
MITHUNA
YOGANATHAN
THERE IS NO
WAVE COLLAPSE

1
00:00:03,350 --> 00:00:02,230
today's guest is mithuna from looking

2
00:00:04,950 --> 00:00:03,360
glass universe

3
00:00:07,110 --> 00:00:04,960
a youtube channel you should subscribe

4
00:00:09,110 --> 00:00:07,120
to which provides explications into

5
00:00:10,950 --> 00:00:09,120
obscure physics and math topics

6
00:00:12,709 --> 00:00:10,960
such as the schrodinger equation and

7
00:00:14,629 --> 00:00:12,719
bohmian mechanics

8
00:00:16,310 --> 00:00:14,639
mithuna is a bright and promising

9
00:00:17,990 --> 00:00:16,320
individual who recently completed her

10
00:00:19,910 --> 00:00:18,000
phd in quantum computing

11
00:00:22,070 --> 00:00:19,920
in cambridge and we cover her thesis

12
00:00:23,670 --> 00:00:22,080
titled the power of restricted quantum

13
00:00:25,670 --> 00:00:23,680

computational models

14
00:00:27,670 --> 00:00:25,680
we also touch on quantum foundations and

15
00:00:28,950 --> 00:00:27,680
self-studying since this channel is

16
00:00:31,109 --> 00:00:28,960
geared toward the deciphering of

17
00:00:33,110 --> 00:00:31,119
variegated theories of everything

18
00:00:35,190 --> 00:00:33,120
for example there's cast drops there's

19
00:00:36,630 --> 00:00:35,200
e8 there's geometric unity there's m

20
00:00:39,670 --> 00:00:36,640
theory there's chris langans

21
00:00:42,549 --> 00:00:39,680
cmtu loop qg so10

22
00:00:43,990 --> 00:00:42,559
etc and math and physics is the language

23
00:00:46,470 --> 00:00:44,000
of the universe or at least some

24
00:00:48,069 --> 00:00:46,480
part of the universe and powerfully so

25
00:00:49,510 --> 00:00:48,079
this means comprehension of math and

26
00:00:51,350 --> 00:00:49,520
physics is beneficial

27
00:00:53,270 --> 00:00:51,360
though to be fair there is the counter

28
00:00:54,709 --> 00:00:53,280
claim by the mystic types that the

29
00:00:56,869 --> 00:00:54,719
logical mind when

30
00:00:59,510 --> 00:00:56,879
over-developed impedes the intuitive

31
00:01:01,510 --> 00:00:59,520
empirical one and that it's this latter

32
00:01:03,670 --> 00:01:01,520
one that's necessary to perceive the

33
00:01:05,750 --> 00:01:03,680
larger truer picture of reality

34
00:01:06,710 --> 00:01:05,760
either way self-studying seems

35
00:01:08,789 --> 00:01:06,720
indispensable

36
00:01:10,310 --> 00:01:08,799
so there will be more interviews on this

37
00:01:11,590 --> 00:01:10,320
topic for example

38
00:01:13,350 --> 00:01:11,600

tomorrow i'm speaking with fields

39
00:01:14,550 --> 00:01:13,360
medalist richard borchards on

40
00:01:18,310 --> 00:01:14,560
self-learning

41
00:01:19,590 --> 00:01:18,320
quantum field theory's connection to the

42
00:01:22,630 --> 00:01:19,600
monster group

43
00:01:24,550 --> 00:01:22,640
and general problem solving

44
00:01:26,390 --> 00:01:24,560
apologies for any tiredness on display

45
00:01:28,469 --> 00:01:26,400
during this podcast as it was

46
00:01:30,390 --> 00:01:28,479
it was the end of a towering day of

47
00:01:32,550 --> 00:01:30,400
studying and fasting

48
00:01:33,429 --> 00:01:32,560
if you'd like to see more conversations

49
00:01:35,749 --> 00:01:33,439
like this

50
00:01:36,469 --> 00:01:35,759
especially those that explore math

51
00:01:38,870 --> 00:01:36,479
physics

52
00:01:41,350 --> 00:01:38,880
philosophy and consciousness at a

53
00:01:42,990 --> 00:01:41,360
relatively high technical level

54
00:01:45,109 --> 00:01:43,000
then please consider supporting at

55
00:01:47,190 --> 00:01:45,119
patreon.com

56
00:01:49,030 --> 00:01:47,200
slash kurt jymungalas right now

57
00:01:50,069 --> 00:01:49,040
preparing and studying for each of these

58
00:01:52,789 --> 00:01:50,079
interviews takes

59
00:01:54,149 --> 00:01:52,799
the vast majority of my time besides the

60
00:01:57,350 --> 00:01:54,159
time that i spend with my wife

61
00:01:58,950 --> 00:01:57,360
and each dollar each patron is not only

62
00:02:01,670 --> 00:01:58,960
a financial boon

63
00:02:03,350 --> 00:02:01,680

but a large motivational gift of

64
00:02:07,109 --> 00:02:03,360
encouragement

65
00:02:09,190 --> 00:02:07,119
thank you and i hope you enjoy

66
00:02:11,430 --> 00:02:09,200
thank you welcome mythana i appreciate

67
00:02:13,190 --> 00:02:11,440
it thank you for appreciating me

68
00:02:14,869 --> 00:02:13,200
congratulations on your doctorate by the

69
00:02:17,270 --> 00:02:14,879
way thank you

70
00:02:18,790 --> 00:02:17,280
uh yeah like i have technically just

71
00:02:19,589 --> 00:02:18,800
finished up but i finished writing about

72
00:02:21,910 --> 00:02:19,599
a year ago

73
00:02:22,869 --> 00:02:21,920
so it's good to finally be done with the

74
00:02:24,390 --> 00:02:22,879
paperwork

75
00:02:25,990 --> 00:02:24,400
you run a channel called looking glass

76
00:02:27,430 --> 00:02:26,000
universe what are some of the aspects of

77
00:02:28,150 --> 00:02:27,440
that that you enjoy the most and what

78
00:02:31,990 --> 00:02:28,160
are some of the

79
00:02:35,430 --> 00:02:32,000
more detrimental aspects a good question

80
00:02:38,309 --> 00:02:35,440
um so i really enjoy um

81
00:02:38,790 --> 00:02:38,319
teaching something that i think i know

82
00:02:45,509 --> 00:02:38,800
on

83
00:02:46,390 --> 00:02:45,519
near as well as i think i do and i need

84
00:02:48,630 --> 00:02:46,400
to end up

85
00:02:50,710 --> 00:02:48,640
learning a whole lot more for for those

86
00:02:52,630 --> 00:02:50,720
videos and often i feel like i learned

87
00:02:54,470 --> 00:02:52,640
more in the process of doing those

88
00:02:56,630 --> 00:02:54,480

videos than like i would even

89
00:02:57,910 --> 00:02:56,640
when i'm researching them for my phd can

90
00:02:58,869 --> 00:02:57,920
you give an example like what was

91
00:02:59,990 --> 00:02:58,879
something that you thought you had

92
00:03:01,110 --> 00:03:00,000
understood and then as you were

93
00:03:02,470 --> 00:03:01,120
explaining it you realized okay there

94
00:03:04,790 --> 00:03:02,480
are holes here

95
00:03:07,030 --> 00:03:04,800
oh my gosh so many things um but like

96
00:03:09,670 --> 00:03:07,040
just just as a whole like

97
00:03:11,670 --> 00:03:09,680
uh something that i like the reason i

98
00:03:13,910 --> 00:03:11,680
started this channel is because i

99
00:03:15,670 --> 00:03:13,920
had done some undergrad classes in

100
00:03:17,270 --> 00:03:15,680
quantum mechanics um

101
00:03:18,550 --> 00:03:17,280
yeah and like done well in them and i

102
00:03:19,509 --> 00:03:18,560
just was like oh well you know i

103
00:03:21,910 --> 00:03:19,519
understand this topic

104
00:03:23,270 --> 00:03:21,920
and people like to learn about quantum

105
00:03:23,990 --> 00:03:23,280
mechanics so i may as well make some

106
00:03:25,990 --> 00:03:24,000
videos

107
00:03:27,670 --> 00:03:26,000
explaining what i know so that's what i

108
00:03:29,830 --> 00:03:27,680
thought this channel would be about

109
00:03:30,789 --> 00:03:29,840
but as soon as i started writing those

110
00:03:32,309 --> 00:03:30,799
videos

111
00:03:33,990 --> 00:03:32,319
i realized like oh i don't know what a

112
00:03:35,589 --> 00:03:34,000
superposition is like

113
00:03:37,190 --> 00:03:35,599

i don't actually know you know

114
00:03:37,990 --> 00:03:37,200
philosophically what this wave function

115
00:03:39,910 --> 00:03:38,000
thing is

116
00:03:41,350 --> 00:03:39,920
um and i realized just basically

117
00:03:44,710 --> 00:03:41,360
everything i thought i knew

118
00:03:46,630 --> 00:03:44,720
i had no idea about and um so i ended up

119
00:03:49,670 --> 00:03:46,640
doing a bunch of research on myself

120
00:03:50,869 --> 00:03:49,680
by myself like i took uh six months off

121
00:03:53,030 --> 00:03:50,879
it was just like reading quantum

122
00:03:54,789 --> 00:03:53,040
mechanics books and then i realized like

123
00:03:56,229 --> 00:03:54,799
there's so much more to this than i

124
00:03:58,309 --> 00:03:56,239
thought from undergrad

125
00:03:59,910 --> 00:03:58,319
and that's what like led me to the phd

126
00:04:00,470 --> 00:03:59,920
kind of like solve some of those

127
00:04:02,390 --> 00:04:00,480
problems

128
00:04:03,670 --> 00:04:02,400
you took six months off just to do

129
00:04:06,470 --> 00:04:03,680
research

130
00:04:08,710 --> 00:04:06,480
um yeah basically just for my own like

131
00:04:12,789 --> 00:04:08,720
offers and i was doing part-time work

132
00:04:15,190 --> 00:04:12,799
to pay for that um but i uh yeah like

133
00:04:15,910 --> 00:04:15,200
basically those six months were devoted

134
00:04:18,710 --> 00:04:15,920
to

135
00:04:19,509 --> 00:04:18,720
um just researching things on my own a

136
00:04:22,950 --> 00:04:19,519
little bit more

137
00:04:24,469 --> 00:04:22,960
so uh yeah like and also making

138
00:04:25,909 --> 00:04:24,479

youtube videos at the same time about

139
00:04:27,430 --> 00:04:25,919
what i've been learning you know part of

140
00:04:28,310 --> 00:04:27,440
when i run this channel i'm curious if

141
00:04:30,070 --> 00:04:28,320
you feel the same

142
00:04:31,590 --> 00:04:30,080
i wonder how is it that people

143
00:04:33,510 --> 00:04:31,600
understand the concepts that they

144
00:04:35,189 --> 00:04:33,520
do without having to explain it to

145
00:04:36,469 --> 00:04:35,199
someone else because part of the

146
00:04:37,990 --> 00:04:36,479
understanding comes from

147
00:04:39,350 --> 00:04:38,000
trying to apprehend it from another

148
00:04:41,510 --> 00:04:39,360
point of view and explain it simply or

149
00:04:43,990 --> 00:04:41,520
explain it from

150
00:04:45,510 --> 00:04:44,000
from some other position and i'm and

151
00:04:46,070 --> 00:04:45,520
there's an advantage to having a youtube

152
00:04:47,430 --> 00:04:46,080
channel

153
00:04:49,350 --> 00:04:47,440
so some people think like you're just

154
00:04:50,550 --> 00:04:49,360
wasting your time because it takes quite

155
00:04:51,670 --> 00:04:50,560
a bit of time to

156
00:04:53,749 --> 00:04:51,680
between the understanding and then

157
00:04:55,590 --> 00:04:53,759
actually putting out a video

158
00:04:56,950 --> 00:04:55,600
but at the same time i wonder how is it

159
00:04:57,990 --> 00:04:56,960
that other people understand what they

160
00:04:59,350 --> 00:04:58,000
do

161
00:05:01,749 --> 00:04:59,360
you know teaching has sort of been

162
00:05:03,430 --> 00:05:01,759
recognized as a very good way to

163
00:05:05,510 --> 00:05:03,440

build understanding yourself for a long

164
00:05:07,189 --> 00:05:05,520
time but um

165
00:05:08,550 --> 00:05:07,199
you the youtube medium i feel is really

166
00:05:10,550 --> 00:05:08,560
special because

167
00:05:11,590 --> 00:05:10,560
you have to try and explain it in a way

168
00:05:13,909 --> 00:05:11,600
that um

169
00:05:15,430 --> 00:05:13,919
someone who may not have the background

170
00:05:18,230 --> 00:05:15,440
can understand as well

171
00:05:19,590 --> 00:05:18,240
and that means you have to rely on way

172
00:05:23,029 --> 00:05:19,600
less assumptions

173
00:05:24,870 --> 00:05:23,039
um and the assumptions are often where

174
00:05:27,029 --> 00:05:24,880
your misunderstandings or

175
00:05:28,469 --> 00:05:27,039
where your not complete understandings

176
00:05:30,070 --> 00:05:28,479
are what's your process of learning

177
00:05:30,790 --> 00:05:30,080
something new in math or physics like do

178
00:05:32,550 --> 00:05:30,800
you just

179
00:05:34,550 --> 00:05:32,560
go to the wikipedia page first do you go

180
00:05:36,550 --> 00:05:34,560
to the stanford encyclopedia

181
00:05:38,310 --> 00:05:36,560
of philosophy do you read it from the

182
00:05:40,070 --> 00:05:38,320
textbook and then how often do you have

183
00:05:42,390 --> 00:05:40,080
to reread and

184
00:05:43,110 --> 00:05:42,400
yeah oh great questions um it depends a

185
00:05:45,270 --> 00:05:43,120
lot on

186
00:05:47,029 --> 00:05:45,280
the topic if it's something in quantum

187
00:05:49,590 --> 00:05:47,039
mechanics now i'll just um

188
00:05:51,189 --> 00:05:49,600

go to the papers read the papers and

189
00:05:52,230 --> 00:05:51,199
then when i don't understand things then

190
00:05:55,029 --> 00:05:52,240
i'll go to

191
00:05:56,150 --> 00:05:55,039
something like um wikipedia or more

192
00:05:58,950 --> 00:05:56,160
likely will be

193
00:06:00,629 --> 00:05:58,960
uh some like textbooks that i trust and

194
00:06:02,230 --> 00:06:00,639
like if they have a section on it then

195
00:06:03,830 --> 00:06:02,240
i'll trust that that section

196
00:06:05,510 --> 00:06:03,840
so for example if it's something quantum

197
00:06:06,870 --> 00:06:05,520
computing or even sort of related to

198
00:06:08,309 --> 00:06:06,880
quantum information

199
00:06:10,230 --> 00:06:08,319
then i will check whether it's in

200
00:06:11,830 --> 00:06:10,240
nielsen and trung if it's there

201
00:06:13,350 --> 00:06:11,840
like that's the bible i'll just read it

202
00:06:16,390 --> 00:06:13,360
from that um but

203
00:06:16,790 --> 00:06:16,400
otherwise like yeah so sort of uh yeah

204
00:06:19,270 --> 00:06:16,800
i'll

205
00:06:20,550 --> 00:06:19,280
read stuff just and then google the bits

206
00:06:22,469 --> 00:06:20,560
that i don't understand

207
00:06:23,830 --> 00:06:22,479
did you ever feel like math or physics

208
00:06:27,189 --> 00:06:23,840
wasn't for you

209
00:06:29,189 --> 00:06:27,199
oh yeah 100 i i definitely

210
00:06:31,270 --> 00:06:29,199
didn't think i would end up in metal

211
00:06:34,390 --> 00:06:31,280
physics um as math especially but

212
00:06:37,670 --> 00:06:34,400
uh even physics so when i was in

213
00:06:38,150 --> 00:06:37,680

high school i was quite like an artsy

214
00:06:40,870 --> 00:06:38,160
kid

215
00:06:42,469 --> 00:06:40,880
you know i enjoyed um like literature

216
00:06:44,710 --> 00:06:42,479
classes and i really loved

217
00:06:46,070 --> 00:06:44,720
painting and i thought i wanted to be a

218
00:06:49,430 --> 00:06:46,080
graphic designer

219
00:06:52,390 --> 00:06:49,440
and then um i took a physics

220
00:06:53,909 --> 00:06:52,400
class about cosmology at some point and

221
00:06:56,390 --> 00:06:53,919
was just blown away by it

222
00:06:57,909 --> 00:06:56,400
completely fell in love was uh certain

223
00:07:00,230 --> 00:06:57,919
that i was going to be a physicist

224
00:07:01,510 --> 00:07:00,240
but even so i was still really really

225
00:07:03,670 --> 00:07:01,520
bad at math

226
00:07:04,710 --> 00:07:03,680
um so i was doing well at physics at the

227
00:07:06,790 --> 00:07:04,720
same time that i was

228
00:07:08,070 --> 00:07:06,800
basically failing math and like in the

229
00:07:11,110 --> 00:07:08,080
lowest grade for

230
00:07:15,110 --> 00:07:11,120
uh lowest band basically in australia um

231
00:07:18,309 --> 00:07:15,120
for math um and uh

232
00:07:19,990 --> 00:07:18,319
like i i kept at it and i

233
00:07:21,990 --> 00:07:20,000
and i decided to put myself into some

234
00:07:23,749 --> 00:07:22,000
really hard math classes just because i

235
00:07:26,390 --> 00:07:23,759
knew i needed it for physics

236
00:07:26,870 --> 00:07:26,400
but i didn't think of myself as a math

237
00:07:30,230 --> 00:07:26,880
person

238
00:07:31,510 --> 00:07:30,240

at all until university where um yeah in

239
00:07:33,270 --> 00:07:31,520
the first year i was doing math classes

240
00:07:34,950 --> 00:07:33,280
and i was doing fairly okay in them and

241
00:07:36,950 --> 00:07:34,960
you know that was all good but they they

242
00:07:39,510 --> 00:07:36,960
weren't like the hardest math classes

243
00:07:40,870 --> 00:07:39,520
but in the second year um i just like

244
00:07:43,670 --> 00:07:40,880
happened to enroll myself

245
00:07:45,029 --> 00:07:43,680
in like a fairly abstract uh like

246
00:07:47,350 --> 00:07:45,039
mathematical course

247
00:07:49,110 --> 00:07:47,360
and just loved it so much like all the

248
00:07:52,070 --> 00:07:49,120
functional analysis

249
00:07:54,710 --> 00:07:52,080
really love the actual functional

250
00:07:56,070 --> 00:07:54,720
analysis but my step in was um abstract

251
00:07:59,749 --> 00:07:56,080
algebra

252
00:08:01,110 --> 00:07:59,759
so uh yeah and like it was really cool

253
00:08:02,550 --> 00:08:01,120
because like you know i remember one of

254
00:08:03,430 --> 00:08:02,560
the first things we were trying to prove

255
00:08:06,550 --> 00:08:03,440
was like

256
00:08:09,830 --> 00:08:06,560
um you know zero plus zero equals zero

257
00:08:10,550 --> 00:08:09,840
and and like getting back to the basics

258
00:08:12,230 --> 00:08:10,560
and understanding

259
00:08:13,670 --> 00:08:12,240
why things are true is like what i

260
00:08:15,430 --> 00:08:13,680
really loved about physics and it was

261
00:08:16,550 --> 00:08:15,440
the same thing that i could love about

262
00:08:17,990 --> 00:08:16,560
math and that

263
00:08:19,909 --> 00:08:18,000

that was an aspect of math that i hadn't

264
00:08:21,350 --> 00:08:19,919
seen in school and so that's why i

265
00:08:22,550 --> 00:08:21,360
thought i was not a math person

266
00:08:24,550 --> 00:08:22,560
because i thought math was just about

267
00:08:26,550 --> 00:08:24,560
like following some algorithms to like

268
00:08:27,909 --> 00:08:26,560
get to an answer that's not that's not

269
00:08:28,309 --> 00:08:27,919
it at all for those people who are

270
00:08:29,909 --> 00:08:28,319
listening

271
00:08:31,670 --> 00:08:29,919
and are interested in physics how

272
00:08:34,790 --> 00:08:31,680
necessary is mathematics to understand

273
00:08:38,230 --> 00:08:34,800
physics yeah i think that

274
00:08:39,110 --> 00:08:38,240
um more than understanding pieces of

275
00:08:43,589 --> 00:08:39,120
mathematics

276
00:08:46,070 --> 00:08:43,599
it's um it's important to understand the

277
00:08:46,710 --> 00:08:46,080
the philosophy of mathematics of in

278
00:08:49,509 --> 00:08:46,720
terms of

279
00:08:51,110 --> 00:08:49,519
how rigorous you have to be and also how

280
00:08:53,269 --> 00:08:51,120
creative you have to be

281
00:08:55,030 --> 00:08:53,279
um and i think that those are things

282
00:08:55,590 --> 00:08:55,040
that people don't usually associate with

283
00:08:57,750 --> 00:08:55,600
math

284
00:08:59,910 --> 00:08:57,760
and so if someone's out there like

285
00:09:03,030 --> 00:08:59,920
thinking like i'm not a math person

286
00:09:05,750 --> 00:09:03,040
i wonder if um you know that feeling

287
00:09:06,710 --> 00:09:05,760
is from from like a misunderstanding

288
00:09:09,430 --> 00:09:06,720

about math

289
00:09:10,630 --> 00:09:09,440
um and if you enjoy physics especially

290
00:09:13,030 --> 00:09:10,640
if you enjoy physics

291
00:09:14,550 --> 00:09:13,040
i can't really even imagine a person who

292
00:09:16,230 --> 00:09:14,560
enjoys physics without

293
00:09:17,750 --> 00:09:16,240
enjoying like the sort of fundamental

294
00:09:19,190 --> 00:09:17,760
parts of maths as well

295
00:09:21,110 --> 00:09:19,200
because ultimately it's about the same

296
00:09:22,070 --> 00:09:21,120
things like getting to the why so how do

297
00:09:23,990 --> 00:09:22,080
you structure your day

298
00:09:25,350 --> 00:09:24,000
methanol how what time do you go to

299
00:09:27,509 --> 00:09:25,360
sleep because i imagine it's like

300
00:09:29,110 --> 00:09:27,519
10 p.m or 11 p.m right there and what

301
00:09:30,230 --> 00:09:29,120
time do you wake up and how often do you

302
00:09:32,389 --> 00:09:30,240
work and

303
00:09:33,590 --> 00:09:32,399
and do you meditate do you have a

304
00:09:36,630 --> 00:09:33,600
schedule

305
00:09:39,430 --> 00:09:36,640
um yeah i try um

306
00:09:39,990 --> 00:09:39,440
so i don't sleep as regularly as i would

307
00:09:42,310 --> 00:09:40,000
like

308
00:09:44,389 --> 00:09:42,320
but i try and you know sleep at eleven

309
00:09:48,310 --> 00:09:44,399
um last night i slept at two

310
00:09:50,389 --> 00:09:48,320
uh so you know that happens um i do

311
00:09:51,509 --> 00:09:50,399
i do meditate i do find that a good way

312
00:09:54,550 --> 00:09:51,519
to start the day

313
00:09:57,190 --> 00:09:54,560

um and then like i mean

314
00:10:00,070 --> 00:09:57,200
what kind of meditation um sort of

315
00:10:03,990 --> 00:10:00,080
mindfulness meditation

316
00:10:06,870 --> 00:10:04,000
um and then i uh have a planner

317
00:10:07,350 --> 00:10:06,880
where i write out my uh goals for the

318
00:10:10,150 --> 00:10:07,360
day

319
00:10:10,949 --> 00:10:10,160
um you know things i'm excited about um

320
00:10:14,949 --> 00:10:10,959
and then also

321
00:10:17,430 --> 00:10:14,959
schedule the day and yeah that that's my

322
00:10:17,990 --> 00:10:17,440
main process it's not like i schedule

323
00:10:19,829 --> 00:10:18,000
every minute

324
00:10:21,110 --> 00:10:19,839
of every day because i'm nowhere near an

325
00:10:23,110 --> 00:10:21,120
organized person

326
00:10:24,389 --> 00:10:23,120
um but i try and vaguely schedule like

327
00:10:25,030 --> 00:10:24,399
what is the most important thing in the

328
00:10:27,670 --> 00:10:25,040
day

329
00:10:29,269 --> 00:10:27,680
and at least like if i can get that one

330
00:10:29,910 --> 00:10:29,279
thing done then i'll feel good about the

331
00:10:32,150 --> 00:10:29,920
day

332
00:10:33,509 --> 00:10:32,160
um and so yeah that's my that's my like

333
00:10:35,670 --> 00:10:33,519
work day and then

334
00:10:37,509 --> 00:10:35,680
um in the evening i like like to drop

335
00:10:38,949 --> 00:10:37,519
down a few little notes about what i'm

336
00:10:41,269 --> 00:10:38,959
going to make youtube videos about

337
00:10:43,430 --> 00:10:41,279
that sort of thing oh okay so you work

338
00:10:45,990 --> 00:10:43,440

on youtube videos each day

339
00:10:47,590 --> 00:10:46,000
just a little bit yeah so for example

340
00:10:49,590 --> 00:10:47,600
what'd you do today

341
00:10:51,269 --> 00:10:49,600
um well so it's just it's morning today

342
00:10:53,590 --> 00:10:51,279
but i'm actually planning

343
00:10:55,350 --> 00:10:53,600
right now in the morning yeah it's it's

344
00:10:58,870 --> 00:10:55,360
uh 10 a.m i think

345
00:11:01,990 --> 00:10:58,880
um but uh i

346
00:11:02,870 --> 00:11:02,000
am planning to make a video today so i

347
00:11:05,190 --> 00:11:02,880
was going to

348
00:11:05,990 --> 00:11:05,200
after this uh write a script out and

349
00:11:09,269 --> 00:11:06,000
just

350
00:11:11,430 --> 00:11:09,279
try and film the video all in one day

351
00:11:13,269 --> 00:11:11,440
which i've never been able to do before

352
00:11:14,710 --> 00:11:13,279
but i'm gonna see if it's possible today

353
00:11:16,389 --> 00:11:14,720
are you able to give a sneak preview

354
00:11:17,670 --> 00:11:16,399
this will go out in a few days so i'm

355
00:11:19,990 --> 00:11:17,680
not sure when your video

356
00:11:21,030 --> 00:11:20,000
will be released ah it doesn't matter

357
00:11:23,350 --> 00:11:21,040
either way um

358
00:11:24,230 --> 00:11:23,360
it's not it's not a secret idea or

359
00:11:26,310 --> 00:11:24,240
anything um

360
00:11:27,269 --> 00:11:26,320
i just want to make a video about what

361
00:11:30,470 --> 00:11:27,279
research

362
00:11:32,870 --> 00:11:30,480
felt like because i think it's a an

363
00:11:33,910 --> 00:11:32,880

experience that's sort of hard to hard

364
00:11:35,190 --> 00:11:33,920
for other people to

365
00:11:38,389 --> 00:11:35,200
um understand if they haven't

366
00:11:40,630 --> 00:11:38,399
experienced it um and

367
00:11:42,069 --> 00:11:40,640
uh yeah and this is yeah just like a

368
00:11:45,829 --> 00:11:42,079
really strange thing to be doing

369
00:11:47,750 --> 00:11:45,839
like to do math research um it

370
00:11:49,590 --> 00:11:47,760
i i was recently talking to another

371
00:11:53,590 --> 00:11:49,600
person who had done a math phd

372
00:11:57,030 --> 00:11:53,600
and um we

373
00:11:59,509 --> 00:11:57,040
we uh talked about like the

374
00:12:00,470 --> 00:11:59,519
the dread of doing math and i think that

375
00:12:02,470 --> 00:12:00,480
that's something that's

376
00:12:04,310 --> 00:12:02,480
really hard for someone who hasn't done

377
00:12:05,430 --> 00:12:04,320
it to understand like doing math

378
00:12:09,110 --> 00:12:05,440
research

379
00:12:10,069 --> 00:12:09,120
um the feeling of is the thing i'm

380
00:12:13,190 --> 00:12:10,079
trying to prove

381
00:12:15,910 --> 00:12:13,200
even true and will i have any like

382
00:12:17,590 --> 00:12:15,920
hope of being able to prove it in in the

383
00:12:20,550 --> 00:12:17,600
three year period that i have

384
00:12:21,350 --> 00:12:20,560
um like yeah the uncertainty is just

385
00:12:23,269 --> 00:12:21,360
unreal

386
00:12:24,710 --> 00:12:23,279
um so yeah i think i want to make a

387
00:12:25,590 --> 00:12:24,720
video about how that feels

388
00:12:26,949 --> 00:12:25,600

how do you deal with the negative

389
00:12:28,389 --> 00:12:26,959
comments on your youtube videos if you

390
00:12:33,990 --> 00:12:28,399
get any

391
00:12:35,590 --> 00:12:34,000
uh i think that's just i've been super

392
00:12:36,230 --> 00:12:35,600
lucky because it's still a very niche

393
00:12:39,829 --> 00:12:36,240
channel

394
00:12:41,670 --> 00:12:39,839
and so you know i um generally just have

395
00:12:42,949 --> 00:12:41,680
really nice people who are coming to

396
00:12:44,310 --> 00:12:42,959
learn something about physics so they're

397
00:12:45,190 --> 00:12:44,320
not the kind of person who would leave a

398
00:12:46,790 --> 00:12:45,200
mean comment

399
00:12:48,949 --> 00:12:46,800
so generally all the comments are really

400
00:12:49,670 --> 00:12:48,959
really lovely do you get emails from

401
00:12:51,190 --> 00:12:49,680
people who

402
00:12:53,030 --> 00:12:51,200
try to give you their interpretation of

403
00:12:54,550 --> 00:12:53,040
quantum mechanics and why

404
00:12:55,910 --> 00:12:54,560
okay so how do you deal with that what

405
00:12:57,030 --> 00:12:55,920
is your mindset do you just categorize

406
00:12:59,030 --> 00:12:57,040
it as spam do you respond do you

407
00:13:02,870 --> 00:12:59,040
actually read it

408
00:13:06,389 --> 00:13:02,880
um the thing is i don't have the um

409
00:13:08,230 --> 00:13:06,399
like time to go through

410
00:13:09,990 --> 00:13:08,240
that sort of thing in detail because

411
00:13:12,949 --> 00:13:10,000
people often will send me

412
00:13:14,710 --> 00:13:12,959
sort of papers that they've read um

413
00:13:17,910 --> 00:13:14,720

sorry papers that they've written

414
00:13:20,230 --> 00:13:17,920
and it's it's just i don't have like the

415
00:13:23,590 --> 00:13:20,240
capacity to to be reading everything

416
00:13:25,110 --> 00:13:23,600
um but i guess like

417
00:13:27,190 --> 00:13:25,120
yeah and so it does suck that like

418
00:13:31,030 --> 00:13:27,200
generally i don't reply

419
00:13:33,350 --> 00:13:31,040
um but it yeah because like

420
00:13:34,710 --> 00:13:33,360
it's it's not that i i'm trying to say

421
00:13:36,629 --> 00:13:34,720
like oh i think that you know

422
00:13:38,310 --> 00:13:36,639
this is all rubbish or whatever it's

423
00:13:40,389 --> 00:13:38,320
more that like i'm definitely not the

424
00:13:43,670 --> 00:13:40,399
right medium to be sending it to

425
00:13:45,990 --> 00:13:43,680
and like i'm just one person and i uh

426
00:13:48,069 --> 00:13:46,000
you know get overwhelmed by the the

427
00:13:51,509 --> 00:13:48,079
amount of emails that i get

428
00:13:53,990 --> 00:13:51,519
on this um and the right median instead

429
00:13:55,030 --> 00:13:54,000
is to like go through the like due

430
00:13:58,310 --> 00:13:55,040
scientific process

431
00:13:59,750 --> 00:13:58,320
of like um you know getting other people

432
00:14:01,350 --> 00:13:59,760
who actually understand this topic

433
00:14:02,629 --> 00:14:01,360
because like i'm not even an expert in a

434
00:14:03,590 --> 00:14:02,639
lot of the things that people are

435
00:14:06,790 --> 00:14:03,600
sending me

436
00:14:07,990 --> 00:14:06,800
um to to like yeah to get people like

437
00:14:10,150 --> 00:14:08,000
that on board

438
00:14:11,829 --> 00:14:10,160

um and then the other thing is that like

439
00:14:15,030 --> 00:14:11,839
the times that i have tried to

440
00:14:18,470 --> 00:14:15,040
engage uh with people via

441
00:14:21,430 --> 00:14:18,480
like email or um uh

442
00:14:22,949 --> 00:14:21,440
like you know i have colds like called

443
00:14:24,150 --> 00:14:22,959
them set up a call and stuff like that

444
00:14:28,230 --> 00:14:24,160
to talk about it

445
00:14:33,110 --> 00:14:28,240
i found that um

446
00:14:38,150 --> 00:14:36,470
i found it hard to interact with

447
00:14:39,750 --> 00:14:38,160
some of these people like i've had some

448
00:14:43,110 --> 00:14:39,760
really bad experiences

449
00:14:46,150 --> 00:14:43,120
um where people kind of

450
00:14:50,230 --> 00:14:48,230
i find it hard to accept when i say that

451
00:14:52,710 --> 00:14:50,240
i think something is not right

452
00:14:53,509 --> 00:14:52,720
and and that that's very difficult to

453
00:14:57,189 --> 00:14:53,519
engage with

454
00:14:59,430 --> 00:14:57,199
um so i try to just avoid it these days

455
00:15:02,069 --> 00:14:59,440
they yell at you or they swear or what

456
00:15:03,350 --> 00:15:02,079
oh no no nothing like that no no people

457
00:15:06,310 --> 00:15:03,360
really nice of course but

458
00:15:07,750 --> 00:15:06,320
but um you know like usually i'm used to

459
00:15:08,389 --> 00:15:07,760
when you're talking about like a

460
00:15:11,990 --> 00:15:08,399
scientific

461
00:15:12,470 --> 00:15:12,000
idea um that that it's a debate where if

462
00:15:14,230 --> 00:15:12,480
you

463
00:15:16,069 --> 00:15:14,240

point out a floor in someone else's

464
00:15:17,110 --> 00:15:16,079
argument they have to properly respond

465
00:15:20,230 --> 00:15:17,120
to that flaw

466
00:15:21,030 --> 00:15:20,240
um whereas instead i find like i've

467
00:15:23,670 --> 00:15:21,040
found

468
00:15:25,030 --> 00:15:23,680
the few times where i've tried this that

469
00:15:27,110 --> 00:15:25,040
the person like

470
00:15:28,310 --> 00:15:27,120
doesn't respond to evidence and that's

471
00:15:31,430 --> 00:15:28,320
like not a way that i'm

472
00:15:35,269 --> 00:15:31,440
used to discussing things i see i see

473
00:15:37,189 --> 00:15:35,279
i see okay so let's get to your research

474
00:15:39,990 --> 00:15:37,199
yeah one of the questions i had is

475
00:15:43,030 --> 00:15:40,000
what's a fat shattering dimension

476
00:15:45,590 --> 00:15:43,040
and and did you point that and

477
00:15:46,550 --> 00:15:45,600
i didn't i didn't politically correct

478
00:15:48,389 --> 00:15:46,560
yes but

479
00:15:49,910 --> 00:15:48,399
sharing director dimensions are

480
00:15:52,389 --> 00:15:49,920
something from

481
00:15:53,509 --> 00:15:52,399
um actually i won't even say that um

482
00:15:54,629 --> 00:15:53,519
there's something from classical

483
00:15:57,030 --> 00:15:54,639
computer science

484
00:15:58,949 --> 00:15:57,040
uh i'm not i can't remember exactly what

485
00:16:00,870 --> 00:15:58,959
context they were originally from

486
00:16:02,470 --> 00:16:00,880
i wanna no i'm not gonna i'm not gonna

487
00:16:05,590 --> 00:16:02,480
say it and get it wrong but anyway

488
00:16:07,030 --> 00:16:05,600

um but but uh they are like quite a

489
00:16:10,310 --> 00:16:07,040
technical definition

490
00:16:13,590 --> 00:16:10,320
um but what they really get at is uh

491
00:16:16,470 --> 00:16:13,600
how um flexible

492
00:16:17,030 --> 00:16:16,480
a group of functions is so by that i

493
00:16:19,269 --> 00:16:17,040
mean

494
00:16:20,389 --> 00:16:19,279
like how well would they fit various

495
00:16:22,949 --> 00:16:20,399
types of data

496
00:16:23,990 --> 00:16:22,959
if if uh if it's just like a a line

497
00:16:25,110 --> 00:16:24,000
right like if we're just talking about

498
00:16:28,069 --> 00:16:25,120
linear functions

499
00:16:29,189 --> 00:16:28,079
they're not very flexible only um like

500
00:16:31,990 --> 00:16:29,199
you know very few

501
00:16:33,189 --> 00:16:32,000
sets of data would would uh fit a

502
00:16:34,550 --> 00:16:33,199
straight line

503
00:16:36,310 --> 00:16:34,560
um and so if you're only allowed

504
00:16:37,910 --> 00:16:36,320
straight lines to fit data

505
00:16:40,550 --> 00:16:37,920
then you'll find that like mostly you

506
00:16:41,829 --> 00:16:40,560
don't do a good job of fitting that data

507
00:16:43,269 --> 00:16:41,839
but on the other hand if you suddenly

508
00:16:44,470 --> 00:16:43,279
allow yourself like any degree

509
00:16:47,829 --> 00:16:44,480
polynomials

510
00:16:50,230 --> 00:16:47,839
um they are much more flexible and so

511
00:16:51,509 --> 00:16:50,240
yeah this fat shattering dimension is

512
00:16:54,710 --> 00:16:51,519
basically trying to

513
00:16:57,189 --> 00:16:54,720

um like characterize different classes

514
00:16:59,590 --> 00:16:57,199
of functions and how flexible they are

515
00:17:01,670 --> 00:16:59,600
ah i see so it assigns them a number as

516
00:17:03,829 --> 00:17:01,680
to how flexible they are

517
00:17:06,069 --> 00:17:03,839
essentially okay now you you were

518
00:17:08,949 --> 00:17:06,079
speaking of abstract algebra before

519
00:17:10,069 --> 00:17:08,959
and from what i understand the polygroup

520
00:17:12,470 --> 00:17:10,079
is

521
00:17:14,789 --> 00:17:12,480
well the clifford group are the

522
00:17:17,909 --> 00:17:14,799
stabilizer circuits are the

523
00:17:19,189 --> 00:17:17,919
normalizers of the polygroup but then

524
00:17:23,510 --> 00:17:19,199
from my understanding

525
00:17:25,429 --> 00:17:23,520
a normalizer is

526
00:17:27,270 --> 00:17:25,439
it's in reference to two sets so there's

527
00:17:27,909 --> 00:17:27,280
a group like a large group g and then a

528
00:17:32,150 --> 00:17:27,919
subset

529
00:17:34,789 --> 00:17:32,160
s and then a normalizer would be

530
00:17:36,070 --> 00:17:34,799
i'm sorry i'm trying to yeah i'm trying

531
00:17:38,870 --> 00:17:36,080
to find a way to say this

532
00:17:39,669 --> 00:17:38,880
so you take from a normalizer g would be

533
00:17:42,070 --> 00:17:39,679
i'm sure you know

534
00:17:42,870 --> 00:17:42,080
but anyway it's almost like commuting in

535
00:17:45,669 --> 00:17:42,880
a sense yeah

536
00:17:46,230 --> 00:17:45,679
okay okay but so what is the larger set

537
00:17:49,590 --> 00:17:46,240
g

538
00:17:52,710 --> 00:17:49,600

they're

539
00:17:55,750 --> 00:17:52,720
as far as i know in a

540
00:17:57,270 --> 00:17:55,760
normalizer okay um all right let me

541
00:17:58,789 --> 00:17:57,280
get these definitions straight in my

542
00:18:01,590 --> 00:17:58,799
head as well um

543
00:18:03,510 --> 00:18:01,600
okay so how i think of um the

544
00:18:04,789 --> 00:18:03,520
relationship between the polygroup and

545
00:18:08,070 --> 00:18:04,799
the clifford group

546
00:18:08,470 --> 00:18:08,080
is uh like you yeah one way to put it is

547
00:18:11,270 --> 00:18:08,480
um

548
00:18:11,830 --> 00:18:11,280
in terms of uh commutation as you're

549
00:18:13,430 --> 00:18:11,840
saying

550
00:18:14,950 --> 00:18:13,440
but another way to think of it is in

551
00:18:19,110 --> 00:18:14,960
terms of conjugation

552
00:18:22,390 --> 00:18:19,120
so what that means is um if i have a

553
00:18:24,230 --> 00:18:22,400
a a poly operator so that's like a

554
00:18:27,430 --> 00:18:24,240
certain type of matrix

555
00:18:29,110 --> 00:18:27,440
um and i conjugate it so i multiply it

556
00:18:29,909 --> 00:18:29,120
on the left and the right and the the

557
00:18:33,190 --> 00:18:29,919
one on the right

558
00:18:36,549 --> 00:18:33,200
uh i take the inverse um

559
00:18:37,750 --> 00:18:36,559
then the result is going to be another

560
00:18:40,710 --> 00:18:37,760
poly operator

561
00:18:42,470 --> 00:18:40,720
um and like if we translate if we put

562
00:18:43,270 --> 00:18:42,480
that back into the language of communi

563
00:18:46,230 --> 00:18:43,280

communing

564
00:18:47,510 --> 00:18:46,240
what it means is um okay so like for for

565
00:18:49,110 --> 00:18:47,520
the audience um

566
00:18:51,350 --> 00:18:49,120
the reason why we care about this is

567
00:18:53,909 --> 00:18:51,360
because uh poly operators

568
00:18:54,549 --> 00:18:53,919
are sort of important quantum gates so

569
00:18:55,750 --> 00:18:54,559
like if you're

570
00:18:58,630 --> 00:18:55,760
if you have a quantum circuit they're

571
00:19:00,230 --> 00:18:58,640
made up of gates um polio operators are

572
00:19:01,669 --> 00:19:00,240
important gates and so are clifford

573
00:19:04,150 --> 00:19:01,679
operators um

574
00:19:05,750 --> 00:19:04,160
now if you had a a clifford operator and

575
00:19:08,230 --> 00:19:05,760
then a poly operator

576
00:19:08,870 --> 00:19:08,240
you can switch their order and what that

577
00:19:11,190 --> 00:19:08,880
would do

578
00:19:12,470 --> 00:19:11,200
is it would the the clifford gate would

579
00:19:14,870 --> 00:19:12,480
stay as it is

580
00:19:16,549 --> 00:19:14,880
um would be the same one but the pulley

581
00:19:19,110 --> 00:19:16,559
would become another pulley

582
00:19:19,750 --> 00:19:19,120
and that's important because like the

583
00:19:21,990 --> 00:19:19,760
poly

584
00:19:23,909 --> 00:19:22,000
like operators have really nice

585
00:19:25,590 --> 00:19:23,919
properties that we want to kind of

586
00:19:28,710 --> 00:19:25,600
preserve under conjugation

587
00:19:30,710 --> 00:19:28,720
we can't exactly keep it um the same

588
00:19:33,110 --> 00:19:30,720

under conjugation because it does

589
00:19:34,150 --> 00:19:33,120
uh change when it becomes when it swaps

590
00:19:36,070 --> 00:19:34,160
with a cliffit

591
00:19:37,510 --> 00:19:36,080
but it still stays a poly which is still

592
00:19:39,669 --> 00:19:37,520
nice and so that's like

593
00:19:41,029 --> 00:19:39,679
the reason why this uh this is like a

594
00:19:41,669 --> 00:19:41,039
really important idea in quantum

595
00:19:43,510 --> 00:19:41,679
computing

596
00:19:45,110 --> 00:19:43,520
how does one go about proving that a

597
00:19:47,830 --> 00:19:45,120
particular quantum algorithm

598
00:19:49,510 --> 00:19:47,840
is efficiently simulable classically so

599
00:19:50,950 --> 00:19:49,520
is it something like you reduce it down

600
00:19:51,270 --> 00:19:50,960
to something else that's been proven to

601
00:19:54,150 --> 00:19:51,280
be

602
00:19:54,870 --> 00:19:54,160
simulable classically oh yeah good

603
00:19:57,029 --> 00:19:54,880
question

604
00:19:58,390 --> 00:19:57,039
um so yeah maybe to give a little

605
00:20:01,830 --> 00:19:58,400
context on like why

606
00:20:04,149 --> 00:20:01,840
um i was interested in that question um

607
00:20:04,870 --> 00:20:04,159
you like might have heard that quantum

608
00:20:07,430 --> 00:20:04,880
computing

609
00:20:07,990 --> 00:20:07,440
is you know better than classical

610
00:20:10,470 --> 00:20:08,000
computing

611
00:20:11,350 --> 00:20:10,480
um and that's in the sort of like um

612
00:20:13,270 --> 00:20:11,360
sense of

613
00:20:15,110 --> 00:20:13,280

algorithmic complexity you know there's

614
00:20:17,430 --> 00:20:15,120
some questions that a

615
00:20:18,870 --> 00:20:17,440
quantum computer can solve in polynomial

616
00:20:21,029 --> 00:20:18,880
time that a

617
00:20:22,870 --> 00:20:21,039
classical computer can it seems only

618
00:20:26,149 --> 00:20:22,880
solve in exponential time

619
00:20:26,710 --> 00:20:26,159
um and uh but what i was interested in

620
00:20:29,190 --> 00:20:26,720
is like

621
00:20:30,230 --> 00:20:29,200
which computations can a quantum

622
00:20:32,149 --> 00:20:30,240
computer do better

623
00:20:33,590 --> 00:20:32,159
like why what's like special about that

624
00:20:36,870 --> 00:20:33,600
quantum computation

625
00:20:39,350 --> 00:20:36,880
um and uh

626
00:20:41,669 --> 00:20:39,360
how like one of the main methods i used

627
00:20:44,070 --> 00:20:41,679
in my thesis to like study this question

628
00:20:45,190 --> 00:20:44,080
um was this idea of efficient classical

629
00:20:47,350 --> 00:20:45,200
simulability

630
00:20:49,750 --> 00:20:47,360
so you have some quantum computations

631
00:20:53,350 --> 00:20:49,760
that are efficiently simulable

632
00:20:55,029 --> 00:20:53,360
um what that means is that computation

633
00:20:56,470 --> 00:20:55,039
could have been done on a classical

634
00:20:58,789 --> 00:20:56,480
computation in

635
00:21:00,630 --> 00:20:58,799
a time like in a similar amount of time

636
00:21:03,990 --> 00:21:00,640
right the difference is polynomial

637
00:21:05,590 --> 00:21:04,000
exactly um and so uh the way

638
00:21:07,510 --> 00:21:05,600

to do that is is actually really

639
00:21:09,110 --> 00:21:07,520
straightforward you find the algorithm

640
00:21:11,669 --> 00:21:09,120
so you have this quantum algorithm and

641
00:21:14,710 --> 00:21:11,679
then you want to prove that there exists

642
00:21:17,350 --> 00:21:14,720
a classical algorithm that is like also

643
00:21:18,950 --> 00:21:17,360
like fast um just find the algorithm

644
00:21:19,830 --> 00:21:18,960
find the classical algorithm literally

645
00:21:21,830 --> 00:21:19,840
write out

646
00:21:23,909 --> 00:21:21,840
what you would have to do step by step

647
00:21:25,830 --> 00:21:23,919
to simulate this quantum algorithm

648
00:21:27,110 --> 00:21:25,840
is there much creativity involved in

649
00:21:29,669 --> 00:21:27,120
that what i mean is that

650
00:21:30,630 --> 00:21:29,679
is it a fairly standard set of a fairly

651
00:21:31,750 --> 00:21:30,640
standard procedure

652
00:21:34,470 --> 00:21:31,760
or do you have to think completely

653
00:21:36,470 --> 00:21:34,480
outside the box oh yeah there's

654
00:21:37,669 --> 00:21:36,480
there's this mathematician her name is

655
00:21:39,669 --> 00:21:37,679
lisa

656
00:21:41,350 --> 00:21:39,679
piccarello have you heard of her she

657
00:21:43,669 --> 00:21:41,360
determined that the conway

658
00:21:44,710 --> 00:21:43,679
knot was a slice and it was like this

659
00:21:46,470 --> 00:21:44,720
unknown problem for

660
00:21:49,110 --> 00:21:46,480
20 years and then she just worked on it

661
00:21:51,909 --> 00:21:49,120
as a grad student and the most

662
00:21:52,470 --> 00:21:51,919
the brilliant part of her of of her

663
00:21:55,750 --> 00:21:52,480

proof

664
00:21:57,029 --> 00:21:55,760
was coming up with another knot like

665
00:21:58,549 --> 00:21:57,039
she had to come up with some nod and

666
00:21:59,510 --> 00:21:58,559
then to prove that it has some property

667
00:22:02,710 --> 00:21:59,520
yeah but just come

668
00:22:04,470 --> 00:22:02,720
coming up with that not it's not trivial

669
00:22:05,990 --> 00:22:04,480
it's a strange not why would you come up

670
00:22:06,789 --> 00:22:06,000
with that so i'm wondering is it the

671
00:22:09,029 --> 00:22:06,799
same with

672
00:22:10,470 --> 00:22:09,039
coming up with an algorithm yeah going

673
00:22:12,070 --> 00:22:10,480
back to that point of like what it feels

674
00:22:14,470 --> 00:22:12,080
like to do math research like

675
00:22:15,270 --> 00:22:14,480
that that's that's the thing like you

676
00:22:17,669 --> 00:22:15,280
never know

677
00:22:19,830 --> 00:22:17,679
where like what is going to be the right

678
00:22:22,230 --> 00:22:19,840
idea that's going to prove this fact

679
00:22:23,029 --> 00:22:22,240
right or even if that fact is true um

680
00:22:25,430 --> 00:22:23,039
and so

681
00:22:27,510 --> 00:22:25,440
you know in her case like that she

682
00:22:30,070 --> 00:22:27,520
probably tried all kinds of things and

683
00:22:31,669 --> 00:22:30,080
uh or you know had some great insight

684
00:22:32,470 --> 00:22:31,679
about like why this knot was like very

685
00:22:34,710 --> 00:22:32,480
related

686
00:22:35,909 --> 00:22:34,720
um it was similar with like you know my

687
00:22:37,990 --> 00:22:35,919
research

688
00:22:39,590 --> 00:22:38,000

not anywhere not to compare myself to

689
00:22:40,149 --> 00:22:39,600
anything like as grand as anything like

690
00:22:43,590 --> 00:22:40,159
that

691
00:22:44,390 --> 00:22:43,600
but um like yeah it you don't know where

692
00:22:47,909 --> 00:22:44,400
you're gonna go

693
00:22:49,110 --> 00:22:47,919
and there is no algorithm for um finding

694
00:22:50,070 --> 00:22:49,120
any of these things

695
00:22:52,390 --> 00:22:50,080
like when you're trying to prove

696
00:22:53,909 --> 00:22:52,400
something it is totally like a new thing

697
00:22:54,310 --> 00:22:53,919
and you have to really like get to the

698
00:22:57,669 --> 00:22:54,320
core

699
00:22:58,870 --> 00:22:57,679
of why it's true to be able to prove it

700
00:23:00,549 --> 00:22:58,880
right i know you said you don't want to

701
00:23:01,830 --> 00:23:00,559
compare yourself to doing anything

702
00:23:02,710 --> 00:23:01,840
anywhere near as grand as that but i

703
00:23:04,789 --> 00:23:02,720
think that you

704
00:23:06,390 --> 00:23:04,799
you have a result and again i skimmed

705
00:23:07,990 --> 00:23:06,400
your paper so please if i get it wrong

706
00:23:09,590 --> 00:23:08,000
it seems like you extended the gotzman

707
00:23:11,750 --> 00:23:09,600
nil theorem and that

708
00:23:13,029 --> 00:23:11,760
gotzmanil is already a fairly remarkable

709
00:23:16,149 --> 00:23:13,039
result which means

710
00:23:16,549 --> 00:23:16,159
yours is groundbreaking no it's really

711
00:23:19,750 --> 00:23:16,559
not

712
00:23:20,230 --> 00:23:19,760
um like absolutely true that the got7

713
00:23:23,350 --> 00:23:20,240

canelo

714
00:23:24,630 --> 00:23:23,360
theorem is got a nail there and it's

715
00:23:26,390 --> 00:23:24,640
i don't know how it's pronounced i just

716
00:23:29,590 --> 00:23:26,400
read it yeah me neither

717
00:23:31,510 --> 00:23:29,600
i always go both ways anyway um is

718
00:23:32,630 --> 00:23:31,520
yeah an absolutely remarkable and like

719
00:23:35,270 --> 00:23:32,640
really important

720
00:23:36,789 --> 00:23:35,280
um theorem in quantum computing uh the

721
00:23:39,590 --> 00:23:36,799
way we extended it

722
00:23:40,149 --> 00:23:39,600
um yeah i am very pleased with but um

723
00:23:43,909 --> 00:23:40,159
like

724
00:23:46,149 --> 00:23:43,919
credit for that because

725
00:23:47,909 --> 00:23:46,159
basically there was another paper that

726
00:23:51,110 --> 00:23:47,919
did a lot of the technical work

727
00:23:53,590 --> 00:23:51,120
but didn't necessarily recognize that um

728
00:23:55,510 --> 00:23:53,600
that by adding like one extra step on

729
00:23:56,789 --> 00:23:55,520
top it would become an extension of the

730
00:23:59,510 --> 00:23:56,799
goddess mcniel theorem

731
00:24:01,190 --> 00:23:59,520
um and so like we we did that and so the

732
00:24:02,789 --> 00:24:01,200
technical work was not that big

733
00:24:04,390 --> 00:24:02,799
it was more the conceptual work of

734
00:24:06,789 --> 00:24:04,400
realizing these things were linked

735
00:24:08,230 --> 00:24:06,799
i see i see okay so goddess menil so

736
00:24:09,990 --> 00:24:08,240
i've been calling it gotzman nil

737
00:24:11,350 --> 00:24:10,000
okay so goddess manil the theorem it

738
00:24:11,990 --> 00:24:11,360

says something about the clifford group

739
00:24:13,750 --> 00:24:12,000
and that

740
00:24:15,830 --> 00:24:13,760
if you take elements from that and

741
00:24:17,190 --> 00:24:15,840
create a circuit then you're

742
00:24:18,870 --> 00:24:17,200
you'll be able to be efficiently

743
00:24:20,710 --> 00:24:18,880
stimulable as well something like that

744
00:24:24,230 --> 00:24:20,720
now what was your extension to it

745
00:24:27,830 --> 00:24:24,240
yeah sure so the gross manual theorem um

746
00:24:29,909 --> 00:24:27,840
says that uh like a very large class

747
00:24:31,350 --> 00:24:29,919
like a surprisingly large class of

748
00:24:33,830 --> 00:24:31,360
quantum computers are

749
00:24:34,390 --> 00:24:33,840
efficiently classically simulable and at

750
00:24:37,350 --> 00:24:34,400
the time

751
00:24:38,630 --> 00:24:37,360
this was this was huge like this is just

752
00:24:39,990 --> 00:24:38,640
really unexpected

753
00:24:41,669 --> 00:24:40,000
because um the class that you're talking

754
00:24:44,470 --> 00:24:41,679
about is like yeah the clifford group

755
00:24:45,190 --> 00:24:44,480
and the clifford group involved like a

756
00:24:47,750 --> 00:24:45,200
lot of

757
00:24:48,310 --> 00:24:47,760
important quantum computations um or

758
00:24:50,549 --> 00:24:48,320
like

759
00:24:51,350 --> 00:24:50,559
sort of things around quantum

760
00:24:53,669 --> 00:24:51,360
computation

761
00:24:55,350 --> 00:24:53,679
um involve the clifford group uh so for

762
00:24:57,750 --> 00:24:55,360
example error correction

763
00:24:58,549 --> 00:24:57,760

and um quantum teleportation super dense

764
00:25:01,590 --> 00:24:58,559
coding all

765
00:25:01,830 --> 00:25:01,600
entirely clifford um and so like this is

766
00:25:15,029 --> 00:25:01,840
a

767
00:25:16,710 --> 00:25:15,039
um uh you will end up with like

768
00:25:18,470 --> 00:25:16,720
universal quantum computing so if you

769
00:25:19,669 --> 00:25:18,480
have like clifford gates plus just like

770
00:25:21,750 --> 00:25:19,679
one other random great

771
00:25:23,430 --> 00:25:21,760
you basically get the whole thing and so

772
00:25:27,430 --> 00:25:23,440
cliffords are in a sense like

773
00:25:29,029 --> 00:25:27,440
any random gate with high probability if

774
00:25:30,630 --> 00:25:29,039
you randomly choose a gate with high

775
00:25:33,750 --> 00:25:30,640
probability you will get

776
00:25:35,669 --> 00:25:33,760
um the universal group uh so

777
00:25:37,350 --> 00:25:35,679
like in a sense you're like one step

778
00:25:38,230 --> 00:25:37,360
away from being universal by being

779
00:25:44,149 --> 00:25:38,240
clifford

780
00:25:46,149 --> 00:25:44,159
entirely classically simulable um like

781
00:25:47,190 --> 00:25:46,159
you can't do any quantum computations

782
00:25:49,510 --> 00:25:47,200
that are super fast

783
00:25:51,430 --> 00:25:49,520
using the cliffords despite all of their

784
00:25:52,470 --> 00:25:51,440
good properties and despite being like a

785
00:25:53,590 --> 00:25:52,480
really big class

786
00:25:55,110 --> 00:25:53,600
and so that's why the guys veneer

787
00:25:56,310 --> 00:25:55,120
theorem is like really interesting and

788
00:25:57,190 --> 00:25:56,320

something that like i was very

789
00:26:00,630 --> 00:25:57,200
interested in

790
00:26:01,190 --> 00:26:00,640
what's special about quantum computing

791
00:26:02,630 --> 00:26:01,200
it's like

792
00:26:04,710 --> 00:26:02,640
it can't be anything that's inside of

793
00:26:06,310 --> 00:26:04,720
the clifford gate group even though

794
00:26:08,230 --> 00:26:06,320
even though a lot of very exciting

795
00:26:09,909 --> 00:26:08,240
things are there like for example bell

796
00:26:10,470 --> 00:26:09,919
states which are the maximally entangled

797
00:26:11,990 --> 00:26:10,480
states

798
00:26:13,590 --> 00:26:12,000
you can very easily make them with

799
00:26:15,430 --> 00:26:13,600
cliffords and yet

800
00:26:17,669 --> 00:26:15,440
somehow that doesn't contribute to like

801
00:26:20,310 --> 00:26:17,679
um quantum speed up which is weird

802
00:26:21,430 --> 00:26:20,320
um so what i was interested in is like

803
00:26:24,789 --> 00:26:21,440
uh

804
00:26:27,990 --> 00:26:24,799
yeah like okay if you add

805
00:26:29,990 --> 00:26:28,000
uh if you add like another if you

806
00:26:31,590 --> 00:26:30,000
have a circuit that has cliffords in it

807
00:26:34,310 --> 00:26:31,600
and then you allow yourself

808
00:26:34,630 --> 00:26:34,320
um like one other gate from outside of

809
00:26:38,470 --> 00:26:34,640
the

810
00:26:41,750 --> 00:26:38,480
that

811
00:26:43,750 --> 00:26:41,760
is it like entirely the whole thing or

812
00:26:45,830 --> 00:26:43,760
or does it matter how many of these you

813
00:26:47,269 --> 00:26:45,840

add like let's say there's a like you've

814
00:26:49,350 --> 00:26:47,279
okay there's this thing called the t

815
00:26:51,750 --> 00:26:49,360
gate which is like the sort of canonical

816
00:26:53,029 --> 00:26:51,760
extra gate that you add to

817
00:26:54,310 --> 00:26:53,039
i had a question about the t-gate

818
00:26:54,870 --> 00:26:54,320
actually that now that you're bringing

819
00:26:57,269 --> 00:26:54,880
up is that

820
00:26:58,470 --> 00:26:57,279
this is that a short name for to folly

821
00:27:00,789 --> 00:26:58,480
or is that like a

822
00:27:02,070 --> 00:27:00,799
phase shift of some kind yeah it's a

823
00:27:05,269 --> 00:27:02,080
phase shift it's um

824
00:27:06,470 --> 00:27:05,279
not the to folly gate uh yeah so they're

825
00:27:08,789 --> 00:27:06,480
totally gay

826
00:27:11,909 --> 00:27:08,799
yeah okay i just want to know because i

827
00:27:15,430 --> 00:27:11,919
read t but i wasn't sure what t meant

828
00:27:17,510 --> 00:27:15,440
from context yeah exactly so okay if i

829
00:27:20,630 --> 00:27:17,520
was just allowed to add one of those in

830
00:27:21,029 --> 00:27:20,640
um is that hard to simulate or if i was

831
00:27:23,590 --> 00:27:21,039
to

832
00:27:25,190 --> 00:27:23,600
add like a polynomial number of those in

833
00:27:25,990 --> 00:27:25,200
like that that definitely is hard to

834
00:27:28,389 --> 00:27:26,000
simulate

835
00:27:29,190 --> 00:27:28,399
um but like what's the in between like

836
00:27:30,950 --> 00:27:29,200
you know

837
00:27:32,389 --> 00:27:30,960
where how does it go from like if you

838
00:27:33,669 --> 00:27:32,399

have zero of them it's completely

839
00:27:35,750 --> 00:27:33,679
classically simulable if you have a

840
00:27:38,950 --> 00:27:35,760
polynomial amount it's universal

841
00:27:39,510 --> 00:27:38,960
like where where like you know how

842
00:27:42,149 --> 00:27:39,520
important

843
00:27:43,350 --> 00:27:42,159
are the is the dependence on t gates and

844
00:27:45,830 --> 00:27:43,360
if if you found

845
00:27:46,789 --> 00:27:45,840
a result like oh adding one extra t gate

846
00:27:48,389 --> 00:27:46,799
makes your thing like

847
00:27:49,669 --> 00:27:48,399
hard to simulate then it would suggest

848
00:27:51,190 --> 00:27:49,679
that the goddess midnight theorem is

849
00:27:52,710 --> 00:27:51,200
just sort of like a weird coincidence

850
00:27:54,070 --> 00:27:52,720
and it's not really that important like

851
00:27:57,110 --> 00:27:54,080
it's not really saying

852
00:27:58,230 --> 00:27:57,120
that like these other other gates are

853
00:28:00,070 --> 00:27:58,240
like super important

854
00:28:01,430 --> 00:28:00,080
it's just a like weird fact that if you

855
00:28:04,549 --> 00:28:01,440
have zero of them that

856
00:28:07,110 --> 00:28:04,559
like you know it doesn't um that it's uh

857
00:28:08,630 --> 00:28:07,120
easy to simulate um so i wanted to know

858
00:28:11,990 --> 00:28:08,640
whether that was the case or

859
00:28:14,549 --> 00:28:12,000
if they're if like the

860
00:28:15,510 --> 00:28:14,559
amount that the difficulty of classical

861
00:28:18,710 --> 00:28:15,520
simulation

862
00:28:20,470 --> 00:28:18,720
scales with the number of tea gates so

863
00:28:22,230 --> 00:28:20,480

as you add more tea gates it gets harder

864
00:28:23,750 --> 00:28:22,240
and harder to classically simulate

865
00:28:25,669 --> 00:28:23,760
um and that's like what you would

866
00:28:27,350 --> 00:28:25,679
suspect if you uh

867
00:28:29,110 --> 00:28:27,360
like if you kind of believe the sort of

868
00:28:31,510 --> 00:28:29,120
moral um like

869
00:28:32,149 --> 00:28:31,520
interpretation of of the goddess manila

870
00:28:34,630 --> 00:28:32,159
theorem

871
00:28:35,669 --> 00:28:34,640
and that's what we basically proved um

872
00:28:38,549 --> 00:28:35,679
that like

873
00:28:38,870 --> 00:28:38,559
you uh oh okay i should i shouldn't say

874
00:28:44,230 --> 00:28:38,880
that

875
00:28:46,230 --> 00:28:44,240
this oh sorry i'm just going to turn my

876
00:28:50,549 --> 00:28:46,240
camera back on all right

877
00:28:53,110 --> 00:28:50,559
it's a dslr yeah uh

878
00:28:54,310 --> 00:28:53,120
it's recording again okay cool um so no

879
00:28:56,310 --> 00:28:54,320
no i i shouldn't say that

880
00:28:58,310 --> 00:28:56,320
like we proved that um that had been

881
00:29:00,149 --> 00:28:58,320
proved that you can classically simulate

882
00:29:02,230 --> 00:29:00,159
like the the difficulty of classical

883
00:29:03,669 --> 00:29:02,240
simulation scales with the number of tea

884
00:29:06,230 --> 00:29:03,679
gates had been proved

885
00:29:06,870 --> 00:29:06,240
but what we proved was um like related

886
00:29:09,909 --> 00:29:06,880
to that

887
00:29:12,549 --> 00:29:09,919
like if you have uh a certain number of

888
00:29:13,190 --> 00:29:12,559

tea gates in your circuit can you in a

889
00:29:15,110 --> 00:29:13,200
sense like

890
00:29:16,549 --> 00:29:15,120
remove out all of the clifford stuff

891
00:29:18,549 --> 00:29:16,559
which is all the easy bits

892
00:29:19,830 --> 00:29:18,559
and just leave like the hard tea gates

893
00:29:22,070 --> 00:29:19,840
behind um

894
00:29:23,110 --> 00:29:22,080
and and we showed that that was possible

895
00:29:25,269 --> 00:29:23,120
um right so

896
00:29:26,630 --> 00:29:25,279
yeah which one of your papers are you

897
00:29:28,149 --> 00:29:26,640
most proud of there's

898
00:29:30,149 --> 00:29:28,159
as far as i can see there are three at

899
00:29:32,470 --> 00:29:30,159
least referenced in your thesis

900
00:29:34,149 --> 00:29:32,480
i'm gonna read them out loud quantum

901
00:29:35,029 --> 00:29:34,159
advantage of unitary clifford circuits

902
00:29:37,669 --> 00:29:35,039
with magic state

903
00:29:39,909 --> 00:29:37,679
inputs the one clean qubit model without

904
00:29:40,470 --> 00:29:39,919
entanglement is classically simulable

905
00:29:42,070 --> 00:29:40,480
and

906
00:29:44,789 --> 00:29:42,080
a condition under which classical

907
00:29:47,430 --> 00:29:44,799
simulability implies efficient state

908
00:29:47,990 --> 00:29:47,440
learnability so which one of those do

909
00:29:51,110 --> 00:29:48,000
you think

910
00:29:51,430 --> 00:29:51,120
is the most significant 100 think it's

911
00:29:58,950 --> 00:29:51,440
the

912
00:30:00,070 --> 00:29:58,960
without entanglement is classically

913
00:30:03,669 --> 00:30:00,080

simulable

914
00:30:05,510 --> 00:30:03,679
uh that that was the result basically

915
00:30:08,710 --> 00:30:05,520
that i started a phd to get

916
00:30:10,710 --> 00:30:08,720
um i and and also

917
00:30:12,950 --> 00:30:10,720
the result that i very nearly didn't get

918
00:30:15,430 --> 00:30:12,960
um despite spending years on it

919
00:30:16,630 --> 00:30:15,440
i maybe spent five years on that that

920
00:30:19,830 --> 00:30:16,640
single topic

921
00:30:21,909 --> 00:30:19,840
um so yeah uh why

922
00:30:24,310 --> 00:30:21,919
it was such a big deal is yeah there's

923
00:30:27,029 --> 00:30:24,320
this very interesting hypothesis

924
00:30:27,510 --> 00:30:27,039
in quantum computing that entanglement

925
00:30:30,149 --> 00:30:27,520
is

926
00:30:30,870 --> 00:30:30,159
the main ingredient of a quantum

927
00:30:34,310 --> 00:30:30,880
computer

928
00:30:35,909 --> 00:30:34,320
that somehow it's like the weird

929
00:30:37,990 --> 00:30:35,919
bit of quantum mechanics that like a

930
00:30:39,590 --> 00:30:38,000
quantum computer's taking advantage of

931
00:30:41,269 --> 00:30:39,600
to get all these speed ups is

932
00:30:44,470 --> 00:30:41,279
entanglement

933
00:30:47,750 --> 00:30:44,480
and um like yeah it's a very

934
00:30:49,990 --> 00:30:47,760
sort of dominant uh like ideology in

935
00:30:51,350 --> 00:30:50,000
quantum computing um despite the fact

936
00:30:54,950 --> 00:30:51,360
that like yeah there's

937
00:30:57,190 --> 00:30:54,960
it hasn't been proved either way um and

938
00:30:58,549 --> 00:30:57,200

like the evidence for it is like i would

939
00:31:01,909 --> 00:30:58,559
say fairly weak

940
00:31:03,350 --> 00:31:01,919
um so evidence that evidence that

941
00:31:04,950 --> 00:31:03,360
entanglement does have something to do

942
00:31:07,590 --> 00:31:04,960
or doesn't have something to do

943
00:31:08,549 --> 00:31:07,600
that it does um like i'd say it's i mean

944
00:31:10,389 --> 00:31:08,559
it's not

945
00:31:12,149 --> 00:31:10,399
maybe weak is the wrong term like it's

946
00:31:14,389 --> 00:31:12,159
just like it's not a strong case it's

947
00:31:18,470 --> 00:31:14,399
suggestive but it's not a strong case

948
00:31:21,110 --> 00:31:18,480
um so like my supervisor and uh

949
00:31:22,070 --> 00:31:21,120
um like his co-author a long time ago

950
00:31:23,990 --> 00:31:22,080
have proved

951
00:31:25,430 --> 00:31:24,000
um that if you have no entanglement

952
00:31:28,950 --> 00:31:25,440
inside of your quantum computer

953
00:31:30,470 --> 00:31:28,960
like your um erls quantum computer

954
00:31:32,070 --> 00:31:30,480
then you get something that's

955
00:31:34,149 --> 00:31:32,080
classically simulable which is very

956
00:31:35,269 --> 00:31:34,159
suggestive that that entanglement's

957
00:31:39,750 --> 00:31:35,279
important

958
00:31:43,350 --> 00:31:39,760
right um but there were some reasons why

959
00:31:48,070 --> 00:31:43,360
um this may like

960
00:31:49,509 --> 00:31:48,080
not sort of extend nicely um one is that

961
00:31:51,590 --> 00:31:49,519
that it works when you have zero

962
00:31:54,070 --> 00:31:51,600
entanglement but it doesn't work well

963
00:31:55,750 --> 00:31:54,080

when you have like a a small but not

964
00:31:56,549 --> 00:31:55,760
zero amount of entanglement like what

965
00:31:57,669 --> 00:31:56,559
you would expect

966
00:31:59,110 --> 00:31:57,679
is similar to what i was saying about

967
00:31:59,990 --> 00:31:59,120
the goddess mcniel theorem you would

968
00:32:01,669 --> 00:32:00,000
expect that like

969
00:32:03,590 --> 00:32:01,679
as you increase the entanglement it

970
00:32:05,669 --> 00:32:03,600
becomes harder and harder to

971
00:32:06,870 --> 00:32:05,679
classically simulate that that result

972
00:32:09,909 --> 00:32:06,880
has never been shown

973
00:32:12,549 --> 00:32:09,919
um and in fact probably

974
00:32:14,149 --> 00:32:12,559
i i suspect it can't be shown exactly by

975
00:32:15,590 --> 00:32:14,159
the way when you say it gets harder and

976
00:32:18,710 --> 00:32:15,600
harder to show that it gets

977
00:32:21,190 --> 00:32:18,720
classically simulated why is it not just

978
00:32:23,029 --> 00:32:21,200
it is classically simulable or not why

979
00:32:25,990 --> 00:32:23,039
is it that there's a continuum

980
00:32:27,509 --> 00:32:26,000
yeah okay so um when we say something's

981
00:32:29,029 --> 00:32:27,519
easy to classically simulate we mean

982
00:32:30,070 --> 00:32:29,039
it's polynomial when it's hard it's

983
00:32:36,389 --> 00:32:30,080
exponential

984
00:32:38,310 --> 00:32:36,399
let's say uh there's some parameter like

985
00:32:40,070 --> 00:32:38,320
the amount of entanglement or the number

986
00:32:40,710 --> 00:32:40,080
of t gates there's some parameter like

987
00:32:43,590 --> 00:32:40,720
that

988
00:32:44,549 --> 00:32:43,600

um where the cost of classically

989
00:32:47,909 --> 00:32:44,559
simulating

990
00:32:48,549 --> 00:32:47,919
this um quantum computer scales with

991
00:32:51,750 --> 00:32:48,559
that term

992
00:32:54,070 --> 00:32:51,760
then

993
00:32:55,190 --> 00:32:54,080
it suggests that like as you add more of

994
00:32:56,549 --> 00:32:55,200
that thing it's getting harder and

995
00:32:59,590 --> 00:32:56,559
hotter i say i see it

996
00:33:02,389 --> 00:32:59,600
yeah okay um yeah so uh

997
00:33:02,789 --> 00:33:02,399
so your one qubit clean model yeah clean

998
00:33:06,070 --> 00:33:02,799
that

999
00:33:09,110 --> 00:33:06,080
okay yeah so um the

1000
00:33:11,990 --> 00:33:09,120
entanglement case hadn't been shown well

1001
00:33:13,509 --> 00:33:12,000
even for um like what we call pure state

1002
00:33:15,350 --> 00:33:13,519
quantum computers and so these are the

1003
00:33:16,789 --> 00:33:15,360
sort of idealized quantum computers that

1004
00:33:19,750 --> 00:33:16,799
have no noise in them

1005
00:33:20,389 --> 00:33:19,760
but um real quantum computers have noise

1006
00:33:22,230 --> 00:33:20,399
in them

1007
00:33:23,990 --> 00:33:22,240
and you might think okay but that's like

1008
00:33:25,750 --> 00:33:24,000
not sort of mathematically relevant like

1009
00:33:27,110 --> 00:33:25,760
okay that's relevant for engineers but

1010
00:33:27,909 --> 00:33:27,120
who cares about that from the maths

1011
00:33:31,669 --> 00:33:27,919
point of view

1012
00:33:33,509 --> 00:33:31,679
these like noisy quantum computers are

1013
00:33:35,909 --> 00:33:33,519

super super interesting because

1014
00:33:37,269 --> 00:33:35,919
they they have like very different

1015
00:33:40,630 --> 00:33:37,279
mathematics and like

1016
00:33:42,710 --> 00:33:40,640
much more complicated and sort of um

1017
00:33:44,710 --> 00:33:42,720
like in a way that the where where like

1018
00:33:46,310 --> 00:33:44,720
i'm almost skeptical of results that are

1019
00:33:47,750 --> 00:33:46,320
approved only for pure state quantum

1020
00:33:48,789 --> 00:33:47,760
computers and not for mixed state

1021
00:33:50,389 --> 00:33:48,799
quantum computers

1022
00:33:52,470 --> 00:33:50,399
because it it feels like that might just

1023
00:33:54,070 --> 00:33:52,480
be a quirk whereas like the real thing

1024
00:33:56,950 --> 00:33:54,080
is these noisy things

1025
00:33:58,630 --> 00:33:56,960
um and so like no result like that had

1026
00:34:00,470 --> 00:33:58,640
been proved for noisy quantum computers

1027
00:34:02,630 --> 00:34:00,480
so like the result you would want is

1028
00:34:03,750 --> 00:34:02,640
um without any entanglement for a noisy

1029
00:34:06,950 --> 00:34:03,760
quantum computer

1030
00:34:08,550 --> 00:34:06,960
there is no uh like if if you have no

1031
00:34:11,109 --> 00:34:08,560
um entanglement in a noisy corner

1032
00:34:12,710 --> 00:34:11,119
computer you have no quantum advantage

1033
00:34:15,510 --> 00:34:12,720
that would be the result that like we

1034
00:34:18,710 --> 00:34:15,520
would love to show is true or false

1035
00:34:20,069 --> 00:34:18,720
um and so i had started this project

1036
00:34:22,389 --> 00:34:20,079
kind of trying to come up with a counter

1037
00:34:23,030 --> 00:34:22,399
example i wanted to find a noisy quantum

1038
00:34:25,190 --> 00:34:23,040

computer

1039
00:34:26,629 --> 00:34:25,200
that had no entanglement that still had

1040
00:34:29,990 --> 00:34:26,639
a quantum advantage

1041
00:34:30,550 --> 00:34:30,000
um and so uh there was like a very good

1042
00:34:31,750 --> 00:34:30,560
candidate

1043
00:34:33,750 --> 00:34:31,760
there's something called the one clean

1044
00:34:35,349 --> 00:34:33,760
cubic model and it's like really

1045
00:34:38,629 --> 00:34:35,359
fascinating basically it's a

1046
00:34:41,750 --> 00:34:38,639
quantum computer that has one qubit

1047
00:34:43,909 --> 00:34:41,760
that is um like clean or pure

1048
00:34:45,510 --> 00:34:43,919
um and what that really means is we know

1049
00:34:48,069 --> 00:34:45,520
exactly what state it's in

1050
00:34:48,629 --> 00:34:48,079
and then you have the rest of the qubits

1051
00:34:51,430 --> 00:34:48,639
in that

1052
00:34:53,270 --> 00:34:51,440
quantum computer are completely dirty in

1053
00:34:54,230 --> 00:34:53,280
other words like we have no idea what

1054
00:34:55,030 --> 00:34:54,240
they're doing they could be doing

1055
00:34:57,430 --> 00:34:55,040
anything

1056
00:34:58,790 --> 00:34:57,440
um and usually if you have like a set of

1057
00:34:59,910 --> 00:34:58,800
just like dirty cubits

1058
00:35:01,190 --> 00:34:59,920
you can't do anything with them because

1059
00:35:02,310 --> 00:35:01,200
like if you don't know anything and you

1060
00:35:03,589 --> 00:35:02,320
do something to them then you still

1061
00:35:06,069 --> 00:35:03,599
don't know anything right

1062
00:35:07,270 --> 00:35:06,079
but adding this like one qubit where you

1063
00:35:10,069 --> 00:35:07,280

do know what's happening

1064
00:35:11,750 --> 00:35:10,079
like completely changes this model so um

1065
00:35:13,349 --> 00:35:11,760
it's like remarkable but like yeah you

1066
00:35:14,550 --> 00:35:13,359
have this one qubit you know and all

1067
00:35:15,190 --> 00:35:14,560
these computes where you don't know

1068
00:35:17,270 --> 00:35:15,200
anything

1069
00:35:18,950 --> 00:35:17,280
you do some processing to it and then

1070
00:35:20,630 --> 00:35:18,960
you measure something at the end that is

1071
00:35:23,510 --> 00:35:20,640
actually genuinely useful

1072
00:35:23,829 --> 00:35:23,520
and can like solve some like problems

1073
00:35:26,230 --> 00:35:23,839
that

1074
00:35:27,109 --> 00:35:26,240
appear to be classically hard to solve

1075
00:35:29,030 --> 00:35:27,119
uh so

1076
00:35:30,550 --> 00:35:29,040
so that's the one clean qubit model but

1077
00:35:32,069 --> 00:35:30,560
the thing that was very interesting

1078
00:35:34,710 --> 00:35:32,079
about it and why it made it a good

1079
00:35:36,710 --> 00:35:34,720
like candidate for me to study was that

1080
00:35:38,710 --> 00:35:36,720
um there's this result that the one

1081
00:35:39,510 --> 00:35:38,720
clean qubit and the rest of those noisy

1082
00:35:41,589 --> 00:35:39,520
qubits

1083
00:35:42,950 --> 00:35:41,599
never become entangled with each other

1084
00:35:43,990 --> 00:35:42,960
despite like throughout the whole

1085
00:35:46,710 --> 00:35:44,000
computation

1086
00:35:47,270 --> 00:35:46,720
which like is very strange because you

1087
00:35:48,950 --> 00:35:47,280
like

1088
00:35:51,430 --> 00:35:48,960

you know the one cleveland cupid is

1089
00:35:53,990 --> 00:35:51,440
clearly somehow the one that's like

1090
00:35:55,990 --> 00:35:54,000
giving its quantum power to the rest of

1091
00:35:57,349 --> 00:35:56,000
the rest of the cubits who have no power

1092
00:35:59,109 --> 00:35:57,359
so you would expect that if there's

1093
00:36:00,950 --> 00:35:59,119
communication between those two sets

1094
00:36:02,390 --> 00:36:00,960
that it would be via entanglement if

1095
00:36:05,349 --> 00:36:02,400
entanglement is important

1096
00:36:07,109 --> 00:36:05,359
um and so like the fact that there's no

1097
00:36:08,790 --> 00:36:07,119
entanglements like very suggestive that

1098
00:36:10,630 --> 00:36:08,800
there's something else going on

1099
00:36:12,230 --> 00:36:10,640
and so i wanted to study the one clean

1100
00:36:13,030 --> 00:36:12,240
qubit model where there's no

1101
00:36:14,950 --> 00:36:13,040
entanglement

1102
00:36:16,310 --> 00:36:14,960
not just between those two qubits those

1103
00:36:17,510 --> 00:36:16,320
like this the clean cube it's not

1104
00:36:19,430 --> 00:36:17,520
volumizing ones

1105
00:36:21,510 --> 00:36:19,440
but within the noisy ones there's no

1106
00:36:23,750 --> 00:36:21,520
entanglement within them as well

1107
00:36:25,430 --> 00:36:23,760
um so like there's no entanglement

1108
00:36:26,950 --> 00:36:25,440
across any of the qubits like none of

1109
00:36:27,510 --> 00:36:26,960
the qubits were allowed to talk to each

1110
00:36:30,950 --> 00:36:27,520
other

1111
00:36:34,230 --> 00:36:30,960
that way um and

1112
00:36:37,109 --> 00:36:34,240
yeah what i found was that um

1113
00:36:39,190 --> 00:36:37,119

like yeah we were studying this topic

1114
00:36:40,069 --> 00:36:39,200
for a long time and i was very very

1115
00:36:42,069 --> 00:36:40,079
convinced

1116
00:36:43,910 --> 00:36:42,079
that this quantum computer with no

1117
00:36:46,069 --> 00:36:43,920
entanglement would have

1118
00:36:47,829 --> 00:36:46,079
like some quantum advantage because it

1119
00:36:49,270 --> 00:36:47,839
was very complicated and

1120
00:36:50,870 --> 00:36:49,280
if it's complicated it suggests that

1121
00:36:52,230 --> 00:36:50,880
it's hard to classically simulate which

1122
00:36:54,710 --> 00:36:52,240
suggests it's doing something that's

1123
00:36:57,670 --> 00:36:54,720
like genuinely quantum um

1124
00:36:58,630 --> 00:36:57,680
but like yeah after a few years of

1125
00:37:00,310 --> 00:36:58,640
working on it

1126
00:37:02,150 --> 00:37:00,320
um it suddenly occurred to me that i

1127
00:37:02,550 --> 00:37:02,160
could i could classically simulate it

1128
00:37:03,990 --> 00:37:02,560
like i

1129
00:37:06,390 --> 00:37:04,000
figured out what the algorithm was and

1130
00:37:07,670 --> 00:37:06,400
it was a huge process from that point

1131
00:37:09,910 --> 00:37:07,680
to like actually writing down the

1132
00:37:12,950 --> 00:37:09,920
algorithm for sure but

1133
00:37:16,069 --> 00:37:12,960
um but yeah like it uh

1134
00:37:17,030 --> 00:37:16,079
it really like surprised me because i

1135
00:37:18,150 --> 00:37:17,040
thought i was going to prove the

1136
00:37:20,230 --> 00:37:18,160
opposite thing

1137
00:37:22,470 --> 00:37:20,240
um right right that we proved this

1138
00:37:24,069 --> 00:37:22,480

instead uh actually

1139
00:37:25,589 --> 00:37:24,079
makes me quite convinced now that

1140
00:37:27,109 --> 00:37:25,599
entanglement is important now do you

1141
00:37:29,190 --> 00:37:27,119
need to know something about the

1142
00:37:31,030 --> 00:37:29,200
dirtiness of the rest of the qubits or

1143
00:37:34,310 --> 00:37:31,040
are they just left as

1144
00:37:36,230 --> 00:37:34,320
noisy and you don't care about how noisy

1145
00:37:37,670 --> 00:37:36,240
yeah you you actually assume that

1146
00:37:38,550 --> 00:37:37,680
they're maximally noisy there's

1147
00:37:41,109 --> 00:37:38,560
something called magic

1148
00:37:41,910 --> 00:37:41,119
distillation and i was reading uh just a

1149
00:37:43,670 --> 00:37:41,920
wikipedia

1150
00:37:45,190 --> 00:37:43,680
article about it and it says okay well

1151
00:37:47,030 --> 00:37:45,200
here's what you can do you can have an

1152
00:37:48,310 --> 00:37:47,040
input you prepare five imperfect states

1153
00:37:50,230 --> 00:37:48,320
then your output is

1154
00:37:52,150 --> 00:37:50,240
in almost your state having a small

1155
00:37:54,790 --> 00:37:52,160
error probability and then you repeat

1156
00:37:55,190 --> 00:37:54,800
until the states have been distilled to

1157
00:38:00,950 --> 00:37:55,200
the

1158
00:38:04,069 --> 00:38:00,960
because it says prepare five imperfect

1159
00:38:05,990 --> 00:38:04,079
states or is that just on wikipedia um

1160
00:38:08,069 --> 00:38:06,000
there's not something about five uh

1161
00:38:10,390 --> 00:38:08,079
but the reason why they would have said

1162
00:38:10,790 --> 00:38:10,400
that i don't remember exactly but i

1163
00:38:15,030 --> 00:38:10,800

think

1164
00:38:18,950 --> 00:38:15,040
the one of the um state distillation

1165
00:38:21,829 --> 00:38:18,960
protocols uh involves

1166
00:38:22,950 --> 00:38:21,839
yeah like a five cupid thing um and

1167
00:38:24,790 --> 00:38:22,960
interestingly um

1168
00:38:26,710 --> 00:38:24,800
state distillation is done by by

1169
00:38:27,030 --> 00:38:26,720
cliffords so so this would have been

1170
00:38:30,470 --> 00:38:27,040
like

1171
00:38:33,910 --> 00:38:30,480
particular five qubit sort of set of

1172
00:38:36,390 --> 00:38:33,920
cube of of um cliffords have you studied

1173
00:38:40,150 --> 00:38:36,400
much of quantum logic

1174
00:38:43,430 --> 00:38:40,160
um no actually almost not at all

1175
00:38:44,950 --> 00:38:43,440
yeah okay well you know either way maybe

1176
00:38:46,630 --> 00:38:44,960
you can speculate i wanted to know

1177
00:38:48,230 --> 00:38:46,640
because girdle's theorem girdles and

1178
00:38:49,270 --> 00:38:48,240
completeness theorem is based in

1179
00:38:51,270 --> 00:38:49,280
classical logic

1180
00:38:52,550 --> 00:38:51,280
and so i'm curious is there a quantum

1181
00:38:54,390 --> 00:38:52,560
logic analog

1182
00:38:55,589 --> 00:38:54,400
and what does quantum logic have to say

1183
00:38:57,510 --> 00:38:55,599
about girdles in completeness theorem

1184
00:38:59,430 --> 00:38:57,520
essentially

1185
00:39:00,790 --> 00:38:59,440
do you have any thoughts on that yeah i

1186
00:39:04,790 --> 00:39:00,800
do um

1187
00:39:08,230 --> 00:39:04,800
so my gut reaction is not much

1188
00:39:12,310 --> 00:39:08,240

um and the reason for that is

1189
00:39:16,310 --> 00:39:12,320
um there's so there's sort of two

1190
00:39:19,430 --> 00:39:16,320
levels of uh computation

1191
00:39:22,630 --> 00:39:21,750
relevant here um there's there's the

1192
00:39:25,510 --> 00:39:22,640
level of like

1193
00:39:27,349 --> 00:39:25,520
decidability um and so this is like what

1194
00:39:28,950 --> 00:39:27,359
the halting problem is about and what

1195
00:39:29,270 --> 00:39:28,960
goals and completeness theorem is like

1196
00:39:32,630 --> 00:39:29,280
you know

1197
00:39:35,030 --> 00:39:32,640
in a sense about um and that is like

1198
00:39:35,990 --> 00:39:35,040
okay if you have a mathematical

1199
00:39:38,069 --> 00:39:36,000
statement

1200
00:39:39,510 --> 00:39:38,079
um can you decide whether it's true or

1201
00:39:41,589 --> 00:39:39,520
false right

1202
00:39:42,870 --> 00:39:41,599
um and like this is sort of like given

1203
00:39:46,310 --> 00:39:42,880
an infinite amount of time

1204
00:39:49,430 --> 00:39:46,320
and resources um and

1205
00:39:51,190 --> 00:39:49,440
then there's like the sort of uh

1206
00:39:53,270 --> 00:39:51,200
compu computational complexity point of

1207
00:39:54,150 --> 00:39:53,280
view which is like okay the same

1208
00:39:55,510 --> 00:39:54,160
question can

1209
00:39:57,829 --> 00:39:55,520
can you decide whether this is true or

1210
00:39:59,990 --> 00:39:57,839
false but can you do it in a

1211
00:40:01,430 --> 00:40:00,000
reasonable like so polynomial amount of

1212
00:40:05,030 --> 00:40:01,440
space and time

1213
00:40:07,109 --> 00:40:05,040

um and the quantum like so

1214
00:40:09,030 --> 00:40:07,119
the the stuff that's proved about like

1215
00:40:11,430 --> 00:40:09,040
turing machines and all of that

1216
00:40:13,430 --> 00:40:11,440
is um true regardless of quantum

1217
00:40:15,829 --> 00:40:13,440
mechanics it's true regardless of like

1218
00:40:16,870 --> 00:40:15,839
what your implementation um like

1219
00:40:20,390 --> 00:40:16,880
mechanism is

1220
00:40:22,069 --> 00:40:20,400
whereas uh the computational complexity

1221
00:40:24,230 --> 00:40:22,079
stuff is where like the quantum versus

1222
00:40:27,190 --> 00:40:24,240
classical like difference really is

1223
00:40:27,990 --> 00:40:27,200
and since um like yeah girdles and

1224
00:40:29,990 --> 00:40:28,000
completeness

1225
00:40:32,470 --> 00:40:30,000
theorem is like on that that side of

1226
00:40:35,589 --> 00:40:32,480
like sort of purely about decidability

1227
00:40:38,710 --> 00:40:35,599
i would i would i would suspect

1228
00:40:39,910 --> 00:40:38,720
that quantum logic doesn't change that

1229
00:40:41,510 --> 00:40:39,920
outcome

1230
00:40:43,030 --> 00:40:41,520
does quantum computing have anything to

1231
00:40:44,630 --> 00:40:43,040
say about the solution

1232
00:40:46,230 --> 00:40:44,640
or solving potentially the halting

1233
00:40:49,109 --> 00:40:46,240
problem no

1234
00:40:51,430 --> 00:40:49,119
because a quantum computer can be

1235
00:40:52,390 --> 00:40:51,440
classically simulated just inefficiently

1236
00:40:55,190 --> 00:40:52,400
right like

1237
00:40:57,349 --> 00:40:55,200
right computation can be can be

1238
00:40:58,550 --> 00:40:57,359

simulated by a classical computer it

1239
00:41:00,710 --> 00:40:58,560
would just take a long time

1240
00:41:02,470 --> 00:41:00,720
and so if you have a quantum computer

1241
00:41:03,990 --> 00:41:02,480
that can solve the halting problem

1242
00:41:06,150 --> 00:41:04,000
then you already have a classical

1243
00:41:07,829 --> 00:41:06,160
computer that can solve your

1244
00:41:09,190 --> 00:41:07,839
so no quantum computers say nothing

1245
00:41:11,030 --> 00:41:09,200
about that is there a difference between

1246
00:41:12,710 --> 00:41:11,040
quantum computers and a probabilistic

1247
00:41:18,829 --> 00:41:12,720
turing machine

1248
00:41:22,230 --> 00:41:18,839
is a um okay wait let me just get this

1249
00:41:26,309 --> 00:41:25,750
yeah um so a probabilistic turing

1250
00:41:29,430 --> 00:41:26,319
machine

1251
00:41:30,150 --> 00:41:29,440
is um like the class of problems the

1252
00:41:32,630 --> 00:41:30,160
class of

1253
00:41:34,550 --> 00:41:32,640
decision problems that a um

1254
00:41:37,750 --> 00:41:34,560
probabilistic turing machine solve

1255
00:41:39,270 --> 00:41:37,760
is uh what we call bqp and there's like

1256
00:41:42,390 --> 00:41:39,280
a strong suspicion in the

1257
00:41:45,589 --> 00:41:42,400
like computing um community that

1258
00:41:47,270 --> 00:41:45,599
uh that this is equal to p and p

1259
00:41:48,630 --> 00:41:47,280
is like this class of problems that you

1260
00:41:50,230 --> 00:41:48,640
can solve with a touring machine like

1261
00:41:53,349 --> 00:41:50,240
just a regular turing machine

1262
00:41:55,750 --> 00:41:53,359
um whereas a quantum computer um

1263
00:41:56,790 --> 00:41:55,760

is is stronger like we suspect than a

1264
00:41:58,069 --> 00:41:56,800
probabilistic

1265
00:42:00,470 --> 00:41:58,079
turing machine although there's some

1266
00:42:03,190 --> 00:42:00,480
like um

1267
00:42:05,030 --> 00:42:03,200
yeah i mean yeah with sensible

1268
00:42:07,430 --> 00:42:05,040
definitions it's definitely stronger

1269
00:42:08,309 --> 00:42:07,440
um but then the question is like is it

1270
00:42:11,430 --> 00:42:08,319
strictly

1271
00:42:13,750 --> 00:42:11,440
class the the

1272
00:42:14,710 --> 00:42:13,760
um class of quantum computations than

1273
00:42:16,390 --> 00:42:14,720
than this one

1274
00:42:17,990 --> 00:42:16,400
like the classical ones so do you find

1275
00:42:18,710 --> 00:42:18,000
that there's any implication for quantum

1276
00:42:20,630 --> 00:42:18,720
computing or

1277
00:42:23,430 --> 00:42:20,640
or your research in general and the

1278
00:42:25,670 --> 00:42:23,440
problem of p equals np

1279
00:42:26,550 --> 00:42:25,680
or is there no relation yeah yeah no no

1280
00:42:30,870 --> 00:42:26,560
absolutely

1281
00:42:33,990 --> 00:42:30,880
um so yeah like

1282
00:42:36,230 --> 00:42:34,000
on the question of p equals mp um

1283
00:42:37,109 --> 00:42:36,240
the fact that p equals mp hasn't been

1284
00:42:41,349 --> 00:42:37,119
proved

1285
00:42:47,270 --> 00:42:44,550
it it's like one of the base assumptions

1286
00:42:50,069 --> 00:42:47,280
of quantum complexity of not quantum

1287
00:42:51,750 --> 00:42:50,079
rather um computational complexity

1288
00:42:53,670 --> 00:42:51,760

and the fact that it hasn't proved been

1289
00:42:55,109 --> 00:42:53,680
proved means that like basically nothing

1290
00:42:57,190 --> 00:42:55,119
else can be proved

1291
00:42:58,309 --> 00:42:57,200
um so like for example our quantum

1292
00:42:59,190 --> 00:42:58,319
computer is better than classical

1293
00:43:02,069 --> 00:42:59,200
computers

1294
00:43:03,109 --> 00:43:02,079
we have lots of evidence to suggest yes

1295
00:43:06,470 --> 00:43:03,119
but we can't prove

1296
00:43:08,150 --> 00:43:06,480
it because if we could prove it um then

1297
00:43:09,750 --> 00:43:08,160
we would already be able to prove that p

1298
00:43:11,430 --> 00:43:09,760
doesn't equal mp because

1299
00:43:12,790 --> 00:43:11,440
um well at least for decision problems

1300
00:43:14,790 --> 00:43:12,800
like if we could find a

1301
00:43:16,470 --> 00:43:14,800
so there's like you know in the decision

1302
00:43:18,230 --> 00:43:16,480
problem hierarchy there's this p

1303
00:43:19,670 --> 00:43:18,240
and then there's like np which we think

1304
00:43:21,510 --> 00:43:19,680
is bigger um

1305
00:43:23,990 --> 00:43:21,520
but if we could even find one problem

1306
00:43:27,190 --> 00:43:24,000
that is definitely in np and not in p

1307
00:43:28,870 --> 00:43:27,200
right we would you know but

1308
00:43:31,109 --> 00:43:28,880
for quantum computing to be better than

1309
00:43:33,829 --> 00:43:31,119
um uh than

1310
00:43:34,150 --> 00:43:33,839
um classical computing we we would have

1311
00:43:40,309 --> 00:43:34,160
to

1312
00:43:41,990 --> 00:43:40,319
that um a quantum computer can solve but

1313
00:43:44,150 --> 00:43:42,000

if that problem existed

1314
00:43:45,990 --> 00:43:44,160
um it probably is inside of np and so

1315
00:43:46,630 --> 00:43:46,000
we've probably already improved p equals

1316
00:43:50,390 --> 00:43:46,640
mp

1317
00:43:52,710 --> 00:43:50,400
um and so yeah like it is a first step

1318
00:43:54,309 --> 00:43:52,720
to proving that quantum computers are

1319
00:43:55,910 --> 00:43:54,319
better than classical computers

1320
00:43:58,069 --> 00:43:55,920
and a first step to many things in

1321
00:43:58,710 --> 00:43:58,079
quantum in computational complexity

1322
00:44:01,430 --> 00:43:58,720
which

1323
00:44:02,470 --> 00:44:01,440
like yeah all depend on on assuming

1324
00:44:04,630 --> 00:44:02,480
that's true

1325
00:44:05,829 --> 00:44:04,640
so prime factorization that's an np

1326
00:44:10,550 --> 00:44:05,839
correct

1327
00:44:13,109 --> 00:44:10,560
um yes but it is not a hundred percent

1328
00:44:14,470 --> 00:44:13,119
proved to not be in p that's the problem

1329
00:44:17,109 --> 00:44:14,480
i see i see

1330
00:44:19,349 --> 00:44:17,119
so in fact no np problems have been

1331
00:44:20,470 --> 00:44:19,359
proved to definitely not be in p

1332
00:44:22,150 --> 00:44:20,480
okay as far as i know there's a

1333
00:44:22,550 --> 00:44:22,160
difference between np problems and then

1334
00:44:26,069 --> 00:44:22,560
np

1335
00:44:28,069 --> 00:44:26,079
complete problems is that okay so is the

1336
00:44:29,990 --> 00:44:28,079
prime factorization np complete or just

1337
00:44:32,470 --> 00:44:30,000
np just mp

1338
00:44:34,150 --> 00:44:32,480

okay okay okay yeah certainly it's

1339
00:44:36,470 --> 00:44:34,160
certainly not complete because we

1340
00:44:39,109 --> 00:44:36,480
don't suspect that quantum computers can

1341
00:44:40,230 --> 00:44:39,119
solve np complete problems

1342
00:44:42,630 --> 00:44:40,240
i don't know if you saw maybe you

1343
00:44:45,829 --> 00:44:42,640
already saw the video it's uh

1344
00:44:48,390 --> 00:44:45,839
it's richard e richard e borcha's

1345
00:44:49,910 --> 00:44:48,400
orchards i might be butchering his name

1346
00:44:51,670 --> 00:44:49,920
anyway for the people listening he's

1347
00:44:53,829 --> 00:44:51,680
coming on this podcast at some point

1348
00:44:54,870 --> 00:44:53,839
he's a feels medalist and he said here's

1349
00:44:57,589 --> 00:44:54,880
how my teapot

1350
00:44:58,950 --> 00:44:57,599
is better as better quantum computer the

1351
00:45:00,390 --> 00:44:58,960
reason is that it can solve a problem

1352
00:45:02,069 --> 00:45:00,400
that quantum computers can't

1353
00:45:03,510 --> 00:45:02,079
and then he's like well what is the

1354
00:45:04,870 --> 00:45:03,520
problem the problem is how many pieces

1355
00:45:06,150 --> 00:45:04,880
can this teapot shatter into

1356
00:45:07,510 --> 00:45:06,160
well this teapot can solve it better

1357
00:45:08,630 --> 00:45:07,520
than a quantum computer is better than

1358
00:45:12,069 --> 00:45:08,640
any computer

1359
00:45:13,910 --> 00:45:12,079
and then he said well this is a foolish

1360
00:45:14,630 --> 00:45:13,920
example and it's contrived on purpose

1361
00:45:16,390 --> 00:45:14,640
because

1362
00:45:18,150 --> 00:45:16,400
when you hear in the media that quantum

1363
00:45:19,109 --> 00:45:18,160

computers are better than classical

1364
00:45:21,829 --> 00:45:19,119
computers it just

1365
00:45:23,589 --> 00:45:21,839
it's like better on what it depends on

1366
00:45:24,630 --> 00:45:23,599
the test so if you design a test that a

1367
00:45:26,950 --> 00:45:24,640
quantum computer is

1368
00:45:27,750 --> 00:45:26,960
efficient at well you haven't said that

1369
00:45:30,069 --> 00:45:27,760
quantum

1370
00:45:31,589 --> 00:45:30,079
computers are better as a whole he he

1371
00:45:34,069 --> 00:45:31,599
said it's like giving an

1372
00:45:35,510 --> 00:45:34,079
intelligence test to an anteater and

1373
00:45:37,030 --> 00:45:35,520
showing that it's but it's smarter than

1374
00:45:38,790 --> 00:45:37,040
einstein because you say that

1375
00:45:40,550 --> 00:45:38,800
the intelligence test is how many ants

1376
00:45:41,990 --> 00:45:40,560
can you eat in a minute it's like okay

1377
00:45:43,430 --> 00:45:42,000
well you can try the test to show that

1378
00:45:47,190 --> 00:45:43,440
this particular

1379
00:45:50,230 --> 00:45:47,200
i i think that um there's one very

1380
00:45:50,710 --> 00:45:50,240
big flaw in that analogy and that is

1381
00:45:55,270 --> 00:45:50,720
that

1382
00:45:57,190 --> 00:45:55,280
would do

1383
00:45:58,950 --> 00:45:57,200
um like everything that a classical

1384
00:46:00,230 --> 00:45:58,960
computer can do a quantum computer can

1385
00:46:02,230 --> 00:46:00,240
do and we can write that

1386
00:46:03,670 --> 00:46:02,240
that algorithm like straight off the bat

1387
00:46:06,150 --> 00:46:03,680
there's nothing there's nothing like

1388
00:46:07,190 --> 00:46:06,160

difficult about that what is up in the

1389
00:46:09,109 --> 00:46:07,200
air is like

1390
00:46:11,270 --> 00:46:09,119
is there extra things that a quantum

1391
00:46:13,510 --> 00:46:11,280
computer can do so i agree with him that

1392
00:46:15,030 --> 00:46:13,520
um you know those extra things may not

1393
00:46:17,030 --> 00:46:15,040
be interesting things and then

1394
00:46:18,950 --> 00:46:17,040
who cares about quantum computing but

1395
00:46:20,230 --> 00:46:18,960
but like it's definitely the case that

1396
00:46:21,589 --> 00:46:20,240
they are better than classical computers

1397
00:46:23,430 --> 00:46:21,599
like that's not the argument

1398
00:46:24,630 --> 00:46:23,440
um the argument is like what things can

1399
00:46:26,550 --> 00:46:24,640
they do and

1400
00:46:28,550 --> 00:46:26,560
well maybe one of the points that he's

1401
00:46:30,230 --> 00:46:28,560
making is like one of the main

1402
00:46:32,390 --> 00:46:30,240
things that we know a quantum computer

1403
00:46:33,190 --> 00:46:32,400
can do well is it can simulate quantum

1404
00:46:34,630 --> 00:46:33,200
mechanics

1405
00:46:36,390 --> 00:46:34,640
so that's like probably one of the

1406
00:46:37,270 --> 00:46:36,400
biggest use cases for quantum computers

1407
00:46:40,390 --> 00:46:37,280
in the future

1408
00:46:42,069 --> 00:46:40,400
like you know drugs are uh like

1409
00:46:43,990 --> 00:46:42,079
like you know molecules are basically

1410
00:46:44,870 --> 00:46:44,000
like quantum machines and it's the

1411
00:46:46,470 --> 00:46:44,880
quantum mechanics

1412
00:46:47,910 --> 00:46:46,480
aspect of them that makes them very hard

1413
00:46:49,990 --> 00:46:47,920

to simulate classically

1414
00:46:51,670 --> 00:46:50,000
um hopefully you know quantum computers

1415
00:46:54,710 --> 00:46:51,680
will be able to do a better job of them

1416
00:46:56,309 --> 00:46:54,720
so like sure like we are designing

1417
00:46:58,390 --> 00:46:56,319
our tests to be like a thing that

1418
00:46:59,750 --> 00:46:58,400
quantum computers can do very well which

1419
00:47:02,230 --> 00:46:59,760
is like quantum mechanics

1420
00:47:03,910 --> 00:47:02,240
um the question is do we care about like

1421
00:47:05,510 --> 00:47:03,920
quantum mechanics

1422
00:47:06,710 --> 00:47:05,520
what's the koch inspector theorem and

1423
00:47:09,430 --> 00:47:06,720
then what does it have to say about

1424
00:47:11,510 --> 00:47:09,440
quantum contextuality

1425
00:47:12,710 --> 00:47:11,520
so i usually say questions because i'll

1426
00:47:14,550 --> 00:47:12,720
say that on other

1427
00:47:16,309 --> 00:47:14,560
sure sure i'm completely getting that

1428
00:47:18,630 --> 00:47:16,319
wrong um anyway so

1429
00:47:19,510 --> 00:47:18,640
um the questions vectors theorem is a

1430
00:47:22,950 --> 00:47:19,520
very um

1431
00:47:25,750 --> 00:47:22,960
important theorem in uh

1432
00:47:28,069 --> 00:47:25,760
quantum foundations and what it's

1433
00:47:29,829 --> 00:47:28,079
addressing is like

1434
00:47:31,349 --> 00:47:29,839
um so you might have heard of hidden

1435
00:47:33,829 --> 00:47:31,359
variable theorems uh

1436
00:47:35,349 --> 00:47:33,839
it's like a way to get around the

1437
00:47:37,270 --> 00:47:35,359
weirdness of quantum mechanics

1438
00:47:38,470 --> 00:47:37,280

so it says that you know there are no

1439
00:47:40,950 --> 00:47:38,480
such thing as

1440
00:47:42,470 --> 00:47:40,960
uh no such things as superpositions like

1441
00:47:43,910 --> 00:47:42,480
these these particles are not doing like

1442
00:47:46,870 --> 00:47:43,920
all possible things at once

1443
00:47:48,870 --> 00:47:46,880
um instead they are in one particular

1444
00:47:51,510 --> 00:47:48,880
place doing one particular thing but

1445
00:47:52,549 --> 00:47:51,520
the way they act is very complicated um

1446
00:47:55,670 --> 00:47:52,559
like it can be

1447
00:47:58,549 --> 00:47:55,680
uh like determined by a

1448
00:47:59,270 --> 00:47:58,559
um you know forces that like take into

1449
00:48:00,710 --> 00:47:59,280
account

1450
00:48:02,309 --> 00:48:00,720
all the possible things they could be

1451
00:48:03,829 --> 00:48:02,319
doing for example like so that's how

1452
00:48:07,510 --> 00:48:03,839
birming mechanics works

1453
00:48:10,069 --> 00:48:07,520
um and there was like quite a

1454
00:48:11,750 --> 00:48:10,079
big push in quantum foundations to like

1455
00:48:13,270 --> 00:48:11,760
try and roll these theorems out

1456
00:48:14,470 --> 00:48:13,280
um which isn't like totally possible

1457
00:48:16,390 --> 00:48:14,480
because like yeah for example bohmian

1458
00:48:16,870 --> 00:48:16,400
mechanics exists it exists like whether

1459
00:48:19,990 --> 00:48:16,880
you

1460
00:48:22,309 --> 00:48:20,000
like it or not um but uh

1461
00:48:23,829 --> 00:48:22,319
what like the question spectre theorem

1462
00:48:26,630 --> 00:48:23,839
tried to do and what like

1463
00:48:27,109 --> 00:48:26,640

um other theorems since have tried to do

1464
00:48:29,030 --> 00:48:27,119
is

1465
00:48:31,750 --> 00:48:29,040
prove that these hidden variable

1466
00:48:33,589 --> 00:48:31,760
theorems have undesirable properties

1467
00:48:35,589 --> 00:48:33,599
um and so what the undesirable property

1468
00:48:38,870 --> 00:48:35,599
that the questions factor theorem shows

1469
00:48:41,990 --> 00:48:38,880
is um something called contextuality

1470
00:48:44,870 --> 00:48:42,000
so what that means is uh

1471
00:48:46,390 --> 00:48:44,880
if you have a variable like a thing that

1472
00:48:47,430 --> 00:48:46,400
the particle is doing that you're

1473
00:48:50,390 --> 00:48:47,440
interested in

1474
00:48:50,870 --> 00:48:50,400
um let's say the spin of the particle so

1475
00:48:54,069 --> 00:48:50,880
uh

1476
00:48:54,950 --> 00:48:54,079
spin like you you wanna like in in

1477
00:48:56,549 --> 00:48:54,960
quantum mechanics

1478
00:48:58,950 --> 00:48:56,559
you would say that the particle is like

1479
00:49:01,030 --> 00:48:58,960
a superposition of spin up and spin down

1480
00:49:02,630 --> 00:49:01,040
but in uh hidden variable theorem

1481
00:49:06,390 --> 00:49:02,640
presumably you'd want to say

1482
00:49:08,549 --> 00:49:06,400
this particle is spin up right and

1483
00:49:10,309 --> 00:49:08,559
um how would you say that well you'd say

1484
00:49:13,030 --> 00:49:10,319
like okay if i measured it now

1485
00:49:13,910 --> 00:49:13,040
and it was spin up um then it was spin

1486
00:49:16,790 --> 00:49:13,920
up before that

1487
00:49:17,829 --> 00:49:16,800
right um but what what the questions

1488
00:49:21,190 --> 00:49:17,839

vector theorem shows

1489
00:49:22,790 --> 00:49:21,200
is that actually um that isn't a good

1490
00:49:25,670 --> 00:49:22,800
way to be thinking about that theorem

1491
00:49:27,589 --> 00:49:25,680
because if i had that same particle

1492
00:49:29,190 --> 00:49:27,599
and instead of measuring it this way

1493
00:49:29,670 --> 00:49:29,200
like with a particular instrument this

1494
00:49:31,910 --> 00:49:29,680
way

1495
00:49:33,030 --> 00:49:31,920
if i turn that instrument on its head um

1496
00:49:35,990 --> 00:49:33,040
and measured

1497
00:49:36,710 --> 00:49:36,000
uh and then like did the sort of like in

1498
00:49:39,349 --> 00:49:36,720
post

1499
00:49:40,069 --> 00:49:39,359
um like figured out like what the spin

1500
00:49:41,030 --> 00:49:40,079
should be

1501
00:49:43,670 --> 00:49:41,040
what do you mean you turn the

1502
00:49:46,150 --> 00:49:43,680
measurement on its head yeah so like

1503
00:49:48,470 --> 00:49:46,160
so this sort of canonical way to measure

1504
00:49:49,270 --> 00:49:48,480
spin is to get a stone garlic machine

1505
00:49:51,510 --> 00:49:49,280
which is like

1506
00:49:53,030 --> 00:49:51,520
has a certain type of magnetic field

1507
00:49:56,470 --> 00:49:53,040
that kind of points upwards

1508
00:49:58,630 --> 00:49:56,480
um and if a particle goes upwards

1509
00:49:59,510 --> 00:49:58,640
we would say that spin up but what we

1510
00:50:01,910 --> 00:49:59,520
could do instead

1511
00:50:02,549 --> 00:50:01,920
is we could turn it on its head now

1512
00:50:06,470 --> 00:50:02,559
literally

1513
00:50:09,510 --> 00:50:06,480

and now a particle that goes

1514
00:50:11,990 --> 00:50:09,520
um oh am i going to get this right

1515
00:50:13,670 --> 00:50:12,000
yeah so now the same particle if it was

1516
00:50:15,990 --> 00:50:13,680
spin up should go down

1517
00:50:17,030 --> 00:50:16,000
um and so we would still say that spin

1518
00:50:18,950 --> 00:50:17,040
up but like

1519
00:50:20,390 --> 00:50:18,960
with but we've measured it differently

1520
00:50:21,190 --> 00:50:20,400
right so it's just the measurement

1521
00:50:23,670 --> 00:50:21,200
operator

1522
00:50:25,510 --> 00:50:23,680
apparatus that is different but like the

1523
00:50:27,670 --> 00:50:25,520
sort of results should be the same

1524
00:50:28,630 --> 00:50:27,680
but what quotient spec has showed is

1525
00:50:31,190 --> 00:50:28,640
that in fact

1526
00:50:31,670 --> 00:50:31,200
if you had that particle um that was

1527
00:50:33,270 --> 00:50:31,680
that

1528
00:50:34,549 --> 00:50:33,280
like you know we're going to measure and

1529
00:50:35,510 --> 00:50:34,559
you measure it the normal way it would

1530
00:50:38,150 --> 00:50:35,520
go spin up

1531
00:50:39,910 --> 00:50:38,160
but if you turn the machine on its head

1532
00:50:40,950 --> 00:50:39,920
now you should expect it to go to spin

1533
00:50:44,549 --> 00:50:40,960
down but it would in fact

1534
00:50:45,510 --> 00:50:44,559
still go spin up um and so that suggests

1535
00:50:48,470 --> 00:50:45,520
that this property

1536
00:50:49,990 --> 00:50:48,480
is not a real property of that object

1537
00:50:53,109 --> 00:50:50,000
it's a property of the way

1538
00:50:56,470 --> 00:50:53,119

we measure the object which like is

1539
00:50:58,309 --> 00:50:56,480
not nice um the the response to the

1540
00:50:59,670 --> 00:50:58,319
quotients of echo theorem though in like

1541
00:51:03,030 --> 00:50:59,680
terms of bohmian mechanics

1542
00:51:05,829 --> 00:51:03,040
or other hidden variable um things is

1543
00:51:06,790 --> 00:51:05,839
well in body mechanics spin is not a

1544
00:51:10,069 --> 00:51:06,800
real property

1545
00:51:12,549 --> 00:51:10,079
of a particle and in fact no

1546
00:51:13,670 --> 00:51:12,559
um like none of the kind of variables

1547
00:51:14,549 --> 00:51:13,680
that you can make from the quotient

1548
00:51:17,670 --> 00:51:14,559
spectra

1549
00:51:19,030 --> 00:51:17,680
theorem are real variables like truly

1550
00:51:19,750 --> 00:51:19,040
considered to be properties of the

1551
00:51:21,510 --> 00:51:19,760
particle

1552
00:51:23,349 --> 00:51:21,520
in both mechanics they're essentially

1553
00:51:24,470 --> 00:51:23,359
emergent properties like in bromine

1554
00:51:26,309 --> 00:51:24,480
mechanics the real

1555
00:51:28,390 --> 00:51:26,319
like properties that matter of the

1556
00:51:29,829 --> 00:51:28,400
particle are its position

1557
00:51:31,589 --> 00:51:29,839
essentially and then you can derive its

1558
00:51:33,430 --> 00:51:31,599
momentum from that um

1559
00:51:35,349 --> 00:51:33,440
so position is the only real variable

1560
00:51:37,270 --> 00:51:35,359
everything else is just like emergent

1561
00:51:38,870 --> 00:51:37,280
and so the fact that like yeah if you

1562
00:51:40,549 --> 00:51:38,880
measure it this way it's up and if you

1563
00:51:42,309 --> 00:51:40,559

measure it that way it's down like

1564
00:51:43,910 --> 00:51:42,319
it doesn't matter to bombing mechanics

1565
00:51:46,790 --> 00:51:43,920
because that wasn't a real property that

1566
00:51:48,870 --> 00:51:46,800
it cared about about the particle anyway

1567
00:51:49,990 --> 00:51:48,880
okay now this rotating of the stern

1568
00:51:51,750 --> 00:51:50,000
gerlac apparatus

1569
00:51:54,230 --> 00:51:51,760
is that a contrived example or is that

1570
00:51:55,990 --> 00:51:54,240
actually in the cochin specter theorem

1571
00:51:57,430 --> 00:51:56,000
ah so the question spoken to theorem is

1572
00:51:59,990 --> 00:51:57,440
a much more general

1573
00:52:00,870 --> 00:52:00,000
theorem than that like um well the

1574
00:52:03,990 --> 00:52:00,880
reason i'm asking

1575
00:52:05,750 --> 00:52:04,000
in that example physics

1576
00:52:07,270 --> 00:52:05,760
is invariant under rotations translation

1577
00:52:07,589 --> 00:52:07,280
and so on so how does the particle even

1578
00:52:09,510 --> 00:52:07,599
know

1579
00:52:11,109 --> 00:52:09,520
if you've rotated your apparatus that it

1580
00:52:11,910 --> 00:52:11,119
oh because if you rotate the apparatus

1581
00:52:13,270 --> 00:52:11,920
you've changed

1582
00:52:15,670 --> 00:52:13,280
the direction of the magnetic field like

1583
00:52:17,270 --> 00:52:15,680
that's real um like if you rotated the

1584
00:52:18,069 --> 00:52:17,280
entire universe then the particle

1585
00:52:19,829 --> 00:52:18,079
wouldn't be able to tell

1586
00:52:21,190 --> 00:52:19,839
but if you rotate a single part within

1587
00:52:23,030 --> 00:52:21,200
it yeah

1588
00:52:24,710 --> 00:52:23,040

okay yeah the question spectrum theorem

1589
00:52:26,069 --> 00:52:24,720
is like way more general um but this is

1590
00:52:27,190 --> 00:52:26,079
like one of the scenarios that it would

1591
00:52:28,790 --> 00:52:27,200
apply to

1592
00:52:31,109 --> 00:52:28,800
why don't you explain what quantum

1593
00:52:33,190 --> 00:52:31,119
decoherence is and why it either solves

1594
00:52:36,390 --> 00:52:33,200
or doesn't solve the measurement problem

1595
00:52:39,430 --> 00:52:36,400
oh that's such a great question um okay

1596
00:52:42,710 --> 00:52:39,440
so uh decoherence is a

1597
00:52:45,510 --> 00:52:42,720
like very on the surface mundane

1598
00:52:46,069 --> 00:52:45,520
thing about quantum mechanics and it's

1599
00:52:49,270 --> 00:52:46,079
just

1600
00:52:53,270 --> 00:52:49,280
uh the fact that um as

1601
00:52:55,030 --> 00:52:53,280
you uh like as you okay so you have

1602
00:52:56,790 --> 00:52:55,040
some particle in a superposition let's

1603
00:52:57,510 --> 00:52:56,800
say a superposition of spin up and spin

1604
00:52:59,349 --> 00:52:57,520
down

1605
00:53:01,270 --> 00:52:59,359
and then something interacts with it

1606
00:53:03,430 --> 00:53:01,280
let's say a photon of light

1607
00:53:04,470 --> 00:53:03,440
and the photon of light will act

1608
00:53:06,470 --> 00:53:04,480
differently if

1609
00:53:08,790 --> 00:53:06,480
the particle is spin up or if it's spin

1610
00:53:10,150 --> 00:53:08,800
down so that light particle will go into

1611
00:53:10,790 --> 00:53:10,160
a different state depending on which of

1612
00:53:13,510 --> 00:53:10,800
those two

1613
00:53:14,950 --> 00:53:13,520

properties it's in um so now in quantum

1614
00:53:15,910 --> 00:53:14,960
mechanics we would say that it's

1615
00:53:18,549 --> 00:53:15,920
entangled

1616
00:53:19,349 --> 00:53:18,559
with uh with the original particle

1617
00:53:21,670 --> 00:53:19,359
because

1618
00:53:23,109 --> 00:53:21,680
um its state depends on the state of the

1619
00:53:24,230 --> 00:53:23,119
original particle so that's like what

1620
00:53:27,589 --> 00:53:24,240
entanglement is

1621
00:53:28,549 --> 00:53:27,599
um and so then uh okay like that's

1622
00:53:30,870 --> 00:53:28,559
that's all good

1623
00:53:31,670 --> 00:53:30,880
but now imagine that that photon just

1624
00:53:33,829 --> 00:53:31,680
like leaves

1625
00:53:35,030 --> 00:53:33,839
and you never see it again and you'll

1626
00:53:36,630 --> 00:53:35,040
never be able to measure it

1627
00:53:39,030 --> 00:53:36,640
but you try and measure your original

1628
00:53:40,710 --> 00:53:39,040
particle now if an or if your original

1629
00:53:42,230 --> 00:53:40,720
particle is in a superposition

1630
00:53:43,910 --> 00:53:42,240
normally you'd be able to tell that it's

1631
00:53:45,670 --> 00:53:43,920
in a superposition you can do like a

1632
00:53:46,630 --> 00:53:45,680
double slit experiment on it something

1633
00:53:48,710 --> 00:53:46,640
similar

1634
00:53:49,750 --> 00:53:48,720
um to tell that it is in that

1635
00:53:51,270 --> 00:53:49,760
superposition

1636
00:53:53,750 --> 00:53:51,280
but even though it's still in a

1637
00:53:55,030 --> 00:53:53,760
superposition um and like nothing has

1638
00:53:56,309 --> 00:53:55,040

changed from the quantum mechanics point

1639
00:53:58,309 --> 00:53:56,319
of view because

1640
00:54:00,230 --> 00:53:58,319
you have no you haven't got access to

1641
00:54:03,430 --> 00:54:00,240
that photon if you do the math

1642
00:54:05,990 --> 00:54:03,440
you can like show that this particle now

1643
00:54:07,190 --> 00:54:06,000
acts as if it's collapsed to one of

1644
00:54:08,470 --> 00:54:07,200
those two states

1645
00:54:10,390 --> 00:54:08,480
like you will not be able to tell the

1646
00:54:12,150 --> 00:54:10,400
difference between a collapsed particle

1647
00:54:13,750 --> 00:54:12,160
and what's really happening which is

1648
00:54:15,430 --> 00:54:13,760
it's still in a superposition but

1649
00:54:17,589 --> 00:54:15,440
a superposition that involves this

1650
00:54:19,910 --> 00:54:17,599
photon that is now inaccessible

1651
00:54:21,270 --> 00:54:19,920
um and so that's like yeah it's on the

1652
00:54:23,430 --> 00:54:21,280
surface a bit mundane

1653
00:54:24,870 --> 00:54:23,440
but um the implications are really

1654
00:54:28,309 --> 00:54:24,880
profound because

1655
00:54:30,069 --> 00:54:28,319
here is a mechanism by which you can get

1656
00:54:31,829 --> 00:54:30,079
measurement collapse without measurement

1657
00:54:34,790 --> 00:54:31,839
collapse like so something that

1658
00:54:36,630 --> 00:54:34,800
looks and feels to us exactly like

1659
00:54:39,270 --> 00:54:36,640
measurement collapse like mathematically

1660
00:54:41,109 --> 00:54:39,280
entirely equivalent and yet all that's

1661
00:54:44,390 --> 00:54:41,119
happening is normal quantum mechanics

1662
00:54:46,870 --> 00:54:44,400
and so you can just get rid of that last

1663
00:54:48,390 --> 00:54:46,880

postulate of quantum mechanics entirely

1664
00:54:50,309 --> 00:54:48,400
and just replace it with like

1665
00:54:51,670 --> 00:54:50,319
just just just delete it and you still

1666
00:54:52,789 --> 00:54:51,680
get the same results

1667
00:54:54,470 --> 00:54:52,799
sorry when you say you can get rid of

1668
00:54:55,829 --> 00:54:54,480
the last postulate of quantum mechanics

1669
00:54:57,990 --> 00:54:55,839
you're referring to

1670
00:54:59,190 --> 00:54:58,000
oh yes the the measurement postulates so

1671
00:55:01,990 --> 00:54:59,200
the collapse postulate

1672
00:55:03,990 --> 00:55:02,000
um that so like yeah there's the the

1673
00:55:06,069 --> 00:55:04,000
thing that's really nasty about quantum

1674
00:55:08,390 --> 00:55:06,079
mechanics and like the

1675
00:55:10,069 --> 00:55:08,400
like i think real problem with quantum

1676
00:55:13,990 --> 00:55:10,079
mechanics is that there's two

1677
00:55:17,510 --> 00:55:14,000
systems there's like what how quantum

1678
00:55:21,030 --> 00:55:17,520
quantum objects like act when there

1679
00:55:22,150 --> 00:55:21,040
is no measurers around and no devices

1680
00:55:24,390 --> 00:55:22,160
around to measure them

1681
00:55:25,270 --> 00:55:24,400
they just like evolve unitarily it's

1682
00:55:27,190 --> 00:55:25,280
very nice

1683
00:55:28,549 --> 00:55:27,200
but then suddenly as soon as you add

1684
00:55:29,190 --> 00:55:28,559
something that you call a measurement

1685
00:55:31,829 --> 00:55:29,200
device

1686
00:55:32,710 --> 00:55:31,839
and like who knows what that is um you

1687
00:55:34,630 --> 00:55:32,720
have to have like

1688
00:55:35,750 --> 00:55:34,640

different rules of physics that are like

1689
00:55:37,990 --> 00:55:35,760
incompatible

1690
00:55:39,030 --> 00:55:38,000
like they just don't work together and

1691
00:55:40,549 --> 00:55:39,040
like this is just

1692
00:55:42,390 --> 00:55:40,559
untenable mathematically and

1693
00:55:45,510 --> 00:55:42,400
philosophically like it's just

1694
00:55:47,589 --> 00:55:45,520
ugly um whereas the

1695
00:55:49,270 --> 00:55:47,599
the whole d coherence thing gives us a

1696
00:55:50,870 --> 00:55:49,280
way out what it says is

1697
00:55:52,870 --> 00:55:50,880
forget about that second regime

1698
00:55:53,750 --> 00:55:52,880
measurements are not real measurements

1699
00:55:56,230 --> 00:55:53,760
are a

1700
00:55:57,829 --> 00:55:56,240
um a phenomenological thing that comes

1701
00:56:01,190 --> 00:55:57,839
from just the regular

1702
00:56:01,990 --> 00:56:01,200
um quantum mechanics uh like there is

1703
00:56:04,630 --> 00:56:02,000
never measurement

1704
00:56:05,589 --> 00:56:04,640
collapse instead um there's only

1705
00:56:07,349 --> 00:56:05,599
superpositions

1706
00:56:09,190 --> 00:56:07,359
but because some parts of those

1707
00:56:11,109 --> 00:56:09,200
superpositions become inaccessible to

1708
00:56:12,630 --> 00:56:11,119
you as like you add more particles and

1709
00:56:14,230 --> 00:56:12,640
they all become entangled and then those

1710
00:56:16,870 --> 00:56:14,240
particles fly off or whatever

1711
00:56:18,870 --> 00:56:16,880
you can't measure them your your object

1712
00:56:20,789 --> 00:56:18,880
that is still in a superposition now

1713
00:56:22,069 --> 00:56:20,799

looks as if it's been measured and

1714
00:56:24,150 --> 00:56:22,079
therefore like

1715
00:56:25,270 --> 00:56:24,160
that is like measurement but it's not a

1716
00:56:27,109 --> 00:56:25,280
real thing it's just a

1717
00:56:28,549 --> 00:56:27,119
an emergent property does this have any

1718
00:56:29,829 --> 00:56:28,559
implications for the many worlds

1719
00:56:32,950 --> 00:56:29,839
interpretation

1720
00:56:35,990 --> 00:56:32,960
yes absolutely um so

1721
00:56:39,430 --> 00:56:36,000
many worlds uh people often take

1722
00:56:42,470 --> 00:56:39,440
this um decoherence as like a

1723
00:56:45,510 --> 00:56:42,480
sort of uh important

1724
00:56:47,910 --> 00:56:45,520
important ingredient in their theorem um

1725
00:56:49,750 --> 00:56:47,920
but they're like many worlds i would say

1726
00:56:51,589 --> 00:56:49,760
uh

1727
00:56:53,030 --> 00:56:51,599
is basically take quantum mechanics

1728
00:56:54,710 --> 00:56:53,040
seriously forget about the measurement

1729
00:56:56,150 --> 00:56:54,720
postulate like it doesn't exist

1730
00:56:57,829 --> 00:56:56,160
and so then the question for them is

1731
00:56:58,870 --> 00:56:57,839
like okay but if you don't have the

1732
00:57:01,910 --> 00:56:58,880
measurement postulate

1733
00:57:03,109 --> 00:57:01,920
how do you how do you um like explain

1734
00:57:04,789 --> 00:57:03,119
what happens in the lab

1735
00:57:06,390 --> 00:57:04,799
where it seems like you know measurement

1736
00:57:07,910 --> 00:57:06,400
happens and collapse happens

1737
00:57:09,750 --> 00:57:07,920
they would just say well it's just

1738
00:57:11,190 --> 00:57:09,760

decoherence so we didn't need

1739
00:57:11,910 --> 00:57:11,200
measurement all along and i would say

1740
00:57:13,829 --> 00:57:11,920
that is the

1741
00:57:15,589 --> 00:57:13,839
many worlds interpretation i thought the

1742
00:57:17,030 --> 00:57:15,599
many worlds is about the splitting of

1743
00:57:18,630 --> 00:57:17,040
the universe because you measure and it

1744
00:57:20,470 --> 00:57:18,640
collapses into one but you're saying

1745
00:57:22,470 --> 00:57:20,480
that forget about collapsing

1746
00:57:24,069 --> 00:57:22,480
it's not yeah it many words i feel like

1747
00:57:26,630 --> 00:57:24,079
that's a misinterpretation

1748
00:57:27,510 --> 00:57:26,640
um many worlds has nothing to do with

1749
00:57:30,870 --> 00:57:27,520
measurement

1750
00:57:32,710 --> 00:57:30,880
um it is what it says

1751
00:57:34,150 --> 00:57:32,720
is if you have some objects in

1752
00:57:38,470 --> 00:57:34,160
superposition

1753
00:57:40,390 --> 00:57:38,480
they never collapse to just one state

1754
00:57:42,309 --> 00:57:40,400
so whereas like the standard

1755
00:57:43,589 --> 00:57:42,319
interpretation says like okay let's say

1756
00:57:45,750 --> 00:57:43,599
i have a

1757
00:57:47,270 --> 00:57:45,760
particle it could be spin up spin down

1758
00:57:50,470 --> 00:57:47,280
um

1759
00:57:52,950 --> 00:57:50,480
i uh measure it and now

1760
00:57:54,630 --> 00:57:52,960
it becomes spin up and i measure spin up

1761
00:57:56,150 --> 00:57:54,640
so there's only one world and that's the

1762
00:57:59,190 --> 00:57:56,160
world where it would spin up

1763
00:58:00,390 --> 00:57:59,200

whereas what many worlds would say is

1764
00:58:02,230 --> 00:58:00,400
okay you have this particle

1765
00:58:04,630 --> 00:58:02,240
superposition of up and down

1766
00:58:06,390 --> 00:58:04,640
you measure it what that really means is

1767
00:58:08,150 --> 00:58:06,400
you interact lots of particles like

1768
00:58:09,589 --> 00:58:08,160
lots of other particles with it they

1769
00:58:12,950 --> 00:58:09,599
decohera

1770
00:58:15,990 --> 00:58:12,960
to you it will look as if the particle

1771
00:58:17,670 --> 00:58:16,000
is um you know spin up or spin down

1772
00:58:19,430 --> 00:58:17,680
but really what's happening is that

1773
00:58:46,470 --> 00:58:19,440
there's still a superposition

1774
00:58:49,990 --> 00:58:48,230
a thought experiment about this called

1775
00:58:51,430 --> 00:58:50,000
quantum suicide and immortality have you

1776
00:58:53,349 --> 00:58:51,440
heard of it

1777
00:58:55,190 --> 00:58:53,359
okay so essentially what i'm wondering

1778
00:58:55,670 --> 00:58:55,200
is under the many worlds interpretation

1779
00:58:58,230 --> 00:58:55,680
do you

1780
00:59:00,549 --> 00:58:58,240
not live forever because if we define

1781
00:59:01,910 --> 00:59:00,559
you as the experiencing you

1782
00:59:04,710 --> 00:59:01,920
because by definition you can't

1783
00:59:07,030 --> 00:59:04,720
experience when you're dead

1784
00:59:09,510 --> 00:59:07,040
so why is it that you don't live forever

1785
00:59:11,670 --> 00:59:09,520
because there's no world where

1786
00:59:12,630 --> 00:59:11,680
where you get to live forever right like

1787
00:59:15,109 --> 00:59:12,640
okay let's say

1788
00:59:15,670 --> 00:59:15,119

um i'm gonna think about myself and all

1789
00:59:17,670 --> 00:59:15,680
of the

1790
00:59:18,950 --> 00:59:17,680
many superpositions i can go into from

1791
00:59:21,670 --> 00:59:18,960
this point

1792
00:59:23,190 --> 00:59:21,680
um so there's many things that could

1793
00:59:24,230 --> 00:59:23,200
happen to me that that put me in

1794
00:59:26,630 --> 00:59:24,240
superposition

1795
00:59:28,309 --> 00:59:26,640
uh maybe like something to do that with

1796
00:59:29,430 --> 00:59:28,319
weather is a quantum fluctuation i don't

1797
00:59:30,309 --> 00:59:29,440
know how that could happen but like

1798
00:59:32,150 --> 00:59:30,319
let's just say

1799
00:59:33,829 --> 00:59:32,160
you know it might rain tomorrow because

1800
00:59:35,430 --> 00:59:33,839
of quantum mechanics or it might not

1801
00:59:36,710 --> 00:59:35,440
so there'll be a version of me that

1802
00:59:37,430 --> 00:59:36,720
experiences the rain and one that

1803
00:59:39,349 --> 00:59:37,440
doesn't

1804
00:59:41,190 --> 00:59:39,359
but in both of those worlds i will die

1805
00:59:44,230 --> 00:59:41,200
eventually like there's no

1806
00:59:47,510 --> 00:59:44,240
immortality there and like in every

1807
00:59:48,789 --> 00:59:47,520
sort of possible world um that is like

1808
00:59:52,309 --> 00:59:48,799
dependent on a quantum

1809
00:59:53,910 --> 00:59:52,319
fluctuation uh like i can't see any of

1810
00:59:56,150 --> 00:59:53,920
those worlds where i become a model

1811
00:59:57,589 --> 00:59:56,160
is there not a world where your dna is

1812
01:00:00,630 --> 00:59:57,599
constantly repaired and the earth

1813
01:00:03,510 --> 01:00:00,640

and the sun doesn't burn out and so on

1814
01:00:05,190 --> 01:00:03,520
so you do live forever so the laws of

1815
01:00:05,750 --> 01:00:05,200
physics have to be obeyed in every one

1816
01:00:08,870 --> 01:00:05,760
of these

1817
01:00:09,589 --> 01:00:08,880
universes um so the sun will inevitably

1818
01:00:13,190 --> 01:00:09,599
burn out

1819
01:00:15,349 --> 01:00:13,200
um just there unless like there is

1820
01:00:16,309 --> 01:00:15,359
i i mean i can't see it but like unless

1821
01:00:18,630 --> 01:00:16,319
there's some

1822
01:00:19,430 --> 01:00:18,640
way for it to not happen quantum

1823
01:00:21,829 --> 01:00:19,440
mechanically

1824
01:00:23,990 --> 01:00:21,839
but i don't think so um so the sun will

1825
01:00:27,109 --> 01:00:24,000
burn out in every one of those universes

1826
01:00:28,390 --> 01:00:27,119
um my dna repairing is not down to

1827
01:00:31,030 --> 01:00:28,400
quantum fluctuations

1828
01:00:31,990 --> 01:00:31,040
it's down to other um other factors

1829
01:00:35,030 --> 01:00:32,000
which like

1830
01:00:36,870 --> 01:00:35,040
couldn't go both ways and so um

1831
01:00:38,789 --> 01:00:36,880
like that that's also not a past

1832
01:00:41,910 --> 01:00:38,799
immortality and how about this

1833
01:00:43,349 --> 01:00:41,920
okay methune is instantly recreated

1834
01:00:44,710 --> 01:00:43,359
you're now 18

1835
01:00:45,829 --> 01:00:44,720
and it's like perfect health you're

1836
01:00:47,030 --> 01:00:45,839
probably already in perfect health but

1837
01:00:49,670 --> 01:00:47,040
you're now 18.

1838
01:00:50,789 --> 01:00:49,680

and there's a is there not a small small

1839
01:00:53,190 --> 01:00:50,799
small chance of that

1840
01:00:54,069 --> 01:00:53,200
occurring right now just a poof version

1841
01:00:56,309 --> 01:00:54,079
of methune

1842
01:00:57,750 --> 01:00:56,319
that breaks the laws of physics somehow

1843
01:00:59,030 --> 01:00:57,760
so the way that i'm imagining this is

1844
01:00:59,990 --> 01:00:59,040
that there's a continuum of where the

1845
01:01:01,829 --> 01:01:00,000
electron can be

1846
01:01:03,349 --> 01:01:01,839
and then that is for every single

1847
01:01:04,950 --> 01:01:03,359
electron in your body and then

1848
01:01:06,630 --> 01:01:04,960
that is also for every single proton in

1849
01:01:08,549 --> 01:01:06,640
your body and so on and so so you just

1850
01:01:11,750 --> 01:01:08,559
transport yourself

1851
01:01:15,030 --> 01:01:11,760
yeah so i think that is a

1852
01:01:17,190 --> 01:01:15,040
that this is like no different from um

1853
01:01:19,510 --> 01:01:17,200
you know if i like because anything

1854
01:01:21,829 --> 01:01:19,520
could uh sort of spontaneously

1855
01:01:23,109 --> 01:01:21,839
um come into being right like because

1856
01:01:26,710 --> 01:01:23,119
because of like

1857
01:01:29,990 --> 01:01:26,720
very freak quantum um uh fluctuations

1858
01:01:32,470 --> 01:01:30,000
but like let's say that you know um

1859
01:01:34,069 --> 01:01:32,480
you're sitting here and then like on the

1860
01:01:36,390 --> 01:01:34,079
other side of the universe

1861
01:01:37,589 --> 01:01:36,400
uh the the eiffel tower just like

1862
01:01:40,710 --> 01:01:37,599
materializes

1863
01:01:43,750 --> 01:01:40,720

on on some other random planet right um

1864
01:01:44,470 --> 01:01:43,760
now it's it's a sort of philosophical

1865
01:01:46,710 --> 01:01:44,480
question

1866
01:01:48,710 --> 01:01:46,720
whether you count that as the eiffel

1867
01:01:52,150 --> 01:01:48,720
tower is it the same thing

1868
01:01:53,990 --> 01:01:52,160
right um and so like if a version of me

1869
01:01:56,789 --> 01:01:54,000
just materializes randomly

1870
01:01:57,349 --> 01:01:56,799
somewhere else in the galaxy uh is is

1871
01:02:00,789 --> 01:01:57,359
that

1872
01:02:03,109 --> 01:02:00,799
it being me because i

1873
01:02:04,309 --> 01:02:03,119
i only have my continuous experience um

1874
01:02:07,670 --> 01:02:04,319
from this body

1875
01:02:09,589 --> 01:02:07,680
um so that that person if if

1876
01:02:11,190 --> 01:02:09,599
if they materialize with all my memories

1877
01:02:12,710 --> 01:02:11,200
of course will think of themselves as me

1878
01:02:15,029 --> 01:02:12,720
but i would think of them as

1879
01:02:16,309 --> 01:02:15,039
as a person distinct from me um and

1880
01:02:19,029 --> 01:02:16,319
there's no sort of

1881
01:02:19,829 --> 01:02:19,039
um contradiction there and also it

1882
01:02:22,630 --> 01:02:19,839
doesn't grant me

1883
01:02:23,910 --> 01:02:22,640
myself any immortality even if uh like

1884
01:02:25,270 --> 01:02:23,920
this keeps happening

1885
01:02:27,190 --> 01:02:25,280
do you think of yourself as the same

1886
01:02:28,470 --> 01:02:27,200
person when you wake up

1887
01:02:30,309 --> 01:02:28,480
um because you're gonna get yeah this is

1888
01:02:33,589 --> 01:02:30,319

it yeah

1889
01:02:35,270 --> 01:02:33,599
um so this is like all you know like

1890
01:02:36,630 --> 01:02:35,280
deep philosophical questions have been

1891
01:02:38,870 --> 01:02:36,640
debated for a long time

1892
01:02:39,910 --> 01:02:38,880
but yes i do think of myself as the same

1893
01:02:41,990 --> 01:02:39,920
person when i wake up

1894
01:02:43,430 --> 01:02:42,000
and something to do with the continuity

1895
01:02:47,029 --> 01:02:43,440
of experience or

1896
01:02:49,270 --> 01:02:47,039
something about being able to um like

1897
01:02:51,190 --> 01:02:49,280
uh remember even if it's inaccurately

1898
01:02:51,990 --> 01:02:51,200
what it was like to be that person

1899
01:02:54,309 --> 01:02:52,000
before

1900
01:02:55,029 --> 01:02:54,319
um like makes me feel like the same

1901
01:02:57,589 --> 01:02:55,039
person

1902
01:02:59,109 --> 01:02:57,599
whereas if there's another version of me

1903
01:02:59,589 --> 01:02:59,119
even if they have the same memories as

1904
01:03:01,589 --> 01:02:59,599
me

1905
01:03:03,270 --> 01:03:01,599
and they themselves therefore think that

1906
01:03:05,510 --> 01:03:03,280
of themselves as me like they

1907
01:03:06,390 --> 01:03:05,520
both of us imagine out like past

1908
01:03:09,510 --> 01:03:06,400
smitherena as

1909
01:03:11,670 --> 01:03:09,520
their past and that is 100 accurate

1910
01:03:13,589 --> 01:03:11,680
i would not would not associate with

1911
01:03:17,029 --> 01:03:13,599
that person because that person is not

1912
01:03:19,270 --> 01:03:17,039
sharing any experiences with me

1913
01:03:20,789 --> 01:03:19,280

i'm curious about the implications if

1914
01:03:22,789 --> 01:03:20,799
the universe is discretized

1915
01:03:24,390 --> 01:03:22,799
spatially or temporally does that have

1916
01:03:25,829 --> 01:03:24,400
any implications for quantum computing

1917
01:03:27,270 --> 01:03:25,839
because i imagine that a large part of

1918
01:03:28,069 --> 01:03:27,280
the power comes from that there's an

1919
01:03:29,430 --> 01:03:28,079
infinite

1920
01:03:31,109 --> 01:03:29,440
amount of intermediate states between

1921
01:03:32,309 --> 01:03:31,119
zero and one and so if you can

1922
01:03:35,829 --> 01:03:32,319
discretize in some

1923
01:03:38,950 --> 01:03:35,839
manner then the the bloch sphere

1924
01:03:40,870 --> 01:03:38,960
is also discretized or is it not that's

1925
01:03:42,630 --> 01:03:40,880
a good question there's different ways

1926
01:03:45,829 --> 01:03:42,640
to discretize right there's just

1927
01:03:47,109 --> 01:03:45,839
discreteness in time in space and

1928
01:03:49,190 --> 01:03:47,119
then what you're talking about which is

1929
01:03:50,789 --> 01:03:49,200
discreetness in terms of um what

1930
01:03:52,630 --> 01:03:50,799
superpositions are allowed

1931
01:03:54,870 --> 01:03:52,640
i can't remember this result of the top

1932
01:03:56,069 --> 01:03:54,880
of my head but i have this vague feeling

1933
01:03:58,630 --> 01:03:56,079
of reading a

1934
01:03:59,670 --> 01:03:58,640
result that was um along the lines of

1935
01:04:01,910 --> 01:03:59,680
discretizing

1936
01:04:02,870 --> 01:04:01,920
what superpositions are allowed and you

1937
01:04:04,230 --> 01:04:02,880
still get like

1938
01:04:05,990 --> 01:04:04,240

the the regular power of quantum

1939
01:04:07,510 --> 01:04:06,000
computing so i would disagree that

1940
01:04:09,349 --> 01:04:07,520
the the power of quantum computing comes

1941
01:04:13,190 --> 01:04:09,359
from the continuity

1942
01:04:15,750 --> 01:04:13,200
uh is there a limit so for example like

1943
01:04:16,390 --> 01:04:15,760
if it's broken up into a thousand

1944
01:04:17,829 --> 01:04:16,400
different

1945
01:04:20,789 --> 01:04:17,839
instead of an infinite amount of

1946
01:04:24,150 --> 01:04:20,799
superposition it's a thousand

1947
01:04:24,710 --> 01:04:24,160
discrete superpositions yeah that would

1948
01:04:26,230 --> 01:04:24,720
certainly

1949
01:04:27,670 --> 01:04:26,240
that would be a problem no that would

1950
01:04:29,190 --> 01:04:27,680
definitely be a problem um i was

1951
01:04:31,109 --> 01:04:29,200
thinking of like if you

1952
01:04:32,470 --> 01:04:31,119
uh discretized it as in like you don't

1953
01:04:33,270 --> 01:04:32,480
allow it to be real numbers but you

1954
01:04:36,549 --> 01:04:33,280
allow it to be

1955
01:04:37,029 --> 01:04:36,559
any um like a rational number um i think

1956
01:04:38,630 --> 01:04:37,039
if you

1957
01:04:40,230 --> 01:04:38,640
start putting into finite numbers yeah

1958
01:04:43,029 --> 01:04:40,240
that would be a problem

1959
01:04:45,829 --> 01:04:43,039
have you heard of wolfram's principle of

1960
01:04:48,230 --> 01:04:45,839
computational equivalence

1961
01:04:49,670 --> 01:04:48,240
um i'm not sure if i have okay so it's

1962
01:04:52,390 --> 01:04:49,680
like an extension of the church

1963
01:04:53,349 --> 01:04:52,400

thesis church turing thesis except he

1964
01:04:56,150 --> 01:04:53,359
says that

1965
01:04:58,309 --> 01:04:56,160
all physical phenomena are have have a

1966
01:05:00,950 --> 01:04:58,319
computational basis

1967
01:05:01,829 --> 01:05:00,960
okay do you agree with that and yeah

1968
01:05:07,910 --> 01:05:01,839
that sounds

1969
01:05:11,029 --> 01:05:07,920
very biased as a person who

1970
01:05:11,829 --> 01:05:11,039
studied quantum computing because like

1971
01:05:13,270 --> 01:05:11,839
the reason why

1972
01:05:15,750 --> 01:05:13,280
quantum computing is interesting to me

1973
01:05:18,150 --> 01:05:15,760
is because i fundamentally accept that

1974
01:05:19,589 --> 01:05:18,160
um that everything in the universe is a

1975
01:05:20,710 --> 01:05:19,599
computation in the sense that a

1976
01:05:22,870 --> 01:05:20,720
computation is like

1977
01:05:24,950 --> 01:05:22,880
you have some objects and they follow

1978
01:05:26,630 --> 01:05:24,960
some rules and that just determines what

1979
01:05:28,870 --> 01:05:26,640
they're doing at the next time step

1980
01:05:31,349 --> 01:05:28,880
and so that like to me is exactly what

1981
01:05:34,870 --> 01:05:31,359
physics is and so i've like yeah no

1982
01:05:38,630 --> 01:05:34,880
no like yeah to me that's

1983
01:05:40,870 --> 01:05:38,640
like definitely true okay great

1984
01:05:42,950 --> 01:05:40,880
okay now you had some some choice words

1985
01:05:45,510 --> 01:05:42,960
to say about the bohmian pilot wave

1986
01:05:48,230 --> 01:05:45,520
theory okay why do you not particularly

1987
01:05:55,109 --> 01:05:51,589
oh i i do particularly like it um so

1988
01:05:57,990 --> 01:05:55,119

i i actually think that um

1989
01:05:59,430 --> 01:05:58,000
like i don't think i believe it um but i

1990
01:06:02,549 --> 01:05:59,440
think that is a really

1991
01:06:05,109 --> 01:06:02,559
really important theory to have in mind

1992
01:06:05,990 --> 01:06:05,119
because a lot of the things that we want

1993
01:06:07,670 --> 01:06:06,000
to say about

1994
01:06:09,829 --> 01:06:07,680
quantum mechanics or we think is like

1995
01:06:12,549 --> 01:06:09,839
obviously true about quantum mechanics

1996
01:06:13,349 --> 01:06:12,559
um binomial mechanic bohmian mechanics

1997
01:06:15,589 --> 01:06:13,359
provides an

1998
01:06:17,349 --> 01:06:15,599
excellent counter example for so it's

1999
01:06:18,150 --> 01:06:17,359
something to like always be keeping in

2000
01:06:19,670 --> 01:06:18,160
mind

2001
01:06:21,510 --> 01:06:19,680
um when you're talking about the

2002
01:06:23,589 --> 01:06:21,520
foundations of quantum mechanics

2003
01:06:24,870 --> 01:06:23,599
and yeah like i think it's an ingenious

2004
01:06:28,069 --> 01:06:24,880
theory i think that

2005
01:06:31,109 --> 01:06:28,079
it doesn't extend well to relativity uh

2006
01:06:33,510 --> 01:06:31,119
which is why i don't think it's true

2007
01:06:34,549 --> 01:06:33,520
but for just straight up quantum

2008
01:06:37,190 --> 01:06:34,559
mechanics itself

2009
01:06:38,549 --> 01:06:37,200
it is like yeah just such a beautiful

2010
01:06:39,270 --> 01:06:38,559
counter example to a lot of things

2011
01:06:40,470 --> 01:06:39,280
people say

2012
01:06:42,230 --> 01:06:40,480
okay i heard you say that on the

2013
01:06:43,029 --> 01:06:42,240

eigenvalues podcast that it doesn't

2014
01:06:43,750 --> 01:06:43,039
extend to

2015
01:06:46,069 --> 01:06:43,760
well you said that it's

2016
01:06:48,470 --> 01:06:46,079
non-renormalizable but i wasn't able

2017
01:06:49,750 --> 01:06:48,480
to find that result did you can you

2018
01:06:51,910 --> 01:06:49,760
there's a paper on that

2019
01:06:53,190 --> 01:06:51,920
i'm assuming there are some papers on

2020
01:06:55,750 --> 01:06:53,200
this but it's not

2021
01:06:58,870 --> 01:06:55,760
it's not that it isn't possible but that

2022
01:07:06,069 --> 01:07:02,630
that it seems so it is probably possible

2023
01:07:09,349 --> 01:07:06,079
to reproduce the

2024
01:07:11,829 --> 01:07:09,359
um like the the phenomena of

2025
01:07:13,750 --> 01:07:11,839
of special relativity but not to

2026
01:07:16,630 --> 01:07:13,760
reproduce the sort of like

2027
01:07:17,990 --> 01:07:16,640
underlying um beauty of special

2028
01:07:20,710 --> 01:07:18,000
relativity which is like

2029
01:07:22,150 --> 01:07:20,720
relativity that um like you know frames

2030
01:07:23,349 --> 01:07:22,160
of reference don't matter and that sort

2031
01:07:25,430 --> 01:07:23,359
of thing

2032
01:07:27,990 --> 01:07:25,440
there's a paper a fairly recent paper

2033
01:07:29,510 --> 01:07:28,000
2019 this guy named pinto pintonetto

2034
01:07:31,430 --> 01:07:29,520
and strove i don't know if you heard of

2035
01:07:33,990 --> 01:07:31,440
them no

2036
01:07:35,510 --> 01:07:34,000
okay well they showed that with a

2037
01:07:38,230 --> 01:07:35,520
bohmian interpretation

2038
01:07:38,950 --> 01:07:38,240

you can have you can have quantum

2039
01:07:42,150 --> 01:07:38,960
gravity

2040
01:07:44,950 --> 01:07:42,160
and in a way that doesn't have the

2041
01:07:47,109 --> 01:07:44,960
the parts of heterotic string theory and

2042
01:07:49,589 --> 01:07:47,119
supersymmetric string theory and

2043
01:07:51,270 --> 01:07:49,599
and loop quantum that they have some

2044
01:07:51,670 --> 01:07:51,280
pastiferous parts to them when it comes

2045
01:07:53,829 --> 01:07:51,680
to

2046
01:07:55,750 --> 01:07:53,839
quantizing gravity so what they used is

2047
01:07:56,630 --> 01:07:55,760
an approach of canonical quantum gravity

2048
01:07:58,630 --> 01:07:56,640
and apparently

2049
01:07:59,910 --> 01:07:58,640
when you use a bomium interpretation it

2050
01:08:03,190 --> 01:07:59,920
helps

2051
01:08:04,630 --> 01:08:03,200
form some even predictive aspects of

2052
01:08:06,430 --> 01:08:04,640
quantum cosmology

2053
01:08:07,990 --> 01:08:06,440
so that's why i was wondering why is it

2054
01:08:09,910 --> 01:08:08,000
non-renormalizable when

2055
01:08:11,270 --> 01:08:09,920
like i couldn't find that result and i i

2056
01:08:12,549 --> 01:08:11,280
heard you say that on the eigenbros

2057
01:08:14,150 --> 01:08:12,559
podcast and i was like where's and then

2058
01:08:15,349 --> 01:08:14,160
they're like yeah it is non-normalizable

2059
01:08:17,110 --> 01:08:15,359
i'm like what yeah

2060
01:08:18,390 --> 01:08:17,120
and i searched for this but i could yeah

2061
01:08:21,590 --> 01:08:18,400
okay so there i

2062
01:08:21,910 --> 01:08:21,600
don't know if i said non-normalizable

2063
01:08:24,870 --> 01:08:21,920

but

2064
01:08:25,590 --> 01:08:24,880
um definitely like the thing that i was

2065
01:08:28,789 --> 01:08:25,600
thinking of

2066
01:08:30,390 --> 01:08:28,799
was um like that that it is frame

2067
01:08:32,709 --> 01:08:30,400
dependent

2068
01:08:33,669 --> 01:08:32,719
um so it has like a privileged frame of

2069
01:08:37,110 --> 01:08:33,679
reference i think

2070
01:08:38,789 --> 01:08:37,120
which is quite like not in the spirit of

2071
01:08:41,590 --> 01:08:38,799
relativity yeah yeah yeah even if it can

2072
01:08:43,990 --> 01:08:41,600
reproduce the results and and like

2073
01:08:45,510 --> 01:08:44,000
to be fair like if it can reproduce the

2074
01:08:48,229 --> 01:08:45,520
results very well

2075
01:08:49,110 --> 01:08:48,239
or even like have good um predictions

2076
01:08:50,630 --> 01:08:49,120
about like

2077
01:08:52,470 --> 01:08:50,640
you know where where all these things

2078
01:08:53,430 --> 01:08:52,480
are gonna go then then that is very

2079
01:08:56,229 --> 01:08:53,440
exciting and

2080
01:08:57,910 --> 01:08:56,239
we like you know maybe should give up on

2081
01:08:58,229 --> 01:08:57,920
like the beauty of relativity a little

2082
01:09:00,390 --> 01:08:58,239
bit

2083
01:09:01,669 --> 01:09:00,400
if it's gonna be useful um so i'm not

2084
01:09:02,149 --> 01:09:01,679
like i don't have a strong position on

2085
01:09:05,110 --> 01:09:02,159
that

2086
01:09:05,590 --> 01:09:05,120
but my my like sort of gut feeling was

2087
01:09:07,110 --> 01:09:05,600
like

2088
01:09:08,630 --> 01:09:07,120

having not read this paper that you're

2089
01:09:11,669 --> 01:09:08,640
mentioning um

2090
01:09:13,669 --> 01:09:11,679
that like if it had to have like a

2091
01:09:15,829 --> 01:09:13,679
sort of privileged frame of reference

2092
01:09:18,789 --> 01:09:15,839
that it would probably make the

2093
01:09:20,390 --> 01:09:18,799
the math of it like kind of too hard to

2094
01:09:23,430 --> 01:09:20,400
like be really workable

2095
01:09:25,269 --> 01:09:23,440
um and so that was why i wasn't

2096
01:09:26,470 --> 01:09:25,279
a fan of it like i didn't feel like it

2097
01:09:27,990 --> 01:09:26,480
could extend well

2098
01:09:29,510 --> 01:09:28,000
do you have an opinion that the laws of

2099
01:09:30,950 --> 01:09:29,520
physics like let's say the theory of

2100
01:09:32,229 --> 01:09:30,960
everything is ultimately beautiful

2101
01:09:33,910 --> 01:09:32,239
symmetric and so on

2102
01:09:36,309 --> 01:09:33,920
or do you or you're like yeah i mean i'm

2103
01:09:39,669 --> 01:09:36,319
not physicist be it as it comes

2104
01:09:41,030 --> 01:09:39,679
yeah no i like i mean i i

2105
01:09:42,470 --> 01:09:41,040
maybe should be one of those people

2106
01:09:43,829 --> 01:09:42,480
who's like oh you know whatever it is

2107
01:09:45,669 --> 01:09:43,839
that's that's the truth

2108
01:09:47,189 --> 01:09:45,679
um but like of course like my training

2109
01:09:50,550 --> 01:09:47,199
is in physics and

2110
01:09:52,870 --> 01:09:50,560
we get this like idea sort of

2111
01:09:53,829 --> 01:09:52,880
hammered into us the whole way along

2112
01:09:55,990 --> 01:09:53,839
that that

2113
01:09:58,229 --> 01:09:56,000

things that are true are beautiful um

2114
01:09:58,709 --> 01:09:58,239
and it just so happens to have been the

2115
01:10:01,910 --> 01:09:58,719
case

2116
01:10:03,510 --> 01:10:01,920
for so long and even in mathematics um i

2117
01:10:04,229 --> 01:10:03,520
feel like this is true that the things

2118
01:10:07,350 --> 01:10:04,239
that are true

2119
01:10:09,990 --> 01:10:07,360
are beautiful because um like

2120
01:10:10,870 --> 01:10:10,000
the beauty of it is like us recognizing

2121
01:10:13,750 --> 01:10:10,880
how

2122
01:10:14,830 --> 01:10:13,760
like elegant and simple the solution is

2123
01:10:18,709 --> 01:10:14,840
um

2124
01:10:20,950 --> 01:10:18,719
and it feels it would just be

2125
01:10:23,110 --> 01:10:20,960
weird for all this like complexity in

2126
01:10:25,350 --> 01:10:23,120
the universe to exist without some like

2127
01:10:26,229 --> 01:10:25,360
very beautiful elegant rules to have

2128
01:10:27,830 --> 01:10:26,239
produced them

2129
01:10:29,910 --> 01:10:27,840
but of course it's like very possible

2130
01:10:30,950 --> 01:10:29,920
and i i you know i don't hold on to it

2131
01:10:32,630 --> 01:10:30,960
too strongly

2132
01:10:34,149 --> 01:10:32,640
we're gonna wrap up but i have some

2133
01:10:36,310 --> 01:10:34,159
specific questions for

2134
01:10:37,590 --> 01:10:36,320
some of the people who are let's say in

2135
01:10:38,870 --> 01:10:37,600
their second year of physics so they're

2136
01:10:40,390 --> 01:10:38,880
just taking quantum mechanics

2137
01:10:42,709 --> 01:10:40,400
and then some audience questions too

2138
01:10:44,470 --> 01:10:42,719

okay so miles ignotus says i'd like to

2139
01:10:46,790 --> 01:10:44,480
know her thoughts on cubism

2140
01:10:48,070 --> 01:10:46,800
yeah okay so this is like a really great

2141
01:10:49,669 --> 01:10:48,080
question and it is

2142
01:10:51,189 --> 01:10:49,679
something that i've been wanting to like

2143
01:10:52,709 --> 01:10:51,199
learn more about to actually make a

2144
01:10:53,990 --> 01:10:52,719
video about and just just generally know

2145
01:10:56,470 --> 01:10:54,000
more about for myself

2146
01:10:57,669 --> 01:10:56,480
um but i don't know enough but my sort

2147
01:11:00,709 --> 01:10:57,679
of gut

2148
01:11:04,870 --> 01:11:00,719
reaction to it is like i just feel

2149
01:11:07,590 --> 01:11:04,880
uncomfortable with um physical theories

2150
01:11:08,390 --> 01:11:07,600
that put that really privileged the

2151
01:11:10,070 --> 01:11:08,400
observer and

2152
01:11:11,510 --> 01:11:10,080
privileged the observer's knowledge

2153
01:11:13,590 --> 01:11:11,520
about the universe and

2154
01:11:14,950 --> 01:11:13,600
kind of almost suggests the universe

2155
01:11:17,030 --> 01:11:14,960
doesn't exist without us

2156
01:11:18,870 --> 01:11:17,040
processing the knowledge and like again

2157
01:11:20,070 --> 01:11:18,880
this is very much my bias like coming

2158
01:11:21,270 --> 01:11:20,080
from physics where

2159
01:11:23,350 --> 01:11:21,280
it's all about like sort of

2160
01:11:24,790 --> 01:11:23,360
objectiveness and like humans being

2161
01:11:26,630 --> 01:11:24,800
removed from the

2162
01:11:28,390 --> 01:11:26,640
like humans kind of stumbling onto the

2163
01:11:29,910 --> 01:11:28,400

universe and like trying to understand

2164
01:11:30,790 --> 01:11:29,920
it as it is rather than creating the

2165
01:11:33,590 --> 01:11:30,800
universe in

2166
01:11:35,110 --> 01:11:33,600
our own minds um so this is my gut

2167
01:11:37,830 --> 01:11:35,120
reaction against cubism

2168
01:11:38,390 --> 01:11:37,840
but i think that there's like a lot of

2169
01:11:40,310 --> 01:11:38,400
um

2170
01:11:41,830 --> 01:11:40,320
interesting mathematics that has been

2171
01:11:45,110 --> 01:11:41,840
derived by cubism

2172
01:11:46,870 --> 01:11:45,120
that like is definitely worth um looking

2173
01:11:47,350 --> 01:11:46,880
into and something that i really want to

2174
01:11:50,550 --> 01:11:47,360
do

2175
01:11:52,310 --> 01:11:50,560
pronouncing that correctly says how can

2176
01:11:53,430 --> 01:11:52,320
a person who is self-studying deal with

2177
01:11:55,350 --> 01:11:53,440
gaps in knowledge

2178
01:11:57,510 --> 01:11:55,360
when i get stuck on a new concept i'm

2179
01:11:59,350 --> 01:11:57,520
often unsure what exactly it is that's

2180
01:12:01,669 --> 01:11:59,360
preventing me from understanding it

2181
01:12:04,630 --> 01:12:01,679
i.e i don't know what i'm missing and

2182
01:12:07,189 --> 01:12:04,640
what i need to study in order to get it

2183
01:12:08,709 --> 01:12:07,199
this is such yeah this is really tough

2184
01:12:10,870 --> 01:12:08,719
like i've

2185
01:12:12,149 --> 01:12:10,880
had the same problem many times when

2186
01:12:16,070 --> 01:12:12,159
studying myself

2187
01:12:19,590 --> 01:12:16,080
um i think uh

2188
01:12:21,510 --> 01:12:19,600

you yeah like in in some ways

2189
01:12:23,030 --> 01:12:21,520
being a beginner and getting stuck in

2190
01:12:25,590 --> 01:12:23,040
these ways is like

2191
01:12:26,310 --> 01:12:25,600
a real privilege and i know this sounds

2192
01:12:29,350 --> 01:12:26,320
really

2193
01:12:32,870 --> 01:12:29,360
weird to say but um

2194
01:12:34,229 --> 01:12:32,880
like being a beginner and uh recognizing

2195
01:12:36,310 --> 01:12:34,239
what you don't know

2196
01:12:38,229 --> 01:12:36,320
is a state that you can like almost not

2197
01:12:39,590 --> 01:12:38,239
get back into in fact i think that

2198
01:12:41,430 --> 01:12:39,600
one of the reasons i like teaching

2199
01:12:42,790 --> 01:12:41,440
beginners is because then i have to put

2200
01:12:44,950 --> 01:12:42,800
myself in that mindset

2201
01:12:46,310 --> 01:12:44,960
um and like yeah so being able to

2202
01:12:48,470 --> 01:12:46,320
recognize what you don't know is like

2203
01:12:50,709 --> 01:12:48,480
really really valuable and as you go on

2204
01:12:52,470 --> 01:12:50,719
you'll basically like plaster over the

2205
01:12:54,229 --> 01:12:52,480
bits that you don't actually understand

2206
01:12:55,830 --> 01:12:54,239
so definitely like try and recognize

2207
01:12:59,030 --> 01:12:55,840
what you don't understand and

2208
01:12:59,590 --> 01:12:59,040
when you get to that situation um like

2209
01:13:00,870 --> 01:12:59,600
if you can

2210
01:13:02,790 --> 01:13:00,880
like look for sort of you know

2211
01:13:04,790 --> 01:13:02,800
introductory textbooks or some

2212
01:13:06,070 --> 01:13:04,800
some material like that and understand

2213
01:13:08,550 --> 01:13:06,080

it from that that's great

2214
01:13:10,390 --> 01:13:08,560
but if it doesn't solve your problem

2215
01:13:12,870 --> 01:13:10,400
like keep that as a question mark

2216
01:13:14,470 --> 01:13:12,880
like you know keep it as like okay i

2217
01:13:16,070 --> 01:13:14,480
still don't understand this bit

2218
01:13:18,070 --> 01:13:16,080
i'm gonna keep this as a question i

2219
01:13:19,990 --> 01:13:18,080
don't know the answer i'll move on

2220
01:13:21,990 --> 01:13:20,000
like i'll read some other things either

2221
01:13:22,950 --> 01:13:22,000
like you know tangentially or i'll just

2222
01:13:25,990 --> 01:13:22,960
go on in

2223
01:13:27,669 --> 01:13:26,000
whatever i'm reading but um as i

2224
01:13:29,430 --> 01:13:27,679
read like if something answers that

2225
01:13:31,669 --> 01:13:29,440
questions for me i'll come back

2226
01:13:33,110 --> 01:13:31,679
i imagine that as you're doing your phd

2227
01:13:34,709 --> 01:13:33,120
you don't have the time to

2228
01:13:36,149 --> 01:13:34,719
go through the books and solve all the

2229
01:13:36,709 --> 01:13:36,159
problems and i know that solving the

2230
01:13:38,950 --> 01:13:36,719
problems

2231
01:13:39,990 --> 01:13:38,960
helps your understanding greatly but

2232
01:13:42,149 --> 01:13:40,000
because you have to

2233
01:13:43,830 --> 01:13:42,159
cover such a vast amount of research so

2234
01:13:45,990 --> 01:13:43,840
quickly that means that

2235
01:13:47,750 --> 01:13:46,000
you have to have a superficial

2236
01:13:49,669 --> 01:13:47,760
understanding of so much but then you

2237
01:13:51,430 --> 01:13:49,679
have to know what is it okay for me to

2238
01:13:53,990 --> 01:13:51,440

have a superficial understanding of

2239
01:13:55,669 --> 01:13:54,000
so that i can pretty much with a hop

2240
01:13:56,390 --> 01:13:55,679
skip and a jump go to the go to where i

2241
01:13:58,310 --> 01:13:56,400
need to be

2242
01:14:01,189 --> 01:13:58,320
so how do you get how do you balance

2243
01:14:05,110 --> 01:14:01,199
that that tightrope of

2244
01:14:08,310 --> 01:14:05,120
of having tenuous knowledge and

2245
01:14:09,270 --> 01:14:08,320
and strengthen deep knowledge okay yeah

2246
01:14:13,189 --> 01:14:09,280
so

2247
01:14:15,270 --> 01:14:13,199
um during my phd

2248
01:14:16,229 --> 01:14:15,280
the thing i was just saying about the

2249
01:14:18,709 --> 01:14:16,239
benefit of being

2250
01:14:19,669 --> 01:14:18,719
a beginner i tried to really take that

2251
01:14:22,310 --> 01:14:19,679
to heart

2252
01:14:22,950 --> 01:14:22,320
um so when there was a topic i didn't

2253
01:14:25,590 --> 01:14:22,960
know

2254
01:14:26,310 --> 01:14:25,600
i mostly avoided it only like kind of

2255
01:14:28,630 --> 01:14:26,320
knowing

2256
01:14:29,350 --> 01:14:28,640
it superficially from talks that i would

2257
01:14:30,790 --> 01:14:29,360
go to

2258
01:14:32,950 --> 01:14:30,800
just enough to kind of like understand

2259
01:14:34,470 --> 01:14:32,960
what the vague like what the problem was

2260
01:14:35,350 --> 01:14:34,480
in that in that area and like what they

2261
01:14:37,110 --> 01:14:35,360
were trying to solve

2262
01:14:38,870 --> 01:14:37,120
but i would like purposely not really

2263
01:14:41,590 --> 01:14:38,880

jump into it and then

2264
01:14:43,110 --> 01:14:41,600
i would like take various topics like

2265
01:14:45,750 --> 01:14:43,120
new topics that i didn't know

2266
01:14:46,390 --> 01:14:45,760
so so one of them was like um conomera

2267
01:14:47,669 --> 01:14:46,400
correction

2268
01:14:49,590 --> 01:14:47,679
like i'd heard about it in a lot of

2269
01:14:52,550 --> 01:14:49,600
talks and i knew what the problem was

2270
01:14:53,430 --> 01:14:52,560
um but i'd never dived into it so then i

2271
01:14:55,830 --> 01:14:53,440
took some time

2272
01:14:57,510 --> 01:14:55,840
to specifically go and read all the

2273
01:14:59,750 --> 01:14:57,520
introductory material on that

2274
01:15:00,550 --> 01:14:59,760
and like really dive into it because i

2275
01:15:02,790 --> 01:15:00,560
feel like

2276
01:15:03,910 --> 01:15:02,800
there isn't that much benefit of having

2277
01:15:06,950 --> 01:15:03,920
like a

2278
01:15:09,430 --> 01:15:06,960
more than superficial knowledge of of

2279
01:15:11,350 --> 01:15:09,440
certain topics of physics uh whereas

2280
01:15:12,950 --> 01:15:11,360
there's a huge amount of benefit to

2281
01:15:15,430 --> 01:15:12,960
being an absolute beginner

2282
01:15:16,229 --> 01:15:15,440
and like really really diving into a

2283
01:15:19,350 --> 01:15:16,239
topic

2284
01:15:20,470 --> 01:15:19,360
um because like yeah i remember one one

2285
01:15:23,110 --> 01:15:20,480
of the examples

2286
01:15:24,149 --> 01:15:23,120
that comes to mind is like uh i try to

2287
01:15:26,630 --> 01:15:24,159
learn about

2288
01:15:27,590 --> 01:15:26,640

um fermions and bosons in the context of

2289
01:15:29,910 --> 01:15:27,600
computing

2290
01:15:31,669 --> 01:15:29,920
um because there was like a bunch of

2291
01:15:34,310 --> 01:15:31,679
really interesting results about like

2292
01:15:34,950 --> 01:15:34,320
boson sampling and um fermionic linear

2293
01:15:38,149 --> 01:15:34,960
optics

2294
01:15:39,270 --> 01:15:38,159
and i wanted to like like i i knew about

2295
01:15:40,550 --> 01:15:39,280
them but i wanted to go back to the

2296
01:15:42,149 --> 01:15:40,560
basics like i want to understand what is

2297
01:15:43,830 --> 01:15:42,159
a feminine what is that boson

2298
01:15:45,189 --> 01:15:43,840
uh what have they got to do with quantum

2299
01:15:48,390 --> 01:15:45,199
computing and

2300
01:15:49,189 --> 01:15:48,400
so like i really really really went back

2301
01:15:52,310 --> 01:15:49,199
to like

2302
01:15:54,709 --> 01:15:52,320
the absolute basics spent ages on it and

2303
01:15:56,630 --> 01:15:54,719
i remember giving this presentation to

2304
01:15:57,910 --> 01:15:56,640
my group and a few other people who are

2305
01:16:00,310 --> 01:15:57,920
there who were

2306
01:16:02,310 --> 01:16:00,320
basically experts in in the topic of

2307
01:16:03,510 --> 01:16:02,320
like how this relates to computing

2308
01:16:06,390 --> 01:16:03,520
and i was talking about something like

2309
01:16:09,189 --> 01:16:06,400
super basic but even so

2310
01:16:10,149 --> 01:16:09,199
like i felt like there was some parts

2311
01:16:13,189 --> 01:16:10,159
where i knew

2312
01:16:14,709 --> 01:16:13,199
stuff better and like i'd been able to

2313
01:16:15,990 --> 01:16:14,719

make some connections that i think

2314
01:16:20,310 --> 01:16:16,000
weren't as clear

2315
01:16:22,310 --> 01:16:20,320
if you um uh like you know

2316
01:16:23,750 --> 01:16:22,320
like again not not as the like the

2317
01:16:24,550 --> 01:16:23,760
experts obviously anymore but the people

2318
01:16:26,310 --> 01:16:24,560
who were like

2319
01:16:27,750 --> 01:16:26,320
fairly well versed in it i feel like

2320
01:16:30,790 --> 01:16:27,760
there was some points in which i

2321
01:16:32,630 --> 01:16:30,800
like knew more than them just from like

2322
01:16:33,750 --> 01:16:32,640
really diving into like but what does

2323
01:16:35,669 --> 01:16:33,760
this mean and where do i have

2324
01:16:37,030 --> 01:16:35,679
uncertainty and just like keep going

2325
01:16:38,709 --> 01:16:37,040
until you really get some get to the

2326
01:16:39,590 --> 01:16:38,719
bottom of it yeah and when you're doing

2327
01:16:41,510 --> 01:16:39,600
this process of

2328
01:16:42,709 --> 01:16:41,520
of diving in and finding out where your

2329
01:16:44,870 --> 01:16:42,719
holes are

2330
01:16:46,630 --> 01:16:44,880
are you taking a blank sheet of paper

2331
01:16:47,189 --> 01:16:46,640
and writing out almost like the feynman

2332
01:16:48,390 --> 01:16:47,199
method

2333
01:16:49,830 --> 01:16:48,400
i'm sure you've heard where you teach

2334
01:16:50,630 --> 01:16:49,840
yourself or you pretend there's a third

2335
01:16:53,830 --> 01:16:50,640
person

2336
01:16:55,110 --> 01:16:53,840
100 yeah so what i do is i collect like

2337
01:16:56,390 --> 01:16:55,120
so in this case it was papers i

2338
01:16:57,590 --> 01:16:56,400

collected a whole bunch of papers but

2339
01:17:00,709 --> 01:16:57,600
you know it could be books

2340
01:17:03,750 --> 01:17:00,719
um i never read through a book uh

2341
01:17:04,950 --> 01:17:03,760
like front to back um like i never sort

2342
01:17:06,310 --> 01:17:04,960
of

2343
01:17:08,790 --> 01:17:06,320
want to get something from just one

2344
01:17:11,990 --> 01:17:08,800
source instead i'll uh

2345
01:17:13,270 --> 01:17:12,000
read one source kind of get like

2346
01:17:15,990 --> 01:17:13,280
something from it

2347
01:17:17,430 --> 01:17:16,000
um like maybe i'll read the introduction

2348
01:17:18,790 --> 01:17:17,440
and then i'll kind of write down what i

2349
01:17:20,310 --> 01:17:18,800
think i know and then i'll go into

2350
01:17:21,669 --> 01:17:20,320
another source and see if that kind of

2351
01:17:23,030 --> 01:17:21,679
like gels well

2352
01:17:24,709 --> 01:17:23,040
um they might be using different

2353
01:17:25,510 --> 01:17:24,719
location they might be looking at it

2354
01:17:28,790 --> 01:17:25,520
from slightly

2355
01:17:31,590 --> 01:17:28,800
different perspective sorry your

2356
01:17:32,790 --> 01:17:31,600
your fans your photographer fans i know

2357
01:17:37,030 --> 01:17:32,800
um

2358
01:17:39,990 --> 01:17:37,040
uh yeah okay so yeah i'll never read

2359
01:17:41,110 --> 01:17:40,000
i'll never read anything um front back

2360
01:17:43,110 --> 01:17:41,120
instead i'll

2361
01:17:44,310 --> 01:17:43,120
read a lot of different things with

2362
01:17:47,350 --> 01:17:44,320
different perspectives

2363
01:17:49,430 --> 01:17:47,360

and as i go i'll like be keeping a um

2364
01:17:50,709 --> 01:17:49,440
like a whole lot of notes where i'm

2365
01:17:52,550 --> 01:17:50,719
basically trying to explain it to myself

2366
01:17:53,910 --> 01:17:52,560
like i'll be like a fermion is

2367
01:17:55,590 --> 01:17:53,920
and then i'll write one definition and

2368
01:17:57,189 --> 01:17:55,600
then in the other source it'll have an

2369
01:17:58,070 --> 01:17:57,199
entirely different but equivalent

2370
01:18:00,709 --> 01:17:58,080
definition

2371
01:18:01,910 --> 01:18:00,719
and i'll like like i'll read that they

2372
01:18:03,110 --> 01:18:01,920
don't reference each other they don't

2373
01:18:03,750 --> 01:18:03,120
talk about how they're related to each

2374
01:18:05,189 --> 01:18:03,760
other so

2375
01:18:07,189 --> 01:18:05,199
then i have to like you know in my

2376
01:18:08,390 --> 01:18:07,199
writing like figure out how is this

2377
01:18:10,390 --> 01:18:08,400
thing that they said

2378
01:18:11,430 --> 01:18:10,400
the same as what they said just in a

2379
01:18:13,110 --> 01:18:11,440
different language and so

2380
01:18:14,630 --> 01:18:13,120
like the translation process is really

2381
01:18:15,350 --> 01:18:14,640
interesting and like i'll learn a lot

2382
01:18:18,870 --> 01:18:15,360
from that

2383
01:18:22,630 --> 01:18:18,880
and then like yeah just just like um

2384
01:18:24,790 --> 01:18:22,640
kind of like keeping many sources uh

2385
01:18:26,709 --> 01:18:24,800
in mind as i'm writing these notes that

2386
01:18:29,430 --> 01:18:26,719
are like how would i explain this to

2387
01:18:29,750 --> 01:18:29,440
someone else is very useful do you find

2388
01:18:31,590 --> 01:18:29,760

that

2389
01:18:33,590 --> 01:18:31,600
books are most helpful or do you watch

2390
01:18:39,030 --> 01:18:33,600
lectures online

2391
01:18:40,310 --> 01:18:39,040
i think it's mostly an attention thing i

2392
01:18:41,030 --> 01:18:40,320
actually kind of find it hard to watch

2393
01:18:44,709 --> 01:18:41,040
video

2394
01:18:47,990 --> 01:18:44,719
um and a lot easier to read uh but

2395
01:18:48,950 --> 01:18:48,000
i what i feel what i find lectures

2396
01:18:52,310 --> 01:18:48,960
better for than

2397
01:18:54,950 --> 01:18:52,320
um than textbooks is to get a

2398
01:18:56,229 --> 01:18:54,960
opinion from the person like opinions

2399
01:18:58,470 --> 01:18:56,239
during talks are so

2400
01:18:59,590 --> 01:18:58,480
useful you get the sort of sense of like

2401
01:19:01,990 --> 01:18:59,600
what this person

2402
01:19:02,870 --> 01:19:02,000
thinks is the interesting parts of this

2403
01:19:04,390 --> 01:19:02,880
field like

2404
01:19:06,470 --> 01:19:04,400
what are the real mysteries according to

2405
01:19:07,510 --> 01:19:06,480
this person whereas i feel like books

2406
01:19:09,110 --> 01:19:07,520
are you know a lot

2407
01:19:10,709 --> 01:19:09,120
a lot more long-winded in their

2408
01:19:13,030 --> 01:19:10,719
introduction so it's harder to get that

2409
01:19:14,390 --> 01:19:13,040
feel of like the person's opinion um but

2410
01:19:15,430 --> 01:19:14,400
then i think books are better for like

2411
01:19:17,189 --> 01:19:15,440
diving in

2412
01:19:18,870 --> 01:19:17,199
i'm gonna just read this one verbatim so

2413
01:19:20,870 --> 01:19:18,880

how is it specifically that

2414
01:19:22,630 --> 01:19:20,880
the mathematical notion of an observable

2415
01:19:23,350 --> 01:19:22,640
as an operator corresponds to a physical

2416
01:19:24,310 --> 01:19:23,360
device

2417
01:19:25,990 --> 01:19:24,320
so what you're doing is you're

2418
01:19:26,390 --> 01:19:26,000
manipulating symbols in the abstract and

2419
01:19:27,990 --> 01:19:26,400
it's not

2420
01:19:29,830 --> 01:19:28,000
clear how it corresponds to what's going

2421
01:19:31,189 --> 01:19:29,840
on experimentally

2422
01:19:33,350 --> 01:19:31,199
now that's something that when you're in

2423
01:19:34,709 --> 01:19:33,360
second third even even for like

2424
01:19:36,709 --> 01:19:34,719
you don't get unless you take

2425
01:19:37,990 --> 01:19:36,719
experimental physics you don't get an

2426
01:19:40,550 --> 01:19:38,000
understanding of so what the heck

2427
01:19:42,070 --> 01:19:40,560
doesn't mean that the operator isn't

2428
01:19:44,070 --> 01:19:42,080
position operator's x and or the

2429
01:19:45,750 --> 01:19:44,080
derivative if it's momentum and so on

2430
01:19:48,149 --> 01:19:45,760
how does that correspond to what's going

2431
01:19:51,110 --> 01:19:48,159
on when you observe in the lab

2432
01:19:52,709 --> 01:19:51,120
yeah yeah these are great questions um

2433
01:19:55,590 --> 01:19:52,719
no this is a great question

2434
01:19:56,630 --> 01:19:55,600
and it confused me for a long time um

2435
01:19:59,669 --> 01:19:56,640
and

2436
01:20:01,910 --> 01:19:59,679
i only kind of realized much later that

2437
01:20:03,430 --> 01:20:01,920
that there is no good science to the way

2438
01:20:04,790 --> 01:20:03,440

that we make the operators in fact

2439
01:20:08,149 --> 01:20:04,800
there's a lot of art to it

2440
01:20:09,750 --> 01:20:08,159
um what we usually do is we so like

2441
01:20:13,030 --> 01:20:09,760
again to make an operator

2442
01:20:13,750 --> 01:20:13,040
for a um measurement you've got to

2443
01:20:16,950 --> 01:20:13,760
consider

2444
01:20:17,510 --> 01:20:16,960
what uh what are you like physically

2445
01:20:19,030 --> 01:20:17,520
doing

2446
01:20:21,030 --> 01:20:19,040
so you know in the stone girl like

2447
01:20:22,950 --> 01:20:21,040
experiment um we're

2448
01:20:25,030 --> 01:20:22,960
actually physically applying a magnetic

2449
01:20:27,030 --> 01:20:25,040
field ultimately that's what we're doing

2450
01:20:28,629 --> 01:20:27,040
um and whatever measurement you're doing

2451
01:20:29,910 --> 01:20:28,639
you're ultimately physically doing

2452
01:20:32,629 --> 01:20:29,920
something

2453
01:20:33,590 --> 01:20:32,639
and you've got to write down like what

2454
01:20:35,189 --> 01:20:33,600
are the

2455
01:20:36,790 --> 01:20:35,199
so the hamiltonian which is essentially

2456
01:20:40,310 --> 01:20:36,800
like what are the forces

2457
01:20:42,149 --> 01:20:40,320
that you're you're you're um uh creating

2458
01:20:43,750 --> 01:20:42,159
in this measurement device and then you

2459
01:20:46,229 --> 01:20:43,760
write that down classically

2460
01:20:47,270 --> 01:20:46,239
and then you just do this sort of like

2461
01:20:50,070 --> 01:20:47,280
cheap trick

2462
01:20:50,870 --> 01:20:50,080
of uh of quantization where you take and

2463
01:20:52,870 --> 01:20:50,880

like the

2464
01:20:54,229 --> 01:20:52,880
the quant like so the classical version

2465
01:20:55,990 --> 01:20:54,239
of um a certain

2466
01:20:57,510 --> 01:20:56,000
object like the magnetic field and then

2467
01:20:58,470 --> 01:20:57,520
you make it a quantum operator and then

2468
01:21:01,590 --> 01:20:58,480
you're like okay

2469
01:21:03,590 --> 01:21:01,600
just do that and there we go that's my

2470
01:21:06,709 --> 01:21:03,600
quantum operator for this this

2471
01:21:08,390 --> 01:21:06,719
measurement whatever i'm doing so it's

2472
01:21:10,229 --> 01:21:08,400
not that satisfying

2473
01:21:13,830 --> 01:21:10,239
what's the operator for determining the

2474
01:21:17,030 --> 01:21:13,840
charge of an electron or its mass

2475
01:21:20,470 --> 01:21:17,040
operators correspond to observables

2476
01:21:21,910 --> 01:21:20,480
yeah so this one is not an observable um

2477
01:21:23,910 --> 01:21:21,920
the reason is because you couldn't

2478
01:21:28,870 --> 01:21:23,920
observe a electron to

2479
01:21:30,629 --> 01:21:28,880
be in a different um

2480
01:21:32,310 --> 01:21:30,639
have a different mass or charge on the

2481
01:21:35,350 --> 01:21:32,320
other hand now that i say that

2482
01:21:37,669 --> 01:21:35,360
um you could come up with a uh

2483
01:21:39,830 --> 01:21:37,679
operator that measures the charge of a

2484
01:21:43,270 --> 01:21:39,840
particle just a random particle

2485
01:21:45,430 --> 01:21:43,280
um i have no clue

2486
01:21:47,189 --> 01:21:45,440
what that operator would look like i

2487
01:21:48,790 --> 01:21:47,199
think you'd have to ask someone who

2488
01:21:50,870 --> 01:21:48,800

actually does experiments how do

2489
01:21:52,790 --> 01:21:50,880
operators look in terms of experiments

2490
01:21:55,750 --> 01:21:52,800
now can one design an experiment and

2491
01:21:57,350 --> 01:21:55,760
work backward to find the operator

2492
01:21:59,510 --> 01:21:57,360
yeah that's what you do you've got to

2493
01:22:01,430 --> 01:21:59,520
look at the experiment look at what

2494
01:22:03,510 --> 01:22:01,440
forces you're applying and then

2495
01:22:04,950 --> 01:22:03,520
write those out do quantization that

2496
01:22:07,669 --> 01:22:04,960
will get you that braid up pretty much

2497
01:22:09,030 --> 01:22:07,679
three more questions ryan conlin says

2498
01:22:10,550 --> 01:22:09,040
when you study how much time do you

2499
01:22:12,229 --> 01:22:10,560
spend thinking about your own particular

2500
01:22:13,750 --> 01:22:12,239
background knowledge and skills that is

2501
01:22:15,590 --> 01:22:13,760
relating it to previous knowledge

2502
01:22:17,030 --> 01:22:15,600
versus how much time do you spend do you

2503
01:22:20,070 --> 01:22:17,040
spend thinking about it

2504
01:22:20,629 --> 01:22:20,080
without relating oh super interesting

2505
01:22:22,070 --> 01:22:20,639
question

2506
01:22:24,149 --> 01:22:22,080
actually i find it's really really

2507
01:22:24,629 --> 01:22:24,159
useful to relate it to your background

2508
01:22:26,870 --> 01:22:24,639
knowledge

2509
01:22:28,390 --> 01:22:26,880
at least for me during the phd um i

2510
01:22:29,350 --> 01:22:28,400
think maybe that's partly a quirk of the

2511
01:22:31,830 --> 01:22:29,360
phd where

2512
01:22:33,510 --> 01:22:31,840
like you you're studying but you also

2513
01:22:34,470 --> 01:22:33,520

want to be able to add something new to

2514
01:22:38,790 --> 01:22:34,480
the knowledge

2515
01:22:40,709 --> 01:22:38,800
from the angle of like

2516
01:22:42,870 --> 01:22:40,719
how can i relate this to those the

2517
01:22:45,110 --> 01:22:42,880
particular quirky things that i know

2518
01:22:46,390 --> 01:22:45,120
um is like a good way to sort of start

2519
01:22:48,470 --> 01:22:46,400
making new things

2520
01:22:50,229 --> 01:22:48,480
um but just generally i think it's like

2521
01:22:53,110 --> 01:22:50,239
really a good strategy

2522
01:22:54,950 --> 01:22:53,120
when you're studying to um you know

2523
01:22:56,470 --> 01:22:54,960
you've learned some new concept

2524
01:22:58,070 --> 01:22:56,480
let's say you've just learned what a

2525
01:23:01,510 --> 01:22:58,080
group is and

2526
01:23:03,590 --> 01:23:01,520
in abstract algebra and uh if you can

2527
01:23:05,910 --> 01:23:03,600
find like some examples that are related

2528
01:23:10,149 --> 01:23:05,920
to things you've learned so for example

2529
01:23:11,510 --> 01:23:10,159
if you related that to the symmetries in

2530
01:23:13,430 --> 01:23:11,520
in relativity because you've just

2531
01:23:14,390 --> 01:23:13,440
learned about relativity that will make

2532
01:23:17,270 --> 01:23:14,400
it

2533
01:23:18,070 --> 01:23:17,280
way more concrete and way easier for you

2534
01:23:19,430 --> 01:23:18,080
to understand

2535
01:23:20,709 --> 01:23:19,440
so i think that is actually a really

2536
01:23:22,229 --> 01:23:20,719
important thing that's like super

2537
01:23:24,390 --> 01:23:22,239
neglected by students so

2538
01:23:26,070 --> 01:23:24,400

yeah like great question at the same

2539
01:23:27,350 --> 01:23:26,080
time i can see how sometimes

2540
01:23:29,189 --> 01:23:27,360
trying to relate it back can be

2541
01:23:30,629 --> 01:23:29,199
counterproductive for example in

2542
01:23:32,709 --> 01:23:30,639
quantum mechanics and sages forget what

2543
01:23:35,030 --> 01:23:32,719
you know that's gonna hold you back

2544
01:23:36,790 --> 01:23:35,040
so at what point do you abandon versus

2545
01:23:39,910 --> 01:23:36,800
relate

2546
01:23:40,790 --> 01:23:39,920
um i think that's uh the thing on

2547
01:23:43,990 --> 01:23:40,800
quantum mechanics

2548
01:23:46,470 --> 01:23:44,000
i think that's not true like uh

2549
01:23:47,430 --> 01:23:46,480
if you're learning quantum mechanics

2550
01:23:48,550 --> 01:23:47,440
mathematically

2551
01:23:51,270 --> 01:23:48,560
like you're trying to understand the

2552
01:23:54,470 --> 01:23:51,280
math it's extremely important

2553
01:23:56,550 --> 01:23:54,480
to relate what you are seeing there to

2554
01:23:58,310 --> 01:23:56,560
what you know about classical mechanics

2555
01:24:00,229 --> 01:23:58,320
um like we were just talking about

2556
01:24:01,750 --> 01:24:00,239
how do you find operators uh well you

2557
01:24:02,390 --> 01:24:01,760
got to know hamiltonian mechanics quite

2558
01:24:04,149 --> 01:24:02,400
well

2559
01:24:05,590 --> 01:24:04,159
that and that's from classical um the

2560
01:24:07,590 --> 01:24:05,600
classical side so

2561
01:24:09,669 --> 01:24:07,600
okay for for your intuitions yes you

2562
01:24:12,950 --> 01:24:09,679
have to let go of a lot you don't know

2563
01:24:14,870 --> 01:24:12,960

but for uh like the the sort of

2564
01:24:17,110 --> 01:24:14,880
machinery often things are building on

2565
01:24:19,110 --> 01:24:17,120
each other michael mcguffin says

2566
01:24:20,790 --> 01:24:19,120
what has she been reading recently and

2567
01:24:22,229 --> 01:24:20,800
then also part two is like if her

2568
01:24:24,950 --> 01:24:22,239
financial incomes were met

2569
01:24:26,870 --> 01:24:24,960
say she's given 10 million dollars what

2570
01:24:29,910 --> 01:24:26,880
would you spend your time doing

2571
01:24:31,350 --> 01:24:29,920
uh books and then time okay cool um

2572
01:24:34,390 --> 01:24:31,360
thank you for those questions uh

2573
01:24:35,510 --> 01:24:34,400
so um what am i reading i'm reading a

2574
01:24:38,870 --> 01:24:35,520
few things um

2575
01:24:41,990 --> 01:24:38,880
i recently finished a book by uh

2576
01:24:45,430 --> 01:24:42,000
the um the

2577
01:24:48,709 --> 01:24:45,440
director of pixar um creativity inc and

2578
01:24:50,229 --> 01:24:48,719
uh it was about how to create like a

2579
01:24:53,430 --> 01:24:50,239
creative product

2580
01:24:55,910 --> 01:24:53,440
in um in a corporation which like

2581
01:24:57,110 --> 01:24:55,920
often kind of stifle creativity uh so

2582
01:24:59,270 --> 01:24:57,120
how do you keep that alive

2583
01:25:00,550 --> 01:24:59,280
that was super interesting um on a sort

2584
01:25:03,430 --> 01:25:00,560
of similar vein

2585
01:25:04,550 --> 01:25:03,440
uh a friend of mine recommended um the

2586
01:25:07,189 --> 01:25:04,560
idea factory

2587
01:25:08,870 --> 01:25:07,199
and that was about bill labs so bell

2588
01:25:10,709 --> 01:25:08,880

labs was like quite famous for

2589
01:25:13,110 --> 01:25:10,719
having invented a whole bunch of like

2590
01:25:16,550 --> 01:25:13,120
really ahead of their times um

2591
01:25:19,750 --> 01:25:16,560
devices and it was a similar deal to

2592
01:25:20,070 --> 01:25:19,760
pixar in a way where like they managed

2593
01:25:21,110 --> 01:25:20,080
to

2594
01:25:22,629 --> 01:25:21,120
come up with like a corporate

2595
01:25:24,229 --> 01:25:22,639
environment because it was a corporation

2596
01:25:26,070 --> 01:25:24,239
it wasn't a university or anything

2597
01:25:28,390 --> 01:25:26,080
a corporate environment that somehow

2598
01:25:31,590 --> 01:25:28,400
could still stimulate um creativity

2599
01:25:33,189 --> 01:25:31,600
and in this case in science um so yeah i

2600
01:25:34,310 --> 01:25:33,199
think that's like a really interesting

2601
01:25:35,910 --> 01:25:34,320
topic to me like something that i'm

2602
01:25:36,470 --> 01:25:35,920
really interested in about like it's

2603
01:25:38,790 --> 01:25:36,480
just

2604
01:25:39,990 --> 01:25:38,800
innovation in general but how do you um

2605
01:25:42,790 --> 01:25:40,000
how do you foster

2606
01:25:43,750 --> 01:25:42,800
it uh and then like i guess if someone

2607
01:25:46,950 --> 01:25:43,760
was to give me

2608
01:25:49,590 --> 01:25:46,960
uh 10 million dollars um there

2609
01:25:50,470 --> 01:25:49,600
are a bunch of product projects that i'm

2610
01:25:57,990 --> 01:25:50,480
um

2611
01:25:59,510 --> 01:25:58,000
very keen on like what

2612
01:26:01,110 --> 01:25:59,520
on understanding what the future of

2613
01:26:05,189 --> 01:26:01,120

education is going to be

2614
01:26:06,550 --> 01:26:05,199
um i think that there needs to be like

2615
01:26:08,229 --> 01:26:06,560
even more research i mean there's like

2616
01:26:09,990 --> 01:26:08,239
lots of great research at the moment but

2617
01:26:13,110 --> 01:26:10,000
even more research and even more focus

2618
01:26:16,629 --> 01:26:13,120
put into like how can we

2619
01:26:18,629 --> 01:26:16,639
really change the way that humans learn

2620
01:26:20,070 --> 01:26:18,639
um so that they are really like

2621
01:26:22,629 --> 01:26:20,080
achieving their maximum

2622
01:26:23,590 --> 01:26:22,639
human potential i think that schools are

2623
01:26:25,430 --> 01:26:23,600
really wonderful

2624
01:26:27,189 --> 01:26:25,440
um and i'm not one of those people who

2625
01:26:28,149 --> 01:26:27,199
is like advocating for like just ripping

2626
01:26:30,149 --> 01:26:28,159
it all down

2627
01:26:31,669 --> 01:26:30,159
um but i think that they're inefficient

2628
01:26:33,430 --> 01:26:31,679
in certain ways like they just have to

2629
01:26:35,189 --> 01:26:33,440
be because of how they were sort of

2630
01:26:36,790 --> 01:26:35,199
made and because of all the various

2631
01:26:39,590 --> 01:26:36,800
pressures that are on schools

2632
01:26:41,430 --> 01:26:39,600
um so i would love to understand like if

2633
01:26:43,270 --> 01:26:41,440
we were going to make it from scratch

2634
01:26:44,629 --> 01:26:43,280
um what what would we keep but what

2635
01:26:46,950 --> 01:26:44,639
would we change

2636
01:26:48,149 --> 01:26:46,960
um have you heard of forgetting this

2637
01:26:49,990 --> 01:26:48,159
guy's name starts with

2638
01:26:52,149 --> 01:26:50,000

peter of the evolutionary institute

2639
01:26:53,830 --> 01:26:52,159
peter peter gray that's right right

2640
01:26:55,430 --> 01:26:53,840
okay so anyway have you heard of peter

2641
01:26:58,709 --> 01:26:55,440
gray's unschooling

2642
01:27:00,310 --> 01:26:58,719
i have but i'm blanking can you

2643
01:27:01,669 --> 01:27:00,320
essentially so it's not like tear down

2644
01:27:02,070 --> 01:27:01,679
the schools but what i'm saying is that

2645
01:27:04,070 --> 01:27:02,080
the

2646
01:27:05,590 --> 01:27:04,080
that kid is taking an evolutionary

2647
01:27:07,830 --> 01:27:05,600
psychological approach to

2648
01:27:08,629 --> 01:27:07,840
learning that kids learn best in mixed

2649
01:27:09,910 --> 01:27:08,639
age groups

2650
01:27:11,590 --> 01:27:09,920
and one of the reasons is that there's

2651
01:27:13,189 --> 01:27:11,600
no bullying because you're eight you're

2652
01:27:13,910 --> 01:27:13,199
not going to compete with a 16 year old

2653
01:27:15,669 --> 01:27:13,920
and you're

2654
01:27:17,030 --> 01:27:15,679
not vice versa and then the 16 year old

2655
01:27:17,350 --> 01:27:17,040
is not going to compete with a 24 year

2656
01:27:20,390 --> 01:27:17,360
old

2657
01:27:21,510 --> 01:27:20,400
and he takes this from observing tribes

2658
01:27:23,669 --> 01:27:21,520
that don't have schools

2659
01:27:25,110 --> 01:27:23,679
and the kids just learn automatically

2660
01:27:26,229 --> 01:27:25,120
because play is so important and when

2661
01:27:27,590 --> 01:27:26,239
they're playing they just

2662
01:27:31,189 --> 01:27:27,600
they happen to learn and it's

2663
01:27:32,629 --> 01:27:31,199

spontaneous and you allow the kid to

2664
01:27:34,790 --> 01:27:32,639
follow their own interests and you

2665
01:27:35,350 --> 01:27:34,800
encourage it yeah instead of imposing

2666
01:27:38,709 --> 01:27:35,360
one

2667
01:27:42,470 --> 01:27:38,719
yeah so i think this this whole movement

2668
01:27:45,510 --> 01:27:42,480
um of inquiry-based learning is

2669
01:27:47,030 --> 01:27:45,520
very very interesting but also um i

2670
01:27:47,750 --> 01:27:47,040
think we have to be a little careful

2671
01:27:50,870 --> 01:27:47,760
with it

2672
01:27:53,990 --> 01:27:50,880
uh i i'm i'm definitely

2673
01:27:54,790 --> 01:27:54,000
for um kids being able to like figure

2674
01:27:56,229 --> 01:27:54,800
out what they like

2675
01:27:58,070 --> 01:27:56,239
themselves and just like go down that

2676
01:27:58,870 --> 01:27:58,080
rabbit hole like that's you know a big

2677
01:28:02,229 --> 01:27:58,880
part of like

2678
01:28:05,270 --> 01:28:02,239
my education was that um but

2679
01:28:08,310 --> 01:28:05,280
i think on the other hand like letting

2680
01:28:10,310 --> 01:28:08,320
kids have completely free reign

2681
01:28:11,750 --> 01:28:10,320
um i mean there has been some research

2682
01:28:15,110 --> 01:28:11,760
about this like

2683
01:28:15,669 --> 01:28:15,120
it just doesn't work as well if you have

2684
01:28:19,189 --> 01:28:15,679
like no

2685
01:28:21,590 --> 01:28:19,199
sort of um either discipline or uh

2686
01:28:23,110 --> 01:28:21,600
like guidance about where to go because

2687
01:28:25,510 --> 01:28:23,120
you know you're not going to expect a

2688
01:28:26,470 --> 01:28:25,520

child playing on their own to rediscover

2689
01:28:29,110 --> 01:28:26,480
mutants laws

2690
01:28:30,709 --> 01:28:29,120
like that's just not possible um but on

2691
01:28:33,270 --> 01:28:30,719
the other hand if you had like a

2692
01:28:34,310 --> 01:28:33,280
a supervising figure who was there to

2693
01:28:37,110 --> 01:28:34,320
like encourage

2694
01:28:37,750 --> 01:28:37,120
uh the you know the interests as they as

2695
01:28:39,430 --> 01:28:37,760
they develop

2696
01:28:40,950 --> 01:28:39,440
and sees that you know this person's

2697
01:28:42,149 --> 01:28:40,960
interested in how things work and it's

2698
01:28:43,990 --> 01:28:42,159
like oh have you read

2699
01:28:45,910 --> 01:28:44,000
these interesting books like that could

2700
01:28:49,270 --> 01:28:45,920
potentially work i think that

2701
01:28:50,070 --> 01:28:49,280
um to make that work uh we need to put

2702
01:28:52,950 --> 01:28:50,080
like a lot

2703
01:28:54,709 --> 01:28:52,960
more thought into just how like we can

2704
01:28:58,070 --> 01:28:54,719
guide that experience without

2705
01:28:59,270 --> 01:28:58,080
um you know fully determining what the

2706
01:29:01,750 --> 01:28:59,280
kid is going to do

2707
01:29:03,270 --> 01:29:01,760
ourselves beer's attitude says it would

2708
01:29:04,390 --> 01:29:03,280
be cool to know her opinion on donald

2709
01:29:06,470 --> 01:29:04,400
hoffman's work

2710
01:29:07,990 --> 01:29:06,480
what is the most fundamental level in

2711
01:29:10,149 --> 01:29:08,000
her opinion i don't know what that

2712
01:29:11,510 --> 01:29:10,159
last sentence means what does she make

2713
01:29:12,870 --> 01:29:11,520

of consciousness so i don't know if

2714
01:29:14,229 --> 01:29:12,880
you've heard of donald hoffman and his

2715
01:29:15,590 --> 01:29:14,239
theories on consciousness but this

2716
01:29:18,070 --> 01:29:15,600
person would like to know

2717
01:29:19,110 --> 01:29:18,080
yeah okay oh that's in because that's

2718
01:29:21,990 --> 01:29:19,120
disappointing because the person's like

2719
01:29:27,910 --> 01:29:25,510
sorry um wait who is this donald hoffman

2720
01:29:33,590 --> 01:29:30,950
is a cognitive scientist

2721
01:29:34,390 --> 01:29:33,600
he's a cognitive scientist who says that

2722
01:29:37,910 --> 01:29:34,400
what we can do

2723
01:29:39,669 --> 01:29:37,920
is model conscious agents with something

2724
01:29:42,310 --> 01:29:39,679
like a

2725
01:29:43,830 --> 01:29:42,320
markov kernel where you just have let's

2726
01:29:45,750 --> 01:29:43,840
say the set of experiences

2727
01:29:47,030 --> 01:29:45,760
you don't even give them names like love

2728
01:29:48,390 --> 01:29:47,040
or what you just give them whatever you

2729
01:29:49,270 --> 01:29:48,400
like and then give them some structure

2730
01:29:52,229 --> 01:29:49,280
like

2731
01:29:53,750 --> 01:29:52,239
well you can read his papers and then he

2732
01:29:55,110 --> 01:29:53,760
says that what you can do from there is

2733
01:29:56,550 --> 01:29:55,120
develop the laws of

2734
01:29:58,149 --> 01:29:56,560
quantum mechanics now i'm skeptical of

2735
01:29:58,790 --> 01:29:58,159
that and i read his research but it's

2736
01:30:00,310 --> 01:29:58,800
something like

2737
01:30:02,390 --> 01:30:00,320
it's so general you've heard of these

2738
01:30:03,510 --> 01:30:02,400

claims like yeah i can derive quantum

2739
01:30:05,430 --> 01:30:03,520
mechanics but i derived it from

2740
01:30:06,790 --> 01:30:05,440
something so general that it

2741
01:30:08,470 --> 01:30:06,800
well i'd be surprised if you couldn't

2742
01:30:09,669 --> 01:30:08,480
derive quantum mechanics from that

2743
01:30:11,750 --> 01:30:09,679
fair enough but either way donald

2744
01:30:14,470 --> 01:30:11,760
hoffman is a bright bright yeah

2745
01:30:15,669 --> 01:30:14,480
a bright bright individual uh yeah sorry

2746
01:30:17,350 --> 01:30:15,679
i couldn't answer that question

2747
01:30:18,950 --> 01:30:17,360
that's right and i also realized that i

2748
01:30:19,750 --> 01:30:18,960
have a question on quantum the quantum

2749
01:30:21,910 --> 01:30:19,760
parallel thesis

2750
01:30:24,470 --> 01:30:21,920
i wanted to know i imagine that you

2751
01:30:26,149 --> 01:30:24,480
think it's true given that you

2752
01:30:28,310 --> 01:30:26,159
adopt the many worlds interpretation but

2753
01:30:30,390 --> 01:30:28,320
i was wondering what are some ways that

2754
01:30:31,990 --> 01:30:30,400
the quantum parallel thesis could be

2755
01:30:34,709 --> 01:30:32,000
true without

2756
01:30:36,149 --> 01:30:34,719
the many world's interpretation um what

2757
01:30:37,910 --> 01:30:36,159
do you mean by the quantum parallel

2758
01:30:41,510 --> 01:30:37,920
thesis quantum parallel

2759
01:30:42,870 --> 01:30:41,520
thesis is that the

2760
01:30:44,550 --> 01:30:42,880
it's something like that the computation

2761
01:30:49,430 --> 01:30:44,560
is being performed

2762
01:30:50,390 --> 01:30:49,440
simultaneously on the superpositions

2763
01:30:52,790 --> 01:30:50,400

okay have you heard of the quantum

2764
01:30:54,070 --> 01:30:52,800
parallel these uh yeah like deutsches

2765
01:30:56,149 --> 01:30:54,080
um yes yeah that's correct that's

2766
01:30:59,430 --> 01:30:56,159
correct that's correct yeah um

2767
01:31:03,350 --> 01:30:59,440
yeah uh i think what i don't

2768
01:31:05,590 --> 01:31:03,360
understand about that idea um

2769
01:31:06,950 --> 01:31:05,600
and what makes me skeptical of it is

2770
01:31:09,669 --> 01:31:06,960
that

2771
01:31:10,870 --> 01:31:09,679
it's not clear how computation from

2772
01:31:13,990 --> 01:31:10,880
distinct branches

2773
01:31:15,669 --> 01:31:14,000
of the superposition can be

2774
01:31:17,030 --> 01:31:15,679
be transferred like how that information

2775
01:31:20,149 --> 01:31:17,040
can be transferred

2776
01:31:22,070 --> 01:31:20,159
um so like let's say you do uh like

2777
01:31:23,990 --> 01:31:22,080
you you want to do a huge number of

2778
01:31:25,110 --> 01:31:24,000
computations so you split into many

2779
01:31:27,270 --> 01:31:25,120
different worlds

2780
01:31:29,270 --> 01:31:27,280
and then you um do one of the

2781
01:31:30,790 --> 01:31:29,280
computations in each one of these words

2782
01:31:32,310 --> 01:31:30,800
then you have the result in each of

2783
01:31:33,350 --> 01:31:32,320
these worlds so let's say you're looking

2784
01:31:35,750 --> 01:31:33,360
for a one

2785
01:31:37,669 --> 01:31:35,760
and world number three has found a one

2786
01:31:38,790 --> 01:31:37,679
and it needs to communicate now to all

2787
01:31:42,629 --> 01:31:38,800
the rest of them

2788
01:31:46,709 --> 01:31:44,550

like the way that that communication is

2789
01:31:50,709 --> 01:31:46,719
done inside of quantum computing

2790
01:31:53,750 --> 01:31:50,719
um it

2791
01:31:54,550 --> 01:31:53,760
it depends on those superpositions not

2792
01:31:56,950 --> 01:31:54,560
being

2793
01:31:57,750 --> 01:31:56,960
um distinct worlds in the sort of many

2794
01:32:02,470 --> 01:31:57,760
world sense

2795
01:32:04,629 --> 01:32:02,480
super like any superposition is not a

2796
01:32:05,830 --> 01:32:04,639
different world it only becomes like a

2797
01:32:07,590 --> 01:32:05,840
different world once

2798
01:32:09,750 --> 01:32:07,600
it interacts with other things and

2799
01:32:12,470 --> 01:32:09,760
therefore can't interact with itself

2800
01:32:12,950 --> 01:32:12,480
anymore like so if you have two if you

2801
01:32:16,870 --> 01:32:12,960
have a

2802
01:32:17,350 --> 01:32:16,880
things um those sort of worlds can kind

2803
01:32:19,110 --> 01:32:17,360
of like

2804
01:32:21,030 --> 01:32:19,120
split in a sense and they become

2805
01:32:22,709 --> 01:32:21,040
distinct from each other but if they

2806
01:32:25,430 --> 01:32:22,719
don't interact with anything else

2807
01:32:26,950 --> 01:32:25,440
they can kind of recon recommend so one

2808
01:32:28,550 --> 01:32:26,960
way that this could happen is like if

2809
01:32:31,990 --> 01:32:28,560
you have a spin particle

2810
01:32:34,229 --> 01:32:32,000
um you start it in spin up and then

2811
01:32:36,149 --> 01:32:34,239
you um change the magnetic field so it

2812
01:32:37,750 --> 01:32:36,159
becomes spin up spin down

2813
01:32:39,350 --> 01:32:37,760

and then you change the magnetic field

2814
01:32:41,590 --> 01:32:39,360
back and so it spin up again

2815
01:32:43,350 --> 01:32:41,600
um like in a way you've deleted the

2816
01:32:44,629 --> 01:32:43,360
superposition but this is like

2817
01:32:46,470 --> 01:32:44,639
this is totally fine and this is what

2818
01:32:47,910 --> 01:32:46,480
happens in quantum computing but

2819
01:32:49,669 --> 01:32:47,920
in many worlds you wouldn't say that

2820
01:32:50,629 --> 01:32:49,679
that was like two worlds and they

2821
01:32:52,070 --> 01:32:50,639
recombined

2822
01:32:56,470 --> 01:32:52,080
for many worlds the worlds can't

2823
01:32:59,990 --> 01:32:56,480
recombine for them to be like worlds

2824
01:33:01,669 --> 01:33:00,000
so yeah anyway basically all right

2825
01:33:03,189 --> 01:33:01,679
i i have a quote here about the many

2826
01:33:06,070 --> 01:33:03,199
worlds interpretation this is hardly the

2827
01:33:07,750 --> 01:33:06,080
most economical view

2828
01:33:09,350 --> 01:33:07,760
the most economical of viewpoints but my

2829
01:33:10,950 --> 01:33:09,360
own personal objections don't spring

2830
01:33:12,629 --> 01:33:10,960
from its lack of economy and

2831
01:33:14,310 --> 01:33:12,639
in particular i don't see why a

2832
01:33:16,310 --> 01:33:14,320
conscious being need be

2833
01:33:17,990 --> 01:33:16,320
aware of only one of the alternatives in

2834
01:33:19,430 --> 01:33:18,000
a linear superposition

2835
01:33:21,669 --> 01:33:19,440
what is it about consciousness that

2836
01:33:23,669 --> 01:33:21,679
demands that one cannot be aware

2837
01:33:25,510 --> 01:33:23,679
of the tantalizing linear combination of

2838
01:33:26,950 --> 01:33:25,520

being both dead and alive

2839
01:33:28,790 --> 01:33:26,960
it seems to me that a theory of

2840
01:33:30,629 --> 01:33:28,800
consciousness will be needed before

2841
01:33:32,470 --> 01:33:30,639
the many worlds viewed can be squared

2842
01:33:34,629 --> 01:33:32,480
with what one actually observes

2843
01:33:36,070 --> 01:33:34,639
so what do you think about this yeah i

2844
01:33:39,350 --> 01:33:36,080
think that that is a

2845
01:33:39,669 --> 01:33:39,360
um a a an understandable objection but i

2846
01:33:41,990 --> 01:33:39,679
think

2847
01:33:43,030 --> 01:33:42,000
like an objection that is um met by the

2848
01:33:46,149 --> 01:33:43,040
mathematics

2849
01:33:47,030 --> 01:33:46,159
um so what i mean is okay let's say you

2850
01:33:49,430 --> 01:33:47,040
have a

2851
01:33:50,390 --> 01:33:49,440
um object that's in a superposition in

2852
01:33:52,390 --> 01:33:50,400
many worlds

2853
01:33:53,830 --> 01:33:52,400
uh like so it's in two different worlds

2854
01:33:56,229 --> 01:33:53,840
um

2855
01:33:57,510 --> 01:33:56,239
it can only experience like so let's say

2856
01:34:00,470 --> 01:33:57,520
it's not a conscious thing

2857
01:34:01,750 --> 01:34:00,480
it's just a let's say an atom um it can

2858
01:34:04,149 --> 01:34:01,760
only experience

2859
01:34:05,110 --> 01:34:04,159
all of the other objects in its world in

2860
01:34:07,270 --> 01:34:05,120
that in the state

2861
01:34:08,950 --> 01:34:07,280
that they are in that world so like in

2862
01:34:09,590 --> 01:34:08,960
this state like so let's say in this

2863
01:34:12,310 --> 01:34:09,600

world

2864
01:34:14,709 --> 01:34:12,320
all of the objects are in state zero and

2865
01:34:16,709 --> 01:34:14,719
in that world they're all in state one

2866
01:34:19,270 --> 01:34:16,719
if you take one of the atoms inside of

2867
01:34:20,310 --> 01:34:19,280
here and you get it to measure one of

2868
01:34:23,030 --> 01:34:20,320
its partners

2869
01:34:23,750 --> 01:34:23,040
it will say that its partner is zero or

2870
01:34:25,110 --> 01:34:23,760
here

2871
01:34:26,550 --> 01:34:25,120
if you got it to measure its partner it

2872
01:34:28,070 --> 01:34:26,560
would say it's one it can only

2873
01:34:30,629 --> 01:34:28,080
experience that world

2874
01:34:31,350 --> 01:34:30,639
like with all of the things that are in

2875
01:34:33,590 --> 01:34:31,360
that world

2876
01:34:34,790 --> 01:34:33,600
as they are like you know um in that

2877
01:34:36,950 --> 01:34:34,800
state and so

2878
01:34:37,910 --> 01:34:36,960
let's say now i'm a conscious being and

2879
01:34:40,390 --> 01:34:37,920
i'm inside of

2880
01:34:41,270 --> 01:34:40,400
like both of these branches um i've just

2881
01:34:44,310 --> 01:34:41,280
done a measurement

2882
01:34:46,950 --> 01:34:44,320
of my um of my atom and

2883
01:34:48,390 --> 01:34:46,960
uh my atom is now like in state zero

2884
01:34:49,830 --> 01:34:48,400
according to in this branch

2885
01:34:51,910 --> 01:34:49,840
and in state one according to that

2886
01:34:54,470 --> 01:34:51,920
branch if i was to if i was

2887
01:34:55,430 --> 01:34:54,480
able to experience both then i should be

2888
01:34:58,070 --> 01:34:55,440

able to see the

2889
01:34:58,790 --> 01:34:58,080
atom being in state zero and in state

2890
01:35:01,510 --> 01:34:58,800
one

2891
01:35:02,870 --> 01:35:01,520
but because of how many words works how

2892
01:35:04,550 --> 01:35:02,880
the mathematics works out

2893
01:35:06,470 --> 01:35:04,560
there is no measurement that i can do

2894
01:35:07,350 --> 01:35:06,480
inside of this world that would show me

2895
01:35:09,510 --> 01:35:07,360
the result one

2896
01:35:10,709 --> 01:35:09,520
it would only say zero and in that world

2897
01:35:12,629 --> 01:35:10,719
i would only say one

2898
01:35:13,990 --> 01:35:12,639
and so there's no like i don't

2899
01:35:15,510 --> 01:35:14,000
experience the other world to me just

2900
01:35:16,070 --> 01:35:15,520
doesn't exist there's no evidence of it

2901
01:35:17,270 --> 01:35:16,080
anywhere

2902
01:35:19,430 --> 01:35:17,280
so of course i don't consciously

2903
01:35:21,350 --> 01:35:19,440
experience it

2904
01:35:23,669 --> 01:35:21,360
oh so now that there's no evidence of it

2905
01:35:27,270 --> 01:35:23,679
anywhere what is the reason for you

2906
01:35:28,790 --> 01:35:27,280
believing in it oh so there's evidence

2907
01:35:31,270 --> 01:35:28,800
there's all the evidence that i

2908
01:35:33,189 --> 01:35:31,280
could possibly want that i'm in the the

2909
01:35:35,109 --> 01:35:33,199
world where everything is in state zero

2910
01:35:37,189 --> 01:35:35,119
when i'm sorry i meant i meant why does

2911
01:35:38,550 --> 01:35:37,199
mathuna mythana sorry

2912
01:35:40,709 --> 01:35:38,560
believe in the many world's

2913
01:35:42,470 --> 01:35:40,719

interpretation if

2914
01:35:43,750 --> 01:35:42,480
to me it seems like a religious choice

2915
01:35:45,109 --> 01:35:43,760
because there's not

2916
01:35:47,189 --> 01:35:45,119
evidence for it unless you just say well

2917
01:35:50,229 --> 01:35:47,199
the math says exactly

2918
01:35:51,430 --> 01:35:50,239
so no um it's it's uh back to that

2919
01:35:55,030 --> 01:35:51,440
question of like

2920
01:35:56,550 --> 01:35:55,040
do i want a um theory of the universe to

2921
01:35:59,830 --> 01:35:56,560
be beautiful or not

2922
01:36:00,550 --> 01:35:59,840
um i my my bias is very much towards

2923
01:36:02,550 --> 01:36:00,560
beauty

2924
01:36:04,229 --> 01:36:02,560
um and i think that many worlds is a

2925
01:36:07,270 --> 01:36:04,239
much more beautiful theorem

2926
01:36:08,709 --> 01:36:07,280
uh theory rather and that's because it

2927
01:36:10,870 --> 01:36:08,719
has less assumptions

2928
01:36:12,229 --> 01:36:10,880
so in a statement there oh many worlds

2929
01:36:14,229 --> 01:36:12,239
is less economical

2930
01:36:16,149 --> 01:36:14,239
in one sense yes if you're like counting

2931
01:36:18,790 --> 01:36:16,159
worlds but i think that's not the

2932
01:36:19,750 --> 01:36:18,800
sort of important sense of like um you

2933
01:36:22,229 --> 01:36:19,760
know how

2934
01:36:22,870 --> 01:36:22,239
economical a theory is how economical it

2935
01:36:25,109 --> 01:36:22,880
is is like

2936
01:36:26,070 --> 01:36:25,119
how many sort of distinct ad hoc rules

2937
01:36:29,510 --> 01:36:26,080
does it have

2938
01:36:31,750 --> 01:36:29,520

and many worlds deletes the ad hoc rule

2939
01:36:33,510 --> 01:36:31,760
that quantum mechanics has and therefore

2940
01:36:35,270 --> 01:36:33,520
i think it is a more economical more

2941
01:36:37,910 --> 01:36:35,280
beautiful theory that's why i believe it

2942
01:36:38,870 --> 01:36:37,920
it's not because of the evidence because

2943
01:36:46,709 --> 01:36:38,880
thank you so much

2944
01:36:50,310 --> 01:36:46,719
um uh after this next youtube video

2945
01:36:50,870 --> 01:36:50,320
um yeah uh well so the thing i've been

2946
01:36:54,070 --> 01:36:50,880
thinking

2947
01:36:54,870 --> 01:36:54,080
the most about is how to improve online

2948
01:36:57,990 --> 01:36:54,880
education

2949
01:37:01,030 --> 01:36:58,000
i think that that's like a really uh

2950
01:37:02,550 --> 01:37:01,040
like interesting and new medium um like

2951
01:37:04,229 --> 01:37:02,560
people on youtube have done

2952
01:37:06,070 --> 01:37:04,239
really wonderful things but i think that

2953
01:37:08,310 --> 01:37:06,080
like we can push it even further

2954
01:37:09,669 --> 01:37:08,320
um so yeah that's the direction i hope

2955
01:37:12,629 --> 01:37:09,679
to to like

2956
01:37:14,390 --> 01:37:12,639
put myself um and like it's sad that i'm

2957
01:37:16,950 --> 01:37:14,400
not doing physics research like i

2958
01:37:18,470 --> 01:37:16,960
i miss it but i feel like this is higher

2959
01:37:20,950 --> 01:37:18,480
impact like i feel like

2960
01:37:22,390 --> 01:37:20,960
the world needs this more than you know

2961
01:37:24,470 --> 01:37:22,400
the small bit of physics that i

2962
01:37:25,430 --> 01:37:24,480
could have contributed wait so are you

2963
01:37:28,310 --> 01:37:25,440

more driven by that

2964
01:37:29,510 --> 01:37:28,320
altruistic part of you or the passion

2965
01:37:30,550 --> 01:37:29,520
part of you that just wants to do

2966
01:37:34,470 --> 01:37:30,560
research

2967
01:37:37,270 --> 01:37:34,480
yeah um i think that um

2968
01:37:39,109 --> 01:37:37,280
yeah like i really am passionate about

2969
01:37:40,470 --> 01:37:39,119
physics research and so it was like a

2970
01:37:43,510 --> 01:37:40,480
super hard decision

2971
01:37:45,510 --> 01:37:43,520
but because um education

2972
01:37:47,189 --> 01:37:45,520
will impact like way more people and

2973
01:37:48,950 --> 01:37:47,199
also because it is still a very

2974
01:37:51,030 --> 01:37:48,960
interesting thing to research

2975
01:37:54,070 --> 01:37:51,040
um ultimately like both of those things

2976
01:37:55,510 --> 01:37:54,080
combined made it a pretty good choice

2977
01:37:58,149 --> 01:37:55,520
thank you so much for spending so much

2978
01:38:01,430 --> 01:37:58,159
time with with me

2979
01:38:03,430 --> 01:38:01,440
and putting up with my sleepy questions

2980
01:38:04,950 --> 01:38:03,440
oh good i'm sorry for that i'm catching

2981
01:38:07,030 --> 01:38:04,960
oh no no no no no it's

2982
01:38:08,709 --> 01:38:07,040
it's all right it's sorry i i just for

2983
01:38:10,709 --> 01:38:08,719
the for weeks and weeks

2984
01:38:11,910 --> 01:38:10,719
like weeks i haven't been getting enough

2985
01:38:14,950 --> 01:38:11,920
sleep and so it just

2986
01:38:18,229 --> 01:38:14,960
compiles and compiles yeah yeah

2987
01:38:19,910 --> 01:38:18,239
and then i've been studying some quantum

2988
01:38:23,109 --> 01:38:19,920

computing to prep for this

2989
01:38:24,950 --> 01:38:23,119
oh no oh thanks so much well

2990
01:38:27,189 --> 01:38:24,960
i'm just going to ask this yeah yeah no

2991
01:38:28,950 --> 01:38:27,199
problem no problem

2992
01:38:31,109 --> 01:38:28,960
there's so many other technic somewhat

2993
01:38:31,750 --> 01:38:31,119
technical questions i had like about zx

2994
01:38:32,629 --> 01:38:31,760
calculus

2995
01:38:34,629 --> 01:38:32,639
and i was wondering about the

2996
01:38:36,229 --> 01:38:34,639
relationship between graph states and

2997
01:38:39,030 --> 01:38:36,239
the spider diagrams are the

2998
01:38:39,910 --> 01:38:39,040
oh my gosh their way of are they this i

2999
01:38:41,510 --> 01:38:39,920
know the graph states

3000
01:38:43,750 --> 01:38:41,520
see the way that i i understand graph

3001
01:38:45,510 --> 01:38:43,760
states are like

3002
01:38:46,950 --> 01:38:45,520
in particle physics there's definement

3003
01:38:48,310 --> 01:38:46,960
diagrams and then there's rules to

3004
01:38:51,189 --> 01:38:48,320
translate those to

3005
01:38:52,550 --> 01:38:51,199
equations looks like graph states have a

3006
01:38:54,149 --> 01:38:52,560
simple rule

3007
01:38:56,830 --> 01:38:54,159
and then i was wondering is there a way

3008
01:38:59,270 --> 01:38:56,840
to go from graph states to zx

3009
01:39:02,229 --> 01:38:59,280
spiders yeah well anyway

3010
01:39:03,990 --> 01:39:02,239
i'm curious is there yeah um i don't

3011
01:39:05,910 --> 01:39:04,000
actually know

3012
01:39:07,669 --> 01:39:05,920
like they have different uses i'm sure

3013
01:39:11,430 --> 01:39:07,679

but yeah as far as i know from

3014
01:39:14,470 --> 01:39:11,440
my depthless understanding of quantum

3015
01:39:15,990 --> 01:39:14,480
computing they're just representations

3016
01:39:18,550 --> 01:39:16,000
of the circuits

3017
01:39:20,070 --> 01:39:18,560
so i don't so i don't see why one is

3018
01:39:21,510 --> 01:39:20,080
more advantageous than the other or why

3019
01:39:22,390 --> 01:39:21,520
they can't be easily translated to one

3020
01:39:25,590 --> 01:39:22,400
another

3021
01:39:28,470 --> 01:39:25,600
yeah that's a good question um yeah

3022
01:39:29,990 --> 01:39:28,480
that is a really good question and i i

3023
01:39:30,390 --> 01:39:30,000
genuinely don't know the answer to that

3024
01:39:33,750 --> 01:39:30,400
yeah

3025
01:39:35,669 --> 01:39:33,760
okay okay well anyway whatever

3026
01:39:36,870 --> 01:39:35,679
anyway well no thank you so much for