Herschel Open Time Key Project:

Herschel survey of Local Galaxies Activity

HerLoGAL

Coordinator: Luigi Spinoglio (IFSI - INAF Roma)

List of people who expressed interest in this KP:

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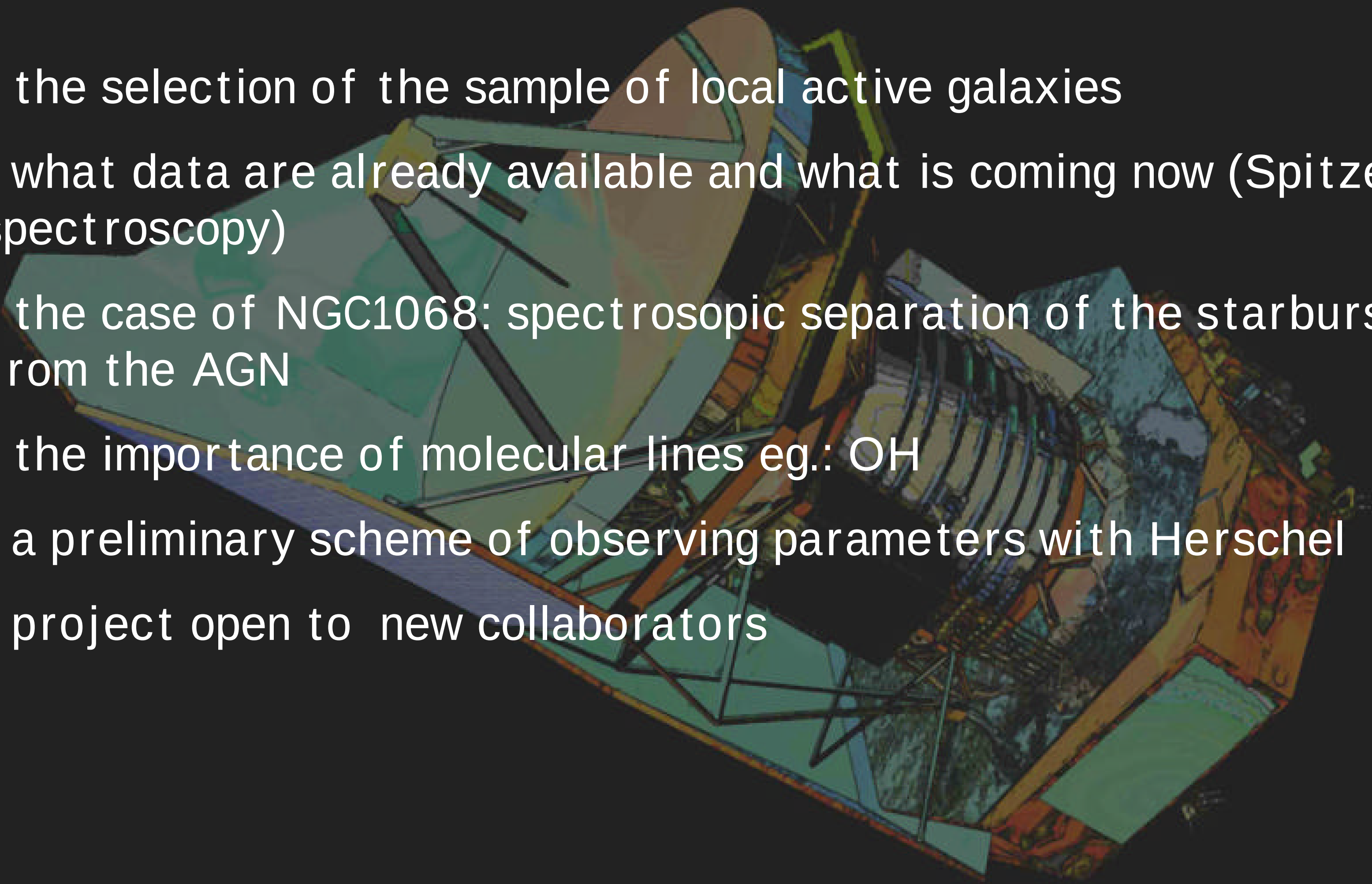
Outline

- the selection of the sample of local active galaxies
- what data are already available and what is coming now (Spitzer spectroscopy)
- the case of NGC1068: spectrosopic separation of the starburst from the AGN
- the importance of molecular lines eg.: OH
- a preliminary scheme of observing parameters with Herschel
- project open to new collaborators



Herschel observations of a complete sample of active and starburst galaxies in the Local Universe

Herschel + Mid-IR (Spitzer) data will have as main goals:

➔ find the interrelations between star formation & black hole accretion and understand how these processes influence the mid-far-IR/submm appearance of galaxies in the Local Universe.

➔ separate the nonthermal (AGN) and thermal (starburst) components in the energy budget of the galaxies

➔ determine the fraction of radiant energy in the local Universe produced by stars and that by black hole accretion, by computing separate luminosity functions for accretion and star formation processes

➔ Establish a "zero redshift" point for the study of galaxy evolution.

SPIRE & PACS imaging: ➔ trace star formation through warm & cold dust
(filling the gap between mid-IR and millimetre wavelengths)

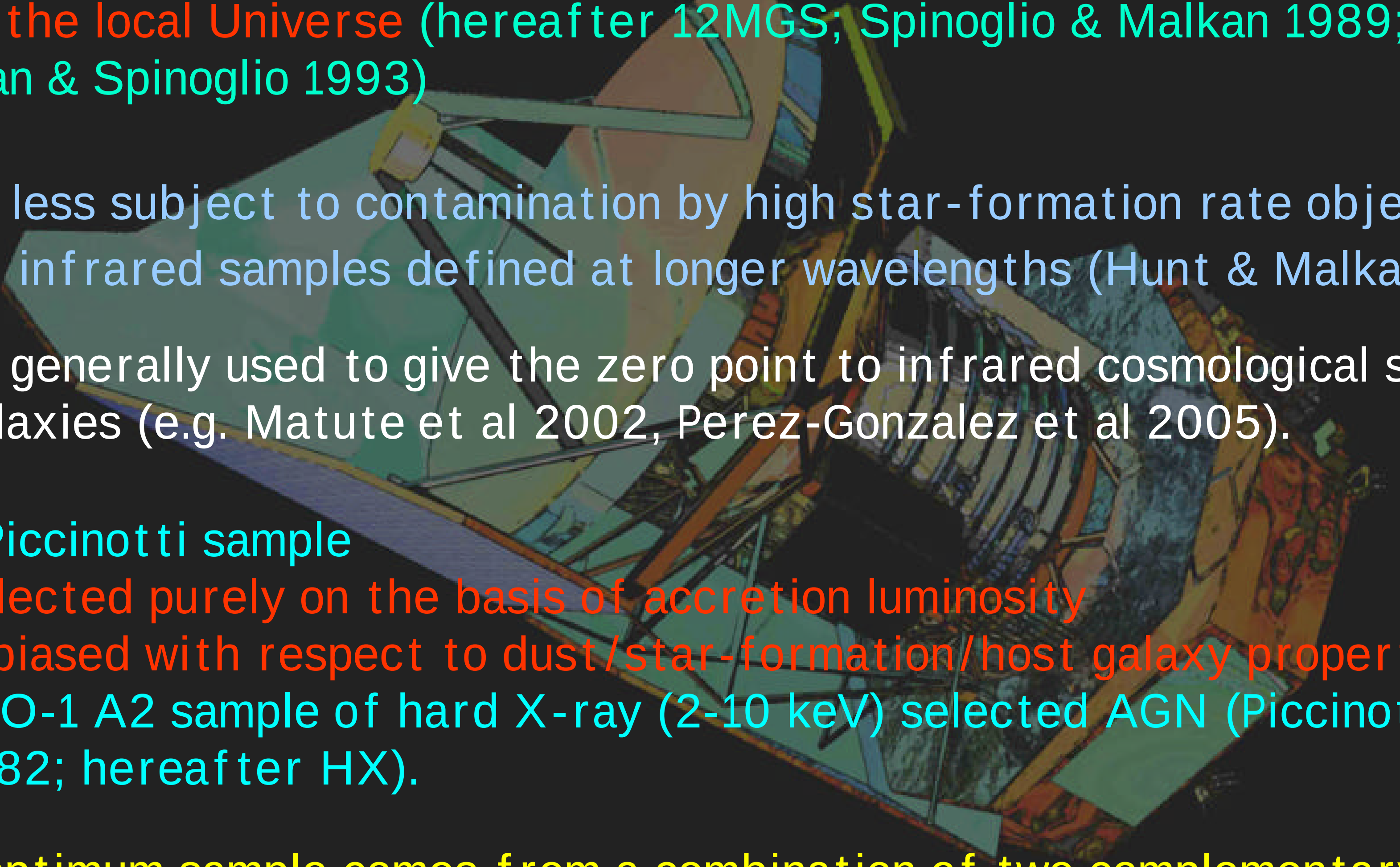
PACS (& HIFI?) spectroscopy: ➔ characterize the emission mechanisms
(stellar photoionization, shocks, PDRs, XDRs)
➔ detect dusty tori, to reconcile the type 1/type 2 observed bimodality.

Need of a well defined statistical sample.

➔ the complete active galaxies sub-samples of the 12μm Galaxy Sample

➔ the hard-X ray selected Piccinotti sample (greatly overlapping the 12MGS)

Why the 12μm + Piccinotti Galaxy Samples ?



The 12μm sample is an IRAS-selected all-sky survey flux-limited to 0.22Jy at 12μm ➔ relatively unbiased sample of active and star forming galaxies from the local Universe (hereafter 12MGS; Spinoglio & Malkan 1989; Rush, Malkan & Spinoglio 1993)

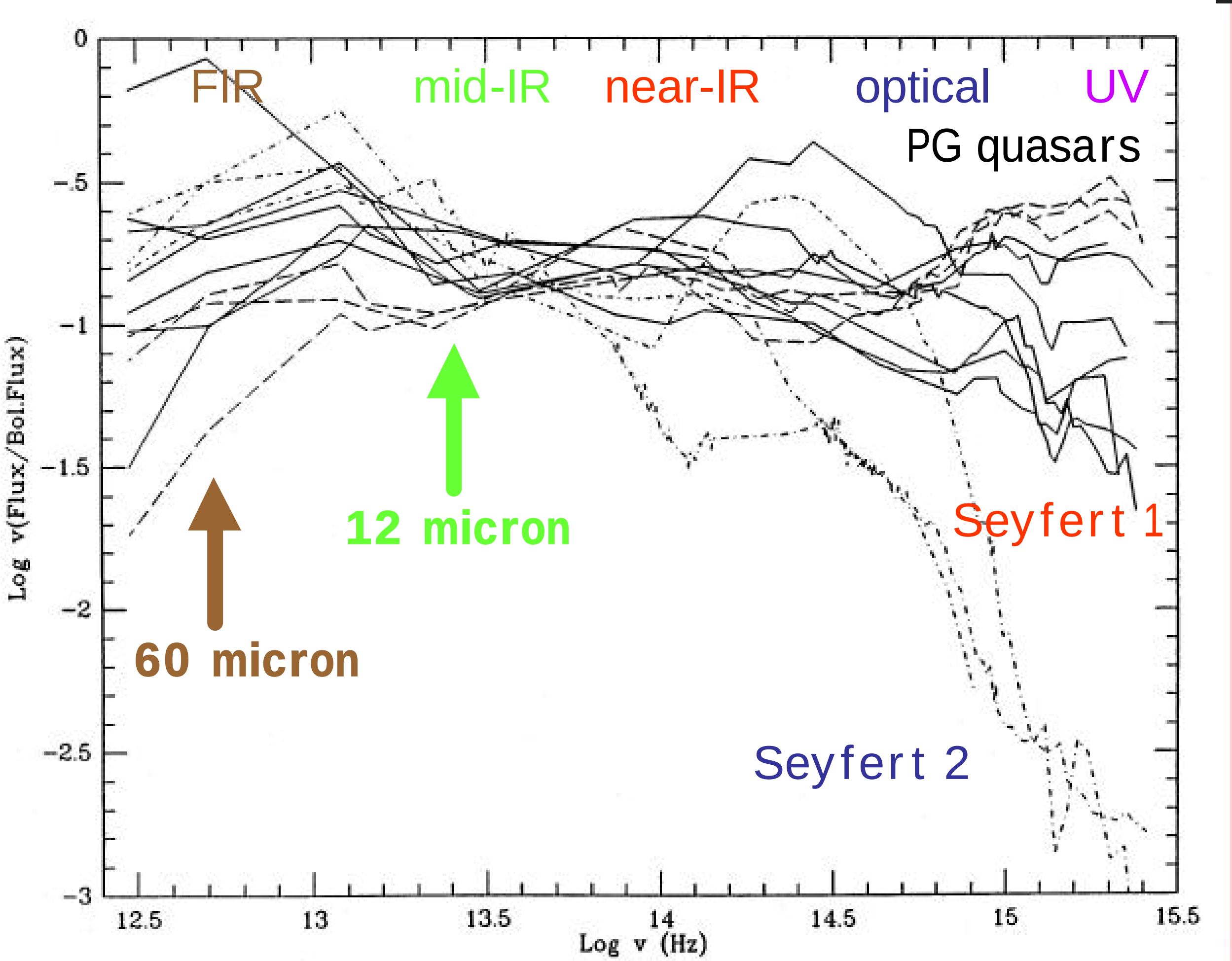
- It is less subject to contamination by high star-formation rate objects than other infrared samples defined at longer wavelengths (Hunt & Malkan 1999).

- It is generally used to give the zero point to infrared cosmological studies of galaxies (e.g. Matute et al 2002, Perez-Gonzalez et al 2005).

The Piccinotti sample
➔ selected purely on the basis of accretion luminosity
➔ unbiased with respect to dust/star-formation/host galaxy properties.
(HEAO-1 A2 sample of hard X-ray (2-10 keV) selected AGN (Piccinotti et al. 1982; hereafter HX).

The optimum sample comes from a combination of two complementary *all-sky* and *flux-limited* (and thus statistically complete) samples, with orthogonal selection biases

Why selecting at 12 micron ?



normalized to the bolometric fluxes (computed from 0.1-100μm.

[Spinoglio & Malkan, 1989]

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.

$F_{12\mu m} \sim 1/5\ F_{bolometric}$ for all types of AGN

➔ 12 μm COMPLETE SAMPLES IN BOLOMETRIC FLUX

HX and 12MGS are statistically complete samples of the nearest and brightest objects over a wide range of luminosity.

The combination of the HX and 12MGS

➔ key advantage to understand the role of AGN in the IR galaxy population.

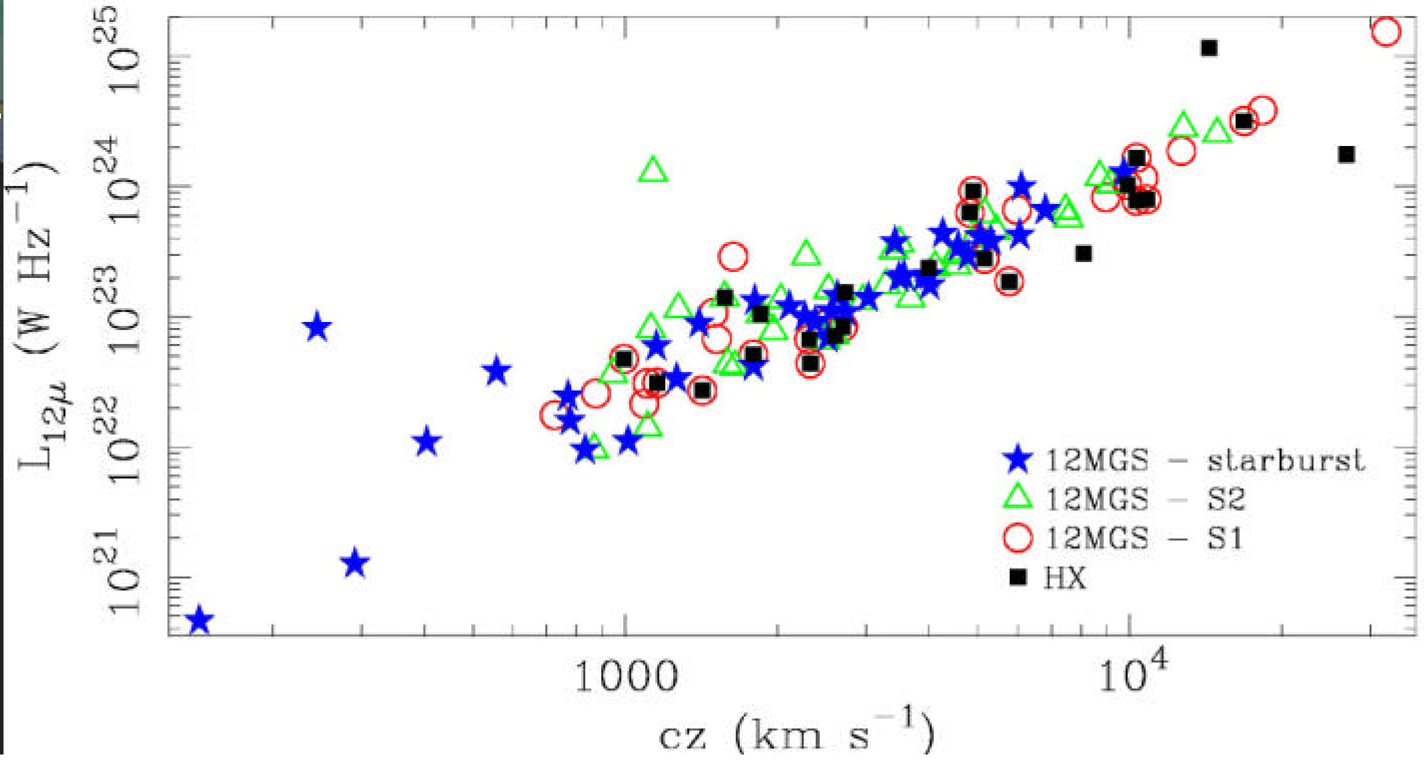
1. the HX sample investigates the FIR spectroscopic and photometric signatures of AGN as a function of accretion power,
2. the 12MGS sample relates these properties to a coherent sample of nearby infrared galaxies.

➔ the ideal reference sample with which to understand the large numbers of distant galaxies which will be discovered in Herschel's imaging survey.

Redshift and 12μm luminosity distribution.

Targets evenly distributed over >2.5 orders of magnitude in luminosity,

Being all-sky flux-limited surveys these are the closest (hence brightest) targets at each luminosity.



The 12MGS + Piccinotti samples contain:

53+6=59 Seyfert 1s,
63 Seyfert 2s,
34 high-luminosity non-Seyfert galaxies LIR > 10^11.5 Lo,
33 LINERs,
~50 optically classified starburst galaxies in the NED database

For a total of 122 Seyfert Galaxies
or 239 sources including LINERS and Starbursts

(Rush, Malkan & Spinoglio 1993; Hunt & Malkan 1999).

AVAILABLE AND PLANNED DATA ON THE 12MGS

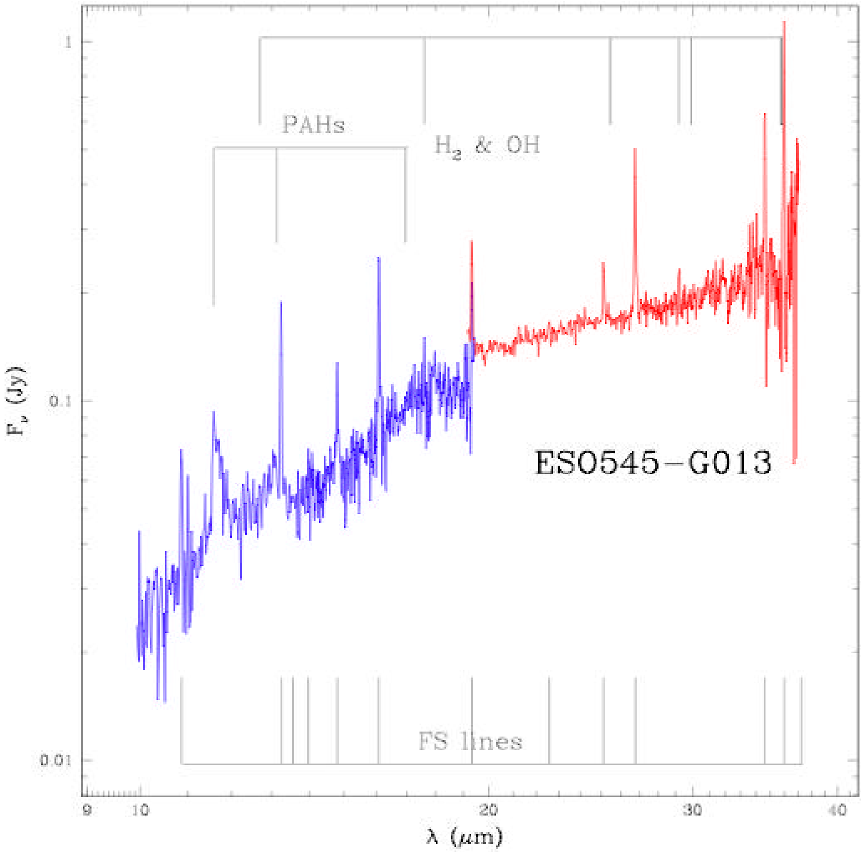
The 12MGS has already a complete set of observations at virtually every other wavelength:

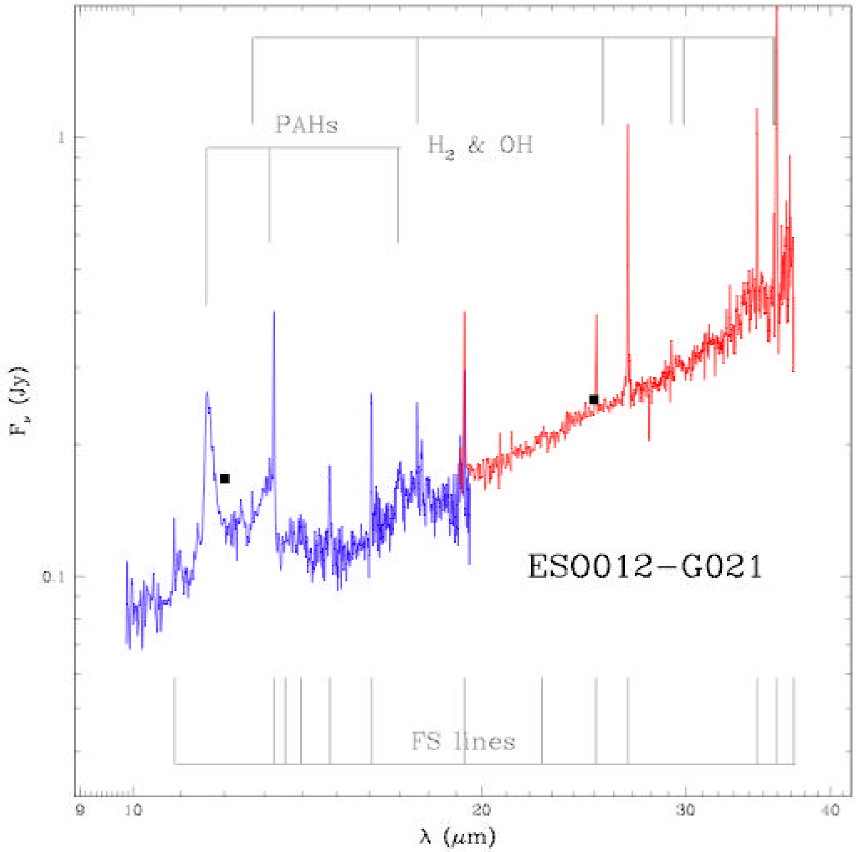
- full IRAS and near-IR coverage (Rush et al. 1993, Spinoglio et al 1995)
- X rays (Rush et al. 1996), Optical & UV spectroscopy,
- radio (Rush, Malkan & Edelson 1996), optical/IR imaging (Hunt et al. 1999),
- ISOCAM mid-IR imaging (Spinoglio et al 2005, in preparation) and
- ISOPHOT data on half of the sample (Spinoglio, Andreani & Malkan 2002).
- 10μm imaging (Gorjian et al. 2004)
- 2.8-4μm spectroscopy (Imanishi 2003)
- Optical spectropolarimetry (Tran 2001, Tran 2003)
- Radio observations (Thean et al. 2000, 2001)
- Spitzer IRS low resolution mapping (Buchanan, Gallimore et al 2006)
- Spitzer IRAC imaging and MIPS SED spectra (Gallimore GO program)

About half of the active galaxies of the 12MGS have been observed by Spitzer IRS at high resolution, many of which are already in the Spitzer public archive.

The other half of the sample is beeing currently observed by Spitzer IRS at high resolution in a GT program by Giovanni Fazio and the CfA team in collaboration with us.

Spitzer IRS high resolution spectra are coming out and being reduced and analysed

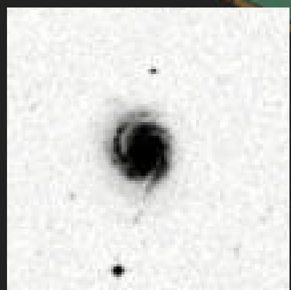




Spitzer spectra:

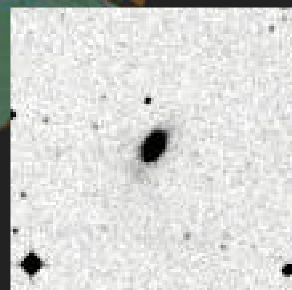
ESO 545- G 013

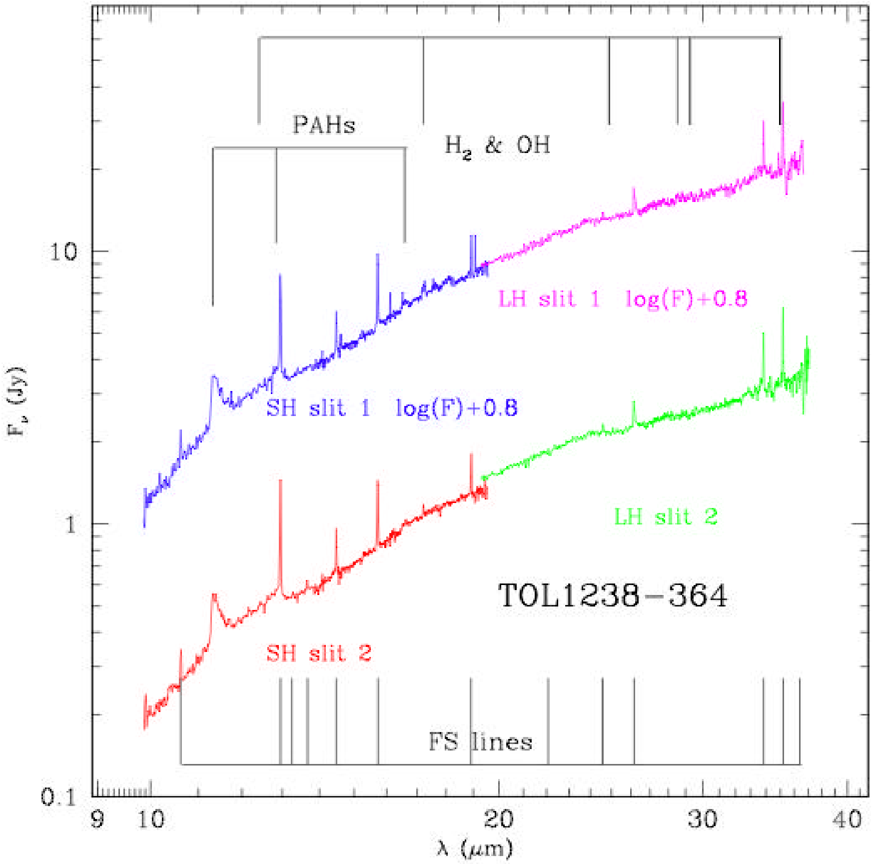
Z=0.0337 Sy1.8

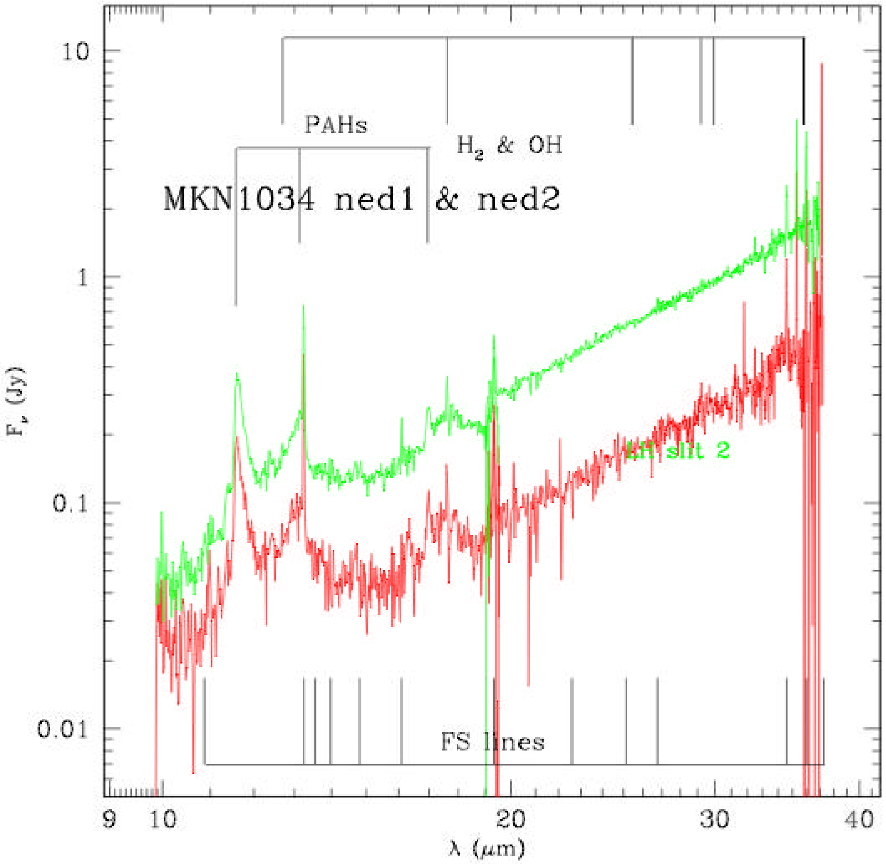


ESO 012- G 021

Z=0.0300 Sy1



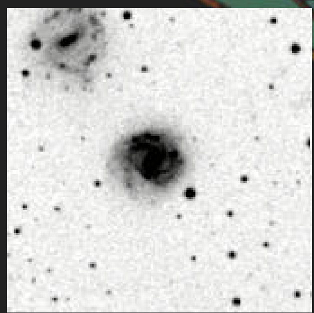




Spitzer spectra:

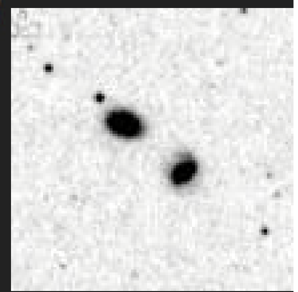
TOL1238-364

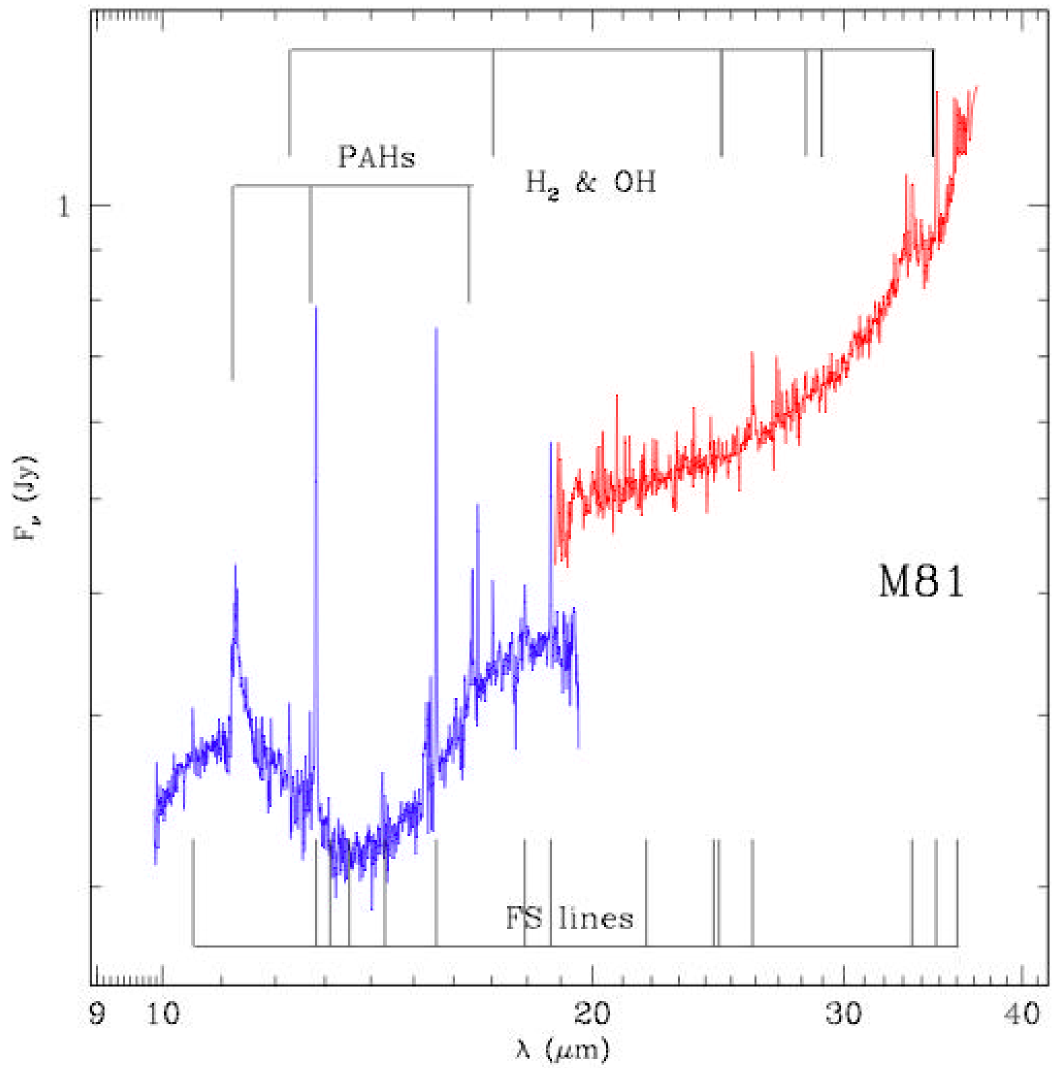
Z=0.0109 Sy2



MKN 1034

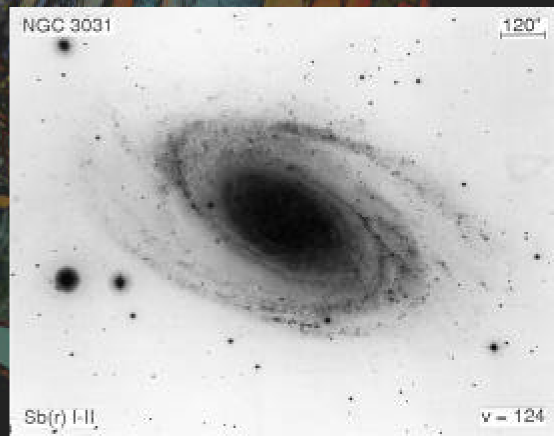
Z=0.0338 HII/Sy1



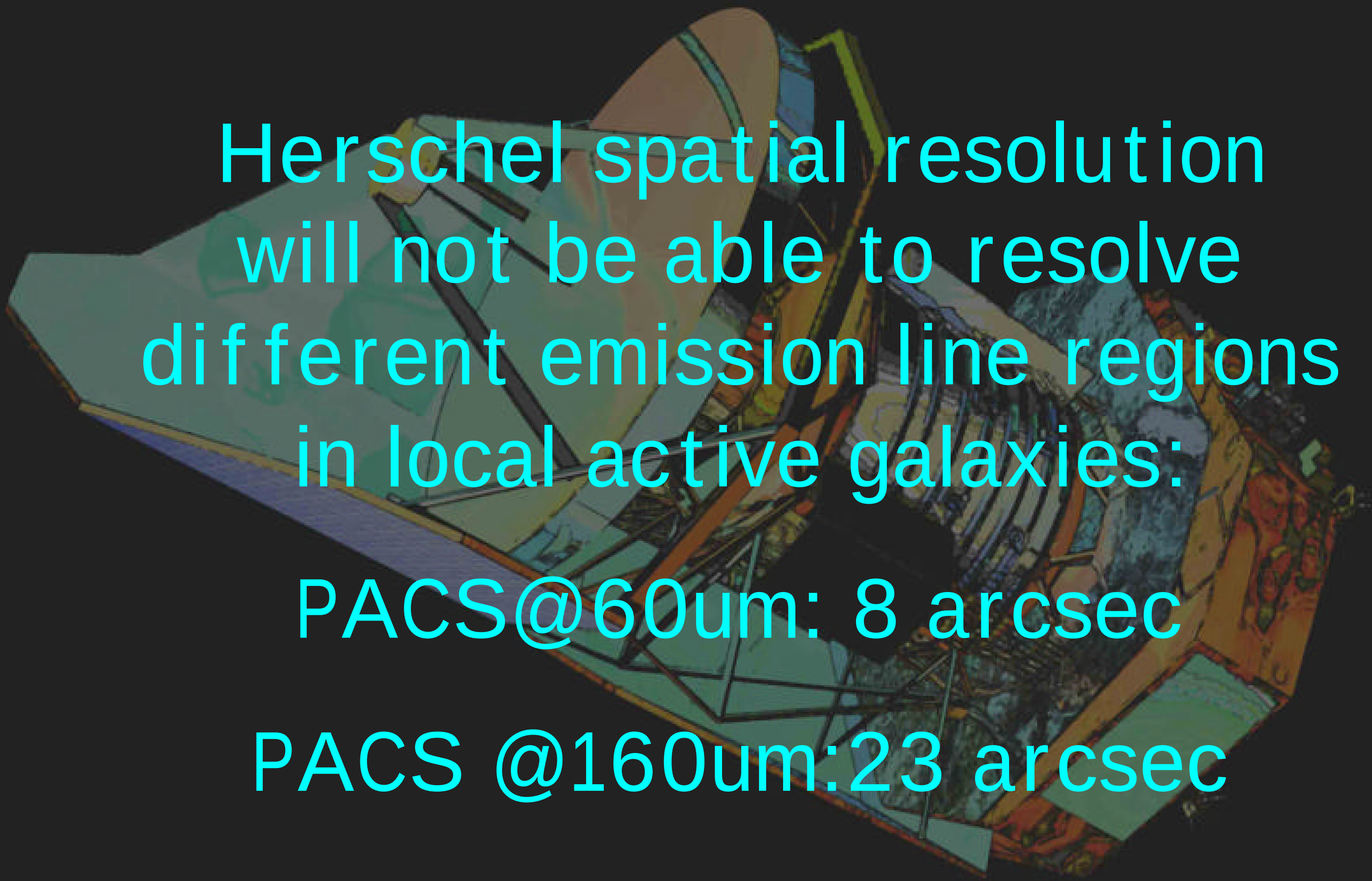


M81 LINER, z=0.0011

Line	intensity [W/cm^2]	S/N
[SIV] 10.51:	1.7546e-21 +/- 0.295	5.9
H2 12.27:	2.9641e-21 +/- 0.393	7.5
[NeII] 12.81:	2.7730e-20 +/- 0.049	56.
[NeIII] 15.55:	1.8356e-20 +/- 0.033	55.
H2 17.03:	2.3460e-21 +/- 0.269	8.7
[FeII] 17.93:	1.8065e-21 +/- 0.362	5.0
[SIII] 18.71:	6.4804e-21 +/- 0.277	23.
[FeII] 24.52:	5.8296e-22 +/- 2.59	2.25
[OIV] 25.89:	4.7251e-21 +/- 0.216	22.
[SIII] 33.48:	7.4343e-21 +/- 0.577	13.
[SiII] 34.81:	1.6755e-20 +/- 0.040	42.



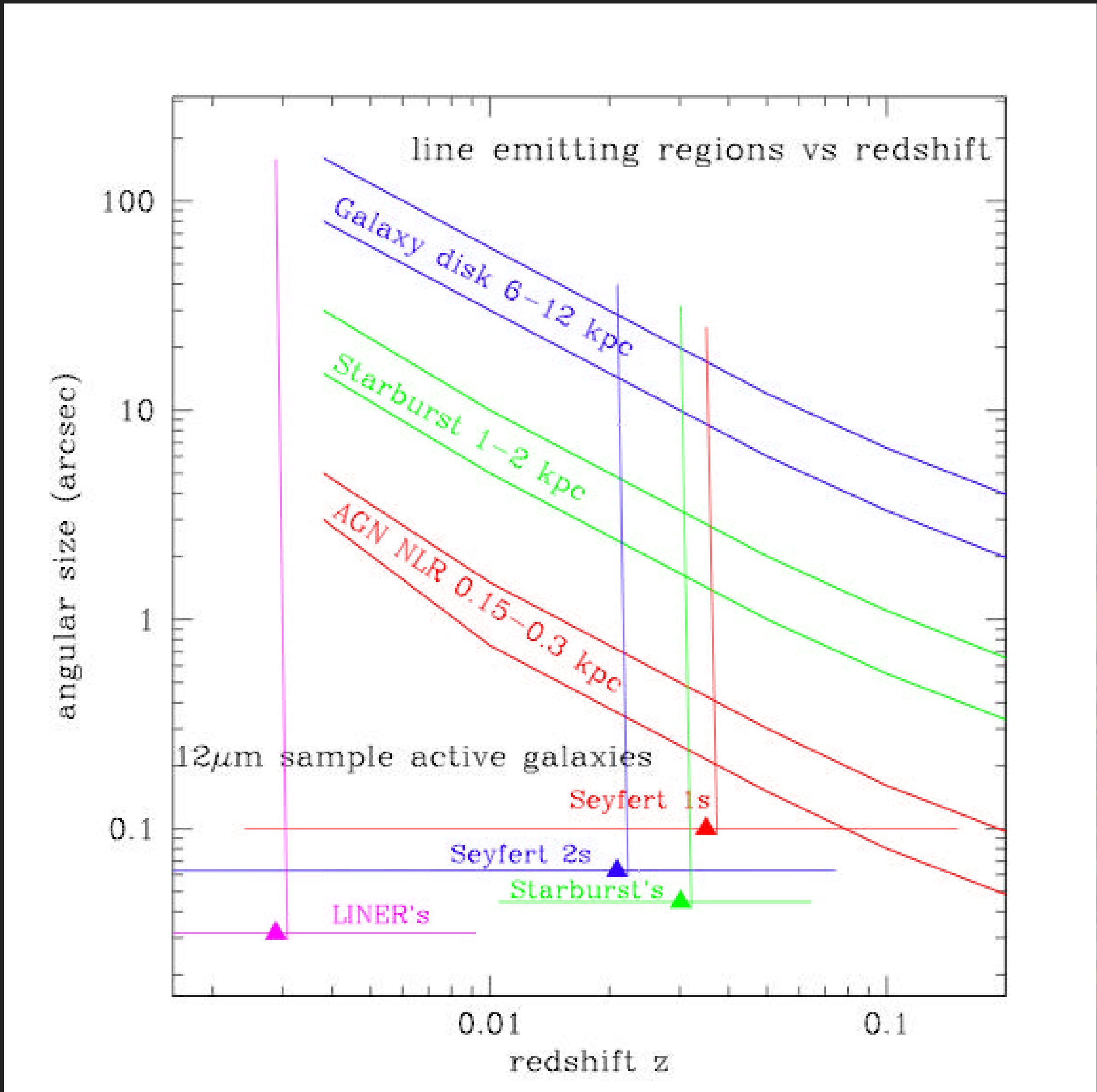
Spitzer high.res. IRS data provided by Howard Smith, CfA



Herschel spatial resolution
will not be able to resolve
different emission line regions
in local active galaxies:

PACS@60um: 8 arcsec

PACS @160um:23 arcsec



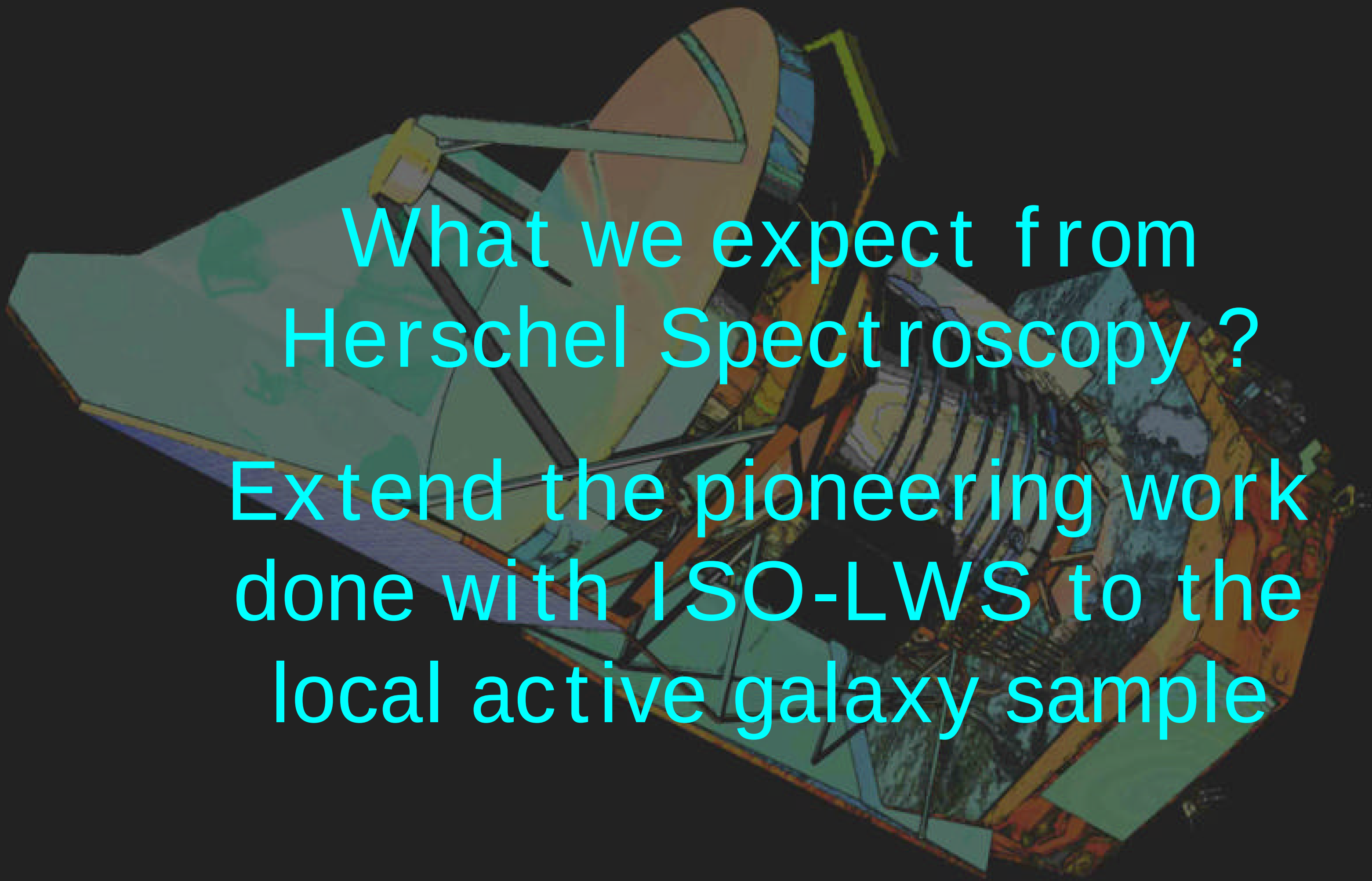
Spatial scales as a function of redshift

spectroscopy is needed to separate emission components from starbursts and AGNs at the Herschel spatial resolution

Only LINER's of the 12μm sample can be spatially resolved

What we expect from Herschel Spectroscopy ?

Extend the pioneering work done with ISO-LWS to the local active galaxy sample

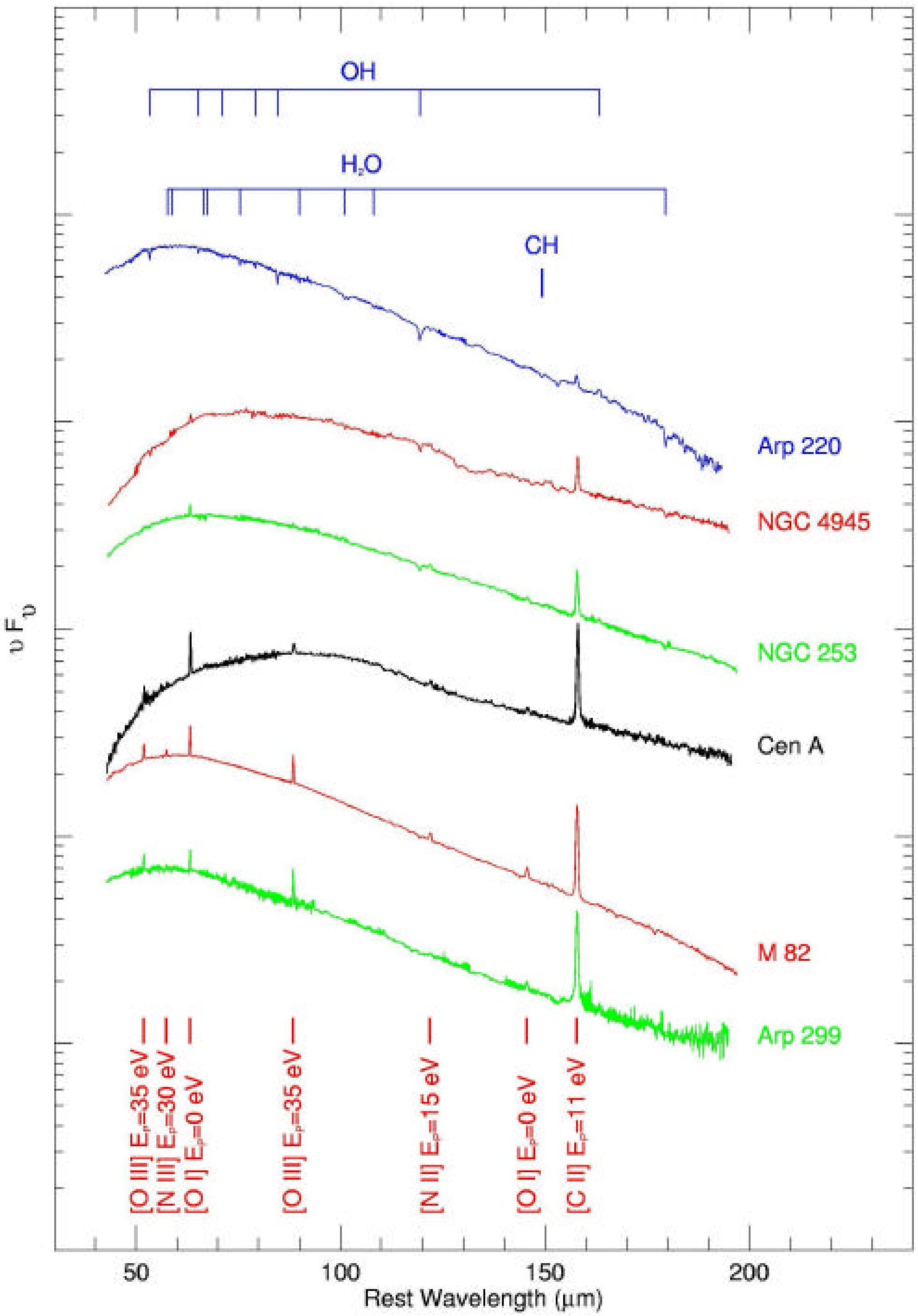


What we learned from ISO-LWS spectra :

LWS: dramatic progression in ionic/atomic fine-structure emission line and molecular/atomic absorption line. (Fischer et al '99)

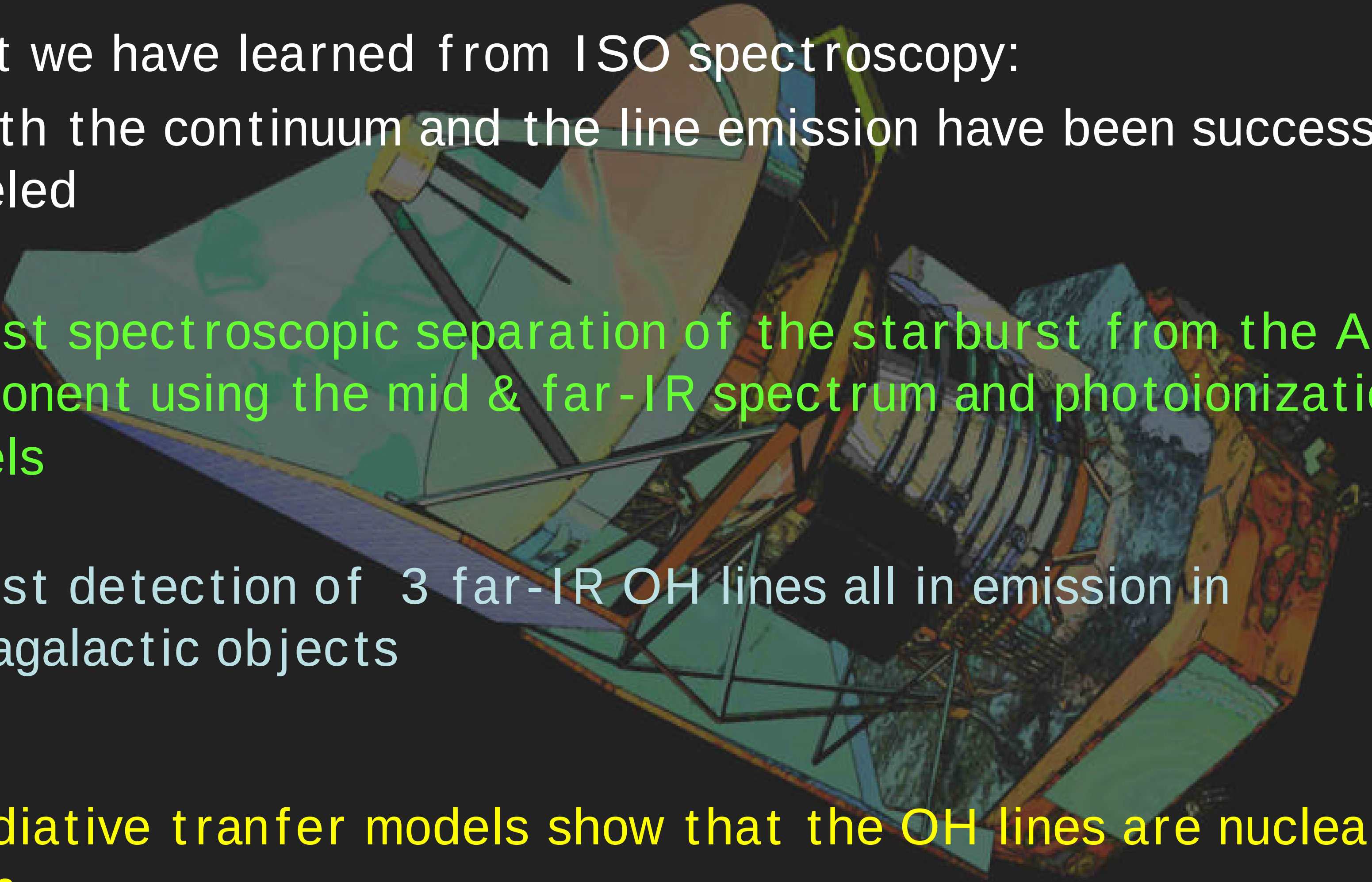
Arp 220:
absorption in lines of OH, H_2O, CH, NH, NH_3, and in [O I]63µm
faint emission in [C I I]158µm line.
molecular absorption in the nuclear region characterized by high excitation due to high IR radiation density (Gonzàlez-Alfonso et al 2004).

NGC 1068:
besides the expected ionic F-S lines:
79, 119 and 163µm OH rotational lines in emission (not in absorption as in every other galaxy yet observed) most probably originated from the nucleus. (Spinoglio et al. 2005).



The case of NGC 1068

With Eduardo Gonzalez-Alfonso, Howard Smith, Jackie Fischer & Matt Malkan,



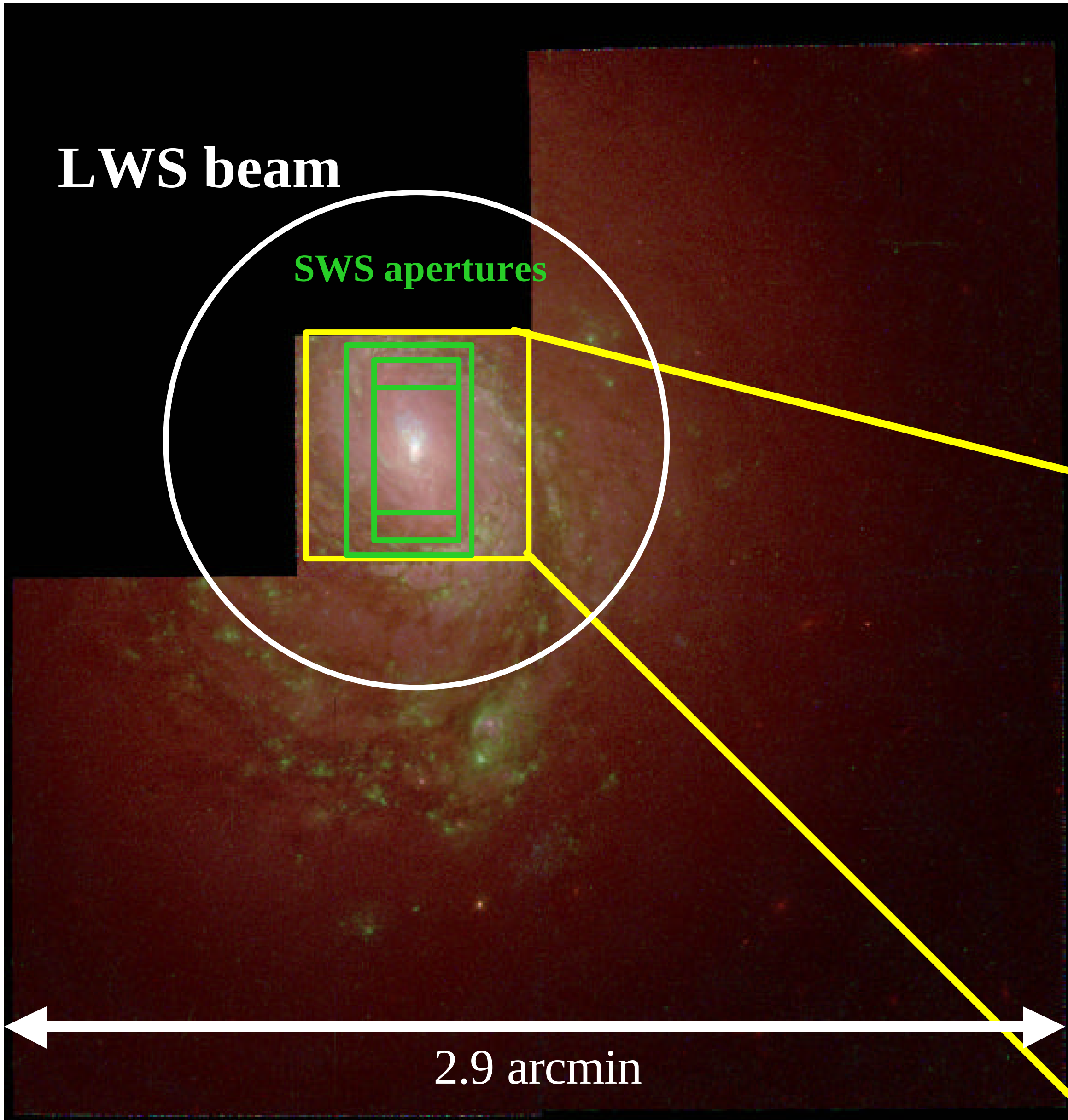
What we have learned from ISO spectroscopy:

- both the continuum and the line emission have been successfully modeled

- first spectroscopic separation of the starburst from the AGN component using the mid & far-IR spectrum and photoionization models

- first detection of 3 far-IR OH lines all in emission in extragalactic objects

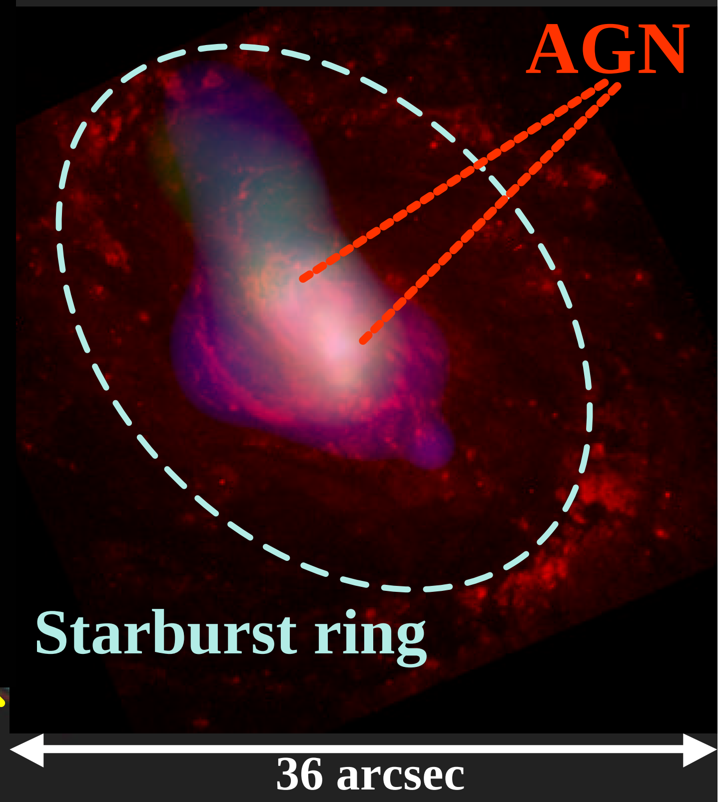
- radiative tranfer models show that the OH lines are nuclear in origin

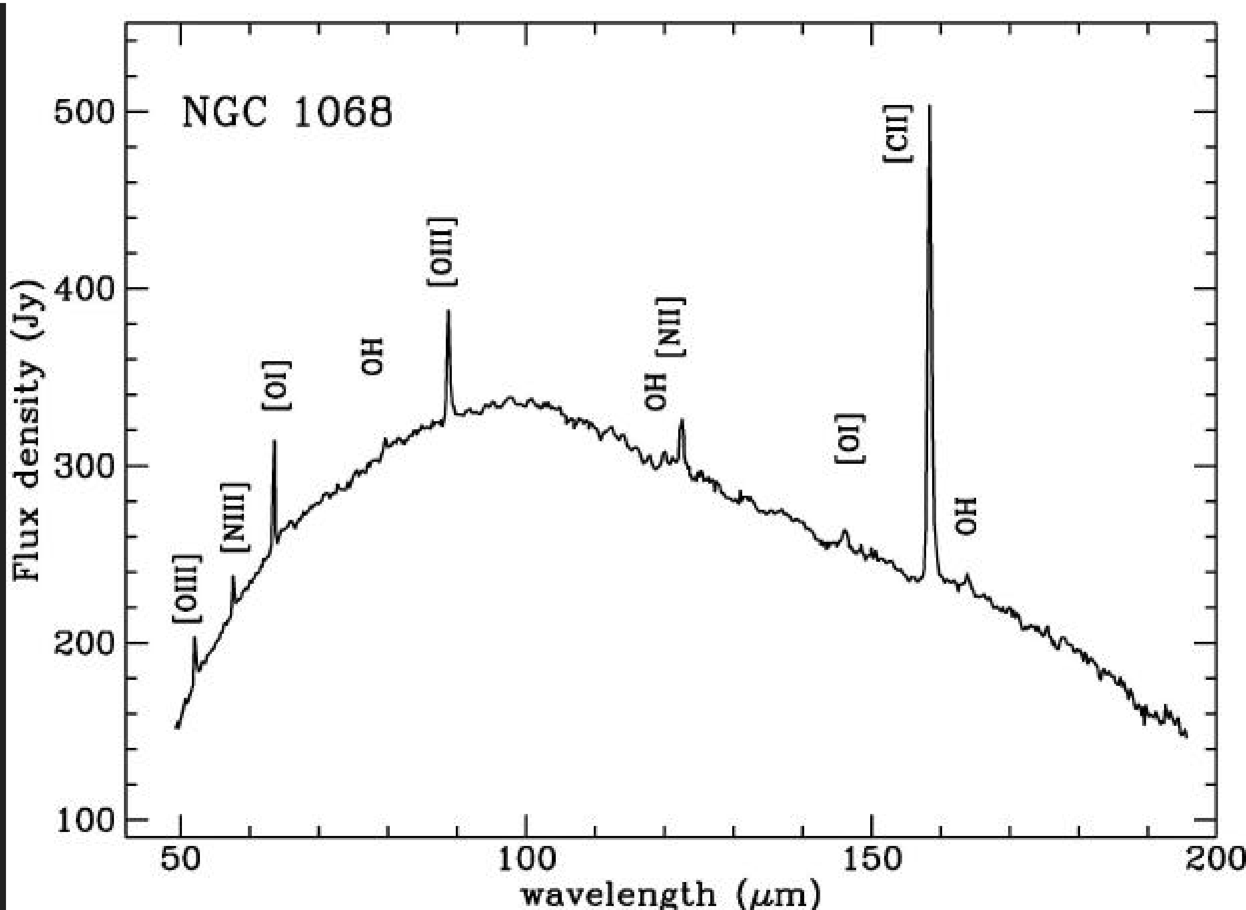


HST three-colour image of the WFPC2 camera ([OIII], Ha+[NII], wide-band 791nm filter)

CHANDRA image overlayed on a HST image (X-ray: green 0.4-0.8 keV, blue 0.8-1.3 keV; optical: red)

X-ray: P.Ogle et al.; Optical: A.Capetti et al.





The LWS spectrum was taken on 1997 July 13 (orbit 605)

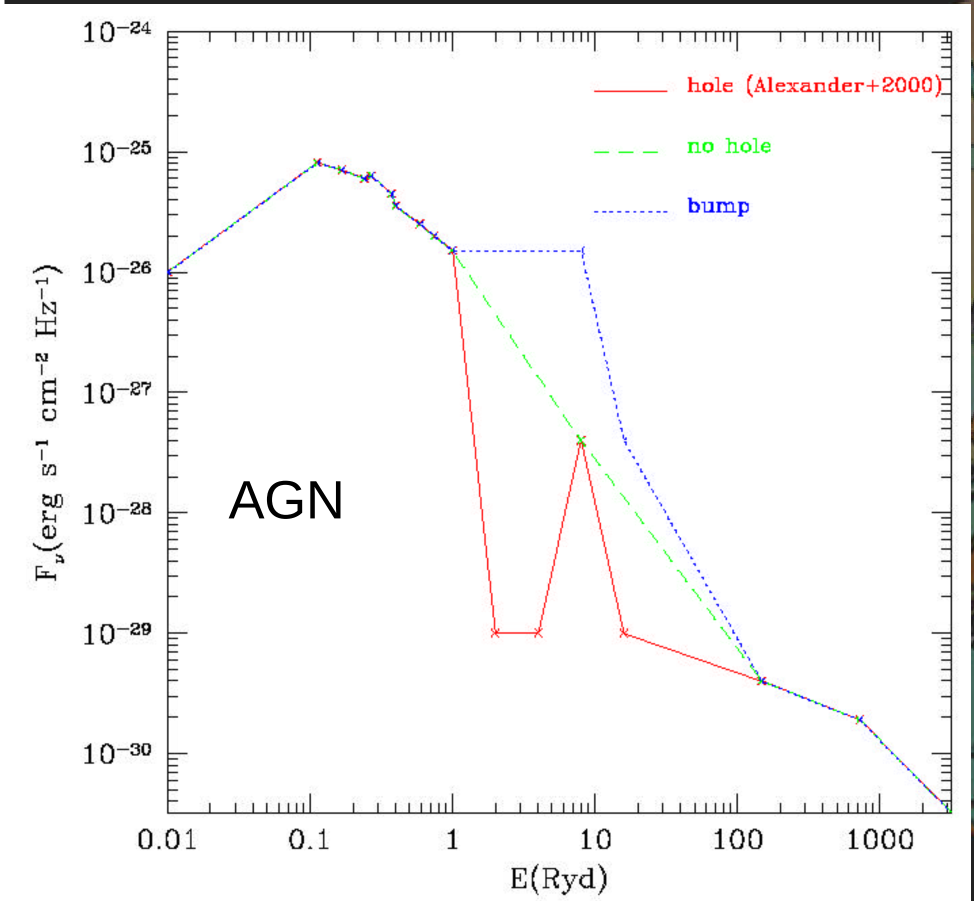
15,730 s.+ 3,390 s. (on + off [CII]157μm only)

Line	Flux ($10^{-16}Wm^{-2}$)
[O III] 51.814μm	114. ± 3.
[N III] 57.317 μm	51.4 ± 2.5
[O I] 63.184 μm	156. ± 1.
[O III] 88.356 μm	111. ± 1.
[N II] 121.897 μm	30.5 ± 1.1

Line	Flux ($10^{-16}Wm^{-2}$)
[O I] 145.525 μm	11.9 ± 0.4
[C II] 157.741 μm	216. ± 1.
OH ??79.11/79.18 μm	14.4 ± 1.5
OH ??119.23/119.4 μm	11.9 ± 1.2
OH ??163.12/163.40μm	7.42 ± 0.65

Infrared spectroscopy to measure the primary ionizing spectrum (NGC1068)

a) AGN primary spectrum

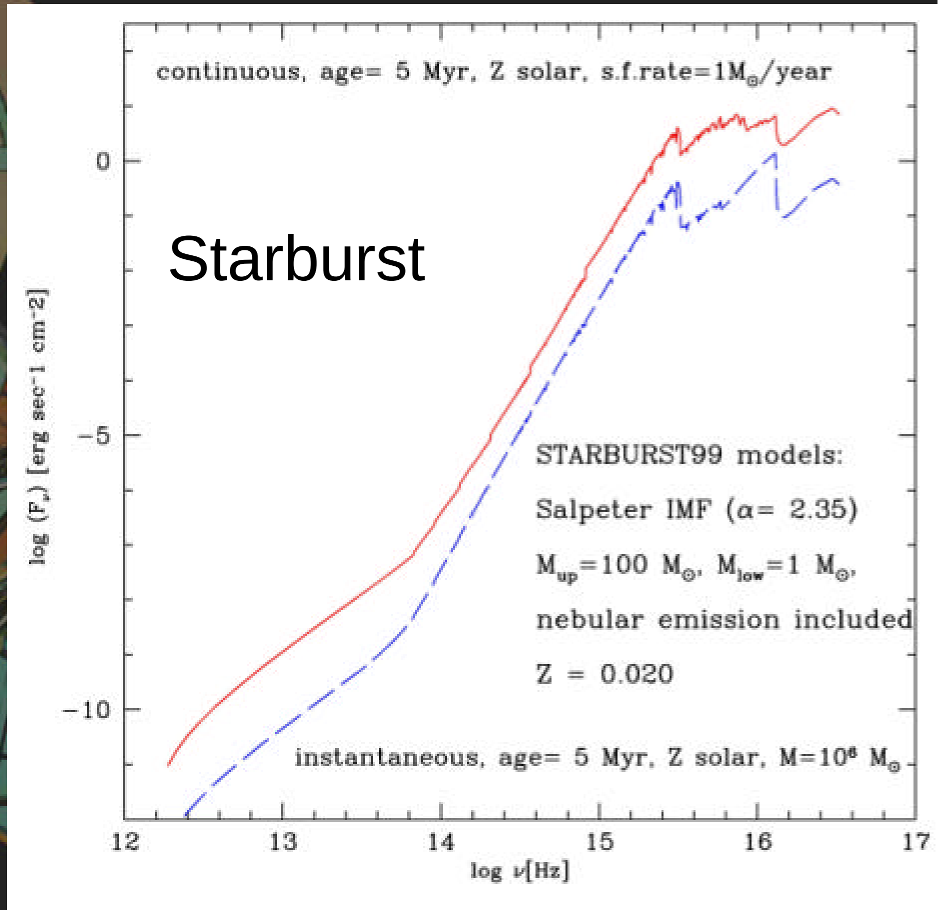


— big "hole" (Alexander et al.2000)

--- "classic" (Pier et al.1994)

..... big blue bump (accretion disc)

b) starburst primary spectrum

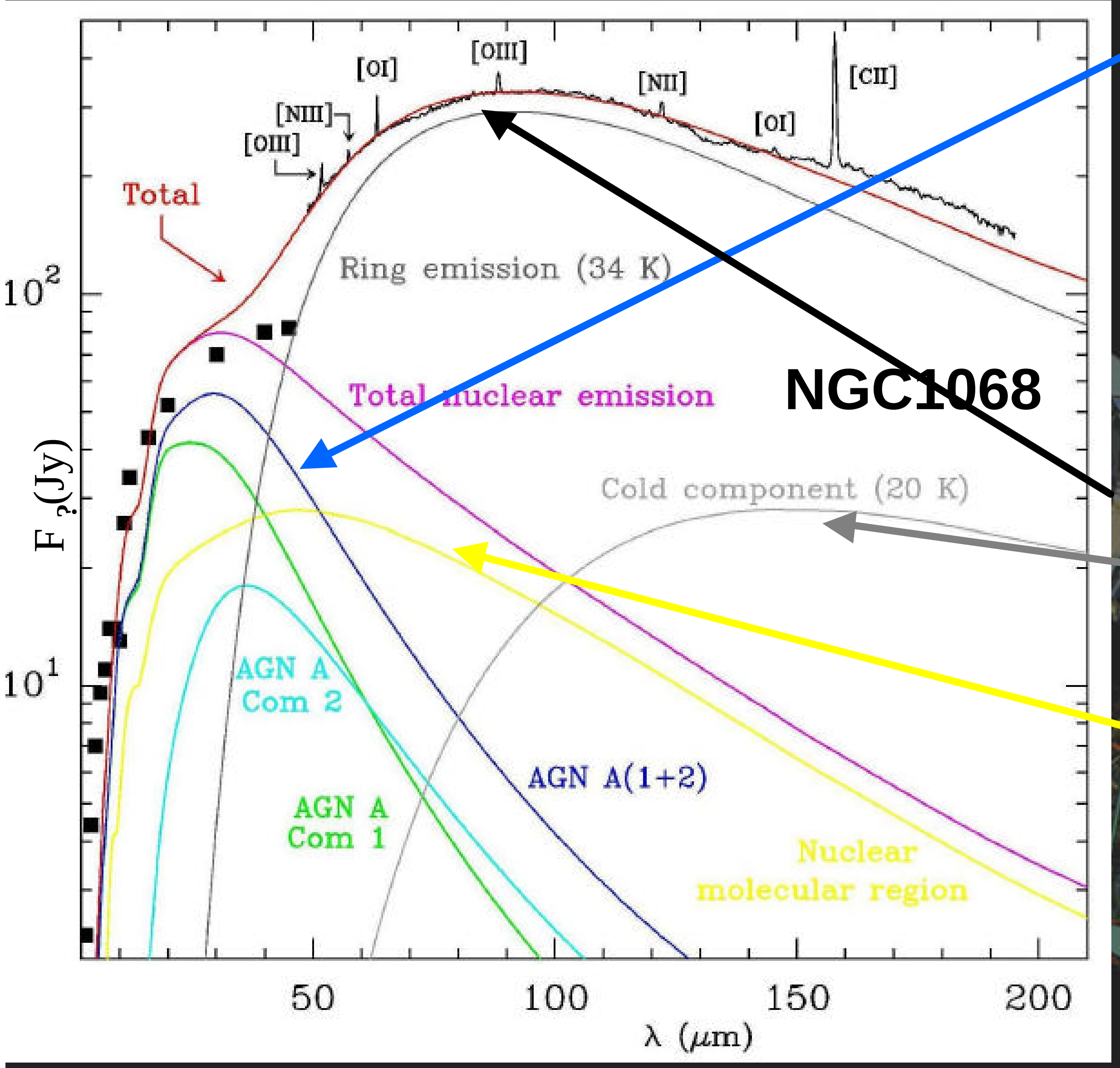


--- instantaneous burst, age: 5 Myrs

— continuous burst, age: 5 Myrs

[Spinoglio et al 2005, ApJ, 623, 123]

Modeling the continuum emission



[Spinoglio et al 2005, ApJ, 623, 123]

From the CLOUDY models

➔ Thermal dust emission from the ionized components: AGN A 1 & AGN A 2. The starburst ionized component produces only 20% of the observed continuum. The missing continuum probably arises from the neutral gas.

Starburst emission:
2 graybodies:
T=34K M= 1.2 x 10^9 Mo
T=20K M= 2 x 10^9 Mo
[CO mass in molecular ring ~4x 10^9 Mo]

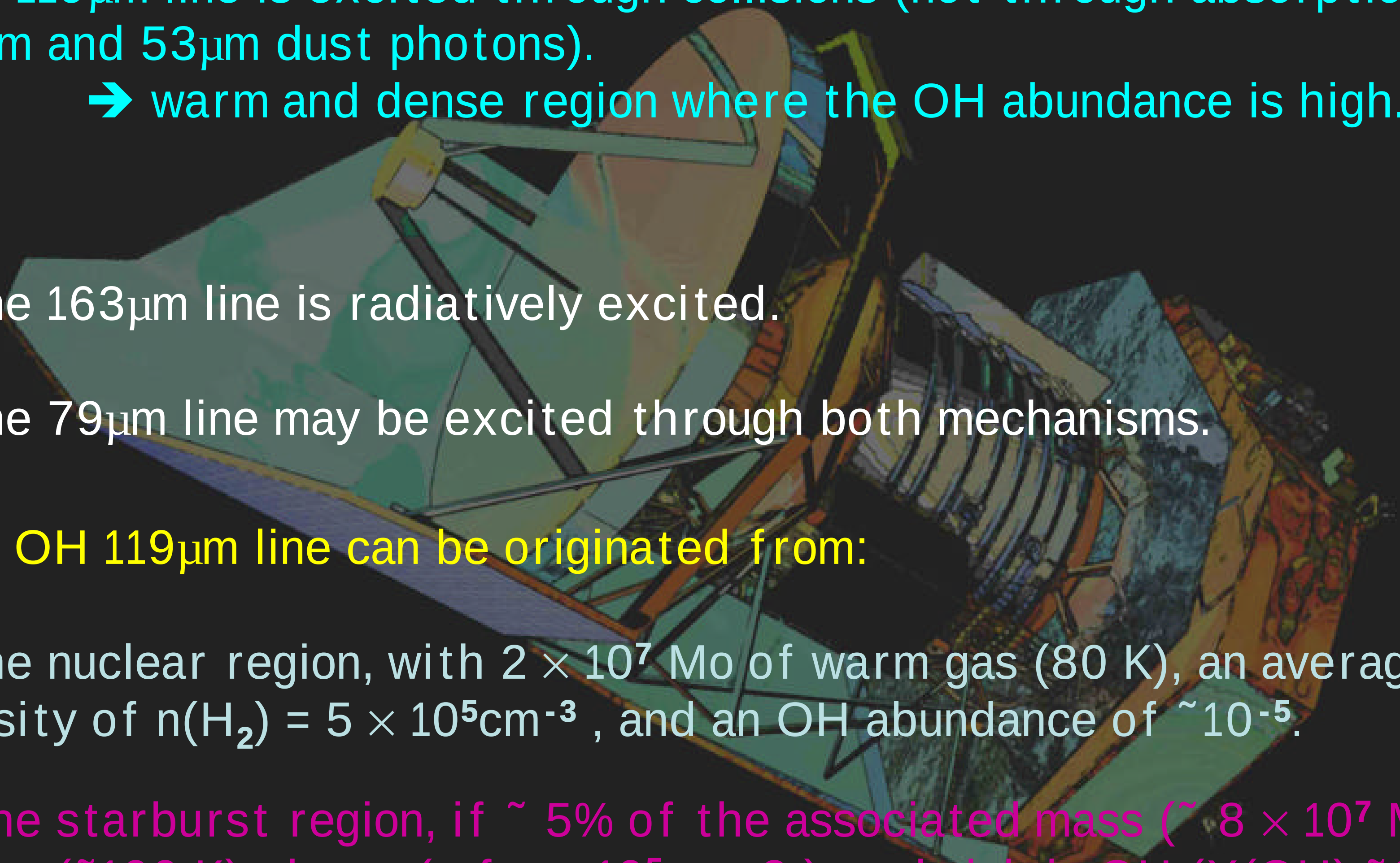
From a spherically symmetric radiative transfer code
(Gonzàlez-Alfonso & Chernicharo)

➔ a nuclear molecular component with $<n(H_2)>=500$ cm^{-3} and $N(H_2)=2x10^{22}$ cm^{-2}

Modeling the OH line emission

The 119μm line is excited through collisions (not through absorption of 35μm and 53μm dust photons).

➔ warm and dense region where the OH abundance is high.



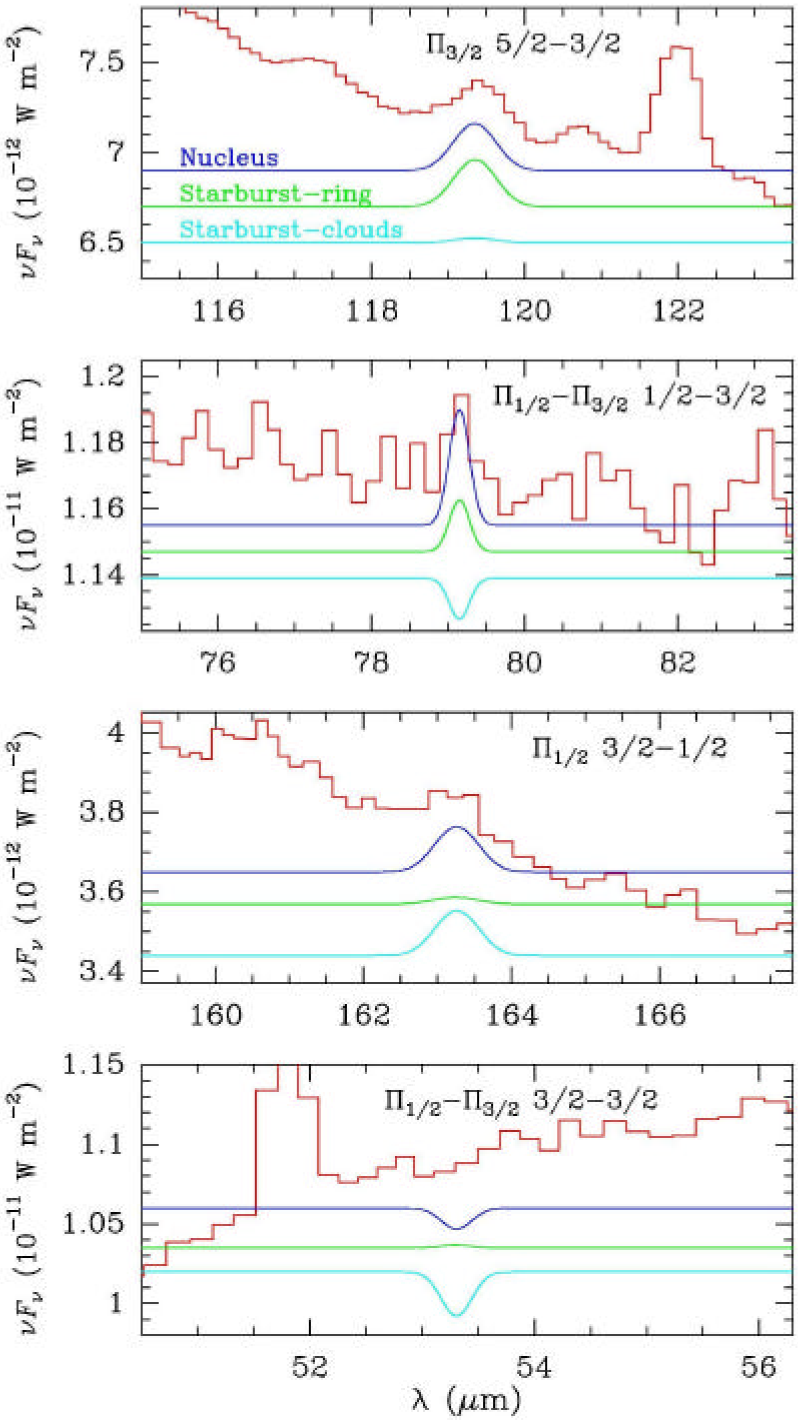
• The 163μm line is radiatively excited.

• The 79μm line may be excited through both mechanisms.

The OH 119μm line can be originated from:

• The nuclear region, with 2×10^7 Mo of warm gas (80 K), an average density of $n(H_2) = 5 \times 10^5 cm^{-3}$, and an OH abundance of ˜10^{-5}.

• The starburst region, if ˜ 5% of the associated mass (˜ 8×10^7 Mo) is warm (˜100 K), dense (a few $\times 10^5$ cm-3), and rich in OH (X(OH) ˜2×10^{-6}).



Radiative transfer non-local, non-LTE models of the OH lines (Gonzàlez-Alfonso & Chernicharo) of nuclear and starburst regions, with radiative and collisional OH excitation.

Nuclear models can explain the emission in the three OH lines.

Starburst models, with a low influence of the FIR emission on the OH excitation, fit the 119μm line, but underestimate the other two lines (see green spectra).

Starburst models with an ensemble of clouds (strong influence of FIR continuum on OH excitation) predict the 119 and 79μm lines very weak or in absorption when the 163μm line is fitted.

→ some contribution from the extended starburst cannot be ruled out

→ the bulk of the OH emission arises in the nuclear region.

→ the high OH abundance needed suggests the presence of an X-ray dominated region.

Spectroscopy with PACS (& HIFI?) :

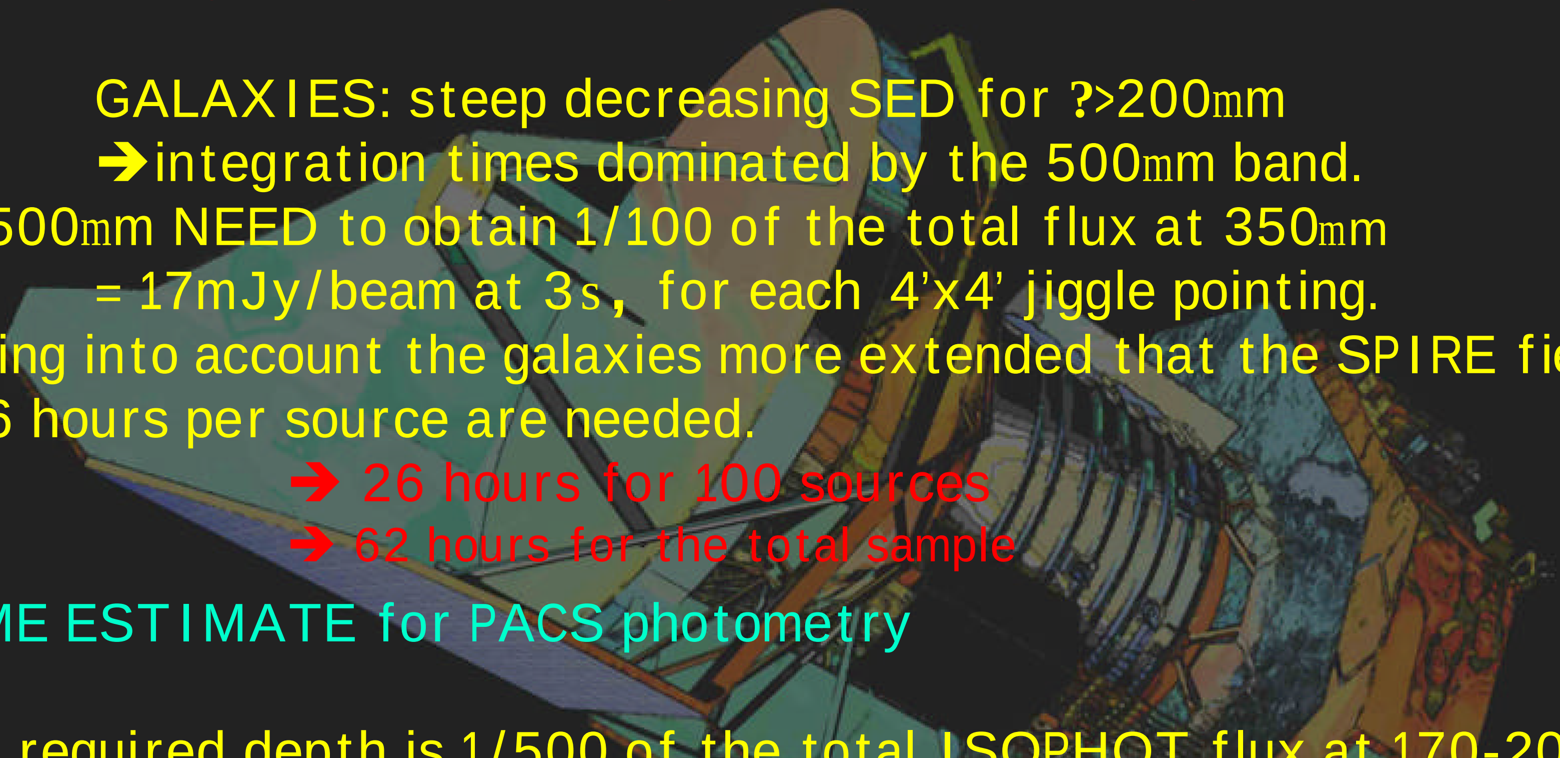
1. Detect the signature of the hypothetical torus with OH and water lines, good tracers of the expected conditions of X-UV illuminated dusty tori.
2. Study statistically the fine structure lines suppression (seen by ISO-LWS in a few ULIRG). Is the line deficit a common feature of starburst/ULIRGs ? Is the extremely high opacity observed a signature of an hidden AGN ?
3. Study statistically the molecular lines in absorption & emission to map excitation, density, temperature in nuclear and extended regions.
4. Spectroscopically resolve the different excitation mechanisms (e.g. shocks, PDR, stellar and nonthermal photoionization) (see e.g. Spinoglio et al 2005)

Photometry with PACS & SPIRE:

1. Trace the star forming regions in both starburst and Seyfert galaxies, measure mass and luminosity involved and detect warm & cold dust (T=10-50K) in the starburst and in the outer regions of the galaxies.
2. Help in determining the precise bolometric luminosity.
3. Distinguish among AGN and starburst dominated galaxies/emission regions through thermal emission.

TIME ESTIMATE for SPIRE photometry

The 5σ, 1 hour sensitivities adopted (Porquerolles, 7-8 October 2003) are: 9.5 mJy at 250μm, 11.5 mJy at 350 μm, 13.5 mJy at 500μm.



GALAXIES: steep decreasing SED for λ>200μm
➔integration times dominated by the 500μm band.
At 500μm NEED to obtain 1/100 of the total flux at 350μm
= 17mJy/beam at 3σ, for each 4'x4' jiggle pointing.
Taking into account the galaxies more extended that the SPIRE field, 0.26 hours per source are needed.

➔ 26 hours for 100 sources
➔ 62 hours for the total sample

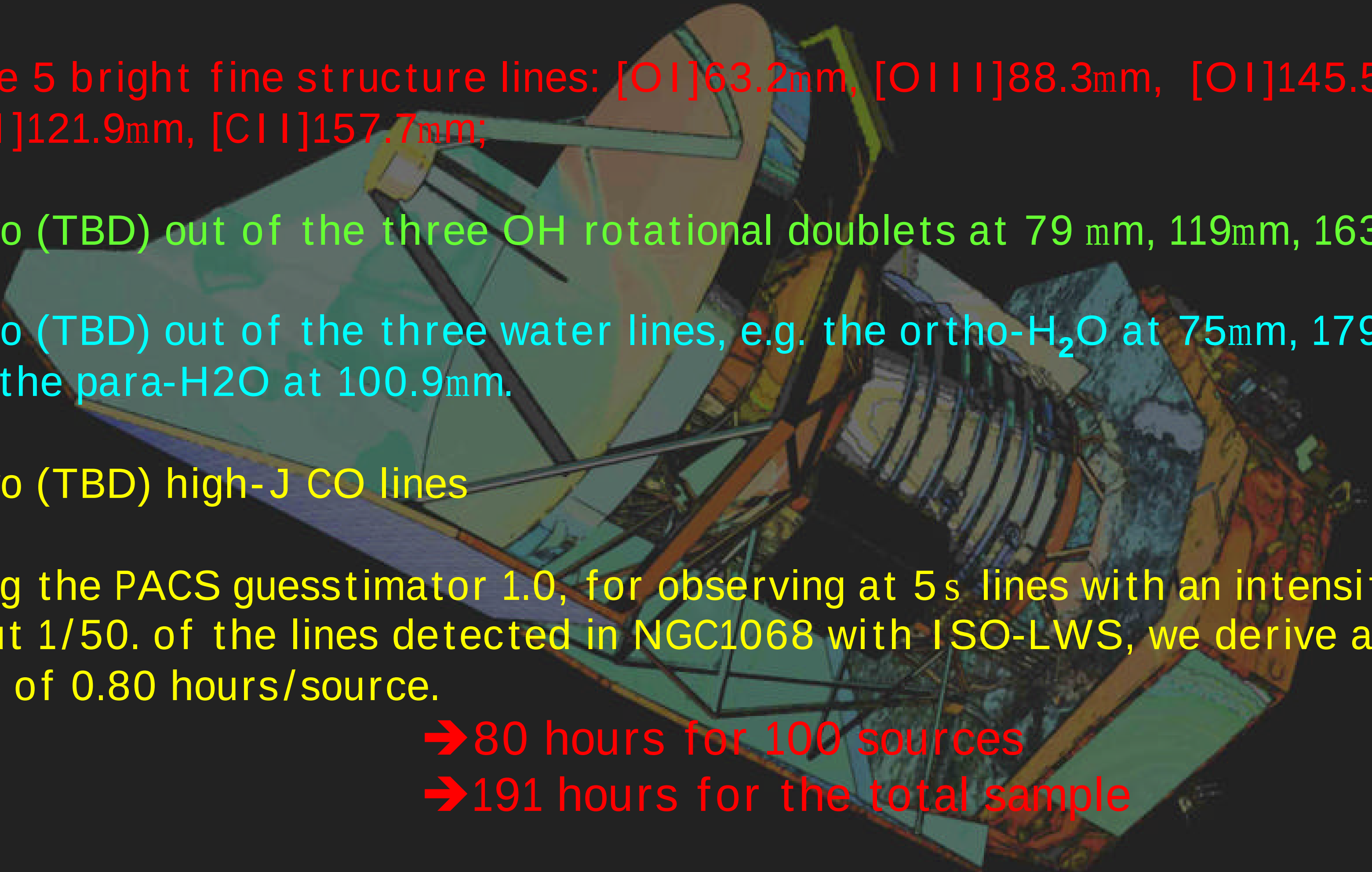
TIME ESTIMATE for PACS photometry

The required depth is 1/500 of the total ISOPHOT flux at 170-200μm.
➔This requires a sensitivity 4mJy at 1σ.
PACS guesstimator ➔ total integration time of 0.16 hours per each 3'.5x1'.75 pointings. Taking into account the galaxies more extended that the PACS field, 0.21 hours per source are needed.

➔ 21 hours for 100 sources
➔ 50 hours for the total sample

VERY PRELIMINARY TIME ESTIMATE for PACS spectroscopy

The preliminary line list is:



- The 5 bright fine structure lines: [OI]63.2μm, [OIII]88.3μm, [OI]145.5μm, [NII]121.9μm, [CII]157.7μm;

- Two (TBD) out of the three OH rotational doublets at 79 μm, 119μm, 163μm;

- Two (TBD) out of the three water lines, e.g. the ortho-H_2O at 75μm, 179μm, and the para-H2O at 100.9μm.

- Two (TBD) high-J CO lines

Using the PACS guesstimator 1.0, for observing at 5σ lines with an intensity of about 1/50. of the lines detected in NGC1068 with ISO-LWS, we derive a total time of 0.80 hours/source.

➔80 hours for 100 sources

➔191 hours for the total sample

Therefore for the whole project 127 hours will be needed for 100 sources and ~300 hours for the total sample.

In the present

The spectroscopic separation of AGN and starburst components in the Local Universe can be done with Spitzer IRS high resolution data

⇒ 50% of the Seyferts belonging to the 12MGS have archive highres IRS spectra. Homogeneous data reduction starting now....

➔ Spitzer GTO program (PI: G. Fazio) is observing the other 50% Seyfert galaxies: reduction & analysis of the first 20 spectra is under way

In a near future

The Herschel survey of Local galaxies Activity (HERLOGA) will be able to study statistically & in detail the molecular spectra (OH, H_2O,CO) and the low excitation FS lines:

-searching for spectroscopic dusty tori signatures,

-probing the starburst component of local galaxies and

-studying the PDR & ISM components.

In a far future

MIRI onboard of JWST (5-30 micron) & ESI onboard of SPICA (30-200 microm) at a sensitivty 100 times better than Herschel will be very powerful for the line diagnostics in high z galaxies.