Local Dark Matter Density from Improved Local Mass Density of Stars and Updated Baryonic Model

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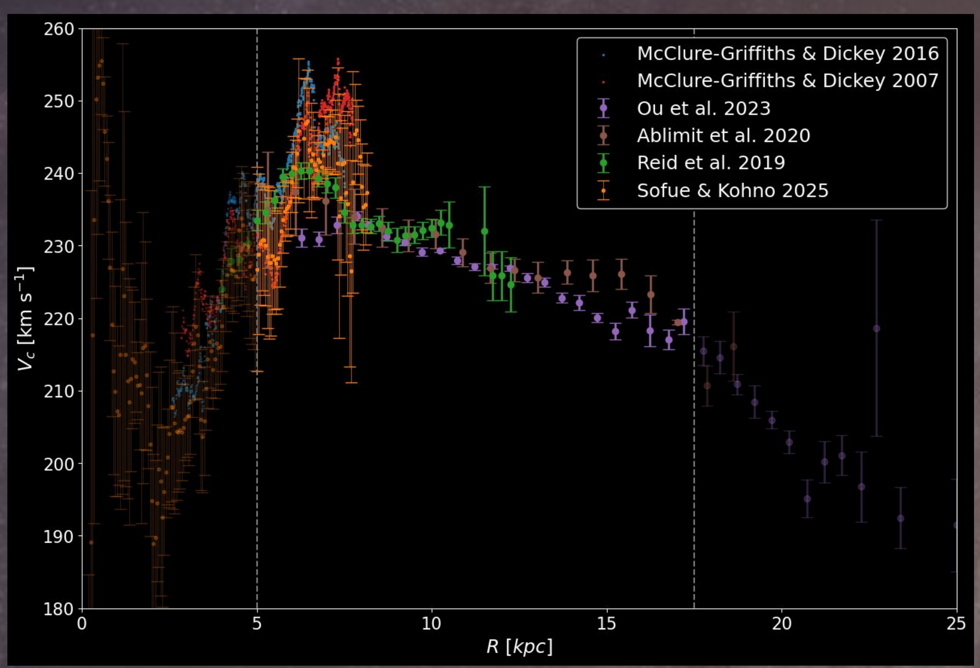
ABSTRACT

We present a new determination of the local dark matter density based on a comprehensive modeling of the Milky Way mass distribution, constrained by an updated Galactic rotation curve. Our analysis combines multiple independent tracers, which include masers, Cepheids, HI/CO gas, and red giant branch stars, thus allowing us to construct a homogenized rotation curve spanning a wide radial range. To mitigate well known systematics, we restrict the analysis to regions where the assumptions of axi-symmetry and dynamical equilibrium are reliable. A key aspect of this work is the explicit treatment of all the uncertainties related to the baryonic matter distribution. We adopted a fully parameterized model for the stellar and gaseous components of the Galaxy, allowing their properties to vary within observational constraints. The Galactic potential is computed using a flexible numerical approach, enabling exploration of a broad class of mass models.

ROTATION CURVE

- HI and CO terminal velocities (McClure-Griffiths & Dickey 2007, McClure-Griffiths & Dickey 2016, Sofue & Kohno 2025)
- Molecular masers (Reid et al. 2019)
- Classical Cepheids (Ablimit et al. 2020)
- Red Giant Branch stars (Ou et al. 2024)

R in the range [5;17.5] kpc



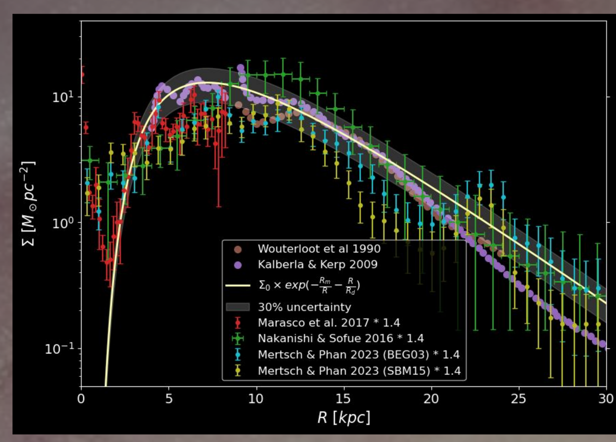
BARYON MODEL

Revised gas model

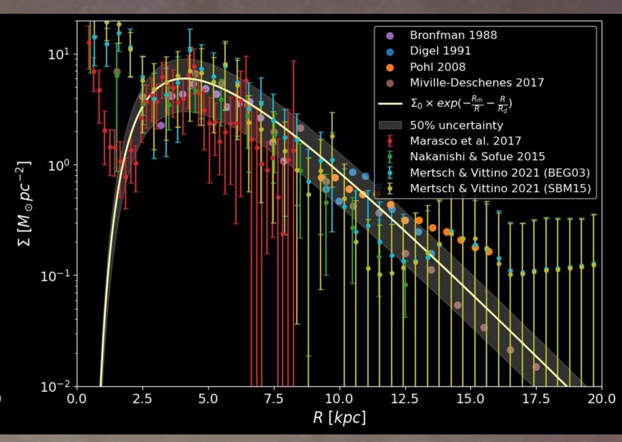
- Atomic gas disk with flaring
- Molecular gas disk with flaring
- Ionized gas disk (Jo et al 2019)

$$\Sigma = \Sigma_0 \times exp(-\frac{R_m}{R} - \frac{R}{R_d})$$

$$\rho(R,z) = \frac{\Sigma(R)}{4 \cdot h_z(R)} \times sech^2(\frac{z}{2 \cdot h_z(R)})$$



Atomic gas surface density



Molecular gas surface density

Star model with recent observations

- Thin disk with flaring (Vieira et al. 2023, Lian et al. 2025, Sanders & Binney 2015)
- Thick disk with flaring (Vieira et al. 2023, Lian et al. 2025, Tkachenko et al 2025)

$$\rho_i(R,z) = exp(-\frac{R - R_\odot}{h_R}) \times sech^2(\frac{z}{h_z})$$

Normalised to observationally derived Local Mass Density (Lutsenko et al. 2025)

- Bulge (Dehnen & Binney 1998)

$$\rho_b = \rho_{b0}\left(\frac{\sqrt{R^2 + (\frac{z}{q})^2}}{r_0}\right)^{-\gamma} exp\left(-\frac{R^2 + (\frac{z}{q})^2}{r_t^2}\right)$$

Normalised to inner dynamical mass (Portail et al. 2016)

- Halo (Deason et al. 2011)

DM HALO MODEL

NFW profile (Navarro, Frenk and White 1997)

$$\rho(r) = \frac{\rho_0}{\frac{r}{r_s}(1 + \frac{r}{r_s})^2}$$

Einasto profile (Einasto 1965)

$$\rho(r) = \frac{M}{4\pi n h^3 \Gamma(3n)} exp(-(\frac{r}{h})^{1/n})$$

FITTING PROCEDURE

MODEL — Potential reconstruction with Agama (Vasiliev 2019)

Informed priors on baryonic model parameters + wide uniform priors for DM halo parameters

Component	Name	Unit	Range	Description
Atomic gas	Σ_{0gas1}	$M_\odot pc^{-2}$	[255.01; 473.59]	Amplitude of the atomic gas density profile
Molecular gas	Σ_{0gas2}	$M_\odot pc^{-2}$	[433.79; 1301.37]	Amplitude of the molecular gas density profile
Stellar disks	h_R	kpc	[3.1; 3.8]	Scale length of the thin stellar disk
Stellar disks	h_{z0}	kpc	[0.27, 0.29]	Scale height of the thin stellar disk at $R_\odot$
Stellar disks	H_R	kpc	[1.9; 2.3]	Scale length of the thick stellar disk
Stellar disks	H_{z0}	kpc	[0.79, 0.81]	Scale height of the thick stellar disk at $R_\odot$
Stellar disks	f_T	–	[0.74, 0.76]	Fraction of thick-to-thin disk density at $R_\odot$
Stellar disks	ρ_{100}	$M_\odot pc^{-3}$	[0.031; 0.052]	Observed local stellar mass density within 100pc
Stellar halo	M_{st_halo}	$M_\odot \times 10^9$	[1.0; 1.8]	Total mass of the stellar halo
Bulge	M_{box}	$M_\odot \times 10^9$	[18.0; 19.0]	Normalization of the internal mass
NFW DM Halo	r_s	kpc	[0.1; 100.0]	Scale radius of NFW profile
NFW DM Halo	M_{NFW}	$M_\odot \times 10^6$	[0.1; 100.0]	Mass enclosed within approximately 5.3 scale radius
Einasto DM Halo	$M_{Einasto}$	$M_\odot \times 10^11$	[0.1; 100.0]	Total mass of Einasto DM halo
Einasto DM Halo	h	kpc	[0.1; 100.0]	Scale radius of Einasto DM halo
Einasto DM Halo	n	–	[0.1; 10.0]	Einasto index

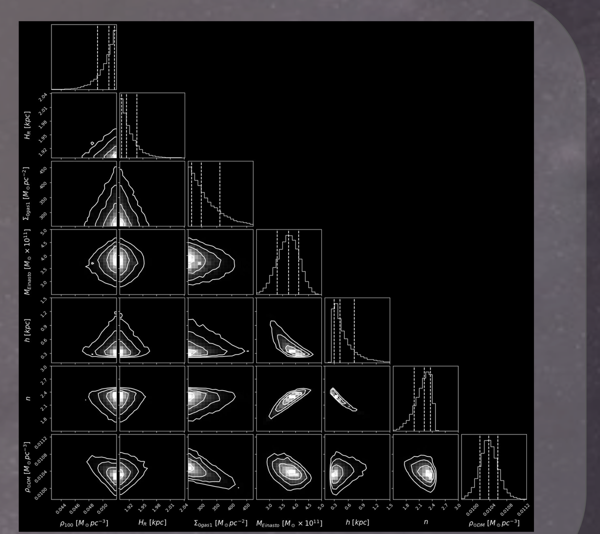
DATA

We combine rotation curve measurements from different tracers into a single dataset. Individual measurements were binned with bin size of 0.5 kpc, with per-bin weighting adjusted to give equal statistical impact across datasets

SAMPLING — Nested sampling (nautilus Lange 2023)

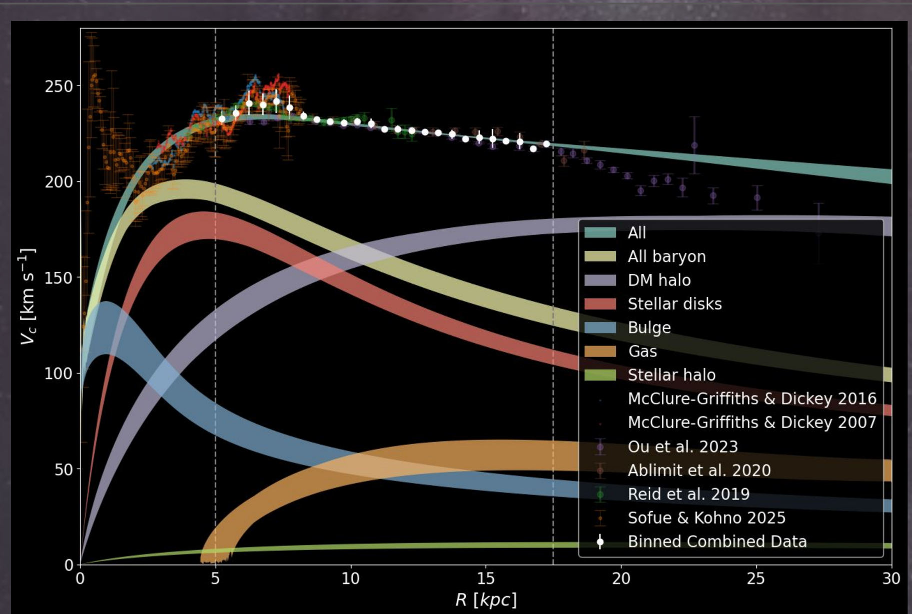
Gaussian likelihood

$$logL = -\frac{1}{2}\sum_i\left(\frac{(x_i-\mu_i)^2}{\sigma_i^2} + ln(2\pi\sigma_i^2)\right)$$

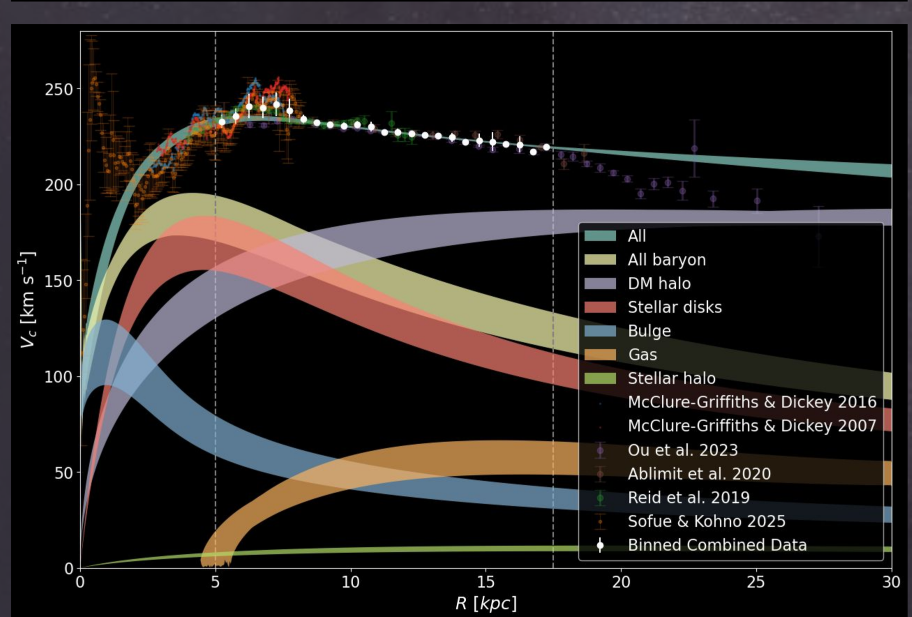


RESULTS

Einasto



NFW



NFW DM Halo	r_s	kpc	$12.61^{+1.37}_{-1.55}$	–
NFW DM Halo	$M_{\rm NFW}$	$M_\odot \times 10^6$	$17.91^{+5.44}_{-3.23}$	–
Einasto DM Halo	$M_{\rm Einasto}$	$M_\odot \times 10^{11}$	–	$3.73^{+0.40}_{-0.43}$
Einasto DM Halo	h	kpc	–	$0.43^{+0.31}_{-0.13}$
Einasto DM Halo	n	–	–	$2.21^{+0.15}_{-0.23}$

Local density DM

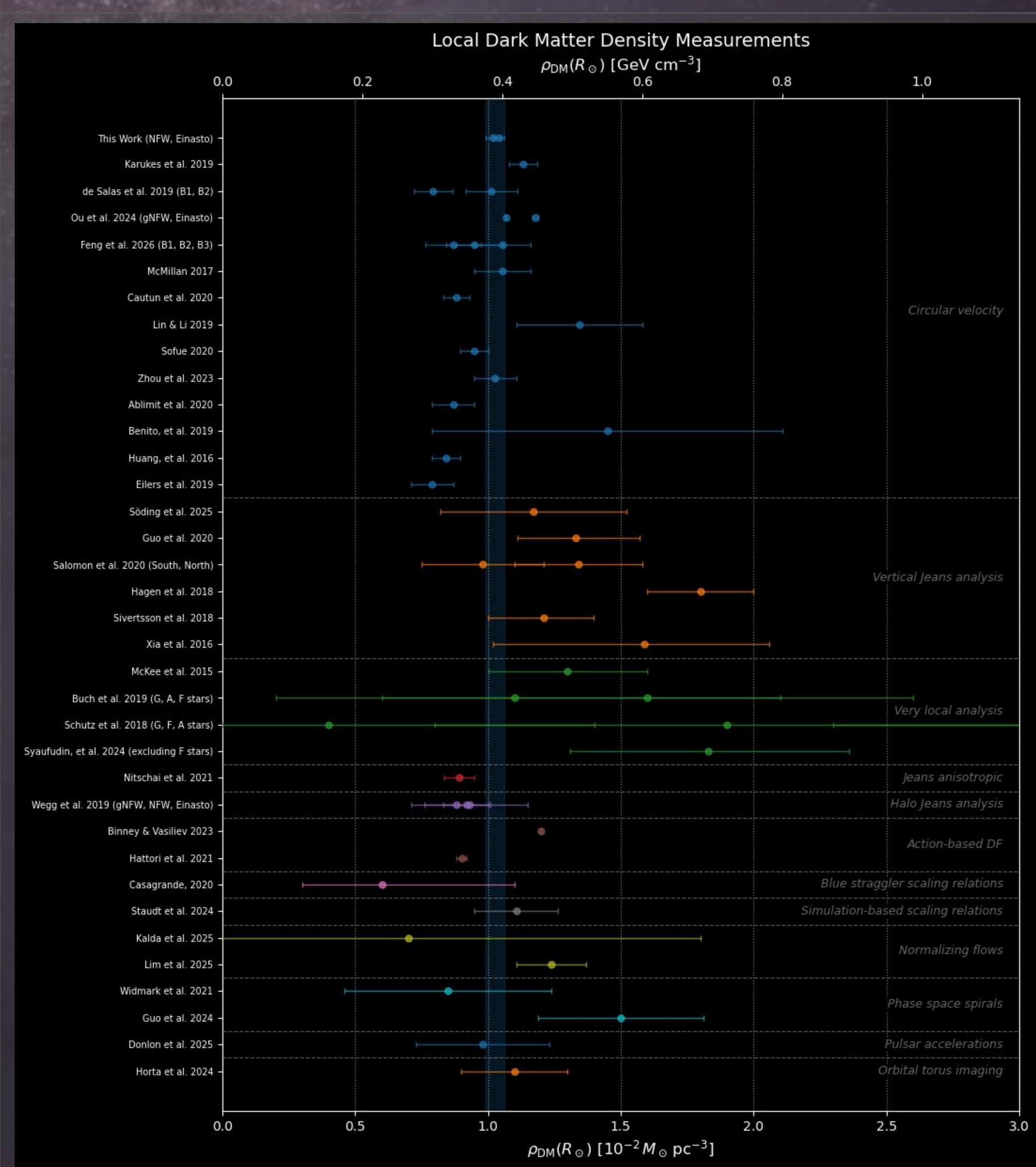
Einasto

0.0104 ± 0.0002 M⊙ pc^{-3} (0.395 ± 0.008 GeV cm^{-3})

NFW

0.0102 ± 0.0003 M⊙ pc^{-3} (0.387 ± 0.011 GeV cm^{-3})

LITERATURE COMPARISON



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Lutsenko et al. 2026 (in prep.)

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