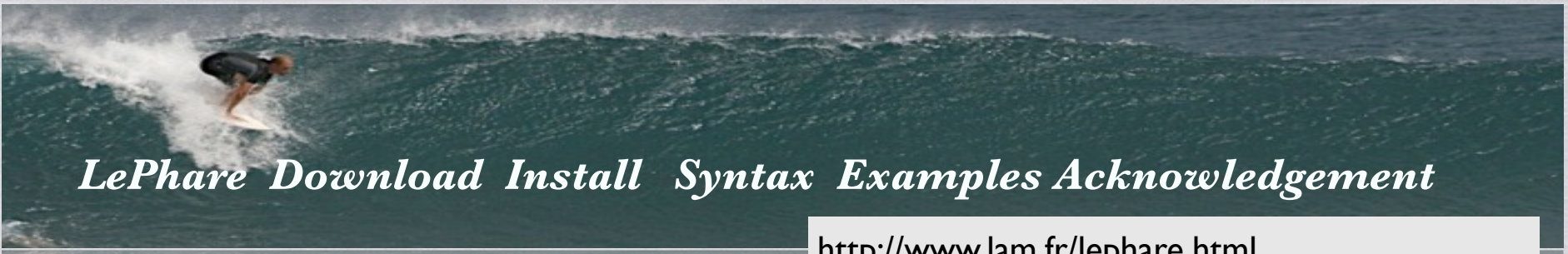


http://www.lam.fr/lephare.html

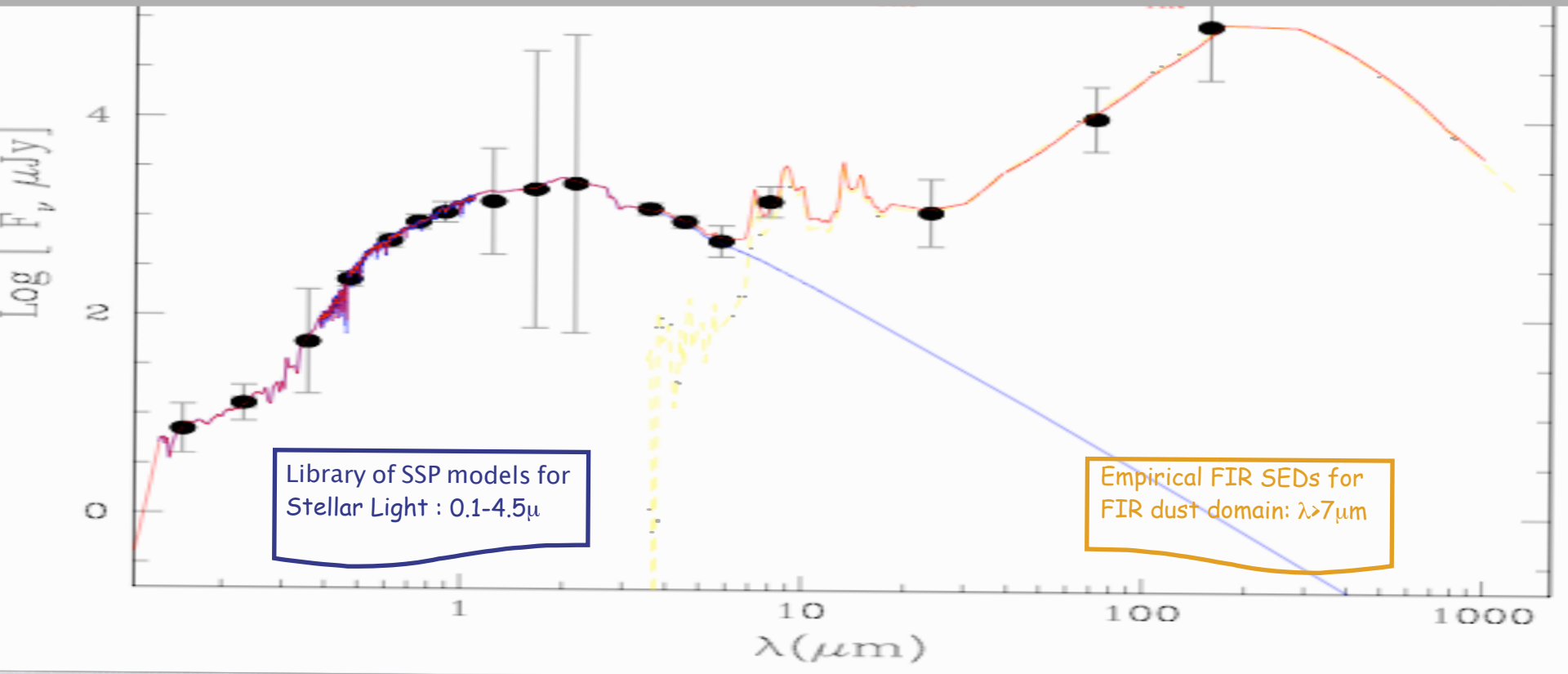
Le Phare

A Photometric software
to measure redshifts
&
galaxy properties

Arnouts S. & Ilbert O.

Aix*Marseille université cnrs LAM

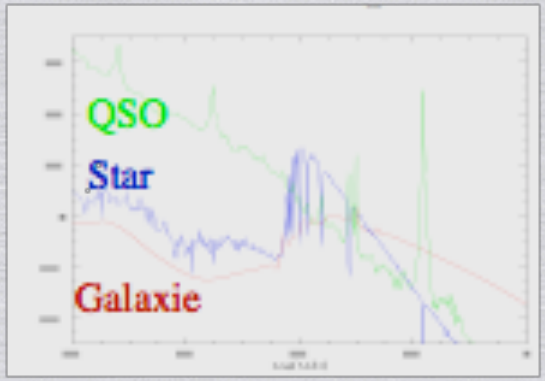
Basic concept



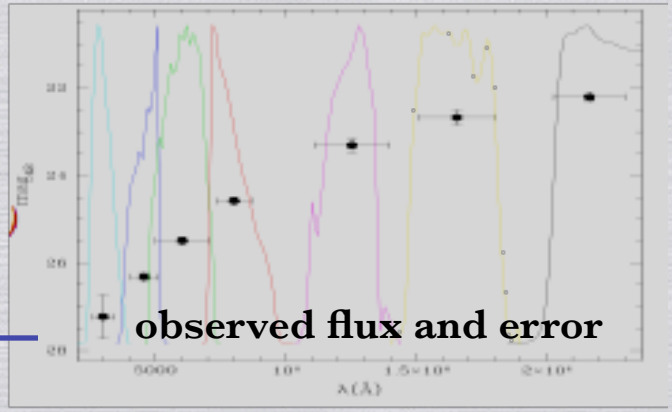
Comparison of the observed and predicted fluxes [SED(z,Type,...)]
via standard χ^2 fitting technique

Basic concept

SED's Libraries



Set of Filters



\+
Extinction
IGM

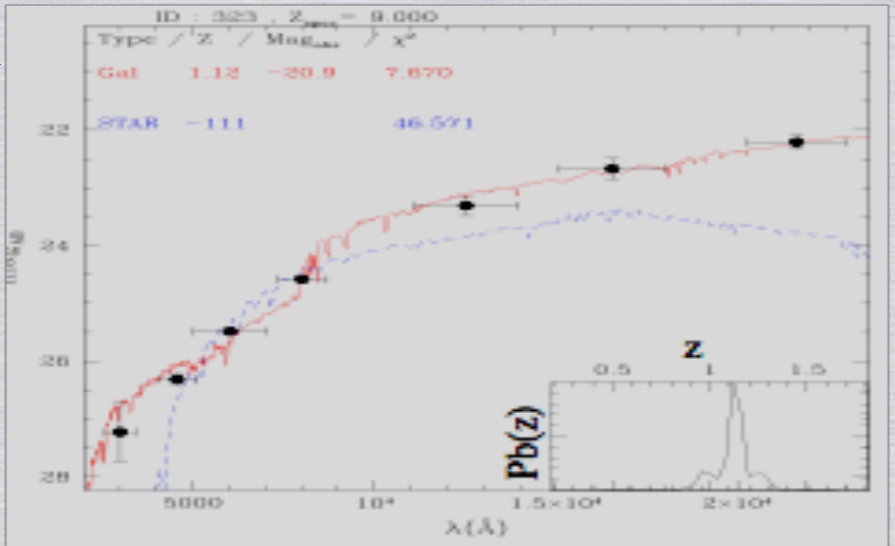
Theoretical flux

χ^2 fitting :

$$\chi^2(z,T,A) = \sum_{f=1}^{N_f} \left(\frac{F^f_{obs} - A \times F^f_{pred}(z,T)}{\sigma^f_{obs}} \right)^2$$

Outputs

Best Redshift Z
Z uncertainties (z-PDFs)
Types , attenuation
\+
Physical parameters:
Masses, Mean Age, SFR, Zo,…
& uncertainties (marg. PDFs)



Basic concept

χ^2 SED fitting technique

Assumptions:

* SED library provides a fair sampling of galaxy's SEDs

Strength :

* Independent of any training datasets [works all z, 0< z <9+]
* uncertainties measure from the Redshift probability distribution function (PDF)
* optimal classifier : Stars / QSOs / Galaxies
* physical parameters for each galaxy [Mass, SFR, Dust, L_{IR},...]

Weakness :

* Can be time consuming compared to NNs

SED fitting Bonus :

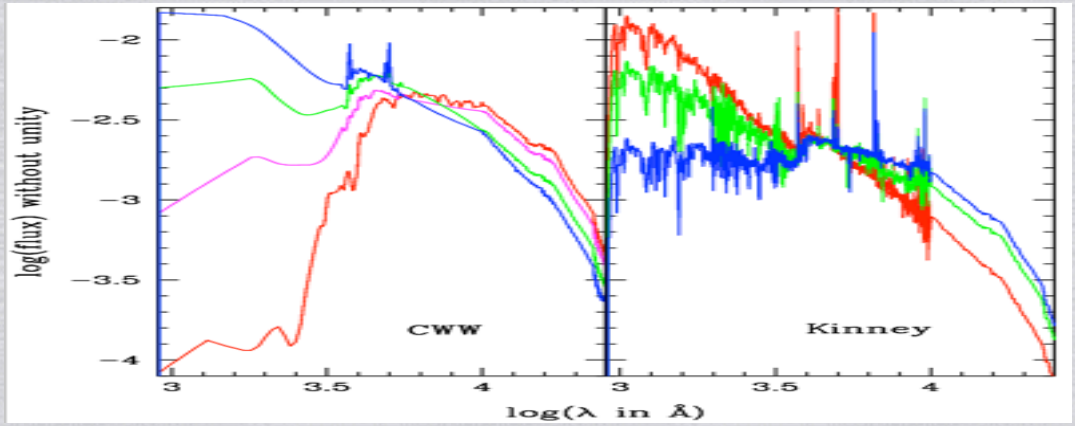
* Easy to perform simulation/mock catalogs in any filterset
  - -1- theoretical description of LFs + surface brightness effects
  - -2- existing deep catalog (like COSMOS)

SED templates

* Observed SED templates in local universe

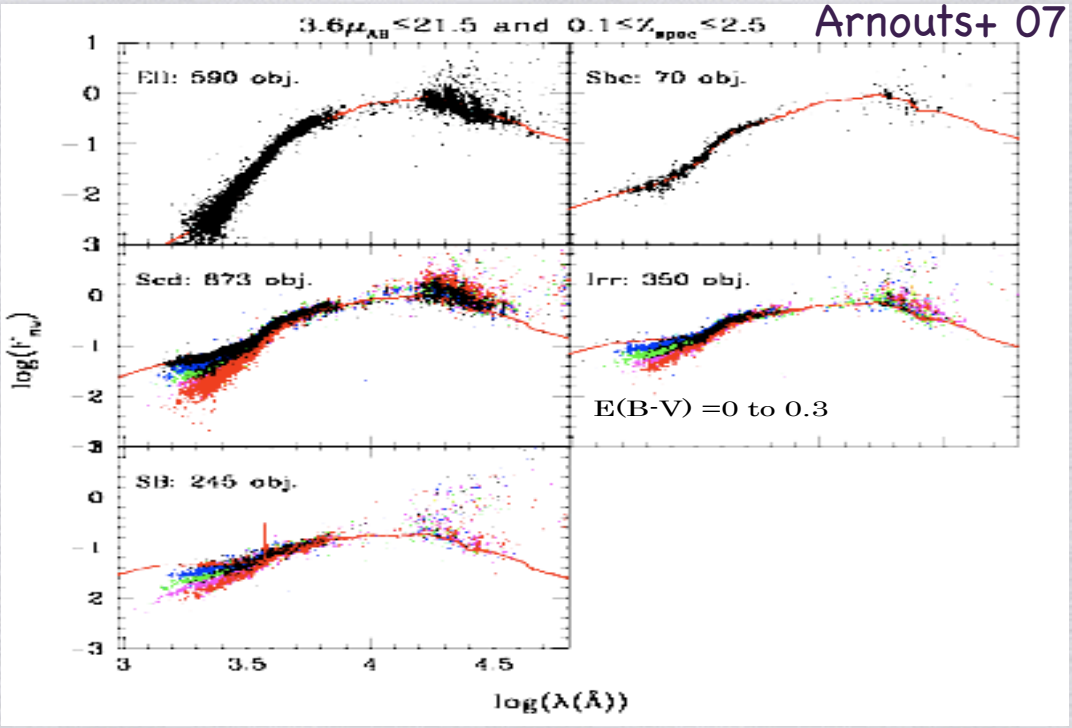
(Coleman, Wu Weedman, 1980 + Kinney+, 1996)

- CWW + Kinney extrapolated in UV and NIR using BC03 library



Empirical Template reconstruction improved in NIR with CFHTLS+SWIRE + spectroscopy

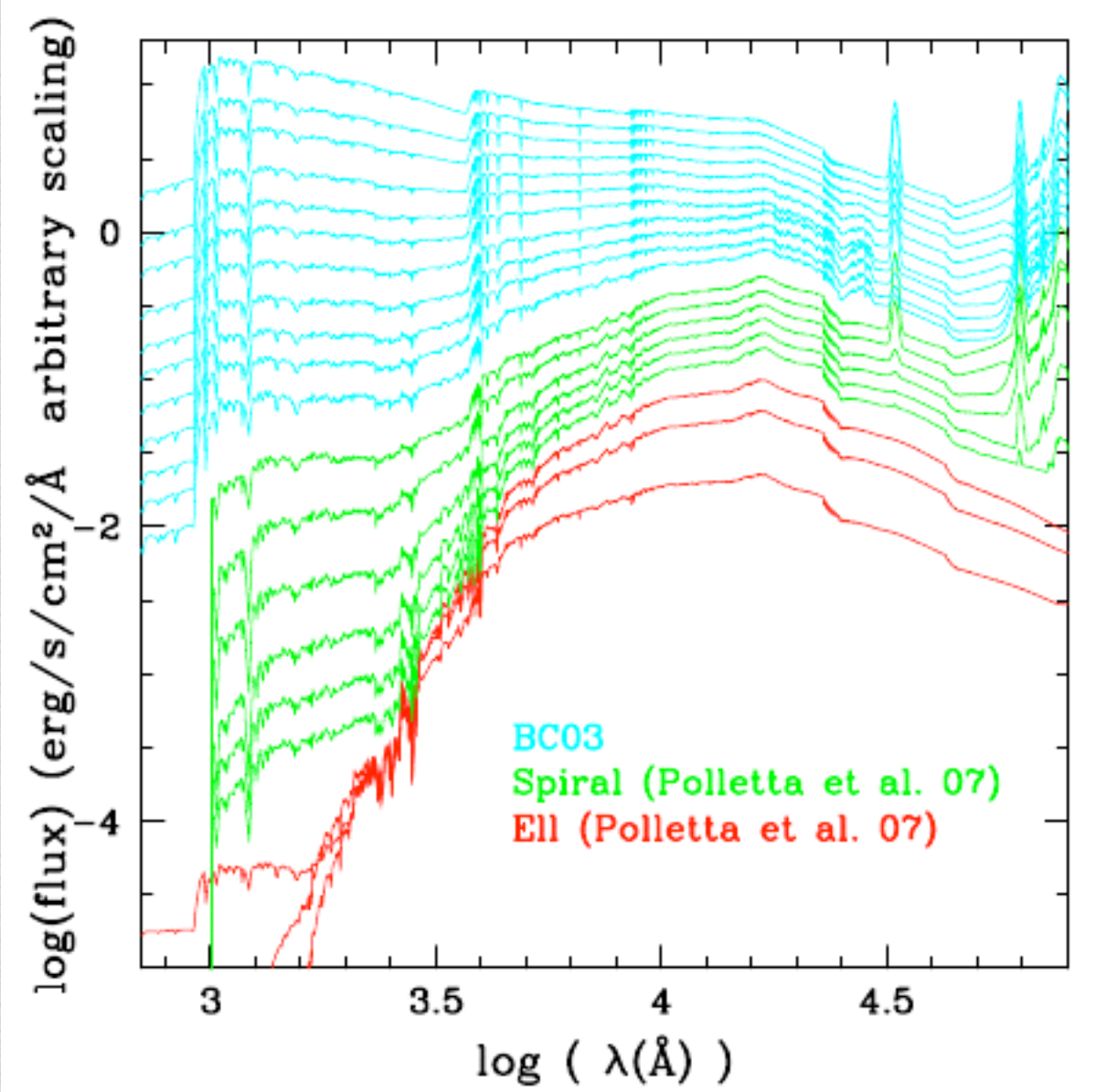
Arnouts+ 07



SED templates

* Observed SED templates for COSMOS *(Ilbert 2009)*

Synthetic set
of templates
-> Pegase
-> BC03/CB07
Empirical set
of templates
-> CWW
-> Polletta et al.



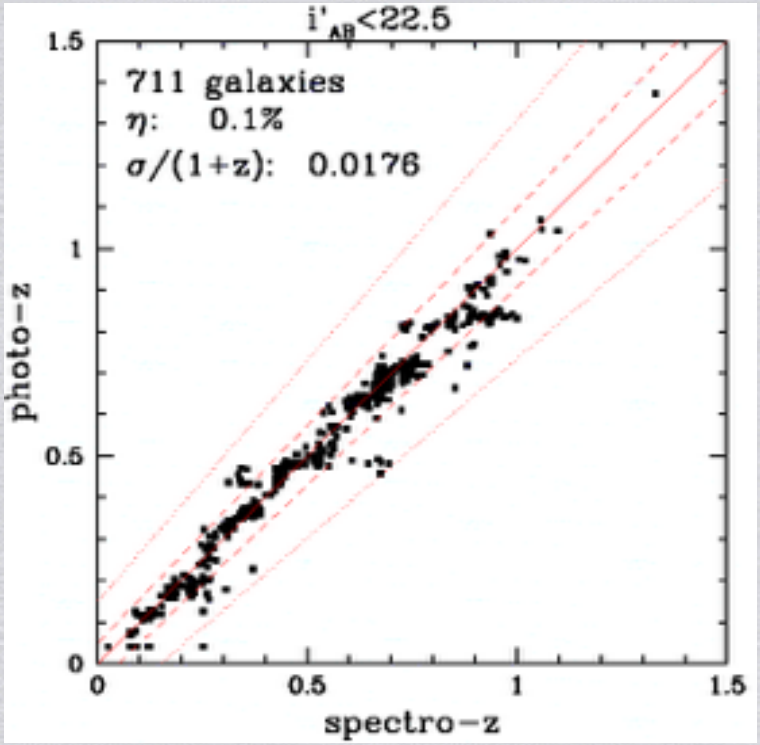
Le Phare's features

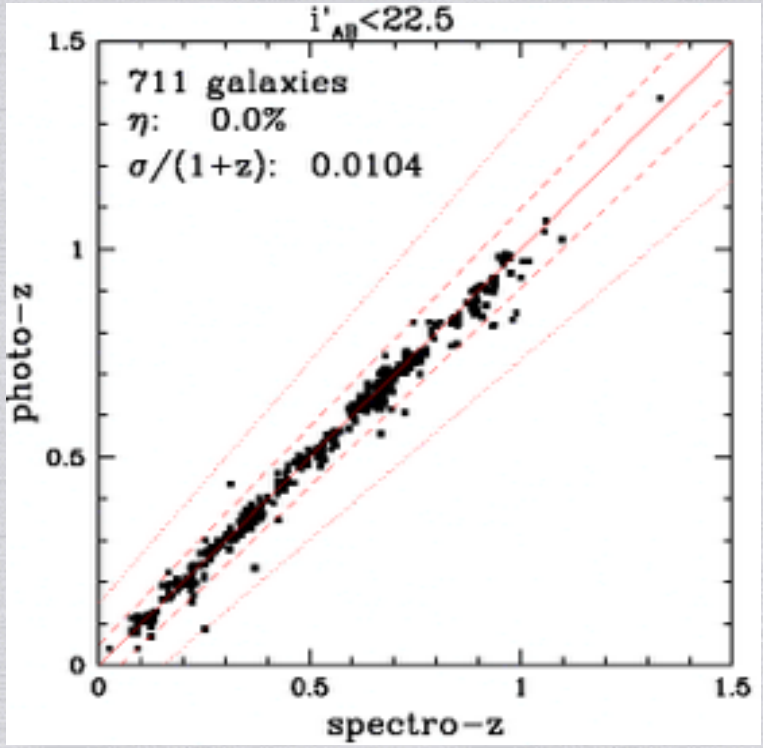
* Many codes on shelves : Hyper-Z, EAZY, ZEBRA, BPZ, Photo-Z, ANNz, DESDM, SkyNet, RVMz, ...

* LePhare's features helping for photo-zs

-1- Automatic Zero-Point Correction of the photometry with spectroscopic sample *(Ilbert+,09)*

$$\psi^2 = \sum_{i' \leq 21.5}^{\mathrm{Ngal}} \left(\left(A \times F^f_{\mathrm{pred}} - F^f_{\mathrm{obs}} + s^f \right) / \sigma^f_{\mathrm{obs}} \right)^2$$



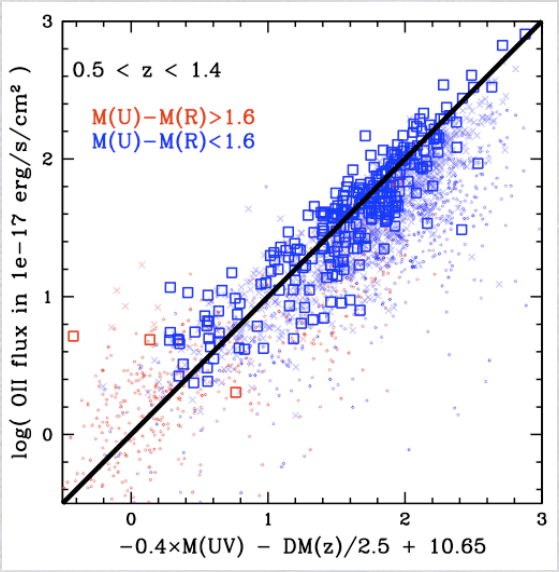


Le Phare's features

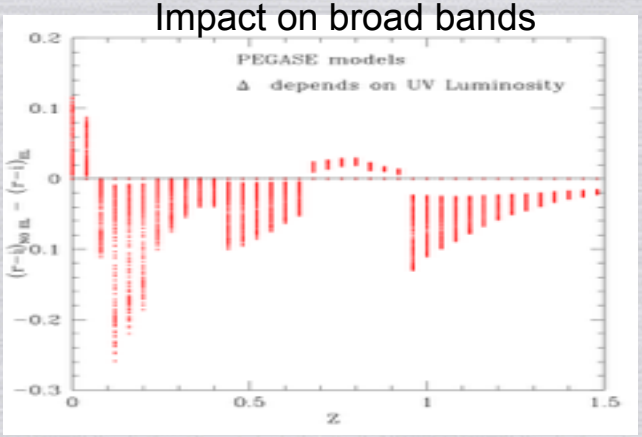
-2- Inclusion of Emission Line scaled with dust-free UV luminosity *(Ilbert+,09)*

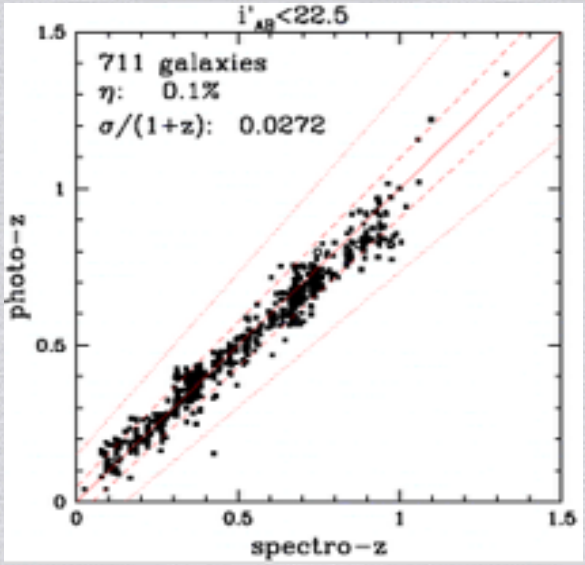
$SFR \propto L_\nu(H\alpha)$ → $H\alpha \longrightarrow H_\beta, H_\delta$

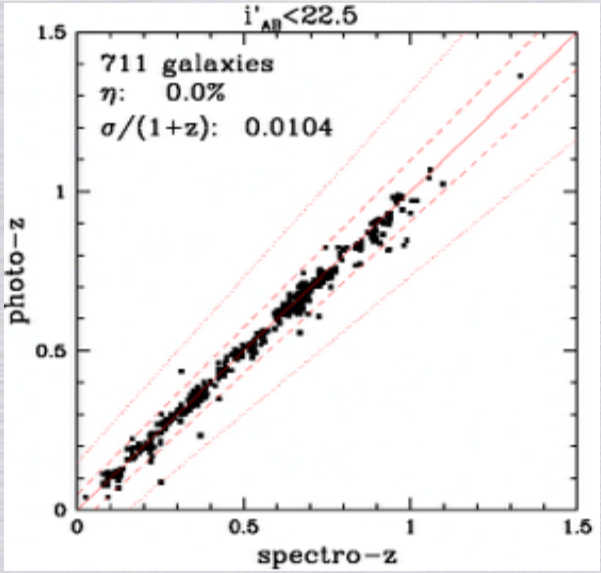
$SFR \propto L_\nu(OII)$ → $OII \longrightarrow OIII_{4959}, OIII_{5007}$



Impact on broad bands

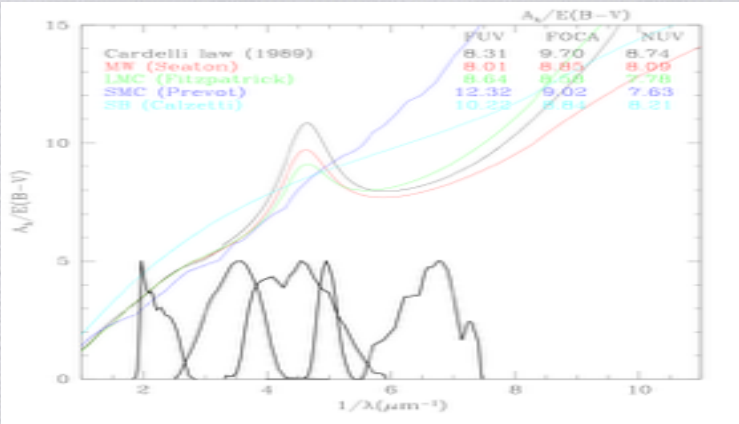




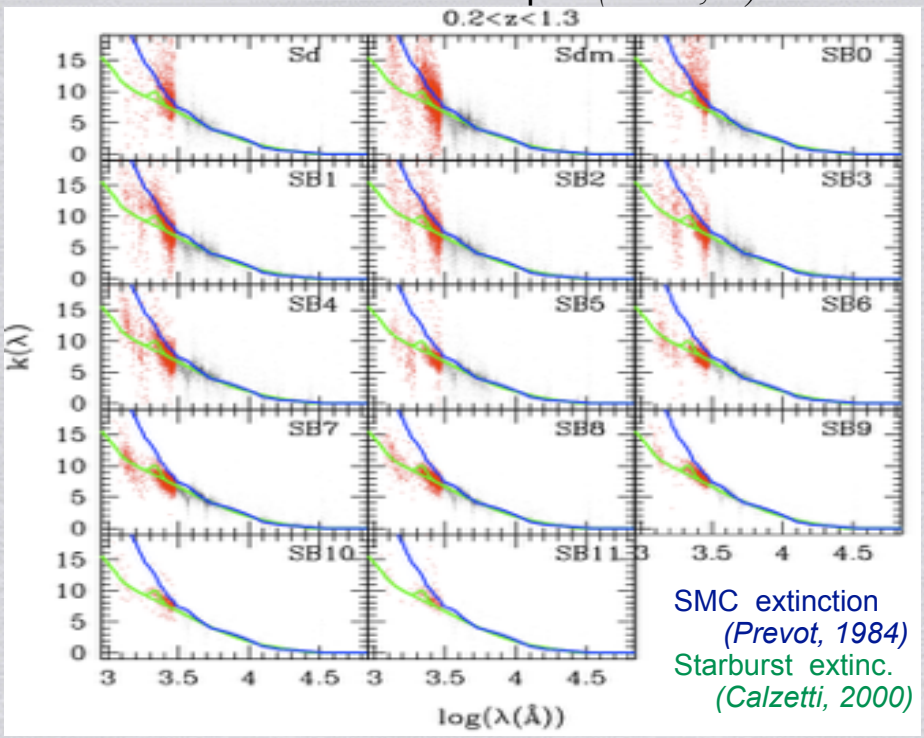


Le Phare's features

-3- Several attenuation Laws for diversity of the observed UV slopes

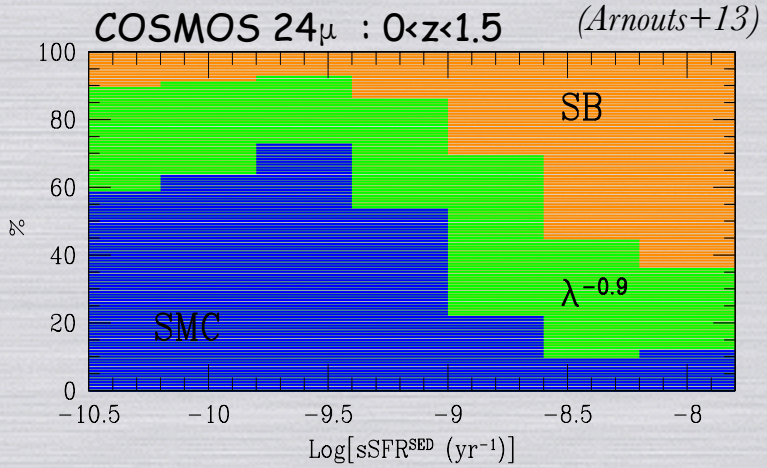


reconstructed UV slopes *(Ilbert+,09)*



SMC extinction *(Prevot, 1984)*

Starburst extinc. *(Calzetti, 2000)*



Le Phare's features

-4- Prior on N(z) for type (T) and mag. Bayesian approach from Benitez+00

$$p(z, T|i'_{AB}) = p(T|i'_{AB})p(z|T, i'_{AB})$$

Margoniner +07

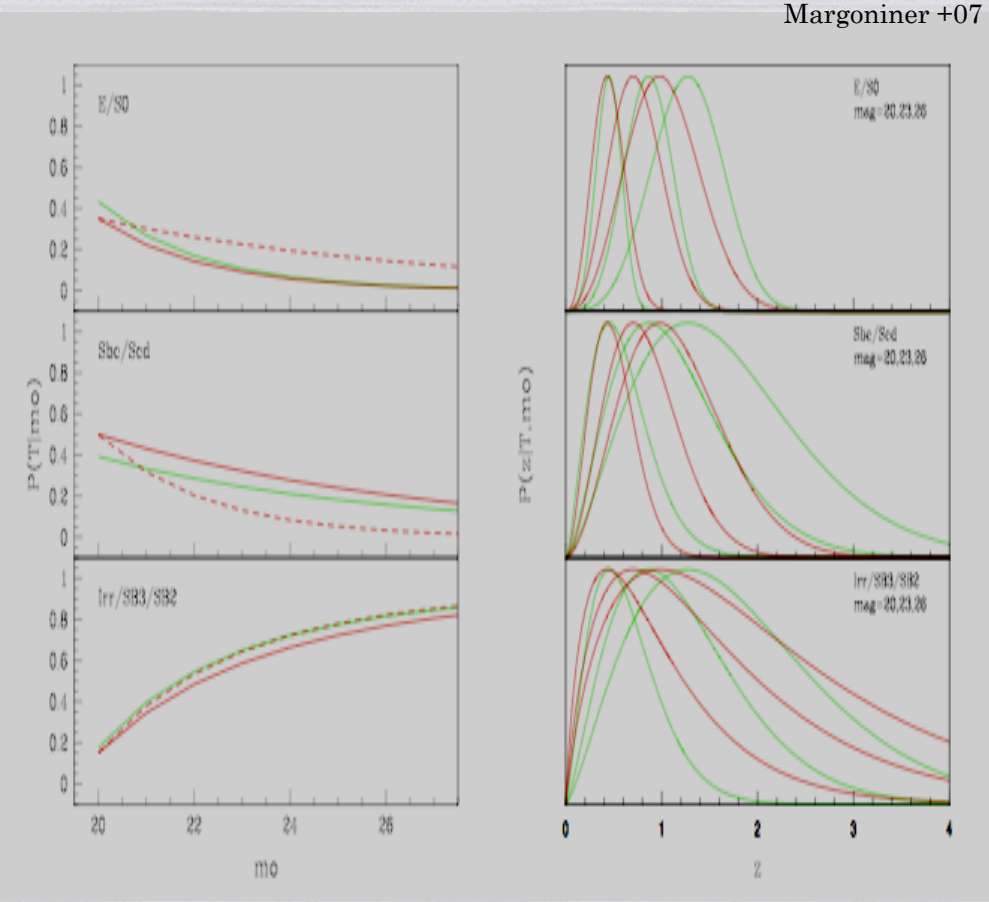
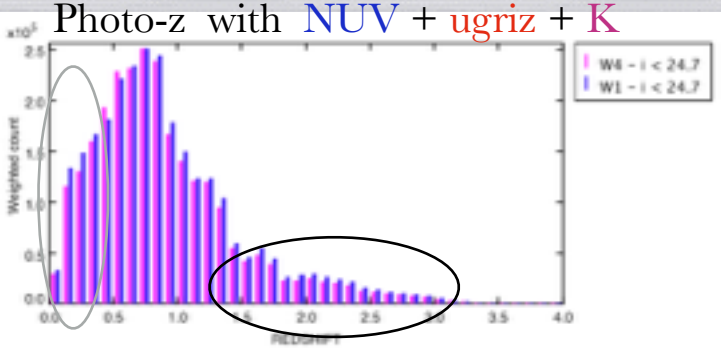
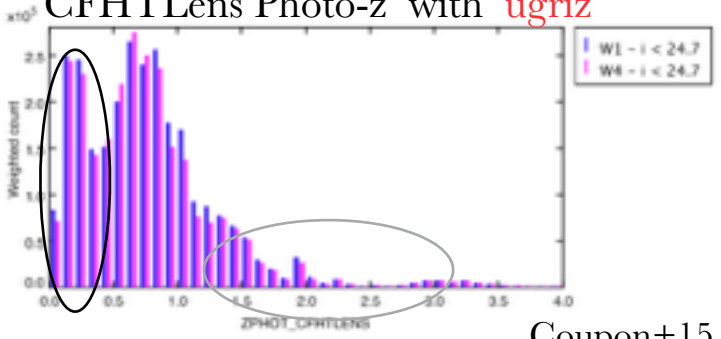


Photo-z with NUV + ugriz + K



CFHTLens Photo-z with ugriz

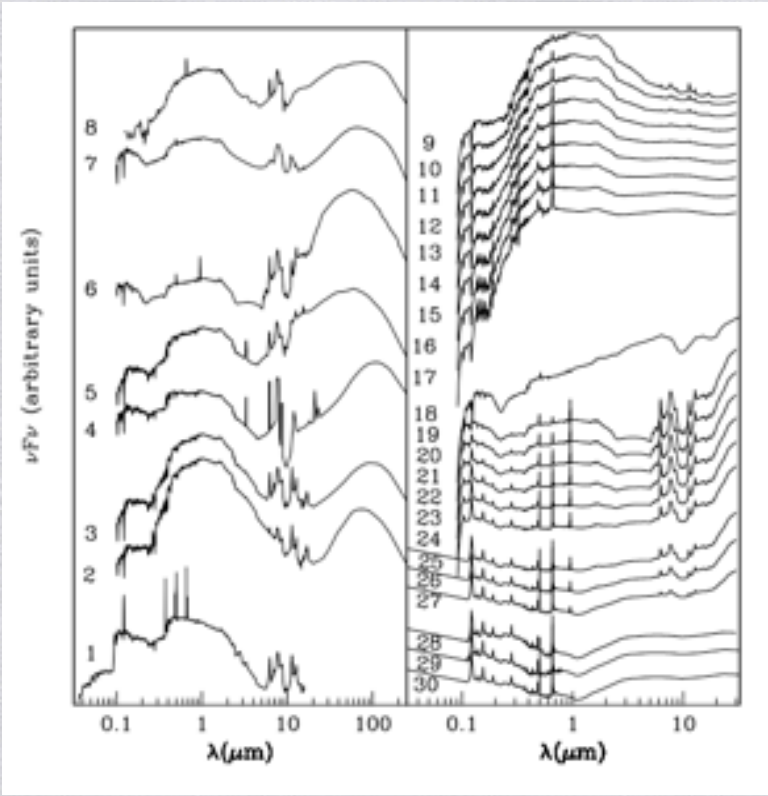


Coupon+15

Le Phare's features

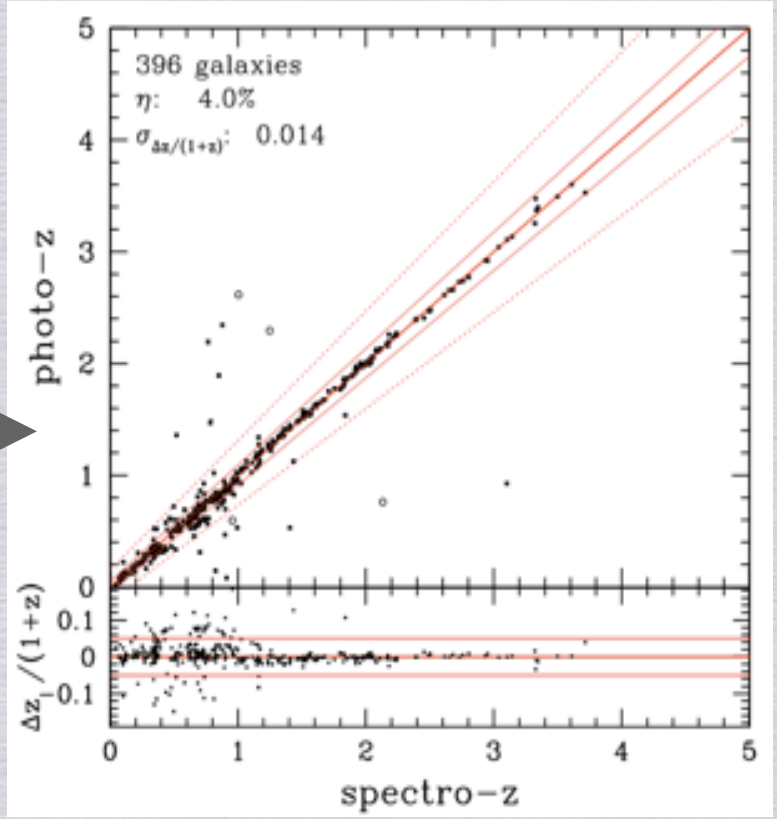
-5- Photo-z for QSO/AGN in COSMOS *(Salvato +08)*

combines QSOs and hybrid models (AGN+galaxy)



application of a

Luminosity prior



Redshifts and uncertainties

Standard approach:

Z_{best} = lowest χ^2_{min} (z)

PDF $\propto$ exp(-0.5 χ^2_{min} (z))

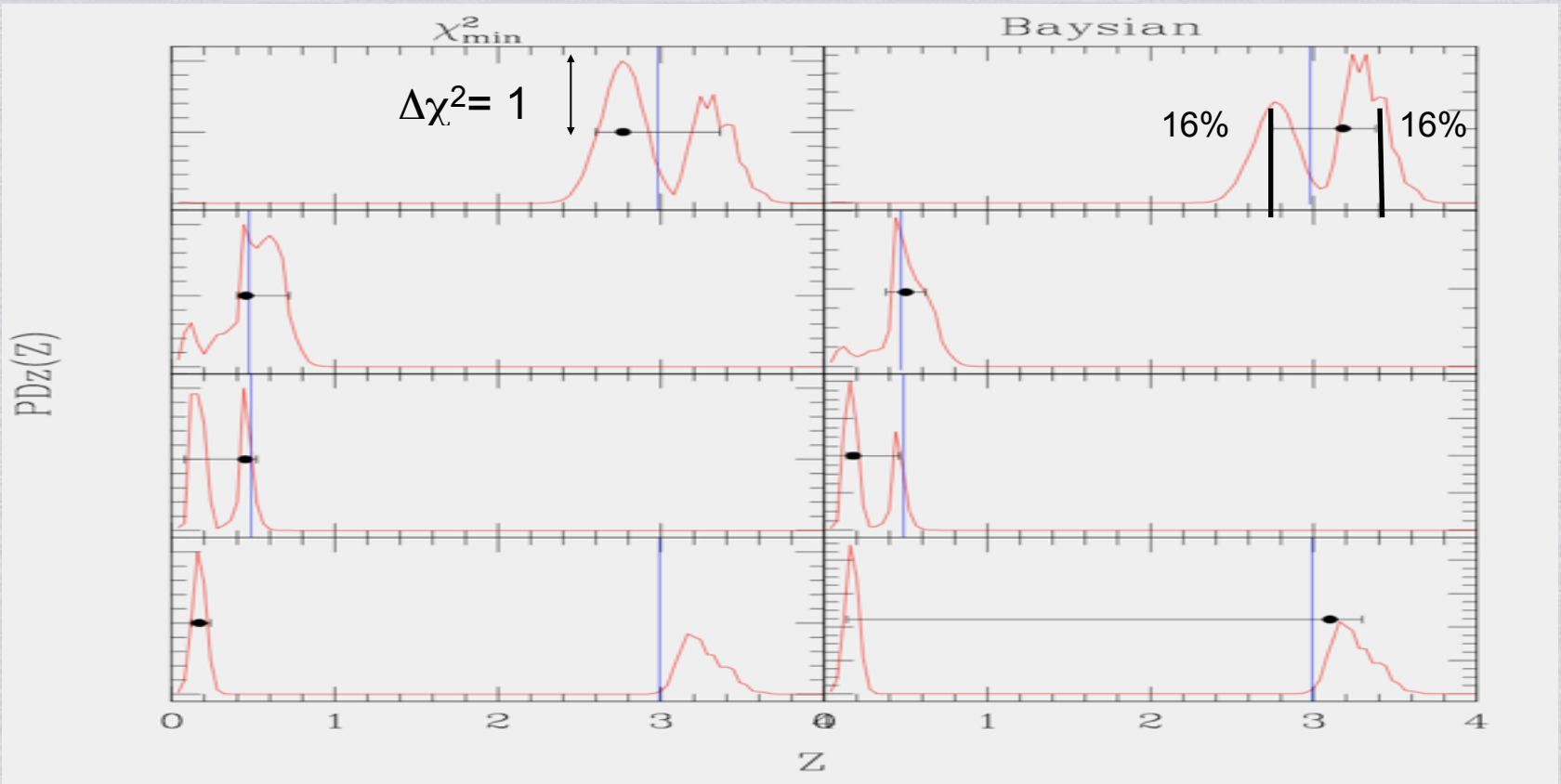
1σ (68%) errorbar computed with $\Delta\chi^2$= 1

Kauffmann's approach (Kauffmann+03)

PDF $\propto \sum_i^{mod}$ exp(-0.5 χ^2_i (z))

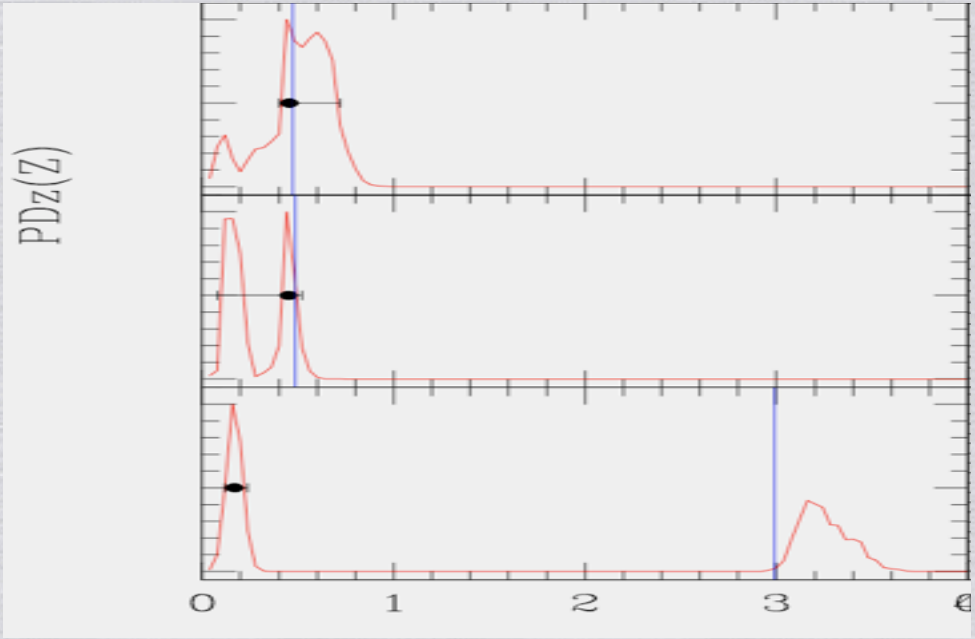
Z_{best} = Median of the PDF

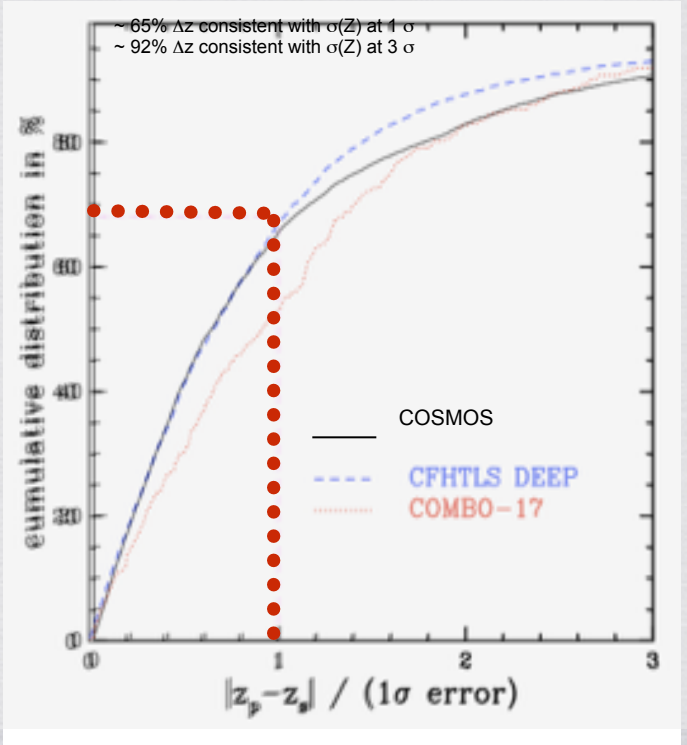
68% errors from the PDF



Redshifts and uncertainties

* Redshift errors and PDF(z) are critical in most of statistical analysis and must be as robust as possible

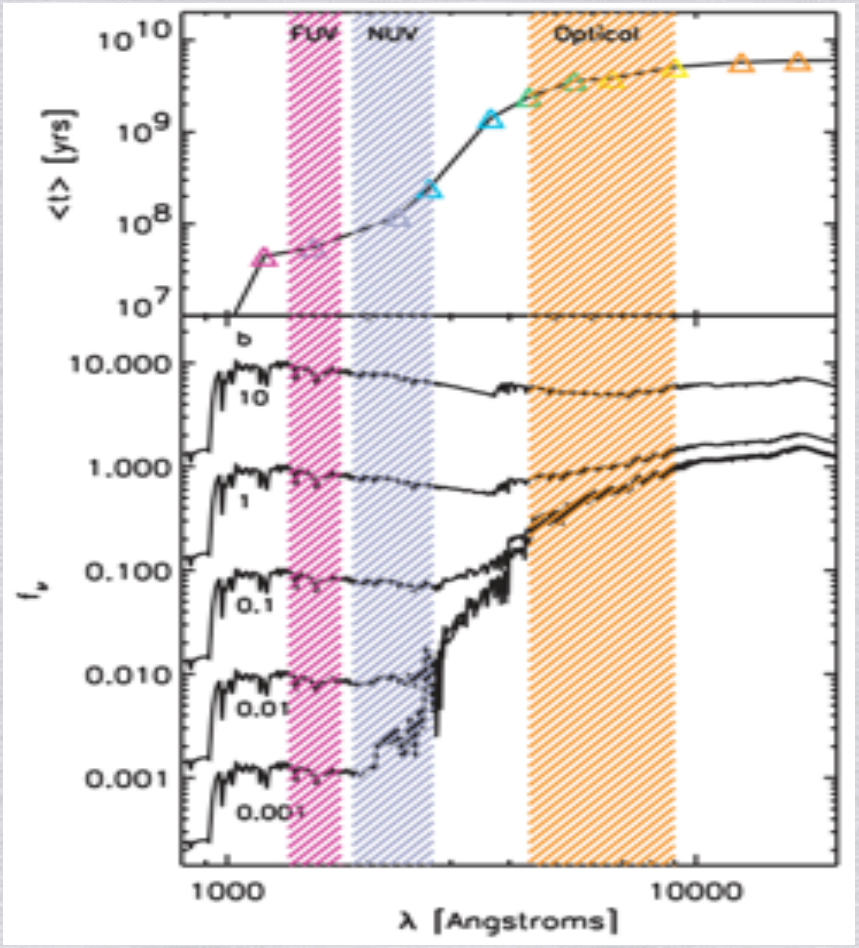




Galaxy properties

-1- Physical parameters from large stellar population synthesis model libraries (PEGASE, BC03, CB07, Maraston,...) with errors from marginalized PDFs.

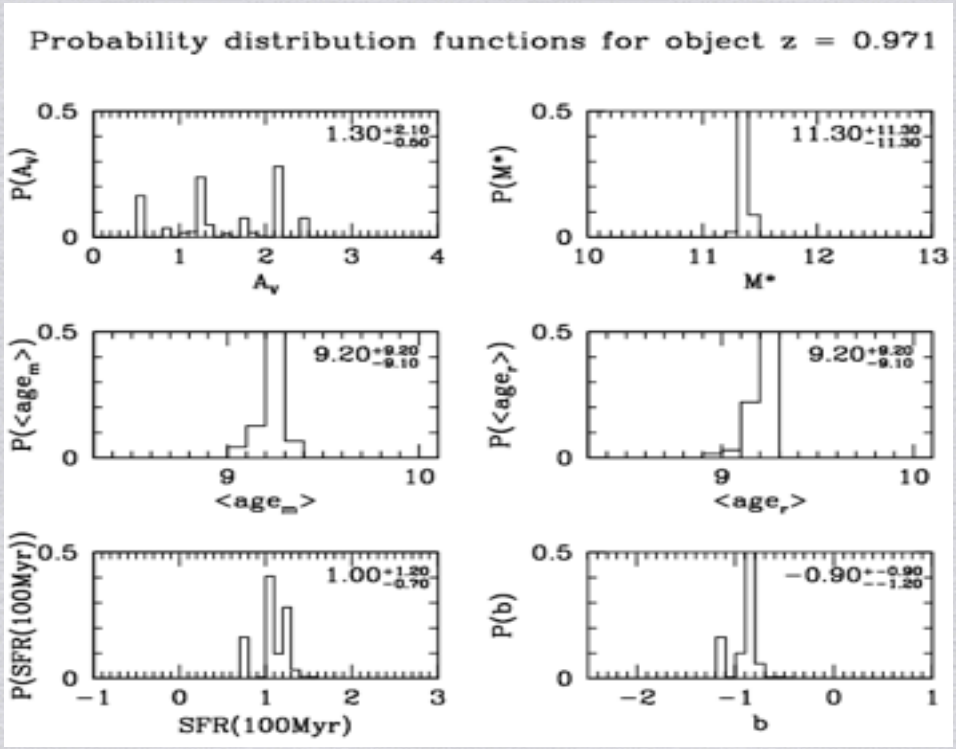
Martin+05



- Probabilities for all models are marginalized over all parameters but the one to be measured.

(Kauffmann+03)

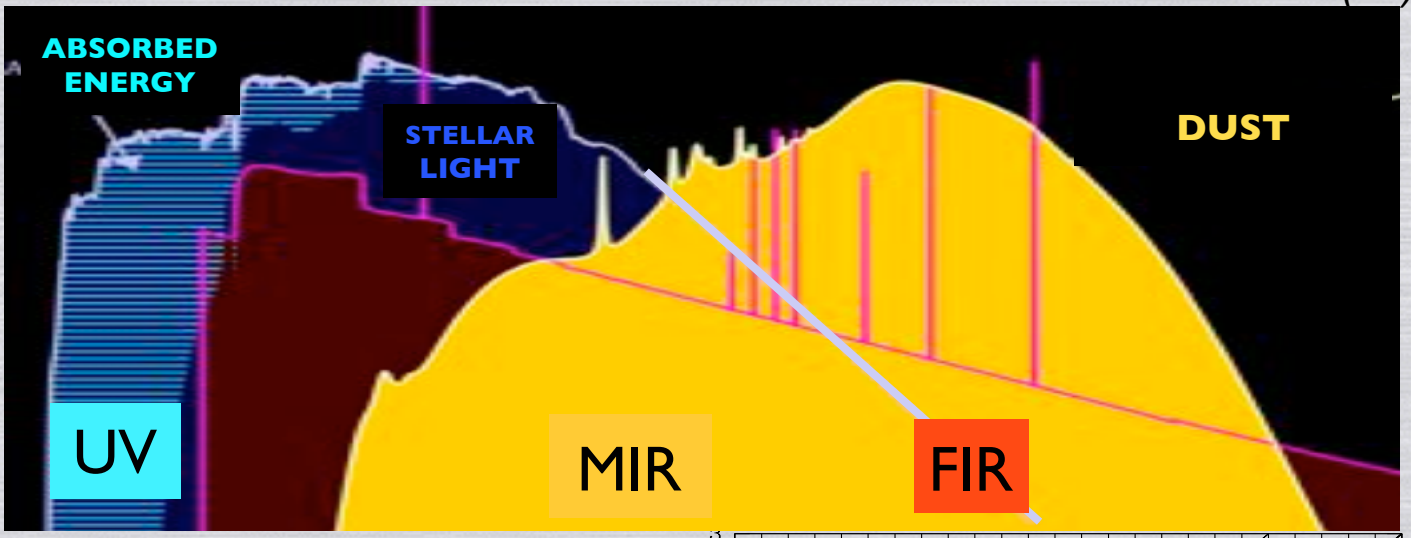
Walcher+07



Galaxy properties

-2- Also it includes FIR to Radio libraries to derive Far-IR luminosity
(with various calibration schemes depending on Instrument)

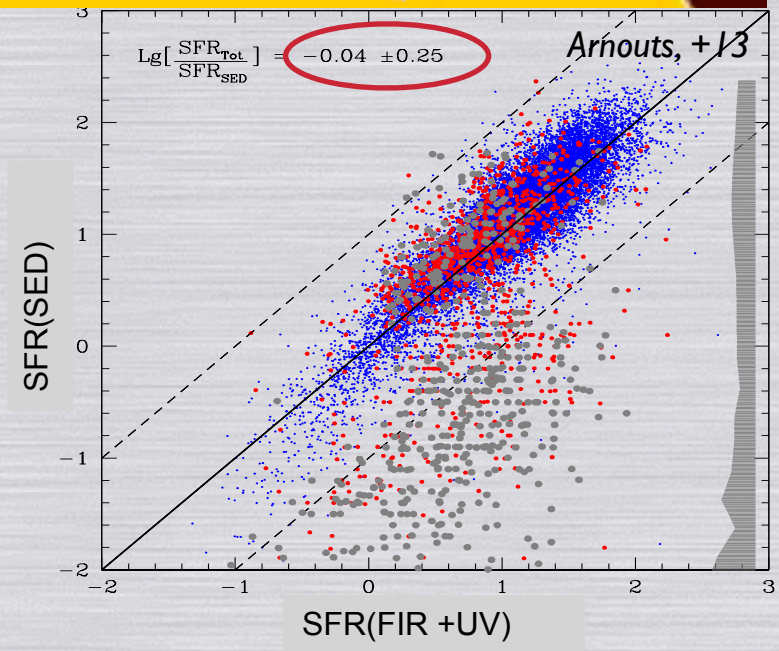
Desert (90)



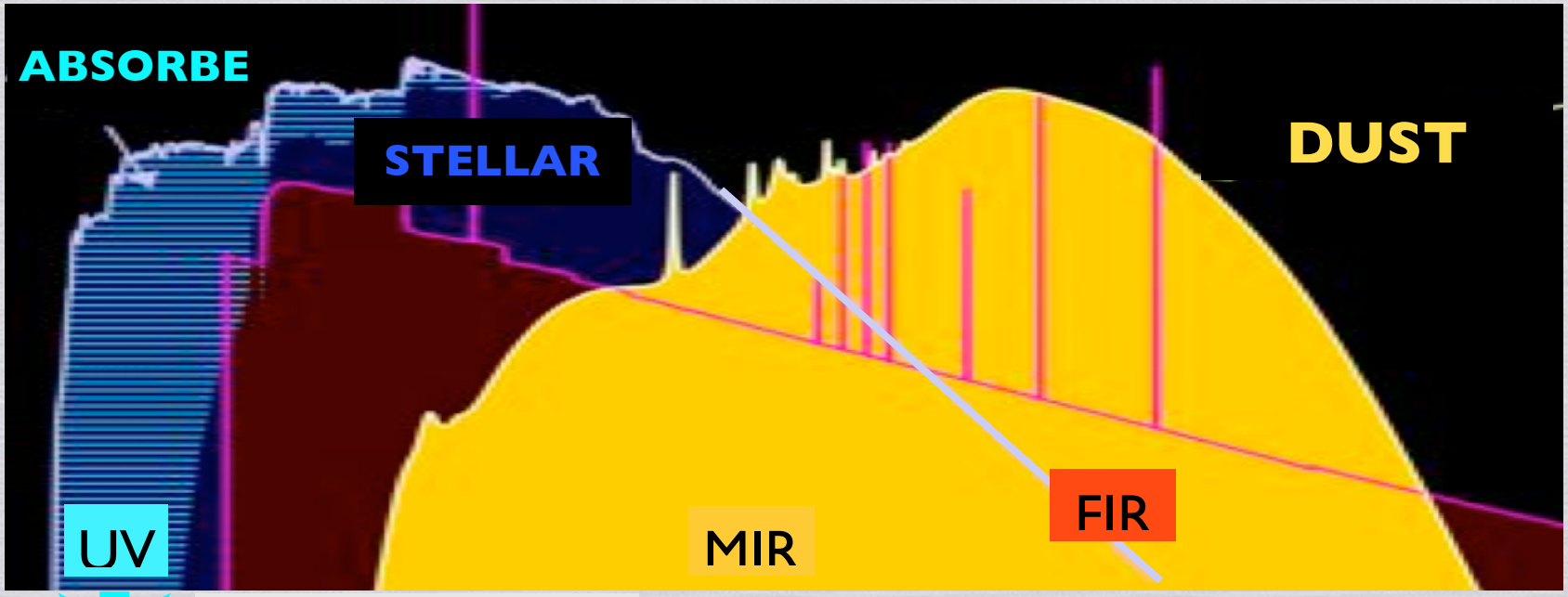
Comparison of SFR derived with SED fitting and SFR from FIR + UV

SED fitting: 0.15<λ<4.5μ + 3 Attenuation Laws

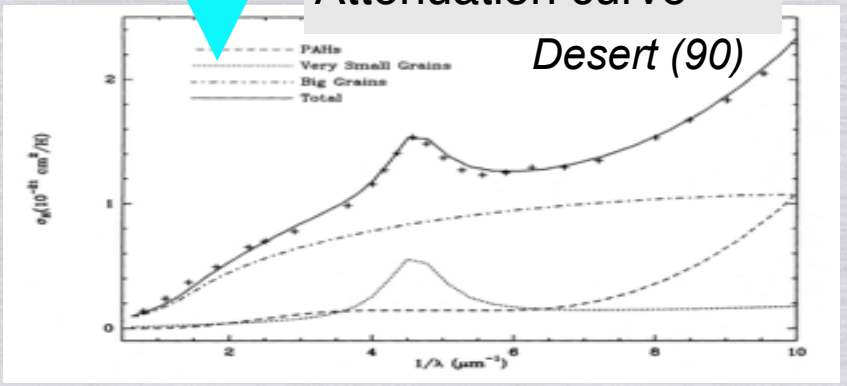
Good agreement over 3 dex of SFR.



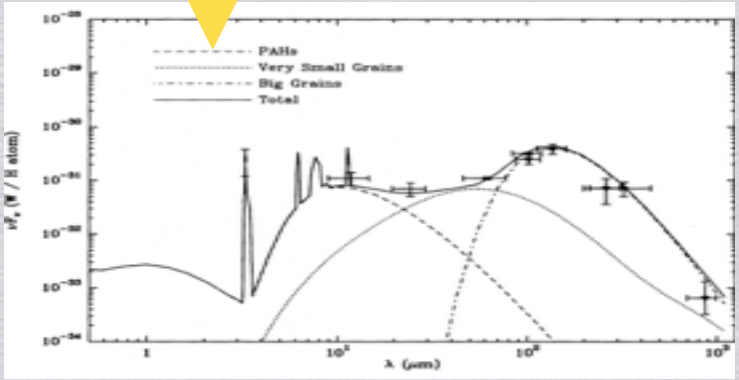
The Role of Dust



Attenuation curve



Far IR emission



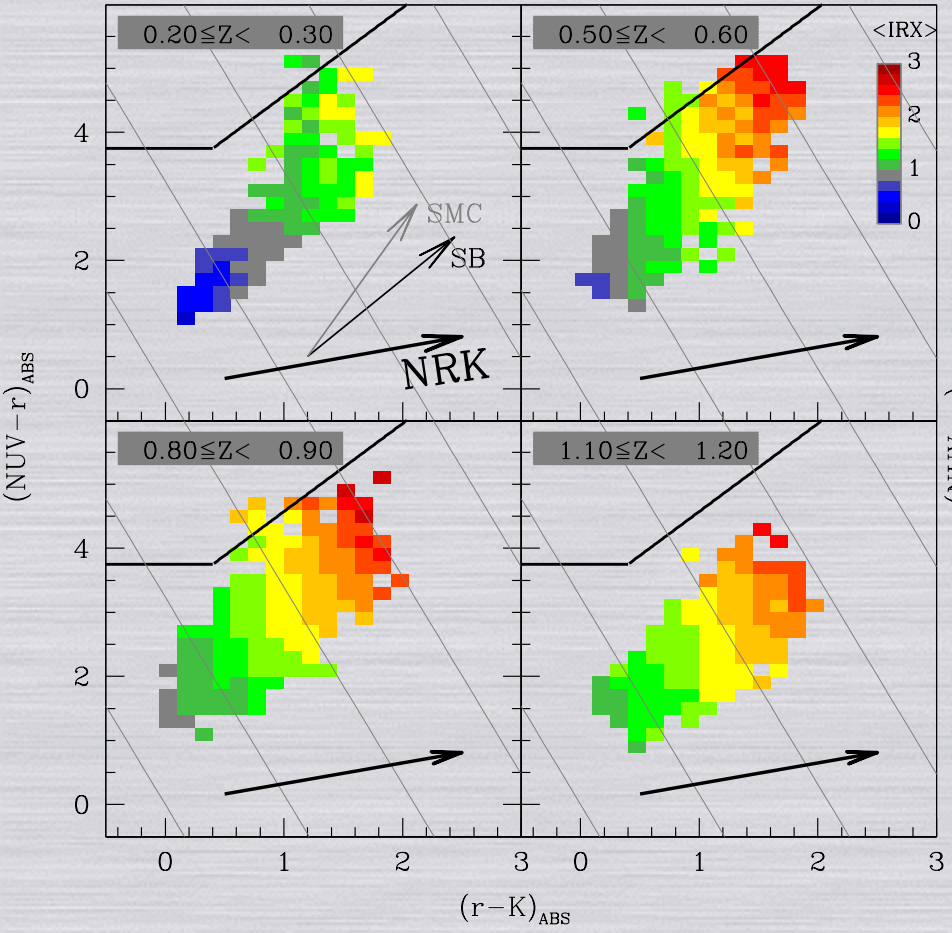
* extinction law (dust composition)
* star / dust distribution
* galaxy geometry

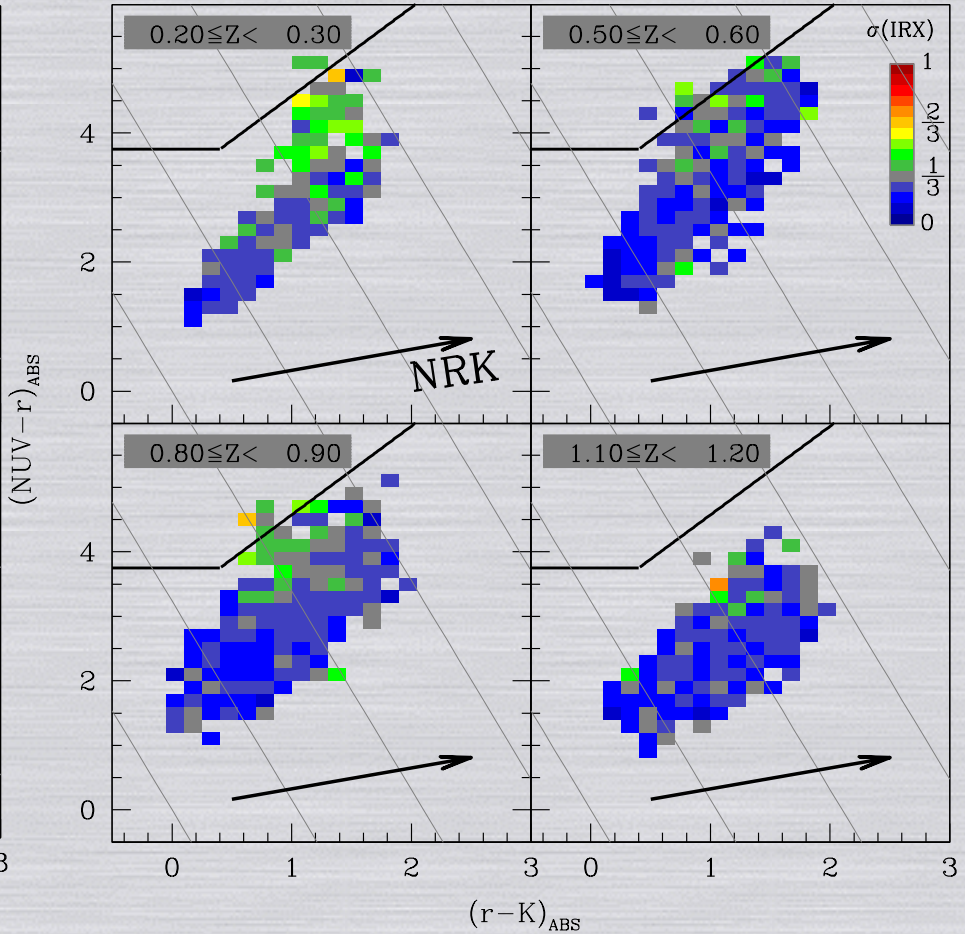
* Dust grain size + composition

Recovering the missing UV photons

Behaviour of the IRX (~L_{IR}/L_{UV}) in the NUV - r - K diagram

Arnouts, +13





a Stripes of constant IRX ⊥ NRK

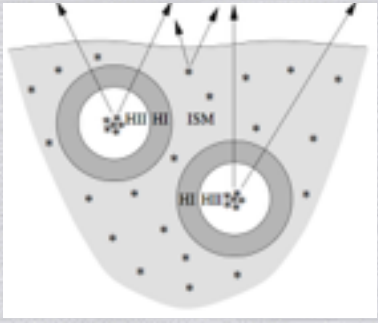
r.m.s <0.3dex

What is the origin of the IRX stripes ?

Can we understand the shape & location of the IRX ?

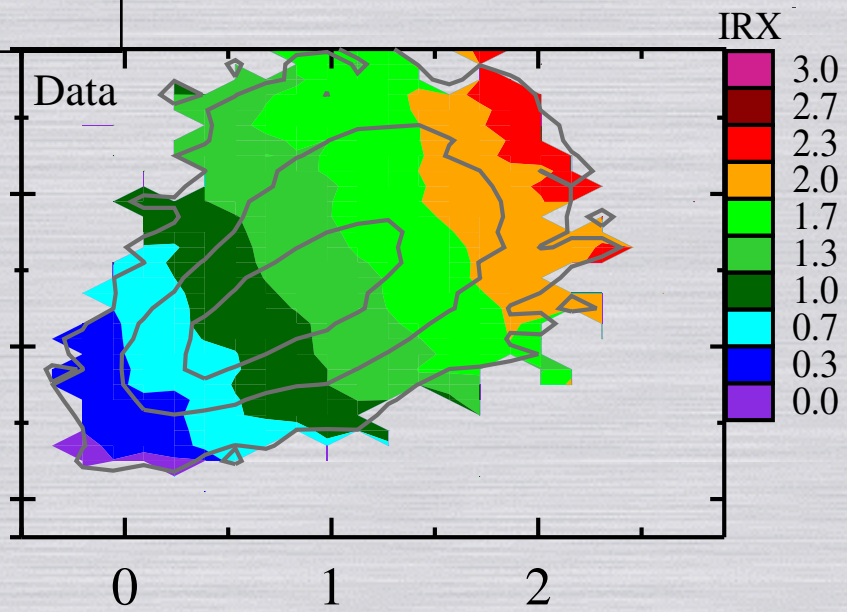
The model's ingredients :

-1- Stochastic SFH from SAM *(Pacifici, 12)* to reproduce the global sSFR distribution of 24um sample



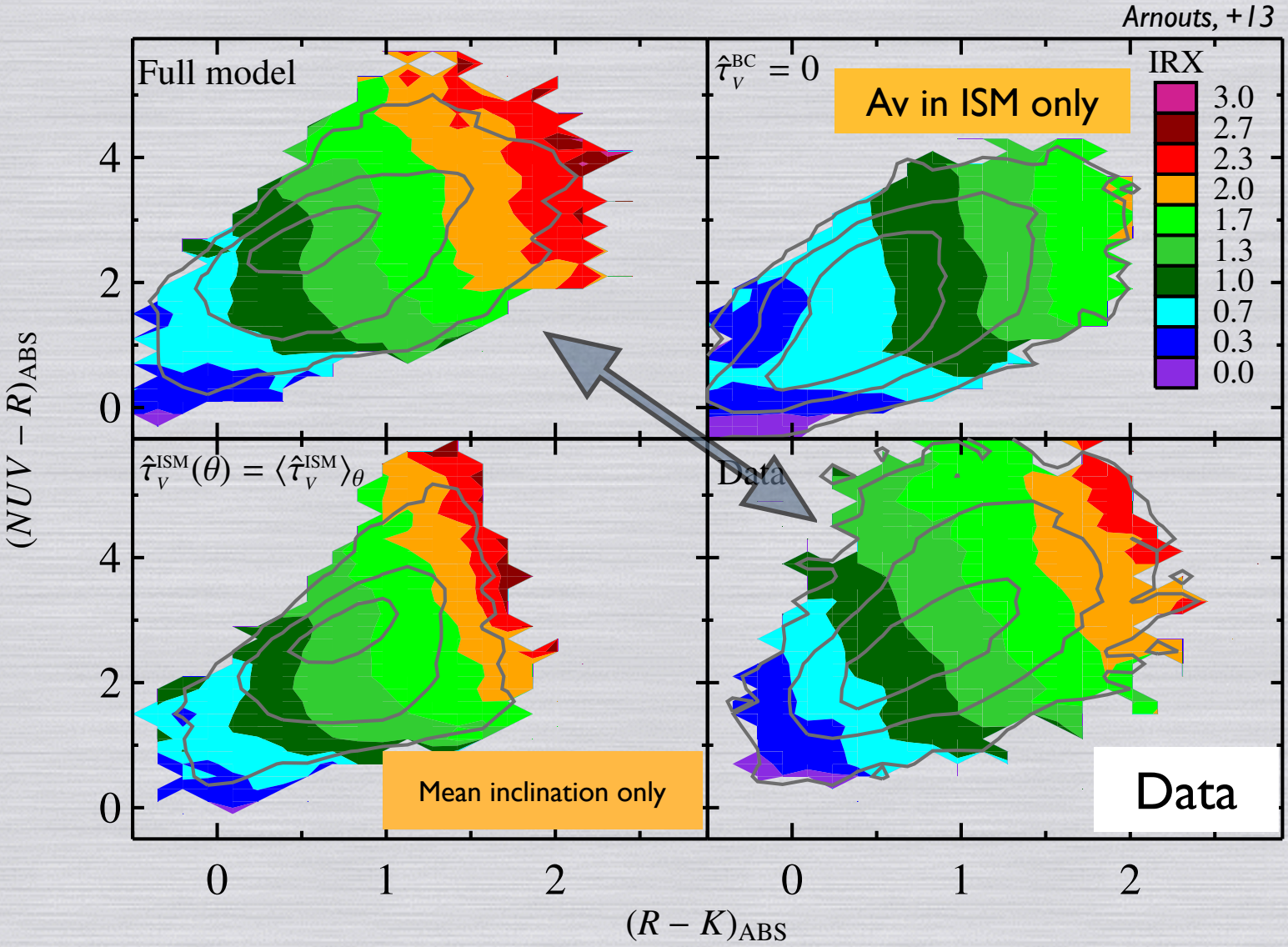
-2- Attenuation :
balance between the ambient ISM and the Birth Clouds
(Charlot & Fall, 00)

-3- Inclination effects *(Chevallard+,2013)*



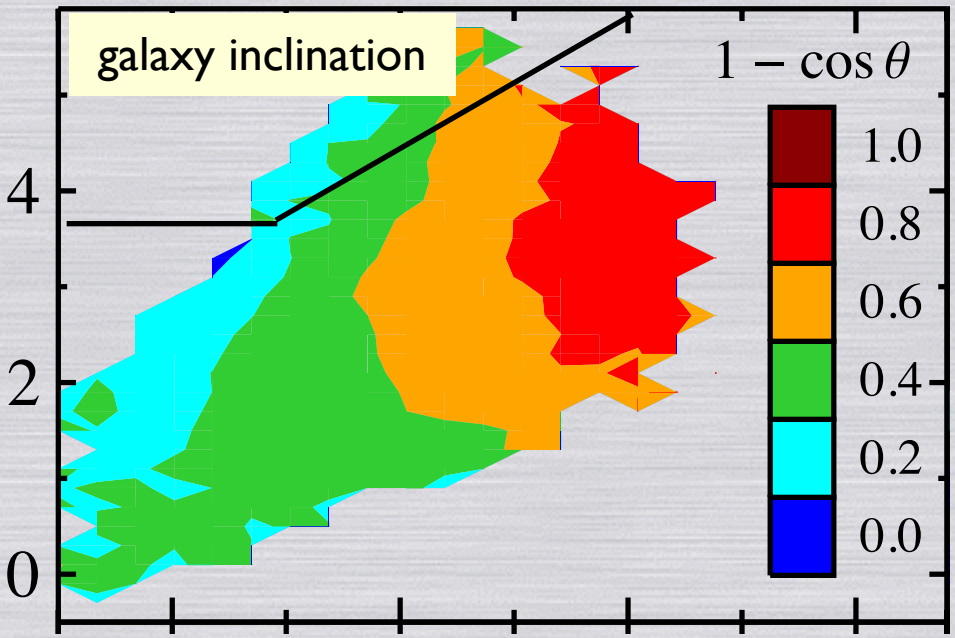
What is the origin of the IRX stripes ?

... Good modeling if we include all the ingredients !

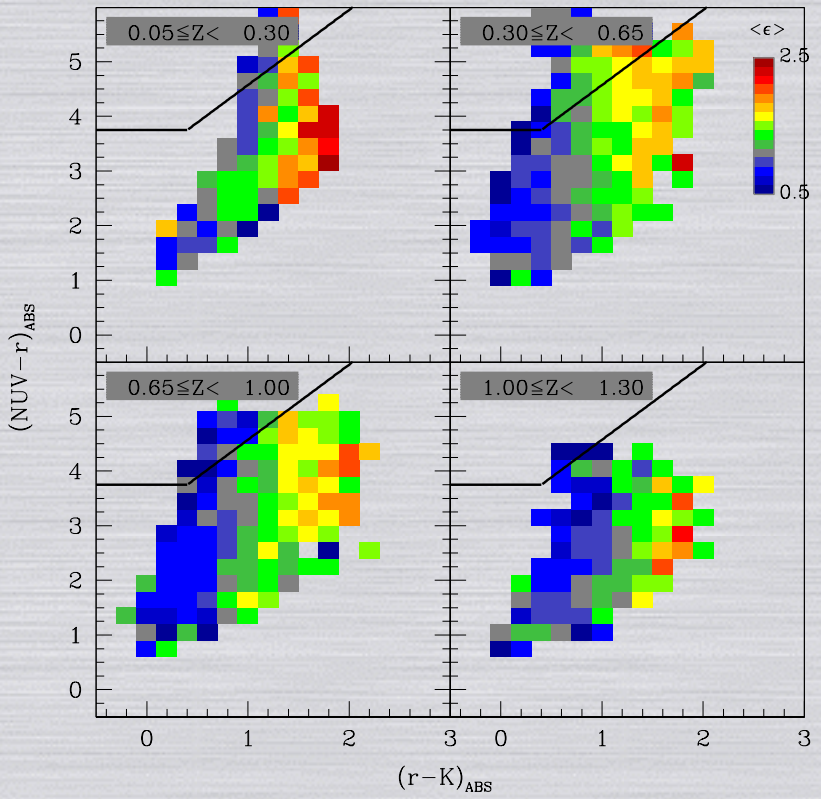


Impact of galaxy inclination

Model prediction for galaxy inclination



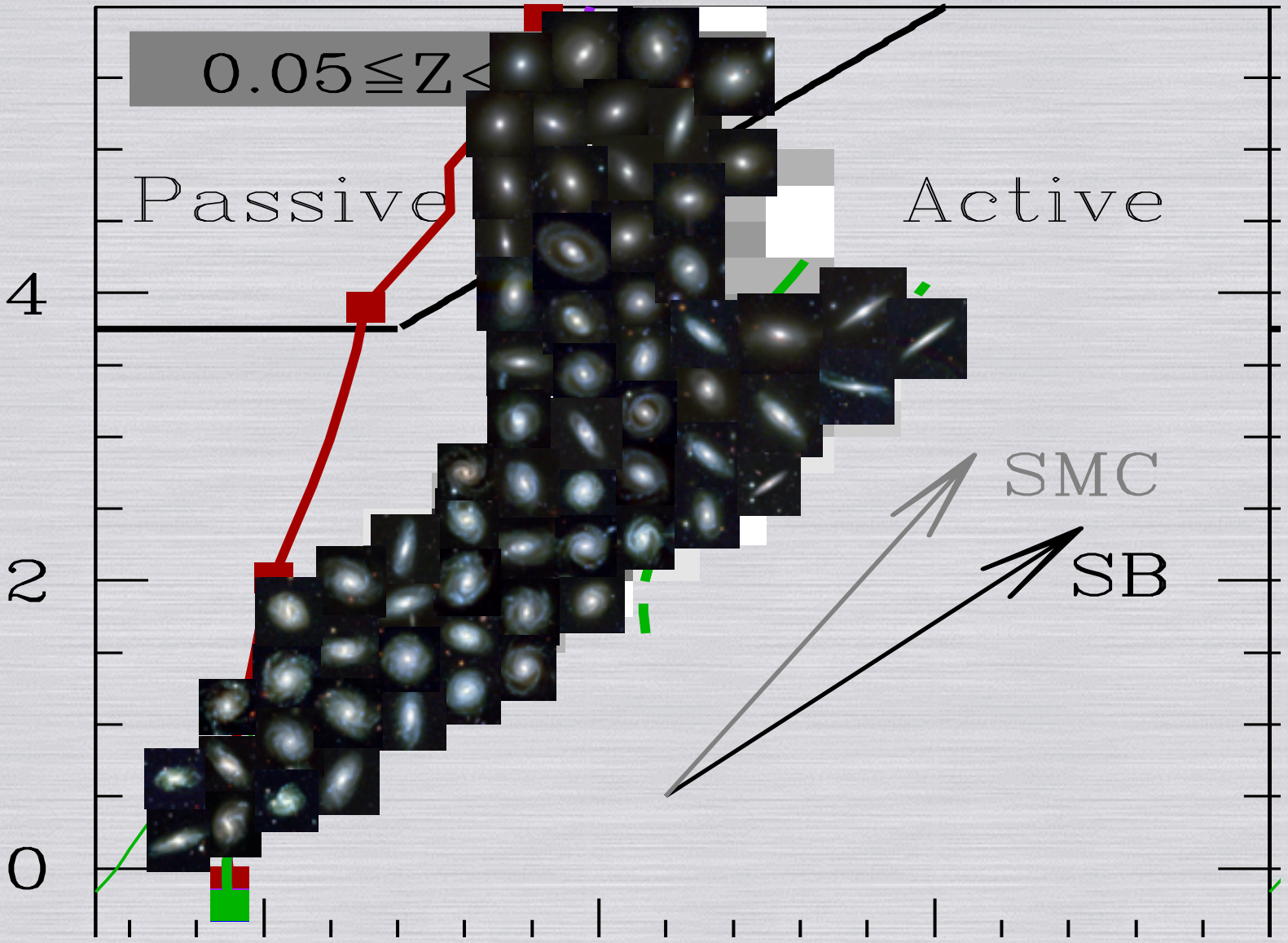
COSMOS ellipticities (Scarlatta+07)



a strong dependence with (R-K) color as observed in the data

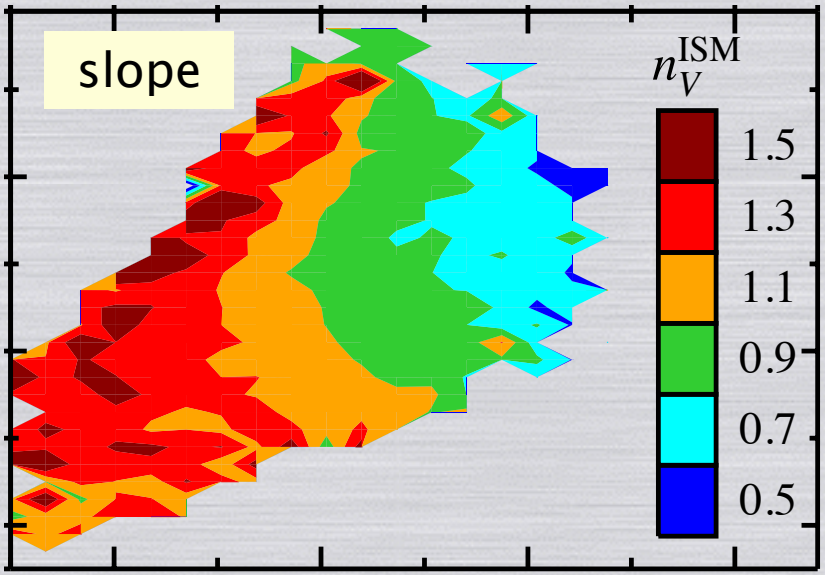
Impact of galaxy inclination

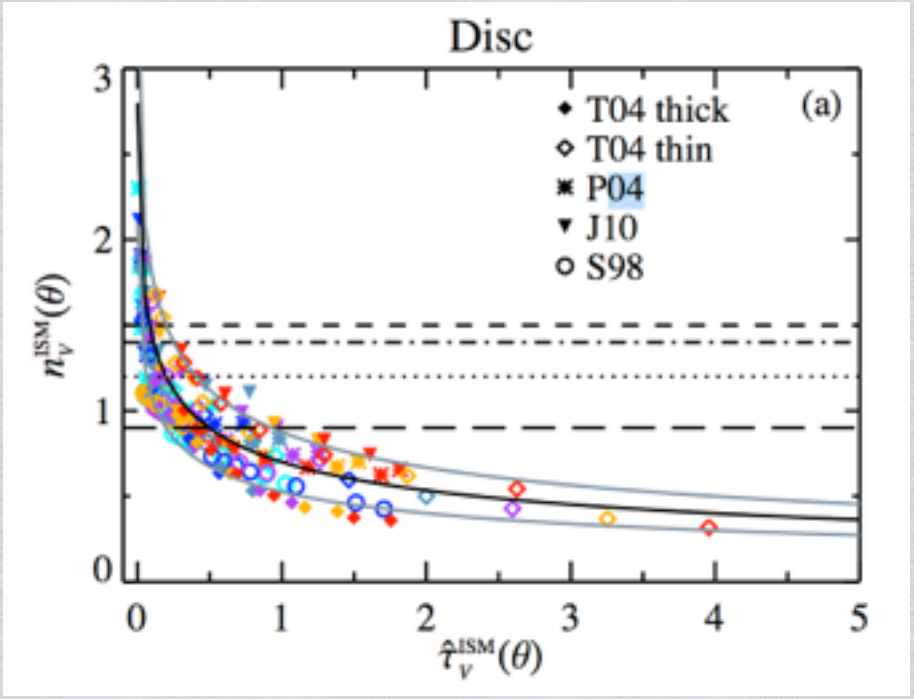
CFHTLS galaxies @ z<0.2
with STIFF U+G+I [Bertin 2006]



a new dust treatment ?

Model prediction
for the slope of the attenuation law near 5500A





Large range of slope for the attenuation curves
* steeper/shallower slopes than LMC and SB laws
* how many attenuation laws do we need ?? :-(

... BUT ...

Chevallard +, 2013 ran full set of RT models. They all predict a quasi-universal relation between slope of the attenuation curves and V-band attenuation optical depth at all galaxy inclinations

In principle, this should simplify the treatment of dust for SED fitting !

Le Phare's structure

* LePhare is defined by 2 environments :
  1 : *all the inputs, SED, filters, …*
  2 : user's env. with intermediate and final products
* it runs in command line with a configuration file
  > *easy to encapsulate in scripts*

* To get informations about your filters

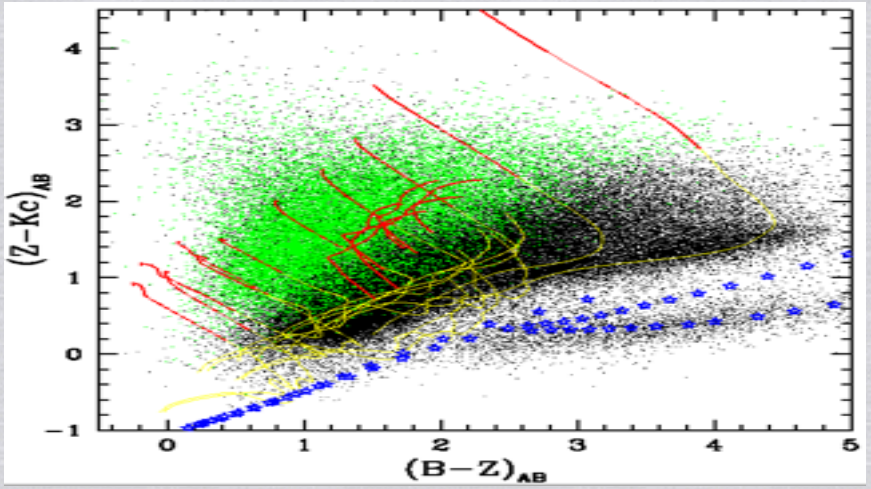
```
waimea-dhcp5:~ stephane$ filter_info -f filter_hdfn.dat
```

# NAME	IDENT	area(A)	lb_moy(A)	lb_eff(A)	FWHM(A	AB-cor	TC-cor	VEGA	M_sun(AB)
F300W	1	853,7	2998,5	2993,3	864,0	1,398	9,990	-21,152	7,433
F450W	2	875,7	4573,4	4512,5	1076,6	-0,074	-0,339	-20,609	5,255
F606W	3	1877,4	6028,1	5827,1	2033,8	0,095	0,161	-21,367	4,720
F814W	4	1445,8	8012,8	7864,4	1373,1	0,417	0,641	-22,322	4,529
Jbb	5	2034,0	12369,9	12211,7	2066,0	0,890	9,990	-23,748	4,559
H	6	3227,4	16459,9	16251,6	3377,0	1,361	9,990	-24,839	4,702
K	7	3853,8	22210,2	21971,0	3967,0	1,881	9,990	-26,012	5,178

```
waimea-dhcp5:~ stephane$ filter_extinc -f filter_hdfn.dat -e extinc_ctio.dat
 Option "-g" not defined
 Option "-o" not defined
########################################
# Computing the ATMOSPHERIC/GALACTIC EXTINCTION #
#      with the following OPTIONS       #
# FILTER_FILE : /Users/stephane/zpuork/Filt/filter_hdfn.dat
# EXT_CURVE   : /Users/stephane/lephare/ext/extinc_ctio.dat
# GAL_CURVE   : CARDELLI law
# OUTPUT      : NONE
########################################
```

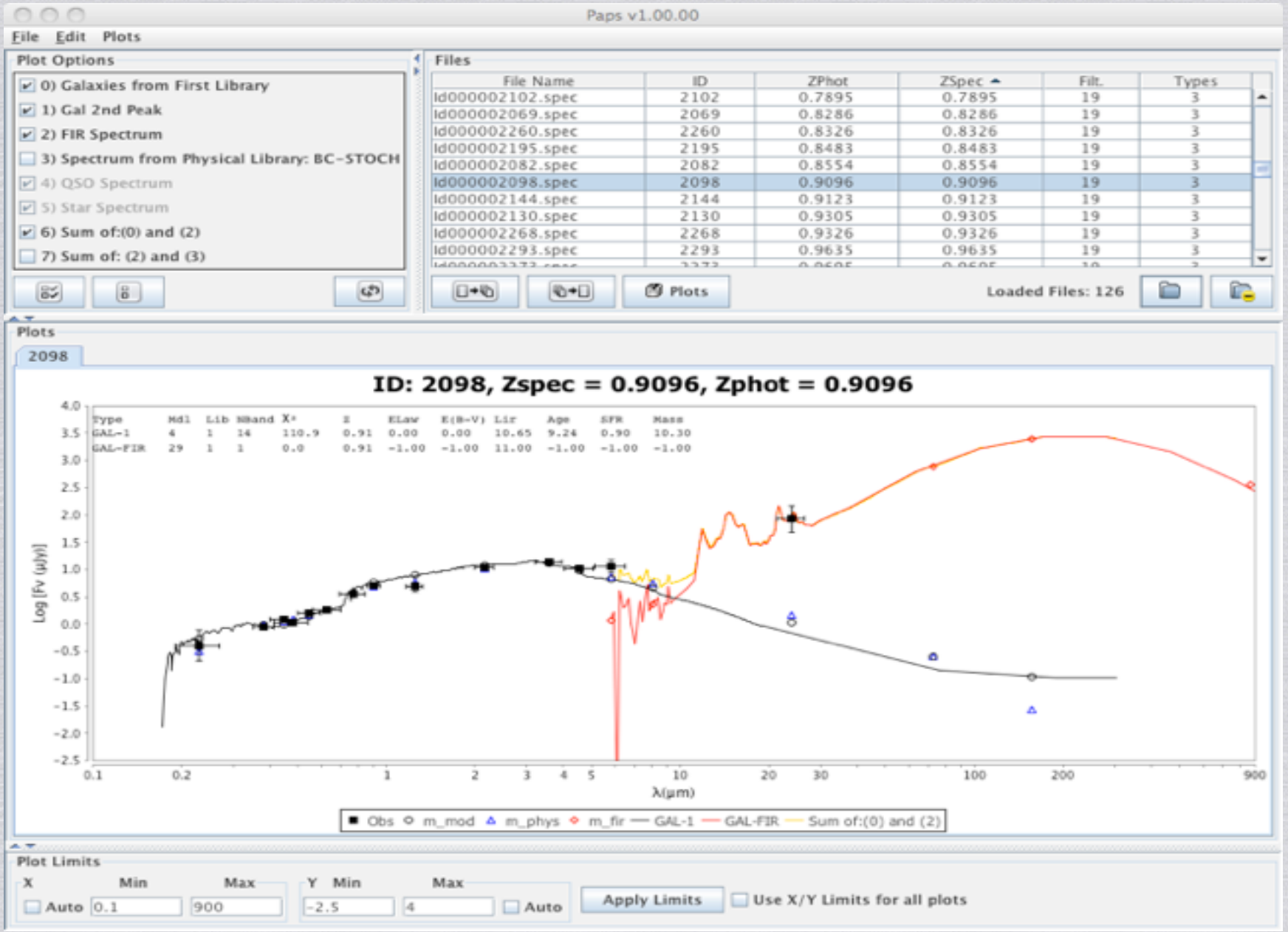
Filters	Ext(mag/airmass	Albda/Av	Albda/E(B-V)
F300W	0.718	1.905	5.904
F450W	0.266	1.266	3.924
F606W	0.132	0.913	2.831
F814W	0.051	0.604	1.873
Jbb	0.030	0.289	0.896
H	nan	0.183	0.566
K	nan	0.112	0.349

* color-color tracks for the libraries vs obs.



Visualization tool : PAPS

PArsing and Plotting Spectra *by A. Draginda (@CFHT, java script)*



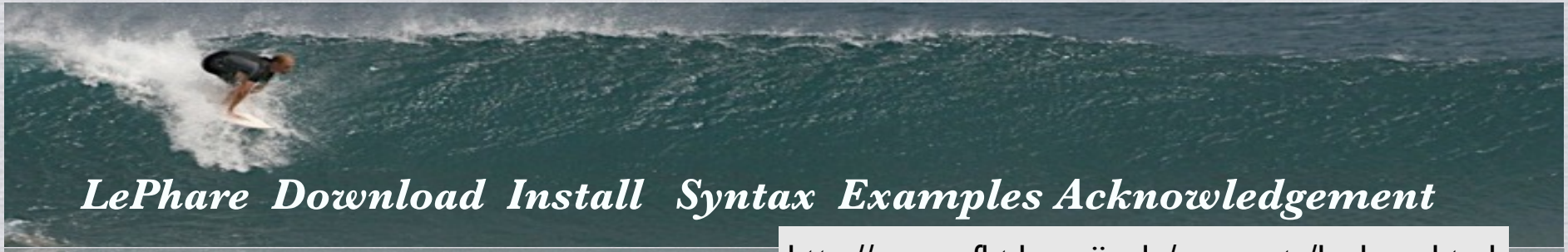
Future scientific developments

* Photo-z + Physical parameters :
  - New treatment of the dust to account for results from Chevalard+14.
    This could simplify the current modeling.

  - AGN contribution ?

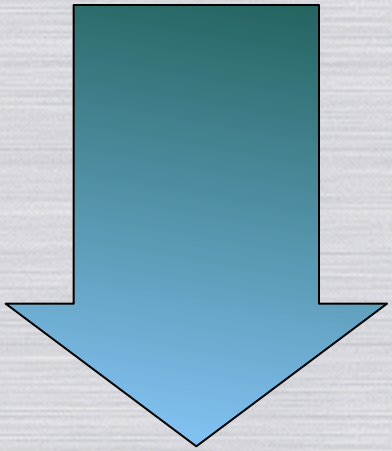
* Physical parameters
  - treat simultaneously the energy budget (FIR and UV emission)

* Extend the SED fitting to a combined approach : Photometry + Spectra



http://www.cfht.hawaii.edu/~arnouts/lephare.html

Le Phare will migrate from Hawaii to Marseille



http://www.lam.fr/lephare.html