A simple model to constrain galaxy properties from their UV, optical and IR SEDs

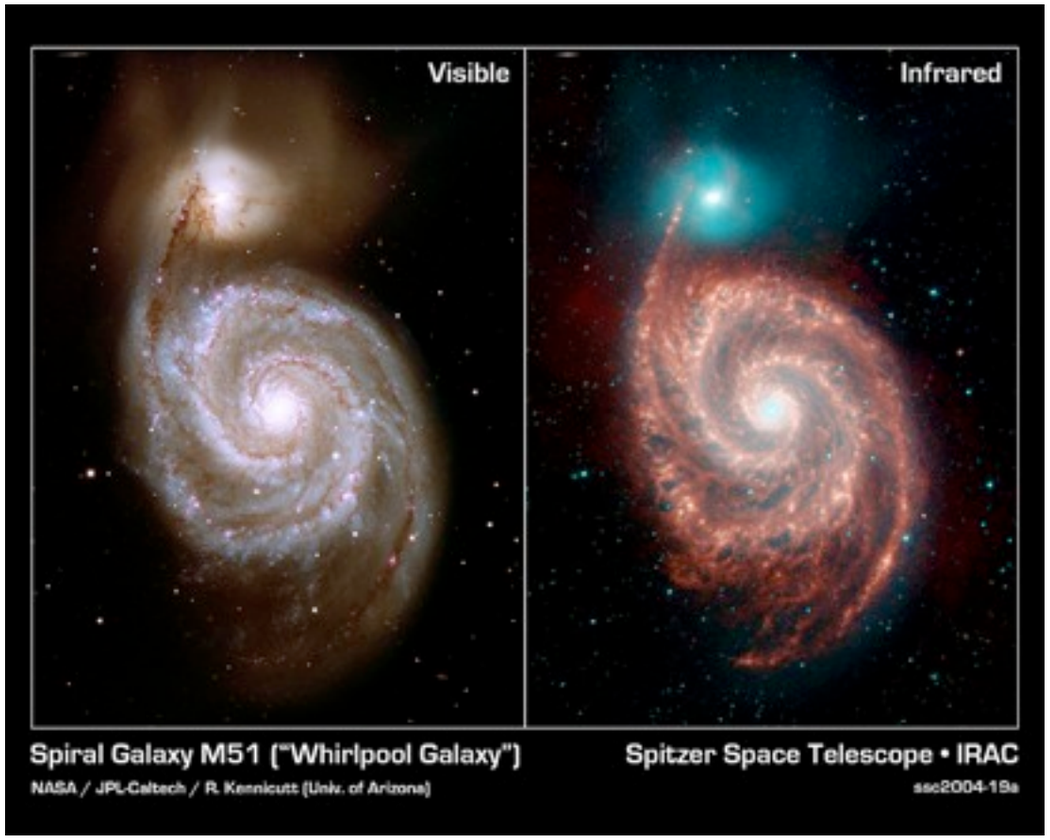


Elisabete da Cunha
MPIA Heidelberg

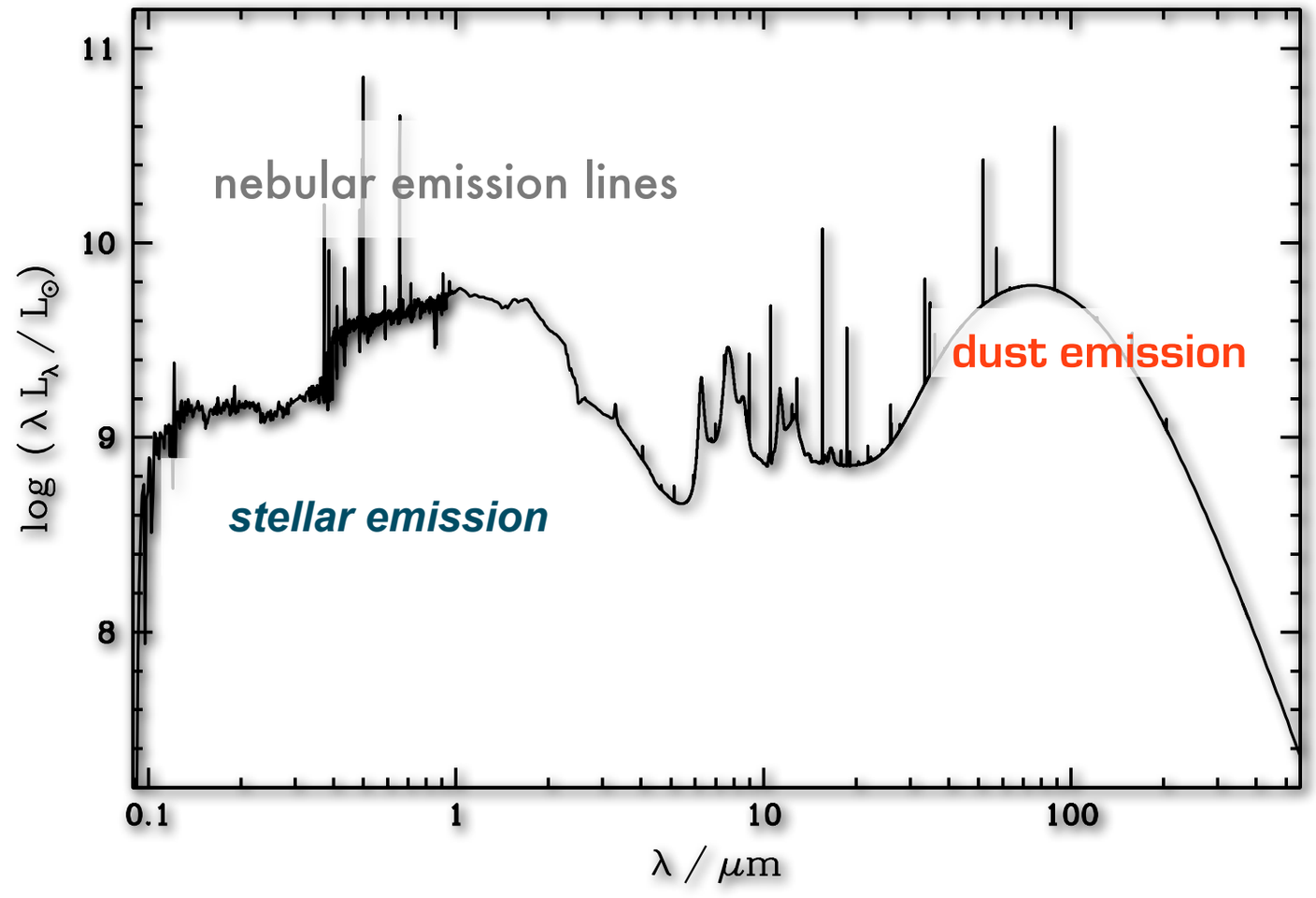
cunha@mpia.de

Stéphane Charlot (IAP), **David Elbaz** (CEA),
Loretta Dunne (Nottingham), **Dan Smith** (Nottingham),
Kate Rowlands (Nottingham), **Haley Gomez** (Cardiff)

Star Formation in Galaxy Clusters, Nice - June 6th & 7th 2011



Interpreting Galaxy Spectral Energy Distributions



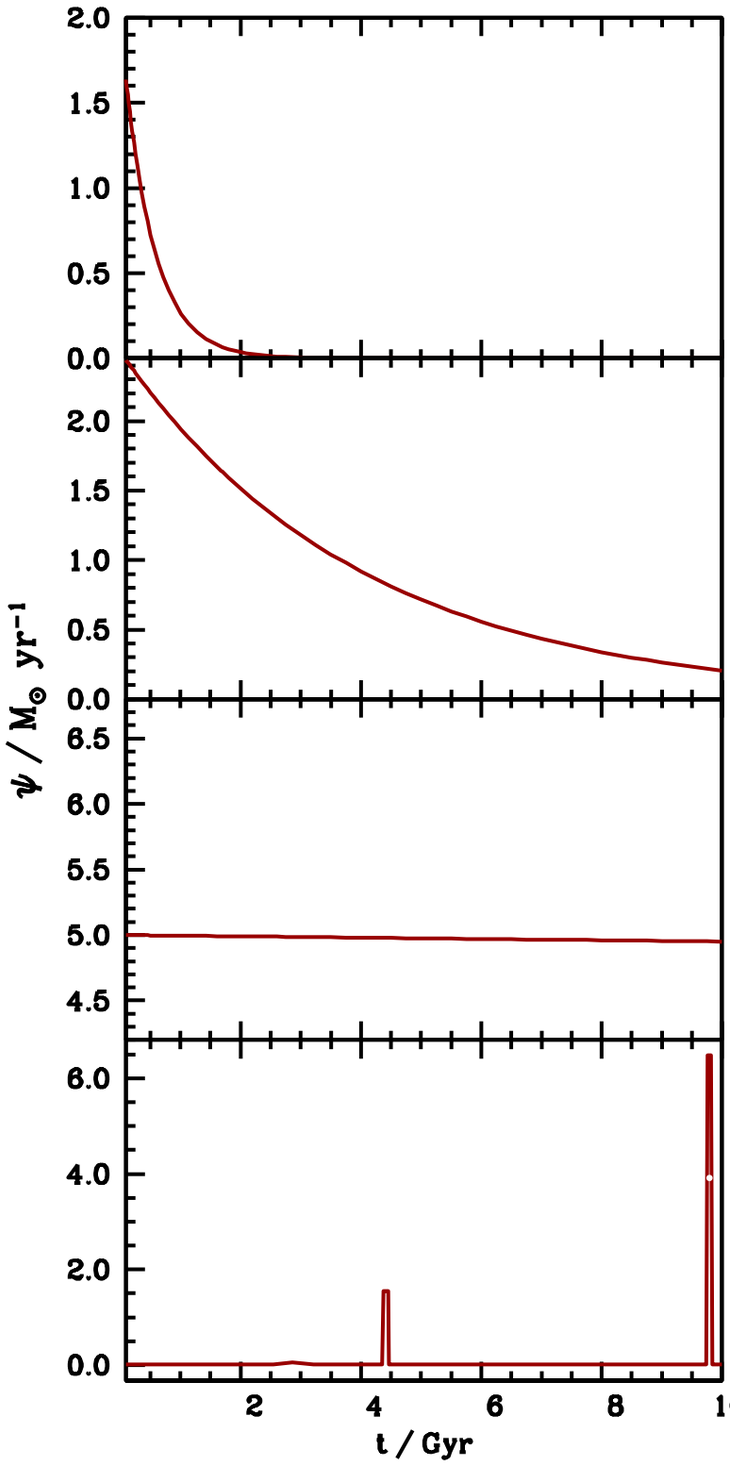
Physical properties of galaxies?
(SFR, stellar mass, dust content...)

Interpret the light emitted by galaxies in terms of physical parameters

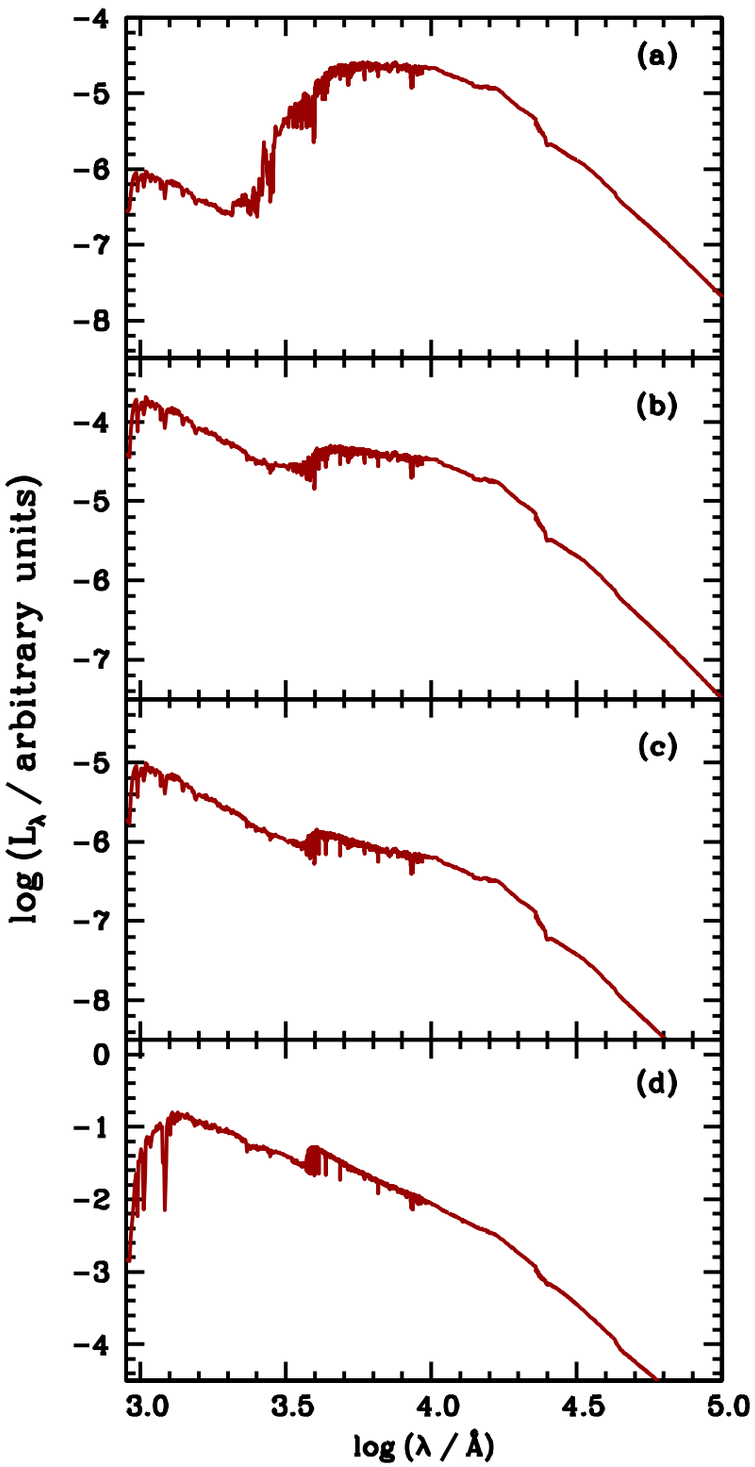
Spectral Energy Distribution Modelling: UV + optical + IR

Emission From Stellar Populations

Star formation history



Total SED at 10 Gyr

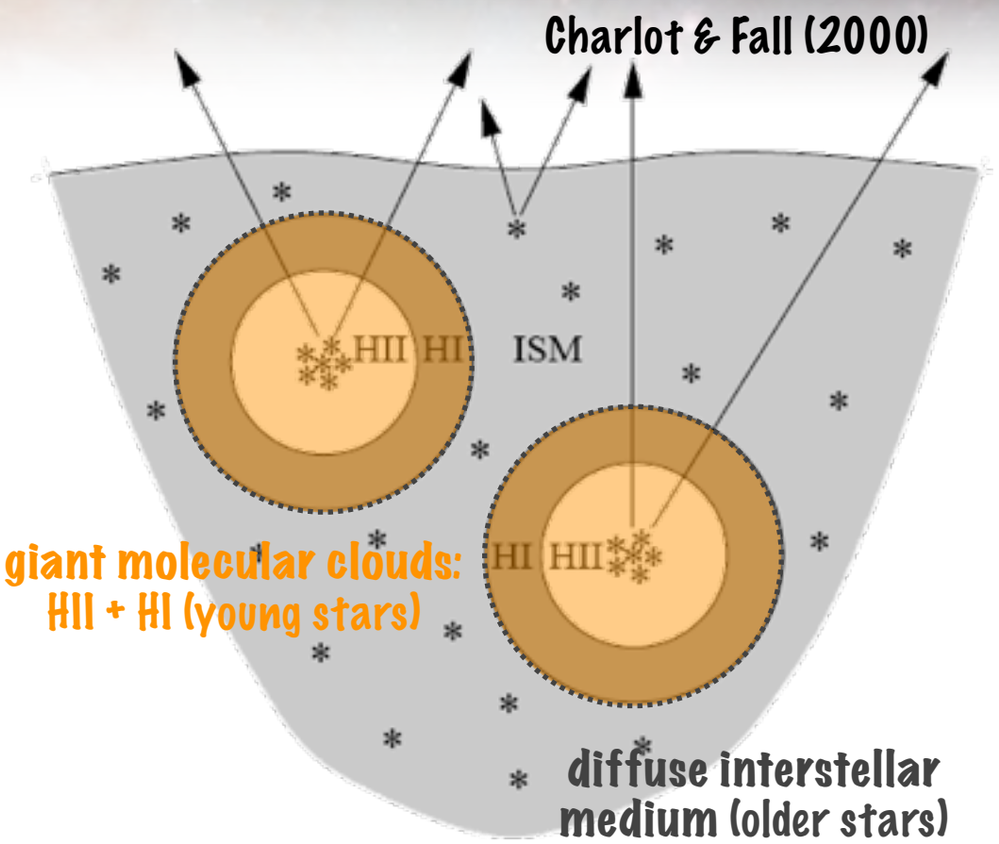


- Latest version of Bruzual & Charlot spectral synthesis models: CB07; improved treatment of TP-AGB stars
- Chabrier IMF
- Main adjustable parameters:
  - age
  - star formation history: exponentially declining + bursts
  - metallicity

The Effect of Dust on SEDs

- Stars are born in dense molecular clouds (birth clouds), which have a lifetime t_{BC}.

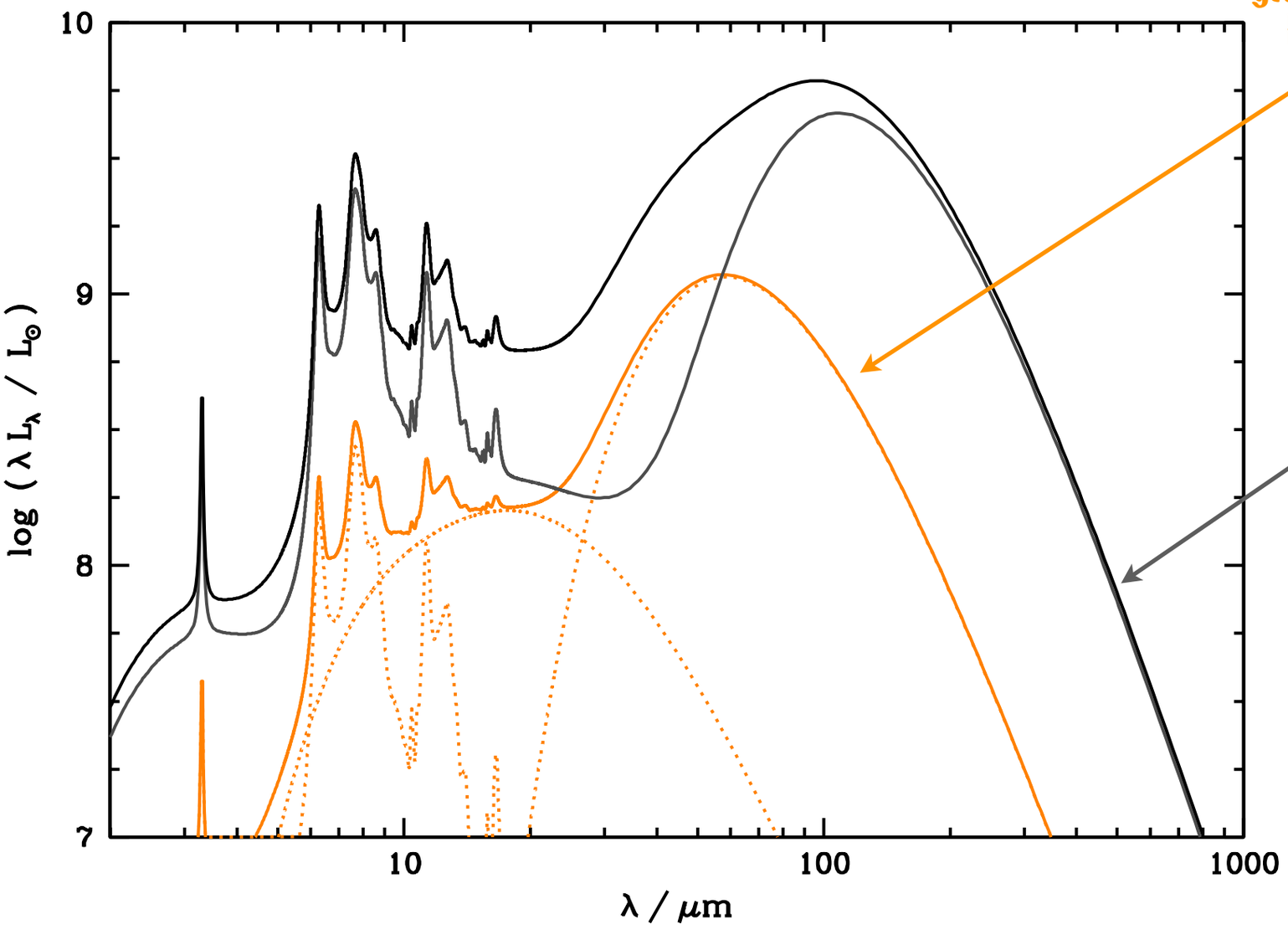
- Attenuation affecting stars older than t_{BC} in the diffuse ISM is only a fraction of that affecting young stars in the birth clouds.

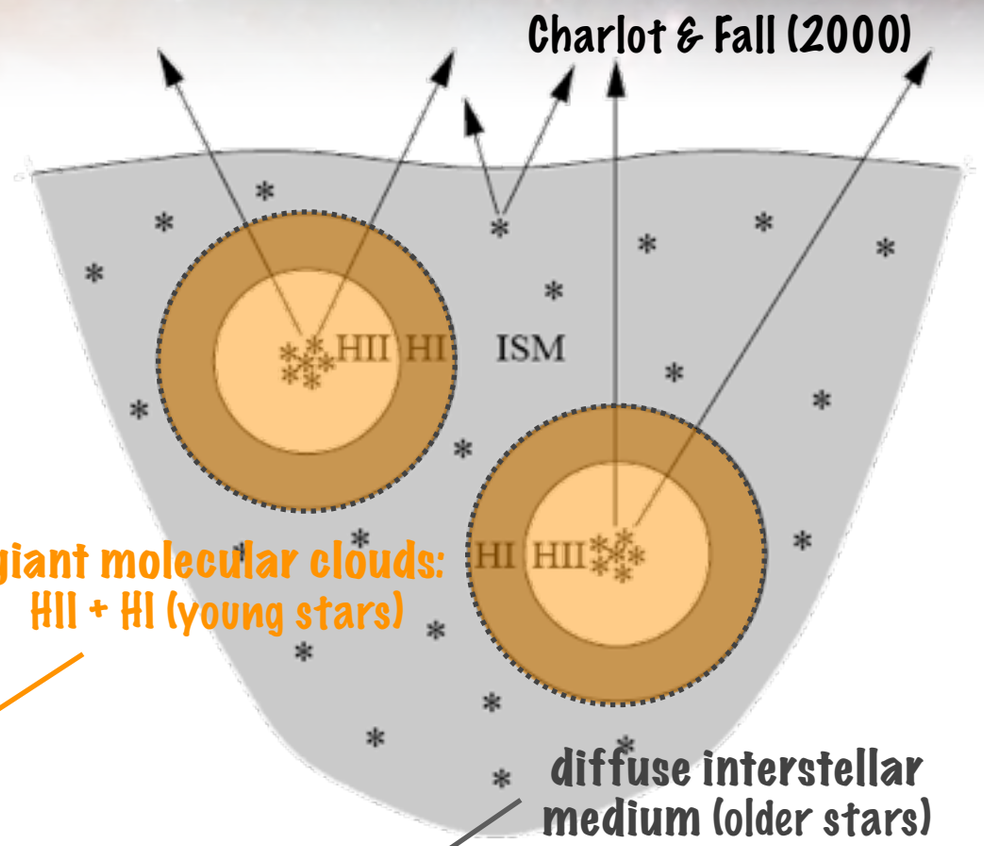


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- Energy balance: Luminosity absorbed by dust is re-radiated in the infrared.

- Dust components:

- PAHs,
- Hot mid-IR continuum,
- Warm dust in thermal equilibrium,
- Cold dust in thermal equilibrium (only diffuse ISM).

Statistical Constraints of Physical Parameters

MODEL PARAMETERS → PRIOR DISTRIBUTIONS → STOCHASTIC MODEL LIBRARIES

STOCHASTIC MODEL LIBRARIES → MODEL SEDs

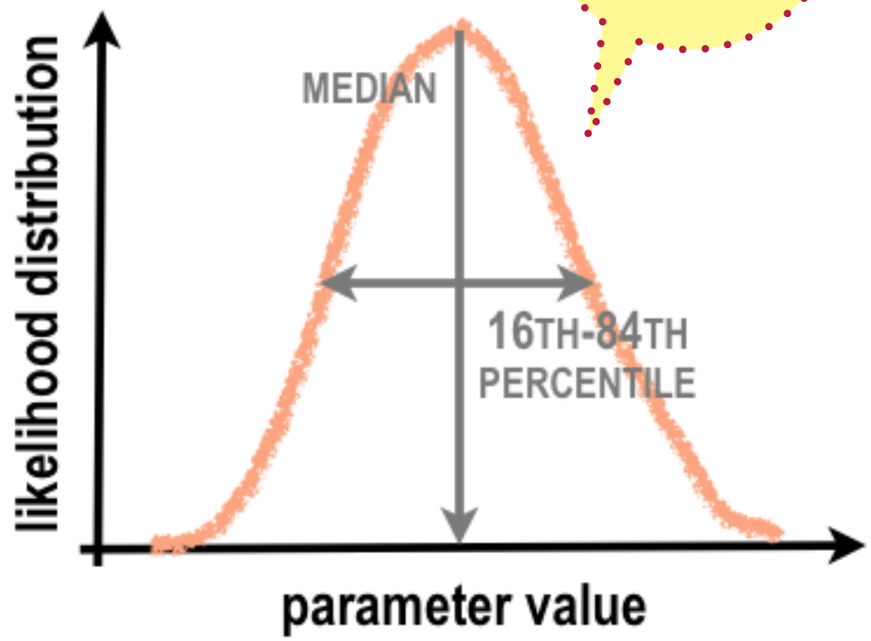
OBSERVED GALAXY SED ↔ COMPUTE CHI2 EACH MODEL ↔ MODEL SEDs

robust parameter estimate + error bar!

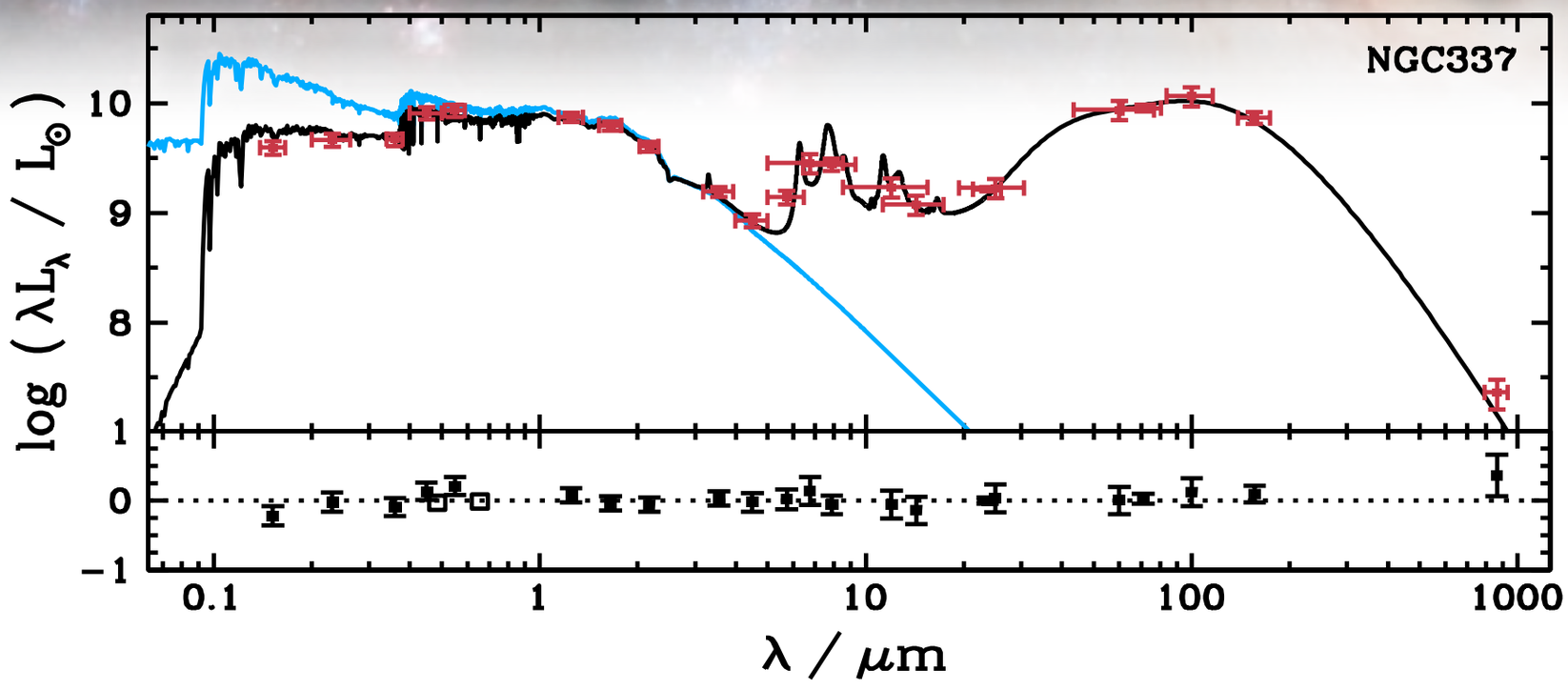
For a given model j described by a random set of parameters:

$$\chi_j^2 = \sum_{i=1}^{N_{\rm obs}} \left(\frac{L_i^{\rm obs} - a_j \times L_j^{\rm mod}}{\sigma_i^{\rm obs}} \right)^2$$

P=EXP(-1/2 CHI2), MARGINALISE



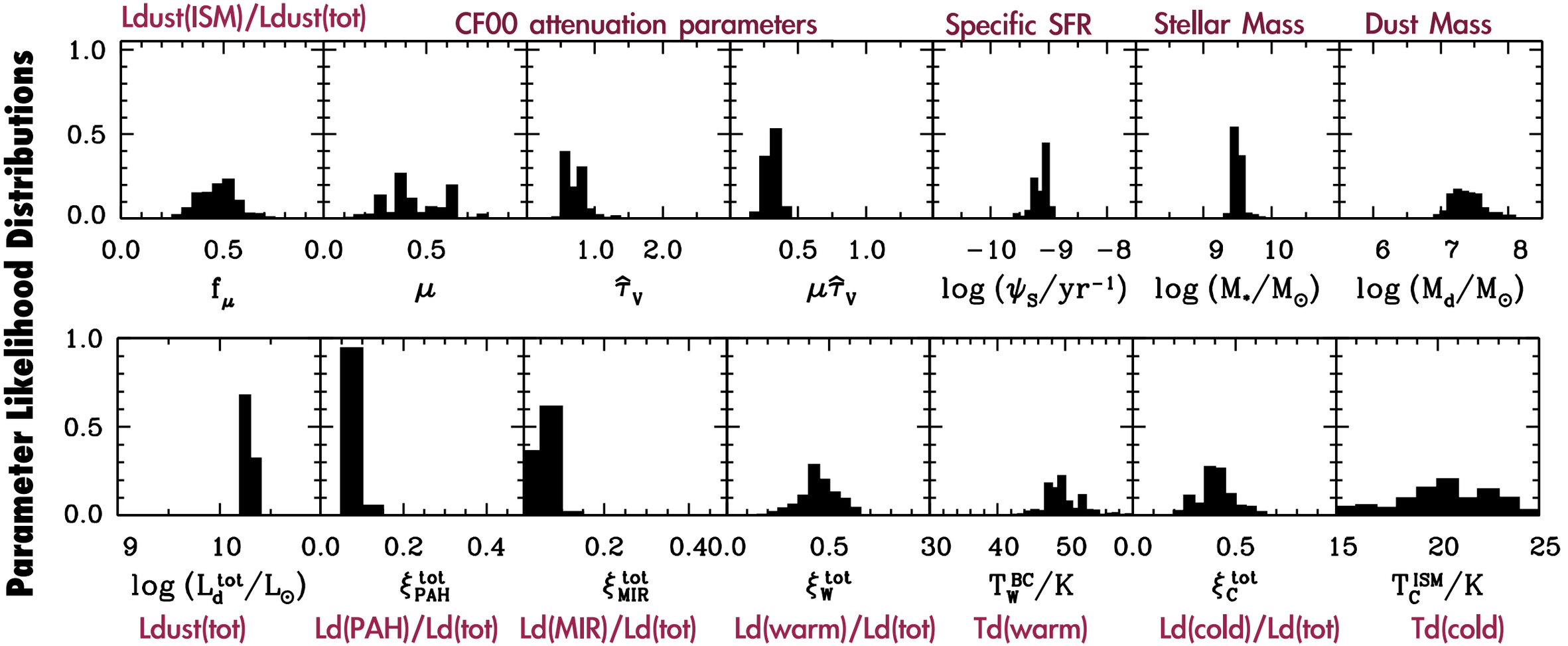
Example: SINGS Local Spiral NGC 337



da Cunha, Charlot & Elbaz (2008)



SINGS Team



MAGPHYS Code

New!

- **MAGPHYS - Multi-wavelength Analysis of Galaxy Physical Properties**

- **User-friendly code publicly available online at**

www.iap.fr/magphys

- **User Input: - catalogue with galaxy redshifts & fluxes**
  - list of photometric bands

- **Output: - best-fit ultraviolet-to-infrared SED**
  - likelihood distributions of physical parameters

MAGPHYS: HowTo

New!

(1) Go to www.iap.fr/magphys and download package

(2) Setup your MAGPHYS directory / compile Fortran code

(3) Prepare user input files

(4) Run MAGPHYS!

MAGPHYS: HowTo

New!

filters.dat

#name	lambda_eff	filter_id	fit?
U	0.346	222	1
B	0.460	223	1
V	0.538	224	1
R	0.652	225	1
I	0.866	226	1
z	0.906	227	1
J	1.20	120	1
Ks	2.20	122	1
IRAC1	3.56	153	1
IRAC2	4.51	154	1
IRAC3	5.76	155	1
IRAC4	8.00	156	1
IRS16	16.	200	1
MIPS24	24.	157	1
MIPS70	70.	158	1
PACS100	100.	170	1
PACS160	160.	171	1
SPIRE250	250.	172	1
SPIRE350	350.	173	1
SPIRE500	500.	174	1

Filter file

d download package

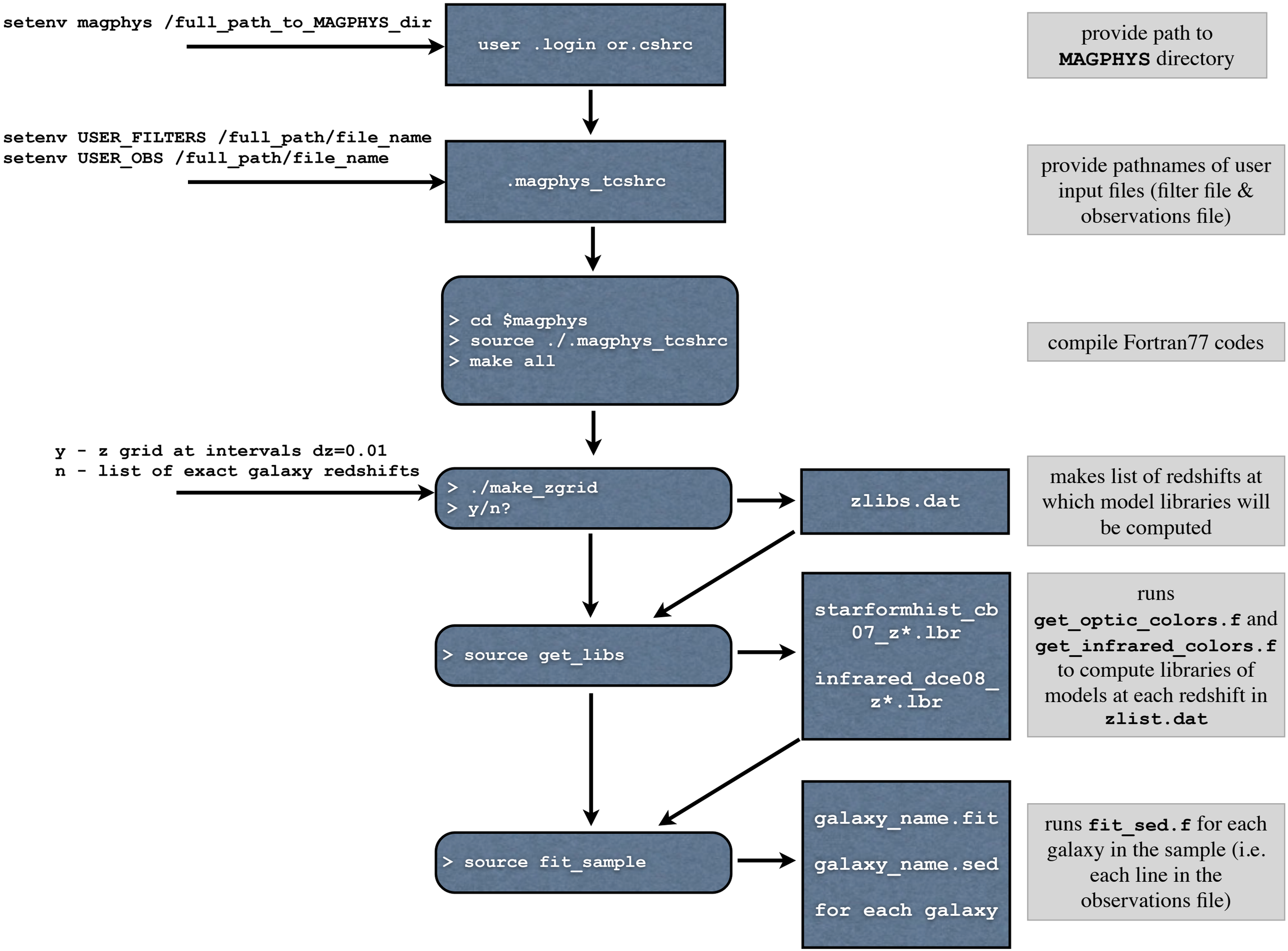
ry / compile Fortran

(4) Run MAGPHYS!

observations.dat

#name	z	F_U(Jy)	sigmaF_U(Jy)	F_B(Jy)	sigmaF_B(Jy)	F_V(Jy)	sigmaF_V(Jy)	F_R(Jy)	sigmaF_R(Jy)
source 1	0.45642	3.733E-06	3.731E-07	5.200E-06	1.537E-07	9.727E-06	2.725E-07	1.837E-05	5.145E-07

Observations file


setenv magphys /full_path_to_MAGPHYS_dir
user .login or.cshrc
provide path to MAGPHYS directory
setenv USER_FILTERS /full_path/file_name
setenv USER_OBS /full_path/file_name
.magphys_tcshrc
provide pathnames of user input files (filter file & observations file)
> cd $magphys
> source ./.magphys_tcshrc
> make all
compile Fortran77 codes
y - z grid at intervals dz=0.01
n - list of exact galaxy redshifts
> ./make_zgrid
> y/n?
zlibs.dat
makes list of redshifts at which model libraries will be computed
> source get_libs
starformhist_cb07_z*.lbr
infrared_dce08_z*.lbr
runs get_optic_colors.f and get_infrared_colors.f to compute libraries of models at each redshift in zlist.dat
> source fit_sample
galaxy_name.fit
galaxy_name.sed
for each galaxy
runs fit_sed.f for each galaxy in the sample (i.e. each line in the observations file)

H-ATLAS

PIs: S. Eales (Cardiff) &
L. Dunne (Nottingham)

- Herschel Open Time Key Project (Eales et al. 2010)
- Will be the largest survey performed with Herschel (550 sq. deg.)
- Shallow survey in 5 bands PACS & SPIRE: 100, 160, 250, 350 & 500 μm (5sigma limits: 132, 126, 32, 37 & 45 mJy)
- Ancillary UV, Optical and NIR photometry

SDP field (14.4 sq. deg.):
~1500 galaxies @ z<0.5, 250μm-selected,

ancillary UV-optical-NIR data from GAMA (Driver et al. 2010)

www.h-atlas.org

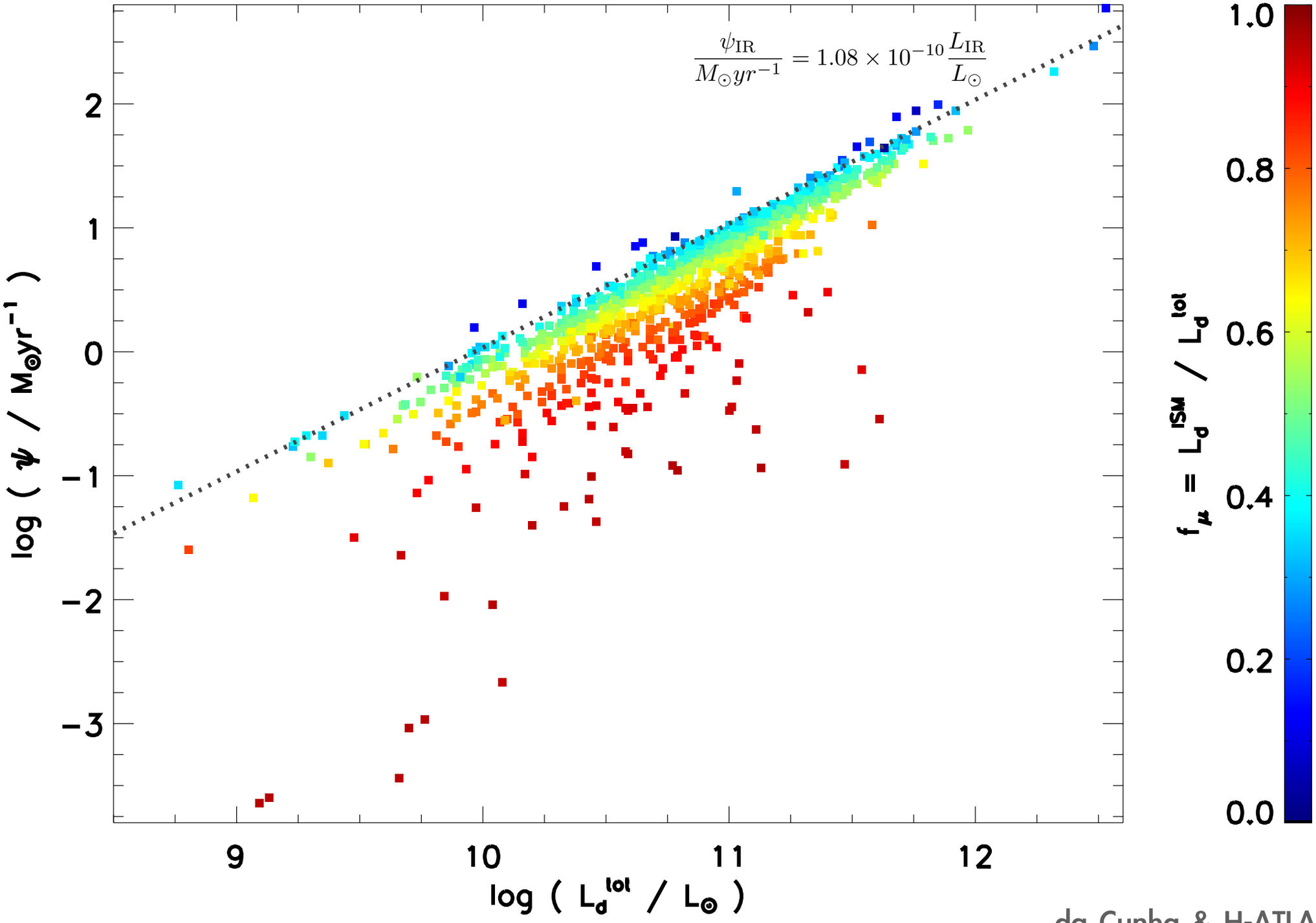
Median Properties of H-ATLAS z<0.5 Galaxies

redshift	0.24
SFR	5 Msun/yr
Stellar mass	10^10.5 Msun
V-band attenuation	0.7 mag
Dust luminosity	10^10.9 Lsun
Dust mass	10^8.16 Msun
Ldust(ISM)/Ldust(total)	0.56

Smith et al., in prep.

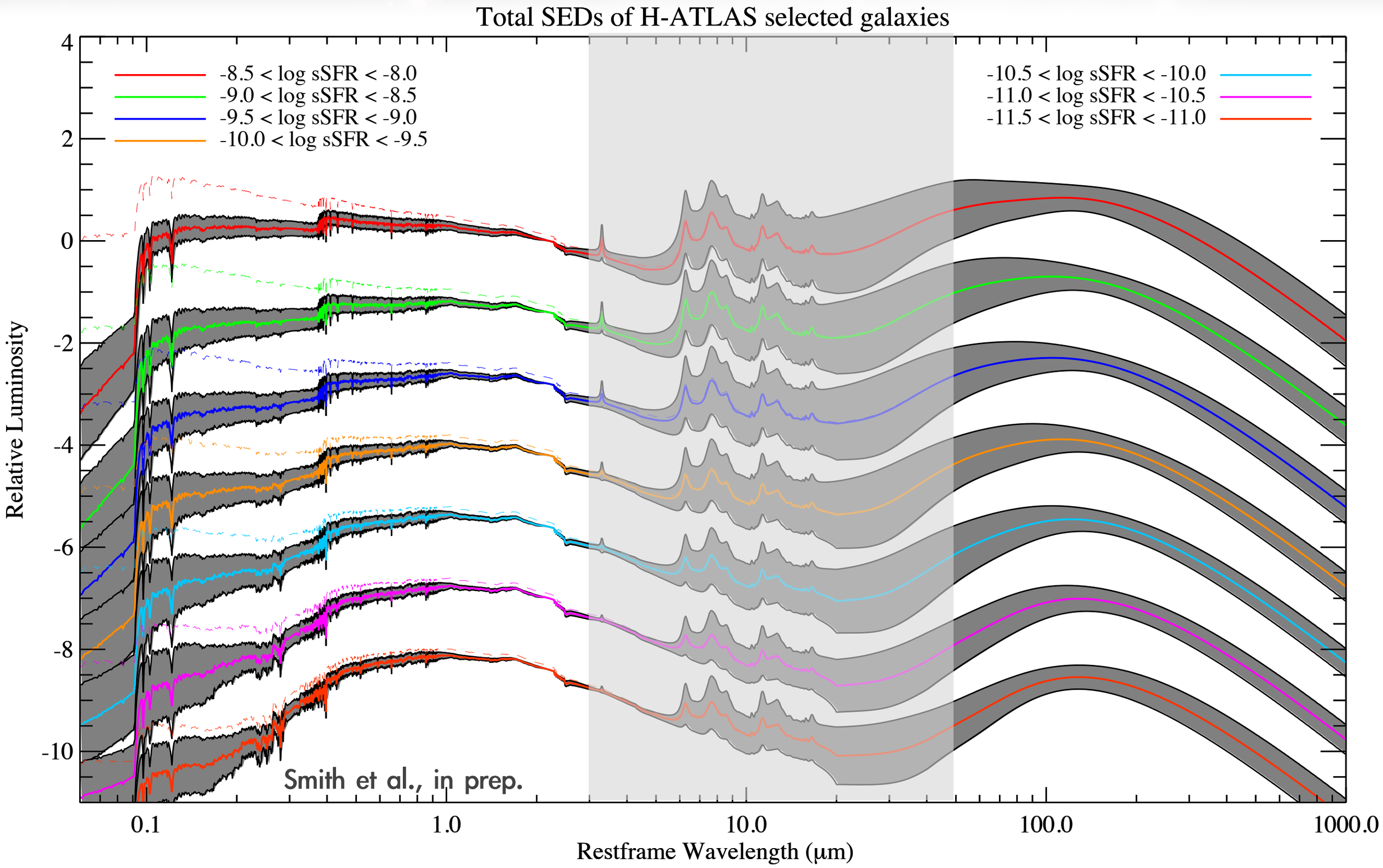
Total IR Luminosity & SFR

- Dust heating by old stellar populations (see also e.g. Sauvage & Thuan 92, Xu & Helou 96, Bendo et al. 2010).

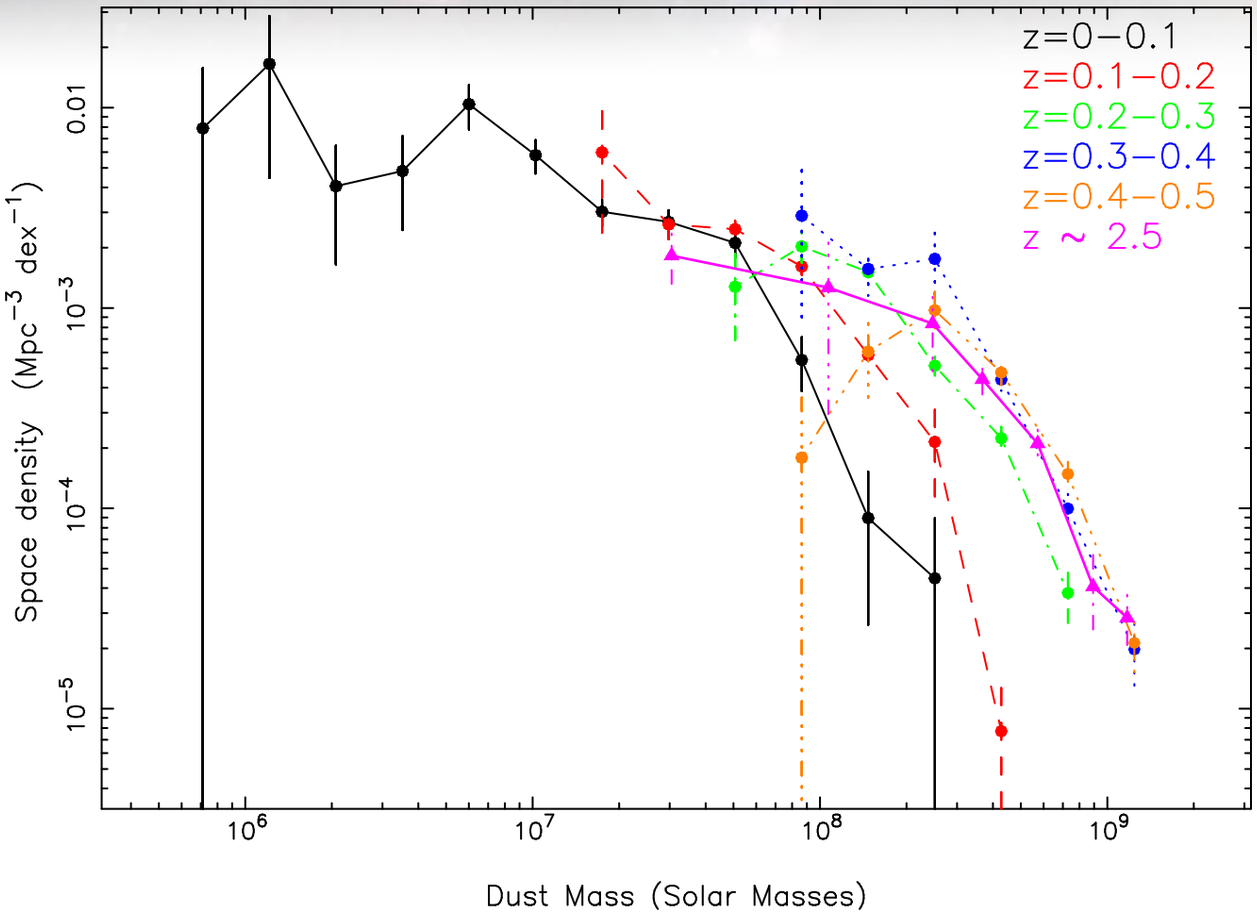


da Cunha & H-ATLAS team, in prep.

SED Shapes of H-ATLAS Galaxies



Evolution Of The Dust Content Of Galaxies

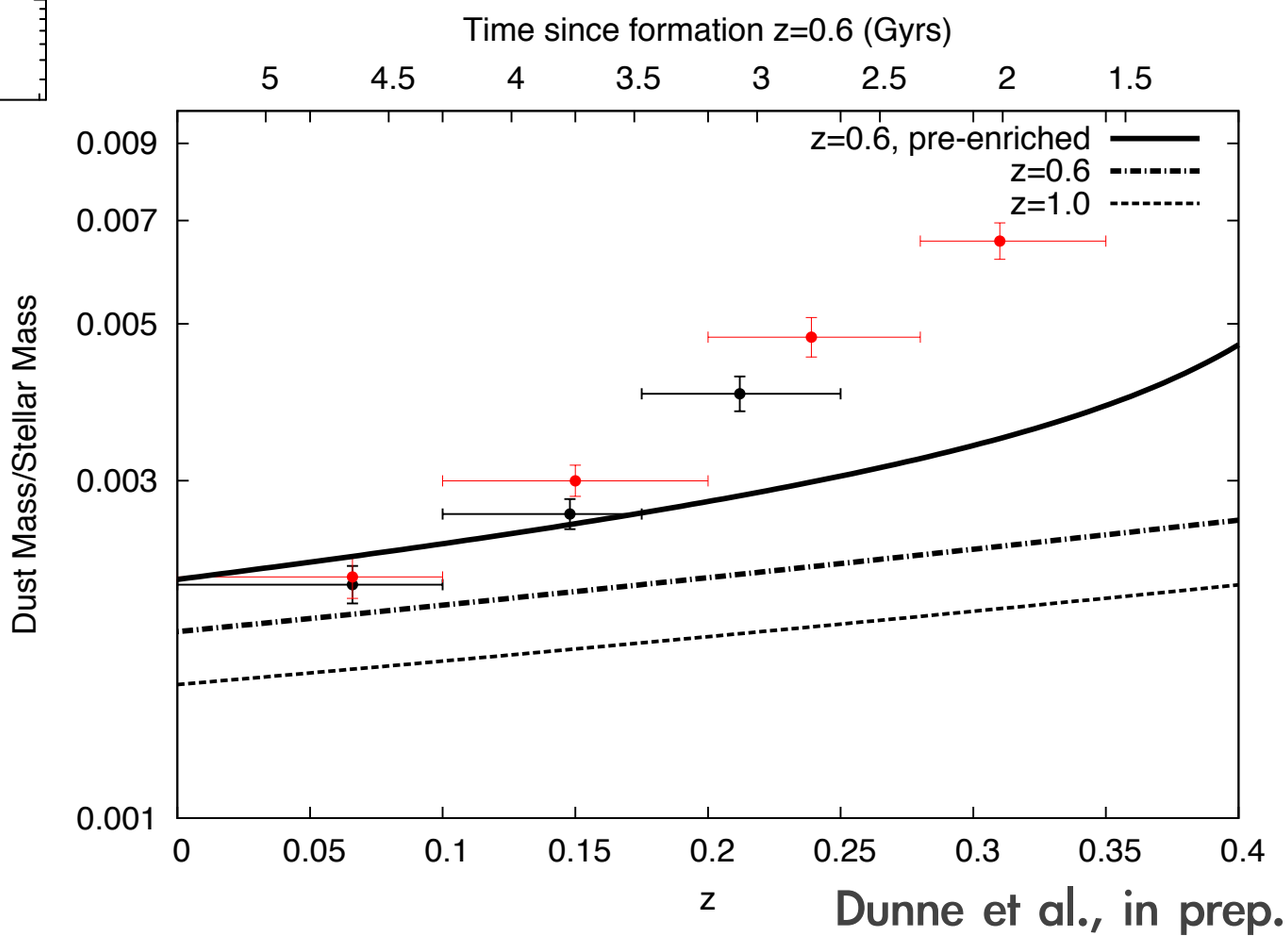


- Evolution of the dust mass function of galaxies in the past 5 billion years of cosmic history.

- At z~0.5, galaxies had dust masses about five times larger than in the local Universe.

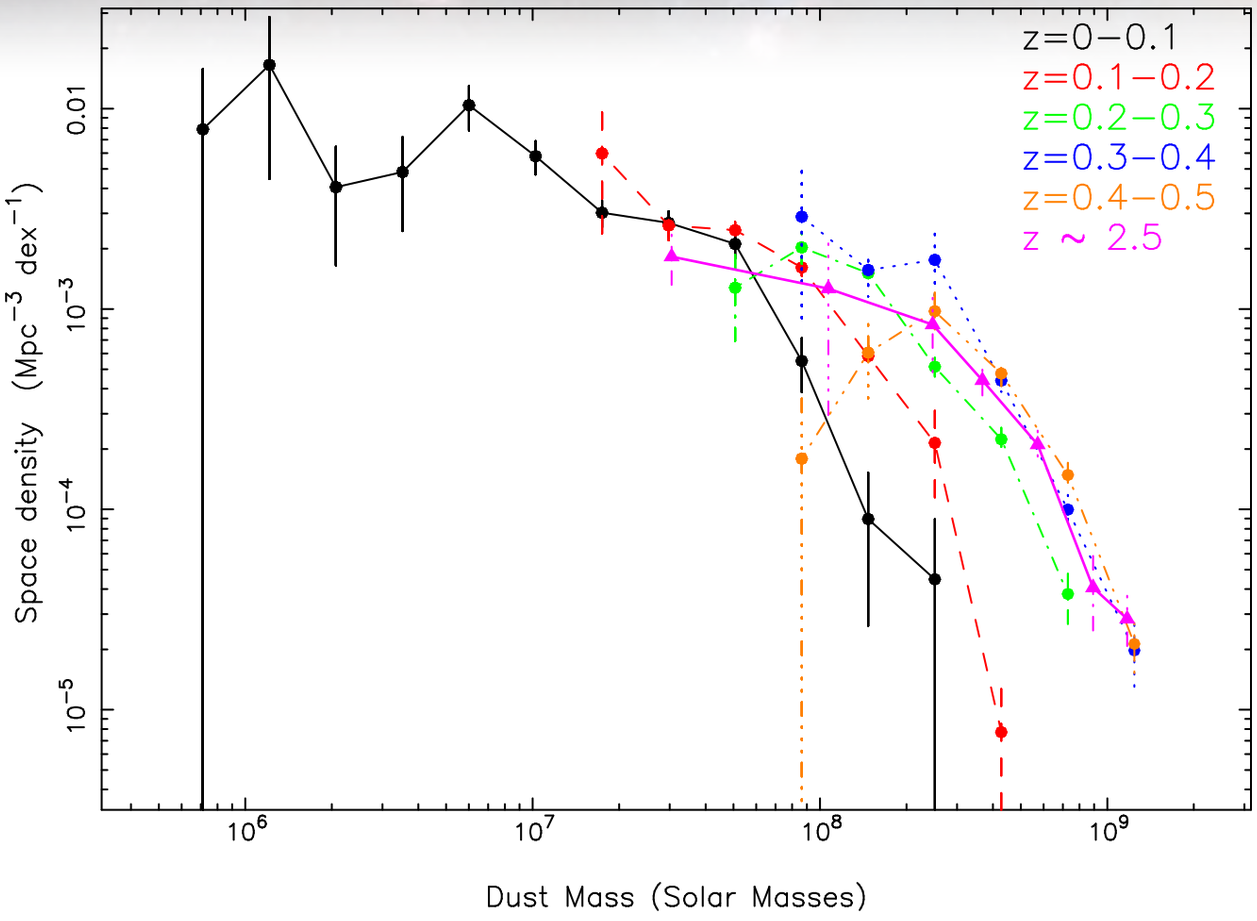
- Difficult to explain with standard MW dust evolution models (Gomez et al., in prep.): H-ATLAS sources seem to be more efficient at converting metals into dust.

- Results suggest time for last SF episode in the last 5-6 Gyrs (to be confirmed by stellar population modelling)



Dunne et al., in prep.

Evolution Of The Dust Content Of Galaxies

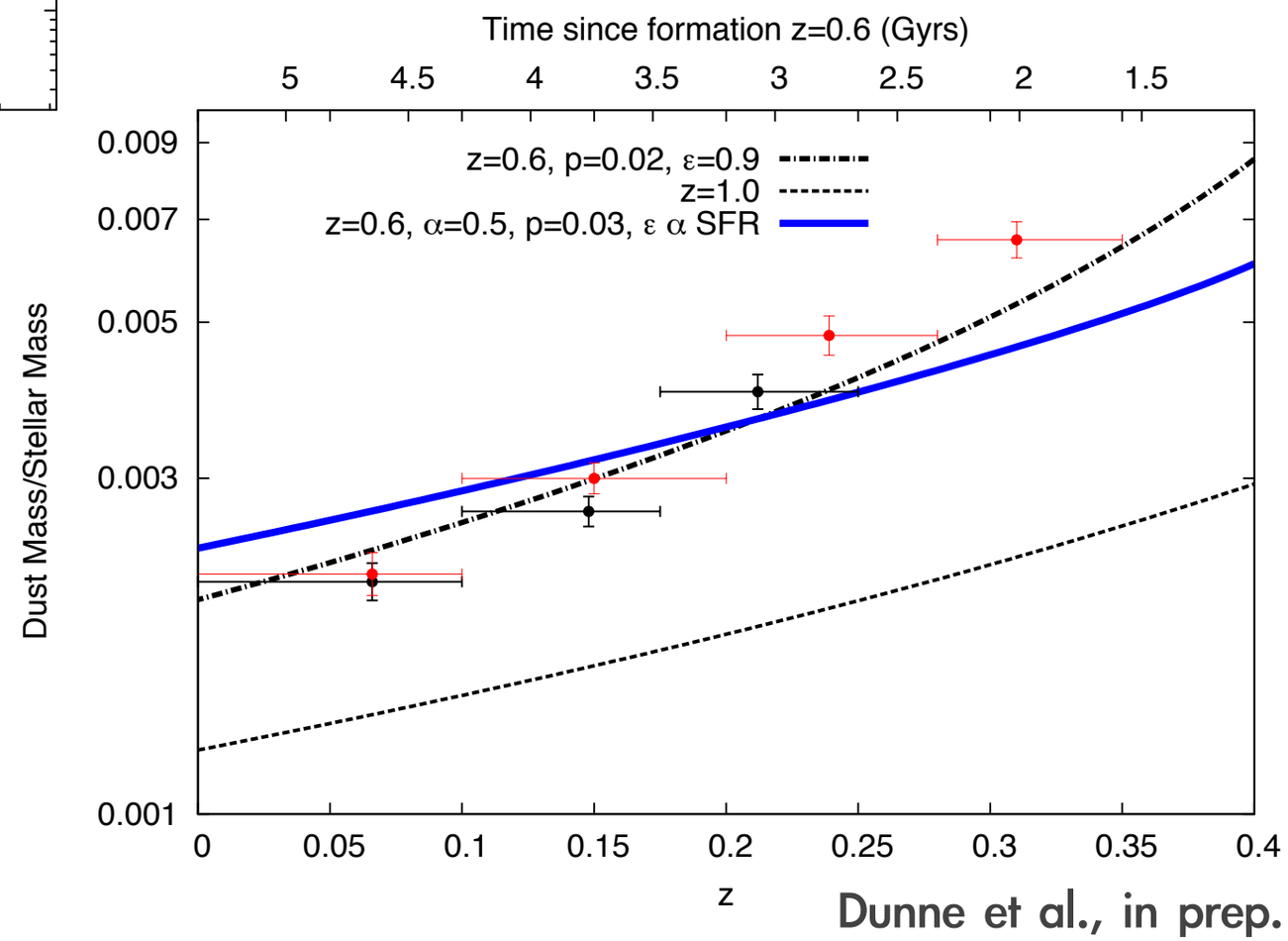


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Dunne et al., in prep.

Summary & Conclusions

- Simple model to interpret consistently the emission from galaxies at UV, optical and IR wavelengths

- Statistical constraints on key galaxy properties: stellar mass, SFR, dust content...

- MAGPHYS - Publicly available code @ www.iap.fr/magphys

- Analysis of large samples - e.g. Herschel ATLAS

- Specific SFR drives the SED shapes of local star-forming galaxies

- H-ATLAS galaxies show a strong evolution in their dust content in the past 5 Gyr