

A photometric and spectroscopic study of dwarf
and giant galaxies:

Spectral ages & Metallicities

Poggianti et al. (2001)

Lifang Xia 18 April, 2008

Outline

- Background
- Data
- Model
- Results
 - index - R relation
 - index - index relation
 - Age - R relation; Metallicity - R relation
 - Age - Metallicity relation
 - index - R relation
- Summary

Background

■ Dwarf galaxies

- Most numerous in local universe
- Building blocks of more massive galaxies
- Earliest cosmic star formation
- Internal and external conditions
 - mass loss due to SN-driven outflows
 - external UV radiation field
- Strongest morphology-density relation

■ Non-star-forming dwarf galaxies

• Local group

varied and complex SFH: wide range of SFR, length and the epoch of star formation episodes, chemical enrichment;

global relation between M-Z-I

mass & environment

• clusters

limited to small samples

broadband photometry and spectroscopic study for dwarf galaxies in Fornax, Virgo, Coma clusters indicate that dwarf galaxies have a wider range of age and metallicity than massive galaxies, and have experienced a more varied SFH

■ Luminous early-type galaxies

tight relation $Mg_2-\sigma$

weak and large scatter for other metal lines

negative correlation of Balmer indices - σ

shell and pair galaxies deviate from $H\beta-\sigma$ and $Mg_2-\sigma$ relation: secondary bursts of star formation

• Z - Mass

Star formation history

Fornax cluster: coeval with a range of Z

cluster and group: large ages with a range of Z

noncluster: intermediate-age or young populations

• Environment effects: older in denser

• Hubble type

luminous E and S0 galaxies: coeval

faint S0 galaxies: large spread of age

■ Large number of spectra, wide spectral coverage,

broad magnitude range,

diversity of environment conditions

⇒ how many and which parameters govern the evolution of low- and high-luminosity cluster galaxies

Sample

- William Herschel Telescope

32.5×50.8 arcmin² (~1×1.5 Mpc) at central and southwest regions

B, R photometry: $M_B = (-20.5, -14)$ ($m-M = 35.16$)

Spectra

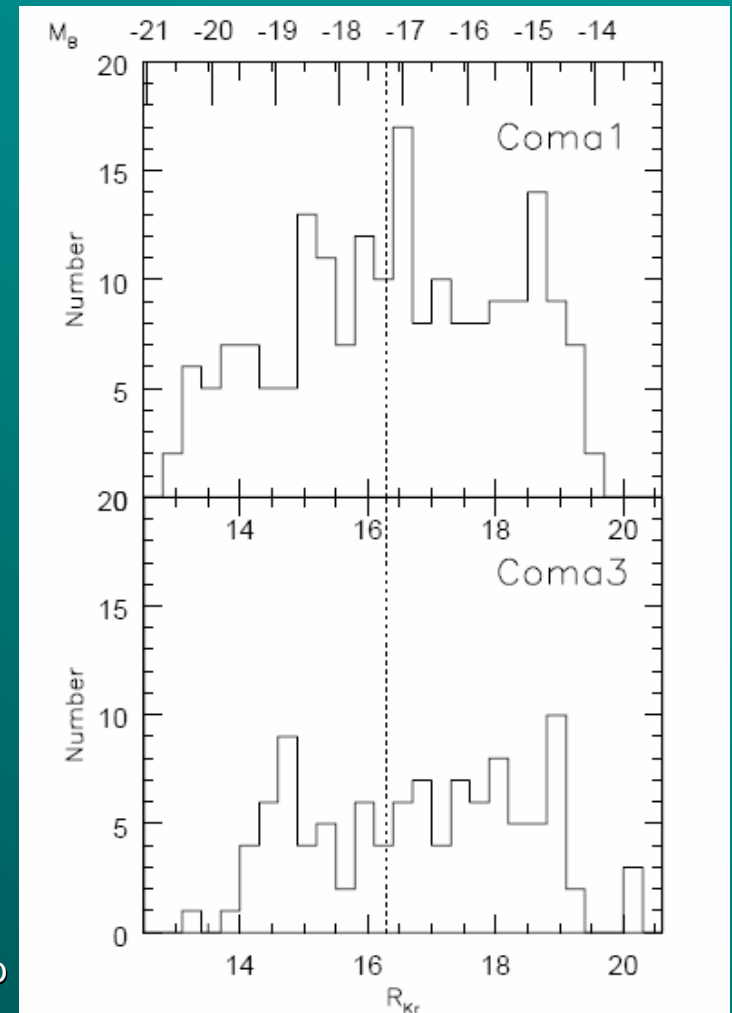
$\lambda = 3600 - 6600 \text{ \AA}$, $R = 6-9 \text{ \AA}$ (~3Å/pixel),
 $D = 2.''7 \sim 1.3 \text{ kpc}$ ($H_0 = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$)

- $v = (4000, 10000) \text{ km/s}$

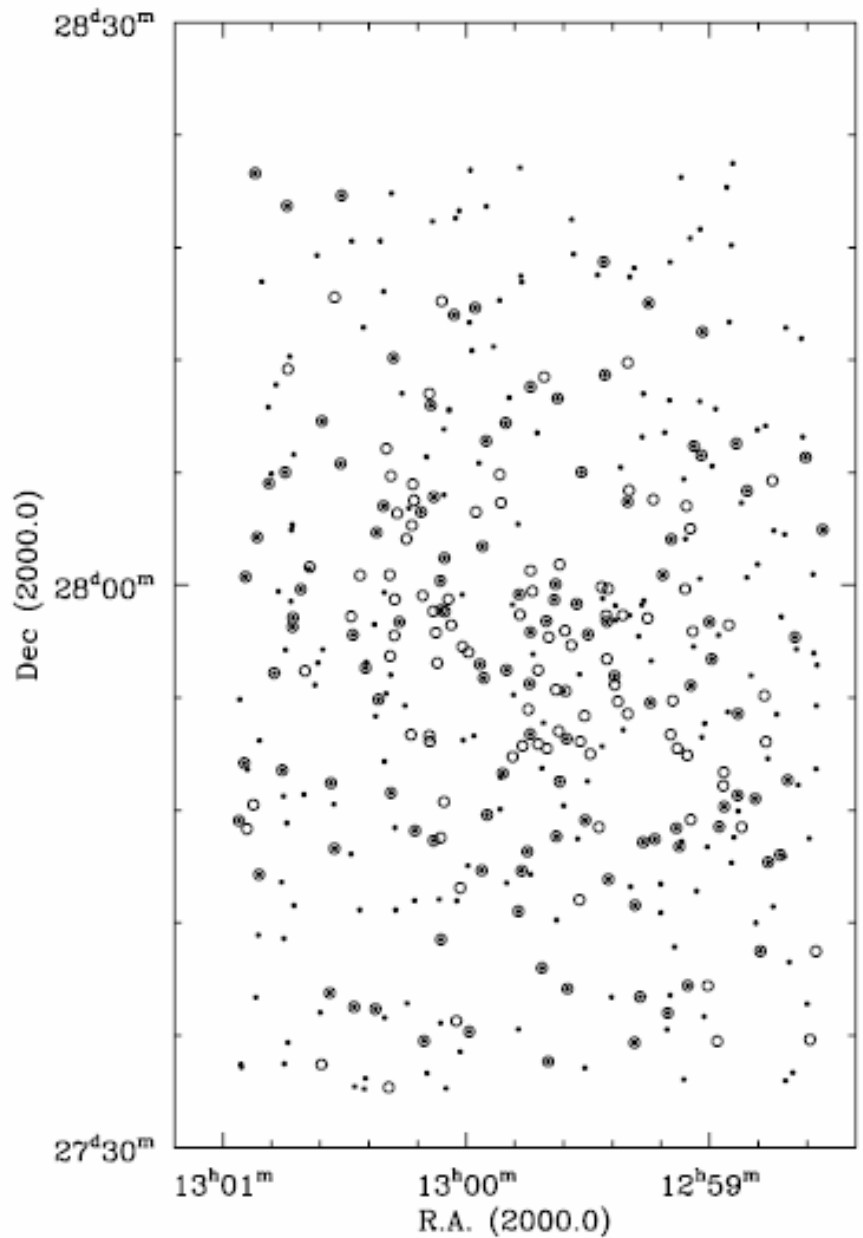
⇒ 189 central + 89 southwest

$R_{3Kr} = 16.3$ ($M_B = -17.3$)

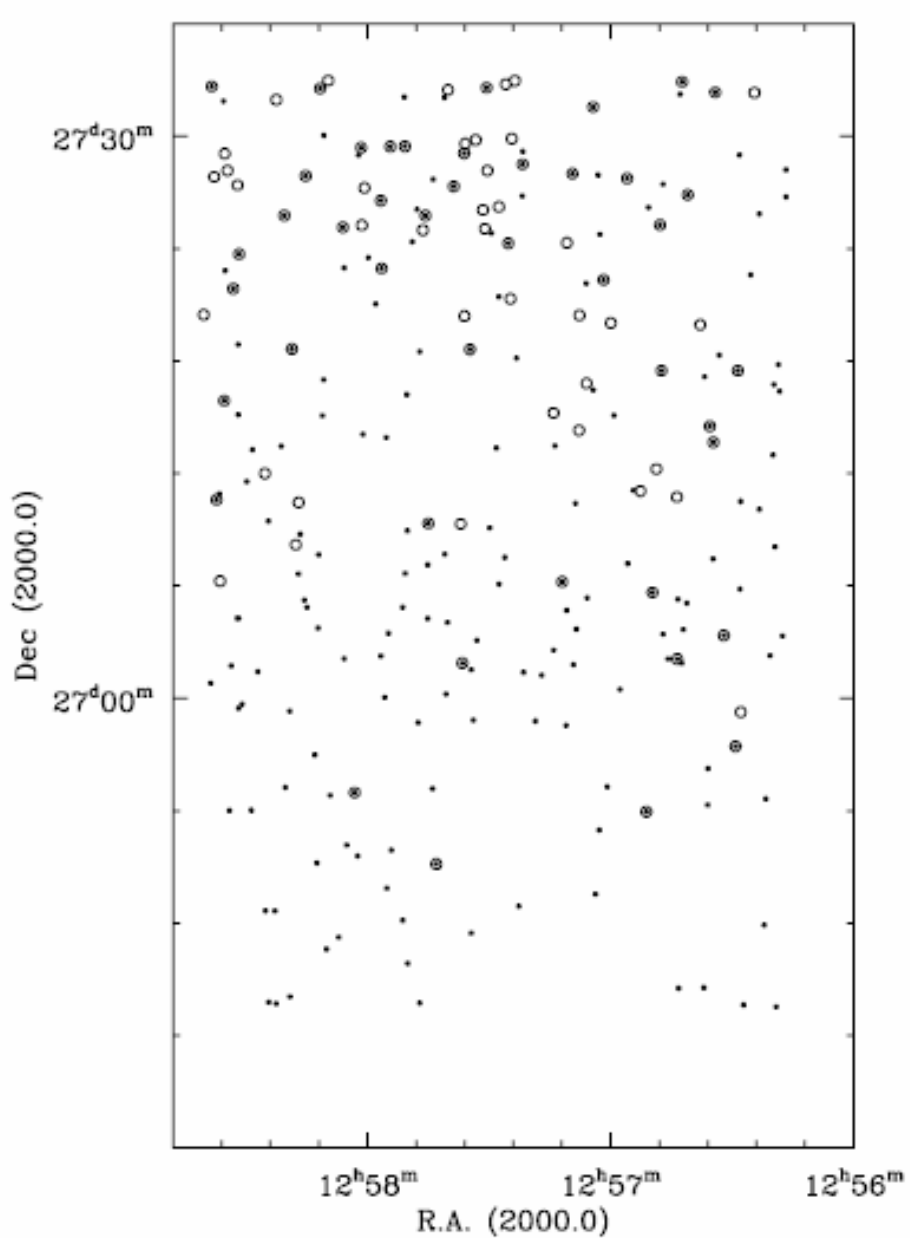
⇒ 160 dwarf + 118 giants



Spatial Distribution of Galaxies in Coma1



Spatial Distribution of Galaxies in Coma3



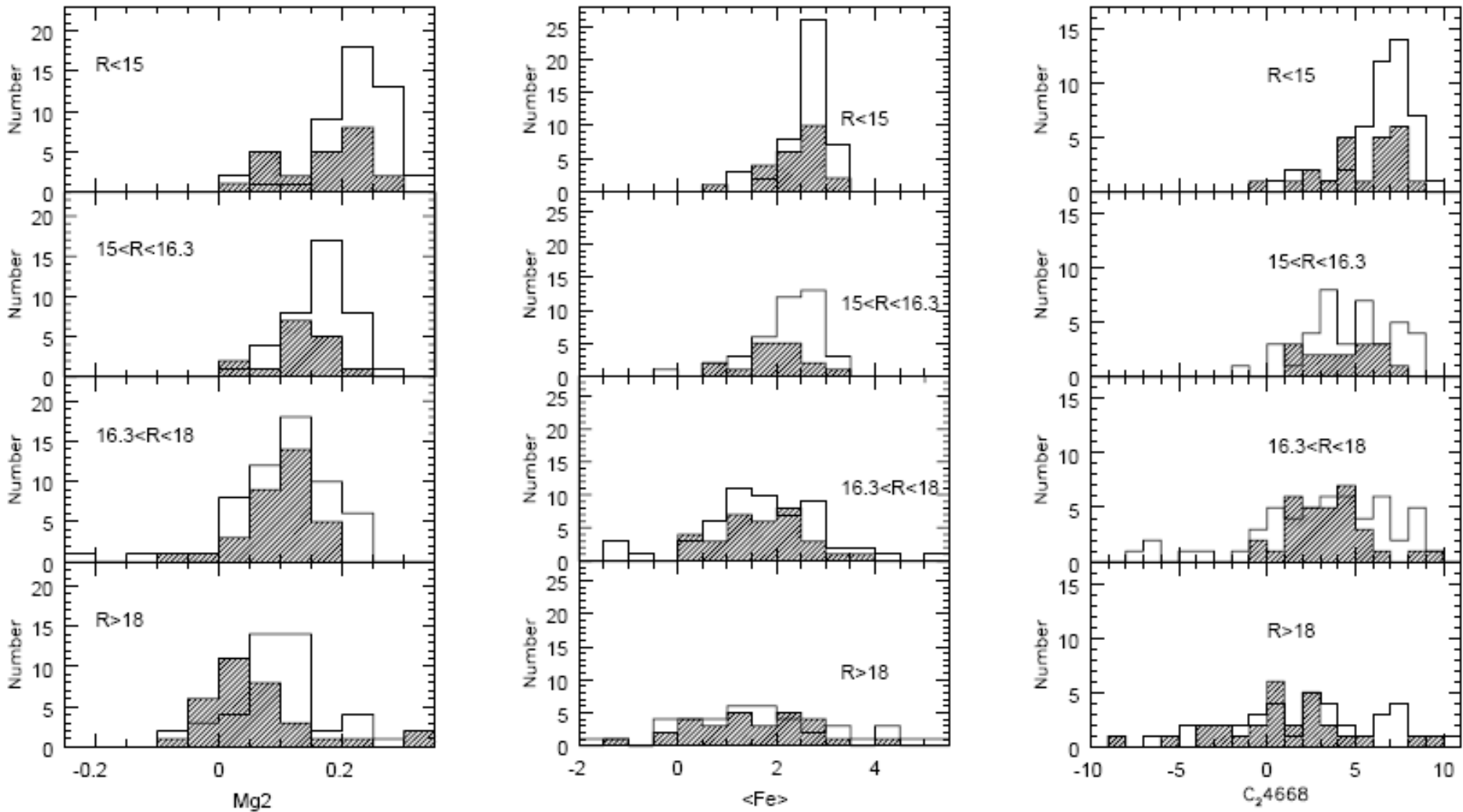
Lick Indices

- Lick/IDS system
 - spectral index system
 - used to investigate the Z and SFH of galaxies
 - without current star formation
- Compare with model
 1. Different resolution
 2. Internal σ
 3. Systematic offsets

INDEX DEFINITIONS					
N_i	Name	Index Bandpass	Blue Bandpass	Red Bandpass	Units
01	CN ₁	4142.125–4177.125	4080.125–4117.625	4244.125–4284.125	mag
02	CN ₂	4142.125–4177.125	4083.875–4096.375	4244.125–4284.125	mag
03	Ca4227	4222.250–4234.750	4211.000–4219.750	4241.000–4251.000	Å
04	G4300	4281.375–4316.375	4266.375–4282.625	4318.875–4335.125	Å
05	Fe4383	4369.125–4420.375	4359.125–4370.375	4442.875–4455.375	Å
06	Ca4455	4452.125–4474.625	4445.875–4454.625	4477.125–4492.125	Å
07	Fe4531	4514.250–4559.250	4504.250–4514.250	4560.500–4579.250	Å
08*	C ₂ 4668	4634.000–4720.250	4611.500–4630.250	4742.750–4756.500	Å
09*	H _{β}	4847.875–4876.625	4827.875–4847.875	4876.625–4891.625	Å
10	Fe5015	4977.750–5054.000	4946.500–4977.750	5054.000–5065.250	Å
11	Mg ₁	5069.125–5134.125	4895.125–4957.625	5301.125–5366.125	mag
12*	Mg ₂	5154.125–5196.625	4895.125–4957.625	5301.125–5366.125	mag
13	Mg b	5160.125–5192.625	5142.625–5161.375	5191.375–5206.375	Å
14	Fe5270	5245.650–5285.650	5233.150–5248.150	5285.650–5318.150	Å
15	Fe5335	5312.125–5352.125	5304.625–5315.875	5353.375–5363.375	Å
16	Fe5406	5387.500–5415.000	5376.250–5387.500	5415.000–5425.000	Å
17	Fe5709	5696.625–5720.375	5672.875–5696.625	5722.875–5736.625	Å
18	Fe5782	5776.625–5796.625	5765.375–5775.375	5797.875–5811.625	Å
19	Na D	5876.875–5909.375	5860.625–5875.625	5922.125–5948.125	Å
20	TiO ₁	5936.625–5994.125	5816.625–5849.125	6038.625–6103.625	mag
21	TiO ₂	6189.625–6272.125	6066.625–6141.625	6372.625–6415.125	mag
22	H δ _A	4083.500–4122.250	4041.600–4079.750	4128.500–4161.000	Å
23	H γ _A	4319.750–4363.500	4283.500–4319.750	4367.250–4419.750	Å
24*	H δ _F	4091.000–4112.250	4057.250–4088.500	4114.750–4137.250	Å
25*	H γ _F	4331.250–4352.250	4283.500–4319.750	4354.750–4384.750	Å
26*	$\langle \text{Fe} \rangle$	(Fe 5270 + Fe 5335)/2			Å
27	[MgFe]	$\sqrt{\text{Mg } b \langle \text{Fe} \rangle}$			Å

Trager et al. (1998); Worthey & Ottaviani (1997)
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Index results

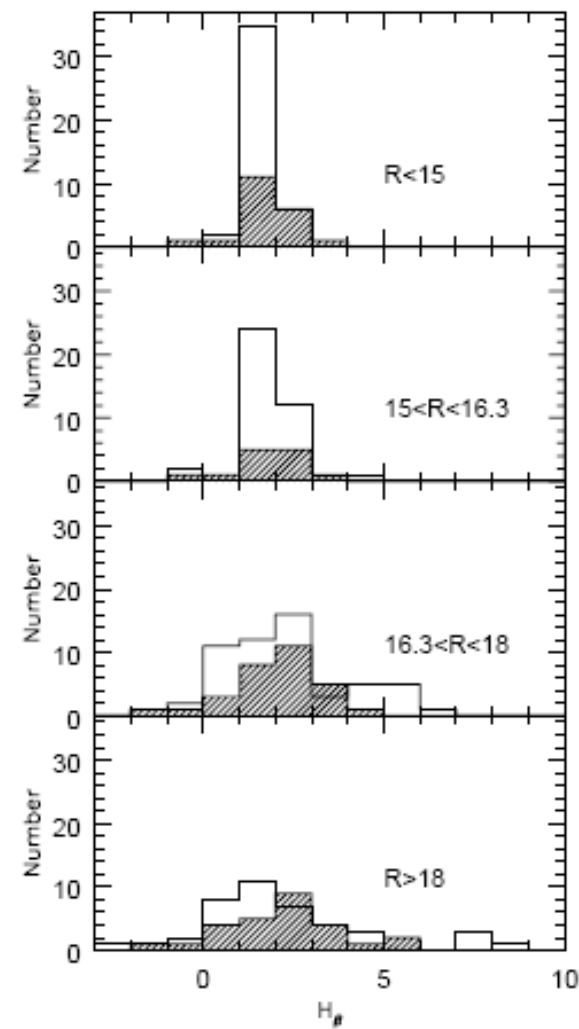
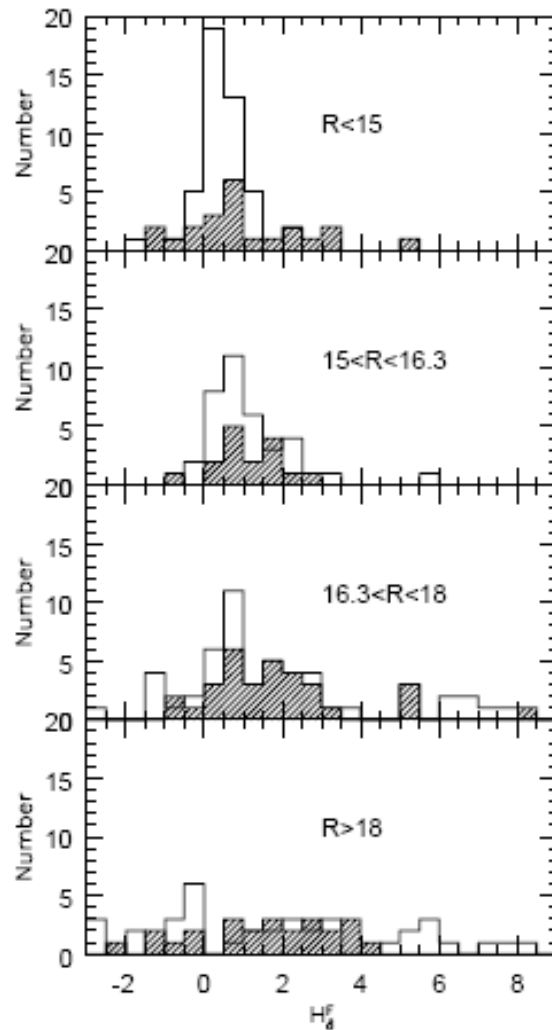
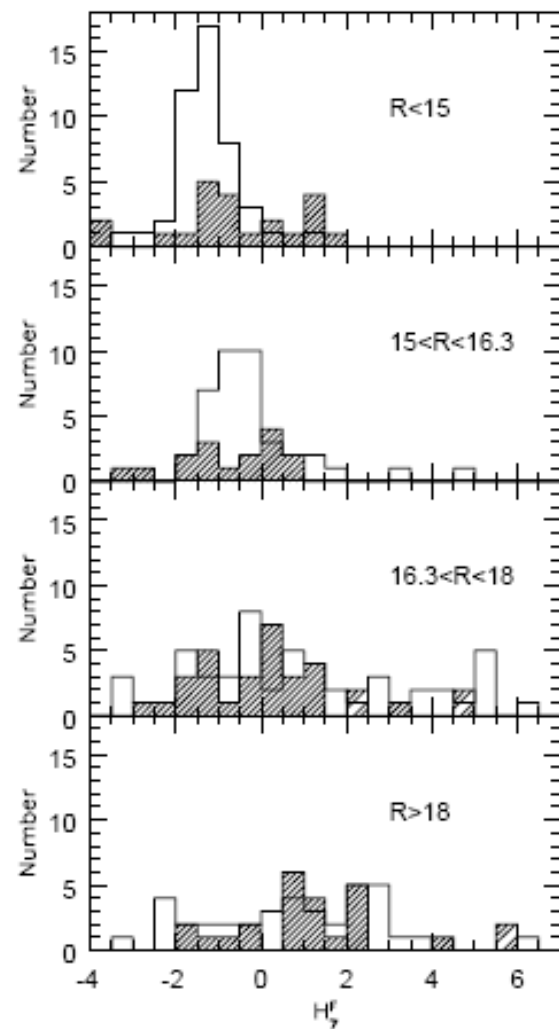


Metallicity-sensitive indices increase with L

Higher proportion of higher Z -indices galaxies in central region

More scattered toward fainter

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Age-sensitive indices decrease with L

Higher proportion of lower age-indices galaxies in central region

More scattered toward fainter

2008-4-18

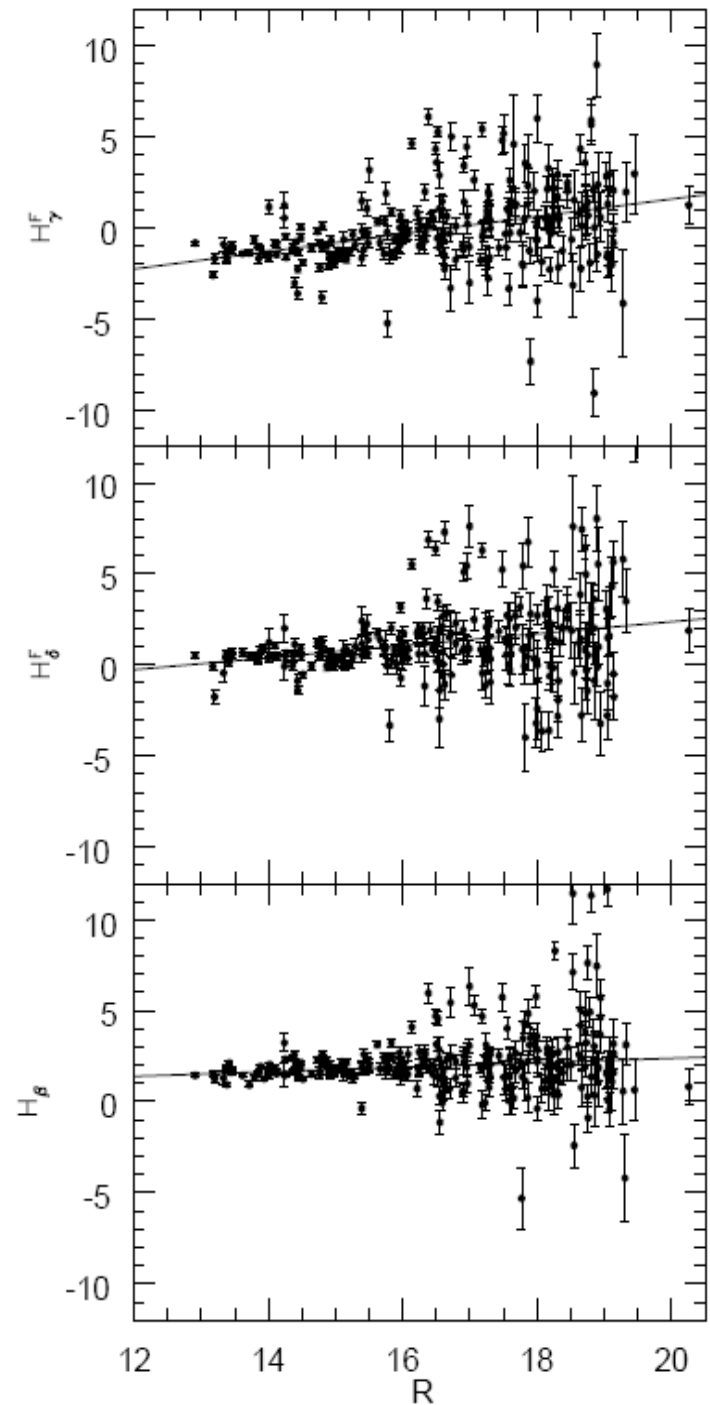
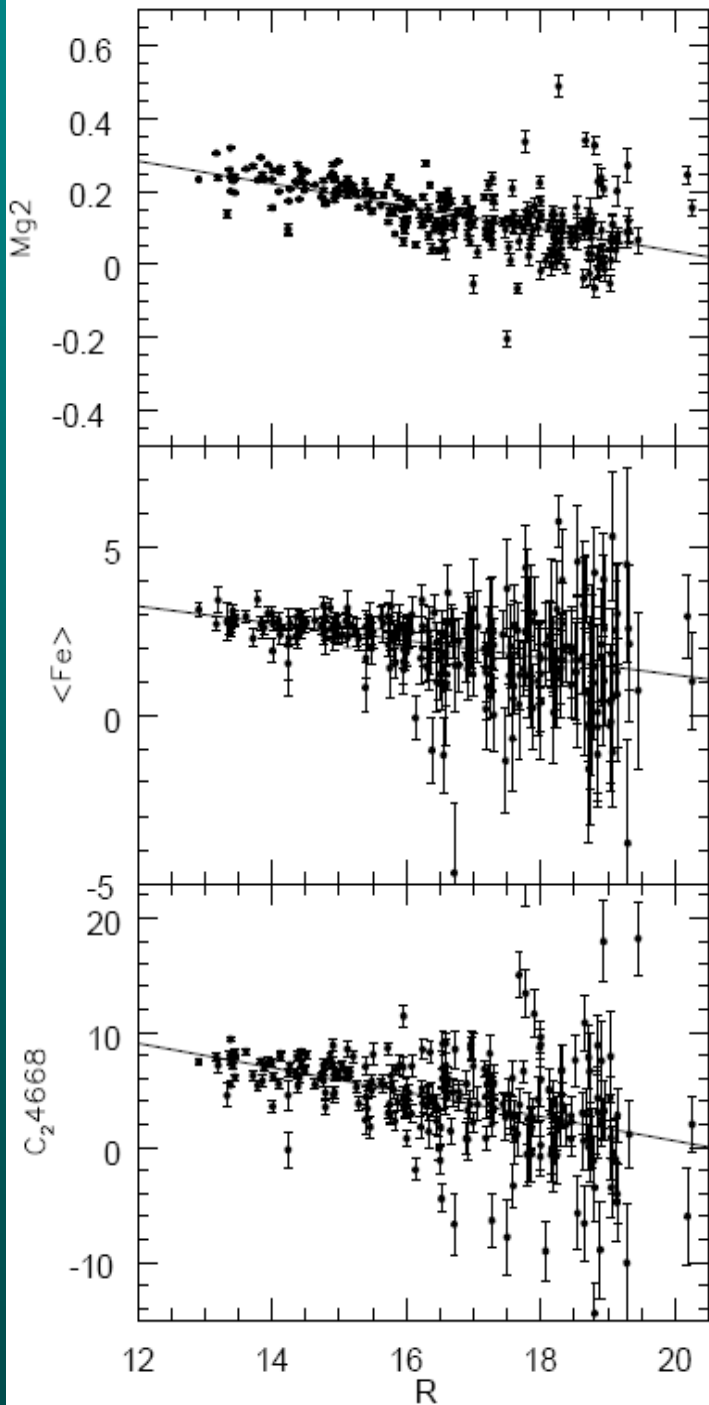
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Relation

Scatter

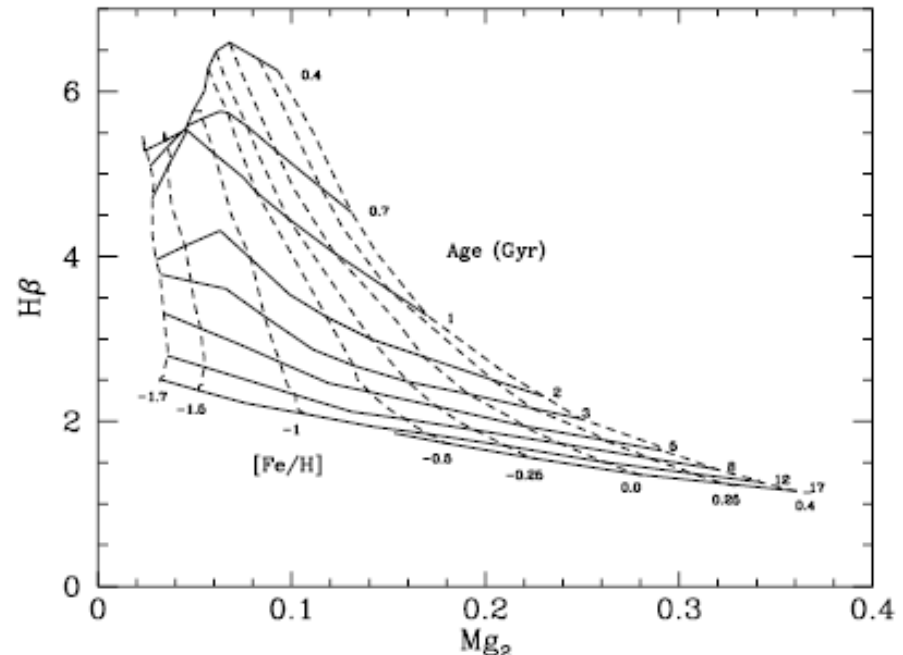
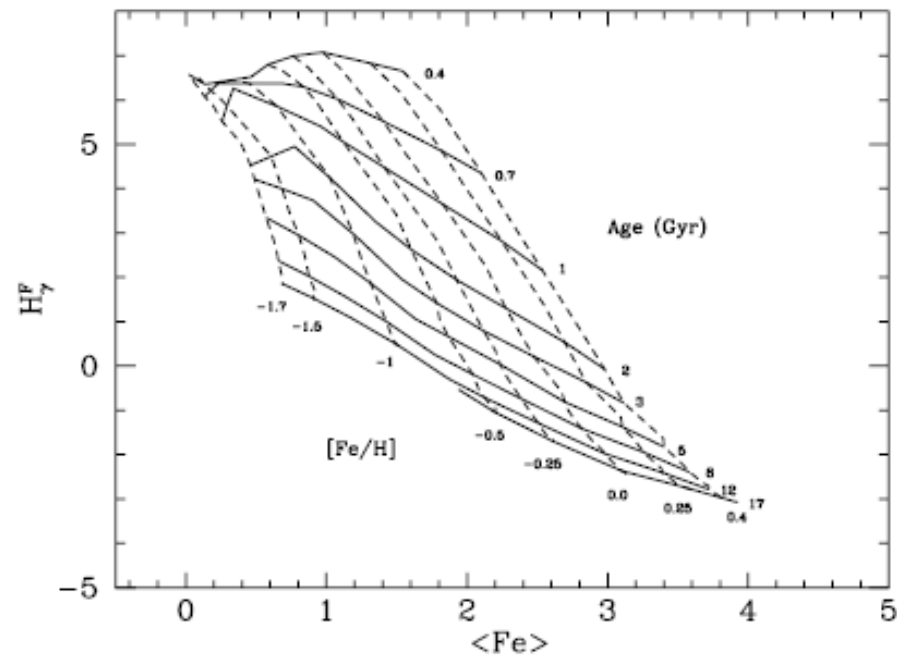
Outliers

Fainter galaxies
are younger or
less metal rich,
or both



Models

- Model of Worthey (1994) based on Padova isochrone library
- Salpeter IMF: $x=2.35$, $M=0.6-120$ Msun
- Blue HB in old populations of low metallicity included to interpret Balmer indices
- Age: 0.4 – 19.9 Gyr
- $[Fe/H]$: -1.7 – 0.4
- Theoretical grids of single stellar populations with estimated L-weighted age and metallicity



Giants

$[Fe/H] > -0.25$,
 $t > 5$ Gyr,
small errors

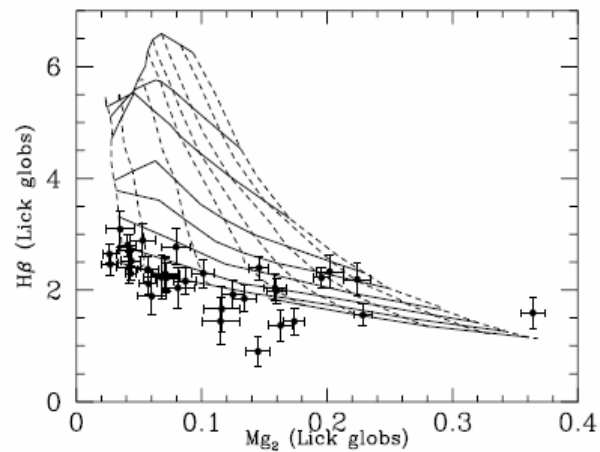
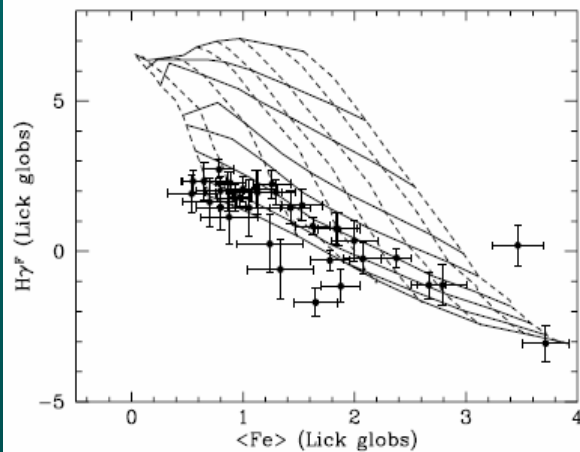
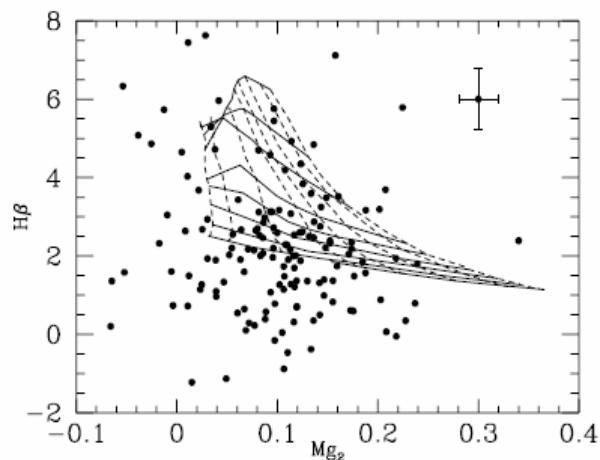
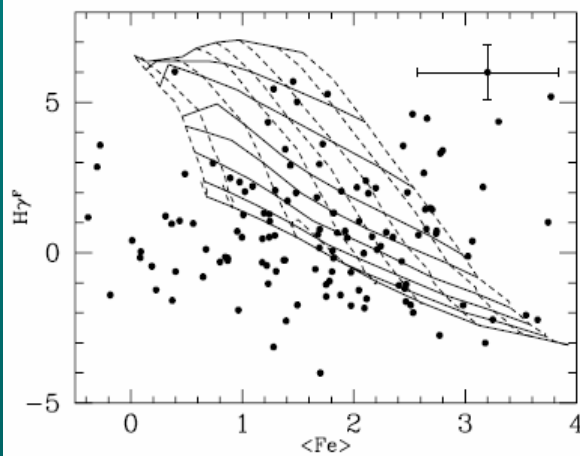
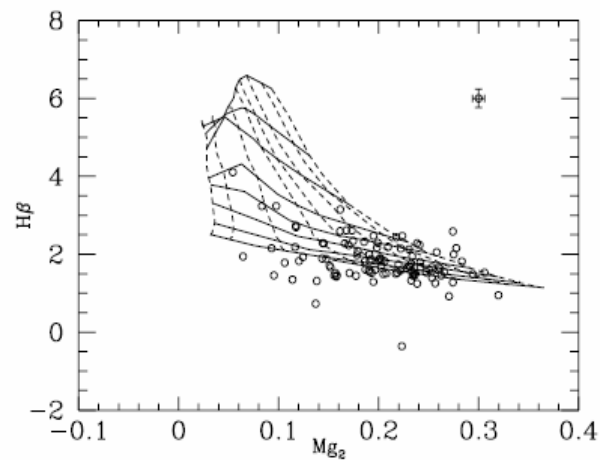
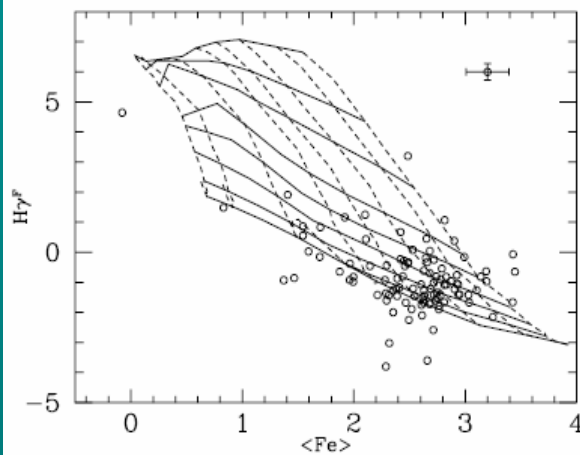
Dwarfs

mostly $[Fe/H] < -0.25$
mostly $t > 3$ Gyr
large errors

Outliers

very low Balmer indices
 $\Rightarrow t > 20$ Gyr

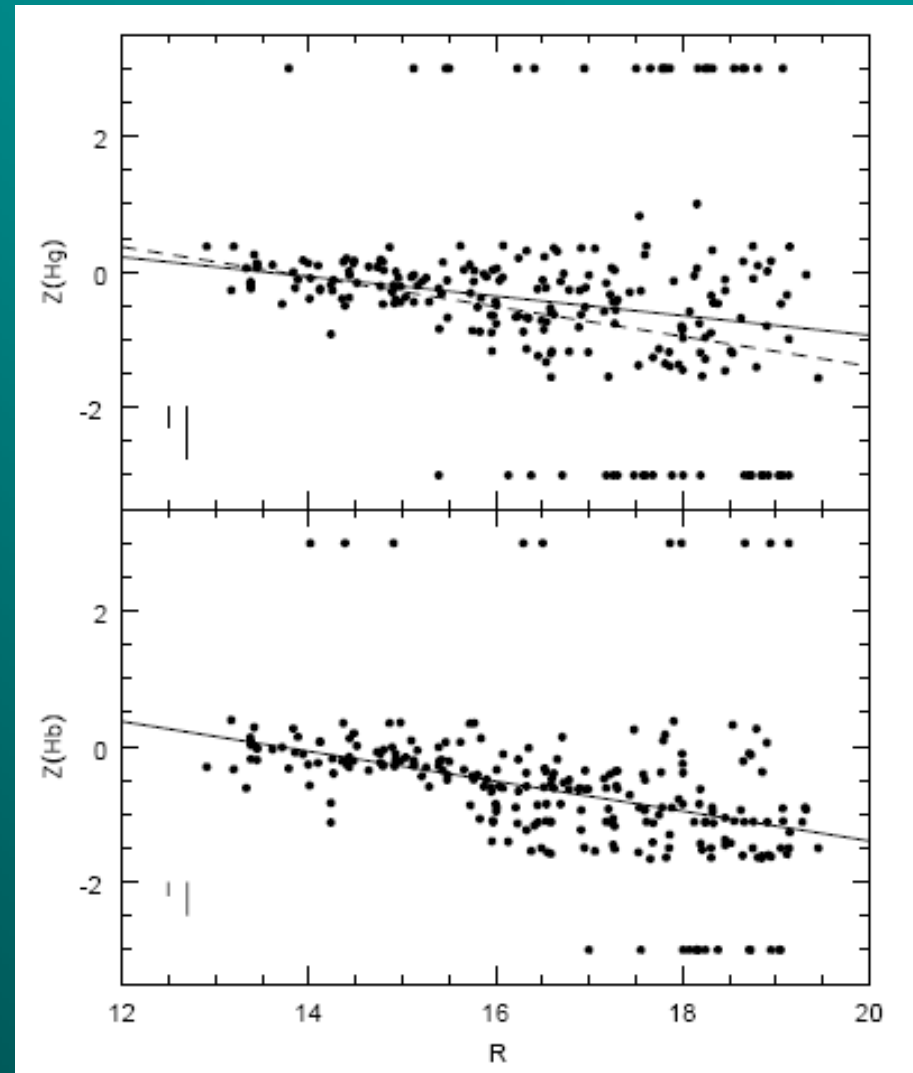
zero points of the models:
fail to reach sufficiently
low Balmer line strength at
old ages because the MS
turnoff is cooler than
models assume
little influence on $Z \Rightarrow$
older ages



Metallicity – magnitude relation

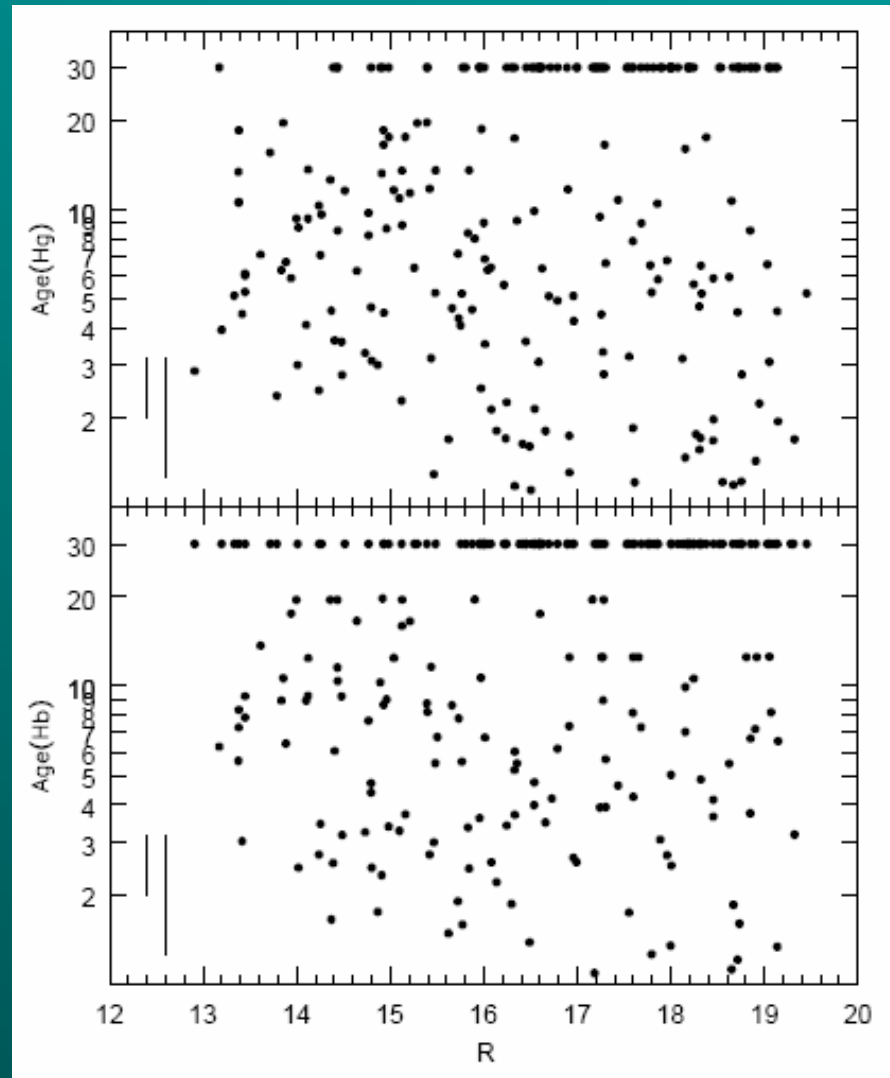
Metallicity increases with
luminosity

Larger scatter at low
luminosity

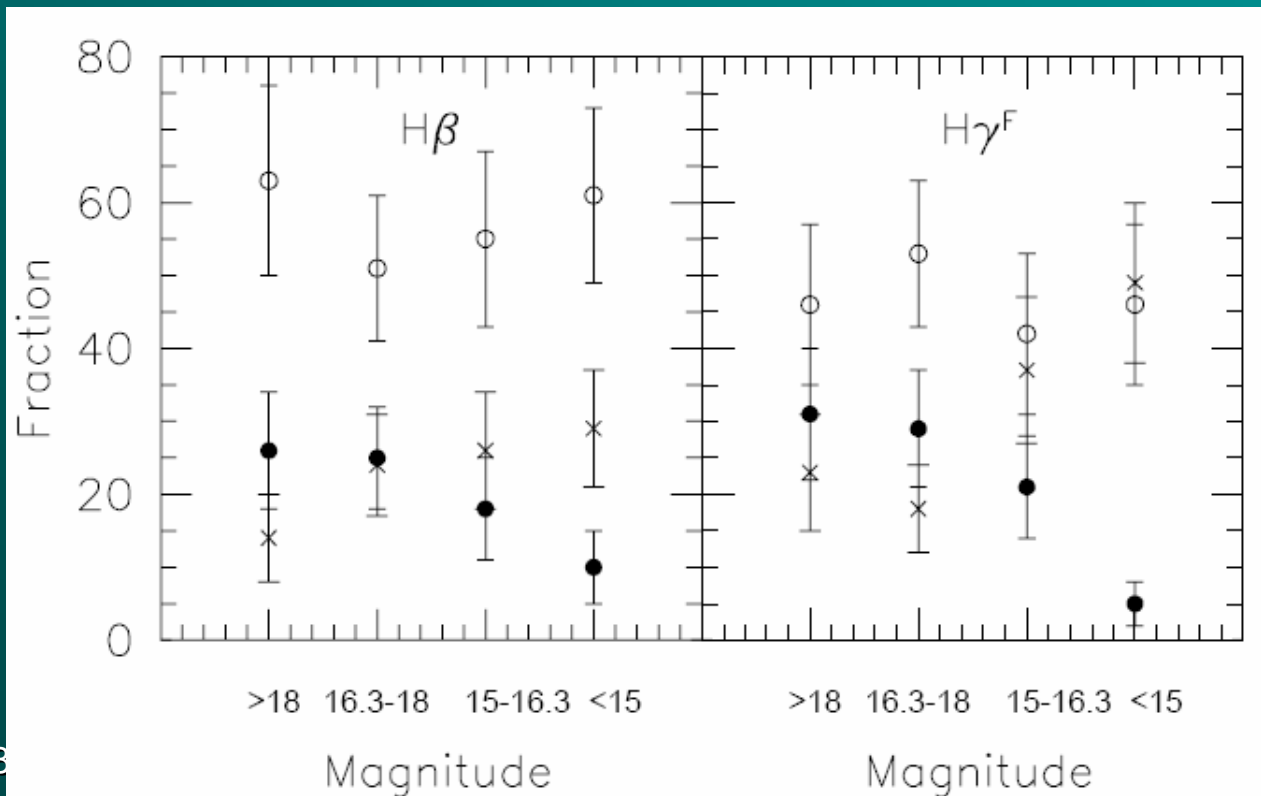


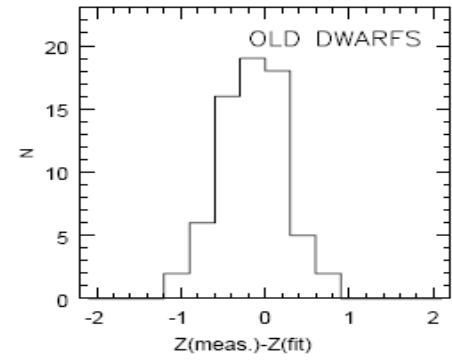
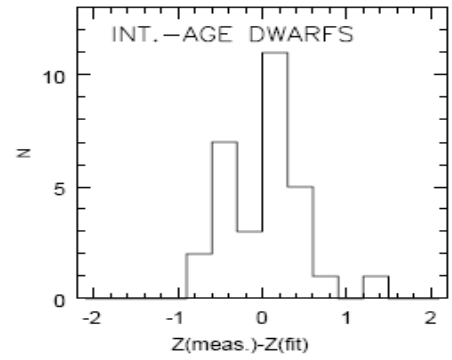
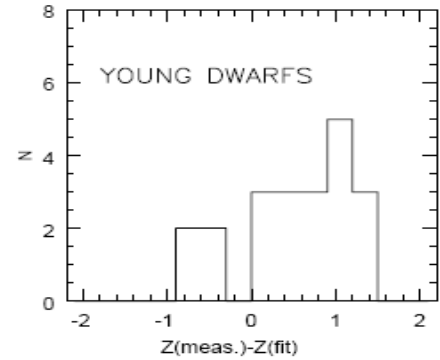
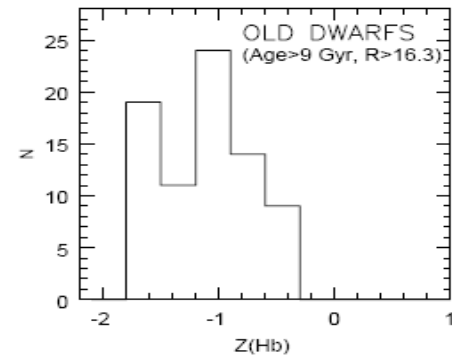
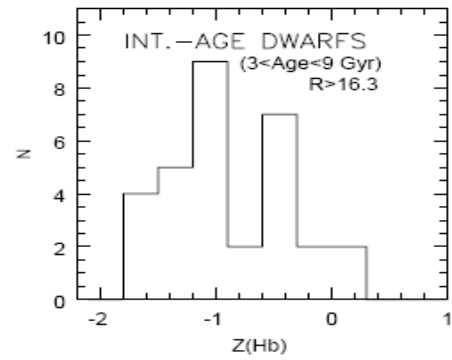
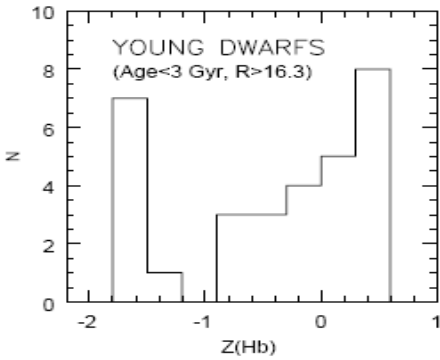
Age – magnitude relation

- Lack of young bright galaxies and old faint galaxies
- Mean age decreases slightly toward fainter magnitude from 9.3 to 7.6 Gyr ($H_{\gamma F}$)
10.0 to 8.4 Gyr (H_{β})



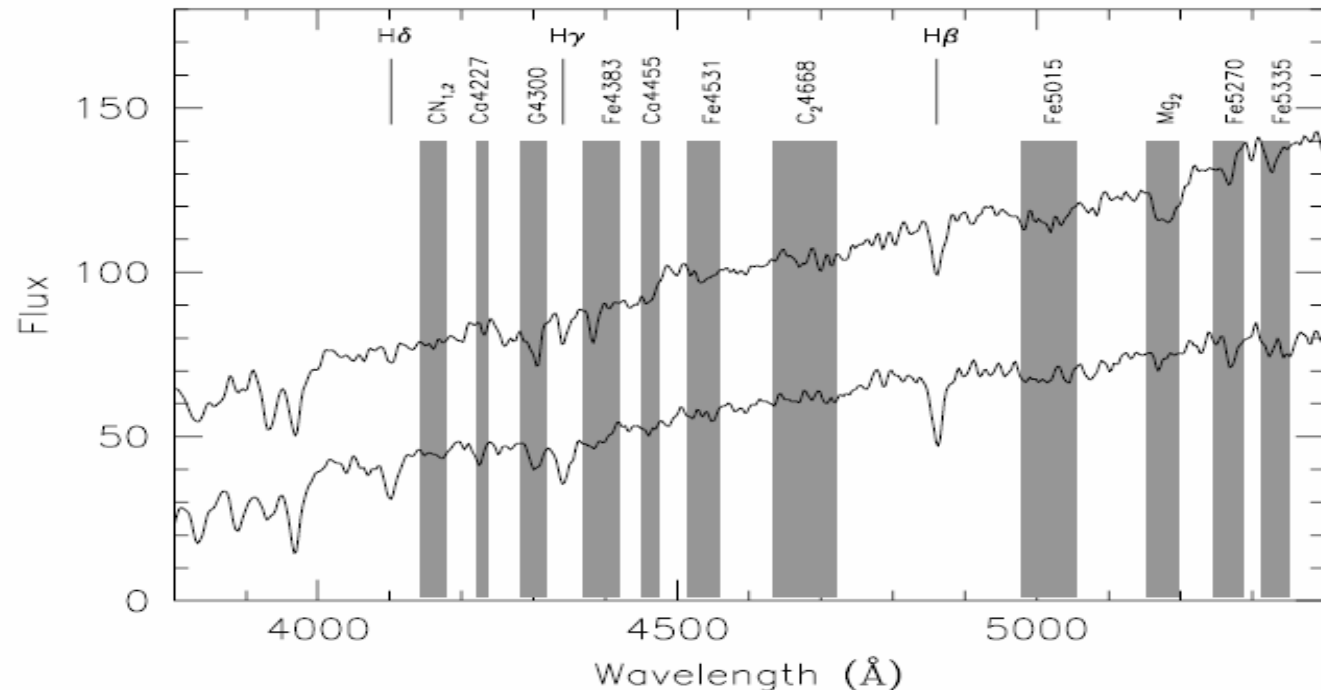
- Age: old $t > 9$ Gyr ($z > 2$)
intermediate $3 < t < 9$ Gyr ($z \sim 0.65$)
young $t < 3$ Gyr ($z < 0.35$)
- Z: metal rich $Z > -0.15$
intermediate $-1 < Z < -0.15$
metal poor $Z < -1$
- L-weighted age represents the epoch of the last episode of significant star formation
 - 50-60% no significant star formation $z < 2$
 - More luminous galaxies active $0.35 < z < 2$
 - More faint galaxies active $z < 0.35$
- Down-sizing effect: last star formation activity occurs at lower redshift for fainter galaxies





Young dwarf galaxies show a bimodal metallicity distribution

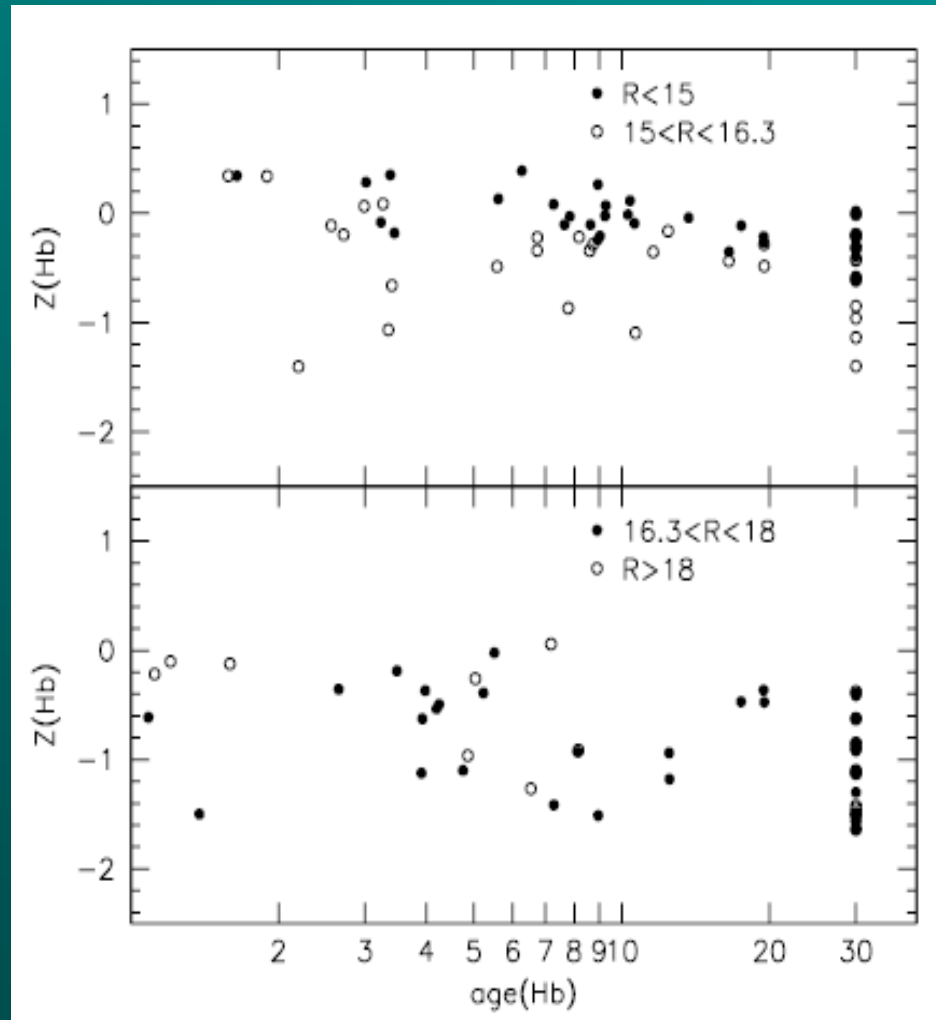
Metal-rich
Metal-poor



Age – metallicity relation

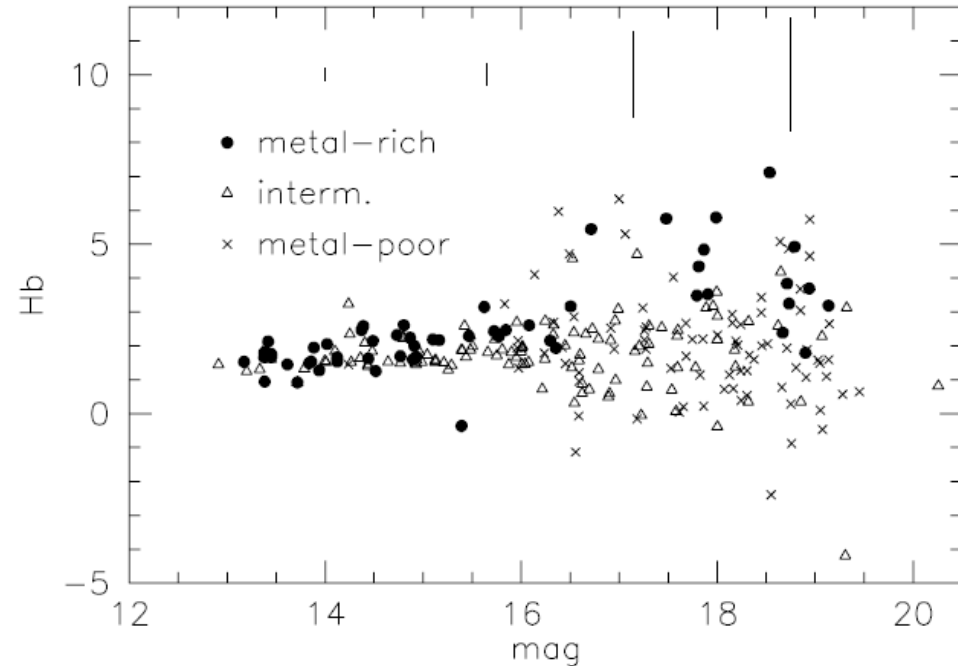
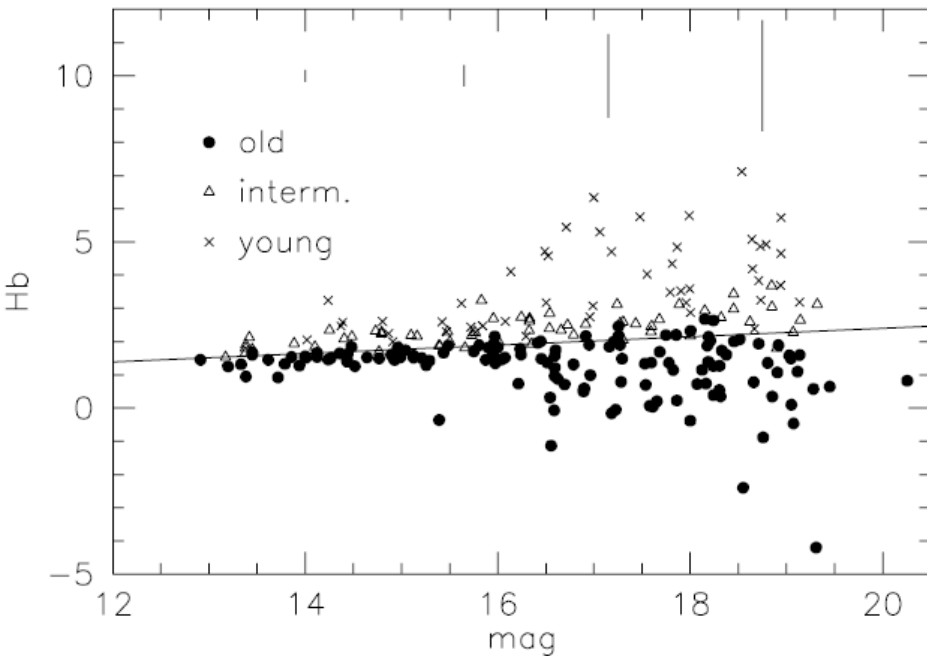
Age-metallicity anticorrelated: younger galaxies tend to be more metal rich

Correlated errors: if age is underestimated, then the metallicity is overestimated



Index-magnitude relation

■ Slope, scatter, outliers

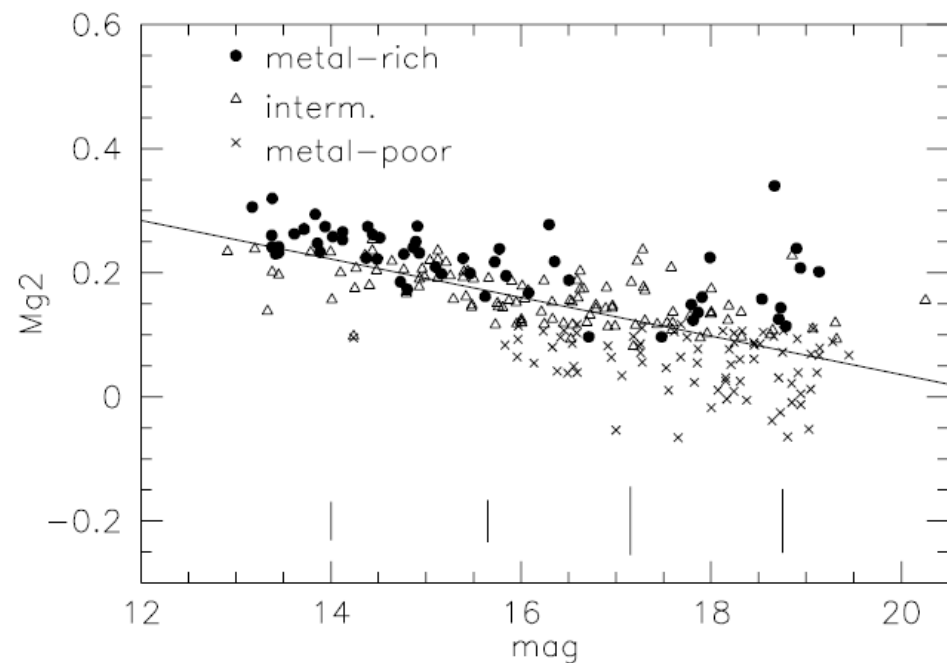
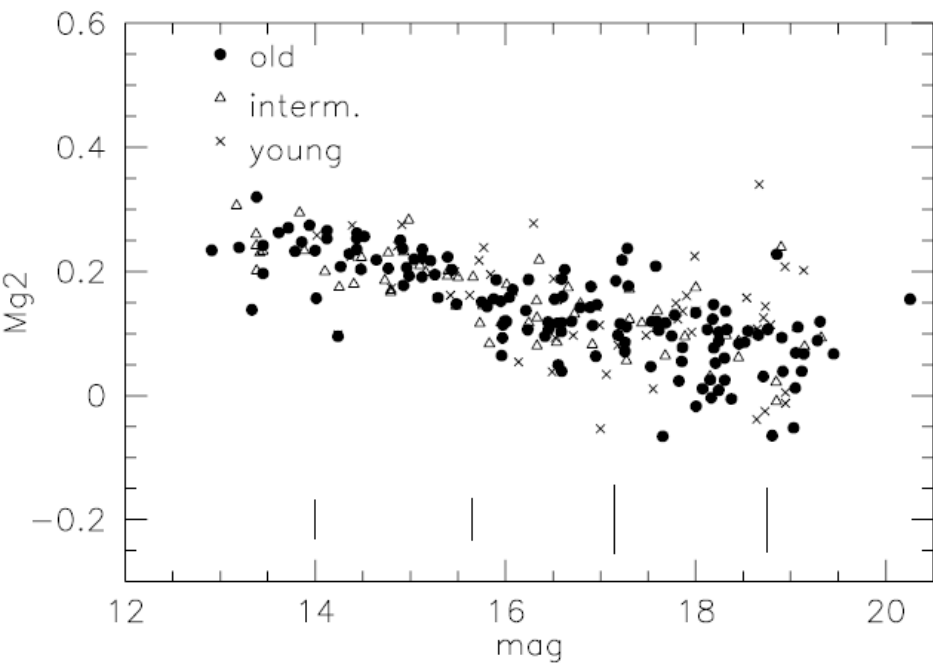


Segregation is evident for age subsamples

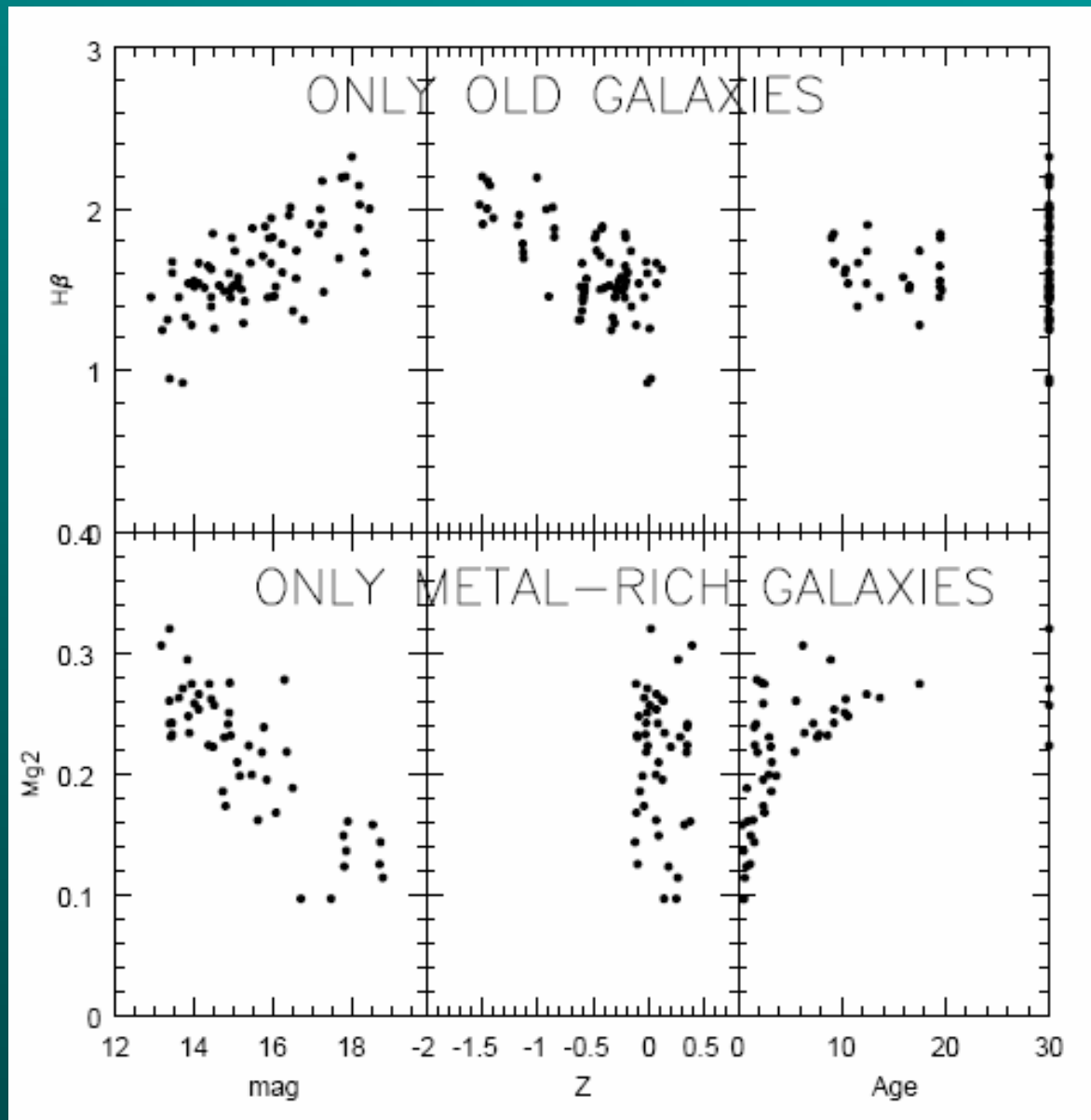
Correlation of H β -R, thickening, zero-point shift

H β anticorrelated with Z, no correlation with age

Metal-rich: Fainter galaxies on average younger



No obvious age segregation
 Metal-rich: fainter galaxies are younger



Summary

- 257 no emission line spectra of Coma member galaxies
 - $\lambda = 3600 - 6600\text{\AA}$
 - $M_B = (-20.5, -14)$
 - $\sim 1 \times 1.5 \text{Mpc}$, center & southwest
- Lick indices & EW of emission lines
 - $H\beta$, $H\gamma_F$, $H\delta_F$ (Age-sensitive indices) correlate with L
 - Mg_2 , Fe, C_24668 (Metallicity-sensitive indices) anti-correlate with L

- (Lick indices, model based on the Padova isochrones)

⇒ L-weighted ages & metallicity

1. Very low Balmer indices ⇒ very old ages
overestimate of the turnoff temperature in model
2. Age: 3-9 Gyr, age slightly decrease for fainter galaxies
no SF at $z < 2$ at any L for 50-60% giants, 30% dwarfs
SF at $0.35 < z < 2$ involves more luminous galaxies
SF at $z < 0.35$ involved higher fraction of faint galaxies than bright galaxies
3. Metallicity: mean Z increases with luminosity
given m , Z lower for southwest than center
4. Bimodal Z distribution of faint L-weighted young galaxies
⇒ composite formation scenario
5. Age – Metallicity anticorrelation at any L
6. index-magnitude relation
age and metallicity variations with luminosity

Thanks!