Mon. Not. R. Astron. Soc. **345,** 1212–1222 (2003)

Some anomalies in the occurrence of debris discs around main-sequence A and G stars

J. S. Greaves* and M. C. Wyatt*
UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ

Accepted 2003 July 18. Received 2003 July 18; in original form 2003 March 14

ABSTRACT

Debris discs consist of large dust grains that are generated by collisions of comets or asteroids around main-sequence stars, and the quantity and distribution of debris may be used to detect the presence of perturbing planets akin to Neptune. We use stellar and disc surveys to compare the material seen around A- and G-type main-sequence stars. Debris is detected much more commonly towards A stars, even when a comparison is made only with G stars of comparable age. Detection rates are consistent with disc durations of ∼0.5 Gyr, which may occur at any time during the main sequence. The higher detection rate for A stars can result from this duration being a larger fraction of the main-sequence lifetime, possibly boosted by a globally slightly larger disc mass than for the G-type counterparts. The disc mass range at any given age is a factor of at least ∼100 and any systematic decline with time is slow, with a power law estimated to not be steeper than $t^{-1/2}$. Comparison with models shows that dust can be expected as late as a few Gyr when perturbing planetesimals form slowly at large orbital radii. Currently, the Solar system has little dust because the radius of the Kuiper Belt is small and hence the time-scale to produce planetesimals was less than 1 Gyr. However, the apparently constant duration of ∼0.5 Gyr when dust is visible is not predicted by the models.

Key words: circumstellar matter – planetary systems: formation – planetary systems: protoplanetary discs.

1 INTRODUCTION

Debris discs were first discovered as far-infrared excesses above the photosphere of nearby normal main-sequence stars, with the prototype being Vega (Aumann et al. 1984). About 15 per cent of stars within ∼25 pc are now thought to possess such discs (Habing et al. 2001). The thermal emission arises from dust grains that generally have sizes above ∼10 μm, and this dust is thought to be continually regenerated by impacts among kilometre-sized comets or asteroids (Dent et al. 2000; Wyatt & Dent 2002). The cool dust temperatures imply a location similar to the Kuiper Belt in our own Solar system, and perturbations in the dust rings can be used as a unique tracer of planets on orbits as large as tens of au (Greaves et al. 1998; Holland et al. 1998). A few stars early in their main-sequence lifetimes also possess mid-infrared emission (Jayawardhana et al. 1998; Koerner et al. 1998; Marsh et al. 2002), indicating warm dust closer to the star, but the lack of such emission from most debris discs implies a cleared 'cavity'. The most plausible explanation of this cavity is the presence of a planetary system – the Solar system would appear very similar to this when viewed externally (Liou & Zook 1999).

An enigma in the study of planetary systems is why some stars should have visible debris while the majority do not. The detected masses of cool dust are 10^{-4} $M_{\oplus}$ or more, while the equivalent mass for the Kuiper Belt is estimated at $\sim 10^{-5}$ $M_{\oplus}$ (Moro-Martín & Malhotra 2003; Landgraf et al. 2002). The standard hypothesis is that debris is generated mainly at early times, when planetesimals are forming and colliding frequently; this time-scale is expected to be comparable to the first ∼0.6 Gyr of the Solar system when the Earth was heavily bombarded (Maher & Stevenson 1988). Stellar surveys in the far-infrared appear to support this hypothesis, with Habing et al. (2001) finding that the disc detection rate drops abruptly for stellar ages of more than 0.4 Gyr (at least for A stars, for which substantial numbers of discs were detected with the *Infrared Space Observatory*, *ISO*). Using *ISO* observations of clusters, Spangler et al. (2001) characterize this mass decline as having the form t^{-2} between 10 Myr and 1 Gyr. The small quantity of dust in the Kuiper Belt would then reflect the large age of the Sun (4.5 Gyr).

Recently, some contrary evidence has emerged. A small number of stars with ages of a few Gyr do possess discs (Decin et al. 2000; Habing et al. 2001), raising the question of how these differ from the Sun. A problem of skewing in the surveys also needs to be addressed: nearly half of the *ISO* detections are of discs around A-type stars, and these are intrinsically young with maximum main-sequence lifetimes around 1 Gyr. This observational effect is unavoidable in

---

*E-mail: jsg@roe.ac.uk (JSG); wyatt@roe.ac.uk (MCW) the far-infrared when more luminous stars are detectable to greater distances: in the case of the Habing et al. (2001) survey, A stars were included to a 25-pc threshold, while the observational limit for G stars was 15 pc. (These were the systematic limits, although a small number of more distant stars was observed in each category.) These selected distances result in an enhanced overall fraction of shorter-lived A stars, versus their local space density, which could skew the results towards a younger disc age.

In this paper, we compare the disc detection rates for A- and G-type main-sequence stars in order to determine whether the apparent mass decline with time is an artefact of biases; estimate the time-scale of disc duration; and consider why the Solar system should be significantly less dusty than the environs of some solar analogues.

2 DATA SURVEY

Debris discs have been discovered largely by a 60-μm excess seen either with the *Infrared Astronomical Satellite* (*IRAS*) or *ISO* satellites. The unbiased *IRAS* survey covered 96 per cent of the sky and uncovered many potential excesses such as the prototype, Vega (Aumann et al. 1984). Subsequent analyses have included correlation with luminosity class (Mannings & Barlow 1998), as giant stars produce dust in their envelopes that can easily be confused with a debris disc signature. Including only dwarf stars, about 200 disc candidates remain. However, some of these are very young stars still in the pre-main-sequence phase, which still possess primordial discs. These are typically very massive and so can be detected to distances of hundreds of parsecs, even with the limited sensitivity of *IRAS*. Hence to produce a distance-limited sample, Habing et al. (2001) and Laureijs et al. (2002) used the *ISO* to search around nearby main-sequence A–K stars for excesses at 25, 60 and 170 μm. The star itself needed to be detected to define the excess, implying that the photospheric flux was required to be about 30 mJy at the primary wavelength of 60 μm. This imposes lower distance limits for some spectral types, inside the overall survey threshold of 25 pc: for example, G stars were not detectable beyond 15 pc. Most binary or variable stars were also excluded, and not all stars were observable during the *ISO* mission. However, within these criteria the sample is representative of the local volume near the Sun, and 17 per cent (14 out of 84) of the stars were found to have discs. A further set of solar-type stars was observed by Decin et al. (2000), based on targets of planetary searches and with more relaxed constraints on distance and stellar flux, and a similar disc fraction was found (17 per cent, five out of 30 stars).

We use the *IRAS* and *ISO* survey results to find the statistics of disc detections around A and G dwarf stars within 25 pc of the Sun. Using a small volume eliminates most of the pre-main-sequence stars [the exception is β Pictoris at 19.3 pc, lying within a comoving group of an estimated age $\sim$12 Myr, (Zuckerman et al. 2001); we include this star although it may be a transition-era object]. Also, very complete catalogues of stellar types and multiplicities are available for a 25 pc sample, and the comparison of A and G stars gives a good contrast in stellar luminosity and lifetime. In comparison B stars have very short main-sequence lifetimes and many have far-infrared excesses that can be attributed to free–free Be emission, while K and M stars have few disc detections and hence less reliable statistics.

Details of the stellar counts are given in the Appendix, and the stars with discs are identified from our data base (http://www.roe.ac.uk/atc/research/ddd/), which summarizes published *IRAS* results in the literature and defines debris as an excess with a secure positional association towards a type IV–V or V dwarf star. The additional *ISO* detections by Habing et al. (2001), Decin et al. (2000) and Spangler et al. (2000) are also included here – *ISO* observed 70 per cent of the single A stars but only ≈20 per cent of single G stars within 25 pc. Stars have been divided by age into broad 'young' and 'old' categories, with all A stars being defined as young (up to ≈1.2 Gyr, Lachaume et al. 1999), and using the survey of Gaidos (1998) to identify similarly young G stars. For ages less than about 0.8 Gyr, these are strong X-ray sources that were visible in the all-sky *ROSAT* survey, and Gaidos (1998) has catalogued all such single stars within 25 pc. At the low-age end, the G stars are thought to all exceed 70 Myr (Gaidos, Henry & Henry 2000), and the A stars (apart from β Pic) are mostly older than 100 Myr, where minimum age estimates can be made (Lachaume et al. 1999). Finally, we classify as 'multiple' any of the A or G stars with a stellar companion (Table 1), regardless of the sky separation of the objects, but note below where adopting Gaidos' alternative definition would affect the statistics. This definition is that a star is single if the companion lies more than 800 au away, since in this case they could be resolved with *ROSAT*.

Table 1. Disc statistics for stars within 25 pc. The number of systems is less than the number of stars because some multiples contain two A or G dwarfs. The A or G star is the primary in all other multiples except for one G star with a slightly brighter companion. Further definitions are given in the text and the Appendix.

	A stars	G stars
Total number of stars	21	188
Total number of systems	19	177
Young single stars	13	22
Old single stars	–	101
Stars in multiple systems	8	65
Young single stars with discs	8	4
Old single stars with discs	–	5
Multiple stars with discs	1	3

3 TRENDS IN THE DATA

The total numbers of stars and discs are given in Table 1. The stellar statistics are well known for the solar neighbourhood, with G stars an order of magnitude more common than A stars, and about one-third of both types of star lying within multiple systems.[1] The only surprise is that the number of young G stars is rather high, since only ≈10 per cent of the population would be expected to be less than 0.8 Gyr old, given the present age of the Galactic disc of about 9 Gyr (Gaidos 1998). The actual fraction, at least among the single stars with age data, is 18 per cent and this appears to be because some of the stars lie in the Local and Ursa Major comoving groups (Gaidos et al. 2000). These nearby associations presumably formed stars within a short period, producing a slight local enhancement of relatively young stars.

Among the single stars, discs have been detected for 62 per cent of the A stars but for only 7 per cent of the G stars. If the sole difference is the typical ages of these types of star, then we would expect $\sim$62 per cent of the young G star sample to possess discs and to have been detected by *IRAS*. However, this predicts around 14 discs among 22 stars, and in fact only four discs have been detected. This is a very clear difference in the disc detection rate, beyond

---

[1] Duquennoy & Mayor (1991) find a slightly greater proportion of multiple systems, 43 per cent, for dwarf stars of types F7–G9 within 22 pc of the Sun.

any age effects. Factors which may affect the disc counts (including biases) are discussed below.

To assess the significance of this difference in detection rate, we place upper and lower bounds on the disc fraction. The A stars have been observed very completely by both *IRAS* and *ISO*. The disc fraction could be reduced slightly if we reclassify wide binaries as single stars, in which case there would be eight discs in 15 single A-star systems, or 53 per cent. An upper bound comes from the fact that three A stars do not have discs, although observed with both *IRAS* and *ISO*; hence the detectable disc fraction cannot exceed 77 per cent. The detection rate for A stars is therefore 62^{+15}_{-9} per cent. For the G stars, the *ISO* coverage was much less complete within 25 pc, so we assume Poisson statistics for a small sample of an overall population. The detection rate for the young G stars is then $4 \pm \sqrt{4}$ discs in 22 systems or 18 ± 9 per cent.[2] This is significantly below the value of 62^{+15}_{-9} per cent for the A stars.

The detection rate among multiple star systems is difficult to assess as the numbers are small; also Gaidos (1998) does not classify any *ROSAT*-identified multiple systems as young because there is some ambiguity as to whether the X-ray emission arises from the G star or a companion. The multiple systems with disc excesses are very diverse, with projected separations of 20 and 180 au for two of the G-type systems (HD 73752 and 214953; Poveda et al. 1994; Fabricius & Makarov 2000), and a very wide separation of >3700 au between HD 20766 and 20807 (only the latter having a disc). For the A stars, HD 139006 is a sub-au eclipsing binary (Schmitt 1998), and we omit the putative disc in the δ Vel system (which has a range of separations from <1 to >75 au, Argyle, Alzner & Horch 2002). This *IRAS* disc detection is now doubtful as the excess was not confirmed by *ISO* ($+1.7\sigma$ was measured by Habing et al. 2001); also a fraction of any weak excess flux could in fact come from a G dwarf in the system. Overall, multiple systems can have discs (see also Wyatt, Dent & Greaves 2003), but the number found is marginally lower than would be expected from the single-star detection rates. These would predict 10 discs around multiple-system stars, whereas only four are actually seen (three if wide multiples are not counted). However, as the *ISO* surveys avoided most multiple systems, the existence of a small number of discs slightly too faint to have been seen with *IRAS* could make the detection rate consistent with that of single stars. Multiple stars are not considered further here.

3.1 Differences in detection rate

If there is a generic decline in debris mass with time, then a higher detection rate for A stars is a natural outcome. The main-sequence era lasts ≈1 Gyr for an A5 star, whereas for a G5 star it is around 12 Gyr. The sharp disc decline after 400 Myr postulated by Habing et al. (2001) would then predict about half of the A stars to have discs and a few per cent of G stars. This is in good agreement with the detection rates of 62 and 7 per cent, respectively. However, this hypothesis fails to explain the detection of a few discs at much later times. In addition, a plot of the *oldest* known stars with discs, by spectral classification, shows that debris is in fact seen well into the main sequence for most stellar types (Fig. 1); the exceptions are very cool stars where few discs have been discovered. For more luminous stars, even the lowest age bounds imply the objects plotted are 25–50 per cent of the way through their main-sequence lifetimes. Dating main-sequence stars is difficult due to the lack of strong evolutionary tracers but several methods have been used in the literature with reasonably robust agreement for these stars (Song et al. 2000, 2001). Assuming ages are approximately correct, the plot suggests that debris can be seen *throughout* the main sequence.

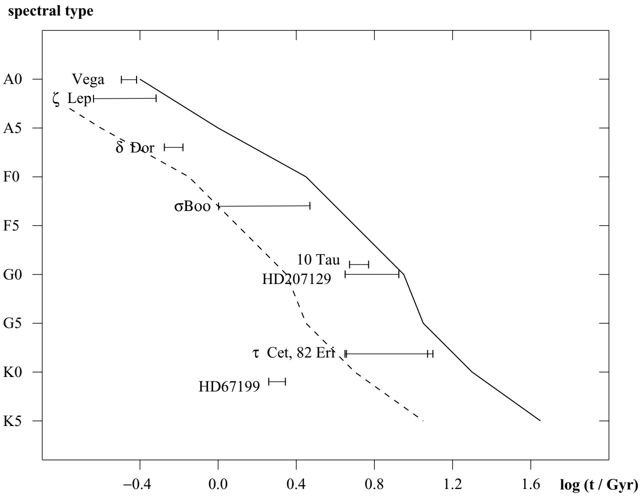

Figure 1. Plot showing the oldest known stars with debris discs, by spectral class from A to K. The solid line shows the approximate duration of the main sequence, from the well-known formula $t = M_*/L_* \times 10$ Gyr, and the dashed line lies at 25 per cent of the main-sequence lifetime. The bars indicate the estimated stellar ages; data are from Habing et al. (2001), Song et al. (2000, 2001), Lachaume et al. (1999), Decin et al. (2000) and Jourdain de Muizon et al. (1999). The age of HD 207129 is debated as its space motions would place it in the young Tucanae stream (Zuckerman & Webb 2000).

If the mass decline is *not* general, then a second plausible hypothesis for the different detection rates is that A star discs are brighter than their counterparts around G stars. This will in fact be the case if the discs are assumed to be physically identical – dust at the same orbital radius will be hotter when in thermal equilibrium with a more luminous star. For example, dust in a Kuiper Belt-like ring at 45 au around a 20-$L_\odot$ star will emit 25 times more flux at 60 μm than the same distribution of dust around a 1-$L_\odot$ star. This assumes blackbody grains with a temperature dependence of $L^{1/4}/\sqrt{r}$ (Backman & Paresce 1993), and hence temperatures of 88 and 41 K, respectively.[3] Thus the G star disc would be 25 times fainter for the same mass, and hence need to be up to five times closer to us to be detected. The largest distance discrepancy will occur if the typical disc is barely detected at 25 pc for an A star, and hence barely detected at 5 pc for a G star.[4]

This hypothesis of very different distance thresholds is not supported by the data. The median distance of the detected A discs is 19 pc, whereas for the G discs it is 16 pc; these values are similar to the median of 20 pc expected if the discs are equally spaced and equally detectable throughout the volume. Also, the number

---

[2] Wichmann, Schmitt & Hubrig (2003) identify four further young G stars within 25 pc from X-ray emission and lithium lines; including these would reduce the disc fraction to 15 ± 8 per cent. Since this stellar survey was not volume limited, it is difficult to include these stars in a consistent manner and these results are not used further.

[3] In the submillimetre regime, the emission is on the Rayleigh–Jeans side of the blackbody curve and so the flux would be only a factor of ≈2 higher for the A star disc.

[4] Strictly, this applies if the observations are purely sensitivity limited. In the case of the *ISO* 60-μm survey by Habing et al. (2001), the barely detected disc would have been 60 per cent of the total (disc plus photosphere) flux of an A5 star at 25 pc, but only 25 per cent of the total flux of a G5 star at 5 pc. The latter detection might also be constrained by calibration accuracy.

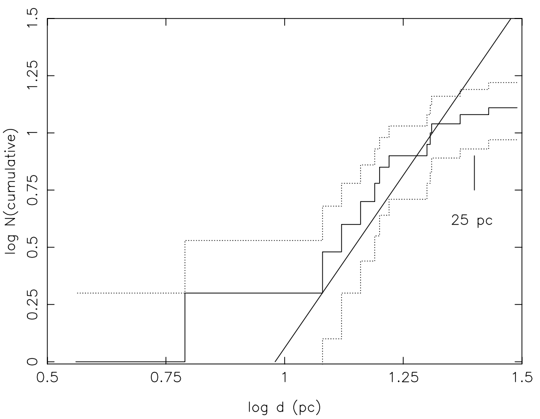

Figure 2. Cumulative numbers of disc detections for the G stars (and error ranges from $N^{1/2}$ counting statistics, dashed lines) plotted against distance. The 12 stars of Table 1 are included, plus one extra star at 27 pc from the disc data base. On a log–log scale, the number of detections should increase with a slope of 3 (solid line), as the volume scales with the cube of the distance. The counts flatten below this line at about 20 pc.

of detected G discs increases approximately linearly with the volume searched (Fig. 2), with evidence of flattening only beyond about 20 pc. The number of 'missed' discs beyond this distance potentially adds slightly to the detection rate, and some lower-mass examples will have been missed (i.e. G stars observed by *IRAS* but not with the greater sensitivity of *ISO*). If the r^3 line in Fig. 2 is extrapolated from 20 to 25 pc, the detections should increase to ∼20 discs with ∼15 around single stars. The single star detection rate would then be 12 ± 3 per cent (assuming $N^{1/2}$ counting statistics for the errors), still lower than the rate for A stars of 62^{+15}_{-9} per cent.

If the A and G detection rates do not differ because of age or sensitivity effects, the reason may lie in an intrinsic difference in the mean disc properties. The submillimetre flux from an optically thin disc is proportional to the mass (and in a more complex manner on temperature, size and emissivity), and Wyatt et al. (2003) have estimated the masses of debris discs for stars where the far-infrared excess has been confirmed with submillimetre observations (see their fig. 4). The absolute values range over two orders of magnitude (a few thousandths to a few tenths of an Earth mass) but the median disc for the high-luminosity stars is about 0.2 $\mathrm{M}_\oplus$, versus about 0.03 $\mathrm{M}_\oplus$ for the low-luminosity stars. If the 60-μm fluxes of the A-star discs were reduced by a factor of a few (as would be the case for a lower mass but the same grain properties) then only α PsA, α Lyr and β Pic would have been detected with good signal-to-noise ratio in the *ISO* survey (Habing et al. 2001). The detection rate would then be only 23 per cent among the single A stars, more comparable to the ≈7–12 per cent of the G stars. We conclude that the disc masses are very varied, but a global difference in mass, with A stars possessing more disc material,[5] could explain the different detection rates for A and G stars.

3.2 Disc lifetime

If the debris mass declines rapidly at an early time in the main sequence, we would expect to detect very few discs among the G stars for which ages exceed 0.8 Gyr. In fact, the decline is not extremely steep: using $N^{1/2}$ counting statistics, the young and old disc frequencies are 18 ± 9 and 5 ± 2 per cent, respectively. Although the numbers of discs are small, the five seen in the older age group (Table A1) are difficult to reconcile with the expectation of zero if there were a steep mass decline with time.

One approach to measuring debris time-scales is to compare the frequency of occurrence with the stellar lifetimes. If we assume that each disc is visible for a fixed time t(disc), then we expect to detect a fraction $f(\mathrm{disc}) = t(\mathrm{disc})/t(\mathrm{star})$ in a stellar population with a spread of ages. Provided the sum of t_0 (the time when debris appears) plus t(disc) is less than t(star), the actual values of t_0 are not important; t(disc) could also represent several episodes of dust formation. This equation can be inverted to estimate the disc time-scale. We adopt typical main-sequence lifetimes of $t(\mathrm{A5}) = 1$ Gyr and $t(\mathrm{G}) = 9$ Gyr (the age of the Galactic disc, Gaidos 1998, although stars later than G0 will eventually exceed this).

The results are in fact consistent with a roughly *constant* value of t(disc). With A and G f(disc) values of 62 and 7 per cent, the corresponding estimates of t(disc) are both 0.6 Gyr. Including multiple systems drops t(disc) to 0.4 Gyr for the A stars but leaves the G-star value unchanged. As a check, the same calculation was made for F and K dwarf stars within 25 pc, and we obtain values of 0.4 and 0.6 Gyr, respectively (including multiple stars for simplicity). For F stars, 17 discs are seen out of 117 stars, and we assume an F5 lifetime of 2.7 Gyr; for K stars the disc statistics are seven out of 112, excluding objects later than K2 since there are no disc detections and adopting the Galactic disc age as t(K). The disc stars are listed in our data base, and the stellar counts are from the Appalachian State catalogue referenced in the Appendix. Combined with Fig. 1, these results support a disc lifetime of around 0.5 Gyr, but not always occurring at an early point in the main sequence.

3.3 Disc mass range

As already noted there is a wide range in disc masses, even for similar stars of roughly equal ages (Wyatt et al. 2003). An informative result from the *ISO* survey (Habing et al. 2001) was that although the sensitivity was five times greater than for the equivalent search made by *IRAS*, only one new disc was detected. These results suggest a bimodal distribution of disc masses, with detected examples having at least $10^{-4}\,\mathrm{M}_\odot$ of dust and a second group of stars being significantly less dusty, perhaps at the level of the Sun, $\sim 10^{-5}\,\mathrm{M}_\oplus$.[6]

A bimodal mass distribution would favour a model where dust is generated and then removed over the time-scale of around 0.5 Gyr derived above (i.e. essentially 'on' and 'off' states), or any briefer episodes that could sum to this period (e.g. associated with destruction of individual bodies, Grogan, Dermott & Durda 2001). The G stars 58 Eri and τ Ceti, which have similar dust masses but ages of around 0.2 and 7 Gyr, respectively (Habing et al. 2001) could be examples supporting dusty 'events' at very different epochs. The dust masses need not be exactly the same in each episode provided that they exceed the detectability threshold.

---

[5] Habing et al. (2001) find on average a *lower* mass for A-star discs compared with G stars, using different assumptions to those of Wyatt et al. (2003). The latter use submillimetre data (and far-infrared data to constrain temperature) and this is thought to be a better method to estimate total mass than far-infrared fluxes alone. Observations at longer wavelengths are sensitive to larger grains, which also dominate the total mass. These different results for mass versus spectral type are therefore likely to be related to the typical grain size detected at different wavelengths.

[6] Habing et al. (2001) argue that the *ISO* 60-μm upper limits correspond to masses around $10^{-5}\,\mathrm{M}_\odot$ but this scales with the assumed particle diameter; adopting 10–100 μm (Dent et al. 2000) instead of 1 μm would raise these limits to 10^{-4}–$10^{-3}\,\mathrm{M}_\odot$ and the detections to $>10^{-3}\,\mathrm{M}_\odot$.

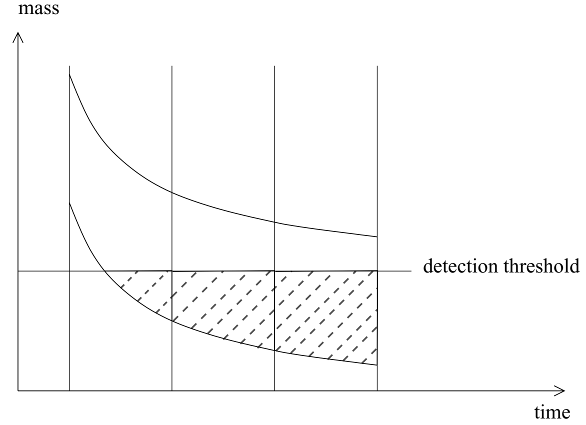

Figure 3. Sketch of a hypothetical decline in disc mass with a broad range at any given age. For mass bins at increasing ages, larger number of stars will fall below the detectability threshold (see the text).

An alternative to this 'on or off' hypothesis is that there is a slow systematic decline in dust mass, but the range between stars of any given age is so large that the decline is obscured observationally. We can set limits on such a decline as sketched in Fig. 3. We assume that at any time there is a range of a factor of 100 between the lowest and highest mass discs, based on the values found by Wyatt et al. (2003). We further assume that there is a smooth distribution in mass within this range, and test whether a power law of the global mass decline can fit the observed detections of G discs. For simplicity, we set the distribution to be rectangular in log-mass, i.e. $\mathrm{d}N/\mathrm{d}(\log M) =$ constant. [There are insufficient numbers of discs to establish any particular mass distribution, but it is more likely to be weighted towards low M values, given the small number of extra detections obtained with *ISO* versus *IRAS*. An equal spread in $\mathrm{d}N/\mathrm{d}(\log M)$ is more low-M weighted than, for example, a constant distribution in $\mathrm{d}N/\mathrm{d}M$.] The numbers of discs were then counted in bins of width $\mathrm{d}(\log t) \approx 1$. This divides conveniently into the young G star group between 0.07 and 0.8 Gyr, and the older group at >0.8 to 9 Gyr, the age of the Galactic disc.

The fraction of discs detected can then be expressed as

$$f_{\rm det} = (\log M_{\rm max} - \log M_{\rm det})/(\log M_{\rm max} - \log M_{\rm min}), \qquad (1)$$

with $M_{\rm max}/M_{\rm min} = 100$ and $M_{\rm det}$ being the constant minimum detectable mass. Describing the mass decline by $M_{\rm max} \propto t^{-\alpha}$, the expression for $f_{\rm det}$ can be differentiated to give the change in detection rate with time:

$$\mathrm{d}(f_{\rm det})/\mathrm{d}(\log t) = -\alpha/\log(M_{\rm max}/M_{\rm min}). \qquad (2)$$

The values of $f_{\rm det}$ for the young and old groups then imply $\alpha \leqslant 0.5$. The mass distribution needs to be verified, but assuming alternatively $\mathrm{d}N/\mathrm{d}M =$ constant then the decline will be flatter, with $\alpha < 0.2$ (or the detection rate will change too greatly over the order of magnitude in age ranges). Thus any global mass drop, with reasonable guesses at the mass distribution, is much shallower than the t^{-2} found by Spangler et al. (2000) for stars up to 1 Gyr old. This is likely to have been an artefact of fitting data that include the sharp mass drop at the end of the pre-main-sequence phase (Wyatt et al. 2003).

4 DISCUSSION

4.1 Comparison to primordial discs

Some properties of the debris discs may be inherited directly from the protoplanetary discs that exist at much earlier times, up to about 10 Myr. A simple hypothesis might be that the debris discs retain the original size of the primordial disc but only a small (but constant) fraction of the mass, with the remainder being accumulated into planets or dispersed. The range of initial masses would then scale downwards to the range of debris masses observed. This model is useful mainly for comparing with observed phenomena, but could be realistic. For example, as planetesimals form in the outer disc, the collisions of kilometre-sized bodies will generate dust. These bodies will presumably exist in numbers proportionate to the original disc density at that point, so the debris mass could simply be inherited directly from the initial mass.

The range of detected disc masses is about a factor of 100 both in the primordial and debris disc phases (Wyatt et al. 2003). For the primordial discs, the mean mass is roughly constant irrespective of spectral type: Thi et al. (2001) have measured dust masses for a sample of Herbig Ae stars and sub-solar mass T Tauri stars, and find average dust masses of 125 and 100 $\mathrm{M}_\oplus$, respectively, while Mannings & Sargent (2000) found up to a factor of 2 mass difference. For the debris discs, a somewhat higher factor was found above, from the median disc mass of 0.2 $\mathrm{M}_\oplus$ for A stars compared with 0.03 $\mathrm{M}_\oplus$ for G stars. This would suggest more dependence on spectral type at later times, but the numbers of detections are small. More apparent is the extreme drop in mass, from a geometric mean of around 100 $\mathrm{M}_\oplus$ at early times to a few 0.01 $\mathrm{M}_\oplus$ in the debris phase. In contrast, the disc sizes do not evolve greatly: Mannings & Sargent (2000) find outer radii of ≈85–450 au for Herbig Ae and T Tauri (gas) discs, whereas the debris discs extend out to between 80 au (Dent et al. 2000) and ∼300 au (Sheret, Dent & Wyatt 2003).

The simplest evolutionary model would therefore be that all discs evolve down in mass by a factor of a few thousand, while retaining the original size. However, the Solar system has a very low debris mass, $\leqslant 4 \times 10^{-5}$ $\mathrm{M}_\oplus$ (Moro-Martín & Malhotra 2003), while requiring at least 50 $\mathrm{M}_\oplus$ of original solid material to make up the present-day planetary cores (Boss et al. 2002). This is a mass decline of $> 10^6$, at least two orders of magnitude larger than the hypothetical constant value. A simple phenomenological model therefore does not provide an adequate description and evolutionary simulations are considered next.

4.2 Comparison with models

Models for the collisional generation of debris typically invoke a perturber that gravitationally stirs the disc of planetesimals: either a planet within the disc, or a companion star (possibly on an eccentric orbit approaching closely at long time intervals), or a 'flyby' encounter with another star not bound to the system.

Table 1 shows that the majority of the discs are not in systems where there is a known stellar companion. M-star companions may escape detection unless very deep optical searches are made, and for example Patience et al. (2002) discovered additional faint stars in two out of 11 systems with radial velocity planets. At projected separations ∼100 au, these M stars are suitably located to affect the planetesimal disc, but such multiple systems are not in fact found to have debris even in sensitive submillimetre searches (Greaves et al. 2003). It is also noteworthy that such undiscovered companion stars could not *produce* an apparent far-infrared excess where there is no disc. The photosphere of an early-M dwarf star would exceed the detection threshold of the *ISO* 60-μm survey (Habing et al. 2001) only inside a distance of 4 pc, and the two disc-excess systems inside this distance (ϵ Eri and τ Ceti) have been confirmed by imaging (Greaves et al. 1998; Greaves et al. 2003). Overall, the presence of a stellar companion does not appear to increase the chance of debris detection.

Instead the disc could be gravitationally stirred by a passing star. This would trigger an episode of dust formation at a random time, and the closeness of the encounter could vary the amount of dust produced, as seen in the observations. However, García-Sanchez et al. (1999) have found that the Sun's closest encounter in a 20-Myr period is a distance exceeding 0.3 pc, which would only perturb the Oort cloud slightly (adding 50 per cent to the number of long-period comets entering the planetary system). Kenyon & Bromley (2002a) have explicitly modelled the dust production for a planetesimal disc perturbed by a passing star, and find that the dust will be bright for $\leqslant$100 Myr, while there is only a 1 per cent chance of a close encounter with a field star in 100 Myr. For a lifetime of 10 Gyr, there would therefore be only one encounter producing a disc lasting for $\leqslant$100 Myr, not the $\sim$500 Myr required by the disc detection rate.

Influences within the planetary system are therefore the most plausible for generating debris. The most comprehensive models for late-time debris discs are those of Kenyon & Bromley (2002b), where the perturber needs to be at least Pluto-sized to produce a substantial dust disc. Dust is generated by collisions amongst planetesimals, and these collisions only occur at a high rate when one body has reached planetary size. This Pluto-like object acts as a gravitational focus, perturbing smaller bodies which then collide more frequently. Because the time-scale to form the large object is longer for larger radii, the effect in the simulations is of waves of dust generation seen successively further out from the star as time progresses. In the published model, the outer disc (radius $\sim$75 au up to 150 au) brightens after 0.3 Gyr and fades at the outer edge as late as 2.5 Gyr. (In fact, the 3-$M_\odot$ star in the model would leave the main sequence well before this time.)

A number of predictions of the model can be tested against the detection statistics and time-scales. In particular, the planetesimal formation time-scale is proportional to the orbital period (Kenyon & Luu 1998) and inversely proportional to the initial disc mass M_0 (Kenyon & Bromley 2002b). For example, for a 100-$M_\odot$ disc around a mid-A star (slightly less than the 3 $M_\odot$ in their model), the outer regions would brighten after about 0.3 Gyr and remain bright until the star leaves the main sequence at around 1 Gyr. This time interval is a reasonable match to the disc lifetime of $\sim$0.6 Gyr estimated above, and hence the detection rate of about 60 per cent of the A stars. However, Habing et al. (2001) find that predominantly the *younger* A stars have discs, rather than the older ones predicted in the model. Secondly, the time-scales would be longer for the same sized disc around a 1-$M_\odot$ star, as the orbital periods are proportional to $1/\sqrt{M_*}$. The outer disc would thus not brighten until 0.5 Gyr, which could explain the lower detection rate in the G-star group up to 0.8 Gyr old. However, *many* of the older G stars might then be expected to have discs, because the dust wave would continue to move outwards, lasting even longer than the 2.5 Gyr in the A-star model.

The radial dependence of the formation time-scale presents some problems. The model could succeed in producing debris up to the late main sequence (Fig. 1), simply by selecting a larger disc size. Additionally, the lack of significant debris in the Kuiper Belt could be explained, as the main population of large bodies lies within 50 au of the Sun and debris production ceases relatively early at this small distance. In fig. 3 of Kenyon & Bromley (2002b), the disc is faint inside 50 au at 1 Gyr and this would scale to 1.7 Gyr for a solar-mass star. At this time 1000 km bodies would have already formed at the outer edge of the Solar system, and when smaller bodies have mostly ground down in collisions, dust can be removed on short time-scales (Dent et al. 2000; Kenyon & Bromley 2002b). Hence we would not expect to observe much dust in the Kuiper Belt at the Sun's age of 4.5 Gyr. However, the model predictions do not match well with the detection statistics, suggesting a disc duration of around 0.5 Gyr. To limit dust generation to a short period, either the disc must be small so the wave reaches the outer edge quickly, or the initial mass must be larger so that it evolves quickly. In either case, the dusty epoch would be near the beginning of the main sequence, whereas the G stars shown in Fig. 1 are older than 25–50 per cent of their lifetimes.

5 CONCLUSIONS

The number counts of discs have shown a much higher detection rate towards A stars than G stars, even when the age difference is eliminated. The detection rates support a disc duration of around 0.5 Gyr, but not always occurring near the start of the main-sequence lifetime. The A discs are then seen more frequently because 0.5 Gyr is a substantial fraction of the main-sequence duration; the discs may also be globally somewhat more massive than those of G discs. The discs may have 'on' and 'off' states with a high contrast in dust mass; if there is a systematic decline it cannot be steeper than about $t^{-1/2}$ for solar-type stars (assuming a simple smooth mass distribution). Several predictions of the Kenyon & Bromley (2002b) models for planetesimal discs are supported by the detection statistics, including the possibility of late-time dust in large discs, and the lack of dust in the Kuiper Belt, for which the biggest bodies should have formed within the first Gyr. However, the apparently constant duration of the dusty episodes is not explained by these models.

ACKNOWLEDGMENTS

We wish to thank Wayne Holland and Bill Dent for many useful discussions, and the referee, Marie Jourdain de Muizon, for very helpful comments. JSG thanks the Royal Astronomical Society for the support provided by the Sir Norman Lockyer Fellowship. This study would not have been possible without the excellent on-line search facilities provided by the NASA NStars project and Appalachian State University, referenced in the Appendix. This research also made use of the SIMBAD data base, operated at CDS, Strasbourg, France.

REFERENCES

Argyle R.W., Alzner A., Horch E.P., 2002, A&A, 384, 171
Aumann H.H. et al., 1984, ApJ, 278, L23
Backman D.E., Paresce F., 1993, in Protostars & Planets,Vol. III. Univ. Arizona Press, Tucson, p. 1253
Boss A.P., Wetherill G.W., Haghighipour N., 2002, Icarus, 156, 291
Decin G., Dominik C., Malfait K., Mayor M., Waelkens C., 2000, A&A, 357, 533
Dent W.R.F., Walker H.J., Holland W.S., Greaves J.S., 2000, MNRAS, 314, 702
Dominik C., Laureijs R.J., Jourdain de Muizon M., Habing H.J., 1998, A&A, 329, L53
Duquennoy A., Mayor M., 1991, A&A, 248, 485
Fabricius C., Makarov V.V., 2000, A&A, 356, 141
Gaidos E.J., 1998, PASP, 110, 1259
Gaidos E.J., Henry G.W., Henry S.M., 2000, AJ, 120, 1006
García-Sánchez J., Preston R.A., Dayton L.J., Weissman P.R., Lestrade J.-F., Latham D.W., Stefanik R.P., 1999, AJ, 117, 1042

Greaves J.S. et al., 1998, ApJ, 506, L133
Greaves J.S., Holland W.S., Jayawardhana R., Wyatt M.C., Dent W.R.F., 2003, MNRAS, in press
Grogan K., Dermott S.F., Durda D.D., 2001, Icarus, 152, 251
Habing H.J. et al., 2001, A&A, 365, 545
Holland W.S. et al., 1998, Nat, 392, 788
Jayawardhana R., Fisher S., Hartmann L., Telesco C., Piña R., Fazio G., 1998, ApJ, 503, L79
Jayawardhana R., Holland W.S., Kalas P., Greaves J.S., Dent W.R.F., Wyatt M.C., Marcy G.W., 2002, ApJ, 570, L93
Jourdain de Muizon M. et al., 1999, A&A, 350, 875
Kenyon S.J., Bromley B.C., 2002a, AJ, 123, 1757
Kenyon S.J., Bromley B.C., 2002b, ApJ, 577, L35
Kenyon S.J., Luu J.X., 1998, AJ, 115, 2136
Koerner D.W., Ressler M.E., Werner M.W., Backman D.E., 1998, ApJ, 503, L83
Lachaume R., Dominik C., Lanz T., Habing H.J., 1999, A&A, 348, 897
Landgraf M., Liou J.-C., Zook H.A., Grün E., 2002, AJ, 123, 2857
Laureijs R.J., Jourdain de Muizon M., Leech K., Siebenmorgen R., Dominik C., Habing H.J., Trams N., Kessler M.F., 2002, A&A, 387, 285
Liou J.-C., Zook H.A., 1999, AJ, 118, 580
Maher K.A., Stevenson D.J., 1988, Nat, 331, 612
Mannings V., Barlow M.J., 1998, ApJ, 497, 330
Mannings V., Sargent A.I., 2000, ApJ, 529, 391
Marsh K. A., Silverstone M.D., Becklin E.E., Koerner D.W., Werner M.W., Weinberger A.J., Ressler M.E., 2002, ApJ, 573, 425
Moro-Martín A., Malhotra R., 2003, AJ, 125, 2255
Patience J. et al., 2002, ApJ, 581, 654
Poveda A., Herrera M.A., Allen C., Cordero G., Lavalley C., 1994, Rev. Mex. A&A, 28, 43
Schmitt J.H.M.M., 1998, A&A, 333, 199
Sheret I., Dent W.R.F., Wyatt M.C., 2003, MNRAS, submitted
Song I., Caillault J.-P., Barrado y Navascués D., Stauffer J.R., Randich S., 2000, ApJ, 533, L41
Song I., Caillault J.-P., Barrado y Navascués D., Stauffer J.R., 2001, ApJ, 546, 352
Spangler C., Sargent A.I., Silverstone M.D., Becklin E.E., Zuckerman B., 2001, ApJ, 555, 932
Thi W.F. et al., 2001, ApJ, 561, 1074
Wichmann R., Schmitt J.H.M.M., Hubrig S., 2003, A&A, 399, 983
Wyatt M.C., Dent W.R.F., 2002, MNRAS, 334, 589
Wyatt M.C., Dent W.R.F., Greaves J.S., 2003, MNRAS, 342, 876
Zuckerman B., Webb R.A., 2000, ApJ, 535, 959
Zuckerman B., Song I., Bessell M.S., Webb R.A., 2001, ApJ, 562, L87

APPENDIX: STELLAR SURVEYS WITHIN 25 pc

Detailed information is available on all known stars within 25 pc of the Sun (the NStars project, http://nstars.arc.nasa.gov/) and on the spectroscopic classification of the majority of stars earlier than type M within 40 pc (the NStars Appalachian State survey, http://stellar.phys.appstate.edu/). Listings of stars with radial velocity planet detections are also available, for example at http://www.obspm.fr/encycl/encycl.html and http://exoplanets.org/. Stellar ages are often difficult to estimate and few catalogues are available; here we have made extensive use of the list of young G and early K stars within 25 pc compiled by Gaidos (1998). This is based on evidence of youth (typically 0.07–0.8 Gyr, Gaidos 2000), shown by the detection of X-ray emission with the *ROSAT* satellite, which observed 92 per cent of the sky. The Gaidos catalogue excludes stars lying in binary or multiple systems with sky separations of 800 au or less, since these could not be resolved by *ROSAT* at distances of about 25 pc.

Given these sources of data, we have chosen to analyse the prevalence of discs around A- and G-type stars within 25 pc. We have compiled a data base of excesses reported from *IRAS* (12–100 μm) and cross-correlated this with the Michigan Spectral Catalog to identify dwarf stars (V or IV–V) with probable debris discs. Positional association within less than the *IRAS* location errors was used to confirm a likely disc excess. This data base has been supplemented with the recent results from the deeper *ISO* surveys (Decin et al. 2000; Habing et al. 2001; Spangler et al. 2001), except that we exclude HD 75732 (Dominik et al. 1998) where the far-infrared flux appears to come from background sources (Jayawardhana et al. 2002). The disc identified by *IRAS* around HD 74956 was not confirmed in *ISO* observations (Habing et al. 2001) and is also excluded from the disc counts.

For the basic stellar data, we adopt the Appalachian State classification, except where no luminosity classification (e.g. V) is given in which case an NStars classification was sought – in practice this only added seven G stars. The multiple systems identified in the NStars catalog were then checked in the SIMBAD data base (http://simbad.u-strasbg.fr/), and eight of the G stars and one of the A stars were found to have companions of the same spectral type. These companions are listed on the same line of the tables as the primary star. The final list has 188 G dwarfs (including 11 G–G pairs) and 21 A dwarfs (with two A–A pairs). The A dwarfs are expected to be complete within 25 pc, but the G-star listing may not be complete: the final tally includes only types V or IV–V and excludes objects which may be G dwarfs but for which no type is yet determined (potentially up to 25 per cent more stars). A small number of G stars was rejected: HD 79096 and 202940 are associated with objects which we reject as G-dwarf companions because the visual magnitudes suggest these are chance alignments with background stars, and HD 12846, 120559 and 179957 have uncertain distances very near the 25-pc boundary. Finally, in cases where more than one possible subclass is listed, then the earlier was chosen (for example, G8/K0V objects are included as G8V), while a few stars that are G-dwarfs in the NStars listing are excluded where given by the Appalachian State catalogue as F9 or K0, for example.

Table A1. G dwarf stars within 25 pc, from the Appalachian State catalogue supplemented by a small number of NStars classifications. Stars are ordered by right ascension. The number of stellar components is given under N_*, with multiples of sky separation >800 au noted as 'wide'. Companion stars were identified using the SIMBAD data base and are listed explicitly where also of type G. 'B' denotes that the G star is the secondary in a multiple. Also noted are stars classed as young from X-ray emission; stars with *IRAS* or *ISO* debris discs; and stars with one or more radial velocity planets; sources of information are given in the text. Stars identified as 'young' have ages less than 0.8 Gyr (Gaidos 1998); all others are 'old' stars presumed to exceed 0.8 Gyr.

Star	D (pc)	Type	N_*	Notes
HD 224930	12.4	G3V	3	
HD 123	20.3	G5V+G8V	2	G companion = GJ 4.1B
HD 1237	17.6	G6V	1	Young; planet
HD 1273	23.0	G2V	2	
HD 1461	23.4	G0V	1	
HD 1835	20.4	G3V	1	Young; *IRAS* disc
HD 4308	21.9	G3V	1	
HD 4614	6.0	G0V	2	
HD 4747	18.8	G8/K0V	1	
HD 4915	22.1	G5V	1	(NStars)
HD 6582	7.6	G5V	2	
HD 9407	21.0	G6V	1	
HD 10307	12.6	G2V	2	
HD 10700	3.6	G8V	1	*IRAS* + *ISO* disc
HD 11131	23.0	G3V	1	(NStars) young
HD 13974	10.8	G0V+G9V	2	G companion in GJ 92 system
HD 14412	12.7	G8V	1	
HD 14802	21.9	G2V	1	
HD 18803	21.2	G8V	1	
HD 18757	22.9	G4V	2	Wide binary
HD 19373	10.5	G0V	1	
HD 20407	24.4	G3V	1	
HD 20766	12.1	G2V	2,'B'	Wide binary (secondary)
HD 20807	12.1	G1V	2	Wide binary (primary); *IRAS* disc
HD 20619	24.7	G5V	1	
HD 20630	9.2	G5V	1	Young
HD 20794	6.1	G8V	1	*ISO* disc
HD 25680	16.7	G5V	1	
HD 26491	23.2	G3V	1	
HD 30495	13.3	G3V	1	Young; *IRAS* + *ISO* disc
HD 32778	22.3	G5V	2	Wide binary
HD 32923	15.9	G4V	1	*IRAS* disc
HD 34721	24.9	G0V	1	
HD 34411	12.6	G0V	1	
HD 36435	19.6	G5V	1	Young
HD 38858	15.6	G4V	1	
HD 39587	8.7	G0V	2	
HD 39855	22.8	G6V	2	
HD 43834	10.1	G5V	1	
HD 42618	23.1	G4V	1	
HD 42807	18.1	G8V	1	
HD 43162	16.7	G5V	1	Young
HD 43587	19.3	G0.5V	2	Wide binary
HD 45270	23.5	G1V	1	
HD 45184	22.0	G2V	1	
HD 48189	21.7	G1/G2V	2	
HD 48682	16.5	G0V	1	*IRAS* disc
HD 50692	17.3	G0V	1	
HD 51419	24.2	G5V	1	
HD 52711	19.1	G4V	1	
HD 53705	16.2	G3V	3	Binary + wide tertiary
HD 54371	24.6	G8V	3	
HD 55575	16.9	G0V	1	
HD 59468	22.5	G5IV-V	1	
HD 59967	21.8	G3V	1	Young
HD 63077	15.2	G0V	2	Wide binary
HD 64096	16.7	G2V+G4V	2	G companion = GJ 291B
HD 64606	19.2	G8V	2	

Table A1 – *continued*

Star	D (pc)	Type	N_*	Notes
HD 62613	17.0	G8V	1	
HD 65907	16.2	G2V	3	Wide binary + wide tertiary
HD 65583	16.8	G8V	1	
HD 68017	21.7	G4V	1	
HD 71148	21.8	G5V	1	
HD 72946	23.4	G5V	3	
HD 73752	19.9	G3/G5V	2	*IRAS* disc
HD 72905	14.3	G1.5V	1	Young; *ISO* disc
HD 75732	12.5	G8V	2	*IRAS* + *ISO* (but not SCUBA) disc; planet; wide binary
HD 76151	17.1	G3V	1	
HD 79096	20.5	G9V	1(2?)	GJ 337B (G9V) probably background
HD 82885	11.2	G8IV-V	2	
HD 84117	14.9	G0V	1	
HD 84737	18.4	G2V	1	
HD 86728	14.9	G1V	1	
HD 88742	22.7	G0V	1	
HD 90156	22.1	G5V	1	
HD 90508	23.6	G1V	2	
HD 92719	23.4	G2/G3V	1	
HD 95128	14.1	G0V	1	Planet
HD 97343	21.6	G8/K0V	1	
HD 97334	21.7	G0V	1	Young
HD 98281	22.0	G8V	1	
HD 100180	23.0	G0V	2	
HD 101177	23.3	G0V	3	
HD 101501	9.5	G8V	1	
HD 102365	9.2	G3/G5V	2	
HD 102438	17.8	G5V	1	
HD 103095	9.2	G8V	1	
HD 108799	25.0	G1/G2V	2	
HD 109358	8.4	G0V	2	
HD 110897	17.4	G0V	1	
HD 111395	17.2	G7V	1	
HD 112914	24.2	G9V	1	
HD 113449	22.1	G5V	1	Young
HD 114710	9.2	G0V	1	
HD 114613	20.5	G3V	1	
HD 114853	24.5	G2V	1	
HD 113283	24.7	G5IV-V	1	
HD 115383	18.0	G0V	1	
HD 115617	8.5	G5V	1	
HD 116442	16.0	G8/K0V	2	(NStars) binary (primary)
HD 116443	16.8	G8/K0V	2,‘B’	(NStars) binary (secondary)
HD 116956	21.9	G9IV-V	1	Young
HD 117043	21.3	G6V	1	
HD 117176	18.1	G5V	1	Planet
HD 120690	19.9	G5V	1	
HD 122742	16.6	G8V	2	
HD 124292	22.3	G8/K0V	1	(NStars)
HD 126053	17.6	G1V	1	
HD 127334	23.6	G5V	1	
HD 128620	1.3	G2V	3	Binary + wide tertiary
HD 128987	23.6	G6V	1	Young
HD 128400	20.3	G5V	1	Young; *IRAS* disc
HD 130307	19.7	G8V	1	
HD 130948	17.9	G2V	1	Young
HD 131156	6.7	G8V	1	
HD 131923	24.5	G5V	1	
HD 133640	12.8	G2V+G2V	3	G companion = GJ 575B
HD 136352	14.6	G2V	1	
HD 137107	18.6	G2V+G2V	2	G companion = HD 137108
HD 139777	22.1	G8IV-V+G5	2	G companion = HD 139813, no luminosity type
HD 140538	14.7	G5V	2	
HD 141004	11.8	G0V	1	

Table A1 – *continued*

Star	D (pc)	Type	N_*	Notes
HD 141272	21.3	G8V	1	Young
HD 143761	17.4	G2V	1	Planet
HD 144287	21.5	G8V	2	
HD 144579	14.4	G8V	2	Wide binary
HD 145958	24.4	G8V+G8V	2	G companion = GJ 615.1B
HD 145825	21.9	G1V	1	
HD 146233	14.0	G1V	1	
HD 147513	12.9	G3/G5V	2	Wide binary with white dwarf
HD 149612	21.7	G3V	1	
HD 152391	16.9	G8V	1	Young
HD 154345	18.1	G8V	1	
HD 157214	14.4	G0V	1	
HD 158614	16.4	G6V+G8IV-V	2	G companion = GJ 678B
HD 159222	23.7	G5V	1	
HD 160269	14.1	G0V	3	Binary + wide tertiary
HD 162004	22.3	G0V	2,‘B’	F5IV-V primary
HD 160691	15.3	G5V	1	Planet
HD 165401	24.4	G0V	1	
HD 165185	17.4	G3V	1	Young
HD 165499	17.8	G0V	1	
HD 168009	22.7	G2V	1	
HD 172051	13.0	G5V	1	
HD 176051	15.0	G0V	2	
HD 177565	17.2	G8V	1	
HD 178428	21.0	G5V	2	
HD 180161	20.0	G8V	1	Young
HD 181321	20.9	G1/G2V	1	
HD 182488	15.5	G8V	1	
HD 184385	20.2	G5V	1	
HD 186408	21.5	G2V	2	Wide binary (primary)
HD 186427	21.5	G5V	2,‘B’	Wide binary (secondary); planet
HD 190067	19.3	G7V	1	
HD 190406	17.7	G1V	1	
HD 189567	17.7	G2V	1	
HD 190248	6.1	G5IV-V	1	
HD 193664	17.6	G3V	1	
HD 194640	19.4	G6/G8V	1	
HD 195564	24.2	G3V	2	
HD 195987	22.2	G9V	2	
HD 196761	14.6	G8/K0V	1	
HD 197076	21.0	G5V	2	Wide binary
HD 197214	22.4	G3/G5V	1	
HD 199288	21.6	G0V	1	
HD 199509	24.2	G3V	1	
HD 202628	23.8	G5V	1	
HD 202940	18.7	G5V	2(3?)	GJ 825.4B (G5V) probably background
HD 203244	20.5	G5V	1	Young
HD 205536	22.1	G8V	1	
HD 206860	18.4	G0V	1	Young
HD 207129	15.6	G2V	1	*IRAS* + *ISO* disc
HD 210277	21.3	G8/K0V	1	(NStars) planet
HD 210918	22.1	G5V	1	
HD 211415	13.6	G1V	2	
HD 212697	20.1	G3V+G3V	2	G companion = HD 212697
HD 214953	23.5	G0V	2	(NStars) *IRAS* disc
HD 217014	15.4	G5V	1	
HD 217813	24.3	G5V	1	Young
HD 220140	19.7	G9V	1	

Table A2. As for Table A1 but for A stars within 25 pc. The 'young' category does not apply (see the text), nor does a 'planet' category exist as A stars do not have lines suitable for radial velocity measurements.

Star	*D* (pc)	Type	N_*	Notes
HD 2262	23.5	A7V	1	*IRAS* disc
HD 11636	18.3	A5V	2	
HD 38678	21.5	A2V	1	*IRAS* + *ISO* disc
HD 39060	19.3	A3V	1	*IRAS* + *ISO* disc
HD 48915	2.6	A0V	2	Binary with white dwarf
HD 60179	15.8	A2V+A2V	6	A companion = HD 60178
HD 74956	24.4	A1V	4	*IRAS* (but not *ISO*) disc
HD 95418	24.3	A1V	1	*IRAS* + *ISO* disc
HD 97603	17.7	A4V	1	
HD 102647	11.3	A3V	1	*IRAS* + *ISO* disc
HD 106591	25.0	A3V	1	
HD 115892	18.0	A2V	1	*IRAS* disc
HD 116656	24.0	A2V	4	Wide multiple if at same distance
HD 116842	24.9	A5V	4,'B'	Wide multiple if at same distance
HD 118098	22.4	A3V	1	
HD 139006	22.9	A0V	2	*IRAS* disc
HD 172167	7.8	A0V	1	*IRAS* + *ISO* disc
HD 187642	5.1	A7IV-V	1	
HD 203280	15.0	A7IV-V	1	
HD 216956	7.7	A3V	1	*IRAS* + *ISO* disc

This paper has been typeset from a TEX/LATEX file prepared by the author.