

# New Asteroid Belt Analogs using WISE

Rahul I. Patel

AAS 225 Thesis Talk

Jan. 8<sup>th</sup>, 2015

Work done in collaboration with **Dr. Stanimir Metchev**,  
**Dr. Aren Heinze** and **Joe Trollo**



This work is partially supported by NASA Origins of Solar Systems  
via subcontract No. 1467483



@ripateLastro

# Storyboard:

## QUESTIONS:

How many undetected exo-asteroid belts are there in Solar neighborhood?

What is the frequency of Solar System analogs?

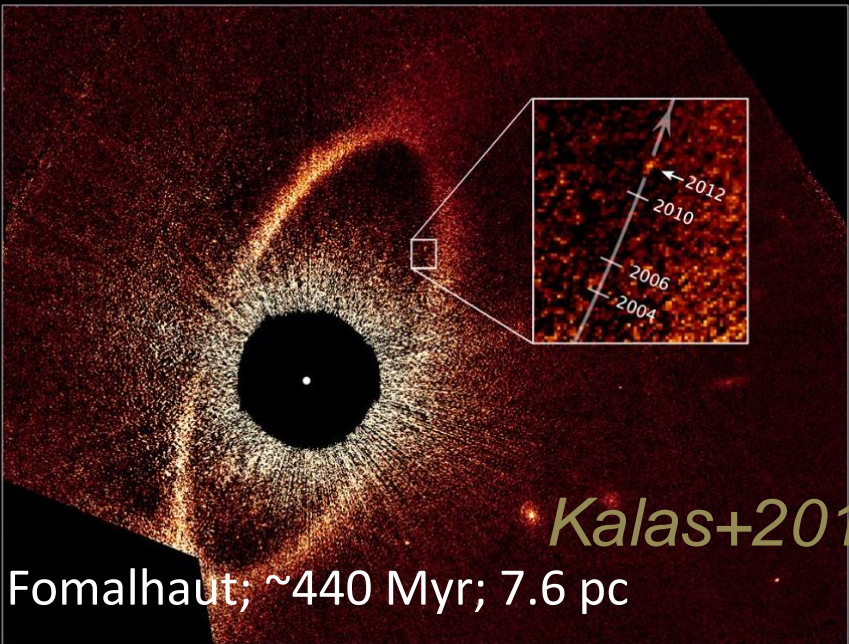
## Approach

Take advantage of 3-30  $\mu\text{m}$  WISE All-Sky data to search for faint nearby exo-asteroid belt systems.

# Studying architecture of exo-debris disks places the Solar System in context.

Fomalhaut System

Hubble Space Telescope • STIS

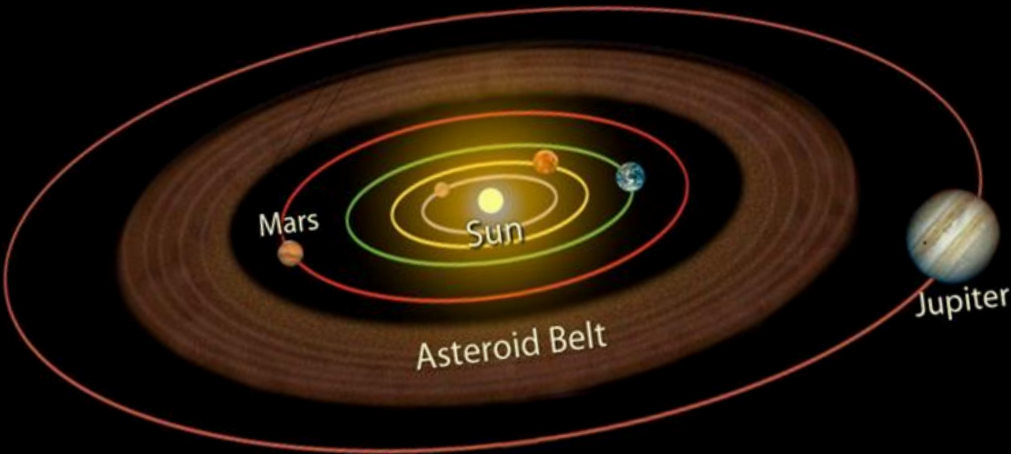
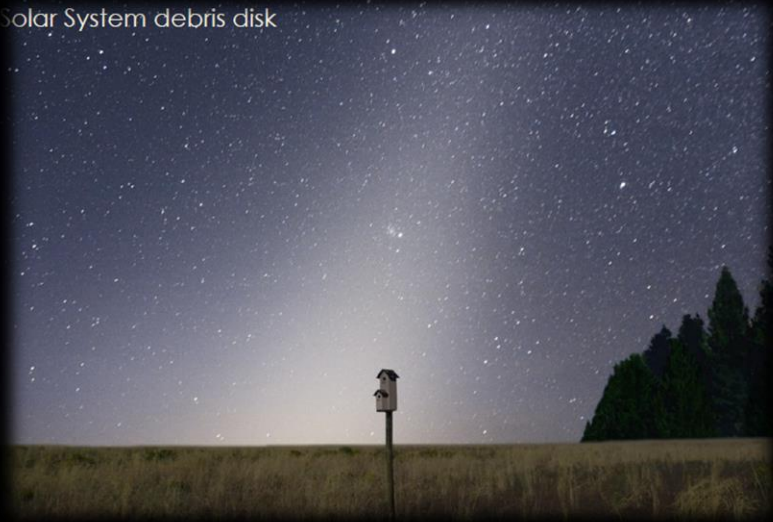


Fomalhaut; ~440 Myr; 7.6 pc

NASA and ESA

STScI-PRC13-01a

Solar System debris disk





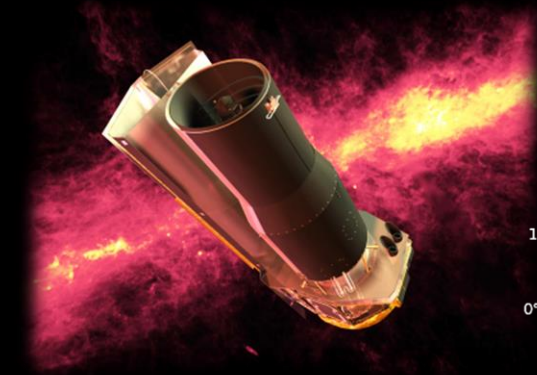
Warm dust probes dynamical activity in inner regions.



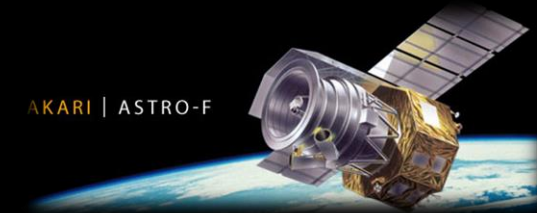
*Matthews+2014 by Kate Su*



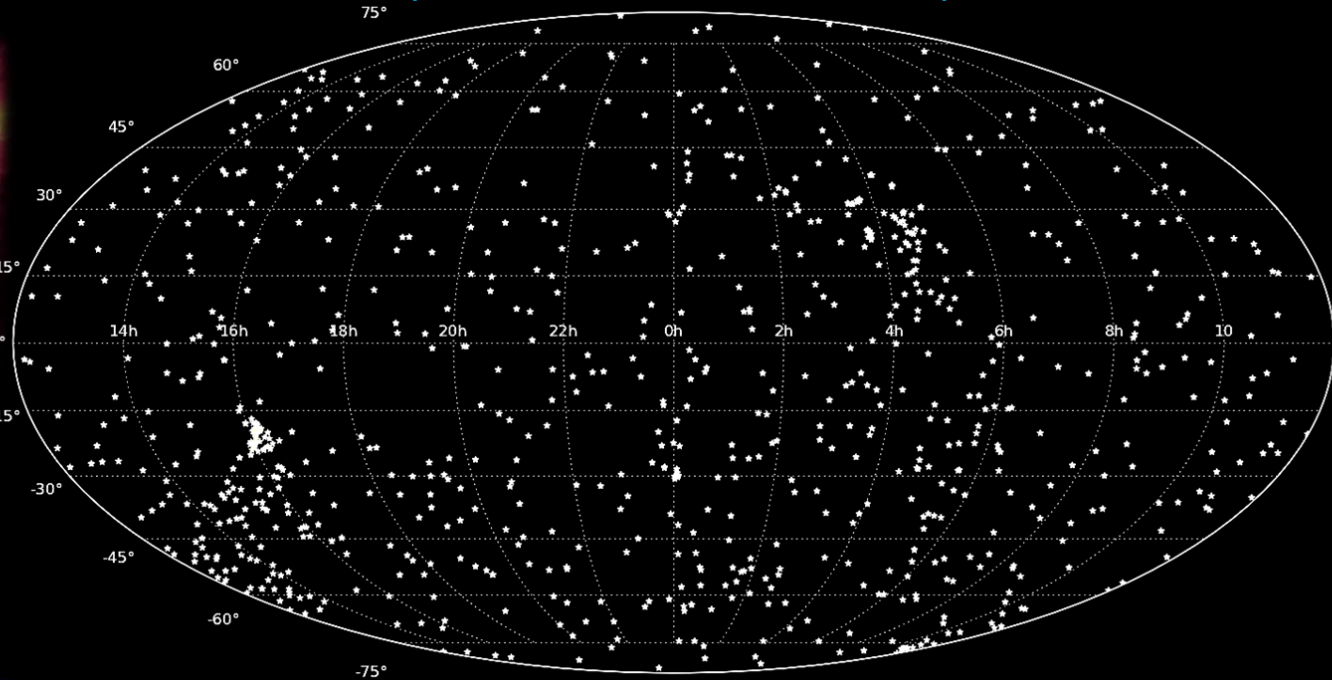
Over past 30 years, >1000 IR excesses detected out to 500 pc;  $\sim 50\% < 75\text{pc}$



*Spitzer, 2003-Present,  
3-180  $\mu\text{m}$*



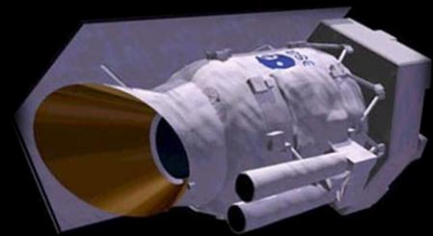
*Akari; 2006-2011*



*Sky positions for  $\sim 900$  protoplanetary and debris  
disk sources*



*Herschel, 2009-2013,  
55-672  $\mu\text{m}$*



*ISO; 1995-1998, 2.5-200  $\mu\text{m}$*

Majority have cold dust emission, while a smaller fraction of stars possess warm dust  
- so then the obvious thing to do is to ...

search for more systems with warm dust

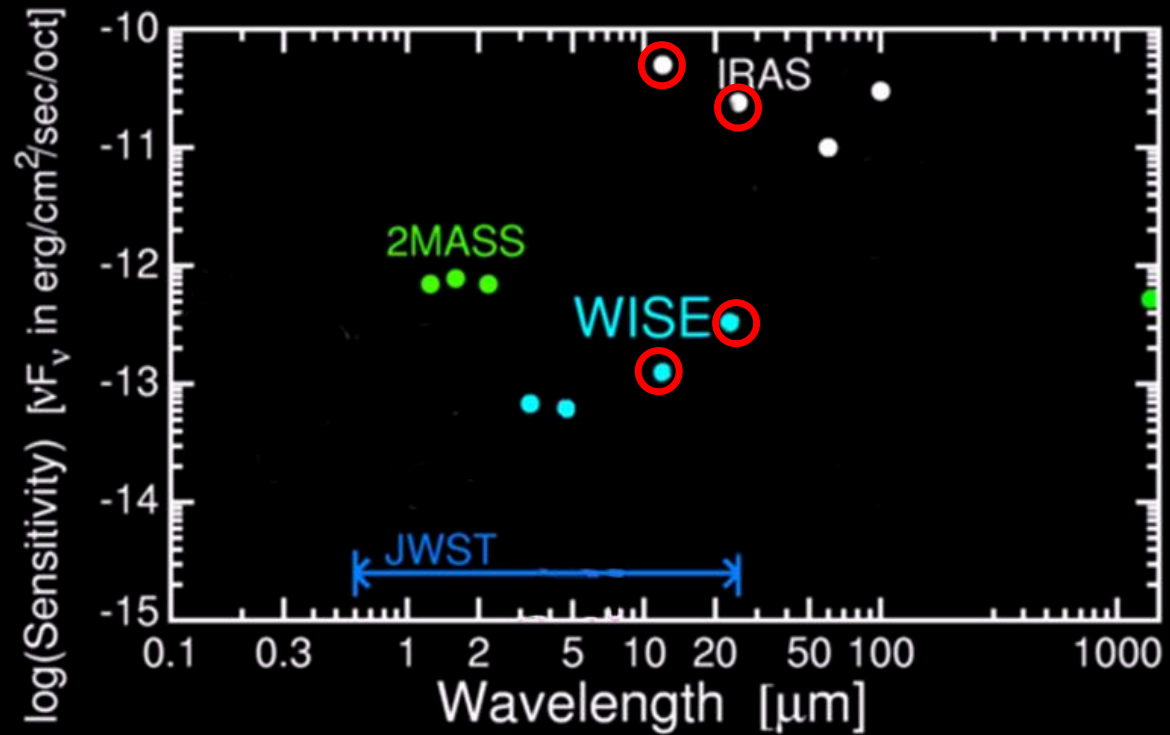


New discoveries from WISE...

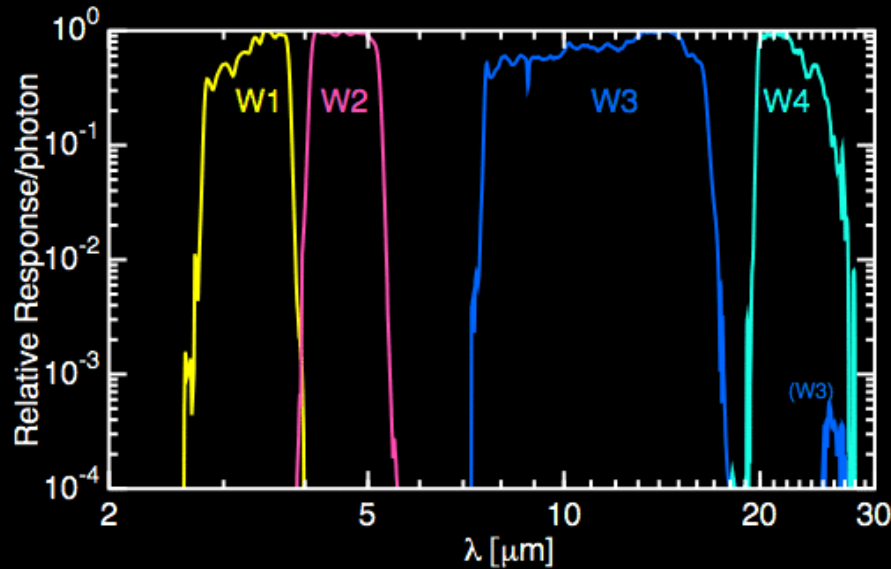
... enable statistical studies  
of debris disks



WISE has greater resolution and sensitivity than IRAS, and greater coverage than pointed surveys.



# WISE mid-IR bands probe dynamical activity in zodiacal dust and asteroid belt regions



**W3- Excess:**

W1-W3

W2-W3

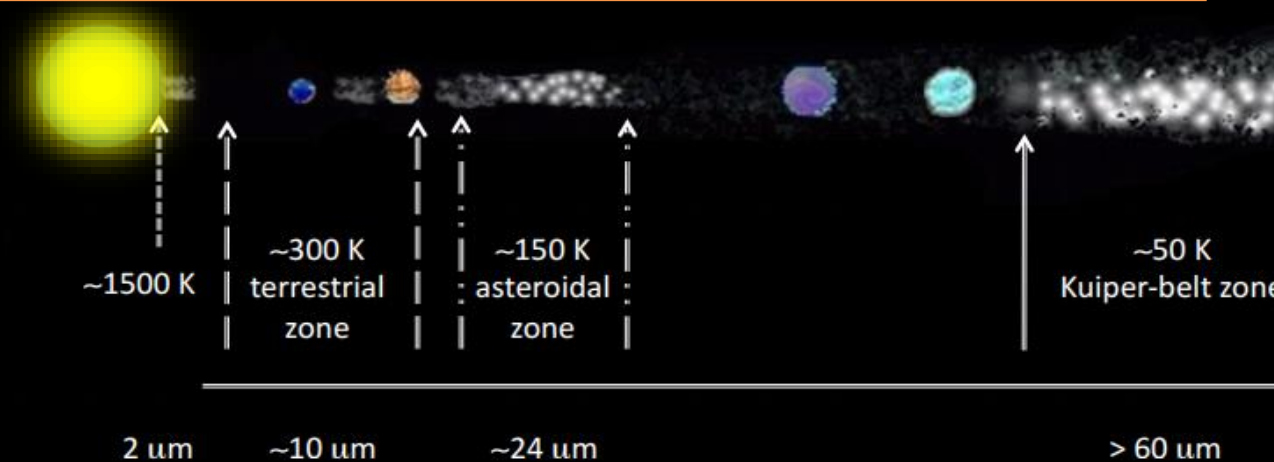
**W4- Excess:**

W1-W4

W2-W4

W3-W4

Solar System debris disk



Matthews+2014 by Kate Su

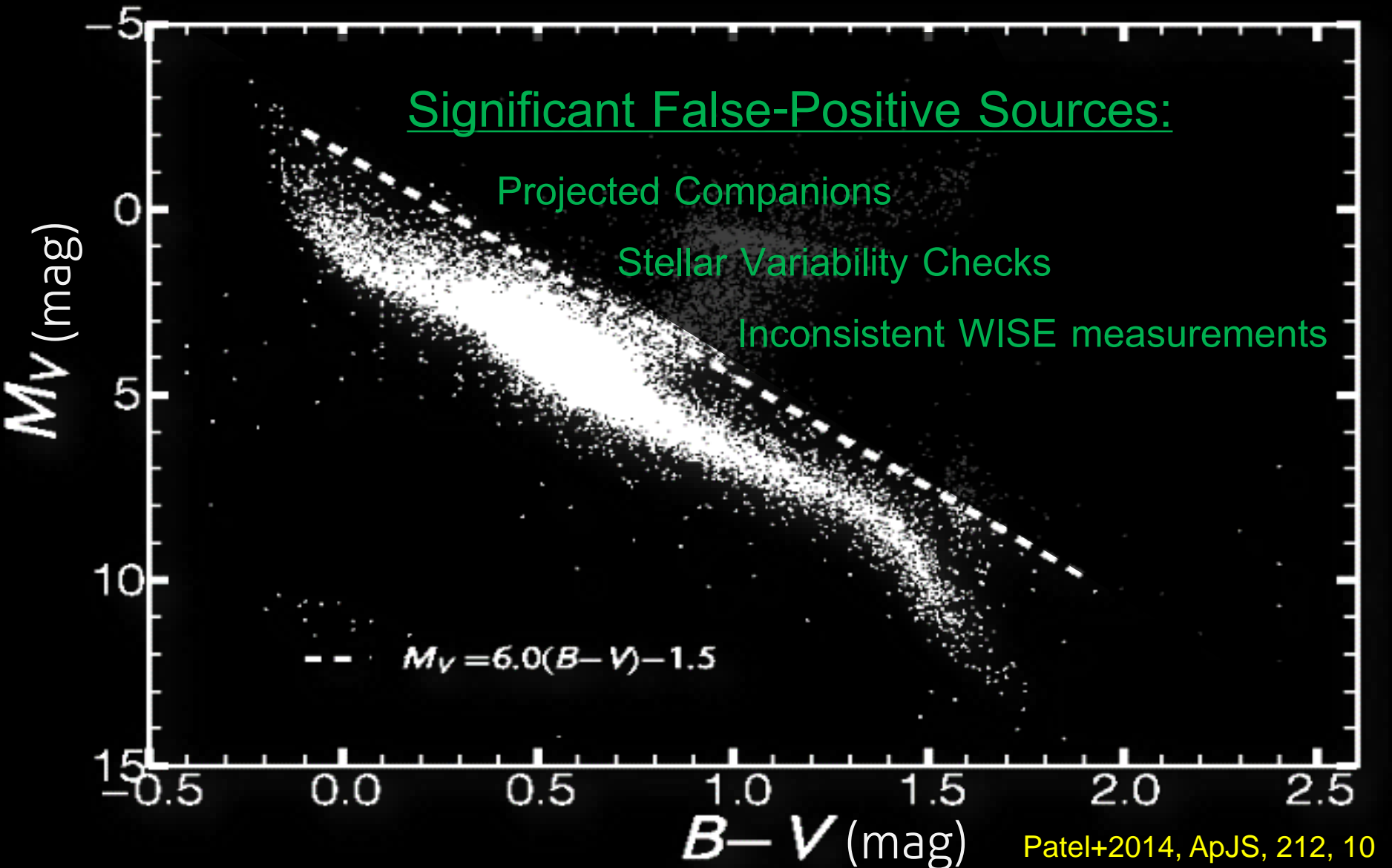
# Colors over photospheric models to search for IR excess

Precise calibration of photosphere required to increase sensitivity to excesses:

- SED fits to multi-epoch photometry from different instruments are subject to relative systematic uncertainties.
- Not the case for multi- $\lambda$  data obtained simultaneously.
  - (e.g. WISE, Spitzer/IRS)

# Sample of Main Sequence Stars

Hipparcos Stars within 120 pc and  $|b| > 5^\circ$





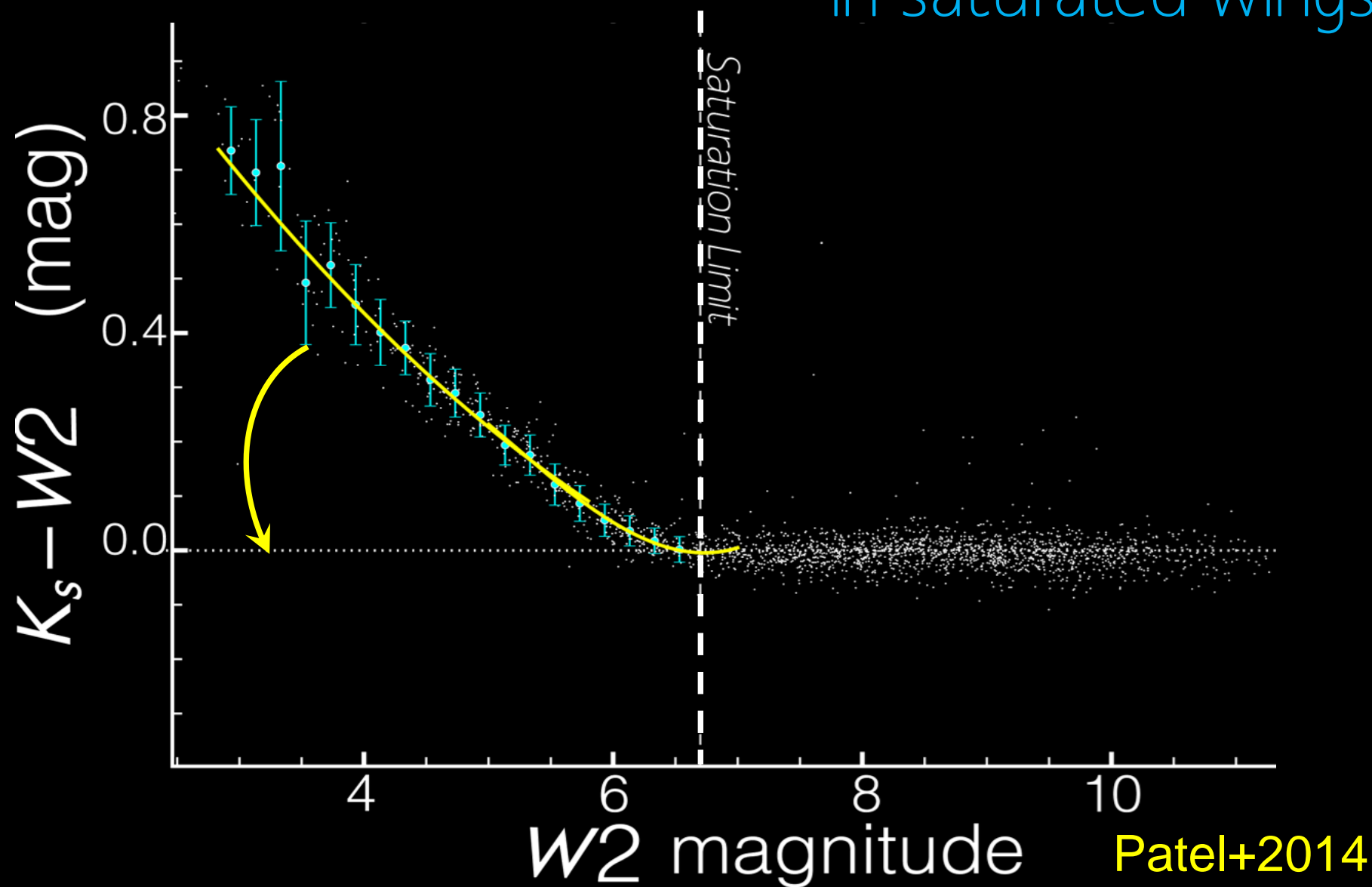
Our WISE excess search improves upon previous attempts because we:

- Apply saturation corrections to include brighter stars.

**Improved sampling of nearby stars**

Patel, R., Metchev, S., & Heinze, A., "*A Sensitive Identification of Warm Debris Disks in the Solar Neighborhood Through Precise Calibration of Saturated WISE Photometry*", 2014, ApJS, 212, 10.

Bright stars were included by correcting trend  
in saturated wings



Our WISE excess search improves upon previous attempts because we:

- Apply saturation corrections to include brighter stars.

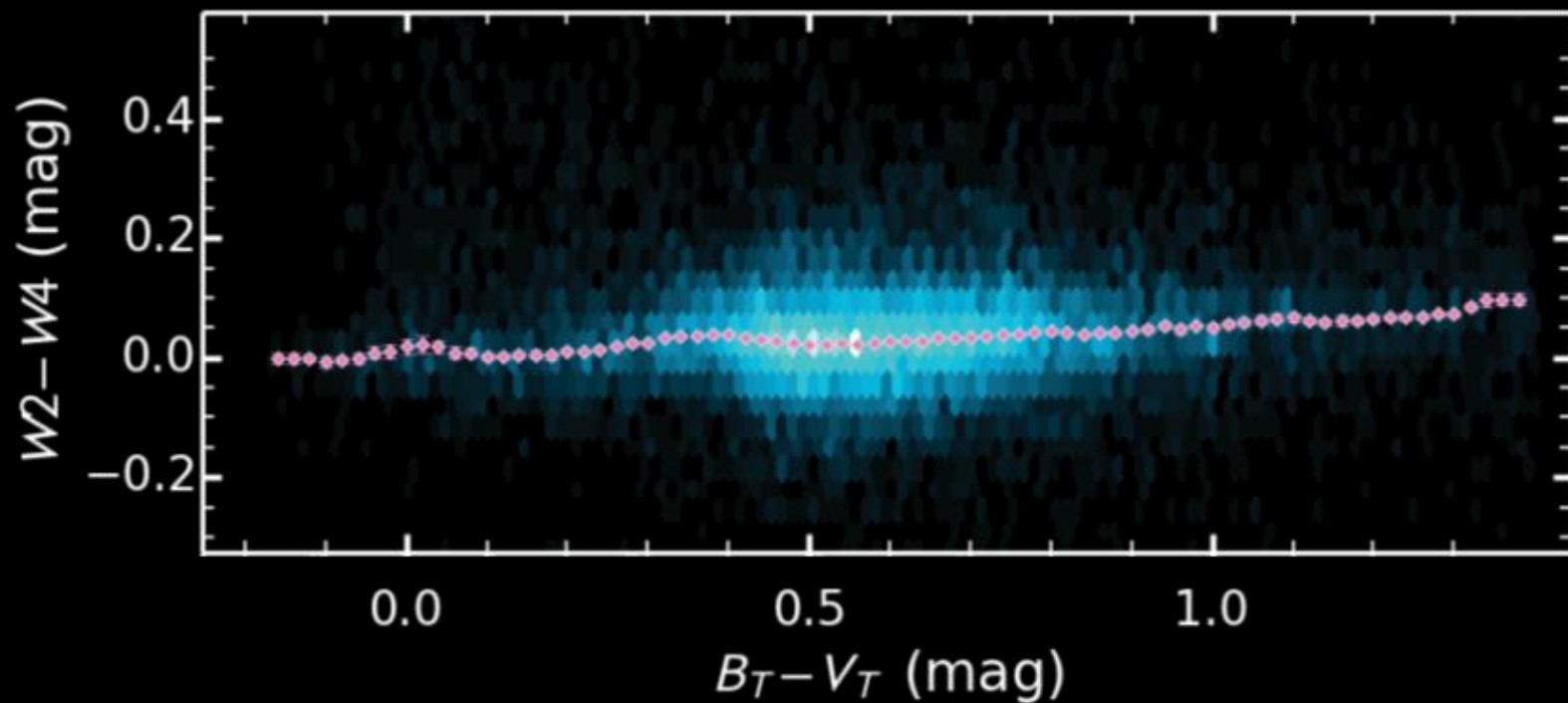
**Improved sampling of nearby stars**

- Empirically calibrate photospheric colors.

**Increase sensitivity to fainter disks**

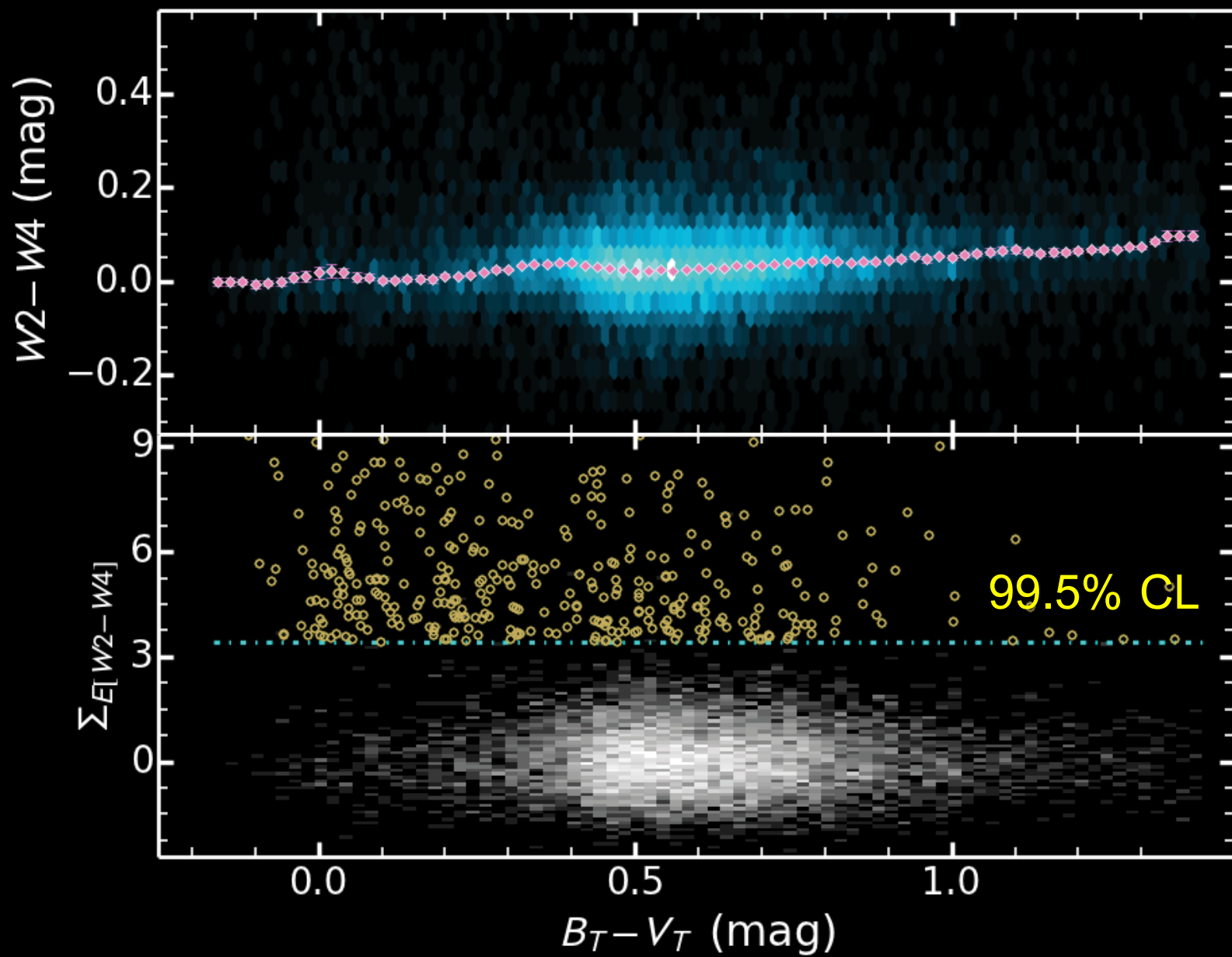
Patel, R., Metchev, S., & Heinze, A., "*A Sensitive Identification of Warm Debris Disks in the Solar Neighborhood Through Precise Calibration of Saturated WISE Photometry*", 2014, ApJS, 212, 10.

# Calculating photospheric WISE colors

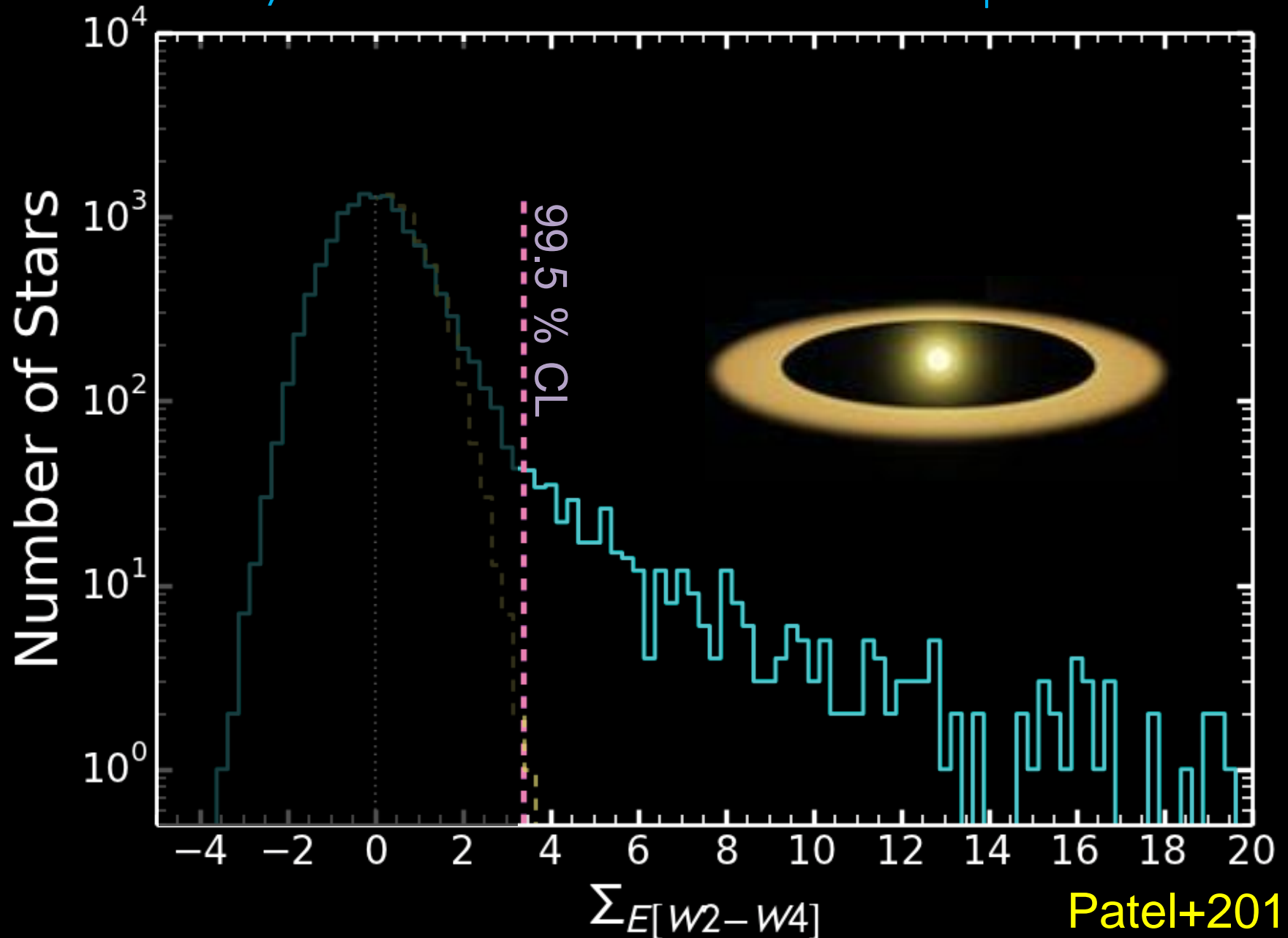


$$\Sigma_E[W_i - W_j] = \frac{(W_i - W_j) - W_{ij}(B_T - V_T)}{\sigma_{ij}}$$





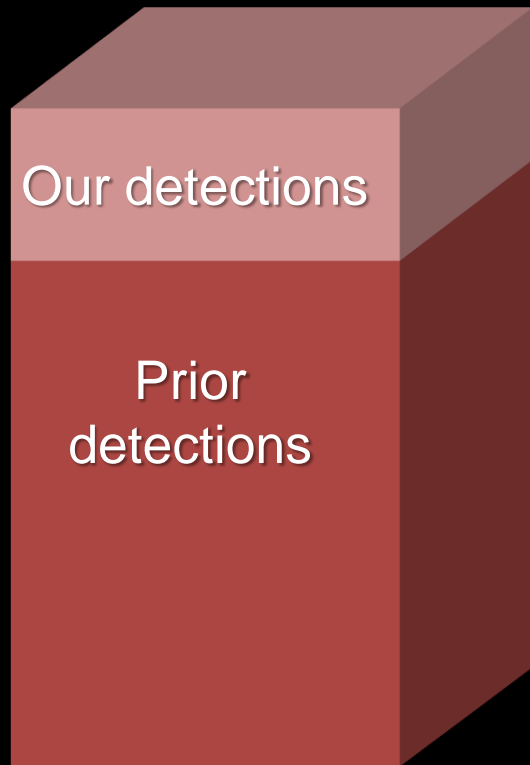
# Uncertainty distribution sets false-positive rate



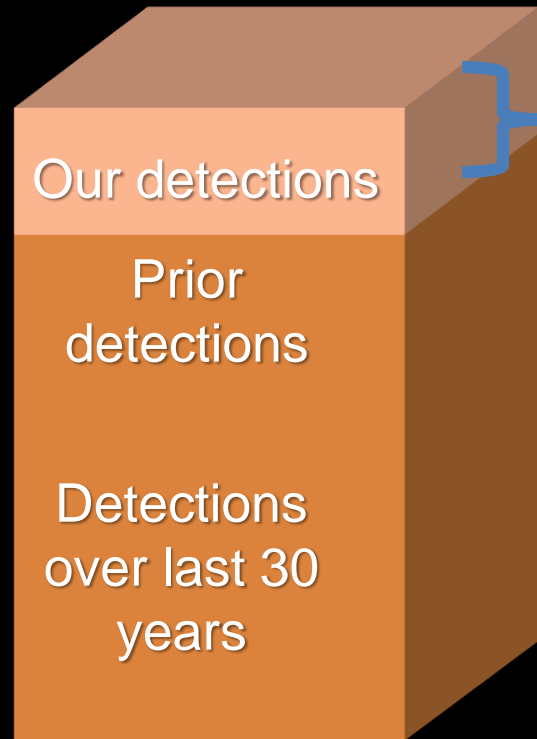
# RESULTS

Increased sensitivity to fainter dust = new disks in already scrutinized volume

35% INCREASE IN 10—30  $\mu\text{m}$  excesses within 75 pc



25% INCREASE IN DISK CENSUS WITHIN 75 PC



Even after a dozen studies using WISE using colors and SED fitting



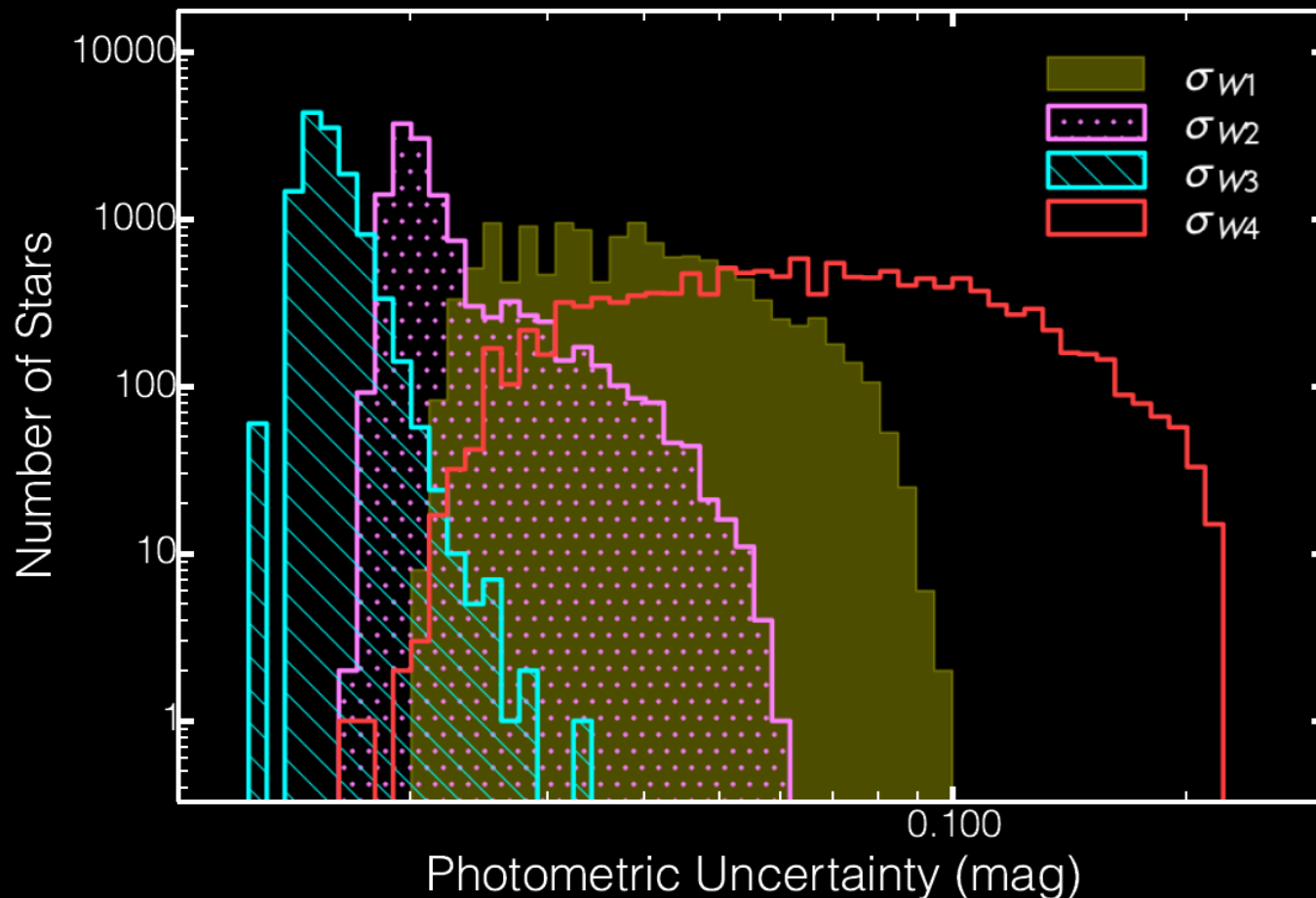
# Verifying Debris Disk Hosts Through A Weighted Combination of WISE Colors

$$\left. \begin{array}{l} E[W1-W4] \\ E[W2-W4] \\ E[W3-W4] \end{array} \right\} \overline{E[W4]}$$

Patel+2015, in preparation

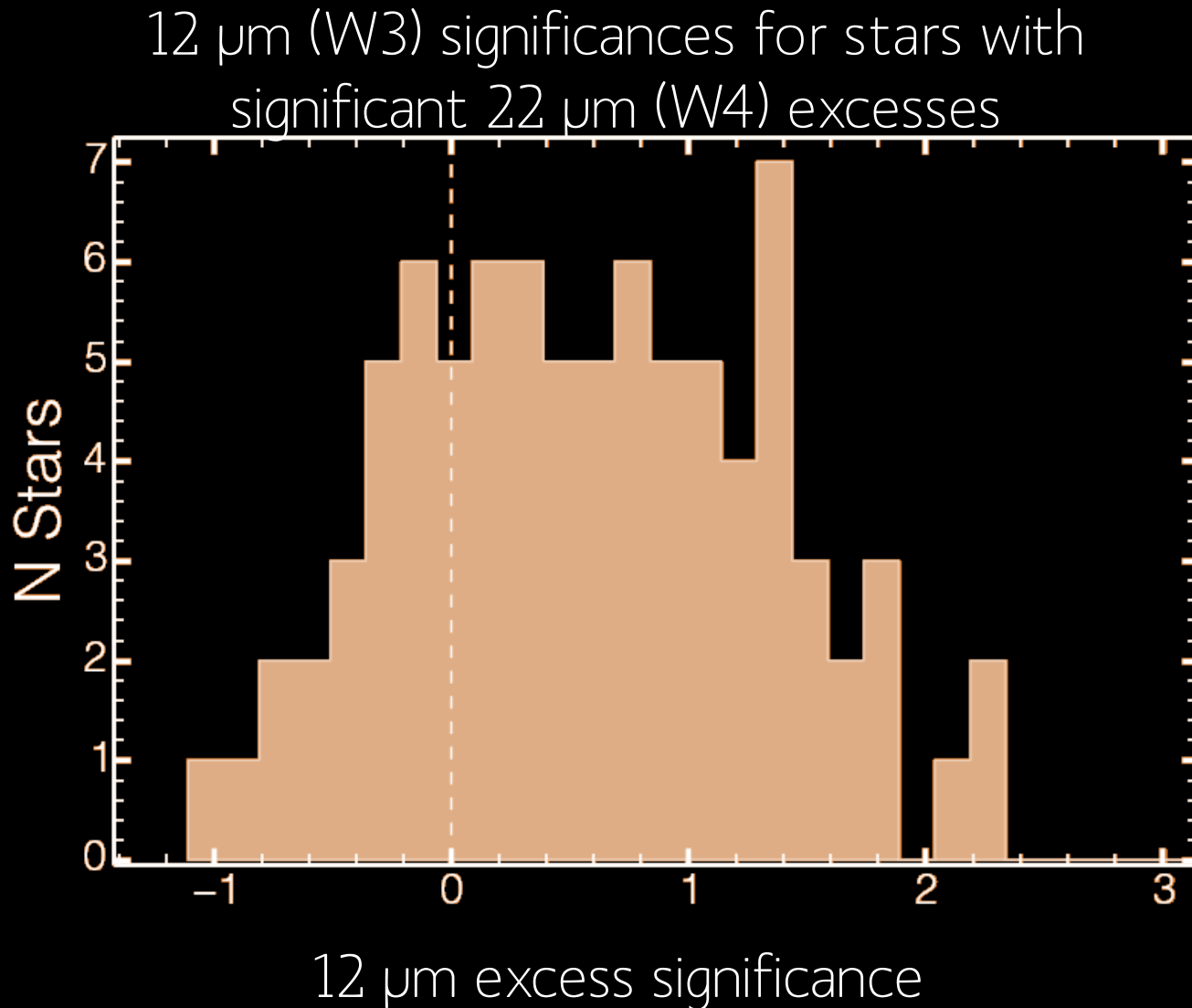
Single-color excess might be real, even without a weighted excess:

- Due to larger uncertainties in  $W1$  and  $W2$  than  $W3$
- if small  $W3$  excess exists



Are we detecting warm dust or emission  
from cold dust?

Aggregate of 22  $\mu\text{m}$  excesses shows a small amount of 12  $\mu\text{m}$  excess  $\rightarrow$  warm dust





# QUESTIONS:

How many undetected exo-asteroid belts are there in Solar neighborhood?

- Used WISE to identify and verify via weighted combination of colors, **>100 new faint disks in 75 pc** around bright stars.
- Substantial increase in known disk population

# QUESTIONS

**What is the frequency of Solar System analogs?**

- What are the stellar ages?
- Are these quiescent evolved planetary systems or young solar system analogues planetary systems?

# Future Direction

- Determine ages for stars to determine stage of dust evolution
  - *Spectroscopic data obtained for majority of stars*
- Follow up with direct imaging to spatially characterize dust
  - *e.g., GPI, SPHERE*