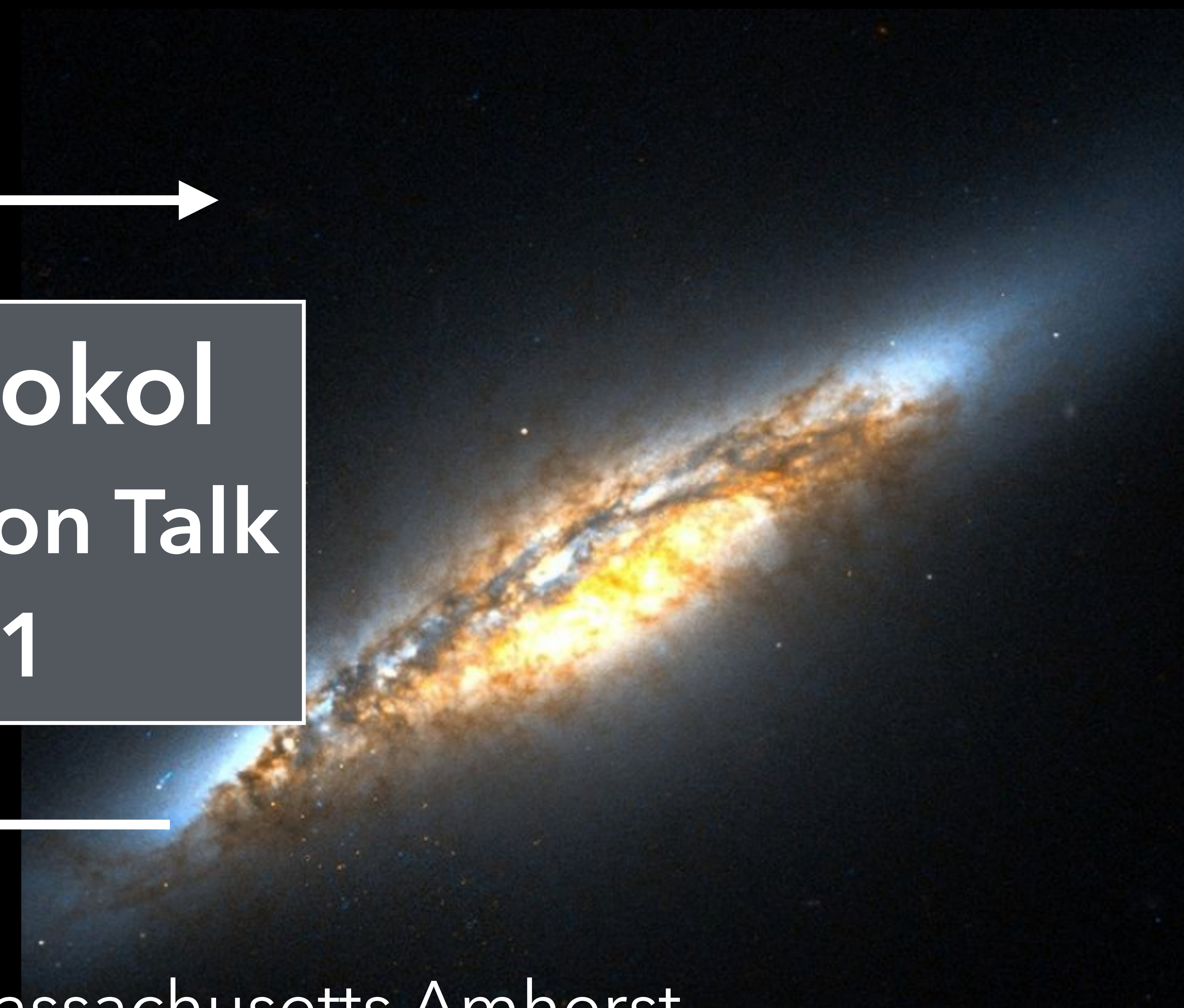
The coeval mass assembly of the universe:

A concurrent SFRD and BHARD for the same galaxies in COSMOS

&

Robustness of AGN SED Decomposition Techniques



Alyssa D. Sokol

AAS Dissertation Talk

1.13.2021

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Collaborators: Dr. Alexandra Pope, Dr. Allison Kirkpatrick, Dr. Kevin Cooke

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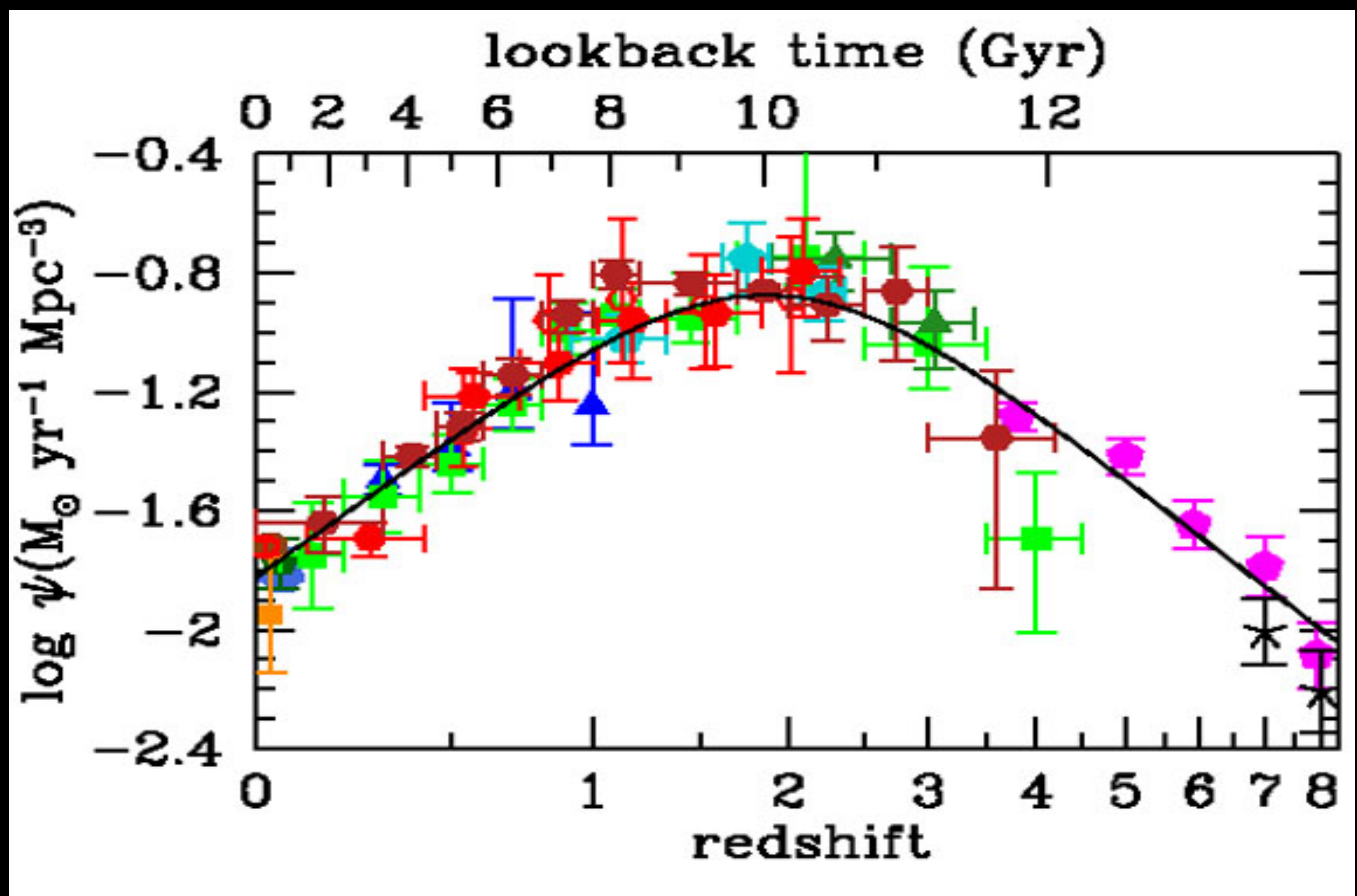
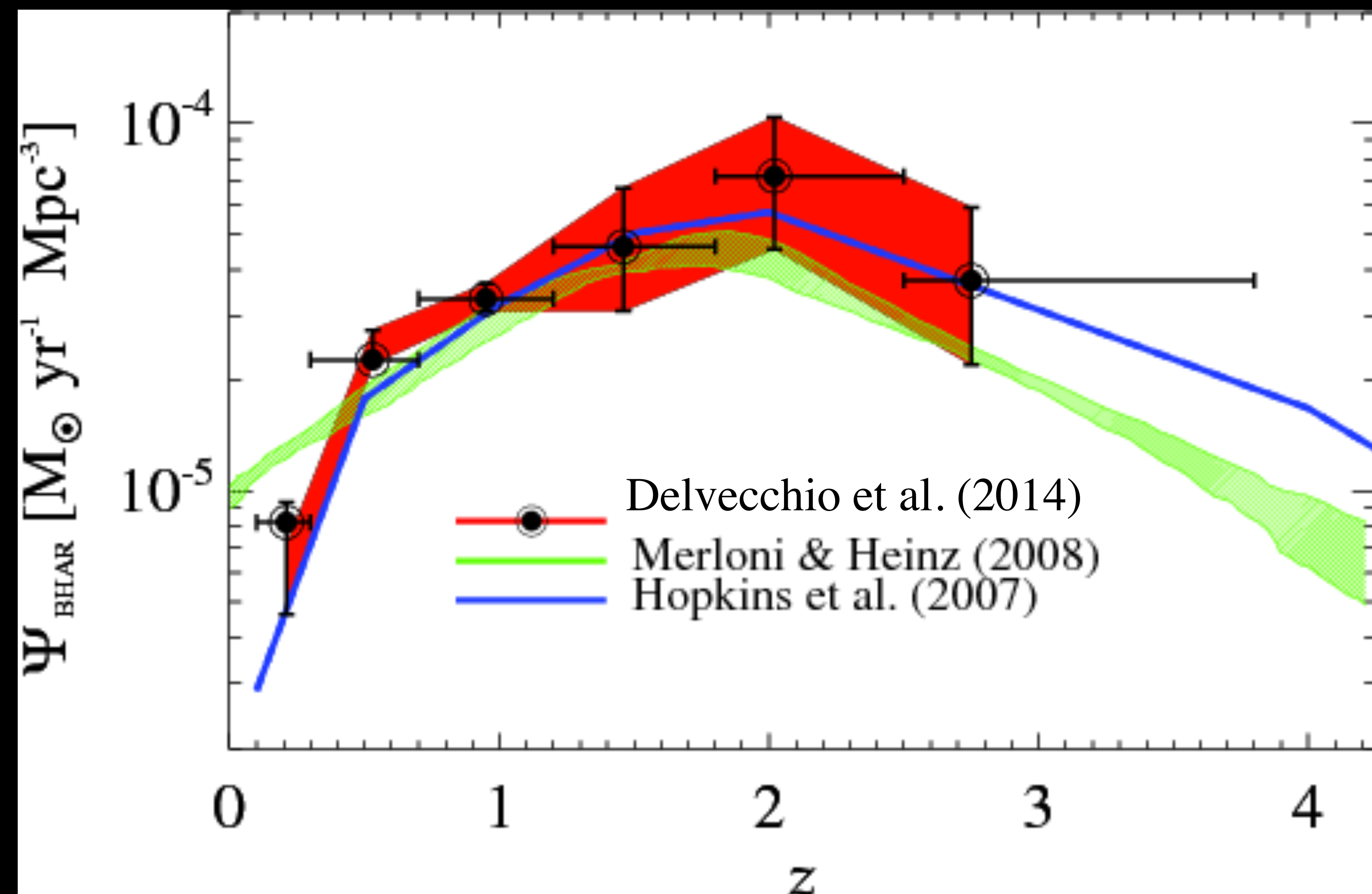
Galaxy-BH connections on larger scale across cosmic time

Star Formation Rate Density (SFRD)



Madau+2014

Black Hole Accretion Rate Density (BHARD)



Delvecchio+2014

- SFRD & BHARD have similar shape; peak at z~2 and decline to present day
- BH accretion and SF both occurring rapidly ~ 10Gyr ago
- Global explanation for the story: Both mechanisms fueled by gas and more is available during epoch
- This is not causal, local relationship because trends <u>do not trace same galaxies!</u> Why not?

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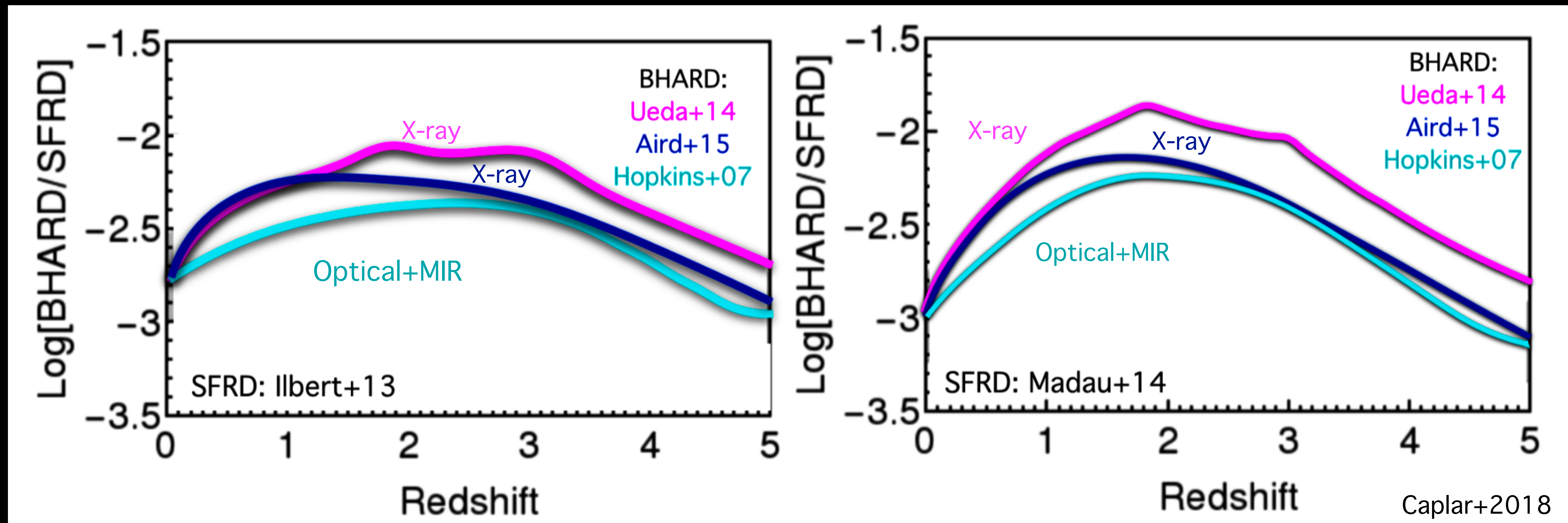
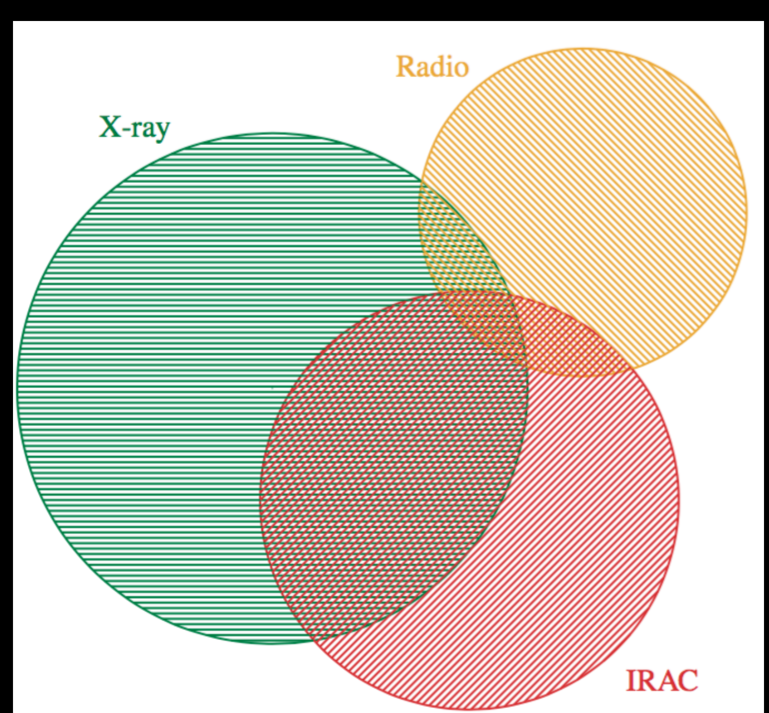
Disjointed AGN samples leave BHARD/SFRD ratio evolution unconstrained

Six different BHARD/SFRD Redshift evolutions for 3 BHARDs and 2 SFRDs

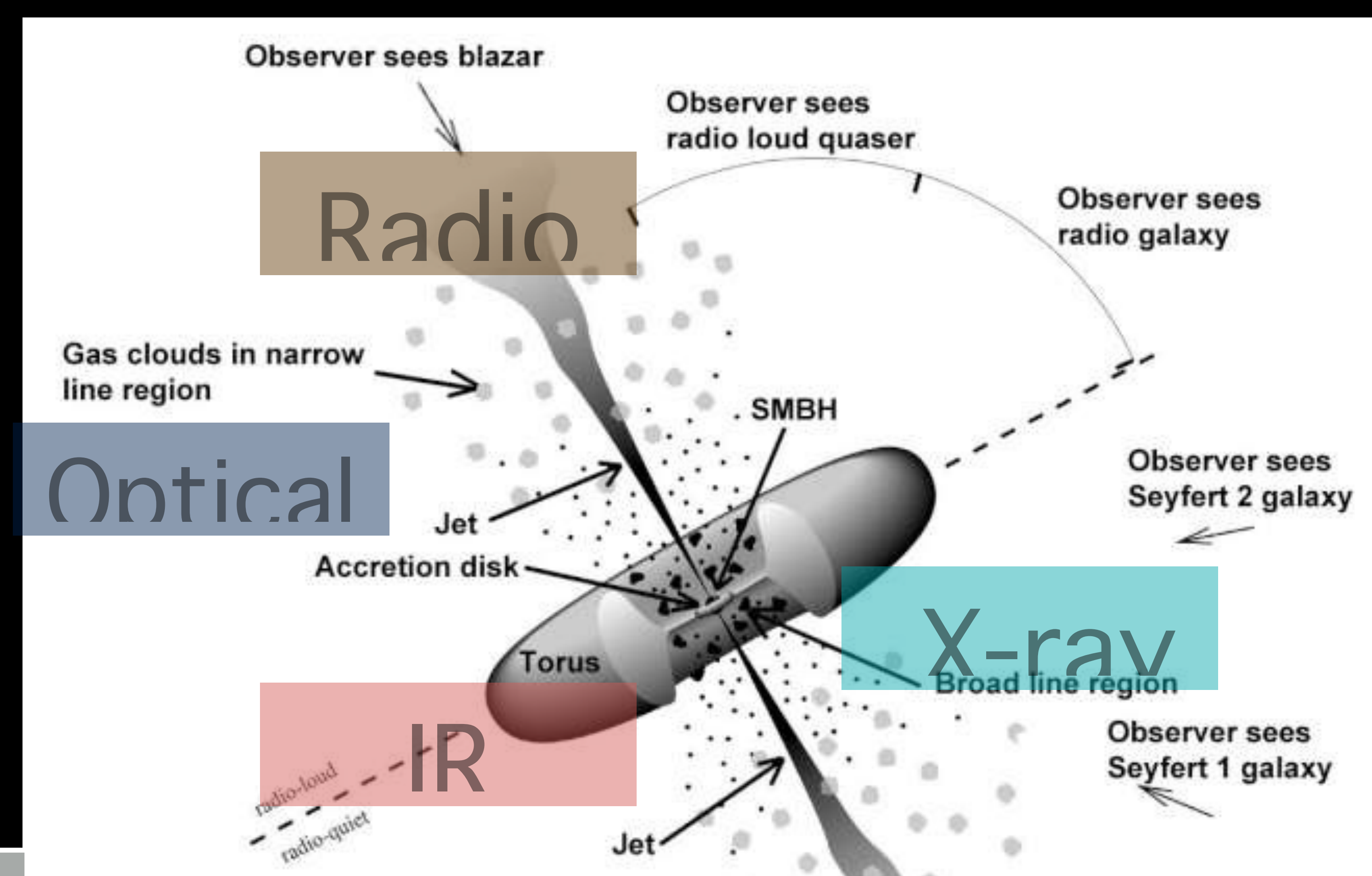


SFRD and BHARD have <u>never</u> been computed yet for a matching galaxy sample in the same study

AGN multi-wavelength selection effects & Minimal overlap:
These trends do not trace the same samples!



Hickox+2009



How do we blend the mismatch?

- To study localized connection both trends must be constructed from the <u>exact same sample</u> with a self-consistent analysis to minimize bias
- <u>Goal:</u> Add new curve to plot above to track co-evolution of the same sources
- Best-accomplished in the Infrared...

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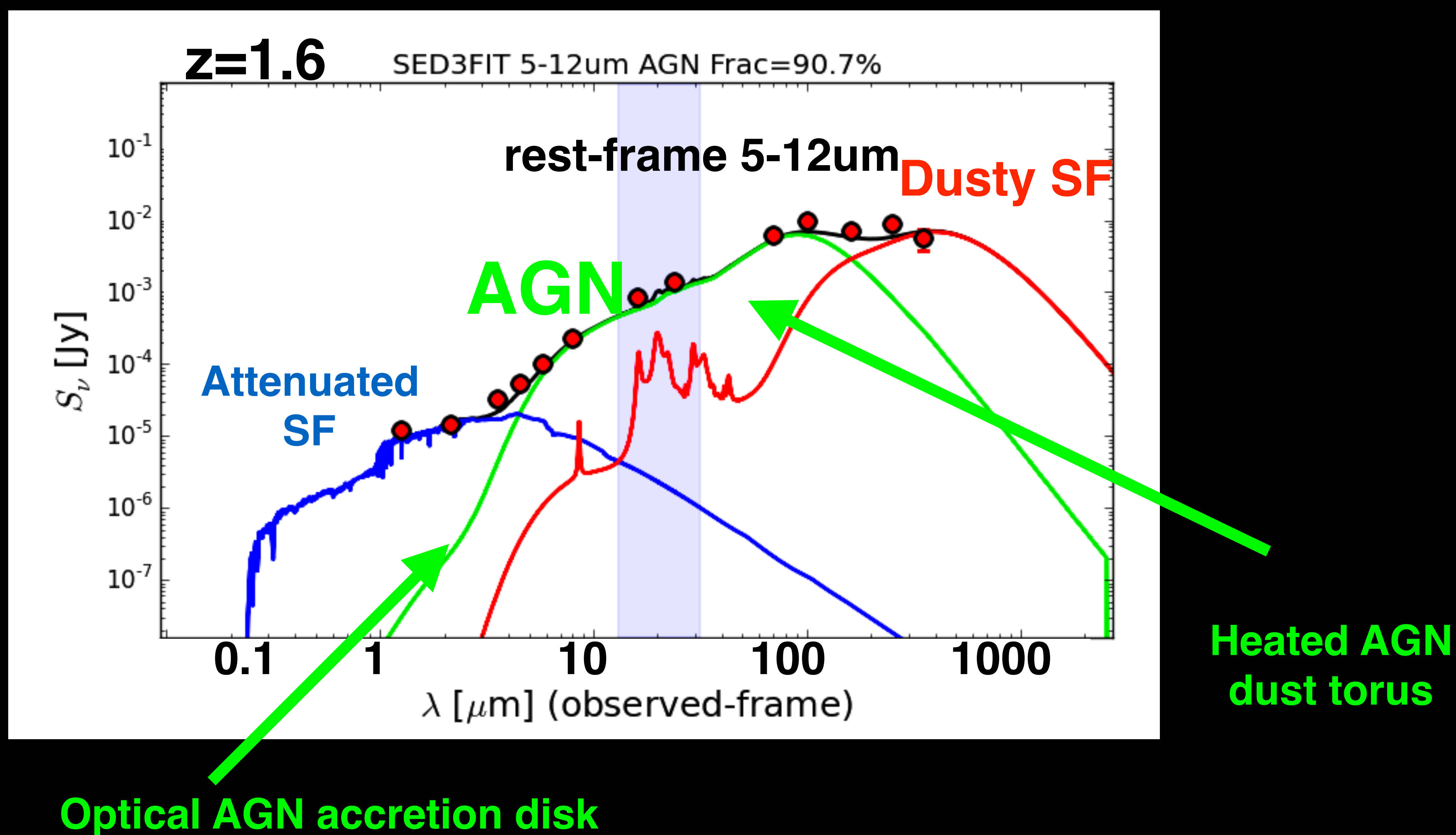
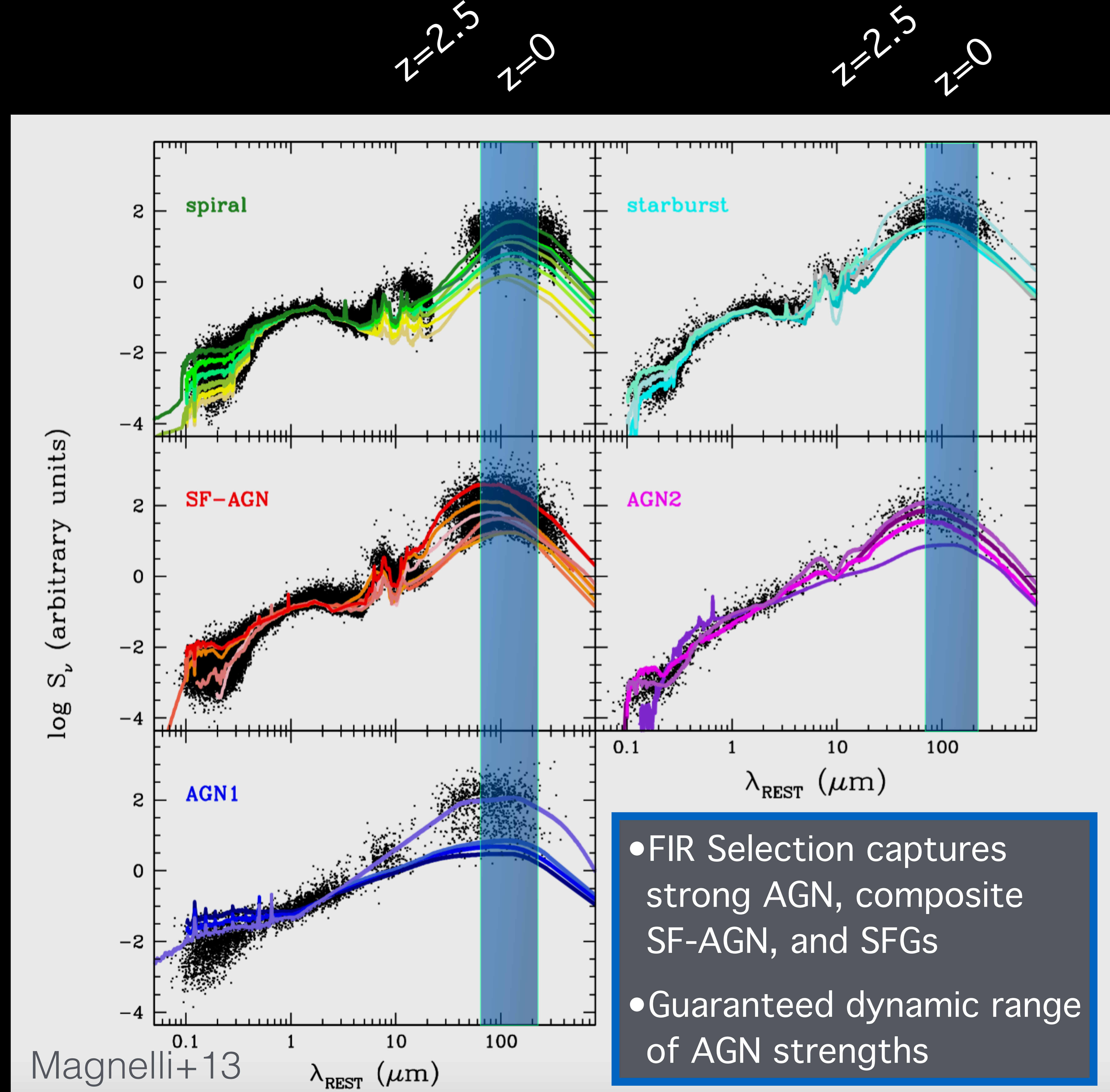
Infrared Selection and SEDs: Unifying populations for SFRD and BHARD

Why Infrared?



- AGN SED and dusty host-galaxy-SF SED overlap

- Dusty environments hospitable for BH Accretion and Stellar mass buildup-> ideal place to study



- FIR Selection captures strong AGN, composite SF-AGN, and SFGs
- Guaranteed dynamic range of AGN strengths

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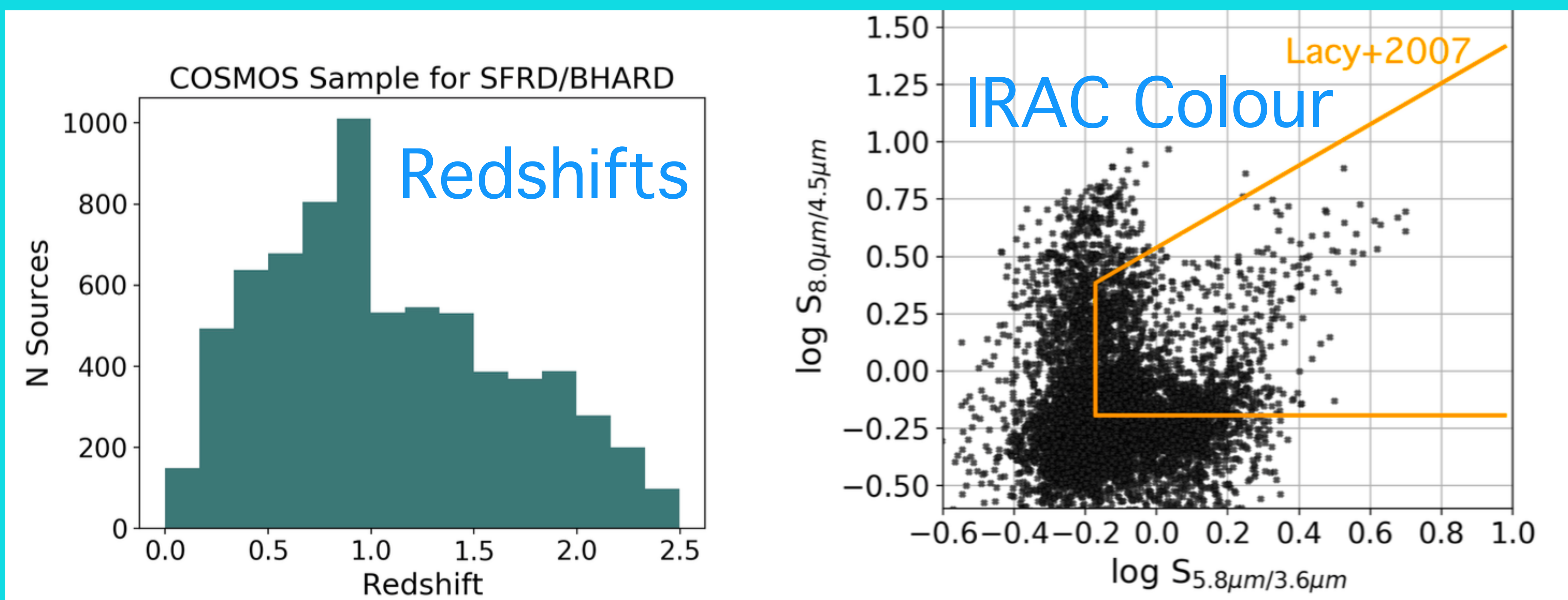
PAPER II: Concurrent SFRD and BHARD (Expected ~June 2021)

Sample Selection:

Herschel 250um-selection in COSMOS field (COSMOS2015 catalog)

- S_{250} > 8.2mJy
- 0<z<2.5
- 7,100 sources total

- 50%-75% of sample expected to have measurable AGN luminosity (Sanjina+12,Kirkpatrick+12)
- Would increase IR BHARD (Delvecchio +14) sample size by ~2-3x



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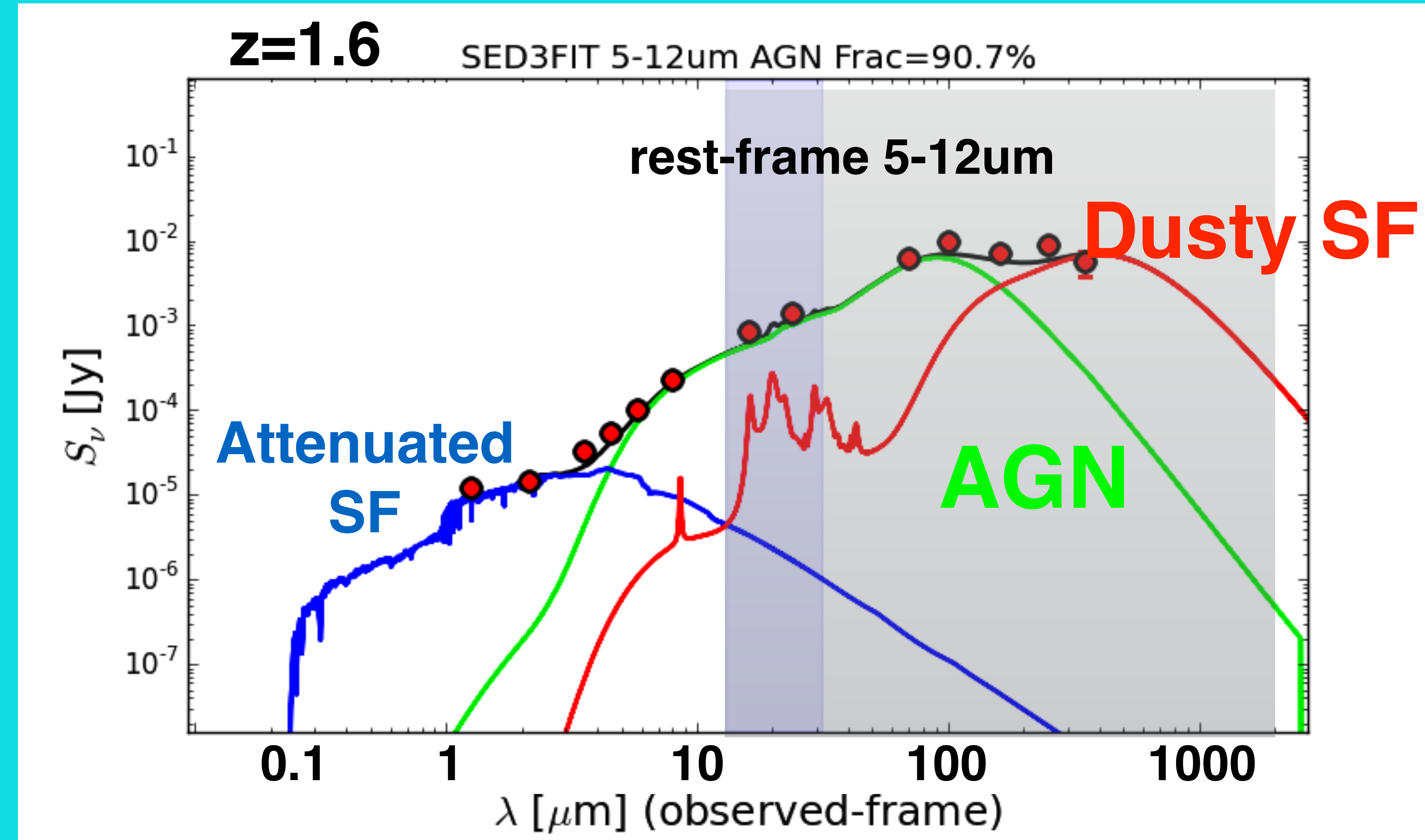
Method to construct SFRD & BHARD: Broadband SED Decomposition

Code: SED3FIT (Berta+13)



Decompose SED into:

$L_{SF,IR}$ & $L_{AGN,IR}$

$L_{SF,IR}$	$L_{AGN,IR}$
IR Lum Functions	Lbol,AGN
SFR Conversion	Lbol,AGN Lum Functior
SFRD	**BHARD**

NEXT: Expanding on methods

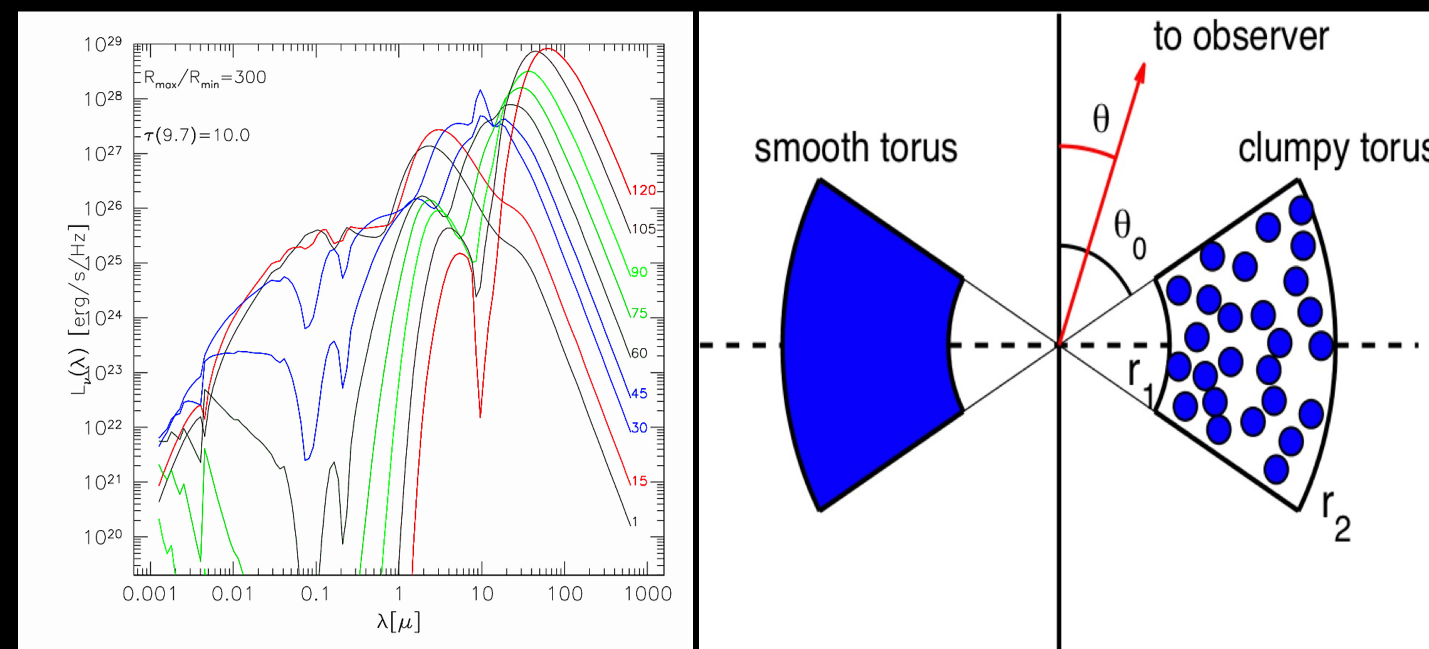
PAPER I: Mid-IR SED Decomposition Tests (Sokol et al. in prep)

What complicates this task of broadband AGN SED Decomposition?

PAPER I Objectives:

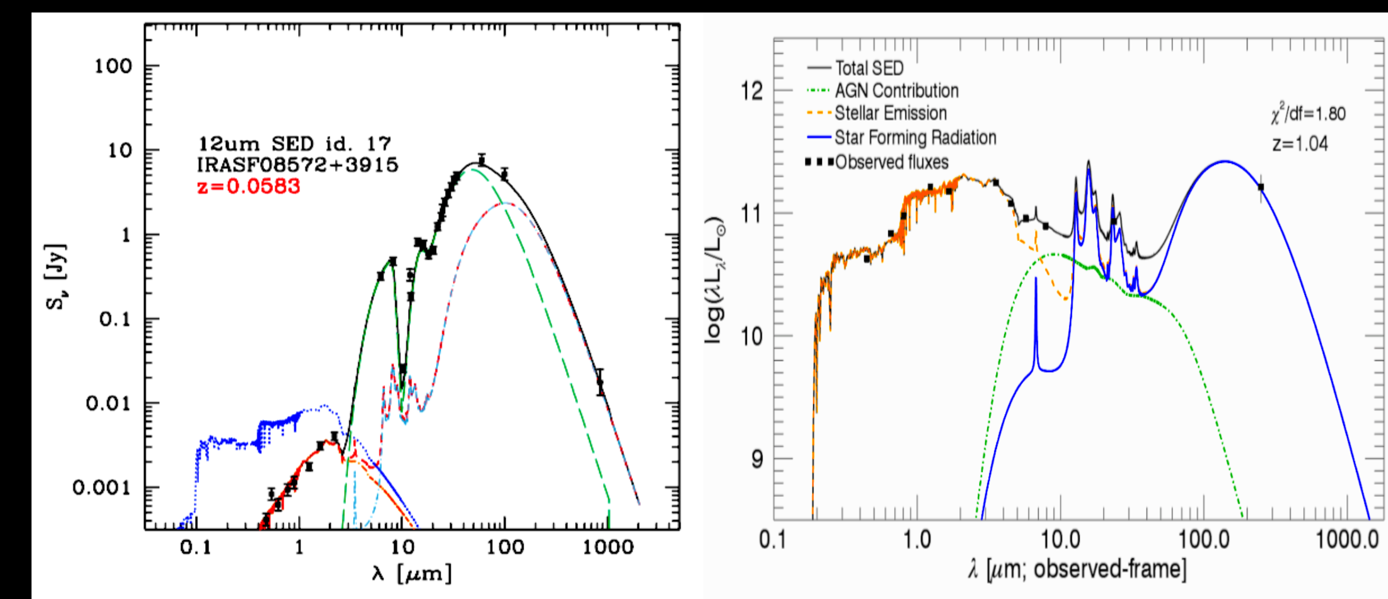
- Characterize AGN SED Decomposition degeneracies, uncertainties, weak AGN pitfalls
- Test sensitivity to wide range of AGN SED parameter space with MIT Supercloud SuperComputer
- Calibrate broadband SED fitting results with decomposition from Spitzer mid-IR Spectroscopy

Many predicted AGN SED shapes & params

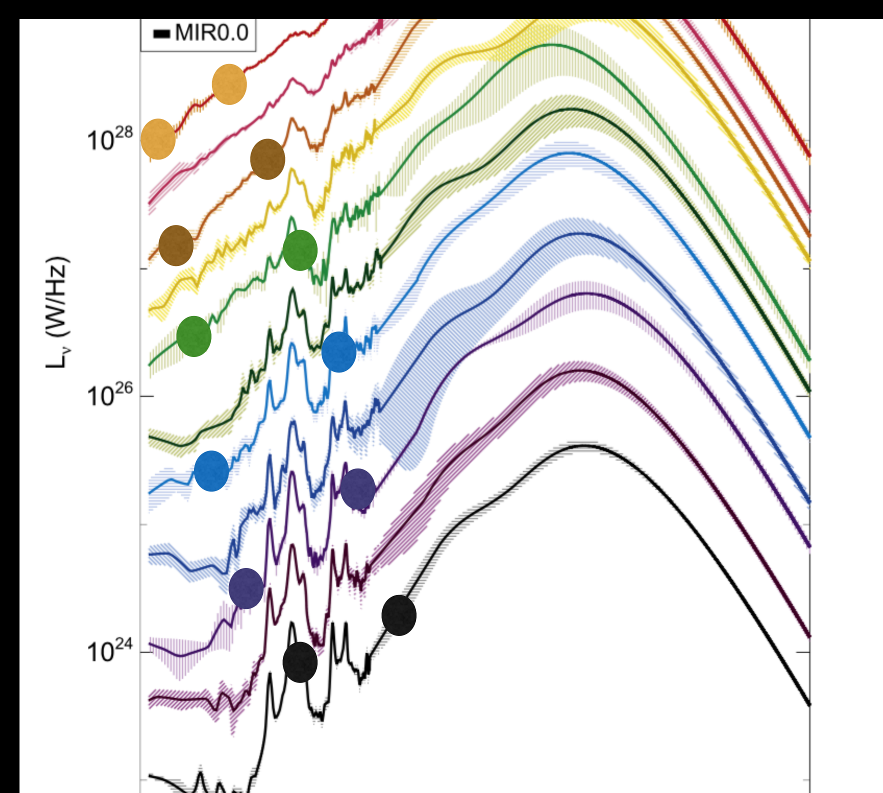


Computationally expensive!

Literature inconsistent with choices on AGN model assumptions



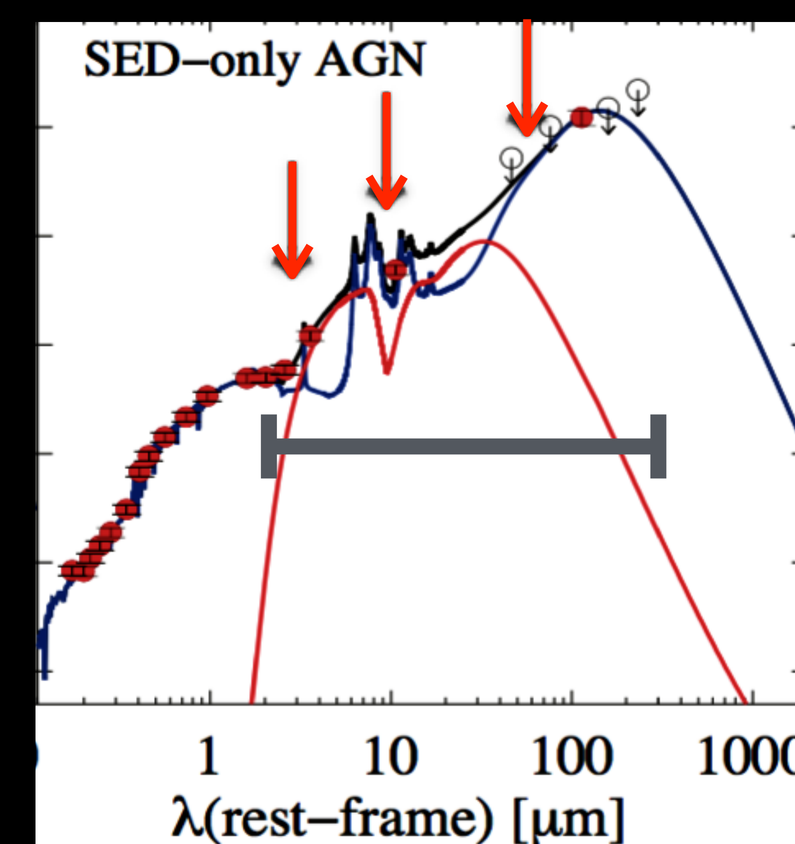
Spectroscopy of 'busy' mid-IR region most telling for AGN strength



~BB decomp relies on 1-2 points redshift throughout this region

How do these factors, all affecting rest-frame mid-IR shape or data coverage, impact/bias our AGN SED Decomposition results?

Significant broadband data gap in mid-IR by AGN SED



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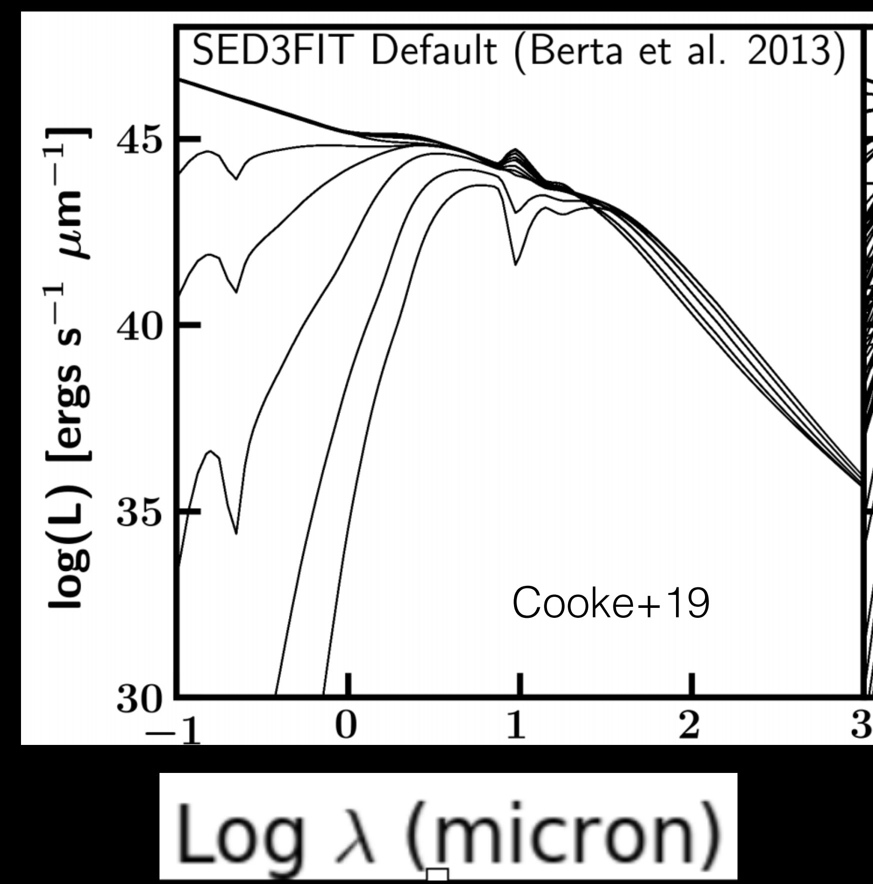
Results1: Sensitivity to AGN Model parameter restrictions

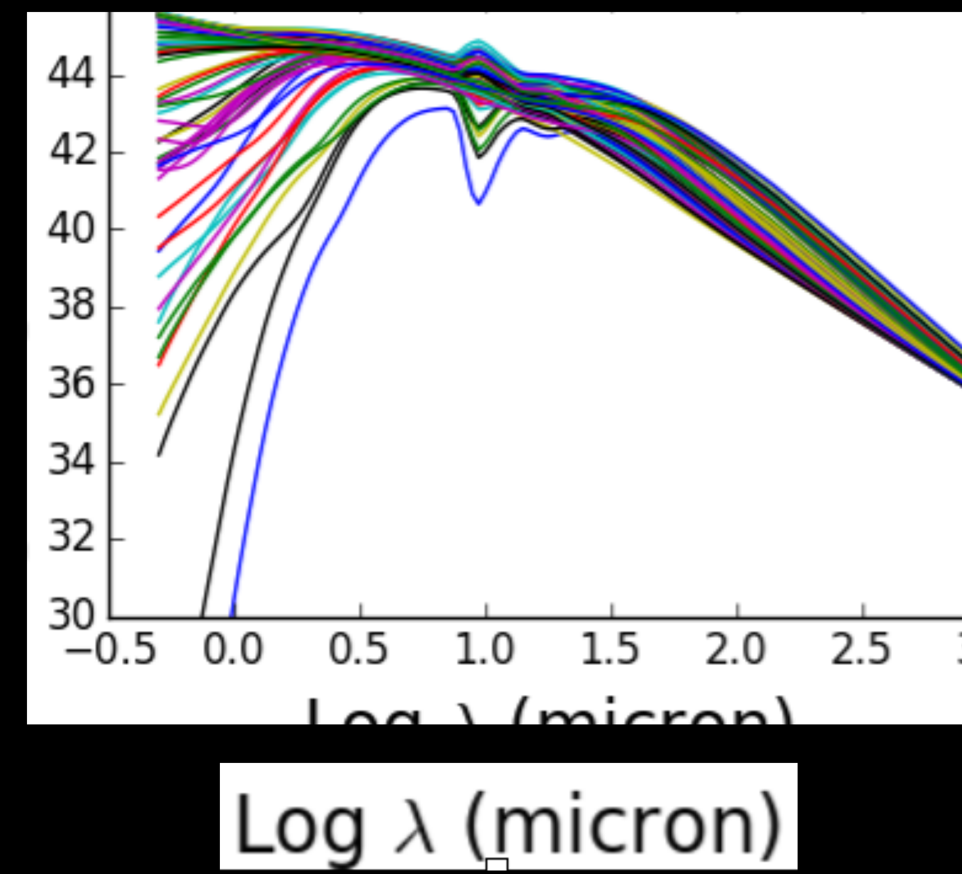
Theoretical AGN models of Fritz+06, Feltre+12

-Excludes highest optical depth (tau=10)
-Only edge-on and face-on viewing angles

10 default models

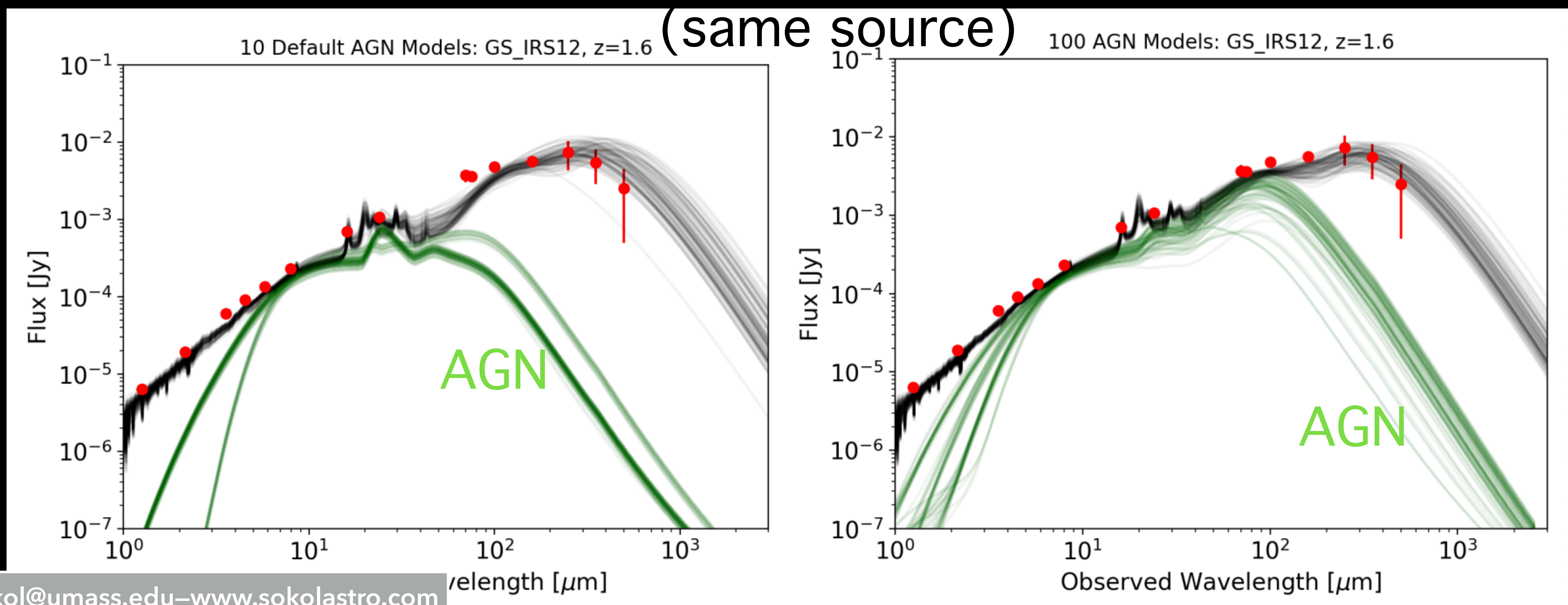


100 lib. samplings



-Allows highest optical depth (tau=10)
-10 viewing angles

(same source)



Takeaways:

- Higher optical depth AGN models gave better fits (lower chi squares)
- Supports extended FIR emission attributable to AGN

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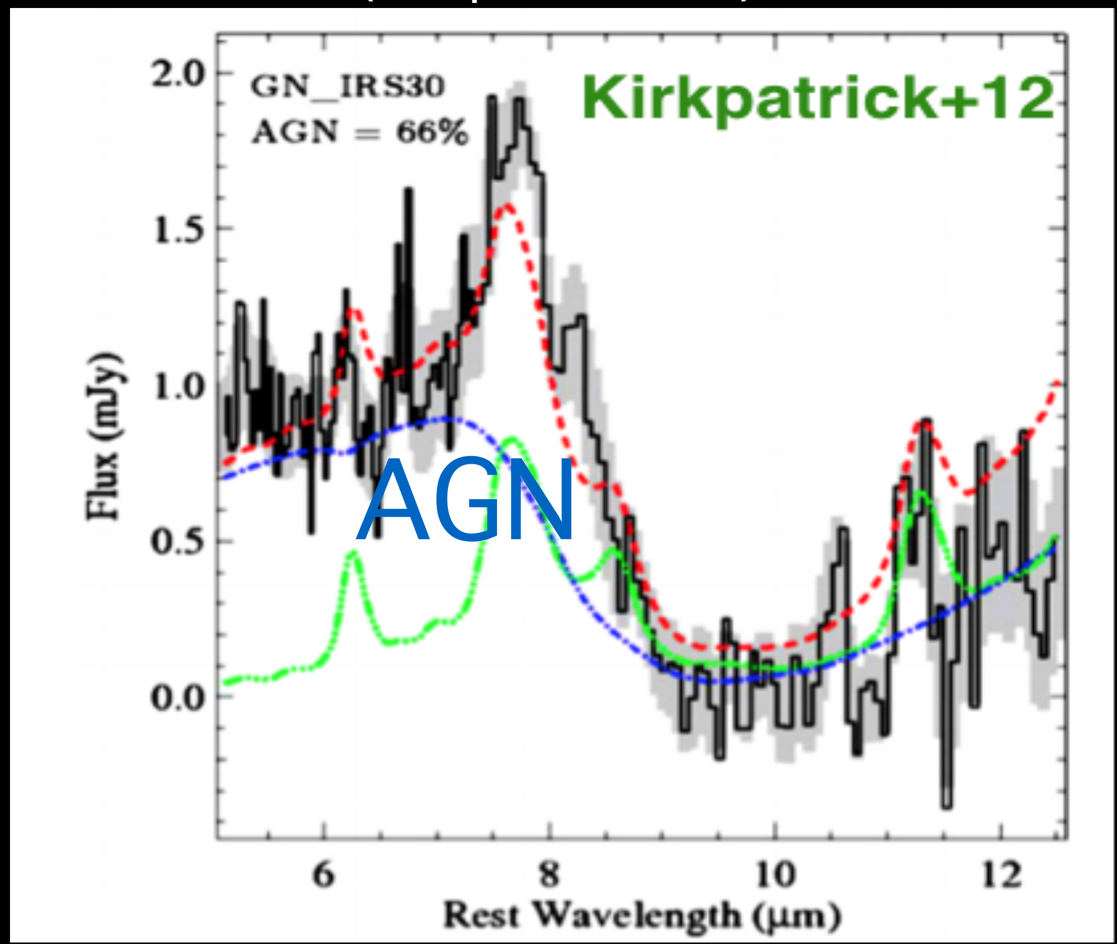
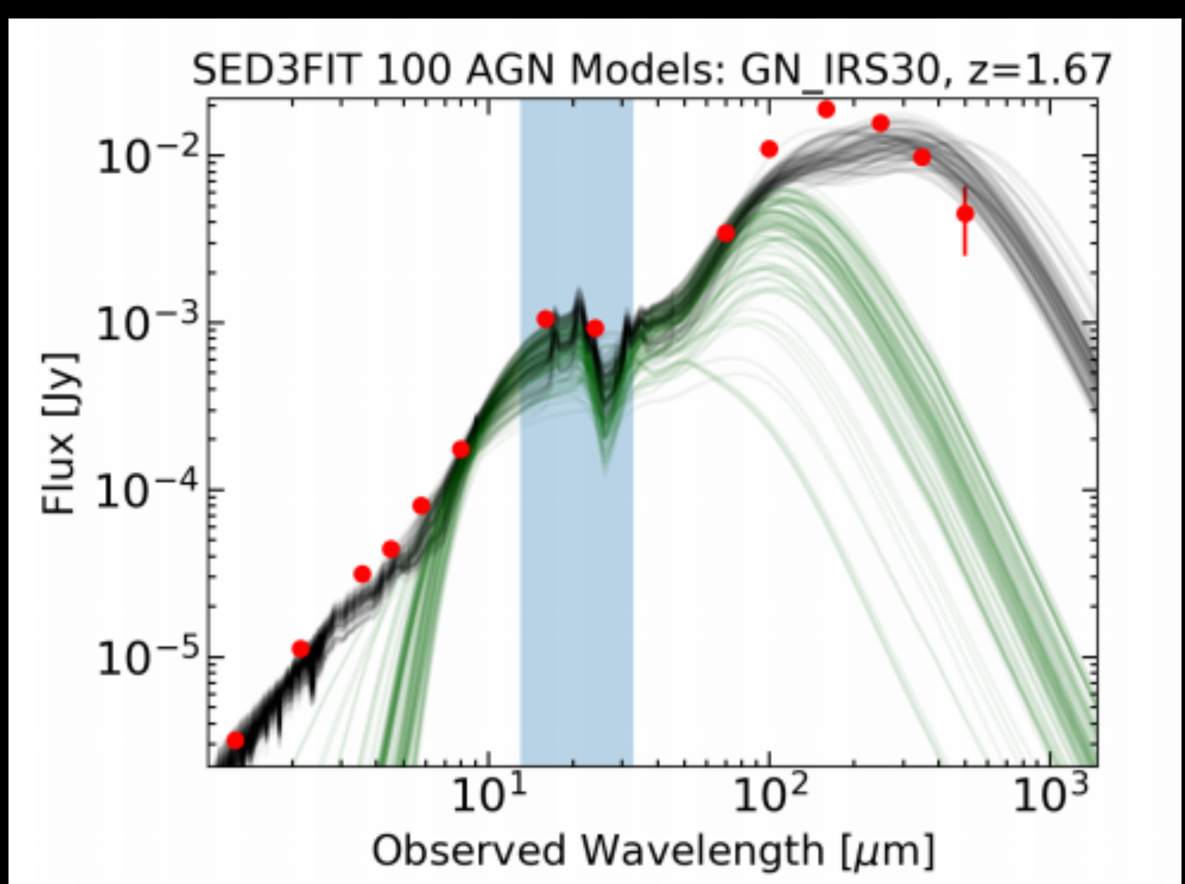
Results 2: Calibrate mid-IR decomposition results with spectroscopic results

Method

IRS mid-IR Spectral Decomposition
(Kirkpatrick+12)



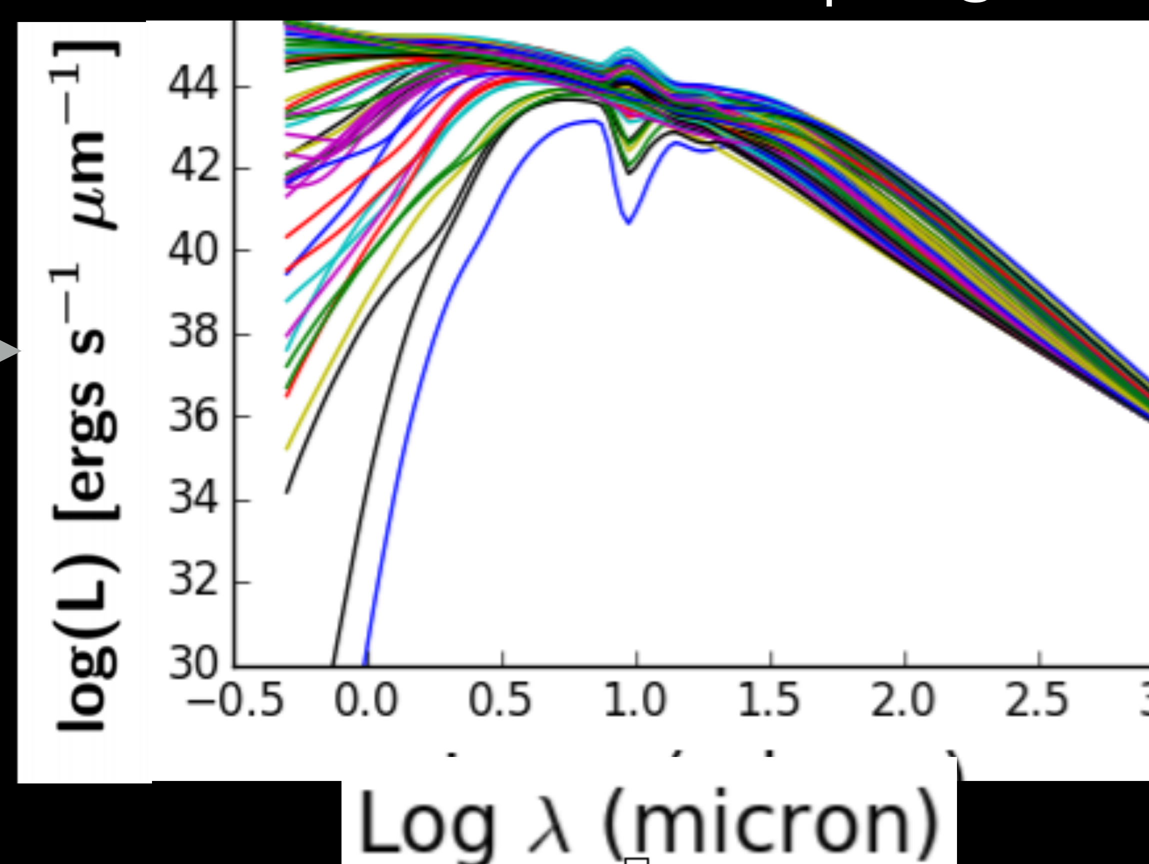
Broadband SED3FIT Fitting
(This work)



AGN Model Treatment

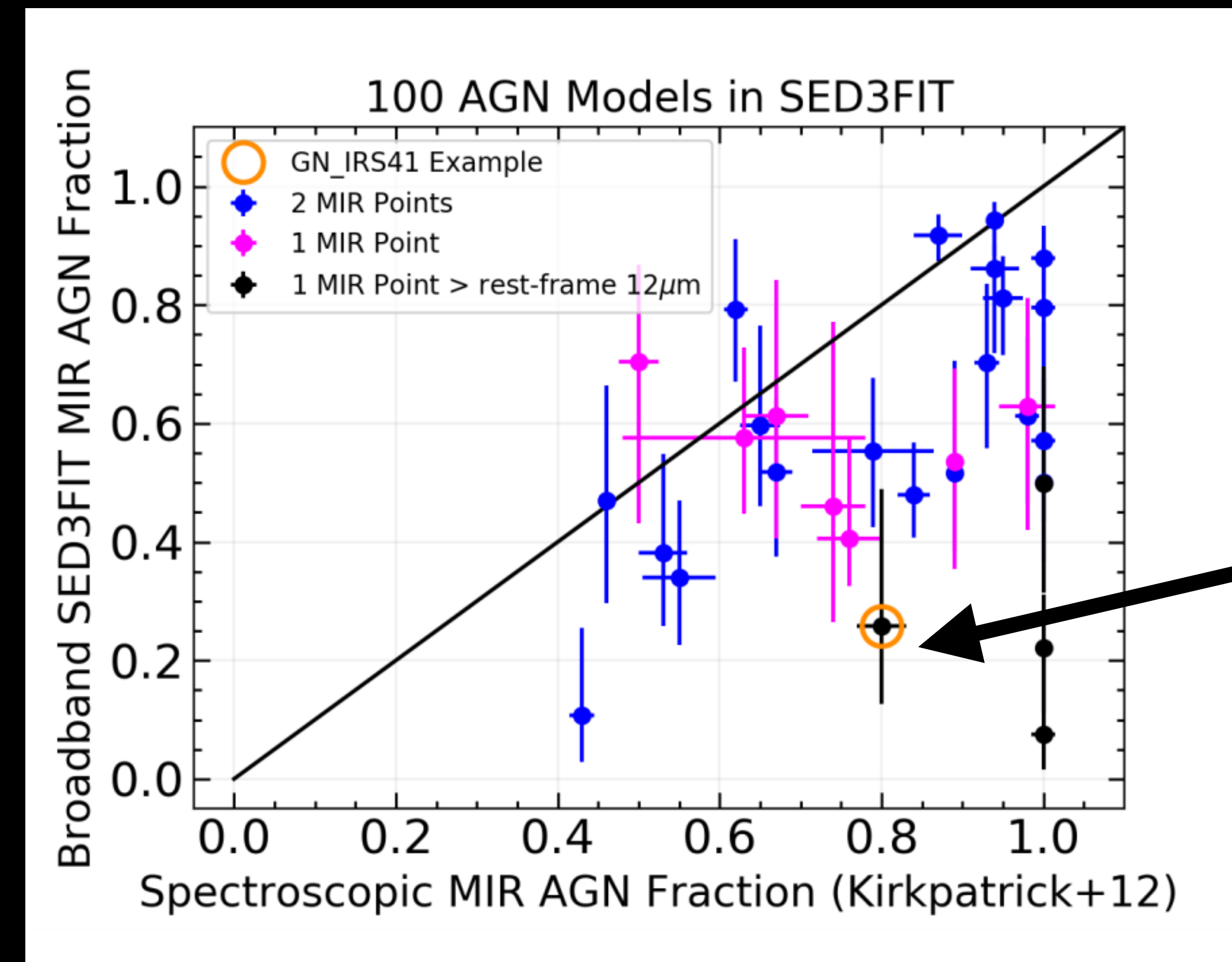
Simple AGN power-law model with applied extinction

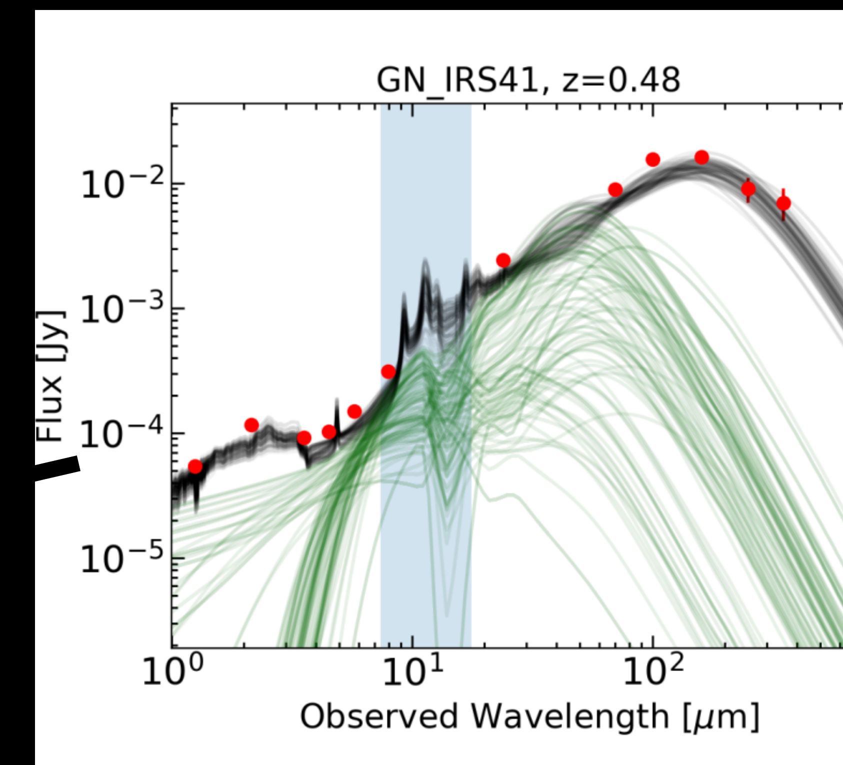
Fritz+06, Feltre+12
AGN Torus Models
100 random lib. samplings



Mid-IR AGN Fraction Comparison

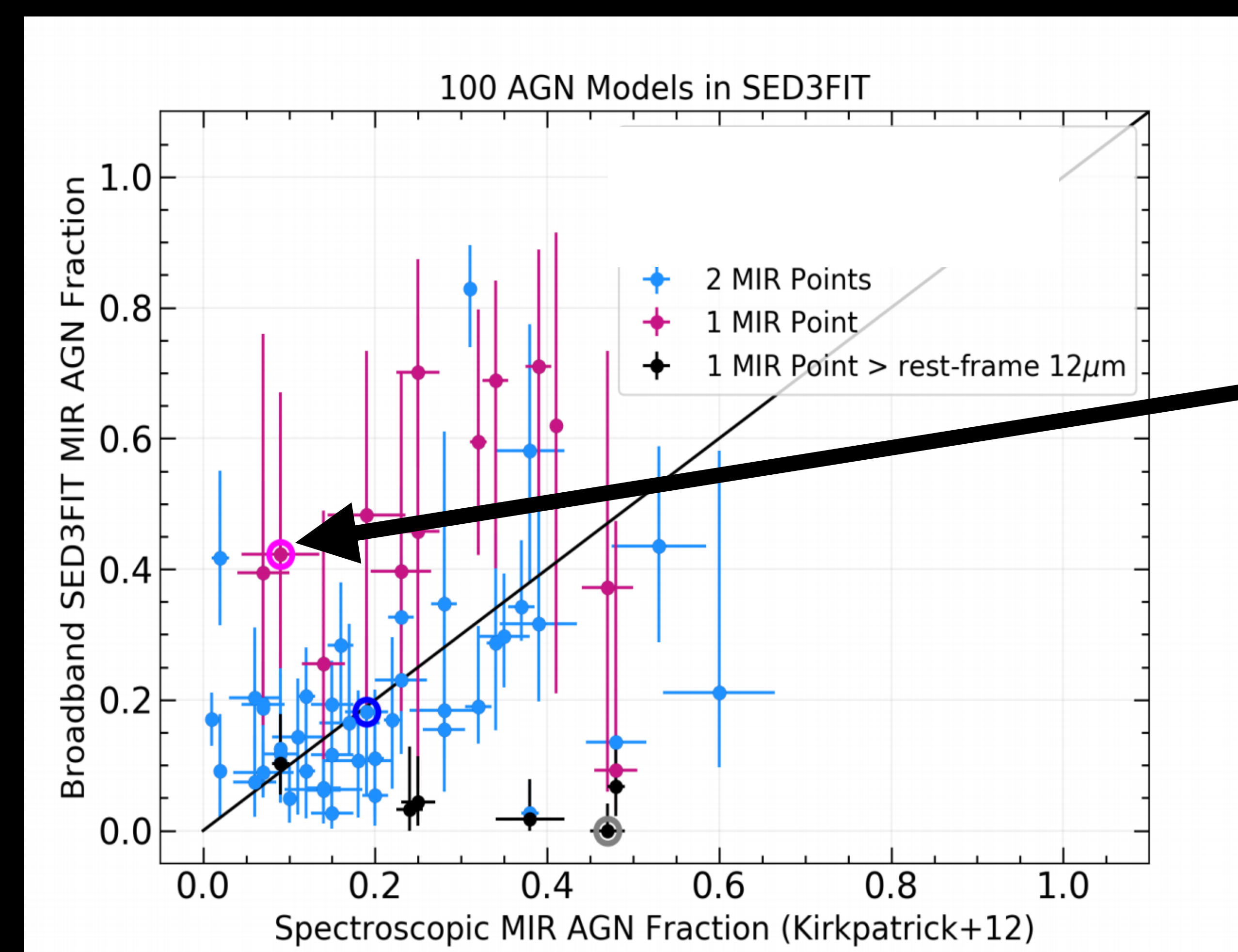
Strong AGN

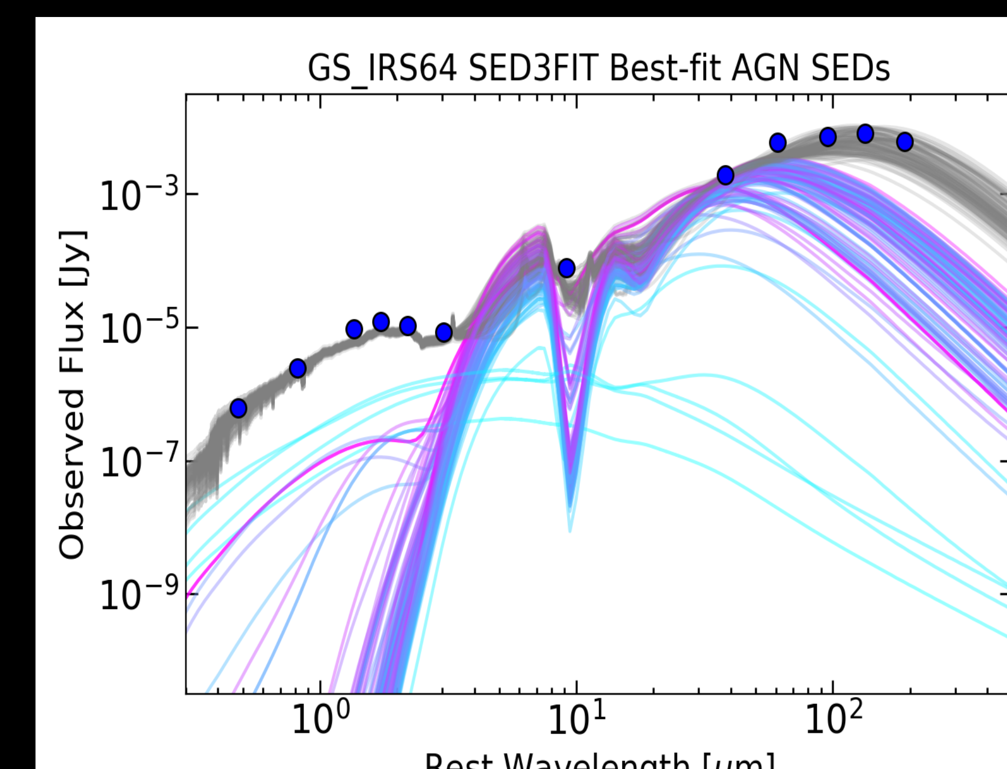




Mid-IR data gap systematically underscores AGN Fraction

Weak AGN





24um point right on top of 9.7 Si feature
MIR AGN Fraction over-estimated

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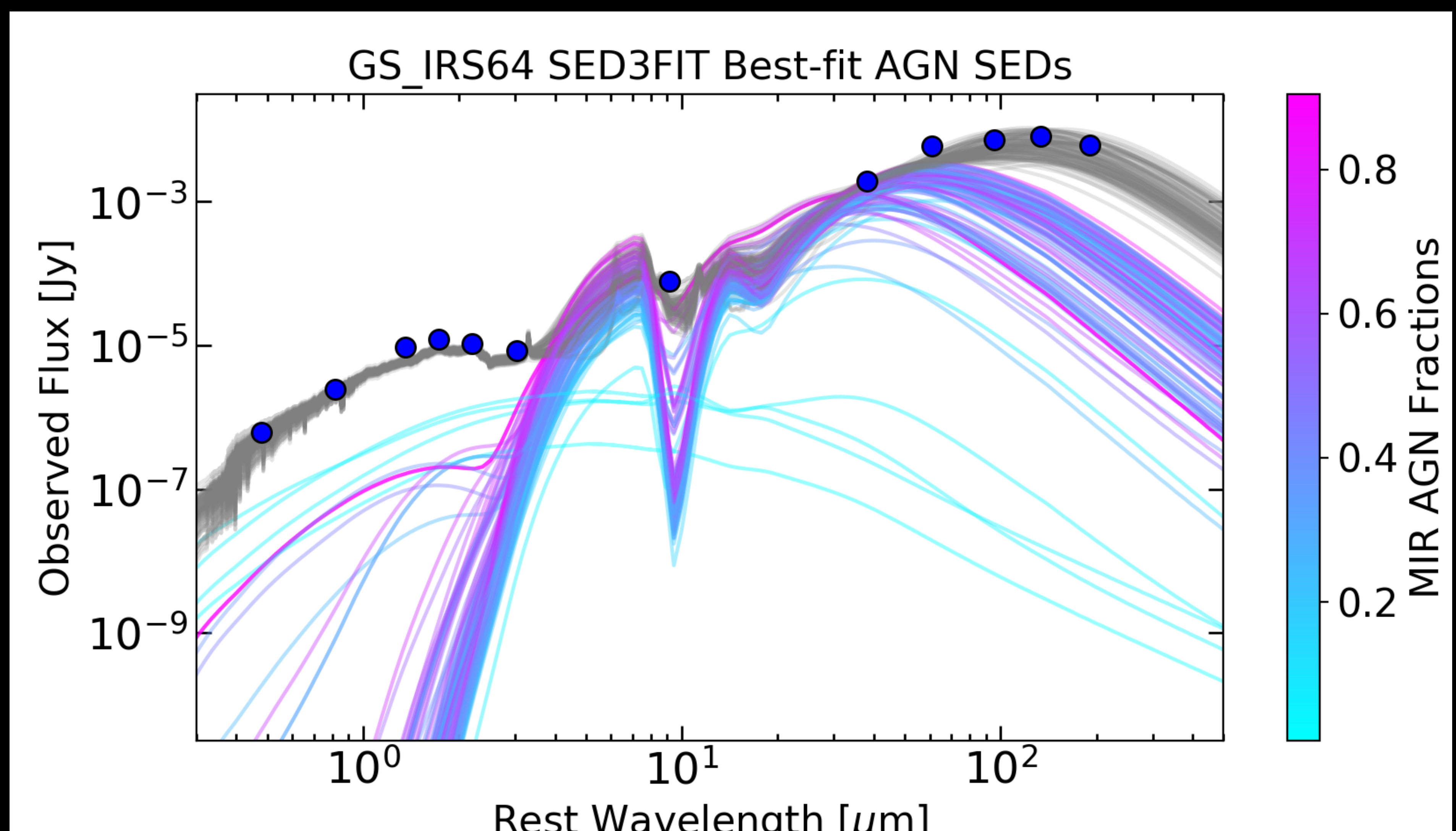
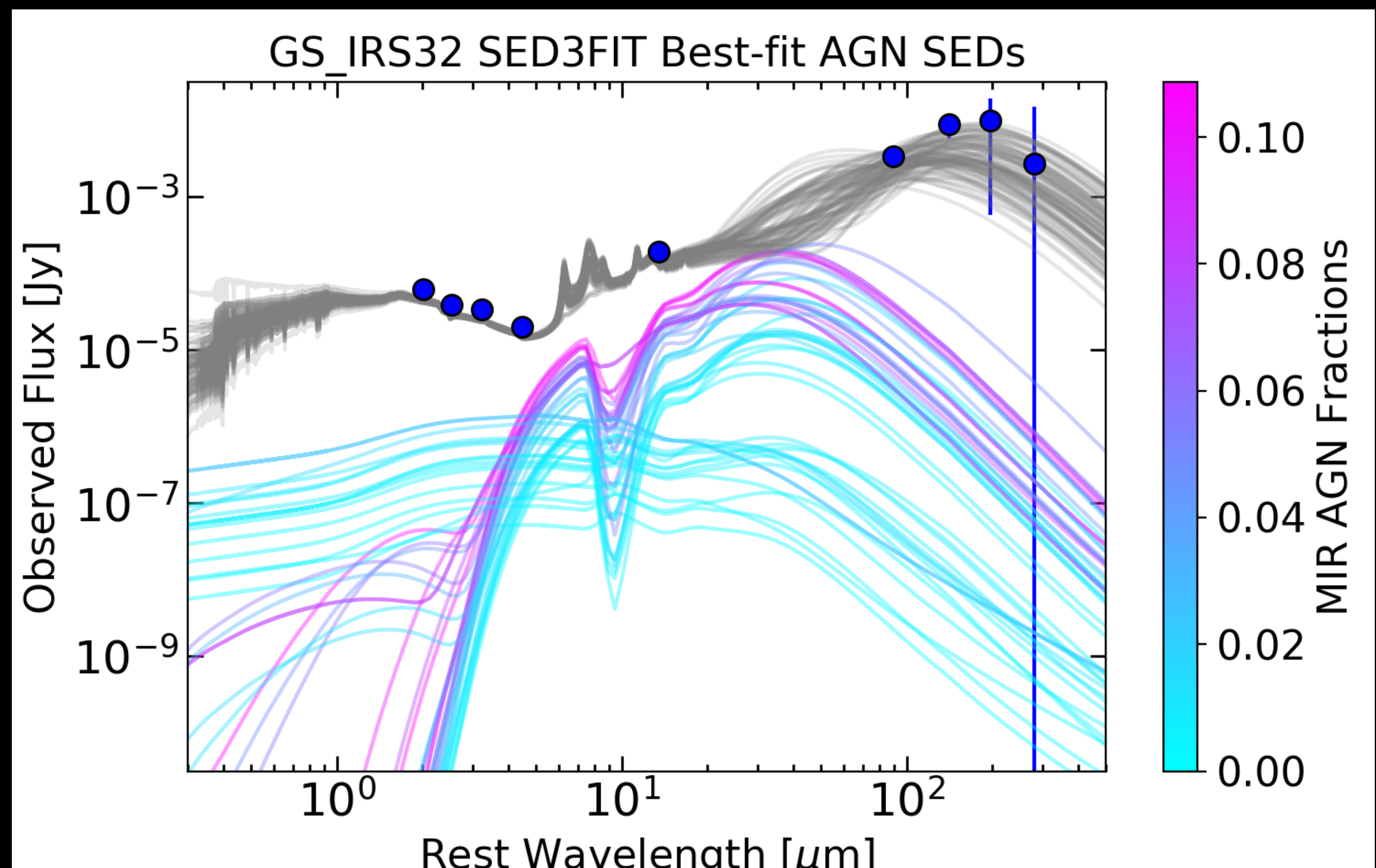
Result 2 Takeaway:

- Location of mid-IR constraints systematically affects BB Decomposition results
- Sensitive to 9.7um Silicate absorption feature in AGN SEDs & choice of models
- Certain redshift ranges will be affected more than others
- JWST will be helpful to improve constraints





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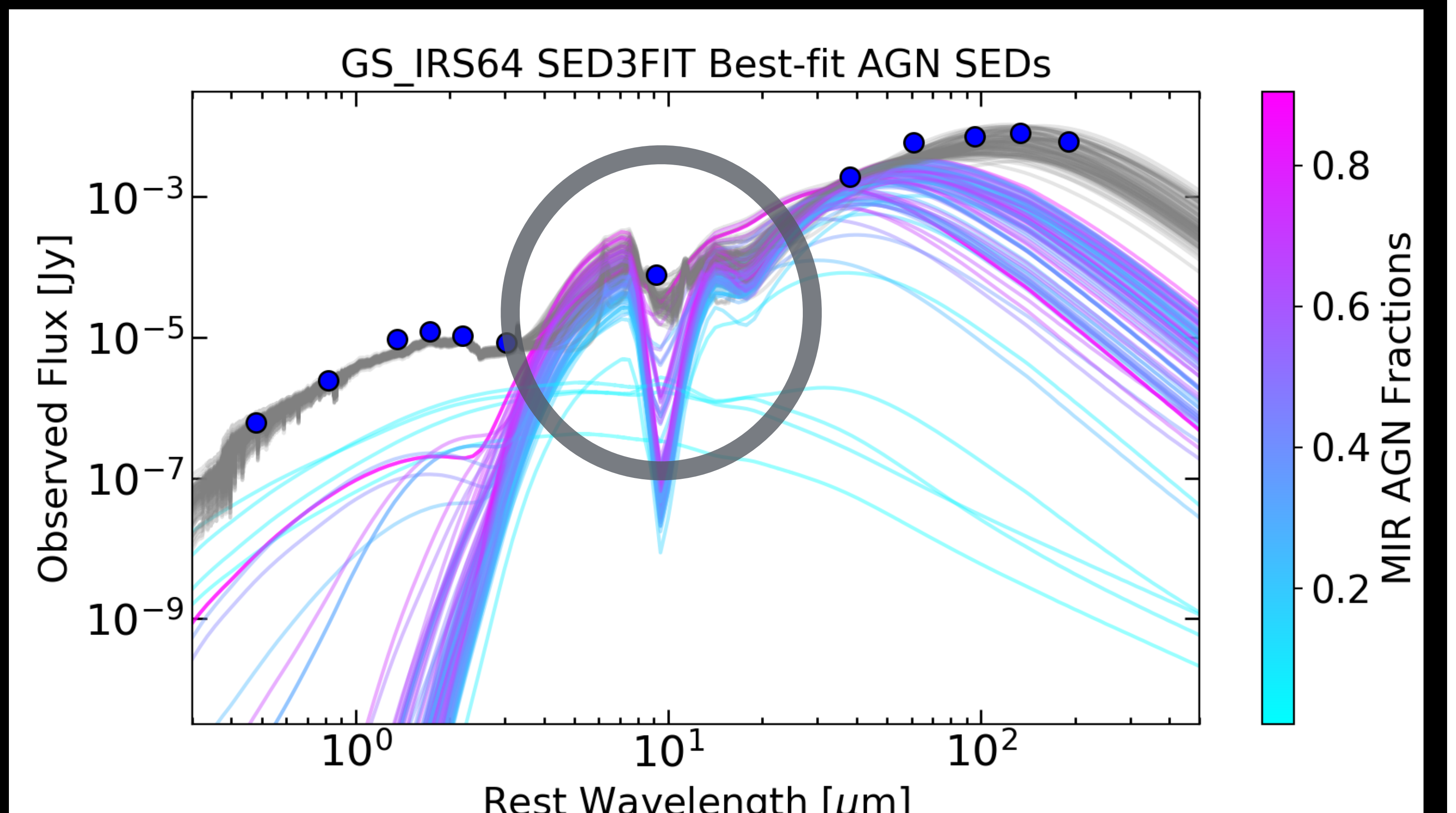
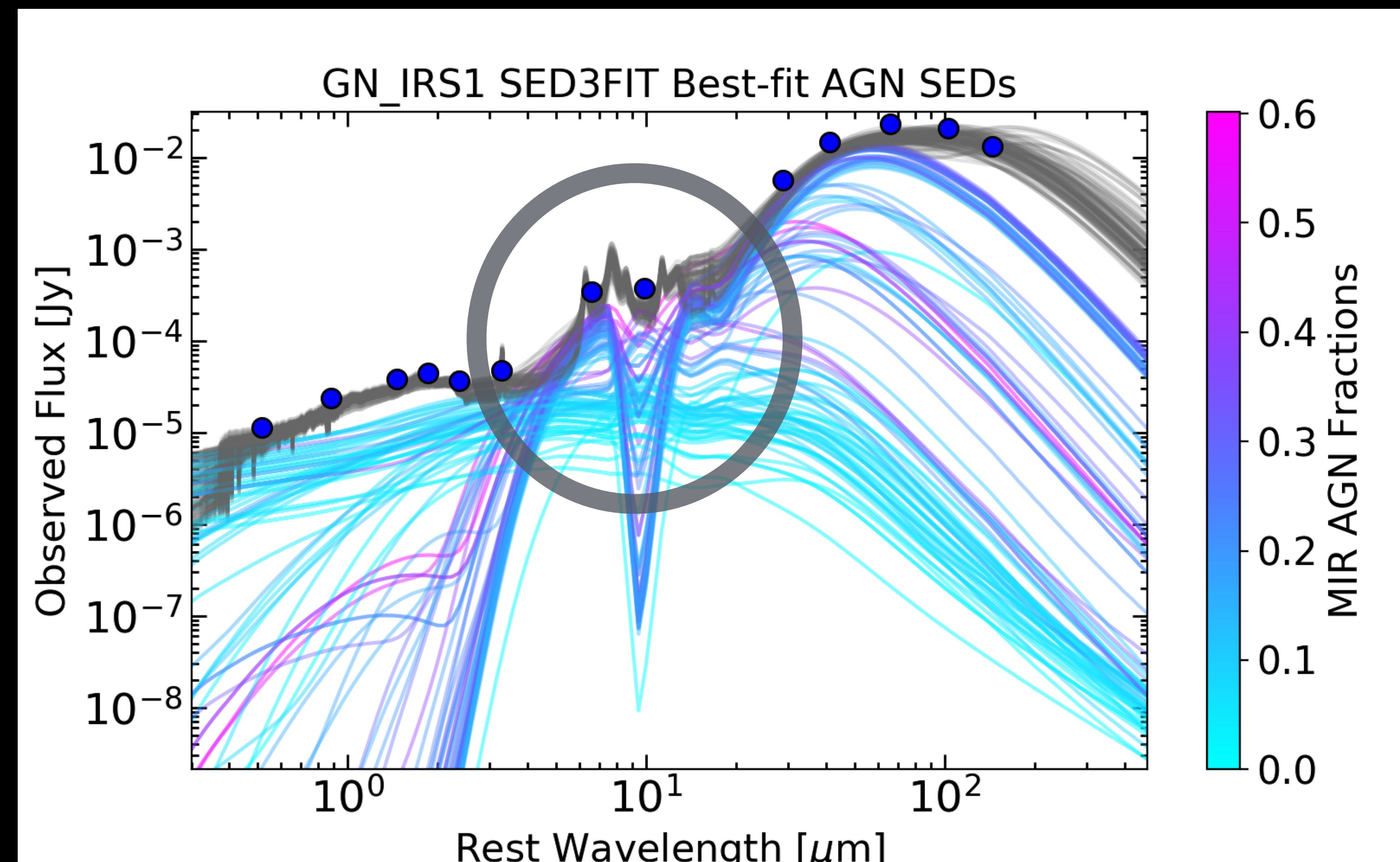
To Elaborate: How much does more data benefit & where ?

- JWST coverage will be beneficial
- Additional test shows rest-frame 5-8um region most significant

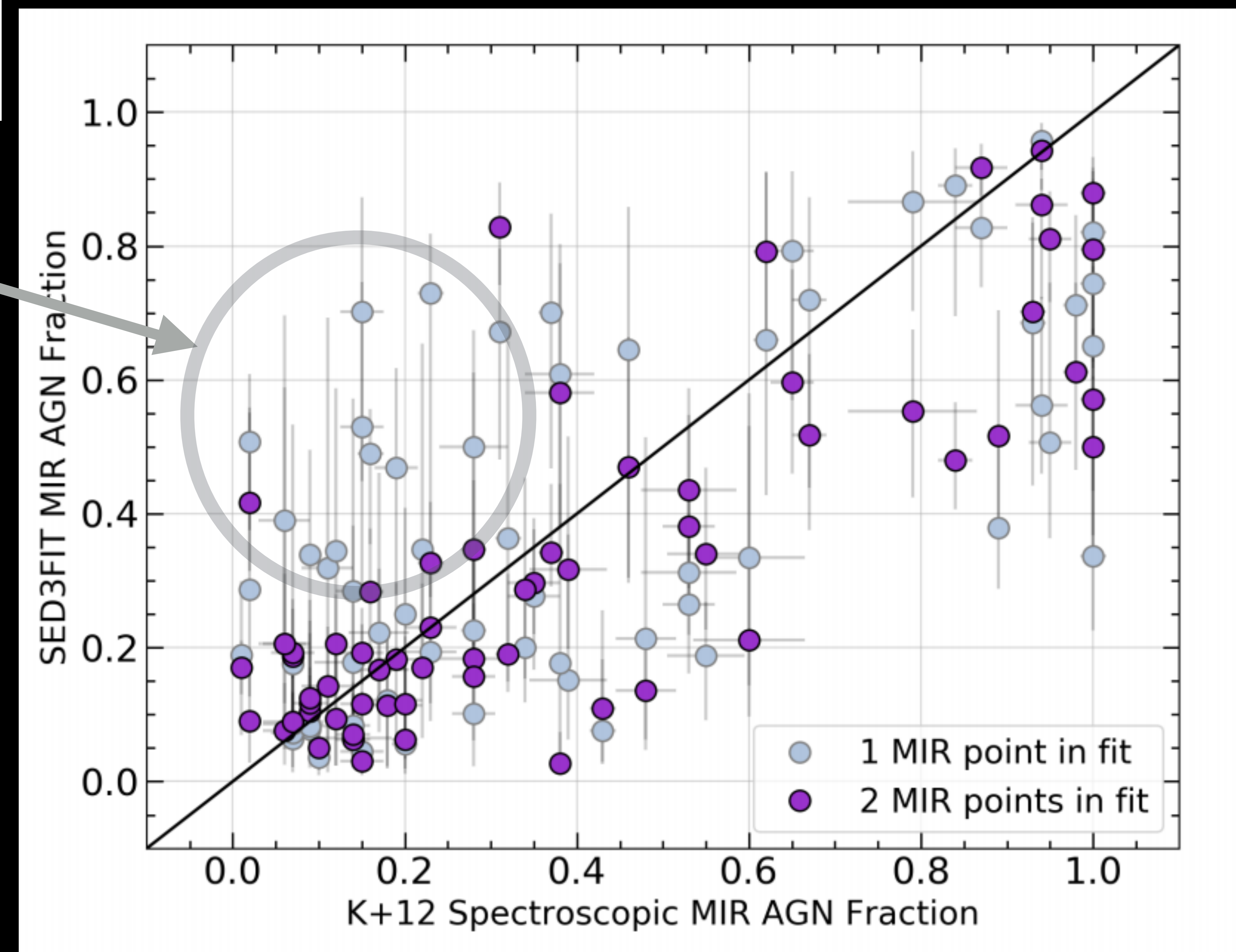




Important Note:
Consideration of high optical depth models especially important for IR studies/BH growth

Testing it out:
Same sources plotted twice
Fit use only 24um (in MIR)
Fit use 16um and 24um (in MIR)

No rest-frame 5-8um coverage



- Most significant difference in fit results were for addition/subtraction of rest-frame 5-8um constraint
- Move closer to one-to-one line

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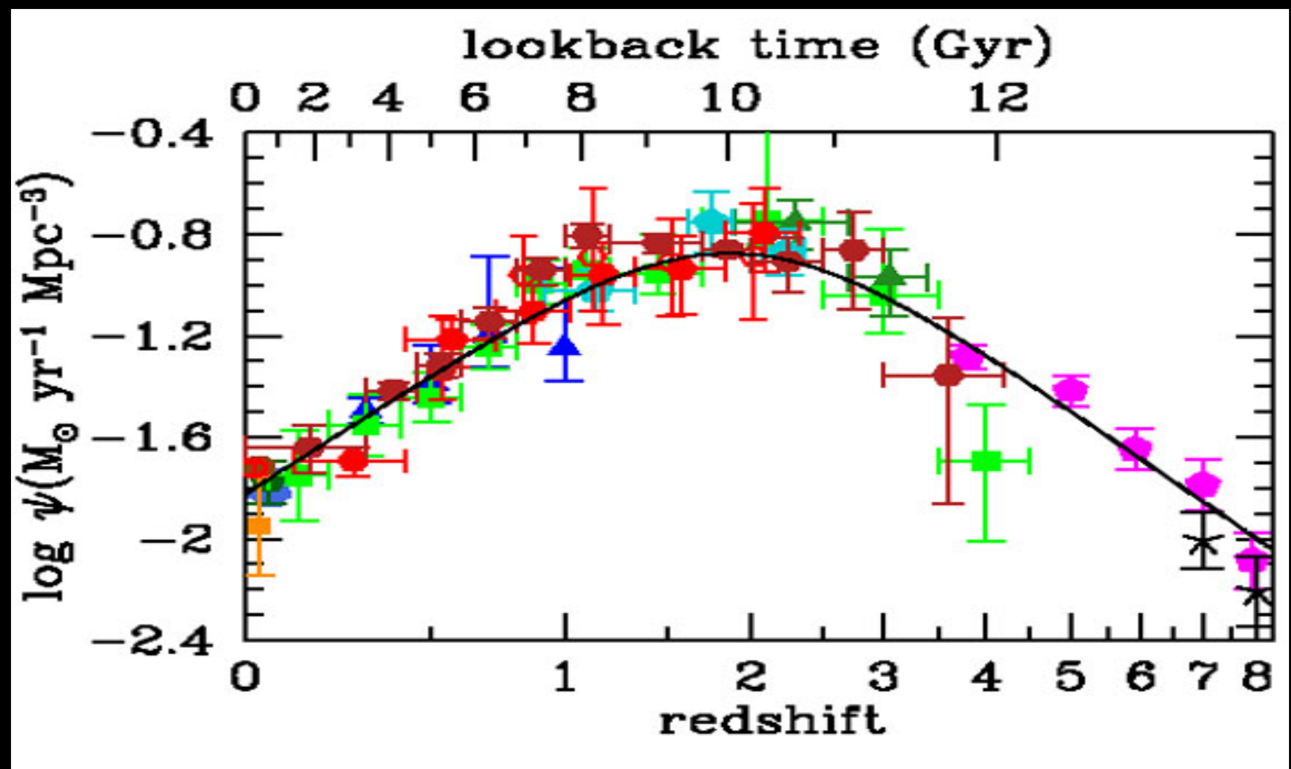
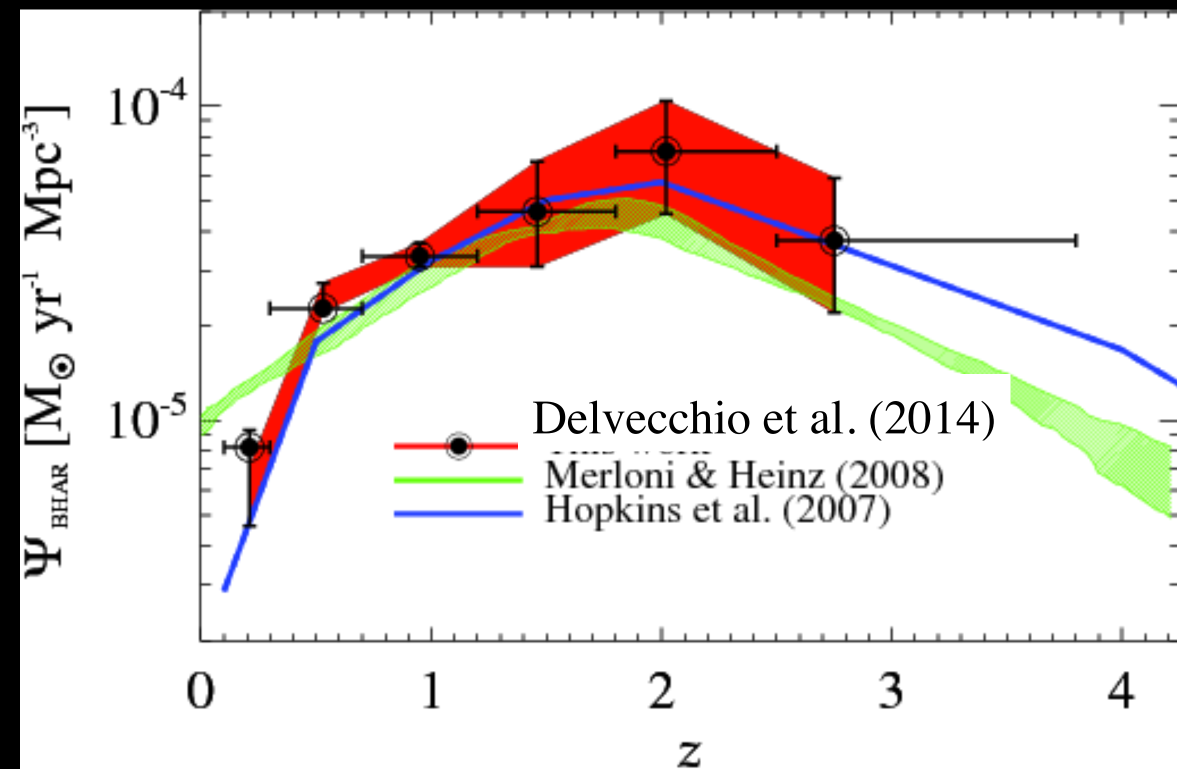
Summary & Why is this important?





Initial objective:

Building SFRD and BHARD from same sample

Requires:

SED decomposition for large sample including AGN of all strengths

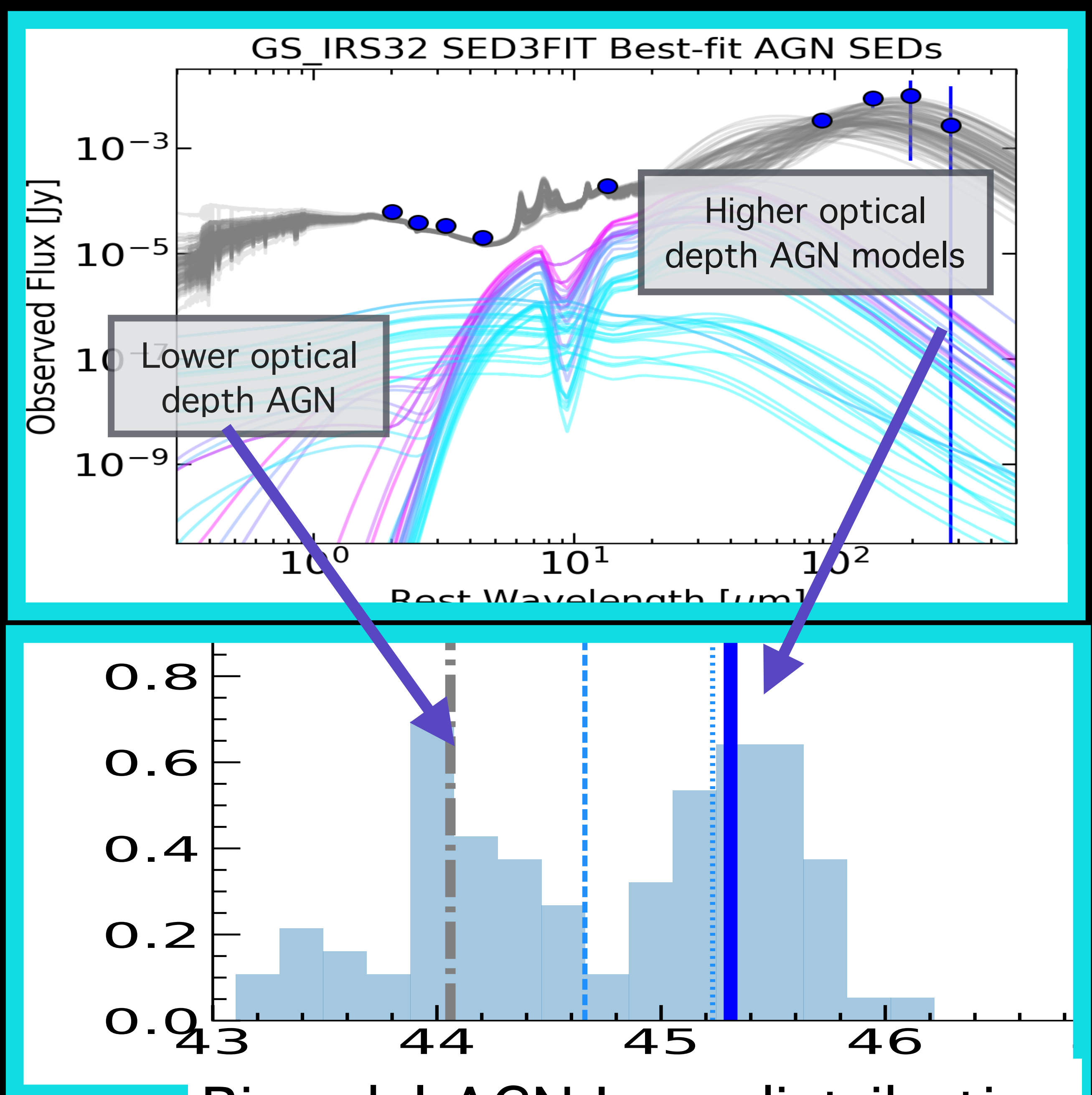
Limited by:

Robustness of decomposition

1-2 broadband points covering mid-IR

Alternative ways of understanding decomposition of large high-z samples & weak AGN

This work fit example:

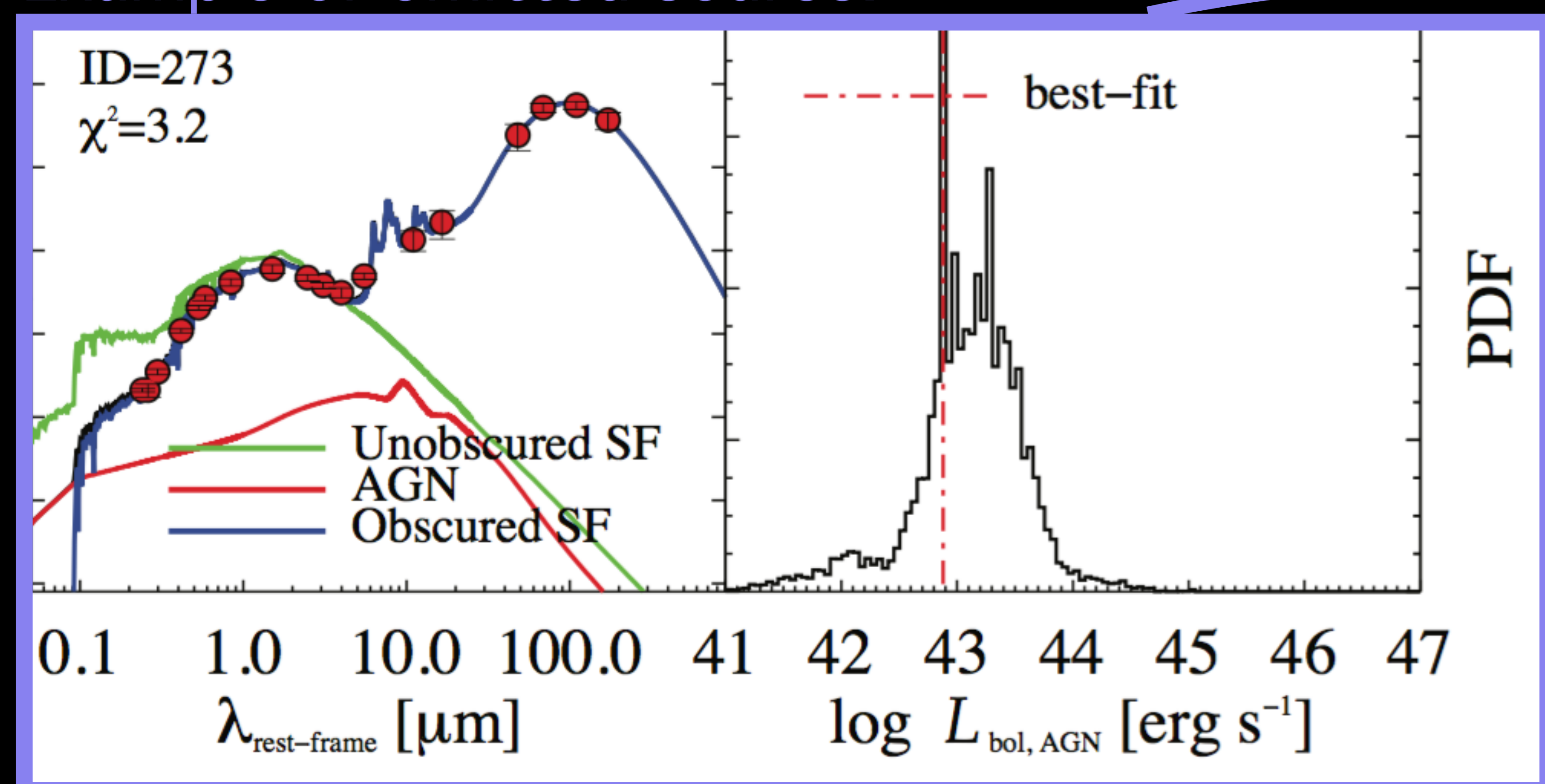


Bimodal AGN Lum distribution

IR-Derived BHARD Method in Delvecchio et al. 2014:

- High optical depth AGN models (tau>6) excluded
- Cut 70% of parent sample with weak AGN component via F-test to produce final sample

Example of omitted source:



Could this source have a higher AGN luminosity or bimodal luminosity PDF if AGN model choices were different?

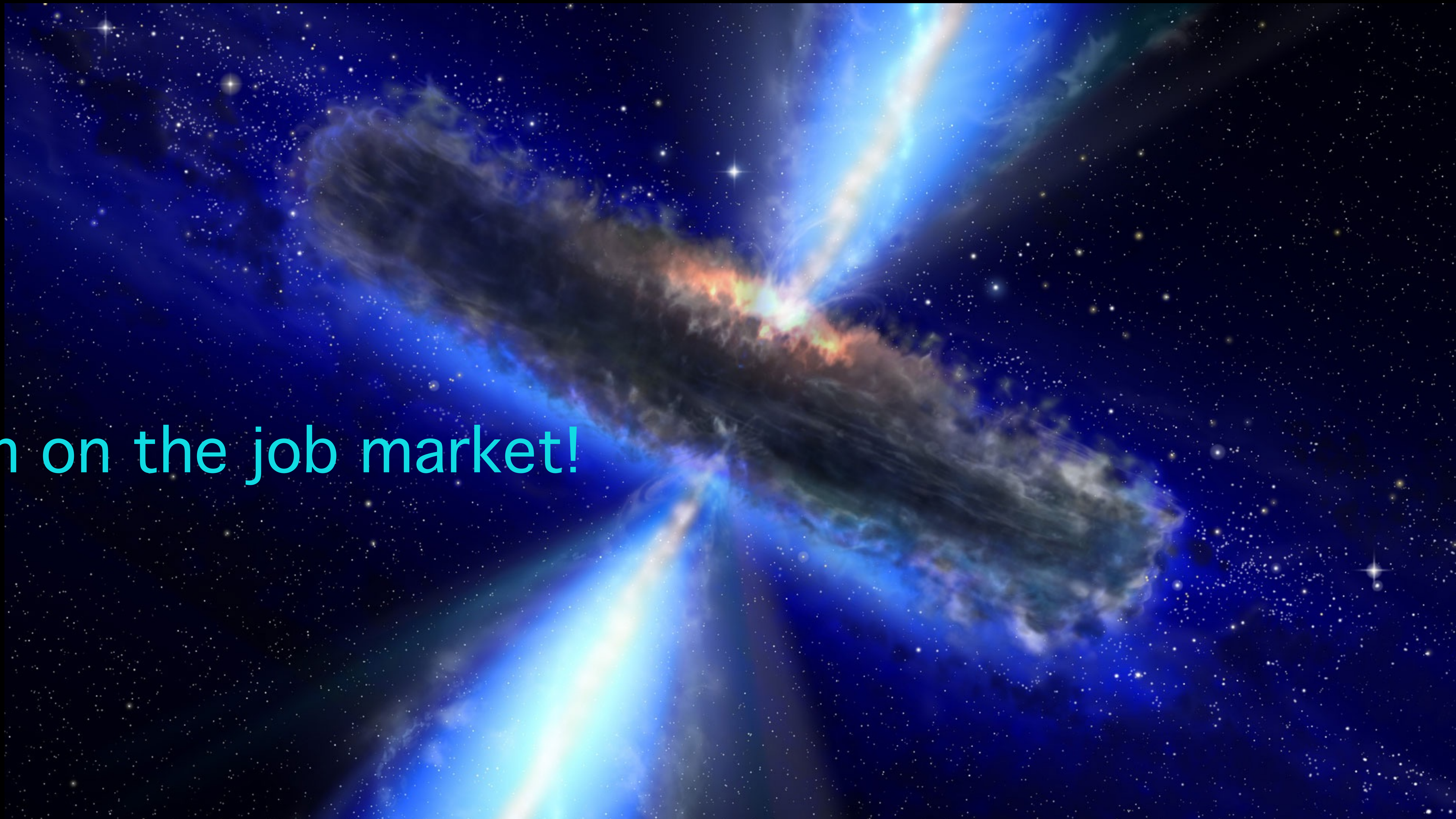
A cautionary tale:

⭐Certain MIR data gaps may be under/over-estimating AGN Luminosity and AGN MIR fraction

⭐Excluding certain AGN models from fitting can bias results

⭐Application of these techniques in the future should consider such biases & systematics

Thank you!



I’m on the job market!

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