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Feedback-Regulated Model for the UV Luminosity Function

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The Luminosity Function

- A notable milestone in the evolution of the universeis the formation of the first galaxies at redshifts of around z~6 to z~15 [1] .
- A key characteristic of this is the population of galaxies according to their luminosity, known as the Ultraviolet Luminosity Function (UVLF).
- This project aims to build a simple feedback-regulated (FR) model that can describe the UVLF, and find best-fit parameters using existing data.

The Basic Feedback-Regulated Model

- We can relate the luminosity to rate of matter converted to star-forming material:

$$\dot{m}_* = \mathcal{K}_{UV} \times L_{UV}$$

- Matter is accreted onto Dark Matter (DM) halos.
- Feedback processes, e.g. shock heating, photoevaporation, supernovae, mean that only a fraction of accreted matter is used in star-formation : $f_* = \frac{\dot{m}_*}{\dot{m}_b}$
- So the luminosity is given by

$$L_{UV}(m_h, z) = \frac{1}{\mathcal{K}_{UV}} \frac{\Omega_b}{\Omega_m} f_*(m_h, z)\, \dot{m}_h(m_h, z)$$

- We can model f_* as [2] :

$$f_*(m_h, z) = \frac{f_{\rm shock}(m_h, z)}{f_{*max}^{-1} + \eta(m_h, z)}$$

$$f_{\rm shock}(m_h, z) = 0.47 \left(\frac{1+z}{4}\right)^a \left(\frac{10^{12} M_\odot}{m_h}\right)^b$$

$$\eta(m_h, z) = c \left(\frac{9}{1+z}\right)^\sigma \left(\frac{10^{11.5} M_\odot}{m_h}\right)^\xi$$

- $f_{\rm shock}(m_h, z)$ is bounded <=1 .
- We use the *halomod* Python package to compute $n_h(m_h, z) := \frac{\mathrm{d}n}{\mathrm{d}m_h}$.
- We define $I(m, z) = \int_m^\infty n_h(m', z)\, \mathrm{d}m'$ and seek $m'_\pm$ that solve $I(m'_\pm, z \pm \mathrm{d}z) - I(m, z) = 0$.
- And now use central differences to compute $\frac{\mathrm{d}m_h}{dz}$ and hence $\dot{m}_h(m_h, z)$.
- Now we can compute the UVLF: $\phi(L) = \frac{\mathrm{d}n}{\mathrm{d}L} = \frac{\mathrm{d}n}{\mathrm{d}m_h} \times \left(\frac{\mathrm{d}L}{\mathrm{d}m_h}\right)^{-1}$, and also express it in the AB Magnitude system.

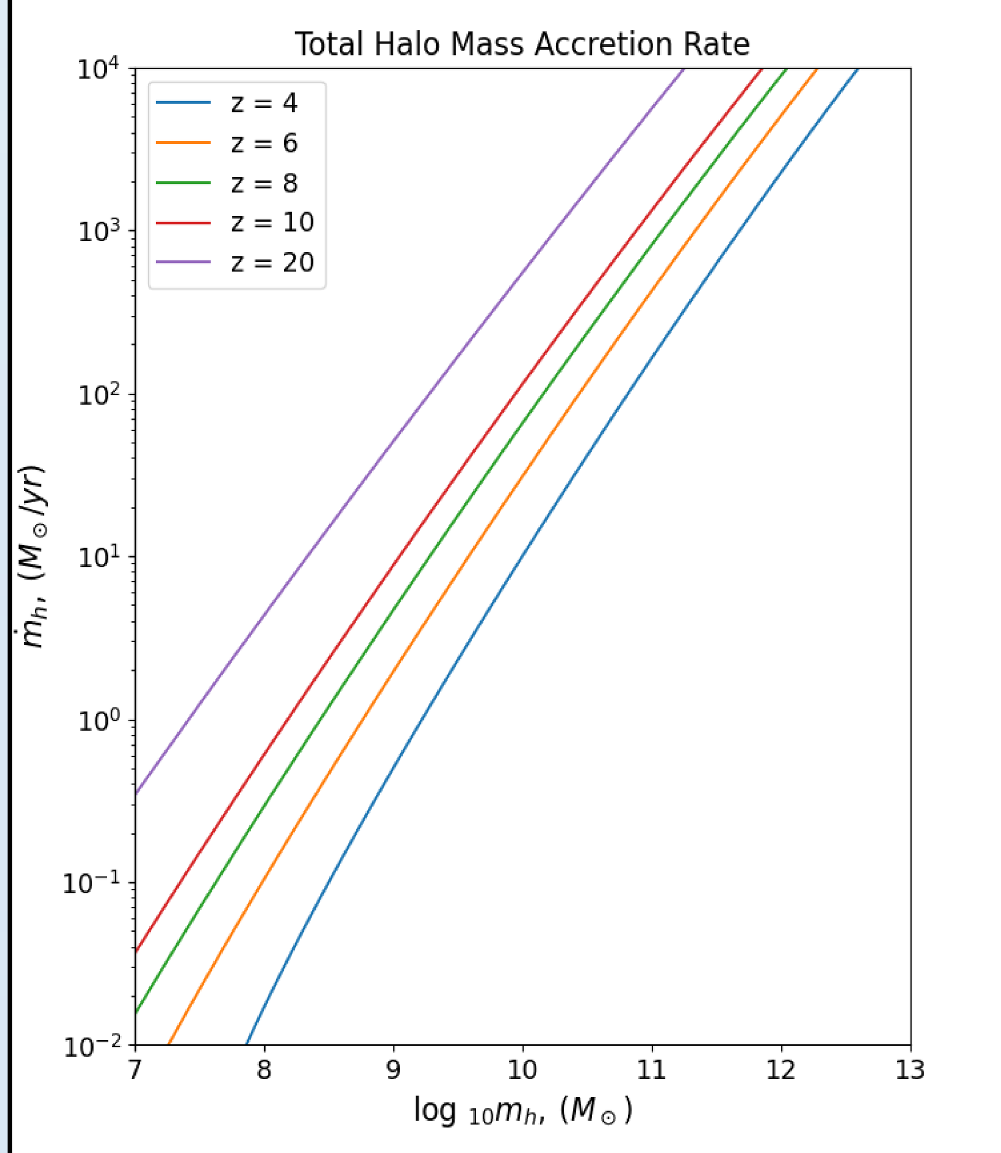


Fig 1: Plot of the total halo mass accreted as a function of halo mass for a number of redshifts, determined by abundance-matching the HMF.

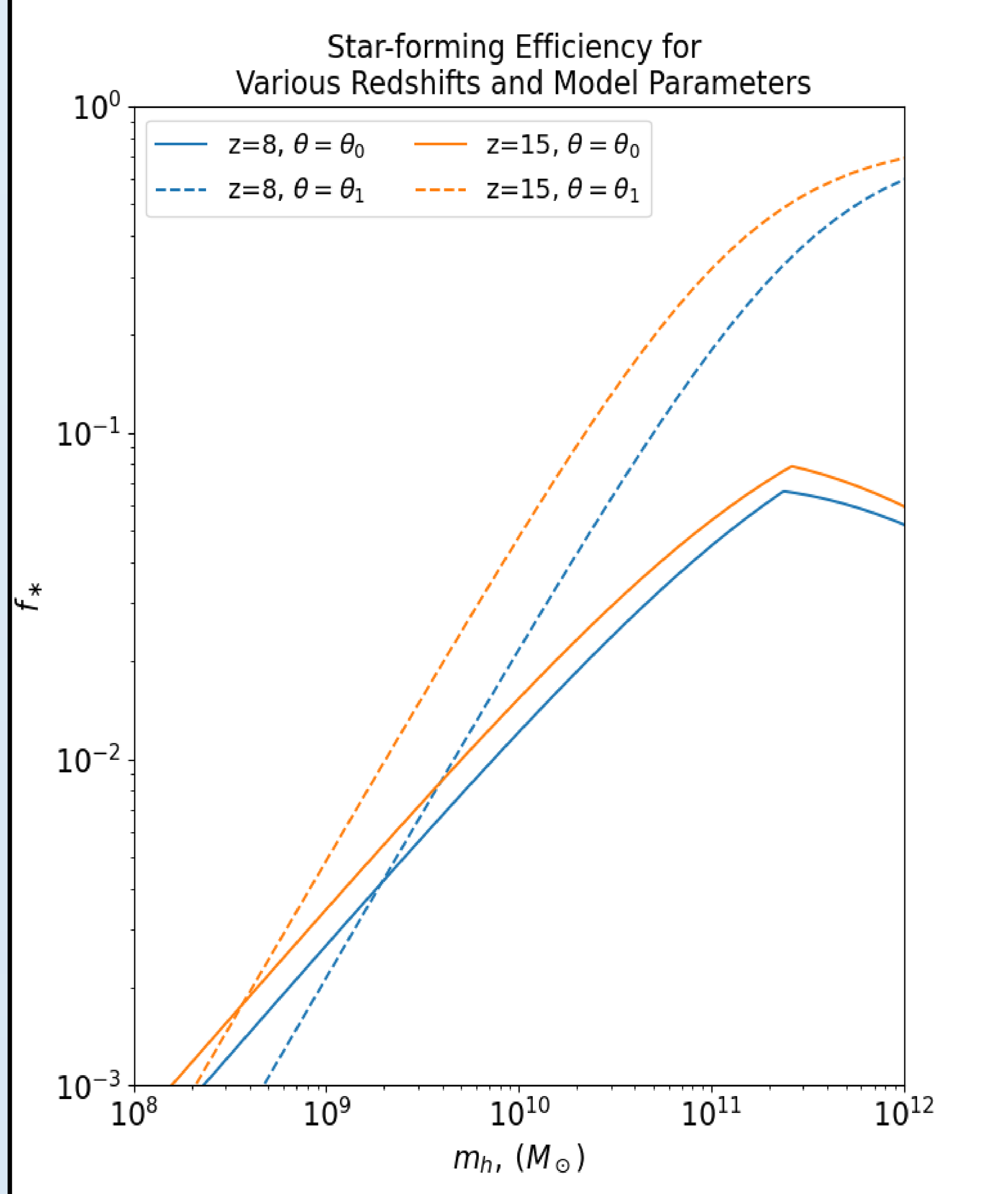


Fig 2: The star-formation efficiency at different redshifts and for different parameters. The "kink" is due to the virial shock probability being bound to 1.

Parameter Estimation

- A Bayesian approach was used to find the best-fit parameters for this model to existing HST WFC3 data.
- The probability distribution around a point was approximated as Gaussian, with separate variances on either side of the mean to account for asymmetric distributions and points given as upper limits.
- The prior range was determined by the physical arguments given in [2], and limitations of implementation.
- The posterior distribution was sampled using the *emcee* Python package, initialising walkers in a Gaussain ball around a first guess in parameter space.

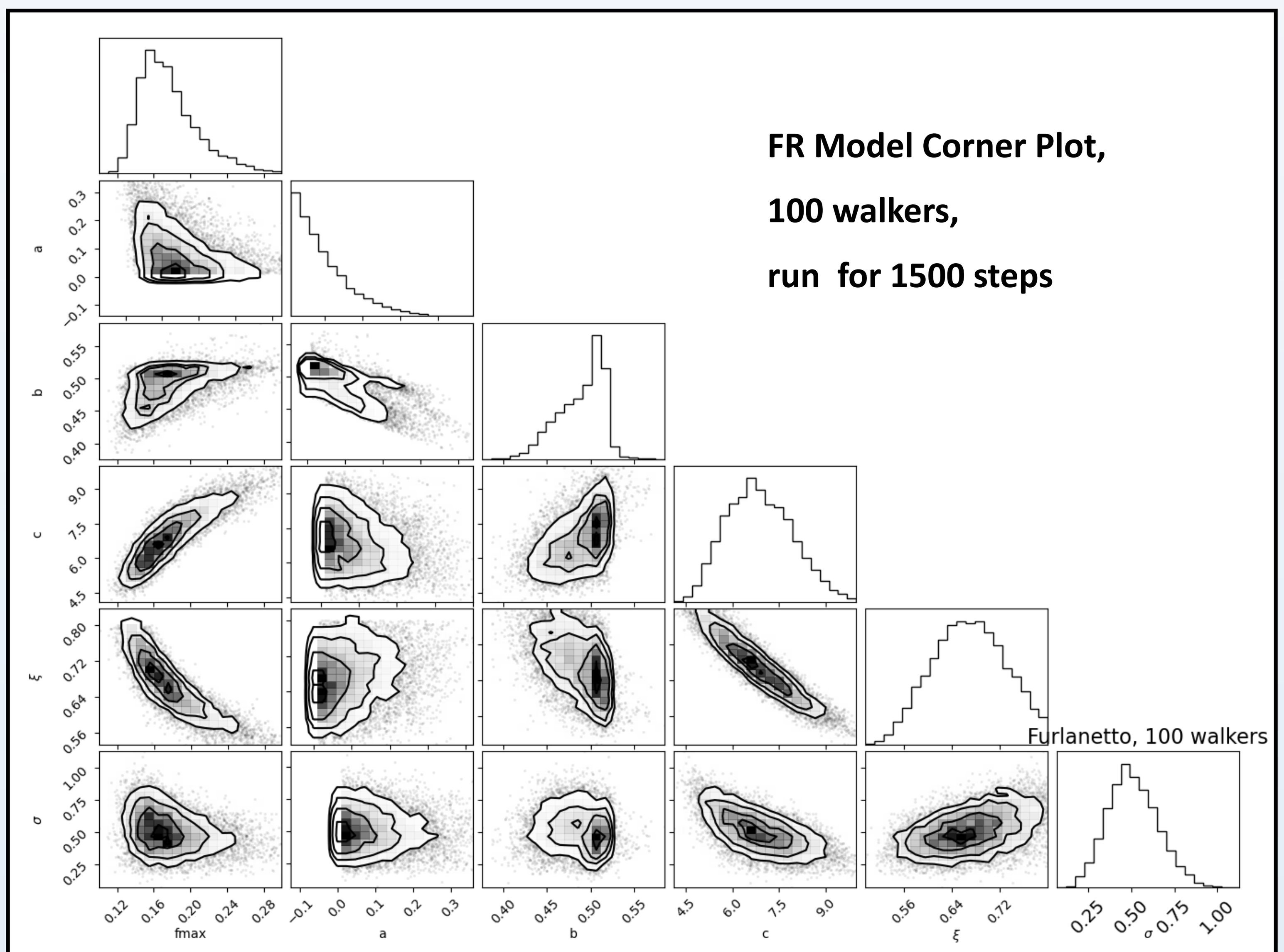
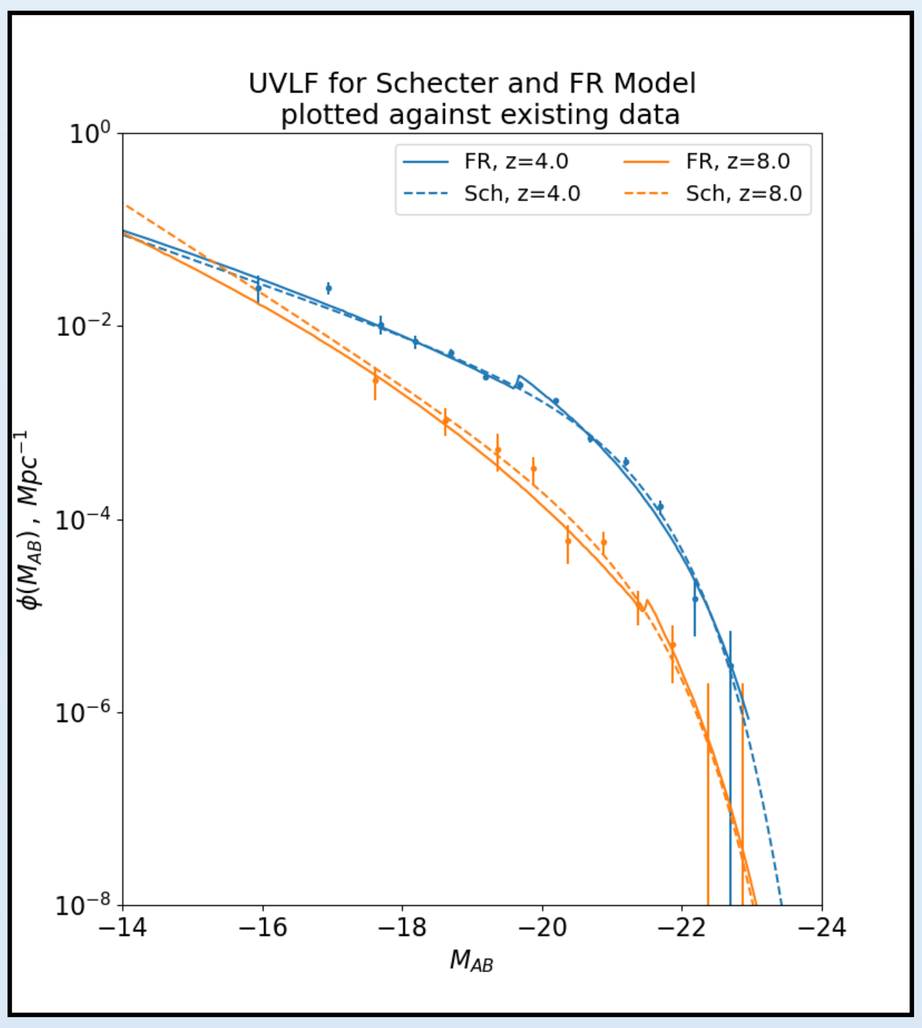


Fig 3: A corner plot for the parameters of a FR model. The prior range is too restrictive but peaks can be seen, indicating that fit-parameters can be found.

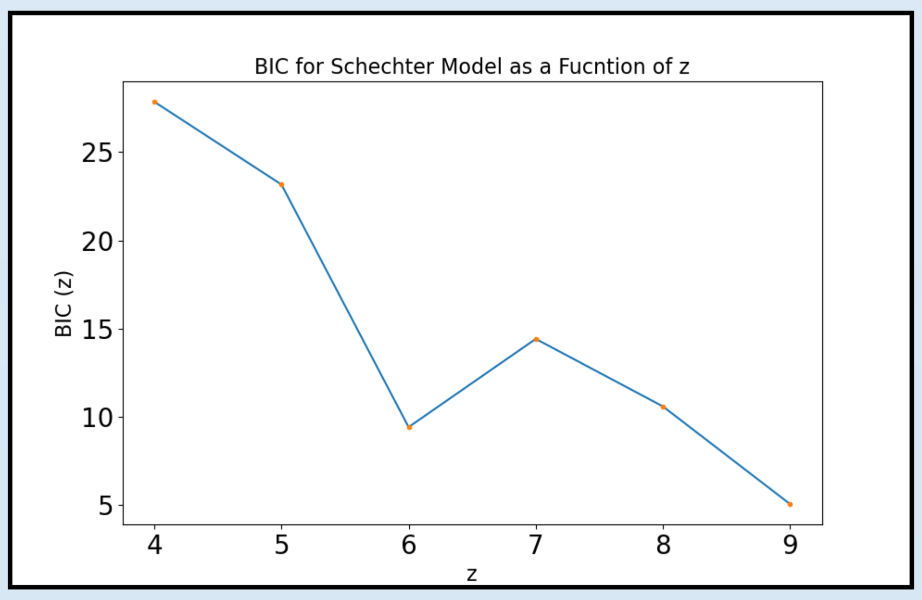
- This plot compares the FR model to the Schechter Function [4], which is a power law with exponential cut-off at the bright-end.
- The FR model currently does not handle upper limit data points.
- Still not a better fit than the Schechter Function in the power-law regime.



- The Bayesian Information Criterion (BIC) is defined as [3]:

$$\mathcal{B} = n_{\rm params} \ln(n_{\rm data}) - 2 \ln(L_{\max})$$

- A lower value is preferred.
- The current model BIC is 142.8



Next Steps

- Need to ensure that the model is working as intended with reliable fit-parameters.
- Then we can simply extrapolate the model to predict the UVLF for different (and future) survey parameters.
- Conversely, the fit parameters can also be predicted for future surveys by generating mock data based on survey parameters, e.g. due to Poisson and Cosmic Variance.

References

[1] S. Zaroubi, "The epoch of reionization", DOI: 10.1007/978- 3- 642- 32362- 1 2.

[2] S. Furlanetto, J. Mirocha, et. al. , "A Minimalist Feedback-Regulated Model for Galaxy Formation During the Epoch of Reionization " DOI: 10. 1093/mnras/stx2132.

[3] G. Schwarz , "Estimating the Dimension of a Model", DOI: 10.1214/aos/1176344136 .

[4] B. Robertson, "Estimating Luminosity Function Constraints from High-Redshift Galaxy Surveys", DOI:10.1088/0004-637X/713/2/1266 .