STELLAR POPULATIONS IN THE KINEMATICAL SUBSYSTEMS OF TWO NEARBY ELLIPTICALS

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Abstract

The spatial distributions of the mean luminosity-weighted stellar age, metallicity, and α/Fe ratio along both photometric axes of two nearby elliptical galaxies have been obtained using Lick index measurements on long slit spectra (1.60m telescope of OPD/LNA) in order to reconstruct the star formation history in their kinematically distinct subsystems. Lick indexes were compared with those of single-aged stellar population (SSP) models. A population synthesis method was also applied in order to help disentangling the age-metallicity degeneracy of these line-strength indexes. The star characteristics are associated with their kinematics: they are older and α-enhanced in the not rotating bulge of NGC 1052 and counter rotating core of NGC 7796, while they show a strong spread of α/Fe ratio and age along the rotating disk of NGC 1052 and an outwards radial decreasing of them outside the core of NGC 7796.

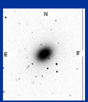
Introduction

The star formation history inside an early-type galaxy is determinate by its formation process (merging, accretion, monolithic collapse or other). Specifically, the stellar metallicity and age radial gradients are dependent on the galaxy merging history (Kobayashi 2004). Moreover, the stellar population parameters like the age and metallicity might be correlated with the stellar kinematics.

In this context, we have studied two distinct ellipticals with intermediate stellar masses (~10^{11} $M_{\odot}$) belonging to low density regions of the local Universe: the Liner prototype E4 NGC 1052, which belongs to a loose group and has a stellar rotating disk, and the E1 NGC 7796 of the field, which shows a kinematically decoupled core (KDC).

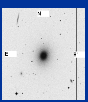
The two ellipticals

▪ NGC 1052



- E4/S0, z=0.00504, M_B=-20.50 (r_e=33.7”, r_{25}=91”)
- Liner prototype showing radio/X-ray jets
- 3rd brightest of a group (11 members)
- stellar rotating disk (i ≈ 90º)
- relatively well studied, including its *central* stellar populations

▪ NGC 7796



- E1, z=0.01097, M_B = -20.79 (r_e=21.2”, r_{25}=66”)
- isolated
- round system with a stellar counter rotating core
- its stellar populations have not been investigated *yet*

Observations

Long slit spectroscopic observations along both photometric axes (λλ4320-6360Å, R=1800, 2.01 Å/pix, σ_{inst}=71 km/s or FWHM≈3Å at 5300Å, slit size of 2.08” x 230”) were carried on the OPD/LNA 1.60m telescope, providing good quality spectra up to almost 1 r_{eff}.

The linear spatial scales were 111 pc/pix and 213 pc/pix for NGC 1052 and NGC 7796, respectively (h_0=0.75).

The signal-to-noise ratio per Å of the aperture spectra are:
for NGC 1052, 9-30 ≤ S/N(/Å) ≤ 34-83,
for NGC 7796, 17-26 ≤ S/N(/Å) ≤ 47-61.

The radial profiles of the line-of-sight velocity dispersion σ_v and the line-of-sight rotational velocity V_{rot} curves were satisfactorily compared with other studies. We have confirmed the presence of a stellar rotating disk (major axis) and a not rotating bulge in NGC 1052. The stellar counter rotating core of NGC 7796 was detected as well. Read Kinematics analysis's Section.

Lick index radial gradients

The Lick indexes from Fe4383 to Na D were measured on the aperture spectra and properly calibrated on the Lick System. For NGC 1052 only, the Mg b, Mg_1 and Mg_2 were corrected due to the effect of emission lines (Goudfrooij & Emsellem 1996), while Fe5015 and Hβ were excluded from the analysis.

The radial gradients of several Lick indexes along both axes were also computed. The central values of some indexes agree with the literature ones.

NGC 1052

The iron index gradients are null (major axis or disc & the majority) and negatively stronger along the minor axis (bulge).

The Mg gradients are quite negative.

Hβ gradient is indeterminate!

NGC 7796

They are more homogeneous along both axes (the majority).

The iron index gradients are null or positive (the majority).

The Mg gradients are quite negative.

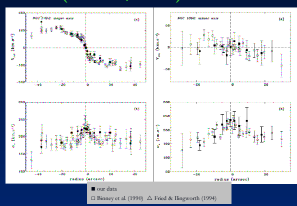
Hβ gradient along each axis is different (zero on average)!

Might exist some radial dependence for the Mg/Fe ratio and C & Na abundances !?

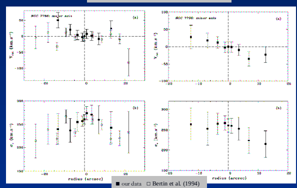
Kinematical analysis

Method: spectral cross-correlation (RVSAO/IRAF)
[literature value]

• NGC 1052
- cz_{helio} OK!
- σ_v^0=204-213 km/s [208 km/s]
- $(V_{rot}/\sigma_v)^*$=0.89 [0.85]
- low Ψ_{est} [i=90º]
- rotating disc (≈ oblate rotator)
- $M_* = 140 \times 10^9$ $M_{\odot}$



• NGC 7796
- cz_{helio} OK!
- σ_v^0=250-253 km/s [259 km/s]
- $(V_{rot}/\sigma_v)^*$=0.15 [none]
- high Ψ_{est} [none]
- low counter rotating core around minor axis
- $M_* = 290 \times 10^9$ $M_{\odot}$



Methods and Results: comparisons with SSP models and population synthesis

Firstly, the analysis of Lick index gradients suggests a possible radial dependency for the Mg/Fe abundance ratio for both galaxies (and maybe for the C and Na abundances).

We have compared our Lick indexes with the predictions of the single-aged stellar population models of Thomas et al. (2003) that take the influence of abundance variations on them into account. We have also performed a stellar population synthesis for each extracted spectrum applying the method of Bica (1988). The relationship between the [Mg/Fe] and the star formation timescale Δt_{SFR} of Thomas et al. (2005) was employed as well.

$$[\alpha/Fe] \approx \frac{1}{5} - \frac{1}{6}\log \Delta t_{SFR}$$

From the SSP comparisons, we have obtained that the stellar populations of the bulge of NGC 1052 have [α/Fe]=+0.2 dex and [Z/$Z_{\odot}$]=+0.4 dex. Along its disk, there is a strong spread of the Mg/Fe ratio (0≤[α/Fe]≤+0.5 dex) associated with a possible outwards radial decreasing of the global metallicity to the solar value. In the core of NGC 7796, the populations have nearly [α/Fe]=+0.45 dex, [Z/$Z_{\odot}$]=+0.35 dex and 12 Gyr, while there is an outwards radial decreasing of the Mg/Fe ratio to the solar value associated with a possible decreasing of the global metallicity and age.

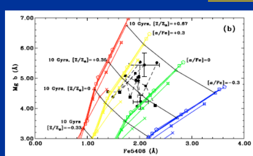
The results of the population synthesis indicate that the nucleus of both ellipticals is dominate by old metal rich stars (~13 Gyr & $Z_{\odot}$). The populations are more homogeneous in the bulge of NGC 1052 than along its disk, where there is an outwards radial decreasing of the presence of the older-richer components together with a respective rising contribution of the younger-metal poor ones. The results for NGC 7796 are analogous: older ages and higher metallicities in the nucleus but with similar radial behavior of age and Z along both axes.

Comparisons with SSP models

The models of Thomas, Maraston & Bender (2003)
- solar-composition isochrones of Castellani et al. (1992) + MS dwarf models of VandenBerg et al. (1983)
- evolutive stellar population synthesis of Maraston (1998) → SSPs with Salpeter's IMF
- stellar fitting function of Worthey (1994) → composite indexes
- response functions of Tripicco & Bell (1995) ↔ α-enhancement predictions

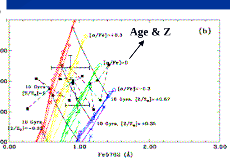
Adopted grid
Ages: 2, 6, 10, 12 and 15 Gyr
[Z/$Z_{\odot}$]: -2.25, -1.35, -0.33, 0.00, +0.35 and +0.67 dex
[α/Fe]: -0.3, 0.0, +0.3 and +0.5 dex

NGC 1052



There is an age-metallicity degeneracy on the Mg-Fe index relations!

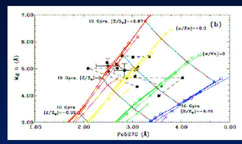
- index errors → δ[α/Fe] ≈ ±0.1 dex
- data of the central spectra with error bars



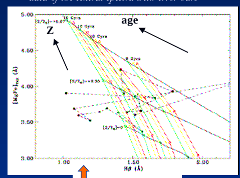
MAJOR axis **data:** ■
minor axis **data:** ●

SSP
ages: 2(✕),6(✦),10(△),12(□),15(⬟) Gyr
[Z/$Z_{\odot}$]: -2.25 → +0.67 (left-bottom to right-up)
[α/Fe]: -0.3 → +0.5 (colors)

NGC 7796

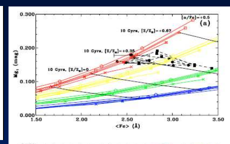


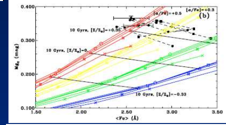
- index errors → δ[α/Fe] ≈ ±0.1 dex
- data of the central spectra with error bars

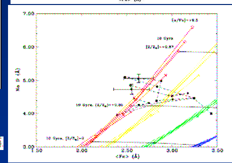


disentangling the age-metallicity degeneracy!

$$[MgFe]_{TMB} = \sqrt{Mg\,b \times (0.72 \times Fe5270 + 0.28 \times Fe5335)}$$







Stellar population synthesis

The method/code of Bica (1988)
- uses integrated spectra of star clusters of the Galaxy → SSPs
- adopts flux normalized spectra at λ5870Å
- computes all spectrum combinations → best solution + E(B-V)
- disentangles the age-metallicity degeneracy

Adopted base of 7 components
- **old (G1, G2, G3)**: 10, 13, 15 Gyr with [Z/$Z_{\odot}$]= 0.0, -0.4, -1.1 dex
- **young (Y1, Y2, Y3)**: 10, 25, 80 Myr with [Z/$Z_{\odot}$]= -0.25, -0.4, -0.5 dex
- H II region (→ SSP with 1 Myr, solar metallicity)

NGC 1052

nucleus:

age	metallicity
G1+G2+G3: 82%, ***dominate!***	G1+Y1 ($Z_{\odot}$): 68%, ***dominate!***
Y1+Y2+Y3: 17%	G2+Y2+Y3 ([Z/$Z_{\odot}$]≈ -0.4 dex): 26%
H II: ~0%	G3 ([Z/$Z_{\odot}$]≈ -1 dex): 4%

at 0.3 r_e:

age	metallicity
G1+G2+G3: 71% (disk) 80% (bulge)	G1+Y1: 49% (disk or Major axis) 65% (bulge or minor axis)
Y1+Y2+Y3: 25% (disc) 16% (bulge)	G2+Y2+Y3: 41% (disk) 26% (bulge)
H II: ~0%	G3: 6% (disk) 7% (bulge)

NGC 7796

nucleus:

age	metallicity
G1+G2+G3: 83%, ***dominate!***	G1+Y1 ($Z_{\odot}$): 58%, ***dominate!***
Y1+Y2+Y3: 14%	G2+Y2+Y3 ([Z/$Z_{\odot}$]≈ -0.4 dex): 31%
H II: ~0%	G3 ([Z/$Z_{\odot}$]≈ -1 dex): 5%

at 0.3 r_e:

age	metallicity
G1+G2+G3: 75% (Major axis) 71% (minor axis)	G1+Y1: 53% (Major axis) 54% (minor axis)
Y1+Y2+Y3: 20% (Major) 25% (minor)	G2+Y2+Y3: 34% (Major) 34% (minor)
H II: ~0%	G3: 8% (Major) 9% (minor)

Conclusions: star formation history and chemical enrichment

In the observed regions of both ellipticals, the α-enhancement is not homogeneous: there is a monothonic radial dependency in NGC 7796. The global metallicity has an outwards decreasing, while the iron abundance is nearly constant outwards. The age shows a strong spatial dispersion possibly connected to the α/Fe spread.

The stellar populations are associated with their kinematical properties: they are older and very α-enhanced in the not rotating bulge of NGC 1052 and the KDC of NGC 7796, while there is strong dispersion of α/Fe and age along the rotating disk of NGC 1052 and an outwards radial decreasing of them in NGC 7796.

Therefore, the bulk of the stars in the bulge of NGC 1052 and KDC of NGC 7796 was formed in an ancient short episode providing an efficient chemical enrichment by SN-II, while in the NGC 1052 disk and outer parts of NGC 7796 the star formation occurred later with larger temporal scales, having made the enrichment by SN-Ia important. Specifically, for NGC 7796 an inside-out formation is plausible, while a merging episode with a drawn out star formation is more acceptable for NGC 1052.

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