Distribution of Baryonic and Dark Matter in spiral and irregular nearby galaxies

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OUTLINE

→ Dark Matter in galaxies

→ Sample

→ Mass models and results
Background & Aim

★ Universe: up to 25% Dark Matter, only 5% baryonic matter
  ➞ Understanding universe ==> understand behaviour of DM

★ Appropriate place to study DM is inside galaxies (spirals & irregulars)
  ➞ contain stars & gas suitable for observation

★ Most of previous authors used HI obs. to study shape of DM in outer parts of galaxies (e.g., Carignan & Freeman 1985, van Albada+ 1985, Randriamampandry+ 2014)

★ However, presence of DM in inner parts of galaxies
  ➞ So DM essential to fit high res. rotation curves of galaxies (e.g, Blais-Ouellette+ 2001, Spano+ 2008)

★ Correlation found: less luminous galaxies have smaller core radii & higher central halo densities

★ This work:
  ✓ study shape of DM in inner parts of galaxies using Hα RC
  ✓ investigate luminosity-core radius-central density correlation
GHASP : Gassendi HAlpha survey of SPirals

★ A sample of 203 galaxies covering all morphological types

★ 1.9m OHP telescope with Fabry-Perot interferometer around the Hα emission line

★ FoV of 6'x6' and high spectral resolution R~15000

★ W1(3.4µm) photometry from WISE

★ FoV of 47'x47' and angular resolution of 6"

★ Final sample: **122 galaxies**
Photometry data used to describe the stellar distribution have been observed in infrared W1(3.4µm) of WISE (Wide-field Infrared Survey Explorer).

<table>
<thead>
<tr>
<th>Non-Decomposed</th>
<th>Decomposed</th>
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<tbody>
<tr>
<td>Very small bulge</td>
<td>Bulge Disk</td>
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<tr>
<td>OR</td>
<td>No bulge</td>
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32% 68%

39 galaxies 83 galaxies

Mostly late type Mostly early type

Sp & Irr Spirals
Example of the structural decomposition of UGC 11466 (left panel) and UGC 8900 (right panel). The lower subpanel represents the fitting residuals.
★The Mass-to-light M/L ratio depends on the composition of the stellar populations.

★The stellar M/L ratio for each galaxy can be calculated as a function of the WISE colour using Cluver et al (2014):

\[
\log\left(\frac{M_{\text{stellar}}}{L_{W_1}}\right) = -2.54(W_1 - W_2) - 0.17
\]

where \( L_{W_1} \) is the luminosity in the \( W_1 \) band and where \( W_1 \) and \( W_2 \) correspond to magnitudes in the \( W_1 \) and \( W_2 \) bands respectively.
To fit the rotation curve, different methods have been used:

Cosmological numerical simulations (NFW) suggest the presence of dark matter halo and predict a cuspy central density profile.

\[ \rho_{NFW}(r) = \frac{\rho_i}{\left(\frac{r}{r_s}\right) \left(1 + \frac{r}{r_s}\right)^2} \]

The final rotation curve is the quadratic sum of the individual contributions of these components:

\[ V_{\text{cir}}(r) = \sqrt{V_{\text{disk}}^2 + V_{\text{bulge}}^2 + V_{\text{halo}}^2} \]

2 techniques for this model: the Best Fit Model (BFM) and the fixed M/L
Mass models

UGC 03463
$M_B=-20.7$; Type=SABbc; $h=3.5$

- blue: disk
- pink: bulge
- green: halo
- red: model
- blue diamond: approaching
- red triangle: receding

NFW (BFM)
$(M/L)_d=0.29$; $(M/L)_b=0.32$; $c=6.7$; $V_{200}=122$; $\chi^2=2.5$

NFW (fixed $M/L$)
$(M/L)_d=0.42$; $(M/L)_b=0.42$; $c=1.3$; $V_{200}=195$; $\chi^2=2.8$
The other way is to assume the shape of the dark matter like a spherical and symmetric distribution (pseudo-isothermal sphere called ISO).

\[
\rho_{iso}(r) = \frac{\rho_0}{\left[1 + \left(\frac{r}{r_0}\right)^2\right]^{\frac{3}{2}}}
\]

We use 3 techniques: the BFM, the Maximum Disk Model (MDM) and the fixed M/L
Example of UGC 3463
Theory of MOND (Modified Newtonian Dynamics) which proposes that there is no dark matter in galaxies and uses the luminous matter to describe the flatness of the rotation curve

\[ V_{\text{rot}}^2 = V_{\text{bar}} \sqrt{1 + 0.5 \left( \sqrt{1 + 4a_0 \times r/V_{\text{bar}}^2} - 1 \right)} \]

With \( V_{\text{bar}}^2 = V_{\text{disk}}^2 + V_{\text{bulge}}^2 \) and \( a_0 \) is the acceleration threshold.

We use 3 techniques: the BFM, the fixed \( a_0 \) and the fixed M/L.

\[ a_0 = 1.21 \times 10^{-8} \text{ cm}^{-2} \]
Example of UGC 3463
Distribution of log c as a function of log $V_{200}$ for the NFW best fit models (BFM) points. The dots represent Sa-Sab, Sb-Sbc, Sc-Sd and Sdm-Im morphological types, respectively. The lines represent the best fit model (BFM) and the fixed M/L model.

Comparison between the reduced $\chi^2$ of NFW and ISO for the best fit model (BFM).
Results

Top: Central halo density versus halo core radius. Bottom: central halo density and core radius versus the absolute magnitude from the ISO best fit models (BFM) points for the whole sample. The lines are the best fit (BFM), the maximum disk (MDM) and the fixed M/L model.
Comparison with previous works

Comparison with previous works.
Top: Central halo density versus halo core radius. Bottom: central halo density and core radius versus the absolute magnitude from the ISO best fit models (BFM) points for no decomposed galaxies. The lines represent our fit, and Kormendy+ 2004 and Randriamampandry+ 2014 fits respectively.
Decomposed galaxies

Top: Central halo density versus halo core radius. Bottom: central halo density and core radius versus the absolute magnitude from the ISO best fit models (BFM) points for decomposed galaxies. The lines represent our fit, and Kormendy+ 2004 and Randriamampandry+ 2014 fits respectively.
To understand the impact of the quality of the rotation curves on the correlations, we have separated the higher quality rotation curves from the lower quality ones.

Halo core radius (Left panel) and central halo density (right panel) versus the absolute magnitude for the whole sample. The **green symbols represent the higher quality rotation curves** (flag 1) while the **red circles show the lower quality rotation curves** (flag 2). The **black line linearly fits the dots (BFM)**.
To understand the impact of the bar on the correlations, we distinguish non-barred galaxies (SA), intermediate barred galaxies (SAB) and barred galaxies (SB).

Halo core radius (Left panel) and central halo density (right panel) versus the absolute magnitude for the whole sample. The blue dots indicate non barred galaxies (SA); the red dots represent moderately barred galaxies (SAB) and the black dots display barred galaxies (SB).
Conclusion and Future work

ISO (BFM) and NFW(BFM) are both acceptable, with ISO giving somewhat better results.

ISO (MDM), ISO and NFW with M/L fixed from colours give also reasonable fits for almost all galaxies.

MOND (BFM), the fit is reasonable for almost all galaxies but we notice a higher discrepancy when using the universal fixed $a_0$ and the fixed M/L, especially in the outer parts of the galaxies.

The relation between the dark halo parameters and the luminosity of the galaxies seems dependent on the morphological types.

The correlations between $r_0$ and $\rho_0$ versus the $M_B$ do not depend on the fact that a galaxy has developed a bar or not.

Compare the dynamic and kinematic proprieties of the local galaxies to the high redshift galaxies.
Thank you!