Rotation Curve decomposition in Search for a Dark Matter Model for Analog Galaxies

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1. What do we know about dark matter?

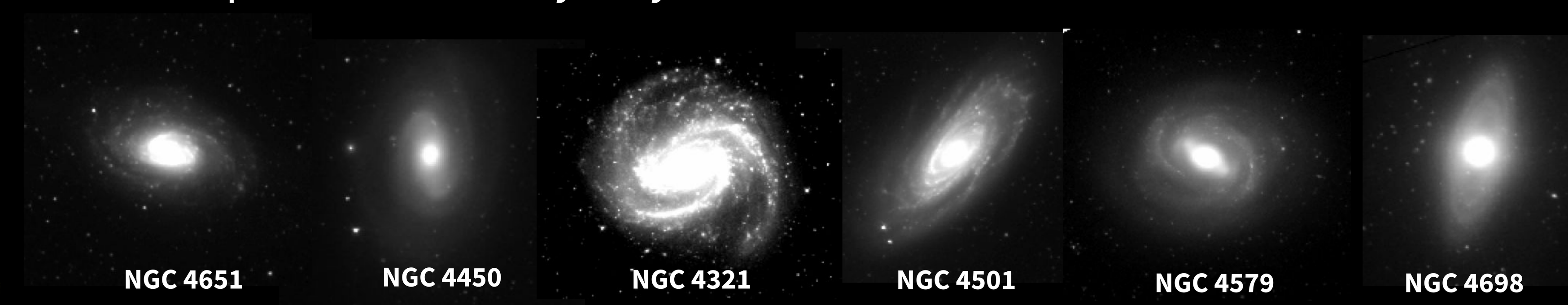
Thanks to contributions from space- and ground-based telescopes, we know that dark matter represents 85% of the total matter in the universe. Despite its predominance, dark matter is known for not interacting electromagnetically. Its presence, so far, is manifested through gravitational effects, where one of its most concrete evidence can be verified through the rotation curves (RC) of disk galaxies. The large-scale structure in the distribution of galaxies as well as the rotation dynamics present in the outskirts of galaxies are examples of phenomena that provide reasonable explanations based on the presence of dark matter.

→ Our sample

The sample is based on both the *Spitzer Survey of Stellar Structure in Galaxies* (S^4G; Sheth et al., 2010) and the *VLA Imaging of Virgo in Atomic gas* (VIVA; Chung et al., 2009). The objects were selected as such based on the maximum rotation velocity of the atomic hydrogen gas (HI) and morphological type similar to the Milky Way.

Object	Morphology	Hubble T-Type	Stellar mass $\left[\log_{10}\left(\frac{M_*}{M_\odot}\right)\right]$	Max. HI velocity $[km\,s^{-1}]$
NGC 4698	Sab	1.7	10.848	201.13
NGC 4501	Sb	3.3	11.184	272.19
NGC 4651	Sc	5.2	10.844	221.65
NGC 4321	SAB	4.1	10.931	283.57
NGC 4450	Sab	2.4	10.718	193.62
NGC 4579	SAB	2.9	11.098	248.63

Our sample is composed of 6 MWAs in the local universe (z < 0.01), no farther than ~20 Mpc from the Milky Way.



This project seeks to provide two main results:

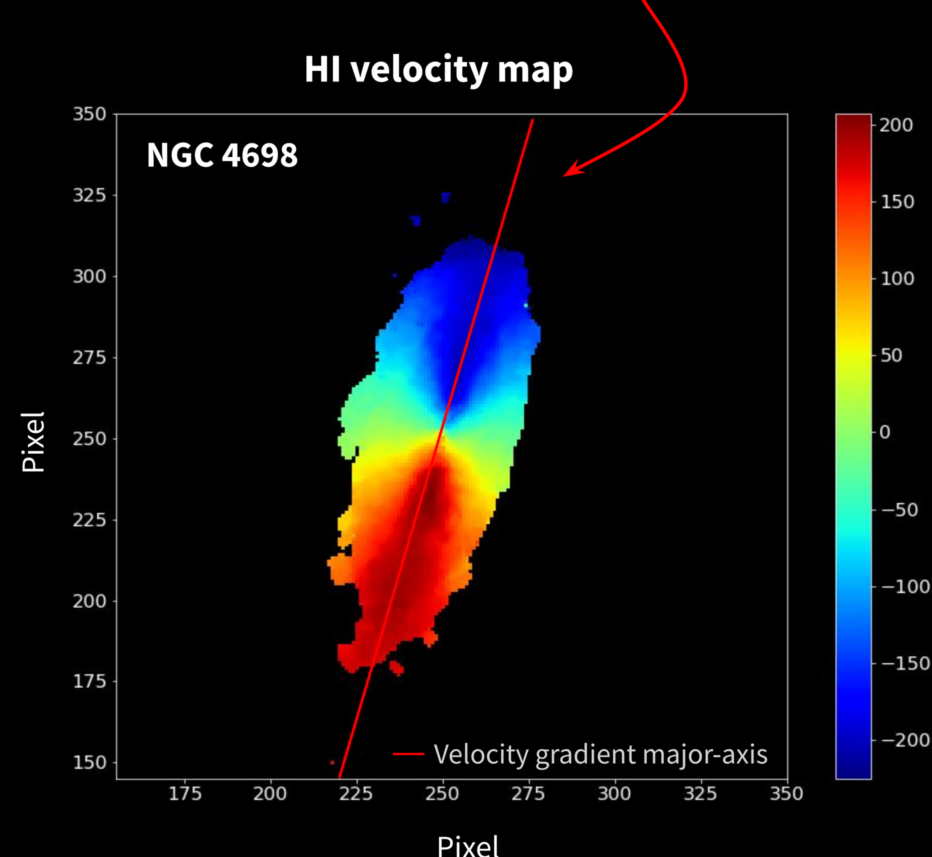
Model the distribution of dark matter in Milky Way analog galaxies

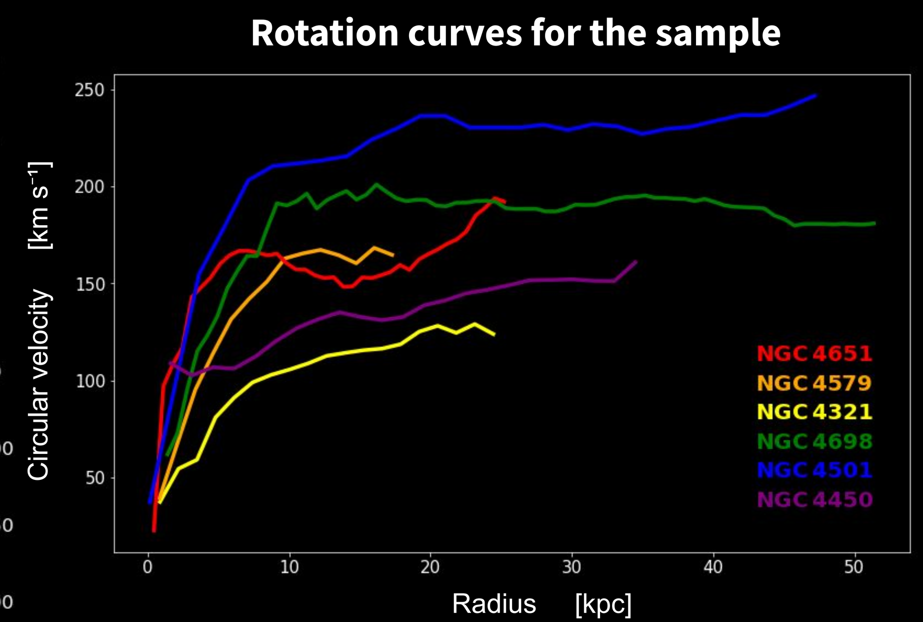
Estimate the local dark matter density using "mirror" galaxies

2. How do we do?

i. Deriving the rotation curves for our sample; the case of NGC 4698

To construct the rotation curves, we used atomic hydrogen datacubes from the VIVA survey. Our method is to trace the velocity profile along the line with the greatest velocity gradient on the HI velocity map.

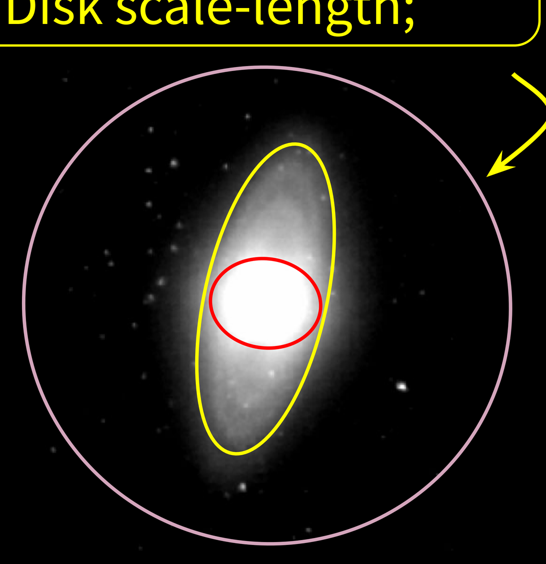




ii. Rotation curves decompositions and modeling

We decompose the RCs into the baryonic and dark matter components using our own developed fitting code in Python. In total, the code uses 5 parameters, two of which are free and found from the modeling.

→ Bulge + Disk masses;
→ Disk scale-length;



Disk: Kuzmin Profile

$$v^2_{disk}(r) = \frac{G\,M_d\,r^2}{(r^2+a^2)^{3/2}}$$

It has proven to be efficient for thin disk galaxies (Kuzmin 1956)

→ Halo mass parameter;
→ Halo scale radius.

Free parameters

Halo: Navarro-Frenk-White Profile (NFW)

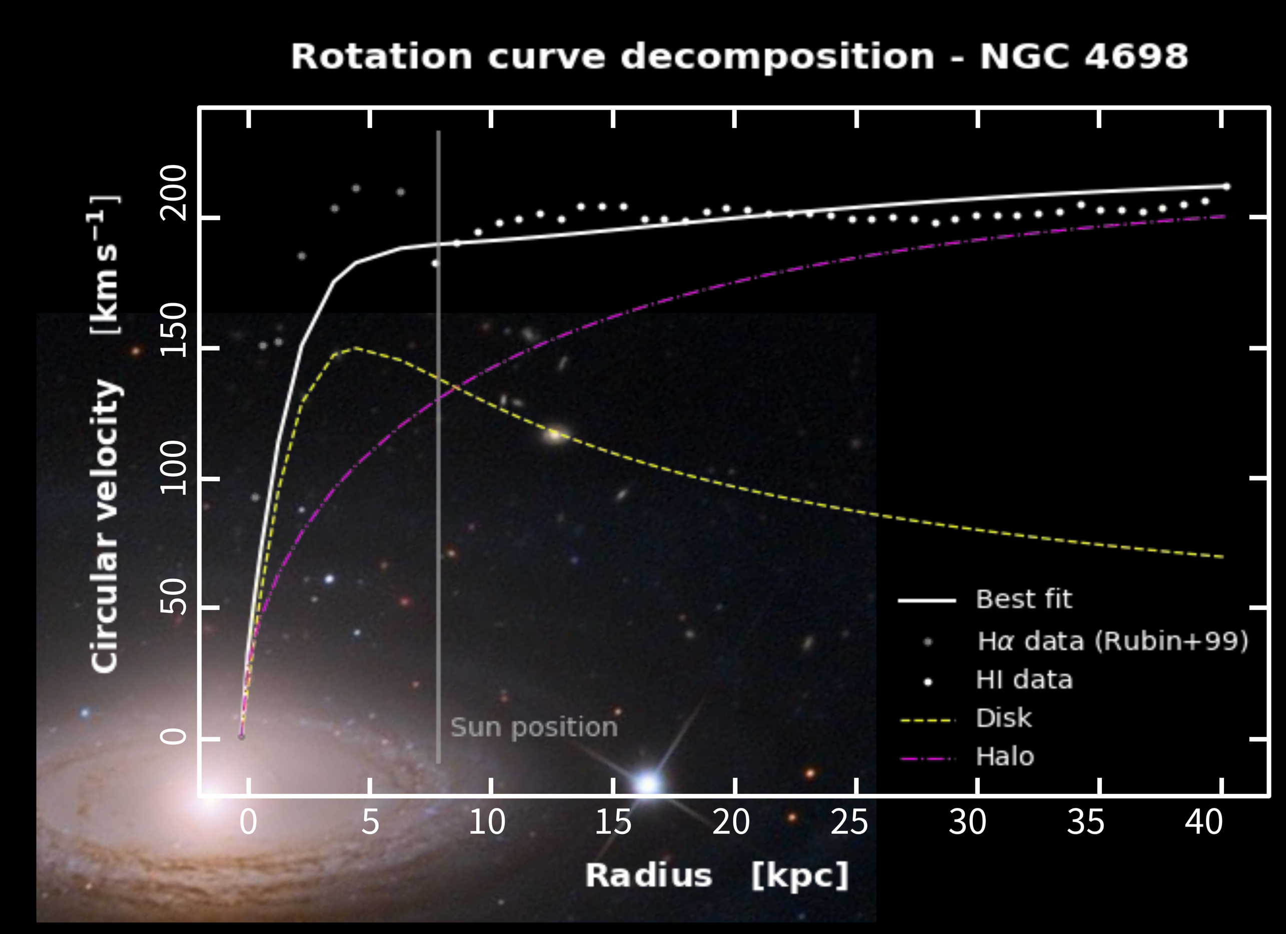
$$v^2_{halo}(r) = r\,\frac{2\,G\,M_h\,(r+r_s)\,\ln\left(\frac{r+r_s}{r}\right) - 2\,G\,M_h\,r}{r^3\,\ln(4) - r^2\,r_s - r^3}$$

3. Our findings

RC decompositions;

The mass of the bulge is considered in the modeling in order to assume it as an extension of the disk.

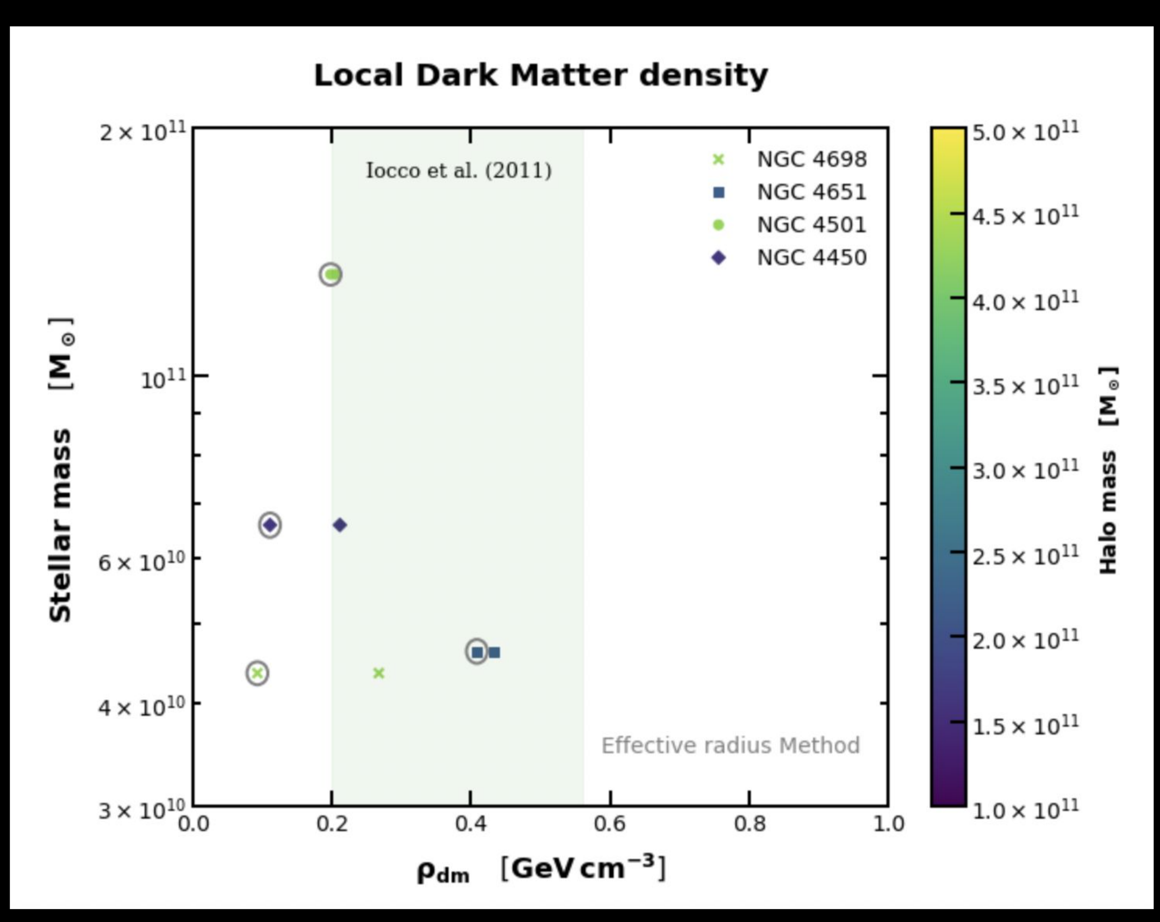
In the inner regions (dynamics governed by dispersion) the modeling returned more interesting results when we combined our HI data with Hα data obtained by Rubin (1999).



Two galaxies in the sample returned fitting problems due to a low amount of HI data and were momentarily left out.

A new approach to estimating the local DM density;

The local dark matter density was calculated using the parameters resulting from the modeling.



For each object the local DM density was calculated using two methods: Using (1) the effective radius and (2) half stellar mass. The first method returned smaller values in all cases. This may be related to an eventual underestimation of the effective radius of the objects. Our results are in strong agreement with previous results in the literature, such as Iocco et al. (2011).

Future work

Improve decomposition using code-to-object adaptation techniques;

Enlarge the sample;

Compare our estimates with simulations of MWAs in the local universe.

References

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