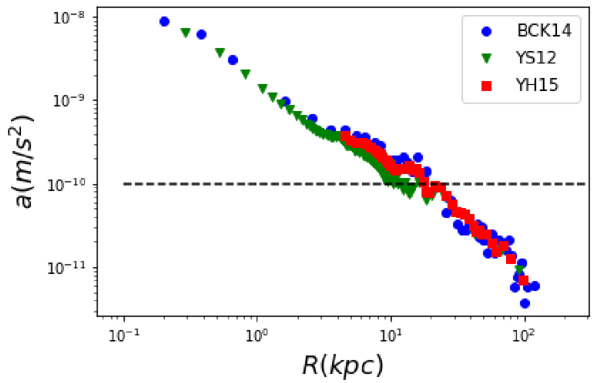
Acceleration Relations in the Milky Way as Differentiators of Modified Gravity Theories



Islam and Dutta
arXiv:1911.11836
Phys. Rev. D 101, 084015 (2020)

Dutta and Islam
arXiv:1808.06923
Phys. Rev. D 98, 124012 (2018)

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Cosmology at Home 2020, Virtual

Phenomenological Acceleration Relations

- Mass Discrepancy Acceleration Relation (MDAR):

  M_{obs} and M_{bar}

- Radial Acceleration Relation (RAR):

$$a_{MLS} = \frac{a^{bar}_{new}}{1 - exp(-(\frac{a^{bar}_{new}}{a_{\dagger}})^{1/2})},$$

McGaugh et al 2016 - MLS

- Halo Acceleration Relation (HAR):

$$a_h = a_{obs} - a^{bar}_{new}.$$

Tian and Ko 2019

Modified Gravity Theories

- Weyl Conformal Gravity:

$$g_{\mu\nu}(x) \rightarrow \Omega^2(x) g_{\mu\nu}(x),$$

Mannheim 1989

$$v_{tot}^2(r) = v_{loc}^2(r) + \frac{\gamma_0 c^2 r}{2} - \kappa c^2 r^2. \quad (3.4)$$

The corresponding centripetal acceleration is thus : $\frac{v_{tot}^2(r)}{r}$. The values of the four universal Weyl gravity parameters are fixed by previous fits to the rotation curves of ∼ 100 galaxies [26–28]: $\beta^* = 1.48 \times 10^5$ cm; $\gamma^* = 5.42 \times 10^{-41}$ cm^{-1}; $\gamma_0 = 3.06 \times 10^{-30}$ cm^{-1} and $\kappa = 9.54 \times 10^{-54}$ cm^{-2}.

Islam and Dutta 2020

- MOND:

$$a_{MOND} = \frac{a_N}{\sqrt{2}}\left[1 + \left(1 + \left(\frac{2a_0}{a_{new}^{bar}}\right)^2\right)^{1/2}\right]^{1/2},$$

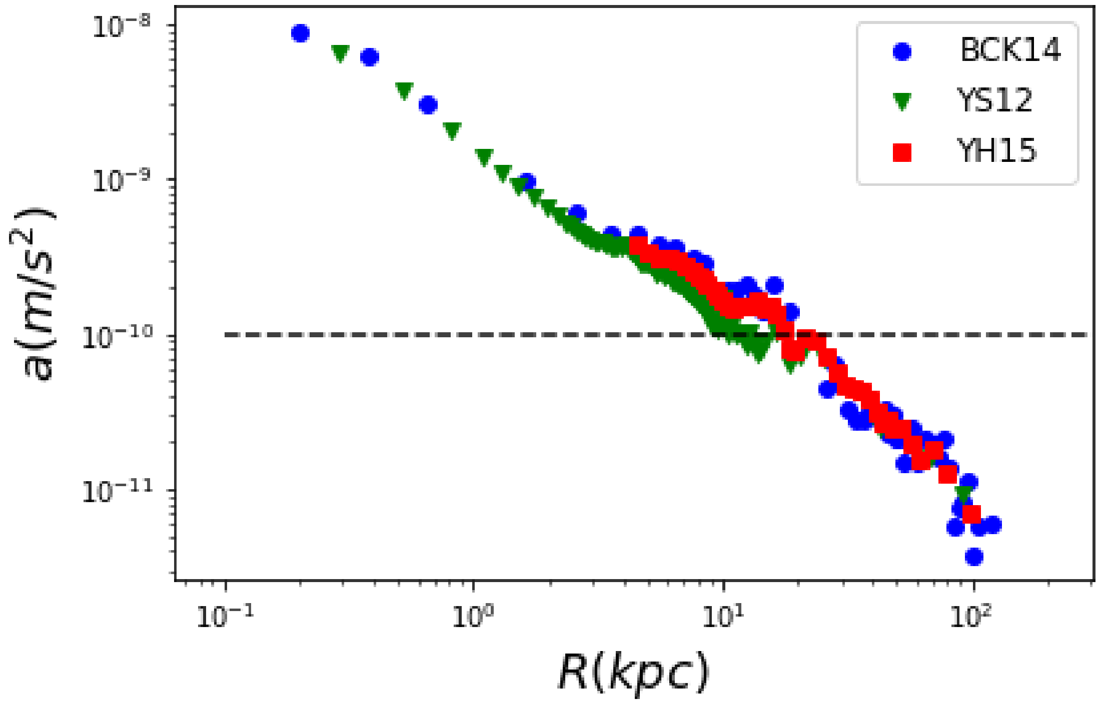
Milogram 1983

Milky Way: Kinematics Data

Bhattacharjee et al 2014 – BCK14
49 Points

Sofue 2012 – YS12
123 Points

Huang et al 2016 – YH16
43 Points



Milky Way: Mass Model

Bulge

Valenti et al 2016

$$\rho(r) = \frac{M_{bulge}}{2\pi^2 t^3} K_0(r/t),$$

Disk

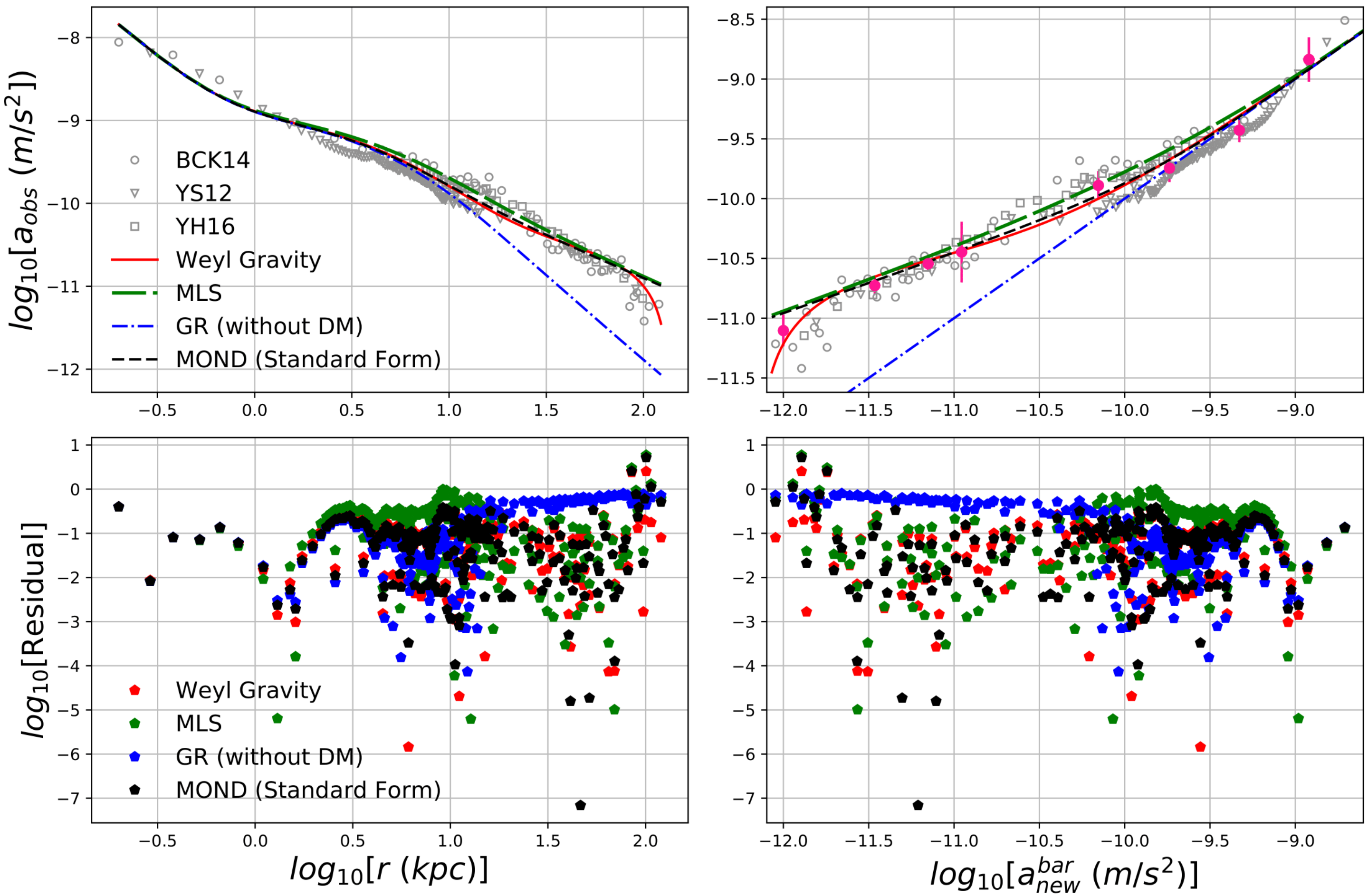
McMilan 2016

$$\Sigma(r) = \Sigma^0 e^{-r/R},$$

TABLE I: **Parameters for the Milky Way mass model [22]**

	Σ_0	R
Thin Stellar Disk	$886.7 \pm 116.2\ M_\odot pc^{-2}$	2.6 ± 0.52 kpc
Thick Stellar Disk	$156.7 \pm 58.9\ M_\odot pc^{-2}$	3.6 ± 0.72 kpc
HI Disk	$1.1 \times 10^{10} M_\odot$	7.0 kpc
H2 Disk	$1.2 \times 10^{9} M_\odot$	1.5 kpc

Radial Acceleration Relation (RAR)

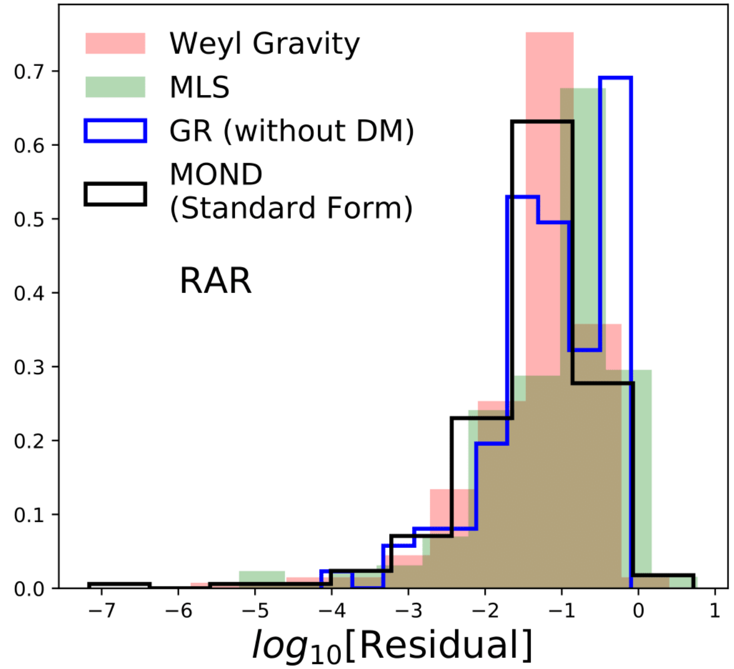


$$Residual = (Data - Model)^2 / Data^2.$$

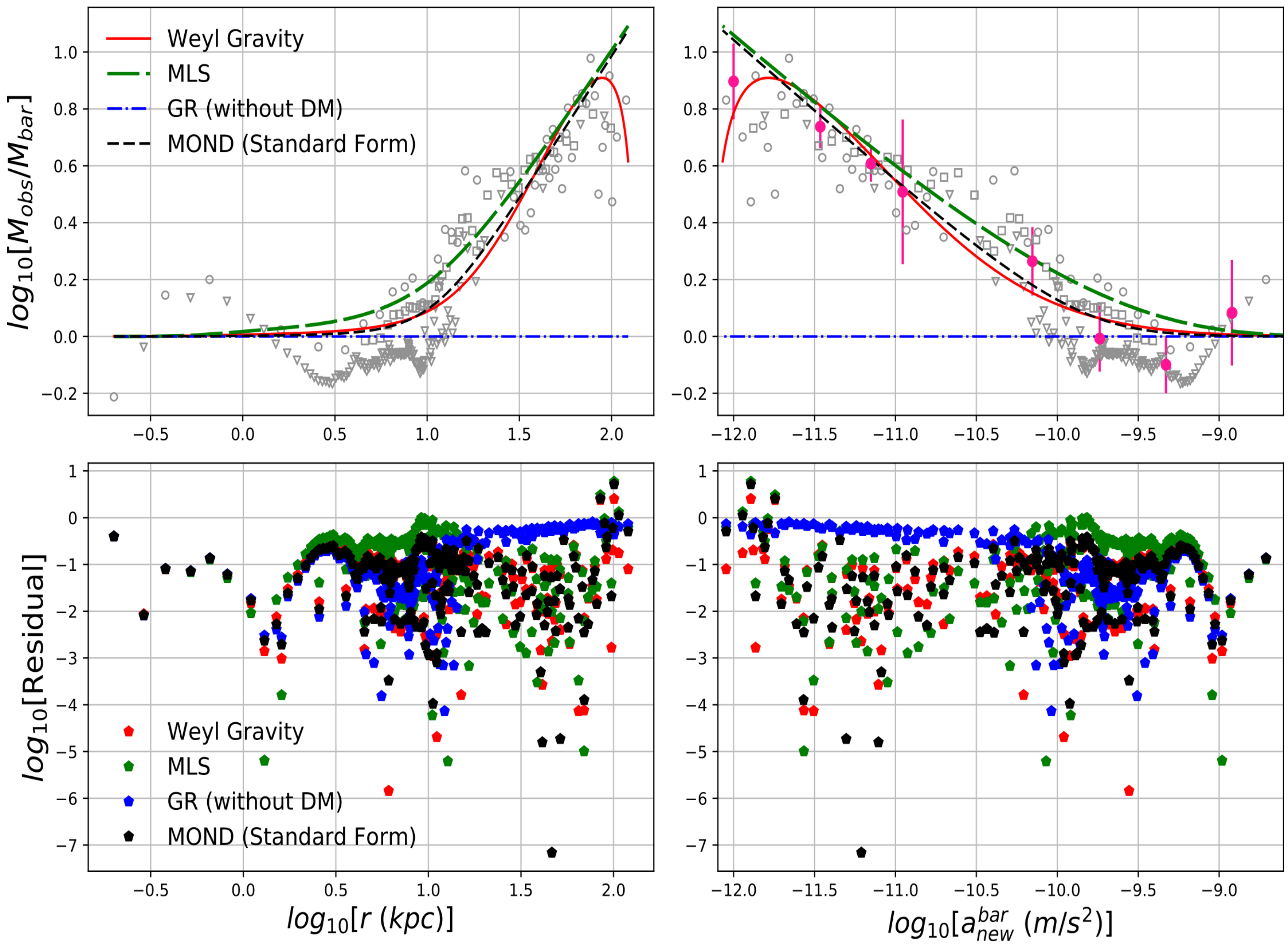
Radial Acceleration Relation (RAR)

TABLE II: **Reduced chi-square values as goodness-of-fits for different theories of gravity and RAR scaling law. No dark matter is assumed. (Section IV A in text)**

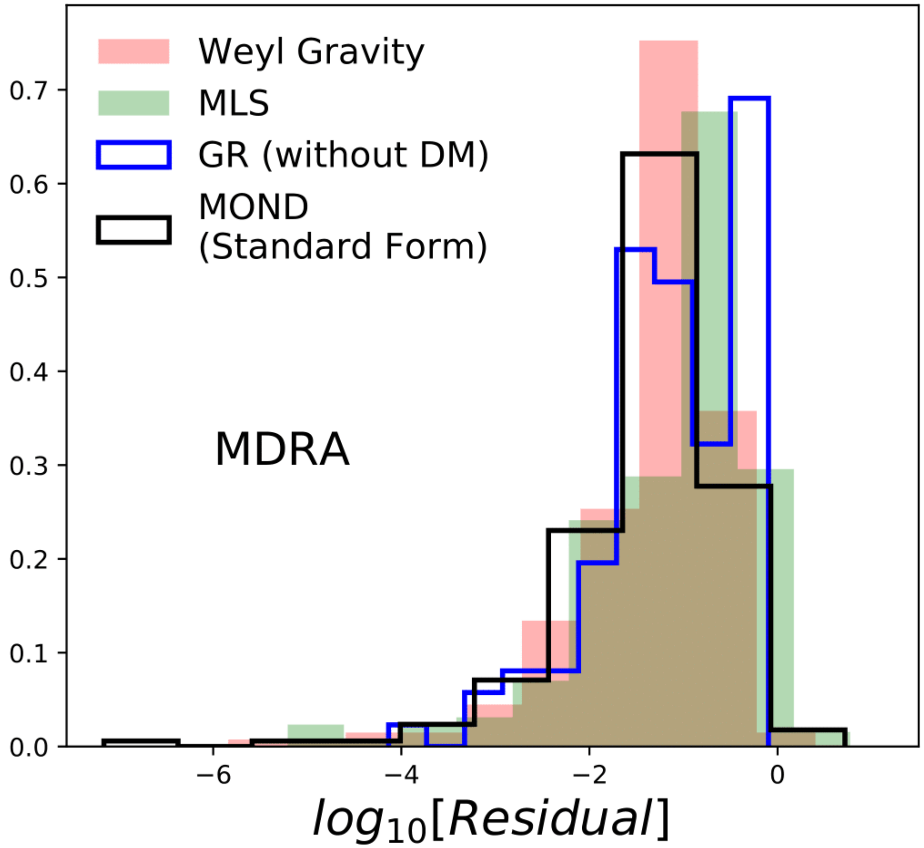
	χ^2/dof
General Relativity (GR) without dark matter	7.56
MOND (Standard Form)	5.90
Weyl Conformal Gravity	6.11
Radial Acceleration Relation / MLS 2016	5.71



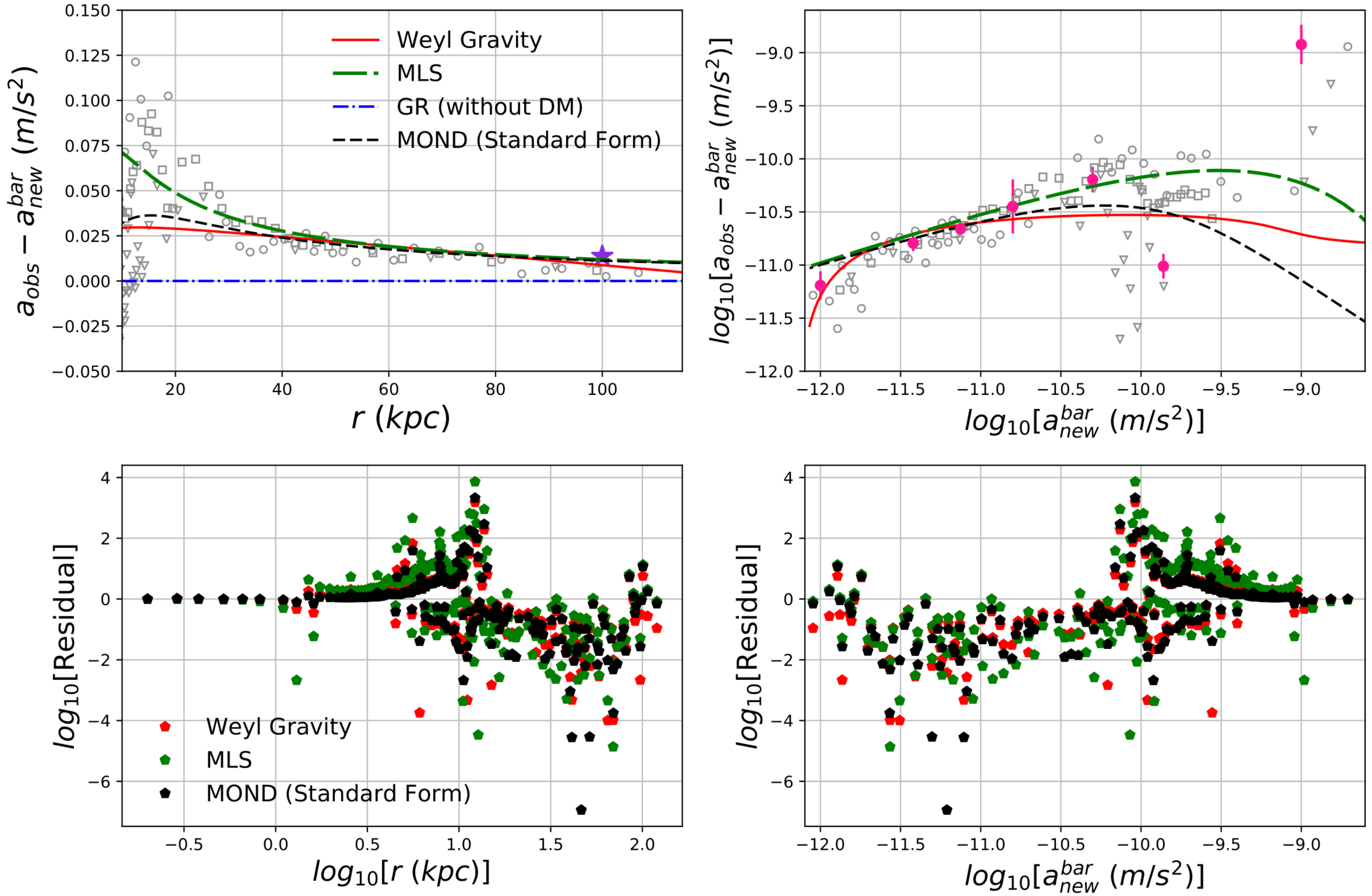
Mass Discrepancy Acceleration Relation (MDAR)



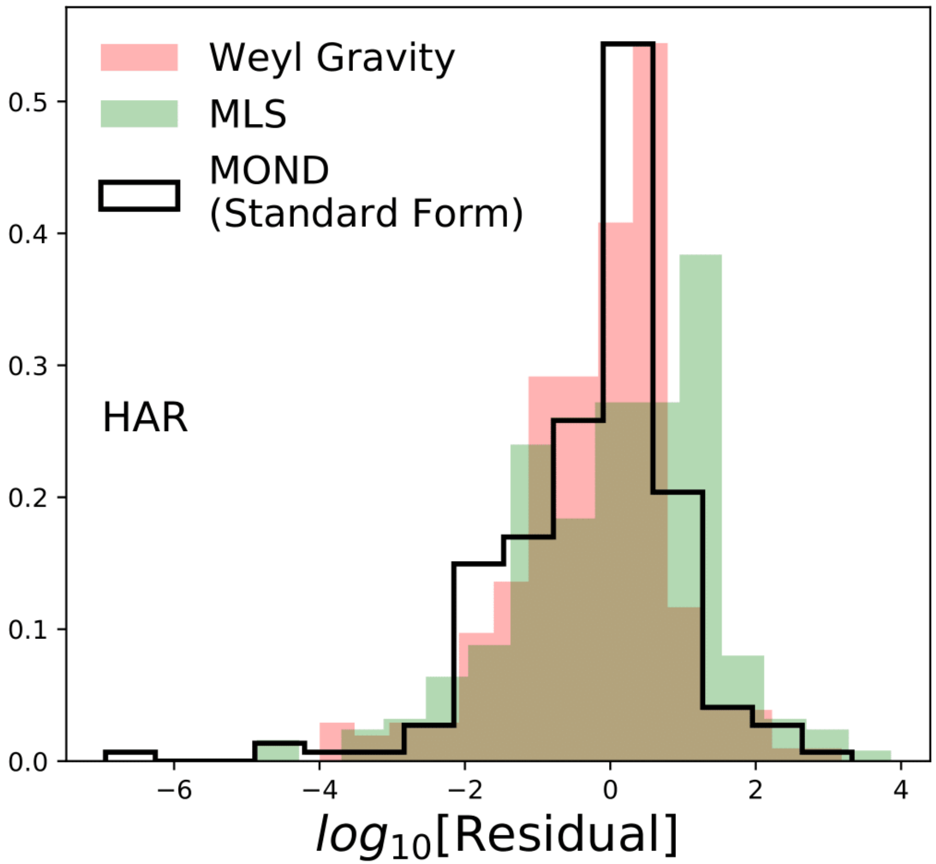
Mass Discrepancy Acceleration Relation (MDAR)



Halo Acceleration Relation (HAR)



Halo Acceleration Relation (HAR)



Conclusion

- Both the modified gravity theories in question as well as RAR can explain the radial acceleration data well
- Data in the a_{obs}–a^{bar}_{new} plane is unable to discriminate between different models or gravity and scaling laws
- a_{halo}–a^{bar}_{new} plane gives a stronger test for them
- Both the high acceleration and low acceleration regime becomes equally important for such test