

# The radial acceleration relation at the EDGE of galaxy formation: challenging its universality in low-mass dwarf galaxies

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## Context

The Radial Acceleration Relation (RAR) links the baryonic mass distribution of galaxies to their observed gravitational acceleration and has been interpreted as evidence for a fundamental connection between baryons and galaxy dynamics. The relation is remarkably tight across many galaxy types and has even been cited as support for modified gravity theories. However, it has primarily been tested in massive, rotationally supported galaxies, and whether it holds in the dark-matter-dominated regime of dwarf galaxies remains unclear.

## Aims

Here we extend the RAR to the lowest baryonic masses yet probed ( $10^4 < M_{\star} / M_{\odot} < 10^{7.5}$ ) using radially resolved stellar kinematics of 12 nearby dwarf galaxies.

The sample combines:

- 8 classical Milky Way dwarf spheroidals from the literature
- 4 ultra-faint dwarfs observed with the MUSE-Faint survey

## Methods

We infer their mass profiles with the Jeans modelling code GravSphere and compare the resulting acceleration profiles with dwarf galaxies from the EDGE  $\Lambda$ CDM simulations.

## Results

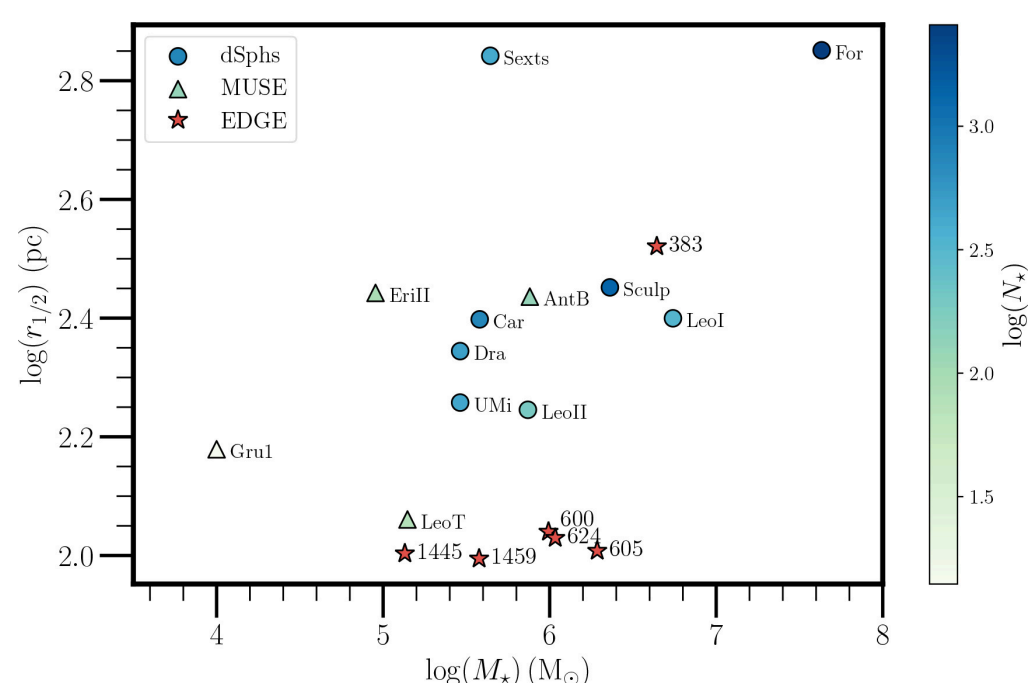
We find that most dwarf galaxies lie systematically above the extrapolated RAR and exhibit significant scatter. The simulated dwarfs show similar behaviour, suggesting that the canonical RAR is not universal.

## Analysis

Using stellar line-of-sight velocities, we infer the galaxies' mass profiles with the Jeans modelling code GravSphere, allowing us to estimate the baryonic and observed accelerations at multiple radii:

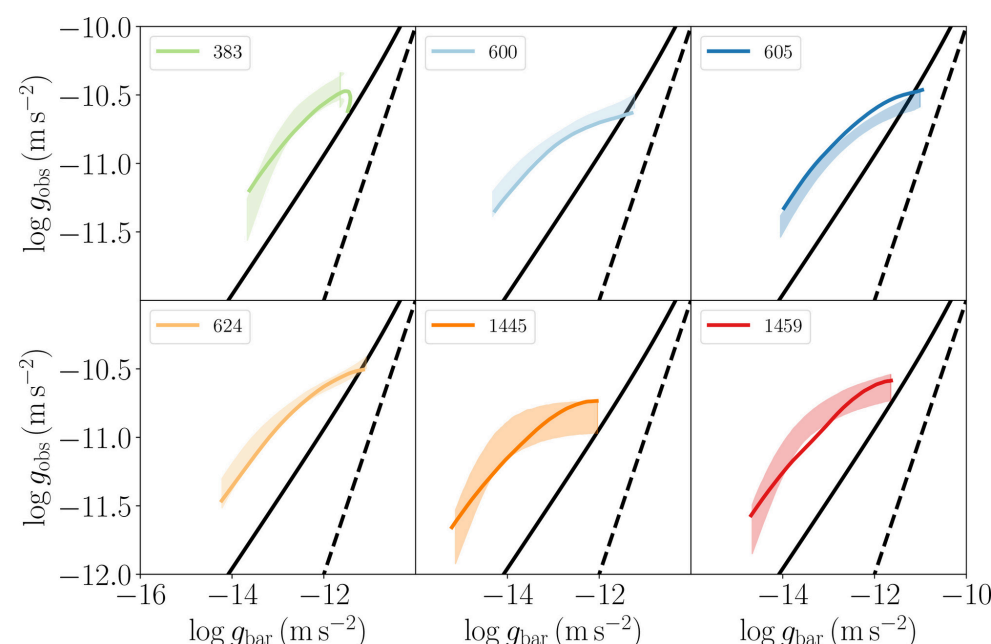
$$g_{\text{bar}}(r) = \frac{GM_{\text{bar}}(<r)}{r^2} \quad g_{\text{obs}}(r) = \frac{GM_{\text{tot}}(<r)}{r^2}$$

**Figure 1:** Stellar mass,  $M_{\star}$ , against the half-light radius,  $r_{1/2}$ , for our galaxy sample. The circles indicate the classical dSphs, and the triangles represent the dwarfs from MUSE-Faint. Objects are colour-coded by the number of stars with velocities available for each object. The red stars represent the EDGE simulated dwarfs.



We then compare the resulting radial acceleration measurements with predictions from EDGE cosmological simulations of isolated dwarf galaxies in a  $\Lambda$ CDM framework.

**Figure 2:** Test of our recovery of RAR by applying GravSphere to mock data drawn from simulated EDGE dwarfs. The shaded band marks the 68% confidence intervals. The true answer (as determined directly from the simulations) is marked by the solid lines. The solid black line marks the RAR derived by McGaugh et al. (2016) for SPARC local spiral galaxies. The dashed black line marks  $g_{\text{obs}} = g_{\text{bar}}$ .

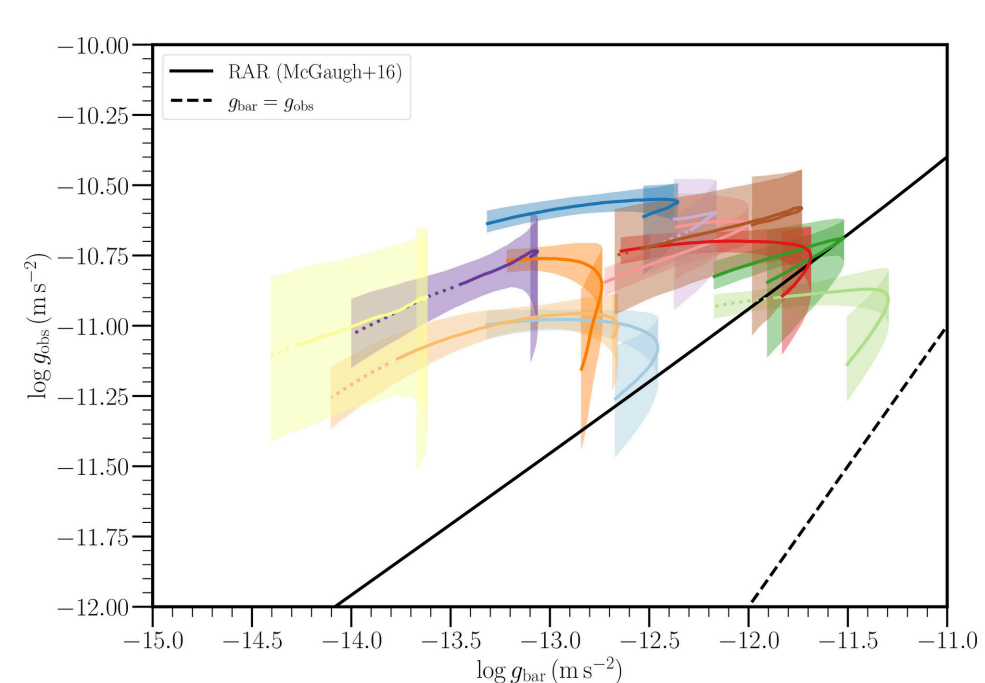


## Discussion

Most observed dwarf galaxies lie systematically above the extrapolated RAR calibrated for more massive galaxies. Individual systems show significant scatter between galaxies in RAR space, with some exhibiting multi-valued behaviour in acceleration.

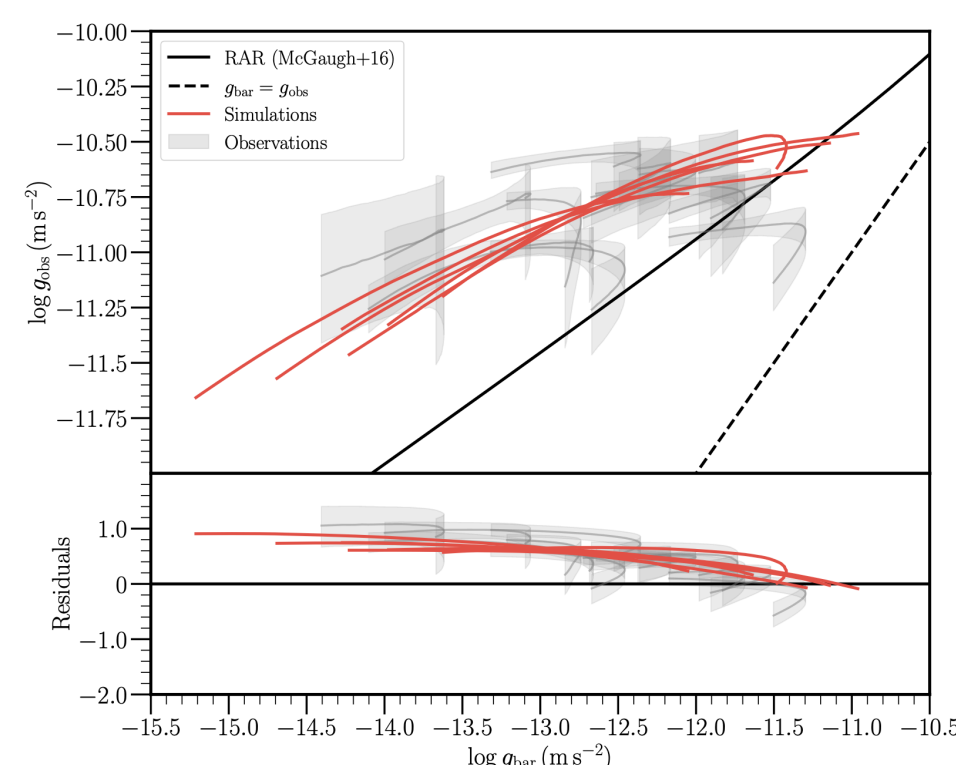


**Figure 3:** Radial acceleration relation (RAR) for our sample of dwarf galaxies. Each colour corresponds to a different galaxy, where the shaded area corresponds to the 68% confidence interval and the solid line marks the median value. The dotted lines correspond to extrapolations beyond the kinematic data range. The solid black line marks the RAR derived by McGaugh et al. (2016) for SPARC local spiral galaxies. The dashed black line marks  $g_{\text{obs}} = g_{\text{bar}}$ .



**Figure 4:** Quantitative comparison of the EDGE simulated RAR with our observed dwarf galaxy sample. The median and 68% scatter in the observed  $g_{\text{obs}}-g_{\text{bar}}$  relations are marked by the grey solid lines and shaded regions, respectively. Solid red lines represent the  $g_{\text{obs}}-g_{\text{bar}}$  relations estimated directly from the simulations. The black solid line corresponds to the RAR derived by McGaugh et al. (2016) for SPARC local spiral galaxies. The black dashed line marks  $g_{\text{obs}} = g_{\text{bar}}$ .

EDGE simulations display a similar offset relative to the canonical RAR, indicating that such behaviour arises naturally in  $\Lambda$ CDM dwarf galaxy formation models.



## Conclusions

- **Low-mass dwarfs deviate from the canonical RAR**  
Most galaxies lie systematically above the relation calibrated for massive systems
- **Large intrinsic scatter**  
The relation shows significant galaxy-to-galaxy variation, and some galaxies exhibit multi-valued behaviour in  $g_{\text{obs}} - g_{\text{bar}}$
- **Not explained by modified gravity effects**  
The External Field Effect predicts deviations in the opposite direction to those observed

- **Robust against observational caveats**  
Possible systematics, such as binary stars and tidal perturbations, cannot explain the systematic offset
  - **Consistent with  $\Lambda$ CDM simulations**  
EDGE simulations reproduce the offset and qualitative scatter, suggesting that stochastic star formation histories and halo assembly drive the diversity
- Low-mass dwarf galaxies provide powerful near-field tests of dark matter and galaxy formation physics.**

