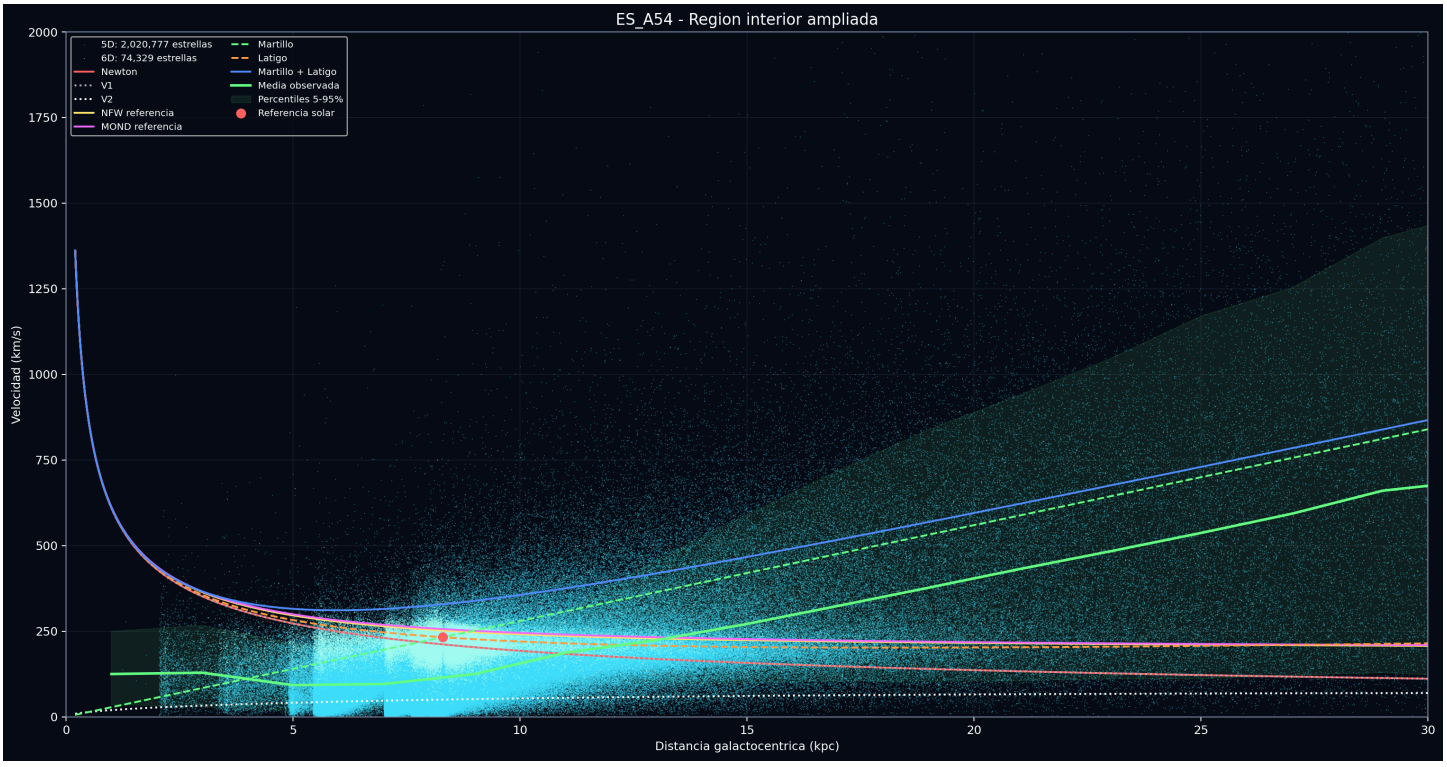
Gaia and the Martillo model: the complete series

Víctor Estrada Díaz · Einstein-VED · November 2026

Eight articles with figures and methods.

3,000,000 records examined · 2,095,106 stars in the comparison.

Comparative transition: approximately 23 kpc using MAE and 19 kpc using RMSE.



Inner region: 0–30 kpc and 0–2,000 km/s. Transverse bounds and spatial speeds calculated from Gaia observations.

Author's work: https://estradad.es/ · Terms: https://estradad.es/licencia.php.
Observational data: ESA/Gaia and the Gaia collaboration.

Reading guide and comparison update

This volume brings together the eight original articles, translated into English. The subsequent ES_9 comparison tested 26 variants: between 30 and 200 kpc, the absolute difference |Martillo – Látigo| reduces MAE from 759.081 to 721.491 km/s (4.952%). Over 0–200 kpc, |Martillo – V2| reduces it from 136.868 to 96.128 km/s (29.766%). V2 explicitly incorporates c; Látigo uses a different parameterization.

The articles retain the account of the original comparison stage. The new combinations improve its comparative results; interpreting this as gravitational disconnection requires a dynamical law. The physical thesis is attributed to the author and distinguished from the scope of the numerical comparison.

Figures: the original Spanish figures are retained as graphical fallbacks. Their English captions explain their meaning; numerical values, formulas, and observational records are unchanged. “Martillo” means “Hammer” and “Látigo” means “Whip”; their Spanish model names are retained throughout.

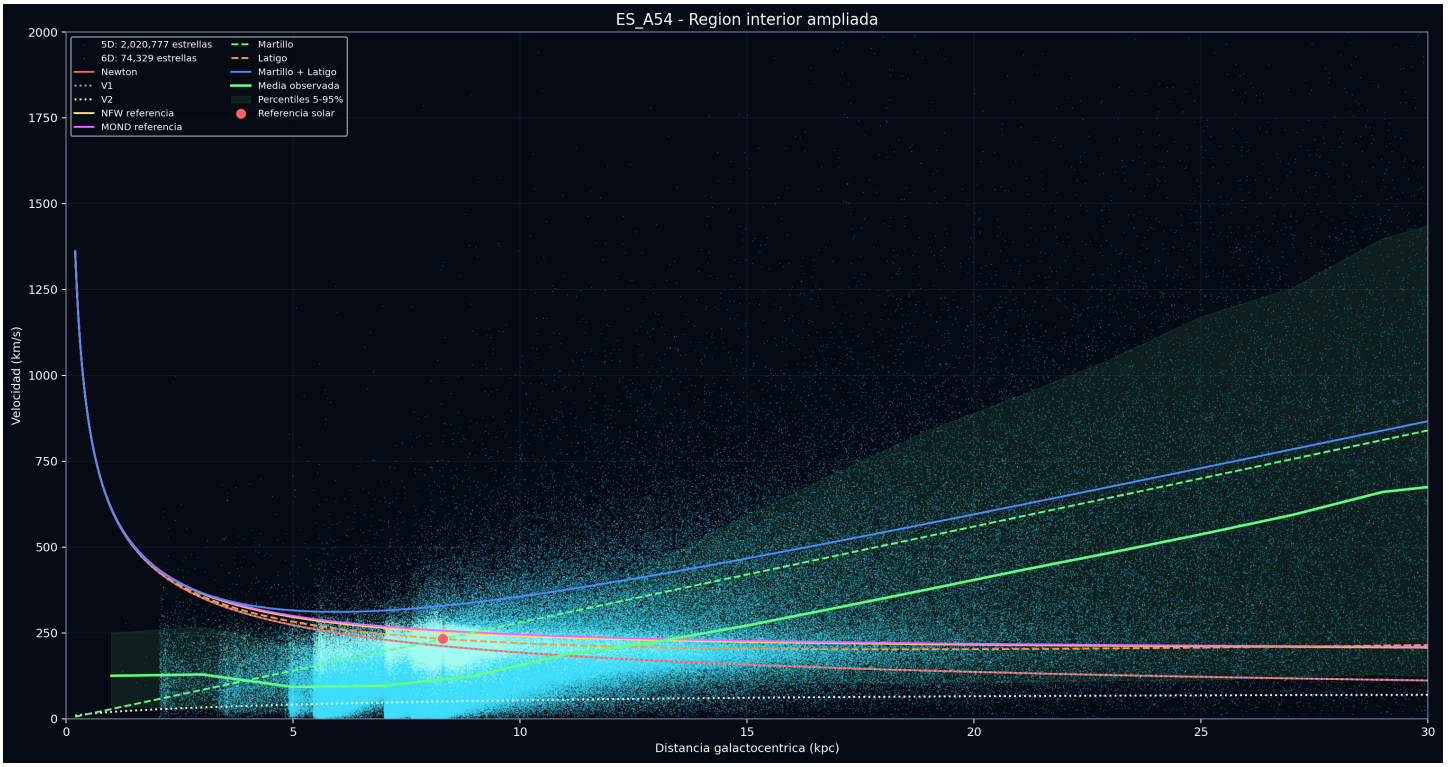
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Gaia challenges the velocity models: more than two million stars

Gaia and the Martillo model · Article 1 of 8

Víctor Estrada Díaz · November 2026



Inner region: 0–30 kpc on the horizontal axis and 0–2,000 km/s on the vertical axis. Points represent quantities calculated from Gaia observations; lines show the models implemented in the program.

What if dark matter were a mistaken interpretation of the galactic-velocity problem? That is the thesis I propose investigating in light of my Gaia analysis.

I have worked with **3,000,000 Gaia DR3 records**. Of these, 2,102,124 allow the kinematic quantity used in my study to be calculated. The plotted and compared sample contains **2,095,106 stars**.

My argument is direct: models must confront individual stars and their velocity distribution, as well as average curves.

When comparing each star with Newton, NFW, and MOND, using the specific formulations and parameters in my program, I find an increasing discrepancy in the outer regions. **My Martillo model has the lowest comparative error in those regions.**

The change in comparative behavior can be located numerically: approximately **23 kpc from the Galactic center** using mean absolute error, and **19 kpc** using root mean square error. These values come from calculating residuals for each star and grouping them by distance.

The question I raise in the context of Vera Rubin's work

The work of **Vera Rubin and Kent Ford** on galactic rotation was fundamental to establishing the dark-matter halo interpretation. The idea of dark matter predates Rubin; attributing its first historical observation to her would be incorrect.

My thesis is that this interpretation of the velocities may have identified the wrong cause. **I propose that invoking dark matter to explain those observations may have been an interpretive error, and that Gaia's data require the question to be reopened.**

The quantitative result of this work is specific: with the parameters used, Martillo is closer to the represented speeds in the outer intervals examined. The historical and physical conclusion about dark matter is the thesis I submit for testing on the basis of that result.

Which velocities are being compared?

I study velocities **as a function of Galactocentric radius**. Most stars in this sample lack spectroscopic radial velocities: for them I calculate a Galactocentric transverse bound. For stars that have radial velocities, I calculate a three-dimensional speed.

The question opening this series is clear: **which explanation better reproduces the result of comparing the predictions with the stars in this sample?**

The following articles present the data, calculations, models, errors, and transition point.

#GaiaDR3 #DarkMatter #VeraRubin #Astrophysics #EinsteinVED

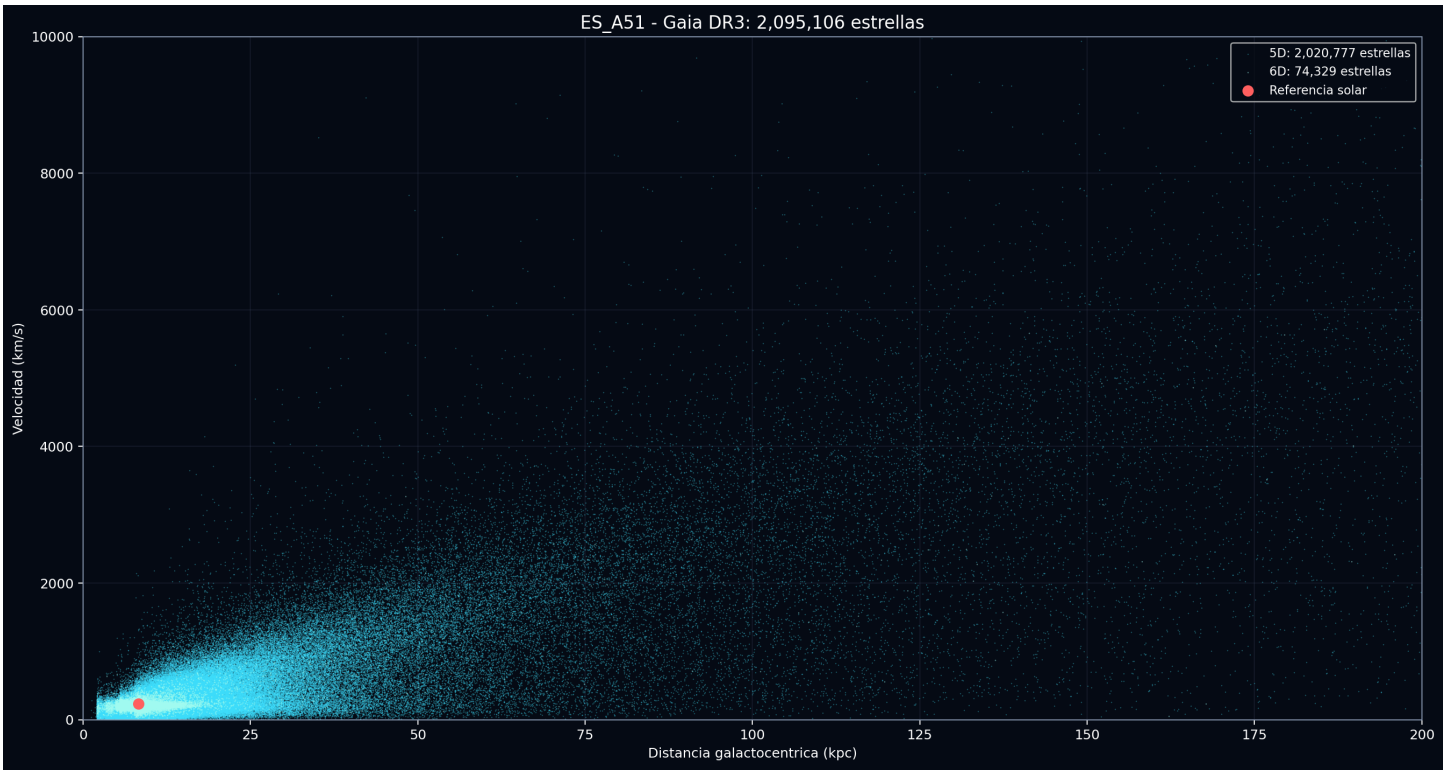
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Three million records: the numbers supporting the comparison

Gaia and the Martillo model · Article 2 of 8

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The plotted sample contains 2,095,106 stars. The axes extend to 200 kpc and 10,000 km/s; the original records remain preserved.

Before discussing a physical interpretation, we need to know exactly what the sample contains.

My study starts with **3,000,000 Gaia DR3 records**. The program preserves the original observations and builds a table of calculated results.

The audit gives the following figures:

- **2,102,124 stars** have the five necessary observations and finite calculated results.
- **74,355** of those stars also have radial velocities.
- **2,095,106 stars** fall within the interval used for the figures and comparison: radius up to 200 kpc and represented speed up to 10,000 km/s.
- This final sample contains **2,020,777 stars without radial velocities** and **74,329 with radial velocities**.

Calculations outside the plotted interval remain in the complete table. Changing an image's framing preserves the original records.

What “each point is a star” means

In figures A51, A53, and A54, each point corresponds to a transformed observational row. Positions and proper motions come from the catalogue; the displayed distances and speeds are calculated from those observations.

This requires distinguishing an observed quantity from a derived one. Gaia provides parallaxes, proper motions, and, for part of the sample, radial velocities. My program performs the transformation to the Galactocentric frame.

Two scales for examining the same problem

The overview figures extend to **200 kpc and 10,000 km/s**. A54 enlarges the region spanning **0–30 kpc and 0–2,000 km/s**.

The A54 framing helps reveal the inner structure. The error calculation retains the comparison sample out to 200 kpc and 10,000 km/s; it is not truncated by the enlargement's vertical limit.

One detail must remain visible: the CSV used lacks `parallax_error` and `ruwe`. Therefore, A52 shows the full sample and states this in its title. Its filename retains an earlier “Gold Filter” designation, but **that quality filter has not been applied in this run**.

These are the exact numbers and scope on which my comparison is built.

#GaiaDR3 #OpenData #Astrometry #Reproducibility

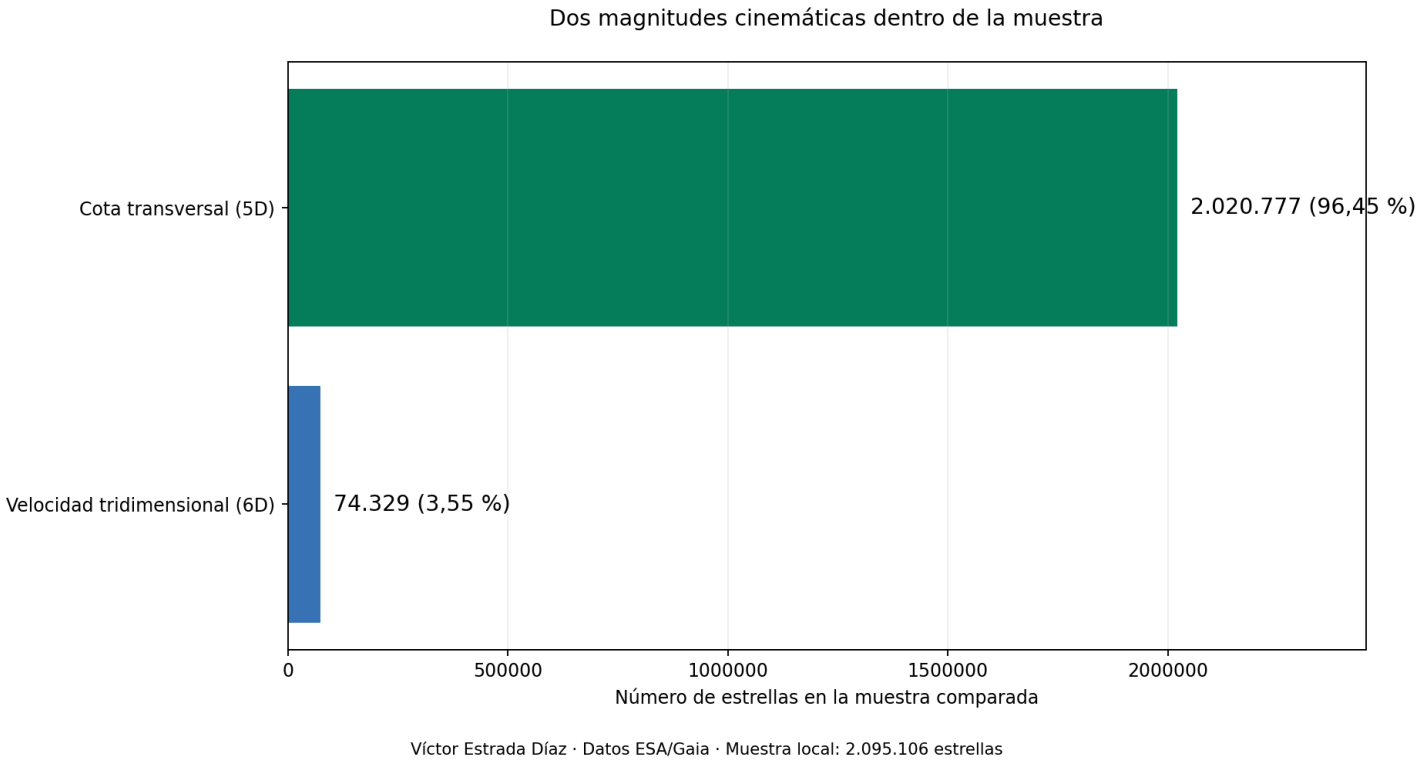
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Which speed do I calculate for each star, and why does it matter?

Gaia and the Martillo model · Article 3 of 8

Víctor Estrada Díaz · November 2026



Composition of the compared sample. 5D: calculated transverse bound; 6D: calculated three-dimensional speed.

A missing radial velocity does not leave a star without kinematic information.

Position, parallax, and proper motions allow an estimate of the transverse component of velocity in the Galactocentric frame. When radial velocity is available, the three-dimensional spatial speed can also be calculated.

For an orthogonal decomposition of the true vector:

$$v^2 = v_\perp{}^2 + v_\parallel{}^2$$

Therefore:

$$v \geq v_\perp$$

The unknown component does not reduce the true magnitude. This geometric relationship justifies studying stars without radial velocities through a transverse bound.

The precision of the calculated bound depends on observational precision and the transformation used. The geometric inequality does not turn an estimate with errors into an exact bound on the true value.

How my sample is constructed

The program uses an explicit solar position and velocity, transforms the observations to the Galactocentric frame, and calculates:

- A transverse quantity for stars without radial velocities.
- A three-dimensional speed for stars with radial velocities.

The comparison sample contains **2,020,777 cases of the first type** and **74,329 of the second**. This difference in size is crucial to interpreting the combined results.

A star's radius and its radial velocity are different quantities

The figures' horizontal axis is distance from the Galactic center. Plotting a speed against that radius does not make it a radial component.

Throughout this series, I refer to **speeds calculated from Gaia as a function of Galactocentric radius**. This defines the quantity confronted with the models.

The consequence for the comparison

The two populations can be examined together and separately. The combined comparison primarily describes the population without radial velocities, because it accounts for approximately 96.45% of the stars in the sample.

The 23 and 19 kpc thresholds reappear in the 5D population. No sustained threshold has been established for the 6D population under the same criterion: the outer bins contain fewer records and do not support automatically transferring the combined conclusion.

The available information deserves to be used with its precise meaning. That is the study's starting point.

#Gaia #StellarKinematics #Astrometry #MilkyWay

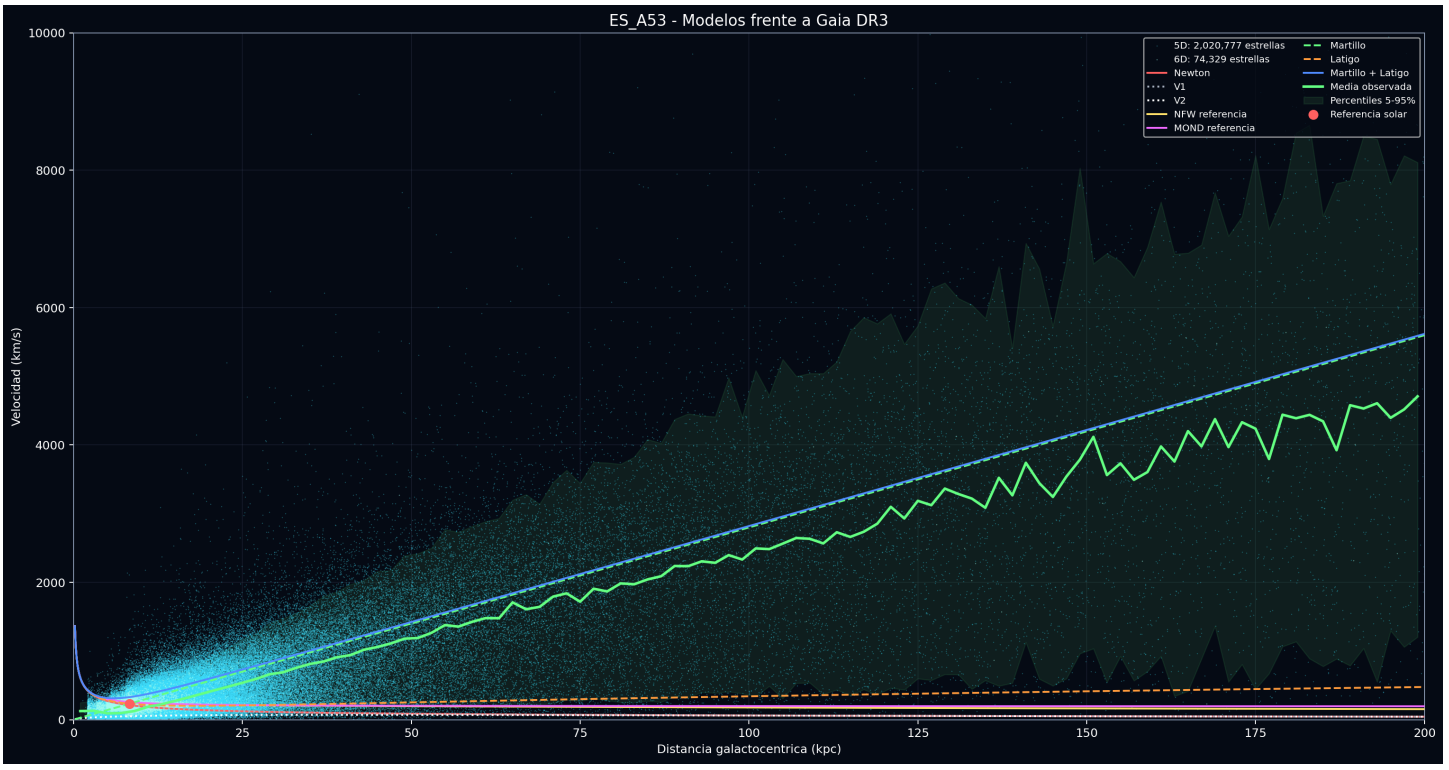
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Each star against the models: how the discrepancy is calculated

Gaia and the Martillo model · Article 4 of 8

Víctor Estrada Díaz · November 2026



Implemented velocity functions against the Gaia sample. Errors are calculated at each star's radius, rather than by visually measuring the separation between curves.

The comparison presented here evaluates each model at each star's radius.

For a star i, the program has a Galactocentric radius r_i and a represented speed v_i. Each model produces its prediction v_model(r_i). The residual is:

$e_i = v_i - v_model(r_i)$

Errors are calculated from those individual residuals and then grouped into distance bins. This allows the change in comparative behavior to be located.

Which models enter the calculation?

The program includes Newton, V1, V2, a reference NFW halo, MOND, Martillo, Látigo, and Martillo + Látigo.

The comparison with conventional models uses the specific versions implemented: a Newtonian reference with fixed baryonic mass, an NFW halo with explicit parameters, and a MOND formulation also defined in the code.

These parameters remain fixed during the comparison. They have not been optimized separately to minimize this sample's errors.

The result therefore refers to these implementations. The label “Newton” in a legend is not equivalent to ruling out every Galactic model constructed with Newtonian gravity.

Two ways of measuring error

Mean absolute error, MAE, averages the magnitudes of the differences. **Root mean square error, RMSE**, penalizes large differences more strongly.

Both provide information. When their transition points differ, that difference shows how the residual distribution influences the ranking.

Which quantities are being compared?

The program's conventional curves describe reference circular speeds. The observational column combines spatial speeds and transverse bounds. The residual calculation is reproducible, but its physical interpretation must retain that distinction.

A more complete test needs to project a stellar population model's predictions into the same observable, including the sample's selection and uncertainties. The present comparison identifies where the implemented functions are closer to or farther from the represented quantity.

The finding I present is quantitative: **the models' ranking changes with distance, and Martillo gains an advantage in the outer regions analyzed**.

#GravitationalModels #GaiaDR3 #DataAnalysis #ScientificMethod

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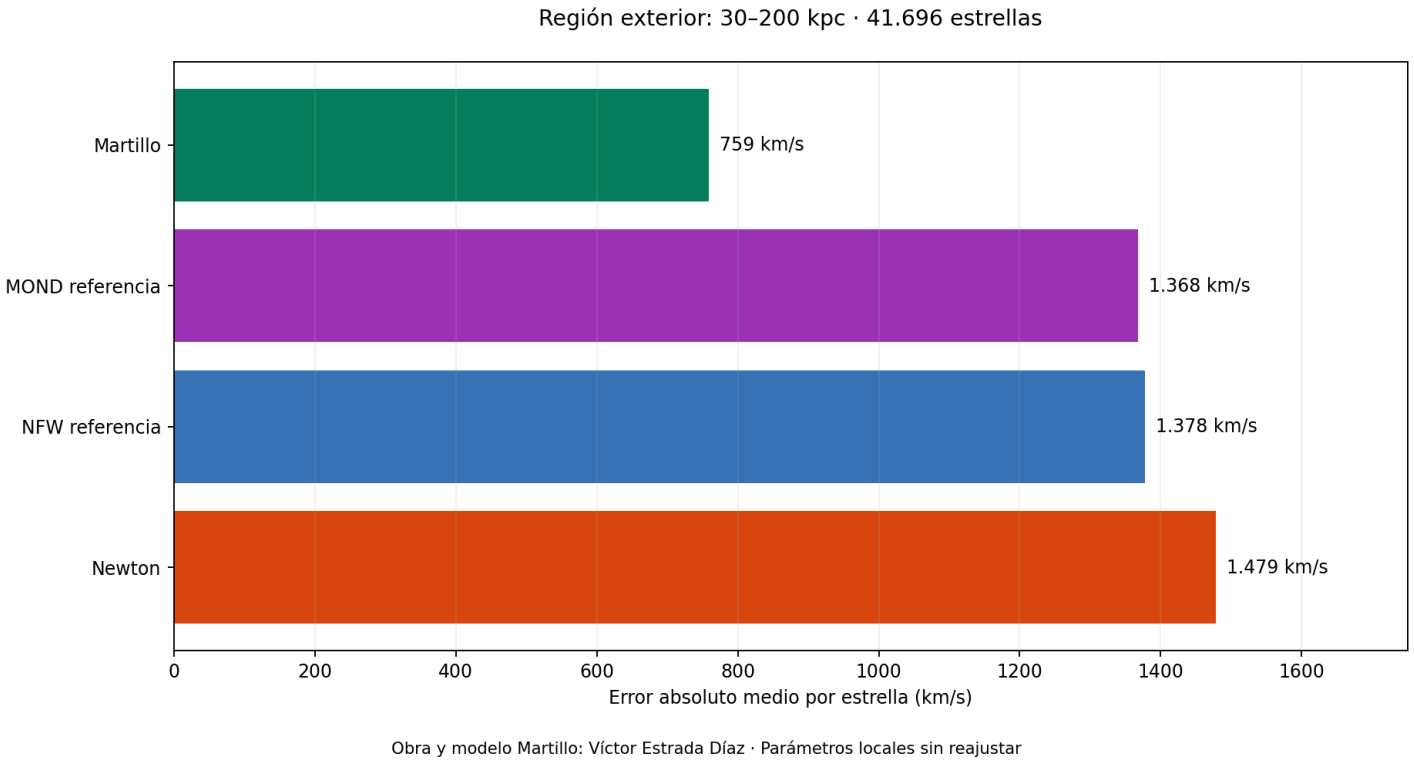
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Martillo: the hypothesis and its outer-region result

Gaia and the Martillo model · Article 5 of 8

Víctor Estrada Díaz · November 2026



Mean absolute error calculated per star between 30 and 200 kpc. A lower value means a closer approximation to the represented quantity in this sample.

My Martillo proposal introduces a speed that increases with radius.

The kinematic formulation used in the program is:

v_Martillo(r) = ωr

The effective angular speed is set using the solar reference adopted in the study:

ω = 232.24 / 8.3 ≈ 27.98 km/s per kpc

My interpretation connects this proposal to motion in a rotating system and the transfer of motion. That physical interpretation needs a dynamical development explaining its origin and conditions of applicability.

The comparison presented here uses the formula as implemented. Its slope is fixed before calculating the sample's errors; it comes from the solar reference, rather than optimization across all residuals.

The result between 30 and 200 kpc

Within this interval, mean absolute error per star is approximately:

- **Martillo: 759 km/s.**
- **Reference MOND: 1,368 km/s.**
- **Reference NFW: 1,378 km/s.**
- **Reference Newton: 1,479 km/s.**

Martillo reduces MAE by approximately **44.5% compared with MOND**, **44.9% compared with NFW**, and **48.7% compared with Newton**, for these implementations and this sample.

The outer-region difference is present in the calculated stellar residuals, as well as being visible in the figures.

The advantage depends on the region

Martillo does not rank first throughout the inner interval. When 0–30 kpc is combined, other models achieve a lower MAE. The region near the Sun contains many more records and weighs particularly heavily in a combined average.

That is why I locate the comparison by distance. A global ranking can conceal precisely the change in behavior I am investigating.

What I argue from these numbers

I argue that Martillo is an alternative deserving deeper physical testing because of its comparative outer-region behavior.

The values still show substantial errors and a broad dispersion. “Better approximation” describes the ranking obtained; it does not mean that each star follows an exactly linear law.

The next article locates the radial transition using two different error measures.

#MartilloModel #EinsteinVED #GalacticDynamics #Gaia

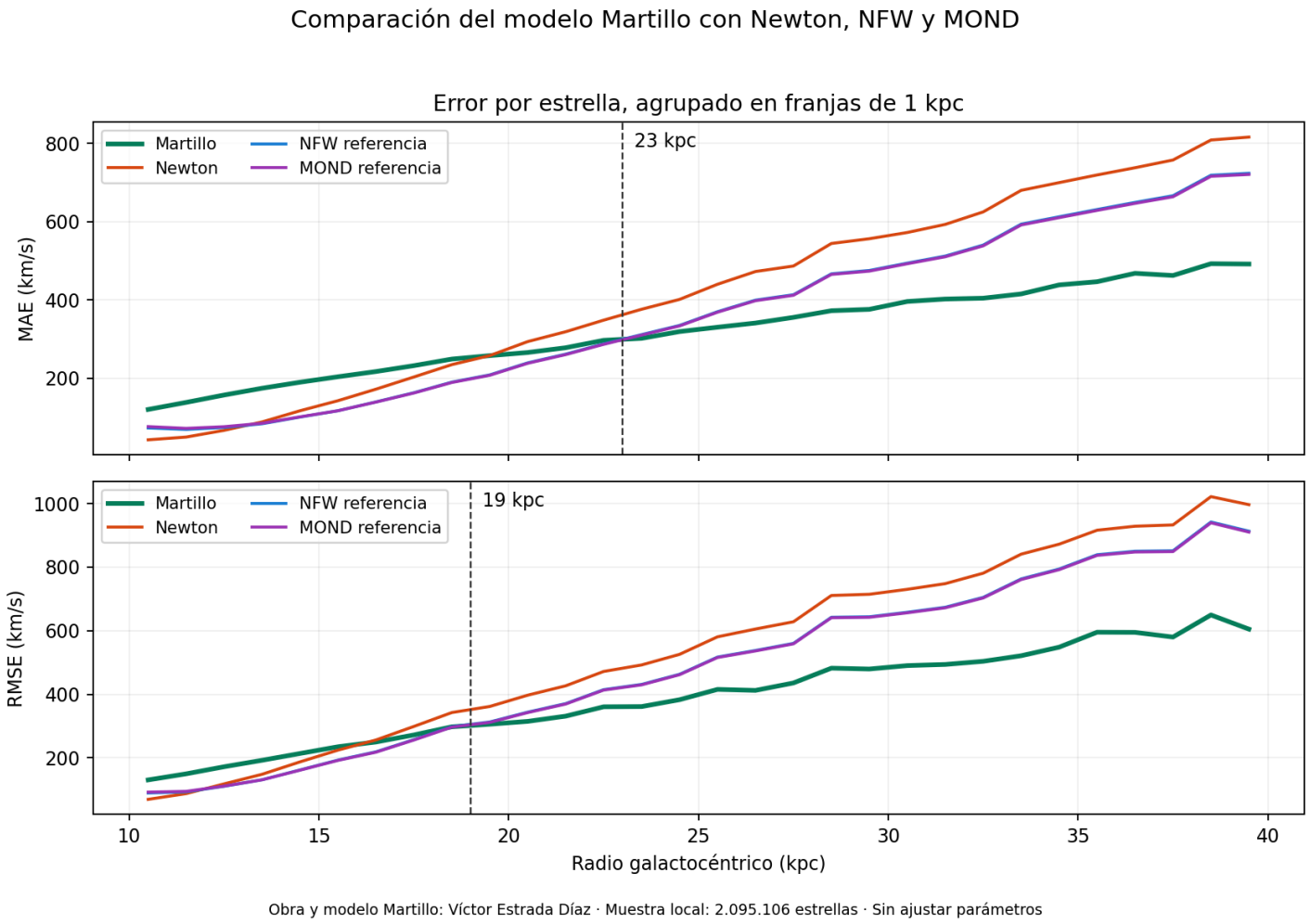
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23 kpc and 19 kpc: where the models' ranking changes

Gaia and the Martillo model · Article 6 of 8

Víctor Estrada Díaz · November 2026



Mean absolute error (top) and root mean square error (bottom), grouped in 1 kpc bins. Vertical lines mark the descriptive thresholds of 23 and 19 kpc.

I have calculated where Martillo's sustained advantage over Newton, NFW, and MOND begins in this sample.

The result depends on how error is measured:

- **MAE: approximately 23 kpc from the Galactic center.**
- **RMSE: approximately 19 kpc from the Galactic center.**

These are Galactocentric radii, not distances from Earth.

How I located the change

I calculate each star's residual against each model and group the results into distance bins. Under this criterion, a bin is valid if it contains at least **100 stars**.

The sustained threshold is placed after the last valid bin in which Martillo fails to outperform all three conventional models simultaneously.

Using **0.5 and 1 kpc bins** gives matching results: 23 kpc for MAE and 19 kpc for RMSE. With 1 kpc bins, the advantage over Newton, NFW, and MOND persists in every subsequent bin out to 100 kpc.

Values on either side of the crossing

Between **22 and 23 kpc**, Martillo's MAE is about **297 km/s**, compared with **287 km/s** for MOND. MOND retains the advantage in that bin.

Between **23 and 24 kpc**, Martillo yields about **302 km/s**, MOND **310 km/s**, NFW **311 km/s**, and Newton **376 km/s**. The ranking changes.

For RMSE, the sustained change appears earlier: between **19 and 20 kpc**, Martillo yields about **306 km/s**, compared with **311 km/s** for MOND, **313 km/s** for NFW, and **362 km/s** for Newton.

Why are there two thresholds?

RMSE gives more weight to large residuals. Martillo's advantage appears earlier under that weighting. MAE responds differently to the collection of differences and places the change farther out.

With 2 and 5 kpc bins, the MAE threshold moves to 24 and 25 kpc; the RMSE threshold moves to 18 and 20 kpc. This variation requires describing the result as an approximate transition.

Between 100 and 200 kpc, some narrow bins contain few records. With **5 kpc bins**, every bin between 25 and 200 kpc meets the 100-star minimum, and Martillo outperforms Newton, NFW, and MOND on both metrics.

The comparative transition is a calculated result. Its physical meaning is the next question to resolve.

#GaiaDR3 #MartilloModel #Statistics #Gravitation

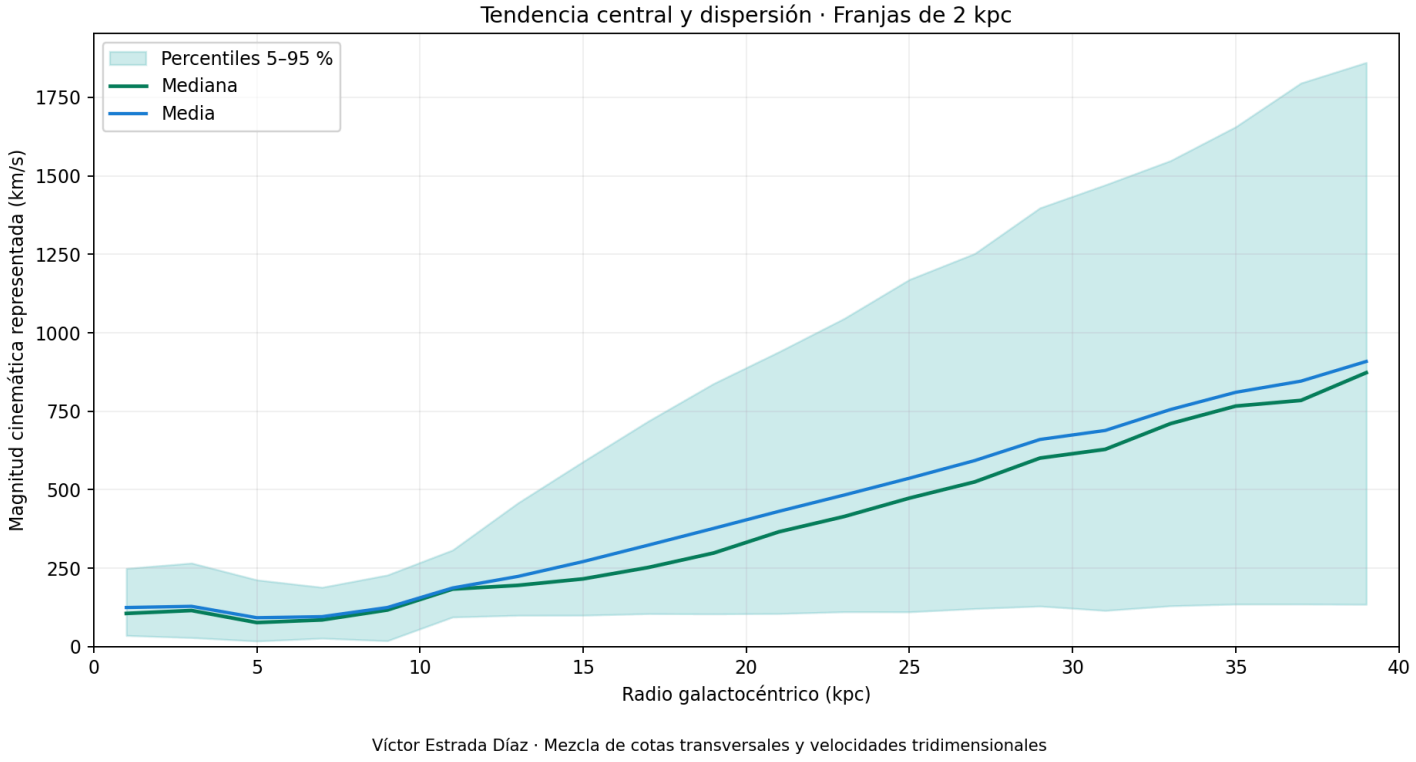
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The dispersion also requires an explanation

Gaia and the Martillo model · Article 7 of 8

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Median and percentiles of the represented quantity, calculated in 2 kpc bins. The band describes the dispersion of values, not uncertainty in the median.

The velocity cloud contains information that an average curve does not fully summarize.

In my figures, stars at similar Galactocentric radii have different values of the represented kinematic quantity. The distribution opens out toward the sample's outer regions.

My argument is that a physical explanation must confront that distribution as well as its central tendency.

Each layer of the figure has a meaning

The cyan points correspond to individual stars. The observed-mean line summarizes radial bins. The 5th–95th percentile band describes the distribution of values within those bins.

The band's boundaries are constructed by connecting summaries calculated every 2 kpc. Their corners arise from that statistical representation. They are not stellar trajectories or demonstrated physical discontinuities.

Distance and speed share a source of uncertainty

The program estimates distance by inverting parallax. That distance also enters the conversion of proper motions to speed. A small or uncertain parallax can therefore affect both axes simultaneously.

Consequently, a structure in the radius–speed plane may combine real dynamics, geometry, observational selection, and error propagation. Its appearance alone does not identify a unique cause.

The comparative result remains the result obtained

These questions do not erase the calculation: **in the outer intervals studied, Martillo achieves lower comparative errors than the Newton, NFW, and MOND references**.

Determining why it gains this advantage requires investigating which part remains when uncertainties, selection, and sample composition are controlled.

The catalogue used lacks the columns required to apply the planned astrometric-quality filter. At this stage, errors have been calculated without uncertainty weighting or a statistical-significance test.

The next comparison

I propose repeating the analysis with quality information and covariances, distance estimates appropriate to each parallax regime, separate 5D and 6D populations, and predictions projected into the same observable.

The reference models must also be fitted and tested under comparable criteria. This will allow the fraction of the current advantage attributable to a more accurate dynamical description to be measured.

The discrepancy has been identified. The next task is to explain its origin.

#GalacticKinematics #Uncertainty #Gaia #ReproducibleScience

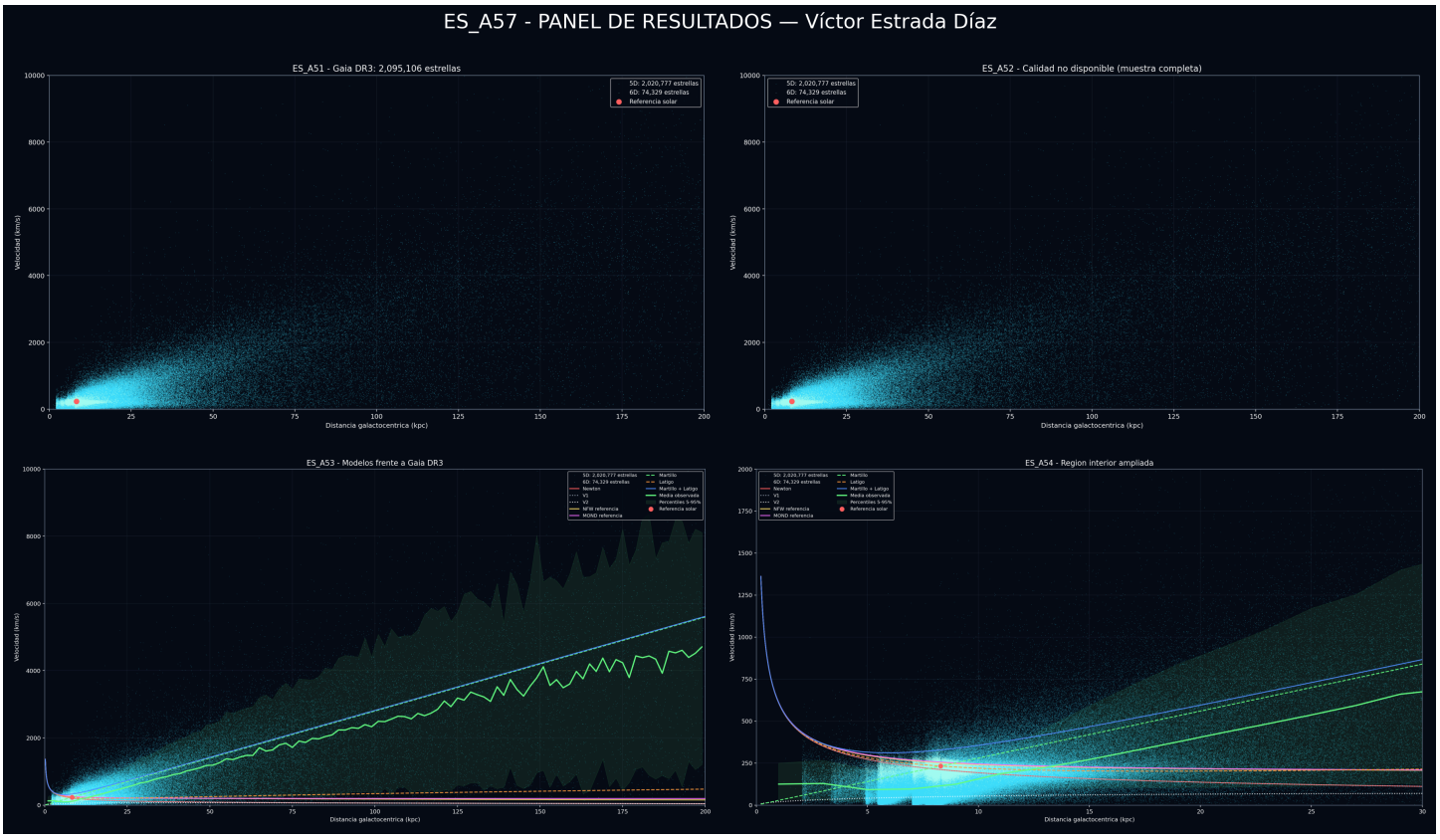
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An invitation to test the Martillo model against the data

Gaia and the Martillo model · Article 8 of 8

Víctor Estrada Díaz · November 2026



Panel containing A51, A52, A53, and A54. A52 represents the full sample because the quality-filter columns are missing; A54 uses limits of 30 kpc and 2,000 km/s.

I present a result that can be reproduced and discussed numerically.

My Gaia analysis finds that, in this sample and with the implemented functions, Martillo outperforms the Newton, NFW, and MOND references in outer regions.

The approximate transition points are **23 kpc using mean absolute error** and **19 kpc using root mean square error**. The calculation evaluates each model at each star's radius and then groups the residuals.

Between 30 and 200 kpc, Martillo's MAE is approximately **759 km/s**, compared with 1,368 for MOND, 1,378 for NFW, and 1,479 for Newton.

My interpretation

I maintain that these results justify examining Martillo as a possible alternative contribution to explaining Galactic dynamics.

My thesis questions the interpretation of velocities that led to attributing part of the phenomenon to dark matter. The comparison presented addresses this kinematic problem; it is not an evaluation of all astronomical and cosmological evidence associated with dark matter.

The discussion must preserve both the strength of the comparative result obtained and the scope of the test actually performed.

The central thesis: finite propagation and response time

As the author, I consider a central issue to be the dynamical consequences of gravitational and spacetime-geometry changes propagating at a finite speed. My hypothesis is that the stationary approximations used in this comparison may omit effects relevant to stellar speeds. This is the physical motivation I propose examining for Martillo and the propagation variants.

The timescales can be calculated. For a change crossing a distance d at speed c, the approximate crossing time is **t = d/c**. With the program's constants, **1 kpc corresponds to 3,261.56 years of propagation**:

- From the Galactic center to the adopted solar position, **8.3 kpc: 27,071 years**.
- Out to **50 kpc: 163,078 years**.
- Out to **100 kpc: 326,156 years**.
- Out to **200 kpc: 652,313 years**.

Thus, 300,000 years corresponds to approximately 92 kpc. At the program's center-to-Sun distance, the value exceeds 15,000 years: it is around 27,000. These are crossing times between points at those separations; the Galactic field results from an extended mass distribution with different separations and histories.

The joint GW170817/GRB 170817A observation by LIGO–Virgo and its collaborators constrained gravitational-wave speed to values extremely close to c. Finite propagation is already part of general relativity: **it would be incorrect to claim that no current model includes it**. LIGO–Virgo result.

The Newtonian, NFW and MOND references implemented in my program use stationary speed functions: they do not calculate retarded gravitational evolution. NFW is a density profile, not a theory that by itself specifies propagation speed. The criticism testable here concerns these implementations and their approximation, rather than all contemporary gravitational theory.

A long crossing time does not itself imply that a star becomes disconnected from the field. General relativity includes motion-dependent terms that compensate the aberration of a force naively directed toward a past position. Carlip's analysis.

My research proposal is to quantify which additional effects survive in a causal dynamical treatment and whether they improve the explanation of the data. The improvements already calculated for mathematical combinations and the identification of their physical cause are distinct stages of that work.

What needs to be reproduced?

The procedure starts from local Gaia records, preserves the sources, and calculates Galactocentric quantities. It then holds the program's parameters fixed, evaluates the predictions for each star, and compares MAE and RMSE by radius.

The thresholds depend on an explicit definition of sustained advantage, a minimum of 100 stars per bin, and the bin width. Results include the combined, 5D, and 6D populations separately.

I invite others to check the calculation, repeat it with better uncertainty information, and test the physical hypotheses that could explain the difference.

What does the panel contain?

The panel contains only **A51, A52, A53, and A54**. A55 is excluded from the document and panel. A54 shows 0–30 kpc and 0–2,000 km/s.

The investigation continues with a specific question: does Martillo's outer-region advantage persist when the comparison incorporates all the observational information and each model's predictions are expressed in the same observable?

That discussion deserves data, calculations, and independent reproduction.

#MartilloModel #EinsteinVED #GaiaDR3 #OpenScience

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