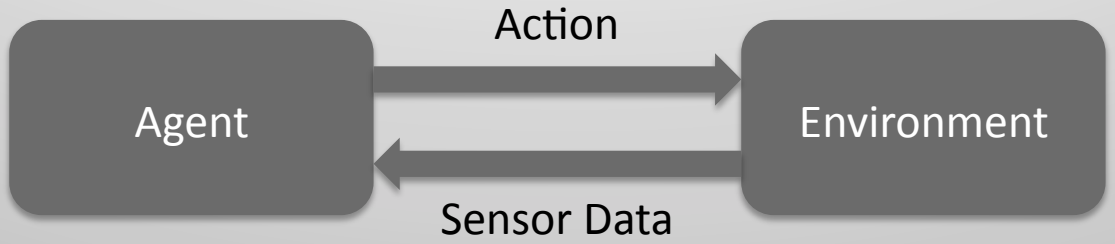
The Truth About Reconstruction

Physics 256B
Benny Brown
Department of Physics
Complexity Sciences Center

Motivation

Agent learning on a robotic experimental platform



1. Agent chooses an action
2. Receive sensor data from environment
3. Update model based on action & sensor data

- Ultimate goal: on-line (real-time) reconstruction
- Immediate goal: off-line (batch mode) reconstruction
  - Causal State-Splitting Reconstruction (CSSR)
  - Subtree Merging

Reconstruction Methods

State Splitting

- Begins by assuming IID process, “bottom up” approach
- New state created when morphs of “children” states are significantly different from “parent” states
- Choose parameter history length ***HL***

Tree Merging

- Parse Tree is created from data
- Subtrees with similar morphs are considered same state
- Choose parameters tree depth ***D*** and morph length ***L***

Processes Inferred

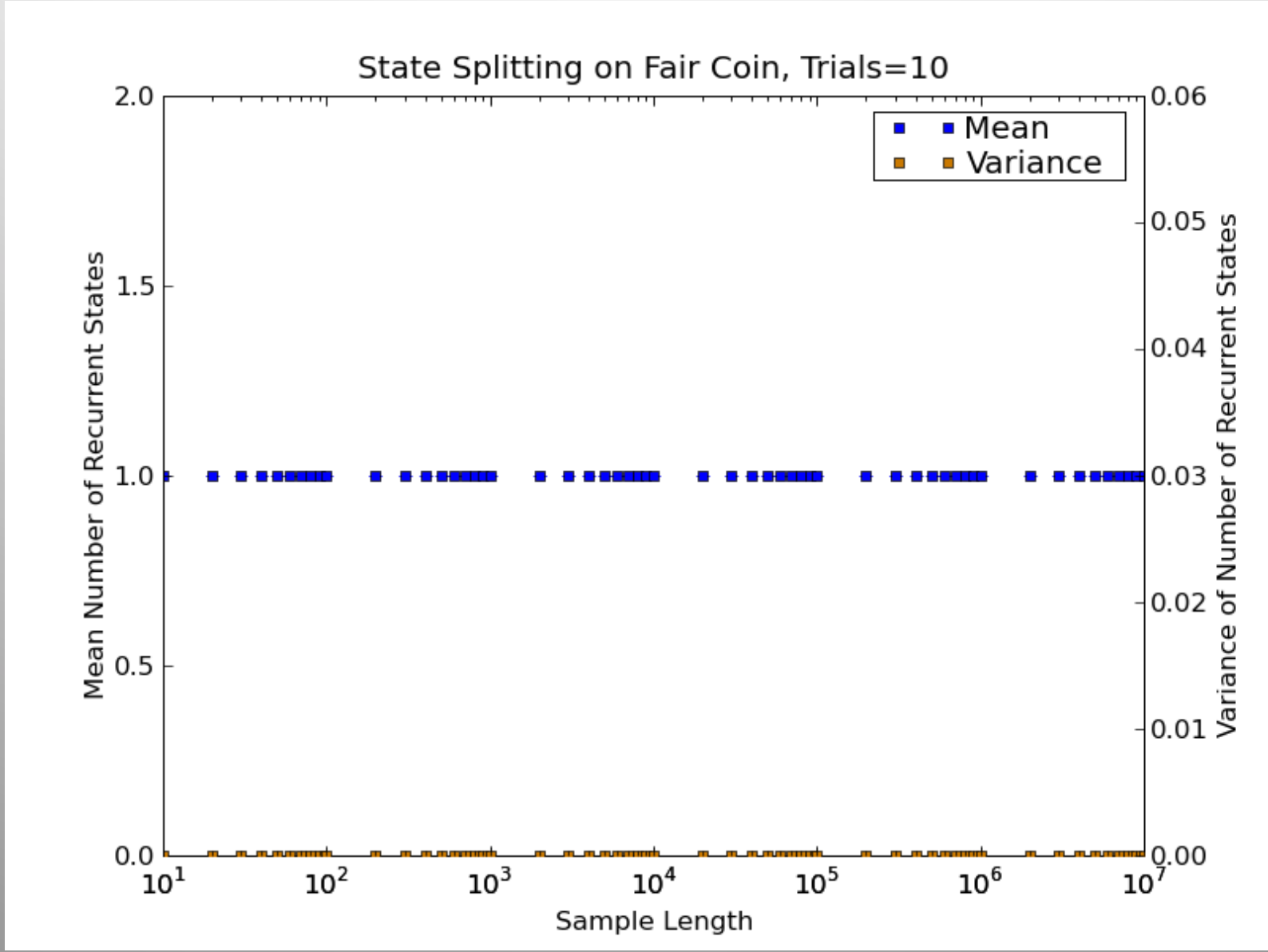
Fair Coin

Golden Mean

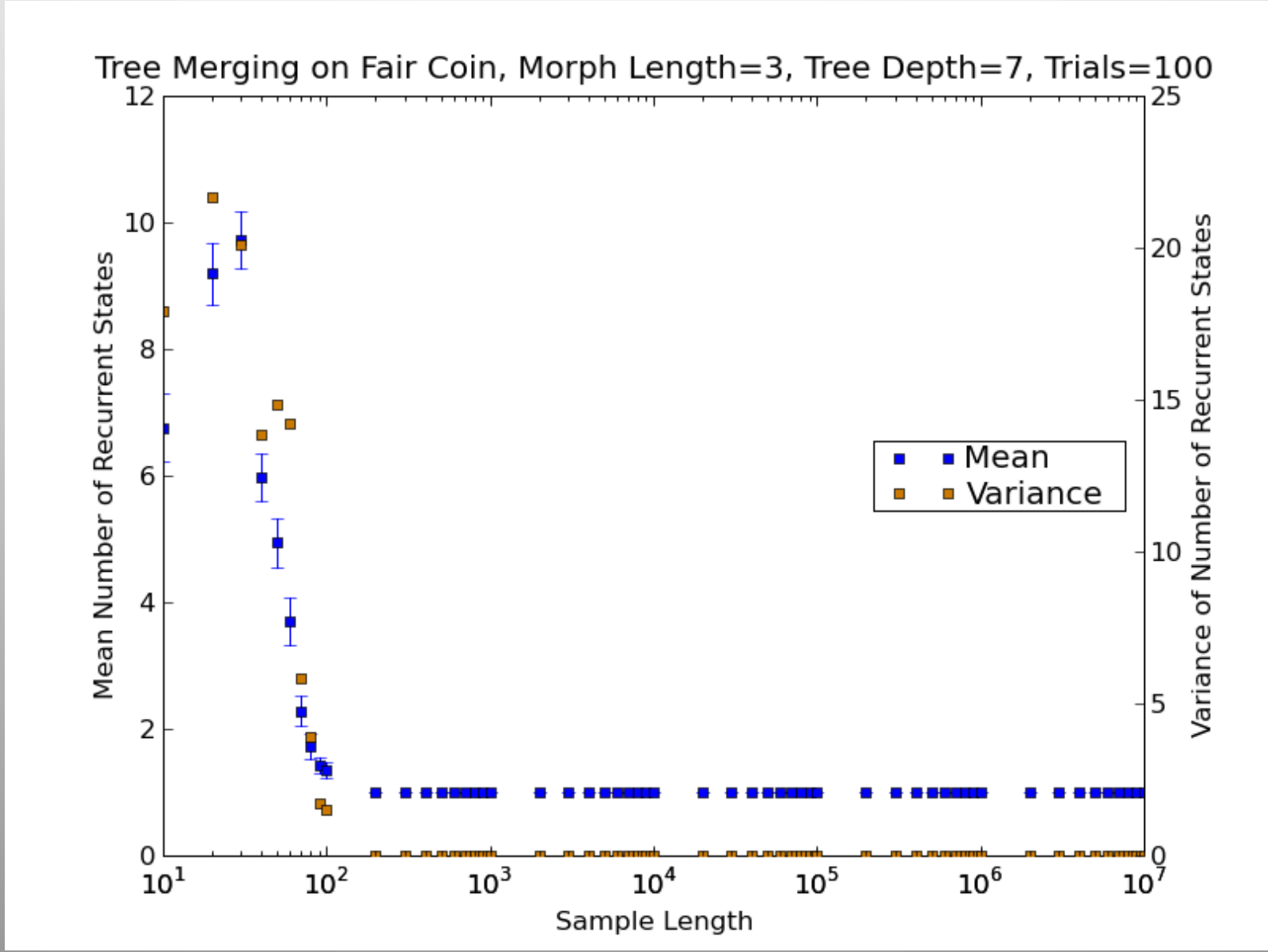
Even

RRXOR

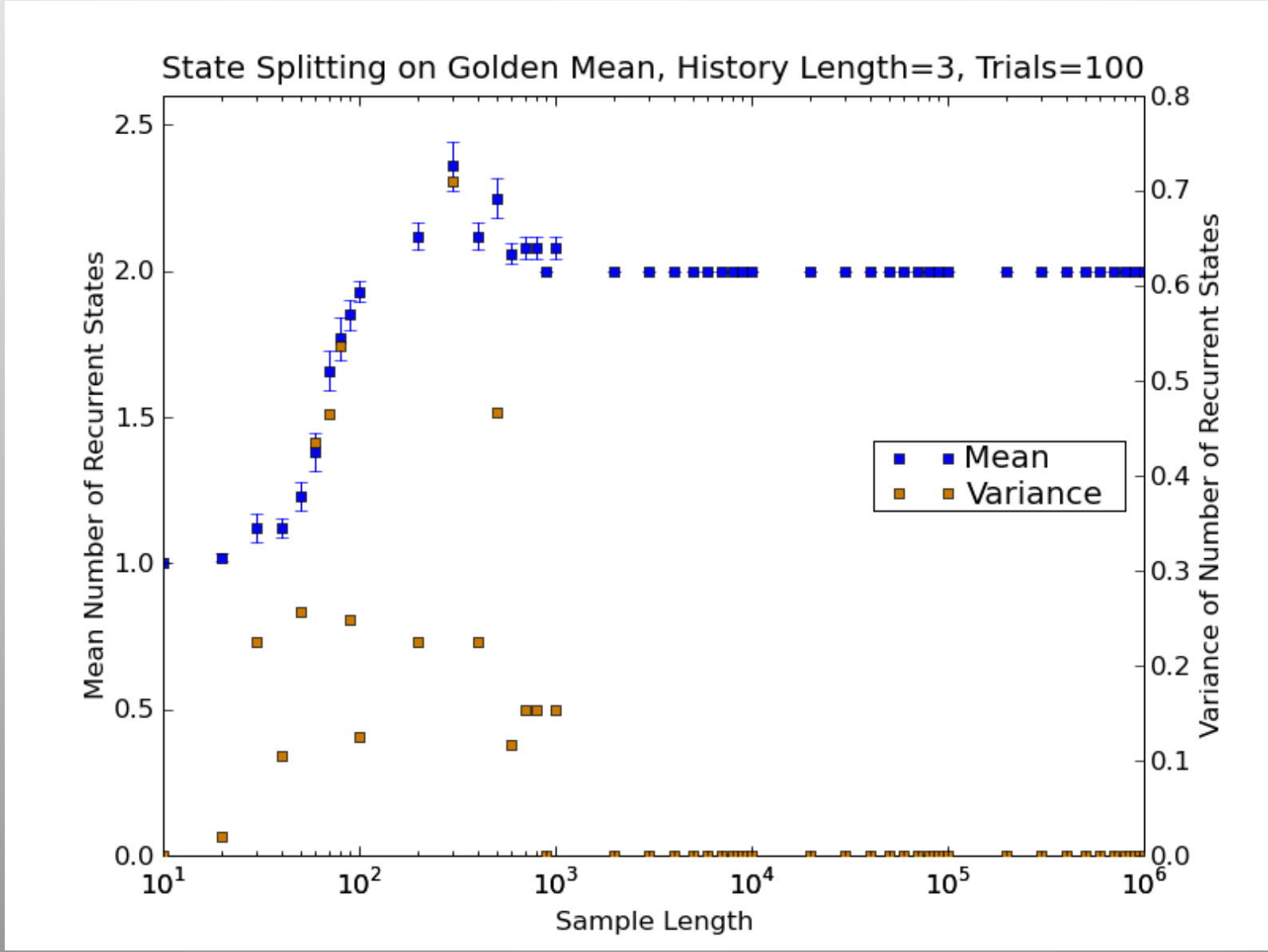
Fair Coin - SS


State Splitting on Fair Coin, Trials=10
Mean
Variance
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
2.0
1.5
1.0
0.5
0.0
0.06
0.05
0.04
0.03
0.02
0.01
0.00
10^1
10^2
10^3
10^4
10^5
10^6
10^7

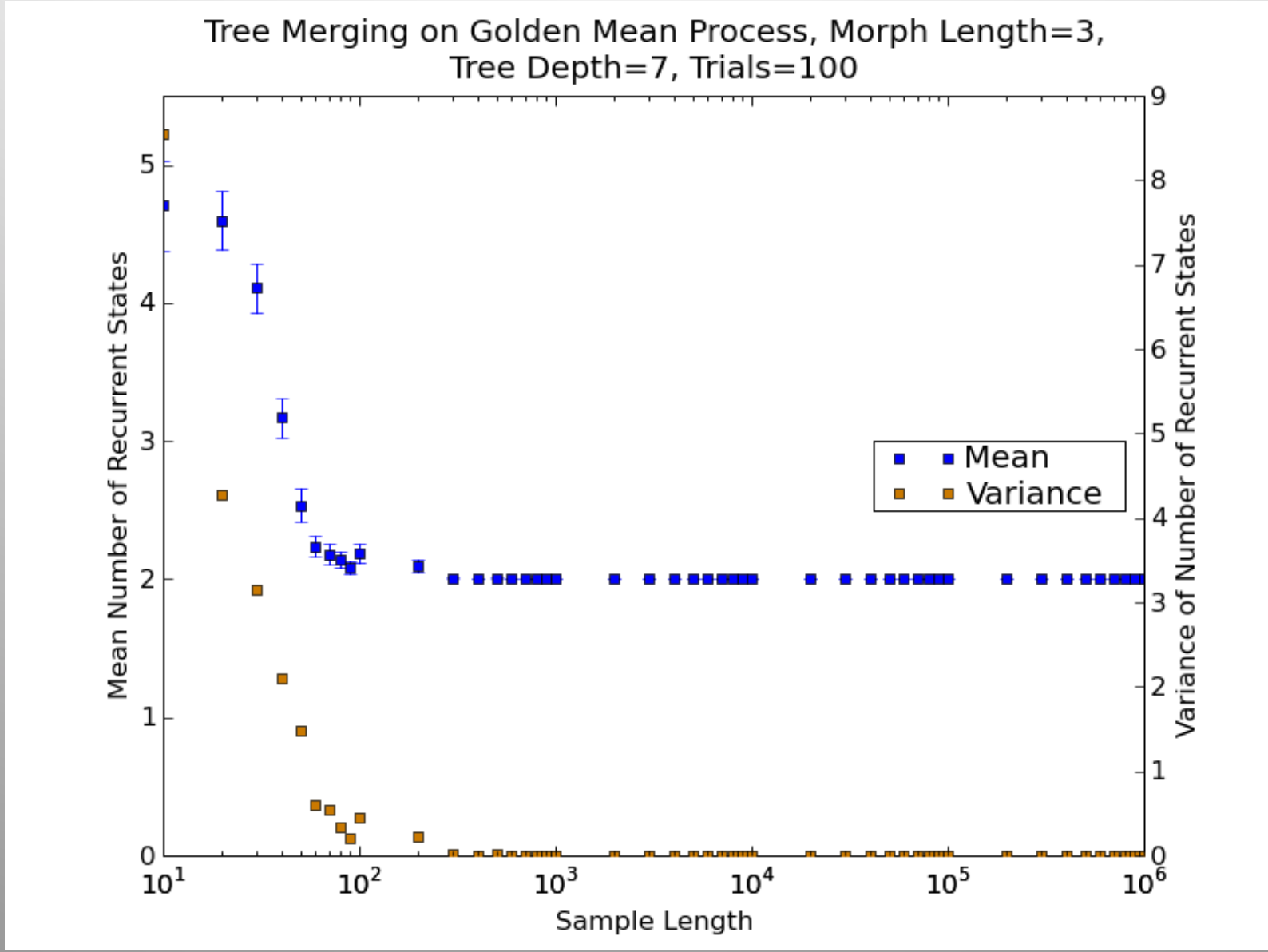
Fair Coin - TM


Tree Merging on Fair Coin, Morph Length=3, Tree Depth=7, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
2
4
6
8
10
12
0
5
10
15
20
25
10^1
10^2
10^3
10^4
10^5
10^6
10^7

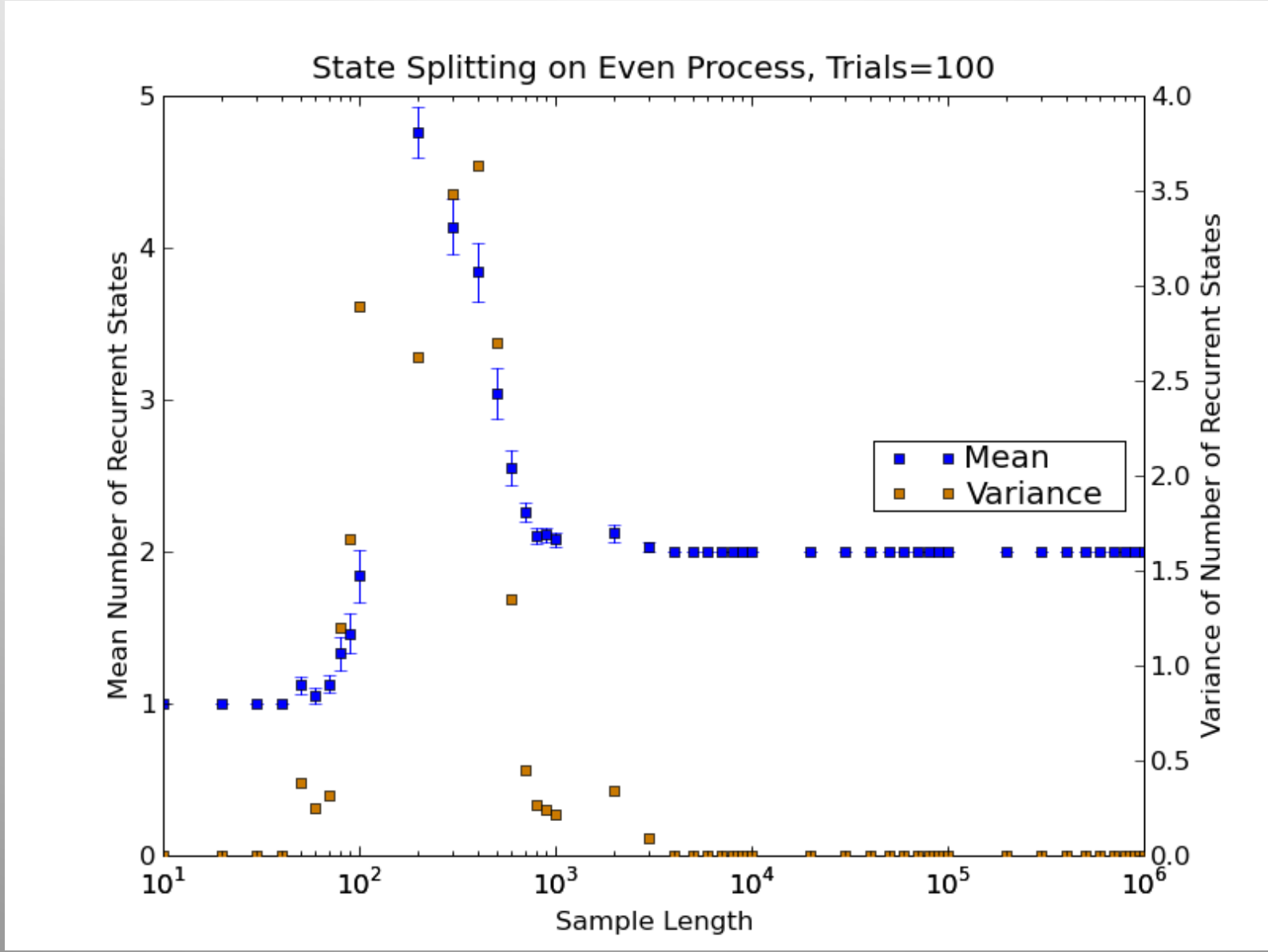
Golden Mean - SS



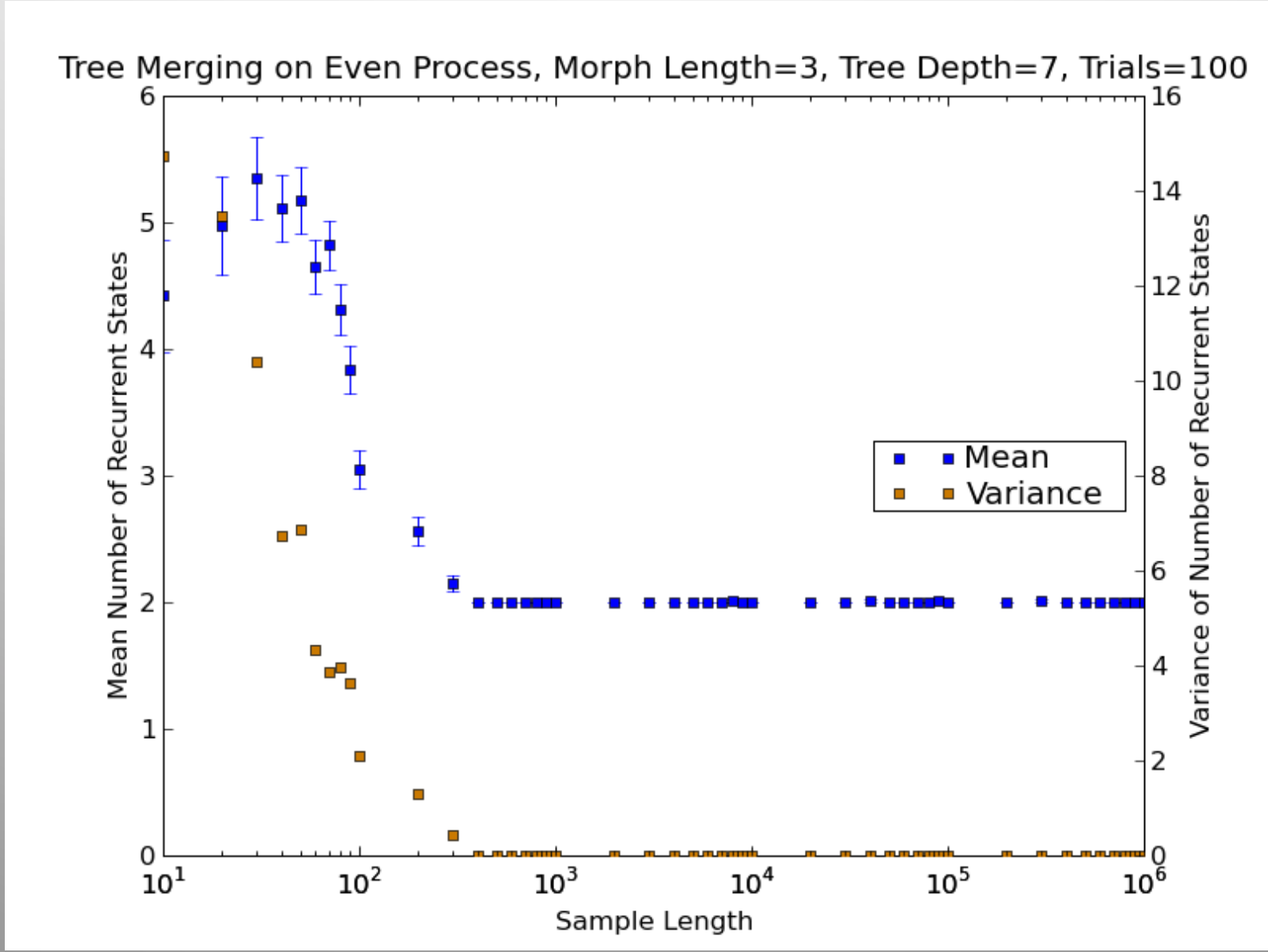
Golden Mean - TM



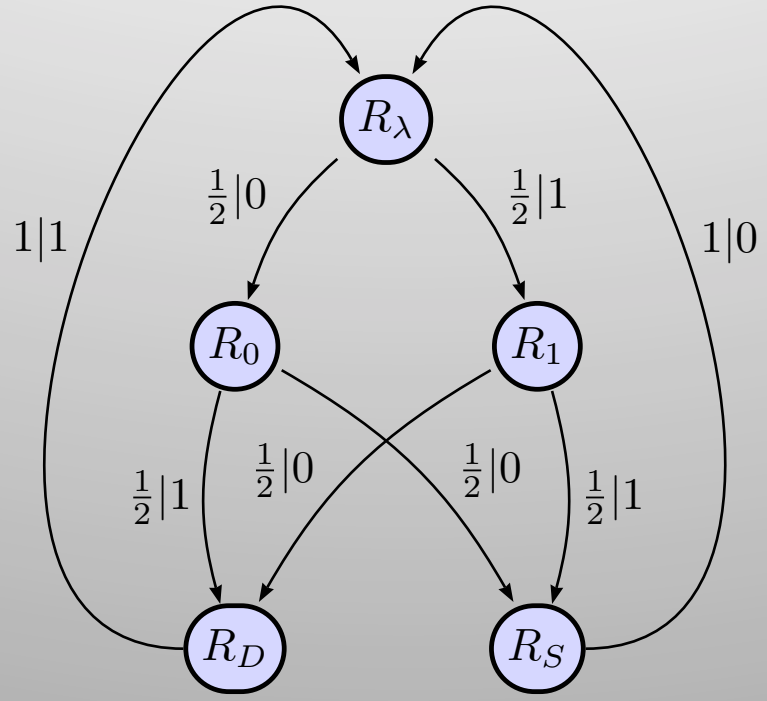
Even - SS


State Splitting on Even Process, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
10^1
10^2
10^3
10^4
10^5
10^6

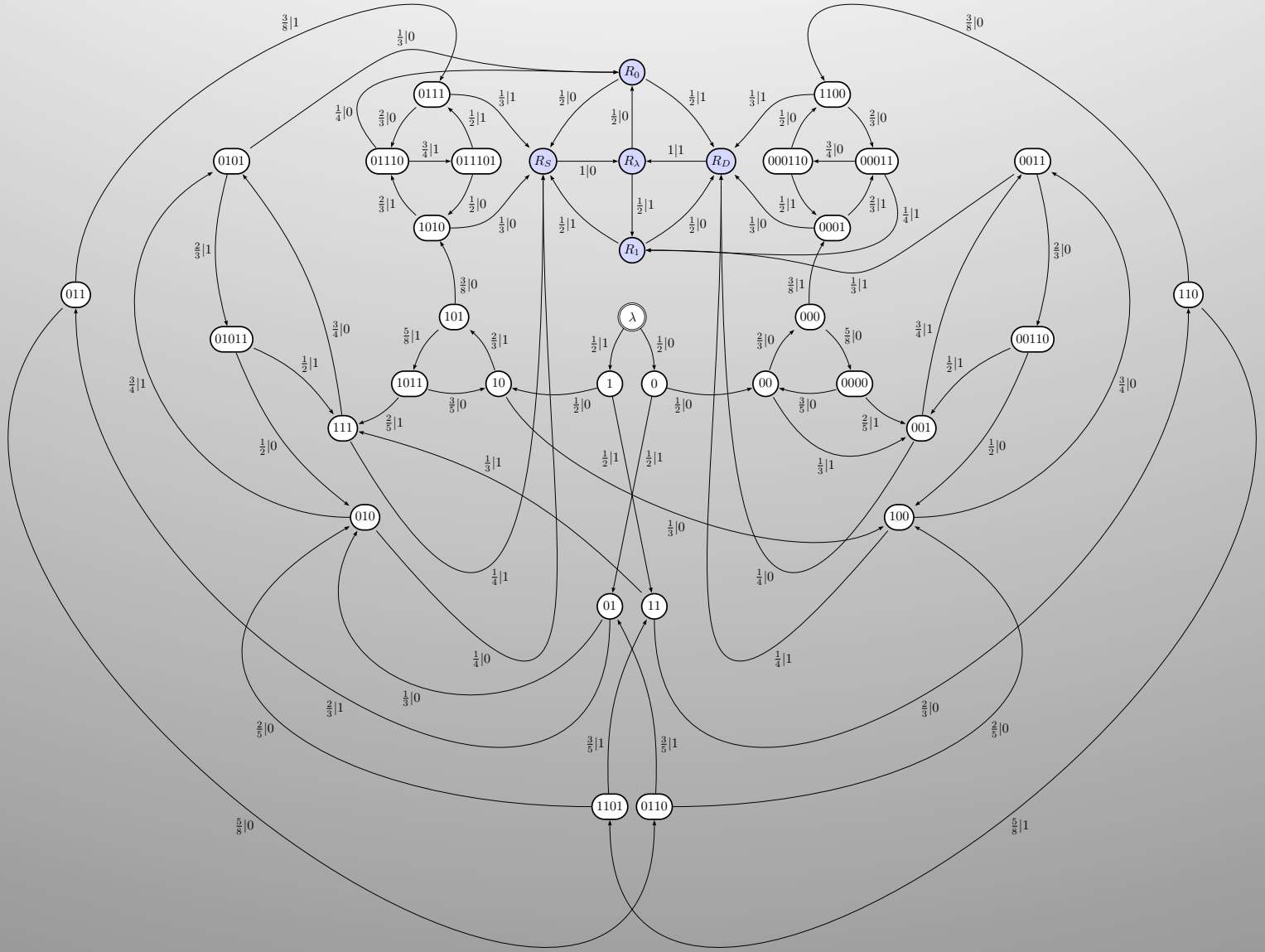
Even - TM


Tree Merging on Even Process, Morph Length=3, Tree Depth=7, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
10^1
10^2
10^3
10^4
10^5
10^6

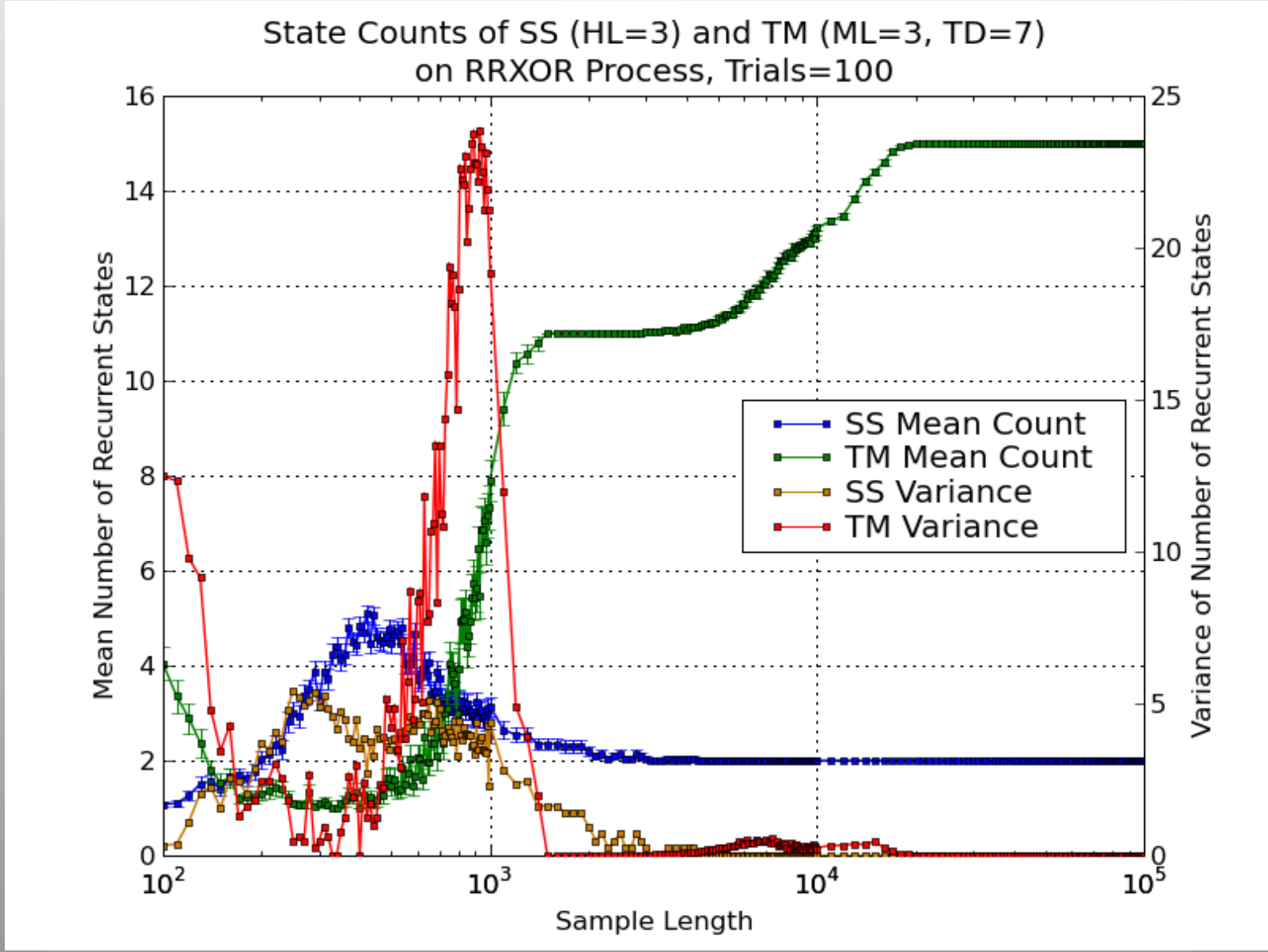
RRXOR Recurrent States



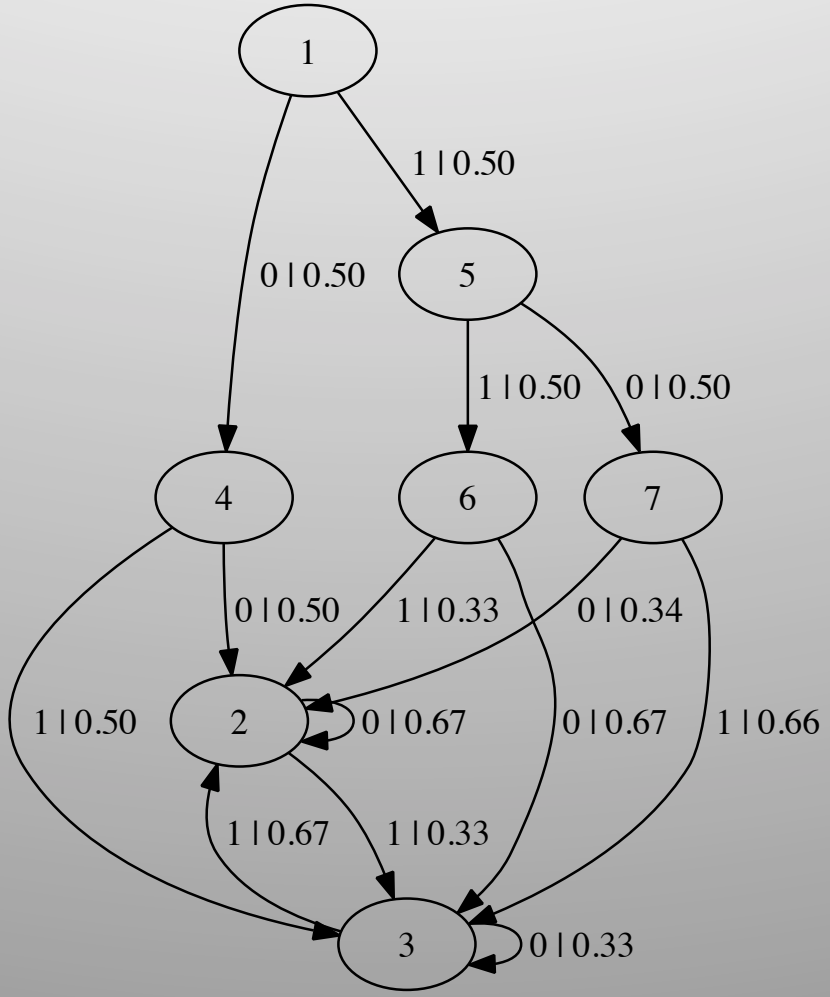
RRXOR States: 31 Transient, 5 Recurrent



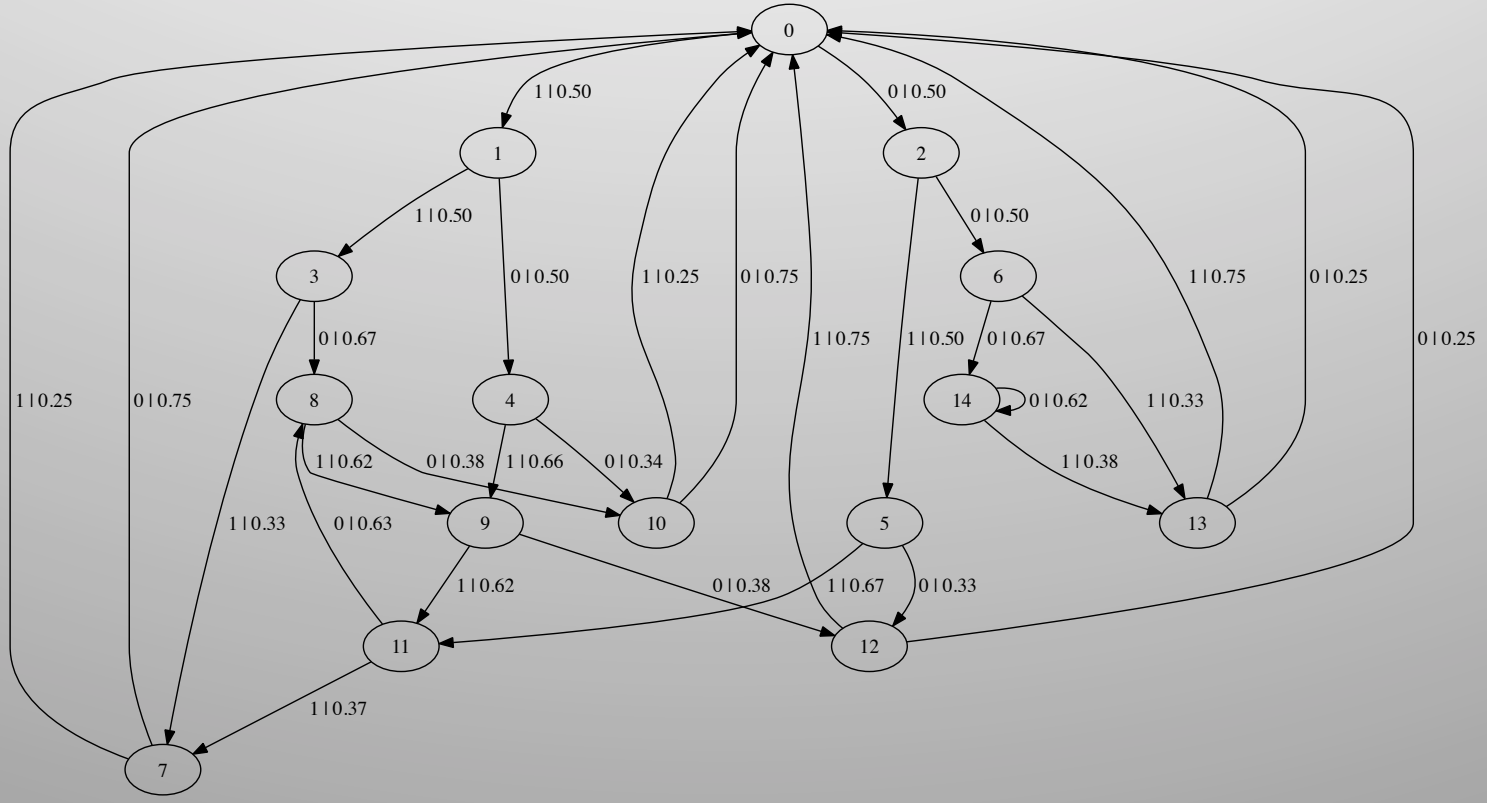
RRXOR: SS & TM


State Counts of SS (HL=3) and TM (ML=3, TD=7)
on RRXOR Process, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
SS Mean Count
TM Mean Count
SS Variance
TM Variance
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
10^2
10^3
10^4
10^5

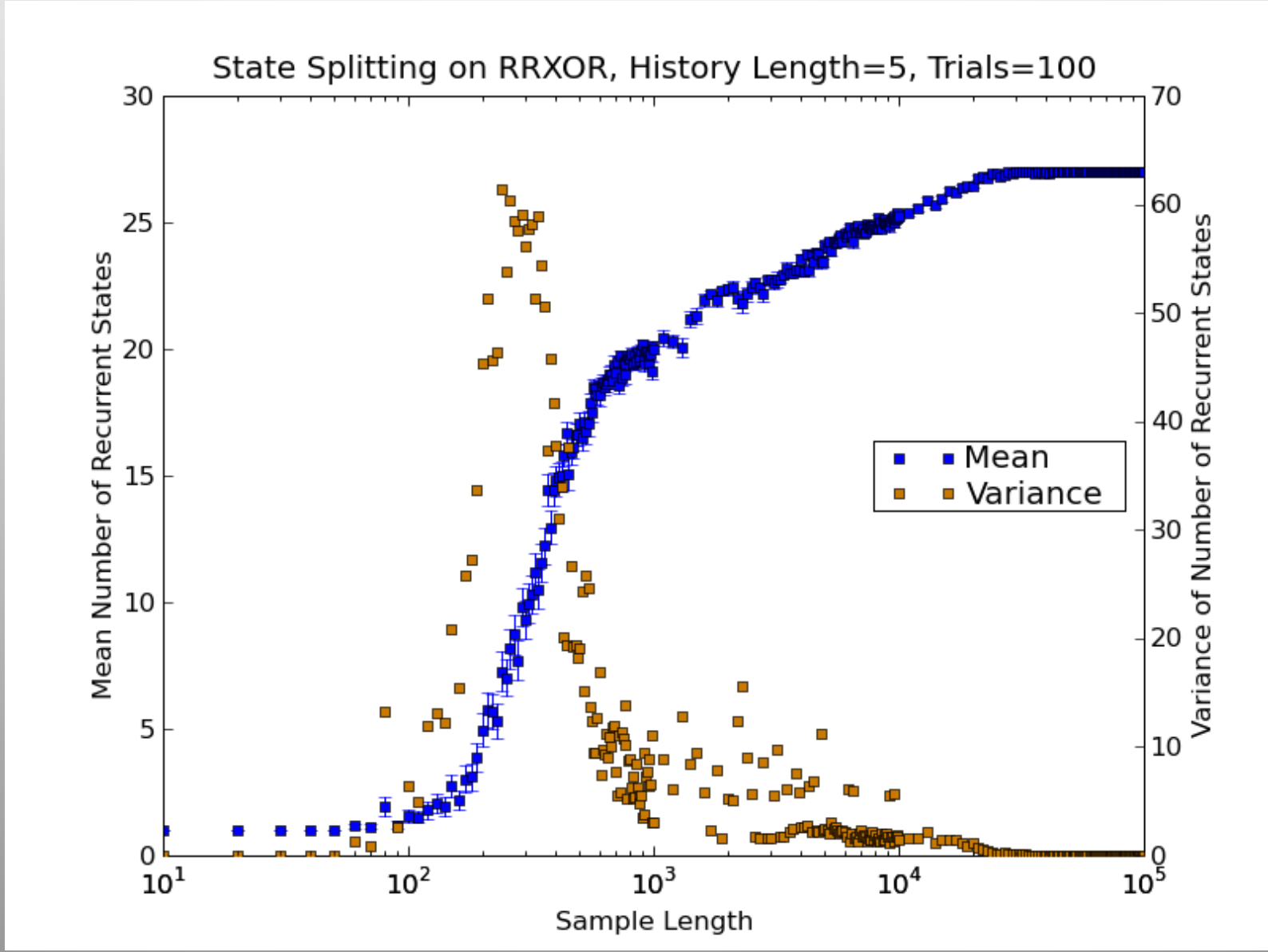
RRXOR: SS


1
1 | 0.50
0 | 0.50
5
1 | 0.50
0 | 0.50
4
6
7
0 | 0.50
1 | 0.33
0 | 0.34
1 | 0.50
2
0 | 0.67
0 | 0.67
1 | 0.66
1 | 0.67
1 | 0.33
3
0 | 0.33

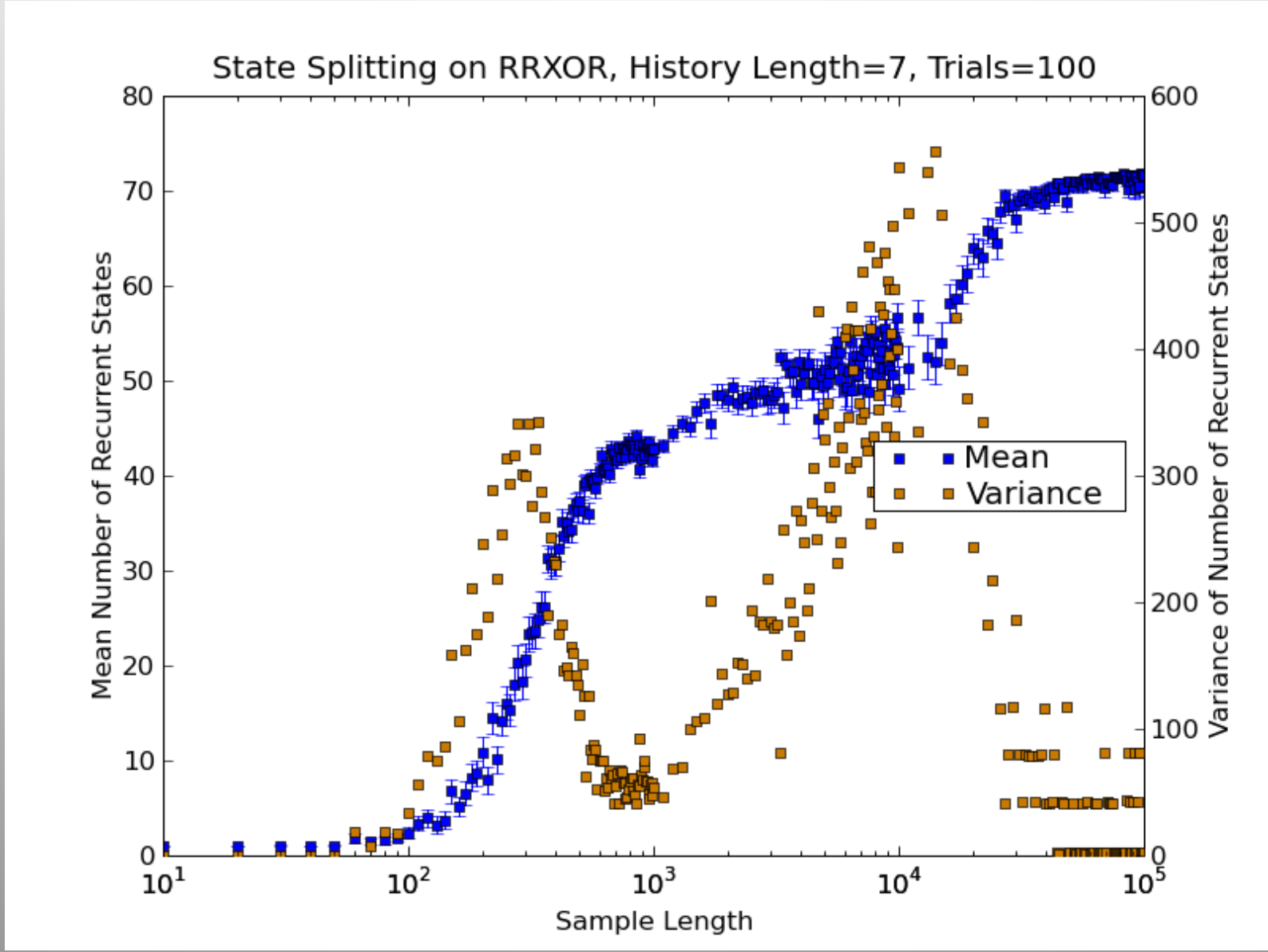
RRXOR - TM


0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
1 | 0.50
0 | 0.50
1 | 0.50
0 | 0.50
0 | 0.50
1 | 0.25
0 | 0.75
1 | 0.75
1 | 0.75
0 | 0.25
0 | 0.25
1 | 0.50
0 | 0.67
0 | 0.67
1 | 0.25
0 | 0.75
0 | 0.62
1 | 0.33
1 | 0.62
0 | 0.38
1 | 0.66
0 | 0.34
1 | 0.38
1 | 0.33
0 | 0.63
1 | 0.62
0 | 0.38
1 | 0.67
0 | 0.33
1 | 0.37

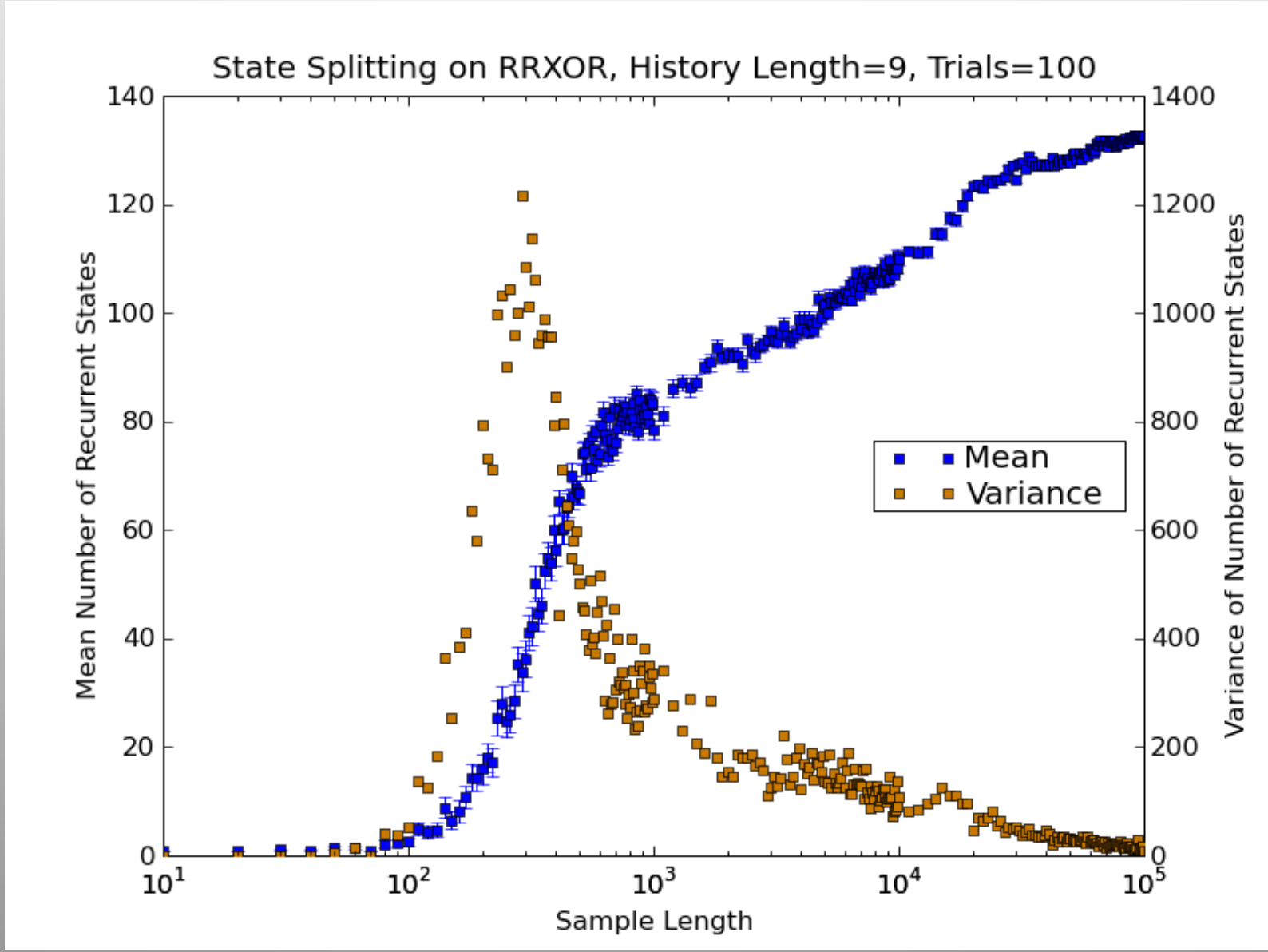
RRXOR – SS, HL=5


State Splitting on RRXOR, History Length=5, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
10^1
10^2
10^3
10^4
10^5

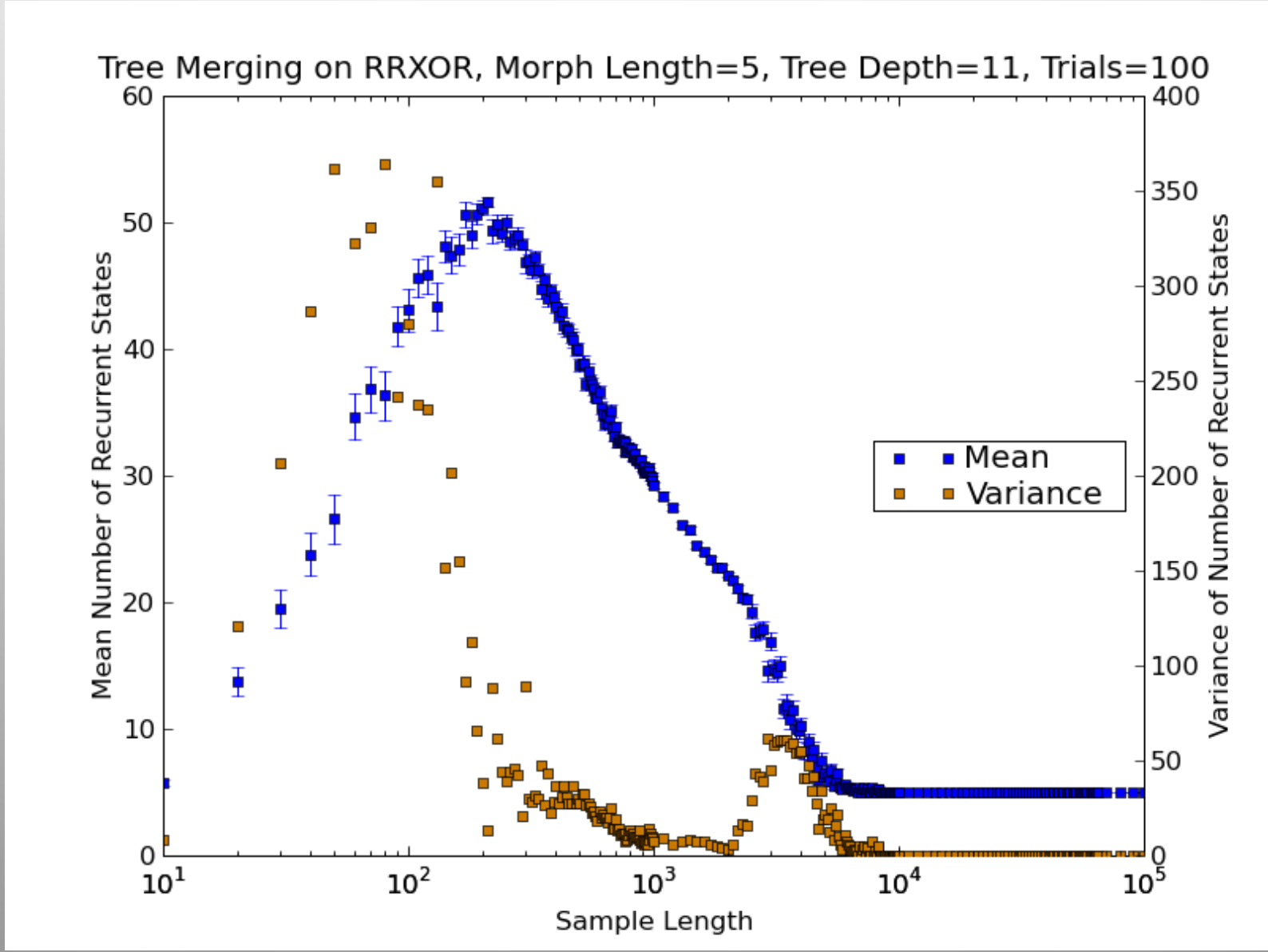
RRXOR – SS, HL=7


State Splitting on RRXOR, History Length=7, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
10^1
10^2
10^3
10^4
10^5

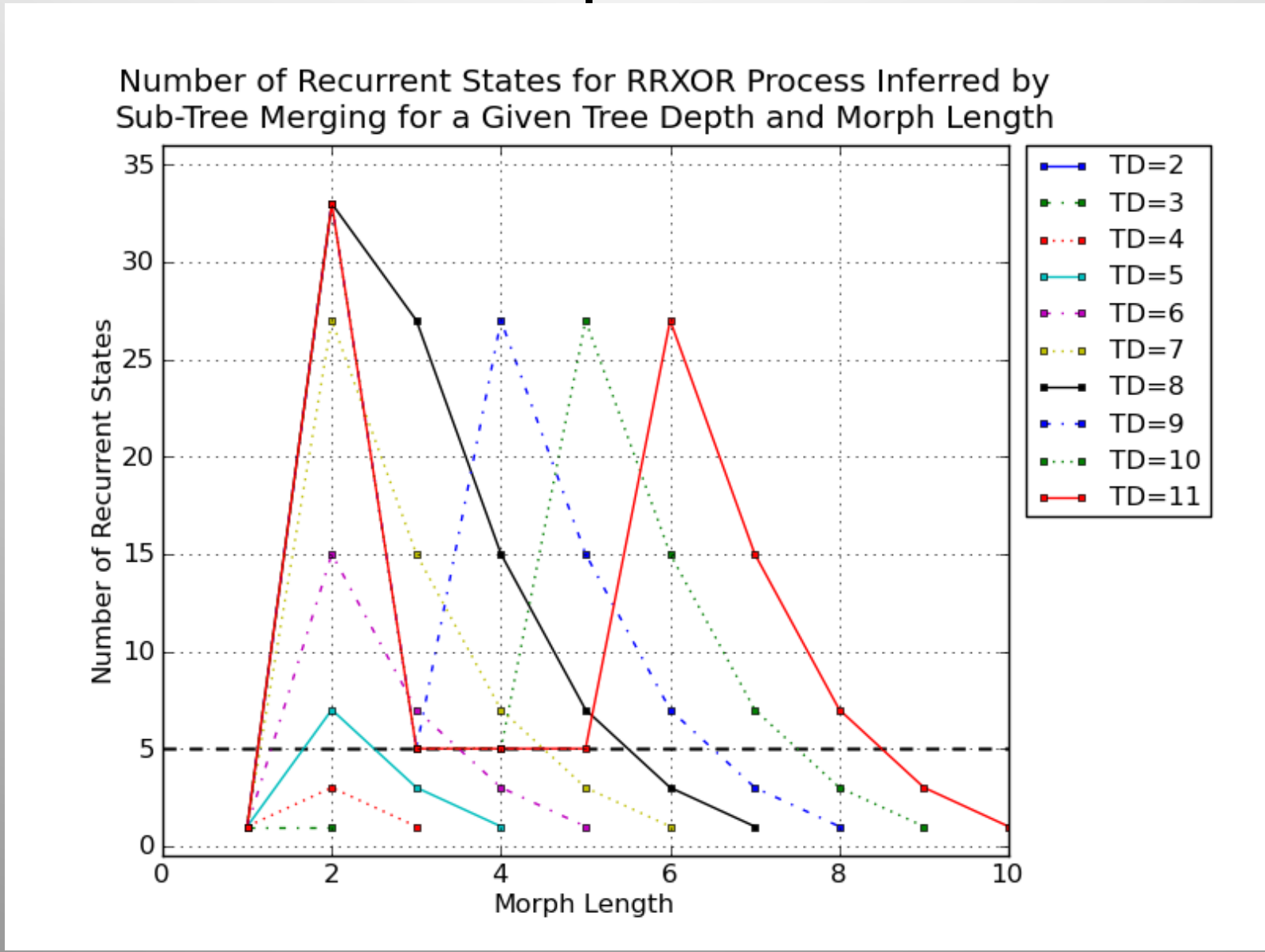
RRXOR – SS, HL=9


State Splitting on RRXOR, History Length=9, Trials=100
Mean Number of Recurrent States
Variance of Number of Recurrent States
Sample Length
Mean
Variance
0
20
40
60
80
100
120
140
0
200
400
600
800
1000
1200
1400
10^1
10^2
10^3
10^4
10^5

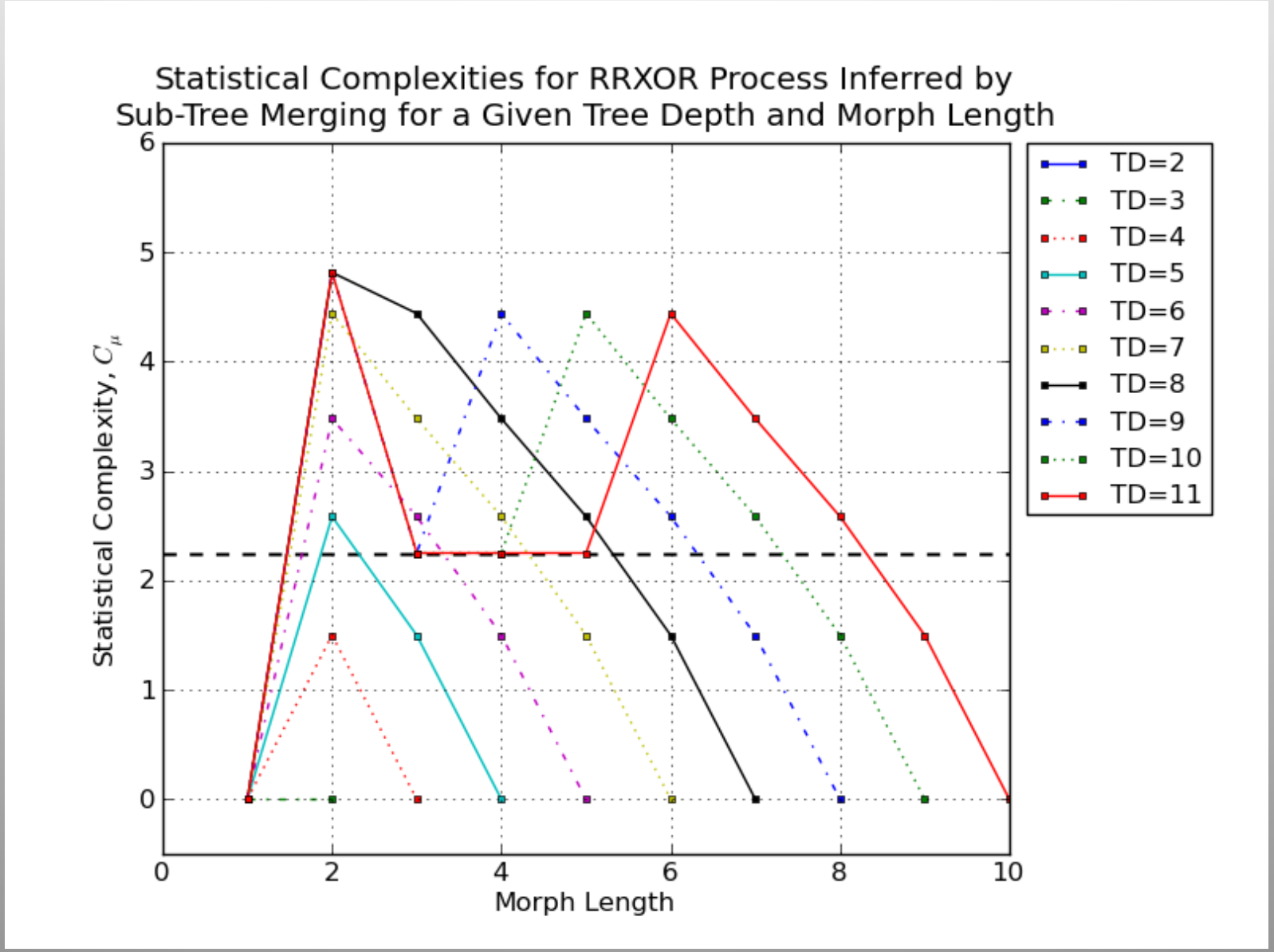
RRXOR – TM, ML=5, TD=11



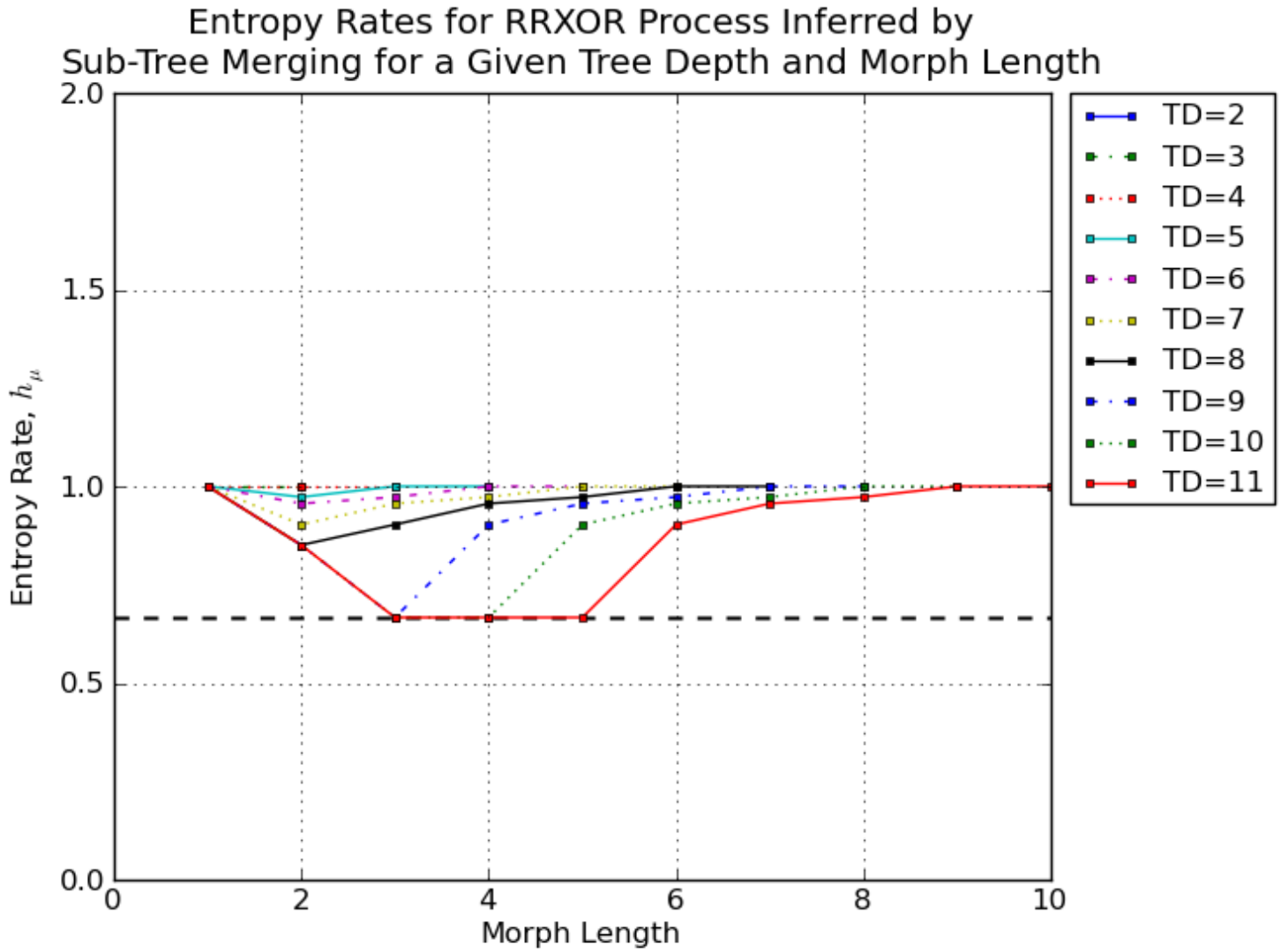
RRXOR – TM Sweep L: Recurrent States



RRXOR – TM Sweep L: C_μ



RRXOR – TM Sweep L: h_μ



TM: Balancing D & L

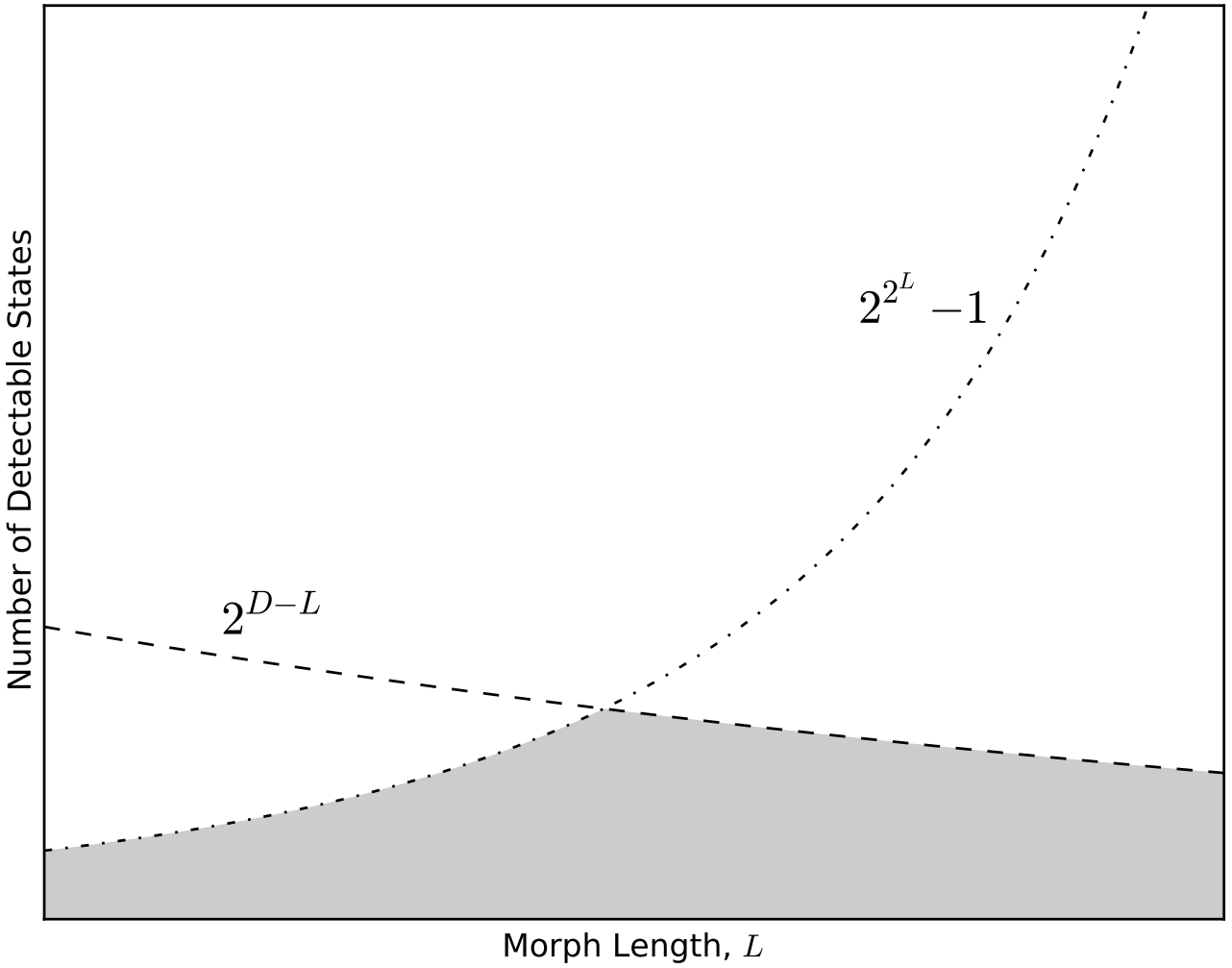
L determines how many (topologically) different morphs TM can detect:

$$2^{2^L} - 1$$

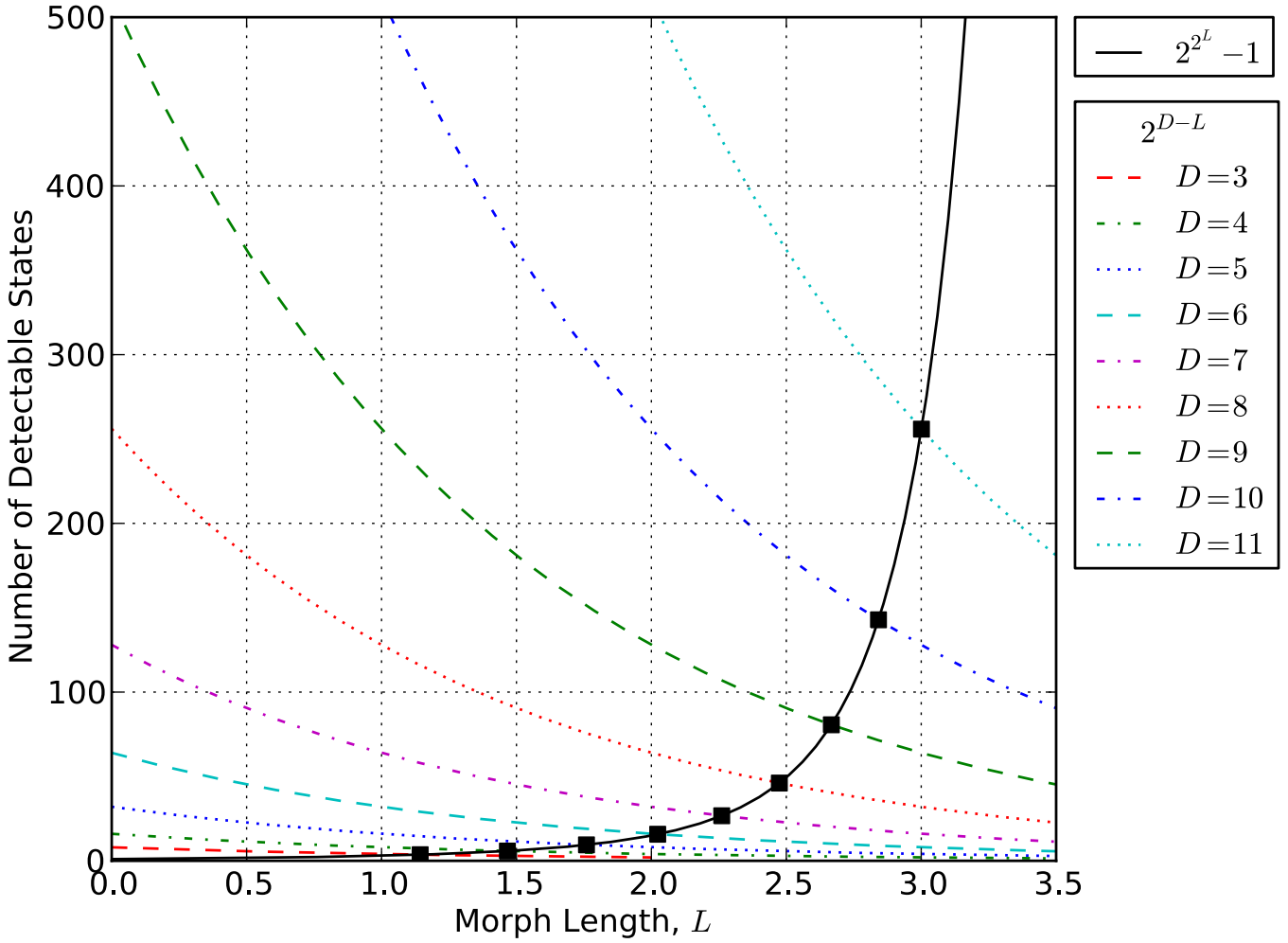
D and L together determine how many subtrees are accessible:

$$2^{D-L}$$

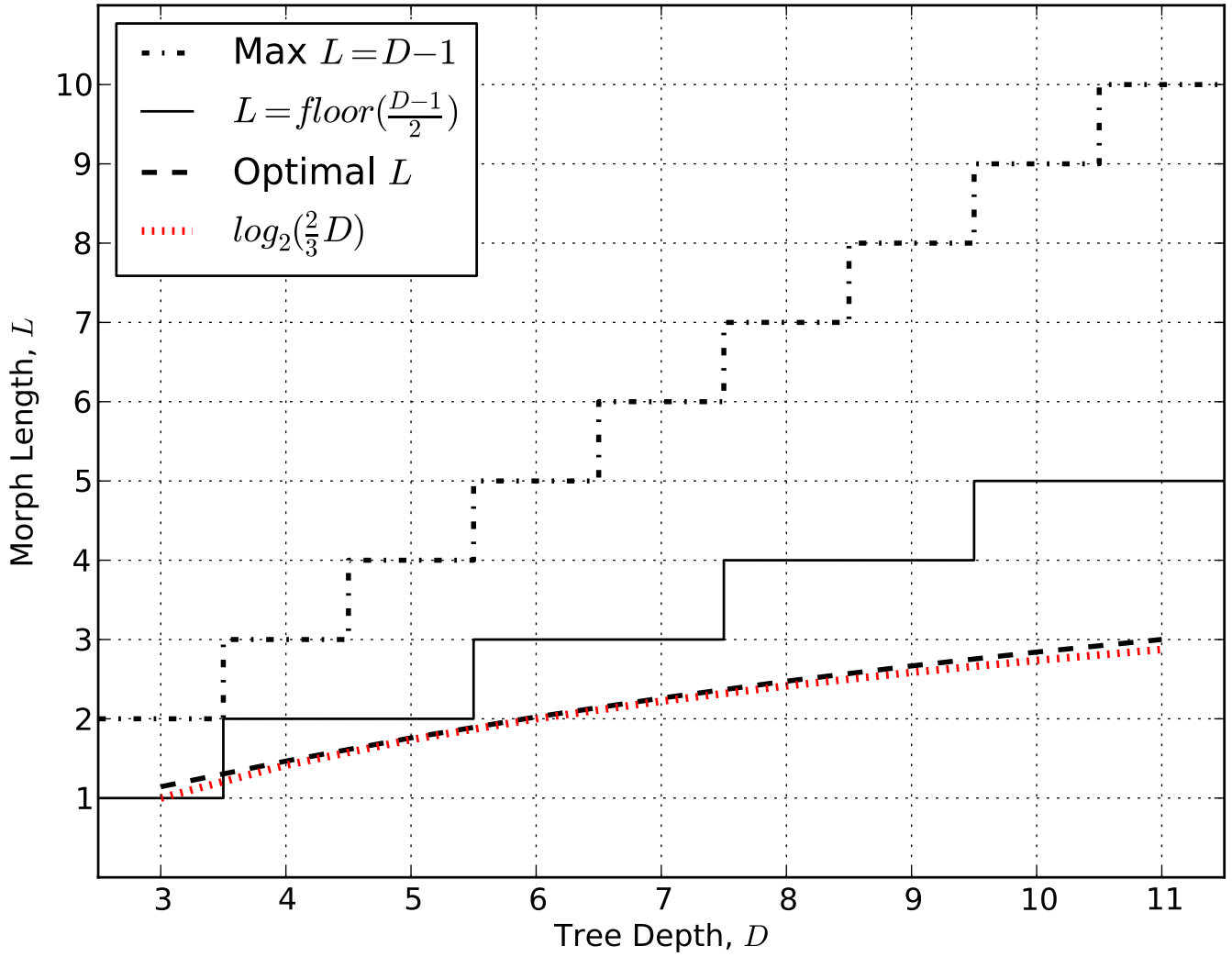
Detectable States



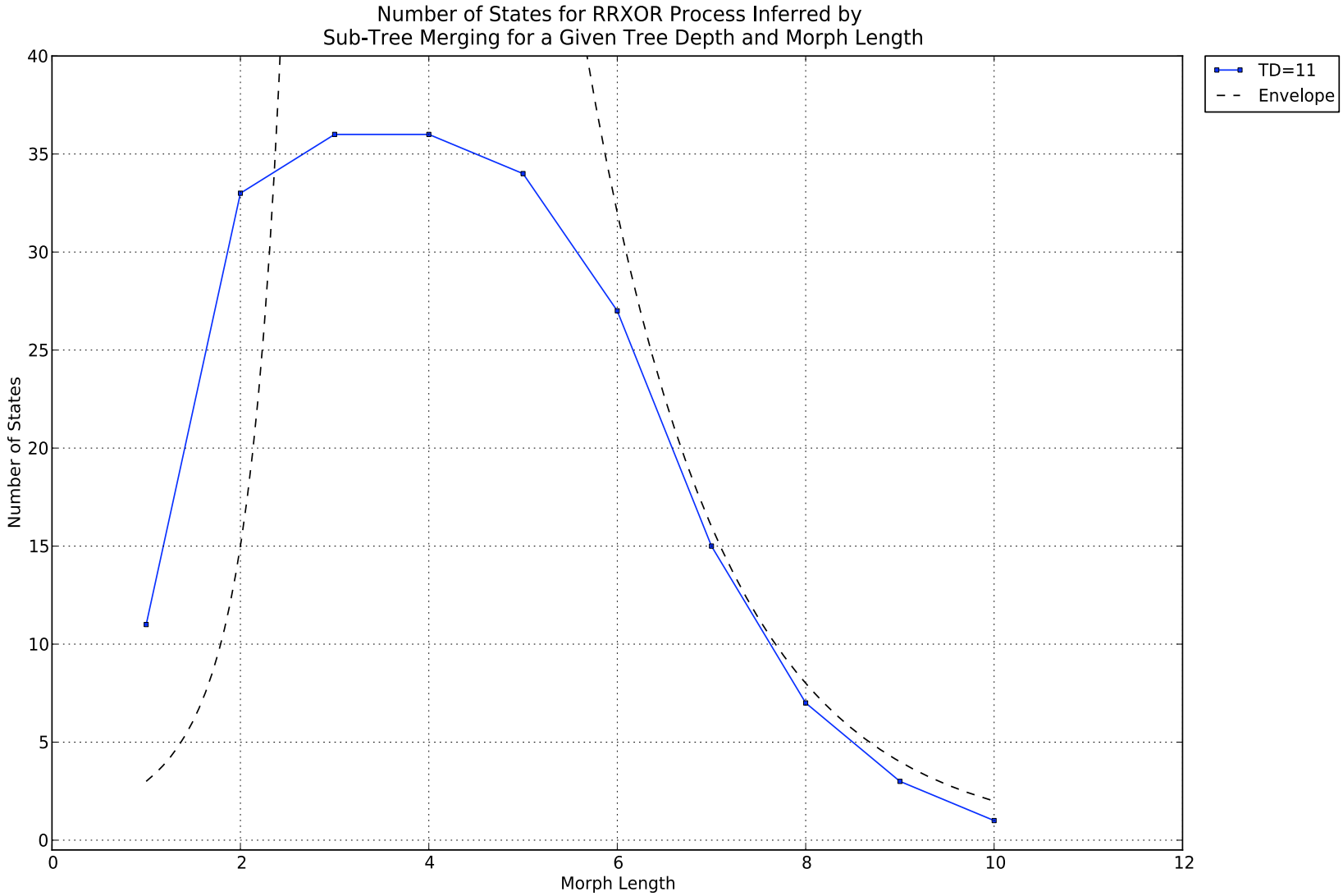
Detectable States for Various Tree Depths, D



Optimal Morph Length, L



Bounded Number of Inferred States



Conclusions & Future Work

- Inference is far from perfect, even for relatively simple processes: Plug-and-Play strongly discouraged
- Model “Glitches” may “spontaneously” occur
- Parameters can have a significant impact on performance, but higher values do not guarantee a correct model
- More comprehensive comparison between SS & TM
  - Which method works best for which cases?
- Why does SS have trouble with complex transient structures?
  - Is it actually the transients that trip it up?
- Can’t wait to see what it infers from real-world experiments
  - Very “sloppy” data… friction, imperfect turns, curved trajectories
  - Highly limited data sample length… may not be able to get 10^5 symbols