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Early Debris Disk Results from the WISE All-Sky Survey

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WISE, The Wide-Field Infrared Survey Explorer

WISE is a NASA medium-class Explorer mission conducting a new all-sky survey in the mid-infrared. The Principal Investigator is Professor Ned Wright of UCLA. WISE launched successfully on a Dela II into an sun-synchronous polar orbit and began surveying the sky at 3.4, 4.6, 12 and 22 μm on 14 January 2010. As of 17 July, the entire sky has been imaged with at least 8 separate 8.8 second frames per position. The focal plane consistst of separate array detectors for each band, utilizing 1024x1024 detections (HgCdTe for 3.4 & 4.6 μm, Si:As for 12 and 22 μm). The achieved SNR 5 point source sensitivity on the ecliptic is 0.08, 0.11, 0.1 and 6 mJy respectively in the four bands and is better elsewhere on the sky (Wright et al. 2010). Thus, WISE is two orders of magnitude more sensitive than IRAS at 12 and 25 μm. At 3.3 and 4.6 μm, WISE is slightly deeper than 2MASS in detection of stellar photospheres. Astrometric errors are less than 0.15 arcsec (1-σ, 1 axis). WISE uses the Spitzer and 2MASS calibration system, with a set of calibration sources arrayed around the ecliptic poles. The photometric repeatability is excellent in all bands. Solid hydrogen cryogen in the secondary tank was exhausted on 06 August, which led the telescope to warm up and a cessation of 22 micron observing. Repeat sky mapping with the other three bands will continue until the primary cryogen talk is exhausted in October 2010. Provisional processing of the existing survey data, including single and multi-frame images and detections, photometry, and astrometry, is available to WISE team members now. The first data release will be in mid-April 2011, with the full sky survey dataset released to the community in early 2012.

Above: WISE Science Team member Deborah Padgett seen with the integrated WISE satellite at Ball Aerospace

Above: WISE launch from the Western Test Range, California, just before dawn on 14 December 2009

WISE and Debris Disks

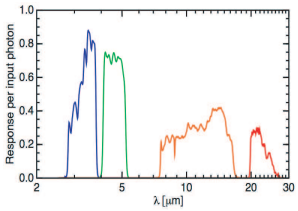
The Spitzer Space Telescope has carried out targeted surveys of solar neighborhood stars and nearby star-forming clouds to characterize the occurrence of warm dust excess around solar type stars. Warm (22 - 24 μm) dust emission is important because it probes the terrestrial planet formation region in the disk within a few AU from the central star with the exact distance depending on the spectral type (Meyer et al. 2008). The transient nature of this emission has been explored by Wyatt et al. (2007), who suggest that warm excess in Gyr-age stars may arise from dynamical instability in an outer asteroidal belt, similar to the purported cause of late heavy bombardment in our solar system, which resurfaced the moon and other terrestrial bodies with craters. A substantial fraction of pre-main sequence stars, and essentially all accretionally active ``classical" T Tauri stars, possess sizeable 24 μm excesses (Muzerolle et al. 2010; Rebull et al. 2010). On the other hand, field stars with infrared excesses at 24 μm are rare. Overall, only 4% of solar-type stars have 24 μm excess (Trilling et al. 2008), and the excess level is typically a fraction of a magnitude.

Stars with warm excess are an important subsample of debris disks as a whole. They tend to have the highest fractional infrared luminosities, making them most suitable for far-IR spectroscopy and high resolution imaging (Kalas et al. 2008; Schneider et al. 2009). Recent studies (Rieke et al. 2005, Carpenter et al. 2009, Trilling et al. 2008, Rebull et al. 2008) indicate that the presence of the warm excess is correlated with youth, appearing at 3x greater frequency for late-type stars with ages $\leq$ 300 Myrs. Indeed, the youth of some stars in the solar neighborhood was originally revealed by their infrared excess emission (Zuckerman & Song 2004). These young systems are in a critical evolutionary period and may be experiencing disturbances analogous to the late heavy bombardment. They are also optimum targets for direct imaging of planetary companions before they cool off and fade beyond detectability. Spitzer surveys for 24 μm excess among field stars have been limited to bright targets, kinematic groups associated with IRAS excess stars, and stars within 25 pc. These searches have failed to find any warm disks around M stars (Gautier et al. 2007), the most numerous stellar type in the galaxy. Examples of potentially transient warm dust belts are in the Gyr-age system HD 69830 (Beichman et al. 2005) and the binary BD+20 307 (Song et al. 2005). WISE provides an important new capability for finding numerous new examples of such sources.

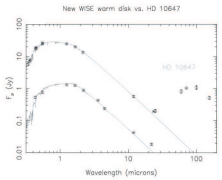
Source Selection: From the 85% sky coverage available in mid-July 2010, we selected the ~2 million WISE sources detected at 22 μm with S/N >10. These were bandmerged to the Hipparcos and Tycho catalogs, yielding matches for ~108 thousand stars. Among these, median [3.6]-[22] colors were derived as a function of stellar B-V. Excess sources were identified as those with [3.6]-[22] colors that differed from the median by more than 4-σ (~> 0.3 mag). This color is within the WISE calibration system and is therefore insensitive to cross-calibration issues. Among the thousands of excess sources thus identified, we focus on those within the 140 distance horizon of the nearest star-forming regions. We recover many known debris disks with small levels of 24 μm excess originally seen in Spitzer MIPS observations, confirming the quality of the current WISE calibration. The quality of each source is confirmed by visual checks of the WISE images; confused or glitched sources were dropped from further consideration, and known image artifacts are flagged by the automated software and confirmed by visual check. Close multiple systems were rejected by through SIMBAD checks, as were all sources within 5° of the galactic plane to ensure low sky backgrounds. Debris disks known from IRAS, ISO, and Spitzer measurements were also excluded. This process identifies approximately 500 warm debris disk candidates.

Results: Exmaple New Debris Disks with 22 micron Excess

SpT	dis (pc)	gal lat	J mag	H mag	K mag	3.5 mag	4.6 mag	13 mag	22 mag
M3	35	-65 :	0.00	0.00	0.00	8.01	7.90	7.77	7.28
M3	11	-38 :	7.95	7.35	7.12	6.87	6.71	6.62	6.40
M2	26	-44 :	8.37	7.77	7.58	7.42	7.28	7.20	6.94
M2	24	80 :	0.00	0.00	0.00	7.18	7.11	6.96	6.62
M0	30	-24 :	8.64	7.97	7.77	7.70	7.63	7.49	7.23
K4	30	-41 :	0.00	0.00	0.00	7.52	7.57	7.49	7.05
K0	45	-48 :	8.01	7.61	7.51	7.47	7.48	7.44	6.96
G9	37	-43 :	7.25	6.87	6.74	6.70	6.74	6.67	6.36
G8	50	-50 :	7.71	7.30	7.20	7.14	7.14	7.09	6.64
G5	46	-53 :	7.55	7.25	7.15	7.11	7.15	7.07	6.78
G5	35	20 :	7.10	6.78	6.69	6.72	6.73	6.56	6.39
F5	50	-29 :	6.41	6.21	6.11	6.26	6.12	6.13	5.80
F5	47	-60 :	6.34	6.08	5.99	5.94	5.88	5.92	5.46
F5	41	-50 :	6.26	6.09	5.98	6.00	5.90	5.93	5.67
B9	69	-20 :	5.67	5.66	5.68	5.57	5.59	5.53	4.61
A5	71	-25 :	6.32	6.30	6.24	6.26	6.24	6.11	5.28
A3	71	-54 :	6.16	6.11	6.10	6.09	6.07	6.09	5.40
A2	62	-22 :	5.99	5.99	5.97	5.92	5.92	5.89	5.16
A1	71	-18 :	6.38	6.39	6.28	6.25	6.25	6.19	4.80
A0	70	-8 :	5.86	5.87	5.87	5.90	5.79	5.75	5.17
A0	69	-8 :	5.94	5.91	5.89	5.94	5.83	5.85	5.29



WISE photometric system response for the four survey bands



Upper curve: optical, near-IR, and far-IR photometry for the HD 10647 debris disk (Liseau et al. 2010) compared to a Kurucz photospheric model. The lower curve shows the same information for a new G8 WISE warm debris disk star. The 22 μm excess is 0.5 mag and detected at S/N= 7. Photometric error bars appear inside the plotted points.

Next Steps

The source selection will be repeated when improved versions of the WISE source catalogs become available. Specific care will be needed to locate high proper motion stars in the catalog, for which 2MASS associations are currently missing.

A spectroscopic investigation of N hemisphere candidates (to measure age indicators) will take place at Palomar in fall 2010.

A paper presenting the new warm disk candidates will be submitted in early 2011.

A Herschel OT1 proposal to characterize the cold outer disk in a subset of the targets was submitted.

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