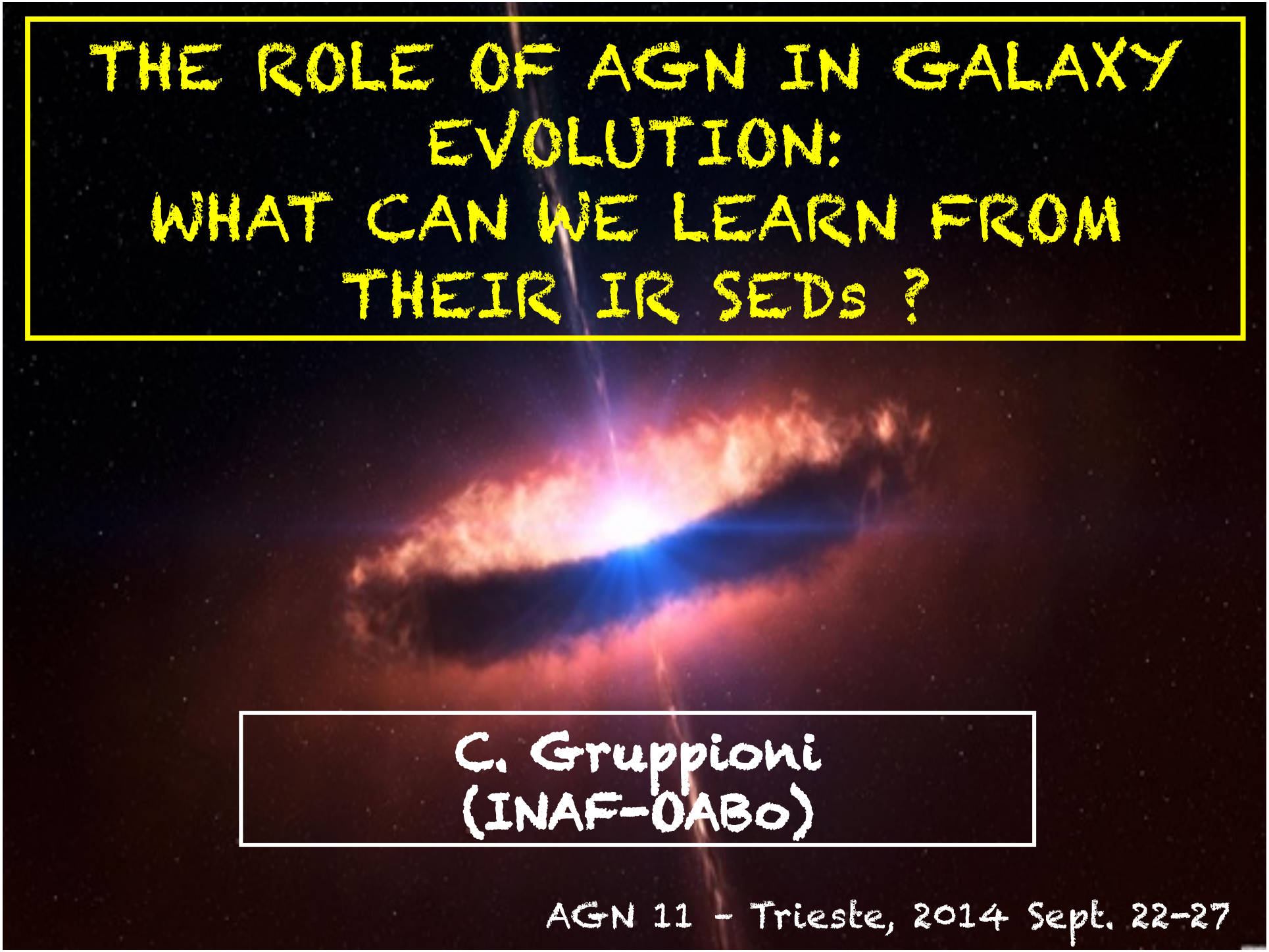
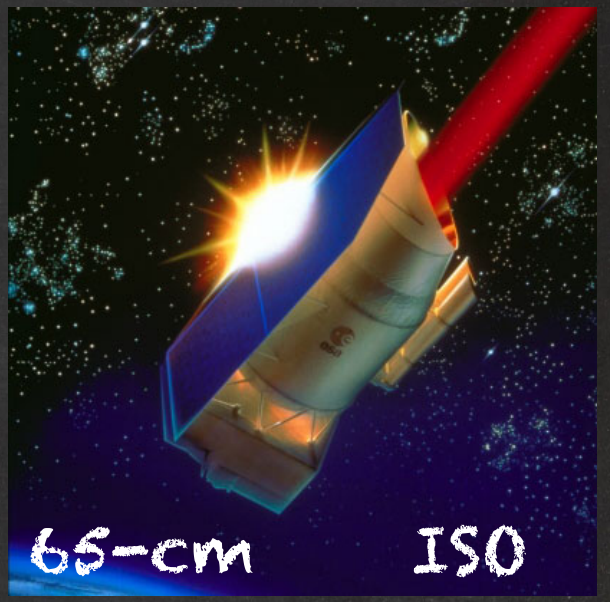
THE ROLE OF AGN IN GALAXY EVOLUTION: WHAT CAN WE LEARN FROM THEIR IR SEDs ?

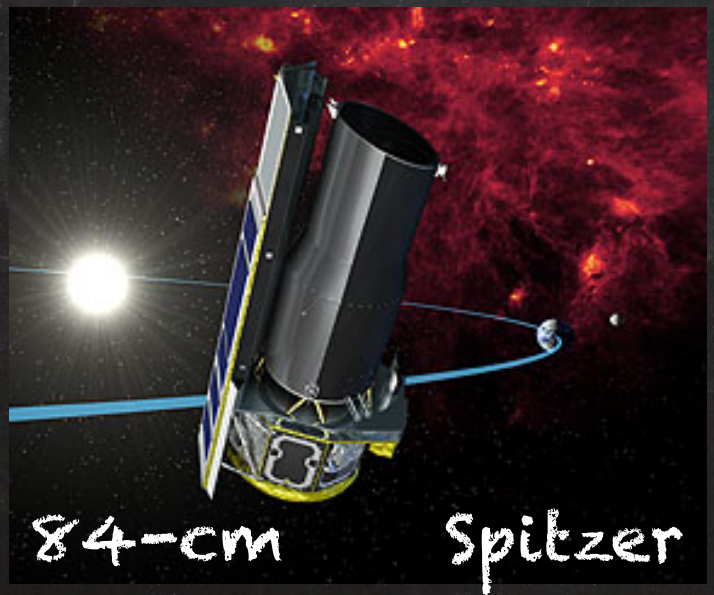


C. Gruppioni
(INAF-OABo)

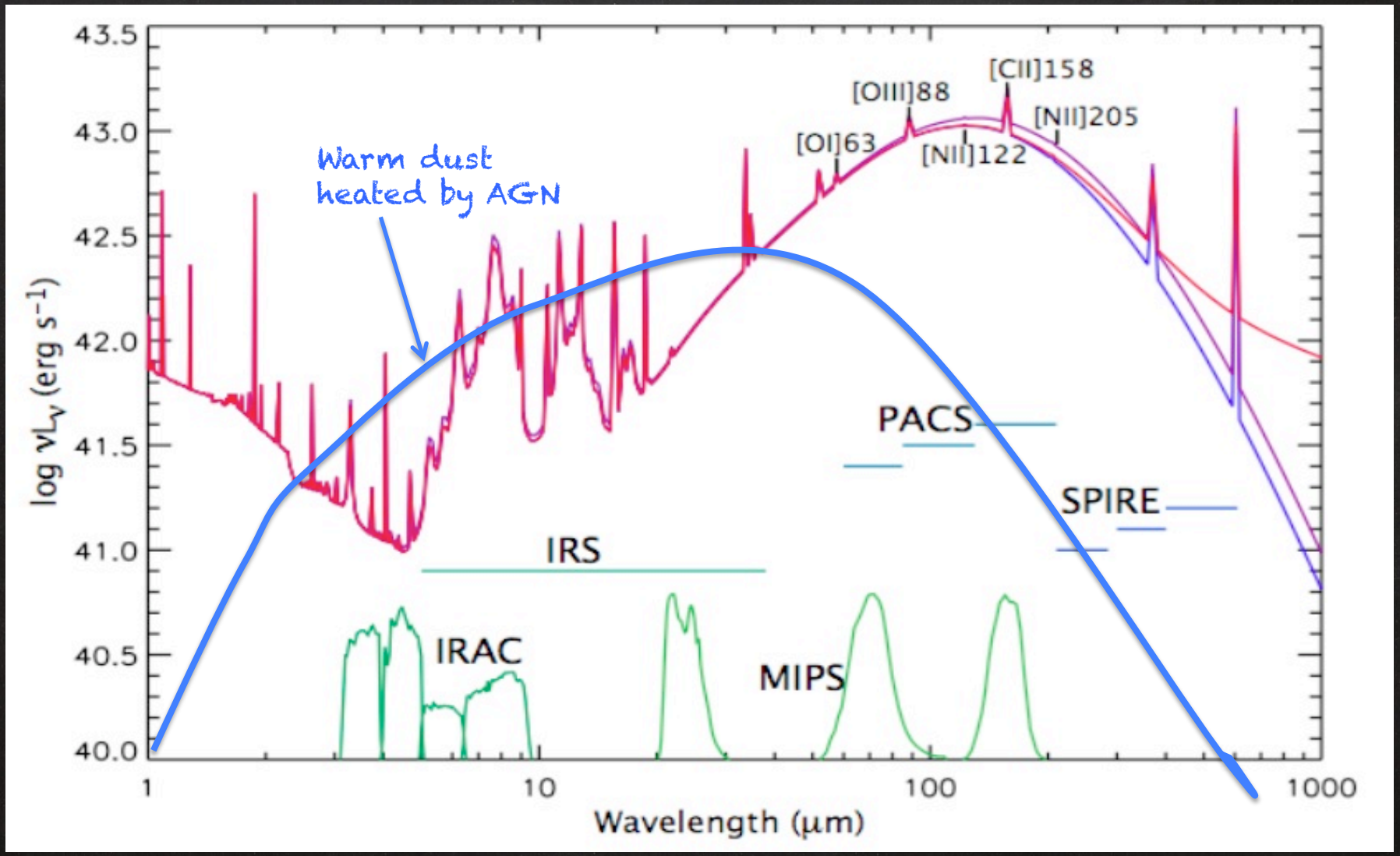
AGN 11 - Trieste, 2014 Sept. 22-27

Some of the Tools of the Trade





The emission of dust: mid and far-IR



IRAS found a mid-IR excess in some galaxy SEDs

25-μm excess observed with IRAS (Miley+ 1984) modeled by Rowan-Robinson & Crawford (1989) as dust thermal emission

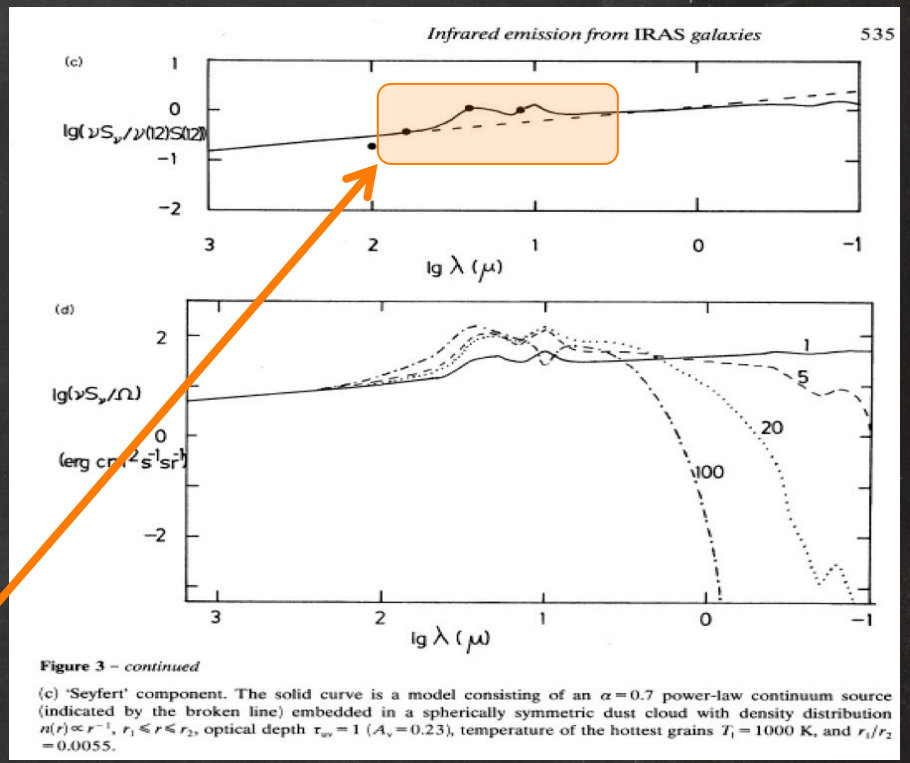


Figure 3 – *continued*

(c) 'Seyfert' component. The solid curve is a model consisting of an $\alpha = 0.7$ power-law continuum source (indicated by the broken line) embedded in a spherically symmetric dust cloud with density distribution $n(r) \propto r^{-1}$, $r_1 \leqslant r \leqslant r_2$, optical depth $\tau_{9\mu} = 1$ ($A_v = 0.23$), temperature of the hottest grains $T_1 = 1000$ K, and $r_1/r_2 = 0.0055$.

Models for infrared emission from *IRAS* galaxies

M. Rowan-Robinson and J. Crawford *Astronomy Unit, Queen Mary College, Mile End Road, London E1 4NS*

Accepted 1988 November 24. Received 1988 November 23; in original form 1988 June 17

Summary. The far-infrared (10–100 μm) spectra of galaxies detected in all four wavelength bands by *IRAS* are modelled in terms of three components: a cool 'disc' component; a warmer 'starburst' component, and a 'Seyfert' component peaking at 25 μm. The luminosity in the 'disc' component is well-correlated with the optical luminosity of the galaxy and this component is interpreted as emission from interstellar dust illuminated by the galaxy's starlight. The 'starburst' component is interpreted as being due to a burst of star formation in the galaxy nucleus and its spectrum is fitted well by a model consisting of hot stars embedded in an optically thick dust cloud. The 'Seyfert' component is interpreted as being due to a power-law continuum source within a dust cloud presumably associated with the narrow-line region of the compact source. The density distribution in this dust cloud behaves as $n(r) \propto r^{-1}$.

The luminosity in the 'starburst' component is correlated with Hubble type and whether or not the galaxy has a bar. The luminosity in the 'Seyfert' component is correlated with the X-ray luminosity of the galaxy, supporting the hypothesis that the central compact power-law continuum source is responsible for illuminating the dust seen emitting in the far-infrared.

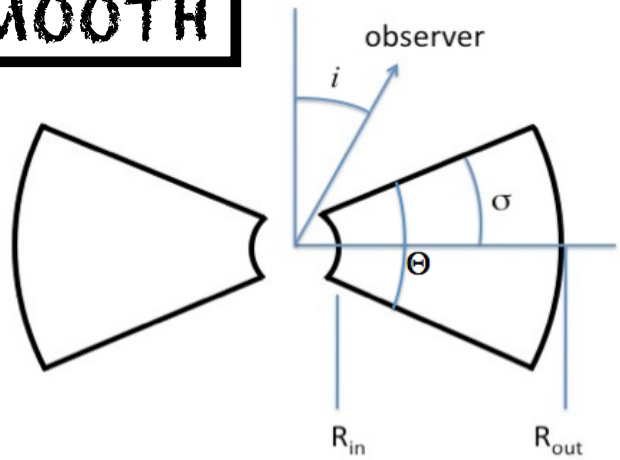
➔ Galaxy SEDs are a mixture of 3 components:

* optically thin 'cirrus'
* M82-like starburst
* AGN dust torus

HOW TO GET A TORUS MODEL

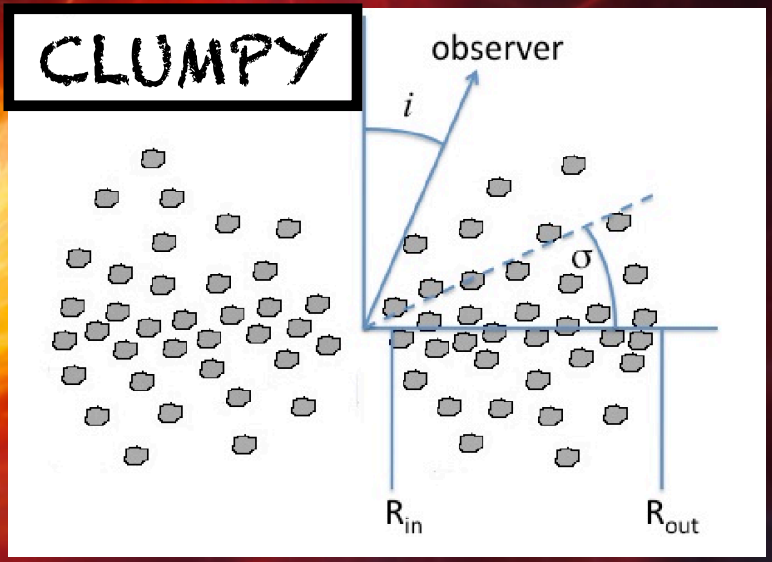
1. geometry
2. dust distribution and properties
3. grid of parameters
4. input primary source
5. solve the radiative transfer eq.
6. SED output

SMOOTH



Pier+Krolik+92, Granato&Danese+94, Stenholm+94, Efstathiou&Rowan-Robinson+95, Manske&Henning +98, van Bemmel&Dullemond+03, Schartmann+05, Fritz+06, Feltre+12

CLUMPY

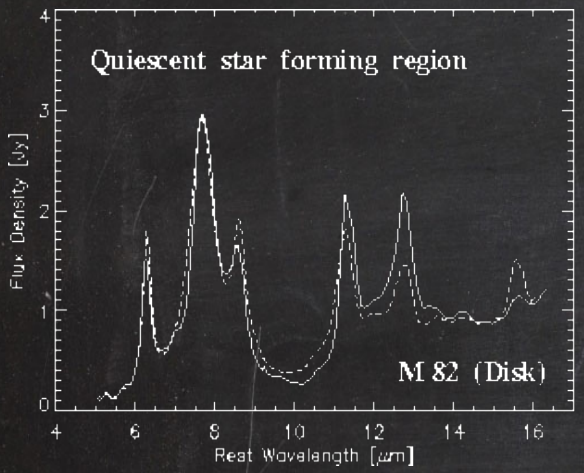


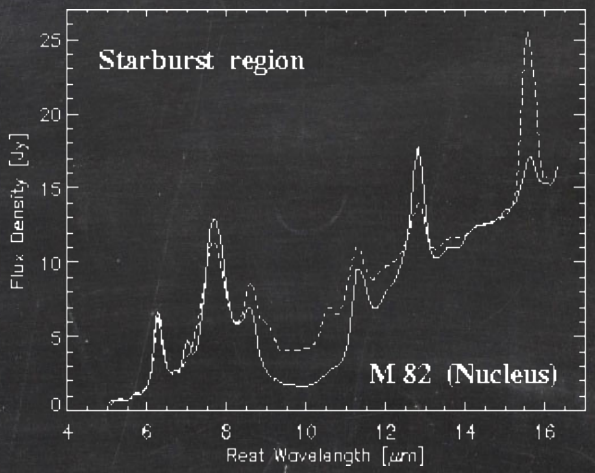
Nenkova+02,08a,b, Dullemond&vanBemmel+05, Hönig+06, Schartmann+08

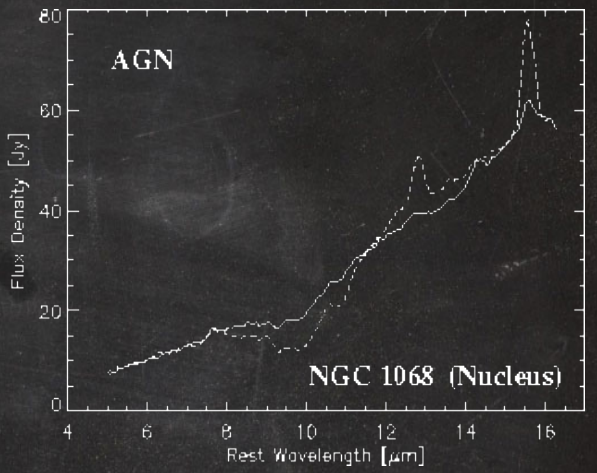
Bi-phase model (Stalevski+13)

Courtesy of A. Feltre

ISO SWS Spectroscopy: powerful tool to distinguish star-formation (PAHs) from AGN activity (continuum)



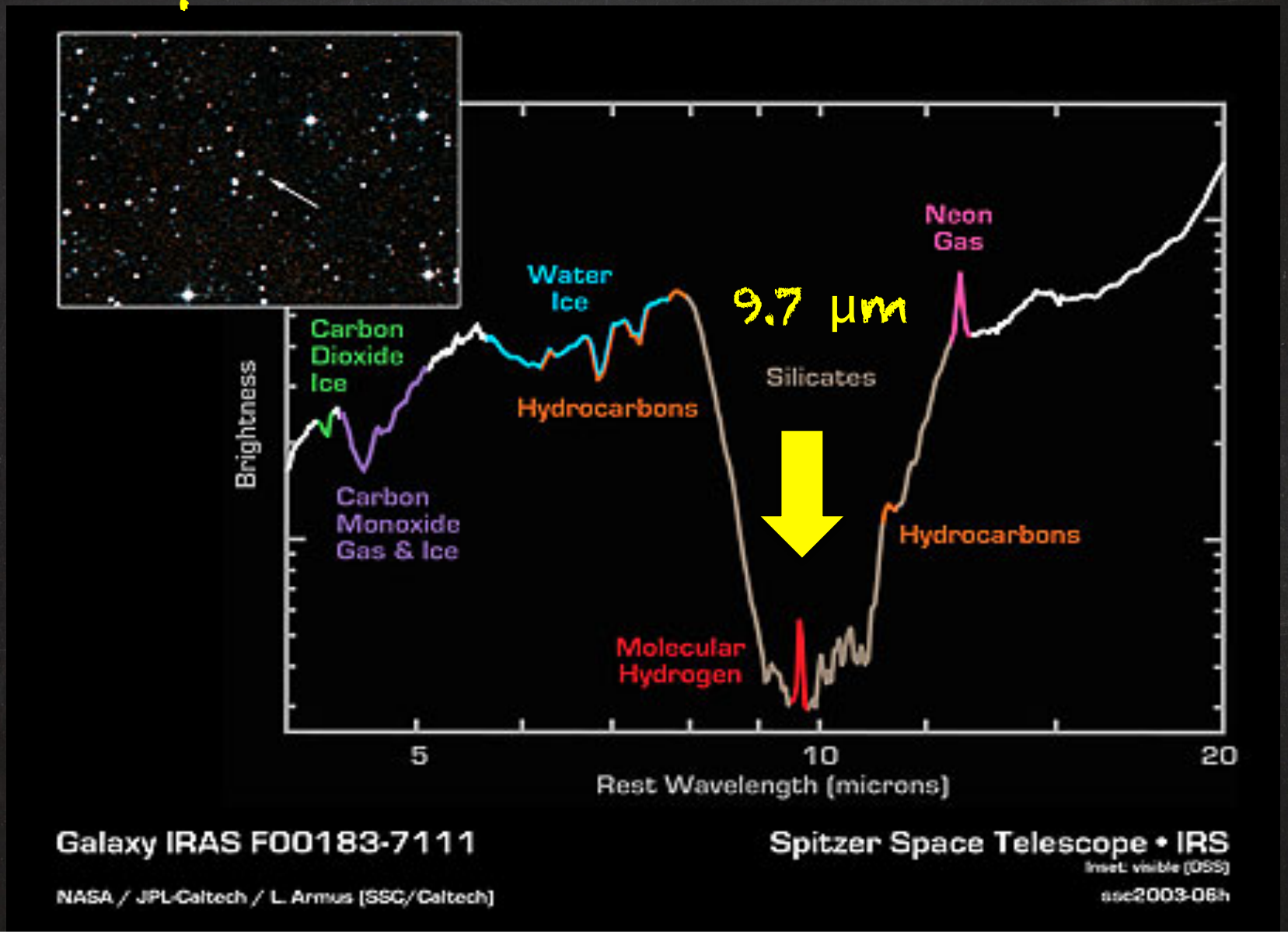




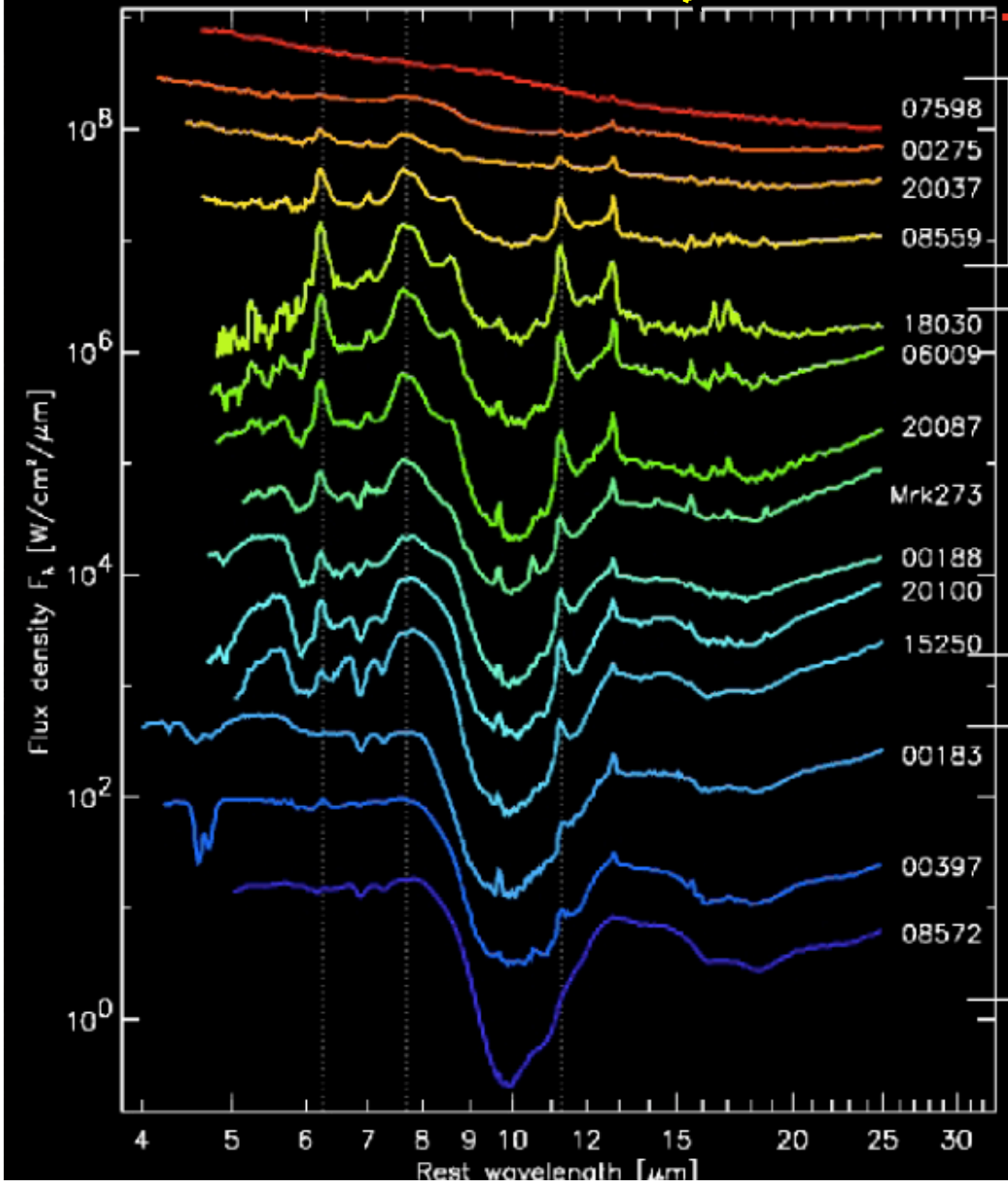
(i.e. Laurent+ 2000)

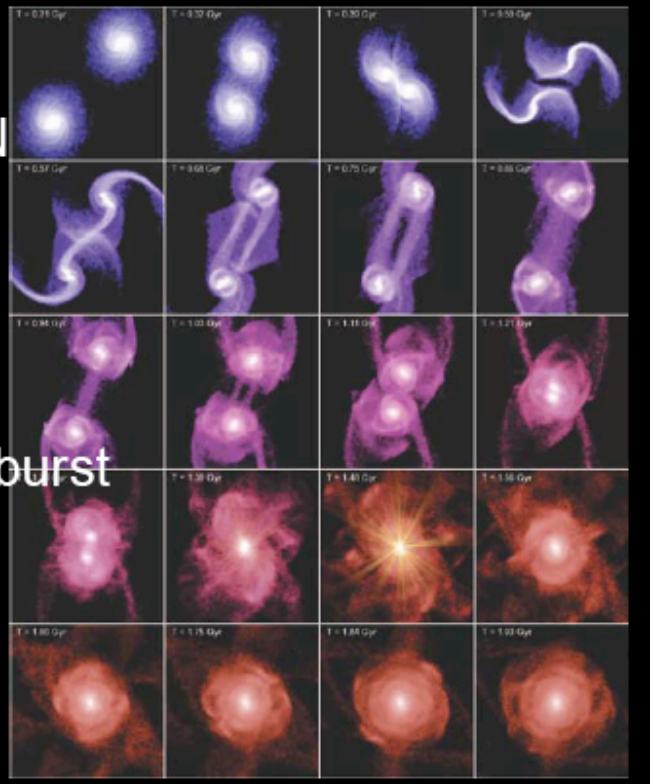
- PAH features: star-formation
- Warm continuum: AGN

Spitzer-IRS: the 9.7 μm silicate absorption feature & obscured AGN



SPITZER-IRS Spectroscopy: AGN vs. SB



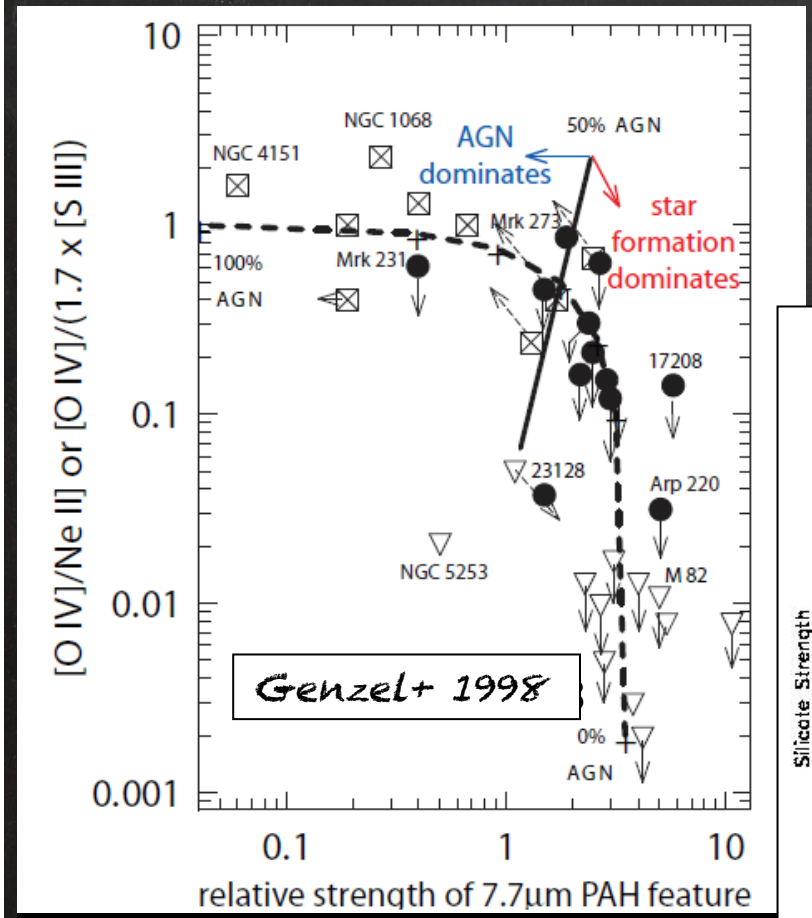


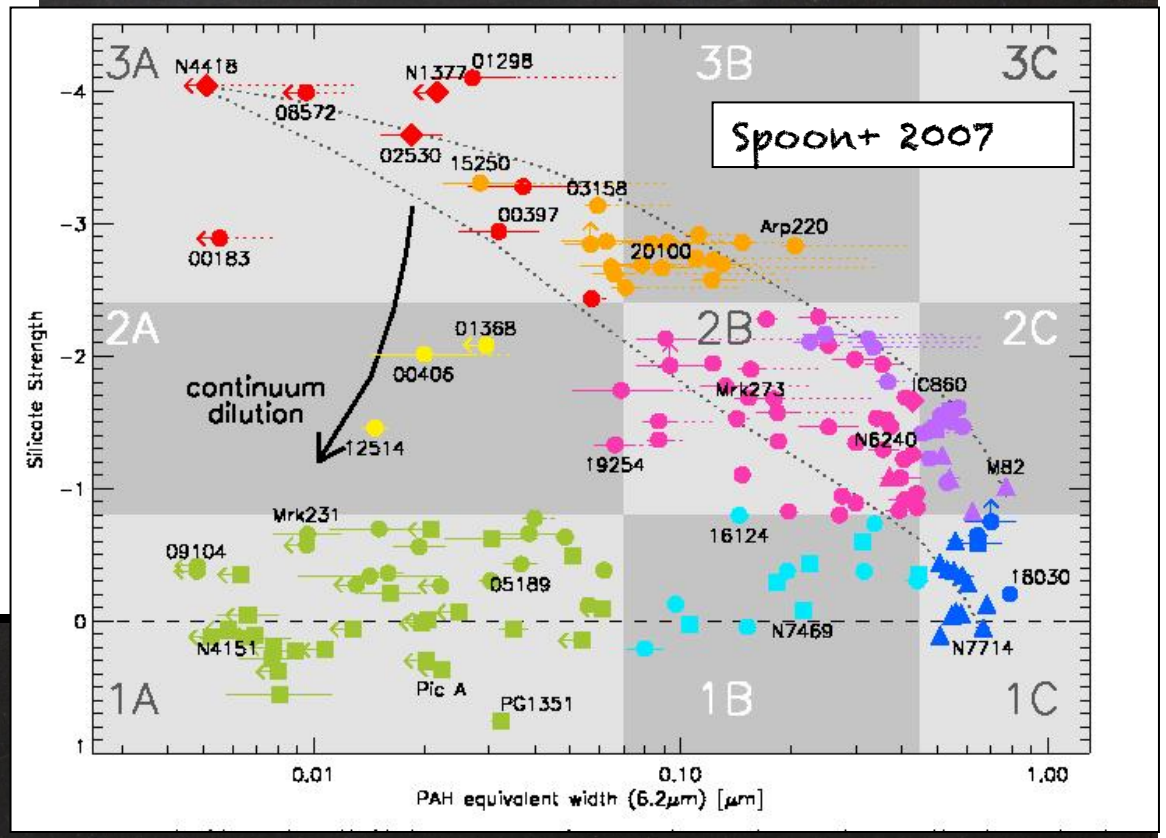
Hopkins et al. 2006

Armus et al. (2006, IRS GTO ULIRG program)

Veilleux et al. (2006, 2009 QUEST)

pre- and post-Spitzer mid-IR line diagnostics for SF galaxies and AGN

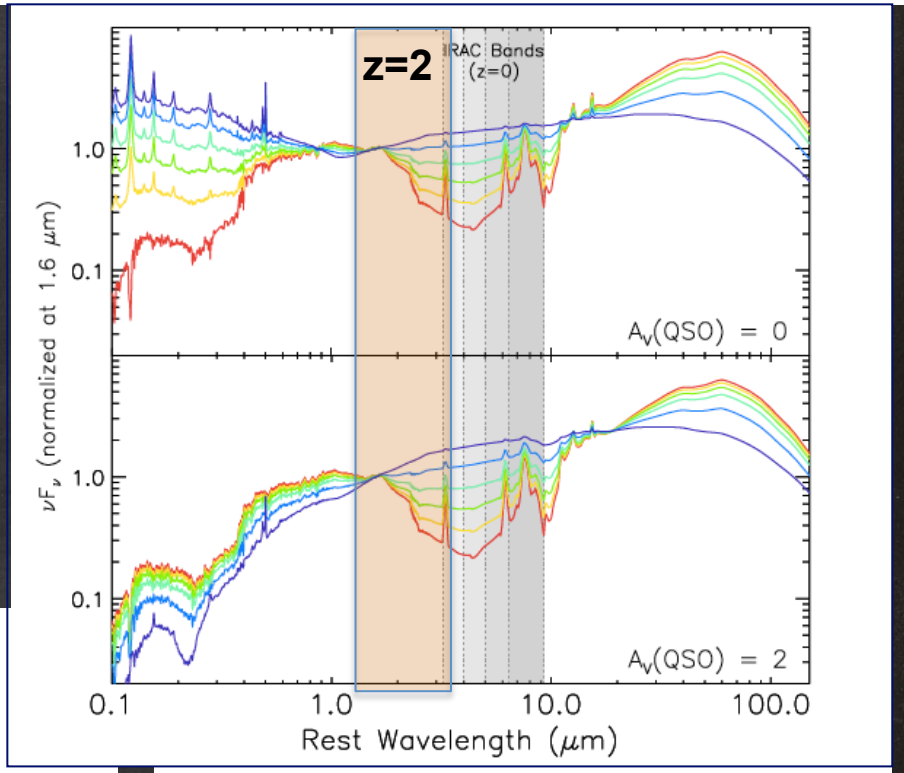


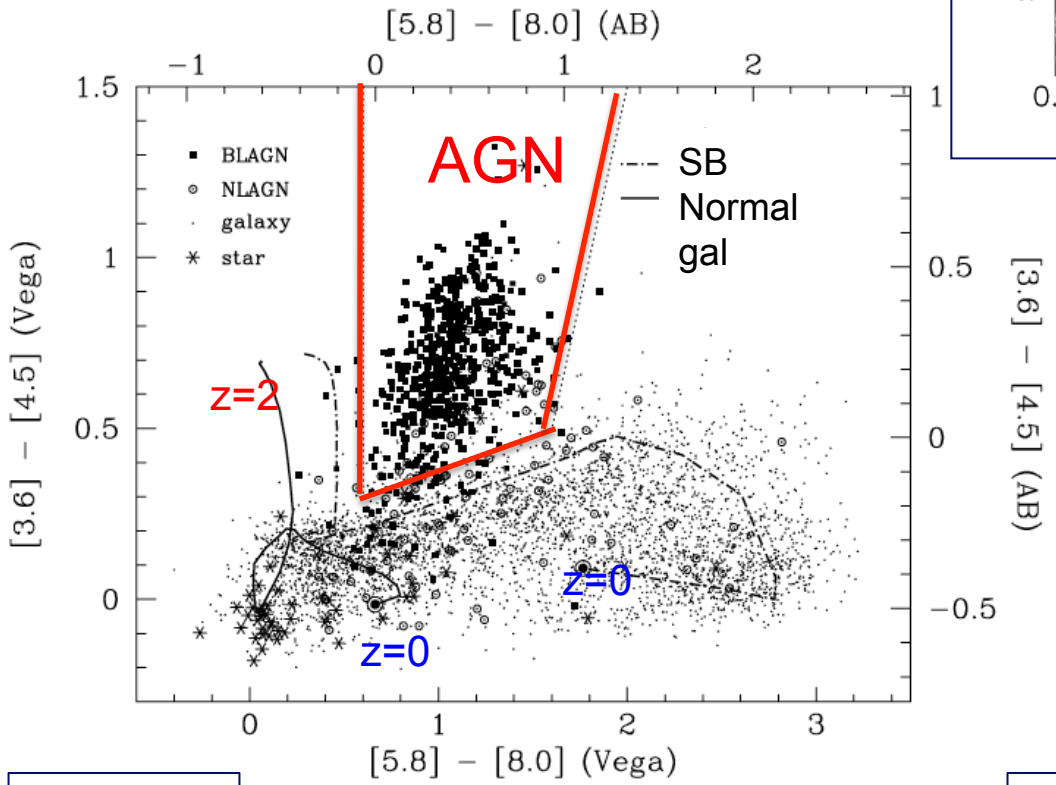


BUT: Spectroscopy is not often available....

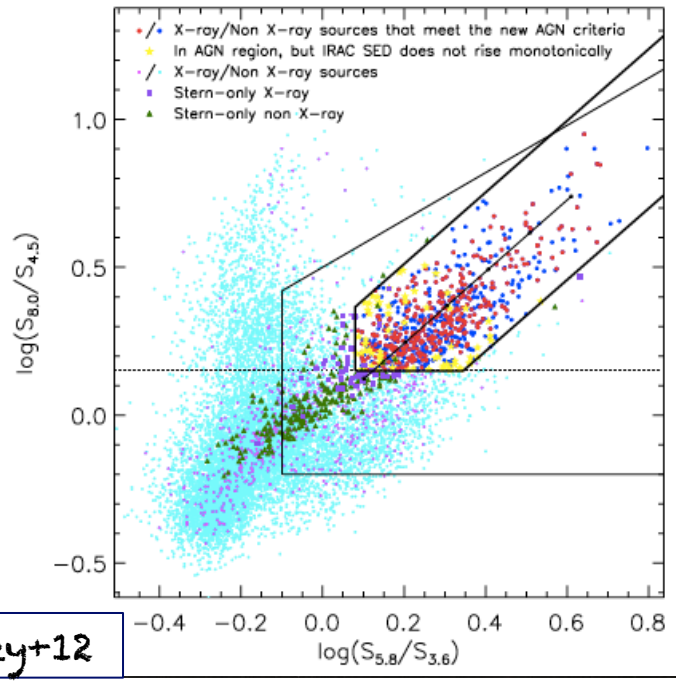
AGN selection from IRAC colours

Problems:
- galaxy contamination
- at z>2 IRAC samples a mixture of stellar and AGN emission
=> difficult to model



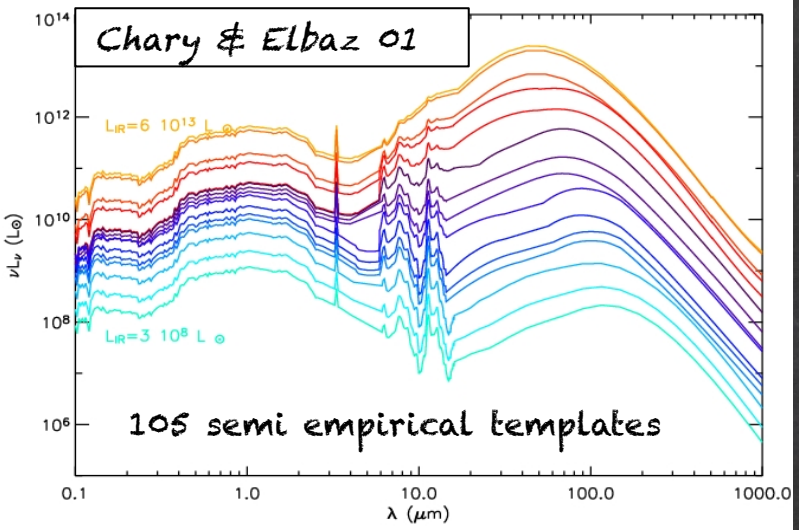


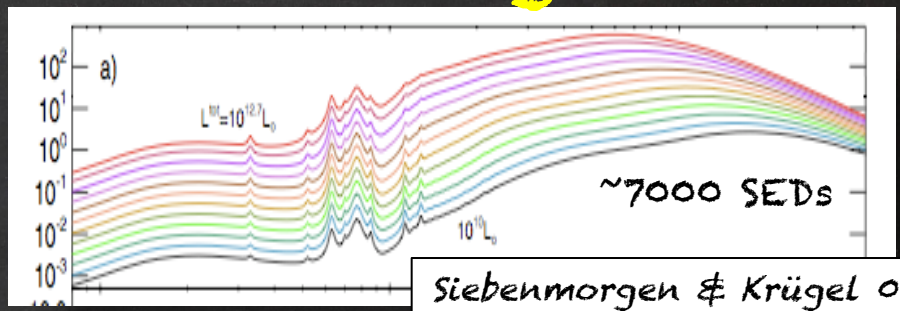
Stern+05

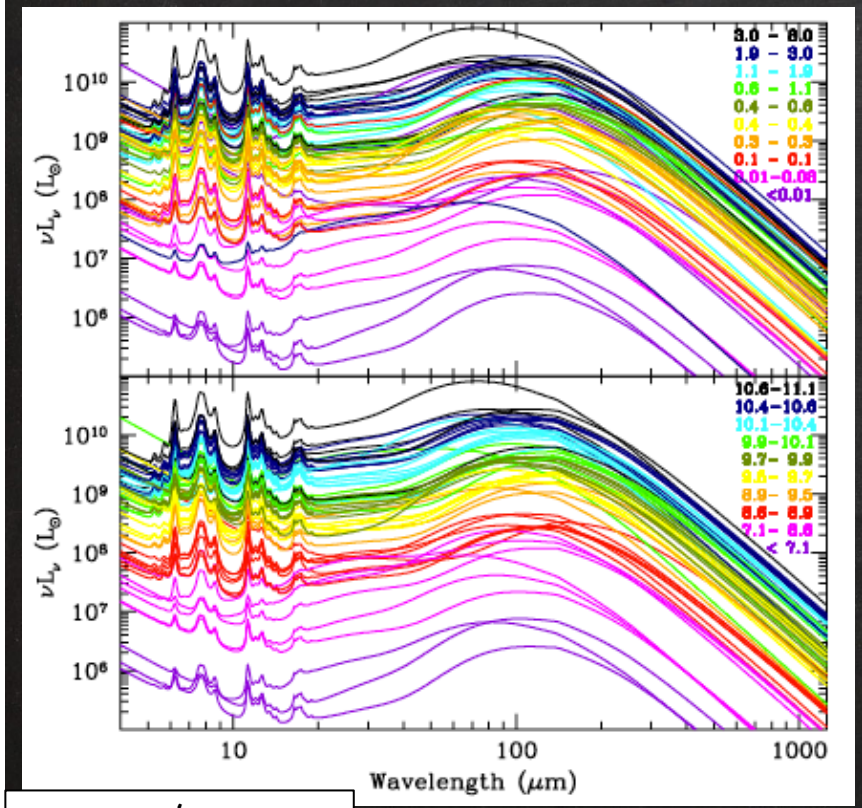


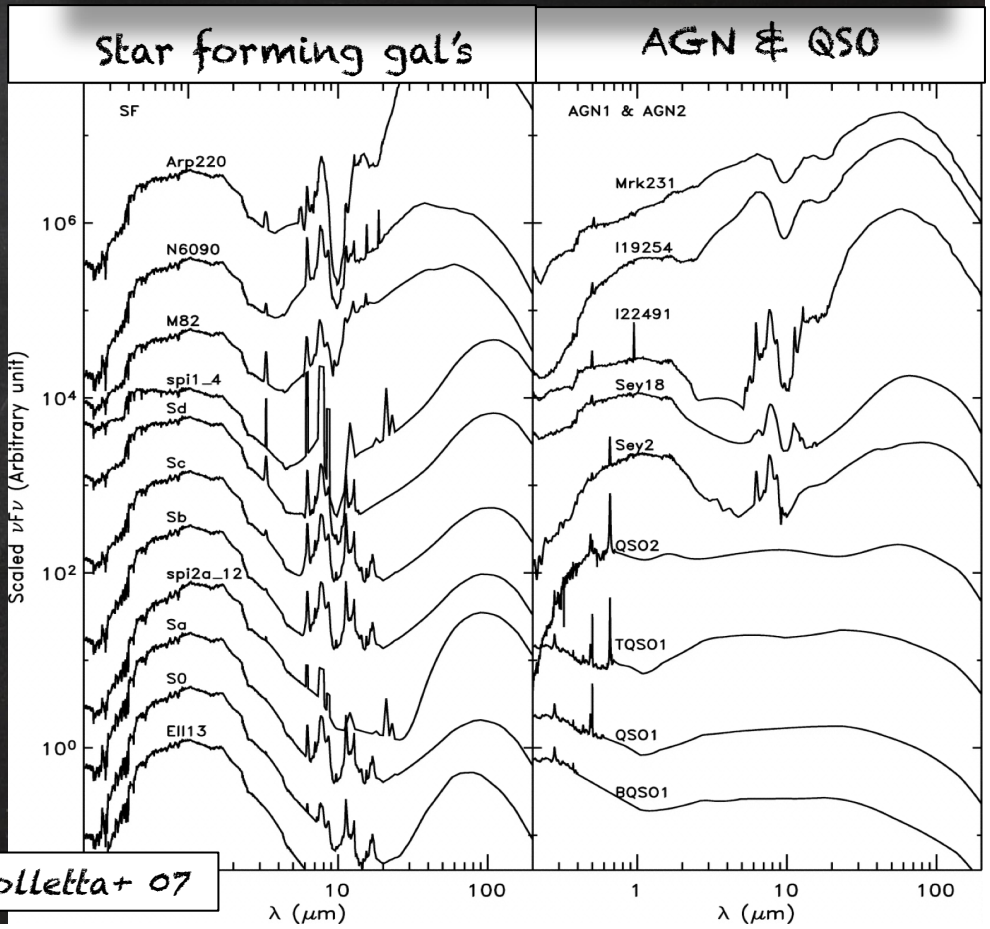
Donley+12

Template SED of normal and active galaxies









Main differences

- Chary & Elbaz 2001: the most popular

It does not consider AGN templates.

A L_{IR} is assigned, given a 24 μm flux and a z

- Dale & Helou 2002: based on f (60 μm)/f(100 μm)

- Polletta+ 2007: semi-empirical templates of different classes of local galaxies and AGN

- Siebenmorgen & Krügel 2007: more than 7000 theoretical templates, no AGN

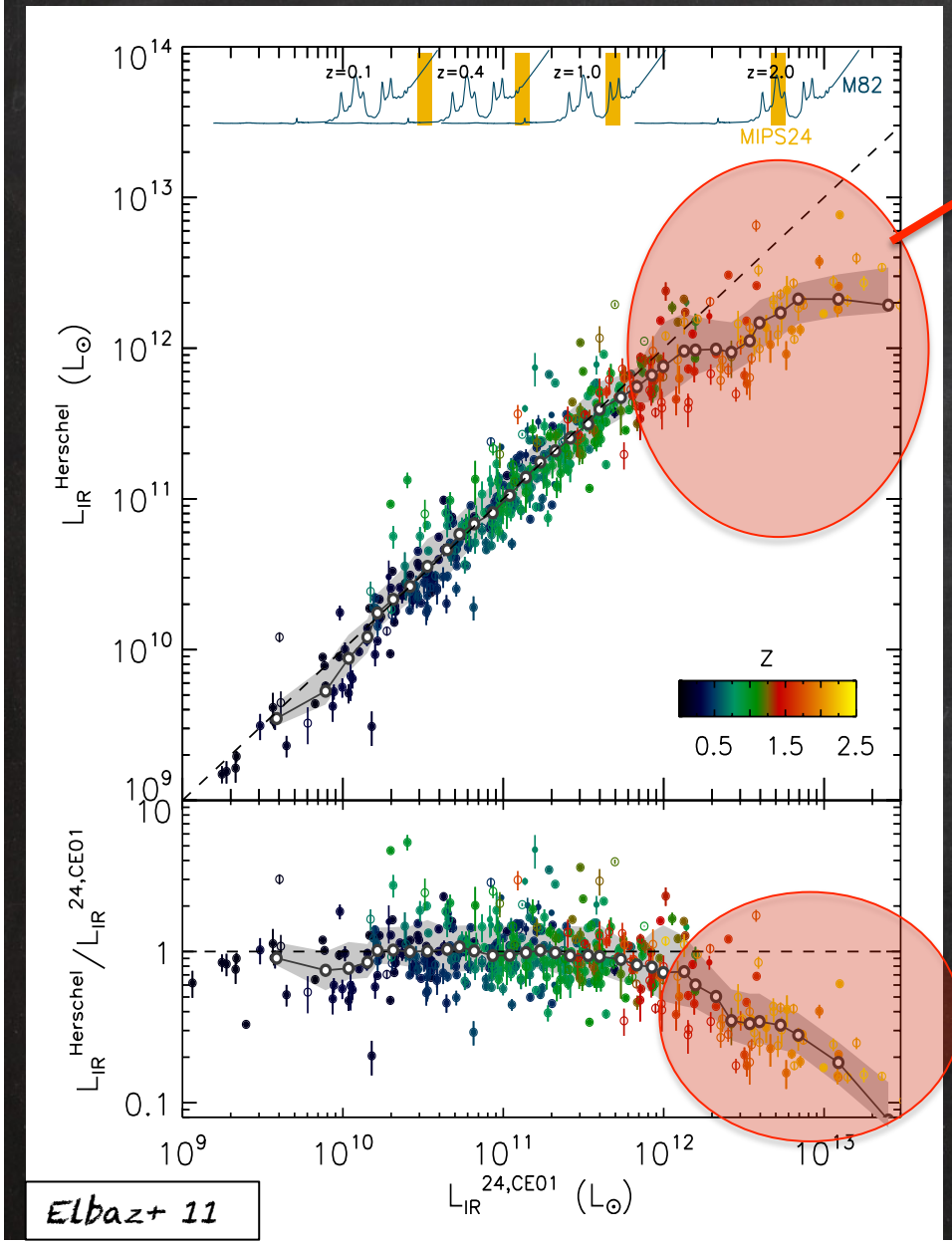
➡ Before Herschel it was just a "personal" choice

The HERSCHEL observatory

Launched May 14th 2009

Died officially April 29th 2013

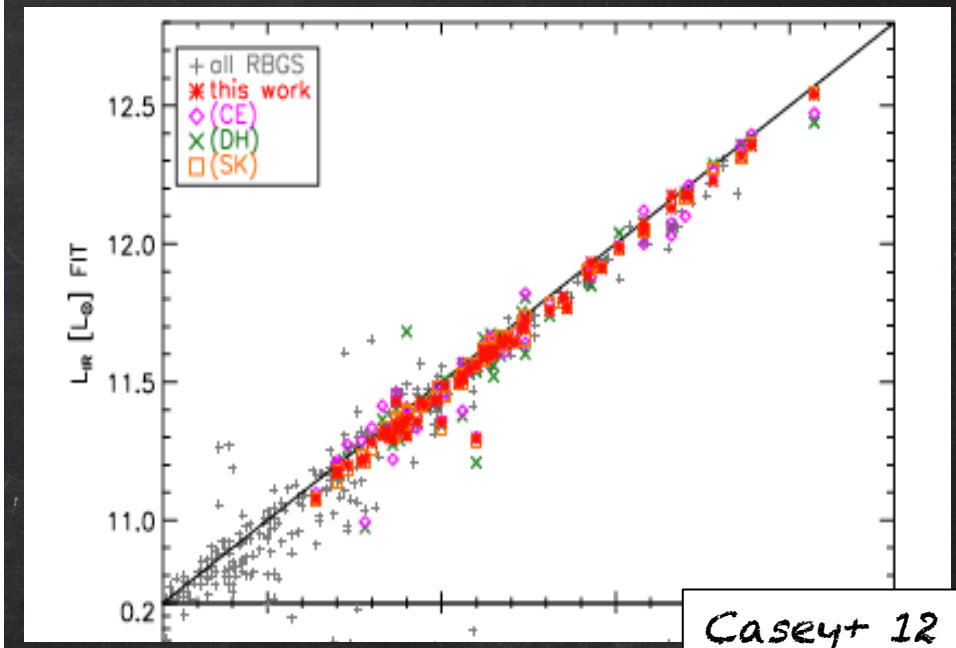
Galaxy SEDs after Herschel



Elbaz+ 11

At z>1.5 CE01 templates fail in estimating L_{IR}

BUT...



Casey+ 12

The measure of L_{IR}^{tot} remains ~robust IF Herschel data are available

Interpretation

The local templates fail in reproducing the SEDs of high redshift galaxies

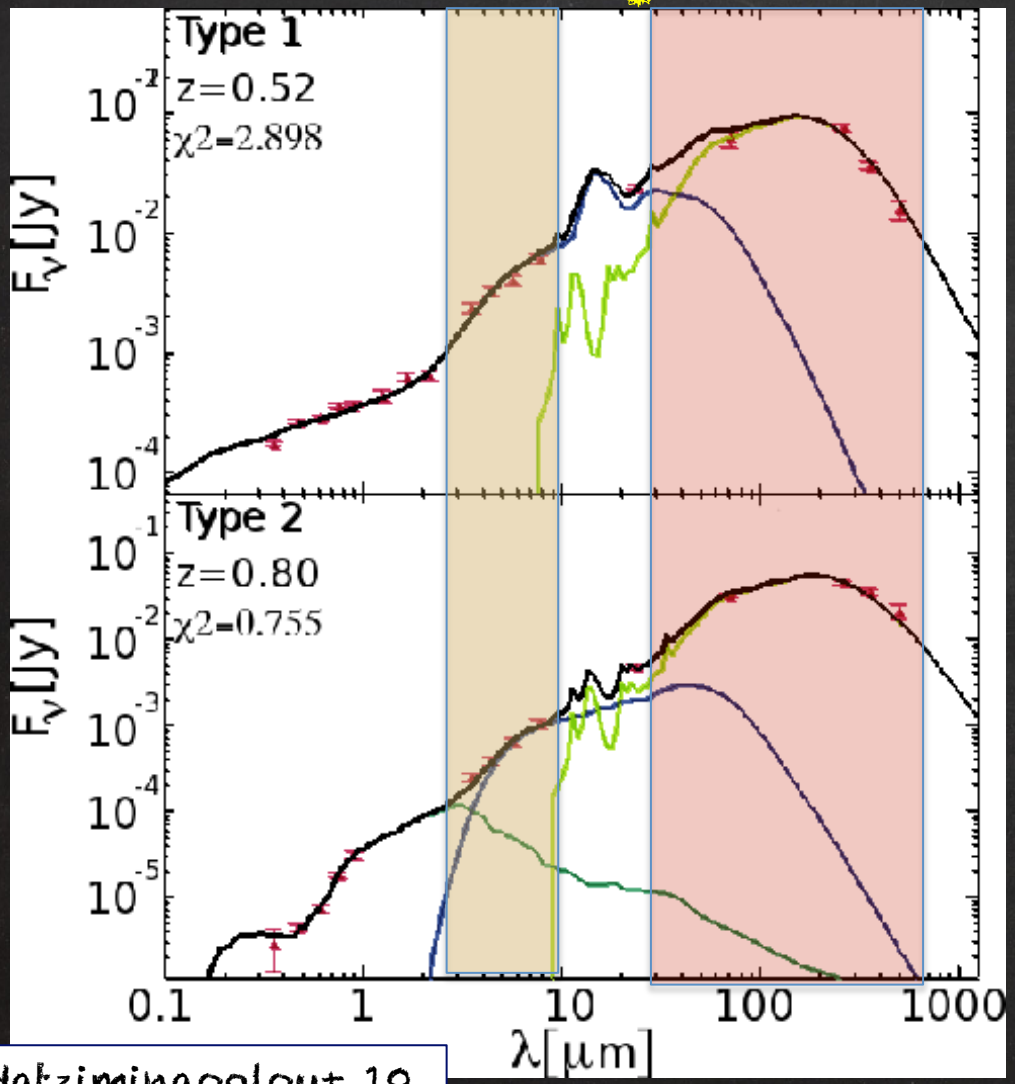
Why?

Because high-z (U)LIRGs are not analogs of local ones.

They are analogs of local "normal" galaxies, Simply scaled in luminosity (luminosity evolution)

Basically NO SED EVOLUTION

AGN SED in the far-IR is always dominated by SF (NOT in the mid-IR)

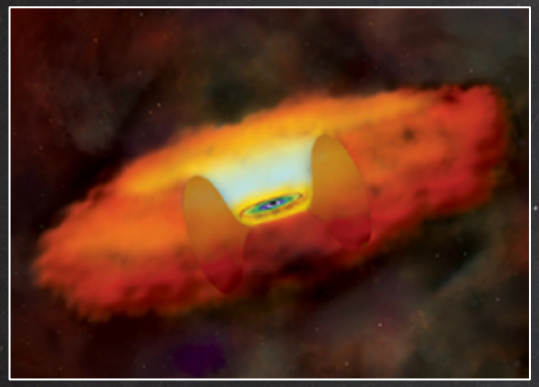


Hatziminaoglou+ 10

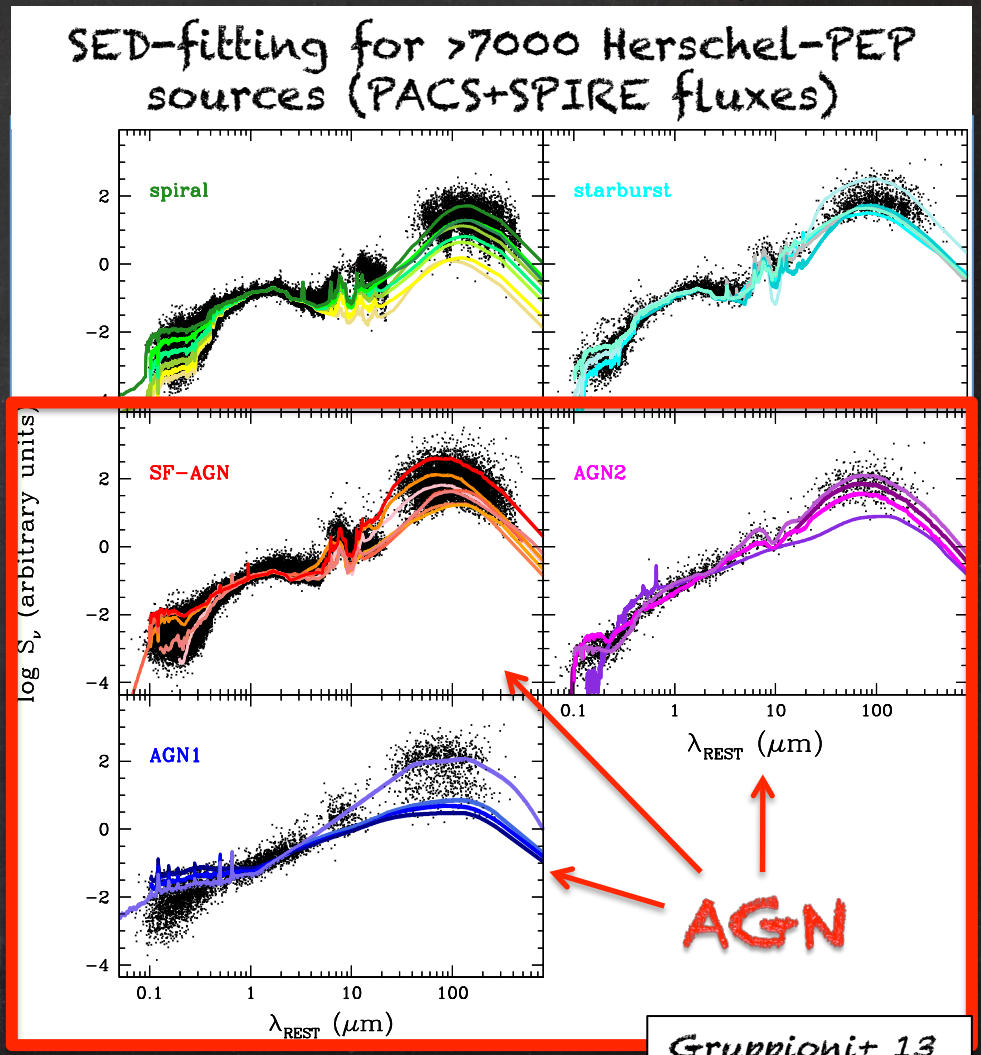
Blue: AGN-torus model
Green: IR starburst
Dark green: stellar component
Black:total SED

- mid-IR sensitive to AGN contribution
- Far-IR dominated by star formation, secure measure of the (obscured) SFR

SED/Galaxy evolution in the IR



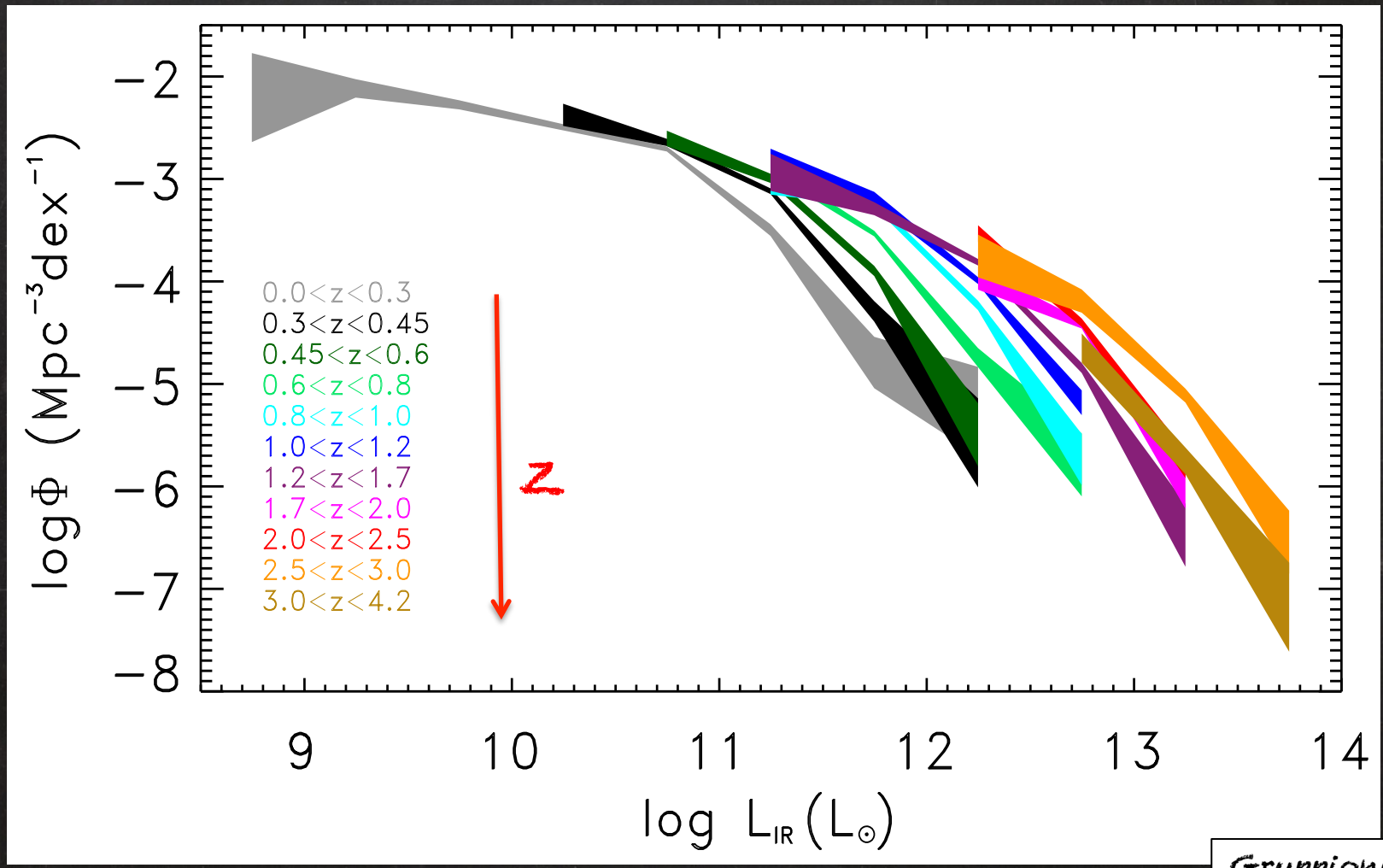
Large variety of IR SEDs :
Many (≥50%) show the presence of AGN
(in agreement with local Spitzer works, i.e. Schmidt+07)



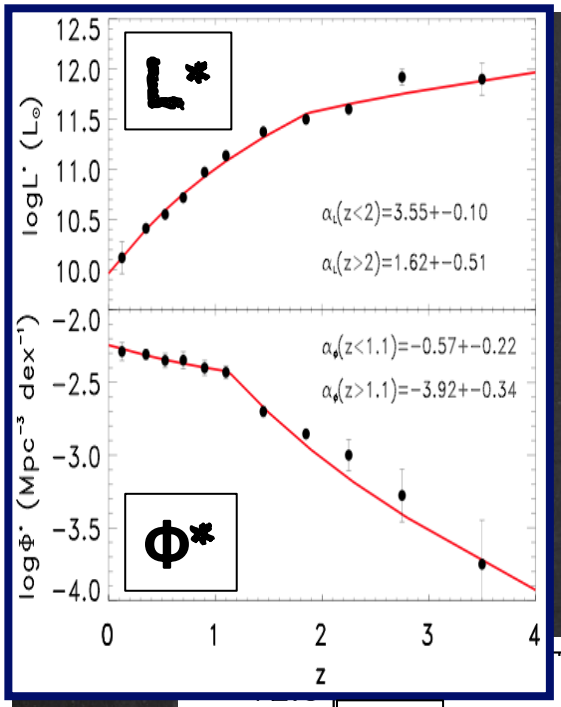
Polletta+ 07 templates still representative of the bulk of Herschel sources up to z~4, with some modifications, mainly for AGN SEDs (higher far-IR, Gruppioni+ 10; +13)

The Total IR LF up to z≈4

→ STRONG EVOLUTION with z



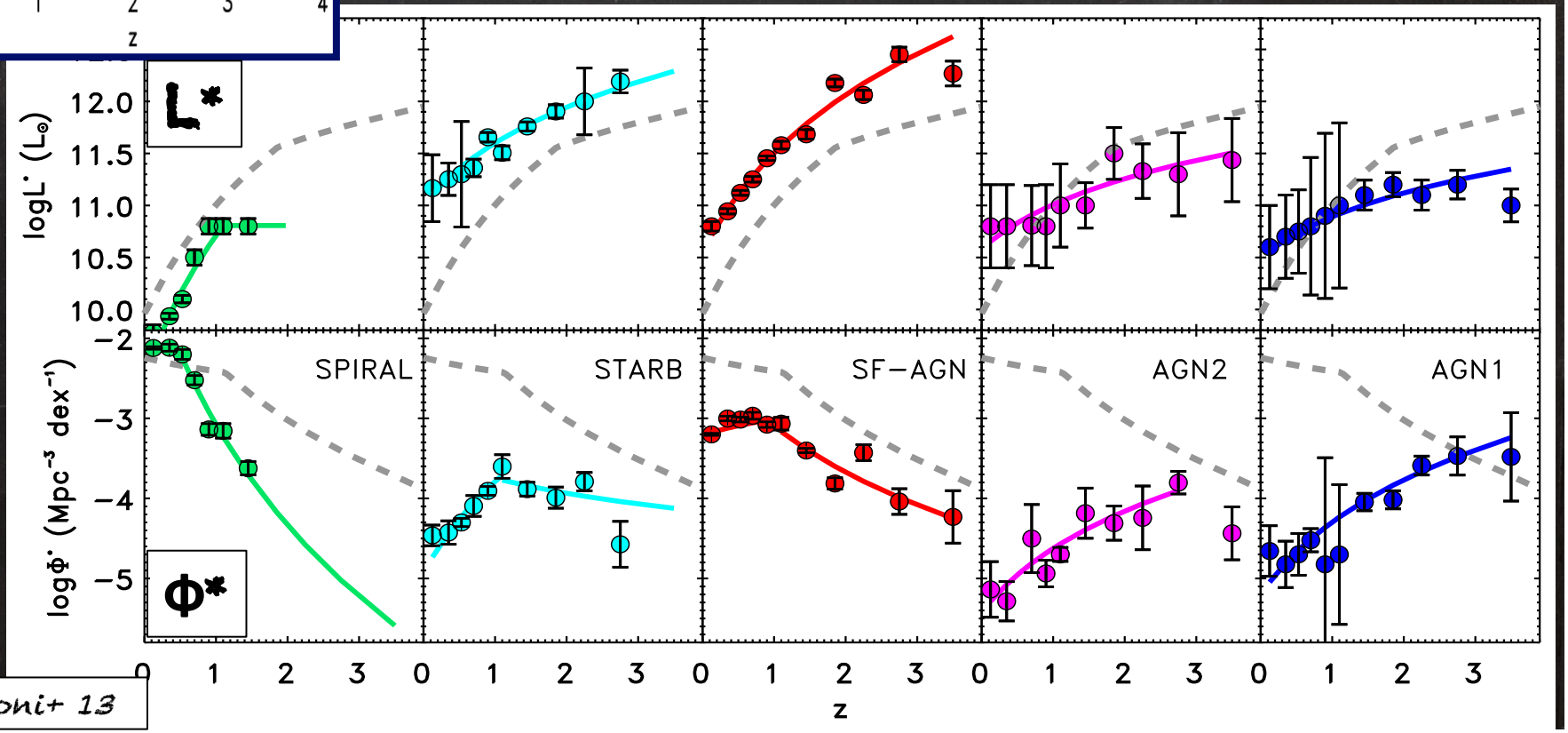
Gruppioni+ 13



GLOBAL EVOLUTION

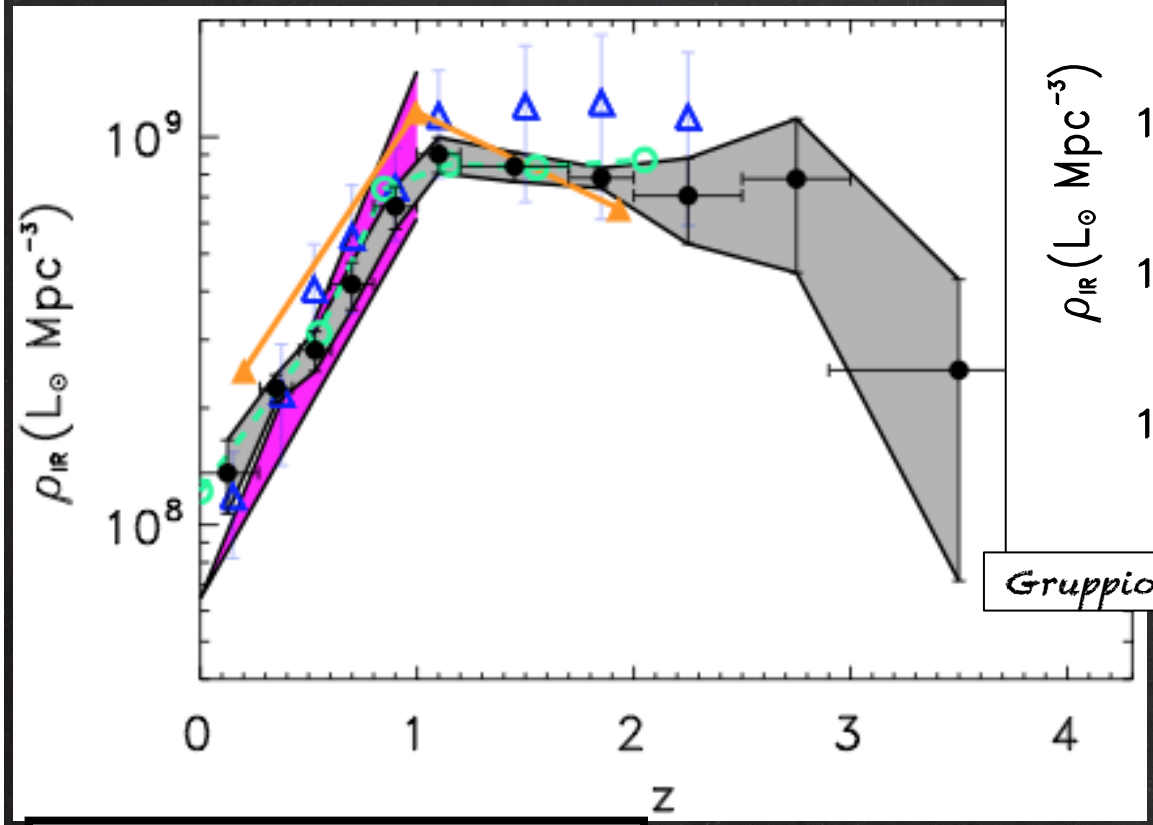
Evolution of the total IR Luminosity Function in terms of L* (luminosity) and Φ* (density) evolution with z

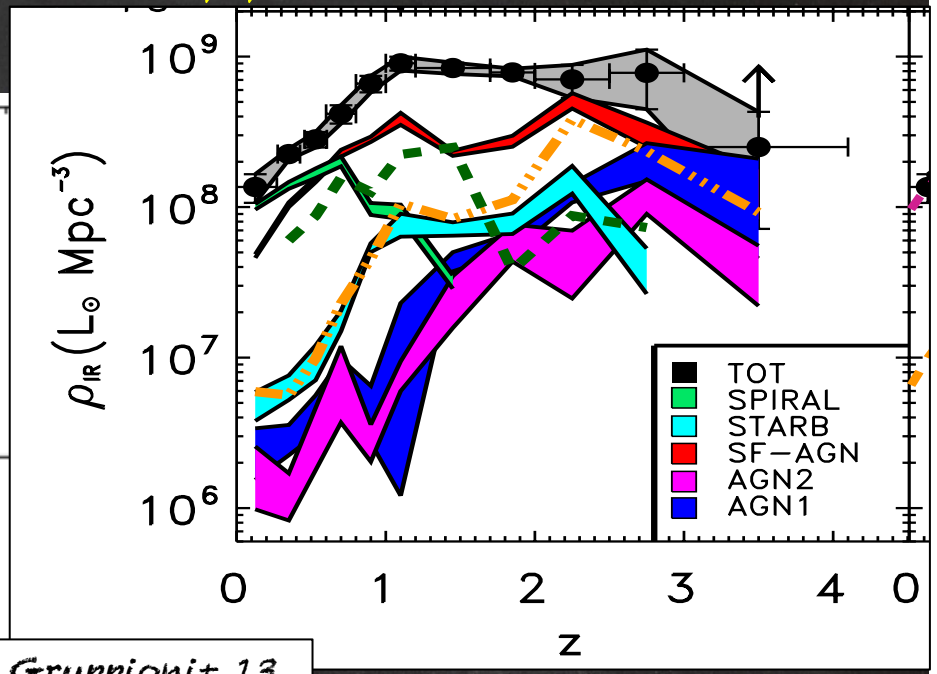
EVOLUTION OF DIFFERENT SED-TYPES



Gruppioni+ 13

The Total IR Luminosity Density ρ_{IR}: contribution from different SEDs





Gruppioni+ 13

Herschel (Gruppioni+13)
Spitzer (Le Floc'h+ 05)
Spitzer (Caputi+ 07)
Spitzer (Magnelli+ 11)
Spitzer (Rodighiero+ 11)

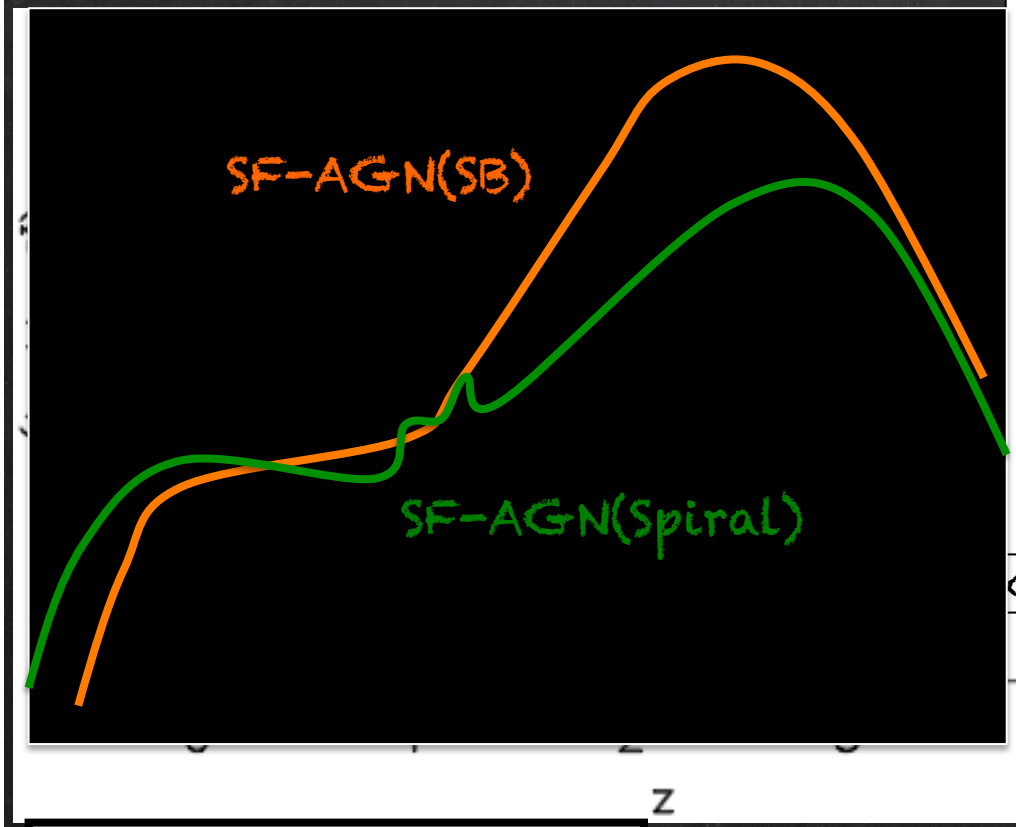
SF-AGN dominate ρ_{IR} at $1 < z < 3$

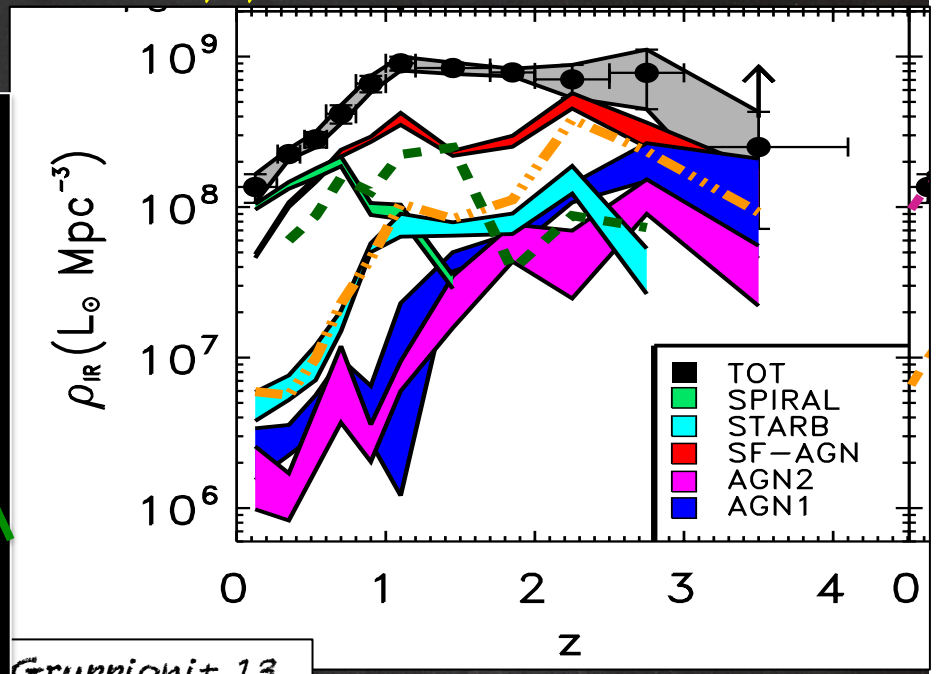
BUT two types of SF-AGN

SF-AGN(Spiral)

SF-AGN(SB)

The Total IR Luminosity Density ρ_{IR}: contribution from different SEDs





Gruppioni+ 13

Herschel (Gruppioni+13)
Spitzer (Le Floc'h+ 05)
Spitzer (Caputi+ 07)
Spitzer (Magnelli+ 11)
Spitzer (Rodighiero+ 11)

SF-AGN dominate ρ_{IR} at $1 < z < 3$

BUT two types of SF-AGN

SF-AGN(Spiral)

SF-AGN(SB)

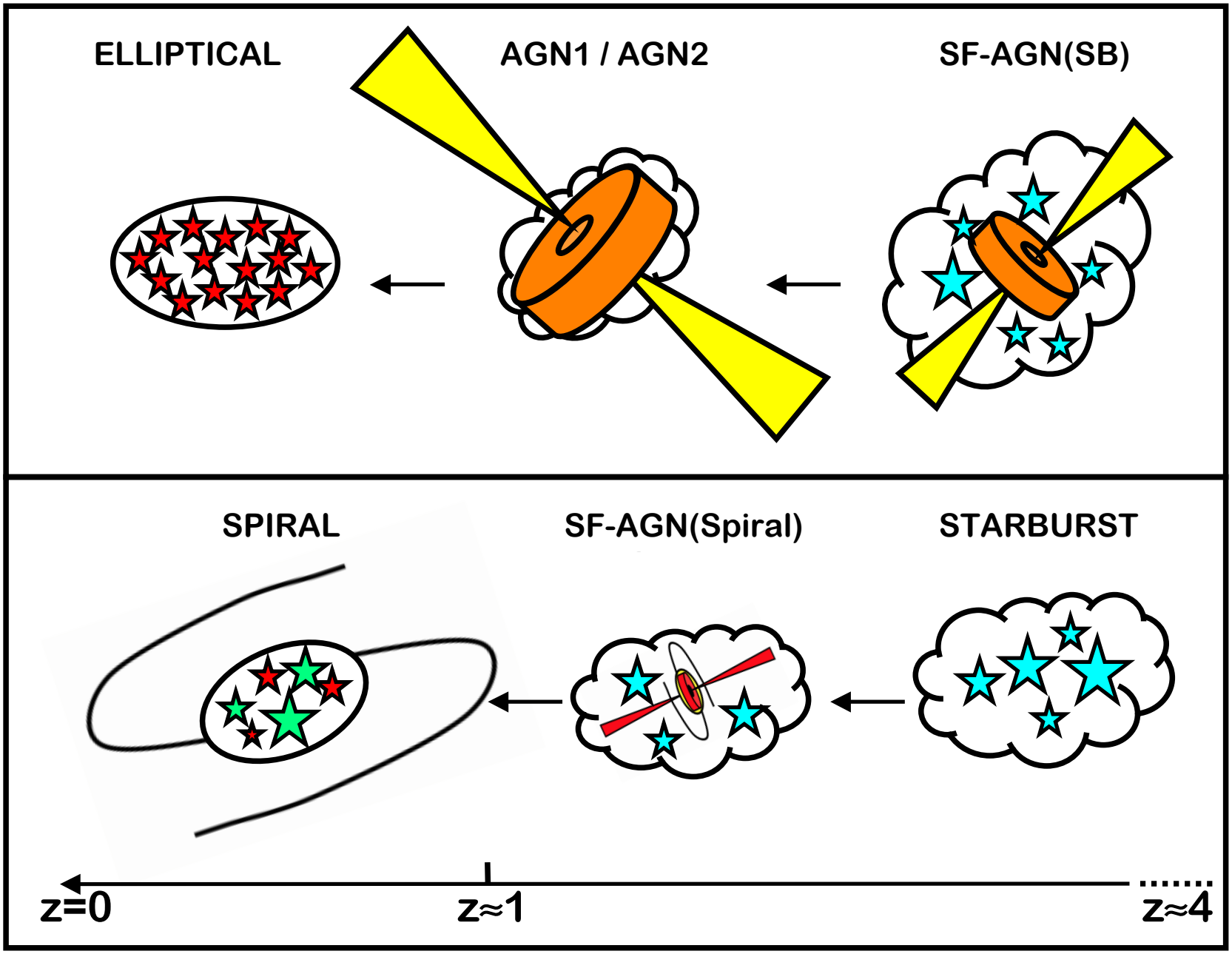
What do we learn ?

Twofold evolutionary scheme for IR gal's:

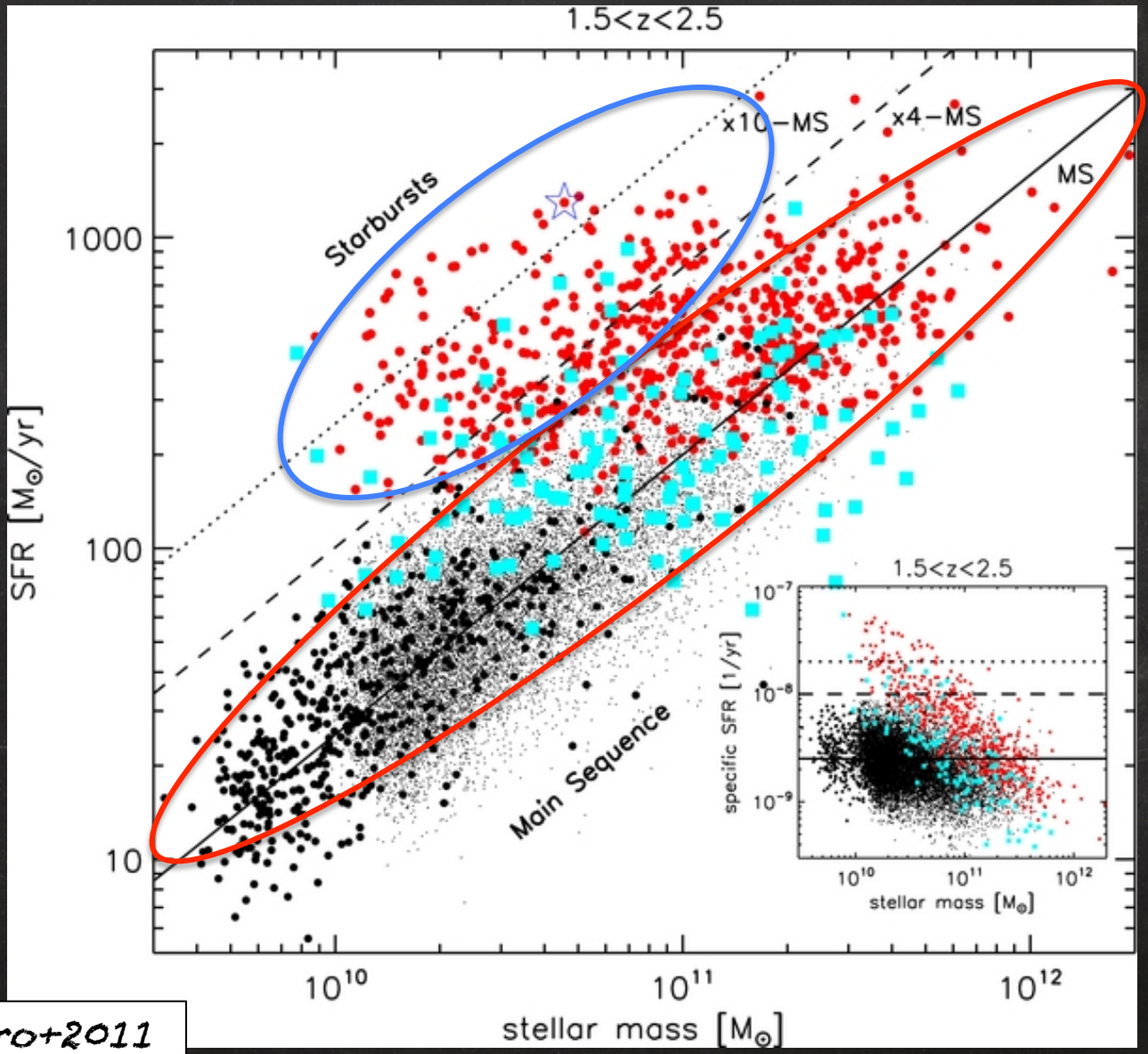
1) AGN-dominated sources detected in far-IR during an active starburst phase
➔ red spheroid?

2) low-l AGN systems: in a (long-lasting) transition phase between moderate starbursts and steady spiral galaxies.

What do we learn ?

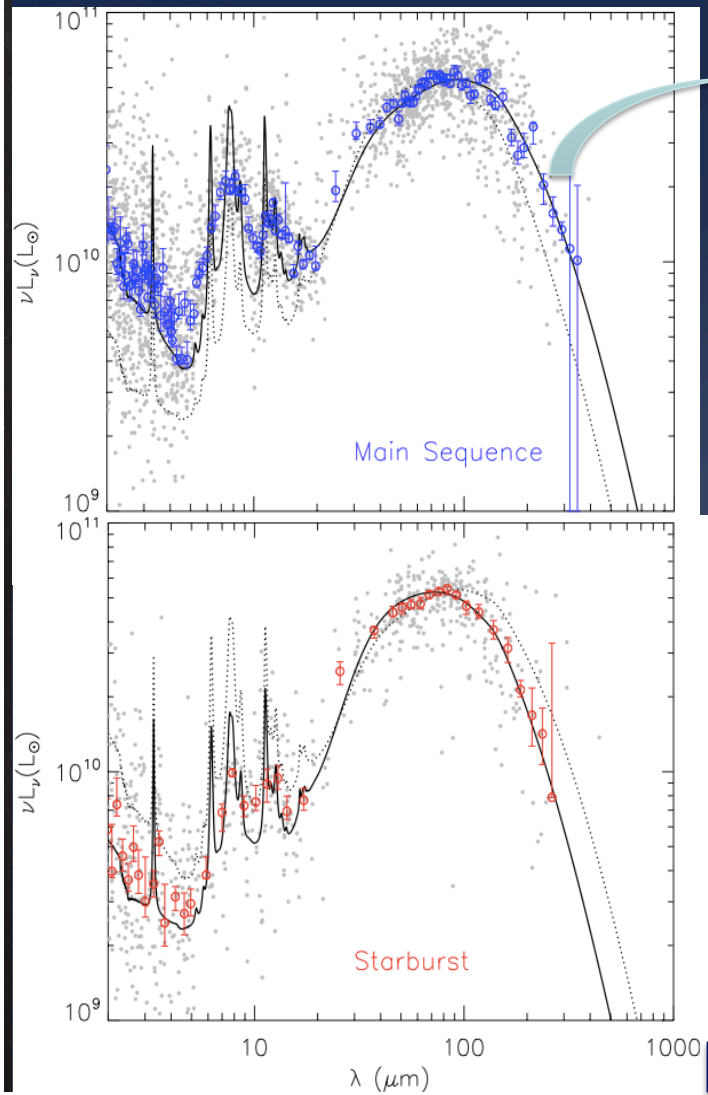


Which is the role of AGN in the SFR-M* relation?

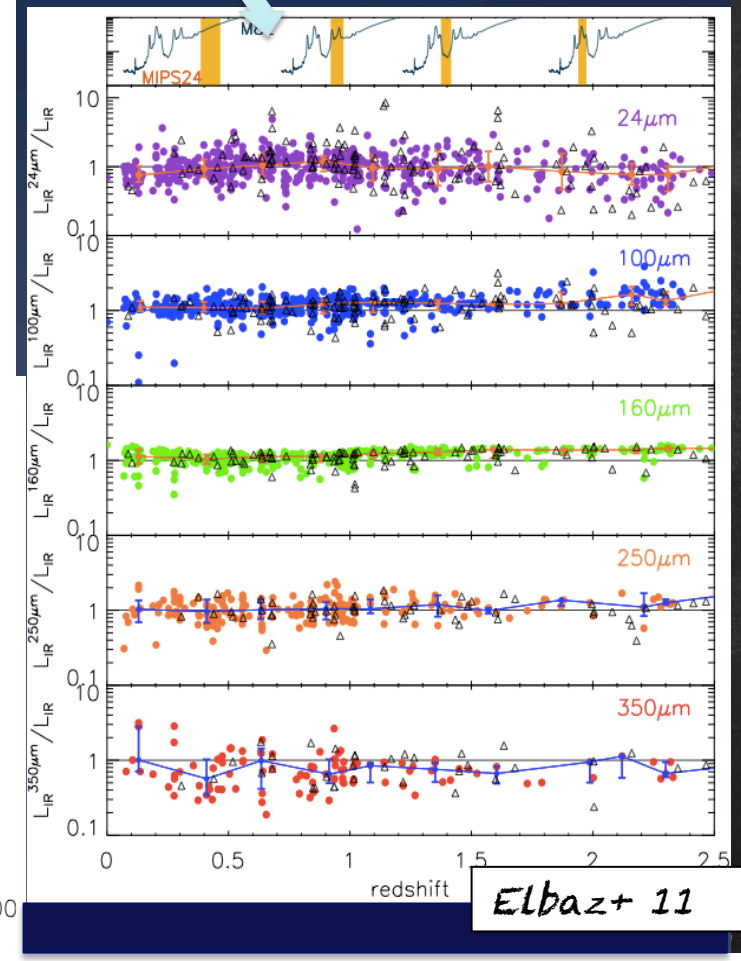


Rodighiero+2011

New Templates for MS and SB galaxies: no AGN?



Proto-typical IR SEDs of
Main Sequence & Starburst galaxies

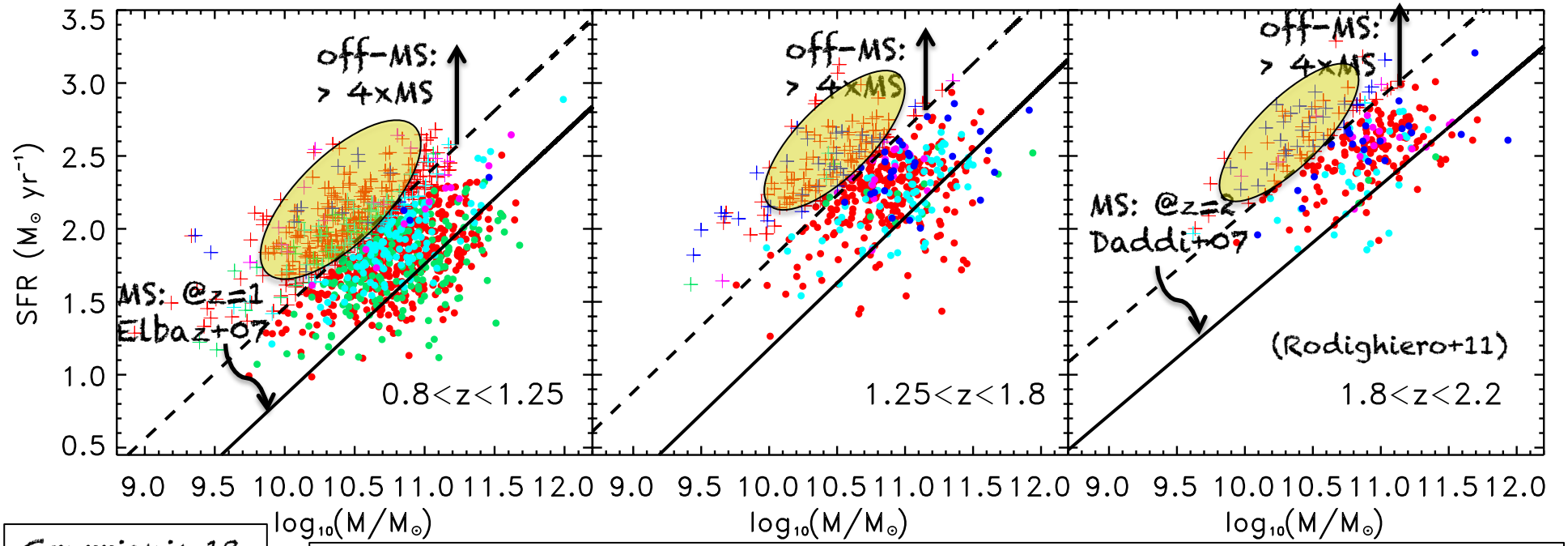


Elbaz+ 11

the mid-to-far IR emission of X-ray active galactic nuclei (AGN) is predominantly produced by star formation

Just 2 prototypical SEDs needed to reproduce all the luminosity relations

Looking at the SED-class of MS/ off-MS sources we find that ...



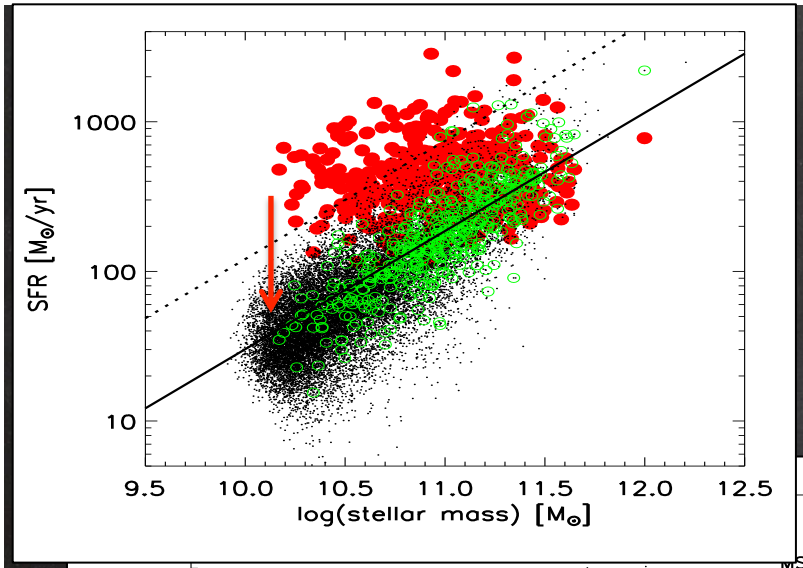
Gruppioni+ 13

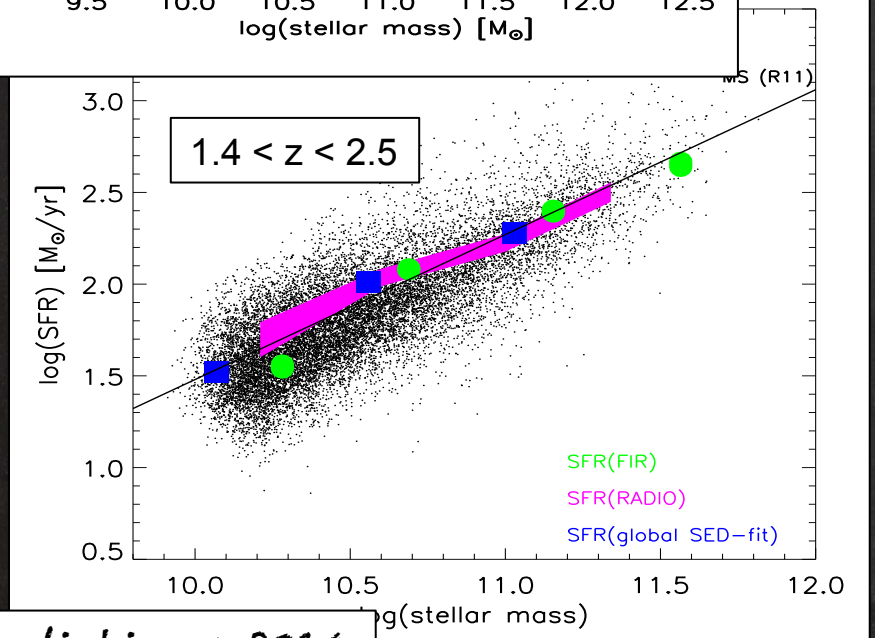
SF-AGN AGN1 AGN2

At any redshfts most of the off-MS sources (SFRs > 4 x $(SFRs)_{MS}$ at a given M*; Rodighiero+ 11) have AGN SEDs (SF-AGN or Power-Law)

High SFRs -> AGN activity -> ?positive Feedback?

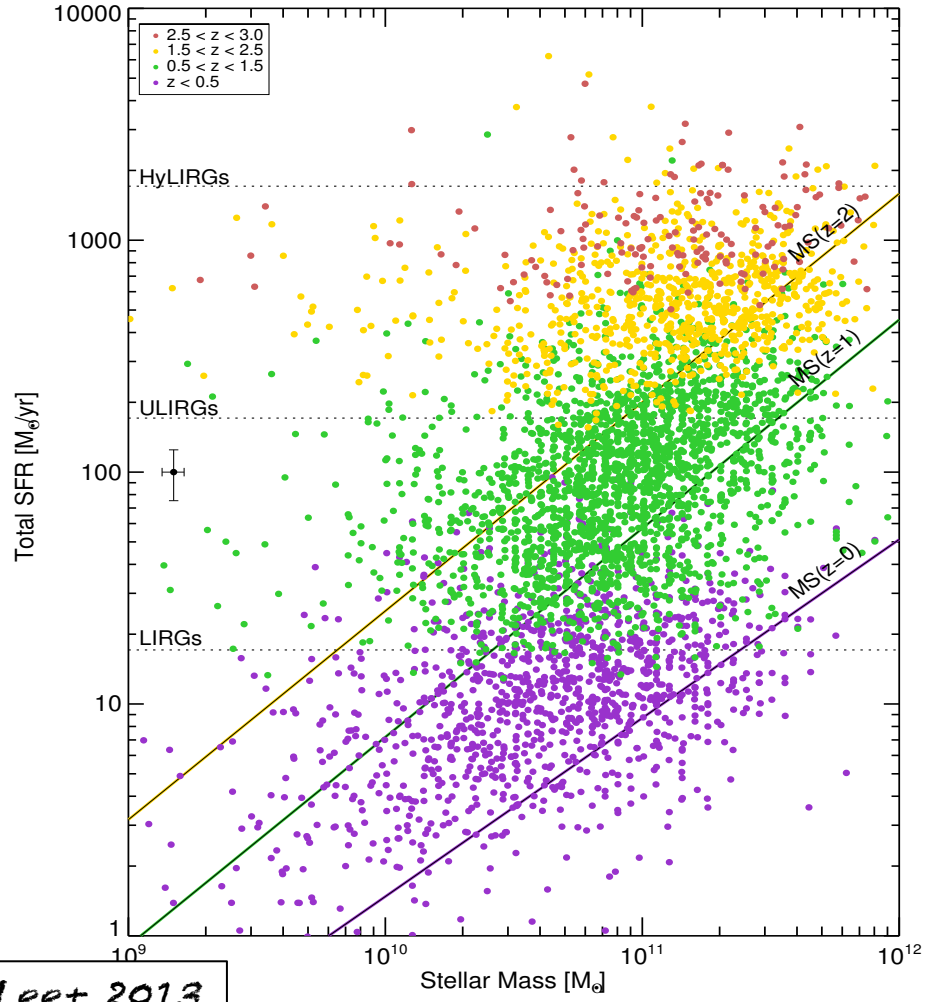
MS or not MS ?





Rodighiero+ 2014

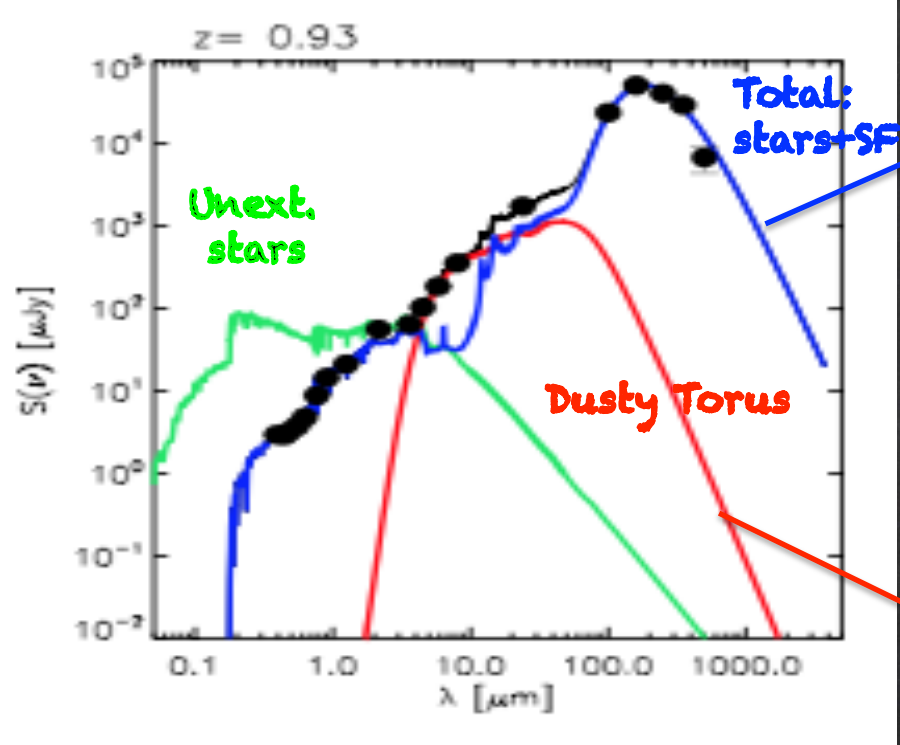
"There is overall agreement between the main sequences derived with the two SFR indicators [IR, UV], when stacking on the PACS maps the BzK-selected galaxies."

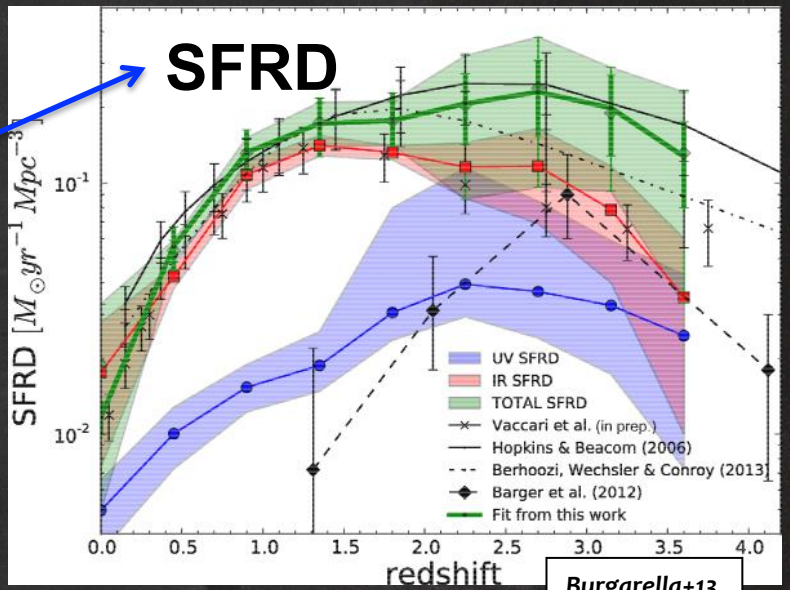


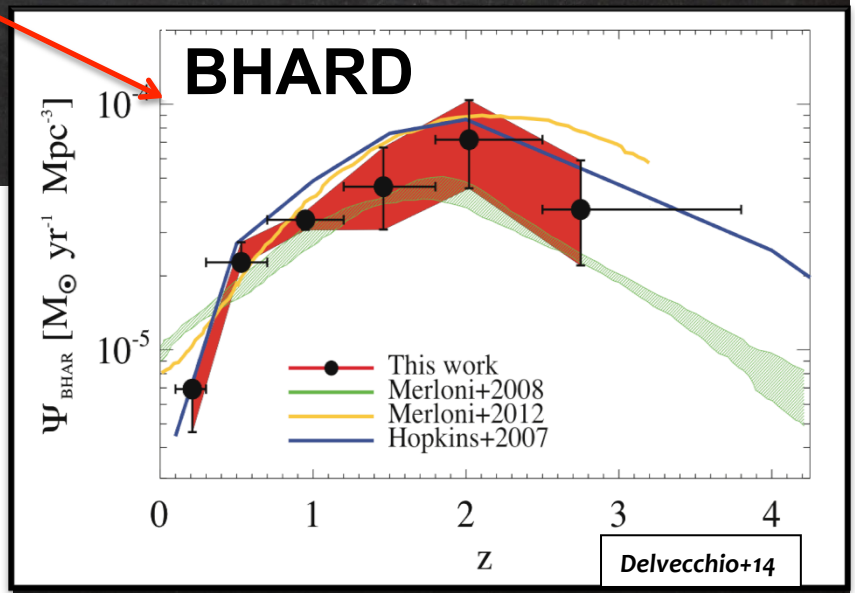
Lee+ 2013

"At all redshifts, we see no evidence that the Herschel- detected galaxies in the COSMOS field concentrate on the nominal main-sequence trends."

BHARD vs z from IR SEDs







I) Galaxy: MAGPHYS (da Cunha+08)
Energy balance

II) Torus: Fritz+ 06 (Feltre+ 13)

[implemented in MAGPHYS by Berta+ 13]

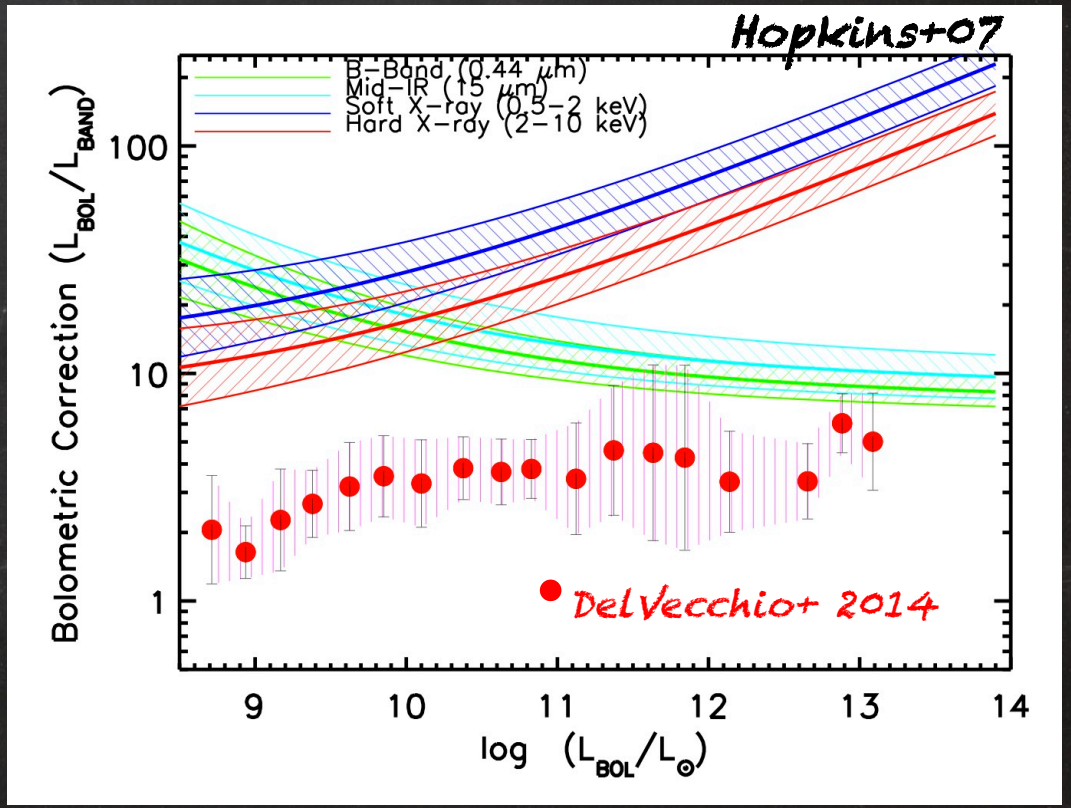
Bolometric Correction

$$K_{BOL} = \left[\frac{L_{accr,INPUT}}{L_{1-1000\,\mu m}} \right]_{BEST-FIT\,MODEL}$$

Almost 1 dex smaller than other bands

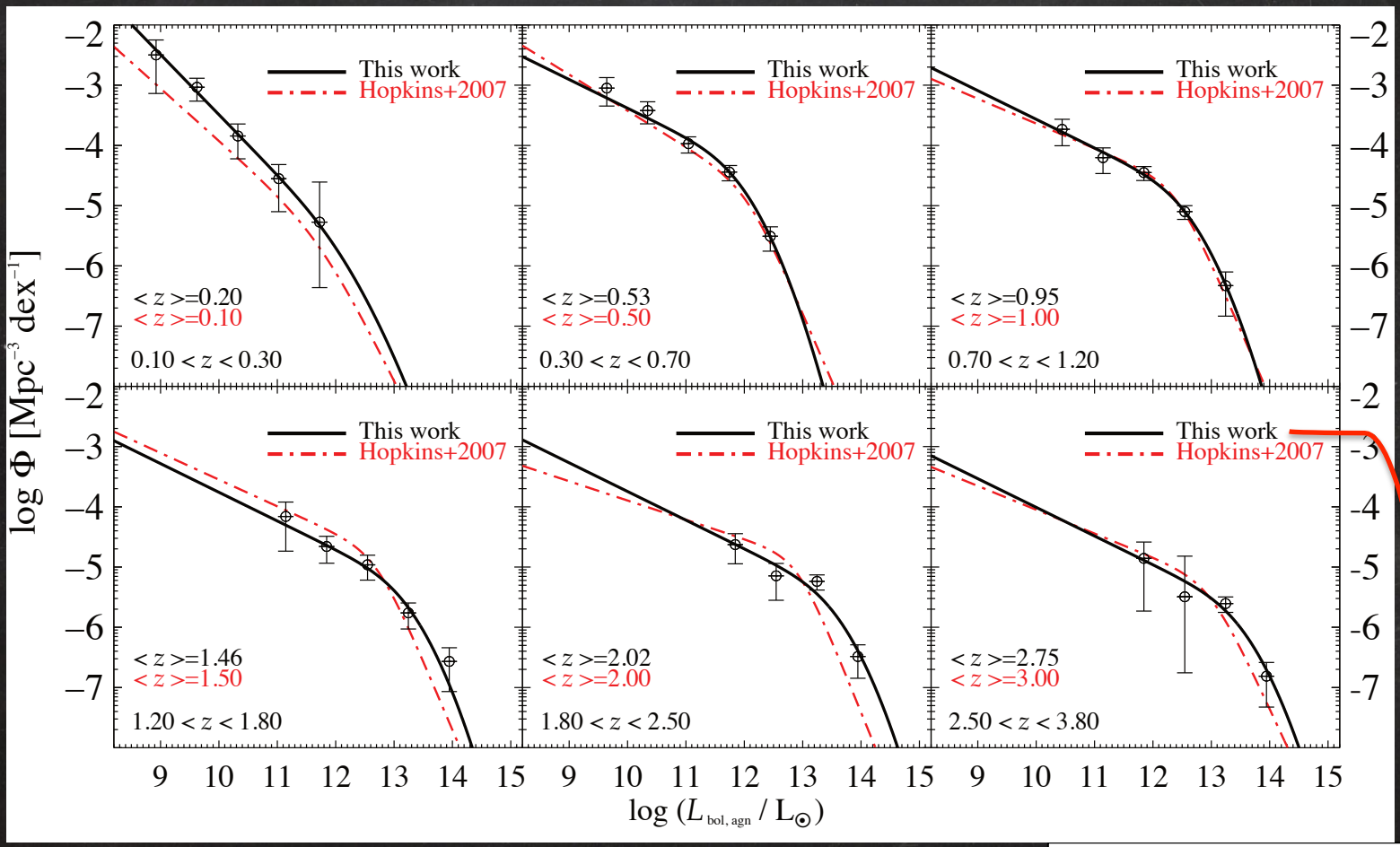
No dependence on bolometric luminosity (required by Hopkins+07 to match type I AGN LF in different bands. Mainly based on Richard+06 SED).

Weakness of IR relies on assumed torus model



BHAR LF

Agreement with Hopkins+ 07:
BUT Completely independent determination



DelVecchio+ 2014

BHAR Density

$$\Psi_{BHAR}(z) = \int_0^{\infty} \frac{(1-\varepsilon_{rad})L_{BOL,AGN}}{\varepsilon_{rad}c^2}\Phi(L_{BOL,AGN})\,d\log L_{BOL,AGN}$$

- **ASSUMPTION**

BH grows mainly by accretion

$L_{BOL} = \varepsilon\ c^2\ dM/dt$

ε = radiative efficiency

- **RESULTS**

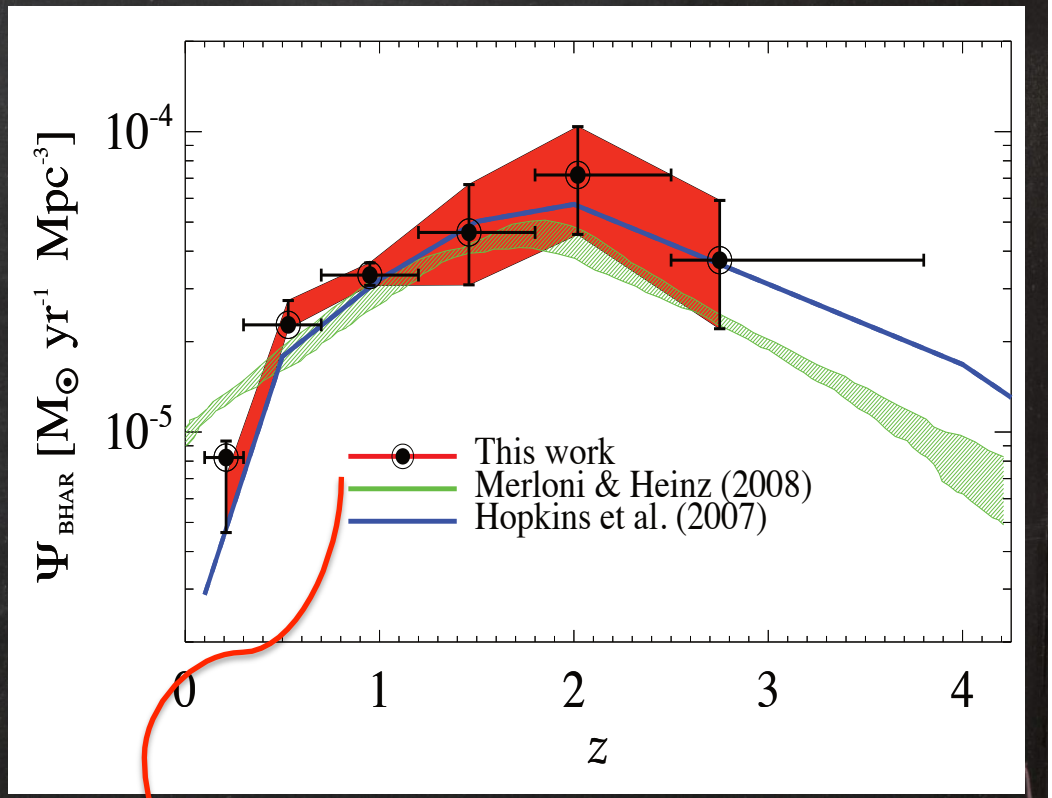
First time ψ_{BHAR} from IR

$\rho_{BH,0} = 4.2 \times 10^5\ M_\odot Mpc^{-3}$ (Shankar, 2009) → $\varepsilon = 0.08$

$0<z<3$

$\psi_{BHAR,IR} \sim \psi_{BHAR,X}$

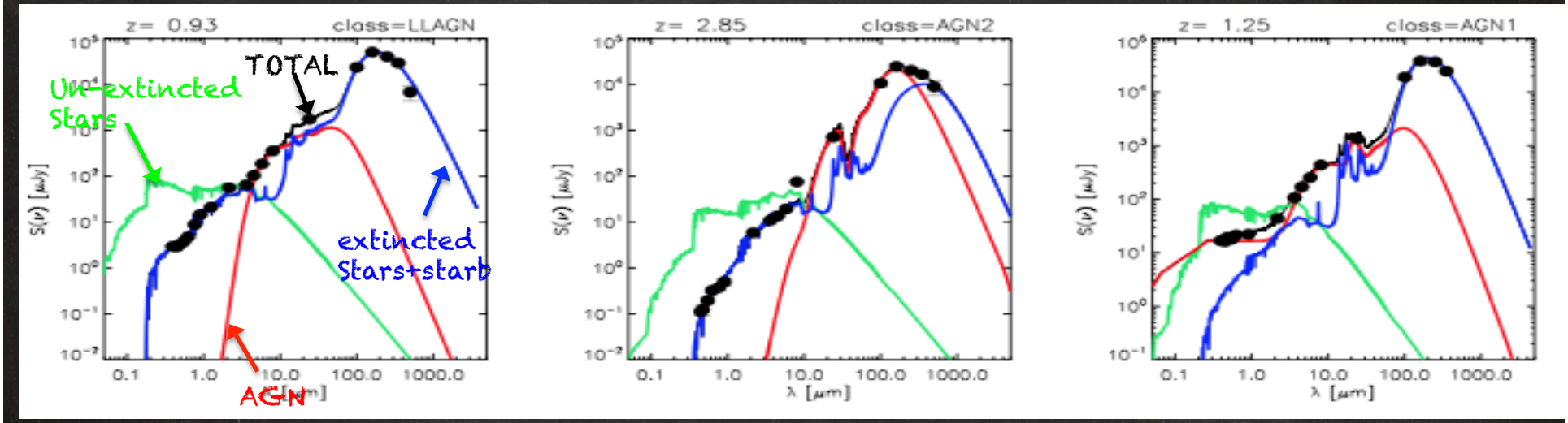
(consistent with Merloni+2012 & Hopkins+2007)



DelVecchio+ 2014

BUT: sources classified on photometric basis only (SED-fitting)

MAGPHYS + AGN
(daCunha+08 + Fritz+06 => Berta+12)



Large degeneracies in AGN models

NEED for spectroscopic classification unaffected by obscuration

Main Herschel Results on SEDs

- Distant (U)LIRGs are NOT analogs of Local (U)LIRGs
- Mergers are not critical and starbursts are not primary in the high-z Universe
- Higher SFR sources have SEDs showing the presence of AGN
- Most AGN reside in normal galaxies
- Far-IR SEDs of AGN dominated by SF
- Be careful in conclusions on SFRs w/o far-IR


Thank You !