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LINKING MASS AND LIGHT IN A SUPERCLUSTER WITH GRAVITATIONAL LENSING AND MULTI-BAND IMAGING

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RESUMEN

Los cúmulos y supercúmulos de galaxias son ideales para investigar los efectos ambientales sobre la evolución galáctica. Combinando estudios de gran campo de lentes gravitacionales débiles con observaciones fotométricas multi-banda, hemos logrado enlazar las distribuciones de materia luminosa y oscura, y nos preguntamos: ¿Cómo se relacionan las propiedades galácticas con las condiciones ambientales? Usando imágenes profundas en la banda R del supercúmulo Abell 901/902 obtenidas del sondeo COMBO-17 aplicamos técnicas de lentes débiles para revelar la distribución de materia oscura, la cual incluye tres cúmulos de galaxias a $z \sim 0.17$, así como estructura filamentar inter-cúmulo. Empleamos los corrimientos al rojo fotométricos y la clasificación espectral que resulta del sondeo en 17 bandas para producir una imágen tridimensional de la estructura luminosa de enfrente, y para trazar los tipos de galaxias y sus propiedades como función de su localización en el campo de densidad subyacente. Hay fuerte evidencia de segregación por tipo, con las regiones más densas pobladas casi exclusivamente por galaxias tempranas. También observamos una densidad superficial de masa crítica, por encima de la cual la formación estelar se ve truncada.

ABSTRACT

Clusters and superclusters of galaxies offer the ideal testing ground with which to investigate the effects of environment on galaxy evolution. With the combination of wide-field weak gravitational lensing studies and multi-band photometric observations, we are able to link distributions of dark and luminous matter and ask: how do galaxy properties correlate with environment? Using deep R-band imaging of the Abell 901/902 supercluster from the COMBO-17 survey, we apply weak lensing techniques to reveal the dark matter distribution, including three galaxy clusters at $z \sim 0.17$ and inter-cluster filamentary structure. We then use the photometric redshifts and spectral classifications resulting from the unique 17-band survey to produce a 3-D view of the luminous foreground structure and to trace galaxy types and properties as a function of their location in the underlying density field. We find strong evidence for segregation by type, with the highest density regions populated almost exclusively by galaxies classified as early-types. We also observe a critical surface mass density above which star-formation activity is truncated.

Key Words: **GRAVITATIONAL LENSING — GALAXIES: CLUSTERS — GALAXIES: EVOLUTION**

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1. INTRODUCTION

The relation between galaxy properties and their environment is of great interest to the study of galaxy evolution. Observationally, a morphology-density relation in rich clusters has long been established (Dressler 1980), and the combination of N-body simulations and semi-analytic modelling (e.g. Benson et al., 2001) is now providing predictions for the joint distributions of dark matter and photometric properties of galaxies within the context of hierarchical structure formation. Gravitational lensing offers the most direct way to observationally uncover this underlying density field. Here we use the powerful combination of weak lensing and multi-band imaging to characterize both the dark matter distribution and the star-formation properties of galaxies within a supercluster, and to discover a connection between the two.

The A901/902 supercluster was observed in 17 bands (5 broad-band, 12 medium-band) with the $0.5^\circ \times 0.5^\circ$ ESO/MPG Wide-Field Imager as part of the COMBO-17 spectrophotometric survey (Wolf et al. 2002). The supercluster consists of three main cluster-sized mass concentrations all at $z \sim 0.17$ and contained within the field of view of the instrument. Preliminary results from a subset of the full dataset were presented in Gray et al. (2002). These include a 2-D map of the dimensionless surface mass density, κ, the result of a weak gravitational lensing reconstruction based on the deep R-band image.

The full multi-colour dataset allows for simultaneous parameter estimation of photometric red-

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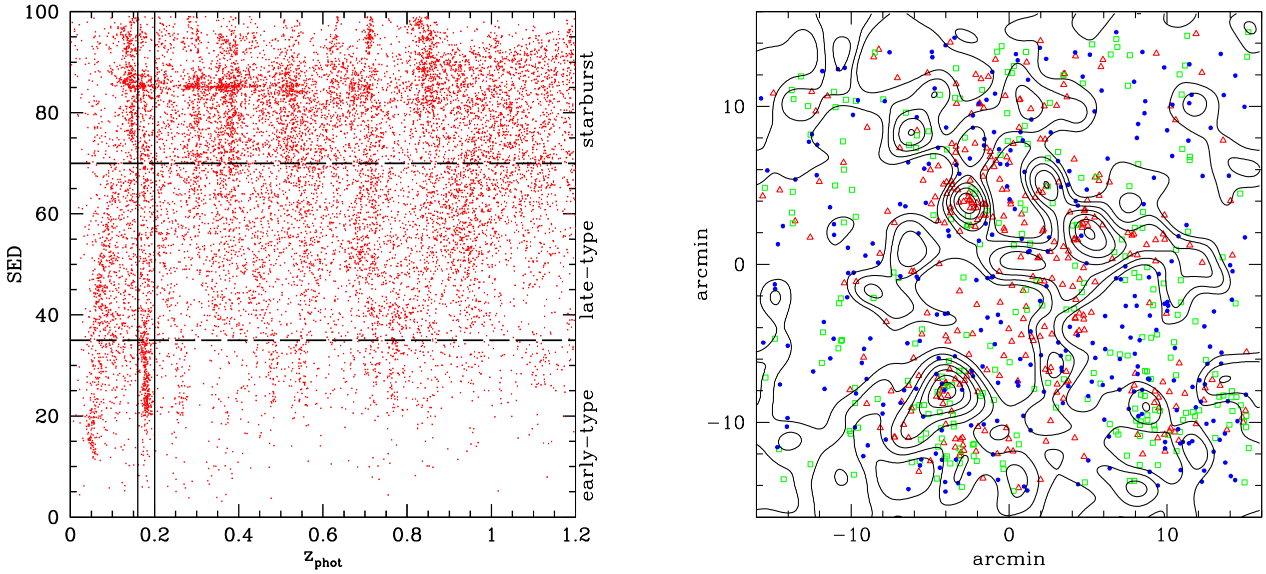

Fig. 1. *Left:* SED classifications *vs.* photometric redshift for all galaxies with $R < 24$ in the A901/902 field. The supercluster galaxies are selected via a slice in redshift space ($0.16 < z_{\rm phot} < 0.2$), and the SED continuum is divided into three discrete classes labelled 'early-type', 'late-type', and 'starburst' according to increasing amounts of star formation. *Right:* Distribution of redshift-selected supercluster galaxies relative to lensing mass map of Gray et al. 2002 (contours). Triangles represent galaxies classified as 'early-types', squares represent 'late-types', and filled circles represent 'starbursts'.

shift ($\sigma_z \sim 0.03$ for $R < 24$) and spectral energy distribution (SED) classification (see Wolf et al. 2001 for details). The SED classifications are based on ten observed average galaxy templates of Kinney et al. (1996), interpolated in steps of 10 to produce a continuum of values from 0–99 (E→Sa→Sbc→SB6→SB1) in order of increasing star-formation activity.

2. LINKING GALAXY PROPERTIES AND ENVIRONMENT

Armed with both SED classifications and photometric redshifts, we are able to accurately isolate those galaxies belonging to the foreground lensing structure as shown in Fig. 1a. First selecting galaxies with $R < 24$ and $0.16 < z < 0.2$, we then further subdivide the supercluster population into three classes according to SED value (0-35, 'early-type'; 35-70, 'late-type'; 70-100, 'starburst'). Fig. 1b shows the distribution of the redshift-selected galaxies relative to the mass map of Gray et al. (2002). A segregation effect by type is clearly evident, with the early-type galaxies much more strongly clustered towards the centres of the mass concentrations than the actively star-forming galaxies.

We find further evidence for this segregation by sampling the lensing mass map at the location of each of the supercluster galaxies. Fig. 2 shows that the highest density regions are populated almost exclusively by those galaxies classified as 'early-types'. Furthermore, there appears to exist a critical surface mass density, $\kappa \sim 0.05$, above which few star-forming galaxies are seen (some of which may be seen in projection against the mass peaks). The fraction of starburst galaxies found in regions with density above this threshold, $f(\kappa > 0.05)$ is 0.03, compared to 0.11 for late-types and 0.22 for early-types. The abrupt transition to a population dominated by passive galaxies at high densities indicates that an environmental effect may be responsible. It is possible that we are observing the truncation of active star formation as galaxies are accreted onto the dense supercluster environment.

3. CONCLUSIONS

Other evidence for a change in galaxy star-formation indices ($V - I$ colour, emission line strength, etc.) with increasing local galaxy *number* density has previously been observed (e.g. Kodama et al. 2001; Balogh et al., this volume). These studies also find evidence for an abrupt thresholding effect occuring at a critical number density. Preliminary calculations indicate that the critical surface mass density found in this study, $\kappa \sim 0.05$, does

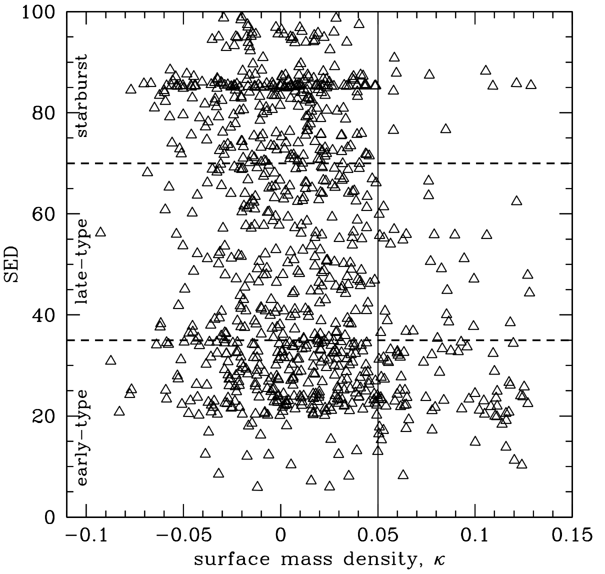

Fig. 2. SED classification *vs.* local surface mass density for each of the supercluster galaxies in the range $0.16 < z_{\rm phot} < 0.2$. A strong segregation by type is seen, with the highest density regions populated almost exclusively by those galaxies classified as 'early-type'. Furthermore, a sharp cut-off at $\kappa \sim 0.05$ is visible, above which active star formation activity appears truncated.

not map onto a corresponding local galaxy number density in a straightforward manner. However, this is likely to be due to the complicated relative distributions of mass and light in this system (discussed in Gray et al. 2002).

The remaining COMBO-17 fields (three further fields already observed and two more forthcoming) cover a wider mass spectrum, including multiple cluster systems, an isolated cluster, and blank fields. Applying the joint lensing and multi-colour analysis to all these fields will help to untangle the relationship between dark matter distribution, local galaxy number density, and galaxy evolution. In the case of the A901/902 field, the dataset is further augmented by high-resolution 2dF spectra and upcoming deep X-ray observations with XMM-Newton.

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