The Stellar Populations Of Low-redshift Clusters

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Project Aims

- To perform a detailed study of the stellar populations of early-type galaxies in clusters
  - Age and metallicity differences between E, S0 and bulge dominated spirals
  - Variation of age and metallicity with cluster radius

- To investigate star-formation (SF) in late-type galaxies in clusters and their surrounds
  - SF history by measuring the mean SF rate on various timescales
  - Variations of SF rate with cluster radius
  - Effects of cluster properties (L_x, richness, dynamical state) on SF rate

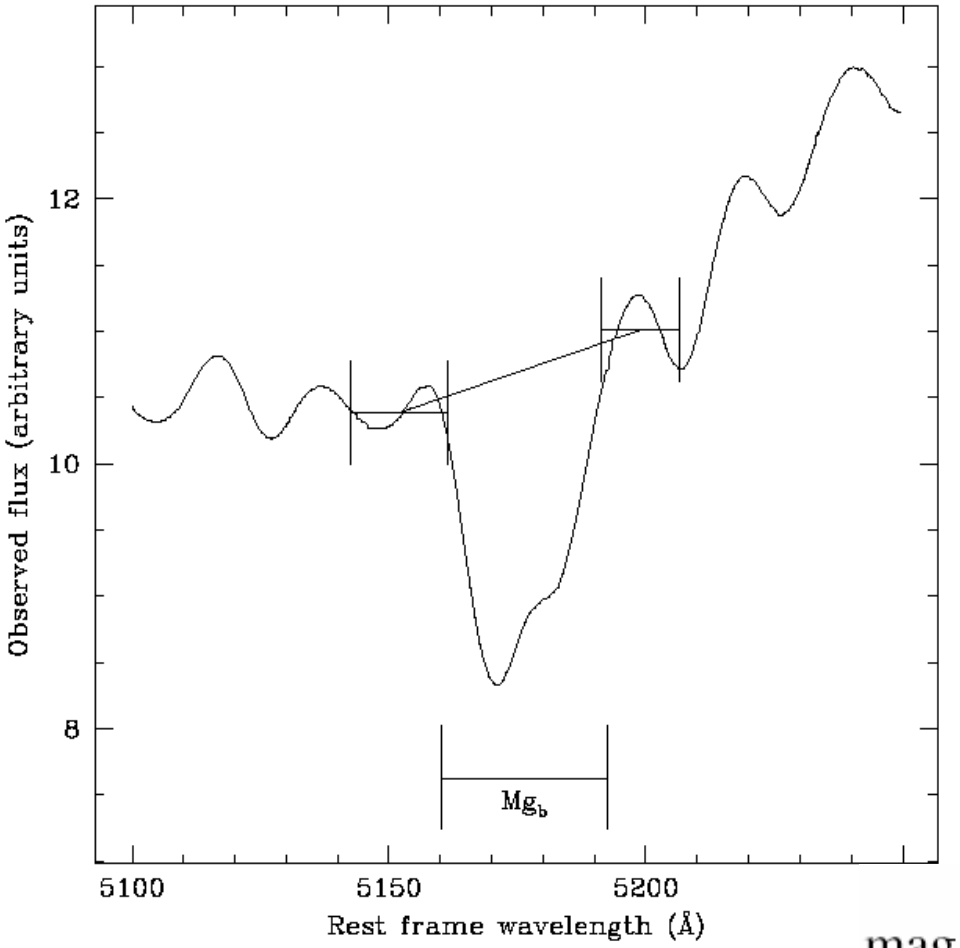
Project Aims

- To search for evolution of the above in the brightest galaxies in rich clusters over nearly half the Hubble time ($0<z<0.55$)

- Measuring central line-strengths in the integrated light from cluster galaxies and comparing the results to predictions from stellar population models to obtain luminosity-weighted relative ages and metallicities

The Lick/IDS System

Burstein et al. (1984)

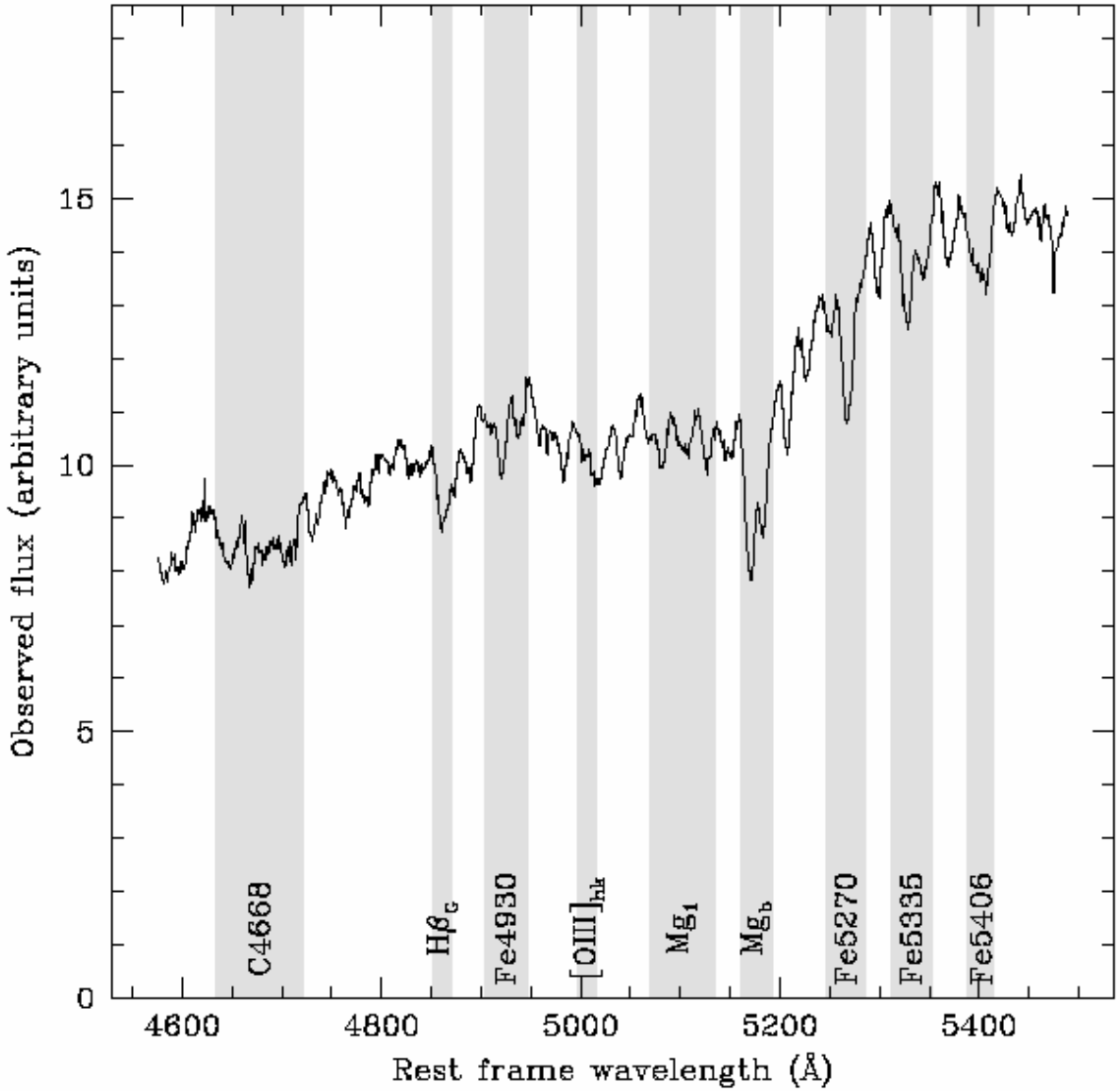


$$F_{\mathrm{P}} = \int_{\lambda_1}^{\lambda_2} \frac{F_\lambda}{(\lambda_2 - \lambda_1)} \mathrm{d}\lambda$$

$$\mathrm{EW} = \int_{\lambda_1}^{\lambda_2} \left(1 - \frac{F_{I\lambda}}{F_{C\lambda}}\right) \mathrm{d}\lambda$$

$$\mathrm{mag} = -2.5 \log_{10} \left[\left(\frac{1}{\lambda_2 - \lambda_1} \right) \int_{\lambda_1}^{\lambda_2} \frac{F_{I\lambda}}{F_{C\lambda}} \mathrm{d}\lambda \right]$$

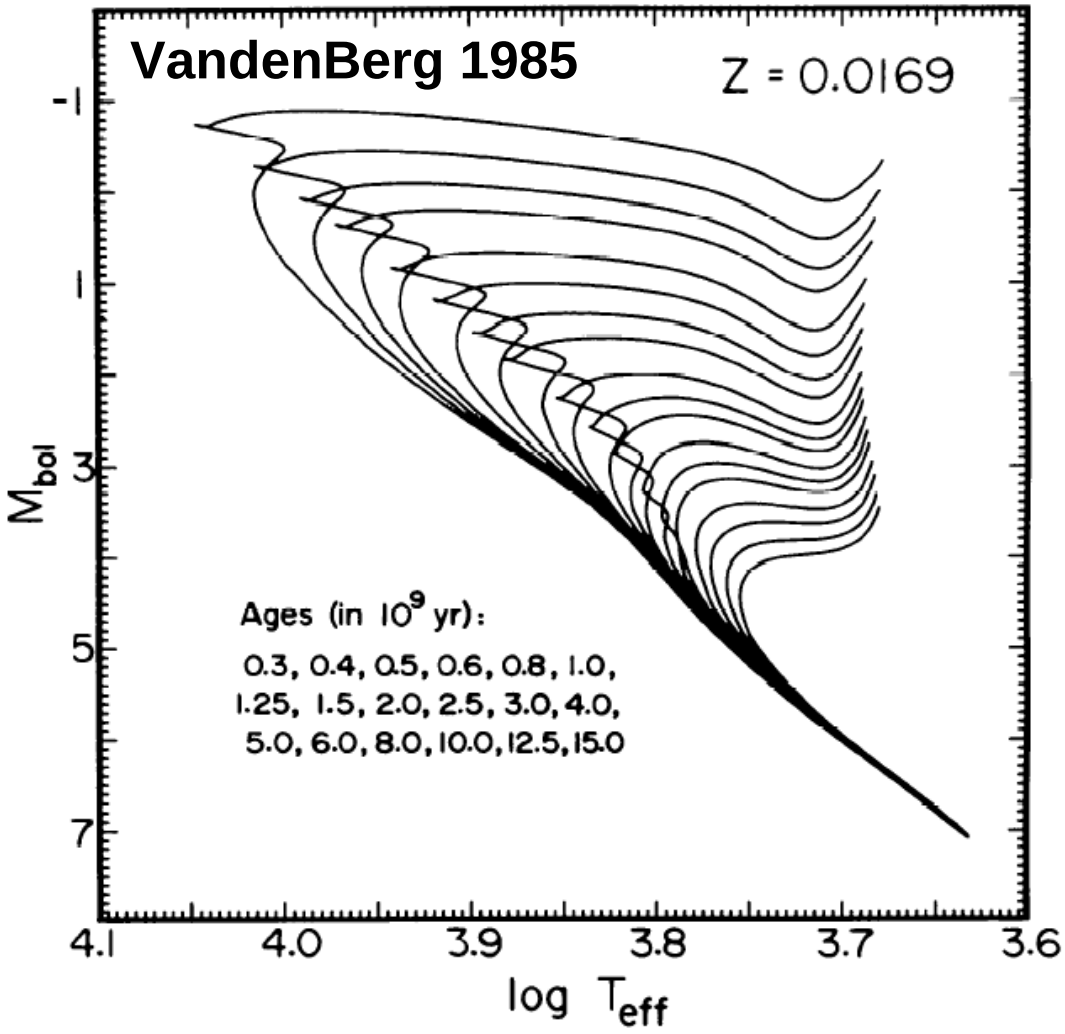
The Lick/IDS System



Stellar Population Models

- Stellar isochrones, (e.g. VandenBerg, 1985; RYI – Green et al., 1987; Padova group)

- Properties of a star as a function of mass for a given age



Stellar Population Models

- Each point on the isochrone represents a parcel of stars of know luminosity, temperature and gravity
- A stellar flux is interpolated from a grid to match the parcel of stars
  - Bessell et al., 1989 & 1991; Kurucz, 1992; Jones, 1997
- The energy from this location is then found by multiplying the above flux by the number and luminosity of the stars in the parcel
- Input parameters: IMF, age (single-burst models), metallicity, abundances…
- Outputs: equivalent widths, colours & surface brightness fluctuation magnitudes

Stellar Population Models

- Variety of models available
  - Bruzual & Charlot (1993)
  - Worthey (1994)
  - Vadekis et al. (1996)
  - Thomas et al. (2002)

- Improvements
  - Non-solar abundances
    - [Mg/Fe] ratios are higher in elliptical galaxies – leading to younger ages; crucial for absolute age and metallicity estimates
  - Modelling of the RGB, AGB (particularly the mass-loss phase)
    - Contribute a large amount of flux to the integrated light

Choice of Indices

- Age/metallicity degeneracy, Worthey (1994)
  - The spectra resulting from a factor of 2 increase in metallicity will be nearly indistinguishable from that produced by a factor of 3 increase in age
- In order to break this degeneracy plot an age-sensitive index against a metallicity-sensitive one
- Age sensitive indices
  - OII, G4300, Hδ, Hγ, $H\beta_G$
- Metallicity:
  - Ca4668, Fe5015, Mg_1, Mg_2, Mg*b*, Fe5270, Fe5335

$$[\mathrm{MgFe}] = \sqrt{\mathrm{Mg_b} \times \langle \mathrm{Fe} \rangle} \qquad \langle \mathrm{Fe} \rangle = \frac{\mathrm{Fe5270} + \mathrm{Fe5335}}{2}$$

Low-redshift Cluster Observations

(z=0.023-0.058)

- 2dF, AAT
  - 2 degree FOV corresponds to 1.3-3.2 Mpc
  - 400 2.1" fibres, corresponds to 1.0-2.4 kpc
  - 300B grating 3700-8100Å, 9Å FWHM
  - 1200V grating 4500-5800Å, 2.2Å FWHM
- 6dF, UK Schmidt
  - 6 degree FOV corresponds to 2.2-5.4 Mpc
  - 150 6.7" fibres, corresponds to 3.1-7.5 kpc
  - 580V grating 3900-5600Å, 5Å FWHM

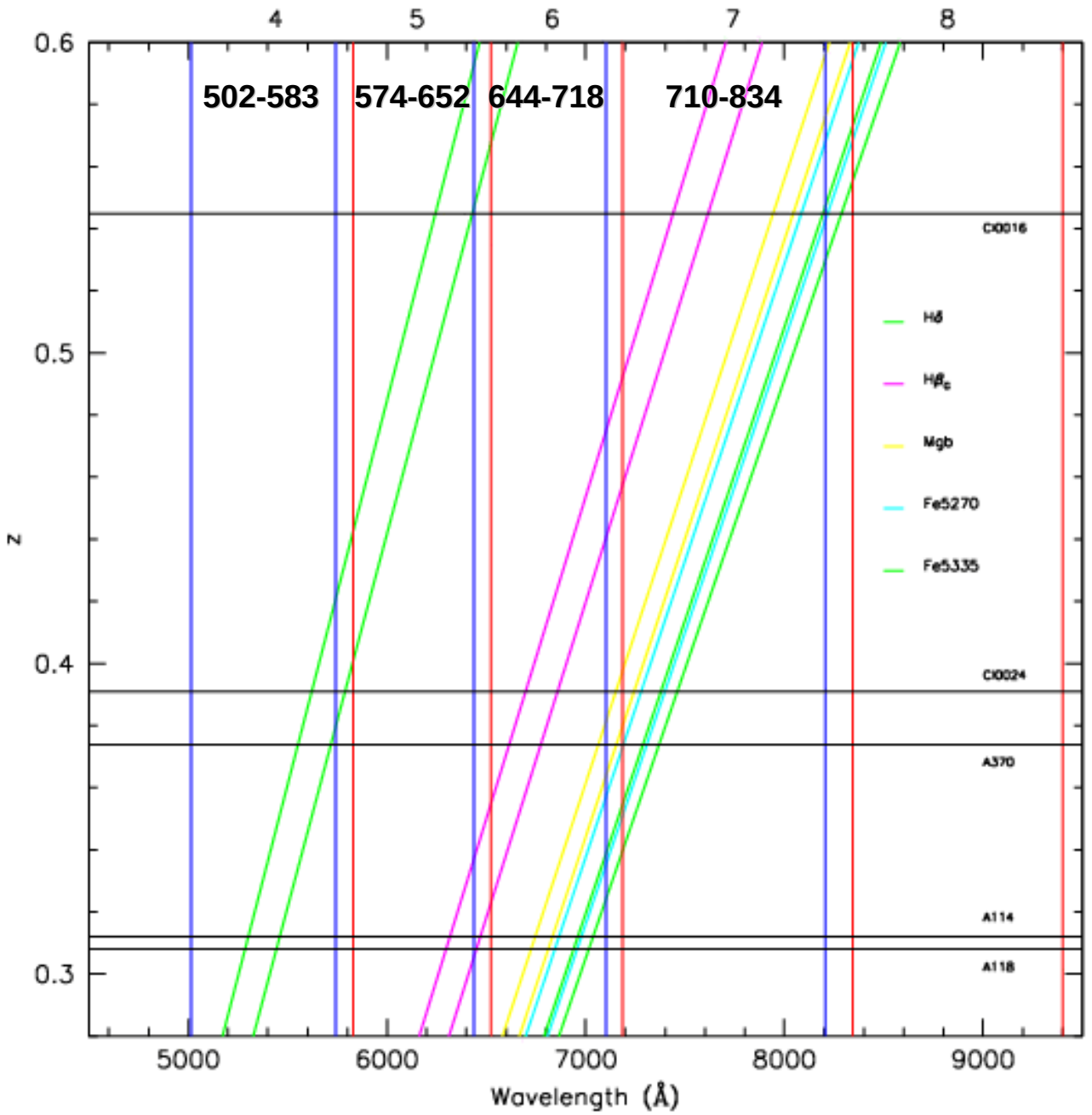
Low-redshift Sample

Name	R.A.	Dec.	z	δ	Rich.	B-M
Coma	12 59 48.7	+27 58 50	0.0231	1008	2	II
A1139	10 58 11.0	+01 36 16	0.0396	504	0	III
A3558	13 27 54.0	-31 29 30	0.0480	727	4	I
A0930	10 07 01.3	-05 37 29	0.0578	907	1	III

Intermediate-redshift Clusters

(z=0.31-0.55)

- FLAMES, VLT UT2
  - 25' FOV corresponds to 0.4Mpc-4.8 Mpc
  - 131 1.2" fibres corresponds to 5.5 kpc-7.7 kpc
  - Use four low-resolution gratings to track indices of interest with redshift
    - LR03: 4501-5078, 4797
    - LR04 5015-5831, 5431
    - LR05 5741-6524, 6142
    - LR06 6438-7184, 6822
    - LR07 7102-8343, 7734



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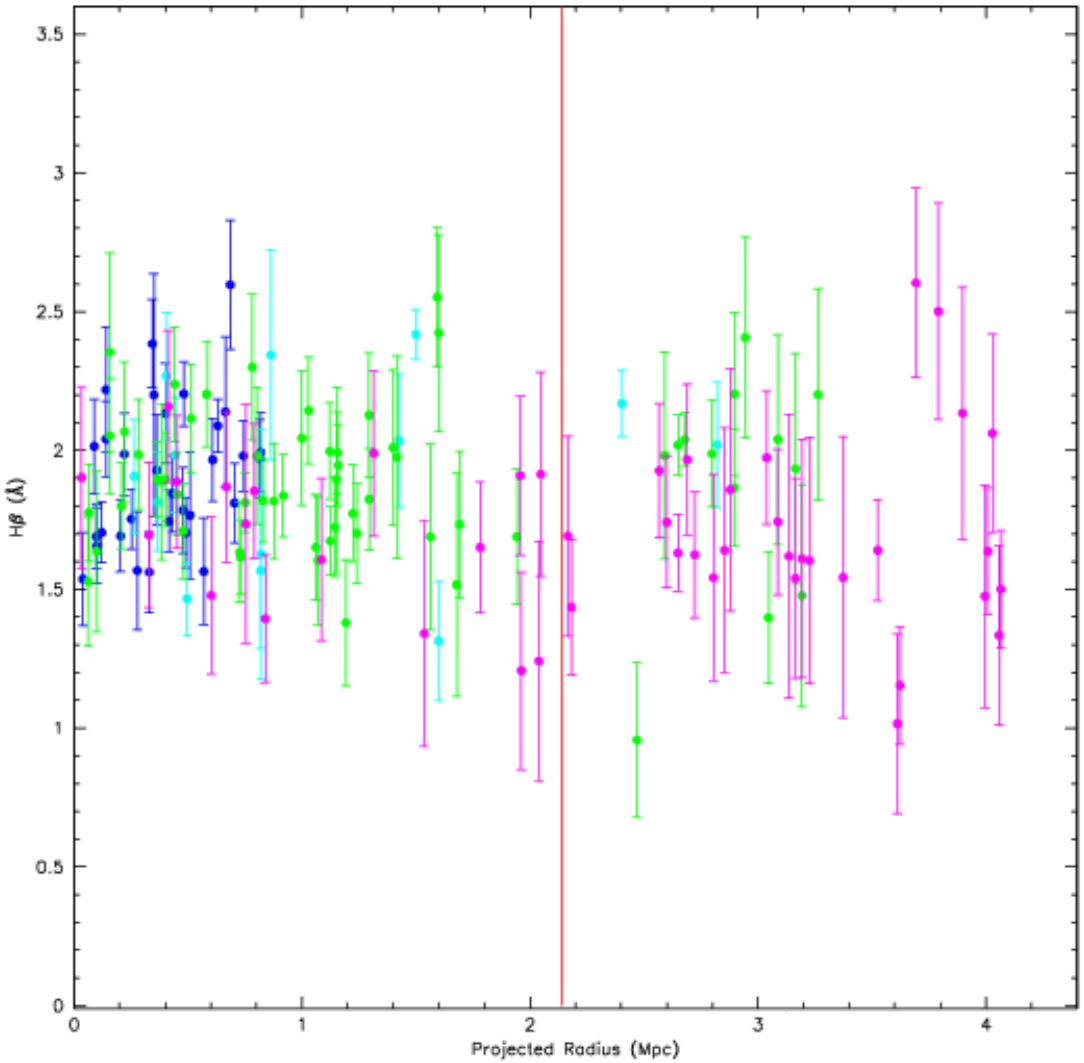
The Intermediate-redshift Sample

Name	R.A.	Dec.	z	δ	Rich.	B-M
A118	00 14 20.7	-30 24 00	0.308	1950	3	III
A114	22 58 48.4	-34 48 09	0.312	1649	2	II-III
A370	02 39 53.8	-01 34 24	0.374	1587	0	II-III
Cl0024	00 26 35.7	+17 09 45	0.391	1339	0	-
Cl0016	00 18 33.5	+16 25 15	0.545	1703	-	-

Age Gradients



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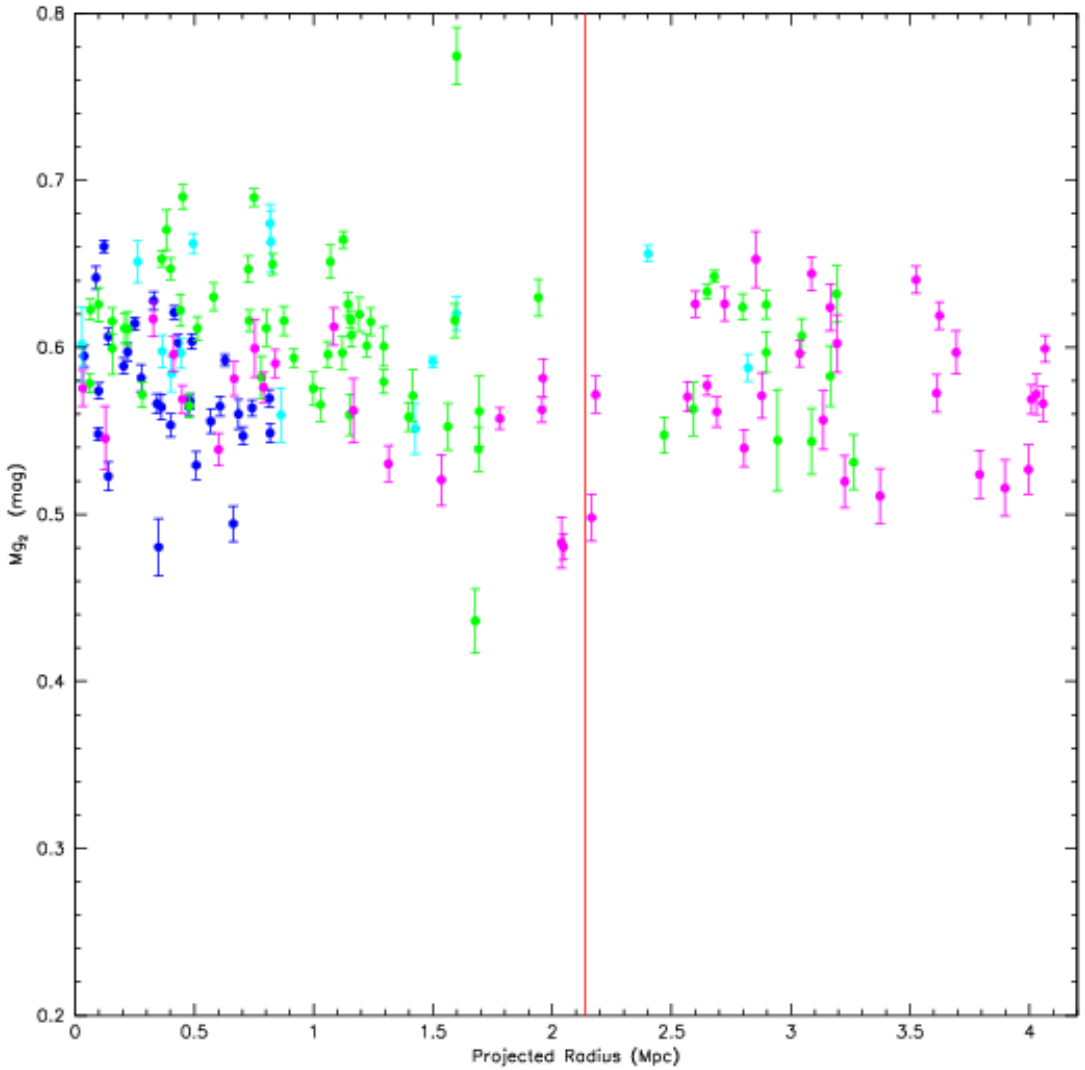
Metallicity Gradients



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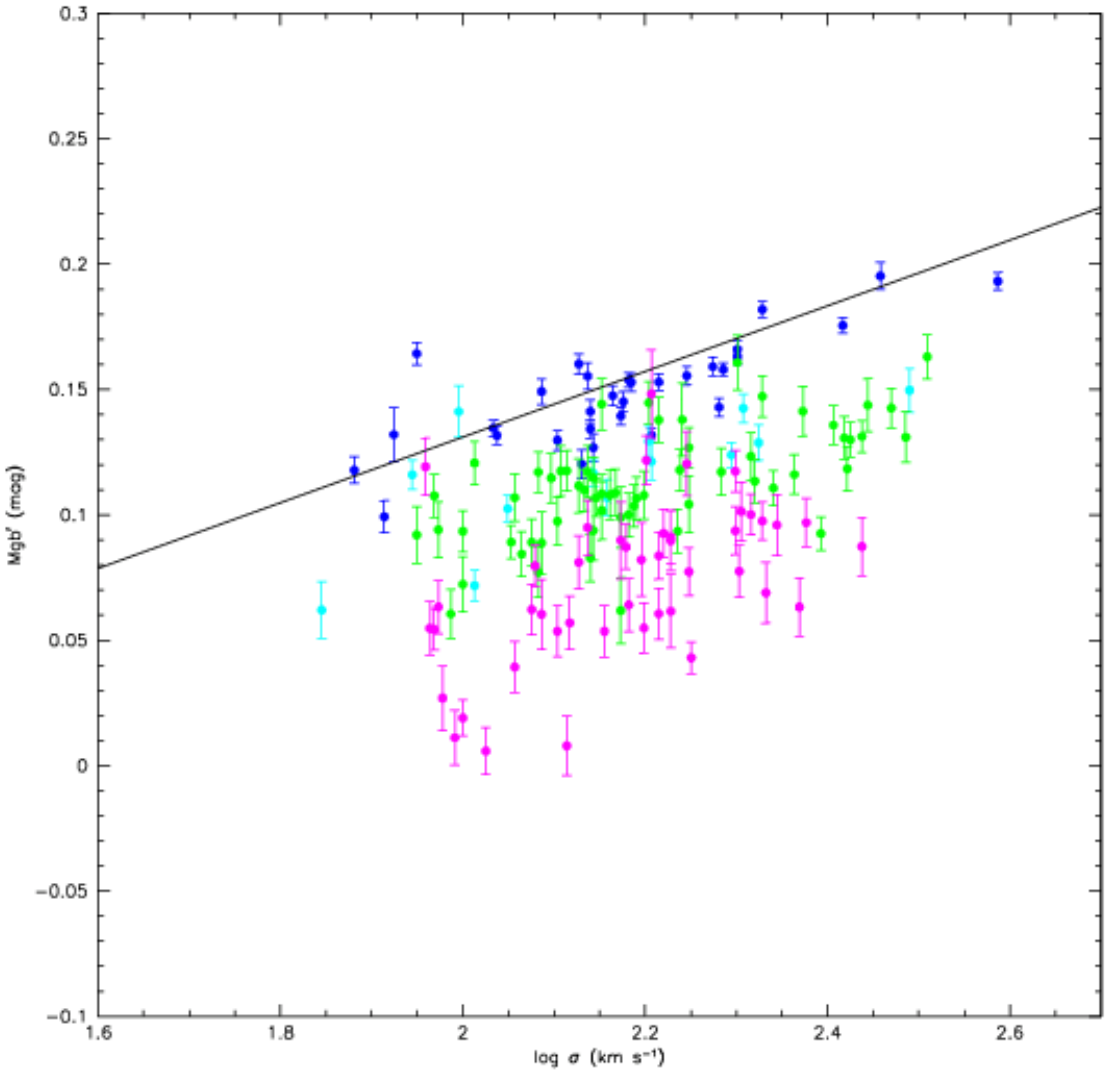
Mg-δ Relation



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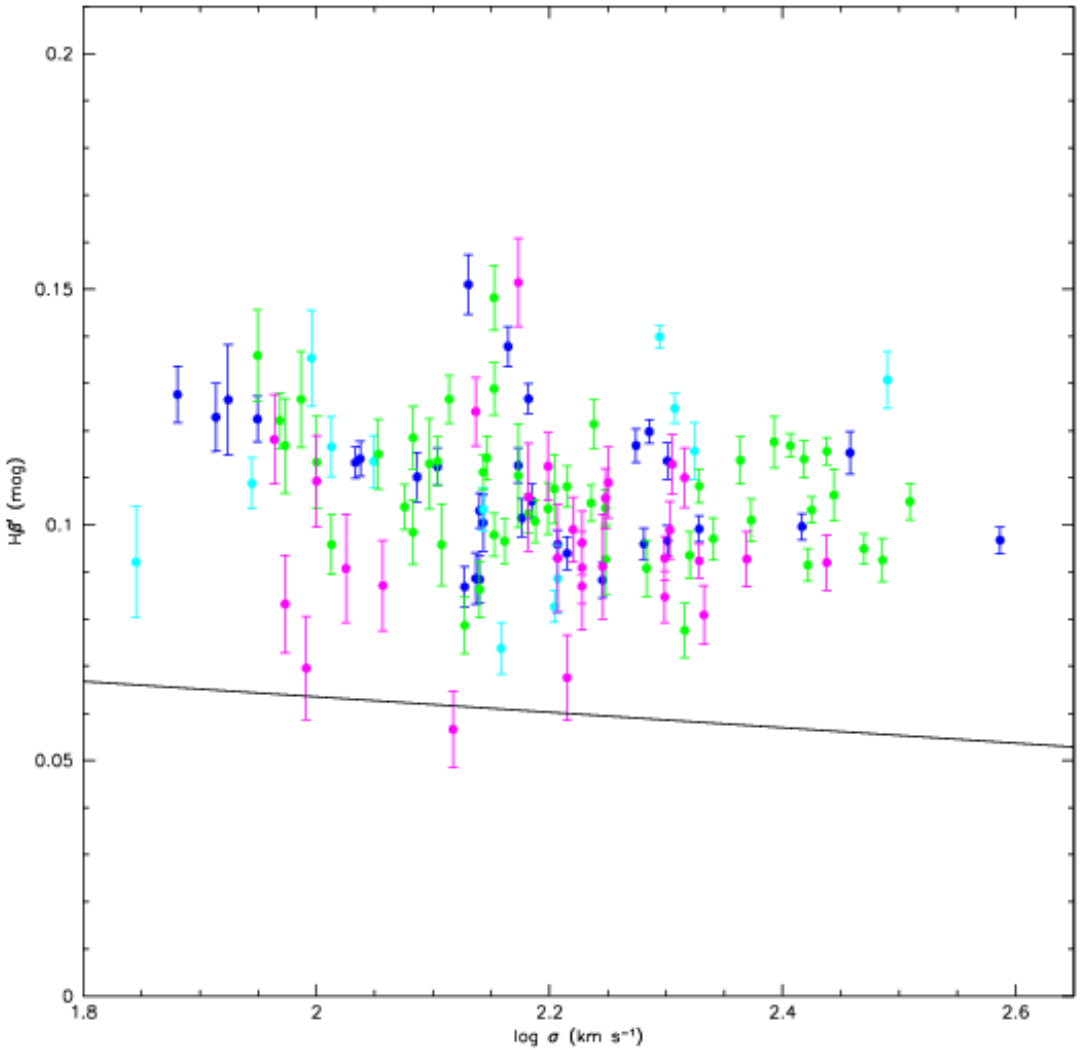
$H\beta_G$-δ Relation



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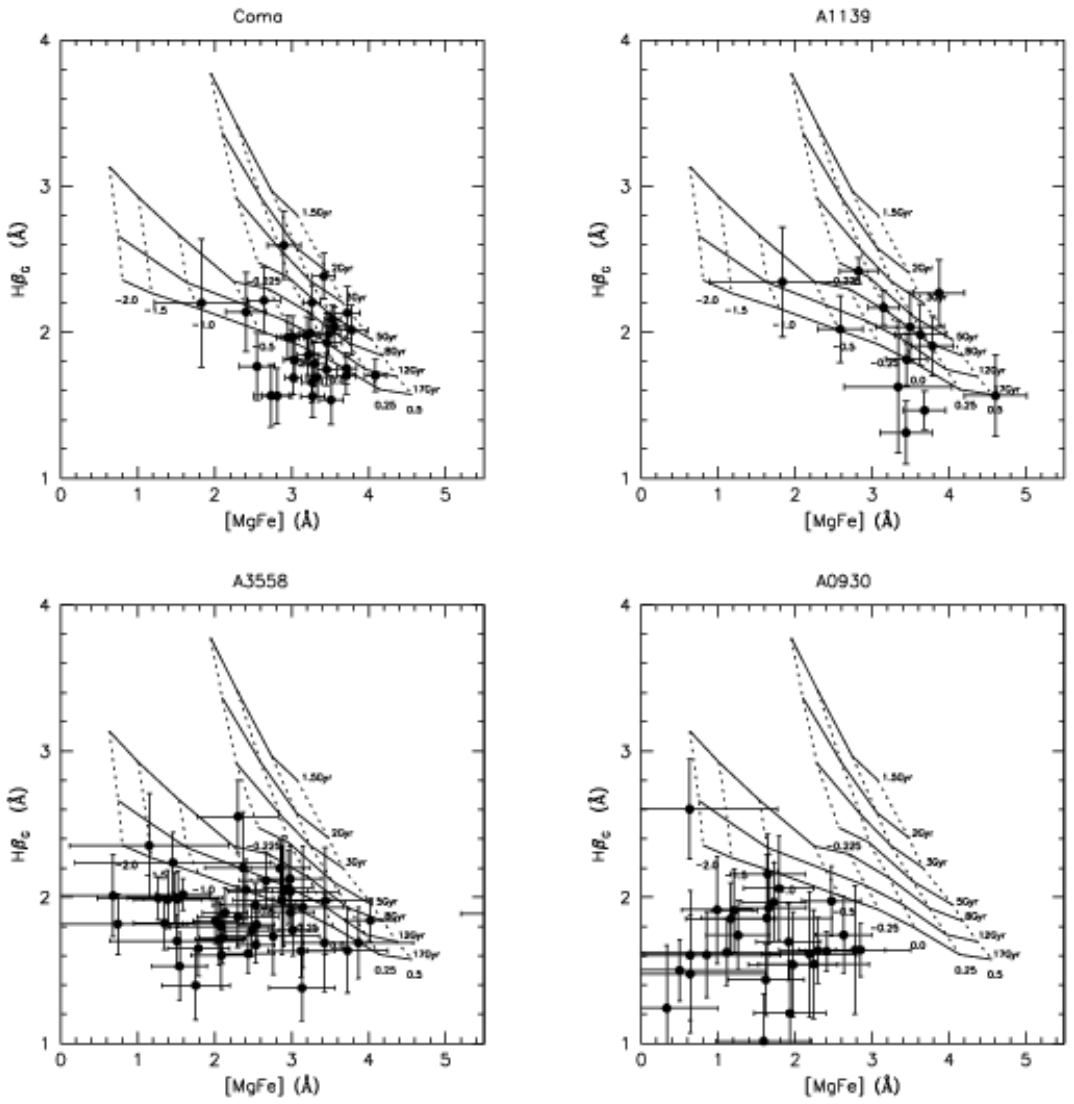
Comparison with Worthey's Models

[MgFe]=0.23±0.17

Age=8.7±4.1



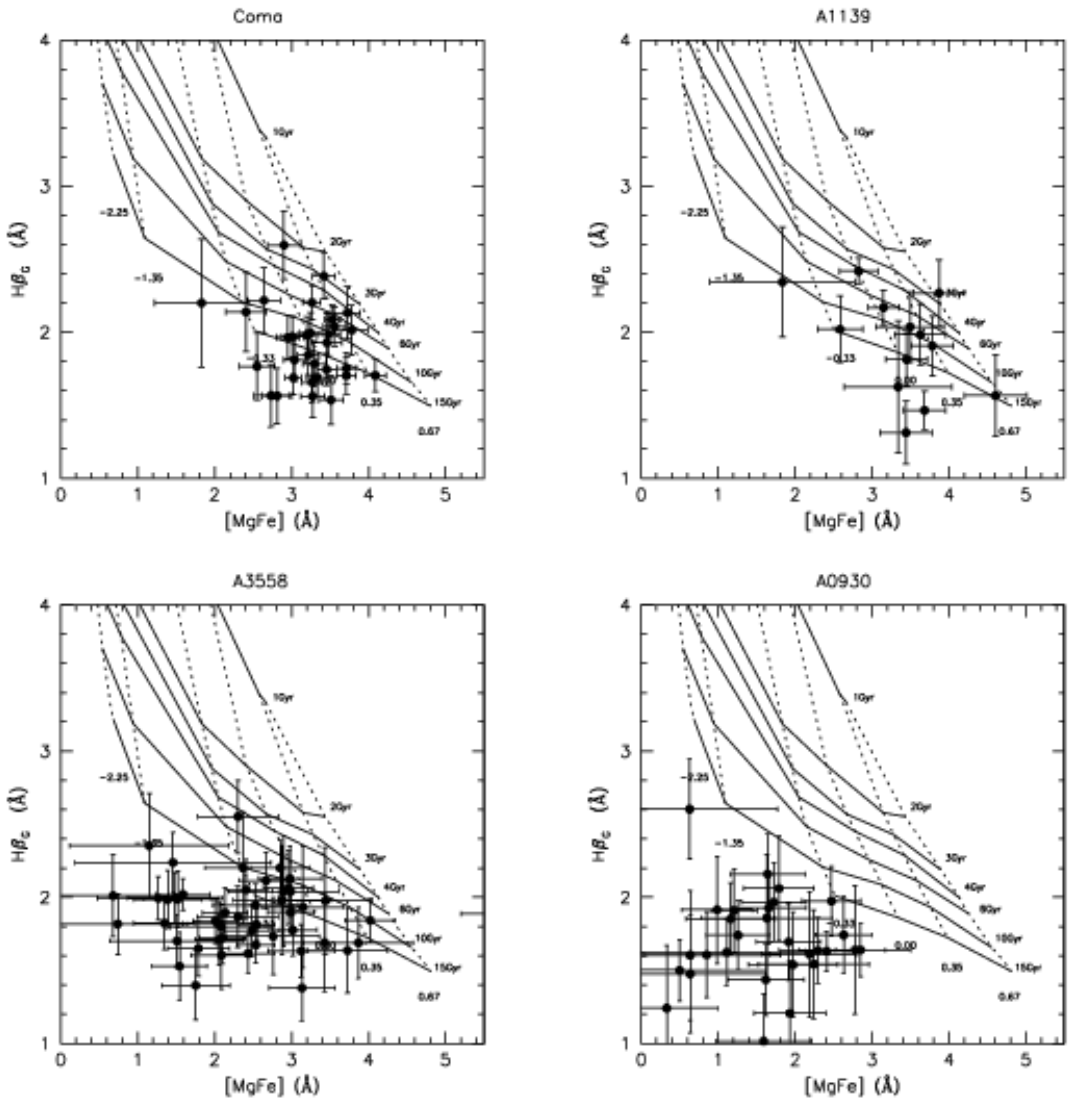
[MgFe]=-0.11±0.35

Age=10.3±4.0

Comparison with Thomas' Models

[MgFe]=0.15±0.23

Age=9.8±3.8



[MgFe]=0.12±0.41

Age=10.3±3.4

Summary

- No detectable metallicity gradient in our low-redshift sample, nor any offsets between clusters
- No detectable age gradients; need to probe the outer reaches of the clusters with 6dF data
- Mg-δ scaling relation with slope consistent with previous studies; massive galaxies more metal-rich than less massive ones
- $H\beta_G$-δ scaling relation with a slope consistent with previous studies; massive galaxies are older than less massive ones
- In order to obtain more accurate relative luminosity-weighted ages and metallicities
  - Check conversion from Hβ to $H\beta_G$
  - Improve Mgb measurements by flux calibrating the data