

## THREE Li-RICH K GIANTS: IRAS 12327–6523, 13539–4153, AND 17596–3952

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### ABSTRACT

We report on spectroscopic analyses of three K giants previously suggested to be Li-rich: IRAS 12327–6523, 13539–4153, and 17596–3952. High-resolution optical spectra and the LTE model atmospheres are used to derive the stellar parameters ( $T_{\text{eff}}$ ,  $\log g$ ,  $[\text{Fe}/\text{H}]$ ), elemental abundances, and the isotopic ratio  $^{12}\text{C}/^{13}\text{C}$ . IRAS 13539–4153 shows an extremely high Li abundance of  $\log \epsilon(\text{Li}) \approx 4.2$ , a value 10 times greater than the present Li abundance in the local interstellar medium. This is the third highest Li abundance yet reported for a K giant. IRAS 12327–6523 shows a Li abundance of  $\log \epsilon(\text{Li}) \approx 1.4$ . IRAS 17596–3952 is a rapidly rotating ( $V \sin i \approx 35 \text{ km s}^{-1}$ ) K giant with  $\log \epsilon(\text{Li}) \approx 2.2$ . Infrared photometry shows the presence of an IR excess, suggesting mass loss. A comparison is made between these three stars and previously recognized Li-rich giants.

*Key words:* stars: abundances — stars: carbon — stars: chemically peculiar — stars: late-type

### 1. INTRODUCTION

The maximum lithium abundance of main-sequence stars of near-solar metallicity spans a small range:  $\log \epsilon(\text{Li}) \approx 3.3$  for  $[\text{Fe}/\text{H}] \approx 0.0$  to  $\log \epsilon(\text{Li}) \approx 3.1$  for  $[\text{Fe}/\text{H}] \approx -0.3$  (Lambert & Reddy 2004). This lithium abundance is identified with that of the interstellar gas from which the stars formed. Lithium is predicted to be destroyed throughout a main-sequence star except in the outermost layers (1%–2% by mass). Even in this thin skin, which includes the atmosphere, lithium may be depleted by processes not yet fully understood. The Sun, for example, has a lithium abundance about a factor of 100 less than the meteoritic abundance.

When a main-sequence star evolves to become a red giant, the convective envelope grows and dilutes the lithium such that its surface abundance is greatly reduced. Iben (1967a, 1967b) predicted that giants of approximately solar metallicity would experience dilution by a factor of 1.8 dex at  $3 M_{\odot}$  and 1.5 dex at  $1 M_{\odot}$ . This dilution occurs at the onset of the first dredge-up that results from the growth of the convective envelope, which also results in predicted changes of the surface (elemental and isotopic) abundances of helium, beryllium, boron, carbon, nitrogen, and oxygen. Adopting the predicted lithium dilution and the maximum observed lithium abundance of main-sequence stars, lithium in red giants is expected to not exceed  $\log \epsilon(\text{Li}) \approx 1.5$ . A red giant star that has evolved through the first dredge-up but has a surface abundance greater than  $\log \epsilon(\text{Li}) \approx 1.5$  is declared to be “Li-rich.”

Li-rich K giants are rare. Since the discovery of the first Li-rich K giant, HD 112127, two decades ago (Wallerstein & Sneden 1982), the collection of Li-rich stars has grown to only about three dozen. Many, such as HD 112127, were discovered serendipitously. Brown et al. (1989) undertook a systematic search for Li-rich stars among K- and late G-type giants. They

found at most 10 Li-rich giants out of the 670 stars observed. Another important survey, known as the “Pico Dias Survey” (PDS), by Gregorio-Hetem et al. (1992) found, as a by-product, potentially Li-rich giants (de la Reza et al. 1997). A few of these PDS candidate Li-rich K giants have been spectroscopically studied to determine their lithium abundance (e.g., Reddy et al. 2002a; Drake et al. 2002).

Here we report results from the first high-resolution spectroscopic analyses of three Li-rich candidates taken from de la Reza et al. (1997), who proposed the stars to be probably Li-rich from the observation that the strength of the  $\text{Li I } \lambda 6707$  doublet was equal to or greater than the strength of the  $\text{Ca I } \lambda 6718$  line. It turns out that the lithium abundances of the three stars are quite different. The most extreme example is IRAS 13539–4153 (also known as PDS 68) with  $\log \epsilon(\text{Li}) \approx 4.1$ , an abundance almost 1 dex higher than the star’s likely initial lithium abundance. The second star, IRAS 17596–3952, has  $\log \epsilon(\text{Li}) \approx 2.2$  and is most probably an Li-rich giant, i.e., a first dredge-up giant with lithium in excess of the limit  $\log \epsilon(\text{Li}) \approx 1.5$ . The third star, IRAS 12327–6523, has  $\log \epsilon(\text{Li}) \approx 1.4$  and so is not a certain Li-rich star; it is possibly a post-first dredge-up star with lithium depleted to the predicted level. Following presentation and discussion of the abundance analysis, we comment on the similarities between the new and previously known Li-rich giants.

### 2. OBSERVATIONS

Spectra of the stars listed in Table 1 were obtained with the 4 m Blanco telescope and the Cassegrain echelle spectrograph at CTIO in Chile. In addition to obtaining spectra of the three Li-rich candidates, we obtained a high-quality spectrum of HD 19745, a Li-rich giant analyzed previously by de la Reza & da Silva (1995).

The spectrograph was set to cover the wavelength interval 5000–8200 Å without gaps at a resolving power of  $R \approx 35,000$ . Each star was exposed thrice, with a total integration time ranging from 60 to 90 minutes. Raw two-dimensional spectra were reduced to one-dimensional wavelength-calibrated spectra using

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TABLE 1  
PROPERTIES OF THE FOUR LI-RICH K GIANTS

Star	$T_{\text{eff}}$ (K)	$\log g$ ( $\text{cm s}^{-2}$ )	$\xi_t$ ( $\text{km s}^{-1}$ )	$V_{\text{helio}}$ ( $\text{km s}^{-1}$ )	[Fe/H] <sup>a</sup>	$V \sin i$	$W_\lambda$ ( $\lambda 6707$ ) (mÅ)	$M/M_\odot$	$L/L_\odot$
HD 19745 <sup>b</sup> .....	4700 ± 100	2.25 ± 0.25	1.5 ± 0.2	-15.4 ± 1.0	-0.05	3.0 ± 1.0	470	2.2 ± 0.6	1.9
IRAS 12327-6523.....	4200 ± 100	1.25 ± 0.25	2.0 ± 0.2	-18.9 ± 1.0	-0.40	7.5 ± 1.0	310	2 ± 1.0	2.9
IRAS 13539-4153.....	4300 ± 100	2.25 ± 0.25	2.0 ± 0.2	-87.3 ± 1.3	-0.13	5.0 ± 1.0	630	0.8 ± 0.7	1.6
IRAS 17596-3952.....	4600 ± 100	2.50 ± 0.50	1.9 ± 0.2	-27.2 ± 2.3	+0.10	35.0 ± 5	300	1.7 ± 0.6	1.7

<sup>a</sup> [Fe/H] =  $\log \epsilon(\text{Fe}) - \log \epsilon(\text{Fe})_\odot$  with the solar iron abundance of  $\log \epsilon(\text{Fe}) = 7.47$  taken from Lodders (2003).

<sup>b</sup> Castilho et al. (2000) obtained  $T_{\text{eff}} = 4750$  K,  $\log g = 2.5$ ,  $\xi_t = 1.2$ , and [Fe/H] = 0.0.

appropriate reduction tools available in the IRAF package. A Th-Ar hollow cathode spectrum provided the wavelength calibration. In each spectrum of an Li-rich candidate star, the signal-to-noise ratio at 6707 Å is between 100 and 200.

### 3. ANALYSIS

#### 3.1. Stellar Properties

Stellar parameters  $T_{\text{eff}}$ ,  $\log g$ , and [Fe/H] were obtained from the spectra by a standard procedure using ATLAS model atmospheres computed using the “no convective overshoot” option (see Robert L. Kurucz’s Web site<sup>2</sup>). The effective temperature ( $T_{\text{eff}}$ ) was obtained from the requirement that all Fe I lines give the same abundance independent of the lower state’s excitation potential (LEP). About 40 Fe I lines spanning the LEP range of 1–5 eV were measured for IRAS 12327–6523 and IRAS 13539–4153, but fewer lines were measurable for the rapidly rotating K giant IRAS 17596–3952. Lines are weak to moderately strong ( $W_\lambda \leq 150$  mÅ). Surface gravity ( $\log g$ ) was obtained with the condition that the Fe I and Fe II lines give the same abundance. The microturbulent velocity ( $\xi_t$ ) was determined by requiring that the Fe I and Ni I lines give the same (Fe or Ni) abundance irrespective of their equivalent widths. The parameters were determined by an iterative process using models selected from the ATLAS grid. Adopted parameters are given in Table 1. Our results for HD 19745 are in good agreement with the previous determination by Castilho et al. (2000).

A full abundance analysis was made with the selected model atmospheres. Lithium abundance and the  $^{12}\text{C}/^{13}\text{C}$  ratio are discussed below. Seventeen elements from Na to Nd in addition to Fe were included in the analysis. Given that [Fe/H]  $\simeq 0$  for the stars that probably belong to the thin disk, one expects [X/Fe]  $\simeq 0$  for the 17 elements. This is what is found to within the measurement errors, except for the suggestion that [Ca/Fe]  $\simeq -0.3$  for IRAS 12327–6523 and IRAS 13539–4153. The detailed analysis was not attempted for the rapidly rotating IRAS 17596–3952.

Inspection of the spectra shows two unusual aspects worthy of comment: unusually broad lines of IRAS 17596–3952 and an asymmetric  $\text{H}\alpha$  profile of IRAS 12327–6523.

The lines of IRAS 17596–3952 are obviously broader than those of the other two stars that have line widths typical of K giants. The additional broadening is attributed to a more rapid than average rotational velocity. To determine the projected rotational velocity ( $V \sin i$ ), we match the observed spectrum to a synthetic spectrum computed with the following broadening parameters: the velocity  $V \sin i$ , a macroturbulent velocity  $V_t$ , and the instrumental profile width. The value  $V_t = 3$   $\text{km s}^{-1}$ , found to be typical of K giants (Gray 1989), was adopted. The

instrumental profile width was taken as a Gaussian with a FWHM = 0.21 Å at 6707 Å as measured from the Th emission lines in the hollow cathode spectrum. The non-Gaussian form (Gray 1976) of the broadening that results from solid-body stellar rotation is incorporated in the line formation code MOOG (Snedden 1973, p. 180). Unblended Fe I lines at 6703.5, 6705.1, and 6170 Å were selected for the estimation of  $V \sin i$ . A  $\chi^2$  test was used to select the best value of  $V \sin i$ . The mean value from the fits to the three Fe I lines is given in Table 1 for each star.

Profiles of the  $\text{H}\alpha$  line in the four stars and Arcturus are shown in Figure 1. It is clear that the  $\text{H}\alpha$  line of IRAS 12327–6523 is distinctly asymmetric, with the line core shifted to the blue relative to the photospheric lines. An asymmetric  $\text{H}\alpha$  line is seen in some other Li-rich giants (Drake et al. 2002).

#### 3.2. Lithium Abundance

An immediate indication that the stars might be Li-rich was found at the telescope from the obvious presence of a strong absorption line attributable to the Li I resonance doublet at 6707.8 Å. Closer inspection also reveals the presence of the excited Li I line at 6103.6 Å in the spectra of IRAS 13539–4153 and HD 19745. Lithium abundances were found by spectrum synthesis.

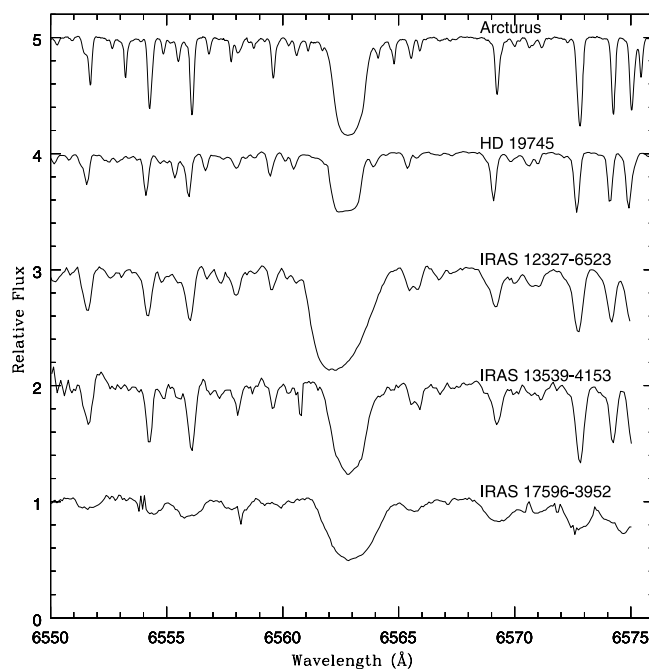


FIG. 1.—Spectra of Li-rich K giants and Arcturus near the  $\text{H}\alpha$  line. Note the asymmetric  $\text{H}\alpha$  profile of IRAS 12327–6523.

<sup>2</sup> See <http://kurucz.harvard.edu>.

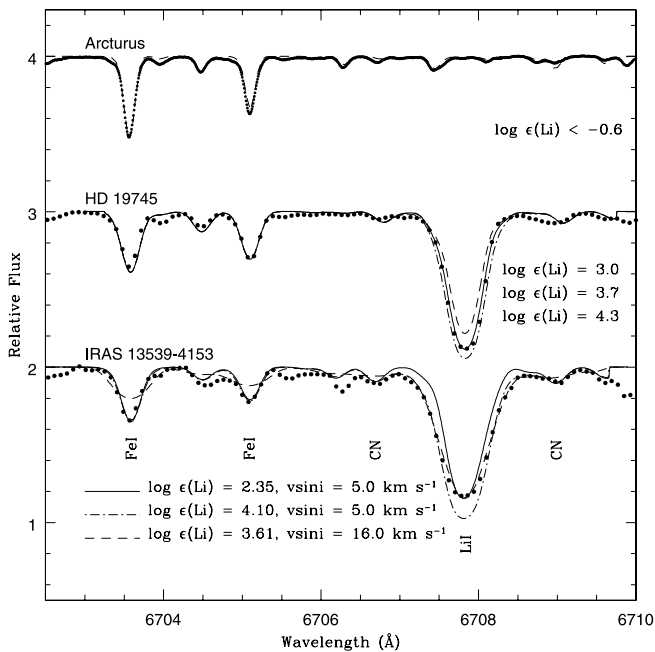


FIG. 2.—Observed (filled circles) and synthetic spectra (lines) of a region around the Li I line at 6707.6 Å for Arcturus, HD 19745, and IRAS 13539–4153. Note the very strong Li I line at 6707.8 Å in HD 19745 and IRAS 13539 and the absence of the same line in Arcturus. The stars have a similar effective temperature. The synthetic spectra with  $\log \epsilon(\text{Li}) < -0.6$  and 3.7 provide the best fit for Arcturus and HD 19745, respectively. See text for a discussion of synthetic spectra for IRAS 13539–4153.

Synthesis of the 6707 Å feature used the critically examined line list in the vicinity of the resonance line taken from Reddy et al. (2002b) with the component structure of the Li I resonance doublet taken from Hobbs et al. (1999). Lithium is assumed to be purely  ${}^7\text{Li}$ . The line list for 10 Å centered on the Li I  $\lambda 6707$  line was tested by successfully reproducing the ultra-high-resolution ( $R \approx 150,000$ ) spectrum (Hinkle et al. 2000) of the very Li-poor K giant Arcturus (see Reddy et al. 2002a for details). Then synthetic spectra were computed and matched to the spectrum of each program star by adjusting the lithium abundance to fit the 6707.8 Å feature. Comparisons of synthetic and observed spectra are shown in Figures 2 and 3. Lithium abundances derived from the LTE analysis are given in Table 2. Uncertainties in the derived lithium abundances (Table 2) are estimated from uncertainties in the atmospheric parameters:  $\delta T_{\text{eff}} = 100$  K,  $\delta \log g = 0.5$ ,  $\delta \xi_r = 0.5$  km s $^{-1}$ , and  $\delta[M/H] = 0.25$  dex lead to uncertainties of 0.25, 0.05, 0.05, and 0.03 dex, respectively.

For IRAS 13539–4153 and HD 19745, the lithium abundances have also been obtained using the subordinate Li I line at 6103 Å. The line list for this region was compiled using Kurucz's line list. In Figure 4 we compare synthetic and observed spectra. The lithium abundances (Table 2) derived from the 6707 and 6103 Å lines are in good agreement for HD 19745 and are also in good agreement with previously published results by de la Reza & da Silva (1995).

In Figure 2 we draw attention to a failure to fit the Li I  $\lambda 6707$  profile of IRAS 13539–4153. The line is broader for its depth than calculated: the abundance  $\log \epsilon(\text{Li}) = 2.35$  fits the core, but  $\log \epsilon(\text{Li}) = 4.1$  is required to fit the wings; however, this abundance produces a central depth greater than observed. The 6103 Å Li I line is matched by the abundance  $\log \epsilon(\text{Li}) = 4.1$  and the  $V \sin i$  of the metal lines. We suppose that this latter abundance is the stellar abundance and that the 6707 Å line's

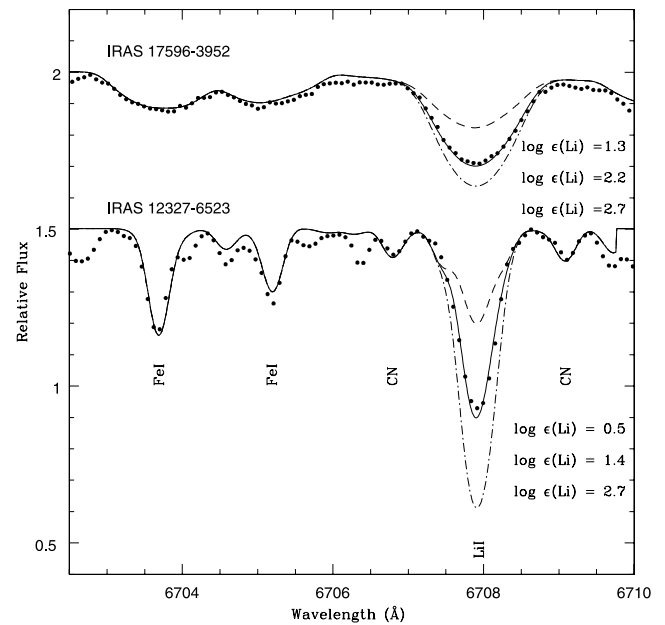


FIG. 3.—Observed (filled circles) and synthetic spectra (lines) of a region around the Li I line at 6707 Å for IRAS 17596–3952 and IRAS 12327–6523. Spectra at 6707 Å were predicted for the three different Li abundances as noted in the figure. The solid lines show the best fits to the observations:  $\log \epsilon(\text{Li}) = 2.0$  for IRAS 17596–3952 and 1.4 for IRAS 12327–6523.

core is affected by emission due to chromospheric activity or by non-LTE effects. It is unclear why IRAS 13539–4153's 6707 Å line is so affected but HD 19745's line of comparable strength is not. (IRAS 13539–4153's 6707 Å profile is well fitted by increasing the  $V \sin i$  to 16 km s $^{-1}$ , but this broadening fits no other lines in the spectrum [see Fig. 2].)

An additional uncertainty arises from our assumption of LTE for line formation. For the super-Li-rich giants HD 19745 and IRAS 13539–4151, non-LTE corrections indicate a correction of 0.1 dex upward for the 6103 Å line and 0.2 dex downward for the 6707 Å line (Carlsson et al. 1994). For the less Li-rich stars IRAS 12327–6523 and IRAS 17596–3952, the non-LTE correction is around 0.1 dex upward for the 6707 Å line. Since these corrections are small and subject to their uncertainties, we include them as part of the overall abundance uncertainty. (The non-LTE abundances are also given in Table 2.) The total error given in Table 2 is the quadratic sum of all the errors discussed above.

### 3.3. The ${}^{12}\text{C}/{}^{13}\text{C}$ Ratio

Standard models make predictions about the first dredge-up's effects on the surface abundances of Li, C, N, and O. Observations of normal red giants confirm these predictions, qualitatively if not always quantitatively. Interpretation of lithium abundances is assisted and possibly complicated by knowledge of the C, N, and O abundances. Here we restrict the analysis to the carbon isotopic ratio  ${}^{12}\text{C}/{}^{13}\text{C}$ . One expects an unevolved star to have a ratio close to  ${}^{12}\text{C}/{}^{13}\text{C} \approx 90$ , the solar photospheric value. A lower ratio ( $\approx 20$ ) is predicted for giants after the first dredge-up. Some giants show even lower  ${}^{12}\text{C}/{}^{13}\text{C}$  ratios.

The  ${}^{12}\text{C}/{}^{13}\text{C}$  ratio was extracted from a complex of  ${}^{13}\text{CN}$  lines at 8005.7 Å and adjacent  ${}^{12}\text{CN}$  lines (Fig. 5). The ratio  ${}^{12}\text{C}/{}^{13}\text{C}$  is determined by spectrum synthesis assuming solar abundances (Lodders 2003) for C and N. For HD 19745 we obtained  ${}^{12}\text{C}/{}^{13}\text{C} = 16 \pm 2$ , which is in good agreement with the ratio of 15 derived by da Silva et al. (1995). For IRAS 12327–6523, we

TABLE 2  
DERIVED LI ABUNDANCES AND CARBON ISOTOPIC RATIOS

Abundance and Feature	IRAS 12327–6523	IRAS 13539–4153	IRAS 17596–3952	HD 19745
LTE $\log \epsilon(\text{Li})$ (Li I $\lambda 6103$ ).....	...	$4.15 \pm 0.3$	...	$3.90 \pm 0.3$
Non-LTE $\log \epsilon(\text{Li})$ (Li I $\lambda 6103$ ).....	...	4.2	...	4.0
LTE $\log \epsilon(\text{Li})$ (Li I $\lambda 6707$ ).....	$1.40 \pm 0.2$	$4.10 \pm 0.3$	$2.2 \pm 0.2$	$3.70 \pm 0.3$
Non-LTE $\log \epsilon(\text{Li})$ (Li I $\lambda 6707$ ).....	1.6	3.9	2.3	3.4
$^{12}\text{C}/^{13}\text{C}$ .....	$6.0 \pm 1$	$\geq 20$	...	$16 \pm 2.0$

obtain  $^{12}\text{C}/^{13}\text{C} = 6 \pm 1$ . A limit of  $^{12}\text{C}/^{13}\text{C} = 20$  was found for IRAS 13539–4153. The spectral lines of IRAS 17596–3952 are too smeared, because of its high rotation, to estimate the ratio. The low  $^{12}\text{C}/^{13}\text{C}$  ratios confirm that the Li-rich giants have experienced the first dredge-up.

#### 4. THE LI-RICH CLANS

When considered with the population of field K giants, our trio stand apart by reason of their high lithium abundance. That is why they were selected for an abundance analysis. The question we consider here is how the trio fit in with the previously analyzed Li-rich giants.

Charbonnel & Balachandran (2000) took advantage of *Hipparcos* parallaxes to estimate the absolute luminosity of Li-rich and Li-normal red giants. They suggested that the Li-rich giants could be divided into three clans: warm giants for which lithium dilution has not been completed, giants at the bump in the luminosity function, and giants in the early phases of asymptotic giant branch (AGB) evolution—see Figure 6.

Our trio (and HD 19745) are not in the *Hipparcos* catalog. Therefore, we estimate their luminosities using the spectroscopically derived  $\log g$  and  $T_{\text{eff}}$  and computed evolutionary tracks for different stellar masses and metallicities (Girardi et al. 2000). By interpolation, we found the track (i.e., stellar mass)

for which the  $\log g$  and  $T_{\text{eff}}$  best agreed with the observed  $\log g$  and  $T_{\text{eff}}$ . The luminosity is then read from the track. Estimated luminosities and masses are given in Table 1. The estimated errors due to uncertainties in model parameters ( $\delta T_{\text{eff}} = 100$  K,  $\delta \log g = 0.25$ , and  $\delta[\text{Fe}/\text{H}] = 0.2$ ) are shown in Table 1. According to their luminosity and effective temperature, the three stars and HD 19745 have completed the dilution associated with the first dredge-up. The stars are shown in Figure 6 with others from our earlier studies. For stars taken from earlier studies, uncertainties of  $\delta T_{\text{eff}} = 100$  K and  $\delta \log g = 0.25$  are assumed (Fig. 6).

The two most Li-rich giants, IRAS 13539–4153 and IRAS 17596–3952, belong to the “bump” clan. Through the spectroscopically estimated luminosity, we also place HD 19745 among this clan. The range of lithium abundances,  $^{12}\text{C}/^{13}\text{C}$  ratios, and  $V \sin i$  covered by these three stars are spanned by the six stars from Charbonnel & Balachandran (2000): the  $V \sin i$  of IRAS 17596–3952 with  $35 \text{ km s}^{-1}$  extends the upper limit, previously set at  $25 \text{ km s}^{-1}$ .

IRAS 12327–6523 is assigned to Charbonnel & Balachandran’s (2000) “early-AGB” clan with its original five members with lithium abundances ranging from  $\log \epsilon(\text{Li}) = 1.5$  to 2.8. IRAS 12327–6523 is now the least lithium-rich of the clan. Strictly speaking, the star is not lithium-rich because standard dilution by the first dredge-up could have left this relatively massive star

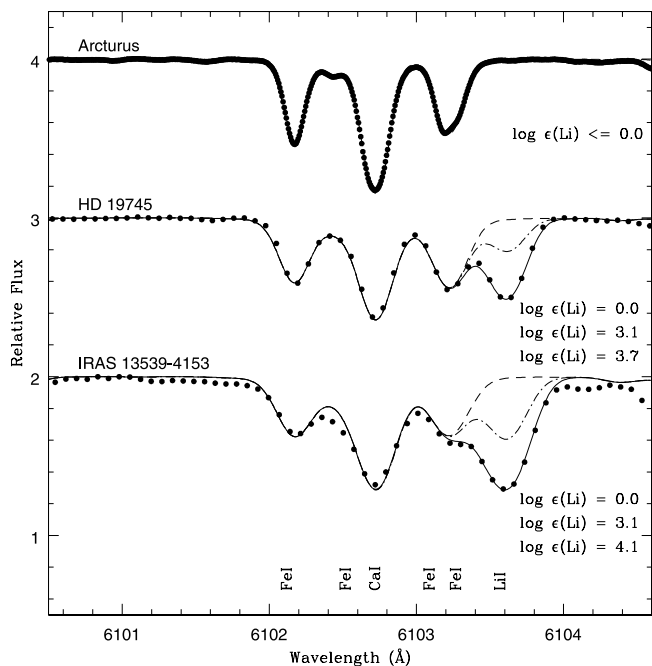


FIG. 4.—Observed (filled circles) and synthetic spectra (lines) of a region around the Li I line at 6103.5 Å for Arcturus, HD 19745, and IRAS 13539–4153. Spectra at 6103 Å were predicted for the three different Li abundances as noted in the figure. The solid lines show the best fits to the observations:  $\log \epsilon(\text{Li}) < -0.6$ , 3.7, and 4.1 for Arcturus, HD 19745, and IRAS 13539–4153, respectively.

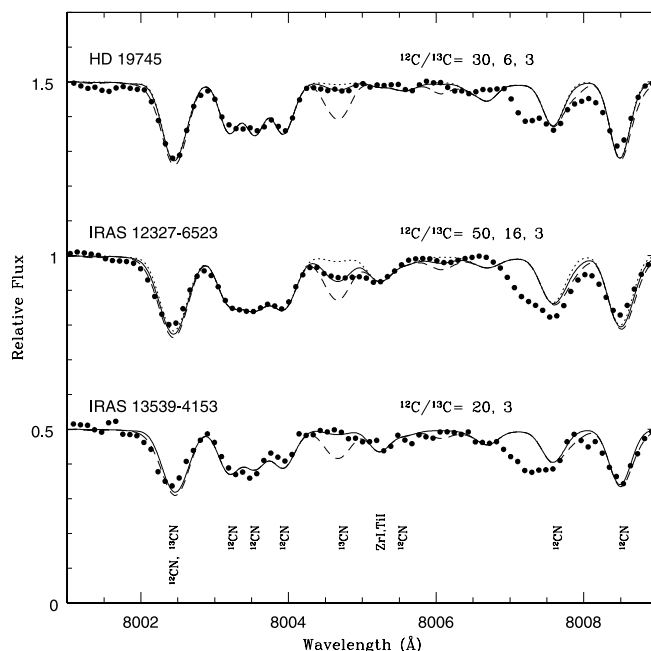


FIG. 5.—Determination of the  $^{12}\text{C}/^{13}\text{C}$  ratio for three Li-rich K giants. In all cases the solid line is the best-predicted spectrum for the  $^{13}\text{CN}$  line at 8004.8 Å, resulting in  $^{12}\text{C}/^{13}\text{C} = 6, 16,$  and  $\geq 20$  for HD 19745, IRAS 12327–6523, and IRAS 13539–4153, respectively.

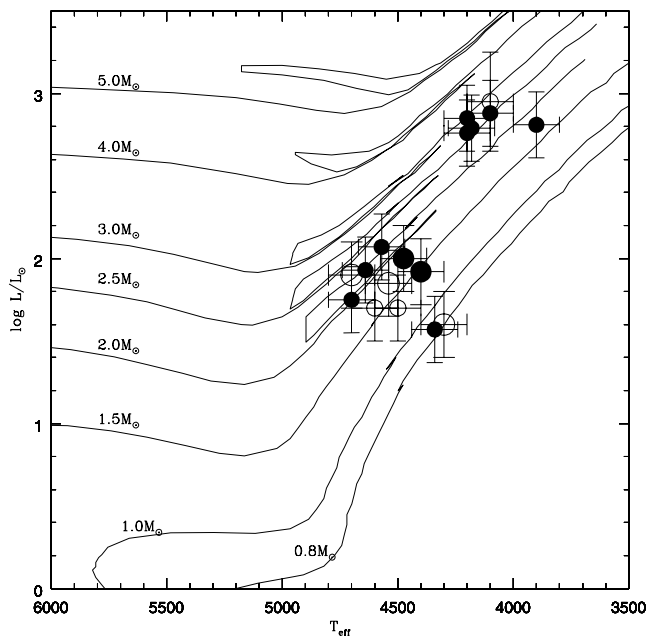


FIG. 6.—Li-rich giants in H-R diagram. Li-rich giants at the early-AGB phase ( $\log L/L_{\odot} = 2.8$ ) and the luminosity function bump ( $\log L/L_{\odot} = 1.8$ ) from Charbonnel & Balachandran (2000) are shown by filled circles. The four Li-rich giants, including HD 19745 from this study and one each from Reddy et al. (2002a) and Drake et al. (2002), are shown by open circles. Larger symbols represent stars with  $\log \epsilon(\text{Li}) \geq 3.3$ , and the smaller symbols represent stars with  $\log \epsilon(\text{Li}) = 1.4\text{--}3.0$ . Evolutionary tracks of  $[\text{Fe}/\text{H}] = 0$  (Girardi et al. 2000) for various masses are shown.

with the now observed abundance. However, standard models of the first dredge-up cannot account for the low  $^{13}\text{C}/^{12}\text{C}$  ( $=6$ ) ratio; a ratio of 20–30 is predicted. It remains to be shown that the lower than expected carbon isotopic ratio can be achieved by modifications to standard models without severe reduction of the surface lithium abundance.

Gregorio-Hetem et al. (1992; also see Gregorio-Hetem et al. 1993) found that the great majority of the Li-rich giants possess an infrared excess. Drake et al. (2002) noted that every Li-rich rapid rotator in a sample of 20 had an infrared excess. Far-IR fluxes from the *IRAS* catalog show that our three stars (and HD 19745) have a strong excess at 12  $\mu\text{m}$  and longer wavelengths, as expected from their designation as *IRAS* sources. Fluxes estimated from the Two Micron All Sky Survey (2MASS)  $J$ ,  $H$ ,

and  $K$  magnitudes show that the IR excess does not extend to these shorter wavelengths. Our three Li-rich stars, therefore, continue the correlation between Li richness and IR excess and, in particular, *IRAS* 17596–3952 strengthens the impression that all Li-rich rapid rotators have a far-IR excess.

## 5. CONCLUDING REMARKS

We have performed the first detailed analysis of three Li-rich candidate K giants and a reanalysis of HD 19745. Two candidates are confirmed as certainly Li-rich: *IRAS* 13539–4153 is among the most Li-rich giants yet analyzed. The status of *IRAS* 12327–6523 as Li-rich might be questioned. Three of the four giants—HD 19745, *IRAS* 13539–4153, and *IRAS* 17596–3952—belong to the RGB clump collection of Li-rich giants, and *IRAS* 12327–6523 belongs to the early-AGB collection in the H-R diagram. This new trio and the other Li-rich giants analyzed previously by us confirm the characteristics of the RGB bump clan that set them apart from other red giants: lithium abundance as high as  $\log(\text{Li}) \simeq 4$ , a far-IR excess, and in the mean a high rotational velocity.

Charbonnel & Balachandran (2000) linked the RGB bump clan to the RGB bump where evolution along the giant branch is slowed when the H-burning shell burns through the molecular weight discontinuity left from the initial growth of the convective envelope that provided the first dredge-up. (The Li-rich giants at higher luminosity and of higher mass were associated with a molecular weight discontinuity predicted to occur in early-AGB stars as a result of the second dredge-up.) Erasure of the molecular weight gradient makes it possible for “extra” mixing to occur between the convective envelope and the top of the H-burning shell. Mixing results in the conversion of  $^3\text{He}$  to  $^7\text{Be}$  and then  $^7\text{Li}$  by the Cameron & Fowler (1971) mechanism. This extra mixing may be internally or externally triggered. A proposed trigger should explain the concentration in luminosity of the Li-rich giants, the tendency for Li-rich giants to be rapid rotators, and the association with a far-IR excess. A reader challenged to take up the search for the trigger might profitably read the proposals advanced by Palacios et al. (2001) and Denissenkov & Herwig (2004).

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