Hidden activity in high-redshift spheroidal galaxies: the mid-Infrared and X-ray view

PADOVA

G. Rodighiero
A. Franceschini
J. Fritz

BOLOGNA

C. Gruppioni
F. Civano
A. Comastri
M. Mignoli
C. Vignali

UCLA

T. Treu

The mid-IR emission in early type galaxies

•Early type galaxies (ellipticals and lenticulars) have been considered for a long time as devoided of interstellar matter. IRAS first discovered a significant fraction of local early-type galaxies containing interstellar gas and dust (Jura et al. 1987; Knapp et al. 1989).

•Later, ISO, with much better sensitivity and higher resolution than IRAS, has shown the presence of Polyciclic Aromatic Hydrocarbon molecules (PAHs) in the mid-Infrared (MIR) spectra of some local early-type galaxies (i.e. Madden et al. 1999; Xilouris et al. 2004).

•These results have been recently confirmed by observations with the Spitzer Space Telescope (Pahre et al. 2004).

The origin of dust responsible for MIR emission in early-type galaxies could be attributed to:

1) merging events (gas and dust often in dust lanes and patches; e.g. Xilouris et al. 2004);

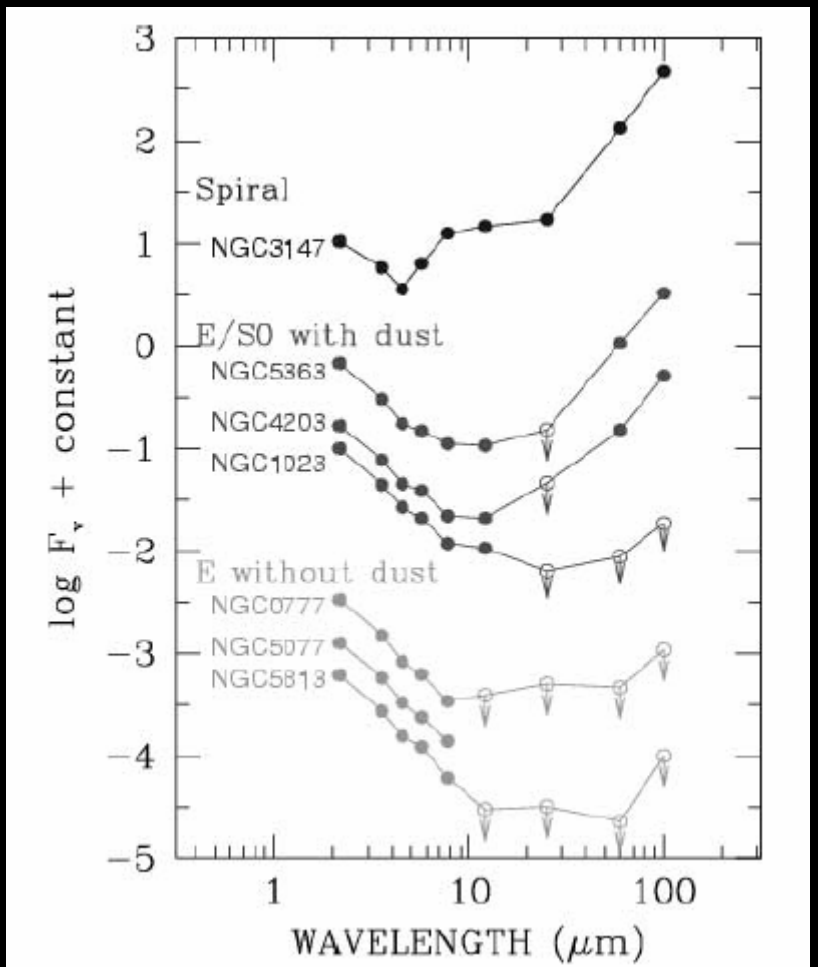
2) cooling flows (dust centrally concentrated; e.g. Fabian et al. 1991);

3) mass loss from late-type stars (dust widely distributed throughout the galaxy; e.g. Knapp et al. 1992, Bressan et al. 2006);

4) presence of an active galactic nucleus (AGN; dust either centrally concentrated or following the light distribution, if due to mass loss).

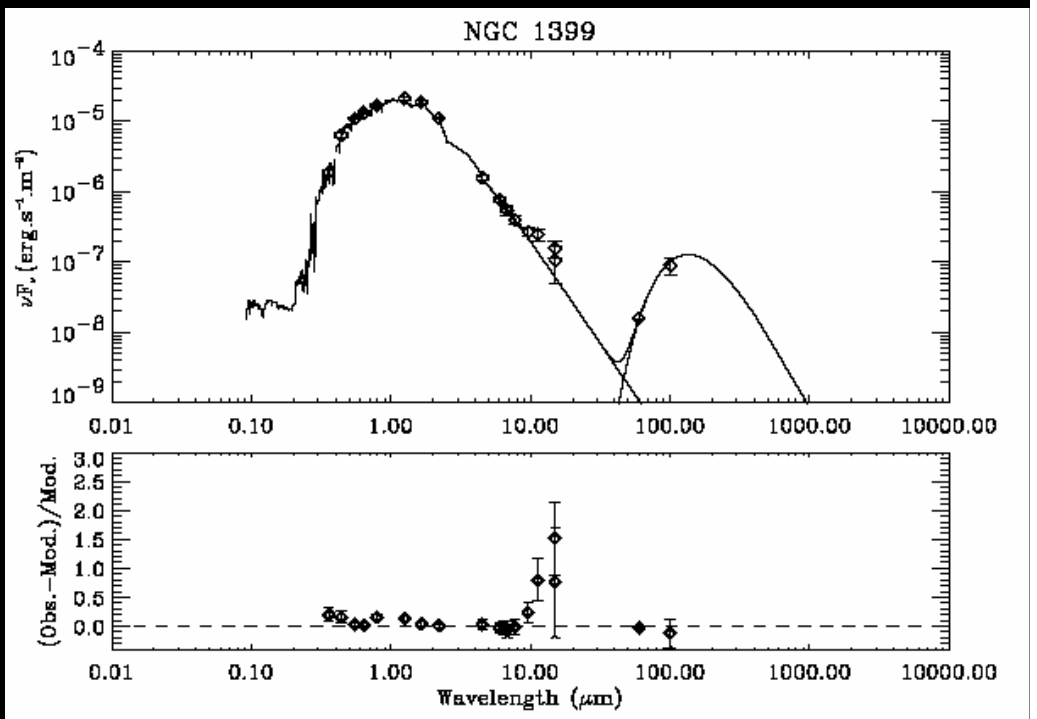
What's happening in the local Universe?

"Mid-infrared observations (3.6–24 micron) of normal giant elliptical galaxies with the *Spitzer Space Telescope* are consistent with pure populations of very old stars with no evidence of younger stars." (Temi et al. 2005)



Pahre et al. 2004

"The distribution of the IR light and the IR colors of elliptical galaxies suggest that the most plausible source of the 12-micron emission is photospheric and circumstellar emission from cool evolved red giant stars." (Knapp et al. 1992)



Xilouris et al. 2004

All these studies suggest that for almost all normal LOCAL elliptical galaxies the mid-IR (12 micron at the rest-frame) emission is extended on the scale of the galaxy and DOES NOT originate in an active nucleus (AGN).

? What happened in the distant Universe ?

The GOODS-North case (130 sq. arcmin)

Morphological selection

We started our selection from a sample of morphologically classified elliptical galaxies in the HDFN. We used the publicly available catalogue of Bundy et al. 2005:

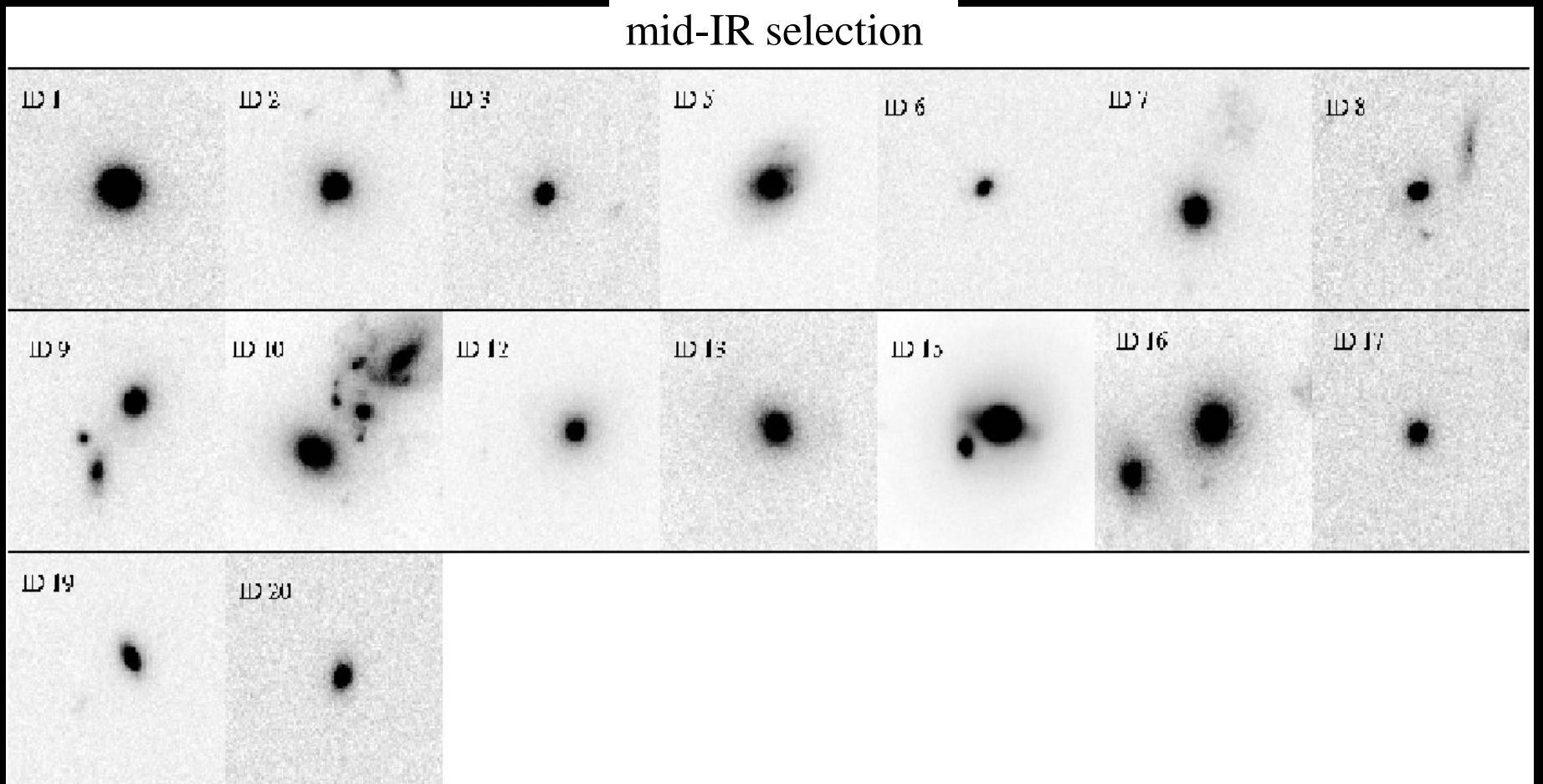
mag_z(AB) < 22,5 --> 168 sources

Mid-IR detection

We have cross-correlated the optical catalogue including the 168 morphologically selected spheroids, with the Spitzer-MIPS 24 micron catalogue provided by the GOODS team (S24 >80 microJy).

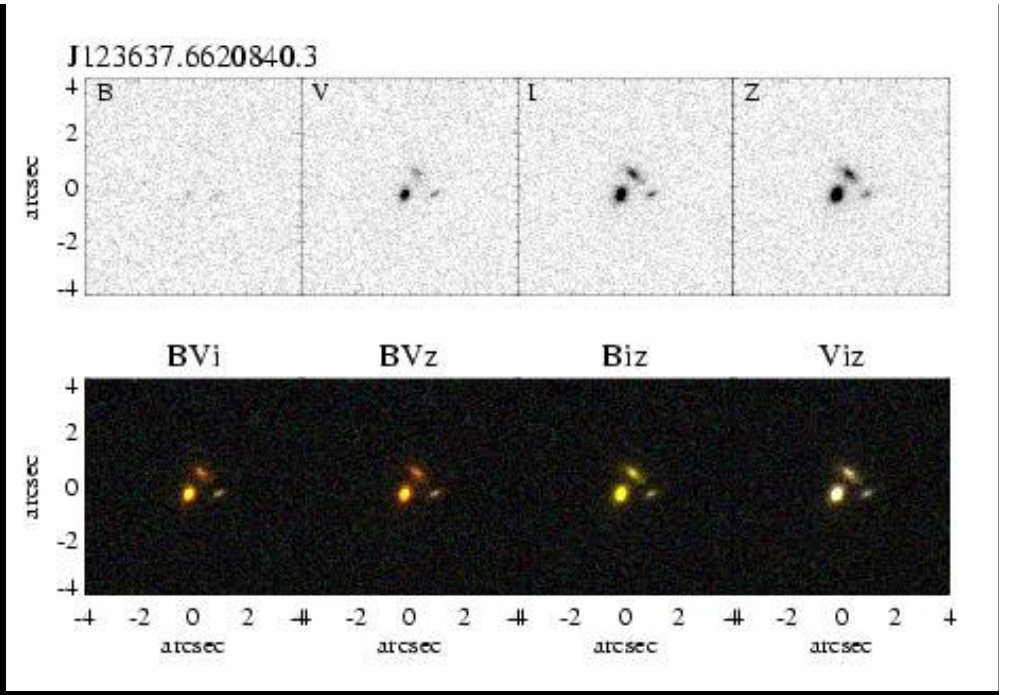
19/168 spheroids have a mid-IR counterpart within a search radius of 1"

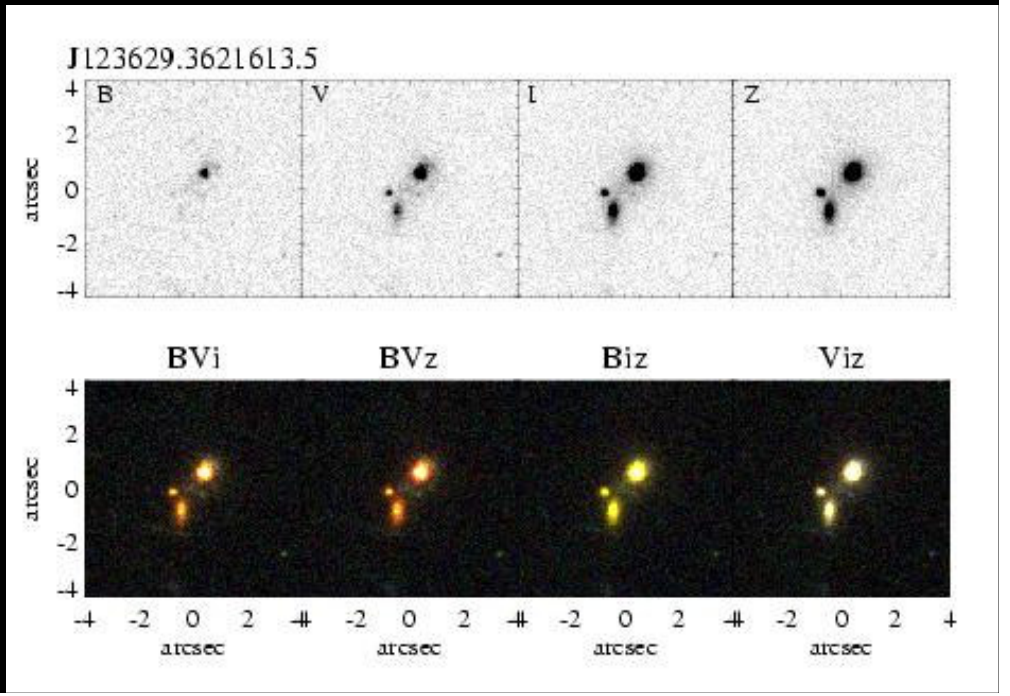
Morphological inspection



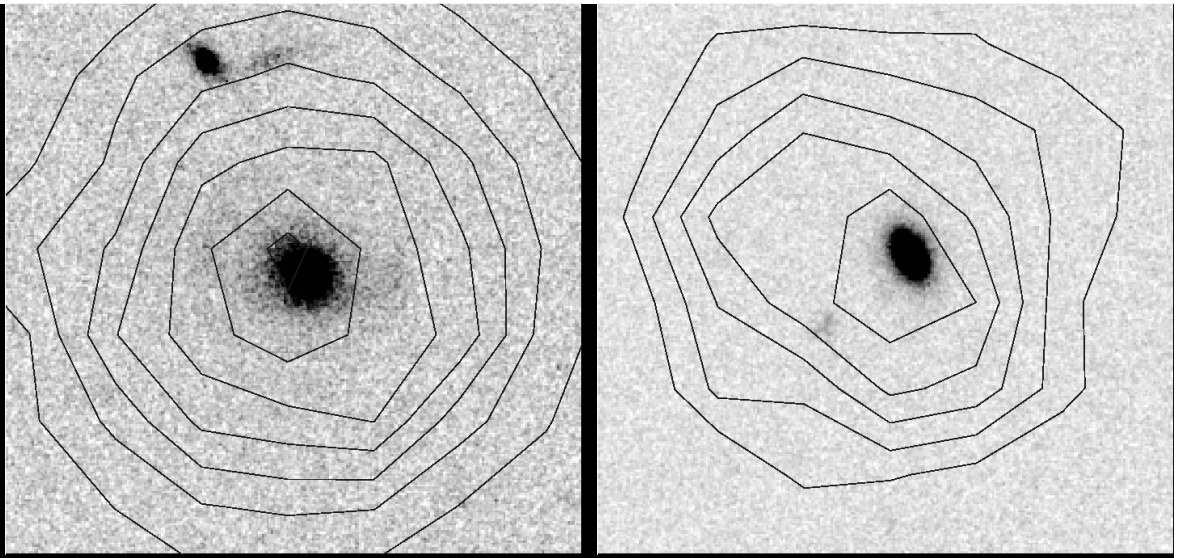
Morphological inspection:

the problem of confused sources



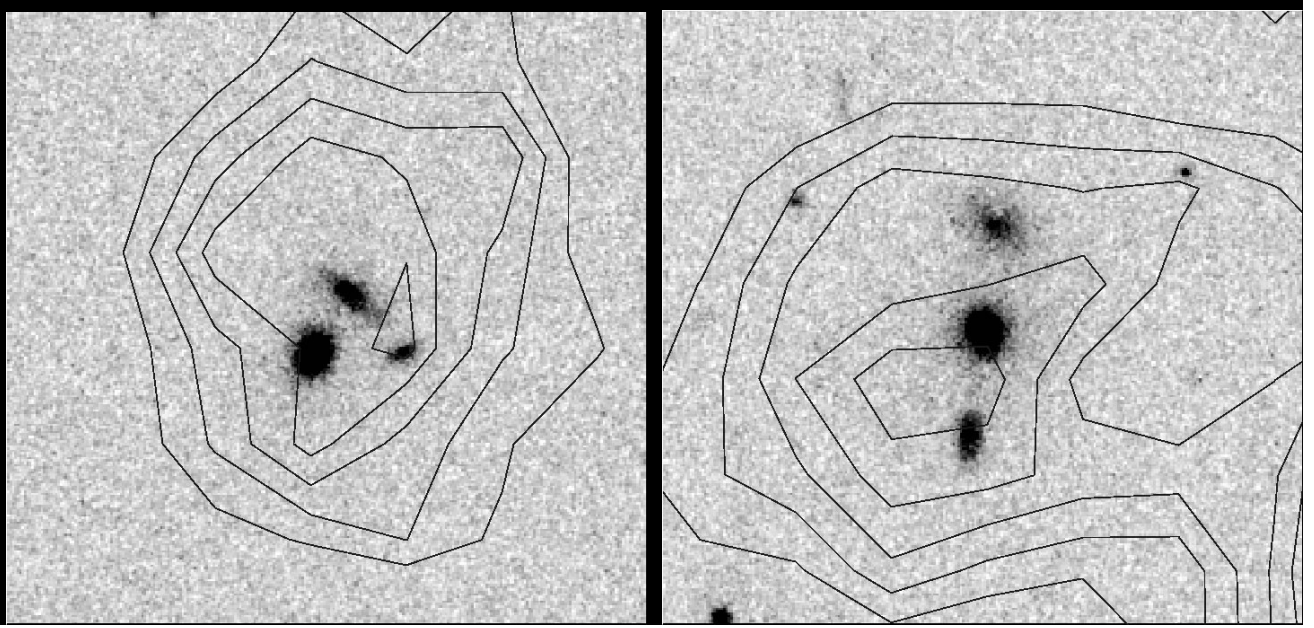


ISOLATED sources



24 micron contours on ACS images

BLENDED sources



Multiwavelength catalogue of spheroids in the HDFN

The availability of optical to IR data allowed us to build a multi-wavelength photometric catalogue for the 19 spheroids showing bright mid-IR emission.

The catalogue includes the following bands:

Spitzer - IRAC 3.6, 4.5, 5.8 and 8.0 micron

Spitzer - MIPS 24 micron

Spitzer - IRS 16 micron

Subaru - U, B, V, R, I, Z and HK' magnitudes

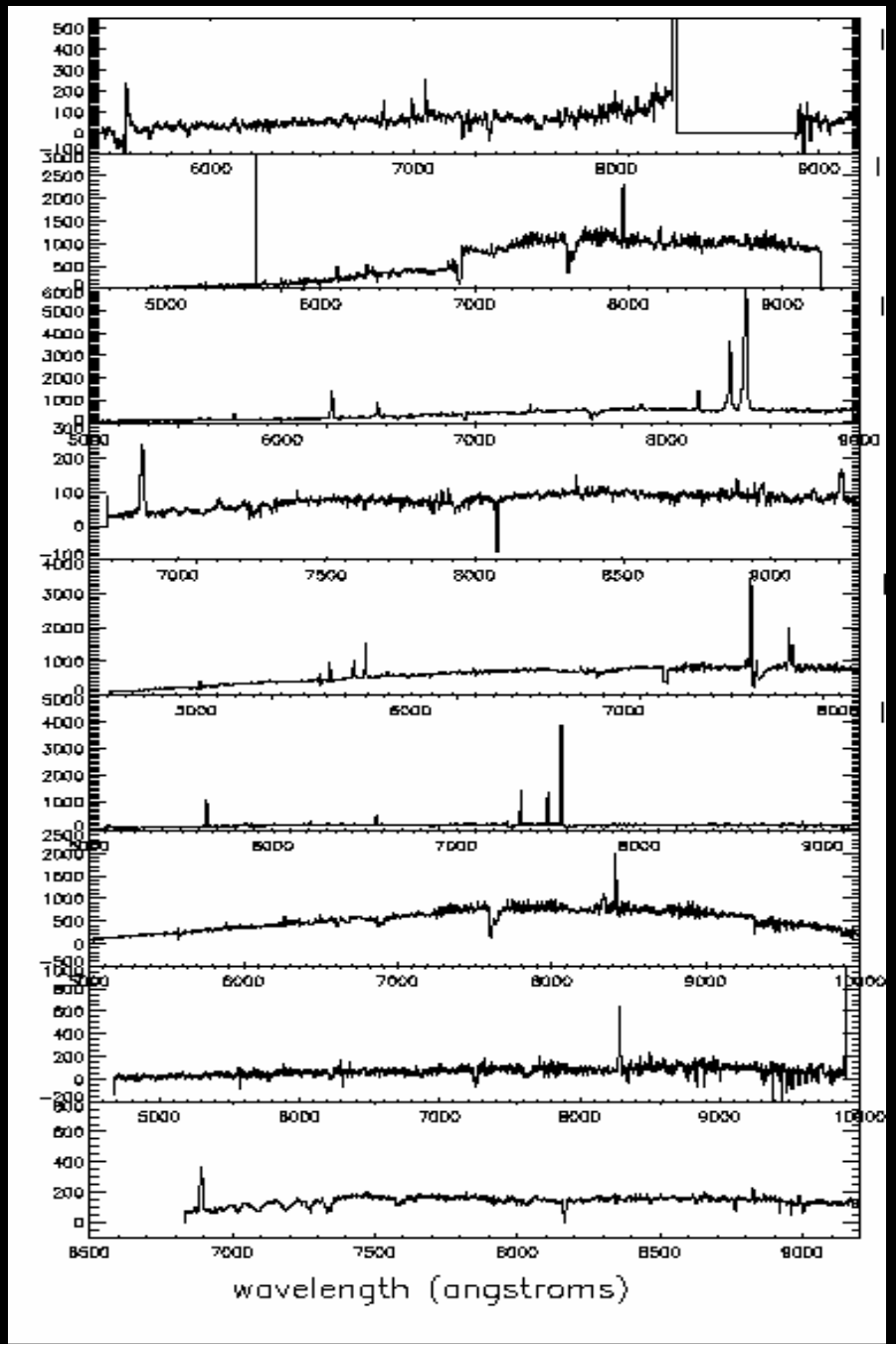
HST - B, V, i, z

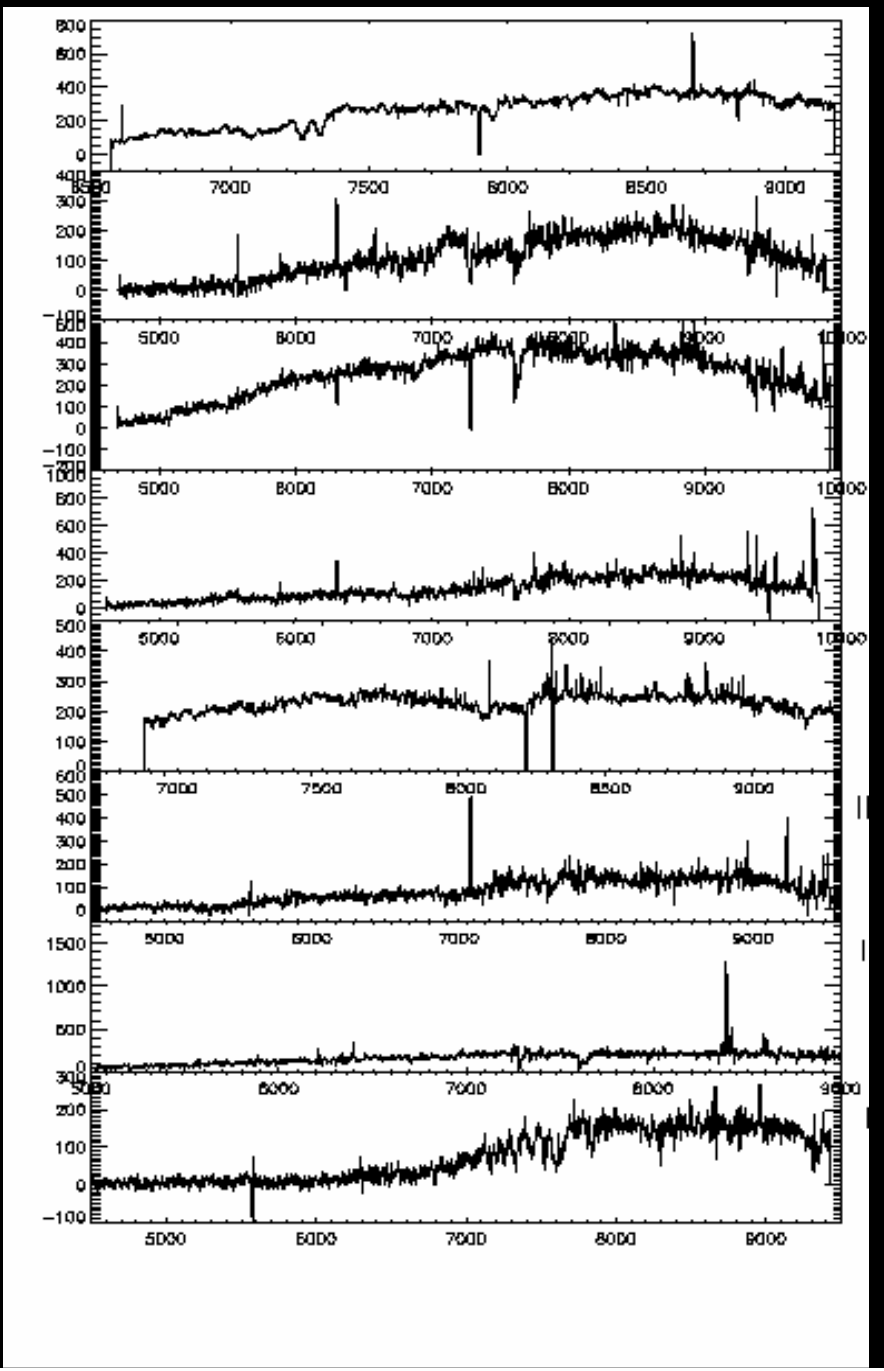
Optical spectroscopy

Redsfhit and spectra for all the 19 sources were available from the Keck team (Wirth et al. 2004):

DEIMOS on the Keck II telescope

Spectra of the 19 early-type sources with mid-IR excess

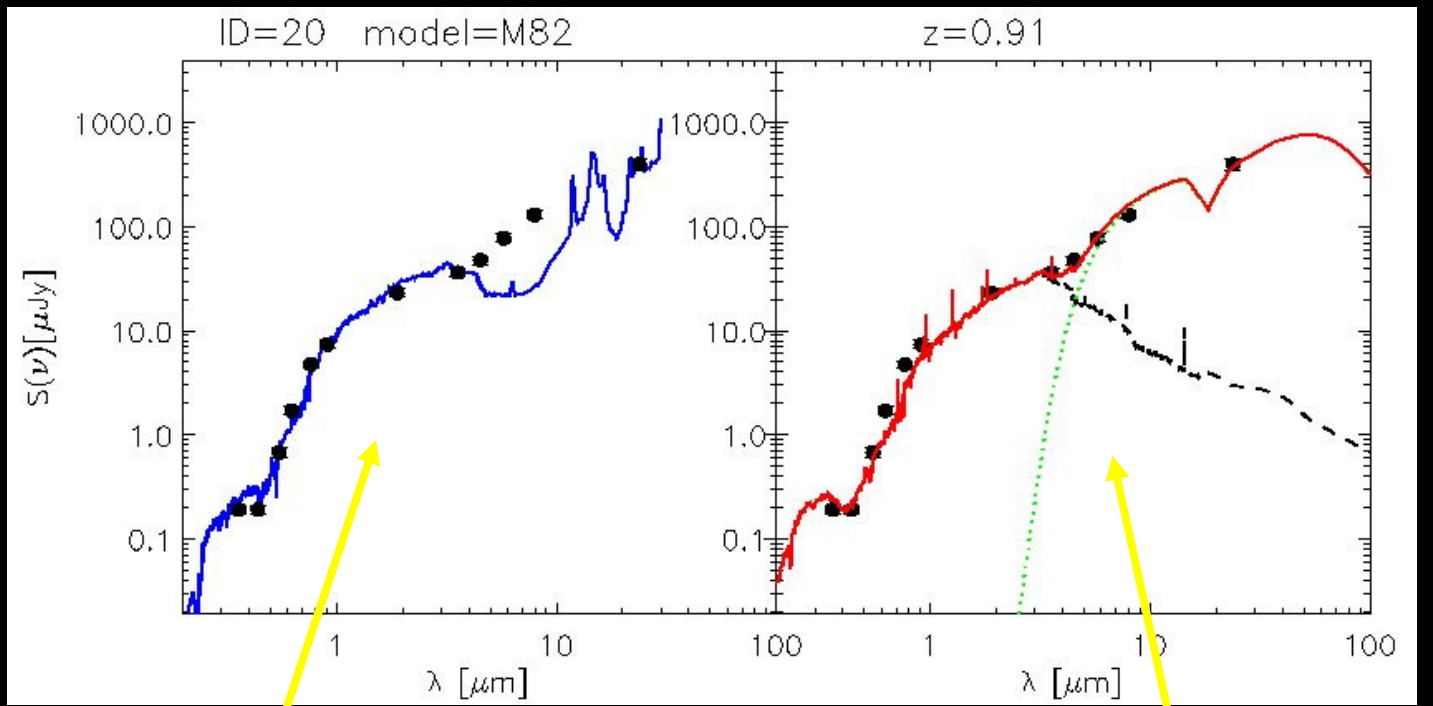




Spectroscopic classification

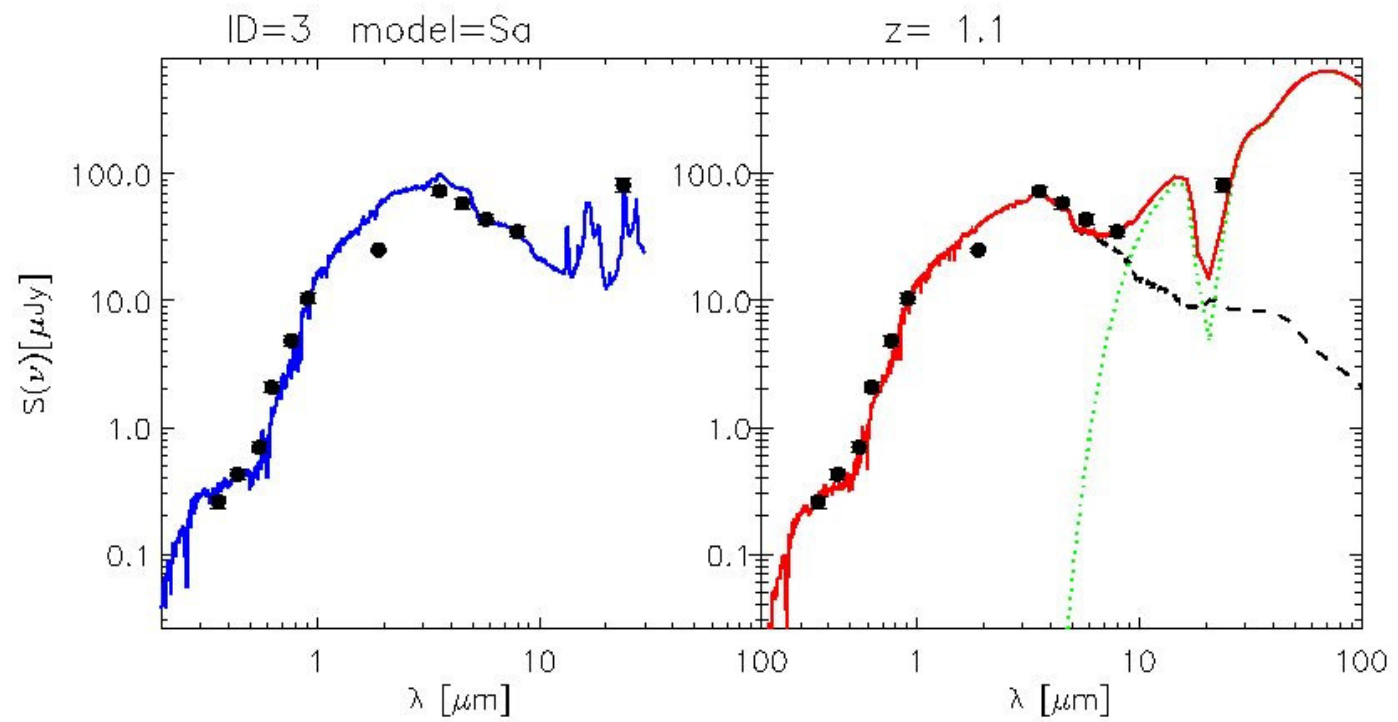
ID	X-ID	z	spectral class
0		0.410	ELG
1	X-067	0.638	Early+[OII]
2	X-082	0.679	AGN2
4	X-113	0.845	LINER
5		0.156	LINER
6		0.512	AGN2
7	X-115	0.680	AGN2
8	X-149	1.223	ELG
9	X-160	0.848	Starforming
10	X-169	0.845	Early-type
11		0.766	Early+[OII]
12		0.277	Early-type
13	X-240	0.961	AGN2
16	X-388	0.231	Early-type
17		0.899	Starforming
19		0.278	Starforming
20		0.911	Early+faint[OII]

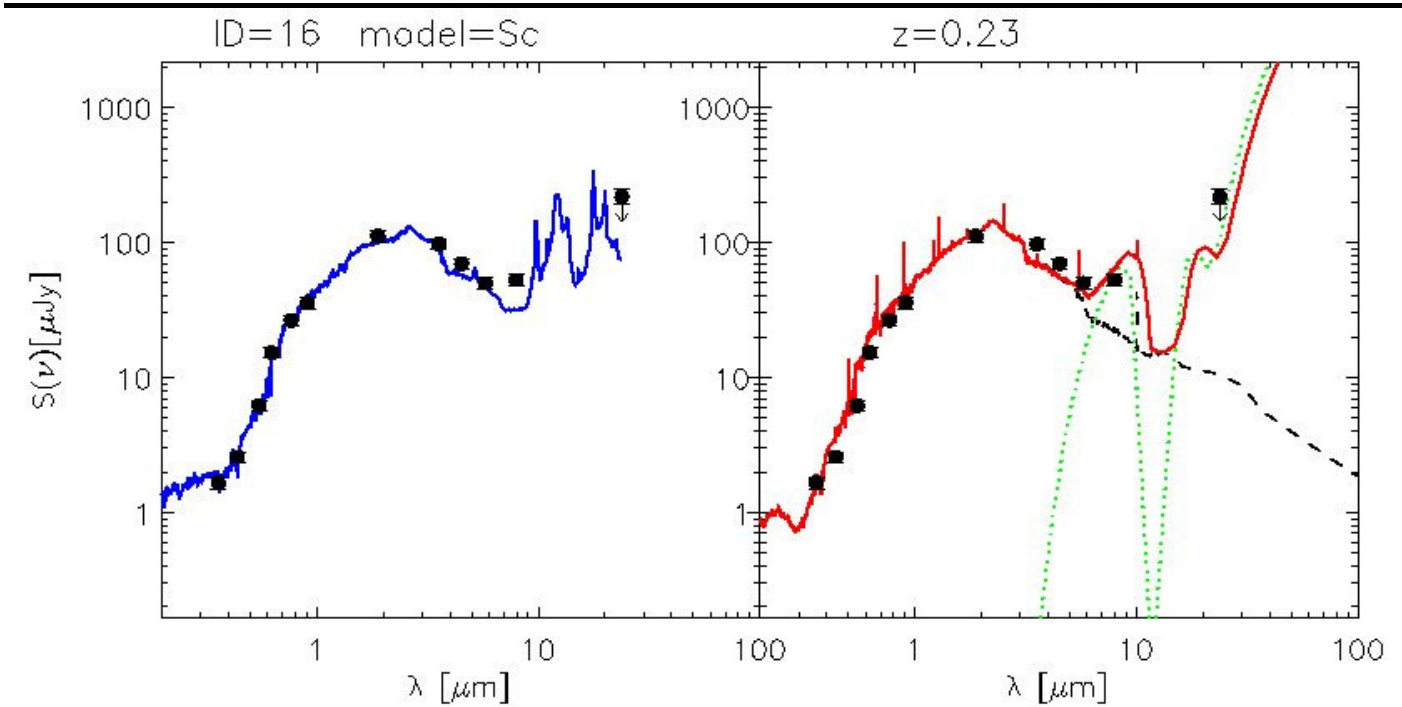
Spectro-photometric analysis



Fit with a library of templates
(courtesy from Polletta et al. in prep.)

Double component fit: old star population + dusty torus
(Fritz et al. 2005)

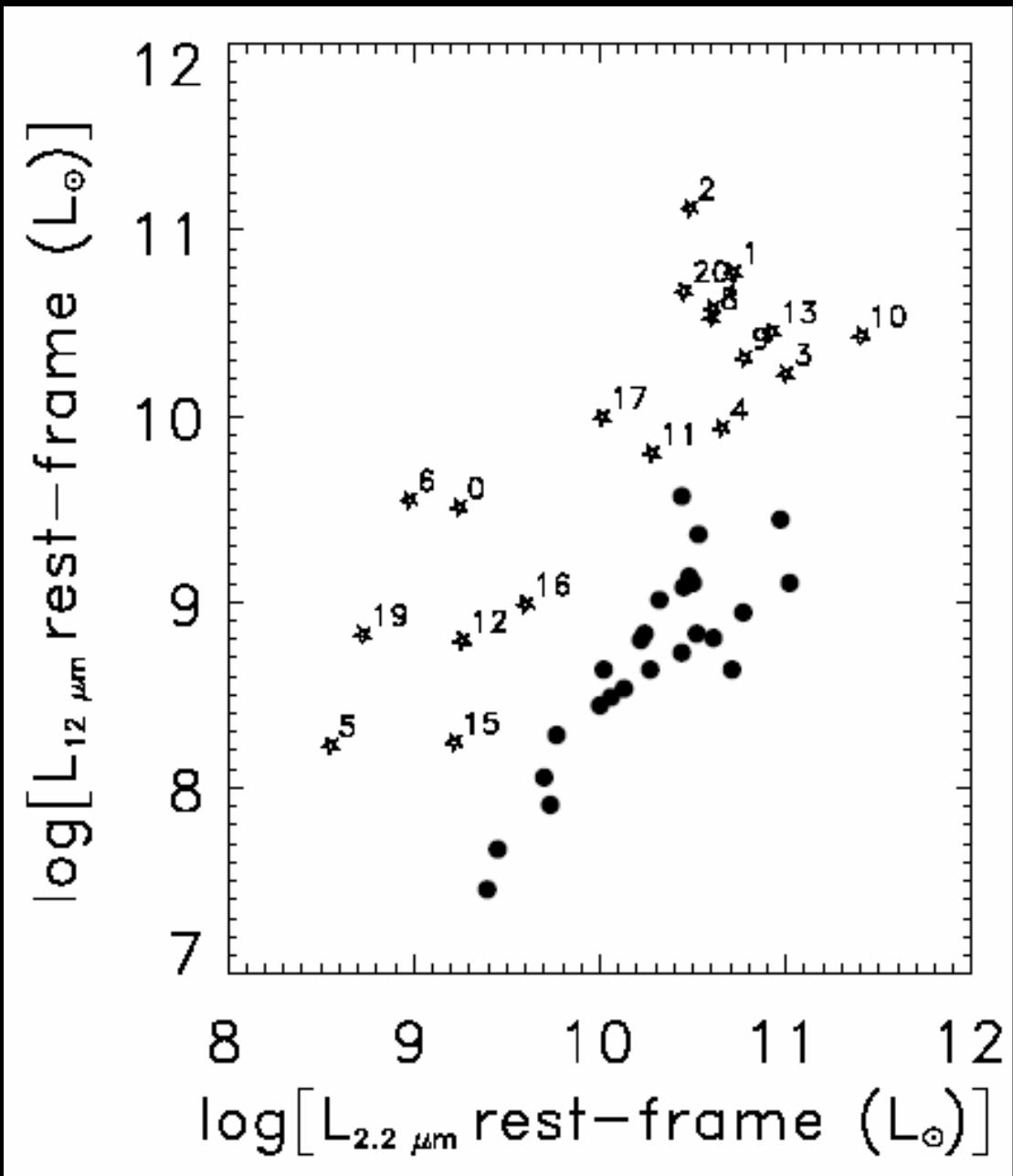




In most cases both a star-forming template or the double component solution provide a reasonable fit

The observed mid-IR excess is never reproduced with the emission of evolved massive stars alone

12 micron versus 2.2 micron luminosity (rest-frame) for MIR emitting early-type galaxies. The HDFN early-type galaxy colors (stars) are compared to those of nearby elliptical galaxies studied by Knapp et al. (1992; filled circles).

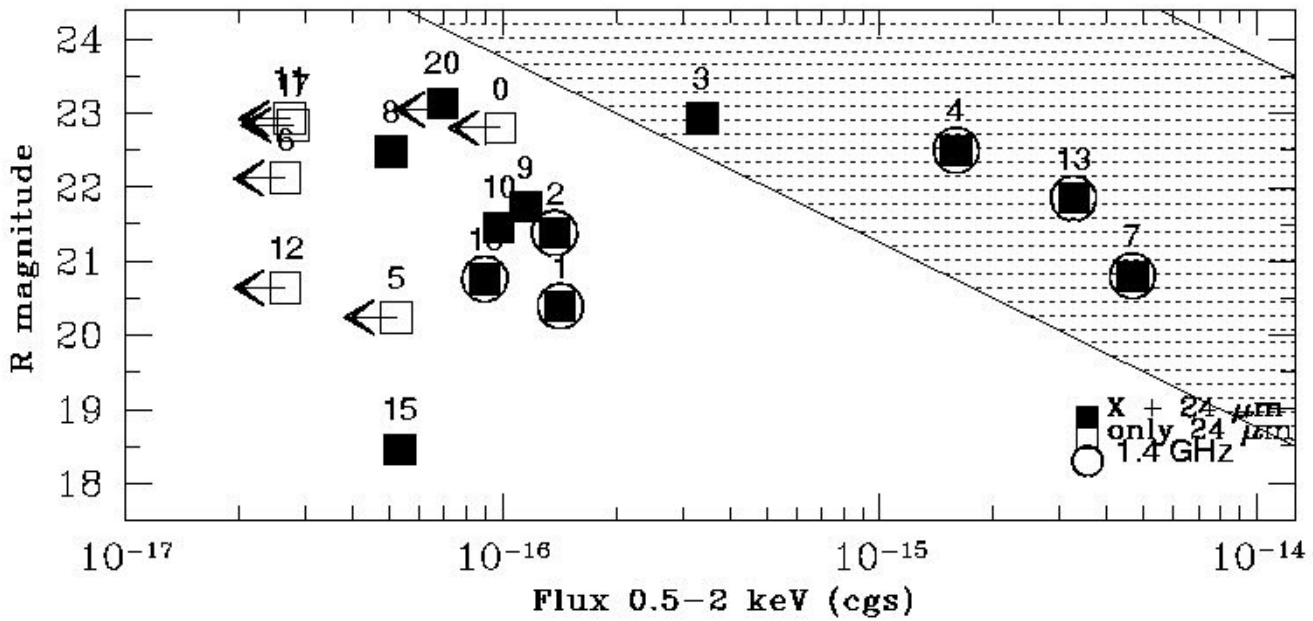


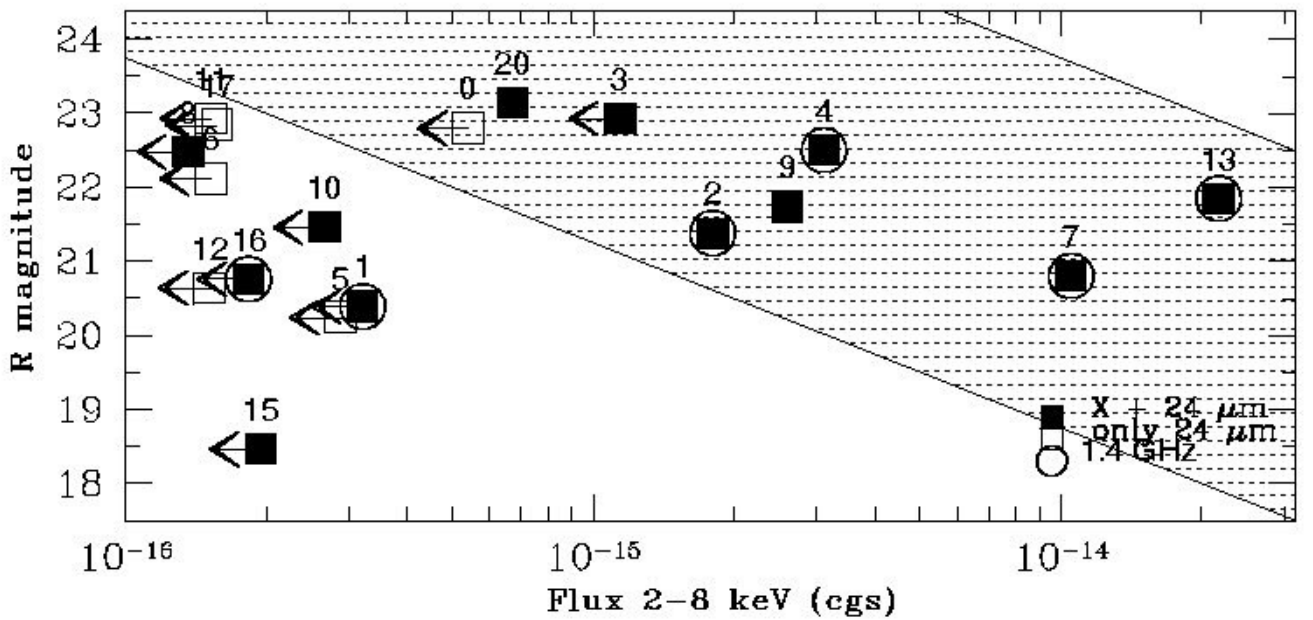
X-ray properties:

CHANDRA observations in the HDFN

More than half (12/19) of the Spitzer-MIPS sources have a unique X-ray counterpart within a searching radius of 2 arcsec

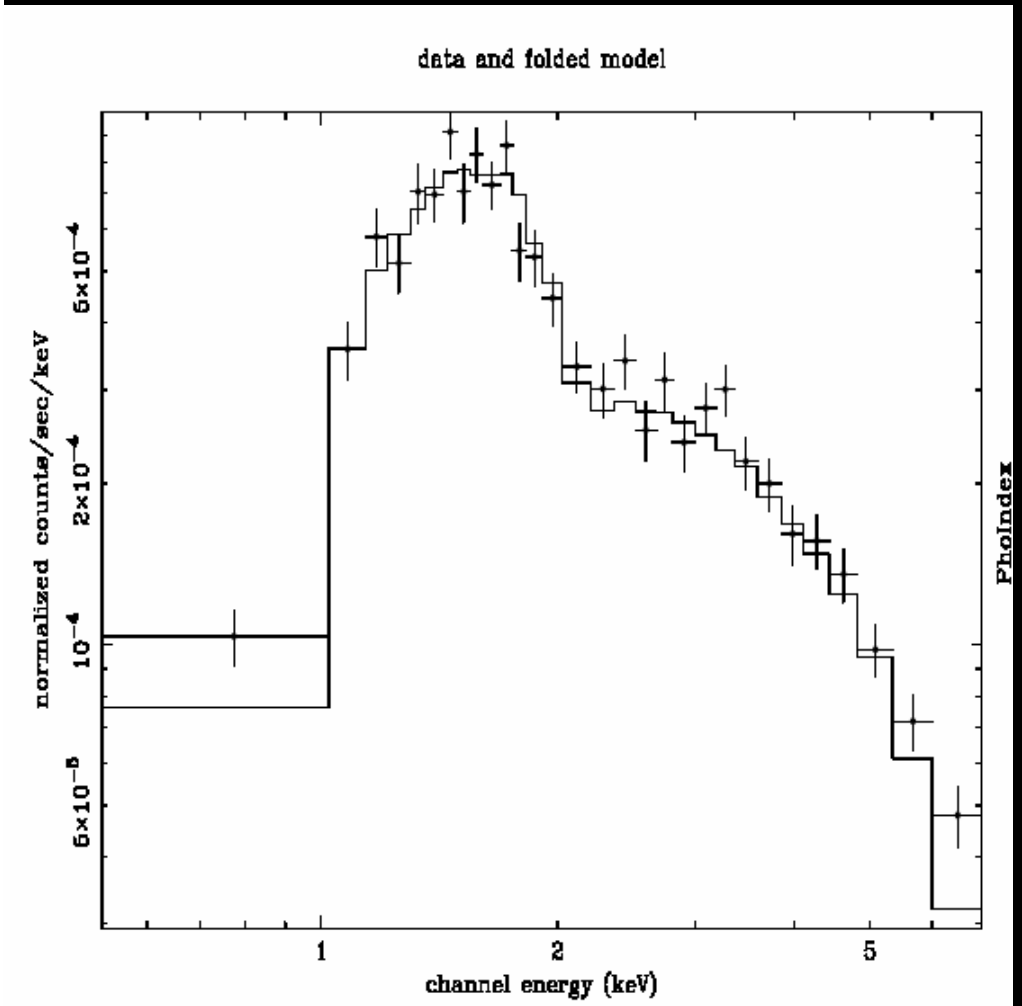
For six out of the seven sources undetected in both soft and hard X-ray bands upper limits were computed.





The six sources detected in the hard band are well within the AGN locus.

X-ray spectral analysis

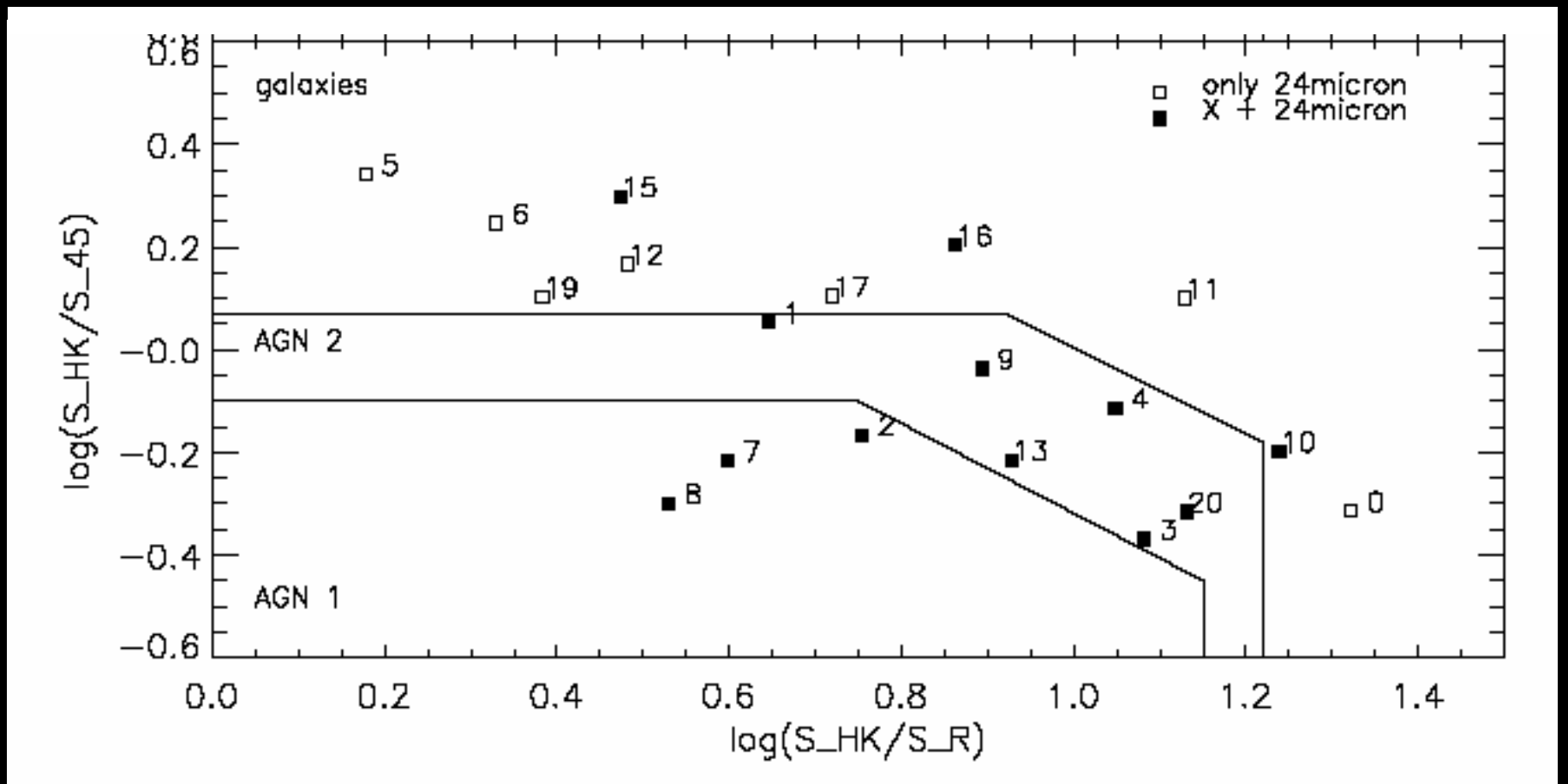


Five out of the six hard X-ray detected sources have a number of counts (> 100) which allow us to perform moderate quality spectral analysis. The spectra were fitted with a power-law model with intrinsic absorption and suggest the presence of a type 2 AGN.

Colour- colour diagnostic

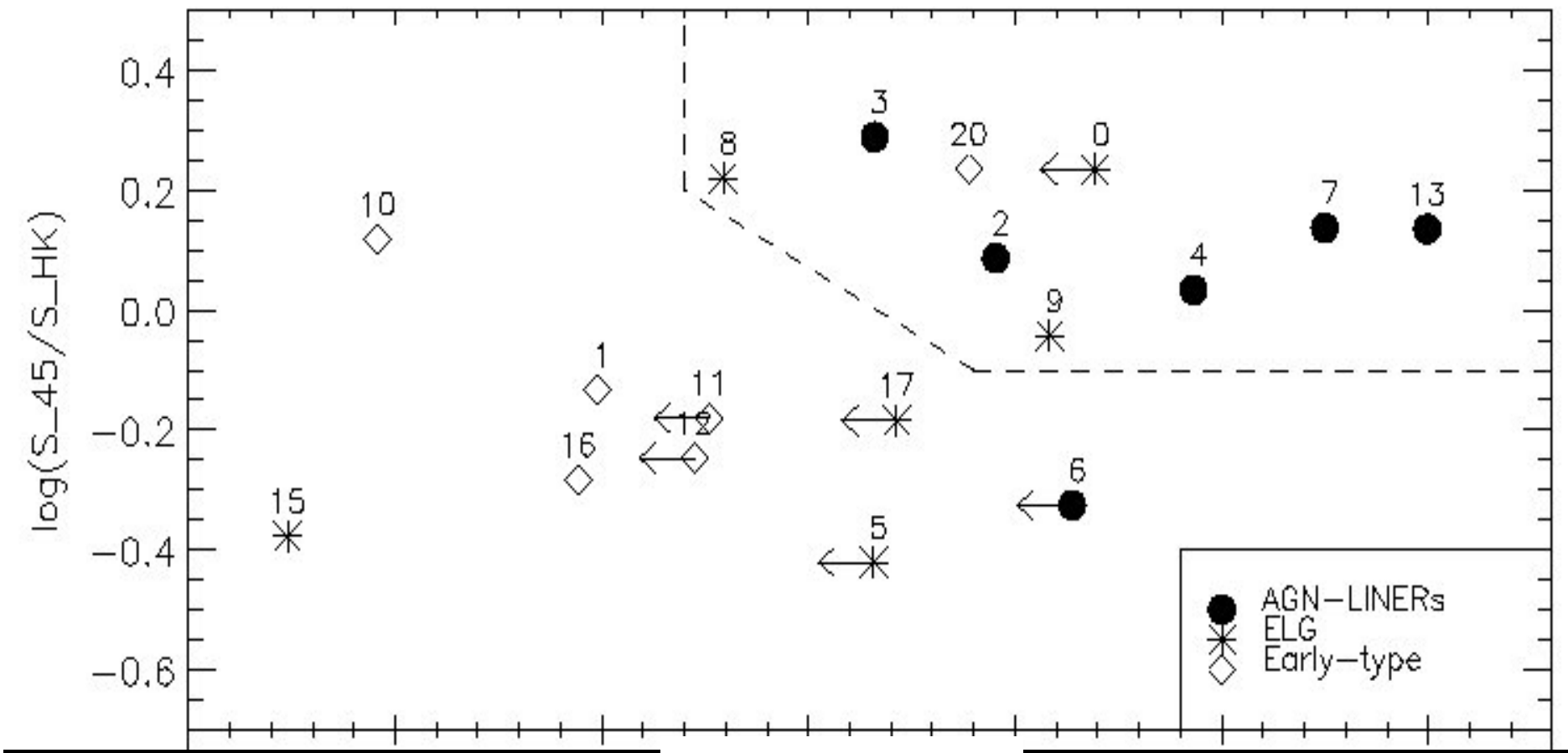
(Franceschini et al. 2005)

The bulk of sources with X-ray detection populate the "AGN" locus

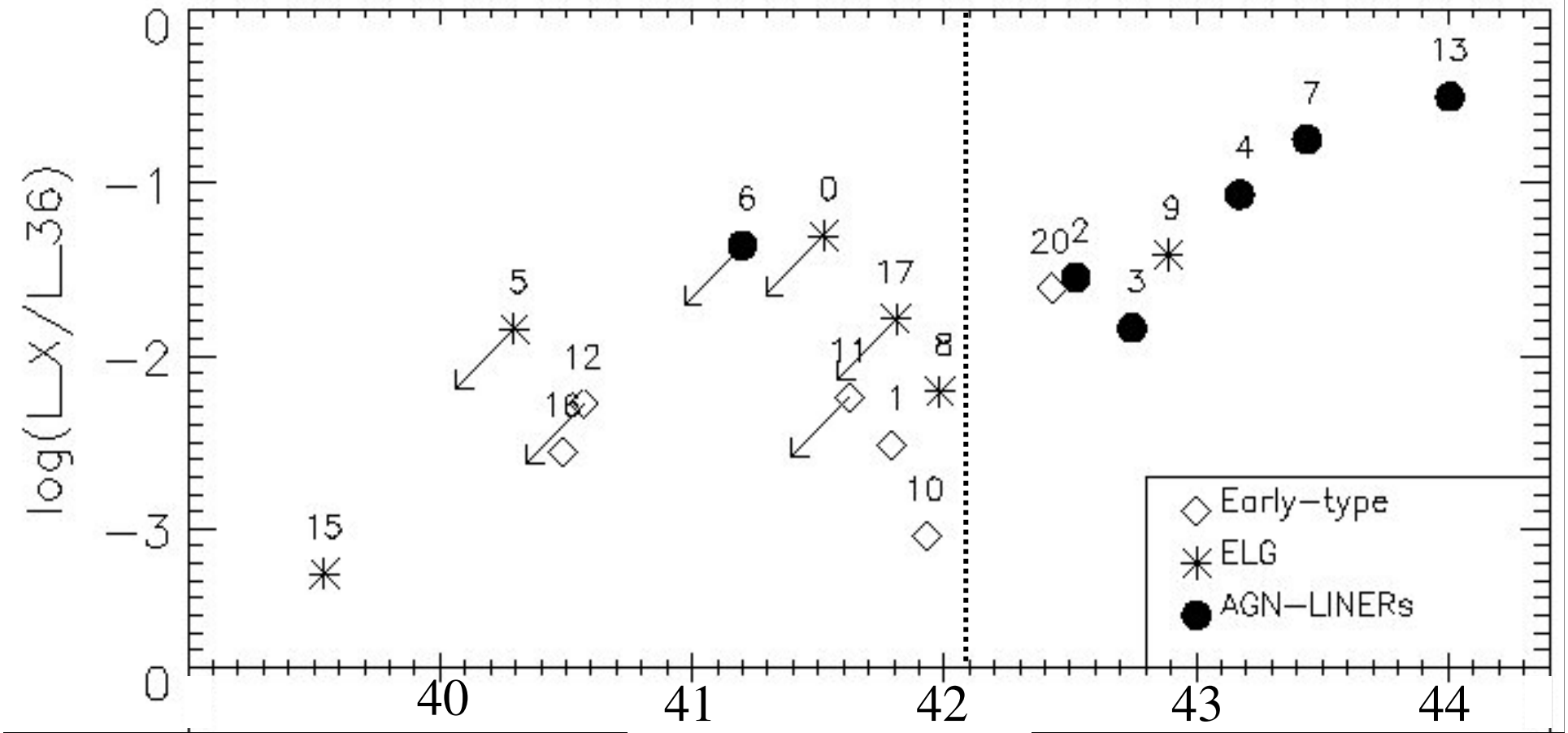


Colour- colour diagnostic versus spectroscopic class:

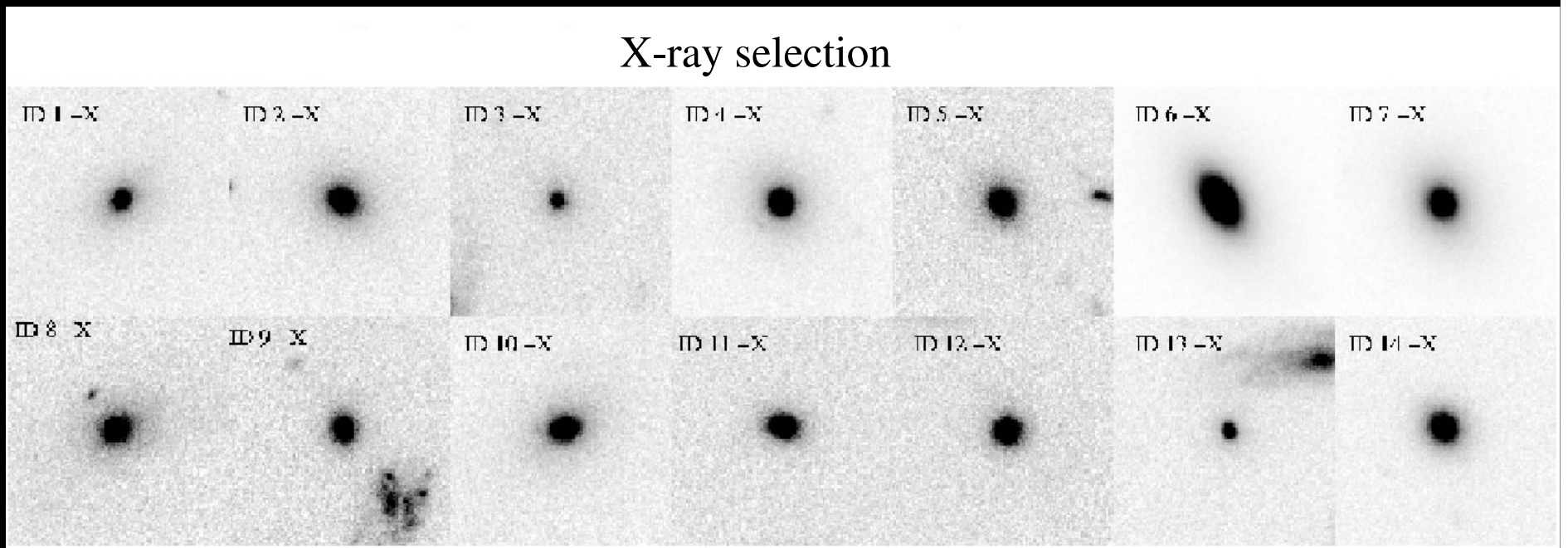
the bulk of sources with AGN spectra are confined within the same region



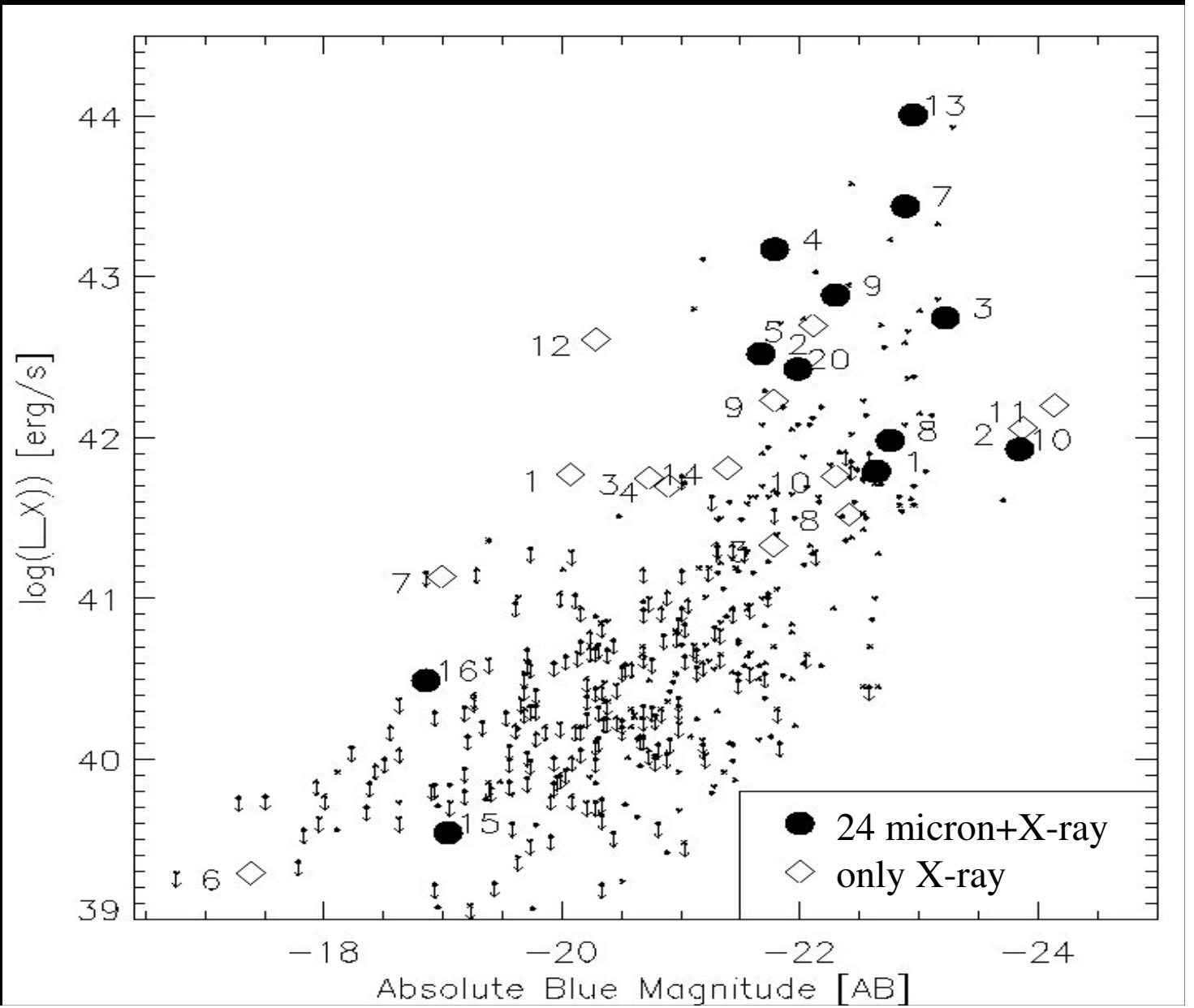
X-ray Luminosities



A comparison sample:
spheroids with X-ray detection lacking a 24 micron emission
==> 14 sources in the GOODS-N

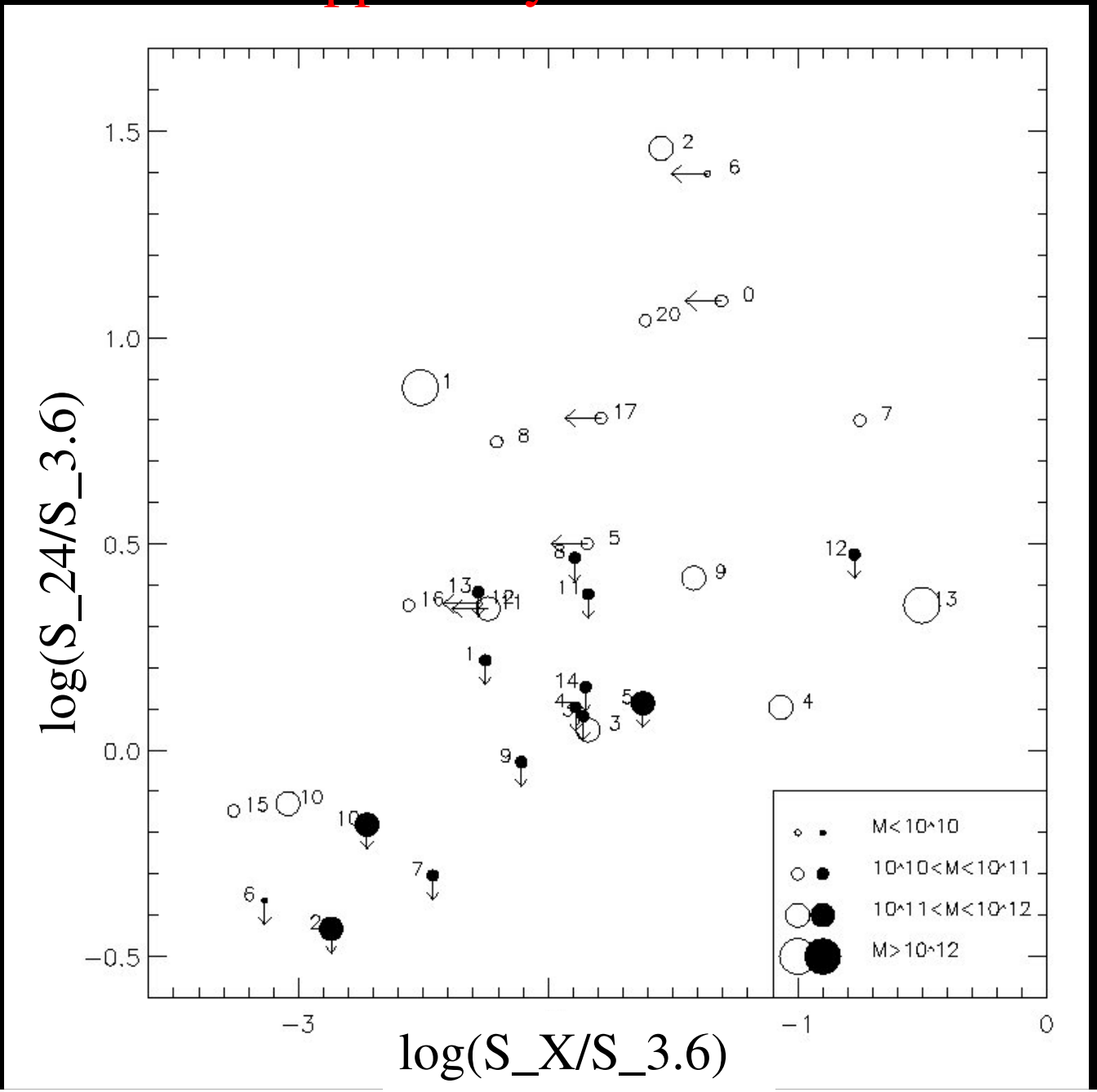


Comparison with a sample of X-ray only detected spheroids



Local sample
Ellis et al. (2006)

Dependence on mass?… apparently not!



Conclusions

•When combining the various diagnostics considered in this work (morphology, spectroscopy, X-ray emissions and colours), we extrapolate a quite heterogeneous scenario about the nature of the mid-IR excess of morphologically selected galaxies at high redshift.

•Locally, the simple emission of post-main sequence stars (like AGB stars) is sufficient to explain the nature of the mid-IR emission detected in ellipticals. At higher redshift, the mid-IR excess requires, in addition to this, the presence of a given amount of activity, both of nuclear type or of star formation.

•More than half of the 19 spheroidal galaxies show some indications for the presence of AGN activity. However star formation is required to explain the spectra of the other sources.

•We conclude that around 20% of the original sample of spheroids (selected in the optical z-band) are detected during phases of prominent activity, probably following an event of merging/interaction.

Finally, we suggest that this particular class of spheroids, with observed mid-IR excess revealing the presence of a given gradient of nuclear activity, might represent the natural product of the joint co-evolution of quasars and bulges.

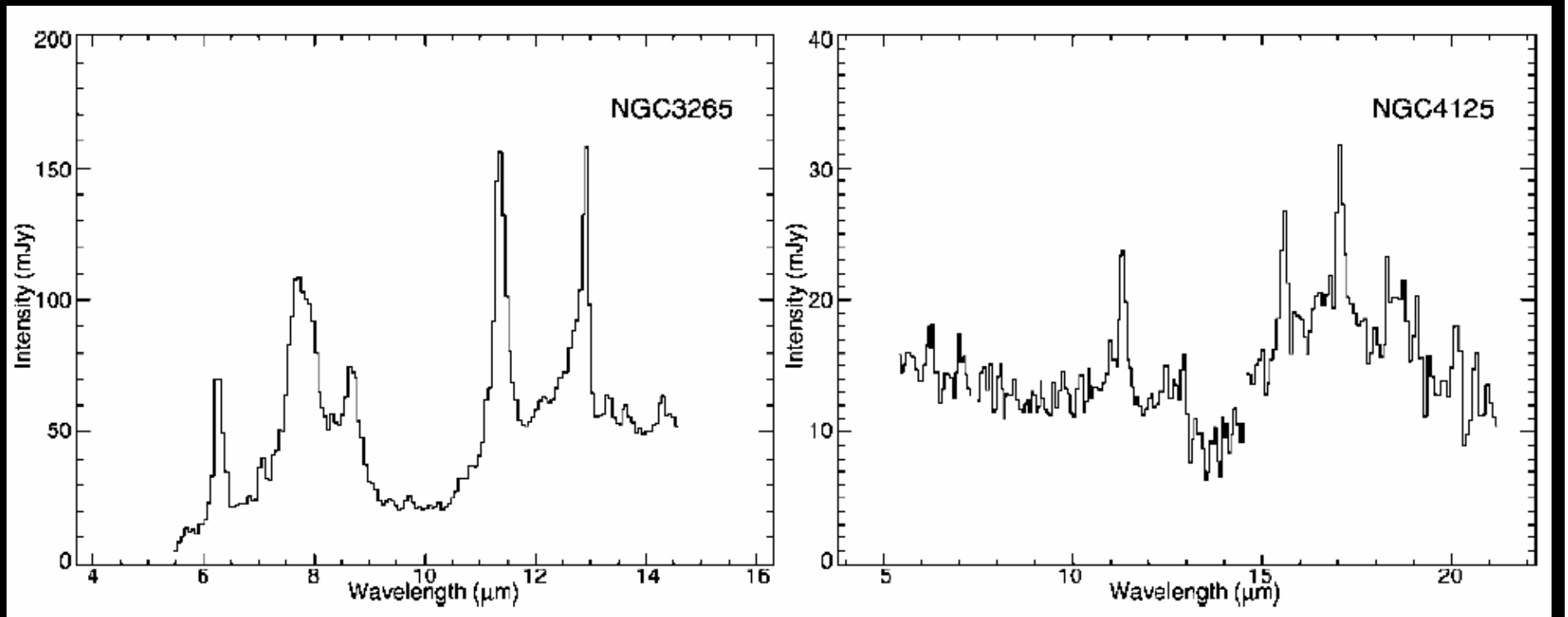
Next steps:

Need to improve the statistics over wider samples

GOODS-South - 130 sq. arcmin, immediate check available

COSMOS - 2 sq. degrees, Spitzer data under reduction

Detection of PAH in local early-type galaxies



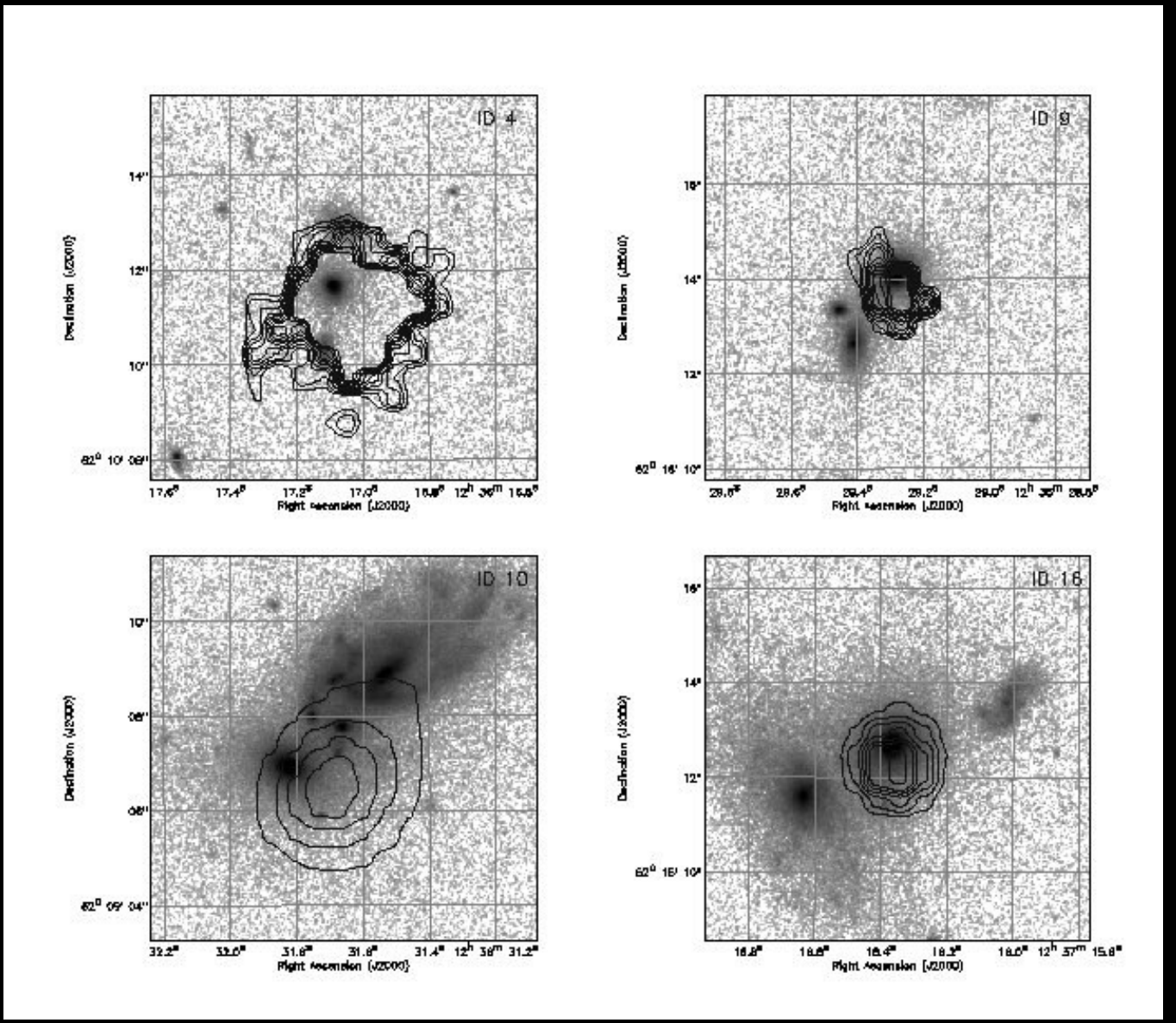
Kaneda et al. 2005 (Spitzer-IRS)

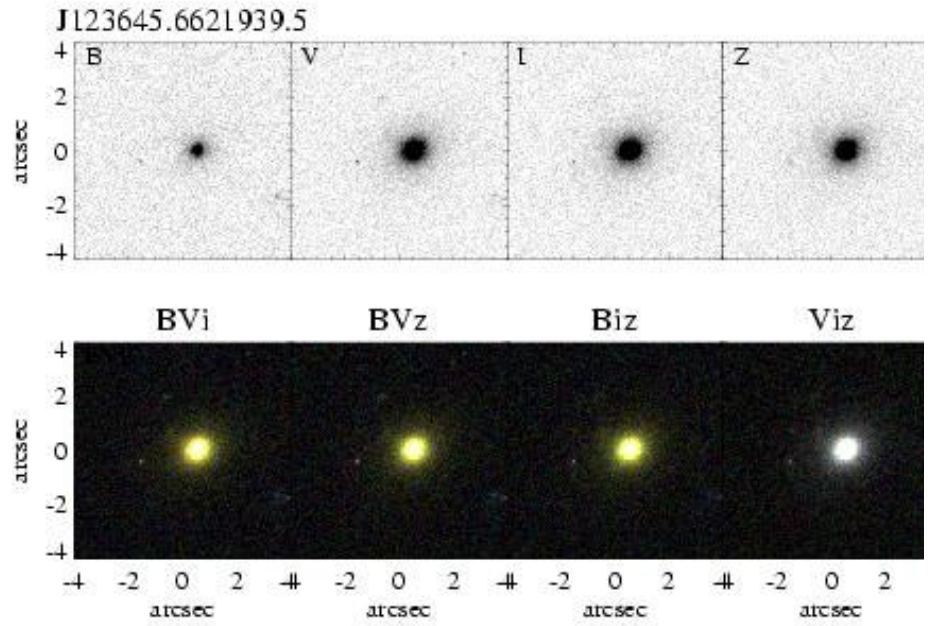
A critical point:

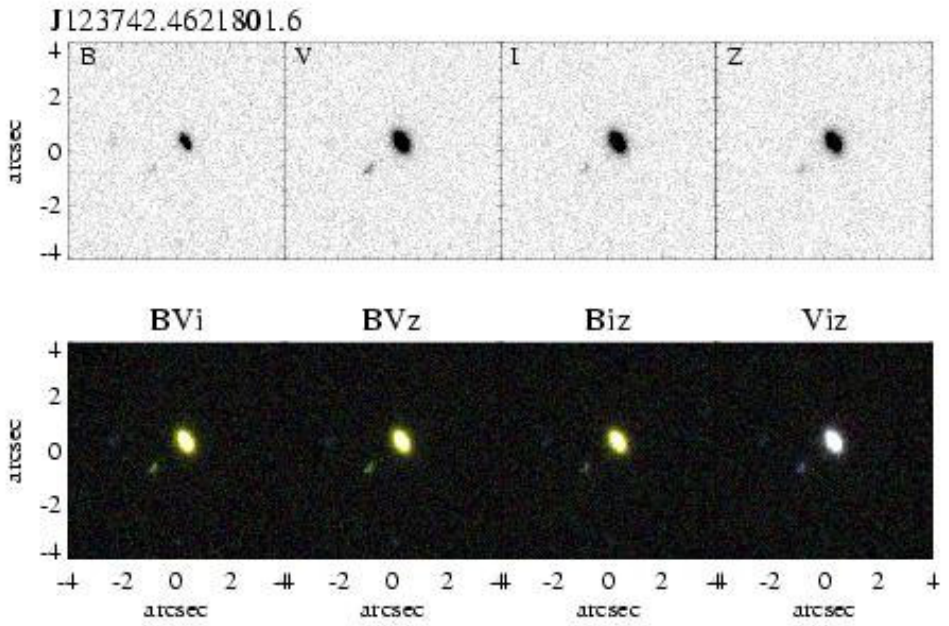
The morphological classication of source at redshift z = 1.

The mis-match between the morphological and spectroscopic classification of some sources could be related to the presence of faint disk structures (where the SF has a major role) that fall below the surface brightness limit and are not revealed even by HST at those cosmic distances. In any case, our sample is composed of bulge-dominated objects which should be dominated by old stellar populations.

X-ray contours for the blend sources







Morphological inspection