A UV-optical/kinematical view of galaxy evolution in the Leo cloud

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Introduction

Groups contain a large fraction (50-60%) of the galaxies in the Local Universe (e.g. Eke et al. 2004, MNRAS, 348, 866; Tago et al. 2008, A&A, 479, 927). Furthermore, the fraction of star forming galaxies in groups lies in between that of clusters (<30%) and that of the general field (>30%) counterparts. This fact suggests the presence of pre-processing mechanisms, acting on galaxies during the formation/virialization of groups, partly quenching star formation well before a groups eventually fall into a cluster (e.g. Zabludoff & Mulchay 1998, ApJ, 498, L5; Bai et al. 2010, ApJ, 713, 637 and reference therein). The impact of the pre-processing operated by the group environments is still under debate, while several mechanism, from merging to strangulation (e.g. Kawata & Mulchaey 2008, ApJ, 672, L103) have been proposed. During the group gravitational collapse, such mechanisms transform field, i.e. gas rich, mostly late-type galaxies, into cluster-like galaxies, i.e. gas poor, mostly early-type galaxies. We present here a UV-optical and kinematical analysis of two groups: USGC U268 and USGC U376 (U268 and U376 hereafter, Ramella et al. 2002, AJ, 123, 2976) located in the Leo cloud.

The sample

USGC U268 and USGC U376 map the associations 21-12+12 and 21-1+1 in the Leo cloud (Tully 88), respectively. Using the catalog of Ramella et al., 2002 (AJ, 123, 2976), U268 is composed of 10 galaxies with <V> = 1454 ± 67 kms^{-1}, an apparent average B magnitude of <B> = 14.26 ± 0.98 and ~30% of early-type galaxies (ETGs, hereafter). U376 is composed of 16 galaxies with <V> = 1110 ± 240 km^{-1}, an apparent average B magnitude of <B> =12.81 ± 1.45 and ~40% of ETGs.
We revisit the group membership using new redshift measures including possibly fainter members.

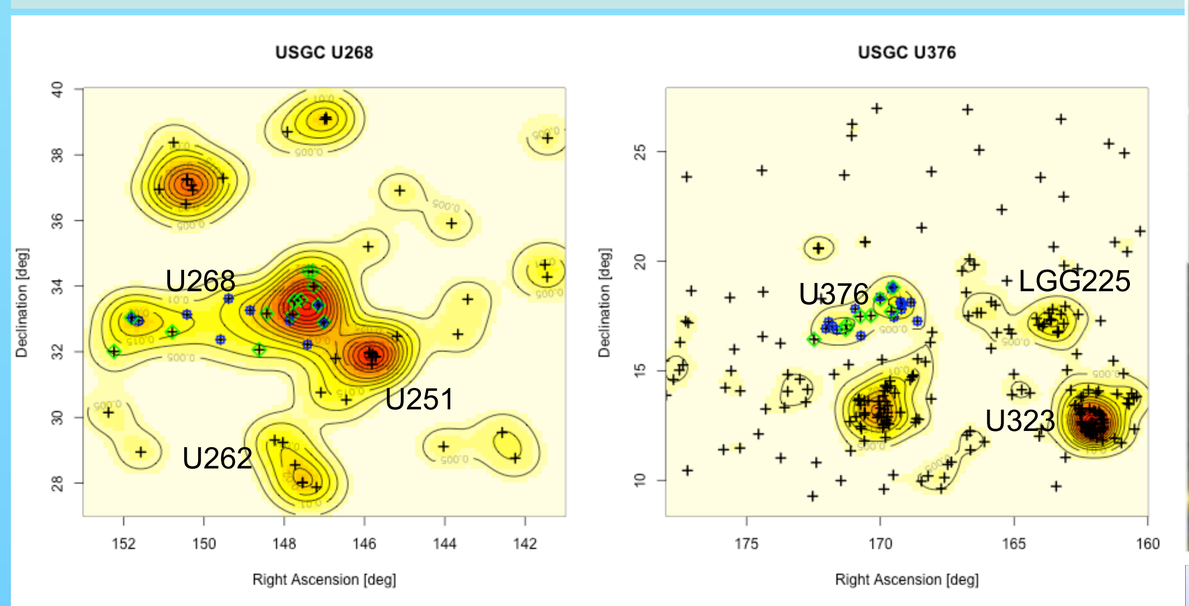

Figure 1 Spatial distribution of galaxies within a box of 4x4 Mpc centred on the brightest member of the two groups (NGC 3003 and NGC 3607, respectively). Blue symbols are the members in the catalog of Ramella et al., (2002), green ones are the candidates members we include. 2D binned kernel-smoothed number density contours are shown.

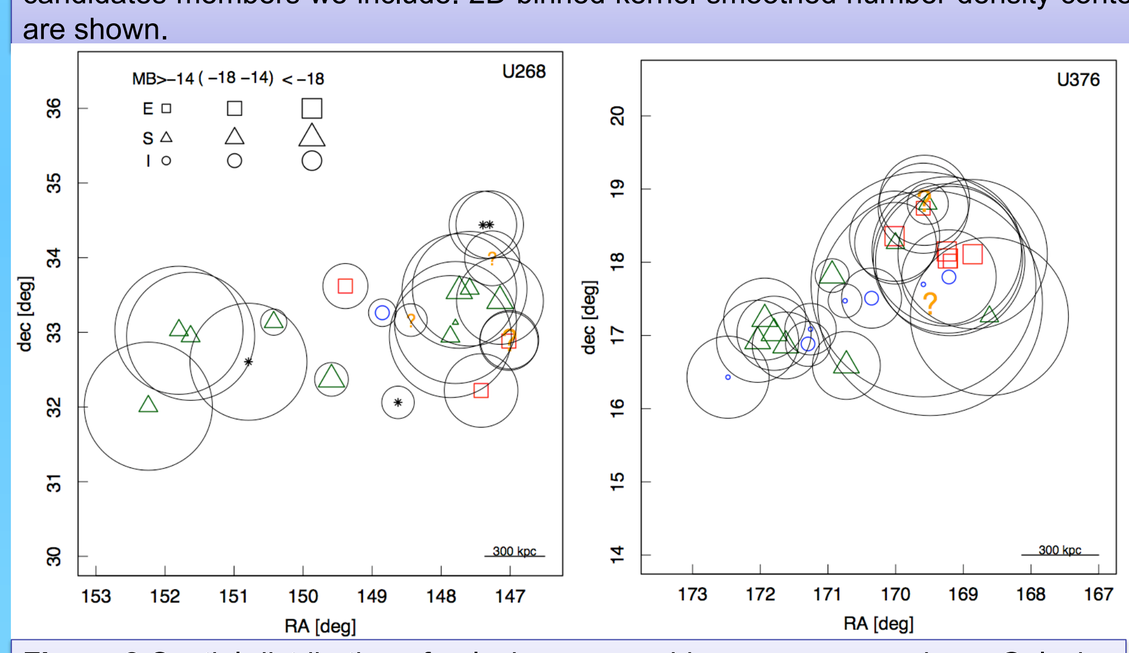

Figure 2 Spatial distribution of galaxies we consider as group members. Galaxies are separated in B magnitude bins and morphological types (unknown types with known B are labeled with ?). Asterisks show galaxies with no B magnitudes and no morphological types; the smallest circles, triangles and squares are galaxies with unknown magnitudes but available morphological types. Dressler & Shectman `bubble-plot', based on four nearest neighborhood is overlaid. The size of black circles is proportional to e^{δ} . An isolated assembly of large bubbles is indicative of a kinematically distinct subgroup.

Observations

1. UV and optical data

The UV imaging was obtained from GALEX (Martin et al. 2005, ApJ, 619, L1) GI6 and archival data in far-UV (FUV, 1344-1786 Å) and near-UV (NUV, 1771-2831 Å). The instrument has a very wide field of view (1.25° diameter) and a spatial resolution of ~4.2" and 5.3" FWHM in FUV and NUV bands respectively, sampled with 1.5x1.5 px (Morrissey et al. 2007, ApJS,173, 682). In addition, we used optical Sloan Digital Sky Survey (SDSS) archival data in five bands (*u, g, r, i,z*; Adelman et al. 2008, ApJS,175, 297).

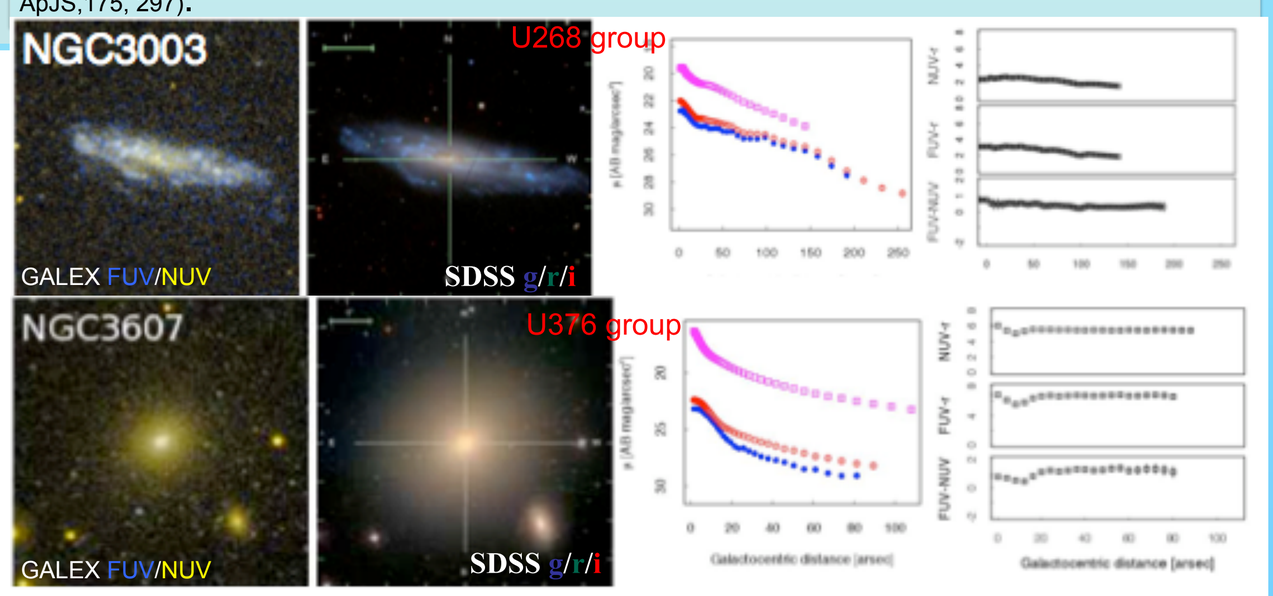

Figure 3 From left to right: color composite UV and SDSS images, UV (FUV blue, NUV red) and optical (SDSS-r magenta) surface luminosity, and color profiles, corrected by galactic extinction of the brightest galaxies in USGC U268 and USGC U376 respectively.

2. 2D kinematical observations

Observations of a subset of spirals in the two groups were done in 2011 February, at the Cassegrain focus of the 2.12m telescope at the Observatorio Astronómico Nacional in San Pedro Màrtir (México), using the scanning Perot - Fabry interferometer PUMA (Rosado et al. 1995).

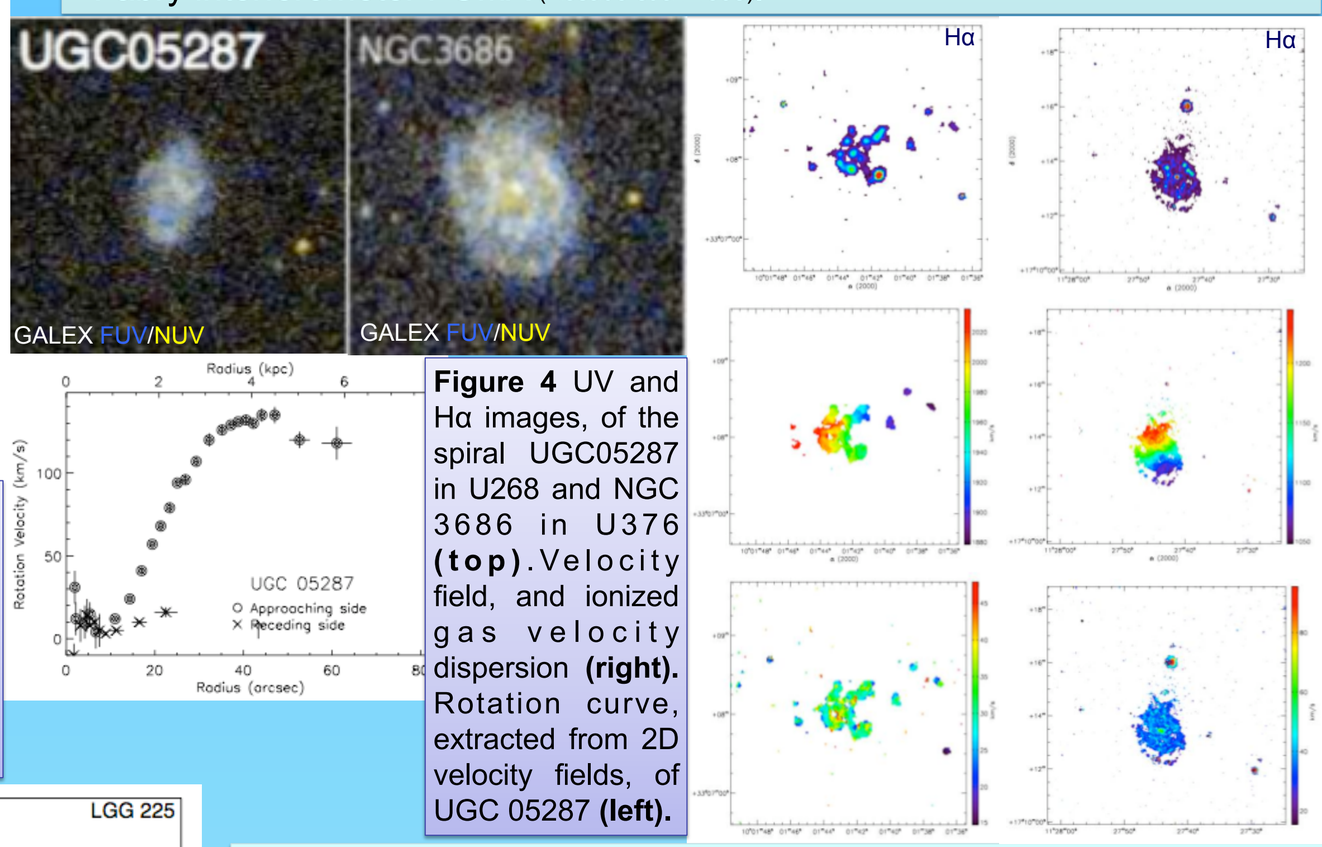

Figure 4 UV and Hα images, of the spiral UGC05287 in U268 and NGC 3686 in U376 **(top)**. Velocity field, and ionized gas velocity dispersion **(right)**. Rotation curve, extracted from 2D velocity fields, of UGC 05287 **(left)**.

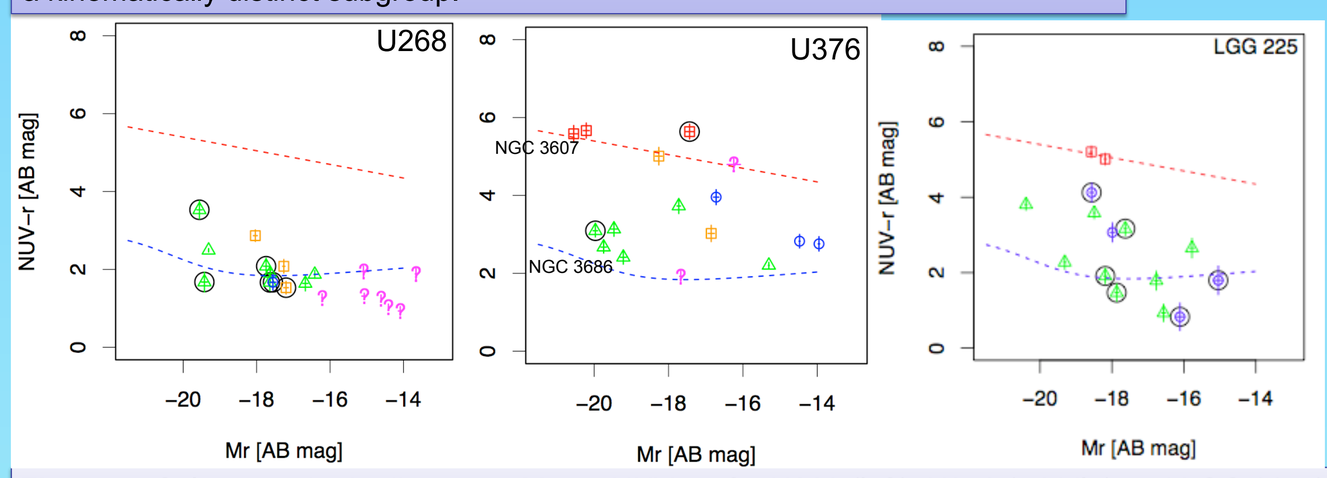

Figure 5 Color magnitude diagrams Mr vs. NUV –r for U268 (left), U376 (middle) and LGG 225 (right, Marino et al. 2010, A&A, 511, A29). We overplot the Wyder et al. 2007 (ApJS, 173,293) fits to the red and blue sequences. Triangles indicate the Spirals, squares ETGs (red ellipticals, yellow S0s), circles irregulars, ? galaxies without morphological classification. Encircled symbols indicate galaxies with interaction signatures.

Insights into group evolution

We investigate the overall properties of the 4 brightest ETGs, and of the 2 spiral galaxies in U376 with smooth particle hydrodynamic (SPH) simulations which include chemo-photometric models (Mazzei & Curir 2003, ApJ, 591, 784). These simulations are able to match the properties of the systems, i.e. their spectral energy distributions (SEDs), kinematics, morphology.

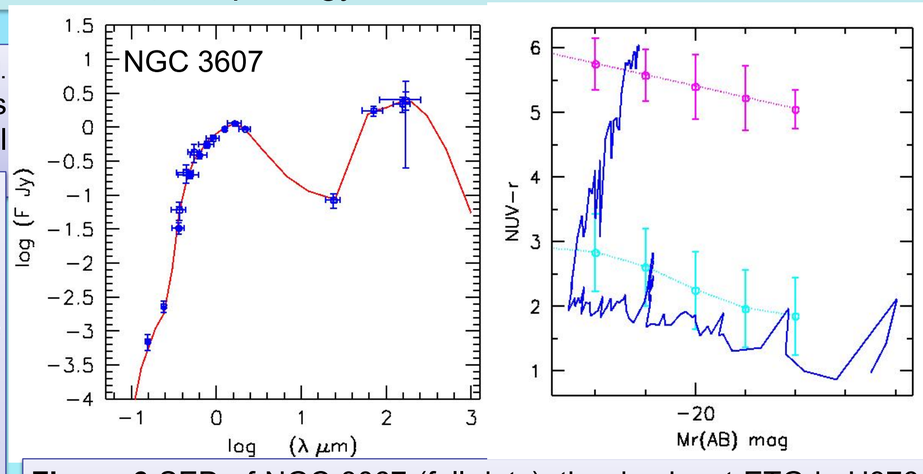

Figure 6 SED of NGC 3067 (full dots), the dominant ETG in U376, with superimposed the SPH best-fit model (red solid line, **left)**. CMD evolution of NGC 3607 (blue line) from the blue sequence to the red one predicted by the same SPH simulation: 2:1 merger with total initial mass $3x10^{12}$ $M_{\odot}$ **(right).** The derived global age of the galaxy is ~12.3 Gyr, the average age of stellar populations within 1 r_{eff} is ~3 Gyr, in well agreement with the measure from optical line strength indices (Annibali et al. 2010, A&A, 19, 40).

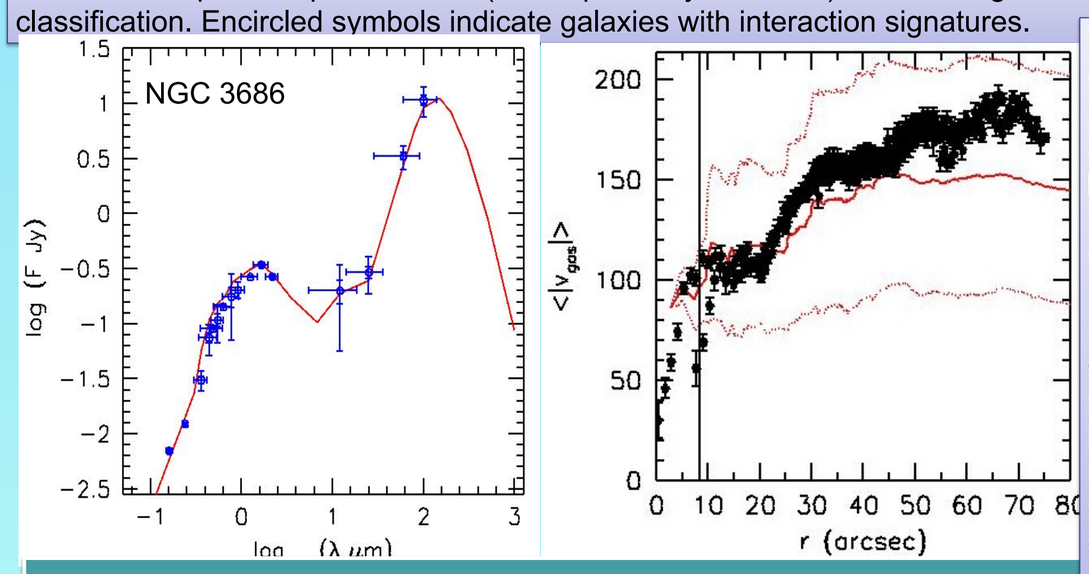

Figure 7 SED of NGC 3686 (full dots), a bright spiral in U376, and superimposed the SPH best-fit model (red solid line, **left).** The rotation curve of NGC 3686 (black dots) and the simulated one (red solid line). Dotted lines represent 1σ errors **(right)**. The age of the galaxy obtained from SPH simulations is 11.8 Gyr. The integrated B-band absolute magnitude from the SPH simulation agrees well with observed value of -19.63 (HYPERLEDA).

Conclusions

U268 and U376 appear in different evolutionary phases. The fraction of early-types is 24% in U268, comparable to field (Calvi et al. 2012 MNRAS, 419, L14) and 38% in U376. In the Mr vs. NUV –r plane, no members of U268 are found in the red sequence, yhey lie in the blue or in the green valley, including ETGs. At odds, the blue sequence of U376 is nearly un-populated with respect to U268, with the larger set of members lying in the green valley. The fraction of galaxies with distorted morphology is 42% in U376 and 70% in U268. SPH simulations well reproduce the SEDs of the 6 brightest galaxies and the rotations curves of 2 spirals in U376. Our analysis suggests that merging and/or interaction episodes drive the evolution of galaxies in the Leo cloud .

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