Obscured AGN in WISE

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In collaboration with Daniel Stern (JPL), Peter Eisenhardt (JPL), Jingwen Wu (UCLA), Chao-Wei Tsai (JPL), Andrew Blain (Leicester), Christopher S. Kochanek (OSU), Dominika Wylezalek (JHU) and the WISE ExGal Team

Outline

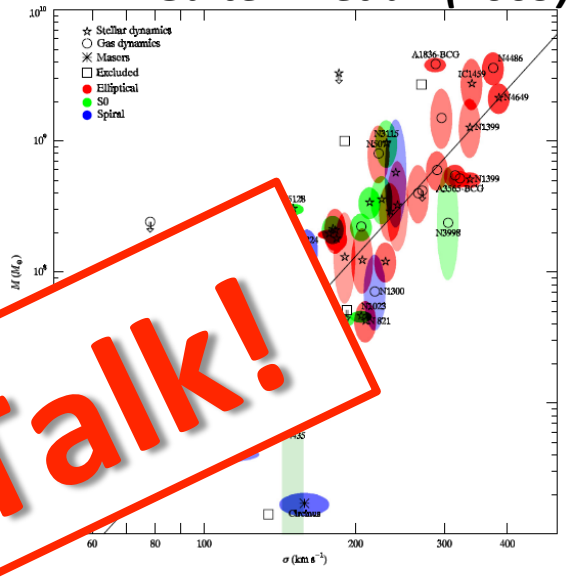
- "Normal" Obscured AGN with WISE
  - Stern et al.(2012, ApJ, 753, 30)
  - Assef et al.(2013, ApJ, 772, 26)
- Hot Dust Obscured Galaxies - Hot DOGs
  - Eisenhardt et al. (2012, ApJ, 755, 173)
  - Wu et al.(2012, ApJ, 756, 96), Wu et al.(2014, ApJ, 793, 8)
  - Stern et al.(2014, ApJ, 794, 102)
  - Jones et al.(2014, MNRAS, 443, 146)
  - Assef et al.(submitted, arXiv:1408.1092)
  - Tsai et al. (submitted, arXiv:1410.1751)

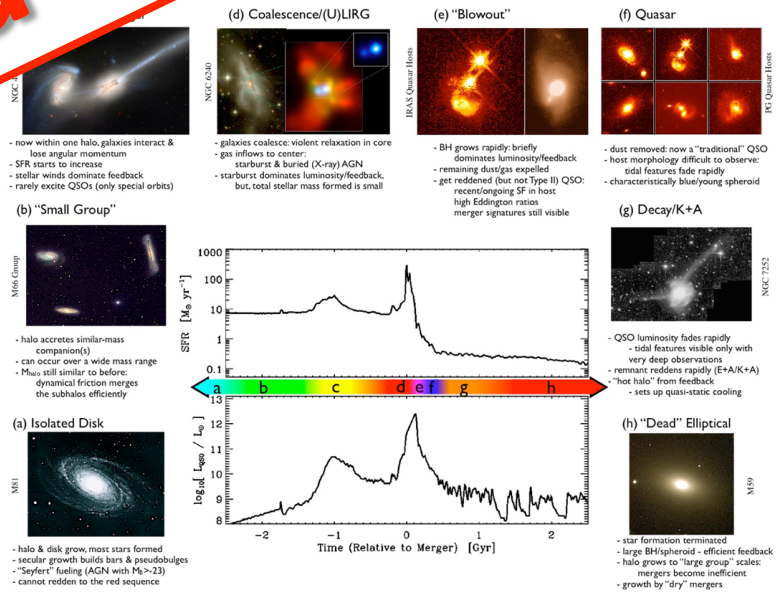
Why Care About Obscured AGN?

- AGN likely play a fundamental role in driving galaxy evolution.
- Relations between host and bl… hole imply a strong degr… evolution.
- One of t… phases expected … of massive galaxies is … obscured phase where AGN feedback stars shutting-down star-formation.

See Nadia's Talk!

Gültekin et al. (2009)





Hopkins et al. (2008)

Normal AGN in WISE

The Role of WISE in Finding AGN

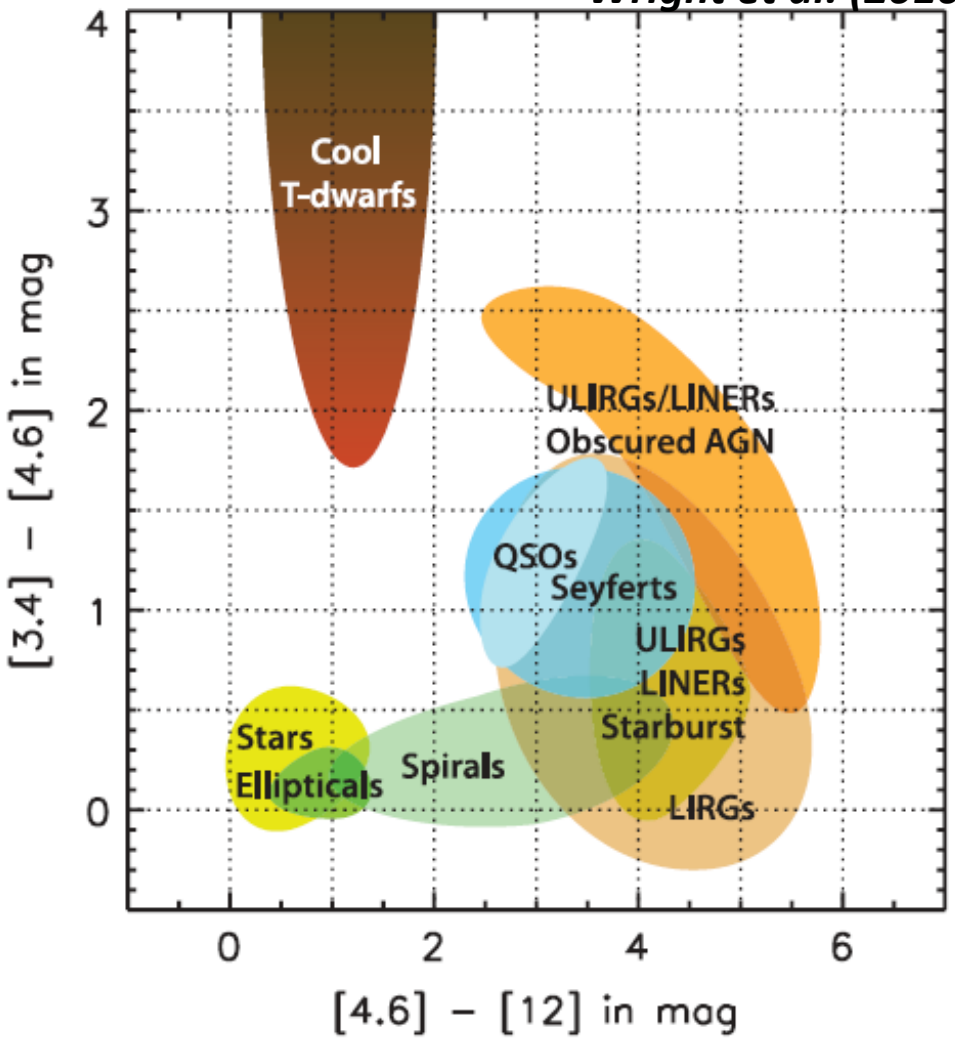
The mid-IR is great for identifying AGN

- Particularly at 3-5 microns
- Hot dust from the Torus is particularly bright and blue
- Most stars are red (Rayleigh-Jeans)

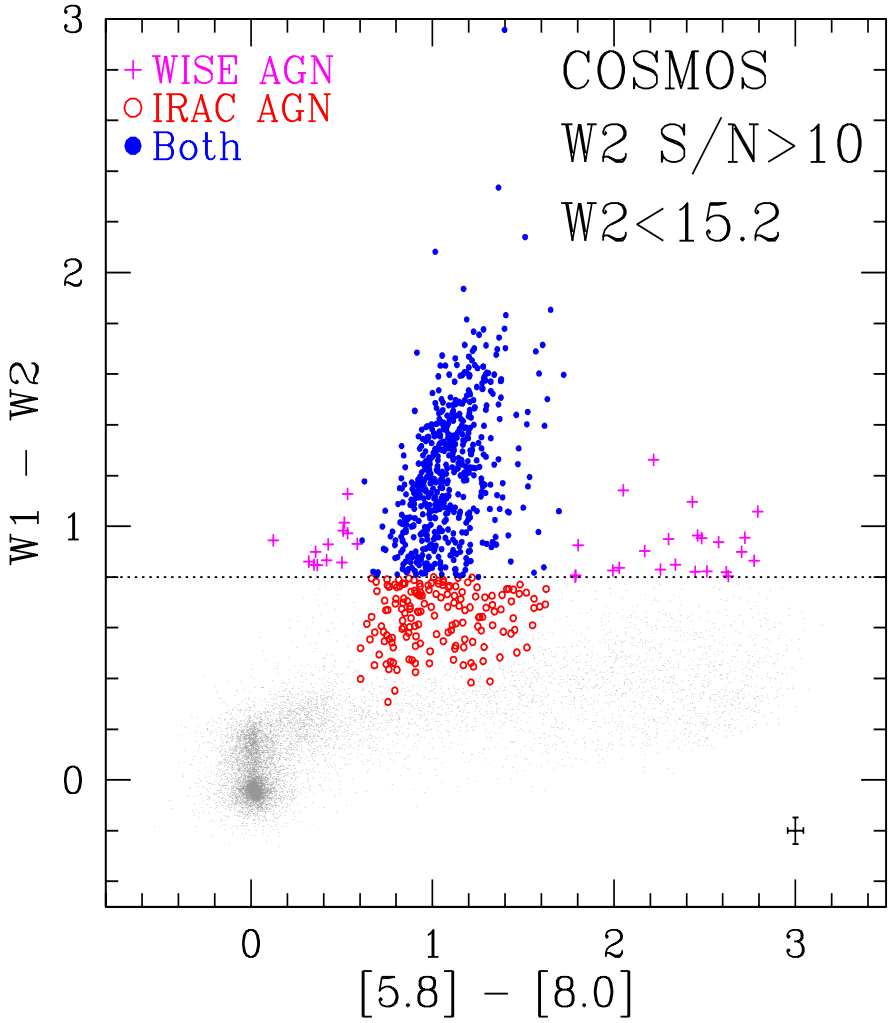
We have known this since Spitzer

- Lacy et al. (2004, 2007), Stern et al.(2005), Alonso-Herrero et al. (2008), Donley et al.(2008, 2012), Assef et al.(2010)

Wright et al. (2010)



WISE AGN Selection



Most IRAC AGN have

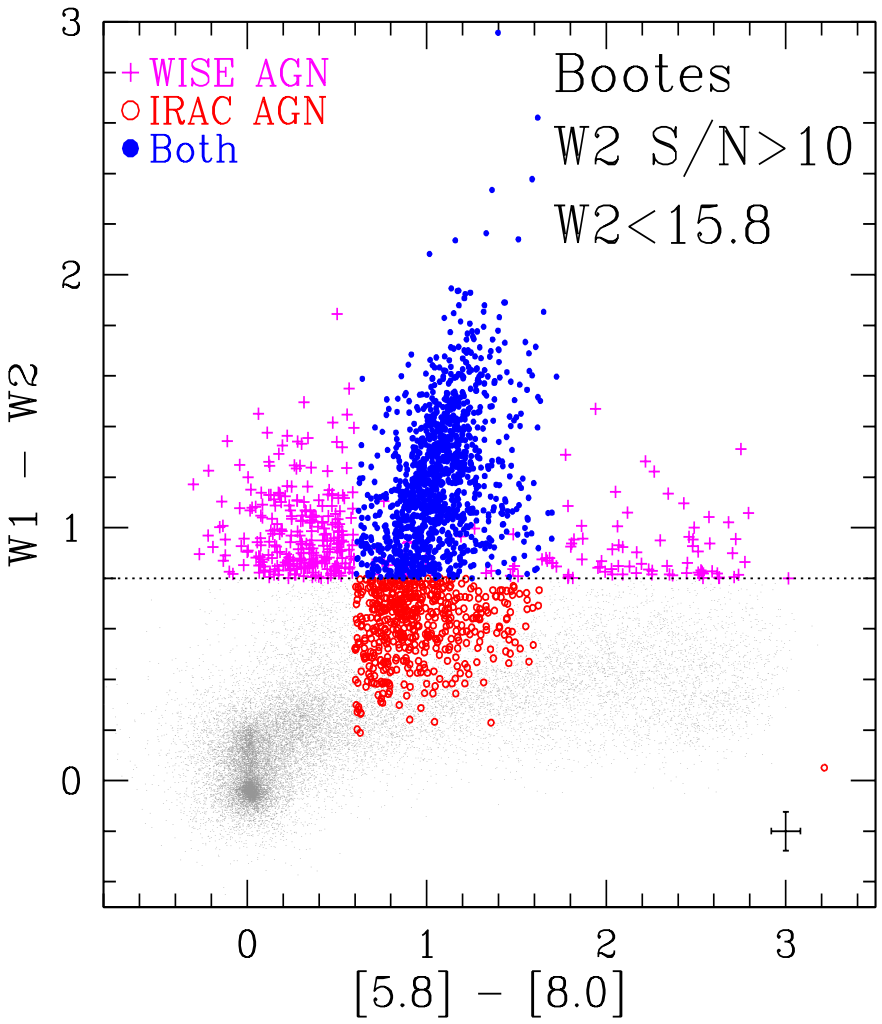
W1-W2 > 0.8

- 95% reliability in COSMOS
- 75% completeness in COSMOS

Stern et al.(2012, ApJ, 753, 30)

See *Assef et al.(2013, ApJ, 772, 26)* for a more universal AGN selection based on W1 and W2.

WISE AGN Selection



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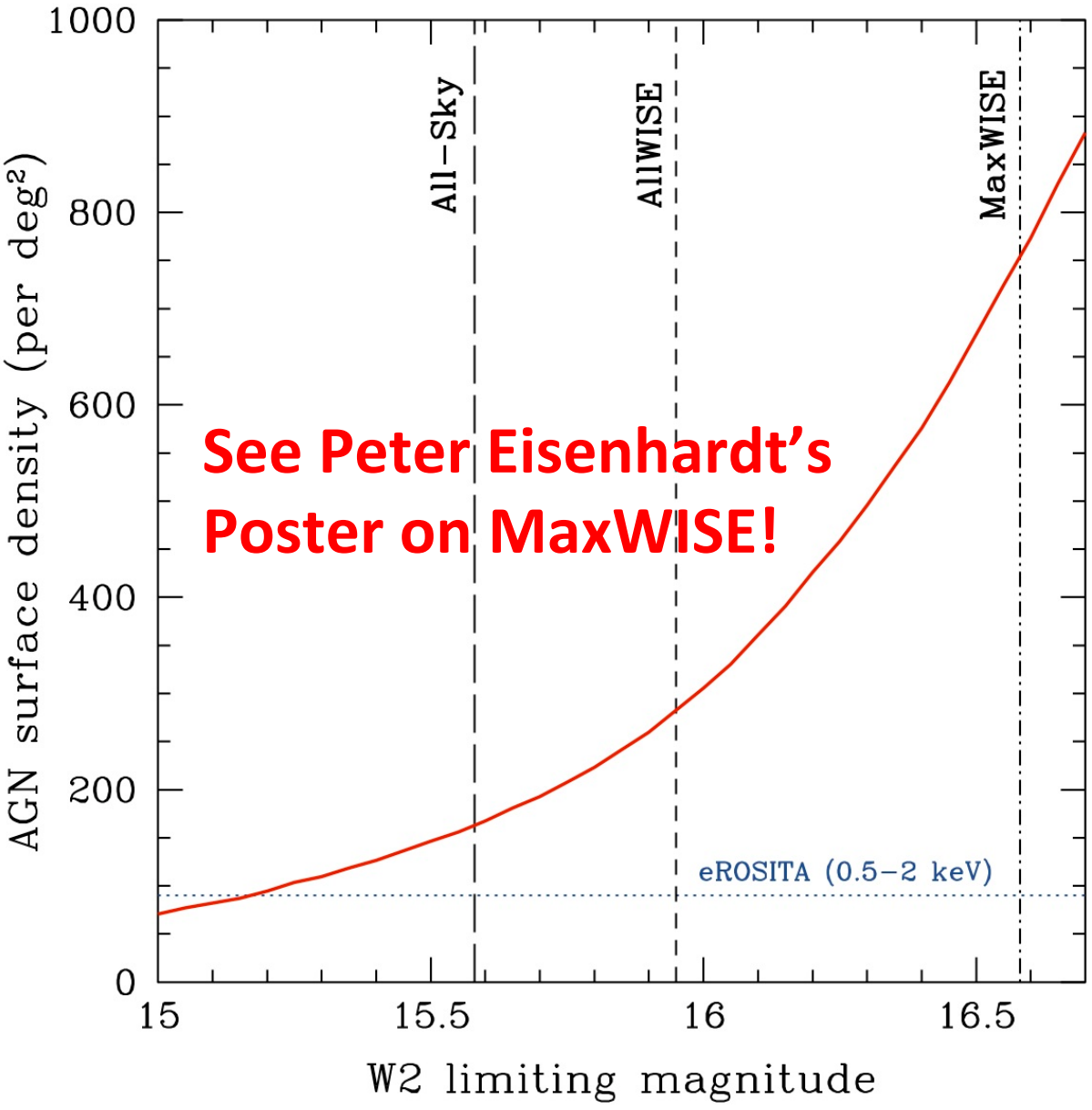
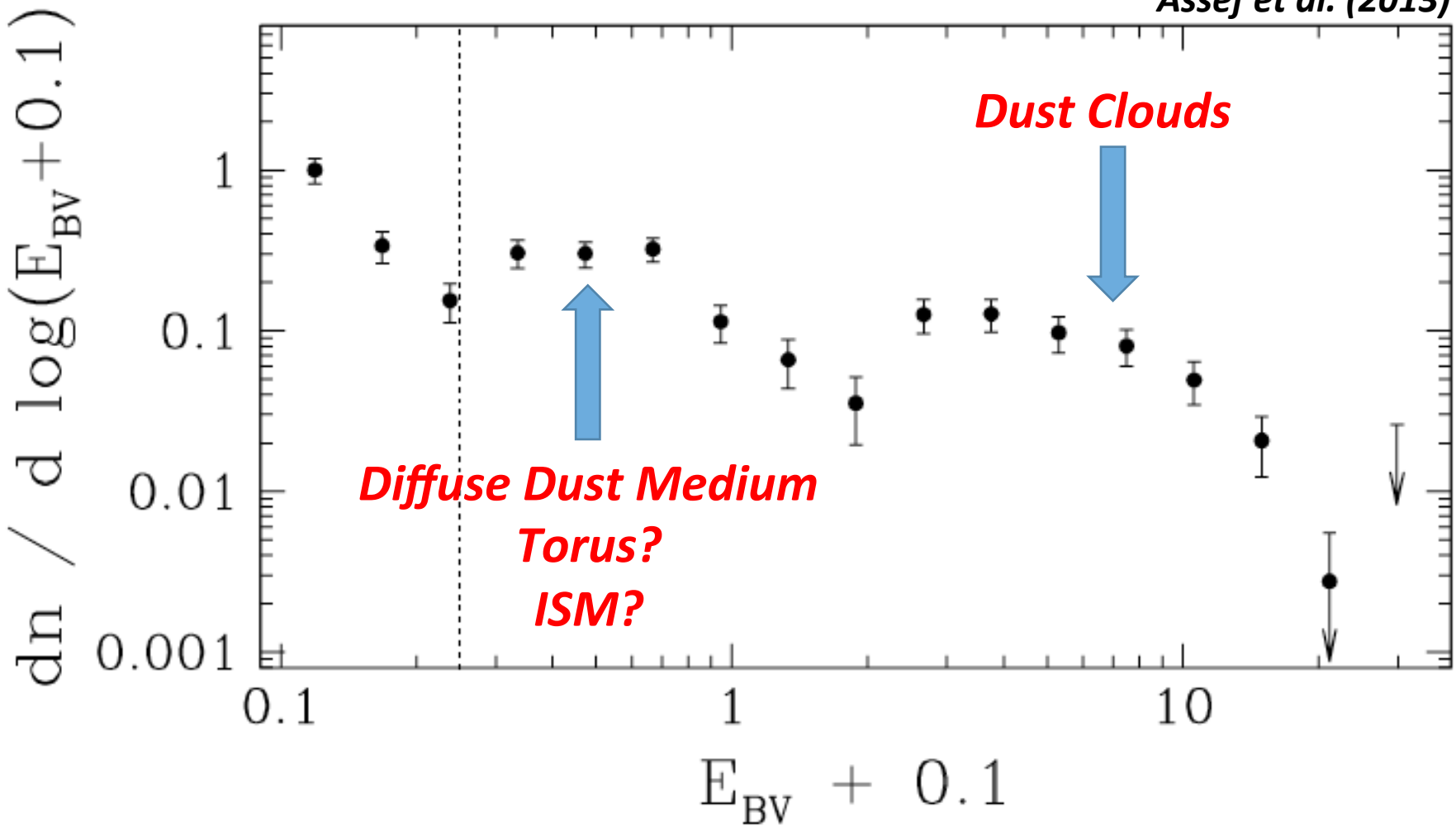
Magnitude De

- W1 and W2 alone a depths
  - Different selection c completeness
  - Our 90% reliability c
    - 6x nominal surfa
    - Increase is prima
  - W3 is great to incluc
    - Jarrett et al. (201



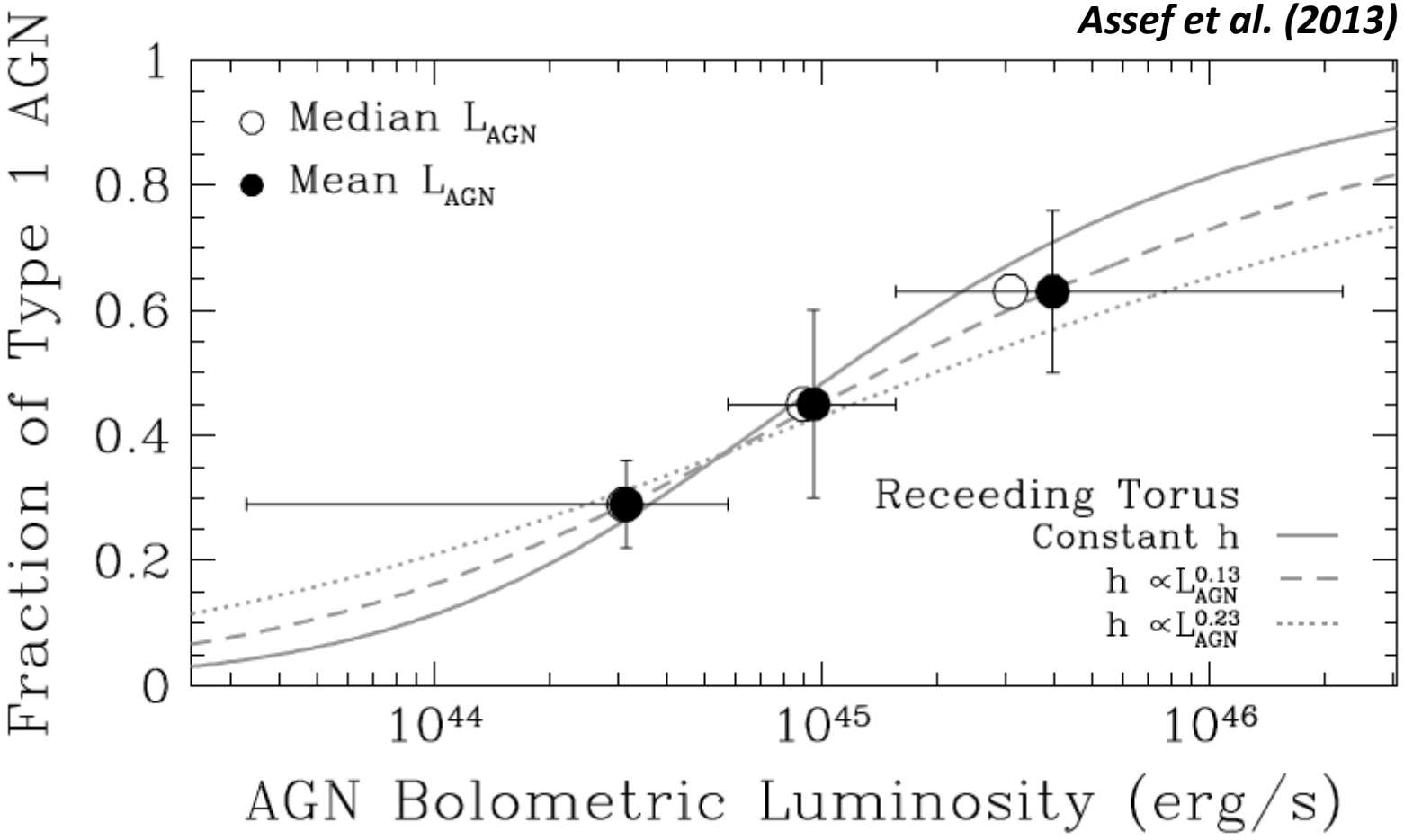
Number of AGN vs. Accretion Disk Obscuration in Bootes

Assef et al. (2013)



Evidence for a Receding Torus?

Assef et al. (2013)



Hot Dust Obscured Galaxies (Hot DOGs)

Assef et al. (submitted, arXiv:1408.1092)

WISE – Most Luminous Galaxies

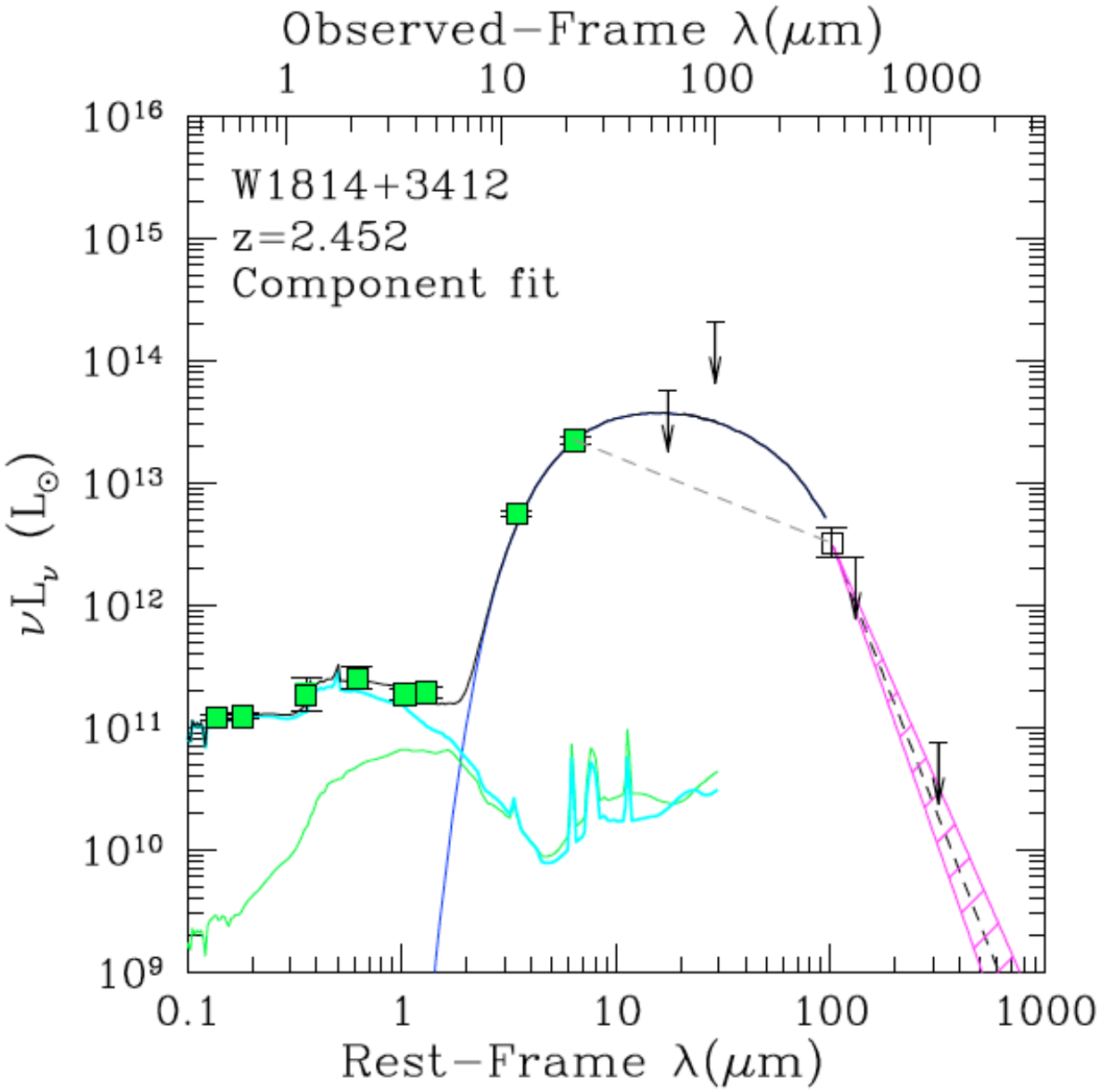
- One goal of WISE is to identify the most luminous galaxies in the universe.

- These galaxies should be very red and bright in the mid-IR (SF/AGN) but most likely very rare.

  Combination of depth + area makes WISE ideal for this.

- As expected, WISE has been very successful at it with the discovery of Hot Dust Obscured Galaxies (Hot DOGs).

  As you have already heard from Chao-Wei Tsai's talk.



First object studied in detail (***Eisenhardt et al. 2012, 755, 173***)

Best fit SED model has

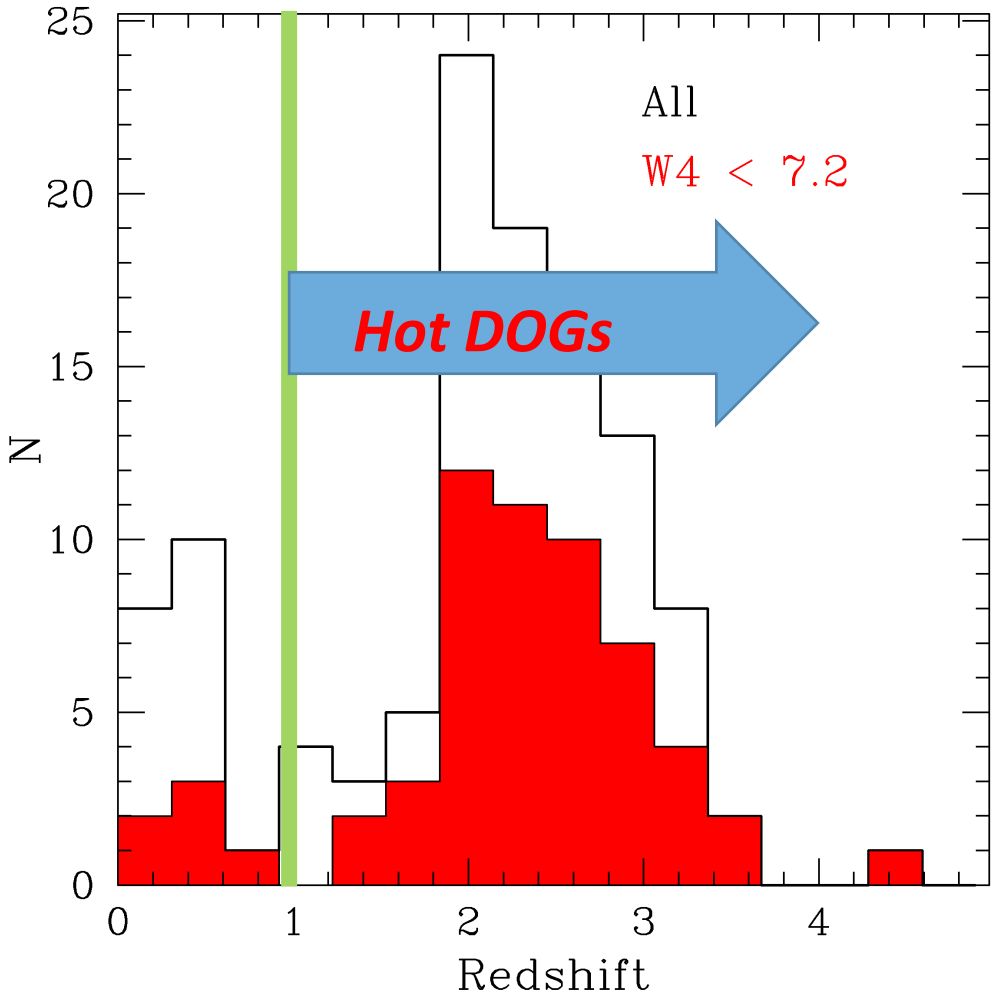
- AGN with A_V ~ 50 mag
- Starburst with ~300 M_{sun}/yr SFR
- $L_{Bol} = 9 \times 10^{13}\ L_\odot$

Adapted from Eisenhardt et al.(2012)

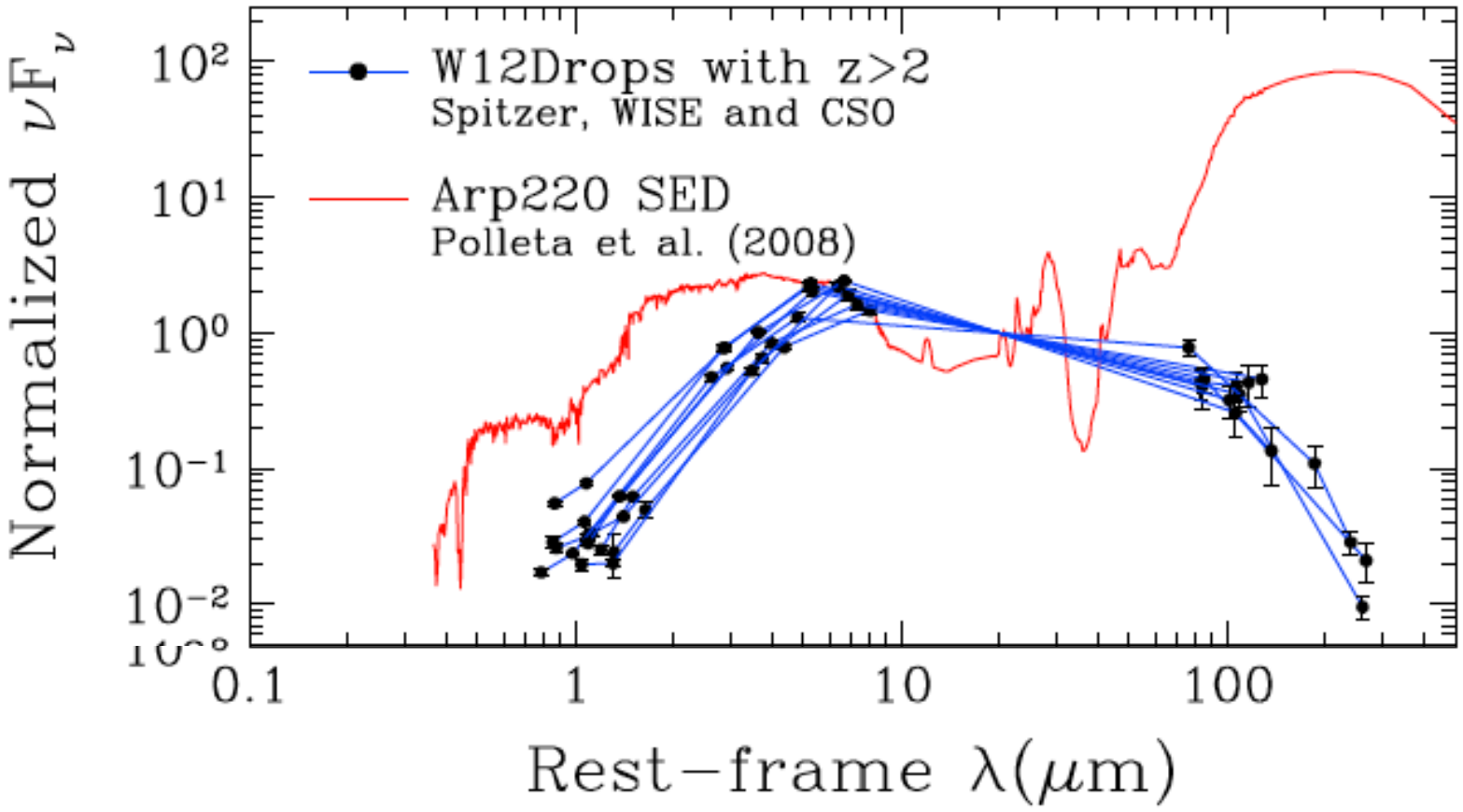
Hot DOGs are at High-z and are Hyper-Luminous

- All at z>1
- Low contamination rate of selection by low-z interlopers
- Highest at z=4.6
  - Will back to this one later on
- All have $L_{IR}>10^{13}L_{\odot}$
  - 10% have $L_{IR} > 10^{14}L_{\odot}$
  - *Wu et al.(2012)*
  - *Tsai et al.(2015)*

Assef et al. (submitted)

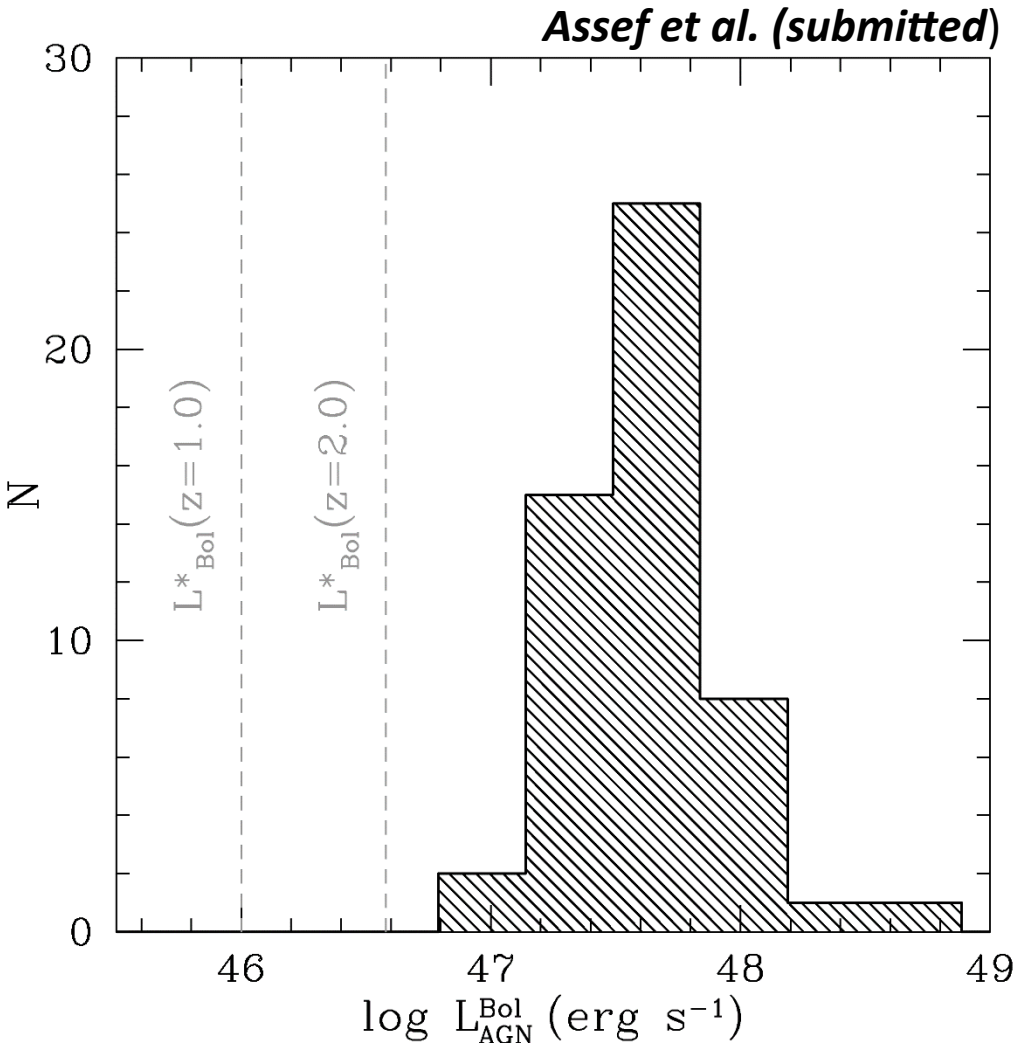


Remarkably Similar SEDs



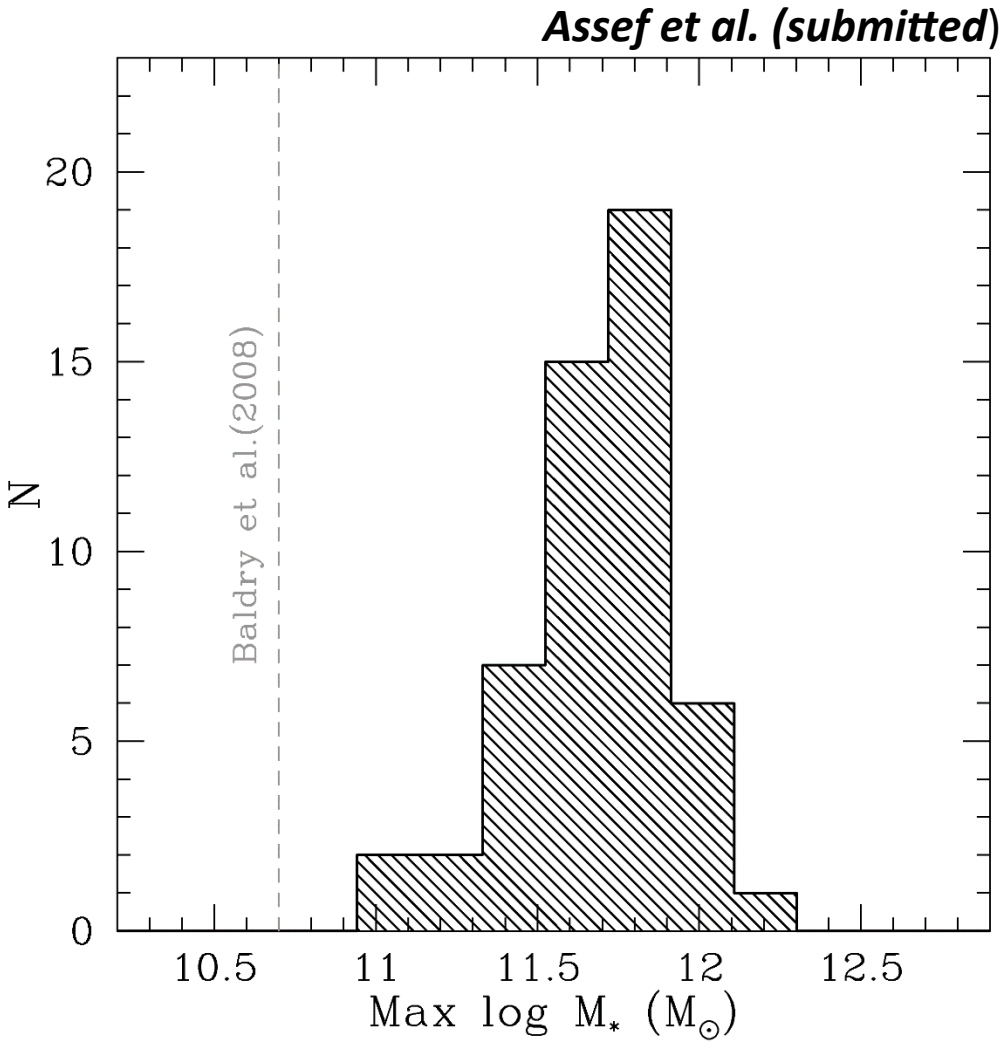
Adapted from Wu et al. (2012, ApJ, 756, 96)

Powered by Very Luminous AGN



- 52 Hot DOGs with
  - Spitzer follow-up
  - Spec-z
  - W4 < 7.2 mag
- Similar SED modeling as for W1814+342
- Significantly brighter than L*
- Among the most luminous AGN

Maximal Stellar Mass



Too few photometric bands to constrain M/L

Upper bound on M/L from

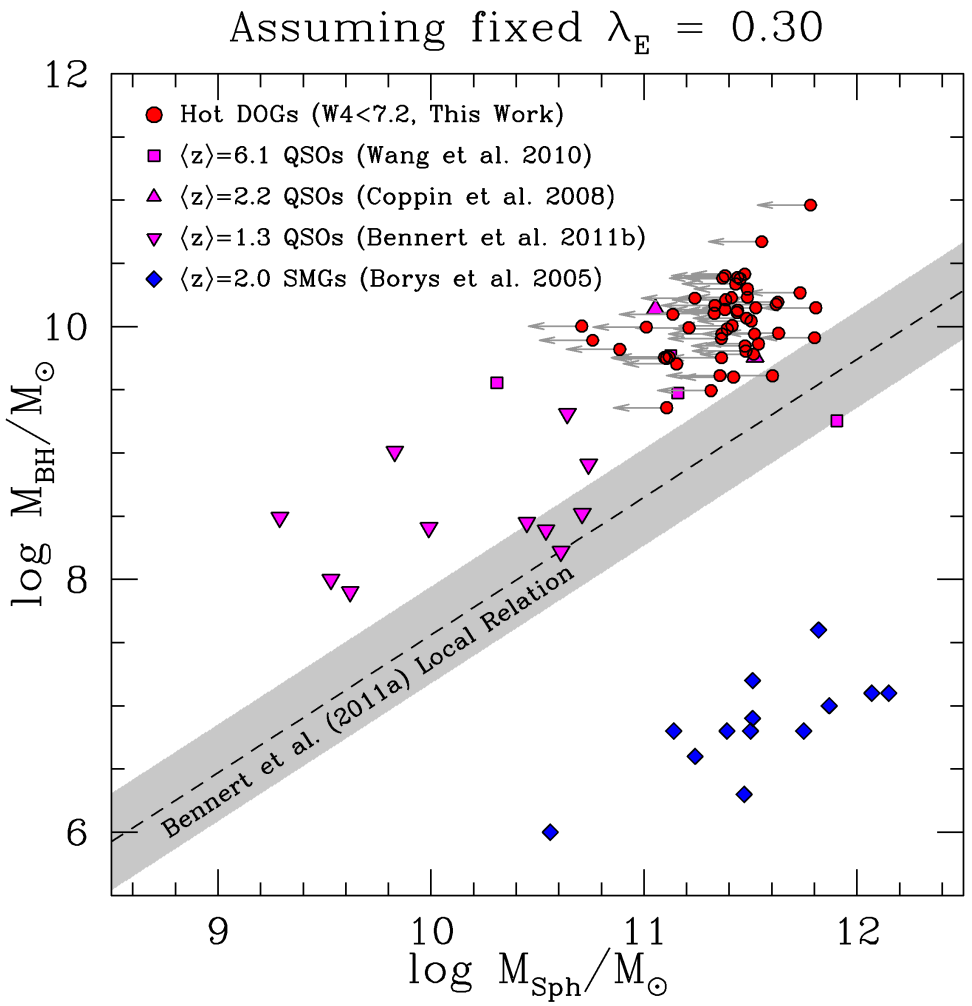
- Maximally old stellar population
- Bruzual & Charlotte (2003) for low TP-AGB contribution
- Bottom-heavy IMF from Conroy & van Dokkum (2013)

Hot DOGs & Local BH-Host Relations

Hot DOGs have very luminous AGN in not so massive galaxies.

Two possibilities

1. BHs much more massive than expected from local relations
2. Super-Eddington luminosities



Assef et al. (submitted)

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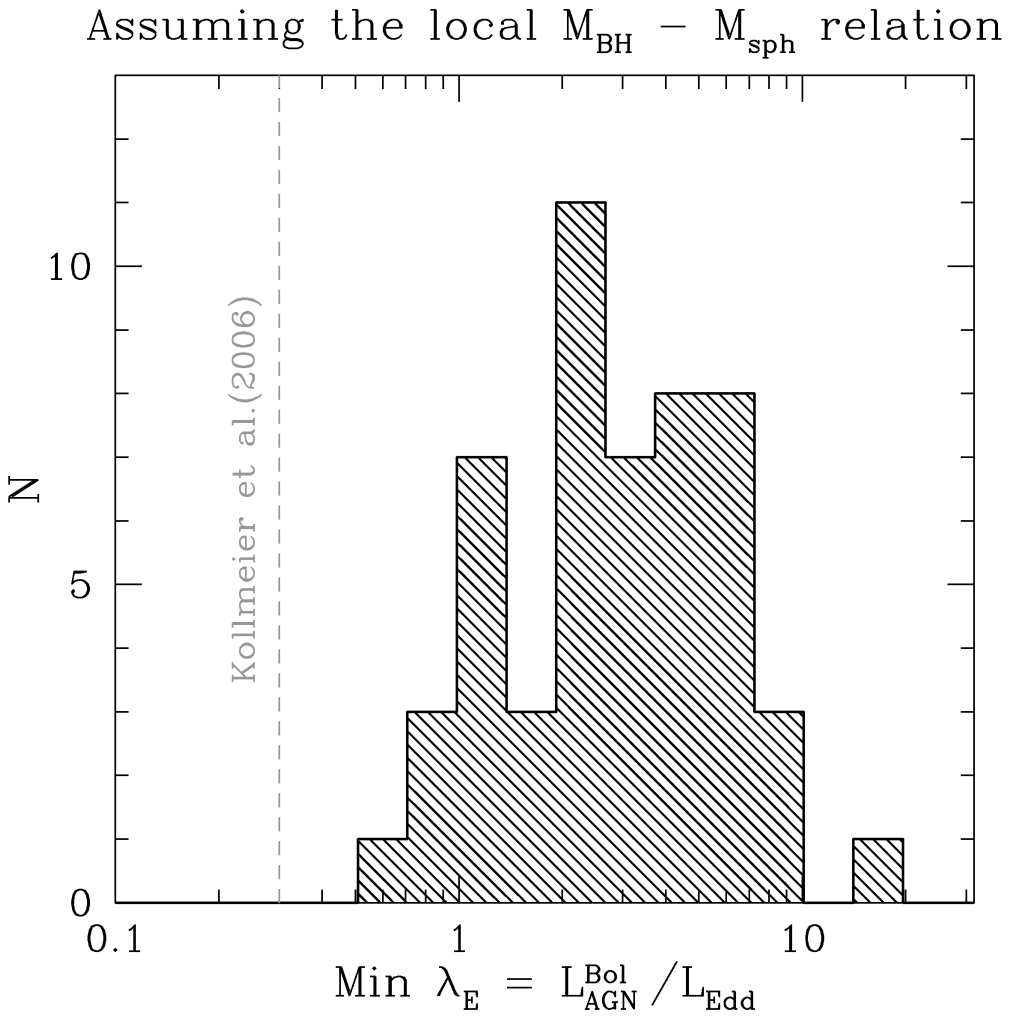
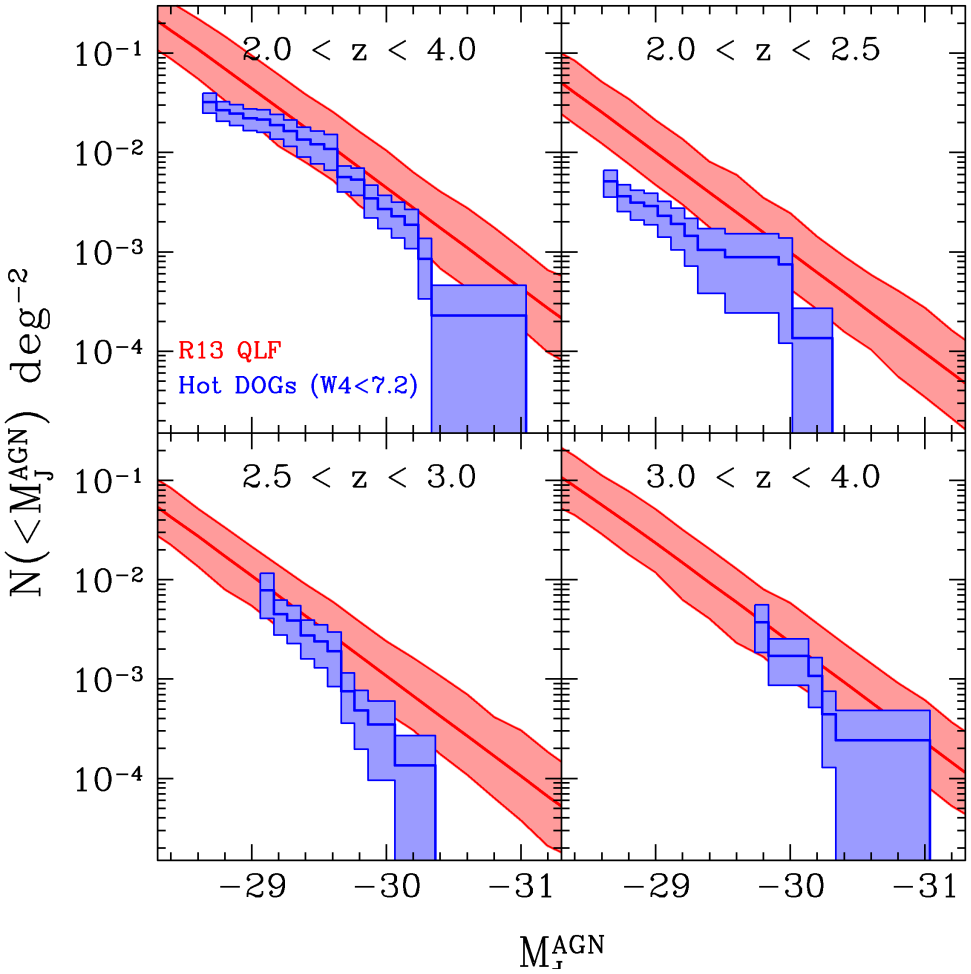


Assef et al. (submitted)

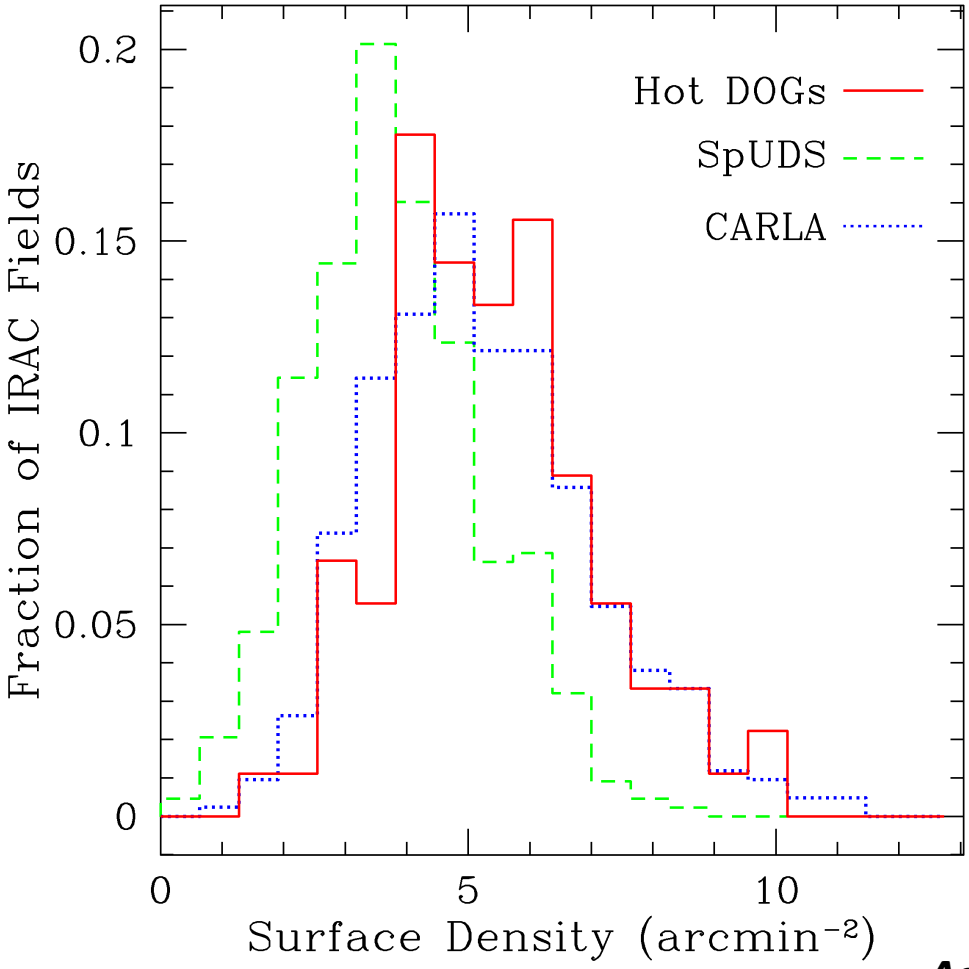
Similar Space Density as Type 1 QSOs



Assef et al. (submitted)

- Although rare, Hot DOGs seem to be as common as Type 1 QSOs.
  - Type 1 QLF from SDSS/BOSS (Ross et al. 2013)
- Half of the most luminous AGN are obscured?
- No clear redshift evolution
  - Sample may be too small

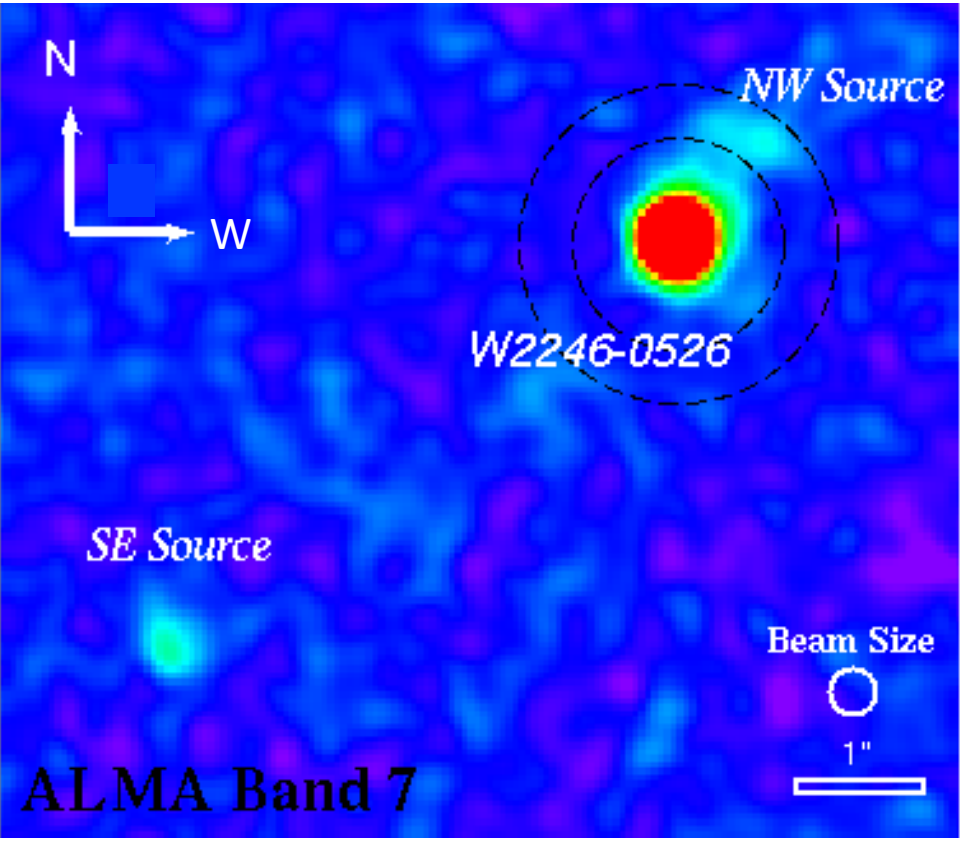
Hot DOGs Live in Dense Environments

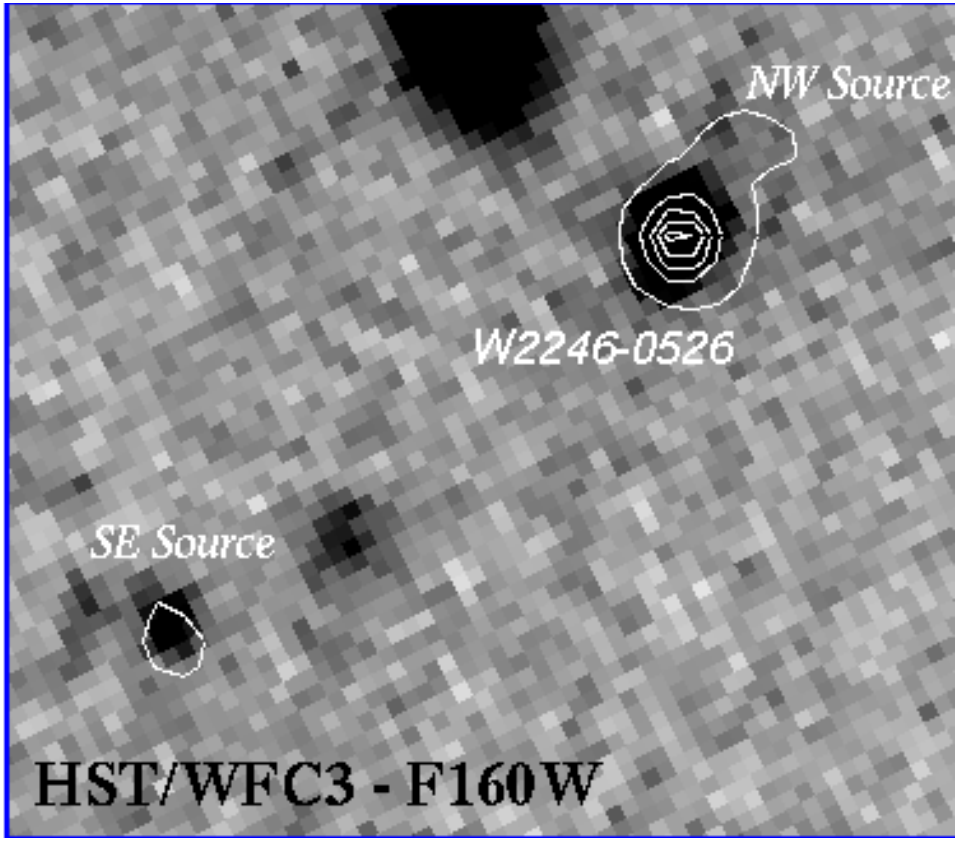


- Based on the projected density of galaxies in IRAC within 1 arcmin.
- More dense than the field (SpUDS)
- Similarly dense to proto-clusters at z~2 (CARLA)

Assef et al. (submitted)

W2246-0526, The Most Luminous Hot Dog
Diaz-Santos et al. (in prep.)





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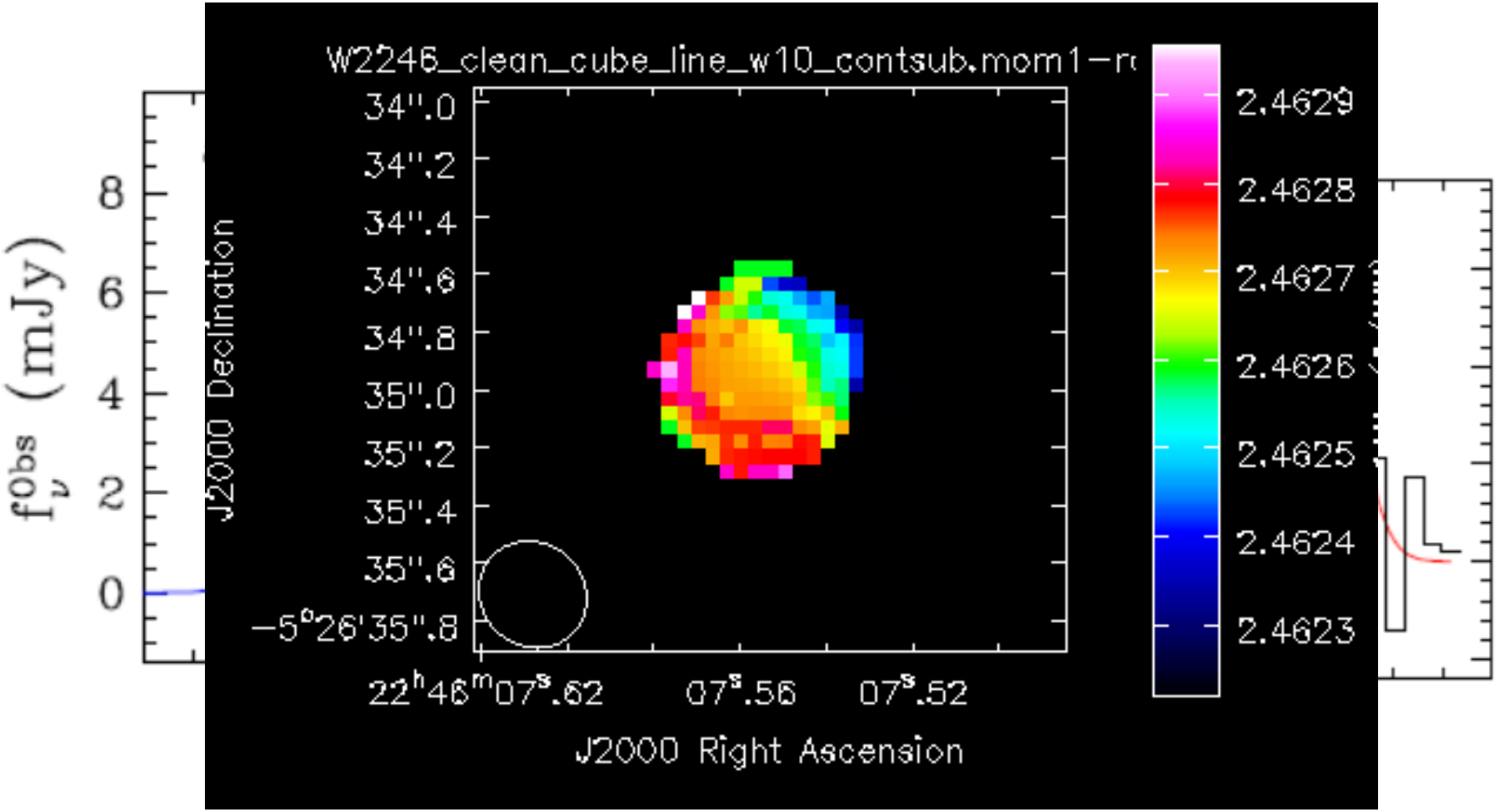


Summary

- WISE is a great tool for finding AGN, particularly obscured ones.
- WISE can help us learn about the properties of the "normal" AGN torus from "simple" counting statistics.
- WISE has identified some of the most extreme AGN dominated galaxies in the Universe
  - Hot DOGs have unique properties, unlike those of any other luminous galaxy population
  - Possibly a significant stage in the evolution of massive galaxies.
- **Many thanks to the entire WISE team!**

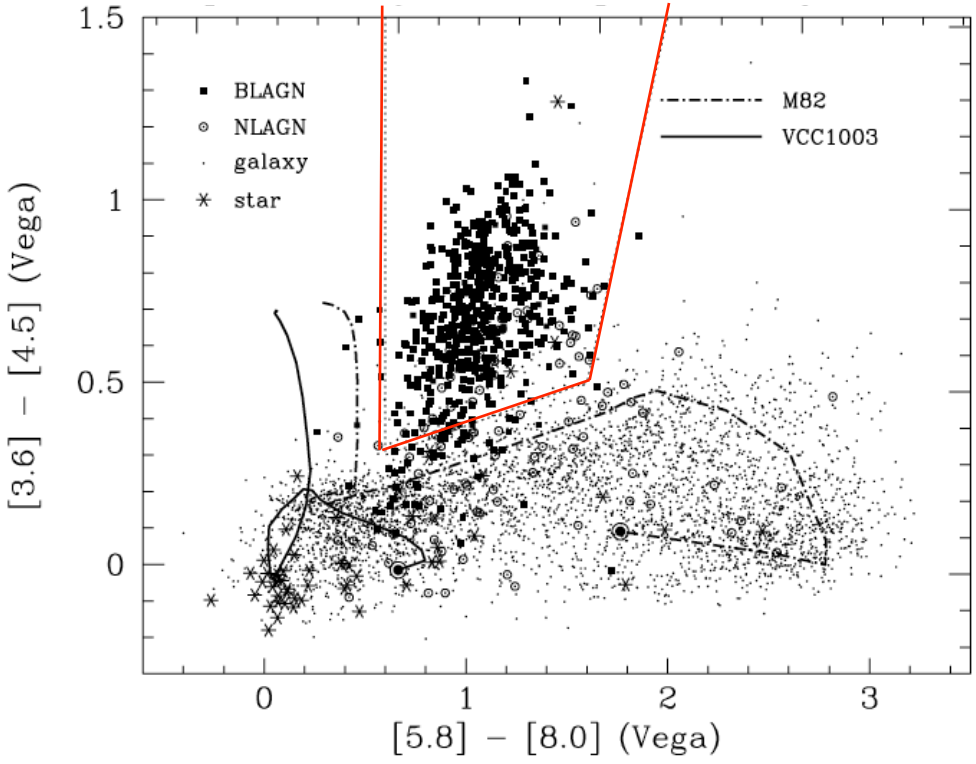
Backup Slides

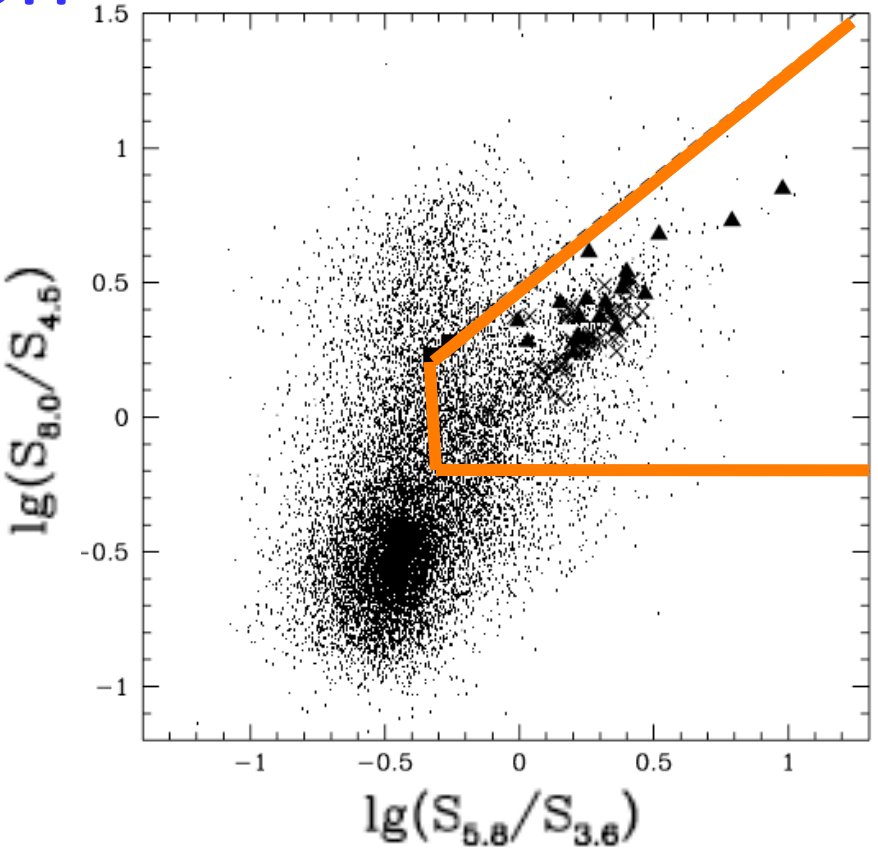
Spitzer AGN Selection

Stern et al. (2005, ApJ, 631, 163)

80% reliable, 80% complete, [4.5] ≈ 16

70% reliable, 50% complete, [4.5] ≈ 17



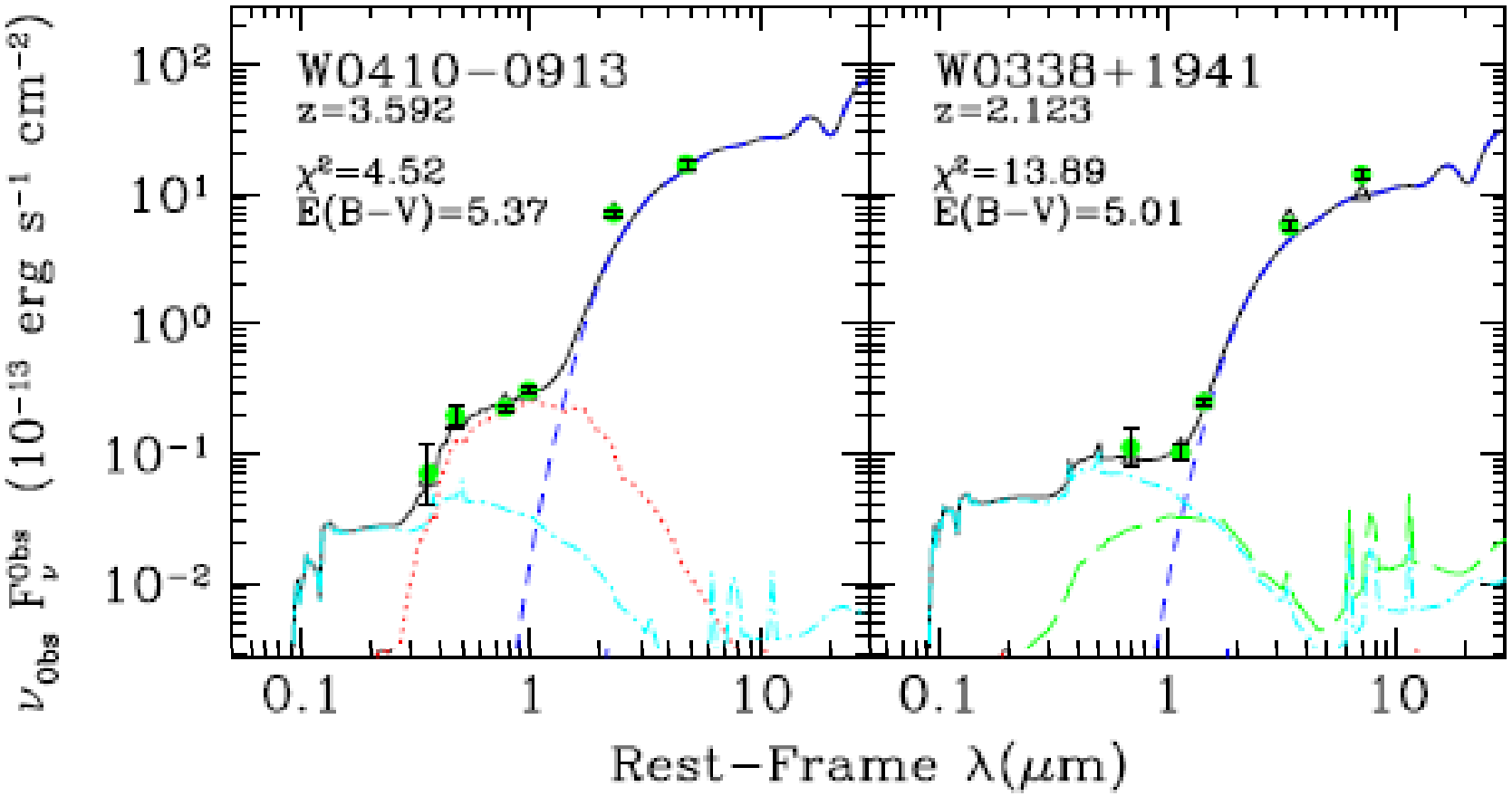


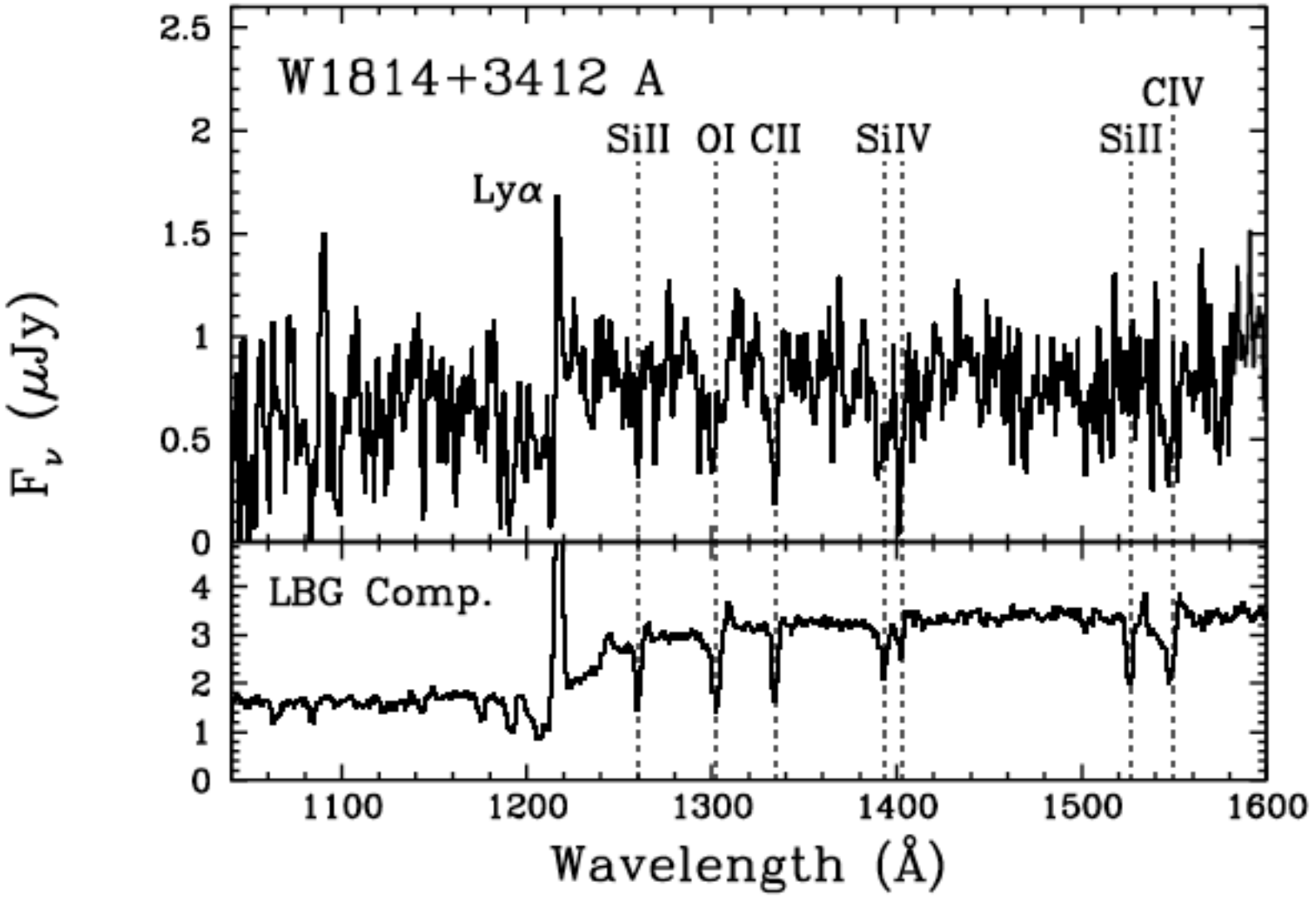
Lacy et al. (2004, ApJS, 154, 166)

40% reliable, 90% complete, [4.5] ≈ 16

40% reliable, 80% complete, [4.5] ≈ 17

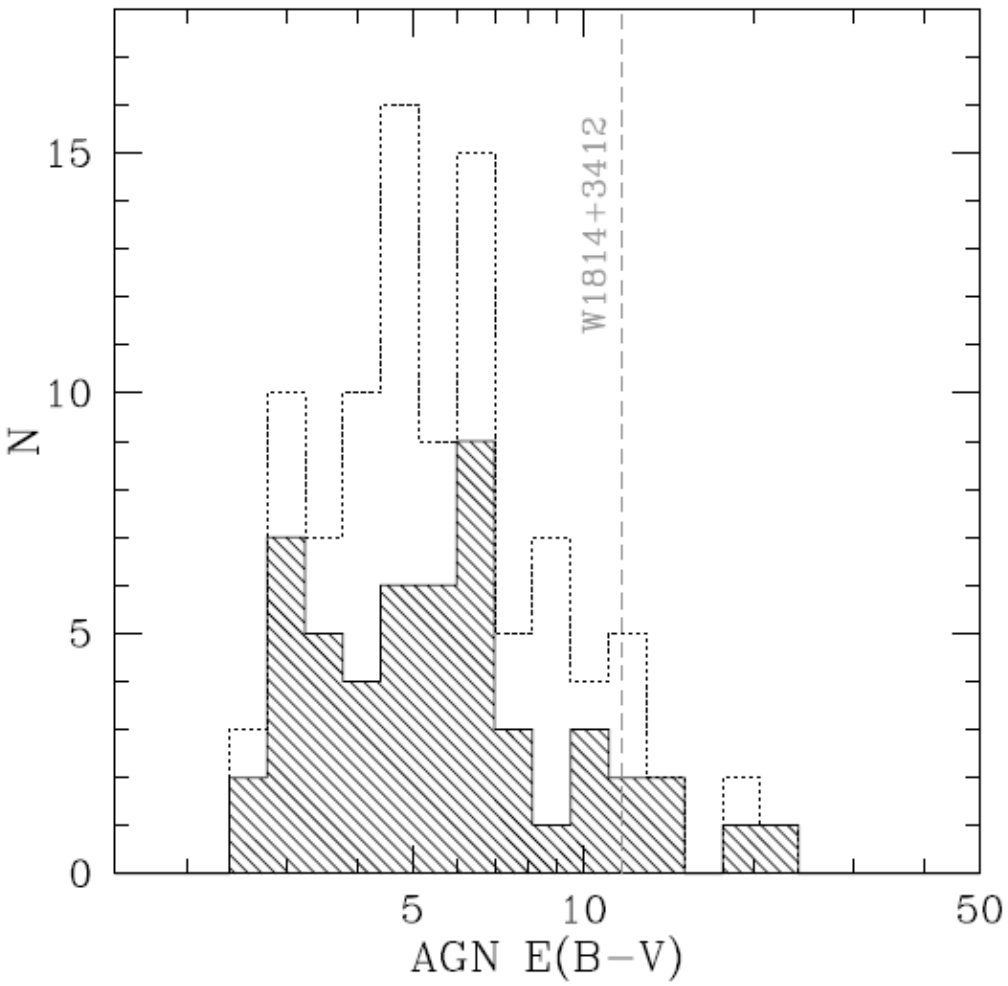
UV – Mid-IR SEDs





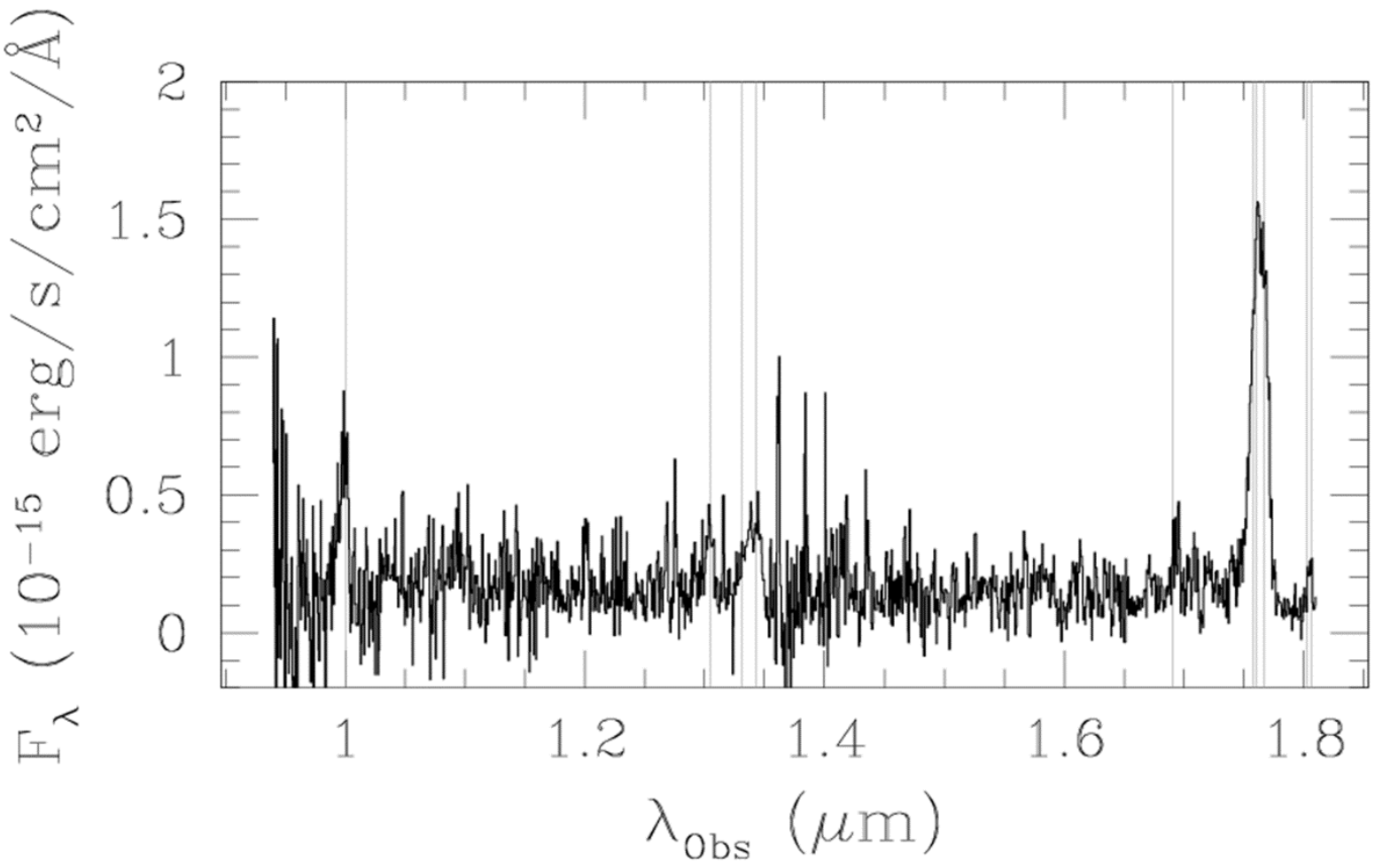
Adapted from Eisenhardt et al.(2012)

AGN Obscuration



- 15-30 mags of extinction
  - Assuming Rv = 3.1
  - Compton thick?
- W1814+3412 more obscured than typical

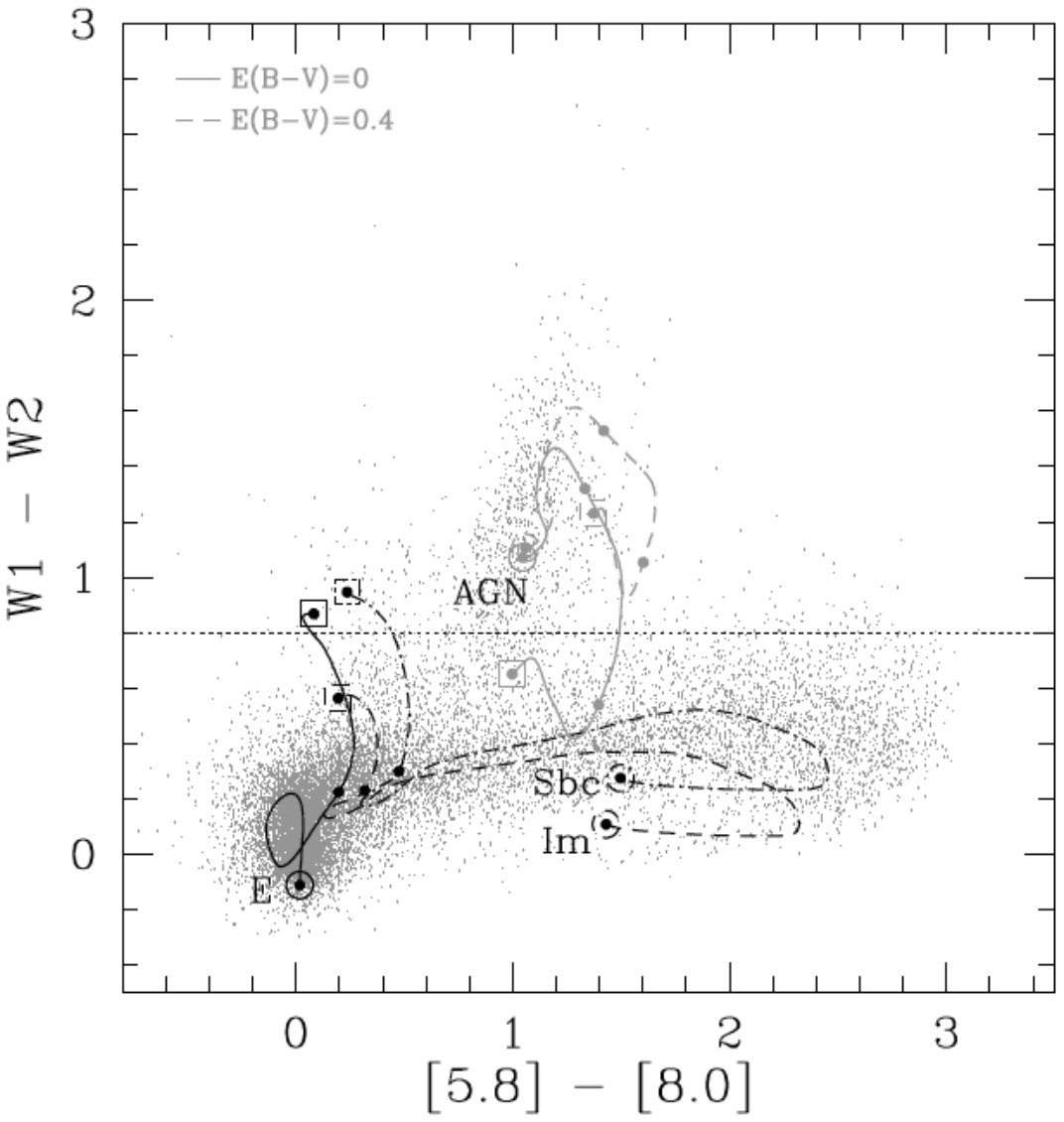
Broad Halpha + Outflows?

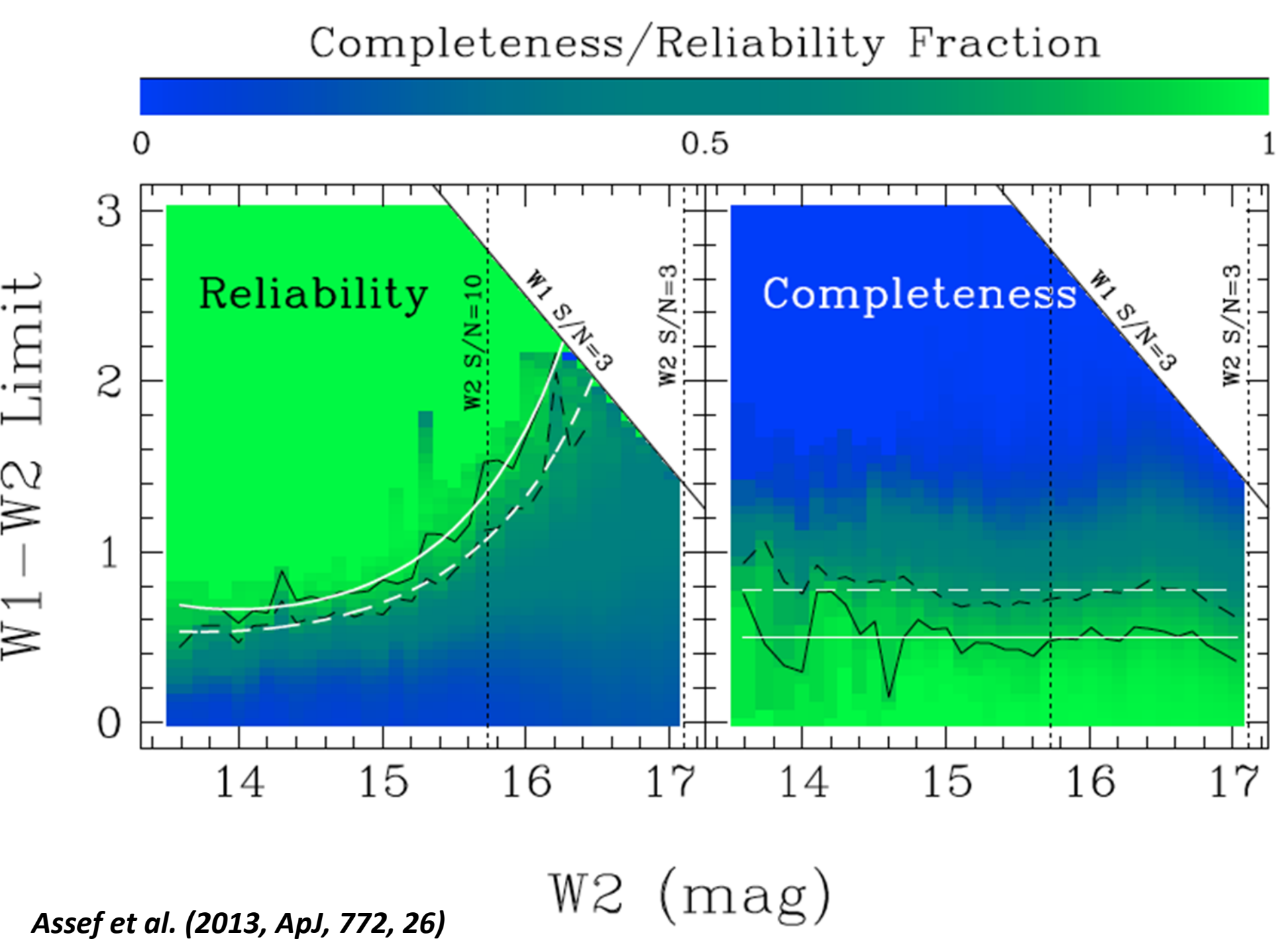


The Role of WISE in Finding AGN

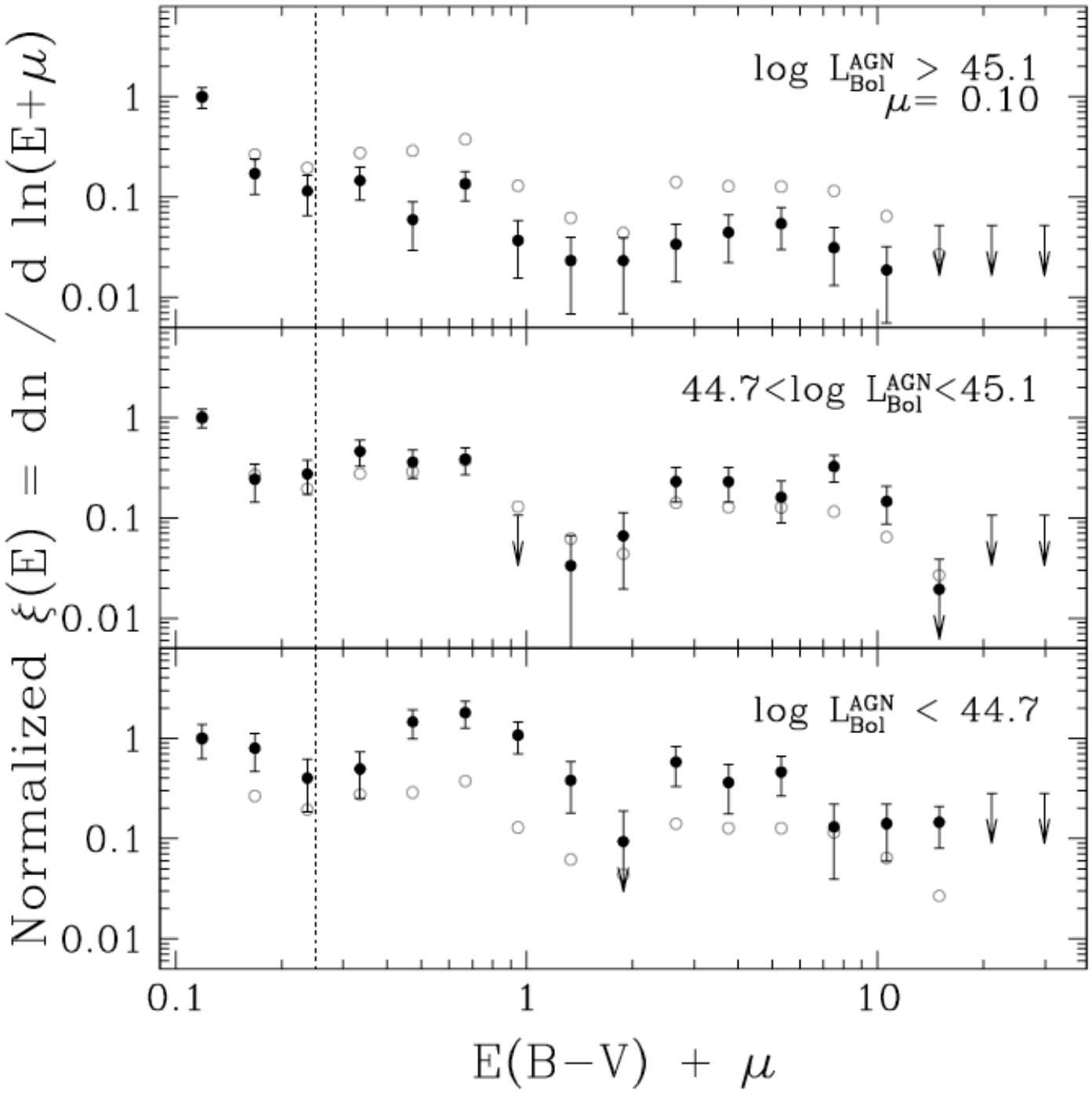
The mid-IR is great fo
- Particularly at 3-5 r
- Hot dust from the Torus is
- Most stars are red (Raylei

We have known this
- Lacy et al. (2004, 2
- Stern et al.(2005)
- Alonso-Herrero et
- Donley et al.(2008,
- Assef et al.(2010)





Assef et al. (2013, ApJ, 772, 26)


log L_{Bol}^{AGN} > 45.1
μ= 0.10
44.7<log L_{Bol}^{AGN}<45.1
log L_{Bol}^{AGN} < 44.7
Normalized ξ(E) = dn / d ln(E+μ)
E(B−V) + μ
0.01
0.1
1
10