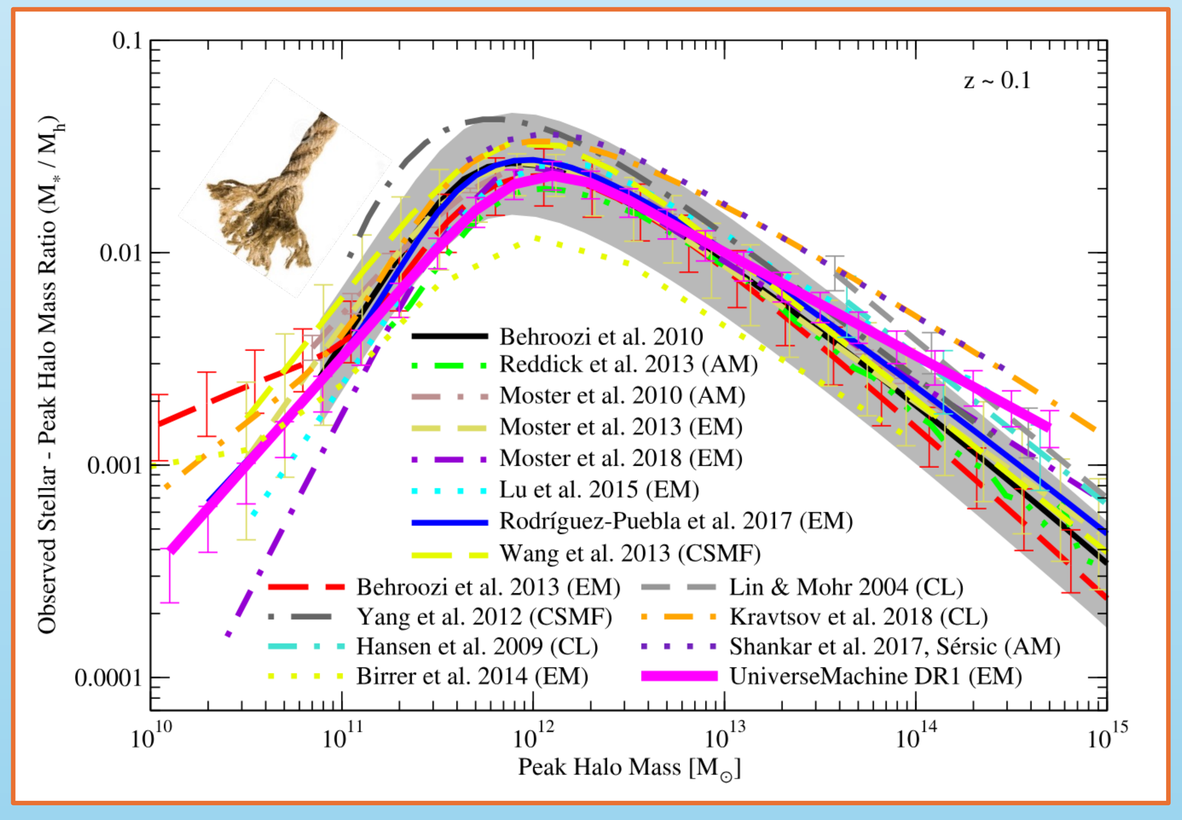
Constraining the Stellar Halo Mass Relation with Surveys of Satellite Galaxies

J. Sebastian Monzon, Frank van den Bosch, Kaustav Mitra
Department of Astronomy, Yale University, New Haven, CT 06520, USA

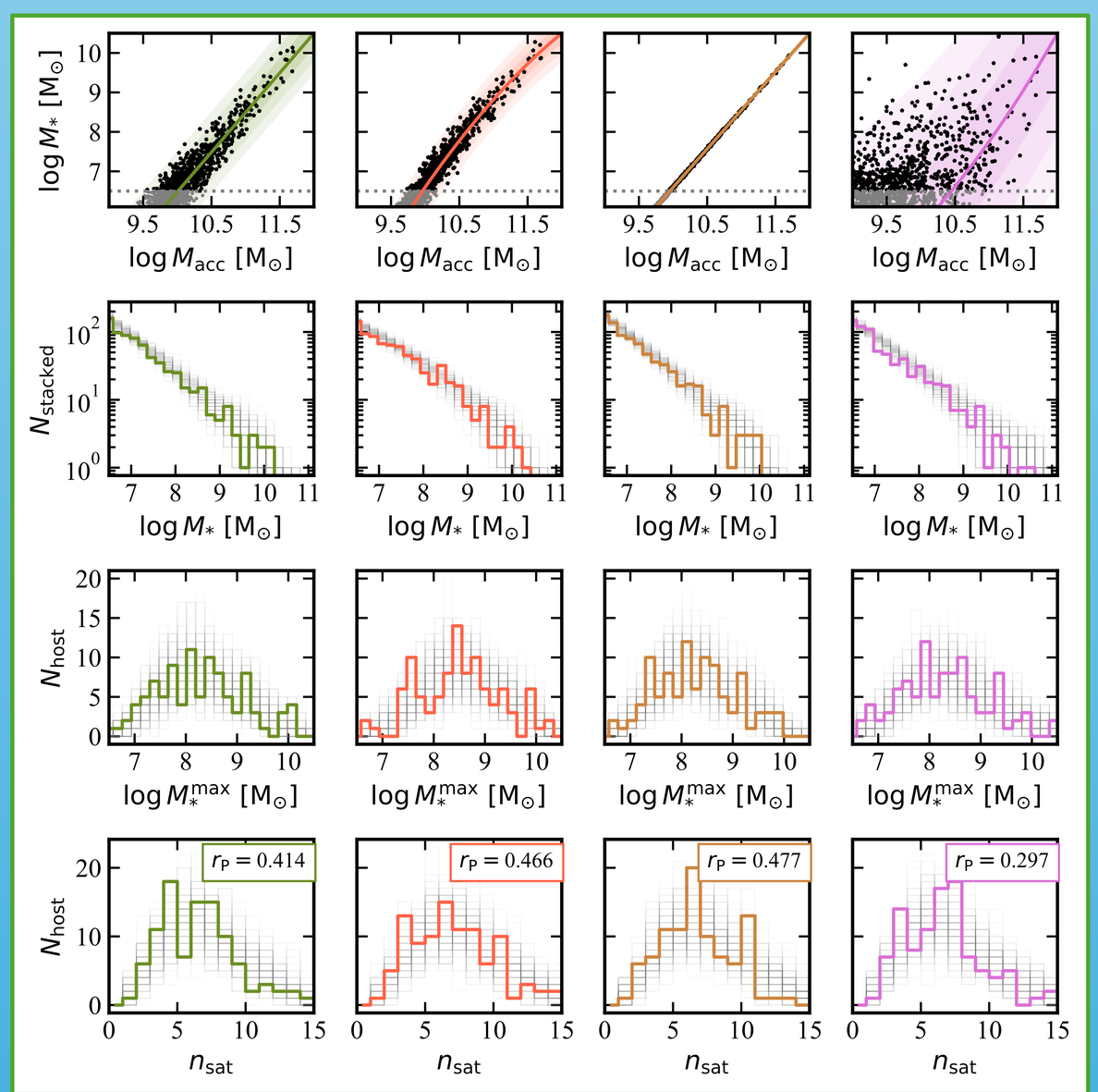
ABSTRACT: The abundance of satellite galaxies around a host galaxy is set by the hierarchical assembly of dark matter halos in the system. We leverage this to investigate the low mass end of the Stellar-to-Halo Mass Relation (SHMR), which is key to constraining theories of galaxy formation and cosmology. We argue that recent analyses of satellite galaxies in the Local Group environment have not adequately modelled the dominant source of scatter in satellite stellar mass functions: the variance in accretion histories for a fixed host halo mass. We present a novel inference framework that properly accounts for halo-to-halo variance in a satellite galaxy survey. Specifically, we use the semi-analytic SatGen model to construct mock satellite galaxy populations consistent with the third data release of the Satellites Around Galactic Analogs (SAGA) survey. We demonstrate that even under the most idealized circumstances, the halo-to-halo variance makes it virtually impossible to put any meaningful constraints on the scatter in the SHMR.

BACKGROUND: The SHMR, is well characterized by a broken power-law relation with a knee around the halo mass of the MW. Above the knee, the stellar mass of central galaxies increases slowly with increasing halo mass and the scatter in the SHMR is typically inferred to be small ~0.15 dex. Below the knee, though, both the slope ($\alpha \equiv$ dlog M/d log Mh), and scatter ($\sigma*$) of the SHMR are extremely poorly constrained. This is because galaxies that are hosted by halos are too faint to be seen out to a significant distance and therefore cannot be a representative volume sample of the Universe.

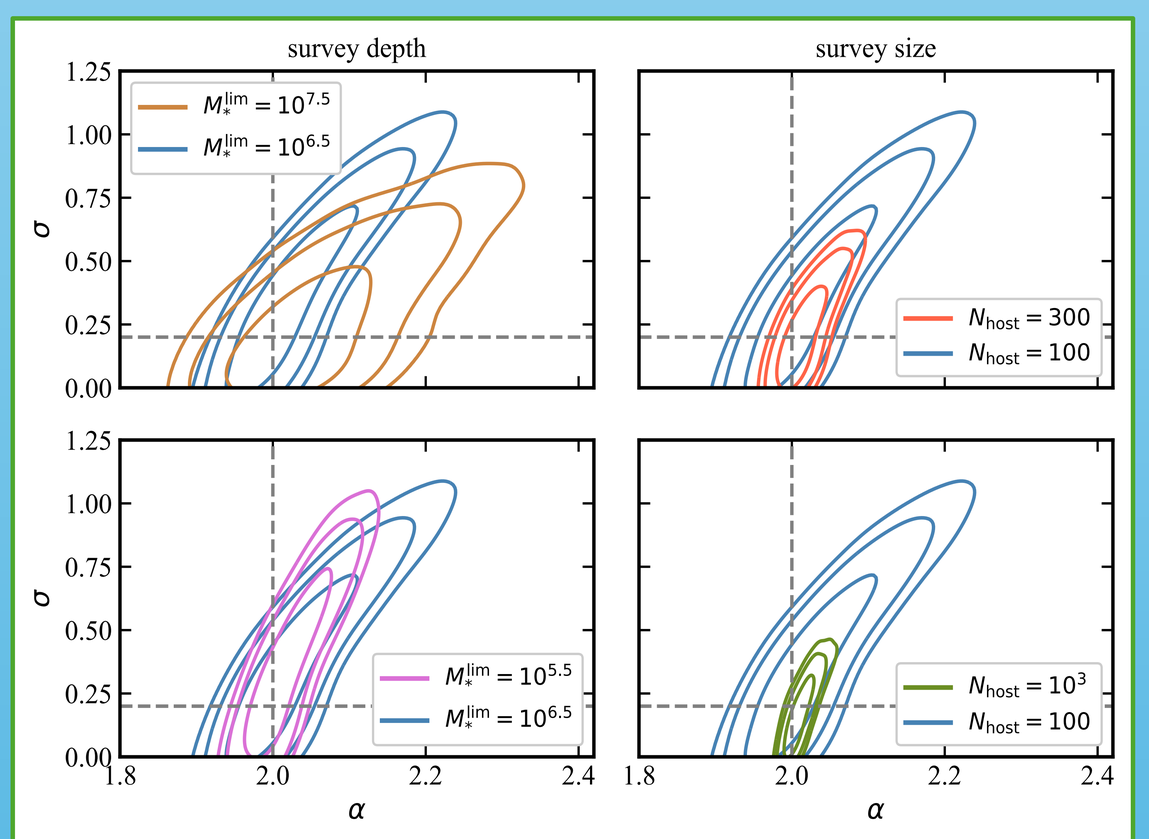
$$\log\left(\frac{M_*}{M^*_{star}}\right) = \alpha\left(\log\left(\frac{M_{peak}}{M^*_{peak}}\right)\right) + \beta(\tau)\left(\log^2\left(\frac{M_{peak}}{M^*_{peak}}\right)\right) + \mathcal{G}(\sigma,\gamma)$$



PARAMETER DEGENERACIES: An illustrative selection of four wildly different SHMRs and their associated summary statistics. The top rows show the actual SHMR (solid lines), and a single mock SAGA survey realization (black asterisks). The second row shows the corresponding "stacked" Satellite Stellar Mass Functions (SSMFs) as thick colored line. The third and fourth rows shows histograms of the most massive satellite per host and the total number of satellites per host, respectively. Notice how virtually indistinguishable these models are in terms of their summary statistics. This shows the difficulty in placing meaningful constraints on the SHMR with a SAGA-like survey.



SURVEY FORECASTS: We conclude that increasing the sample size of a SAGA-like survey by a factor 3 has more merit than pushing down for a magnitude limit that is a factor of 10 fainter than the current limit. This is realistic with advent of upcoming surveys like Pan-STARRS, DESI, Vera Rubin Observatory and the Roman Space Telescope.



References:
Behroozi et al. 2019; Jiang et al. 2021; Munshi et al 2021; Danieli et al. 2023; Nadler et al. 2024

Contact:
s.monzon@yale.edu
https://jsmonzon.github.io/