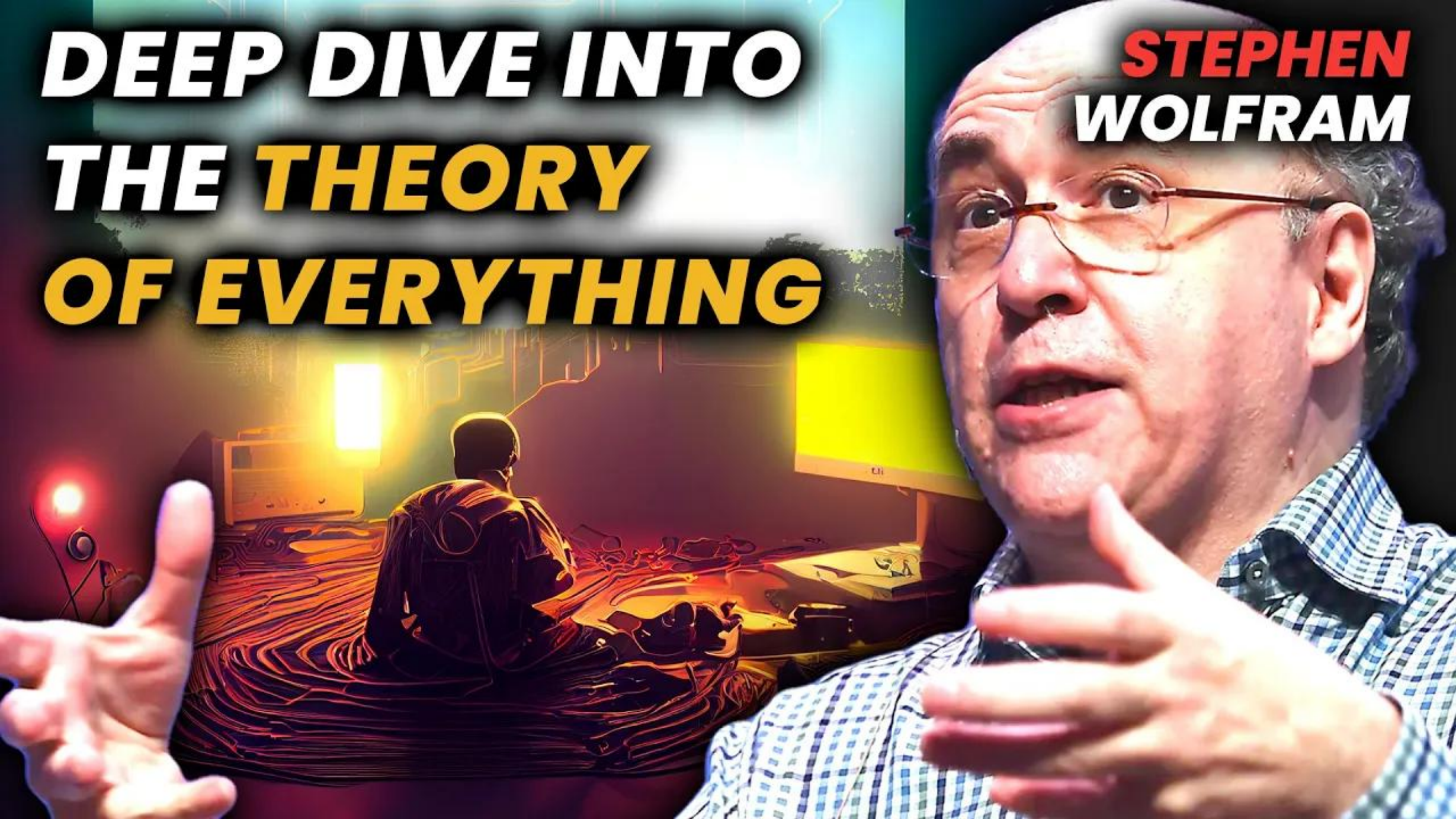


# DEEP DIVE INTO THE **THEORY** OF **EVERYTHING**

**STEPHEN  
WOLFRAM**



1  
00:00:03,590 --> 00:00:01,670  
stephen wolfram is one of the most

2  
00:00:05,590 --> 00:00:03,600  
inventive and prolific people on the

3  
00:00:06,710 --> 00:00:05,600  
planet he's the rare trifecta of a

4  
00:00:08,549 --> 00:00:06,720  
computer scientist

5  
00:00:09,990 --> 00:00:08,559  
a physicist and a business person who

6  
00:00:12,150 --> 00:00:10,000  
founded wolfram research

7  
00:00:13,430 --> 00:00:12,160  
designed mathematica which is a program

8  
00:00:16,150 --> 00:00:13,440  
that almost each

9  
00:00:17,910 --> 00:00:16,160  
mathematician physicist uses especially

10  
00:00:18,790 --> 00:00:17,920  
engineers as well as wolf from alpha

11  
00:00:21,029 --> 00:00:18,800  
which powers

12  
00:00:22,390 --> 00:00:21,039  
siri this may be the most wide-ranging

13  
00:00:24,710 --> 00:00:22,400

interview with steven

14

00:00:26,470 --> 00:00:24,720

that exists we talk about aliens or

15

00:00:26,950 --> 00:00:26,480

alien life and the communication with

16

00:00:29,029 --> 00:00:26,960

them

17

00:00:29,990 --> 00:00:29,039

cryptocurrency the nature of infinity

18

00:00:31,669 --> 00:00:30,000

and the reality to

19

00:00:33,270 --> 00:00:31,679

infinity he even gives a template as to

20

00:00:33,990 --> 00:00:33,280

how to build your own theory of

21

00:00:35,910 --> 00:00:34,000

everything which

22

00:00:37,430 --> 00:00:35,920

separates him from others because most

23

00:00:39,110 --> 00:00:37,440

of the time people are proposing

24

00:00:41,110 --> 00:00:39,120

their own theory of everything keep in

25

00:00:41,750 --> 00:00:41,120

mind that the podcasts on theories of

26

00:00:44,310 --> 00:00:41,760

everything

27

00:00:45,190 --> 00:00:44,320

tend to be a bit more abstruse and

28

00:00:47,110 --> 00:00:45,200

technical

29

00:00:49,029 --> 00:00:47,120

if you don't follow some of the jargon

30

00:00:50,229 --> 00:00:49,039

that's okay the point is that you stick

31

00:00:52,150 --> 00:00:50,239

through anyway till the end

32

00:00:53,750 --> 00:00:52,160

to get an overview and then it's in the

33

00:00:55,750 --> 00:00:53,760

re-watching that the actual

34

00:00:57,590 --> 00:00:55,760

information is gleaned this was a live

35

00:00:57,990 --> 00:00:57,600

stream which is now reposted with better

36

00:01:00,470 --> 00:00:58,000

video

37

00:01:01,990 --> 00:01:00,480

and audio and while i was live streaming

38

00:01:02,709 --> 00:01:02,000

at the end i gave some of my thoughts

39

00:01:04,549 --> 00:01:02,719

which i've

40

00:01:06,310 --> 00:01:04,559

included at the end of this as well they

41

00:01:07,990 --> 00:01:06,320

include objections that i may have or

42

00:01:09,270 --> 00:01:08,000

questions that i'd like you to explore

43

00:01:10,630 --> 00:01:09,280

and perhaps you can give me

44

00:01:12,230 --> 00:01:10,640

your thoughts your answers in the

45

00:01:13,830 --> 00:01:12,240

discord or leave them in the comments

46

00:01:14,630 --> 00:01:13,840

section below the sponsor of today's

47

00:01:17,270 --> 00:01:14,640

podcast is

48

00:01:19,030 --> 00:01:17,280

algo algo is an end-to-end supply chain

49

00:01:20,870 --> 00:01:19,040

optimization software company

50

00:01:22,789 --> 00:01:20,880

with software that helps business users

51

00:01:24,630 --> 00:01:22,799

optimize sales and operations

52

00:01:26,469 --> 00:01:24,640

planning to avoid stockouts reduce

53

00:01:29,109 --> 00:01:26,479

returns and inventory write downs

54

00:01:30,469 --> 00:01:29,119

while reducing inventory investment it's

55

00:01:33,109 --> 00:01:30,479

a supply chain ai

56

00:01:35,190 --> 00:01:33,119

that drives smart ioi headed by a bright

57

00:01:36,710 --> 00:01:35,200

individual by the name of amjad hussein

58

00:01:37,510 --> 00:01:36,720

another supporter of the podcast is

59

00:01:40,789 --> 00:01:37,520

brilliant

60

00:01:42,149 --> 00:01:40,799

t-o-e

61

00:01:44,069 --> 00:01:42,159

if you'd like twenty percent off their

62

00:01:45,030 --> 00:01:44,079

annual subscription and i'll be speaking

63

00:01:46,310 --> 00:01:45,040

more on that

64

00:01:47,830 --> 00:01:46,320

later if you'd like to hear more

65

00:01:48,950 --> 00:01:47,840

conversations like this then please do

66

00:01:52,710 --> 00:01:48,960

consider supporting

67

00:01:54,710 --> 00:01:52,720

at patreon.com i've also recently opened

68

00:01:55,510 --> 00:01:54,720

up a crypto account and a paypal account

69

00:01:57,190 --> 00:01:55,520

and if you like

70

00:01:59,270 --> 00:01:57,200

you can donate there i plan on having

71

00:02:01,429 --> 00:01:59,280

many more conversations like this

72

00:02:03,670 --> 00:02:01,439

at the end of august there's going to be

73

00:02:05,429 --> 00:02:03,680

yoshibak and donald hoffman coming up

74

00:02:07,590 --> 00:02:05,439

at the end of this month i'm speaking to

75

00:02:09,350 --> 00:02:07,600

chris langan he's the person who has

76

00:02:11,190 --> 00:02:09,360  
reportedly the highest iq

77

00:02:12,390 --> 00:02:11,200  
in america and has a theory of

78

00:02:14,150 --> 00:02:12,400  
everything called the cognitive

79

00:02:16,150 --> 00:02:14,160  
theoretic model of the universe

80

00:02:17,190 --> 00:02:16,160  
there's also a discord with the link in

81

00:02:19,030 --> 00:02:17,200  
the description

82

00:02:21,110 --> 00:02:19,040  
if you'd like to discuss the topics in

83

00:02:22,790 --> 00:02:21,120  
this podcast or other podcast in real

84

00:02:24,630 --> 00:02:22,800  
time to chat with other people who are

85

00:02:26,710 --> 00:02:24,640  
like yourself thank you so much

86

00:02:28,550 --> 00:02:26,720  
and enjoy cure i like your colored

87

00:02:33,430 --> 00:02:28,560  
background that's very stylish

88

00:02:36,550 --> 00:02:35,990

so okay so tell me just for before we

89

00:02:38,470 --> 00:02:36,560

before we get

90

00:02:39,910 --> 00:02:38,480

started here just give me a sense of who

91

00:02:41,750 --> 00:02:39,920

your viewers are

92

00:02:43,830 --> 00:02:41,760

sure sure they're generally

93

00:02:46,070 --> 00:02:43,840

mathematicians and physicists as well as

94

00:02:47,030 --> 00:02:46,080

amateur mathematicians and physicists

95

00:02:48,550 --> 00:02:47,040

people who are interested in

96

00:02:50,470 --> 00:02:48,560

consciousness as well so we'll talk a

97

00:02:51,910 --> 00:02:50,480

bit about consciousness okay

98

00:02:53,990 --> 00:02:51,920

so how long have you been doing this

99

00:02:55,350 --> 00:02:54,000

podcast i've been doing it for almost a

100

00:02:57,509 --> 00:02:55,360

year and i'm surprised that

101  
00:02:59,270 --> 00:02:57,519  
i was super excited that it's growing

102  
00:03:01,910 --> 00:02:59,280  
the way it is

103  
00:03:03,190 --> 00:03:01,920  
and well just i just hope people

104  
00:03:04,309 --> 00:03:03,200  
continue to be interested in those

105  
00:03:06,390 --> 00:03:04,319  
intellectual things when they're not

106  
00:03:08,949 --> 00:03:06,400  
locked at home with a pandemic

107  
00:03:09,670 --> 00:03:08,959  
yeah that's right that's right if i look

108  
00:03:11,589 --> 00:03:09,680  
around

109  
00:03:13,350 --> 00:03:11,599  
it's i'm just focused on you i have

110  
00:03:14,550 --> 00:03:13,360  
notes here i'm when i think i always

111  
00:03:17,350 --> 00:03:14,560  
don't worry about it don't worry about

112  
00:03:20,070 --> 00:03:17,360  
it okay you won't distract me

113  
00:03:21,509 --> 00:03:20,080

great great great i think that the

114

00:03:24,070 --> 00:03:21,519

ingeniousness of

115

00:03:25,509 --> 00:03:24,080

steven a view of what you've done is

116

00:03:27,030 --> 00:03:25,519

difficult to overstate

117

00:03:30,830 --> 00:03:27,040

with regard to the tools you provided

118

00:03:32,949 --> 00:03:30,840

mathematicians and engineers

119

00:03:35,910 --> 00:03:32,959

physicists you've

120

00:03:36,949 --> 00:03:35,920

not only provided concrete computational

121

00:03:37,910 --> 00:03:36,959

tools but also

122

00:03:40,070 --> 00:03:37,920

i don't know if you've heard of this

123

00:03:41,670 --> 00:03:40,080

concept called psychotechnologies

124

00:03:43,190 --> 00:03:41,680

the language is a psychotechnology it's

125

00:03:44,830 --> 00:03:43,200

what changes the way that you

126

00:03:47,190 --> 00:03:44,840

communicate and think

127

00:03:48,710 --> 00:03:47,200

and it's a good time i haven't heard

128

00:03:49,509 --> 00:03:48,720

that term so that's an interesting

129

00:03:50,949 --> 00:03:49,519

though

130

00:03:53,030 --> 00:03:50,959

great sounds a little bit sinister

131

00:03:55,190 --> 00:03:53,040

though

132

00:03:56,789 --> 00:03:55,200

well i don't intend to be sinister it is

133

00:04:00,149 --> 00:03:56,799

important to give people

134

00:04:02,070 --> 00:04:00,159

frameworks to think within but uh uh

135

00:04:03,910 --> 00:04:02,080

yeah much of the critiques that i've

136

00:04:05,830 --> 00:04:03,920

read of yours are ad hominins they're

137

00:04:07,350 --> 00:04:05,840

not from people who have

138

00:04:09,190 --> 00:04:07,360

read your work and i find that

139

00:04:10,470 --> 00:04:09,200

frustrating because as i'm researching

140

00:04:13,509 --> 00:04:10,480

firstly just so you know i've gone

141

00:04:14,229 --> 00:04:13,519

through the jonathan gerrard archive

142

00:04:15,509 --> 00:04:14,239

papers

143

00:04:17,270 --> 00:04:15,519

almost each of them as well as your

144

00:04:19,110 --> 00:04:17,280

bulletins and it's so

145

00:04:20,629 --> 00:04:19,120

tricky at least i find it frustrating

146

00:04:22,150 --> 00:04:20,639

because people who are commenting on you

147

00:04:22,790 --> 00:04:22,160

are commenting at an extremely high

148

00:04:25,030 --> 00:04:22,800

level

149

00:04:26,469 --> 00:04:25,040

at what they perceive you're doing or

150

00:04:29,590 --> 00:04:26,479

what they perceive you think

151  
00:04:32,150 --> 00:04:29,600  
you're doing with what you're doing and

152  
00:04:32,790 --> 00:04:32,160  
i'm curious if you get frustrated as

153  
00:04:35,830 --> 00:04:32,800  
well

154  
00:04:37,830 --> 00:04:35,840  
one one feature of uh you know

155  
00:04:39,670 --> 00:04:37,840  
i do what i do because i'm interested in

156  
00:04:42,550 --> 00:04:39,680  
doing what i do so to speak

157  
00:04:43,030 --> 00:04:42,560  
i'm not really doing it because i'm you

158  
00:04:45,030 --> 00:04:43,040  
know

159  
00:04:46,870 --> 00:04:45,040  
trying to convince other people that

160  
00:04:47,909 --> 00:04:46,880  
what we're doing is incredibly clever or

161  
00:04:51,590 --> 00:04:47,919  
whatever

162  
00:04:54,230 --> 00:04:51,600  
and you know so the the the kind of

163  
00:04:55,510 --> 00:04:54,240

if i had spent my life kind of saying

164

00:04:56,870 --> 00:04:55,520

what do other people think about what

165

00:04:58,550 --> 00:04:56,880

i'm doing

166

00:05:00,710 --> 00:04:58,560

i wouldn't have done most of the things

167

00:05:03,990 --> 00:05:00,720

i've ever done and

168

00:05:04,550 --> 00:05:04,000

i think as a matter of fact the thing

169

00:05:07,590 --> 00:05:04,560

that's been

170

00:05:10,230 --> 00:05:07,600

actually a surprise to me is

171

00:05:12,230 --> 00:05:10,240

how very positive so many people

172

00:05:14,070 --> 00:05:12,240

particularly in the physics community

173

00:05:15,430 --> 00:05:14,080

are being about the project that we're

174

00:05:17,670 --> 00:05:15,440

doing you know

175

00:05:19,029 --> 00:05:17,680

it's a surprise partly because 20 years

176

00:05:21,189 --> 00:05:19,039

ago

177

00:05:22,950 --> 00:05:21,199

when i released my new kind of science

178

00:05:25,510 --> 00:05:22,960

book

179

00:05:27,110 --> 00:05:25,520

it's uh you know i'm enough of a student

180

00:05:28,310 --> 00:05:27,120

of the history of science that i kind of

181

00:05:29,510 --> 00:05:28,320

understand a little bit about what

182

00:05:31,029 --> 00:05:29,520

happens when

183

00:05:32,870 --> 00:05:31,039

when paradigm shifts when sort of

184

00:05:36,310 --> 00:05:32,880

changes of thinking occur

185

00:05:39,430 --> 00:05:36,320

and one is absolutely should expect

186

00:05:40,790 --> 00:05:39,440

that uh the the benign thing that

187

00:05:41,830 --> 00:05:40,800

happens is people just keep doing what

188

00:05:43,270 --> 00:05:41,840

they were doing before and they

189

00:05:44,550 --> 00:05:43,280

completely ignore whatever the new

190

00:05:46,469 --> 00:05:44,560

paradigm is

191

00:05:47,830 --> 00:05:46,479

the less benign thing is people get out

192

00:05:49,110 --> 00:05:47,840

their pitchforks

193

00:05:50,950 --> 00:05:49,120

and they say we don't want a new

194

00:05:52,550 --> 00:05:50,960

paradigm we're you know

195

00:05:54,870 --> 00:05:52,560

go away we just want to keep doing what

196

00:05:56,629 --> 00:05:54,880

we've been doing and what i found when

197

00:05:58,469 --> 00:05:56,639

when the new kind of science book came

198

00:06:00,710 --> 00:05:58,479

out 20 years ago

199

00:06:02,230 --> 00:06:00,720

in pretty much every field other than

200

00:06:03,749 --> 00:06:02,240

fundamental physics

201  
00:06:05,590 --> 00:06:03,759  
people were like oh this is kind of

202  
00:06:06,870 --> 00:06:05,600  
interesting you know we don't mind

203  
00:06:09,270 --> 00:06:06,880  
having a new paradigm we've

204  
00:06:11,029 --> 00:06:09,280  
you know we're they're uh or maybe they

205  
00:06:11,350 --> 00:06:11,039  
said we don't care but mostly they were

206  
00:06:13,990 --> 00:06:11,360  
most

207  
00:06:16,390 --> 00:06:14,000  
fields it was like this idea of using

208  
00:06:18,230 --> 00:06:16,400  
computation as a foundation for modeling

209  
00:06:19,510 --> 00:06:18,240  
this seems interesting this seems like

210  
00:06:23,510 --> 00:06:19,520  
something we should explore

211  
00:06:27,189 --> 00:06:23,520  
and they did the one place where that

212  
00:06:29,670 --> 00:06:27,199  
was um where it was a lot of pitchforks

213  
00:06:30,629 --> 00:06:29,680

um was a little strange to me because

214

00:06:32,870 --> 00:06:30,639

you know i

215

00:06:33,990 --> 00:06:32,880

used to be a professional theoretical

216

00:06:36,870 --> 00:06:34,000

physicist so to speak so

217

00:06:37,350 --> 00:06:36,880

i you know i i knew that crowd of people

218

00:06:39,029 --> 00:06:37,360

um

219

00:06:40,469 --> 00:06:39,039

and it was a bit surprising to me you

220

00:06:43,110 --> 00:06:40,479

know i i said to many of them

221

00:06:43,990 --> 00:06:43,120

i'm surprised you care why do you care

222

00:06:45,510 --> 00:06:44,000

so much

223

00:06:46,950 --> 00:06:45,520

and they were like because what you're

224

00:06:48,790 --> 00:06:46,960

doing is going to destroy all the stuff

225

00:06:49,830 --> 00:06:48,800

we've been doing and it's like i don't

226

00:06:51,670 --> 00:06:49,840

think so

227

00:06:53,350 --> 00:06:51,680

you know if we're doing something it's

228

00:06:54,629 --> 00:06:53,360

complementary to what's what's being

229

00:06:56,870 --> 00:06:54,639

done elsewhere

230

00:06:58,469 --> 00:06:56,880

not uh not something that at

231

00:07:02,309 --> 00:06:58,479

cross-purposes so okay

232

00:07:04,309 --> 00:07:02,319

so 20 years goes by and now uh

233

00:07:05,990 --> 00:07:04,319

for a whole variety of reasons not the

234

00:07:08,790 --> 00:07:06,000

least uh being uh

235

00:07:09,749 --> 00:07:08,800

jonathan gorad and and max piskanhofen

236

00:07:11,670 --> 00:07:09,759

and other people

237

00:07:13,510 --> 00:07:11,680

sort of saying yes we'll we'll help you

238

00:07:15,990 --> 00:07:13,520

actually push this thing forward

239

00:07:16,870 --> 00:07:16,000

um i get started on the project again

240

00:07:19,909 --> 00:07:16,880

two things

241

00:07:22,070 --> 00:07:19,919

surprised me first thing is that the new

242

00:07:26,230 --> 00:07:22,080

paradigm that that we've kind of

243

00:07:30,870 --> 00:07:26,240

built out is much more

244

00:07:33,510 --> 00:07:30,880

uh sort of much more

245

00:07:34,950 --> 00:07:33,520

not complementary but much more uh kind

246

00:07:36,309 --> 00:07:34,960

of supportive

247

00:07:37,990 --> 00:07:36,319

of a lot of existing mathematical

248

00:07:39,670 --> 00:07:38,000

physics than i had expected

249

00:07:41,909 --> 00:07:39,680

that's one thing that's an intellectual

250

00:07:44,629 --> 00:07:41,919

thing the biggest surprise is

251

00:07:46,390 --> 00:07:44,639

the sociological response has been

252

00:07:49,670 --> 00:07:46,400

basically positive

253

00:07:51,589 --> 00:07:49,680

um and uh you know it's it's not a

254

00:07:52,629 --> 00:07:51,599

trivial thing to introduce something

255

00:07:55,270 --> 00:07:52,639

which is sort of a

256

00:07:56,469 --> 00:07:55,280

a significant change of a bunch of ideas

257

00:07:58,629 --> 00:07:56,479

in a field

258

00:07:59,510 --> 00:07:58,639

and have people feel like yes that's a

259

00:08:01,589 --> 00:07:59,520

good thing it's

260

00:08:03,589 --> 00:08:01,599

it's uh it's something that people can

261

00:08:05,749 --> 00:08:03,599

get behind so i'm sure there's all kinds

262

00:08:08,309 --> 00:08:05,759

of coping about all kinds of things

263

00:08:08,869 --> 00:08:08,319

and i have to say i'm pretty pretty uh

264

00:08:13,029 --> 00:08:08,879

it's

265

00:08:15,589 --> 00:08:13,039

read it i don't know what's there

266

00:08:18,230 --> 00:08:15,599

i don't really care it's um you know i

267

00:08:21,350 --> 00:08:18,240

think one thing to realize about

268

00:08:23,510 --> 00:08:21,360

about my kind of activities

269

00:08:25,110 --> 00:08:23,520

is from my point of view one of the

270

00:08:27,909 --> 00:08:25,120

things that i get

271

00:08:29,830 --> 00:08:27,919

you know personally most fulfilled by is

272

00:08:30,550 --> 00:08:29,840

thinking that the things that i build

273

00:08:32,630 --> 00:08:30,560

whether they're

274

00:08:33,829 --> 00:08:32,640

practical technological tools whether

275

00:08:36,149 --> 00:08:33,839

they're ideas

276

00:08:37,750 --> 00:08:36,159

are things other people have fun with to

277

00:08:40,389 --> 00:08:37,760

me for whatever reason of you know

278

00:08:41,110 --> 00:08:40,399

personal peculiarity or whatever i like

279

00:08:43,750 --> 00:08:41,120

that that's

280

00:08:44,870 --> 00:08:43,760

like that's that's really nice i i like

281

00:08:48,470 --> 00:08:44,880

feeling that way

282

00:08:49,110 --> 00:08:48,480

i also recognize that you know any time

283

00:08:51,829 --> 00:08:49,120

one has

284

00:08:53,509 --> 00:08:51,839

a degree of visibility in the world one

285

00:08:55,430 --> 00:08:53,519

becomes kind of

286

00:08:57,430 --> 00:08:55,440

a thing that gets battered around by

287

00:08:59,190 --> 00:08:57,440

people of like look you know i can use

288

00:09:00,870 --> 00:08:59,200

this person as an example of this point

289

00:09:03,350 --> 00:09:00,880

that i'm making about this or

290

00:09:05,190 --> 00:09:03,360

you know look i i you know i need to

291

00:09:06,870 --> 00:09:05,200

hate this person because

292

00:09:08,550 --> 00:09:06,880

this and that and the other you know

293

00:09:09,990 --> 00:09:08,560

because it makes me look good for this

294

00:09:10,790 --> 00:09:10,000

group of people or whatever it is who

295

00:09:13,350 --> 00:09:10,800

knows what

296

00:09:14,550 --> 00:09:13,360

you know that's what you sign up for um

297

00:09:16,150 --> 00:09:14,560

if you're doing things that have

298

00:09:18,310 --> 00:09:16,160

visibility in the world

299

00:09:19,750 --> 00:09:18,320

and as far as i'm concerned you know

300

00:09:22,870 --> 00:09:19,760

it's it's uh

301  
00:09:24,949 --> 00:09:22,880  
insofar as i'm kind of the the mascot of

302  
00:09:25,670 --> 00:09:24,959  
or the anti-mascot for this or that

303  
00:09:27,350 --> 00:09:25,680  
thing

304  
00:09:29,190 --> 00:09:27,360  
it's like okay that's fine it has very

305  
00:09:32,550 --> 00:09:29,200  
little to do with me so to speak

306  
00:09:34,070 --> 00:09:32,560  
um so i would say that the thing that's

307  
00:09:37,829 --> 00:09:34,080  
been interesting is

308  
00:09:38,870 --> 00:09:37,839  
is uh uh you know

309  
00:09:41,590 --> 00:09:38,880  
there's been a lot there are a lot of

310  
00:09:43,590 --> 00:09:41,600  
fields now where there's a pretty good

311  
00:09:45,110 --> 00:09:43,600  
uh sort of back and forth connection

312  
00:09:46,790 --> 00:09:45,120  
between the things that we've been doing

313  
00:09:48,790 --> 00:09:46,800

with our physics project

314

00:09:49,990 --> 00:09:48,800

and the kinds of uh often quite

315

00:09:51,509 --> 00:09:50,000

sophisticated mathematical

316

00:09:53,509 --> 00:09:51,519

physics that people have been developing

317

00:09:54,790 --> 00:09:53,519

in those areas and as far as i'm

318

00:09:56,310 --> 00:09:54,800

concerned that's

319

00:09:57,910 --> 00:09:56,320

that's really cool i mean it's really

320

00:10:00,310 --> 00:09:57,920

nice it's i i really

321

00:10:02,069 --> 00:10:00,320

excited that people in these fields

322

00:10:03,670 --> 00:10:02,079

sometimes their fields which have been

323

00:10:05,269 --> 00:10:03,680

a little bit marooned because they've

324

00:10:07,110 --> 00:10:05,279

been or a little bit sort of

325

00:10:08,069 --> 00:10:07,120

adrift because they're fields where

326

00:10:09,430 --> 00:10:08,079

there's a lot of interesting

327

00:10:10,550 --> 00:10:09,440

mathematical structure

328

00:10:13,509 --> 00:10:10,560

but they don't really know how it

329

00:10:14,710 --> 00:10:13,519

connects to the real world so to speak

330

00:10:16,150 --> 00:10:14,720

and now we're giving them a way to

331

00:10:17,350 --> 00:10:16,160

connect and often and giving them a way

332

00:10:18,870 --> 00:10:17,360

to understand

333

00:10:20,630 --> 00:10:18,880

why their mathematical structure is more

334

00:10:23,750 --> 00:10:20,640

natural than they thought and so on

335

00:10:24,870 --> 00:10:23,760

and i think for me personally the uh the

336

00:10:26,870 --> 00:10:24,880

fact that

337

00:10:28,710 --> 00:10:26,880

people in those fields are excited about

338

00:10:29,350 --> 00:10:28,720

this that's really cool i really like

339

00:10:31,829 --> 00:10:29,360

that

340

00:10:33,190 --> 00:10:31,839

um so but perhaps i didn't since i

341

00:10:34,790 --> 00:10:33,200

didn't hear all the words of the

342

00:10:36,310 --> 00:10:34,800

question you asked maybe i wasn't

343

00:10:38,389 --> 00:10:36,320

answering them i'm not used to this

344

00:10:40,150 --> 00:10:38,399

particular recording mechanism so

345

00:10:41,670 --> 00:10:40,160

uh that can't be absolutely certain but

346

00:10:42,949 --> 00:10:41,680

it looks right

347

00:10:45,350 --> 00:10:42,959

why don't you give a three-minute

348

00:10:47,430 --> 00:10:45,360

synopsis i know that's difficult

349

00:10:49,750 --> 00:10:47,440

as to your theory for those who are

350

00:10:52,710 --> 00:10:49,760

unacquainted

351

00:10:54,630 --> 00:10:52,720

well gosh so i've been working on this

352

00:10:56,069 --> 00:10:54,640

for like 40 years so it's a little bit

353

00:10:58,790 --> 00:10:56,079

hard to compress but

354

00:11:00,630 --> 00:10:58,800

but i suppose as gradually as one learns

355

00:11:03,190 --> 00:11:00,640

more about what one's talking about

356

00:11:04,069 --> 00:11:03,200

it becomes easier to explain all right

357

00:11:07,509 --> 00:11:04,079

let's

358

00:11:10,310 --> 00:11:07,519

talk about physics and kind of um

359

00:11:10,710 --> 00:11:10,320

what's the universe made of so to speak

360

00:11:13,430 --> 00:11:10,720

and

361

00:11:15,590 --> 00:11:13,440

i think one of the things that has been

362

00:11:18,550 --> 00:11:15,600

the the first question is

363

00:11:19,430 --> 00:11:18,560

uh we think about things like space and

364

00:11:21,030 --> 00:11:19,440

time

365

00:11:23,110 --> 00:11:21,040

and the traditional view of something

366

00:11:25,910 --> 00:11:23,120

like space has been

367

00:11:26,230 --> 00:11:25,920

it's this thing that you put things in

368

00:11:29,990 --> 00:11:26,240

it

369

00:11:33,030 --> 00:11:30,000

of a background

370

00:11:34,630 --> 00:11:33,040

and you get to specify a position here

371

00:11:36,230 --> 00:11:34,640

or there in space that's been kind of

372

00:11:39,750 --> 00:11:36,240

the idea of space

373

00:11:43,590 --> 00:11:39,760

since uh euclid and so on so

374

00:11:46,310 --> 00:11:43,600

one of the the basic points in uh

375

00:11:47,590 --> 00:11:46,320

kind of the the models that we've

376

00:11:50,230 --> 00:11:47,600

developed is

377

00:11:51,030 --> 00:11:50,240

uh there's something space is made of

378

00:11:53,670 --> 00:11:51,040

something

379

00:11:55,910 --> 00:11:53,680

just like a fluid like water you might

380

00:11:57,030 --> 00:11:55,920

think of it as just a continuous fluid

381

00:11:59,990 --> 00:11:57,040

where you can like

382

00:12:01,190 --> 00:12:00,000

uh put something anywhere in the fluid

383

00:12:03,190 --> 00:12:01,200

actually you can't

384

00:12:04,949 --> 00:12:03,200

it's made of discreet molecules bouncing

385

00:12:05,829 --> 00:12:04,959

around and and so we think it is with

386

00:12:08,310 --> 00:12:05,839

space

387

00:12:09,509 --> 00:12:08,320

that uh sort of at the lowest level at

388

00:12:11,910 --> 00:12:09,519

very small scales

389

00:12:13,590 --> 00:12:11,920

space is just made of a whole collection

390

00:12:15,910 --> 00:12:13,600

of discrete elements we can think of

391

00:12:18,550 --> 00:12:15,920

them as like geometrical points

392

00:12:19,350 --> 00:12:18,560

but they're not points that have a known

393

00:12:22,829 --> 00:12:19,360

position

394

00:12:24,790 --> 00:12:22,839

in anything they're just discrete

395

00:12:26,310 --> 00:12:24,800

elements and the only thing we know

396

00:12:27,829 --> 00:12:26,320

about those elements is how they're

397

00:12:28,470 --> 00:12:27,839

connected to other elements so it's kind

398

00:12:31,910 --> 00:12:28,480

of like

399

00:12:34,310 --> 00:12:31,920

the the the points since that exists

400

00:12:36,069 --> 00:12:34,320

in the universe are sort of friends with

401  
00:12:36,790 --> 00:12:36,079  
other points and we build up this whole

402  
00:12:39,910 --> 00:12:36,800  
network

403  
00:12:42,150 --> 00:12:39,920  
of connections between points and so

404  
00:12:43,990 --> 00:12:42,160  
our our universe as it is today might

405  
00:12:46,870 --> 00:12:44,000  
have maybe 10 to the 400

406  
00:12:47,910 --> 00:12:46,880  
of these uh of these sort of atoms of

407  
00:12:50,550 --> 00:12:47,920  
space

408  
00:12:51,509 --> 00:12:50,560  
that make it up so sort of the first

409  
00:12:54,069 --> 00:12:51,519  
point is

410  
00:12:54,790 --> 00:12:54,079  
everything in the universe is just space

411  
00:12:57,110 --> 00:12:54,800  
so

412  
00:12:58,870 --> 00:12:57,120  
what uh all of the particles and

413  
00:12:59,990 --> 00:12:58,880

electrons and quarks and all those kinds

414

00:13:02,230 --> 00:13:00,000

of things they're all

415

00:13:03,590 --> 00:13:02,240

just features of this details of the

416

00:13:05,750 --> 00:13:03,600

connections between these

417

00:13:07,590 --> 00:13:05,760

atoms of space so sort of the first

418

00:13:09,509 --> 00:13:07,600

thing is what's the universe made of

419

00:13:10,870 --> 00:13:09,519

it's made of space what space made of

420

00:13:14,310 --> 00:13:10,880

space is made of this

421

00:13:16,310 --> 00:13:14,320

giant network of of nodes giant network

422

00:13:19,110 --> 00:13:16,320

of discrete elements

423

00:13:20,710 --> 00:13:19,120

and we don't even from that no wire

424

00:13:22,550 --> 00:13:20,720

space three-dimensional that the thing

425

00:13:25,430 --> 00:13:22,560

could be connected any way at once

426

00:13:26,310 --> 00:13:25,440

what happens is that on a large scale

427

00:13:28,310 --> 00:13:26,320

something which is

428

00:13:30,470 --> 00:13:28,320

discretely connected like that can

429

00:13:31,990 --> 00:13:30,480

behave as if it is for example a

430

00:13:34,389 --> 00:13:32,000

three-dimensional manifold

431

00:13:35,829 --> 00:13:34,399

on a large scale and and for example one

432

00:13:37,430 --> 00:13:35,839

thing that can happen and we think does

433

00:13:38,790 --> 00:13:37,440

happen in the early universe

434

00:13:40,710 --> 00:13:38,800

is that the universe goes from being

435

00:13:42,790 --> 00:13:40,720

essentially an infinite dimensional

436

00:13:44,550 --> 00:13:42,800

uh network where things are everything

437

00:13:45,910 --> 00:13:44,560

sort of connected to everything else

438

00:13:47,590 --> 00:13:45,920

to this sort of more or less

439

00:13:48,150 --> 00:13:47,600

three-dimensional so far as we know

440

00:13:49,509 --> 00:13:48,160

right now

441

00:13:51,030 --> 00:13:49,519

perfectly three-dimensional though we

442

00:13:52,150 --> 00:13:51,040

suspect there are some dimension

443

00:13:54,470 --> 00:13:52,160

fluctuations

444

00:13:55,910 --> 00:13:54,480

um that exists today so okay so that's

445

00:14:00,069 --> 00:13:55,920

sort of what space

446

00:14:02,870 --> 00:14:00,079

is then what's time well

447

00:14:04,870 --> 00:14:02,880

the the the point is the idea is that

448

00:14:07,110 --> 00:14:04,880

there are these definite rules

449

00:14:08,629 --> 00:14:07,120

that will say if there's a piece of

450

00:14:10,230 --> 00:14:08,639

network that looks like this

451  
00:14:12,230 --> 00:14:10,240  
transform it into one that looks like

452  
00:14:13,030 --> 00:14:12,240  
that and that's continually happening

453  
00:14:15,430 --> 00:14:13,040  
throughout this

454  
00:14:16,470 --> 00:14:15,440  
this network that represents uh the

455  
00:14:18,470 --> 00:14:16,480  
structure of space

456  
00:14:19,509 --> 00:14:18,480  
and the content of the universe and so

457  
00:14:21,910 --> 00:14:19,519  
what's what

458  
00:14:23,509 --> 00:14:21,920  
um uh what we're what we're seeing then

459  
00:14:25,430 --> 00:14:23,519  
is a sort of progression

460  
00:14:27,350 --> 00:14:25,440  
of all of these little updates of this

461  
00:14:29,670 --> 00:14:27,360  
network that represents space

462  
00:14:31,670 --> 00:14:29,680  
and that progress of all those updates

463  
00:14:32,949 --> 00:14:31,680

corresponds to the progress of time

464

00:14:34,949 --> 00:14:32,959

and one of the things that's unusual

465

00:14:36,310 --> 00:14:34,959

about that is for the last hundred years

466

00:14:38,150 --> 00:14:36,320

or so in physics people have kind of

467

00:14:39,910 --> 00:14:38,160

assumed space and time is sort of

468

00:14:41,990 --> 00:14:39,920

the same kind of thing one knows about

469

00:14:42,389 --> 00:14:42,000

relativity one knows that sort of

470

00:14:46,629 --> 00:14:42,399

there's

471

00:14:49,189 --> 00:14:46,639

space with time yet in our theory

472

00:14:50,550 --> 00:14:49,199

space is this extension of this this as

473

00:14:53,670 --> 00:14:50,560

it is turns out to be a

474

00:14:54,389 --> 00:14:53,680

hyper graph this network basically and

475

00:14:56,550 --> 00:14:54,399

time

476  
00:14:57,670 --> 00:14:56,560  
is the progressive sort of inexorable

477  
00:15:00,069 --> 00:14:57,680  
computation

478  
00:15:01,430 --> 00:15:00,079  
of the next configuration of the network

479  
00:15:02,710 --> 00:15:01,440  
based on rewriting the previous

480  
00:15:04,790 --> 00:15:02,720  
configuration

481  
00:15:06,949 --> 00:15:04,800  
so one of the things that is sort of an

482  
00:15:09,670 --> 00:15:06,959  
early thing to realize in our models

483  
00:15:10,629 --> 00:15:09,680  
is this question of of so how does

484  
00:15:12,150 --> 00:15:10,639  
things how does something like

485  
00:15:15,110 --> 00:15:12,160  
relativity arise

486  
00:15:17,110 --> 00:15:15,120  
well the answer is if you are an entity

487  
00:15:18,790 --> 00:15:17,120  
embedded within this network

488  
00:15:20,870 --> 00:15:18,800

it turns out that the only thing you are

489

00:15:23,670 --> 00:15:20,880

ever sensitive to is kind of the

490

00:15:24,150 --> 00:15:23,680

the the network of causal relationships

491

00:15:26,470 --> 00:15:24,160

between

492

00:15:27,990 --> 00:15:26,480

updating events and it turns out there's

493

00:15:30,870 --> 00:15:28,000

a few more steps here but

494

00:15:32,310 --> 00:15:30,880

it turns out that uh with uh with

495

00:15:33,670 --> 00:15:32,320

certain conditions on the way those

496

00:15:37,030 --> 00:15:33,680

updatings work

497

00:15:39,269 --> 00:15:37,040

it is the case that uh uh

498

00:15:40,949 --> 00:15:39,279

basically special relativity comes out

499

00:15:42,550 --> 00:15:40,959

of that we can talk in more detail about

500

00:15:45,189 --> 00:15:42,560

how that works

501  
00:15:46,230 --> 00:15:45,199  
so the next thing that happens is this

502  
00:15:47,670 --> 00:15:46,240  
the space

503  
00:15:50,150 --> 00:15:47,680  
just made up from this network it's sort

504  
00:15:51,749 --> 00:15:50,160  
of the the the the continuum limit of

505  
00:15:53,350 --> 00:15:51,759  
this network in the sense it's like

506  
00:15:55,910 --> 00:15:53,360  
you've got these atoms of space

507  
00:15:57,749 --> 00:15:55,920  
underneath and then a large scale space

508  
00:15:58,790 --> 00:15:57,759  
is like kind of a fluid made up of lots

509  
00:16:01,749 --> 00:15:58,800  
of atoms

510  
00:16:02,230 --> 00:16:01,759  
um that uh behaves in the continuous way

511  
00:16:04,550 --> 00:16:02,240  
that we're

512  
00:16:05,670 --> 00:16:04,560  
used to to perceiving it and then it

513  
00:16:08,310 --> 00:16:05,680

turns out

514

00:16:09,509 --> 00:16:08,320

that you can get space in any other

515

00:16:11,189 --> 00:16:09,519

dimensions you can get space with

516

00:16:14,710 --> 00:16:11,199

different kinds of curvature

517

00:16:17,590 --> 00:16:14,720

one of the big results is that you can

518

00:16:19,189 --> 00:16:17,600

get uh the the the way the curvature

519

00:16:20,870 --> 00:16:19,199

arises in space

520

00:16:22,230 --> 00:16:20,880

is exactly the way that einstein's

521

00:16:24,870 --> 00:16:22,240

equations for gravity

522

00:16:26,389 --> 00:16:24,880

say curvature should arise roughly

523

00:16:28,550 --> 00:16:26,399

energy momentum

524

00:16:30,470 --> 00:16:28,560

mass these are all associated with

525

00:16:32,710 --> 00:16:30,480

levels of activity in the network

526

00:16:35,030 --> 00:16:32,720

and roughly levels of activity in the

527

00:16:36,310 --> 00:16:35,040

network produce curvature in the network

528

00:16:38,790 --> 00:16:36,320

in just the way that einstein's

529

00:16:41,910 --> 00:16:38,800

equations say that uh

530

00:16:44,629 --> 00:16:41,920

energy momentum in in physical

531

00:16:45,829 --> 00:16:44,639

space-time should produce curvature in

532

00:16:47,749 --> 00:16:45,839

in space

533

00:16:48,949 --> 00:16:47,759

so that's that's a pretty important

534

00:16:51,030 --> 00:16:48,959

thing i actually knew that back in the

535

00:16:53,910 --> 00:16:51,040

1990s that these models

536

00:16:55,990 --> 00:16:53,920

um could uh reproduce general relativity

537

00:16:58,389 --> 00:16:56,000

reproduce einstein's equations

538

00:16:59,749 --> 00:16:58,399

so then the next big sort of pillar of

539

00:17:00,710 --> 00:16:59,759

20th century physics is quantum

540

00:17:02,470 --> 00:17:00,720

mechanics

541

00:17:04,230 --> 00:17:02,480

they're really literally probably two or

542

00:17:05,270 --> 00:17:04,240

maybe three pillars of 20th century

543

00:17:07,510 --> 00:17:05,280

physics

544

00:17:09,510 --> 00:17:07,520

general relativity the theory of gravity

545

00:17:11,669 --> 00:17:09,520

uh quantum mechanics

546

00:17:12,789 --> 00:17:11,679

and also to some extent statistical

547

00:17:15,510 --> 00:17:12,799

mechanics

548

00:17:17,590 --> 00:17:15,520

which also uh sort of comes out from the

549

00:17:19,429 --> 00:17:17,600

formalism of these models but it's

550

00:17:20,710 --> 00:17:19,439

maybe it's not the first thing to

551

00:17:23,350 --> 00:17:20,720

explain here

552

00:17:24,630 --> 00:17:23,360

but um so how does quantum mechanics

553

00:17:25,990 --> 00:17:24,640

arise well first thing is what is

554

00:17:27,669 --> 00:17:26,000

quantum mechanics what is the

555

00:17:29,270 --> 00:17:27,679

what is the important feature of quantum

556

00:17:32,549 --> 00:17:29,280

mechanics basically

557

00:17:33,669 --> 00:17:32,559

in classical physics before the 1920s or

558

00:17:36,070 --> 00:17:33,679

so

559

00:17:38,150 --> 00:17:36,080

people thought that in physics there

560

00:17:40,870 --> 00:17:38,160

were definite equations of motion

561

00:17:43,190 --> 00:17:40,880

things behave in definite ways you throw

562

00:17:45,909 --> 00:17:43,200

a ball it goes in a definite trajectory

563

00:17:47,669 --> 00:17:45,919

when what quantum mechanics says is no

564

00:17:49,029 --> 00:17:47,679

that doesn't isn't what happens

565

00:17:51,029 --> 00:17:49,039

instead there are many possible

566

00:17:52,630 --> 00:17:51,039

histories that develop and

567

00:17:54,789 --> 00:17:52,640

the the universe has many possible

568

00:17:55,430 --> 00:17:54,799

histories and all we get to be sensitive

569

00:17:57,909 --> 00:17:55,440

to

570

00:17:58,789 --> 00:17:57,919

is some kind of aggregated probability

571

00:18:00,789 --> 00:17:58,799

of what happens

572

00:18:02,470 --> 00:18:00,799

not knowing specifically what the

573

00:18:04,150 --> 00:18:02,480

history of the universe is

574

00:18:06,789 --> 00:18:04,160

well it turns out in our models that's

575

00:18:09,430 --> 00:18:06,799

something that inevitably works that way

576  
00:18:11,029 --> 00:18:09,440  
and um what happens is we're talking

577  
00:18:11,909 --> 00:18:11,039  
about sort of the rewriting of this big

578  
00:18:14,390 --> 00:18:11,919  
network

579  
00:18:15,350 --> 00:18:14,400  
and the point is that there isn't just

580  
00:18:17,110 --> 00:18:15,360  
one

581  
00:18:18,789 --> 00:18:17,120  
possible rewrite that happens at any

582  
00:18:19,669 --> 00:18:18,799  
given time there are many possible

583  
00:18:21,190 --> 00:18:19,679  
rewrites

584  
00:18:22,950 --> 00:18:21,200  
and each of those different possible

585  
00:18:24,870 --> 00:18:22,960  
rewrites represents

586  
00:18:26,630 --> 00:18:24,880  
essentially taking the universe in a

587  
00:18:29,510 --> 00:18:26,640  
different path of history

588  
00:18:30,070 --> 00:18:29,520

but the critical fact is that just as

589

00:18:31,590 --> 00:18:30,080

there are

590

00:18:33,190 --> 00:18:31,600

there might be two possible rewrites

591

00:18:34,150 --> 00:18:33,200

that could happen and they produce a

592

00:18:36,630 --> 00:18:34,160

branching

593

00:18:38,150 --> 00:18:36,640

of two parts of history so also it will

594

00:18:40,150 --> 00:18:38,160

turn out when there are other

595

00:18:42,070 --> 00:18:40,160

rewritings that can happen later that

596

00:18:43,110 --> 00:18:42,080

actually these branches can merge so you

597

00:18:44,950 --> 00:18:43,120

end up with something

598

00:18:47,110 --> 00:18:44,960

which is this whole graph of possible

599

00:18:48,950 --> 00:18:47,120

histories we call it a multi-way graph

600

00:18:51,830 --> 00:18:48,960

and in this multi-way graph there is

601  
00:18:54,470 --> 00:18:51,840  
both branching and merging of histories

602  
00:18:56,070 --> 00:18:54,480  
and that uh that process of branching

603  
00:18:58,150 --> 00:18:56,080  
and merging of histories

604  
00:18:59,590 --> 00:18:58,160  
that ends up being the story of quantum

605  
00:19:01,350 --> 00:18:59,600  
mechanics basically

606  
00:19:03,430 --> 00:19:01,360  
and one of the things that sort of a

607  
00:19:05,430 --> 00:19:03,440  
thing to to think about is

608  
00:19:07,110 --> 00:19:05,440  
when we look at they have this whole

609  
00:19:08,870 --> 00:19:07,120  
multi-way graph of all these branching

610  
00:19:12,310 --> 00:19:08,880  
histories of the universe

611  
00:19:13,430 --> 00:19:12,320  
and we say let's let's imagine that we

612  
00:19:16,310 --> 00:19:13,440  
are observing that

613  
00:19:17,350 --> 00:19:16,320

we are uh it's a little bit hard to

614

00:19:19,830 --> 00:19:17,360

imagine because

615

00:19:20,710 --> 00:19:19,840

what's happening is we our brains our

616

00:19:23,270 --> 00:19:20,720

minds

617

00:19:23,830 --> 00:19:23,280

are the are themselves embedded in this

618

00:19:26,470 --> 00:19:23,840

multi-way

619

00:19:28,070 --> 00:19:26,480

graph so just as the universe is

620

00:19:31,029 --> 00:19:28,080

breaking into all these different

621

00:19:32,470 --> 00:19:31,039

parts of history so too are our brains

622

00:19:33,270 --> 00:19:32,480

breaking into all these different parts

623

00:19:35,430 --> 00:19:33,280

of history

624

00:19:37,590 --> 00:19:35,440

so in a sense what's happening is it's a

625

00:19:38,390 --> 00:19:37,600

branching brain observing a branching

626  
00:19:40,070 --> 00:19:38,400  
universe

627  
00:19:42,150 --> 00:19:40,080  
you have to kind of think about what is

628  
00:19:44,549 --> 00:19:42,160  
how do you how do you kind of

629  
00:19:46,310 --> 00:19:44,559  
how does a how does the brain how does

630  
00:19:49,430 --> 00:19:46,320  
our mind make sense of

631  
00:19:51,029 --> 00:19:49,440  
that universe and what you realize is

632  
00:19:53,029 --> 00:19:51,039  
that you're kind of defining what we

633  
00:19:54,710 --> 00:19:53,039  
might call reference frames

634  
00:19:56,710 --> 00:19:54,720  
kind of quantum reference frames they're

635  
00:19:58,390 --> 00:19:56,720  
analogous to the reference frames that

636  
00:20:00,310 --> 00:19:58,400  
we think about in relativity where

637  
00:20:02,310 --> 00:20:00,320  
reference frames typical inertial frames

638  
00:20:03,990 --> 00:20:02,320

are things like you are at rest you're

639

00:20:05,110 --> 00:20:04,000

traveling at a certain velocity

640

00:20:07,190 --> 00:20:05,120

et cetera et cetera et cetera there's

641

00:20:07,909 --> 00:20:07,200

kind of a quantum analog of those and

642

00:20:10,149 --> 00:20:07,919

that's

643

00:20:12,070 --> 00:20:10,159

the way that we perceive this multi-way

644

00:20:14,630 --> 00:20:12,080

graph of possible histories

645

00:20:16,470 --> 00:20:14,640

and so when we say let's pick a

646

00:20:18,070 --> 00:20:16,480

particular quantum reference frame

647

00:20:19,510 --> 00:20:18,080

uh corresponds to more or less a

648

00:20:22,789 --> 00:20:19,520

particular time

649

00:20:24,390 --> 00:20:22,799

um and that let's then ask

650

00:20:26,870 --> 00:20:24,400

what is the sort of slice of this

651  
00:20:29,029 --> 00:20:26,880  
multi-way graph

652  
00:20:29,909 --> 00:20:29,039  
defined by this quantum reference frame

653  
00:20:31,590 --> 00:20:29,919  
what we have is

654  
00:20:33,430 --> 00:20:31,600  
all these different possible histories

655  
00:20:35,190 --> 00:20:33,440  
and they're all kind of laid out

656  
00:20:37,029 --> 00:20:35,200  
in some sense histories can be close to

657  
00:20:37,909 --> 00:20:37,039  
each other if they had common ancestors

658  
00:20:39,190 --> 00:20:37,919  
recently

659  
00:20:40,549 --> 00:20:39,200  
histories could be further away from

660  
00:20:42,390 --> 00:20:40,559  
each other if they didn't have a common

661  
00:20:43,909 --> 00:20:42,400  
ancestor for a long time and so on

662  
00:20:45,909 --> 00:20:43,919  
all these histories are kind of laid out

663  
00:20:48,070 --> 00:20:45,919

in some kind of space we call that

664

00:20:50,149 --> 00:20:48,080

branchial space the space of branches

665

00:20:52,549 --> 00:20:50,159

the space of quantum branches

666

00:20:54,230 --> 00:20:52,559

and that branchial space it's not like

667

00:20:54,870 --> 00:20:54,240

physical space it's not like something

668

00:20:57,270 --> 00:20:54,880

where

669

00:20:57,990 --> 00:20:57,280

you have ordinary motion from one place

670

00:21:01,029 --> 00:20:58,000

to another

671

00:21:02,630 --> 00:21:01,039

but in branchial space um there is it's

672

00:21:04,789 --> 00:21:02,640

it's a layout of possible histories of

673

00:21:05,990 --> 00:21:04,799

the uh possible states of the universe

674

00:21:08,470 --> 00:21:06,000

effectively

675

00:21:09,430 --> 00:21:08,480

so one of the things that i find really

676

00:21:11,830 --> 00:21:09,440

neat

677

00:21:13,510 --> 00:21:11,840

is that you can talk about motion in

678

00:21:16,470 --> 00:21:13,520

physical space you can talk about

679

00:21:17,909 --> 00:21:16,480

uh for example uh you know even ever

680

00:21:18,310 --> 00:21:17,919

since newton we've we've kind of had

681

00:21:20,070 --> 00:21:18,320

this

682

00:21:22,070 --> 00:21:20,080

principle that if things aren't acted on

683

00:21:23,830 --> 00:21:22,080

by a force they will keep going in a

684

00:21:25,590 --> 00:21:23,840

state of uniform motion

685

00:21:27,110 --> 00:21:25,600

so it's kind of like things go in

686

00:21:28,070 --> 00:21:27,120

straight lines if you leave them by

687

00:21:29,669 --> 00:21:28,080

themselves

688

00:21:31,990 --> 00:21:29,679

and kind of einstein's big idea in

689

00:21:33,190 --> 00:21:32,000

general artillery was to think that yes

690

00:21:34,630 --> 00:21:33,200

things do go in

691

00:21:37,590 --> 00:21:34,640

kind of straight lines in the sense that

692

00:21:41,430 --> 00:21:37,600

their shortest paths geodesic paths

693

00:21:43,750 --> 00:21:41,440

but space can be curved and then what

694

00:21:46,149 --> 00:21:43,760

might be to the thing kind of its

695

00:21:48,549 --> 00:21:46,159

straight line path to the outside

696

00:21:49,430 --> 00:21:48,559

is a curved path and because that

697

00:21:51,669 --> 00:21:49,440

curvature

698

00:21:52,549 --> 00:21:51,679

is associated with energy momentum that

699

00:21:54,230 --> 00:21:52,559

is what

700

00:21:55,750 --> 00:21:54,240

leads to the effect of gravity so to

701  
00:21:56,870 --> 00:21:55,760  
speak so physical space that's how

702  
00:21:58,470 --> 00:21:56,880  
things work

703  
00:22:00,710 --> 00:21:58,480  
turns out in branch shield space they

704  
00:22:03,190 --> 00:22:00,720  
work in essentially exactly the same way

705  
00:22:04,149 --> 00:22:03,200  
except now in terms of the equations of

706  
00:22:06,230 --> 00:22:04,159  
gravity

707  
00:22:07,990 --> 00:22:06,240  
we have uh the equations of quantum

708  
00:22:10,070 --> 00:22:08,000  
mechanics and quantum field theory

709  
00:22:11,669 --> 00:22:10,080  
um and essentially what's happening is

710  
00:22:13,990 --> 00:22:11,679  
that there are sort of paths in

711  
00:22:16,710 --> 00:22:14,000  
branchial space that are being followed

712  
00:22:18,710 --> 00:22:16,720  
and we are seeing deflections of those

713  
00:22:21,350 --> 00:22:18,720

paths actually associated also

714

00:22:22,870 --> 00:22:21,360

with energy momentum and the way those

715

00:22:25,430 --> 00:22:22,880

deflections work

716

00:22:26,789 --> 00:22:25,440

uh exactly gives one the path integral

717

00:22:28,870 --> 00:22:26,799

of quantum mechanics

718

00:22:29,909 --> 00:22:28,880

so the the thing that's really pretty

719

00:22:32,549 --> 00:22:29,919

neat is

720

00:22:33,750 --> 00:22:32,559

i mean one of many very neat things but

721

00:22:36,789 --> 00:22:33,760

one thing that i

722

00:22:39,430 --> 00:22:36,799

just found uh really was a very wow

723

00:22:41,029 --> 00:22:39,440

moment about a year and a bit ago now

724

00:22:43,830 --> 00:22:41,039

gosh you can't believe it so long

725

00:22:44,149 --> 00:22:43,840

um the uh congratulations by the way

726

00:22:47,830 --> 00:22:44,159

it's

727

00:22:49,510 --> 00:22:47,840

um uh yeah well time time inexorably

728

00:22:52,310 --> 00:22:49,520

moves forward right so

729

00:22:53,430 --> 00:22:52,320

it's it's um no but i think the the um

730

00:22:55,110 --> 00:22:53,440

uh

731

00:22:57,110 --> 00:22:55,120

that you know sort of a wow moment was

732

00:22:59,029 --> 00:22:57,120

realizing that that the einstein

733

00:23:00,950 --> 00:22:59,039

equations in physical space

734

00:23:02,310 --> 00:23:00,960

are basically the same thing as the

735

00:23:04,950 --> 00:23:02,320

feynman path integral

736

00:23:06,789 --> 00:23:04,960

in bronchial space so in a sense general

737

00:23:09,350 --> 00:23:06,799

relativity and quantum mechanics

738

00:23:11,350 --> 00:23:09,360

are the same theory just played out in

739

00:23:13,830 --> 00:23:11,360

these different kinds of space

740

00:23:15,750 --> 00:23:13,840

and uh that has a lot of implications

741

00:23:17,669 --> 00:23:15,760

because it kind of shows one

742

00:23:19,110 --> 00:23:17,679

how there are correspondences between

743

00:23:21,430 --> 00:23:19,120

general relativity and quantum

744

00:23:22,789 --> 00:23:21,440

and quantum mechanics and the sort of

745

00:23:25,909 --> 00:23:22,799

the sort of uh

746

00:23:27,350 --> 00:23:25,919

i don't know intersectional cases uh

747

00:23:29,110 --> 00:23:27,360

when one's dealing with black holes and

748

00:23:29,590 --> 00:23:29,120

so on but but so that's a that's at

749

00:23:32,870 --> 00:23:29,600

least

750

00:23:33,990 --> 00:23:32,880

one level of um uh the story of our

751

00:23:36,390 --> 00:23:34,000

models of physics

752

00:23:38,470 --> 00:23:36,400

and um uh you know there's a lot of

753

00:23:40,230 --> 00:23:38,480

detail a lot of things that are now

754

00:23:42,149 --> 00:23:40,240

it's now clear yes we really can

755

00:23:42,630 --> 00:23:42,159

reproduce exactly what happens in you

756

00:23:44,390 --> 00:23:42,640

know

757

00:23:45,990 --> 00:23:44,400

black hole mergers we can reproduce what

758

00:23:47,669 --> 00:23:46,000

happens in quantum computing

759

00:23:50,549 --> 00:23:47,679

we can reproduce all these other kinds

760

00:23:53,510 --> 00:23:50,559

of things and we're starting to have

761

00:23:55,510 --> 00:23:53,520

kind of ideas about uh you know a lot of

762

00:23:57,350 --> 00:23:55,520

i know a lot of experimental physicists

763

00:23:58,950 --> 00:23:57,360

who keep on saying to me when are you

764

00:23:59,590 --> 00:23:58,960

going to give us actual experiments to

765

00:24:01,669 --> 00:23:59,600

do

766

00:24:03,350 --> 00:24:01,679

and we're getting closer you know it's

767

00:24:04,789 --> 00:24:03,360

no point in telling them

768

00:24:06,470 --> 00:24:04,799

there's a lot of actual physics and

769

00:24:08,710 --> 00:24:06,480

astrophysics and so on to be done

770

00:24:11,190 --> 00:24:08,720

to work out exactly what to look for but

771

00:24:14,070 --> 00:24:11,200

i mean another direction here that that

772

00:24:15,029 --> 00:24:14,080

uh is well there's several directions i

773

00:24:18,789 --> 00:24:15,039

mean one is

774

00:24:20,870 --> 00:24:18,799

kind of understanding um

775

00:24:23,430 --> 00:24:20,880

i've had sort of in the last few months

776

00:24:26,470 --> 00:24:23,440

kind of a deeper understanding

777

00:24:27,669 --> 00:24:26,480

of uh what kind of observers of the

778

00:24:31,590 --> 00:24:27,679

universe we actually

779

00:24:33,190 --> 00:24:31,600

are and how consciousness relates to

780

00:24:34,950 --> 00:24:33,200

what kinds of things we do and don't

781

00:24:36,630 --> 00:24:34,960

observe about the universe and what

782

00:24:38,549 --> 00:24:36,640

consequences that has

783

00:24:40,230 --> 00:24:38,559

for the kinds of laws the kinds of

784

00:24:41,350 --> 00:24:40,240

physical laws that we believe are going

785

00:24:44,070 --> 00:24:41,360

on in the universe

786

00:24:45,190 --> 00:24:44,080

that's one direction another direction

787

00:24:48,149 --> 00:24:45,200

is

788

00:24:49,750 --> 00:24:48,159

trying to understand if we can say yes

789

00:24:51,110 --> 00:24:49,760

we have this simple rule that's updating

790

00:24:51,590 --> 00:24:51,120

this hypergraph and so on and then you

791

00:24:53,350 --> 00:24:51,600

say

792

00:24:55,029 --> 00:24:53,360

why is it that simple rule not another

793

00:24:57,269 --> 00:24:55,039

one what i've realized

794

00:24:58,070 --> 00:24:57,279

recently what we realized a while ago

795

00:25:01,350 --> 00:24:58,080

but it's become

796

00:25:04,710 --> 00:25:01,360

a lot crisper now is this idea

797

00:25:06,310 --> 00:25:04,720

that actually there is the um in some

798

00:25:07,830 --> 00:25:06,320

sense the universe can be running all

799

00:25:11,110 --> 00:25:07,840

possible rules

800

00:25:12,789 --> 00:25:11,120

and we are we are seeing some kind of

801  
00:25:15,669 --> 00:25:12,799  
reference frame not in

802  
00:25:17,350 --> 00:25:15,679  
physical space or in branchial space but

803  
00:25:19,269 --> 00:25:17,360  
in this thing we call rule space the

804  
00:25:22,310 --> 00:25:19,279  
space of all possible rules

805  
00:25:23,909 --> 00:25:22,320  
we are essentially picking a particular

806  
00:25:25,110 --> 00:25:23,919  
description language a particular

807  
00:25:27,190 --> 00:25:25,120  
reference frame

808  
00:25:29,750 --> 00:25:27,200  
with which to understand the universe

809  
00:25:30,149 --> 00:25:29,760  
and so the sort of paradox of why or

810  
00:25:33,430 --> 00:25:30,159  
this

811  
00:25:35,269 --> 00:25:33,440  
why does the universe follow one

812  
00:25:36,870 --> 00:25:35,279  
particular rule and not others

813  
00:25:39,190 --> 00:25:36,880

turns out the answer is it follows all

814

00:25:41,669 --> 00:25:39,200

possible rules and we are just

815

00:25:43,110 --> 00:25:41,679

at some place in rullial space observing

816

00:25:45,990 --> 00:25:43,120

it in a particular way

817

00:25:48,070 --> 00:25:46,000

and that has the big surprise to me

818

00:25:50,470 --> 00:25:48,080

recently last month or so

819

00:25:52,149 --> 00:25:50,480

has been realizing that i actually think

820

00:25:53,590 --> 00:25:52,159

we can get a serious answer to a

821

00:25:54,630 --> 00:25:53,600

question like why does the universe

822

00:25:56,070 --> 00:25:54,640

exist

823

00:25:57,830 --> 00:25:56,080

and as a matter of fact the thing that

824

00:26:00,149 --> 00:25:57,840

comes out of that is

825

00:26:01,669 --> 00:26:00,159

the realization that as soon as we say

826  
00:26:03,830 --> 00:26:01,679  
the universe exists

827  
00:26:05,269 --> 00:26:03,840  
and as soon as we give that argument we

828  
00:26:06,390 --> 00:26:05,279  
are forced into a position that

829  
00:26:09,029 --> 00:26:06,400  
mathematics

830  
00:26:10,230 --> 00:26:09,039  
in some sense fundamentally exists too

831  
00:26:11,510 --> 00:26:10,240  
which is something you know people like

832  
00:26:12,710 --> 00:26:11,520  
plato have said but

833  
00:26:15,029 --> 00:26:12,720  
something very different from the way

834  
00:26:16,710 --> 00:26:15,039  
that people have uh uh

835  
00:26:18,710 --> 00:26:16,720  
assumed the foundations of mathematics

836  
00:26:20,230 --> 00:26:18,720  
work so you asked me for a three minute

837  
00:26:20,789 --> 00:26:20,240  
i'm sure that wasn't three minutes but

838  
00:26:26,549 --> 00:26:20,799

um

839

00:26:27,350 --> 00:26:26,559

not talked about a lot of the

840

00:26:29,350 --> 00:26:27,360

intuitional

841

00:26:30,870 --> 00:26:29,360

underpinnings that are necessary for

842

00:26:32,149 --> 00:26:30,880

this theory of physics

843

00:26:34,390 --> 00:26:32,159

concepts like the principle of

844

00:26:35,990 --> 00:26:34,400

computational equivalence computational

845

00:26:37,269 --> 00:26:36,000

irreducibility and so on i mean

846

00:26:39,430 --> 00:26:37,279

what's basically happened in the

847

00:26:42,549 --> 00:26:39,440

building of this this theory

848

00:26:43,669 --> 00:26:42,559

is uh it's sort of the result of well

849

00:26:47,110 --> 00:26:43,679

it's i guess it's now

850

00:26:50,070 --> 00:26:47,120

40 years of my uh activities

851  
00:26:51,190 --> 00:26:50,080  
um that in the first of the first layer

852  
00:26:53,750 --> 00:26:51,200  
is probably

853  
00:26:54,470 --> 00:26:53,760  
you know i i used to do sort of

854  
00:26:56,470 --> 00:26:54,480  
traditional

855  
00:26:58,390 --> 00:26:56,480  
quantum field theory general relativity

856  
00:27:00,390 --> 00:26:58,400  
particle physics kinds of things so i

857  
00:27:01,510 --> 00:27:00,400  
i know that stuff fairly well although

858  
00:27:04,149 --> 00:27:01,520  
although it's

859  
00:27:05,590 --> 00:27:04,159  
kind of it's a a rip van winkle type

860  
00:27:06,470 --> 00:27:05,600  
situation for me because that was 40

861  
00:27:09,590 --> 00:27:06,480  
years ago

862  
00:27:11,350 --> 00:27:09,600  
and i'm right now kind of um it's it

863  
00:27:12,950 --> 00:27:11,360

hasn't changed as much as you might have

864

00:27:13,430 --> 00:27:12,960

thought a field might change like if i

865

00:27:15,590 --> 00:27:13,440

look at

866

00:27:16,710 --> 00:27:15,600

biology over that period of time you

867

00:27:18,310 --> 00:27:16,720

know there were all these things in

868

00:27:20,710 --> 00:27:18,320

biology where it's like i learned stuff

869

00:27:21,350 --> 00:27:20,720

about cells 40 years ago 45 years ago

870

00:27:23,110 --> 00:27:21,360

whatever

871

00:27:24,549 --> 00:27:23,120

and it was like that's an organelle of

872

00:27:26,870 --> 00:27:24,559

unknown function

873

00:27:28,950 --> 00:27:26,880

and now there's a whole you know vast

874

00:27:30,950 --> 00:27:28,960

journals devoted to exactly what you

875

00:27:32,549 --> 00:27:30,960

know the golgi complex does or something

876

00:27:34,070 --> 00:27:32,559

something like this so so in a sense

877

00:27:35,750 --> 00:27:34,080

that field has advanced a lot more than

878

00:27:38,230 --> 00:27:35,760

physics over that period of time

879

00:27:39,830 --> 00:27:38,240

but i think um the uh you know sort of

880

00:27:40,630 --> 00:27:39,840

that layer then there's the layer that

881

00:27:43,190 --> 00:27:40,640

i've spent

882

00:27:44,070 --> 00:27:43,200

years building practical technology for

883

00:27:47,190 --> 00:27:44,080

actually

884

00:27:50,310 --> 00:27:47,200

computing things and uh both

885

00:27:51,830 --> 00:27:50,320

the the level of understanding of how

886

00:27:53,190 --> 00:27:51,840

formal systems work

887

00:27:55,190 --> 00:27:53,200

that has come with the process of

888

00:27:56,549 --> 00:27:55,200

designing wolfram language and

889

00:27:58,310 --> 00:27:56,559

mathematica and so on

890

00:28:00,710 --> 00:27:58,320

that has been really critical to what we

891

00:28:01,029 --> 00:28:00,720

built and then the very practicalities

892

00:28:02,549 --> 00:28:01,039

of

893

00:28:04,789 --> 00:28:02,559

you know so we actually have an

894

00:28:06,789 --> 00:28:04,799

environment in which to do experiments

895

00:28:08,230 --> 00:28:06,799

we can you know do graph theory easily

896

00:28:10,710 --> 00:28:08,240

and things like this

897

00:28:11,350 --> 00:28:10,720

and then the whole new kind of science

898

00:28:14,230 --> 00:28:11,360

development

899

00:28:15,909 --> 00:28:14,240

of what simple programs do understanding

900

00:28:16,710 --> 00:28:15,919

principles of that and so on and i

901  
00:28:19,110 --> 00:28:16,720  
realized there's a

902  
00:28:21,190 --> 00:28:19,120  
there's in the end a fairly tall tower

903  
00:28:24,630 --> 00:28:21,200  
that we've ended up relying on

904  
00:28:27,510 --> 00:28:24,640  
uh to uh uh to kind of construct

905  
00:28:28,870 --> 00:28:27,520  
this theory and i you know to me is this

906  
00:28:31,510 --> 00:28:28,880  
funny feeling because

907  
00:28:32,230 --> 00:28:31,520  
you know i'm i'm really excited that we

908  
00:28:34,149 --> 00:28:32,240  
managed to

909  
00:28:35,909 --> 00:28:34,159  
get this done and it's gone a lot better

910  
00:28:37,750 --> 00:28:35,919  
than i expected it would go

911  
00:28:39,990 --> 00:28:37,760  
but it almost didn't happen i mean it

912  
00:28:42,070 --> 00:28:40,000  
very very nearly didn't happen

913  
00:28:43,110 --> 00:28:42,080

and you know the question that i might

914

00:28:45,430 --> 00:28:43,120

ask myself is

915

00:28:47,190 --> 00:28:45,440

if it hadn't happened when would it have

916

00:28:50,070 --> 00:28:47,200

happened otherwise

917

00:28:50,870 --> 00:28:50,080

and the answer is i don't know 50 years

918

00:28:53,350 --> 00:28:50,880

100 years

919

00:28:54,070 --> 00:28:53,360

i don't know it wasn't it wasn't a thing

920

00:28:56,070 --> 00:28:54,080

where

921

00:28:57,830 --> 00:28:56,080

you know it wasn't like all the stars

922

00:28:59,510 --> 00:28:57,840

were lined up for everybody so to speak

923

00:29:01,830 --> 00:28:59,520

it was a particular

924

00:29:03,430 --> 00:29:01,840

series of things that are kind of the

925

00:29:05,269 --> 00:29:03,440

story of my life and then people like

926

00:29:07,909 --> 00:29:05,279

jonathan who had their own

927

00:29:08,389 --> 00:29:07,919

uh things that they bring into this um

928

00:29:11,350 --> 00:29:08,399

you know

929

00:29:12,389 --> 00:29:11,360

it's kind of a an unexpected and unusual

930

00:29:14,789 --> 00:29:12,399

alignment

931

00:29:17,110 --> 00:29:14,799

plus it turned out we managed to get a

932

00:29:20,549 --> 00:29:17,120

lot further than we ever expected to get

933

00:29:21,830 --> 00:29:20,559

so it's some uh anyway that's that's a

934

00:29:25,510 --> 00:29:21,840

little bit of an outline of

935

00:29:28,870 --> 00:29:27,669

where we are i suppose i mean there's

936

00:29:31,190 --> 00:29:28,880

there's a lot more to say about the

937

00:29:33,110 --> 00:29:31,200

details of what's happening with the

938

00:29:34,630 --> 00:29:33,120

models and and how we compute things

939

00:29:36,149 --> 00:29:34,640

from them and so on but

940

00:29:37,990 --> 00:29:36,159

you ask for a basic introduction that's

941

00:29:39,590 --> 00:29:38,000

my attempt to the basic introduction

942

00:29:41,350 --> 00:29:39,600

what's the difference between the causal

943

00:29:43,909 --> 00:29:41,360

graph and the multi-way graph

944

00:29:44,950 --> 00:29:43,919

is one a transitive reduction of the

945

00:29:47,350 --> 00:29:44,960

other are they the same

946

00:29:48,389 --> 00:29:47,360

no no they're different kinds of things

947

00:29:55,430 --> 00:29:48,399

so

948

00:29:55,750 --> 00:29:55,440

graphs oh look there we go there's a

949

00:29:57,510 --> 00:29:55,760

nice

950

00:29:59,830 --> 00:29:57,520

this is a multi-way or a causal that's a

951  
00:30:00,630 --> 00:29:59,840  
causal graph that that thing is a causal

952  
00:30:04,230 --> 00:30:00,640  
graph

953  
00:30:05,590 --> 00:30:04,240  
so okay sorry there are a lot of kinds

954  
00:30:07,350 --> 00:30:05,600  
of graphs running around

955  
00:30:09,269 --> 00:30:07,360  
that's right that's fine and each one of

956  
00:30:10,630 --> 00:30:09,279  
these nodes represents a hypergraph in

957  
00:30:11,990 --> 00:30:10,640  
and of itself and then these lines

958  
00:30:13,830 --> 00:30:12,000  
represent updating rules that's

959  
00:30:16,389 --> 00:30:13,840  
that's a causal graph so that that's a

960  
00:30:16,870 --> 00:30:16,399  
no each one of those nodes represents an

961  
00:30:22,310 --> 00:30:16,880  
event

962  
00:30:23,430 --> 00:30:22,320  
okay let's let's go through the kinds of

963  
00:30:26,389 --> 00:30:23,440

graphs

964

00:30:27,510 --> 00:30:26,399

so first kind of graph is the spatial

965

00:30:30,310 --> 00:30:27,520

hypograph

966

00:30:30,710 --> 00:30:30,320

that represents the structure of space

967

00:30:37,990 --> 00:30:30,720

its

968

00:30:41,350 --> 00:30:38,000

are relations between atoms of space

969

00:30:43,909 --> 00:30:41,360

okay and at any moment in time

970

00:30:44,389 --> 00:30:43,919

you can imagine that you've taken a

971

00:30:46,789 --> 00:30:44,399

slice

972

00:30:48,470 --> 00:30:46,799

representing the current moment in time

973

00:30:50,789 --> 00:30:48,480

there is a spatial hypergraph that

974

00:30:52,870 --> 00:30:50,799

represents the structure of the universe

975

00:30:54,950 --> 00:30:52,880

okay so that's first first level of

976

00:30:58,470 --> 00:30:54,960

graph the second thing is

977

00:31:02,950 --> 00:30:58,480

that graph then evolves and it evolves

978

00:31:06,070 --> 00:31:02,960

by events that take a particular

979

00:31:08,310 --> 00:31:06,080

set of hyper edges combine them together

980

00:31:10,310 --> 00:31:08,320

and produce another set of hyper edges

981

00:31:11,830 --> 00:31:10,320

or another some set of atoms of space

982

00:31:12,549 --> 00:31:11,840

that produces another set of atoms of

983

00:31:14,230 --> 00:31:12,559

space

984

00:31:16,230 --> 00:31:14,240

so it's like a you're running all these

985

00:31:16,630 --> 00:31:16,240

little functions you've got you've got

986

00:31:21,430 --> 00:31:16,640

this

987

00:31:24,470 --> 00:31:21,440

structure

988

00:31:26,070 --> 00:31:24,480

with lots of um lots of pieces in it

989

00:31:27,830 --> 00:31:26,080

and they're these functions that are

990

00:31:29,350 --> 00:31:27,840

running on particular parts of that data

991

00:31:33,029 --> 00:31:29,360

structure to produce

992

00:31:35,990 --> 00:31:33,039

uh new uh pieces of a new data structure

993

00:31:37,509 --> 00:31:36,000

every update event that's an event so

994

00:31:39,590 --> 00:31:37,519

the causal graph

995

00:31:41,509 --> 00:31:39,600

is the network of causal relationships

996

00:31:43,909 --> 00:31:41,519

between those updating events

997

00:31:45,190 --> 00:31:43,919

so why are there why are those updating

998

00:31:46,549 --> 00:31:45,200

events connected

999

00:31:48,710 --> 00:31:46,559

well the reason they're connected is

1000

00:31:49,509 --> 00:31:48,720

because a particular updating event

1001

00:31:51,830 --> 00:31:49,519

needs something

1002

00:31:53,909 --> 00:31:51,840

as input it needs to use certain

1003

00:31:54,549 --> 00:31:53,919

hyperedges certain atoms of space as its

1004

00:31:57,269 --> 00:31:54,559

input

1005

00:31:58,149 --> 00:31:57,279

and the question is are those hyperedges

1006

00:32:00,870 --> 00:31:58,159

up to date

1007

00:32:03,430 --> 00:32:00,880

do they have those and so there's a a

1008

00:32:06,070 --> 00:32:03,440

set of causal relationships between

1009

00:32:07,029 --> 00:32:06,080

these updating events where one updating

1010

00:32:11,350 --> 00:32:07,039

event

1011

00:32:14,070 --> 00:32:11,360

can uh it has it is it has a

1012

00:32:15,110 --> 00:32:14,080

it has a causal dependence on a previous

1013

00:32:18,149 --> 00:32:15,120

updating event

1014

00:32:19,909 --> 00:32:18,159

so you get this this graph that connects

1015

00:32:21,190 --> 00:32:19,919

that represents the causal relationships

1016

00:32:23,990 --> 00:32:21,200

between updating events

1017

00:32:25,029 --> 00:32:24,000

that's a directed graph uh if you go

1018

00:32:26,710 --> 00:32:25,039

from one event

1019

00:32:28,470 --> 00:32:26,720

and you follow its arrows you're

1020

00:32:29,350 --> 00:32:28,480

basically going into events that are in

1021

00:32:31,909 --> 00:32:29,360

the future

1022

00:32:32,710 --> 00:32:31,919

so those arrows represent a time-like

1023

00:32:34,710 --> 00:32:32,720

path

1024

00:32:36,870 --> 00:32:34,720

just following those arrows is a

1025

00:32:40,470 --> 00:32:36,880

possible time-like path

1026

00:32:43,350 --> 00:32:40,480

so you can also ask two events

1027

00:32:44,950 --> 00:32:43,360

could they happen at the same time so

1028

00:32:46,710 --> 00:32:44,960

there are events that couldn't possibly

1029

00:32:49,029 --> 00:32:46,720

happen at the same time because they are

1030

00:32:50,789 --> 00:32:49,039

they're in a chain one following from

1031

00:32:52,950 --> 00:32:50,799

another in a timeline

1032

00:32:54,230 --> 00:32:52,960

sequence so those couldn't possibly

1033

00:32:55,909 --> 00:32:54,240

happen at the same time

1034

00:32:57,750 --> 00:32:55,919

there's no reference frame there's no

1035

00:32:59,590 --> 00:32:57,760

assignment of simultaneity

1036

00:33:02,389 --> 00:32:59,600

which will allow those things to happen

1037

00:33:05,110 --> 00:33:02,399

at the same time so what what can occur

1038

00:33:06,230 --> 00:33:05,120

is that but in this it's a partially

1039

00:33:10,310 --> 00:33:06,240

ordered set

1040

00:33:13,350 --> 00:33:10,320

of updating events and in that post set

1041

00:33:15,509 --> 00:33:13,360

there are things where you can have

1042

00:33:17,269 --> 00:33:15,519

two updating events which can be

1043

00:33:18,789 --> 00:33:17,279

considered to happen at the same time

1044

00:33:20,870 --> 00:33:18,799

you can have a reference frame

1045

00:33:21,909 --> 00:33:20,880

where those two updating events could

1046

00:33:23,509 --> 00:33:21,919

happen happen

1047

00:33:25,590 --> 00:33:23,519

you say they happen at the same time you

1048

00:33:26,630 --> 00:33:25,600

couldn't do that if they were in a chain

1049

00:33:28,710 --> 00:33:26,640

one after the other

1050

00:33:31,029 --> 00:33:28,720

but you can do that if they're in what

1051

00:33:33,990 --> 00:33:31,039

in post-set language is an anti-chain

1052

00:33:36,149 --> 00:33:34,000

yeah a doodle correspond to the

1053

00:33:38,470 --> 00:33:36,159

different lines that are separating

1054

00:33:40,070 --> 00:33:38,480

which i imagine they're separating into

1055

00:33:43,029 --> 00:33:40,080

quote-unquote branches of space

1056

00:33:45,350 --> 00:33:43,039

possible that's a possible foliation of

1057

00:33:48,389 --> 00:33:45,360

that causal graph so what that means is

1058

00:33:51,350 --> 00:33:48,399

that that is a possible choice of what

1059

00:33:52,070 --> 00:33:51,360

updating events should be considered

1060

00:33:54,070 --> 00:33:52,080

simultaneous

1061

00:33:55,430 --> 00:33:54,080

to what other ones and just like in

1062

00:33:57,750 --> 00:33:55,440

relativity theory

1063

00:33:59,430 --> 00:33:57,760

there are multiple different possible

1064

00:34:01,990 --> 00:33:59,440

foliations of space-time

1065

00:34:03,750 --> 00:34:02,000

so there are multiple different uh

1066

00:34:05,590 --> 00:34:03,760

choices of what you consider to be

1067

00:34:09,510 --> 00:34:05,600

simultaneous so to speak

1068

00:34:12,710 --> 00:34:09,520

um and that uh that's the um

1069

00:34:15,349 --> 00:34:12,720

so the causal graph okay the the

1070

00:34:17,190 --> 00:34:15,359

the ordinary causal graph is the network

1071

00:34:20,310 --> 00:34:17,200

of causal relationships

1072

00:34:23,829 --> 00:34:20,320

between updating events in

1073

00:34:26,550 --> 00:34:23,839

space or in space time now

1074

00:34:27,430 --> 00:34:26,560

okay so that's that's one level of graph

1075

00:34:29,430 --> 00:34:27,440

the other

1076

00:34:30,950 --> 00:34:29,440

the next thing that we can talk about is

1077

00:34:33,750 --> 00:34:30,960

the multi-way graph

1078

00:34:33,990 --> 00:34:33,760

and then not to sound too confusing but

1079

00:34:37,270 --> 00:34:34,000

there's

1080

00:34:38,230 --> 00:34:37,280

also a multi-way causal graph um ah ah

1081

00:34:40,230 --> 00:34:38,240

okay okay

1082

00:34:41,349 --> 00:34:40,240

and the multi-way causal graph is just

1083

00:34:43,589 --> 00:34:41,359

so you know stephen i

1084

00:34:45,430 --> 00:34:43,599

i read virtually each one of the archive

1085

00:34:46,710 --> 00:34:45,440

papers and for some reason this

1086

00:34:48,470 --> 00:34:46,720

is a sticking point for me what's the

1087

00:34:50,069 --> 00:34:48,480

causal graph versus the multi-way graph

1088

00:34:52,230 --> 00:34:50,079

are they the same while they're defined

1089

00:34:53,990 --> 00:34:52,240

in the same document so it'd be unlikely

1090

00:34:55,510 --> 00:34:54,000

i i wrote this kind of technical

1091

00:34:56,470 --> 00:34:55,520

introduction to our project where i have

1092

00:34:57,910 --> 00:34:56,480

an appendix

1093

00:34:59,750 --> 00:34:57,920

that simply lists all the different

1094

00:35:01,510 --> 00:34:59,760

kinds of graphs because i knew people

1095

00:35:02,950 --> 00:35:01,520

and one of the things that was you know

1096

00:35:04,310 --> 00:35:02,960

there's a practicality of doing a big

1097

00:35:06,630 --> 00:35:04,320

project like this

1098

00:35:08,470 --> 00:35:06,640

you know there was a funny moment when

1099

00:35:10,710 --> 00:35:08,480

we did the colors

1100

00:35:12,069 --> 00:35:10,720

for all these graphs because what we

1101  
00:35:13,430 --> 00:35:12,079  
realized is you know you're just drawing

1102  
00:35:14,470 --> 00:35:13,440  
all these graphs and you see one of

1103  
00:35:16,550 --> 00:35:14,480  
these graphs and it's like

1104  
00:35:18,230 --> 00:35:16,560  
what on earth is this and we realized if

1105  
00:35:19,349 --> 00:35:18,240  
we have consistent coloring of these

1106  
00:35:21,030 --> 00:35:19,359  
different graphs

1107  
00:35:23,510 --> 00:35:21,040  
at least as soon as you see a graph you

1108  
00:35:24,069 --> 00:35:23,520  
say i mean we kind of joke that there's

1109  
00:35:26,550 --> 00:35:24,079  
this

1110  
00:35:28,470 --> 00:35:26,560  
color we call branchial pink which is

1111  
00:35:29,990 --> 00:35:28,480  
the color of our branchial graphs which

1112  
00:35:31,270 --> 00:35:30,000  
is yet another kind of we haven't even

1113  
00:35:34,630 --> 00:35:31,280

talked about yet

1114

00:35:36,470 --> 00:35:34,640

um but uh you know the the um uh

1115

00:35:37,670 --> 00:35:36,480

the causal graph we have you know the

1116

00:35:40,470 --> 00:35:37,680

events are in yellow

1117

00:35:42,150 --> 00:35:40,480

the edges are in brown the spatial graph

1118

00:35:44,230 --> 00:35:42,160

it's all sort of blue

1119

00:35:45,670 --> 00:35:44,240

um and the multi-way graph well let's

1120

00:35:48,550 --> 00:35:45,680

talk about the multi-way graph

1121

00:35:49,430 --> 00:35:48,560

so the multi-way graph in the simplest

1122

00:35:51,190 --> 00:35:49,440

form

1123

00:35:53,510 --> 00:35:51,200

the nodes of the multi-way graph are

1124

00:35:55,750 --> 00:35:53,520

complete states of the universe

1125

00:35:57,190 --> 00:35:55,760

so the paths in the multi-way graph

1126  
00:35:58,950 --> 00:35:57,200  
correspond to

1127  
00:36:00,230 --> 00:35:58,960  
possible histories for the whole

1128  
00:36:02,390 --> 00:36:00,240  
universe

1129  
00:36:04,150 --> 00:36:02,400  
um now that's what we might call the

1130  
00:36:06,230 --> 00:36:04,160  
global multi-way graph

1131  
00:36:07,829 --> 00:36:06,240  
um there's been a big effort max

1132  
00:36:09,589 --> 00:36:07,839  
piskanov has been the main one

1133  
00:36:11,190 --> 00:36:09,599  
sort of pushing this to have these

1134  
00:36:12,950 --> 00:36:11,200  
things we can call local multi-way

1135  
00:36:14,630 --> 00:36:12,960  
graphs

1136  
00:36:17,190 --> 00:36:14,640  
they're hard to understand but they're

1137  
00:36:19,349 --> 00:36:17,200  
important and they will help us to

1138  
00:36:21,829 --> 00:36:19,359

understand quantum field theory a lot

1139

00:36:23,510 --> 00:36:21,839

but they just uh they're there but the

1140

00:36:25,270 --> 00:36:23,520

global multi-way graph

1141

00:36:26,630 --> 00:36:25,280

every node is a complete state of the

1142

00:36:29,750 --> 00:36:26,640

universe

1143

00:36:33,349 --> 00:36:29,760

and so so then

1144

00:36:36,390 --> 00:36:33,359

the multi-way causal graph is asking

1145

00:36:38,470 --> 00:36:36,400

of those complete states of the universe

1146

00:36:39,510 --> 00:36:38,480

what are the causal relationships

1147

00:36:42,710 --> 00:36:39,520

between

1148

00:36:44,470 --> 00:36:42,720

universe

1149

00:36:47,109 --> 00:36:44,480

and that gives us the multi-way causal

1150

00:36:50,390 --> 00:36:47,119

graph and the the ordinary multi-way

1151  
00:36:51,670 --> 00:36:50,400  
of the ordinary causal graph is a is a

1152  
00:36:53,510 --> 00:36:51,680  
is a kind of a slice

1153  
00:36:54,870 --> 00:36:53,520  
of the multi-way causal graph so the

1154  
00:36:56,150 --> 00:36:54,880  
multi-way causal graph

1155  
00:36:58,069 --> 00:36:56,160  
represents the set of causal

1156  
00:37:00,710 --> 00:36:58,079  
relationships including

1157  
00:37:02,710 --> 00:37:00,720  
both things that could happen at

1158  
00:37:04,150 --> 00:37:02,720  
different places in space

1159  
00:37:05,910 --> 00:37:04,160  
and things that can happen on different

1160  
00:37:08,150 --> 00:37:05,920  
branches of history so

1161  
00:37:09,510 --> 00:37:08,160  
one talks about events being time-like

1162  
00:37:11,510 --> 00:37:09,520  
separated that is one

1163  
00:37:12,790 --> 00:37:11,520

they follow from each other in time

1164

00:37:14,470 --> 00:37:12,800

another possibility is that they're

1165

00:37:16,950 --> 00:37:14,480

space-like separated

1166

00:37:19,109 --> 00:37:16,960

that is those events correspond could

1167

00:37:22,069 --> 00:37:19,119

correspond to the same time

1168

00:37:23,910 --> 00:37:22,079

but they are separated in space there's

1169

00:37:25,510 --> 00:37:23,920

a third possibility which is they can be

1170

00:37:26,950 --> 00:37:25,520

branch-like separated

1171

00:37:29,109 --> 00:37:26,960

which means that they're occurring on

1172

00:37:30,870 --> 00:37:29,119

different branches of quantum history

1173

00:37:32,630 --> 00:37:30,880

and so there's all three of those time

1174

00:37:34,310 --> 00:37:32,640

like separation space like separation

1175

00:37:37,030 --> 00:37:34,320

branch-like separation

1176  
00:37:38,950 --> 00:37:37,040  
in the multi-way causal graph all three

1177  
00:37:41,990 --> 00:37:38,960  
kinds of separation occur

1178  
00:37:44,790 --> 00:37:42,000  
and um the the question of which one

1179  
00:37:46,470 --> 00:37:44,800  
uh you know any two events can be both

1180  
00:37:47,190 --> 00:37:46,480  
space-like separated and branch-like

1181  
00:37:48,550 --> 00:37:47,200  
separated

1182  
00:37:50,630 --> 00:37:48,560  
or they can be just branch-like

1183  
00:37:52,870 --> 00:37:50,640  
separated and so on and

1184  
00:37:53,750 --> 00:37:52,880  
that's a that object the multi-wave

1185  
00:37:56,230 --> 00:37:53,760  
causal graph

1186  
00:37:57,910 --> 00:37:56,240  
okay so for the spatial hypograph we

1187  
00:37:59,510 --> 00:37:57,920  
believe that it's continuum limit when

1188  
00:38:01,510 --> 00:37:59,520

you look at a large number of nodes

1189

00:38:02,630 --> 00:38:01,520

is like ordinary spaces like a manifold

1190

00:38:06,069 --> 00:38:02,640

it's like um

1191

00:38:07,990 --> 00:38:06,079

uh for the uh for the multi

1192

00:38:09,829 --> 00:38:08,000

for the ordinary causal graph it's the

1193

00:38:10,870 --> 00:38:09,839

same kind of thing it's like a minkowski

1194

00:38:13,829 --> 00:38:10,880

space it's like

1195

00:38:14,790 --> 00:38:13,839

the space you probably know that that

1196

00:38:17,109 --> 00:38:14,800

ordinary

1197

00:38:17,990 --> 00:38:17,119

you know something like euclidean space

1198

00:38:20,470 --> 00:38:18,000

has this feature

1199

00:38:21,829 --> 00:38:20,480

that you can move one way you can move

1200

00:38:23,750 --> 00:38:21,839

back you know every

1201  
00:38:25,750 --> 00:38:23,760  
every path you can go down you can you

1202  
00:38:27,510 --> 00:38:25,760  
can reverse it and go the other way

1203  
00:38:29,670 --> 00:38:27,520  
right that's a feature of ordinary space

1204  
00:38:33,030 --> 00:38:29,680  
i can move this way i can move that way

1205  
00:38:34,710 --> 00:38:33,040  
um in space time that's not how it works

1206  
00:38:36,390 --> 00:38:34,720  
we get to go forwards in time we don't

1207  
00:38:39,510 --> 00:38:36,400  
get to go backwards in time

1208  
00:38:41,190 --> 00:38:39,520  
and so that corresponds to the limit the

1209  
00:38:43,030 --> 00:38:41,200  
limiting structure is not euclidean

1210  
00:38:44,950 --> 00:38:43,040  
space but a minkowski space

1211  
00:38:46,550 --> 00:38:44,960  
and so that's the same kind of thing

1212  
00:38:48,630 --> 00:38:46,560  
with our causal graph

1213  
00:38:49,990 --> 00:38:48,640

the limiting structure is a minkowski

1214

00:38:51,510 --> 00:38:50,000

signature space

1215

00:38:54,230 --> 00:38:51,520

that is it can be in general a curved

1216

00:38:56,230 --> 00:38:54,240

space just like in general relativity

1217

00:38:57,829 --> 00:38:56,240

the multi-way causal graph we don't

1218

00:38:59,349 --> 00:38:57,839

understand very well yet what its

1219

00:39:02,630 --> 00:38:59,359

continuum limit is

1220

00:39:04,230 --> 00:39:02,640

it's a it's a weird kind of minkowski

1221

00:39:07,349 --> 00:39:04,240

like hilbert space

1222

00:39:09,349 --> 00:39:07,359

interesting and um it it a special case

1223

00:39:12,470 --> 00:39:09,359

of it is probably twister space

1224

00:39:13,109 --> 00:39:12,480

which is um uh this idea that's this

1225

00:39:14,630 --> 00:39:13,119

kind of neat

1226

00:39:17,270 --> 00:39:14,640

trick with complex numbers that roger

1227

00:39:20,150 --> 00:39:17,280

penrose invented back in the 1960s

1228

00:39:21,510 --> 00:39:20,160

as a way to understand um uh well to

1229

00:39:22,870 --> 00:39:21,520

think about sort of quantum mechanics

1230

00:39:24,550 --> 00:39:22,880

and space time and so on

1231

00:39:25,910 --> 00:39:24,560

but it's it's a that seems to be a

1232

00:39:26,950 --> 00:39:25,920

special case of the multi-way causal

1233

00:39:28,470 --> 00:39:26,960

graph but there's a

1234

00:39:30,870 --> 00:39:28,480

there needs to be a generalization of

1235

00:39:33,430 --> 00:39:30,880

that made to be able to um

1236

00:39:35,109 --> 00:39:33,440

uh to see how to um to see what that

1237

00:39:36,870 --> 00:39:35,119

continuum limit looks like

1238

00:39:38,870 --> 00:39:36,880

and and we can keep going and it's

1239

00:39:40,950 --> 00:39:38,880

things get wilder i mean we start

1240

00:39:43,829 --> 00:39:40,960

talking about some

1241

00:39:45,190 --> 00:39:43,839

oh well i mean the the yeah i mean there

1242

00:39:46,470 --> 00:39:45,200

are a lot of kinds of graphs running

1243

00:39:48,790 --> 00:39:46,480

around here

1244

00:39:50,390 --> 00:39:48,800

does causal invariance apply to one of

1245

00:39:51,430 --> 00:39:50,400

the graphs not the others or all the

1246

00:39:53,349 --> 00:39:51,440

graphs

1247

00:39:54,710 --> 00:39:53,359

causal variance is a feature of causal

1248

00:39:57,990 --> 00:39:54,720

graphs and

1249

00:39:59,829 --> 00:39:58,000

what it is telling you is that well

1250

00:40:01,750 --> 00:39:59,839

it's also a feature of multi-way graphs

1251  
00:40:03,670 --> 00:40:01,760  
let me be specific there's the condition

1252  
00:40:05,270 --> 00:40:03,680  
placed of causal invariance is that one

1253  
00:40:08,069 --> 00:40:05,280  
placed on the causal graph or is that

1254  
00:40:09,750 --> 00:40:08,079  
one placed on the multi-way graph

1255  
00:40:11,030 --> 00:40:09,760  
it applies to both it has it has

1256  
00:40:12,230 --> 00:40:11,040  
consequences for both of them they're

1257  
00:40:13,990 --> 00:40:12,240  
different consequences

1258  
00:40:16,470 --> 00:40:14,000  
the consequence of the multi-way graph

1259  
00:40:17,990 --> 00:40:16,480  
is it implies that in a simple

1260  
00:40:19,829 --> 00:40:18,000  
sense in simple sense which isn't

1261  
00:40:21,750 --> 00:40:19,839  
completely correct it says

1262  
00:40:22,870 --> 00:40:21,760  
every time there's a branch there's also

1263  
00:40:25,750 --> 00:40:22,880

a merge

1264

00:40:27,589 --> 00:40:25,760

every every time the the the the the

1265

00:40:29,270 --> 00:40:27,599

Pods of history diverge they will also

1266

00:40:31,349 --> 00:40:29,280

converge in the future

1267

00:40:33,030 --> 00:40:31,359

now it isn't that's confluence correct

1268

00:40:34,630 --> 00:40:33,040

that's confluence that's right okay

1269

00:40:36,550 --> 00:40:34,640

the and and causal and variance is a

1270

00:40:38,630 --> 00:40:36,560

generalization of that that also applies

1271

00:40:40,870 --> 00:40:38,640

to the infinite time case

1272

00:40:42,710 --> 00:40:40,880

right okay so one of the conditions for

1273

00:40:43,270 --> 00:40:42,720

causal or causal invariance implies

1274

00:40:46,870 --> 00:40:43,280

global

1275

00:40:48,630 --> 00:40:46,880

confluence what else is necessary

1276  
00:40:50,870 --> 00:40:48,640  
for causal invariance so one of the

1277  
00:40:52,870 --> 00:40:50,880  
conditions is global confluence

1278  
00:40:54,230 --> 00:40:52,880  
yes i mean it's its own separate

1279  
00:40:57,430 --> 00:40:54,240  
condition i mean it's a

1280  
00:40:59,670 --> 00:40:57,440  
it's a condition what it implies is that

1281  
00:41:02,710 --> 00:40:59,680  
the multi-way causal graph

1282  
00:41:05,990 --> 00:41:02,720  
breaks down into a whole collection of

1283  
00:41:08,870 --> 00:41:06,000  
individual non-multi-way single-way

1284  
00:41:10,309 --> 00:41:08,880  
causal graphs that is given a particular

1285  
00:41:13,589 --> 00:41:10,319  
branch of history

1286  
00:41:15,510 --> 00:41:13,599  
there is a a a causal graph and that

1287  
00:41:17,910 --> 00:41:15,520  
causal graph is independent of the

1288  
00:41:18,790 --> 00:41:17,920

of the microscopic order of updates so

1289

00:41:20,390 --> 00:41:18,800

in other words

1290

00:41:21,910 --> 00:41:20,400

the whole idea of causal variance which

1291

00:41:25,030 --> 00:41:21,920

was sort of a concept that i

1292

00:41:28,950 --> 00:41:25,040

i came up with in the in the 1990s um

1293

00:41:31,589 --> 00:41:28,960

was um uh this idea of okay so

1294

00:41:33,270 --> 00:41:31,599

you have all these updates and you can

1295

00:41:34,790 --> 00:41:33,280

say well what order should i do these

1296

00:41:37,910 --> 00:41:34,800

updates in

1297

00:41:39,190 --> 00:41:37,920

okay and you can looked at from the

1298

00:41:40,630 --> 00:41:39,200

outside of the system

1299

00:41:42,710 --> 00:41:40,640

you do these updates in different orders

1300

00:41:45,510 --> 00:41:42,720

you'll get different results

1301

00:41:47,109 --> 00:41:45,520

the the interesting fact is when certain

1302

00:41:50,150 --> 00:41:47,119

properties hold

1303

00:41:51,589 --> 00:41:50,160

the causal graph not the individual

1304

00:41:52,870 --> 00:41:51,599

sequence of updatings that you can

1305

00:41:56,069 --> 00:41:52,880

change the order of those

1306

00:41:57,990 --> 00:41:56,079

but the causal graph that connects those

1307

00:42:00,230 --> 00:41:58,000

different updates that gives the causal

1308

00:42:03,030 --> 00:42:00,240

relationships between those updates

1309

00:42:04,390 --> 00:42:03,040

that is the same for systems that are

1310

00:42:05,829 --> 00:42:04,400

causal invariant that's the importance

1311

00:42:08,710 --> 00:42:05,839

of causal and variance

1312

00:42:10,470 --> 00:42:08,720

is that the causal graph remains the

1313

00:42:12,870 --> 00:42:10,480

same and that's what pretty directly

1314

00:42:16,069 --> 00:42:12,880

leads to special relativity

1315

00:42:18,309 --> 00:42:16,079

so it's a feature of uh that's

1316

00:42:19,109 --> 00:42:18,319

that's a feature that the causal graph

1317

00:42:21,910 --> 00:42:19,119

is a unique

1318

00:42:23,829 --> 00:42:21,920

causal graph it could be the case that

1319

00:42:24,470 --> 00:42:23,839

as you do different updating orders for

1320

00:42:25,990 --> 00:42:24,480

things

1321

00:42:28,230 --> 00:42:26,000

that you end up with different causal

1322

00:42:31,510 --> 00:42:28,240

graphs but you don't

1323

00:42:32,230 --> 00:42:31,520

and and so that's the feature of causal

1324

00:42:34,710 --> 00:42:32,240

invariance

1325

00:42:35,829 --> 00:42:34,720

that gives you a unique causal graph and

1326

00:42:38,150 --> 00:42:35,839

that's why

1327

00:42:39,270 --> 00:42:38,160

sort of played in the in the relativity

1328

00:42:41,349 --> 00:42:39,280

situation

1329

00:42:42,870 --> 00:42:41,359

that's why different choices of

1330

00:42:44,630 --> 00:42:42,880

reference frames give you the same

1331

00:42:45,670 --> 00:42:44,640

physics that's the sort of underlying

1332

00:42:48,630 --> 00:42:45,680

cause of that

1333

00:42:51,270 --> 00:42:48,640

of that effect now you know what we've

1334

00:42:54,390 --> 00:42:51,280

understood in more recently

1335

00:42:55,829 --> 00:42:54,400

is causal variance can be an effective

1336

00:42:57,510 --> 00:42:55,839

causal invariance

1337

00:42:59,349 --> 00:42:57,520

that can be a kind of trickle-down

1338

00:43:02,630 --> 00:42:59,359

effect from

1339

00:43:03,990 --> 00:43:02,640

something much more uh

1340

00:43:06,870 --> 00:43:04,000

well again it's kind of complicated

1341

00:43:10,390 --> 00:43:06,880

because this is a an idea of jonathan's

1342

00:43:13,270 --> 00:43:10,400

is sort of to induce causal invariants

1343

00:43:14,230 --> 00:43:13,280

through what are called completions in

1344

00:43:20,630 --> 00:43:14,240

the

1345

00:43:23,990 --> 00:43:20,640

think is becoming clear

1346

00:43:25,670 --> 00:43:24,000

is that that we had thought

1347

00:43:26,790 --> 00:43:25,680

oh there are all these possible rules

1348

00:43:27,589 --> 00:43:26,800

only some of them will be causal

1349

00:43:29,829 --> 00:43:27,599

invariant

1350

00:43:31,910 --> 00:43:29,839

but it turns out that by the time we're

1351  
00:43:34,790 --> 00:43:31,920  
looking at kind of the trickle down

1352  
00:43:35,589 --> 00:43:34,800  
from this uh sort of universal possible

1353  
00:43:37,829 --> 00:43:35,599  
rules

1354  
00:43:38,870 --> 00:43:37,839  
there is an inevitable effect of causal

1355  
00:43:41,030 --> 00:43:38,880  
invariance there

1356  
00:43:43,030 --> 00:43:41,040  
so we we don't have to worry about oh

1357  
00:43:44,870 --> 00:43:43,040  
can we find a particular rule

1358  
00:43:46,390 --> 00:43:44,880  
that has these causal variance features

1359  
00:43:47,190 --> 00:43:46,400  
this this is a bit complicated and i'm

1360  
00:43:48,790 --> 00:43:47,200  
skipping

1361  
00:43:50,230 --> 00:43:48,800  
many steps and talking about this but

1362  
00:43:51,670 --> 00:43:50,240  
i'm trying to give a sense that

1363  
00:43:53,910 --> 00:43:51,680

that causal variance which we had

1364

00:43:55,270 --> 00:43:53,920

thought was a kind of a special property

1365

00:43:56,630 --> 00:43:55,280

it's like you know be a prime number

1366

00:43:58,950 --> 00:43:56,640

rather than just be a number

1367

00:44:00,390 --> 00:43:58,960

it's kind of inevitable the level of

1368

00:44:02,230 --> 00:44:00,400

causal variance needed is sort of an

1369

00:44:04,230 --> 00:44:02,240

inevitable consequence

1370

00:44:05,829 --> 00:44:04,240

of this sort of trickle down from

1371

00:44:06,710 --> 00:44:05,839

thinking about all possible rules for

1372

00:44:08,950 --> 00:44:06,720

the universe

1373

00:44:10,790 --> 00:44:08,960

this is a detail but never mind this

1374

00:44:12,470 --> 00:44:10,800

never mind this

1375

00:44:14,309 --> 00:44:12,480

um what are you what i haven't seen much

1376

00:44:15,990 --> 00:44:14,319

of an exploration of in the archive

1377

00:44:16,870 --> 00:44:16,000

papers is rulial space and that could

1378

00:44:19,109 --> 00:44:16,880

just be because

1379

00:44:19,990 --> 00:44:19,119

i haven't read the right ones okay so so

1380

00:44:23,589 --> 00:44:20,000

i i wrote

1381

00:44:25,750 --> 00:44:23,599

one uh piece about rule space

1382

00:44:27,510 --> 00:44:25,760

investigating a particular example of it

1383

00:44:30,390 --> 00:44:27,520

for touring machines

1384

00:44:31,910 --> 00:44:30,400

um and uh you know it's a very junior

1385

00:44:33,430 --> 00:44:31,920

version of the universe so to speak to

1386

00:44:34,069 --> 00:44:33,440

imagine the universe is just a turing

1387

00:44:36,630 --> 00:44:34,079

machine

1388

00:44:37,190 --> 00:44:36,640

so you know turing it just has this tape

1389

00:44:39,430 --> 00:44:37,200

where

1390

00:44:41,190 --> 00:44:39,440

there's uh symbols written on the tape

1391

00:44:42,710 --> 00:44:41,200

ones or zeros for example

1392

00:44:44,550 --> 00:44:42,720

and there's the turing machine has this

1393

00:44:47,589 --> 00:44:44,560

head that's walking up and down the

1394

00:44:51,109 --> 00:44:47,599

tape and um according to fixed

1395

00:44:53,270 --> 00:44:51,119

rules so

1396

00:44:55,270 --> 00:44:53,280

an ordinary turing machine just has a

1397

00:44:58,309 --> 00:44:55,280

fixed set of rules so it sees

1398

00:45:00,069 --> 00:44:58,319

a particular symbol on the tape it looks

1399

00:45:00,630 --> 00:45:00,079

up its sort of table for what it should

1400

00:45:02,390 --> 00:45:00,640

do

1401  
00:45:03,670 --> 00:45:02,400  
it moves the left or the right it writes

1402  
00:45:05,109 --> 00:45:03,680  
a different symbol on the tape

1403  
00:45:07,270 --> 00:45:05,119  
that's what an ordinary turing machine

1404  
00:45:08,550 --> 00:45:07,280  
does you can also have a multi-way

1405  
00:45:10,230 --> 00:45:08,560  
turing machine

1406  
00:45:12,630 --> 00:45:10,240  
where just like all these other

1407  
00:45:14,630 --> 00:45:12,640  
multi-way systems instead of it doing a

1408  
00:45:16,309 --> 00:45:14,640  
definite thing at every step

1409  
00:45:17,750 --> 00:45:16,319  
it has multiple things that it can do at

1410  
00:45:19,510 --> 00:45:17,760  
each step and so that

1411  
00:45:21,910 --> 00:45:19,520  
you then end up getting this multi-way

1412  
00:45:22,550 --> 00:45:21,920  
graph of possible histories of turing

1413  
00:45:24,309 --> 00:45:22,560

machines

1414

00:45:26,069 --> 00:45:24,319

yeah okay so then what you can do is you

1415

00:45:27,990 --> 00:45:26,079

can say well let me consider all

1416

00:45:30,790 --> 00:45:28,000

possible touring machines

1417

00:45:31,670 --> 00:45:30,800

interesting so that then is rualial space

1418

00:45:33,109 --> 00:45:31,680

that's a that's

1419

00:45:35,510 --> 00:45:33,119

in this particular example with this

1420

00:45:36,870 --> 00:45:35,520

particular coordination that is a rule

1421

00:45:39,990 --> 00:45:36,880

space of turing machines

1422

00:45:41,910 --> 00:45:40,000

where you're looking at the maximally uh

1423

00:45:43,030 --> 00:45:41,920

sort of non-deterministic turing machine

1424

00:45:46,069 --> 00:45:43,040

the turing machine

1425

00:45:49,109 --> 00:45:46,079

that where it can do any possible thing

1426

00:45:51,349 --> 00:45:49,119

um and that so

1427

00:45:52,550 --> 00:45:51,359

so one of the things that is interesting

1428

00:45:54,150 --> 00:45:52,560

is you might say

1429

00:45:56,630 --> 00:45:54,160

well if it can do any possible thing how

1430

00:45:57,910 --> 00:45:56,640

come there's any structure to the space

1431

00:45:59,750 --> 00:45:57,920

the reason there's a structure to the

1432

00:46:01,109 --> 00:45:59,760

space is the following you're saying i'm

1433

00:46:02,309 --> 00:46:01,119

starting off all possible touring

1434

00:46:04,710 --> 00:46:02,319

machines

1435

00:46:05,750 --> 00:46:04,720

and they do all possible things but the

1436

00:46:08,069 --> 00:46:05,760

point is that

1437

00:46:09,589 --> 00:46:08,079

two turing machines that start the same

1438

00:46:10,790 --> 00:46:09,599

and then branch into two different

1439

00:46:12,870 --> 00:46:10,800

states

1440

00:46:14,950 --> 00:46:12,880

it can be the case that those turing

1441

00:46:16,470 --> 00:46:14,960

machines can also merge that is those

1442

00:46:19,670 --> 00:46:16,480

two different states

1443

00:46:22,309 --> 00:46:19,680

can both end up uh

1444

00:46:23,430 --> 00:46:22,319

being being transformed to the same

1445

00:46:25,589 --> 00:46:23,440

state so

1446

00:46:27,510 --> 00:46:25,599

that phenomenon that when you have many

1447

00:46:30,550 --> 00:46:27,520

possible states

1448

00:46:31,670 --> 00:46:30,560

and you apply many possible rules

1449

00:46:33,030 --> 00:46:31,680

you can end up with something where

1450

00:46:34,309 --> 00:46:33,040

there's sort of this entanglement

1451  
00:46:36,790 --> 00:46:34,319  
between states

1452  
00:46:37,910 --> 00:46:36,800  
induced by the use of these rules so in

1453  
00:46:40,470 --> 00:46:37,920  
a sense it's this

1454  
00:46:41,829 --> 00:46:40,480  
it's the fact that identical states

1455  
00:46:45,109 --> 00:46:41,839  
merge

1456  
00:46:46,790 --> 00:46:45,119  
that leads to a kind of entanglement in

1457  
00:46:48,790 --> 00:46:46,800  
this multi-way graph

1458  
00:46:49,990 --> 00:46:48,800  
and that's what makes rural space

1459  
00:46:52,550 --> 00:46:50,000  
non-trivial

1460  
00:46:53,670 --> 00:46:52,560  
and so then the question is what is this

1461  
00:46:57,349 --> 00:46:53,680  
limit

1462  
00:46:59,270 --> 00:46:57,359  
of um uh

1463  
00:47:01,670 --> 00:46:59,280

you know when you have when you have

1464

00:47:04,069 --> 00:47:01,680

this limit of of all possible

1465

00:47:05,829 --> 00:47:04,079

rules being applied what is the thing

1466

00:47:07,270 --> 00:47:05,839

you get from this limit of all possible

1467

00:47:09,589 --> 00:47:07,280

rules being applied

1468

00:47:10,710 --> 00:47:09,599

and that object is this rule multi-way

1469

00:47:12,870 --> 00:47:10,720

graph

1470

00:47:14,309 --> 00:47:12,880

and uh that's that's kind of the the

1471

00:47:15,589 --> 00:47:14,319

object that represents kind of the

1472

00:47:18,710 --> 00:47:15,599

universal possible

1473

00:47:20,630 --> 00:47:18,720

universes so to speak so i mean these

1474

00:47:22,309 --> 00:47:20,640

are this this gets fairly abstract and

1475

00:47:23,270 --> 00:47:22,319

it's it's you know you can understand

1476

00:47:26,630 --> 00:47:23,280

this

1477

00:47:28,230 --> 00:47:26,640

i mean the the uh um

1478

00:47:29,829 --> 00:47:28,240

there's a whole kind of world of higher

1479

00:47:32,390 --> 00:47:29,839

category theory and so on

1480

00:47:33,990 --> 00:47:32,400

which provides a framework for thinking

1481

00:47:34,870 --> 00:47:34,000

about these kinds of things that i think

1482

00:47:36,230 --> 00:47:34,880

is useful

1483

00:47:38,309 --> 00:47:36,240

i think a bunch has been done it's one

1484

00:47:40,630 --> 00:47:38,319

of these places of sort of mathematical

1485

00:47:43,990 --> 00:47:40,640

physics mathematics kind of area

1486

00:47:50,549 --> 00:47:44,000

where um you know a lot has been built

1487

00:47:57,030 --> 00:47:54,630

the um um uh

1488

00:48:00,390 --> 00:47:57,040

a lot that has been built turns out to

1489

00:48:04,390 --> 00:48:03,670

you know i'm extremely impressed with

1490

00:48:07,829 --> 00:48:04,400

this model

1491

00:48:09,589 --> 00:48:07,839

both it's its simplicity and his power

1492

00:48:10,950 --> 00:48:09,599

i don't like to give my opinions usually

1493

00:48:12,630 --> 00:48:10,960

when i'm interviewing someone because

1494

00:48:13,750 --> 00:48:12,640

the audience doesn't particularly care

1495

00:48:18,470 --> 00:48:13,760

about what i think

1496

00:48:22,710 --> 00:48:18,480

and in some ways it detracts but i

1497

00:48:24,470 --> 00:48:22,720

i find i find plenty of it to be fun

1498

00:48:26,870 --> 00:48:24,480

in the sense that there are these

1499

00:48:28,549 --> 00:48:26,880

elemental elements these novelties

1500

00:48:29,990 --> 00:48:28,559

then you're wondering well okay so we

1501

00:48:31,109 --> 00:48:30,000

have these hyper graphs we have updating

1502

00:48:33,030 --> 00:48:31,119

rules and so on

1503

00:48:34,390 --> 00:48:33,040

and we have our laws of physics okay how

1504

00:48:36,549 --> 00:48:34,400

can this limit to that

1505

00:48:37,829 --> 00:48:36,559

and i imagine much of the working

1506

00:48:39,030 --> 00:48:37,839

sessions i've only watched a couple

1507

00:48:42,150 --> 00:48:39,040

imagine them

1508

00:48:44,870 --> 00:48:42,160

that they're quite enjoyable oh yeah

1509

00:48:46,230 --> 00:48:44,880

i do this because it's fun i mean it's

1510

00:48:48,309 --> 00:48:46,240

as simple as that but but

1511

00:48:50,470 --> 00:48:48,319

you know one thing i would like to say

1512

00:48:52,549 --> 00:48:50,480

about this you've got a model over here

1513

00:48:53,990 --> 00:48:52,559

you've got physics that we know over

1514

00:48:56,549 --> 00:48:54,000

here

1515

00:48:58,950 --> 00:48:56,559

one of the things that is an important

1516

00:49:01,190 --> 00:48:58,960

kind of intuitional thing to realize is

1517

00:49:02,390 --> 00:49:01,200

don't reverse engineer from the physics

1518

00:49:04,390 --> 00:49:02,400

we think we know

1519

00:49:06,230 --> 00:49:04,400

that is a tremendous tendency of people

1520

00:49:07,750 --> 00:49:06,240

to do that and it's a tremendous you

1521

00:49:10,069 --> 00:49:07,760

know we know all this stuff

1522

00:49:12,790 --> 00:49:10,079

so let's figure out that must mean that

1523

00:49:15,910 --> 00:49:12,800

underneath it is this this and this

1524

00:49:17,670 --> 00:49:15,920

that's not how this was built this was

1525

00:49:20,549 --> 00:49:17,680

given this

1526  
00:49:22,630 --> 00:49:20,559  
you know very simple framework what

1527  
00:49:24,309 --> 00:49:22,640  
consequences does it have

1528  
00:49:26,870 --> 00:49:24,319  
now is it going to intersect with actual

1529  
00:49:28,470 --> 00:49:26,880  
physics or did we just miss completely

1530  
00:49:30,230 --> 00:49:28,480  
and is this a model of nothing in

1531  
00:49:31,990 --> 00:49:30,240  
particular the

1532  
00:49:33,829 --> 00:49:32,000  
you know it's very important that you

1533  
00:49:36,870 --> 00:49:33,839  
build up from the simple

1534  
00:49:39,270 --> 00:49:36,880  
model and then you see where you build

1535  
00:49:41,030 --> 00:49:39,280  
and it so happens that the amazing thing

1536  
00:49:42,309 --> 00:49:41,040  
that was really the big surprise of a

1537  
00:49:44,630 --> 00:49:42,319  
year and a bit ago

1538  
00:49:46,069 --> 00:49:44,640

is you know the thing we built is

1539

00:49:47,829 --> 00:49:46,079

physics basically

1540

00:49:49,270 --> 00:49:47,839

and that's the thing that was that was

1541

00:49:50,069 --> 00:49:49,280

sort of the big surprise it might not

1542

00:49:53,190 --> 00:49:50,079

have been

1543

00:49:54,150 --> 00:49:53,200

you know as it's turning out okay i now

1544

00:49:57,990 --> 00:49:54,160

realize

1545

00:50:00,390 --> 00:49:58,000

years ago that it's sort of inevitable

1546

00:50:01,750 --> 00:50:00,400

that this has to be physics but that

1547

00:50:04,230 --> 00:50:01,760

wasn't obvious to me

1548

00:50:05,430 --> 00:50:04,240

as we were building it and it's it's the

1549

00:50:07,670 --> 00:50:05,440

thing that's been

1550

00:50:09,589 --> 00:50:07,680

really interesting to me is the

1551  
00:50:10,710 --> 00:50:09,599  
realization that not only is it a model

1552  
00:50:12,230 --> 00:50:10,720  
of physics

1553  
00:50:14,710 --> 00:50:12,240  
it's also a model of a whole bunch of

1554  
00:50:17,030 --> 00:50:14,720  
other things and

1555  
00:50:18,630 --> 00:50:17,040  
that you know i have the experience with

1556  
00:50:19,589 --> 00:50:18,640  
cellular automata that i worked on for

1557  
00:50:21,589 --> 00:50:19,599  
many years

1558  
00:50:23,270 --> 00:50:21,599  
so cellular automata are just these

1559  
00:50:25,190 --> 00:50:23,280  
extremely simple programs

1560  
00:50:26,549 --> 00:50:25,200  
where you just have a line of cells

1561  
00:50:27,270 --> 00:50:26,559  
let's say each one is either black or

1562  
00:50:29,589 --> 00:50:27,280  
white

1563  
00:50:30,950 --> 00:50:29,599

and then a series of steps you update

1564

00:50:32,470 --> 00:50:30,960

the color of a cell according to the

1565

00:50:33,910 --> 00:50:32,480

color of the cell above it and to its

1566

00:50:36,309 --> 00:50:33,920

left and right let's say

1567

00:50:37,750 --> 00:50:36,319

you might have thought that a simple

1568

00:50:39,190 --> 00:50:37,760

rule like that would always lead to

1569

00:50:40,710 --> 00:50:39,200

simple patterns of behavior

1570

00:50:43,349 --> 00:50:40,720

but the big discovery that i made in the

1571

00:50:44,950 --> 00:50:43,359

early 1980s is that that's not true

1572

00:50:47,349 --> 00:50:44,960

that you can get very complicated

1573

00:50:48,630 --> 00:50:47,359

behavior even from very simple rules

1574

00:50:50,790 --> 00:50:48,640

and the thing that happened with

1575

00:50:51,910 --> 00:50:50,800

cellular automata is they're very

1576

00:50:53,990 --> 00:50:51,920

minimal models

1577

00:50:56,790 --> 00:50:54,000

they're just you have a line of cells or

1578

00:50:58,309 --> 00:50:56,800

you have a a array of cells or whatever

1579

00:50:59,829 --> 00:50:58,319

and you're applying these local rules

1580

00:51:00,950 --> 00:50:59,839

and you're updating the thing very

1581

00:51:03,270 --> 00:51:00,960

minimal model

1582

00:51:04,309 --> 00:51:03,280

so then you roll the clock forward a few

1583

00:51:06,549 --> 00:51:04,319

decades

1584

00:51:08,390 --> 00:51:06,559

and you realize oh gosh there are models

1585

00:51:09,510 --> 00:51:08,400

that use cellular automata for zillions

1586

00:51:12,150 --> 00:51:09,520

of different things

1587

00:51:12,549 --> 00:51:12,160

from you know road traffic flow to you

1588

00:51:16,069 --> 00:51:12,559

know

1589

00:51:18,630 --> 00:51:16,079

the way leaves work to the way that um

1590

00:51:19,990 --> 00:51:18,640

i don't know catalysts and and camera

1591

00:51:22,150 --> 00:51:20,000

and surfaces work

1592

00:51:24,150 --> 00:51:22,160

to the way all kinds of different things

1593

00:51:25,190 --> 00:51:24,160

all kinds of to mollusk pigmentation

1594

00:51:27,430 --> 00:51:25,200

patterns whatever

1595

00:51:29,750 --> 00:51:27,440

all kinds of different things and so in

1596

00:51:31,510 --> 00:51:29,760

a sense you have this very minimal model

1597

00:51:33,030 --> 00:51:31,520

which in that particular case assumes a

1598

00:51:34,710 --> 00:51:33,040

certain structure of space and time but

1599

00:51:36,790 --> 00:51:34,720

you have a very minimal model

1600

00:51:38,309 --> 00:51:36,800

and that model ends up being a model of

1601  
00:51:39,910 --> 00:51:38,319  
lots of kinds of things so in a sense

1602  
00:51:42,630 --> 00:51:39,920  
it's unsurprising

1603  
00:51:43,430 --> 00:51:42,640  
that this much more flexible model that

1604  
00:51:46,549 --> 00:51:43,440  
we have

1605  
00:51:48,710 --> 00:51:46,559  
that we built for physics ends up

1606  
00:51:50,069 --> 00:51:48,720  
looking like it's going to be a really i

1607  
00:51:51,910 --> 00:51:50,079  
mean you know very

1608  
00:51:53,910 --> 00:51:51,920  
powerful model for the foundations of a

1609  
00:51:55,589 --> 00:51:53,920  
whole bunch of other fields as well

1610  
00:51:57,270 --> 00:51:55,599  
and the thing that's really interesting

1611  
00:51:58,630 --> 00:51:57,280  
about that is you know so i've been

1612  
00:51:59,670 --> 00:51:58,640  
doing a whole bunch of work on meta

1613  
00:52:00,950 --> 00:51:59,680

mathematics

1614

00:52:03,349 --> 00:52:00,960

the kind of overall structure of

1615

00:52:05,829 --> 00:52:03,359

mathematics where where the nodes

1616

00:52:07,430 --> 00:52:05,839

are not atoms of space but the nodes are

1617

00:52:09,109 --> 00:52:07,440

mathematical theorems

1618

00:52:11,430 --> 00:52:09,119

and the relationships between them are

1619

00:52:12,630 --> 00:52:11,440

proofs of one theorem from another

1620

00:52:13,910 --> 00:52:12,640

well you might say what does that what

1621

00:52:15,750 --> 00:52:13,920

on earth does that have to do with the

1622

00:52:18,470 --> 00:52:15,760

structure of the physical universe

1623

00:52:20,230 --> 00:52:18,480

but it turns out that it looks like the

1624

00:52:22,150 --> 00:52:20,240

the formalistic structure of that

1625

00:52:23,510 --> 00:52:22,160

is the same as the structure of the

1626  
00:52:26,309 --> 00:52:23,520  
physical universe

1627  
00:52:26,870 --> 00:52:26,319  
and that's um that's something that's uh

1628  
00:52:32,150 --> 00:52:26,880  
both

1629  
00:52:34,069 --> 00:52:32,160  
the most important thing for me is

1630  
00:52:35,430 --> 00:52:34,079  
it means that you get to have this kind

1631  
00:52:37,109 --> 00:52:35,440  
of cross-connection

1632  
00:52:38,470 --> 00:52:37,119  
of the ideas from metamathematics and

1633  
00:52:39,910 --> 00:52:38,480  
the ideas from physics

1634  
00:52:42,309 --> 00:52:39,920  
so in physics we've learned a lot of

1635  
00:52:44,309 --> 00:52:42,319  
stuff about how general relativity works

1636  
00:52:46,710 --> 00:52:44,319  
how all these kinds of things work so

1637  
00:52:48,790 --> 00:52:46,720  
now we get to import those ideas

1638  
00:52:50,950 --> 00:52:48,800

into meta mathematics and we get to

1639

00:52:53,190 --> 00:52:50,960

import the ideas of mathematical logic

1640

00:52:55,589 --> 00:52:53,200

into physics and so by realizing that

1641

00:52:57,430 --> 00:52:55,599

the underlying formalism is the same

1642

00:52:59,910 --> 00:52:57,440

we get to make that kind of uh

1643

00:53:00,790 --> 00:52:59,920

conversion and this formalism also seems

1644

00:53:02,790 --> 00:53:00,800

to be

1645

00:53:04,710 --> 00:53:02,800

uh really the right formalism to think

1646

00:53:06,390 --> 00:53:04,720

about distributed computing

1647

00:53:08,549 --> 00:53:06,400

it may very well be the right formalism

1648

00:53:11,589 --> 00:53:08,559

to think about systems biology

1649

00:53:14,630 --> 00:53:11,599

and it uh the the one that i've been

1650

00:53:16,069 --> 00:53:14,640

poking at a lot recently is economics

1651  
00:53:17,349 --> 00:53:16,079  
and it may well be the right formalism

1652  
00:53:18,390 --> 00:53:17,359  
to think about that in each of these

1653  
00:53:21,270 --> 00:53:18,400  
applications

1654  
00:53:22,870 --> 00:53:21,280  
the details of of what the corresponding

1655  
00:53:23,750 --> 00:53:22,880  
what the thing that's like the atoms of

1656  
00:53:25,670 --> 00:53:23,760  
spaces

1657  
00:53:26,950 --> 00:53:25,680  
are different and the details of how it

1658  
00:53:28,390 --> 00:53:26,960  
works is different

1659  
00:53:30,230 --> 00:53:28,400  
but the point is that the overall

1660  
00:53:32,309 --> 00:53:30,240  
structure the overall formalism

1661  
00:53:34,390 --> 00:53:32,319  
seems to carry over and that allows you

1662  
00:53:35,750 --> 00:53:34,400  
to use sort of big ideas from one field

1663  
00:53:37,829 --> 00:53:35,760

in another field

1664

00:53:40,069 --> 00:53:37,839

so that's that's been uh you know it's

1665

00:53:41,990 --> 00:53:40,079

it's a it's a more global theory

1666

00:53:44,710 --> 00:53:42,000

than i ever imagined it could possibly

1667

00:53:47,430 --> 00:53:44,720

be and and i've realized that um

1668

00:53:48,069 --> 00:53:47,440

the you know the fundamental uh sort of

1669

00:53:49,589 --> 00:53:48,079

struggle

1670

00:53:51,510 --> 00:53:49,599

in a sense for these theories is the

1671

00:53:53,750 --> 00:53:51,520

following you have a simple rule

1672

00:53:56,150 --> 00:53:53,760

underneath but that simple rule just

1673

00:53:58,309 --> 00:53:56,160

like in my cellular automata

1674

00:53:59,990 --> 00:53:58,319

the simple rule leads to very

1675

00:54:01,109 --> 00:54:00,000

complicated behavior but it leads to

1676  
00:54:03,190 --> 00:54:01,119  
behavior that is

1677  
00:54:04,630 --> 00:54:03,200  
computationally irreducible in the sense

1678  
00:54:06,630 --> 00:54:04,640  
it's complicated enough

1679  
00:54:08,150 --> 00:54:06,640  
you can't tell what's going to happen

1680  
00:54:09,910 --> 00:54:08,160  
without basically just running the rule

1681  
00:54:11,910 --> 00:54:09,920  
and seeing what happens

1682  
00:54:12,950 --> 00:54:11,920  
so then the thing which i should have

1683  
00:54:16,630 --> 00:54:12,960  
been able to figure out

1684  
00:54:18,230 --> 00:54:16,640  
but didn't is in assume that there's a

1685  
00:54:20,150 --> 00:54:18,240  
simple underlying rule for the universe

1686  
00:54:22,150 --> 00:54:20,160  
there's computational irreducibility

1687  
00:54:23,589 --> 00:54:22,160  
that produces immense complexity in the

1688  
00:54:25,670 --> 00:54:23,599

behavior of the universe

1689

00:54:26,950 --> 00:54:25,680

how come we can figure out anything

1690

00:54:28,710 --> 00:54:26,960

about the universe

1691

00:54:30,069 --> 00:54:28,720

how come we can even say the universe

1692

00:54:31,589 --> 00:54:30,079

follows definite laws

1693

00:54:34,150 --> 00:54:31,599

how come we can predict what's going to

1694

00:54:36,470 --> 00:54:34,160

happen at all why isn't it just a whole

1695

00:54:37,589 --> 00:54:36,480

mass of irreducibility and what you

1696

00:54:39,510 --> 00:54:37,599

realize is

1697

00:54:41,589 --> 00:54:39,520

within any computational irreducible

1698

00:54:42,549 --> 00:54:41,599

system there are always these pockets of

1699

00:54:44,309 --> 00:54:42,559

reduceability

1700

00:54:46,390 --> 00:54:44,319

there are always pockets yeah there are

1701

00:54:48,150 --> 00:54:46,400

always pockets of reducibility it's it's

1702

00:54:49,670 --> 00:54:48,160

so there is no way to construct the

1703

00:54:51,270 --> 00:54:49,680

system that's computationally

1704

00:54:52,150 --> 00:54:51,280

irreducible that has no pockets of

1705

00:54:54,630 --> 00:54:52,160

reducibility

1706

00:54:55,589 --> 00:54:54,640

i believe that to be correct okay but i

1707

00:54:58,789 --> 00:54:55,599

mean there

1708

00:55:00,549 --> 00:54:58,799

no i mean that's a to

1709

00:55:02,950 --> 00:55:00,559

fully formalize that notion would be

1710

00:55:04,950 --> 00:55:02,960

quite interesting i suspect that you can

1711

00:55:07,349 --> 00:55:04,960

get some formalization through speed up

1712

00:55:11,030 --> 00:55:07,359

theorems in in computation theory

1713

00:55:12,309 --> 00:55:11,040

but um i think it's it is intuitively

1714

00:55:15,750 --> 00:55:12,319

fairly obvious

1715

00:55:17,430 --> 00:55:15,760

but if as you try and nail it down um uh

1716

00:55:18,789 --> 00:55:17,440

there will be you know i think the speed

1717

00:55:19,430 --> 00:55:18,799

up theorems are the way to think about

1718

00:55:22,470 --> 00:55:19,440

that

1719

00:55:25,670 --> 00:55:22,480

in a somewhat more formal way but um

1720

00:55:27,430 --> 00:55:25,680

so in any case the the um uh the thing

1721

00:55:28,710 --> 00:55:27,440

that one realizes is

1722

00:55:31,349 --> 00:55:28,720

so there are these pockets of

1723

00:55:33,510 --> 00:55:31,359

reducibility that exists

1724

00:55:35,750 --> 00:55:33,520

and the thing that is sort of the the

1725

00:55:37,510 --> 00:55:35,760

big surprise is

1726

00:55:39,430 --> 00:55:37,520

those pockets correspond to the big

1727

00:55:41,910 --> 00:55:39,440

theories of physics

1728

00:55:43,430 --> 00:55:41,920

each one has probed some pocket now the

1729

00:55:46,390 --> 00:55:43,440

next question is

1730

00:55:47,510 --> 00:55:46,400

are there other pockets that have never

1731

00:55:49,030 --> 00:55:47,520

been discovered that are

1732

00:55:50,710 --> 00:55:49,040

theories of physics that we just don't

1733

00:55:52,549 --> 00:55:50,720

know that are complete

1734

00:55:53,910 --> 00:55:52,559

global theories like general somebody

1735

00:55:55,990 --> 00:55:53,920

like quantum mechanics

1736

00:55:57,829 --> 00:55:56,000

but we don't know them and what i

1737

00:56:01,510 --> 00:55:57,839

realized recently is

1738

00:56:05,190 --> 00:56:01,520

that the the kind of the the

1739

00:56:06,069 --> 00:56:05,200

you know the reason that we know those

1740

00:56:07,750 --> 00:56:06,079

theories

1741

00:56:09,589 --> 00:56:07,760

is because there are certain attributes

1742

00:56:10,630 --> 00:56:09,599

that we as observers of the universe

1743

00:56:13,190 --> 00:56:10,640

have

1744

00:56:14,069 --> 00:56:13,200

and those attributes lead us to those

1745

00:56:15,990 --> 00:56:14,079

theories so

1746

00:56:17,990 --> 00:56:16,000

the attributes are things like that we

1747

00:56:20,870 --> 00:56:18,000

have a computationally bounded

1748

00:56:21,990 --> 00:56:20,880

way of understanding the universe now

1749

00:56:24,470 --> 00:56:22,000

that's one of them

1750

00:56:27,190 --> 00:56:24,480

another one is that we have a definite

1751

00:56:31,030 --> 00:56:27,200

thread of experience in time

1752

00:56:32,789 --> 00:56:31,040

we we are we are not operating with many

1753

00:56:33,750 --> 00:56:32,799

many many threads of experience we have

1754

00:56:35,589 --> 00:56:33,760

a definite

1755

00:56:37,670 --> 00:56:35,599

sort of thread of consciousness that we

1756

00:56:40,309 --> 00:56:37,680

follow we're not um

1757

00:56:42,309 --> 00:56:40,319

uh and that and in fact the thing i

1758

00:56:45,349 --> 00:56:42,319

realized just in the last week actually

1759

00:56:47,109 --> 00:56:45,359

um is uh uh

1760

00:56:49,349 --> 00:56:47,119

one of the things that is non-trivial in

1761

00:56:52,069 --> 00:56:49,359

our models is the notion of

1762

00:56:53,910 --> 00:56:52,079

uh maintaining your identity so to speak

1763

00:56:56,710 --> 00:56:53,920

so in this hypergraph

1764

00:56:57,990 --> 00:56:56,720

every every atom of space is being

1765

00:57:00,789 --> 00:56:58,000

destroyed a new one is being

1766

00:57:02,470 --> 00:57:00,799

created all the time so the question is

1767

00:57:05,349 --> 00:57:02,480

how come you and me

1768

00:57:05,990 --> 00:57:05,359

seem like we sort of exist through time

1769

00:57:08,630 --> 00:57:06,000

turns out

1770

00:57:09,910 --> 00:57:08,640

our atoms of space are being destroyed

1771

00:57:12,470 --> 00:57:09,920

and recreated

1772

00:57:13,910 --> 00:57:12,480

you know whatever it is 10 to 100 times

1773

00:57:16,390 --> 00:57:13,920

per second

1774

00:57:18,470 --> 00:57:16,400

so in other words how come we are a

1775

00:57:20,710 --> 00:57:18,480

thing we maintain our identity

1776

00:57:21,670 --> 00:57:20,720

that is a non-trivial fact about us as

1777

00:57:25,190 --> 00:57:21,680

observers

1778

00:57:27,349 --> 00:57:25,200

that we we we consider ourselves to

1779

00:57:29,589 --> 00:57:27,359

maintain our identity

1780

00:57:31,829 --> 00:57:29,599

and through time the thing i realized

1781

00:57:34,470 --> 00:57:31,839

just recently is there's a similar

1782

00:57:36,630 --> 00:57:34,480

way in which we do that in space it is

1783

00:57:38,309 --> 00:57:36,640

not obvious that there would be a pure

1784

00:57:41,109 --> 00:57:38,319

notion of motion

1785

00:57:42,950 --> 00:57:41,119

that is that you could move you know as

1786

00:57:45,270 --> 00:57:42,960

i move from here to there

1787

00:57:46,549 --> 00:57:45,280

the atoms of space that are in me are

1788

00:57:50,069 --> 00:57:46,559

different

1789

00:57:52,230 --> 00:57:50,079

and right yet me i have an identity

1790

00:57:53,510 --> 00:57:52,240

that i think i can carry around i can

1791

00:57:55,990 --> 00:57:53,520

carry it through time

1792

00:57:57,270 --> 00:57:56,000

i carry it around in space the

1793

00:58:00,630 --> 00:57:57,280

assumption

1794

00:58:02,549 --> 00:58:00,640

that i maintain that identity is

1795

00:58:05,109 --> 00:58:02,559

what ends up being sort of a tail that

1796

00:58:06,549 --> 00:58:05,119

wags eventually that gives us the laws

1797

00:58:09,109 --> 00:58:06,559

of physics that we know

1798

00:58:11,190 --> 00:58:09,119

in other words if we did not have that

1799

00:58:13,670 --> 00:58:11,200

assumption about ourselves

1800

00:58:15,670 --> 00:58:13,680

we would have different laws of physics

1801  
00:58:18,710 --> 00:58:15,680  
and if we didn't have

1802  
00:58:19,990 --> 00:58:18,720  
for example the the notion that

1803  
00:58:22,069 --> 00:58:20,000  
oh i don't know this quantum

1804  
00:58:23,910 --> 00:58:22,079  
measurements occur the notion that we

1805  
00:58:26,870 --> 00:58:23,920  
we collapse all these different parts of

1806  
00:58:29,750 --> 00:58:26,880  
history into a single definite outcome

1807  
00:58:30,069 --> 00:58:29,760  
that is directly related to the fact

1808  
00:58:33,829 --> 00:58:30,079  
that

1809  
00:58:36,069 --> 00:58:33,839  
identity through time

1810  
00:58:37,510 --> 00:58:36,079  
that in other words if if we just said

1811  
00:58:38,950 --> 00:58:37,520  
oh i don't care about that

1812  
00:58:40,870 --> 00:58:38,960  
i'm not going to maintain a definite

1813  
00:58:42,069 --> 00:58:40,880

identity through time i'm perfectly

1814

00:58:45,510 --> 00:58:42,079

happy to have myself

1815

00:58:48,630 --> 00:58:45,520

branched a zillion times

1816

00:58:51,670 --> 00:58:48,640

then you no longer get this idea

1817

00:58:53,030 --> 00:58:51,680

that we imagine about quantum mechanics

1818

00:58:54,789 --> 00:58:53,040

that there are somewhat there are

1819

00:58:58,309 --> 00:58:54,799

definite outcomes that occur

1820

00:59:00,710 --> 00:58:58,319

so in other words it's it's our our

1821

00:59:02,710 --> 00:59:00,720

way of constructing ourselves and the

1822

00:59:04,309 --> 00:59:02,720

way we think about ourselves

1823

00:59:06,630 --> 00:59:04,319

and the way we kind of perceive the

1824

00:59:08,069 --> 00:59:06,640

universe that drives the structure of

1825

00:59:10,710 --> 00:59:08,079

the laws of physics that

1826

00:59:11,990 --> 00:59:10,720

that we know so one of the things that

1827

00:59:13,510 --> 00:59:12,000

that obviously leads to

1828

00:59:15,750 --> 00:59:13,520

is well maybe there are completely other

1829

00:59:17,430 --> 00:59:15,760

laws of physics and a completely other

1830

00:59:19,670 --> 00:59:17,440

sort of plane of existence

1831

00:59:20,549 --> 00:59:19,680

that we are utterly unfamiliar with and

1832

00:59:23,589 --> 00:59:20,559

i think that's

1833

00:59:24,390 --> 00:59:23,599

almost undeniably the case that that

1834

00:59:25,670 --> 00:59:24,400

exists

1835

00:59:27,430 --> 00:59:25,680

and that's probably one of the reasons

1836

00:59:28,870 --> 00:59:27,440

why you know when you say what about

1837

00:59:31,030 --> 00:59:28,880

other intelligence in the universe why

1838

00:59:34,549 --> 00:59:31,040

haven't we met all the aliens and so on

1839

00:59:36,150 --> 00:59:34,559

well because actually their

1840

00:59:37,910 --> 00:59:36,160

sort of perception of the universe may

1841

00:59:40,549 --> 00:59:37,920

be so different from ours

1842

00:59:42,069 --> 00:59:40,559

it's kind of incoherently different and

1843

00:59:44,829 --> 00:59:42,079

it's not something where

1844

00:59:46,069 --> 00:59:44,839

our our narrative about how the universe

1845

00:59:47,910 --> 00:59:46,079

works

1846

00:59:49,670 --> 00:59:47,920

kind of carries over to those those

1847

00:59:52,549 --> 00:59:49,680

those kinds of uh

1848

00:59:53,589 --> 00:59:52,559

places so it's it's a it's in a sense

1849

00:59:55,510 --> 00:59:53,599

it's a rather humbling

1850

00:59:57,109 --> 00:59:55,520

experience because you're realizing that

1851

00:59:58,309 --> 00:59:57,119

that you know all the stuff we built in

1852

01:00:00,470 --> 00:59:58,319

physics and so on

1853

01:00:01,589 --> 01:00:00,480

is all we built it because that's the

1854

01:00:03,910 --> 01:00:01,599

way that we

1855

01:00:05,910 --> 01:00:03,920

parse the universe so to speak and were

1856

01:00:07,190 --> 01:00:05,920

we to parse the universe differently

1857

01:00:09,270 --> 01:00:07,200

we would have completely different views

1858

01:00:10,870 --> 01:00:09,280

of physics um

1859

01:00:13,190 --> 01:00:10,880

and i mean i think the thing that has

1860

01:00:15,349 --> 01:00:13,200

been well this is this week's issue

1861

01:00:16,630 --> 01:00:15,359

is thinking about that in terms of

1862

01:00:18,549 --> 01:00:16,640

mathematics

1863

01:00:19,750 --> 01:00:18,559

insofar as we believe that there is this

1864

01:00:21,430 --> 01:00:19,760

kind of object

1865

01:00:23,109 --> 01:00:21,440

that represents the mathematics of all

1866

01:00:26,069 --> 01:00:23,119

possible mathematicses

1867

01:00:27,030 --> 01:00:26,079

and that we are merely as mathematicians

1868

01:00:29,510 --> 01:00:27,040

so to speak

1869

01:00:31,589 --> 01:00:29,520

we are merely observers observing some

1870

01:00:34,309 --> 01:00:31,599

slice of that object

1871

01:00:35,750 --> 01:00:34,319

what is the what is the analog of the

1872

01:00:37,030 --> 01:00:35,760

constraints of consciousness and the

1873

01:00:39,510 --> 01:00:37,040

physical world

1874

01:00:41,270 --> 01:00:39,520

on the on sort of what is a mathematical

1875

01:00:43,109 --> 01:00:41,280

consciousness so to speak that's my

1876  
01:00:44,630 --> 01:00:43,119  
that's my that's my personal homework

1877  
01:00:46,230 --> 01:00:44,640  
exercise for the week

1878  
01:00:47,750 --> 01:00:46,240  
um that's interesting so this

1879  
01:00:49,270 --> 01:00:47,760  
consciousness that we have isn't

1880  
01:00:51,270 --> 01:00:49,280  
necessarily that

1881  
01:00:52,710 --> 01:00:51,280  
we can't communicate with any other

1882  
01:00:54,390 --> 01:00:52,720  
being because

1883  
01:00:56,630 --> 01:00:54,400  
the laws of physics that they perceive

1884  
01:00:58,549 --> 01:00:56,640  
is incoherent do they perceive coherent

1885  
01:01:01,270 --> 01:00:58,559  
laws

1886  
01:01:03,910 --> 01:01:01,280  
yes i think so i think so i mean but the

1887  
01:01:07,030 --> 01:01:03,920  
way you think about it is this

1888  
01:01:08,390 --> 01:01:07,040

in this kind of rualial space different

1889

01:01:10,390 --> 01:01:08,400

points in rule space

1890

01:01:12,710 --> 01:01:10,400

correspond to different description

1891

01:01:15,829 --> 01:01:12,720

languages for the universe

1892

01:01:17,270 --> 01:01:15,839

so just like in physical space

1893

01:01:18,789 --> 01:01:17,280

we have a view of the universe that's

1894

01:01:19,750 --> 01:01:18,799

based on the fact that we're sitting on

1895

01:01:21,430 --> 01:01:19,760

the earth

1896

01:01:22,950 --> 01:01:21,440

you know which is in some corner of some

1897

01:01:25,349 --> 01:01:22,960

galaxy that's in some corner of the

1898

01:01:26,630 --> 01:01:25,359

universe we have a point of view on the

1899

01:01:28,230 --> 01:01:26,640

universe based on where we are in

1900

01:01:30,870 --> 01:01:28,240

physical space

1901

01:01:32,470 --> 01:01:30,880

so similarly in rule space we have a

1902

01:01:35,109 --> 01:01:32,480

point of view on the universe that's

1903

01:01:37,109 --> 01:01:35,119

based on where we are in rural space

1904

01:01:38,150 --> 01:01:37,119

now the question that we can ask is just

1905

01:01:39,270 --> 01:01:38,160

like we can ask for the

1906

01:01:41,030 --> 01:01:39,280

extraterrestrials

1907

01:01:42,309 --> 01:01:41,040

do they live in alpha centauri or do

1908

01:01:44,390 --> 01:01:42,319

they live in you know

1909

01:01:46,309 --> 01:01:44,400

25 light years away or whatever where do

1910

01:01:46,870 --> 01:01:46,319

they live in physical space relative to

1911

01:01:48,309 --> 01:01:46,880

us

1912

01:01:51,030 --> 01:01:48,319

we can also ask the question whether

1913

01:01:53,910 --> 01:01:51,040

they live in rural space relative to us

1914

01:01:56,150 --> 01:01:53,920

we've not mapped out rule space nearly

1915

01:01:57,829 --> 01:01:56,160

as well as we mapped out physical space

1916

01:02:00,390 --> 01:01:57,839

so we don't really have a good sense of

1917

01:02:02,230 --> 01:02:00,400

those um those distances and those

1918

01:02:03,510 --> 01:02:02,240

what that corresponds to but that's kind

1919

01:02:04,710 --> 01:02:03,520

of the way to think about it and i i

1920

01:02:07,190 --> 01:02:04,720

would love to know

1921

01:02:08,230 --> 01:02:07,200

you know how close is the nearest

1922

01:02:10,710 --> 01:02:08,240

civilization

1923

01:02:12,470 --> 01:02:10,720

in rural space people say you know let's

1924

01:02:14,789 --> 01:02:12,480

go check out the stars

1925

01:02:16,230 --> 01:02:14,799

you know the nearby stars and you know

1926

01:02:17,270 --> 01:02:16,240

look at the ones with exoplanets and

1927

01:02:19,029 --> 01:02:17,280

things like that

1928

01:02:20,390 --> 01:02:19,039

and uh you know but there's a different

1929

01:02:23,270 --> 01:02:20,400

question which is

1930

01:02:24,150 --> 01:02:23,280

kind of in in rural space what's the

1931

01:02:27,910 --> 01:02:24,160

closest

1932

01:02:30,230 --> 01:02:27,920

recognize so to speak

1933

01:02:31,190 --> 01:02:30,240

and i don't know the answer to this and

1934

01:02:33,510 --> 01:02:31,200

that's some

1935

01:02:35,589 --> 01:02:33,520

uh but i think to the observer

1936

01:02:38,470 --> 01:02:35,599

themselves

1937

01:02:40,150 --> 01:02:38,480

i think it is almost tautological that

1938

01:02:43,029 --> 01:02:40,160

things will seem coherent

1939

01:02:43,990 --> 01:02:43,039

so for example to do an exercise let's

1940

01:02:47,910 --> 01:02:44,000

consider two

1941

01:02:49,510 --> 01:02:47,920

intelligences that aren't us okay so one

1942

01:02:51,349 --> 01:02:49,520

that i'm always fond of mentioning is

1943

01:02:52,069 --> 01:02:51,359

you know the weather has a mind of its

1944

01:02:53,349 --> 01:02:52,079

own

1945

01:02:55,270 --> 01:02:53,359

it has you know it's doing these

1946

01:02:58,069 --> 01:02:55,280

sophisticated computations

1947

01:02:59,430 --> 01:02:58,079

but it doesn't have this kind of single

1948

01:03:00,390 --> 01:02:59,440

thread of consciousness type thing i

1949

01:03:02,549 --> 01:03:00,400

mean we have

1950

01:03:04,230 --> 01:03:02,559

in our brains we have actual you know

1951

01:03:06,150 --> 01:03:04,240

structures in our brains

1952

01:03:07,510 --> 01:03:06,160

that lead us to have this sort of single

1953

01:03:09,270 --> 01:03:07,520

thread of attention

1954

01:03:10,549 --> 01:03:09,280

that kind of sequentializes all of our

1955

01:03:13,270 --> 01:03:10,559

experiences

1956

01:03:14,470 --> 01:03:13,280

and when you know when people sort of

1957

01:03:16,870 --> 01:03:14,480

lose that

1958

01:03:17,910 --> 01:03:16,880

they become unconscious so to speak and

1959

01:03:19,430 --> 01:03:17,920

and you know we've got

1960

01:03:21,510 --> 01:03:19,440

you can still have plenty of neurons

1961

01:03:22,549 --> 01:03:21,520

firing in your brain but not have

1962

01:03:24,549 --> 01:03:22,559

consciousness

1963

01:03:27,510 --> 01:03:24,559

you don't have this integration of of

1964

01:03:29,190 --> 01:03:27,520

kind of the single thread of experience

1965

01:03:30,950 --> 01:03:29,200

and the weather is sort of a bit like

1966

01:03:32,069 --> 01:03:30,960

that it's got lots of not neurons but

1967

01:03:34,230 --> 01:03:32,079

it's got lots of

1968

01:03:35,270 --> 01:03:34,240

fluid processes sort of firing all over

1969

01:03:37,750 --> 01:03:35,280

the planet

1970

01:03:40,069 --> 01:03:37,760

and but it doesn't seem to have any kind

1971

01:03:40,950 --> 01:03:40,079

of sort of single thread of experience

1972

01:03:42,950 --> 01:03:40,960

that's going on

1973

01:03:44,950 --> 01:03:42,960

so that's sort of an example of and if

1974

01:03:46,549 --> 01:03:44,960

we say can we communicate with the

1975

01:03:48,950 --> 01:03:46,559

weather

1976

01:03:50,390 --> 01:03:48,960

well not any way that we know i mean we

1977

01:03:50,630 --> 01:03:50,400

we we have something where it's sort of

1978

01:03:52,870 --> 01:03:50,640

an

1979

01:03:53,670 --> 01:03:52,880

incoherently different experience of the

1980

01:03:55,829 --> 01:03:53,680

universe

1981

01:03:56,789 --> 01:03:55,839

than the one we have now if we put

1982

01:03:59,829 --> 01:03:56,799

ourselves

1983

01:04:02,309 --> 01:03:59,839

in the mindset of the weather does it

1984

01:04:06,230 --> 01:04:02,319

have a coherent view of what's going on

1985

01:04:08,870 --> 01:04:06,240

to itself probably tautologically yes

1986

01:04:10,549 --> 01:04:08,880

um maybe a better example that's maybe a

1987

01:04:12,309 --> 01:04:10,559

little bit closer at hand which i have

1988

01:04:15,829 --> 01:04:12,319

not thought through completely

1989

01:04:17,910 --> 01:04:15,839

is sort of distributed ais so

1990

01:04:19,510 --> 01:04:17,920

in other words you've got an ai but it

1991

01:04:20,710 --> 01:04:19,520

isn't just one ai it's a whole network

1992

01:04:23,670 --> 01:04:20,720

of computers

1993

01:04:23,910 --> 01:04:23,680

and it's like what is its experience of

1994

01:04:28,390 --> 01:04:23,920

the

1995

01:04:29,349 --> 01:04:28,400

imagine is going on because

1996

01:04:30,630 --> 01:04:29,359

for example you've got all these

1997

01:04:31,750 --> 01:04:30,640

different ais they've got all these

1998

01:04:34,309 --> 01:04:31,760

sensors

1999

01:04:35,510 --> 01:04:34,319

and they're seeing things that happen

2000

01:04:37,430 --> 01:04:35,520

those sensors

2001  
01:04:38,950 --> 01:04:37,440  
might be separated by distances that are

2002  
01:04:41,990 --> 01:04:38,960  
quite large compared to

2003  
01:04:44,069 --> 01:04:42,000  
you know that takes significant time to

2004  
01:04:46,069 --> 01:04:44,079  
for signals to travel between them you

2005  
01:04:46,710 --> 01:04:46,079  
know what is its view of the universe so

2006  
01:04:48,069 --> 01:04:46,720  
to speak

2007  
01:04:49,990 --> 01:04:48,079  
it's very different from ours because

2008  
01:04:51,510 --> 01:04:50,000  
we're we're localized at a particular

2009  
01:04:54,309 --> 01:04:51,520  
point in space

2010  
01:04:55,990 --> 01:04:54,319  
um etc so it's kind of a good exercise

2011  
01:04:57,829 --> 01:04:56,000  
to try and think through in fact i was

2012  
01:04:59,190 --> 01:04:57,839  
i was sort of trying to inventory and i

2013  
01:05:02,390 --> 01:04:59,200

i think it's a great

2014

01:05:03,750 --> 01:05:02,400

setup for a piece of science fiction

2015

01:05:06,150 --> 01:05:03,760

more difficult than i can

2016

01:05:07,750 --> 01:05:06,160

than i can certainly muster which is

2017

01:05:08,870 --> 01:05:07,760

imagine all these different scenarios

2018

01:05:12,309 --> 01:05:08,880

imagine you are

2019

01:05:14,150 --> 01:05:12,319

an organism that spans a galaxy

2020

01:05:15,829 --> 01:05:14,160

how does the universe look to you

2021

01:05:18,870 --> 01:05:15,839

imagine you're an organism

2022

01:05:20,309 --> 01:05:18,880

that routinely ends up on different

2023

01:05:21,029 --> 01:05:20,319

sides of the event horizons of black

2024

01:05:22,950 --> 01:05:21,039

holes

2025

01:05:25,029 --> 01:05:22,960

what does the universe look to you

2026

01:05:28,150 --> 01:05:25,039

imagine you're an organism

2027

01:05:29,829 --> 01:05:28,160

so to speak that lives on photons that's

2028

01:05:32,950 --> 01:05:29,839

associated with photons

2029

01:05:33,589 --> 01:05:32,960

you know where basically no time has

2030

01:05:35,670 --> 01:05:33,599

passed

2031

01:05:36,710 --> 01:05:35,680

from the last scattering surface a few

2032

01:05:38,549 --> 01:05:36,720

hundred thousand years after the

2033

01:05:41,109 --> 01:05:38,559

beginning of the universe and now

2034

01:05:42,630 --> 01:05:41,119

if you're a photon so it's kind of like

2035

01:05:44,150 --> 01:05:42,640

what are these different views of the

2036

01:05:46,710 --> 01:05:44,160

universe that you have

2037

01:05:47,510 --> 01:05:46,720

if you are uh implemented in different

2038

01:05:50,710 --> 01:05:47,520

ways

2039

01:05:52,150 --> 01:05:50,720

and you know there are probably uh sort

2040

01:05:53,109 --> 01:05:52,160

of implementation levels for the

2041

01:05:55,190 --> 01:05:53,119

universe

2042

01:05:56,470 --> 01:05:55,200

that involve kind of just recognizing

2043

01:05:58,309 --> 01:05:56,480

different features

2044

01:06:00,069 --> 01:05:58,319

of this whole network of atoms of space

2045

01:06:01,829 --> 01:06:00,079

and so on completely different from the

2046

01:06:04,390 --> 01:06:01,839

ones that we recognize

2047

01:06:05,029 --> 01:06:04,400

in um you know in our analysis of of the

2048

01:06:09,990 --> 01:06:05,039

structure of

2049

01:06:12,950 --> 01:06:10,000

of the universe so i mean that that's um

2050

01:06:13,670 --> 01:06:12,960

uh anyway that that's that's kind of my

2051

01:06:19,910 --> 01:06:13,680

um

2052

01:06:21,910 --> 01:06:19,920

it seems like there are two issues here

2053

01:06:22,870 --> 01:06:21,920

about extraterrestrial life or

2054

01:06:24,789 --> 01:06:22,880

intelligent life

2055

01:06:26,309 --> 01:06:24,799

one is whether or not we can communicate

2056

01:06:27,270 --> 01:06:26,319

with them and the other is that we can

2057

01:06:29,510 --> 01:06:27,280

perceive them

2058

01:06:31,029 --> 01:06:29,520

so when we're saying that we don't see

2059

01:06:32,309 --> 01:06:31,039

extraterrestrial life the argument

2060

01:06:34,150 --> 01:06:32,319

you've given seems to be that we can't

2061

01:06:35,670 --> 01:06:34,160

communicate or be extremely unlikely

2062

01:06:38,470 --> 01:06:35,680

that we'd be able to communicate

2063

01:06:39,829 --> 01:06:38,480

with it if we were to encounter it but

2064

01:06:40,630 --> 01:06:39,839

does that mean that we can't perceive it

2065

01:06:43,589 --> 01:06:40,640

we can see

2066

01:06:45,029 --> 01:06:43,599

for example a whirlpool or a hurricane

2067

01:06:45,990 --> 01:06:45,039

whether or not we can communicate with

2068

01:06:48,069 --> 01:06:46,000

it is another issue

2069

01:06:49,670 --> 01:06:48,079

so i mean the first step is there's a

2070

01:06:51,589 --> 01:06:49,680

level where we don't even see it because

2071

01:06:53,270 --> 01:06:51,599

it's it's it's features of the structure

2072

01:06:54,870 --> 01:06:53,280

of space that we are simply not paying

2073

01:06:56,870 --> 01:06:54,880

any attention to

2074

01:06:59,029 --> 01:06:56,880

you know there there's some detail it's

2075

01:07:01,109 --> 01:06:59,039

like like for example

2076

01:07:02,309 --> 01:07:01,119

one of my guesses about you know i like

2077

01:07:07,589 --> 01:07:02,319

to think about

2078

01:07:09,349 --> 01:07:07,599

people make mistakes in the past

2079

01:07:11,270 --> 01:07:09,359

how were things that became obvious

2080

01:07:14,069 --> 01:07:11,280

later not seen before

2081

01:07:14,549 --> 01:07:14,079

and so a question about today's sciences

2082

01:07:16,230 --> 01:07:14,559

what

2083

01:07:18,710 --> 01:07:16,240

is there in today's science that people

2084

01:07:21,589 --> 01:07:18,720

will say i can't believe

2085

01:07:23,430 --> 01:07:21,599

that they didn't see this and i'll give

2086

01:07:24,549 --> 01:07:23,440

you an example one that i suspect is is

2087

01:07:26,470 --> 01:07:24,559

one of those

2088

01:07:28,309 --> 01:07:26,480

so you look at a gas it's got a bunch of

2089

01:07:30,150 --> 01:07:28,319

molecules bouncing around

2090

01:07:31,510 --> 01:07:30,160

we say the gas has certain pressure it

2091

01:07:33,349 --> 01:07:31,520

has a certain temperature

2092

01:07:34,630 --> 01:07:33,359

but all those details about all the gas

2093

01:07:36,870 --> 01:07:34,640

molecules bouncing around

2094

01:07:38,549 --> 01:07:36,880

we just say that's entropy there's no

2095

01:07:40,470 --> 01:07:38,559

there's no detail there that we care

2096

01:07:43,190 --> 01:07:40,480

about it's just random

2097

01:07:44,230 --> 01:07:43,200

that's probably wrong there's probably

2098

01:07:47,190 --> 01:07:44,240

another

2099

01:07:49,430 --> 01:07:47,200

you know whole pile of other properties

2100

01:07:52,069 --> 01:07:49,440

that we should be thinking about there

2101

01:07:53,029 --> 01:07:52,079

but we're just not paying attention to

2102

01:07:55,510 --> 01:07:53,039

so to speak

2103

01:07:56,309 --> 01:07:55,520

and so that's that's an example of of a

2104

01:07:58,390 --> 01:07:56,319

place where

2105

01:07:59,589 --> 01:07:58,400

sort of the extraterrestrials could be

2106

01:08:02,150 --> 01:07:59,599

all around us

2107

01:08:02,950 --> 01:08:02,160

and we just wouldn't know it because

2108

01:08:05,910 --> 01:08:02,960

they are

2109

01:08:06,950 --> 01:08:05,920

sort of their civilization so to speak

2110

01:08:09,029 --> 01:08:06,960

lives in

2111

01:08:10,150 --> 01:08:09,039

features of space that we are simply not

2112

01:08:11,829 --> 01:08:10,160

paying attention to

2113

01:08:13,349 --> 01:08:11,839

so that's one possibility another

2114

01:08:16,470 --> 01:08:13,359

possibility is

2115

01:08:19,669 --> 01:08:16,480

uh yes there are

2116

01:08:21,990 --> 01:08:19,679

things that we can perceive

2117

01:08:23,030 --> 01:08:22,000

but they just don't make any sense to us

2118

01:08:26,229 --> 01:08:23,040

it isn't it doesn't

2119

01:08:27,430 --> 01:08:26,239

uh you know it's like um uh like the

2120

01:08:30,630 --> 01:08:27,440

weather for example

2121

01:08:33,590 --> 01:08:30,640

where it doesn't uh it

2122

01:08:34,149 --> 01:08:33,600

it makes i mean you know it makes no

2123

01:08:36,070 --> 01:08:34,159

sense

2124

01:08:38,309 --> 01:08:36,080

we don't have you know what would you

2125

01:08:39,590 --> 01:08:38,319

talk to the weather about you know what

2126

01:08:41,430 --> 01:08:39,600

is its experience

2127

01:08:42,709 --> 01:08:41,440

in order to you know what do we talk to

2128

01:08:44,309 --> 01:08:42,719

animals about well

2129

01:08:45,829 --> 01:08:44,319

not a lot really because you know

2130

01:08:47,510 --> 01:08:45,839

there's certain emotional

2131

01:08:49,669 --> 01:08:47,520

kind of commonality that we have with

2132

01:08:52,149 --> 01:08:49,679

animals at some level but mostly

2133

01:08:53,990 --> 01:08:52,159

we can't really have a a philosophical

2134

01:08:54,870 --> 01:08:54,000

discussion with your average bear so to

2135

01:08:58,789 --> 01:08:54,880

speak

2136

01:09:01,910 --> 01:08:58,799

um and uh the i think the reason

2137

01:09:04,870 --> 01:09:01,920

uh you know that that's something that

2138

01:09:06,309 --> 01:09:04,880

it it isn't you know there's a separate

2139

01:09:09,189 --> 01:09:06,319

level of issue

2140

01:09:10,070 --> 01:09:09,199

of sort of the the um uh sort of this

2141

01:09:12,070 --> 01:09:10,080

this um

2142

01:09:14,390 --> 01:09:12,080

beyond just perceiving that the thing is

2143

01:09:16,309 --> 01:09:14,400

out there it's like why is it doing what

2144

01:09:17,749 --> 01:09:16,319

it's doing do we have a story about why

2145

01:09:19,430 --> 01:09:17,759

it's doing what it's doing

2146

01:09:21,669 --> 01:09:19,440

do you know if we don't have any such

2147

01:09:23,590 --> 01:09:21,679

understanding and even across time

2148

01:09:25,590 --> 01:09:23,600

for for our own species you know you

2149

01:09:27,030 --> 01:09:25,600

look at archaeological remains

2150

01:09:28,630 --> 01:09:27,040

from a few thousand years ago it's like

2151

01:09:29,669 --> 01:09:28,640

what on earth were they thinking we have

2152

01:09:31,110 --> 01:09:29,679

no idea

2153

01:09:33,030 --> 01:09:31,120

you know what would be our

2154

01:09:33,510 --> 01:09:33,040

communications it might we might be you

2155

01:09:35,590 --> 01:09:33,520

know we

2156

01:09:37,189 --> 01:09:35,600

put ourselves down a time machine which

2157

01:09:38,149 --> 01:09:37,199

i don't think can exist but anyway

2158

01:09:42,229 --> 01:09:38,159

imagine it

2159

01:09:45,590 --> 01:09:42,239

um you know and when we say uh to some

2160

01:09:48,789 --> 01:09:45,600

the the to some um um you know

2161

01:09:49,990 --> 01:09:48,799

person from 3000 years ago uh you know

2162

01:09:52,229 --> 01:09:50,000

what are you doing

2163

01:09:54,070 --> 01:09:52,239

oh they give a whole explanation about

2164

01:09:55,830 --> 01:09:54,080

you know they're pleasing the gods by

2165

01:09:56,870 --> 01:09:55,840

doing this thing that does this that

2166

01:09:58,149 --> 01:09:56,880

does that

2167

01:10:01,189 --> 01:09:58,159

and it's like what the heck are you

2168

01:10:03,270 --> 01:10:01,199

talking about you know we have no common

2169

01:10:04,550 --> 01:10:03,280

uh framework for thinking about these

2170

01:10:06,790 --> 01:10:04,560

kinds of things

2171

01:10:07,669 --> 01:10:06,800

um so i think that that's you know the

2172

01:10:09,910 --> 01:10:07,679

the level

2173

01:10:12,470 --> 01:10:09,920

at which communication is possible is is

2174

01:10:14,550 --> 01:10:12,480

pretty it's pretty narrow

2175

01:10:16,070 --> 01:10:14,560

is there a way in which this entire

2176

01:10:19,270 --> 01:10:16,080

hypergraph or our entire

2177

01:10:20,950 --> 01:10:19,280

universe is conscious much like you

2178

01:10:21,350 --> 01:10:20,960

mentioned we can have consciousness or

2179

01:10:23,430 --> 01:10:21,360

different

2180

01:10:25,030 --> 01:10:23,440

into alien intelligence running through

2181

01:10:26,070 --> 01:10:25,040

us in an ether that we can't interact

2182

01:10:28,470 --> 01:10:26,080

with either because

2183

01:10:29,590 --> 01:10:28,480

computationally irreducible so we can't

2184

01:10:32,790 --> 01:10:29,600

we don't discern it

2185

01:10:36,470 --> 01:10:32,800

or because well because

2186

01:10:40,470 --> 01:10:36,480

whatever reason so so yes i mean

2187

01:10:42,070 --> 01:10:40,480

okay there are sort of

2188

01:10:44,310 --> 01:10:42,080

there's intelligence there's

2189

01:10:45,430 --> 01:10:44,320

consciousness i think they're somewhat

2190

01:10:48,470 --> 01:10:45,440

different

2191

01:10:50,149 --> 01:10:48,480

so intelligent in any definition of that

2192

01:10:51,590 --> 01:10:50,159

that is a generalization beyond the

2193

01:10:53,510 --> 01:10:51,600

purely human

2194

01:10:54,630 --> 01:10:53,520

i think in in any reasonable definition

2195

01:10:57,030 --> 01:10:54,640

one would say the universe is

2196

01:11:00,070 --> 01:10:57,040

intelligent

2197

01:11:02,070 --> 01:11:00,080

it is yes it is okay the now

2198

01:11:04,310 --> 01:11:02,080

conscious it's a little bit more tricky

2199

01:11:05,590 --> 01:11:04,320

because it seems that consciousness is

2200

01:11:09,189 --> 01:11:05,600

actually a step down

2201  
01:11:10,870 --> 01:11:09,199  
from intelligence that is you can be you

2202  
01:11:11,350 --> 01:11:10,880  
know all those individual neurons all

2203  
01:11:13,990 --> 01:11:11,360  
those

2204  
01:11:15,750 --> 01:11:14,000  
like our immune system might be

2205  
01:11:18,070 --> 01:11:15,760  
something that is doing computations as

2206  
01:11:19,910 --> 01:11:18,080  
sophisticated as our brains for all we

2207  
01:11:21,030 --> 01:11:19,920  
we can tell the immune system is you

2208  
01:11:23,030 --> 01:11:21,040  
know has all these complicated

2209  
01:11:24,870 --> 01:11:23,040  
interactions between cells and so on

2210  
01:11:26,709 --> 01:11:24,880  
but yet there's something a little

2211  
01:11:28,229 --> 01:11:26,719  
different about the way the computations

2212  
01:11:30,070 --> 01:11:28,239  
that our brains do

2213  
01:11:31,510 --> 01:11:30,080

from from the ones our immune system

2214

01:11:34,229 --> 01:11:31,520

does or that seems to be

2215

01:11:34,950 --> 01:11:34,239

and one of the differences is that we

2216

01:11:39,110 --> 01:11:34,960

have this

2217

01:11:41,430 --> 01:11:39,120

notion of a single thread of experience

2218

01:11:43,750 --> 01:11:41,440

and that's a feature of of the kind of

2219

01:11:46,950 --> 01:11:43,760

thing that our brains do

2220

01:11:47,990 --> 01:11:46,960

that isn't an immediate feature of the

2221

01:11:52,390 --> 01:11:48,000

way that

2222

01:11:55,030 --> 01:11:52,400

computational processes

2223

01:11:56,870 --> 01:11:55,040

that sort of seem like that that have

2224

01:11:58,630 --> 01:11:56,880

intelligent like behavior

2225

01:12:01,110 --> 01:11:58,640

it's not a feature of those so

2226

01:12:02,950 --> 01:12:01,120

consciousness i i have come to think

2227

01:12:05,110 --> 01:12:02,960

is a step down from intelligence

2228

01:12:08,550 --> 01:12:05,120

consciousness is a specific

2229

01:12:10,070 --> 01:12:08,560

uh sort of a specific

2230

01:12:12,390 --> 01:12:10,080

thing that gets added on top of

2231

01:12:14,870 --> 01:12:12,400

intelligence that is

2232

01:12:15,750 --> 01:12:14,880

sort of this the single thread of time

2233

01:12:17,669 --> 01:12:15,760

story

2234

01:12:19,030 --> 01:12:17,679

and also this computational boundedness

2235

01:12:20,870 --> 01:12:19,040

but that kind of

2236

01:12:22,630 --> 01:12:20,880

that's kind of a necessary thing but

2237

01:12:24,709 --> 01:12:22,640

it's it's this it's this idea of a

2238

01:12:27,910 --> 01:12:24,719

single thread of time i think

2239

01:12:31,270 --> 01:12:27,920

is is sort of a critical feature of that

2240

01:12:32,950 --> 01:12:31,280

adds kind of um uh that's the layer that

2241

01:12:34,229 --> 01:12:32,960

adds consciousness so does the universe

2242

01:12:36,149 --> 01:12:34,239

have that

2243

01:12:37,750 --> 01:12:36,159

not really the universe doesn't have

2244

01:12:40,149 --> 01:12:37,760

that in fact the universe

2245

01:12:41,669 --> 01:12:40,159

in our models it's got all these atoms

2246

01:12:43,189 --> 01:12:41,679

of space that are doing all these things

2247

01:12:45,030 --> 01:12:43,199

all over the universe

2248

01:12:46,870 --> 01:12:45,040

there's no single thread of time there's

2249

01:12:48,310 --> 01:12:46,880

no single thread of experience

2250

01:12:50,229 --> 01:12:48,320

lots of different things are happening

2251

01:12:51,669 --> 01:12:50,239

all over the universe lots of different

2252

01:12:53,590 --> 01:12:51,679

space-like separated things are

2253

01:12:55,110 --> 01:12:53,600

happening lots of different branch-like

2254

01:12:57,590 --> 01:12:55,120

separated things are happening

2255

01:12:59,189 --> 01:12:57,600

so there isn't that single thread type

2256

01:13:01,510 --> 01:12:59,199

type experience

2257

01:13:03,430 --> 01:13:01,520

so i think in that sense i would i would

2258

01:13:05,510 --> 01:13:03,440

say that in that what seems to be the

2259

01:13:06,870 --> 01:13:05,520

appropriate definition of consciousness

2260

01:13:09,110 --> 01:13:06,880

the appropriate generalization of

2261

01:13:11,750 --> 01:13:09,120

consciousness beyond the merely human

2262

01:13:13,110 --> 01:13:11,760

wouldn't encompass the universe um

2263

01:13:17,510 --> 01:13:13,120

intelligence would encompass the

2264

01:13:21,270 --> 01:13:19,030

you mentioned photons not having an

2265

01:13:23,270 --> 01:13:21,280

experience of time in your model do you

2266

01:13:24,550 --> 01:13:23,280

have a conceptualization of photons

2267

01:13:26,709 --> 01:13:24,560

because it seems like there's different

2268

01:13:27,510 --> 01:13:26,719

time steps and time is just the

2269

01:13:31,189 --> 01:13:27,520

inelectable

2270

01:13:32,390 --> 01:13:31,199

sequence of updating so what's a photon

2271

01:13:36,229 --> 01:13:32,400

is it one that goes

2272

01:13:39,270 --> 01:13:36,239

well we're not sure yet completely

2273

01:13:41,350 --> 01:13:39,280

but um uh

2274

01:13:42,950 --> 01:13:41,360

the possibility of something moving at

2275

01:13:44,470 --> 01:13:42,960

the speed of light the speed of light is

2276

01:13:47,510 --> 01:13:44,480

defined in our models

2277

01:13:48,229 --> 01:13:47,520

by you have one event and you say how

2278

01:13:49,990 --> 01:13:48,239

many other

2279

01:13:51,270 --> 01:13:50,000

events does that event lead to that's

2280

01:13:53,750 --> 01:13:51,280

the light cone

2281

01:13:54,870 --> 01:13:53,760

of uh of what you produce and so photons

2282

01:13:57,430 --> 01:13:54,880

have to live on the

2283

01:13:58,550 --> 01:13:57,440

uh at least close to the the edges of

2284

01:14:00,550 --> 01:13:58,560

that light cone

2285

01:14:01,669 --> 01:14:00,560

and so that's that's sort of what tells

2286

01:14:03,270 --> 01:14:01,679

us something about

2287

01:14:04,709 --> 01:14:03,280

the kind of structures that photons

2288

01:14:05,830 --> 01:14:04,719

correspond to we don't know exactly what

2289

01:14:08,229 --> 01:14:05,840

they are yet

2290

01:14:08,870 --> 01:14:08,239

i think the thing that one can realize

2291

01:14:16,950 --> 01:14:08,880

is

2292

01:14:19,430 --> 01:14:16,960

if you are an entity within our system

2293

01:14:20,630 --> 01:14:19,440

you have you are you are using

2294

01:14:23,910 --> 01:14:20,640

computation

2295

01:14:25,430 --> 01:14:23,920

to progress so to speak and you can use

2296

01:14:26,550 --> 01:14:25,440

that computation if you're just sitting

2297

01:14:28,870 --> 01:14:26,560

still

2298

01:14:31,030 --> 01:14:28,880

all that computation gets used to

2299

01:14:33,189 --> 01:14:31,040

actually move you forward in time

2300

01:14:34,390 --> 01:14:33,199

all that computation gets used to figure

2301

01:14:36,550 --> 01:14:34,400

out the next

2302

01:14:38,310 --> 01:14:36,560

configuration that you have in time if

2303

01:14:40,390 --> 01:14:38,320

you're also moving

2304

01:14:41,990 --> 01:14:40,400

some of that computation has to be used

2305

01:14:43,669 --> 01:14:42,000

up in recomputing

2306

01:14:45,270 --> 01:14:43,679

what you're like at a different place in

2307

01:14:47,030 --> 01:14:45,280

space that's interesting that's

2308

01:14:48,149 --> 01:14:47,040

basically what leads to time dilation

2309

01:14:51,189 --> 01:14:48,159

and relativity

2310

01:14:52,870 --> 01:14:51,199

is that you're trading off the use of

2311

01:14:54,790 --> 01:14:52,880

uh you know you're trading off the

2312

01:14:56,390 --> 01:14:54,800

computation used for motion

2313

01:14:58,470 --> 01:14:56,400

with the computation used for time

2314

01:15:00,950 --> 01:14:58,480

evolution so if you are

2315

01:15:02,390 --> 01:15:00,960

if you have motion then you get to use

2316

01:15:03,189 --> 01:15:02,400

less of that computation for time

2317

01:15:05,990 --> 01:15:03,199

evolution

2318

01:15:07,350 --> 01:15:06,000

and time effectively runs more slowly um

2319

01:15:08,630 --> 01:15:07,360

and so for photons

2320

01:15:10,470 --> 01:15:08,640

there's probably there's there's

2321

01:15:11,910 --> 01:15:10,480

presumably an extreme version of that

2322

01:15:13,830 --> 01:15:11,920

but we don't understand the details of

2323

01:15:16,390 --> 01:15:13,840

that yet

2324

01:15:18,149 --> 01:15:16,400

when it comes to real space there's a

2325

01:15:20,630 --> 01:15:18,159

quote i believe i took it from

2326

01:15:22,470 --> 01:15:20,640

one of your papers it says the principle

2327

01:15:24,709 --> 01:15:22,480

of computational equivalence implies a

2328

01:15:26,709 --> 01:15:24,719

fixed maximum speed row

2329

01:15:29,110 --> 01:15:26,719

in rule space now is this principle

2330

01:15:30,790 --> 01:15:29,120

taken as an axiom or is it derived

2331

01:15:32,630 --> 01:15:30,800

and and how exactly do you derive that

2332

01:15:35,830 --> 01:15:32,640

maximum speed

2333

01:15:39,110 --> 01:15:35,840

without that axiom or can you okay

2334

01:15:40,550 --> 01:15:39,120

so the epistemology of science is more

2335

01:15:41,510 --> 01:15:40,560

complicated than people often give it

2336

01:15:42,709 --> 01:15:41,520

credit for

2337

01:15:46,390 --> 01:15:42,719

the principle of computational

2338

01:15:49,750 --> 01:15:48,149

it has a complicated epistemological

2339

01:15:51,270 --> 01:15:49,760

status

2340

01:15:54,229 --> 01:15:51,280

somewhat similar to the second law of

2341

01:15:56,310 --> 01:15:54,239

thermodynamics somewhat similar to

2342

01:15:58,390 --> 01:15:56,320

things like the church touring thesis

2343

01:16:00,950 --> 01:15:58,400

they're all the same kind of thing

2344

01:16:03,350 --> 01:16:00,960

so the second law of thermodynamics is

2345

01:16:06,149 --> 01:16:03,360

both a definition of heat

2346

01:16:08,070 --> 01:16:06,159

and a statement about how systems in the

2347

01:16:10,630 --> 01:16:08,080

universe tend to work

2348

01:16:11,189 --> 01:16:10,640

and a mathematically provable thing it

2349

01:16:12,709 --> 01:16:11,199

is both

2350

01:16:14,310 --> 01:16:12,719

all of those things are none of those

2351

01:16:15,430 --> 01:16:14,320

things so in other words

2352

01:16:18,470 --> 01:16:15,440

the principle of computational

2353

01:16:21,110 --> 01:16:18,480

equivalence if you

2354

01:16:21,910 --> 01:16:21,120

is something for which we actually have

2355

01:16:23,750 --> 01:16:21,920

good

2356

01:16:25,270 --> 01:16:23,760

evidence that is the principle of

2357

01:16:26,470 --> 01:16:25,280

computational equivalence basically says

2358

01:16:27,910 --> 01:16:26,480

if you have a system that operates

2359

01:16:30,149 --> 01:16:27,920

according to rules

2360

01:16:32,070 --> 01:16:30,159

if the behavior that you see is not

2361

01:16:34,630 --> 01:16:32,080

obviously simple

2362

01:16:36,630 --> 01:16:34,640

the the behavior will correspond to a

2363

01:16:37,510 --> 01:16:36,640

computation that is as sophisticated as

2364

01:16:40,070 --> 01:16:37,520

anything

2365

01:16:40,630 --> 01:16:40,080

that's the basic statement so it implies

2366

01:16:43,110 --> 01:16:40,640

that

2367

01:16:44,790 --> 01:16:43,120

your average thing even though its rules

2368

01:16:46,390 --> 01:16:44,800

may be simple so long as its behavior

2369

01:16:48,470 --> 01:16:46,400

isn't obviously simple

2370

01:16:50,149 --> 01:16:48,480

will tend to be for example computation

2371

01:16:51,990 --> 01:16:50,159

universal

2372

01:16:53,990 --> 01:16:52,000

to interrupt sorry what do you mean by

2373

01:16:55,750 --> 01:16:54,000

isn't obviously simple

2374

01:16:57,270 --> 01:16:55,760

so can you give me an example of

2375

01:16:59,189 --> 01:16:57,280

something that is

2376

01:17:00,470 --> 01:16:59,199

computationally inequivalent yeah yeah

2377

01:17:03,430 --> 01:17:00,480

right so so

2378

01:17:05,430 --> 01:17:03,440

repetitive behavior is obviously simple

2379

01:17:06,550 --> 01:17:05,440

nested fractal behavior is obviously

2380

01:17:10,070 --> 01:17:06,560

simple

2381

01:17:11,750 --> 01:17:10,080

it's things where we can readily predict

2382

01:17:12,790 --> 01:17:11,760

where we can use a much simpler

2383

01:17:16,149 --> 01:17:12,800

computation

2384

01:17:18,470 --> 01:17:16,159

to jump ahead where we can say uh

2385

01:17:19,990 --> 01:17:18,480

you know you've shown me a few steps now

2386

01:17:21,590 --> 01:17:20,000

i know what's going to happen

2387

01:17:23,510 --> 01:17:21,600

i can predict a billion steps in the

2388

01:17:24,870 --> 01:17:23,520

future what's going to happen now all of

2389

01:17:27,189 --> 01:17:24,880

these concepts

2390

01:17:28,229 --> 01:17:27,199

there so so that's what it means to be

2391

01:17:31,350 --> 01:17:28,239

computationally

2392

01:17:34,470 --> 01:17:31,360

that that's what it means to be not uh

2393

01:17:36,229 --> 01:17:34,480

you know to to be to not seem like it

2394

01:17:40,149 --> 01:17:36,239

has complicated behavior

2395

01:17:41,590 --> 01:17:40,159

now as you start trying to i mean

2396

01:17:43,189 --> 01:17:41,600

the thing that's interesting about all

2397

01:17:46,149 --> 01:17:43,199

of these principles

2398

01:17:47,510 --> 01:17:46,159

is that as you start trying to put

2399

01:17:49,510 --> 01:17:47,520

stakes in the ground of what does this

2400

01:17:53,030 --> 01:17:49,520

precisely mathematically mean

2401

01:17:55,350 --> 01:17:53,040

you realize that the thing is

2402

01:17:56,790 --> 01:17:55,360

it ends up being you know the principle

2403

01:17:59,830 --> 01:17:56,800

of computational equivalence

2404

01:18:00,149 --> 01:17:59,840

is at some level an abstract fact about

2405

01:18:03,910 --> 01:18:00,159

some

2406

01:18:07,030 --> 01:18:03,920

about rules it's an abstract fact

2407

01:18:09,430 --> 01:18:07,040

um and it can be proved at least in

2408

01:18:12,470 --> 01:18:09,440

certain examples as an abstract fact

2409

01:18:15,510 --> 01:18:12,480

but you might say that thing over there

2410

01:18:17,270 --> 01:18:15,520

i can i don't see how it's simple

2411

01:18:18,630 --> 01:18:17,280

so it must be computationally as

2412

01:18:20,310 --> 01:18:18,640

sophisticated as anything

2413

01:18:21,830 --> 01:18:20,320

but then somebody can say oh you missed

2414

01:18:22,790 --> 01:18:21,840

this particular way in which it was

2415

01:18:25,189 --> 01:18:22,800

simple

2416

01:18:26,790 --> 01:18:25,199

so you know and that's why it isn't as

2417

01:18:28,070 --> 01:18:26,800

computationally sophisticated

2418

01:18:30,229 --> 01:18:28,080

but then you can say that sort of

2419

01:18:32,390 --> 01:18:30,239

tautological because if

2420

01:18:34,070 --> 01:18:32,400

if it's computationally sophisticated

2421

01:18:35,590 --> 01:18:34,080

that's basically the statement that it

2422

01:18:36,630 --> 01:18:35,600

doesn't have any simple way to work out

2423

01:18:39,030 --> 01:18:36,640

what it does so

2424

01:18:40,229 --> 01:18:39,040

it's it's the the thing that's important

2425

01:18:42,149 --> 01:18:40,239

about principle of computational

2426

01:18:45,110 --> 01:18:42,159

equivalence is that it is a

2427

01:18:47,030 --> 01:18:45,120

a conceptual framework for thinking

2428

01:18:48,070 --> 01:18:47,040

about how things work that is people had

2429

01:18:50,950 --> 01:18:48,080

the idea

2430

01:18:52,550 --> 01:18:50,960

including me that you have simple rules

2431

01:18:55,110 --> 01:18:52,560

you'll have simple behavior

2432

01:18:57,669 --> 01:18:55,120

it's not true and this principle tells

2433

01:19:00,070 --> 01:18:57,679

you that it is maximally not true

2434

01:19:01,830 --> 01:19:00,080

in other words whenever it seems like it

2435

01:19:02,550 --> 01:19:01,840

might not be the case that the behavior

2436

01:19:04,709 --> 01:19:02,560

is simple

2437

01:19:07,030 --> 01:19:04,719

it really isn't and it is sort of as

2438

01:19:10,870 --> 01:19:07,040

sophisticated as you can possibly get

2439

01:19:13,590 --> 01:19:10,880

so the the um with respect to speed in

2440

01:19:17,189 --> 01:19:13,600

royal space

2441

01:19:20,870 --> 01:19:17,199

that assumption of a maximum upper limit

2442

01:19:24,390 --> 01:19:22,550

yeah you could derive the upper limit

2443

01:19:26,550 --> 01:19:24,400

from the church touring thesis

2444

01:19:28,950 --> 01:19:26,560

which is a a sort of subset of the

2445

01:19:32,550 --> 01:19:28,960

principle of computational equivalence

2446

01:19:32,870 --> 01:19:32,560

so that so i mean that particular thing

2447

01:19:37,830 --> 01:19:32,880

is

2448

01:19:40,950 --> 01:19:37,840

think it needs um

2449

01:19:44,229 --> 01:19:40,960

uh to derive the upper limit what what

2450

01:19:45,350 --> 01:19:44,239

what is not obvious is that the typical

2451  
01:19:47,510 --> 01:19:45,360  
light cone

2452  
01:19:48,390 --> 01:19:47,520  
will have a surface that is like that in

2453  
01:19:51,110 --> 01:19:48,400  
royal space

2454  
01:19:53,669 --> 01:19:51,120  
that needs pce so what it's saying is

2455  
01:19:57,189 --> 01:19:53,679  
the church touring thesis would say

2456  
01:19:57,830 --> 01:19:57,199  
that there exists things that go as fast

2457  
01:20:04,470 --> 01:19:57,840  
as

2458  
01:20:07,110 --> 01:20:04,480  
your average light cone in rural space

2459  
01:20:10,310 --> 01:20:07,120  
will in fact expand at that speed

2460  
01:20:11,350 --> 01:20:10,320  
um that's interesting so so okay so that

2461  
01:20:16,830 --> 01:20:11,360  
then

2462  
01:20:21,910 --> 01:20:18,149  
uh

2463  
01:20:24,070 --> 01:20:21,920

so the maximum speed in royal space

2464

01:20:25,030 --> 01:20:24,080

is essentially telling you something

2465

01:20:27,590 --> 01:20:25,040

about the actual

2466

01:20:28,870 --> 01:20:27,600

raw processing power of the universe

2467

01:20:31,189 --> 01:20:28,880

it's telling you

2468

01:20:32,229 --> 01:20:31,199

um i mean it's i was i think i'd written

2469

01:20:33,669 --> 01:20:32,239

somewhere in a

2470

01:20:35,350 --> 01:20:33,679

in kind of you could you could take it

2471

01:20:36,229 --> 01:20:35,360

in any kind of computational units but

2472

01:20:37,750 --> 01:20:36,239

you can say

2473

01:20:39,990 --> 01:20:37,760

you know number of wolfram language

2474

01:20:43,110 --> 01:20:40,000

tokens processed per second

2475

01:20:45,430 --> 01:20:43,120

is by the universe it's kind of one one

2476

01:20:48,629 --> 01:20:45,440

way of of measuring that

2477

01:20:51,830 --> 01:20:48,639

something we realized recently is that

2478

01:20:54,070 --> 01:20:51,840

um coarse graining

2479

01:20:55,910 --> 01:20:54,080

that is the process of not looking at

2480

01:20:57,270 --> 01:20:55,920

every detail but looking only at a large

2481

01:20:58,830 --> 01:20:57,280

scale which you use in statistical

2482

01:21:01,830 --> 01:20:58,840

mechanics and so on

2483

01:21:03,750 --> 01:21:01,840

um course screening in rule space

2484

01:21:04,950 --> 01:21:03,760

is making a higher level description

2485

01:21:06,470 --> 01:21:04,960

language

2486

01:21:07,830 --> 01:21:06,480

so in other words you can make a

2487

01:21:09,030 --> 01:21:07,840

description language that's really at

2488

01:21:10,550 --> 01:21:09,040

the lowest level

2489

01:21:13,030 --> 01:21:10,560

where you're actually describing how

2490

01:21:14,470 --> 01:21:13,040

every everything works or you can have a

2491

01:21:16,870 --> 01:21:14,480

higher level language

2492

01:21:18,550 --> 01:21:16,880

which describes only more in in sort of

2493

01:21:19,669 --> 01:21:18,560

higher level terms what's going on

2494

01:21:22,390 --> 01:21:19,679

what's the relationship between

2495

01:21:26,830 --> 01:21:22,400

computational irreducibility and

2496

01:21:29,590 --> 01:21:26,840

undecidability general undecidability so

2497

01:21:30,870 --> 01:21:29,600

um also the relationship between the

2498

01:21:32,709 --> 01:21:30,880

reducibility and the

2499

01:21:34,390 --> 01:21:32,719

principle of computational equivalence

2500

01:21:35,910 --> 01:21:34,400

does one require the other can you

2501  
01:21:36,790 --> 01:21:35,920  
imagine a world with one but not the

2502  
01:21:38,070 --> 01:21:36,800  
other

2503  
01:21:39,750 --> 01:21:38,080  
so principle of computational

2504  
01:21:41,189 --> 01:21:39,760  
equivalence implies computational

2505  
01:21:43,590 --> 01:21:41,199  
releasability

2506  
01:21:44,470 --> 01:21:43,600  
and and basically they're really locked

2507  
01:21:47,189 --> 01:21:44,480  
together

2508  
01:21:48,310 --> 01:21:47,199  
because what happens is you have a

2509  
01:21:49,910 --> 01:21:48,320  
system

2510  
01:21:52,709 --> 01:21:49,920  
it's computing what it's going to do

2511  
01:21:53,990 --> 01:21:52,719  
next you are an observer of that system

2512  
01:21:55,350 --> 01:21:54,000  
you're trying to predict what it's going

2513  
01:21:57,990 --> 01:21:55,360

to do next

2514

01:21:59,430 --> 01:21:58,000

the question is can you jump ahead of it

2515

01:22:01,110 --> 01:21:59,440

and figure out what it's going to do

2516

01:22:02,629 --> 01:22:01,120

sort of more efficiently than it does

2517

01:22:04,229 --> 01:22:02,639

itself

2518

01:22:07,189 --> 01:22:04,239

principle of computational equivalence

2519

01:22:09,830 --> 01:22:07,199

says you sorry you're stuck being just

2520

01:22:11,430 --> 01:22:09,840

computationally equivalent to the system

2521

01:22:13,310 --> 01:22:11,440

and that's what leads to computational

2522

01:22:15,750 --> 01:22:13,320

irreducibility

2523

01:22:18,149 --> 01:22:15,760

undecidability is an infinite time limit

2524

01:22:21,189 --> 01:22:18,159

of computational irreducibility

2525

01:22:25,110 --> 01:22:21,199

computational irreducibility

2526  
01:22:25,510 --> 01:22:25,120  
is a if you say what's the system going

2527  
01:22:27,669 --> 01:22:25,520  
to do

2528  
01:22:28,709 --> 01:22:27,679  
in the end after an infinite amount of

2529  
01:22:32,470 --> 01:22:28,719  
time

2530  
01:22:34,629 --> 01:22:32,480  
the answer uh can be

2531  
01:22:36,470 --> 01:22:34,639  
well in order if it's computationally

2532  
01:22:38,229 --> 01:22:36,480  
irreducible the only way to find that

2533  
01:22:39,750 --> 01:22:38,239  
out is to wait for a potentially

2534  
01:22:41,830 --> 01:22:39,760  
infinite amount of time

2535  
01:22:43,430 --> 01:22:41,840  
so if you say i really want to know in

2536  
01:22:44,070 --> 01:22:43,440  
finite time what's the system going to

2537  
01:22:46,790 --> 01:22:44,080  
do

2538  
01:22:47,750 --> 01:22:46,800

the answer is sorry it's computationally

2539

01:22:49,669 --> 01:22:47,760

irreducible

2540

01:22:52,470 --> 01:22:49,679

the only way to know that infinite time

2541

01:22:54,310 --> 01:22:52,480

answer is to wait an infinite time

2542

01:22:55,830 --> 01:22:54,320

so that that's the reason that um so

2543

01:22:57,590 --> 01:22:55,840

those uh you know

2544

01:22:59,030 --> 01:22:57,600

computational irreducibility implies

2545

01:23:04,830 --> 01:22:59,040

undecidability

2546

01:23:04,840 --> 01:23:09,189

uh um

2547

01:23:12,550 --> 01:23:11,830

i don't think so i think it might be uh

2548

01:23:14,629 --> 01:23:12,560

associated with

2549

01:23:16,070 --> 01:23:14,639

some things called intermediate degrees

2550

01:23:16,950 --> 01:23:16,080

which are an idea that you can have a

2551

01:23:18,830 --> 01:23:16,960

system which has

2552

01:23:21,189 --> 01:23:18,840

undecidability without computational

2553

01:23:23,590 --> 01:23:21,199

universality which i tend to think is

2554

01:23:25,189 --> 01:23:23,600

is not really it's not a real thing it's

2555

01:23:27,030 --> 01:23:25,199

a it's something people

2556

01:23:28,470 --> 01:23:27,040

imagine can happen in systems but i

2557

01:23:29,189 --> 01:23:28,480

don't think it will actually end up

2558

01:23:30,629 --> 01:23:29,199

happening

2559

01:23:32,870 --> 01:23:30,639

it's something where you can construct

2560

01:23:34,709 --> 01:23:32,880

examples which are kind of special put

2561

01:23:36,310 --> 01:23:34,719

up jobs where you essentially have a

2562

01:23:37,990 --> 01:23:36,320

universal computer inside

2563

01:23:39,430 --> 01:23:38,000

but you've chopped off all its input

2564

01:23:41,430 --> 01:23:39,440

output mechanisms

2565

01:23:43,030 --> 01:23:41,440

enough that it can't act as a universal

2566

01:23:44,229 --> 01:23:43,040

computer but can still have

2567

01:23:45,669 --> 01:23:44,239

undecidability and i

2568

01:23:47,510 --> 01:23:45,679

don't think that's a i don't think

2569

01:23:50,149 --> 01:23:47,520

that's a real real thing

2570

01:23:51,990 --> 01:23:50,159

but um uh yeah so so those are

2571

01:23:54,149 --> 01:23:52,000

undecidability is infinite time limits

2572

01:23:55,669 --> 01:23:54,159

of irreducibility basically

2573

01:23:57,270 --> 01:23:55,679

speaking of what's real or what's not

2574

01:24:01,350 --> 01:23:57,280

real is infinity

2575

01:24:05,990 --> 01:24:01,360

real who's infinity i mean

2576

01:24:09,750 --> 01:24:07,669

you can write down you know in wolfram

2577

01:24:11,669 --> 01:24:09,760

language there's a symbol infinity

2578

01:24:14,070 --> 01:24:11,679

that represents infinity and one over it

2579

01:24:15,189 --> 01:24:14,080

is zero and you can say lots of things

2580

01:24:19,350 --> 01:24:15,199

about it

2581

01:24:22,950 --> 01:24:19,360

if you want to ask the question can i

2582

01:24:26,870 --> 01:24:22,960

make an infinite

2583

01:24:28,470 --> 01:24:26,880

um can i sort of actualize infinity

2584

01:24:30,390 --> 01:24:28,480

that's this is a complicated question

2585

01:24:32,229 --> 01:24:30,400

because you can

2586

01:24:35,189 --> 01:24:32,239

certain kinds of infinities can be just

2587

01:24:38,310 --> 01:24:35,199

made symbolic and reasoned in terms of

2588

01:24:39,270 --> 01:24:38,320

to explicitly make infinity is a

2589

01:24:41,590 --> 01:24:39,280

different thing

2590

01:24:42,629 --> 01:24:41,600

than to reason in terms of infinity you

2591

01:24:44,709 --> 01:24:42,639

know we can write down

2592

01:24:46,310 --> 01:24:44,719

trans-finite numbers and we can do all

2593

01:24:46,950 --> 01:24:46,320

kinds of reasoning about transfinite

2594

01:24:49,030 --> 01:24:46,960

numbers

2595

01:24:50,229 --> 01:24:49,040

that doesn't mean we can explicitly in

2596

01:24:51,750 --> 01:24:50,239

our universe

2597

01:24:53,430 --> 01:24:51,760

make a birthday cake that's a

2598

01:24:56,310 --> 01:24:53,440

trans-finite number so to speak

2599

01:24:58,709 --> 01:24:56,320

i mean we we can't um so the question of

2600

01:25:00,229 --> 01:24:58,719

actualization in the universe versus

2601  
01:25:01,990 --> 01:25:00,239  
symbolic representation is a little bit

2602  
01:25:04,310 --> 01:25:02,000  
of a tricky question

2603  
01:25:05,990 --> 01:25:04,320  
okay forget about us making infinity is

2604  
01:25:07,990 --> 01:25:06,000  
there a quality of the universe that's

2605  
01:25:08,629 --> 01:25:08,000  
infinite at all so for example infinite

2606  
01:25:10,629 --> 01:25:08,639  
space

2607  
01:25:12,550 --> 01:25:10,639  
infinite computational speed infinite

2608  
01:25:14,950 --> 01:25:12,560  
memory storage

2609  
01:25:16,149 --> 01:25:14,960  
and and how can we enter even if there

2610  
01:25:17,910 --> 01:25:16,159  
was an infinite

2611  
01:25:19,189 --> 01:25:17,920  
is there a way that we could tell is

2612  
01:25:21,430 --> 01:25:19,199  
there an experiment

2613  
01:25:23,270 --> 01:25:21,440

that would let us know that infinity

2614

01:25:25,350 --> 01:25:23,280

exists in some way shape or form

2615

01:25:26,950 --> 01:25:25,360

or is it somehow irreducible it would

2616

01:25:28,470 --> 01:25:26,960

look like noise to us

2617

01:25:30,070 --> 01:25:28,480

well i think we can wait for an infinite

2618

01:25:32,149 --> 01:25:30,080

time we'll know in the infinite future

2619

01:25:35,990 --> 01:25:32,159

we'll know if the universe is infinite

2620

01:25:40,950 --> 01:25:36,000

i mean i i think that before that we can

2621

01:25:45,350 --> 01:25:40,960

um you know the

2622

01:25:47,510 --> 01:25:45,360

the question for example is space uh

2623

01:25:49,590 --> 01:25:47,520

you know infinitely divisible that would

2624

01:25:53,510 --> 01:25:49,600

be a question we might ask

2625

01:25:56,550 --> 01:25:53,520

um i think

2626

01:25:58,550 --> 01:25:56,560

our models look like they're going to

2627

01:25:59,910 --> 01:25:58,560

make some very specific predictions

2628

01:26:01,669 --> 01:25:59,920

about what happens in

2629

01:26:03,510 --> 01:26:01,679

fast rotating black holes and things

2630

01:26:05,189 --> 01:26:03,520

like this where

2631

01:26:07,030 --> 01:26:05,199

they will kind of see through there'll

2632

01:26:09,350 --> 01:26:07,040

be a microscope that kind of sees

2633

01:26:10,310 --> 01:26:09,360

through down to the actual fabric of

2634

01:26:12,709 --> 01:26:10,320

space time

2635

01:26:14,229 --> 01:26:12,719

and actually sees these discrete things

2636

01:26:16,390 --> 01:26:14,239

and were we to be able to use that

2637

01:26:18,470 --> 01:26:16,400

microscope and work to see

2638

01:26:20,470 --> 01:26:18,480

you know where to just keep seeing you

2639

01:26:21,750 --> 01:26:20,480

know finer and finer and finer detail

2640

01:26:23,590 --> 01:26:21,760

you know in other words we look through

2641

01:26:25,430 --> 01:26:23,600

a physical microscope and

2642

01:26:27,189 --> 01:26:25,440

we're used to seeing oh you know the

2643

01:26:27,990 --> 01:26:27,199

biological organism actually is made of

2644

01:26:29,110 --> 01:26:28,000

cells oh

2645

01:26:30,550 --> 01:26:29,120

you know we look it's actually made of

2646

01:26:32,070 --> 01:26:30,560

molecules the molecules made our atoms

2647

01:26:35,189 --> 01:26:32,080

the atoms are made of whatever

2648

01:26:35,990 --> 01:26:35,199

you know and the question is space right

2649

01:26:39,110 --> 01:26:36,000

now we might

2650

01:26:40,870 --> 01:26:39,120

think our microscope for space we just

2651  
01:26:42,550 --> 01:26:40,880  
look and it keeps on looking the same

2652  
01:26:44,470 --> 01:26:42,560  
it's always indivisible you know it's

2653  
01:26:46,470 --> 01:26:44,480  
always it's always divisible

2654  
01:26:47,669 --> 01:26:46,480  
and the question is what we're saying in

2655  
01:26:49,830 --> 01:26:47,679  
this theory

2656  
01:26:51,750 --> 01:26:49,840  
is no at some point you'll see the atoms

2657  
01:26:52,470 --> 01:26:51,760  
of space now you don't really get to do

2658  
01:26:55,430 --> 01:26:52,480  
that

2659  
01:26:57,110 --> 01:26:55,440  
because you are embedded your microscope

2660  
01:26:58,310 --> 01:26:57,120  
is made of the same atoms of space so

2661  
01:26:59,110 --> 01:26:58,320  
you don't really get to make a

2662  
01:27:00,390 --> 01:26:59,120  
microscope

2663  
01:27:02,310 --> 01:27:00,400

that directly sees that so you have to

2664

01:27:04,070 --> 01:27:02,320

use more indirect techniques

2665

01:27:05,510 --> 01:27:04,080

to be able to kind of sense the presence

2666

01:27:06,790 --> 01:27:05,520

of these atoms of space

2667

01:27:08,790 --> 01:27:06,800

but you could certainly imagine

2668

01:27:11,030 --> 01:27:08,800

something where

2669

01:27:12,870 --> 01:27:11,040

uh you know you could you could predict

2670

01:27:14,470 --> 01:27:12,880

we don't know what scale precisely these

2671

01:27:19,350 --> 01:27:14,480

atoms of space occur

2672

01:27:22,390 --> 01:27:21,590

uh you you're sort of making the

2673

01:27:24,950 --> 01:27:22,400

universe

2674

01:27:26,709 --> 01:27:24,960

be in in such an extreme condition that

2675

01:27:27,430 --> 01:27:26,719

you kind of see through to the structure

2676  
01:27:29,350 --> 01:27:27,440  
of space

2677  
01:27:30,470 --> 01:27:29,360  
it's very similar if you're going

2678  
01:27:33,030 --> 01:27:30,480  
through a fluid

2679  
01:27:33,669 --> 01:27:33,040  
you know a typical you know a car going

2680  
01:27:35,910 --> 01:27:33,679  
through air

2681  
01:27:37,669 --> 01:27:35,920  
doesn't know air is made of molecules it

2682  
01:27:40,629 --> 01:27:37,679  
just knows there's a flow of air

2683  
01:27:41,990 --> 01:27:40,639  
a hypersonic plane missile or something

2684  
01:27:43,590 --> 01:27:42,000  
going through air

2685  
01:27:45,750 --> 01:27:43,600  
absolutely does know that air is made of

2686  
01:27:46,310 --> 01:27:45,760  
molecules of oxygen and nitrogen and so

2687  
01:27:48,629 --> 01:27:46,320  
on

2688  
01:27:49,590 --> 01:27:48,639

because at that speed you've kind of

2689

01:27:52,870 --> 01:27:49,600

broken down

2690

01:27:54,790 --> 01:27:52,880

this continuum structure of space

2691

01:27:56,229 --> 01:27:54,800

in that case of a fluid of the air

2692

01:27:57,430 --> 01:27:56,239

you've broken down the continuum

2693

01:27:59,189 --> 01:27:57,440

structure of the air

2694

01:28:00,629 --> 01:27:59,199

and you are sensitive to the presence of

2695

01:28:01,430 --> 01:28:00,639

individual molecules with particular

2696

01:28:03,750 --> 01:28:01,440

properties

2697

01:28:05,910 --> 01:28:03,760

and so the question is can we find

2698

01:28:06,629 --> 01:28:05,920

extreme situations in space-time for

2699

01:28:08,790 --> 01:28:06,639

example

2700

01:28:10,390 --> 01:28:08,800

where we're similarly sensitive to the

2701

01:28:13,110 --> 01:28:10,400

underlying structure

2702

01:28:14,870 --> 01:28:13,120

of of space and you know there's a

2703

01:28:16,550 --> 01:28:14,880

decent chance that we may have examples

2704

01:28:18,149 --> 01:28:16,560

of that

2705

01:28:20,390 --> 01:28:18,159

usually when talking about whether or

2706

01:28:21,270 --> 01:28:20,400

not space is discretized or on a lattice

2707

01:28:23,510 --> 01:28:21,280

in some way

2708

01:28:24,470 --> 01:28:23,520

people say well we have these fluids and

2709

01:28:25,669 --> 01:28:24,480

then as you

2710

01:28:26,709 --> 01:28:25,679

investigate further you find out that

2711

01:28:27,750 --> 01:28:26,719

they're atoms and we thought that they

2712

01:28:29,590 --> 01:28:27,760

were continuous

2713

01:28:31,110 --> 01:28:29,600

but then as you investigate the atoms

2714

01:28:32,550 --> 01:28:31,120

further you'll find out that they're

2715

01:28:34,070 --> 01:28:32,560

quantum fields

2716

01:28:35,830 --> 01:28:34,080

and obviously then you can say well

2717

01:28:39,350 --> 01:28:35,840

those quantum fields are discretized

2718

01:28:40,830 --> 01:28:39,360

do you think that there's a place in

2719

01:28:44,390 --> 01:28:40,840

your models

2720

01:28:47,750 --> 01:28:44,400

for continuity underneath

2721

01:28:52,310 --> 01:28:47,760

what seems like discrete points so

2722

01:28:55,590 --> 01:28:53,510

anything that i can think of as

2723

01:28:57,510 --> 01:28:55,600

continuous there's some way maybe

2724

01:28:59,590 --> 01:28:57,520

a simplicial decomposition to make it

2725

01:29:01,590 --> 01:28:59,600

discrete but then also the same you can

2726

01:29:03,750 --> 01:29:01,600

apply step functions of a certain

2727

01:29:05,030 --> 01:29:03,760

width from something continuous to make

2728

01:29:06,709 --> 01:29:05,040

something discrete

2729

01:29:09,189 --> 01:29:06,719

so when someone says well this is

2730

01:29:11,590 --> 01:29:09,199

obviously discrete well

2731

01:29:14,310 --> 01:29:11,600

the argument can can be turned on itself

2732

01:29:17,750 --> 01:29:14,320

the thing to understand

2733

01:29:18,229 --> 01:29:17,760

the formalism of our models is probably

2734

01:29:21,350 --> 01:29:18,239

most

2735

01:29:26,310 --> 01:29:21,360

humanly stated in terms of hypographs

2736

01:29:30,709 --> 01:29:28,550

basically certainly the case that there

2737

01:29:31,830 --> 01:29:30,719

are for example algebraic formulations

2738

01:29:33,350 --> 01:29:31,840

of what we're doing

2739

01:29:35,030 --> 01:29:33,360

in fact some of the things from category

2740

01:29:38,310 --> 01:29:35,040

theory look that way

2741

01:29:40,229 --> 01:29:38,320

where you can think about it as features

2742

01:29:42,870 --> 01:29:40,239

of some continuous space

2743

01:29:44,950 --> 01:29:42,880

you know it is you know some algebraic

2744

01:29:46,790 --> 01:29:44,960

geometry feature of some continuous

2745

01:29:49,990 --> 01:29:46,800

space etc etc etc

2746

01:29:51,270 --> 01:29:50,000

the net result is it's just the same as

2747

01:29:53,030 --> 01:29:51,280

this hypergraph

2748

01:29:54,310 --> 01:29:53,040

but it is presented as something that

2749

01:29:57,669 --> 01:29:54,320

looks like

2750

01:29:59,110 --> 01:29:57,679

you know topological uh you know aspects

2751  
01:30:02,149 --> 01:29:59,120  
of the homotopies of

2752  
01:30:03,270 --> 01:30:02,159  
continuous spaces or something but it

2753  
01:30:05,910 --> 01:30:03,280  
looks like

2754  
01:30:07,510 --> 01:30:05,920  
but but a different interpretation is

2755  
01:30:10,470 --> 01:30:07,520  
that it's just this hypogolf

2756  
01:30:12,149 --> 01:30:10,480  
so there's nothing particularly special

2757  
01:30:13,590 --> 01:30:12,159  
about this hypergraph except that it's

2758  
01:30:15,669 --> 01:30:13,600  
the most human

2759  
01:30:17,189 --> 01:30:15,679  
relatable version of what's going on

2760  
01:30:19,830 --> 01:30:17,199  
i'll give you an analogy

2761  
01:30:21,270 --> 01:30:19,840  
in theory of computation you can think

2762  
01:30:22,709 --> 01:30:21,280  
about lambda calculus you can think

2763  
01:30:23,910 --> 01:30:22,719

about combinators you can think about

2764

01:30:26,149 --> 01:30:23,920

register machines

2765

01:30:27,990 --> 01:30:26,159

or you can think about turing machines

2766

01:30:29,990 --> 01:30:28,000

turing machines are the

2767

01:30:32,790 --> 01:30:30,000

you know at least in the early such

2768

01:30:34,310 --> 01:30:32,800

systems where the most human relatable

2769

01:30:36,790 --> 01:30:34,320

you know way of thinking about

2770

01:30:39,030 --> 01:30:36,800

computation and i think that there are

2771

01:30:41,830 --> 01:30:39,040

different formulations of our models

2772

01:30:42,950 --> 01:30:41,840

that uh some of them we can see now some

2773

01:30:43,830 --> 01:30:42,960

of them will probably emerge in the

2774

01:30:46,149 --> 01:30:43,840

future

2775

01:30:48,790 --> 01:30:46,159

that look different with respect to that

2776

01:30:50,950 --> 01:30:48,800

now there's a more extreme possibility

2777

01:30:51,990 --> 01:30:50,960

which i don't know if it's the case and

2778

01:30:54,149 --> 01:30:52,000

i'm trying to not

2779

01:30:55,910 --> 01:30:54,159

repeat mistakes of history so to speak

2780

01:30:57,030 --> 01:30:55,920

here you know when einstein invented

2781

01:30:59,830 --> 01:30:57,040

general artillery

2782

01:31:00,950 --> 01:30:59,840

one of the things that uh came up was

2783

01:31:03,270 --> 01:31:00,960

the theory as he

2784

01:31:04,870 --> 01:31:03,280

first set it up implied that the

2785

01:31:06,629 --> 01:31:04,880

universe expands

2786

01:31:08,229 --> 01:31:06,639

and he was like that can't possibly be

2787

01:31:09,910 --> 01:31:08,239

right you know

2788

01:31:11,910 --> 01:31:09,920

surely that isn't right so let me add

2789

01:31:13,590 --> 01:31:11,920

this extra cosmological term

2790

01:31:15,750 --> 01:31:13,600

to uh to prevent the cosmological

2791

01:31:18,550 --> 01:31:15,760

constant and so on to prevent

2792

01:31:18,790 --> 01:31:18,560

the universe from expanding well turned

2793

01:31:21,110 --> 01:31:18,800

out

2794

01:31:23,750 --> 01:31:21,120

it was true that the universe expanded

2795

01:31:26,229 --> 01:31:23,760

and he shouldn't worry too much about it

2796

01:31:27,590 --> 01:31:26,239

well in our models the most obvious

2797

01:31:30,709 --> 01:31:27,600

possibility

2798

01:31:33,270 --> 01:31:30,719

is that this uh hypograph

2799

01:31:35,110 --> 01:31:33,280

is progressively subdividing itself it's

2800

01:31:38,229 --> 01:31:35,120

getting bigger and bigger and bigger

2801

01:31:41,189 --> 01:31:38,239

um and the the distance

2802

01:31:42,870 --> 01:31:41,199

one meter is corresponding to more and

2803

01:31:44,629 --> 01:31:42,880

more and more

2804

01:31:45,669 --> 01:31:44,639

sort of separate atoms of space if you

2805

01:31:47,030 --> 01:31:45,679

lined them up and looked at their

2806

01:31:48,790 --> 01:31:47,040

connections and so on it will be a

2807

01:31:50,070 --> 01:31:48,800

larger number of connections that would

2808

01:31:51,990 --> 01:31:50,080

have to be made

2809

01:31:54,310 --> 01:31:52,000

to correspond to a meter of physical

2810

01:31:54,870 --> 01:31:54,320

space so one thing which i have to say

2811

01:31:56,470 --> 01:31:54,880

it does

2812

01:31:58,550 --> 01:31:56,480

look in these models is if it's

2813

01:32:01,110 --> 01:31:58,560

suggesting it's the way it happens

2814

01:32:02,550 --> 01:32:01,120

is that in fact the amount of the number

2815

01:32:04,790 --> 01:32:02,560

of atoms of space is

2816

01:32:05,910 --> 01:32:04,800

rapidly increasing in the history of the

2817

01:32:07,910 --> 01:32:05,920

universe

2818

01:32:09,110 --> 01:32:07,920

and if that's the case one of the most

2819

01:32:12,709 --> 01:32:09,120

bizarre possibilities

2820

01:32:13,910 --> 01:32:12,719

is you say okay you say i've got an

2821

01:32:15,910 --> 01:32:13,920

experiment it's going to test whether

2822

01:32:18,390 --> 01:32:15,920

the universe is discrete

2823

01:32:19,830 --> 01:32:18,400

as i run the experiment the universe is

2824

01:32:21,510 --> 01:32:19,840

subdividing itself

2825

01:32:23,669 --> 01:32:21,520

so if the experiment said i'm going to

2826

01:32:25,990 --> 01:32:23,679

test is the universe discrete at the

2827

01:32:28,070 --> 01:32:26,000

level of 10 to the minus 200 meters by

2828

01:32:30,390 --> 01:32:28,080

the time that experiment has been run

2829

01:32:31,990 --> 01:32:30,400

the universe will have subdivided itself

2830

01:32:35,030 --> 01:32:32,000

to be 210 to

2831

01:32:37,270 --> 01:32:35,040

10 to the minus 220 meters or something

2832

01:32:38,390 --> 01:32:37,280

and so in other words it will always be

2833

01:32:40,070 --> 01:32:38,400

running away from you

2834

01:32:42,470 --> 01:32:40,080

it will always be subdividing itself

2835

01:32:43,910 --> 01:32:42,480

faster than you can painted subdivision

2836

01:32:46,550 --> 01:32:43,920

it's kind of like the ultimate epsilon

2837

01:32:47,669 --> 01:32:46,560

delta proof in in calculus or something

2838

01:32:49,669 --> 01:32:47,679

you're watching this channel because

2839

01:32:51,350 --> 01:32:49,679

you're interested in theoretical physics

2840

01:32:52,870 --> 01:32:51,360

consciousness and the ostensible

2841

01:32:54,229 --> 01:32:52,880

connection between the two what's

2842

01:32:55,030 --> 01:32:54,239

required to follow some of these

2843

01:32:56,790 --> 01:32:55,040

arguments is

2844

01:32:59,030 --> 01:32:56,800

facility with mathematics as well as

2845

01:32:59,669 --> 01:32:59,040

discernment of the underlying physical

2846

01:33:01,110 --> 01:32:59,679

laws and

2847

01:33:03,030 --> 01:33:01,120

you may think that this is beyond you

2848

01:33:05,189 --> 01:33:03,040

but that's false brilliance provides

2849

01:33:06,470 --> 01:33:05,199

pelucid explanations of abstruse

2850

01:33:08,870 --> 01:33:06,480

phenomenon such as

2851

01:33:10,550 --> 01:33:08,880

quantum computing general relativity and

2852

01:33:13,030 --> 01:33:10,560

even group theory when you hear that the

2853

01:33:13,990 --> 01:33:13,040

standard model is based on  $u_1$  cross  $su_2$

2854

01:33:15,990 --> 01:33:14,000

cross  $su_3$

2855

01:33:17,830 --> 01:33:16,000

that's group theory for example now this

2856

01:33:19,990 --> 01:33:17,840

isn't just for neophytes either

2857

01:33:21,350 --> 01:33:20,000

for example i have a degree in math and

2858

01:33:23,110 --> 01:33:21,360

physics and i still found

2859

01:33:25,750 --> 01:33:23,120

some of the intuitions given in these

2860

01:33:27,270 --> 01:33:25,760

lessons to vastly aid my penetration

2861

01:33:29,270 --> 01:33:27,280

into these subjects for example

2862

01:33:30,950 --> 01:33:29,280

electricity and magnetism sign up today

2863

01:33:34,070 --> 01:33:30,960

at brilliant.org

2864

01:33:34,790 --> 01:33:34,080

tow that is t-o-e for free you'll also

2865

01:33:36,950 --> 01:33:34,800

get 20

2866

01:33:38,790 --> 01:33:36,960

off the annual premium subscription try

2867

01:33:41,270 --> 01:33:38,800

four of the lessons at least don't

2868

01:33:43,189 --> 01:33:41,280

stop before four and i think you'll be

2869

01:33:45,270 --> 01:33:43,199

greatly surprised at the ease at which

2870

01:33:46,390 --> 01:33:45,280

you comprehend subjects you previously

2871

01:33:48,629 --> 01:33:46,400

had trouble grocking

2872

01:33:50,790 --> 01:33:48,639

links are in the description is there a

2873

01:33:51,910 --> 01:33:50,800

way to test the discretization of space

2874

01:33:54,310 --> 01:33:51,920

or time

2875

01:33:57,510 --> 01:33:54,320

in the cosmic background radiation

2876

01:34:00,310 --> 01:33:57,520

because of how quickly it inflated

2877

01:34:00,709 --> 01:34:00,320

maybe even that inflation no maybe i

2878

01:34:02,629 --> 01:34:00,719

mean

2879

01:34:05,270 --> 01:34:02,639

we've been looking at this what what if

2880

01:34:09,830 --> 01:34:05,280

the universe starts infinite dimensional

2881

01:34:11,270 --> 01:34:09,840

um what um uh and gradually cools down

2882

01:34:13,030 --> 01:34:11,280

to being three-dimensional

2883

01:34:14,550 --> 01:34:13,040

we expect there to be some dimension

2884

01:34:16,070 --> 01:34:14,560

fluctuations left over

2885

01:34:18,070 --> 01:34:16,080

they may have survived for hundreds of

2886

01:34:19,669 --> 01:34:18,080

thousands of years they would lead to

2887

01:34:20,709 --> 01:34:19,679

perturbations in the cosmic microwave

2888

01:34:23,990 --> 01:34:20,719

background

2889

01:34:25,669 --> 01:34:24,000

um and uh that we don't yet know what

2890

01:34:27,189 --> 01:34:25,679

those perturbations are like we're just

2891

01:34:28,310 --> 01:34:27,199

trying to work out what the analog of

2892

01:34:29,669 --> 01:34:28,320

the standard

2893

01:34:31,350 --> 01:34:29,679

you know robertson walker friedman

2894

01:34:34,870 --> 01:34:31,360

robertson walker metric

2895

01:34:36,390 --> 01:34:34,880

uh for a kind of a a um a homogeneous

2896

01:34:37,669 --> 01:34:36,400

universe what that's like when the

2897

01:34:39,350 --> 01:34:37,679

dimension changes we

2898

01:34:40,709 --> 01:34:39,360

we don't know we did some live streams

2899

01:34:41,510 --> 01:34:40,719

recently actually exploring that

2900

01:34:43,270 --> 01:34:41,520

question

2901  
01:34:44,950 --> 01:34:43,280  
we don't know the answer yet it changed

2902  
01:34:46,629 --> 01:34:44,960  
from infinite to a finite so

2903  
01:34:48,950 --> 01:34:46,639  
infinity is real or you're saying

2904  
01:34:49,590 --> 01:34:48,960  
infinite as a standard for an extremely

2905  
01:34:51,189 --> 01:34:49,600  
large

2906  
01:34:53,189 --> 01:34:51,199  
dimensional system more like extremely

2907  
01:34:55,669 --> 01:34:53,199  
large because you can't even

2908  
01:34:56,390 --> 01:34:55,679  
make a sense of a if if you have a graph

2909  
01:34:58,870 --> 01:34:56,400  
that's sort of

2910  
01:35:00,390 --> 01:34:58,880  
completely connected there's no sense of

2911  
01:35:01,750 --> 01:35:00,400  
dimension because dimension requires

2912  
01:35:03,350 --> 01:35:01,760  
that you take limits

2913  
01:35:04,790 --> 01:35:03,360

of larger and larger distances in the

2914

01:35:06,310 --> 01:35:04,800

graph but there is no

2915

01:35:08,629 --> 01:35:06,320

if everything's connected everything is

2916

01:35:10,470 --> 01:35:08,639

distance one away so there's no way to

2917

01:35:11,990 --> 01:35:10,480

get far away and talk about what the

2918

01:35:13,510 --> 01:35:12,000

large scale limit of that is

2919

01:35:15,270 --> 01:35:13,520

how do you get the dimension of time in

2920

01:35:17,109 --> 01:35:15,280

your model because i can understand

2921

01:35:17,750 --> 01:35:17,119

space and there's a hos door for a top

2922

01:35:21,590 --> 01:35:17,760

of lodge

2923

01:35:23,590 --> 01:35:21,600

but with growing up a ball of radius

2924

01:35:27,430 --> 01:35:23,600

but how do you grow a ball of radius

2925

01:35:30,790 --> 01:35:27,440

time it's the dimension of time defined

2926

01:35:33,350 --> 01:35:30,800

so time is is

2927

01:35:35,350 --> 01:35:33,360

multi you know time is going in this

2928

01:35:38,629 --> 01:35:35,360

multi-way graph so time

2929

01:35:41,350 --> 01:35:38,639

to begin with has in a sense

2930

01:35:42,070 --> 01:35:41,360

it is an assumption that is a very

2931

01:35:43,669 --> 01:35:42,080

consciousness

2932

01:35:45,430 --> 01:35:43,679

related assumption that time is one

2933

01:35:46,950 --> 01:35:45,440

dimensional that is

2934

01:35:48,870 --> 01:35:46,960

that there is a single thread of

2935

01:35:51,510 --> 01:35:48,880

experience is basically

2936

01:35:53,350 --> 01:35:51,520

saying we're going to conflate time

2937

01:35:55,430 --> 01:35:53,360

until it is one dimensional

2938

01:35:57,270 --> 01:35:55,440

that is our view of the universe as soon

2939

01:35:58,870 --> 01:35:57,280

as we put in these foliations

2940

01:36:00,629 --> 01:35:58,880

we are essentially assuming that time is

2941

01:36:03,270 --> 01:36:00,639

one dimensional it doesn't need to be

2942

01:36:05,109 --> 01:36:03,280

time can be time can be off with you

2943

01:36:07,030 --> 01:36:05,119

know there can be many different

2944

01:36:08,950 --> 01:36:07,040

uh paths many different histories of the

2945

01:36:11,750 --> 01:36:08,960

universe that never knit together

2946

01:36:13,109 --> 01:36:11,760

that the the the fact that those those

2947

01:36:15,189 --> 01:36:13,119

things are knitted together

2948

01:36:16,790 --> 01:36:15,199

is an assumption that's closely related

2949

01:36:19,350 --> 01:36:16,800

to kind of the generalized view of

2950

01:36:20,550 --> 01:36:19,360

consciousness

2951

01:36:22,390 --> 01:36:20,560

i don't know what you call this meta

2952

01:36:24,470 --> 01:36:22,400

mathematical space if it's proof space

2953

01:36:26,229 --> 01:36:24,480

or what but as i was imagining it

2954

01:36:28,229 --> 01:36:26,239

nodes on a graph and there's some

2955

01:36:29,910 --> 01:36:28,239

diagrammatic rewriting rules

2956

01:36:31,669 --> 01:36:29,920

does that mean that you can make

2957

01:36:35,030 --> 01:36:31,679

rigorous the notion of what

2958

01:36:38,149 --> 01:36:35,040

beauty is you know erdos has the book

2959

01:36:40,070 --> 01:36:38,159

by saying that it's a geodesic in proof

2960

01:36:40,950 --> 01:36:40,080

space or meta-mathematical space well i

2961

01:36:41,990 --> 01:36:40,960

don't know that's a good question

2962

01:36:44,629 --> 01:36:42,000

whether whether

2963

01:36:45,430 --> 01:36:44,639

whether urdosh proofs from the book is

2964

01:36:48,470 --> 01:36:45,440

going to be

2965

01:36:50,950 --> 01:36:48,480

geodesic paths in um

2966

01:36:52,149 --> 01:36:50,960

uh in proofs in theorem space so to

2967

01:36:54,950 --> 01:36:52,159

speak

2968

01:36:56,070 --> 01:36:54,960

my guess is not my guess is most of the

2969

01:36:57,910 --> 01:36:56,080

shortest proofs

2970

01:37:00,390 --> 01:36:57,920

will be absolutely incomprehensible to

2971

01:37:02,070 --> 01:37:00,400

us humans so they may be i mean i think

2972

01:37:04,070 --> 01:37:02,080

urdosh's view of the book

2973

01:37:06,390 --> 01:37:04,080

was kind of a god-given book the proofs

2974

01:37:08,229 --> 01:37:06,400

may be well understandable to god but

2975

01:37:08,709 --> 01:37:08,239

sorry the humans don't get to understand

2976

01:37:11,030 --> 01:37:08,719

them

2977

01:37:12,709 --> 01:37:11,040

i mean in other words it it the shortest

2978

01:37:13,750 --> 01:37:12,719

it's like the shortest algorithm for

2979

01:37:15,830 --> 01:37:13,760

something

2980

01:37:17,669 --> 01:37:15,840

is usually not a human comprehensible

2981

01:37:19,990 --> 01:37:17,679

algorithm

2982

01:37:21,350 --> 01:37:20,000

so it's a trade-off of and this is very

2983

01:37:23,669 --> 01:37:21,360

related to what

2984

01:37:24,470 --> 01:37:23,679

what a mathematical consciousness really

2985

01:37:26,790 --> 01:37:24,480

is

2986

01:37:28,149 --> 01:37:26,800

because to say it's it's following

2987

01:37:30,229 --> 01:37:28,159

geodesics

2988

01:37:31,669 --> 01:37:30,239

is probably to say it's an optimized

2989

01:37:34,070 --> 01:37:31,679

mathematician but not a

2990

01:37:36,629 --> 01:37:34,080

not something closely modeled by a human

2991

01:37:38,229 --> 01:37:36,639

mathematician

2992

01:37:40,070 --> 01:37:38,239

one time i heard you speculate and

2993

01:37:41,990 --> 01:37:40,080

perhaps it's not perhaps it's worked out

2994

01:37:44,149 --> 01:37:42,000

even farther than what i saw that

2995

01:37:45,510 --> 01:37:44,159

particles are black holes in branchial

2996

01:37:48,470 --> 01:37:45,520

space

2997

01:37:49,350 --> 01:37:48,480

uh maybe we'll see not not properly

2998

01:37:52,470 --> 01:37:49,360

worked out yet

2999

01:37:55,990 --> 01:37:52,480

i mean i think that black holes yeah

3000

01:37:57,830 --> 01:37:56,000

i mean that that's a um the relationship

3001

01:38:00,070 --> 01:37:57,840

between particles and black holes

3002

01:38:01,669 --> 01:38:00,080

is an interesting one i'm i'm you know

3003

01:38:03,270 --> 01:38:01,679

for for anybody younger

3004

01:38:06,790 --> 01:38:03,280

who's who's paying attention to this i

3005

01:38:08,390 --> 01:38:06,800

have to tell a story i was probably 1974

3006

01:38:11,350 --> 01:38:08,400

1975 i was probably

3007

01:38:13,109 --> 01:38:11,360

14 15 years old i go to some talk by

3008

01:38:15,030 --> 01:38:13,119

some fancy physicist

3009

01:38:16,709 --> 01:38:15,040

and um they're talking about black holes

3010

01:38:18,629 --> 01:38:16,719

and whatever else so i go up to this

3011

01:38:22,310 --> 01:38:18,639

person afterwards and i say

3012

01:38:24,390 --> 01:38:22,320

you know uh you know could particles be

3013

01:38:26,870 --> 01:38:24,400

small black holes

3014

01:38:28,149 --> 01:38:26,880

right the person says oh no no you don't

3015

01:38:30,229 --> 01:38:28,159

understand anything

3016

01:38:31,750 --> 01:38:30,239

it's you know they're all completely

3017

01:38:34,709 --> 01:38:31,760

different kinds of things

3018

01:38:36,629 --> 01:38:34,719

so okay now we're another 45 years later

3019

01:38:38,790 --> 01:38:36,639

and turns out it might actually be true

3020

01:38:39,990 --> 01:38:38,800

so don't listen to what the the main

3021

01:38:41,430 --> 01:38:40,000

moral of that is

3022

01:38:44,229 --> 01:38:41,440

you know if you go to the talks by the

3023

01:38:46,950 --> 01:38:44,239

fancy physicists and um and

3024

01:38:48,550 --> 01:38:46,960

uh i mean i i wasn't you know at the

3025

01:38:51,750 --> 01:38:48,560

time it just seemed like

3026

01:38:53,430 --> 01:38:51,760

the feature of black holes these no hair

3027

01:38:54,470 --> 01:38:53,440

theorems for black holes the fact that

3028

01:38:56,390 --> 01:38:54,480

black holes

3029

01:38:58,229 --> 01:38:56,400

have this feature that there are only

3030

01:38:59,910 --> 01:38:58,239

certain aspects of black holes that seem

3031

01:39:02,229 --> 01:38:59,920

to be visible from the outside

3032

01:39:03,430 --> 01:39:02,239

just seem to me as the 14 year old me or

3033

01:39:05,990 --> 01:39:03,440

something

3034

01:39:06,790 --> 01:39:06,000

as being you know that seems awfully

3035

01:39:08,470 --> 01:39:06,800

like

3036

01:39:11,109 --> 01:39:08,480

what you find with particles that there

3037

01:39:13,350 --> 01:39:11,119

are limited number of kinds of particles

3038

01:39:15,189 --> 01:39:13,360

that uh just as there are limited number

3039

01:39:18,229 --> 01:39:15,199

of kinds of black holes

3040

01:39:20,310 --> 01:39:18,239

and um turns out as i say

3041

01:39:21,990 --> 01:39:20,320

the main the main takeaway from that is

3042

01:39:23,830 --> 01:39:22,000

um uh

3043

01:39:25,030 --> 01:39:23,840

you know so i'm applying that to myself

3044

01:39:27,350 --> 01:39:25,040

so just as i

3045

01:39:29,750 --> 01:39:27,360

may say to somebody about some idea you

3046

01:39:31,990 --> 01:39:29,760

know that couldn't possibly be that way

3047

01:39:33,990 --> 01:39:32,000

um you know wait another few decades and

3048

01:39:38,229 --> 01:39:34,000

maybe it'll turn out to be right

3049

01:39:41,109 --> 01:39:38,239

but um what are snake states

3050

01:39:43,030 --> 01:39:41,119

oh this is a complicated story that and

3051

01:39:45,189 --> 01:39:43,040

i'm running out of time so we probably

3052

01:39:47,109 --> 01:39:45,199

let let's not let's not dive down that

3053

01:39:48,950 --> 01:39:47,119

that term i mean

3054

01:39:51,510 --> 01:39:48,960

even if even if that led to some

3055

01:39:52,629 --> 01:39:51,520

wonderful puns about snakes on a plane

3056

01:39:53,990 --> 01:39:52,639

and things like this

3057

01:39:56,390 --> 01:39:54,000

do you have any fineman stories that you

3058

01:39:57,189 --> 01:39:56,400

haven't told before that i haven't told

3059

01:40:00,709 --> 01:39:57,199

before

3060

01:40:01,590 --> 01:40:00,719

um or how about this you mentioned one

3061

01:40:03,910 --> 01:40:01,600

time

3062

01:40:05,430 --> 01:40:03,920

perhaps more that feynman is

3063

01:40:06,790 --> 01:40:05,440

misapprehended as someone who has an

3064

01:40:08,870 --> 01:40:06,800

extreme understanding he does

3065

01:40:10,390 --> 01:40:08,880

but he was great at calculation and that

3066

01:40:11,189 --> 01:40:10,400

calculation allowed him to understand

3067

01:40:12,950 --> 01:40:11,199

and perceive

3068

01:40:14,790 --> 01:40:12,960

apprehend what other misunderstandings

3069

01:40:16,229 --> 01:40:14,800

or false impressions do people have

3070

01:40:18,149 --> 01:40:16,239

about feynman that you're able to see

3071

01:40:21,030 --> 01:40:18,159

from the inside

3072

01:40:23,109 --> 01:40:21,040

oh the one that always drove him crazy

3073

01:40:24,470 --> 01:40:23,119

was um and you know you mentioned at the

3074

01:40:27,750 --> 01:40:24,480

beginning of uh

3075

01:40:30,790 --> 01:40:27,760

of this you know people sort of uh

3076

01:40:32,950 --> 01:40:30,800

uh ad hominem attacks that uh

3077

01:40:34,790 --> 01:40:32,960

that i may get which i'm blissfully

3078

01:40:38,310 --> 01:40:34,800

unaware of for the most part but but

3079

01:40:41,669 --> 01:40:38,320

um the um you know

3080

01:40:43,430 --> 01:40:41,679

uh uh people one of the things that

3081

01:40:46,070 --> 01:40:43,440

drove firemen crazy

3082

01:40:46,550 --> 01:40:46,080

was that people thought of him as you

3083

01:40:50,870 --> 01:40:46,560

know

3084

01:40:52,070 --> 01:40:50,880

would listen to anything et cetera et

3085

01:40:55,590 --> 01:40:52,080

cetera et cetera

3086

01:40:58,310 --> 01:40:55,600

but in fact like all of us you know

3087

01:40:59,590 --> 01:40:58,320

he got impatient he valued his time etc

3088

01:41:00,950 --> 01:40:59,600

etc etc

3089

01:41:03,109 --> 01:41:00,960

and so when people would kind of get

3090

01:41:05,669 --> 01:41:03,119

close to him and he would be like

3091

01:41:06,310 --> 01:41:05,679

kind of snarky with them and so on they

3092

01:41:08,629 --> 01:41:06,320

would say

3093

01:41:10,310 --> 01:41:08,639

oh my gosh you know you're supposed to

3094

01:41:12,790 --> 01:41:10,320

be this this wonderfully

3095

01:41:13,830 --> 01:41:12,800

nice you know positive person and

3096

01:41:15,430 --> 01:41:13,840

actually

3097

01:41:17,270 --> 01:41:15,440

you're kind of snarky that's terrible

3098

01:41:19,189 --> 01:41:17,280

that's horrible i'm i'm

3099

01:41:20,950 --> 01:41:19,199

i'm you know that's that's very

3100

01:41:22,709 --> 01:41:20,960

horrifying so so actually one of the

3101

01:41:26,070 --> 01:41:22,719

things he always used to tell me is

3102

01:41:29,270 --> 01:41:26,080

don't don't appear to be too nice

3103

01:41:29,830 --> 01:41:29,280

because it's actually a worse life than

3104

01:41:32,149 --> 01:41:29,840

um

3105

01:41:32,870 --> 01:41:32,159

uh uh than the other so to speak i'm not

3106

01:41:35,350 --> 01:41:32,880

sure that i've

3107

01:41:36,550 --> 01:41:35,360

intentionally taken that to heart but um

3108

01:41:39,830 --> 01:41:36,560

it was one of those things

3109

01:41:43,590 --> 01:41:39,840

but i think here's the thing that um

3110

01:41:46,550 --> 01:41:43,600

uh i talked a lot to dick feynman about

3111

01:41:47,350 --> 01:41:46,560

quantum mechanics and he would always

3112

01:41:48,629 --> 01:41:47,360

say

3113

01:41:49,910 --> 01:41:48,639

you know we don't really understand

3114

01:41:51,270 --> 01:41:49,920

quantum mechanics you know we can

3115

01:41:52,550 --> 01:41:51,280

calculate this and that

3116

01:41:53,669 --> 01:41:52,560

we don't really understand it we don't

3117

01:41:54,709 --> 01:41:53,679

have an intuitive understanding of

3118

01:41:56,149 --> 01:41:54,719

what's going on

3119

01:41:57,350 --> 01:41:56,159

it's a shame he's not still around

3120

01:41:58,709 --> 01:41:57,360

because i would really have had a good

3121

01:42:00,870 --> 01:41:58,719

time telling him about the stuff we

3122

01:42:02,070 --> 01:42:00,880

figured out now and it's you know one of

3123

01:42:03,990 --> 01:42:02,080

the things i remember

3124

01:42:05,990 --> 01:42:04,000

just these endless conversations about

3125

01:42:06,229 --> 01:42:06,000

why does thermodynamics  $\theta$  minus  $\beta$

3126

01:42:14,070 --> 01:42:06,239

h

3127

01:42:17,189 --> 01:42:14,080

answer

3128

01:42:18,629 --> 01:42:17,199

and it's it's pretty neat and it's um i

3129

01:42:22,950 --> 01:42:18,639

think that um

3130

01:42:26,310 --> 01:42:24,709

i mean another thing that we don't yet

3131

01:42:27,430 --> 01:42:26,320

know they'll be interesting to see how

3132

01:42:29,430 --> 01:42:27,440

it plays out

3133

01:42:30,950 --> 01:42:29,440

you know one of dick feynman's most

3134

01:42:32,950 --> 01:42:30,960

famous probably single most famous

3135

01:42:35,669 --> 01:42:32,960

invention was fyman diagrams

3136

01:42:37,109 --> 01:42:35,679

this way of calculating uh things in

3137

01:42:39,590 --> 01:42:37,119

quantum field theory

3138

01:42:41,189 --> 01:42:39,600

um and one of the features of feynman

3139

01:42:42,550 --> 01:42:41,199

diagrams is

3140

01:42:45,510 --> 01:42:42,560

the simple ones are pretty easy to

3141

01:42:47,189 --> 01:42:45,520

compute but there's this whole series of

3142

01:42:48,070 --> 01:42:47,199

finin diagrams for any particular thing

3143

01:42:48,870 --> 01:42:48,080

and they get more and more and more

3144

01:42:50,390 --> 01:42:48,880

complicated

3145

01:42:52,390 --> 01:42:50,400

and they get unbelievably more difficult

3146

01:42:53,590 --> 01:42:52,400

to compute so for example right now

3147

01:42:55,510 --> 01:42:53,600

there's a big sort of flap

3148

01:42:57,350 --> 01:42:55,520

because the anomalous magnetic moment of

3149

01:42:58,229 --> 01:42:57,360

the muon which is computed using feynman

3150

01:42:59,750 --> 01:42:58,239

diagrams

3151  
01:43:01,510 --> 01:42:59,760  
there's a disagreement apparently

3152  
01:43:04,229 --> 01:43:01,520  
between the experiment and the theory

3153  
01:43:05,350 --> 01:43:04,239  
that sort of why is that the case well

3154  
01:43:07,189 --> 01:43:05,360  
you know it could be

3155  
01:43:08,790 --> 01:43:07,199  
that one of the things that happens is

3156  
01:43:11,030 --> 01:43:08,800  
these series of diagrams

3157  
01:43:12,709 --> 01:43:11,040  
we don't actually know that the ones

3158  
01:43:14,950 --> 01:43:12,719  
that we can't compute yet

3159  
01:43:16,390 --> 01:43:14,960  
are really as small as we think they are

3160  
01:43:18,070 --> 01:43:16,400  
and anyway one of the things that i

3161  
01:43:20,550 --> 01:43:18,080  
think may come out

3162  
01:43:22,070 --> 01:43:20,560  
is we may have an actual method for

3163  
01:43:22,629 --> 01:43:22,080

doing computations in quantum field

3164

01:43:25,109 --> 01:43:22,639

theory

3165

01:43:26,709 --> 01:43:25,119

that avoids feynman diagrams and and

3166

01:43:29,030 --> 01:43:26,719

feynman always thought

3167

01:43:30,149 --> 01:43:29,040

that he thought said firemen diagrams

3168

01:43:33,590 --> 01:43:30,159

are a crazy idea

3169

01:43:35,750 --> 01:43:33,600

he would always say and um you know i i

3170

01:43:37,510 --> 01:43:35,760

you know i can't believe people think

3171

01:43:39,270 --> 01:43:37,520

you know that there's got to be a better

3172

01:43:40,390 --> 01:43:39,280

way to do this this is a crazy way to do

3173

01:43:42,149 --> 01:43:40,400

it there's got to be a better way to do

3174

01:43:44,149 --> 01:43:42,159

it maybe we'll have such a way

3175

01:43:45,750 --> 01:43:44,159

i'm not sure there's there's also hints

3176

01:43:49,669 --> 01:43:45,760

of of better ways that

3177

01:43:52,310 --> 01:43:49,679

involve the um uh the whole ads cft

3178

01:43:53,350 --> 01:43:52,320

uh business which is pretty closely

3179

01:43:54,870 --> 01:43:53,360

related i think

3180

01:43:56,629 --> 01:43:54,880

to correspondence between physical and

3181

01:43:58,470 --> 01:43:56,639

branchial space in our models so

3182

01:44:00,310 --> 01:43:58,480

it may end up being the same idea in the

3183

01:44:01,830 --> 01:44:00,320

end is there some relationship between

3184

01:44:03,430 --> 01:44:01,840

the holographic principle and

3185

01:44:05,030 --> 01:44:03,440

particles being associated with black

3186

01:44:07,750 --> 01:44:05,040

holes in branchial space

3187

01:44:08,390 --> 01:44:07,760

ads cft correspondence that's probably a

3188

01:44:09,510 --> 01:44:08,400

large

3189

01:44:11,750 --> 01:44:09,520

question you don't have time to answer

3190

01:44:12,550 --> 01:44:11,760

now we don't know yet i mean it looks

3191

01:44:15,189 --> 01:44:12,560

like

3192

01:44:15,910 --> 01:44:15,199

the the holographic principle is a story

3193

01:44:18,470 --> 01:44:15,920

of

3194

01:44:19,510 --> 01:44:18,480

the multi-way causal graph being able to

3195

01:44:22,149 --> 01:44:19,520

be projected

3196

01:44:23,590 --> 01:44:22,159

both in a spatial direction and in a

3197

01:44:25,669 --> 01:44:23,600

branchial direction

3198

01:44:26,870 --> 01:44:25,679

and that it's basically the same graph

3199

01:44:28,550 --> 01:44:26,880

but you're taking two different

3200

01:44:30,550 --> 01:44:28,560

projections of that graph

3201

01:44:32,310 --> 01:44:30,560

and the fact that it's the same graph is

3202

01:44:33,669 --> 01:44:32,320

why there's a holographic principle

3203

01:44:36,070 --> 01:44:33,679

that relates those two different

3204

01:44:37,270 --> 01:44:36,080

projections that's that's probably how

3205

01:44:40,149 --> 01:44:37,280

it's going to work out

3206

01:44:40,390 --> 01:44:40,159

that seems to be how it will work out um

3207

01:44:46,830 --> 01:44:40,400

and

3208

01:44:47,990 --> 01:44:46,840

the um but i'm you you're now having me

3209

01:44:51,350 --> 01:44:48,000

really

3210

01:44:55,030 --> 01:44:51,360

troll my memory for for um

3211

01:44:57,510 --> 01:44:55,040

uh i'm trying to think about

3212

01:44:58,950 --> 01:44:57,520

some dick feynman stories that are

3213

01:45:00,709 --> 01:44:58,960

related to um

3214

01:45:02,070 --> 01:45:00,719

i mean i'm thinking about things that we

3215

01:45:03,830 --> 01:45:02,080

now know

3216

01:45:05,270 --> 01:45:03,840

so to speak that were things that i

3217

01:45:09,189 --> 01:45:05,280

talked to him about

3218

01:45:13,030 --> 01:45:09,199

um and uh um

3219

01:45:16,950 --> 01:45:13,040

yeah that he would dismiss

3220

01:45:17,830 --> 01:45:16,960

um no i mean he always believed there

3221

01:45:19,430 --> 01:45:17,840

was something

3222

01:45:21,030 --> 01:45:19,440

funky about quantum mechanics that there

3223

01:45:22,149 --> 01:45:21,040

was something more to understand that it

3224

01:45:24,629 --> 01:45:22,159

really wasn't

3225

01:45:25,430 --> 01:45:24,639

that what had been done to that time

3226

01:45:29,189 --> 01:45:25,440

which is now

3227

01:45:29,669 --> 01:45:29,199

early 1980s um was just a calculational

3228

01:45:32,310 --> 01:45:29,679

method

3229

01:45:33,189 --> 01:45:32,320

wasn't a a real understanding so to

3230

01:45:35,189 --> 01:45:33,199

speak

3231

01:45:36,629 --> 01:45:35,199

i would say that um yeah okay there's

3232

01:45:36,870 --> 01:45:36,639

another thing i remember i talked to him

3233

01:45:40,070 --> 01:45:36,880

at

3234

01:45:43,430 --> 01:45:40,080

thermodynamics

3235

01:45:46,709 --> 01:45:43,440

which i finally understood in the 1990s

3236

01:45:48,310 --> 01:45:46,719

and uh um i remember we had a huge

3237

01:45:51,990 --> 01:45:48,320

argument at one point

3238

01:45:54,070 --> 01:45:52,000

where he was claiming that the fact that

3239

01:45:54,870 --> 01:45:54,080

the universe is as orderly as it is

3240

01:45:57,430 --> 01:45:54,880

today

3241

01:45:57,990 --> 01:45:57,440

is a fluctuation which i was just like

3242

01:46:01,030 --> 01:45:58,000

that's a

3243

01:46:02,310 --> 01:46:01,040

stupid thing to say our whole universe

3244

01:46:04,390 --> 01:46:02,320

if you say our whole universe in its

3245

01:46:05,910 --> 01:46:04,400

current stages of fluctuation that's not

3246

01:46:07,750 --> 01:46:05,920

a useful scientific theory

3247

01:46:10,310 --> 01:46:07,760

because you're saying with respect to

3248

01:46:11,109 --> 01:46:10,320

our theory everything about what exists

3249

01:46:13,189 --> 01:46:11,119

today

3250

01:46:14,629 --> 01:46:13,199

is an exception and then you don't have

3251

01:46:16,709 --> 01:46:14,639

a theory of what

3252

01:46:18,310 --> 01:46:16,719

you know of what exists today but we i

3253

01:46:18,870 --> 01:46:18,320

remember we had a huge argument about

3254

01:46:22,470 --> 01:46:18,880

this

3255

01:46:24,390 --> 01:46:22,480

have to i

3256

01:46:25,910 --> 01:46:24,400

i had to agree that there was a bunch

3257

01:46:28,870 --> 01:46:25,920

that i didn't understand about

3258

01:46:29,270 --> 01:46:28,880

thermodynamics and nor did he and i

3259

01:46:31,030 --> 01:46:29,280

think

3260

01:46:32,390 --> 01:46:31,040

finally we've understood how that works

3261

01:46:33,510 --> 01:46:32,400

and it's a story of computational

3262

01:46:35,189 --> 01:46:33,520

irreducibility

3263

01:46:37,030 --> 01:46:35,199

and i should have been able to tell that

3264

01:46:39,430 --> 01:46:37,040

story actually even at that time

3265

01:46:40,310 --> 01:46:39,440

i just didn't wasn't um wasn't smart

3266

01:46:42,310 --> 01:46:40,320

enough to see that

3267

01:46:45,270 --> 01:46:42,320

um that connection for another probably

3268

01:46:48,550 --> 01:46:45,280

ten years after that

3269

01:46:50,310 --> 01:46:48,560

okay last fluff question has to do with

3270

01:46:51,750 --> 01:46:50,320

cryptocurrencies and what you see is the

3271

01:46:53,430 --> 01:46:51,760

future of cryptocurrencies

3272

01:46:59,350 --> 01:46:53,440

let me read it specifically because it

3273

01:47:03,189 --> 01:47:00,870

what is the future of cryptocurrencies

3274

01:47:05,270 --> 01:47:03,199

this is from amjad

3275

01:47:07,109 --> 01:47:05,280

many ceos are buying crypto as a store

3276

01:47:10,310 --> 01:47:07,119

of value your thoughts on it who is

3277

01:47:12,149 --> 01:47:10,320

satoshi nakamoto your views on bitcoin

3278

01:47:14,550 --> 01:47:12,159

and proof of work algorithms versus

3279

01:47:15,990 --> 01:47:14,560

ethereum and proof of stake

3280

01:47:17,270 --> 01:47:16,000

quite a few questions when there's a

3281

01:47:19,189 --> 01:47:17,280

long story because we've been quite

3282

01:47:21,270 --> 01:47:19,199

involved in the whole crypto world

3283

01:47:23,430 --> 01:47:21,280

um for a variety of different reasons

3284

01:47:25,990 --> 01:47:23,440

but i'll tell you the thing that is most

3285

01:47:28,870 --> 01:47:26,000

ironic to me about the crypto world

3286

01:47:30,390 --> 01:47:28,880

which is back in the 1980s you know i

3287

01:47:32,149 --> 01:47:30,400

had this idea about computational

3288

01:47:33,669 --> 01:47:32,159

irreducibility the idea that you might

3289

01:47:34,709 --> 01:47:33,679

need to do an irreducible amount of

3290

01:47:38,870 --> 01:47:34,719

computation

3291

01:47:40,629 --> 01:47:38,880

to work certain things out i

3292

01:47:42,149 --> 01:47:40,639

i have some considerable reason to

3293

01:47:45,590 --> 01:47:42,159

believe that

3294

01:47:50,070 --> 01:47:45,600

that um uh

3295

01:47:51,030 --> 01:47:50,080

the um the creator of bitcoin um was

3296

01:47:53,510 --> 01:47:51,040

aware of my

3297

01:47:55,510 --> 01:47:53,520

work about computational irreducibility

3298

01:47:58,470 --> 01:47:55,520

and so the thing that is kind of

3299

01:47:59,030 --> 01:47:58,480

the most ironic most bizarre thing is

3300

01:48:00,550 --> 01:47:59,040

that

3301

01:48:02,550 --> 01:48:00,560

when i thought about computational

3302

01:48:06,709 --> 01:48:02,560

disability in the 1980s

3303

01:48:10,070 --> 01:48:09,189

i imagined it as this limitation on

3304

01:48:12,470 --> 01:48:10,080

science this

3305

01:48:13,750 --> 01:48:12,480

principle about something formal and

3306

01:48:17,430 --> 01:48:13,760

mathematical

3307

01:48:19,750 --> 01:48:17,440

i had no idea that decades later

3308

01:48:21,750 --> 01:48:19,760

there would be you know whatever it is

3309

01:48:23,669 --> 01:48:21,760

some number of percentage points of the

3310

01:48:24,950 --> 01:48:23,679

of the total energy production of the

3311

01:48:27,350 --> 01:48:24,960

world would be

3312

01:48:29,030 --> 01:48:27,360

burnt in computational irreducibility

3313

01:48:31,430 --> 01:48:29,040

it's an utterly bizarre

3314

01:48:32,870 --> 01:48:31,440

it's kind of like you you know if for

3315

01:48:35,990 --> 01:48:32,880

somebody like me i build

3316

01:48:37,990 --> 01:48:36,000

theories i build tools and then the

3317

01:48:39,430 --> 01:48:38,000

world goes on and eventually uses those

3318

01:48:41,669 --> 01:48:39,440

theories and those tools

3319

01:48:42,629 --> 01:48:41,679

for things that are just i mean that one

3320

01:48:44,470 --> 01:48:42,639

was something

3321

01:48:46,390 --> 01:48:44,480

so far out of left field that i couldn't

3322

01:48:48,149 --> 01:48:46,400

see coming that it's remarkable

3323

01:48:50,390 --> 01:48:48,159

that that that idea of proof work is

3324

01:48:52,390 --> 01:48:50,400

completely crazy i mean it's it's a

3325

01:48:54,470 --> 01:48:52,400

it to be fair it's it's a it's very

3326

01:48:55,910 --> 01:48:54,480

amusing and completely crazy

3327

01:48:57,510 --> 01:48:55,920

and you know i have certainly thought

3328

01:48:58,629 --> 01:48:57,520

about is there a way to do something

3329

01:49:01,109 --> 01:48:58,639

like proof of work

3330

01:49:03,270 --> 01:49:01,119

that generates useful computation and i

3331

01:49:05,750 --> 01:49:03,280

have not yet figured out how to do that

3332

01:49:07,109 --> 01:49:05,760

but with respect to cryptocurrency and

3333

01:49:09,830 --> 01:49:07,119

for example the question

3334

01:49:11,590 --> 01:49:09,840

why is there value in cryptocurrency you

3335

01:49:13,109 --> 01:49:11,600

know i had thought well to get value in

3336

01:49:14,470 --> 01:49:13,119

economics you have to actually be making

3337

01:49:16,470 --> 01:49:14,480

something in the real world

3338

01:49:17,990 --> 01:49:16,480

and i thought for a while you know we've

3339

01:49:20,229 --> 01:49:18,000

been a lot involved in computational

3340

01:49:21,589 --> 01:49:20,239

contracts the idea of expressing

3341

01:49:24,149 --> 01:49:21,599

what would otherwise be contracts

3342

01:49:25,669 --> 01:49:24,159

written in legalese in

3343

01:49:27,589 --> 01:49:25,679

in computational language because we

3344

01:49:27,990 --> 01:49:27,599

have kind of the unique computational

3345

01:49:29,990 --> 01:49:28,000

language

3346

01:49:31,910 --> 01:49:30,000

that can talk about the real world and

3347

01:49:33,990 --> 01:49:31,920

that is therefore capable of having

3348

01:49:35,109 --> 01:49:34,000

you know contracts about the real world

3349

01:49:36,709 --> 01:49:35,119

written in it

3350

01:49:39,030 --> 01:49:36,719

so we've done quite a bit of work on

3351  
01:49:40,629 --> 01:49:39,040  
that and i sort of imagine my belief as

3352  
01:49:43,990 --> 01:49:40,639  
a few years ago was

3353  
01:49:46,629 --> 01:49:44,000  
that when computational contracts

3354  
01:49:48,070 --> 01:49:46,639  
are the dominant form of contracts that

3355  
01:49:49,270 --> 01:49:48,080  
cryptocurrencies just become a

3356  
01:49:52,550 --> 01:49:49,280  
convenient

3357  
01:49:53,910 --> 01:49:52,560  
mechanism for uh for

3358  
01:49:56,870 --> 01:49:53,920  
sort of servicing computational

3359  
01:49:58,709 --> 01:49:56,880  
contracts but then

3360  
01:50:00,470 --> 01:49:58,719  
the question is is there intrinsic value

3361  
01:50:02,550 --> 01:50:00,480  
in a cryptocurrency

3362  
01:50:03,990 --> 01:50:02,560  
and so this relates to the question of

3363  
01:50:05,830 --> 01:50:04,000

well why is there intrinsic value in

3364

01:50:07,669 --> 01:50:05,840

anything in economics

3365

01:50:10,070 --> 01:50:07,679

and so that relates to what is the

3366

01:50:11,109 --> 01:50:10,080

foundational theory of economics and so

3367

01:50:11,990 --> 01:50:11,119

this is something i've been thinking

3368

01:50:13,910 --> 01:50:12,000

about

3369

01:50:16,149 --> 01:50:13,920

and you know i think that the the

3370

01:50:17,510 --> 01:50:16,159

elementary actions in economics are

3371

01:50:19,510 --> 01:50:17,520

transactions

3372

01:50:21,350 --> 01:50:19,520

and i think that what's happening is

3373

01:50:22,709 --> 01:50:21,360

that this whole giant network of

3374

01:50:23,910 --> 01:50:22,719

transactions

3375

01:50:25,750 --> 01:50:23,920

why does this sound like something

3376

01:50:27,030 --> 01:50:25,760

what's out elsewhere well because i

3377

01:50:28,870 --> 01:50:27,040

think it maybe is

3378

01:50:31,030 --> 01:50:28,880

it's something not unlike the giant

3379

01:50:33,270 --> 01:50:31,040

network of updatings of this

3380

01:50:34,629 --> 01:50:33,280

spatial hypergraph and so on it's all

3381

01:50:35,669 --> 01:50:34,639

these different transactions happening

3382

01:50:39,109 --> 01:50:35,679

in the world

3383

01:50:39,990 --> 01:50:39,119

and the story ends up being that what is

3384

01:50:44,790 --> 01:50:40,000

value

3385

01:50:46,870 --> 01:50:44,800

price is something related to

3386

01:50:48,550 --> 01:50:46,880

okay so so think about it this way i

3387

01:50:49,830 --> 01:50:48,560

i've been using this thing last few

3388

01:50:52,070 --> 01:50:49,840

weeks at least

3389

01:50:53,589 --> 01:50:52,080

you know somebody wants to buy a cookie

3390

01:50:55,750 --> 01:50:53,599

the person they want to buy it from

3391

01:50:59,030 --> 01:50:55,760

eventually wants to rent a movie

3392

01:51:02,629 --> 01:50:59,040

the question is is there in

3393

01:51:03,669 --> 01:51:02,639

a certain world where it's ai bots all

3394

01:51:06,070 --> 01:51:03,679

the way down

3395

01:51:07,589 --> 01:51:06,080

one could imagine that they arranged

3396

01:51:09,189 --> 01:51:07,599

this network of transactions so the

3397

01:51:11,270 --> 01:51:09,199

person who wants to buy the cookie

3398

01:51:12,870 --> 01:51:11,280

eventually is giving value to the person

3399

01:51:13,669 --> 01:51:12,880

who wants to rent the movie they barter

3400

01:51:15,750 --> 01:51:13,679

everything

3401

01:51:16,950 --> 01:51:15,760

so that's what happens no money is

3402

01:51:19,910 --> 01:51:16,960

involved it's just

3403

01:51:22,629 --> 01:51:19,920

bought to bot transactions right so the

3404

01:51:24,709 --> 01:51:22,639

question is what is money what is price

3405

01:51:26,310 --> 01:51:24,719

and i think what it could be thought of

3406

01:51:27,589 --> 01:51:26,320

as i think i i don't know if this will

3407

01:51:30,390 --> 01:51:27,599

really work out

3408

01:51:30,790 --> 01:51:30,400

that it is just like you have all these

3409

01:51:33,350 --> 01:51:30,800

uh

3410

01:51:35,510 --> 01:51:33,360

sort of interactions in space and so on

3411

01:51:36,149 --> 01:51:35,520

and in aggregate you can think about

3412

01:51:37,990 --> 01:51:36,159

them

3413

01:51:39,350 --> 01:51:38,000

as having certain gravitational fields

3414

01:51:40,709 --> 01:51:39,360

certain this that and the other certain

3415

01:51:43,030 --> 01:51:40,719

aggregate properties

3416

01:51:44,070 --> 01:51:43,040

that is a description of all of those

3417

01:51:48,390 --> 01:51:44,080

microscopic

3418

01:51:51,589 --> 01:51:48,400

so i have this slight guess

3419

01:51:54,629 --> 01:51:51,599

that value and price

3420

01:51:55,510 --> 01:51:54,639

are associated with sort of an aggregate

3421

01:51:57,430 --> 01:51:55,520

version

3422

01:51:58,709 --> 01:51:57,440

of all these microscopic processes that

3423

01:52:01,750 --> 01:51:58,719

are going on and

3424

01:52:04,629 --> 01:52:01,760

the most bizarre thing is that what

3425

01:52:07,430 --> 01:52:04,639

leads those things to have a sort of a

3426  
01:52:08,790 --> 01:52:07,440  
a robust value is computational

3427  
01:52:11,669 --> 01:52:08,800  
irreducibility

3428  
01:52:13,510 --> 01:52:11,679  
so the absolutely bizarre possibility is

3429  
01:52:15,030 --> 01:52:13,520  
that the transactions that go on an

3430  
01:52:18,229 --> 01:52:15,040  
economic system

3431  
01:52:19,910 --> 01:52:18,239  
are sort of in aggregate

3432  
01:52:22,390 --> 01:52:19,920  
they are a whole story of computational

3433  
01:52:23,189 --> 01:52:22,400  
irreducibility and the reason that they

3434  
01:52:26,229 --> 01:52:23,199  
build up

3435  
01:52:27,350 --> 01:52:26,239  
some definite sort of uh sort of solid

3436  
01:52:30,149 --> 01:52:27,360  
sense of price

3437  
01:52:31,510 --> 01:52:30,159  
or value is because you sort of can't un

3438  
01:52:33,030 --> 01:52:31,520

unravel that computational

3439

01:52:35,030 --> 01:52:33,040

irreducibility

3440

01:52:37,030 --> 01:52:35,040

and so in some sense the computational

3441

01:52:40,149 --> 01:52:37,040

irreducibility is the source

3442

01:52:42,149 --> 01:52:40,159

of robust value in economics and then

3443

01:52:43,510 --> 01:52:42,159

that in a sense the bizarre thing then

3444

01:52:46,310 --> 01:52:43,520

is proof-of-work

3445

01:52:47,109 --> 01:52:46,320

is a is a crazy sort of inner bottle

3446

01:52:49,189 --> 01:52:47,119

version

3447

01:52:51,350 --> 01:52:49,199

of that process so to speak proof of

3448

01:52:52,149 --> 01:52:51,360

work yes the proof of work is is ends up

3449

01:52:55,189 --> 01:52:52,159

being sort of the

3450

01:52:58,310 --> 01:52:55,199

the bottled up version of that that idea

3451

01:53:00,149 --> 01:52:58,320

although it's it's a it's a poor way to

3452

01:53:03,109 --> 01:53:00,159

to think about that and i think that the

3453

01:53:06,070 --> 01:53:03,119

so you know what i'm imagining is that

3454

01:53:08,470 --> 01:53:06,080

that the very fact that so many people

3455

01:53:11,510 --> 01:53:08,480

are doing things with cryptocurrencies

3456

01:53:11,990 --> 01:53:11,520

is almost by definition a proof that

3457

01:53:14,470 --> 01:53:12,000

they have

3458

01:53:15,030 --> 01:53:14,480

value that is it could be the case that

3459

01:53:16,149 --> 01:53:15,040

you say well

3460

01:53:18,709 --> 01:53:16,159

everybody is doing things as a

3461

01:53:20,870 --> 01:53:18,719

speculator which might be close to true

3462

01:53:22,229 --> 01:53:20,880

but even so by the time there's a

3463

01:53:23,430 --> 01:53:22,239

complicated enough network of

3464

01:53:25,910 --> 01:53:23,440

transactions

3465

01:53:27,189 --> 01:53:25,920

that is in a sense building you up a

3466

01:53:28,950 --> 01:53:27,199

real value

3467

01:53:30,390 --> 01:53:28,960

even though those transactions don't

3468

01:53:32,310 --> 01:53:30,400

happen to actuate

3469

01:53:33,830 --> 01:53:32,320

particularly in the in the quotes real

3470

01:53:35,750 --> 01:53:33,840

world i mean this is

3471

01:53:37,189 --> 01:53:35,760

you know for somebody like me who builds

3472

01:53:38,950 --> 01:53:37,199

sort of a model of of the

3473

01:53:41,030 --> 01:53:38,960

universe that is in a sense a nice

3474

01:53:42,550 --> 01:53:41,040

abstract model one's asking

3475

01:53:43,990 --> 01:53:42,560

is there a fundamental difference

3476

01:53:46,229 --> 01:53:44,000

between the processes that are going on

3477

01:53:47,750 --> 01:53:46,239

in this purely abstract cryptocurrency

3478

01:53:49,750 --> 01:53:47,760

and in something that is connected to

3479

01:53:51,109 --> 01:53:49,760

the real world and buying cookies and so

3480

01:53:53,109 --> 01:53:51,119

on in the real world

3481

01:53:55,270 --> 01:53:53,119

and the answer is i'm increasingly

3482

01:53:57,430 --> 01:53:55,280

coming to the belief that there is a

3483

01:53:59,109 --> 01:53:57,440

a notion of a store of value that

3484

01:54:01,350 --> 01:53:59,119

doesn't have to do with

3485

01:54:02,950 --> 01:54:01,360

uh sort of the the details of that now

3486

01:54:03,990 --> 01:54:02,960

as a practical matter you know what's

3487

01:54:06,070 --> 01:54:04,000

going to happen with

3488

01:54:07,270 --> 01:54:06,080

with all those cryptocurrencies you know

3489

01:54:09,030 --> 01:54:07,280

i have no idea

3490

01:54:10,310 --> 01:54:09,040

you know i we've been involved with the

3491

01:54:12,950 --> 01:54:10,320

cryptocurrency world

3492

01:54:14,390 --> 01:54:12,960

so you know at this point i am the the

3493

01:54:15,750 --> 01:54:14,400

proud owner of a certain amount of

3494

01:54:17,750 --> 01:54:15,760

cryptocurrency

3495

01:54:20,149 --> 01:54:17,760

and um you know it's been interesting

3496

01:54:23,109 --> 01:54:20,159

for me because i've i've never done

3497

01:54:24,310 --> 01:54:23,119

uh you know our technology over language

3498

01:54:26,790 --> 01:54:24,320

and mathematica and so on

3499

01:54:29,270 --> 01:54:26,800

get widely used by quant finance people

3500

01:54:32,390 --> 01:54:29,280

um but i've i've never personally done

3501

01:54:34,870 --> 01:54:32,400

kind of um uh you know trading of of

3502

01:54:35,990 --> 01:54:34,880

of those things on any kind of serious

3503

01:54:39,430 --> 01:54:36,000

kind of actual

3504

01:54:41,030 --> 01:54:39,440

uh trading screens type basis and so

3505

01:54:42,070 --> 01:54:41,040

you know it's kind of it's kind of a

3506

01:54:43,830 --> 01:54:42,080

funny thing because you know i have a

3507

01:54:45,350 --> 01:54:43,840

company with lots of people in it but

3508

01:54:47,669 --> 01:54:45,360

in the end you know we we've gotten

3509

01:54:49,430 --> 01:54:47,679

cryptocurrency from from a bunch of

3510

01:54:50,310 --> 01:54:49,440

companies that we work with and it's

3511

01:54:51,669 --> 01:54:50,320

like what do we do with this

3512

01:54:54,310 --> 01:54:51,679

cryptocurrency my

3513

01:54:56,070 --> 01:54:54,320

my long time cfo was like you can't you

3514

01:54:57,430 --> 01:54:56,080

know we can't accept this cryptocurrency

3515

01:54:57,830 --> 01:54:57,440

what the heck are we going to do with it

3516

01:54:59,189 --> 01:54:57,840

and

3517

01:55:00,870 --> 01:54:59,199

you know how do we account for it in so

3518

01:55:01,430 --> 01:55:00,880

anyway we finally solved those problems

3519

01:55:05,750 --> 01:55:01,440

but

3520

01:55:09,270 --> 01:55:05,760

an amusing time

3521

01:55:12,390 --> 01:55:09,280

a few weeks ago when i was was both um

3522

01:55:13,910 --> 01:55:12,400

uh spending some number of hours working

3523

01:55:15,109 --> 01:55:13,920

on the question of why does the universe

3524

01:55:17,830 --> 01:55:15,119

exist

3525

01:55:19,510 --> 01:55:17,840

and multitasking between that and

3526

01:55:21,990 --> 01:55:19,520

cryptocurrency trading

3527

01:55:24,229 --> 01:55:22,000

and that was kind of a an interesting um

3528

01:55:26,390 --> 01:55:24,239

interesting personal experience

3529

01:55:28,149 --> 01:55:26,400

you were actively trading crypto what's

3530

01:55:28,950 --> 01:55:28,159

that we're just you're actively trading

3531

01:55:31,270 --> 01:55:28,960

crypto

3532

01:55:32,790 --> 01:55:31,280

yes because i because we got a bunch of

3533

01:55:35,830 --> 01:55:32,800

cryptocurrency and

3534

01:55:38,229 --> 01:55:35,840

we uh you know my calculation is

3535

01:55:38,950 --> 01:55:38,239

by the time it's uh well the real

3536

01:55:40,870 --> 01:55:38,960

problem was

3537

01:55:42,550 --> 01:55:40,880

that within my company it was like who

3538

01:55:43,510 --> 01:55:42,560

do we delegate the cryptocurrency

3539

01:55:45,430 --> 01:55:43,520

trading to

3540

01:55:46,709 --> 01:55:45,440

and generally the the general principle

3541

01:55:49,350 --> 01:55:46,719

of companies is

3542

01:55:50,709 --> 01:55:49,360

you know the ceo it starts with the ceo

3543

01:55:51,910 --> 01:55:50,719

and then they try and find somebody to

3544

01:55:53,990 --> 01:55:51,920

delegate it to

3545

01:55:55,910 --> 01:55:54,000

and if you know we have about 800 people

3546

01:55:57,510 --> 01:55:55,920

but you know if none of them

3547

01:55:59,270 --> 01:55:57,520

was kind of volunteering i'm going to be

3548

01:56:01,270 --> 01:55:59,280

the cryptocurrency trader

3549

01:56:03,270 --> 01:56:01,280

it kind of sticks with the ceo but but i

3550

01:56:05,669 --> 01:56:03,280

was also just interested to get some

3551

01:56:07,910 --> 01:56:05,679

intuitive feeling for it um which i

3552

01:56:09,910 --> 01:56:07,920

think i do have now a better feeling for

3553

01:56:11,270 --> 01:56:09,920

um but it was just a from a purely

3554

01:56:13,910 --> 01:56:11,280

personal point of view the

3555

01:56:15,589 --> 01:56:13,920

the um the couple of days that i i

3556

01:56:18,790 --> 01:56:15,599

happen to spend sort of um

3557

01:56:21,030 --> 01:56:18,800

uh uh multitasking between figuring out

3558

01:56:21,510 --> 01:56:21,040

why the universe exists and figuring out

3559

01:56:23,109 --> 01:56:21,520

um

3560

01:56:25,350 --> 01:56:23,119

how we should move this or that between

3561

01:56:26,550 --> 01:56:25,360

cryptocurrencies was uh was an

3562

01:56:29,189 --> 01:56:26,560

interesting um

3563

01:56:30,310 --> 01:56:29,199

experience let's say um i would say that

3564

01:56:33,030 --> 01:56:30,320

the uh

3565

01:56:35,430 --> 01:56:33,040

uh you know we're actually we have all

3566

01:56:37,350 --> 01:56:35,440

the all the apparatus in orphan language

3567

01:56:38,790 --> 01:56:37,360

to build some very fancy analytics for

3568

01:56:40,870 --> 01:56:38,800

understanding what happens with

3569

01:56:42,229 --> 01:56:40,880

cryptocurrencies and we are we're just

3570

01:56:44,870 --> 01:56:42,239

starting to do that

3571

01:56:46,070 --> 01:56:44,880

and um you know it's so deeply analogous

3572

01:56:48,870 --> 01:56:46,080

to what's happened in quant

3573

01:56:49,189 --> 01:56:48,880

quantitative finance it's um i think

3574

01:56:52,229 --> 01:56:49,199

it's

3575

01:56:54,310 --> 01:56:52,239

uh uh you know the question of

3576

01:56:56,310 --> 01:56:54,320

of is there going to be some store of

3577

01:56:58,310 --> 01:56:56,320

value in the world that isn't

3578

01:56:59,910 --> 01:56:58,320

gold and isn't fiat currency the answer

3579

01:57:01,589 --> 01:56:59,920

is presumably yes

3580

01:57:02,950 --> 01:57:01,599

unless governments get so freaked out

3581

01:57:06,070 --> 01:57:02,960

about it they managed to

3582

01:57:07,430 --> 01:57:06,080

to to sort of smash it um i think that

3583

01:57:09,030 --> 01:57:07,440

the uh

3584

01:57:10,950 --> 01:57:09,040

you know is it good for the world though

3585

01:57:14,550 --> 01:57:10,960

that's a more complicated question

3586

01:57:17,750 --> 01:57:14,560

um is it uh um is it something where

3587

01:57:19,030 --> 01:57:17,760

um you know where one can understand you

3588

01:57:20,790 --> 01:57:19,040

know is there some way

3589

01:57:22,470 --> 01:57:20,800

actually it's a good exercise you know

3590

01:57:23,990 --> 01:57:22,480

in this theory of economics that i'm

3591

01:57:25,750 --> 01:57:24,000

sort of slowly developing

3592

01:57:28,149 --> 01:57:25,760

there are going to be analogs of things

3593

01:57:30,149 --> 01:57:28,159

like time dilation

3594

01:57:31,990 --> 01:57:30,159

and things like the einstein equations

3595

01:57:33,350 --> 01:57:32,000

it's a it's a necessary feature of this

3596

01:57:34,870 --> 01:57:33,360

very aggregated

3597

01:57:36,550 --> 01:57:34,880

thing of lots of these transactions and

3598

01:57:38,310 --> 01:57:36,560

so then the question is well

3599

01:57:39,910 --> 01:57:38,320

one of the things i was joking with as

3600

01:57:43,350 --> 01:57:39,920

we were working on this a bit

3601  
01:57:45,750 --> 01:57:43,360  
that inflation in economics

3602  
01:57:47,189 --> 01:57:45,760  
might turn out to be bizarrely similar

3603  
01:57:48,709 --> 01:57:47,199  
to inflation

3604  
01:57:50,390 --> 01:57:48,719  
in cosmology what do you mean that

3605  
01:57:53,270 --> 01:57:50,400  
there's an analog of the einstein field

3606  
01:57:54,870 --> 01:57:53,280  
equations in economics

3607  
01:57:56,310 --> 01:57:54,880  
well you've got a whole space of

3608  
01:57:57,830 --> 01:57:56,320  
transactions right you've got all these

3609  
01:58:00,149 --> 01:57:57,840  
transactions happening

3610  
01:58:01,430 --> 01:58:00,159  
and you've got uh this question is

3611  
01:58:02,390 --> 01:58:01,440  
you've got all these transactions

3612  
01:58:04,830 --> 01:58:02,400  
happening

3613  
01:58:06,070 --> 01:58:04,840

and one thing is to say there's a global

3614

01:58:08,470 --> 01:58:06,080

price

3615

01:58:09,589 --> 01:58:08,480

but actually that probably isn't true

3616

01:58:10,390 --> 01:58:09,599

you've got all these transactions

3617

01:58:13,189 --> 01:58:10,400

happening and they're all

3618

01:58:14,390 --> 01:58:13,199

interwoven in certain ways and you ask

3619

01:58:17,510 --> 01:58:14,400

questions like

3620

01:58:19,750 --> 01:58:17,520

is that space for example arbitrage

3621

01:58:21,830 --> 01:58:19,760

you know you go around a loop it's like

3622

01:58:23,510 --> 01:58:21,840

going around a loop in space-time

3623

01:58:25,830 --> 01:58:23,520

you go around a loop between this

3624

01:58:27,589 --> 01:58:25,840

transaction and it goes in time it goes

3625

01:58:29,030 --> 01:58:27,599

to that transaction and so on

3626

01:58:31,109 --> 01:58:29,040

the question of whether there is an

3627

01:58:32,790 --> 01:58:31,119

arbitrage opportunity becomes a question

3628

01:58:35,910 --> 01:58:32,800

of whether there's curvature

3629

01:58:37,750 --> 01:58:35,920

in this kind of economic space um and so

3630

01:58:39,669 --> 01:58:37,760

that's that's the beginning

3631

01:58:41,589 --> 01:58:39,679

i haven't worked this theory out okay so

3632

01:58:43,030 --> 01:58:41,599

i don't know how it's all going to work

3633

01:58:43,830 --> 01:58:43,040

but that's sort of the beginning of the

3634

01:58:46,390 --> 01:58:43,840

story

3635

01:58:48,470 --> 01:58:46,400

um and so that that's uh and you know

3636

01:58:50,870 --> 01:58:48,480

these questions about um

3637

01:58:52,790 --> 01:58:50,880

uh you know economic activity and and

3638

01:58:54,709 --> 01:58:52,800

deflection of gd6 and so on

3639

01:58:56,629 --> 01:58:54,719

i haven't worked all this stuff out but

3640

01:58:57,910 --> 01:58:56,639

i have this feeling that there may be a

3641

01:58:59,109 --> 01:58:57,920

correspondence

3642

01:59:01,589 --> 01:58:59,119

and that corresponds will be very

3643

01:59:03,350 --> 01:59:01,599

interesting because it allows one then

3644

01:59:04,390 --> 01:59:03,360

to leverage both the intuition from

3645

01:59:06,709 --> 01:59:04,400

finance

3646

01:59:07,669 --> 01:59:06,719

and the intuition from physics and merge

3647

01:59:09,669 --> 01:59:07,679

them together

3648

01:59:11,430 --> 01:59:09,679

i mean i i have a friend who's long

3649

01:59:13,189 --> 01:59:11,440

well-known person who's a

3650

01:59:15,270 --> 01:59:13,199

who's was spent a lot of time as a

3651

01:59:17,109 --> 01:59:15,280

trader and for him

3652

01:59:19,030 --> 01:59:17,119

sort of you know for me things are

3653

01:59:19,669 --> 01:59:19,040

functions they increase they decrease

3654

01:59:21,830 --> 01:59:19,679

whatever

3655

01:59:23,270 --> 01:59:21,840

for him everything is a put or a call

3656

01:59:23,669 --> 01:59:23,280

and i always have to try to remember you

3657

01:59:27,430 --> 01:59:23,679

know

3658

01:59:29,750 --> 01:59:27,440

that's just some function that is

3659

01:59:30,870 --> 01:59:29,760

you know some particular uh you know

3660

01:59:33,510 --> 01:59:30,880

payoff function as

3661

01:59:34,870 --> 01:59:33,520

a function of price but um uh so you

3662

01:59:36,390 --> 01:59:34,880

know these different intuitions that you

3663

01:59:39,030 --> 01:59:36,400

get in different places

3664

01:59:40,629 --> 01:59:39,040

um have uh uh like you know the notion

3665

01:59:41,830 --> 01:59:40,639

of volatility that we're very familiar

3666

01:59:44,390 --> 01:59:41,840

with in in the

3667

01:59:45,750 --> 01:59:44,400

in the financial case you know how does

3668

01:59:47,750 --> 01:59:45,760

that map into

3669

01:59:49,109 --> 01:59:47,760

fluctuations in space time in a physics

3670

01:59:50,310 --> 01:59:49,119

case or something i don't know

3671

01:59:52,070 --> 01:59:50,320

i don't know what the correspondence

3672

01:59:52,390 --> 01:59:52,080

will be but these are these are things

3673

01:59:56,070 --> 01:59:52,400

that

3674

01:59:57,350 --> 01:59:56,080

um um uh i think there was one other

3675

01:59:58,550 --> 01:59:57,360

part to that question which i perhaps

3676

02:00:01,669 --> 01:59:58,560

now have forgotten but

3677

02:00:02,629 --> 02:00:01,679

but about um uh about cryptocurrency

3678

02:00:04,790 --> 02:00:02,639

look i think that the

3679

02:00:06,629 --> 02:00:04,800

the thing that's interesting proof of

3680

02:00:09,830 --> 02:00:06,639

work algorithms versus ethereum

3681

02:00:12,390 --> 02:00:09,840

and proof of stake yeah i mean look

3682

02:00:13,750 --> 02:00:12,400

there are many we just actually did a

3683

02:00:16,709 --> 02:00:13,760

little conference about

3684

02:00:17,430 --> 02:00:16,719

distributed consensus which is a story

3685

02:00:20,629 --> 02:00:17,440

of

3686

02:00:22,790 --> 02:00:20,639

whole collection

3687

02:00:24,310 --> 02:00:22,800

of different ways to come to consensus

3688

02:00:27,189 --> 02:00:24,320

about what has happened

3689

02:00:28,950 --> 02:00:27,199

and in fact what we realized is that uh

3690

02:00:30,310 --> 02:00:28,960

both work i did on cellular automata and

3691

02:00:31,669 --> 02:00:30,320

other people did on cellular automata

3692

02:00:34,470 --> 02:00:31,679

back a long time ago

3693

02:00:36,629 --> 02:00:34,480

is deeply relevant there's this uh uh

3694

02:00:39,990 --> 02:00:36,639

blockchain called nkn

3695

02:00:42,950 --> 02:00:40,000

uh that is some uh nkn needless to say

3696

02:00:44,070 --> 02:00:42,960

sort of rhymes with nks my new kind of

3697

02:00:46,310 --> 02:00:44,080

science thing

3698

02:00:47,109 --> 02:00:46,320

and their their system is very much

3699

02:00:50,470 --> 02:00:47,119

based on

3700

02:00:52,149 --> 02:00:50,480

using

3701

02:00:54,629 --> 02:00:52,159

a notion of consensus that is a

3702

02:00:55,910 --> 02:00:54,639

distributed consensus based on graph

3703

02:00:58,310 --> 02:00:55,920

cellular automata

3704

02:01:00,070 --> 02:00:58,320

that is different from the the sort of

3705

02:01:01,270 --> 02:01:00,080

the the proof-of-work proof-of-stake

3706

02:01:03,270 --> 02:01:01,280

type approach

3707

02:01:04,310 --> 02:01:03,280

so it's a their variety of differences

3708

02:01:06,629 --> 02:01:04,320

that one is a i think

3709

02:01:07,750 --> 02:01:06,639

a rather interesting one that uh some

3710

02:01:07,990 --> 02:01:07,760

other people are trying to do as well

3711

02:01:10,470 --> 02:01:08,000

but

3712

02:01:13,430 --> 02:01:10,480

nkn is probably the most um uh the sort

3713

02:01:16,790 --> 02:01:13,440

of most broadly deployed version of that

3714

02:01:17,589 --> 02:01:16,800

um i think that the um uh that's an

3715

02:01:21,510 --> 02:01:17,599

example of

3716

02:01:23,669 --> 02:01:21,520

of um um i mean

3717

02:01:26,149 --> 02:01:23,679

the thing that the thing to realize

3718

02:01:29,350 --> 02:01:26,159

about about blockchain

3719

02:01:31,430 --> 02:01:29,360

is computation general idea

3720

02:01:33,350 --> 02:01:31,440

they're different form factors they're

3721

02:01:34,149 --> 02:01:33,360

different workflows in which computation

3722

02:01:35,750 --> 02:01:34,159

is used

3723

02:01:37,270 --> 02:01:35,760

what's happening in blockchain is

3724

02:01:39,030 --> 02:01:37,280

autonomous computation

3725

02:01:40,709 --> 02:01:39,040

that's what computational contracts will

3726

02:01:43,270 --> 02:01:40,719

be there they are

3727

02:01:44,870 --> 02:01:43,280

purely autonomous computation that no

3728

02:01:47,350 --> 02:01:44,880

human initiated it

3729

02:01:48,870 --> 02:01:47,360

it wasn't you know it's not it isn't

3730

02:01:51,830 --> 02:01:48,880

just living in a cloud it's

3731

02:01:53,669 --> 02:01:51,840

living in a way where where something

3732

02:01:57,030 --> 02:01:53,679

might happen in the real world

3733

02:02:00,070 --> 02:01:57,040

that actuates what ends up being a giant

3734

02:02:02,310 --> 02:02:00,080

chain of events in the kind of uh

3735

02:02:04,310 --> 02:02:02,320

in the sort of blockchain world and this

3736

02:02:05,750 --> 02:02:04,320

kind of autonomous computation

3737

02:02:07,430 --> 02:02:05,760

is you know it's kind of the ai's

3738

02:02:08,390 --> 02:02:07,440

takeover type scenario because it's

3739

02:02:09,830 --> 02:02:08,400

basically

3740

02:02:11,830 --> 02:02:09,840

you know you end up with these giant

3741

02:02:13,589 --> 02:02:11,840

chains of autonomous computations

3742

02:02:14,870 --> 02:02:13,599

and that's an interesting situation to

3743

02:02:16,550 --> 02:02:14,880

try to understand

3744

02:02:18,950 --> 02:02:16,560

and there are a lot of things that you

3745

02:02:21,990 --> 02:02:18,960

know something like an nft is a very

3746

02:02:24,149 --> 02:02:22,000

simple kind of uh

3747

02:02:25,990 --> 02:02:24,159

thing about autonomous computation but

3748

02:02:26,709 --> 02:02:26,000

there are vastly more complex versions

3749

02:02:28,310 --> 02:02:26,719

of that

3750

02:02:29,830 --> 02:02:28,320

and we're only at the very very early

3751

02:02:31,830 --> 02:02:29,840

stages of understanding

3752

02:02:33,350 --> 02:02:31,840

sort of what's possible in this in this

3753

02:02:34,629 --> 02:02:33,360

world of autonomous computation i think

3754

02:02:36,790 --> 02:02:34,639

the thing maybe i can

3755

02:02:38,149 --> 02:02:36,800

can end with is the the statement that

3756

02:02:41,910 --> 02:02:38,159

um uh

3757

02:02:44,390 --> 02:02:41,920

you know in in just as all these um

3758

02:02:45,589 --> 02:02:44,400

all these sort of interactions in

3759

02:02:46,870 --> 02:02:45,599

between atoms of space

3760

02:02:48,950 --> 02:02:46,880

to kind of what knit together the

3761

02:02:50,709 --> 02:02:48,960

structure of space i think these

3762

02:02:51,830 --> 02:02:50,719

transactions and economics are what kind

3763

02:02:54,390 --> 02:02:51,840

of knit together

3764

02:02:55,589 --> 02:02:54,400

the economic system and lead to sort of

3765

02:02:57,189 --> 02:02:55,599

coherence

3766

02:02:59,350 --> 02:02:57,199

in things like prices and economic

3767

02:03:00,229 --> 02:02:59,360

systems and it's kind of interesting to

3768

02:03:02,709 --> 02:03:00,239

see

3769

02:03:03,430 --> 02:03:02,719

uh what um you know when you have a a

3770

02:03:05,030 --> 02:03:03,440

fork

3771

02:03:06,629 --> 02:03:05,040

in a blockchain it's like an event

3772

02:03:09,189 --> 02:03:06,639

horizon in uh

3773

02:03:11,030 --> 02:03:09,199

in physical space time and uh and when

3774

02:03:27,030 --> 02:03:11,040

you have you know these closed

3775

02:03:31,030 --> 02:03:28,629

next few months available something i'm

3776

02:03:34,310 --> 02:03:31,040

i'm uh you know for me it's always some

3777

02:03:36,149 --> 02:03:34,320

uh it's a crazy thing because you know

3778

02:03:37,510 --> 02:03:36,159

i work in these different fields and

3779

02:03:39,270 --> 02:03:37,520

something like economics i've sort of

3780

02:03:40,070 --> 02:03:39,280

paid attention to it for decades but i

3781

02:03:43,350 --> 02:03:40,080

don't really

3782

02:03:45,030 --> 02:03:43,360

know it in great detail and um uh here i

3783

02:03:46,790 --> 02:03:45,040

am thinking about sort of reforming the

3784

02:03:48,470 --> 02:03:46,800

foundations of this field

3785

02:03:49,910 --> 02:03:48,480

and um it's a scary thing because it's

3786

02:03:51,270 --> 02:03:49,920

kind of like how much of the field

3787

02:03:52,790 --> 02:03:51,280

should i really know

3788

02:03:54,470 --> 02:03:52,800

if i start knowing too many of the

3789

02:03:56,629 --> 02:03:54,480

details i'm already

3790

02:03:57,510 --> 02:03:56,639

sunk in the mud you know it's very hard

3791

02:03:59,109 --> 02:03:57,520

to think

3792

02:04:00,950 --> 02:03:59,119

you know to stick your head out of the

3793

02:04:02,470 --> 02:04:00,960

mud so to speak because you're already

3794

02:04:04,229 --> 02:04:02,480

oh but i know that it's you know

3795

02:04:04,629 --> 02:04:04,239

marginal utility of this and that the

3796

02:04:05,750 --> 02:04:04,639

other

3797

02:04:07,189 --> 02:04:05,760

but at the same time you need to

3798

02:04:08,149 --> 02:04:07,199

familiarize yourself so how do you

3799

02:04:09,910 --> 02:04:08,159

strike that balance

3800

02:04:11,430 --> 02:04:09,920

yeah well it's a challenge right and i'm

3801

02:04:14,390 --> 02:04:11,440

i'm for economics i'm

3802

02:04:14,790 --> 02:04:14,400

i i keep on um uh sort of poking away

3803

02:04:15,990 --> 02:04:14,800

and i

3804

02:04:17,910 --> 02:04:16,000

you know i have friends who are

3805

02:04:20,149 --> 02:04:17,920

economists and i talk to them a bit and

3806

02:04:21,430 --> 02:04:20,159

and you know i'm still at the stage with

3807

02:04:22,790 --> 02:04:21,440

economics where

3808

02:04:25,030 --> 02:04:22,800

where everybody tells me something i

3809

02:04:26,149 --> 02:04:25,040

didn't know already eventually in most

3810

02:04:27,669 --> 02:04:26,159

fields that i work on

3811

02:04:29,109 --> 02:04:27,679

there comes this moment where most

3812

02:04:30,470 --> 02:04:29,119

things that i hear about are things that

3813

02:04:32,790 --> 02:04:30,480

i can readily fit in

3814

02:04:34,069 --> 02:04:32,800

to something i already know and and i'm

3815

02:04:36,390 --> 02:04:34,079

still still on the

3816

02:04:37,990 --> 02:04:36,400

still on the the upward curve with

3817

02:04:38,390 --> 02:04:38,000

economics but it always helps me with

3818

02:04:39,669 --> 02:04:38,400

that

3819

02:04:42,069 --> 02:04:39,679

understanding field particularly one as

3820

02:04:43,990 --> 02:04:42,079

complicated as economics to have

3821

02:04:45,910 --> 02:04:44,000

my own kind of theory about it because

3822

02:04:48,069 --> 02:04:45,920

then as i learn new things i have at

3823

02:04:49,990 --> 02:04:48,079

least a chance to fit them in to

3824

02:04:52,310 --> 02:04:50,000

just to a framework that i've already

3825

02:04:53,270 --> 02:04:52,320

built all right unfortunately i really

3826

02:04:55,669 --> 02:04:53,280

have to go

3827

02:04:57,109 --> 02:04:55,679

but um uh this has been fun lots of

3828

02:05:01,510 --> 02:04:57,119

interesting questions um

3829

02:05:06,470 --> 02:05:04,470

i didn't get to perhaps 70 percent of

3830

02:05:10,709 --> 02:05:06,480

the questions maybe even 80 percent

3831

02:05:13,990 --> 02:05:12,390

if some of you are more familiar with

3832

02:05:14,870 --> 02:05:14,000

the technical aspects of wolfram's

3833

02:05:18,550 --> 02:05:14,880

theory

3834

02:05:21,270 --> 02:05:18,560

i was curious about if the global

3835

02:05:22,390 --> 02:05:21,280

hyperbolicity condition means that there

3836

02:05:24,390 --> 02:05:22,400

are no

3837

02:05:25,510 --> 02:05:24,400

naked singularities or is he using that

3838

02:05:28,390 --> 02:05:25,520

simply as a way of

3839

02:05:29,109 --> 02:05:28,400

foliating into spatial surfaces to solve

3840

02:05:32,149 --> 02:05:29,119

the

3841

02:05:33,109 --> 02:05:32,159

einstein equations

3842

02:05:35,510 --> 02:05:33,119

but he doesn't think global

3843

02:05:36,950 --> 02:05:35,520

hyperbolicity is actually

3844

02:05:39,910 --> 02:05:36,960

intrinsic to our universe it doesn't

3845

02:05:42,950 --> 02:05:39,920

seem like it is because

3846

02:05:45,830 --> 02:05:42,960

our universe is a dissider space not an

3847

02:05:47,990 --> 02:05:45,840

anti-deer space

3848

02:05:49,270 --> 02:05:48,000

if any of you can help me out with that

3849

02:05:53,109 --> 02:05:49,280

that would be

3850

02:05:53,830 --> 02:05:53,119

wonderful oh right i wanted to know if

3851  
02:05:56,229 --> 02:05:53,840  
global

3852  
02:05:57,270 --> 02:05:56,239  
confluence meant that at any two points

3853  
02:05:59,910 --> 02:05:57,280  
on this manifold

3854  
02:06:00,629 --> 02:05:59,920  
that represent our world spatially at

3855  
02:06:03,189 --> 02:06:00,639  
least

3856  
02:06:04,149 --> 02:06:03,199  
that they will necessarily causally

3857  
02:06:05,589 --> 02:06:04,159  
influence each other

3858  
02:06:07,350 --> 02:06:05,599  
at some point because he did seem to

3859  
02:06:09,189 --> 02:06:07,360  
indicate that there's an expansion of

3860  
02:06:12,390 --> 02:06:09,199  
the universe inherent in its models

3861  
02:06:15,589 --> 02:06:12,400  
but at the same time any two points are

3862  
02:06:16,950 --> 02:06:15,599  
going to be causally connected with

3863  
02:06:18,069 --> 02:06:16,960

global confluence at least that's the

3864

02:06:20,149 --> 02:06:18,079

way that i see it

3865

02:06:21,910 --> 02:06:20,159

so if anyone here can help me out with

3866

02:06:22,950 --> 02:06:21,920

that either you can email me that would

3867

02:06:26,390 --> 02:06:22,960

be great

3868

02:06:27,589 --> 02:06:26,400

and while i have you here i'm curious

3869

02:06:31,030 --> 02:06:27,599

why you think

3870

02:06:38,870 --> 02:06:31,040

that there's such an adverse reaction to

3871

02:06:42,790 --> 02:06:40,310

i think i'm not quite sure about that

3872

02:06:47,189 --> 02:06:42,800

because it is

3873

02:06:47,199 --> 02:06:53,109

but at the same time there are also

3874

02:06:56,229 --> 02:06:55,270

there is also resistance to even

3875

02:06:57,830 --> 02:06:56,239

penrose's

3876

02:06:59,510 --> 02:06:57,840

ideas so at first i was thinking well

3877

02:07:01,510 --> 02:06:59,520

maybe you have to be a professor but

3878

02:07:04,149 --> 02:07:01,520

penrose is not liked by other professors

3879

02:07:06,229 --> 02:07:04,159

because he has outlandish ideas

3880

02:07:07,990 --> 02:07:06,239

with regard to consciousness and the

3881

02:07:10,310 --> 02:07:08,000

origins of the universe and his cyclical

3882

02:07:11,669 --> 02:07:10,320

model

3883

02:07:13,350 --> 02:07:11,679

and then there's weinstein who gets

3884

02:07:14,149 --> 02:07:13,360

criticized too and then there's garrett

3885

02:07:16,629 --> 02:07:14,159

lisi

3886

02:07:18,470 --> 02:07:16,639

i was wondering why there are a couple

3887

02:07:21,270 --> 02:07:18,480

people

3888

02:07:23,510 --> 02:07:21,280

one named chiara chiara marletto and

3889

02:07:24,470 --> 02:07:23,520

then another named sabrina gonzalez that

3890

02:07:27,669 --> 02:07:24,480

have their own

3891

02:07:29,109 --> 02:07:27,679

intriguing ideas about physics and they

3892

02:07:31,510 --> 02:07:29,119

don't get criticized and i'm

3893

02:07:32,229 --> 02:07:31,520

curious if that's because they're women

3894

02:07:34,390 --> 02:07:32,239

and so

3895

02:07:35,589 --> 02:07:34,400

academia wants to show how diverse and

3896

02:07:39,350 --> 02:07:35,599

equitable they are

3897

02:07:42,709 --> 02:07:41,589

or if it's something else i'm not sure

3898

02:07:44,470 --> 02:07:42,719

no we didn't touch on bell's

3899

02:07:44,870 --> 02:07:44,480

inequalities though i believe stephen

3900

02:07:46,790 --> 02:07:44,880

has

3901

02:07:48,149 --> 02:07:46,800

see plenty of what stephen said for

3902

02:07:49,350 --> 02:07:48,159

example that quantum mechanics in

3903

02:07:51,189 --> 02:07:49,360

general relativity are

3904

02:07:52,629 --> 02:07:51,199

unified in that the path the way that

3905

02:07:54,069 --> 02:07:52,639

the formalism that leads you to the path

3906

02:07:55,030 --> 02:07:54,079

integral is the same that leads to the

3907

02:07:56,790 --> 02:07:55,040

einstein equations

3908

02:07:58,870 --> 02:07:56,800

they're just in different spaces as far

3909

02:07:59,189 --> 02:07:58,880

as i can tell that's not proven it's

3910

02:08:00,709 --> 02:07:59,199

just

3911

02:08:04,310 --> 02:08:00,719

it seems to be the case in the models or

3912

02:08:08,229 --> 02:08:04,320

the simulations that that they have

3913

02:08:10,709 --> 02:08:08,239

tested as for bell's inequality

3914

02:08:11,910 --> 02:08:10,719

i also don't know if steven's ideas on

3915

02:08:14,149 --> 02:08:11,920

that are

3916

02:08:17,510 --> 02:08:14,159

proven or if they're just surmising if

3917

02:08:19,030 --> 02:08:17,520

they're just conjectures right now

3918

02:08:20,709 --> 02:08:19,040

right dc atoms you can say that they're

3919

02:08:21,510 --> 02:08:20,719

avoiding testable predictions but that's

3920

02:08:23,510 --> 02:08:21,520

false because

3921

02:08:24,629 --> 02:08:23,520

steven isn't at all he's actively

3922

02:08:27,270 --> 02:08:24,639

looking for how he can

3923

02:08:28,069 --> 02:08:27,280

test his theory same with penrose and i

3924

02:08:30,709 --> 02:08:28,079

don't see any

3925

02:08:32,470 --> 02:08:30,719

testable or falsifiable predictions

3926  
02:08:33,270 --> 02:08:32,480  
coming from chiara or sabrina at least

3927  
02:08:35,109 --> 02:08:33,280  
not yet

3928  
02:08:37,350 --> 02:08:35,119  
but i haven't studied their models much

3929  
02:08:40,390 --> 02:08:37,360  
so it can't simply be that i don't know

3930  
02:08:41,669 --> 02:08:40,400  
why there's vitriol toward stephen eric

3931  
02:08:44,550 --> 02:08:41,679  
weinstein penrose

3932  
02:08:45,750 --> 02:08:44,560  
to some degree even julian barber but

3933  
02:08:48,229 --> 02:08:45,760  
there's not toward

3934  
02:08:49,750 --> 02:08:48,239  
chiara and sabrina is it because they're

3935  
02:08:51,669 --> 02:08:49,760  
young is it because they're women is it

3936  
02:08:54,950 --> 02:08:51,679  
because their models are just

3937  
02:08:58,470 --> 02:08:54,960  
superlative compared to

3938  
02:09:00,870 --> 02:08:58,480

lisi garrett lisey or barber or penrose

3939

02:09:03,109 --> 02:09:00,880

i don't know

3940

02:09:04,709 --> 02:09:03,119

okay for the people watching if you want

3941

02:09:06,950 --> 02:09:04,719

to continue conversations

3942

02:09:08,629 --> 02:09:06,960

especially at a especially about

3943

02:09:11,669 --> 02:09:08,639

consciousness theoretical physics

3944

02:09:13,109 --> 02:09:11,679

and intersection between the two then

3945

02:09:14,870 --> 02:09:13,119

there's a discord

3946

02:09:16,149 --> 02:09:14,880

the discord is in the description of all

3947

02:09:18,550 --> 02:09:16,159

of the videos as well as

3948

02:09:20,629 --> 02:09:18,560

in the youtube page somewhere you can

3949

02:09:21,910 --> 02:09:20,639

click discord

3950

02:09:23,910 --> 02:09:21,920

right where there's a twitter and a

3951

02:09:25,750 --> 02:09:23,920

paypal and a patreon and so on there's a

3952

02:09:28,790 --> 02:09:25,760

discord link

3953

02:09:35,030 --> 02:09:32,950

this channel is meant to be more of a

3954

02:09:37,830 --> 02:09:35,040

i know strange it's strange it's meant

3955

02:09:39,430 --> 02:09:37,840

to be more of a community than it is

3956

02:09:41,189 --> 02:09:39,440

well it's it's a mission rather than a

3957

02:09:43,109 --> 02:09:41,199

podcast and

3958

02:09:45,030 --> 02:09:43,119

i see that as what separates it and the

3959

02:09:47,030 --> 02:09:45,040

mission is explicating toes

3960

02:09:48,629 --> 02:09:47,040

and advancing toes and furthering our

3961

02:09:51,270 --> 02:09:48,639

understanding of the universe

3962

02:09:52,069 --> 02:09:51,280

it's not a podcast per se like joe rogan

3963

02:09:54,950 --> 02:09:52,079

or

3964

02:09:56,629 --> 02:09:54,960  
even lex friedman where they're

3965

02:09:58,149 --> 02:09:56,639  
interested in speaking to people and

3966

02:10:01,109 --> 02:09:58,159  
i don't mean this in any demeaning way

3967

02:10:03,750 --> 02:10:01,119  
because their podcasts are far

3968

02:10:04,870 --> 02:10:03,760  
far superior to mine there's a certain

3969

02:10:07,189 --> 02:10:04,880  
high level

3970

02:10:08,550 --> 02:10:07,199  
at which they operate and that's because

3971

02:10:10,709 --> 02:10:08,560  
they're interested in many different

3972

02:10:12,069 --> 02:10:10,719  
topics and they're generally interested

3973

02:10:14,069 --> 02:10:12,079  
in conversing with people

3974

02:10:15,910 --> 02:10:14,079  
and i'm not particularly or this podcast

3975

02:10:18,149 --> 02:10:15,920  
isn't about conversing in that same way

3976

02:10:19,270 --> 02:10:18,159

it's more about office hours is one way

3977

02:10:20,470 --> 02:10:19,280

that i described and i'm trying to

3978

02:10:22,550 --> 02:10:20,480

clarify my own thinking

3979

02:10:23,669 --> 02:10:22,560

but another is that we have a aim and

3980

02:10:26,550 --> 02:10:23,679

the aim is

3981

02:10:27,189 --> 02:10:26,560

the theory of everything explicating

3982

02:10:30,550 --> 02:10:27,199

them

3983

02:10:30,790 --> 02:10:30,560

because there are around 200 as far as i

3984

02:10:33,990 --> 02:10:30,800

can

3985

02:10:37,270 --> 02:10:35,669

if you would like to further that aim

3986

02:10:39,510 --> 02:10:37,280

then please join the discord

3987

02:10:42,470 --> 02:10:39,520

if anyone is watching and is

3988

02:10:43,830 --> 02:10:42,480

mathematically or physically inclined

3989

02:10:45,830 --> 02:10:43,840

when i say physically inclined i mean

3990

02:10:48,390 --> 02:10:45,840

mathematical physics

3991

02:10:49,669 --> 02:10:48,400

and you can tell me if the adm

3992

02:10:52,149 --> 02:10:49,679

decomposition from

3993

02:10:53,350 --> 02:10:52,159

wolfram's model is necessary in order

3994

02:10:55,189 --> 02:10:53,360

for them to derive

3995

02:10:57,189 --> 02:10:55,199

general relativity that's as far as i

3996

02:10:59,350 --> 02:10:57,199

can see it is

3997

02:11:01,350 --> 02:10:59,360

but at the same time so if the adm

3998

02:11:04,550 --> 02:11:01,360

decomposition requires you to be able to

3999

02:11:05,830 --> 02:11:04,560

foliate your space time into spatial

4000

02:11:07,830 --> 02:11:05,840

dimensions

4001  
02:11:09,109 --> 02:11:07,840  
and then sequentially move forward or

4002  
02:11:10,629 --> 02:11:09,119  
backward in time and

4003  
02:11:12,550 --> 02:11:10,639  
that doesn't seem to be what

4004  
02:11:15,589 --> 02:11:12,560  
characterizes our world

4005  
02:11:18,950 --> 02:11:15,599  
but it seems to be

4006  
02:11:21,990 --> 02:11:18,960  
essential in wolfram's models

4007  
02:11:24,470 --> 02:11:22,000  
and i'm wondering is it essential

4008  
02:11:25,990 --> 02:11:24,480  
as well as even if it is so this adm

4009  
02:11:28,870 --> 02:11:26,000  
decomposition it's

4010  
02:11:29,589 --> 02:11:28,880  
not as if that's on solid foundation

4011  
02:11:33,350 --> 02:11:29,599  
there's a

4012  
02:11:36,550 --> 02:11:33,360  
dis proof of the adm decomposition from

4013  
02:11:39,750 --> 02:11:36,560

kirush cheva and kuzmin but

4014

02:11:43,109 --> 02:11:39,760  
that dis proof itself is contested

4015

02:11:45,990 --> 02:11:43,119  
okay i gotta get going i should

4016

02:11:47,750 --> 02:11:46,000  
i should eat and i should sleep and

4017

02:11:50,470 --> 02:11:47,760  
spend some time with my wife

4018

02:11:53,109 --> 02:11:50,480  
if you all would like to see more

4019

02:11:57,350 --> 02:11:53,119  
conversations like this then please

4020

02:12:00,390 --> 02:11:57,360  
do consider going to [patreon.com](https://patreon.com)

4021

02:12:00,870 --> 02:12:00,400  
i will leave a link right now every

4022

02:12:03,510 --> 02:12:00,880  
dollar

4023

02:12:04,229 --> 02:12:03,520  
indeed does help tremendously so here's

4024

02:12:08,310 --> 02:12:04,239  
one

4025

02:12:09,270 --> 02:12:08,320  
into this podcast i spent so much time

4026

02:12:12,390 --> 02:12:09,280

sitting

4027

02:12:13,109 --> 02:12:12,400

that i was able to get a standing desk

4028

02:12:15,910 --> 02:12:13,119

which is

4029

02:12:16,790 --> 02:12:15,920

what you're seeing right now using some

4030

02:12:19,830 --> 02:12:16,800

of the funds

4031

02:12:22,390 --> 02:12:19,840

and that i just got this recently that

4032

02:12:25,350 --> 02:12:22,400

helps tremendously because

4033

02:12:26,870 --> 02:12:25,360

my legs and my well you can understand

4034

02:12:28,950 --> 02:12:26,880

how a standing desk helps

4035

02:12:30,229 --> 02:12:28,960

so if you do want do want to see more

4036

02:12:31,830 --> 02:12:30,239

conversations like this

4037

02:12:33,990 --> 02:12:31,840

if you for whatever reason want to make

4038

02:12:36,149 --> 02:12:34,000

it easier on kurt

4039

02:12:37,830 --> 02:12:36,159

or you would like to see more podcasts

4040

02:12:40,750 --> 02:12:37,840

more frequently

4041

02:12:42,629 --> 02:12:40,760

then please do consider going to

4042

02:12:44,950 --> 02:12:42,639

patreon.com and donating

4043

02:12:46,149 --> 02:12:44,960

a dollar ten dollars fifty dollars

4044

02:12:48,470 --> 02:12:46,159

whatever you feel like

4045

02:12:49,990 --> 02:12:48,480

you can afford or you would whatever you

4046

02:12:53,750 --> 02:12:50,000

feel like you would like to give

4047

02:12:54,310 --> 02:12:53,760

thank you so much yeah grayson that's

4048

02:12:56,229 --> 02:12:54,320

correct

4049

02:12:57,910 --> 02:12:56,239

so when i asked a question that i

4050

02:13:00,470 --> 02:12:57,920

expected an answer that would take

4051

02:13:01,430 --> 02:13:00,480

three minutes it would span the length

4052

02:13:02,950 --> 02:13:01,440

of 10 minutes

4053

02:13:05,350 --> 02:13:02,960

and i'm just thinking come on steven

4054

02:13:08,550 --> 02:13:05,360

time is money you know this

4055

02:13:11,030 --> 02:13:08,560

let's let's hurry this up because i have

4056

02:13:24,149 --> 02:13:11,040

150 questions to get to and that's not

4057

02:13:27,430 --> 02:13:25,910

all right everyone thank you so much for

4058

02:13:31,189 --> 02:13:27,440

watching and i hope that