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Narrow-band Continuum Colors of Distant Cluster Populations

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Abstract

Photometry of distant cluster populations addresses many issues in galaxy evolution studies. Color evolution, Butcher-Oemler effect, cD galaxy construction and S0 galaxy formation are all processes visible through detailed photometry. In recent years, spectroscopy has gained dominance in cluster studies (due to the growth in multi-fiber spectrographs) providing line indice measurements and kinematic information. However, photometry still has its advantages of deeper limiting magnitude and spatial resolution with properly selected filter sets. For the past decade, we have used a set of narrow band filters around the 4000Å break 'redshifted' to each cluster's velocity to avoid k-corrections and provide for photometric membership selection. These datasets compliment the work of spectral studies. For example, our narrow band colors focusing on the mean star formation rates averaged over the past Gyr rather than instantaneous rates giving by emission lines.

In this poster, we present new results for A2218 (z=0.18) and A2125 (z=0.25), two clusters with intermediate redshifts, but very different cluster properties. A2218 is a dense, elliptical-rich cluster (Bautz-Morgan type II) similar to Coma in its evolutionary appearance. A2125 is a less dense, more open cluster (Bautz-Morgan type II-III), although similar in richness. As we will see below, A2125 has a more developed blue population than A2218 (the Butcher-Oemler effect), although both clusters have significant numbers of blue galaxies (normal star-forming or starburst) compared to a present-day cluster. The red population are identical in A2125 and A2218 and well fit by passive evolution models.

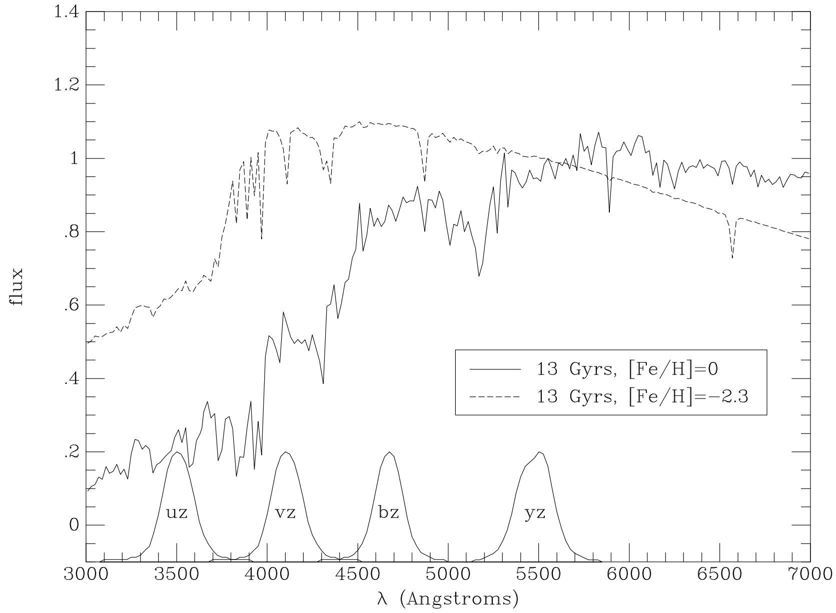

Fig. 1.1. The Strömgren system consists of four filter (*uz*,*vz*,*bz*,*yz*, shown above) which are centered around the 4000Å break. The *bz* and *yz* filters (λ_{eff} = 4675Å and 5500Å), sample the relatively line free region longward of 4600Å and produce a temperature color index, $bz-yz$. The second region is a band shortward of 4600Å, but above the Balmer discontinuity and is exploited by the *vz* filter (λ_{eff} = 4100Å). This region is strongly influenced by metal absorption lines (i.e. Fe, CN) particularly for spectral classes F to M which dominate the contribution of light in old stellar populations. The third region is a band shortward of the Balmer discontinuity or below the effective limit of crowding of the Balmer absorption lines. This region is explored by the *uz* filter (λ_{eff} = 3500Å). The advantages to the Strömgren system for galaxy evolution are: (1) Cluster membership is assigned based on photometric criteria, thus the ability to examine the lower luminosity galaxies in distant clusters that spectroscopy can not reach (2) The mean star formation rate is defined by spectrophotometric criteria, as compared to morphological appearance. Principal moment analysis allows us to divided our samples into E (old), S- (passive, S0-type), S (disk star formation rates) and S+ (starburst, high star formation rates). These spectrophotometric classifications are used to study the blue population in clusters (the Butcher-Oemler effect). (3) For quiescent objects (i.e. ellipticals and S0's) our color indices resolve (in a limited fashion) age and metallicity effects. Since galaxies are a mix of stellar populations of various metallicities, we have adopted a series of multi-metallicity models, calibrated to globular cluster data, which match spectroscopic results. Armed with these indices, we study the color-magnitude (mass-metallicity) relation in distant clusters and mean age of ellipticals as a function of luminosity (mass).

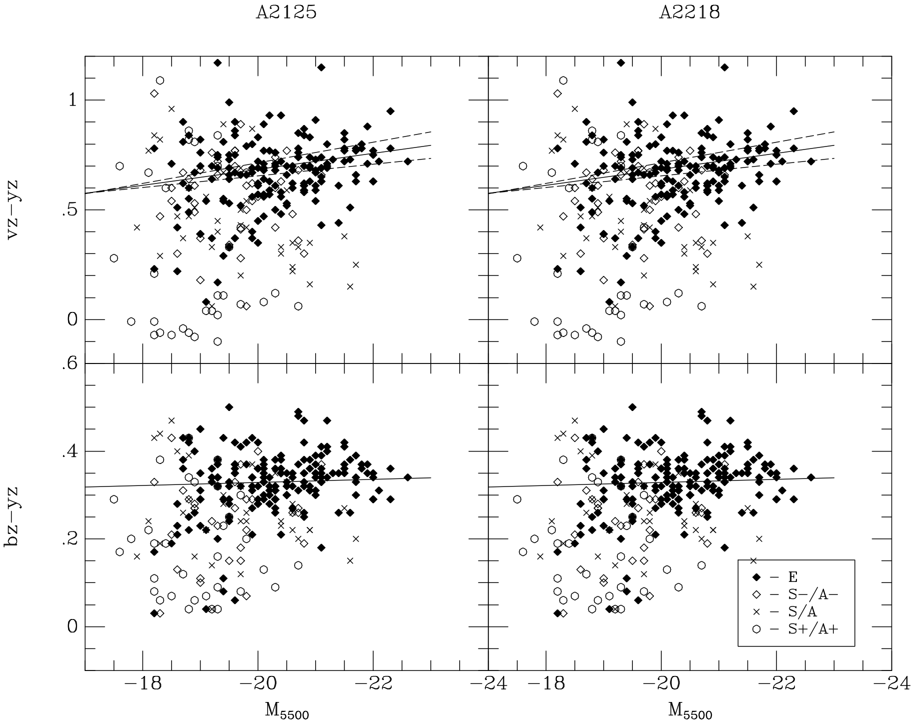

Fig. 1.2. The above two diagrams are the color-magnitude relations for A2218 ($z = 0.18$) and A2125 ($z = 0.25$). The two color indices, vz-yz and bz-yz, are shown. The various symbols display the spectrophotometric classifications based on all four filters. Points to note: (1) A2218 is a denser, richer cluster than A2125, but have similar absolute numbers of blue galaxies (for comparison, Coma has no galaxies bluer than bz-yz=0.2 at M<-19). Since A2218 is richer, its blue fraction is lower than A2125, although there is clearly a blue population present. (2) The solid lines are fits to Coma and Fornax data (O'Dell, Schombert and Rakos 2002) and are adequate fits to A2218 and A2125 with some minor, but important differences (see figure on average colors). (3) While vz-yz is more sensitive to metallicity effects than bz-yz, the lack of any correlation in bz-yz indicates an age effect, such that lower luminosity ellipticals are older (have higher mean stellar ages) then giant cluster ellipticals.

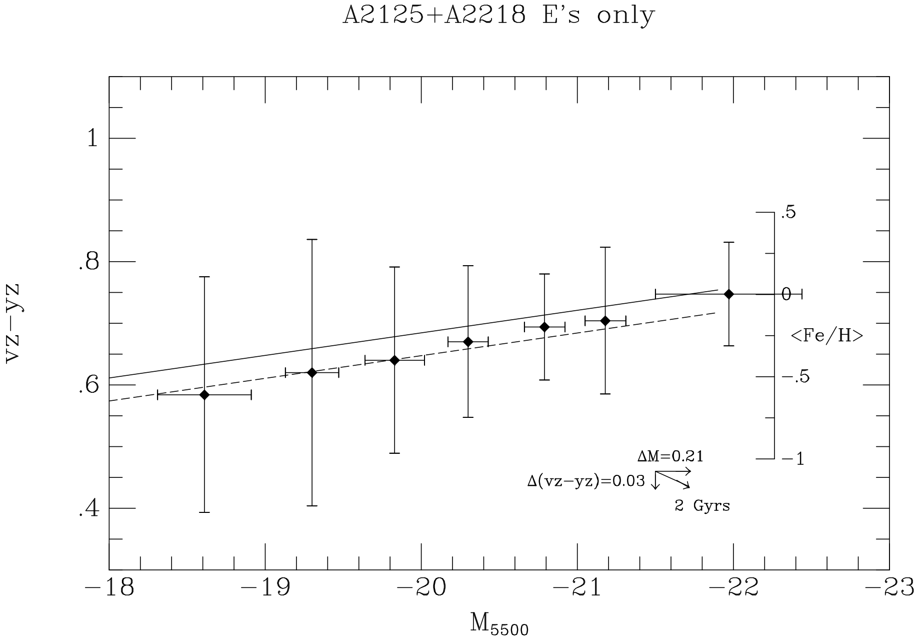

Fig. 1.3. The above diagram displays the average colors of ellipticals in luminosity bins of 0.5 mags from -18 to -22.5. The solid line is the best fit Coma/Fornax CMR. The dotted line is the expected change in the CMR for 2 Gyrs of evolution (based on Bruzual & Charlot models) which corresponds to the lookback time for A2125 and A2218 based on Benchmark cosmology values. The colors of both clusters elliptical population agrees well with passive evolution expectations. Also shown is the mean metallicity scale for the CMR based on multi-metallicity models to the Coma/Fornax data.

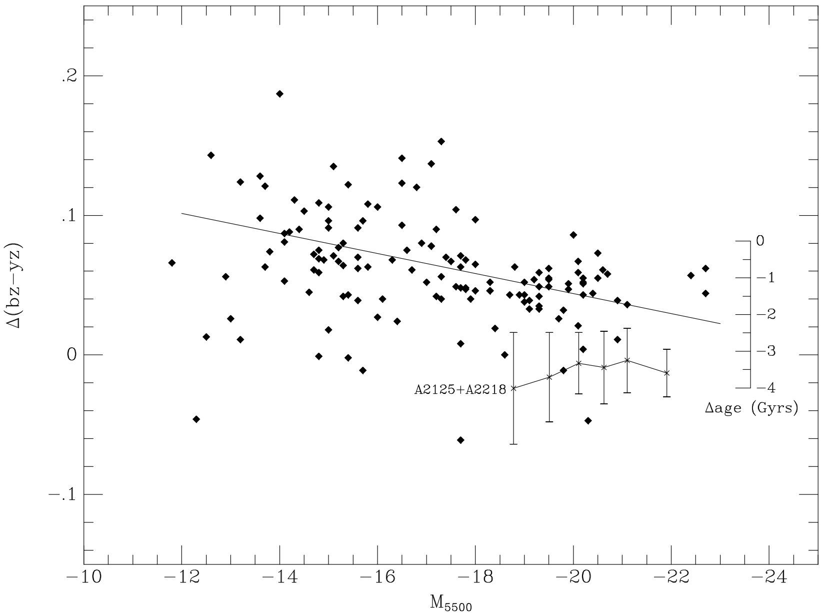

Fig. 1.4. $\Delta(bz-yz)$ index measures the mean age of the underlying stellar population in quiescent objects such as ellipticals. Data for the Coma and Fornax cluster are shown with a clear signature of younger mean age with increasing luminosity. Binned data for A2125 and A2218 are also shown. There is no clear trend with luminosity, although the mean age of ellipticals is 2 Gyrs younger than similar luminosity galaxies in Coma, in agreement with a lookback time of 2 Gyrs for redshift 0.2 clusters.

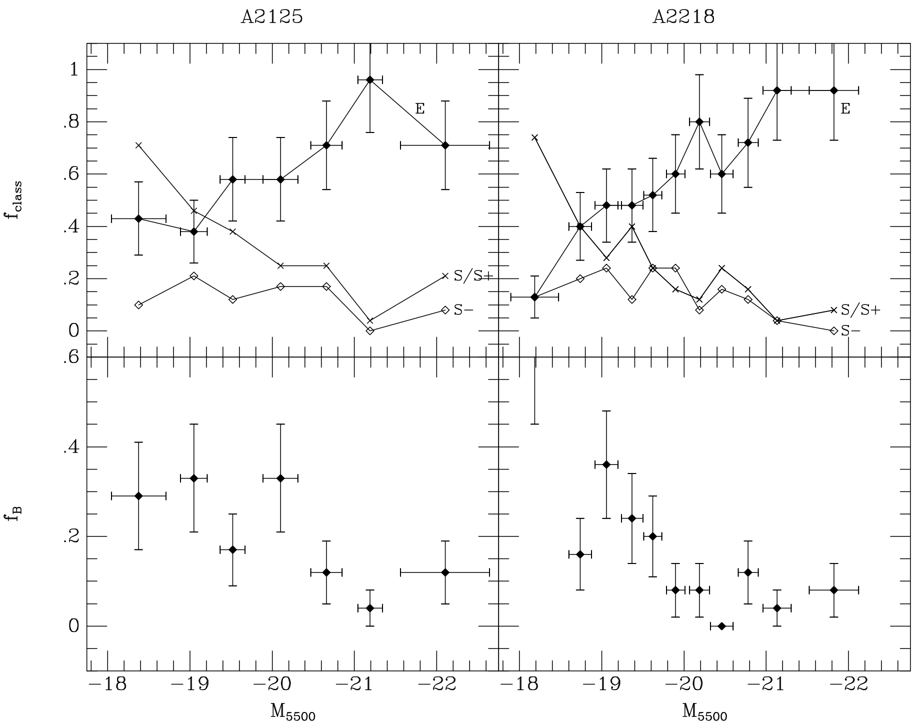

Fig. 1.5. Population fractions for A2125 and A2218, as given by spectrophotometric classification (top panel), and the blue fraction (bottom panel) as a function of absolute luminosity. A2125 displays the classic Butcher-Oemler effect by having a bright blue population of star-forming and starburst galaxies. Both clusters have increasing blue fractions with decreasing luminosity (the dwarf starburst population), however, some of these galaxies are dwarf ellipticals with low metallicity colors.