SDSS (g-r) colors of isolated galaxies

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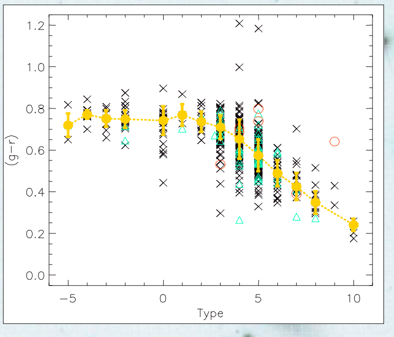
Several processes can affect a galaxy over its lifetime. If effects of interaction with companions are minimized, it is possible to focus on secular evolutionary processes. We present a study of the SDSS (g-r) colors of isolated galaxies in the AMIGA project (Analysis of the interstellar Medium of Isolated GAlaxies; http://www.amiga.iaa.es). Assuming that color is an indicator of the star formation history, this work better records the signature of passive star formation via pure secular evolution. We focused on median values for the main morphological subtypes found in the AMIGA sample (66% Sb-Sc and 14% E/S0) and compared them with equivalent measures of galaxies in denser environments. The main results of this study include: 1) a tendency for AMIGA spiral galaxies to be redder than similar type galaxies in close pairs, but 2) no clear difference when we compare with galaxies in other (e.g. group) environments; 3) a Gaussian distribution of the (g-r) color of isolated galaxies, as might be expected in the case of pure secular evolution; and 4) a smaller median absolute deviation in colors for isolated galaxies compared to both wide and close pairs.

(g–r) color as a function of morphological type



• We used the model magnitudes of SDSS-DR8 for deriving colors in our sample. A careful revision of the morphologies was performed by Sulentic et al. (2006) for the whole CIG sample based on POSS II images. We recently revised those morphologies using CCD images available either from SDSS or our own data for 843 galaxies, including those studied here.

Fig. 1. Distribution of the rest–frame (g-r) color as a function of Hubble type.

• The reddest median values of (g-r) are found for early–type galaxies (Fig. 1), although median (g-r) values remain essentially constant out to T=3 (Sb). Beginning with type Sb we see a decrease in median (g-r) as expected if this sequence reflects a uniformly decreasing contribution from an old stellar population. The objects suspected on being involved in interactions (red circles) are outside the normal trend of the median values, but the colors of the AMIGA galaxies that present asymmetries (blue triangles) agree with the colors of symmetric galaxies.

• We found a higher color dispersion for spiral subtypes in the AMIGA sample than that expected for this sample minimally affected by environmental effects, which are apparently responsible of inducing color dispersion.

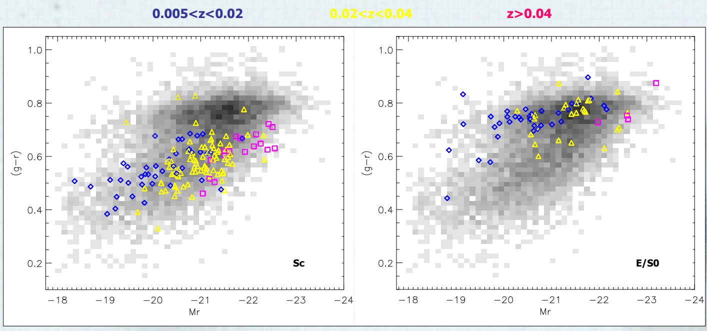


Fig. 2. (g − r) color–magnitude diagram for the Sc (left) and E/S0 (right) galaxies in the AMIGA sample.

• The color-magnitude diagram of the AMIGA sample is shown in Fig. 2, where it is compared with the Nair & Abraham (2010) . Our Sc galaxies (left) follow the blue sequence, showing that the major source of color dispersion is connected with the color-luminosity trend. We find a tendency for galaxies of fixed absolute magnitude to be (g−r) ~0.08 redder at lower recession velocities, implying that the color measures in our sample could be increasingly affected by bulge light at lower recession velocities. In the case of the AMIGA early-type (E/S0) galaxies (right), there is no color trend with recession velocity, and we notice only a slight trend between color and luminosity.

• We found little evidence for a green valley in our sample, with most spirals redder than (g−r)= 0.7 having spurious colors (~80%) caused by effects such as a star projected onto or very close to the galaxy, a high degree of asymmetry, or a high uncertainty in the extinction correction due to their high inclination.

Data and sample selection

• The AMIGA project is producing and analyzing a multiwavelength database for a refinement of the Catalog of Isolated Galaxies (CIG; Karachentseva 1973, n=1050 galaxies). A complete revision of distances, magnitudes and velocities from updated values of HyperLeda catalog has been performed with the help of scientific workflows developed in the frame of the Wf4Ever project. These data may be accessed through a Virtual Observatory compliant interface and a Conesearch VO service.

• For this work we have used a subsample of 657 AMIGA galaxies that fulfill: a) the selection criteria detailed in Verley et al. (2007b), b) Vr>1500 km/s, and c) completeness limit as decided in Verdes-Montenegro et al. (2005). These conditions imply that the evolution of all galaxies in our starting sample is dominated by their intrinsic properties. Crossmatch of this sample with the SDSS-III (Data Release 8, DR8 Aihara et al. 2011) and further cleaning lead to a final studied sample of 466 isolated galaxies.

Color dependence on environment

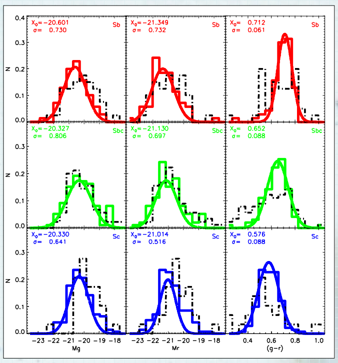
• Effects of environment in the star formation of galaxies are expected to influence their colors. In this sense, the isolated galaxies are likely to show passive star formation, and then redder colors than galaxies in denser environments.

• We have compared (g−r) median colors of AMIGA sample with - Nair & Abraham (2010) sample & EFIGI catalog (Baillard et al. 2011), both including galaxies in a wide range of environments, and - the catalog of isolated pairs (CPG, Karachentsev 1972), separated into close (CLO) and wide interacting (WID) pairs for different morphological bins (see the table below).

• While a good agreement has been found for the colors of early-type galaxies in all samples, the median values for the AMIGA sample are a slightly bluer (but within the errors) than the other samples in the range T = −5 to T = 0.

Type	T	AMIGA	NAIR	EFIGI	CPG (WID)	CPG (CLO)
E	-5	0.72±0.06	0.78±0.03	0.78±0.03	0.79±0.03	0.76±0.03
E	-4	0.77±0.02	–	0.78±0.02	0.80±0.08	0.79±0.04
E/S0	-3	0.75±0.04	0.76±0.05	0.77±0.04	0.79±0.06	0.77±0.07
S0	-2	0.75±0.04	0.76±0.04	0.76±0.04	0.78±0.06	0.77±0.06
S0	-1	–	–	0.78±0.06	0.72±0.05	0.73±0.09
S0/a	0	0.74±0.07	–	0.76±0.07	0.77±0.05	0.78±0.04
Sa	1	0.77±0.05	0.71±0.06	0.73±0.05	0.72±0.11	0.71±0.09
Sab	2	0.74±0.05	0.69±0.07	0.72±0.07	0.71±0.10	0.67±0.15
Sb	3	0.71±0.06	0.67±0.08	0.71±0.08	0.71±0.13	0.69±0.12
Sbc	4	0.65±0.09	0.61±0.08	0.66±0.07	0.63±0.12	0.59±0.14
Sc	5	0.57±0.08	0.56±0.08	0.62±0.09	0.69±0.12	0.51±0.15
Scd	6	0.49±0.06	0.46±0.07	0.58±0.09	0.55±0.11	0.51±0.17
Sd	7	0.42±0.06	0.42±0.06	0.47±0.08	0.34±0.17	0.43±0.10
Sdm	8	0.35±0.05	0.41±0.07	0.44±0.12	0.48±0.07	0.30±0.12
Sm	9	–	0.36±0.09	0.40±0.16	–	0.56±0.13
Im	10	0.24±0.03	0.33±0.10	0.29±0.09	–	0.29±0.12

• The median values of colors for the Nair & Abraham (2010) and close pair samples for the (Sb-Sc) spirals are consistent but slightly bluer than our sample. For the comparison with Nair & Abraham (2010), the differences in color may be due to their morphologies classifications used in both samples. We find their morphologies to be earlier than ours, with a mean deviation of ~1.5 for each Hubble type. The differences in color of close pairs seem to be more robust because the colors of wide pairs are as red as the colors of isolated galaxies. The scatter is also larger for the close pairs.



• Interenstingly, while the color distribution of each morphological type of AMIGA sample has a Gaussian distribution (Fig. 3), the color histogram for the close pairs of the CPG sample follows a non-Gaussian distribution. The loss of Gaussianity in the distribution of color can be interpreted as an effect of the environmental nurture that occurs in a sample of pairs.

Fig. 3. Distribution of absolute magnitudes in the g-band (left), r-band (center) and (g − r) color (right) for all Sb (top), Sbc (middle) and Sc (bottom) galaxies. The solid lines represent the AMIGA sample and the dashed lines are the distribution of the CPG.

Conclusions

- The color distributions of morphological subtypes for a sample where effects of environmental nurture have been minimized can be well described as Gaussian distributions with FWHM (g − r) =0.1–0.2. Indeed, this Gaussianity was not observed in the sample of galaxy pairs.
- The median value of (g−r) for Sb-Sc galaxies seems to be bluer when interactions exist. Nevertheless, no difference was found in the (g−r) color of early-type galaxies, which suggests that the bluer color of spirals in pairs is presumably due to interaction enhanced star formation.
-We found little evidence for a green valley in our sample, with most spirals redder than (g−r)= 0.7 having spurious colors (~80%).
- Our sample of isolated galaxies show a lower median absolute deviation in color than that in pairs of galaxies, where a more active star formation and, perhaps, a higher dust diffusion caused by the interaction, are also sources of color dispersion. The mean colors and dispersions for isolated galaxy subtypes (especially E/S0 and Sb-Sc) are likely the best nurture–free measures obtained so far.

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