Self-similar galaxy dynamics below the de Sitter scale of acceleration

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van Putten, 2018, MNRAS **481**, L26

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Tensions shimmering with Physics beyond ΛCDM?

H_0 tension problem (3.8σ, Riess et al. 2017)

de Sitter is unstable?

ΛCDM ruled out in the future,

ΛCDM cannot hold to all orders today

Ó Colgáin, van Putten, Yavartanoo, arXiv:1807.07451 (2018)

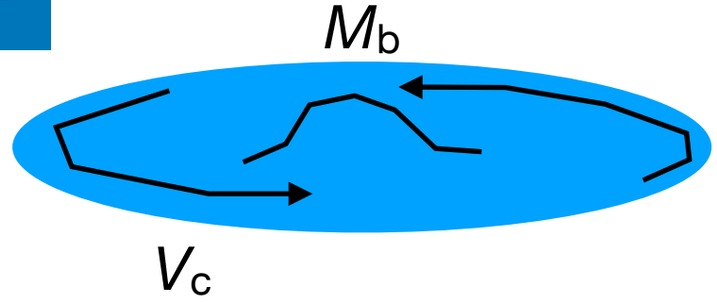
ΛCDM galaxies vs SPARC data

6σ gap about $a_{dS} = cH$

Galaxy dynamics tracing H?

this talk

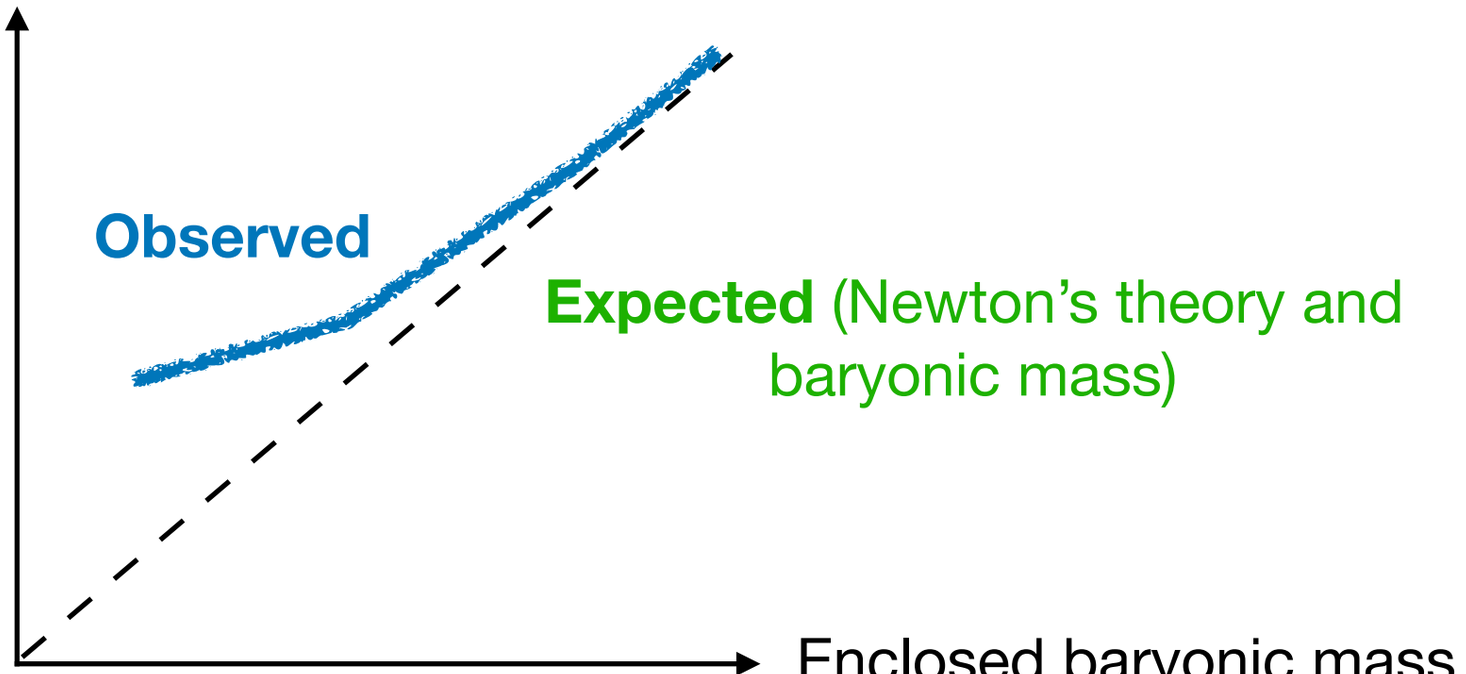
"Missing mass" in spiral galaxies



Spectroscopy

Observed/Expected radial acceleration

$$\frac{\alpha}{a_N} = \frac{V_c^2 / r}{V_b^2 / r}$$



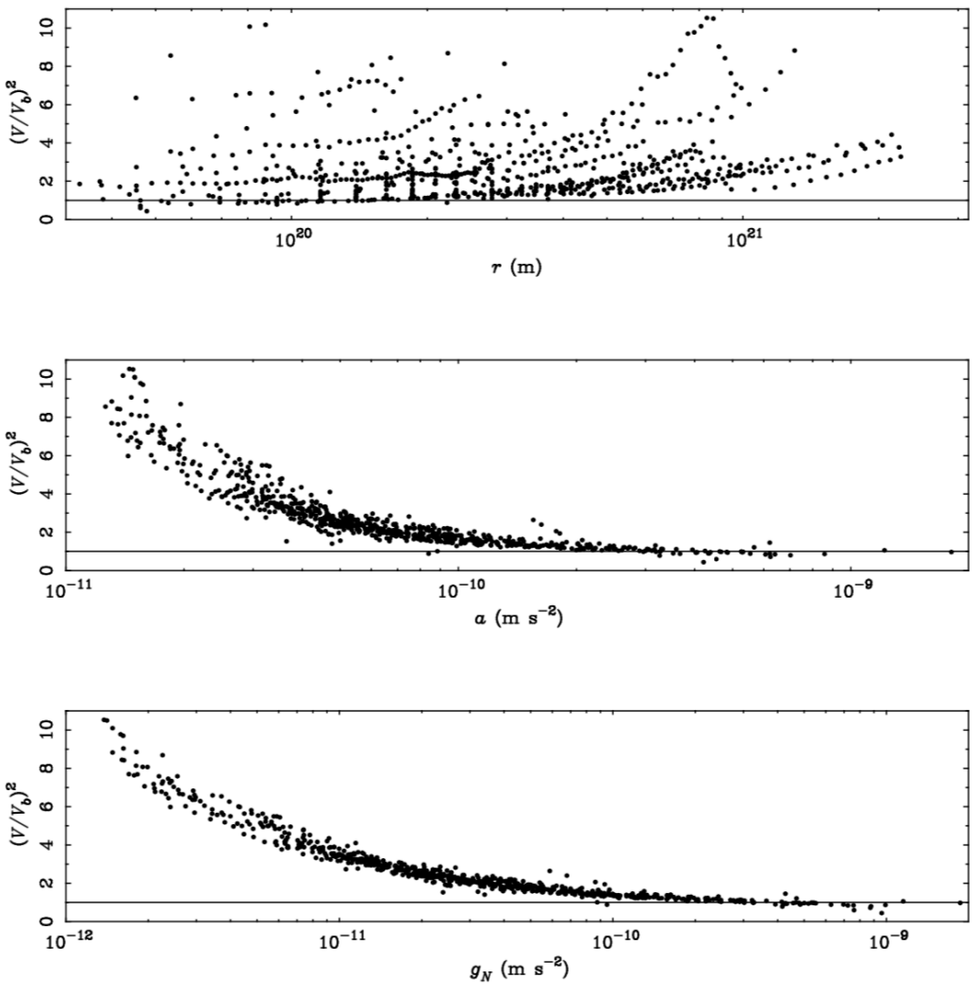
Photometry

$$a_N \equiv -\frac{GM_b}{r^2}$$

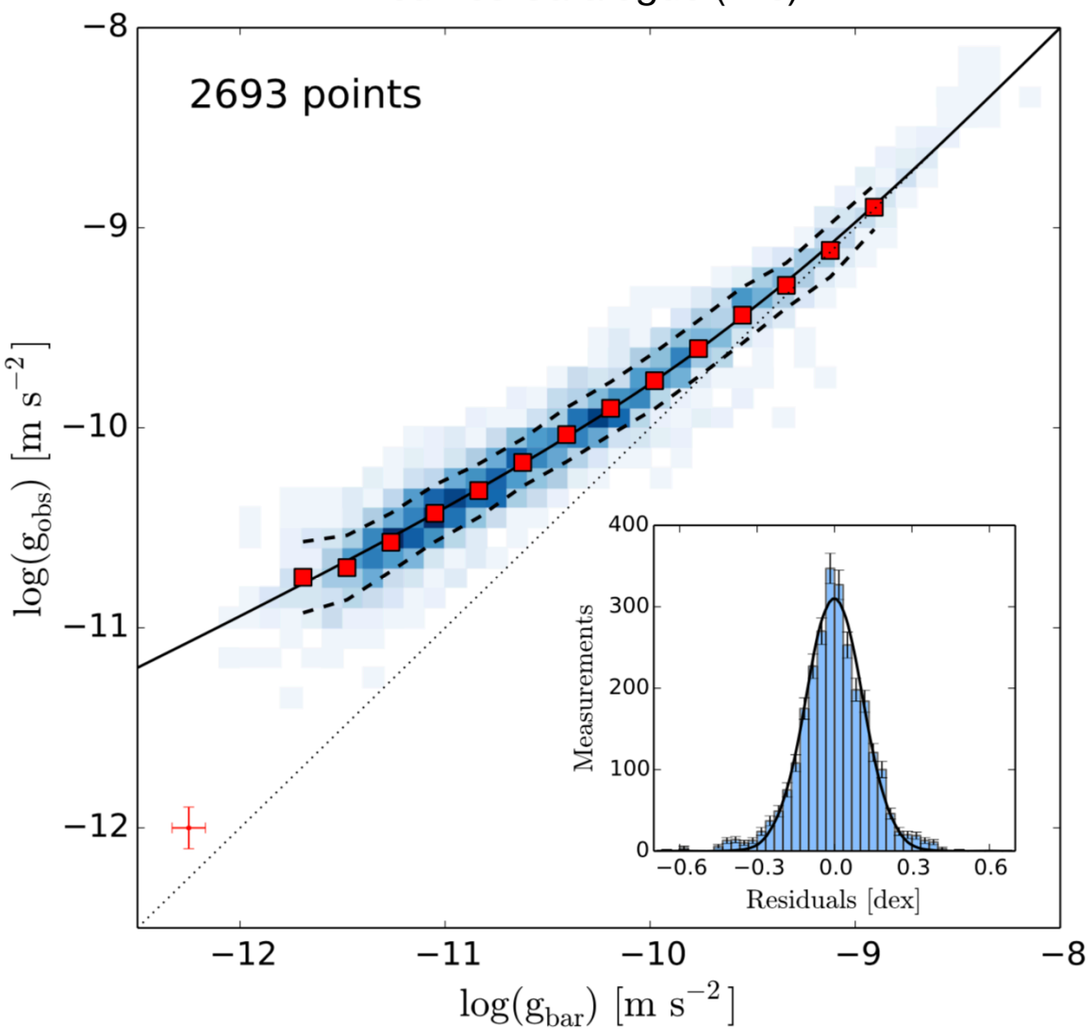
Famae, B., & McGaugh, S.S., 2012, LRR, 15, 10

McGaugh, S.S., Lelli, F., & Shombert, J., 2016, PRL, 117, 201101

SPARC data



SPARC: *Spitzer* Photometry and Accurate Rotation curves Catalogue (z=0)



Famae, B., & McGaugh, S.S., 2012, LRR, 15, 10

McGaugh, S.S., Lelli, F., & Shombert, J., 2016, PRL, 117, 201101

Normalize to a_{dS}

Photometry

$$\varsigma = \frac{a_N}{a_{dS}}, \quad a_{dS} \equiv cH$$

Spectroscopy

Radial acceleration^{-1} $\frac{a_N}{\alpha}$

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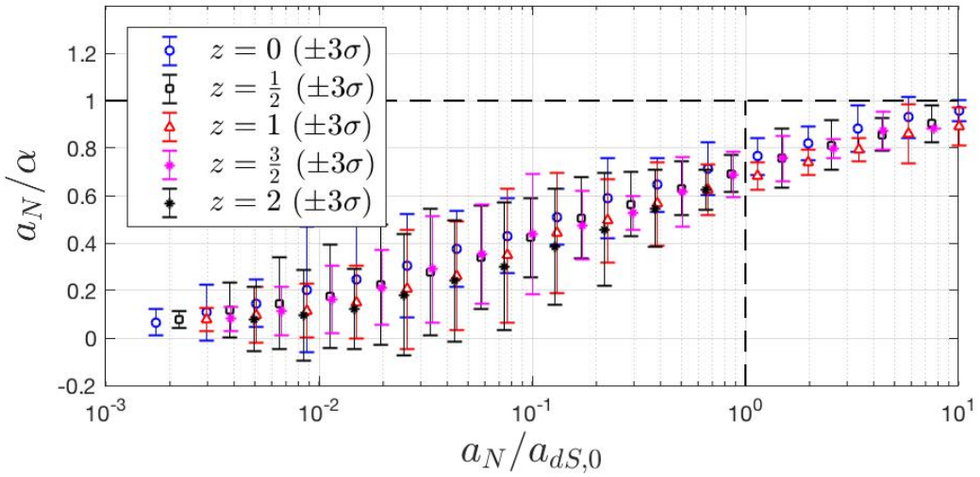
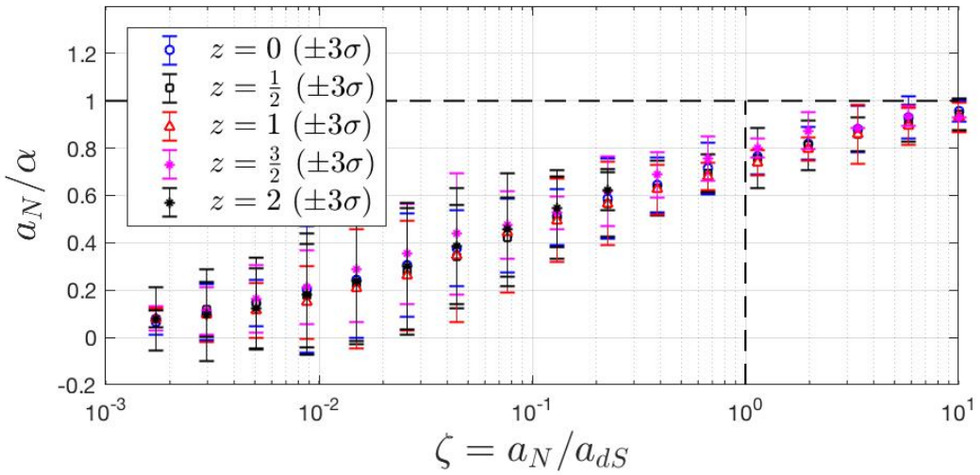
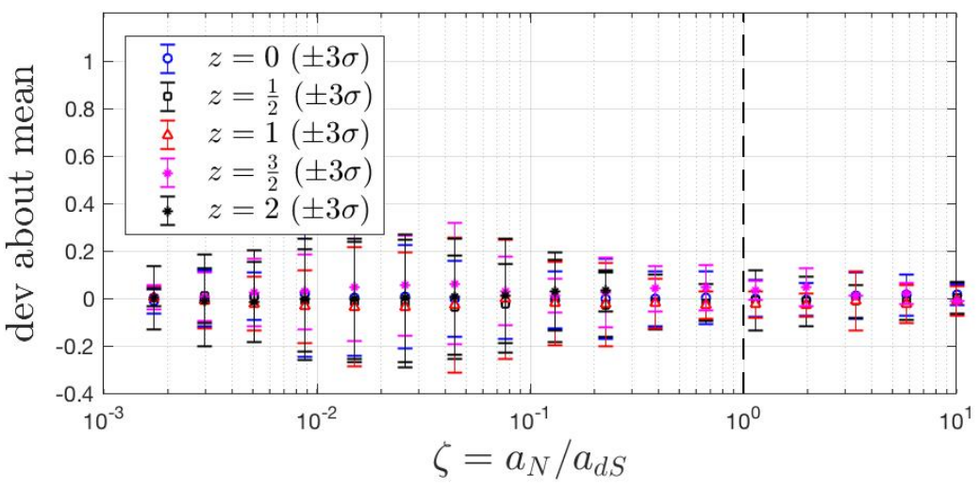
ΛCDM galaxy models in MUGS2







McMaster Unbiased Galaxy Simulations 2

Keller, B.W., Wadsley, J., Benincasa, S.M., & Couchmanm, H.M.P., 2014, MNRAS, 442, 3013

Keller, B.W., Wadsley, J., & Couchman, H.M.P., 2016, MNRAS, 463, 1431

Keller, B.W., & Wadsley, J.W., 2017, ApJ, 835, L17

Self-similar galaxy dynamics

tracing background cosmology

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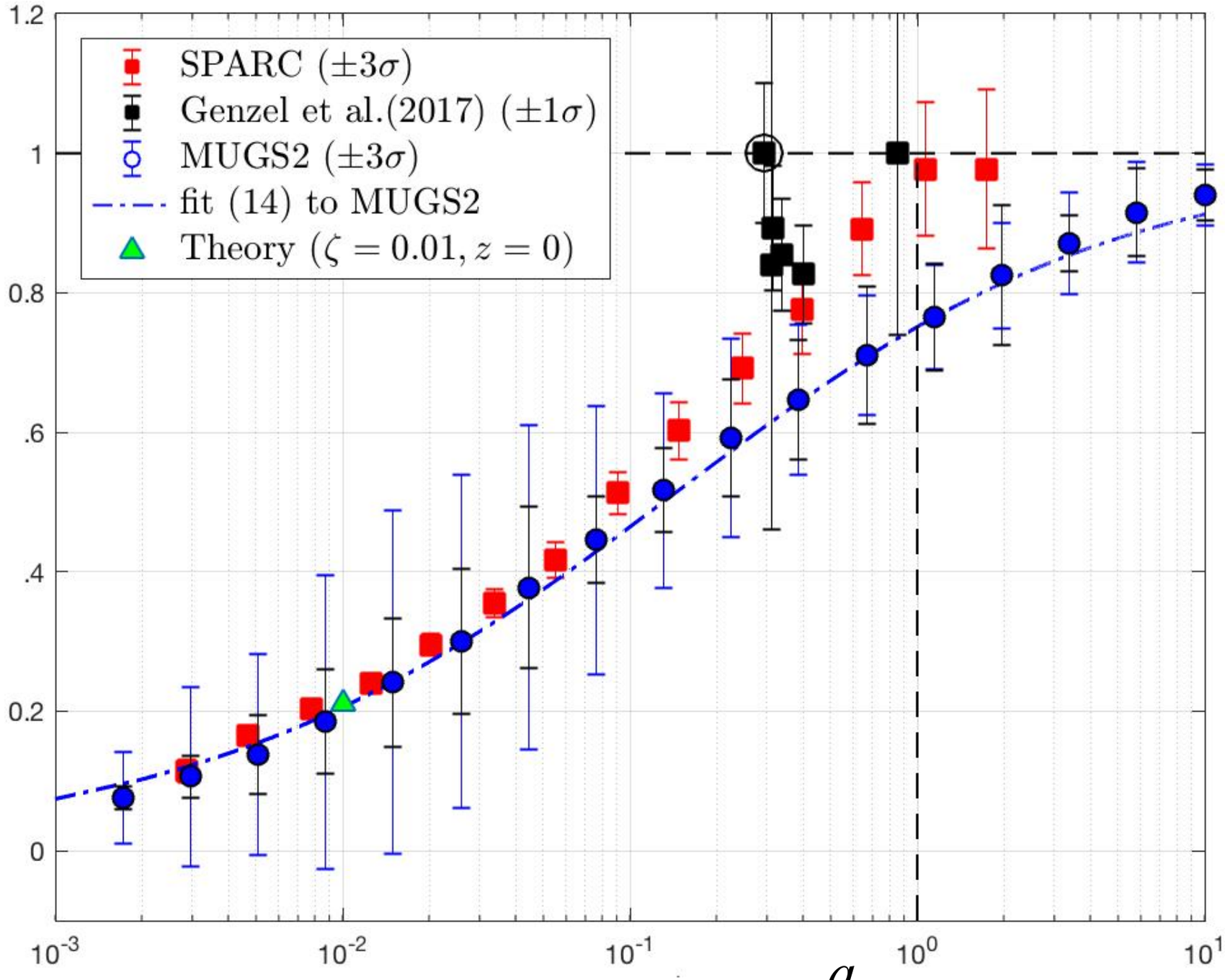
ΛCDM/MUGS2 vs SPARC



$$\frac{a_N}{\alpha}$$

6σ

at ζ=1

$$\varsigma = \frac{a_N}{a_{dS}}$$

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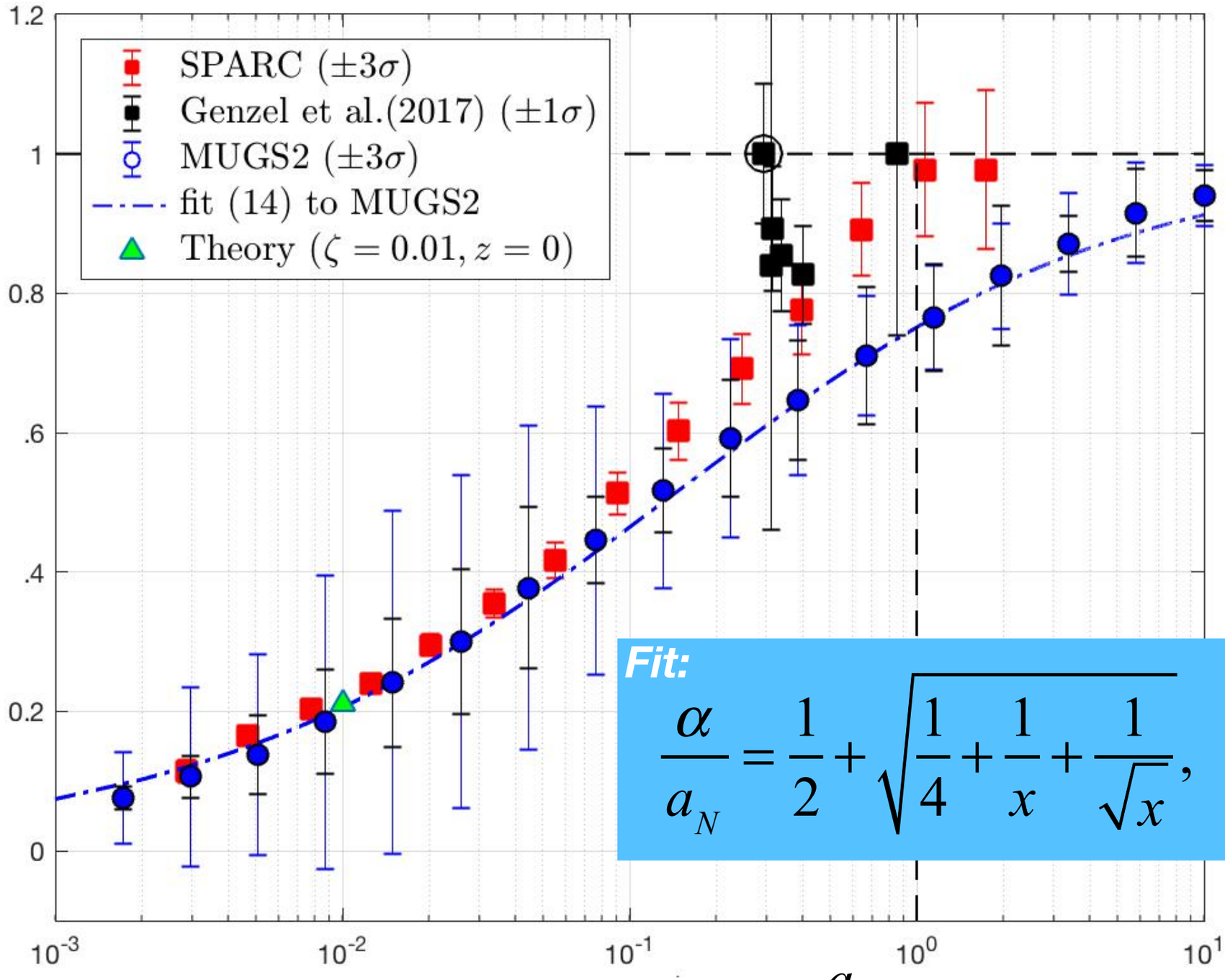
ΛCDM/MUGS2 vs SPARC



$$\frac{a_N}{\alpha}$$

6σ

at ζ=1

Fit:

$$\frac{\alpha}{a_N} = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{1}{x} + \frac{1}{\sqrt{x}}}, \quad x = 4\pi\varsigma$$

$$\varsigma = \frac{a_N}{a_{dS}}$$

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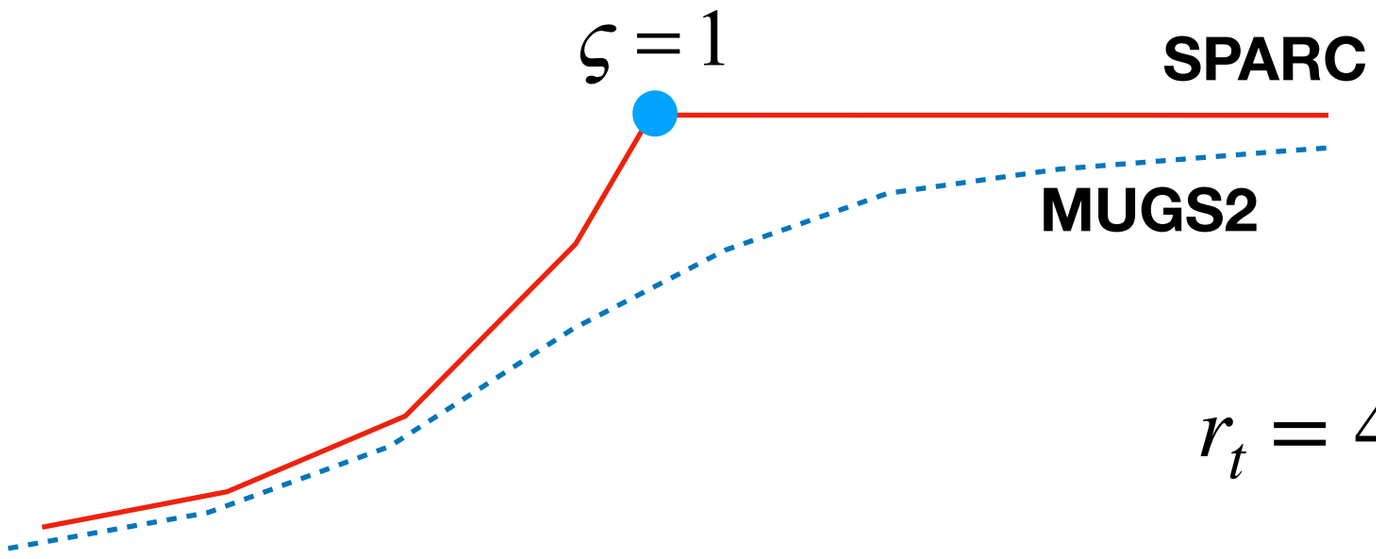
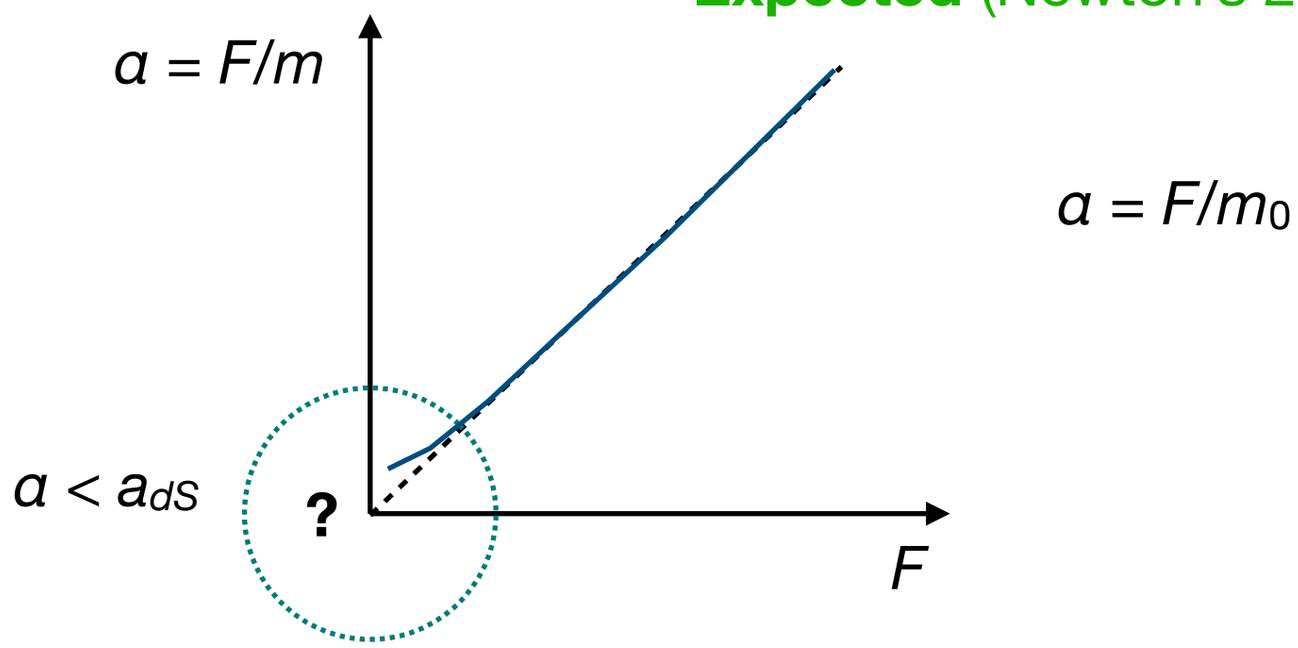
C^0 Galaxy dynamics



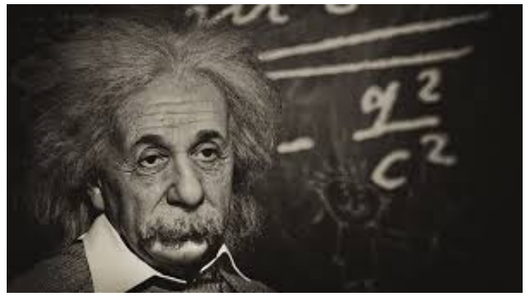
$$r_t = 4.7 M_{11}^{1/2} (H_0/H)^{1/2} \textbf{kpc}$$

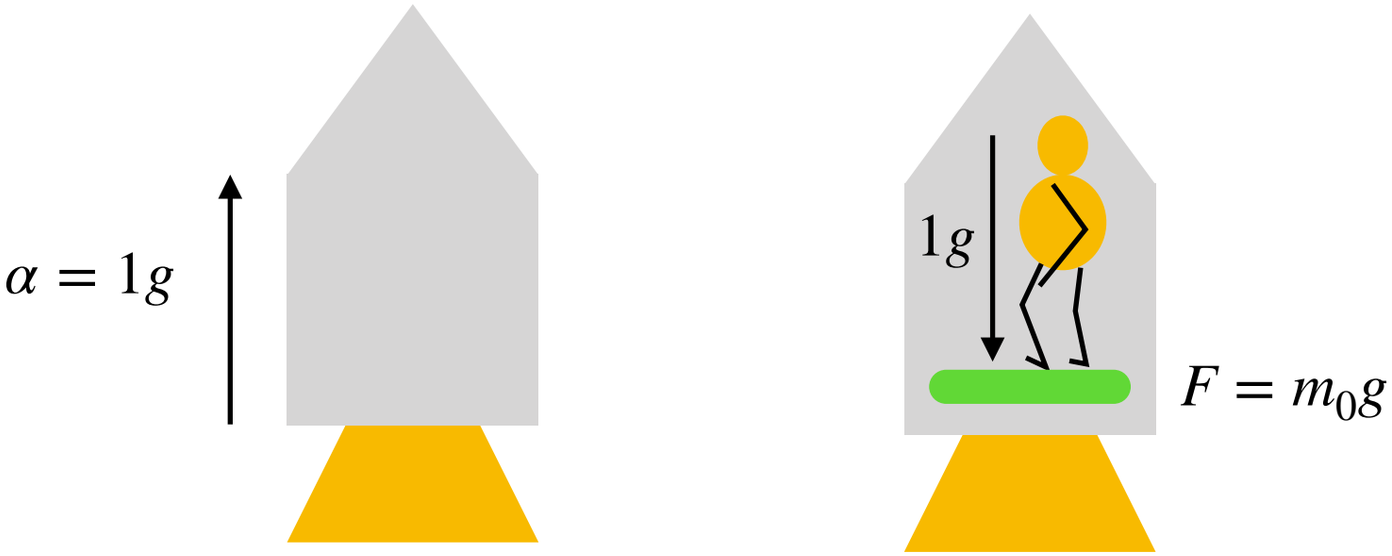
Expected (Newton's 2nd law)



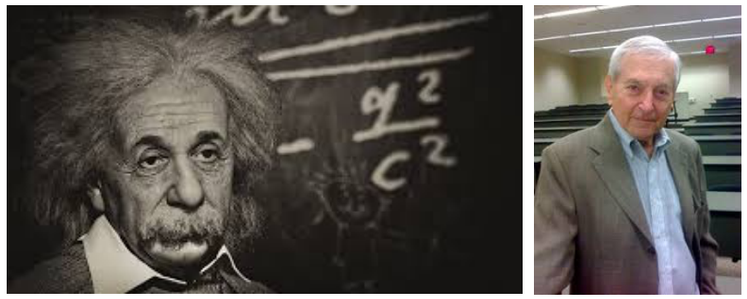
6σ gap: Problem of inertia… ?

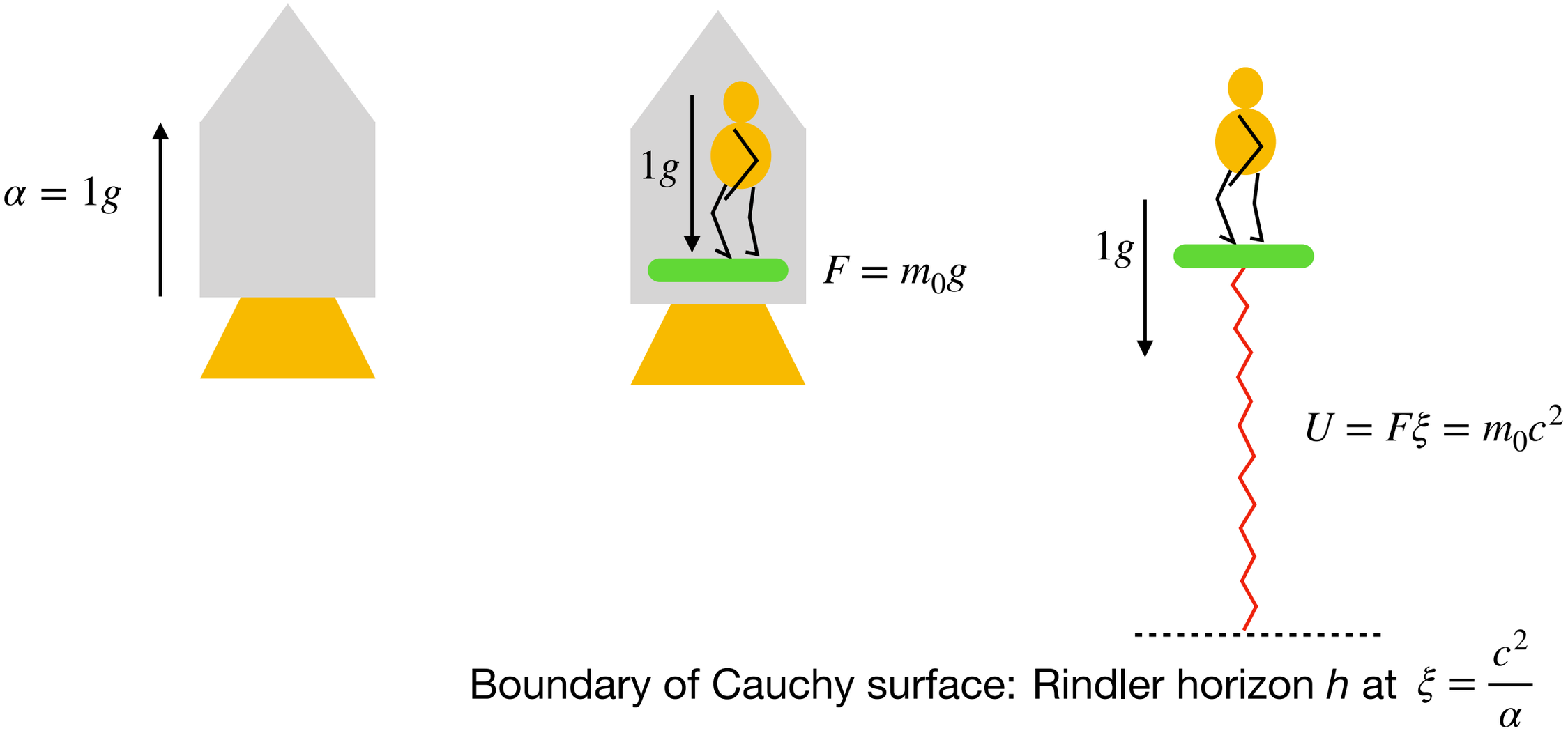
Equivalence Principle





Extended Equivalence Principle

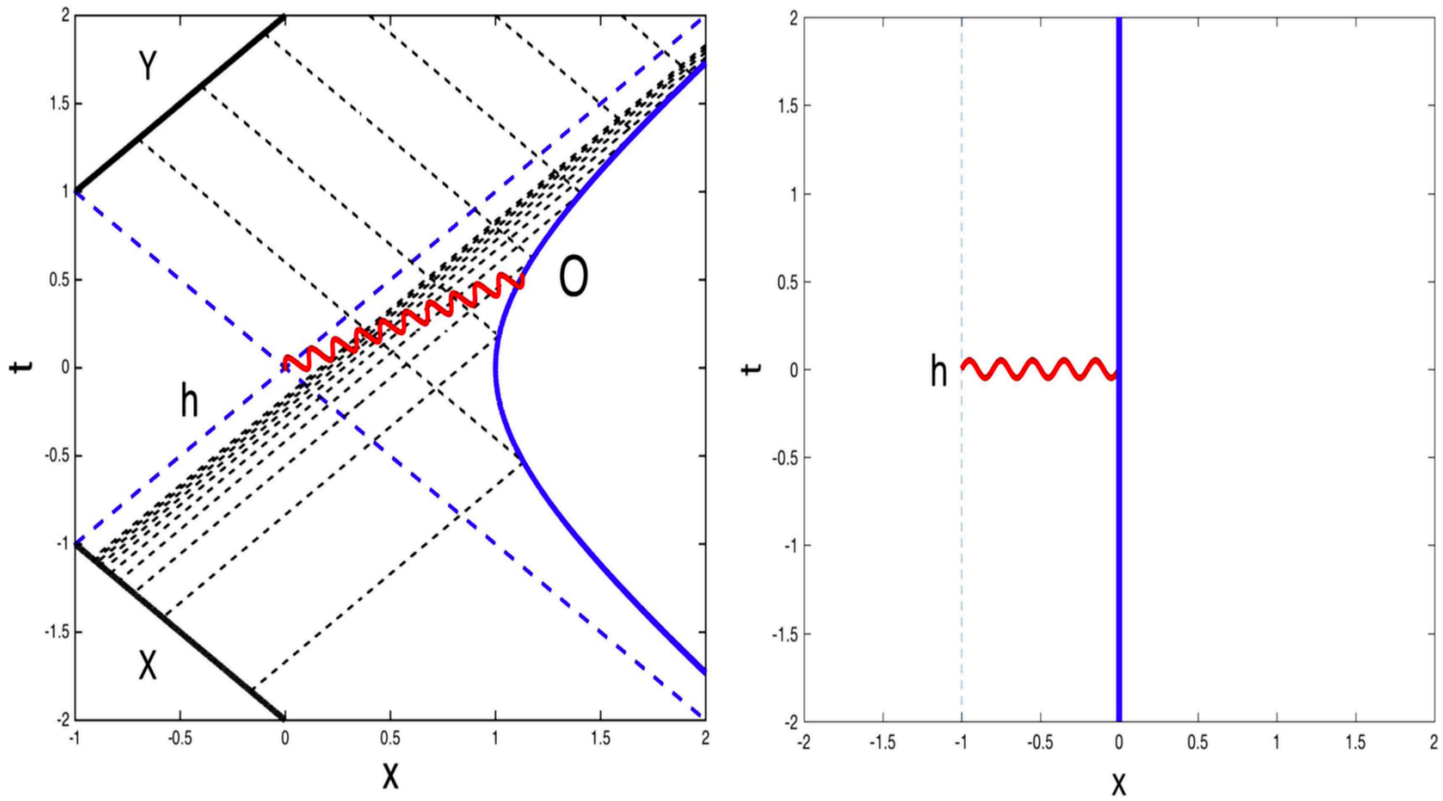




Newtonian inertia = Gravitational binding energy to *h*

van Putten, 2017, ApJ, 837, 22; ApJ, 848, 28

Origin inertia is nonlocal



Origin: entanglement entropy at Unruh temperature *h* set by α.

On a cosmological background with cosmological horizon $\mathcal{H}$ at Hubble radius

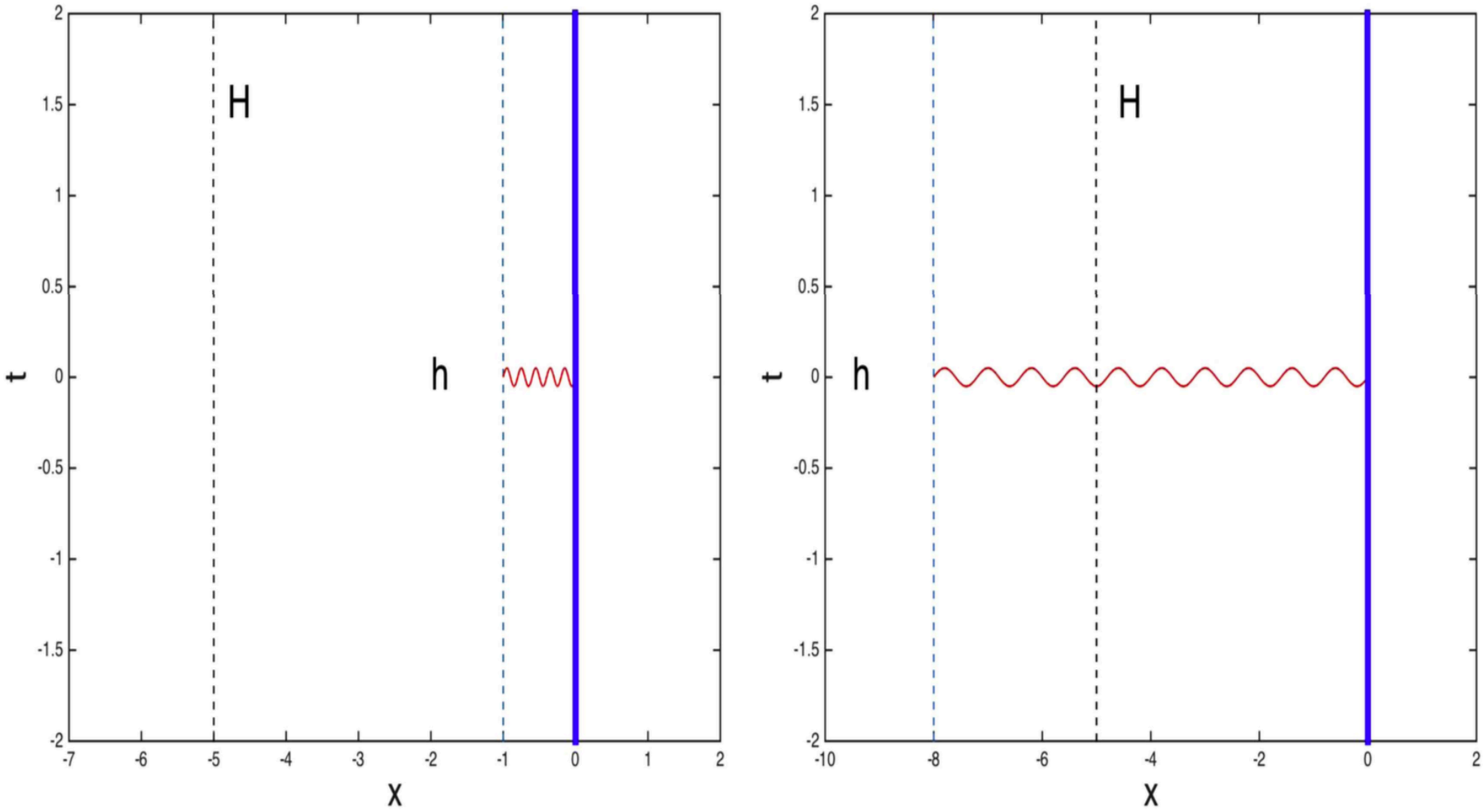
$$R_H = \frac{c^2}{a_{dS}} = \frac{c}{H}$$

h and $\mathcal{H}$ are both apparent horizons …

van Putten, 2017, ApJ, 837, 22; ApJ, 848, 28

$\mathcal{H}$-constraint on inertia

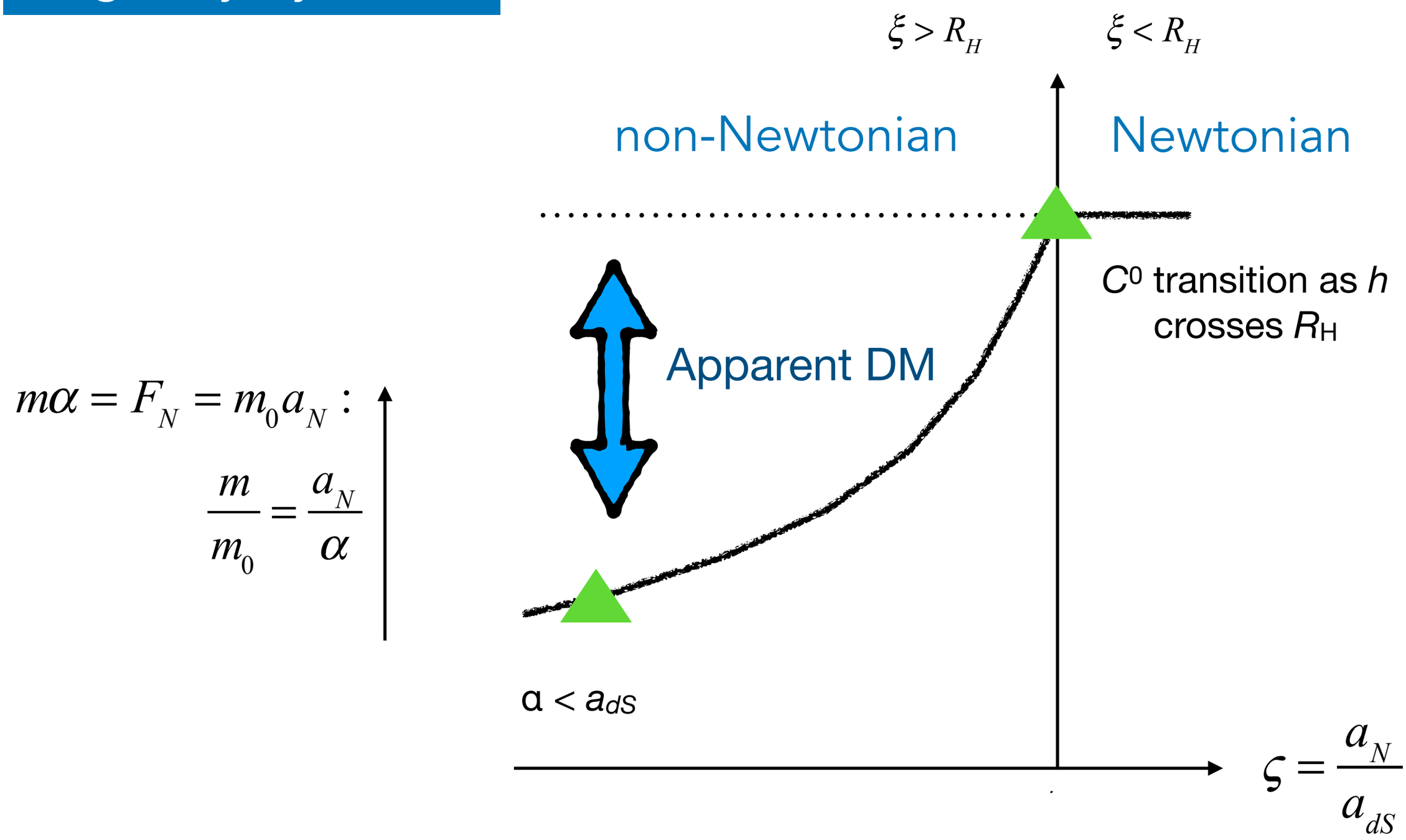
U to boundary of Cauchy surface: up to *h* or $\mathcal{H}$, **whichever is more nearby (causality):**



C^0 transition in *U* as α crosses a_{dS}

van Putten, 2017, ApJ, 837, 22; ApJ, 848, 28

C^0 galaxy dynamics

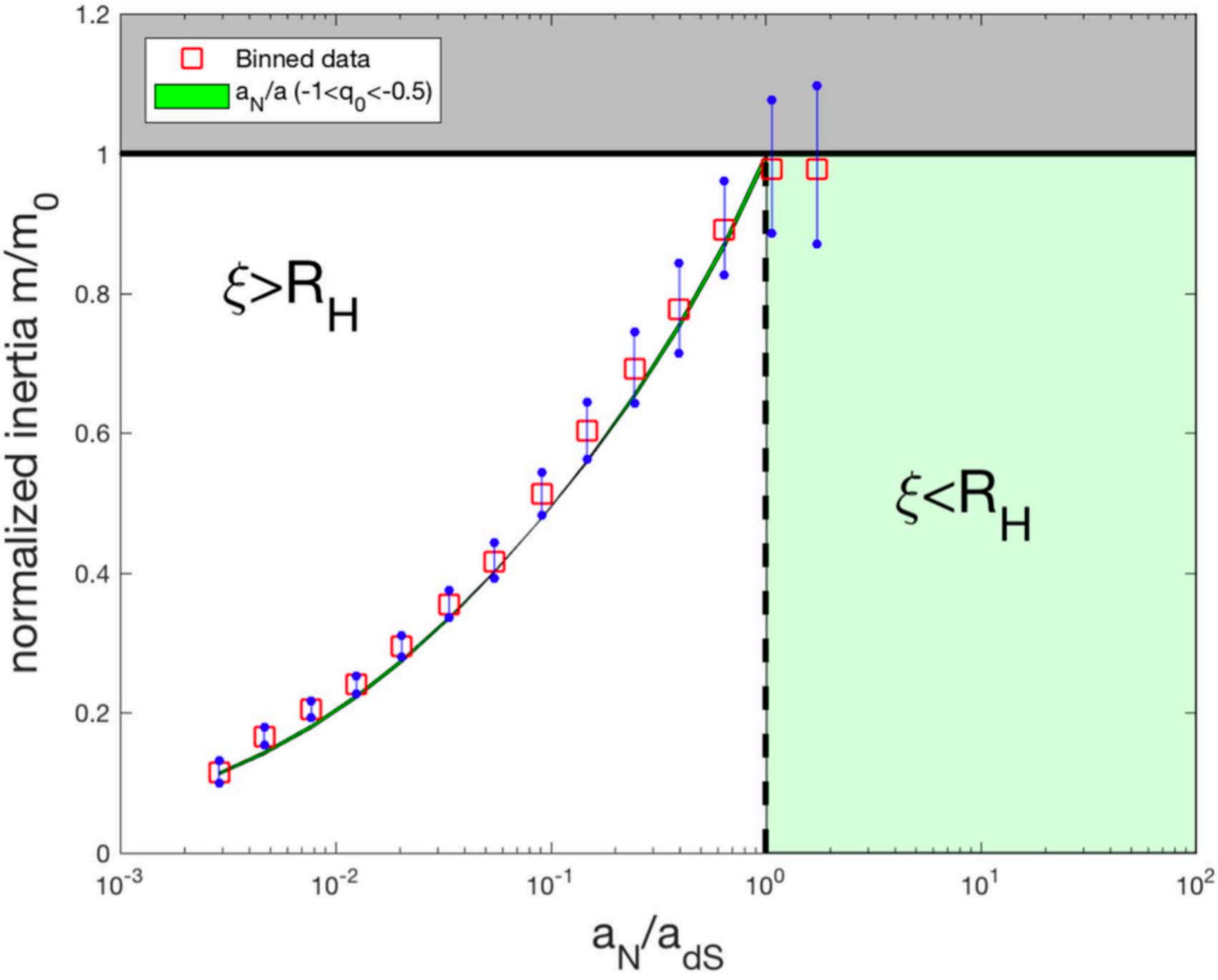


Same E_k and U_N: invariant Lagrangian and Hamiltonian

van Putten, 2017, ApJ, 848, 28

Confrontation with SPARC

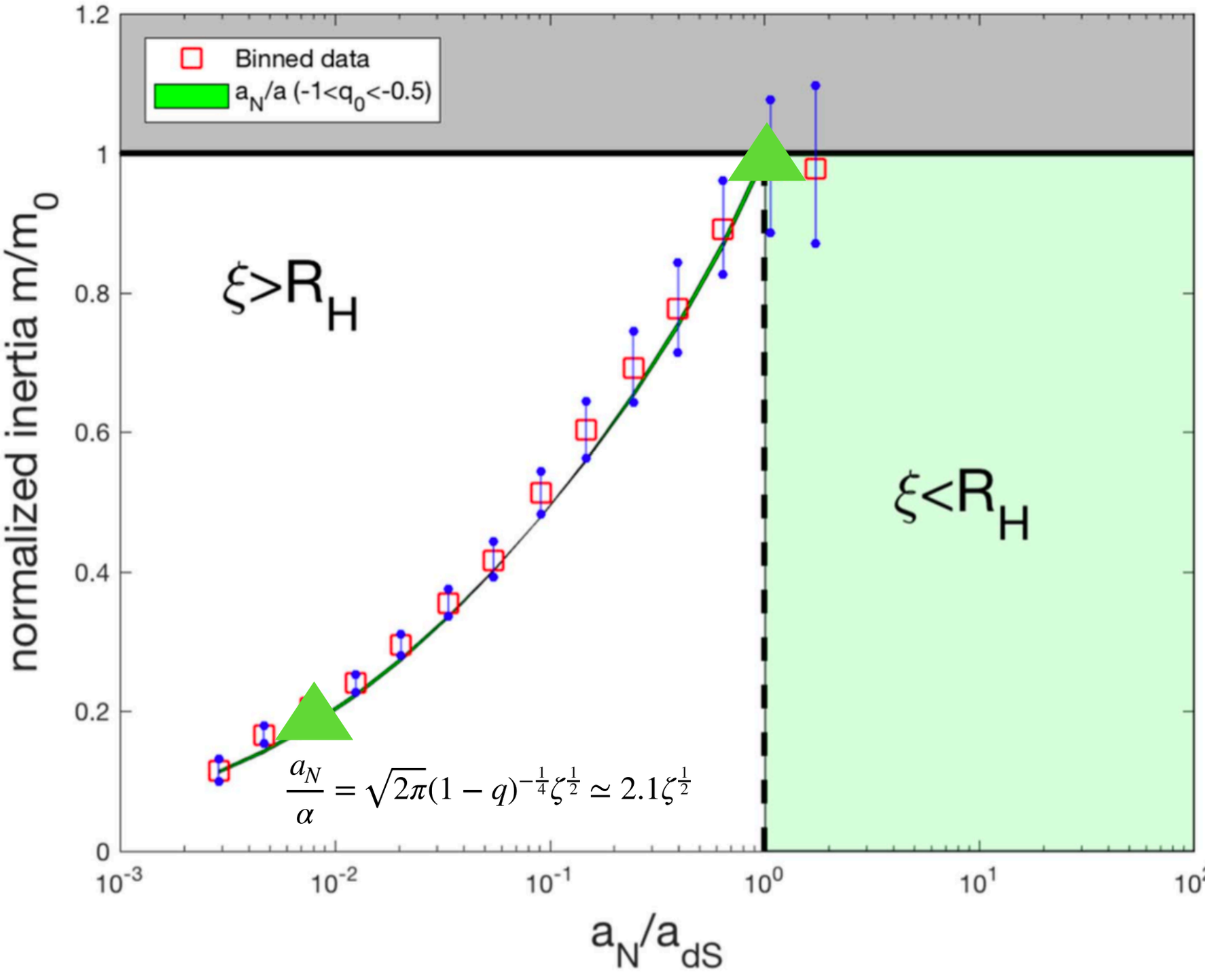
The Astrophysical Journal, 837:22 (8pp), 2017 March 1



van Putten, 2017, ApJ, 837, 22

Confrontation with SPARC

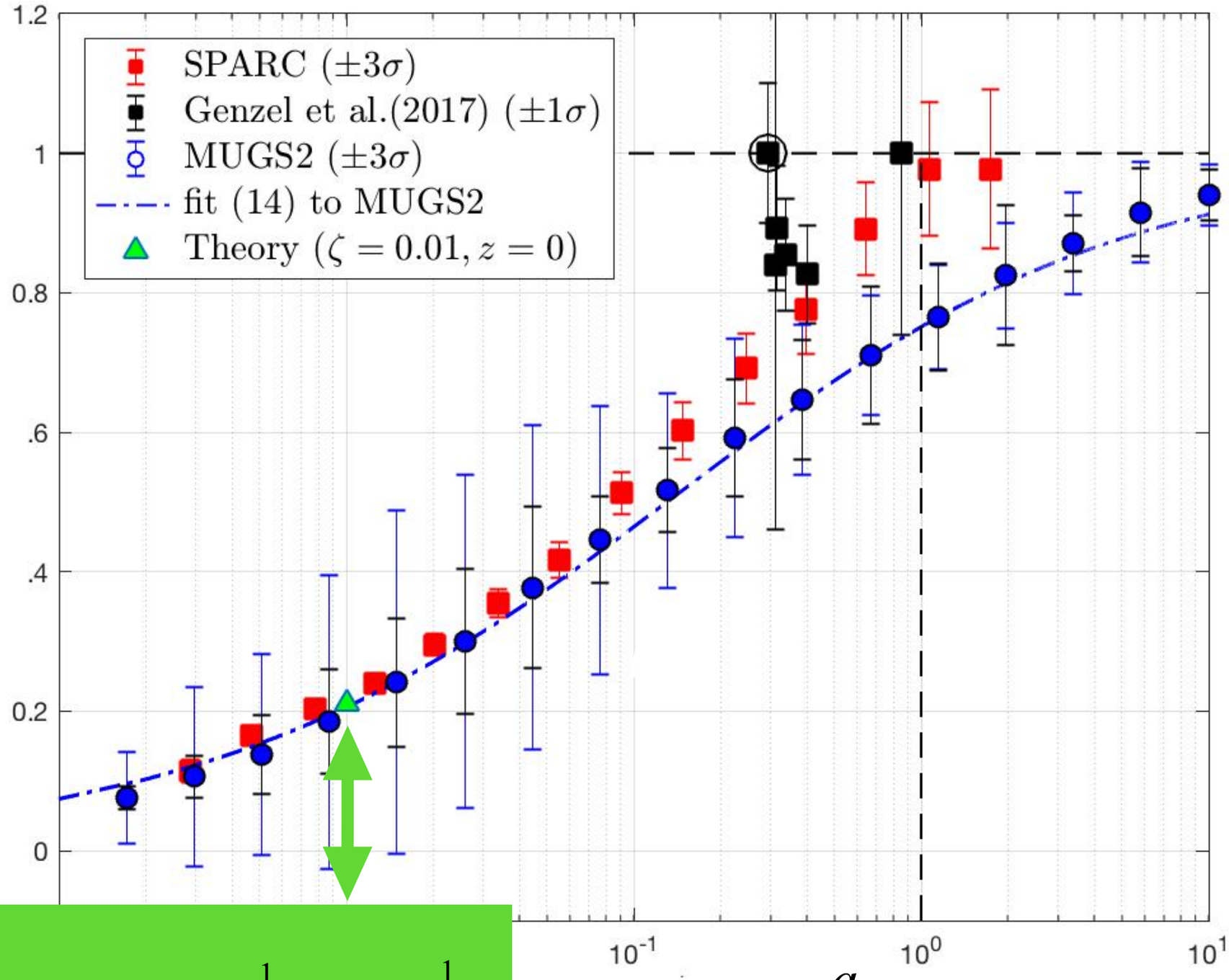
THE ASTROPHYSICAL JOURNAL, 837:22 (8pp), 2017 March 1



theory

van Putten, 2017, ApJ, 837, 22

ΛCDM/MUGS2 vs SPARC



$$\frac{a_N}{\alpha}$$

6σ

at ζ=1

Theory:

$$\frac{\alpha}{a_N} = \sqrt{2\pi\varsigma}\left(1-q\right)^{-\frac{1}{4}} \cong 2.1\varsigma^{\frac{1}{2}}$$

$$\varsigma = \frac{a_N}{a_{dS}}$$

van Putten, 2018, MNRAS, 481, L26

Conclusions

Galactic evolution in a cosmological vacuum with a running de Sitter scale of acceleration $a_{dS} = cH$:

SPARC galaxies appear C^0, effectively self-similar in $\varsigma = a_N/a_{dS}$

6σ gap ΛCDM/MUGS2-SPARC about $\varsigma=1$

Confrontation of Newton's 2nd law with SPARC

$m<m_0$ ($\varsigma<1$), $U=mc^2$ drops below Newtonian value $U=m_0c^2$ (h crosses $\mathcal{H}$).

No DM on galactic scales

$$\lambda >> r_t = 4.7 M_{11}^{1/2} (H_0/H)^{1/2} \textbf{kpc}$$

m_{DM} << mass of fuzzy DM

Expected tangible result from lab experiments:

accurate null-results

van Putten, 2015, MNRAS, 450, L48;
2018, MNRAS, 481, L26

van Putten, 2017, ApJ, 837, 22; ApJ, 848, 28