EF CHAMAELEONTIS: WARM DUST ORBITING A NEARBY 10 Myr OLD STAR

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ABSTRACT

Most Vega-like stars have far-infrared excess (60 μm or longward in IRAS, ISO, or Spitzer MIPS bands) and contain cold dust (≤150 K) analogous to the Sun’s Kuiper Belt region. However, dust in a region more akin to our asteroid belt and thus relevant to the terrestrial planet building process is warm and produces excess emission in mid-infrared wavelengths. By cross-correlating Hipparcos dwarfs with the MSX catalog, we found that EF Cha, a member of the recently identified, ~10 Myr old, “Cha-Near” moving group, possesses prominent mid-infrared excess. N-band spectroscopy reveals a strong emission feature characterized by a mixture of small, warm, amorphous, and possibly crystalline silicate grains. Survival time of warm dust grains around this A9 star is ≤10^3 yr, much less than the age of the star. Thus, grains in this extrasolar terrestrial planetary zone must be of a “second generation” and not a remnant of primordial dust and are suggestive of substantial planet formation activity. Such second generation warm excess occurs around ~13% of the early-type stars in nearby young stellar associations.

Subject headings: circumstellar matter — infrared: stars — planetary systems: protoplanetary disks — stars: individual (EF Chamaeleontis)

1. INTRODUCTION

In our solar system, zodiacal dust grains are warm (≥150 K) and found within ~3 AU of the Sun. Slow but persistent collisions between asteroids complemented by material released from comets now replenish these particles. Similar warm dust particles around other stars are also expected and would be manifested as excess mid-infrared emission.

The implication of “warm” excess stars for the terrestrial planet-building process has prompted many searches, including several pointed observing campaigns with Spitzer (Gorlova et al. 2004; Rieke et al. 2005; Low et al. 2005; Beichman et al. 2005, 2006; Bryden et al. 2006; Hines et al. 2006; Gorlova et al. 2006; Smith et al. 2006). However, a lack of consensus about what constitutes a “warm excess” has resulted in ambiguity and some confusion in the field. For example, Spitzer surveys with MIPS revealed a number of stars with excess emission in the 24 μm band. However, very few of these may turn out to be genuine “warm excess” stars, because the detected 24 μm emission is mostly the Wien tail of emission cold (T < 150 K) dust grains (Rhee et al. 2007).

For blackbody grains, T_dust = T_{star} (R_{star}/(2R_{dust}))^{1/2}, where R_{dust} is the distance of a grain from a star of radius R_{star} and temperature T_{star}. Due to the dependence of T_dust on T_{star} and R_{star}, the terrestrial planetary zone (TPZ) around high-mass stars extends further out than that around low-mass stars. Therefore, R_{dust} is not a good way to define the TPZ, while dust equilibrium temperature is equally applicable to all main-sequence stars. In our solar system, T_dust is 150 K near the outer boundary of the asteroid belt (~3.5 AU), and the zodiacal dust particles are sufficiently large (~30 μm) that they do radiate like blackbodies. To specify a TPZ independent of the mass of the central star, we define the TPZ to be the region where T_dust ≥ 150 K. Then an A0 star has 25 AU, and an M0 star has 0.9 AU as the outer boundary of their TPZ.

Because of the way it is defined, TPZ applies only to the location of grains that radiate like a blackbody.

According to the Spitzer surveys listed above, the presence of dust in the TPZ characterized by excess in the mid-IR is quite rare for stars ≥10 Myr old. For ages in the range of 8–30 Myr, a posited period of the terrestrial planet formation in our solar system, only a few stars appear to possess warm dust according to our analysis (see § 5 and Table 1): η Cha, a B8 member of 8 Myr old η Cha cluster (Mamajek et al. 1999); η Tel and HD 172555, A0- and A7- type members of the 12 Myr old β Pic moving group (Zuckerman et al. 2001b; Zuckerman & Song 2004); HD 3003, an A0 member of the 30 Myr old Tucana/Horologium moving group (Zuckerman et al. 2001b); and HD 113766, an F3 binary star (1.2° separation; Dommanget & Nys 1994), in the Lower Centaurus Crux (LCC) Association (Chen et al. 2005).

In this paper, we present the A9 star EF Cha, another example of this rare group of stars with warm dust at the epoch of terrestrial planet formation.

2. MSX SEARCH FOR MID-IR EXCESS STARS

Hipparcos, 2MASS, and Mid Course Experiment (MSX; Egan et al. 2003) sources were cross-correlated to identify main-sequence stars with excess emission at mid-IR wavelengths. Out of ~68,000 Hipparcos dwarfs with M_V ≥ 6.0 (B – V) – 2.0 (see Rhee et al. 2007 for an explanation of this M_V constraint) in a search radius of 10°, ~1000 stars within 120 pc of Earth were identified with potential MSX counterparts.

Spectral energy distributions (SED) were created for all ~1000 MSX identified Hipparcos dwarfs. Observed fluxes from Tycho-2 B_T and V_T, and 2MASS J, H, and K_s were fit to a stellar atmospheric model (Hauschildt et al. 1999) via a χ^2 minimization method (see Rhee et al. 2007, for detailed description of SED fitting). From these SED fits, about 100 Hipparcos dwarfs were retained that showed apparent excess emission in the MSX 8 μm band (that is, the ratio [MSX flux-photosphere flux]/MSX flux uncertainty must be >3.0). Since a typical positional 3σ uncertainty of MSX is ~6'' (Clarke et al. 2005) and MSX surveyed the Galactic plane, a careful background check is required to eliminate contamination sources. By overplotting the 2MASS sources on
the Digital Sky Survey (DSS) images, we eliminated more than half of the apparent excess stars that included any dubious object (i.e., extended objects, extremely red objects, etc.) within a 10″ radius from the star. Among the stars that passed this visual check, EF Cha was selected for follow-up observations at the Gemini South Telescope. Independent *IRAS* detections at 12 and 25 μm made EF Cha one of the best candidates for further investigation.

3. GROUND-BASED FOLLOW-UP OBSERVATIONS AND MIPS PHOTOMETRY

An *N*-band image and a spectrum of EF Cha were obtained using the Thermal Region Camera Spectrograph (T-ReCS) at the Gemini South Telescope in March and July of 2006 (GS-2006A-Q-10), respectively. Thanks to the queue observing mode at Gemini Observatory, the data were obtained under good seeing and photometric conditions. The standard “beam-switching” mode was used in all observations in order to suppress sky emission and radiation from the telescope. Data were obtained chopping the secondary at a frequency of 2.7 Hz and nodding the telescope every ~30 s. Chopping and nodding were set to the same direction, parallel to the slit for spectroscopy.

Standard data reduction procedures were carried out to reduce the image and the spectrum of EF Cha at *N* band. Raw images were first sky subtracted using the sky frame from each chop pair. Bad pixels were replaced by the median of their neighboring pixels. Aperture photometry was performed with a radius of 9 pixels (0.9″) and sky annuli of 14–20 pixels. The spectrum of a standard star (HD 129078) was divided by a Planck function with the star’s effective temperature (4500 K), and this ratioed spectrum was then divided into the spectrum of EF Cha to remove telluric and instrumental features. The wavelength calibration was performed using atmospheric transition lines from an unchopped raw frame. The one-dimensional spectrum was extracted by weighted averaging of 17 rows.

For the *N*-band imaging photometry, the on-source integration time of 130 s produced S/N > 30 with FWHM ~ 0.54″. For the *N*-band spectrum, a 886 s on-source exposure resulted in S/N > 20.

### Table 1

| Star | Spectral Type | *V* (mag) | *D* (pc) | *R* (K) | *T* (K) | *T*<sub>rad</sub> (K) | *r* (<10⁻⁵) | Age (Myr) | Excess Only | Disk Characteristics | Membership | References |
|------|---------------|-----------|----------|---------|---------|-----------------|------------|-----------|-------------|---------------------|------------|------------|
| η Cha | B8<sup>b</sup> | 5.5 | 97 | 2.37 | 6000 | 250 | 0.9 | Yes | Primordial/Debris | η Cha | 1 |
| EF Cha | A9 | 7.5 | 106 | 1.92 | 7400 | 240 | 10 | Yes | Primordial/Debris | Cha-Near | 2 |
| HD 113766 | F3 V | 7.5 | 131 | 1.37 | 7000 | 350 | 10<sup>d</sup> | Yes | Primordial/Debris | LCC | 3, 5, 6 |
| HD 172555 | A7 V | 4.8 | 29 | 1.52 | 8000 | 320 | 8.1 | Yes | Primordial/Debris | Cha | 3, 4, 6 |
| η Tel | A0V | 5.0 | 48 | 1.61 | 9600 | 150 | 2.1 | Yes | Primordial/Debris | Cha | 3, 4, 6 |
| HD 3003 | A0 V | 5.1 | 46 | 1.59 | 9600 | 200 | 0.92 | Yes | Primordial/Debris | Tucana/Horologium | 7, 8 |
| β Pic | A5 V | 3.9 | 19 | 1.37 | 8600 | 110 | 26 | No | Debris | Cha | 4 |
| HD 98800 | K5 Ve | 9.1 | 47 | 1.56 | 4200 | 160 | 1100 | No | Primordial/Debris | TWA | 7, 9 |
| TW Hya | K8 Ve | 11.1 | 56 | 1.11 | 4000 | 150 | 2200 | No | Primordial/Debris | TWA | 7, 9 |
| Hen 3-600 | M3 | 12.1 | 42<sup>f</sup> | 3200 | 250 | 1000 | 8 | No | Primordial/Debris | TWA | 7, 9 |
| EP Cha | K5.5<sup>b</sup> | 11.2 | 97 | 1.39 | 4200<sup>b</sup> | 8<sup>g</sup> | 1300<sup>g</sup> | 8 | No | Primordial/Debris | η Cha | 11, 12 |
| ECHA J0843.3–7905 | M3.25<sup>b</sup> | 14.0 | 87 | 0.87 | 3400<sup>b</sup> | 8<sup>g</sup> | 2000<sup>g</sup> | 8 | No | Primordial/Debris | η Cha | 11, 12 |
| ECHA J0843.3–7905 | M3.25<sup>b</sup> | 14.0 | 87 | 0.87 | 3400<sup>b</sup> | 8<sup>g</sup> | 2000<sup>g</sup> | 8 | No | Primordial/Debris | η Cha | 11, 12 |
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| HD 113766 | F3 V | 7.5 | 131 | 1.37 | 7000 | 350 | 10<sup>d</sup> | Yes | Primordial/Debris | LCC | 3, 5, 6 |
| HD 113766 | F3 V | 7.5 | 131 | 1.37 | 7000 | 350 | 10<sup>d</sup> | Yes | Primordial/Debris | LCC | 3, 5, 6 |

Notes.— *R*, and *T* were obtained by fitting the observed optical and near-IR measurements with NextGen stellar atmosphere model (Hauschildt et al. 1999). *T*<sub>rad</sub>, and τ were estimated by fitting blackbody curves to the infrared excess emission.

<sup>a</sup> Estimated using a total integrated flux for a given distance (col. 4) assuming that each star is a single object.

<sup>b</sup> From Luhman & Steeghs (2004).

<sup>c</sup> Multiple systems: HD 113766 (binary), HD 98800 (quadruple), Hen 3–600 (triple), and EN Cha (binary) from Zuckerman & Song (2004).

<sup>d</sup> Mamajek et al. (2002) estimate the age of LCC at ~16 Myr. However, Song et al. (2007) report a younger age of ~10 Myr.

<sup*e</sup> Based on the single temperature blackbody fit to the dominant cold excess. However, additional warm excess emission exists above the 110 K model fit, indicating the presence of warm dust in the terrestrial planetary zone.

<sup>f</sup> Estimated photometric distance from Zuckerman & Song (2004). This lower limit τ is estimated from our two-temperature dust component fit to the infrared excess emission. No dust temperature is given because its IR excess emission cannot be fit with a single temperature blackbody. However, a significant excess emission at mid-IR wavelengths exists which is not the Wien tail of emission from cold dust grains.

<sup>g</sup> No SED fitting was attempted to estimate stellar radius and temperature as well as dust parameters.

<sup>h</sup> Based on the distance of 85 pc (Silverstone et al. 2006) from Earth.

References.— (1) Mamajek et al. 1999; (2) This paper; (3) Schuetz et al. 2005; (4) Zuckerman et al. 2001a; (5) Chen et al. 2005; (6) Chen et al. 2006; (7) Zuckerman & Song 2004; (8) Smith et al. 2006; (9) Low et al. 2005; (10) Silverstone et al. 2006; (11) Mamajek et al. 2002; (12) Megeath et al. 2005; (13) Kessler-Silacci et al. 2006.
1.167 for the 24 μm image given at the SSC MIPS website4 with aperture radius of 13" and sky inner and outer annuli of 20" and 32", respectively. For MIPS 70 μm data, we estimated 3 σ upper limits to the nondetection on the mosaic image that we produced using MOPEX software on BCD images.

4. RESULTS

Table 2 lists the mid-IR measurements of EF Cha from MSX, IRAS, MIPS, and Gemini T-ReCS observations. The T-ReCS N-band image (FOV of 28.8″×21.6″) confirmed that no other mid-IR source appears in the vicinity of EF Cha, and that the mid-IR excess detected by the space observatories (IRAS and MSX) originates solely from EF Cha. A strong silicate emission feature in the N-band spectrum (Fig. 1) indicates the presence of warm, small (a ≤ 5 μm; see Fig. 6 in Rhee & Larkin 2006) dust particles. Amorphous silicate grains dominate the observed emission feature. However, crystalline silicate structure, probably forsterite, appears as a small bump near 11.3 μm (Kessler-Silacci et al. 2006). Polycyclic aromatic hydrocarbon (PAH) particles can also produce an emission feature at 11.3 μm. However, absence of other strong PAH emission features at 7.7 and 8.6 μm indicates that the weak 11.3 μm feature does not arise from PAHs. Furthermore, although PAH particles do appear in some very young stellar systems, they have not been detected around stars as old as 10 Myr. In contrast, crystalline silicates such as olivine, forsterite, etc. are seen in a few such stellar systems (Song et al. 2005; Schuetz et al. 2005; Beichman et al. 2006; Lisse et al. 2007).

The dust continuum excess of EF Cha was fit with a single-temperature blackbody curve at 240 K by matching the flux density at 13 μm and the MIPS 70 μm upper limit (Fig. 1). The 3 σ upper limit at the MIPS 70 μm band indicates that the dust temperature should not be colder than 240 K. Figure 1 shows that MIPS 24 μm flux is ~30 mJy lower than IRAS 25 μm flux. Due to the small MIPS aperture size compared with IRAS, MIPS 24 μm flux often comes out smaller when nearby contaminating sources are included in the large IRAS beam. The ground-based T-ReCS (28.8″×21.6″) image of EF Cha at N-band, however, shows no contaminating source in the vicinity of EF Cha. Thus, the higher flux density at IRAS 25 μm perhaps indicates the presence of a significant silicate emission feature near 18 μm included in the wide passband of the IRAS 25 μm filter (18.5–29.8 μm). A recent Spitzer IRS observation of another warm excess star, BD +20 307 (Song et al. 2005), shows a similar discrepancy between the IRAS 25 μm flux and MIPS 24 μm flux in the presence of a significant silicate emission feature at ~18 μm (Weinberger et al. 2007, in preparation), consistent with our interpretation. MIPS 24 μm flux is slightly above our 240 K dust continuum fit. The wide red wing of an 18 μm silicate emission feature could contribute to a slight increase in MIPS 24 μm flux.

5. DISCUSSION

5.1. Debris Disk Characteristics of EF Cha

EF Cha was detected in the ROSAT X-ray All Sky Survey with L_X/L_bol = 10^{-4.68}, which suggests a very young age for an A9 star (see Fig. 4 in Zuckerman & Song 2004). On the basis of this X-ray measurement, Hipparcos distance (106 pc), location in the sky (RA = 12h07m, decl. = −79°), and proper motion (pm RA = −40.2 ± 1.2 and pm decl. = −8.4 ± 1.3 mas yr^{-1}), EF Cha is believed to be a member of the “Cha-Near” moving group (avg. RA = 12h00m and avg. decl. = −79°, avg. pm RA = −41.13 ± 1.3 and avg. pm decl. = −3.32 ± 0.86 mas yr^{-1}; Zuckerman & Song 2004; this paper), which is ~10 Myr old and typically ~90 pc from Earth.

Large blackbody grains in thermal equilibrium at 240 K would be located ~4.3 AU from EF Cha, while small grains, especially those responsible for the silicate emission features in our N-band spectrum, radiate less efficiently and could be located at >4.3 AU. Recent Spitzer MIPS observations confirmed that none of the aforementioned (§ 1) warm excess stars have a cold dust population, indicating few large grains at large distances (Chen et al. 2006; Smith et al. 2006). Lack of cold large grains, in turn, suggests local origin of the small grains seen in these warm excess stars. Lacking cold excess (from Spitzer MIPS 70 μm data), small grains in EF Cha should originate in the TPZ, probably by the breakup of large grains in the TPZ, rather than inward migration from an outer disk. Even in the unlikely event that silicate emission comes from small grains in an outer disk that were blown away by radiation pressure in Vega (Su et al. 2005), the dominant carrier of 240 K continuum emission would still be large grains (A. Li 2007, private communication).

The fraction of the stellar luminosity reradiated by dust, τ, is ~10^{-3}, which was obtained by dividing the infrared excess between 7 and 60 μm by the bolometric stellar luminosity. This τ is ~10,000 times larger than that of the current Sun’s zodiacal cloud (~10^{-7}) but appears to be moderate for known debris disk systems at similar ages (see Fig. 4 in Rhee et al. 2007). Rhee et al. (2007) show that the ratio of dust mass to τ of a debris system is proportional to the inverse square of dust particle semimajor axis for semimajor axes between ~9 and ~100 AU. For systems with dust radius <9 AU, this relationship overestimates the dust mass.

### Table 2

| Band   | Central Wavelength (μm) | Flux Density (mJy) | Adopted Photospheric Flux Density (mJy) | Excess Flux Density (mJy) | Instrument |
|--------|------------------------|-------------------|----------------------------------------|--------------------------|------------|
| 8 μm   | 8.28                   | 167 ± 9           | 119                                    | 48                       | MSX        |
| N      | 10.4                   | 164 ± 14          | 84                                     | 80                       | Gemini/T-ReCS |
| N      | 7.7–12.97              | ...               | ...                                    | ...                      | ...        |
| 12 μm  | 11.5                   | 152 ± 32          | 58                                     | 94                       | IRAS       |
| 24 μm  | 24.0                   | 80 ± 4            | 14                                     | 66                       | MIPS       |
| 25 μm  | 23.7                   | 110 ± 21          | 14                                     | 96                       | IRAS       |
| 70 μm  | 70.0                   | <22.4^a           | 1.7                                    | <20.7^a                  | MIPS       |

*Note:* Both MSX and IRAS flux densities were color-corrected using the method described in Rhee et al. (2007).

^a 3 σ upper limit to the nondetection.

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4 See http://ssc.spitzer.caltech.edu/mips/apercorr/.
Instead, we calculate the mass of a debris ring around EF Cha using

\[ M_{\text{dust}} \geq \frac{16}{3} \pi R_{\text{dust}}^2 \rho_s \langle a \rangle \]

(eq. [4] in Chen & Jura 2001), where \( \rho_s \) is the density of an individual grain, \( L_{\text{IR}} \) is the dust luminosity, and \( \langle a \rangle \) is the average grain radius. Because Chen & Jura (2001) analyzed \( \zeta \) Lep, a star of similar spectral type to EF Cha, we adopt their model for grain size distribution. Assuming \( R_{\text{dust}} = 4.3 \, \text{AU} \), \( \rho_s = 2.5 \, \text{g cm}^{-3} \), and \( \langle a \rangle = 3 \, \mu\text{m} \), the dust mass is \( 4.8 \times 10^{22} \, \text{g} \sim 10^{-5} \, M_{\odot} \). Grains with \( a = 3 \, \mu\text{m} \) will radiate approximately as blackbodies at wavelengths shorter than \( \sim 2\pi a \sim 20 \, \mu\text{m} \). As may be seen from Figure 1, most of the excess IR emission at EF Cha appears at wavelengths \( \lesssim 20 \, \mu\text{m} \).

For blackbody grains at \( \sim 4.3 \, \text{AU} \) with, for example, radius \( a = 3 \, \mu\text{m} \), the Poynting-Robertson (P-R) drag timescale \( 5 \) is only \( 8 \times 10^3 \, \text{yr} \), much less than 10 Myr. Yet smaller grains with \( a < 1.3 \, \mu\text{m} \) would be easily blown away by radiation pressure on a much shorter timescale. Successive collisions among grains can effectively remove dust particles by grinding down large bodies into smaller grains, which then can be blown out. The characteristic collision time (orbital period/\( \tau \)) of dust grains at 4.3 AU from this A9 star is \( \sim 10^4 \, \text{yr} \). Both P-R time and collision time were derived assuming no gas was present in the disk. While gas has not been actively searched for in EF Cha, few debris disk systems at \( \gtrsim 10 \, \text{Myr} \) show presence of gas, indicating early dispersal of gas (Pascucci et al. 2006). The possibility of an optically thin gas disk surviving around a \( \sim 10 \, \text{Myr} \) system was investigated by Takeuchi & Artymowicz (2001). However, their model of gas disk is pertinent to cool dust at large distances (\( \gtrsim 120 \, \text{AU} \)), but not to warm dust close to the central star as in EF Cha. In addition, a recent study of OB associations shows that the lifetime of a primordial inner disk is \( \lesssim 3 \, \text{Myr} \) for Herbig Ae/Be stars (Hernández et al. 2005). Based on the very short timescales of dust grain removal, essentially all grains responsible for significant excess emission at EF Cha in the mid-IR are, therefore, likely to be second generation, not a remnant of primordial dust.

5.2. Debris Disk Systems in the TPZ during the Epoch of Planet Formation

The presence of hot dust has been recognized around other \( \sim 10 \, \text{Myr} \) stars, for example, TW Hya, HD 98800, and Hen 3-600 in the TW Hydrae Association. Interesting characteristics of these
systems are their large $\tau \approx 10^{-2}$ and late-K and M spectral types. TW Hya and Hen 3-600 show a flat IR SED up to 160 \mu m consistent with active accretion in their disks (Low et al. 2005). Combined with the presence of substantial gas emission lines from TW Hya, the observed infrared excess emission, at least for these two stars, appears to arise from gaseous dusty disks left over from the protostellar environment. On the other hand, a lack of gas emission (Dent et al. 2005) and the quadruple nature of the HD 98800 system has invoked a flared debris disk as an alternative explanation for its large infrared excess emission (Furlan et al. 2002). Many young stars come in multiple systems. However, they hardly display such a high $\tau$ as that of HD 98800. Thus, the dust disk around HD 98800 might be an unusual transient phenomenon such that it still contains a dust population composed of a mixture of primordial grains and replenished debris. Some stars display a mixture of warm and cold grains, where the overall infrared excess emission is dominated by the cold dust. Table 1 summarizes the currently known disk systems with warm dust regardless of spectral type and the presence of cold excess or remnant primordial dust at $\sim 8 \ldots 30$ Myr.

What separates EF Cha from the stars described in the previous paragraph is that most of the infrared excess emission, if not all, arises from warm dust in the TPZ, and as described in $\S$ 5.1, these grains are, clearly, not a remnant of the protostellar disk. Recent Spitzer MIPS observation shows null detection of EF Cha at 70 \mu m band, leaving the presence of substantial cold dust unlikely (see Fig. 1). This result is consistent with the recent Spitzer observations of other similar Table 1 early-type warm excess systems ($\eta$ Tel, HD 3003, HD 172555, and HD 113766) in which cold dust from a region analogous to the Sun’s Kuiper Belt objects is missing (Chen et al. 2006; Smith et al. 2006). In the following discussion, we characterize warm excess stars as those with warm dust in the TPZ only and without cold excess (i.e., we exclude stars like $\beta$ Pictoris).

The fact that all currently known warm excess stars at ages between 8 and 30 Myr belong to nearby stellar moving groups offers an excellent opportunity to address how frequently warm excess emission appears among young stars in the solar neighborhood. Zuckerman & Song (2004) list suggested members of stellar moving groups and clusters (i.e., $\eta$ Cha cluster, TW Hydra association, $\beta$ Pictoris moving group, Cha-Near moving group, and Tucana/Horologium association) at ages 8–30 Myr, within 100 pc of Earth. Currently Spitzer MIPS archive data are available for all 18 members of the $\eta$ Cha cluster, all 24 members of TWA, all 52 members of Tucana/Horologium, 25 out of 27 $\beta$ Pic moving group, and 9 out of 19 members of Cha-Near moving group. Multiple systems were counted as one object unless resolved by Spitzer. For example, in the $\beta$ Pictoris Moving Group, HD 155555A, HD 155555B, and HD 155555C were counted as a single object; however, HIP 10679 and HIP 10680 were counted as two objects.

Table 1 shows that the characteristics of dust grains depend on the spectral type of the central star. All six warm debris disks considered in this paper harbor early-type central stars (earlier than F3). However, late-type stars in Table 1 (for example, PDS 66, a K1 V star from LCC) sometimes show characteristics of T Tauri-like disk excess (e.g., $\tau > 10^{-2}$, flat IR SED, etc.) even at $\sim 10$ Myr (Silverstone et al. 2006). Such apparent spectral dependency per-haps arises from the relatively young ages ($\sim 10$ Myr) of these systems in which late-type stars still possess grains mixed with primordial dust due to a longer dust removal timescale (Hernández et al. 2005). In the above-mentioned five nearby stellar moving groups, 38 out of 129 stars with Spitzer MIPS measurements have spectral types earlier than G0. Therefore, we find $\sim 13\%$ (5/38) occurrence rate for the warm excess phenomenon among the stars with spectral types earlier than G0 in the nearby stellar groups at 8–30 Myr. ($\beta$ Pic is the only early-type star among the remaining 33 that has both warm and cold dust.) For LCC, at least one (HD 113766) out of 20 early-type members is a warm excess star giving 5% frequency (see Tables 1 and 2 in Chen et al. 2005). This rate can reach a maximum of 30% when we take into account five early-type LCC members that show excess emission at 24 \mu m but have only upper-limit measurements at MIPS 70 \mu m band. G0 type was chosen to separate the apparently different early- and late-type populations, because no G-type star except T Cha appears in Table 1. Furthermore, the spectral type of T Cha is not well established (G2-G8), and it may be a K-type star like other K/M stars in Table 1. Rhee et al. (2008, in preparation) analyze all spectral types in the young nearby moving groups and conclude that the warm excess phenomenon with $\tau \sim 10^{-4}$ occurs for between 4% and 7%; this uncertainty arises because some stars have only upper limits to their 70 \mu m fluxes.

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6 128 stars with Spitzer data plus EF Cha. EF Cha, which appeared in Mamajek et al. (2000) was inadvertently omitted from the suggested members of Cha-Near moving group by Zuckerman & Song (2004), but its membership is included in this paper. Since the warm excess in EF Cha was found by MSX and IRAS surveys less sensitive than Spitzer MIPS, the addition of EF Cha to the homogeneous pool of MIPS surveyed stars does not increase the warm excess occurrence rate inappropriately, because MIPS would have easily detected it. In the near future, even if new members are added to these nearby stellar associations, we believe the overall occurrence rate would remain similar to the current estimate, because most A- through early-M-type members of these stellar associations, excepting perhaps the Cha-Near moving group, are already well established through extensive searches and almost all the members are already surveyed by Spitzer MIPS.

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