(A) Probabilistic Mixed-type Missing (PMM)

Dynamic lineage tracing

Target sites

site k

Start (t=0)

Time

End (t=τ)

CTMC with rate $\mathbf{Q}^{(k)}$

Single-cell sequencing

Dropout $\mathbf{\Phi}$

Observed site k

dropout   heritable missing   dropout
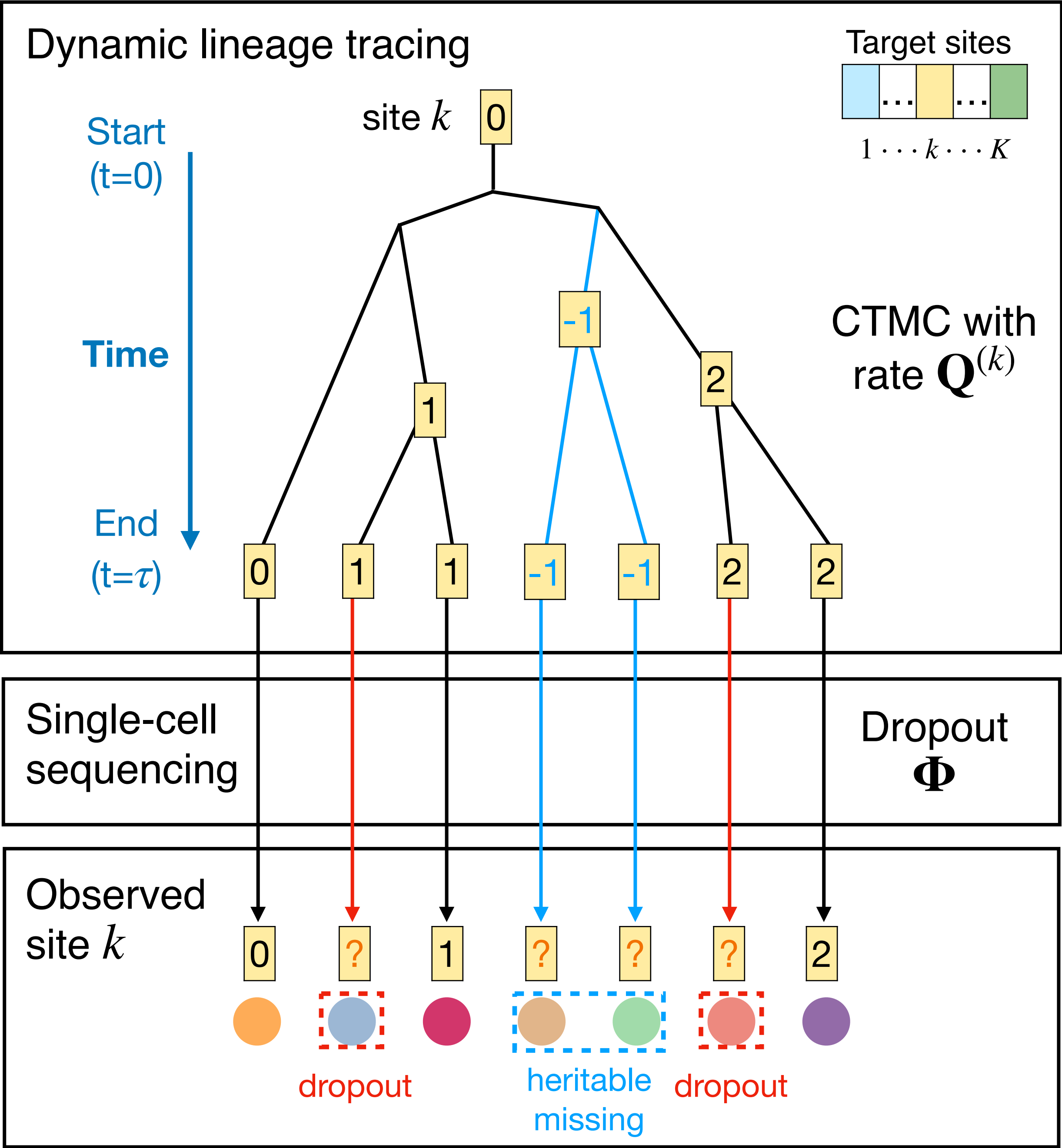
(B) Maximum Likelihood Inference under PMM model

Target sites

cells

character matrix $\mathbf{D}$

Input

🐫 LAML

$$\max_{T,\mathbf{\Theta}} \mathcal{P}(\mathbf{D}; T, \mathbf{\Theta})$$

Output

(1) Imputed character matrix

Target sites

cells

(2) Time-resolved lineage tree

Time

(3) Estimated mutation rate, heritable missing rate, and dropout rate