The GAMA Group Catalogue: Construction & Application(s)

Meiert W. Grootes
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With
A. S. G. Robotham, R. J. Tuffs
and the GAMA team
I) The GAMA Group Catalogue (G$^3$C)  
On behalf of Aaron S. G. Robotham  

II) Science using the G$^3$C  
Gas-fuelling as a function of environment (Grootes et al, in prep.)
GAMA spec-z:
- Deep & wide
- High completeness even in dense regions

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Galaxy and Mass Assembly (GAMA): the GAMA galaxy group catalogue ($G^3Cv1$)

Constructing FoF Groups

- At the simplest level we:
  - Calculate the GAMA luminosity function (LF).
  - Require that galaxies are significantly linked when they are locally overdense.
  - Do this separately radially and in projection.
  - Then construct groups out of common linking.

- Algorithm is calibrated on mock GAMA lightcones (Millenium Simulation + SAM).
  - quantitative optimization

Robotham+2011
Robustly determine critical parameters $\sigma$ and group center

Gapper estimate (Beers+1990, Eke+2004) for $\sigma$

Iterative CoL for group center
Direct Group Properties

- Robustly determine critical parameters $\sigma$ and group center
- Gapper estimate (Beers+1990, Eke+2004) for $\sigma$
- Iterative CoL for group center
- Combine with robust estimate of group radius

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- Worry about correlated bias
- No evidence for strong correlated biases
- Viable mass estimator

$M \propto \sigma R^2$ : Mass estimator

Robotham+2011
$M_\alpha \sigma R^2$ : Mass estimator

\[
A(N_{\text{FoF}}, z_{\text{FoF}}) = A_c + \frac{A_N}{\sqrt{N_{\text{FoF}}}} + \frac{A_z}{\sqrt{z_{\text{FoF}}}}.
\]

<table>
<thead>
<tr>
<th>$r_{AB}$</th>
<th>$A_c$</th>
<th>$A_N$</th>
<th>$A_z$</th>
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<tbody>
<tr>
<td>$\leq 19.0$</td>
<td>$-4.3 \pm 3.1$</td>
<td>$22.5 \pm 1.7$</td>
<td>$3.1 \pm 1.1$</td>
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<tr>
<td>$\leq 19.4$</td>
<td>$-1.2 \pm 1.7$</td>
<td>$20.7 \pm 1.4$</td>
<td>$2.3 \pm 0.6$</td>
</tr>
<tr>
<td>$\leq 19.8$</td>
<td>$+2.0 \pm 1.4$</td>
<td>$17.9 \pm 1.1$</td>
<td>$1.5 \pm 0.4$</td>
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$M_\alpha \sigma R^2$ : Mass estimator

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So what is going on at low mass?

- Problem appears to be that the mocks (MS + SA) produce far too many compact groups.

- It would appear that the recipe used for “simulating” dynamical friction is far too crude, and doesn’t merge groups rapidly enough.
The GAMA Galaxy Group Catalog

<table>
<thead>
<tr>
<th>Region</th>
<th>Groups</th>
<th>Gals in Groups</th>
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<tbody>
<tr>
<td>G02</td>
<td>3,476</td>
<td>10,172</td>
</tr>
<tr>
<td>G02 (XXL)</td>
<td>1,919</td>
<td>5,836</td>
</tr>
<tr>
<td>G09</td>
<td>7,558</td>
<td>22,845</td>
</tr>
<tr>
<td>G12</td>
<td>8,235</td>
<td>25,443</td>
</tr>
<tr>
<td>G15</td>
<td>8,045</td>
<td>24,980</td>
</tr>
<tr>
<td>G23</td>
<td>2,692</td>
<td>7,968</td>
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Generally we place ~40% of GAMA r<19.8 galaxies into groups.

Credit: A. Robotham
• Red circles indicate full extent of GAMA group

• Black crosses indicate XXL sources (all within XXLN cat) within this extent.

• Gray points indicate all other XXL sources.

• 3,222 / 9,474 XXLN objects lie within the projected extent of *known* GAMA groups.
Beyond Groups: Filaments, Tendrils, and Voids

Galaxy and Mass Assembly (GAMA): Fine filaments of galaxies detected within voids

# Current GAMA Group Papers

<table>
<thead>
<tr>
<th>Year</th>
<th>Paper Title</th>
<th>Authors</th>
<th>Reference</th>
<th>Year Published</th>
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<tr>
<td>2014...</td>
<td>Herschel-ATLAS/GAMA:How does the far-IR luminosity function depend on galaxy group properties?</td>
<td>Guo, Qi; Lacey, Cedric; Norberg, Peder; Cole, Shaun;</td>
<td>2014arXiv1401.0986G</td>
<td>01/2014</td>
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<td>2014MNRAS.440..762O</td>
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**Galaxy evolution**

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**Current GAMA Group Papers**
II) Gas-fuelling as a Function of Environment
Why Bother with Gas-fuelling?

DM Structure formation well understood in context of LCDM but processes by which baryonic mass component of galaxies is assembled are much more unclear.
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**Why Bother with Gas-fuelling?**
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Why Bother?

DM Structure formation well understood in context of LCDM but processes by which baryonic mass component of galaxies is assembled are much more unclear.

LACKS direct empirical reference/constraints!!

Remedy this situation using GAMA

Approach:
Use local spirals as test particles and use their SFR to probe influence of environment on processes driving galaxy evolution; isolate relevant processes as far as possible
Basic Requirements:

- Ability to probe wide range of environments down to low halo masses
  The G$^3$C provides the perfect database

- Ability to isolate galaxy-galaxy interactions from galaxy-IGM interactions
  do not consider close pairs/interacting galaxies

- Ability to isolate galaxy specific effects, in particular morphology
  Select a complete morphologically defined sample unbiased in SFR
  and employ SSFR-M* relation

- Sensitivity to timescales $<< t_{\text{dyn}} \approx 1 \text{ Gyr}$
  Use NUV as starformation rate trace

- Very high precision in intrinsic SFR measures to be sensitive to small
  effects due to environment
  Use radiation-transfer based attenuation corrections

- Consider satellite & central galaxies separately
Group Central spirals show enhanced SFR

Median SFR of satellite spirals suppressed w.r.t Field
GAMA Satellite Spirals by Environment

Global Overdensity

Group Compactness

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Grootes et al, in prep.
GAMA Satellite Spirals by Environment

Grootes et al, in prep.
The Role of AGN

Without AGN

With AGN

Grootes et al, in prep.
AGN: Central or not

Non-central AGN

Central AGN

Grootes et al, in prep.
Majority of satellite spirals form stars at the rate of field counterparts! Gas-fuelling appears to be on-going for these objects!

Presence of a (central) AGN influences the size of the population of spiral satellites with suppressed SFR. Implies AGN feedback mechanism acting through IGM.

- X-ray data would be great to try to:
  - Look at IGM of (stacked) selected groups w and w/o AGN
  - Characterize the properties of the (central) AGN in selected groups
• To create meaningful group catalogues we need to understand the biases expected by choosing different approaches to grouping

• Solution is to test on mock catalogues- created by Alex Merson (Durham) and Peder Norberg (see Merson 2013). This is a combination of the Millennium Simulation (MS) plus the GALFORM Semi-Analytic (SAM) galaxy formation recipe on top.

• 27 GAMA like volumes (z= 0 -> 0.5, 48 sqdeg) exist with known associations between dark matter halos and semi-analytic galaxies (Richard Bower 2006).

• In some sense, we need an approaching to grouping that does “the best job” at recovering correct groupings
• Chosen approach is to optimise for both finding halos and accurately determining purity of halos

• To find halos we say match is successful when bijective: more than ½ of mock group is in same group as more than ½ of FoF group
  - Find fraction of bijective FoF and mock groups where N>5 (because this is hard)

• To find halo purity find fraction of galaxies that are common as a fraction of best matching FoF/ mock group
  - Scale by multiplicity and calculate overall purity for FoF and mock groups

• This approach penalises over AND under grouping!
Groups: Technical Points

\[ E_{\text{FoF}} = \frac{N g_{\text{bij}}}{N g_{\text{FoF}}} \]

\[ E_{\text{mock}} = \frac{N g_{\text{bij}}}{N g_{\text{mock}}} \]

\[ E_{\text{tot}} = E_{\text{FoF}} E_{\text{mock}} \]

Group detection FoM
1 if perfect

\[ Q_{\text{FoF}} = \frac{\sum_{i=1}^{N g_{\text{FoF}}} P_{\text{FoF}}[i] \cdot N m_{\text{FoF}}[i]}{\sum N m_{\text{FoF}}} \]

\[ Q_{\text{mock}} = \frac{\sum_{i=1}^{N g_{\text{mock}}} P_{\text{mock}}[i] \cdot N m_{\text{mock}}[i]}{\sum N m_{\text{mock}}} \]

\[ Q_{\text{tot}} = Q_{\text{FoF}} Q_{\text{mock}} \]

Group purity FoM
1 if perfect

\[ S_{\text{tot}} = E_{\text{tot}} Q_{\text{tot}} \]

Final cost function to optimise. 1 if perfect.

N bijective groups
N FoF groups

N bijective groups
N mock groups

N bijective galaxies in FoF groups
N galaxies in FoF groups

N bijective galaxies in mock groups
N galaxies in mock groups

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Area: 280 deg²

~250,000 spec z

Placed between shallow and deep surveys

Robust against cosmic variance

Probes LSS over cosmological volume

www.gama-survey.org
Much effort has been put into ensuring GAMA is highly complete on compact (sub 30’’) scales.

Implemented “greedy” tiling (details in Robotham et al 2010)

In dense regions SDSS drops to ~50% completeness. High completeness inside the group/cluster scale requires multi-pointing strategy.

GAMA >98% complete overall and >95% complete for 5 neighbours within 40”

... but not any old redshifts
Use Galaxy Zoo classifications as benchmark.

Consider multiple parameters NOT linked to SF but may separate E's and Sp's.

Adaptively discretize parameter space and define subvolume linked to Sp's.

Test using independently classified samples and independent observables.

Grootes et al., 2013, submitted
Best parameter combination is \((\log(n), \log(r_e), M_i)\)

- Very pure samples of spirals (< 2% contamination by visually classified ellipticals)
- Completeness of GZ spirals @ \(\geq 77\%\)
- Very good recovery of H\(\alpha\) EQW distribution
- Good recovery of T-type distribution, slight bias against S0/Sa

Pure sample with robust morphologies including quiescent sources.

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22.-26.07.2013

Figs from Grootes et al., 2013 submitted
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Figs from Grootes et al., 2013.
UV SFR → total SFR, short timescale (~100 Myr)

- Heavily affected by attenuation (~2 mag, ~1mag due to orientation)
- Use Rad. Trans. Modeling (Popescu+2011)
- Estimate input using only optical info (calibrated on sources with FIR data; H-ATLAS)

Spirals following \((\log(n), \log(r_e), M_\text{d})\) after correction very tight \((\sigma \approx 0.27 \text{ dex})\)

Single PL \((\gamma = -0.5)\)

Significant reduction in scatter w.r.t standard attenuation correction methods \(\rightarrow\) precision and sensitivity
939 spirals in 584 groups with $z<0.13$; ~4000 Field spirals

GAMA Field spirals as whole spiral sample (similar scatter)

Merging systems (including spiral) show enhanced SFR

Close Pairs (50/h kpc 1000 km/s) similar to Field

'isolated' group spirals show suppressed median SFR

Dist. of GAMA group parameters highly similar between group w/ & w/o spiral (being investigated further)

XMM-XXL consortium meeting 22.-26.07.2013