Modeling dusty galaxies

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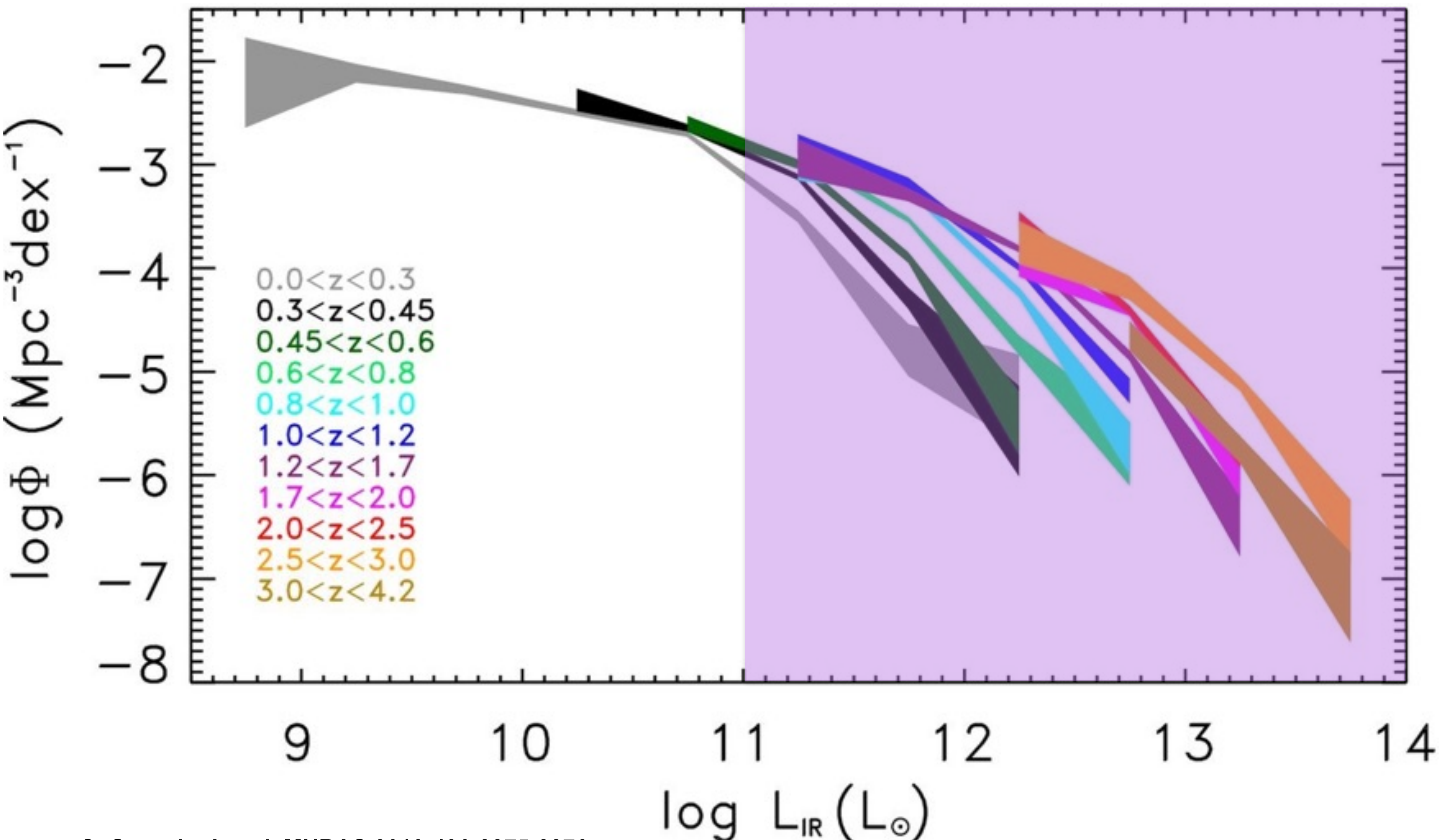
Galpath-Catalina Island, August 5, 2016

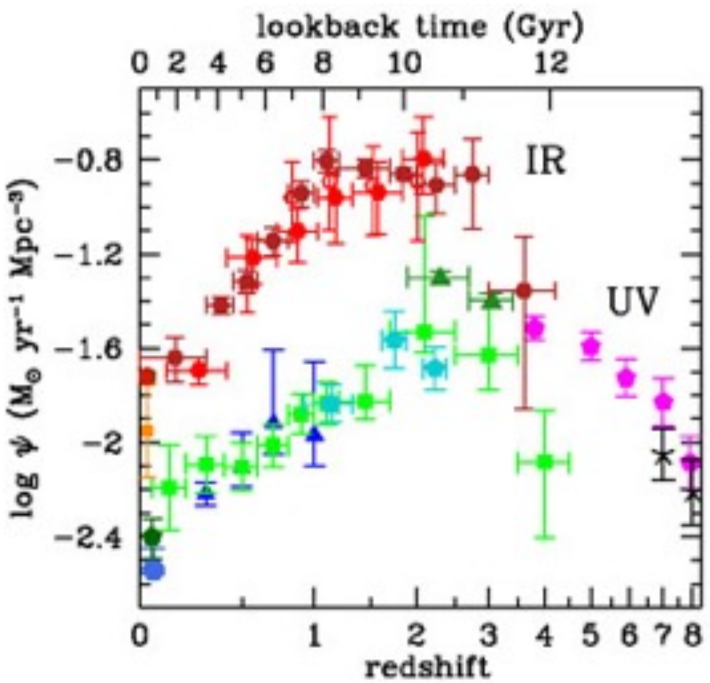
Total IR luminosity function estimated by combining the data from the four PEP fields using the Avni & Bahcall (1980) method plotted in all the different redshift intervals considered in this study, from z ~ 0 to z ~ 4.

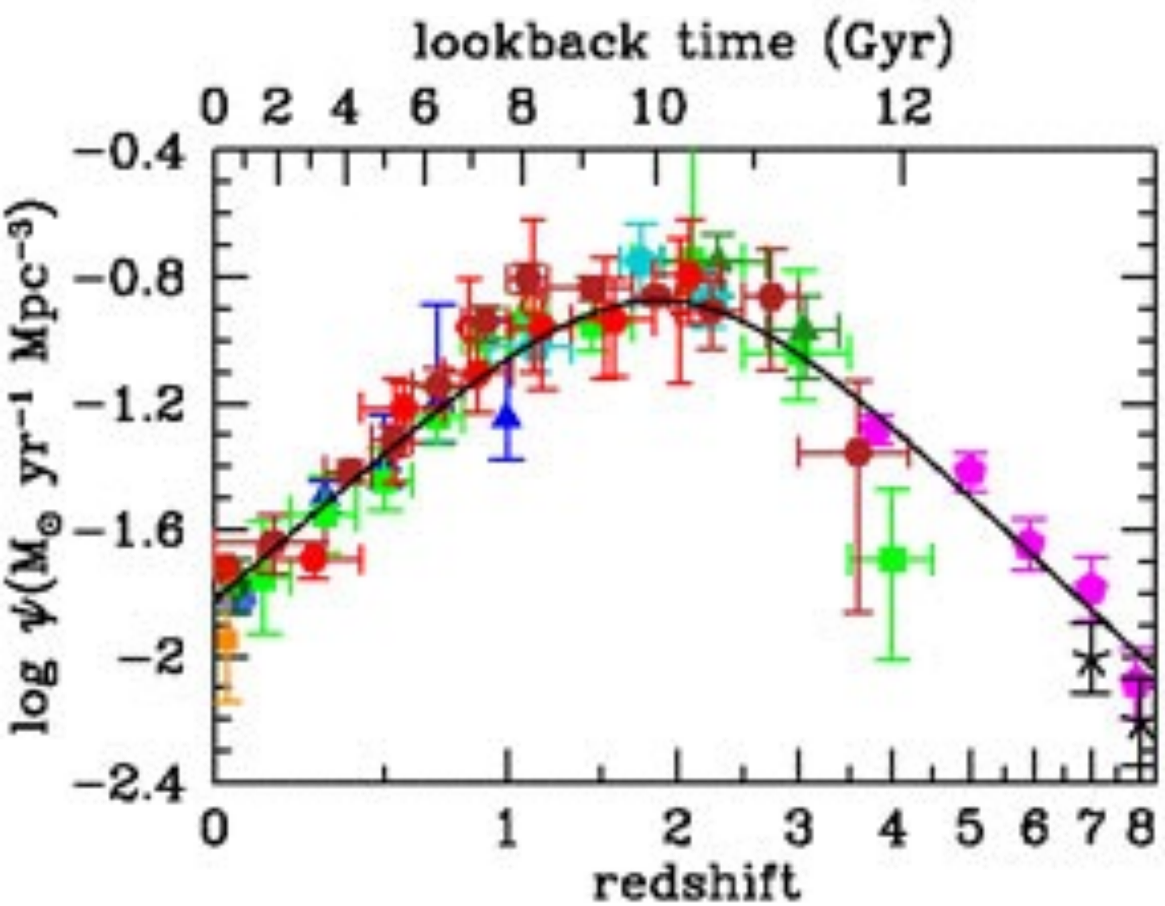


C. Gruppioni et al. MNRAS 2013;436:2875-2876

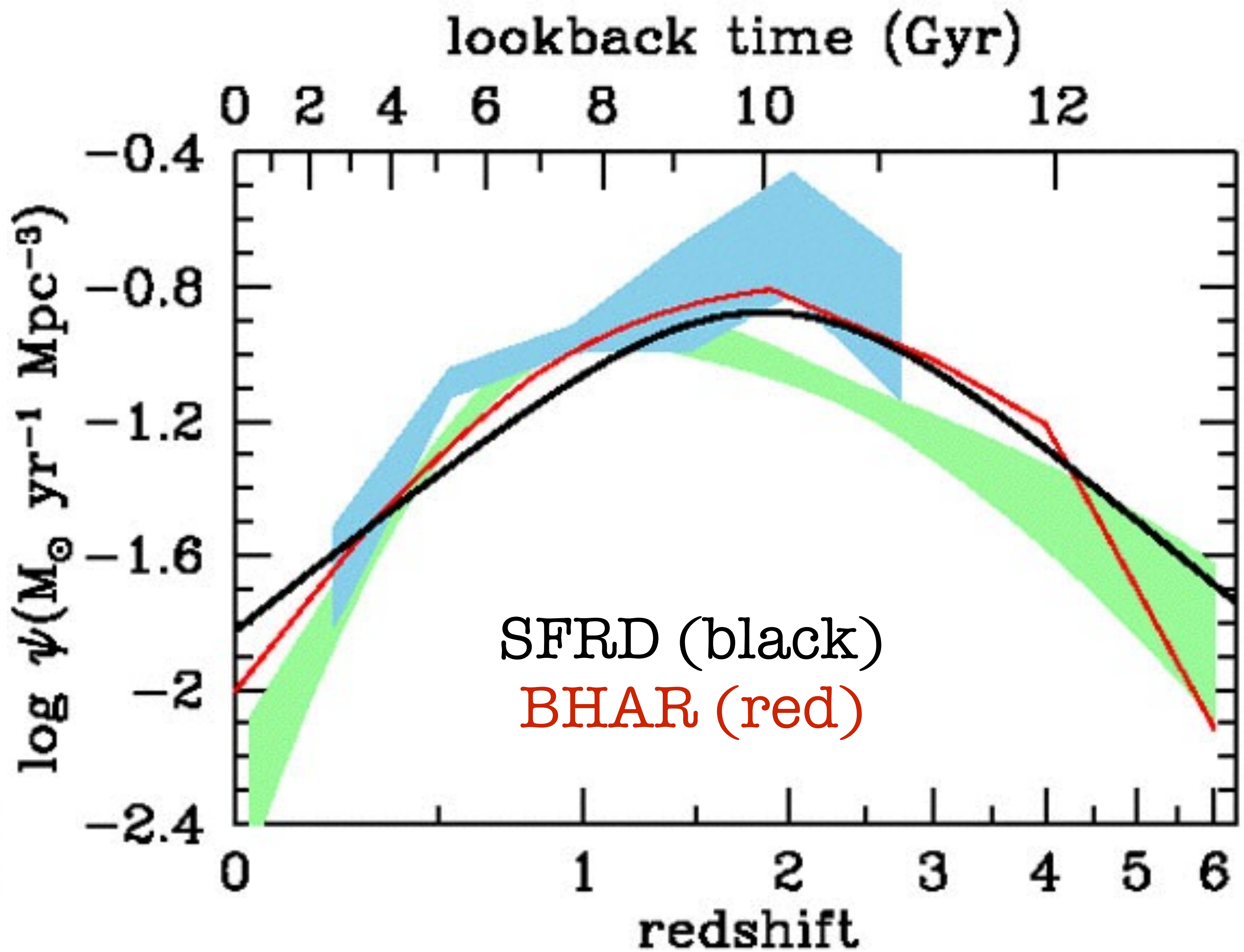
MONTHLY NOTICES of the Royal Astronomical Society

1 Introduction





Madau&Dickinson2014



(recall E.Treister's talk)

Summary

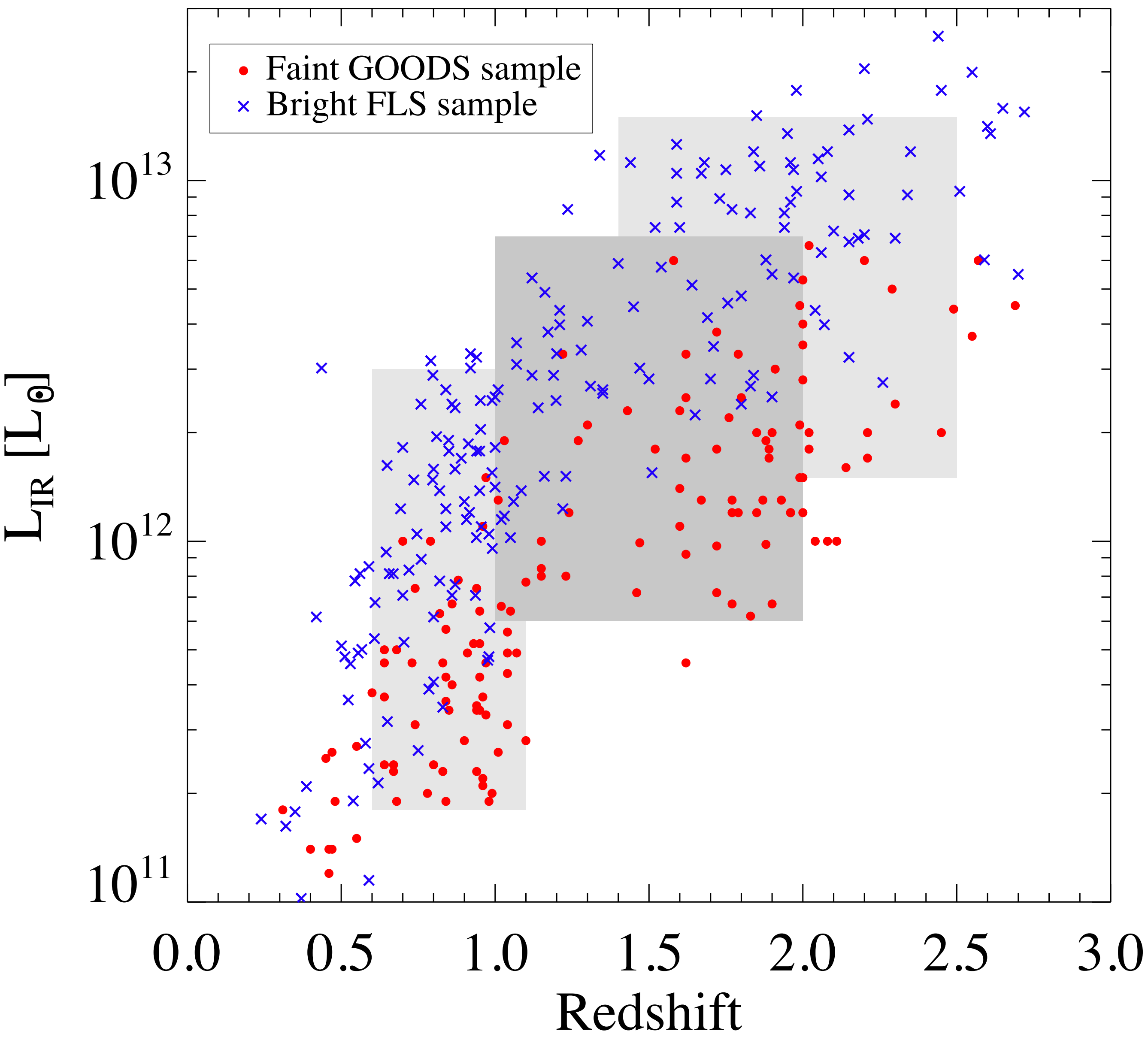
- New **public IR SED templates that are appropriate for high-z dusty galaxies, composites and AGN**. **(Kirkpatrick et al. 2015, ApJ)**

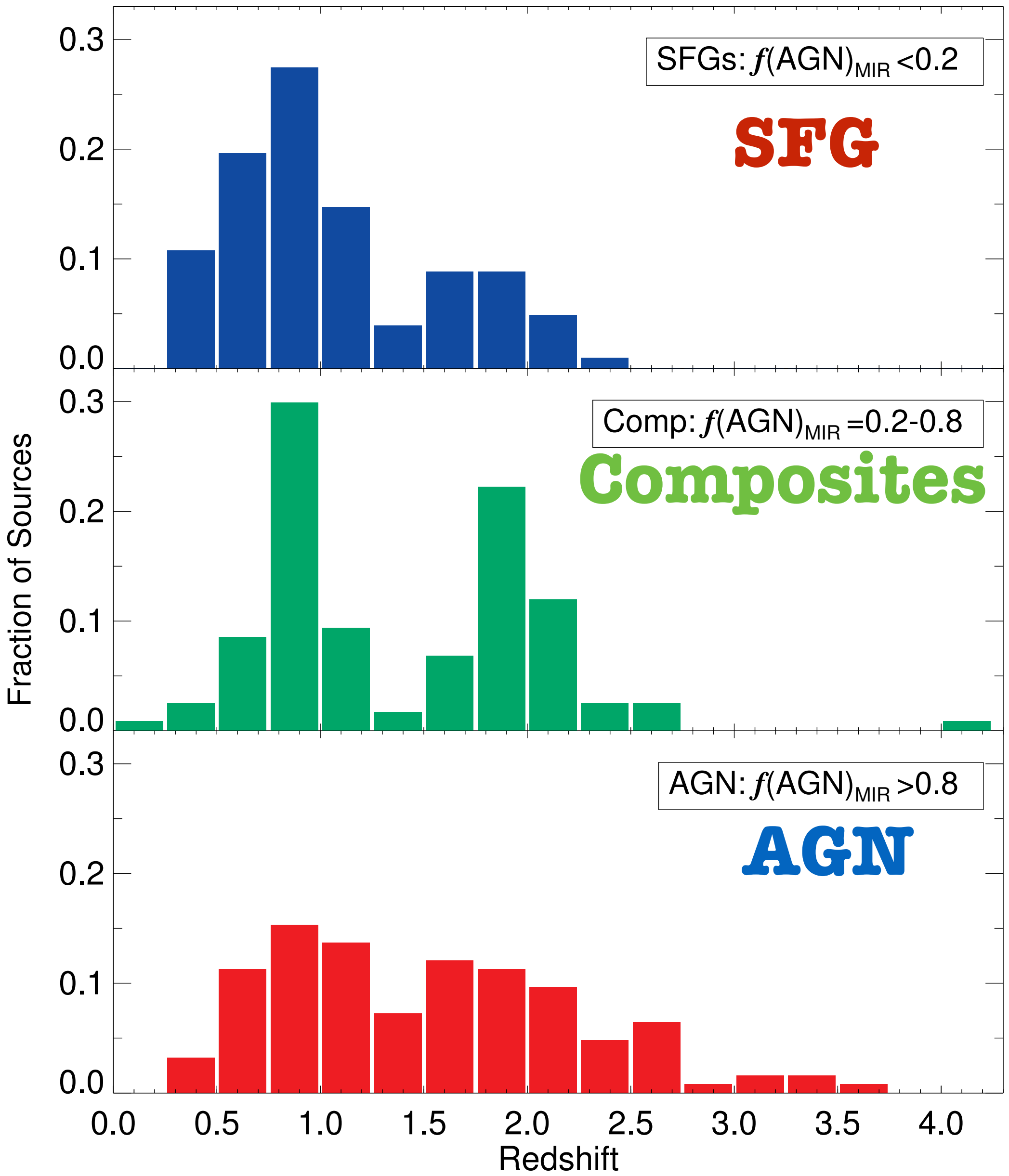
- Differences in IR SEDs of SFG at z~0 and z~1-2 with local SFGs consistent with evolution of the main sequence. **(Kirkpatrick et al. 2016, in prep.)**

- GADGET+Sunrise simulations are able to reproduce the range of SEDs seen in our sample. But we find significant systematic uncertainties in the AGN fraction inferred from the IR SED, the host galaxy processing of the AGN light is significant. **(Roebuck et al. 2016, ApJ, in review)**

- **SurveySim: a new, public MCMC-based code to model the evolution of the IR luminosity function.** **(Kurinsky et al. 2016, ApJ, in review)**

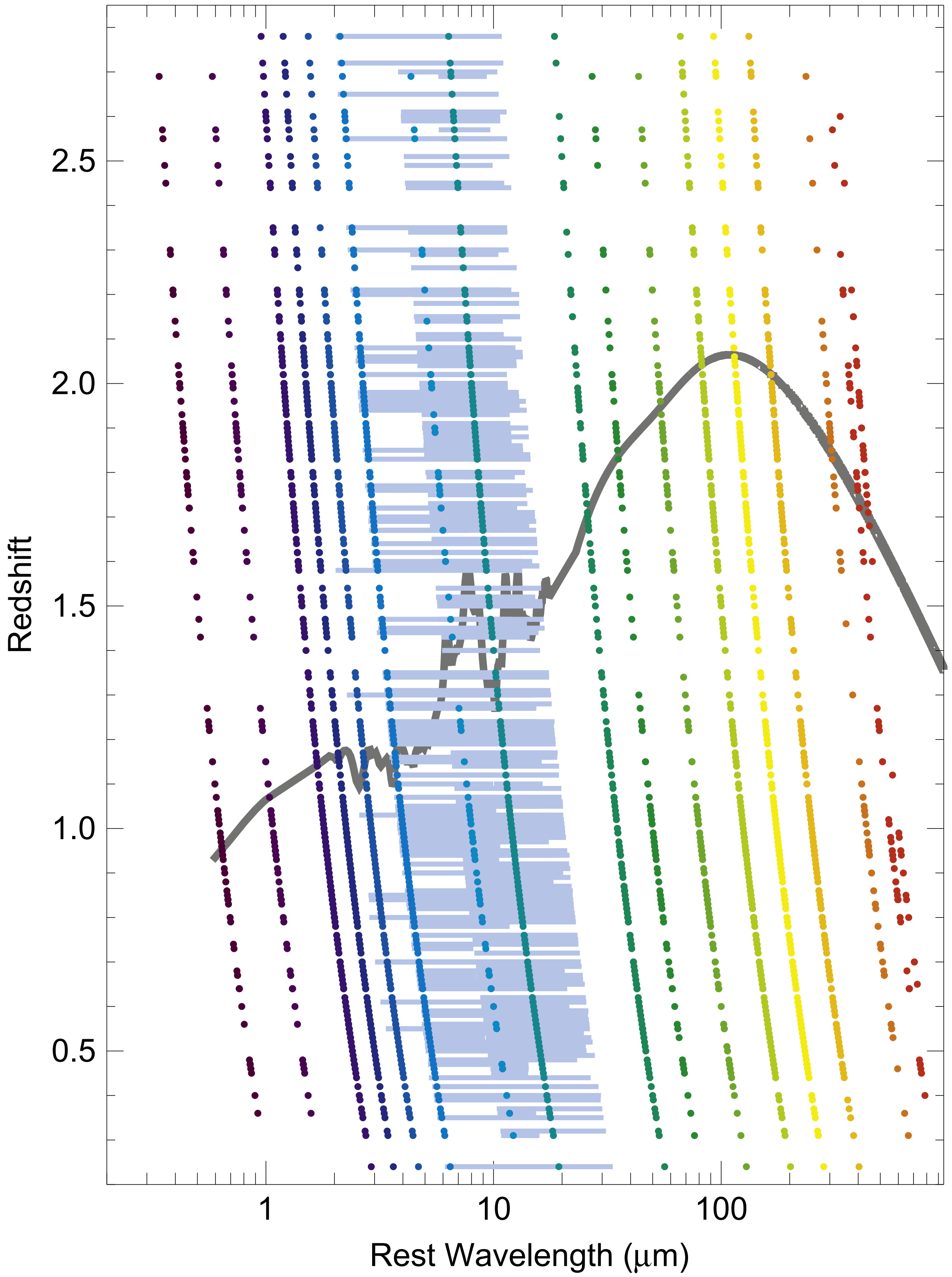
Our 24um-selected supersample of ~**340 galaxies all with IRS mid-IR spectra**. The L-z space is well sampled allowing us to study trends with both luminosity and redshift.





based on PAH strength

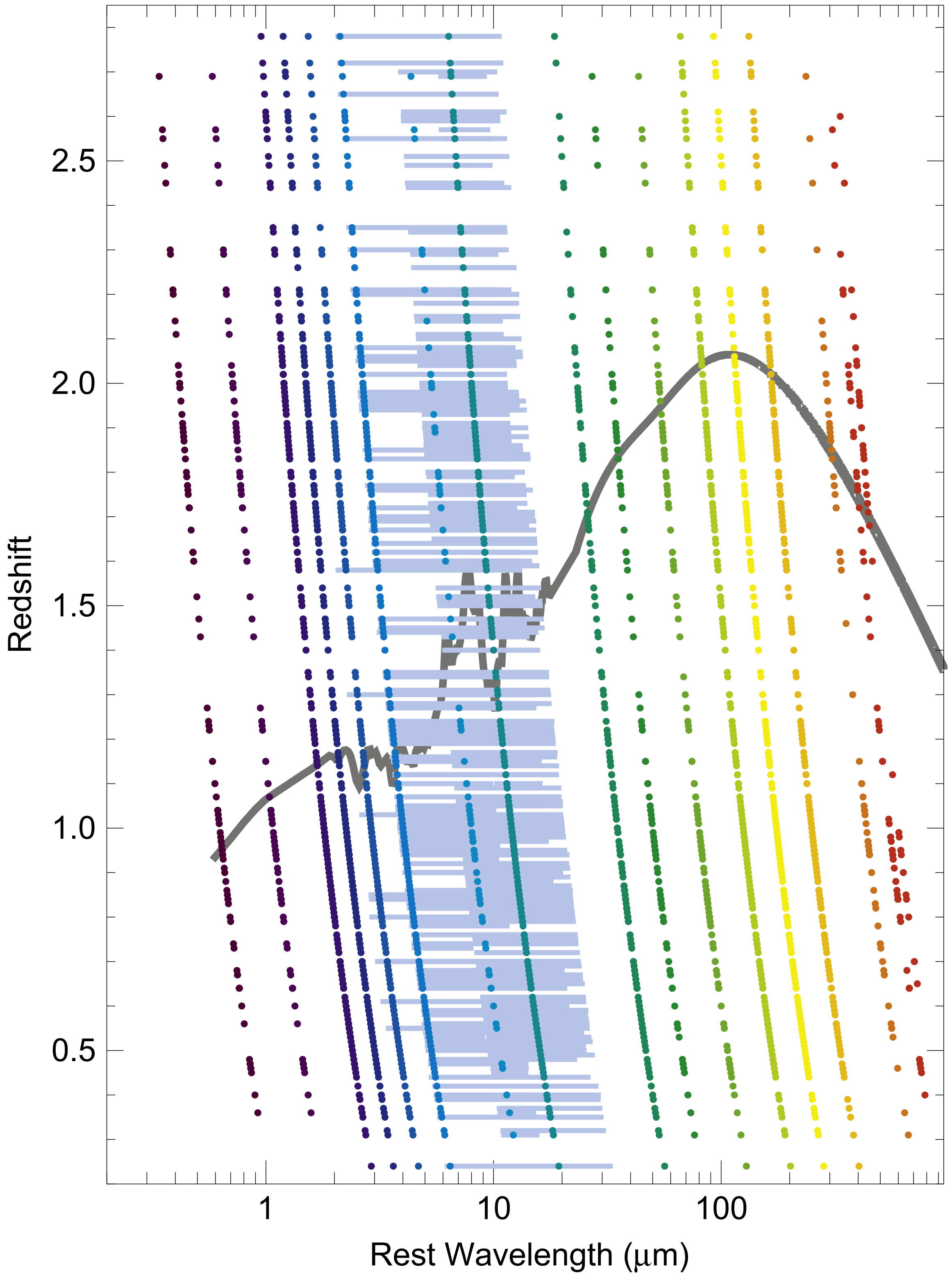
Kirkpatrick, Pope, AS et al. 2015

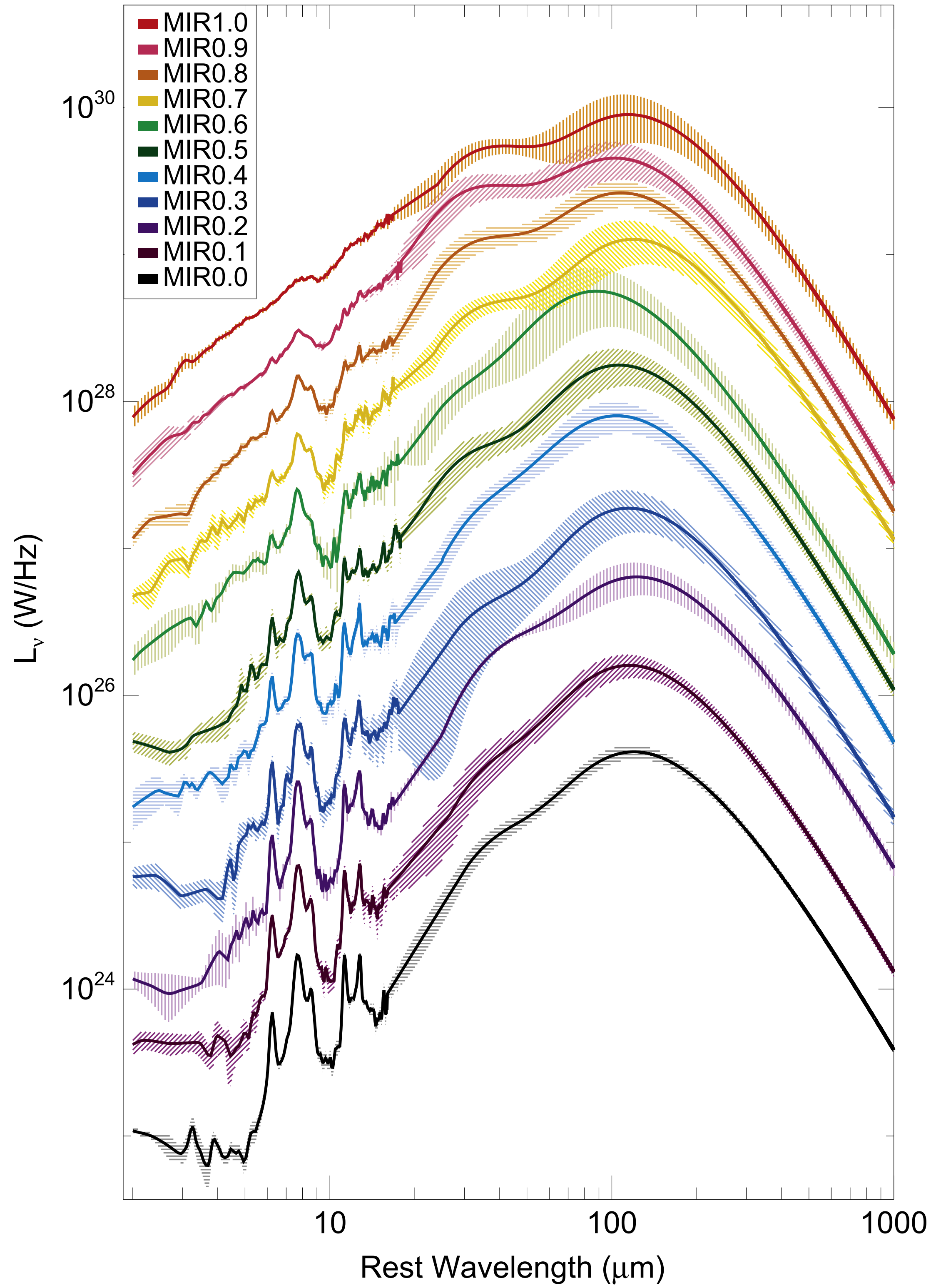


Exceptional
IR SED coverage

Kirkpatrick, Pope, AS, et al. 2015

2 SED characterization





SED templates public: http://daisy.astro.umass.edu/~pope/Kirkpatrick2015/

$f(AGN)_{MIR}<0.2$=**SFG**

$0.2<f(AGN)_{MIR}<0.8$= **Composite**

$f(AGN)_{MIR}>0.8$=**AGN**

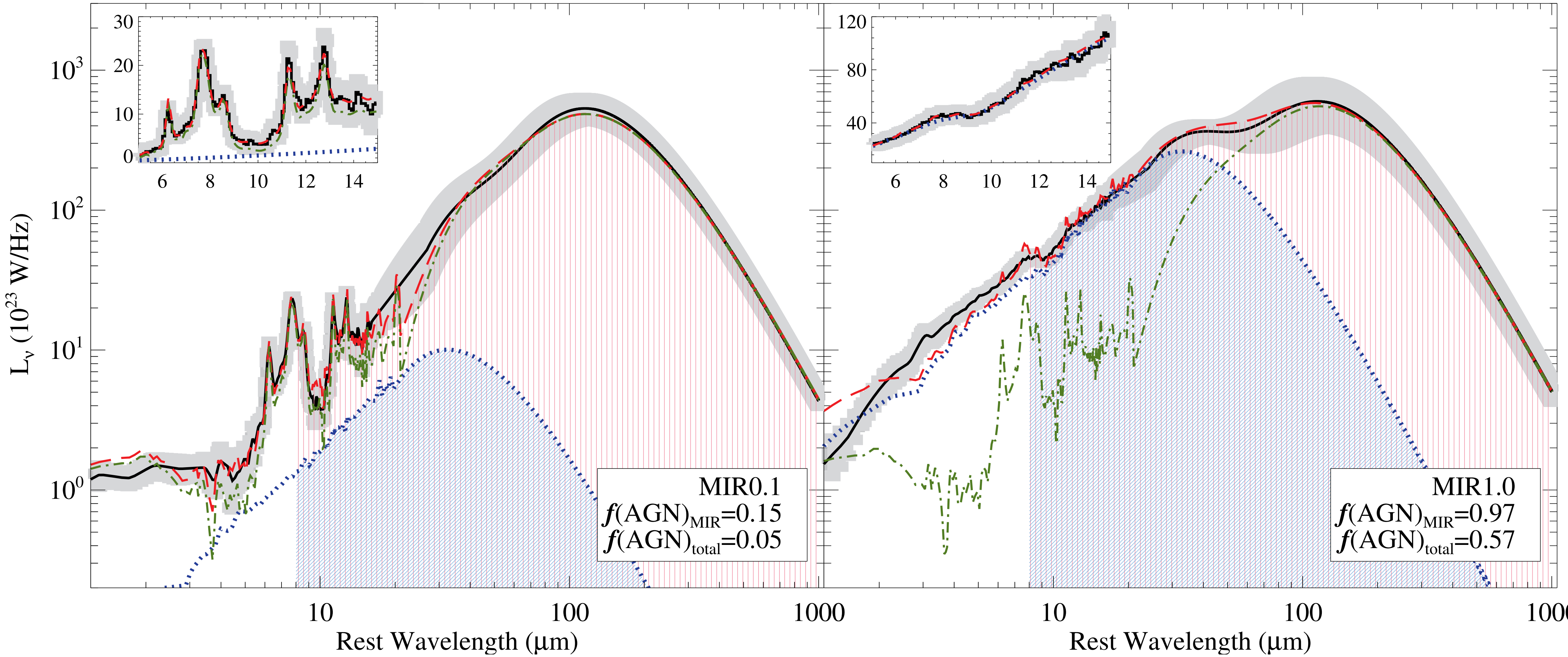
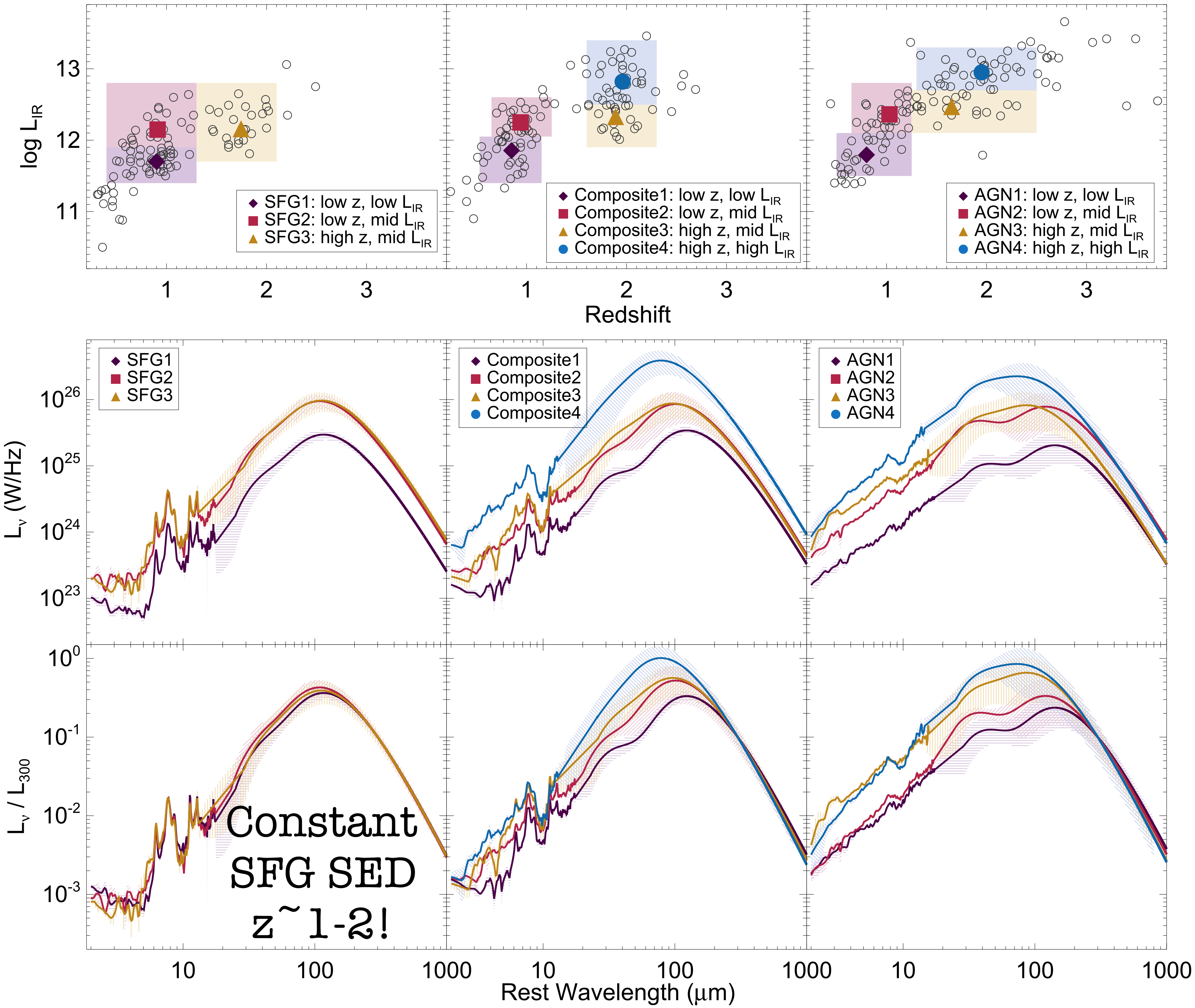


FIG. 13.— We illustrate our full IR decomposition technique for a star forming template (MIR0.1, left) and an AGN template (MIR1.0, right). We find a best fit model (red dashed line) by simultaneously fitting the $z\sim1$ Star Forming SED (green dot-dashed line) and Featureless AGN SED (blue dotted line), with extinction if required, from Kirkpatrick et al. (2012). We then integrate under the AGN component (blue dotted line) to calculate $f(\mathrm{AGN})_{\mathrm{total}}$ which is the fraction of L_{IR}(8-1000 μm) due to AGN heating. We have illustrated the integrated portion of the model and AGN component with the shaded regions. In the insets, we show the mid-IR decomposition (Equation 1), used to calculate $f(\mathrm{AGN})_{\mathrm{MIR}}$ from 5-15 μm.

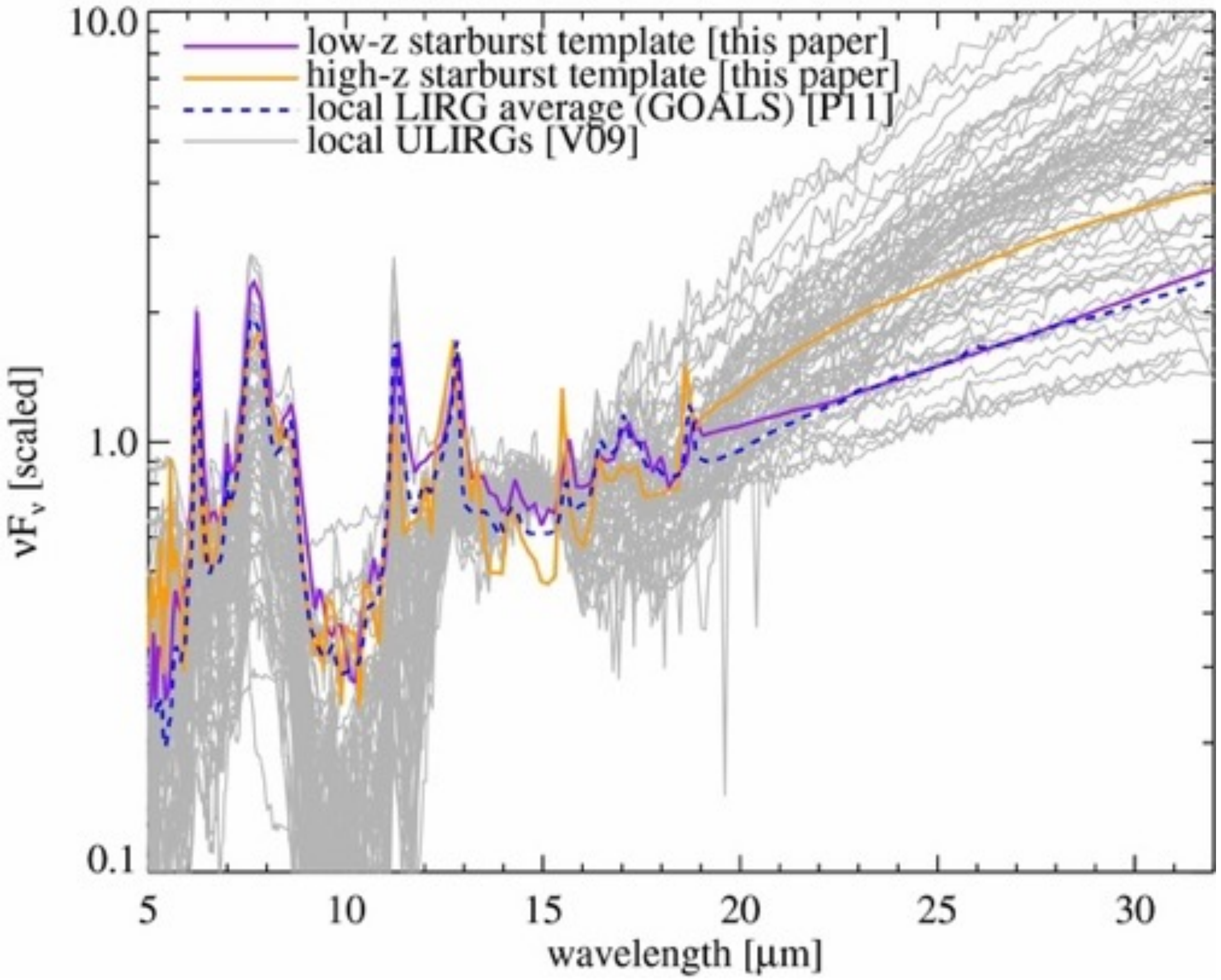
Kirkpatrick et al. 2015

2 SED characterization



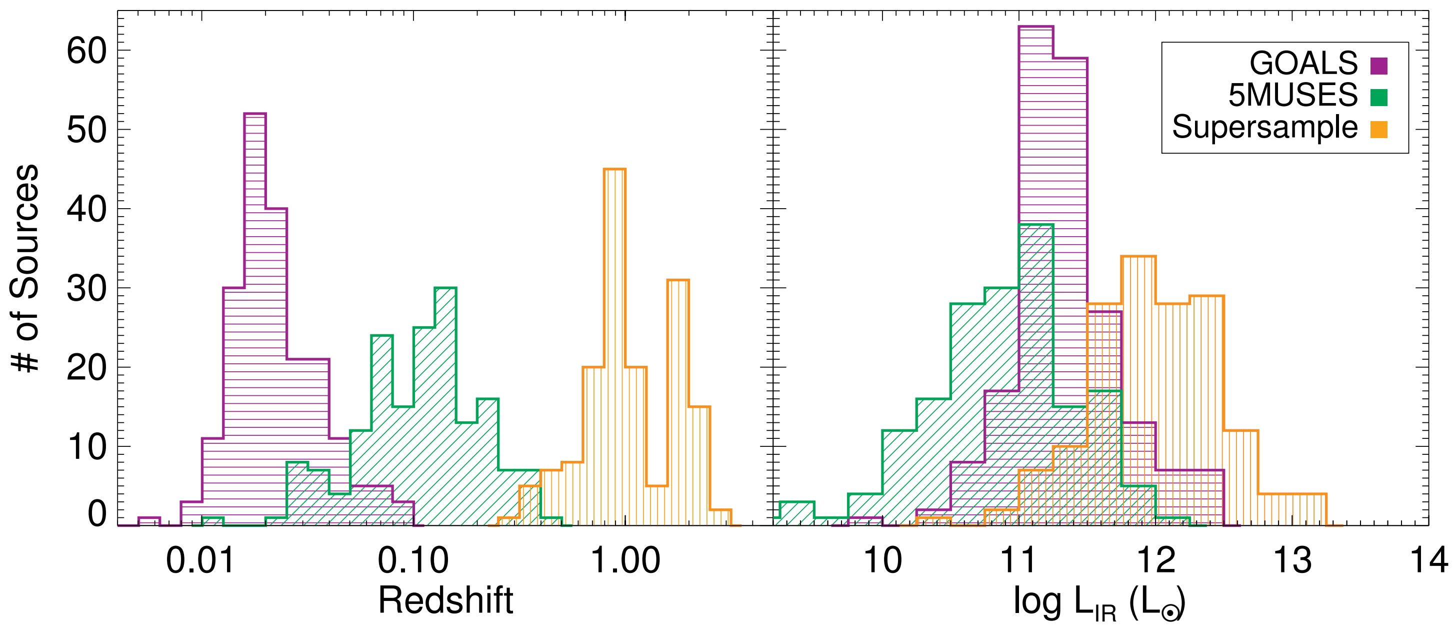
Kirkpatrick, Pope, AS, et al. 2015

2 SED characterization

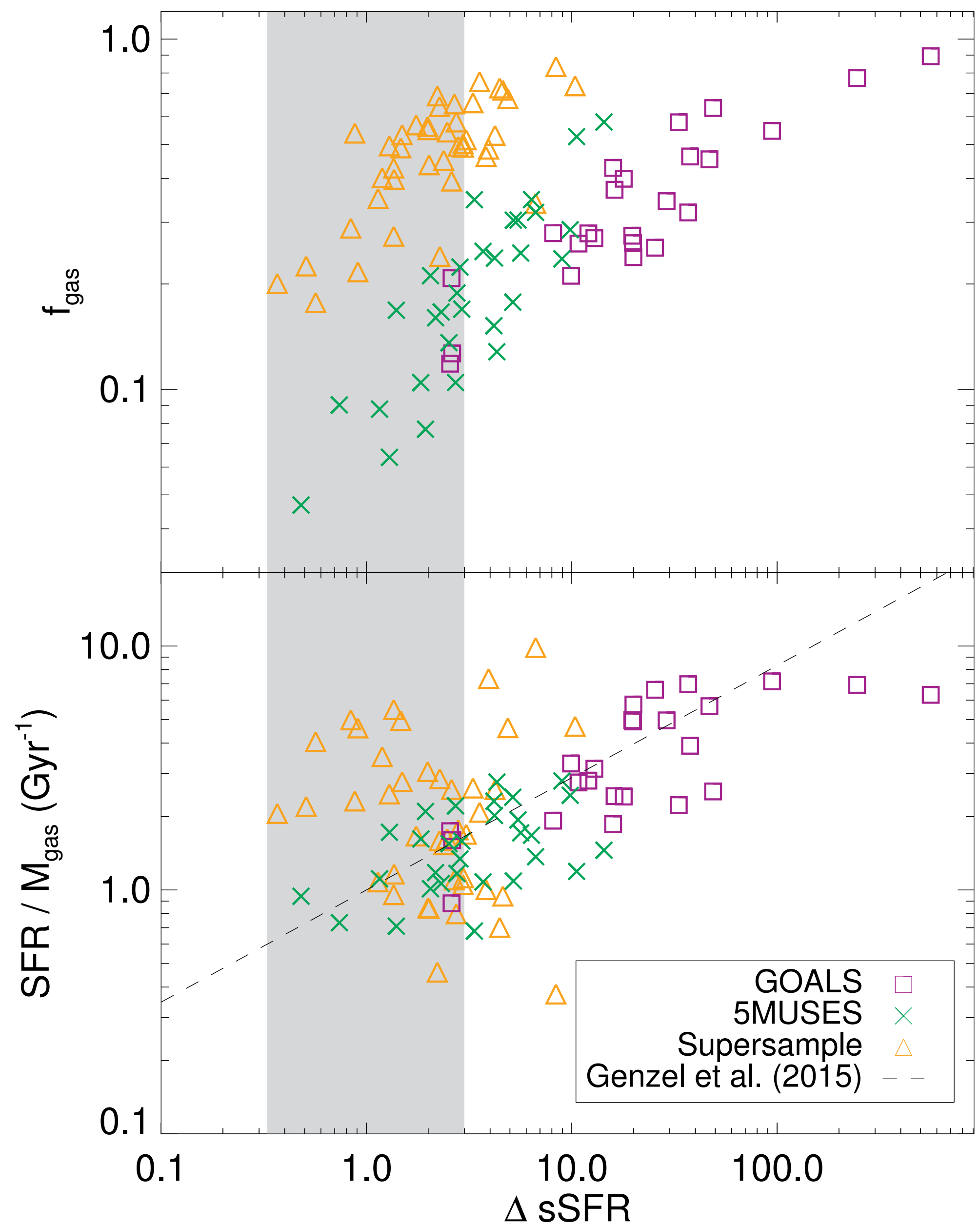


Mid-IR spectra of local
ULIRGs (thin grey lines) much redder/dust obscured
than those of z~1-2 ULIRGs (thicker purple/orange curves)
(AS et al. 2012)

2 SED characterization



here only
include SFG
from the Supersample



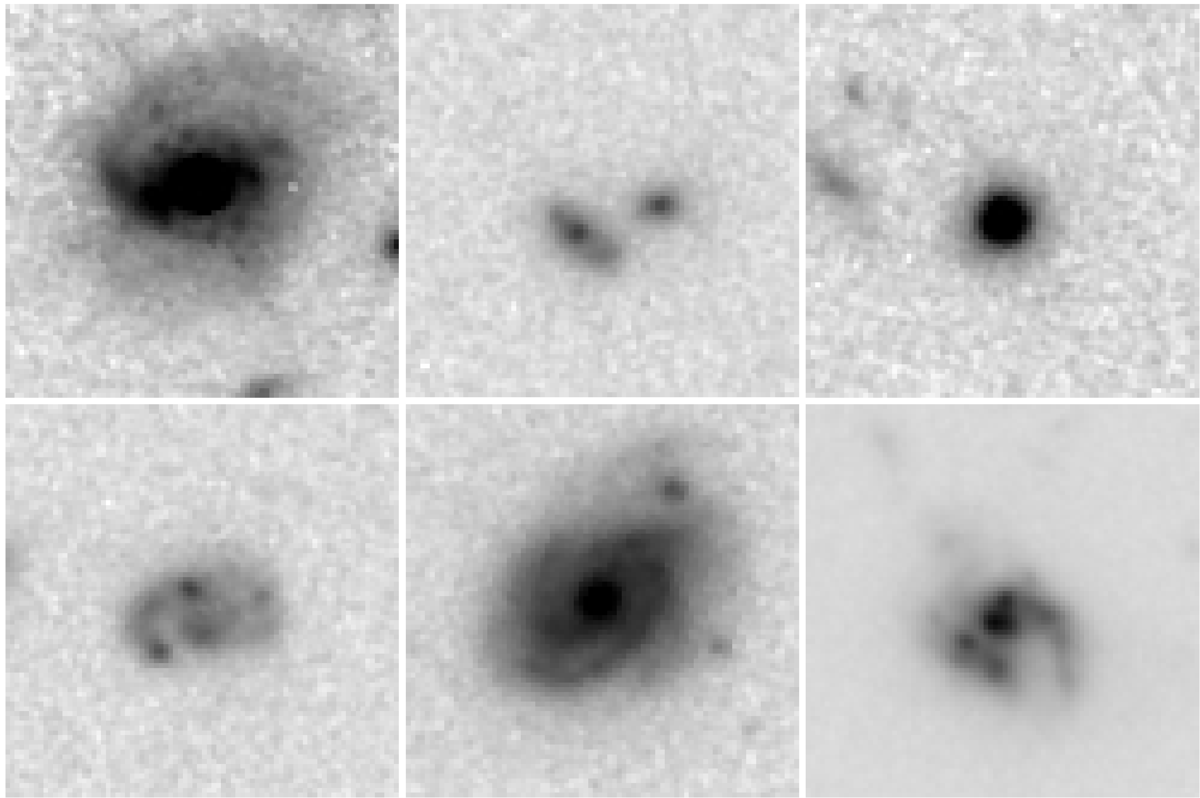
Distance from MS
as given in Elbaz+2011

Kirkpatrick, Pope, AS, et al. 2016, in prep.

2 SED characterization

Future/ongoing work:

~75% of the sample have HST images (inc. Zamojski et al. 2011 and as part of Jayhan Kartaltepe's WFC3 GOODS-S sample). Want to directly link mid-IR properties with morphologies — building upon Zamojski et al. 2011.



CANDELS images

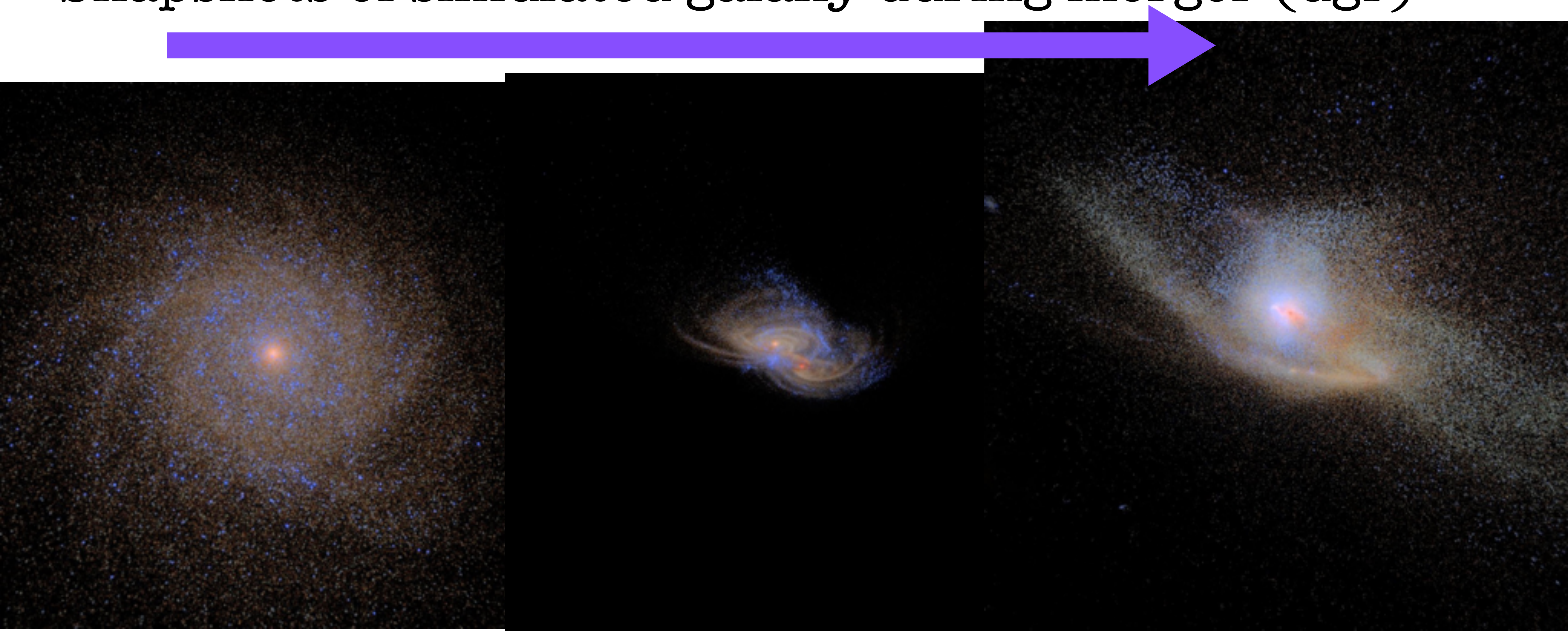
3 Simulations comparison

GADGET+Sunrise merger simulation

(movie by Patrik Jonsson, Greg Novak, and Joel Primack)

(recall Greg Snyder's talk on Monday)

Snapshots of simulated galaxy during merger (ugr)



Sunrise (see Jonsson et al. 2006) is a Monte Carlo Radiative transfer code that properly simulates the effects of dust absorption and re-emission for merger simulations produced by GADGET. Simulated SEDs for each timesteep of the merger and for 7 different viewing angles are produced.

3 Simulations results

A summary of the simulations library, key properties:

TABLE 1
Model Progenitor Initial Properties

Progenitor Name	$M_{\rm STARS}$ (h^{-1} M$_\odot$)	$f_{\rm gas}$	Reference Name[g]
M1	3.78×10^9	0.26	M1[a,e]
M2	1.18×10^{10}	0.21	M2[a,e]
M3	4.23×10^{10}	0.16	M3[a,e]
M4	3.39×10^{10}	0.40	vc3[d,f]
M5	4.08×10^{10}	0.60	c5[b]
M6	1.56×10^{10}	0.60	c6[d]
M7	2.08×10^{10}	0.80	b5[c]
M8	8.00×10^{10}	0.80	b6[c]

[a] Jonsson et al. (2010).
[b] Hayward et al. (2011).
[c] Hayward et al. (2012).
[d] Snyder et al. (2013).
[e] Lanz et al. (2014).
[f] Hayward & Smith (2015).

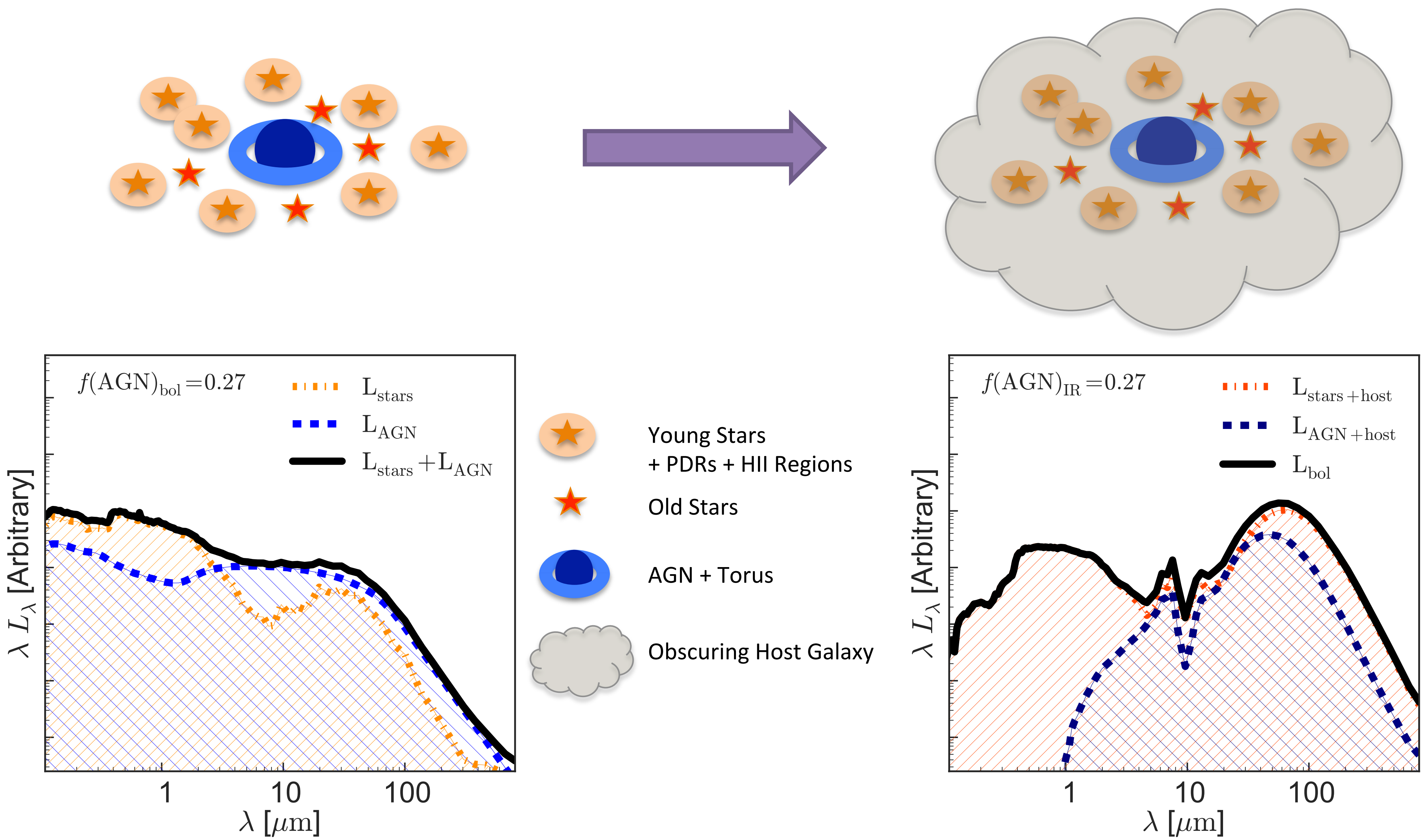
The evolution of each of the 8 models is simulated as an isolated disk, as well as a major merger (of 2 identical progenitors – mostly using the "e" orbit from Cox et al.).

M4, M6, M7, M8 also have boosted AGN merger runs.

Total: 20 simulations

Roebuck, AS, et al. 2016, in review.

3 Simulations results

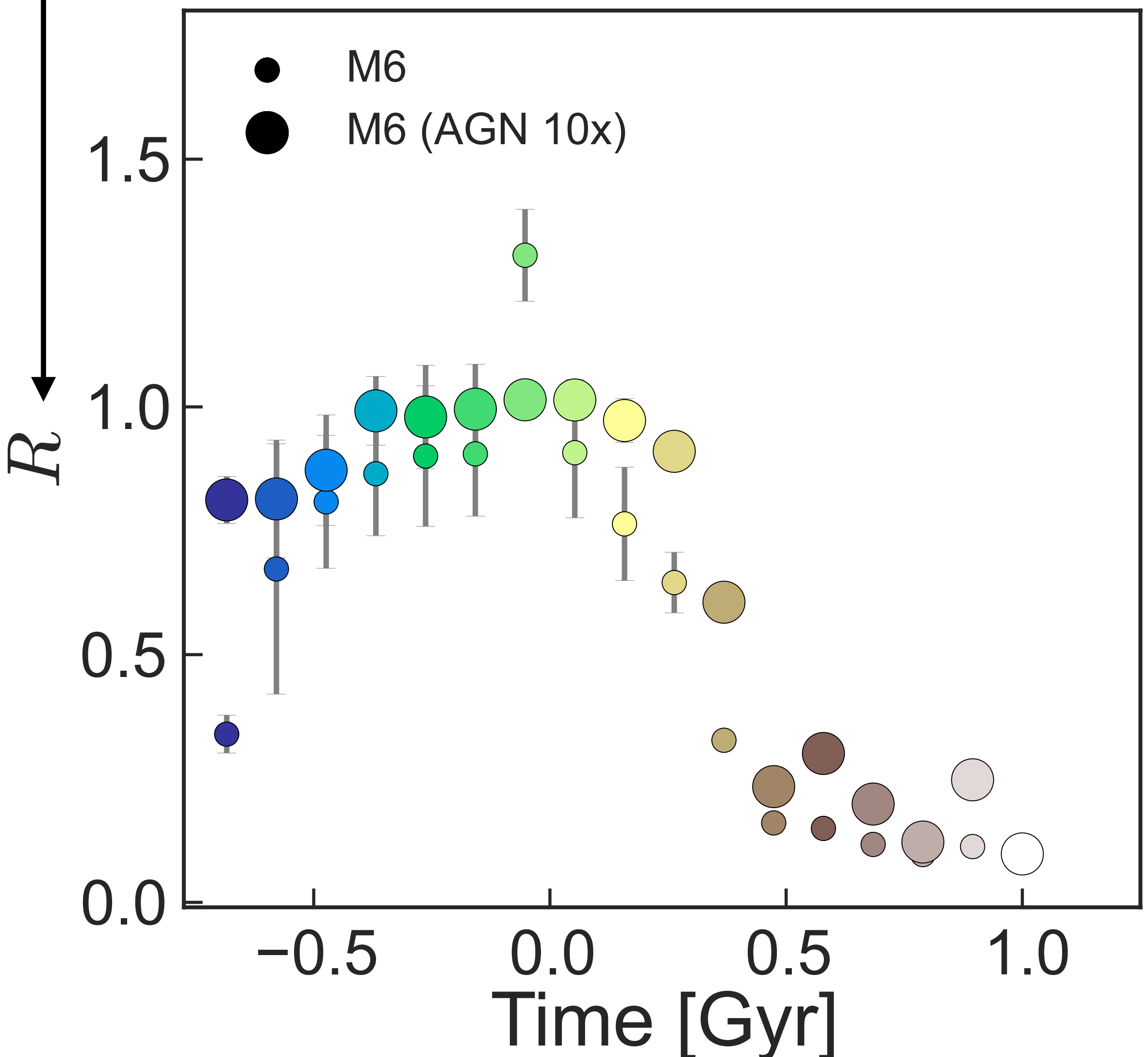


Before Host Dust Processing

After Host Dust Processing

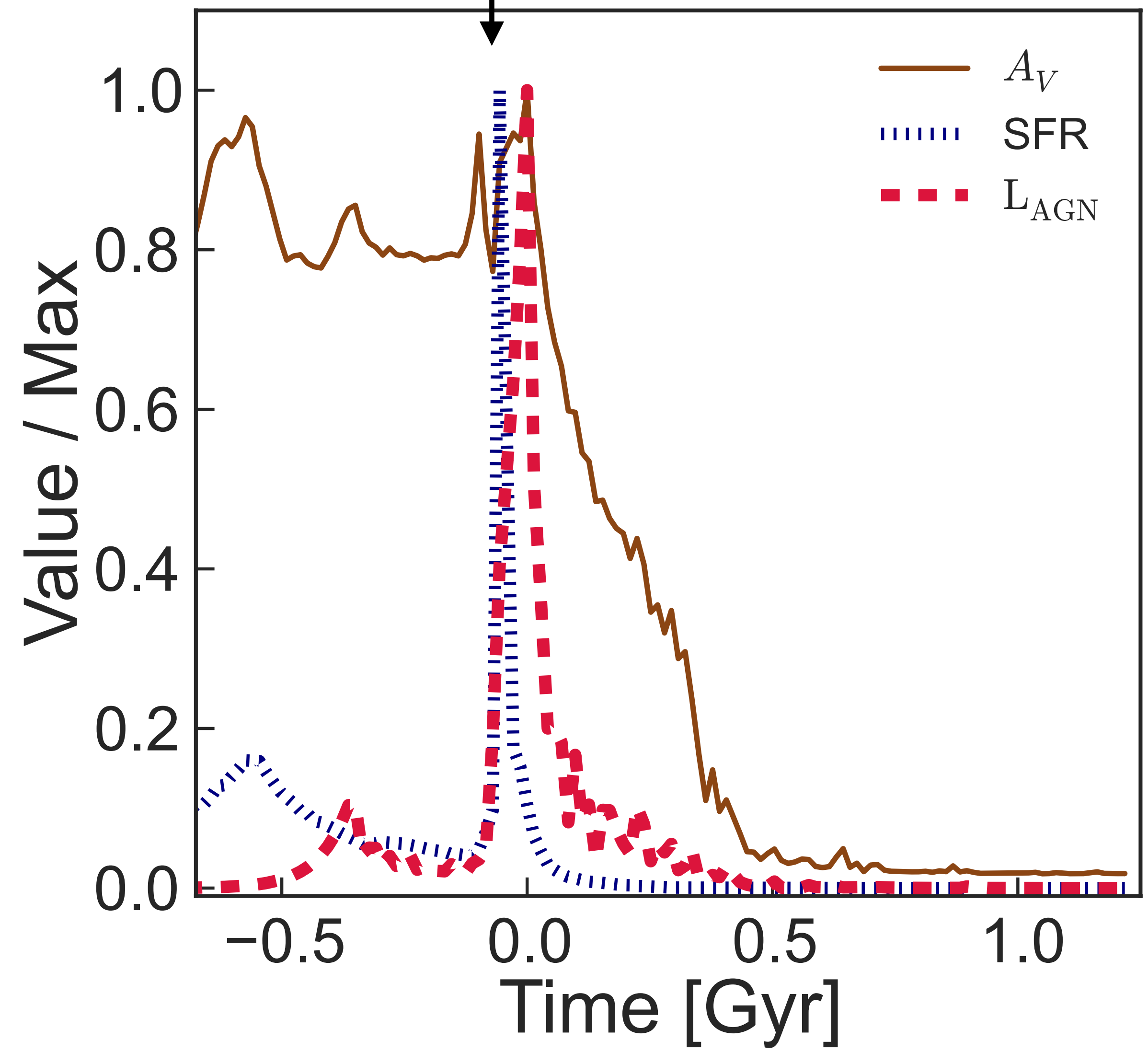
Can estimate how much of the IR (8-1000um) luminosity is due to the AGN. Can compare how that relates to the true (bolometric) fraction of AGN to the power (AGN+stars) in the galaxy.

Ratio of bolometric to IR-only AGN fraction estimates



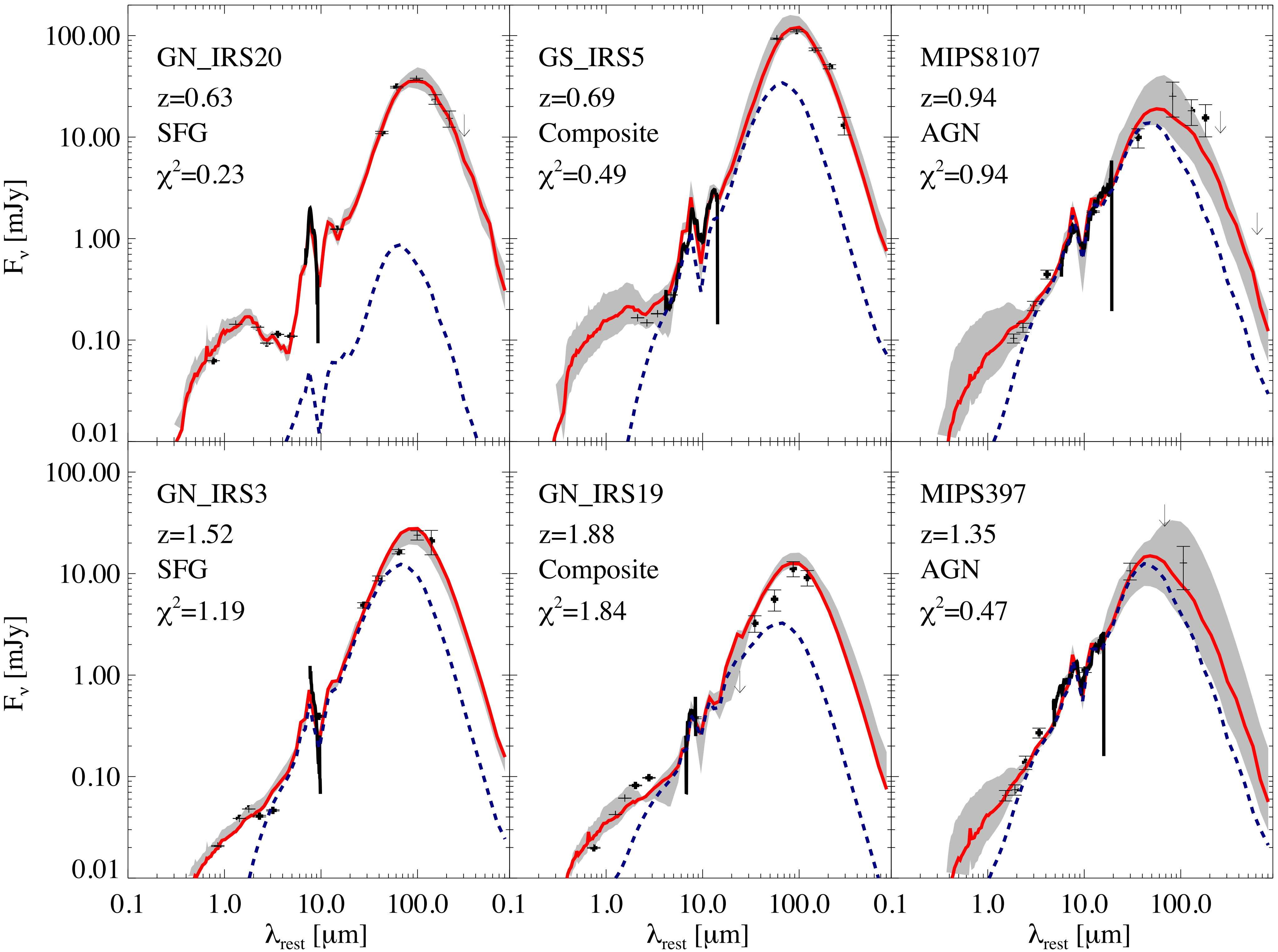
coalescence

coalescence



Roebuck, AS, et al. 2016

3 Simulations comparison

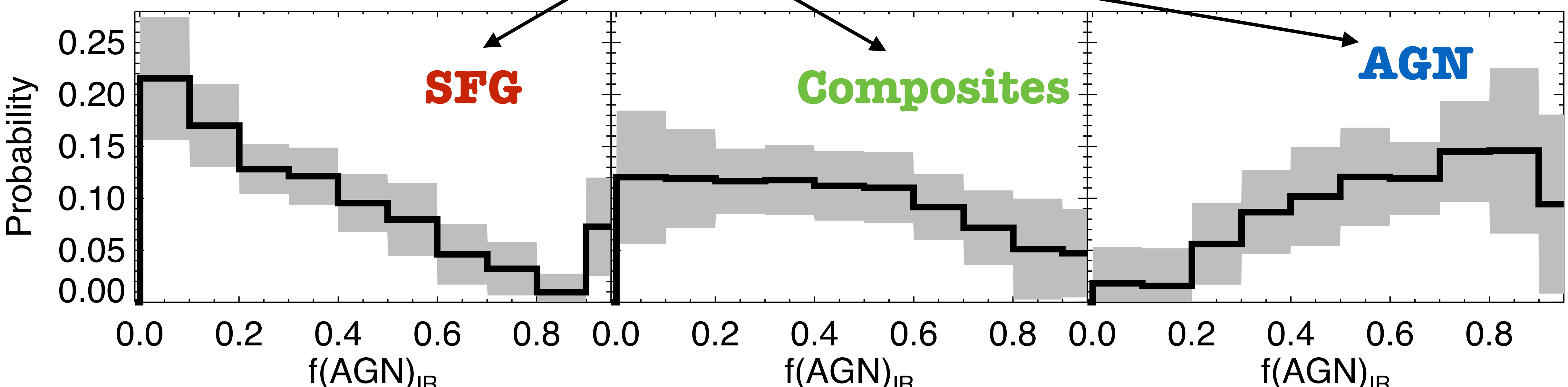


94% of the sample have $\chi^2_{red} < 3$

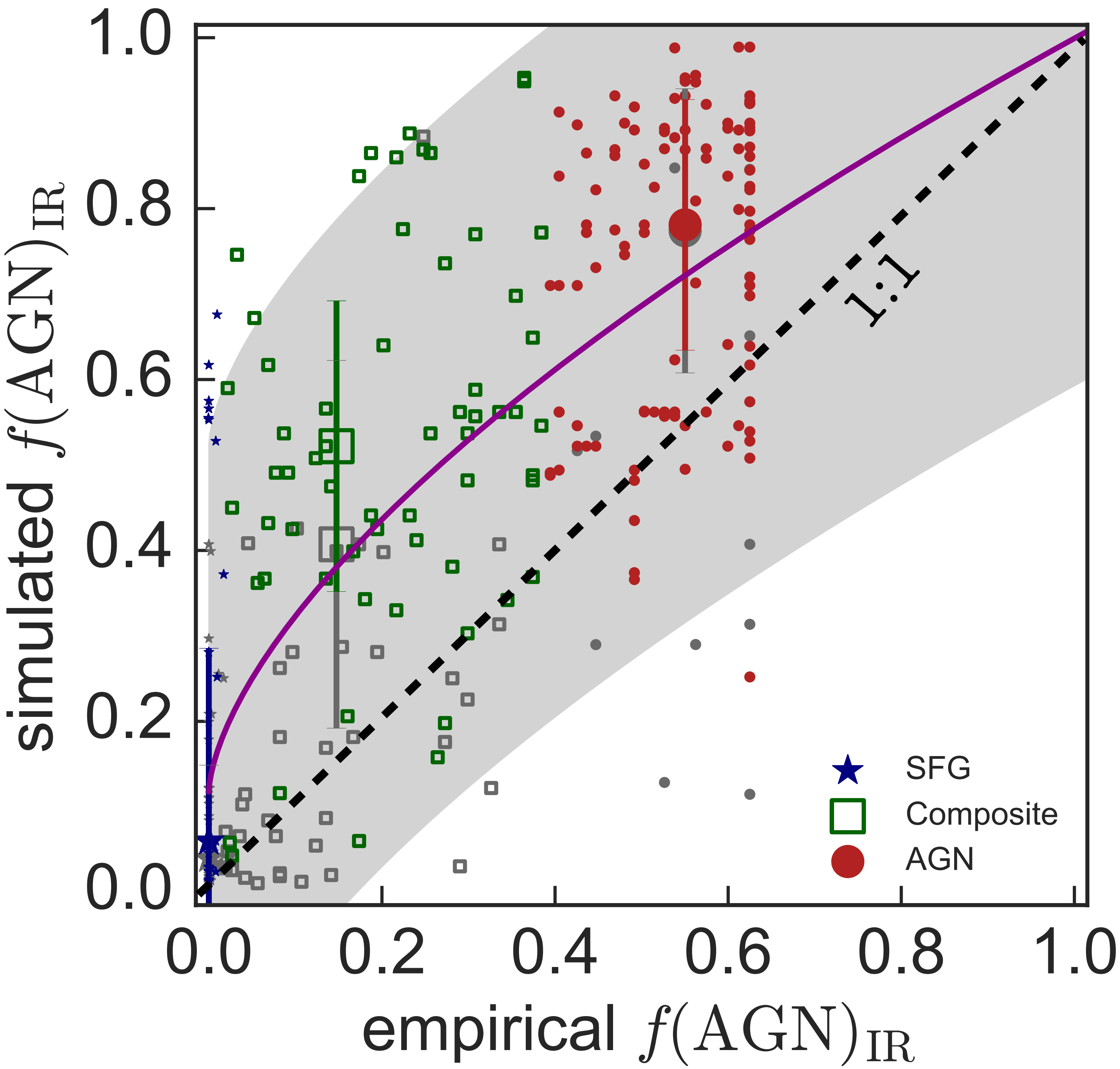
AGN
total

1) Simulated AGN fractions in broad agreement with empirical classification.
2) Very large systematic uncertainties – i.e. similarly good fits are achievable with a wide range of AGN fractions!

grouped based on empirical mid-IR AGN fraction



simulated AGN IR fraction



Broad agreement between empirical-based and simulations-based IR AGN fraction estimates

Simulations-based fractions tend to be somewhat higher suggesting the role of AGN in heating the galaxy's dust is *underestimated*.

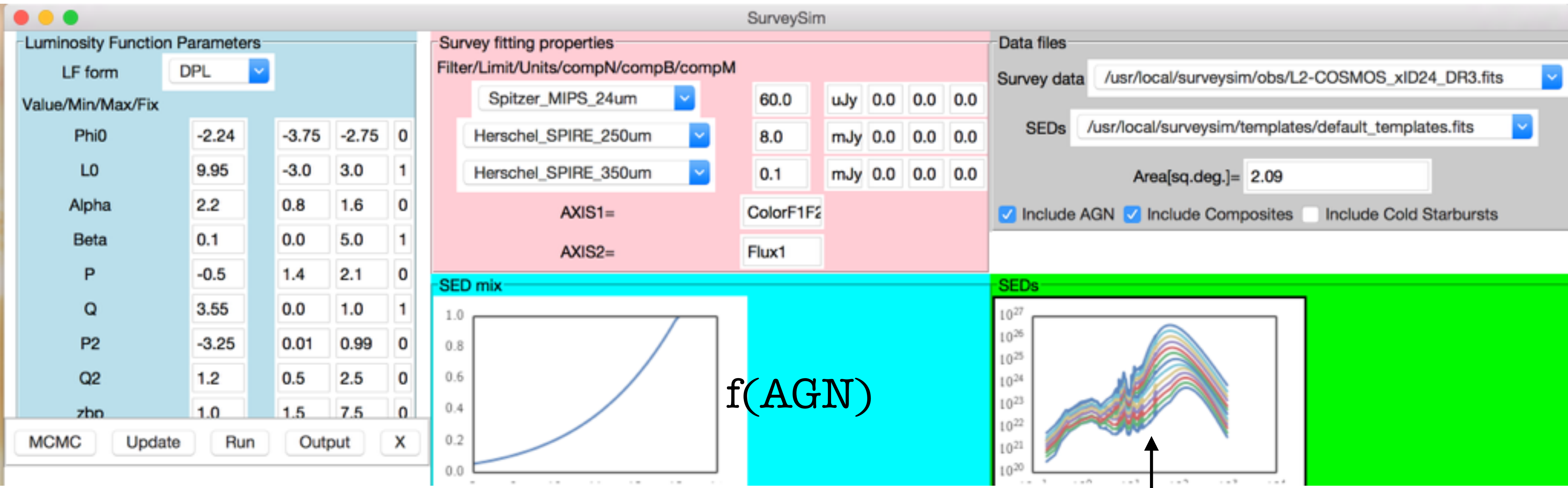
as in Kirkpatrick et al. 2015

Caveats/work in progress:

- Higher resolution simulations; Galaxies too smooth now which for example doesn't allow for Type 1 AGN
- Better treatment of accretion onto the AGN and the change in AGN SED with accretion rate;
- Cosmological context especially allowing for gas inflow.

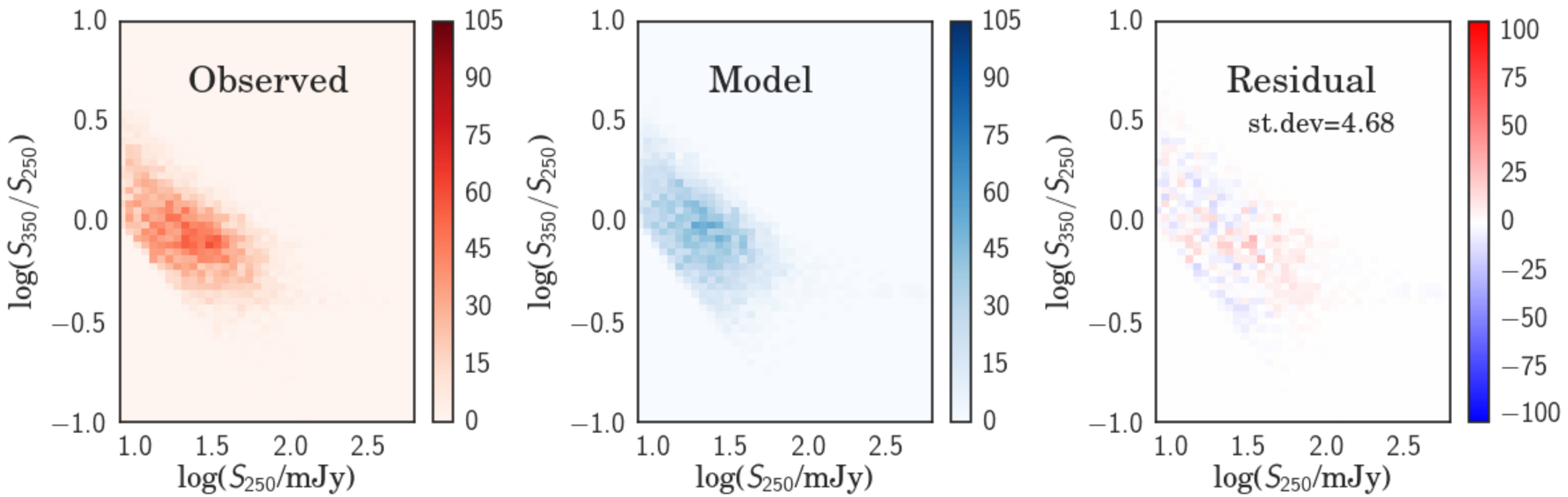
Stay tuned!

SurveySim is a new MCMC-based galaxy survey LF evolution fitting tool.
The code is public: http://cosmos2.phy.tufts.edu/~asajina/SurveySim.html

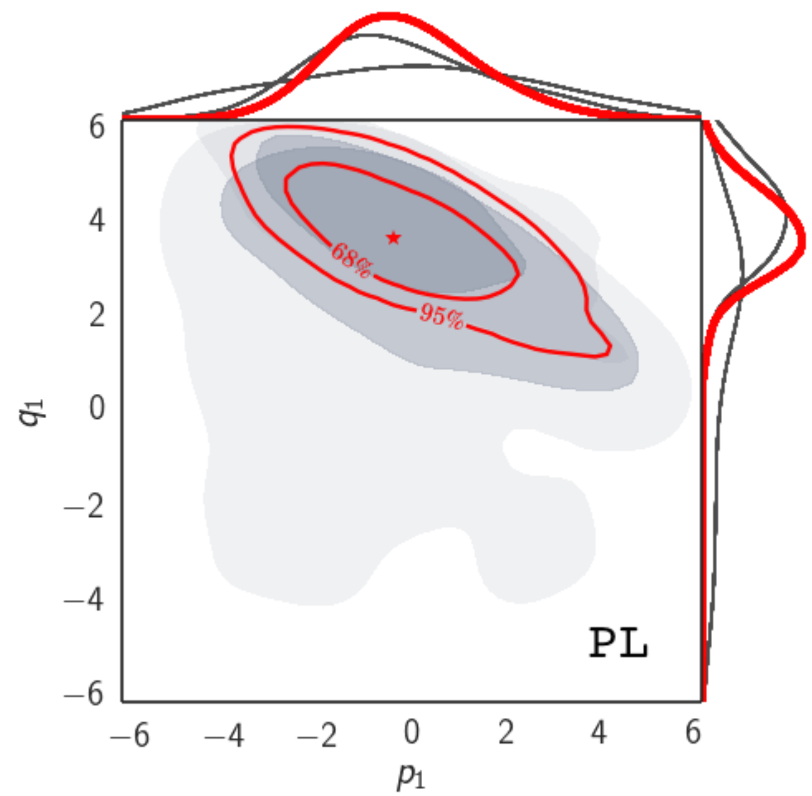


log(Lir)

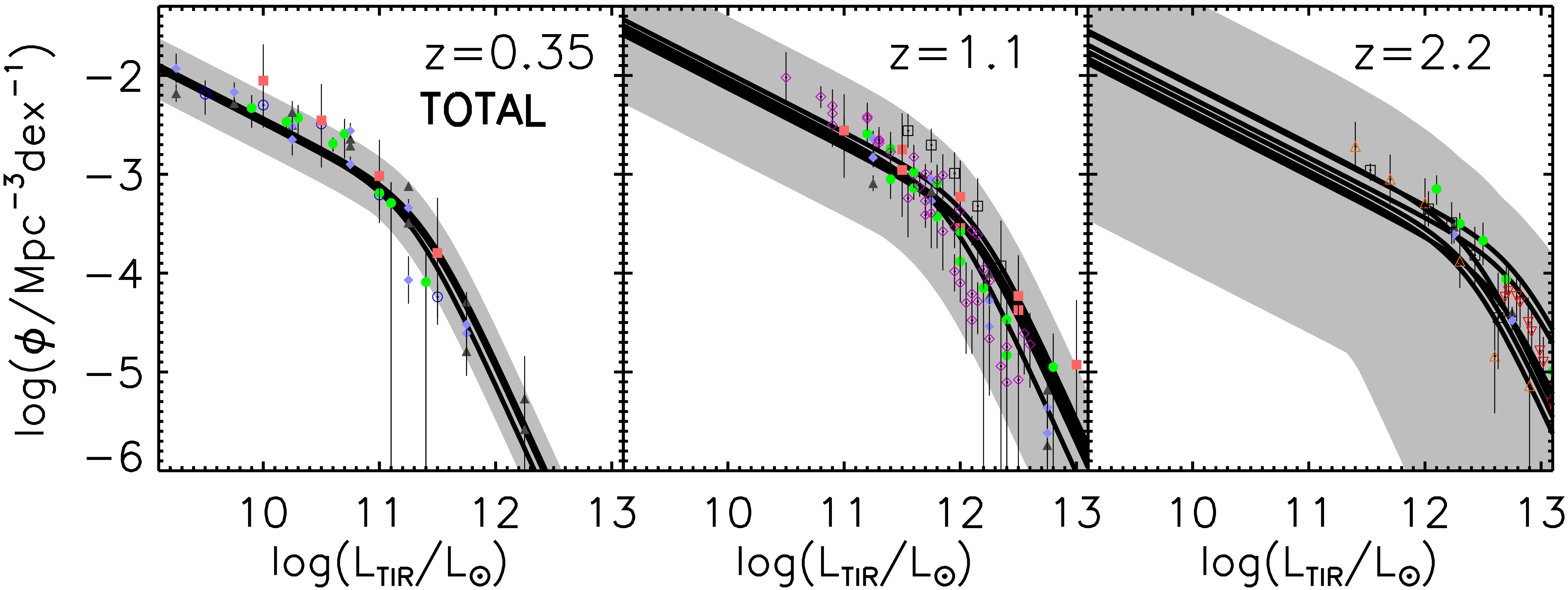
SED library
Kirkpatrick+15
plus Rieke+09 and Mullaney+11 for z=0



this example based on COSMOS-Hermes data.

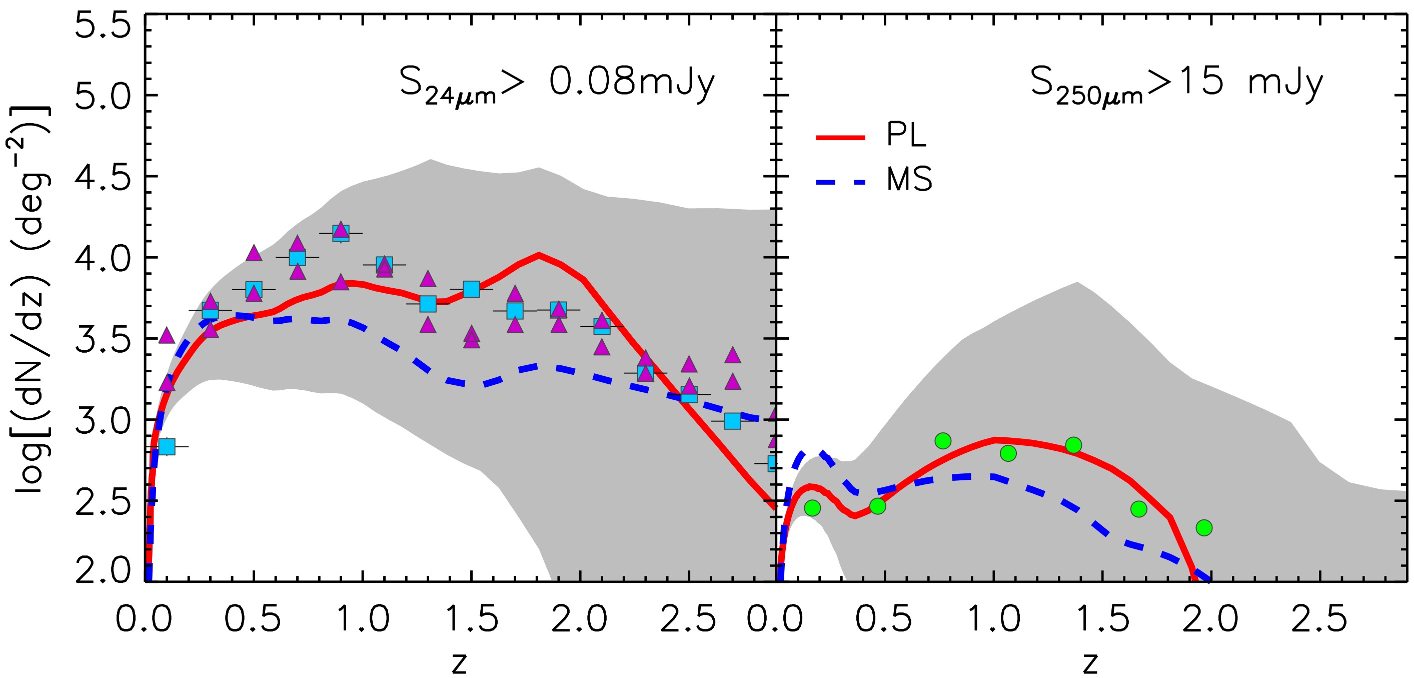


Kurinsky, AS, Bonato et al. 2016



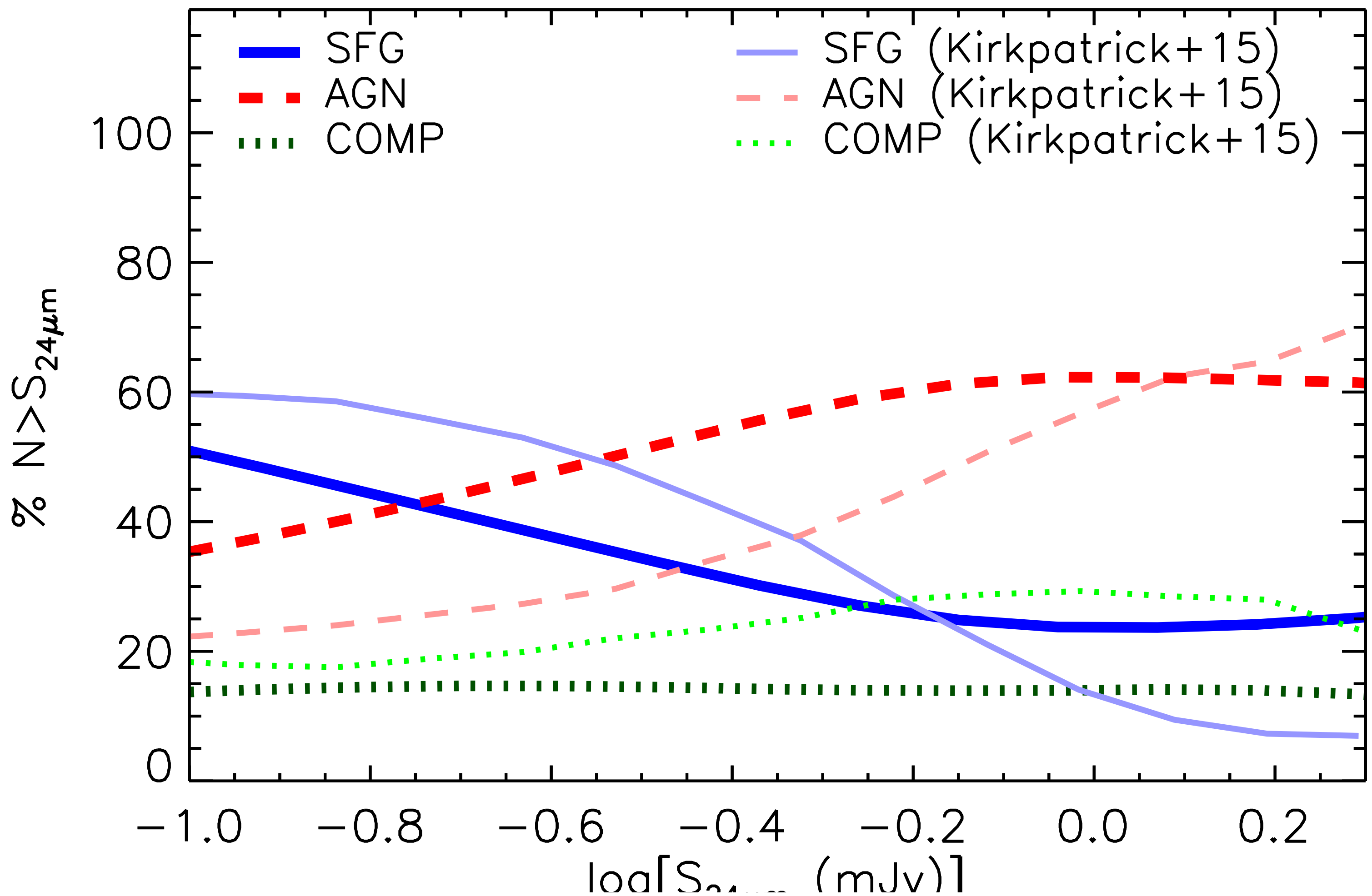
The best-fit IR luminosity function evolution compared with measurements from the literature. The black curves are the results of different runs.

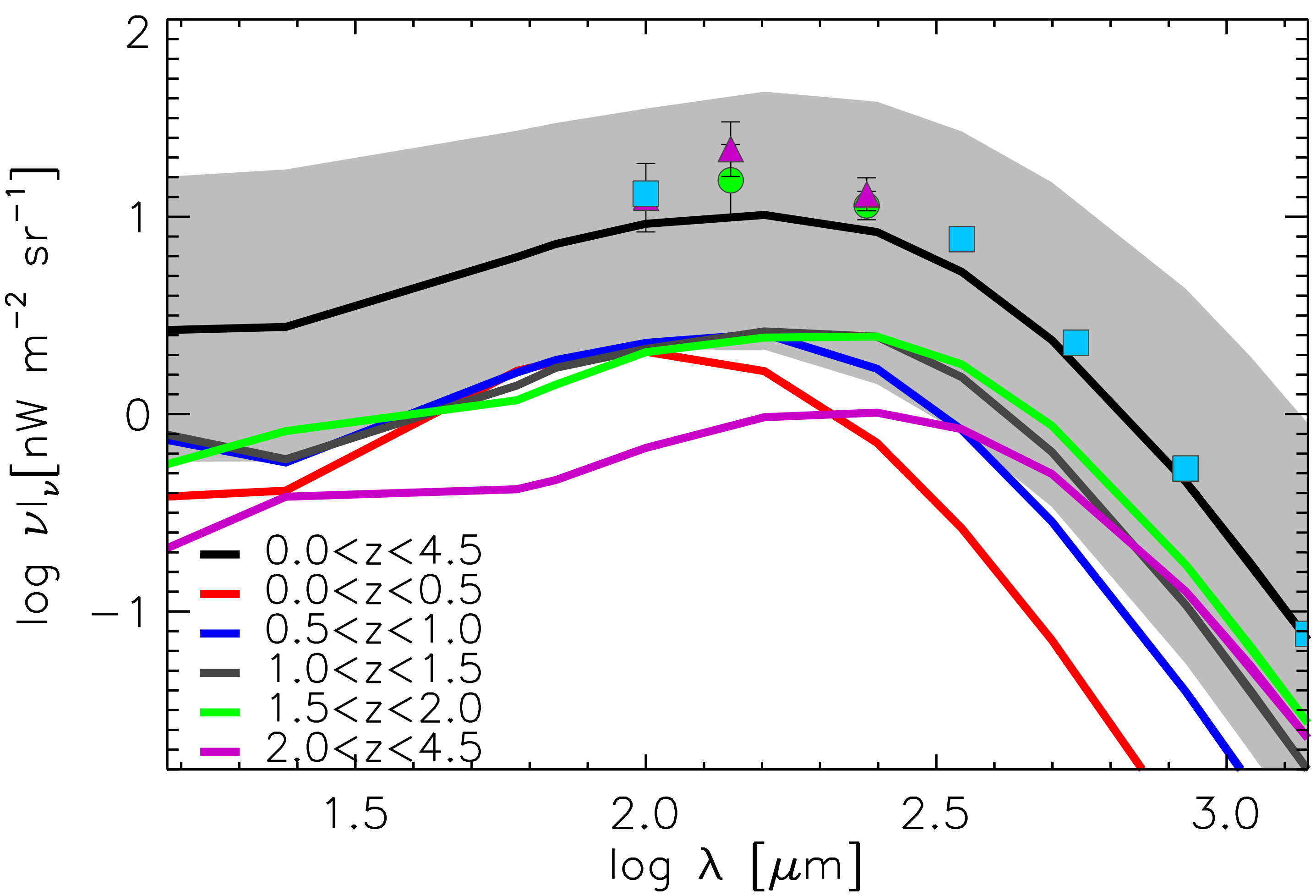
Kurinsky, AS, Bonato et al. 2016



predicted redshift distributions

predicted breakdown by type (SFG, AGN or Composite)





We find good agreement with the overall Cosmic Infrared Background as well as prior estimated of its redshift breakdown (Jauzac+2011).

Kurinsky, AS, Bonato et al. 2016

5 Summary

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