An Extensive Study of the Scatter in the Radial Acceleration Relation in Spiral Galaxies

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Calculating Radial Acceleration

- Radial Acceleration Relation (RAR) connects observed and expected radial acceleration
- **Observed** RAR from a rotation curve
- **Expected** RAR from a light profile
- Uncertainty in observed RAR is mostly from velocity and distance (10 - 20%)
- Uncertainty from expected RAR is mostly from M*/L (0.13 dex)

$$g_{obs} = \frac{(V/\sin(i))^2}{Rd}$$

$$g_{bar} = \frac{G\Upsilon 10^{-(M_\odot - m)/2.5}}{R^2}$$

The Radial Acceleration Relation (RAR)

- Lelli et al. 2017 [1] presented the RAR for 154 spiral galaxies from the SPARC (Spitzer Photometry and Accurate Rotation Curves [2]) survey
- SPARC covers a wide range of galaxy parameter space
- Using a single parameter, MOND, relation they fit the data
- RAR scatter measured to be 0.13 dex, seemingly consistent with being intrinsically zero [1]
- Potentially challenging the ΛCDM paradigm

$$g_{obs} = \frac{g_{bar}}{1 - e^{-\sqrt{g_{bar}/g_\dagger}}}$$

Collecting More Data

- Data collated from 6 surveys to test zero scatter hypothesis [2,3,4,5,6,7]
- Over 1500 galaxies in new sample
- Combined collection of > 80,000 data points in new RAR analysis
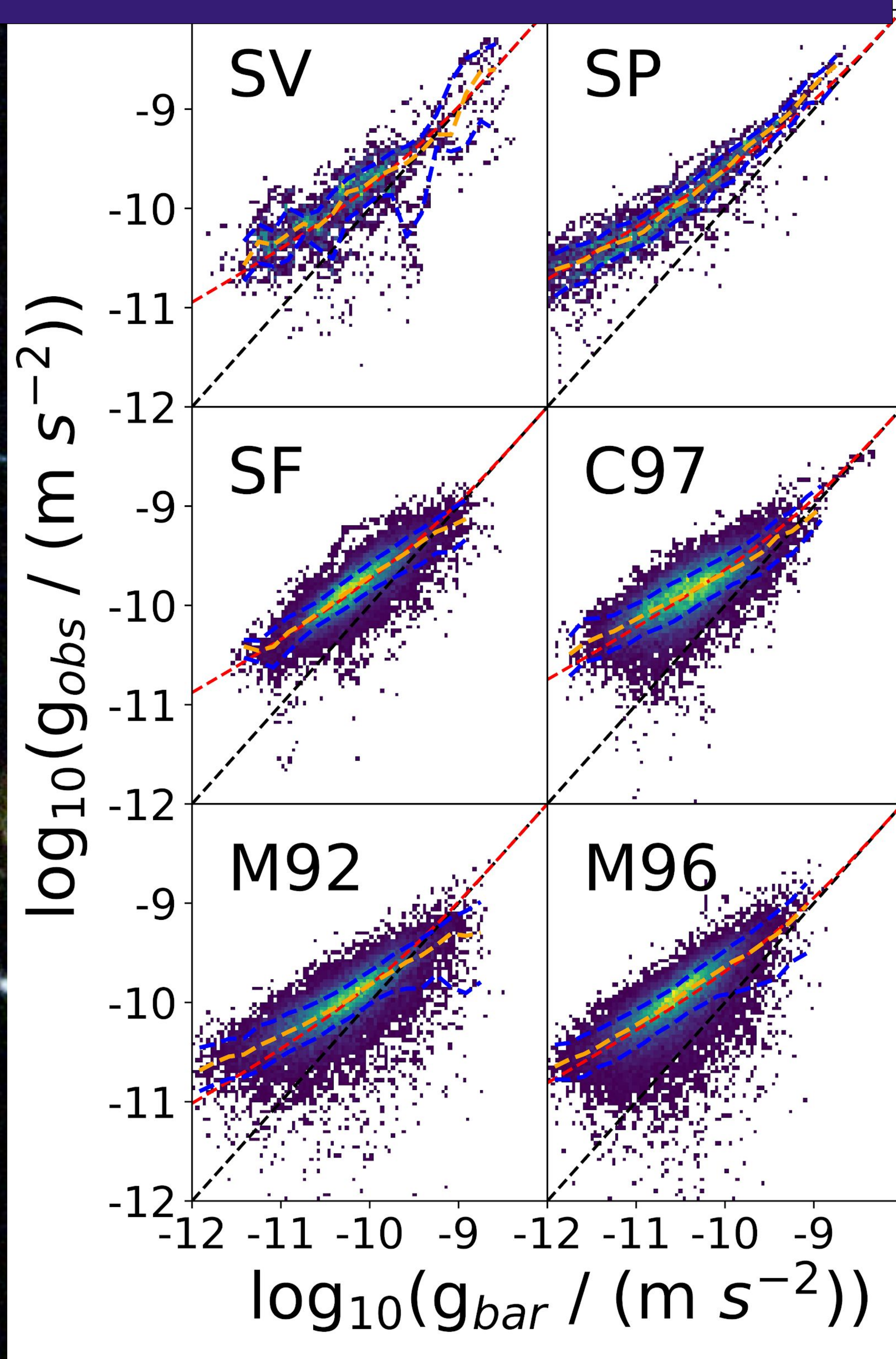- Mostly Sb and Sc type galaxies

Measuring The RAR Scatter

- Each dataset fit to RAR separately
- $g_\dagger$ ranges from 0.75 - 3.83 · 10^{-10} m·s^{-2}
- Bootstrap uncertainty 0.08 · 10^{-10} m·s^{-2}
- Measured forward scatter in residuals ranges from 0.15 - 0.28 dex

Observational RAR
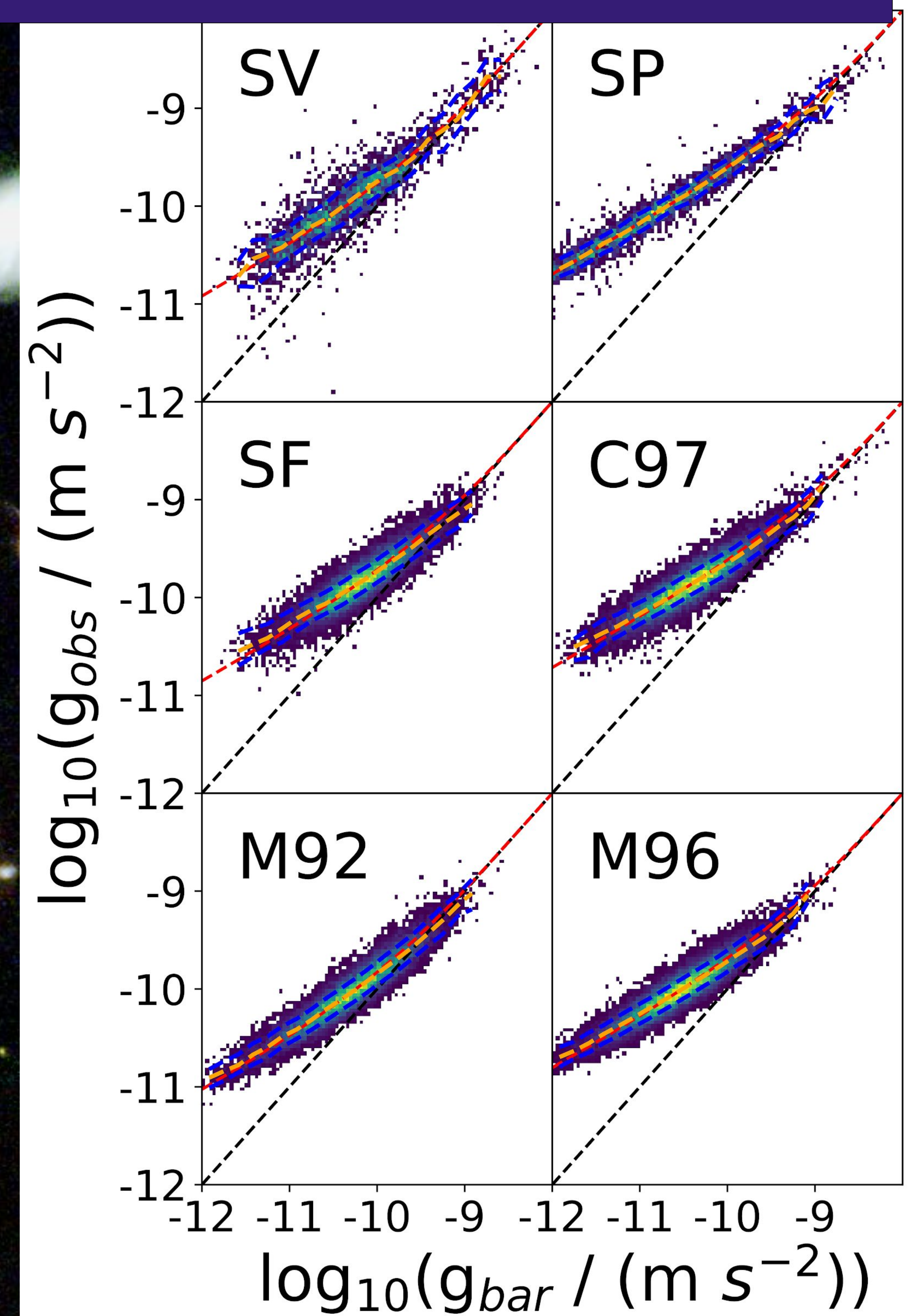

Simulated RAR

Simulating The RAR Scatter

- Monte-Carlo simulations used to test the zero scatter hypothesis
- Zero scatter assumed by projecting every point to observed RAR
- Using reported uncertainties, each datapoint "re-observed"
- Forward scatter in the residuals ranges from 0.1 - 0.15 dex
- In all cases, scatter is below that from the observed RAR

Conclusions

- More than order of magnitude increase in the amount of data
- RAR shows systematic differences between each survey
- Monte-Carlo sampling with reported uncertainties reflects expected scatter
- Observational uncertainties alone cannot explain the RAR scatter
- Consistent with the ΛCDM paradigm and galaxy formation models

Future Work

- Thin disk potential
- Resolved M*/L's
- Bulge/Disk decompositions

References

1. Lelli et al. 2017, ApJ - 836, 152
2. Lelli et al. 2016, AJ - 152, 157
3. Ouellette et al. 2017, ApJ - 843, 74
4. Courteau et al. 2000, ApJ - 544, 636
5. Courteau 1997, AJ - 114, 2402
6. Mathewson et al. 1992, ApJS - 81, 413
7. Mathewson et al. 1996, ApJS - 107, 97