

How Close to Chemical Equilibrium?

Use Entropy

- Coarse-grain by polymer length, $\{N_L\}$.

- Given a macrostate $\{N_L\}$ the number of possible configurations is:

$$W = \prod_L^{L_{\max}} \frac{(N_L + 2^L - 1)!}{N_L!(2^L - 1)!}$$

- Entropy is defined as $S = k_B \text{Log } W$.
- Chemical Equilibrium is reached when entropy is maximized (S_{eq}), with the constraint that there are N total molecules.
- Simulate until steady state and consider it lifelike if the entropy is less than αS_{eq} .

1
00:00:09,740 --> 00:00:08,629
okay hello my name is a benin toy and

2
00:00:11,900 --> 00:00:09,750
today i would like to present the

3
00:00:14,060 --> 00:00:11,910
effects of a spatial diffusion on a

4
00:00:15,770 --> 00:00:14,070
model of people iike revolution worked

5
00:00:18,769 --> 00:00:15,780
i'm doing with my postdoctoral advisor

6
00:00:20,060 --> 00:00:18,779
professor Halle and collaborator iron

7
00:00:22,910 --> 00:00:20,070
wine being all at the university of

8
00:00:25,640 --> 00:00:22,920
minnesota-twin cities so some are quick

9
00:00:27,589 --> 00:00:25,650
motivation a protein first origin of

10
00:00:29,210 --> 00:00:27,599
life model can resolve against paradox

11
00:00:31,370 --> 00:00:29,220
which is the low probability of

12
00:00:33,440 --> 00:00:31,380
generating a randomly constructing a

13
00:00:35,330 --> 00:00:33,450

starter naked gene and we assume an

14

00:00:37,340 --> 00:00:35,340

initiative enters the formation of a

15

00:00:38,900 --> 00:00:37,350

network of interacting molecules assumed

16

00:00:41,420 --> 00:00:38,910

to be polymers but not necessarily

17

00:00:42,830 --> 00:00:41,430

proteins we have a no genome and we

18

00:00:45,440 --> 00:00:42,840

assume that it comes much later and

19

00:00:47,270 --> 00:00:45,450

unlike previous similar models we assume

20

00:00:49,670 --> 00:00:47,280

here that a necessary condition for a

21

00:00:51,590 --> 00:00:49,680

pre biochemical system is it is that it

22

00:00:55,549 --> 00:00:51,600

may be that it be a stationary state out

23

00:00:56,930 --> 00:00:55,559

of equilibrium so real quickly would

24

00:01:00,430 --> 00:00:56,940

like to go over a caufman like binary

25

00:01:02,900 --> 00:01:00,440

polymer model so my reactions are

26

00:01:04,759 --> 00:01:02,910

ligation and our ligation incision of

27

00:01:07,480 --> 00:01:04,769

binary polymers so here I have just an

28

00:01:10,789 --> 00:01:07,490

example reaction so $0 + 10 \rightarrow 10$

29

00:01:14,030 --> 00:01:10,799

catalyzed by polymer 11 gets ligated in

30

00:01:16,609 --> 00:01:14,040

$20 + 10 \rightarrow 10$ and then the opposite direction

31

00:01:18,230 --> 00:01:16,619

is a season and so to make our network

32

00:01:20,179 --> 00:01:18,240

give it a maximum polymer length value

33

00:01:22,670 --> 00:01:20,189

which we call L_{max} which is a parameter

34

00:01:24,590 --> 00:01:22,680

in era and our model we go through each

35

00:01:28,039 --> 00:01:24,600

possible reaction of the form $A + B$

36

00:01:29,630 --> 00:01:28,049

goes to A be catalyzed by C and included

37

00:01:31,940 --> 00:01:29,640

in the network with probability P which

38

00:01:33,560 --> 00:01:31,950

is another primary model and the

39

00:01:34,999 --> 00:01:33,570

chemical species in the network form an

40

00:01:37,539 --> 00:01:35,009

autocatalytic set which will be

41

00:01:41,450 --> 00:01:37,549

elaborated on in coal Matthyse's talk

42

00:01:43,249 --> 00:01:41,460

preceding mine and so for dynamics we

43

00:01:44,840 --> 00:01:43,259

come with our chemical network that we

44

00:01:46,130 --> 00:01:44,850

just made we combine it with reaction

45

00:01:48,469 --> 00:01:46,140

rates to generate an artificial

46

00:01:49,969 --> 00:01:48,479

chemistry then so classically simulate

47

00:01:52,940 --> 00:01:49,979

the following a master differential

48

00:01:55,370 --> 00:01:52,950

equation so NL is basically the number

49

00:01:58,219 --> 00:01:55,380

of polymers of species L and all these

50

00:02:00,260 --> 00:01:58,229

terms represent the reaction rate self

51

00:02:02,840 --> 00:02:00,270

in a ligation incision and the

52

00:02:04,639 --> 00:02:02,850

parameters in our model are p I max the

53

00:02:07,069 --> 00:02:04,649

number of food particles and the maximum

54

00:02:09,949 --> 00:02:07,079

number of particles that we can have in

55

00:02:12,130 --> 00:02:09,959

our system now i'd like to just give a

56

00:02:13,850 --> 00:02:12,140

brief general structure of what we did

57

00:02:16,010 --> 00:02:13,860

so for

58

00:02:18,950 --> 00:02:16,020

different p values we generate multiple

59

00:02:20,780 --> 00:02:18,960

networks typically 10,000 and that check

60

00:02:22,580 --> 00:02:20,790

if they're viable and all viable means

61

00:02:25,220 --> 00:02:22,590

is that it's possible to go from the

62

00:02:27,800 --> 00:02:25,230

food set all the way to a molecule

63

00:02:30,400 --> 00:02:27,810

amount of length I max given the

64

00:02:32,720 --> 00:02:30,410

reactions in the network and then we do

65

00:02:34,460 --> 00:02:32,730

then we do multiple dynamical

66

00:02:36,290 --> 00:02:34,470

simulations with the random with random

67

00:02:38,210 --> 00:02:36,300

dish with random initial conditions

68

00:02:39,830 --> 00:02:38,220

using a given by little Network combined

69

00:02:42,620 --> 00:02:39,840

with reaction rates until a steady state

70

00:02:45,110 --> 00:02:42,630

is reached so here you know these have

71

00:02:47,360 --> 00:02:45,120

them the viable networks labeled in blue

72

00:02:49,550 --> 00:02:47,370

and then the non viable my clitoris

73

00:02:50,900 --> 00:02:49,560

labeled in red and so for each viable

74

00:02:54,710 --> 00:02:50,910

network we didn't actually assist

75

00:02:58,100 --> 00:02:54,720

dynamic we do dynamic runs and depending

76

00:03:00,140 --> 00:02:58,110

on whether or not they're in a 0 and

77

00:03:01,760 --> 00:03:00,150

then we count basically after we run

78

00:03:03,080 --> 00:03:01,770

into steady stages reach we count the

79

00:03:04,130 --> 00:03:03,090

number of life like steady States by

80

00:03:05,840 --> 00:03:04,140

checking if the systems out of

81

00:03:08,060 --> 00:03:05,850

equilibrium so basically with these runs

82

00:03:10,040 --> 00:03:08,070

we just check if they're out of

83

00:03:11,600 --> 00:03:10,050

equilibrium or not and with this we now

84

00:03:13,100 --> 00:03:11,610

have a measurement for the public of a

85

00:03:16,790 --> 00:03:13,110

forming of life-like state for a given

86

00:03:18,620 --> 00:03:16,800

value of P so I would like to go over

87

00:03:20,930 --> 00:03:18,630

where Kaufman in our group differ

88

00:03:22,789 --> 00:03:20,940

someone Kaufman simulated these models

89

00:03:25,160 --> 00:03:22,799

he saw population growth with increasing

90

00:03:26,960 --> 00:03:25,170

p so here i have a little example or red

91

00:03:29,259 --> 00:03:26,970

is the population as a function of time

92

00:03:31,729 --> 00:03:29,269

simulation time we see that increases

93

00:03:33,259 --> 00:03:31,739

over the system might be growing but it

94

00:03:36,580 --> 00:03:33,269

might be chemical in chemical

95

00:03:39,110 --> 00:03:36,590

equilibrium so here I have these two

96

00:03:41,030 --> 00:03:39,120

runs with the same pic p value in

97

00:03:44,030 --> 00:03:41,040

artificial chemistry and also the same

98

00:03:45,680 --> 00:03:44,040

chemical network and this one although

99

00:03:48,050 --> 00:03:45,690

it's growing which is a chemical

100

00:03:49,370 --> 00:03:48,060

equilibrium and here in the green line I

101
00:03:52,610 --> 00:03:49,380
have a measure what we mean by a

102
00:03:54,530 --> 00:03:52,620
chemical equilibrium or one is where the

103
00:03:56,090 --> 00:03:54,540
system is chemical equilibrated in 0 as

104
00:03:58,039 --> 00:03:56,100
the system is not chemically

105
00:04:00,500 --> 00:03:58,049
equilibrated we see that this one

106
00:04:02,420 --> 00:04:00,510
reaches chemical equilibrium whereas

107
00:04:04,370 --> 00:04:02,430
this one grows to a maximum what stays

108
00:04:05,960 --> 00:04:04,380
out of a chemical equilibrium and is

109
00:04:08,000 --> 00:04:05,970
trapped in kinetically trapped in the

110
00:04:09,560 --> 00:04:08,010
nonequilibrium steady state which we

111
00:04:11,560 --> 00:04:09,570
postulate be a necessary condition for

112
00:04:13,640 --> 00:04:11,570
life and that this non-equilibrium

113
00:04:15,500 --> 00:04:13,650

constraint reduces the probability of

114

00:04:17,960 --> 00:04:15,510

life like systems at large p given the

115

00:04:20,360 --> 00:04:17,970

maxim giving a maximum value at a small

116

00:04:22,909 --> 00:04:20,370

value p so here i have a figure from a

117

00:04:23,610 --> 00:04:22,919

previously published paper where i have

118

00:04:35,570 --> 00:04:23,620

the

119

00:04:38,760 --> 00:04:35,580

value or p 0.005 so now I'd like to

120

00:04:40,500 --> 00:04:38,770

explain you know how do we how close the

121

00:04:43,620 --> 00:04:40,510

system is that chemical equilibrium we

122

00:04:46,620 --> 00:04:43,630

use a entropy so a core screen by Palmer

123

00:04:48,840 --> 00:04:46,630

length so NL basic NL is the number of

124

00:04:50,100 --> 00:04:48,850

followers of length l and we have a

125

00:04:52,439 --> 00:04:50,110

distribution of these for all the

126

00:04:54,540 --> 00:04:52,449

different lengths and i given maximum

127

00:04:56,969 --> 00:04:54,550

state the number of possible

128

00:04:59,310 --> 00:04:56,979

configurations is given as w given as

129

00:05:01,770 --> 00:04:59,320

this formula and we say the entropy is

130

00:05:04,560 --> 00:05:01,780

defined as s which is equal to $k_B \log W$

131

00:05:06,120 --> 00:05:04,570

and this is a thermodynamic more of a

132

00:05:08,010 --> 00:05:06,130

thermodynamic entropy rather than from

133

00:05:09,689 --> 00:05:08,020

information and should be we say

134

00:05:12,900 --> 00:05:09,699

chemical equilibrium is reached when any

135

00:05:14,580 --> 00:05:12,910

this entropy is maximized which we call

136

00:05:16,980 --> 00:05:14,590

seq with the constraint that there in

137

00:05:18,659 --> 00:05:16,990

total molecules of the system and we

138

00:05:20,460 --> 00:05:18,669

simulate until steady state and

139

00:05:23,219 --> 00:05:20,470

concerted life like if the entropy is

140

00:05:24,540 --> 00:05:23,229

less than alpha times seq where alpha is

141

00:05:29,279 --> 00:05:24,550

a parameter in our model that's between

142

00:05:31,469 --> 00:05:29,289

0 and 1 so now like to go into why we

143

00:05:33,570 --> 00:05:31,479

want to extend this to diffusion through

144

00:05:35,400 --> 00:05:33,580

space and motivations so wondering how

145

00:05:37,560 --> 00:05:35,410

my spatial structure effect prebiotic

146

00:05:39,300 --> 00:05:37,570

evolution and so from force of

147

00:05:40,589 --> 00:05:39,310

motivations wondering if the non

148

00:05:42,510 --> 00:05:40,599

equilibrium states of the model without

149

00:05:44,219 --> 00:05:42,520

diffusion survive interaction with the

150

00:05:46,430 --> 00:05:44,229

environment through diffusion so this

151
00:05:48,839 --> 00:05:46,440
gets into the cup arm

152
00:05:51,089 --> 00:05:48,849
compartmentalization that the test was

153
00:05:52,529 --> 00:05:51,099
going over earlier and we're also

154
00:05:53,790 --> 00:05:52,539
wondering if their collective effects

155
00:05:55,620 --> 00:05:53,800
which might suggest the beginnings of

156
00:05:59,730 --> 00:05:55,630
multicellularity so this sort of goes

157
00:06:02,040 --> 00:05:59,740
into complexity so now I'd like to go

158
00:06:04,560 --> 00:06:02,050
over our Spacely extended model we study

159
00:06:06,870 --> 00:06:04,570
64 sites arranged as an eight-by-eight

160
00:06:08,640 --> 00:06:06,880
to the periodic lattice and you have a

161
00:06:11,730 --> 00:06:08,650
little sketch where these squares

162
00:06:13,890 --> 00:06:11,740
represent sites and insight an inside

163
00:06:16,110 --> 00:06:13,900

each site there's the same our official

164

00:06:18,420 --> 00:06:16,120

chemistry and our molecules are allowed

165

00:06:20,730 --> 00:06:18,430

to diffuse from site to site at a at a

166

00:06:22,650 --> 00:06:20,740

rate parameterize by ADA and due to

167

00:06:25,710 --> 00:06:22,660

computational limitations we sell it we

168

00:06:27,779 --> 00:06:25,720

set a l max equal to 6 so now that we

169

00:06:29,969 --> 00:06:27,789

have a space under model not only can be

170

00:06:31,890 --> 00:06:29,979

chemically equilibrating diffuse if you

171

00:06:35,820 --> 00:06:31,900

leak will rate so i just wanted to go

172

00:06:37,260 --> 00:06:35,830

over how we can parse out the system to

173

00:06:39,540 --> 00:06:37,270

be partially and completely

174

00:06:42,540 --> 00:06:39,550

equilibria so now that we have space in

175

00:06:44,820 --> 00:06:42,550

the model or a purple our polymer length

176

00:06:47,340 --> 00:06:44,830

distribution also depends on a space

177

00:06:49,920 --> 00:06:47,350

which we call and we call it and we call

178

00:06:53,970 --> 00:06:49,930

we label that point P in this macro

179

00:06:56,910 --> 00:06:53,980

macro state space with them with the 384

180

00:06:58,860 --> 00:06:56,920

dimensions and like i said before can be

181

00:07:00,420 --> 00:06:58,870

diffusible equilibrated which we call

182

00:07:02,760 --> 00:07:00,430

the diffusive lee did and locally live

183

00:07:04,980 --> 00:07:02,770

that just means all the particles of

184

00:07:06,600 --> 00:07:04,990

length L are evenly distributed across

185

00:07:09,330 --> 00:07:06,610

lettuce and has a different distribution

186

00:07:11,970 --> 00:07:09,340

is so and we label at PD on this macro

187

00:07:13,770 --> 00:07:11,980

space and the system can also be

188

00:07:15,840 --> 00:07:13,780

chemically equilibrated at each site

189

00:07:19,380 --> 00:07:15,850

which we call diffusive lee live locally

190

00:07:22,230 --> 00:07:19,390

dead and that just we label that as pc

191

00:07:24,510 --> 00:07:22,240

on this macro space the system could

192

00:07:26,880 --> 00:07:24,520

also be chemically and diffusive lee

193

00:07:29,940 --> 00:07:26,890

equilibrated and which we call total

194

00:07:31,830 --> 00:07:29,950

equilibrated and we just called dead and

195

00:07:34,230 --> 00:07:31,840

if it is not diffusive lee or chemically

196

00:07:36,600 --> 00:07:34,240

collaborated we call it the diffusive

197

00:07:39,300 --> 00:07:36,610

lee live in locally life and so how to

198

00:07:42,150 --> 00:07:39,310

how the check how far the system is away

199

00:07:44,310 --> 00:07:42,160

from these different partial equilibria

200

00:07:47,100 --> 00:07:44,320

we basically take the Euclidean distance

201
00:07:49,410 --> 00:07:47,110
between the distributions so we have the

202
00:07:50,970 --> 00:07:49,420
distributions of the system point and

203
00:07:53,090 --> 00:07:50,980
the what it should be if it's partially

204
00:07:56,220 --> 00:07:53,100
that in this case partially the

205
00:07:57,450 --> 00:07:56,230
partially diffusely equilibrated and we

206
00:08:01,140 --> 00:07:57,460
just basically take your Clayton

207
00:08:02,940 --> 00:08:01,150
distance we call that rd the distance

208
00:08:04,710 --> 00:08:02,950
between the system point and the point

209
00:08:06,330 --> 00:08:04,720
out which is diffusive lee equilibrated

210
00:08:08,640 --> 00:08:06,340
in our see the distance between the

211
00:08:12,720 --> 00:08:08,650
system point and the point on which it's

212
00:08:14,010 --> 00:08:12,730
chemically calibrated at each site so

213
00:08:15,630 --> 00:08:14,020

now i just want to show an example of

214

00:08:17,370 --> 00:08:15,640

results for these two distances in a

215

00:08:21,030 --> 00:08:17,380

simulated non-equilibrium steady States

216

00:08:24,900 --> 00:08:21,040

so here's a really to look at this so

217

00:08:27,630 --> 00:08:24,910

this is a scatterplot with to about

218

00:08:30,450 --> 00:08:27,640

20,000 runs or the color of the point

219

00:08:32,340 --> 00:08:30,460

denotes the HP ratio and and note that

220

00:08:35,220 --> 00:08:32,350

we already require that the entry ratio

221

00:08:37,020 --> 00:08:35,230

to be less than 0.6 and these to

222

00:08:39,510 --> 00:08:37,030

normalize distances that I defined

223

00:08:43,830 --> 00:08:39,520

earlier so now with the scatter plot we

224

00:08:45,390 --> 00:08:43,840

can start labeling these steady states

225

00:08:47,010 --> 00:08:45,400

depending on how far they are from

226

00:08:50,260 --> 00:08:47,020

either being diffusive Lee or chemically

227

00:08:52,600 --> 00:08:50,270

equilibrated so if the system is

228

00:08:54,340 --> 00:08:52,610

diffusive Lee equilibrated so it's close

229

00:08:56,380 --> 00:08:54,350

to this too it's a diffusive

230

00:08:57,940 --> 00:08:56,390

equilibrated point of far away from its

231

00:09:00,550 --> 00:08:57,950

chemical equilibrated point we call it

232

00:09:02,470 --> 00:09:00,560

diffusely dead locally alive so the

233

00:09:05,170 --> 00:09:02,480

points in here are considered dee dee la

234

00:09:06,760 --> 00:09:05,180

if it is system is chemically

235

00:09:08,560 --> 00:09:06,770

collaborated but far away from its

236

00:09:11,170 --> 00:09:08,570

diffusive the equilibrated point we call

237

00:09:13,120 --> 00:09:11,180

the system diffusely a live locally did

238

00:09:15,940 --> 00:09:13,130

and in which in which you will encompass

239

00:09:18,160 --> 00:09:15,950

all the points in this compartment and

240

00:09:19,300 --> 00:09:18,170

then if the system is both far away from

241

00:09:20,890 --> 00:09:19,310

being chemically Enda feasibly

242

00:09:23,230 --> 00:09:20,900

equilibrated we say it's the fuse of the

243

00:09:26,470 --> 00:09:23,240

alive and locally alive and it will end

244

00:09:28,540 --> 00:09:26,480

would be all the points in this part now

245

00:09:30,670 --> 00:09:28,550

with this we can start forming

246

00:09:31,990 --> 00:09:30,680

probabilities so here i have the

247

00:09:34,660 --> 00:09:32,000

probabilities of forming these three

248

00:09:38,140 --> 00:09:34,670

states which are the high taxes on all

249

00:09:41,050 --> 00:09:38,150

these plots as a function of P data so p

250

00:09:43,330 --> 00:09:41,060

is that width axis and the ada is the

251
00:09:44,830 --> 00:09:43,340
depth axis on all these plots and some

252
00:09:47,890 --> 00:09:44,840
things the note is the probability of

253
00:09:49,960 --> 00:09:47,900
finding these da LD tald states is

254
00:09:53,140 --> 00:09:49,970
fairly low compared to the others and

255
00:09:55,240 --> 00:09:53,150
that we get the similar results with the

256
00:09:56,950 --> 00:09:55,250
single site model for the DD la states

257
00:09:58,720 --> 00:09:56,960
or starting from p equal to 0 and

258
00:10:00,340 --> 00:09:58,730
increasing key we see that the

259
00:10:03,070 --> 00:10:00,350
probability formula flights state goes

260
00:10:05,440 --> 00:10:03,080
up and comes back down well that's not

261
00:10:07,980 --> 00:10:05,450
the case when we look at these diffusely

262
00:10:10,060 --> 00:10:07,990
and locally alive states or the

263
00:10:12,550 --> 00:10:10,070

probability formula lifelike state seems

264

00:10:14,980 --> 00:10:12,560

to taper off even at the seams that

265

00:10:17,680 --> 00:10:14,990

there seems to be still life like states

266

00:10:20,320 --> 00:10:17,690

even at a high p value so looking at

267

00:10:23,170 --> 00:10:20,330

these states we see that they display

268

00:10:26,290 --> 00:10:23,180

these cancer like explosions so here i

269

00:10:27,880 --> 00:10:26,300

have the entropy ratio as a then this is

270

00:10:30,790 --> 00:10:27,890

for a single run i have the entropy

271

00:10:32,740 --> 00:10:30,800

ratio as a function of time and we see

272

00:10:34,510 --> 00:10:32,750

that in the it starts off in some metal

273

00:10:36,520 --> 00:10:34,520

stable state where we don't consider it

274

00:10:39,510 --> 00:10:36,530

live because it's HP ratio is greater

275

00:10:42,190 --> 00:10:39,520

than 0.6 but after some time and all sun

276
00:10:44,500 --> 00:10:42,200
the system goes down into another stable

277
00:10:46,360 --> 00:10:44,510
into another metastable state where it

278
00:10:50,050 --> 00:10:46,370
is now considered a life since it's it

279
00:10:51,520 --> 00:10:50,060
is its entropy ratios less than 0.6 so

280
00:10:53,230 --> 00:10:51,530
looking at a screen shot before and

281
00:10:55,270 --> 00:10:53,240
after this jump we see that before the

282
00:10:59,050 --> 00:10:55,280
jump that they're rough they're less

283
00:11:01,060 --> 00:10:59,060
than 100 non food particles per site but

284
00:11:03,010 --> 00:11:01,070
after the jump with it at this bread

285
00:11:05,920 --> 00:11:03,020
eggs we see that all of a sudden

286
00:11:09,930 --> 00:11:05,930
the number of food particles on one and

287
00:11:12,940 --> 00:11:09,940
one side goes up to 900 so this would be

288
00:11:14,380 --> 00:11:12,950

considered the pulley diffusely out of

289

00:11:18,130 --> 00:11:14,390

equilibrium since all the particles are

290

00:11:21,010 --> 00:11:18,140

mostly on one side and no pep this is

291

00:11:23,050 --> 00:11:21,020

for a very very low value for ADA so if

292

00:11:25,360 --> 00:11:23,060

we increase say that we see that we see

293

00:11:27,820 --> 00:11:25,370

in a collective effect where within were

294

00:11:32,740 --> 00:11:27,830

these this explosion spreads so here i

295

00:11:35,110 --> 00:11:32,750

have the same the ratio of the entropies

296

00:11:36,460 --> 00:11:35,120

as a function of time and we see like

297

00:11:38,950 --> 00:11:36,470

before it starts off in some type of

298

00:11:43,240 --> 00:11:38,960

metastable state and then right before

299

00:11:46,240 --> 00:11:43,250

this is a cliff it we see one side

300

00:11:47,770 --> 00:11:46,250

explode and then in that explosion will

301
00:11:49,720 --> 00:11:47,780
spread to other sites before it reaches

302
00:11:51,790 --> 00:11:49,730
a minimum and then we see the entropy

303
00:11:56,050 --> 00:11:51,800
ratio go up to one since the system is

304
00:11:58,450 --> 00:11:56,060
starting to be totally equilibrated so

305
00:12:00,730 --> 00:11:58,460
just serve some conclusions I've stated

306
00:12:02,860 --> 00:12:00,740
most of this before there were you know

307
00:12:04,930 --> 00:12:02,870
we started we kind of likelihood it as a

308
00:12:08,290 --> 00:12:04,940
function of PA de these lifelike States

309
00:12:11,070 --> 00:12:08,300
cataract characterized as da la da LD

310
00:12:13,540 --> 00:12:11,080
and DD LA and we see that these DD LA so

311
00:12:15,190 --> 00:12:13,550
you see that the dvla States closely

312
00:12:20,590 --> 00:12:15,200
reproduced the states in earlier single

313
00:12:23,440 --> 00:12:20,600

site model these da LD life likes states

314

00:12:25,180 --> 00:12:23,450

are rare the ala exhibit he's explosive

315

00:12:26,350 --> 00:12:25,190

like growth and then for some future

316

00:12:28,210 --> 00:12:26,360

work we'd like to explore some other

317

00:12:35,380 --> 00:12:28,220

forms of spatial I'm homogeneity which I

318

00:12:41,140 --> 00:12:35,390

have listed here thank you we have time

319

00:12:43,330 --> 00:12:41,150

for some questions hi very interesting

320

00:12:47,170 --> 00:12:43,340

talk I am wondering about the polymers

321

00:12:49,750 --> 00:12:47,180

which polymer stating are possible on

322

00:12:51,520 --> 00:12:49,760

earth like since you would it be well

323

00:12:53,260 --> 00:12:51,530

that's the thing we'd yeah we didn't

324

00:12:56,020 --> 00:12:53,270

have that much yeah because we wanted to

325

00:12:57,370 --> 00:12:56,030

be as abstract as possible so we didn't

326

00:12:59,350 --> 00:12:57,380

we didn't want to have any like

327

00:13:00,790 --> 00:12:59,360

terrestrial life like bias in our models

328

00:13:04,510 --> 00:13:00,800

so that's why we have a you know very

329

00:13:06,490 --> 00:13:04,520

simple simple model but we don't there

330

00:13:12,030 --> 00:13:06,500

are couple applications but I can't

331

00:13:17,139 --> 00:13:15,460

as a no to that question there are at

332

00:13:18,910 --> 00:13:17,149

least a couple laps where people have

333

00:13:20,650 --> 00:13:18,920

looked at these types of systems and RNA

334

00:13:26,500 --> 00:13:20,660

chemistry as well as like peptide

335

00:13:28,780 --> 00:13:26,510

chemistry so it's except the RNA I was

336

00:13:35,769 --> 00:13:28,790

wondering is there other possible

337

00:13:38,650 --> 00:13:35,779

palmer's any other question okay next we