*Wide-field Infrared Survey Explorer*

# Optical Spectroscopic Survey of High Latitude *WISE* Selected Sources *(submitted)*

**Sean Lake**[1], E. L. Wright[1], S. Petty[1], R. J. Assef[2,3], T. H. Jarrett[4], S. A. Stanford[5,6], D. Stern[2], C.-W. Tsai[4]

[1]*University of California, Los Angeles*
[2]*Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109*
[3]*NASA Postdoctoral Program Fellow*
[4]*Infrared Processing and Analysis Center (IPAC), California Institute of Technology, Pasadena, CA 91125, USA*
[5]*Department of Physics, University of California, Davis, CA 95616*
[6]*Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, Livermore CA 94551*

Acknowledgements
This publication 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.

**Abstract**

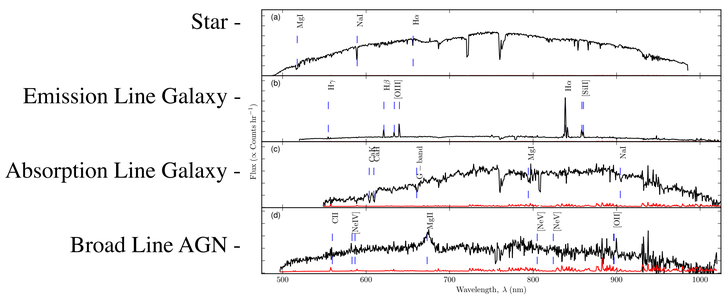
We report on the results of an optical spectroscopic survey at high Galactic latitude ($|b| \geq 30°$) of a sample of *WISE*-selected targets, grouped by *WISE* W1 ($\lambda_{\rm eff} = 3.4\,\mu$m) flux, which we use to characterize the sources *WISE* detected. We observed 762 targets in 10 disjoint fields centered on ultra-luminous infrared galaxy (ULIRG) candidates using the DEIMOS spectrograph on Keck II. We find $0.30 \pm 0.02$ galaxies arcmin$^{-2}$ with a median redshift of $z = 0.33 \pm 0.01$ for the sample with W1 $\geq 120\,\mu$Jy. The foreground stellar densities in our survey range from $0.23 \pm 0.07$ arcmin$^{-2}$ to $1.1 \pm 0.1$ arcmin$^{-2}$ for the same sample. We obtained spectra that produced science grade redshifts for $\geq 90\%$ of our targets for sources with W1 flux $\geq 120\,\mu$Jy that also had $i$-band flux $\gtrsim 18\,\mu$Jy. We used for targeting very preliminary data reductions available to the team in August of 2010. Our results therefore present a conservative estimate of what is possible to achieve using *WISE*'s Preliminary Data Release for the study of field galaxies.

## *Survey Characterisitics:*

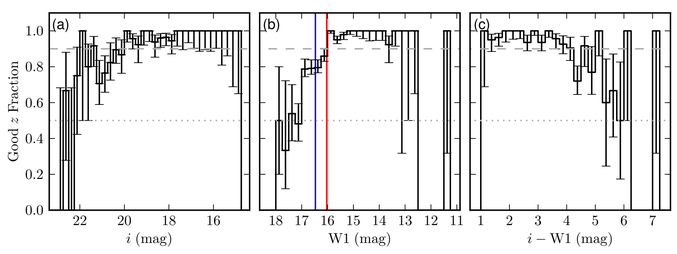
- Area: 57.8 $\mu$Sr (0.190 deg$^2$)
- Median redshift: $0.48 \pm 0.02$
- *WISE* W1 (3.4 $\mu$m) selected
- Targets:

| class, | avail, tried, good |
|---|---|
| - $F_{W1} \geq 120\,\mu$Jy, | 626, 72%, 97% |
| $-120 > F_{W1} \geq 80\,\mu$Jy, | 319, 41%, 84% |
| - $80 > F_{W1}$, | 636, 30%, 62% |

### Typical Spectra:




### Success Rate vs Magnitude:



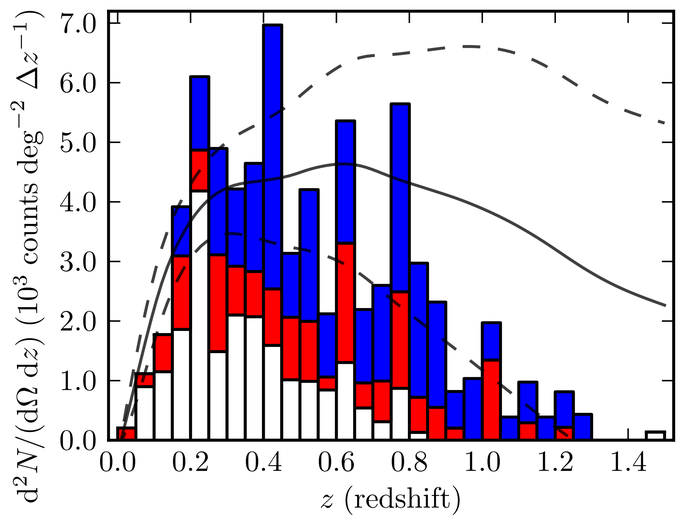

Our success rate versus *WISE* W1 (Vega), Sloan i (AB), and W1-i color. Sample boundaries highlighted with blue & red lines.

## Survey Uniqueness - Photometric Detection Rates:

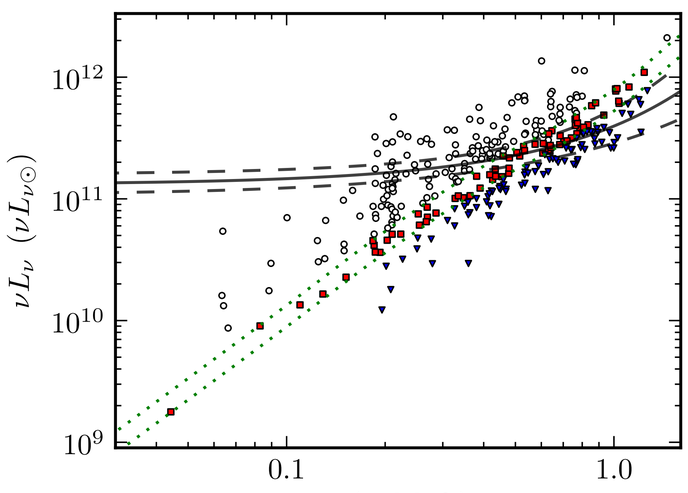
| Filter Name | Emission Galaxies ($f_{Q>2}$ [$N_{\rm tot}$]) | Absorption Galaxies ($f_{Q>2}$ [$N_{\rm tot}$]) | Broad-lined AGN ($f_{Q>2}$ [$N_{\rm tot}$]) | Stars ($f_{Q>2}$ [$N_{\rm tot}$]) |
|---|---|---|---|---|
| $u$ | 58.8% [97] | 29.1% [79] | 91.7% [12] | 79.4% [209] |
| $g$ | 77.3% [97] | 89.9% [79] | 100.0% [12] | 99.0% [209] |
| $r$ | 80.4% [97] | 91.1% [79] | 100.0% [12] | 99.0% [209] |
| $i$ | 81.4% [97] | 96.2% [79] | 100.0% [12] | 99.0% [209] |
| $z$ | 80.4% [97] | 94.9% [79] | 100.0% [12] | 99.0% [209] |
| $J$ | 6.1% [165] | 16.1% [143] | 17.6% [17] | 80.2% [338] |
| $H$ | 6.1% [165] | 16.1% [143] | 11.8% [17] | 78.7% [338] |
| $K$ | 6.1% [165] | 15.4% [143] | 17.6% [17] | 66.0% [338] |
| W1 | 98.2% [165] | 100.0% [143] | 100.0% [17] | 100.0% [338] |
| W2 | 85.5% [165] | 93.7% [143] | 94.1% [17] | 94.7% [338] |
| W3 | 50.9% [165] | 11.9% [143] | 64.7% [17] | 8.9% [338] |
| W4 | 17.6% [165] | 9.8% [143] | 23.5% [17] | 6.2% [339] |

Note. — The fraction of targets with high quality ($Q > 2$) spectra detected ($\sigma \leq 1.0$ mag) by each photometric band, with the number of total available targets in brackets next to the fraction in percent. The photometry used to construct this table came from SDSS DR8, 2MASS, and *WISE*.

## Redshifts & Luminosities:

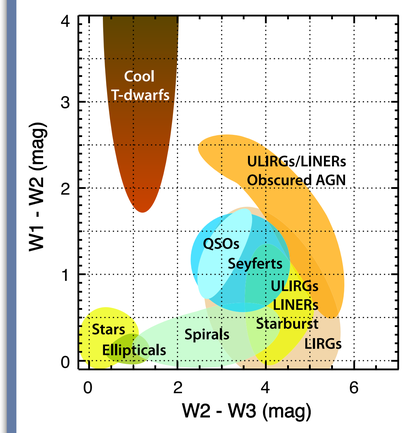



- Redshift Distribution - Shows improvement needed in 3.4 $\mu$m LF
  - Bar height attempt rate corrected.
  - White is $F_{W1} \geq 120\,\mu$Jy, Red is $120 > F_{W1} \geq 80\,\mu$Jy, and Blue is $80 > F_{W1}$.
  - The black line is the $F_{W1} \geq 80\,\mu$Jy prediction based on integrating a Schechter luminosity function using the parameters from Dai et al. (2009). The dashed line is the 1-σ confidence band. The over-prediction is likely due to faster than other measurements $L_*$ evolution.

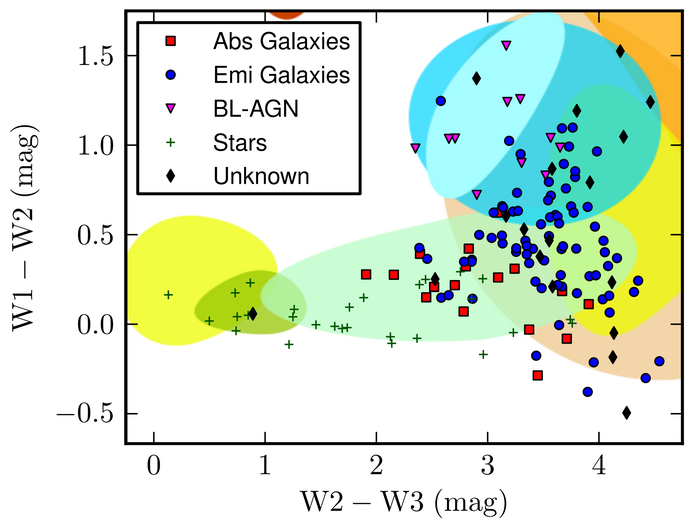



- Target Luminosities - shows redshift to which *WISE* sees $L_*$
  - White is $F_{W1} \geq 120\,\mu$Jy, Red is $120 > F_{W1} \geq 80\,\mu$Jy, and Blue is $80 > F_{W1}$.
  - Green dotted lines are sample boundaries.
  - Black line is $L_*(z)$ from Dai et al. (2009) with 1-σ confidence band as dashed lines.

## *WISE* Colors:

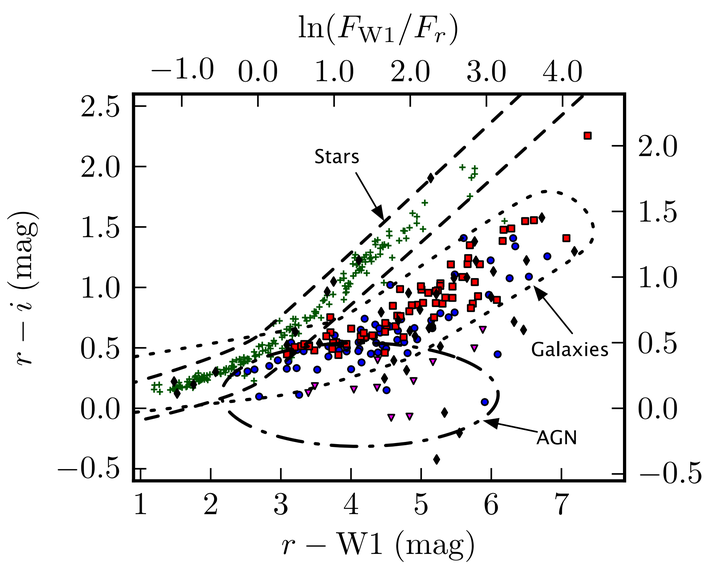



- Predicted Colors
  - Regions highlighted are based on the SWIRE templates of Polletta et al. (2007) augmented with the GRASIL dust models of Silva et al.(1998)



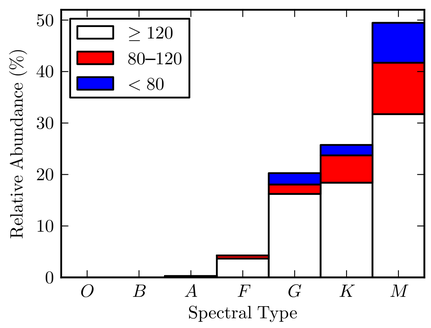

- Observed Colors: the power of *WISE* alone
  - Note that the photometric uncertainty in outlier stars is such that no firm conclusions can be drawn about their W2-W3 color. We also cannot rule out background contamination dominating *WISE* colors and foreground stars dominating the DEIMOS spectra.
  - All data have magnitude uncertainties ≤ 1.0 in all bands used.

## *WISE*-Sloan Colors:



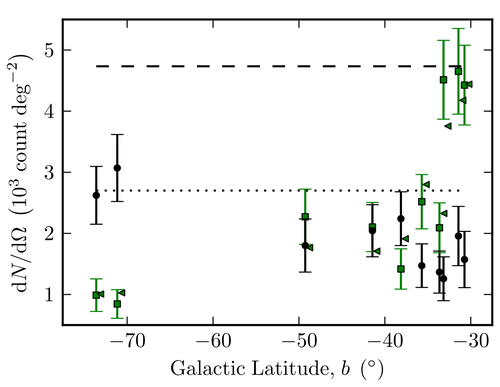

- Observed Colors - photometric classification of red objects
  - An example of *WISE*-Sloan colors with regions where targets from our survey fall.
  - We fixed the size and shape of the labeled regions with DEIMOS data alongside a quasi-random selection of sources from the SDSS-DR8 spectroscopic catalog (not shown).
  - Demonstrates that the majority of sources we did not succeed in finding spectra for are extragalactic.
  - All data have magnitude uncertainties ≤ 1.0 in all bands used.

## Stellar Results:

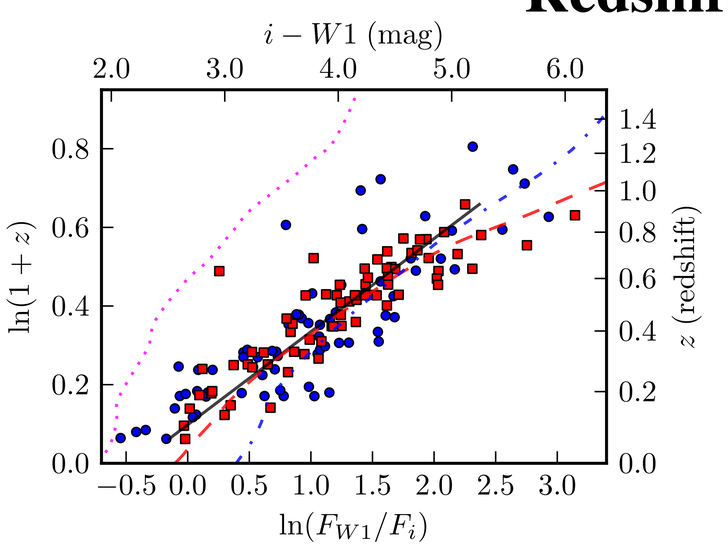



- Spectral classification of stellar targets.
  - Classifications good to ± ½ class or better.

- $F_{W1} \geq 80\,\mu$Jy source densities by Galactic latitude.
  - Green squares are measured stellar densities, triangles are predictions based on Jarrett et al. (1994). Precise agreement.
  - Black circles are measured galaxy densities. Dashed line is the prediction based on integrating a Schechter LF using parameters from Dai et al. (2009). Dotted line is the 1 sigma error in the prediction. Big disagreement.




## Redshifts & Color:




- Color-Redshift Correlation: 1-color photo-z's!
  - An example *WISE*-Sloan color plotted against redshift.
  - The 1.6 $\mu$m maximum in galaxy SEDs produces a nice redshift-color correlation.
  - We fit the color to a linear function of ln(1+z) for galaxies below redshift 1, where the maximum passes through the W1 passband. Grey line is the fit.
  - Red squares are absorption line galaxies and blue circles are narrow-line emission galaxies.
  - The blue, red, and magenta lines are empirical SED templates from Assef et al. (2010), respectively.
  - All data have magnitude uncertainties ≤ 1.0 in all bands used.

- Mathematical Details:
  - Model: $y = m(x - x_0) + b$
  - Likelihood: $-\ln(\mathcal{L}) = \frac{1}{2}\sum_{i=1}^{N}\left[\frac{(y_i - m[x_i - x_0] - b)^2}{(\sigma_{y,i}^2 + [m\sigma_{x,i}]^2 + \sigma_{\rm ext}^2)} + \frac{1}{2}\ln\left(\sigma_{y,i}^2 + [m\sigma_{x,i}]^2 + \sigma_{\rm ext}^2\right)\right]$
  - Definition: $x_0 = \langle x_i \rangle$ with weights : $w_i = \left(\sigma_{y,i}^2 + [m\sigma_{x,i}]^2 + \sigma_{\rm ext}^2\right)^{-1} \Rightarrow$ $= 0.364$
  - Parameters:

| $y$-variable | slope ($m$) | $y$-intercept ($b$) | Scatter ($\sigma_{\rm ext}$) |
|---|---|---|---|
| $\ln(F_{W1}/F_i)$ | $4.2 \pm 0.2$ | $1.05 \pm 0.03$ | $0.33 \pm 0.02$ |
| $i - W1$ | $4.6 \pm 0.2$ mag | $3.81 \pm 0.03$ mag | $0.36 \pm 0.02$ mag |

http://wise.astro.ucla.edu

UCLA