Isolated Galaxies and Isolated Satellite Systems

H. B. Ann
Pusan National University, Korea

In collaboration with
Changbeom Park
&
Yun-Young Choi
Korea Institute for Advanced Study, Korea
Granada, 12 May 2008
Content

• Isolated galactic satellite systems, from the SDSS Dr4plus sample (Ann, Park & Choi (2008)).

• Isolated galaxies in the local universe, on going project using SDSS DR7. I will present a preliminary results only, with an emphasis on the strategy to find out isolated galaxies.
Search for isolated satellite systems

- Galactic satellite systems are good places to inspect the environmental dependence of galaxy morphology and to study the galaxy formation process since they are abundant and very localized systems with a size of less than 1 Mpc. However, there are only a few satellite systems of which their faint members are observed.

- Thanks to the galaxy redshift survey such as SDSS and 2DFGRS, it is now possible to undertake a statistical approach to understand the galactic satellite systems.
Data

• Primary sample of data is a subset of DR4plus which is a large scale structure sample extracted from the spectroscopic Main galaxy Sample of the SDSS DR5 (Adelman-McCarthy et al. 2007).

• We added 5503 galaxies brighter than $r_{pet} = 14.5$ from various catalogs including NED. The total number of galaxies used here is 370,789 with known redshift and photometry.

• We used a flat $\Lambda$CDM cosmology with density parameters $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$. 
Two steps to find out isolated satellite systems

1) look for isolated galaxies brighter than $M_r = -19$ in the volume limited sample defined by redshift range ($0.02 < z < 0.0472$) and the limiting survey magnitude ($M_r < -18$).

The target galaxy is isolated if $r_p$ to its nearest neighbor is greater than $r_{\text{virtar}} + r_{\text{virnei}}$. Here, neighbor is the galaxies with $M_{r, \text{nei}} < M_{r, \text{tar}} + 1$ with velocity difference $\Delta V_{\text{tar-nei}} < 1000 \text{ kms}^{-1}$

$\rightarrow 8883$ isolated galaxies
• We defined **virial radius** of a galaxy as the projected radius ($r_p$) where the mean mass density within the sphere of a radius $r_p$ is 200 times the critical density ($\rho_c$).

$$r_{\text{vir}} = \left(\frac{3\gamma L}{4\pi 200\rho_c}\right)^{1/3}$$

$\gamma = 2$ for E/S0

$\gamma = 1$ for Sp/Irr

$r_{\text{vir}} : 300 \, h^{-1}\text{kpc}, 240 \, h^{-1}\text{kpc}$ for early and late types with $M_r = -20$
2) Once the bright isolated galaxies were found, we searched for satellites associated with them among galaxies brighter than $M_r=-18$, by using two selection criteria:

(1) projected separation ($r_p$) is less than the smaller of $1\ h^{-1}\text{Mpc}$ and $d - r_{\text{vir, nei}}$, where $d$ is the projected distance of the neighbor.

(2) magnitude difference between host and satellite is greater than 1 mag.

$\rightarrow$ 2254 hosts and 4,986 satellites
Isolated hosts and their satellites

Mean host luminosity:
\[ M_r = -20.47 \]

Mean satellite luminosity:
\[ M_r = -18.67 \]
Morphology classification

• We classify the morphology of host galaxies by the visual inspection because visual classification is accurate for bright galaxies.

• However, we mainly employed the automated classifier of Park & Choi (2005) for satellites. The visual classification is used as a complementary one, especially for bright satellites or those suffering from close interactions or mergers.
Morphology classification

Early

Late

Park & Choi 2005
• Early type fractions of satellites hosted by early type galaxies are higher than those for late type hosts at least out to 350 $h^{-1}$kpc, which is roughly the virial radius of early type hosts.
Surface density of satellites

- Surface density of early type satellites associated with early type hosts decreases very rapidly. This is the reason for the more rapid decrease of early type satellite fraction in early type hosts than those in the late type hosts.
The background density plays a role in determining the morphology of satellites. However, host morphology and $r_p$ play a decisive role, suggesting hydrodynamic interactions at $r_p < r_{\text{vir,host}}$. 

$$\rho_{20}(x)/\bar{\rho} = \sum_{i=1}^{20} \gamma_i L_i W_i(|x_i - x|)/\bar{\rho}$$

$$\bar{\rho} = \sum_{\text{all}} \gamma_i L_i / V$$
• The galactic conformity found above is not much affected by the choice of $\Delta m$ (1, 1.5, 2, 2.5), $\Delta V$ and limiting $r_p$.

• We obtained qualitatively the same results with fixed survey radius eg, $r_p = 800 \text{kpc} \ h^{-1}$. 
8353 satellites in 3472 systems:

\[ \Delta m = 2, \quad \Delta v = 500 \text{km/s} \]

\[ r_p = 800 \text{kpc} \, h^{-1} \]
Isolated galaxies

What do isolated galaxies mean?

They are thought to be as

1) passively evolving galaxies formed in isolation via gravitational collapse of a primordial protogalactic cloud (Marcum et al. 2004).

and commonly defined as the galaxies with no companions brighter than a magnitude difference ($\Delta m$) within a projected distance ($r_p$) and a radial velocity difference ($\Delta V$).

eg, $\Delta m=1$, $r_p = 1 \ h^{-1} \text{Mpc}$, $\Delta V=1000 \text{km/s}$
• However, we employed the projected distance to the nearest neighbor normalized by the virial radius of the nearest neighbor, $r_p/r_{\text{vir, nei}}$, as a measure of isolation along with the background density, since galactic conformity in satellite systems is most pronounced for the satellite galaxies at $r_p/r_{\text{vir, host}} < 1$, and the morphology and distance to the nearest neighbor play a decisive role in determining the morphology of a target galaxy (Park, Gott & Choi 2008, Park & Choi 2009),
Effect of neighbor

• Morphology of a galaxy depends on the distance to the neighbor galaxy.

• At \( r < 0.5h^{-1}\text{Mpc} \), morphology of a galaxy strongly depends on the morphology of the neighbor.

Park, Gott, & Choi (2008)
SDSS DR7 galaxies \( (n \approx 10^5) \)

- \( 0.02 < z < 0.04724 \)
- \( 0.01 < Z < 0.02 \)
Local background density

\[ \rho = \frac{n}{4\pi r_p^2} \]

where

- \( n \) is the number of galaxies brighter than \( M_r^* \) within \( r_p \)
- Normalized by the mean density of the volume limited sample (0.02 < z < 0.05)
The diagram shows a scatter plot with two axes: 

- The x-axis represents $\log(\rho/\bar{\rho})$. 
- The y-axis represents $\log(r/r_{\text{vir}})$. 

The plot is segmented into different regions based on the value of $r_p$: 

- Green region: $r_p < 0.5$ Mpc. 
- Pink region: $0.5 < r_p < 1$ Mpc. 
- Blue region: $1 < r_p < 2$ Mpc. 
- Light blue region: $r_p > 2.0$ Mpc.
Luminosity of mostly isolated E/S0 galaxies

N=24261 (30%)
N=84 (13%)

Mr
u-r colors of mostly isolated E/S0 galaxies
Luminosity distribution of galaxies in $0.02<z<0.05$
Isolated satellite systems
Conclusions

• Morphology conformity prevails in the galactic satellite systems of which typical size is less than 1Mpc.
• Morphology conformity holds for both high and low density environment.
• The origin of the conformity in morphology is thought to be mainly hydrodynamic effects.
• The projected distance to the nearest neighbor normalized by the virial radius of the nearest neighbor along with the background density provide a useful diagnostics for the selection of isolated galaxies.
Thank you!