Kelvins. During the first dredge up (FDU) process, matters circulate from the surface of a star to the bottom of its convective shell, bringing a large amount of lithium down into the deep layers where they can hardly survive. Thus, the severe depletion of Li in the atmosphere of a giant star is the natural consequence of stellar evolution (Iben 1967a, 1967b). Assuming an initial abundance of A(Li) = 3.3 dex for a main-sequence star of approximately solar metallicity and mass above ~1.4 M_☉, diluted for ~60 times due to FDU, its Li abundance will be below 1.5 dex when it finishes FDU.

The predicted depletion has been confirmed by a large number of observations of giants (Brown et al. 1989; Lind et al. 2009; Liu et al. 2014; Kirby et al. 2016, for example). However, Wallerstein & Sneden (1982) reported a K giant with A(Li) up to 3.2 dex. Since then, about 600 giants with A(Li) over 1.5 dex were reported with object IDs/positions and Li abundances (e.g., Brown et al. 1989; Reddy & Lambert 2005; Kumar et al. 2011; Ruchti et al. 2011; Kirby et al. 2012; Martell & Shetrone 2013; Adamów et al. 2014; Casey et al. 2016; Li et al. 2018; Smiljanic et al. 2018; Deepak & Reddy 2019; Singh et al. 2019a, 2019b; Zhou et al. 2019). Furthermore, a number of Li-rich giants with special features have been found (e.g., Kumar & Reddy 2009; Adamów et al. 2012; Silva Aguirre et al. 2014; Yan et al. 2018). In addition, methods of searching for Li-rich giants from low-resolution spectra were reported in different works (e.g., Martell & Shetrone 2013; Kumar et al. 2018; Casey et al. 2019). All of these efforts largely expanded the Li-rich family and provided observational constraints that helped to understand how Li is enhanced in the evolved stars (e.g., Alexander 1967; Cameron & Fowler 1971; Sackmann & Boothroyd 1999; Siess & Livio 1999; Denissenkov & Herwig 2004; Charbonnel & Lagarde 2010) and even how Li evolved in each scale of our Galaxy (e.g., Fu et al. 2018; Carlos et al. 2019; Cescutti & Molaro 2019).

Although a considerable amount of Li-rich giants have been reported, they are still rare objects compared to the huge amount of normal ones. The ratio of Li-rich to normal giants is very low. Brown et al. (1989) found that only ~1.5% of giants are Li-rich in nearby stars, and similar ratios were reported by Kumar et al. (2011), Liu et al. (2014), etc. Observations of the Galactic bulge revealed a slightly lower ratio of 0.5%–0.7% (Gonzalez et al. 2009; Lebzelter et al. 2012), and an analogy result was found for the Galactic thick-disk objects by Monaco et al. (2011). The ratios estimated from large survey programs are ~0.9% from the Gaia-ESO survey (Casey et al. 2016; Smiljanic et al. 2018), ~0.8% from the Radial Velocity Experiment survey (RAVE) sample (Ruchti et al. 2011), ~2.0% from the Penn State-Torun Centre for Astronomy Planet Search (PTPS) data (Adamów et al. 2014) and ~0.2%–0.3% from Sloan Digital Sky Survey and the Gaia and the Galactic Archeology with HERMES (GALAH) data (Martell & Shetrone 2013; Deepak & Reddy 2019). Li-rich giants have been sporadically reported due to their rareness in the past ~40 yr. Although hundreds of Li-rich giants with object IDs/positions and abundances available to the astronomy
community for further study, their data were usually obtained from different works, introducing tricky biases due to the diverse methods, samples, data qualities, etc. For a better understanding the Li-rich phenomenon in the evolved stars, a catalog of Li-rich giants identified by systematic and coherent method from massive spectroscopic survey program is thus essential.

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey (Cui et al. 2012; Zhao et al. 2012) has finished its six years of the phase-I survey in the low-resolution mode \((R \approx 1800)\) and has begun its phase-II survey in a combination of low- and medium-resolution modes \((R \approx 7500)\). The low-resolution spectra observed by LAMOST to date number over 10 million. It is almost certain that large amount of Li-rich giants are hidden in this vast database. The scope of this study is to systematically search for Li-rich giants from LAMOST data release 7 (DR7) low-resolution spectra data and to derive the Li abundances from a template-matching method. We present a catalog of Li-rich giants obtained from LAMOST including the LAMOST ID, position, effective temperature, surface gravity, metallicity, Li abundance, etc.

The paper is assembled as follows. In Section 2, we briefly describe the giant sample selected from the LAMOST low-resolution spectra. The method and procedure of deriving the Li abundances and error estimation are described in detail in Section 3, and in Section 4, we present the results of our Li-rich sample. Finally, a short discussion and summary are given in Section 5.

2. Stellar Sample

In this study, we used LAMOST low-resolution spectra obtained from 2011 October to 2019 June, and the stellar atmospheric parameters \((T_{\text{eff}}, \log g, [\text{Fe}/\text{H}])\) and radial velocities \((\text{RV})\) determined by the LAMOST Stellar Pipeline (LASP; Luo et al. 2015). The giants were selected based on the following criteria: \(\log g < 3.5\) and \(T_{\text{eff}} < 5600\) K, which are revised from Liu et al. (2014). We got rid of the objects of \(3.5 < \log g < 4.0\) when \(4600 < T_{\text{eff}} < 5600\) K, which were also identified as giants by Liu et al. (2014), because they are contaminated by the newly formed stars with a slightly higher rate. The final sample includes 814,268 giants. Figure 1 shows the Hertzsprung–Russell (HR) diagram of all the stellar objects observed by the LAMOST low-resolution mode, and the giant sample is in the box with the red dashed line.

3. Method

A template-matching method has been adopted to determine the Li abundances in the term of [Li/Fe], and then they are converted into the expression of A(Li) by the relationship of \(A(\text{Li}) = \frac{\text{[Li]} - \text{[Fe]}}{\text{[Fe]}} + \frac{\text{[Fe]}}{\text{[H]}} + A(\text{Li})_{\odot}\). Our method of deriving the [Li/Fe] is similar to the method adopted by Li et al. (2016), which is based on the LAMOST stellar parameter pipeline at Peking University (LSP3; Xiang et al. 2015) and was developed to determine the [\(\alpha/\text{Fe}\)] from LAMOST low-resolution spectra.

3.1. The Synthetic Template Spectra

The SPECTRUM synthesis code (v2.76, 2010) based on the Kurucz ODFNEW atmospheric models (Castelli & Kurucz 2003) with the standard abundance distribution of Grevesse & Sauval (1998) was used to calculate the template spectra. We applied the atomic line data of Li presented by Shi et al. (2007). In our calculations, a fixed microturbulence of 1.5 km s\(^{-1}\) and a resolution of 2 Å have been adopted for all template spectra. The resolution of the LAMOST spectra is approximately 2.8 Å on average and varies with each individual fiber (Xiang et al. 2015). Templates will be degraded in resolution according to each observed spectrum before matching.

We set the grids as follows: \(3800 < T_{\text{eff}} < 5600\) K in steps of 100 K, \(0.0 < \log g < 4.0\) in steps of 0.25 dex, \(-2.6 < [\text{Fe}/\text{H}] < 0.4\) in steps of 0.2 dex, and \(-3.0 < [\text{Li}/\text{Fe}] < 6.9\) in steps of 0.1 dex. As the Li I resonance line at 6708 Å mixed with the nearby Ca I line at 6717 Å for fast rotation stars, we took account of the influence of the \(\alpha\)-enhancement: the \(\alpha\)-element abundances enhanced by 0.4 dex for stars of [Fe/H] < −0.6 dex. The Li I resonance lines varying with \(A(\text{Li})\) from 1.0 to 3.5 dex in four sets of atmospheric parameters are presented in Figure 2.

3.2. Measuring the Li Abundances

Although the subordinate lines at 6104 and 8126 Å can be detected for some objects with extremely high Li abundance, they are usually too weak to be detectable in the low-resolution spectra. So the strongest Li I resonance line at 6708 Å is used to derive the Li abundances.

The spectra from LAMOST adopt the vacuum wavelength scale, so we converted the vacuum wavelength to the air wavelength after corrected the wavelength by the radial velocity. The process to determine the Li abundances follows two steps:

First, for an object, we generated a set of templates with [Li/Fe] that varies from −3.0 to 6.9 and adopted the atmospheric parameters from LASP by interpolating the grid of the templates. To check how reliable the interpolated template spectra are, we took three templates from the grids and

![HR diagram of the stars observed by the LAMOST low-resolution mode. The giant sample was identified by the following criteria: log g < 3.5 dex and Teff < 5600 K, as shown in the box with red dashed line.](image-url)
Figure 2. Li resonance lines varying with $A(\text{Li})$ from 1.0 to 3.5 dex in four sets of atmospheric parameters. The atmospheric parameters are marked in the sequence of $T_{\text{eff}}$, $\log g$, $[\text{Fe}/\text{H}]$, and different $A(\text{Li})$ marked by different colors in each panel.

Figure 3. Comparison of the original templates (red dashed line) and calculated ones interpolated from adjacent grids (black solid line) for three cases. Their atmospheric parameters ($T_{\text{eff}}$, $\log g$, $[\text{Fe}/\text{H}]$, and $[\text{Li}/\text{Fe}]$) are presented, and the residual of the flux values are also plotted at the bottom of each panel.
interpolated their counterparts and plotted them in Figure 3. It shows that there is a negligible difference between the original and interpolated ones, which will have no obvious impact on our results.

Second, we calculated the chi-square ($\chi^2$) between each template and the observed spectrum over the wavelength range of 6704–6712 Å, which covers the Li I resonance line at 6708 Å. The $\chi^2$ is defined as:

$$\chi^2 = \frac{\sum (O_i - T_i)^2}{\sigma_i^2},$$

where $O_i$ and $T_i$ are the flux of the $i_{th}$ point of the observed and the template spectrum, respectively; $\sigma_i$ is the error of the observed flux at $i_{th}$ pixel; and $N$ is the amount of pixels used in calculation.

Similar to Xiang et al. (2015), we directly matched the non-normalized observed spectra with the templates. As our targets are giants whose spectra have many absorption lines, it is not easy to estimate the continuum level, so this could be worse for the low signal-to-noise ratio (S/N) spectra. Before calculating the $\chi^2$ value, we corrected the spectral shape between the object and the template on the wavelength range of 6600–6800 Å with a third-order polynomial fitting. The $\chi^2$ array was fitted with a Gaussian plus a second-order polynomial to get the minimum $\chi^2$ value, and the corresponding value of $[\text{Li}/\text{Fe}]$ is determined. Then, $A(\text{Li})$ can be derived.

The Li I resonance line at 6708 Å is easily drowned out by noise leading to an invalid result. So, we define three values: (a) the depth of the Li I resonance line at 6708 Å ($D$), (b) the average noise over the wavelength range of 6600–6800 Å ($N$), and (c) the standard deviation of the residuals between the object spectrum and the best-matching template ($S$).

For each spectrum, we require the following conditions been satisfied:

$$D > N \text{ and } D > S.$$ 

The rationale of these two constraints is that the Li I resonance line should be strong enough in order to affirm the reliability. We automatically eliminate the invalid targets and a small percentage of giants with $A(\text{Li}) \geq 1.5$ remained ($\sim 3.4\%$).

Then, we visually checked them carefully one by one, and the main considerations are: whether the Li I resonance line is obviously unaffected by the noise and the spectrum has credible quality, and whether the Li I line of observed spectrum is matchable to the best-fitting template. We eliminated the unmatched or bad quality spectra, and we also inspected whether there are emission lines of N II around H$_\alpha$ and S II around Li resonance in order to get rid of the newly formed objects. Particularly, for the extremely strong Li line at 6708 Å, we checked the other Li I lines (6104 Å and 8126 Å) and the repeated observations if it had any.

Figure 4 shows several examples of different $A(\text{Li})$. The light blue region is the wavelength range to calculate $\chi^2$ value, the blue dots represent the observed spectrum, and the red solid line is the best-matching template.

### 3.3. Error Estimation

The errors of our $A(\text{Li})$ measurements have two aspects: systematic error due to the intrinsic errors in our method and random errors mainly due to the quality of the observed spectra and/or the uncertainties of the stellar parameters.

#### 3.3.1. Systematic Error

The systematic error of our result is estimated by comparing the Li abundance derived from our method to that from the high-resolution (H.Res.) spectra. In our catalog, 59 Li-rich giants are reported by other high-resolution studies (Anthony-Twarog et al. 2013; Martell & Shetrone 2013; Kumar et al. 2018; Li et al. 2018; Yan et al. 2018; Zhou et al. 2018, 2019; Singh et al. 2019b; H.-L. Yan et al. 2019, in preparation). We derived $A(\text{Li})_{\text{LAMOST}}$ of these objects using the LAMOST spectra and the stellar atmospheric parameters provided in the
literature. The left panel plots $A(L)_{\text{LAMOST}}$ against $A(L)_{\text{Hodgkin}}$ with the one-to-one correspondence as a solid line and the corrected as a dashed line after an overall shift of 0.09 dex; different markers and colors stand for different reporters. The right panel shows the distribution of differences between $A(L)_{\text{LAMOST}}$ and $A(L)_{\text{Hodgkin}}$ and the result of the Gaussian fit overplotted with a red solid line.

Figure 5.

Table 1: Information of the Li-rich Giants Reported by Previous Works

| ID               | $T_{\text{eff}}$ (K) | $\log g$ (dex) | $[\text{Fe/H}]$ (dex) | $A(L)_{\text{LAMOST}}$ (dex) | $A(L)_{\text{Hodgkin}}$ (dex) | Reference                     |
|------------------|----------------------|----------------|------------------------|-------------------------------|-------------------------------|--------------------------------|
| NGC6819-W007017  | 4636                 | 2.72           | 0.09                   | 2.4                           | 2.3                           | Anthony-Twarog et al. (2013)   |
| SDSS J1310-0012  | 4550                 | 1.0            | −1.54                  | 2.6                           | 2.15                          | Martell & Shetrone (2013)      |
| SDSS J0652+4052  | 4900                 | 2.9            | 0.04                   | 3.4                           | 3.3                           | Martell & Shetrone (2013)      |
| SDSS J2353+5728  | 5025                 | 3.0            | 0.23                   | 3.5                           | 3.1                           | Martell & Shetrone (2013)      |
| SDSS J0304+3823  | 5125                 | 2.6            | −0.2                   | 2.6                           | 2.4                           | Martell & Shetrone (2013)      |
| LAMOST J0714+1600| 5179                 | 2.4            | −2.16                  | 2.5                           | 2.42                          | Li et al. (2018)               |
| LAMOST J0302+1356| 5206                 | 2.3            | −1.74                  | 2.5                           | 2.34                          | Li et al. (2018)               |
| LAMOST J2146+2732| 5243                 | 2.75           | −1.73                  | 3.2                           | 2.85                          | Li et al. (2018)               |
| TYC 3521-581-1   | 4670                 | 2.3            | −0.09                  | 4.1                           | 3.68                          | Zhou et al. (2018)             |
| TYC 429-2097-1   | 4696                 | 2.25           | −0.36                  | 4.6                           | 4.63                          | Yan et al. (2018)              |
| KIC2305930       | 4750                 | 2.38           | −0.5                   | 4.3                           | 4.2                           | Kumar et al. (2018)            |
| KIC12645107      | 4850                 | 2.62           | −0.2                   | 3.4                           | 3.24                          | Kumar et al. (2018)            |
| TYC 1751-1713-1  | 4830                 | 2.58           | −0.25                  | 4.2                           | 4.15                          | Singh et al. (2019a)           |
| J024710.97+432606.0| 4315               | 2.18           | −0.16                  | 3.6                           | 3.24                          | Zhou et al. (2019)             |
| J055908.81+120339.7| 4920              | 2.77           | −0.37                  | 4.3                           | 3.89                          | Zhou et al. (2019)             |
| J060649.27+212504.9| 5188              | 3.16           | −0.32                  | 2.6                           | 2.53                          | Zhou et al. (2019)             |
| J063943.47+170424.2| 5004              | 3.37           | −0.28                  | 4.2                           | 4.07                          | Zhou et al. (2019)             |
| J074051.22+241938.3| 4986              | 2.72           | −0.17                  | 3.9                           | 4.08                          | Zhou et al. (2019)             |
| J107124.77+144913.0| 4796              | 2.75           | −0.14                  | 3.8                           | 3.51                          | Zhou et al. (2019)             |
| J117172.43+461282.3| 4971              | 2.67           | −0.15                  | 3.2                           | 3.05                          | Zhou et al. (2019)             |
| J225902.66+054256.2| 4514              | 2.15           | −0.1                   | 3.1                           | 3.25                          | Zhou et al. (2019)             |
| J235043.31+361105.7| 4716              | 1.71           | −0.58                  | 2.1                           | 2.31                          | Zhou et al. (2019)             |
| J071813.82+500452.6| 4529              | 2.26           | 0.02                   | 2.8                           | 2.62                          | Zhou et al. (2019)             |
| J072619.82+295808.2| 4605              | 1.81           | −0.34                  | 3.4                           | 2.96                          | Zhou et al. (2019)             |
| J072840.88+070417.4| 4608              | 1.6            | −0.28                  | 2.6                           | 2.47                          | Zhou et al. (2019)             |
| J085929.54+005654.2| 4018              | 0.62           | −0.47                  | 1.8                           | 2.18                          | Zhou et al. (2019)             |
| J103249.02+143714.8| 5072              | 2.79           | −0.37                  | 3.5                           | 3.48                          | Zhou et al. (2019)             |
| J110236.56+133610.3| 4895              | 2.61           | −0.35                  | 2.3                           | 2.18                          | Zhou et al. (2019)             |
| J122223.29+321817.2| 4430              | 2.18           | 0.08                   | 3.8                           | 4.03                          | Zhou et al. (2019)             |
| J122525.23+071638.0| 4764              | 2.16           | −0.19                  | 2.1                           | 2.06                          | Zhou et al. (2019)             |
| J132315.70+034347.4| 4189              | 1.63           | 0.04                   | 1.7                           | 1.85                          | Zhou et al. (2019)             |
| J143038.38+532629.5| 4133              | 1.22           | −0.45                  | 1.7                           | 1.7                           | Zhou et al. (2019)             |
| J153707.04+182421.0| 4722              | 2.11           | −0.06                  | 2.6                           | 2.52                          | Zhou et al. (2019)             |
| J161035.91+331604.8| 4113              | 1.27           | −0.79                  | 2.8                           | 2.41                          | Zhou et al. (2019)             |
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3.3.2. Random Errors

In our results, 2746 giants have repeated observations; these could be used to estimate the random errors. We plotted the differences in $A$(Li) between repeated observations as a function of $S/N$, $T_{\text{eff}}$, log $g$, [Fe/H], and $A$(Li) in Figure 6. In panel (a), all the 2746 objects with repeated observations are included, which shows that the random errors are sensitive to the $S/N$ decreasing from 0.3 to 0.1 dex with an increasing $S/N$. In order to avoid the influence of the $S/N$, only 1118 objects with high-quality data ($S/N \geq 200$) were used in the rest panels. Panels (b) and (c) show that the random errors increase from 0.1 to 0.2 dex with increasing $T_{\text{eff}}$ or log $g$, which may be due to the fact that the lithium line at 6708 Å is stronger at low $T_{\text{eff}}$ or log $g$. The random errors have no obvious relation to the [Fe/H], as shown in panel (d), which may be because the strength of the lithium line has no obvious relationship to [Fe/H]. And panel (e) shows that the scatter of the differences of $A$(Li) remains same when $A$(Li) goes from 2.0 to 4.5 and is slightly larger in the bin of $1.5 \leq A$(Li) $< 2.0$. Note that the lithium line at 6708 Å is strong enough to be detected when $A$(Li) is higher than 2.0. The typical value of random errors is 0.2 dex.

4. Results

The giants with $A$(Li) $\geq 1.5$ are usually defined as Li-rich giants. In our results, 10,535 Li-rich giants are identified. Their information is listed in Table 2, including the LAMOST ID, positions, stellar atmospheric parameters provided by LASP, $A$(Li), and the observed date. Figure 7 shows the histograms of the number of our Li-rich giant sample versus $T_{\text{eff}}$, log $g$, and [Fe/H], respectively. For the distribution of temperature, there is a peak around 4800 K, and there might be another peak around 5100 K. There are two clear peaks around log $g$ $\sim 2.5$ and 3.5 dex, the first is corresponding to the red giant branch and red clump stars. In addition, the distribution of metallicity shows a clear peak around [Fe/H] $\sim -0.15$ and a symmetric profile from $-0.8$ to $+0.5$ dex. For the stars with metallicity lower than $-0.8$ dex, there seems to be a second peak in the range of $-1.5$ to $-1.0$ dex. Figure 8 shows that the number declines with an increasing $A$(Li). The number distribution of $1.5$ dex $\leq A$(Li) $\leq 1.7$ dex is noticeably against the overall trend. This could be because the lithium line is too weak to be detected on the low-resolution spectra when $A$(Li) is smaller than 1.7 dex. Our sample stars in the HR diagram were displayed with a background of all giant samples in Figure 9, and the two group stars around log $g$ of 2.5 and 3.5 dex can also be found.

5. Summary

In this work, we search for Li-rich giants from the LAMOST low-resolution spectra and find 10,535 Li-rich giants with $A$(Li) $\geq 1.5$ dex, which is 1.29% of the all giants in our sample. We developed a method to derive Li abundance for giants from the low-resolution spectra based on template matching. We estimate that the systematic error is $\sim 0.1$ dex and the random error is around 0.2 dex.

Figure 6. Differences in $A$(Li) between multiple observations vs. $S/N$, $T_{\text{eff}}$, log $g$, [Fe/H], and $A$(Li). All the 2746 objects with repeated observations are included in panel (a); only 1118 objects with high-quality data ($S/N \geq 200$) were used in the rest panels. The bin sizes are 100, 200 K, 0.3 dex, 0.3 dex, and 0.5 dex, respectively. The red dots are the mean value and the error bars are the standard deviation of the differences in every bin.

literature, and we show the detailed information for 34 published stars in Table 1. In Figure 5, we present the comparison between $A$(Li)$_{\text{LAMOST}}$ and $A$(Li)$_{\text{HRes}}$ for all the 59 stars. Figure 5 shows a good consistency with an offset of 0.09 dex and a dispersion of 0.24 dex between our measurements and the results derived by high-resolution spectra in the literature. Thus, we consider the systematic error of our result is less than 0.1 dex.
The number distribution of our sample in temperature shows two peaks around 4800 K and 5100 K, respectively. There are also two clear peaks around 2.5 dex and 3.5 dex in \( \log g \).

We found a symmetric distribution in the metallicity range of \(-0.8\) to \(+0.5\) dex, while there seems a second peak around \(-1.25\) dex.

As expected, we found that there is a decline in the number density with increasing Li abundances.

This is the largest Li-rich giant sample up to date, which will help us to investigate the lithium evolution in evolved stars in further work. In the Paper II, we will analysis the properties of

| LAMOST ID         | R.A.          | Decl.         | \( T_{\text{eff}} \) | \( \log g \) | \([\text{Fe/H}]\) | \( A(\text{Li}) \) | DATE       |
|-------------------|---------------|---------------|-----------------------|-------------|----------------|----------------|------------|
| LAMOST J000001.30 +494500.7 | 00:00:01.30 | +49:45:00.7 | 4439 | 2.5 | 0.5 | 2.2 | 2014 Oct 06 |
| LAMOST J000005.50 +454110.6 | 00:00:05.50 | +45:41:10.6 | 4803 | 2.4 | −0.1 | 3.4 | 2015 Oct 14 |
| LAMOST J000007.78 +410505.4 | 00:00:07.78 | +41:05:05.4 | 5259 | 3.3 | 0.2 | 2.7 | 2014 Dec 18 |
| LAMOST J000022.92 +544825.2 | 00:00:22.92 | +54:48:25.2 | 4906 | 2.4 | −0.4 | 4.1 | 2014 Nov 20 |
| LAMOST J000036.02 +273038.9 | 00:00:36.02 | +27:30:38.9 | 4958 | 2.4 | −0.8 | 2.7 | 2016 Dec 10 |
| LAMOST J000041.35 +585002.3 | 00:00:41.35 | +58:50:02.3 | 4689 | 2.7 | 0.1 | 3.5 | 2014 Nov 20 |
| LAMOST J000048.98 +092600.9 | 00:00:48.98 | +09:26:00.9 | 4979 | 3.2 | −0.4 | 1.6 | 2016 Dec 16 |
| LAMOST J000108.96 +072932.9 | 00:01:08.96 | +07:29:32.9 | 4731 | 2.5 | −0.2 | 3.6 | 2016 Dec 16 |
| LAMOST J000119.92 +082335.9 | 00:01:19.92 | +08:23:35.9 | 4801 | 2.3 | −0.5 | 2.4 | 2016 Dec 16 |
| LAMOST J000133.56 +554937.3 | 00:01:33.56 | +55:49:37.3 | 4904 | 2.4 | −0.0 | 1.6 | 2014 Nov 20 |
| LAMOST J000143.05 +254549.5 | 00:01:43.05 | +25:45:49.5 | 4655 | 2.6 | 0.2 | 1.6 | 2016 Dec 10 |
| LAMOST J000151.65 +265848.4 | 00:01:51.65 | +26:58:48.4 | 5071 | 2.5 | −0.5 | 4.7 | 2016 Dec 10 |
| LAMOST J000156.01 +372623.2 | 00:01:56.01 | +37:26:23.2 | 4519 | 2.2 | −0.4 | 3.7 | 2012 Nov 30 |
| LAMOST J000201.61 +445049.1 | 00:02:01.61 | +44:50:49.1 | 4948 | 2.5 | −0.4 | 3.6 | 2015 Oct 14 |
| LAMOST J000205.10 +384906.2 | 00:02:05.10 | +38:49:06.2 | 4937 | 3.1 | −0.1 | 1.6 | 2014 Oct 05 |
| LAMOST J000206.98 +472520.2 | 00:02:06.98 | +47:25:20.2 | 4640 | 2.9 | 0.3 | 1.9 | 2013 Oct 30 |
| LAMOST J000211.20 +532701.4 | 00:02:11.20 | +53:27:01.4 | 4830 | 2.4 | −0.3 | 3.0 | 2014 Oct 06 |
| LAMOST J000227.22 +493429.9 | 00:02:27.22 | +49:34:29.9 | 3989 | 1.4 | −0.2 | 2.7 | 2017 Oct 16 |
| LAMOST J000230.61 +582629.3 | 00:02:30.61 | +58:26:29.3 | 5139 | 2.8 | 0.1 | 2.5 | 2014 Nov 20 |
| LAMOST J000242.92 +435331.3 | 00:02:42.92 | +43:53:31.3 | 5194 | 2.5 | −0.4 | 1.6 | 2014 Dec 18 |

Figure 7. Histograms of our Li-rich giant sample as functions of \( T_{\text{eff}} \), \( \log g \), and \([\text{Fe/H}]\). The bin sizes are 50 K, 0.1 dex, and 0.1 dex, respectively. The distribution of Li-rich giants in temperature shows two peaks around 4800 and 5100 K. For surface gravity, there are two clear peaks around \( \log g \sim 2.5 \) and 3.5 dex. And the distribution of our Li-rich sample in metallicity shows a clear peak around \([\text{Fe/H}] \sim −0.15\) dex. For metal-poor stars, there may be a second peak around \(-1.25\) dex.
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Figure 8. Histogram of $A(\text{Li})$ of our Li-rich giant sample. The bin size is 0.1 dex. The number of lithium giants for each bin declines with an increasing $A(\text{Li})$ except the first bin.

Figure 9. HR diagram of our Li-rich giant sample (colored). The all giants are also presented (gray).

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