

PACS spectra of Seyfert galaxies and the importance of MIR/FIR spectroscopy

Luigi Spinoglio (IAPS-INAF, Roma)

Local Seyfert galaxies are a powerful laboratory to study co-habitation of BH powered nuclei and star formation disks.

The 12 μ m Seyfert Galaxy Sample is sampling nuclear activity in galaxies at redshift zero and contains enough objects (~ 120) to derive statistical results.

Recent results from Spitzer show the power of mid-IR lines to discriminate between accretion and star formation processes.

Herschel can help in distinguish the two phenomena through line ratio diagrams involving [OI] emission.

These diagnostic tools can be very effective to study galaxy evolution at high redshift with the future spectrometers onboard of SPICA

My collaborators:

Miguel Pereira-Santaella (IAPS-INAF), Kalliopi Dasyra (Obs. de Paris), Silvia Tommasin (Tel Aviv Univ.),
Gemma Busquet (IAPS-INAF), Luca Calzoletti (ASI-ASDC), Matt Malkan (UCLA)

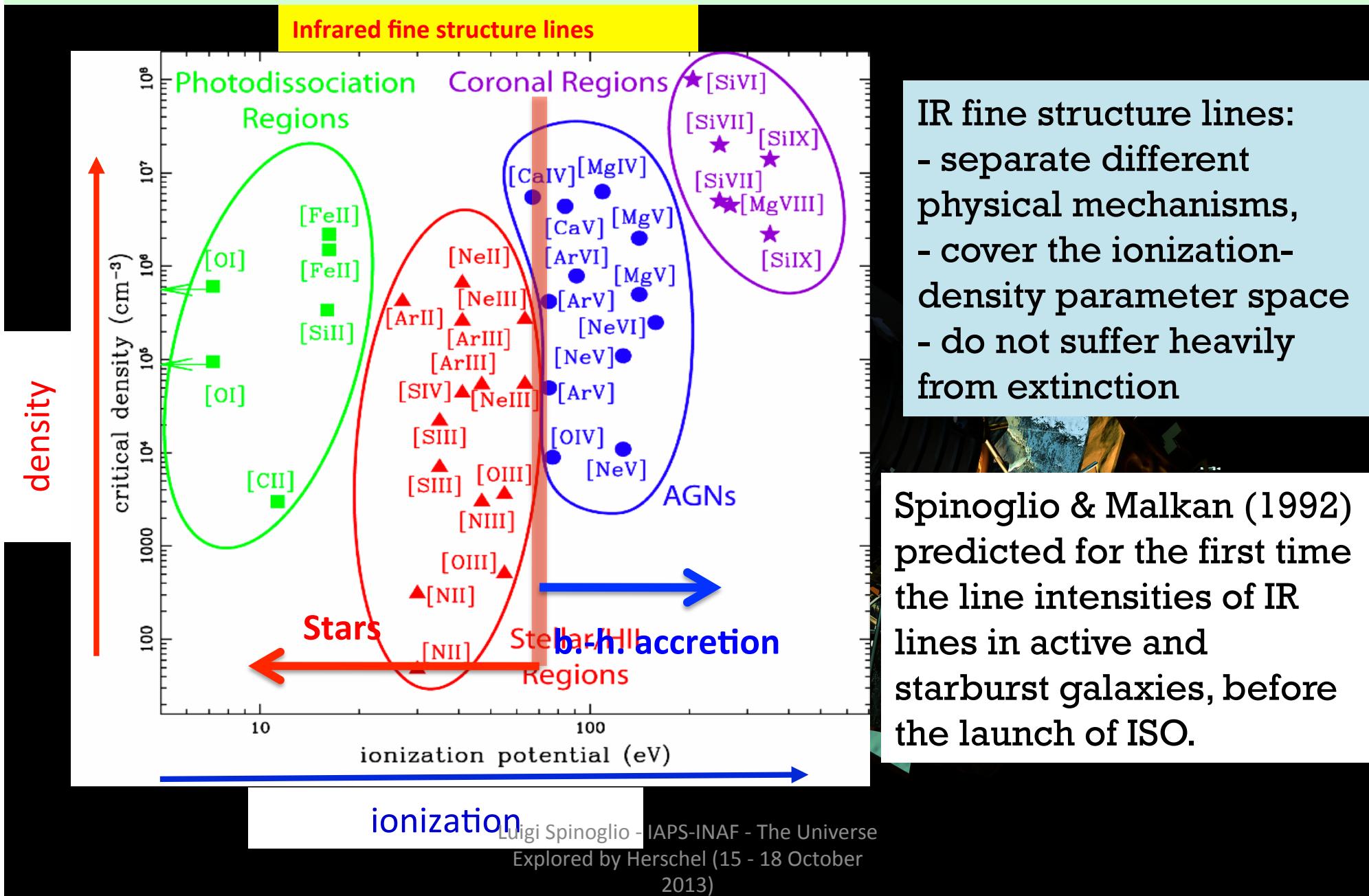
Comparing different wavelengths for separating AGN and SF

No single criteria distinguish AGN & SF → limits and potentialities of different techniques

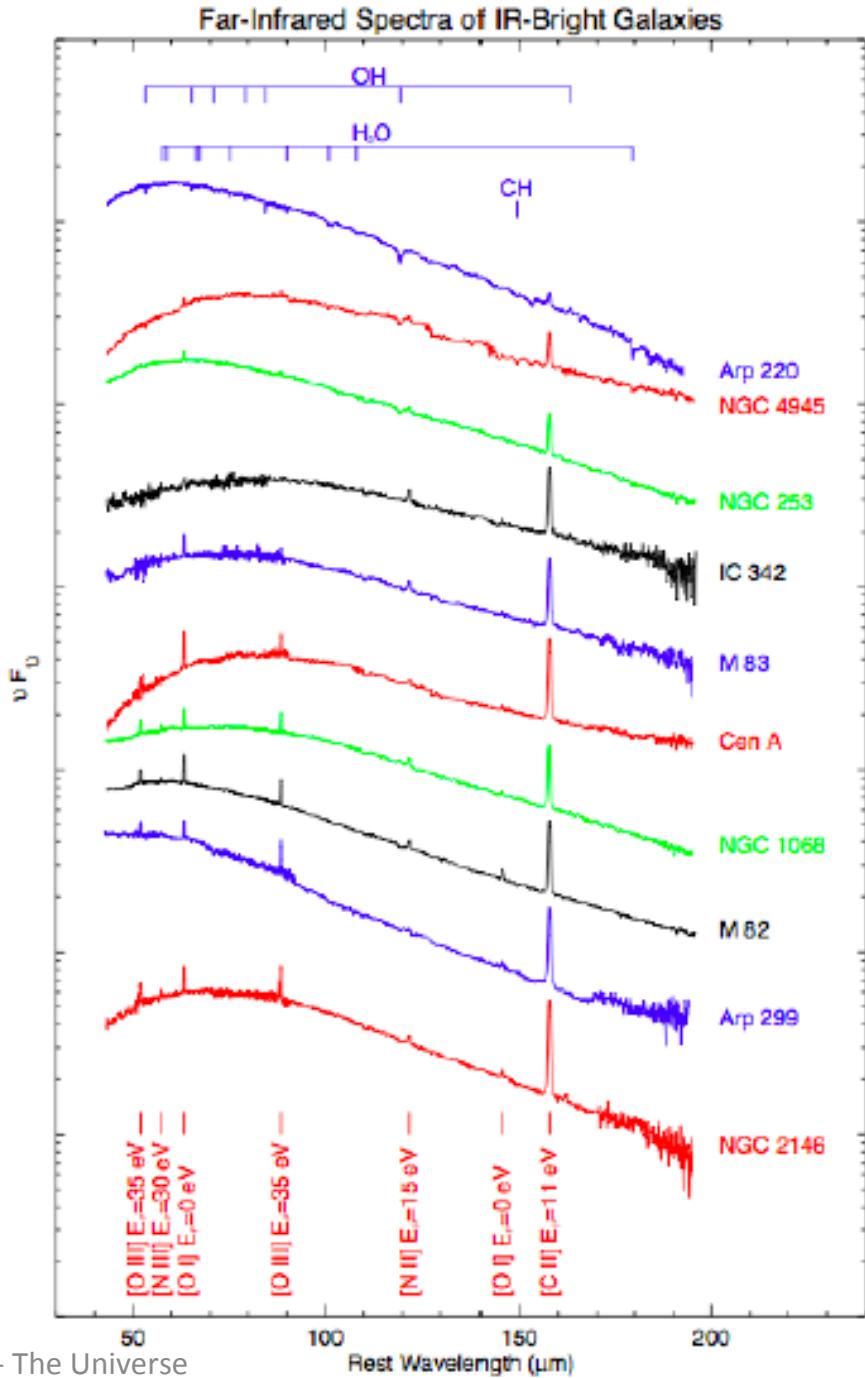
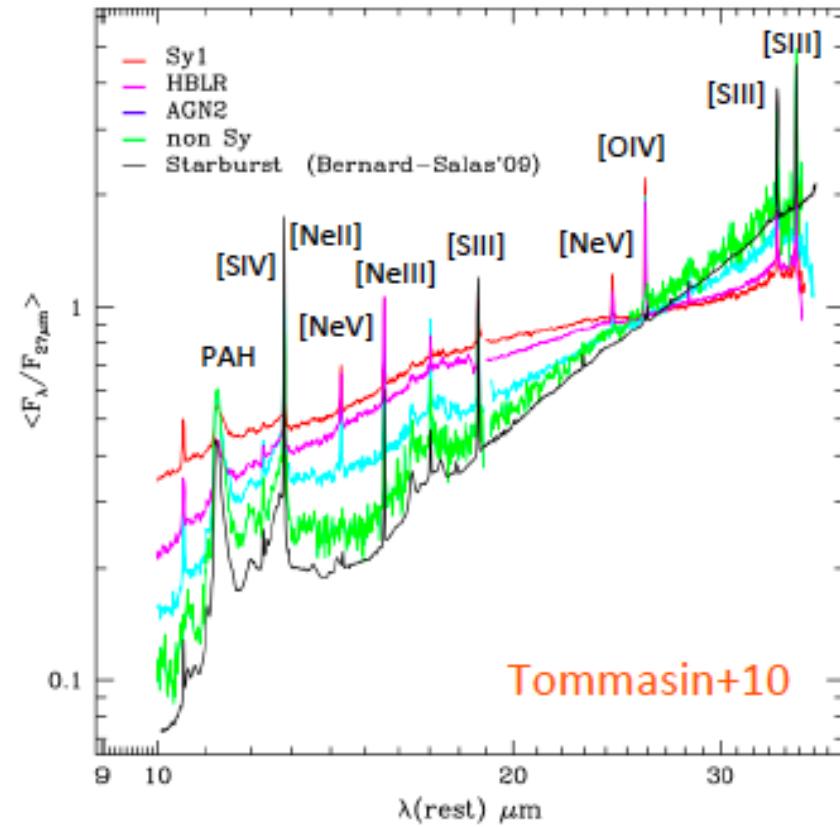
- UV/Optical/NIR observations → galaxy morphology and spectra,
BUT they seriously suffer from dust obscuration
- X-ray observations → good tracers of AGN,
BUT only weak X-ray emission can be detected from star formation
BUT heavily-obscured AGN (Compton-thick) completely lost.
- Radio observations (EVLA, SKA) → can detect AGN and SF to large z and can see through gas and dust, → measure morphology and spectral SED, detect polarization and variability,
BUT not always redshifts can be measured. (at its highest frequencies SKA will measure redshifted molecular lines in the ISM of galaxies).
- mm/submm observations (e.g. ALMA, CCAT) → spectra from SF (redshifted CO, CII, etc.), BUT need to find AGN tracers. One candidate is CO: SLED different from PDR (SF) and XDR (AGNs).

Rest-frame MIR/FIR imaging spectroscopy → complete view of galaxy evolution and the role of BH and SF because it can (provided that large field of view and high sensitivity can be reached)
→ trace simultaneously both SF and AGN,
→ measure redshifts
→ see through large amounts of dust.
→ the most promising technique.

Why infrared spectroscopy is the best tool to isolate star formation and accretion?

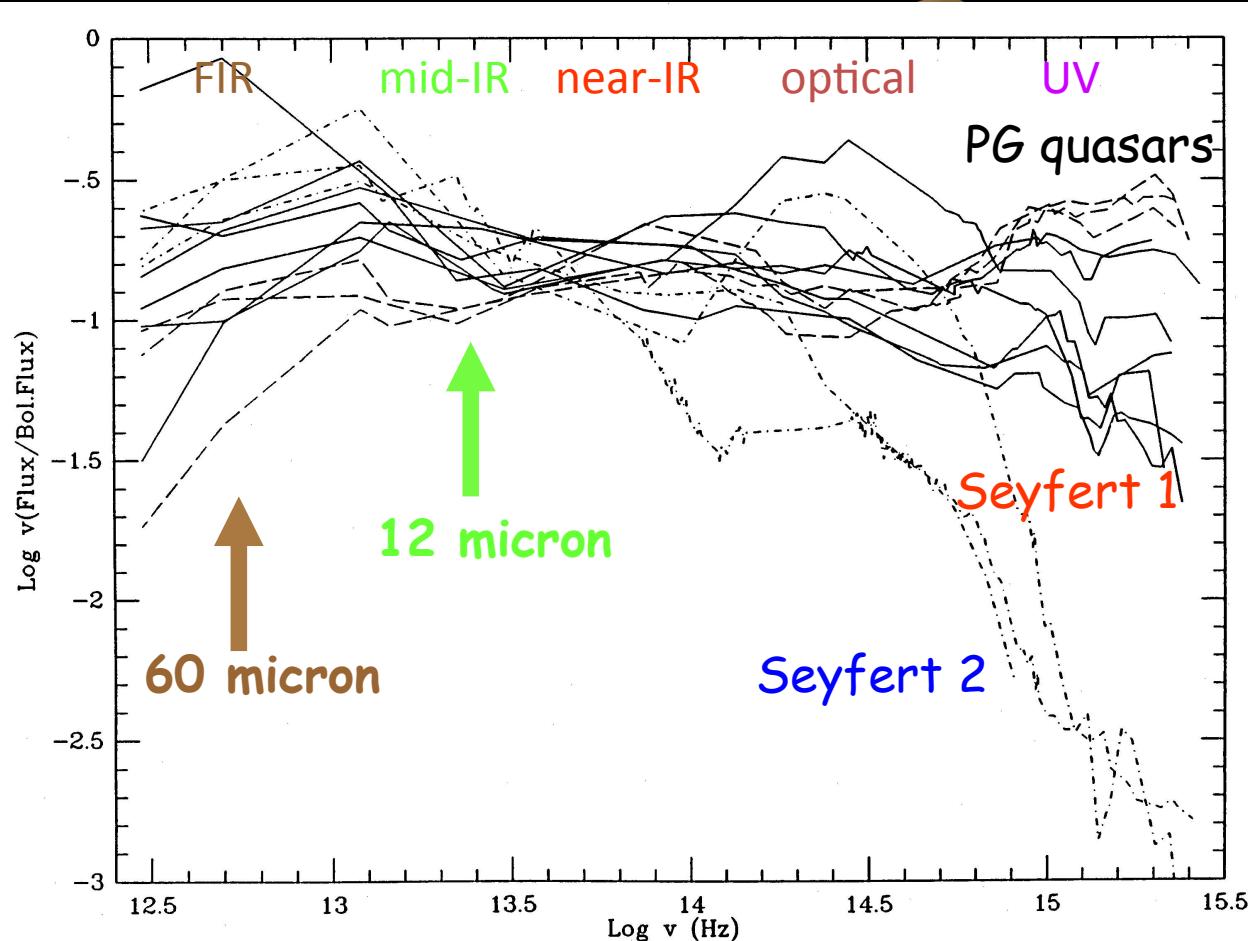


Plenty of strong mid- and far-IR features to detect high-z galaxies and measure redshifts



A survey of nuclear activity in the Local Universe through selection of continuum emission in the mid-IR (Spinoglio & Malkan 1989)

$F_{12\mu\text{m}} \approx 1/5 F_{\text{bolometric}}$ for all types of AGN → 12 μm COMPLETE SAMPLES IN BOLOMETRIC FLUX



Dust absorbs the continuum at short wavelengths and re-emit it in the FIR.

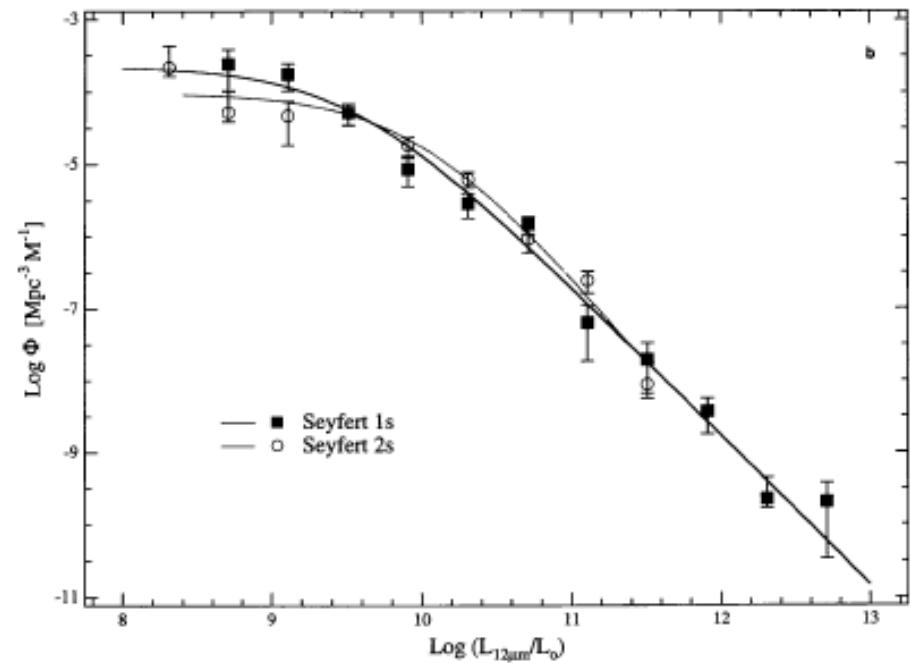
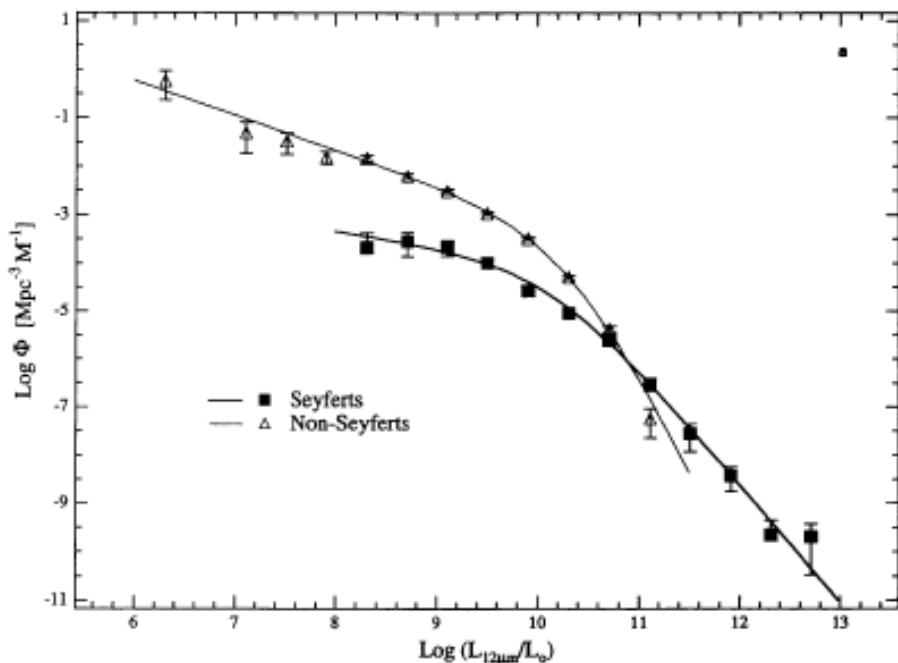
There is a spectral interval (7-12μm) at which the absorption of the original continuum is balanced by the thermal emission.

Spectral energy distributions of 13 AGN normalized to the bolometric fluxes (computed from 0.1-100μm) [Spinoglio & Malkan, 1989; Spinoglio et al. 1995]

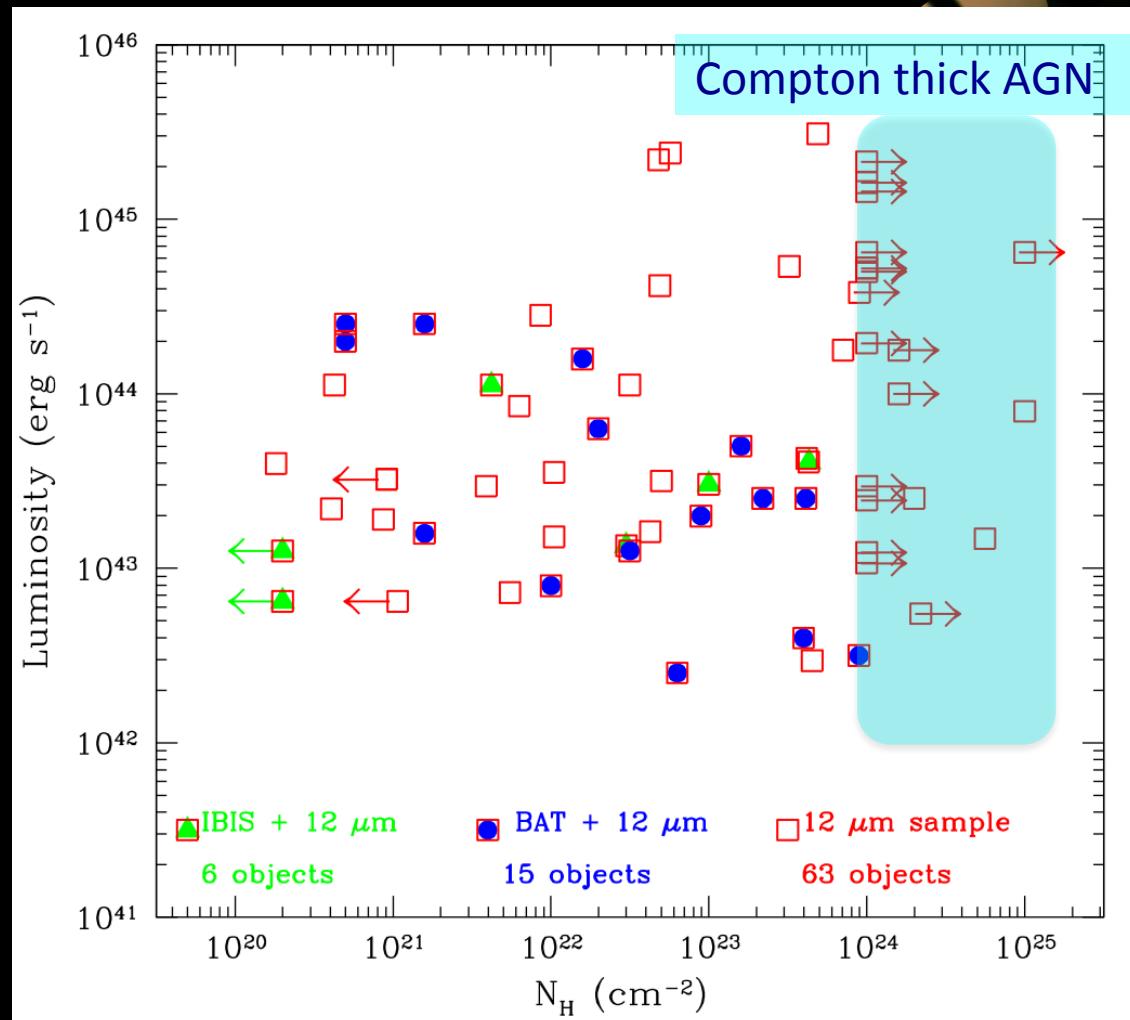
The extended 12 μ m Galaxy Sample (Rush, Malkan & Spinoglio 1993)

The sample of 893 galaxies was extracted from the IRAS FSC-2, defined by a total (ADDSCAN) 12 μ m flux limit of 0.22~Jy. Completeness is verified to 0.30~Jy, below which we have quantified the incompleteness down to 0.22~Jy for our statistical analysis. The Seyfert subsample is the largest unbiased sample of Seyfert galaxies (53 Seyfert 1 and qso, 63 Seyfert 2 and 2 blazar, in total 118, i.e. 13% of the total sample) ever assembled and is complete not only to 0.30~Jy at 12 μ m, but also with respect to a bolometric flux limit of 2.0×10^{-10} erg s $^{-1}$ cm $^{-2}$.

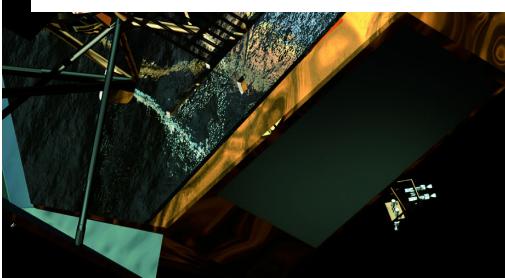
The AGN luminosity functions (LFs) are more complete than those of the optically selected CfA Seyfert galaxies for all luminosities and AGN types.



12 μm selection for local AGN is covering also the COMPTON thick objects missed in Hard-X rays surveys

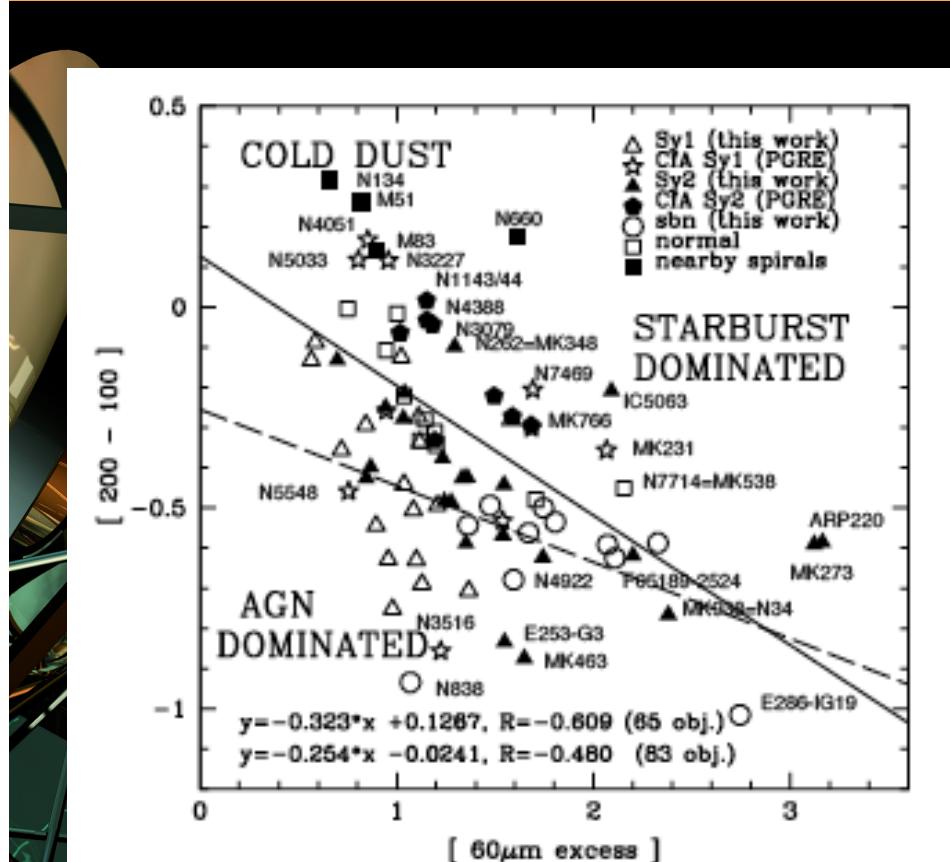
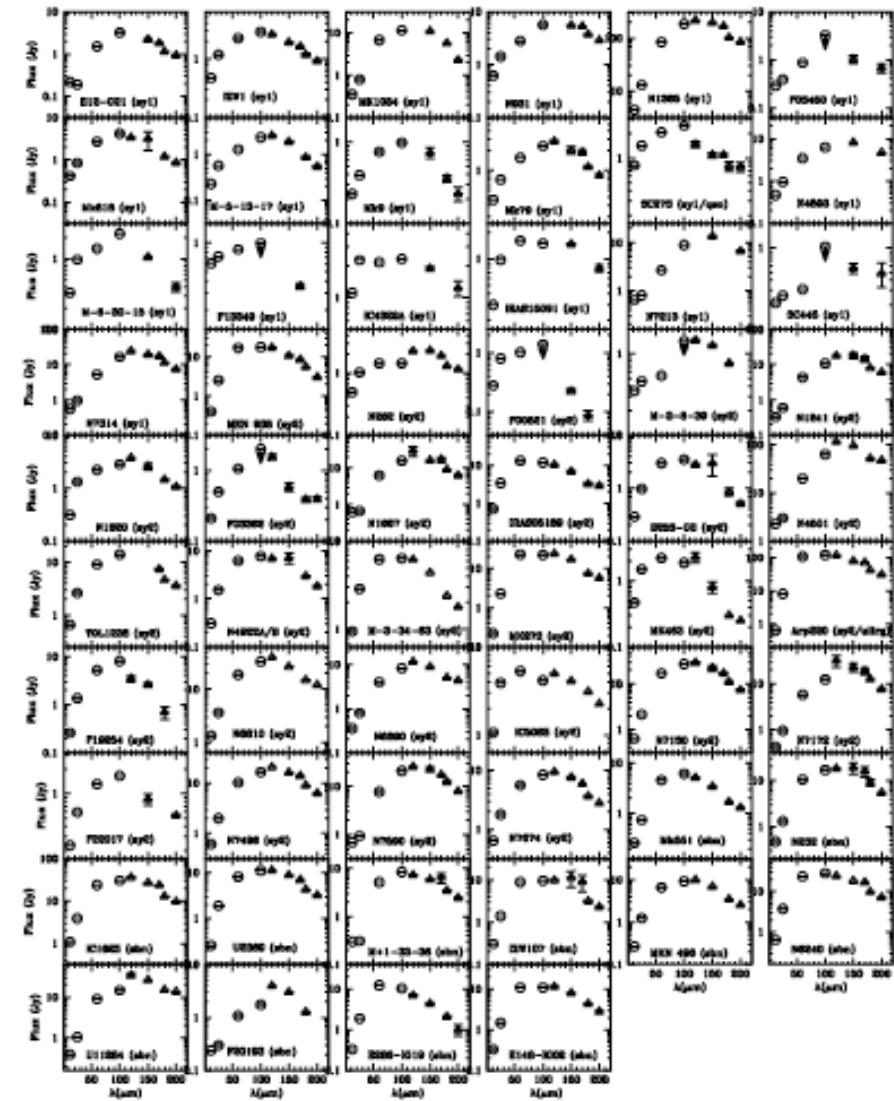


WIDE COVERAGE of the Luminosity-Hydrogen absorption column density PLANE of all objects of the 12 μm active galaxy sample detected at hard X-rays (with a measured column density N_{H}).



Few results from the other satellites:

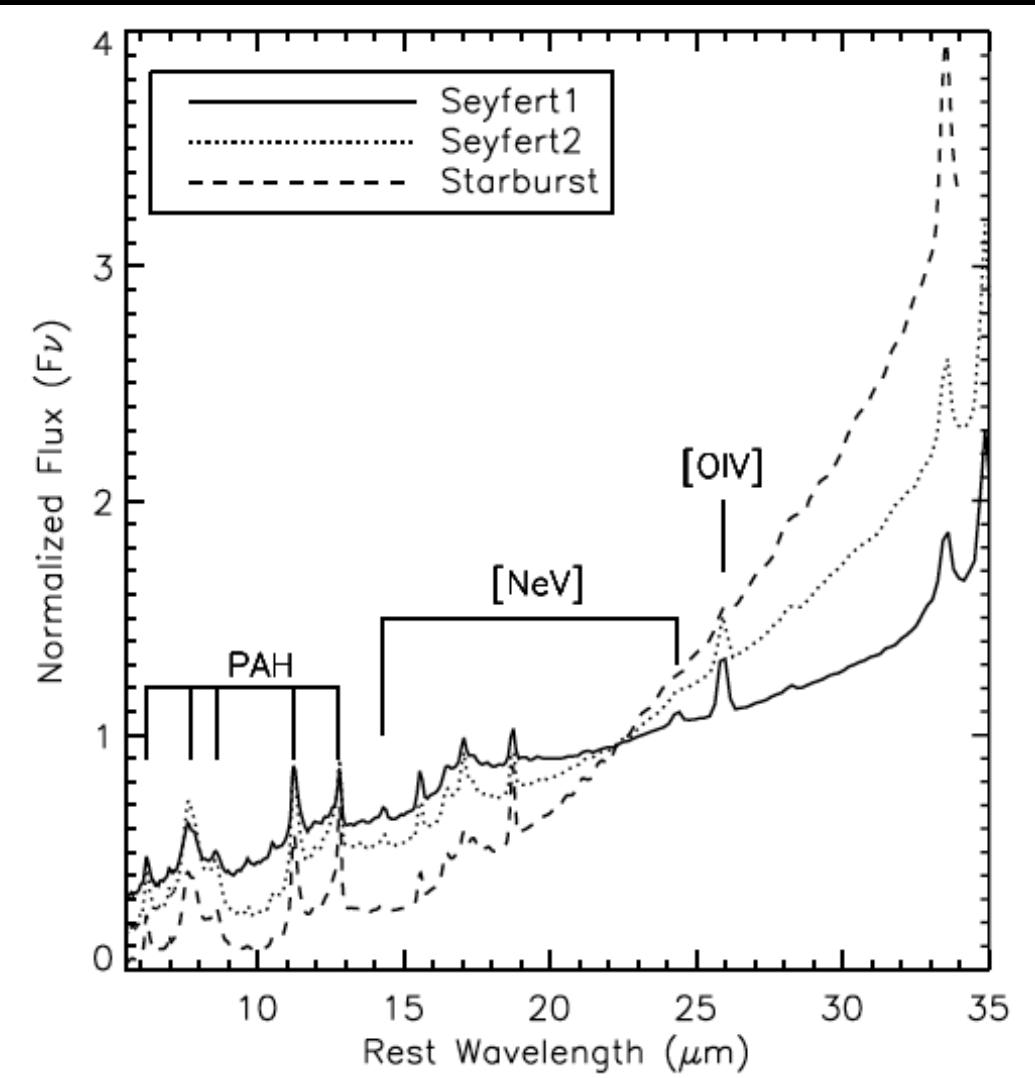
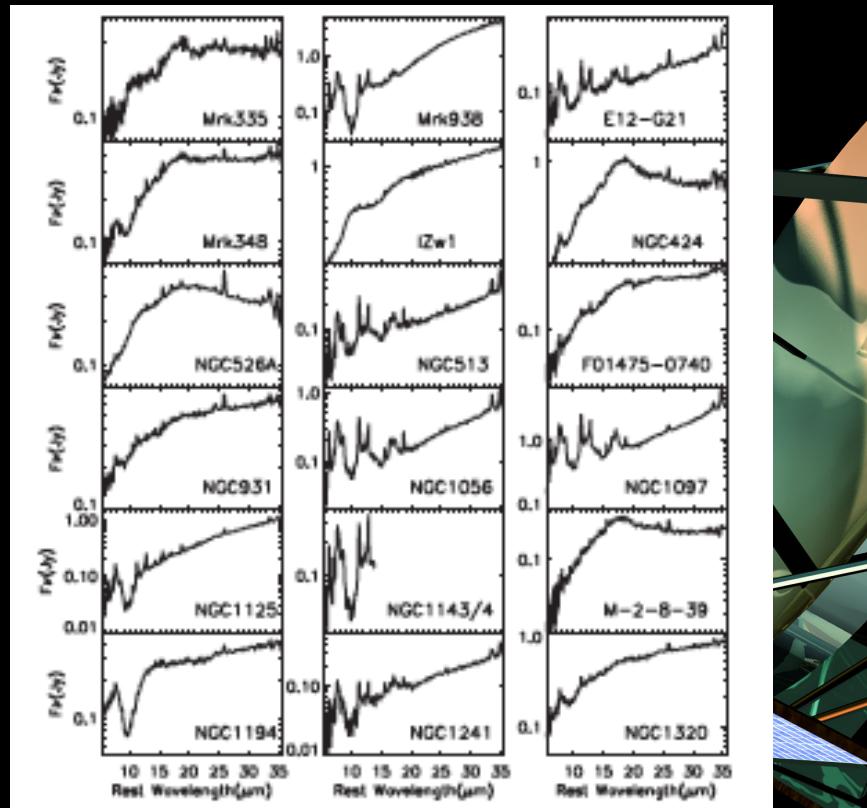
1. ISO observed the long wavelength emission of the 12 μ m Seyfert galaxy sample:



Spinoglio, Andreani & Malkan 2002, ApJ

Few results from the other satellites:

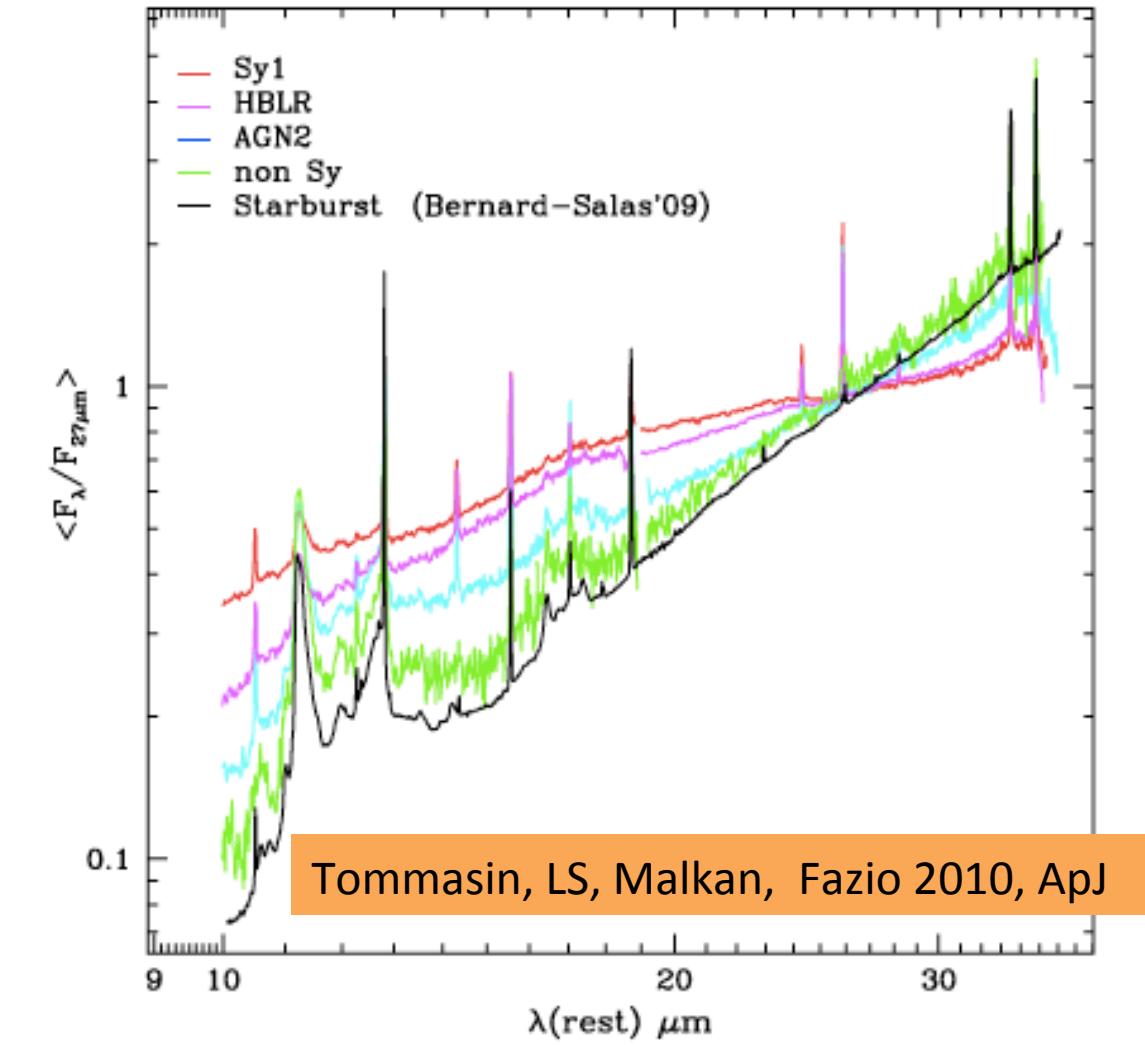
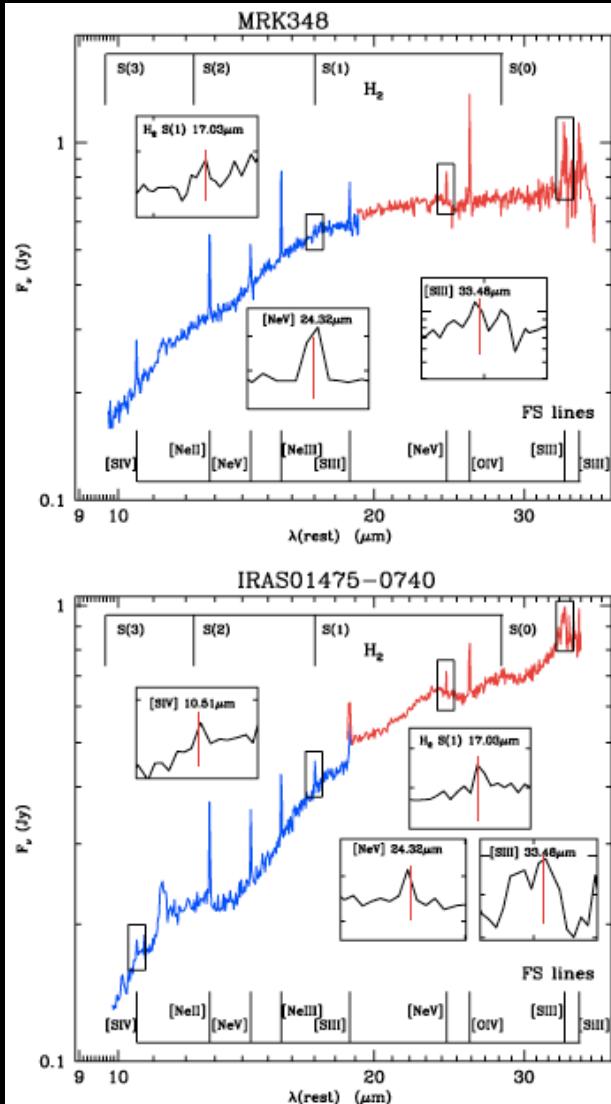
2. Spitzer made low resolution spectroscopy of the 12 μ m Seyfert galaxy sample:



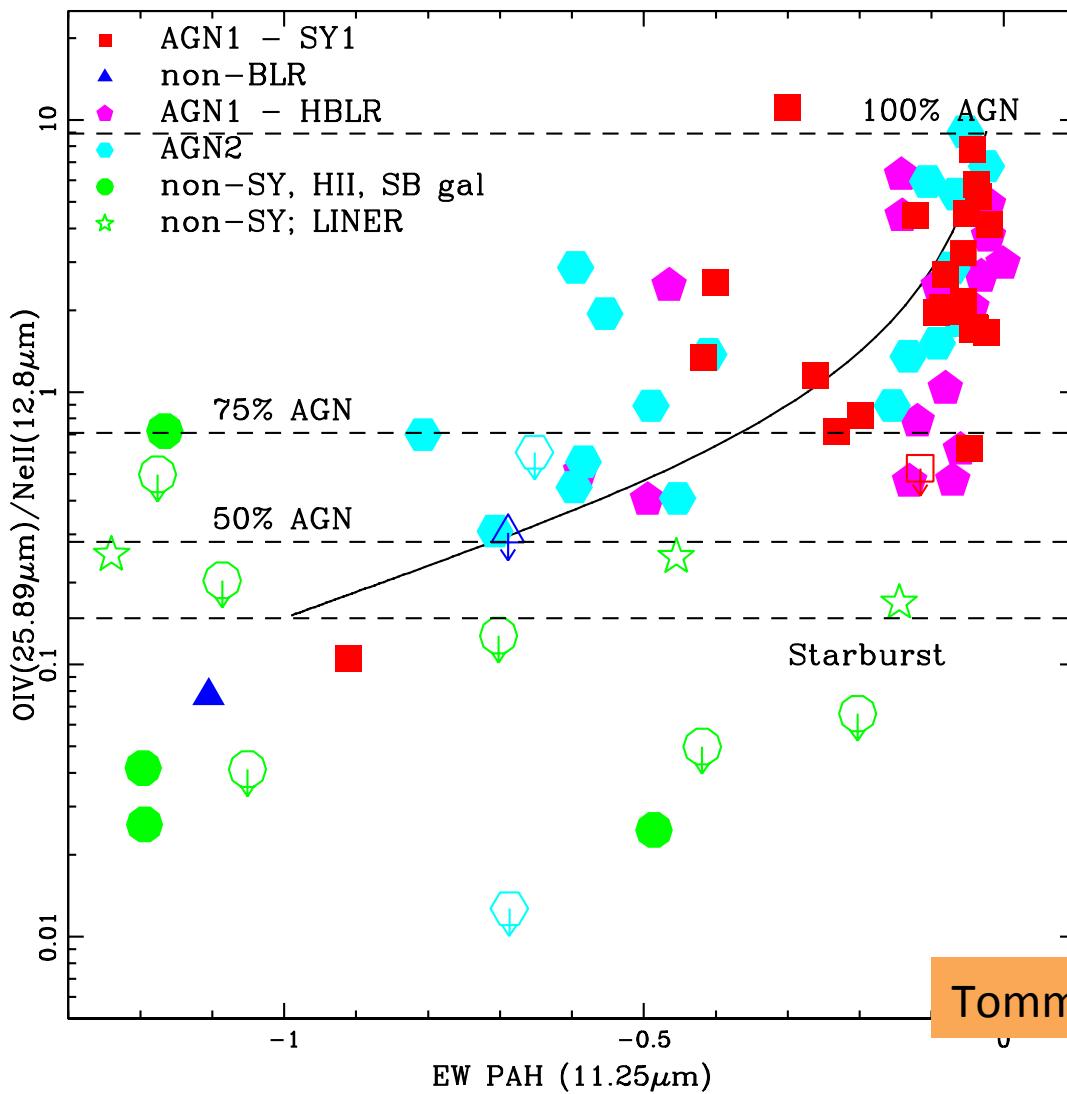
Wu, Charmandaris+ LS+ 2009, ApJ

Few results from the other satellites:

3. Spitzer made high resolution spectroscopy of the 12 μ m Seyfert galaxy sample:

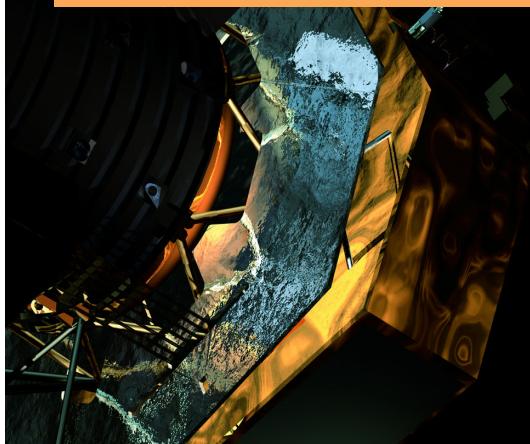


Spitzer spectroscopy results



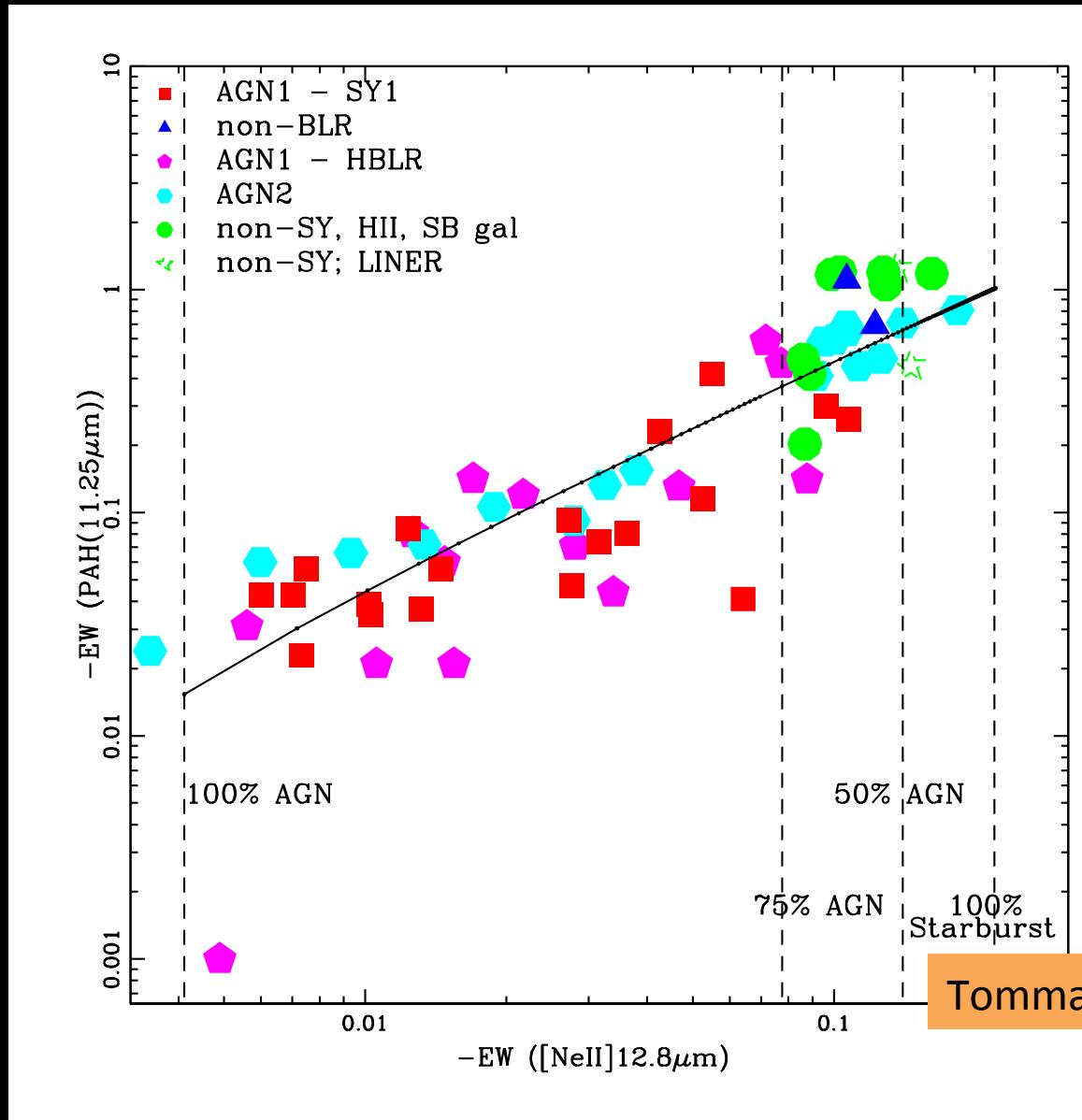
Power of mid-IR lines and features to discriminate between AGN and SF emission in local galaxies:

[OIV]26 μm /[Nell]12.8 μm ratio vs. EW of PAH at 11.25 μm



Tommasin, LS, Malkan, Fazio 2010, ApJ

Spitzer spectroscopy results



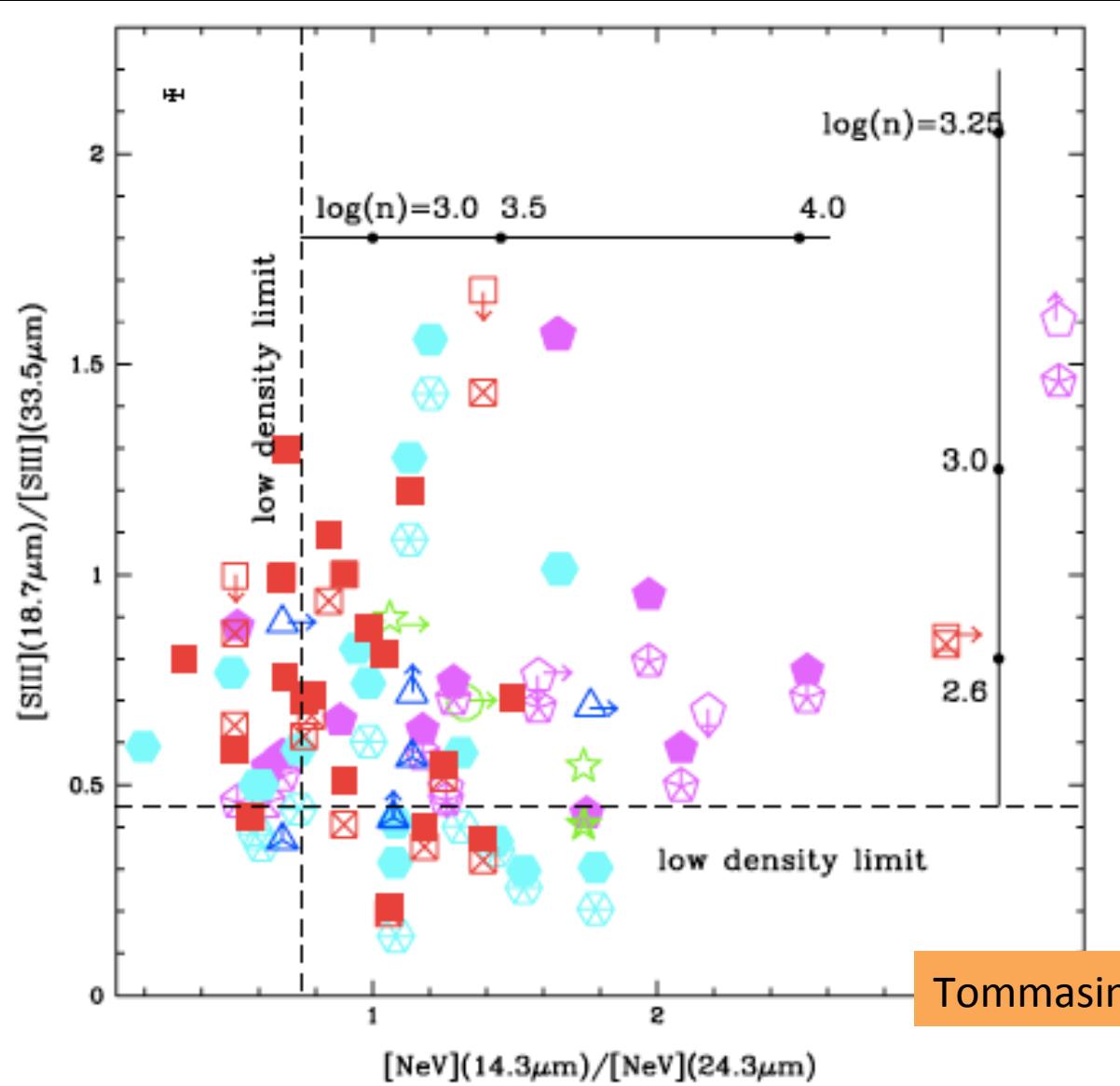
Tommasin, LS, Malkan, Fazio 2010, ApJ

Power of mid-IR lines and features to discriminate between AGN and SF emission in local galaxies:

EW [N II] $12.8\mu\text{m}$ vs. EW of PAH at $12.5\mu\text{m}$



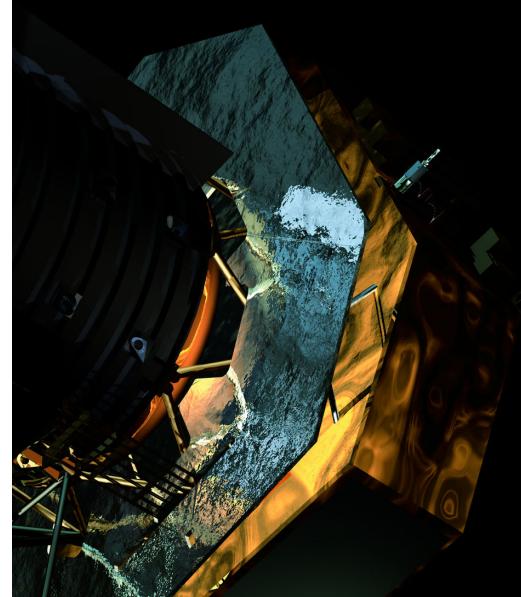
Spitzer spectroscopy results



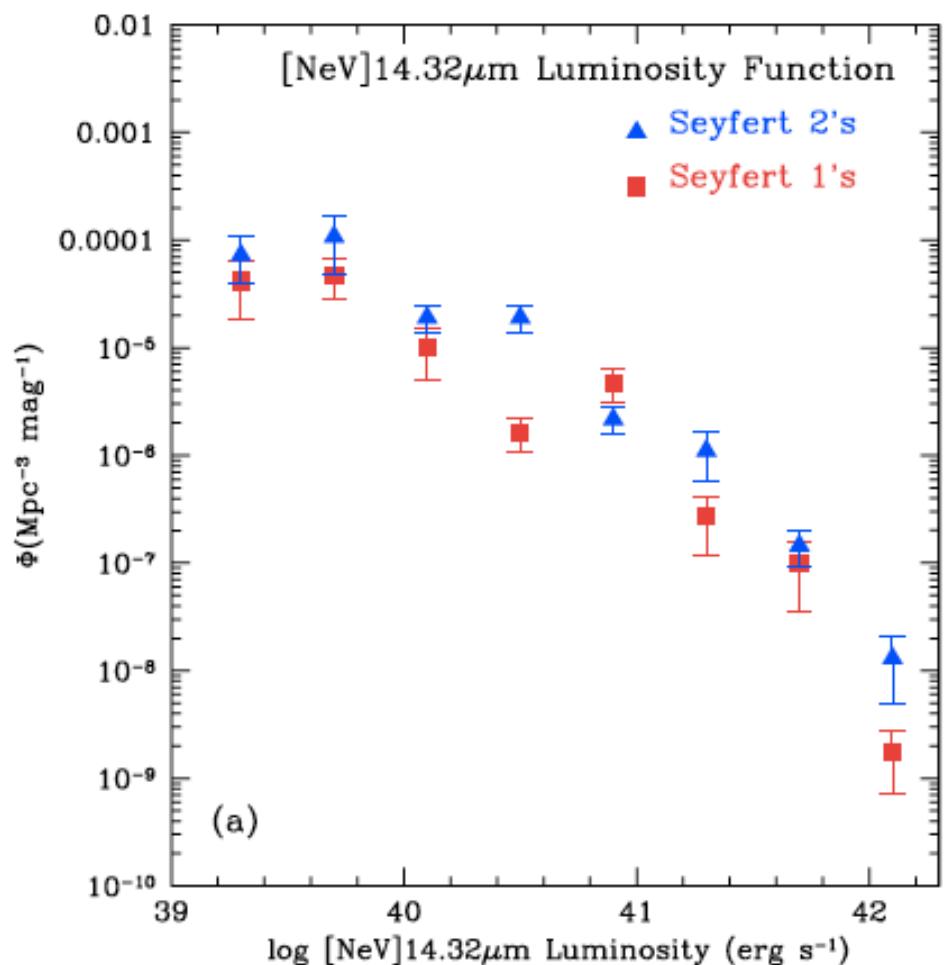
Tommasin, LS, Malkan, Fazio 2010, ApJ

Power of mid-IR lines and to measure the gas density in HII regions (SF emission) and AGN narrow Line Regions

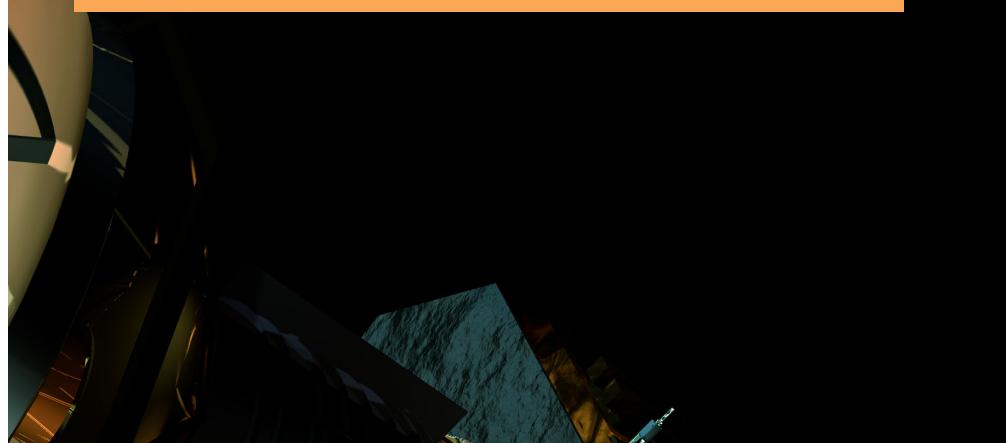
[NeV]14.3μm/[NeV]24.3μm
vs. [SIII]18μm/[SIII]33μm



Spitzer spectroscopy results



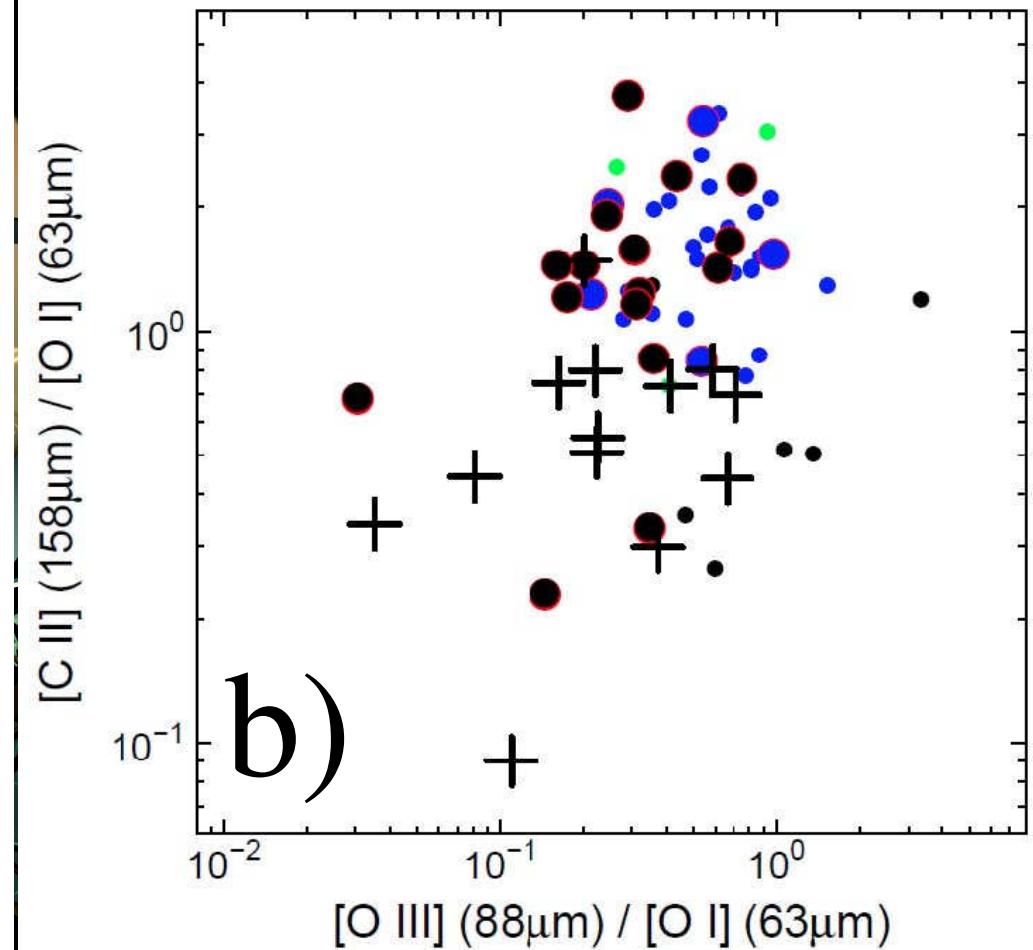
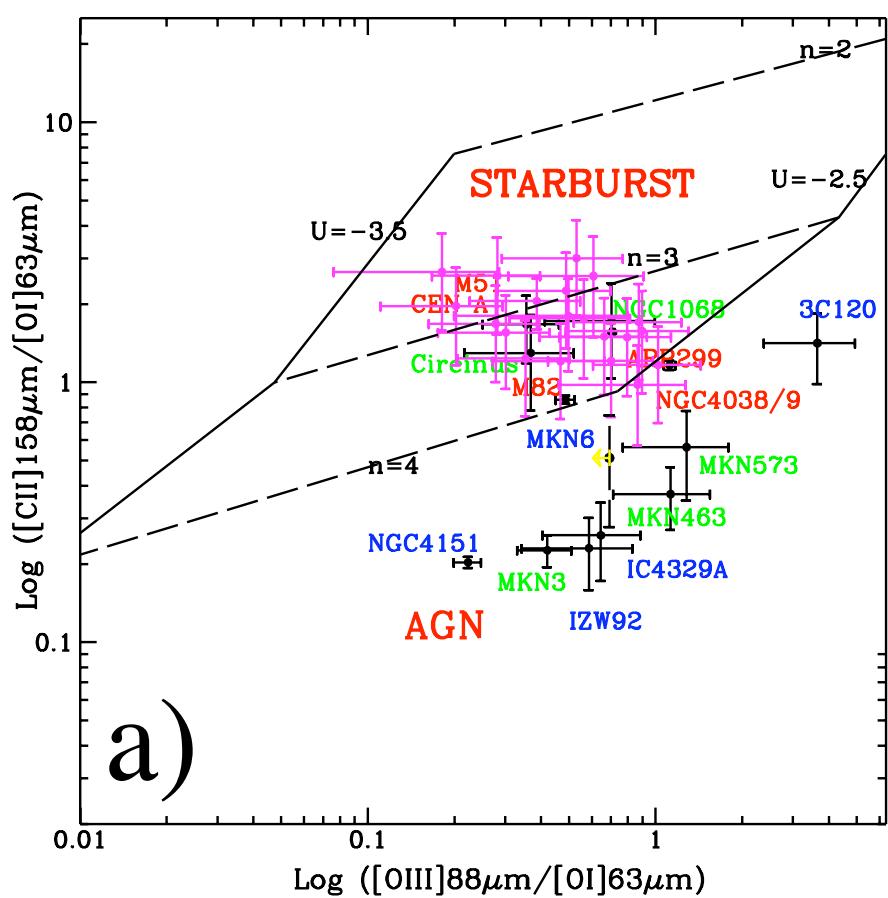
Power to measure BH accretion rate through the [NeV] lines



The mid-IR [Ne v] lines are unambiguous tracers of the AGN NLR. We therefore use the [Ne v] line luminosity function of all Seyfert galaxies to estimate the accretion power in the local universe within a volume out to $z = 0.03$. We find that the power originating from accretion at $19\ \mu m$ is $\sim 2 \times 10^{46}\ erg\ s^{-1}$, about four times less than the bolometric power. For comparison, the power related to star formation and stellar evolution in the Seyfert galaxies population at $19\ \mu m$ is one-tenth of that one from accretion.

Tommasin, LS, Malkan, Fazio 2010, ApJ

FIR lines can discriminate between AGN and SF- dominated galaxies

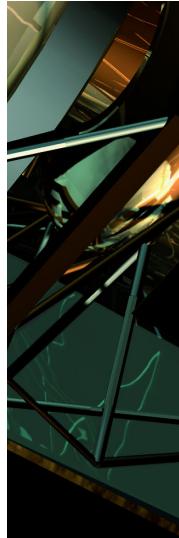


ISO-LWS spectra Spinoglio+2000 => Herschel-PACS spectra Gracia-Caprio+2011 (in prep.)

Thanks to two GT programs (*Bright Seyfert Nuclei: PACS spectroscopy*, PI: LS, 14.0 hours allocated + *PACS spectroscopy of bright Seyfert galaxies in the [OIV]26μm line*"PI: LS, 18.0 hours allocated) PACS spectroscopy has been obtained for a limited number (24) of Seyfert galaxies of the 12μm Active Galaxy Sample

Name	RA (2000)	DEC(2000)	F12	F25	F60	F100	log (Jy)	log (FIR/B)	log (LIR/Lo)	D. (Mpc)	type		%AGN
											old	new	
NGC1056	02h42m48.3s	+28d34m27s	0.32	0.48	5.46	9.79	2.61	9.66	22.1	S2	non-Sy	68%	
UGC5101	09h35m51.6s	+61d21m11s	0.25	1.03	11.54	20.23	3.65	11.75	168.7	Ulrig	non-Sy	-	
NGC3227	10h23m30.6s	+19d51m54s	0.66	1.76	7.82	17.59	1.92	9.61	16.5	S1	AGN1	85%	
NGC3982	11h56m28.1s	+55d07m31s	0.50	0.83	6.56	15.23	2.21	9.50	15.8	S2	AGN2	81%	
NGC4051	12h03m09.6s	+44d31m53s	0.85	1.59	7.13	23.92	1.86	9.22	10.0	NLS1	AGN1	-	
NGC4388	12h25m46.7s	+12d39m44s	0.99	3.46	10.24	18.10	2.39	10.36	36.1	S2	HBLR	91%	
TOL1238-364	12h40m52.8s	-36d45m21s	0.64	2.26	7.51	10.73	2.59	10.41	46.8	S2	HBLR	84%	
NGC7130	21h48m19.5s	-34d57m05s	0.58	2.11	16.48	25.57	2.93	11.11	69.2	S2	non-Sy	77%	
NGC7172	22h02m01.9s	-31d52m11s	0.43	0.76	5.71	12.29	2.48	10.17	37.2	S2	AGN2	85%	
NGC7582	23h18m23.5s	-42d22m14s	1.62	6.43	49.10	72.92	2.75	10.60	22.5	S2	AGN2	69%	

Source	Type	α (J2000) (h:m:s)	δ (J2000) ($^{\circ}$: ' : '')	z	v (km s $^{-1}$)
NGC 5256		3:38:17.5	+48:16:37	0.027863	8353
MRK 509		20:44:09.7	-10:43:25	0.034397	10312
MRK 3		06:15:36.3	+71:02:15	0.013509	4050
NGC 7582		23:18:23.5	-42:22:14	0.005254	1575
NGC 3516		11:06:47.5	+72:34:07	0.008836	2649
IRAS18216		18:21:57.3	+64:20:36	0.297000	>30000
PKS 1345		13:47:33.3	+12:17:24	0.121740	>30000
NGC 5506		14:13:14.9	-03:12:27	0.006181	1853
IC 4329a		13:49:19.2	-30:18:34	0.016054	4813
MRK 1066		02:59:58.6	+36:49:14	0.012025	3605
UGC 2608		03:15:01.4	+42:02:09	0.023343	6998
NGC 4507		12:35:36.6	-39:54:33	0.011801	3538
NGC 5728		14:42:23.9	-17:15:11	0.009353	2804
3C120		04:33:11.1	+05:21:16	0.033010	9896

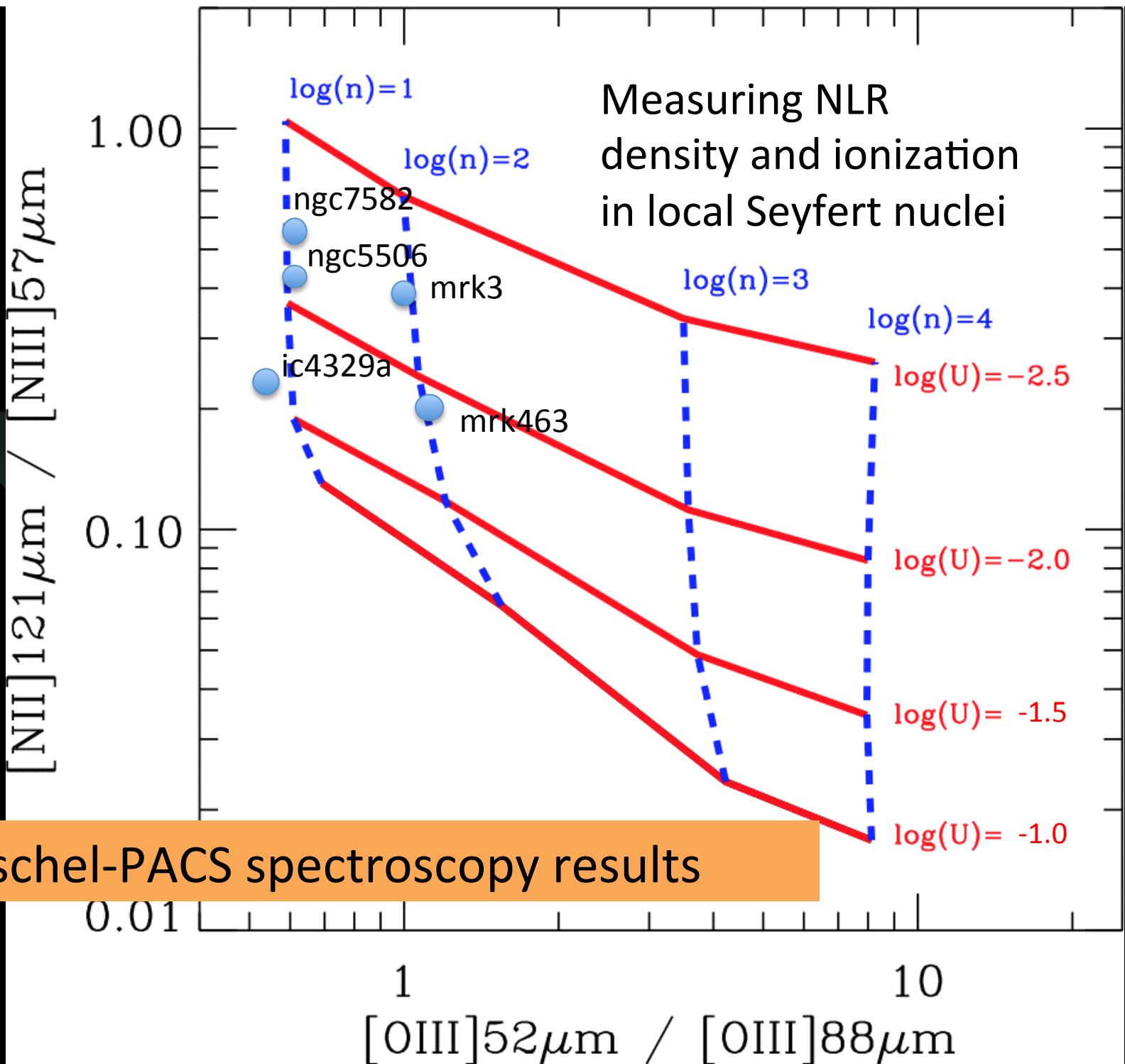


We have fully reduced the PACS spectroscopic data on the 24 Seyfert galaxies with pipeline 10.1

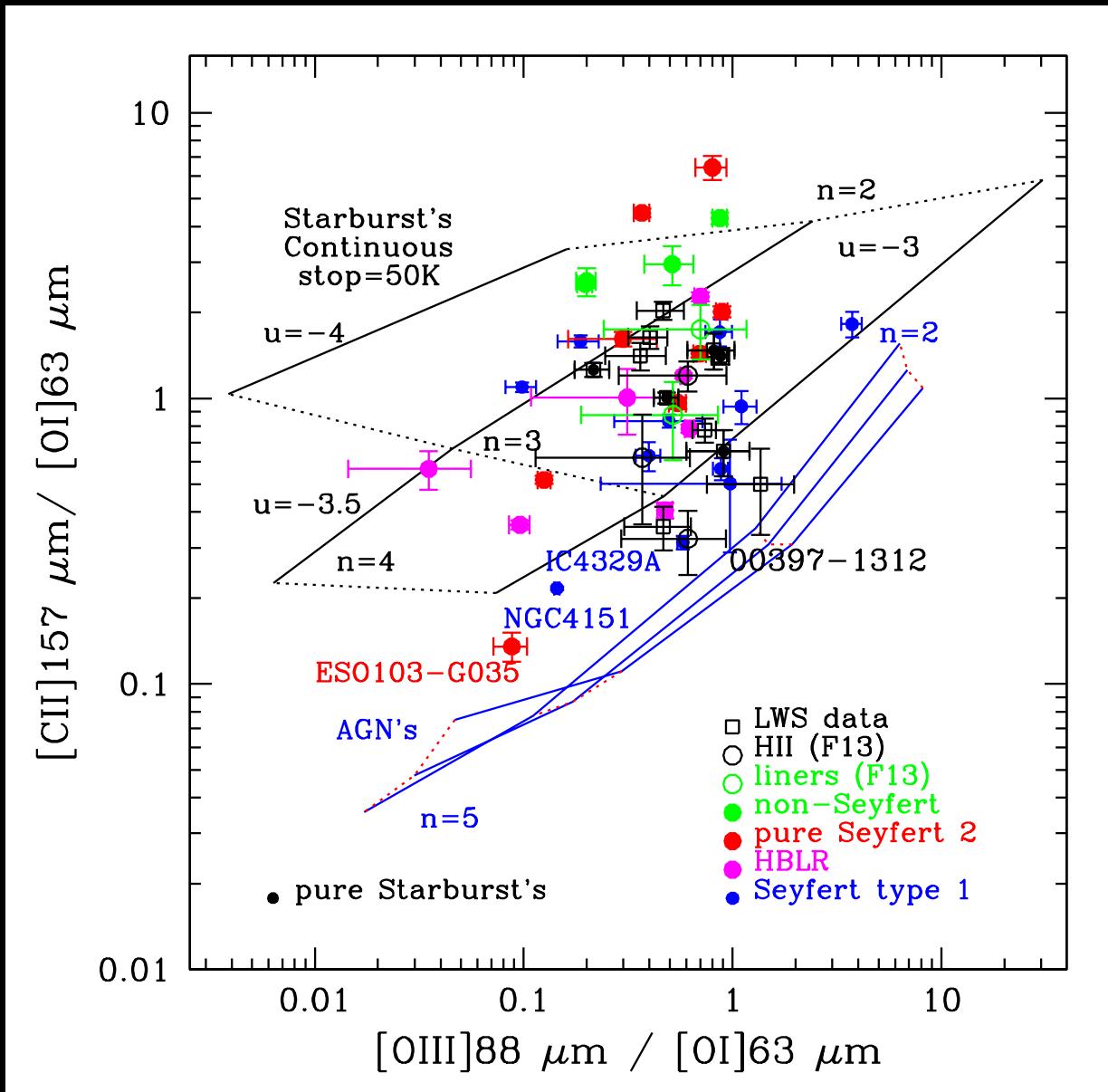
We have started the analysis with the use of photoionization models and line ratio diagrams. This work is still in progress (Spinoglio et al 2013, in prep.)

A Seyfert spectra GT1 program with SPIRE FTS will be presented **this afternoon by Miguel Pereira-Santaella**. The SPIRE spectra on 11 galaxies are published (Pereira-Santaella, LS +2013). The SPIRE spectrum of NGC1068 is published within the VNG KP (Spinoglio+2012) (2013)

Herschel-PACS spectroscopy results



Herschel-PACS spectroscopy results



FIR Line ratios are plotted against the photoionization models:

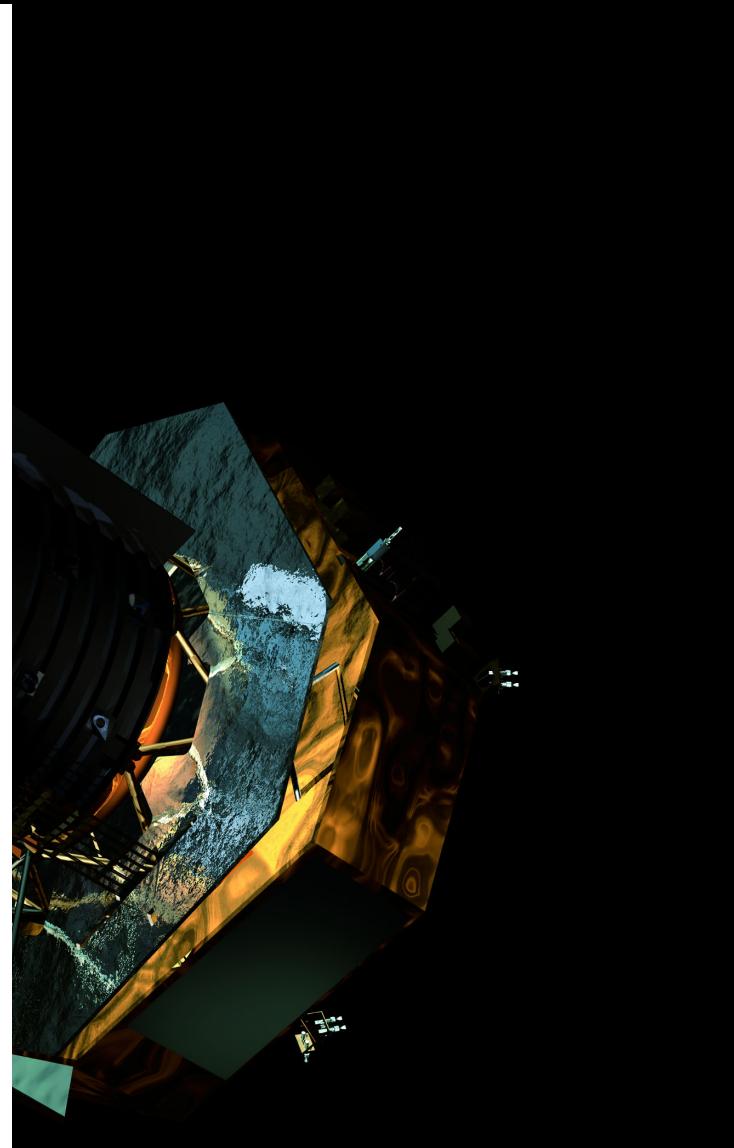
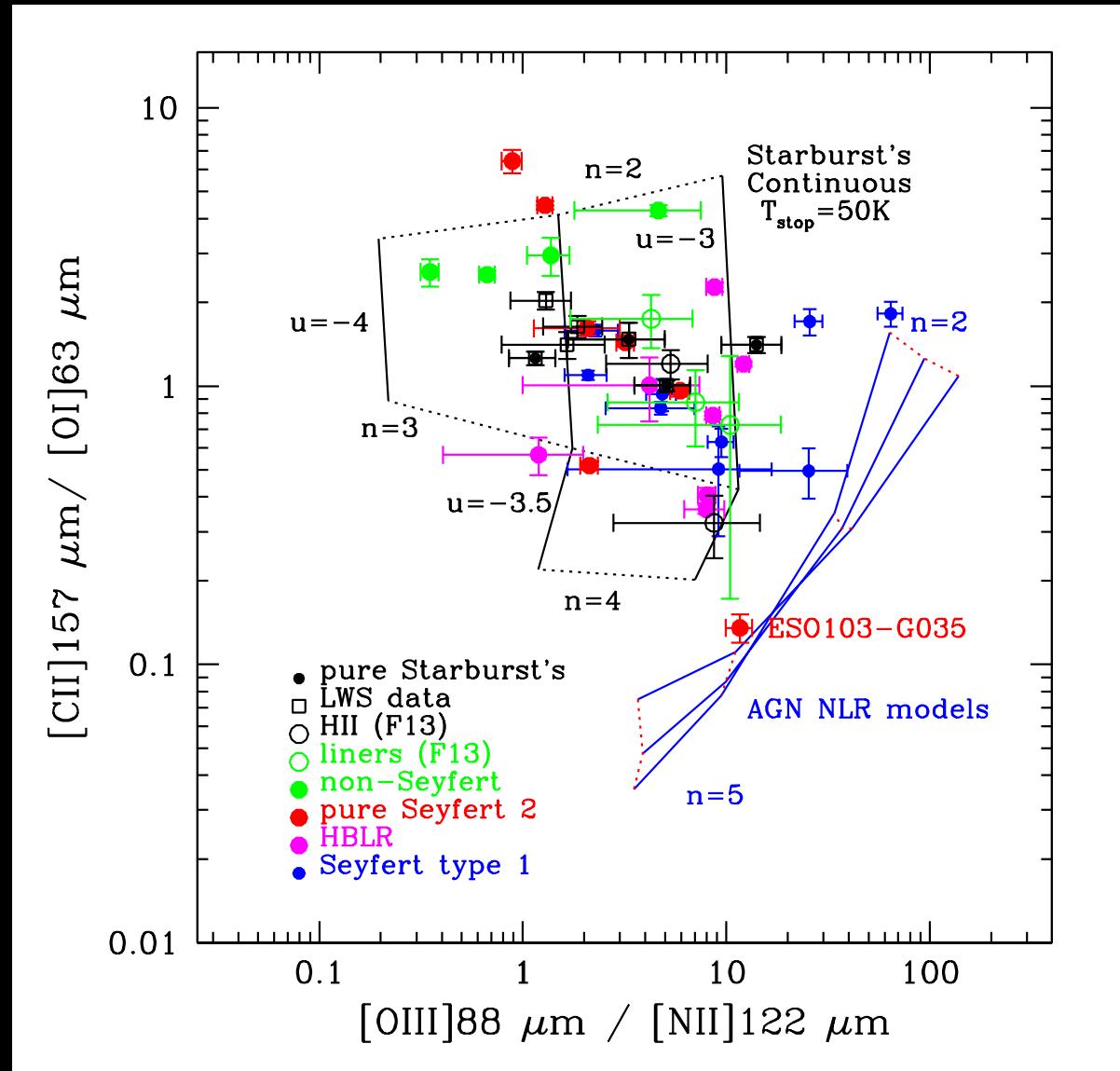
continuum starburst models (black grid)

AGN NRL models (blue grid)

as a function of ionization potential and density

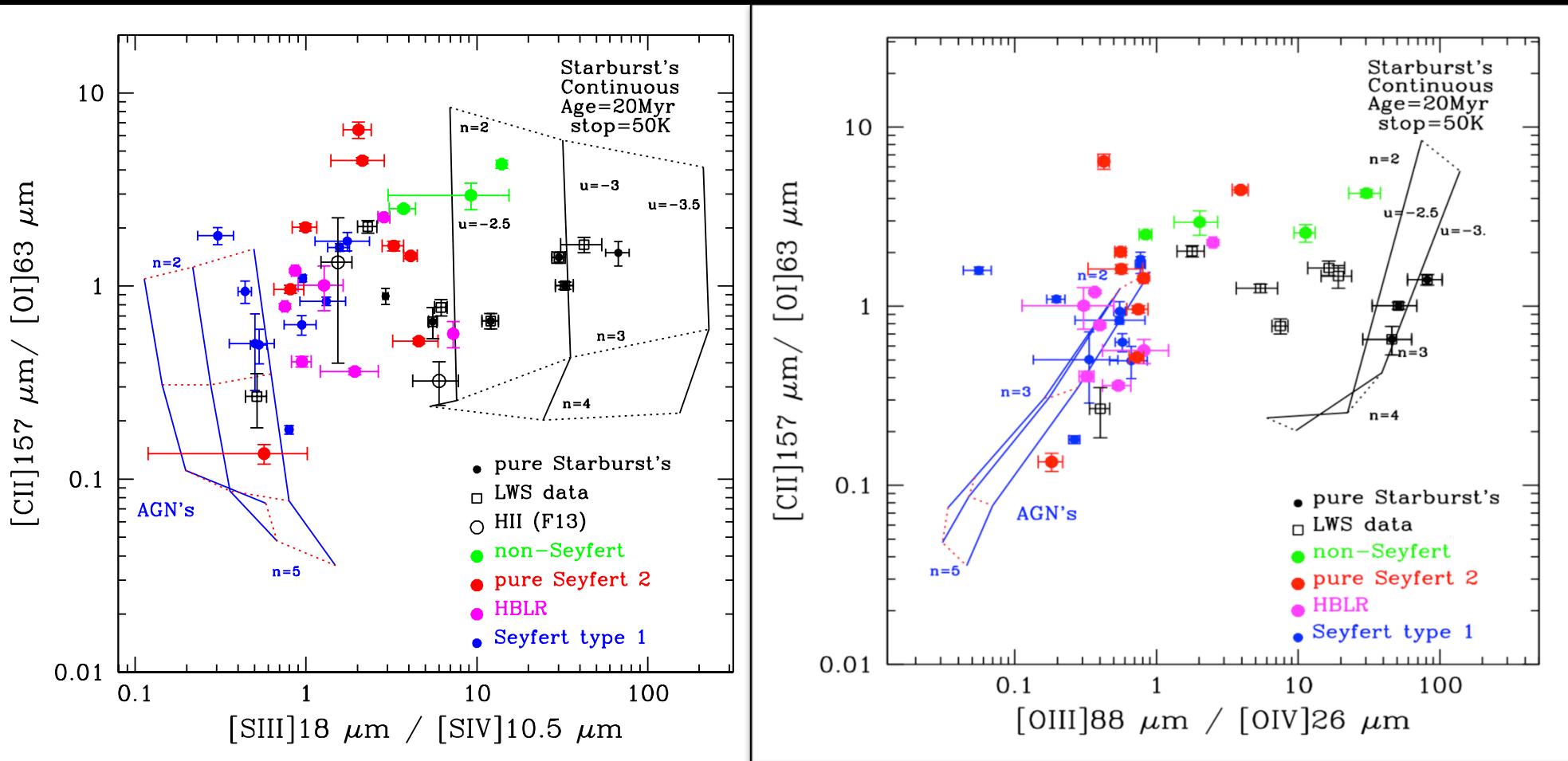
Models are made with CLOUDY constant density and Starburst99 input spectra for SF And “cloudy” AGN continua for NLR Spinoglio+2013, in prep.

Herschel-PACS spectroscopy results



Luigi Spinoglio - IAPS-INAF - The Universe
Explored by Herschel (15 - 18 October
2013)

Herschel-PACS + Spitzer-IRS spectroscopy results



The aim of the present study is to model the local Seyfert galaxy population, distinguishing the behavior of Seyfert type 1, from the Hidden Broad Line Region objects (as characterized from optical polarization), from the Seyfert type 2 galaxies and the lower excitation galaxies (e.g. LINERs).

This classification was already studied using the mid-IR lines and features and it will be complemented with the FIR fine structure lines detected with PACS spectroscopy.

The comparison between the observed line ratios and photoionization models using AGN Narrow Line Region primary spectra and starburst spectra will tell us about the gas ionization, density, abundances.

The ratio of IR fine structure lines to optical forbidden lines of the same species will be able to prove how much dust extinction is at work in these objects (e.g. LS +Malkan1992).

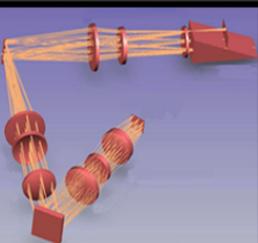
Extending the sample to all 12 μ m selected Seyfert galaxies in the Herschel Archive (~ 60 objects) will allow us to derive statistical conclusions on the behavior of Seyfert galaxies and compare them with optically selected starburst galaxies in the Local Universe.

What is next: SPICA JAXA + ESA Cosmic Vision

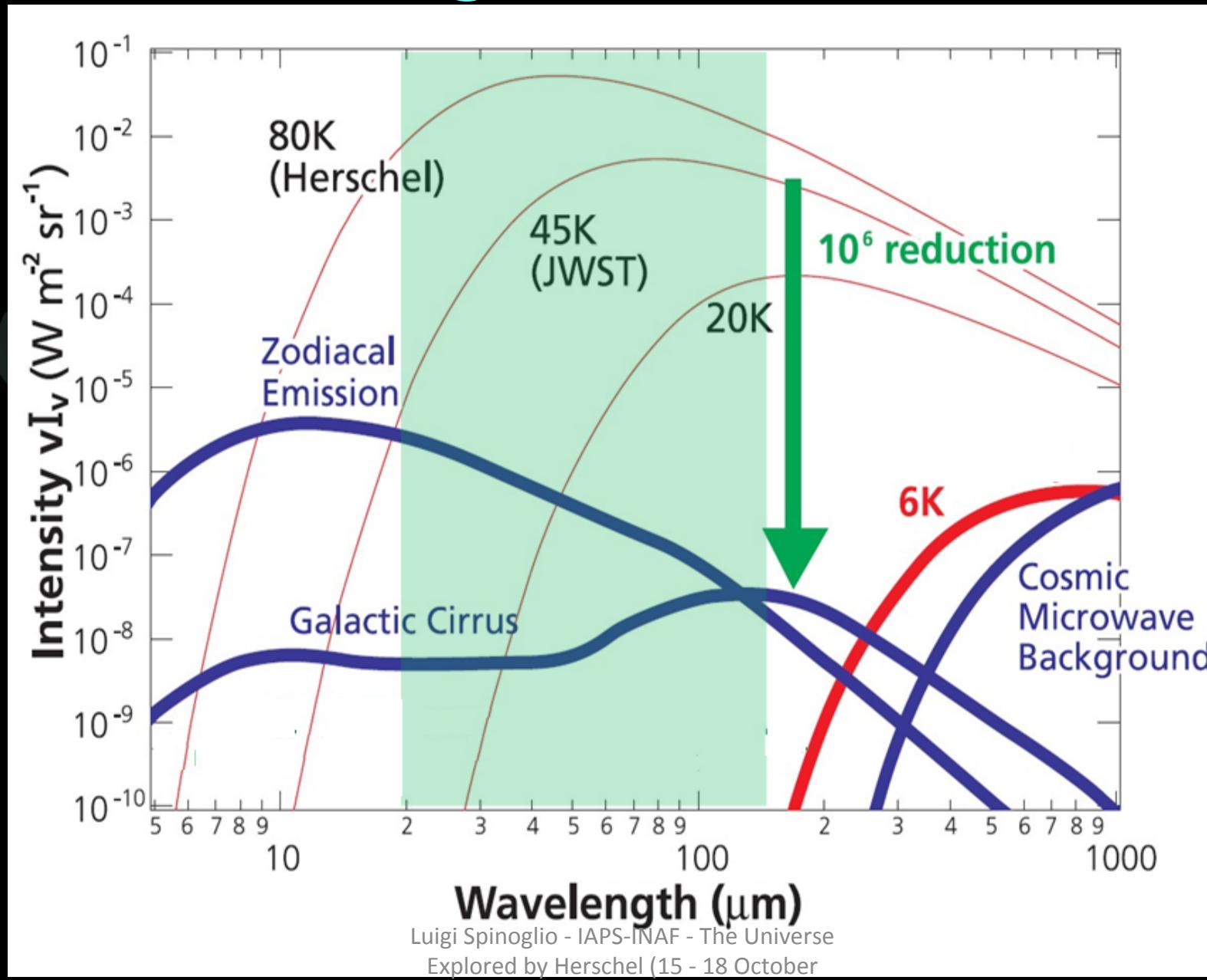
3.2 m telescope
Cooled to < 6K

Instruments cover 5- 210 μ m

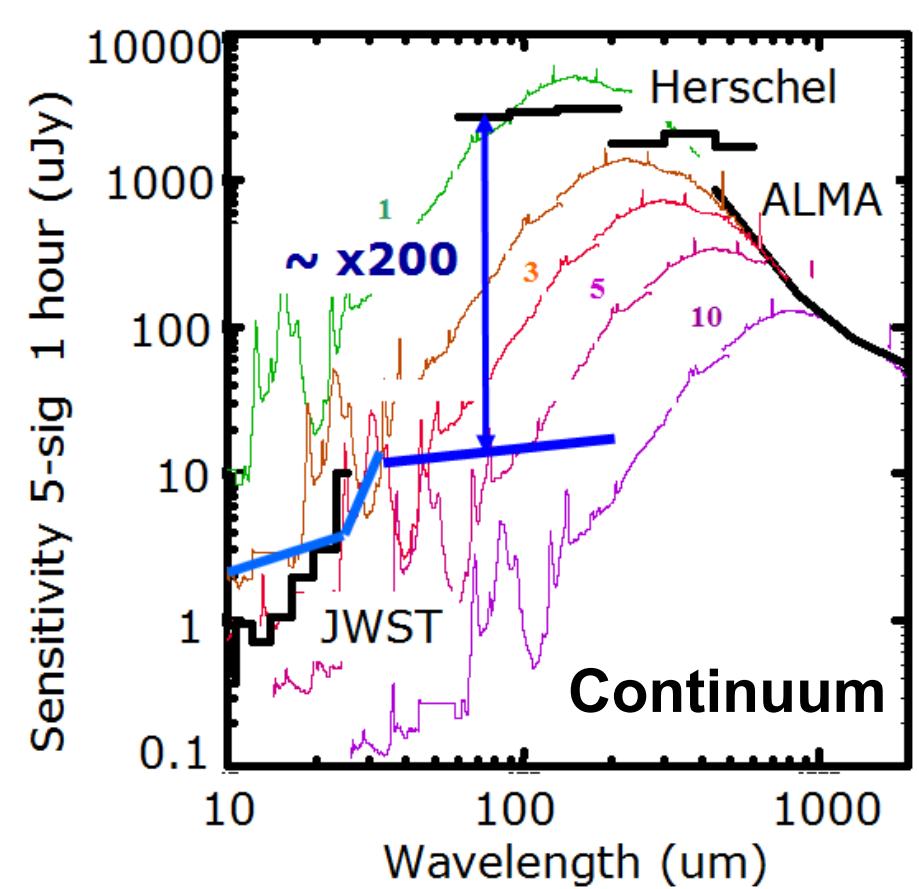
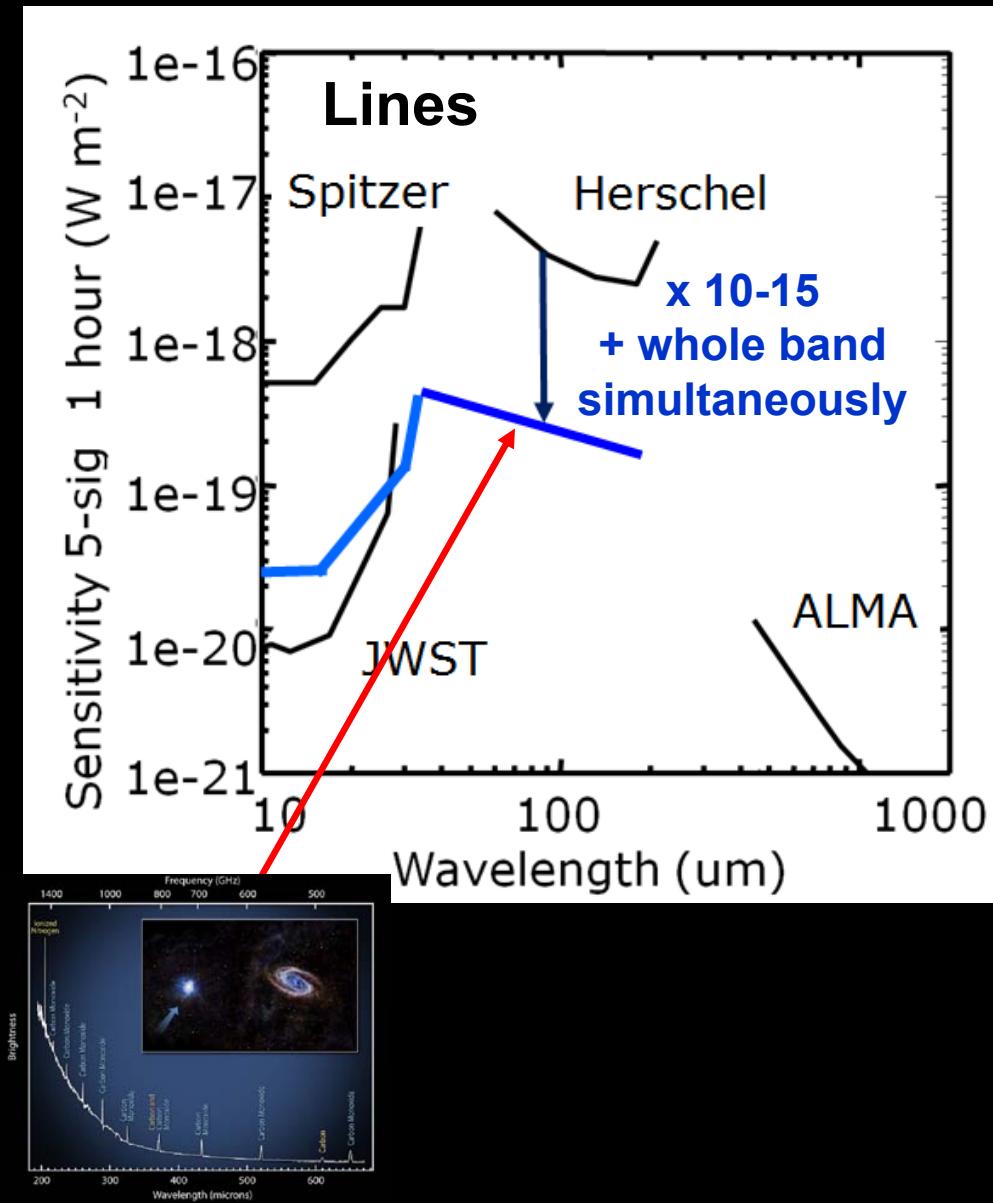
- MIR spectro-photometer
- **SAFARI=FIR imaging spectrometer**
→ galaxy evolution, star formation
- MIR Medium/High Resolution Spectrometer
- MIR coronagraph → EXOPLANETS
- Focal Plane Camera dedicated to guidance
- US FIR and sub-mm spectrometer – optional



Thermal Backgrounds

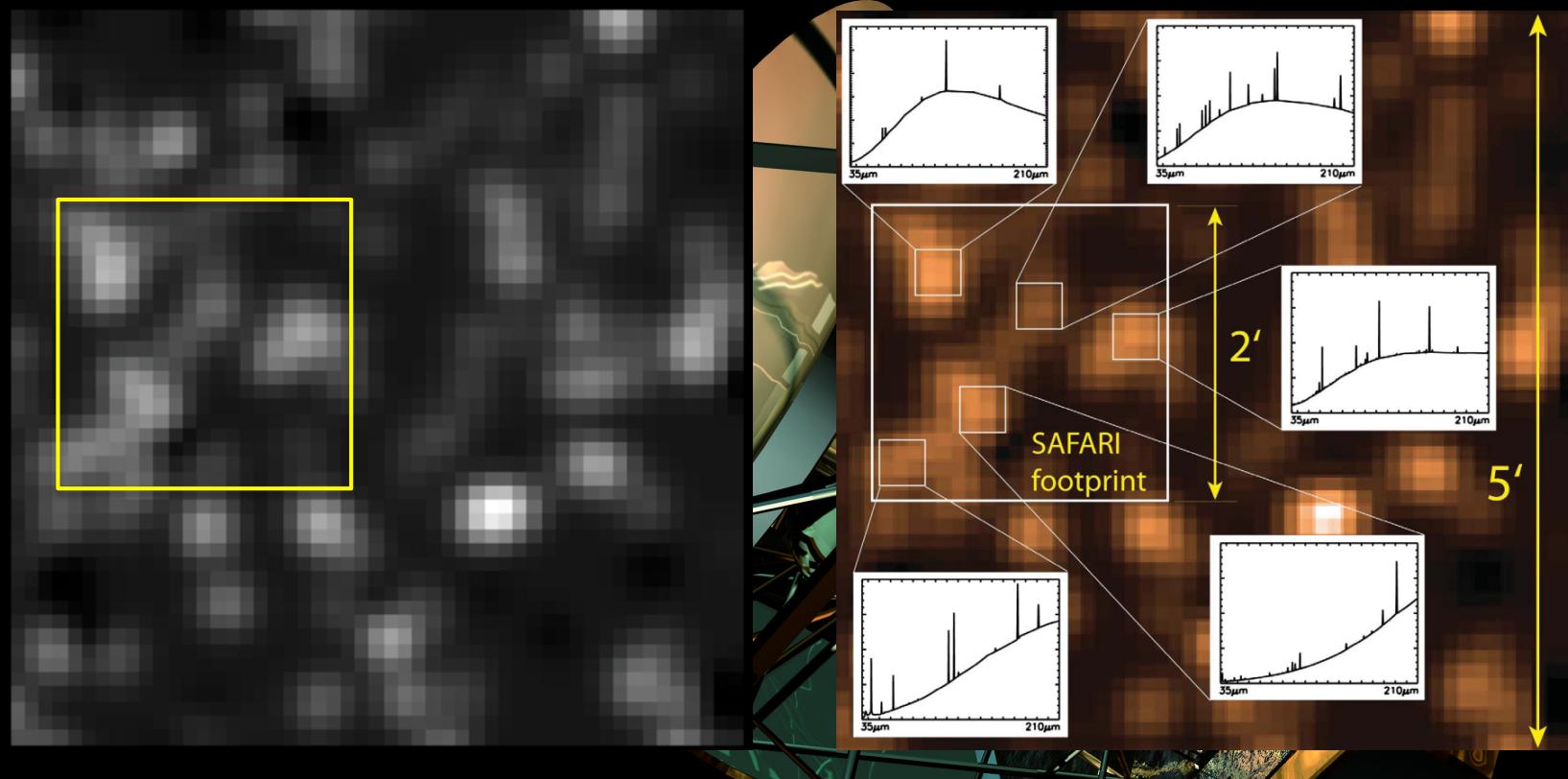


SPICA Sensitivity



The Multiplex Advantage

Looking closer at the SPIRE background sources



SPICA FIR FTS will take spectra of 7-10 sources/field

Images Rosenbloom, Oliver, Smith, Raab private communication

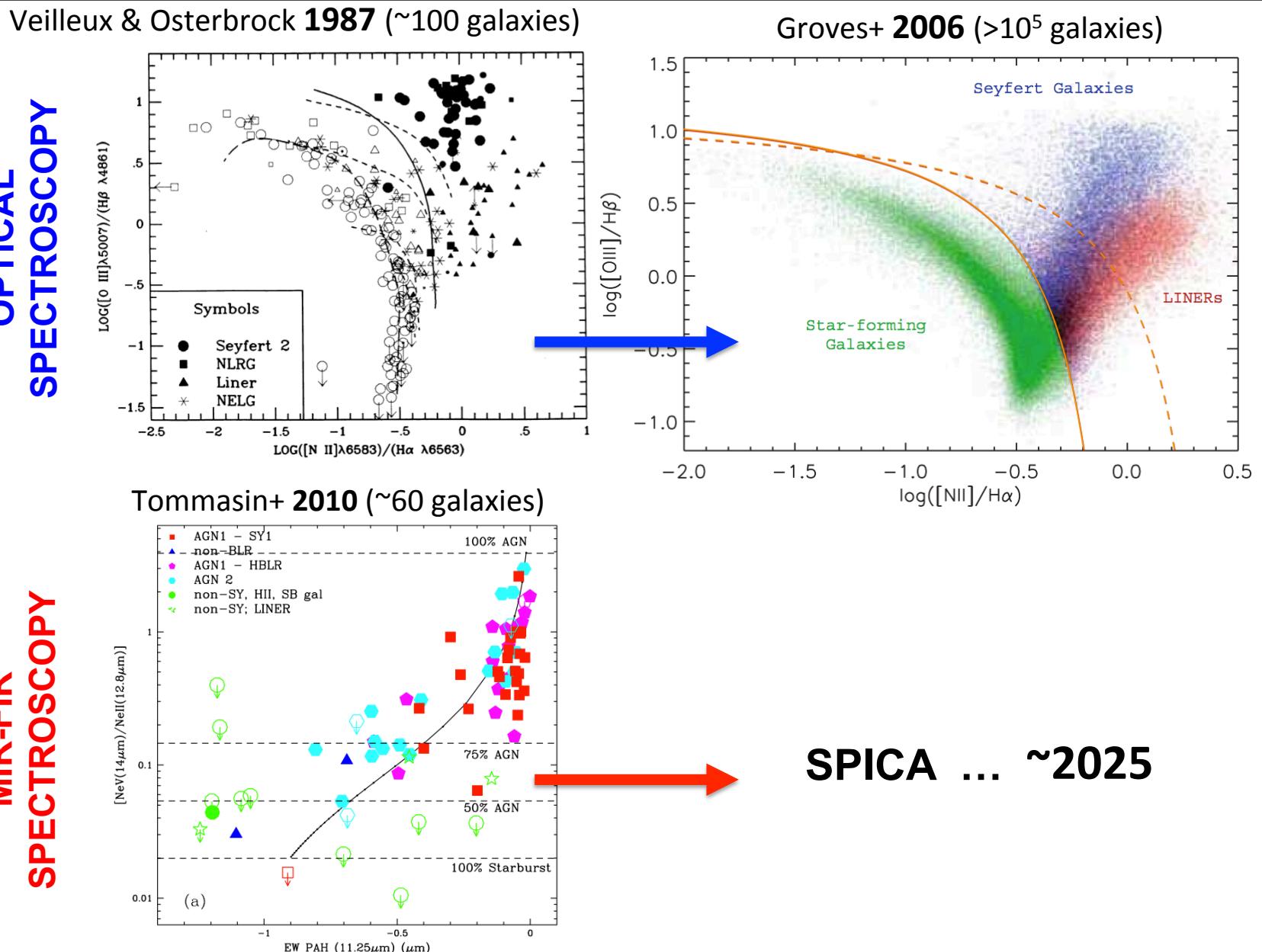
Luigi Spinoglio - IAPS-INAF - The Universe

Explored by Herschel (15 - 18 October

2013)

MIR-FIR SPECTROSCOPY

OPTICAL SPECTROSCOPY



Conclusions:

MIR/FIR spectroscopy can distinguish between accretion powered and Star formation dominated galaxies

The gas properties (ionization, density, primary radiation field, abundances as well as reddening) can be measured with the use of line ratio diagrams and photoionization models.

Although without an approved dedicated program, Herschel has detected FIR emission lines in about 40-50% of the 12 μ m selected Seyfert/IR bright AGNs and the study of the archive may produce statistically significant results on the accretion vs. star formation activity in the Local Universe.

We will anyway have to wait for the SPICA mission to be able to observe a complete sample of objects in the Local Universe, as well as to study systematically the occurrence of accretion and starburst emission along cosmic times.

Announcement:

Within the FISICA (Far Infrared Space Interferometer Critical Assessment) FP7 project (P.I. Giorgio Savini, UCL, UK),

“The First FISICA Workshop: Science Goals of a Sub-arcsecond Far-infrared Space Observatory”, whose main themes are the science goals of high resolution FIR imaging and spectroscopy,

will be held in Rome next 17-18 February 2014.

I will make a first announcement next week, however:

If you wish to participate, please contact me: luigi.spinoglio@iaps.inaf.it

