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Optical-NIR colour gradients in cluster early-type galaxies at z∼0.3: monolithic collapse ruled out? ⋆

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Abstract. Optical and near-infrared colour gradients are derived for the first time for a significant sample of cluster galaxies at $z \sim 0.3$. The large wavelength baseline provided by the combination of optical and NIR allows to constrain the origins of colour gradients: metallicity gradients cannot be the only cause of the colour gradients observed at $z = 0.3$ and in the local galaxies. As a consequence, the simple picture of a monolithic collapse seems to be ruled out.

Key words. galaxies: evolution – galaxies: fundamental parameters – galaxies: clusters: general

1. Optical-NIR colour gradients

Colour gradients in galaxies are the sign of radial changes in stellar populations, since old and metal-rich populations have redder colours than young and metal-poor ones. Colour gradients thus probe the radial distribution in age and/or metallicity of stellar populations. The knowledge of the origin of colour gradients would have a deep impact on the possible galaxy evolution scenarios: only a metallicity gradient is expected if galaxies formed in a monolithic collapse followed by passive evolution, while age gradients would originate from merging.

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In local early-type galaxies colour gradients in optical wavebands are known to be small (-0.05 mag dex^{-1} in the average; e.g. Michard 2000), while the average optical-NIR colour gradient is significantly higher (~ -0.14; Peletier et al. 1990; Pahre et al. 1998). Because of the well known age-metallicity degeneracy, colours alone cannot discriminate between the two origins of gradients in local galaxies.
In order to break this degeneracy, colour gradients need to be studied at different redshifts, in the same way as the study of the colour-magnitude relation at different redshifts allowed to establish its origin as a metallicity sequence Recent data for cluster early-type galaxies at intermediate redshifts show that optical gradients remained constant since at least $z \sim 0.6$ (Tamura et al. 2000; Saglia et al. 2000). This result seems to be consistent with the origin

of optical colour gradients as pure metallicity gradients. Such a conclusion is however undermined by the small wavelength range explored, an only the combination with NIR wavebands can improve our understanding of the origins of colour gradients. NIR wavebands are primarily sensitive to the red populations and are less affected by extinction and by small amounts of blue stars. Moreover, owing to the large wavelength baseline provided by optical-NIR colours, the weight of observational errors becomes small (Peletier et al. 1990).
Structural parameters (half-light radius, effective surface brightness and Sersic index) in the V, R and K wavebands are here used to derive optical and NIR colour gradients in galaxies belonging to the rich cluster AC 118 at $z \sim 0.3$. The samples consist in $N = 58$ galaxies $(V - R)$ and $N = 93$ galaxies $(R - K)$. Galaxies were selected by photometric redshifts. The samples include objects that are brighter than $R = 21$ and $V = 20.5$ and have half-light radii larger than 0.15 arcsec. The colour gradients were computed from the parameters of the light profiles. Details may be found in La Barbera et al. (2002).
Optical gradients agree with those measured in the other two existing samples at comparable redshifts ($z = 0.37$, Tamura & Ohta 2000 and $z = 0.38$, Saglia et al. 2000). Our data thus confirm that optical colour gradients are close to those in local galaxies. Optical-NIR colour gradients, on the contrary, are much larger (in absolute value) than in local galaxies: -0.49 mag dex^{-1} instead of -0.14 mag dex^{-1}. Previous measurements of optical-NIR gradients in distant galaxies concern six galaxies with redshifts ranging from 0.46 to 1.03 (Hinkley & Im 2001), so that the present sample constitutes the first homogeneous and significant ground on which to discuss the evolution of optical-NIR colour gradients.

2. Origins of colour gradients

In order to understand the origins of such large optical-NIR gradients at $z = 0.3$, we adopted two different models in which colour gradients are driven by 'pure age' or by 'pure metallicity' gradients.
The conclusion is that the 'pure age' model is able to explain the observed evolution of the optical-NIR gradients but predicts a wrong optical gradient at $z = 0.3$. The 'pure metallicity' model is able to reconcile both gradients at $z = 0.3$ but fails to predict the observed evolution of the optical-NIR gradient. It is conceivable that a more realistic model in which age and metallicity would be combined in a self-consistent picture will be able to explain the observed evolution of colour gradients. The constraint imposed by the optical-NIR colour gradient seems however rather sharp: metallicity gradients alone cannot explain the data, and age gradients must be present.
As a consequence, the present results seem to rule out the scenario of monolithic collapse for galaxy formation.

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