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Extending the Radial Acceleration Relation using Weak Gravitational Lensing with the Kilo-Degree Survey

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ABSTRACT
TBW

Key words: gravitational lensing: weak – Surveys – methods: statistical – galaxies: haloes – cosmology: dark matter, theory – gravitation.

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1 INTRODUCTION

It has been known for several decades that the outer regions of galaxies rotate faster than would be expected from Newtonian dynamics based on their luminous baryonic mass. This was first discovered by Rubin (1983) through measuring galactic rotation curves of optical disks, and by Bosma (1981) through measuring hydrogen profiles at larger radii. The excess gravity implied by these measurements have been generally attributed to an invisible substance named Dark Matter (DM), a term coined earlier by Zwicky (1937) when he discovered the missing mass problem by measuring the dynamics of galaxies in clusters. Following more recent observations using Weak gravitational Lensing (WL, Hoekstra et al. 2004; von der Linden et al. 2014; Mandelbaum 2015), Baryon Acoustic Oscillations (BAO's, Eisenstein et al. 2005; Blake et al. 2011) and the Cosmic Microwave background (CMB, Spergel et al. 2003; Planck XIII 2016), cold dark matter[1] (CDM) became a key ingredient of the current standard model of cosmology: the ΛCDM model. In this paradigm, CDM accounts for $\Omega_{\rm CDM} = 0.266$ of the critical density in the Universe, while the cosmological constant Λ used to explain the accelerated expansion of the Universe accounts for $\Omega_\Lambda = 0.685$.

Although the ΛCDM model successfully describes the behavior of DM on a wide range of scales, no conclusive evidence for the existence of DM particles has been found so far (despite years of enormous effort; for an overview, see Bertone et al. 2005; Bertone & Tait 2018). This still leaves some room for alternative theories of gravity, such as Modified Newtonian Dynamics (MOND, Milgrom 1983) and the more recent theory of Emergent Gravity (EG, Verlinde 2016). In these theories particle DM does not exist, and all gravity is due to baryonic matter (or in the case of EG, the interaction between baryonic matter and the entropy associated with dark energy). Hence one of the main properties of these theories, is that the mass discrepancy in galaxies correlates strongly with their baryonic mass distribution. Such a correlation is indeed observed, first as the (baryonic) Tully-Fisher relation (TFR, Tully & Fisher 1977) between the total luminous mass of a spiral galaxy and its asymptotic rotation velocity (Pierce & Tully 1988; Bernstein et al. 1994; McGaugh et al. 2000; McGaugh 2012), then as the strong correlation of the mass discrepancy as a function of galaxy radius with the enclosed luminous mass (Sanders 1986, 1996; McGaugh 2004; Sanders & Noordermeer 2007; Wu & Kroupa 2015). Particularly, the latest results from McGaugh et al. (2016) and

2 DATA

2.1 KiDS source galaxies

Write the beginning. Need to know:

- What changes as we go to KiDS-1000 (K1000 paper?).

[1] DM particles that moved at non-relativistic speeds at the time of recombination, as favoured by measurements of the CBM (Planck XVI 2014) and the Lyman-α forest (Viel et al. 2013).

2.2 GAMA foreground galaxies

Write everything.

2.3 KiDS foreground selection

Still need to know:

- Maciek's GL-KiDS selection criteria for K1000.
- Angus' stellar mass method for K1000.

2.4 MICE mock galaxies

Write everything.

2.5 Bahamas mock galaxies

Written by Kyle?

3 DATA ANALYSIS

3.1 Isolated galaxy selection

Write the beginning. Still need to know:

- how to test the isolation criterion.

3.2 Lensing measurement

Write the beginning. Still need to know:

- How (if?) the GGL-pipeline changes with K1000.

3.3 Conversion to radial acceleration

Still need to know: whether we will use the SIS assumption or linear interpolation.

- Test both methods using the Bahamas simulation.

4 THEORETICAL PREDICTIONS

4.1 Analytical CDM model

Written by Kyle?

4.2 Modified Newtonian Dynamics

Write everything.

4.3 Emergent Gravity

Write everything.

5 RESULTS

Write when the results are ready. I still need:

- The K1000 lensing catalogues with ANNz redshifts and stellar masses.
- The results from the Bahamas simulation.

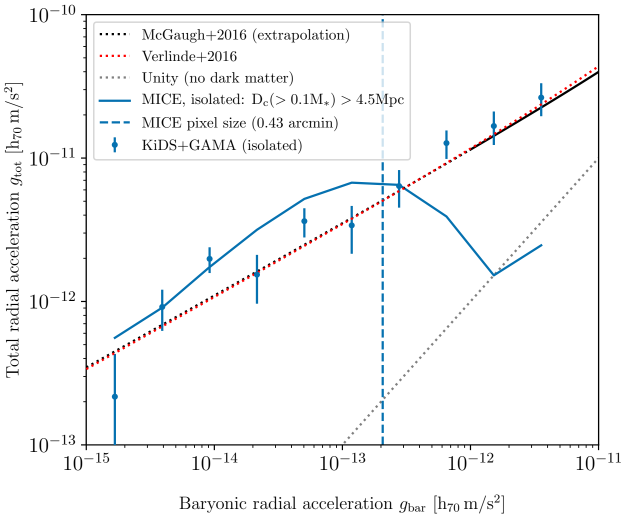

Figure 1. TBW

5.1 Isolated galaxies

5.2 Stellar mass bins

6 DISCUSSION AND CONCLUSION

Write at the end.

ACKNOWLEDGEMENTS

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REFERENCES

Bernstein G. M., Guhathakurta P., Raychaudhury S., Giovanelli R., Haynes M. P., Herter T., Vogt N. P., 1994, AJ, 107, 1962
Bertone G., Tait T. M. P., 2018, Nature, 562, 51
Bertone G., Hooper D., Silk J., 2005, Phys. Rep., 405, 279
Blake C., et al., 2011, MNRAS, 415, 2892
Bosma A., 1981, AJ, 86, 1791
Eisenstein D. J., et al., 2005, ApJ, 633, 560
Hoekstra H., Yee H. K. C., Gladders M. D., 2004, ApJ, 606, 67
von der Linden A., et al., 2014, MNRAS, 439, 2
Mandelbaum R., 2015, in Cappellari M., Courteau S., eds, IAU Symposium Vol. 311, Galaxy Masses as Constraints of Formation Models. pp 86–95 (arXiv:1410.0734)
McGaugh S. S., 2004, ApJ, 609, 652
McGaugh S. S., 2012, AJ, 143, 40
McGaugh S. S., Schombert J. M., Bothun G. D., de Blok W. J. G., 2000, ApJ, 533, L99
McGaugh S. S., Lelli F., Schombert J. M., 2016, Physical Review Letters, 117, 201101
Milgrom M., 1983, ApJ, 270, 365
Pierce M. J., Tully R. B., 1988, ApJ, 330, 579
Planck XIII x., 2016, A&A, 594, A13
Planck XVI x., 2014, A&A, 571, A16
Rubin V. C., 1983, Scientific American, 248, 96
Sanders R. H., 1986, MNRAS, 223, 539
Sanders R. H., 1996, ApJ, 473, 117
Sanders R. H., Noordermeer E., 2007, MNRAS, 379, 702
Spergel D. N., et al., 2003, ApJS, 148, 175
Tully R. B., Fisher J. R., 1977, A&A, 54, 661
Verlinde E. P., 2016, preprint, (arXiv:1611.02269)
Viel M., Becker G. D., Bolton J. S., Haehnelt M. G., 2013, Phys. Rev. D, 88, 043502
Wu X., Kroupa P., 2015, MNRAS, 446, 330
Zwicky F., 1937, ApJ, 86, 217

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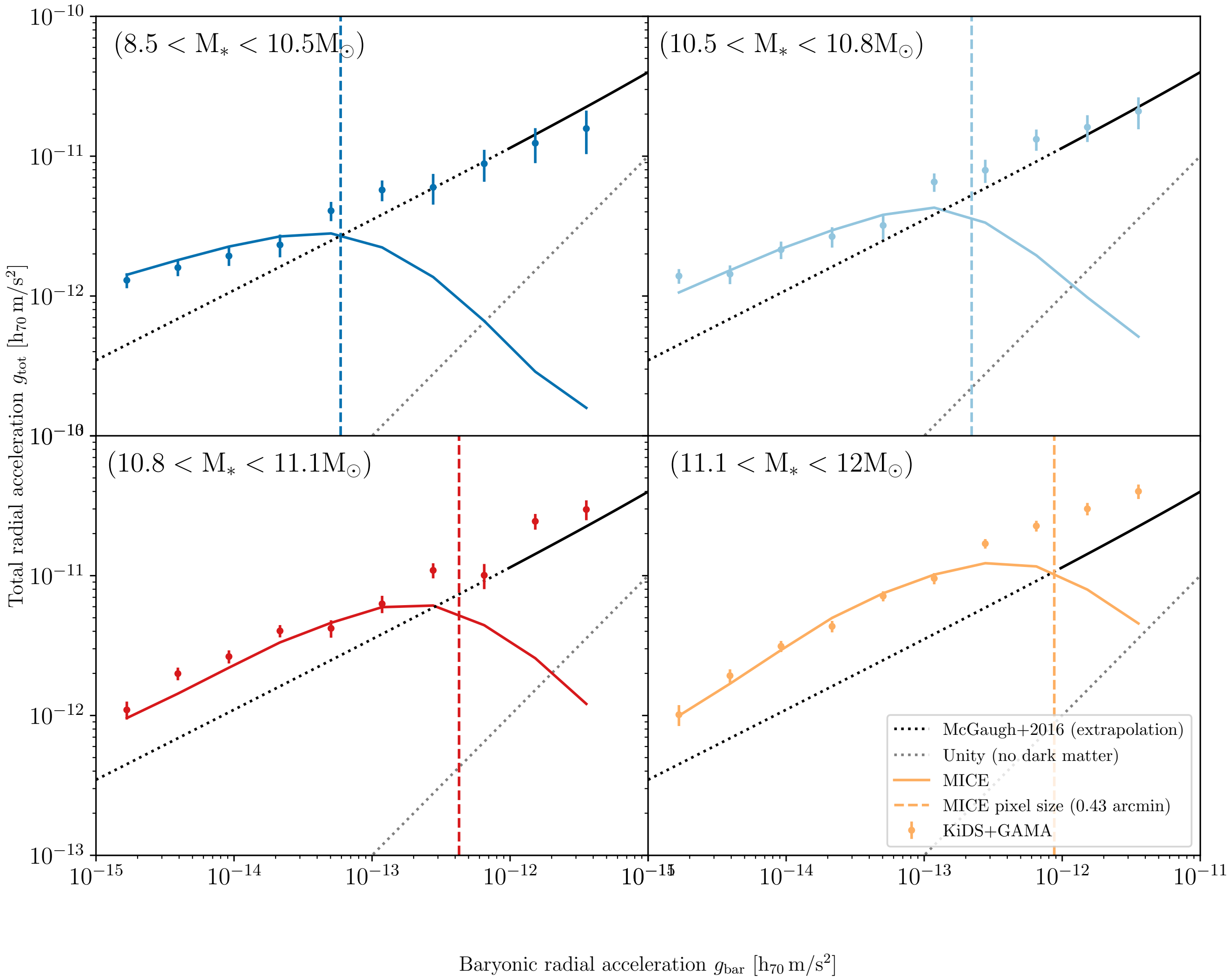

(8.5 < M* < 10.5M⊙)
(10.5 < M* < 10.8M⊙)
(10.8 < M* < 11.1M⊙)
(11.1 < M* < 12M⊙)
Total radial acceleration $g_{\rm tot}$ [h70 m/s²]
Baryonic radial acceleration $g_{\rm bar}$ [h70 m/s²]
McGaugh+2016 (extrapolation)
Unity (no dark matter)
MICE
MICE pixel size (0.43 arcmin)
KiDS+GAMA

Figure 2. TBW

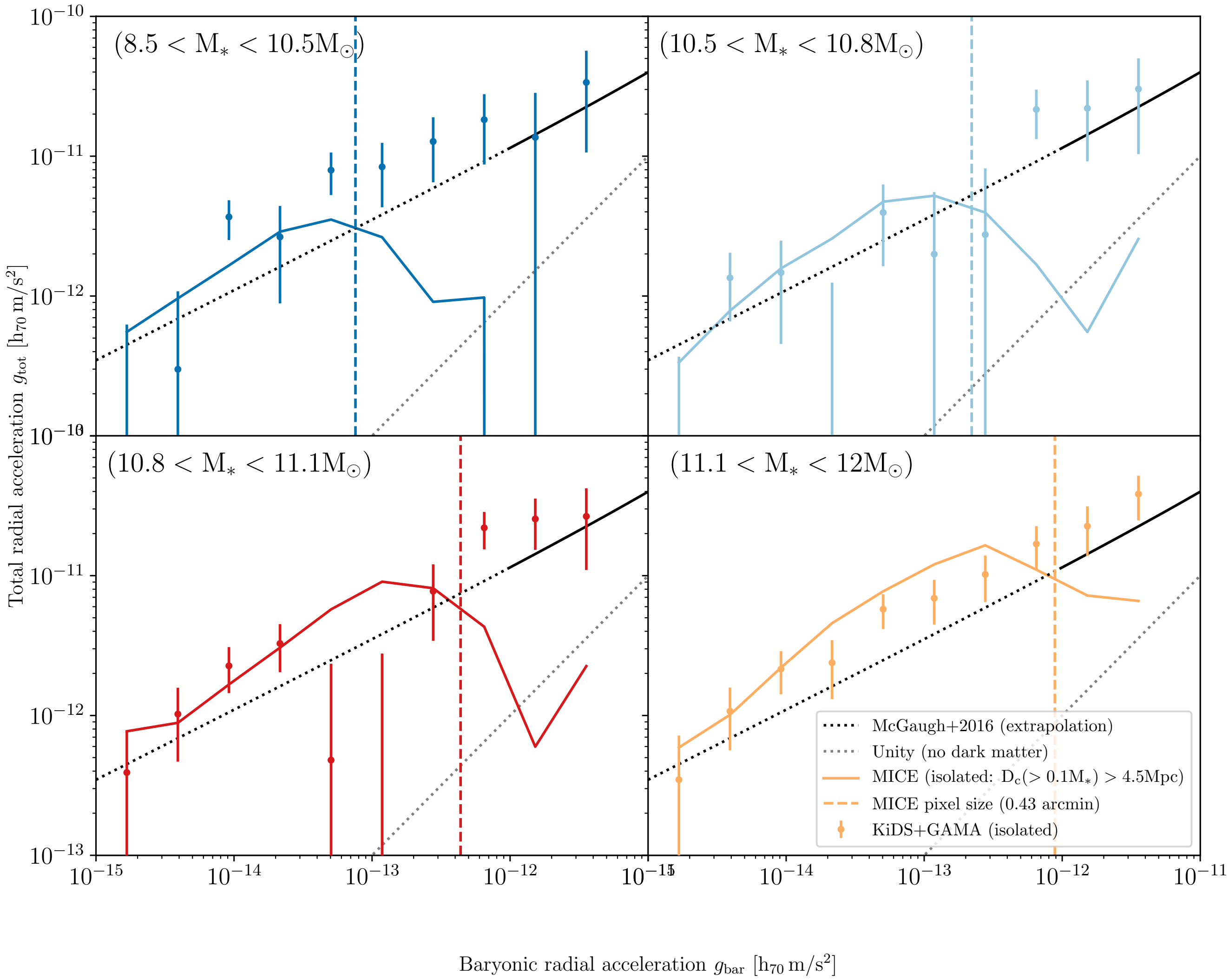

Figure 3. TBW

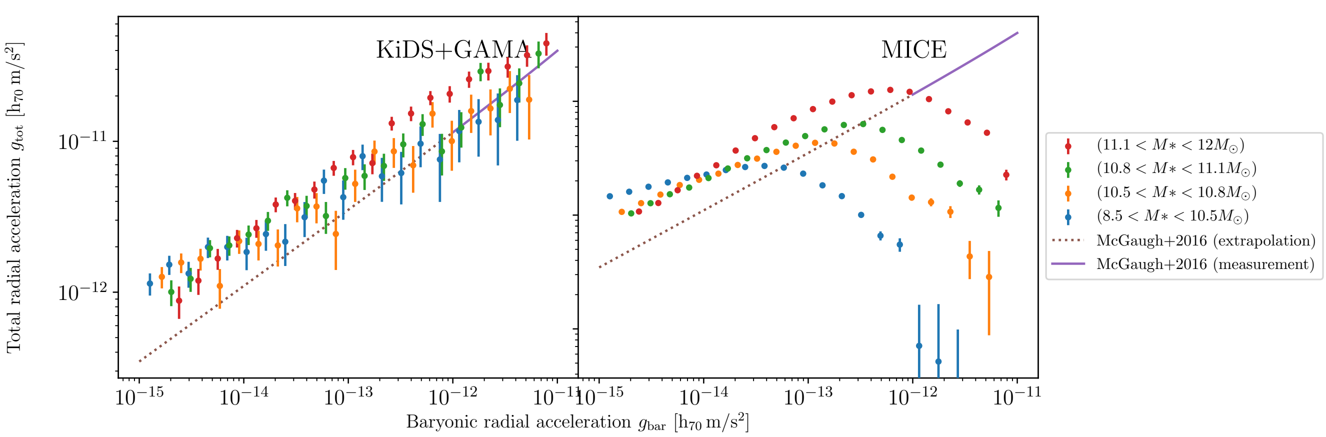

Figure 4. TBW