Finding Debris Disks & Other Faint Sources Around Bright Objects In WISE.

Rahul I. Patel[1],

Stanimir Metchev[1,2], Aren Heinze[1] & Joe Trollo[2]

WISE @ 5

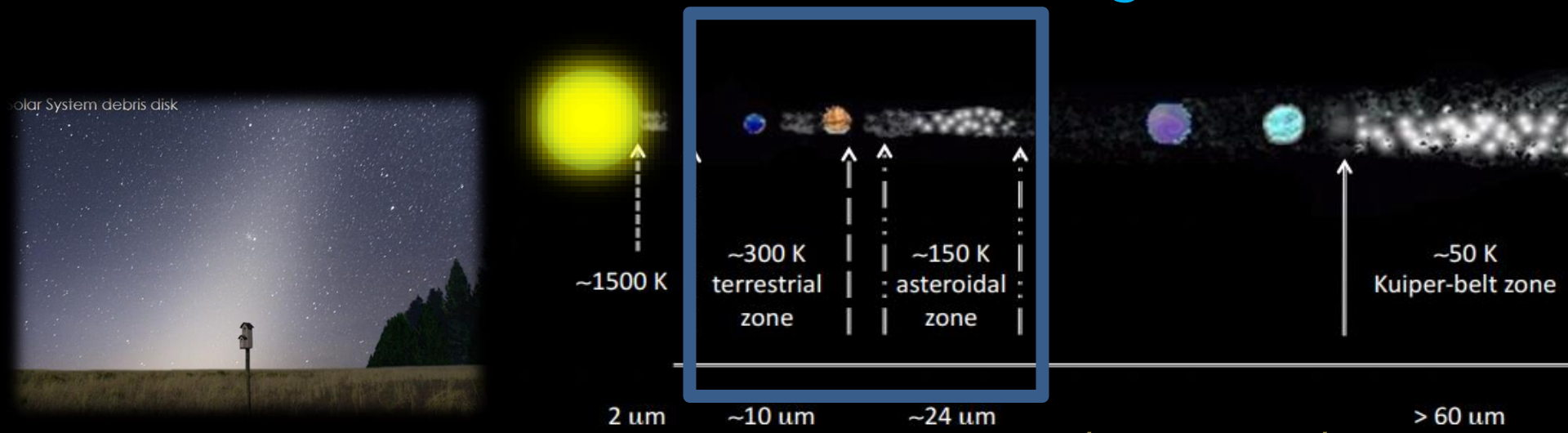
[1] Stony Brook University

[2] Western University · Canada

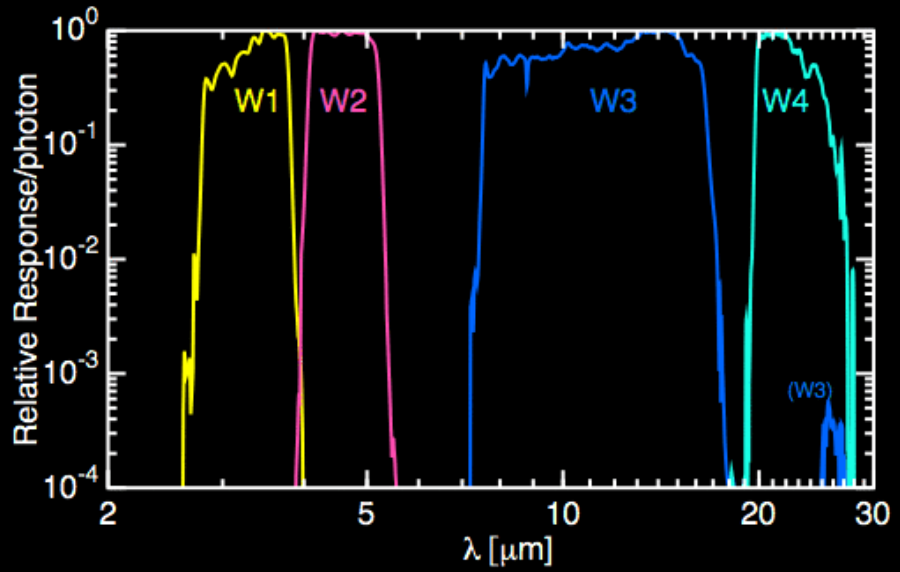
This work is partially supported by NASA Origins of Solar Systems via subcontract No. 1467483

@ripatel_astro

WISE mid-IR colors probe dynamical activity in zodiacal dust and asteroid belt regions.



Matthews+2014 by Kate Su



W3- Excess:
W1-W3
W2-W3

W4- Excess:
W1-W4
W2-W4
W3-W4

We choose colors over fitting SEDs to search for IR excesses.

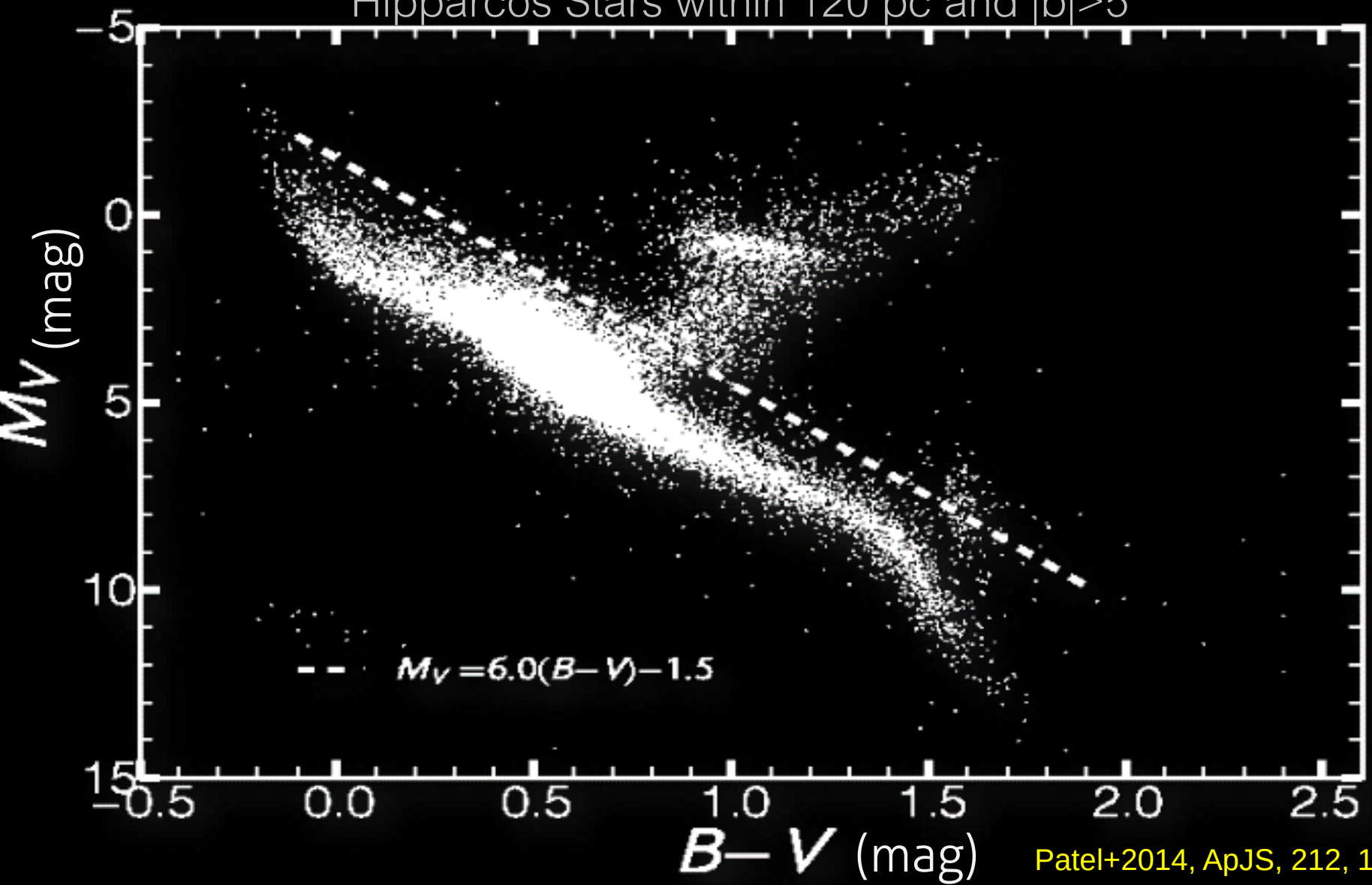
Precise calibration of photosphere required to increase sensitivity to fainter excesses:

- SED fits to multi-epoch photometry from different instruments are subject to relative systematic uncertainties.

- Not the case for multi-λ data obtained:
  - simultaneously.
  - on same photometric system.
  - (e.g. WISE, Spitzer/IRS)
  - WISE for 1st time (as all sky mission) allows simultaneous measurement of photospheric and excess wavelengths.

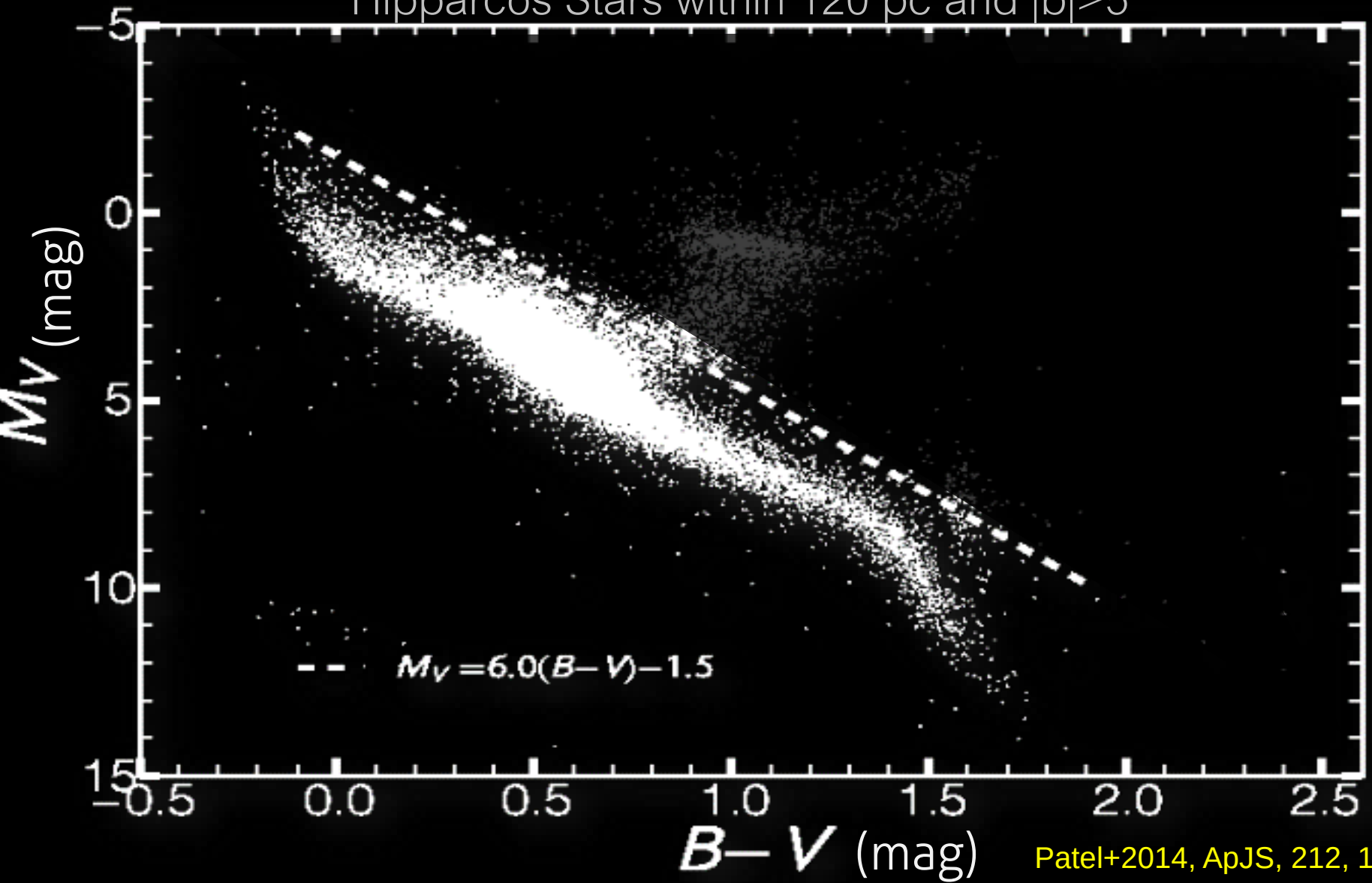
We only used data from the
All-Sky Catalog.

Our sample consists of main-sequence Hipparcos stars.



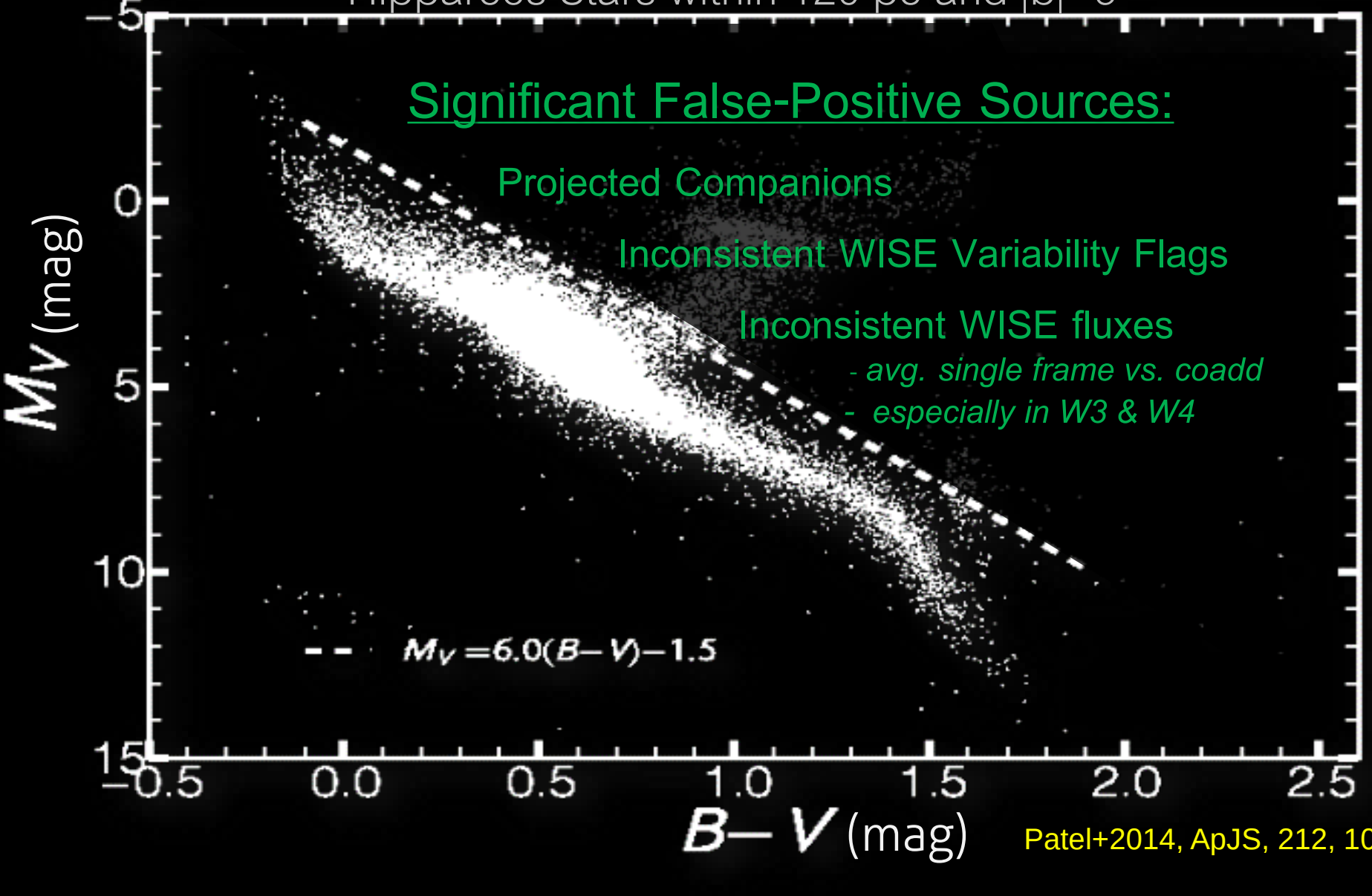
Patel+2014, ApJS, 212, 10

Our sample consists of main-sequence Hipparcos stars.



Patel+2014, ApJS, 212, 10

Our sample consists of main-sequence Hipparcos stars.

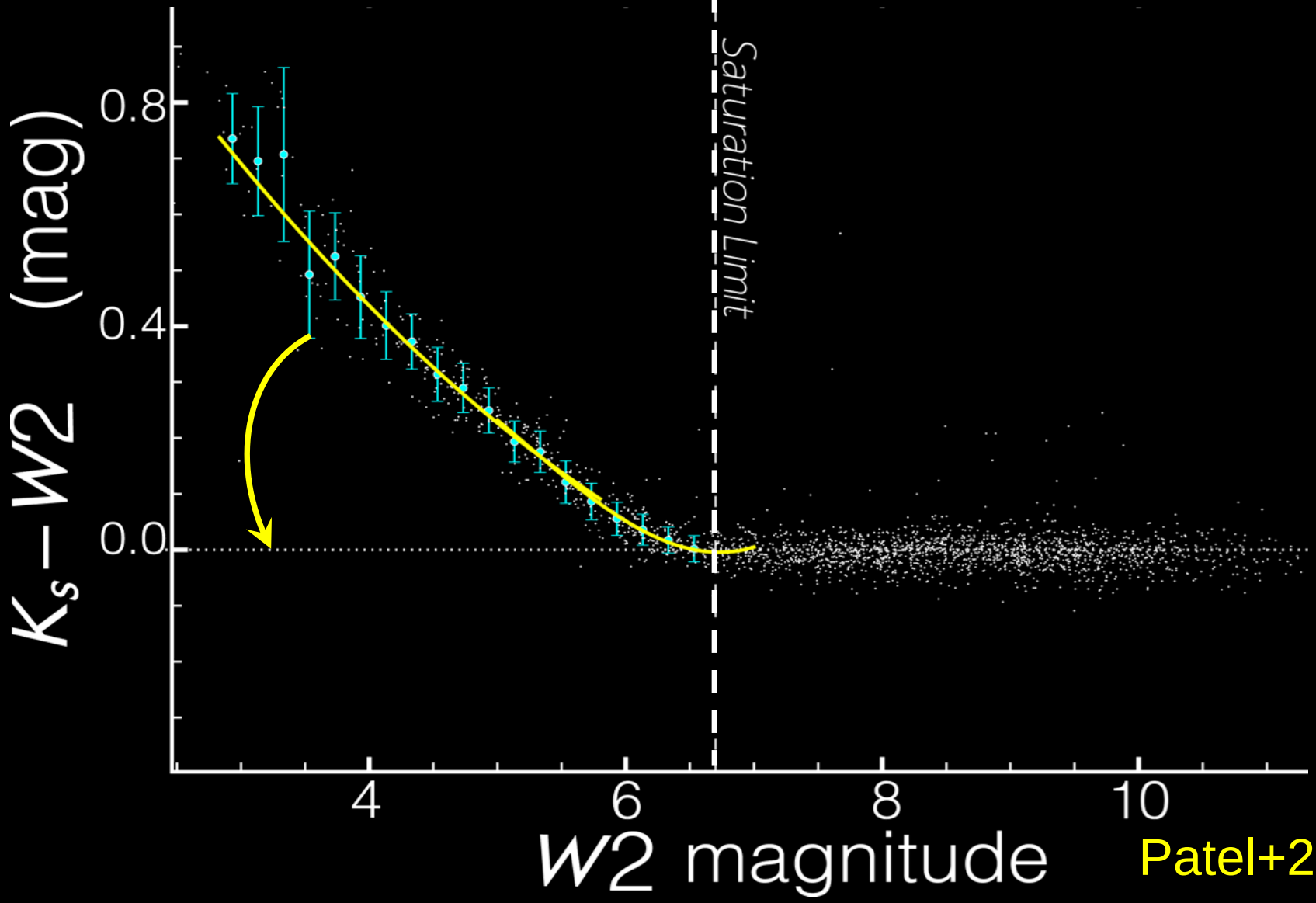


Patel+2014, ApJS, 212, 10

Our WISE excess search adds onto previous work because we:

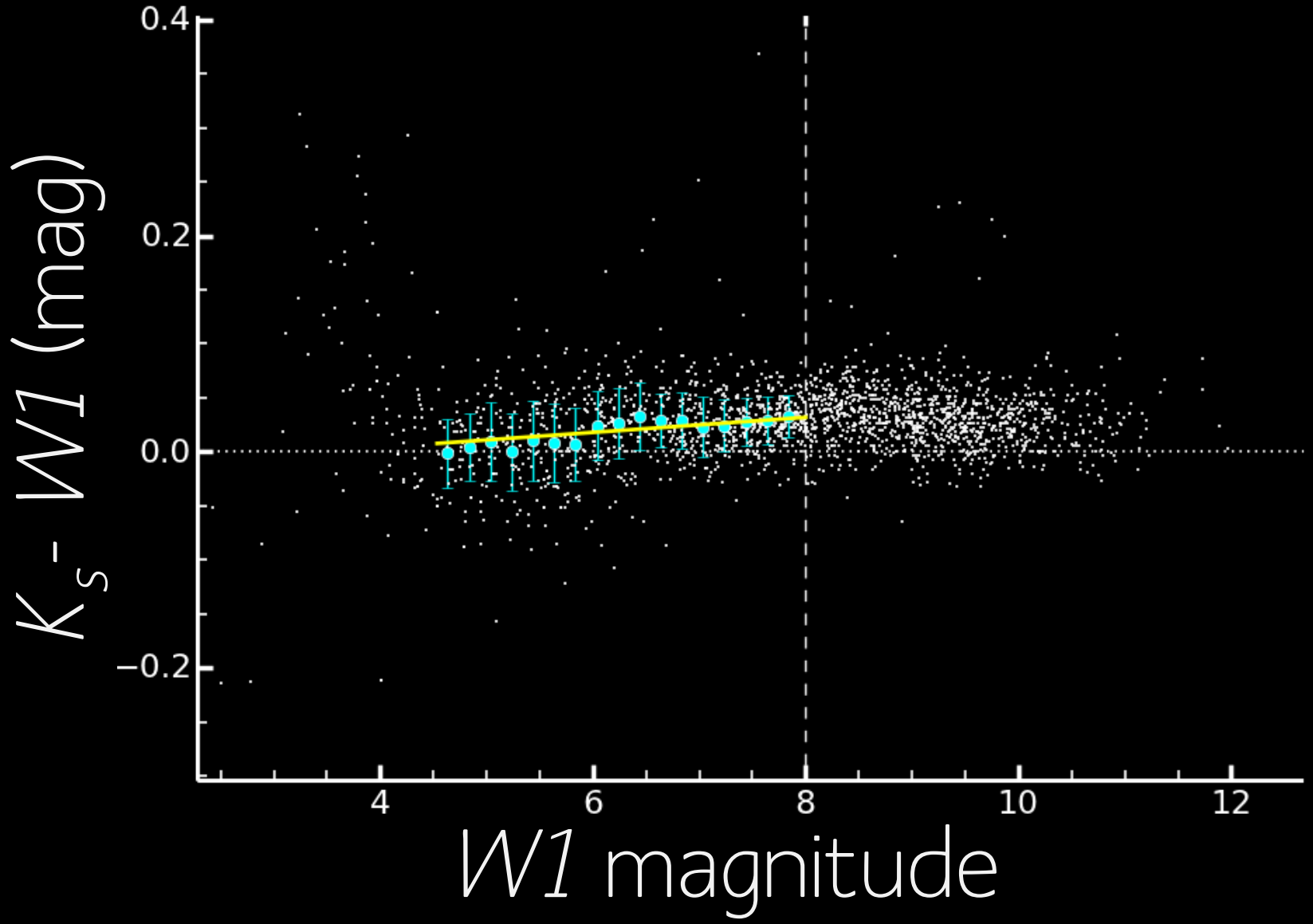
- Apply saturation corrections to include brighter stars.
  Include more of the nearby stars

Bright stars were included by correcting trend in saturated wings.



Patel+2014

W1 also shows non-linearity, for which we correct

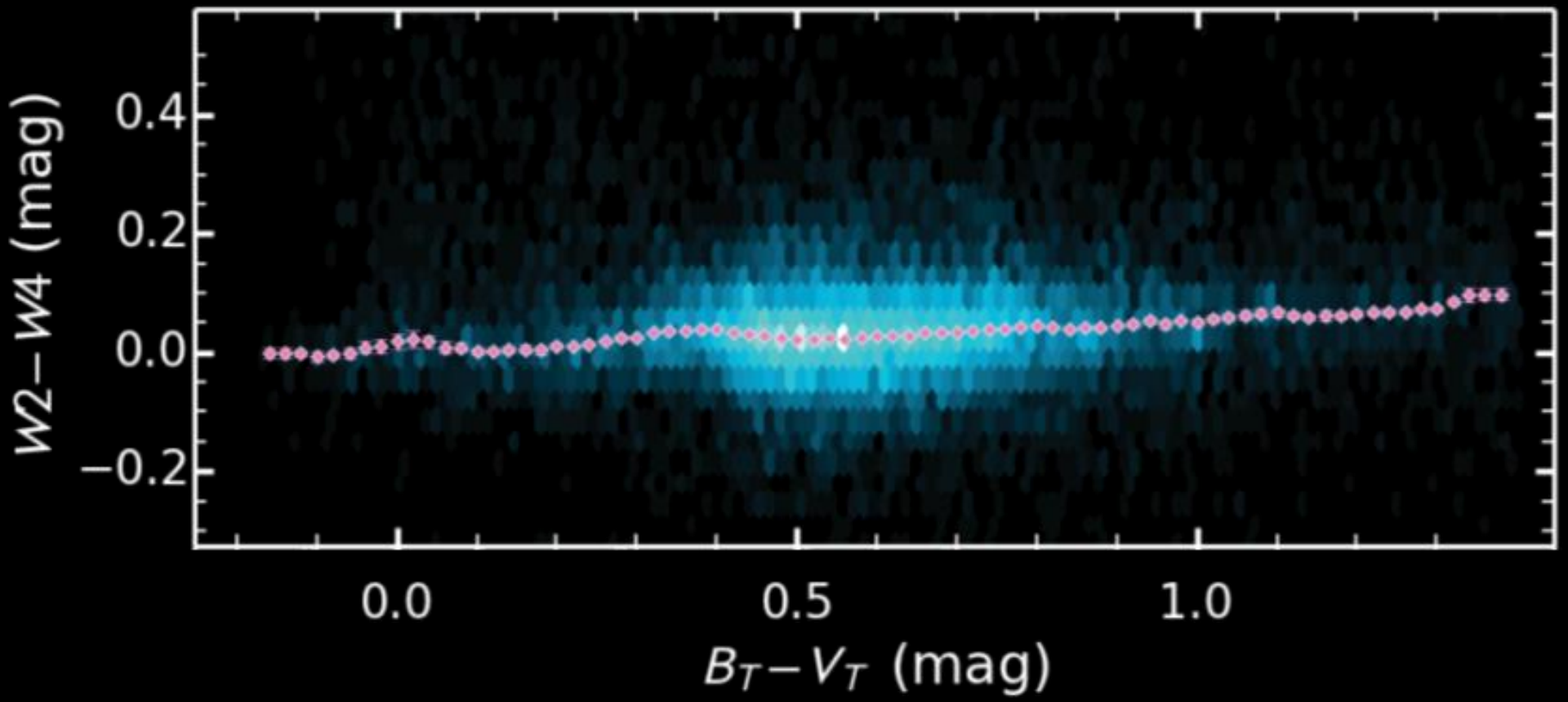


Our WISE excess search improves upon previous work because we:

- Apply saturation corrections to include brighter stars.
  Include more of the nearby stars

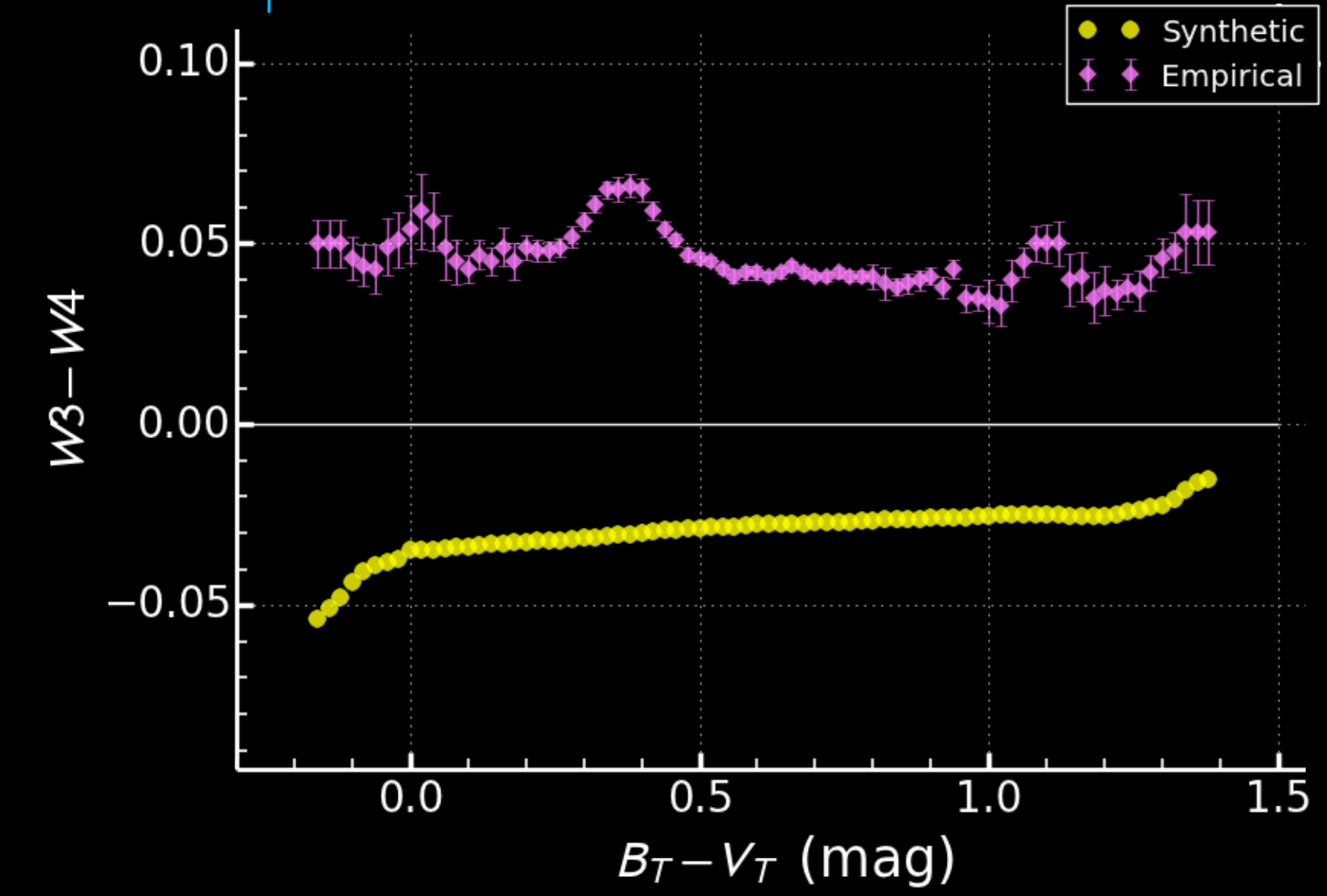
- Empirically calibrate photospheric colors.
  Increase sensitivity to fainter disks

Empirical WISE photospheric colors were determined using <120 pc Hipparcos stars.

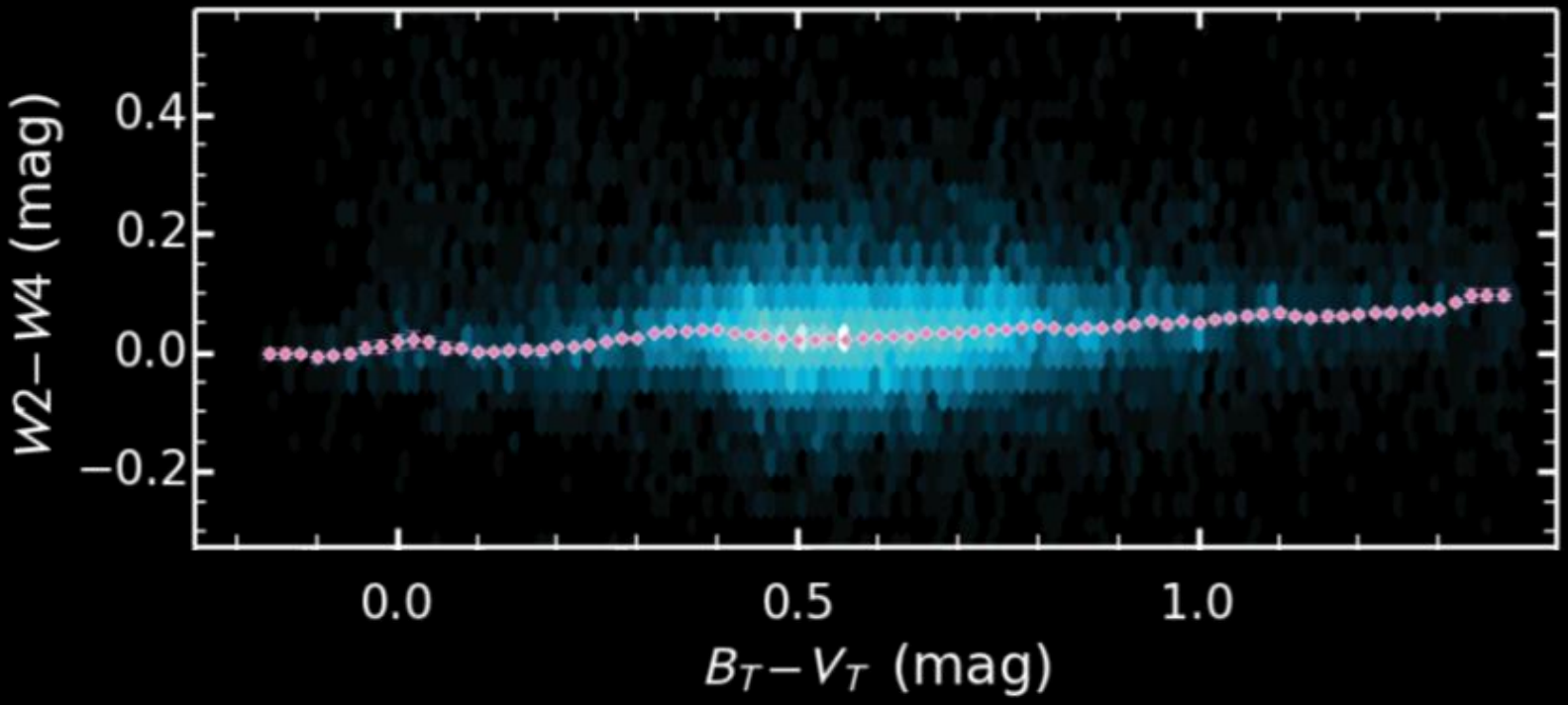


Patel+2014

WISE synthetic photospheric colors are bluer than empirical colors.

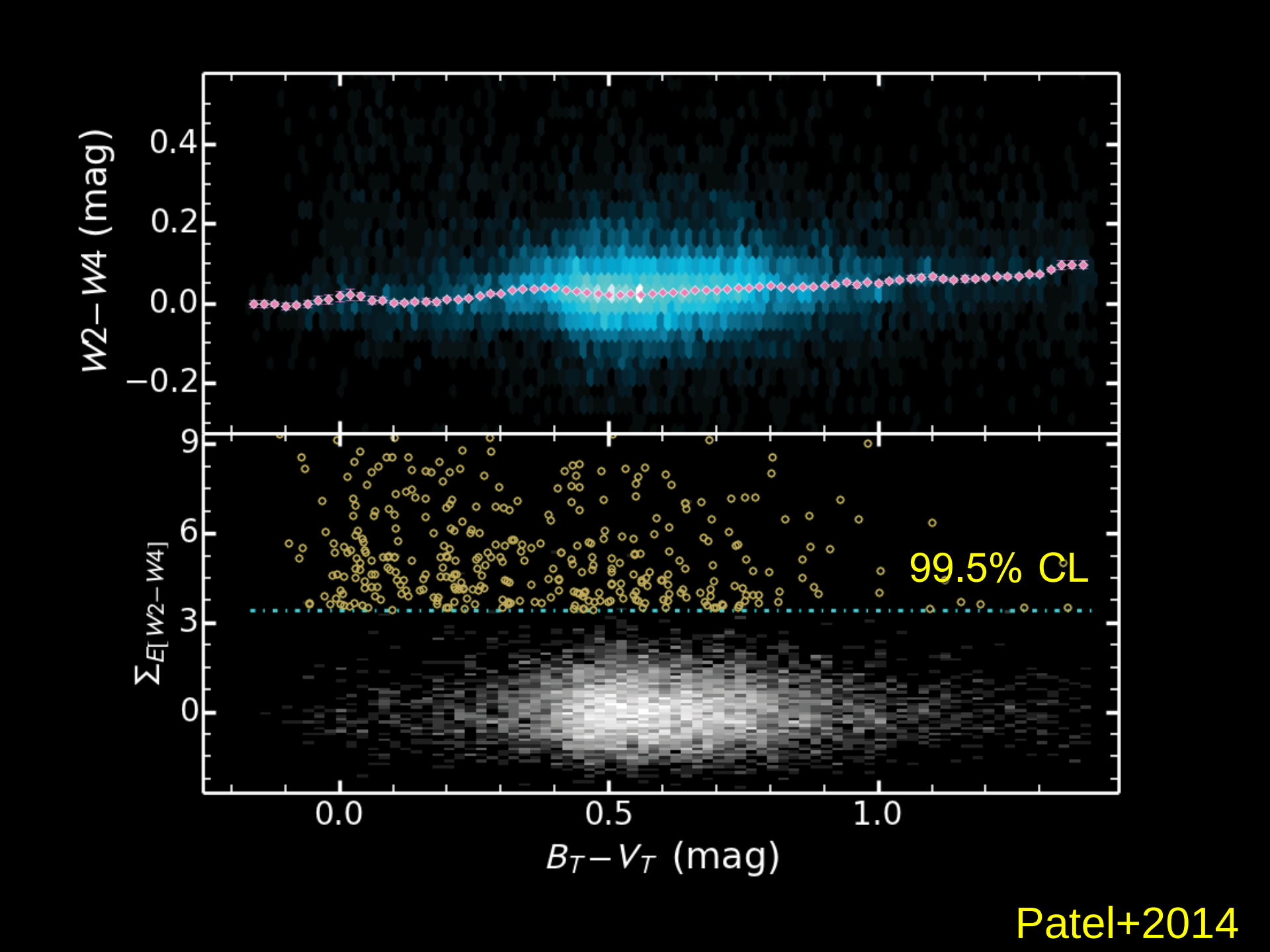


Excess significances were calculated after subtracting empirical photospheric colors.

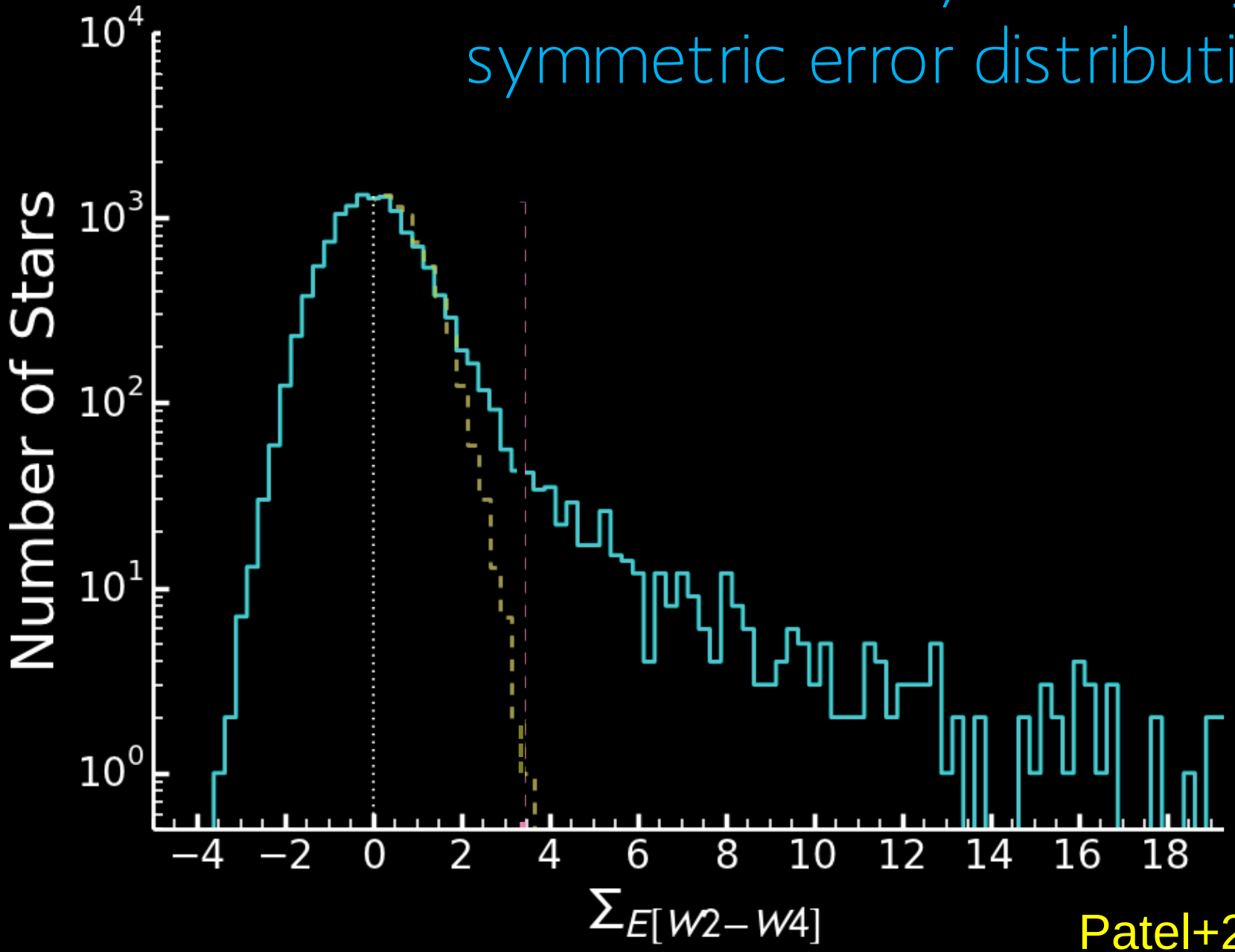


$$\Sigma_{E[Wi-Wj]} = \frac{(Wi - Wj) - W_{ij}(B_T - V_T)}{\sigma_{ij}}$$

Patel+2014

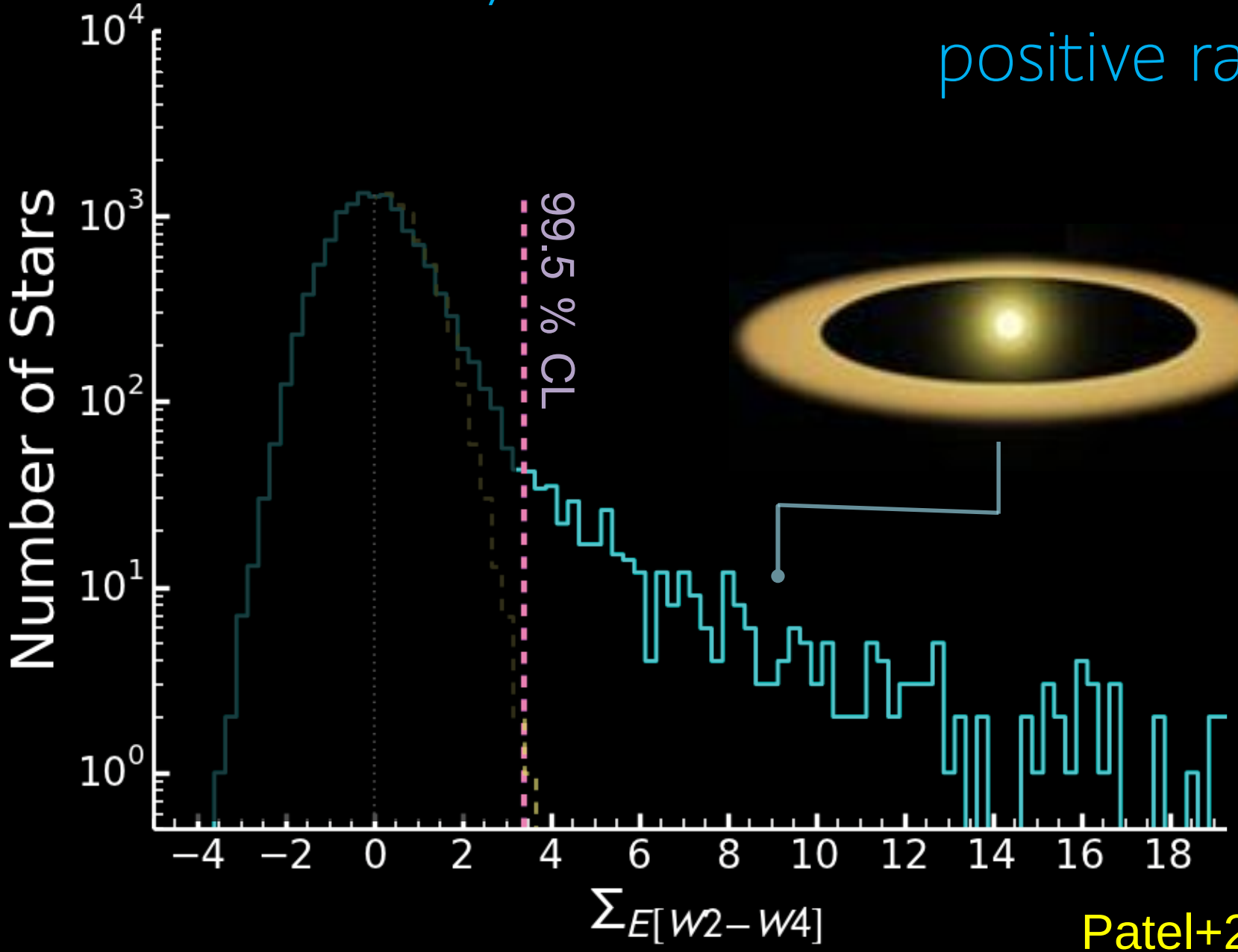

W2−W4 (mag)
0.4
0.2
0.0
−0.2
Σ E[W2−W4]
9
6
3
0
99.5% CL
0.0
0.5
1.0
BT−VT (mag)
Patel+2014

Uncertainties estimate by assuming a symmetric error distribution



Patel+2014

Uncertainty distribution sets the false positive rate.

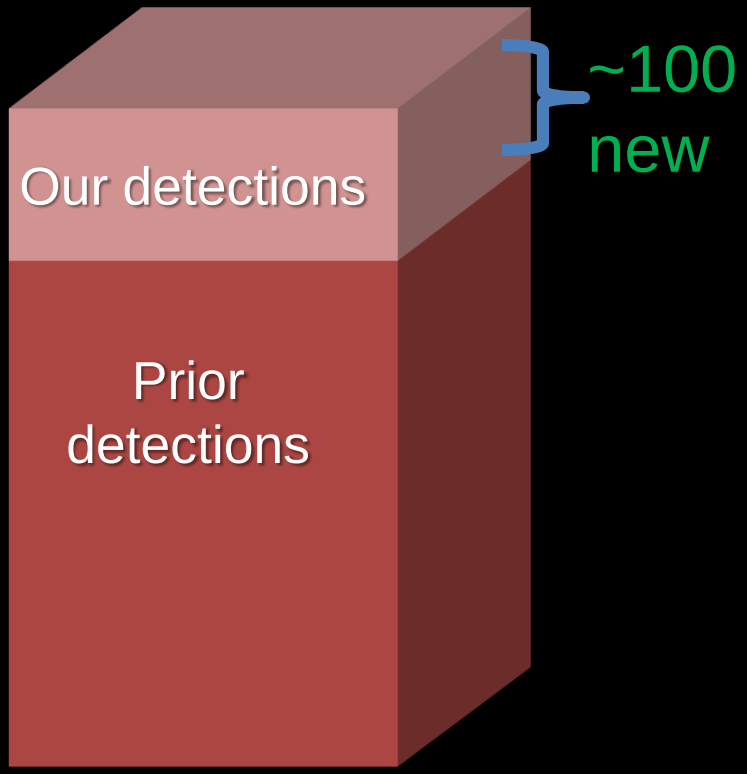


Patel+2014

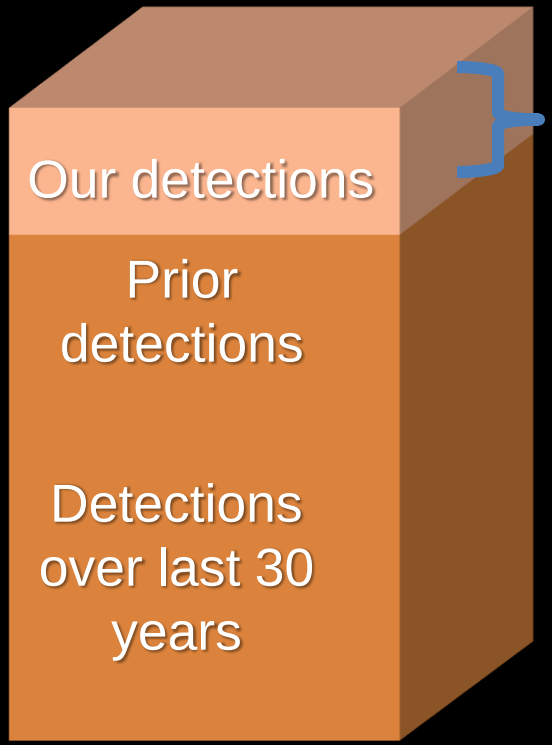
RESULTS

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

35% INCREASE IN 10—30 μm excesses within 75 pc



25% INCREASE IN DISK CENSUS WITHIN 75 PC



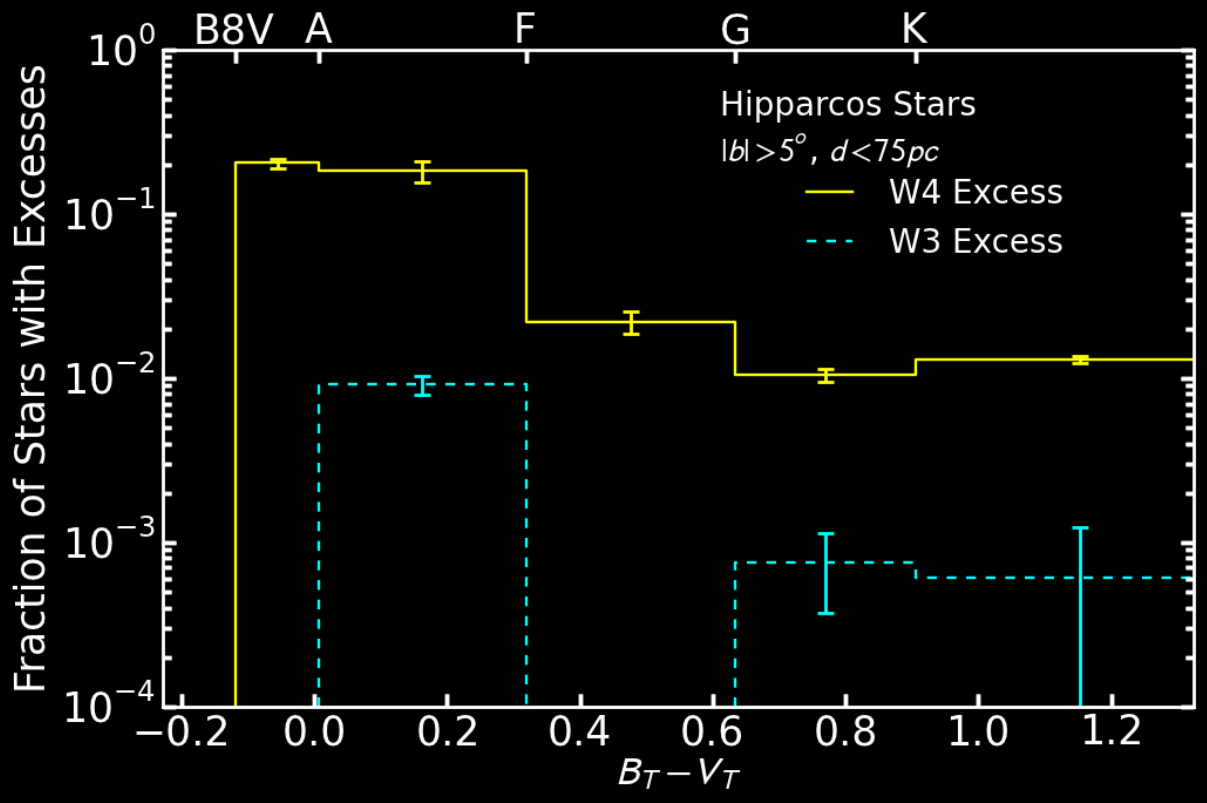
Even after a dozen studies using WISE using colors and SED fitting

Incidence Rate Of Excesses (d<75 pc)

W3 Excesses: W4 Excesses:

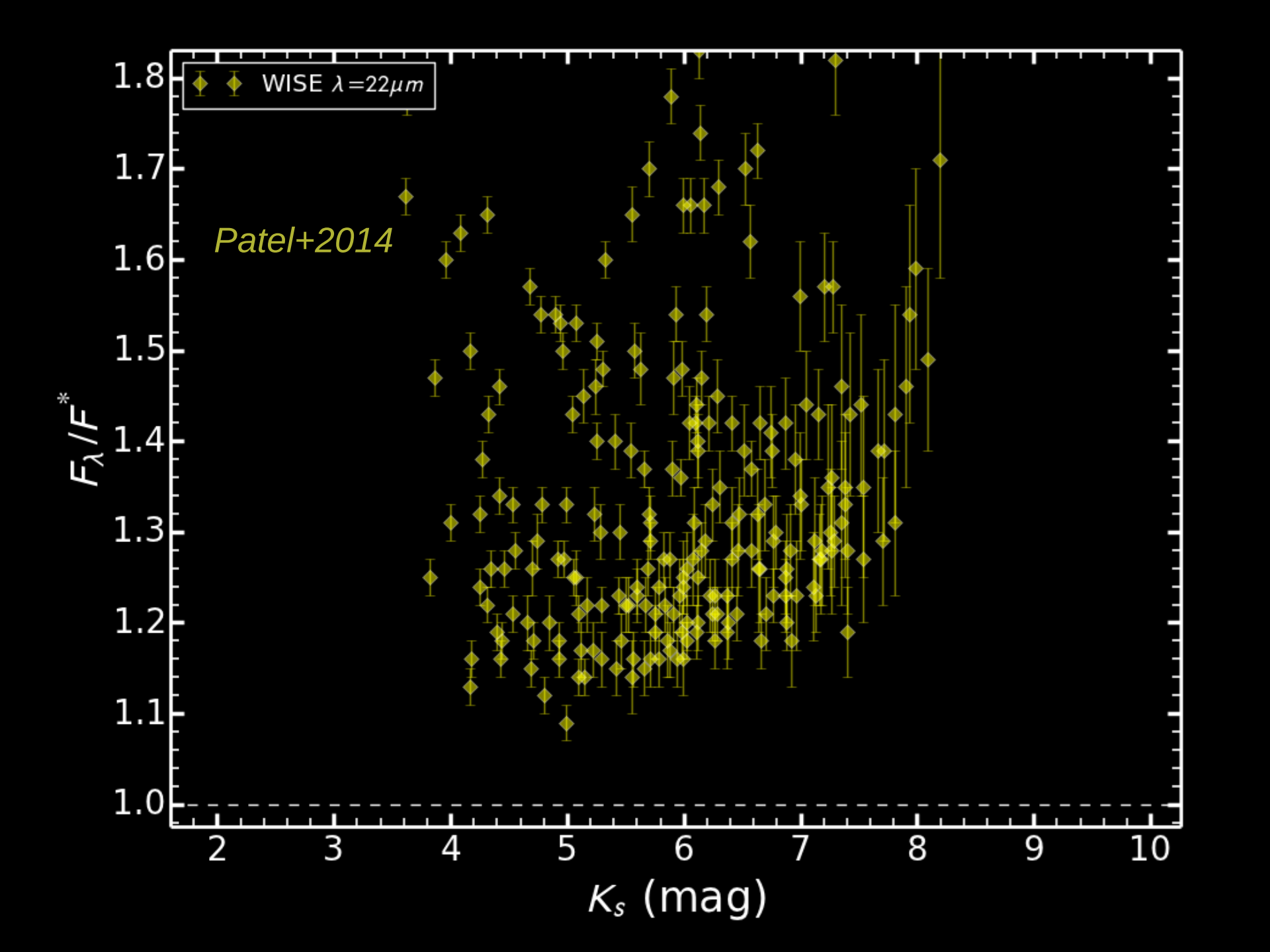
FGK: 0.04 – 0.08% FGK: 1.4–1.8 % (4% from MIPS24, 12% Spitzer/IRS)

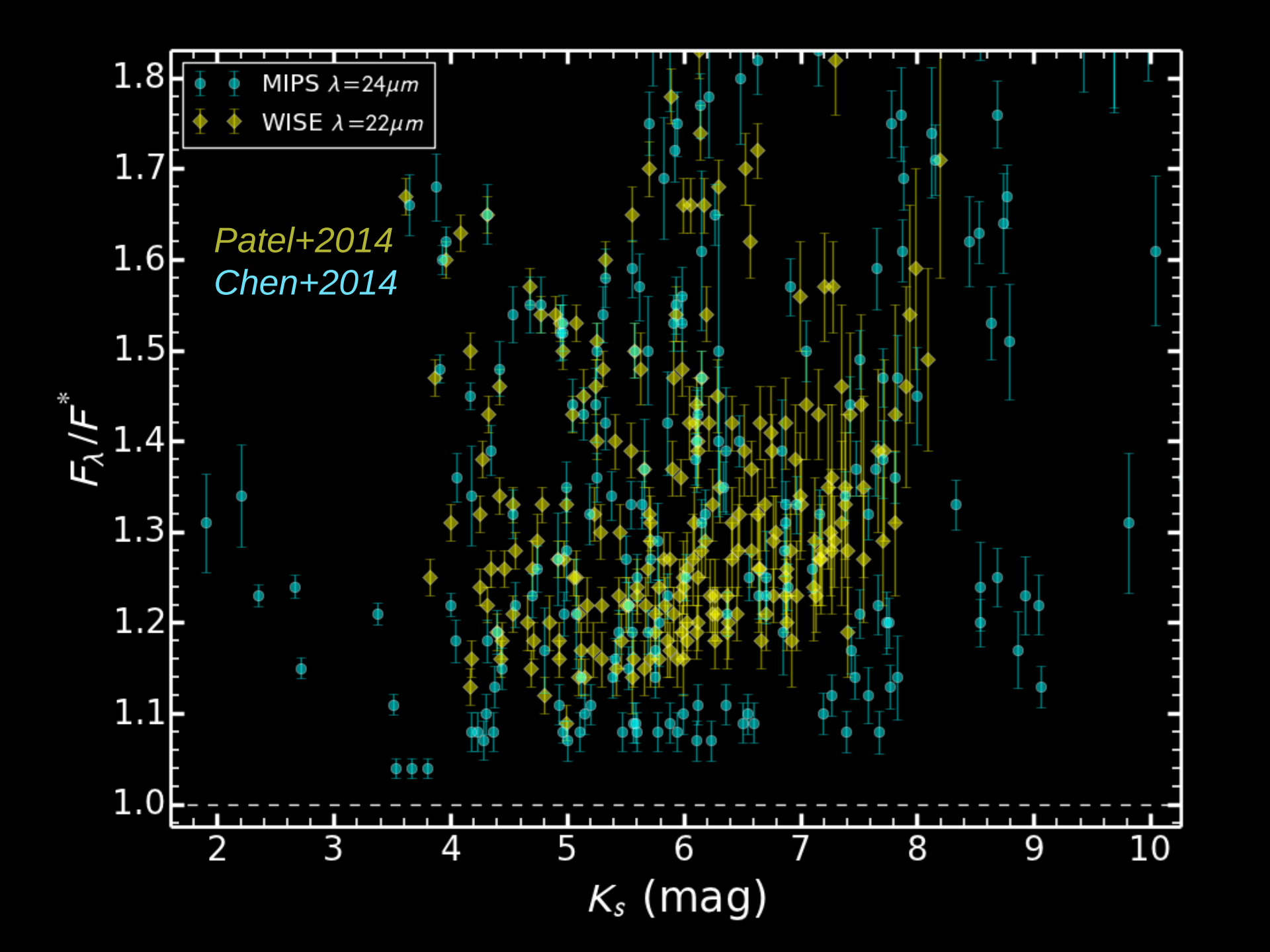
AB: 0.8 – 1.0 % AB: 16–22 % (32% from MIPS24, 7% MIPS24,> 600 Myr)

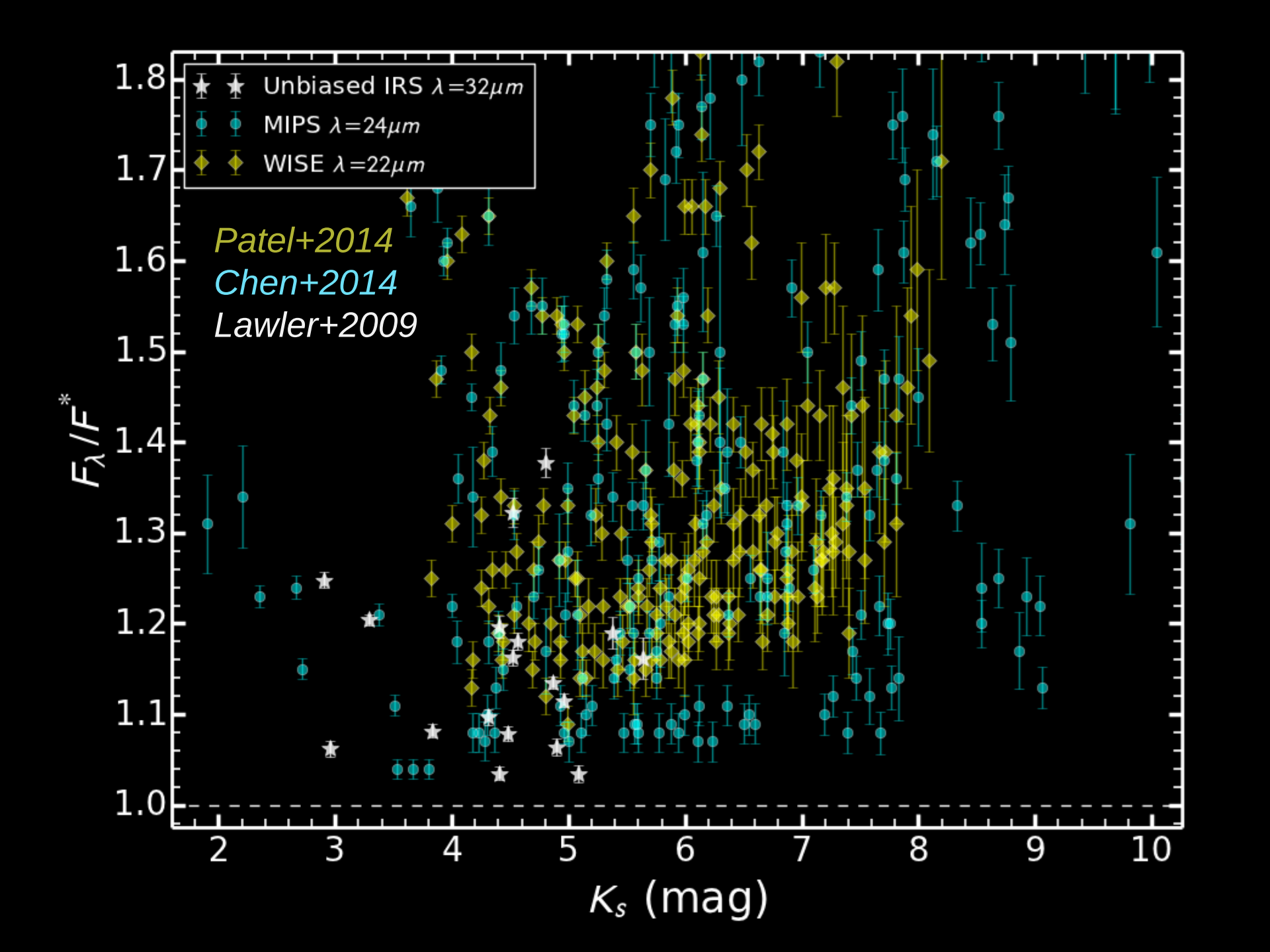


Su+2006;
Trilling+2008
Lawler+2009
Kennedy+2013

Patel+2014

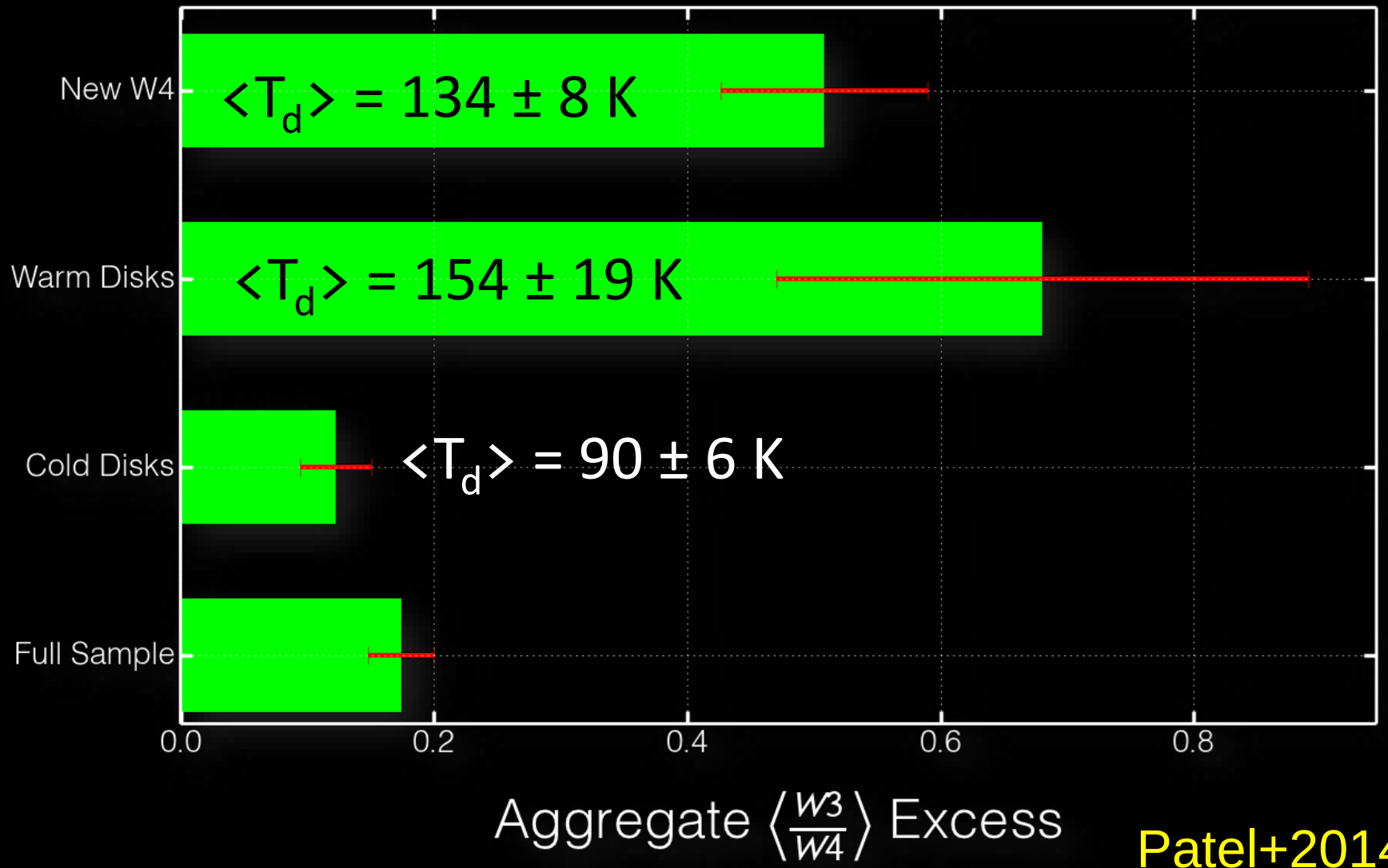

WISE λ=22μm
Patel+2014
F_λ / F^*
K_s (mag)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
2
3
4
5
6
7
8
9
10


MIPS λ=24μm
WISE λ=22μm
Patel+2014
Chen+2014
F_λ / F^*
K_s (mag)
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
2
3
4
5
6
7
8
9
10


Unbiased IRS λ=32μm
MIPS λ=24μm
WISE λ=22μm
Patel+2014
Chen+2014
Lawler+2009
F_λ / F^*
K_s (mag)
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
2
3
4
5
6
7
8
9
10

Are we detecting warm dust or emission from cold dust?

Aggregate W3 excess indicates that warm dust is present in typical W4 excess system.

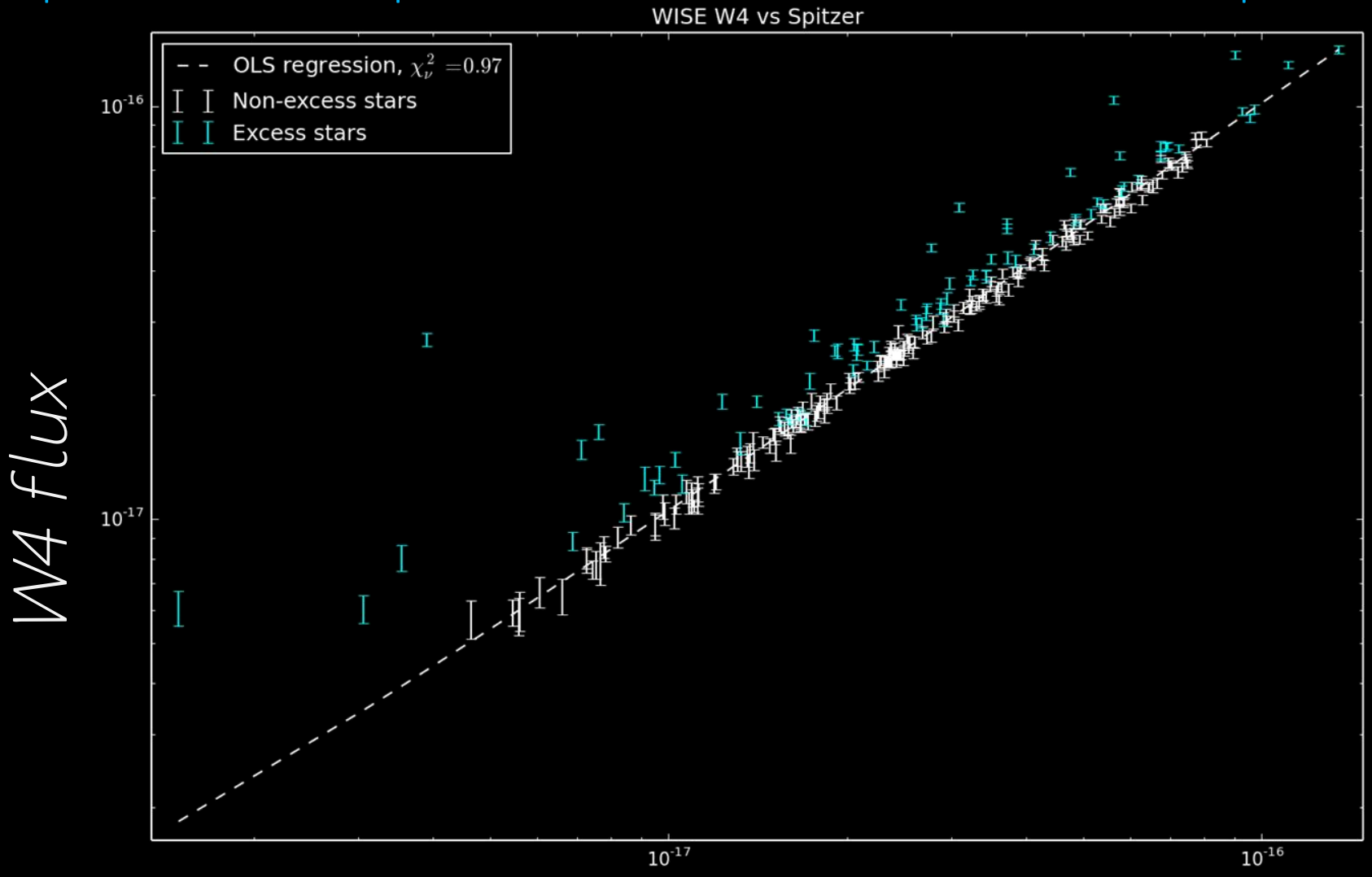


Patel+2014

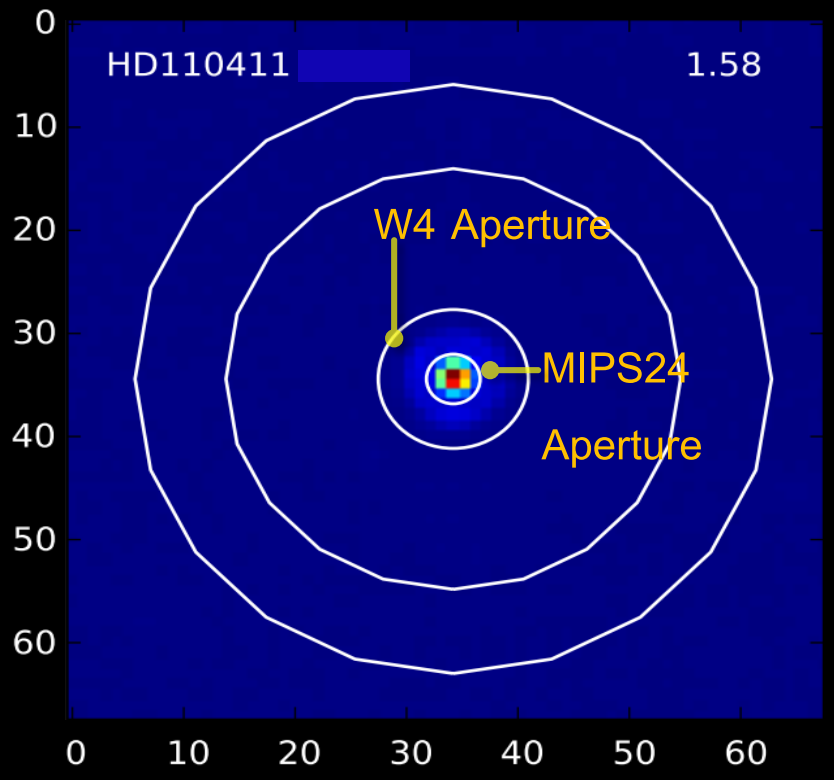
Lessons Learned I:

W4 fluxes are overestimated for red sources.

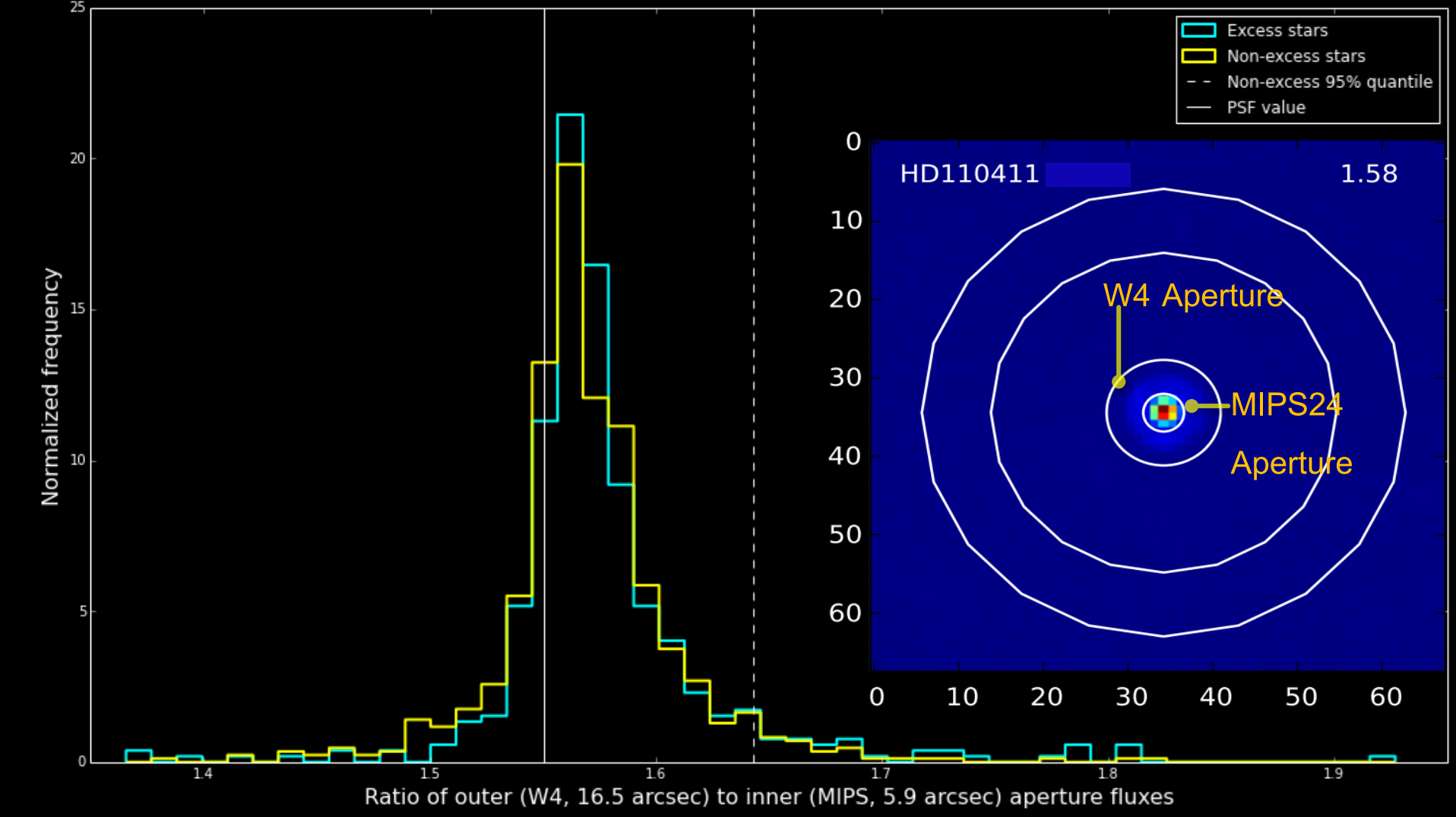
W4 flux is larger for stars with excesses than expected compared to observations with Spitzer.



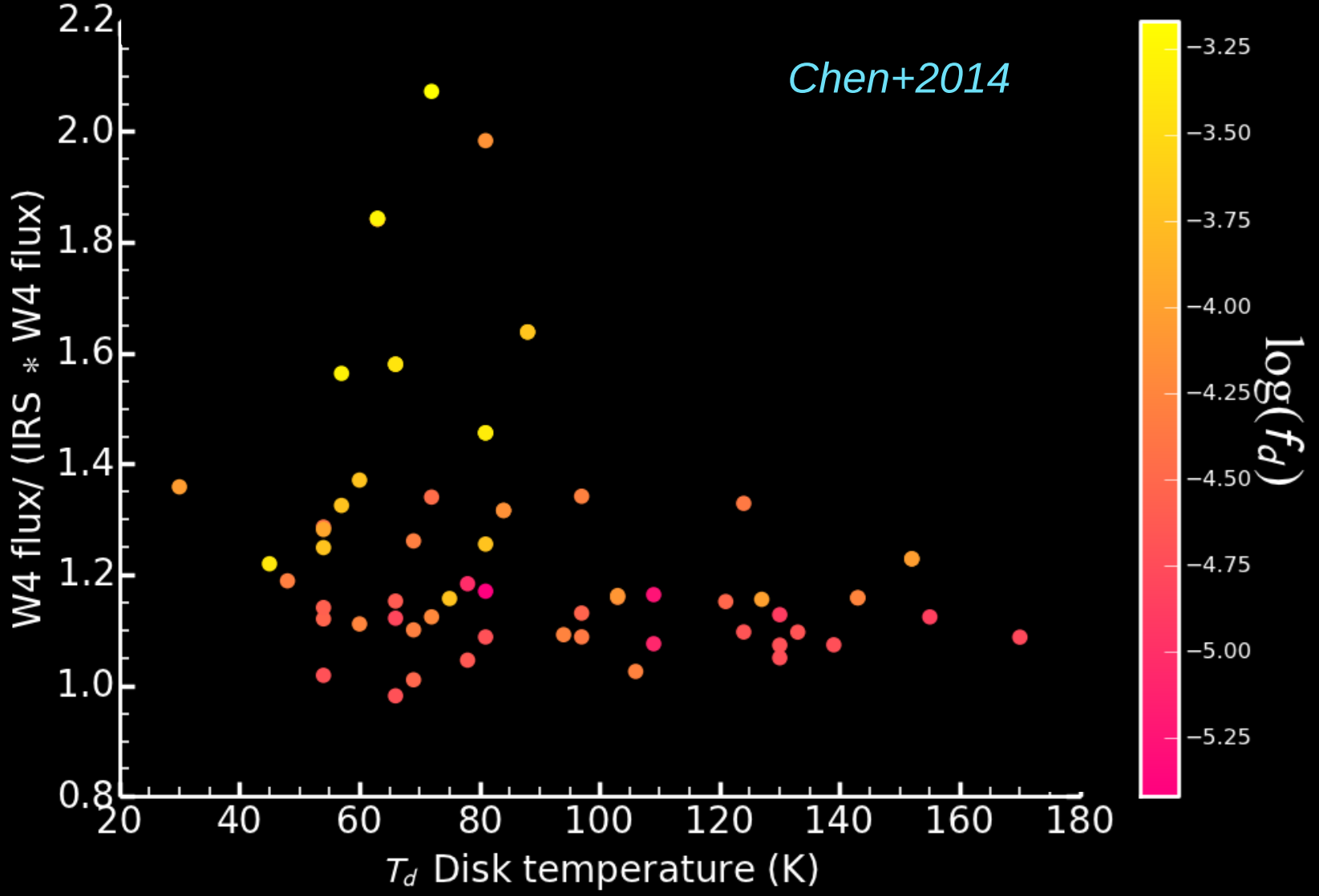
Is Spitzer resolving these disks?



Discrepancy is not due to resolved disks from Spitzer.



Colder and brighter disks show more W4 flux than in IRS measured W4 flux.



Lessons Learned II:

All-Sky vs. AllWISE

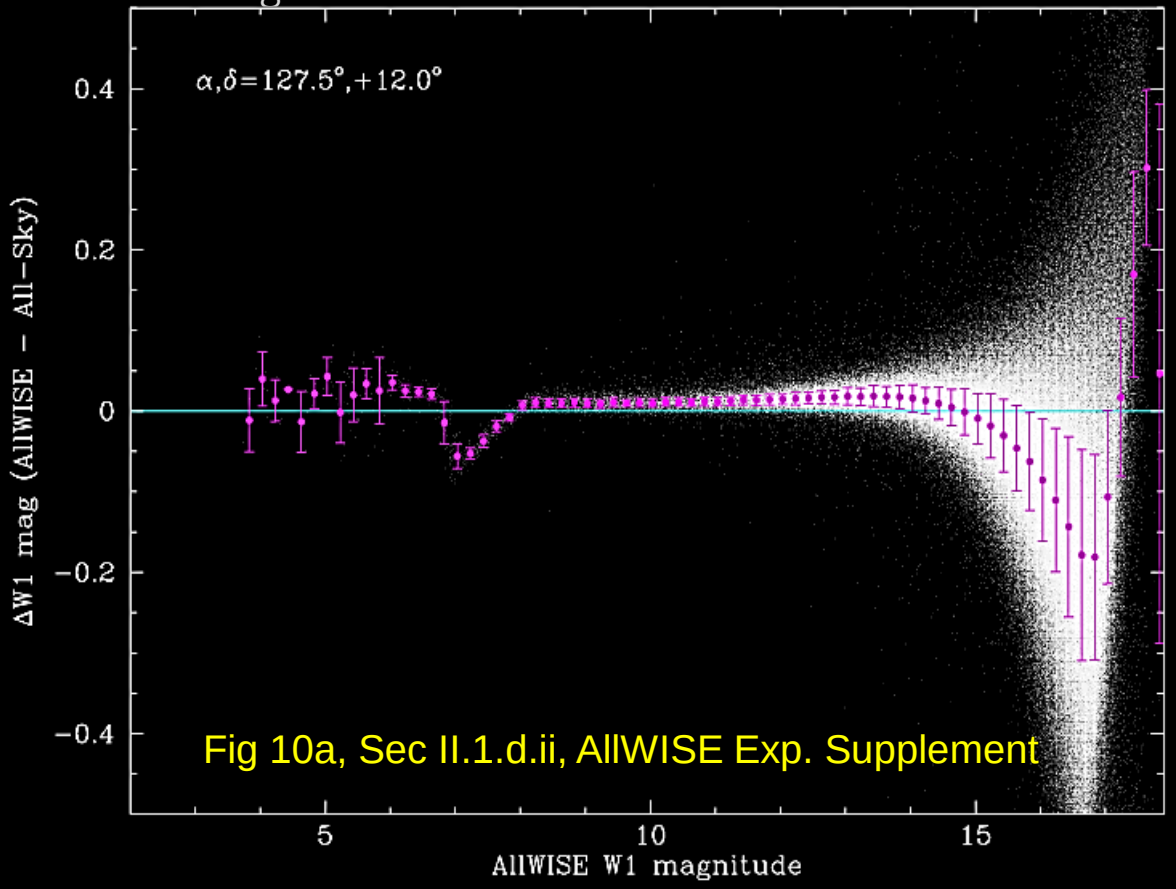
Stick to All-Sky for bright sources

Stick to All-Sky Release for bright stars.

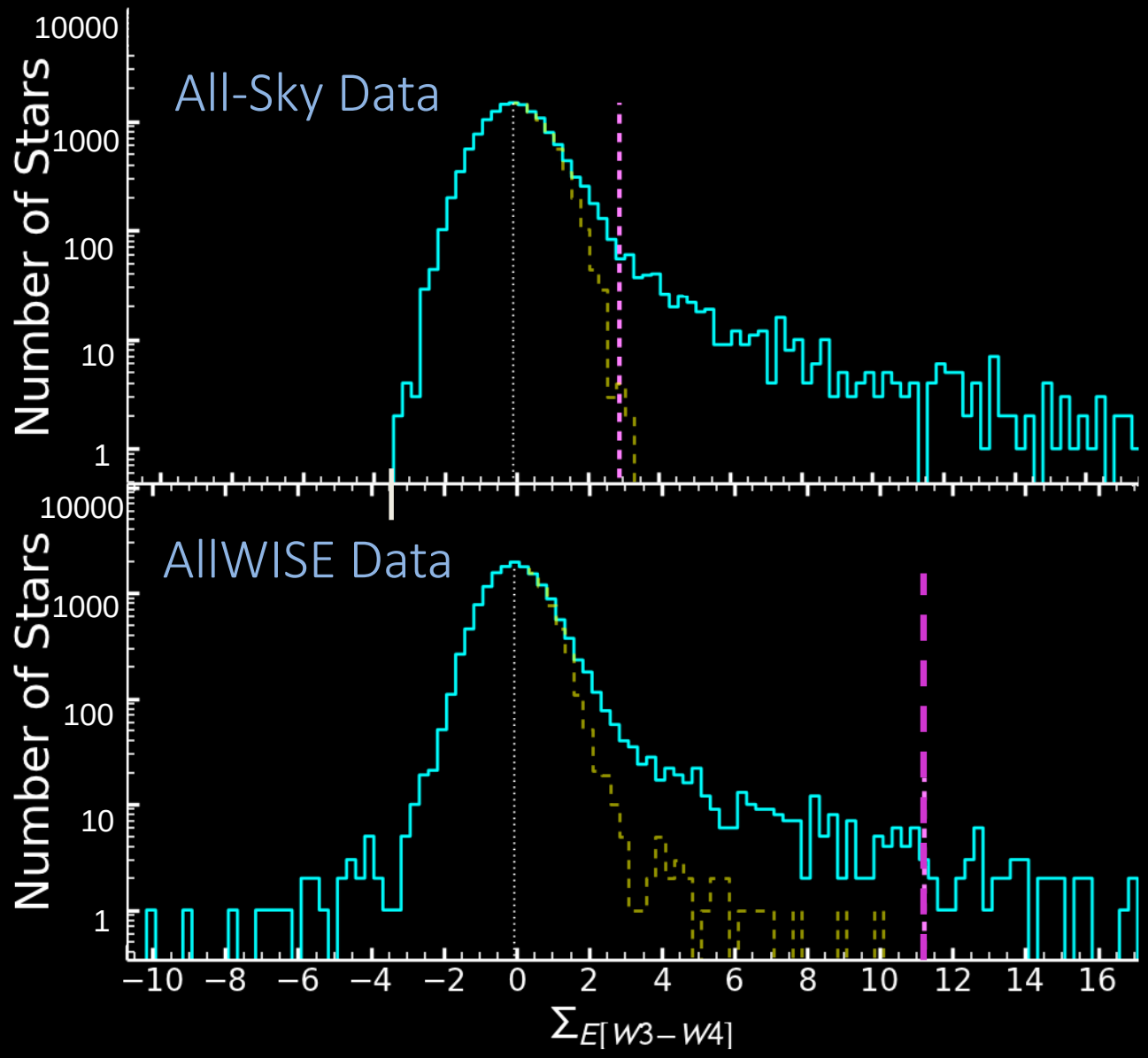
For saturated stars in W1 & W2:

- “AllWISE photometry…may not be as accurate as …in the [All-Sky Release]”

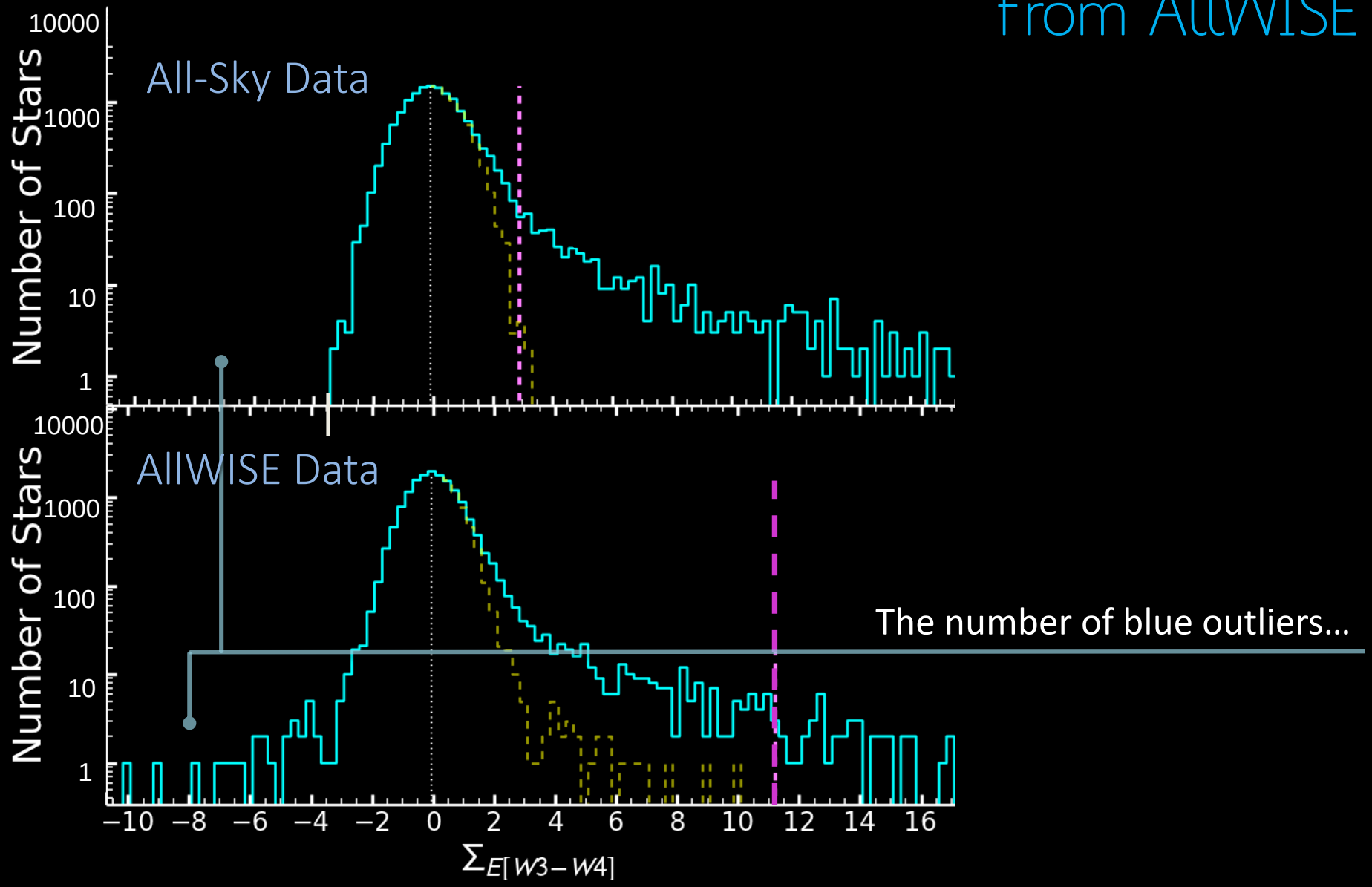
- fluxes “…have much larger uncertainties and …scatter in the AllWISE release [compared to] the WISE All-Sky Release Catalog”



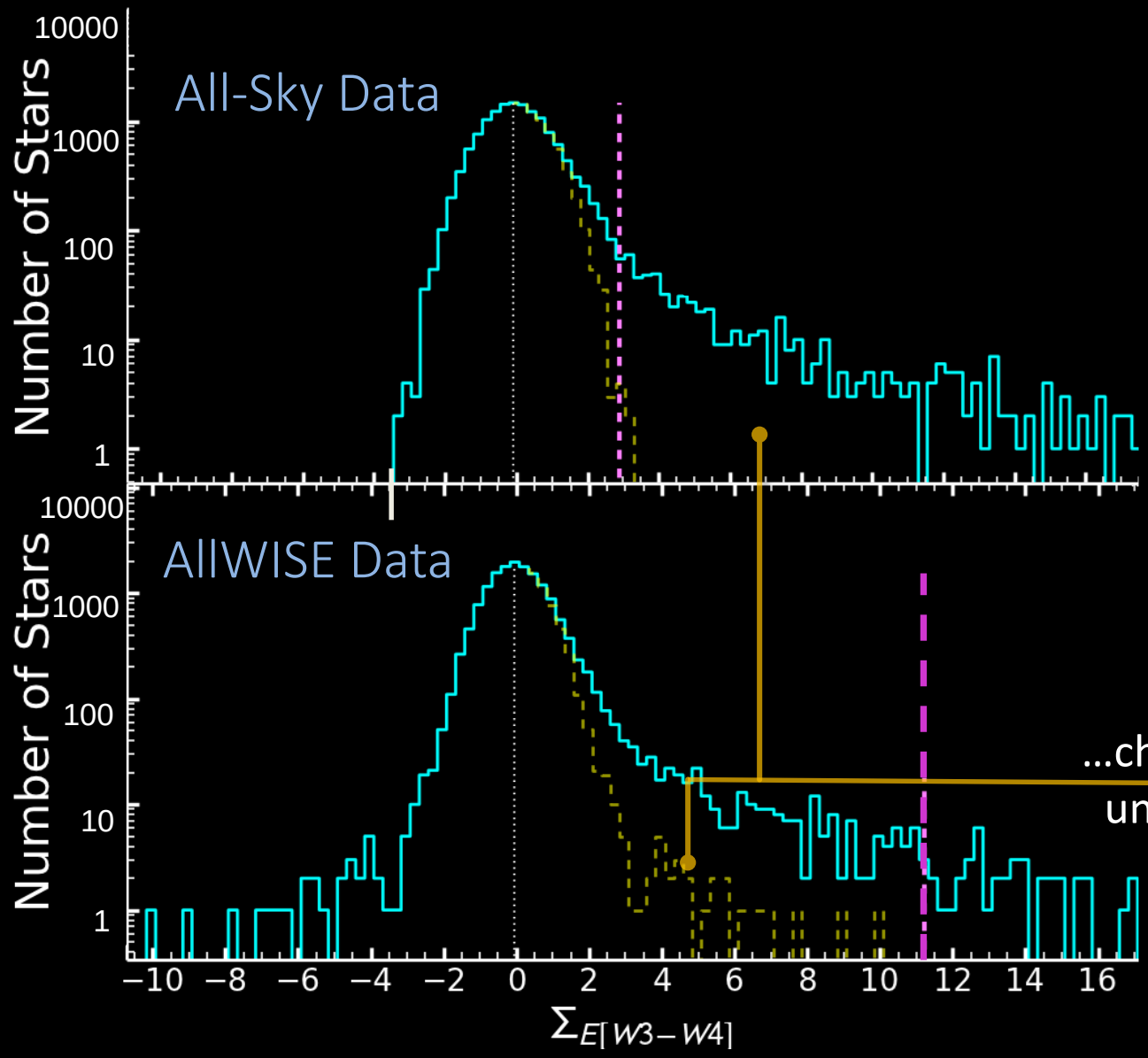
Best to use W3 from All-Sky for bright stars than from AllWISE



Best to use W3 from All-Sky for bright stars than from AllWISE

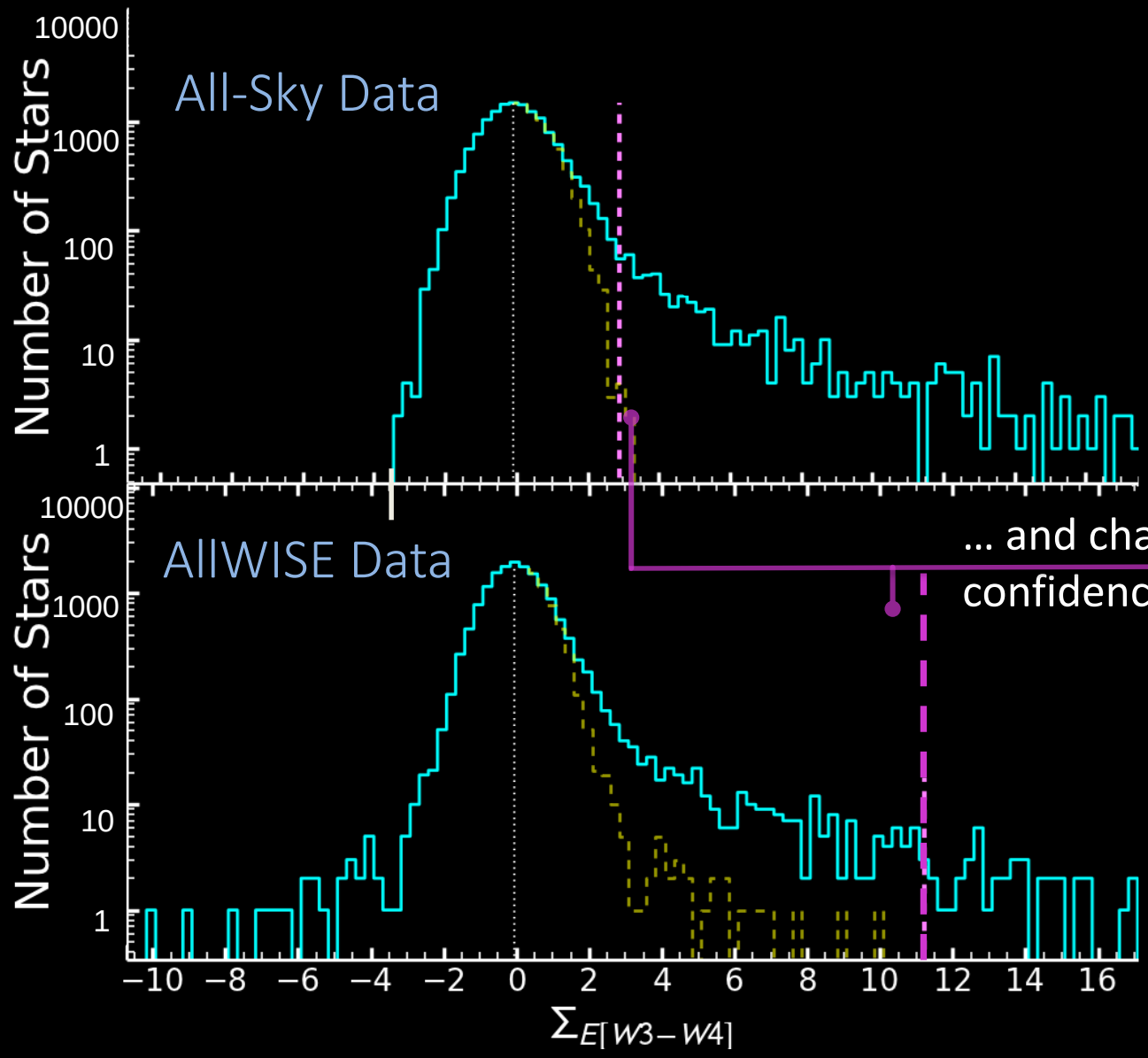


Best to use W3 from All-Sky for bright stars than from AllWISE



…changes the width of the uncertainty distribution…

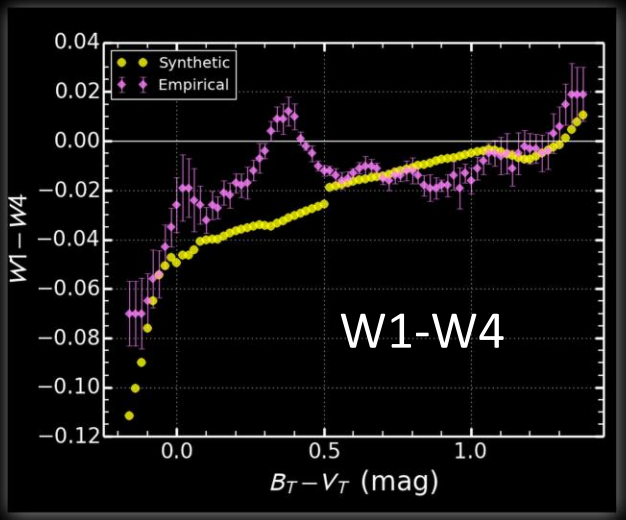
Best to use W3 from All-Sky for bright stars than from AllWISE

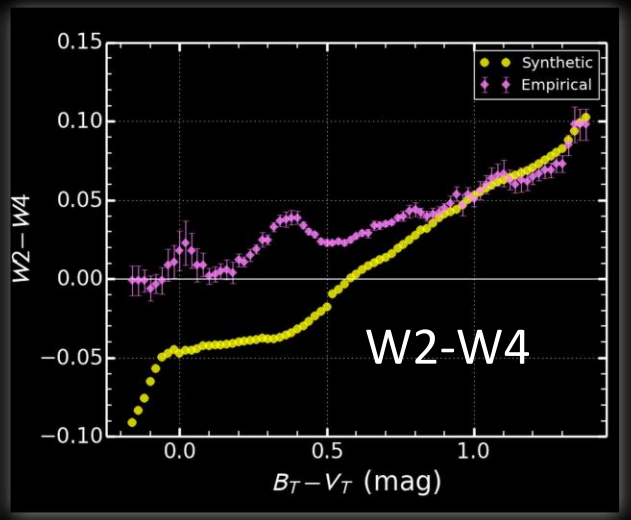


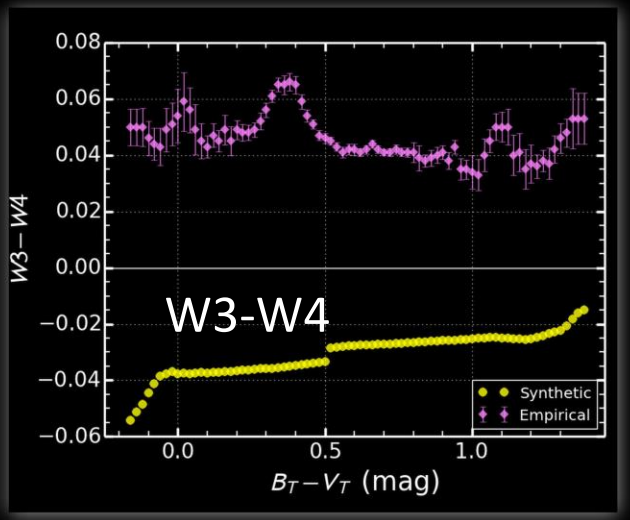
… and changes position of confidence threshold.

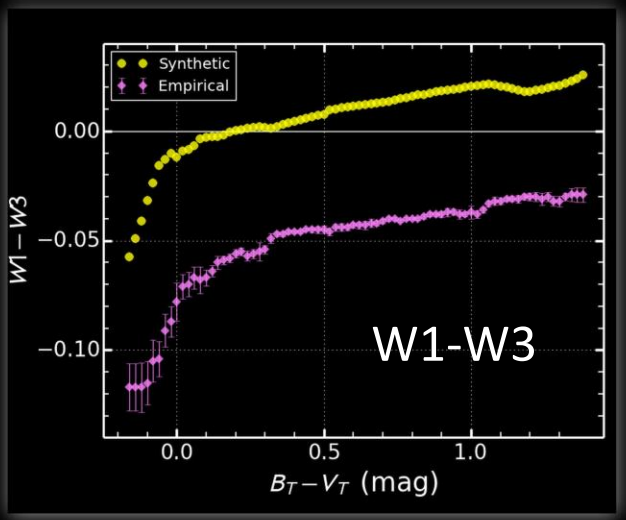
Lessons Learned III:

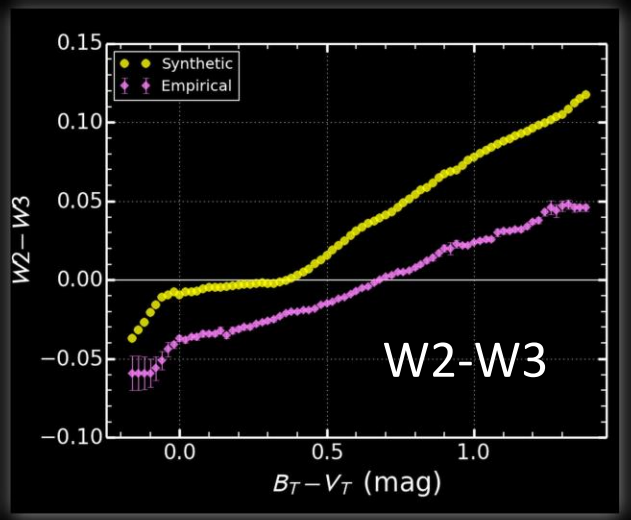
Synthetic vs. Empirical photospheric colors

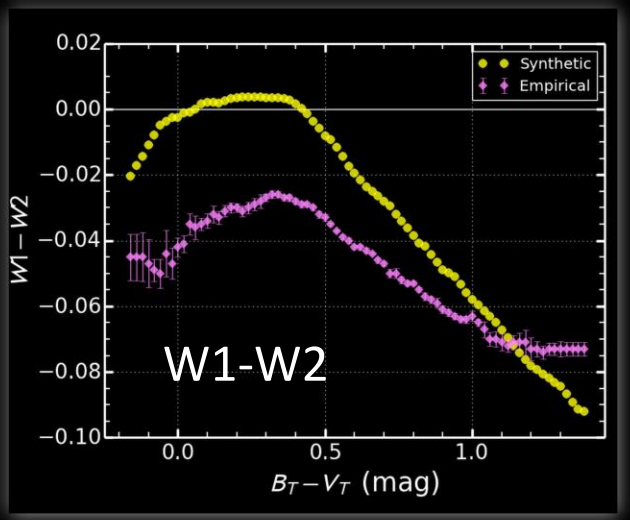

Synthetic
Empirical
W1-W4
$W1-W4$
B_T-V_T (mag)


Synthetic
Empirical
W2-W4
$W2-W4$
B_T-V_T (mag)


Synthetic
Empirical
W3-W4
$W3-W4$
B_T-V_T (mag)

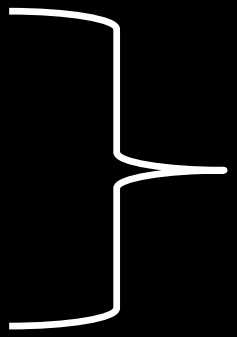

Synthetic
Empirical
W1-W3
$W1-W3$
B_T-V_T (mag)


Synthetic
Empirical
W2-W3
$W2-W3$
B_T-V_T (mag)


Synthetic
Empirical
W1-W2
$W1-W2$
B_T-V_T (mag)

Verifying Debris Disk Hosts Through A Weighted Combination of WISE Colors

E[W1-W4]
E[W2-W4]
E[W3-W4]

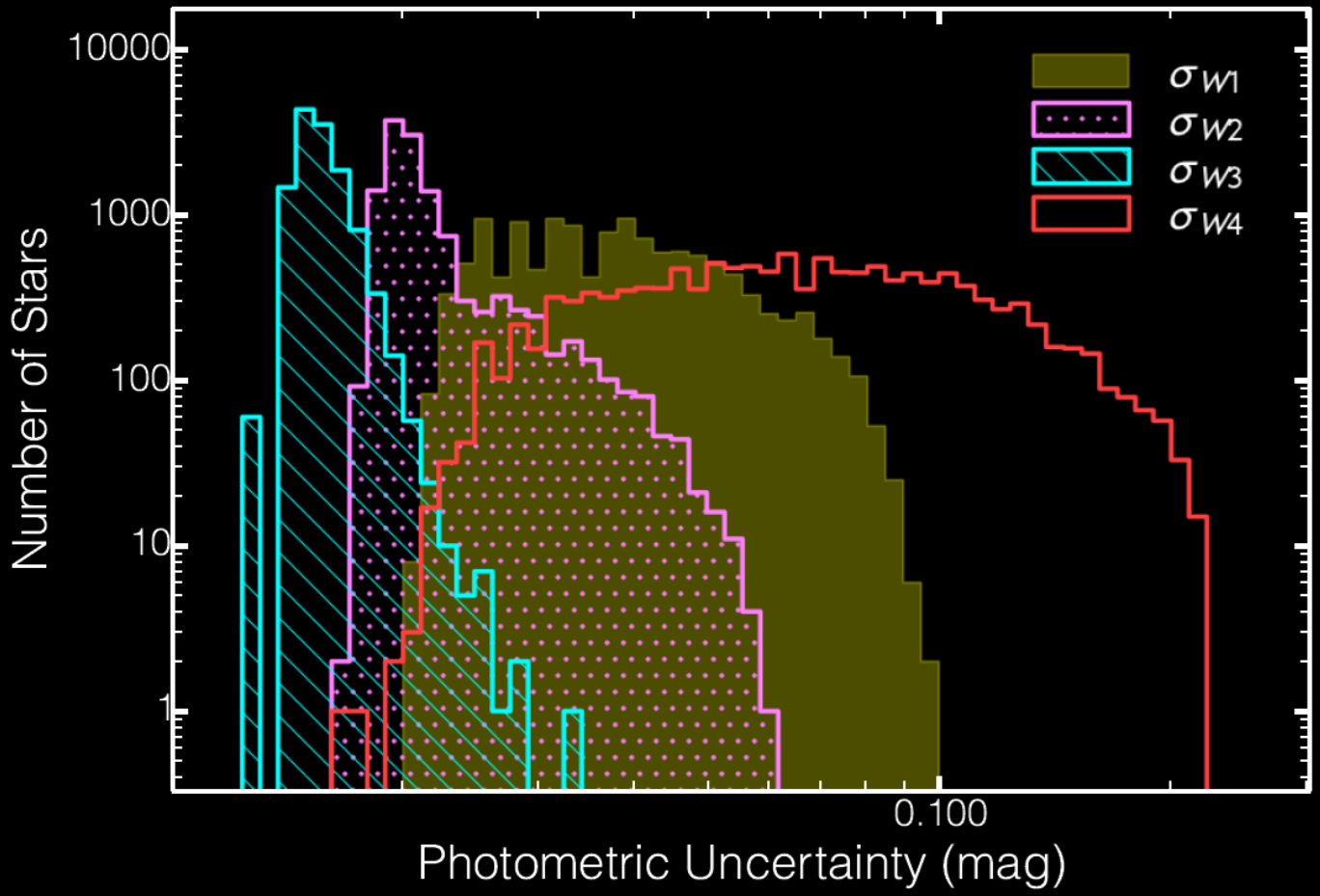


$\overline{E[W4]}$

Patel+2015, in preparation

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

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



Summary:

Results:

- Expanded debris disks census by 25% within 75 pc (98 new disks)
- Incidence rates: 20% for AB stars & 1% for FGK stars.
- Aggregate evidence of warm dust.

New Techniques:

- Saturation corrections
- Photospheric calibration

Lessons Learned

- W4 flux overestimation substantial for cold bright disks.
- Stick to All-Sky for bright stars as cautioned by online supplement **– even for W3!**
- There are differences between the WISE synthetic and empirical photospheric colors.