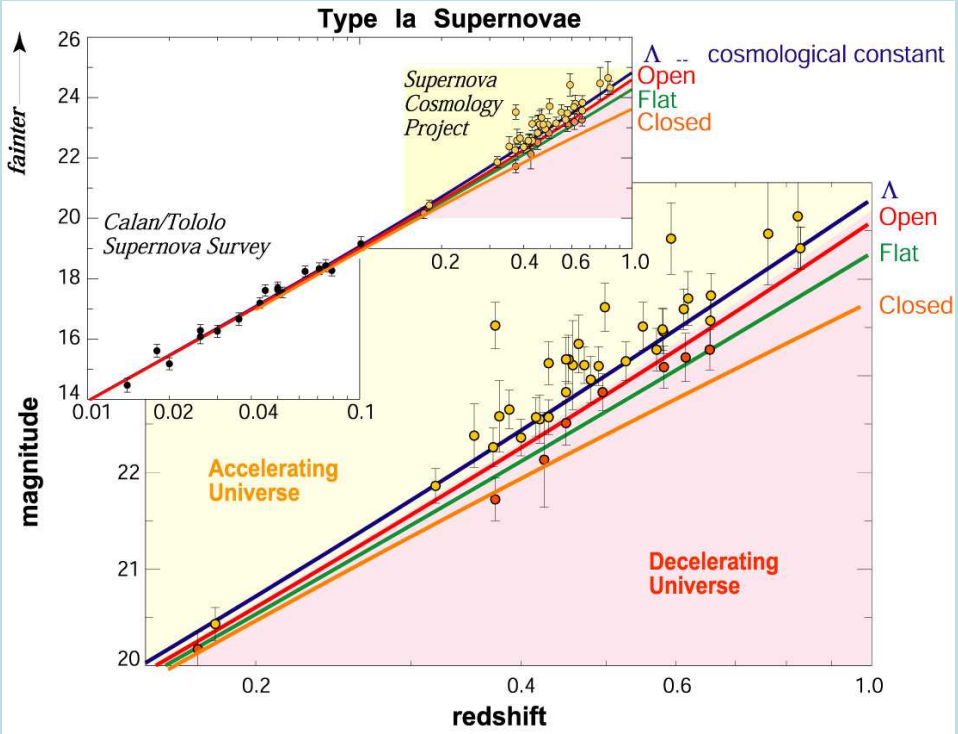
Systematic errors in Cosmology

y distance => m-M

Hipothesis: The absolute magnitude it is always the same for each binary system which produces a SNIa: standard candle

•Empirical fact: the width of the light curve of the SNIa is related on the brighness in the maximum (Phillips 1993)

•But it seems that this magnitude may depend on the metallicity of binarys system or host galaxy

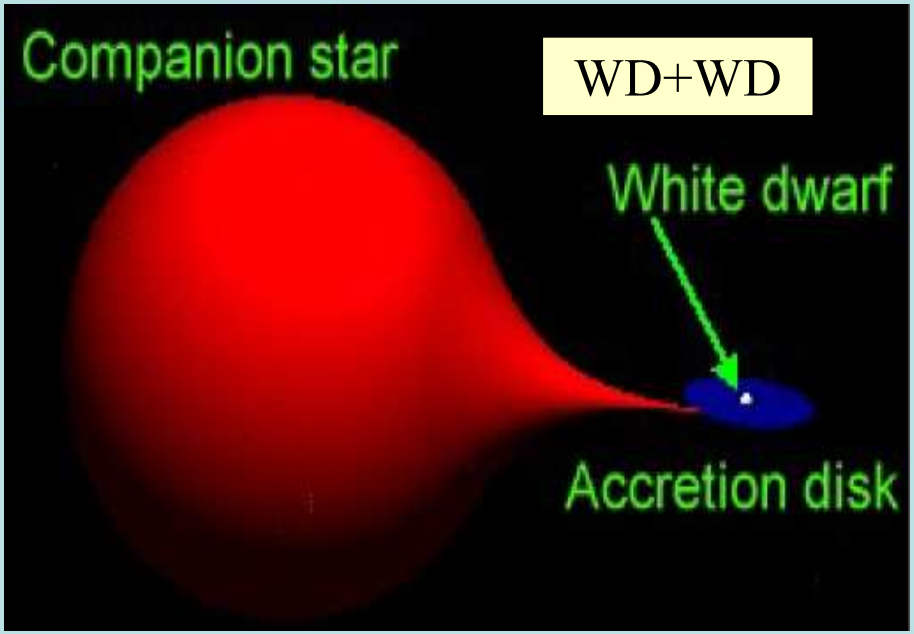


Eje x: el redshift z

Acurate values if it is obtained spectroscopically but new surveys use photometric techniques to determine it

The technique is based in the spectral energy distributions (SEDs) of galaxies and in some features of them as D4000 (break 4000A)

SN-Ia: binary systems



- Las SN Ia are in all type of galaxies.
- The most important characteristic is the Iron ejected ~ 0.6 M¤.

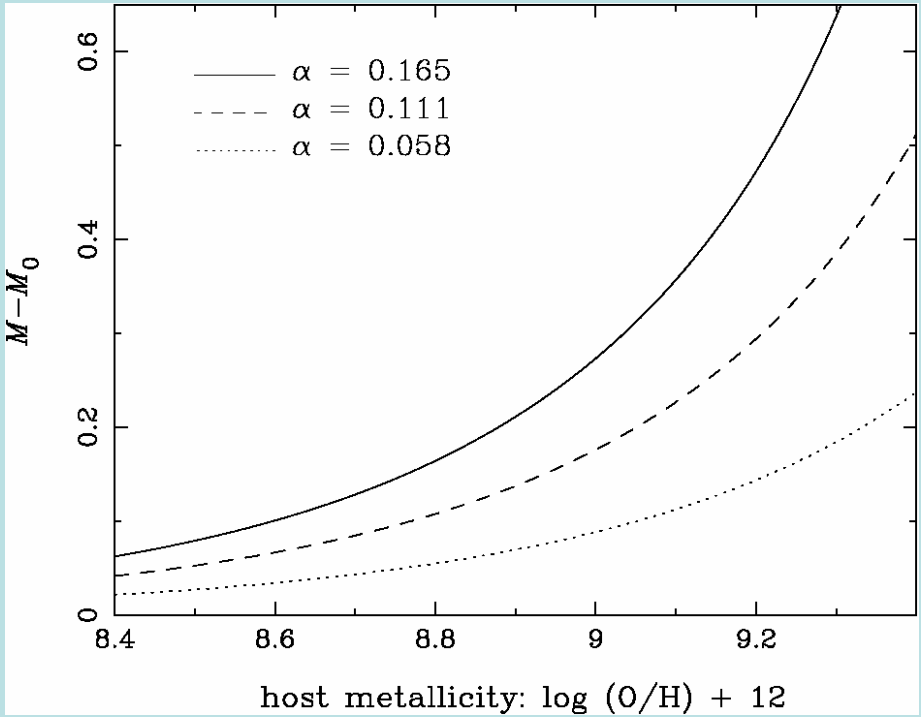
The SNIa form in a binary system in which the evolved component is a CO-WD acreting the companio star mass. This way a nuclear deflagration is produced.

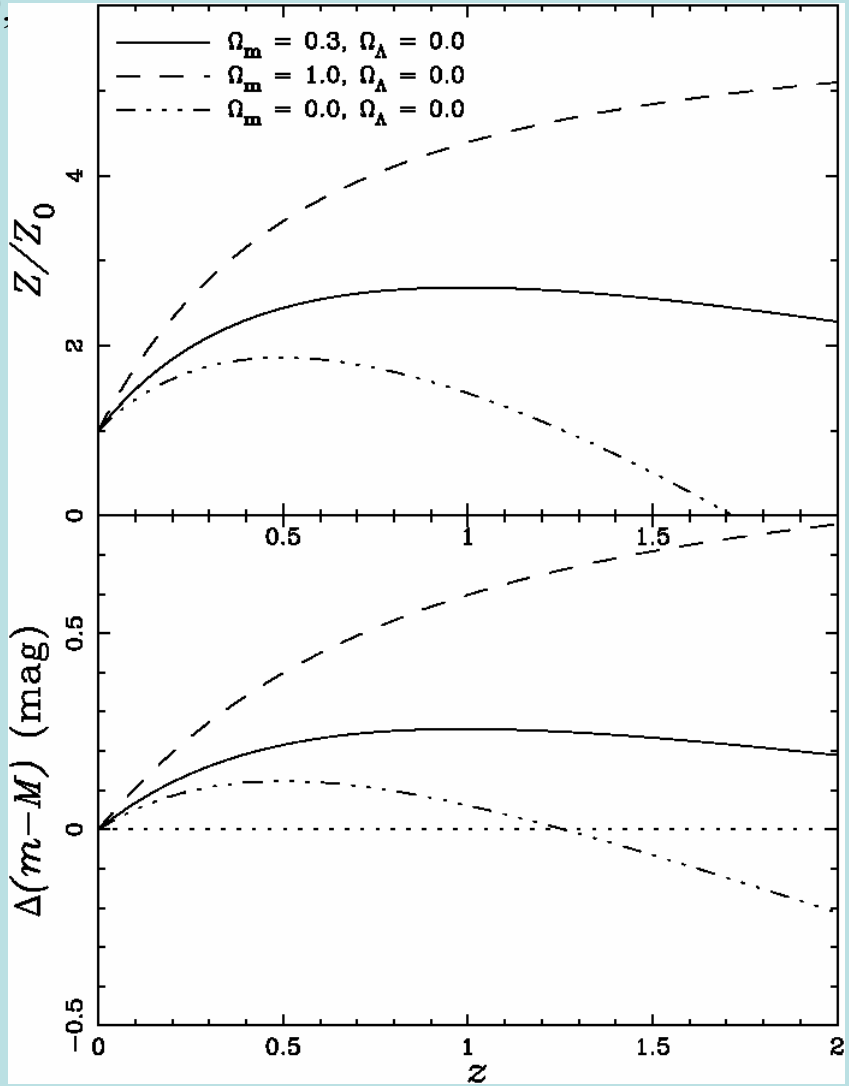
The deflagration front propagates by electrons moving at subsonic velocities. The wave preceding the wave front eject the star without any rest

The stars of the binary systen are in the range 3 -- 16 Msol

SNIa theoretical models (Podsiadlowski et al. 2006)

- Excess of neutrons in the CO core of the WD, which determines the ratio stable/instable Ni
- The excess of neutrons depends of the abundance of elements ^{56}Fe y ^{22}Ne: $\eta_{56}=4X(^{56}Fe)/56$
- The opacity of ejection determines the explosion magnitude which, in turn, depends on the synthesized ^{56}Ni





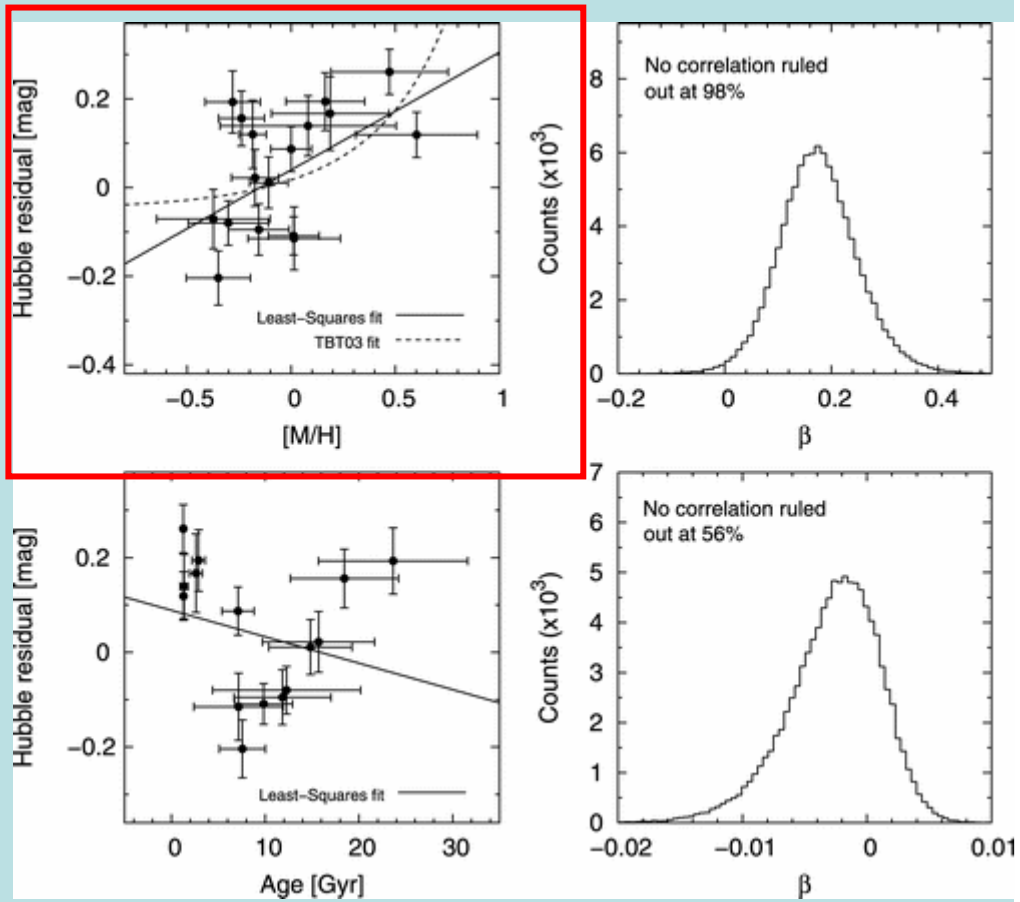
Supernovae in Early-Type Galaxies: Directly Connecting Age and Metallicity with Type Ia Luminosity (Gallagher et al.2008)

Abstract:

We have obtained optical spectra of 29 early-type (E/S0) galaxies that hosted Type Ia supernovae (SNe Ia). We have measured absorption-line strengths and compared them to a grid of models to extract the relations between the supernova properties and the luminosity-weighted age/composition of the host galaxies.

... We find that SN Ia distance residuals in the Hubble diagram are correlated with host-galaxy metal abundance with higher iron abundance galaxies hosting less-luminous supernovae.

…This result, particularly the secondary dependence on metallicity, has significant implications for the determination of the equation-of-state parameter, w=P/(ρc2), and could impact planning for future dark-energy missions



We conclude that the failure to apply a metallicity correction to SN Ia magnitudes could potentially introduce a 9% error into current and future measurements of *w*.

Estudio de las SNIa de SDSS y de la metalicidad de las galaxias anfitrionas

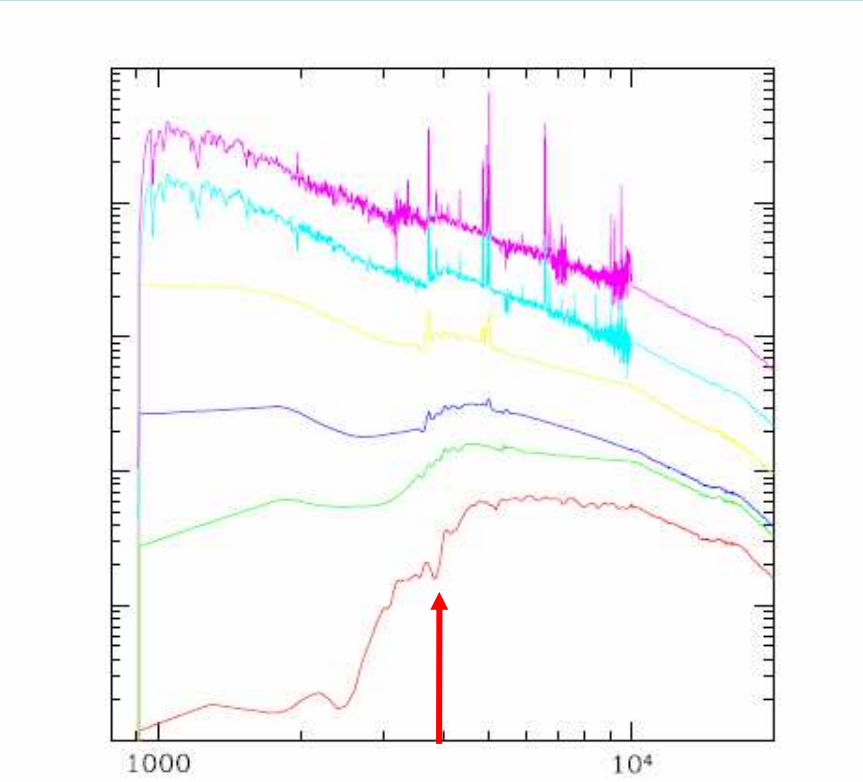
- Campaña de observación en 2007 (4 noches en total, Francisco Castander, Ramon Miquel, Mercedes Mollá, Lluis Galbany). Hemos obtenido espectros de una muestra de SNIa de SDSS para determinar su redshift espectrofotométrico. (Basset et al. 2007a, Basset et al. 2007b, Goobar etal. 2007, Dilday etal 2009a, Dilday et al. 2009b)
- Podemos usar la muestra de datos de SNIa de SDSS
- Objetivo: Estimar las incertidumbres estadísticas en m-M debidas a la evolución de la metalicidad
- Propuesta de tesis de Lluis Galbany, codirigida con R. Miquel.
  - Estudio de las curvas de luz
  - Determinación de la magnitud en el máximo

❖ Estimar la metalicidad de las galaxias anfitriones (espectros/ datos fotométricos)

❖ Buscar correlaciones como la encontrada por Gallagher et al. (2008)

Systematic errors in the photometric redshift determination

The idea is to compare the observed magnitudes $m_\lambda(z=0)$ with those given by some templates empírical (Coleman, 1980, Kennicutt 1992) or galaxy models (Bruzual & Charlot 2003)



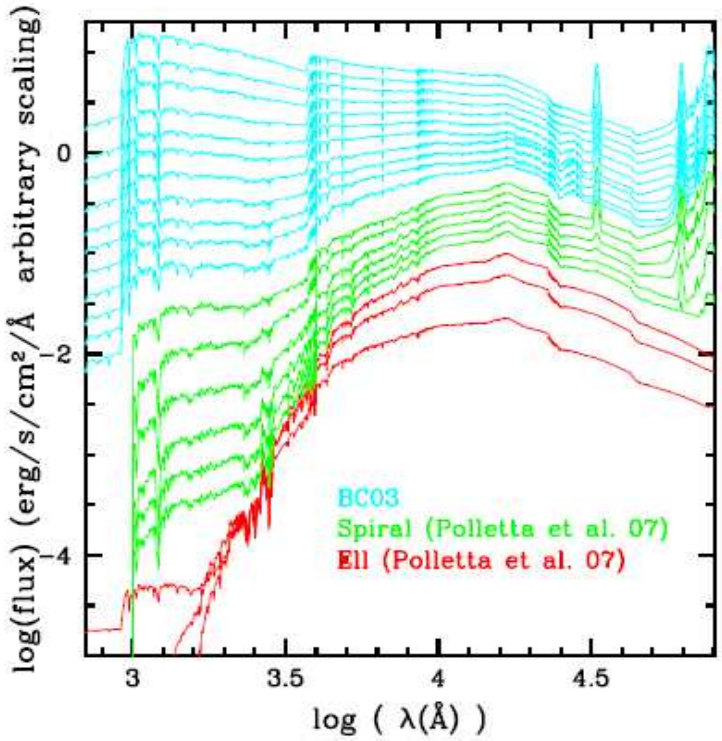


Fig. 1.— SED templates. The flux scale is arbitrary. The top 12 SEDs (cyan) are generated with Bruzual & Charlot (2003). The spiral (green) and elliptical (red) SEDs are from Polletta et al. (2007).

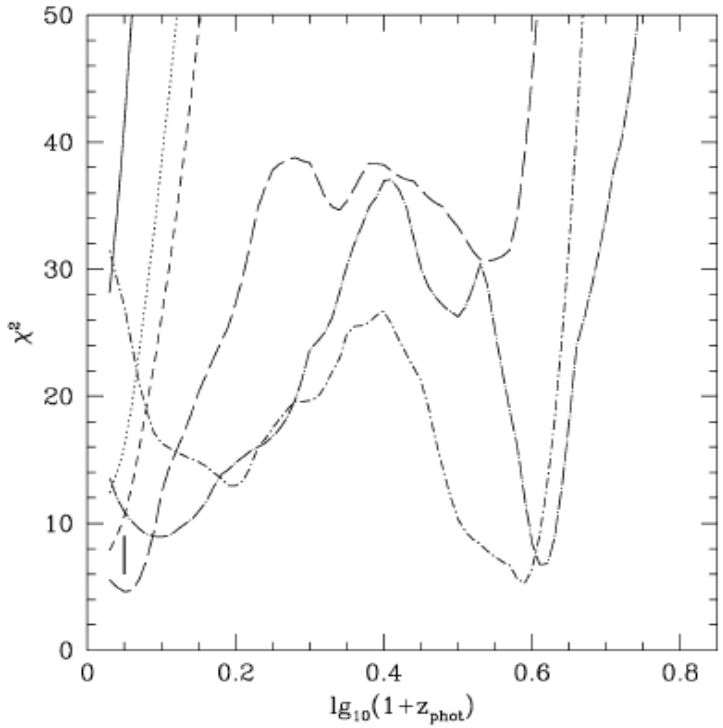
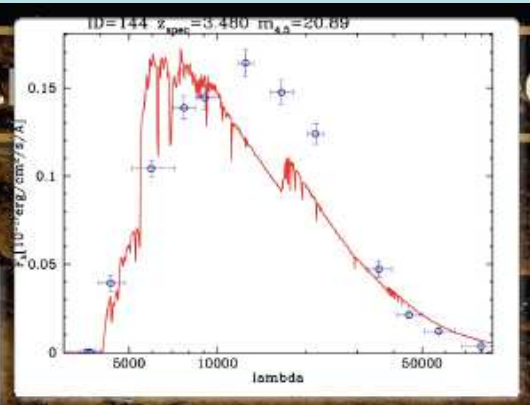
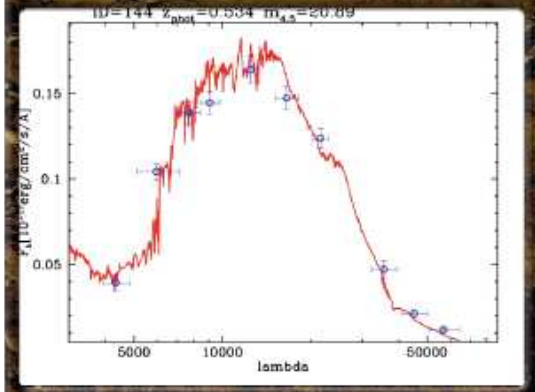
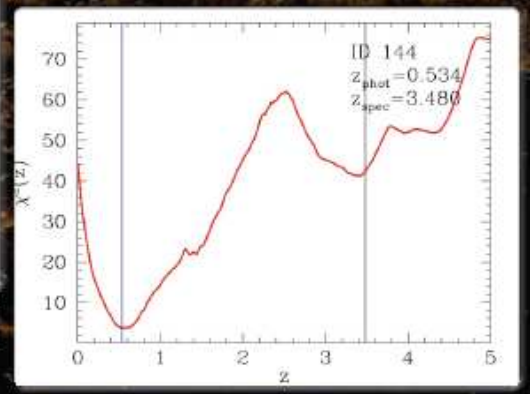


Figure 7. Reduced $\chi^2[=\chi^2/(n-2)]$ as a function of $\log_{10}(1+z_{phot})$ for the six sed types, for HDF 4–916.0 ($n = 7$). The vertical bar denotes the minimum χ^2 at $\log_{10}(1+z_{phot}) = 0.05$, and there are aliases at 0.10, 0.20, 0.59 and 0.61, of which the one at 0.59 is statistically significant. There is no minimum corresponding to the reported spectroscopic redshift at $\log_{10}(1+z_{spectr}) = 0.280$.







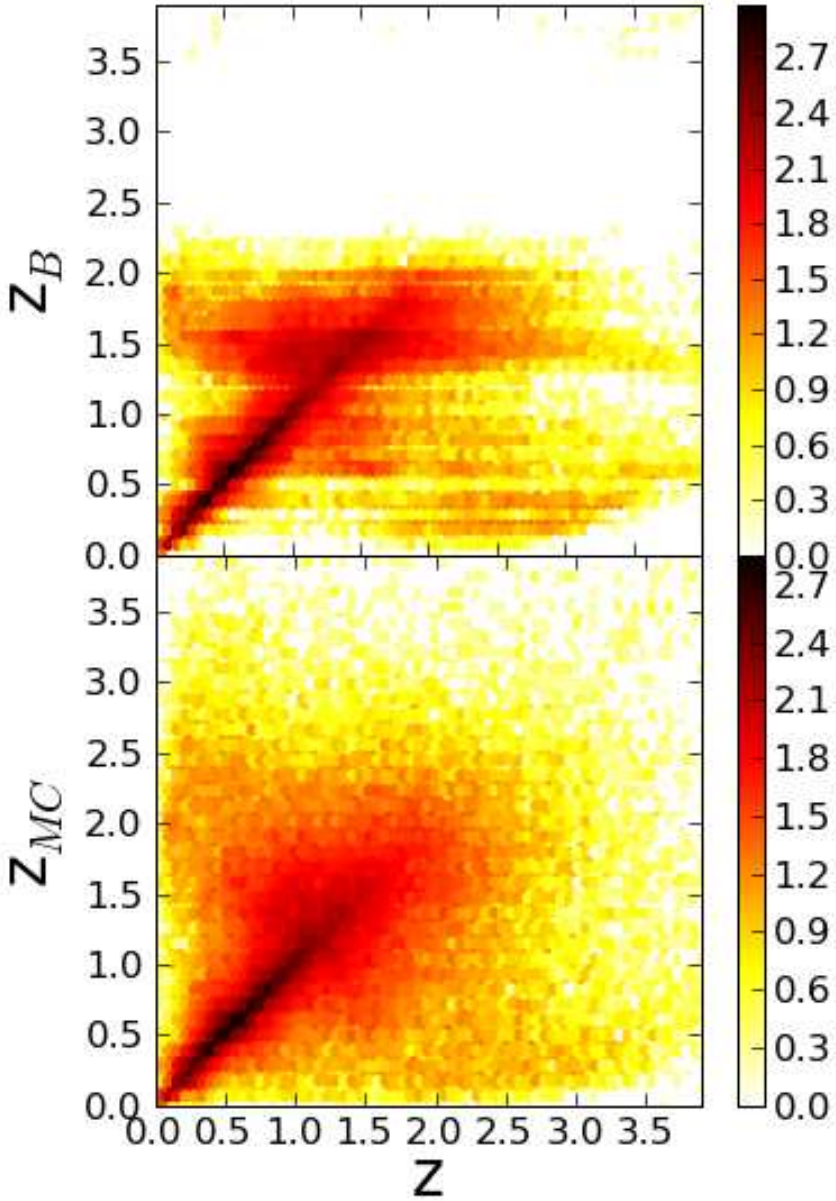
de

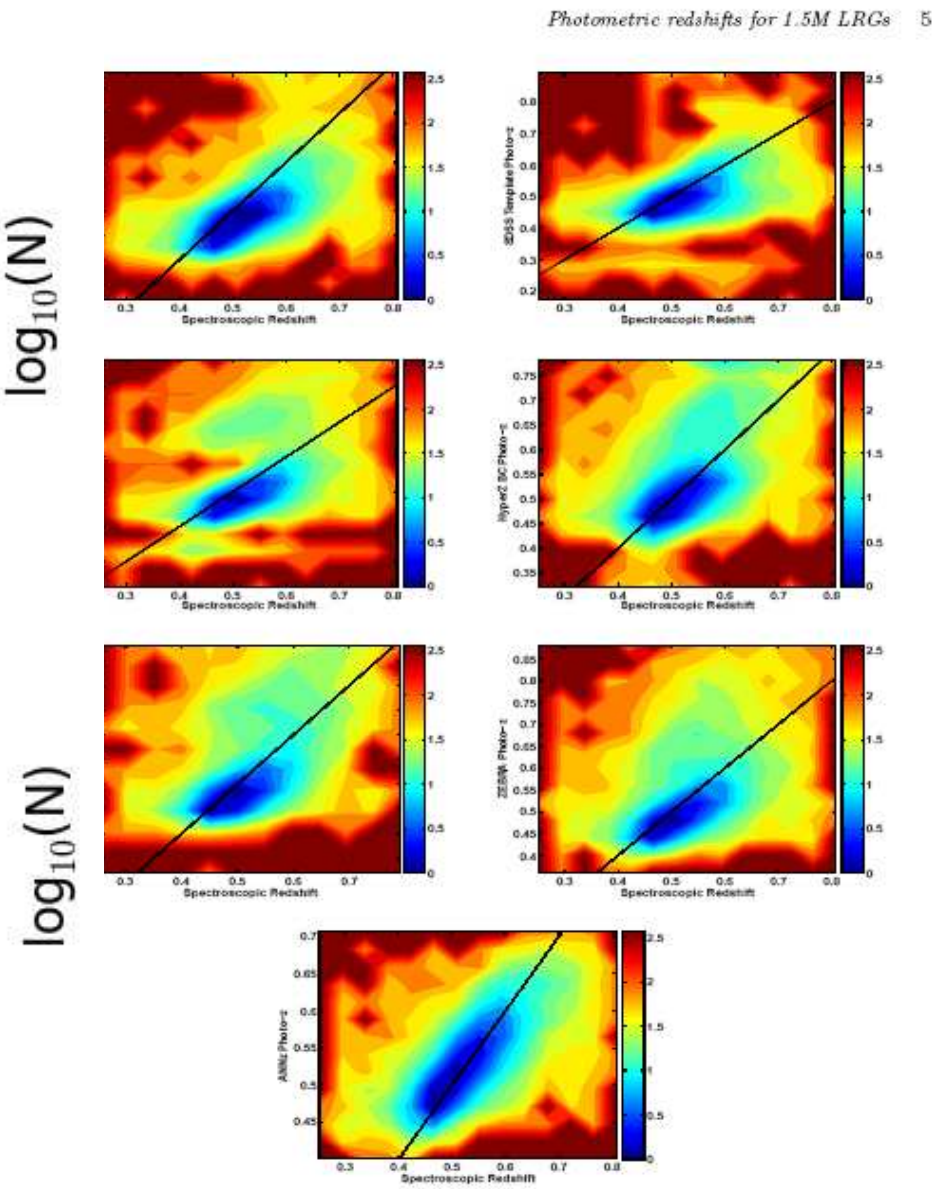
best fi
at z_{spe}

best fi
at z_{pho}

χ^2

single emission line, identified as Lyα, if [OII] $z_{spec} \approx z_{phot}$


z_B
z_{MC}
z
$\log_{10}(N)$
$\log_{10}(N)$


Photometric redshifts for 1.5M LRGs 5
Spectroscopic Redshift
Density plots of spectroscopic versus photometric redshift for each of the public photo-z codes described in § 3.1. The plots
oded and the scale is exponential. A colour difference of one is equivalent to the density being decreased by a factor of e. The
lines show where the spectroscopic redshift is equal to the photometric redshift.
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Possible points to take into account

•Ilbert et al. 2008 (astroph 0809.2101): The χ_2 template-fitting method is meaninful <u>only if the color-z relation predicted from the templates is a good representation of the observed color-z relation</u>. Uncertainties in the zero-point offsets of photometric bands can lead to systematic shifts...

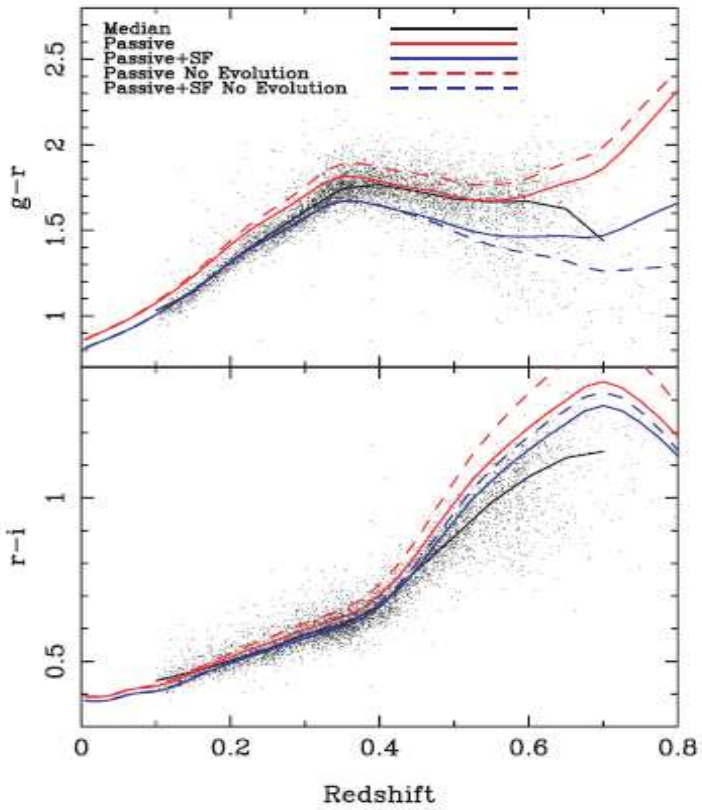


Figure 1. The $g-r$ and $r-i$ colours of the SDSS and 2SLAQ LRGs as a function of redshift (points). The solid black line shows the median of the points with the coloured lines showing the model tracks described in the text with (solid line) and without (dashed line) evolution applied.

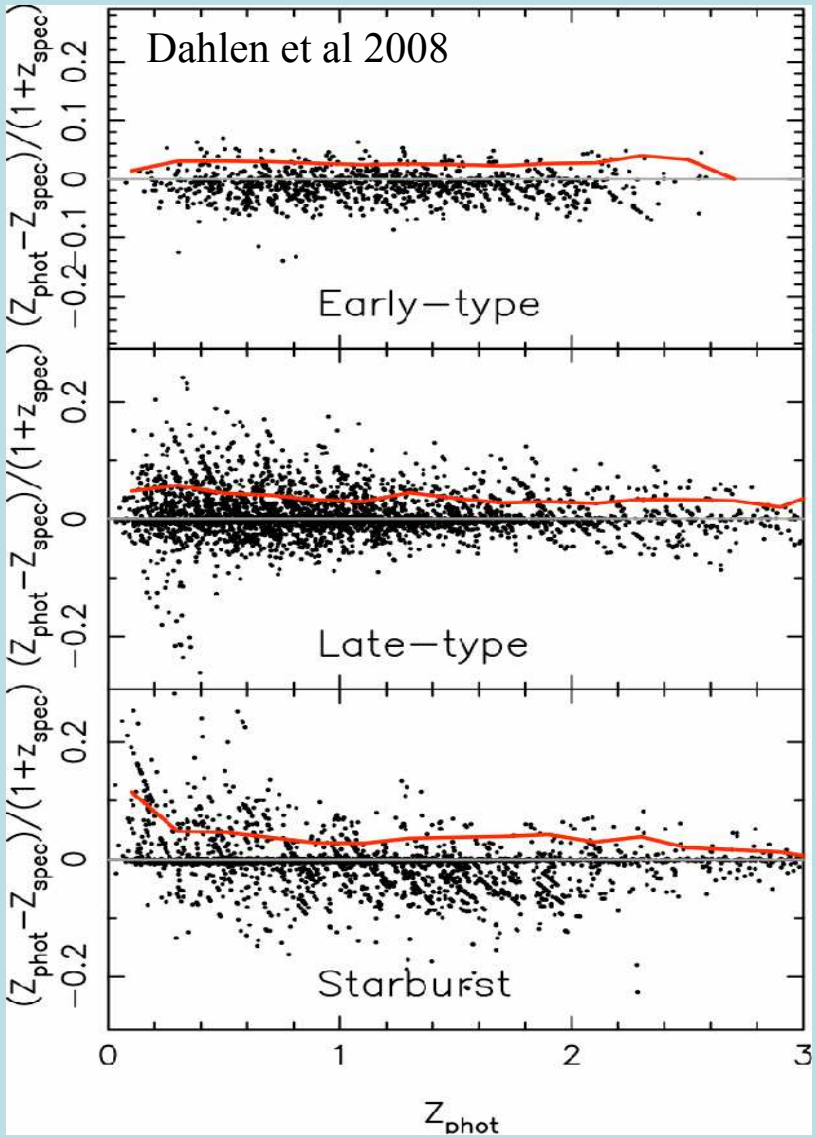
•Empirical templates: The comparison is done through the K correction:

$$flux_{obs} = flux_{emi}/(1+z)$$
$$\lambda_{obs} = \lambda_{emi}(1+z)$$

This implies that the galaxy evolution is not taken into account: **m=M+5logD+K**

There are changes in the expected magnitudes when evolution is included. BETTER!

For z > 0.5 it may be important



Magnelli et al 2009

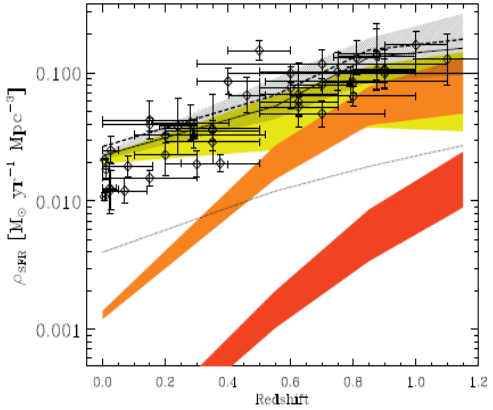
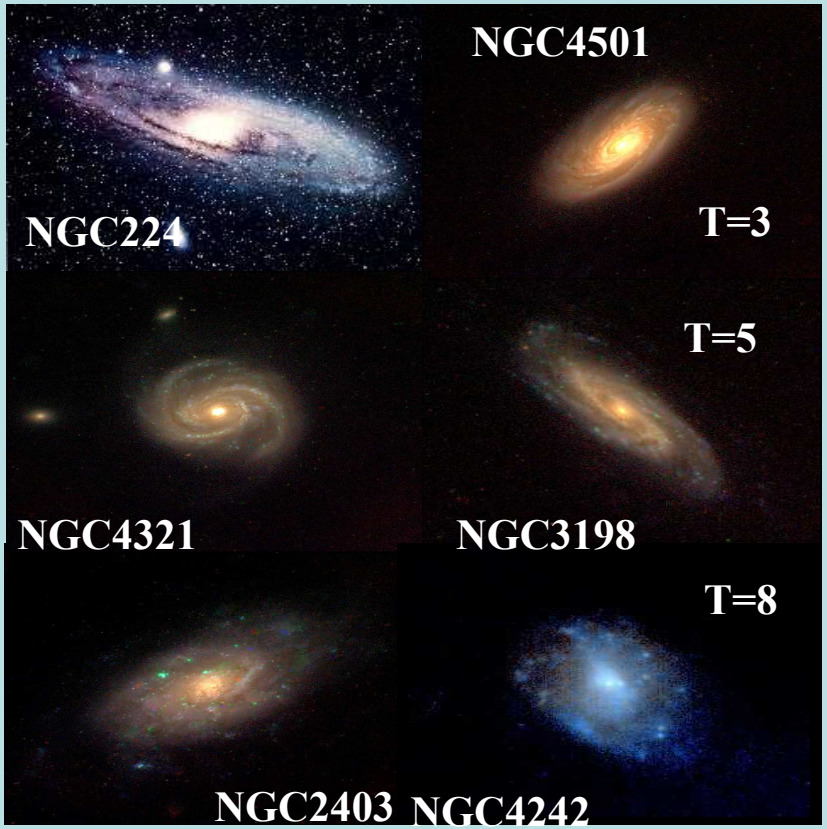
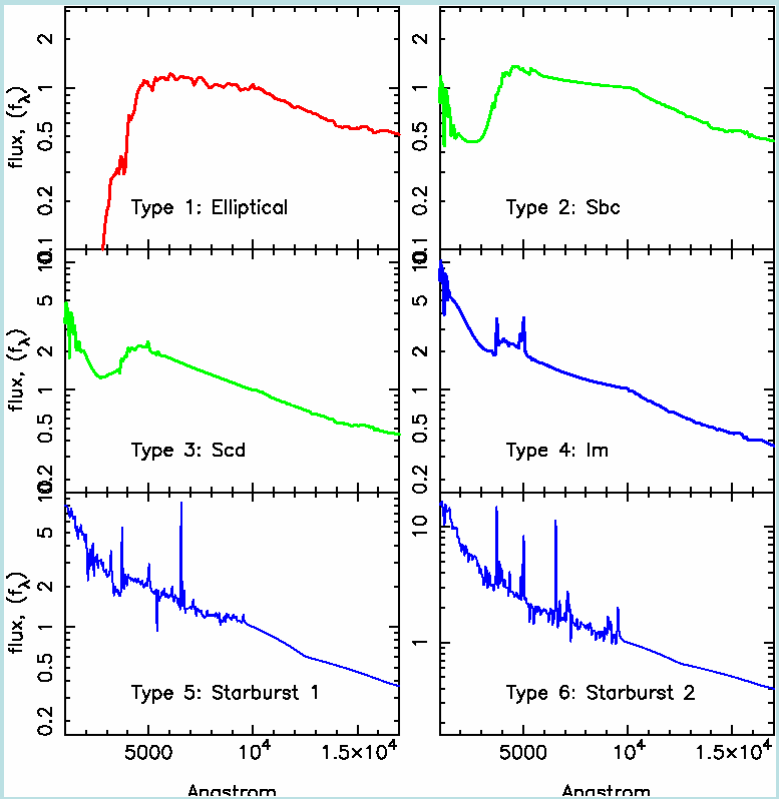


Fig. 15. Evolution of the comoving star formation rate density up to $z \sim 1.3$ (*striped area*) and the relative contribution of normal galaxies (i.e $7 < \log(L_{IR}) < 11$; *yellow filled area*), LIRGs (i.e $11 < \log(L_{IR}) < 12$; *orange filled area*) and, ULIRGs (i.e $12 < \log(L_{IR})$; *red filled area*). The areas were defined using all the solutions compatible with the total infrared LF within 1 σ. The solid line represents the best fit to the total SFR density. The dottes line represents the SFR measured using the UV light not corrected from dust extinction. The dashed line represents the total SFR density defined as the sum of the SFR density estimated by the infrared and of the SFR density obtained from the UV light uncorrected of dust extinction. Open diamonds are taken from Hopkins (2004) and represent the SFR densities estimates using various estimators. Filled triangles represent the SFR density estimated by Seymour et al. (2008) using deep radio observations.

- **The dispersion is smaller for early type galaxies than for the late star forming ones.**
- **The star formation in the Universe was higher in the past: It is necessary to take into account the possible galaxy evolution**





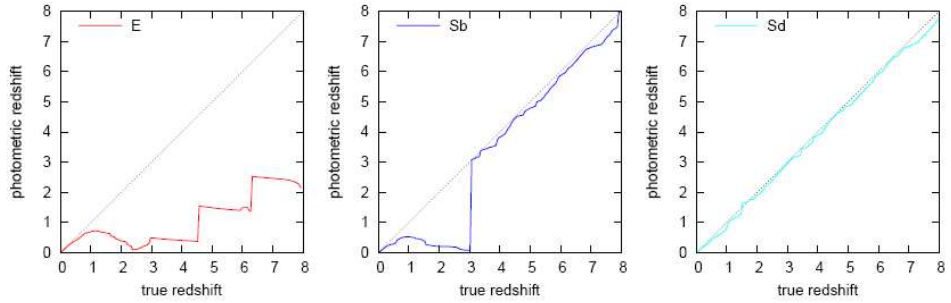
The classification of galaxies in the Hubble sequence is related with the arm and the bulge/disc ratio

The early type galaxies have a clear shape and form their stars some time ago

The late galaxies are chaotic and are forming stars even now

Importance of evolutionary corrections for phot. redshifts

Direct comparison of templates with and without evolution

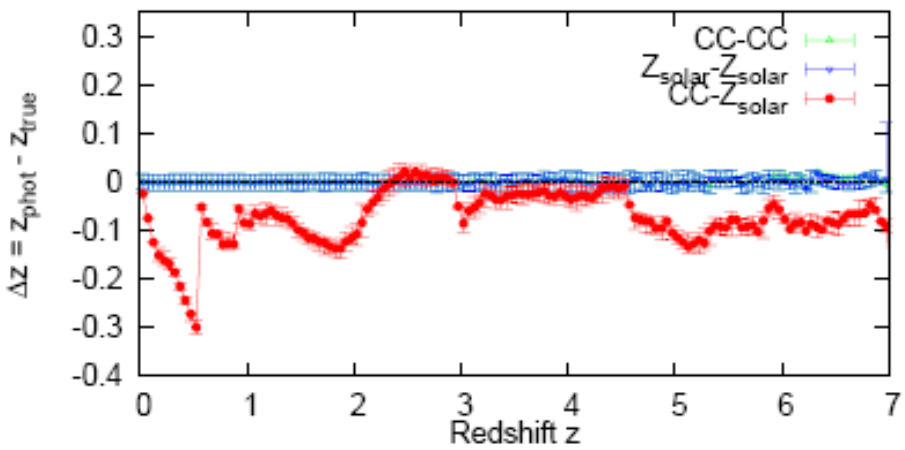


Without accurate evolutionary corrections:

Significant underestimation of photometric redshifts,
in particular for early galaxy types.

Kotulla et al (2008)

Kotulla & Fritze (2009): the use of solar templates in the photometric determination of redshift may produce a bias of deltaz =0.1



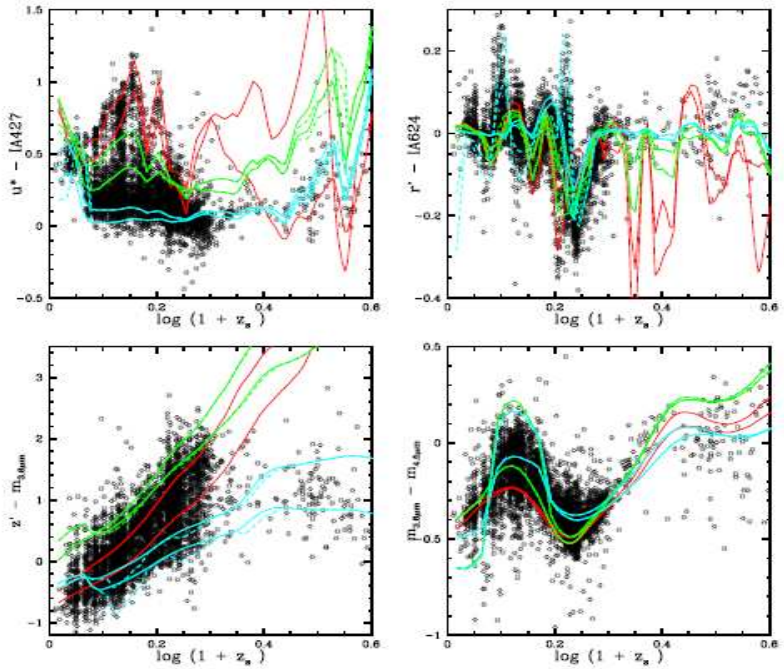


Fig. 2.— The observed colors and redshifts (z_s) for the spectroscopic sample galaxies (open stars). The solid lines are the predicted colors as a function of redshift for some SEDs of the library (red: Elliptical and green: Spiral from Polletta et al. 2007 ; cyan: Bruzual & Charlot 2003). The solid curves are the predicted colors without including emission lines (no reddening for the elliptical templates, $E(B-V) = 0.2$ for the late types) whereas the dashed curves are the same templates including the emission line fluxes (assuming $M_{FUV} = -20$ in this example). The top right panel clearly shows that the emission lines can change the colors up to 0.4 mag.

Comparison of observed colors with different templates:

red- Elliptical,

green_ Spiral

Cyan: Bruzual & Charlot Models

- The color oscillation are well explained by the contribution of the **emission lines** like Ha, OIII and OII.

- Including emission lines improves the accuracy by a factor of 2.5

Impact of sub-solar metallicities on galaxy spectra

Kotulla & Fritze (2008)

Compared to equal-mass solar-metallicity galaxies, sub-solar metallicity galaxies ...

- ... are bluer
  ⇒ underestimate ages
- ... are brighter
  ⇒ overestimate masses
- ... have stronger emission-lines
  ⇒ overestimate SFR

if solar-metallicity calibrations are used (Bicker & Fritze 2005)

L108 *C. Maraston et al.*

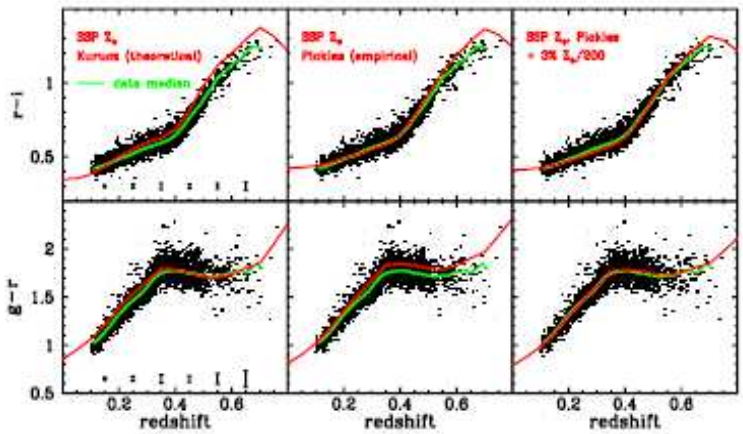
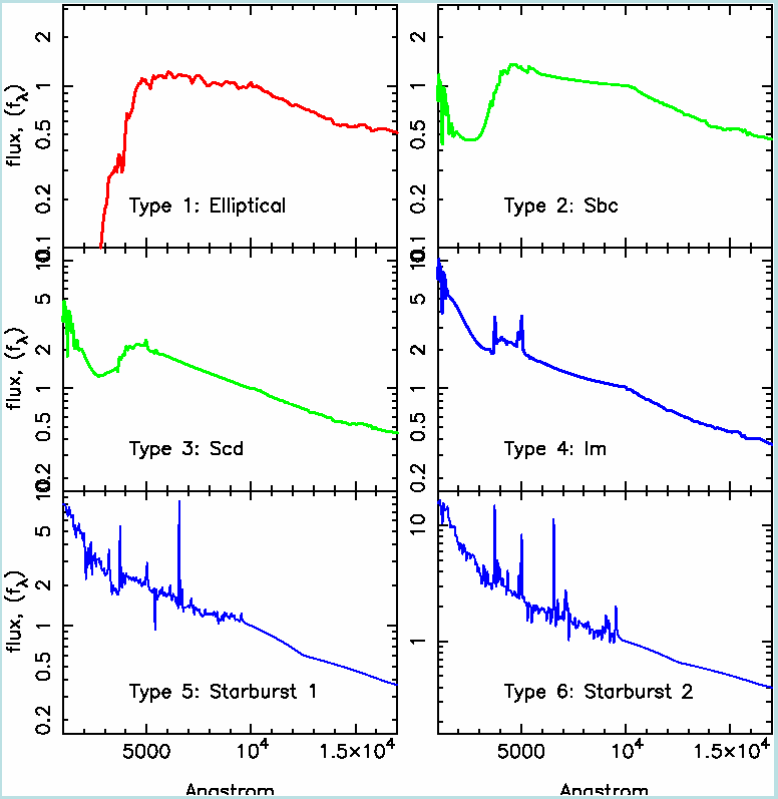
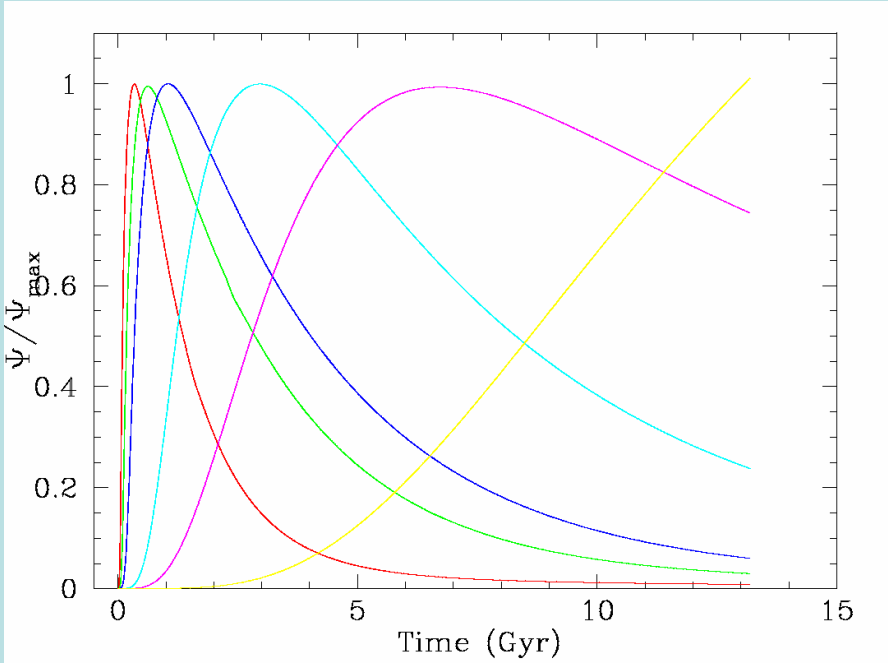
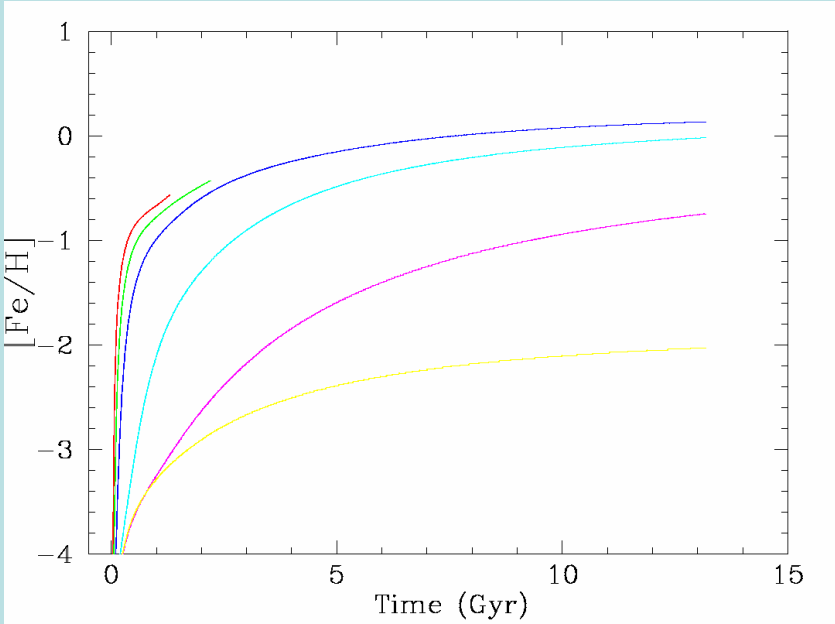


Figure 1. The $g-r$ and $r-i$ colours of LRGs as functions of redshift (points; data from W06). The median is given by the green line. Typical errors as function of redshift indicated by the error bars. Left-hand panels: a solar-metallicity passively evolving, single-burst model with an age of 12 Gyr at redshift zero (red line). Middle panels: same data as in the left-hand panel. The stellar population model uses the Pickles (1998) empirical spectral library instead of the theoretical one (see the text). Right-hand panels: same data as in the left-hand panel with a composite model with 3 per cent by mass of metal-poor [Z/H] = −2.2 stars. Both the metal-rich and the metal-poor component are 12 Gyr old at redshift zero. The metal-rich component uses the Pickles (1998) empirical spectral library.

The shape of the SED proceeds from the star formation and metal enrichment histories





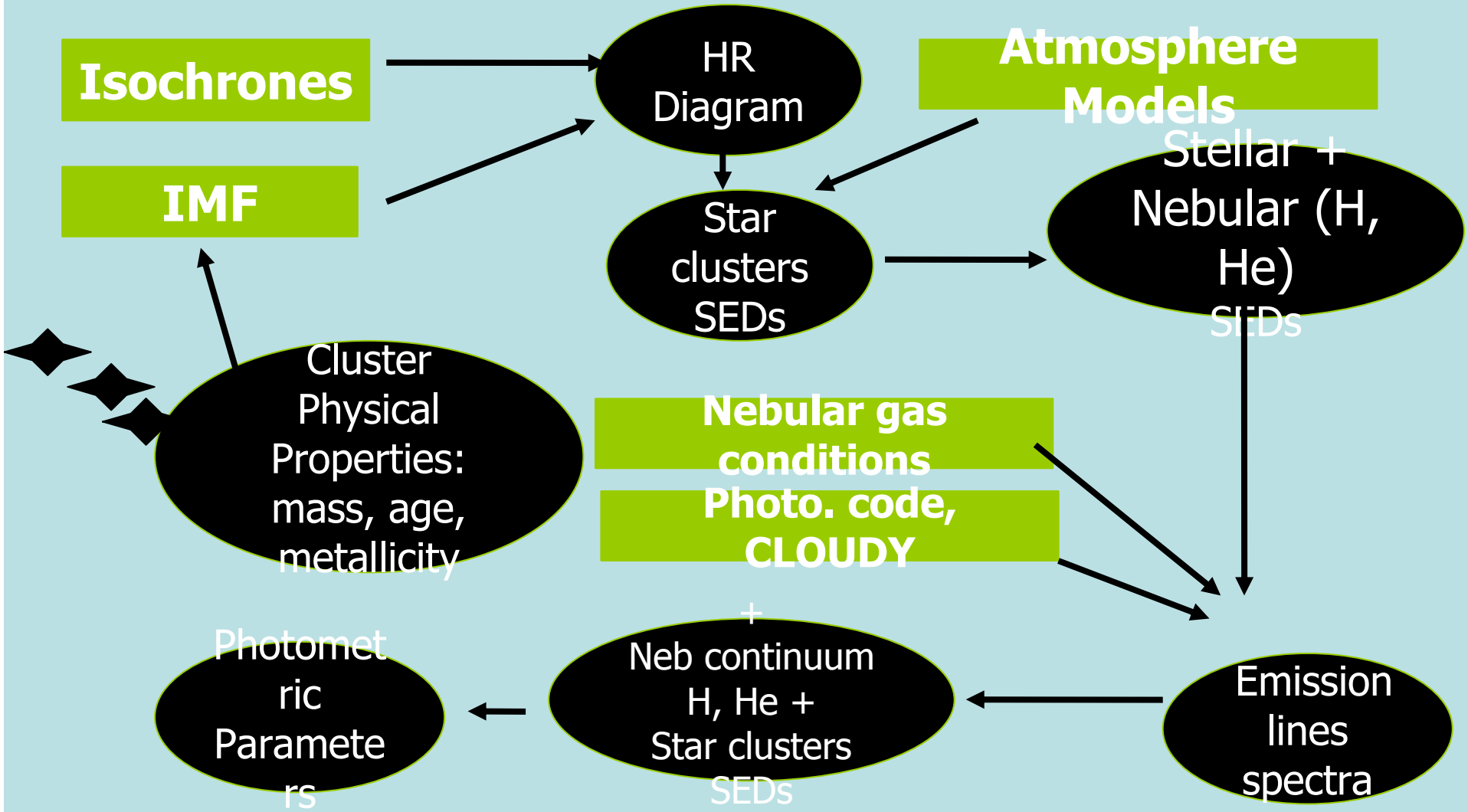


Aim: to compute realistic SEDs with galaxy models using SFH and SMR, evolutionary histories

Work Description

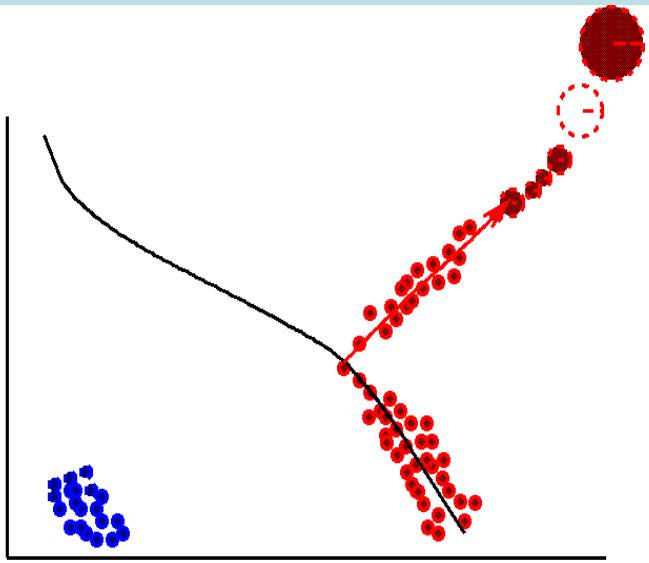
- **To update our evolutionary synthesis code (Mollá & García-Vargas, 2002) for Single Stellar Populations (SSPs), including:**
  - **The youngest stellar populations (1 Myr),**
  - **The nebular continuum contribution,**
  - **Massive star models from Smith et al. (2002): mass loss**
  - **Planetary nebulae models from Rausch et al. (2003),**
  - **Emission lines**
  - **Low metallicity (Z=0.0001, 0.0004) stellar populations**
  - **Mollá et al. (2009, MNRAS,aceptado, astro-ph 0905.3664),**
- **To use these models to compute the luminosity evolution of theoretical galaxies from Mollá & Díaz (2005) & Mollá et al. (2006)**
- **Self-consistent calculation of the dust from the molecular clouds and metallicity of each galaxy: extinction**
- **To apply these templates in photometrical redshift code: to reduce systematical errors**

Work Description: SSPs



Model Parameters: Isochrones

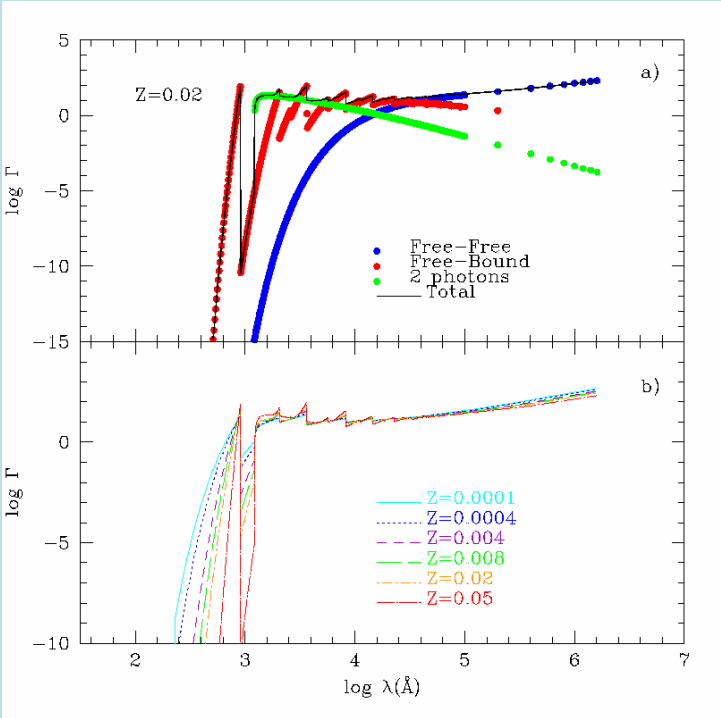
- Isochrones selection: New Padova set specifically computed for this piece of work.
- Broad age and metallicity coverage and detailed treatment of mass-loss at both, young ages (O, B, WR) and old ages (post-AGB until planetary nebula)
- Z = 0.0001, 0.0004, 0.004, 0.008, 0.02 and 0.05 (1/50 to > 2.5 solar)
- Ages, logt = 5.00 to 10.30 High age resolution (up to logt=0.01, depending on the age)
- Specific stars: WN, WC, etc. are identified in the isochrones to assing the spectra



T = 10 billion years old --> just red stars left; lots of white dwarfs; no stars more massive than one solar mass left on the main sequence

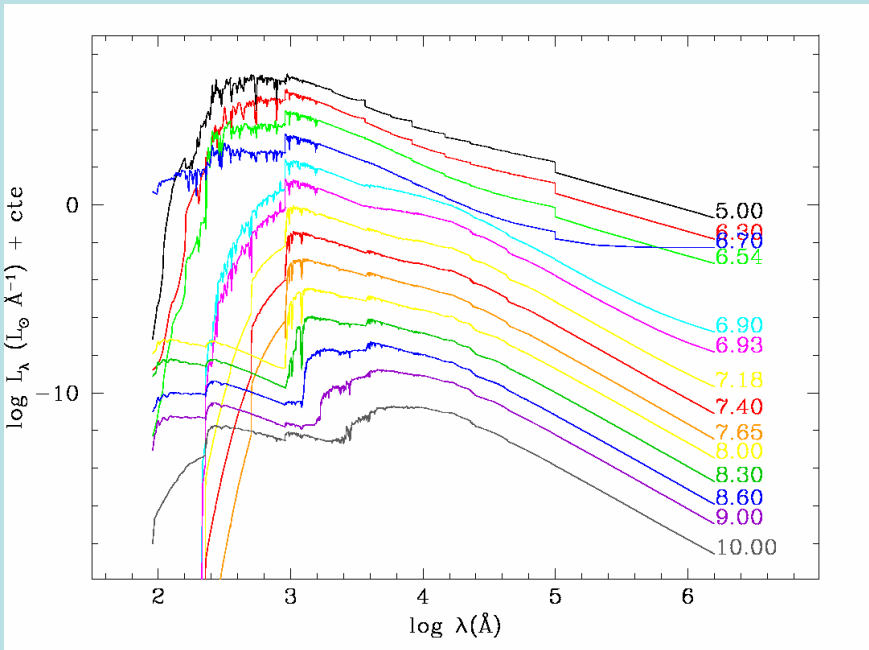
Model Parameters: Atmospheres

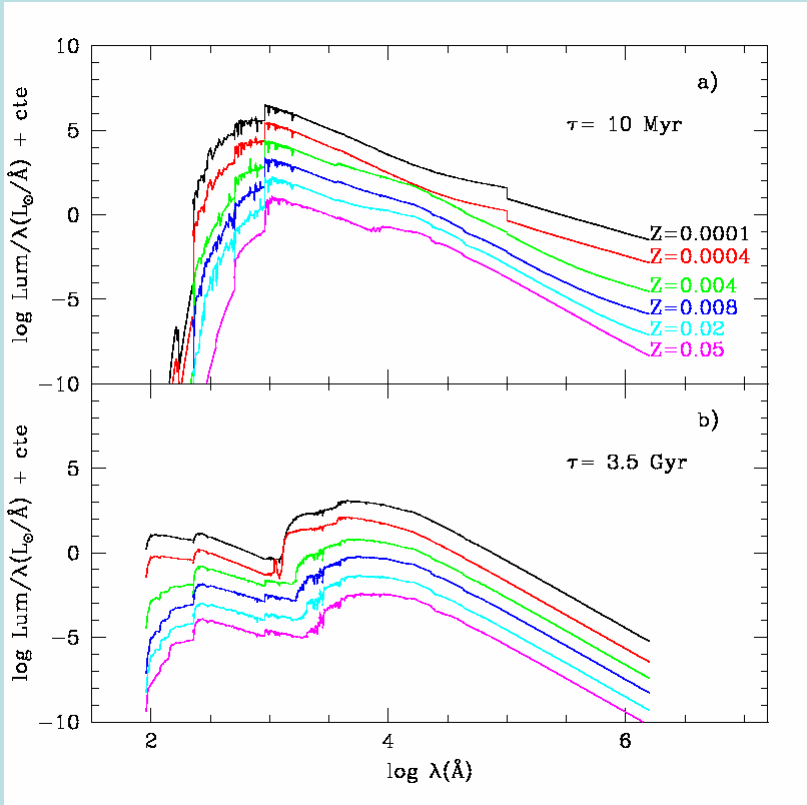
- For stars with Teff < 25.000 we use the models by Lejeune Th. Cuisinier F. & Buser R. (1997). Excellent coverage in Teff, Z and logg.
- For O, B and WR we use non-LTE line blanketed models by Smith, Norris & Crowther (2002) at Z=0.001, 0.004, 0.008, 0.02 and 0.04
- For post-AGB and PN we have included the NLTE models by Rauch (2003) up to 220.000 K and black bodies for higher temperatures. These models include all elements from H to Ni. Teff ranges between 50.000K and 190.000K and logg between 5.00 and 8.00

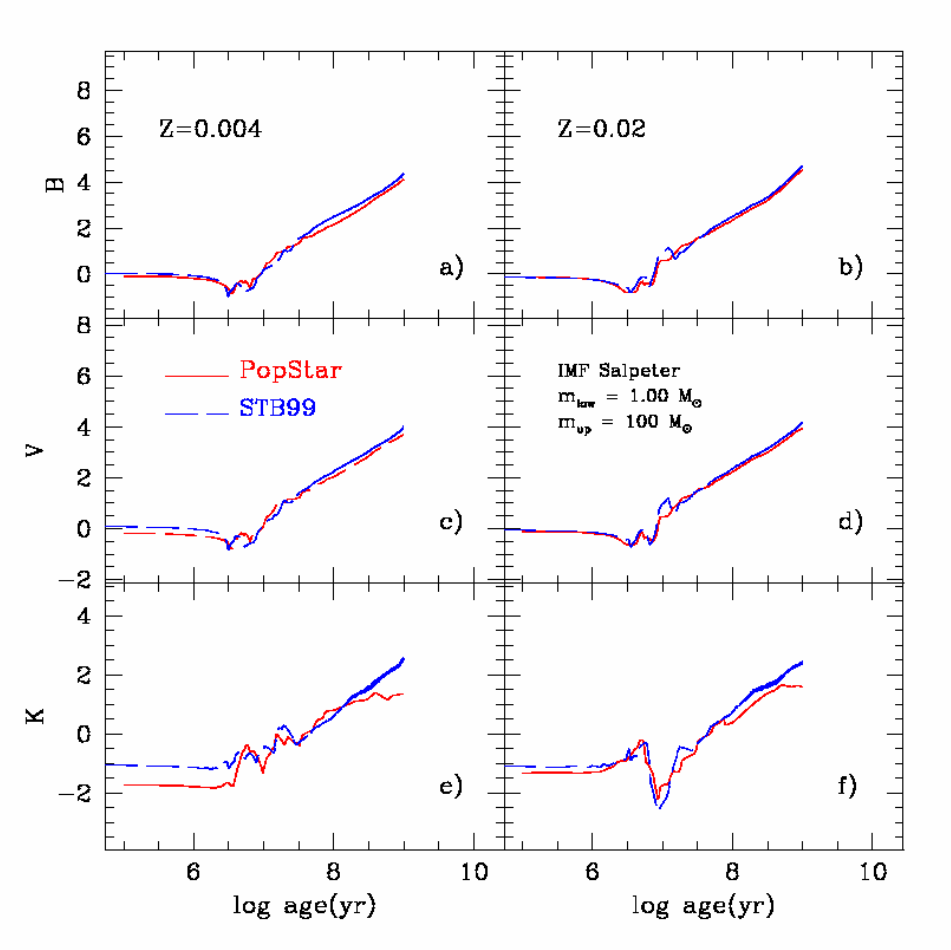


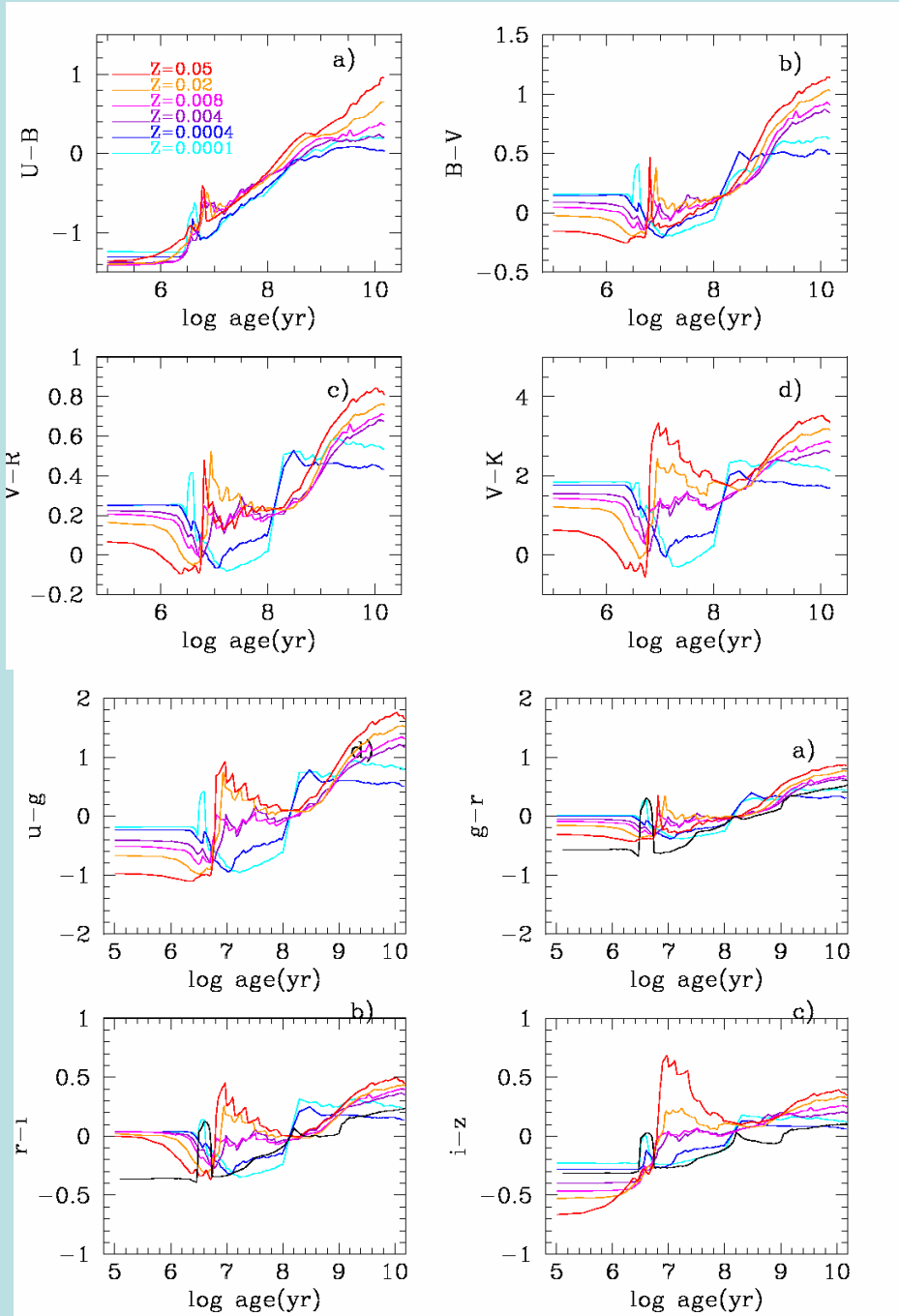
The function Γ is the sum of the emission coefficients for Hydrogen and Helium, including both free-free and free-bound contributions, and the emission coefficient due to the two-photons continuum.

Spectral Energy distributions for different ages and metallicities









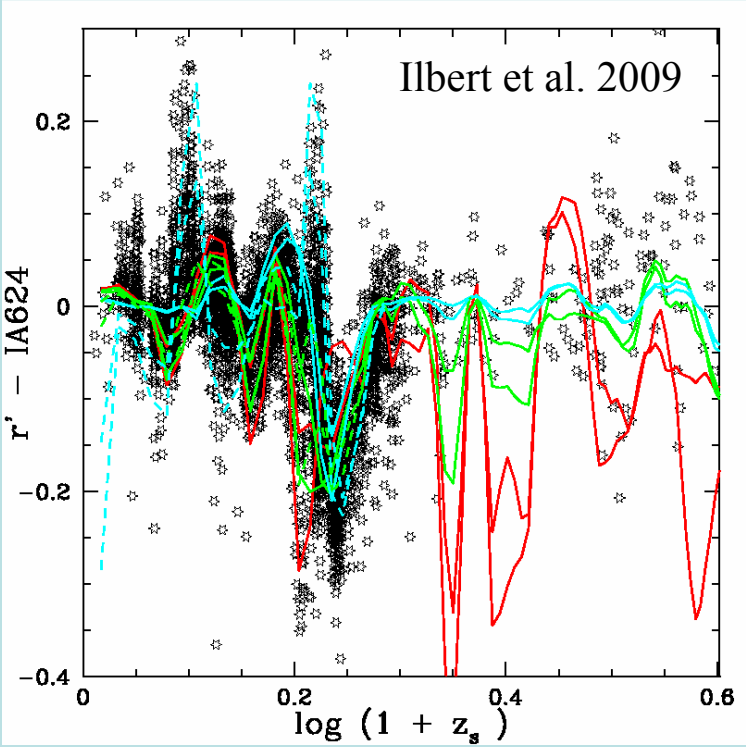
Red colors for young stellar populations mainly for low Zmet

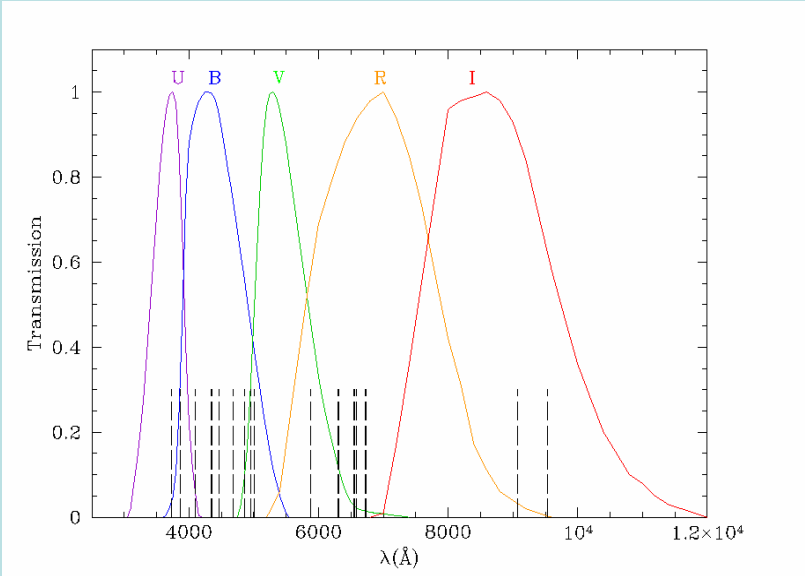
Same values for young and intermediate stellar populations

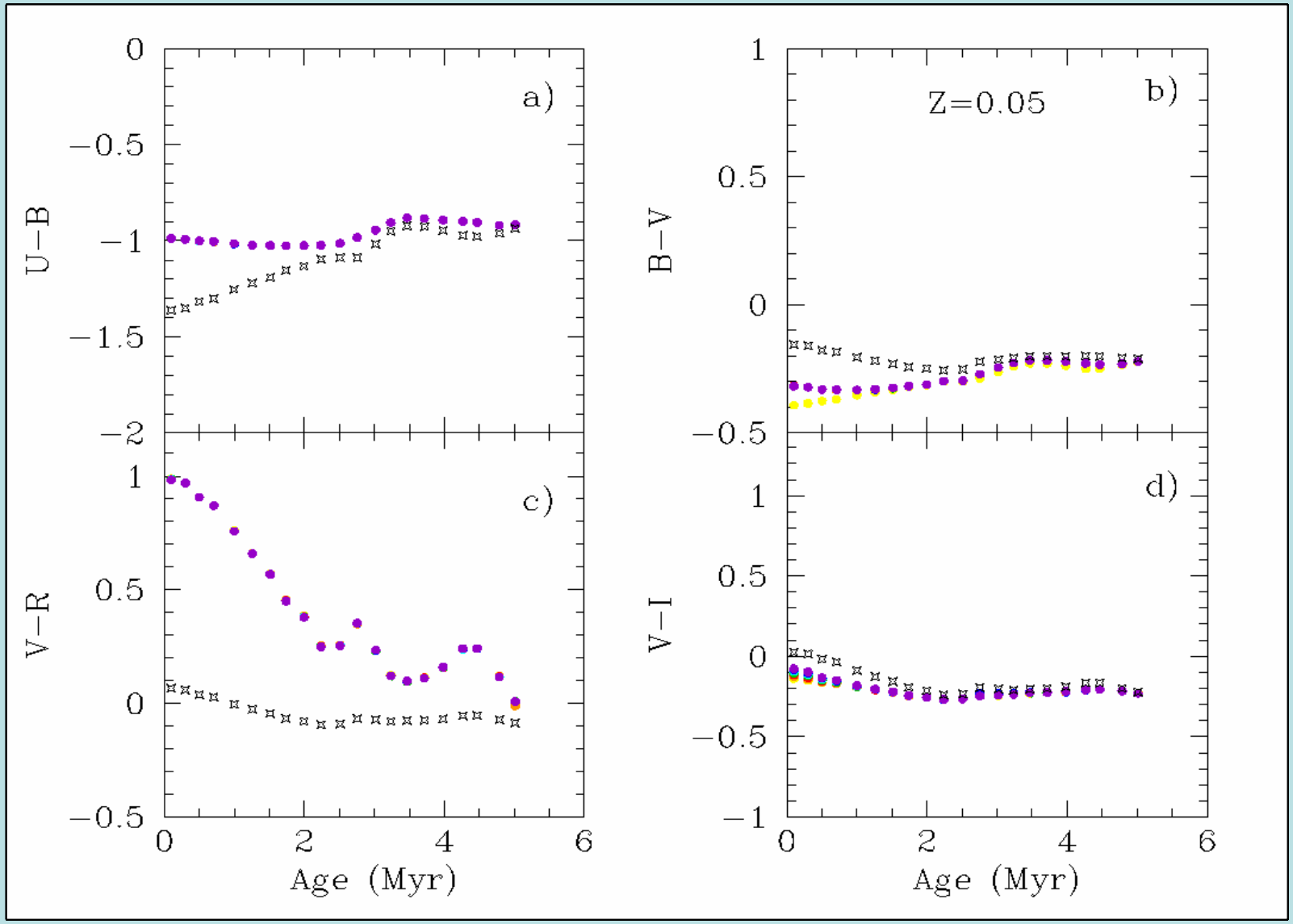
Well tuned for all types of galaxies: young pop. as STB99 and the old ones as BC and others (E)

Emission lines: CLOUDY

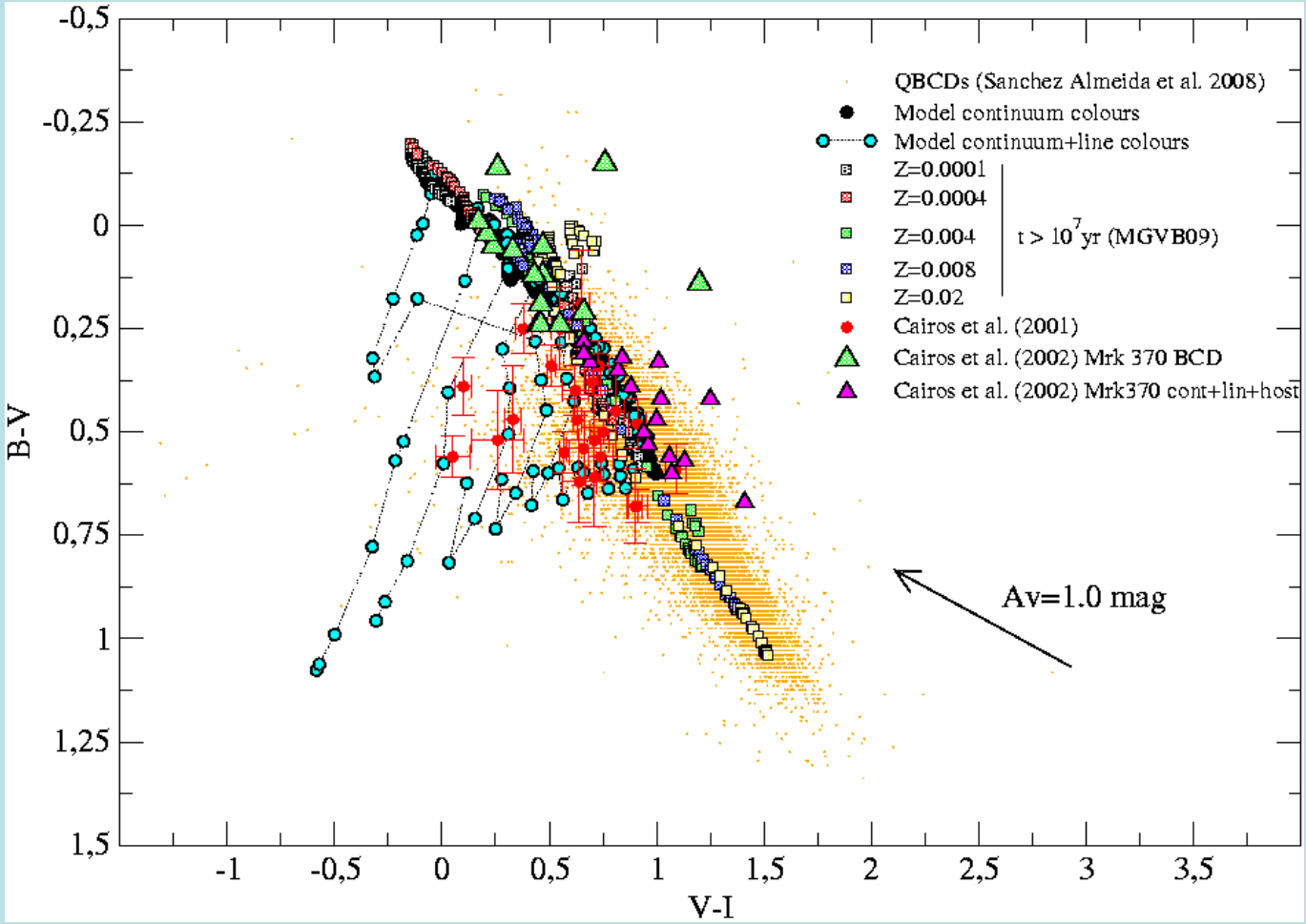
3727[OII]	3869[NeIII]	4102 Hδ	4340 Hγ
4363[OIII]	4471 HeI	4686 HeII	4861 Hβ
4959[OIII]	5007[OIII]	5871 HeI	6300[OI]
6312[SIII]	6548[NII]	6563 Hα	6584[NII]
6716[SII]	6731[SII]	9069[SIII]	9532[SIII]







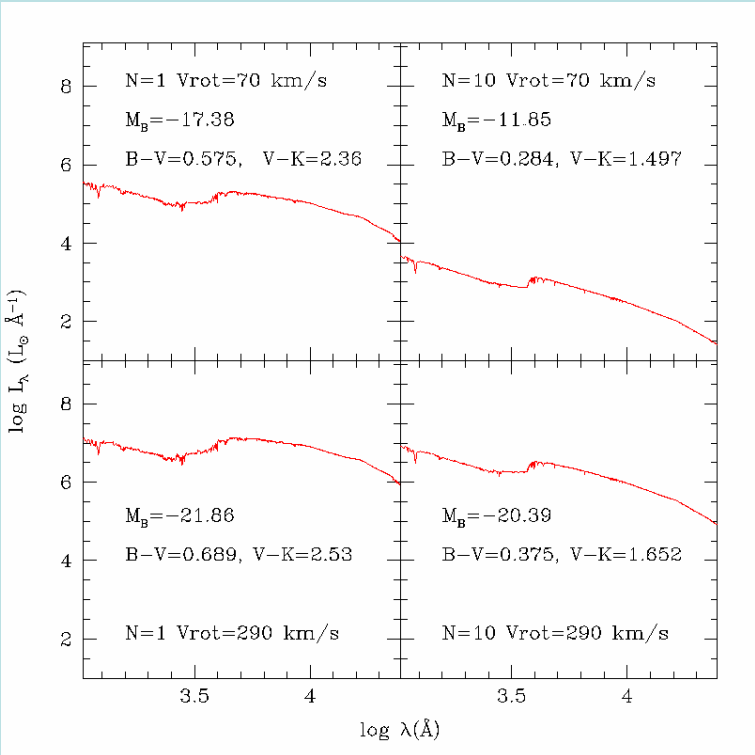
Changes in colors due to the emission lines


QBCDs (Sanchez Almeida et al. 2008)
Model continuum colours
Model continuum+line colours
Z=0.0001
Z=0.0004
Z=0.004
Z=0.008
Z=0.02
t > 10^7 yr (MGVB09)
Cairos et al. (2001)
Cairos et al. (2002) Mrk 370 BCD
Cairos et al. (2002) Mrk370 cont+lin+host
Av=1.0 mag
B-V
V-I
-0,5
-0,25
0
0,25
0,5
0,75
1
1,25
1,5
-1
-0,5
0
0,5
1
1,5
2
2,5
3
3,5

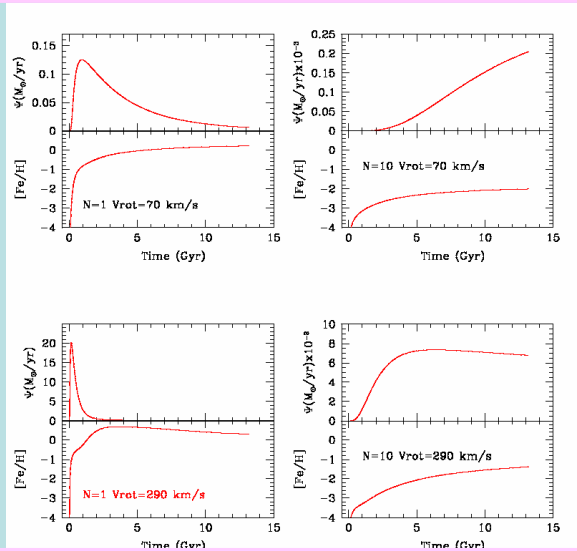
By using the star formation history and the age-metallicity relations obtained from the described chemical evolution models (Mollá & Díaz 2005), we calculate the spectral energy distribution (SED) $F_\lambda(t)$ for each galaxy from the deconvolution equation:

$$F_\lambda = \int S_\lambda(\tau, Z)\Psi(t-\tau)dt$$

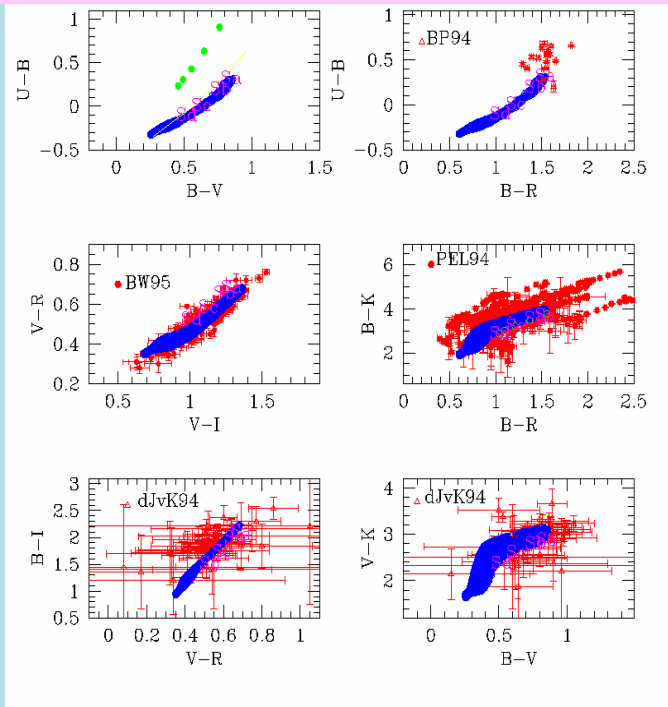
Resulting spectral energy distributions for the modeled galaxies



Star formation and metal enrichment histories resulting from chemical evolution models for different galaxy masses and Ns



Resulting Colours: present time, local Universe

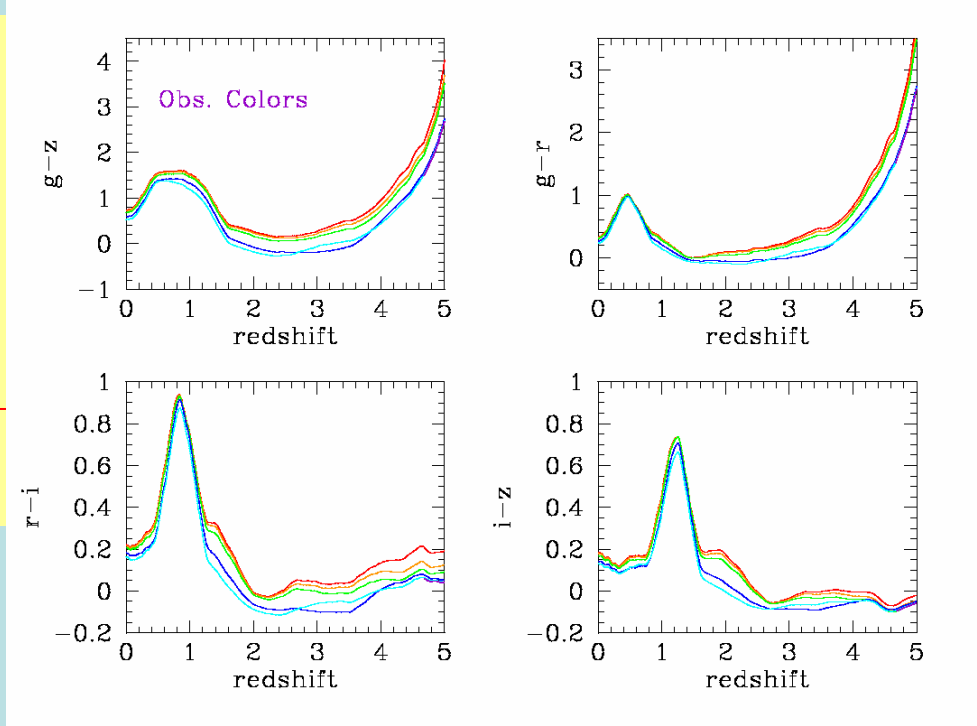


$F(\lambda, t)$ $\xrightarrow{F(\lambda*(1+z),t)/(1+z)}$ z

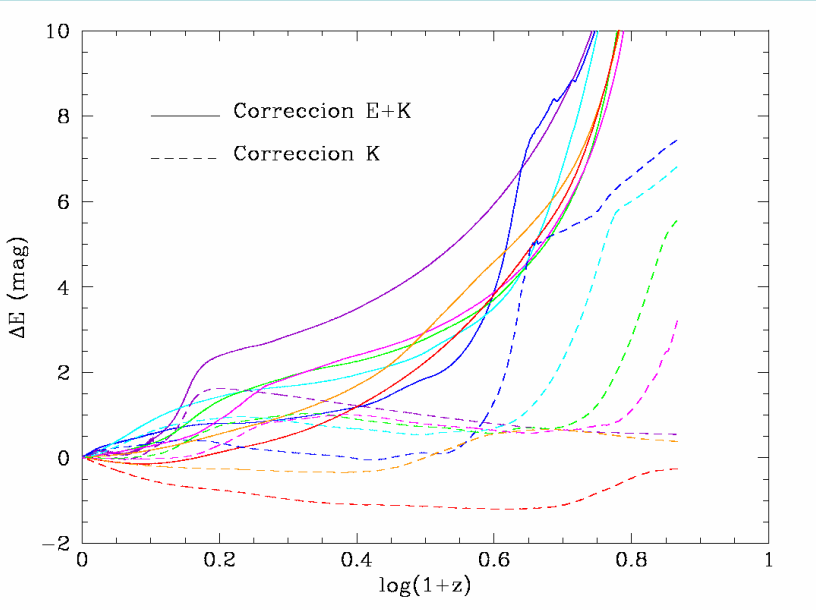
… …..

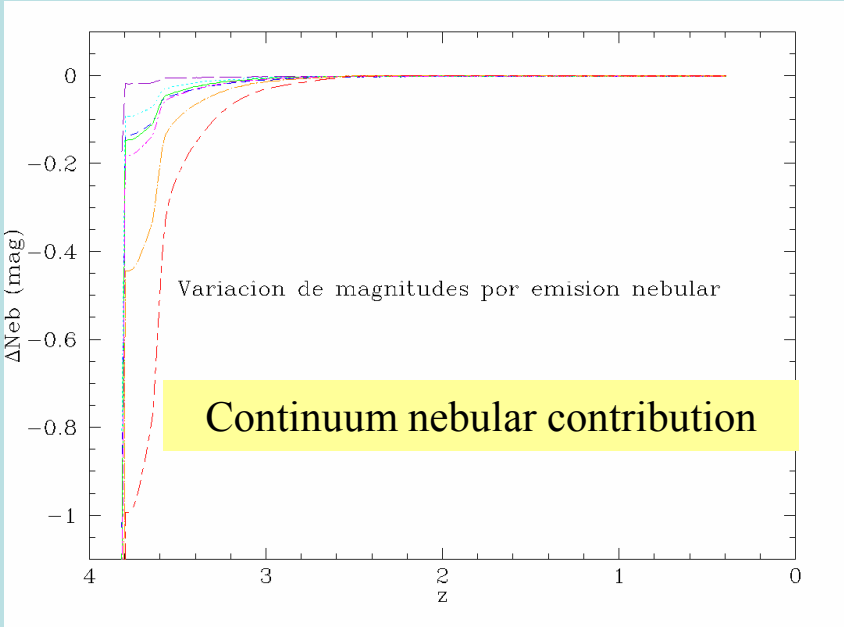
$F(\lambda,t_0)$ $\xrightarrow{F(\lambda*(1+z),t_0)/(1+z)}$ $z=0$

M_0 $\xrightarrow{m_{obs}= M_0+ EC + KC+ 5\log d_L}$

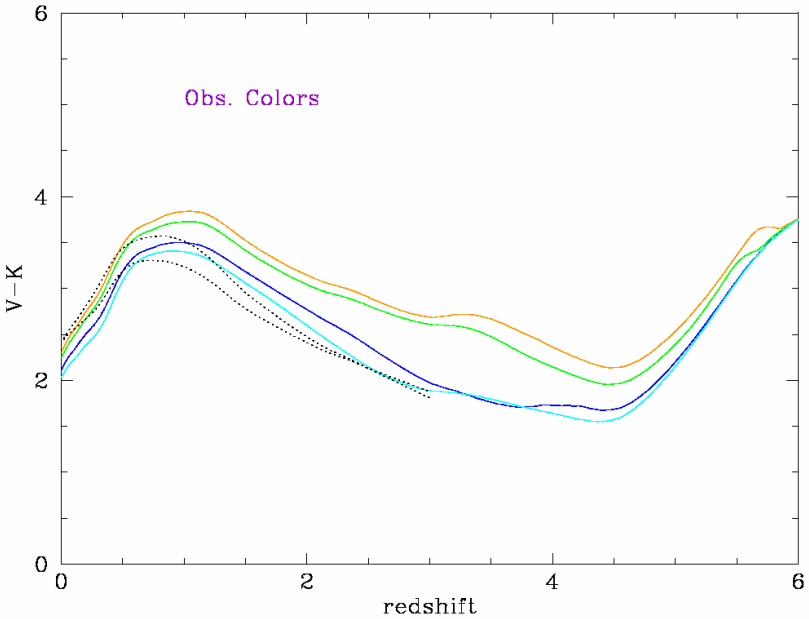


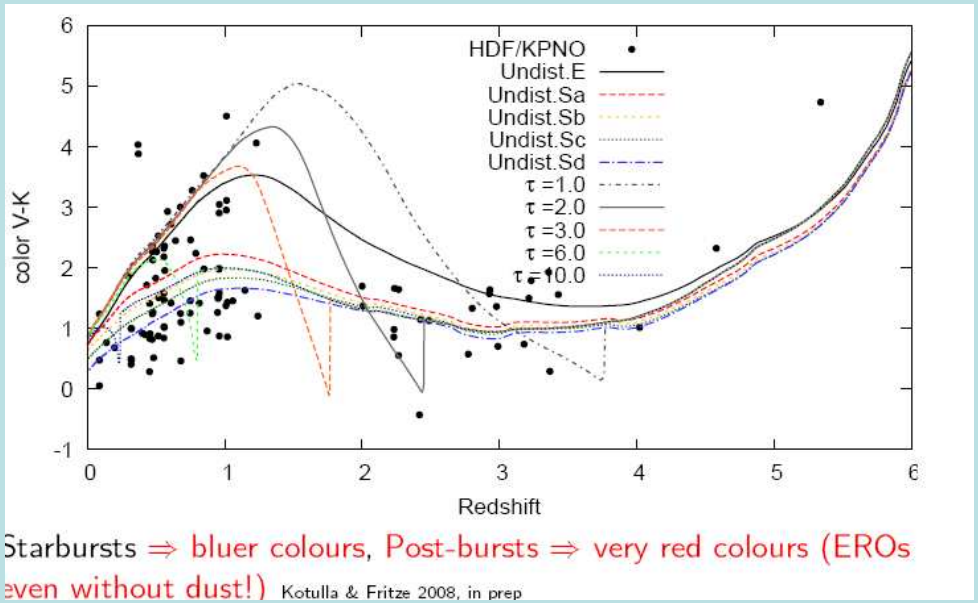
The correction including the evolutionary contributions is different than the classical K correction



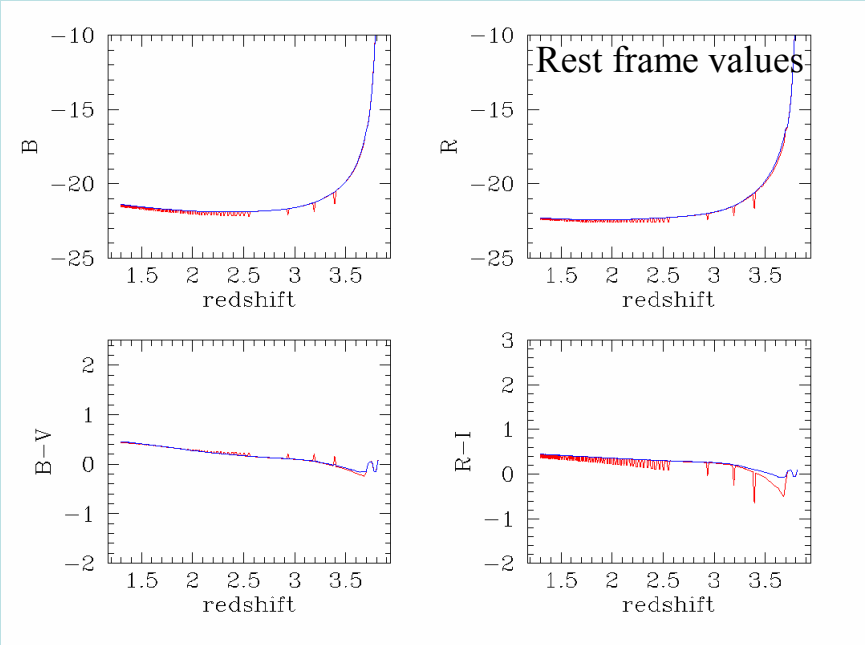


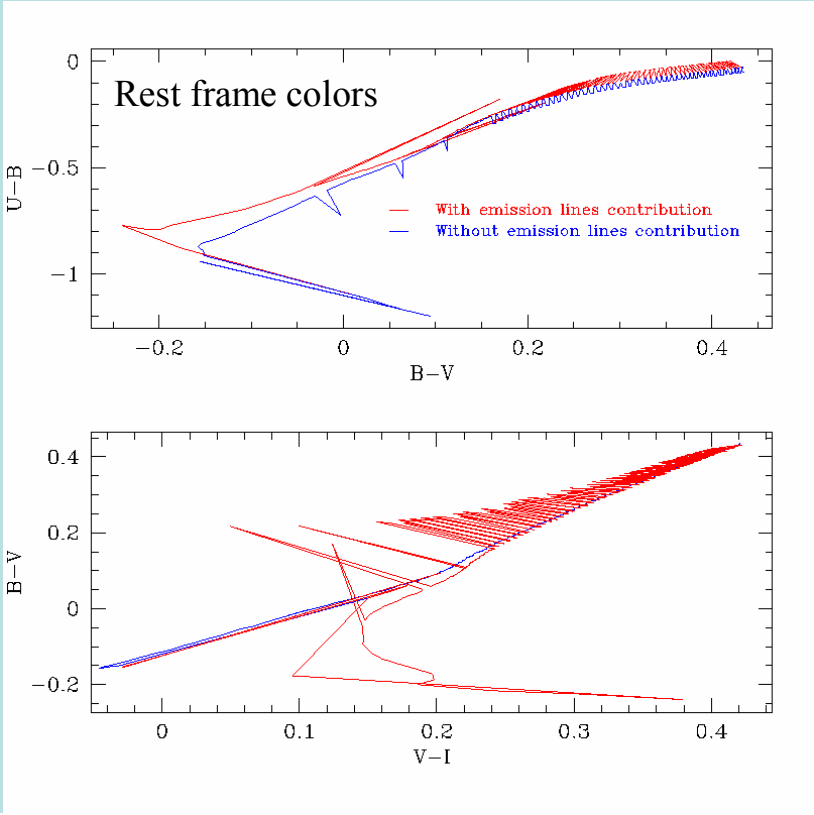
Continuum nebular contribution





Preliminary results





Summary

- **Templates: galaxy models including evolution are necessary**
- **The SSP´s SEDs are calculated with an update code (Mollá et al 2009)**
  - **The effect of the low metallicity stellar populations is important**
  - **The nebular contribution reddens the spectra of young populations**
  - **The emission line contribution changes dramatically the color-color diagrams**
- **The theoretical galaxy SEDs and colors for the present time are done. These models are calibrated with the local Universe data**
- **The galaxy evolutionary models are in progress…**
  - **Rest-frame magnitudes and colors**
  - **Predicted observed magnitudes and colors**
  - **K and evolutionary corrections**
- **To include the emission lines**
- **To check the templates with observed data**
- **To use them with a photometric redshift code to check for systematic errors**

Resumen

- **Los diferentes métodos o códigos muestran diferencias en cuanto a los resultados y su precisión asociada: mejor modelos que templates**
- **La manera de calcular las magnitudes a otro redshift cuando se usan templates empíricos se hace a través de la corrección K:**

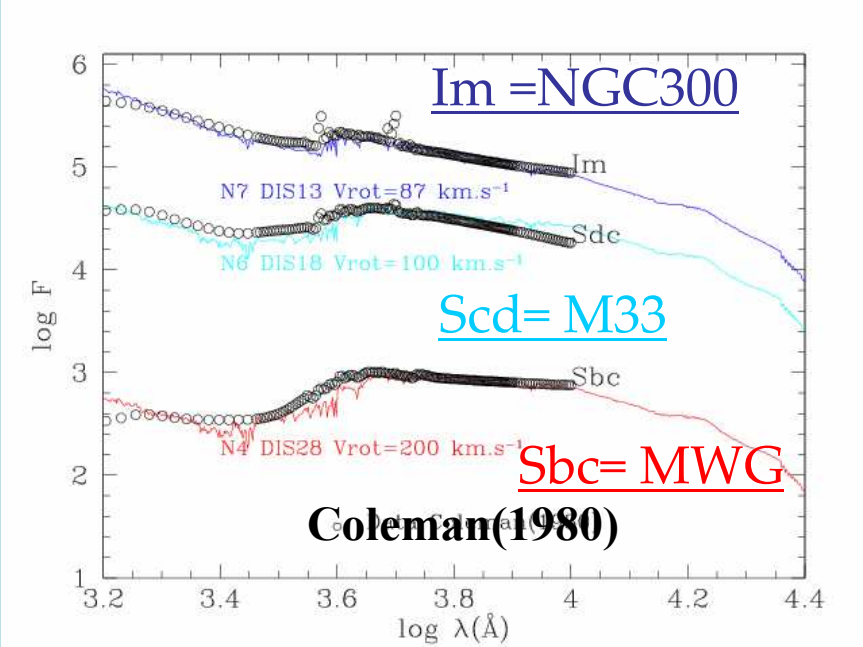
$$\text{flujo}_{obs} = \text{flujo}_{emi}/(1+z)$$

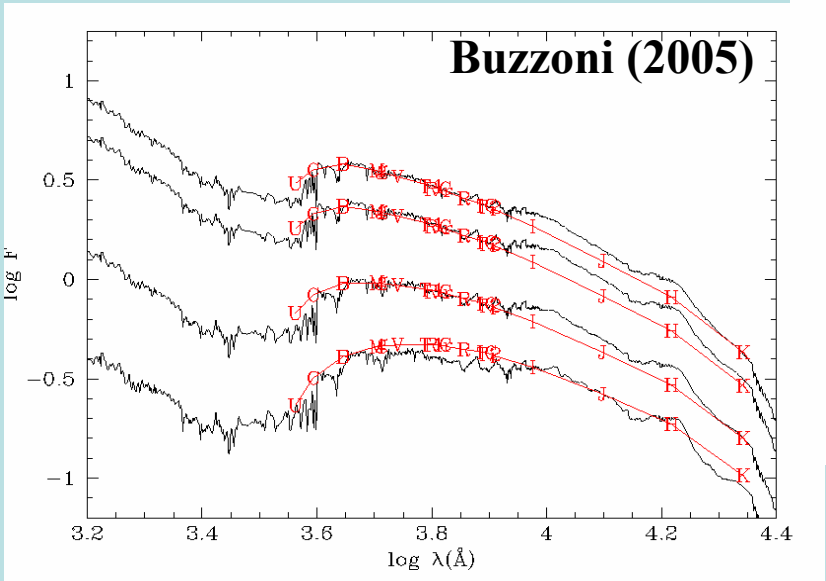
$$\lambda_{obs} = \lambda_{emi}(1+z)$$

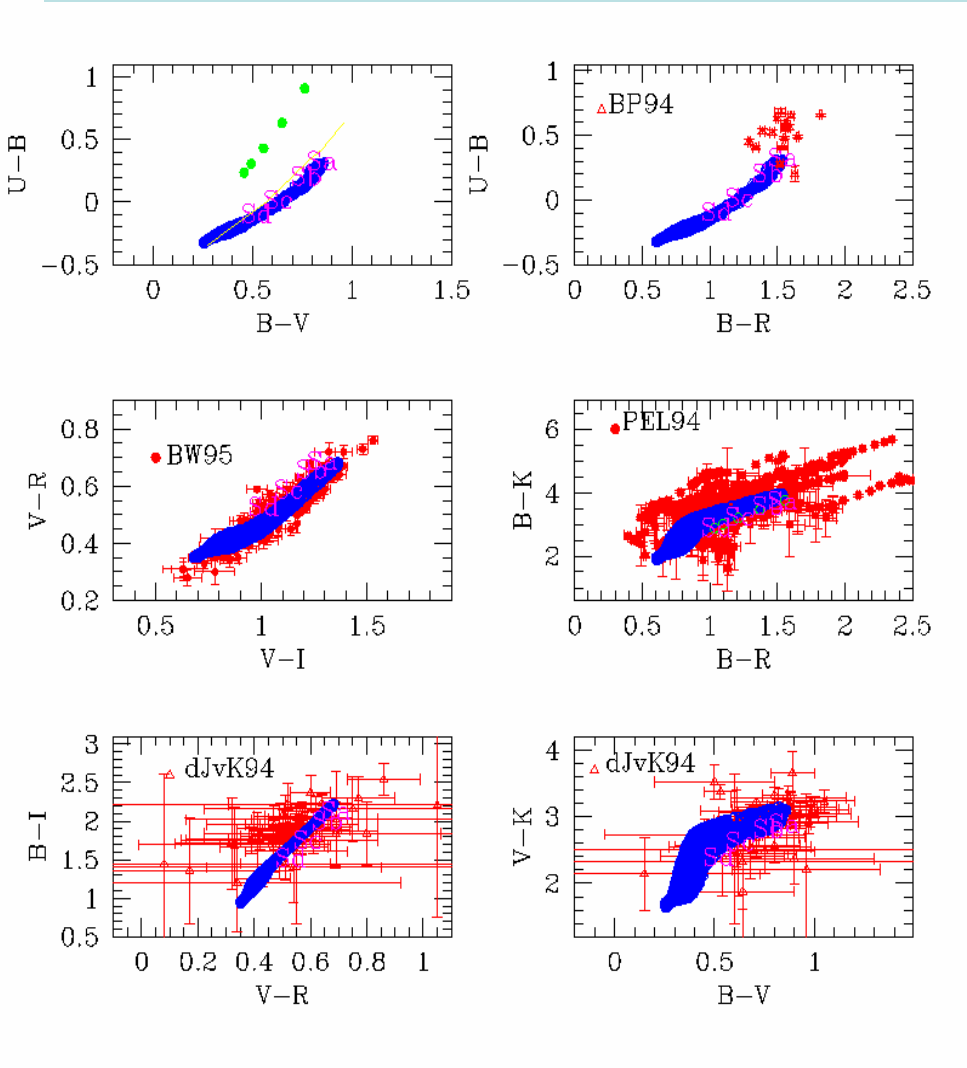
Esto implica que la evolución de las galaxias no se tiene en cuenta: m=M+5logD+K

- **La formación estelar en el Universo fue más alta en el pasado que ahora: el impacto de esta formación estelar y de la variación de Zmet es más importante a alto redshift: m=M+5logD+K+E**
- **Para tener en cuenta esa evolución hay que usar modelos de galaxias. Ya algunos modelos suponen una historia de formación estelar pero no la variación de la metalicidad producida**
- **Cada tipo de galaxia tiene una historia evolutiva que produce un enriquecimiento químico diferente**
- **Las líneas de emisión pueden ser importantes**
- **Las poblaciones de baja metalicidad son diferentes de las solares**
- **La extinción o enrojecimiento de cada galaxia depende de la cantidad de polvo, asociada a nubes moleculares y brotes de formación estelar**

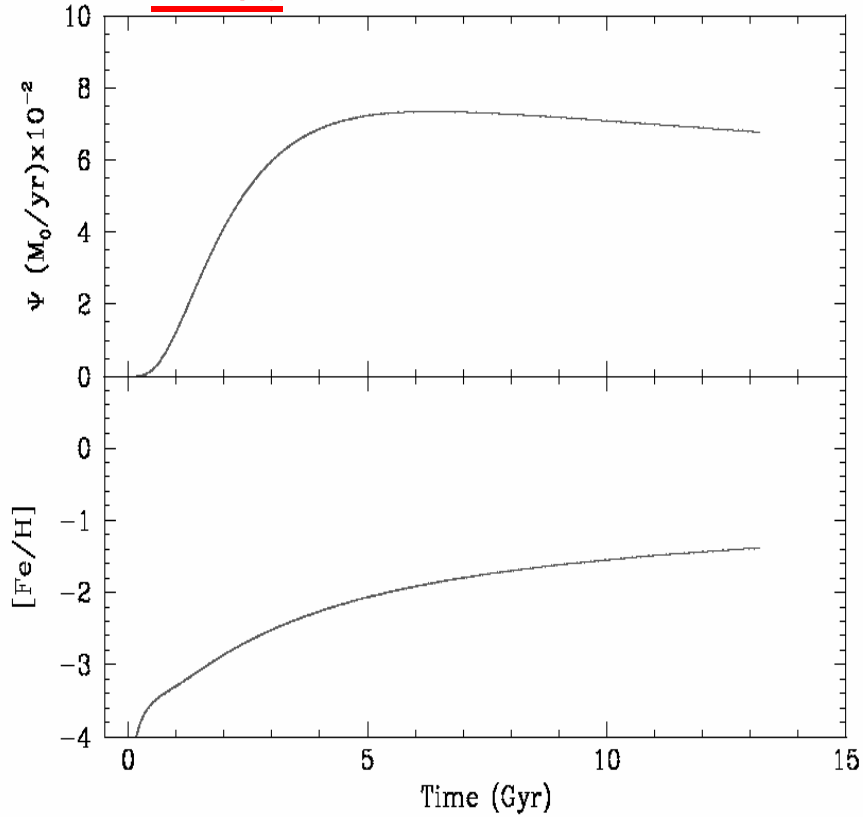
SEDs and colors for some galaxy models:





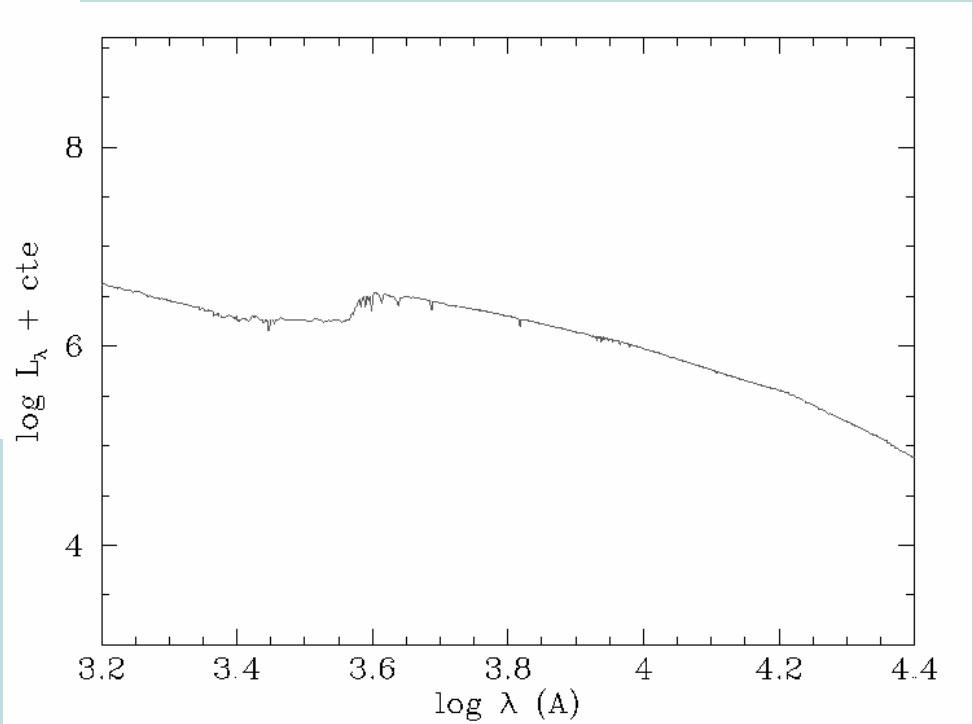


N=10 Vrot= 290 km/s

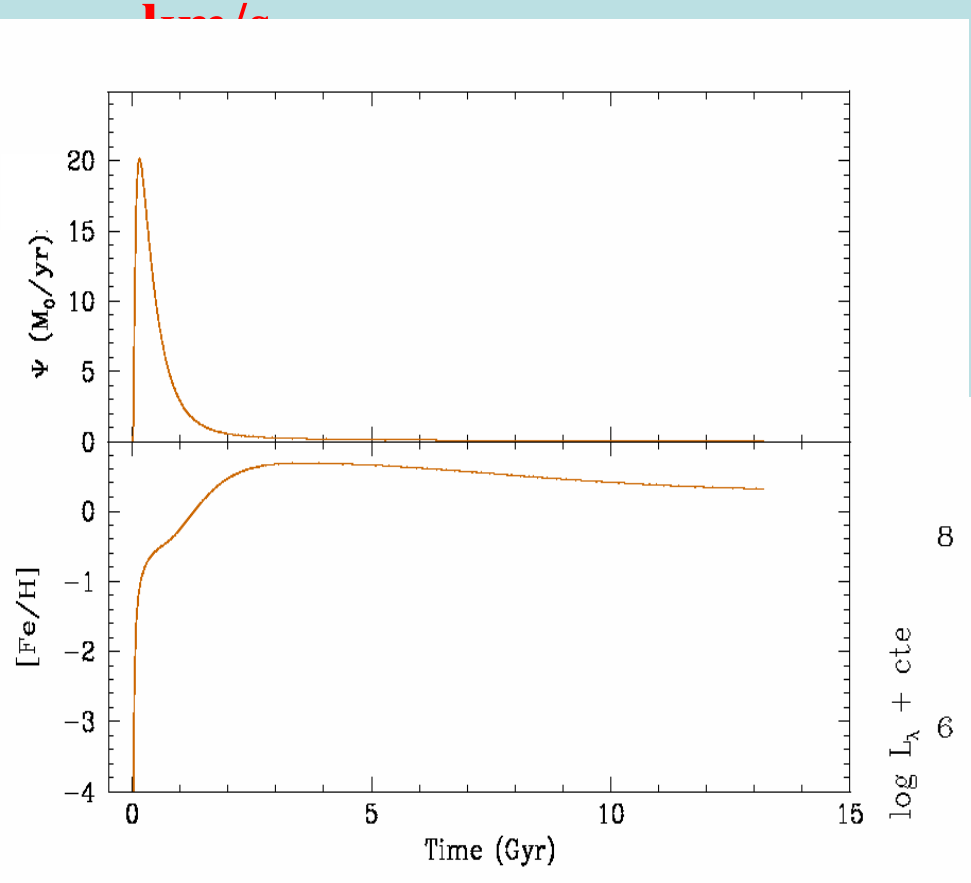


Low metallicity
[Fe/H] =-1.4

SFH almost constant
~0.08 Msun/yr

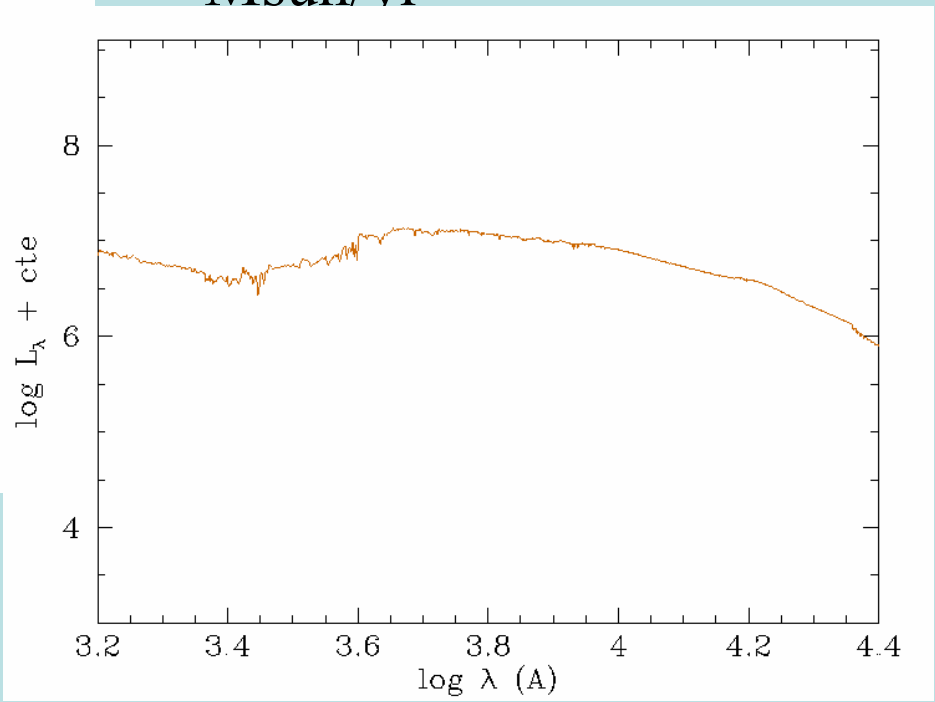


N=1 Vrot= 290 km/s

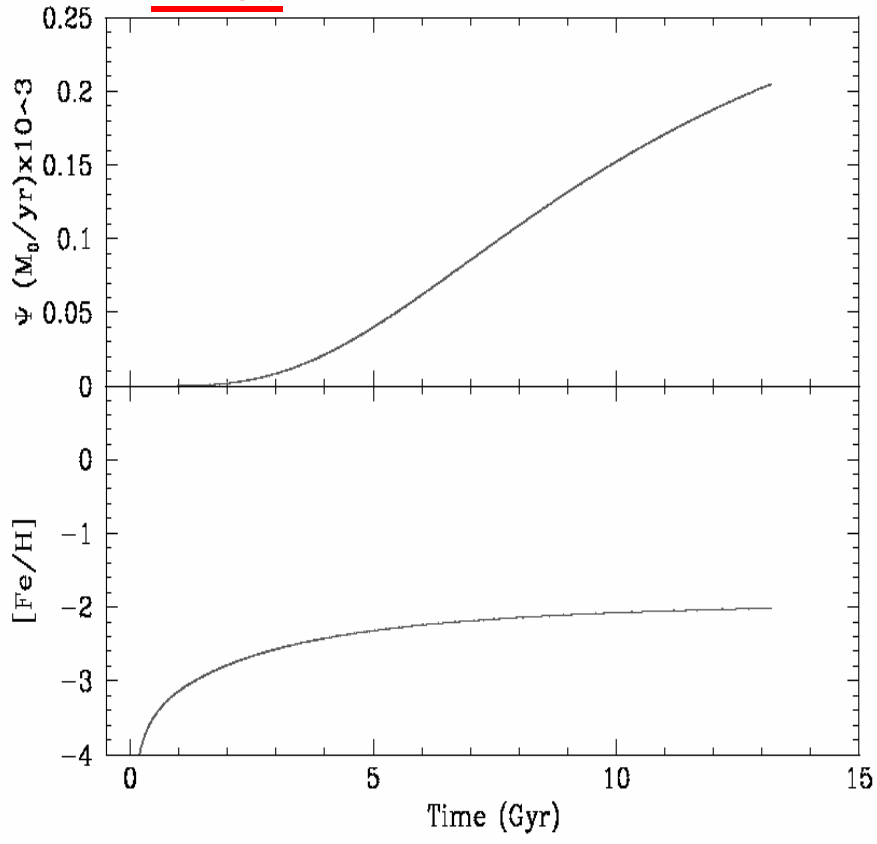


High metallicity
[Fe/H] =0.2

SFH starburst ~20 Msun/yr



N=10 Vrot= 70 km/s

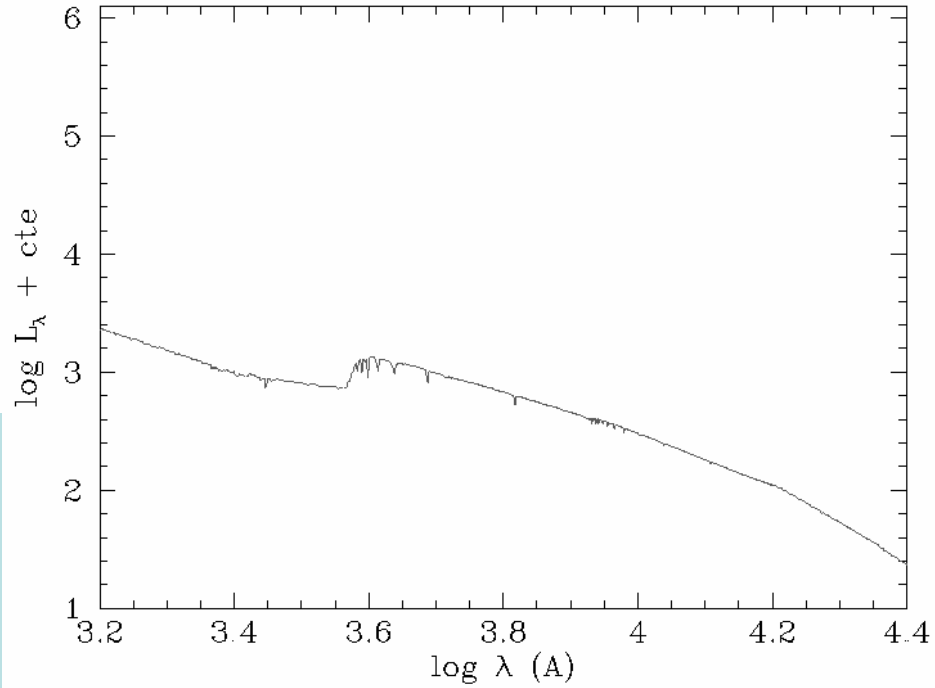


Vey low metallicity [Fe/H] =-2.0

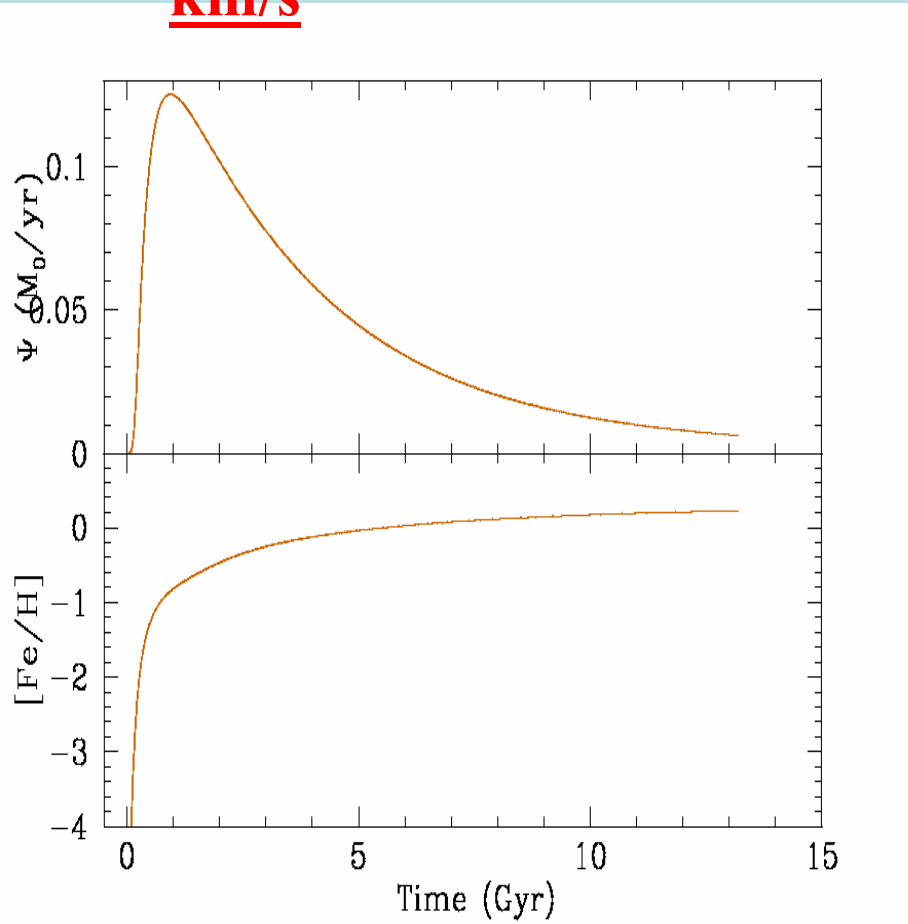
SFH increasing

~2 10 $^{-4}$ Msun/yr

Mean age ~2 Gyr



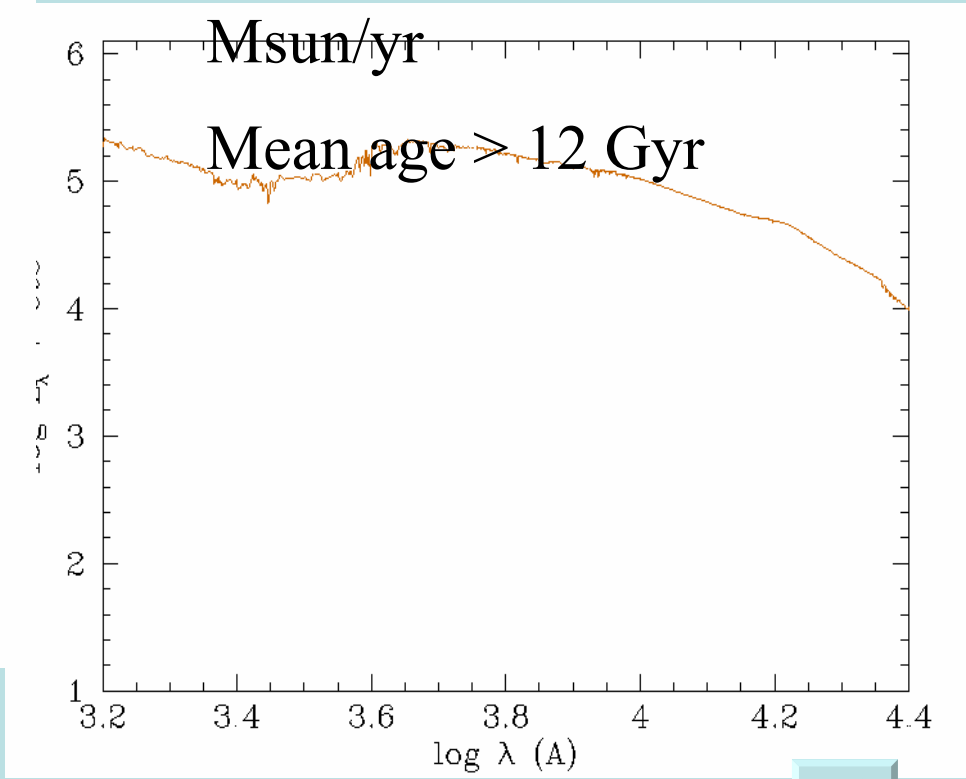
N=1 Vrot= 70 km/s



High metallicity
[Fe/H] =0.2

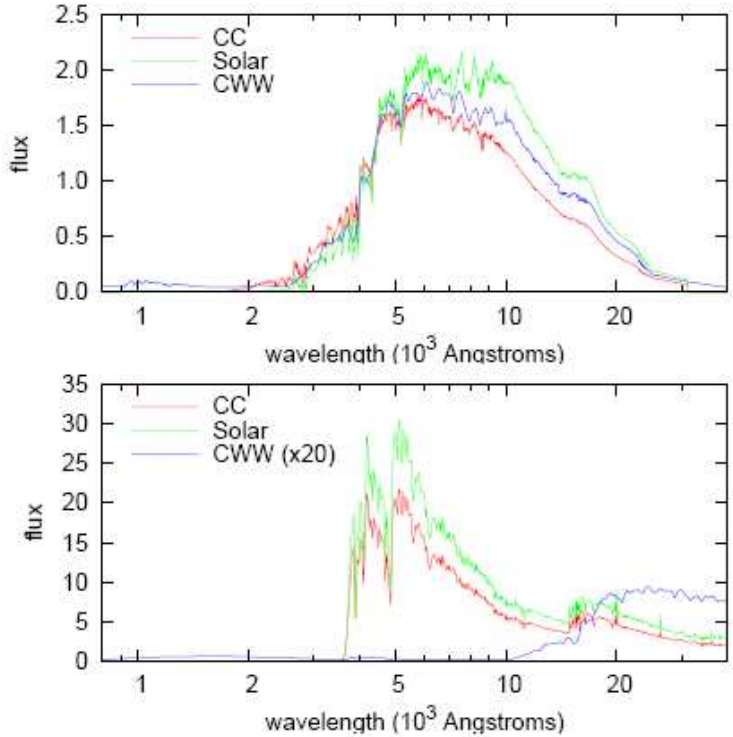
SFH max ~0.1 Msun/yr

Mean age > 12 Gyr

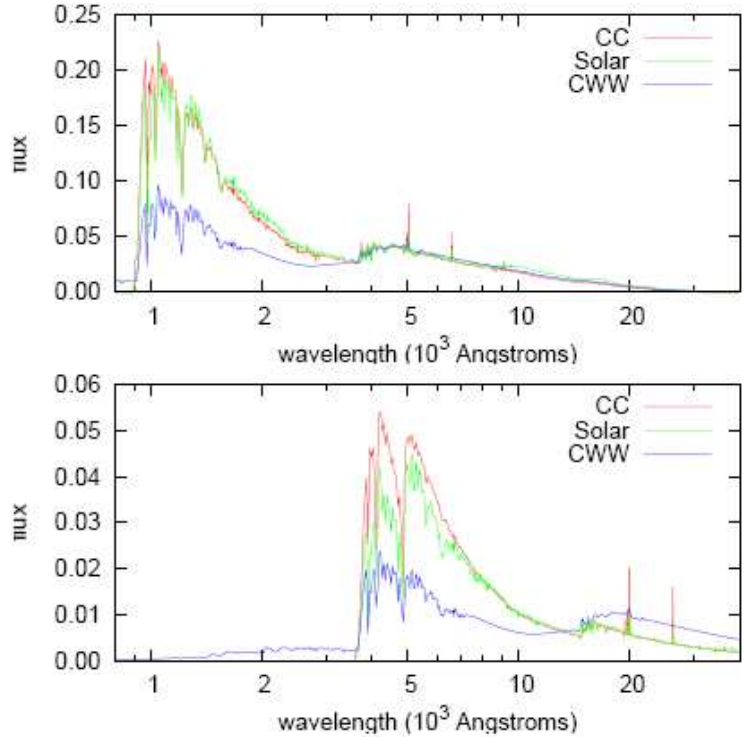


Importance of evolutionary corrections for phot. redshifts

Spectral evolution of E- and Sd-type galaxies with redshift



Elliptical model: z=0 & z=3



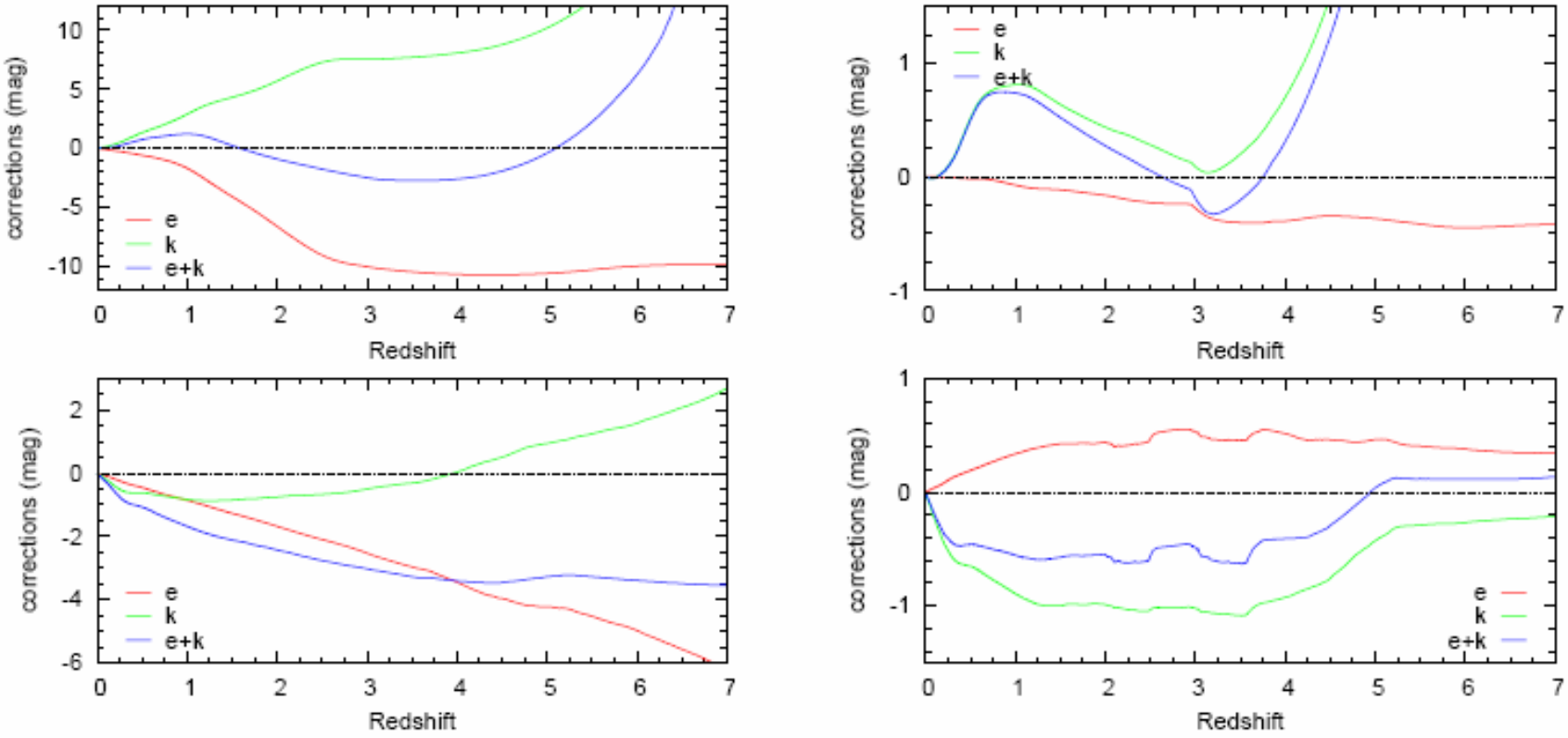
Sd model: z=0 & z=3

Corrección K y Corrección Evolutiva

Evolutionary and cosmological corrections

Kotulla et al. (2009)

Both e- and k-corrections strongly depend on filter and galaxy type!



E-model, V & K-band

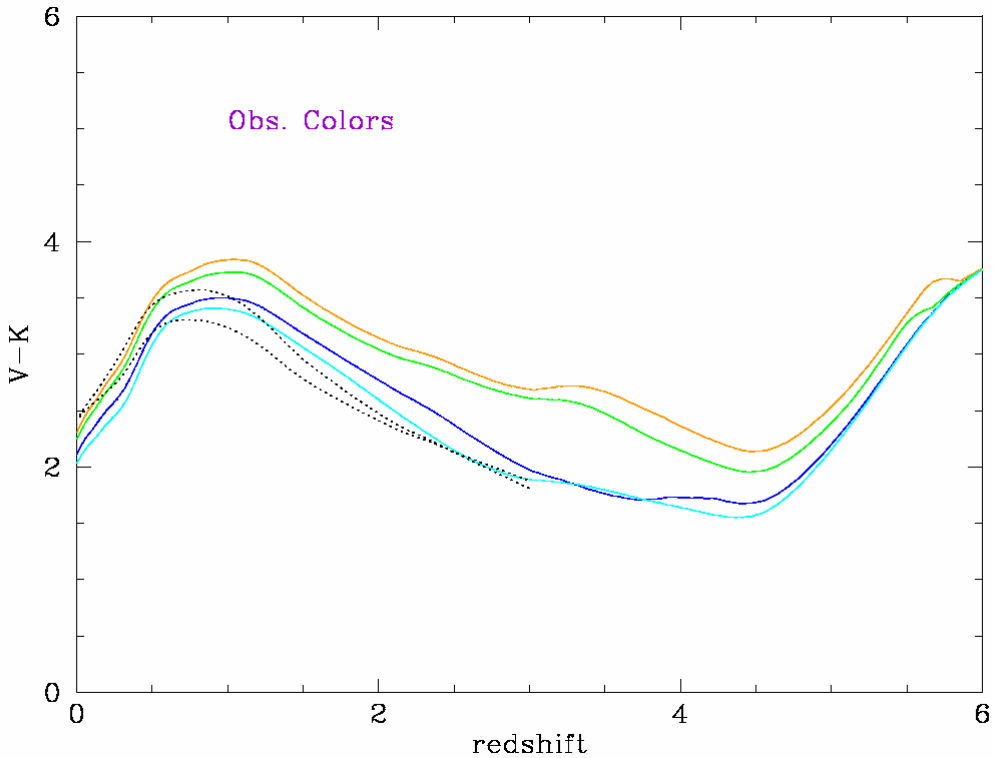
Sd-model, V & K-band

Impact of sub-so

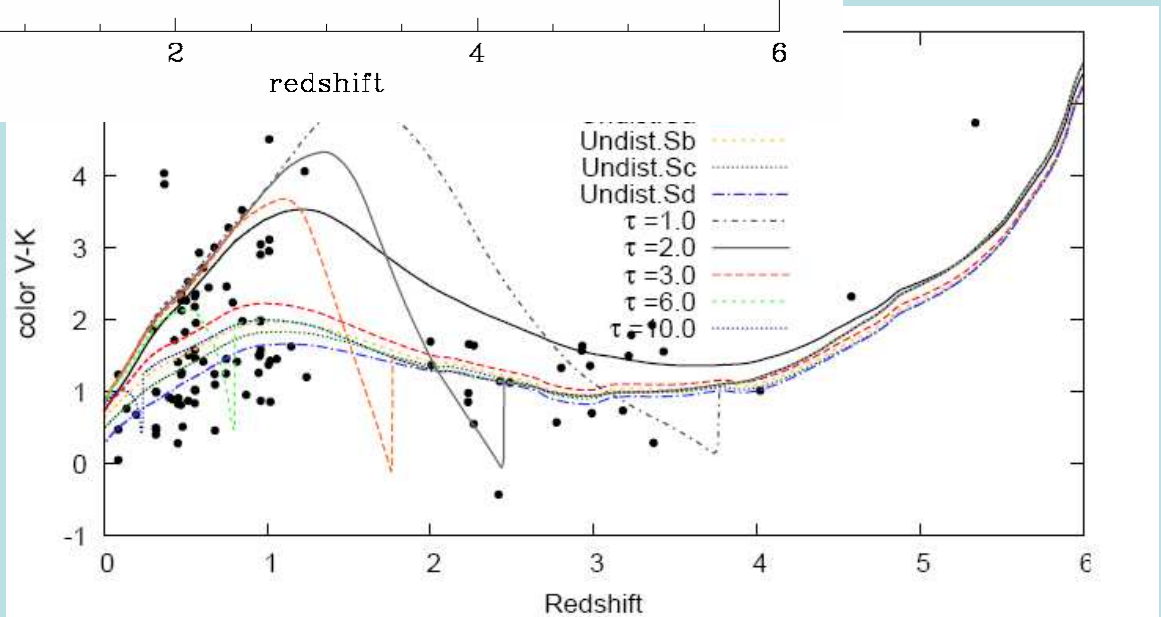
Compared to equal-ma
metallicity galaxies ...

- ... are bluer
  ⇒ underestimate
- ... are brighter
  ⇒ overestimate m
- ... have stronger
  ⇒ overestimate S

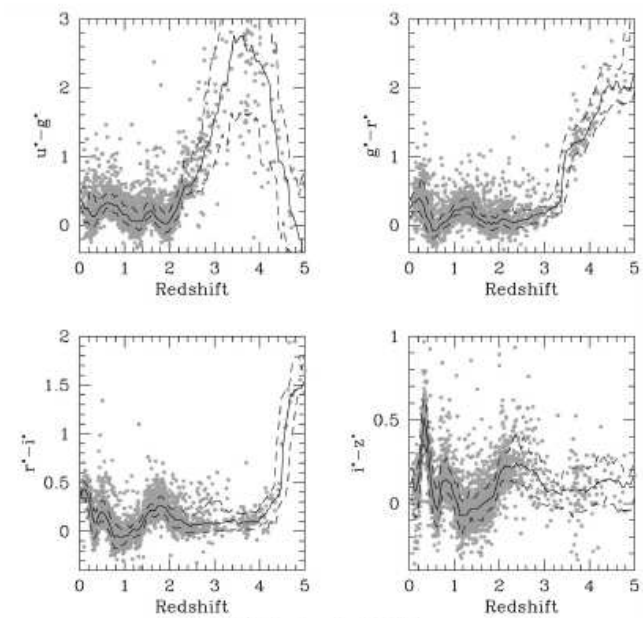
if solar-metallicity calib



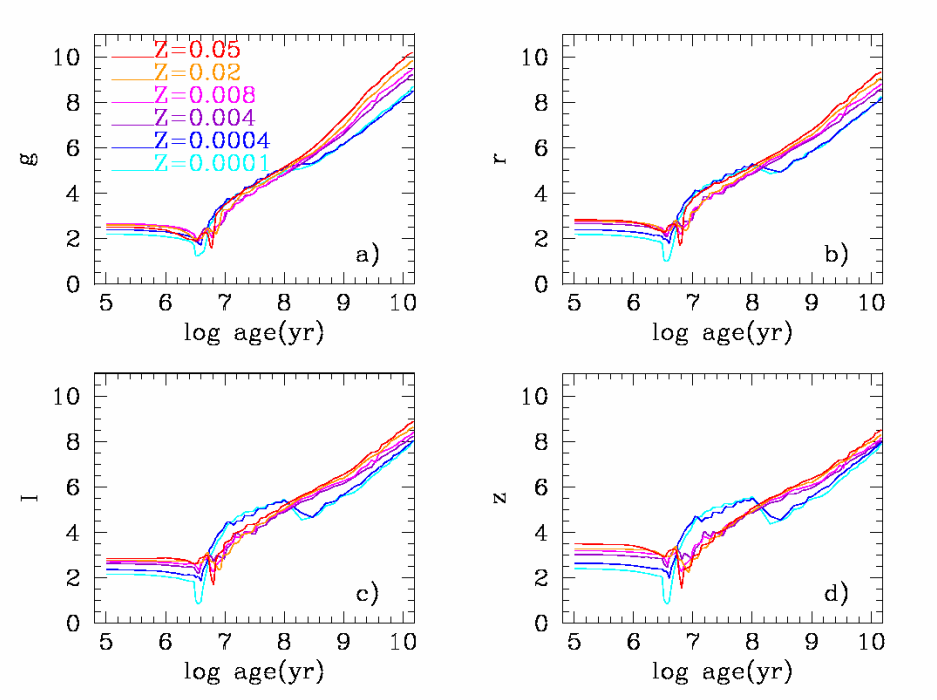
La formación estelar produce líneas de emisión que puede afectar a los colores/magnitudes en banda ancha y "engañar" cuando se hacen ajustes observaciones-modelos



Starbursts ⇒ bluer colours, Post-bursts ⇒ very red colours (EROs even without dust!) Kotulla & Fritze 2008, in prep



Richards et al. 2001


Z=0.05
Z=0.02
Z=0.008
Z=0.004
Z=0.0004
Z=0.0001
g
r
I
z
a)
b)
c)
d)
log age(yr)
0
2
4
6
8
10
5
6
7
8
9
10