The AGN Population in the LSST Era

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Introduction

LSST will be great for AGN

Will find more AGN than any survey before by at least an order of magnitude

300+ million AGN observed

20 million identified by LSST

50+ million identified by LSST + additional data

- Euclid, eROSITA, WFIRST, etc.
- NEOCAM will also be great if approved

Characterizing the population

LSST will probe AGN to much fainter optical limits than any other large scale survey

Possibility to characterize AGN populations well beyond the knee of the QLF

- Imaging is deep enough it will likely allow to characterize their environments.

AGN Identification is far from trivial

- Only ~20% of the observed AGN will be identified by LSST

It is not the ones we see, but those we don’t that matter

Characterizing the Population

Issue is that missing AGN are not random

- Missing specific populations can have important effects on conclusions about AGN
- Particularly important for galaxy evolution
- Need to at least understand if not solve

Main biases that need to be considered:

- Confusion with stellar locus
- Obscuration – Reddened type 1 and type 1.8/1.9/2 AGN
- Host Dilution

Confusion with the Stellar Locus

Great issue for optical color selection

- E.g., Fan et al. (1999) , Richards et al. (2006)

Happens at z of about 2-3

Variability selection will help

- Time dilation lowers the light curve duration
- Highest L QSOs may not vary enough in 10 years to detect variability in all bands

Lack of astrometry should be enough to identify them.

Host Dilution

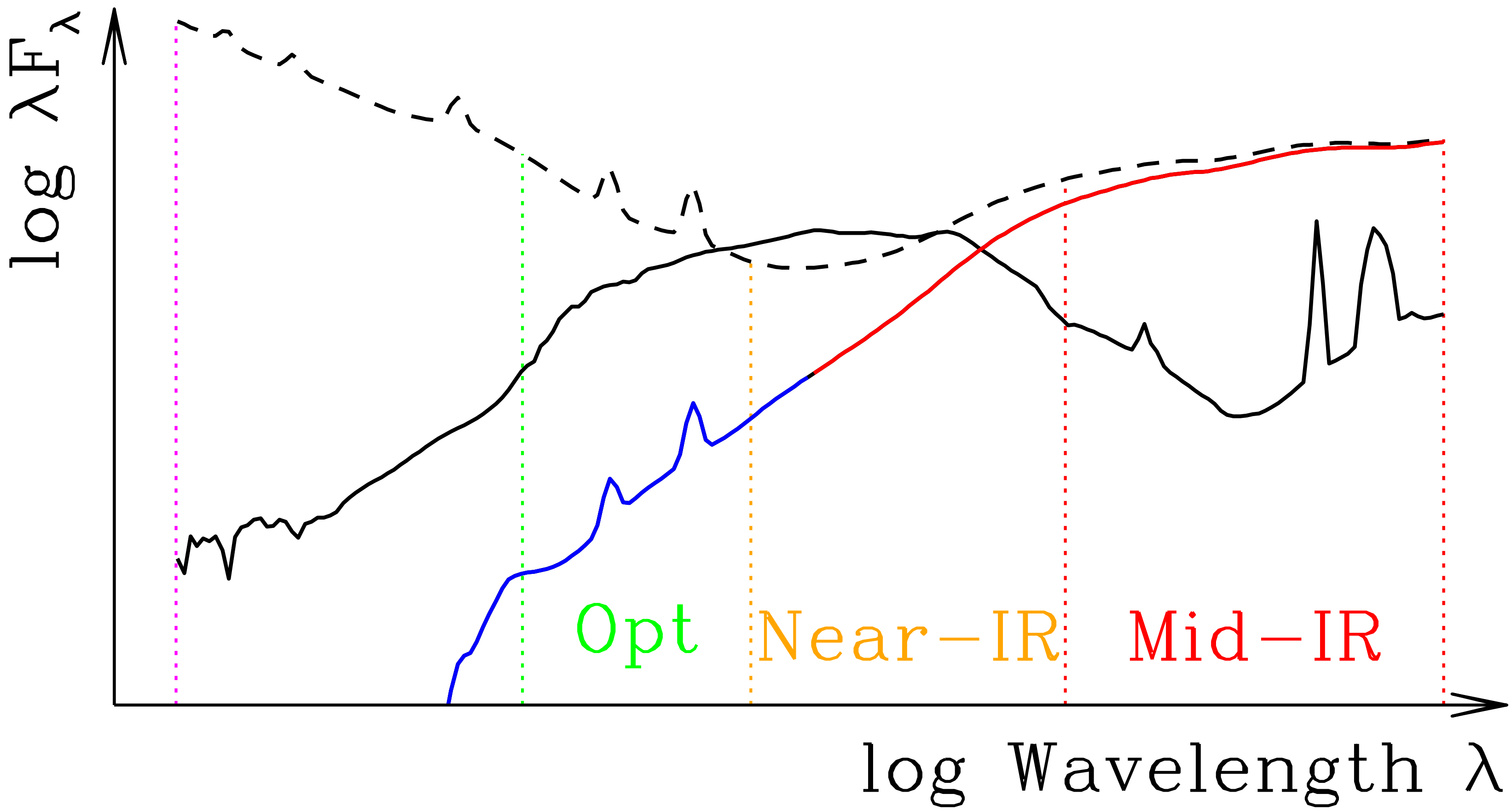
Likely one of the biggest issue for AGN studies in LSST

Color identification criteria works because AGN are different than galaxies

- Flipside is that AGN need to dominate the SED to be identified
- Need to trade completeness with reliability

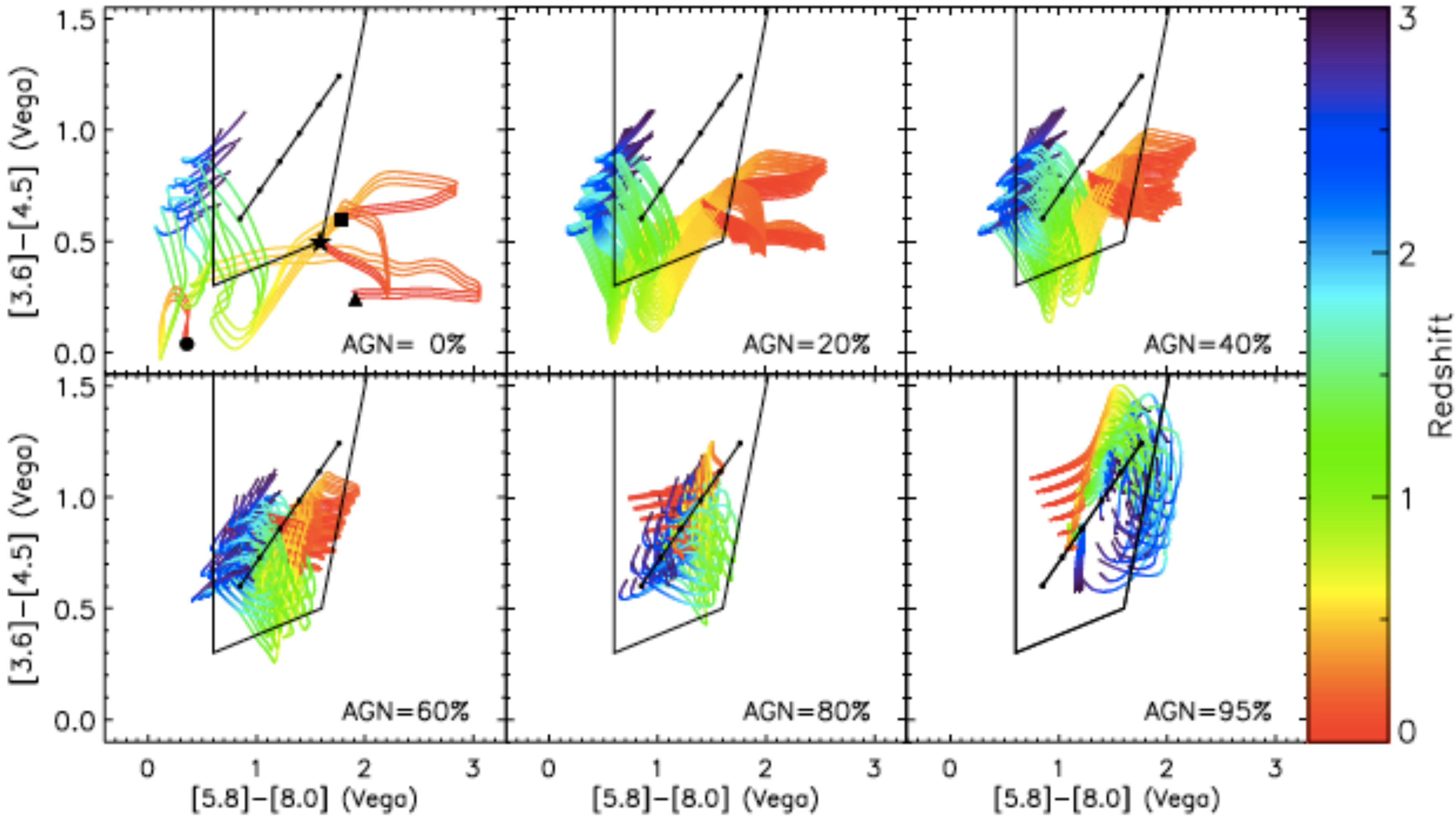
Dominating over the host in the optical is a function of

- AGN Luminosity
- Host Stellar Mass
- Host Unobsured Star-Formation Rate
- Redshift
- Obscuration of the AGN



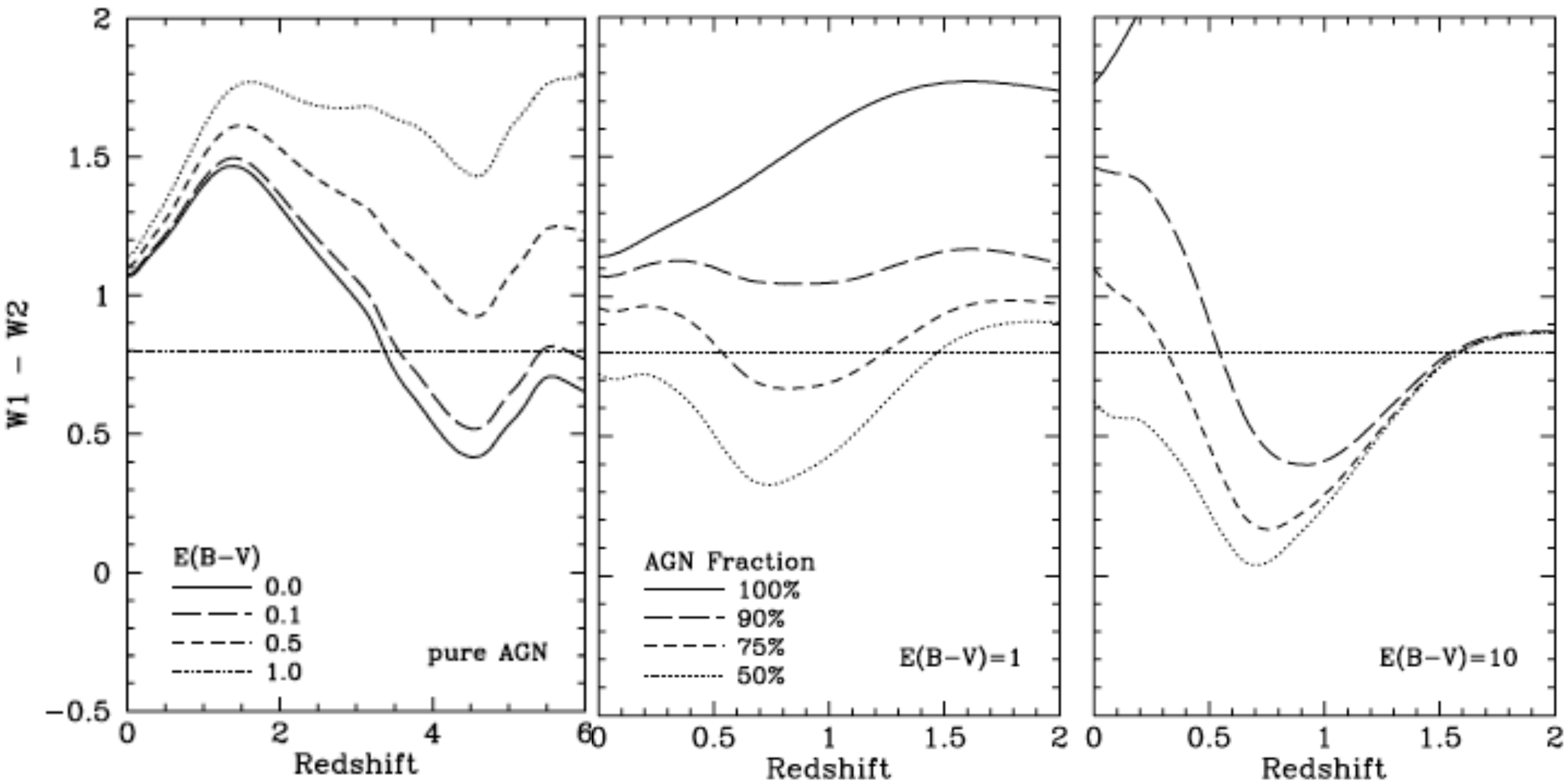
Templates from Assef et al. (2010)

MIR Experience – Host Dilution



Donley et al. (2012, ApJ, 748, 142)

MIR Experience – Obscuration and z



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

Luminosity Ratio Bias

In the mid/near-IR, the emission of the host galaxy is more related to the stellar mass than to the SFR

At these λ, L_{Host} is related to M_{BH} so L_{AGN}/L_{host} is a proxy for the Eddington ratio = L_{AGN}/L_{Edd}

IR criteria are biased against low Eddington ratios.

- Effectively biased against low-L AGN, but because of low L/Ledd and B/T

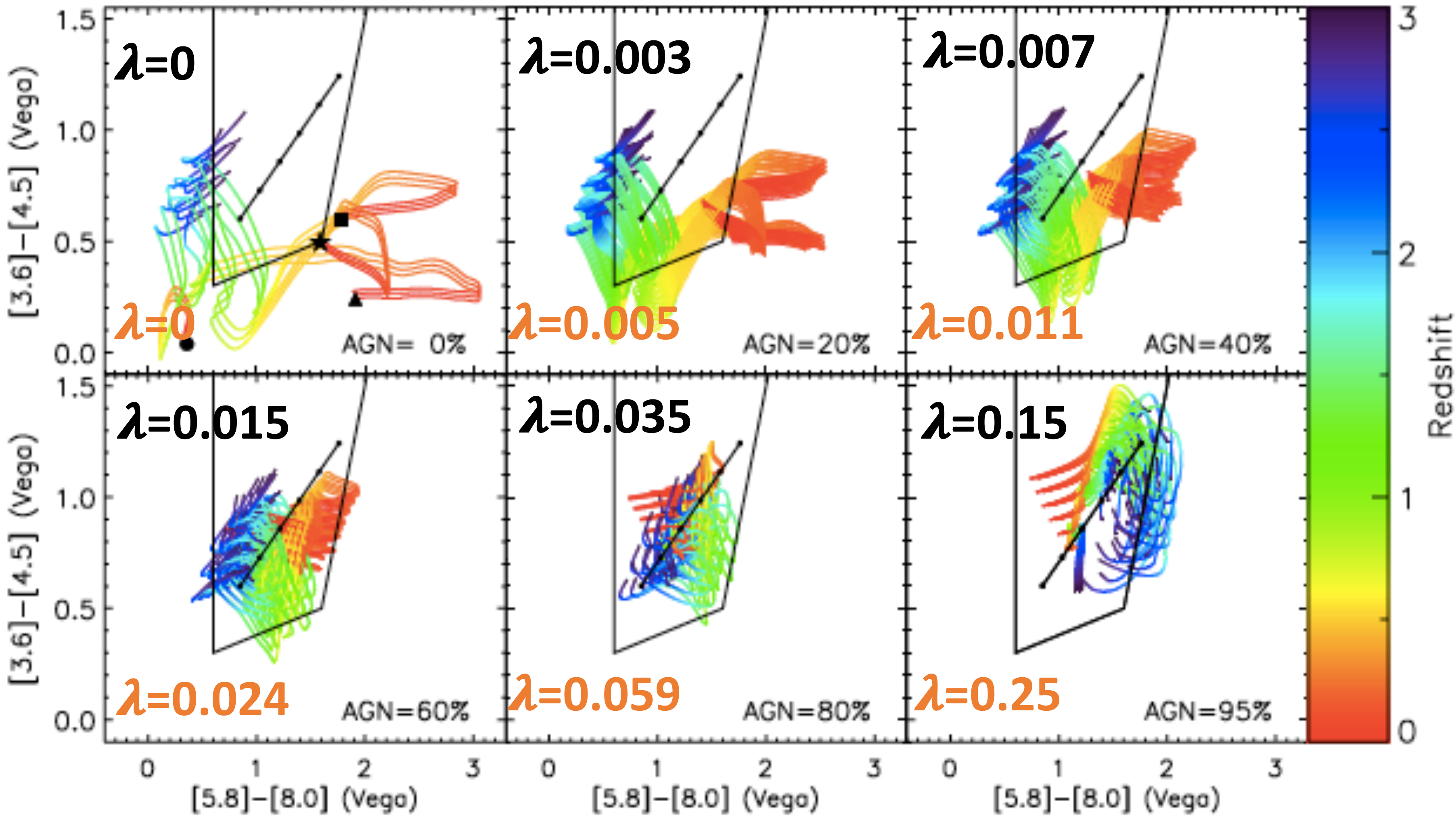
Importance of bias depends on the selection criteria, redshift and obscuration

- Need to consider all when analyzing selection function effects

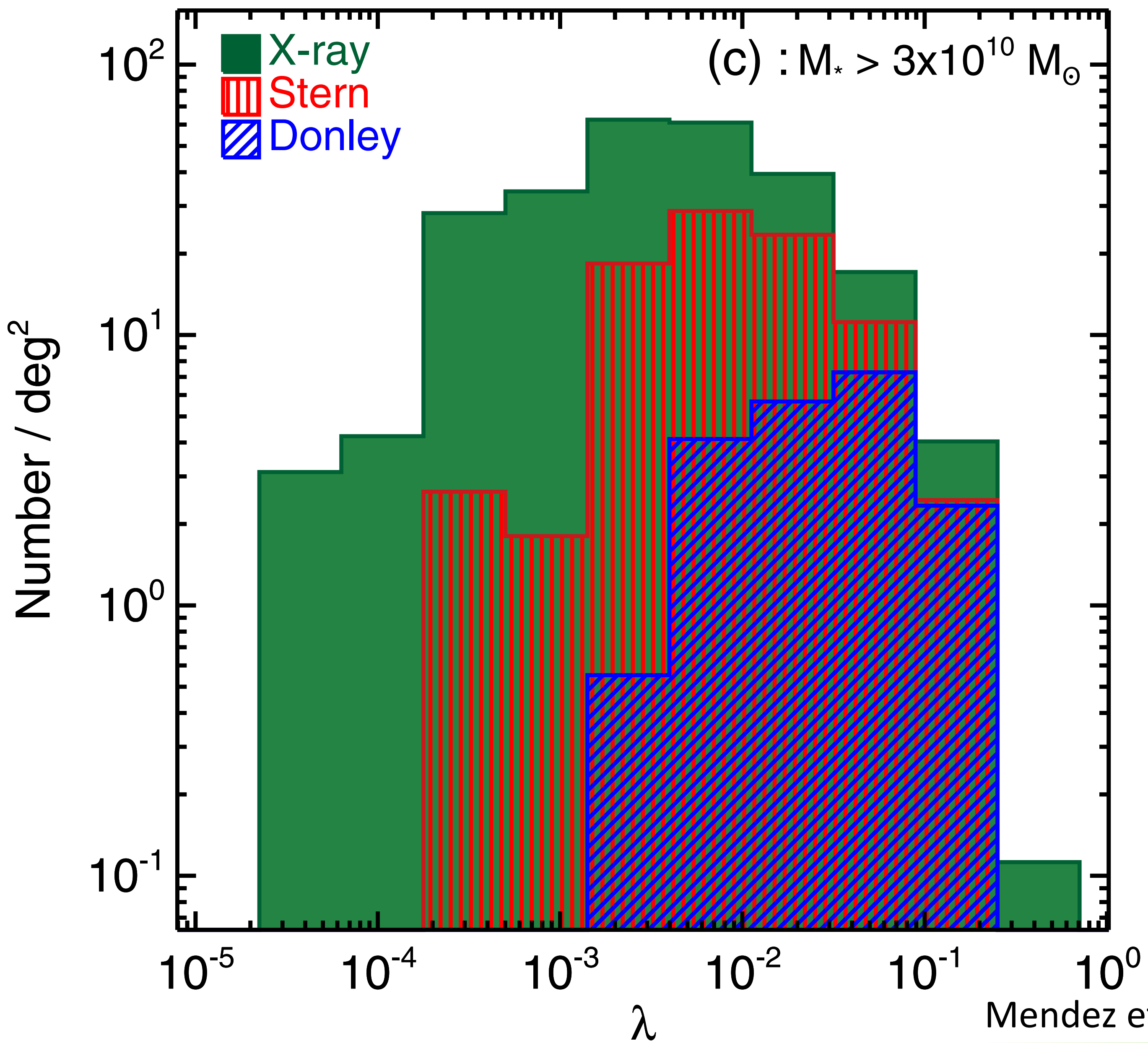
AGN vs Host Luminosity Bias

$L_{AGN} = 10^{10} L_{sun}$

$L_{AGN} = 10^{12} L_{sun}$



Donley et al. (2012, ApJ, 748, 142)



Mendez et al. (2013)

Host Dilution in the Optical

It is a more complicated case than in the IR

Optical color selection is biased against low Eddington ratios

- This needs to be fully modeled and taken into account for galaxy evolution studies
- Somewhat better for optical than IR because host peaks in the NIR

Additionally, host dilution in the optical means

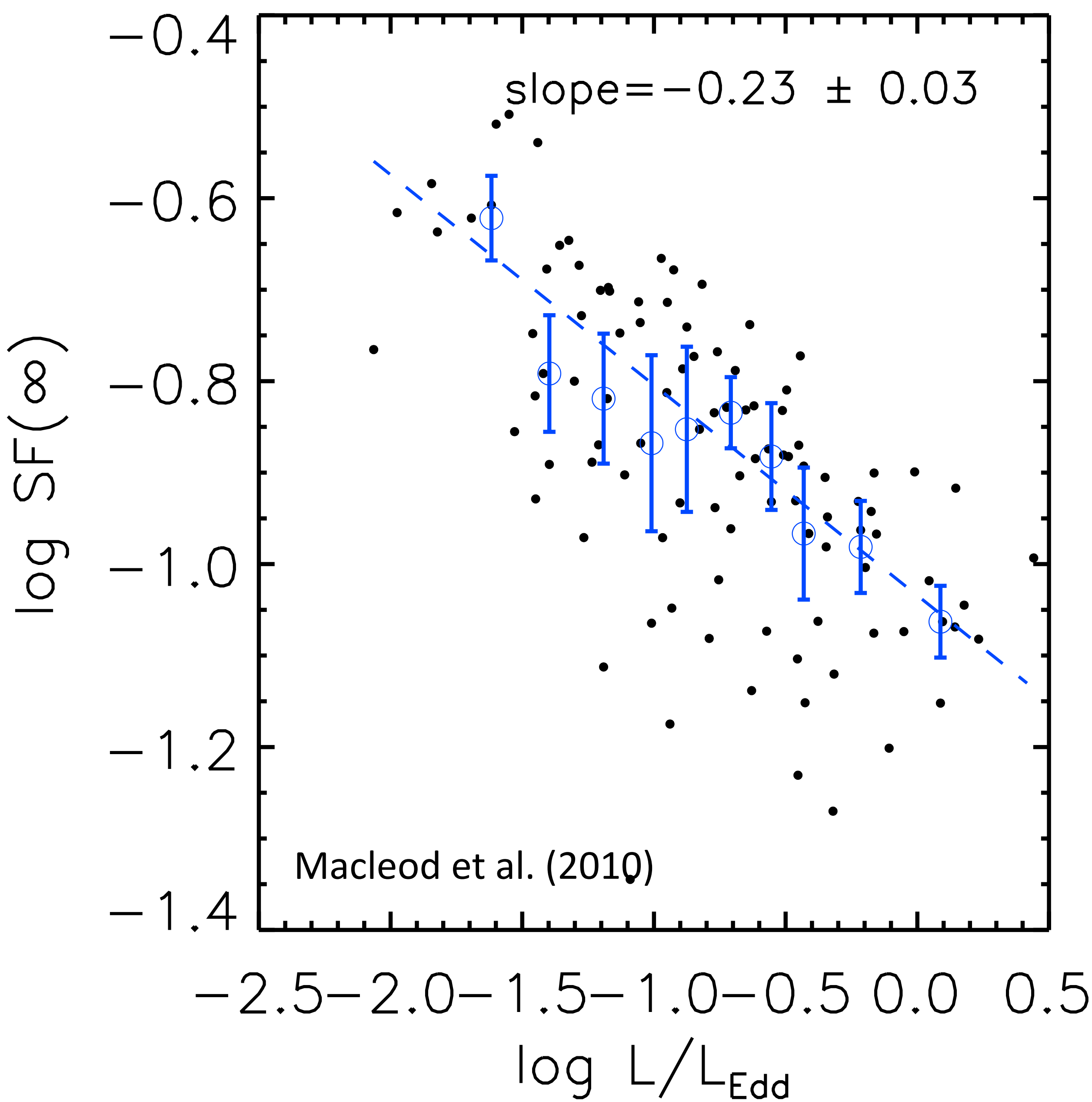
- Bias against AGN in SF galaxies
  - Could have significant impact in gal evol studies where both are important
- Bias against reddening
  - Light reddening can already have an impact

How to Solve it?

- Variability should be able to help, at least in nearby objects
  - Lower time dilation
  - Fainter
  - Variability amplitude is higher for L/Ledd (Macleod et al. 2010)

- X-rays
  - Notably insensitive to this issue
  - Unfortunately eROSITA is rather shallow

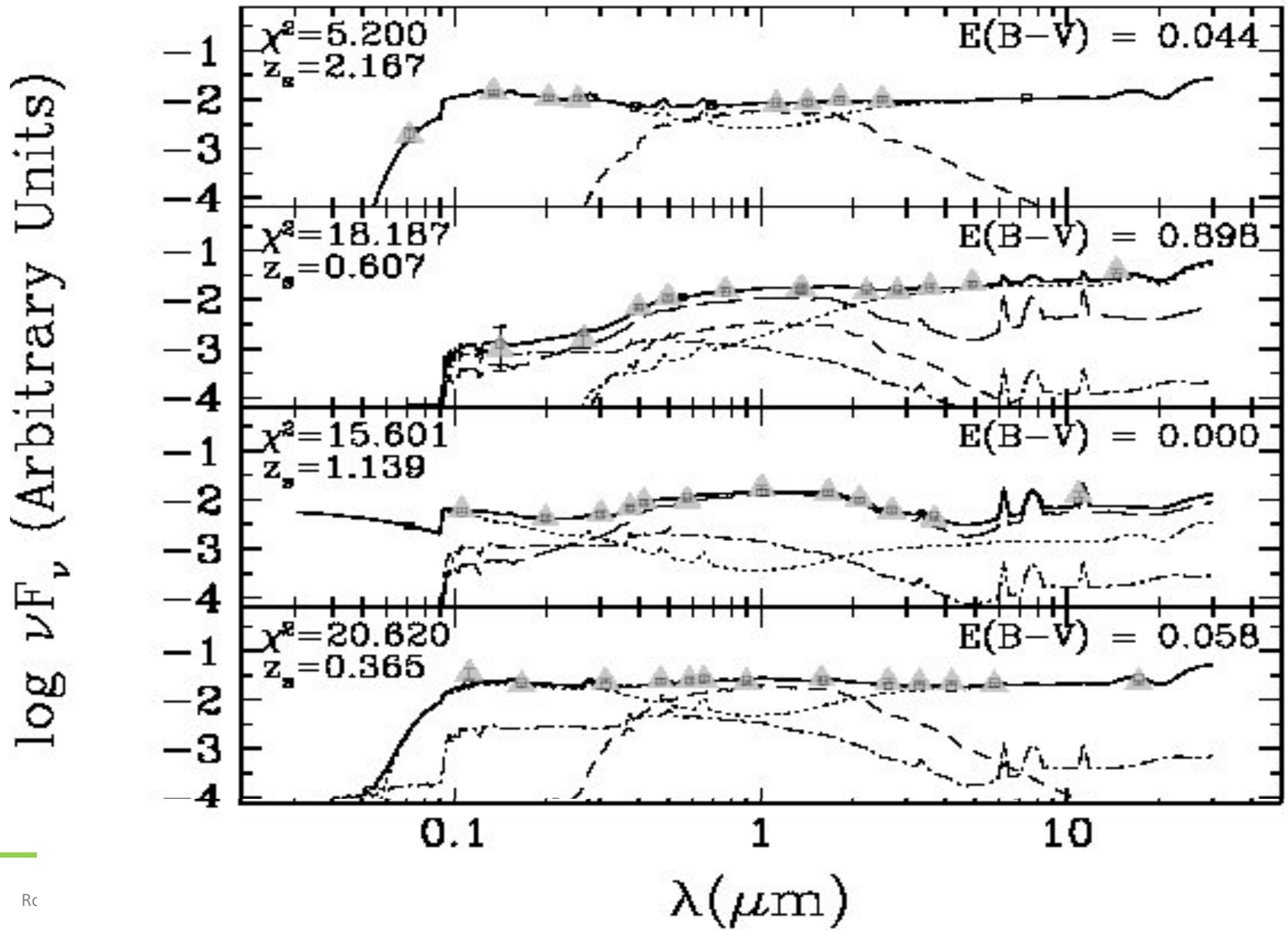
- SED fitting
  - Not as efficient to do without other anchoring data points in the IR
  - Should be easy to implement with Euclid or WFIRST or Deep drilling fields
  - L_{AGN}/L_{Host} notably independent of redshift accuracy (more or less)



slope=−0.23 ± 0.03
Macleod et al. (2010)
log SF(∞)
log L/L_Edd
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−2.5 −2.0 −1.5 −1.0 −0.5 0.0 0.5

Examples of AGN SED Fitting

Assef et al. (2010)

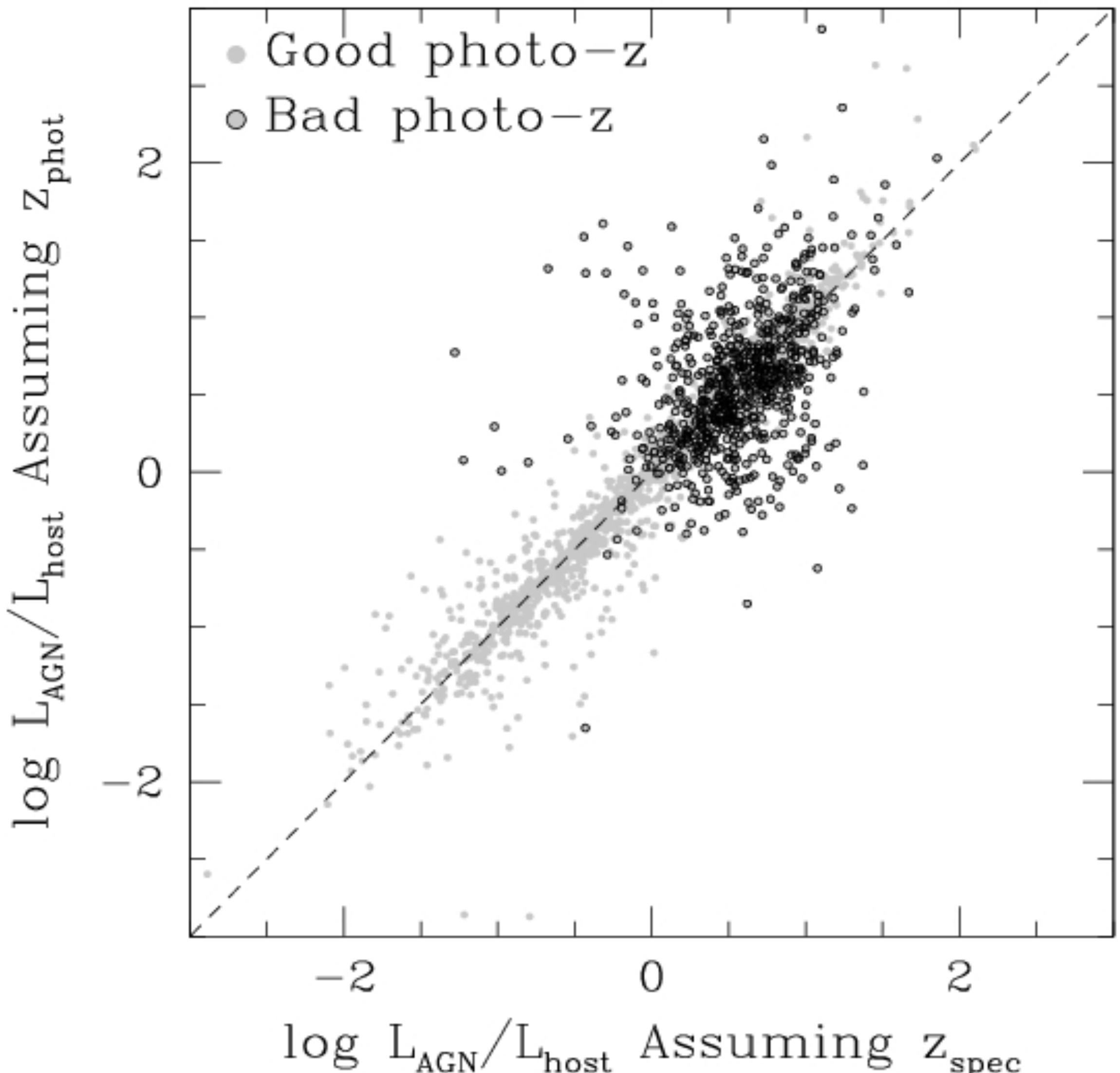


Rc

Decomposition not very sensitive to z

Estimates of L_{AGN}/L_{Host} ratio are independent of z_{phot} accuracy

Plot shows the ratio of the bolometric luminosities of the AGN to Host components assuming the best fit photo-z and the spec-z



Obscured AGN in LSST

- >50% of AGN are obscured
  - Might depend on AGN luminosity
  - Non-trivial at the highest luminosities
- LSST will be limited in identifying reddened AGN
  - Y-band photometry will give it a significant edge over SDSS
  - Unlikely to identify type 2 AGN
- Will need identification from other surveys
  - Euclid and WFIRST will add the NIR to help identify mildly obscured AGN
  - (un)WISE will help some with type 2, but rather shallow. NEOCAM?
  - eROSITA will help also with type 2 AGN, but also shallow
  - Deep drilling fields

LSST - Hosts

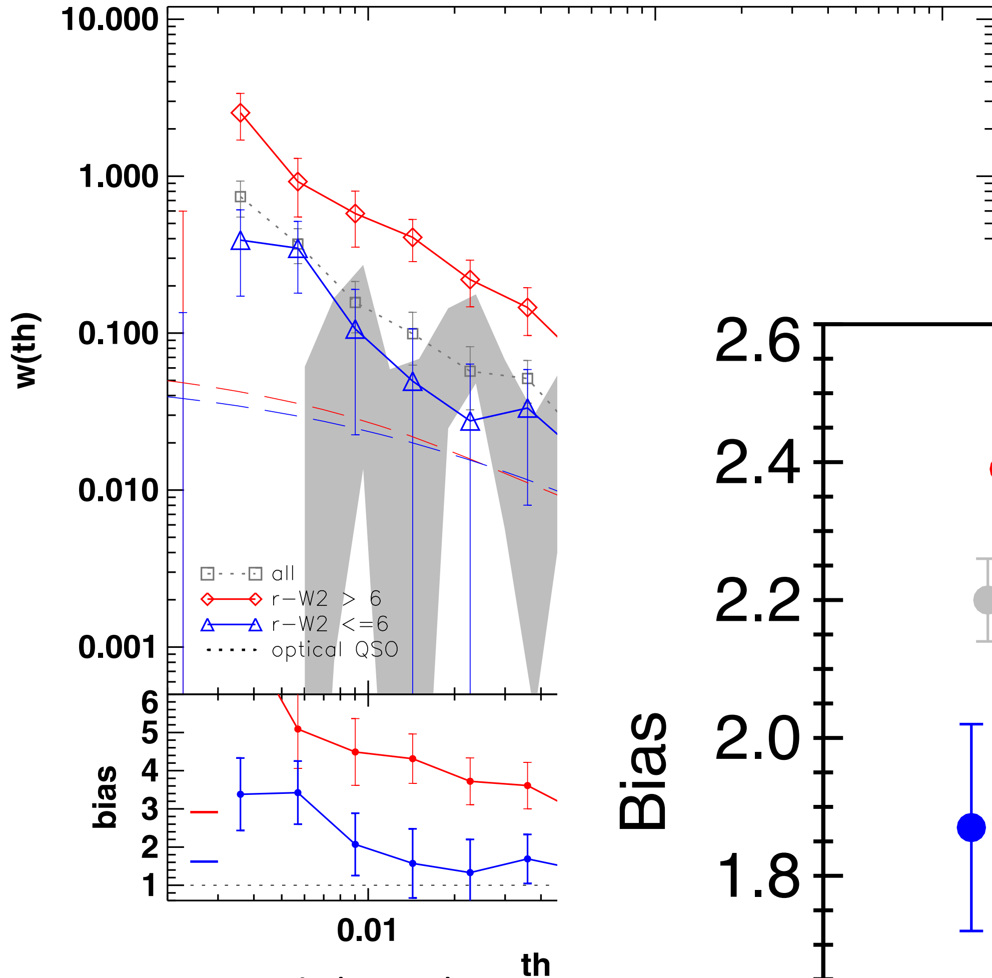
- While not able to identify them, LSST will see the host galaxies
- Important to characterize the host galaxies
  - Unobscured SFRs and Stellar Mass
  - AGN and galaxy evolution
  - AGN feedback
- Improved photometric redshifts
  - Stability and depth of LSST photometry will help enormously with photo-zs
  - Inherently bad for type 1 QSOs, but work well for type 2
  - Spectroscopy much easier for type 1

Cross-Correlation Function of Obscured vs. Unobscured AGN

- Cross correlation find that type 2 AGN cluster more tightly than type 1 AGN
  - Donoso et al. (2014), di Pompeo et al. (2014, 2016, 2017)
  - Although see Mendez et al. (2016)
  - Suggest that there is a population of highly obscured type 2 AGN with a high clustering fraction.

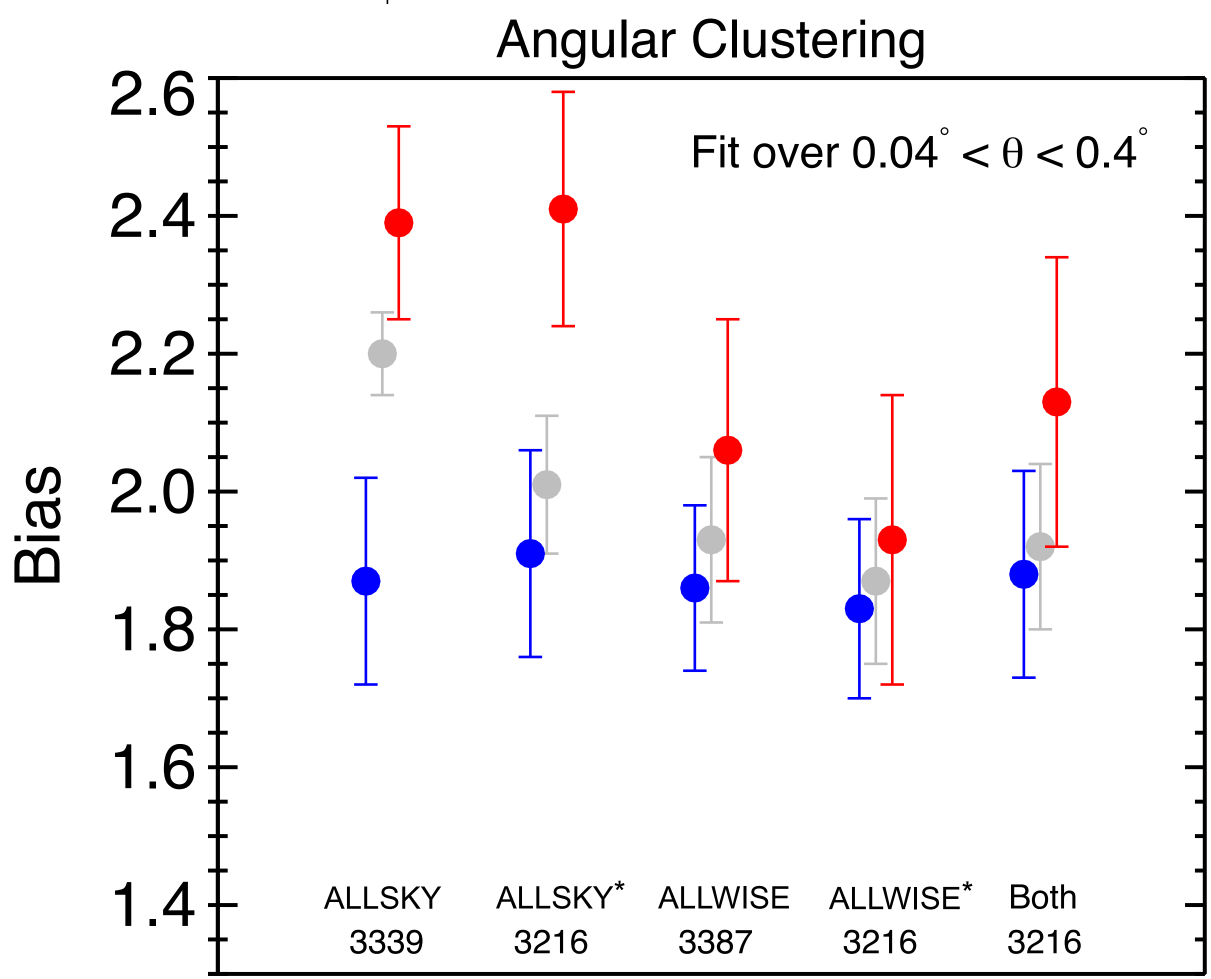
- LSST could allow to test this when coupled with eROSITA
  - NEOCAM
  - Possibly with Euclid too

- Analysis only needs P(z) to first order
  - Would be great to have more redshifts, but unlikely
  - Use variability to get P(z)?



Donoso et al. (2014)

Di Pompeo et al. (2016)

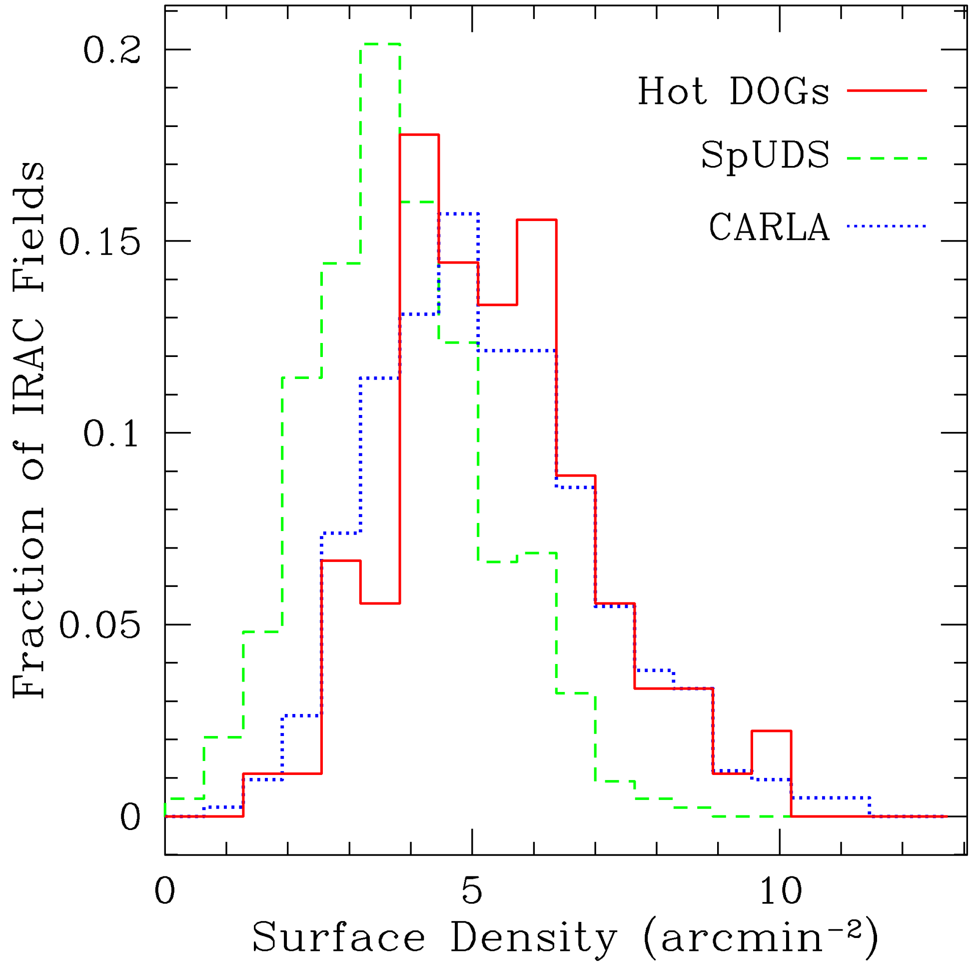


Overdensities Around Luminous QSOs

Assef et al. (2015)

Euclid + LSST (+NEOCAM) can help characterize galaxies around luminous AGN

- Photo-z
- Unobscured SFR
- Stellar mass



Conclusions

LSST will have a major impact in AGN studies

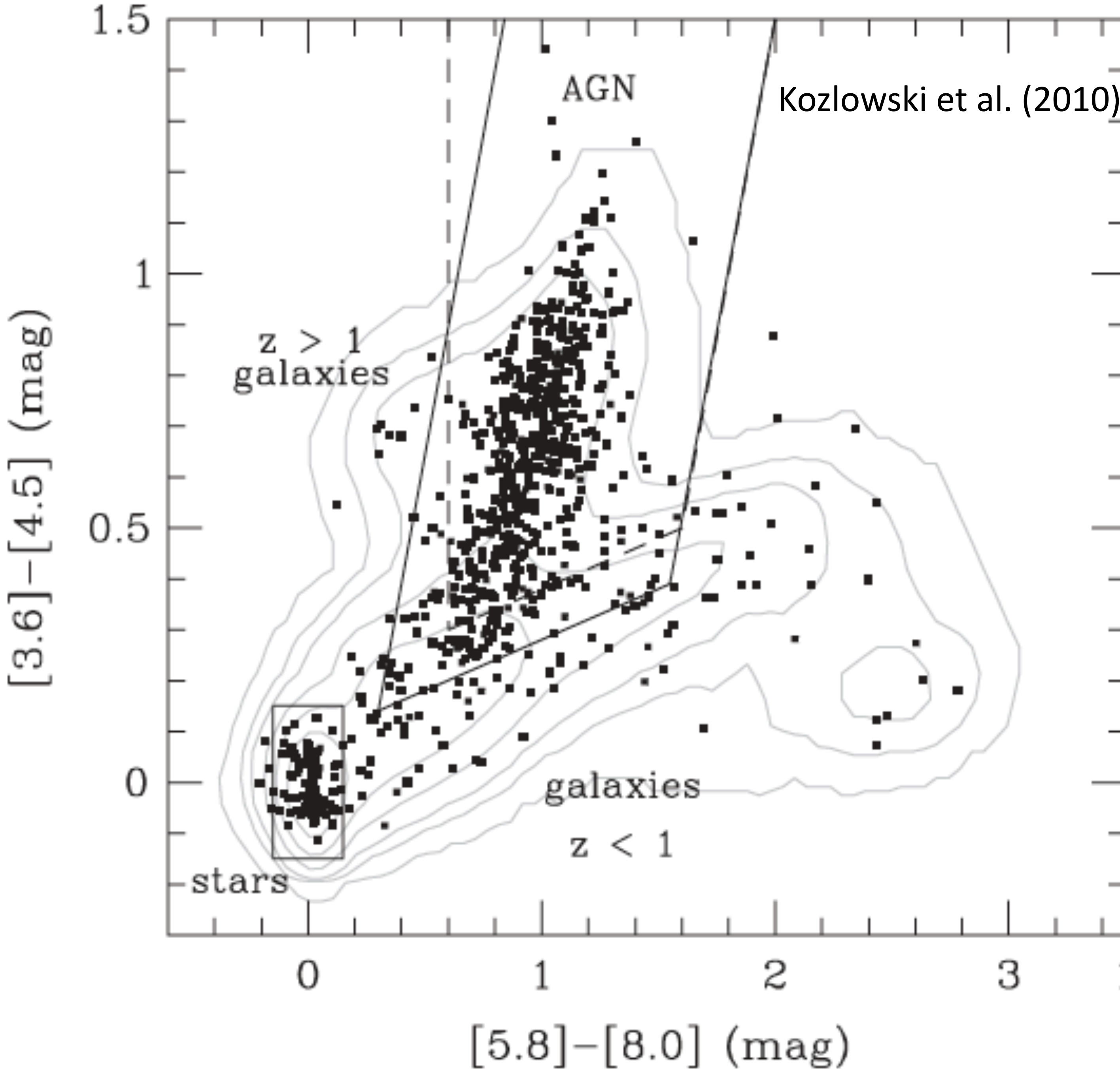
Problem: Need to control for selection biases

- Primarily host dilution
- Biased against low Eddington ratios
- Biased against AGN in star forming galaxies

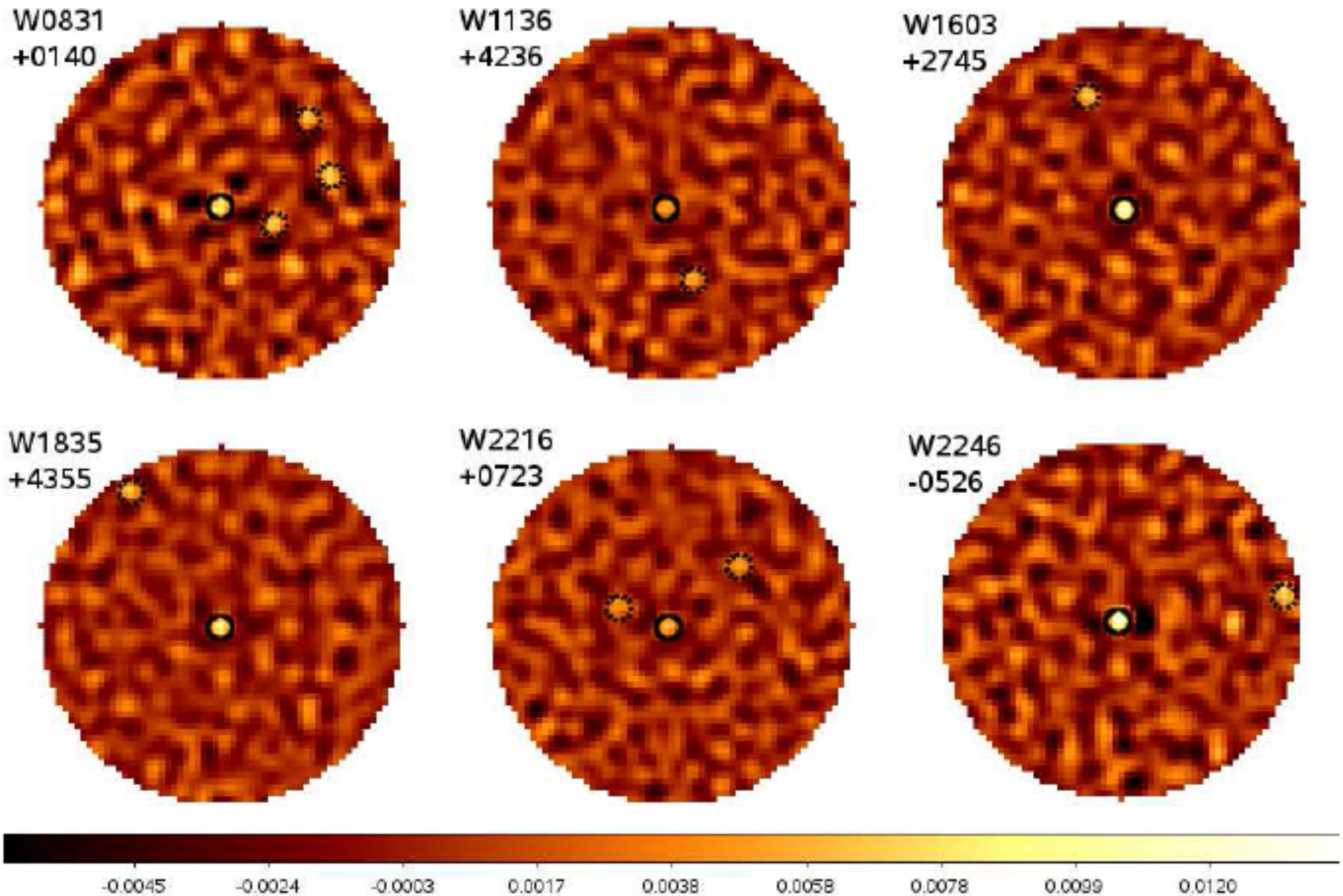
Combined with other surveys, LSST will be great for characterizing obscured AGN

- Need Euclid, eROSITA, and/or NEOCAM
- Impact will be limited for LSST alone

Backup Slides

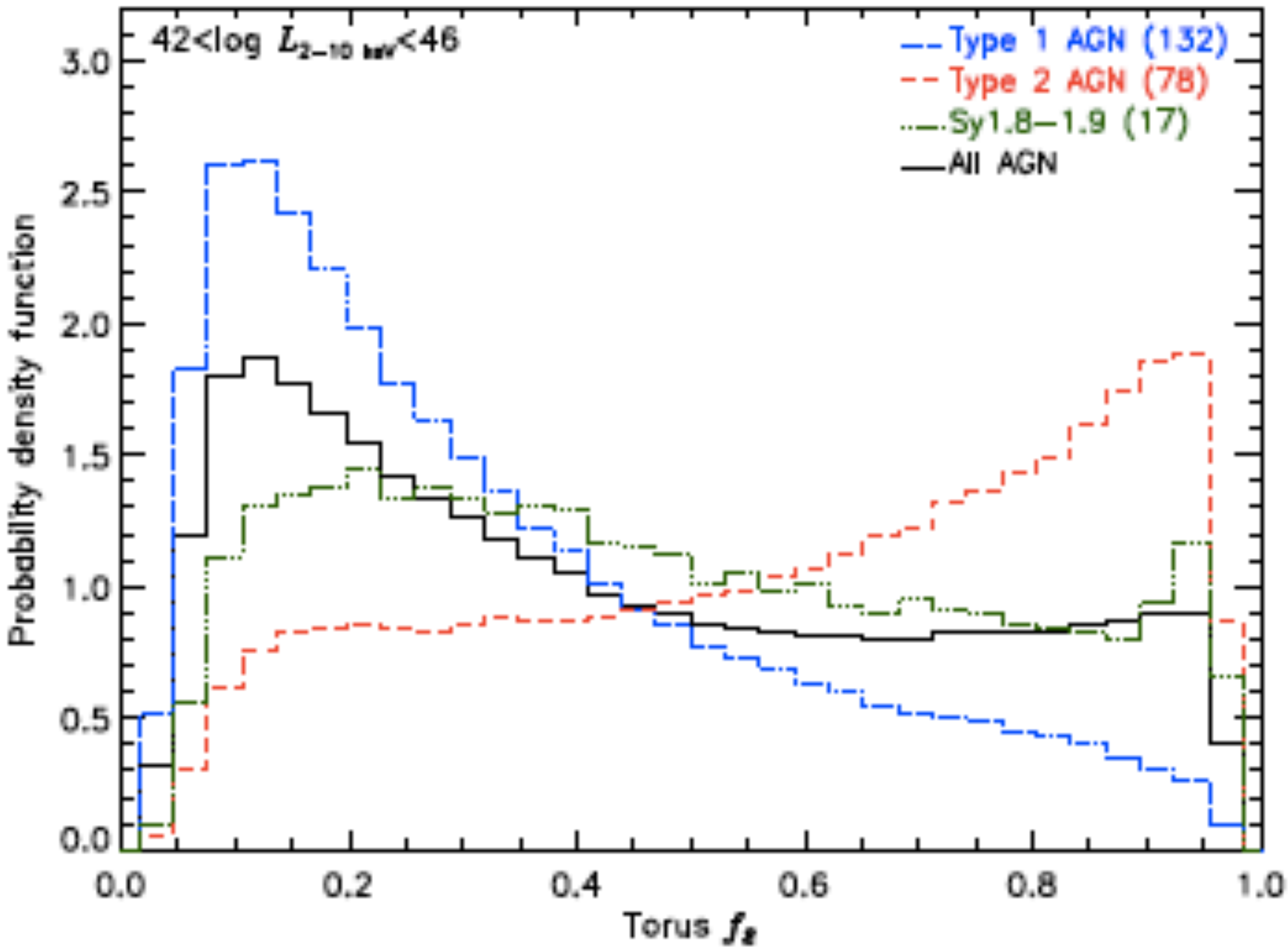


Kozlowski et al. (2010)
AGN
z > 1
galaxies
galaxies
z < 1
stars
1.5
1
0.5
0
0
1
2
3
[3.6]−[4.5] (mag)
[5.8]−[8.0] (mag)

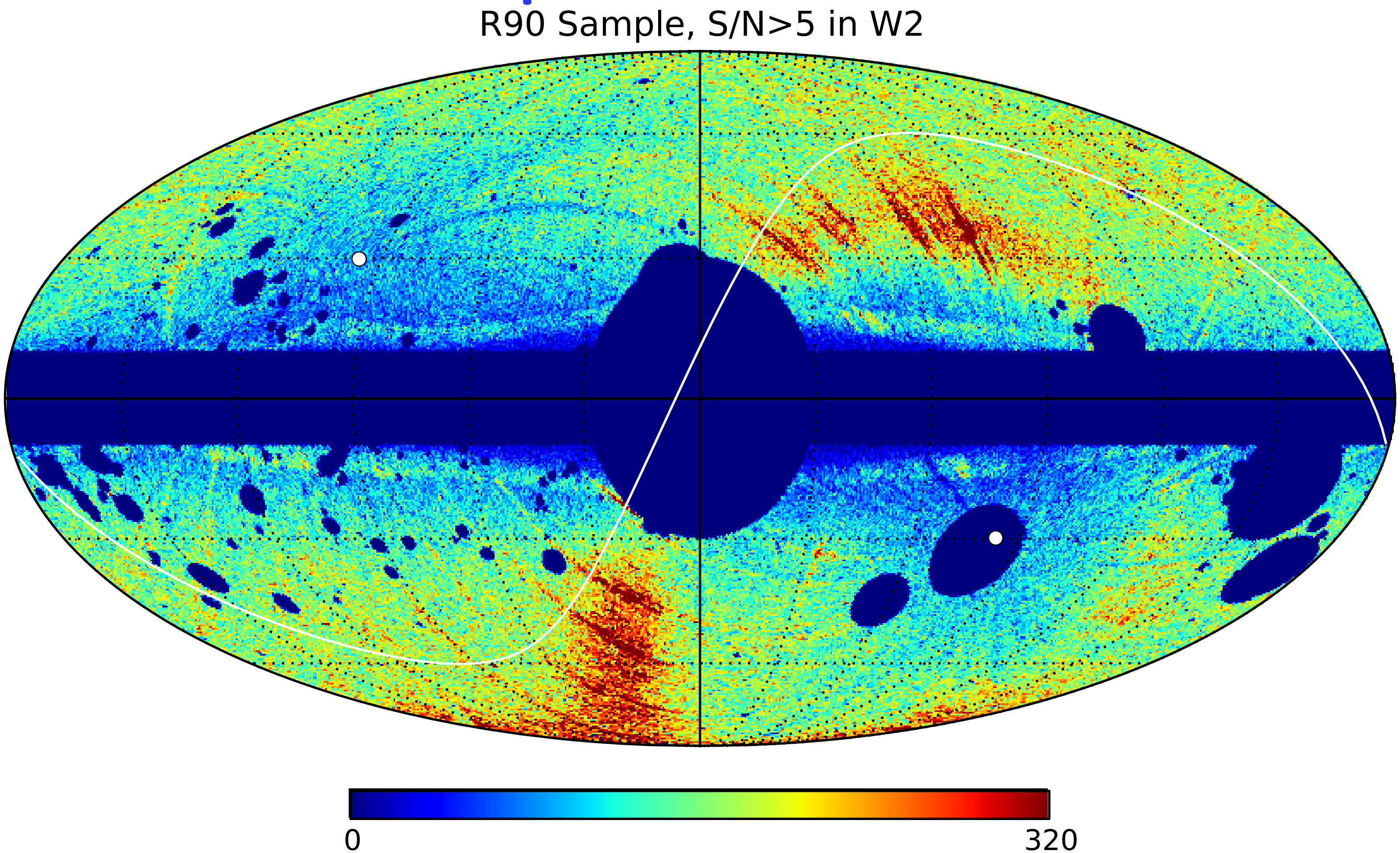

W0831
+0140
W1136
+4236
W1603
+2745
W1835
+4355
W2216
+0723
W2246
-0526
-0.0045
-0.0024
-0.0003
0.0017
0.0038
0.0058
0.0078
0.0099
0.0120

Covering fractions

Mateos et al. (2016)

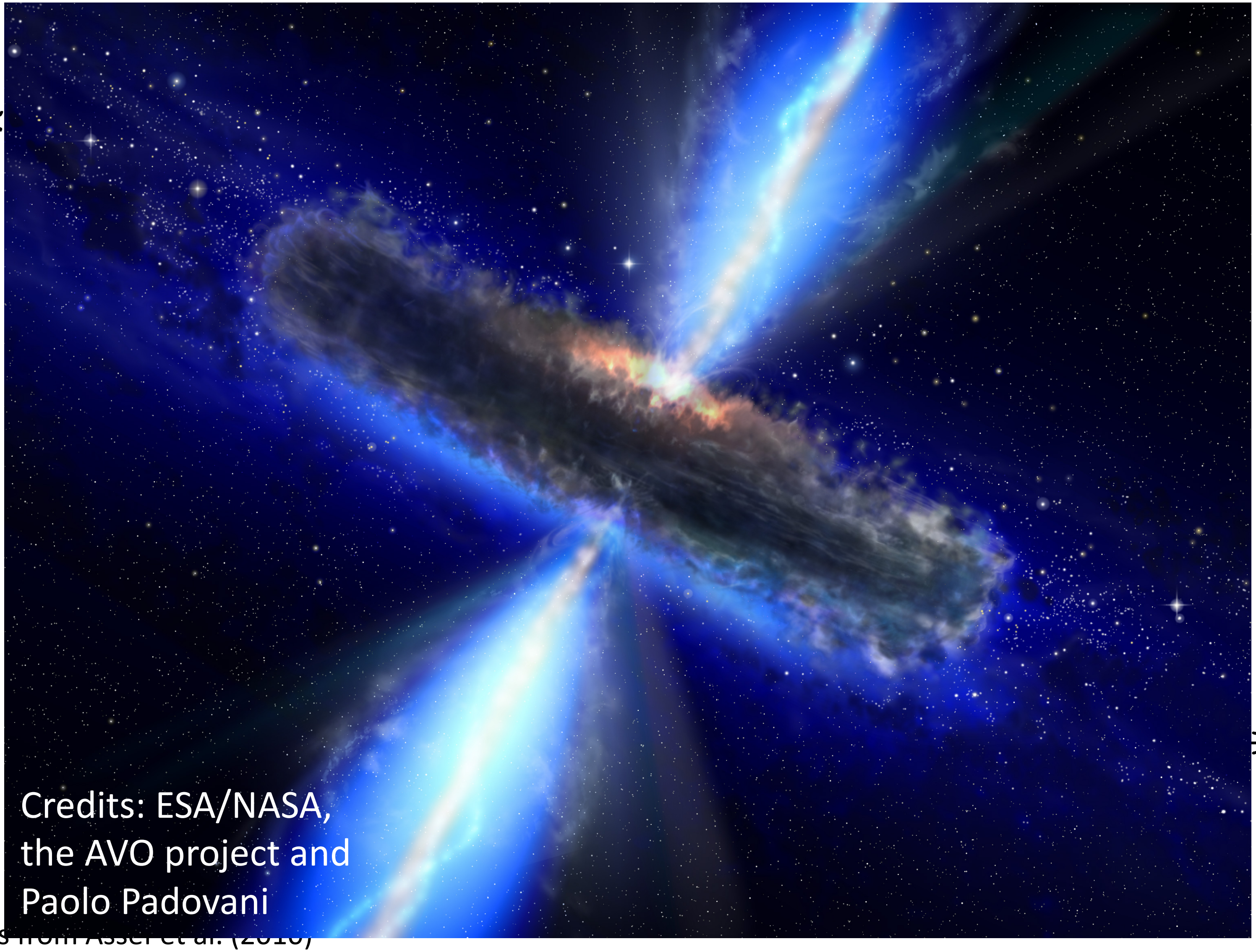


WISE AGN Maps



4.5M AGN (90% reliability) – Assef et al. (in prep)

$\log \lambda F_\lambda$



λ

Templates from Assef et al. (2010)