The Astrophysical Journal, 757:7 (6pp), 2012 September 20 doi:10.1088/0004-637X/757/1/7

WISE DETECTIONS OF DUST IN THE HABITABLE ZONES OF PLANET-BEARING STARS

Farisa Y. Morales[1], D. L. Padgett[2], G. Bryden[1], M. W. Werner[1], and E. Furlan[3,4]
[1] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; Farisa@jpl.nasa.gov
[2] Goddard Space Flight Center, Greenbelt, MD 20771, USA
[3] National Optical Astronomy Observatory, Tucson, AZ 85719, USA
Received 2012 May 5; accepted 2012 July 17; published 2012 August 28

ABSTRACT

We use data from the *Wide-field Infrared Survey Explorer* (*WISE*) all-sky release to explore the incidence of warm dust in the habitable zones around exoplanet-host stars. Dust emission at 12 and/or 22 μm ($T_{\rm dust} \sim 300$ and/or $\sim$150 K) traces events in the terrestrial planet zones; its existence implies replenishment by evaporation of comets or collisions of asteroids, possibly stirred by larger planets. Of the 591 planetary systems (728 extrasolar planets) in the Exoplanet Encyclopaedia as of 2012 January 31, 350 are robustly detected by *WISE* at $\geqslant 5\sigma$ level. We perform detailed photosphere subtraction using tools developed for *Spitzer* data and visually inspect all the *WISE* images to confirm bona fide point sources. We find nine planet-bearing stars show dust excess emission at 12 and/or 22 μm at $\geqslant 3\sigma$ level around young, main-sequence, or evolved giant stars. Overall, our results yield an excess incidence of $\sim$2.6% for stars of all evolutionary stages, but $\sim$1% for planetary debris disks around main-sequence stars. Besides recovering previously known warm systems, we identify one new excess candidate around the young star UScoCTIO 108.

Key words: circumstellar matter – infrared: planetary systems – planets and satellites: formation – stars: individual (UScoCTIO 108)

Online-only material: color figures

1. INTRODUCTION

The recent release of the *Wide-field Infrared Survey Explorer* (*WISE*; Wright et al. 2010) all-sky survey provides an opportunity to explore the incidence of warm circumstellar dust for a large sample of stars. The *WISE* data set covers 100% of the sky at four infrared bands W1,...,W4 centered at 3.4, 4.6, 12, and 22 μm wavelengths that are sensitive to thermal emission from objects at temperatures similar to our Earth ($\sim$300 K), asteroid belt, and the interior zodiacal cloud (165–250 K). In this work, we use this all-sky data set to search for dust in the habitable zones around exoplanet-bearing stars.

In the last two decades, over 700 exoplanets have been revealed and confirmed, primarily from radial velocity (RV) and transit studies, plus $\sim$2300 announced candidates for the *Kepler* mission (Batalha et al. 2012) awaiting confirmation.[5] The majority of these planets are in systems very different from our own, with Neptune-size or bigger planets, too large and often too close to the host star to be habitable. On the other hand, a significant fraction of planetary debris disks have warm dust ($T_{\rm dust} \sim 200$ K). Following up on results from *Infrared Astronomical Satellite* and *Infrared Space Observatory*, surveys by the *Spitzer Space Telescope* (Werner et al. 2004) found that many nearby stars are surrounded by dust that is thought to be generated by collisions between asteroids and/or sublimation of comets. Of the $\sim$350 debris disks measured individually with *Spitzer* (Chen et al. 2005; Su et al. 2006; Beichman et al. 2006; Trilling et al. 2008; Carpenter et al. 2009; Plavchan et al. 2009), $\sim$70 are known to have warm components with $T_{\rm dust} > 150$ K (Morales et al. 2011).

Among the *Spitzer* discoveries are the first systems known to have both orbiting dust and exoplanets (Beichman et al. 2005; Bryden et al. 2009). The relationship between planets and debris is unclear except in the general sense that the debris is indicative of planetary system formation, so one might expect to see some association. Several prominent A-type stars with imaged planets also have bright debris disks (Fomalhaut, HR 8799, and β Pic; Kalas et al. 2008; Marois et al. 2008; Lagrange et al. 2009), further suggesting a link between the two phenomena. The question is whether the presence of planets enhances, depresses, or is neutral in terms of the frequency or observability of dust systems.

Here, we use *WISE* data to attempt to find evidence of comet/asteroid activity in the habitable zones of stars known to harbor exoplanets, and thereby examine the link between planets and debris. Several groups have already searched for similar planet–debris relationships using *WISE*. Krivov et al. (2011) used data from the preliminary *WISE* release, covering 57% of the sky, to search for dust around 52 systems with transiting exoplanets finding zero 3σ excess detections in any single *WISE* band (where σ refers to the fractional infrared excess statistical significance). But by combining $<3\sigma$ excesses in W3 and W4, Krivov et al. (2011) identify two candidate excess detections that remain to be confirmed. With the Kepler Objects of Interest (KOI) Catalogue of candidate transiting exoplanets (not necessarily planet bearing), Lawler & Gladman (2012) find the fraction of stars with warm excesses to be $\sim$3% using the recently released all-sky *WISE* survey. Also using the all-sky *WISE* release and *Kepler*'s KOIs, Ribas et al. (2012) identify 13 transiting planet systems with IR excess ($>2\sigma$) at 12 and/or 22 μm, out of a 546 star sample. Only four are $\geqslant 3\sigma$ detections for a corresponding detection rate of $\sim$0.7%.

Unlike the previous work, our study makes use of the *WISE* all-sky release and focuses on the set of confirmed exoplanets, including not just transiting planets, but also those detected by RV measurements or by direct imaging. We do not consider the *Kepler* candidate objects, but our sample does overlap with

[4] Visitor, Infrared Processing and Analysis Center, Caltech, Pasadena, CA 91125, USA.
[5] *Extrasolar Planets Encyclopaedia*, http://exoplanet.eu/

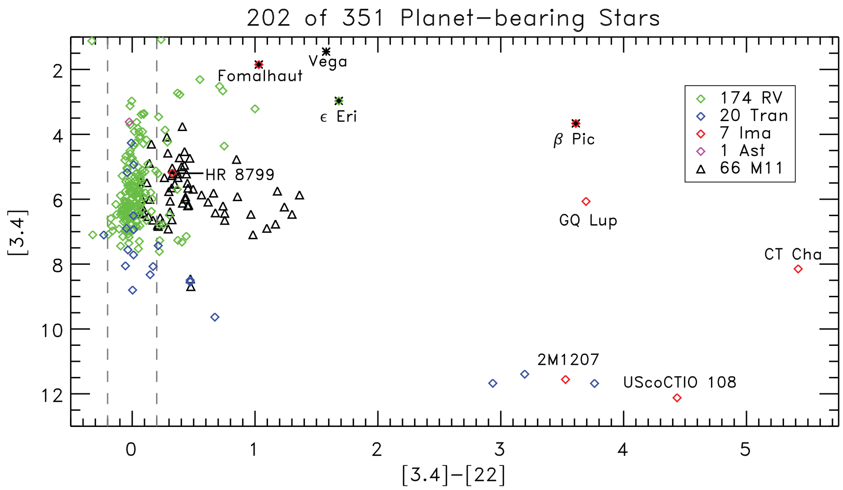

Figure 1. Color–magnitude diagram for planet-bearing stars in our sample, color-coded by planet discovery method. The 202 out of 350 planet-bearing stars in our sample plotted here, mostly from transiting ("Tran") and RV studies, have *WISE* W4 photometry with $S/N_{Total} \geqslant 3$. In the legend, "Ima" stands for the direct imaging method used to identify substellar-mass companions, and "Ast" for astrometry. Most are main-sequence stars without excess emission and found between the vertical dashed lines ($[3.4] - [22] \approx 0.2$), while interesting excess candidates populate the region with $[3.4] - [22] > \sim 0.2$. Also included are the well-known "Fab Four" debris disks, Vega, Fomalhaut, β Pic, ϵ Eri (asterisks), and 66 well-characterized *Spitzer* warm debris disk (triangles) from Morales et al. (2011) labeled "M11" in the legend. A visual inspection of *WISE* images of the non-labeled green triangles with $[3.4] - [22] > \sim 0.2$ reveals that their W1 data are contaminated by excess flux from diffraction halo artifacts and/or the W4 data are contaminated by background emission. 2M1207 and UScoCTIO108 are substantially fainter than the rest of the planet–star–dust systems; this "limit" is due to the apparent magnitudes of the confirmed companions rather than the *WISE* detection limits.

(A color version of this figure is available in the online journal.)

Krivov et al. (2011) and Ribas et al. (2012) for a handful of confirmed transiting systems.

For comparison, Padgett et al. (2012) searched for circumstellar warm dust using the *WISE* all-sky data set, while considering all Hipparcos stars within 120 pc, as well as Tycho stars with proper motions >30 mas yr^{-1}. Their results suggest that the frequency of warm excess emission associated with stellar sources is $\lesssim 2\%$ at the *WISE* sensitivity limits.

In Section 2, we describe the data for our chosen sample of target stars. Based on this data, we next (Section 3) determine which planet-bearing stars have evidence for warm dust by fitting the spectral energy distribution (SED) and visually inspecting the *WISE* images. In Section 4, we interpret the results and summarize our findings in Section 5.

2. SAMPLE SELECTION AND THE *WISE* DATA

Our starting target list consists of 591 planetary systems (with 728 extrasolar planets) given in the Exoplanet Encyclopaedia as of 2012 January 31 (Schneider et al. 2011). The Schneider et al. compilation includes planetary-mass companions detected using all methods presently utilized, i.e., RV or astrometry, transit studies, micro-lensing, pulsar timing, and direct imaging. Searching through the *WISE* all-sky catalog (which includes all data taken during the *WISE* full cryogenic mission phase), we find 350 individual planet–star systems that have *WISE* photometric data within a 5″ search radius. The vast majority are well within an arcsec. In addition to the *WISE* flux measurements from profile-fitting photometry, each *WISE* catalog entry gives positions, astrometric and photometric uncertainties, and flags for reliability,[6] which we used to decide which flux measurements in W1,. . .,W4 are used (or discarded) during the batch-processing analysis described below. The remaining 241 stars are too faint for the *WISE* 5σ point source sensitivity limits of $\sim$0.08, 0.11, 1, and 6 mJy in bands W1,. . .,W4 (*WISE*; Wright et al. 2010). Figure 1 is a color–magnitude diagram color-coded by planet discovery method, to illustrate how stars with infrared excess emission can be initially identified. Most stars do not have excess (i.e., $[3.4] - [22] \sim 0$), but the *WISE* fluxes reveal an interesting sample of objects with $[3.4] - [22] > \sim 0.2$.

3. ANALYSIS

3.1. SED Fitting

To measure excess emission at the *WISE* wavelengths, we require a precise method to subtract off the stellar photosphere. We start by compiling near-IR Two Micron All Sky Survey (2MASS) data (cross-correlated with the *WISE* catalog) and optical Tycho photometry (Høg et al. 2000) from the NASA Exoplanet Archive.[7] For the SED fitting, we use previously developed advanced tools built to study large samples of debris disks as seen by *Spitzer* (Morales et al. 2009, 2011). These tools χ^2 fit the SEDs of each of the 350 exoplanet-bearing stars to derive the photosphere and disk contributions. The latter can be approximated by a blackbody corresponding to the characteristic temperature of the dust grains, and NextGen models are used to model the contribution of the stellar photospheres.

While our expectation is to find dust emission primarily at longer wavelengths, our SED fitting method can detect excess emission at any dust temperature (it is sensitive to any *WISE* waveband, not just W3 and W4).

In order to identify a significant amount of excess emission, the total signal-to-noise ratio (S/N) can be expressed as

$$\left(\frac{S}{N}\right)_T = \frac{F_\star + F_d}{\sigma} = \left(\frac{S}{N}\right)_\star + \left(\frac{S}{N}\right)_d, \qquad (1)$$

where the uncertainty, σ, is a combination in quadrature of the uncertainty in the *WISE* photometry and calibration^2. Thus, the

[6] See the Explanatory Supplement to the *WISE* All-Sky Data Release Products, http://wise2.ipac.caltech.edu/docs/release/allsky/expsup/#dataprods.

[7] http://exoplanetarchive.ipac.caltech.edu/

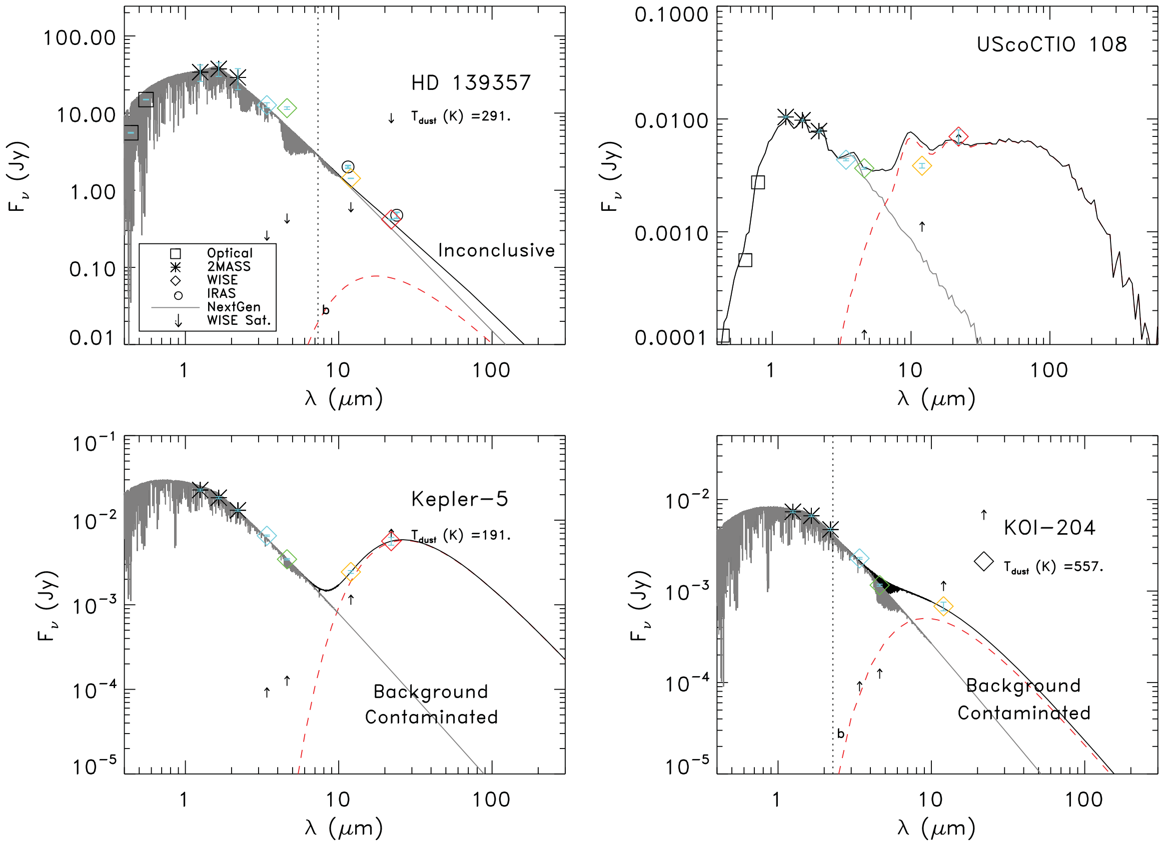

Figure 2. SEDs for four representative objects of the initial 23 excess candidates, $(S/N)_{dust} \geqslant 3$, selected after the SED fitting analysis. The *WISE* W1,. . .,W4 profile-fit photometry is plotted as cyan, green, orange and red diamonds with cyan error bars (when uncertainty is unavailable we plot a black diamond and the measurement is not used in the fit). Overlaid in gray are the best-fit stellar atmosphere models. The best-fit warm blackbodies are plotted as red dashed curves, while the sum of components in solid black. 2MASS *JHKs* fluxes (Cutri et al. 2003) are plotted as asterisks, while optical photometry as squares. Using the separations of the planetary-mass companions from their parent stars, the vertical dashed lines correspond to the locations in wavelength where the exoplanets would peak in emission if in thermal equilibrium with the parent stars. The SED fit of HD 139357, a giant star (K4 III), suggests the presence of excess emission at 22 μm; but this stars is bright, with W1,. . .,W3 above the *WISE* saturation levels, so the W1,. . .,W3 are not used in the fitting analysis. USco CTIO 108, an 11 Myr old M7 type star, is a young stellar source with an imaged substellar companion 670 AU from the star. As a young late-type star, its SED is modeled using the Robitaille grid (Robitaille et al. 2006, 2007), and it may have an optically thick accreting disk. The bottom two planet-bearing star SEDs, Kepler 5 and KOI 204, have SEDs that appear to have warm dust emission while using the *WISE* photometry, but lack a point source at the location of the star in the *WISE* images. These two are therefore dropped from our final list of planetary systems with warm dust.

(A color version of this figure is available in the online journal.)

fractional excess can be expressed as

$$\frac{F_d}{F_\star} = \left[\frac{\left(\frac{S}{N}\right)_T}{\left(\frac{S}{N}\right)_d} - 1 \right]^{-1}. \quad (2)$$

These expressions hold under the assumption that the observational uncertainties are much greater than the uncertainty of the SED fit. Objects detected by *WISE* with an S/N of 5, for example, allow us to measure excess emission ($F_{dust}/F_\star$) down to a factor of 1.5 above photospheric emission levels (with 3σ significance on dust), while we can detect fainter excesses in brighter objects.

By applying these equations, we find that 23 of the 350 planet-host stars result in an S/N of 3 or greater for the dust emission, $(S/N)_{dust} \geqslant 3$, in W3 and/or W4. The remaining 327 planet-bearing stars have photospheric SEDs, where no statistically significant excess is observed at the *WISE* bands. Of the 23 planet-bearing stars studied here, most lack excess emission in the W1 and W2 *WISE* bands, except for a small subsample of young stellar sources where excess is seen in all *WISE* bands. Subsequently, young systems are modeled using the Robitaille grid (Robitaille et al. 2006, 2007) for young stellar source. Figure 2 shows the SED fitting results of four representative objects of the 23 planetary systems yielding $(S/N)_{dust} \geqslant 3$.

The 23 systems show IR excess when using the W1,. . .,W4 photometric measurements available in the *WISE* catalog. However, because *WISE* is an all-sky survey, it is certain that some of its photometry, obtained via an automatic profile-fit pipeline, will suffer from background contamination, so our next step is to inspect the *WISE* images.

3.2. Visual Inspection

We downloaded fits files from the IRSA archive for the 1′.4 × 1′.4 regions surrounding each of the 23 SED-fit candidate disks. Although the *WISE* all-sky release source catalog provides four-band photometry at the location of each W1 (3.4 μm) point source, a large number of objects with cataloged fluxes have no evidence of a corresponding point source in W3 and/or W4. After a visual inspection of the *WISE* images on the 23 *WISE* excess candidates identified via SED fitting, we find 9 stars with planetary mass companions (β Pic, ϵ Eri, HR 8799, 2M1207, CT Cha, GQ Lup, LkCa 15, UScoCTIO 108, and HD 139357) are bona fide point sources at the location of the *WISE*

Table 1
Planet-bearing Stars with *WISE* Warm Excess

Name	Spectral Type	K (mag)	Dist.[a] (pc)	Age[a] (Myr)	N_{pl}	Planet Discovery Method	W3 F_ν (Jy)	W3 $F_d/F_\star$	W3 $[\mathrm{S/N}]_d$	W4 F_ν (Jy)	W4 $F_d/F_\star$	W4 $[\mathrm{S/N}]_d$	T_d (K)
Main-sequence stars													
β Pic	A6V	3.5	19	12	1	Imaging	2.474	-	-	7.897	22.8	16.6	<199
ϵ Eri	K2V	1.8	3.2	660	1	RV	5.689	-	-	2.530	0.75	7.5	<148
HR 8799	A5V	5.2	39	60	4	Imaging	0.237	0.1	2.1	0.094	0.46	4.9	275
Young stars													
2M1207	M8	11.9	52	8	1	Imaging	0.005	4.2	15.8	0.005	6.47	6.7	-
CT Cha	K7	8.7	165	2	1	Imaging	0.334	22.3	20.5	0.673	132.5	17.0	-
GQ Lup	K7eV	7.1	140	1	1	Imaging	0.534	16.7	20.1	0.930	93.6	16.2	-
LkCa 15	K5V	8.2	145	2	1	Imaging	0.152	8.2	18.9	0.309	54.5	16.3	-
UScoCTIO 108	M7	12.5	145	11	1	Imaging	0.004	4.0	12.3	0.007	22.5	6.1	-
Evolved star													
HD 139357[b]	K4III	3.4	121	3100	1	RV	1.426	-	-	0.418	0.21	3.0	<291
Previously known to harbor warm dust emission, but without significant *WISE* excess													
Fomalhaut[c]	A4V	0.9	7.7	430	1	imaging	-	-	-	3.900	0.15	2.2	<293
HD 10647[d]	F9V	4.3	17.3	4800	1	RV	0.600	-	-	0.218	0.14	2.0	<83

Notes. Table listing nine planetary systems with significant *WISE* excesses, $(\mathrm{S/N})_{\mathrm{dust}} \geqslant 3$, at 12 (W3) and/or 22 μm (W4) using the all-sky *WISE* data release. Our detections of IR excesses are divided into three categories: main-sequence debris disks, young disks, and dust around an evolved star in the giant phase. An entry of "-" under the W3 columns corresponds to values not used in fits due to saturation problems and thus no excess is computed. An entry "-" under the T_d column means that a single dust temperature is not computed since young stars with disks are modeled with a wide distribution of dust temperatures. The last two entries, Fomalhaut and HD 10647, are known to harbor warm dust emission ~20 μm from *Spitzer* studies, but are below the detection limit of the *WISE* W4 band.
[a] Distance and age estimates as provided in the Exoplanet Encyclopaedia.
[b] Inconclusive due to the high uncertainty in flux values.
[c] Warm dust emission identified by *Spitzer* photometry (Stapelfeldt et al. 2004).
[d] Warm dust emission identified by *Spitzer* spectrum (Chen et al. 2006).

profile-fit photometry in W3 and/or W4. The rest[8] have photometric values in the *WISE* catalog that are likely due to background emission in the beam of the stars. Of the nine stars (Table 1) that survive the visual discrimination process, two have previously unknown indication of warm excess emission, one of which is a robustly detected young stellar source (UScoCTIO 108), and a bright class III giant (HD 139357).

Figure 3 shows *WISE* bands W1,. . .,W4 images for the four planetary systems in Figure 2. The first two sources show point-like emission at the location of the stars, while the last two (Kepler 5 and KOI 204) lack a point source in band W3 and W4; we find that the flux entries in the *WISE* catalog for these two objects are due to background flux likely resulting from stellar or interstellar emission in the projected neighborhood of the planet-bearing stars. The only new robustly detected disk candidate presented here, UScoCTIO 108, is clearly seen in excess in both W3 and W4 *WISE* bands, with a total S/N of 21 and 6.4 at 12 and 22 μm, and an $(\mathrm{S/N})_{\mathrm{dust}}$ of 12.3 and 6.1, respectively. Although some low-level contamination from background emission can be observed in the W4 band, we conclude that the IR excess from UScoCTIO 108 is primarily circumstellar; we find the nebulosity in its neighborhood to have flux intensity $\lesssim$10% that of the central source using a smaller aperture extraction.

4. INTERPRETATION AND DISCUSSION

Our detections of IR excess can be easily divided into three sub-categories—young thick disks, main-sequence debris disks, and dust around evolved stars.

[8] CoRoT-10, CoRoT-14, CoRoT-19, CoRoT-8, CoRoT-9, HD 73526, Kepler-5, WASP-23, OGLE 2003-BLG-235, Oph 11, HU Aqr, KOI-204, UZ For, and WD 0806-661B.

4.1. Young Disks

Five of the nine warm excess systems in our sample are young stellar sources, 2M1207, CT Cha, GQ Lup, LkCa 15, and UScoCTIO 108, and all show warm dust excess emission at both W3 and W4 wavebands. Using *Spitzer*, these objects have been previously known to harbor warm dust (Riaz et al. 2006; Manoj et al. 2011; Kessler-Silacci et al. 2006; Espaillat et al. 2007), except for UScoCTIO 108. This star, a young stellar source in the nearest OB association Scorpius–Centaurus, is an 11 Myr old M7 type star, 142 ± 2 pc away (Pecaut et al. 2012). Discovered by direct imaging, UScoCTIO 108 is orbited by at least one substellar-mass companion ($M = 16^{+3}_{-2}\,M_J$) at a distance of 670 AU from the star (Béjar et al. 2008). A simple SED fit (Figure 2) to the *WISE* data using the Robitaille grid suggests that this object has an optically thick disk. It has excess flux ratios ($F_d/F_\star$) of 4.0 in W3, and greater than 20 times the expected photosphere in W4. We estimate a disk mass accretion rate $\approx 1.3 \times 10^{-10}\,M_{\mathrm{sun}}\,\mathrm{yr}^{-1}$, $L_{\mathrm{Tot}} \approx 0.016\,L_\odot$, $R_{\mathrm{disk}} \approx 43$ AU, and a disk mass of $M_{\mathrm{disk}} \approx 6.73 \times 10^{-6}\,M_\odot$, assuming an inclination angle of ~76° and $A_V = 1.63$.

4.2. Main-sequence Debris Disks

Our search yields three planetary systems around main-sequence stars that have measurable *WISE* excesses at levels $\geqslant$20% above that expected from the photosphere in the W4 *WISE* band: β Pic, ϵ Eri, and HR 8799. With $(\mathrm{S/N})_{\mathrm{dust}} > \sim 5$, all three star–planet systems are already known to harbor warm dust emission (Wahhaj et al. 2003; Backman et al. 2009; Su et al. 2009).

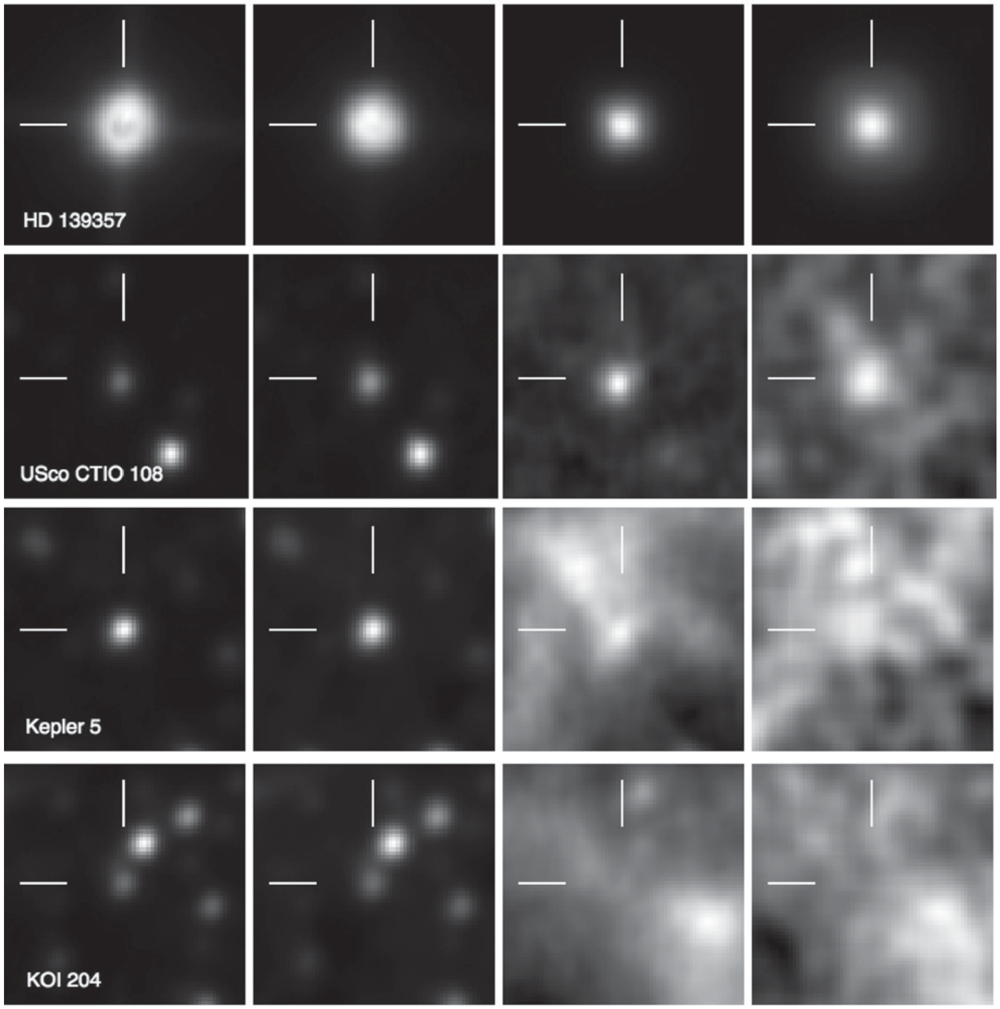

Figure 3. $1'.4 \times 1'.4$ *WISE* images (W1,. . .,W4 from left to right) in min–max linear scales of the four planet-bearing stars in Figure 2. After visual inspection, we find that HD 139357 and UScoCTIO 108 are clear point sources in all bands. UScoCTIO 108 has some low-level contamination due to background emission in the W4 band of $\lesssim$10% that of the central source using a small aperture extraction. Kepler 5 and KOI 204 (bottom two rows) have SEDs in Figure 2 with apparent *WISE* excesses but lack a point source at the location of the star in bands W3 and W4. We find that the reported W3 and W4 fluxes in the all-sky *WISE* catalog for these two planet-bearing star examples are due to background emission and not necessarily related to the planet–star system.

4.3. Dust around Evolved Stars

There is one evolved star in our final excess candidate list, HD 139357, with spectral type K4 III and 121 pc from the Sun. It is orbited by a giant planet discovered using the RV technique; a $9.8 \pm 2.2\, M_J$ exoplanet at 2.4 ± 0.2 AU (Döllinger et al. 2009). The SED fit in Figure 2 of HD 139357 suggests the presence of excess emission at 22 μm, but this star is bright ($K = 3.4$ mag), with photometry above the *WISE* saturation levels in W1,. . .,W3 which are thus not used in the fitting analysis. Although the photometric extrapolations for W1,. . .,W3 are provided in the *WISE* all-sky catalog and the *WISE* images show this giant star as a point source in infrared emission, the accuracy of the W1,. . .,W3 measurements are highly uncertain. With a borderline $(S/N)_{\rm dust} = 3$ in W4 and because it survives our discriminating filters, this star remains in Table 1 but is still inconclusive until its photometry can be more accurately measured. One possible explanation for warm dust around giants comes from Jura (2004) and Jones (2008), who propose that as stars ascend the red giant branch and become more luminous, thermal sublimate from comet-like bodies in an analog to the Kuiper Belt could occur and therefore dust would be released into the surroundings.

4.4. On the Overall Sample

For the seven cases of directly imaged substellar-mass companions (two main-sequence and five young stars), the warm dust is inferred to be located interior to the imaged planet(s), where the dust is asteroidal in temperature and the planets are gas giants. On the other hand, the planetary companions detected using the RV technique around ϵ Eri and HD 139357 are exoplanets found within a few AU (~3.4 and ~2.4 respectively) from the parent stars, and may influence the origin and evolution of the warm dust.

In the case of ϵ Eri (K2V), the planet ($1.55 \pm 0.24\, M_J$) is only 3.4 ± 0.4 AU from the star and an asteroidal belt is thought to be unstable. According to Reidemeister et al. (2011), the observed warm dust can stem from the outer "Kuiper Belt," get transported inward by Poynting–Robertson drag, and the inner planet may have little effect on the distribution of warm dust.

5. SUMMARY AND CONCLUSIONS

In summary, of the 591 planetary system (728 extrasolar planets) in the Exoplanet Encyclopaedia as of 2012 January

31, 350 are robustly detected by *WISE*, and nine stars have mid-IR excesses ($S/N_{dust} \geqslant 3$) measurable with *WISE* at 12 and/or 22 μm (W3 and/or W4). The excess emission is indicative of dust at characteristic temperatures that correspond to the habitable and/or terrestrial zones around the stars.

Overall, the ~2.6% incidence of warm dust emission from planet-bearing stars is lower than that of ~4% from unbiased samples studied with the *Spitzer Space Telescope* (Bryden et al. 2006; Trilling et al. 2008; Lawler et al. 2009; Carpenter et al. 2009). Note that *Spitzer* determinations may go to dust fractional excesses as low as ~10%, where with *WISE* we achieve $\gtrsim$20% above the photosphere (Fomalhaut and HD 10647 in Table 1, for example, have fractional excess <20% at ~20 μm as seen by *Spitzer* but are only $\sim 2\sigma$ with *WISE* W4). Also, some of the stars in our sample are fainter than the corresponding *Spitzer* targets. Thus, it is not surprising that the incidence of warm dust around planet-bearing stars as seen with *WISE* is somewhat lower than the pointed surveys using *Spitzer*.

The stars considered here can be divided into three categories as a function of their evolutionary state—young, main sequence, and evolved (Table 1). In that case, there are three warm debris disk robustly confirmed by *WISE* around the ~350 main-sequence planet-bearing stars, for an incidence of excess of ~1% (where for the young stars only, the incidence is closer to ~38%). The low warm debris disk incidence is in agreement with Padgett et al. (2012), but lower than some recent studies focusing on *Kepler* candidate planetary system (Ribas et al. 2012; Lawler & Gladman 2012). Based on a detailed analysis of all *Kepler*-observed objects, Kennedy & Wyatt (2012) conclude that the previous *Kepler*-based studies were contaminated by background galaxies.

In conclusion, using the *WISE* all-sky data release,

1. We recover previously known warm excess systems above a dust detection limit of $F_{d,\mathrm{W4}}/F_\star \gtrsim 0.2$; stars just below this threshold (e.g., Fomalhaut and HD 10647) only yield $\sim 2\sigma$ excesses.
2. We find one unambiguous new excess system around the young stellar source UScoCTIO 108. Although the region around this object shows some low-level background emission, the target is robustly detected at both W3 and W4.
3. The fraction of planet-bearing stars with *WISE* 12 and/or 22 μm excesses is ~2.6% including young, main-sequence, and evolved stars, but ~1% for planetary debris disks around main-sequence stars only.
4. The identification of mid-IR excesses using the *WISE* all-sky release requires the examination of the images in all cases to confirm the presence of a bona fide point source at the location of the star.

The large number of W3 and W4 entries in the *WISE* all-sky catalog (170 and 30 million with $>2\sigma$ detections in each band), although they are not all high S/N stellar sources, offers a unique opportunity to explore the incidence of warm dust (down to the sensitivity of *WISE*) for all stellar sources, and not only for those where substellar companions have been identified. Determining the incidence of warm dust is important to further our understanding of the matter available to form planets in the habitable zones around stars, and the processes by which rocky terrestrial-like bodies form.

The research described in this publication was carried out with internal R&TD funding at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. This publication makes use of data products from the Two Micron All Sky Survey (2MASS) and from the SIMBAD Web site. This publication also makes use of data products from the *Wide-field Infrared Survey Explorer*, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration. This research has made use of the NASA Exoplanet Archive, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program.

REFERENCES

Backman, D., Marengo, M., Stapelfeldt, K., et al. 2009, ApJ, 690, 1522
Batalha, N. M., Rowe, J. F., Bryson, S. T., et al. 2012, arXiv:1202.5852B
Beichman, C. A., Bryden, G., Rieke, G. H., et al. 2005, ApJ, 622, 1160
Beichman, C. A., Bryden, G., Stapelfeldt, K. R., et al. 2006, ApJ, 652, 1674
Béjar, V. J. S., Zapatero Osorio, M. R., Pérez-Garrido, A., et al. 2008, ApJ, 673, L185
Bryden, G., Beichman, C. A., Carpenter, J. M., et al. 2009, ApJ, 705, 1226
Bryden, G., Beichman, C. A., Trilling, D. E., et al. 2006, ApJ, 636, 1098
Carpenter, J. M., Bouwman, J., Mamajek, E. E., et al. 2009, ApJS, 181, 197
Chen, C. H., Patten, B. M., Werner, M. W., et al. 2005, ApJ, 634, 1372
Chen, C. H., Sargent, B. A., Bohac, C., et al. 2006, ApJS, 166, 351
Cutri, R. M., Skrutskie, M. F., van Dyk, S., et al. 2003, VizieR Online Data Catalog, 2246
Döllinger, M. P., Hatzes, A. P., Pasquini, L., et al. 2009, A&A, 499, 935
Espaillat, C., Calvet, N., D'Alessio, P., et al. 2007, ApJ, 670, L135
Høg, E., Fabricius, C., Makarov, V. V., et al. 2000, A&A, 355, L27
Jones, M. H. 2008, MNRAS, 387, 845
Jura, M. 2004, ApJ, 603, 729
Kalas, P., Graham, J. R., Chiang, E., et al. 2008, Science, 322, 1345
Kennedy, G. M., & Wyatt, M. C. 2012, arXiv:1207.0521K
Kessler-Silacci, J., Augereau, J.-C., Dullemond, C. P., et al. 2006, ApJ, 639, 275
Krivov, A. V., Reidemeister, M., Fiedler, S., Löhne, T., & Neuhäuser, R. 2011, MNRAS, 418, L15
Lagrange, A.-M., Gratadour, D., Chauvin, G., et al. 2009, A&A, 493, L21
Lawler, S. M., Beichman, C. A., Bryden, G., et al. 2009, ApJ, 705, 89
Lawler, S. M., & Gladman, B. 2012, ApJ, 752, 53
Manoj, P., Kim, K. H., Furlan, E., et al. 2011, ApJS, 193, 11
Marois, C., Macintosh, B., Barman, T., et al. 2008, Science, 322, 1348
Morales, F. Y., Rieke, G. H., Werner, M. W., et al. 2011, ApJ, 730, L29
Morales, F. Y., Werner, M. W., Bryden, G., et al. 2009, ApJ, 699, 1067
Padgett, D. L., Liu, W., Stapelfeldt, K., Fajardo-Acosta, S., & Leisawitz, D. 2012, ApJ, in press
Pecaut, M. J., Mamajek, E. E., & Bubar, E. J. 2012, ApJ, 746, 154
Plavchan, P., Werner, M. W., Chen, C. H., et al. 2009, ApJ, 698, 1068
Reidemeister, M., Krivov, A. V., Stark, C. C., et al. 2011, A&A, 527, A57
Riaz, B., Gizis, J. E., & Hmiel, A. 2006, ApJ, 639, L79
Ribas, Á., Merín, B., Ardila, D. R., & Bouy, H. 2012, A&A, 541, 38
Robitaille, T. P., Whitney, B. A., Indebetouw, R., & Wood, K. 2007, ApJS, 169, 328
Robitaille, T. P., Whitney, B. A., Indebetouw, R., Wood, K., & Denzmore, P. 2006, ApJS, 167, 256
Schneider, J., Dedieu, C., Le Sidaner, P., Savalle, R., & Zolotukhin, I. 2011, A&A, 532, A79
Stapelfeldt, K. R., Holmes, E. K., Chen, C., et al. 2004, ApJS, 154, 458
Su, K. Y. L., Rieke, G. H., Stansberry, J. A., et al. 2006, ApJ, 653, 675
Su, K. Y. L., Rieke, G. H., Stapelfeldt, K. R., et al. 2009, ApJ, 705, 314
Trilling, D. E., Bryden, G., Beichman, C. A., et al. 2008, ApJ, 674, 1086
Wahhaj, Z., Koerner, D. W., Ressler, M. E., et al. 2003, ApJ, 584, L27
Werner, M. W., Roellig, T. L., Low, F. J., et al. 2004, ApJS, 154, 1
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868