ON INFRARED EXCESSES ASSOCIATED WITH Li-RICH K GIANTS

LUISA M. REBULL1, JOLEEN K. CARLBERG2,7, JOHN C. GIBBS3, J. ELIN DEEB4, ESTEFANIA LARSEN5, DAVID V. BLACK6, SHAILYN ALTEPETER7, ETHAN BUCKSBEE8, SARAH CASHEN3, MATTHEW CLARKE5, ASHWING DATTAA, EMILY HODGSON3, AND MEGAN LINCE3

1 Spitzer Science Center (SSC) and Infrared Science Archive (IRSA), Infrared Processing and Analysis Center (IPAC), 1200 E. California Blvd., California Institute of Technology, Pasadena, CA 91125, USA; rebull@ipac.caltech.edu
2 NASA Goddard Space Flight Center, Code 667, Greenbelt, MD 20771, USA
3 Glencoe High School, 2700 NW Glencoe Rd., Hillsboro, OR 97124, USA
4 Bear Creek High School, 9800 W. Dartmouth Pl., Lakewood, CO 80227, USA
5 Millard South High School, 14905 Q St., Omaha, NE 68137, USA
6 Walden School of Liberal Arts, 4230 N. University Ave., Provo, UT 84604, USA

Received 2015 May 18; accepted 2015 July 2; published 2015 September 28

ABSTRACT

Infrared (IR) excesses around K-type red giants (RGs) have previously been discovered using Infrared Astronomy Satellite (IRAS) data, and past studies have suggested a link between RGs with overabundant Li and IR excesses, implying the ejection of circumstellar shells or disks. We revisit the question of IR excesses around RGs using higher spatial resolution IR data, primarily from the Wide-field Infrared Survey Explorer. Our goal was to elucidate the link between three unusual RG properties: fast rotation, enriched Li, and IR excess. Our sample of RGs includes those with previous IR detections, a sample with well-defined rotation and Li abundance measurements with no previous IR measurements, and a large sample of RGs asserted to be Li-rich in the literature; we have 316 targets thought to be K giants, about 40% of which we take to be Li-rich. In 24 cases with previous detections of IR excess at low spatial resolution, we believe that source confusion is playing a role, in that either (a) the source that is bright in the optical is not responsible for the IR flux, or (b) there is more than one source responsible for the IR flux as measured in IRAS. We looked for IR excesses in the remaining sources, identifying 28 that have significant IR excesses by ~20 μm (with possible excesses for 2 additional sources). There appears to be an intriguing correlation in that the largest IR excesses are all in Li-rich K giants, though very few Li-rich K giants have IR excesses (large or small). These largest IR excesses also tend to be found in the fastest rotators. There is no correlation of IR excess with the carbon isotopic ratio, 12C/13C. IR excesses by 20 μm, though relatively rare, are at least twice as common among our sample of Li-rich K giants. If dust shell production is a common by-product of Li enrichment mechanisms, these observations suggest that the IR excess stage is very short-lived, which is supported by theoretical calculations. Conversely, the Li-enrichment mechanism may only occasionally produce dust, and an additional parameter (e.g., rotation) may control whether or not a shell is ejected.

Key words: infrared: stars – stars: evolution – stars: late-type

Supporting material: machine-readable and VO table

1. INTRODUCTION

As stars evolve from the main-sequence (MS) to the red giant branch (RGB), they exhibit several characteristic changes. As the outer layers expand and cool, the star’s rotation rate slows, the convection zone deepens and a series of shell-burning and core-burning phases begin to take place. A number of RGB K-type giants, however, exhibit uncharacteristically rapid rotation rates that also seem to be correlated with high lithium abundances, A(Li) (e.g., Carlberg et al. 2012, hereafter C12). These higher rotation rates and A(Li) are inconsistent with those predicted by standard stellar evolutionary models. It has also been suggested that many of these high-Li RGB stars have infrared (IR) excesses suggestive of a circumstellar shell or disk (de la Reza et al. 1996, 1997; Drake et al. 2002, and references therein). Various hypotheses have been proposed to explain the combination of high Li, rapid rotation rates, and IR excesses, including the accretion of nearby giant planets equivalent to a few Jupiter masses (e.g., Siess & Livio 1999) or a newly triggered nuclear fusion stage that could eject a dusty shell (e.g., de la Reza et al. 2015 and references therein).

The de la Reza et al. (1997; dLR97) study (and related studies) used data from the Infrared Astronomy Satellite (IRAS; Neugebauer et al. 1984), which surveyed at 12, 25, 60, and 100 μm. The spatial resolution, however, was relatively low, up to a few arcminutes. Despite the relatively low spatial resolution, many stars with IR excesses were identified (e.g., Gillett 1986; Paresce & Burrows 1987). In some regions with high source density, identifying the optical counterpart to the IR source can be difficult, but in many cases, the counterparts are easily identifiable. dLR97, as well as other studies, used these IRAS data to look for K giants with IR excesses.

Data are now available from the much higher spatial resolution (6′′–12′′) and much more sensitive Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). WISE surveyed the whole sky at 3.4, 4.6, 12, and 22 μm. While WISE does not detect wavelengths longer than IRAS channel 2 (25 μm), it is much higher spatial resolution, and can provide insight into how to interpret the IRAS data at 60 and 100 μm.

Some investigations subsequent to dLR97 have begun to question the connection between IR excesses and lithium abundance in red giants (RGs). Fekel & Watson (1998) found 6 giants with larger than typical lithium abundances out of 39 giants with IR excess (as determined from IRAS), which they point out is a similar fraction of stars with enhanced Li as found

7 NASA Postdoctoral Program Fellow.
in normal field giants. Jasniewicz et al. (1999) finds 8 Li-rich stars out of 29 stars with IR excesses (also as determined via IRAS), finding no correlation between Li abundance and IR excess. Lebzelter et al. (2012) report on 3 Li-rich giants (out of more than 400 studied), none of which have IR excesses suggestive of mass loss. The IR excesses in their paper were identified based on WISE data, but were limited to 12 μm and shorter because few of their targets were detected at 22 μm. However, they also looked for evidence of gas mass loss in their spectra, and found none. Kumar et al. (2015) report on a search for IR excesses in 2000 K giants. None of their far-IR excess sources are lithium-rich, and of their 40 Li-rich sources, they identify seven as having IR excess of any sort. These authors combined IRAS and WISE data to look for IR excesses.

In the present paper, we have also combined IRAS and WISE data, as well as data from several other IR surveys as discussed below. Large IR excesses are easily identified in the spectral energy distributions (SEDs), and we used tools developed in the context of the study of young stars to look for small but significant excesses. We started with the dlR97 IRAS-selected targets; these IRAS-selected targets are all quite bright in the IR. We added to this the sample from C12, who assembled a set of K giants consisting of rapid and slow rotators in which the relationship between $v \sin i$, lithium abundances, and carbon isotope ratios ($^{12}$C/$^{13}$C) could be explored with an intention of exploring evidence for planetary accretion. The C12 sample was assembled without regard to IR excess, so these objects are on average much fainter in the IR than the dlR97 sample. Finally, many Li-rich K giants (and candidates) have been reported in the literature, many of which are not in the dlR97 or C12 samples. We have included such Li-rich K giants in our sample. We looked for IR excesses among all of these targets, performing visual inspection of multi-wavelength images and assembling broadband SEDs for our targets.

We now assemble the list of targets (Section 2), and search various archives for images and photometry for these targets (Section 3). Then we drop some stars from our sample, some by necessity due to missing data, and some because they are likely subject to source confusion (Section 4). From the remaining sample, we can identify sources likely to have an IR excess (Section 5). Then we discuss some properties of the sample as a whole (Section 6). We find few stars with IR excesses, so our ability to find correlations with abundances is somewhat limited, but we discuss this in Section 7 before summarizing in Section 8.

2. ASSEMBLING THE TARGET LIST

There are 82 targets published in dlR97. They obtained spectra of the targets on their list, and reported the targets as Li-rich if the Li line at $\lambda 6708$ had an intensity comparable to or higher than the Ca I line at $\lambda 6718$. If the Li abundance was actually known, they took those with abundances larger than log $\epsilon$ (Li) = 1.2 dex as Li-rich. Many of the targets have HD numbers, and thus finding coordinates for an optical counterpart is straightforward. However, many of their targets have only IRAS names, and so they took spectra of objects they believed to be counterparts of the sources listed; see discussion below. The target position we used for these sources is that reported in the IRAS catalogs.

There are 86 K giants reported in C12. Comparing this to the targets from dlR97, there is only one source in common between them, HD 31993. C12 reports lithium abundances, $v \sin i$, and $^{12}$C/$^{13}$C ratios, among other things, for their targets. Not all of these targets are Li-rich.

There is wide-ranging literature reporting on Li-rich K giants (and candidates). We compiled 149 additional targets that have been identified either consistently or at one time as confirmed or possible Li-rich K giants, but not included in either the dlR97 or the C12 samples. They include targets from Adamów et al. (2014), Anthony-Twarog et al. (2013), Carney et al. (1998), J. K. Carlberg et al. (2015, in preparation), Castilho et al. (2000), Drake et al. (2002), Fekel & Watson (1998), Hill & Pasquini (1999), Jasniewicz et al. (1999), Kirby et al. (2012), Kraft et al. (1999), Kumar et al. (2011) and references therein, Liu et al. (2014), Luck & Heiter (2007), Martell & Shetrone (2013), Monaco et al. (2014), Pilachowski et al. (2003), Ruchti et al. (2011), Silva Aguirre et al. (2014), Smith et al. (1999), and Torres et al. (2000). Kumar et al. (2015) appeared as we were finishing our analysis, and it has similar goals as the present paper. It uses as a starting point the list of 2000 low-mass K giants from Kumar et al. (2011), so all of the Li-rich sources from that sample are already in our sample. All of the literature sources are identified simply as “literature sources” in Table 1; the Appendix identifies the paper of origin for any given target.

Our complete list of 316 targets appears in Table 1. We obtained R.A., decl, positions for these targets, most of which are quite bright in the optical, primarily from SIMBAD, though literature was consulted for fainter sources as required. The positions we used are in Table 1, which also includes all the bandmerged brightness measurements discussed below. In the Appendix, Table 6 collects a few special notes about any special circumstances attached to that star, e.g., information about typos in previously published tables, or necessary tweaks to the positions. There are copious notes in the main text about targets called out as special (e.g., those with IR excesses).

3. ARCHIVAL DATA

In this section, we discuss the catalogs we searched for detections of our sources; they are summarized in Table 2, along with the fraction of the sample having matches in each of these catalogs. Table 1 includes all the crossmatched sources (names and reported brightnesses) discussed below.

3.1. Overall Approach to Archival Data

All of the large-area catalogs described here were merged by position with a catalog-dependent search radius to the position we obtained for our targets as described above. Typically, the closest source by position was taken to be the match, and often the best match was within 1″. However, each source was investigated in the images from the Palomar Observatory Digital Sky Survey, the Sloan Digital Sky Survey (SDSS), 2MASS, and WISE. Nebulosity, source confusion, or extended sources were all noted. SEDs were constructed (using zero points if necessary as provided in the corresponding survey documentation) as an additional check on the source matching—obvious discontinuities in the SED suggested problems with source matching, and a better match was sought (but not always found). If a source other than the closest source by position was determined to be a better match, then the match was forced to be the better match, even if it was >1″ away. We primarily used the Infrared Science Archive (IRSA) tool FinderChart\(^{8}\) for this process, along with

\[^{8}\) http://irsa.ipac.caltech.edu/applications/finderchart/\]
Table 1
Contents of Online Catalog

| Format | Units | Label       | Explanations                                                                 |
|--------|-------|-------------|-----------------------------------------------------------------------------|
| A2     | ...   | name        | name of source                                                               |
| F1.6   | deg.  | R.A.        | R.A. of source (J2000)                                                       |
| F1.6   | deg.  | Decl.       | decl. of source (J2000)                                                      |
| A6     | ...   | dir97       | flag to indicate source is part of the dir97 sample                          |
| A4     | ...   | C12         | flag to indicate star is part of the C12 sample                               |
| A5     | ...   | lit         | flag to indicate star is selected from the literature as a Li-rich giant (but not C12 or dir97) |
| A4     | ...   | LirichLit   | value of "yes" means source is identified in the literature as a Li-rich giant |
| A4     | ...   | LirichHere  | value of "yes" means source is selected here as a Li-rich giant               |
| F7.2   | ...   | AlLiNLTE    | Al(Li) under the assumption of NLTE from the literature                      |
| F7.2   | ...   | AlLiLTE     | Al(Li) under the assumption of LTE from the literature                       |
| A2     | ...   | Jlim        | limit flag for Al(Li) under the assumption of LTE from the literature        |
| F5.1   | ...   | Cratiol     | limit flag on \(^{13}C/^{12}C\) ratio                                       |
| F5.1   | km s\(^{-1}\) | vsini     | projected rotational velocity \(v \sin i\) in km s\(^{-1}\) from the literature |
| I5     | K     | Teff        | Effective temperature from the literature                                    |
| F5.1   | ...   | logg        | log \(g\) from the literature                                               |
| F6.2   | mag   | Umag        | Vega-based magnitude in \(U\) band                                           |
| F6.2   | mag   | Bmag        | Vega-based magnitude in \(B\) band                                           |
| F6.2   | mag   | Vmag        | Vega-based magnitude in \(V\) band                                           |
| F6.2   | mag   | Rmag        | Vega-based magnitude in \(R\) band                                           |
| F6.2   | mag   | Jmag        | Vega-based magnitude in \(J\) band                                           |
| F6.2   | mag   | Kmag        | Vega-based magnitude in \(K\) band                                           |
| F6.2   | mag   | Hmag        | Vega-based magnitude in \(H\) band                                           |
| F6.2   | mag   | Qmag        | Vega-based magnitude in \(Q\) band                                           |
| F6.2   | mag   | Knmag       | Vega-based magnitude in \(K\) band                                          |
| A2     | ...   | Jlim        | limit flag for 2MASS \(J\) band                                              |
| A2     | ...   | Jqual       | 2MASS data quality flag for \(J\) (A = best)                                |
| A2     | ...   | Hlim        | limit flag for 2MASS \(H\) band                                              |
| A2     | ...   | Hqual       | 2MASS data quality flag for \(H\) (A = best)                                |
| A2     | ...   | Klim        | limit flag for 2MASS \(K\) band                                              |
| A2     | ...   | Kqual       | 2MASS data quality flag for \(K\) (A = best)                                |
| A18    | ...   | DENISname   | Name from DENIS catalog                                                      |
| F6.2   | mag   | Imag        | Vega-based DENIS magnitude in \(I\) band                                     |
| F6.2   | mag   | Jmag        | Vega-based DENIS magnitude in \(J\) band                                     |
| F6.2   | mag   | Knmag       | Vega-based DENIS magnitude in \(K\) band                                     |
| A2     | ...   | Wlim        | limit flag for WISE-1 ([3.4])                                               |
| F6.2   | mag   | W1mag       | Vega-based magnitude in WISE-1 ([3.4])                                       |
| F6.2   | mag   | W1merr      | Vega-based magnitude error in WISE-1 ([3.4]); value of \(-9\) for those measures that are limits |
| A2     | mag   | W1qual      | WISE-1 ([3.4]) data quality flag (A = best)                                 |
| A2     | ...   | W2lim       | limit flag for WISE-2 ([4.6])                                               |
| F6.2   | mag   | W2mag       | Vega-based magnitude in WISE-2 ([4.6])                                       |
| F6.2   | mag   | W2merr      | Vega-based magnitude error in WISE-2 ([4.6]); value of \(-9\) for those measures that are limits |
| A2     | mag   | W2qual      | WISE-2 ([4.6]) data quality flag (A = best)                                 |
### Table 1 (Continued)

| Format | Units | Label | Explanations |
|--------|-------|-------|--------------|
| A2     | ...   | W3lim | limit flag for WISE-3 ([12]) |
| F6.2   | mag   | W3mag | Vega-based magnitude in WISE-3 ([12]) |
| F6.2   | mag   | W3merr| Vega-based magnitude error in WISE-3 ([12]); value = −9 for those measures that are limits |
| A2     | mag   | W3qual| WISE-3 ([12]) data quality flag (A = best) |
| A2     | ...   | W4lim | limit flag for WISE-4 ([22]) |
| F6.2   | mag   | W4mag | Vega-based magnitude in WISE-4 ([22]) |
| F6.2   | mag   | W4merr| Vega-based magnitude error in WISE-4 ([22]); value = −9 for those measures that are limits |
| A2     | mag   | W4qual| WISE-4 ([22]) data quality flag (A = best) |
| A27    | ...   | SEIPname | Name from SEIP source list |
| A2     | mag   | I1mag | Vega-based magnitude in IRAC-1 ([3.6]) |
| F6.2   | mag   | I1merr| Vega-based magnitude error in IRAC-1 ([3.6]) |
| A2     | mag   | I2mag | Vega-based magnitude in IRAC-2 (4.5) |
| F6.2   | mag   | I2merr| Vega-based magnitude error in IRAC-2 (4.5) |
| A2     | mag   | I3mag | Vega-based magnitude in IRAC-3 (5.8) |
| F6.2   | mag   | I3merr| Vega-based magnitude error in IRAC-3 (5.8) |
| A2     | mag   | I4mag | Vega-based magnitude in IRAC-4 (8) |
| F6.2   | mag   | I4merr| Vega-based magnitude error in IRAC-4 (8) |
| A2     | mag   | M1mag | Vega-based magnitude in MIPS-1 (24) |
| F6.2   | mag   | M1merr| Vega-based magnitude error in MIPS-1 (24) |
| A14    | ...   | IRASPSName | Name from IRAS Point Source Catalog (PSC) |
| F6.2   | mag   | IRASPSMag | Vega-based magnitude in IRAS-1 ([12]) from PSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRASPSFlux | flux density in Jy in IRAS-1 from PSC |
| A2     | mag   | IRASPSQual | Data quality flag for IRAS-1 from PSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA2PSMag | Vega-based magnitude in IRAS-2 ([25]) from PSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA2PSFlux | flux density in Jy in IRAS-2 from PSC |
| A2     | mag   | IRA2PSQual | Data quality flag for IRAS-2 from PSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA3PSMag | Vega-based magnitude in IRAS-3 ([60]) from PSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA3PSFlux | flux density in Jy in IRAS-3 from PSC |
| A2     | mag   | IRA3PSQual | Data quality flag for IRAS-3 from PSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA4PSMag | Vega-based magnitude in IRAS-4 ([100]) from PSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA4PSFlux | flux density in Jy in IRAS-4 from PSC |
| A2     | mag   | IRA4PSQual | Data quality flag for IRAS-4 from PSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA1FSMag | Vega-based magnitude in IRAS-1 ([12]) from FSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA1FSFlux | flux density in Jy in IRAS-1 from FSC |
| A2     | mag   | IRA1FSQual | Data quality flag for IRAS-1 from FSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA2FSMag | Vega-based magnitude in IRAS-2 ([25]) from FSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA2FSFlux | flux density in Jy in IRAS-2 from FSC |
| A2     | mag   | IRA2FSQual | Data quality flag for IRAS-2 from FSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA3FSMag | Vega-based magnitude in IRAS-3 ([60]) from FSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA3FSFlux | flux density in Jy in IRAS-3 from FSC |
| A2     | mag   | IRA3FSQual | Data quality flag for IRAS-3 from FSC (3 = best, 1 = limit) |
| F6.2   | mag   | IRA4FSMag | Vega-based magnitude in IRAS-4 ([100]) from FSC; errors taken to be 0.22 mag |
| F9.2   | Jy    | IRA4FSFlux | flux density in Jy in IRAS-4 from FSC |
| A2     | mag   | IRA4FSQual | Data quality flag for IRAS-4 from FSC (3 = best, 1 = limit) |
| A28    | ...   | AKARIName | Name from AKARI IRC catalog, v1 |
| F9.2   | Jy    | AKARI9fd | flux density in Jy in 9 microns from AKARI IRC |
| F9.2   | Jy    | AKARI9fder | error in flux density in Jy in 9 microns from AKARI IRC |
| F9.2   | Jy    | AKARI11fd | flux density in Jy in 11 microns from AKARI IRC |
| F9.2   | Jy    | AKARI11fder | error in flux density in Jy in 11 microns from AKARI IRC |
| A28    | ...   | AKARIName | Name from AKARI FIS catalog, v1 |
| F9.2   | Jy    | AKARI65fd | flux density in Jy in 65 microns from AKARI FIS |
| F9.2   | Jy    | AKARI65fder | error in flux density in Jy in 65 microns from AKARI FIS |
| F9.2   | Jy    | AKARI90fd | flux density in Jy in 90 microns from AKARI FIS |
| F9.2   | Jy    | AKARI90fder | error in flux density in Jy in 90 microns from AKARI FIS |
| F9.2   | Jy    | AKARI140fd | flux density in Jy in 140 microns from AKARI FIS |
| F9.2   | Jy    | AKARI140fder | error in flux density in Jy in 140 microns from AKARI FIS |
| F9.2   | Jy    | AKARI160fd | flux density in Jy in 160 microns from AKARI FIS |
| F9.2   | Jy    | AKARI160fder | error in flux density in Jy in 160 microns from AKARI FIS |
| A18    | ...   | MSXName | Name from MSX catalog |
| F9.2   | Jy    | MSX6fd | flux density in Jy in MSX Band A (7.76 μm) |
| F9.2   | Jy    | MSX6fder | error in flux density in Jy in MSX Band A (7.76 μm)—as reported, may be very large |
| F9.2   | Jy    | MSXB1fd | flux density in Jy in MSX Band B1 (4.29 μm) |
the one-to-one catalog matching feature in the IRSA catalog search tool. Significant issues with images and SEDs will be discussed in the next section (Section 4).

3.2. Primary Catalogs

The 2MASS (Skrutskie et al. 2006) obtained data over the whole sky at $JHK_s$ bands. We found matches to most of our sources well within 1′′—a histogram of distances peaks strongly below 0′′.2. However, ~10% of the targets (largely those still having original coordinates from IRAS) required larger (by-eye) matches, up to 15″ away. Many of our targets are quite bright and are therefore saturated in the 2MASS catalog. For most of these, we can obtain at least estimates of $K_s$ from the Naval Observatory Merged Astrometric Dataset (NOMAD; Zacharias et al. 2005), though empirically we have found that the errors as reported there are likely significantly underestimated, perhaps representing statistical errors only (not including systematics). For one source, the $JHK_s$ brightnesses had to be retrieved from the extended source catalog (rather than the point source catalog; PSC). For many of our bright targets, the formal photometric quality as reported in 2MASS may be poor, but the points are in good agreement with the rest of the SED assembled here. We thus retained 2MASS measurements even if the photometric quality was deemed poor by the 2MASS pipeline. (About 60% of the sources with 2MASS counterparts have $K_s$ photometric quality “A”; ~35% have nominal photometric quality “D” or worse.) Limits reported in the catalog were retained as limits here.

2MASS provides the coordinate system to which other catalogs including WISE are anchored, so, given the very close positional matches for 2MASS, we expected (and found) comparable high-quality matches with those other catalogs.

IRAS surveyed the sky in 1983 in four bands, 12, 25, 60, and 100 μm. As the first all-sky infrared survey, it is relatively low spatial resolution and relatively shallow. The PSC (Beichman et al. 1988) reports on sources smaller than 0′.5–2′ in the in-scan direction (where the native survey pixels are rectangular). The typical FWHM of sources in the IRAS Sky Survey Atlas (ISSA) data products (which is what appears in FinderChart) is 3′.4–4′.7. The IRAS Faint Source Catalog (FSC; Moshir et al. 1992) is a reprocessing of the IRAS data that obtains, among other things, better positional accuracy and reaches fainter flux densities. We searched both the IRAS PSC and FSC for counterparts to our sources. Since the dIR97 sources were selected based on IRAS properties, all of them have detections in the PSC, and 36 are also detected in the FSC. Nearly half (103/235) of our remaining sources have IRAS detections in either the PSC or FSC in any band, though only about a third of the C12 sources have an IRAS detection (in any band). Overall, 181 have sources in either the PSC or FSC, and 99 have counterparts in both the PSC and FSC.

The IRAS data (where available) for our targets appear in Table 1. We used the non-color corrected flux density at the various bands as reported in the catalogs, and used the Vega zero points as reported in the online IRAS documentation10 to convert the flux densities to magnitudes, namely 28.3, 6.73, 1.19, and 0.43 Jy for the four bands, respectively. No errors are reported, so we took a flat 20% flux density uncertainty, which is 0.22 mag. We merged catalogs without regard to flux quality, though the quality is noted in our catalog. Nearly all of the detected sources are the highest quality (qual = 3) in both the PSC and FSC at 12 μm, but >80% of these sources are the lowest quality in the PSC and FSC at 100 μm (qual = 1). The lowest quality measurements are, according to the documentation, meant to be limits. In some cases, even the nominal limits are in good agreement with detections from other instruments. We retained the measurements and the flux quality flags in our database.

WISE surveyed the whole sky at 3.4, 4.6, 12, and 22 μm; all of the available WISE data taken between 2010 January and 2011 February were incorporated into the AllWISE catalog (Cutri et al. 2014), which we used for this work. In three cases, brightnesses for a target had to be retrieved from the AllWISE catalog of rejections. Since the dIR97 sources were selected based on the relatively shallow IRAS data, many were saturated at least one WISE band; many fewer of the C12 sources were saturated. Of the WISE detections, only those with data quality flags “A,” “B,” or “C” were retained, but most detections were “A” or “B”; the fraction of detections with data quality flag “C” is 10%, 5%, 1%, and 3% for the four WISE channels, respectively. For many of our very bright targets, the formal photometric quality as reported in WISE may be poor, but the points are in good agreement with the rest of the SED; limits from the catalog were retained in our database.

Given the relatively low spatial resolution of IRAS compared to 2MASS or WISE, we did not necessarily expect to find very close positional matches to sources with solely IRAS positions. However, many sources whose coordinates were the original IRAS positions found very close matches in 2MASS and/or WISE, demonstrating the high quality of those original IRAS positions. The places where IRAS did not match well were

| Format | Units | Label | Explanations |
|--------|-------|-------|--------------|
| F9.2   | Jy    | MxsB1fderr | error in flux density in Jy in MSX Band B1 (4.29 μm)—as reported, may be very large |
| F9.2   | Jy    | MxsB2fd | flux density in Jy in MSX Band B2 (4.35 μm) |
| F9.2   | Jy    | MxsB2derr | error in flux density in Jy in MSX Band B2 (4.35 μm)—as reported, may be very large |
| F9.2   | Jy    | MxsCfd | flux density in Jy in MSX Band C (11.99 μm) |
| F9.2   | Jy    | MxsCderr | error in flux density in Jy in MSX Band C (11.99 μm)—as reported, may be very large |
| F9.2   | Jy    | MxsDfd | flux density in Jy in MSX Band D (14.55 μm) |
| F9.2   | Jy    | MxsDerr | error in flux density in Jy in MSX Band D (14.55 μm)—as reported, may be very large |
| F9.2   | Jy    | MxsEf | flux density in Jy in MSX Band E (20.68 μm) |
| F9.2   | Jy    | MxsEferr | error in flux density in Jy in MSX Band E (20.68 μm)—as reported, may be very large |

(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms.)

9 http://irsa.ipac.caltech.edu/IRASdocs/issa.exp.sup/ch1/C.html
10 http://irsa.ipac.caltech.edu/IRASdocs/exp.sup/ch6/C2a.html
Table 2
Overview of Photometric Studies and Data Included

| Dataset | Band(s) Used | Search Radius\(^a\) (″) | Fraction with Match | Notes |
|---------|--------------|--------------------------|--------------------|-------|
| 2MASS   | \(JHK\), (1.2–2.2 \(\mu\)m) | 1\(^b\) | 304/316 = 96% | primary catalog; many saturated |
| WISE    | 3.4, 4.5, 12, 22 \(\mu\)m | 1 | 311/316 = 98% | primary catalog; many saturated in part. (~20% of sample required >1″ counterpart match) |
| IRAS    | 12, 25, 60, 100 \(\mu\)m | <20 | PSC: 159/316 = 50%; FSC: 121/316 = 38% | data used for original de la Reza studies |
| AKARI   | 9, 18, 65, 90, 140, 160 \(\mu\)m | 1 | IRC: 221/316 = 70%; FIS: 36/316 = 11% | supplementary data (~20% of IRC sources that had matches required >1″ counterpart match, most of the FIS required >1″.) |
| MSX     | 4.3, 4.4, 7.8, 12.0, 14.6, 20.6 \(\mu\)m | 20 | 54/316 = 17% | supplementary data |
| SEIP    | 3.6, 4.5, 5.8, 8, 24 \(\mu\)m | 1 | 39/316 = 12% | very low fractional coverage |
| DENIS   | 0.82, 1.25, 2.15 \(\mu\)m | 1 | 83/316 = 26% | provides deeper \(K_s\) than 2MASS; only 58 have \(K_s\) and none of those are lacking in 2MASS \(K_s\) |
| SDSS    | \(ugriz\) (0.29–0.91 \(\mu\)m) | 2 | 94/316 = 30% | supplementary data |
| NOMAD, C12 | \(UBVR\) (0.36–0.7 \(\mu\)m) | 1 | 277/316 = 88% | literature data from NOMAD or C12 |

Notes.
\(^a\) Characteristic distance to source match; some sources with poor positions required a much larger search radius.
\(^b\) Most sources found a match within 1″ (histogram of distances peaks strongly below 0′′2), but ~10% required larger (by-eye) matches.
largely those where source confusion pulled the photocenter position off from the brightest source in WISE; see additional discussion on source confusion issues below.

All of the abundances and associated information ($T_{\text{eff}}$, log $g$) were most often taken from the papers reporting the star as Li-rich—see the Appendix table for the specific literature reference. We allowed A(Li) from the non-local thermodynamic-equilibrium (NLTE) estimates to take precedence over LTE estimates, but in some cases, only LTE abundances were available. In a few cases, only Li equivalent widths were available in the literature, in which case we did not even attempt to estimate an $A$(Li), and thus the sources are effectively dropped from analysis requiring A(Li). In $\sim 20$ cases, McDonald et al. (2012) provided a $T_{\text{eff}}$ estimate when no other was available from the literature. For the 14 stars with super-solar metallicities in C12, we provide corrected NLTE abundances here.

3.3. Secondary Catalogs

The AKARI mission (Murakami et al. 2007) surveyed the sky in 2006–2007, in wavelengths between 1.8 and 180 $\mu$m using two instruments, the Infrared Camera (IRC) and the Far-Infrared Surveyor (FIS). We searched the IRC catalog for counterparts at 9 and 18 $\mu$m, and the FIS catalog for counterparts at 65, 90, 140, and 160 $\mu$m. A large fraction ($\sim 70\%$) of our sources have a counterpart in at least one IRC band; relatively few ($\sim 11\%$) of our sources have a counterpart in at least one FIS band. The AKARI data cover the whole sky, and can provide valuable data to help populate the SEDs of our targets. For the majority of targets where we have AKARI counterparts, the AKARI data are consistent with WISE and/or IRAS measurements. We did not sort the AKARI matches by photometric quality; because our sources are bright, even those with low photometric quality flags matched the existing SED quite well. For the FIS sources where the photometric quality is the lowest, no errors are given, so we adopted a conservative uncertainty of 50% for those sources.

The Midcourse Space Experiment (MSX; Egan et al. 2003) surveyed the Galactic Plane in 1996–1997 at several bands between 8 and 21 $\mu$m—Band $A = 7.76$ $\mu$m, $B1 = 4.29$ $\mu$m, $B2 = 4.35$ $\mu$m, $C = 11.99$ $\mu$m, $D = 14.55$ $\mu$m, and $E = 20.68$ $\mu$m. The spatial resolution of these images range from 20″ to 72″. Relatively few (just 54) of our targets have MSX counterparts, in no small part because of sky coverage, but the lower sensitivity of the MSX instruments also plays a role. The errors we report in Table 1 are the errors reported in the MSX catalog, and as such may be very large.

The Deep Near Infrared Survey of the Southern Sky (DENIS) conducted a survey of the southern sky at $I$, $J$, and $K$ bands. It is deeper than 2MASS. In several cases, because the search radius for a counterpart had to be large, it was clear upon construction of the SEDs that the nearest source by position was not the best match (often because a fainter source was closer to the given position than the real target), and so the match was rejected. In the end, only 58 of our targets have a $K_s$ magnitude from DENIS, and none of those are lacking a 2MASS $K_s$. Therefore, the DENIS measurements do not play a role in identification of IR excesses, but were retained in those few cases to better define the SED.

The entire archive of photometric 3–24 $\mu$m cryogenic-era Spitzer Space Telescope (Werner et al. 2004) data has been reprocessed and images and source lists released as part of the Enhanced Imaging Products (SEIP). Spitzer is generally more sensitive (and has higher spatial resolution) than WISE or AKARI. However, the SEIP source list is limited to those with signal-to-noise ratios greater than 10. Because Spitzer is a pointed mission, the entire sky is not covered, and only 12% of our sources have counterparts in the SEIP source list. These measurements were retained in those few cases specifically because they are higher spatial resolution, and can provide valuable insight into the reliability of the flux densities provided by IRAS, AKARI, and WISE. We have found that the errors as reported in the SEIP are likely statistical and probably do not include a calibration uncertainty floor. We have added 4% errors in quadrature to the reported errors.

The SDSS (see, e.g., Ahn et al. 2014 and references therein) has surveyed a significant fraction of the sky at $ugriz$ (optical) bands. These data, where available, help define the Wien side of our objects’ SEDs; they do not aid in calculation of IR excesses, but they “guide the eye” to identify the photosphere. About 30% of our targets have SDSS counterparts in at least one band. Several more of our targets appear in SDSS images, but are far too bright for reliable photometry. We used images and photometry as retrieved via IRSA’s FinderChart.

The Digitized Sky Survey (DSS) is a digitization of the photographic sky survey plates from the Palomar (the Palomar Observatory Sky Survey, POSS) and UK Schmidt telescopes. We used images from the DSS retrieved via IRSA’s FinderChart to check on source confusion and multiplicity.

NOMAD reports broadband optical photometry for most of our targets; C12 reports optical photometry for their targets. Those values were included in our database, as for the SDSS optical data above, to define the short-wavelength side of the SED.

4. DROPPED SOURCES

In this section, we describe the set of targets that we have to drop from our dataset because they are not detected at sufficient bands (Sections 4.1, 4.2), or that are likely subject to source confusion where the IRAS detection is likely composed of more than one source, or where the bright source in POSS is not responsible for the IR flux (Section 4.3). The 24 sources we identify as subject to source confusion come from studies with sources first identified in the low spatial resolution IRAS data and followed up in the optical.

4.1. Sources with Very Sparse SEDs

There are 10 sources that do not appear in many of the catalogs we used here, such that they have very sparsely populated SEDs. These SEDs are sparse enough that they cannot be handled in the same way as the other sources in the set—they have no $K_s$ or [22] measures, and sometimes no WISE data at all. These sources are listed in Table 3. All of these very sparse SED stars are from Kirby et al. (2012), and are in dwarf spheroidal galaxies. They are just too far away to be detected in enough bands in the surveys we used. Comments on these objects appear in Table 3. For each source, we inspected the SED and the photometry, looking for any evidence of IR excess at the available bands, and found none.

These 10 sparse SED sources are, of necessity, frequently dropped from subsequent figures and discussion here. We reiterate, however, that they are all from the “additional literature” sample; none are from C12 or dIR97.
Sources with Relatively Sparse SEDs Beyond 10 \( \mu \)m

There are 36 sources that have relatively well-populated SEDs, but are missing detections past 10 or 20 \( \mu \)m. We cannot treat those sources in exactly the same way as the rest of the stars in the set, but at least we can constrain whether or not there is an IR excess, more so than for the stars in the previous section. These sources are listed in Table 3. There are two sources for which an IR excess cannot be ruled out given the available detections. The star known as “For 90067” could be consistent with an IR excess at 8 \( \mu \)m, given the available IRAC data, but the error on the [8] point is large. (Following the approach below in Section 5.4, but customized to this star, \( \chi_{K,8} \) is 3.1.) SDSS J0632+2604 has a much more convincing excess, with [3.4]–[12] = 1.45.
These sources do not often appear in the subsequent figures and discussion, because they are, for example, missing [22], and thus cannot appear in a figure plotting [3.4]–[22]. However, the two possible excess sources here are sometimes included in the counts of sources with IR excesses, and where we do so, we note it explicitly. Nearly all of these sources (26/36) are objects we take to be Li-rich. Of these, SDSS J0632+2604 has the largest IR excess and also the largest Li abundance, with \( A(\text{Li})_{\text{LTE}} = 4.2 \) dex.

None of these relatively sparse sources are from the dIR97 sample. Seven of them are from C12, and the remainder are from the “additional literature” sample.

### 4.3. Source Confusion

As mentioned above, it is often the case that a bright source in \( \text{IRAS} \) is also a bright source in the optical, but sometimes this is not a good assumption. Now that 2MASS and \( \text{WISE} \) images are available, it is far easier than it was in the 1990s to identify sources over 3 orders of magnitude in wavelength (0.5–100 \( \mu \)m). In 24 of our targets, we believe that there are likely issues of source confusion. In these cases, at least one of the following things can be seen in the images: (a) the IR excess seen in the \( \text{IRAS} \) images is due to more than one \( \text{WISE} \) (or 2MASS) source, likely unresolved in the \( \text{IRAS} \) catalog; or (b) the nearest bright source in POSS, which is most likely the source for which an optical spectrum to measure lithium was obtained, is not responsible for most of the IR flux density detected via \( \text{IRAS} \).

For the first kind of source confusion, where the IR excess seen in \( \text{IRAS} \) is due to more than one \( \text{WISE} \) source, understanding the original \( \text{IRAS} \) resolution is important, because these issues of \( \text{IRAS} \) spatial resolution can be subtle. Figure 1 shows a \( \text{WISE} \) 12 \( \mu \)m image of one of our targets, IRAS06365+0223, with circles overlaid to represent the various possible \( \text{IRAS} \) resolutions. The image is 300\( '' \) = 5\( '' \) on a side. The original \( \text{IRAS} \) PSC was derived from images that had pixels that were substantially rectangular, but included sources believed to be point sources with sizes less than \( \sim 0.5–2.0 \) in the in-scan direction. \(^{11}\) The small green circle in Figure 1 is representative of this 12 \( \mu \)m 0.5 resolution, and the large blue circle is representative of this 100 \( \mu \)m 2\( '' \) resolution. Note that these are shown in the figure as circles, whereas in reality, this resolution is only obtained in the in-scan direction, which is roughly along lines of ecliptic longitude; the resolution is considerably worse in the cross-scan direction. (For this target, lines of ecliptic longitude are locally about 5\( ^\circ \) east of north, but this angle varies over the sky.) The typical FWHM of sources in the ISSA data products (ISSA images are shown in FinderChart) is 3.4–4.7\(^{12}\), which is represented by the large red circle in Figure 1 at 3.4 (diameter). The multiple sources seen in this \( \text{WISE} \) image, for example, are likely convolved together for at least some of the \( \text{IRAS} \) measurements. This is an important factor in several of the \( \text{IRAS} \) sources we discuss in this section, meaning that the IR flux attributed to a single optical source may not be correct, and the IR excess previously measured for a given optical source may be significantly overestimated.

The second kind of source confusion, where the bright source in POSS is not responsible for the IR flux, is source confusion of a different nature. In many cases, it is a good assumption that the bright source in \( \text{IRAS} \) is also the bright source in POSS. However, in a significant number of cases, all the sources in the region are of comparable brightness in POSS, or the optically bright source is not the source of most of the IR light. Now that 2MASS and \( \text{WISE} \) are available, we can trace the source across wavelengths to securely identify the optical counterpart in the POSS images. In these cases, however, the spectrum obtained to assess lithium may very well have been of the bright POSS source, and not of the origin of the IR flux at all, especially in those cases where no optical counterpart can be found in the POSS images.

To demonstrate these issues of source confusion, we provide POSS, 2MASS, and \( \text{WISE} \) images for each of the 24 targets in Figures 2–7, specifically to allow readers to follow the same sources across wavelengths. (The FITS images can be interactively explored via IRSA’s FinderChart.) For each of these figures, either a multi-color or single band image appears for each of POSS, 2MASS, and \( \text{WISE} \), and the images are 300\( '' \) on a side unless specified. For POSS, it is either DSS2 Blue/Red or the blue, green, and red bands, respectively, or it is a single-band DSS2 Red. For 2MASS, \( JHK_s \) corresponds to blue/green/red, respectively, and for \( \text{WISE} \), [3.4], [4.5], and [12] correspond to blue/green/red unless specified. The source position is indicated with a small blue circle; white or black hash marks above and to the left help guide the eye to this position. A brief discussion of each of these sources appears in Table 4; a briefer still summary appears in the figure itself and the caption.

SEDs for these 24 sources appear in Figures 8 and 9. These SEDs correspond in most cases to the source position measured in \( \text{IRAS} \), but may or may not be the origin of all of the \( \text{IRAS} \) flux density, or correspond to the optically bright source. Because we are matching sources largely by position to the sources in the catalogs, in several of the cases illustrated in Figures 2–7 where the true counterpart is is impossible to match, the counterparts across catalogs are not the same source, and the SED clearly

---

11 http://irsa.ipac.caltech.edu/IRASdocs/exp.sup/ch5/A2.html
12 http://irsa.ipac.caltech.edu/IRASdocs/issa.exp.sup/ch1/C.html
betrays this conglomeration of sources (see notes in Table 4). IRAS18334–0631 (PDS 524) (Figure 9, 3rd row center) is the clearest example of this, where AKARI and MSX are seeing the same source, but it is a different source than the source that 2MASS, DENIS, and WISE identify, both of which are inconsistent with the flux densities measured in IRAS.

Eight of these sources have SEDs that do not resemble isolated stars. They rise steadily from 1 to 20 or even 100 μm and beyond. These would be SEDs consistent with extragalactic sources, or very heavily obscured stars of any age. These sources are noted in Table 4; IRAS16128–5109 is one of the best examples (Figure 8, 3rd row center). This source has measurements from 2MASS, WISE, MSX, AKARI, and IRAS, with the energy density at ~20 μm being ~5 orders of magnitude larger than the energy density at ~1 μm. The IRAS data suggest a rollover in this SED near 60 μm. Most of these...
steep SEDs turn over at long wavelengths, but two of these eight sources have a peak in the SED at $\sim 22 - 25 \mu m$, shorter than the others. These two sources, IRAS14198–6115 and IRAS14257–6023, are 100" on a side to better show the source that is very red in 2MASS and dominating the measured flux by WISE bands. The brightest source in POSS is the one appearing as white in 2MASS to the north and slightly west of the target position, which is not responsible for the IR flux. IRAS16128–5109, is not a point source in the IR, and is very bright (saturated in WISE) by 22\,\mu m. Single bands are shown in the optical, NIR, and MIR to better show the nebulosity.

Figure 3. (Notation is as in Figure 2.) Four rows are: (1) IRAS12236–6302 (PDS 354). The blue arc immediately above the target in WISE can be seen to be three distinct sources in 2MASS and, combined, are the brightest thing in the POSS 300" images. These sources are not responsible for most of the IR flux measured at the target position. (2) IRAS14198–6115. There are two sources here that are distinct in 2MASS and marginally resolved in [3.4], but are indistinguishable by [22]. (3) IRAS14257–6023. Images are 100" on a side to better show the source that is very red in 2MASS and is dominating the measured flux by WISE bands. The brightest source in POSS is the one appearing as white in 2MASS to the north and slightly west of the target position, but it is not responsible for the IR flux. (4) IRAS16128–5109. This is not a point source in the IR, and is very bright (saturated in WISE) by [22]. Single bands are shown in the optical, NIR, and MIR to better show the nebulosity.

One of these sources, IRAS17211–3458, is worthy of a few additional comments here because it is the most borderline of these source confusion cases. The images shown in Figure 5 (second row) show a small concave arc of sources in the optical near the target location; by $H$ (middle panel), it is a convex arc of sources, where only two sources (including our target) are bright in the POSS+2MASS images—they appear white in the 2MASS image in Figure 5. We identified source confusion here in part because these two sources are of comparable brightness at POSS, but also because WISE has trouble resolving the three close, IR-bright sources. WISE identifies some faint nebulosity here; in the WISE image in Figure 5, the surface brightness is barely visible. However, there are Spitzer data here too, which resolves complex striated nebulosity; see Figure 10. The IRAS target position is $\sim 2''$ from the nearest 2MASS source, which is
larger than typical uncertainties over the whole catalog. The Spitzer source corresponding to this object does not appear in the SEIP, perhaps because it either is or appears to be slightly resolved because of the high surface brightness nebulosity surrounding it. The SED (Figure 9, top center) is the source closest to the target position, where available. On the face of it, its shape would be consistent with a photosphere with large excess. That, plus the fact that there is a POSS source exactly at the location of the IRAS source (and is presumably the object for which an optical spectrum to assess lithium was obtained), could conceivably place it in the set of objects with large excesses identified and discussed below. However, based on the images, bands longer than 12 μm (WISE, MSX, AKARI, IRAS) certainly are measuring net flux density from more than one point source, plus nebulosity near (in projection) to the source. This is also the point at which the SED starts to significantly diverge from the apparent photosphere. Because of this ambiguity, we have left it in the set of confused sources.

**Figure 4.** (Notation is as in Figure 2.) Four rows are: (1) IRAS16227–4839. There are two sources here that are resolved in 2MASS and marginally resolved at [3.4], but merged by [22], with the more northerly source dominating the IR flux. The more southerly source is brighter in POSS. (2) IRAS16252–5440. There is a cluster of sources that is responsible for the IR flux, with the target position at the photocenter. The field has no clearly dominant source in POSS. (3) IRAS16514–4625 (PDS 432). A dark cloud is apparent in 2MASS and WISE. The brightest source in the optical is the center of the source seen in WISE as blue but not a point source because it aggregates three sources seen in 2MASS. The source that dominates by [22] is faint at [3.4]. (4) IRAS17102–3813. Images are 100′ on a side to better show the trio of sources seen at JHKs that become a smear dominated by the two sources to the southeast by [22]. The optically brightest source may contribute some but not all of the 22 μm flux density.
It is not tagged as a Li-rich source in dlr97, so even if we were able to add it to the analysis we perform below, it is unlikely to have contributed significantly.

Because of the ambiguity about the sources and their counterparts, these 24 sources have to be dropped from our sample. IRAS07419–2514 was identified as a possible K giant in Torres et al. (2000), and PDS 97 (IRAS17554–3822) is from de la Reza et al. (1996). The remaining 22 sources compose ~30% of the original dlr97 sample. We drop these sources from the bulk of our analysis, but show them in certain plots where relevant below.

5. SOURCES WITH IR EXCESSES BY ~25 μm

5.1. Overview of Approach

Having omitted the objects for which we have substantial difficulty making matches across catalogs above, we have now a subset of objects for which we have established reliable multi-wavelength matches across catalogs. All of these objects have no or little ambiguity in the images to which we have access, e.g., they appear as clean point sources. We can now inspect the resultant assembled SEDs for evidence of an IR excess.
In assessing whether or not a star has an IR excess, one needs to compare a measure of brightness at relatively short wavelengths (expected to be dominated by the stellar photosphere) with that at relatively long wavelengths, where dust emission is likely to be present. We take a two-pronged approach to identifying excesses. There are some objects for which an IR excess is immediately apparent upon inspection of the SED; no detailed analysis is required. These objects are summarized in Section 5.2 and detailed in Section 5.3. There are other objects for which the IR excess is more subtle. For these latter objects, we employ an approach developed in the context of finding small IR excesses around young stars, which is described in Section 5.4. Details of objects found to have these more subtle IR excesses can be found in Section 5.5. Table 5 summarizes the stars we identify as having either a large or small IR excess.

5.2. Overview: Sources with Very Large Excesses

There are 19 stars whose SEDs immediately reveal significant IR excesses at wavelengths <20 μm, and maintain large excesses out to at least 25 μm. These sources
often have detections in more surveys than just WISE; they often have data from MSX, AKARI, IRAS, and even Spitzer. Over the entire sample, including these sources with large excesses, the data from these various surveys are in reasonably good agreement, though some objects have more scatter than others. (The scatter could be due to complex backgrounds and variable beamsize across the surveys, or even intrinsic variability in the source.) If there is disagreement, however, it is typically IRAS that overestimates the flux density from the object, which makes sense since IRAS is the lowest spatial resolution of all the surveys used here.

The SEDs for these objects with unambiguous, large excesses appear in Figures 11 and 12. For stars without circumstellar dust (at least those warm enough to have the peak of their photospheric SED be at $< 1 \mu m$), measurements in the IR ($> 2 \mu m$) should fall on a line consistent with a Rayleigh–Jeans (R-J) slope. To guide the eye, in Figures 11 and 12, we have added an R-J line extended from $2 \mu m$. All of the sources with very large excesses can be seen to deviate from this line.

Figure 7. (Notation is as in Figure 2.) Four rows are: (1) IRAS18397–0400. The brightest source in the IR has no optical counterpart, and is dominated by the longest wavelengths. The brightest POSS source is blue in WISE. (2) IRAS18559+0140. There is no optical source at the target position; the bright POSS source to the southwest is not bright at all in the IR and is blue in the WISE data; the target’s IRAS flux has contributions from several sources, most likely including the flux from the bright source to the upper left, pulling the photocenter off of the bright clump of sources to the right. (3) IRAS19083+0119 (PDS 562). The brightest source in the IR has no optical counterpart, and is strongly dominated by the longest wavelengths. The brightest POSS source is blue in WISE. (4) IRAS19210+1715. There is no optical source at the target position; the bright POSS source to the east can be seen in the IR, but the target position matches the very red source to the west, which most likely dominates the IRAS flux.
Table 4

Objects that are Dropped from the Main Sample

| Name | Src | Conf* | Steep SED? | Notes |
|------|-----|-------|------------|-------|
| IRAS06365+0223 | x | x | ... | Target position on an optically faint source within a grouping of optically bright sources, and corresponds to a very red, resolved source seen as resolved in Ke (fluxes retrieved from 2MASS extended source catalog). This extended source is the origin of most of the long-wavelength flux. dlR97 source. |
| IRAS07419–2514 | x | x | ... | Target position in among a grouping of optically bright sources, with somewhat different sources bright in the IR. Position corresponds to the photocenter of the aggregate source seen by IRAS. Because target center does not correspond to an optically detected target, there are no short-wavelength measurements in the SED (so it appears to have a sparse SED). Source identified in Torres et al. (2000), and notes there say that IRAS flux may come from CO cloud WB 1046. IRAS flux probably attributable to ~ 5 IR-bright sources seen in WISE. |
| IRAS09553–5621 | (m?) | x | ... | Target position in between two sources that are comparably bright at 4.6 μm. Only one source is apparent at optical through Ke, and by 22 μm, the sources have merged into one apparent source, likely responsible for the measured IRAS flux. SED assembled from closest source by position and thus may represent fluxes from different sources. Steep SED. AKARI consistent with IRAS at longest bands. dlR97 source. |
| IRAS11044–6127 | x | x | x | High surface density of comparably bright sources in the optical; no easily visible source exactly at the target position in the optical. There is a faint source that starts to appear in 2MASS images, and a source to the west that becomes bright. The source exactly at the target position is still faint and blended with a source to the south at 3.4 μm. The target source is rising fast and dominates by 12 μm, dominating all the sources in the field by 22 μm (and therefore probably dominates the measured IRAS flux). Steep SED. dlR97 source. |
| IRAS12236–6302(PDS 354) | x | x | ... | Another crowded field with comparably bright sources in POSS; there is an optically brighter source above and to the west of the target position that can be seen to be three distinct sources in 2MASS. In WISE, these sources are not resolved and form a blue arc immediately above the target. A source at the target location strongly dominates the field at 12 and 22 μm, and is presumably responsible for most of the IRAS flux (and, for that matter, that from MSX and AKARI). Steep SED. dlR97 source. Torres et al. (2000) mention that their optical spectrum of the source they took to be the counterpart of the IR emission has strong Hα emission and could be an H n region. |
| IRAS14198–6115 | (m?) | x | ... | There are two sources here that are distinct in 2MASS and marginally resolved in [3-4] (though AllWISE catalog identifies only one), but are indistinguishable by [22]. There are several sources in this vicinity in the optical. SED assembled from closest source by position and thus likely represents fluxes from different sources. dlR97 source. |
| IRAS14257–6023 | (m?) | x | ... | The brightest source in POSS is to the north and slightly west of the target position, but it is not responsible for the IR flux. There is a source to the southeast that is very red in 2MASS and is dominating the measured flux by WISE bands, and is likely responsible for the IRAS flux. SED assembled from closest source by position and thus may represent fluxes from different sources. dlR97 source. |
| IRAS16128–5109 | x | x | x | This is not a point source in the IR, and is very bright (saturated) by [22]. It appears in SIMBAD as an H n region; the morphology of the image suggests a dense clump of sources from which emanate long streamers of extended emission. Steep SED. dlR97 source. |
| IRAS16227–4839 | x | ... | ... | There are two sources that are resolved in 2MASS and marginally resolved at [3-4], but merged by [22], with the more northerly source dominating the IR flux. The more southerly source is brighter in POSS. Some extended emission visible in WISE. dlR97 source. |
| IRAS16252–5440 | x | ... | ... | This is also PDS 146. In POSS, there is a high surface density of comparably bright sources. By 2MASS, an aggregate of at least 4 IR-bright sources is apparent. In WISE, it can be seen that the target position corresponds roughly to the photocenter of the aggregate of sources seen at [12]. The brightest source by [22] is to the east of the target position and is probably responsible for most of the IRAS flux. The SED we have assembled for this source corresponds to the source closest by position to the target position, and as such does not represent correctly the source of the longest wavelength flux, dlR97 source. Torres et al. (1995) lists this as “other” and “probably not young;” and later implies it may be a normal MS star. |
| IRAS16514–4625(PDS 432) | x | x | x | A dark cloud is apparent near this source in WISE images. The brightest source in the optical is to the northwest of the target position, which is resolved into at least 3 sources in 2MASS. The source that dominates the IR by [22] (and probably also IRAS) is faint at [3-4]. Steep SED. dlR97 source. Torres et al. (2000) list it as a confirmed giant but the source that was measured may not be responsible for the IR flux. |
| IRAS17102–3813 | (m?) | x | ... | A trio of sources seen at 2MASS become a smear dominated by the two sources to the southeast by [22]. The optically brightest source may contribute some but not all of the [22] (and IRAS) flux. SED assembled from closest source by position and thus may represent fluxes from different sources. dlR97 source. |
| IRAS17120–4106 | x | ... | ... | Nothing is at the target position in POSS, though there is a source straight east of the target position. That easterly source persists through [3-4]. There is a faint source closer to the target position appearing by Ke. The two sources are barely resolved at [3-4], and merge by [12] and [22]. Given the [22] photocenter, some flux is likely attributable to each source, even in WISE, dlR97 source. |
| IRAS17211–3458 | (m?) | x | ... | Two comparably bright sources are resolved in POSS, and in 2MASS. The two sources are barely resolved at [3-4] and merge by [12] and [22]. SED assembled from closest source by position, so may represent fluxes from different sources. dlR97 source. See text for additional discussion. |
| Name                  | Src Conf\(^a\) | Steep SED\(^b\) | Notes                                                                                                                                 |
|-----------------------|----------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------|
| IRAS17442–2441        | x (m?)         | ...            | The DSS images are dense with sources of comparable brightness, though there is a source close to the target position. Similarly, in 2MASS, no source dominates, though there is a source close to the target location. There is a source at the target position and another comparably bright one to the west just resolved at [3.4]; they merge by [12] and [22]. SED assembled from closest source by position and thus may represent fluxes from different sources. \(\text{dIR97 source.}\) |
| PDS 97(IRAS17554–3822) | x (m?)         | ...            | Target position in between two sources of comparable brightness at POSS and 2MASS. It is also between two comparably bright sources at [3.4] and [4.6]; by [12] the easterly source dominates, and by [22], all the flux is likely from the easterly source. Source from de la Reza et al. (1996), Gregorio-Hetem et al. (1992) list it as a high velocity giant with strong Li, and “incorrect identification in PSC” because KL Cra is 78° east, outside error ellipse. SIMBAD lists it as a T Tauri. |
| IRAS17576–1845        |                | ...            | The multi-wavelength images suggest extinction in this field. The source position is reasonably close to a bright POSS source, but the target position can be seen to have several sources in 2MASS and \(\text{WISE.}\) The source dominating at [22] (and presumably \(\text{IRAS bands}\)) is “smeary” at [3.4], \(\text{dIR97 source.}\) Coudella et al. (1995) list it as a candidate to be related to high-mass star forming regions with an ultracompact H\(\text{II}\) region, though it remained undetected in their survey. |
| IRAS17582–2619        | x              | x              | The brightest source in the IR has no optical counterpart, and the IR is strongly dominated by the longest wavelengths. The optically brightest source is to the west of the target source, and has faded substantially by [12] and [22] \(\mu\)\text{m.} Steep SED to 20 \(\mu\)\text{m, well-defined, with data from multiple surveys in good agreement with each other. Turnover from steep SED happens abruptly at } \sim 20 \mu\text{m, shorter wavelengths than most of the other steep SEDs identified here (the other one like this is IRAS19083 +0119(PDS 562)). \(\text{dIR97 source.}\) SIMBAD lists this as an OH/IR star. Yoon et al. (2014) and references therein identify it as a post-AGB star (OH/IR 02-1.68). It appears in Ramos-Larios et al. (2012) and as a heavily obscured post-AGB star or PN candidate, and García-Lario et al. (1997) as a PN candidate. It appears in de la Reza et al. (2015) as an early AGB star. |
| IRAS17590–2412        |                | ...            | The brightest source in the IR has no optical counterpart, and is strongly dominated by the longest wavelengths. Diffuse emission can also be seen in the field in various bands. \(\text{dIR97 source.}\) Messineo et al. (2004) identify a SiO emitter in this region but suggest that it may not be associated with the source from which an optical spectrum had been obtained by \(\text{dIR97.}\) They note that this \(\text{IRAS source is the only mid-infrared source within its 86 GHz beam.}\) |
| IRAS18334–0631(PDS 524)| x (m?)         | ...            | There is no optical source at the target position; the target’s \(\text{IRAS flux likely has contributions from several sources in this} \) vicinity, including a source resolved as an arc in \(\text{WISE \[3.4 \text{and } 4.6\text{] \text{precisely at the target position. The brightest POSS source is to the northwest of the target, and the brightest source by } \text{K}_{\text{s}} \text{is to the southwest. The brightest source by [22] is to the northeast. SED assembled from closest source by position and thus likely represents fluxes from different sources. \(\text{dIR97 source.}\)}}\) |
| IRAS18397–0400        |                | ...            | The brightest source in the IR has no optical counterpart, and is dominated by the longest wavelengths. The brightest POSS source is to the northeast, though it is no longer the brightest source by 2MASS. The source responsible for most of the IR flux is slightly to the west of the target position, and is visible in 2MASS. \(\text{MSX measurements have very large errors but are consistent with the rest of the SED. \(\text{dIR97 source.}\)}}\) |
| IRAS18559+0140        | x (m?)         | ...            | There is no optical source at the target position; a bright POSS source is to the southwest and is not bright at all in the IR. The target’s \(\text{IRAS flux has contributions from several sources, including a small clump to the east; the photocenter is pulled to the west, off of the bright clump of sources, and this offset of the \(\text{IRAS position is the farthest off from the} \) \(\text{WISE source in the entire dataset. The assembled SED corresponds to the closest source by position and as such does not represent the brightest IR source here, and likely represents more than one source. \(\text{dIR97 source.}\)}}\) |
| IRAS19083+0119(PDS 562)| x              | x              | The brightest source in the IR has no optical counterpart, and is strongly dominated by the longest wavelengths. There is a faint source at the target position by \(\text{K}_{\text{s}}\) and it rises quickly through the \(\text{WISE bands. Steep SED, with data from several surveys in good agreement with each other. Turnover from steep SED happens near } \sim 20 \mu\text{m, shorter wavelengths than most of the other steep SEDs identified here (the other one like this is IRAS17582–2619). \(\text{dIR97 source.}\) SIMBAD lists it as a possible planetary nebula. Yoon et al. (2014) and references therein identify it as a post-AGB star.}\) |
| IRAS19210+1715        | x              | x              | There is no optical source at the target position; though there is a bright POSS source to the east, which can be seen in the IR. However, the target position matches a very red source, marginally visible in the 2MASS images, and rising quickly through the \(\text{WISE bands, which most likely dominates the} \) \(\text{IRAS flux. There may be a contribution at [22] from a nearby source bright at [12]. Steep SED. \(\text{dIR97 source.}\)}}\) |

Notes.  
\(^a\) This column is populated if the object is likely subject to source confusion of either of the sorts described in the text. “x (m?)” indicates that there may be multiple sources represented in the SED, e.g., the object shown in the SED at 2 \(\mu\text{m} \) may not be the same object as that shown at 22 \(\mu\text{m.}\)  
\(^b\) This column is populated if the object’s SED rises steadily from 2 to at least 20 \(\mu\text{m, as described in the text.}\)
Out of these 19 stars with large IR excesses, 14 (73%) are from the dlR97 sample, five are from the literature sample, and none are from C12. However, four of the 19 may not be K giants—one of the dlR97 stars, IRAS17578–1700, is a carbon star, one of the stars from the literature sample, V385 Sct, is a very cool S-type star, and the other two may be too cool to be first ascent K giants. Some of these stars have detections indicating that the SEDs are rising beyond 90 μm, suggesting that sub-mm observations are needed to constrain the outer extent of the IR excess. Some of these objects have been identified in recent literature (e.g., Kumar et al. 2015) as having an IR excess, but for others, this is the first confirmation that the objects have an IR excess using data more recently obtained than IRAS.

5.3. Notes on Sources with Very Large Excesses

IRAS00483–7347. This is an extremely well-populated SED, with data from WISE, MSX, AKARI, IRAS, and even Spitzer. However, the SED is wide compared to other SEDs in this study. The SED suggests that K, is not on the R-J side of the SED, perhaps because the star is significantly cooler than a K giant. A R-J line extended from 2 μm as shown, or even a R-J line extended from ~5 μm, suggests a substantial IR excess around this star. Data from multiple sources are in good agreement with each other, and AKARI suggests that there is a significant long-wavelength component to the IR excess, with the SED rising again at the longest wavelengths. This source is identified in Castilho et al. (1998) as a Li-rich K giant, though no T_eff estimates are available in the literature. This star may be too cool to be a K giant, though it clearly has a large IR excess. Additional spectroscopy of this source would be helpful for a better understanding of the T_eff and where the excess starts.

HD 19745. The IR excess for this source starts to appear past 10 μm; WISE and AKARI are in good agreement. IRAS overestimated the IR flux density from this star, but it still has a clear excess. This source is known to be a Li-rich K giant (Reddy & Lambert 2005), and is incorrectly identified in SIMBAD as a T Tauri. Reddy & Lambert (2005) identify it as a red clump star. This star was identified in Kumar et al. (2015) as having an IR excess.

IRAS03520–3857. This object is a dlR97 source, and it had to be offset from the nominal IRAS position by 11'' to pick up the counterparts, which is very large in the context of the other positional shifts needed in the rest of our sample. However, the field is relatively clean (consisting of one bright source) and is not suggestive of source confusion. There is good agreement between WISE, AKARI, and IRAS for 10–20 μm. There is about an order of magnitude more energy density emerging at 10–20 μm than at 3–4 μm. However, compared to other sources here, there are few detections blueward of ~2 μm, and it would be nice to see the SED turn over to define the Wien side of the SED. This object is identified in two papers as a possible galaxy based on IRAS colors (Saunders et al. 2000; Wang & Rowan-Robinson 2009) but is not identified as a confirmed galaxy in either paper. SIMBAD identifies it as a “peculiar star.” This source has no T_eff in the literature.

IRAS04376–3238. This object’s IR excess starts at least by 5 μm, if not actually at 3 μm. WISE, AKARI, and IRAS are in good agreement. However, compared to other sources here, there are few detections blueward of ~2 μm, and it would be nice to see the SED turn over to define the Wien side of the SED. This object is identified as a K giant in Torres et al. (2000), but as a candidate T Tauri in Magnani et al. (1995). It does have an SED consistent with SEDs found in young stars (see, e.g., Rebull et al. 2011). SIMBAD lists it as a “peculiar star.” Spectroscopy would be useful to distinguish a young star with low gravity from an old star with low gravity, and assess its Li abundance. (An uncertain equivalent width for Li is given for it in Torres et al. 2000, but no abundance.) This source has no T_eff in the literature.

IRAS07227–1320(PDS 132). This star has a substantial IR excess that evidently starts abruptly between 4.6 and 7.8 μm. AKARI, MSX, WISE, and IRAS are consistent with each other. This object is part of the dlR97 sample, and Torres et al. (2000) list it as a confirmed giant. However, Torres et al. (1995) lists this as “other” and “probably not young” in their paper on young stars; it is implied to be a normal MS star. García-Lario et al. (1997) identify it as a possible PN (planetary nebula) based on its IR excess. It is identified as a post-AGB star and an M1 I giant in Suárez et al. (2006). Szczepańcik et al. (2007) identify it as “not a post-AGB (asymptotic giant branch) star,” but Yoon et al. (2014) identify it as a post-AGB star of type M3 IV. This source has no T_eff in the literature. Additional data are needed to clarify the status of this object.

IRAS07456–4722(PDS 135). This star’s IR excess is small at 3.4 and 4.6 μm, but becomes substantial by ~10 μm. There is scatter but generalized agreement among IRAS, AKARI, and WISE. This object is part of the dlR97 sample. Torres et al. (2000) list it as a confirmed giant, though Torres et al. (1995) categorize it as a “Probable post-FU Ori star.” SIMBAD lists it as a T Tauri, apparently on the basis of Torres et al. (1995). As with other sources here, it has an SED consistent with SEDs found in young stars (see, e.g., Rebull et al. 2011), and spectroscopy would be useful to distinguish a young star with low gravity from an old star with low gravity. This source has no T_eff in the literature.

IRAS07577–2806(PDS 260). There is good agreement between WISE, AKARI, MSX, and IRAS here, and there is more energy density near 20 μm (from dust) than near 1 μm (from the photosphere). AKARI provides detections out past 100 μm. The IR excess may start at 3.4 μm. This source is from the dlR97 set, and Torres et al. (2000) list it as a confirmed giant. SIMBAD identifies it as a post-AGB star, and reference García-Lario et al. (1997), but this object does not appear in the paper. Szczepańcik et al. (2007) retain it as a candidate AGB star. It does not have a T_eff in the literature.

HD 233517. This star’s SED suggests an excess that starts past 5 μm. This is an original dlR97 source, and this star was identified in Kumar et al. (2015) as having an IR excess, as well as in Fekel & Watson (1998), Jasniowicz et al. (1999), and Drake et al. (2002), among others.

IRAS08359–1644. This SED suggests an IR excess that most likely starts at ~10 μm. WISE and IRAS (and the single AKARI point) are in good agreement with each other. Torres et al. (2000) identify this source as a Li-rich K giant. No other information about this source is apparently available (including T_eff); additional data would be useful.

HD 96195. This SED is more complicated than ones above. Reliable WISE points at the shortest two bands do not exist; MSX provides a link between K and [12]. MSX, AKARI, WISE, and IRAS are all in rough agreement between 10 and 20 μm, though there is some scatter (and large error bars in one case). Assuming that K, is on the photosphere (and on the R-J side of the SED, that is, assuming that this source is hot enough), there is a significant IR excess by 10 μm: K, ≈ 12 = 1.14 mag. We

The Astronomical Journal, 150:123 (45pp), 2015 October

Rebull et al.
Figure 8. SEDs for things that are likely subject to source confusion, part 1. Notation for all SEDs in this paper is as follows. The axes are log $F_\lambda$ in cgs units (erg s$^{-1}$ cm$^{-2}$) and log $\lambda$ in microns. Symbols: cyan + are literature UBRI; black + are SDSS ugriz; black diamonds are 2MASS JHK; blue squares are Denis IJK; black circles are from Spitzer/IRAC; black stars are WISE; yellow × are AKARI; cyan triangles are MSX; black squares are Spitzer/MIPS (24 μm); red downward pointing triangles are IRAS PSC and FSC. Any arrows are limits at the corresponding wavelength. Error bars are indicated as vertical black bars at the center of each point. See text and Table 4 for discussion of individual objects.
Figure 9. SEDs for things that are likely subject to source confusion, part 2; notation is as described in Figure 8. See text and Table 4 for discussion of individual objects.
identified in Kumar et al. (2015) as having an IR excess. While it is listed as a confirmed Li-rich K giant in several studies (e.g., Kumar & Reddy 2009; Kumar et al. 2011, among others), it also appears in Valenti et al. (2003) as a T Tauri candidate, though no usable spectra are reported of this object in that paper. SIMBAD has adopted the “T Tauri” categorization. The \( ^{12}\text{C}/^{13}\text{C} \) ratio is only a limit (>20; Reddy & Lambert 2005), and cannot conclusively determine whether early RGB first dredge-up mixing (which lowers \( ^{12}\text{C}/^{13}\text{C} \) from the main sequence value) has occurred.

\[ \text{IRAS16086--5255 (PDS 410).} \] This star’s IR excess likely starts between 2 and 3 \( \mu \text{m} \); there is more energy density near 20 \( \mu \text{m} \) (from dust) than near 1 \( \mu \text{m} \) (from the photosphere). There is good agreement among WISE, MSX, AKARI, and IRAS. This star is part of the dIR97 sample, and is listed in Torres et al. (2000) as a confirmed giant. However, SIMBAD categorizes it as “post-AGB, proto-PN,” and Szczepańcik et al. (2007) retain it as a candidate AGB. No \( T_{\text{eff}} \) is available.

\[ \text{IRAS17578--1700.} \] This star has a substantial IR excess that may start at \( K_s \); it may also be too cool for \( K_s \) to be on the R-J side of the SED. There is good agreement between MSX, AKARI, WISE, and IRAS, though there are no viable WISE points at the shortest two bands. This object is part of the dIR97 sample. Chen et al. (2007), and references therein including Lloyd Evans (1991) identify it as a J-type carbon star based on optical spectra and IR excesses, and that categorization is inherited by SIMBAD. This star is likely too cool to be a K giant, and moreover is likely to be a carbon star.

\[ \text{IRAS17596--3952 (PDS 485).} \] This object is part of the dIR97 sample, and its position had to be slightly adjusted from the nominal IRAS position to pick up the counterparts, but the field is relatively clean and is not suggestive of source confusion. This star’s IR excess likely starts between 2 and 3 \( \mu \text{m} \); there is a larger excess by \( \sim 10 \mu \text{m} \), and WISE, AKARI, and IRAS are in good agreement where the points exist. This star was identified in Kumar et al. (2015) as having an IR excess. It is a confirmed Li-rich K giant (e.g., Reddy & Lambert 2005; Kumar et al. 2011).

\[ \text{V385 Sct.} \] This is a very bright star, and the \( K_s \) mag may not be on the R-J side of the SED; it may be too cool to be a K giant. There are no WISE data for the shortest two bands, and MSX fills the gap between 2 and 10 \( \mu \text{m} \). There is scatter among the MSX, WISE, AKARI, and IRAS data, likely because it is so bright. It does seem to have an obvious IR excess, however. It appears in Castilho et al. (2000) and Pereyra et al. (2006) as a Li-rich K giant. However, it appears as GCSS 557 in Stephenson (1976) and is identified as star of type S in there and subsequent literature (such as Stephenson 1984, where it is CSS 1043). Stars of type S have ZrO bands as well as TiO bands, and other abundance anomalies; they are thermally pulsing AGBs that experience substantial dredge-up. It seems unlikely to be a first-ascent Li rich K giant. The \( T_{\text{eff}} \) value for it from the literature (Castilho et al. 2000) is \( \sim 3300 \) K, so it is also too cool to be a first-ascent K giant.

\[ \text{PDS 100.} \] There may be a small excess at 3.4 and 4.6 \( \mu \text{m} \), but there is a clear excess by \( \sim 10 \mu \text{m} \), as seen by WISE, AKARI, and IRAS. This star is part of the dIR97 set, and is also known as V859 Aql. SIMBAD indicates it as a T Tauri, but the literature is clear that it is instead a Li-rich K giant (Reddy et al. 2002, among others). This star was identified in Kumar et al. (2015) as having an IR excess.

\[ \text{HD 219025.} \] This star is also known as BI Ind, and its IR excess starts between 2 and 3 \( \mu \text{m} \). There is a viable WISE...
Table 5
Sources with IR Excesses

| Name                        | [3.4]–[22] | μ10 | Sample                        | Data Codes | Dropc | Lited | Starl |
|-----------------------------|------------|-----|--------------------------------|------------|-------|-------|-------|
| IRAS00483–7347              | 4.71       | (large) | Castilho et al. (1998)     | W M A I S  | D?  | ... | <2   |
| NGC 362 V2                  | 1.13       | 9.7 | Smith et al. (1999)         | W S        | ... | 5    |       |
| HD 19745                    | 2.32       | (large) | dlr97, Kumar et al. (2011) | W A I      | ... | IRx 10 |       |
| IRAS03520–3857              | 8.80       | (large) | dlr97              | W A I      | ... | 2?   |       |
| IRAS04376–3238              | 3.83       | (large) | Torres et al. (2000)       | W A I      | ... | 3?   |       |
| IRAS07227–1320(PDS 132)     | 6.64       | (large) | dlr97              | W M A I    | ... | ... | 5?   |
| IRAS07456–4722(PDS 135)     | 5.40       | (large) | dlr97              | W A I      | ... | 3?   |       |
| HD 65750                    | ...        | ... | dlr97, Castilho et al. (2000) | (W) A I    | ... | IRx 2? |       |
| IRAS07577–2806(PDS 260)     | 8.75       | (large) | dlr97              | W M A I    | ... | ... | 3?   |
| HD 233517                   | 5.53       | (large) | dlr97, Kumar et al. (2011) | W A I      | ... | IRX 10 |       |
| IRAS08359–1644              | 6.00       | (large) | Torres et al. (2000)       | W A I      | ... | 3?   |       |
| G0928+73.2600               | 0.63       | 6.4 | C12                         | W          | ... | 22   |       |
| HD 96195                    | ...        | ... | Castilho et al. (2000)      | (W) M A I  | D?  | IRX 10 |       |
| Tyc0276-00327-1             | 0.36       | 3.4 | C12                         | W A        | ... | 22   |       |
| IRAS12327–6523(PDS 355)     | 3.56       | (large) | dlr97              | W M A I    | ... | 2    |       |
| HD 111830                   | 0.63       | 3.7 | dlr97              | W A I S    | ... | 22   |       |
| PDS 365(IRAS13331–5838)     | 7.37       | (large) | dlr97, Kumar et al. (2011) | W M A I    | ... | IRX 2? |       |
| PDS 68(IRAS13559–4153)      | 6.04       | (large) | dlr97, Kumar et al. (2011) | W A I      | ... | IRX 10 |       |
| IRAS16068–5255(PDS 410)     | 9.75       | (large) | dlr97              | W M A I    | ... | 3?   |       |
| HD 146834                   | 1.07       | 2.6 | dlr97              | W A S      | ... | IRX 20?|       |
| IRAS17578–1700              | ...        | ... | dlr97, Kumar et al. (2011) | W A I      | ... | <2   |       |
| IRAS17596–3952(PDS 485)     | 5.15       | (large) | dlr97, Kumar et al. (2011) | W A I      | ... | IRX 3? |       |
| V385 5ct                    | ...        | ... | Castilho et al. (2000)      | (W) M A I  | D?  | ... | 3?   |
| IRAS19012–0747              | 1.39       | 7.2 | dlr97              | W M A I    | ... | 10?  |       |
| IRAS19038–0026              | 1.45       | 4.9 | Castilho et al. (2000)      | W A I      | ... | IRX 10 |       |
| PDS 100                     | 5.86       | (large) | dlr97, Kumar et al. (2011) | W A I      | ... | IRX 4? |       |
| Tyc9112-00430-1             | 0.86       | 3.1 | Ruchti et al. (2011)       | W          | ... | 22   |       |
| HD 210925                   | 3.74       | 9.6 | dlr97, Kumar et al. (2011) | W A I      | ... | IRX 3 |       |

Notes.
- a Note that up to two more stars with IR excess could be identified from the relatively sparse SEDs in Section 4.2; these are For 90067 and SDSS J0632+2604, with SDSS J0632+2604 being more compelling.
- b W = WISE data in SED, with "(W)" meaning some bands are missing; M = MSX data in SED; A = AKARI data in SED; I = IRAS data in SED; S = Spitzer data in SED.
- c This column is populated if there is a reasonable likelihood that the star is not a K giant, e.g., of the sort appropriate for this study. "D?" means we are fairly confident it should be dropped, and "D?" means there is some doubt as to whether it should be dropped; see text.
- d This column is populated if recent literature has already identified this source as having an IR excess.
- e This column contains the approximate wavelength, in microns, of the start of the IR excess.

5.4. Overview: Sources with Small Excesses

Identifying smaller excesses around the remaining stars requires more analysis than simply SED inspection. We can quantitatively compare the brightness at 2–3 μm (which should be dominated by the stellar photosphere in these cases where there is not much circumstellar dust to create an IR excess). With that at relatively long wavelengths, where dust emission may be present. In considering significant IR excesses, the IR excess is larger than any uncertainties in calibration. However, for small excesses, well-defined errors are important; uncertainties in calibration should be taken into account, and it becomes more important to use data that are uniformly obtained, calibrated, and processed so as to minimize systematics. Additionally, data obtained not over decades but obtained in time minimize influence from intrinsic stellar variation. WISE data meet these criteria, as the data are uniformly obtained (at nearly the same time), reduced, and calibrated. Therefore, [3.4]–[22] is essentially an ideal metric with which to identify IR excesses.

There have been several approaches in the literature used to determine with confidence whether or not a star has an IR excess. For example, Mizusawa et al. (2012) tested several methods of finding IR excesses in F stars. To identify sources with small IR excesses, we adopt here the following approach (as in Mizusawa et al. 2012, or Trilling et al. 2008). We calculate

$$\chi = \frac{\text{[3.4]–[22]}_{\text{observed}} - \text{[3.4]–[22]}_{\text{predicted}}}{\sigma_{\text{[3.4]–[22]}}}$$

and take as a significant excess those stars for which χ > 3. For K giants, [3.4]–[22]predicted is 0, but for cooler objects (such as M giants), the predicted value is not 0 (see, e.g., Gautier et al. 2007). Mizusawa et al. (2012) were able to combine χ...
Figure 11. SEDs for sources with large IR excesses, part 1; notation is as described in Figure 8, with an additional line with a Rayleigh–Jeans slope extended from $K_s$ (e.g., if $K_s$ is on the photosphere, the photosphere longward of $K_s$ should fall on this line). All of these objects have a significant excess above this line. See text and table for discussion of individual objects.
calculations for two independent measures of IR excess for most of the targets in their sample, using $K_s$ and $\lambda_{3.4}$–$\lambda_{22}$. We do not have such uniform independent measures of IR excess, so for the most part, we use $\lambda_{3.4}$–$\lambda_{22}$. In order for the $\chi$ calculation to be successful, however, one needs good estimates of the star’s brightness at the relevant bands, as well as good estimates of the error on that measurement. Many of our targets are very bright, and saturated in $K_s$ and $\lambda_{3.4}$, which limits our ability to correctly estimate brightnesses (and errors) and therefore $\chi$. However, we can use the existing measurements and reported errors to identify objects that are likely to have a small IR excess.

Table 5 includes $\lambda_{3.4}$–$\lambda_{22}$ and $\chi_{\lambda_{3.4},\lambda_{22}}$ for the sources with IR excesses. (Note that the $\chi$ values as calculated for the objects with large and obvious IR excesses above in Section 5.2 are often $>100$, despite there being, in some cases, an IR excess even at 3.4 $\mu$m.)

There are nine stars we identify as having small but significant excesses, and their SEDs appear in Figure 13. Two of the stars with small IR excesses are from the C12 sample, three are from the dIR97 sample, and the remaining four come from the literature sample of Li-rich giants. One may be too cool to be a K giant. Two have been recently identified in the literature as having an IR excess. Comments on each of these excess objects follow in the next section.
5.5. Notes on Sources with Small Excesses

NGC 362 V2. There are Spitzer data for this source, and Spitzer agrees well with WISE. There is a small IR excess here. By inspection of the SED, the excess probably starts relatively early in the SED, $\sim 5 \mu m$, for a small excess. (The specific values are $[3.4]-[22] = 1.13$ mag, $\chi_{[3.4],[22]} = 9.7$.) The star is identified as a Li-rich K giant in Smith et al. (1999).

HD 65750. This star is very bright, and as such is missing 3.4 and 4.6 $\mu m$ data (and the $K_s$ data come from NOMAD). There are, however, WISE, AKARI, and IRAS, all of which are in good agreement with each other. This source can be seen in the SED to have an excess; it has no [3.4], but $\chi_{K,[22]} = 11$. It is highly nebulous at POSS, though not at longer bands, so the measured IR flux is not likely contaminated by extended emission. This source comes from the dlr97 sample; it appears in Castilho et al. (2000) as a Li-rich giant. SIMBAD says this is V341 Car, a pulsating variable star of type M0III. It has a $T_{\text{eff}}$ of 3600, so it is most likely a borderline case for being a first ascent K giant. McDonald et al. (2012) identified it as having an IR excess in their study of IR excesses around Hipparcos stars, calling it out (HIP 38834) in their Table 3 of luminous giant stars with detected circumstellar emission (their $E_{IR} = 5.88$).

G0928+73.2600. This star does not have a very well-populated SED, or an immediately obvious IR excess based on the SED, but the $\chi$ calculation supports there being a small but
significant IR excess here ([3.4]–[22] = 0.63 mag, \(\chi_[3.4,22] = 6.4\)). This star is identified as a particularly interesting source in C12 and Carlberg et al. (2010) because it has particularly high Li (\(\Delta\text{Li}_{\text{NLTE}} = 3.30\) dex), relatively rapid rotation (8.4 km s\(^{-1}\)), and high \(^{12}\text{C}/^{13}\text{C}\) (28). We have more discussion of this source in Section 6.4 below.

TyC0276-00327-1. This source does not have an immediately obvious IR excess from the SED (which is also not terribly well populated), but the \(\chi\) calculation supports there being a very small but significant IR excess here ([3.4]–[22] = 0.36 mag, \(\chi_[3.4,22] = 3.4\)). In the images, it appears within the extended halo of emission associated with an extended source (possibly a galaxy) that is bright at [12] and [22]. It is possible that this may affect the IR excess, though the AllWISE catalog does profile fitting photometry that should take into account this higher background. Additional data to secure the association of the IR excess with this object would be helpful. This object is from the C12 sample, but is unremarkable in that study, showing low Li, slow rotation, and average \(\text{[C}/^{12}\text{C}]\).

**HD 111830.** On first glance at the SED, this object seems to have good agreement with photospheric measurements from \(K_s\) to 25 \(\mu\)m, with WISE, AKARI, IRAS, and even Spitzer/MIPS falling on the R-J line to 25 \(\mu\)m. However, IRAS and AKARI, if detecting flux density truly associated with this source, identify a substantial IR excess at bands longer than 50 \(\mu\)m. There turns out to be a small but significant excess at 22 \(\mu\)m ([3.4]–[22] = 0.63 mag, \(\chi_[3.4,22] = 3.7\)). \(K_s–[24] = 0.4\) mag, consistent with a small excess. This star is part of the dlR97 sample; it appears in Jasniwicz et al. (1999) as Li-rich but is listed in their table with an upper limit on the Li abundance.

**HD 146834.** This source is also HR 6076. In POSS, there is nebulousity (and SIMBAD categorizes it as “star in nebula”). It is very bright in 2MASS and WISE, with no strong nebular emission, though there is some faint extended emission in the background at 12 and 22 \(\mu\)m. It has WISE, Spitzer (IRAC and MIPS), and AKARI data, all of which are in fairly good agreement. However, near 20 \(\mu\)m, it is confusing. AKARI measures 860 (±15) mJy at 18 \(\mu\)m, WISE measures 797 (±12) mJy at 22 \(\mu\)m, and MIPS measures significantly less, 528 mJy, at 24 \(\mu\)m. The original error at 24 \(\mu\)m reported in the SEIP is ±16 mJy, and is likely underestimated, so we have added a 4% error floor, as described above; the net error is 21 mJy, still not enough to bring the measures into alignment within 1\(\sigma\). The \(K_s\) mag is bright, and its error is also likely underestimated. Following the measurements and errors as reported, however, \([3.4]–[22] = 1.07, \chi_[3.4,22] = 2.6\), and \(K_s–[24] = 1.19, \chi_[24] = 3.2\). The errors on [3.4] and \(K_s\) are both large, which lowers the \(\chi\) values. It is difficult to decide if the excess here is real and significant. We have opted to call the excess significant because there are three measures of the brightness near 20 \(\mu\)m, and it does seem to be significantly brighter near 20 \(\mu\)m than the photospheric expectations based on the brightness near 2–3 \(\mu\)m. It also has some long-wavelength AKARI detections; if AKARI is measuring flux associated solely with this star, then it has a significant long-wavelength excess. It appears in McDonald et al. (2012) as having a small IR excess in their study of IR excesses around Hipparcos stars (their \(E_{\text{IR}} = 1.532\)). It is from the dlR97 sample.

**IRAS19012–0747.** There are two sources here in close proximity in POSS, but the target position matches one of the two optically bright sources. Both sources can be seen in J through [12], though the target source is clearly dominating, and overwhelms any flux from the apparent companion by [22] (and presumably in IRAS). While source confusion is possible, it’s reasonably likely that a spectrum was obtained of the source of most of the IR flux. This source has WISE, AKARI, and MSX data, all of which are in good agreement with each other. IRAS and AKARI, if detecting flux density truly associated with this source, identify a substantial IR excess at bands longer than 25 \(\mu\)m. At ~20 \(\mu\)m, it has a weaker excess—[3.4]–[22] = 1.39, \(\chi_[3.4,22] = 7.2\). This star is part of the dlR97 sample (though its name was incorrectly IRAS19012–0742 in the published table).

It appears in Pereyra et al. (2006) as a Li-rich K giant.

IRAS19038–0026. \(K_s\) for this object may not be on the R-J side of the SED; it may be too cool to be a K giant. There does not seem to be significant IR excess at 3.4 or 4.6 \(\mu\)m, but the MSX, AKARI, WISE, and IRAS points suggest an excess may be present starting at ~10 \(\mu\)m. By >20 \(\mu\)m, assuming that the IRAS and AKARI points are detecting flux density truly associated with this source, there is a substantial IR excess. At ~20 \(\mu\)m, it has a more subtle excess—[3.4]–[22] = 1.45, \(\chi_[3.4,22] = 4.9\). This object appears in Castillo et al. (2000) and Pereyra et al. (2006) as a Li rich giant, but it may be too cool to be a K giant. The \(T_{\text{eff}}\) that appears in the literature for it is ~3600 K.

**TyC9112-00430-1.** This source does not have an immediately obvious IR excess from the SED, but the \(\chi\) calculation supports there being a small but significant IR excess here: \([3.4]–[22] = 0.86, \chi_[3.4,22] = 3.1\). It is identified as a Li-rich K giant in Ruchti et al. (2011).

### 6. DISCUSSION: CHARACTERISTICS OF THE ENTIRE IR EXCESS SAMPLE

We started with 316 sources. Out of those, 10 have too sparsely populated SEDs for us to sensibly place any strong restrictions on whether or not there is an excess. There are 36 sources that have relatively sparse SEDs, and are often missing at least the [22] band. For these, we can put some constraints on whether or not there is an IR excess, and 2 out of those 36 sources could plausibly have an IR excess. There are 24 sources that we suspect are subject to source confusion, and we drop them from the sample. There are 218 sources with well-populated SEDs and no evidence for IR excesses out to ~20 \(\mu\)m. There are 28 sources that have well-populated SEDs that do, in fact, have evidence for an IR excess. Out of those 28, 5 are probably giants but may not be K giants. We conclude that IR excesses are rare among our sample of K giants, at best ~10%. Given the biases in our sample (described in detail below), this fraction is probably less in Li-rich RGs and substantially less in Li-poor RGs.

We now examine our ensemble population in several different ways.

#### 6.1. Comparison of IR Excesses to Literature

Not all of our IR excess sources are newly identified as having an IR excess; after all, dlR97 and others in the literature identified these sources based on their IR properties. However, one important goal of our paper was to reassess the IR excesses in these sources given the higher spatial resolution data now available. Other recent papers have identified IR excesses in some of our targets using similar or the same data; McDonald et al. (2012) and Kumar et al. (2015) both identify sources with IR excesses. Kumar et al. (2015) has similar goals to our paper, and many targets overlap. We recover all 7 of their IR excess K giants.
McDonald et al. (2012) did an analysis of more than 107,000 Hipparcos stars, incorporating data from IRAS, SDSS, DENIS, 2MASS, MSX, AKARI, and WISE, in order to identify stars with an IR excess. Out of our targets, 118 are included in the catalog presented in McDonald et al. (2012). Only some of the IR excess objects are explicitly discussed in McDonald et al. (2012), so only one of our objects (HD 65750) is mentioned there as having an IR excess; we agree that it has an IR excess. Following the prescription laid out in their paper (in their Figure 7 and associated discussion), however, 5 more objects (out of the 118 we have in common) can be identified as having at least potentially significant IR excesses: HD 6665, HD 96195, Tyc3917-01107-1, HD 203136, and HD 219025. Two of those (HD 96195, HD 219025) are ones we have already identified above as having IR excesses. The remaining three (HD 6665, Tyc3917-01107-1, and HD 203136) do not appear to us to have excesses (Figure 14); we investigated why the McDonald et al. calculations might have identified them as excess objects. HD 6665 has the IRAS 12 μm point slightly above the photosphere, but all other detections are on the photosphere ([3.4]–[22] = 0.09; the value of $E_{\text{IR}}$ calculated by McDonald et al. is 2.16, likely a result of the IRAS point being slightly high. Tyc3917-01107-1 is in a nearly identical situation, though in this case, the IRAS 12 μm point is closer to the photosphere; the McDonald et al. $E_{\text{IR}}$ is 1.73, and [3.4]–[22] = 0.07, so again, not likely to have a real excess. HD 203136 has some irregularities in its SED, where there is a lot of scatter among the the MSX, AKARI, and IRAS points near 8–12 μm; they are inconsistent with each other and the rest of the SED, and all of them are too high compared to the WISE [12] and [22] points. The McDonald et al. $E_{\text{IR}}$ comes out to be 4.89 most likely because the MSX, AKARI, and IRAS photometric points are high. We take WISE to be the most reliable, because it has the highest spatial resolution; [3.4]–[22] = −0.21 ± 0.14, so there is no detectable IR excess in this object.

Thus, we conclude that we have recovered all of the recent literature-identified IR excess sources. We have identified 18 more objects out of our aggregate data that have IR excesses, though not all of them may be first ascent K giants.

Many of the sources in our sample had been identified as IR excess sources from IRAS measurements. All 21 of the sources with the largest IRAS IR excesses ([12]–[25] > 0.5 mag) from detections—not limits—in the PSC are recovered as IR excess sources here. Nearly all, 11 of 14, of the sources with detections and [12]–[25] > 0.5 in the FSC are recovered. There are just three sources (HD 76066, HD 112859, HD 203251) for which the FSC detections at [12] and [25] result in [12]–[25] > 0.5, but the measured WISE flux densities are substantially lower than the IRAS FSC flux densities, such that these stars do not have detectable IR excesses. The [3.4]–[22] for these objects are 0.05, 0.08, 0.08 mag, respectively, so these sources do not have measurable IR excesses to 22 μm. This is probably a direct result of the higher spatial resolution of WISE better measuring the flux density of the target.

However, many of the sources with smaller measured IRAS excesses are not recovered as IR excess sources. In the SEDs for these cases, one can often see the IRAS PSC suggesting an IR excess, the IRAS FSC suggesting less of an excess, and WISE (and sometimes AKARI) suggesting a smaller or no excess. (Similarly, and more dramatically, the upper limits are often pushed lower and lower in the SEDs.) In these cases, what is most likely going on is that the increased spatial resolution and the fainter sensitivity reached resolves out extended emission and/or source multiplicity, lowering the overall measured flux density. However, there are also some noticeable calibration offsets between IRAS and 2MASS+WISE; see Section 6.5 below.

6.2. SED Interpretation

IR excess around stars is commonly interpreted as due to circumstellar dust in a shell or disk or ring. In Table 5, we...
include an approximate wavelength at which the excess appears. Sources where the IR excess is already present between 2 and 5 \( \mu m \) likely have very large disks or envelopes of dust that reach nearly all the way in to the star. Sources where the IR excess does not start until 10 or 20 \( \mu m \) likely have shells or rings of dust, where there is a gap between the star and the dust. Obtaining total dust masses would require detailed modeling of the star–dust SED (plus assumptions about the composition of the dust) and is beyond the scope of this paper. On the whole, larger excesses likely correspond to larger \( K \) giants, but it could also be residual debris or be subject to source confusion. The scatter in the \( K \sim [22] \) versus \( [3.4] \sim [22] \) is a nearly ideal metric with which to assess IR excesses, many of our objects are saturated at \([3.4] \). Therefore, it is worthwhile to examine the \( K \sim [22] \) plot as well; see Figure 16. More sources are included in this plot, and there are still very large excesses here, even among the objects thought to be \( K \) giants. There is more scatter in the \( K \sim [22] \) photometric loci, reflecting some of the larger uncertainties in the measurements of the (bright) stars in \( K \).

Many of the reddest sources (redward of \([3.4] \sim [22] \sim 5 \) or \([K] \sim [22] \sim 5 \)) in either of these figures are the dropped sources; their location in this diagram is not surprising given some of the SEDs shown in Figures 8 and 9. Still, many of the large IR excess \( K \) giants we identified above are very red in this diagram. For context, young stars in Taurus (which are known to have substantial dusty disks and envelopes) have a typical \([3.4] \sim [22] \sim 4 \), though some extend to \([3.4] \sim [22] \sim 10 \) (Rebull et al. 2011). The range of IR excesses for the objects we believe to be \( K \) giants is comparable to the range of IR excesses found in young stars. Some of the IR excesses seen in these \( K \) giants are very large indeed, with many well past 4 out to 10. However, these large IR excesses are not distributed uniformly among the subsamples. The dlR97 sample includes the large excesses; the excesses in the literature Li-rich sample are much more moderate. The C12 sample has very few excesses, and those are quite small.

**6.3. Color–Magnitude Diagrams**

Another view of the IR excesses for the entire sample can be obtained by plotting \([3.4] \) versus \([3.4] \sim [22] \), as illustrated in Figure 15. Photospheres (that is, stars without any circumstellar dust) should have \([3.4] \sim [22] \sim 0 \). All of the sources significantly redward of \([3.4] \sim [22] \sim 0 \) are either identified as IR excess sources or are identified as subject to source confusion (Section 4.3 above). Even though \([3.4] \sim [22] \) is a nearly ideal metric with which to assess IR excesses, many of our objects are saturated at \([3.4] \). Therefore, it is worthwhile to examine the \( K \sim [22] \) plot as well; see Figure 16. More sources are included in this plot, and there are still very large excesses here, even among the objects thought to be \( K \) giants. There is more scatter in the \( K \sim [22] \) photometric loci, reflecting some of the larger uncertainties in the measurements of the (bright) stars in \( K \).

**6.4. C12 Sample**

Recall that the dlR97 sample is biased toward IR-bright sources, and the literature sample is strongly biased toward high A(Li) stars. The C12 sample of RGs is unbiased with respect to A(Li) and IR excess, though it does have a larger proportion of fast rotators than a random RG field population.
Additionally, it has A(Li), ν sin i, and $^{12}\text{C}/^{13}\text{C}$ measured for every star in the sample, in contrast to the rest of the sources, for which only some of these parameters are available. We had hoped that we would detect IR excesses in enough of these sources to look for correlations. However, only two of the C12 sources (G0928+73.2600 and Tyc0276-00327-1) have any excesses, and they are both small, <0.6 mag. Out of the whole 86-star C12 sample, the fraction of stars with an IR excess is 2%. Considering just those with well-populated SEDs to make the photosphere that a small IR excess is suggested. The two stars with a significant IR excess are split in terms of properties. Tyc0276-00327-1 has a subsolar Li abundance (A(Li)_{NLT} = -0.24 dex), a slow rotator (4.2 km s$^{-1}$), and has an average $^{12}\text{C}/^{13}\text{C}$ (17). However, G0928+73.2600 is a particularly interesting star (C12; Carlberg et al. 2010) because it has particularly high Li (A(Li)_{NLT} = 3.30 dex), relatively rapid rotation (8.4 km s$^{-1}$), and high $^{12}\text{C}/^{13}\text{C}$ (28).

G0928+73.2600 was also included in the ensemble of Li-rich stars in Kumar et al. (2011). Its location on a Hertzsprung-Russell (H–R) diagram is similar to many other Li-rich RGS in that sample. Kumar et al. (2011) noted that many Li-rich RGS have properties consistent with red clump stars, and suggested the possibility that an episode of Li regeneration may occur during the He flash for some RGS. G0928 is noteworthy among that sample of RGS for having the largest $^{12}\text{C}/^{13}\text{C}$. (The importance of $^{12}\text{C}/^{13}\text{C}$ in interpreting Li-rich stars is described in more detail in Section 7 below.) Carlberg et al. (2010) and C12 argued in favor of external replenishment as a source of the high Li given its relatively high $^{12}\text{C}/^{13}\text{C}$.

6.5. The dlR97 Sample and the Original IRAS Color–Color Diagram

The dlR97 sample is strongly biased toward sources that are bright in the IR, and so it is not surprising that there are many more bright IR sources, and large IR excesses, found in the dlR97 sample than in either the C12 or the “other literature” samples. In de la Reza et al. (1996), dlR97, and Siess & Livio (1999), there is a plot of IRAS colors for their targets, which they use to describe a proposed evolutionary sequence of objects in the diagram. This plot is described as a color–color diagram, where the following is their definition of color:

$$[\lambda_1 - \lambda_2] = \log(F_2) - \log(F_1)$$  \hspace{1cm} (2)

where λ is wavelength and F is flux density. In more recent papers, driven at least in part by Spitzer and WISE work, the convention for color is instead truly a difference of magnitudes:

$$M_1 - M_2 = 2.5 \times \log \left(\frac{F_2}{F_1}\right).$$  \hspace{1cm} (3)

And in the IR, where the band names are often the wavelength of the bandpass, this difference in magnitudes would be written, e.g., $[\lambda_1] - [\lambda_2]$. In any case, the shape (if not the specific values) of the distribution of points in the dlR97 color–color plot is recovered by using [12]–[25] and [25]–[60] defined as in Equation (3).

In Figure 17, we have made the plot analogous to that from dlR97 and collaborators, namely [25]–[60] against [12]–[25], just for the original dlR97 sample. The first panel uses the values from the IRAS PSC, as in dlR97. The shape of the overall distribution is similar to what they have obtained, in that there is a locus near [12]–[25] ~ 0 extending up to a range of [25]–[60] values, and a broad “bubble” of points extending to the right. However, we find that the upper envelope of the distribution (near [12]–[25] = 1–4, and [25]–[60] ~ 3–4) is defined entirely by objects we suspect should be dropped from the sample because they are subject to source confusion. Removing these points from the plot significantly reduces the range of colors found for K giants. We have also indicated which of these sources are the ones for which we have identified an IR excess. Most of the PSC points that are still thought to be K giants with [12]–[25] > 0.5 are also ones we identify as having an IR excess, but there are several that we do not recover. These sources are identified in at least one of [12], [25], or [60] with data quality flag = 1, e.g., a limit, not a detection. dlR97 started from the Pico dos Dias Survey (DDS; Gregorio-Hetem et al. 1992), which reports having started from the IRAS PSC, only the high-quality detections. However, several of the points in our version of this diagram (which, again, is just the dlR97 sample) do not have high quality detections at all 3 of the relevant IRAS bands.

The second panel of Figure 17 uses the IRAS FSC instead of the PSC, again, just for the dlR97 sample. (Recall from Section 3.2 above that 36 of the dlR97 objects are also detected in the FSC in any band, so not all of the objects from the first panel appear in the second panel.) All of the objects we suspect should be dropped do not have FSC measurements, so they do not appear in the second panel. Again, most of the sources with detections (not limits) in [12], [25], and [60], and large excesses with [12]–[25] > 0.5, are also ones we identify as having an IR excess, but there is one that we do not recover. (It is HD 76066, discussed above as having significantly lower WISE flux densities than IRAS, and not really having an excess.) Interestingly, in moving between the PSC and FSC plots, the envelope delineating the red excursion of the distribution of points shrinks dramatically in size, and there are fewer points within the “bubble”—more points are on the [12]–[25] ~ 0 locus where no IR excess is measured. Whereas ~45% of the K giants in the first panel have [12]–[25] > 0.5 mag, by the second panel, just ~30% have [12]–[25] > 0.5 mag. However, there are fewer objects overall in the second panel.

We can carry this further—both IRAS and WISE had a 12 μm channel, and IRAS had a 25 μm channel, close to the WISE 22 μm channel. Though the filter bandpasses are far from identical, they ought to give similar estimates of the
broadband IR excess near their respective wavelengths. In the third panel of Figure 17, we have used the WISE [12] in place of the IRAS [12], and WISE [22] in place of the IRAS [25]; for 60 μm, we retain the IRAS FSC values. All of the objects from the middle panel with WISE detections at [12] and [22] appear in the third panel. The distribution continues to shrink toward the [12]–[22] = 0 locus, with now only ~20% of the sources having [12]–[22] > 0.5 mag. As higher spatial resolution and more sensitive observations are available, the apparent IR excesses shrink.

However, in using WISE in place of the IRAS bands, we are implicitly assuming that the two missions are calibrated in the same fashion, or at least consistently with each other. It is possible that the change in distributions (the shrinking of the “bubble”) of points between the panels of Figure 17 can be accounted for, at least in part, by different calibrations of the instruments. To investigate this, we compared the IRAS PSC to the FSC first, as a check, to make sure that they were internally calibrated consistently with respect to each other. Then, we compared the IRAS FSC to the WISE values. In all cases, we used our entire sample, but only those with data quality flags 3 or 2. The comparison of the 12 and 25 μm channels (calculating (PSC-FSC)/PSC) with the values in magnitudes (showing that they are indeed well-matched to each other, with no significant average offset between them). For [12], the center of the best-fit Gaussian to the distribution is 0 mag, with a width of 0.04 mag. For [25], the center is 0.02 mag, and the width is 0.04 mag. However, in comparing the WISE and IRAS FSC 12 μm channels, there is a clear offset of ~30% between WISE and IRAS, in the direction of the FSC being brighter. (At [12], calculating (FSC-WISE)/FSC in mag, the center of the Gaussian is 0.26 mag and the width is 0.05 mag.) For 25 μm, we expected larger differences between WISE and IRAS because of the different bandpasses. There is an offset between IRAS FSC and WISE of ~15%. (The center of the Gaussian is 0.14 mag, and the width is 0.06 mag.) It is again in the direction of the FSC being brighter. Once one is made aware of this offset, one can see it systematically in the SEDs of the ensemble where both IRAS and WISE are available. This effect is in the same direction one would expect if the higher spatial resolution of WISE was resolving out background contributions to the IRAS flux, which may still be a part of what is going on. (We note that we only did this comparison for the objects in our sample, not the entire IRAS or WISE catalogs or over a controlled range of backgrounds. Such a comparison is beyond the scope of our study.) Nonetheless, the net effect in the last panel of Figure 17 is to move the envelope of points left and up. First, on the x-axis in this panel, [12] and [22] now both come from WISE, and are internally well-calibrated, so stars without excesses are closely clumped near 0 in [12]–[22]. They are more tightly clumped than they were for IRAS, which collapses part of the distribution. Stars with excesses have slightly smaller [12]–[22] (from WISE) on average than [12]–[25] (from IRAS), because the systematic calibration offset for [12] is slightly larger than for [25] ([22]). Second, on the y-axis, [60] is still from IRAS, presumably well-calibrated internally to the other IRAS bands. Since both [12] and [25] are slightly systematically brighter compared to WISE, if we assume [60] is also slightly brighter as a result of calibration systematics, this will push the distribution of points slightly up in the diagram—which can be seen in the figure.

So, we conclude that some (but not all) of the reduction in the range of points in Figure 17 can be accounted for in the different calibrations of IRAS and WISE. The average calibration effect for the ensemble is on the order of a few tenths of a magnitude. However, the movement of individual objects between plots is primarily a reflection of more accurate measurements of the IR flux from the stars.

Kumar et al. (2015) also made plots like our Figure 17, though in the same units as dIR97 (using Equation (2)). Their plots have similar distributions of points as ours do.

7. ABUNDANCES AND ROTATION RATES

One of our original goals of this paper was to seek a correlation between lithium abundance (and rotation rate and
the $^{12}$C/$^{13}$C ratio) and IR excess in K giants, but with only ~10% of our sample likely to have IR excesses, our ability to test correlations with IR excess is somewhat limited. However, we can still infer some things about the relationship among these parameters. In order to better understand these relationships, however, we need to make sure that our already biased sample is as clean and internally consistent as possible.

We now discuss how we limit the sample to identify Li-rich stars, and likely first ascent K giants, and look at the relationship between IR excess, Li abundance, rotation rate, and $^{12}$C/$^{13}$C.

7.1. Definition of Li-rich

A substantial number of objects were added to our sample on the basis of a paper in the literature asserting that the K giant was Li-rich. However, everyone does not use the same definition of Li-rich. For example, dIR97 did not report Li abundances, but identified certain stars as Li-rich based on equivalent widths. C12 included Li abundances, and determined them under both LTE and NLTE assumptions. Other literature sources sometimes report only equivalent widths, or only LTE abundances. If we were to rely solely on literature reporting, 183/316 sources are Li-rich.

However, we wished to be a bit more restrictive, or at least internally consistent. For those sources for which we have NLTE Li abundances, we took those with $A$(Li)$_{NLTE}$ $\geq$ 1.5 dex as Li-rich. If there was no NLTE abundance available, we took those with $A$(Li)$_{LTE}$ $\geq$ 1.5 dex as Li-rich. If there was no abundance in the literature (e.g., just equivalent widths), we did not identify it as Li-rich. If we thought (based on the analysis above) that it was not a K giant, we did not identify it as Li-rich (that includes the 24 dropped sources, the carbon star, and the S-type star). A total of 62 sources are missing $A$(Li), including the dropped sources. Using this approach, 139 stars in our sample are Li-rich. Unfortunately, 10 of these sources are the ones with very sparse SEDs, and 29 more have relatively sparse SEDs (though both of the sources identified as having an IR excess from these SEDs are Li-rich). Just 9 of the remaining 100 sources have well-populated SEDs and an IR excess. There are 115 that are Li-poor, 7 of which have sparse SEDs, and 6 of which have an IR excess.

7.2. Restrictions on log g and $T_{\text{eff}}$

This study is aimed at understanding the Li-IR connection for K giants (first ascent RGB stars and red clump stars); however, we have already noted above that some of our sample are suspected to be more evolved AGB stars or other non-K-giant contaminants. We can try to limit the contamination by requiring that there be an estimate of log g and $T_{\text{eff}}$, and that these values fall within a certain range.

We identify stars with log g $\geq$ 3.5 as not likely giants. This selection should weed out subgiant and dwarf stars for which high Li may not be unusual. Out of the entire set of 316 (~24 confused sources), 46 have no log g estimate available to our knowledge. Of the remaining sources, 16 have log g $\geq$ 3.5 (with 2 more having exactly 3.5 being left in the sample).

We can put both upper and lower constraints on $T_{\text{eff}}$. Temperatures <3700 K are likely to be AGB stars, not first ascent K giants, because the AGB reaches cooler temperatures. On the upper end, temperatures >5200 K are likely to be dwarf stars or subgiants that have not yet completed first dredge-up (the deepening of the convection zone that reduces the surface Li abundances during the post-MS phase). Out of the entire set of 316 (~24 confused sources), 20 have no $T_{\text{eff}}$ estimate at all. Of the ones with $T_{\text{eff}}$, 6 are cooler than 3700 K, several of which we identified above as "likely too cool" for our sample. There are 3 stars with $T_{\text{eff}}$ = 5200 K (left in our sample), and there are 19 hotter than 5200 K.

The net loss of objects out of our sample by requiring that there be an $A$(Li) and that $T_{\text{eff}}$ and log g are in the correct range is 97 objects (some objects counted in more than one omission category above), leaving 219 in the sample. That sample includes the 10 very sparse SEDs, and 33 of the relatively sparse SEDs. Of the 219, 119 (54% ± 6%) are Li-rich as per our definition above (with 10 ± 26 of those being the very sparse/relatively sparse SEDs). Just 13/219 (6% ± 2%) of this sample have an IR excess. Bringing Li into it, 11/119 (9 ±3%) of the Li-rich stars have an IR excess, and 2/100 ($^{+0.6}_{-0}$%) of the Li-poor stars have an IR excess (with 7 sparse SEDs included).

The sparse SEDs included in the above calculation likely miss more subtle IR excesses, so we can repeat the analysis on the subset of 176 stars with well-populated SEDs. There are 83 stars in this sub-sample that are Li-rich, 93 that are Li-poor, and 11 that have an IR excess. Of the Li-rich stars, 9/83 (11% ± 3%) have an IR excess; of the Li-poor stars, 2/93 ($^{+2}_{-1}$%) have an IR excess. Although we are well into the regime of small-number statistics, IR excesses appear to be at least 2–3 times as common among Li-rich stars compared to Li-poor stars. Kumar et al. (2015) came to a similar conclusion, that IR excesses are rare in the general K giant population. They found that only ~1% of RGs (their sample is dominated by Li-poor stars) have an IR excess. Of the 40 Li-rich stars in their sample, they find 7 (18% ± 4%) with an IR excess.

7.3. Relationships Among $A$(Li), $v$ sin i, $^{12}$C/$^{13}$C, and IR Excess

For the rest of this section, we will only use the cleanest possible sample of 176 RGs with $T_{\text{eff}}$ and log g consistent with K giant stars, and with well-populated SEDs, from the prior section.

Figure 18 shows $A$(Li)$_{NLTE}$ versus [3.4]–[22] for the 176 stars in the cleanest possible sample. This plot suggests that if a star has a large IR excess, it probably has a large $A$(Li), but having a large $A$(Li) does not mean that it necessarily has a large IR excess. Smaller excesses can be found at all abundance levels. Very similar results are obtained if LTE rather than NLTE lithium abundances are used, or if $K_c$–[22] is used instead of [3.4]–[22]. Within the sample of Li-rich objects with IR excesses, there does not seem to be a trend that, say, the largest Li abundances are always found with the largest IR excesses.

Figure 19 shows $A$(Li)$_{NLTE}$ versus $v$ sin i. Fast-rotating stars also often (but not exclusively) have large $A$(Li), which has been previously noted (e.g., Drake et al. 2002). What is further revealed by this plot is that many of the fast rotating, Li-rich stars are also those with IR excesses. Half of the Li-rich stars that also show fast rotation have an IR excess, whereas only one Li-rich star among the more populated slow rotators has an IR excess. Additionally, only one RG with an IR excess shows neither high rotation nor enriched Li. Thus, having both high Li and fast rotation is a stronger predictor for an IR excess than high Li.

---

13 The errors presented here are assumed to be the larger of either Poisson errors or the binomial approximation found in the appendix of Burgasser et al. (2005).
Figure 18. $A(Li)_{\text{LTE}}$ vs. $[3.4]-[22]$ for the 176 stars in the cleanest possible sample. The vertical line at $[3.4]-[22] = 0$ indicates the photospheric locus, and the red points are the IR excess stars. The horizontal line at $A(Li) = 1.5$ dex indicates our adopted division between Li-rich and not Li-rich. The entire (available) sample is plotted in the upper left, and the component samples ($dlR97$, $C12$, and the other literature) are shown in separate panels. A very similar plot is obtained if $A(Li)_{\text{NLTE}}$ is used instead of $A(Li)_{\text{LTE}}$, or $K_{s,[22]}$ rather than $[3.4]-[22]$. If a star has a large IR excess, it probably has a large $A(Li)$, but having a large $A(Li)$ does not necessarily indicate it has a large IR excess.

Figure 19. $A(Li)_{\text{LTE}}$ vs. $v\sin i$ in km s$^{-1}$ for the cleanest possible sample. The vertical line at 8 km s$^{-1}$ divides the fast from the slow rotators. The red points are the IR excess stars. The horizontal line at $A(Li) = 1.5$ dex is the division between Li-rich and not Li-rich. The entire (available) sample is plotted in the upper left, and the component samples ($dlR97$, $C12$, and the other literature) are shown in separate panels. A very similar plot is obtained if $A(Li)_{\text{NLTE}}$ is used instead of $A(Li)_{\text{LTE}}$. Fast-rotating stars also often (but not exclusively) have large $A(Li)$, and often also have an IR excess.

differential rotation was not sufficiently fast to increase Li at the surface. Magnetic buoyancy is another possible model (e.g., Guandalini et al. 2009).

Planet engulfment that does not trigger fast mixing could be identified with higher than expected Li, but with a relatively high $^{12}\text{C}/^{13}\text{C}$. In Figure 21, the $C12$ sample shows the most homogeneously measured $^{12}\text{C}/^{13}\text{C}$ and the only sample unbiased toward Li. The stars generally show the expected linear trend of lower $^{12}\text{C}/^{13}\text{C}$ and lower $A(Li)$ for stars that experience different degrees of mixing. Other panels of the plot show the addition of the large sample of all the literature Li-rich stars, which span a large range of $^{12}\text{C}/^{13}\text{C}$. Red circles again indicate IR excess. Stars with the clearest sign of substantial internal mixing (very low $^{12}\text{C}/^{13}\text{C}$ and high Li) show no evidence of an IR excess. However, this is not entirely unexpected. As pointed out by Denissenkov & Herwig (2004), the timescale over which a shell is ejected and dissipates (e.g., the timescale for the IR excess to appear/disappear) is of order $10^{4}$ to $10^{6}$ years, compared to the timescale of Li regeneration, which is of order $10^{2}$ to $10^{6}$ years. Very low values of $^{12}\text{C}/^{13}\text{C}$ are only reached at the latest stages of Li regeneration, well after the IR excess has disappeared. Figure 21 does, however, exhibit a tantalizing correlation between the Li and $^{12}\text{C}/^{13}\text{C}$ of many of the IR excess stars in this plot. We offer no explanation for this trend but suggest that it may be informative on the conditions of the star when the shell is ejected. Adding additional objects to this plot (via determinations of $^{12}\text{C}/^{13}\text{C}$) will likely further illuminate any relationship.

Given the relative shortness of the IR phase compared to the Li synthesis phase, one would expect little change in $A(Li)$ for any particular star as it traverses the IR color–color diagram (Figure 17). This expectation is confirmed by the fact that we
do not see a correlation between level of Li-richness and the strength of the IR-excess (Figure 18). Furthermore, since IR excess is seen around a wide range of $A(\text{Li})$, we can speculate that the Li regeneration reaches different maximum $A(\text{Li})$ values in each star.

### 7.4. Biases and Future Work

An additional concern in interpreting Figures 18–20 is that our sample has many substantial biases within it. One very significant bias is that many of the sources were discovered based on their IRAS colors, e.g., they are biased toward IR-bright sources. The subsamples are separated out in Figures 18–20 specifically because of this bias—a substantial fraction of the diR97 sample and a smaller fraction of the literature sample is based on IRAS colors. In Figure 18, it can be seen that all of the large IR excesses are from the diR97 sample. (Some of the large excesses seen in, e.g., the literature sample in Figure 15 do not appear in this plot because they do not have log $g$ or $T_{\text{eff}}$ in the correct range, etc.) Those largest excesses draw the eye and dominate the relationships found in the plots. The relationships are not as obvious in just the C12 sample, which is the least biased with respect to IR properties.

To first order, we hoped we could try to constrain the influence of this bias by omitting K giants known primarily by their IRAS names. Only five of the sources making it into our “cleanest possible” sample have IRAS names, but four of them are among the largest IR excesses ([3.4]–[22] > 2).

We also have biases in the sample due to the incomplete information for stars in the sample. A number of the IR excess sources have no $T_{\text{eff}}$ and/or log $g$ and were removed from our detailed analysis of IR excess among K giants. Furthermore, half of the Li-rich sample has no measure of $^{12}\text{C}/^{13}\text{C}$ and/or $v \sin i$. This makes comparisons between, e.g., Figures 19 and 20, difficult because the IR excess stars appearing in each plot are not all the same stars. Follow-up high resolution optical spectra to measure these missing stellar parameters would be extremely valuable.

It is also worth considering if the objects with the largest excesses are not really old dusty giants ascending the giant branch, but young dusty giants, still contracting along their Hayashi track. This could explain both the very large excesses as well as the high lithium abundances, since young stars are known to often have high $A(\text{Li})$. Young, actively accreting stars with substantial disks would have strong and variable Hα profiles, and have significant variability at essentially all wavelengths, both of which are different than expectations for old giant stars. Detailed isotopic ratios (such as $^{12}\text{C}/^{13}\text{C}$) that trace mixing and chemical evolution would also be of help. Additional detailed spectroscopic data and modeling is required to distinguish old dusty stars from young dusty stars.

### 8. CONCLUSIONS

In the past, diR97 and others have suggested a connection between enhanced lithium and IR excesses in K giants. However, others (e.g., Fekel & Watson 1998; Jasniwicz et al. 1999; Lebzelter et al. 2012; Kumar et al. 2015) have questioned the association between Li and IR abundances. We have assembled a set of 316 targets thought to be K giants, two-thirds of which are thought to be Li-rich, in order to test the association between IR excesses and lithium abundances. The targets come from the diR97 study (biased toward IR-bright sources), the C12 study (assembled with limited biases to test correlations of various stellar parameters), and a wide variety of literature identifying Li-rich K giants. For these targets, we assembled a multiwavelength catalog spanning optical through...
We inspected each source in as many different images as possible. In 24 cases, all identified first as IR-bright sources with IRAS, we believe that source confusion is playing a role, in that either (a) the source that is bright in the optical (and most likely the source of which a spectrum was obtained to assess lithium) is not responsible for the IR flux, or (b) there is more than one source responsible for the IR flux as measured in IRAS.

We looked for IR excesses by \( \sim 20 \mu m \) using two different approaches: (a) simple SED construction and assessment, and (b) an approach drawn from studies of young stars used to identify small but significant IR excesses. We identify 19 stars with large IR excesses, and 9 more stars that have small but significant IR excesses. However, 5 of these 28 may not be first ascent K giants. (There are 2 more K giants that may have IR excesses by \( \sim 10 \mu m \), identified from relatively sparse SEDs.)

Ten of the 28 clear IR excess K giants were already recently identified in the literature as having IR excesses, but this is the first recent confirmation of IR excess for 18 of these targets. Some of these giants have IR excesses that start at or before 5 \( \mu m \), but others have excesses that start near 20 \( \mu m \).

IR excesses by 20 \( \mu m \), though rare, are about twice as common among Li-rich K giants (11), as in Li-poor K giants (2.5). Despite identifying very few IR excesses (by number or fraction of sample), we find that if a RG has a large IR excess, it probably has a large A(Li) and is a fast rotator, but having a large A(Li) (or being a fast rotator) does not mean that it necessarily has a large IR excess. Smaller excesses can be found at all abundance levels. This is consistent with the idea that the IR excess lifetime of a single ejected shell is very short-lived compared to the timescale of Li enrichment. It could also suggest that not all Li-rich stars eject shells, and some other parameter (such as fast rotation, or even rotation history) dictates whether shell ejection occurs. Stars with the clearest sign of substantial internal mixing (very low \( ^{12}C/^{13}C \) and high Li) show no evidence of an IR excess. This could be also explained by a shorter timescale for the IR excess than the Li regeneration, since the lowest \( ^{12}C/^{13}C \) are realized near the end of the Li-enrichment stage. An external Li regeneration mechanism identified in the literature is planet injection. However, we identify only one of the three best candidates for planet accretion listed in C12 as having a measurable IR excess, and it is a small excess. The largest IR excesses are all found in the dIR97 sample, which is strongly biased toward IR-bright objects. There remains a possibility that at least some of these largest excess objects may not be old dusty stars, but instead young dusty stars.

Support provided for this work by the NASA/IPAC Teacher Archive Research Program (NITARP; http://nitarp.ipac.caltech.edu), which partners small groups of high school educators with a mentor astronomer for an authentic research project. It receives funding from the NASA ADP program and the IPAC archives. We acknowledge the following students who helped out at various phases of this project: Rosie Buhrely, Julie Herring, Kendall Jacoby, and Elena Mitchell, from Walden School of Liberal Arts. J. K. C. was supported by an appointment to the NASA Postdoctoral Program at the Goddard Space Flight Center, administered by Oak Ridge Associated Universities through a contract with NASA. This research has made extensive use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. The Digitized Sky Survey was produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166. The images of these surveys are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. The plates were processed into the present compressed digital form with the permission of these institutions.” Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy Office of Science. The SDSS-III web site is http://www.sdss3.org/. SDSS-III is managed by the Astrophysical Research Consortium for the Participating Institutions of the SDSS-III Collaboration including the University of Arizona, the Brazilian Participation Group, Brookhaven National Laboratory, University of Cambridge, Carnegie Mellon University, University of Florida, the French Participation Group, the German Participation Group, Harvard University, the Instituto de Astrofisica de Canarias, the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, New York University, Ohio State University, Pennsylvania State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University. This publication makes use of data products from the 2MASS, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This publication makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration. This research is based on observations with AKARI, a JAXA project with the participation of ESA. This work is based in part on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. This research made use of data products from the Midcourse Space Experiment. Processing of the data was funded by the Ballistic Missile Defense Organization with additional support from NASA Office of Space Science. This research has also made use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. This research has made use of NASA’s Astrophysics Data System (ADS) Abstract Service, and of the SIMBAD database, operated at CDS, Strasbourg, France.

### APPENDIX

#### NOTES ON INDIVIDUAL SOURCES

Table 6 contains human-readable notes on the entire set of sources; position, photometric, and abundance data are in the machine-readable table in Table 1. Detailed notes on the sources we suspect are subject to source confusion appear in Table 4. Much more detailed notes on the sources we believe have IR excesses are in Section 5.
| Name           | dIR97 | C12 | Other Lit | Status | Notes                                                                 |
|----------------|-------|-----|-----------|--------|----------------------------------------------------------------------|
| HD 787         | dIR97 |     | ...       | (no excess) | ...                                                                   |
| Tyc3663-01966-1| ...   | ... | Adamów et al. (2014) | (no excess) | ...                                                                   |
| HD 4893        | ...   | ... | Castilho et al. (2000) | (no excess) | May be too cool to be a K giant. Not Li rich.                        |
| IRAS00483–7347 | ...   | ... | Castilho et al. (1998) | IR excess (but maybe not K giant) | ...                                                                   |
| Scl 1004838    | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                   |
| HD 4893        | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                   |
| NGC 362 V2     | ...   | ... | Smith et al. (1999) | IR excess (small) | ...                                                                   |
| HD 6665        | ...   | ... | Kumar et al. (2011) | (no excess) | Identified in McDonald et al. (2012) as having an IR excess, but IR excess is not real. |
| HD 7087        | ...   | ... | Liu et al. (2014) | (no excess) | ...                                                                   |
| HD 8676        | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                   |
| HD 9746        | dIR97 | ... | ...       | (no excess) | ...                                                                   |
| HD 10437       | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                   |
| HD 12203       | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                   |
| CPD-55395      | dIR97 | ... | ...       | (no excess) | ...                                                                   |
| HD 13189       | ...   | ... | C12       | ...       | (no excess) | ...                                                                   |
| HD 15866       | ...   | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess) | ...                                                                   |
| For 55609      | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                   |
| For 60521      | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                   |
| Tyc3300-00133-1| ...   | ... | Adamów et al. (2014) | (no excess) | ...                                                                   |
| For 90067      | ...   | ... | Kirby et al. (2012) | sparse SED but possible IR excess | ...                                                                   |
| For 100650     | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                   |
| Tyc3304-00090-1| ...   | ... | Adamów et al. (2014) | (no excess) | ...                                                                   |
| Tyc1780-00654-1| ...   | C12 | ...       | (no excess) | ...                                                                   |
| HD 17144       | ...   | ... | Drake et al. (2002) | (no excess) | ...                                                                   |
| SDSS J0245+7102| ...   | ... | Martell & Shetrone (2013) | (no excess) | ...                                                                   |
| Tyc0647-00254-1| ...   | ... | C12       | ...       | (no excess) | ...                                                                   |
| SDSS J0301+7159| ...   | ... | Martell & Shetrone (2013) | (no excess) | ...                                                                   |
| G0300+00.29    | ...   | C12 | ...       | sparse SED but probably no IR excess | ...                                                                   |
| Tyc3318-01333-1| ...   | ... | Adamów et al. (2014) | (no excess) | ...                                                                   |
| SDSS J0304+3823| ...   | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess | ...                                                                   |
| Tyc5868-00337-1| ...   | C12 | ...       | (no excess) | ...                                                                   |
| HD 19745       | dIR97 | ... | ...       | IR excess | ...                                                                   |
| Tyc3314-01371-1| ...   | ... | Adamów et al. (2014) | (no excess) | ...                                                                   |
| HD 21078       | ...   | ... | Fekel & Watson (1998) | (no excess) | ...                                                                   |
| G0319+56.5830  | ...   | C12 | ...       | (no excess) | ...                                                                   |
| HD 21018       | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                   |
| G0319+56.6888  | ...   | C12 | ...       | (no excess) | ...                                                                   |

Table 6
Special Notes on Targets
Table 6
(Continued)

| Name                        | dIR97 | C12 | Other Lit | Status       | Notes | At(Li), log g, Teff ? |
|-----------------------------|-------|-----|-----------|--------------|-------|----------------------|
| Tyc5881-01156-1             | ...   | C12 | ...       | (no excess)  |       | Not Li rich.         |
| IRAS03520–3857              | dIR97 |     | ...       | IR excess    |       | No A(Li). No Teff. No log g. |
| HD 26162                    | ...   | C12 | ...       | (no excess)  |       | Not Li rich.         |
| Tyc3340-01195-1             | ...   | ... | ...       | (no excess)  |       | Not Li rich.         |
| HD 27497                    | ...   | ... | Jasniewicz et al. (1999) | (no excess) |       | Not Li rich.         |
| RAVEJ043154.1–063210        | ...   | ... | Ruchti et al. (2011) | sparse SED but probably no IR excess |       | Teff too warm to be RG. |
| IRAS04376-3238              | ...   | ... | Torres et al. (2000) | IR excess |       | Also CD-32 1919. No A(Li). No Teff. No log g. |
| HD 30238                    | dIR97 |     | ...       | (no excess)  |       | Not Li rich.         |
| HD 30197                    | ...   | ... | Liu et al. (2014), Lack & Hettler (2007) | (no excess) |       | ... |
| Tyc0684-00553-1             | ...   | ... | Adamów et al. (2014) | (no excess) |       | ... |
| HD 30834                    | dIR97 |     | ...       | (no excess)  |       | ... |
| Tyc5904-00513-1             | ...   | C12 | ...       | (no excess)  |       | Not Li rich.         |
| G0453+0.90                  | C12   |     | ...       | sparse SED but probably no IR excess |       | ... |
| HD 31993                    | dIR97 | C12 | ...       | (no excess)  |       | Only target in common between dIR97 and C12 Not Li rich. |
| HD 34198                    | C12   |     | ...       | (no excess)  |       | Also UU Lep Not Li rich. |
| HD 33798                    | ...   | ... | Drake et al. (2002) | (no excess) |       | log g too large to be RG. |
| HD 33363                    | C12   |     | ...       | (no excess)  |       | ... |
| HD 35084                    | ...   | ... | Liu et al. (2014), Lack & Hettler (2007) | (no excess) |       | T_eff too warm to be RG. log g too large to be RG. |
| SDSS J0535+0514             | ...   | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess |       | ... |
| HD 37719                    | ...   | ... | Kumar et al. (2011) | (no excess) |       | ... |
| Be 21 T50                   | ...   | ... | Hill & Pasquini (1999) | sparse SED but probably no IR excess |       | Hill & Pasquini call this T33 but it is not; based on photometry from Tosi et al. (1998), it is T50. |
| HD 39853                    | dIR97 |     | ...       | (no excess)  |       | ... |
| HD 40359                    | ...   | ... | Fekel & Watson (1998) | (no excess) |       | ... |
| HD 40168                    | ...   | ... | Kumar et al. (2011) | (no excess) |       | ... |
| HD 40827                    | ...   | ... | Kumar et al. (2011) | (no excess) |       | ... |
| HD 43827                    | ...   | ... | Jasniewicz et al. (1999) | (no excess) |       | Not Li rich. No log g. |
| Tyc1890-01314-1             | C12   |     | ...       | (no excess)  |       | Not Li rich.         |
| HD 44889                    | ...   | ... | Castilho et al. (2000) | (no excess) |       | Not Li rich.         |
| SDSS J0632+2604             | ...   | ... | Martell & Shetrone (2013) | sparse SED but probably IR excess |       | ... |
| Tr5 3416                    | ...   | ... | Monaco et al. (2014) | sparse SED but probably no IR excess |       | ... |
| HD 47536                    | C12   |     | ...       | (no excess)  |       | WISE measurements from AllWISE reject catalog Not Li rich. |
| IRAS06365+0223              | dIR97 |     | ...       | drop due to source confusion |       | No A(Li). No Teff. No log g. |
| G0639+56.6179               | ...   | C12 | ...       | (no excess)  |       | ... |
|                            |       |     |           |              |       | G0639+56.6179        |
| Name                  | dIR97 | C12 | Other Lit                  | Status                     | Notes                      | At(Li), log g, T\(_{\text{eff}}\)? |
|-----------------------|-------|-----|----------------------------|----------------------------|----------------------------|-----------------------------------|
| SDSS J0652+4052       |       |     | Martell & Shetrone (2013)  | (no excess)                 |                           |                                   |
| Tyc3402-00280-1       |       | C12 |                             | (no excess)                 |                           |                                   |
| SDSS J0654+4200       |       |     | Martell & Shetrone (2013)  | sparse SED but probably no IR excess |                           |                                   |
| HD 51367              |       |     |                             | (no excess)                 |                           |                                   |
| G0653+16.552          |       | C12 |                             | sparse SED but probably no IR excess |                           |                                   |
| G0654+16.235          |       | C12 |                             | sparse SED but probably no IR excess |                           |                                   |
| HIP 35253             |       | C12 |                             | (no excess)                 |                           |                                   |
| SDSS J0720+3036       |       |     | Martell & Shetrone (2013)  | sparse SED but probably no IR excess |                           |                                   |
| HD 57669              |       |     |                             | (no excess)                 |                           |                                   |
| IRAS07227−1320(PDS 132)| dIR97|     |                             | IR excess                   | Also GSC 05408–03215.    |                                   |
| HD 59686              |       | C12 |                             | (no excess)                 |                           |                                   |
| HIP 36896             |       | C12 |                             | (no excess)                 |                           |                                   |
| NGC 2423 3            |       |     | J. K. Carberg et al. (2015, in preparation) | (no excess)                 |                           |                                   |
| IRAS07419−2514        |       |     | Torres et al. (2000)       | drop due to source confusion | Target position is photocenter of small group of objects. Torres et al. (2000) notes IRAS flux may come from CO cloud WB 1046. |                                   |
| HD 62509(Pollux)      |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| IRAS07456−4722(PDS 135)| dIR97|     |                             | IR excess                   |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Tyc5981-00414-1       |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 63798              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 65750              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 65228              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Tyc1938-00311-1       |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| IRAS07577−2806(PDS 260)| dIR97|     |                             | IR excess                   |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| G0804+39.4755         |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| SDSS J0808_0815       |       |     | Martell & Shetrone (2013)  | sparse SED but probably no IR excess |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Tyc195-02087-1        |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 70522              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 65228              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Tyc1938-00311-1       |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| IRAS07577−2806(PDS 260)| dIR97|     |                             | IR excess                   |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| G0804+39.4755         |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| SDSS J0808_0815       |       |     | Martell & Shetrone (2013)  | sparse SED but probably no IR excess |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Tyc195-02087-1        |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 70522              |       |     |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| HD 233517             |       |     |                             | IR excess                   | Also identified in Kumar et al. (2015) as an IR excess star, among many other references. |                                   |
| Tyc205-01287-1        |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| G0827−16.3424         |       | C12 |                             | (no excess)                 |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| SDSS J0831+5402       |       |     | Martell & Shetrone (2013)  | sparse SED but probably no IR excess |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| IRAS08359−1644        |       |     | Torres et al. (2000)       | IR excess                   |                           | No A(Li). No T\(_{\text{eff}}\). No log g. |
| Name                  | dIR97 | C12 | Other Lit | Status | Notes                                                                 |
|-----------------------|-------|-----|-----------|--------|----------------------------------------------------------------------|
| HD 73108              | ...   | C12 | ...       | (no excess) | ...                                                                    |
| G0840+56.9122         | ...   | C12 | ...       | (no excess) | ...                                                                    |
| G0840+56.5839         | ...   | C12 | ...       | (no excess) | ...                                                                    |
| HD 76066              | dIR97 | ... | ...       | (no excess) | IRAS FSC [12]–[25] > 0.5 but WISE says no excess. No A(Li), No T eff, No log g. |
| HD 77361              | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                    |
| HD 78668              | ...   | ... | Liu et al. (2014) | (no excess) | ...                                                                    |
| G0909-05.211          | ...   | C12 | ...       | (no excess) | ...                                                                    |
| Tyc3809-01017-1       | ...   | C12 | ...       | (no excess) | ...                                                                    |
| G0912-05.11           | ...   | C12 | ...       | (no excess) | ...                                                                    |
| G0928+73.2600         | ...   | C12 | ...       | IR excess (small) | ...                                                                    |
| HD 82227              | dIR97 | ... | ...       | (no excess) | ...                                                                    |
| HD 82421              | dIR97 | ... | ...       | (no excess) | ...                                                                    |
| HD 82734              | ...   | ... | Liu et al. (2014) | (no excess) | ...                                                                    |
| SDSS J0936+2935       | ...   | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess | ...                                                                    |
| G0935-05.152          | ...   | C12 | ...       | sparse SED but probably no IR excess | ...                                                                    |
| G0946+00.48           | ...   | C12 | ...       | sparse SED but probably no IR excess | ...                                                                    |
| HD 85444              | ...   | ... | Liu et al. (2014) | (no excess) | ...                                                                    |
| IRAS09553-5621        | dIR97 | ... | ...       | drop due to source confusion | ...                                                                    |
| Leol 71032            | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                    |
| Leol 60727            | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                    |
| Leol 32266            | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                    |
| Leol 21617            | ...   | ... | Kirby et al. (2012) | sparse SED but probably no IR excess | ...                                                                    |
| C1012254-203007       | ...   | ... | Ruchti et al. (2011) | sparse SED but probably no IR excess | ...                                                                    |
| HD 88476              | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                    |
| Tyc3441-00140-1       | ...   | C12 | ...       | (no excess) | ...                                                                    |
| BD+202457             | ...   | ... | J. K. Carlberg et al. (2015, in preparation) | (no excess) | ...                                                                    |
| Tyc5496-00376-1 = BD-12d3141 | ... | ... | Ruchti et al. (2011) | (no excess) | ...                                                                    |
| HD 90082              | ...   | ... | Castilho et al. (2000) | (no excess) | WISE measurements from AllWISE reject catalog Not Li rich. T eff too cool to be RG. |
| Tyc3005-00827-1       | ...   | C12 | ...       | (no excess) | ...                                                                    |
| HD 90633              | ...   | ... | Kumar et al. (2011) | (no excess) | ...                                                                    |
| HD 92253              | dIR97 | ... | ...       | (no excess) | ...                                                                    |
| G1053+00.15           | ...   | C12 | ...       | (no excess) | ...                                                                    |
| Tyc2521-01716-1       | ...   | C12 | ...       | (no excess) | ...                                                                    |
| HD 95799              | dIR97 | ... | ...       | (no excess) | ...                                                                    |
| Name                  | dIR97 | C12 | Other Lit            | Status                                                                 | Notes                                      | At(Li), log g, Teff ? |
|----------------------|-------|-----|----------------------|------------------------------------------------------------------------|--------------------------------------------|-----------------------|
| HD 96195             | ...   | C12 | Castilho et al. (2000) | IR excess (but maybe not K giant) identified in McDonald et al. (2012) | May be too cool to be a K giant. Identified in McDonald et al. (2012) as having an IR excess. | Not Li rich. Teff too cool to be RG.    |
| SDSS J1105+2850      | ...   |     | Martell & Shetrone (2013) | sparse SED but probably no IR excess                                 | ...                                        | Teff too warm to be RG. log g too large to be RG. |
| IRAS11044–6127       | dIR97 | ... | ...                   | drop due to source confusion                                           | Optical counterpart hard to locate, steep SED. | No A(Li). No Teff. No log g.            |
| HD 96996             | dIR97 | ... | ...                   | (no excess)                                                             | ...                                        | No A(Li). No Teff. No log g.            |
| HD 97472             | dIR97 | ... | ...                   | (no excess)                                                             | ...                                        | No A(Li). No log g.                    |
| Leo II C-7-174       | ...   | C12 | Kirby et al. (2012)   | sparse SED but probably no IR excess                                   | ...                                        | Not Li rich.                         |
| HD 102845            | ...   | C12 | Liu et al. (2014)     | (no excess)                                                             | ...                                        | Not Li rich.                         |
| Tyc 5523–00830-1     | ...   | C12 | (no excess)           | Also HD 103915. In halo of bright galaxy(?) that appears by 12, 22 μm. Likely high background, but probably ok. | ...                                        | Not Li rich.                         |
| Tyc 0276–00327-1     | ...   | C12 | IR excess (small)     | ...                                                                    | Not Li rich.                               |
| G1200+67.3882        | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| Tyc 6094–01204-1     | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| HD 104985            | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| Tyc 2527–01442-1     | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| G1213+33.15558       | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| HD 107484            | ...   | C12 | Kumar et al. (2011)   | (no excess)                                                             | ...                                        | Not Li rich.                         |
| NGC 4349 127         | ...   | C12 | J. K. Carlberg et al. (2015, in preparation) | (no excess)                                                             | ...                                        | Not Li rich.                         |
| HD 108225            | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| IRAS12236–6302(PDS 354) | dIR97 | ... | ...                   | drop due to source confusion                                           | Cluster of possible sources. Steep SED. Torres et al. (2000) mention that optical spectrum of source taken as counterpart has strong Hα emission and could be an H II region. | No A(Li). No Teff. No log g. |
| HD 108471            | dIR97 | ... | ...                   | (no excess)                                                             | ...                                        | No A(Li).                            |
| IRAS12327–6523(PDS 355) | dIR97 | ... | ...                   | IR excess                                                               | ...                                        | No A(Li).                            |
| HD 109742            | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| M68-A96–Cl* NGC 4590 HAR 1257 | ...   | C12 | Ruchti et al. (2011) | sparse SED but probably no IR excess                                     | The coordinates in the paper are incorrect; used finding chart, Figure 2, in Alcaino (1977) to ID by eye. | Not Li rich.                         |
| G1240+56.8464        | ...   | C12 | (no excess)           | ...                                                                    | Not Li rich.                               |
| HD 111217            | dIR97 | ... | (no excess)           | ...                                                                    | No A(Li).                                  |
| HD 111830            | dIR97 | ... | (no excess)           | ...                                                                    | No A(Li).                                  |
| HD 112859            | ...   | C12 | (no excess)           | IRAS FSC [12]–[25] > 0.5 but WISE says no excess.                       | ...                                        | No A(Li). No log g.                   |
| SDSS J1310.0012      | ...   | C12 | Martell & Shetrone (2013) | sparse SED but probably no IR excess                                   | ...                                        | Not Li rich.                         |
| HD 115478            | ...   | C12 | Liu et al. (2014)     | (no excess)                                                             | WISE measurements from AllWISE reject catalog | ...                                        | Not Li rich.                         |
| HD 115659            | ...   | C12 | ...                   | (no excess)                                                             | ...                                        | ...                                   |
| Name                        | dlR97 | C12 | Other Lit                        | Status                  | Notes       | At(Li), log g, T\text{eff} ? |
|-----------------------------|-------|-----|----------------------------------|-------------------------|-------------|-----------------------------|
| HD 116010                   | ...   | C12 | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 116292                   | ...   | ... | Liu et al. (2014), Kumar et al. (2011) | (no excess)             | ...         | ...                         |
| CVn 195, 195                | ...   | ... | Kirby et al. (2012)              | sparse SED but probably no IR excess | ...         | ...                         |
| CVn 196, 129                | ...   | ... | Kirby et al. (2012)              | sparse SED but probably no IR excess | ...         | ...                         |
| G1331+00.13                 | ...   | C12 | ...                              | (no excess)             | ...         | Not Li rich.                |
| PDS 365(IRAS13331–5838)     | dlR97 | ... | ...                              | IR excess               | ...         | ...                         |
| HD 118319                   | ...   | ... | Kumar et al. (2011)              | (no excess)             | ...         | Not Li rich.                |
| HD 118344                   | dlR97 | ... | ...                              | (no excess)             | ...         | No A(Li). No log g.         |
| HD 118839                   | ...   | C12 | ...                              | (no excess)             | ...         | Not Li rich.                |
| M3-IV101=Cl° NGC 5272 SK 557 | ...   | ... | Kraft et al. (1999), Pilachowski et al. (2003), Ruchti et al. (2011) | sparse SED but probably no IR excess | ...         | ...                         |
| HD 119853                   | dlR97 | ... | ...                              | (no excess)             | ...         | No A(Li). No log g.         |
| HD 120048                   | ...   | ... | Liu et al. (2014)                | (no excess)             | ...         | ...                         |
| HD 120602                   | dlR97 | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 121710(9Boo)             | dlR97 | ... | ...                              | (no excess)             | ...         | Not Li rich. No log g.      |
| PDS 68(IRAS13539–4153)      | dlR97 | ... | ...                              | IR excess               | ...         | Not Li rich.                |
| Tyc3027-01042-1             | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 12430                    | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| Tyc0319-00231-1             | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 124897(Arcturus)         | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 125618                   | dlR97 | ... | ...                              | (no excess)             | ...         | No A(Li). No T\text{eff}. No log g. |
| Tyc1469-01108-1             | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| IRAS14198–6115              | dlR97 | ... | ...                              | drop due to source confusion | Cluster of possible sources. | No A(Li). No T\text{eff}. No log g. |
| G1421+28.4625               | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| RAVEJ142546.2-154629        | ...   | ... | Ruchti et al. (2011)             | (no excess)             | ...         | T\text{eff} too warm to be RG. No log g. |
| HD 126868                   | ...   | ... | Jasniewicz et al. (1999)         | (no excess)             | ...         | No A(Li). No T\text{eff}. No log g. |
| IRAS14257–6023              | dlR97 | ... | ...                              | drop due to source confusion | Cluster of possible sources. | ...         |
| SDSS J1432+0814             | ...   | ... | Martell & Shetrone (2013)        | sparse SED but probably no IR excess | ...         | ...                         |
| HD 127740                   | ...   | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess)             | ...         | T\text{eff} too warm to be RG. log g too large to be RG. |
| Tyc0913-01248-1             | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| Tyc0914-00571-1             | C12   | ... | ...                              | (no excess)             | ...         | Not Li rich.                |
| HD 128309                   | dlR97 | ... | ...                              | (no excess)             | ...         | No A(Li). No T\text{eff}. No log g. |
| HD 129955                   | dlR97 | ... | ...                              | (no excess)             | ...         | No A(Li). No T\text{eff}. No log g. |
| HD 131530                   | dlR97 | ... | ...                              | (no excess)             | ...         | ...                         |
| HD 133086                   | ...   | ... | Kumar et al. (2011)              | (no excess)             | ...         | Not Li rich.                |
| Tyc0347-00762-1             | C12   | ... | ...                              | (no excess)             | ...         | ...                         |
| Name                  | dIR97 | C12 | Other Lit        | Status                                      | Notes                                      | At(Li), log g, $T_{\text{eff}}$? |
|-----------------------|-------|-----|------------------|---------------------------------------------|--------------------------------------------|----------------------------------|
| M5 V42                | …     | …   | Carney et al. (1998) | (no excess)                                   | …                                         | …                                |
| SDSS J1522+0655       | …     | …   | Martell & Shetrone (2013) | sparse SED but probably no IR excess | …                                         | …                                |
| HD 137759             | …     | C12 | …                | (no excess)                                   | …                                         | …                                |
| HD 136525             | …     | …   | Liu et al. (2014), Lack & Heiter (2007) | (no excess)                                   | …                                         | …                                |
| HD 138688             | …     | …   | Jasniewicz et al. (1999) | (no excess)                                   | …                                         | …                                |
| G1551+22.9456         | …     | C12 | …                | (no excess)                                   | …                                         | …                                |
| SDSS J1607+0447       | …     | …   | Martell & Shetrone (2013) | sparse SED but probably no IR excess | …                                         | …                                |
| HD 14506              | …     | …   | Jasniewicz et al. (1999) | (no excess)                                   | …                                         | …                                |
| HD 145457             | …     | …   | Kumar et al. (2011) | (no excess)                                   | …                                         | …                                |
| IRAS16086–5255(PDS 410) | dIR97 | …   | …                | IR excess                                     | …                                         | T$_{\text{eff}}$ too warm to be RG. log g too large to be RG. |
| IRAS16128–5109        | dIR97 | …   | …                | drop due to source confusion                  | Appears in SIMBAD as an H II region; the morphology of the image suggests a dense clump of sources from which emanate long streams of extended emission. | No A(Li), No T$_{\text{eff}}$. No log g. |
| HD 146850             | dIR97 | …   | …                | (no excess)                                   | …                                         | …                                |
| HD 146834             | dIR97 | …   | …                | IR excess (small)                             | Also HR 6076. Also identified in McDonald et al. (2012) as having an IR excess. | No A(Li), No log g. |
| HD 148293             | dIR97 | …   | …                | (no excess)                                   | …                                         | …                                |
| Tyc2043–00747-1       | …     | C12 | …                | (no excess)                                   | …                                         | …                                |
| IRAS16227–4839        | dIR97 | …   | …                | drop due to source confusion                  | Match forced to be IR-bright source (not found automatically given this position). | No A(Li), No T$_{\text{eff}}$. No log g. |
| HD 148317             | …     | …   | Liu et al. (2014), Lack & Heiter (2007) | (no excess)                                   | …                                         | T$_{\text{eff}}$ too warm to be RG. log g too large to be RG. |
| IRAS16252–5440        | dIR97 | …   | …                | drop due to source confusion                  | Also PDS 146. Cluster of IR-bright sources. | No A(Li), No T$_{\text{eff}}$. No log g. |
| HD 150902             | …     | …   | Kumar et al. (2011) | (no excess)                                   | …                                         | …                                |
| HIP 81437             | …     | C12 | …                | (no excess)                                   | …                                         | …                                |
| G1640+56.6327         | …     | C12 | …                | (no excess)                                   | …                                         | …                                |
| IRAS16514–4625(PDS 432) | dIR97 | …   | …                | drop due to source confusion                  | Torres et al. (2000) list it as a confirmed giant but the source that was measured may not be responsible for the IR flux. Cluster of sources, steep SED. | No A(Li), No T$_{\text{eff}}$. No log g. |
| HD 153135             | dIR97 | …   | …                | (no excess)                                   | …                                         | …                                |
| HD 152786             | …     | …   | Jasniewicz et al. (1999) | (no excess)                                   | …                                         | …                                |
| HD 153687             | …     | …   | Jasniewicz et al. (1999) | (no excess)                                   | …                                         | …                                |
| HD 155646             | …     | …   | Liu et al. (2014), Lack & Heiter (2007) | (no excess)                                   | …                                         | …                                |
| IRAS17102–3813        | dIR97 | …   | …                | drop due to source confusion                  | Cluster of sources.                        | No A(Li), No T$_{\text{eff}}$. No log g. |
| IRAS17120–4106        | dIR97 | …   | …                | drop due to source confusion                  | Two possible sources.                      | No A(Li), No T$_{\text{eff}}$. No log g. |
| HD 156115             | dIR97 | …   | …                | (no excess)                                   | …                                         | …                                |
| Name                  | dIR97 | C12 | Other Lit | Status                      | Notes | At(Li), log g, $T_{\text{eff}}$? |
|----------------------|-------|-----|-----------|-----------------------------|-------|-----------------------------|
| HD 156061            | dIR97 |     |           | (no excess)                 |       | No A(Li), No log g.         |
| IRAS17211–3458       | dIR97 |     |           | drop due to source confusion| Two possible sources. |
| HD 157457            |       |     | Jasniewicz et al. (1999) | (no excess) |                   |
| HD 157919            |       |     | Liu et al. (2014), Luck & Hei-| (no excess) |                   |
| IRAS17442–2441       | dIR97 |     |           | drop due to source confusion| Cluster of possible sources. |
| PDS 97(IRAS17554–3822) |     |     | de la Reza et al. (1996)   | drop due to source confusion| Target position in between two sources of comparable brightness. |
| IRAS17576–1845       | dIR97 |     |           | drop due to source confusion| The multi-wavelength images suggest extinction in this field. Coa- |
| IRAS17578–1700       | dIR97 |     |           | IR excess (but maybe not K giant) | IR excess star. Also C’ 2514, CGCS 3922—likely carbon star. |
| HD 162298            | dIR97 |     |           | (no excess)                 |       | No A(Li), No log g.         |
| G1800+61.12976       |       |     | C12       | (no excess)                 |       | No A(Li), No log g.         |
| IRAS17582–2619       | dIR97 |     |           | drop due to source confusion| Brightest source in IR has no optical counterpart. SIMBAD lists this |
| IRAS17590–2412       | dIR97 |     |           | drop due to source confusion| Position shifted slightly to pick up WISE source. Diffuse emission |
| IRAS17596–3952(PDS 485) |     |     |           | IR excess (but maybe not K giant) | Position shifted slightly to pick up WISE source. Also identified in |
| Tyc0435-03332-1      |       |     | Adamów et al. (2014)      | (no excess) |                   |
| HD 164712            | dIR97 |     |           | (no excess)                 |       | No A(Li), No log g.         |
| HD 167304            |       |     | Kumar et al. (2011)       | (no excess) |                   |
| HD 170527            |       |     | Kumar et al. (2011)       | (no excess) |                   |
| HD 169689            |       |     | Jasniewicz et al. (1999)  | (no excess) |                   |
| V385 Sct             |       |     | Castilho et al. (2000)    | IR excess (but maybe not K giant) | Too cool to be a K giant. S-type star. |
| IRAS18334–0631(PDS 524) |     |     |           | drop due to source confusion| No optical source at the target position, and cluster of IR sources. |
| Tyc3105-00152-1      |       |     | Adamów et al. (2014)      | (no excess) |                   |
| Tyc3917-01107-1      |       |     | Adamów et al. (2014)      | (no excess) | Identified in McDonald et al. (2012) as having an IR excess, but IR |
| IRAS18397–0400       | dIR97 |     |           | drop due to source confusion| Brightest source in the IR has no optical counterpart. |
| Tyc3930-00681-1      |       |     | Adamów et al. (2014)      | (no excess) |                   |
| HD 175492            |       |     | Jasniewicz et al. (1999)  | (no excess) |                   |
**Table 6**  
(Continued)

| Name | dLR97 | C12 | Other Lit | Status | Notes | At(Li), log g, T<sub>eff</sub>? |
|------|-------|-----|-----------|--------|-------|-------------------------|
| IRAS18559+0140 | dLR97 | ... | ... | drop due to source confusion | No optical source at the target position, and cluster of IR sources. | No A(Li). No T<sub>eff</sub>. No log g. |
| HD 176588 | dLR97 | ... | ... | (no excess) | ... | ... |
| SDSS J1901+3808 | ... | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess | ... | ... |
| HD 176884 | ... | ... | Jasniwicz et al. (1999) | (no excess) | Name as appearing in dLR97 had a typo; this is the correct name. | No A(Li). | Not Li rich. |
| IRAS19012–0747 | dLR97 | ... | ... | IR excess (small) | ... | ... |
| HD 177830 | ... | C12 | ... | (no excess) | ... | ... |
| IRAS19038–0026 | ... | ... | Castilho et al. (2000) | IR excess (small but maybe not K giant) | May be too cool to be a K giant. | Not Li rich. T<sub>eff</sub> too cool to be RG. |
| HD 177366 | dLR97 | ... | ... | (no excess) | ... | ... |
| HD 178168 | ... | ... | Castilho et al. (2000) | (no excess) | ... | ... |
| SDSS J1909+3837 | ... | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess | ... | ... |
| IRAS19083+0119 (PDS 562) | dLR97 | ... | ... | drop due to source confusion | Brightest source in the IR has no optical counterpart. Steep SED. | No A(Li). No T<sub>eff</sub>. No log g. |
| KIC 5000307 | ... | ... | Silva Aguirre et al. (2014) | (no excess) | ... | ... |
| HD 181154 | dLR97 | ... | ... | (no excess) | ... | No A(Li). No log g. |
| IRAS19210+1715 | dLR97 | ... | ... | drop due to source confusion | Brightest source in the IR has no optical counterpart. Steep SED. | No A(Li). No T<sub>eff</sub>. No log g. |
| HD 182900 | ... | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess) | ... | T<sub>eff</sub> too warm to be RG. log g too large to be RG. |
| HD 182901 | ... | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess) | ... | T<sub>eff</sub> too warm to be RG. log g too large to be RG. |
| HD 183492 | ... | ... | Kumar et al. (2011) | (no excess) | ... | ... |
| HD 183202 | dLR97 | ... | ... | (no excess) | ... | ... |
| PDS 100 | dLR97 | ... | ... | IR excess | Also V859 Aql and IRAS19285+0517. Also identified in Kumar et al. (2015) as IR excess star. | No A(Li). No T<sub>eff</sub>. No log g. |
| G1936+61.14369 | ... | C12 | ... | (no excess) | ... | Not Li rich. |
| HD 185194 | ... | ... | Liu et al. (2014) | (no excess) | ... | ... |
| KIC 4937011 | ... | ... | Anthony-Twarog et al. (2013) | sparse SED but probably no IR excess | ... | ... |
| HD 187114 | dLR97 | ... | ... | (no excess) | ... | ... |
| RAVE192544.9–600813 | ... | ... | Ruchti et al. (2011) | (no excess) | ... | ... |
| Tyc1058-02865-1 | ... | ... | Adamów et al. (2014) | (no excess) | ... | ... |
| HD 188376 | ... | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess) | ... | ... |
| HD 188993 | ... | ... | Liu et al. (2014), Luck & Heiter (2007) | (no excess) | ... | ... |
| HD 190299 | dLR97 | ... | ... | (no excess) | ... | ... |
| HD 191277 | ... | C12 | ... | (no excess) | ... | Not Li rich. |
| SDSS J2019+6012 | ... | ... | Martell & Shetrone (2013) | sparse SED but probably no IR excess | ... | ... |
| Name                  | dR97 | C12 | Other Lit                                      | Status          | Notes                                                                 | At(Li), log g, \(T_{\text{eff}}\) |
|----------------------|------|-----|----------------------------------------------|-----------------|-----------------------------------------------------------------------|----------------------------------|
| HD 194317(39Cyg)     | dR97 |     |                                              | (no excess)     |                                                                       |                                  |
| HD 194937            |      |     |                                              | (no excess)     |                                                                       |                                  |
| Tyc9112-00430-1      |      |     | Ruchti et al. (2011)                         | IR excess (small)|                                                                       |                                  |
| Tyc2185-00133-1      | C12  |     |                                              | (no excess)     |                                                                       |                                  |
| HD 202261            |      |     | Liu et al. (2014), Luck & Heiter (2007),      | (no excess)     |                                                                       |                                  |
| HD 203136            |      |     | Kumar et al. (2011)                         | (no excess)     |                                                                       |                                  |
| HD 203251            | dR97 |     |                                              | (no excess)     | IRAS FSC [12]–[25] > 0.5 but WISE says no excess.                    | Not Li rich. No log g.           |
| HD 204540            | dR97 |     |                                              | (no excess)     |                                                                       |                                  |
| HD 205349            |      |     | Kumar et al. (2011)                         | (no excess)     |                                                                       | Not Li rich. No log g.           |
| HD 206445            | C12  |     |                                              | (no excess)     |                                                                       |                                  |
| G2290+56.3466        | C12  |     | Ruchti et al. (2011)                         | (no excess)     |                                                                       | Not Li rich. No log g.           |
| SDSS J2200+4559      |      |     | Martell & Shetrone (2013)                   | sparse SED but possibly no IR excess |                                                                       |                                  |
| SDSS J2206+4531      |      |     | Martell & Shetrone (2013)                   | sparse SED but possibly no IR excess |                                                                       |                                  |
| HD 212271            |      |     | Liu et al. (2014)                           | (no excess)     |                                                                       |                                  |
| HD 212430            |      |     | Liu et al. (2014)                           | (no excess)     |                                                                       |                                  |
| HD 213619            |      |     | Liu et al. (2014), Luck & Heiter (2007)     | (no excess)     |                                                                       |                                  |
| HD 213930            |      |     | Liu et al. (2014)                           | (no excess)     |                                                                       |                                  |
| HD 214995            |      |     | Liu et al. (2014), Luck & Heiter (2007),      | (no excess)     |                                                                       |                                  |
| HD 217352            | dR97 |     |                                              | (no excess)     |                                                                       |                                  |
| HD 218527            |      |     |                                              | (no excess)     |                                                                       |                                  |
| HD 219025            | dR97 |     |                                              | IR excess       | Also BI Ind. Also identified in Kumar et al. (2015) as an IR excess star.|                                  |
| Tyc8448-00121-1      |      |     | Ruchti et al. (2011)                         | (no excess)     |                                                                       |                                  |
| HD 219449            |      | C12 |                                              | (no excess)     |                                                                       | Not Li rich. No log g.           |
| HD 221776            | dR97 |     |                                              | (no excess)     |                                                                       | Not Li rich. No log g.           |
| HD 221862            | C12  |     |                                              | (no excess)     |                                                                       | Not Li rich. No log g.           |
| SDSS J2353+5728      |      |     | Martell & Shetrone (2013)                   | (no excess)     |                                                                       |                                  |
| SDSS J2356+5633      |      |     | Martell & Shetrone (2013)                   | (no excess)     |                                                                       |                                  |
