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Recovering isolated galaxies from large scale surveys: problems and strategies

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Abstract. The large survey programs being performed nowadays, being the SDSS their flagship, provide us with morphological parameters which allow for extraction of large galaxy samples. We will analyze the methodology for obtaining an AMIGA-like catalogue of isolated galaxies from the SDSS DR5 photometric catalogue of galaxy objects, together with the roadblocks found in the process, and suggested workarounds.

1. Introduction

The Catalogue of Isolated Galaxies (CIG) by Karachentseva (1973), basis for the AMIGA sample (Verdes-Montenegro et al. 2005), was compiled using a visual search on photographic plates. In the era of the Virtual Observatory and large surveys, however, the automated compilation of isolated galaxy samples not only becomes feasible, but potentially less biased and error prone.

There are previous examples of automatic extraction of isolated galaxy samples in the literature, some of them mimicking Karachentseva's criterion, as is the case of Allam et al. (2005). The search of compact groups uses similar constraints, and a recent example of automated extraction of them in galaxy catalogues is shown by McConnachie et al. (2009).

With automatically extracted samples, combined with the extra parameters derived by the SDSS pipeline, it is possible to estimate the degree of isolation of the selected galaxies, using for instance the tidal forces or local density estimations characterised in Verley et al. (2007a,b). Additionally, we gain the ability to re-do the studies, and apply them to similar catalogues in the southern hemisphere, so that an all-sky sample of isolated galaxies can be finally assembled. In this proceeding we will focus on the automatic extraction of a CIG (or AMIGA) like sample of isolated galaxies.

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2.   Implementing Karachentseva's isolation criterion on the SDSS

A galaxy i, with angular diameter D_i is considered isolated, following Karachentseva's criterion, if the projected distance between it and neighbor j, P_{ij}, verifies

$$P_{ij} \geq 20 \times D_j \tag{1}$$

for all j galaxies with diameter D_j, also verifying

$$\frac{1}{4}D_i \leq D_j \leq 4 \times D_i \tag{2}$$

Allam et al. (2005) reformulates eq. 2, changing it for a relative magnitude difference comparison:

$$|g_i - g_j| > 3.0 \tag{3}$$

where g_i is the g magnitude of galaxy i; both approaches are equivalent assuming constant surface brightness profiles. We tried both approximations in our testing.

As the SDSS spectrometric catalogue is known to be complete only up to Petrosian magnitude r brighter than 17.7 (Adelman-McCarthy et al. 2007), we will make use of the SDSS photometric catalogue of objects identified as galaxies. We targeted SDSS DR5, but as the SDSS table schemata for DR7 have only added columns to specify clean objects, our procedure is valid also for SDSS DR7.

Using CasJobs, we selected objects from the `PhotoObj` table view with `type = 3` (Galaxy), and g magnitudes between 10 and 15. For convenience during the testing, we applied a RA/Dec cut:

$$206.6 < \quad \text{RA} < \quad 228.5$$
$$31.4 < \quad \text{Dec} < \quad 35.5$$

which gave us a test field containing around 98000 objects, with 2 CIG galaxies (CIG 613 & CIG 642) among them.

After downloading the test field data, a Python script was run to check galaxy isolation, marking galaxy i as not isolated if any galaxy within 80 times D_i in the test frame (the maximum relevant distance, giving the size comparison) which verified eq. 2 did not verify eq. 1. A second script used eqs. 3 and 1 instead.

The two approaches resulted to be largely equivalent, but the results gave a lot more allegedly isolated galaxies than the two CIGs. If the factor of 20 in eq. 1 was increased, the results provided none of the two CIGs, and retained some objects in the center which did not appear to be isolated galaxies, plus objects along the frame border (an artifact of the reduced sample).

3.   Problems found and strategies to avoid them

In order to understand why the two CIGs in the test frame could not be recovered as isolated, we checked visually the frame and found several problems, mainly the misclassification of stars as galaxies, and item blending.
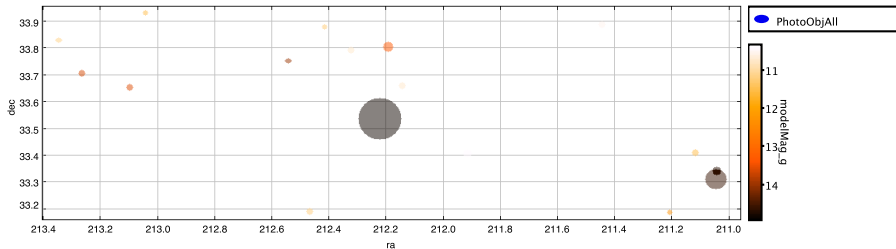
Figure 1.　Object positions, radii, and magnitudes for in subset of the test field around CIG 613 (center object). Magnitude is shown in the color scale (darker is less bright), while radii are proportional to the Petrosian radius for each object.

As we intend to recover a catalogue of truly isolated galaxies, without resorting to visual inspection but at the latest stage, we need to find a way to objectively distinguish stars which have been misclassified as galaxies by the original SDSS pipeline[1].

Figure 1 shows how CIG 613 (the central, largest dark circle) is bigger than the surrounding objects, but less bright than most companion objects, which exhibit a much higher surface brightness. This shows that there are parameters, or combinations of parameters, helpful to objectively improve SDSS' star-galaxy separation. In fact, such kind of star-galaxy separation had already been independently performed by Collister et al. (2007), disregarding SDSS `type` entirely, based also on additional information from the SDSS photometric catalogue itself. However, their star-galaxy separation algorithm includes photometric redshift estimation, which is not reliable in the the local universe, due to the strong influence of peculiar velocities.

Of the large number of columns available for `PhotoObj`[2], several provide information about the reliability of the SDSS pipeline's star/galaxy separation, such as `probPSF`, `lnLStar`, plus other parameters such as `lnLExp` , `lnLDeV`, and many others. However, many of them showed binary, non-continuous values, and where not useful for building a separation. The most promising single parameter, able by itself to perform an effective separation, is `lnLStar_g`. The lowest absolute value of `lnLStar_g` for a CIG galaxy was higher than 29100 (for CIG 299), with the rest of CIG's having $abs($`lnLStar_g`$)$ above 40000.

This is shown in figure 2, where we plot the normalized distribution of $abs($`lnLStar_g`$)$ values across the SDSS DR5 galaxies of our test field (red line), and the CIG galaxies with SDSS DR5 counterpart (green). For comparison, we have plotted also the histogram for SDSS star objects (`type = 6`; in green), and

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[1]The original SDSS photometric star-galaxy separation is done using the difference between modeled profiles (linear combination of the best-fitting De Vaucouleurs and exponential profiles) and PSF model magnitudes.

[2] `http://cas.sdss.org/dr5/en/help/browser/description.asp?n=PhotoObj&t=V` In particular, `probPSF` is the probability of the object being a star; `lnLStar` is the ln of star fitting likelihood; `lnLExp` and `lnLDeV` are the ln of the likelihood for the object fitting an exponential disk or a De Vaucouleurs profile. These parameters are available for each *ugriz* color.
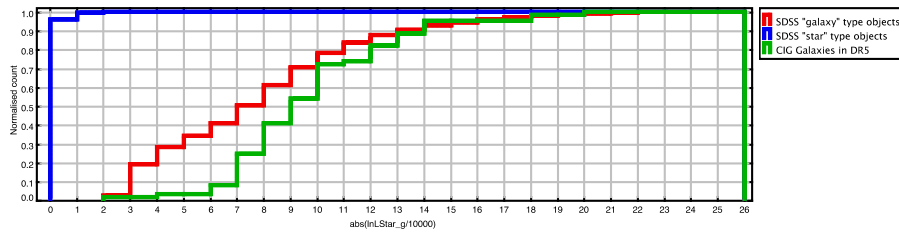
Figure 2.   Normalized cumulative frequency histogram for the absolute value of `lnLStar_g`, both for SDSS galaxies with $10 \leq mag_g \leq 15$ (red), CIG galaxies with SDSS DR5 counterparts (green), and SDSS stars with the same magnitude cut (blue).

we can see that the absolute value of `lnLStar_g` is below 10000 for more than 95% of star objects.

4.   Conclusions and Future Work

We have seen that in order to use the SDSS Photometric catalogue for retrieving galaxy properties, and estimate their isolation degree, the basic star-galaxy separation provided by the SDSS pipeline is not enough, and more work is needed in order to be able to obtain meaningful results regarding the isolation of galaxies.

The analysis of available parameters, however, has shown to be promising in achieving a more accurate star-galaxy separation which, combined with data mining and clustering tools, may finally allow a reuse of SDSS photometric data for this kind of studies.

In the future, we will continue pursuing an automated isolated galaxy sample builder system, using data mining techniques in order to find out the parameters with the best star-galaxy separation properties, and be able to extend the selection of isolated galaxies to similar catalogues in the future.

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