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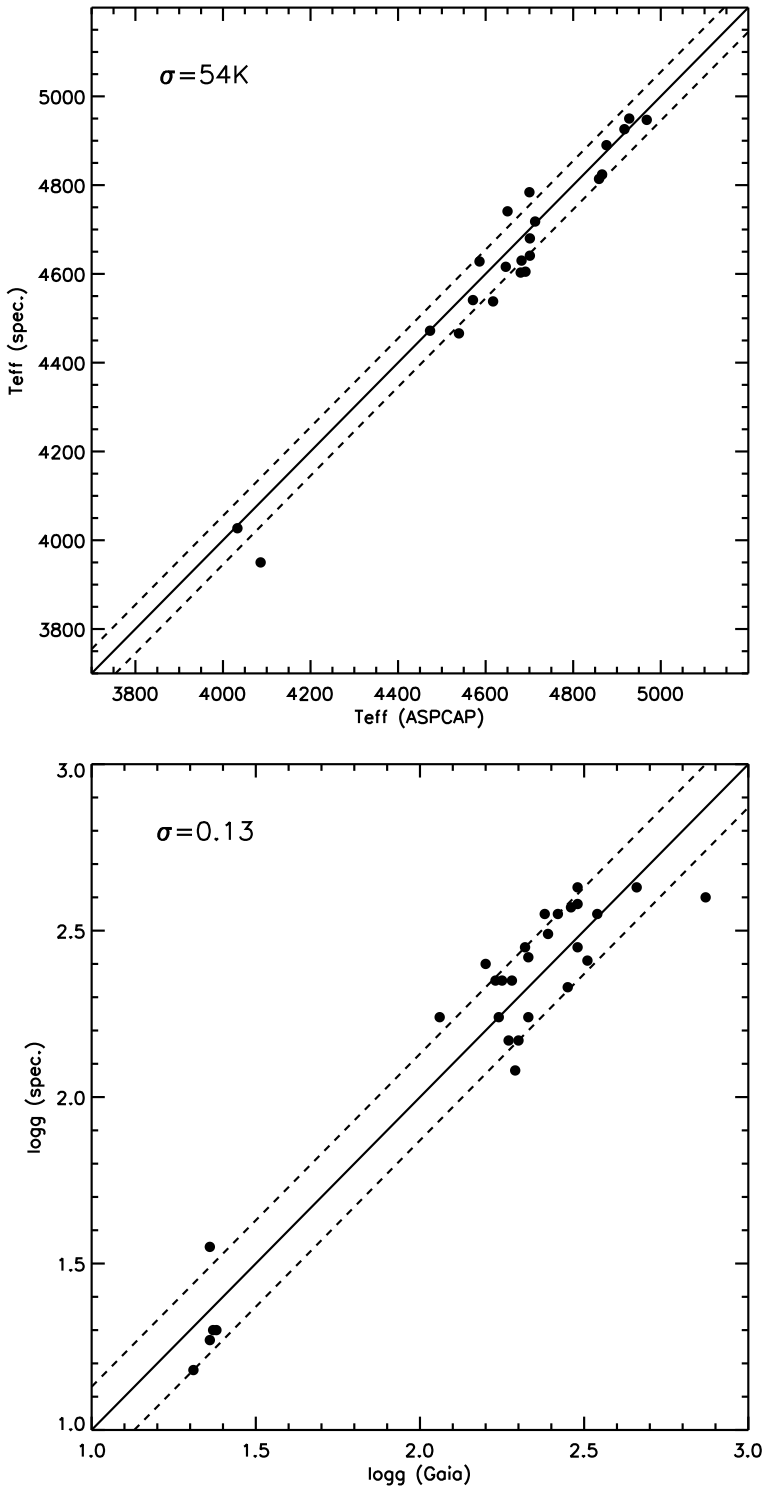
Supplementary information

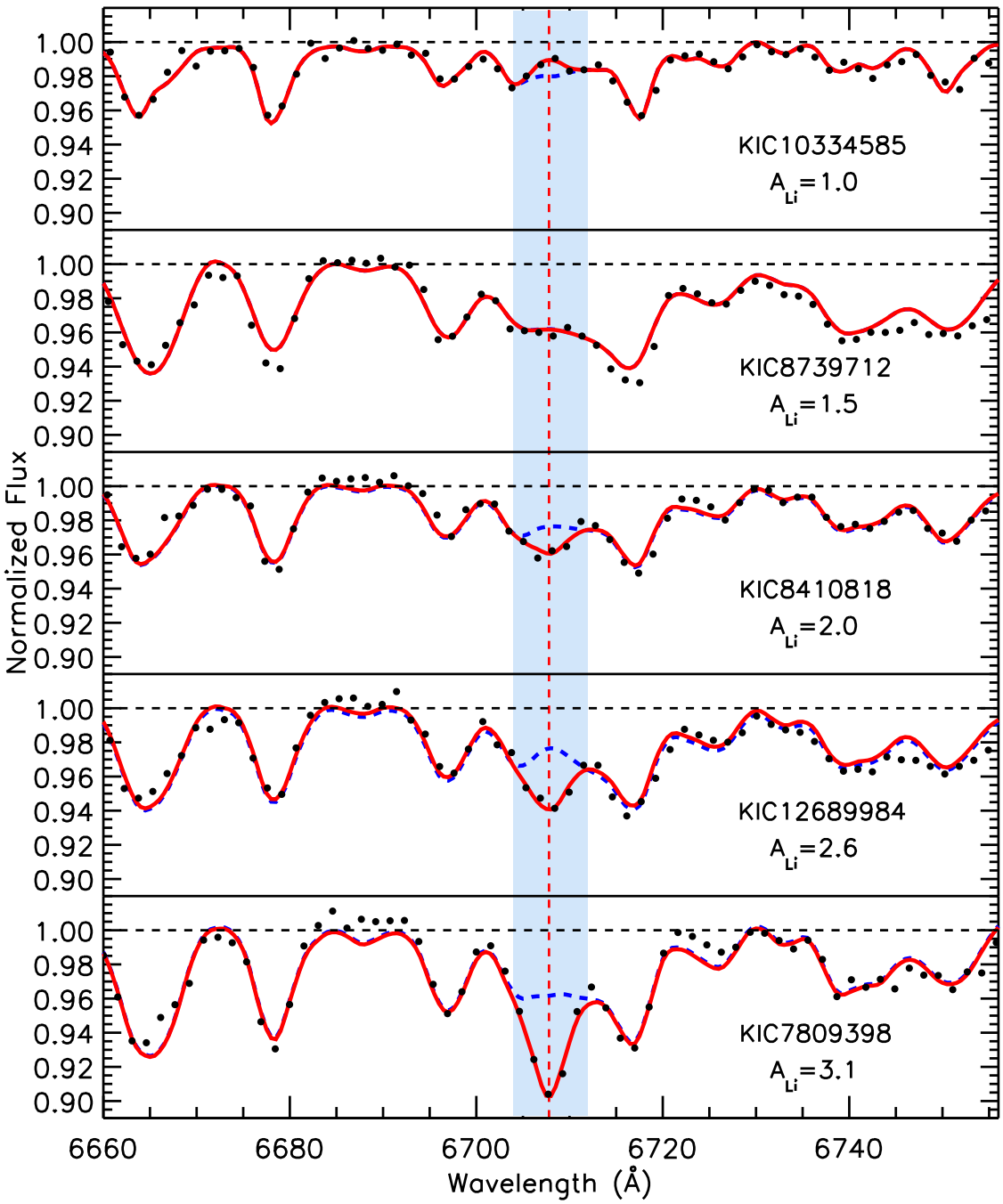
Most lithium-rich low-mass evolved stars revealed as red clump stars by asteroseismology and spectroscopy

In the format provided by the authors and unedited

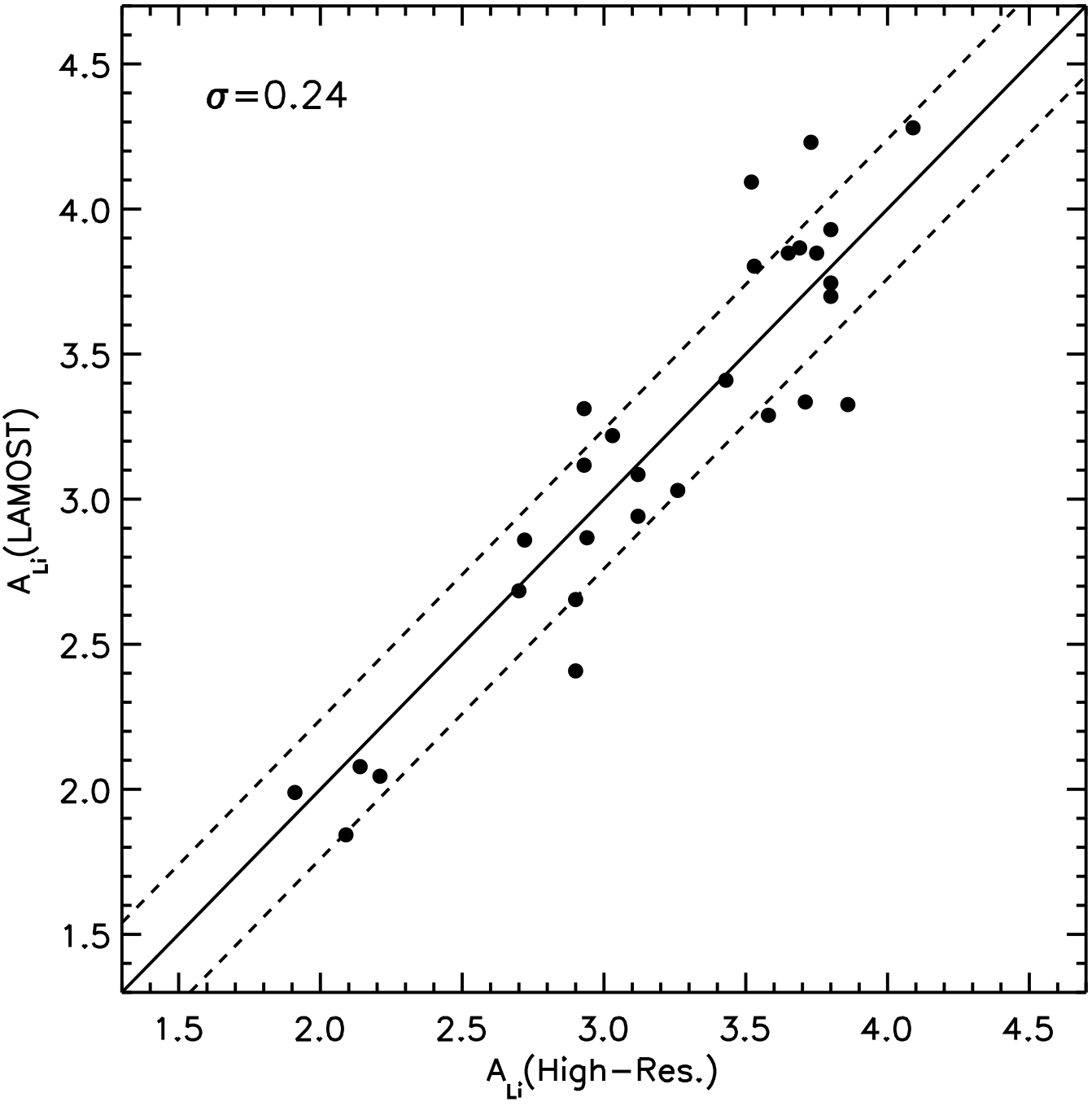
New Insights into the Lithium-rich Giant Stars from the Asteroseismic Data



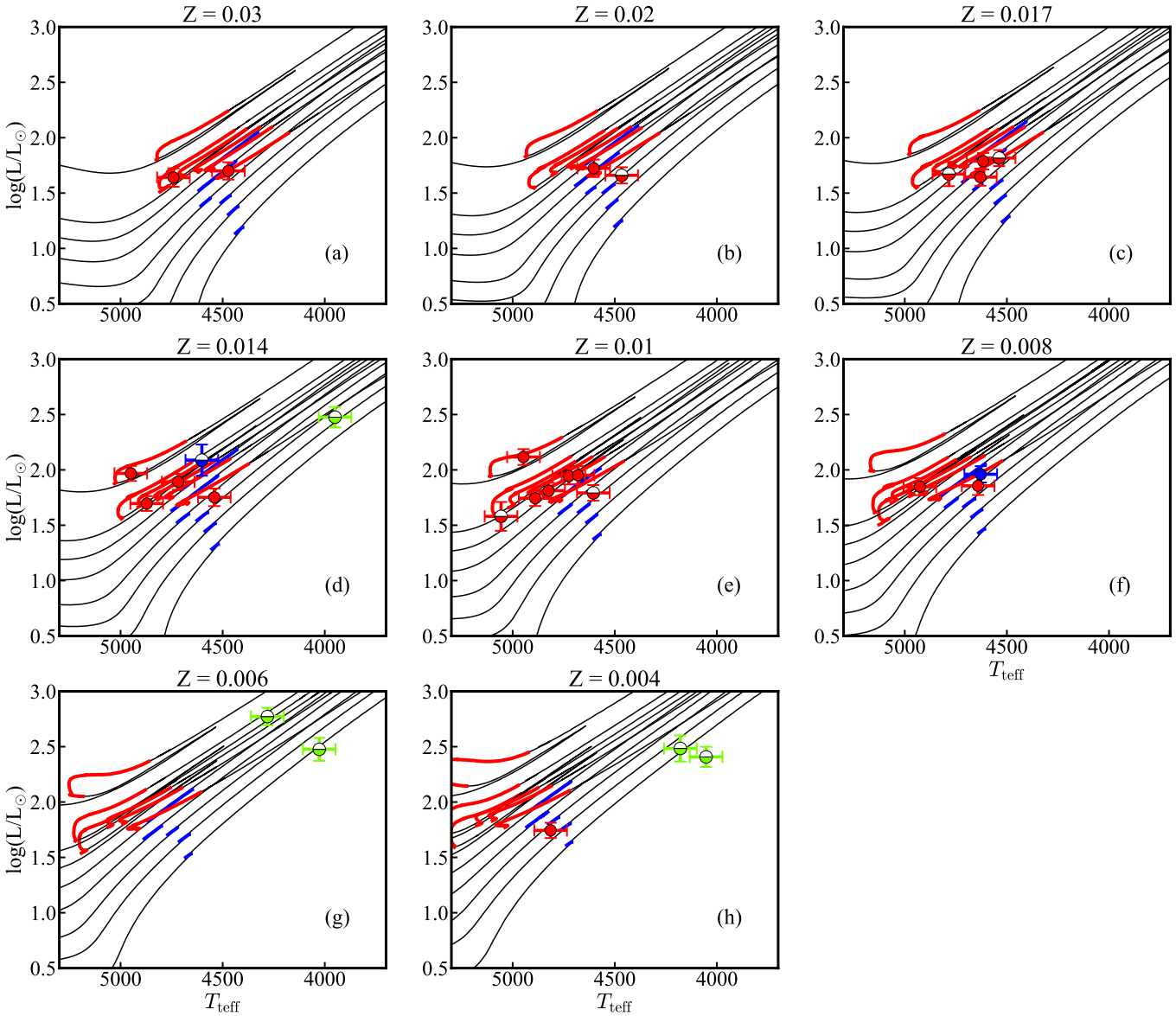
Supplementary Fig. 1. The comparison of the stellar parameters between spectroscopic method and other methods. The $T_{\rm eff}$ used for comparison is obtained from ASPCAP, and the $\log g$ is calculated from *Gaia* parallaxes. The solid line represents a 1:1 ratio, and the dashed line marked the standard deviation in each panel. The number of stars for compare and the standard deviation is labeled in each panel.



Supplementary Fig. 2. The LAMOST spectra and their best template matching. The black dots represent the observed low-resolution spectra by LAMOST, and the red solid lines are the best-fitted templates. The templates are calculated with stellar parameters from LAMOST DR7 and the fitted Li abundance. The color of light blue indicates the region that is used to calculate the chi-square during the fitting. The Li abundances and star ID are given in each panel. Note the vertical axis is the normalized flux and has been zoomed into the range of $0.90-1.02$.



Supplementary Fig. 3. The comparison between the Li abundances derived from the low- and high-resolution data. The Li abundances used here are derived from 6708 Å line. Symbols and labels are similar to Supplementary Fig. 1.



Supplementary Fig. 4. The locations of 29 Li-rich giants on the H-R diagram. The tracks are plotted from 0.8 $M_\odot$ to 2.0 $M_\odot$ with interval of 0.2 $M_\odot$, plus a track of 2.6 $M_\odot$ (the top one). Stars are divided into eight groups based on their metallicity for corresponding tracks. The symbols are as same as that in Fig. 2.

Supplementary Table 1. The observation information of Li-rich giants in the high-resolution sample.

ID1	KIC	Vmag mag	Obs.Date	Telescope	Instrument	Res. $\lambda/\Delta\lambda$	SNR
J1849+4840	11068543	11.530	2017-08-05	Subaru	HDS	$\sim 45,000$	104
J1854+4316	7587353	11.739	2015-05-29	APF	""	$\sim 80,000$	87
J1859+4507	8869656	9.368	2017-10-06	Lijiang-2.4m	HiRES	$\sim 30,000$	88
J1901+4944	11651091	11.393	2017-08-05	Subaru	HDS	$\sim 45,000$	85
J1905+4834	11019752	11.076	2017-08-05	Subaru	HDS	$\sim 45,000$	92
J1907+5000	11805390	9.804	2016-10-09	APF	""	$\sim 80,000$	97
J1917+5145	12645107	11.442	2017-08-04	Subaru	HDS	$\sim 45,000$	77
J1920+5203	12784683	11.462	2016-10-11	APF	""	$\sim 80,000$	73
J1928+3741	2305930	11.111	2015-05-20	APO-3.5m	ARCES	$\sim 32,000$	123
J1929+4423	8366758	12.500	2017-08-04	Subaru	HDS	$\sim 45,000$	104
J1930+4942	11663387	12.591	2016-11-16	Subaru	HDS	$\sim 45,000$	82
J1931+4521	9024667	12.286	2017-08-04	Subaru	HDS	$\sim 45,000$	76
J1931+4639	9833651	12.519	2016-11-17	Subaru	HDS	$\sim 45,000$	94
J1934+4108	5881715	11.781	2016-10-19	APF	""	$\sim 80,000$	80
J1934+3858	3858850	12.444	2016-11-16	Subaru	HDS	$\sim 45,000$	67
J1936+4938	11615224	11.159	2015-09-04	APO-3.5m	ARCES	$\sim 32,000$	118
J1937+4339	7898227	12.915	2016-11-16	Subaru	HDS	$\sim 45,000$	68
J1938+4006	5021453	11.381	2018-09-16	APO-3.5m	ARCES	$\sim 32,000$	146
J1938+4338	7899597	13.610	2016-11-17	Subaru	HDS	$\sim 45,000$	81
J1939+4614	9596106	11.664	2017-08-05	Subaru	HDS	$\sim 45,000$	75
J1945+4337	7905528	11.924	2015-06-23	APF	""	$\sim 80,000$	90
J1949+4750	10616012	11.454	2015-06-11	APO-3.5m	ARCES	$\sim 32,000$	126
J1951+4618	9665729	9.302	2017-09-25	Lijiang-1.8m	HRS	$\sim 37,000$	114
J1951+4647	9907856	12.451	2017-08-04	Subaru	HDS	$\sim 45,000$	89
J1956+4116	5989157	12.278	2016-11-17	Subaru	HDS	$\sim 45,000$	132
J1957+4550	9364778	11.204	2017-08-04	Subaru	HDS	$\sim 45,000$	96
J0331+1933	210778970	13.442	2016-11-17	Subaru	HDS	$\sim 45,000$	93
J0828+2244	212136170	13.318	2016-11-16	Subaru	HDS	$\sim 45,000$	39
J1119-0104	201392458	13.439	2017-02-19	Subaru	HDS	$\sim 45,000$	45

Supplementary Table 2. The spectroscopic results of Li-rich giants in the high-resolution sample. The evolutionary phase are indicated in the seventh column, with '1' represents RGB stars, '2' represents RC stars, and '3' represents highly evolved RGB or AGB stars for which asteroseismology data is not available. The 'star'(*) indicates that the phase is derived from asteroseismic analysis. The phase without * is derived using the criterion described in this paper.

id	KIC	$T_{\rm eff}$ K	$\log g$	[Fe/H]	ξ_t km s^{-1}	phase	A(Li)$_{\rm NLTE}$
J1849+4840	11068543	3950	1.30	-0.15	1.15	3	2.83 ± 0.05
J1854+4316	7587353	4616	2.24	0.00	1.46	2*	3.48 ± 0.10
J1859+4507	8869656	4872	2.55	-0.10	0.97	2*	3.61 ± 0.09
J1901+4944	11651091	4466	2.55	0.10	1.30	2	2.65 ± 0.09
J1905+4834	11019752	4605	2.42	-0.21	1.40	2	2.81 ± 0.08
J1907+5000	11805390	4950	2.58	-0.06	1.84	2*	2.24 ± 0.10
J1917+5145	12645107	4824	2.55	-0.24	1.15	2*	3.30 ± 0.09
J1920+5203	12784683	4890	2.63	-0.25	1.28	2*	2.79 ± 0.08
J1928+3741	2305930	4814	2.35	-0.59	1.37	2*	3.90 ± 0.03
J1929+4423	8366758	4741	2.17	0.20	1.49	2*	3.24 ± 0.10
J1930+4942	11663387	4630	2.45	0.00	1.25	2*	3.43 ± 0.04
J1931+4521	9024667	4541	2.35	-0.06	1.31	2*	2.79 ± 0.10
J1931+4639	9833651	4603	2.41	0.11	0.97	2*	3.40 ± 0.09
J1934+4108	5881715	4725	2.33	-0.18	1.28	2*	3.38 ± 0.11
J1934+3858	3858850	4472	2.17	0.26	1.45	2*	2.95 ± 0.09
J1936+4938	11615224	4680	2.24	-0.22	1.30	2*	2.84 ± 0.02
J1937+4339	7898227	4179	1.30	-0.76	1.70	3	2.81 ± 0.13
J1938+4006	5021453	4718	2.40	-0.10	1.20	2*	3.62 ± 0.08
J1938+4338	7899597	4641	2.45	-0.40	1.60	2*	3.39 ± 0.06
J1939+4614	9596106	4628	2.24	-0.31	1.52	1*	2.18 ± 0.06
J1945+4337	7905528	4027	1.18	-0.49	1.38	3	3.49 ± 0.01
J1949+4750	10616012	4538	2.35	0.02	1.30	2	3.48 ± 0.08
J1951+4618	9665729	4281	1.55	-0.46	1.95	3	2.13 ± 0.03
J1951+4647	9907856	4926	2.49	-0.30	1.25	2*	2.51 ± 0.05
J1956+4116	5989157	4053	1.27	-0.73	1.80	3	3.05 ± 0.02
J1957+4550	9364778	4947	2.57	-0.16	1.44	2*	3.43 ± 0.03
J0331+1933	210778970	5057	2.60	-0.22	1.25	2	3.08 ± 0.10
J0828+2244	212136170	4602	2.08	-0.14	0.70	1	1.92 ± 0.08
J1119-0104	201392458	4784	2.63	0.02	1.10	2	2.95 ± 0.09

Supplementary Table 3. The uncertainties of the Li abundance caused by the uncertainties of the stellar parameters. The stellar parameters (namely $T_{\rm eff}$, $\log g$, and [Fe/H]) of the two stars are shown in the bracket following their IDs.

	$T_{\rm eff}$ (K) +100	$T_{\rm eff}$ (K) -100	$\log g$ +0.2	$\log g$ -0.2	[Fe/H] +0.2	[Fe/H] -0.2	ID
uncertainty of $A_{\rm Li}$	+0.15	-0.17	+0.00	-0.01	+0.00	-0.01	Star 1 (4699, 2.42, 0.0)
	+0.16	-0.18	+0.01	-0.01	+0.00	-0.00	Star 2 (4589, 2.44, -0.4)