Morphology Distribution of Compact Group Galaxies

By

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What are Compact Groups?

- **Similar environment to the early universe**
  - High Number Density and Low Velocity → strong tidal forces
- **Dynamically bound systems**
  - Short time scales due to merging
- **Our Compact Groups (CG) can be broken up into two subsections:**
  - Hickson Compact Groups (HCG)
  - Redshift Survey Compact Groups (RSCG)

![HCG 92 Image](image_url)
Star formation in CG

- Star formation in this extreme environment
  - IRAC looked at PAH* emission as a tracer of warm dust and SF
- Gap in MIR colors between gas rich and gas poor galaxies
  - Indicating a short crossing time
- The canyon region is where the number distribution of galaxies falls less than half of the median
- Walker 2010 found that the canyon is distinct characteristic of CG

*PAH=polycyclic aromatic hydrocarbon

Walker et al. 2012
Compact Groups in Optical

- **3 regions in optical**
  - **Red Sequence**
    - Mainly ellipticals (red stars)
  - **Blue Cloud**
    - Mainly spirals (blue stars)
  - **Green Valley**
    - Transition of blue stars dying off and galaxy becoming redder
    - Short crossing time ~ lifetime of blue stars
- **Did not find a connection in the canyon to GV**
- **CGs do not show the same trend as field galaxies (contours)**
  - **CGs don’t show characteristics of the blue cloud or green valley**
Optical vs. Mid-IR (Optmir)

- When comparing the optical and MIR we gain insight on star formation in CGs.
- Larger population of optically red galaxies than blue.

1. Blue MIR + Red Opt \(\rightarrow\) “Red and Dead”
2. Red MIR + Red Opt \(\rightarrow\) “Dusty”
3. Red MIR + Blue Opt \(\rightarrow\) “Current SF”
4. Blue MIR + Blue Opt \(\rightarrow\) “SF Recently ended”

- Large spread in MIR red.

![Graph showing the comparison between optical and mid-IR colors](image)
When comparing the optical and MIR we gain insight on star formation in CGs.

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- Large spread in MIR red
- Morphology only indicates spirals and ellipticals
- With current morphology, no ties between type and location
Why should we care?

- Similar environment to the early universe
- More than just elliptical and spiral, WISE can indicate activity in the galaxies
- The evolution of galaxies and how they interact
- Snapshots of different points of merging in groups
- Final result is galaxy mergers, indication of how large elliptical galaxies form?

HCG 44
Science Questions

- How do WISE classifications compare to NASA/IPAC Extragalactic Database (NED) and the literature?
- How does activity affect where galaxies fall in the “Optmir” plot?
  - Does this give insight on stages of star formation?
- Does this give an indication on the types of galaxies in the “Green Valley?”
  - Are they a transition from blue cloud to red sequence?
- Compact groups have strong tidal forces, how does this effect the HI gas in and in between the galaxies?

HCG 59
Data

33 Compact Groups (CGs) [129 galaxies]

Chosen from Hickson Compact Group (HCG) and Redshift Survey Compact Group (RSCG) catalogs

- **HCG:**
  - Palomar Sky Survey
  - Isolation
  - Magnitude limited
  - Compactness

- **RSCG:**
  - Minimum redshift
  - Other selection criteria similar to HCG

Selection criteria included CGs that have both Spitzer and Sloan data available
WISE Data

- Use WISE point source catalog
- Cores of galaxies point sources
  - Determining spatial extent of galaxies is difficult
- Use bands 3.4, 4.6, and 12 μm

SDSS image with WISE point source catalog
Our findings

- A lot more than just spirals and ellipticals
- We see the activity of the galaxies
- A wide spread in \([4.6]–[12]\) but a narrow band in \([3.4]–[4.6]\)
- We also see a gap in the wise data, falls around spiral regions, separating active and inactive galaxies
Comparison With NED

Main Catalog:
- de Vaucouleurs et al. 1991
  - Similar to Hubble’s identification process
  - Incompleteness

- Classified galaxies based on the color-color
  - Took into account errors

- Found 2 QSOs, 2 Seyferts, Starbursts, ULIRGS/LINERS, and LIRGS
**HCG 96**

**4 Member Galaxies**

<table>
<thead>
<tr>
<th>Member</th>
<th>NED ID</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>SA</td>
<td>QSO</td>
</tr>
<tr>
<td>B</td>
<td>SAB0</td>
<td>Elliptical</td>
</tr>
<tr>
<td>C</td>
<td>S</td>
<td>Spiral/LIRG</td>
</tr>
<tr>
<td>D</td>
<td>N/A</td>
<td>Starburst</td>
</tr>
</tbody>
</table>

**Optical**

**MIR**

![Image of HCG 96 with member galaxies and corresponding optical and MIR images]
Connection with Spitzer

- Colors correspond to location in Spitzer MIR plot
  - Red (warm dust/PAHs) is mostly in the active starforming region
  - Blue is mainly spirals and ellipticals → inactive

- Canyon
  - We only see one MIR canyon galaxy falling in our canyon (H79B)
H79B consistently falls in the under dense (canyons) regions of both plots.

Nothing extremely unusual in optical and MIR, besides a cold tidal tail.

Besides canyon, nothing unusual in wise.
### Proposed Evolutionary Sequences

<table>
<thead>
<tr>
<th>Type</th>
<th>H I content</th>
<th>Member morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Rich</td>
<td>Spiral/ Irregular</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>Elliptical/ Lenticular</td>
</tr>
</tbody>
</table>

- **Type I (HI rich)**: $\log \frac{M_{\text{HI}}}{M_{\text{dyn}}} > 0.9$
- **Type II (HI intermediate)**: $0.9 > \log \frac{M_{\text{HI}}}{M_{\text{dyn}}} > 0.8$
- **Type III (HI poor)**: $\log \frac{M_{\text{HI}}}{M_{\text{dyn}}} < 0.8$

Sequence B: gas stripped from galaxies
- star formation between galaxies
- bright group x-ray halo
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<th>Type III</th>
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**Sequence A:** gas contained in galaxies
- Star formation within galaxies
- No/faint group x-ray halo

**Sequence B:** gas stripped from galaxies
- Star formation between galaxies
- Bright group x-ray halo
HI connection?

For the groups that had HI contour data, we plotted Sequence A and Sequence B.
HI connection?

- In one of the galaxies (H96A) we see a significant correlation between HI and location in WISE.
  - The location seems to be correlated to the amount of HI in the galaxy.
- Oversaturation in MIR image.
- In the evolutionary sequence this group is classified as Sequence B, Type II group.
Our conclusions

- Classified galaxies based on activity
  - Better than photometric plates
- Compared to NED
  - A systematic identification
  - Identified QSOs
- Identification of canyon galaxies
  - Smaller canyon region needed?
- Correlation between HI content and activity of CGs in WISE morphology

HCG 79


Age Estimation

Evolutionary track based on stellar synthesis models from Marigo et al. (2008)
Connection to canyon galaxies

- Looking at the Optical-MIR plot we can group 4 regions
- Want to see if there is a connection to location in wise color-color plot
  - Does location in optmir indicate underlying properties of the galaxy type or vise versa?
- There is a trend similar to the curve in the MIR
- Not a one-to-one mapping
Sequence A: gas contained in galaxies

star formation within galaxies

Sequence B: gas stripped from galaxies

star formation between galaxies
HCG 56

5 Member Galaxies

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<tr>
<td>E</td>
<td>SB0</td>
<td>Spiral</td>
</tr>
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</table>

SDSS image

Optical

MIR

Spitzer 3-color image

HCG 56

log(F_{4.6}/F_{[3.6]}) vs log([3.6]/[4.6])

Cool T-dwarfs
ULIRGs/LINERs, Obscured AGN
QSOs, Seyferts
LINERs
Starbursts
LIRGs
Stars
Ellipticals
Spirals

[4.6]-[12] (mag)

[-0.5, 6.0]
HCG 92

- **4 Members Galaxies**
- **1 foreground galaxy**

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<td>QSO</td>
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<td>D</td>
<td>E2</td>
<td>Spiral</td>
</tr>
<tr>
<td>E</td>
<td>N/A</td>
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**Optical**

**MIR**

SDSS image

Spitzer 3-color image

HCG 92

[4.6]-[12] (mag)
Galaxies in Canyon

HCG 79B, HCG 57B, HCG 37E, HCG 57H

HCG 57  HCG 37  HCG 79
The Project

- Using WISE data to see where group members fall in the specified regions
  - Using 33 groups from Walker et al. 2012 survey
- Science Questions:
  - How does morphology affect where galaxies fall in the "Optmir" plot?
    - Does this give insight on stages of star formation?
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