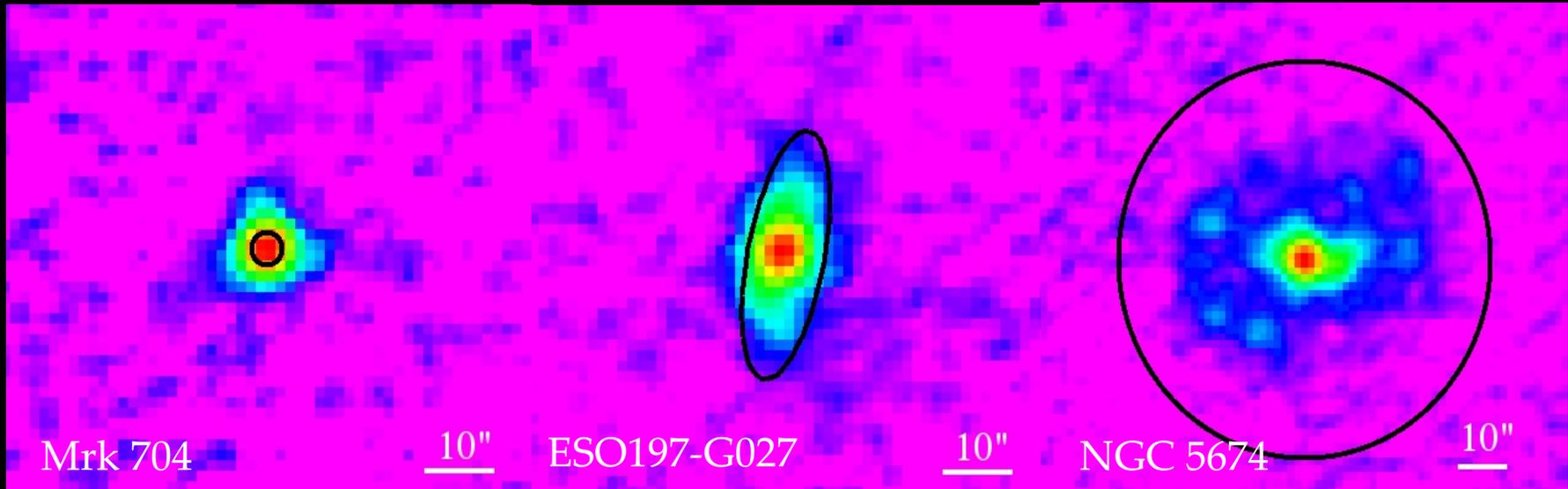


The Far-IR View of an Ultra-Hard X-ray Selected Sample of AGN



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Marcio Meléndez (UMDCP)
Amy Barger (U. Wisconsin)
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“The Universe Explored by Herschel”
October 16, 2013
ESA/ESTEC Noordwijk, Netherlands

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1. Motivation, sample, and flux extraction
 - Large unbiased, low-z sample of AGN
 - Aperture photometry to extract fluxes
2. $L_{\text{AGN}}-L_{\text{FIR}}$ correlations, FIR colors and comparison to “normal” SF galaxies
 - All wavebands correlated with AGN lum. for Sy 1
 - SPIRE FIR colors indicate presence of radio jet
3. SFR density of AGN
 - Almost all sources have majority of FIR flux from point source
 - SFR density for large fraction of AGN above threshold for SF-driven winds

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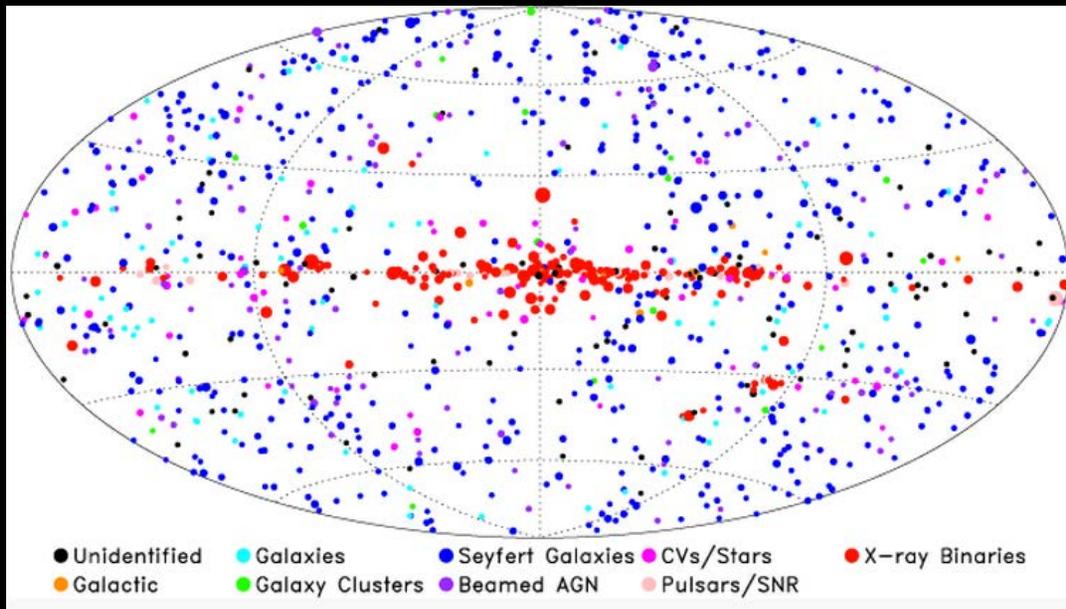
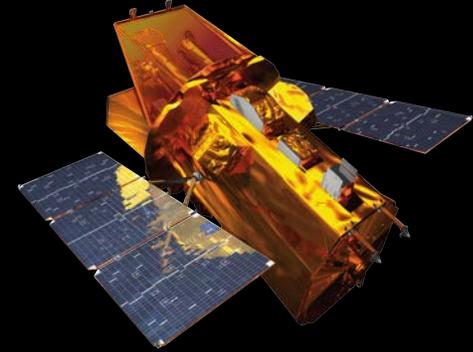
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Motivation

- Close connection between supermassive black hole (SMBH) and host galaxy properties ($M_{\text{BH}}-\sigma$, $M_{\text{BH}}-M_{\text{bulge}}$, etc.)
- Points to coevolution of galaxy and SMBH
- Active Galactic Nuclei (AGN) feedback invoked to explain coevolution
- Far-IR (FIR) emission = Star Formation heated dust. What is the AGN contribution to FIR?
- Need reference AGN sample with high angular resolution (*Herschel*) in FIR to determine true AGN contribution

The *Herschel*-BAT Sample

- 313 AGN selected from *Swift*/Burst Alert Telescope (BAT) 58 month catalog (14-195 keV)
- $z < 0.05$
- Greatly reduces selection bias
- Flux-limited sample

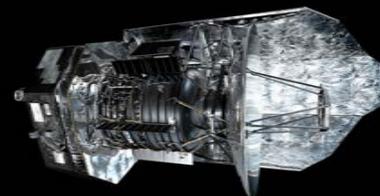


149 Sy 1-1.5 (Sy 1)
155 Sy 1.8 – 2 (Sy 2)
5 LINER
4 “Other” AGN

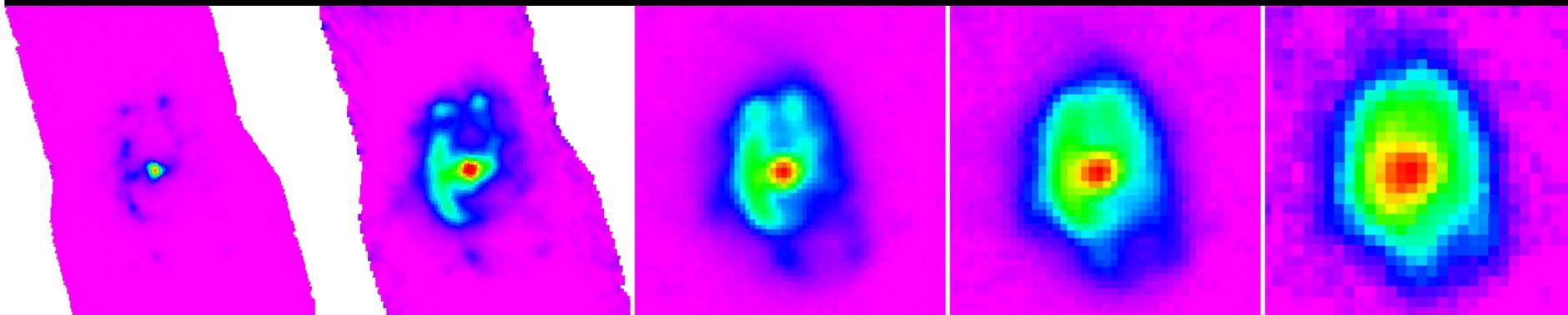
$$L_{\text{BAT}} \sim 10^{41} - 10^{45} \text{ ergs s}^{-1}$$

Herschel Observations

- PACS: 70 and 160 μm in mini-scan mode
 - Two 3' scan legs, 4" step, 70° and 110° scan angles
 - 20"/sec speed – 3'x1' images
- SPIRE: 250, 350, and 500 μm in small-map mode
 - 30"/sec speed, 2 orthogonal scan angles, 5' homogeneous coverage
- Data reduced to Level 1 using HIPE v8
- Images created with Scanamorphos v19 (Roussel 2013)
- Pixel sizes of 1.4", 2.85", 4.5", 6.25", 9" for 70-500 μm images
- Pixel size = $\frac{1}{4}$ * PSF FWHM



NGC 6221



PACS 70

PACS 160

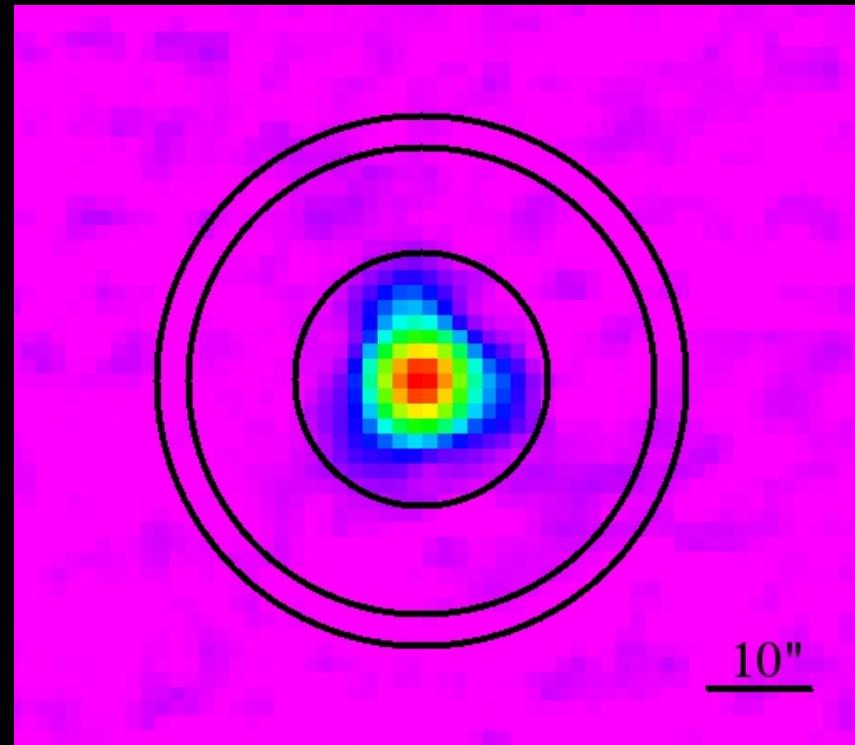
SPIRE 250

SPIRE 350

SPIRE 500

Flux Extraction

- Aperture photometry using annularSkyAperturePhotometry task within HIPE or DS9 “Funcnts” tool
- Concentric annulus to estimate background
- All sources $< 5\sigma$ considered non-detections and only upperlimits reported
- 70 μm : 94% detected
- 160 μm : 83% detected
- 250 μm : 85% detected
- 350 μm : 69% detected
- 500 μm : 46% detected



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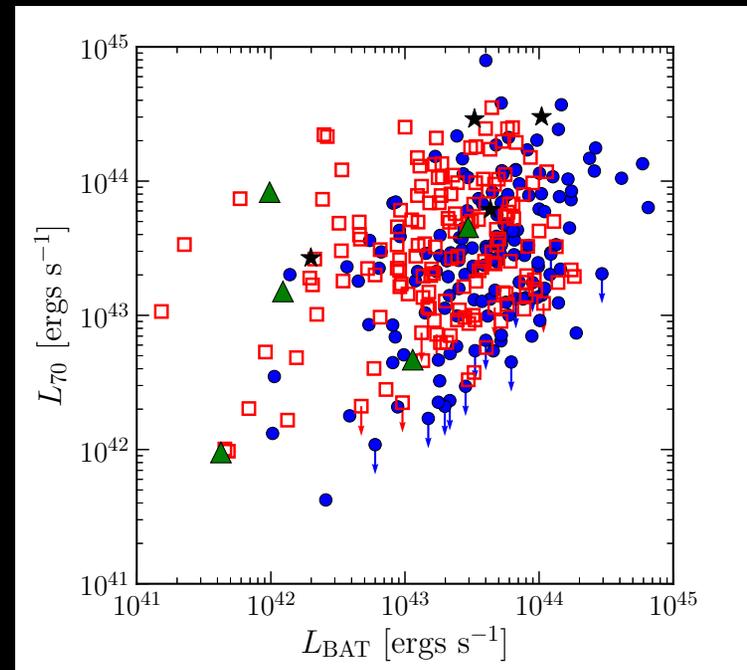
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$L_{\text{FIR}}-L_{\text{BAT}}$ Correlations

- Tested correlations using partial Kendall tau test and survival analysis
- Takes into account correlation with distance and upper limits
- Type 1 AGN correlated at ALL Herschel wavebands with BAT luminosity
- Type 2 AGN NOT correlated at ANY Herschel waveband with BAT luminosity

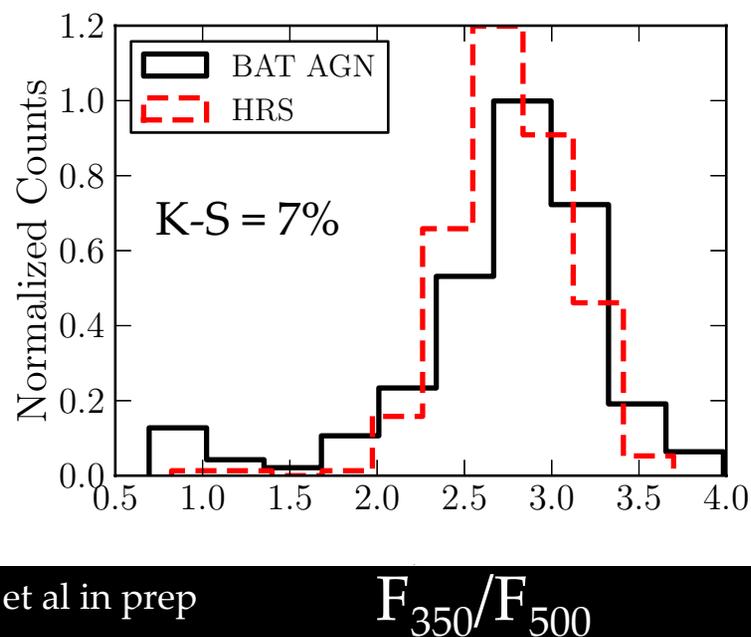
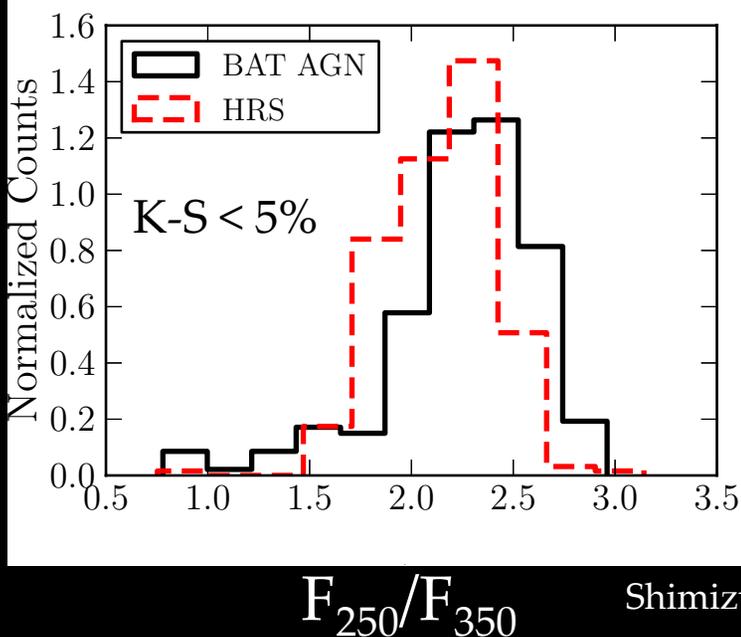
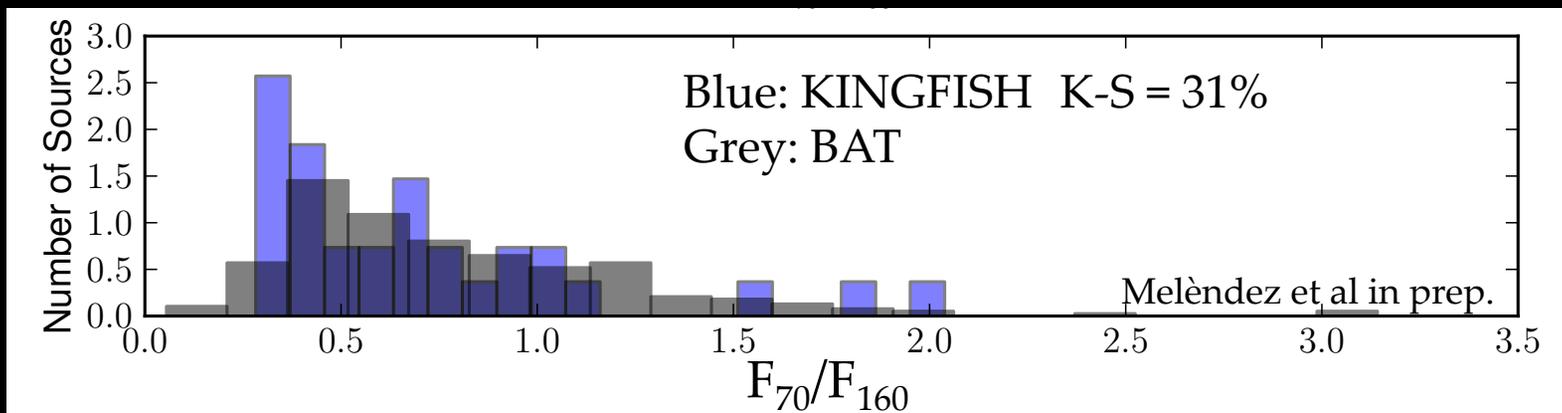
Blue dots = Sy 1
Red squares = Sy 2
Green triangles = LINER
Black stars = "Other" AGN
Melendez et al in prep



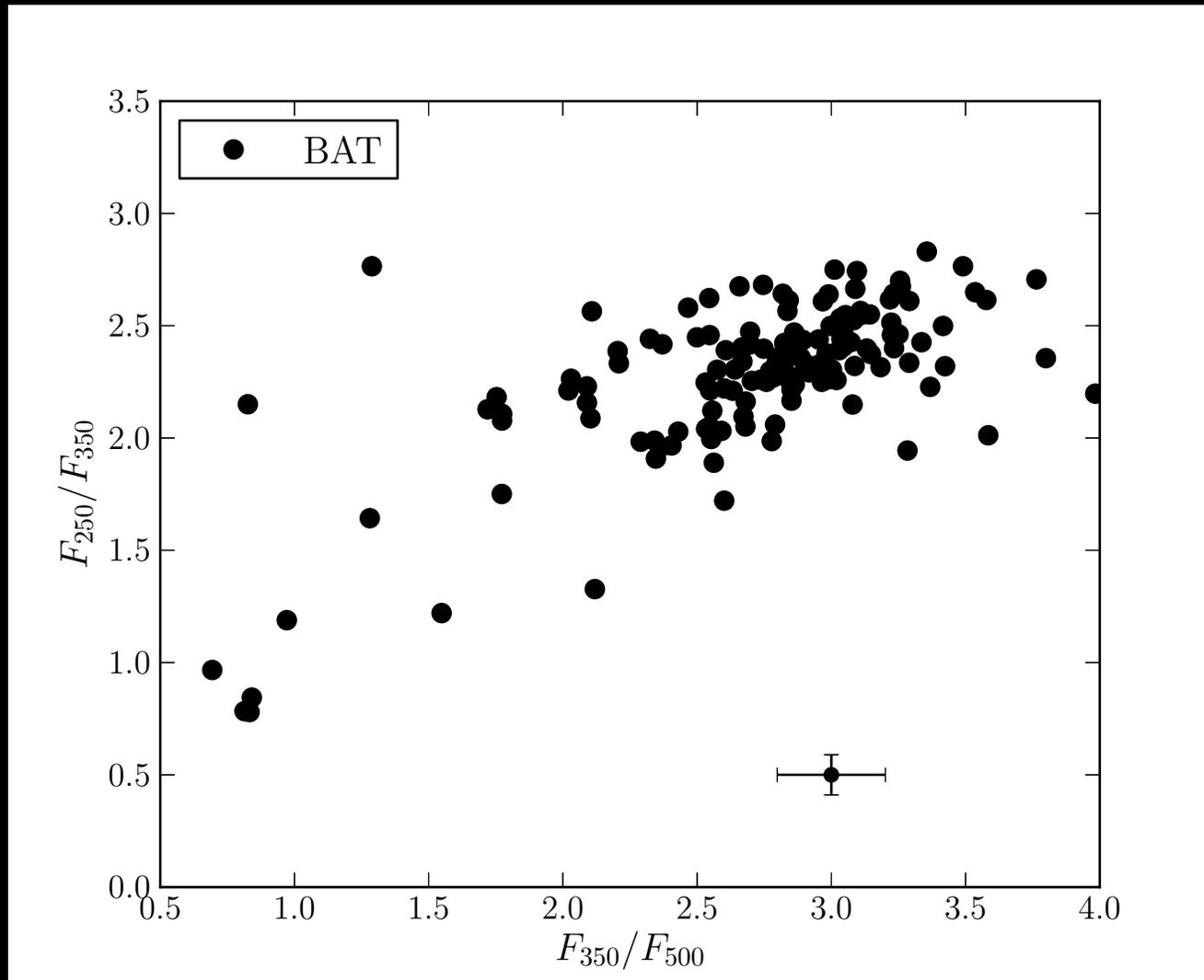
PACS Color Not Different than “Normal Galaxies” SPIRE Colors Different

KINGFISH: Dale et al 2012

HRS: Ciesla et al. 2012

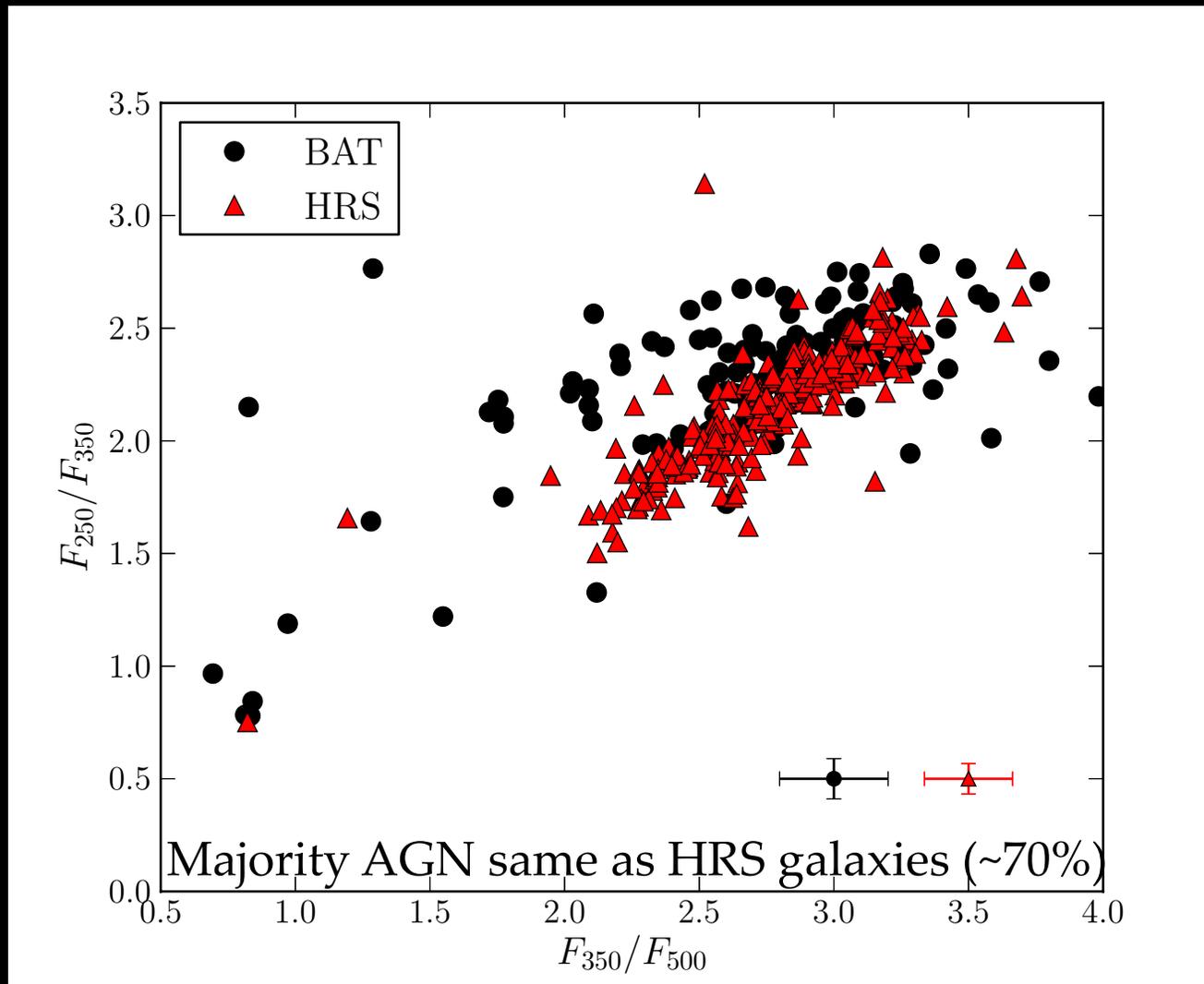


FIR Colors: Comparison to “Normal” Galaxies



Shimizu et al in prep

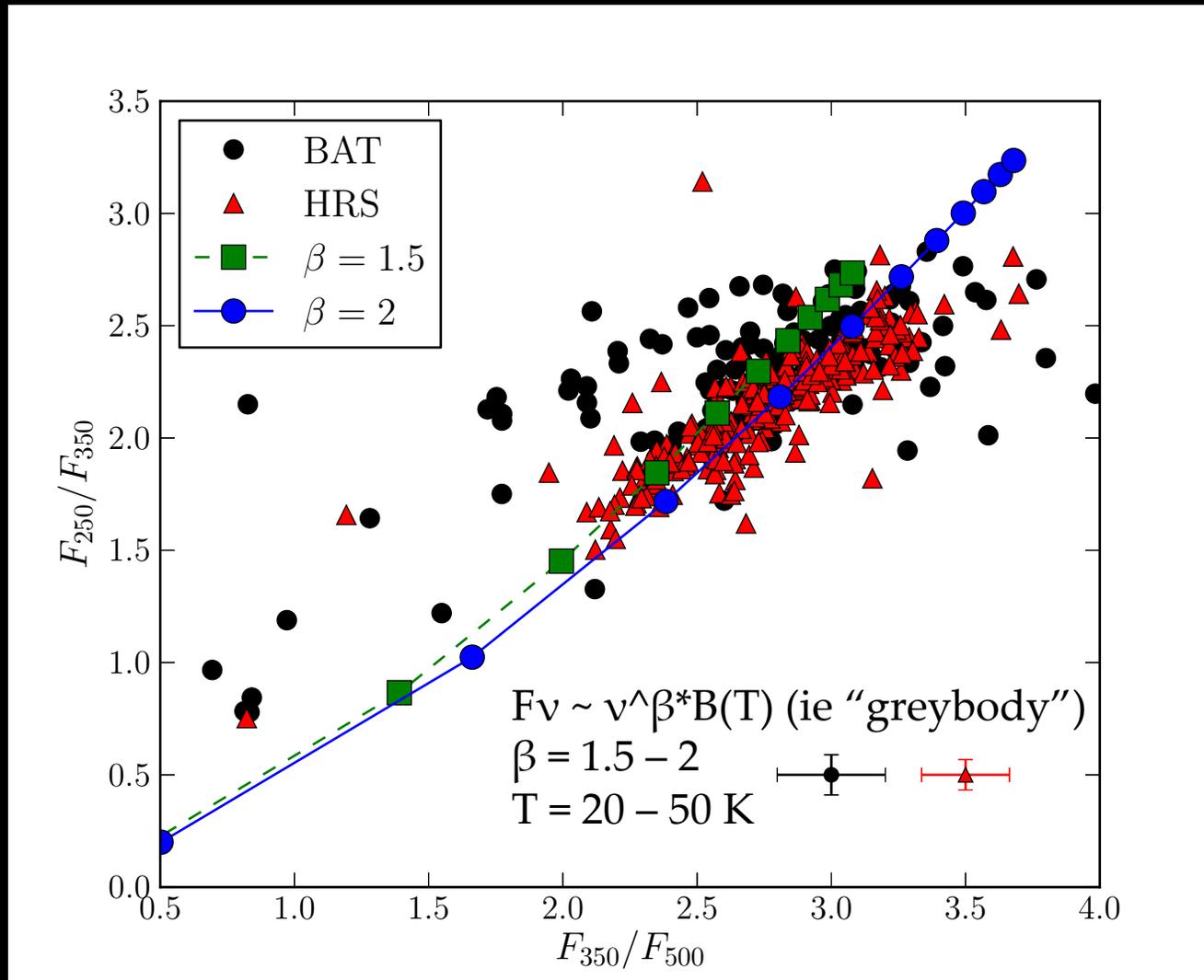
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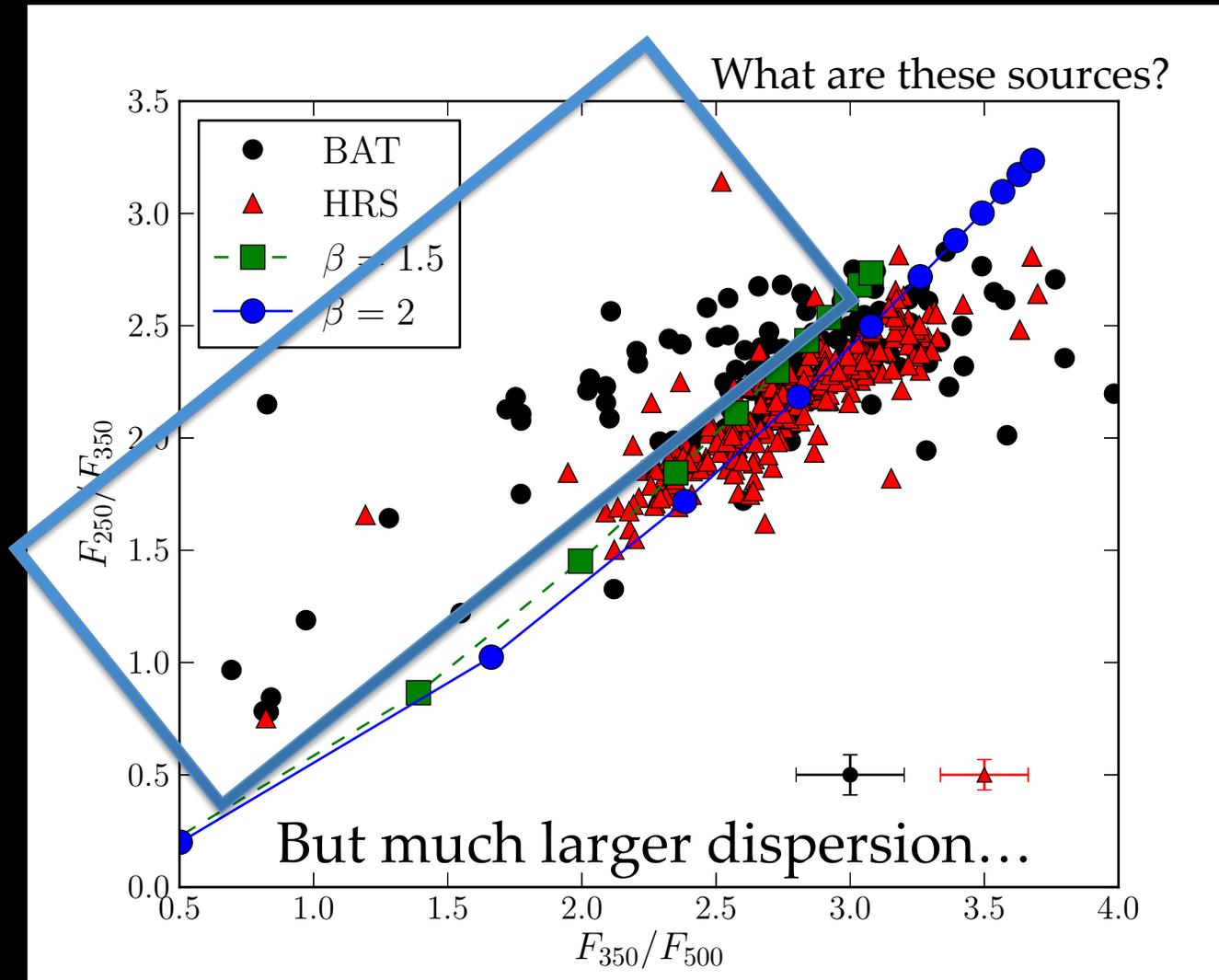
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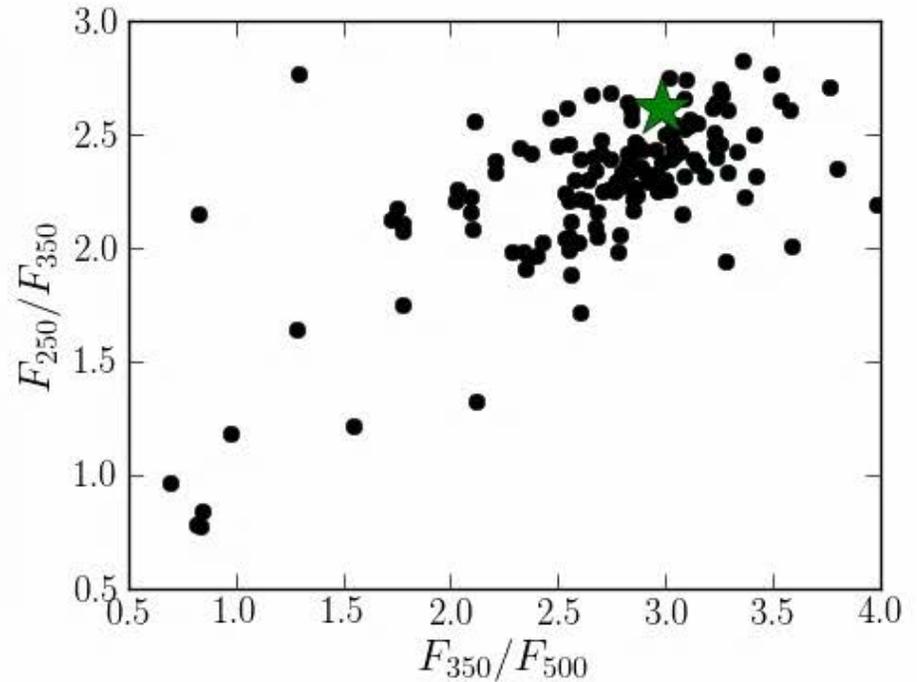
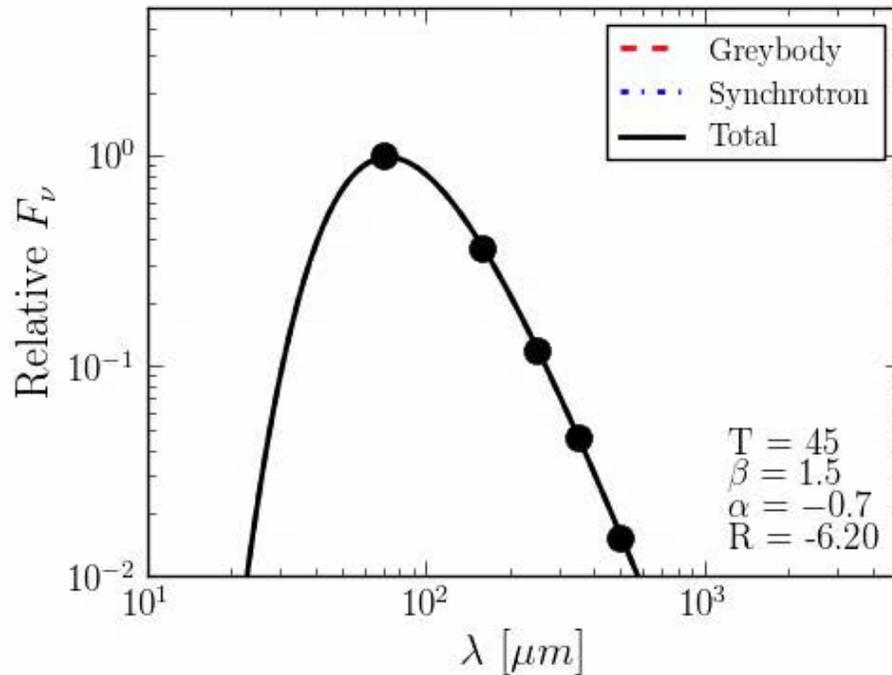
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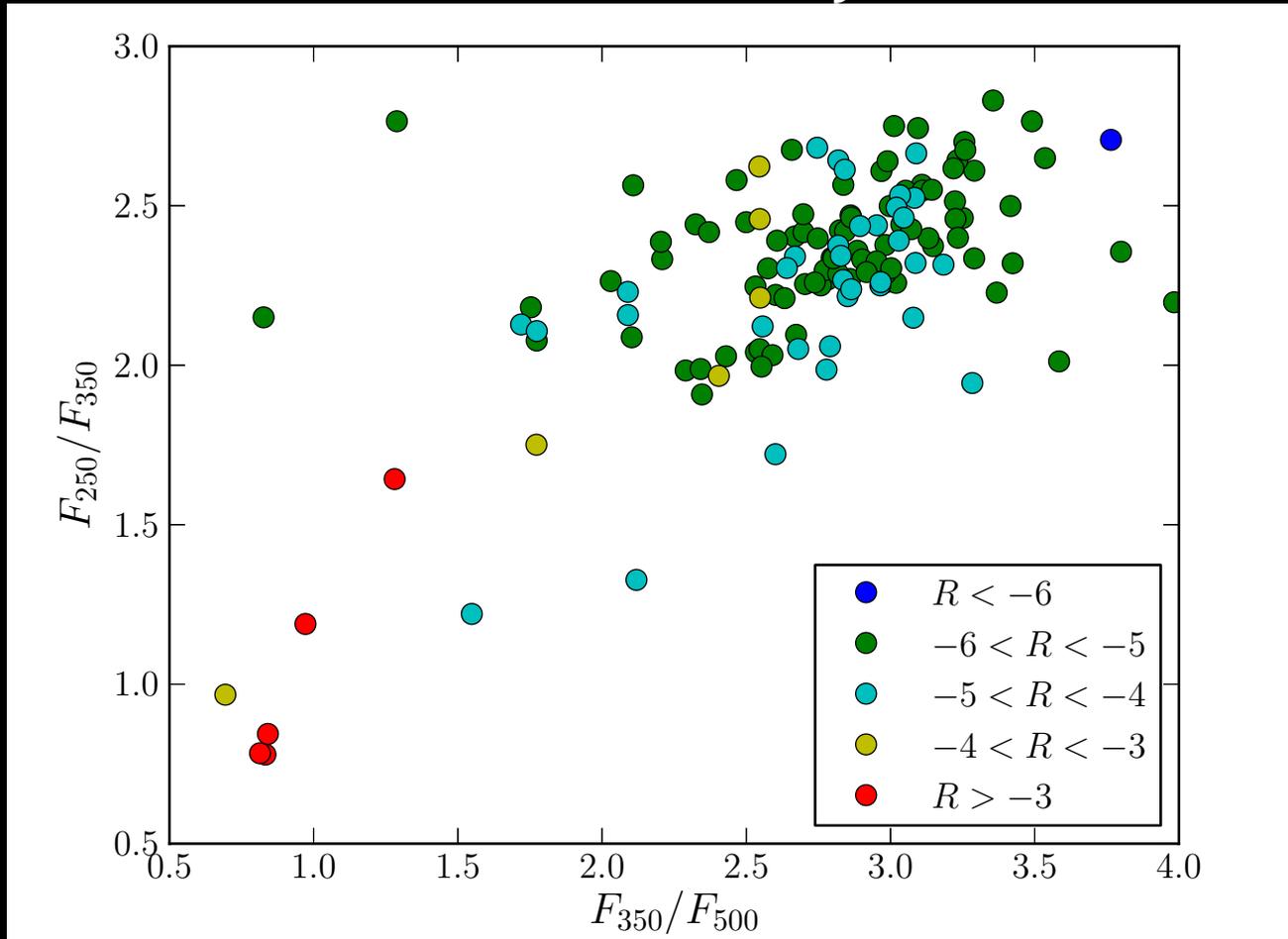
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FIR = SF + Jet?

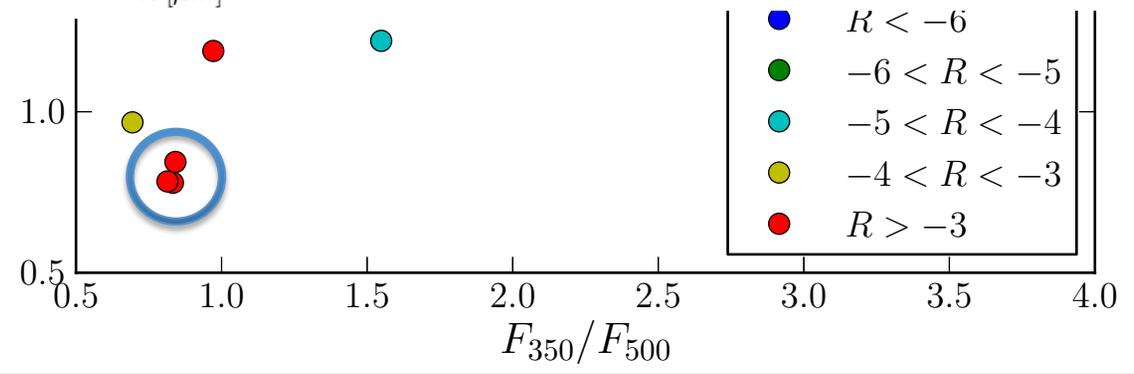
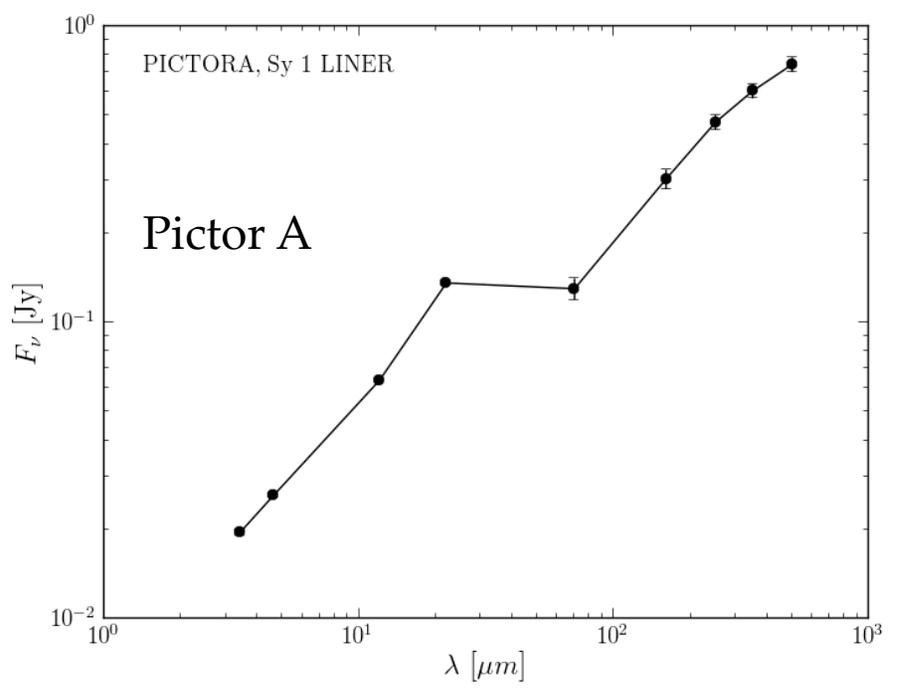
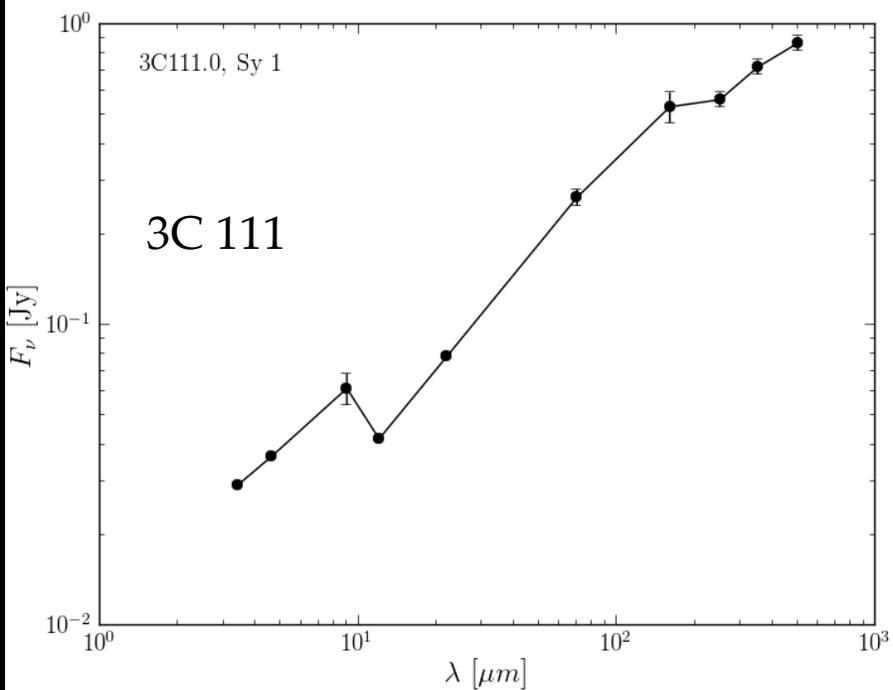


- Hypothesis: Increasing radio loudness causes change in FIR colors
- Use radio loudness parameter, $R = \log(L_{6\text{cm}}/L_{70\mu\text{m}})$

FIR = SF + Jet?

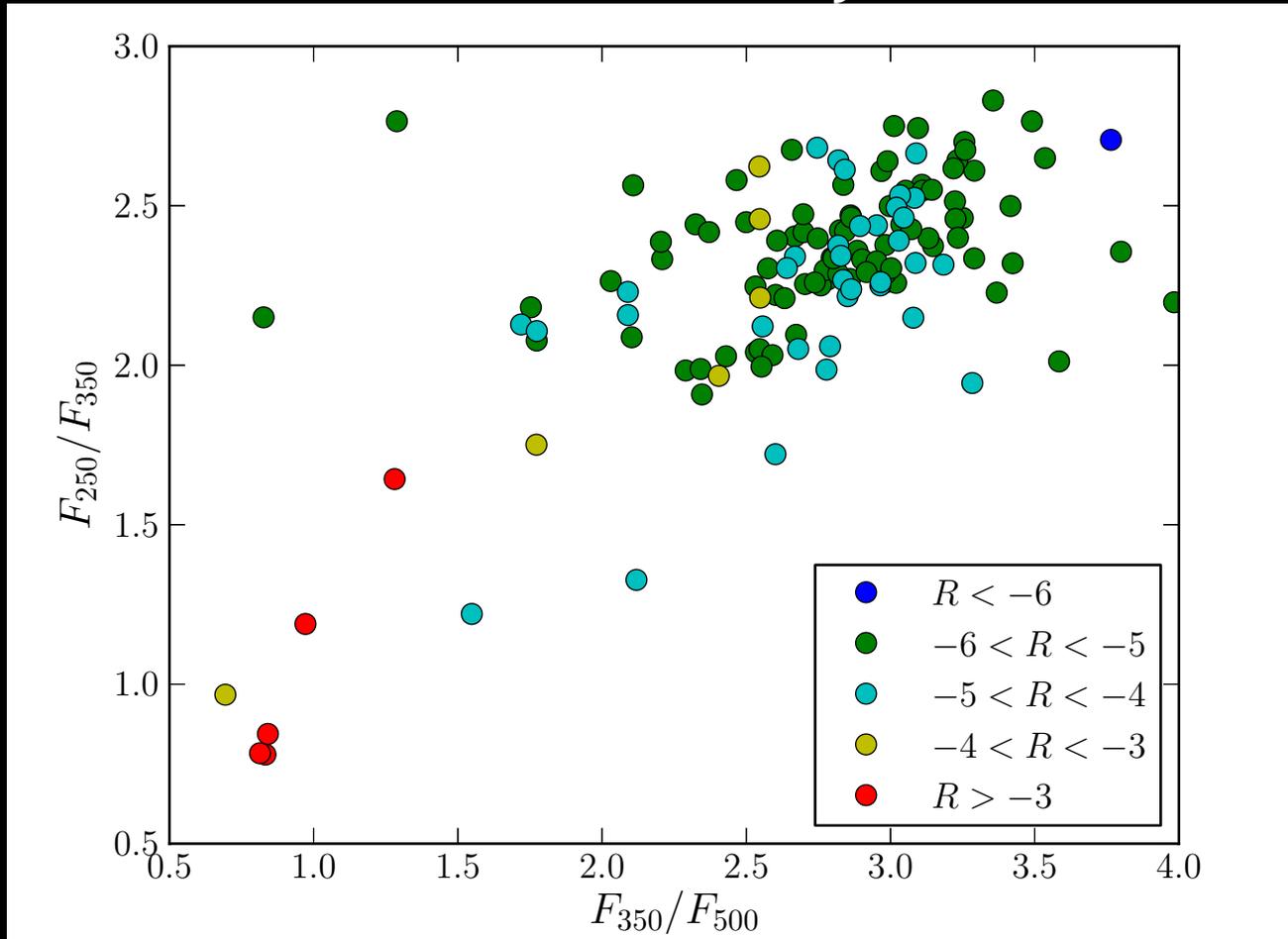


- Determined R from archival radio fluxes (NVSS, SUMSS)
- Radio loudness only explains most extreme sources (yellow and red)



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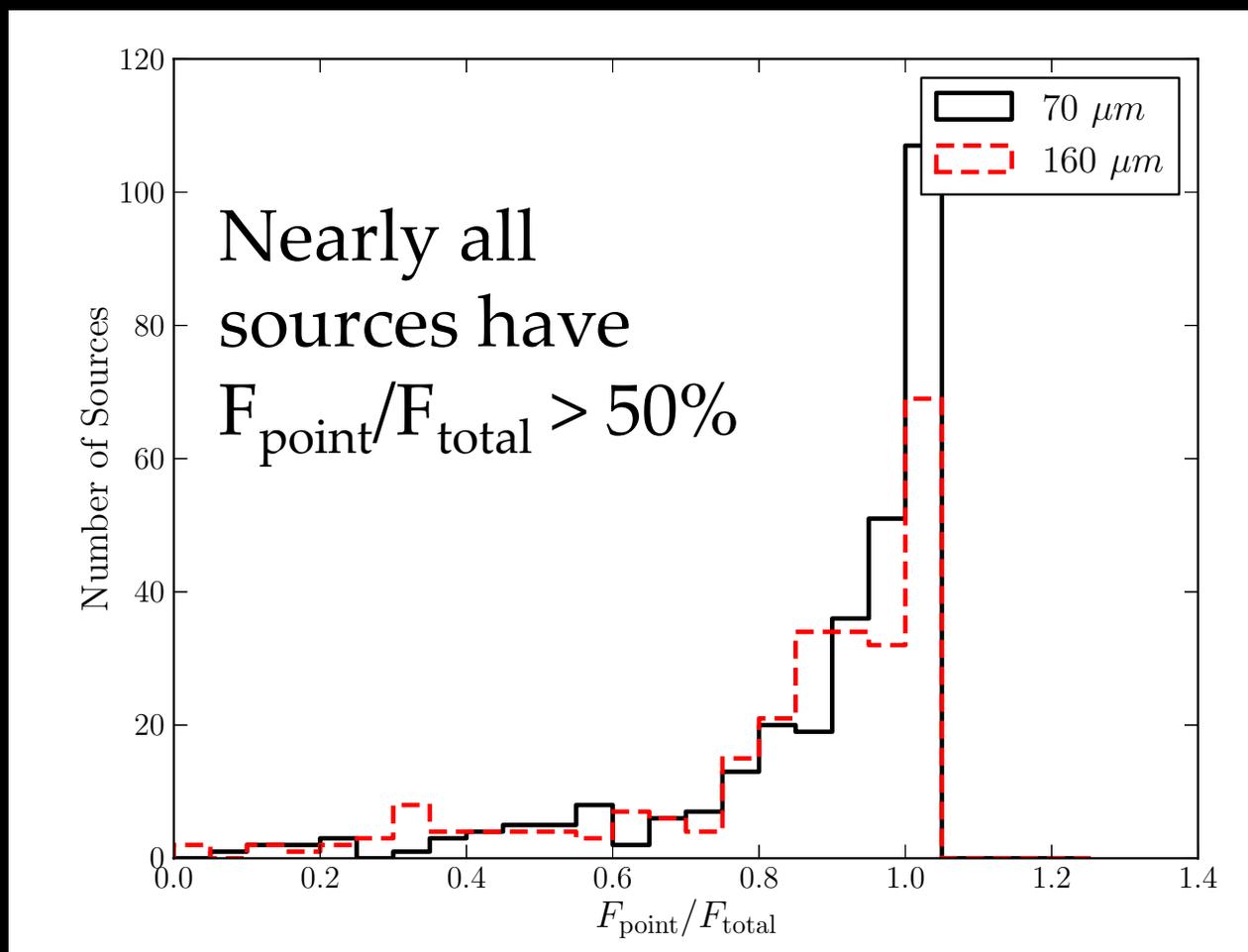
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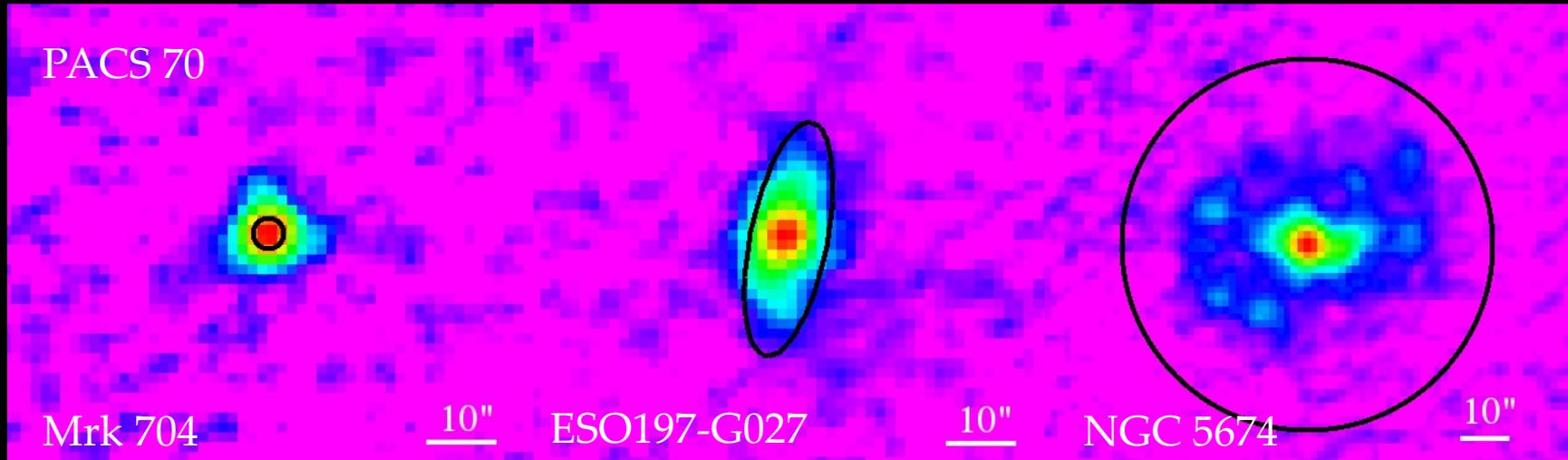
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Point Source Contribution to FIR



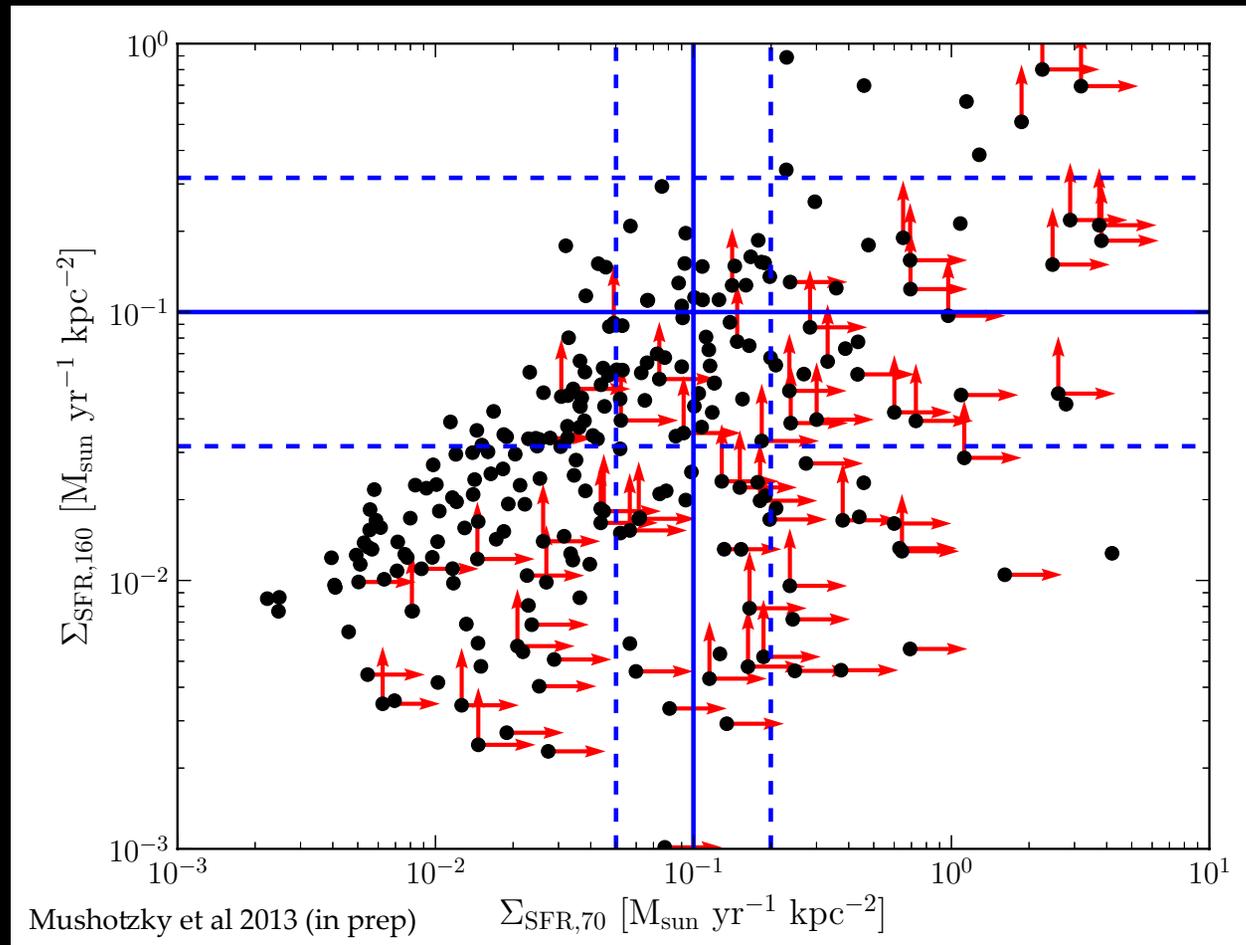
F_{point} = Flux within small point source aperture
6" for 70 μm , 12" for 160 μm

Measuring SFR density



- Used GALFIT (Peng+ 2002) with Gaussian model or aperture radius to estimate FIR sizes of sources
- Upper limits for point sources determined by increasing FWHM of Gaussian until $\Delta\chi^2 = 3\sigma$
- Monochromatic SFR calibrations from Calzetti et al. 2010
- $\text{SFR} \sim 0.1 - 100 M_{\text{sun}} \text{yr}^{-1}$

Starburst-driven Winds in AGN?



70 μm : 35 – 55% $> 0.1 \text{ M}_{\text{sun}} \text{ yr}^{-1} \text{ kpc}^{-2}$ (Heckman 2002 threshold)

160 μm : 20 – 30% $> 0.1 \text{ M}_{\text{sun}} \text{ yr}^{-1} \text{ kpc}^{-2}$

Large fraction of AGN could be living in nuclear starburst

Summary and Future Work

- Measured the FIR (70 – 500 μm) fluxes of a large, unbiased sample of AGN using *Herschel Space Observatory*
- FIR luminosities correlated with BAT luminosity for Sy 1 suggesting an AGN contribution to FIR
- SPIRE colors can separate galaxies based on increased radio loudness
- SFR density $>$ Heckman 2002 threshold for large fraction of AGN

Work in progress...

- Full SED modeling to determine AGN contribution
- Determination of AGN bolometric corrections