Falsification claims of MOND and their corresponding rebuttal(s)

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	Title (Original article)	Author, year, and link	**Falsification claim**	Title (Rebuttal article)	Author, year, and link	**Rebuttal**	Comments on the claim
1a)	Shell galaxies and alternatives to the dark matter hypothesis	L. Hernquist & P. J. Quinn, 1987b https://ui.adsabs.harvard.edu/abs/1987ApJ...312...17H/abstract	The expected number of shells and their radial distribution predicted using MOND are in disagreement with the observed total. The predicted number of shells exceeded the observations by 70%.	What shells around NGC 3923 tell us about Modified Dynamics	M. Milgrom, 1988. https://ui.adsabs.harvard.edu/abs/1988ApJ...332...86M/abstract	After correcting some inadequacies in the analysis, and model assumptions of Hernquist and Quinn 1987b, the galaxy does not seem to be discrepant with MOND.	
1b)				Testing the Hypothesis of Modified Dynamics with Low Surface Brightness Galaxies and Other Evidence. (Sec 3.2)	McGaugh & De Blok, 1998 https://ui.adsabs.harvard.edu/abs/1998ApJ...499...66M/abstract	A brief description of the claim and its rebuttal. The authors argue that it is a simple problem of phase-space wrapping and not a direct test of the MOND force law.	
1c)				Testing MOND gravity in the shell galaxy NGC 3923	Bilek et al, 2013. https://ui.adsabs.harvard.edu/abs/2013A%26A...559A.110B/abstract	The authors run simulations of NGC 3923 in MOND and find that the shells are consistent with MOND.	
2)	Dark matter in Spiral galaxies. II Galaxies with HI rotation curves	S. M. Kent, 1987. https://ui.adsabs.harvard.edu/abs/1987AJ.....93..816K/abstract	The results show a large deviation in the best fitting a_0 among the observed galaxies.	On the use of Modified Dynamics to test the rotation curves	M. Milgrom, 1988. https://ui.adsabs.harvard.edu/abs/1988ApJ...333..689M/abstract	In the original paper, the observed HI mass was not included in predicting the rotation curves. Once that was included, there was no significant tension.	This is not a falsification claim, rather a correction to the method of analyses which yielded correct results.
3)	Testing Modifications of Gravity	G. Lake, 1989. https://ui.adsabs.harvard.edu/abs/1989ApJ...345L..17L/abstract	Systematic failure of MOND as the predicted Rotation curves (Rcs) of six Dwarf Spirals falls below the observed RCs.	Criticism of Lake's analysis of the rotation curves of Dwarf Spirals	M. Milgrom, 1991 https://ui.adsabs.harvard.edu/abs/1991ApJ...367..490M/abstract	Milgrom discusses individual galaxies from Lake's sample and shows that if one broadly corrects for the distances/inclinations, they do not pose a serious problem.	

4)	Analysis of X-ray clusters in the framework of Modified Newtonian Dynamics	D. Gerbal et al, 1992. https://ui.adsabs.harvard.edu/abs/1992A%26A...262..395G/abstract	The authors claim that MOND is not a potential alternative to Dark Matter as it is in strong disagreement with galaxy cluster observations. The predicted mass is much smaller than the observed mass. The authors conclude, *"It is no longer Dark matter or MOND but Dark matter or MOND and Dark matter".*	Criticism of Gerbal et al's analysis of X-ray clusters in the light of Modified Dynamics	M. Milgrom, 1993. https://ui.adsabs.harvard.edu/abs/1993A%26A...273L...5M/abstract	Milgrom provides a detailed criticism of the method of analysis used for the study. He also provides the correct procedure to be used for the study to test MOND using galaxy clusters .	This is not a rebuttal to the claim, rather a well-motivated suggestion to ensure fair and robust methodologies to test MOND.
5)	The HI Structure of Nine Intrinsically Faint Dwarf Galaxies	K. Y. Lo et al, 1993. https://articles.adsabs.harvard.edu/pdf/1993AJ....106..507L	The inferred mass according to MOND is smaller than the observed HI mass of seven galaxies	Modified Dynamics Predictions Agree with Observations of the HI Kinematics in Faint Dwarf Galaxies Contrary to the Conclusions of Lo, Sargent, and Young	M. Milgrom, 1994. https://articles.adsabs.harvard.edu/pdf/1994ApJ...429..540M	By applying the correct MOND mass estimator, the systems are brought in full agreement with MOND	
6a)	Dwarf Spheroidals and Non-Newtonian gravity	Gerhard & Spergel, 1992. https://ui.adsabs.harvard.edu/abs/1992ApJ...397...38G/abstract	MOND cannot account for the observed kinematic properties of dwarf spheroidals around the Milky Way, cases in point are, Fornax, Draco, and Ursa Minor Dwarf galaxies.	MOND and the seven Dwarfs	M. Milgrom, 1995. https://ui.adsabs.harvard.edu/abs/1995ApJ...455..439M/abstract	The measurement uncertainties were quite large to provide strong conclusions. New, updated measurements show that all the dwarfs are perfectly consistent with MOND.	
6b)				Testing the Hypothesis of Modified Dynamics with Low Surface Brightness Galaxies and Other Evidence. (Sec 3.1)	McGaugh & De Blok, 1998 https://ui.adsabs.harvard.edu/abs/1998ApJ...499...66M/abstract	The authors did the analysis again with improved data and found that there is no significant tension between observations and MOND.	

7)	Geometrical Evidence for Dark Matter: X-Ray Constraints on the Mass of the Elliptical Galaxy NGC 720	Buote & Canizares, 1994. https://ui.adsabs.harvard.edu/abs/1994ApJ...427...86B/abstract	In any modified theory of gravity, the isopotential surface presumably traced by the gas should not differ from that determined by the dominant stars. Any significant difference would impose a geometrical requirement for a dark mass component.	Testing the Hypothesis of Modified Dynamics with Low Surface Brightness Galaxies and Other Evidence. (Sec 3.1)	McGaugh & De Blok, 1998 https://ui.adsabs.harvard.edu/abs/1998ApJ...499...66M/abstract	Both dark matter and MOND imply potentials consistent with or slightly rounder than the isophotes of the stars and rounder than the X-ray isophotes. The interpretation of NGC 720 seems difficult with either dark matter or MOND if we accept the data at face value.	At the present time, these and other data for giant elliptical galaxies provide only weak and indirect tests of MOND. None of these data clearly contradict it.
8)	The bright side of dark matter	A. Edery, 1999. https://ui.adsabs.harvard.edu/abs/1999PhRvL..83.3990E/abstract	The author claims that without dark matter it is not possible to explain the motion of particles on galactic scales in terms of geodesic on a four-dimensional.	Comment on “The Bright Side of Dark Matter”	Bekenstein et al, 2000. https://ui.adsabs.harvard.edu/abs/2000PhRvL..85.1346B/abstract	The authors show the arguments of Edery to be invalid and no such claimed results are obtained from these calculations.	This is not a direct falsification of MOND. It is a a general calculation.
9)	How Cold Dark Matter theory explains Milgrom’s law.	M. Kaplinghat & M. Turner, 2002. https://ui.adsabs.harvard.edu/abs/2002ApJ...569L..19K/abstract	The authors claim that Milgrom’s law can be naturally derived from the cold dark matter paradigm.	Do Modified Dynamics follow the cold dark matter paradigm?	M. Milgrom, 2002. https://ui.adsabs.harvard.edu/abs/2002ApJ...571L..81M/abstract	The outcome pertains only to a small statement of MOND. Other predictions independent of a_0 could not be reproduced in this scenario.	There are other conclusions that Milgrom mentions in his article, but only one is mentioned here.
10)			When Andromeda IV was thought to be a satellite of MOND, the discrepancy between the latter and And IV was huge, since it is gas-dominated and had a reasonable inclination.	On the Nature of Andromeda IV	Ferguson et al, 2000. https://ui.adsabs.harvard.edu/abs/2000AJ....120..821F/abstract	Proper distance measures placed And IV at a distance D > 5 Mpc, well outside the local group, thus reconciling it with MOND.	An example of an incorrect distance measurement, leading to a false alarm.
11)	A Dearth of Dark Matter in Ordinary Elliptical Galaxies	Romanowsky et al, 2003. https://ui.adsabs.harvard.edu/abs/2003Sci...301.1696R/abstract	The authors do not claim to falsify MOND, in particular.	Modified Newtonian Dynamics and the “Dearth of Dark Matter in Ordinary Elliptical Galaxies”	M. Milgrom & R.H Sanders, 2003. https://ui.adsabs.harvard.edu/abs/2003ApJ...599L..25M/abstract	The authors show that the galaxies under consideration are fully consistent with MOND.	
12)	Testing MOND with VIRGOHI21	Scott Funkhouser, 2005. https://articles.adsabs.harvard.edu/pdf/2005MNRAS.364..237F	Object Virgo HI21 was thought to be a “dark galaxy” that was dark matter dominated. The authors claim that the internal dynamics of the “galaxy” cannot be explained by MOND.	Tidal debris from high-velocity collisions as fake dark galaxies: A numerical model of VIRGO HI21	P. -A Duc and F. Bournaud, 2008. https://ui.adsabs.harvard.edu/abs/2008ApJ...673..787D/abstract	Virgo HI21 was shown to be a cloud of tidal debris formed from a high-velocity collision, and is not a rotationally supported system	An example of misidentification of an object leading to a false alarm.

						as was thought to be.	
13)	Discovery of a Ring-like Dark Matter structure in the core of the galaxy cluster C1 0024+17	Jee et al, 2008. https://ui.adsabs.harvard.edu/abs/2007ApJ...661..728J/abstract	There seems to be an offset between the mass concentration centroid and the ICM clump centroid. MOND cannot explain this offset because it predicts the mass centroid to coincide with the ICM clump.	Rings and Shells as "Dark Matter" artifacts	M.Milgrom & R.H Sanders, 2008. https://ui.adsabs.harvard.edu/abs/2008ApJ...678..131M/abstract	The authors show that the structure is reproducable in MOND. The properties of the structure depend on the interpolating function in MOND.	
14)	A direct empirical proof of existence of dark matter	Clowe et al, 2006. https://arxiv.org/pdf/astro-ph/0608407.pdf	The authors claim that the offset between total mass and total baryonic mass peaks cannot be explained by any non-dark matter gravity theory.	Equilibrium configurations of 11 eV sterile neutrinos in MONDian galaxy clusters	Angus et al, 2006. https://ui.adsabs.harvard.edu/abs/2007ApJ...654L..13A/abstract	Showing that the discrepancy with MOND is not different than that already present in all galaxy clusters. Conceding the need for this component to be collisionless.	
15)	A tale of two galaxies: light and mass in NGC 891 and NGC 7814	Fraternali et al, 2011 https://ui.adsabs.harvard.edu/abs/2011A%26A...531A..64F/abstract	NGC 7814 was claimed to be highly problematic for MOND as it required a very high mass-to-light ratio for bulge, and also the MOND interpolation function did not work for this galaxy.	The dynamics of the bulge dominated galaxy NGC 7814 in MOND	Angus et al, 2012. https://ui.adsabs.harvard.edu/abs/2012A%26A...543A..76A/abstract	By ensuring a superior fit to the radial surface brightness profile, and by virtue of a double Sérsic fit to the bulge, good fits to the rotation curve with typical values for both mass-to-light ratios were produced.	The model rotation curve of a mass distribution in MOND is extremely sensitive to the bulge-disk decomposition.
16)	Is Holmberg-II beyond MOND theory	F. J. Sanchez-Salcedo and A. M. Hidalgo-Gamez, 2011 https://arxiv.org/abs/1105.2612	The authors claimed that MOND overestimates the rotation curve of Holmberg II. It was claimed that Holmberg II rules out MOND with high significance.	Isolated and non-isolated dwarfs in terms of modified Newtonian dynamics	Gentile et al, 2012. https://ui.adsabs.harvard.edu/abs/2012A%26A...543A..47G/abstract	By re-modelling the HI data cube, it was shown that Ho II's inclination was closer to face-on. This implies that Ho II has a higher rotational velocity in its outer parts and is consistent with MOND.	An example of overestimated inclination angle.
17a)	The Globular Cluster NGC 2419: A Crucible for Theories of Gravity	Ibata et al, 2011. https://ui.adsabs.harvard.edu/abs/2011ApJ...738..186I/abstract	Isotropic MOND models cannot reproduce the kinematics of the distant Galactic globular cluster NGC 2419 given its luminosity.	NGC 2419 does not challenge modified Newtonian dynamics	R. H. Sanders, 2012. https://ui.adsabs.harvard.edu/abs/2012MNRAS.419L..6S/abstract	Non-isothermal MOND models, approximated by high-order polytropic spheres, are consistent with the observations.	

17b)	Polytropic Model Fits to the Globular Cluster NGC 2419 in Modified Newtonian Dynamics	Ibata et al, 2011. https://ui.adsabs.harvard.edu/abs/2011ApJ...743...43I/abstract	The properties of NGC 2419 are hard to explain using MOND assuming a constant polytropic equation of state.	NGC 2419 does not challenge MOND, Part 2	R. H. Sanders, 2012. https://ui.adsabs.harvard.edu/abs/2012MNRAS.422L..21S/abstract	Allowing the equation of state to vary with radius allows MOND to be consistent. Work also highlights the possibility of other systematics, e.g. rotation within the sky plane.	
18a)	Absence of a fundamental acceleration scale in galaxies	Rodrigues et al, 2018 https://ui.adsabs.harvard.edu/abs/2018NatAs...2..668R/abstract	The authors claim that the probability of existence of a fundamental acceleration that is common to all the galaxies is essentially zero, which rules out MOND as a fundamental theory for galaxies at more than 10 σ.	A common Milgromian acceleration scale in nature	Kroupa et al, 2018. https://arxiv.org/pdf/1811.11754.pdf	The authors show that this claim relies largely on galaxies with uncertain distances, and/or edge-on orientations. By applying quality data cuts, all the galaxies in the sample can be explained in MOND.	
18b)				Presence of a fundamental acceleration scale in galaxies	McGaugh et al, 2018 https://ui.adsabs.harvard.edu/abs/2018NatAs...2..924M/abstract	We performed a Bayesian analysis1 on galaxy rotation curves from the SPARC database and found strong evidence for a characteristic acceleration scale $a_{0.}$	
18c)				Overconfidence in Bayesian analyses of galaxy rotation curves	Cameron et al, 2020 https://ui.adsabs.harvard.edu/abs/2020NatAs...4..132C/abstract		
18d)	Reply to `Presence of a fundamental acceleration scale in galaxies' and `A common Milgromian acceleration scale in nature'	Rodrigues et al, 2018. https://ui.adsabs.harvard.edu/abs/2018NatAs...2..927R/abstract	The authors argue that McGaugh et al, 2018 and Kroupa et al, 2018 do not solve the problem claimed by Rodrigues et al, 2018.				
18e)	Reply to: Overconfidence in Bayesian analyses of galaxy rotation curves	Rodrigues et al, 2020 https://ui.adsabs.harvard.edu/abs/2020NatAs...4..134R/abstract	The authors provide a reply to Cameron et al, 2020.	A cautionary tale in fitting galaxy rotation curves with Bayesian techniques. Does Newton's constant vary from galaxy to galaxy?	Li et al, 2021 https://ui.adsabs.harvard.edu/abs/2021A%26A...646L..13L/abstract	The authors point out the errors in the methods of analyses. They further show that the methods used by the authors yield different Newton's constant.	.

19a)	A Galaxy lacking Dark Matter	Van Dokkum et al, 2018. https://ui.adsabs.harvard.edu/abs/2018Natur.555..629V/abstract	The authors claim that the velocity dispersion of the galaxy predicted by MOND is more than two times higher than the observed one.	MOND and the dynamics of NGC 1052 -DF2	Famaey et al, 2018. https://ui.adsabs.harvard.edu/abs/2018MNRAS.480..473F/abstract	Considering the uncertainties in the MOND interpolating function, the stellar mass-to-light ratio, and 3D distance to the host galaxy, the MOND predicted velocity dispersion is not in conflict with the observations	
19b)				Does the galaxy NGC 1052 - DF2 falsify Milgromian dynamics?	Kroupa et al, 2019. https://ui.adsabs.harvard.edu/abs/2018Natur.561E...4K/abstract	The velocity dispersion is in very good agreement with the observed one if the external field from NGC 1052 is taken into account correctly.	This article has multiple rebuttals (see next), all of them showing that the galaxy is consistent with MOND.
19c)				A new formulation of the external field effect in MOND and numerical simulations of ultra-diffuse dwarf galaxies – application to NGC 1052-DF2 and NGC 1052-DF4	Haghi et al, 2019. https://ui.adsabs.harvard.edu/abs/2019MNRAS.487.2441H/abstract	The authors show that the velocity dispersion is well consistent with MOND after including the contribution from the external field effect.	This problem is associated with the measurement of distance: Just how far away are they from us?
20)	A Break in Spiral Galaxy Scaling Relations at the upper limit of Galaxy mass	Ogle et al, 2019. https://arxiv.org/pdf/1909.09080.pdf	The authors claim to observe a break in the BTFR at the high mass ($\log_{10}$ M/M_Sun > 11.5) end where super spirals are observed. This break is inconsistent with MOND.	Rotation curves & scaling relations of extremely massive Spirals.	Teodoro et al, 2021. https://arxiv.org/pdf/2109.03828.pdf	The authors study a sample of Super Spirals and conclude that there is no break in the BTFR at the high mass end.	
21)	No need for Dark Matter: Resolved kinematics of the ultra diffuse galaxy AGC 114905	Mancera-Pina et al, 2021 https://ui.adsabs.harvard.edu/abs/2022MNRAS.512.3230M/abstract	The authors claim that MOND predicts the rotational velocity of the UDG AGC 114905 to be smaller than observed.	Overestimated inclinations of Milgromian Disc galaxies: The case of the ultra diffuse galaxy AGC 114905	Banik et al, 2022. https://ui.adsabs.harvard.edu/abs/2022MNRAS.513.3541B/abstract	The authors show that disc galaxies in MOND can be non-axisymmetric and due to this their inclination can be overestimated. Allowing for this inclination, the galaxy is reconciled with MOND.	

Important Links

	Type of the source	Title of the source	Author(s)	Link to the source
1)	Review article	Modified Newtonian Dynamics as an alternative to Dark Matter	R. H. Sanders & S. S. McGaugh (2002)	https://ui.adsabs.harvard.edu/abs/2002ARA%26A..40..263S/abstract
2)	Review article	Modified Newtonian Dynamics, an Introductory Review	R. Scarpa (2006)	https://ui.adsabs.harvard.edu/abs/2006AIPC..822..253S/abstract
3)	Review article	Local-Group tests of dark-matter concordance cosmology Towards a new paradigm for structure formation	Kroupa et al, 2010	https://ui.adsabs.harvard.edu/abs/2010A%26A...523A..32K/abstract
4)	Review article	The Dark Matter Crisis: Falsification of the Current Standard Model of Cosmology	P. Kroupa (2012)	https://ui.adsabs.harvard.edu/abs/2012PASA...29..395K/abstract
5)	Review article	Modified Newtonian Dynamics (MOND): Observational Phenomenology and Relativistic Extensions	B. Famaey & S. S McGaugh (2012)	https://ui.adsabs.harvard.edu/abs/2012LRR....15...10F/abstract
6)	Review article	The MOND phenomenology	B. Famaey & S. S. McGaugh (2013)	https://ui.adsabs.harvard.edu/abs/2013arXiv1310.4009F/abstract
7)	Review article	Challenges for LCDM and MOND	B. Famaey & S. S. McGaugh (2013)	https://ui.adsabs.harvard.edu/abs/2013JPhCS.437a2001F/abstract
8)	Review webpage	The MOND paradigm of modified dynamics	M. Milgrom (2014)	http://www.scholarpedia.org/article/The_MOND_paradigm_of_modified_dynamics
9)	Review article	A Tale of Two Paradigms: the Mutual Incommensurability of ΛCDM and MOND	S. S. McGaugh (2014)	http://astroweb.case.edu/ssm/papers/CJP_review.pdf
10)	Review article	The "Missing Mass Problem" in Astronomy and the Need for a Modified Law of Gravity	S. Trippe (2014)	https://ui.adsabs.harvard.edu/abs/2014ZNatA..69..173T/abstract
11)	Review article	The failures of the standard model of cosmology require a new paradigm	P. Kroupa, M. Pawlowski, & M. Milgrom	https://arxiv.org/abs/1301.3907

			(2015)	
12)	Review article	Lessons from the Local Group (and Beyond) on Dark Matter	P. Kroupa (2015)	https://ui.adsabs.harvard.edu/abs/2015llg..book..337K/abstract
13)	Review article	Galaxies as simple dynamical systems: observational data disfavor dark matter and stochastic star formation	P. Kroupa (2015)	https://ui.adsabs.harvard.edu/abs/2015CaJPh..93..169K/abstract
14)	Review article	Predictions and Outcomes for the Dynamics of Rotating Galaxies	S. S. McGaugh (2020)	https://ui.adsabs.harvard.edu/abs/2020Galax...8...35M/abstract
15)	Review article	From galactic bars to the Hubble tension: weighing up the astrophysical evidence for Milgromian gravity	Banik & Zhao (2022)	https://arxiv.org/abs/2110.06936
16)	Webpage	MOND pages	Stacy McGaugh	http://astroweb.case.edu/ssm/mond/
17)	Blog	The Dark Matter Crisis	Pavel Kroupa	https://darkmattercrisis.wordpress.com/
18)	Blog	Triton station	Stacy McGaugh	https://tritonstation.com/new-blog-page/
19)	Blog post	“MOND for dummies”. Guest post on the Dark Matter crisis blog	David Levitt	https://darkmattercrisis.wordpress.com/2022/04/04/67-mond-for-dummies/
20)	Youtube playlist	Playlist of talks on MOND that are available on Youtube.	Mark Huisjes	https://www.youtube.com/playlist?list=PLx_Kb7k7Ux1lAtODpNCM_GICe_VuRw_PJ