Characterisation of an Isolated Galaxy Sample: Astrophysical Implications

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 Which properties are due to internal secular evolution and which to external influences

 Reference sample with minimum influence from the environment

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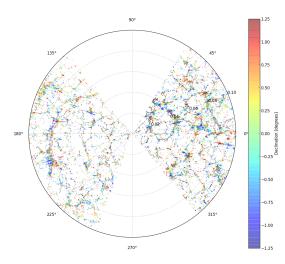
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Kent 2013, S. Duarte Puertas & E. Ramos Carmona]

http://www.blender.org

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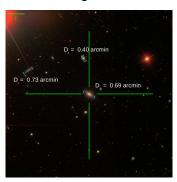
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- Analysis of the interstellar Medium of Isolated GAlaxies
- Catalogue of Isolated Galaxies [CIG, Karachentseva 1973]



1050 CIG galaxies 2D isolation criterion:

$$\bullet \ \frac{1}{4} D_P \le D_i \le 4 D_P$$

•
$$R_{iP} \leq 20 D_i$$

No similar-size galaxies in their close environments

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Refinement of the sample

- Positions [Leon & Verdes-Montenegro 2003]
- Redshift and distances [Verdes-Montenegro et al. 2005]
- Morphologies [Sulentic et al. 2006]
- Isolation degree [Verley et al. 2007b,c]

Multiwavelength characterisation of the ISM

- Optical [Sulentic et al. 2006, Durbala et al. 2008, 2009, Sabater et al. 2008, 2012, Fernández Lorenzo et al. 2012, 2013]
- Hα [Verley et al. 2007a]
- Near & far infrared [Lisenfeld et al. 2007]
- Radiocontinuum [Leon et al. 2008]
- Atomic gas [Espada et al. 2005, 2011]
- Molecular gas [Lisenfeld et al. 2012]
- Public database

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The SDSS

[York et al. 2000

http://www.sdss3.org



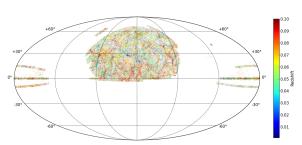
2.5 m Telescope [Gunn et al. 2006]

Apache Point Observatory, New Mexico

SDSS-DR9 [Eisenstein et al. 2011]

Photometry: 208,478,448 galaxies

Spectroscopy: 952,740 galaxies



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Projected density to the kth nearest neighbour:

[Verley et al. 2007b.c, Sabater et al. 2013, Argudo-Fernández et al. 2013a]

$$\eta_k \propto \log\left(\frac{k-1}{V(r_k)}\right)$$

$$V(r_k) = \frac{4}{3}\pi r_k^3$$

Tidal strength (estimation of gravitational interaction):

$$Q_{iP} \equiv \frac{F_{\text{tidal}}}{F_{\text{bind}}}$$

$$\log Q_{iP} \propto 0.4 \left(m_r^P - m_r^i\right) + 3 \log \left(\frac{D_P}{R_{iP}}\right)$$

and
$$Q = \log(\sum_i Q_{iP})$$

Data and methodology

The **main aims** of this thesis are:

to refine the photographic-based CIG and to provide an improvement of the quantification of the isolation degree with respect to previous works. using both photometry and spectroscopy;

to identify and quantify the effects of the physical satellite distribution around galaxies in the CIG, as well as the effects of the Large Scale Structure (LSS):

to construct a catalogue of galaxies isolated in 3-dimension, and build catalogues of physically associated isolated pairs and isolated triplets.

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Methodology: photometry

[Argudo-Fernández et al. 2013a

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CIG galaxies in the SDSS



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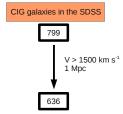
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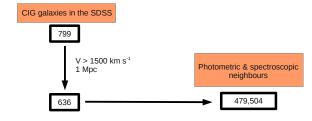
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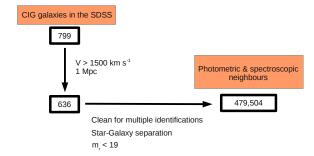
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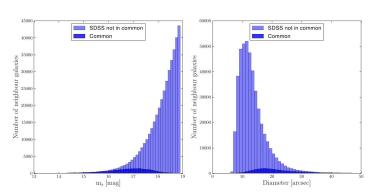
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• Fainter & smaller neighbours



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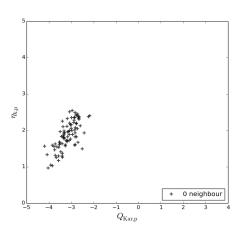
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- 636 CIG galaxies in the photometric SDSS
- 86 CIG galaxies pass the CIG isolation criterion



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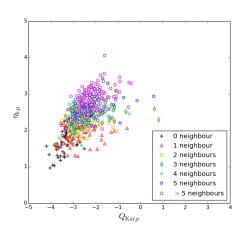
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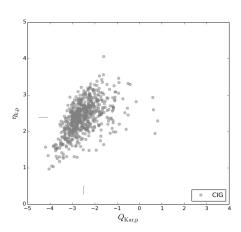
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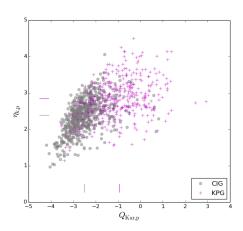
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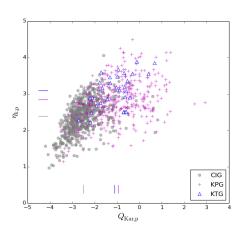
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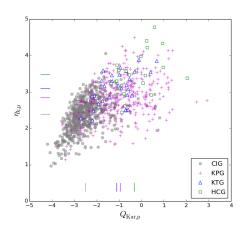
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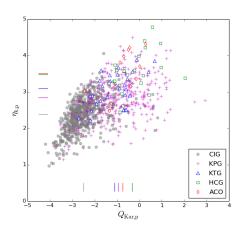
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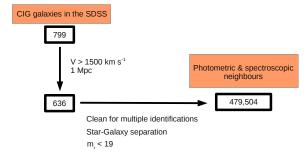
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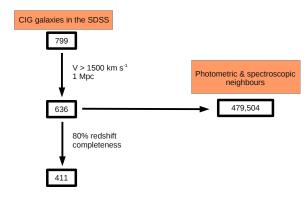
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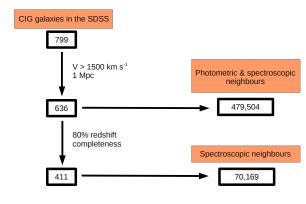
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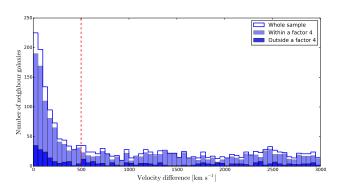


Spectroscopic isolation criterion

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- 411 CIG galaxies in the spectroscopic SDSS
- 347 CIG galaxies pass the CIG isolation criterion
- 105 CIG galaxies pass ∆v ≤ 500 km s⁻¹
- ullet 50% of the companions by the CIG isolation criterion show very high Δv
- 92% of similar Δv are not considered as companions



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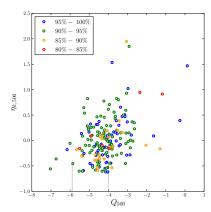
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Spectroscopic isolation parameters

- Correction for redshift incompleteness
- More than 80% of neighbours have spectroscopic redshifts
- Photometric redshifts up to 20% of neighbours



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- Fainter & smaller neighbours
- Nearby dwarf galaxies not taken into account by the CIG isolation criterion
- 50% of the companions by the CIG isolation criterion are **background galaxies** showing very high Δv
- 92% of similar Δv are not considered as companions

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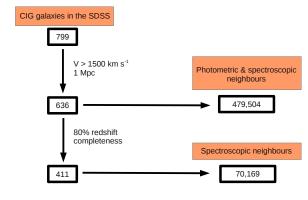
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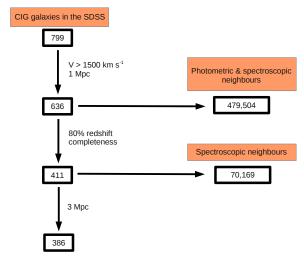
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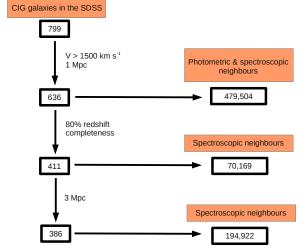
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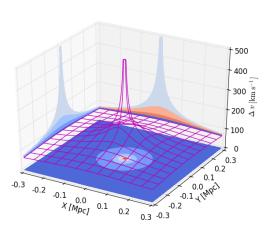
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$$v_{\rm esc} = \sqrt{\frac{2GM_P}{R_{iP}}}$$



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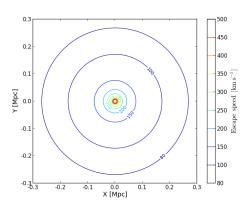
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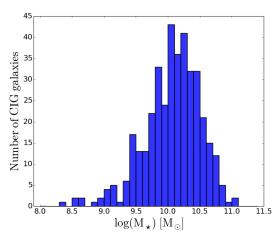
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 Derived optical parameters on SDSS g-, r-, and i-images using SExtractor [Bertin & Arnouts 1996]

 K correction rest-frame magnitudes and stellar masses [Blanton et al. 2007]



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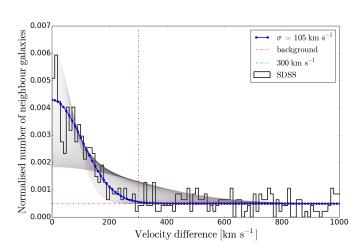
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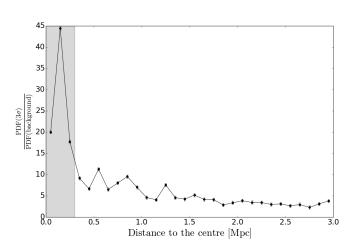
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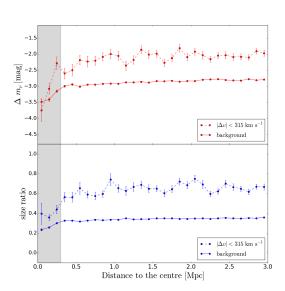
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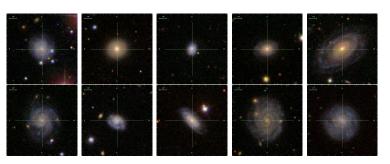
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Physical satellites

Isolation criterion

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- 386 CIG galaxies
- 37 CIG galaxies (10% of the sample) with physically bound satellites
- 10 most isolated (no neighbours within 3 Mpc):



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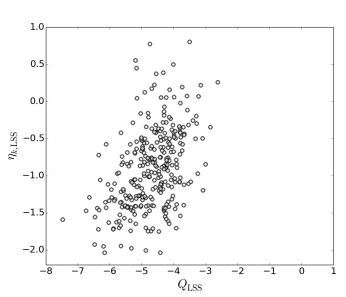
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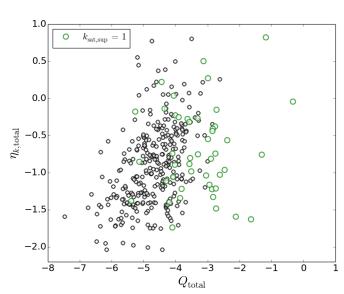
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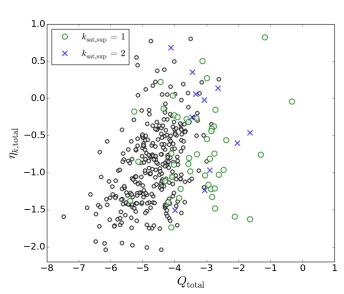
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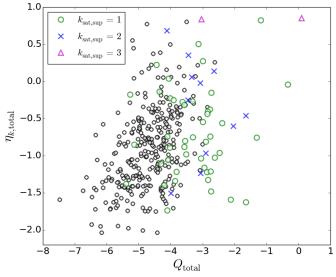
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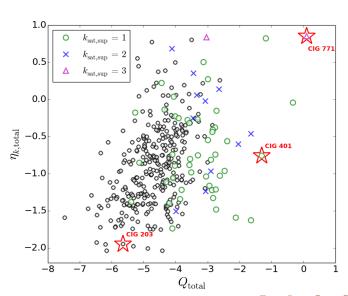
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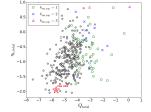
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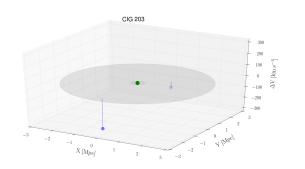


Influence of the environment







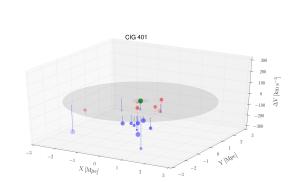




Influence of the environment

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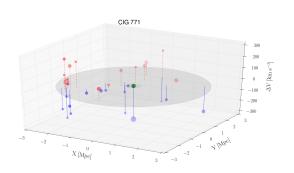
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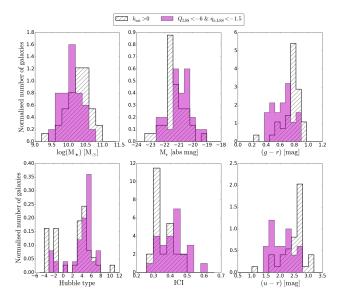
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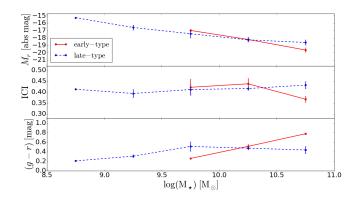
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- 10% of the sample have physically bound satellites
- 90% of the sample have no physically bound satellites but may suffer interactions with fly-by galaxies
- CIG galaxies show continuous degree of connection with the LSS
- Clear segregation between younger and older systems, confirmed by the nature of the physically associated galaxies

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Primary galaxies 11 < m < 15.7 0.005 < z < 0.080 80% z completeness

34 127

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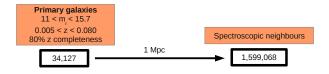
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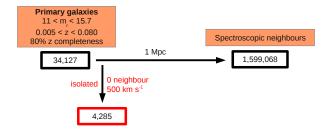
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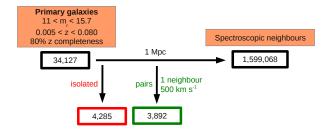
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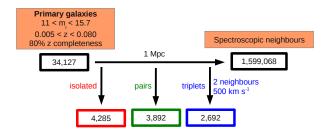
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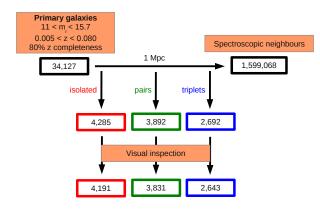
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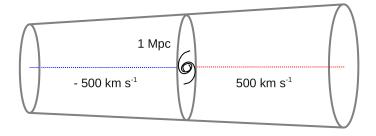
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Physical definition of isolated galaxies

- \bullet Field radius of 1 Mpc: crossing time $\sim~5.2\,\mbox{Gyr}$
- $\Delta v \leq 500 \, \mathrm{km \, s^{-1}}$ to avoid physical associations
- 4,191 isolated galaxies



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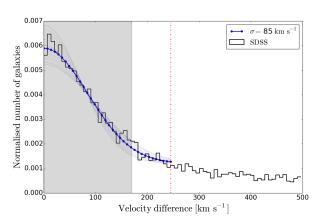
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- Gaussian distribution $\sigma = 85 \, \mathrm{km \, s^{-1}}$
- Pairs & triplets: $\Delta v \le 170 \, \text{km s}^{-1} \, \& \, d \le 450 \, \text{kpc}$
- Close pairs & triplets: $\Delta v \le 170 \,\mathrm{km \, s^{-1}} \, \& \, d \le 160 \,\mathrm{kpc}$



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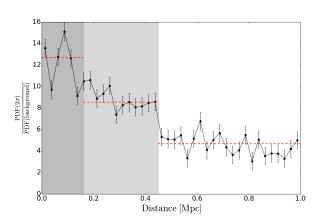
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- Gaussian distribution $\sigma = 85 \, \mathrm{km} \, \mathrm{s}^{-1}$
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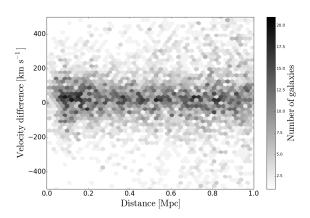
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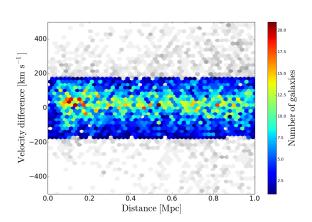
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- Pairs & triplets: $\Delta v \le 170 \, \text{km s}^{-1} \, \& \, d \le 450 \, \text{kpc}$
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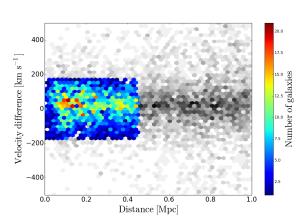
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- Pairs & triplets: $\Delta v \le 170 \, \text{km s}^{-1} \, \& \, d \le 450 \, \text{kpc}$

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• Close pairs & triplets: $\Delta v \leq 170 \,\mathrm{km}\,\mathrm{s}^{-1}$ & $d \leq 160 \,\mathrm{kpc}$



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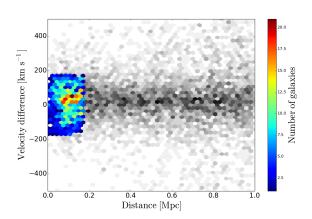
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- Pairs & triplets: $\Delta v \le 170 \, \text{km s}^{-1} \, \& \, d \le 450 \, \text{kpc}$
- Close pairs & triplets: $\Delta v \le 170 \,\mathrm{km \, s^{-1}} \, \& \, d \le 160 \,\mathrm{kpc}$



Redshift distributions

- 4,191 isolated galaxies
- 1,270 isolated pairs
- 300 isolated triplets

30

Normalised number of galaxies

10

0.00

0.01

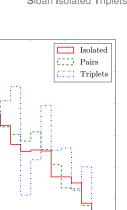
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0.03

Sloan Isolated Galaxies (SIG)

Sloan Isolated Pairs (SIP)

Sloan Isolated Triplets (SIT)



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Catalogues

0.04 0.05 0.06 0.07 0.08 Redshift

nar

- 4,191 isolated galaxies
- 494 isolated pairs
- 45 isolated triplets

Sloan Isolated Galaxies (SIG)

Sloan Isolated Pairs (SIP)

Sloan Isolated Triplets (SIT)



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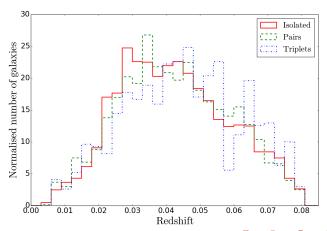
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- 801 isolated galaxies
- 217 isolated pairs
- 16 isolated triplets

Sloan Isolated Galaxies (SIG)

Sloan Isolated Pairs (SIP)

Sloan Isolated Triplets (SIT)



solation of the CIC galaxies

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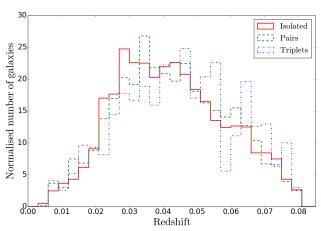
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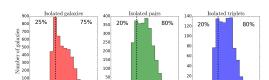
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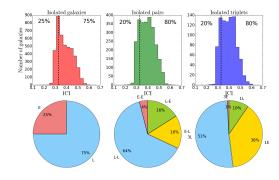
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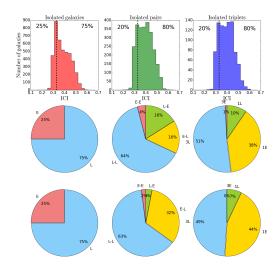
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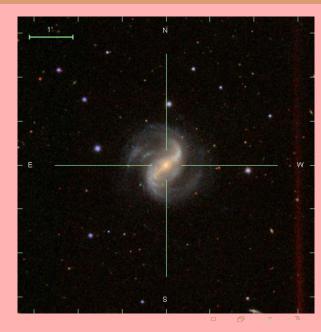
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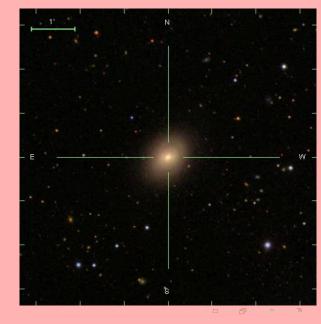
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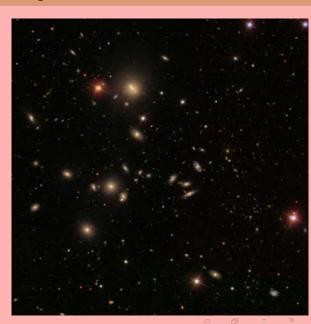
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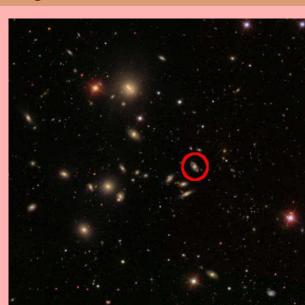




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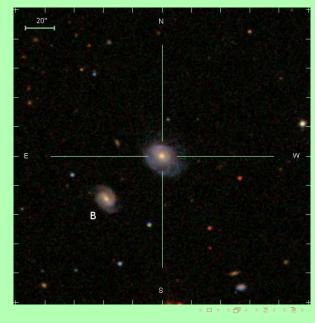
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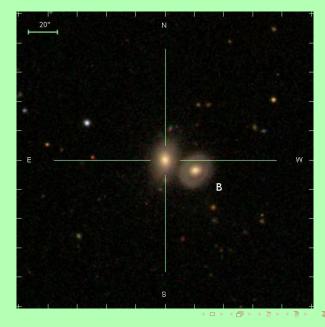
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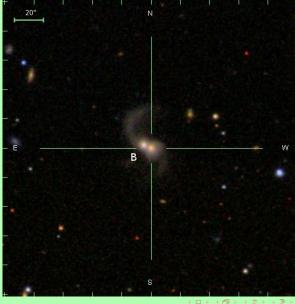
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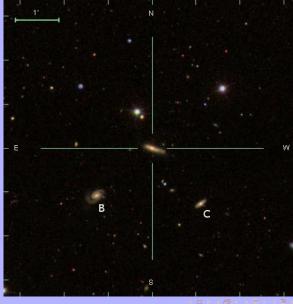
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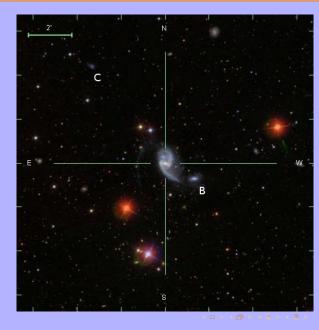
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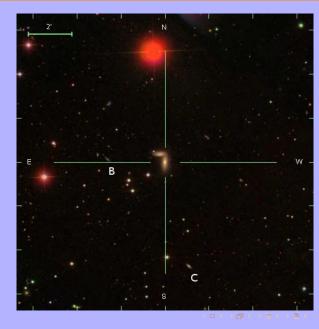
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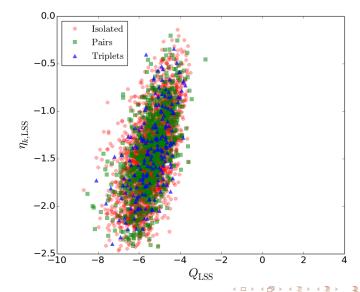
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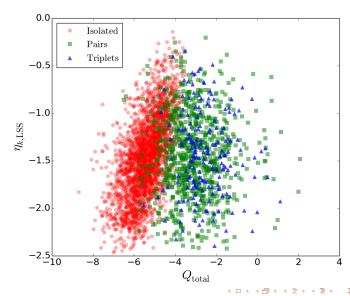
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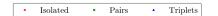
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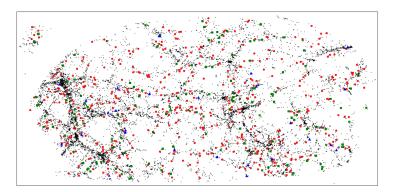
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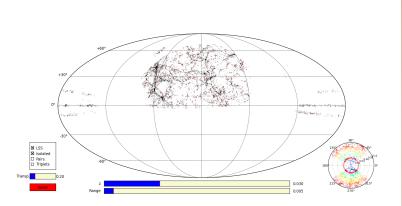


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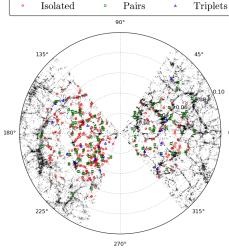
Wedge diagram



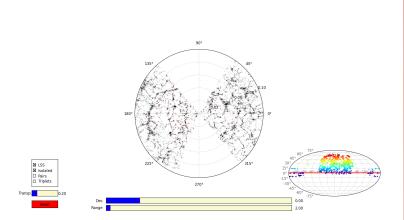


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S. Duarte Puertas & F. Bamos Carmona



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[Vanderplas et al. 2012, Ivezic et al. 2013]

 $-1.25^{\circ} < \delta < 1.25^{\circ}$



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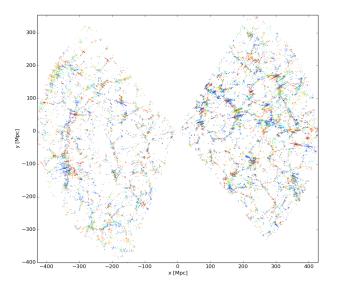
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CONCIDENCE



[Vanderplas et al. 2012, Ivezic et al. 2013]

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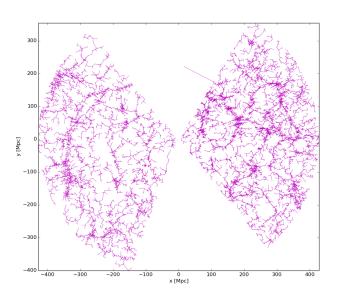
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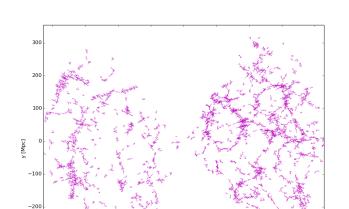




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-300

-400

-300

-200

-100

100

x [Mpc]

200

300

400

hreshold 2.9 Mpc

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[Vanderplas et al. 2012, Ivezic et al. 2013]



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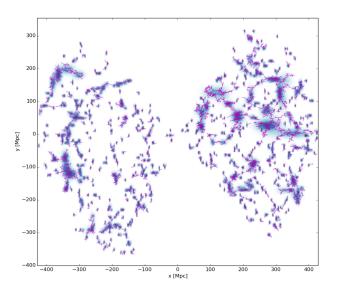
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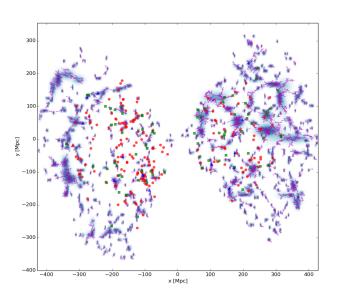
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Belation to the LSS

- SIG catalogue: 4,191 isolated galaxies which represent about 12% of the considered galaxies in the local Universe
- SIP catalogue: 1,270 isolated pairs which represent about 7% of the considered galaxies in the local Universe.
- SIT catalogue: 300 isolated triplets which represent about 3% of the considered galaxies in the local Universe
- Generally differ from the void population of galaxies
- Most of the isolated galaxies, isolated pairs, and isolated triplets, belong to the outer parts of filaments, walls, and clusters

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Summary

To understand the **role of the environment in the formation and evolution of galaxies** it is necessary to have a reference sample where the effects of the environment are minimised and quantified.

- Revision of the isolation of the CIG galaxies
- Effects of the environment on the CIG galaxies
- Isolated galaxies, isolated pairs, and isolated triplets

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- Revision of the isolation of the CIG galaxies
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Summary

To understand the **role of the environment in the formation and evolution of galaxies** it is necessary to have a reference sample where the effects of the environment are minimised and quantified.

- Revision of the isolation of the CIG galaxies
- Effects of the environment on the CIG galaxies
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Summary

To understand the **role of the environment in the formation and evolution of galaxies** it is necessary to have a reference sample where the effects of the environment are minimised and quantified.

- Revision of the isolation of the CIG galaxies
- Effects of the environment on the CIG galaxies
- Isolated galaxies, isolated pairs, and isolated triplets

November 8th, 2013

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In the first part of this thesis work, we aim to **refine the photographic-based CIG** and to provide an improvement of the quantification of the isolation degree with respect to previous works, **using both photometry and spectroscopy from the SDSS-DR9**. Our main conclusions are the following:

- The availability of the spectroscopic data allows us to check the validity of the CIG isolation criterion within a field radius of 1 Mpc, and we conclude that it is not fully efficient.
- About 50% of the neighbours considered as potential companions in the photometric study are in fact background objects.
- On the other hand, we also find that about 92% of neighbour galaxies that show recession velocities similar to the corresponding CIG galaxy are not considered by the CIG isolation criterion as potential companions.
- These neighbours are most likely dwarf systems which may have a considerable influence on the evolution of the central CIG galaxy.

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In the second part of this thesis work we identify and quantify the **effects of the physical satellite distribution** around galaxies in the CIG, as well as the effects of the **Large Scale Structure (LSS)**. Our main findings are the following:

- The CIG galaxies are distributed following the LSS of the local Universe, although presenting a large heterogeneity in their degree of connection with it, from galaxies with physically bound satellites (10% of the sample) to galaxies without neighbours in the first 3 Mpc around them.
- Isolated galaxies are in general bluer, with likely younger stellar populations with respect to older, redder CIG galaxies with physical satellites. Reciprocally, the satellites are redder and with older stellar populations around massive early-type CIG galaxies, while they have a younger stellar content around massive late-type CIG galaxies.
- There is a clear segregation between younger and older systems, confirmed by the nature of the physically bound galaxies.

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In light of the above findings, we use spectroscopic data from the SDSS to automatically and homogeneously compile catalogues of 4,191 isolated galaxies, 1,270 isolated pairs, and 300 isolated triplets in the local Universe ($z \le 0.080$) without being biased by projected neighbours. Our main results are the following:

- Most of the isolated galaxies, isolated pairs, and isolated triplets, belong to the outer parts of filaments, walls, and clusters, and generally differ from the void population of galaxies.
- The physical companions in pairs and triplets play a prevailing role in the tidal strengths Q_{pair} and Q_{triplet} exerted on the primary galaxies. This local tidal strength due to the physical companions is two orders of magnitude higher than the tidal strength due to the LSS.
- We find no difference in their degree of interaction with the LSS, which may suggest that they have a common origin in their formation and evolution.

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