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DUSTY DEBRIS DISKS AS SIGNPOSTS OF PLANETS: IMPLICATIONS FOR *SPITZER SPACE TELESCOPE*

B. ZUCKERMAN AND INSEOK SONG
Department of Physics and Astronomy, Center for Astrobiology, University of California, Los Angeles,
Los Angeles, CA 90095-1562; ben@astro.ucla.edu, song@astro.ucla.edu
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ABSTRACT

Submillimeter and near-infrared images of cool dusty debris disks and rings suggest the existence of unseen planets. At dusty but nonimaged stars, semimajor axes of associated planets can be estimated from the dust temperature. For some young stars these semimajor axes are greater than $1''$ as seen from Earth. Such stars are excellent targets for sensitive near-infrared imaging searches for warm planets. To probe the full extent of the dust and hence of potential planetary orbits, *Spitzer* observations should include measurements with the 160 μm filter.

Subject headings: astrobiology — infrared: stars — planetary systems: protoplanetary disks

1. INTRODUCTION

At near-infrared wavelengths, adaptive optics on 8 m class ground-based telescopes and the NICMOS camera on the *Hubble Space Telescope* (*HST*) can probe regions within a few arcseconds of nearby stars. In such regions, for stars younger than ~100 Myr, warm massive planets can be detected. Dozens of such young stars within ~60 pc of Earth have been identified (Song et al. 2003; Zuckerman & Song 2004 and references therein).

Extant images at submillimeter and near-infrared wavelengths of cool dusty debris disks at main-sequence stars (the so-called Vega phenomenon) usually show substantial spatial structure (e.g., Holland et al. 1998, 2003; Greaves et al. 1998; Schneider et al. 1999; Krist et al. 2000; Koerner, Sargent, & Ostroff 2001; Wilner et al. 2002; Weinberger et al. 2002; Weinberger, Becklin, & Zuckerman 2003; Wahhaj et al. 2003; Clampin et al. 2003; Zuckerman 2001 and references therein). Specifically, the dusty regions around ϵ Eri, Vega, Fomalhaut, β Pic, and HD 141569 all show obvious nonaxisymmetric structure. HR 4796 is orbited by a narrow dusty ring. Only the dust at TW Hya has, so far, failed to reveal any structure of note.

Excepting perhaps HD 141569 (Clampin et al. 2003 and references therein), the most likely explanation of the observed structures is gravitational perturbations by planets with semimajor axes comparable to the radius of the dusty rings and disks. For Vega, a 3 Jupiter mass ($M_{\rm J}$) planet is suggested (Wilner et al. 2002), while for ϵ Eri either a 0.2 $M_{\rm J}$ (Ozernoy et al. 2000) or a 0.1 $M_{\rm J}$ (Quillen & Thorndike 2002) planet has been proposed. Indeed, *COBE* found that Earth is led and trailed in its orbit around the Sun by clumps of dust particles (Reach et al. 1995). Additional discussions of planet/disk interactions can be found in Holland et al. (2003), Kenyon & Bromley (2002a, 2004), Kuchner & Holman (2003), Wyatt & Dent (2002), and Wyatt (2003).

Alternative mechanisms to generate structure in the dusty disks of other stars have been proposed but likely account for very few, if any, of the observed structures. Kalas, Deltorn, & Larwood (2001) investigated the possibility that a recent close encounter with a passing star generated the structure observed in the northeast arm of the β Pic disk. While such an encounter might occur on rare occasions, such low-probability events cannot plausibly generate dusty structure in a high percentage of the Vega-like stars (e.g., Kenyon & Bromley 2002b). Takeuchi & Artymowicz (2001) proposed that ring structure, such as is observed at HR 4796, could be generated by dust particles migrating in an optically thin gaseous disk. This mechanism is implausible as an explanation for most, and perhaps all, of the observed dusty structures because of (1) their often dramatic nonaxisymmetric shape and (2) the lack of evidence of gas at a majority of the above-listed stars, including even the model prototype HR 4796 (e.g., Zuckerman 2001 and references therein).

As a consequence of the above observations and arguments, one may reasonably assume that most stars with imaged dust emission have at least one planet on a wide orbit (tens of AU). From this assumption it follows that at stars with photometrically detected (but not yet imaged) dust there is a high probability of orbiting planets, including at least one with a semimajor axis comparable to that of the dimensions of the dust disk.

Extrapolating from the preceding, one might speculate that young stars that do not have dust detectable by *Spitzer* do not possess planets on wide orbits (see discussion at end of § 2). Although dust has not yet been measured directly in the Sun's Kuiper Belt, dust is very likely present, and its presence is consistent with the existence of a planet (Neptune) at a roughly comparable distance from the Sun. Indeed, as has been pointed out by numerous researchers, with but few exceptions (e.g., Chen & Jura 2001), the dusty disks detected around main-sequence stars (by *IRAS* and the *Infrared Space Observatory* [*ISO*]) are likely analogs of the Kuiper Belt.

Twenty years ago, when *IRAS* discovered the Vega phenomenon, astronomers wondered whether a substantial link connected the presence of dust with planets. While stars with imaged dust remain frustratingly few in number, the common and striking structures that are seen now suggest that the link is substantial and that dusty stars represent excellent targets for planet searches.

For main-sequence stars with circumstellar dust detected by *IRAS* and/or *ISO*, the measured dust temperature is an indication of how far from a star the dust is located. In the following section we outline how the dust can be used to guide imaging planet searches and list specific stars at which to search.

2. SEARCHING FOR PLANETS AT DUSTY STARS

The *IRAS* database has been the prime source for identification of dusty main-sequence stars. A few additional stars were added by *ISO* studies. A list of surveys for circumstellar dust appears in § 3 of Zuckerman (2001), who remarked that, within certain constraints, the Ph.D. thesis of M. Silverstone (2000) represents the most comprehensive search to date of the *IRAS* catalogs for Vega-like stars.

In the discussion that follows and in Table 1, we focus primarily on stars listed in Silverstone's thesis. One of his constraints was that *IRAS* detected excess emission (due to the presence of dust) at 60 μm wavelength. Thus, all stars in Table 1 are orbited by some dust that is sufficiently warm to radiate significantly at 60 μm. Table 1 also includes HIP 13402 and HIP 71284 from Habing et al. (2001). Not all IR excess stars in Silverstone (2000) appear in our Table 1. For example, we excluded stars beyond 100 pc from Earth and stars with

TABLE 1

Stars with Dusty Debris Disks

HIP (1)	HD (2)	Sp. Type (3)	V (mag) (4)	D (pc) (5)	$R_{\rm star}$ ($R_\odot$) (6)	$T_{\rm star}$ (K) (7)	$T_{\rm dust}$ (K) (8)	$R_{\rm dust}$ (AU) (9)	Angle (arcsec) (10)	τ ($\times 10^{-4}$) (11)	Age (Myr) (12)	Age Method[a] (13)	Notes[b] (14)
490..............	105	G0 V	7.5	40.2	1.16	5800	60	27	0.68	5	≲100	a, b, c	1
6878............	8907	F8	6.7	34.2	1.34	5800	60	31	0.92	3	200?	a, b, c	1
7345............	9672	A1 V	5.6	61.3	1.96	8600	70	74	1.21	6	20?	ZFK	2
7805............	10472	F2 IV–V	7.7	66.6	1.40	6400	80	22	0.34	6	30	ZSW	
7978............	10647	F8 V	5.5	17.4	0.99	6200	55	31	1.81	3	300?	a, b, c	
8102............	10700	G8 V	3.6	3.6	0.79	5400	70	12	3.26	0.1	7000??	a, b	1
10670...........	14055	A1 Vnn	4.0	36.1	2.09	9400	65	109	3.03	0.6	100?	a, d	
11360...........	15115	F2	6.8	44.8	1.30	6800	65	36	0.79	5	100?	a, b, c	1
11847...........	15745	F0	7.5	63.7	1.30	6800	75	27	0.42	12	30?	d, e	1
12964...........	17390	F3 IV–V	6.6	45.1	1.47	6800	80	27	0.59	2	300??	a	
13005...........	. . .	K0	8.1	67.7	2.22	5000	60	39	0.57	14	?	b, e	3
13402...........	17925	K1 V	6.0	10.4	0.73	5200	60	14	1.32	0.8	≲100	a, b, c	1
16449...........	21997	A3 IV–V	6.7	73.8	1.64	8400	65	68	0.93	3	100?	d	
16537...........	22049	K2 V	3.7	3.2	0.70	5200	50	19	5.90	0.7	730	S2000	1
18859...........	25457	F5 V	5.4	19.2	1.15	6400	75	21	1.09	0.8	30	a, b, c	1
22226...........	30447	F3 V	7.9	78.1	1.31	6600	70	29	0.37	11	≲100	e	
22263...........	30495	G3 V	5.5	13.3	0.99	5600	70	16	1.19	0.6	300?	a, b	1
22845...........	31295	A0 V	4.6	37.0	1.56	9400	80	54	1.45	0.3	100?	a, d	
25486...........	35850	F7 V:	6.3	26.8	1.24	6000	45	55	2.06	0.2	12	ZSBW	1
32435...........	53842	F5 V	7.5	57.3	1.46	6200	70	29	0.50	4.5	30?	a, b, c	
33690...........	53143	K0 IV–V	6.8	18.4	0.92	5200	60	17	0.94	2.5	300?	a, b, c	
35457...........	56099	F8	7.6	86.8	2.17	6200	45	70	0.80	12	>500?	a, b, e	4
42430...........	73752	G3–5 V	5.0	19.9	1.83	5600	80	17	0.83	0.3	>600	S2000	5
42438...........	72905	G1.5 Vb	5.6	14.3	0.99	5800	60	23	1.62	0.1	200?	a, b, c	1
44001...........	76582	F0 IV	5.7	49.3	1.89	7600	80	43	0.85	3	300??	a, d	
44923...........	78702	A0–1 V	5.9	79.9	2.13	9600	35	400	5.00	2.5	100?	d	
52462...........	92945	K1 V	8.0	21.6	0.81	5000	60	14	0.65	7	100	SBZ	
57632...........	102647	A3 Vvar	2.1	11.1	1.81	8400	100	32	2.90	0.2	50	S2001	
60074...........	107146	G2 V	7.0	28.5	1.02	5800	55	28	1.00	12	≲100	a, b, c, e	
61960...........	110411	A0 V	4.9	36.9	1.55	8800	90	37	1.00	0.3	100??	a, d	
63584...........	113337	F6 V	6.0	37.4	1.67	6600	90	22	0.60	1	50?	a, b	6
68593...........	122652	F8	7.2	37.2	1.18	6000	75	19	0.51	3	300?	a, b, c	
69682...........	124718	G5 V	8.9	61.3	1.03	5600	80	13	0.21	27	>500	a, b, c, e	7
70344...........	126265	G2 III	7.2	70.1	2.31	5800	75	35	0.50	2	>500	a, b	
70952...........	127821	F4 IV	6.1	31.7	1.35	6600	50	59	1.84	1.5	200?	a, b	
71284...........	128167	F3 Vvar	4.5	15.5	1.46	6400	50	60	3.86	0.1	1000??	a, b, c	1
76829...........	139664	F5 IV–V	4.6	17.5	1.38	6600	100	15	0.86	0.9	200?	a, b, c	1
81800...........	151044	F8 V	6.5	29.4	1.26	6000	60	32	1.09	0.8	>500	a, b	1
85157...........	157728	F0 IV	5.7	42.8	1.63	7600	75	42	0.97	3	100?	a, d	
86305...........	159492	A7 V	5.2	42.2	1.75	8200	90	36	0.87	1	200?	a, d	1
87108...........	161868	A0 V	3.8	29.1	1.92	9400	70	87	2.97	0.6	200?	a, d	
87815...........	164330	K0	7.7	83.2	2.30	5600	70	37	0.44	9	>500	a, b, e	
88399...........	164249	F5 V	7.0	46.9	1.36	6400	70	28	0.60	19	12	ZSBW	1
90936...........	170773	F5 V	6.3	36.1	1.45	6600	50	63	1.75	5	200?	a, b, c	1
92024...........	172555	A7	4.8	29.2	1.61	7800	280	3	0.11	5	12	ZSBW	
93542...........	176638	A0 Vn	5.1	56.3	2.33	9800	100	56	1.00	0.7	200?	a, d	
95261...........	181296	A0 Vn	5.0	47.7	1.63	9800	110	32	0.68	0.8	12	ZSBW	1
95270...........	181327	F5.5 V	7.0	50.6	1.44	6400	65	35	0.68	32	12	ZSBW	
99273...........	191089	F5 V	7.5	53.5	1.40	6400	100	14	0.27	13	≲100	a, b, c, e	
101612.........	195627	F1 III	4.5	27.6	1.86	7000	55	75	2.69	1	200?	a, d	
102409.........	197481	M1 Ve	8.8	9.9	0.76	3800	80	4	0.43	1	12	ZSBW	
105388.........	202917	G5 V	8.7	45.9	0.94	5400	100	7	0.15	6	30	ZW	1
107022.........	205536	G8 V	7.1	22.1	0.93	5800	75	14	0.63	3	>500	a, b	

TABLE 1—*Continued*

HIP (1)	HD (2)	Sp. Type (3)	V (mag) (4)	D (pc) (5)	$R_{\rm star}$ ($R_\odot$) (6)	$T_{\rm star}$ (K) (7)	$T_{\rm dust}$ (K) (8)	$R_{\rm dust}$ (AU) (9)	Angle (arcsec) (10)	τ ($\times 10^{-4}$) (11)	Age (Myr) (12)	Age Method[a] (13)	Notes[b] (14)
107412.........	206893	F5 V	6.9	38.9	1.30	6400	60	37	0.95	2	200?	a, b	1
107649.........	207129	G2 V	5.6	15.6	0.98	6000	50	35	2.26	1.4	600	SZB	1
108809.........	209253	F6-7 V	6.9	30.1	1.09	6200	85	14	0.48	0.9	200??	a, b, c	1
114189.........	218396	A5 V	6.0	39.9	1.42	7400	50	78	1.95	1.4	30	a, d	1
116431.........	221853	F0	7.3	71.2	1.66	6600	90	22	0.31	12	$\lesssim$100	e	1

NOTE.—Calculations use 1 AU = 200 $R_\odot$.

[a] Age methods: S2000: Song et al. 2000; S2001: Song et al. 2001; SBZ: Song, Bessell, & Zuckerman 2002; ZFK: Zuckerman, Forveille, & Kastner 1995; ZSBW: Zuckerman et al. 2001a; ZSW: Zuckerman et al. 2001b; ZW: Zuckerman & Webb 2000; SZB: Song et al. 2003; a: *UVW*; Zuckerman & Song 2004; b: X-ray emission; e.g., Song et al. 2003; c: lithium age; Song et al. 2003; d: location on an A star Hertzsprung-Russell diagram; Lowrance et al. 2000; e: dust (if $\tau \gtrsim 10^{-3}$, then age $\lesssim 10^8$ yr; Spangler et al. 2001).

[b] 1. ISO 60, 90, 100, and/or 170 μm fluxes available from Silverstone 2000 and/or Habing et al. 2001; see Figs. 1–8.

2. HIP 7345 (=49 Cet) is the only known main-sequence A-type star with CO emission detected with a radio telescope (ZFK), thus suggesting a very young age. However, its Galactic space motion *UVW* (−23, −17, −4) with respect to the Sun is not indicative of extreme youth (*U* is positive toward the Galactic center).

3. Based on the offset between the 12 and 60 μm *IRAS* positions, the apparent 60 μm excess is probably from a galaxy at position angle ~70° and ~45″ from HIP 13005.

4. HIP 35457 is a 0.″16 binary. The very large τ seems inconsistent with the old age implied by the absence of *ROSAT* All Sky X-ray emission and the star's Galactic space motion (*UVW*).

5. HIP 42430 is a 1.″0 binary.

6. M star companion LDS 2662 is very young on the basis of its location on an M_K vs. $V-K$ color-magnitude diagram (e.g., Fig. 2 in SZB).

7. The Galactic space motion (*UVW*) and absence of lithium and of X-ray emission all suggest that HIP 69682 is an old star. There is no evidence on the Digital Sky Survey and 2MASS All Sky QuickLook images (*JHK*$_s$) of a nearby galaxy. Yet τ is very large.

small dust optical depth τ (see below for definition of τ). We examined each putative excess star on the Digital Sky Survey plates and eliminated a few where it appears likely that the apparent far-IR stellar excess was instead emission from a galaxy near the star in the plane of the sky. We also have not included the big three (Vega, Fomalhaut, and β Pic) in Table 1. We felt that these have been analyzed and imaged to death already and we have nothing to add. The same might be said about ϵ Eri, but we included it in Table 1 because it well illustrates the conservative nature of the entries in columns (9) and (10) of Table 1 (see discussion below).

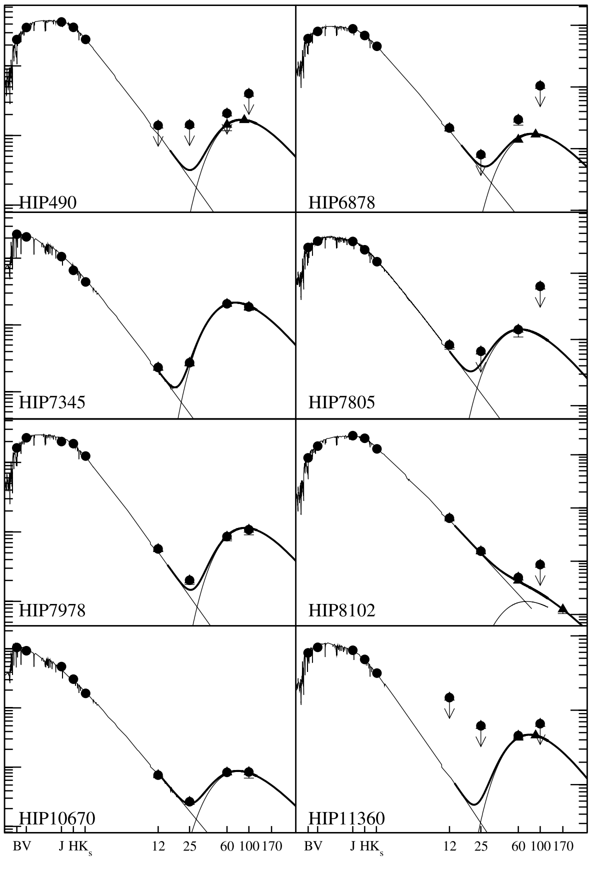

FIG. 1.—SEDs of stars with dusty debris disks with B and V fluxes from *Hipparcos*, *JHK*$_s$ from 2MASS, and 12, 25, 60, and 100 μm from *IRAS*. In addition, 60, 90, 100, and 170 μm fluxes (*triangles*) are from *ISO*.

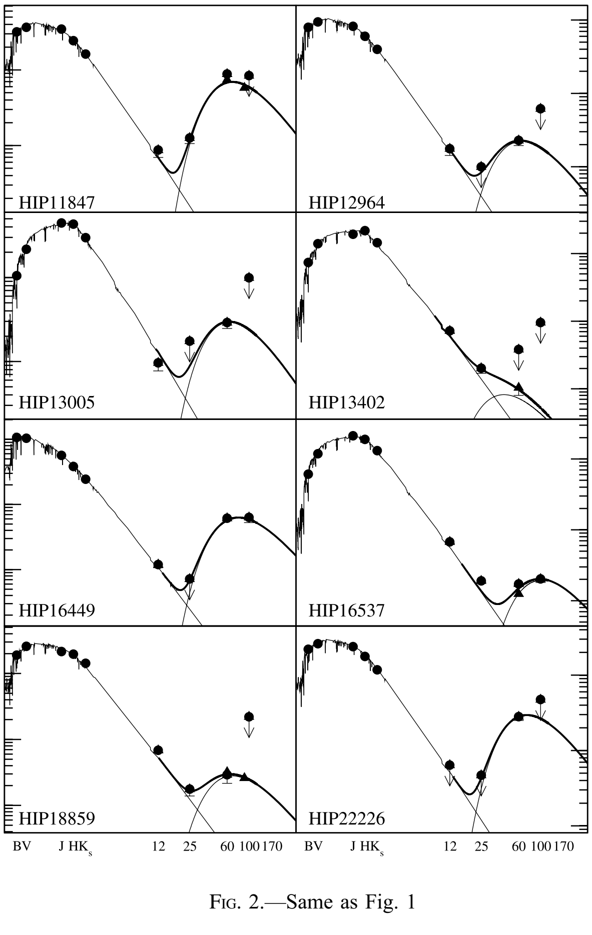

FIG. 2.—Same as Fig. 1

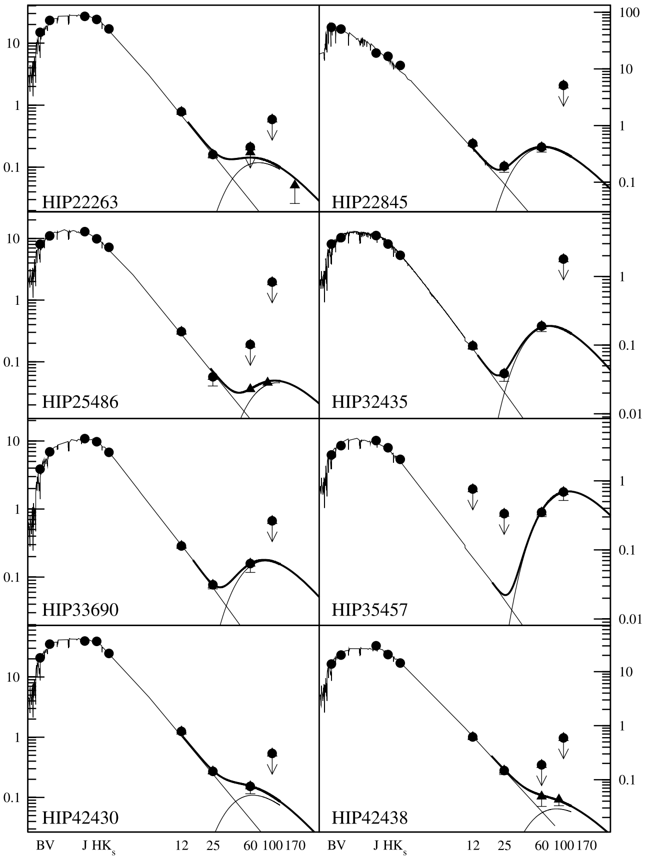

FIG. 3.—Same as Fig. 1

For Table 1 stars, we have constructed spectral energy distributions (SEDs) using optical, Two Micron All Sky Survey (2MASS), *IRAS*, and, when available, *ISO* fluxes. Synthetic stellar spectra of Hauschildt et al. (1999; $Z = 0.02$ and $\log g = 4.5$ model) are used in our SED fit process. Dust emission model parameters were found from eye-fitting model dust emission to *IRAS* (and *ISO* for some cases) measured fluxes (Figs. 1–8). By assuming that the dust particles radiate like blackbodies at temperature $T_{\rm dust}$, one may derive their characteristic orbital radii ($R_{\rm dust}$). These are indicated in column (9) of Table 1, in AU. Also indicated in Table 1 are the apparent angular radii (col. [10]) that characterize the dust distributions as seen from Earth.

$R_{\rm dust}$ was calculated from $R_{\rm dust} = (R_{\rm star}/2)(T_{\rm star}/T_{\rm dust})^2$, where $R_{\rm star}$ and $T_{\rm star}$ are given in columns (6) and (7) of Table 1 and are obtained from the SED fit and the distance D between Earth and star (col. [5]). We can check the accuracy of $R_{\rm star}$ estimation directly for HIP 8102 (=τ Ceti) for which the Very Large Telescope (VLT) interferometer measured a stellar radius of 0.773 $R_\odot$ (Pijpers et al. 2003); our technique yields 0.79 $R_\odot$. An independent team of investigators (Kervella et al. 2004), who also use the VLT interferometer, report a radius of 0.804 $R_\odot$ for HIP 8102. In addition, they measure 0.738 $R_\odot$ for HIP 16537 (ϵ Eri); our technique yields 0.70 $R_\odot$.

For many of the listed stars, these $R_{\rm dust}$ are "conservative" in that substantial amounts of dust might exist at larger distances. For example, particles at the *IRAS* color temperature that are small and radiate less effectively than blackbodies in the far-IR will be located farther from the star than indicated in Table 1. Also, particles that are too cold to radiate much at 60 μm would not have been detected by *IRAS*.

Zuckerman & Becklin (1993) deduced that for the A-type stars Vega, Fomalhaut, and β Pic, there is not much dust too cold to have been detected by *IRAS*. This conclusion was confirmed by Holland et al. (1998) and by Harvey & Jefferys (2000). In addition, Holland et al. noted that the dominant radiating particles at Fomalhaut appear to be behaving like blackbodies.

In contrast, at some stars there is substantial evidence (summarized in § 4.2 of Zuckerman 2001) for particles at larger distances than implied by the *IRAS* color temperature and the blackbody assumption. The characteristic dust orbital radius (19 AU) calculated (Table 1) from the *IRAS* color temperature for the K2 star ϵ Eri (HIP 16537) is a few times smaller than the radius of the dust ring imaged by Greaves et al. (1998) at 800 μm wavelength. Should dust be present $\gtrsim$100 AU from late-type stars, then such stars are insufficiently luminous to heat all surrounding dust to the $\sim$30 K required for the generation of substantial 60 μm emission. For example, a G0 star can heat large (blackbody) particles to $\sim$30 K at a distance of 100 AU. The corresponding distances for K0 and M0 stars are only $\sim$65 and 25 AU, respectively.

In addition, even for some early-type stars, our expression for $R_{\rm dust}$ will underestimate the true extent of the dust distribution. For example, at HR 4796, our SED fit implies $R_{\rm star}$, $T_{\rm star}$, and $T_{\rm dust}$ of 1.86 $R_\odot$, 9200 K, and 100 K, respectively, which yields a calculated $R_{\rm dust} = 37$ AU. However, the radius of the dusty ring imaged by NICMOS with *HST* is $\sim$65 AU (see, e.g., Fig. 1 in Zuckerman 2001).

In column (11) of Table 1, τ is the total energy emitted by dust grains divided by the bolometric luminosity of the star; it is a measure of the fraction of the ultraviolet and visual

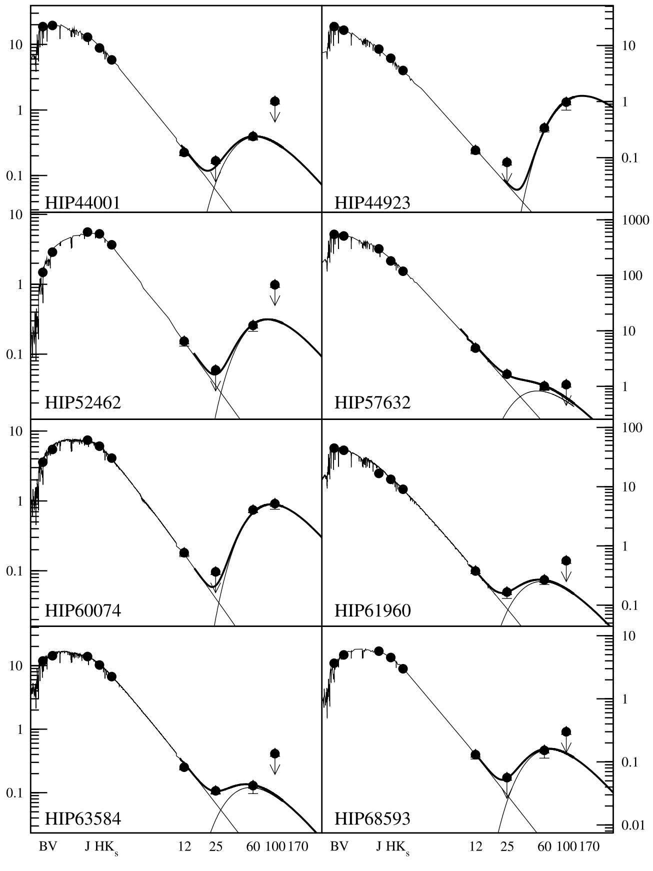

FIG. 4.—Same as Fig. 1

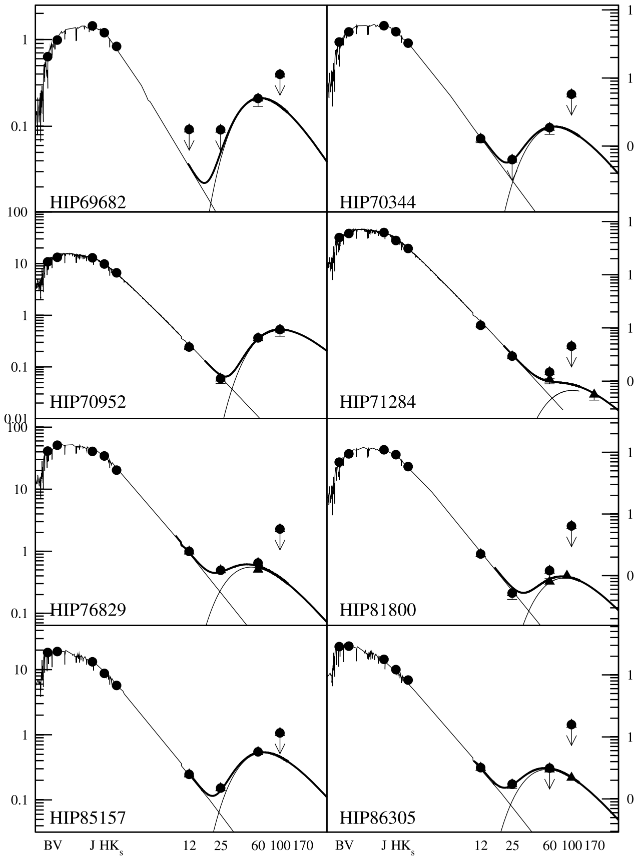

FIG. 5.—Same as Fig. 1, with 60 and 100 μm fluxes (*triangles*) for HIP 86305 from Silverstone (2000).

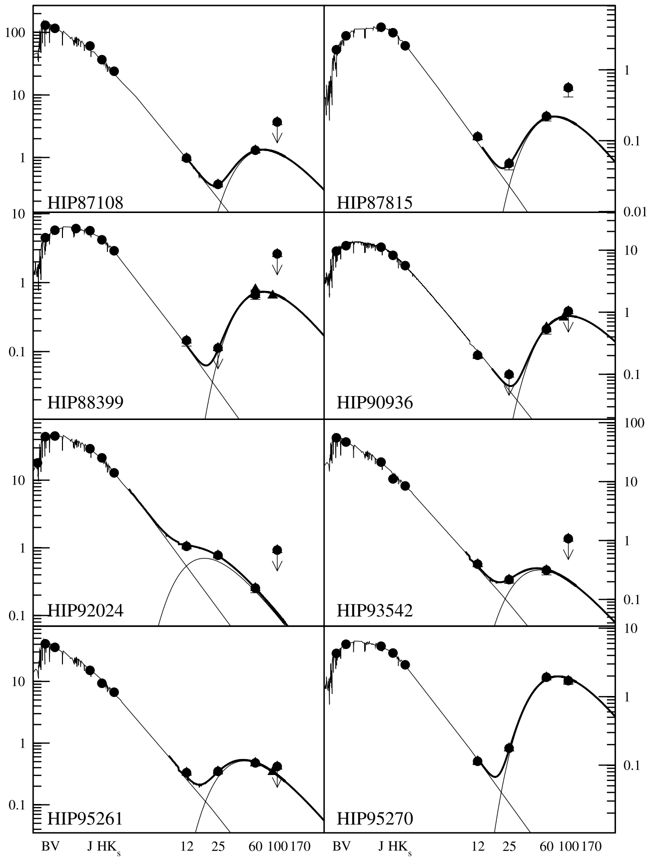

FIG. 6.—Same as Fig. 1

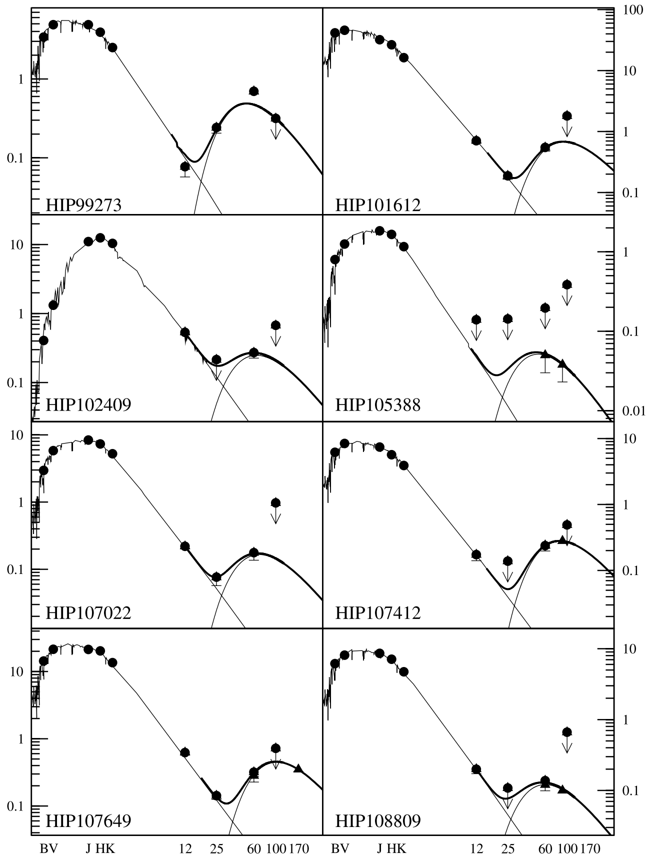

FIG. 7.—Same as Fig. 1

light emitted by the star that is absorbed by the orbiting dust particles. The listed values of τ, which are obtained from the SEDs shown in Figures 1–8, usually agree reasonably well with values of τ given in Silverstone (2000), although discrepancies of a factor of 2 or 3 sometimes appear. The value of τ may be used as one age indicator. From Spangler et al. (2001), if $\tau \gtrsim 0.001$, then a star is probably not older than ~100 Myr. It may be seen that most stars in Table 1 with multiple age indicators conform to this rule, but there are a few potential exceptions, notably HIP 35457, HIP 69682, and HIP 87815.

Additional techniques for estimating stellar ages are listed in Zuckerman et al. (2001a) and Song et al. (2003). We used a variety of techniques, indicated in column (13) of Table 1, to deduce the ages in column (12). Some of the ages are quite secure, others not so secure (one question mark) or quite uncertain (two question marks).

Planet detection with current adaptive optics (AO) imaging systems on large telescopes requires planet-star separations of at least $1''$–$2''$. In addition, a planet must be sufficiently warm to radiate at near-IR wavelengths. Long integrations on nearby stars with ages of hundreds of millions of years can probe down to a few Jupiter masses (e.g., Macintosh et al. 2003). Ages of tens of millions of years or less are required if planets of 1 $M_{\rm J}$ are to be detected. Thus, to optimize imaging planet searches, accurate stellar ages are required.

Because AO (and *HST*/NICMOS) sensitivities are telescope, elevation, and wavelength specific and because H, K', and L' thermal fluxes from planets with temperatures $\lesssim$700 K are based on model predictions and not on observations, it is not possible to give a general prescription regarding which stars in

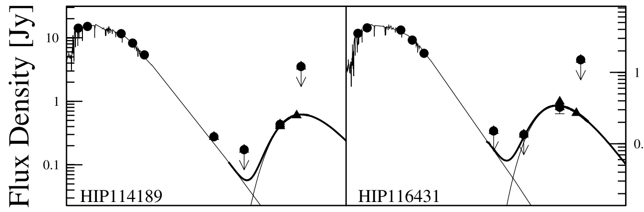

FIG. 8.—Same as Fig. 1

Table 1 should be observed with AO and at what wavelength. Indeed, an AO system has been commissioned on the VLT only within the past year, and Gemini North and South and Subaru have had no or only rudimentary AO systems.

That said, for a given star/dust angular separation (col. [10] in Table 1), planet detectability is maximized by observing the youngest, closest stars to Earth. For example, a 2 M_J planet will fade by 5–6 mag, in an absolute sense and also relative to the brightness of its star, at the *H* and *K* bands as it ages from 10 to 100 Myr. Similarly, a planet 50 pc from Earth will be 3.5 mag fainter than a comparably warm one only 10 pc away (while the star/planet contrast is independent of distance). Then there is stellar spectral type to consider. A planet of given mass, age, and semimajor axis will be harder to detect close to an intrinsically luminous A-type star than one of K type. However, if more massive planets, perhaps with larger semimajor axes, form near the relatively more massive stars, then this might more than compensate for the unfavorable contrast ratio. In any event, because AO systems (unlike *HST*/NICMOS) are not well suited to detection of extended objects, near-infrared light scattered by dust, even for stars with large τ, is very unlikely to hamper planet detection.

Both observation (Spangler et al. 2001; Metchev, Hillenbrand, & Meyer 2004) and theory suggest that, on average, young stars will have a dustier "Kuiper Belt" than old stars. On the basis of the mass of Neptune, the mass ($\sim 3\ M_{\rm Nep}$) of the proposed planet on a wide orbit at ϵ Eri, and the decrease of τ with time indicated in Figure 2 of Spangler et al. (2001), a star of age $\lesssim$ a few hundred million years with a similarly massive planet on a wide orbit would have $\tau \gtrsim 10^{-5}$. *Spitzer* should generally be capable of detecting τ as small as 10^{-6}. Thus, if the dust-planet connection is as strong as we suggest, then Jupiter-mass planets on wide orbits will rarely, if ever, be detected around young stars that lack *Spitzer*-detected far-IR excess emission. The same may be true for Saturn or even Neptune mass planets, although these, of course, will be much harder to detect.

3. CONCLUSIONS

Recent imaging observations and analysis of structure in the dusty debris disks that surround a handful of nearby stars suggest that they possess planets on wide orbits (tens of AU). Thus, dusty stars, whether imaged or not, are excellent targets for planet searches. Young stars with cool dust make the best targets for adaptive optics and *HST* imaging programs. Older stars and those with somewhat warmer dust might be better investigated with precision radial velocities. While the earliest searches of the *IRAS* catalogs revealed mostly A-type Vega-like stars, which are not suitable for study by the precision radial velocity technique, a majority of stars in Table 1 are of later spectral types.

Looking toward the future, one anticipates that *Spitzer* will search for dusty debris at all nearby stars that have been identified as very young (e.g., Zuckerman et al. 2001a; Song et al. 2003). Since the presence of cool dust would point toward the existence of planets on wide orbits accessible to adaptive optics, it is important that the *Spitzer* programs include measurements with the 160 μm filter.

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