Measuring the Starburst-AGN Connection with an Ultra-Hard X-ray Selected Sample

Taro Shimizu

AGN vs. Star Formation Workshop

7/28/14

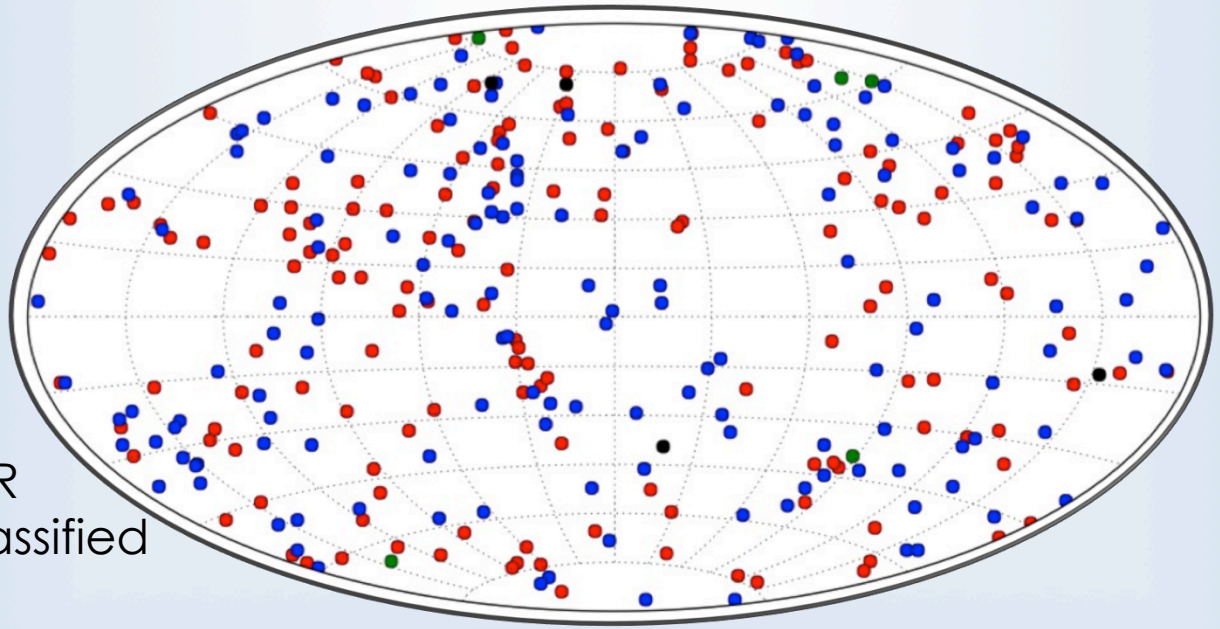
Collaborators: Richard Mushotzky, Marcio Melendez, Mike Koss, Amy Barger, Len Cowie

Outline

- Sample selection and observations
- FIR colors and morphology of BAT AGN
  - Very similar to normal star-forming galaxies
  - AGN seem to be compact
- IR SED fitting allows for estimates of T_{dust}, β, L_{IR}, L_{FIR}, L_{MIR}
  - Only weak correlation between L_{FIR} and L_X
- The main sequence and BAT AGN
  - Large fraction of AGN lie below main sequence

Swift/BAT AGN Sample

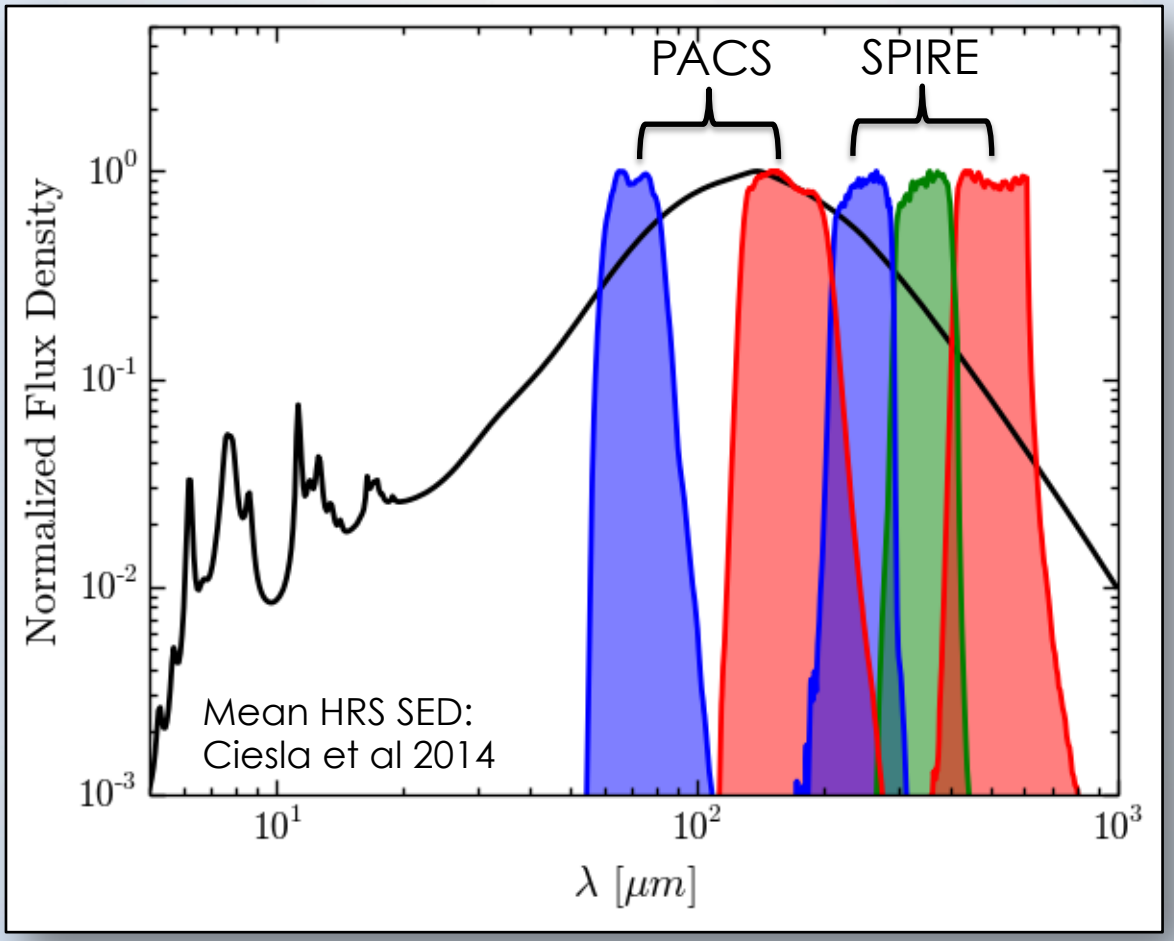
Blue: Sy 1
Red: Sy 2
Green: LINER
Black: Unclassified



Galactic Coordinates

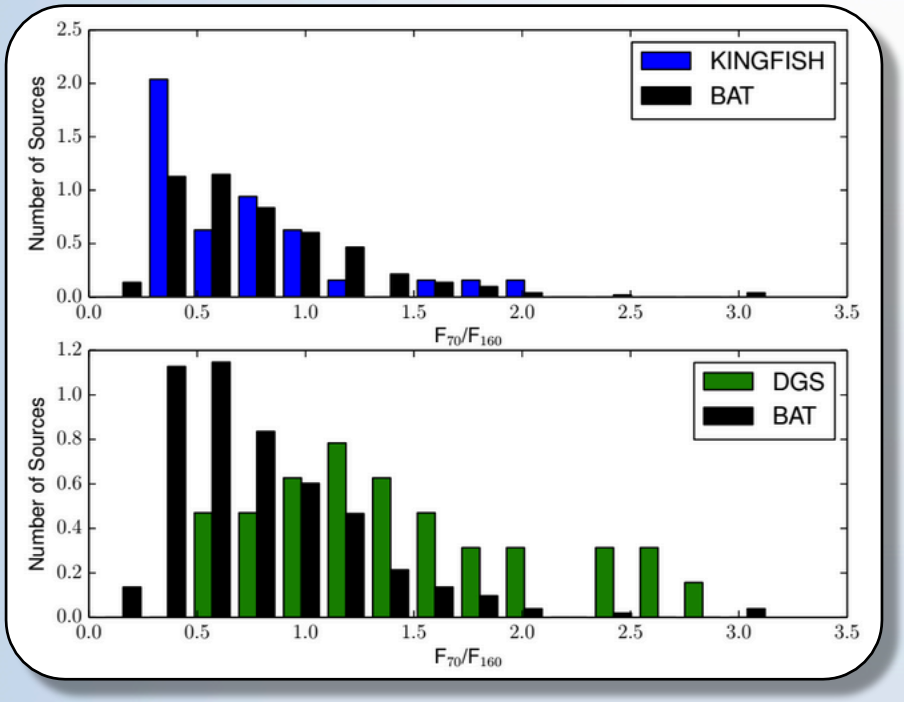
- Selected from the 58 month *Swift*/BAT catalog (14-195 keV)
- $z < 0.05$ for local reference sample
- Exploit *Herschel* angular resolution
- 149 Seyfert 1, 157 Seyfert 2, 6 LINER, 1 Unclassified
- Reduces contamination and selection bias
- $L_{BAT} = 10^{41} – 10^{45}$ erg s^{-1}

Herschel Observations



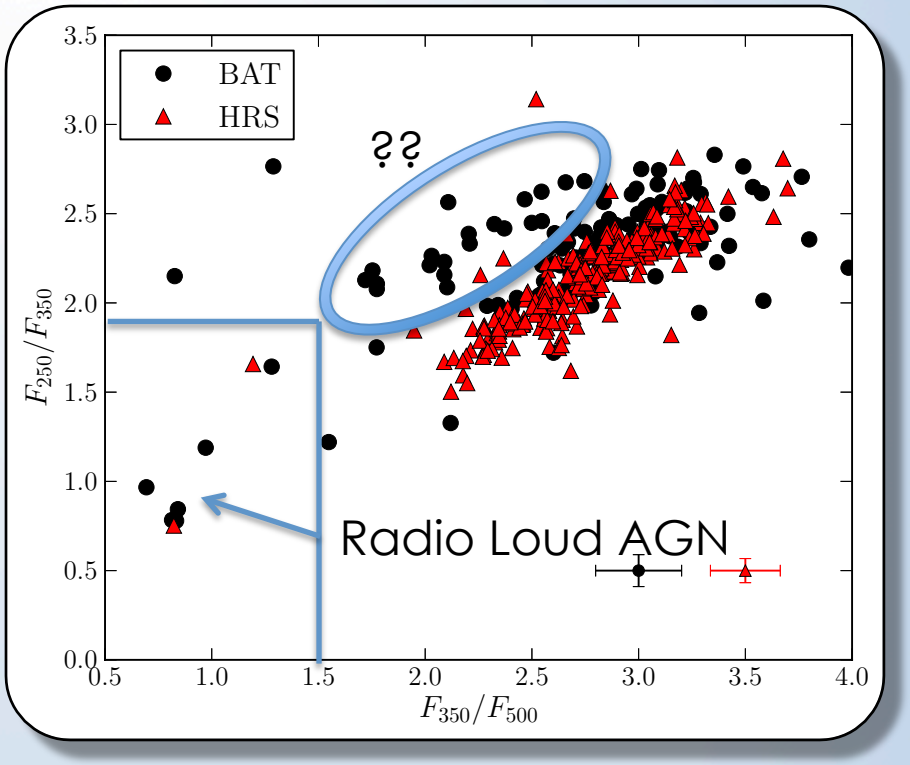
- Imaging from 70- 500 microns
- Spans the peak in FIR allowing for accurate estimation of star formation

FIR Colors Are Similar to SF Galaxies



PACS color more similar to KINGFISH sample than Dwarf Galaxy Survey (DGS)

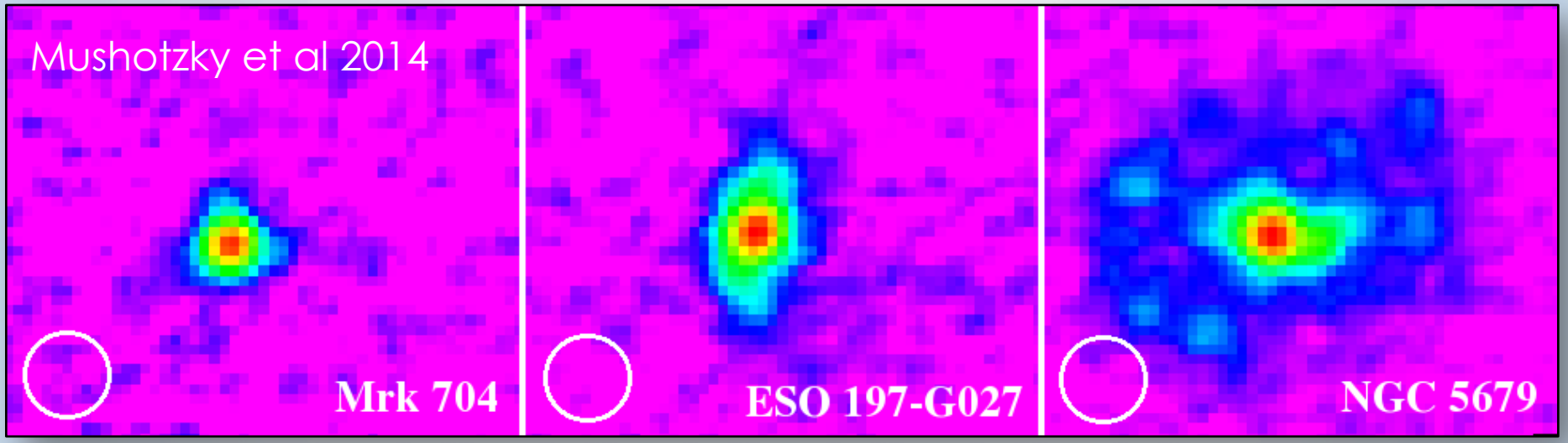
Meléndez et al 2014 (submitted to ApJ)



70% of SPIRE colors very similar to *Herschel Reference Survey* (HRS)

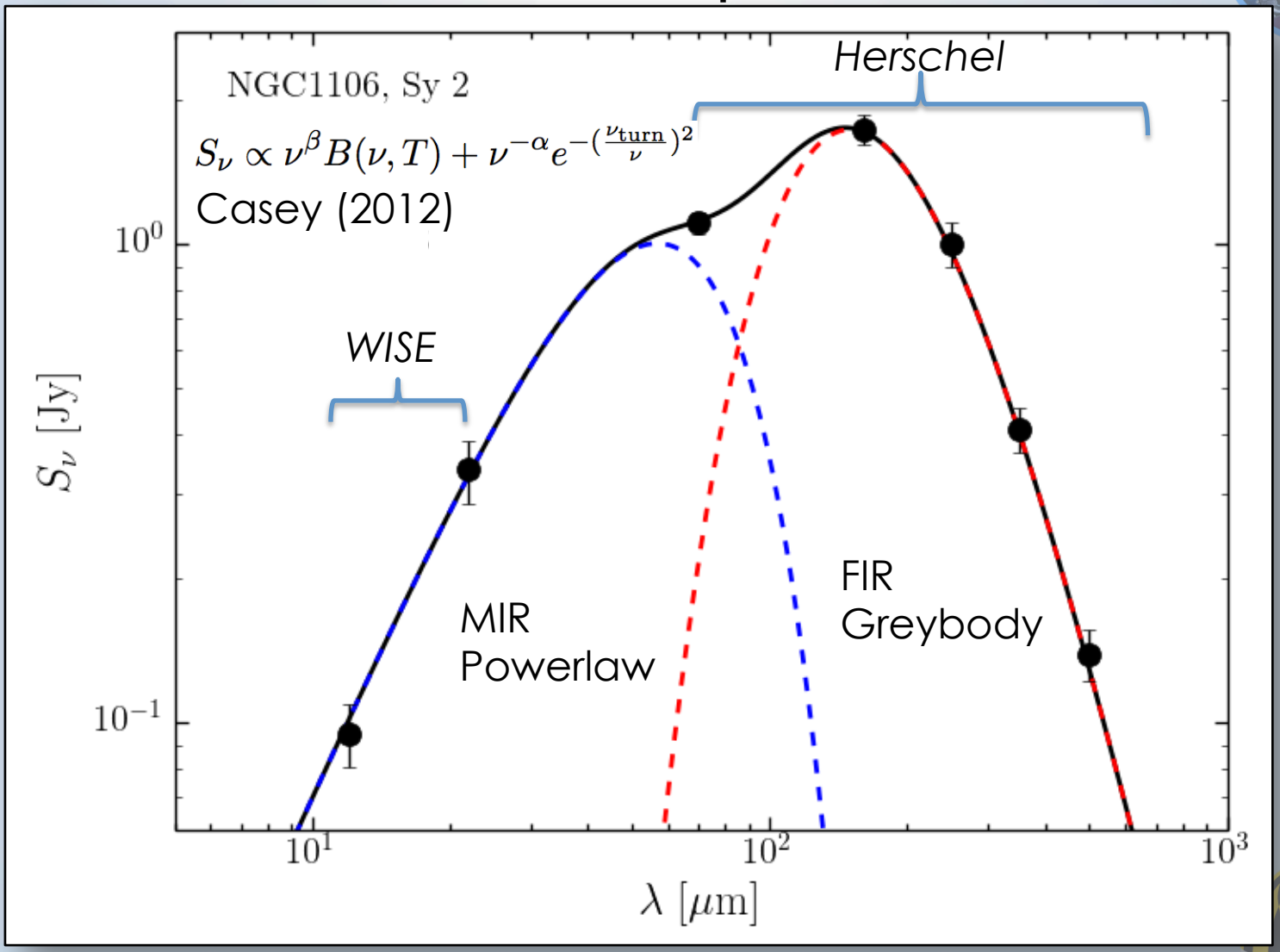
Shimizu et al 2014 (in prep)

AGN Host Galaxies Are Compact



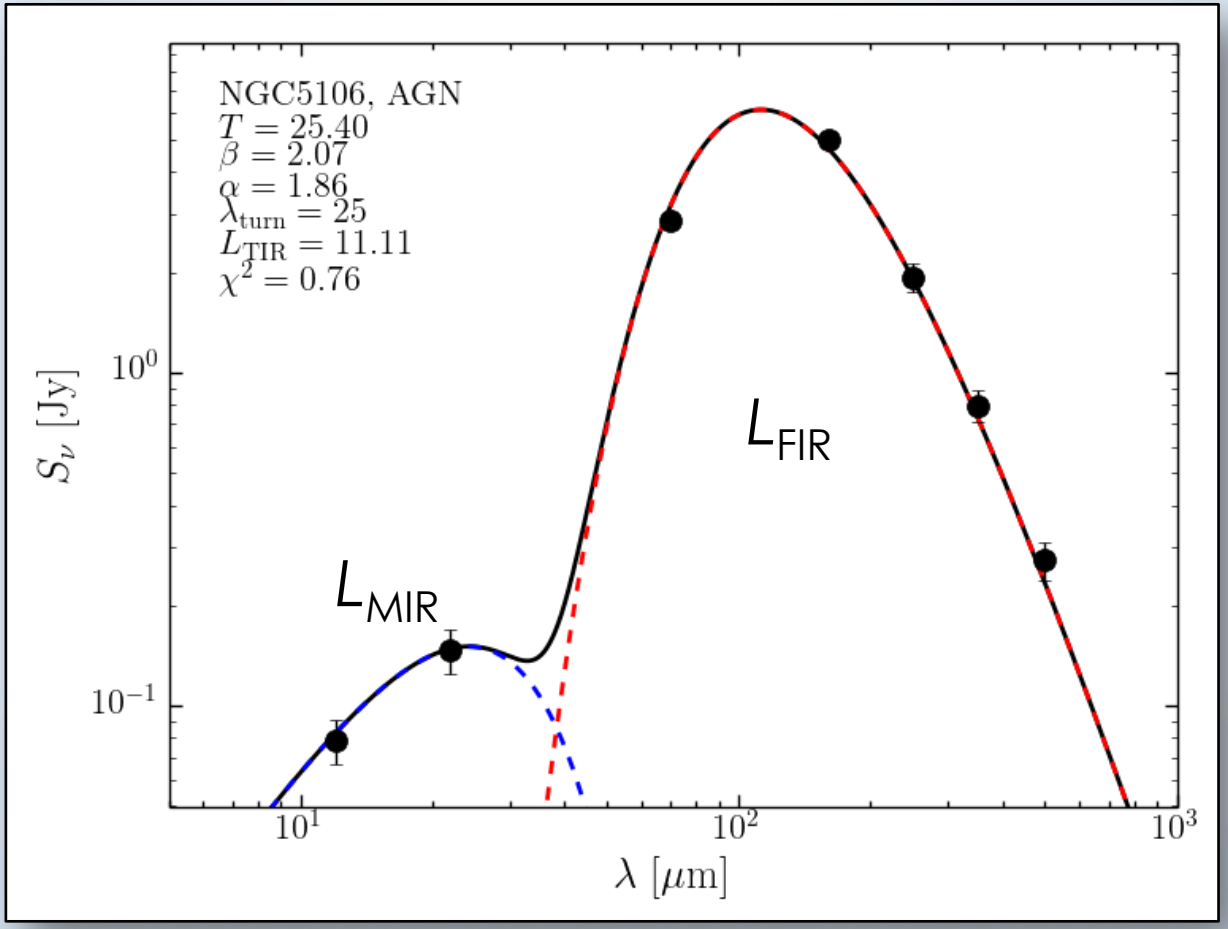
- 37% are unresolved with sizes estimated < 2 kpc
- 35% partially extended with sizes ~ 5 kpc
- 28% fully extended with sizes ~ 10 kpc
- Leads to large star formation surface density possibly capable of driving winds

SED Decomposition



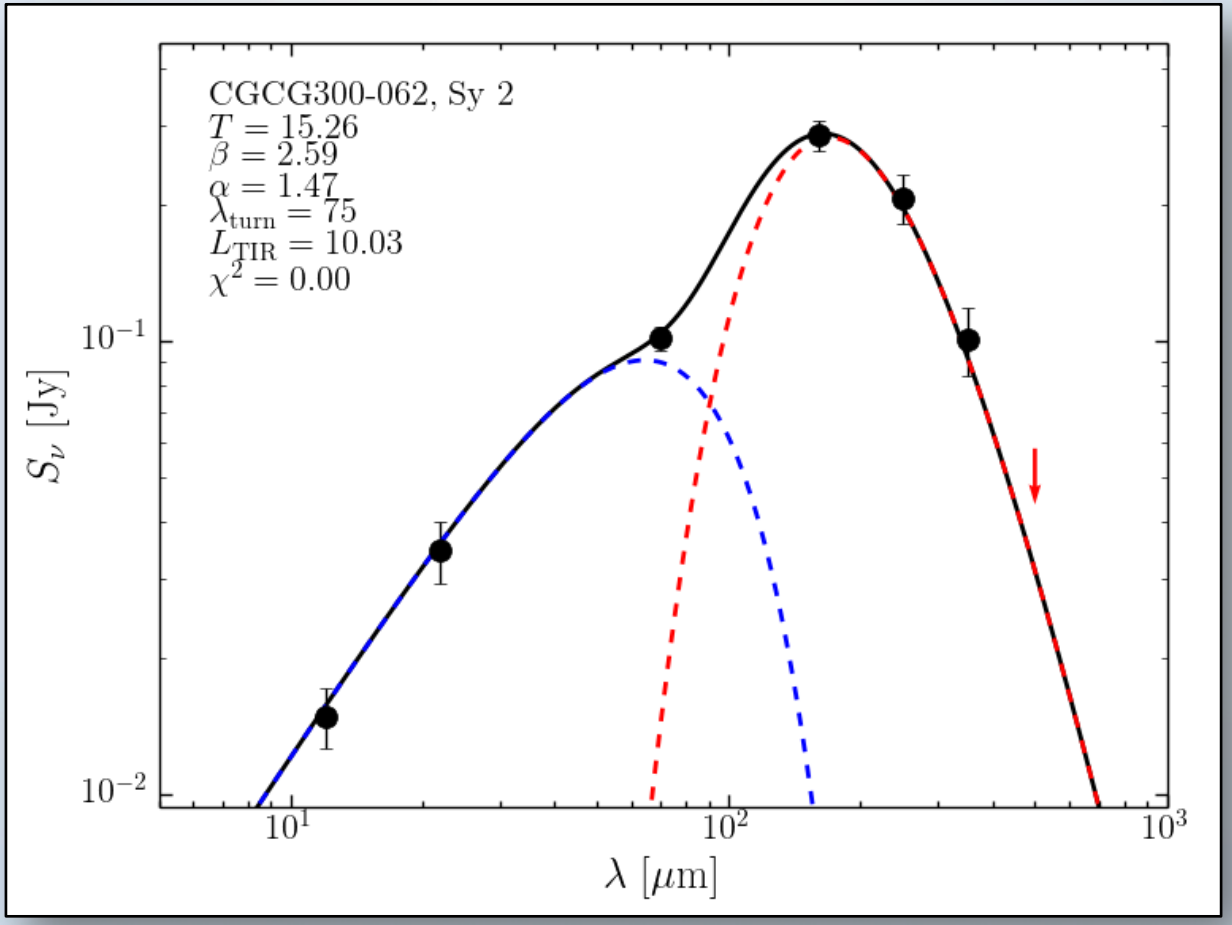
Shimizu et al 2014 in prep

The Many Shapes of AGN SEDs



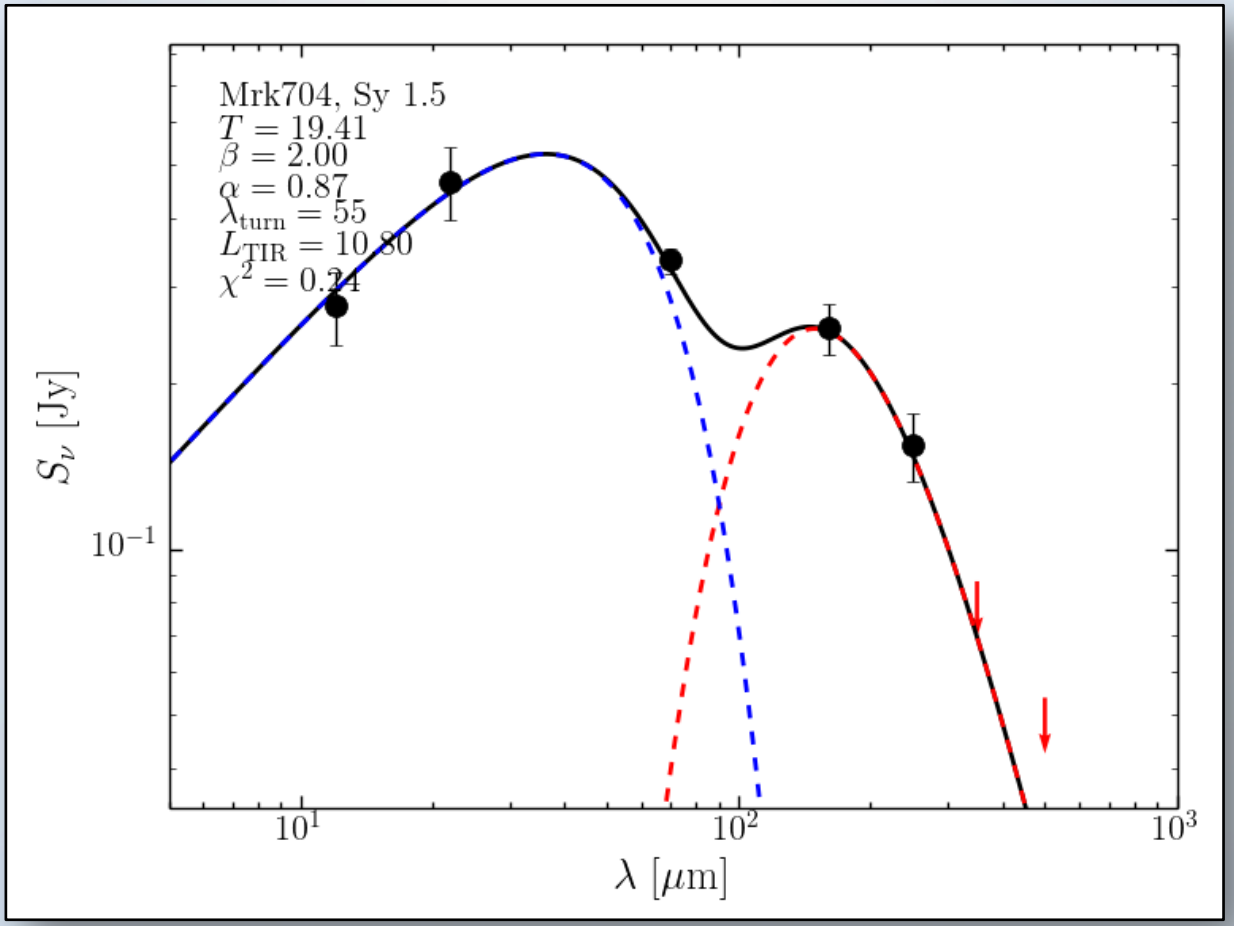
$L_{MIR}/L_{FIR} = 0.16$

The Many Shapes of AGN SEDs



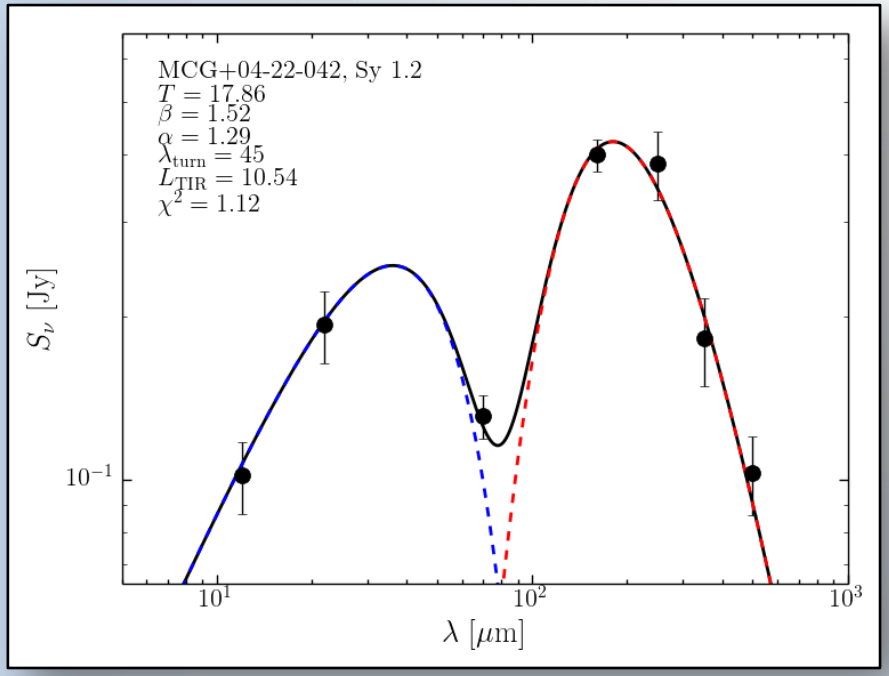
L_{MIR}/L_{FIR} = 2.1

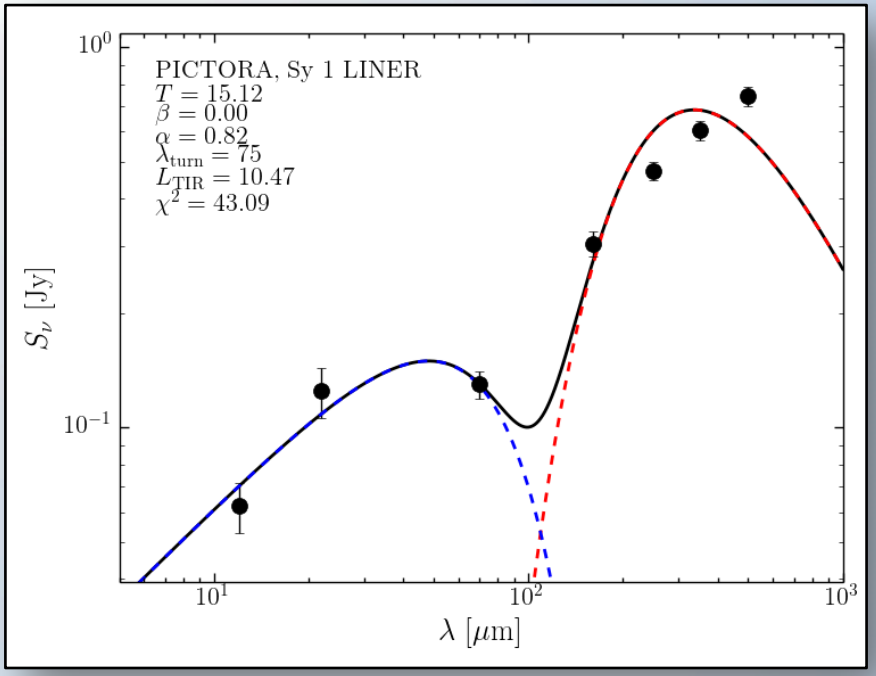
The Many Shapes of AGN SEDs



L_{MIR}/L_{FIR} = 20

The Many Shapes of AGN SEDs



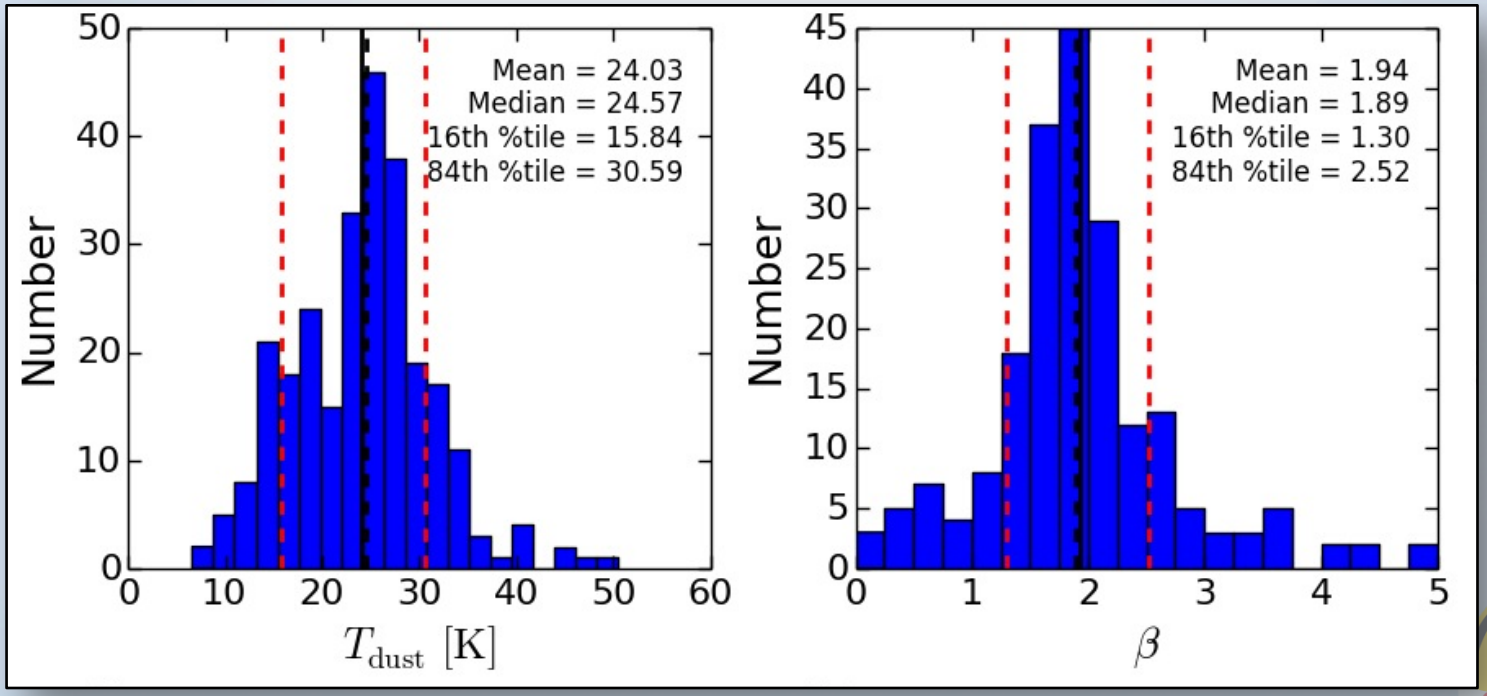


- Clear double peaked SED

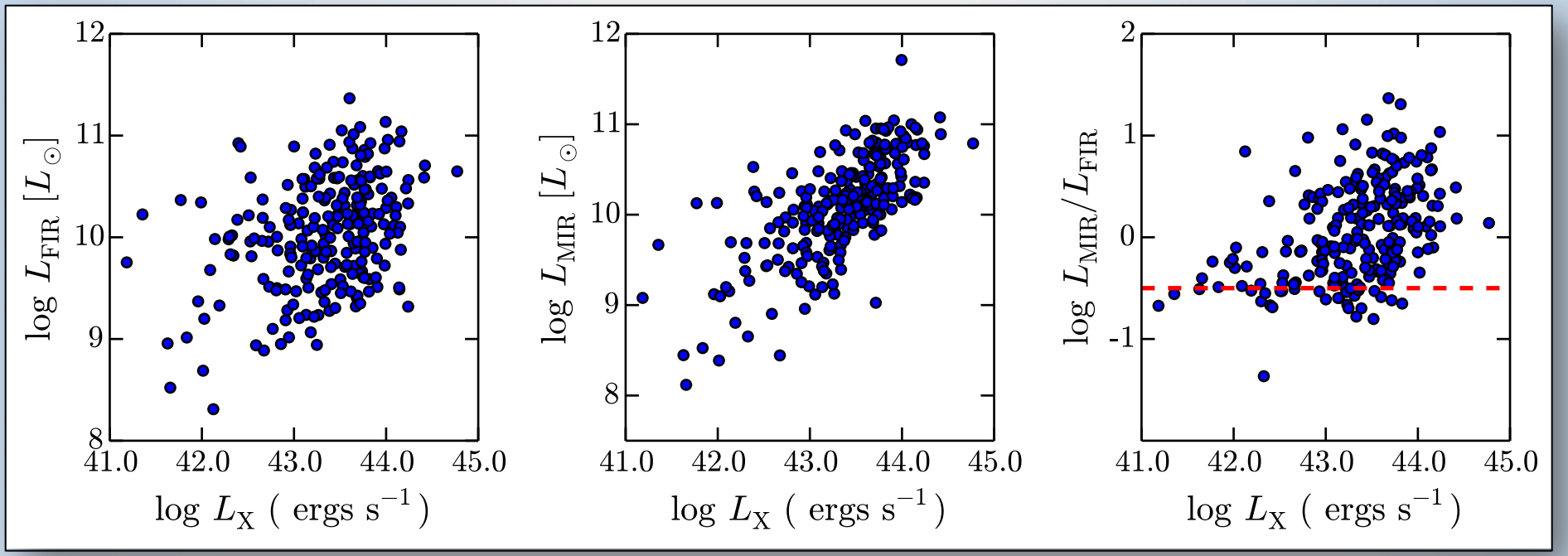
- Radio Loud AGN
- SED dominated by synchrotron component
- Only ~5 sources

T_{dust} and Emissivity Distribution

Mean $T_{dust} \approx 24$ K and mean $\beta \approx 2$
very similar to inactive SF galaxies



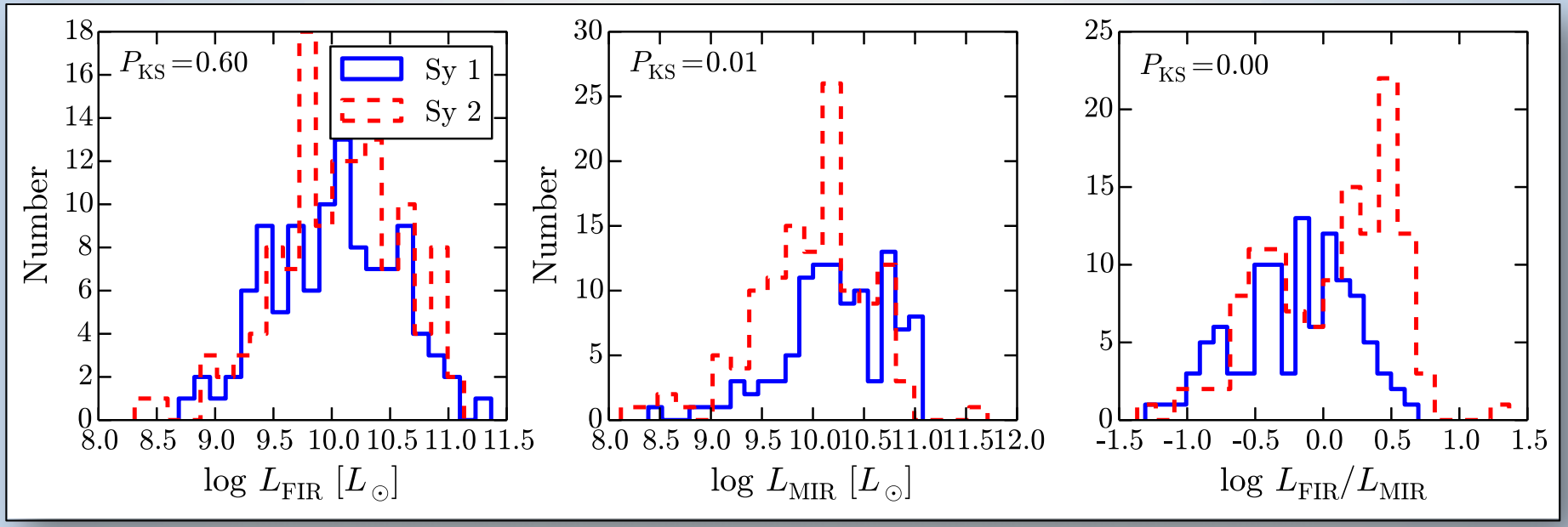
Correlation with X-ray Luminosity



- No correlations with T_{dust} and β
- Weak correlations with L_{FIR}
- Strong correlations with L_{MIR}, and L_{FIR}/L_{MIR}

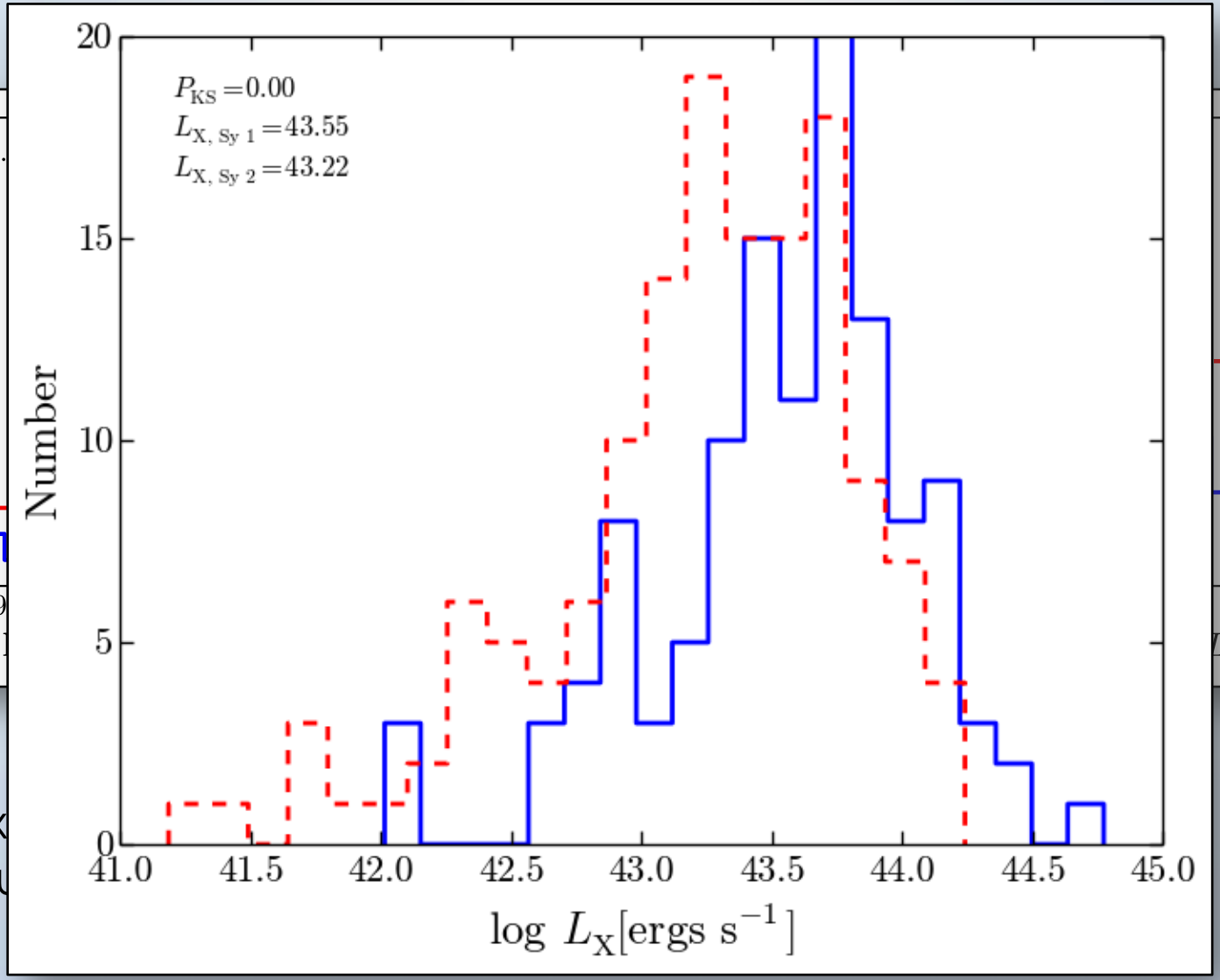
- SF only weakly related to AGN strength

Seyfert 1s and 2s Have Similar IR Properties



- Except in L_{MIR} and L_{FIR}/L_{MIR} distributions
- Due to different L_X distribution for Sy 1s and 2s

Seyfert 1s and 2s Have Similar IR Properties



- Ex
- Du

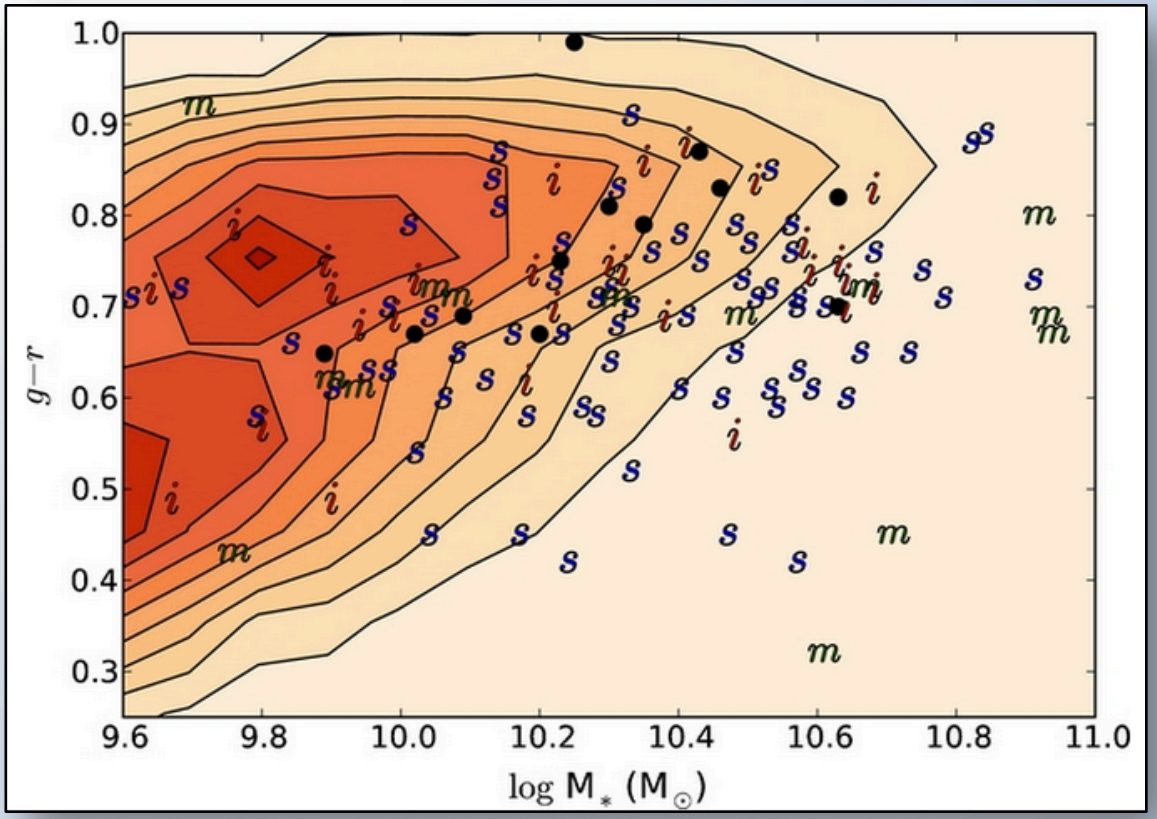
Morphology and Colors of BAT AGN

- S = Spiral
- I = Intermediate
- Black dot = Elliptical
- M = merger

- BAT AGN have higher rate of spirals and mergers than inactive galaxies

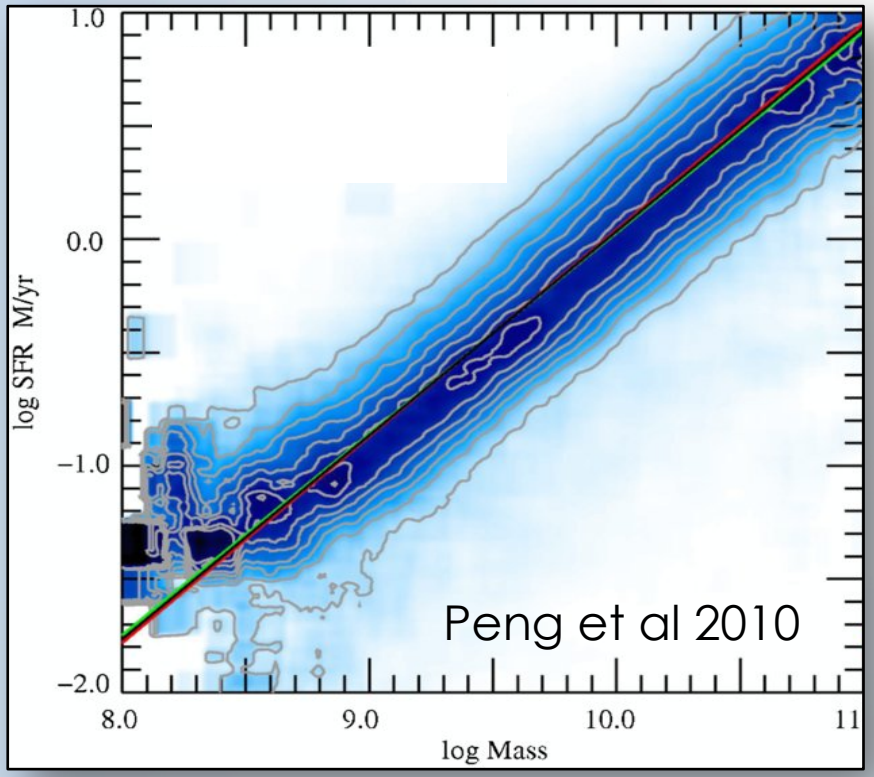
- BAT AGN also are much more massive (mean M_{star} = 10.28 compared to 9.45 M_{sun}

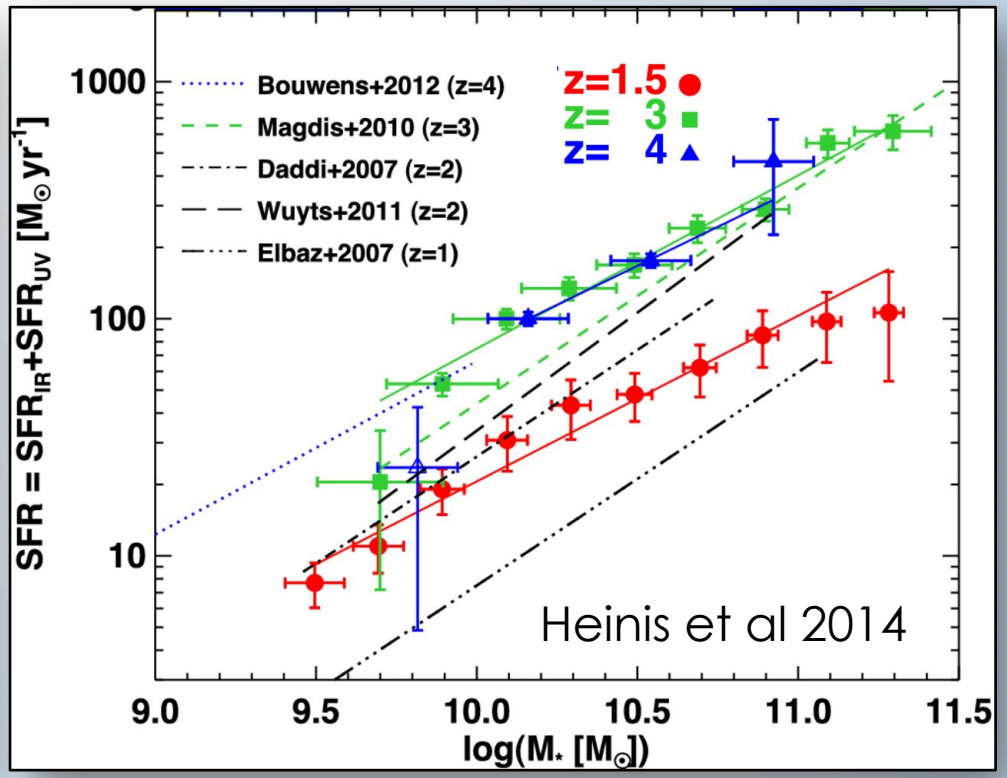
- Appear to have "green" colors



Koss et al (2011)

The Main Sequence of SF

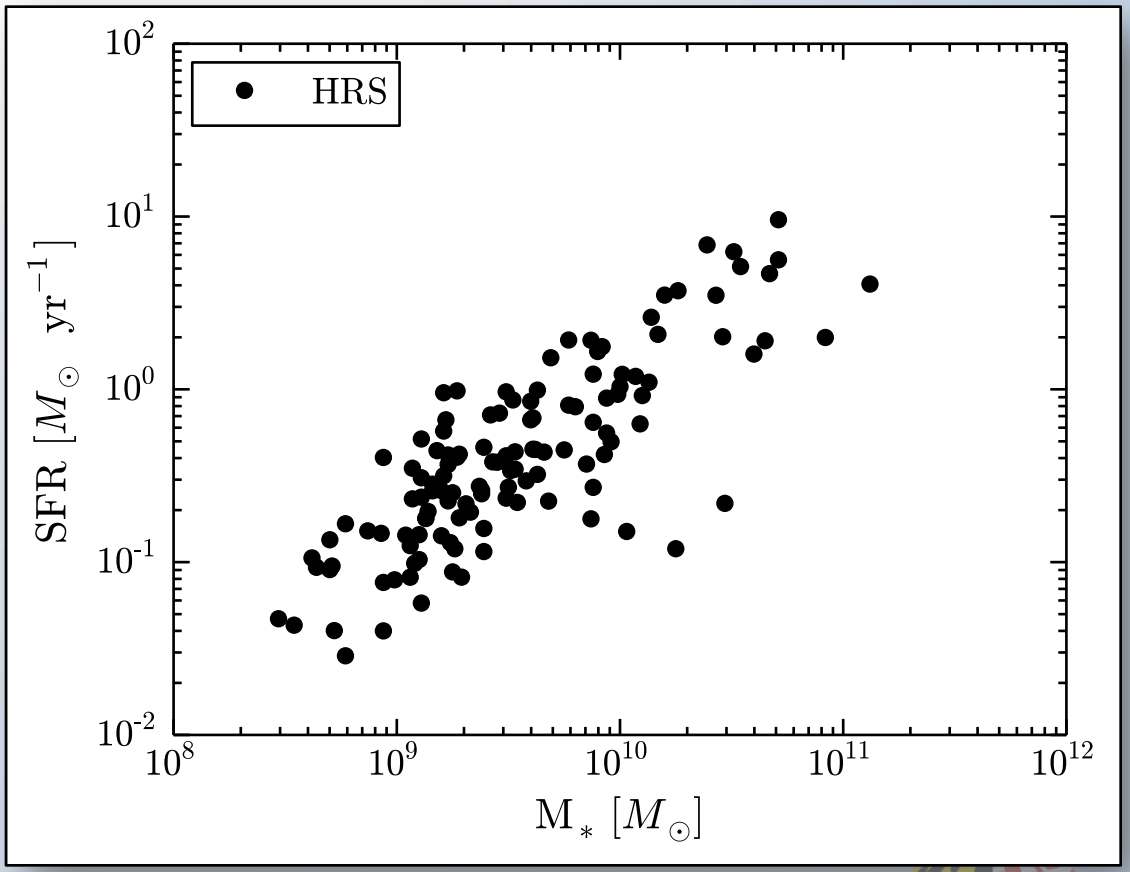




- Tight ($\sigma \sim 0.3$ dex) correlation between SFR and M_* for SF galaxies
- Exists up to z~4 with only change in normalization
- Where are AGN host galaxies located?

Defining the Main Sequence (MS)

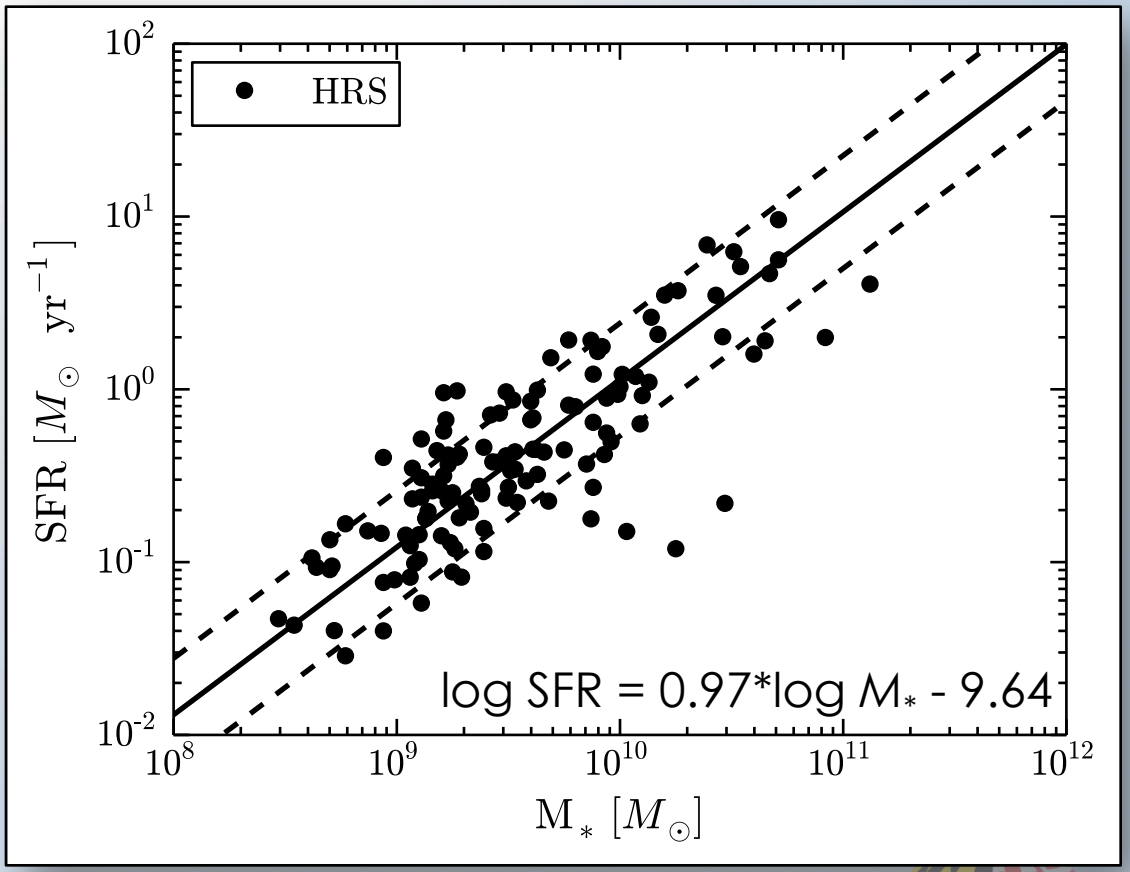
- Key issue is consistency in measuring SFR and stellar mass
- Obtained photometry for *Herschel Reference Survey* (HRS, Boselli et al 2010)
- K-band selected normal galaxy sample
- Fit using same model as BAT AGN
- SFR = $L_{IR}/2.57 \times 10^{-43}$ (Kennicutt & Evans 2012)



Shimizu et al 2014 (in prep)

Defining the Main Sequence (MS)

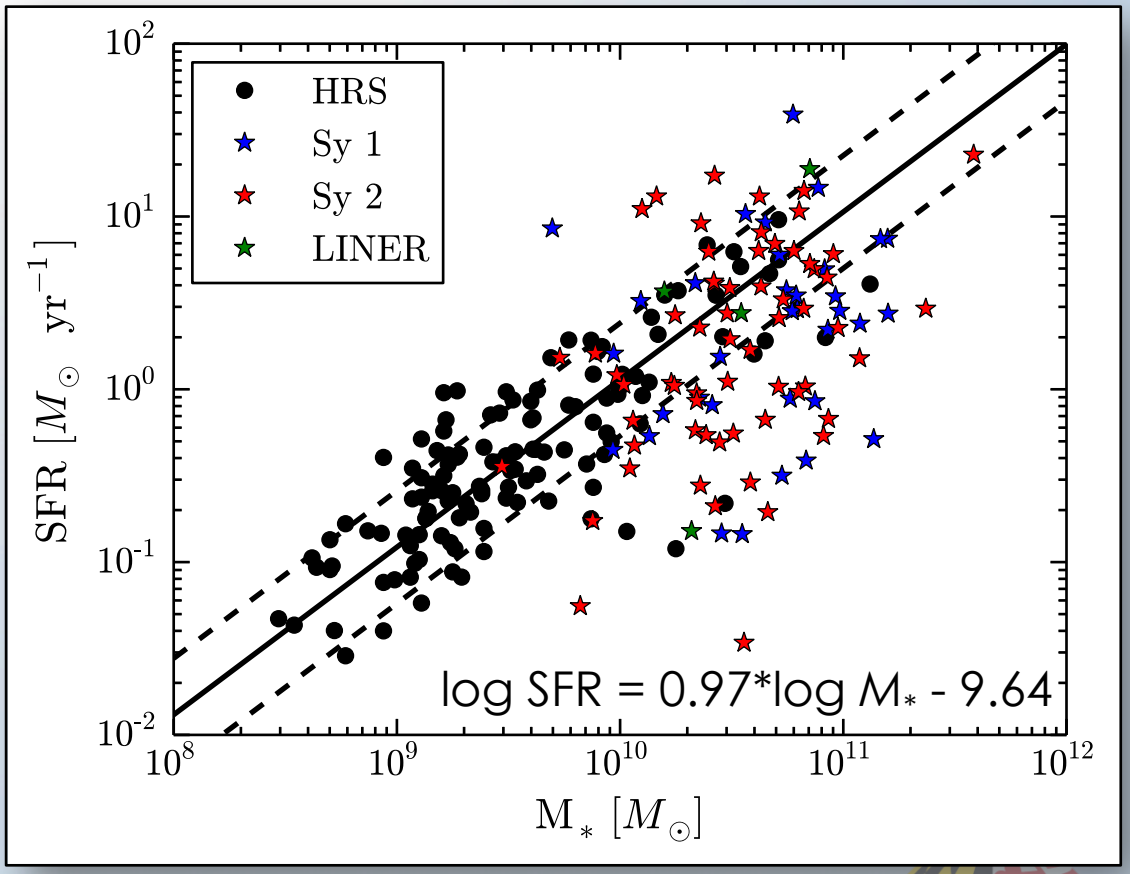
- Key issue is consistency in measuring SFR and stellar mass
- Obtained photometry for *Herschel Reference Survey* (HRS, Boselli et al 2010)
- K-band selected normal galaxy sample
- Fit using same model as BAT AGN
- SFR = $L_{IR}/2.57 \times 10^{-43}$ (Kennicutt & Evans 2012)



Shimizu et al 2014 (in prep)

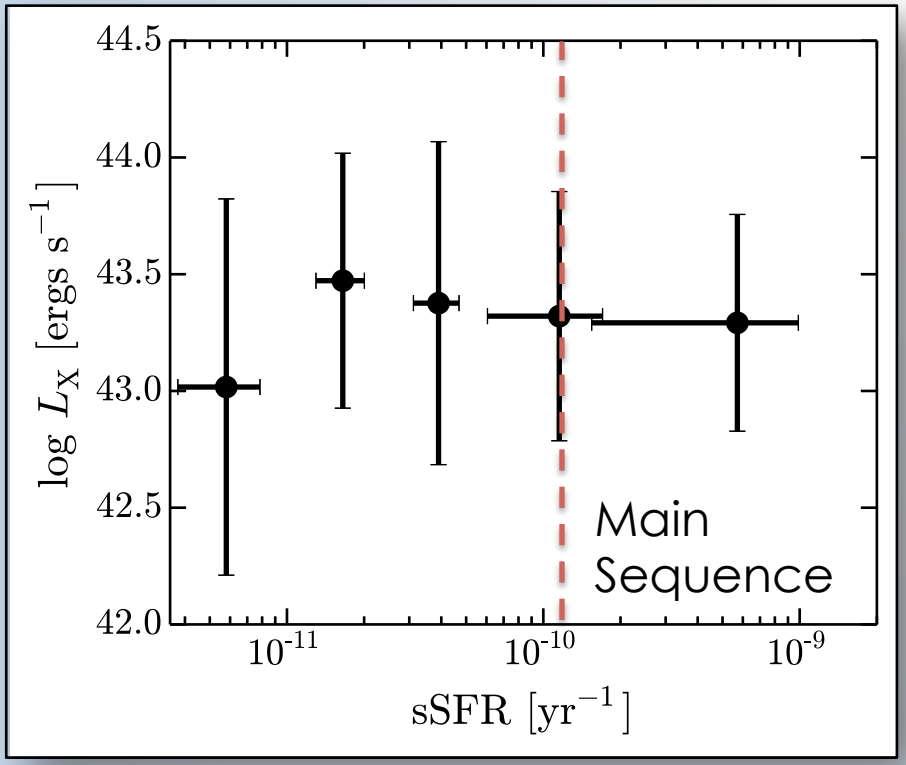
BAT AGN and the Main Sequence

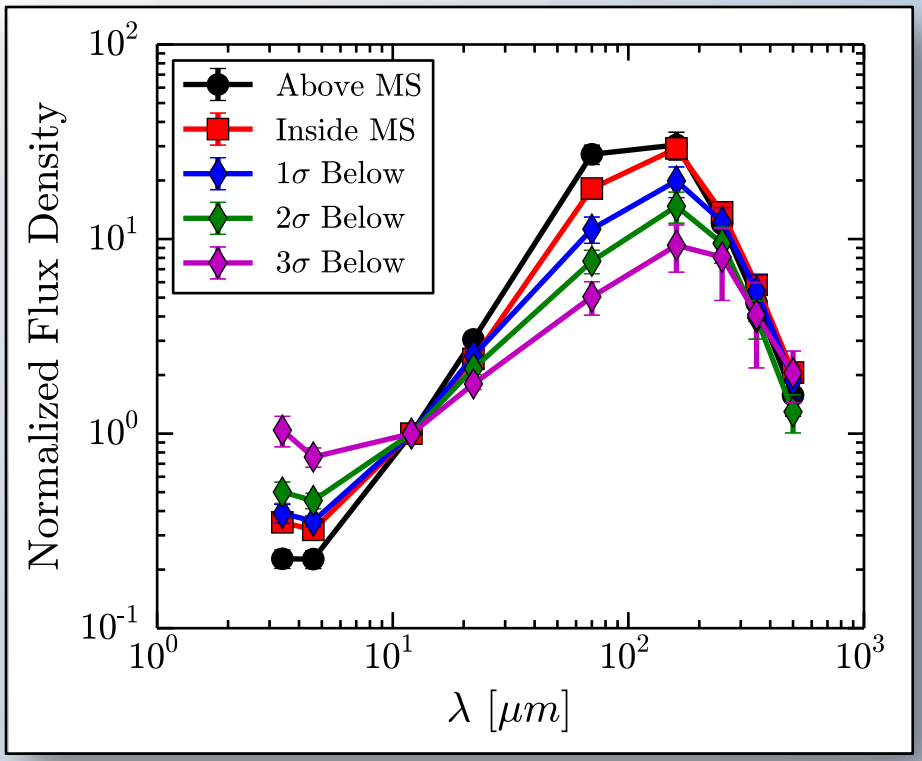
- BAT AGN and HRS SFR and stellar mass determined with same methods
- 14% AGN Above MS
- 40% AGN Inside MS
- 46% AGN Below MS
- Split Below region into 3
  - > 1 σ (16%)
  - > 2 σ (13%)
  - > 3 σ (17%)
- Large fraction of AGN with decreased sSFR = SFR/M_*



Shimizu et al 2014 (in prep)

sSFR Not Correlated with L_X

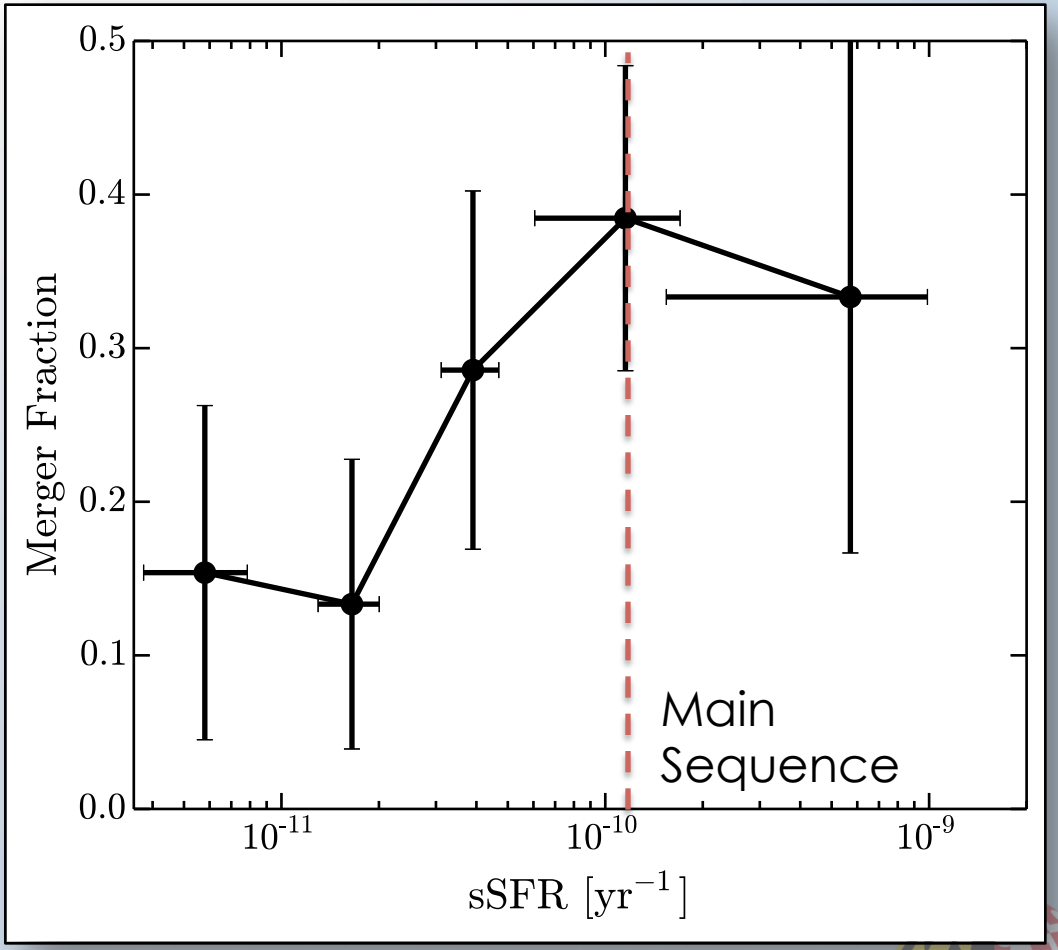




- Increase in T_{dust} and $L_{grey}/L_{powerlaw}$
- Clear change in SED shape consistent with decreasing SFR

Increase in Merger Fraction with sSFR

- Merger defined as AGN with companion
  - < 30 kpc away
  - < 500 km/s radial velocity
- Very high rate (~40%) of mergers in BAT AGN above and in the MS
- Merger boosting SFR?
- AGN quenching SFR?



Have we seen evidence for Feedback?

- Built the largest FIR collection of z < 0.05 ultra-hard X-ray confirmed AGN with *Herschel*
- ~50% of AGN < 5 kpc in FIR
- IR SED shape is related to the AGN strength with high luminosity (>43 ergs s^{-1}) dominating overall L_{IR}
- Star Formation only seems weakly related to *instantaneous* AGN luminosity.
- *40-50%* reside below the main sequence
  - AGN phenomenon is related to quenching of SF
  - Is it the cause?

More Work to Do!

- Compare the FIR properties with MIR *Spitzer/IRS* spectra
- Study the AGN-dominated sample
  - Can torus models reproduce the FIR?
- What are the FIR properties of the mergers?
- Compare FIR with CO/radio images