Selecting Seyfert galaxies with nuclear AGN-dominated far-infrared emission

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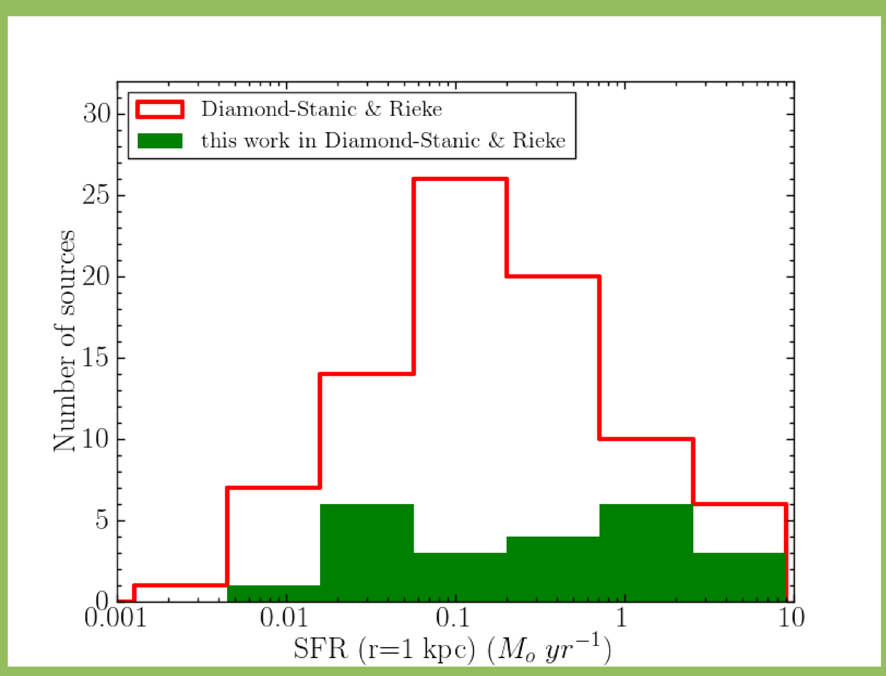
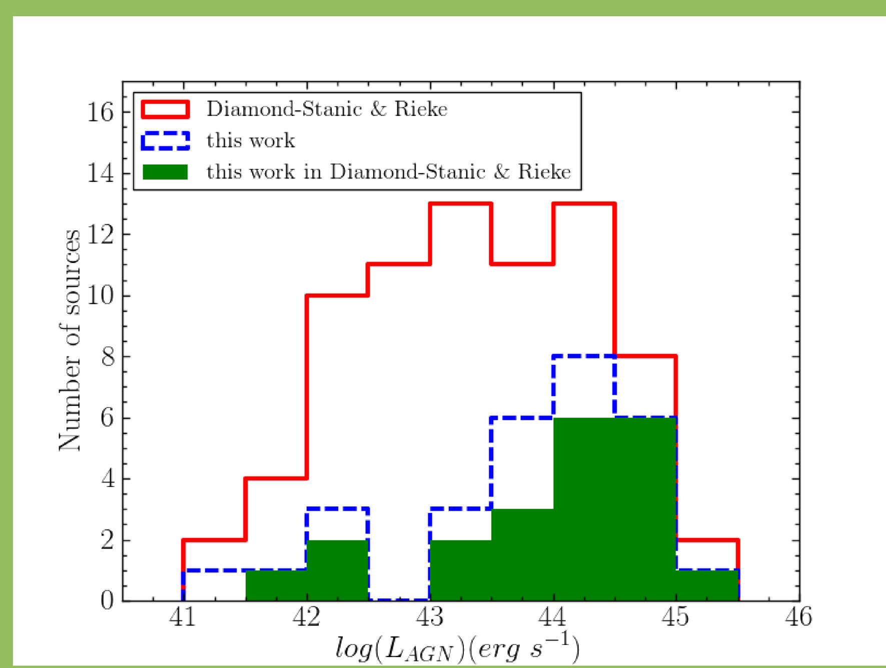
(based on García-González J. et al., 2016, MNRAS, 458, 4512)

Abstract: **We present far-infrared (FIR) 70 − 500 µm imaging observations obtained with Herschel/PACS and SPIRE of 33 nearby (median distance of 30 Mpc) Seyfert galaxies from the Revised Shapley-Ames (RSA) catalogue. We obtain the FIR nuclear (r = 1 kpc and r = 2 kpc) and integrated spectral energy distributions (SEDs). We estimate the unresolved nuclear emission at 70 µm and we fit the nuclear and integrated FIR SEDs with a grey body model. We find that the integrated FIR emission of the RSA Seyferts in our sample is dominated by emission from the host galaxy, with dust properties similar to those of normal galaxies (non AGN). We use four criteria to select galaxies whose nuclear 70 µm emission is dominated by the AGN: (1) elevated 70/160 µm flux ratios, (2) spatially resolved, high dust temperature gradient, (3) 70 µm excess emission with respect to the fit of the FIR SEDs with a grey body, and (4) excess of nuclear SFR obtained from 70 µm over SFR from mid-infrared indicators. 16 galaxies (48 per cent of the initial sample) satisfy at least one of these conditions, whereas 10 satisfy half or more. After careful examination of these, we select six bona fide candidates (18 per cent of the initial sample) and estimate that ∼ 40 − 70 per cent of their nuclear (r = 1 − 2 kpc) 70 µm emission is contributed by dust heated by the AGN.**

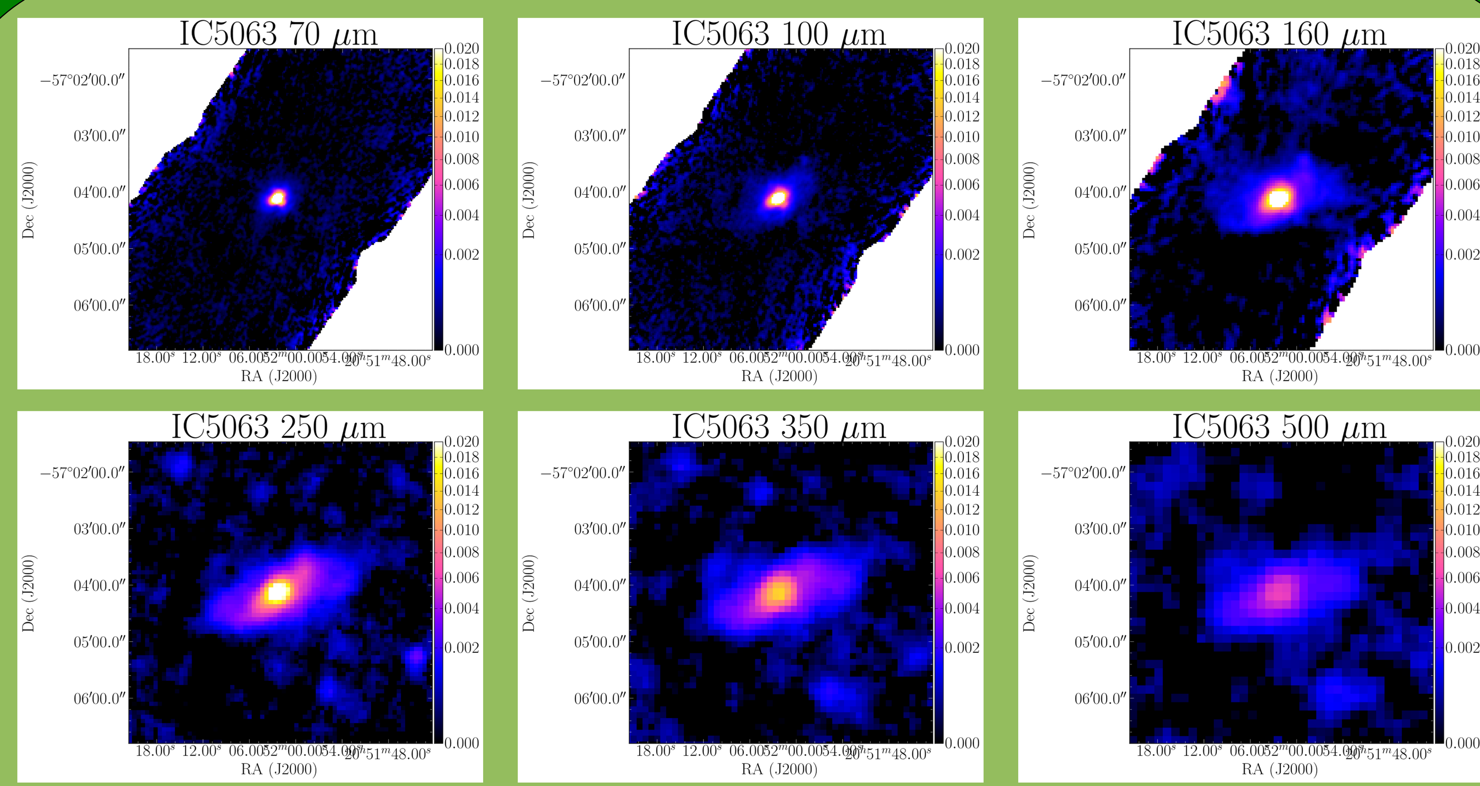
1. Comparison of our sample and the galaxies in Diamond-Stanic & Rieke (2012)





Our sample is not statistically different in terms of the the star formation rate although it only includes the most luminous AGN $L_{bol} > 10^{43}$ erg s^{-1} when compared to the Diamond-Stanic & Rieke (2012) RSA sample. This is because in general low-luminosity AGN are not bright in the mid-IR and thus few meet our requirement of having high angular resolution MIR spectroscopy obtained from the ground.

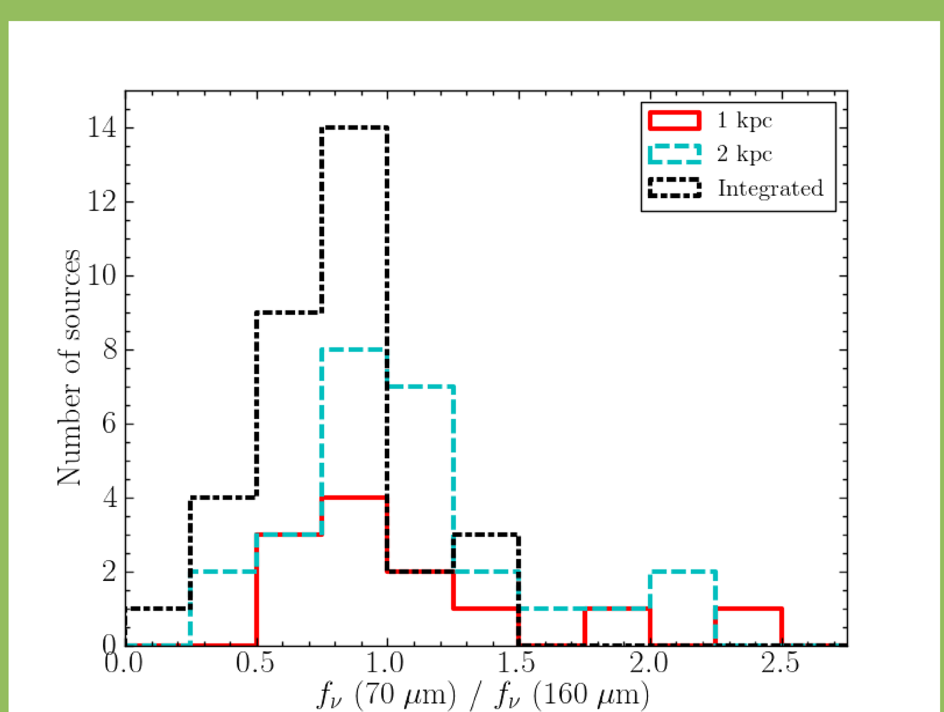
2. Example of the Herschel/PACS and SPIRE mosaics of IC 5063



We performed circular aperture photometry with radii of 1 kpc, 2 kpc and the total galaxy

3. Identifying galaxies with significant 70 µm emission due to AGN-heated dust: 4 criteria

Elevated f_ν (70 µm)/ f_ν (160 µm) flux ratios



Distribution of the f_ν (70 µm)/f_ν (160 µm) flux ratio within = 1 kpc (12 galaxies, solid red line), within r = 2 kpc (26 galaxies, dashed cyan line), and for the integrated galaxy (33 galaxies, dash–dotted black line) for the RSA Seyferts.

The flux ratios for the nuclear regions tend to be higher than those measured for the entire galaxies.

If the f_ν (70 µm)/f_ν (160 µm) flux ratios are higher than the typical values for star-forming galaxies, this might indicate that part of the nuclear 70 µm emission is due to the dust heated by the AGN instead of star formation.

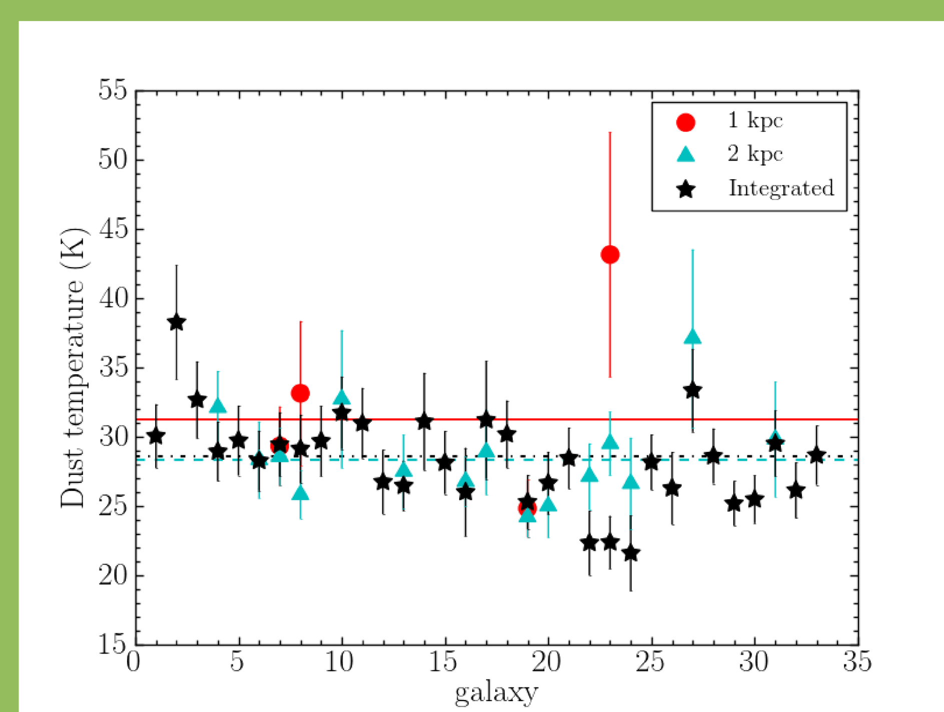
We select nine galaxies with this criterium.

Dust temperature gradient higher than typical star-forming galaxies

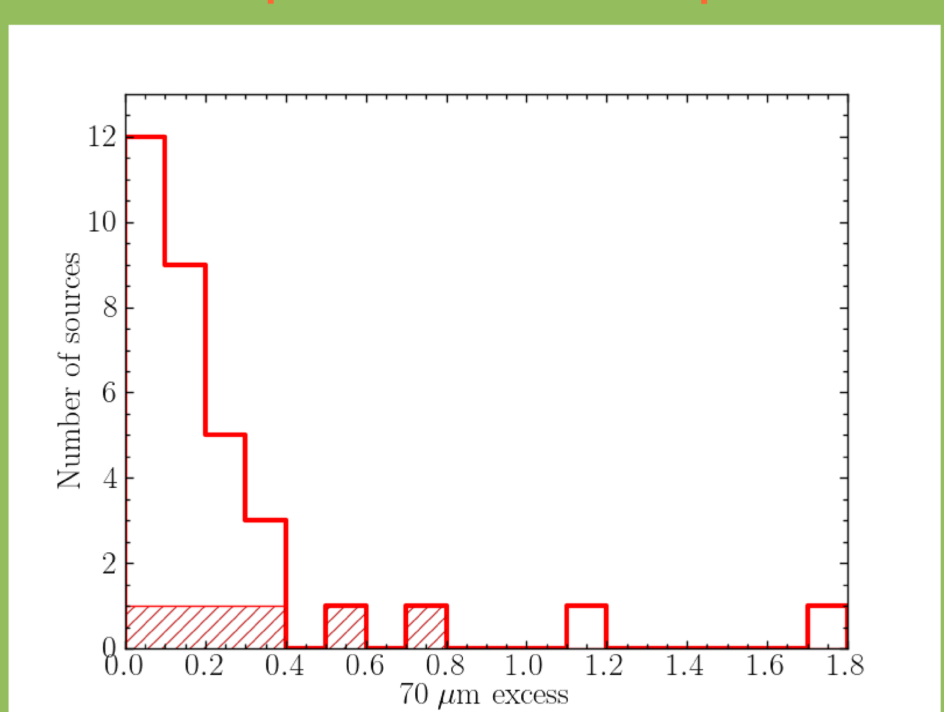
Dust temperature obtained through a grey body fit of the SED. We show the fitted temperature if available for r = 1 kpc (4 galaxies, red circles), r = 2 kpc (15 galaxies, cyan triangles), and the total galaxy (33 galaxies, black stars). The horizontal lines indicate the median values for r = 1 kpc (solid red line), r = 2 kpc (dashed cyan line) and total galaxy (dash–dotted black line).

If the nuclear dust temperature is higher than the typical values of star-forming galaxies, this may indicate that the nuclear dust is not only heated by star forming but also by the AGN.

We select three galaxies with higher dust temperature gradient than the typical values in our sample.



Excess 70 µm emission with respect to the fit of the FIR SEDs with a grey body



Distribution of the 70 µm integrated flux excesses calculated as $\frac{f_\nu(obs) - f_\nu(model)}{f_\nu(model)}$, where the f_ν (model) is obtained through a β= 2 grey body fitting for each galaxy.

The 70 µm excess with respect to the fit of the FIR SEDs with a grey body with β = 2 could in principle indicate that this emission is not only due to star formation but that there is some contribution from the AGN.

We select seven galaxies with this criterium.

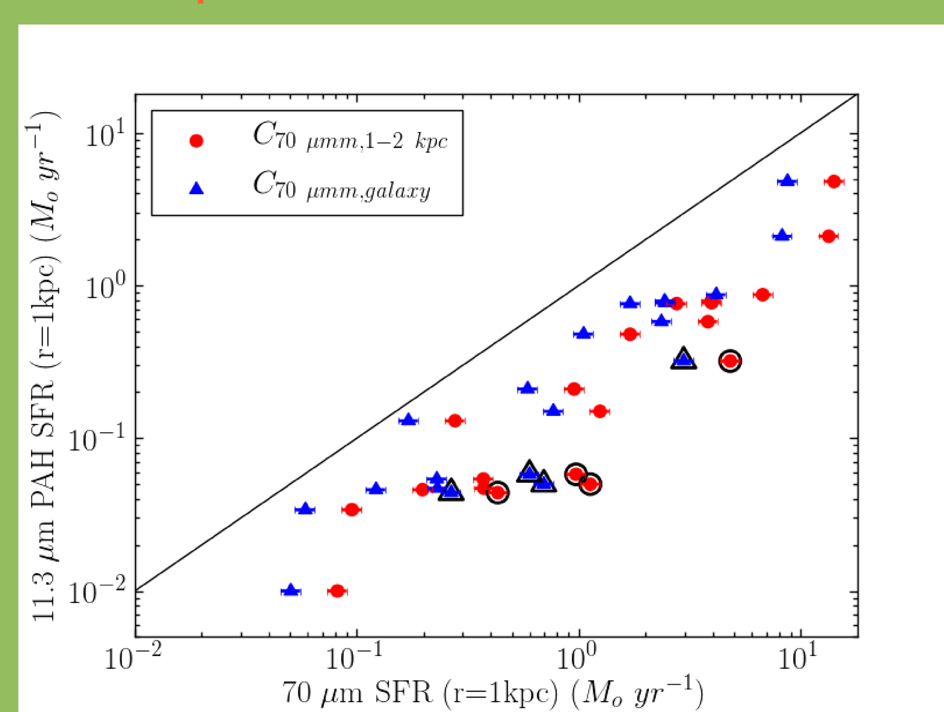
Excess of nuclear SFR obtained from 70 µm over SFR from MIR indicators

Nuclear SFR (r = 1 kpc) from the 70 µm luminosity versus the 11.3 µm PAH SFR (r = 1 kpc) from DSR2012. The black line indicates the 1:1 relation.

All the nuclear 70 µm-based SFR are systematically higher than those obtained by Diamond-Stanic & Rieke (2012) using the 11.3 µm PAH feature luminosity.

The most discrepant values of SFR could indicate that part of the nuclear 70 µm emission of these galaxies is due to the dust heated by the AGN.

We select four galaxies with this criterium.



3. Inspection of the candidates

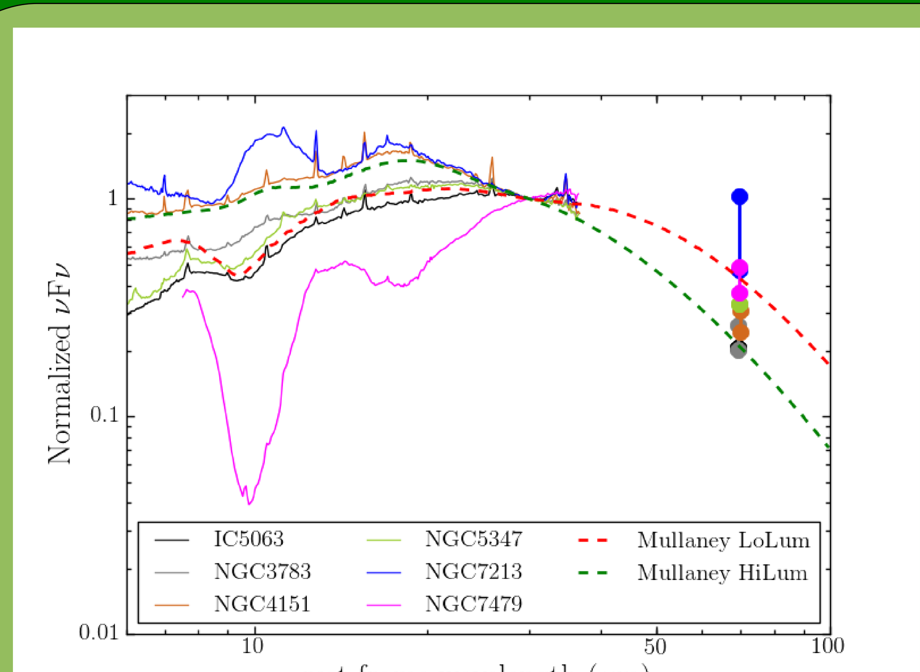
16 galaxies (48 per cent of the sample) satisfy at least one of the criteria, while 10 of them fit at least half of the criteria. To be conservative, we only consider the 10 RSA Seyferts in our sample that satisfy half or more of the criteria

We discarded two of them, NGC 4253 and Mrk 1066, as both show 11.3 µm PAH emission in the inner 0.5 arcsec and high SFR within r = 1 kpc scales. This probably suggests that the elevated fν (70 µm)/fν (160 µm) flux ratios are due to strong star formation rather than AGN dominated fluxes at 70 µm.

We also discarded NGC 4579 and NGC 4725. Both galaxies show a significant excess at 70 µm with respect to the β = 2 grey body fit to the integrated SED. However, if we assumed that the excess is entirely due to dust heated by the AGN, then the AGN flux at 70 µm would be similar to the measured nuclear r = 1 kpc flux for NGC 4579 and more than 20 times brighter than that arising from the nuclear region for NGC 4725. We therefore conclude that the 70 µm nuclear emission for these two galaxies is not dominated by dust heated from the AGN.

We are left with six (18 per cent of the sample) bona fide candidates, namely, IC 5063, NGC 3783, NGC 4151, NGC 5347, NGC 7213, and NGC 7479.

4. MIR and FIR emission of the candidates to significant nuclear 70 µm AGN emission



Spitzer/IRS SL+LL spectra for the six galaxies, normalized at 30 µm, the estimated AGN 70 µm flux ranges plotted together with the average SEDs (dashed lines) of the low-luminosity and high-luminosity AGN of Mullaney et al. (2011), all of them normalized at 30 µm. All our candidates have MIR and 70 µm AGN emission entirely consistent with the empirically determined low- and high-luminosity AGN templates of Mullaney et al. (2011).

We used the different criteria to estimate the range of the AGN flux at 70 µm. For each galaxy we only used the criteria satisfied. We estimated that ∼ 40 − 70 per cent of their nuclear (r = 1 − 2 kpc) 70 µm emission is contributed by dust heated by the AGN.

CONCLUSIONS: The four criteria defined in this work provide a good way to select statistically Seyferts with significant contribution of the AGN at 70 µm using Herschel data. After the inspection of the 10 RSA Seyfert galaxies that satisfy half or more of the criteria, we select six (18 per cent of the sample) bona fide candidates and estimate that ∼ 40 − 70 per cent of their nuclear (r = 1 − 2 kpc) 70 µm emission is contributed by dust heated by the AGN. Our FIR method to select galaxies whose nuclear 70 µm emission has a significant AGN contribution for optically selected Seyferts produces similar results to the Mullaney et al. (2011) MIR based method for X-ray-selected AGN, in terms of the fraction of galaxies dominated by the AGN at 70 µm and the spectral shapes between 5 and 70 µm.

REFERENCES: Diamond-Stanic A. M., Rieke G. H., 2012, ApJ, 746, 168; García-González J. et al., 2016, MNRAS, 458, 4512; Mullaney J. et al., 2011, MNRAS, 414, 1082