In the search for an optimal compact groups finder

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Monday 24th June, 2019
FRIENDS OF FRIENDS MEETING
MARCH 30TH - APRIL 3RD, 2020
CÓRDOBA, ARGENTINA

Invited Speakers
Stefano Borgani (INAF, Italy)
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Gian Luigi Granato (INAF, Italy)
Gabriela de Lucia (INAF, Italy)
Guillermo Bosch (UNLP, Argentina)
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Ornela Marioni
Gabriel Oio
Walter Weidmann
Dante Paz

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Sofía Cora (IALP, Argentina)
Nelson Padilla (PUC, Chile)
Ariel Sanchez (MPE, Germany)
Hernán Muriel (IAFE - Argentina)
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Compact Groups of Galaxies

Highly dense galaxy systems that contain their brightest galaxies within a small isolated region.

Figure: First Compact Groups Identified. Left: Stephan's Quintet (1877) - Right: Seyfert's Sextet (1948)
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Identification Criteria of CGs

Hickson criteria:

Population: $4 \leq N \leq 10; (m - m_b \leq 3)$

Compactness: $\mu \leq \mu_{\text{lim}}$

Isolation: $\Theta_n > 3 \Theta_G; (m - m_b \leq 3)$
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Candidates in projection

$\implies$ Redshift is only used to reject interlopers
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Candidates in projection

FoF criteria:

Friends-of-Friends algorithm

Compactness criterion
Over the years, several authors have identified CGs on different galaxy catalogs replicating the original criteria by Hickson or using the percolation algorithm Friends-of-Friends.


**Mock catalogs:** Díaz-Giménez & Mamon 2010; Díaz-Giménez et al. 2012, 2018; McConnachie et al. 2008.
Catalogues of CGs

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**Mock catalogs:** Díaz-Giménez & Mamon 2010; Díaz-Giménez et al. 2012, 2018; McConnachie et al. 2008.

- Different surveys (apparent magnitude limit, coverage sky)
- Different bands (R, r, Ks, u)
- Different criteria (Hickson-like, FoF-like)
- With or without spectroscopic information

Due to this, comparing compact group samples is a difficult task.
Criteria Problems

Completeness: Are there groups that cannot be identified?
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50–70% CGs are physically dense groups. The percentage of chance alignment in the CG catalogs depends on the photometric band that is been used.

(McConnachie et al. [2008], Díaz-Giménez & Mamon [2010], Díaz-Giménez et al. [2012], Díaz-Giménez & Zandivarez [2015], Taverna et al. [2016])
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Completeness: √

Purity: ×
Motivation

Criteria affected by observational properties

Can we build a criteria free of observational biases?
Criteria affected by observational properties

Can we build a criteria free of observational biases?

Low % Real CGs → CGs samples highly contaminated by chance alignments

Can we improve the purity of the catalogs of CGs?
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The aim of this work is to develop an independent algorithm able to identify isolated physically dense CGs, free from observational biases.

Goal

Maximize the % of real groups in the observational catalogs.
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**3D CG_m:** Ideal sample
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**Goal**
Maximize the % of real groups in the observational catalogs.

**Objectives**

3D \( CG_m \): Ideal sample

**HMCG**: Observable sample

**Box Simulation**

3D Criteria (Box)

CGs in real space

Mock Catalog

Hickson Criteria

CGs in redshift space

3D \( CG_m \)

CGs in redshift space

HMCG

\( m_i \leq m_{lim} \)
New 3-D Criteria for identifying CGs

With the aim of preserving the original idea of Hickson, we kept the main features of the classical criteria (Hickson, 1982): compactness, population and isolation.

Criteria:

- **Compactness**: Friends-of-Friends (FoF) algorithm in real space (Davis et al, 1985). We adopted a high over-density contrast limit to ensure the compactness of our groups,

  \[ \frac{\delta \rho}{\rho} \geq 1000 \]

- **Population**: only groups having 4 or more members,

  \[ N \geq 4 \]

How many selected groups are isolated?

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New 3-D Criteria for identifying CGs

- **Isolation I**: we selected only the HDGs that are not substructures of loose groups.

- **Isolation II**: we selected those groups that inside of $3 \times R_{\text{vir}}$ there not exist other galaxies (number density profile)
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**Isolation II:** we selected those groups that inside of $3 \times R_{\text{vir}}$ there not exist other galaxies (number density profile)

The final real compact groups in 3-D are those groups that also fulfill the previous criterion, and we named them as CGs.
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Compact groups selection

Tools:

- Numerical simulation: Millennium I [Springel et al., 2005]

- Semi-analytical models of galaxy formation (SAMs):
  - Guo11 [Guo et al., 2011]
  - Guo13 [Guo et al., 2013]
  - Hen15 [Henriques et al., 2015]
Compact groups selection

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We built a super box of twice the size of the simulation box \((2 \times L_{\text{box}} \sim 1000 \text{Mpc}/h)\) to reach in the future the redshift depth of the SDSS observational catalog.
We apply 3D Algorithm to a superbox \((L_{\text{box}} \sim 1000\text{Mpc})\)

- FoF identification with \(\frac{\delta \rho}{\rho} \geq 1000\)
- \(N \geq 4\)
- Are not a substructure of other loose groups
- Isolated system

Catalog of CGs
Compact groups selection: 3D $CG_m$

We apply 3D Algorithm to a superbox ($L_{box} \sim 1000 Mpc$)

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Catalog of CGs in real space

Using the 3D catalog of CGs, we placed an observer on one corner of the simulation super-box

- we computed the $r$-band apparent magnitudes (galaxy members).
- We restricted the sample to those that have 4 or more members with $r < r_{lim}$ ($r_{lim} = 17.77$)
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Compact groups selection: $3D \ CG_m$

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Introducing an observer, Hen15 SAM is the most efficient at recovering compact groups.
To compare our ideal CGs with a sample of classical CGs, we constructed a mock catalogue of galaxies in redshift space.

Our mock catalogue is built by observing the simulation from a corner of the super-box. We set an apparent magnitude limit $r = 17.77$, equal to the limit we set on the $CG_m$ to match the SDSS spectroscopic catalog for later comparison.

- $\alpha, \delta$: x, y, z positions
- z: Hubble flow + radial velocities (line-of-sight direction)
- rest-frame galaxy apparent magnitudes: from the rest-frame absolute magnitudes + DM
- observer-frame apparent magnitudes: k corrections.

With this information, we identify CGs in redshift space.
Using this Modified Hickson algorithm to identify CGs:

- Four or more galaxy members ($\Delta r \leq 3$)
- isolated in a cylinder ($\Delta r \leq 3$),
- Compact ($\mu_r \leq \mu_{\text{limit}}$)
- All of the members are velocity concordant

HMCGs identified:

- G11: 478
- G13: 288
- H15: 188
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Comparison between 3D $CG_m$ and $HMCG$

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Box Simulation

3D Criteria
- CGs in real space
  - $m_i \leq m_{lim}$

Mock Catalog
- Hickson Criteria
  - CGs in redshift space
- HMCG

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What about the completeness and purity of the HMCG sample?
Results

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**Completeness:** How many 3D CG$_m$ are HMCG?

- **Guo11:** 42 out of 211 (20 %)
- **Guo13:** 21 out of 222 (11 %)
- **Hen15:** 13 out of 115 (15 %)
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**Purity:** How many 3D CG$_m$ recover the HMCG?

- Guo11: 42 out of 478 (11 %)
- Guo13: 21 out of 288 (10 %)
- Hen15: 13 out of 188 (12 %)
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Conclusions and Future Work

- We designed a new algorithm in real space and applied it to semianalytical galaxies.
- We study the 3D $CG_m$ in redshift space and we compare it with the HMCG sample.

The Hickson-like samples have low purity and completeness compared to our ideal 3D CG.

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Work in progress

What are the observational constraints that best recover the 3D sample?
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**Preliminary result:** we found that the observational properties of Hickson-like samples do not reproduce well those of the 3D CGs.

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![Boxplot](image.png)

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G11  G13  H15
Acknowledgements

Thanks

Grazie mille

Gracias
References I

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