Inferring the dark matter density with the spatial distribution of dark matter halos

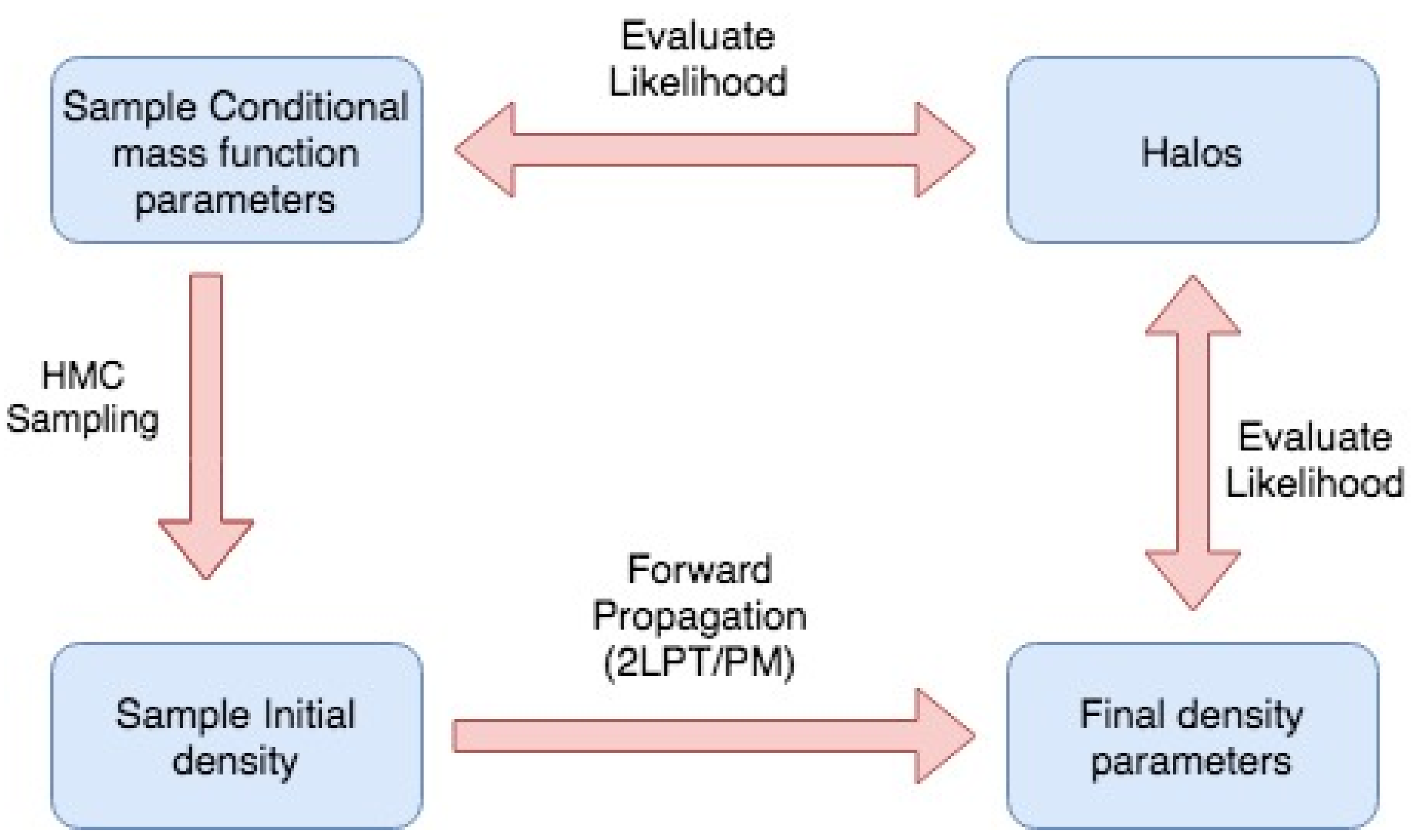
Bayesian Forward modelling of the large-scale structure

Supranta S. Boruah[1,2], **Michael J. Hudson**[1,2], **Guilhem Lavaux**[3]
[1] University of Waterloo, Waterloo Canada
[2] Perimeter Institute for Theoretical Physics, Waterloo, Canada
[3] Institut d'Astrophysique de Paris, Paris, France
ssarmabo@uwaterloo.ca

Motivation

- Inferring the dark matter distribution from the observations of biased tracers(galaxies/halos) is one of the main inference challenge in cosmology.
- Need to incorporate observational effects such as selection effects, redshift-space distortions in a systematic way
- Bayesian Forward modelling is a way forward in achieving this.

Our Approach



Conditional Mass function

We empirically model the mass function conditioned on background density(as defined in the voxels containing them). The conditional mass function can be well-modelled as a sum of two contributions, what we term as the primary and the secondary contributions. The primary contribution can be well modelled as a log-normal distribution and the secondary contribution can be modelled with a Schechter function,

$$n_p = \frac{n_{p0}}{M_p} \exp\left(- \frac{\log^2(M/M_p)}{2\sigma_M^2} \right)$$
$$n_s = \frac{n_{s0}}{M_s} \left(\frac{M}{M_s}\right)^{\alpha} \exp\left(- \frac{M}{M_s} \right)$$

Further the parameters depends on density.

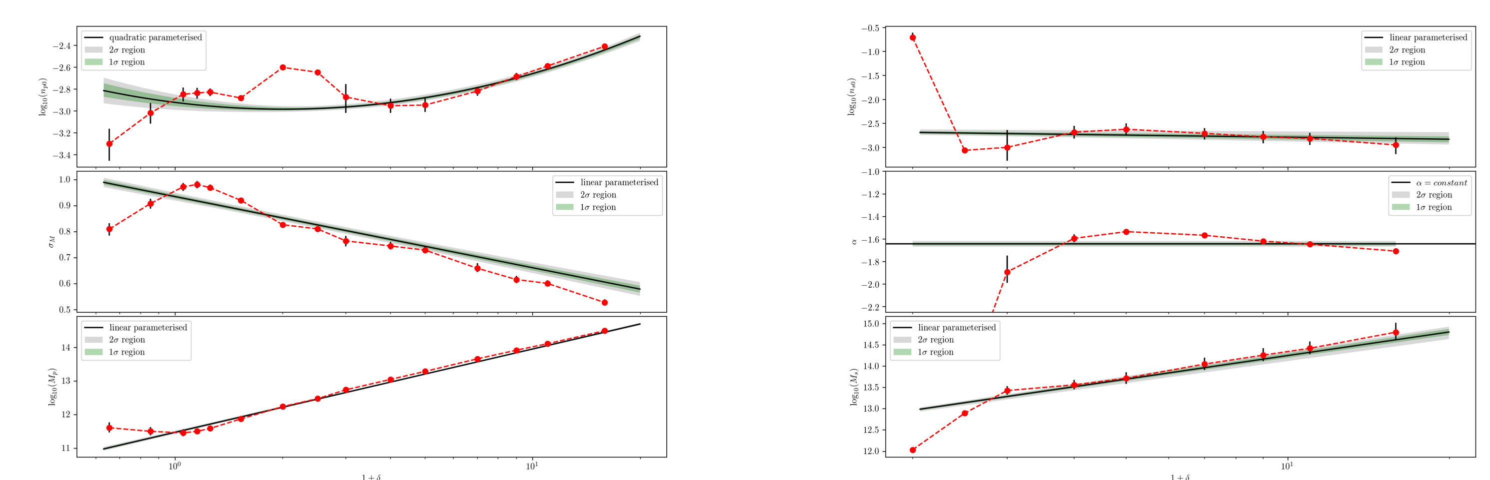


Figure 2: Density dependence of the conditional mass function parameters.

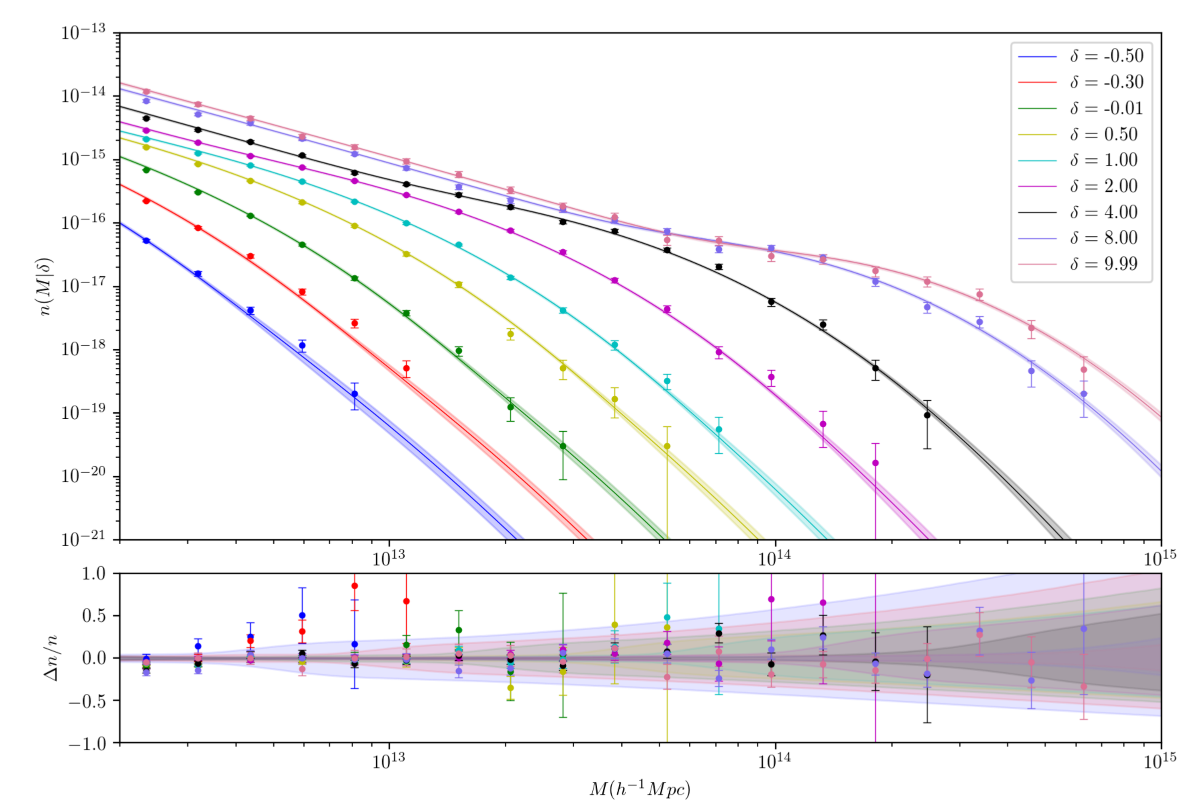


Figure 3: Jointly inferred conditional mass function.

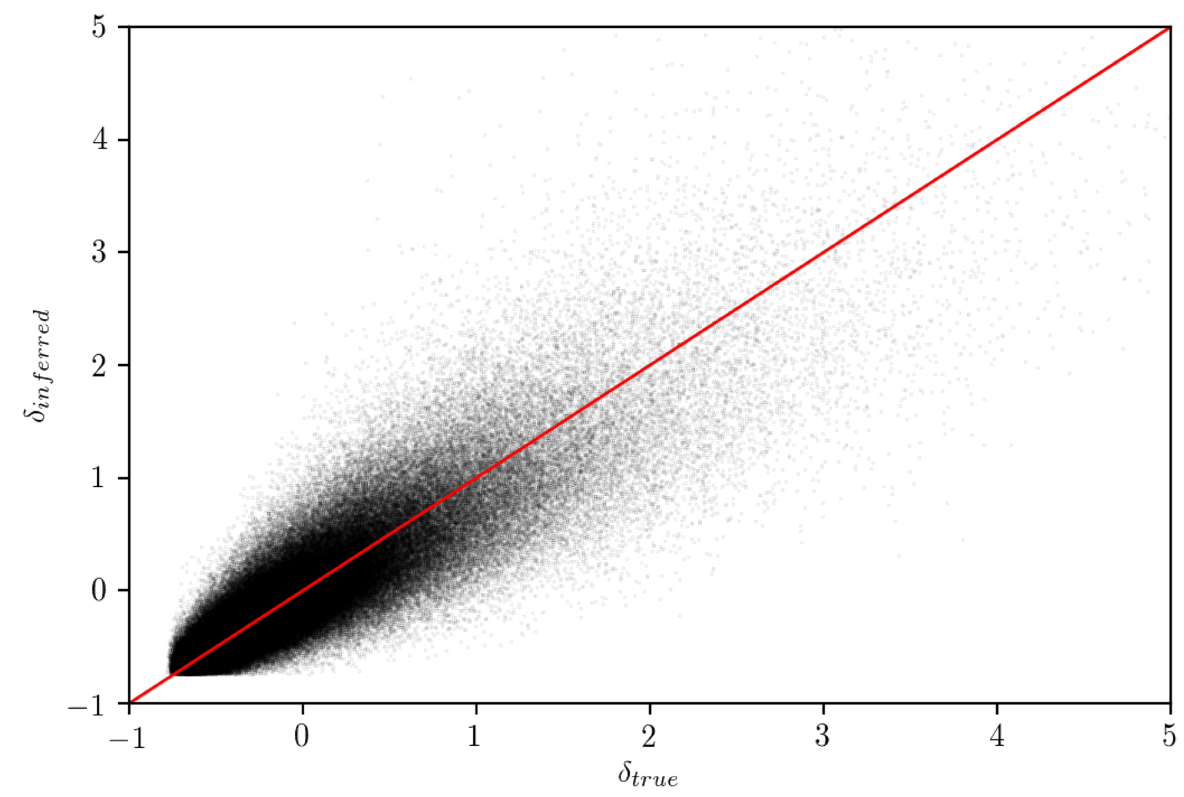


Figure 4: A preliminary reconstruction without forward propagation of initial density

Likelihood

Assuming the distribution of the dark matter halos to be a Poisson sampling from the conditional mass function, we arrive at the following likelihood.

$$\log(\mathcal{P}(\{M_j\}, \delta)) = -V \int_{M_{th}}^{\infty} n(M|\delta) dM + \sum_{\text{halos}} \log(n(M_i|\delta)) + \text{constant}, \quad (1)$$

The simple analytic dependence of the likelihood on different parameters allows for Hamiltonian Monte Carlo sampling of these parameters.

References

[1] Jens Jasche and Guilhem Lavaux. Physical Bayesian modelling of the non-linear matter distribution: new insights into the Nearby Universe. 2018.

[2] Jens Jasche and Benjamin D. Wandelt. Bayesian physical reconstruction of initial conditions from large scale structure surveys. *Mon. Not. Roy. Astron. Soc.*, 432:894, 2013.

[3] Michael J. Hudson Supranta S. Boruah and Guilhem Lavaux. Bayesian forward modelling of the large scale structure using dark matter halos. *In Preparation*.