Warm Debris Disks
with WISE and Herschel

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and the WISE Science Team
Project Overview

**Salient Features**
- 4 imaging channels covering 3 - 25 microns wavelength
- 40 cm telescope operating at <17K
- Two stage solid hydrogen cryostat
- Delta launch from WTR: 14 Dec 2009
- Sun-synchronous 6am 530km orbit
- Scan mirror provides efficient mapping
- Expected life: 10 months, actual 7.7-9.5
- 4 TDRSS tracks per day

**Science**
- Sensitive all sky survey with 8X redundancy
  - Find the most luminous galaxies in the universe
  - Find the closest stars to the sun
  - Provide an important catalog for JWST
  - Provide lasting research legacy

Wide Field Infrared Survey Explorer
WISE Summary

• Launched 14 Dec 2009
• Band centers 3.4, 4.6, 12 & 22 microns
• Sensitivity better than 0.08, 0.11, 1 & 6 mJy
• Saturation at 0.3, 0.5, 0.7 & 10 Jy point sources
• Angular Resolution 6, 6, 6 & 12 arc-seconds
• Position accuracy about 0.15 arc-seconds 1σ 1-axis for high SNR
• Completed all-sky survey 17 July, big tank ran out hydrogen 5 Aug, little tank empty on 29 Sep, two-band survey for asteroids continued until 1 Feb 2011.
• Data releases:
  - 57% of the sky was released on April 2011
  - All-sky release was last week - 14 March 2012!
• Data products include image atlas and source catalog
  http://irsa.ipac.caltech.edu/Missions/wise.html
DIRBE 3.5 microns
IRAS 12 microns
WISE
3.4, 4.6, 12 microns
47’ FOV
2.75” pixels
6” FWHM
V482 Car
33 seconds in the life of WISE:
3 of >7000 frames/day

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Debris Disk Frequency from Spitzer Surveys (Trilling et al. 2008)
WISE Debris Disk Survey Goals

• *Spitzer* showed that 24 µm excess was rare among solar–type main sequence stars - all sky survey can complete inventory of these objects; WISE 100x more sensitive than IRAS

• 22 µm excess more common at young ages – potential way to identify young field stars (and thus young planets)

• Find new strong-excess disks for high resolution follow-up imaging with HST, ALMA, etc.
WISE Debris Disk
Survey Strategy

- Hipparcos/Tycho/Gliese catalogs correlated with All-sky survey (final WISE processing) – 25964 HIP matches
- Position search radius of 5” (including proper motions)
- Distances out to 120 pc
- Spectral types B – M
- Candidates have W1-W4 > 25% greater than 4σ significance
- W1 > 3.5 to avoid worst saturation effects
- Every candidate has been examined in the WISE and 2MASS images for confusing sources and positional shifts in centroid from band to band; note problems and rejects
• 518 Hipparcos/WISE stars have apparent 22 micron excess > 4σ
• 348 are new (not previously determined to have excess in mid- to far-IR as of late 2011)
• 170 are previously known debris disk stars from IRAS, ISO, Spitzer, Akari
• Typical Hipparcos/WISE positional offset (WISE band 1) of 0.1-0.2")
Debris Disks in Hipparcos Stars, d < 120 pc

- B stars: 34 out of 282 \(12.1\pm 2.0\%\)
- A stars: 243 out of 2466 \(9.5 \pm 0.6\%\)
- F stars: 163 out of 10757 \(1.5 \pm 0.1\%\)
- G stars: 67 out of 7489 \(0.9 \pm 0.1\%\)
- K stars: 11 out of 4477 \(0.2 \pm 0.1\%\)
- M stars: 0 out of 493* \(0.0 \pm 0.3\%\)

* Using colors. Photospheric fitting in progress
HR Diagram for WISE
Debris Disk Candidates
HR Diagram for WISE Debris Disk Candidates
WISE 12 µm Excess Stars

- 66 Hipparcos/WISE stars within 120 pc with 12 micron excess
- Many are previously known PMS stars (few with inaccurate distances)
- 12 µm flux density of most measured for first time
- Largely a subset of 22 µm excess stars; few are too faint for reliable 22 µm measurements
- 28 new 12/22 µm excess stars
**Caveat Emptor**

- Confusion is big issue for fainter stars
- Confusion often suggested by positional shift of emission centroid at long wavelengths
- Very saturated W1 sources produce false excess
- Photometric contamination from bright 22 µm companions and diffuse background nebulosity may produce false excess sources
- Astrophysical mimics include bright AGN, PN, cataclysmic variables, K and M giants
- Bottom line – always check the images
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Caveat Emptor
WISE Debris Disk
Hubble Follow-up

• Cycle 19 12 orbits approved on STIS for coronagraphic wedge imaging of 6 nearby WISE debris disk candidates

• Objective is to detect scattered light from cold dust disk in objects with newly detected warm dust IR excess

• Two objects observed to date

What we hope to see!

HST/STIS image of HD 141569 (IRAS/Spitzer disk)
Keck High Contrast Follow-up to WISE Debris Disk Sources

- Excess at 22 mm indicates dynamical stirring & stellar youth.

- ~40 A-stars with WISE 22 mm excess already observed (February, October 2011); Now need common proper motion to confirm candidates

- Three more Keck nights in June 2012 PI: Sasha Hinkley (Caltech)

- Data Analysis (speckle reduction) ongoing by Hinkley, Mawet (ESO)
- CPM Follow-up needed for any candidate companions
Herschel/PACS Photometry of WISE Debris Disk Candidates

• For most of its debris disk candidates, WISE only gives a single photometric point for the excess.

• Does this emission arise from
  • A warm inner belt in the terrestrial planet region (such as for HD 69830, BD+20 307) ?
  • Wien side of emission from cold/massive outer belt ?

• Full characterization of the detected disks requires Herschel
  - dust temperature
  - Fractional luminosity / total dust content
WISE Debris Disk Candidate Herschel Observations

- Herschel/PACS 70 & 160 micron imaging 99 new WISE 22 micron excess FGK stars
- 71/82 sources detected to date at 70 µm
- 36 detected at 160 µm
Resolved Sources

- 8 PACS detections in this class
- Disks or nearby heated ISM?
HIP 35198 looks like an interesting cold disk. However, the PACS images showed the 70 micron source is 8” from the star position. This offset is hidden in the WISE data because the stellar photosphere still dominates at 22 µm. 17 of our PACS 70µm detections are > 4” from the stellar position.
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HIP 117481 Spectral Energy Distribution

\[ \frac{\lambda F_\lambda}{\lambda} \times 10^{-7} \]

10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7}

Wavelength (microns)
TYC 614–525–1 Spectral Energy Distribution
TYC 251–1015–1 Spectral Energy Distribution

\[ \lambda F_\lambda \]

Wavelength (microns)

10^{-13} \ 10^{-12} \ 10^{-11} \ 10^{-10} \ 10^{-9} \ 10^{-8}
HIP 67497 Spectral Energy Distribution
HIP 64837 Spectral Energy Distribution

\[ \lambda F(\lambda) \]

Wavelength (microns)
Disk Properties

- Temperature estimates based on ratio of 22 µm to 70 µm excess emission
- Temperatures of dust range from 60 – 150 K
- Roughly equal numbers of “cold” < 80 K and “warm” > 100 K systems are found
- Fractional luminosities range 0.05-2x beta Pic
- Sources with 12 µm excess appear to be younger than sample as a whole (Sco-Cen)
- Some sources show evidence of multiple temperature components in SED
Future Work

• Extend debris disk survey to greater distances, fainter stars; A star photospheres visible to several hundred pc
• Concentration on individual sources and samples of interest (stars with planets, etc.)
• Kinematic associations for new disk candidates
• Better characterization of WISE data “gotchas”
• Uniform spectral classification and spectral age indicators for new disk hosts (Palomar)

This talk 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.