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 outlows

    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-σ

  weak and large scatter for other metal lines

  negative correlation of Balmer indices - σ

  shell and pair galaxies deviate from $H\beta$-σ and Mg2-σ 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

  $\Rightarrow$ how many and which parameters govern the evolution of low- and high-luminosity cluster galaxies

Sample

- William Herschel Telescope

  32.5×50.8 arcm^2 (~1×1.5 Mpc) at central and southwest regions

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

  Spectra

  λ= 3600 - 6600 Å, R= 6-9 Å (~3Å/pixel),

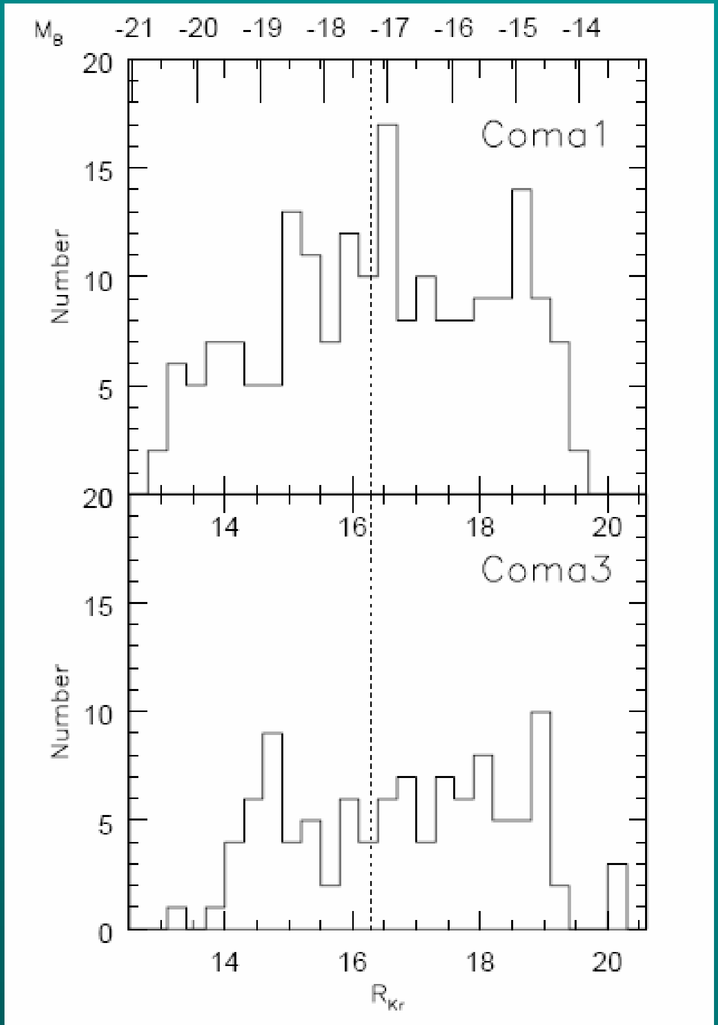
  D=2."7 ~1.3kpc (H_0=65kms^{-1}Mpc^{-1})

- v= (4000, 10000) km/s

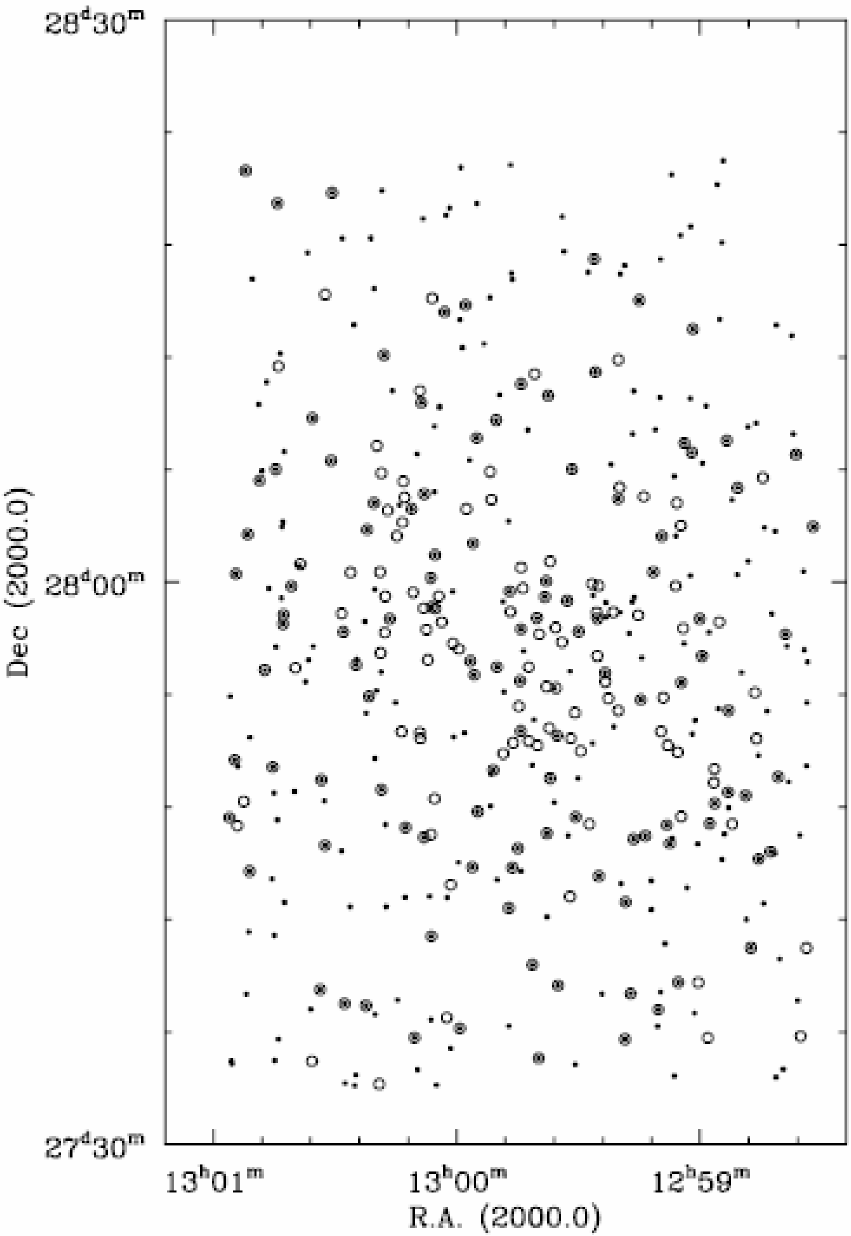
  ⇒ 189 central + 89 southwest

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

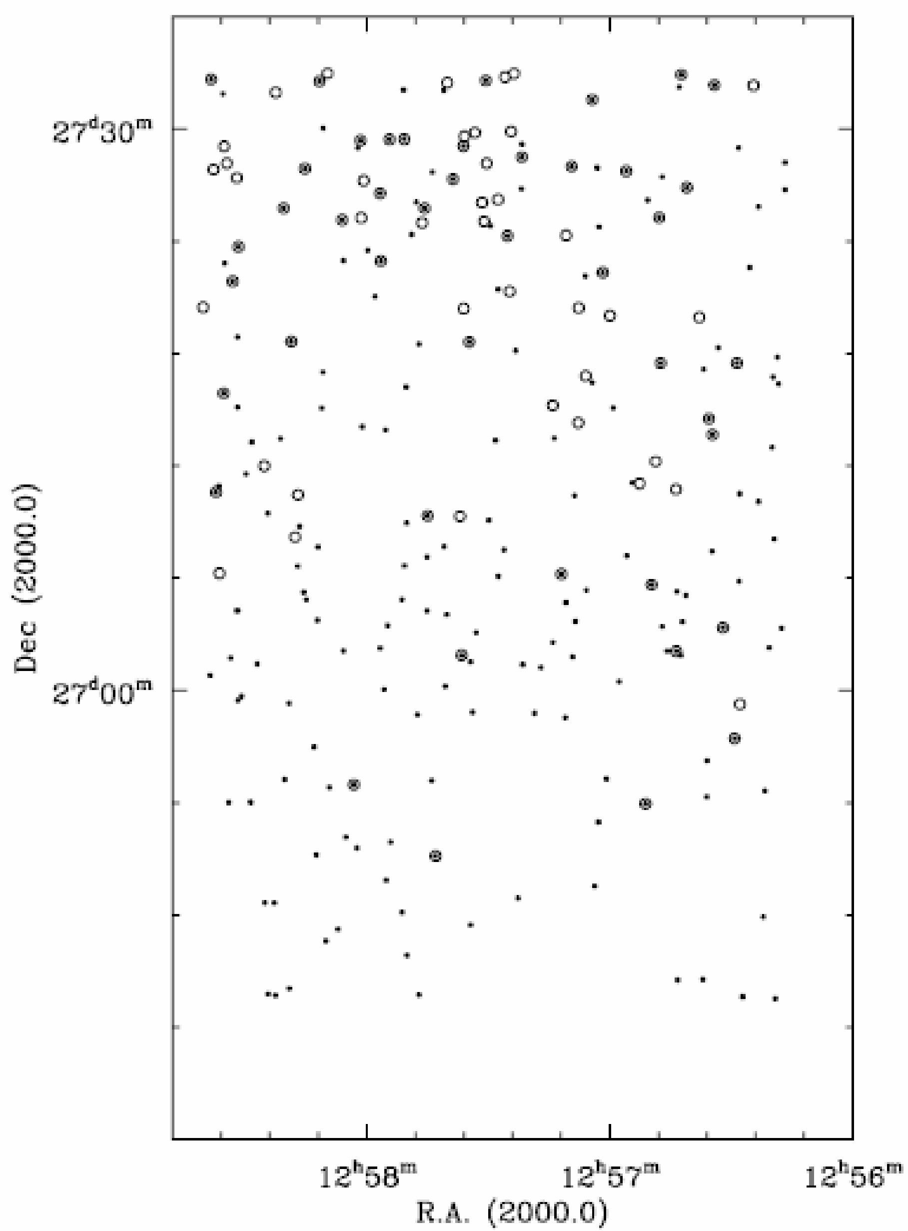
  ⇒ 160 dwarf + 118 giants



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

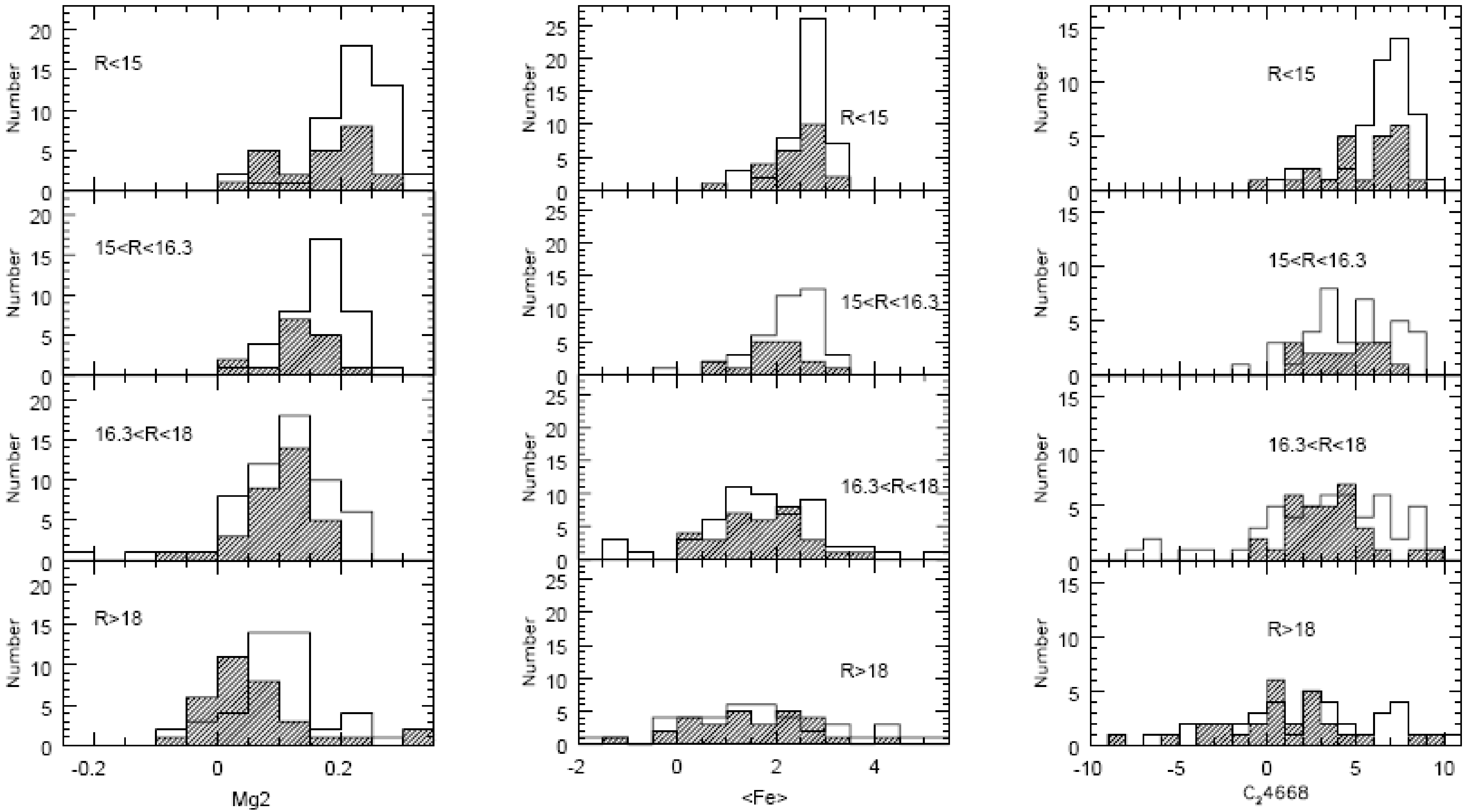
  1. Different resolution
  2. Internal σ
  3. Systematic offsets

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	$H\delta_A$	4083.500–4122.250	4041.600–4079.750	4128.500–4161.000	Å
23	$H\gamma_A$	4319.750–4363.500	4283.500–4319.750	4367.250–4419.750	Å
24*	$H\delta_F$	4091.000–4112.250	4057.250–4088.500	4114.750–4137.250	Å
25*	$H\gamma_F$	4331.250–4352.250	4283.500–4319.750	4354.750–4384.750	Å
26*	$\langle Fe \rangle$	(Fe 5270+Fe 5335)/2			Å
27	[MgFe]	$\sqrt{\mathrm{Mg}\, b \langle \mathrm{Fe} \rangle}$			Å

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

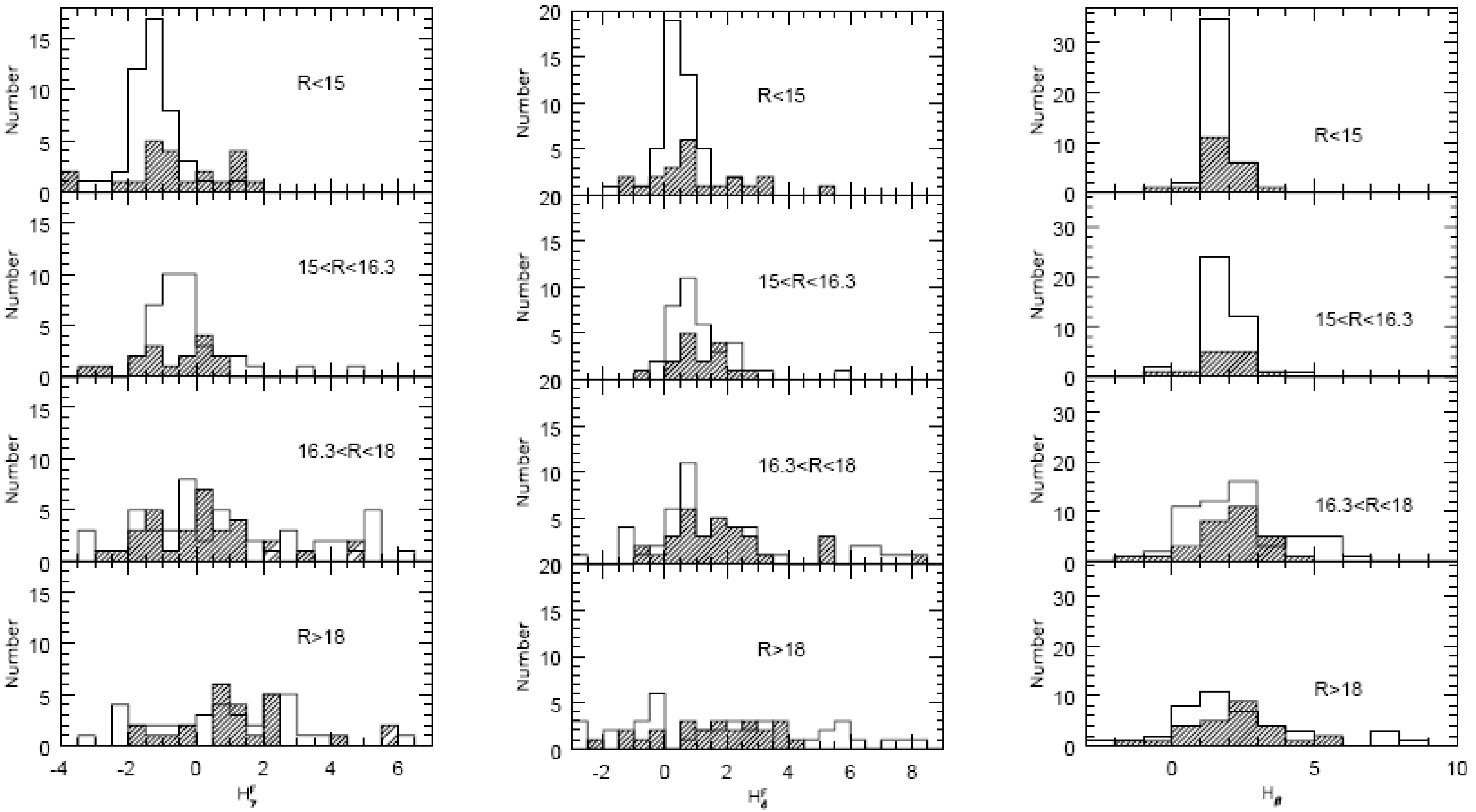
Index results



Metallicity-sensitive indices increase with L

Higher proportion of higher Z-indices galaxies in central region

More scattered toward fainter



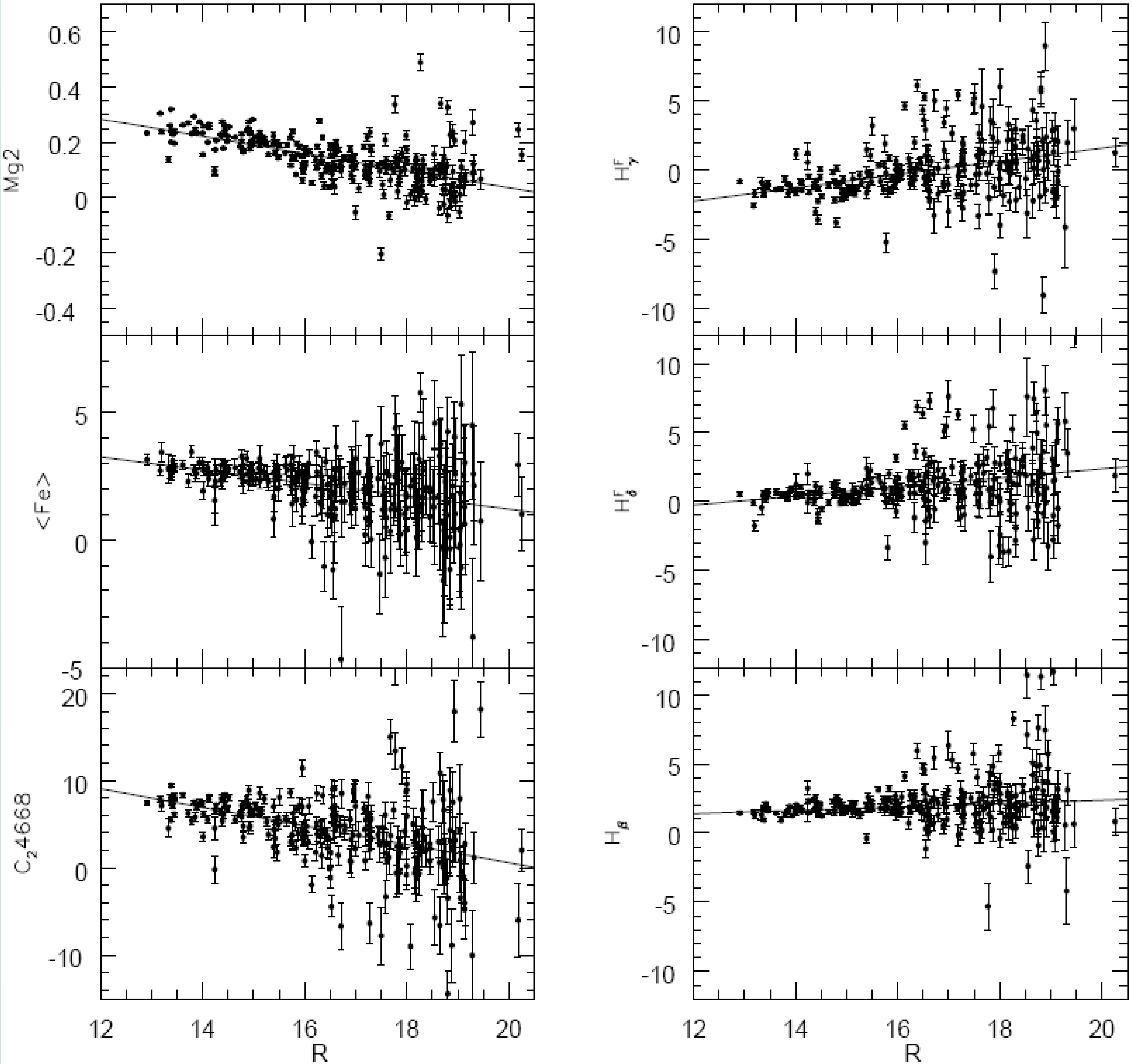
Age-sensitive indices decrease with L
Higher proportion of lower age-indices galaxies in central region
More scattered toward fainter

Relation

Scatter

Outliers

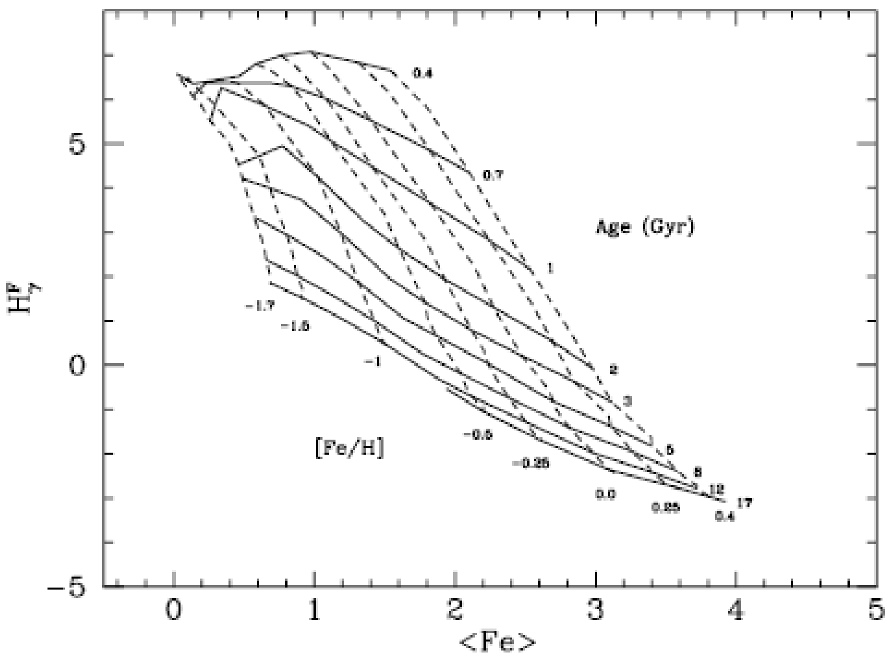
Fainter galaxies are younger or less metal rich, or both

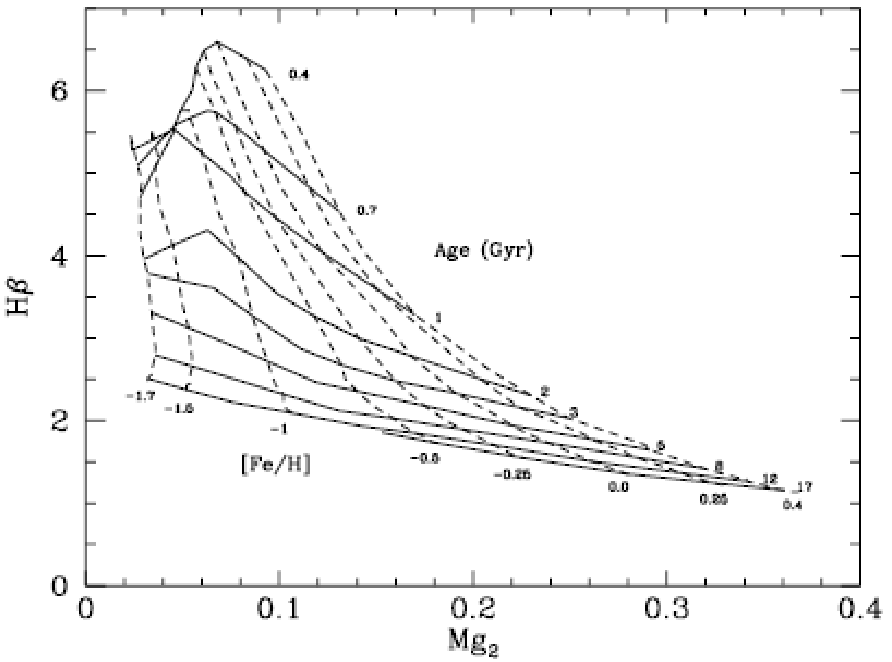


2008-4-18

Models

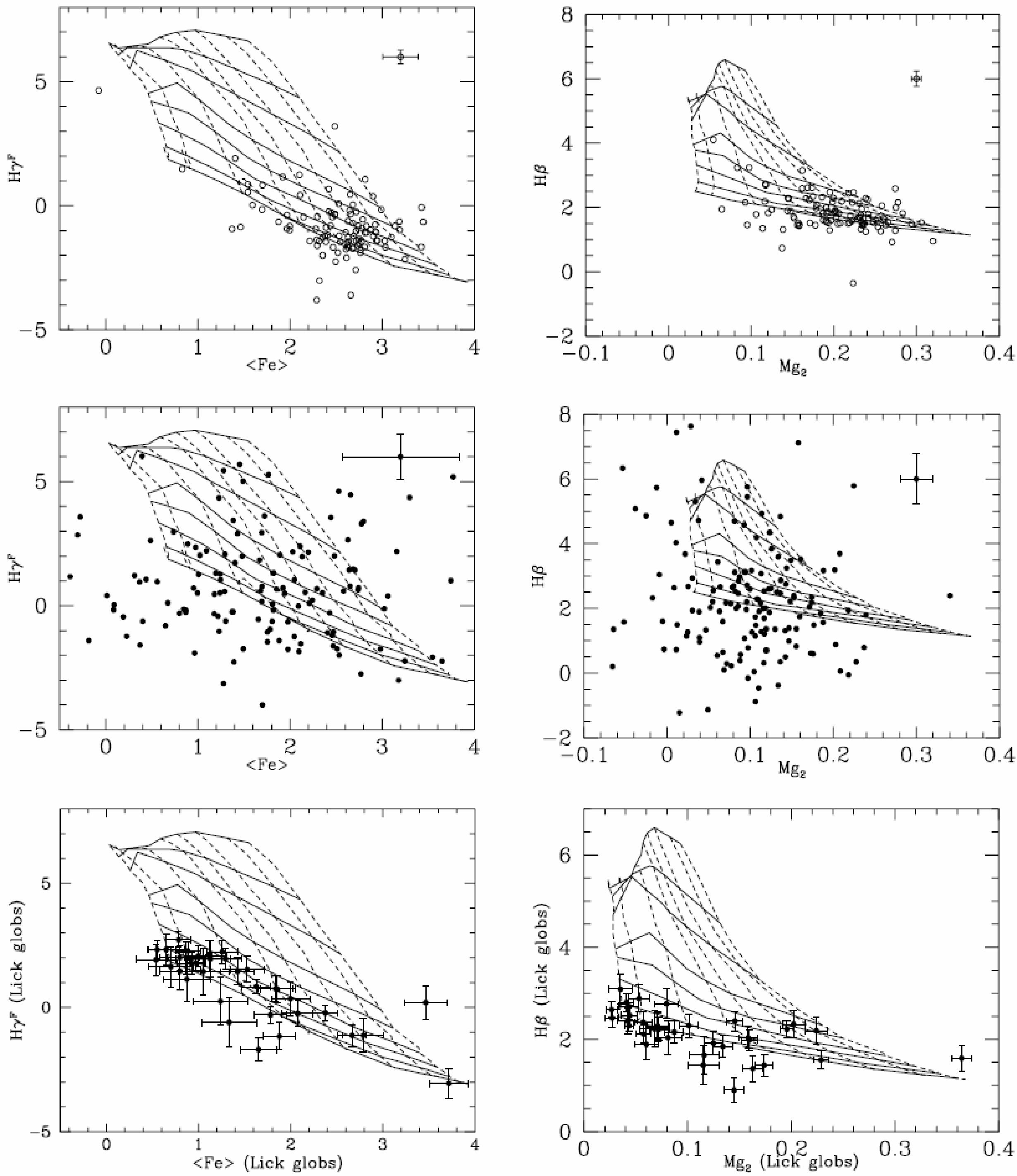
- Model of Worthey (1994) based on Padova isochrone library
  - Salpeter IMF: x=2.35, M=0.6-120 Msun
  - Blue HB in old populations of low metallicity included to interprete Balmer indices
  - Age: 0.4 – 19.9 Gyr
  - [Fe/H]: -1.7 – 0.4
- Theoretical grids of single stellar populations with estimated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

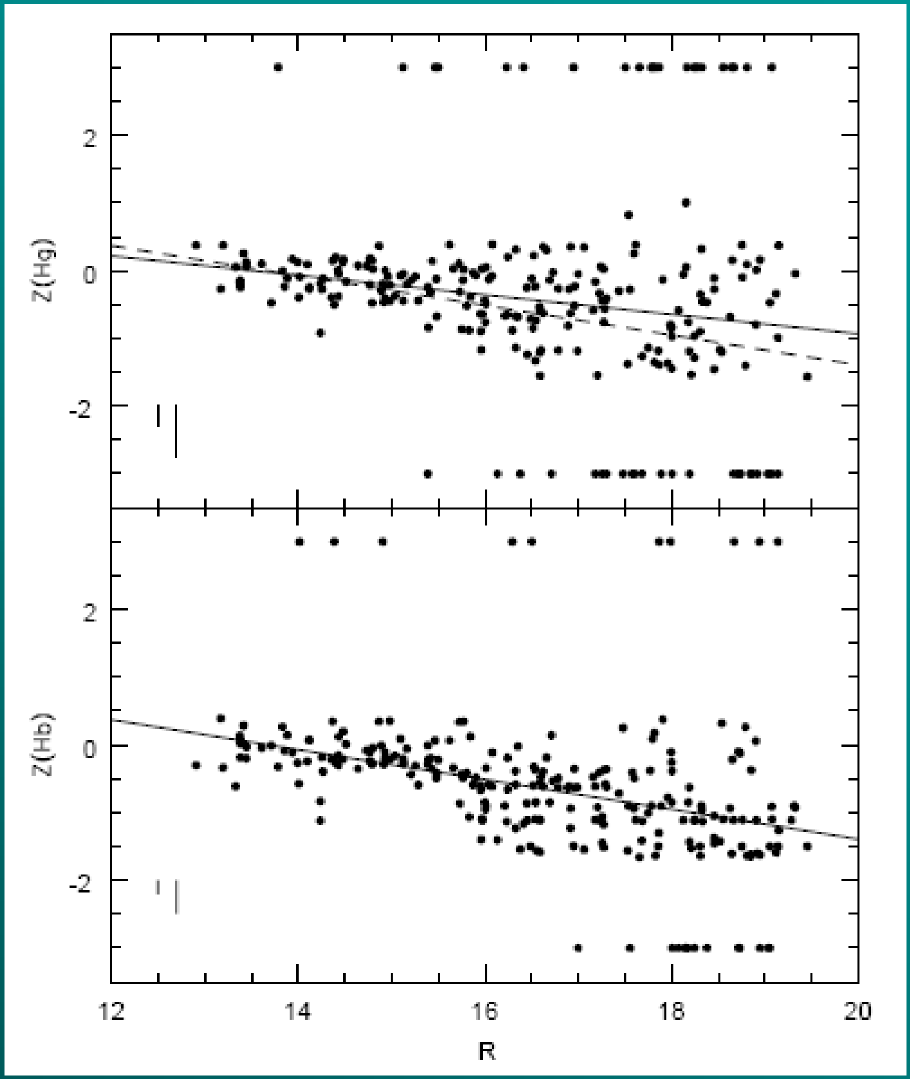
little influence on Z => older ages



Metallicity – magnitude relation

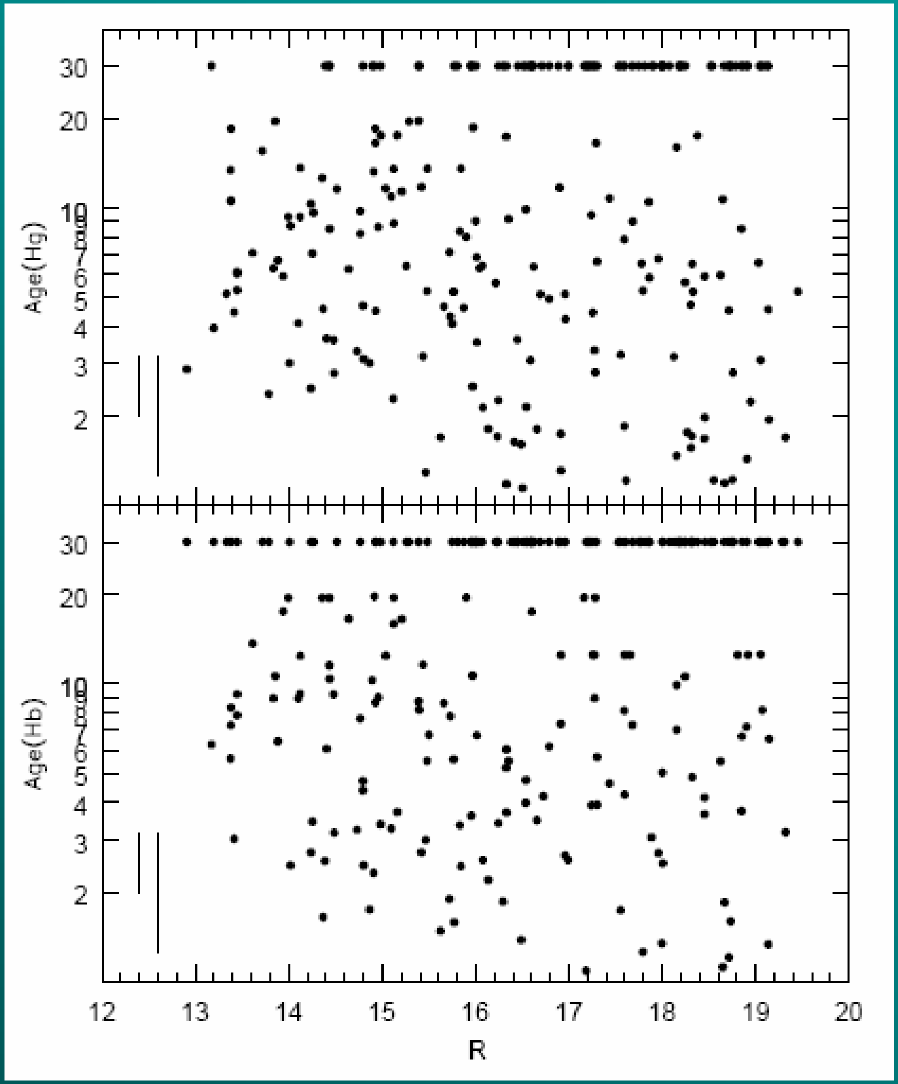
Metallicity increases with luminosity

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 ($H\beta$)



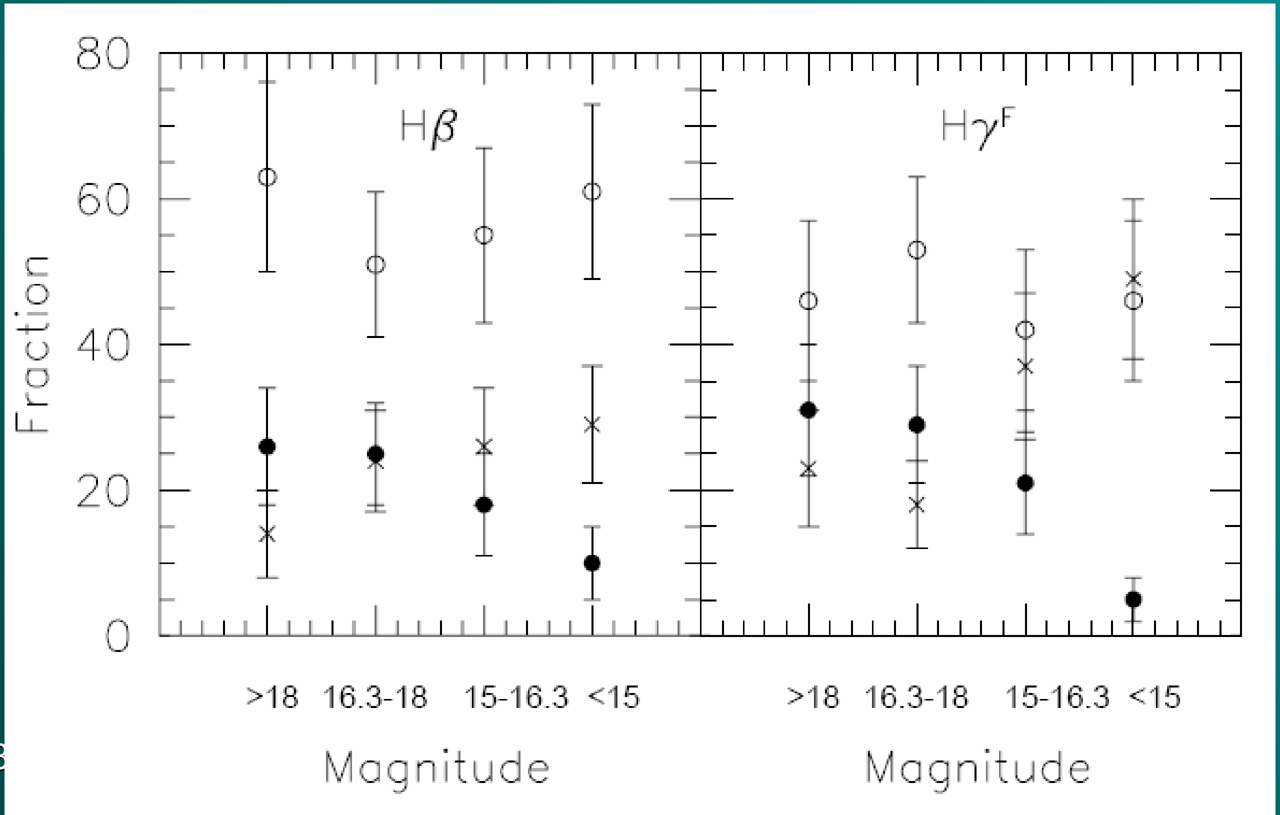
- Age: old t > 9 Gyr (z > 2)
  intermediate 3 < t < 9 Gyr (z ~ 0.65)
  young t < 3 Gyr (z < 0.35)

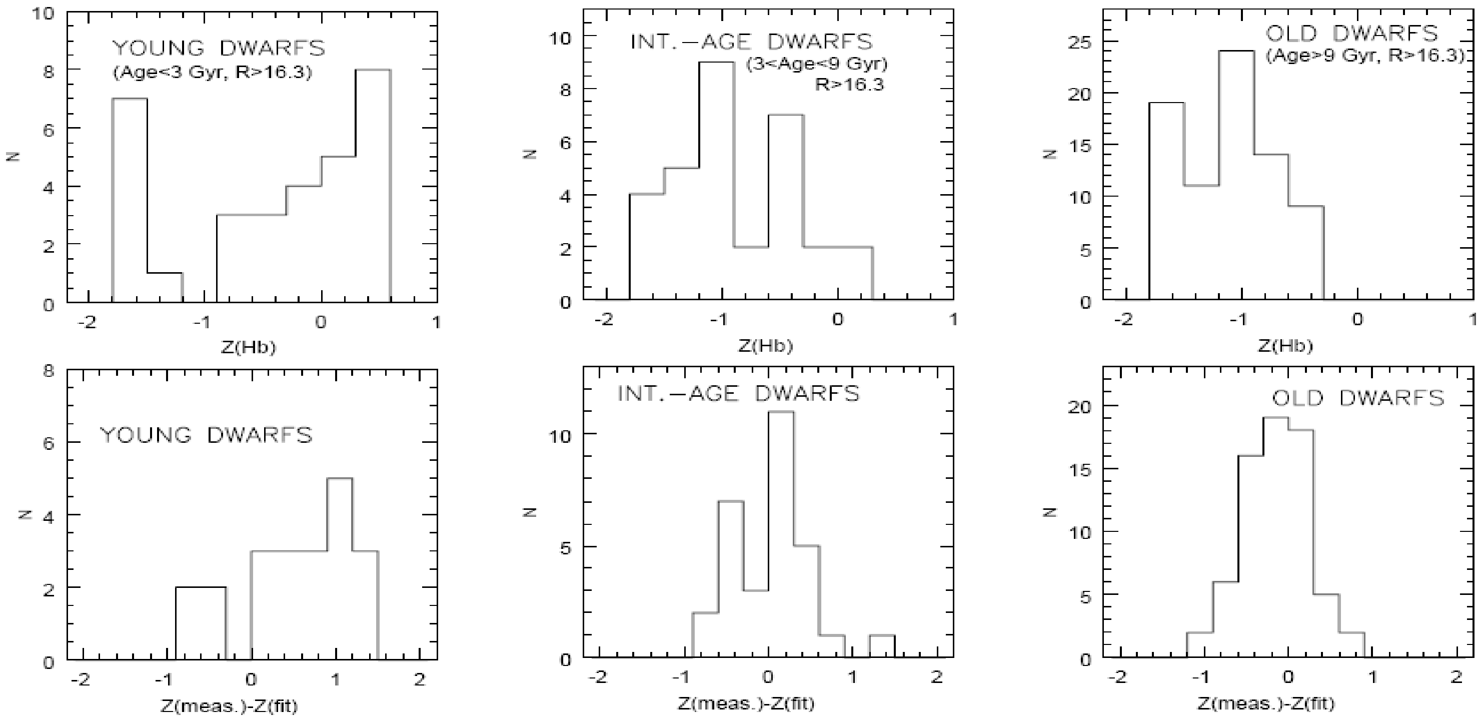
Z: metal rich Z > -0.15
intermediate -1 < Z < -0.15
metal poor Z < -1

- L-weighted age represents the epoch of the last episode of significant star formation

1. 50-60% no significant star formation z < 2
2. More luminous galaxies active 0.35 < z < 2
3. More faint galaxies active z < 0.35

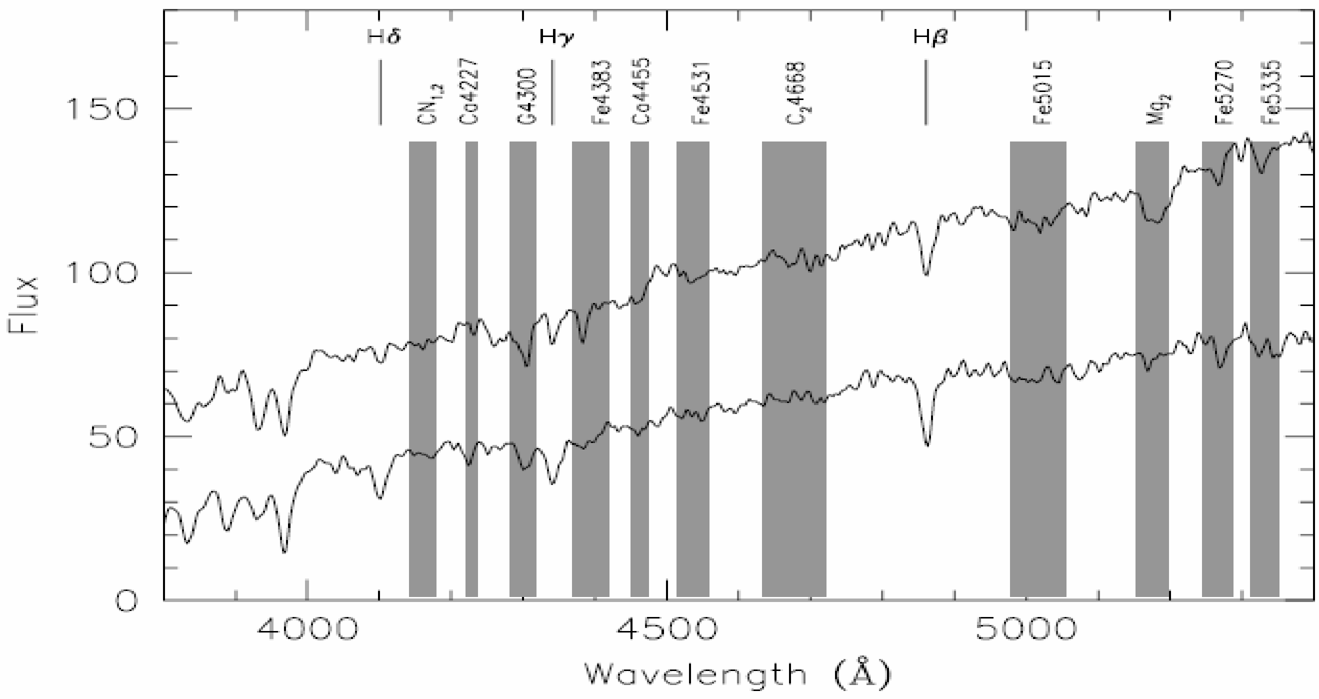
- Down-sizing effect: last star formation activity occurs at lower redshift for fainter galaxies





Young dwarf galaxies show a bimodal metallicity distribution

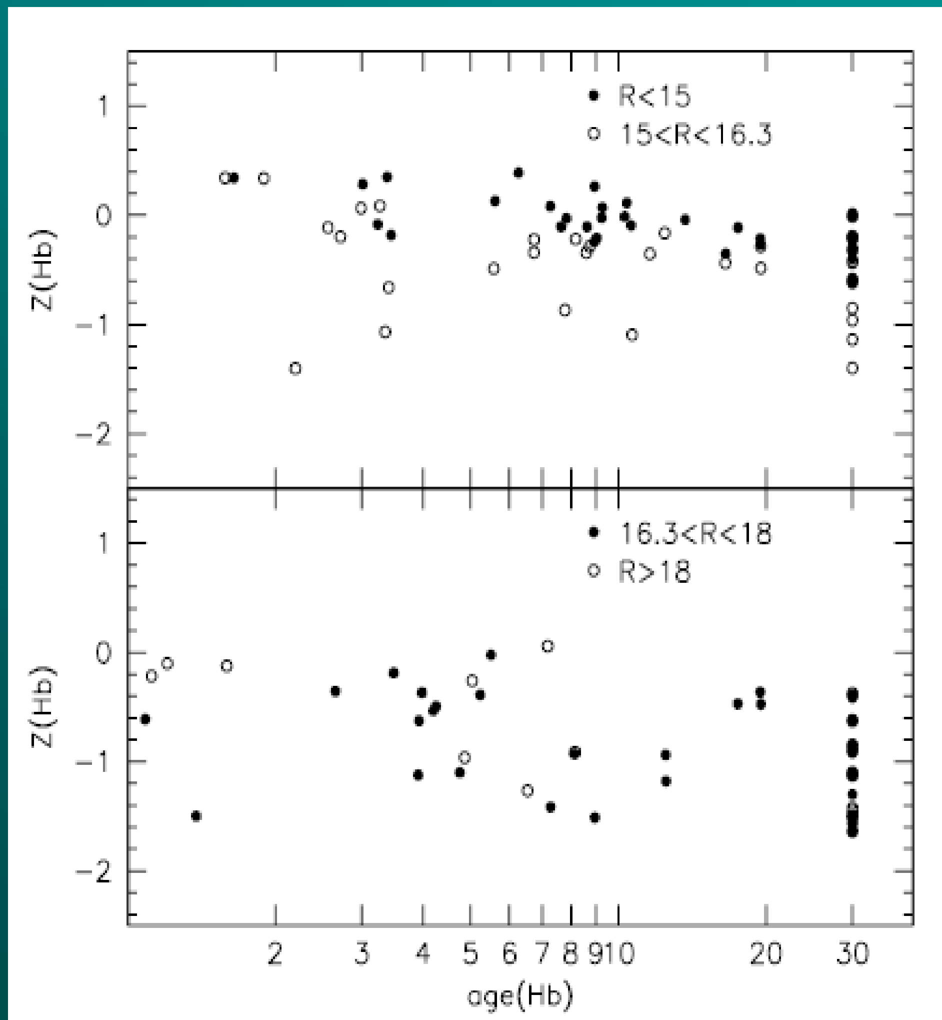
Metal-rich
Metal-poor



2008-4-18

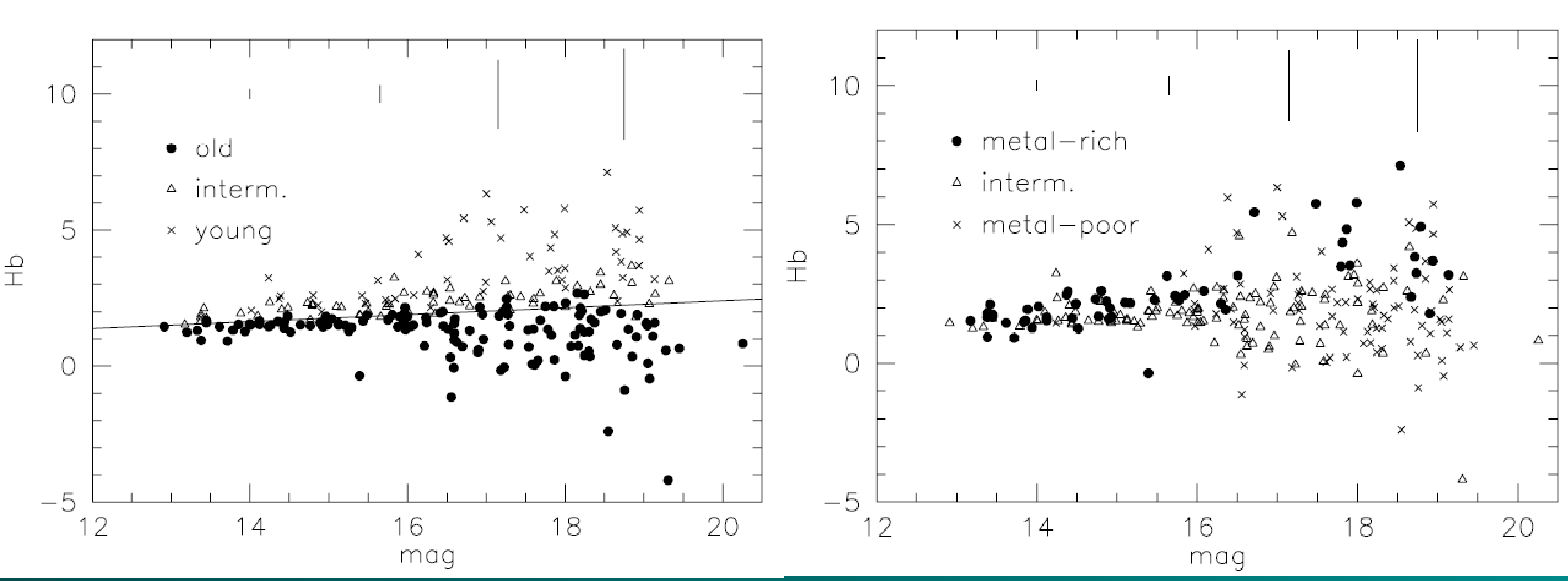
Age – metallicity relation

Age-metallicity anticorrelated: younger galaxies tend to be more metal rich
Correlated errors: if age is underestimated, then the metallicity is overestimated

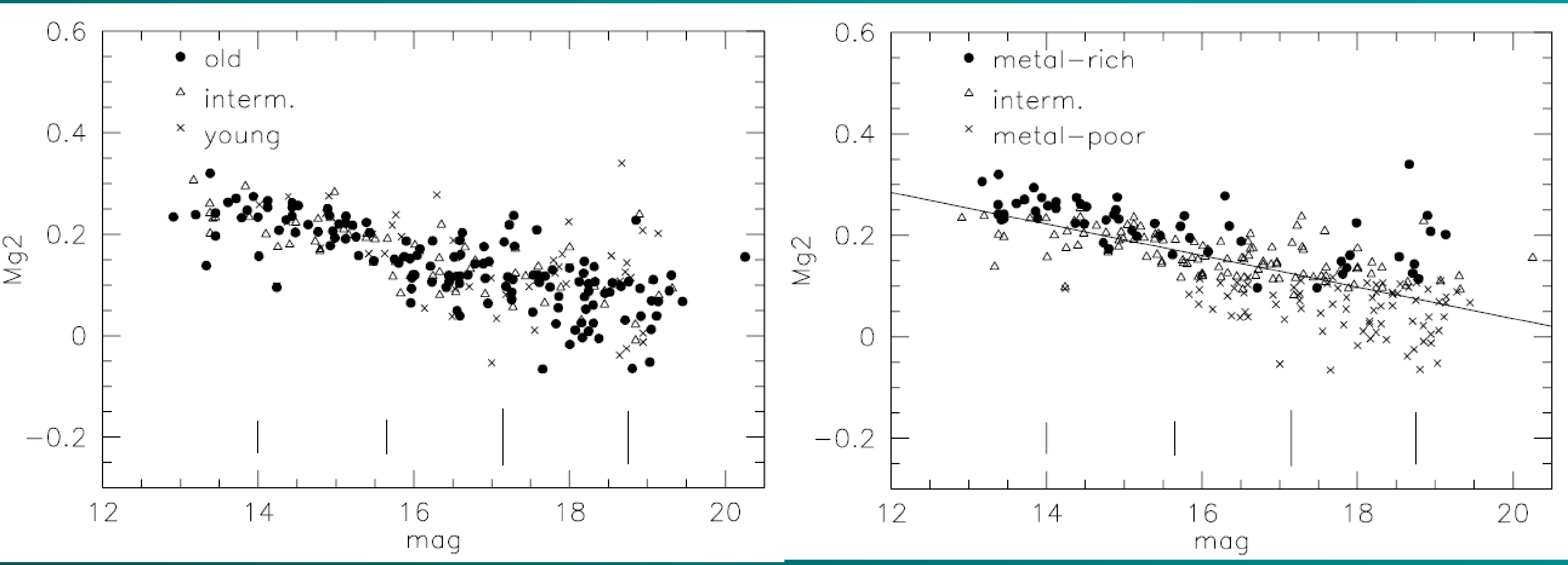


Index-magnitude relation

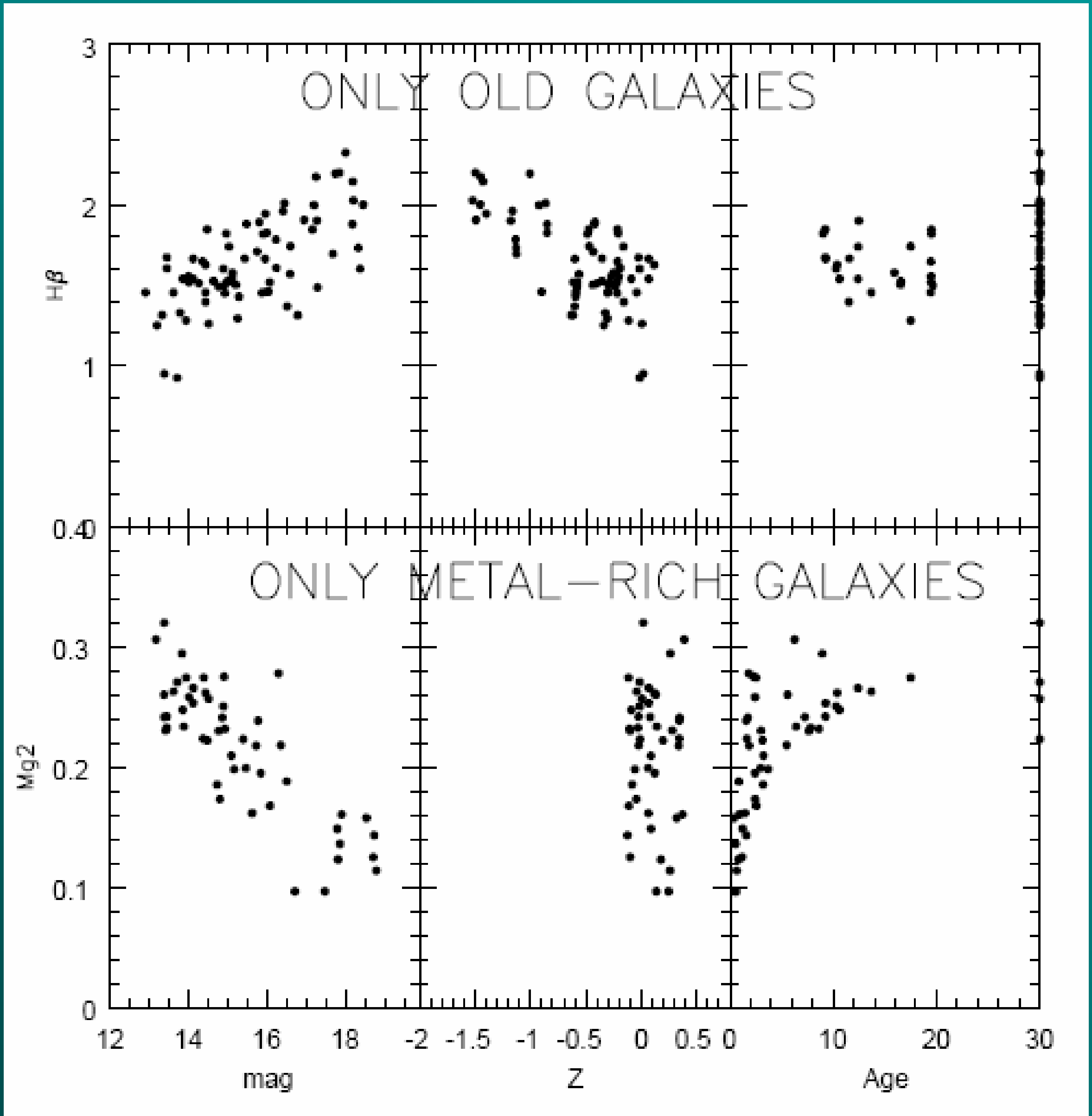
- Slope, scatter, outliers



Segregation is evident for age subsamples
Correlation of Hβ-R, thickening, zero-point shift
Hβ anticorrelated with Z, no correlation with age
Metal-rich: Fainter galaxies on average younger



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



ONLY OLD GALAXIES
ONLY METAL-RICH GALAXIES
Hβ
Mg2
3
2
1
0.4
0.3
0.2
0.1
0
12
14
16
18
-2
-1.5
-1
-0.5
0
0.5
10
20
30
mag
Z
Age

Summary

- 257 no emission line spectra of Coma member galaxies
  λ = 3600 - 6600Å
  M_B = (-20.5, -14)
  ~1x1.5Mpc, 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_2$4668 (Metallicity-sensitive indices) anti-correlate with L

- (Lick indices, model based on the Padova isochrones) $\Rightarrow$ L-weighted ages & metallicity

1. Very low Balmer indices $\Rightarrow$ 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
   $\Rightarrow$ composite formation scenario

5. Age – Metallicity anticorrelation at any L
6. index-magnitude relation
   age and metallicity variations with luminosity

Thanks!