Constraining the Milky Way Mass Profile with Phase-Space Distribution of Satellite Galaxies

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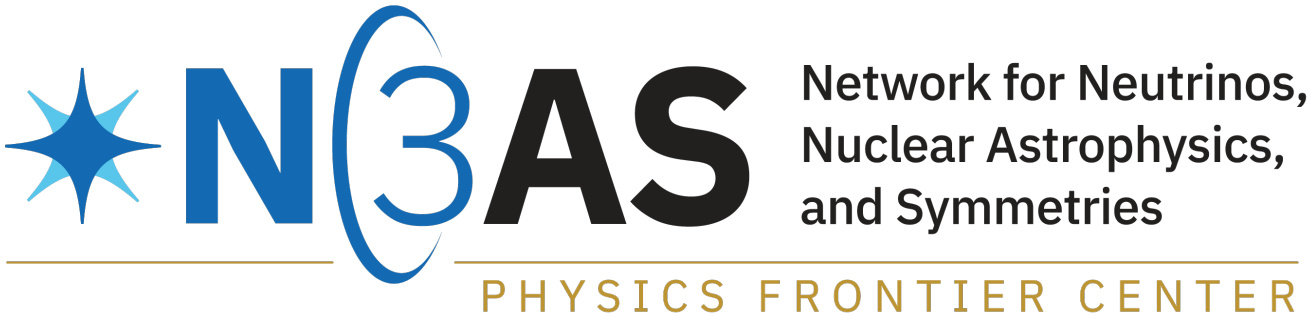


Constraining the Milky Way Mass Profile with Phase-space Distribution of Satellite Galaxies

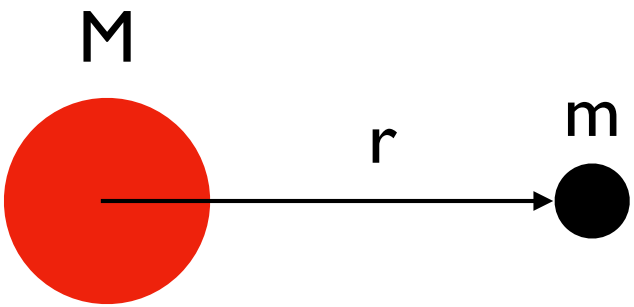
Li, Qian, Han, Li, Wang, & Jing 2020

A Versatile and Accurate Method for Halo Mass Determination from Phase-space Distribution of Satellite Galaxies

Li, Qian, Han, Wang, & Jing 2019

Determination of Dark Matter Halo Mass from Dynamics of Satellite Galaxies

Li, Jing, Qian, Yuan, & Zhao 2017



orbital parameters of m

$$\vec{F} = -G\frac{Mm}{r^2}\hat{r}$$

concentrated mass M

A galaxy has an extended density profile

Navarro-Frenk-White (NFW) profile

$$\rho(r) = \frac{\rho_s}{(r/r_s)(1+r/r_s)^2}$$

Virial radius, halo mass, & concentration

$$M = \int_0^R \rho(r) 4\pi r^2 dr = 200\rho_{\rm cri}\frac{4\pi}{3}R^3$$

$$(r_s, \rho_s) \rightleftarrows (M, c = R/r_s)$$

Phase-space distribution of tracers

Tracers are in dynamical equilibrium with the host halo

$$\Rightarrow \frac{d^6 N}{d^3\vec{r} d^3\vec{v}} \equiv \frac{d^6 N}{d^6\vec{w}} = f(\vec{r}, \vec{v})$$

Internal dynamics is similar for all halos

$$\Rightarrow \tilde{f}(\vec{r}/r_s, \vec{v}/v_s) \text{ is universal}$$

$$v_s = r_s \sqrt{4\pi G \rho_s}$$

Jeans theorem

$$f(\vec{r},\vec{v}) = f(E,L)$$

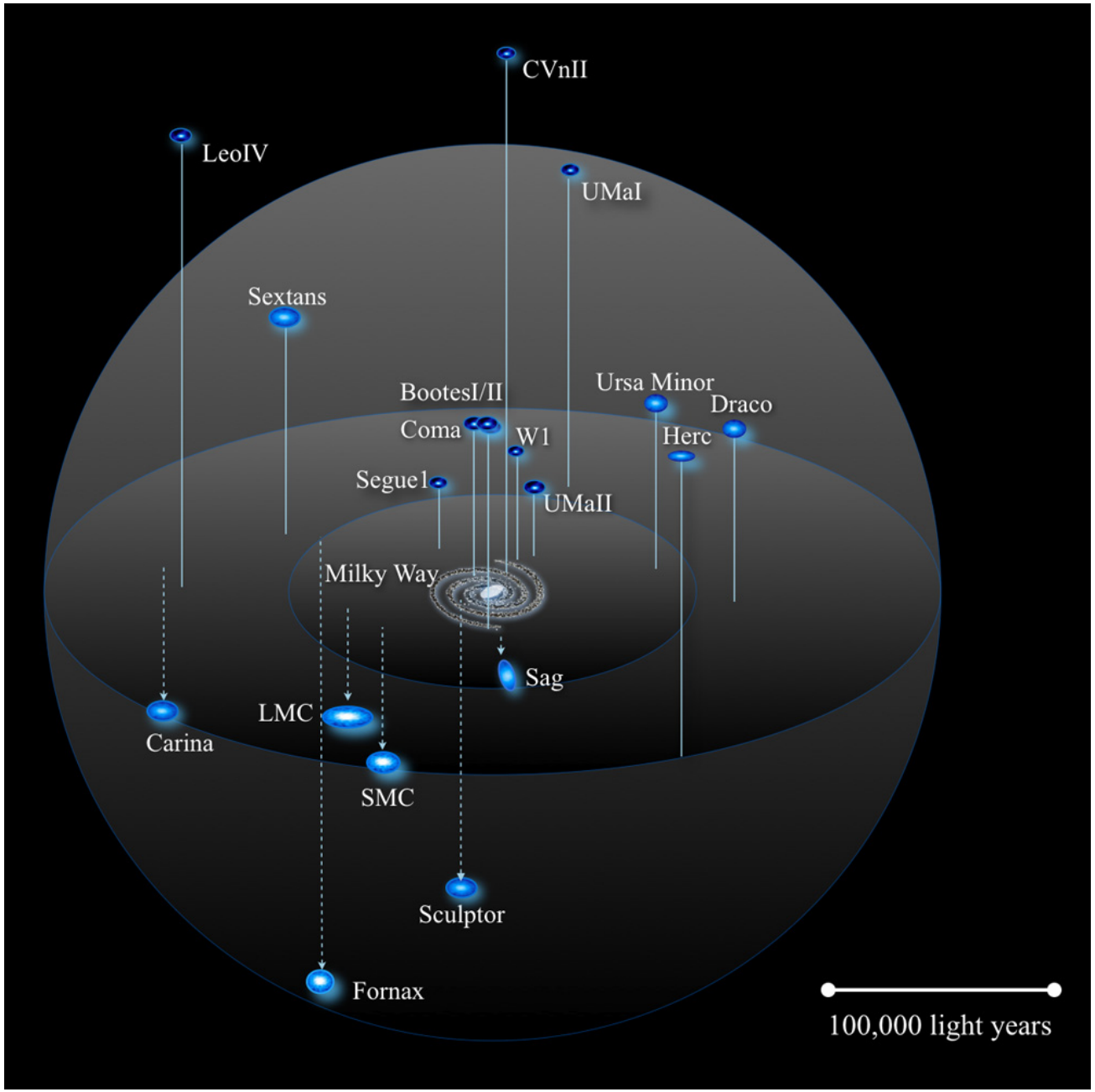
$$\Rightarrow p(\vec{w}|M,c) \equiv f(E,L) = \frac{1}{r_s^3 v_s^3}\tilde{f}(\tilde{E},\tilde{L})$$

$$\tilde{E} = E/v_s^2,\ \ \tilde{L} = L/(r_s v_s)$$

Bayesian statistics

$$p(M,c|\{\vec{w}_i\}) \propto p(M)p(c|M)\prod_{i=1}^{N_{\rm tr}} p(\vec{w}_i|M,c)$$

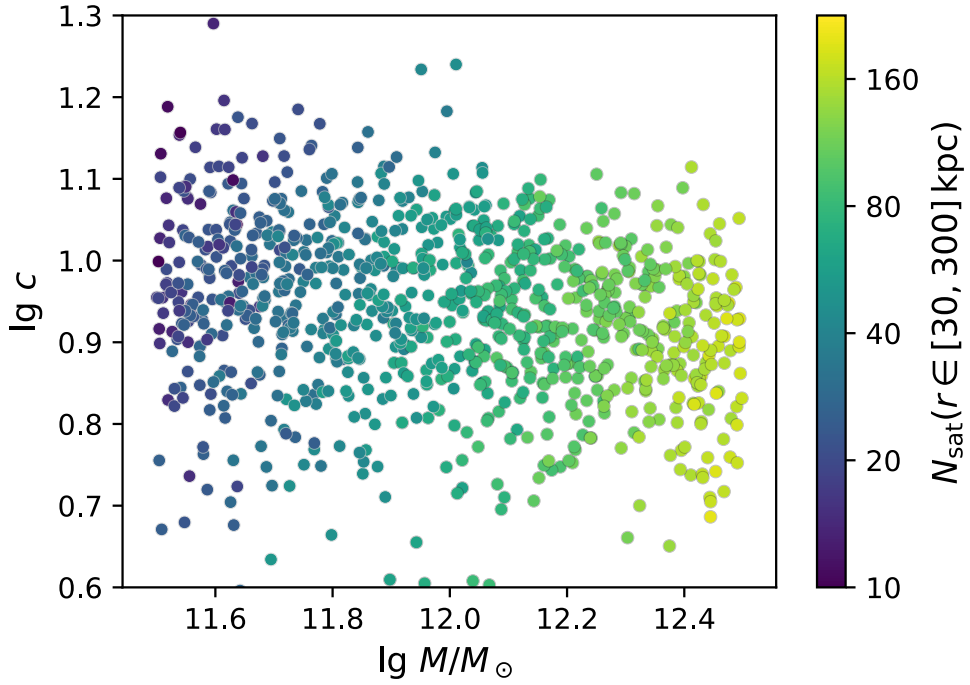
Dwarf satellite galaxies as tracers



Cosmological simulation: Millennium II

$$11.5 \leq \lg M/M_\odot \leq 12.5$$

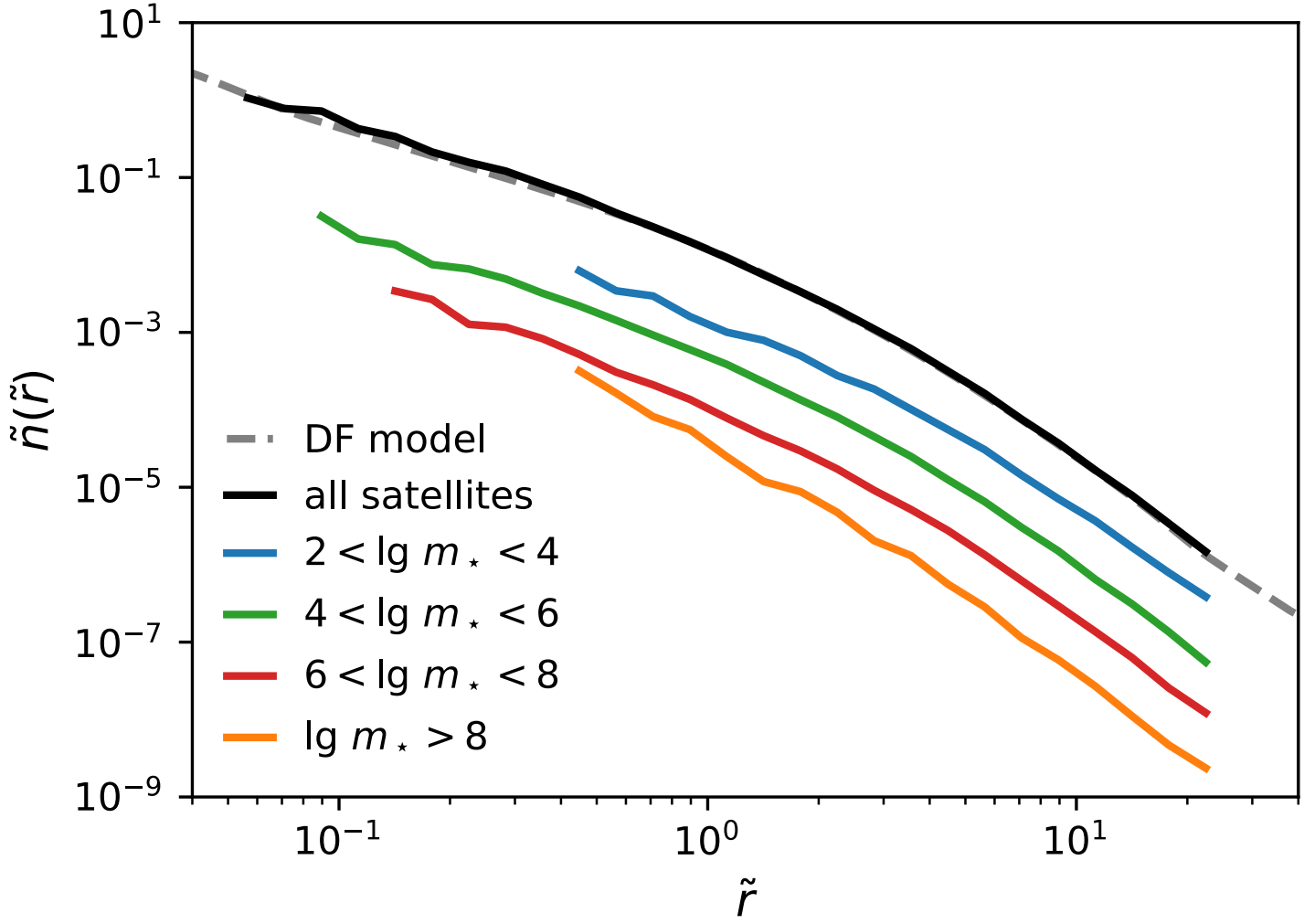
940 Milky Way-like halos



$$p(\lg c|M) = \mathcal{N}(0.94 - 0.077 \lg(M/10^{12} M_\odot), 0.11)$$

Galaxy catalog from semi-analytical model for galaxy formation

104,315 satellites with $r \leq 25 r_s$



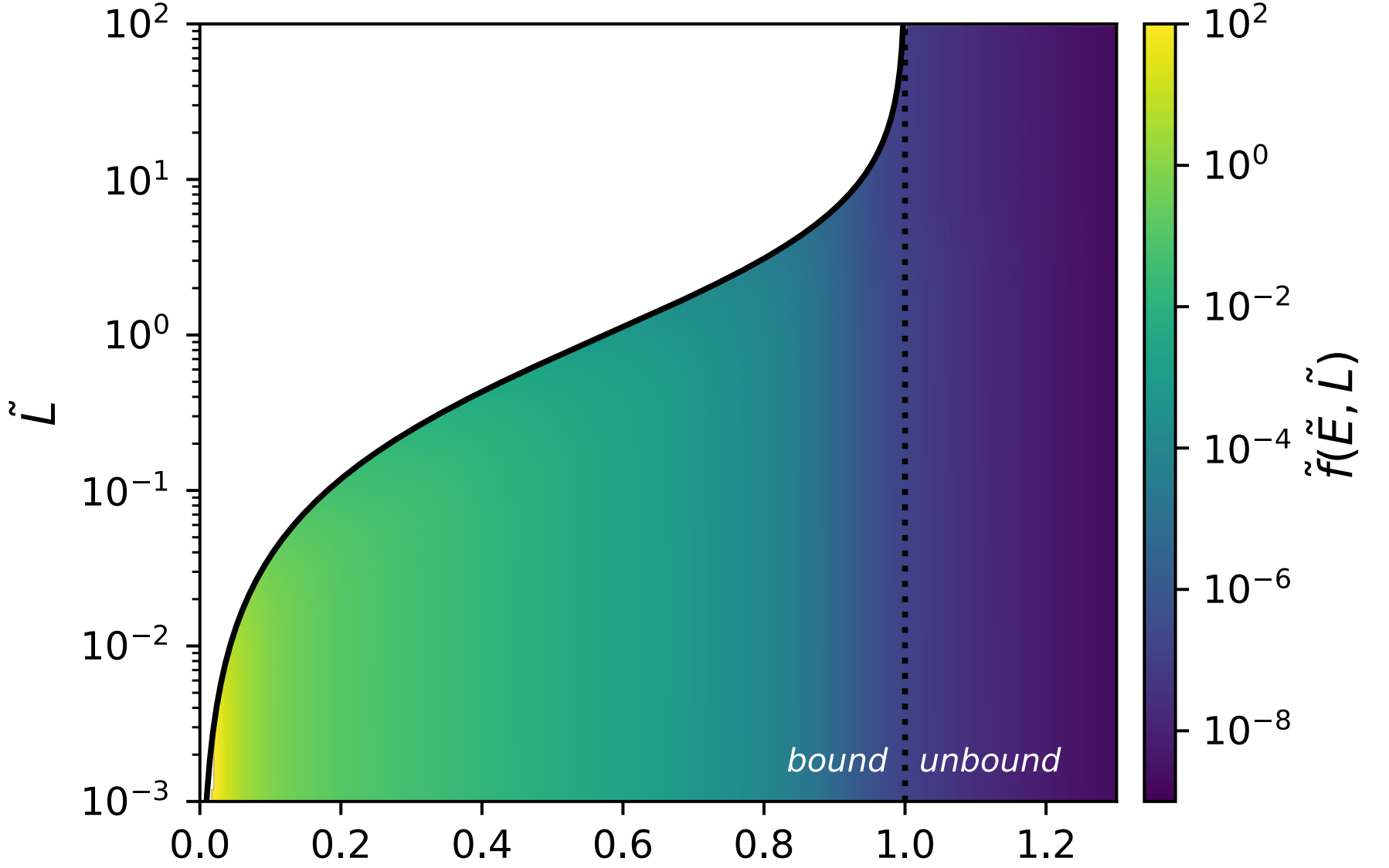
Construction of phase-space distribution function (DF)

$$f(r, v_r, v_t) 8\pi^2 r^2 v_t dr dv_r dv_t$$
$$= p(r|E, L) p(E, L) dr dE dL$$

$$p(r|E, L)dr = \frac{dr}{v_r(r, E, L) T_r(E, L)}$$

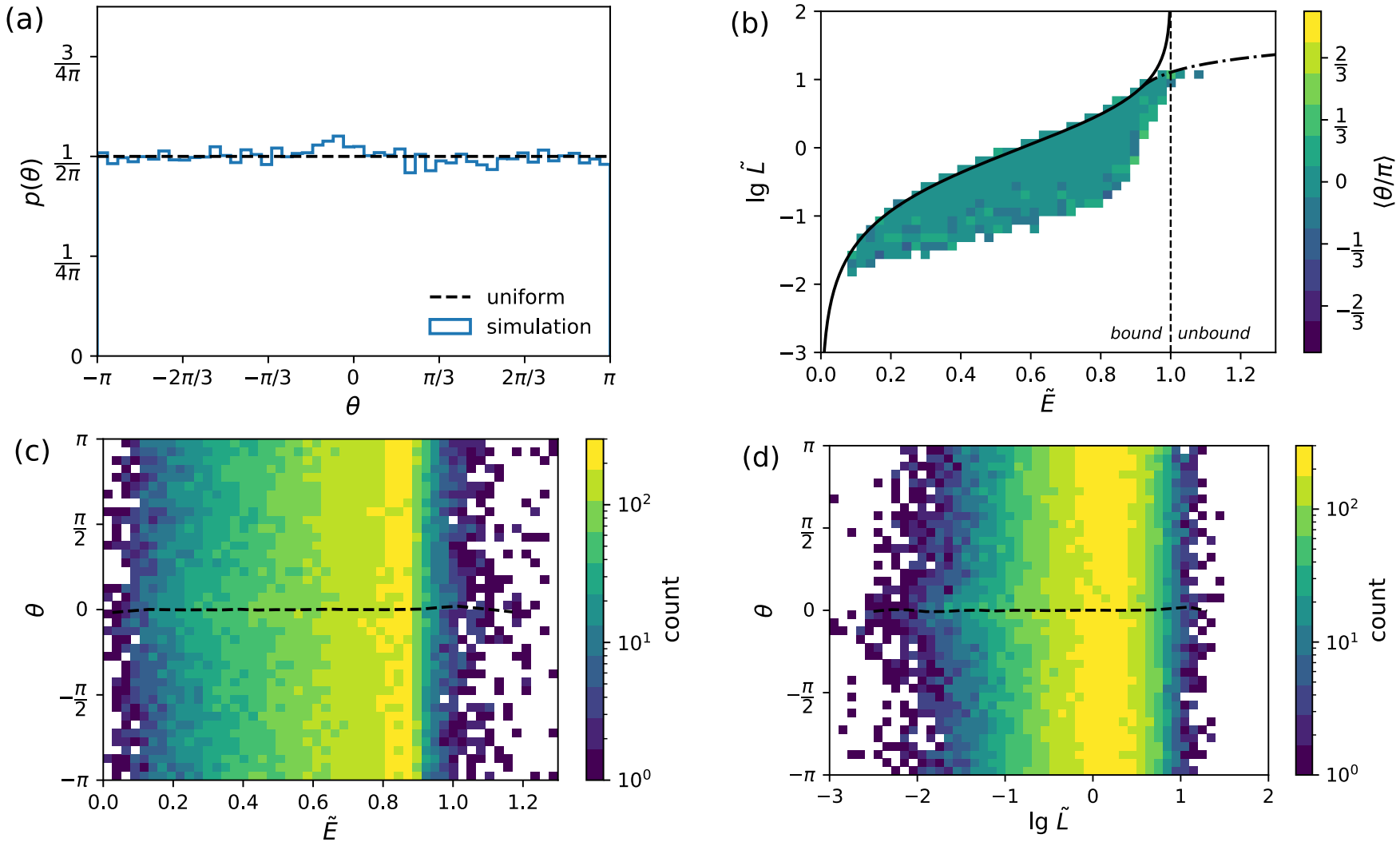
$$\Rightarrow f(r, v_r, v_t) = f(E, L) = \frac{p(E, L)}{8\pi^2 L T_r(E, L)}$$

Constructed DF

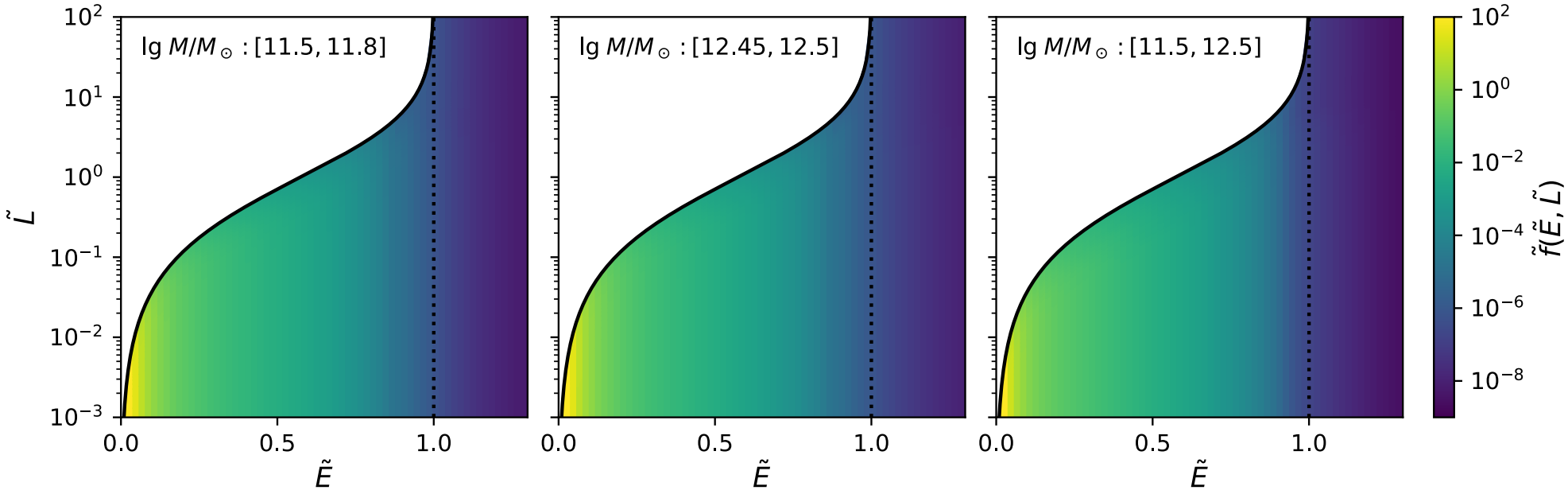


Check on steady state

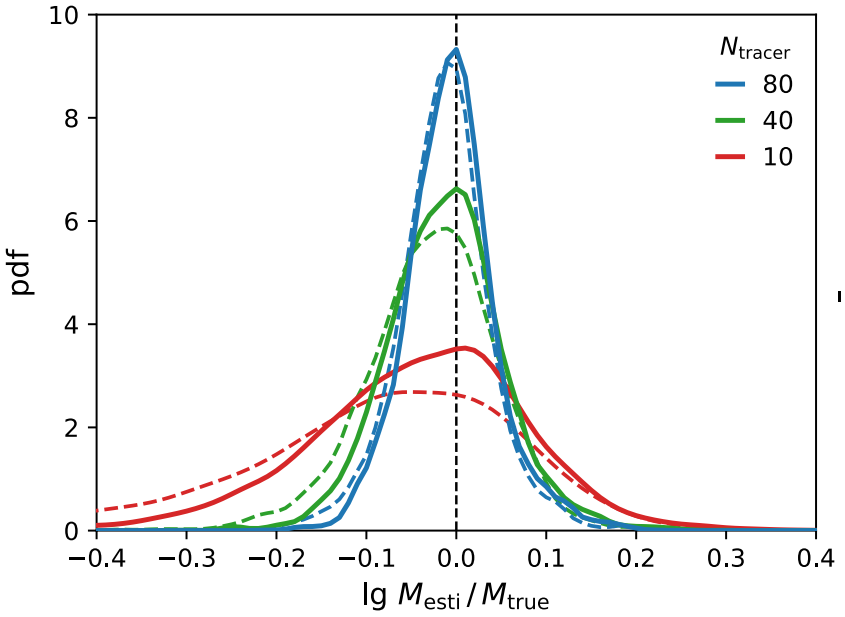
$$p(r,E,L)dr = \frac{dr}{v_r(r,E,L)T_r(E,L)} = p(\theta|E,L)d\theta = \frac{d\theta}{2\pi}$$

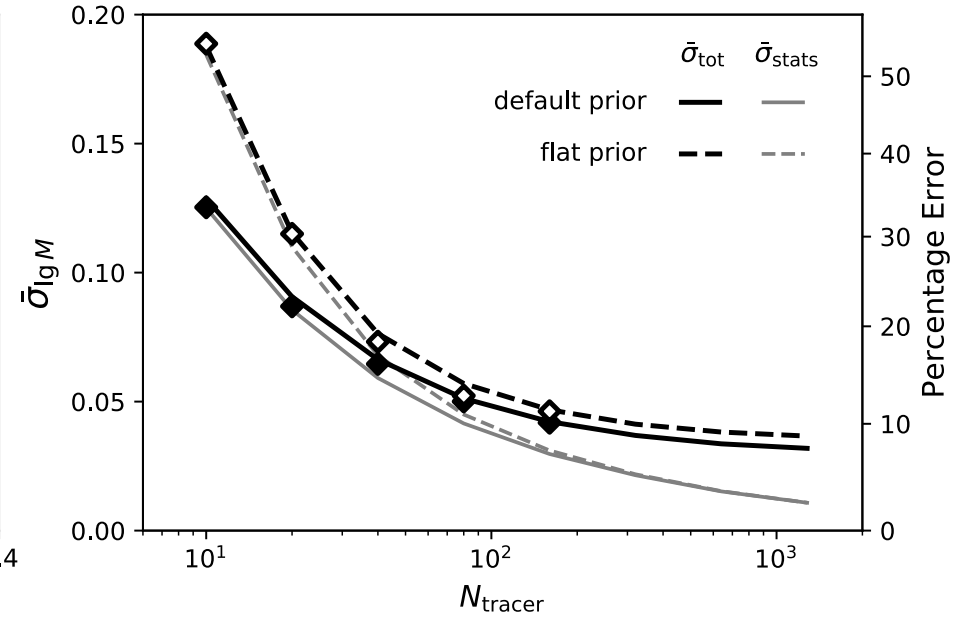


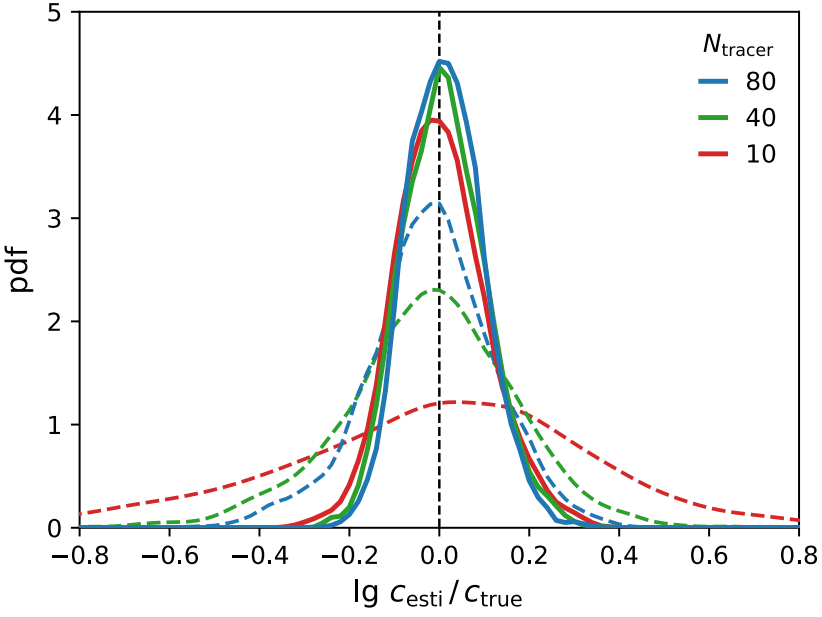
Check on similarity of internal dynamics

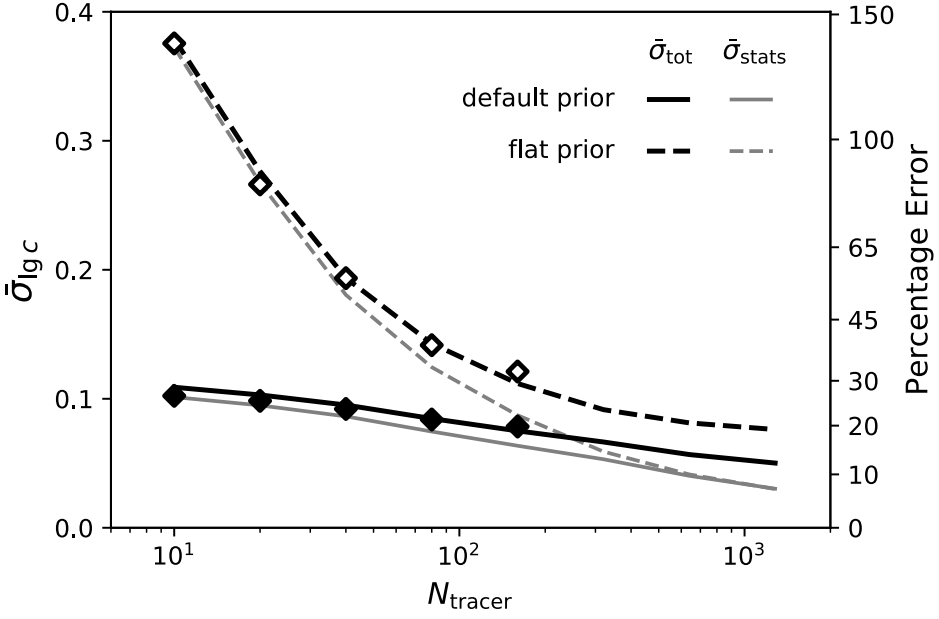


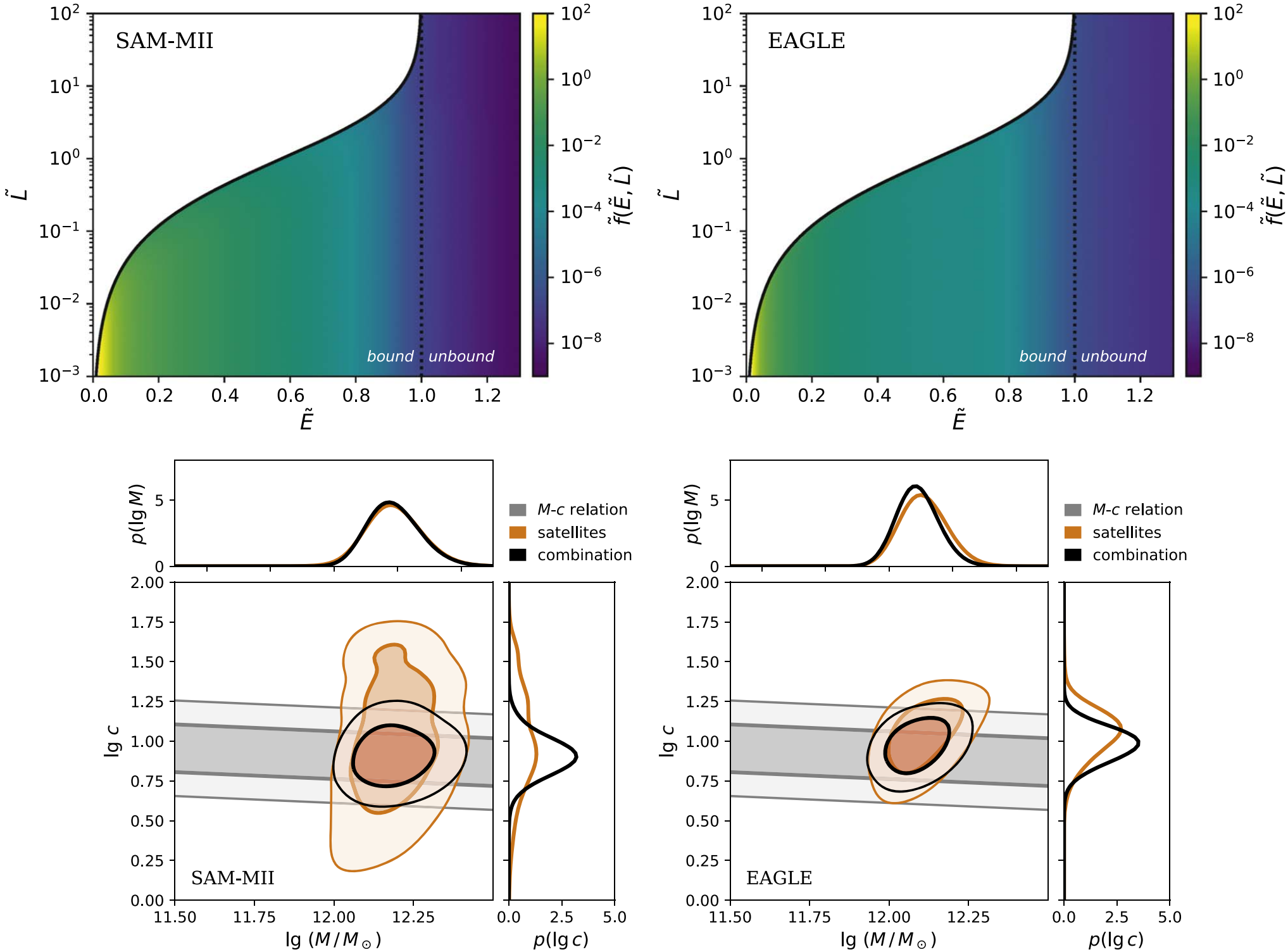
Results from mock tests







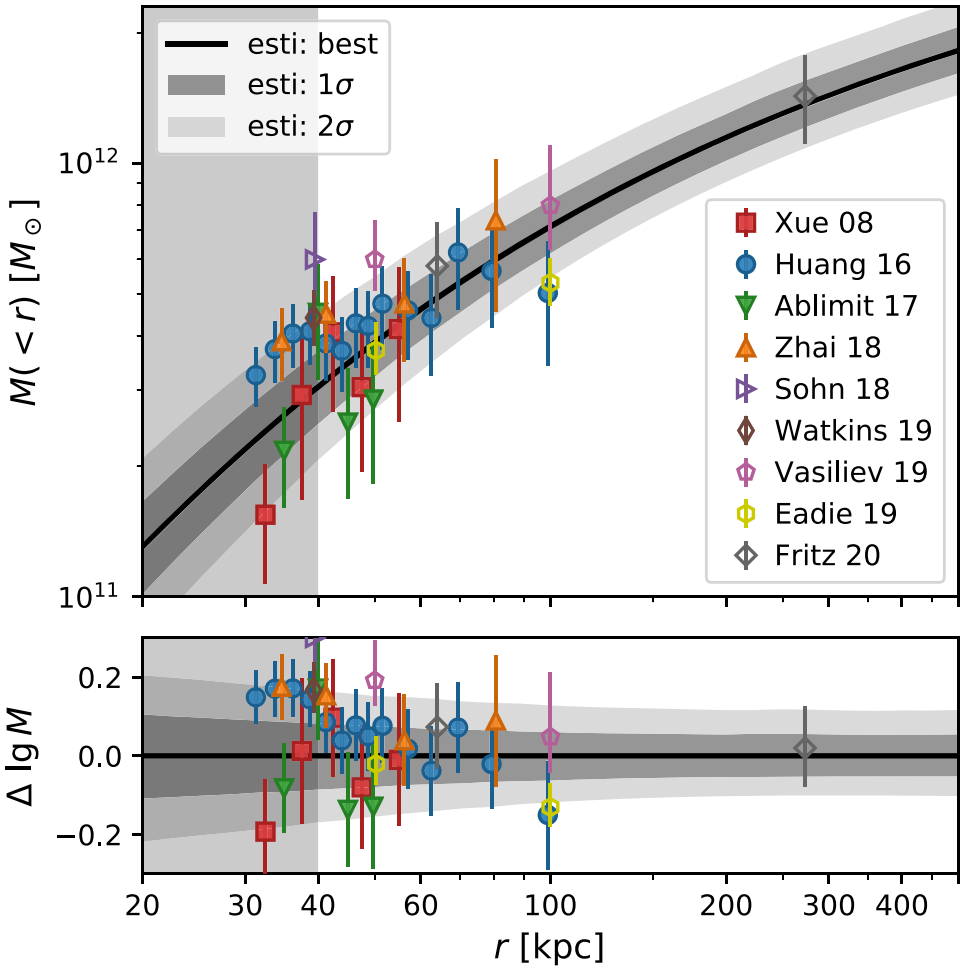


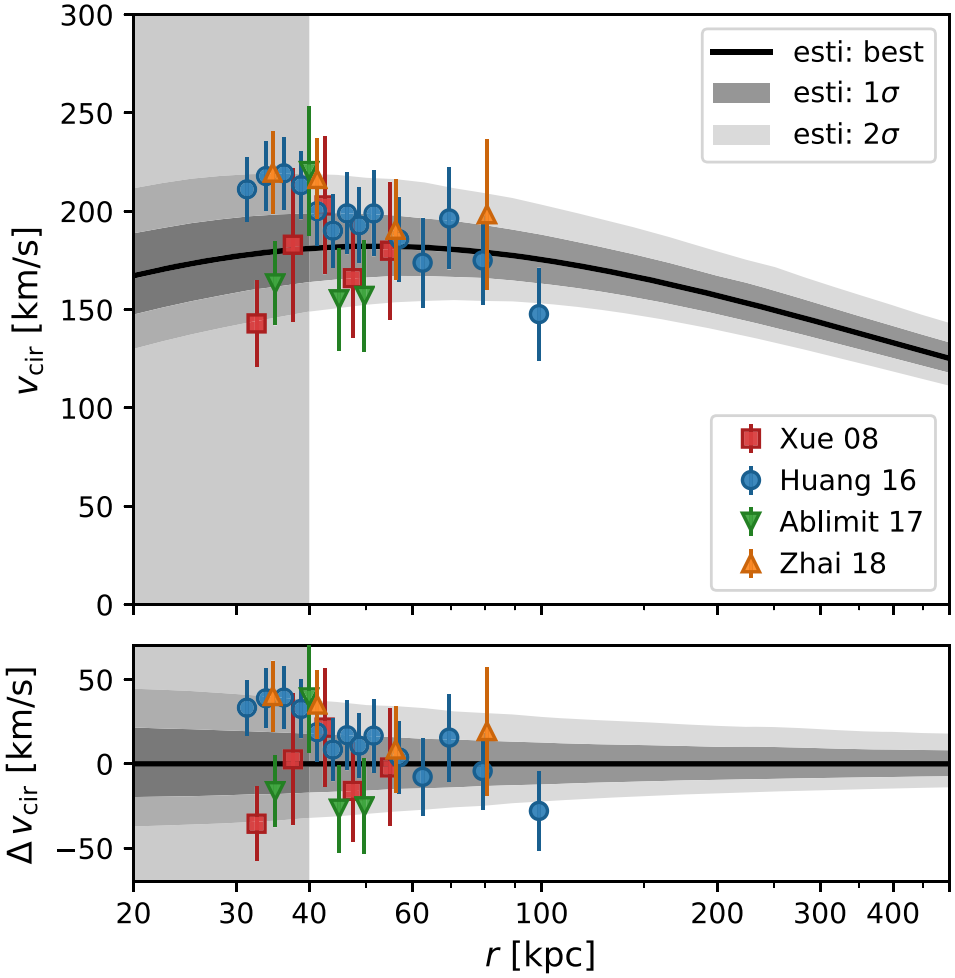

SAM-MII
EAGLE
bound
unbound
$\tilde{L}$
$\tilde{E}$
$\tilde{f}(\tilde{E},\tilde{L})$
$p(\lg M)$
$p(\lg c)$
M-c relation
satellites
combination
lg c
lg $(M/M_\odot)$

28 satellite galaxies

$$M = 1.23^{+0.21}_{-0.18} \times 10^{12}\, M_\odot,\ c = 9.4^{+2.8}_{-2.1}$$

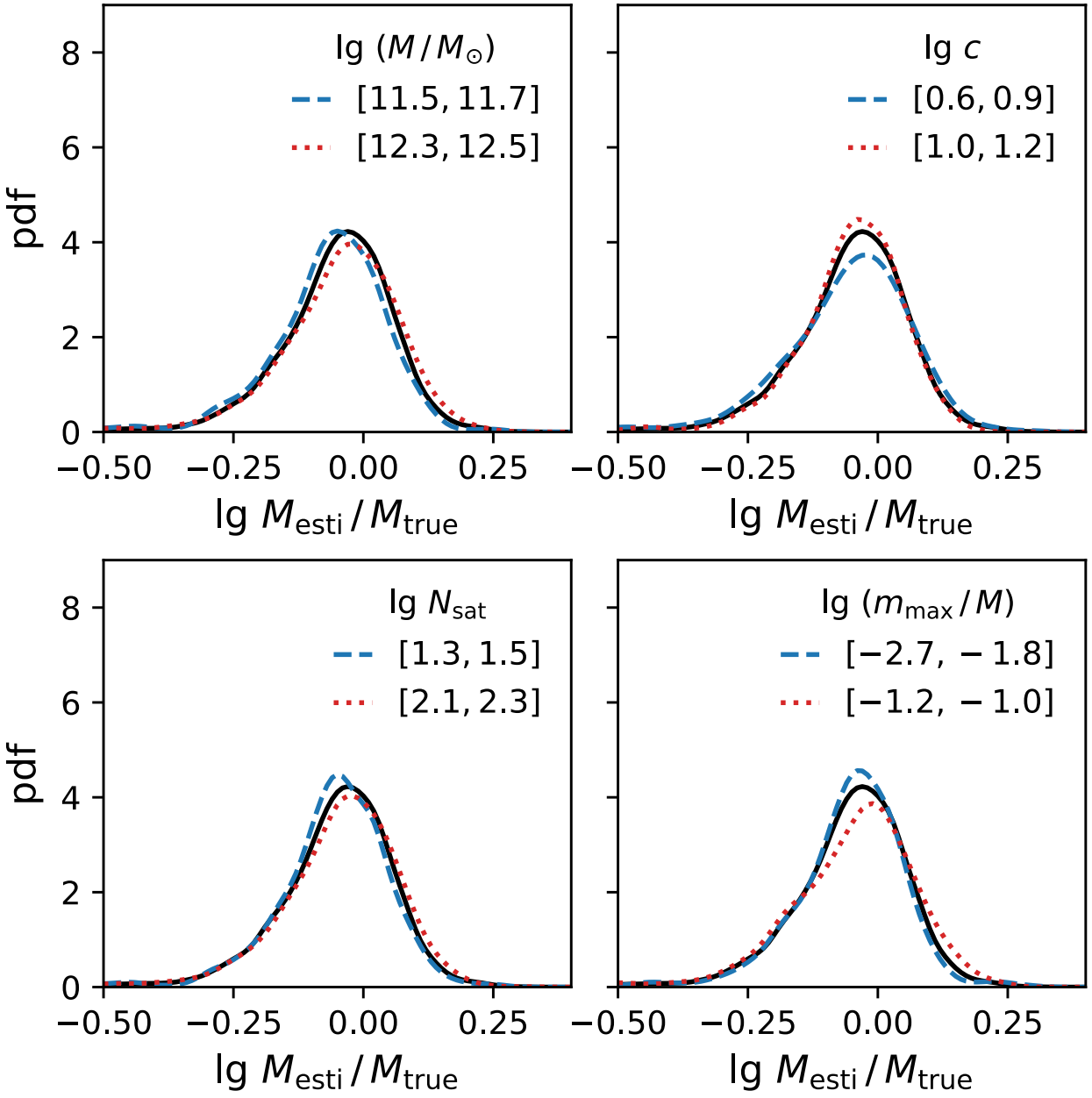
~5% scatter in M across hydro simulations





Test of dependence on various factors

(20 tracers with flat prior on c)



Comparison with other methods

(80 tracers with flat prior on c)