Infrared Surveys: Spitzer

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Talk outline

Why IR?

Cosmic IR Background

Astrophysical processes & sources

IR satellites

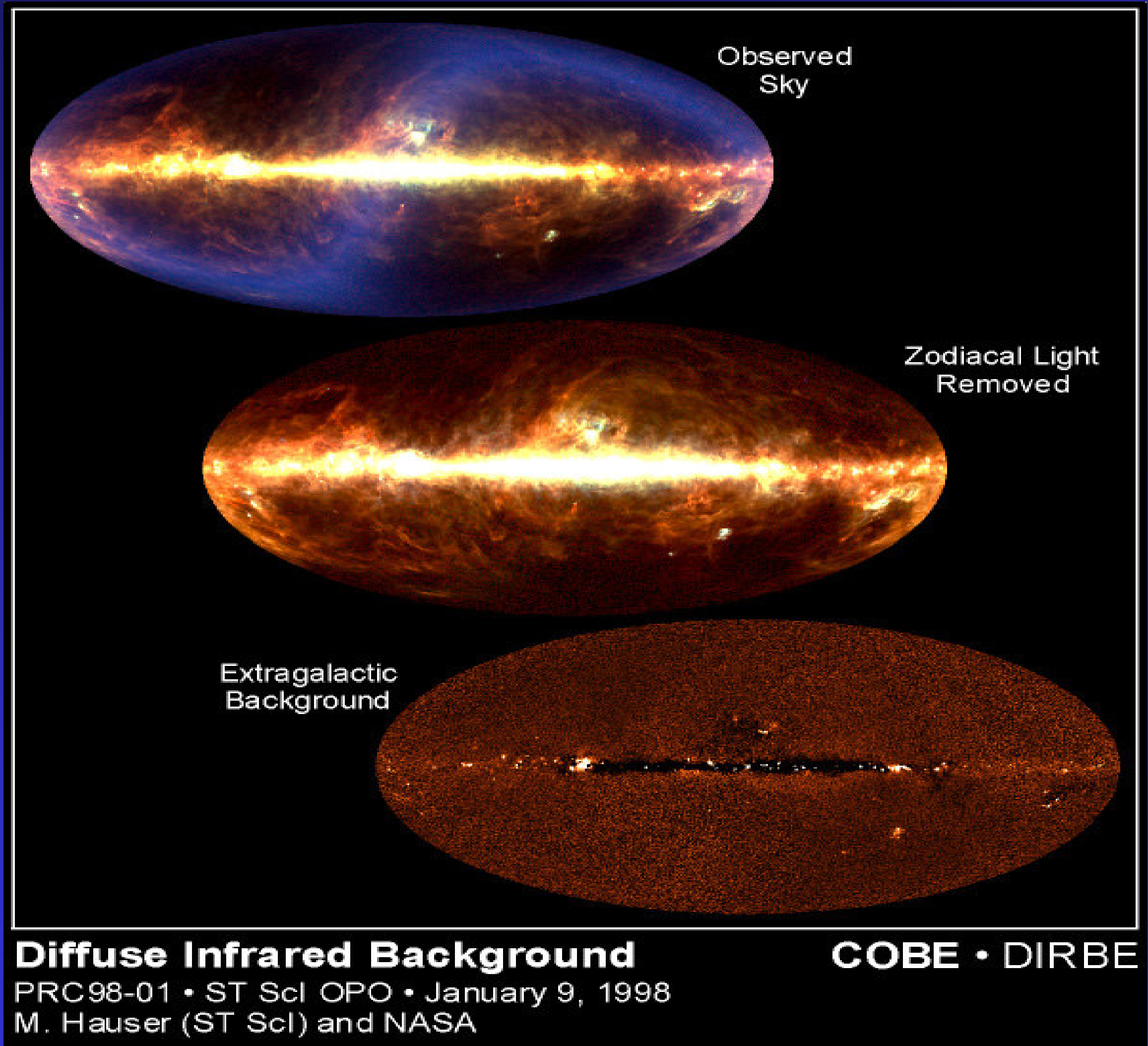
Spitzer Surveys & Results:

Nature of sources emitting in the IR surveys

Modelling the Galaxy/AGN evolution in the IR

Open issues

Background IR pre-Spitzer



COBE - 240 μm

Hauser & Dwek 1998

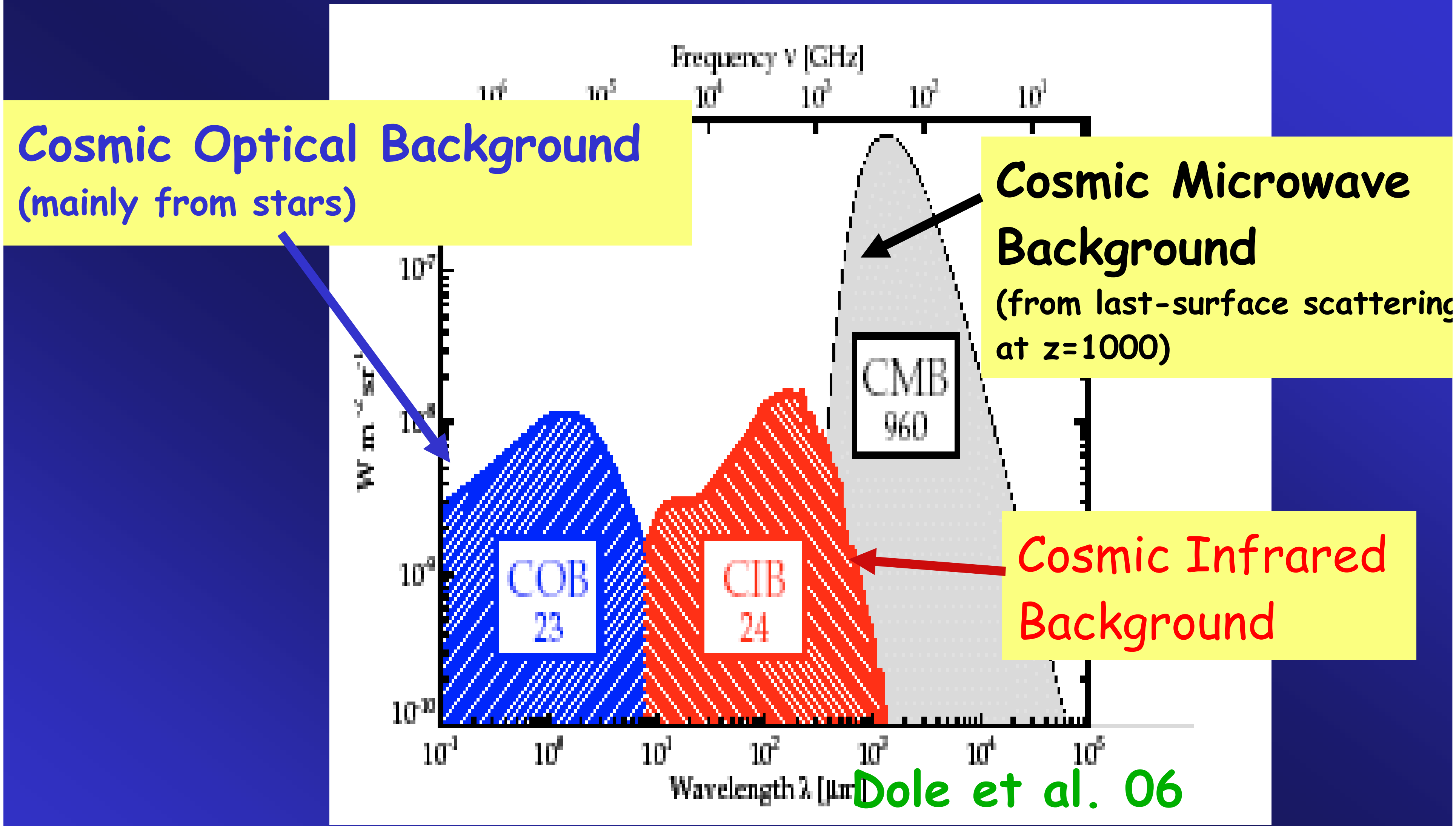
After removing foreground emission

Zodiacal light +

our galaxy

⇩

Intense extragalactic IR background



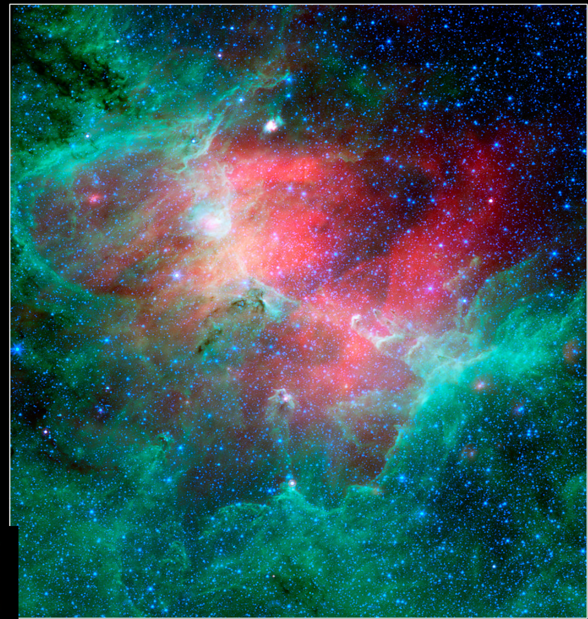
- CMB dominates
- IR background ~Opticial background
- Origin of the IR cosmic background ??

Extragalactic sources associated to IR emission

Galaxy→ Nucleosynthesis

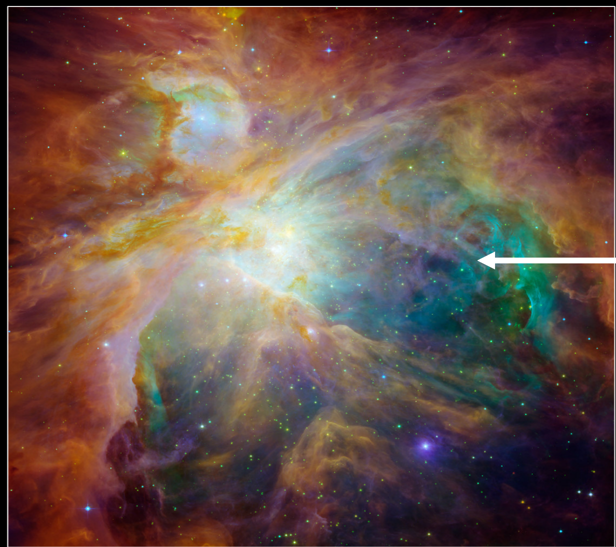
Dust in envelopes surronding starforming regions.

UV/Optical photons produces by stars



ared Eagle Nebula (M16) Spitzer Space Telescope • IRAC • MIPS

A / JPL-Caltech / N. Flagey (IAS/SSC) & the MIPSGAL Science Team ssc2007-01a



The Orion Nebula Spitzer Space Telescope • IRAC

Hubble Space Telescope • ACS • WFI

← Cavities (stellar winds)

Red: 8 μm

Orange: 3.6 μm

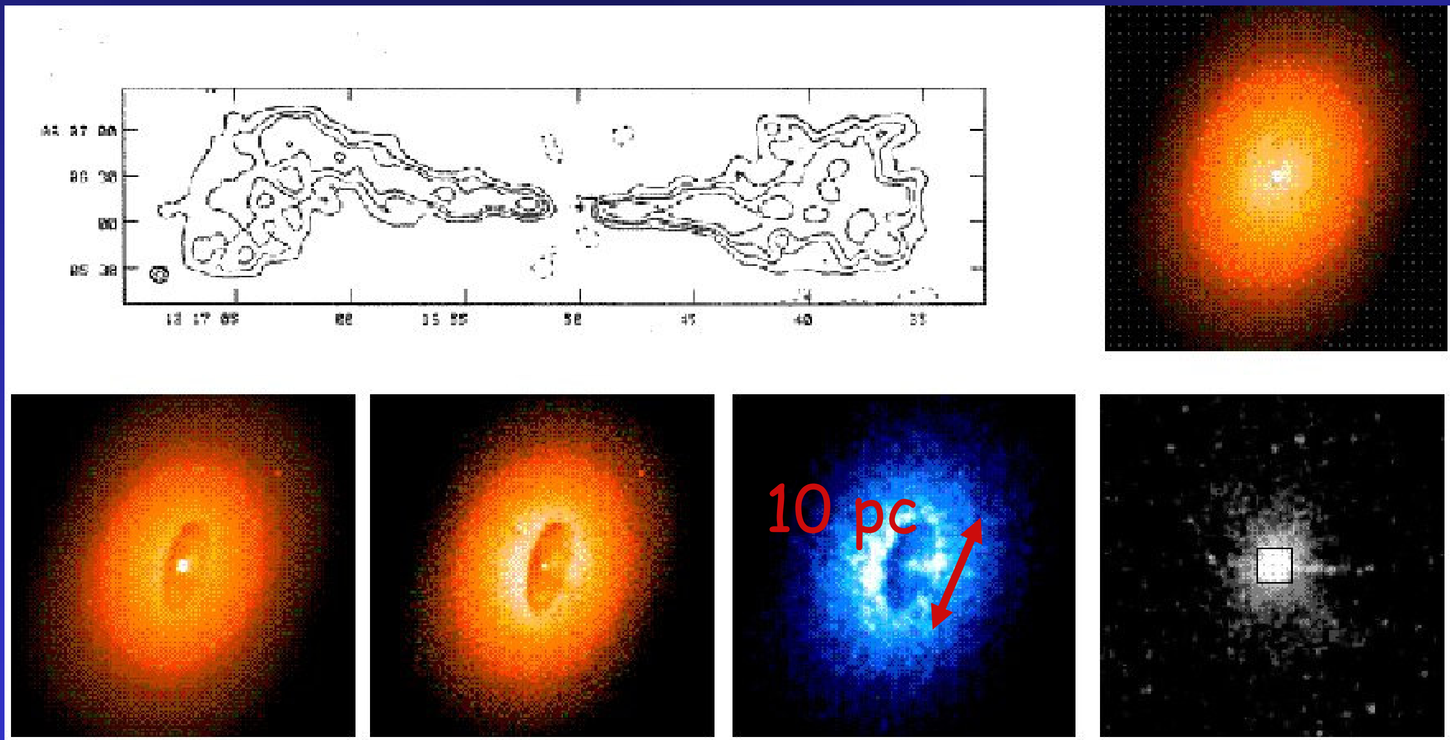
B/V: blue-green

AGN: Accretion around black holes

Dust in envelopes (tori?) around central black holes.

UV/Optical photons produced by accretion disks.

3C270
Chiaberge et al. 03



1.6μm

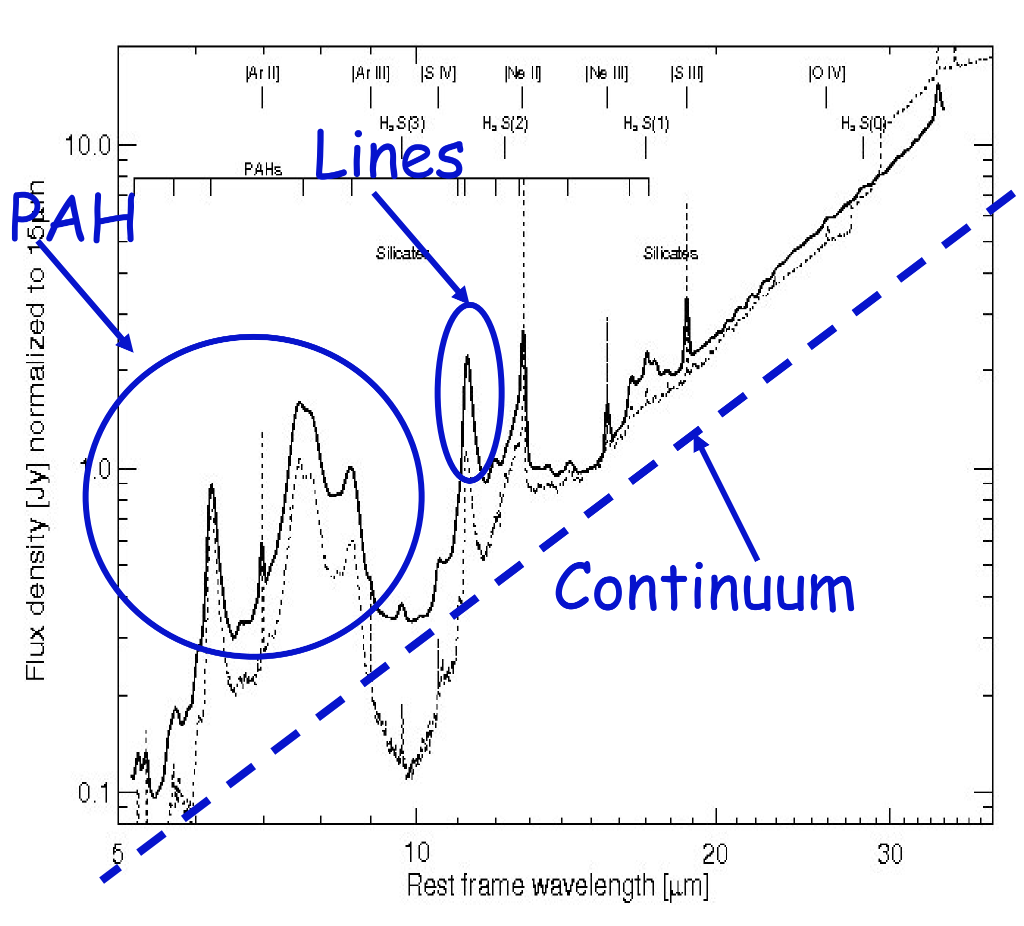
6700 5500 2300 (UV) X-ray

Typical IR spectra

Continuum: Thermal emission (grey body) from dust grain (~ 0.01 μm) heated by UV/Optical photon $B(\nu) \sim (1-e^{-\tau})B(\nu)_{plank}$ τ: optical depth

Broad band emission:
Polycyclic aromatic hydrocarbons (PAH) excited by UV/Optical photons (MIR).
6.2, 7.7, 8.6, 11.3 μm

Forbidden lines of ionized gas: NeII (12.8μm), SIV (10.5 μm)...
Some need high photon energy, presumably associated to AGN.



Exploring the IR (8-1000 μm) Universe:

From space to avoid absorption from atmosheric gasses

IRAS satellite (1983)
ISO satellite (1996)
Spitzer satellite (2003- 2009)

IRAS Satellite (z<0.2)

- Explore the local Universe

- 30% of the energetic output in IR from galaxies emerges in these bands.

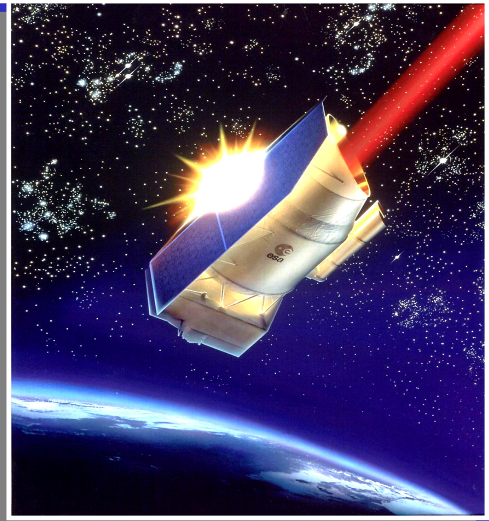
- New galaxies class: galaxies forming stars at > 20 $M_{\odot}$/yr radiate the bulk of their luminosity above 5 μm:

LIGs: $11 \leq \log(L_{IR}/L_{\odot}) < 12$
ULIGs: $12 \leq \log(L_{IR}/L_{\odot}) < 13$
HyLIGs: $13 \leq \log(L_{IR}/L_{\odot}) < 14$

→Were LIGs/ULIGs more numerous in the past? Are distant LIGs/ULIGs similar to local ones? What do they teach us about star- and galaxy-formation connections?

ISO Satellite($z \leq 1.5$)

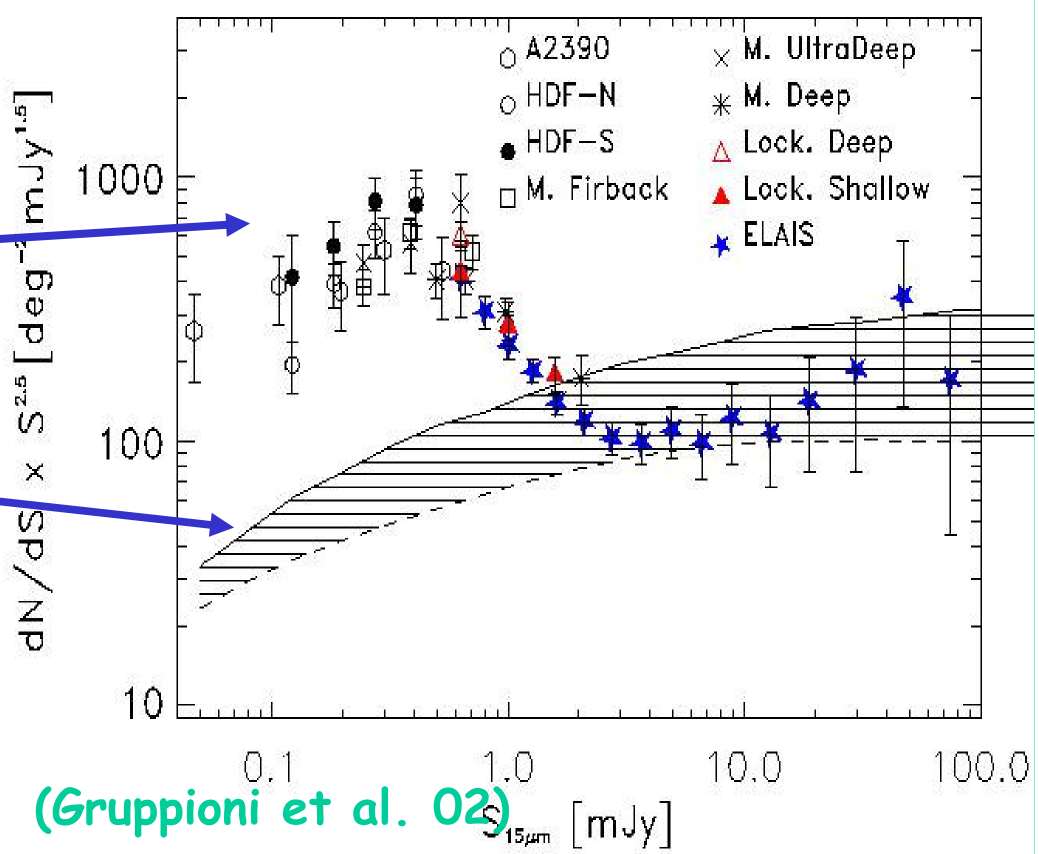
Explore distant Universe ($z<1.5$) thanks 1000 times better sensitivity than IRAS (especially in the *LW3* ISOCAM filter: 12 - 18 μm).**Open a new cosmological window**



↓Surveys at different depths & area

Strong excess of faint galaxies with respect **non evolution predictions**

➔ galaxies were **more numerous** e/o **more luminous** in the past



(Gruppioni et al. 02)

To understand IRAS/ISO/Spitzer counts

On the observational side

Identified IR sources by multi-band follow + z determination (z, nature, luminosities)

On the model side

Backward evolutionary model to reproduce the sources counts, z-distribution, luminosity function

i.e. Devriendt & Guiderdoni '00; Dole et al. '00; Chary & Elbaz '01; Pearson '01, '05; Franceschini et al. '01, '03, 08; Xu et al. '01, '03; Rowan-Robinson '03, '08; Lagache, Dole & Puget '03; Pozzi et al. '04; Gruppioni et al. '05

Observations….

➔ **Most are star-forming galaxies**, often showing irregular/merging morphologies see review Elbaz et al. 04, Oliver & Pozzi 04

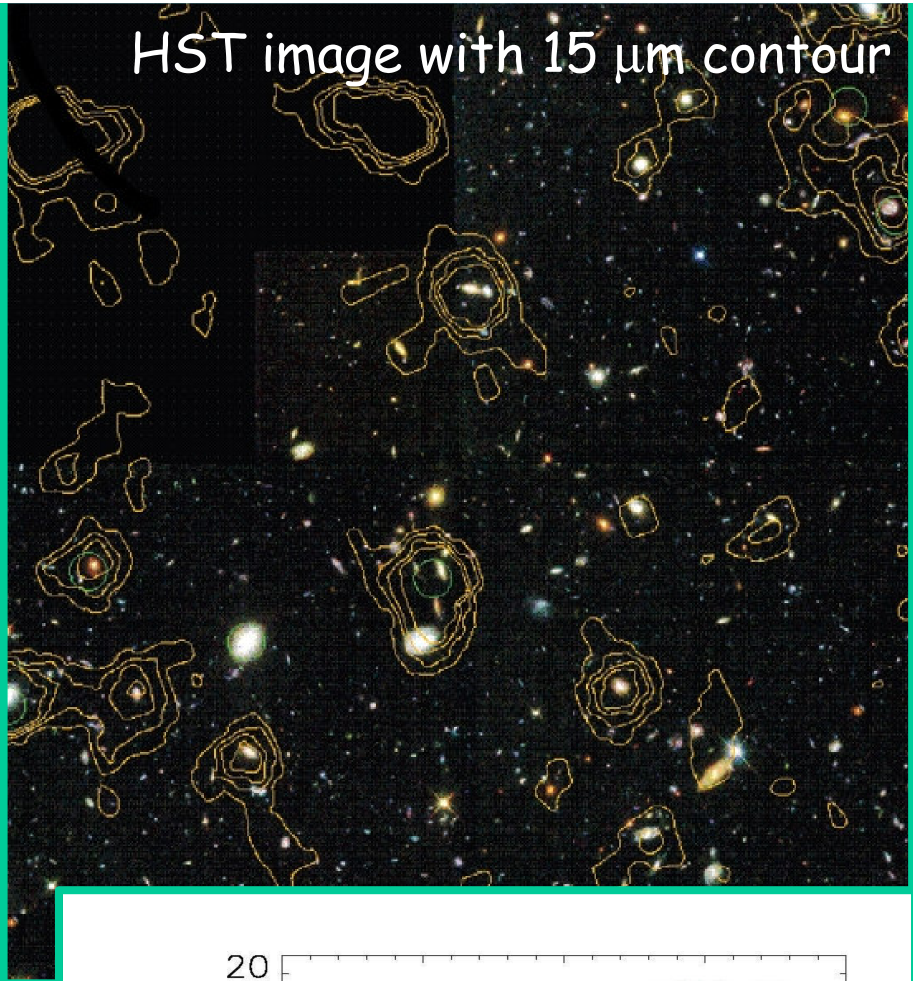
➔ $\langle L_{15} \rangle \sim 10^{10-11} L_\odot$, $\langle z \rangle \approx 0.8$ LIGs !!! (deep surveys)

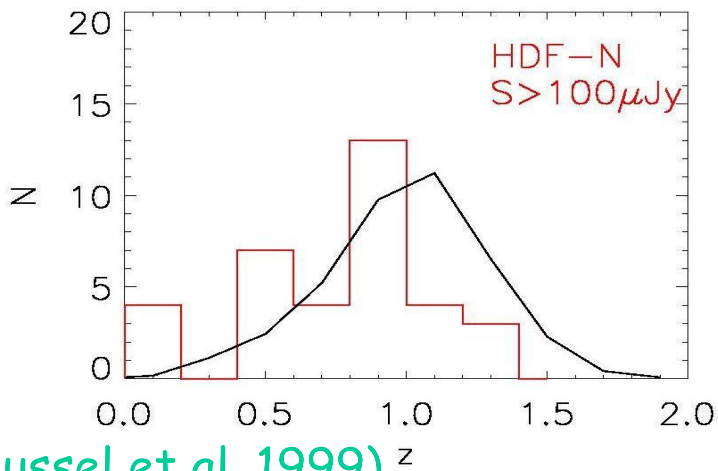
➔ AGN <15-20% *(Fadda et al. 02, La Franca et al. 04) from optical spectroscopy*

LIG is an important phase in galaxy life: a galaxy might experience several bursts of intense SF.

Comoving IR luminosity due to LIGs ~ 70 times larger at z~1 than today

HST image with 15 μm contour



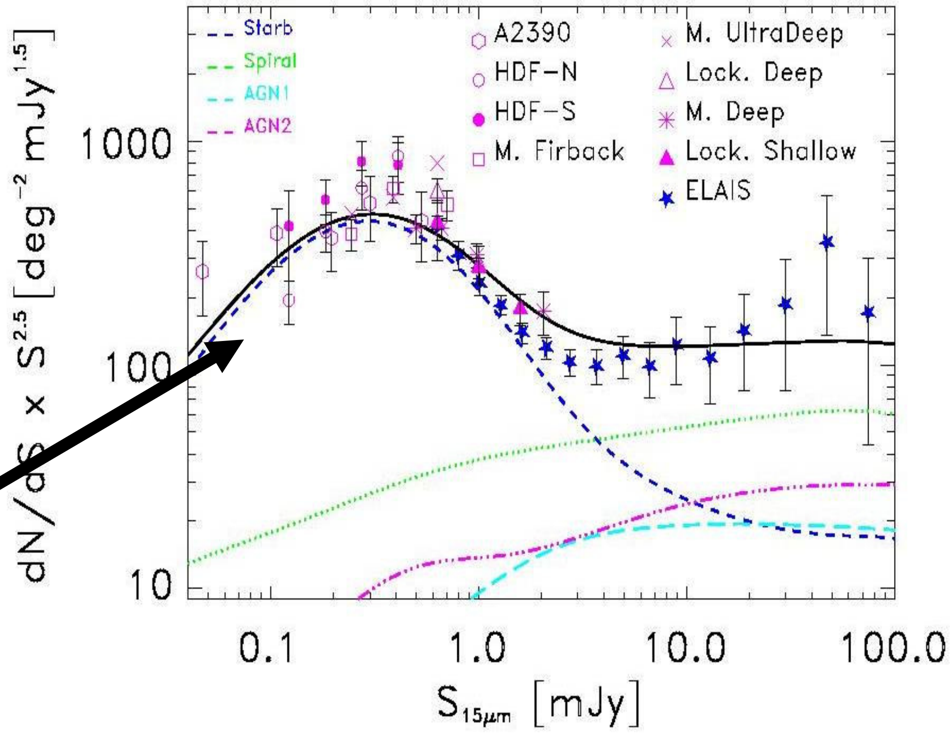


(Aussel et al. 1999)

Backward models:

•Reproduce the observables (counts, z-distirbution, nature) **evolving a set of parametric local luminosity functions** $\Phi(L,z=0)$

•Search for the best-fitting parameters of Φ and the evolution **using Maximum-likelihood Method** *(e.g. Marshall et al. 198*
minimize the function
$S = -2 \sum^{N}_{i=1} \ln \Phi(z_i,L_i)$
$+2\int\int (z,L)\Omega(z,L)\Theta(z,L)(dV/dz)dz$



Pozzi, Gruppioni, Oliver et al. 04

4 Populations

1) <u>**Starburst fast evolving**</u>
$L \sim (1+z)^{3.2}$, $\rho \sim (1+z)^{3.5}$

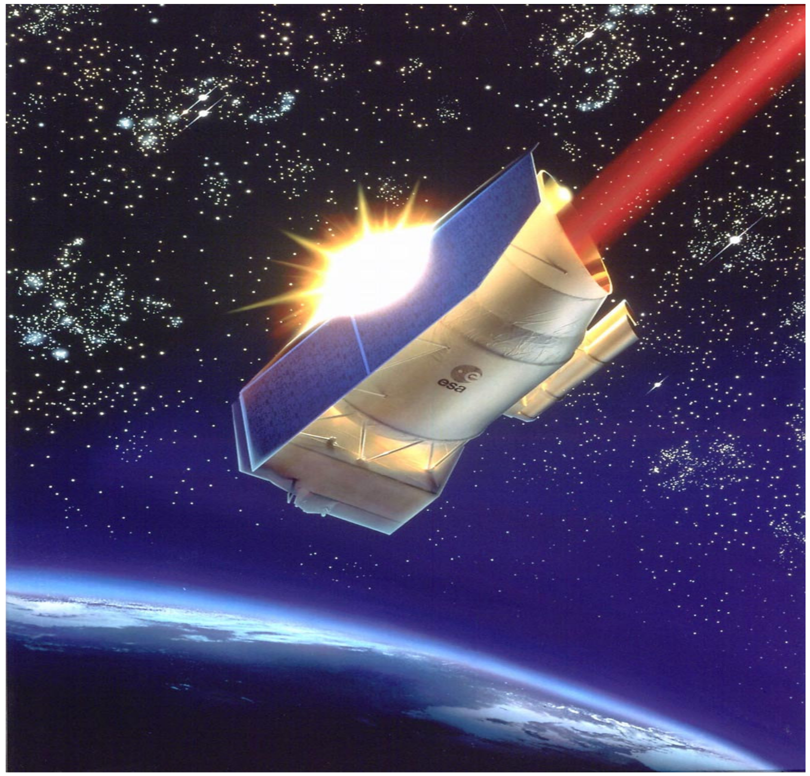
2) Spiral non evolving

3) AGN1 $L \sim (1+z)^{3}$

4) AGN2 $L \sim (1+z)^{2.5}$

From IRAS/ISO to Spitzer (2003)

Spitzer extends the Universe explored by ISO To high-z (z ≈3).



In particular,3 instruments

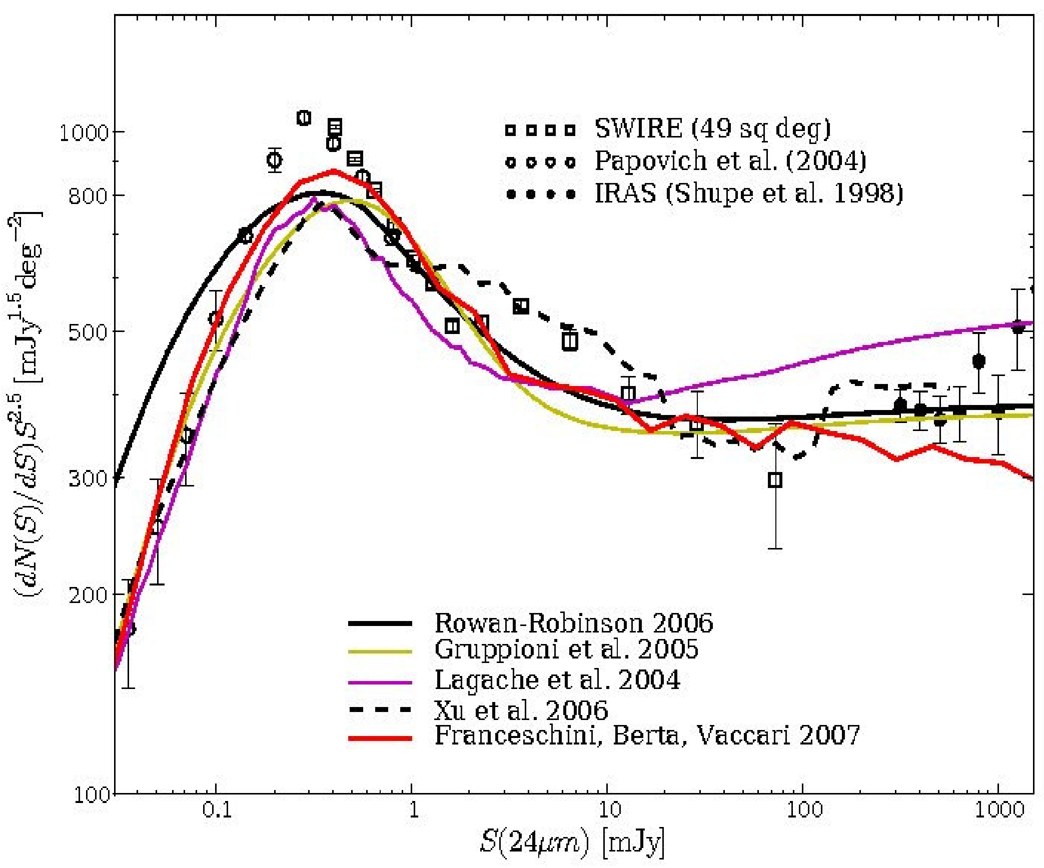
- **IRAC:3.6,4.5,5.8,8μm**
- **MIPS: 24, 70, 160μm**
- **IRS spectrometer (up to R~600)**

➔MIPS 24-μm analogs of the 15-μm sources but high-z thanks to k-correction&sensitivity)
➔IRS spectra

... What is *SPITZER* finding in terms of galaxy evolution?

Confirm the strong Evolution found by ISO.

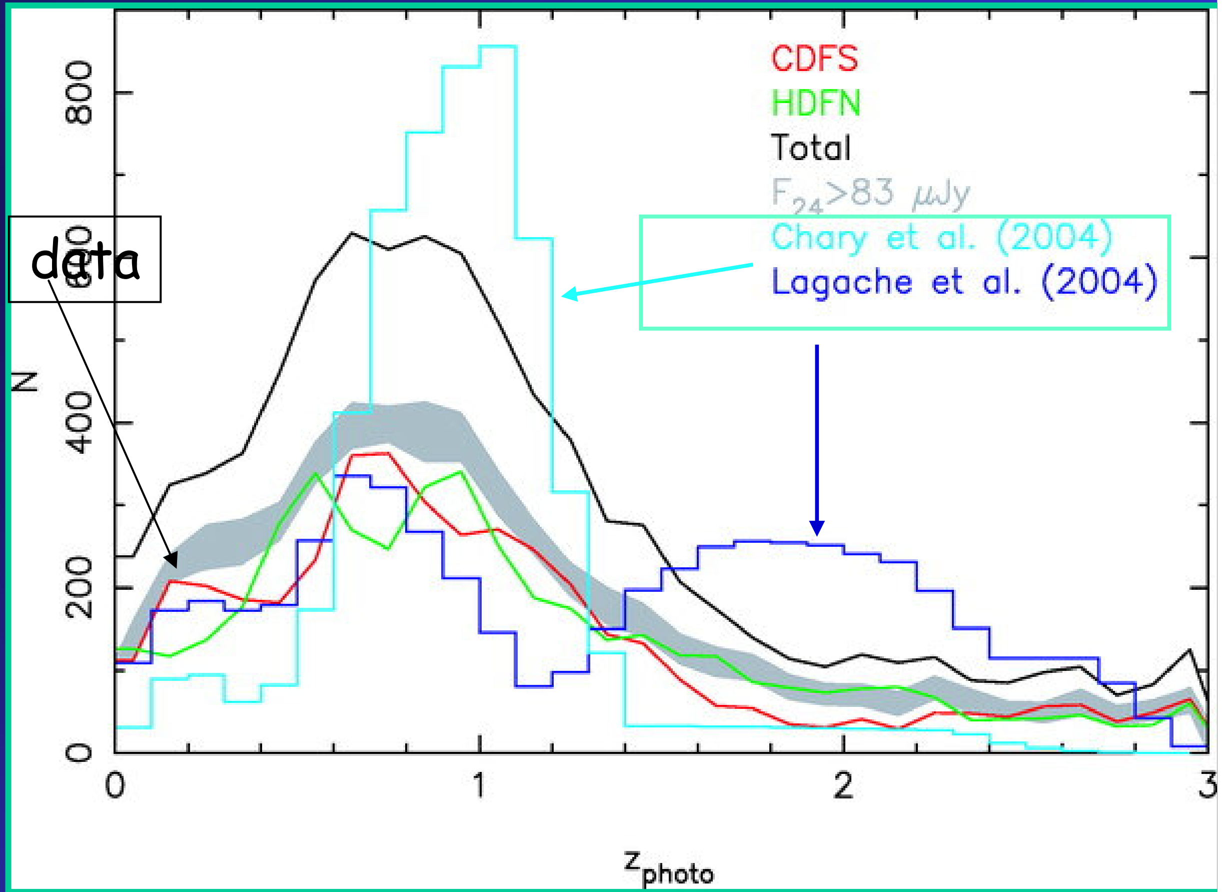
Models based on ISO able to reproduce Source counts



Shupe et al. 2008

Spitzer view galaxies from z=0 to z≈3

Models **DO NOT** reproduce z-distributions



Le Floc'h et al. 2005

Need to up-date models

Extend the library SEDs SED using new Spizer/IRS data. In particular main weakness **the role of obscured-AGN.** Obscured AGN difficult to identify by optical spectroscopy so under-estimated.

Does IR Reveal Hidden AGN Activity?

1) IRS spectroscopy

2) Complete IR SED analysis

AGN and starburst activity occur simultaneously in luminous high-z forming galaxies

➔ from 10% up to 50 % of the MIPS sources harbour an AGNs

IRS spectra

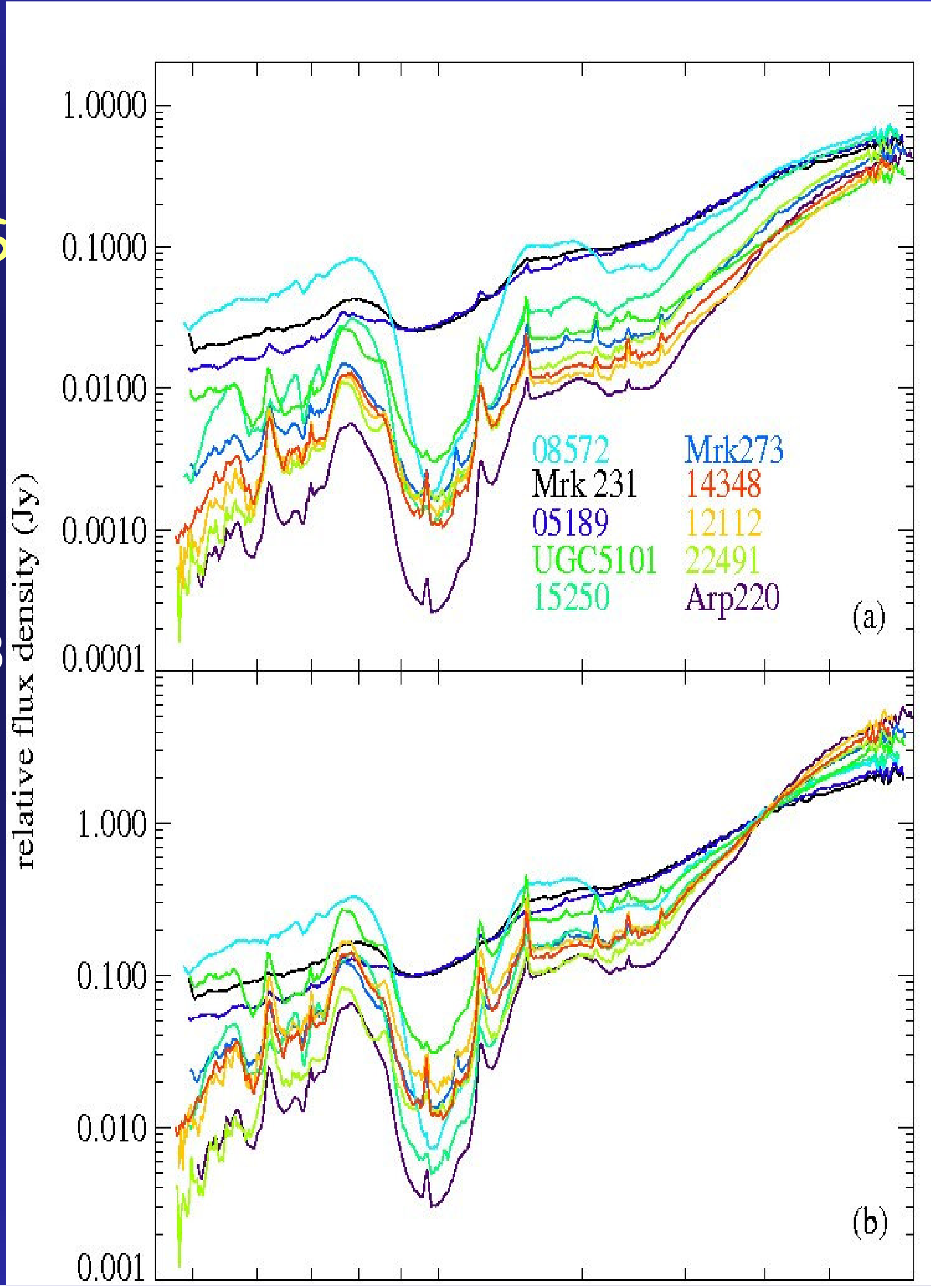
IRS spectra of 10 Local ULIGS

*No "characteristic" ULIG spectra

*From featureless to deep silicate (9.7 μm) absorption.

*NeV (14.3 μm) indicating AGN in 3 ULIGs

Armus et al. 07



New NIR/MIR diagnostic plot to separate AGN/starburst
(Spoon et al. 2007)

6.2μm PAH versus Si strength (9.7μm)

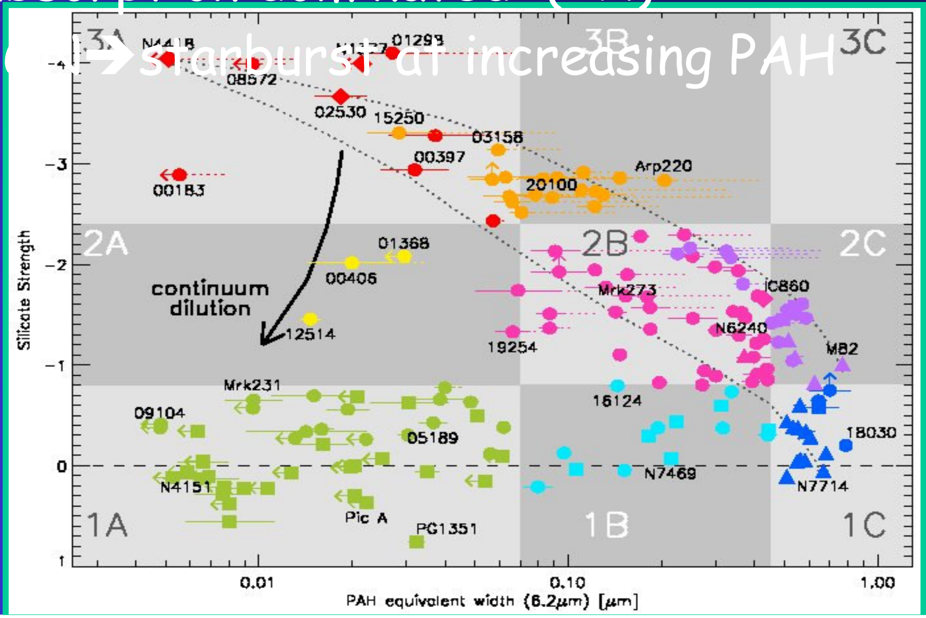
3 extremes:

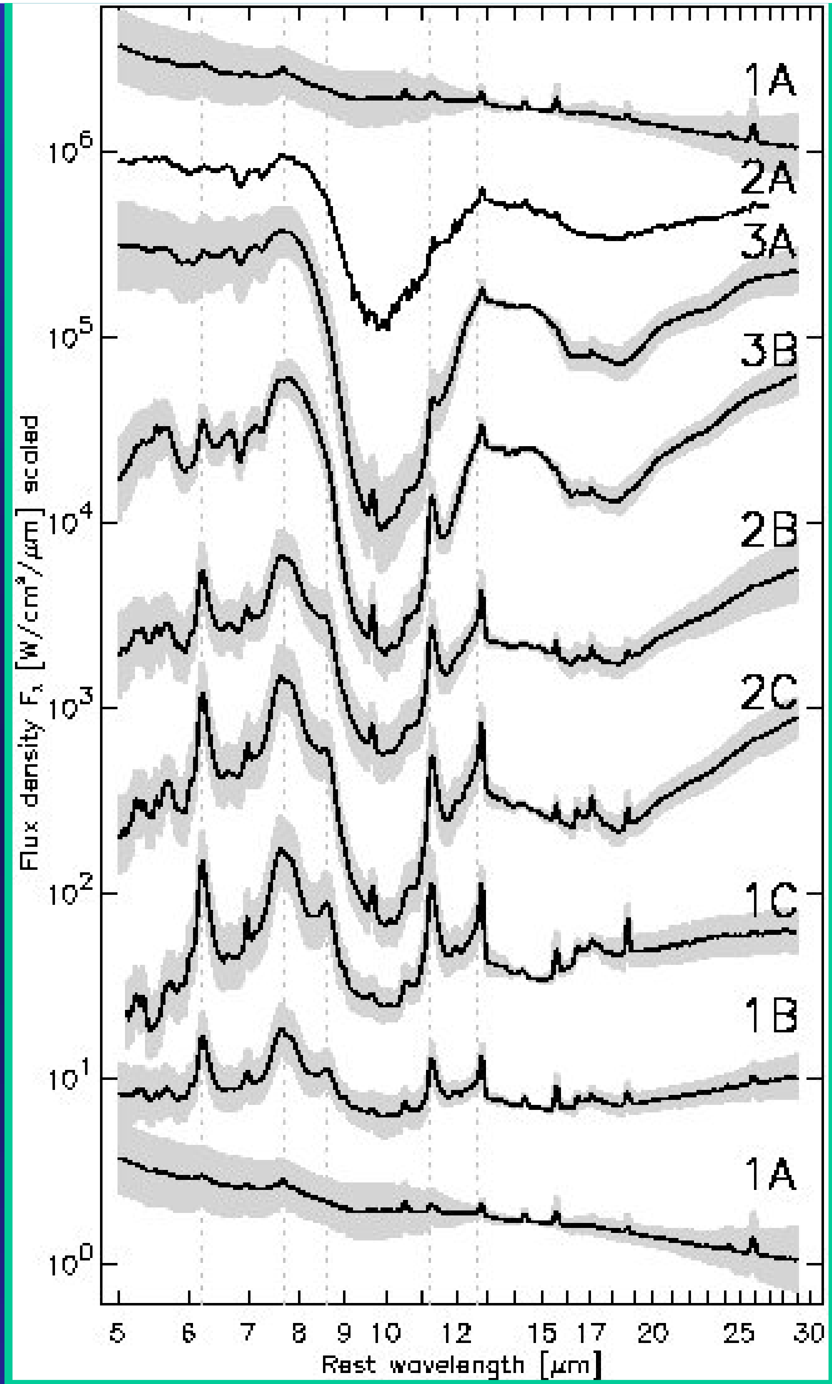
*AGN-heated hot dust: 1A

*PAH (starburst) dominated spectra(1C)

*absorption dominated (2A)

AGN → starburst at increasing PAH

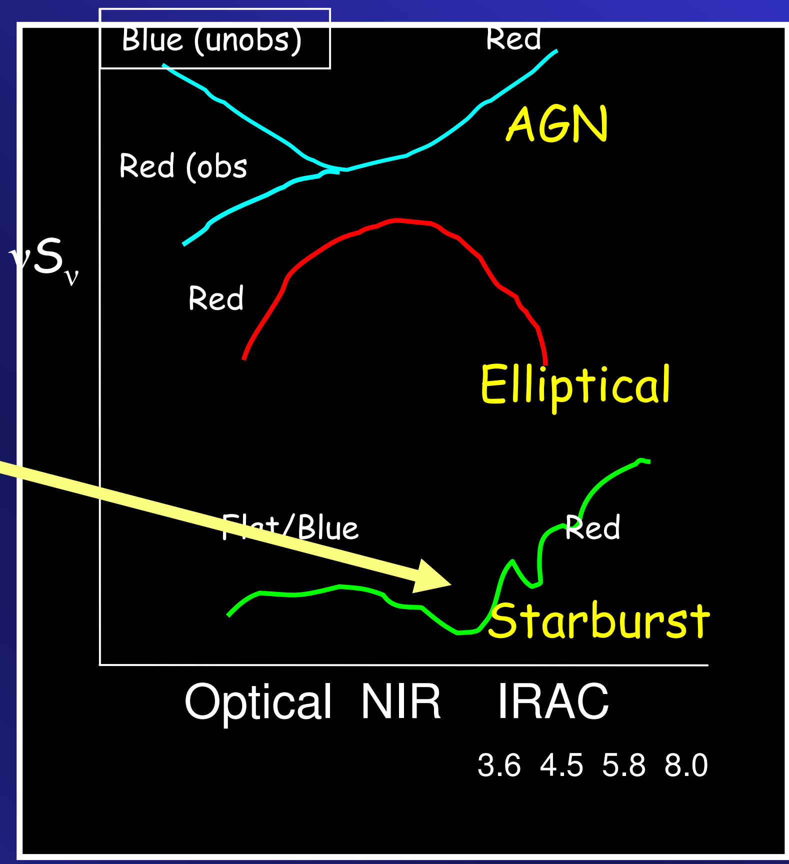




SED in NIR-/MID-IR

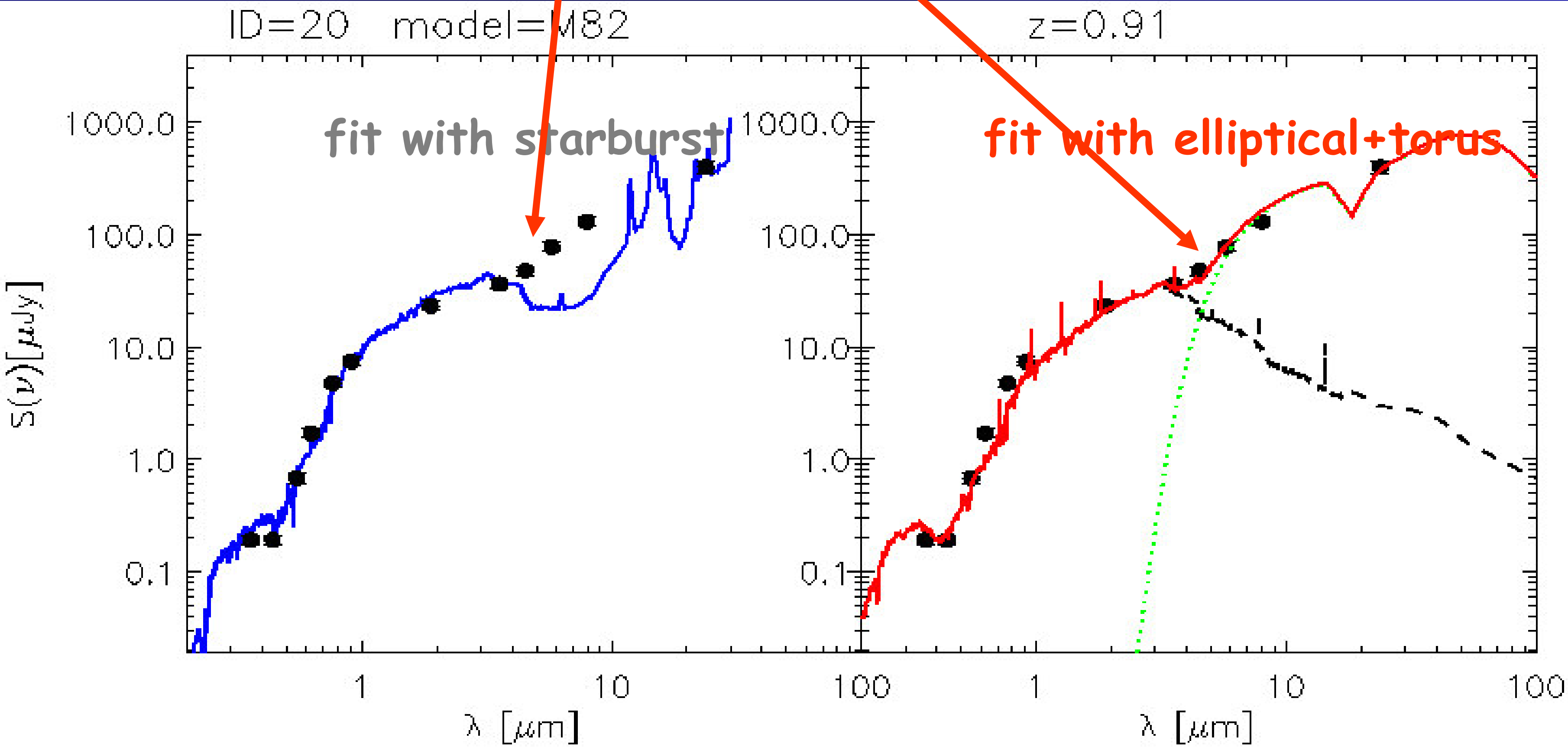
Other hints that LIGs/ULIGs harbour an AGN from SEDs in NIR/MIR

Crucial range: near-/mid-infrared (NIR/MIR) where galaxy SEDs have a dip (2-5 μm) and the hot dust heated by the AGN start contributing, filling up the dip.



➜ Broad-band SEDs: MIR in excess with respect to expectations for galaxies (Polletta et al. 07, Gruppioni et al. 08)

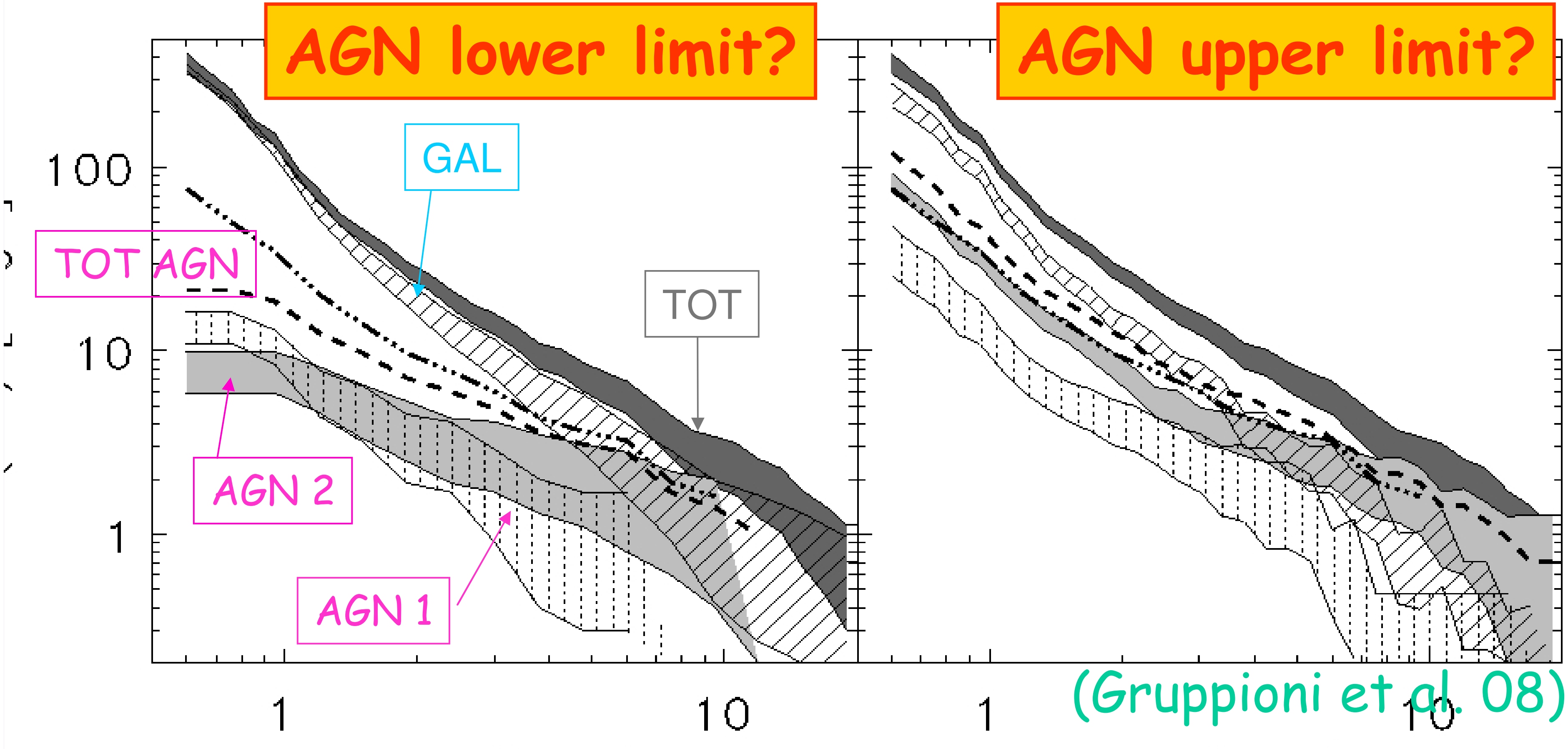
SED well fitted by evolved stellar population (reproducing opt/NIR) + dusty torus heated by AGN (reproducing MIR/FIR)



STRONG IMPACT ON EVOLUTIONARY MODELS!

- Observed Source Counts:

Spectroscopic classification　　SED classification



(Gruppioni et al. 08)

Summary

Nearly half of the energy output of the extragalactic sources in the IR band (8-1000μm)

Main Spitzer results:

MIPS/24 μm: Detection of IR sources (starburst/AGN) up to z~3.

IRS spectroscopy: Many starburst galaxies harbour an obscured AGN. Coeval nuclear and star formation activity.

Evolutionary models based on previous satellite (ISO) need to be revised to reproduce the Spitzer observables.

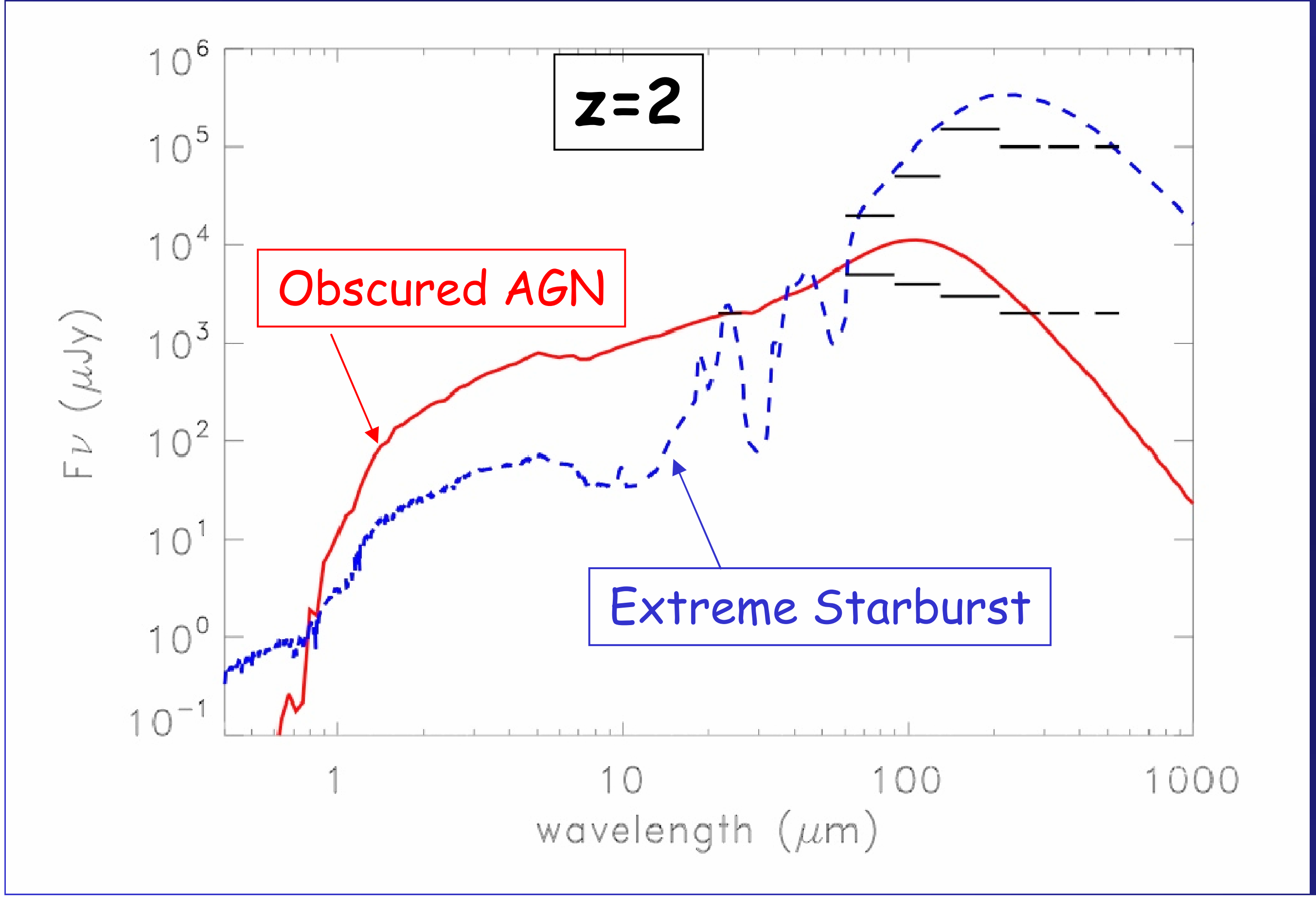
➔ more objects harbour an AGN.

Need a complete census and characterization of IR SEDs.

How Herschel will help….see Gruppioni talk!!!

…need for *HERSCHEL*?

Locate the peak of dust emission in High-z AGN/galaxies → dust Temperature detailed SEDs in FIR



↓

Better Galaxy/AGN Separation!

↓

Better Galaxy Formation and Evolution Models

→ Stacking analysis:

di sorgenti rivelate a 24 mm(S_{24}> 60 μJy) separate per bin di S_{24} (Dole et al. 06)

Campi: CDFS, Lockmann, HDFN: ~ 19000 sorgenti 24 μm

The Cosmic Infrared Background resolved by Spitzer

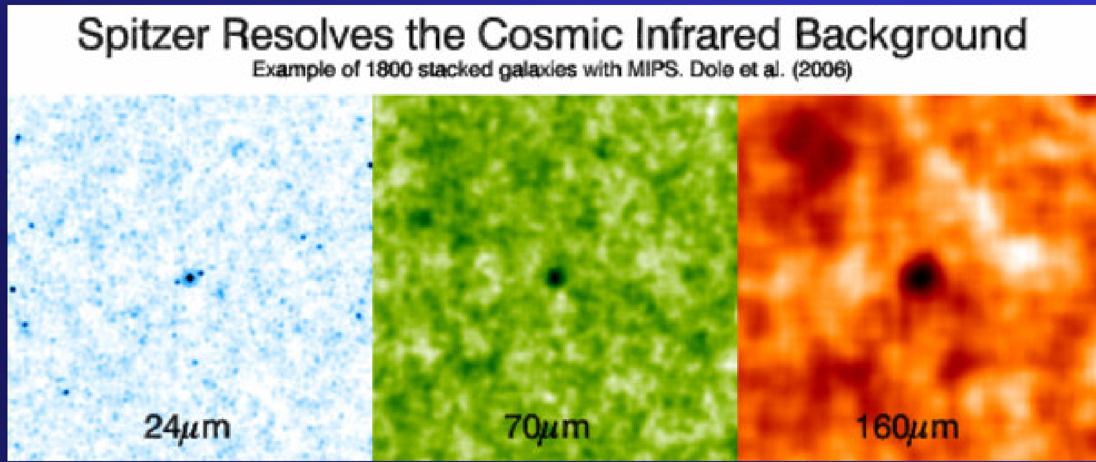
H. Dole et al. (2006)

Institut d'Astrophysique Spatiale, Universite Paris-Sud 11, CNRS

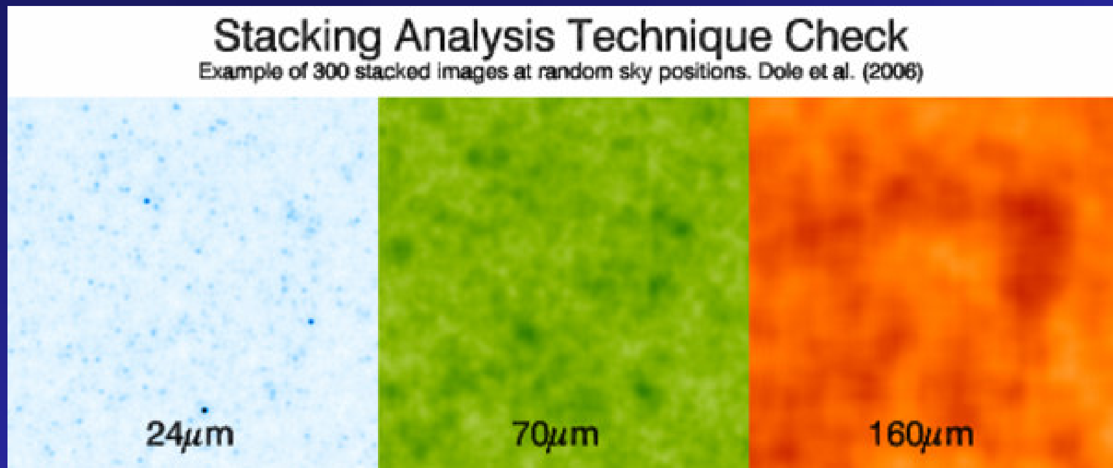
http://www.ias.u-psud.fr/irgalaxies

Credit: H. Dole/IAS/Arizona/NASA/JPL-Caltech

Sorgenti sommate posizione 24 μm



Sorgenti sommate con random offset



Sorgenti rivelate in ogni bin S_{24} mm

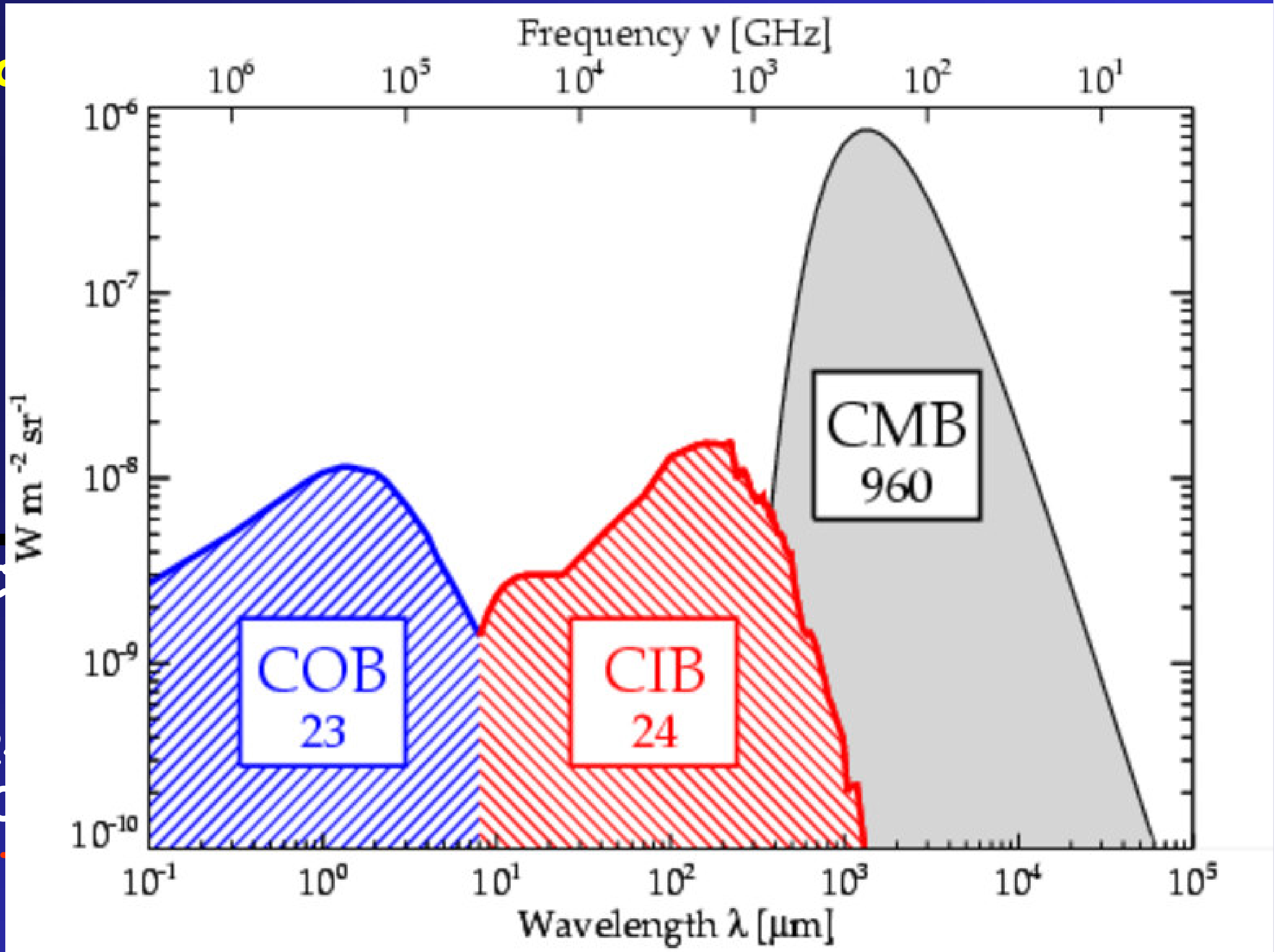
Guadagno: factor of 10 in flux @ 70, 160 !

S_{24}= 100 μJy have S_{70}~0.5 mJy S_{160}~3 mJy

Background IR Spitzer/stacking analysis

Percentuale fondo riso
sorgenti 24 μm :

80 % @ 24 um
90 (20) % @ 70 um
70 (7) % @ 160 um



- Intensità pari quella C
  (CIR + COB 5 % CMB
- Conoscendo z-distr. 2
  (Le Floc'h 05, Caputi C
  CIRB composto sorgen
  come COB (~20-30%

→ Abbiamo già scoperto tutto?
Perchè Hershel 60-670 μm ?

empirici anche nelle sole bande
IR……

Conteggi a 24 μm

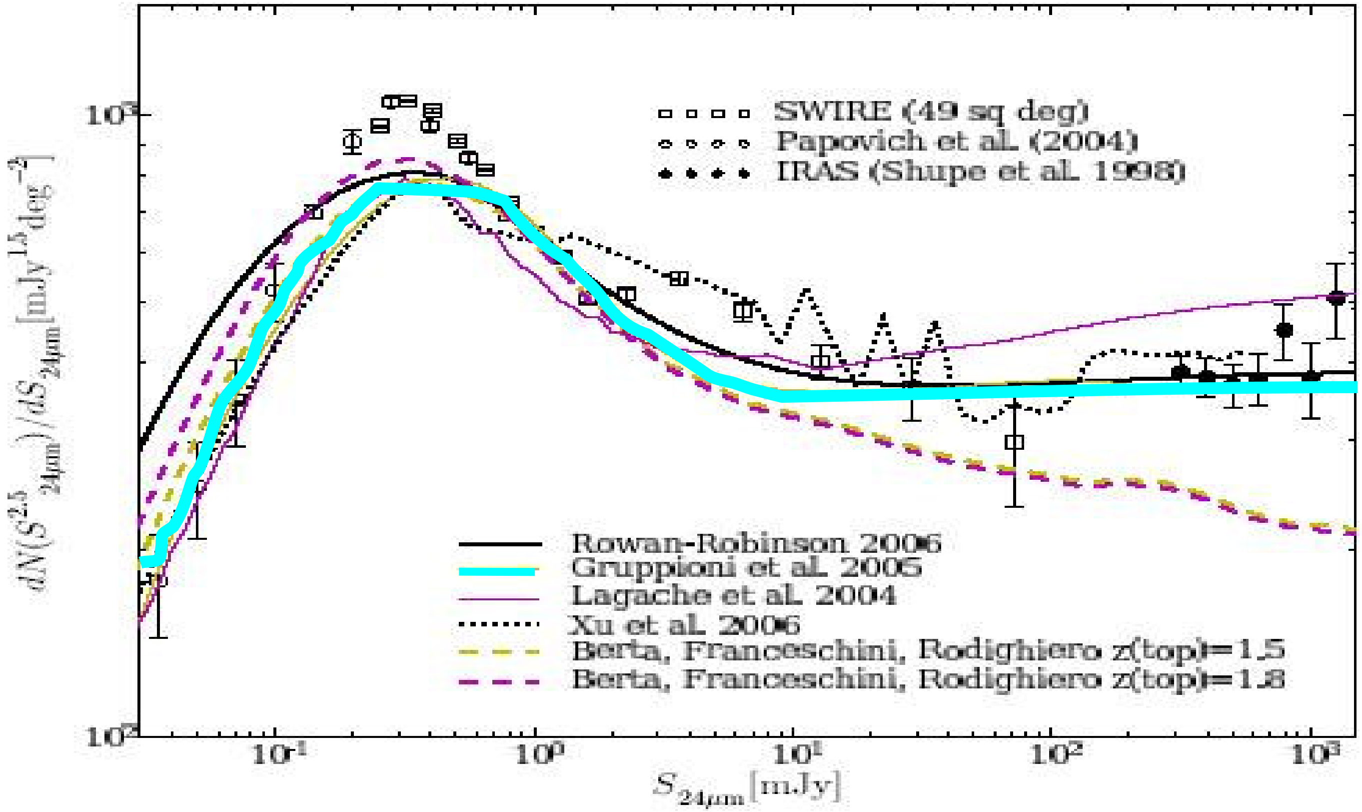


Fig. 6.— Plot of normalized number counts with several models overlaid.

Shupe et al. submitted

Necessario rivedere modelli alla luce
risultati fotometrici e spettroscopici di SPITZER !!!

forse accrescimento non è un fenomeno cosí marginale ….

Herschel (60-670 μm)
permetterá rivelare direttamente
flusso rivelata da Spitzer solo statisticamente
(stacking analysis)