1. EVIDENCE FOR MERGER SIGNATURES IN THE LINE-STRENGTH GRADIENTS OF ELLIPTICAL GALAXIES

2. A UNIVERSAL RELATION BETWEEN METALLICITY AND POTENTIAL DEPTH FOR ALL HOT STELLAR SYSTEMS?

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ABSTRACT In the *first* part of this paper it is shown that those giant ellipticals which presumably formed in a violent merging process (as inferred from their peculiar core kinematics) reflect the details of the merging in their Mg_2-index profiles. In the *second* part it is demonstrated that, independent from other structural parameters, central Mg_2 index and central velocity dispersion σ_o (presumably representing the mean depth of the potential well) follow a unique relationship for all types of hot stellar systems (including diffuse dwarf ellipticals, compact ellipticals, bulges and giant ellipticals).

1. Evidence for merger signatures in the line-strength gradients of elliptical galaxies

INTRODUCTION: In recent years it became evident that probably up to 1/3 of luminous ellipticals contain cores which are kinematically de-coupled from the main-bodies of the galaxies (for a review, see [1]). This de-coupling can plausibly be only achieved if these ellipticals coalesced from constituents which had transformed most of their mass into stars already, i.e. from galaxy-like objects. In the merging process the stars violently relaxed and formed an anisotropic main body, while some fraction of the gas settled in the core of the merger remnant and formed stars in a starburst (a process which is presumably still observed today in some IRAS galaxies). Because stars and gas reacted differently in the merging process the final mean angular momentum vectors of gas and stars can differ considerably. This is most likely the origin of the peculiar cores observed in lumimous ellipticals. Some of these objects may still form today (e.g. [2]) but the majority of them is presumably quite old, especially when located in clusters of galaxies.

The basic question now is whether the details of the merging process not only

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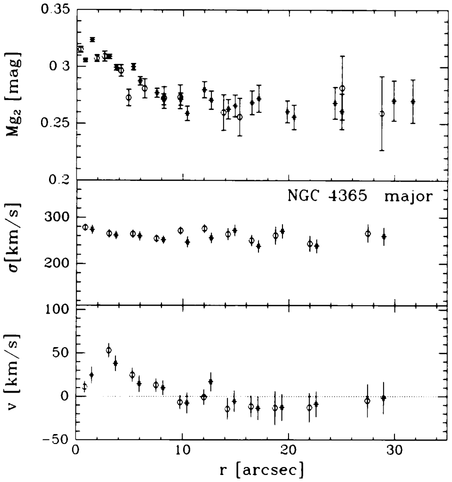
show in the kinematics but also in the metallicity/stellar population profiles of these galaxies. Previous studies [3] based on color index profiles could not uncover any indications but were limited by the difficulty of seeing corrections and sky subtraction on small-field CCDs. These latter problems are much less severe in case of line strength indices which can be derived from a single longslit spectrum and no comparison between different exposures (as in the case of color studies) is necessary. Indeed, in all the results shown below, it was found that sky subtraction errors are much smaller than the errors caused by photon noise. Only in the inner parts the gradients may have been somewhat weakend due to seeing effects but this does not affect the conclusions. The data shown here were obtained with the 3.5 m telescope on Calar Alto, Spain during several observing runs between 1987 and 1989.



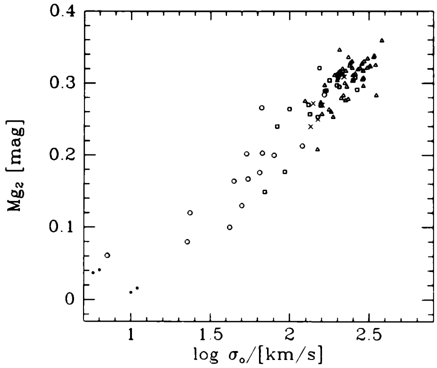


Figure 1 (left): Rotation velocity v, dispersion σ and Mg_2-index against radius r in NGC 4365. In the v and σ plots different symbols refer to different sides from the center along the *major* axis of the galaxy. In the Mg_2 plot, stars refer to the *major* axis, circles to the *minor* axis.

Figure 2 (right): Central Mg_2 against central σ_o for diffuse and compact low luminosity ellipticals (circles), ellipticals of intermediate luminosity (squares), luminous ellipticals (triangles), bulges (crosses) and dwarf spheroidals (dots).

RESULTS. Four ellipticals (NGC 4365, 4406, 4494, 5322) known to have peculiar core kinematics were analysed with respect to their line-strength profiles in Mg_2, <Fe> and H_β (line-strength indices in accordance with [4]. In *all* of them it was found that the Mg_2-index profile exhibits a discontinuous change of slope at roughly the same radius at which the peculiar core kinematics starts to show up. One example is presented in Fig.1 (NGC 4365). Outside the kinematic transition radius between core and main body (at $\approx$ 8 arcsec in NGC 4365) the Mg_2 gradient is rather weak, while inside of this radius the Mg_2-index rises steeply. The other indices (not shown here) show similar behaviour, but relative change with respect to MG_2 is not the same in all galaxies. This may indicate that core and mainbody not only have different metallicities but also that other parameters (like age, or the ratio of iron peak to light elements) are different (see also Faber, this conference). In a first simplified interpretation the Mg_2 profile can be understood in terms of a superposition of a lower metallicity main body having a only shallow gradient in Mg_2 and a higher metallicity core region which shows de-coupled kinematics and formed as a consequence of the merger event. The high metallicity of the core can be explained by the reasonable assumption that it formed from pre-enriched material and that, because of the depth of the potential well, the metals produced during the central starburst were well confined to the central region and could not escape from the galaxy. Furthermore, the central starburst may have produced stars with an IMF different from the one which was typical for the main body stars and this may possibly cause a radially changing [Mg/Fe]. The in some objects observable low Mg_2 gradient in the main body may be the residual of the Mg_2 gradients in the progenitor objects, these are expected to be weakened but not erased by merging (the more tightly bound parts of the progenitors are also more tightly bound in the merger product, see e.g. [5]).

2. A universal relation between metallicity and potential depth for all types of hot stellar systems?

It is well known that the metallicity of hot stellar systems correlates with their mass (e.g. [6], [7]). As realized by [8] there is however considerable scatter around the mean relation with the residuals from the Mg_2-luminosity correlation being correlated with the residuals from the mean velocity-dispersion luminosity relation. Since at a given luminosity higher velocity dispersion indicates higher surface brightness (because of the virial theorem), this in turn implies that at a given luminosity objects of higher surface brightness also have higher metallicity (see the papers by Gregg and Prugniel, this conference). Therefore, surface brightness is a second parameter in determining the metallicity of hot stellar systems. This can also be interpreted in the sense that metallicity is more closely correlated with the mean depth of the potential well (which roughly scales with the velocity dispersion) than with the mass of the object.

It is crucial for our understanding of the star formation history in hot stellar systems whether the metallicity velocity-dispersion relationship is different for different types of hot stellar systems or whether a universal relation exists. In order to investigate this question diffuse and compact dwarf ellipticals (dE's, cE's) in the Virgo cluster and the three brightest dE companions of M 31 (NGC 147, 185, 205) were observed with high spectral resolution at the Calar Alto 2.2m and 3.5m telescopes. Spatially resolved kinematics was derived (see [9]) and Mg_2 line-strengths were obtained and calibrated to the Faber/Burstein system. Furthermore, data of bulges of S0 galaxies (from the data set of Paquet et al., this conference) and of bright ellipticals with high accuracy kinematic data (see [1]) were compiled and added to the sample. Finally, the Mg_2 values of 5 dwarf spheroidal companions were estimated on the basis of their metallicity derived from cm-diagrams ([7]) and using the globular cluster based Mg_2-[Fe/H] calibration of [4]. In this way it was possible to derive for a large variety of hot stellar systems (dwarf spheroidals, diffuse and compact dwarf ellipticals, bulges and luminous ellipticals) a standardized data set covering 15 mag in luminosity, 10 mag/arcsec^2 in surface brightness, a factor 30 in velocity dispersion, and about a factor 100 in metallicity.

As shown in Fig.2, all the various types of hot stellar systems, independent from their large variety in structure and kinematics, follow a single, apparently universal relation between Mg_2 index and velocity dispersion. This is most remarkable since, e.g., giant ellipticals have been influenced by merging (see above) and faint ellipticals most likely suffered from wind-driven mass-loss (see e.g. [10]). Several important conclusions can be drawn on the basis of Fig.2:

(1) As the Mg_2-index is moderately age dependent, the age spread at a given velocity dispersion (or depth of the potential well) cannot be very large. There is however an indication that some part of the scatter in the Mg_2-σ_o-relation is indeed due to the presence of intermediate age stars (in case of luminous E's this has been shown by [11]; in case of dE's this is indicated by the presence of dust and gas).

(2) *The metallicity spread at a given potential depth/velocity dispersion cannot be large* either. This requires that the various formation/evolution processes (wind-driven mass-loss, merging) influence σ_o and Mg_2 in a similar way.

(3) Since the [Mg/Fe] ratio most likely depends on metallicity, Mg_2 can only be representative for the abundance of light elements. The [Fe/H]-σ_o-relation may flatten significantly at high velocity dispersions (see also part 1 of this paper).

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Questions:

Renzini: How do you fit the Mg_2-σ relation with the merging scenario?

Bender: There is probably no simple answer to that question but it may all work out well if merging is accompanied by dissipation and star formation, as I tried to indicate in the first part of my talk.