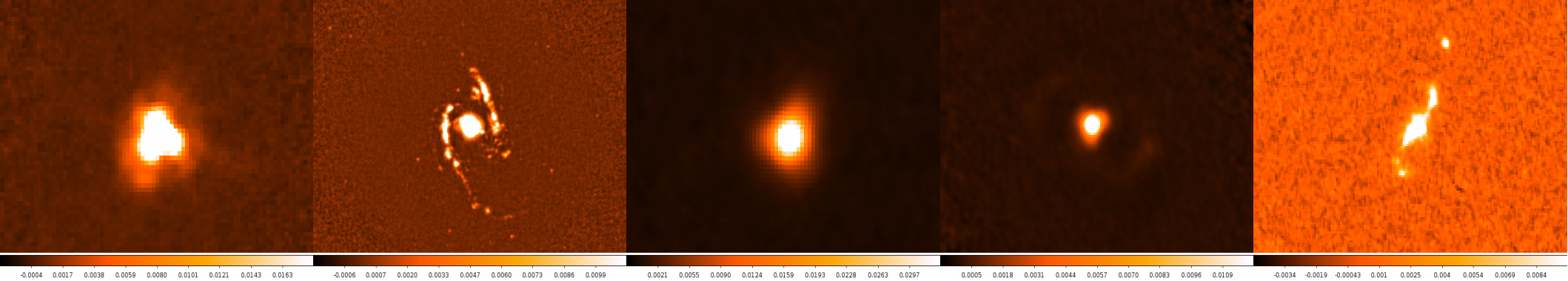


The nuclear and integrated FIR emission of Seyfert galaxies

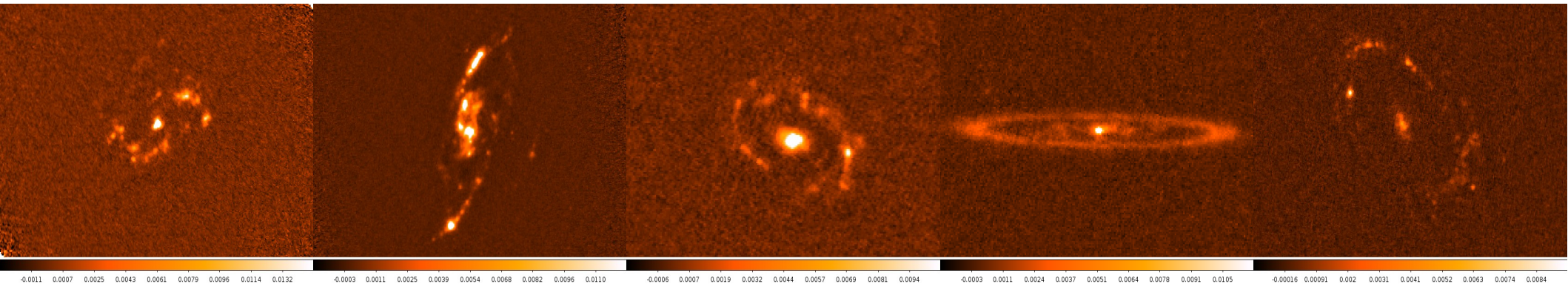
Judit García González

Collaborators:
Almudena Alonso Herrero
Antonio Hernán Caballero
Miguel Sánchez Portal
Los Piratas

IFCA
Instituto de Física de Cantabria

CSIC
Consejo Superior de Investigaciones Científicas

UC
Universidad de Cantabria

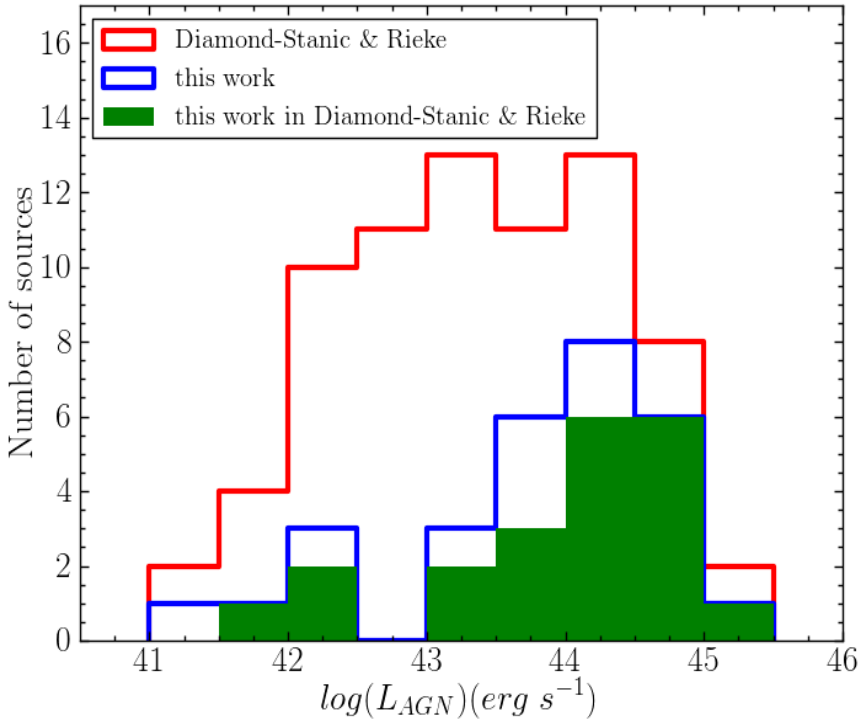


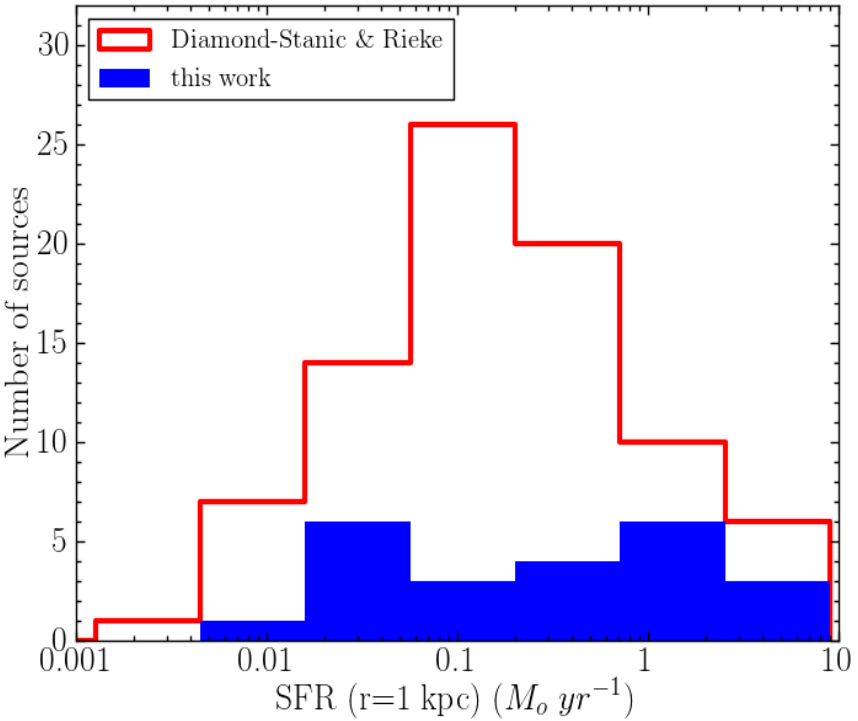
Goals

- Study the FIR nuclear and integrated emission of local Seyfert galaxies taking advantage of Herschel angular resolution.
- Select galaxies with AGN-dominated nuclear 70 μm emission. Four criteria:
  - Elevated 70/160 μm flux ratios with respect to the typical colours of star forming galaxies.
  - Nuclear dust temperature higher than typical values of star forming galaxies.
  - 70 μm excess emission with respect to the fit of the FIR SEDs with a grey body.
  - Comparison of nuclear SFR obtained from 70 μm and mid-IR indicators.

The sample and observations

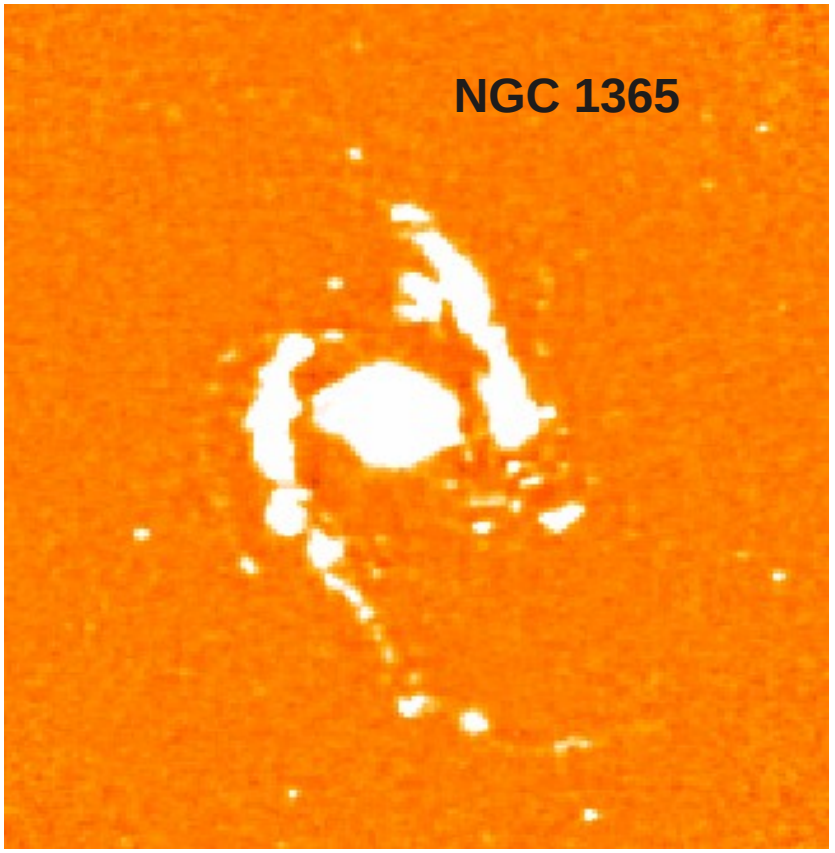
- 33 local Seyfert galaxies from the Revised Shapley-Ames catalogue (RSA sample)

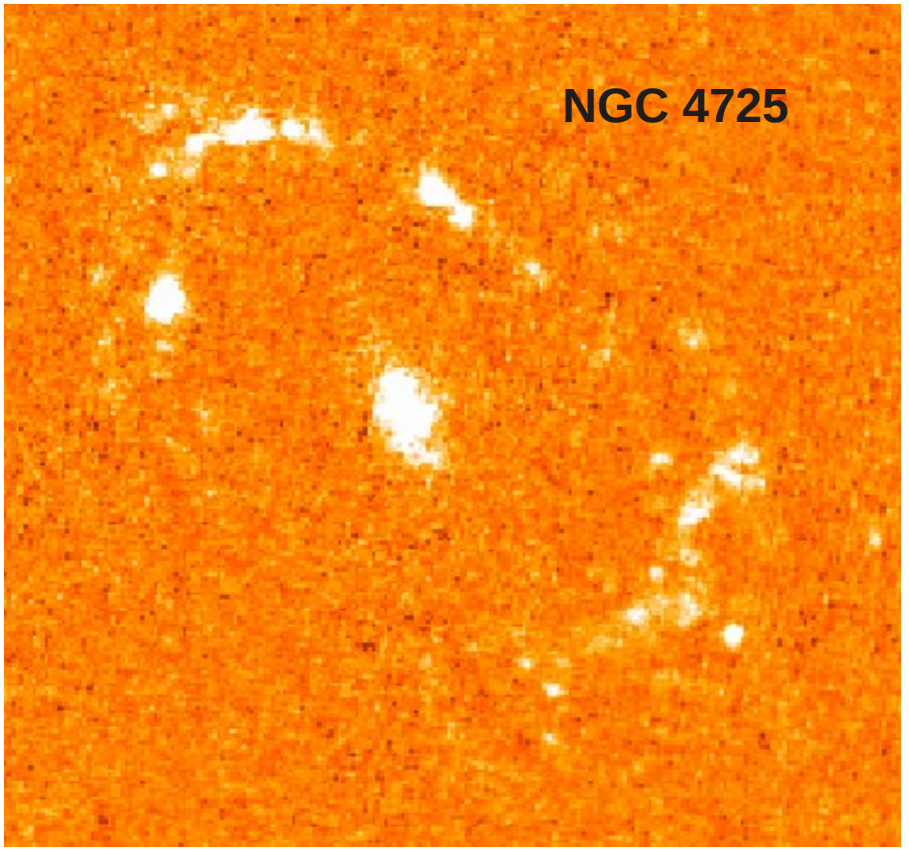




Median distance of 30 Mpc.
Angular resolution of 5.6 arcsec at 70 μm, median physical resolution of 0.8 kpc.

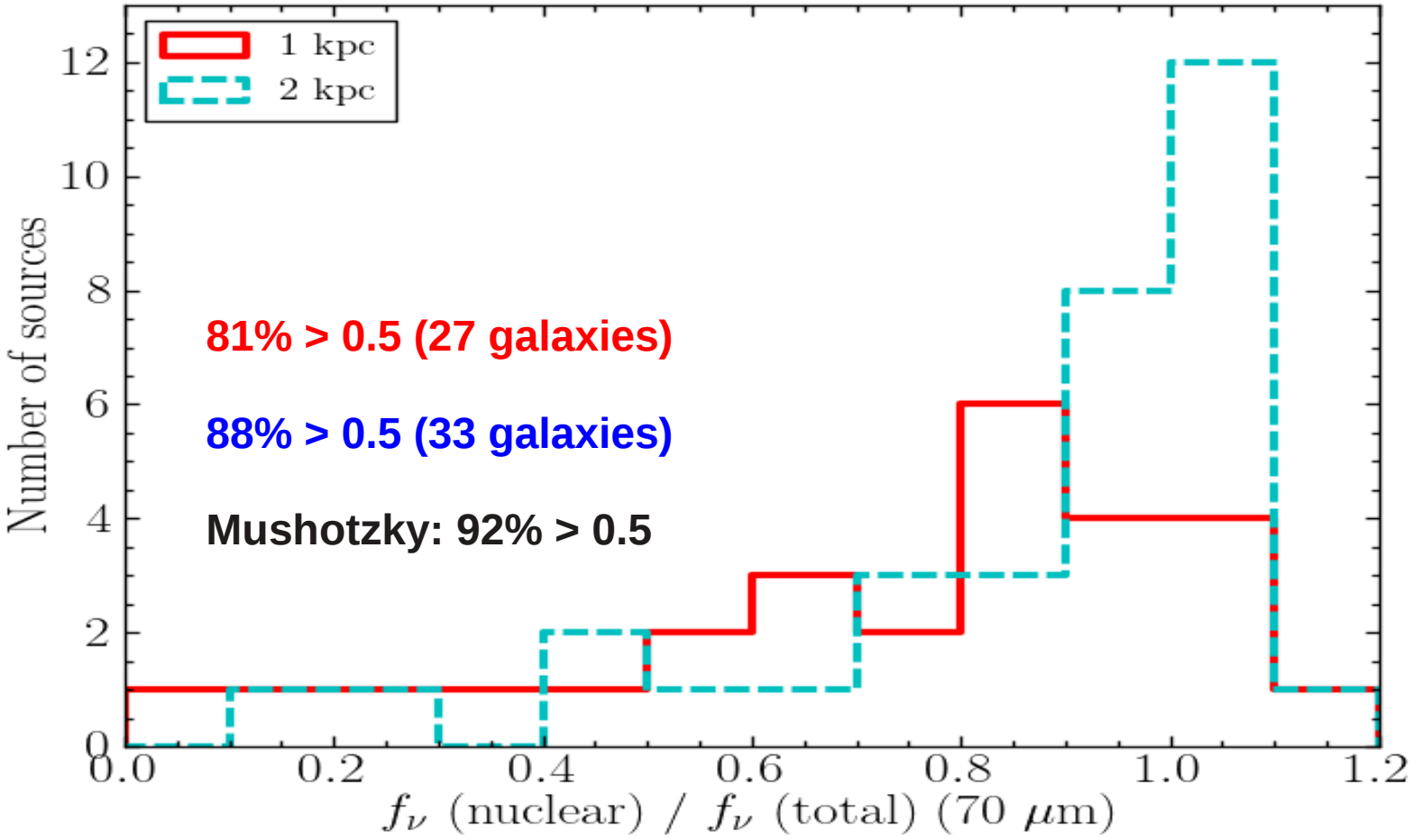
The sample and photometry





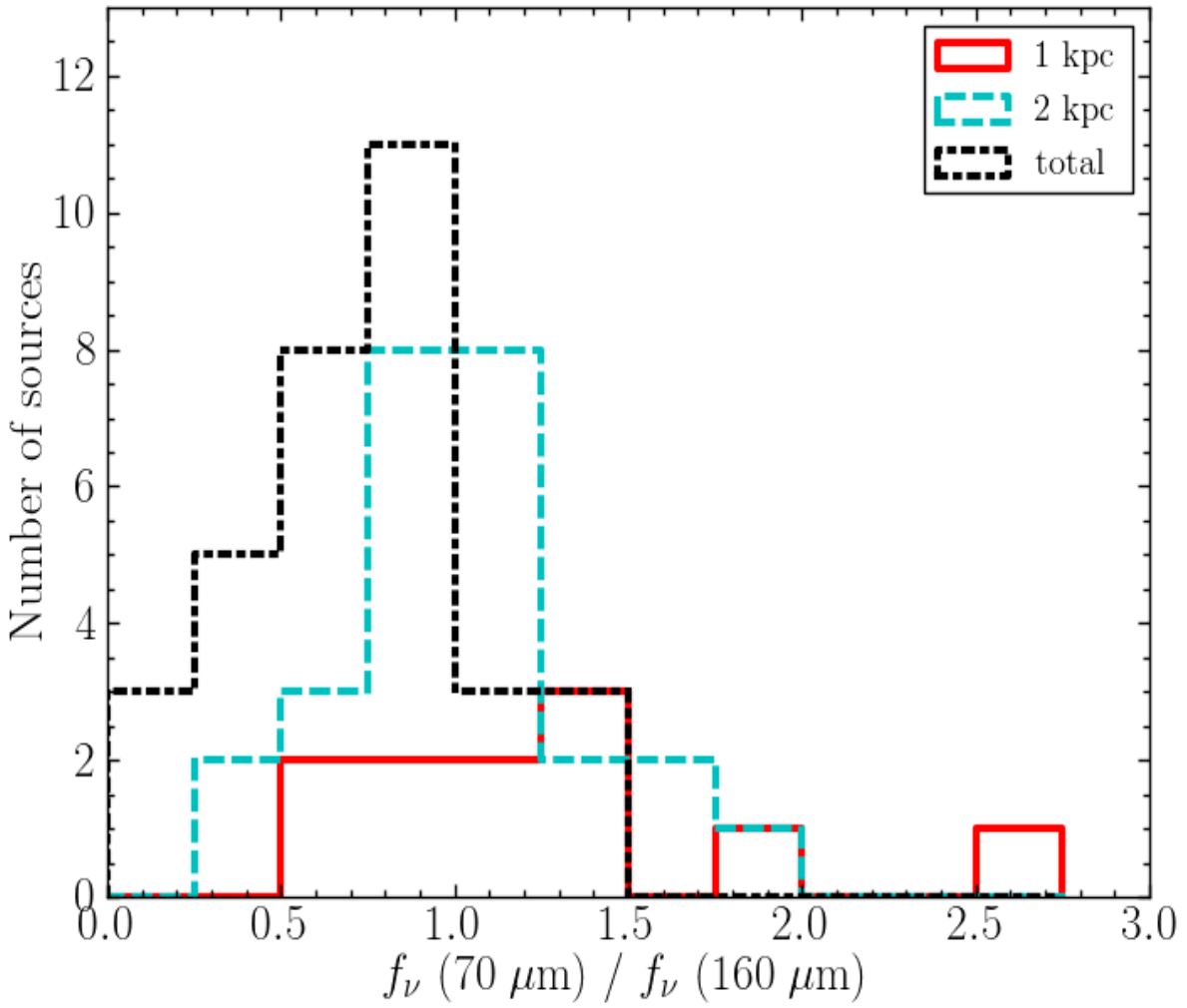
Aperture photometry for a radius of 1 kpc, 2 kpc, and the total galaxy (apertures with a diameter higher than 1.5 times the FWHM of each band)

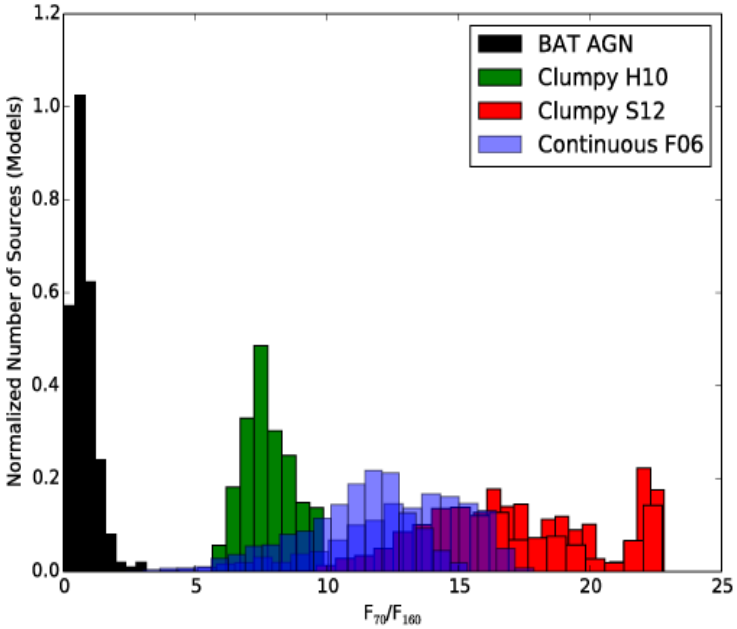
Results: unresolved 70 micron emission



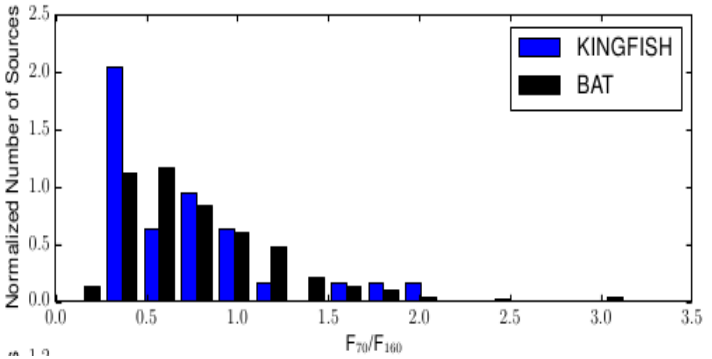
39 % are point-like at 70 microns (FWHM < 6”) ⇒ the 70 μm emission originates in regions with sizes (diameters) of less than ~ 0.5 − 2 kpc

Results: 70/160 μm flux ratios



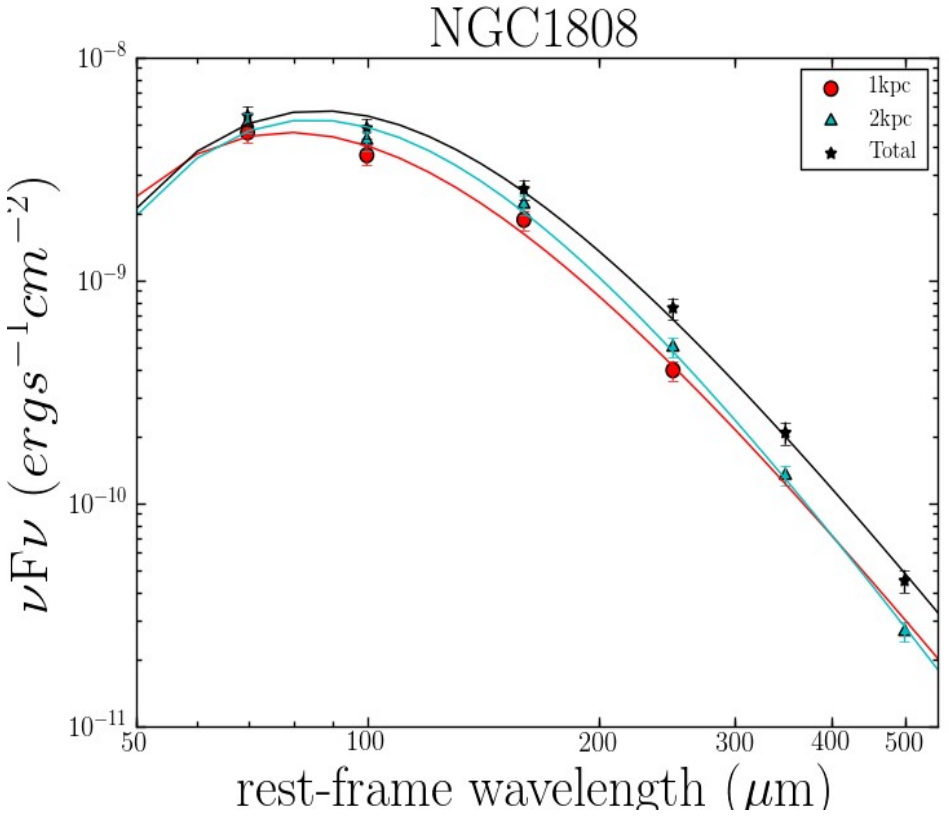


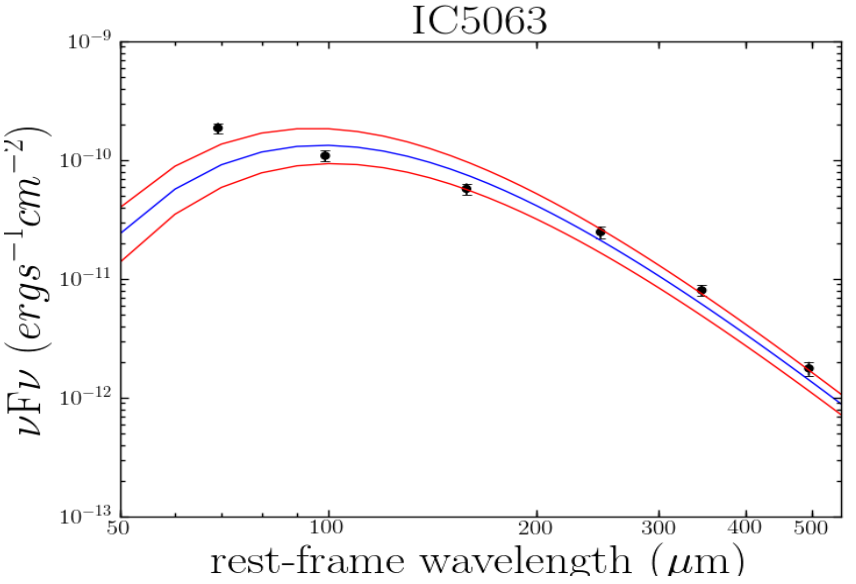
Meléndez et al. (2014)



K-S test: 70/160 μm flux ratios of our galaxies, the BAT AGN sample and the normal galaxies are statistically indistinguishable.

Grey-body fitting

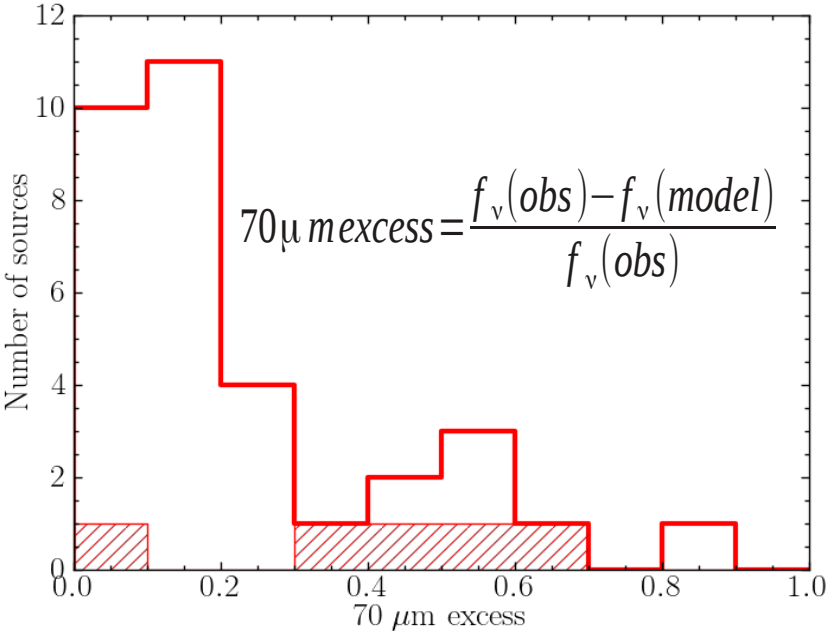




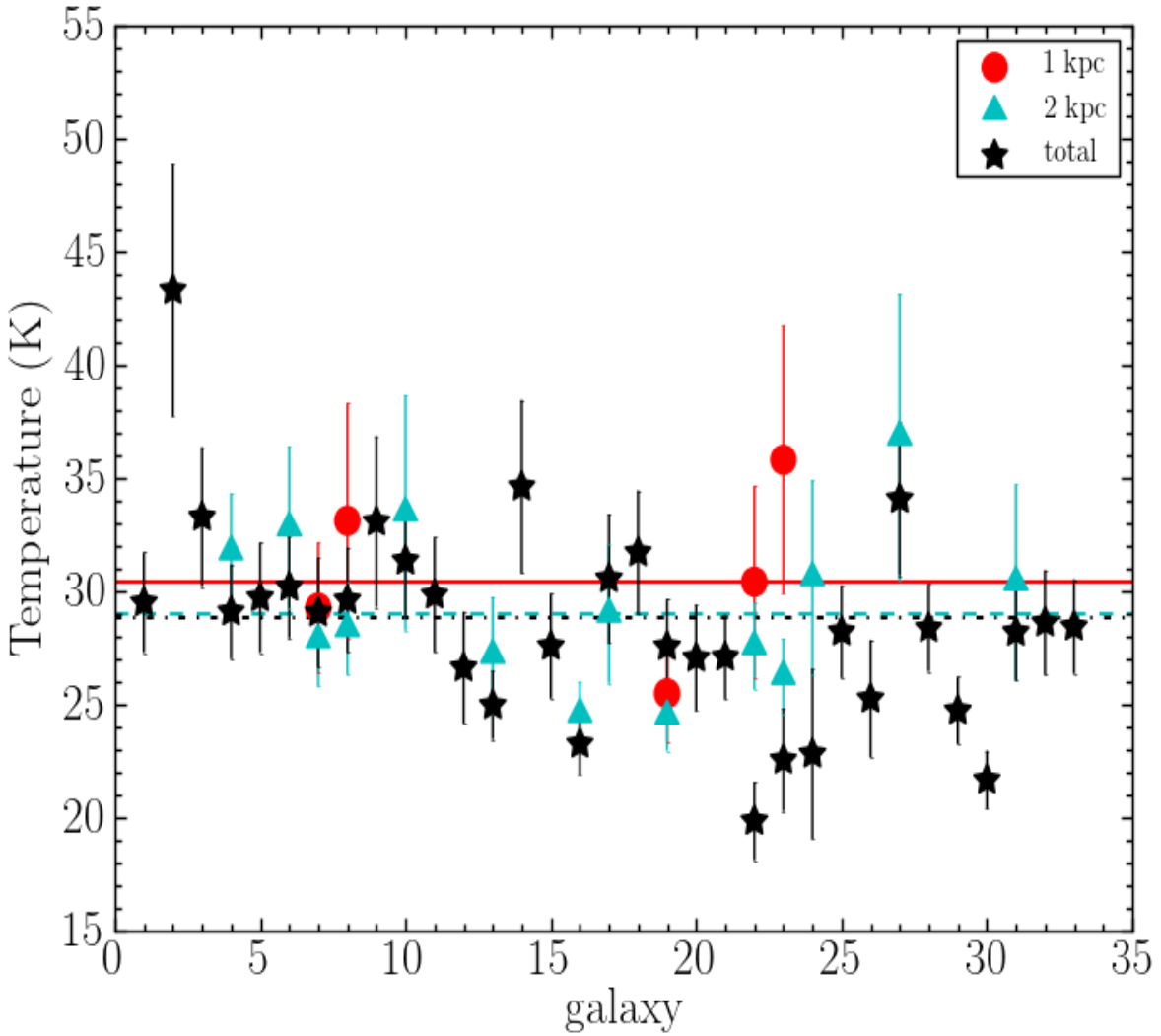
Grey-body with dust emissivity β=2

Fits are always better without 70 μm data point

Evidence of AGN dust heating *contamination* at 70 μm?



Results: grey-body fitting



Free parameter β

Dust temperature decreases from 1 kpc to 2 kpc and to integrated

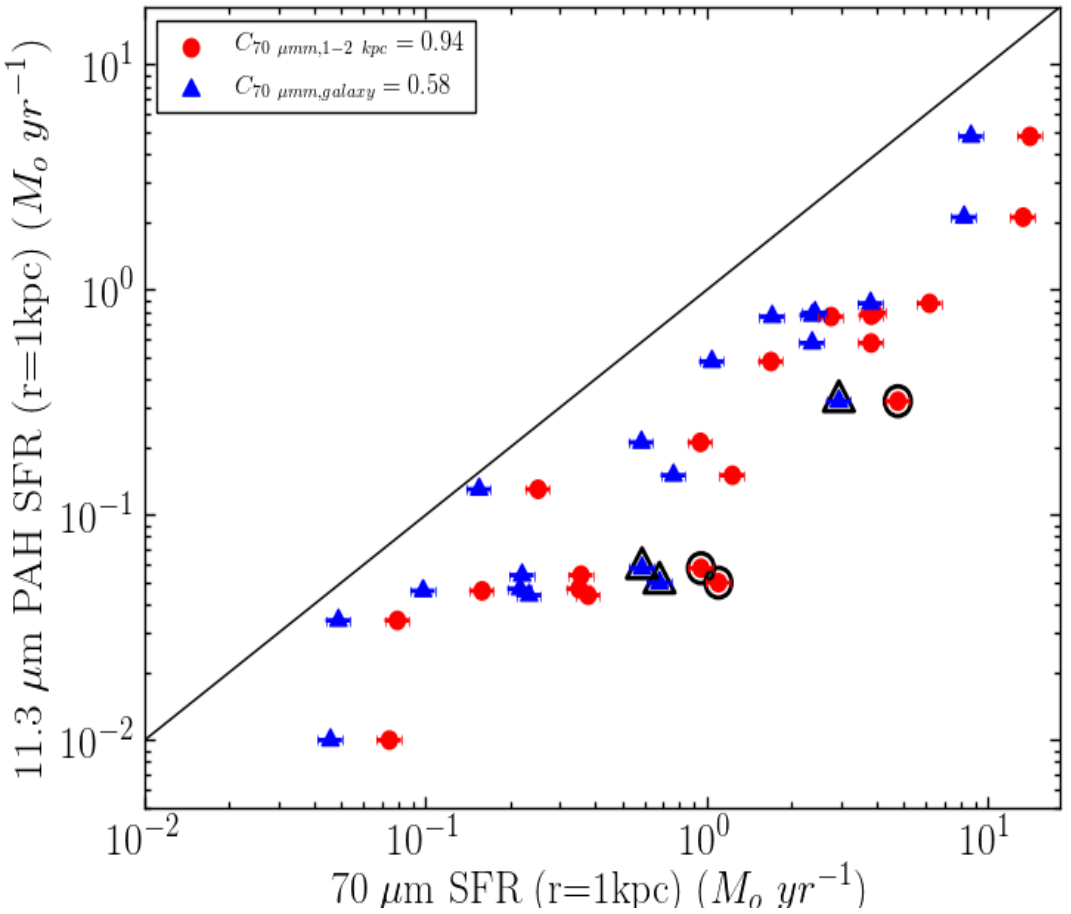
Median temperature:

1 kpc: 30 K

2 kpc: 29 K

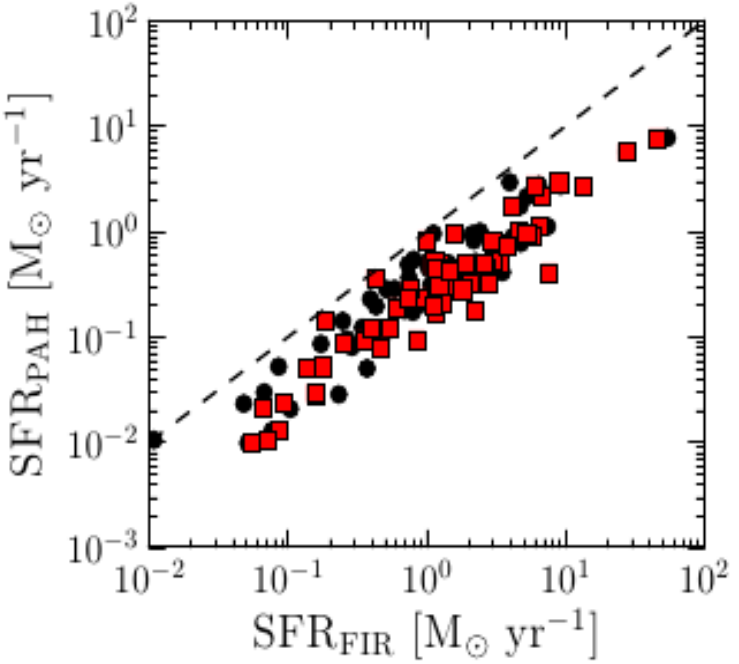
Total : 28 K

Comparison of nuclear SFR



$$SFR(70\ \mu m)(M_\odot\ yr^{-1}) = C_{70\ \mu m,\ region} \times 10^{-43} \times L(70\ \mu m)(erg\ s^{-1})$$

Muzotsky et al. (2014)



Discrepancy with the PAH derived SFR could be due to:

PAHs are being destroyed by the AGN.
There is a systematic in the calibrations.
There is an AGN contribution at 70 μm.
It is due to the aperture correction.

AGN-dominated nuclear 70 μm emission galaxies

- Elevated 70/160 μm flux ratios

  (8 galaxies)

- Nuclear dust temperature higher than typical star forming galaxies

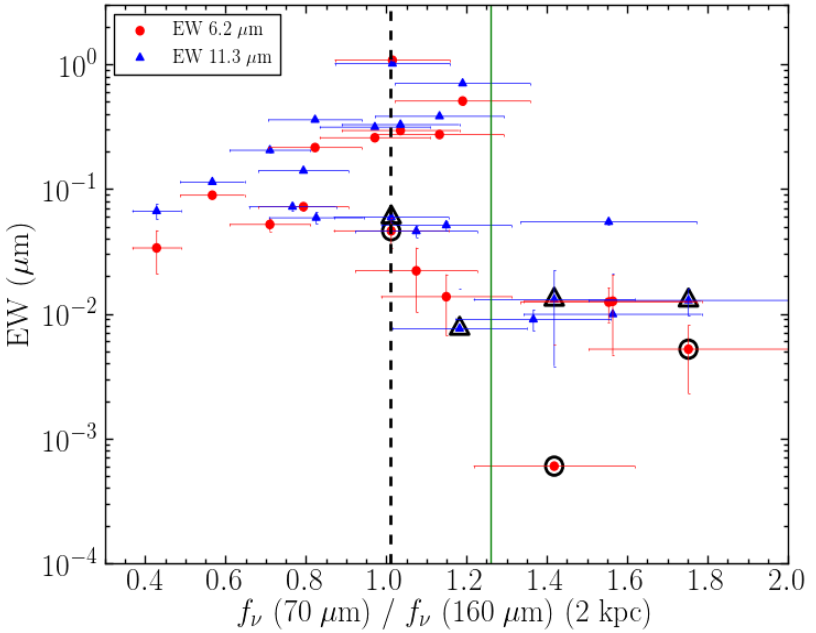
  (14 galaxies)

- 70 μm excess emission with respect to the fit of the FIR SEDs with a grey body with β=2

  (7 galaxies)

- Comparison of nuclear SFR obtained from 70 μm and mid-IR indicators

  (3 galaxies)



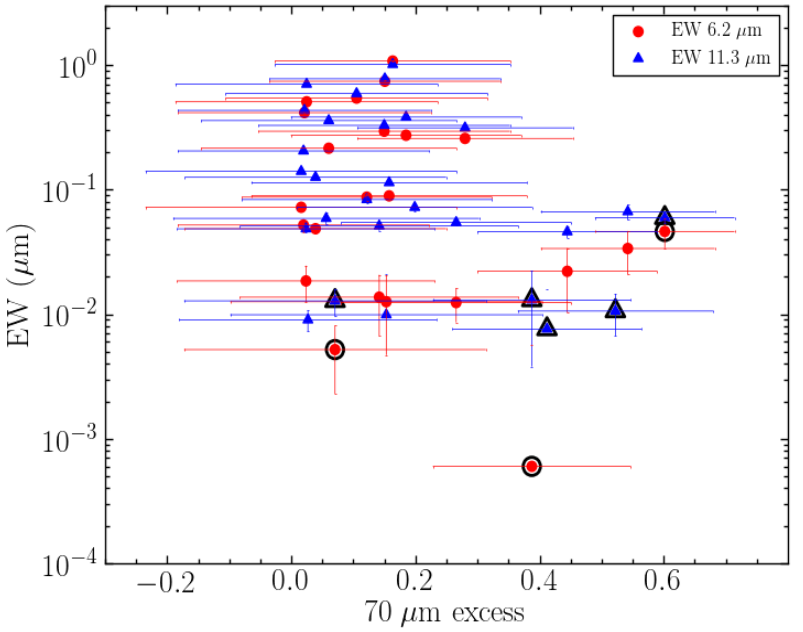


Table 7. Summary of criteria to select galaxies with a signficant AGN contribution at 70 μm. In bold are marked galaxies satisfying at least half of the criteria.

Galaxy	#1 $f_\nu(70\,\mu\mathrm{m})/f_\nu(160\,\mu\mathrm{m})$			#2 $T_{\mathrm{region}}/T_{\mathrm{tot}}$		#3	#4	criteria
	$r = 1$ kpc	$r = 2$ kpc	tot	$r = 1$ kpc	$r = 2$ kpc	70 μm excess	$\mathrm{SFR}_{70\mu\mathrm{m}}/\mathrm{SFR}_{\mathrm{D-S}}$ $r = 1$ kpc	
ESO323-G077	-	-	x	-	-	x	-	0/2
IC5063	-	-	✓	-	-	✓	-	2/2
Mrk1066	-	-	✓	-	-	x	-	1/2
NGC1068	✓	✓	x	-	x	x	-	1/3
NGC1320	-	x	x	-	-	x	-	0/2
NGC1365	x	x	x	-	x	x	x	0/4
NGC1386	x	x	x	x	x	x	x	0/4
NGC1808	x	x	x	x	x	x	-	0/3
NGC2110	-	x	x	-	-	x	-	0/2
NGC2273	-	x	x	-	x	x	x	0/4
NGC2992	-	x	x	-	-	x	x	0/3
NGC3081	-	x	x	-	-	✓	x	1/3
NGC3227	x	x	x	-	x	x	x	0/4
NGC3281	-	✓	✓	-	-	x	x	1/3
NGC3783	-	✓	x	-	-	x	✓	2/3
NGC4051	x	x	x	-	x	x	x	0/4
NGC4151	✓	✓	x	-	x	x	✓	2/4
NGC4253	-	-	✓	-	-	x	-	1/2
NGC4258	x	x	x	x	x	✓	x	1/4
NGC4388	-	x	x	-	-	x	x	0/3
NGC4507	-	-	x	-	-	x	-	0/2
NGC4579	x	x	x	✓	✓	✓	x	2/4
NGC4594	x	x	x	✓	x	x	x	1/4
NGC4725	-	x	x	-	✓	✓	x	2/4
NGC5135	-	-	x	-	-	x	-	0/2
NGC5347	-	x	x	-	-	✓	-	1/2
NGC5506	-	✓	✓	-	x	x	x	1/4
NGC7130	-	-	x	-	-	x	-	0/2
NGC7172	-	x	x	-	-	x	x	0/3
NGC7213	-	x	x	-	-	x	x	0/3
NGC7465	-	x	x	-	x	x	-	0/3
NGC7479	-	x	x	-	-	✓	✓	2/3
NGC7582	x	x	x	-	-	x	x	0/3

Table 7. Summary of criteria to select galaxies with a signficant AGN contribution at 70 μm. In bold are marked galaxies satisfying at least half of the criteria.

Galaxy	#1 $f_\nu(70\,\mu m)/f_\nu(160\,\mu m)$ $r = 1$ kpc	$r = 2$ kpc	tot	#2 T_{region}/T_{tot} $r = 1$ kpc	$r = 2$ kpc	#3 70 μm excess	#4 $SFR_{70\mu m}/SFR_{D-S}$ $r = 1$ kpc	criteria
ESO323-G077	-	-	x	-	-	x	-	0/2
IC5063	-	-	✓	-	-	✓	-	2/2
~~**Mrk1066**~~	-	-	✓	-	-	x	-	1/2
NGC1068	✓	✓	x	-	x	x	-	1/3
NGC1320	-	x	x	-	-	x	-	0/2
NGC1365	x	x	x	-	x	x	x	0/4
NGC1386	x	x	x	x	x	x	x	0/4
NGC1808	x	x	x	x	x	x	-	0/3
NGC2110	-	x	x	-	-	x	-	0/2
NGC2273	-	x	x	-	x	x	x	0/4
NGC2992	-	x	x	-	-	x	x	0/3
NGC3081	-	x	x	-	-	✓	x	1/3
NGC3227	x	x	x	-	x	x	x	0/4
NGC3281	-	✓	✓	-	-	x	x	1/3
NGC3783	-	✓	x	-	-	x	✓	2/3
NGC4051	x	x	x	-	x	x	x	0/4
NGC4151	✓	✓	x	-	x	x	✓	2/4
~~**NGC4253**~~	-	-	✓	-	-	x	-	1/2
NGC4258	x	x	x	x	x	✓	x	1/4
NGC4388	-	x	x	-	-	x	x	0/3
NGC4507	--	--	--	--	-	x	-	0/2
~~**NGC4579**~~	--	--	--	--	✓	✓	x	2/4
NGC4594	--	--	--	--	x	x	x	1/4
~~**NGC4725**~~	--	--	--	--	✓	✓	x	2/4
NGC5135	-	-	x	-	-	x	-	0/2
NGC5347	-	x	x	-	-	✓	-	1/2
NGC5506	-	✓	✓	-	x	x	x	1/4
NGC7130	-	-	x	-	-	x	-	0/2
NGC7172	-	x	x	-	-	x	x	0/3
NGC7213	-	x	x	-	-	x	x	0/3
NGC7465	-	x	x	-	x	x	-	0/3
NGC7479	-	x	x	-	-	✓	✓	2/3
NGC7582	x	x	x	-	-	x	x	0/3

High nuclear SFR

High nuclear SFR

70 μm excess > nuclear flux

70 μm excess > nuclear flux

Candidates to nuclear 70 μm AGN-dominated emission

- 15 galaxies (45% of the sample) satisfy at least one of these criteria
- 9 of them satisfy half of the criteria
- 5 RSA Seyfert galaxies (15% of the initial sample) whose nuclear (r= 1−2 kpc) 70 μm emission has a significant (~40−50%) contribution from hotter dust, presumably heated by the AGN:
  - IC 5063
  - NGC 3783
  - NGC 4151
  - NGC 5347
  - NGC 7479

  None of them show 11.3 μm PAH emission on scales of less than 100 pc or high nuclear SFR.

Summary

- We have studied the nuclear and integrated 70-500 μm emission of 33 local Seyfert galaxies.
- 88% of the sample have a nuclear (r = 2 kpc) contribution to the total 70 μm emission greater than 50%.
- The majority of the galaxies have 70/160 μm flux ratios and dust temperatures ($20 < T < 43$ K) compatible with those of normal galaxies.
- We put forward four criteria to select galaxies with nuclear 70 μm AGN dominated emission: (1) elevated 70/160 μm flux ratios, (2) nuclear dust temperature higher than typical star forming galaxies, (3) 70 μm excess emission with respect to the fit of the FIR SEDs with a grey body with $\beta=2$, and (4) comparison of nuclear SFR obtained from 70 μm and mid-IR indicators.
- 15 galaxies (45% of the sample) satisfy at least one of these criteria, whereas 9 satisfy half or more of the criteria.
- We select 5 bona-fide candidates: IC 5063, NGC 3783, NGC 4151, NGC 5347, and NGC 7479.