Chopping Onions

Modelling Halo Sparsity to Constrain Cosmology

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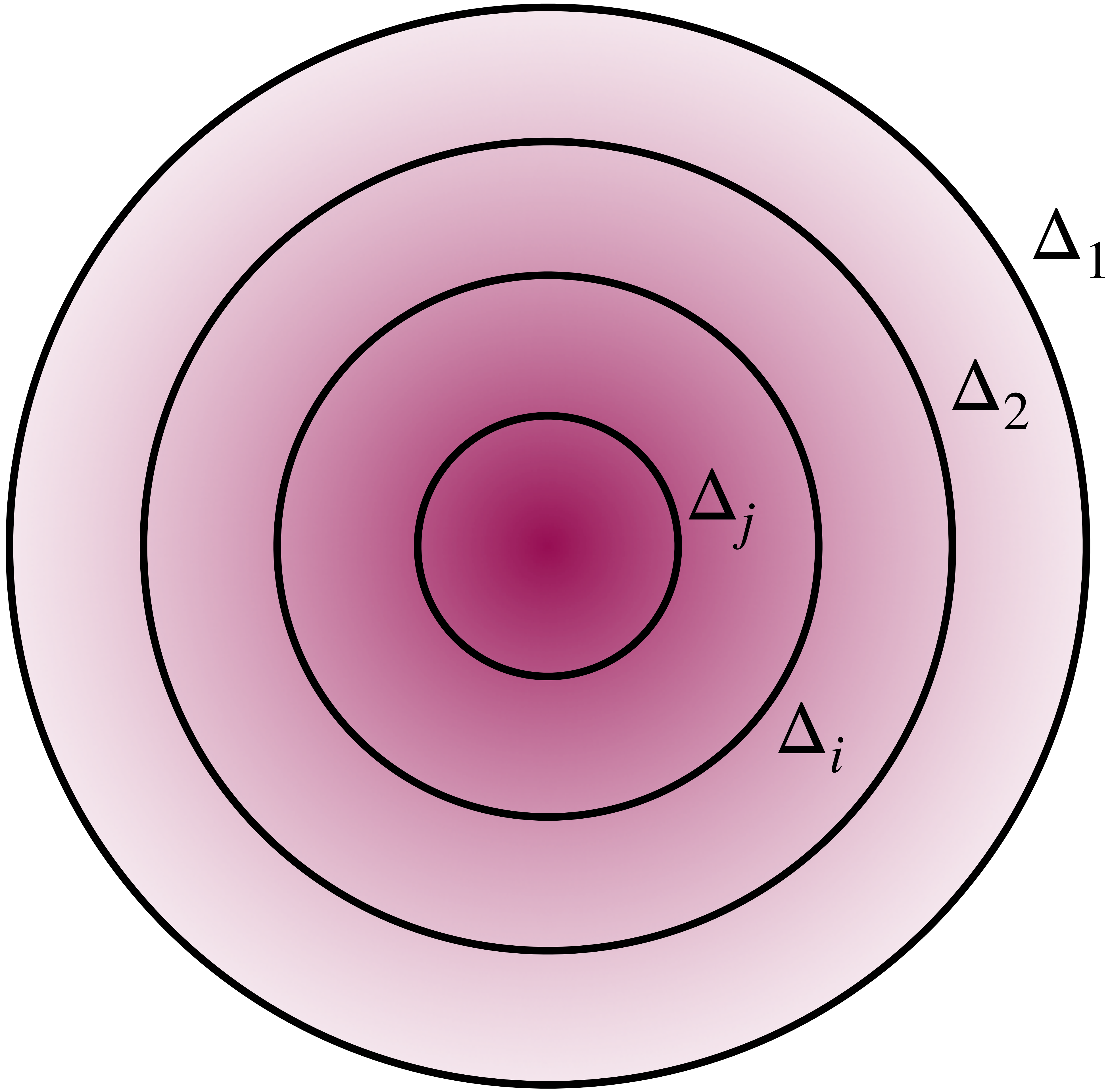
Road Map

- Halo Sparsity
- Stochastic Modelling of Haloes for Sparsity
- Merger Trees and Mass Transfer (Ongoing)

Haloes as Onions: Halo Sparsity

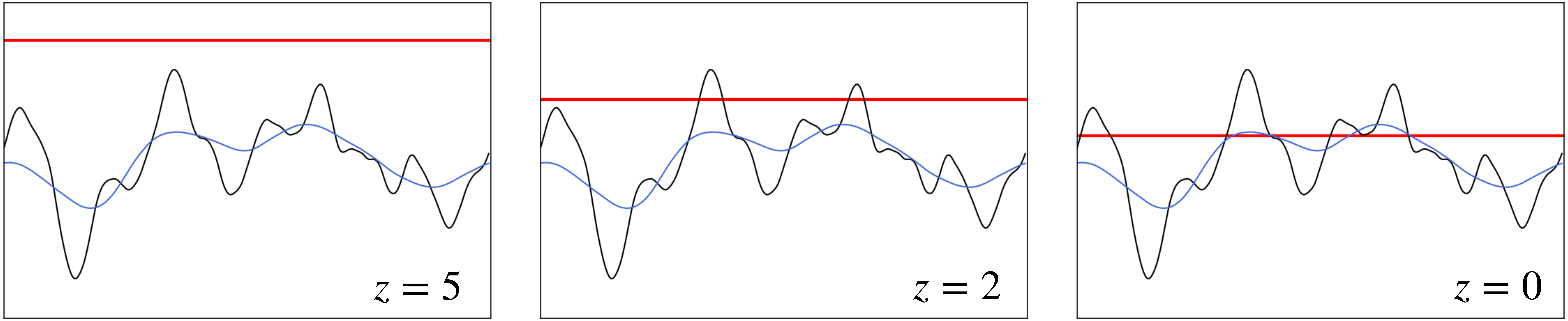


$$s_{\Delta_1,\Delta_2} = \frac{M_{\Delta_1}}{M_{\Delta_2}}$$

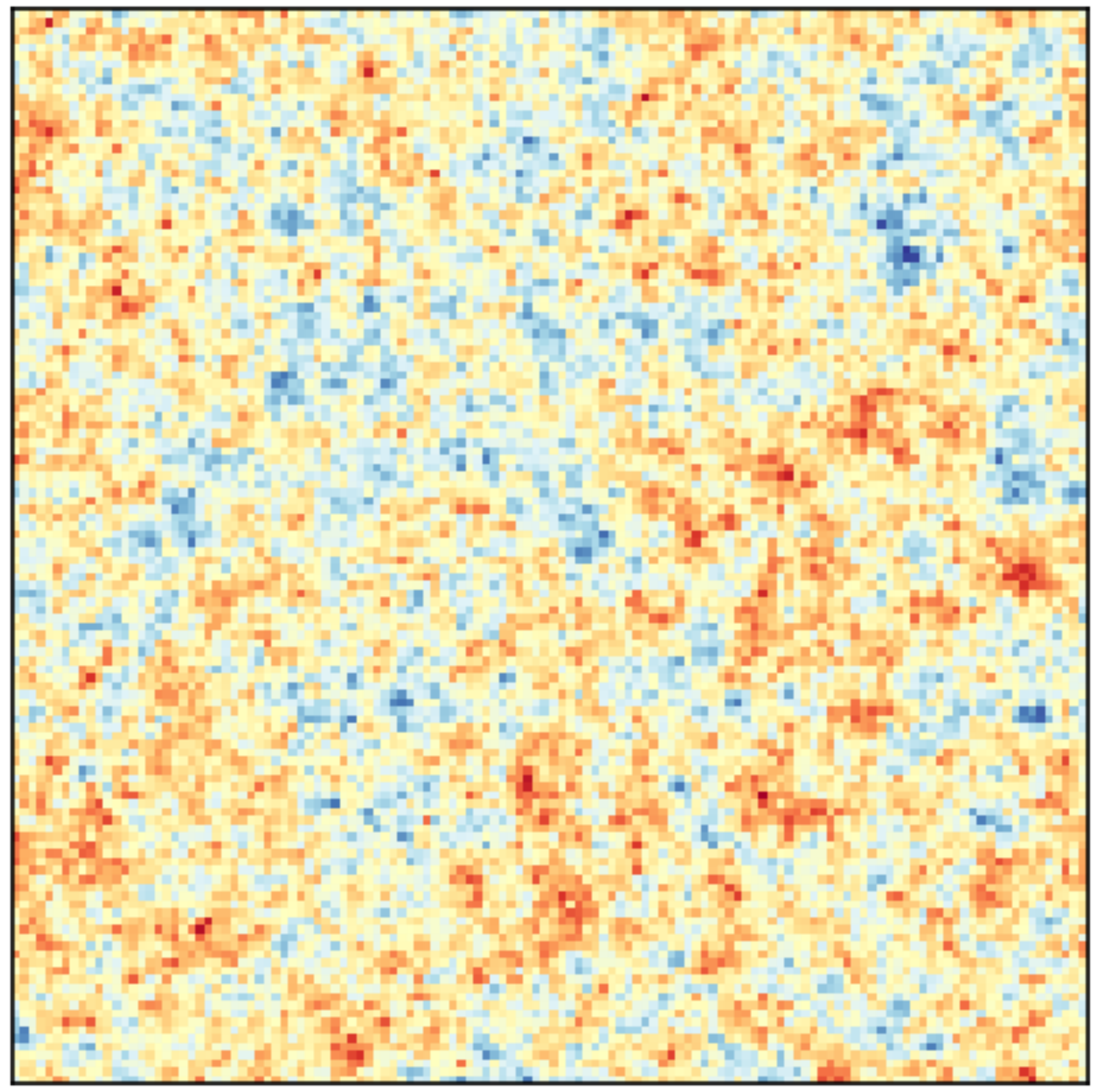
- Shape
- Simple
- Nice Behaviour
- Cosmology Dependent

Balmès et al. 2014, Corasaniti et al. 2018, Corasaniti & Rasera 2019, …

Stochastic modelling of Haloes



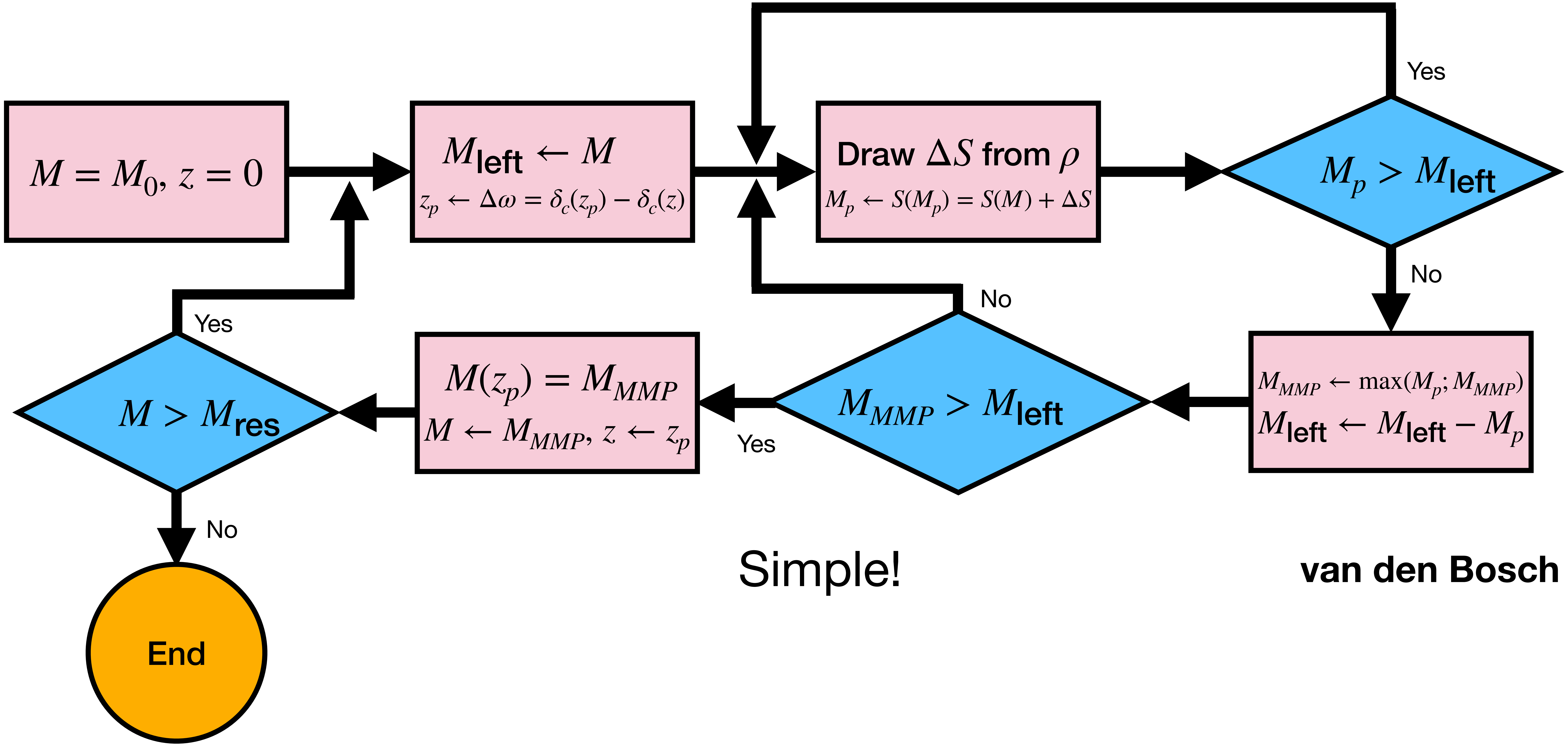
- Filter density field (Top hat, Gaussian, Sharp-k)
  - Assigns M (— $10^{12}M_\odot$ — $10^{14}M_\odot$) to excursion S
- Apply barrier — $\omega(z)$
- “Count” collapsed objects above $\omega(z)$



Excursion Set Theory: Bond et al. 1991

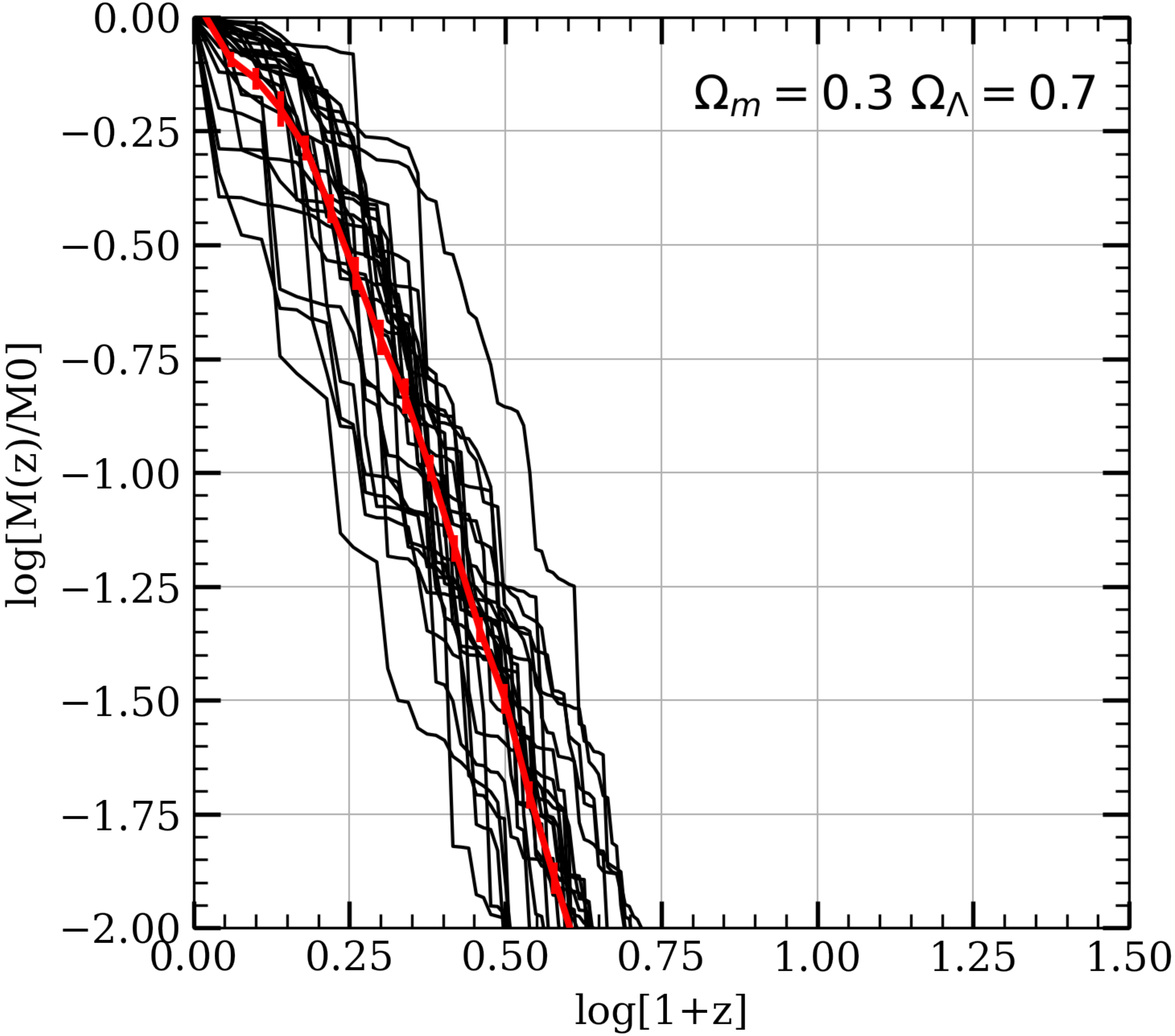
$$\rho(M_1, z_1 \,|\, M_0, z_0) d\Delta S = \frac{1}{\sqrt{2\pi}} \frac{\Delta\omega}{\Delta S^{3/2}} \exp\left[-\frac{\Delta\omega^2}{2\Delta S}\right] d\Delta S$$

M and z mapped onto S and ω



Simple!

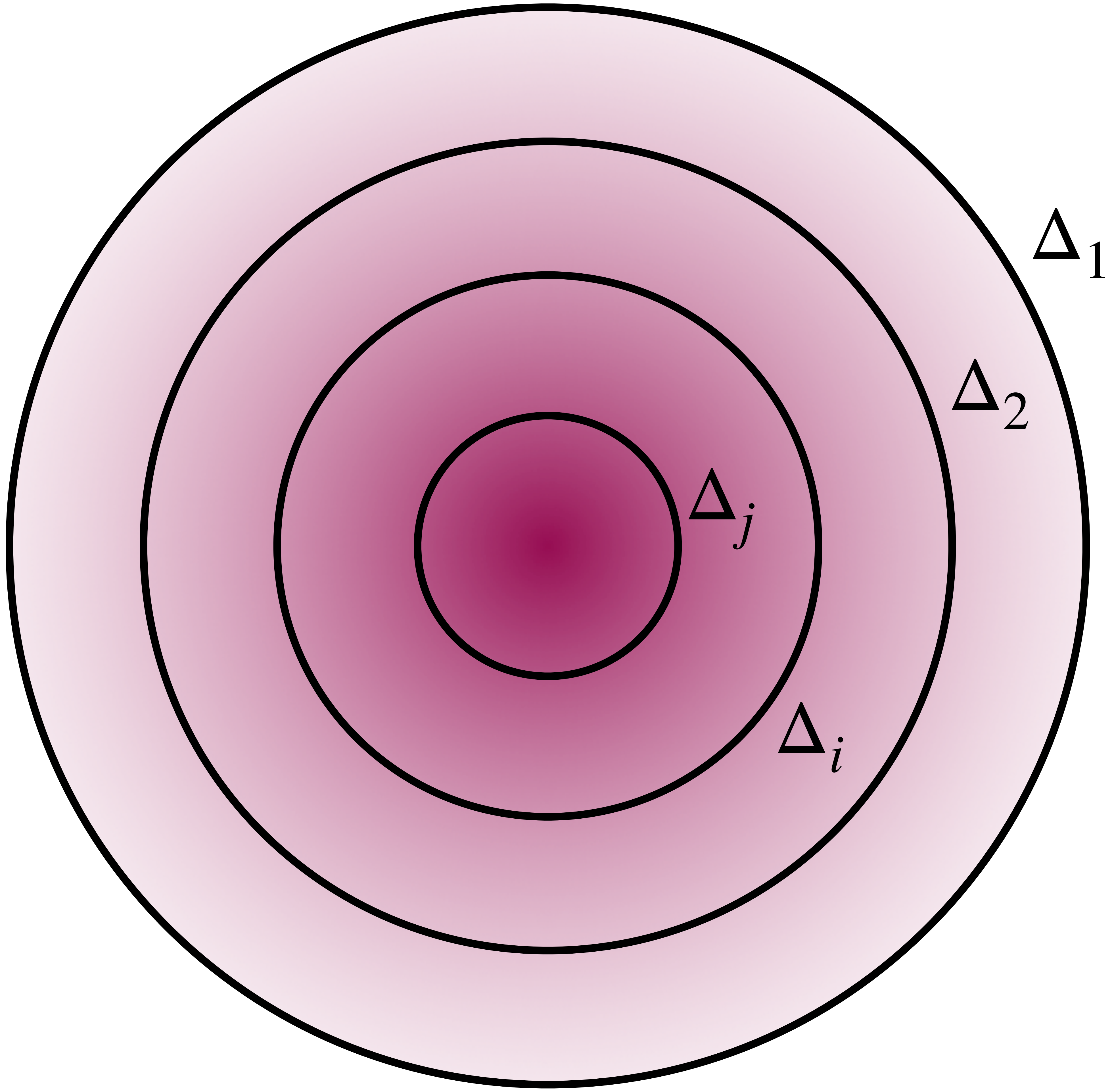
van den Bosch 2002



Mean Mass Accretion History

What is M?

What is M?



$$s_{\Delta_1,\Delta_2} = \frac{M_{\Delta_1}}{M_{\Delta_2}}$$

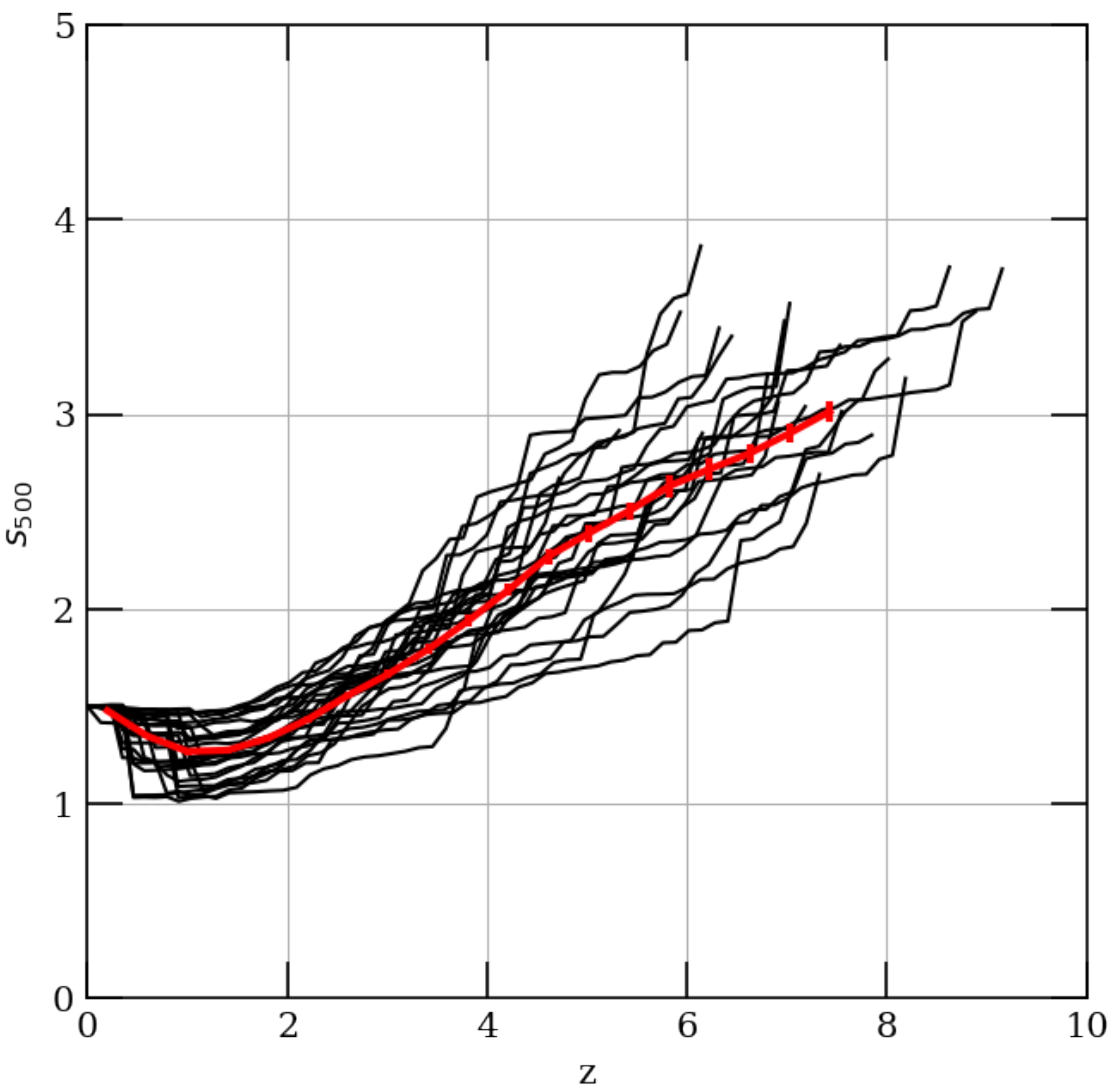
$$\rho(s\,|\,S)ds = \frac{|\,T(s\,|\,S)\,|}{\sqrt{2\pi}(s-S)^{3/2}} \exp\left\{\frac{(\omega(s)-\omega(S))^2}{2(s-S)}\right\} ds$$

$$T(s\,|\,S) = \sum_{n=0}^{5} \frac{(s-S)^n}{n!} \frac{\partial^n(\omega(s)-\omega(S))}{\partial s^n}$$

a, α and β fitted with Simulations

$$\omega(z,M) = \sqrt{a}\,\omega_c(z)\left\{1+\beta\left[\frac{S(M)}{a\omega_c^2(z)}\right]^{\alpha}\right\}$$

Sheth & Tormen (2002)



2 — Synchronised Random Number Generators

2 — Over-densities

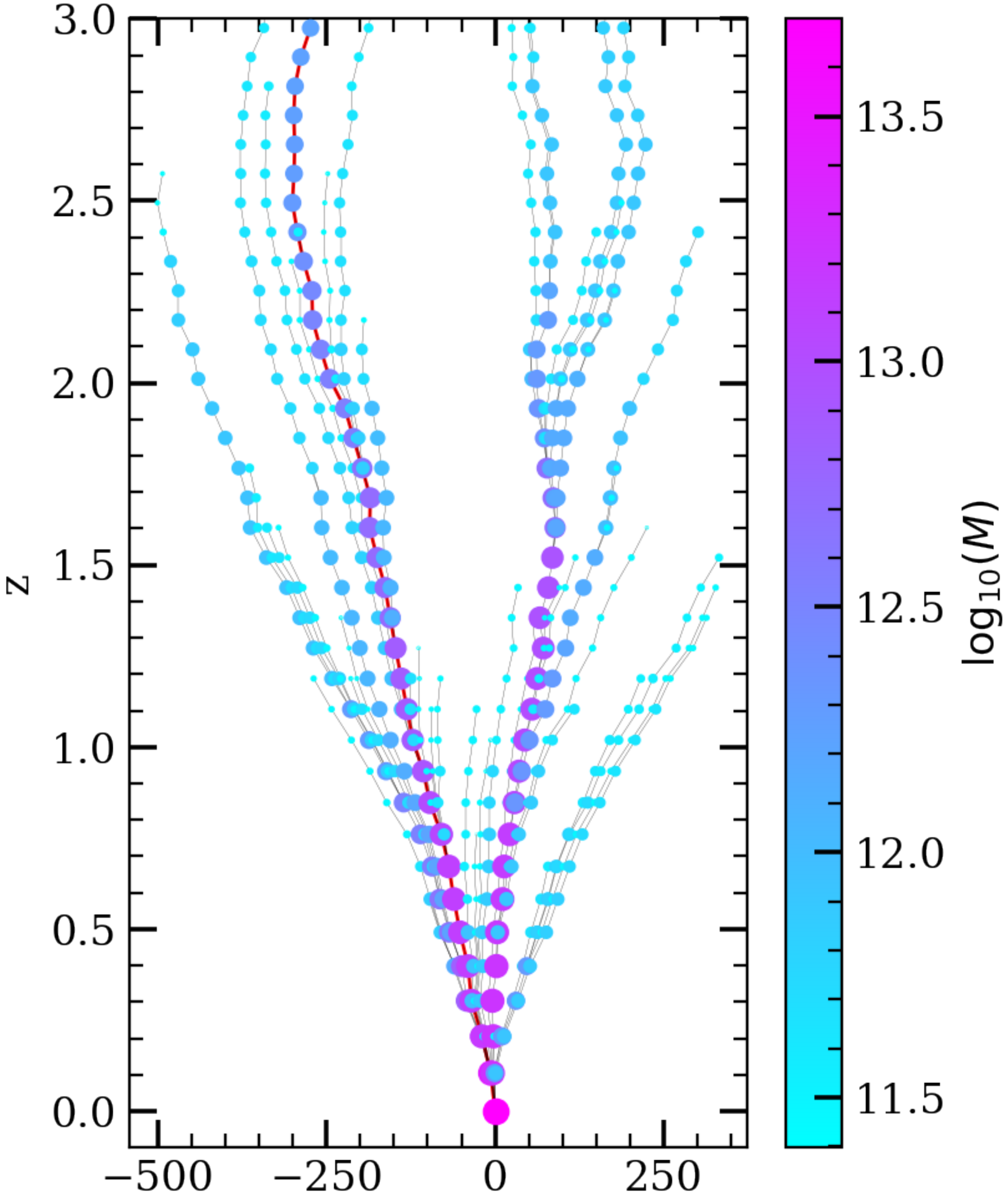
Profit?

Requiring* $M_{\Delta_1} > M_{\Delta_2}$

Breaks the algorithm

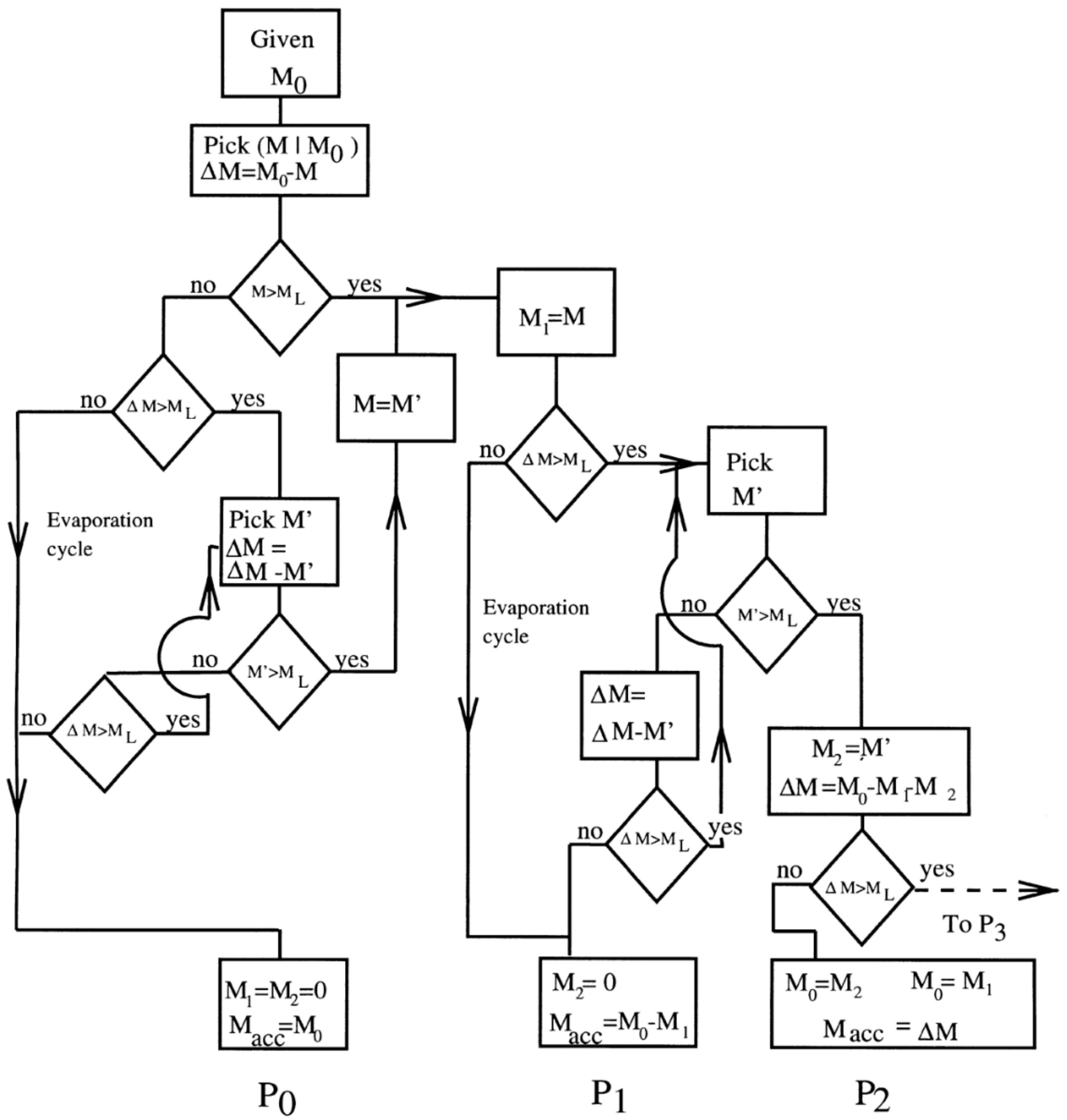
*Assuming $\Delta_2 > \Delta_1$

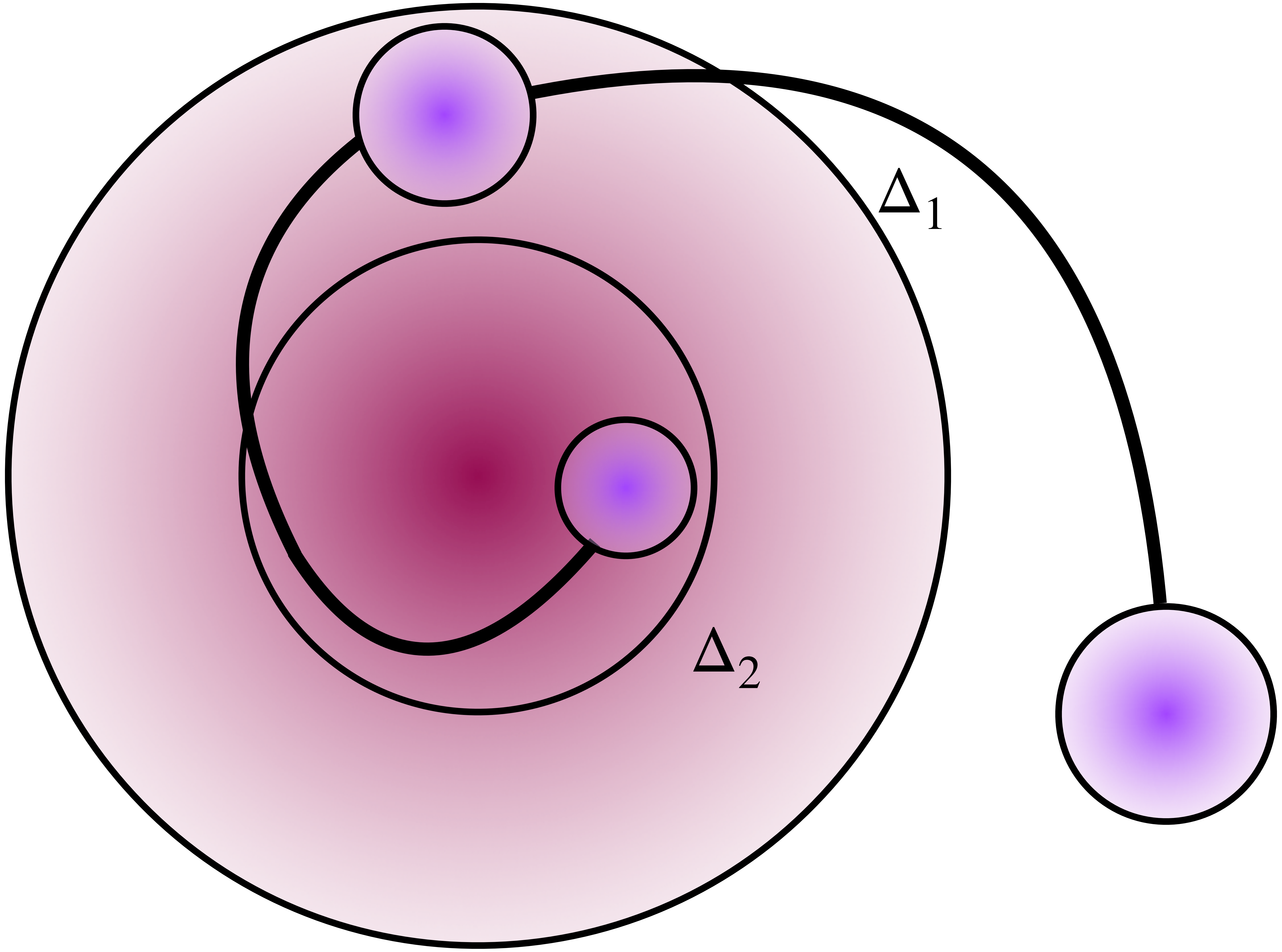
Merger Trees and Mass Transfer (Ongoing)



N-Progenitor Merger Trees

Somerville & Kolatt (1999)





- Dynamical Friction
- Tidal Forces
- Mass-loss

- Pseudo-Evolution
- Smooth Accretion
- Major Mergers

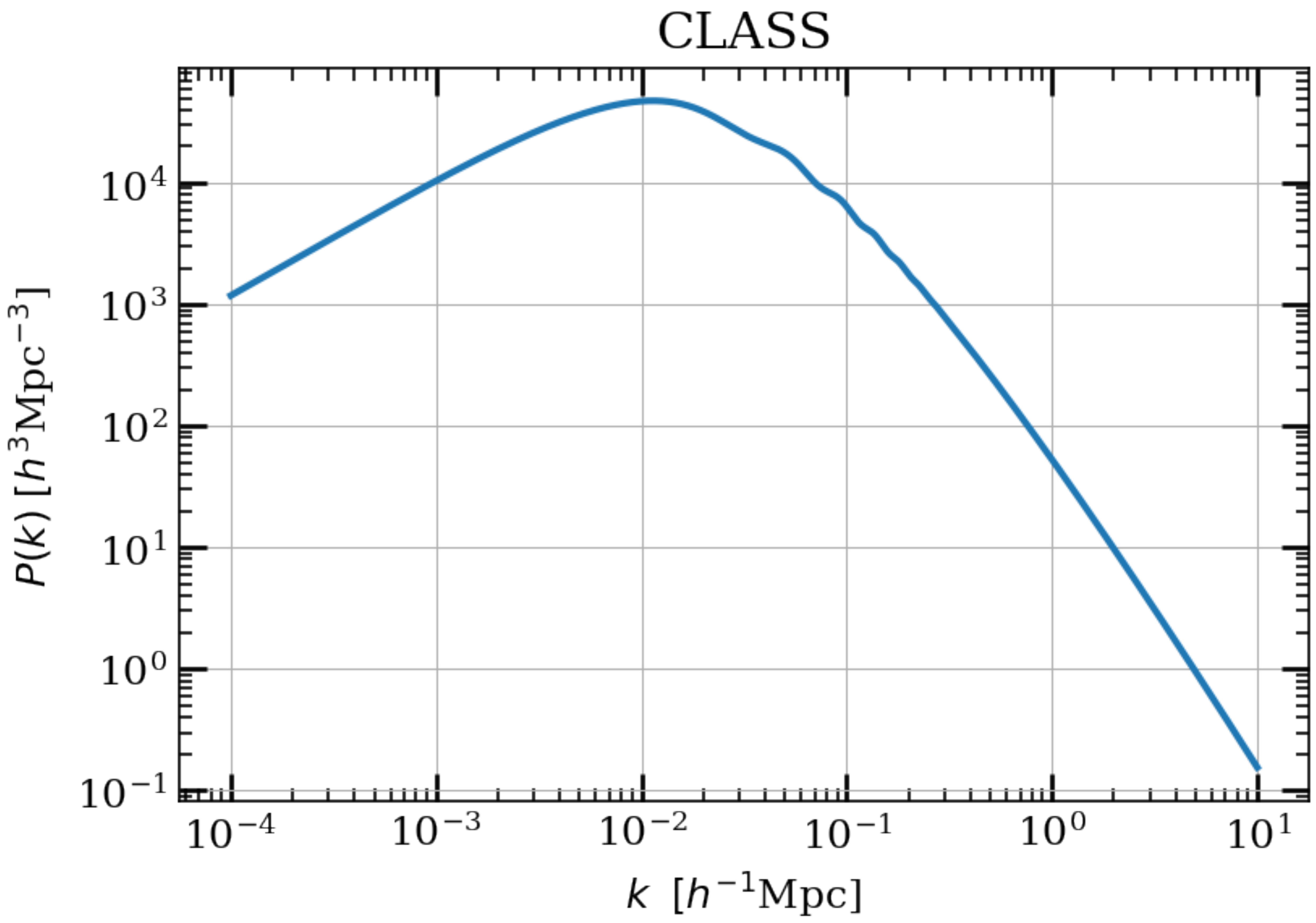
Contributions

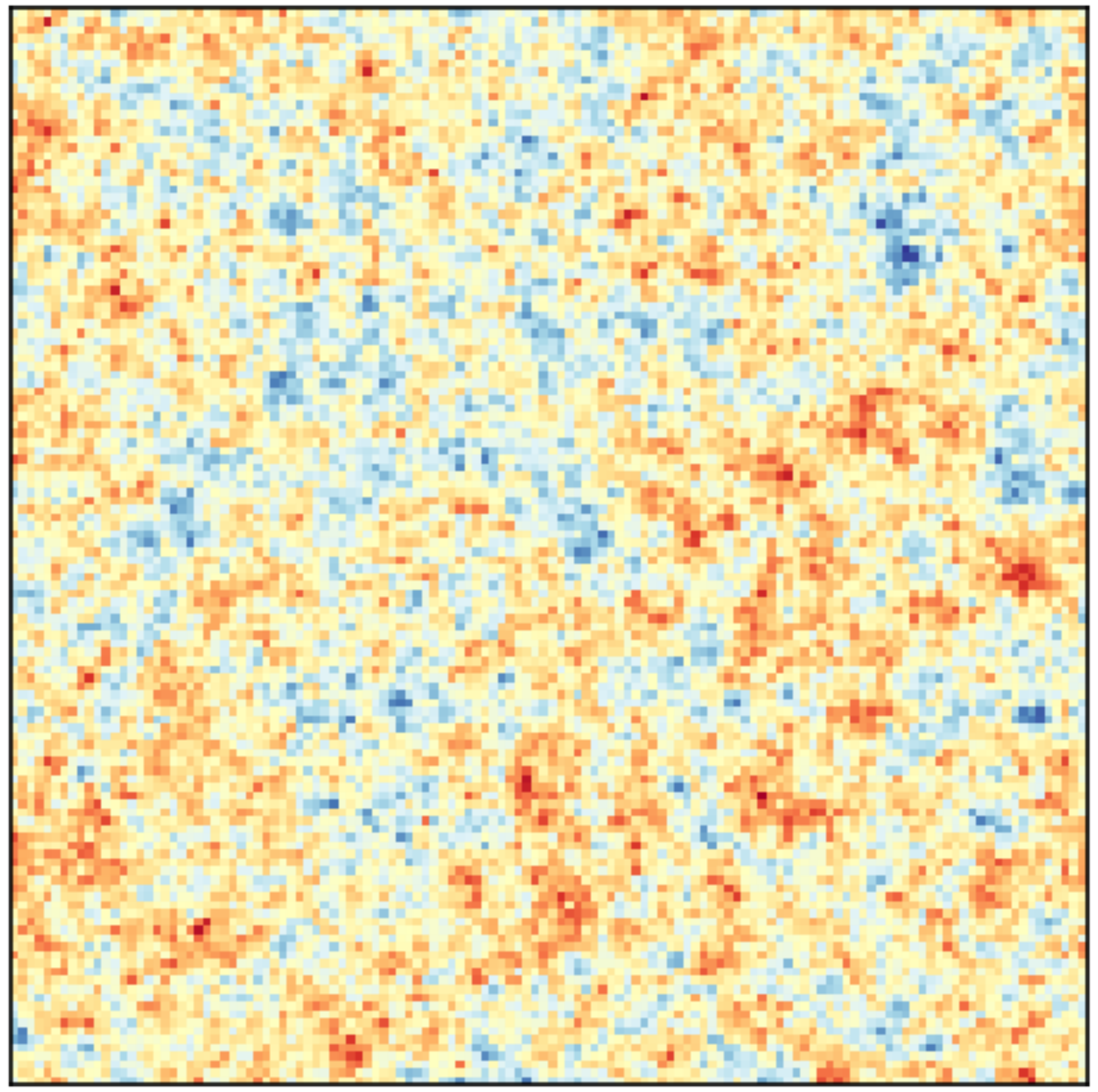
- **Implementation** of Mentioned algorithms
- **Adapting** these Algorithms to the problem at hand
- **Analysing** the results or **Understanding** why it doesn't work
- **Attacking** from a new direction

Upcoming

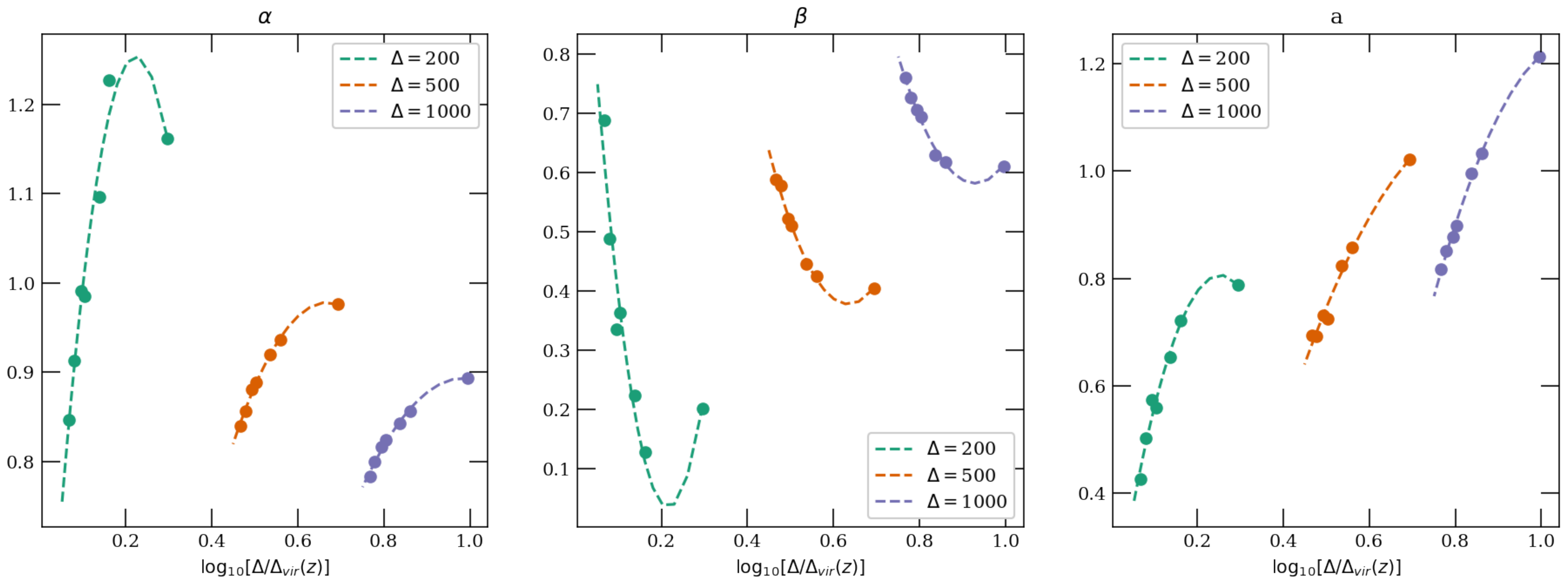
- **Adapting** Merger trees to <u>Mass Definitions</u> and <u>Ellipsoidal Collapse</u>
- **Efficient** descriptions for the transfert of mass between M_{Δ_1} and M_{Δ_2}

Stochastic modelling of Haloes





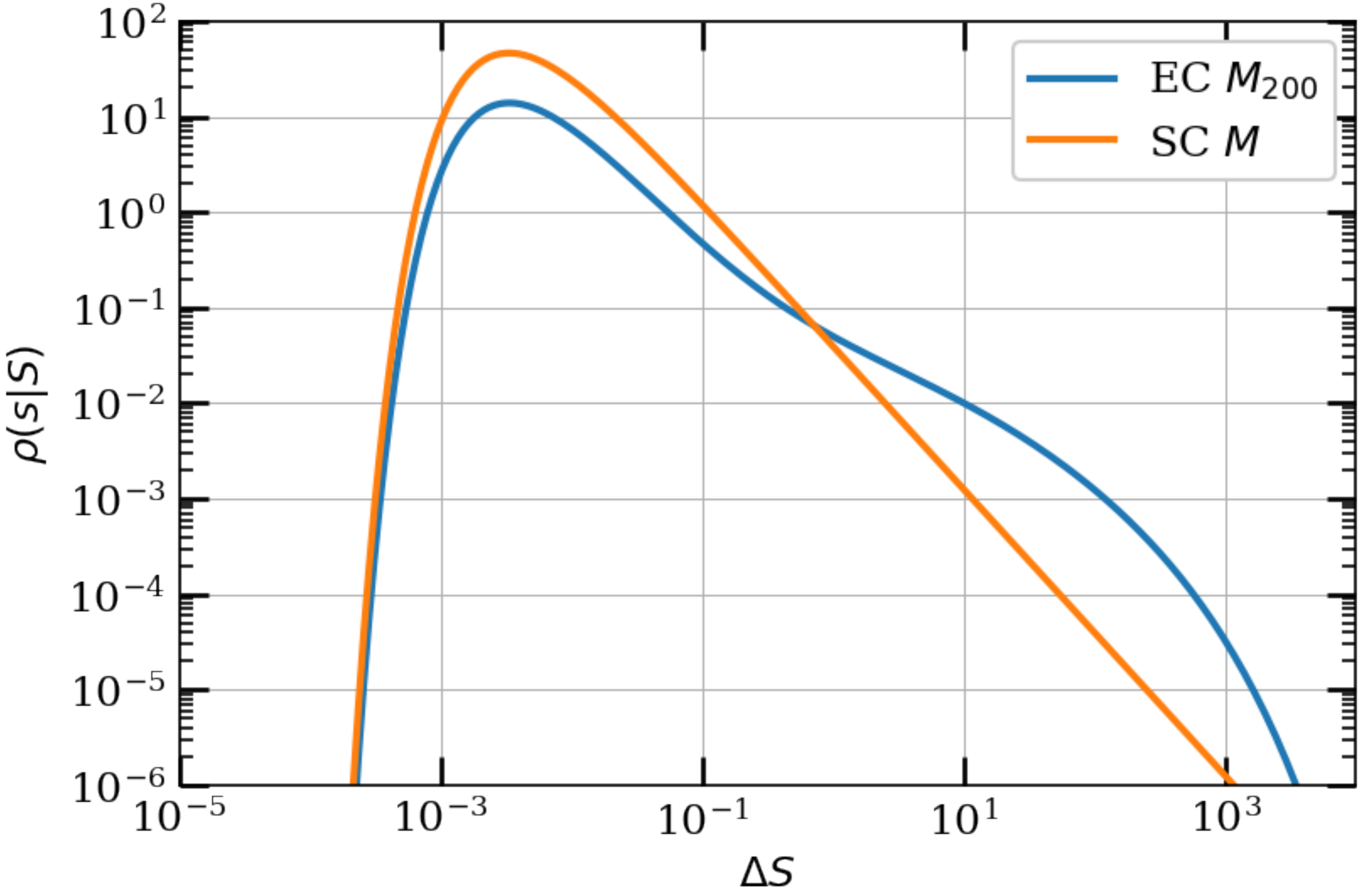
CLASS: Lesgourgues et al. 2011

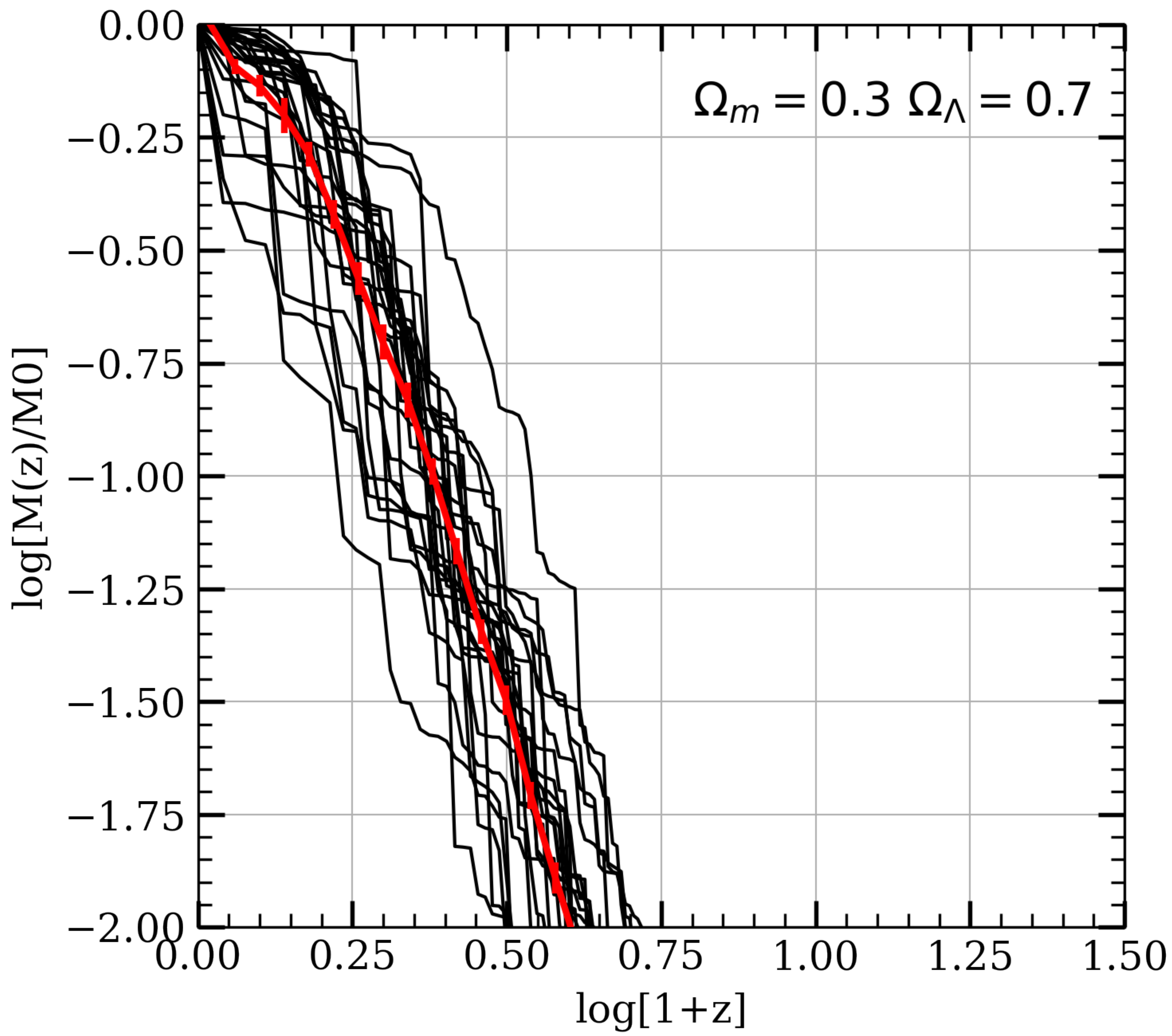


$$\begin{cases} a_{200} &= 0.13110258677390363 + 5.314507951320118x - 10.455568695024462x^2 \\ \alpha_{200} &= 0.4021596603794647 + 7.623156828252741x - 17.04941191288354x^2 \\ \beta_{200} &= 1.2725656263642258 - 11.47321231846788x + 26.587940467738854x^2 \end{cases}$$

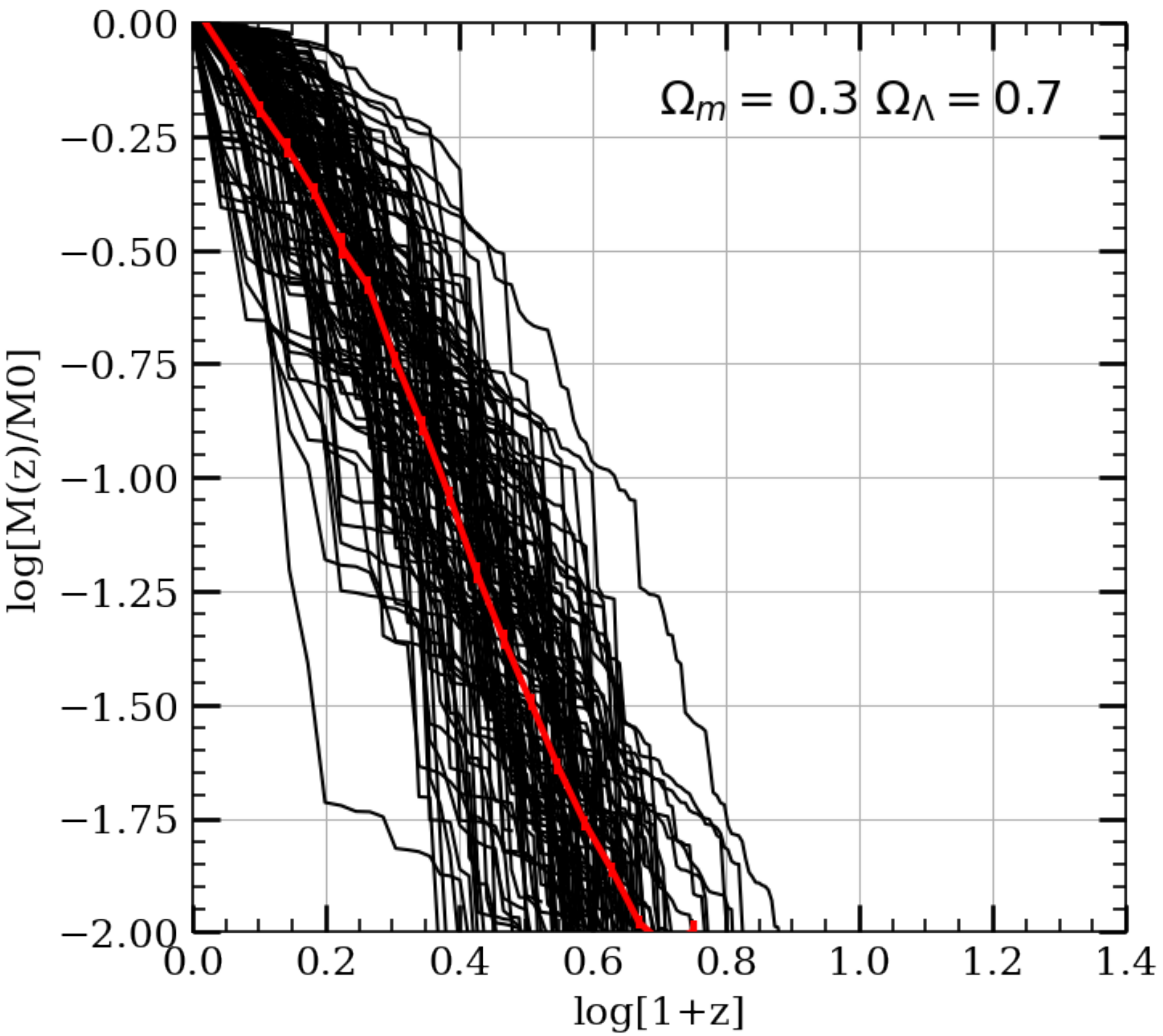
$$\begin{cases} a_{500} &= -0.9049576547887282 + 4.64738925537608x - 2.694948167238448x^2 \\ \alpha_{500} &= -0.4960050313855722 + 4.404985881738474x - 3.2904668041780116x^2 \\ \beta_{500} &= 3.4371440157410325 - 9.637258005997909x + 7.590173511505164x^2 \end{cases}$$

$$\begin{cases} a_{1000} &= -3.9140931838871516 + 9.561018245547054x - 4.429937365822789x^2 \\ \alpha_{1000} &= -1.2526989768614654 + 4.3535214433486695x - 2.2078340223834587x^2 \\ \beta_{1000} &= 6.38587656381367 - 12.491250281463294x + 6.721095771718661x^2 \end{cases}$$

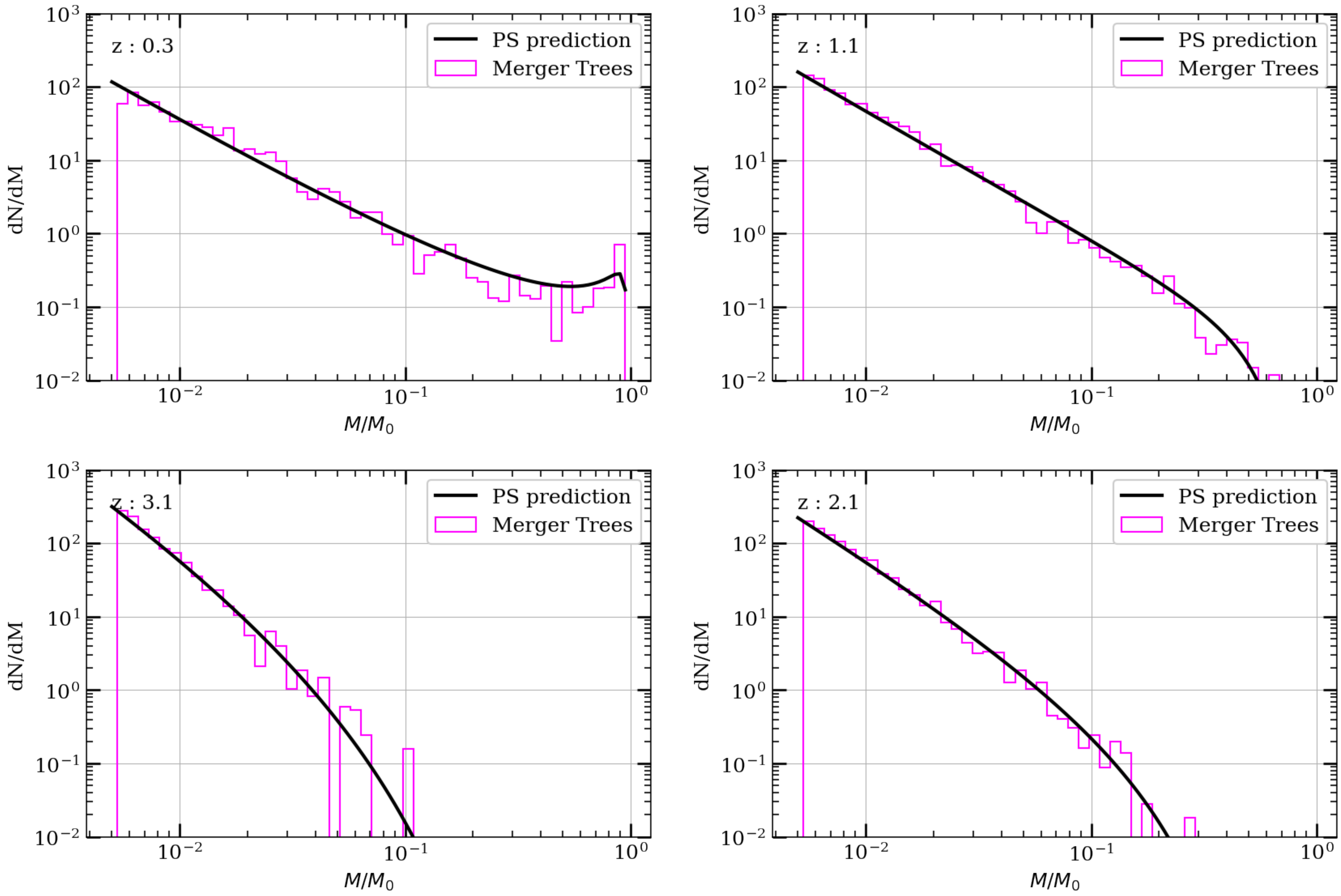

EC M_{200}
SC M
$\rho(s|S)$
ΔS
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-5}
10^{-3}
10^{-1}
10^{1}
10^{3}



Spherical Collapse MAH



Spherical Collapse Merger Trees


z : 0.3
z : 1.1
z : 3.1
z : 2.1
PS prediction
Merger Trees
dN/dM
M/M_0
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}