Mass Distribution in Hickson Compact Groups of Galaxies

Henri Plana¹ - Philippe Amram ² - Claudia Mendes de Oliveira ³ - Chantal Balkowski ⁴

¹- Laboratório de Astrofísica Teórica e Observacional - Ilhéus
Brazil: e-mail: plana@uesc.br

²- Laboratoire d’Astrophysique de Marseille - Marseille
France: e-mail: philippe.amram@oamp.fr

³- Instituto de Astronomia e Geofísica - São Paulo
Brazil: e-mail: oliveira@astro.iag.usp.br

⁴- Observatoire de Paris - GEPI - Meudon
France: e-mail: balkowski@obspm.fr
References

- Amram et al. 2003 A&A 42, 865
- Barnes et al. 2004 AJ 128, 2724
- Blais-Ouellette 2000 PhD Thesis
- Donato et al. 2004 MNRAS 353, L17
- Garrido et al. 2005 MNRAS 362, 127
- Mendes de Oliveira et al. 2003 AJ 126, 2635
- Nishiura et al. 2000 AJ 120, 2355
- Plana et al. 2003 AJ 125, 1736
- Zaho 1996 MNRAS 278, 488

Acknowledgement

- HP thanks the Brazilian Cnpq for its financial support to attend this conference and the LAM for its financial support during the visit of HP at the LAM in Marseille in Feb 2007 to prepare this work.
Introduction

- For the past ten years a few studies have been carried out on Compact Groups of galaxies to see the influence of dense environment on galaxy's dynamics and kinematics (Nishiura et al. 2000, Rubin, Hunter & Ford 1991).

- Since 1995, we launched an observational program in order to obtain rotation curves from 2D velocity fields observed using a scanning Perot Fabry. After studying particular cases such as HCG16 or HCG92 we began to consider our whole sample (Amram et al 2003, Plana et al. 2003).

- Mendes de Oliveira et al. (2003) showed the Tully Fisher relation for 23 rotation curves of late type galaxies from the total of 100 observed galaxies. The study shows that HCGs follow the TF relation with some galaxies being brighter than expected from the relation in relation of their low mass. Some RCs are showing strong asymetry due to interaction.

- The next step is to investigate the distribution of the dark halo for these galaxies.
The data and Samples

- We have fit 19 rotations curves from the sample of Mendes de Oliveira et al. 2003. Six galaxies did not have satisfactory J photometry.
- In order to determine the dark halo shape, we allied both the stellar light contribution coming from the photometry and the dark halo contribution from the RCs.
- We used the model developed by Carignan & Freeman (1985) and modified by Blais-Ouellette (2000) to fit the RCs. The surface brightness profile is transformed into a mass distribution for the stellar disk and the stellar bulge assuming a variable but radially constant M/L ratios for both the stellar disk and the Bulge.
- The main interest of this study is to be compared with similar studies in different environments. We compared the shape of the dark halo with Barnes et al. (2004) and the GHASP survey (Epinat et al 2007 in preparation - Garrido et al. 2005).
Photometry and profile decomposition

- Surface brightness profiles have been built using the J band from the 2MASS survey because it probes better the mass dominant stellar component.
- We have fitted ellipses to the isophotes of the J band images using ELLIPSE task of the SDSDAS package with IRAF. We only fixed the center of the ellipse in the fitting parameters and we usually used a 0.2 arcsec space between two ellipses.
- In order to use the mass model, we perform a decomposition of the surface brightness profile in the classical two components:
  
  an exponential disk $\mu = \mu_0 + 1.0857 \frac{r}{r_0}$
  
  an $r^{1/4}$ bulge profile $\mu = \mu_e + 8.3268 \left[ (r/r_e)^{1/4} + (r/r_t)^4 \right]$
To perform the decomposition we used an home made program based on a minimized square routine from the MINUIT package. The program first fits the disk using a visual estimate on the profile. It then subtracts the fitted disk and adjusts the bulge. The operation is repeated by interaction in order to minimize the $\chi^2$ of each disk and bulge parameters.

We then have five parameters, two for the disk

$\mu_0$: the central surface brightness,

$r_0$: the disk scale parameter

and three for the bulge

$\mu_e$: the central surface brightness

$r_e$ and $r_t$: scales factors
We fit the rotation curve of each galaxy using the model developed by Carignan & Freeman (1985) and revised by Blais-Ouellette (2000). This model calculates the contribution of each velocity component (bulge, disk and halo) using the photometric profile decomposition for the luminous contribution (bulge and disk) and a predetermined density profile for the halo. The result of the quadratic sum of each velocity component is fitted to the observational rotation curve by minimizing the $\chi^2$ in the four dimensions space: $(M/L)_{\text{disk}}, (M/L)_{\text{bulge}}, \rho_0$ and $R_0$.

For this study we used a spherical distribution that represents the dark halo, the so called isothermal sphere (ISO model) with a density profile given by:

$$\rho(r) = \rho_0 / [1 + (r/R_0)^2]$$

and the Navarro, Frenk and White (1996) (NFW) density profile:

$$\rho(r) = \rho_c / [(r/R_c) (1 + r/R_c)]$$

We also fit the RCs using the Maximum Disk Model (MDM), by finding the highest contribution of the disk in the RC.
<table>
<thead>
<tr>
<th>HCG</th>
<th>$\mu_0$</th>
<th>$r_0$</th>
<th>$\mu_c$</th>
<th>$r_c$</th>
<th>$r_1$</th>
<th>$M/L_{disk}$</th>
<th>$M/L_{bulge}$</th>
<th>$R_d$</th>
<th>$\rho_0$</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>07c</td>
<td>19.12</td>
<td>7.21</td>
<td>14.70</td>
<td>9.02</td>
<td>2.81</td>
<td>0.05</td>
<td>0.55</td>
<td>6.00</td>
<td>0.050</td>
<td>4.29</td>
</tr>
<tr>
<td>10d</td>
<td>17.18</td>
<td>2.47</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.60</td>
<td>1.00</td>
<td>1.80</td>
<td>0.175</td>
<td>0.39</td>
</tr>
<tr>
<td>16a</td>
<td>17.64</td>
<td>3.98</td>
<td>9.91</td>
<td>3.16</td>
<td>3.12</td>
<td>0.40</td>
<td>0.20</td>
<td>1.60</td>
<td>0.500</td>
<td>7.61</td>
</tr>
<tr>
<td>16c</td>
<td>16.6</td>
<td>1.44</td>
<td>12.35</td>
<td>9.92</td>
<td>2.86</td>
<td>0.03</td>
<td>0.11</td>
<td>6.00</td>
<td>0.130</td>
<td>3.00</td>
</tr>
<tr>
<td>19a</td>
<td>0.00</td>
<td>0.00</td>
<td>9.95</td>
<td>1.88</td>
<td>25.06</td>
<td>0.10</td>
<td>0.00</td>
<td>9.00</td>
<td>0.024</td>
<td>39.53</td>
</tr>
<tr>
<td>19b</td>
<td>18.75</td>
<td>3.12</td>
<td>11.90</td>
<td>0.84</td>
<td>2.71</td>
<td>0.05</td>
<td>0.14</td>
<td>8.00</td>
<td>0.012</td>
<td>3.13</td>
</tr>
<tr>
<td>87a</td>
<td>17.62</td>
<td>6.78</td>
<td>12.80</td>
<td>10.58</td>
<td>5.32</td>
<td>0.05</td>
<td>0.00</td>
<td>8.80</td>
<td>0.009</td>
<td>1.01</td>
</tr>
<tr>
<td>87c</td>
<td>18.26</td>
<td>2.85</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.10</td>
<td>3.50</td>
<td>0.126</td>
<td>2.07</td>
</tr>
<tr>
<td>88a</td>
<td>17.21</td>
<td>4.56</td>
<td>13.01</td>
<td>11.02</td>
<td>2.65</td>
<td>1.75</td>
<td>1.05</td>
<td>21.00</td>
<td>0.016</td>
<td>0.90</td>
</tr>
<tr>
<td>88b</td>
<td>18.13</td>
<td>4.56</td>
<td>9.10</td>
<td>1.12</td>
<td>4.27</td>
<td>1.50</td>
<td>0.20</td>
<td>45.00</td>
<td>0.013</td>
<td>3.64</td>
</tr>
<tr>
<td>88c</td>
<td>17.95</td>
<td>2.09</td>
<td>19.72</td>
<td>3882</td>
<td>3.54</td>
<td>0.45</td>
<td>0.30</td>
<td>19.50</td>
<td>0.007</td>
<td>5.89</td>
</tr>
<tr>
<td>88d</td>
<td>17.94</td>
<td>2.85</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.97</td>
<td>0.10</td>
<td>14.50</td>
<td>0.010</td>
<td>1.2</td>
</tr>
<tr>
<td>89a</td>
<td>19.62</td>
<td>12.48</td>
<td>13.30</td>
<td>6.81</td>
<td>5.31</td>
<td>0.80</td>
<td>1.20</td>
<td>18.00</td>
<td>0.013</td>
<td>1.28</td>
</tr>
<tr>
<td>89b</td>
<td>18.17</td>
<td>4.24</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.70</td>
<td>1.00</td>
<td>2.00</td>
<td>0.189</td>
<td>1.28</td>
</tr>
<tr>
<td>89c</td>
<td>18.51</td>
<td>2.12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.10</td>
<td>1.00</td>
<td>6.00</td>
<td>0.052</td>
<td>0.28</td>
</tr>
<tr>
<td>91a</td>
<td>18.13</td>
<td>7.42</td>
<td>13.15</td>
<td>20.69</td>
<td>8.44</td>
<td>0.10</td>
<td>1.00</td>
<td>2.00</td>
<td>0.350</td>
<td>33.14</td>
</tr>
<tr>
<td>91c</td>
<td>18.76</td>
<td>5.08</td>
<td>14.80</td>
<td>12.78</td>
<td>4.26</td>
<td>0.70</td>
<td>0.00</td>
<td>3.00</td>
<td>0.010</td>
<td>1.66</td>
</tr>
<tr>
<td>96c</td>
<td>16.39</td>
<td>1.29</td>
<td>12.43</td>
<td>3.83</td>
<td>2.50</td>
<td>0.16</td>
<td>0.05</td>
<td>18.00</td>
<td>0.005</td>
<td>0.81</td>
</tr>
<tr>
<td>100d</td>
<td>18.11</td>
<td>1.68</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.10</td>
<td>0.10</td>
<td>3.00</td>
<td>0.019</td>
<td>91.76</td>
</tr>
</tbody>
</table>

1 Hickson Group; 2 Disk central surface brightness; 3 Scale length in kpc; 4 Bulge central surface brightness; 5 Characteristic radius in kpc; 6 Generalized characteristic radius kpc; 7 Mass / Luminosity ratio for the disk in $M_\odot/L_\odot$; 8 Mass / Luminosity ratio for the bulge in $M_\odot/L_\odot$; 9 Characteristic radius for the Dark Halo in kpc; 10 Central density for the dark halo in $M_\odot \text{ pc}^{-3}$.
Fig. 1 Rotation Curve of HCG 88a with the Disk, Bulge and Halo components.

Fig. 2 SBA galaxy HCG 88a. J surface brightness profile with the bulge + disk decomposition.

- $\mu_0 = 13.02$
- $r_e = 28.42$
- $r_h = 6.83$
- $\mu_0 = 17.21$
- $r_0 = 11.77$

- $M/L_{\text{bulge}} = 1.050 \frac{M_\odot}{L_\odot}$
- $M/L_{\text{disk}} = 1.790 \frac{M_\odot}{L_\odot}$
- $R_0 = 21.000$ kpc
- $\rho_0 = 0.016 \frac{M_\odot}{pc^3}$
- $\chi = 0.90$
Figure 3 - Correlations between the 3 models - ISO - NFW - MDM

Figure 4 - Correlations compared with the Barnes sample for the ISO model
Figure 5 - Correlations with the GHAPS sample for the ISO model
Results - Conclusions

- We fit 19 RCs of Galaxies in dense environment with different mass models.
- Central dark halo density and the core radius show a very tied correlation, using the three models: isothermal, NFW and maximum disk. The scale length, also seems to be related with the core radius, but the relation is weaker (Figure 4). Donato et al. (2004) show a much stronger relation.
- Scale length vs Core Radius seems to show different correlation for our HCG sample and the sample from Barnes (2004). Barnes (2004) sample is formed by late type galaxies but in different environment (clusters galaxies, field galaxies).
- Comparison with the GHASP survey of isolated galaxies confirmed the correlation between dark halo central density and the core radius. On the other hand nothing can be said for the relation between Scale length vs Core Radius.
- The M/L for the disk seems to show a more scattered range of values for the Barnes and GHASP sample than for the HCG.